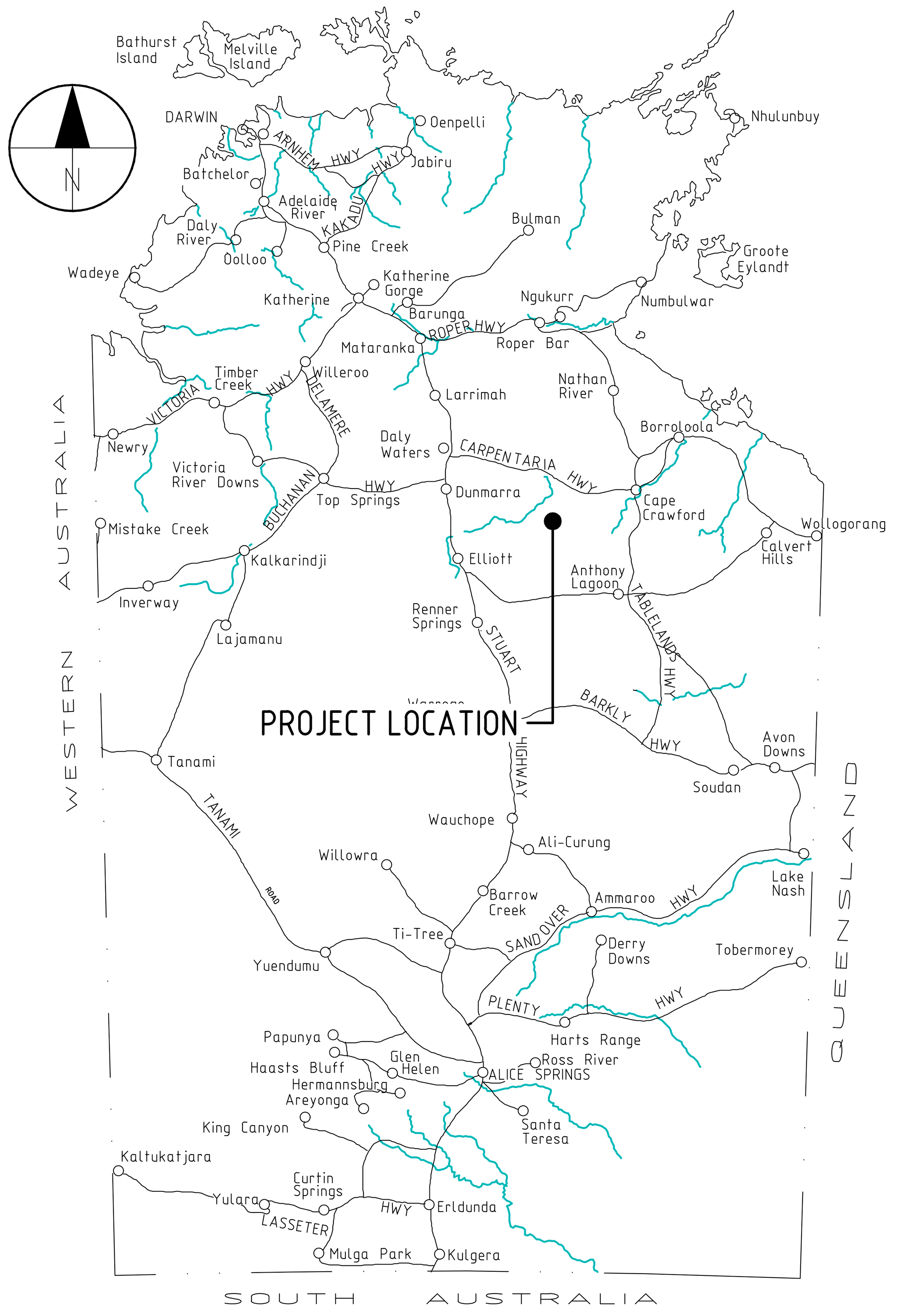
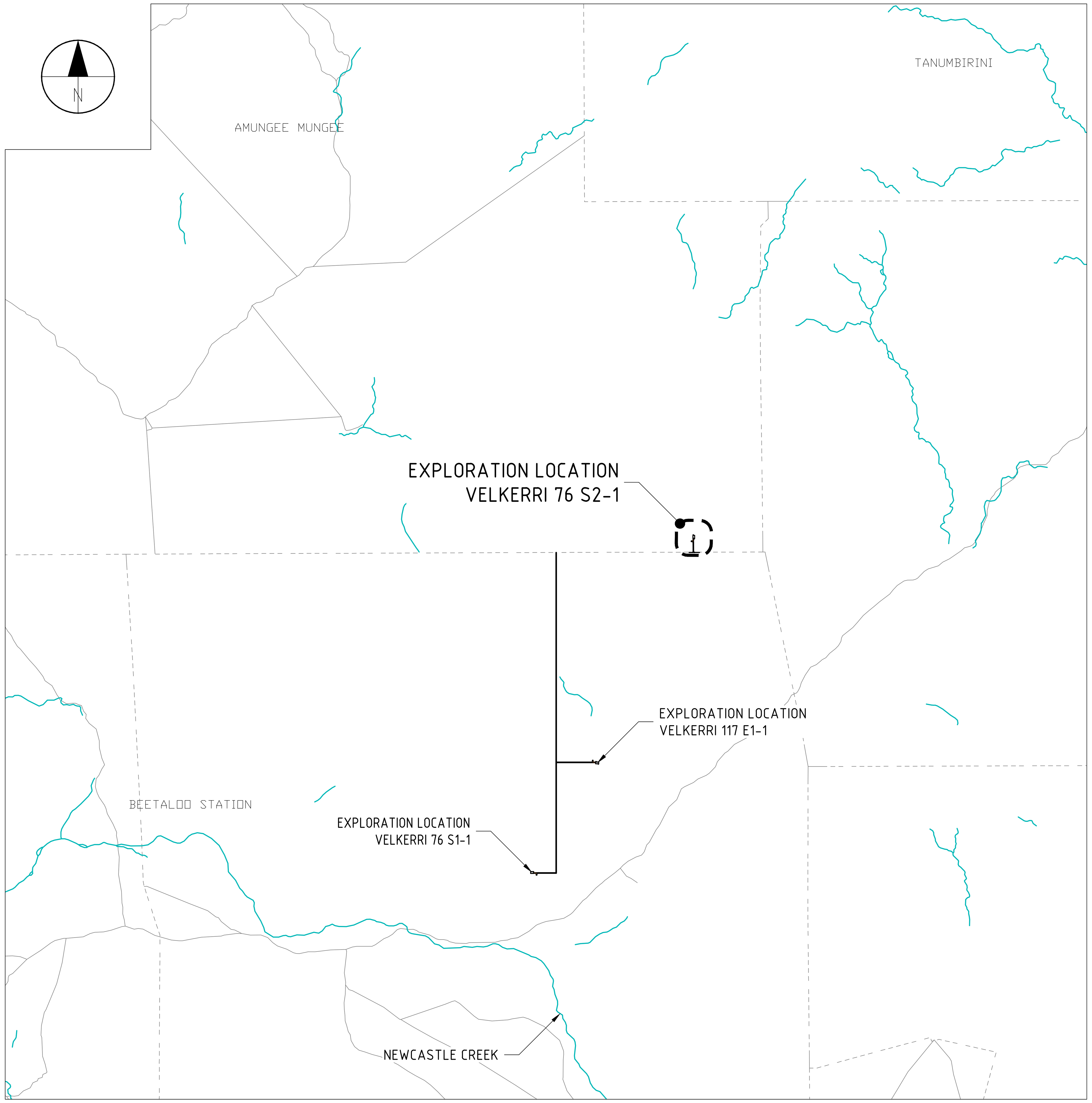
Appendix A: Engineering Drawings, Specifications and Layouts



LOCALITY MAP

SCALE 0 100 150 200 250 300 Kilometers



LOCALITY PLAN

SCALE (km) 0 2 4 6 8 10 1:200,000 (A1)

DRAWING SCHEDULE

DRAWING NUMBER	DESCRIPTION
CIVIL	
NT-2050-20-DH-0007	LOCALITY MAP, LOCALITY PLAN, DRAWING SCHEDULE, GENERAL NOTES
NT-2050-20-DA-0023	DRILL PAD, ACCOMODATION CAMP AND WATER TANK GENERAL ARRANGEMENT PLAN
NT-2050-20-DA-0026	DRILL PAD, ACCOMODATION CAMP AND WATER TANK EARTHWORKS GENERAL ARRANGEMENT PLAN
NT-2050-20-DD-0023	DESIGN DETAILS
NT-2050-20-DD-0031	MUD SUMP DETAILS
NT-2050-20-DD-0025	PAD ACCESS ROAD
NT-2050-20-DD-0032	PAD INTERSECTION DETAIL
NT-2050-20-DD-0027	DRILLING CELLAR DETAILS
NT-2050-15-MP-0022	DRILL PAD, ACCOMODATION CAMP AND WATER TANK EROSION AND SEDIMENT CONTROL PLAN
STANDARD DRAWINGS	
C(S)3310	STOCK FENCE DESIGN AND DETAILS

LEGEND

EXISTING

- PIPELINE
- FENCE
- PRINCIPAL ROAD
- UNSEALED TRACK
- WATERCOURSE

GENERAL NOTES

1. ALL DIMENSIONS ARE IN METRES UNLESS NOTED OTHERWISE.
2. ALL WORKS TO BE CARRIED OUT IN ACCORDANCE WITH THE APPROVED MANAGEMENT PLAN REQUIREMENTS.
3. NO CONSTRUCTION WORKS ARE TO BE CARRIED OUT OUTSIDE THE APPROVED WORK CORRIDOR BOUNDARIES.
4. CONSTRUCTION FACILITY AREA LOCATIONS TO BE APPROVED BY THE SUPERINTENDENT PRIOR TO WORKS COMMENCING.
5. THE CONTRACTOR IS TO LIAISE WITH SERVICE PROVIDERS AND THE RELEVANT AUTHORITIES TO ENSURE ALL CONSTRUCTION WORKS ARE CARRIED OUT IN ACCORDANCE WITH SERVICE PROVIDERS AND RELEVANT AUTHORITIES REQUIREMENTS.
6. NO SERVICES WERE PRESENT OR PROVIDED BY DBYD AT THE TIME OF DESIGN AND ARE THEREFORE NOT SHOWN, HOWEVER THE CONTRACTOR IS RESPONSIBLE FOR CONDUCTING A SEARCH PRIOR TO WORKS BEING CARRIED OUT. ANY DAMAGE TO EXISTING SERVICES IS TO BE RE-INSTATED AT THE CONTRACTORS EXPENSE.
7. SIGNAGE TO BE INSTALLED PRIOR TO ROAD USE.
8. THIS DRAWING MAY BE USED FOR TEMPORARY ACCESS APPLICATION TO NT ROADS.

PRELIMINARY

NOT FOR CONSTRUCTION

DRAWING NO.	REFERENCE DRAWING TITLE	REV	DATE	REVISION DESCRIPTION	DRAWN	DWG CHECK	DESIGN	ENG DES CHECK	OE DRAFT SUPER	OE PROJECT APPROVAL
-	-	A	21.03.2019	PRELIMINARY ISSUE	CD	-	-	-	-	-

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PROJECT 60480548 BEETALOO EXPLORATION — DRAWING OFFICE DARWIN — PROJECT APPROVALS - OTHERS

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DESIGN	-	— . — . —
ENG DES CHECK	-	— . — . —
DRAFT. SUPER.	-	— . — . —
PROJECT APPROVAL	-	— . — . —

TITLE: BEETALOO EXPLORATION DRILL CAMPAIGN
VELKERRI 76 S2-1
LOCALITY MAP, LOCALITY PLAN, DRAWING SCHEDULE, GENERAL NOTES

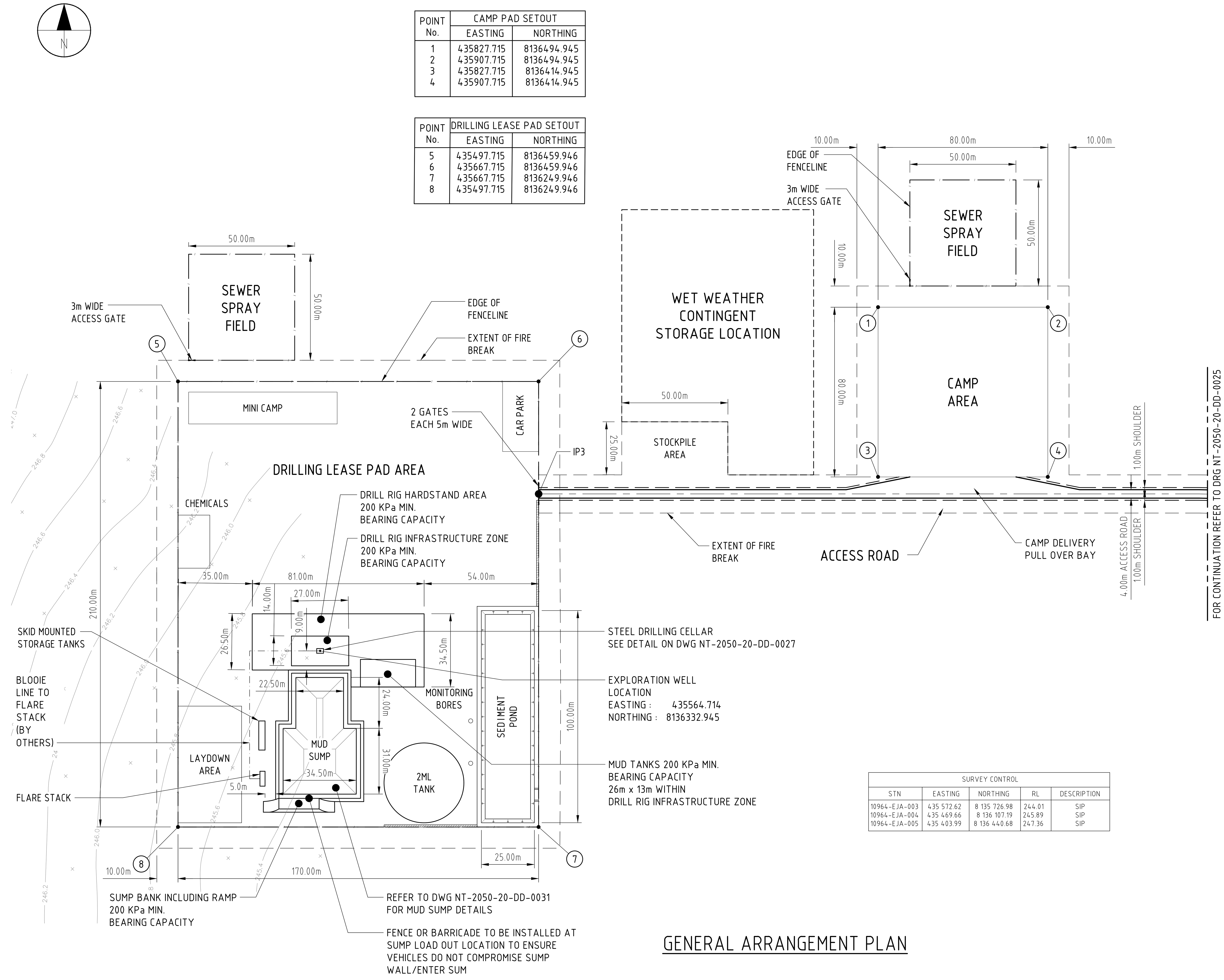
PROJECT NO. — MOD NO. — SCALE AS NOTED

DRAWING NO. NT-2050-20-DH-007 — REVISION A — A1

CADFILE NT-2050-20-DH-0007.dwg

POINT No.	CAMP PAD SETOUT	
	EASTING	NORTHING
1	435827.715	8136494.945
2	435907.715	8136494.945
3	435827.715	8136414.945
4	435907.715	8136414.945

POINT No.	DRILLING LEASE PAD SETOUT	
	EASTING	NORTHING
5	435497.715	8136459.946
6	435667.715	8136459.946
7	435667.715	8136249.946
8	435497.715	8136249.946



SURVEY CONTROL				
STN	EASTING	NORTHING	RL	DESCRIPTION
10964-EJA-003	435 572.62	8 135 726.98	244.01	SIP
10964-EJA-004	435 469.66	8 136 107.19	245.89	SIP
10964-EJA-005	435 403.99	8 136 440.68	247.36	SIP

GENERAL ARRANGEMENT PLAN

LEGEND

EXISTING

CONTOURS

PROPOSED

ACCESS ROAD CENTERLINE
EDGE OF PAVEMENT
EDGE OF SHOULDER
EDGE OF FOOTPATH
EXTENT OF CLEARING - (EXTENT OF FIRE BREAK)
EDGE OF FENCELINE

NOTES:

1. ALL DIMENSIONS ARE IN METRES UNLESS NOTED OTHERWISE.
2. REFER TO NORTHERN TERRITORY STANDARD DRAWING C(S)3310 FOR TYPICAL STOCK FENCE DETAILS.
3. SEWER SPRAY FIELD AREA IS NOT TO BE CLEARED. SPRAY PIPES LAID ON EXISTING VEGETATION BY OTHERS.
4. LEASE AND CAMP PAD TO BE COMPACTED TO 120KPA BEARING CAPACITY UNLESS OTHERWISE NOTED.
5. LEASE HARDSTAND PAD TO BE COMPACTED TO 200 KPA BEARING CAPACITY.
6. ALL WORKS TO BE CARRIED OUT IN ACCORDANCE WITH THE APPROVED MANAGEMENT PLAN REQUIREMENTS.
7. NO CONSTRUCTION WORKS ARE TO BE CARRIED OUT OUTSIDE THE APPROVED WORK CORRIDOR BOUNDARIES.
8. CONSTRUCTION FACILITY AREA LOCATIONS TO BE APPROVED BY THE SUPERINTENDENT PRIOR TO WORKS COMMENCING.
9. THE CONTRACTOR IS TO LIAISE WITH SERVICE PROVIDERS AND THE RELEVANT AUTHORITIES TO ENSURE ALL CONSTRUCTION WORKS ARE CARRIED OUT IN ACCORDANCE WITH SERVICE PROVIDERS AND RELEVANT AUTHORITIES REQUIREMENTS.
10. THE CONTRACTOR IS TO CARRY OUT A DBYD AND LOCATE AND MARK SERVICES ON SITE. ANY DAMAGE TO EXISTING SERVICES IS TO BE RE-INSTATED AT THE CONTRACTORS EXPENSE.
11. SIGNAGE TO BE INSTALLED PRIOR TO ROAD USE.
12. REFER TO DRAWING NT-2050-20-DD-0031 FOR MUD SUMP DETAILS AND DRAWING NT-2050-20-DD-0027 FOR STEEL DRILLING CELLAR DETAILS.
13. THE NOMINATED AREA BOUND BY SETOUT POINTS D1 TO D4 IS TO BE A UNIFORMLY GRADED PAD.
14. FINISH SURFACE LEVELS ARE TO FOLLOW EXISTING SURFACE LEVELS AS NEAR AS POSSIBLE AND TO THE GRADES SPECIFIED ON THE DRAWINGS.
15. FIREBREAK CLEARINGS AROUND DRILLING LEASE AND CAMP PAD ARE TO BE USED FOR STORAGE OF TOPSOIL AND VEGETATION AS REQUIRED.
16. FOR ROAD SETOUT TABLE REFER TO DRG. NT-2050-20-DD-0025.
17. HARDSTAND AND LEASE PAD FINISHED SURFACE LEVELS TO BE EQUAL OR SMOOTH TRANSITION TO AVOID BATTERS OF STEPS.
18. CAMP PAD AREA CROSSFALL TO BE NO GREATER THAN 1%.
19. NO ESC DEVICE CAN BE INSTALLED IN CRITICAL RIG AREA WITHOUT APPROVAL BY WELLSITE REP.
20. CATTLE PANEL FENCING TO BE INSTALLED AROUND MUD SUMP.

PRELIMINARY

NOT FOR CONSTRUCTION

SCALE (m) 0 10 20 30 40 50 1:1000 (A1)

DRAWING NO.	REFERENCE DRAWING TITLE
NT-2050-20-DD-0027	DRILLING CELLAR DETAILS
NT-2050-20-DD-0023	DESIGN DETAILS

REV	DATE	REVISION DESCRIPTION	DRAWN	DWG CHECK	DESIGN	ENG DES CHECK	DE DRAFT SUPER	DE PROJECT APPROVAL
A	21.03.2019	PRELIMINARY ISSUE	CD	-	-	-	-	-

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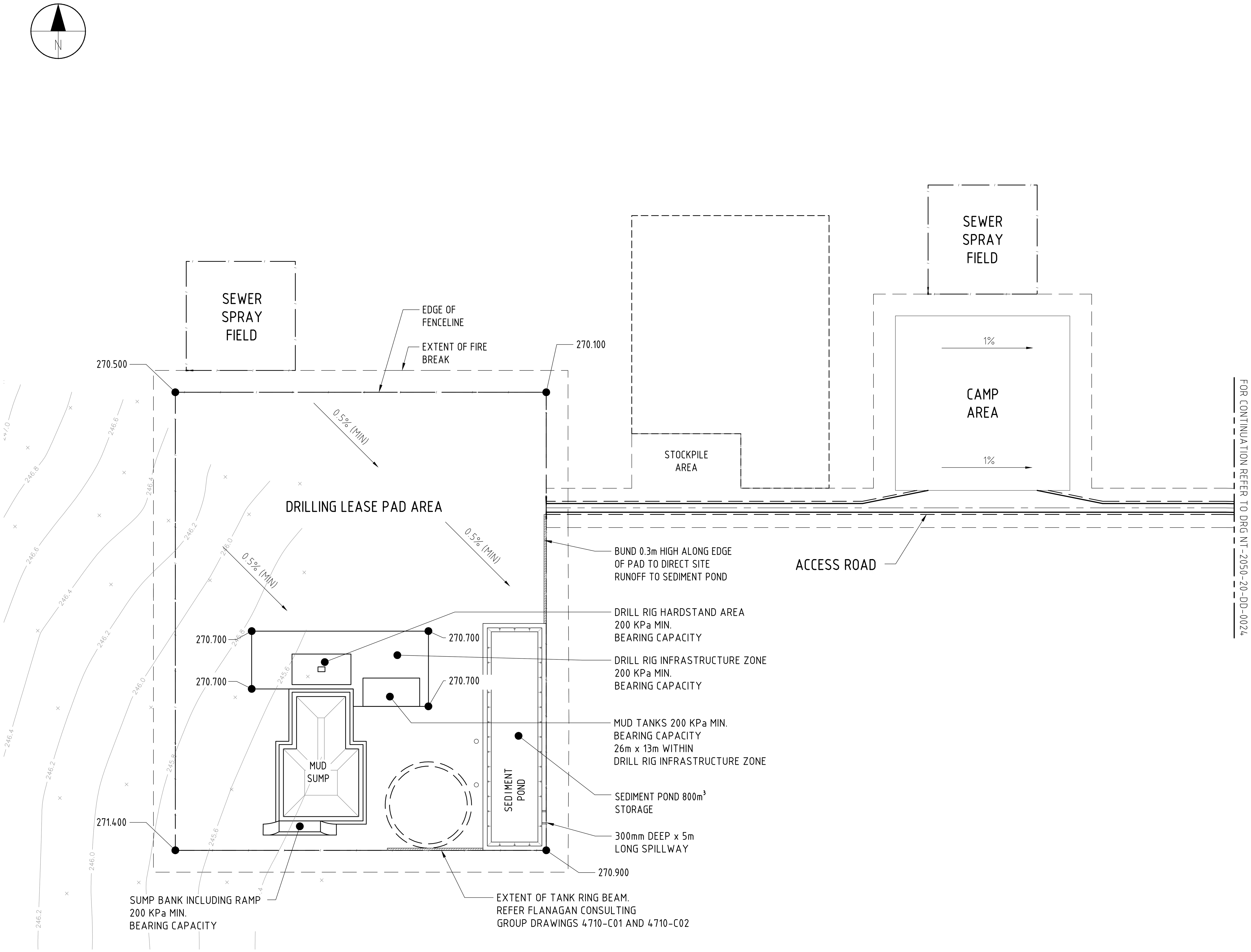
ENG DES CHECK	-	- . - . -
ORIGIN DRAFT. SUPER.	-	- . - . -
ORIGIN PROJECT APPROVAL	-	- . - . -

TITLE
BEETALOO EXPLORATION DRILL CAMPAIGN
VELKERRI 76 S2-1
DRILL PAD, ACCOMODATION CAMP AND WATER TANK
GENERAL ARRANGEMENT PLAN

PROJECT NO. | MOD NO. | DRAWING NO. NT-2050-20-DA-0023 | REVISION A

SCALE 1:1000 @ A1 | CADFILE NT-2050-20-DA-0023.dwg | A1

Thu, 18 Apr 2019 - 1:50pm P:\604X\60480548\5. CAD\20-SHEETS\VELKERRI 76 S2-1\NT-2050-20-DA-0023.DWG Dudley, Calvin



GENERAL ARRANGEMENT PLAN

LEGEND

EXISTING

CONTOURS

PROPOSED

ACCESS ROAD CENTERLINE

EDGE OF PAVEMENT

EDGE OF SHOULDER

EDGE OF FOOTPATH

EXTENT OF CLEARING - (EXTENT OF FIRE BREAK)

EDGE OF FENCELINE

NOTES:

1. ALL DIMENSIONS ARE IN METRES UNLESS NOTED OTHERWISE.
2. LEASE AND CAMP PAD TO BE COMPACTED TO 120KPA BEARING CAPACITY UNLESS OTHERWISE NOTED.
3. LEASE HARDSTAND TO BE COMPACTED TO 200 KPA BEARING CAPACITY.
4. BULK EARTHWORKS ARE TO BE MINIMISED WHERE POSSIBLE.
5. ROAD AND PAD PAVEMENTS ARE TO BE CONSTRUCTED TO FOLLOW EXISTING SURFACE LEVELS AS NEAR AS POSSIBLE AND TO THE GRADES SPECIFIED ON THE DRAWINGS.
6. CONTRACTOR IS RESPONSIBLE TO FIND/LOCATE EXISTING SERVICES. ANY DAMAGE TO EXISTING SERVICES TO BE RE-INSTATED AT THE CONTRACTORS EXPENSE.
7. ALL WORKS TO BE CARRIED OUT IN ACCORDANCE WITH THE APPROVED MANAGEMENT PLAN REQUIREMENTS.
8. NO CONSTRUCTION WORKS ARE TO BE CARRIED OUT OUTSIDE THE APPROVED WORK CORRIDOR BOUNDARIES.
9. CONSTRUCTION FACILITY AREA LOCATIONS TO BE APPROVED BY THE SUPERINTENDENT PRIOR TO WORKS COMMENCING.
10. TABLE DRAINS ARE TO BE CUT ALONG THE LENGTH OF THE ROAD AND ALL ROAD PAVEMENTS ARE TO HAVE A 4% CROSSFALL IN ACCORDANCE WITH THE ROAD CROSS-SECTION DETAILED ON DWG. NT-2050-20-DD-0023.
11. REFER TO DWG NT-2050-20-DD-0023 FOR ROAD PAVEMENT DETAILS. LAYDOWN AND VEHICLE AREA, LEASE PAD AND ACCOMMODATION PAD ARE TO BE STRIPPED OF 150mm AND THEN RIPPED AND RE-COMPACTED TO 95%MMDD. DRILL PAD IS TO BE TESTED FOR REQUIRED BEARING CAPACITIES AND THE ORIGIN SITE SUPERVISOR NOTIFIED IF THIS CAN NOT BE ACHIEVED.
12. REFER TO DRAWING NT-2050-20-DD-0031 FOR MUD SUMP DETAILS AND DRAWING NT-2050-20-DD-0027 FOR STEEL DRILLING CELLAR DETAILS.
13. FOR TANK RING BEAM DETAIL REFER FLANAGAN CONSULTING GROUP DRAWINGS 4710-C01 AND 4710-C02.
14. FINAL DRILLING LEASE PAD AREA GRADE TO BE CONFIRMED ON SITE BY ORIGIN SITE SUPERVISOR.

PRELIMINARY

NOT FOR CONSTRUCTION

SCALE (m) 0 10 20 30 40 50 1:1000 (A1)

DRAWING NO.	REFERENCE DRAWING TITLE
NT-2050-20-DD-0027	DRILLING CELLAR DETAILS
NT-2050-20-DD-0023	DESIGN DETAILS

REV	DATE	REVISION DESCRIPTION	DRAWN	DWG CHECK	DESIGN	ENG DES CHECK	OE DRAFT SUPER	OE PROJECT APPROVAL
A	21.03.2019	PRELIMINARY ISSUE	CD	-	-	-	-	-

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	BY	DATE
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DWG CHECK	-	— . — . —
DESIGN	-	— . — . —
ENG DES CHECK	-	— . — . —
ORIGIN DRAFT. SUPER.	-	— . — . —
ORIGIN PROJECT APPROVAL	-	— . — . —

TITLE
BEETALOO EXPLORATION DRILL CAMPAIGN
VELKERRI 76 S2-1
DRILL PAD, ACCOMODATION CAMP AND WATER TANK EARTHWORKS
GENERAL ARRANGEMENT PLAN

PROJECT NO.

MOD NO.

SCALE 1:1000 @ A1

DRAWING NO. NT-2050-20-DA-0026

REVISION A

CADFILE NT-2050-20-DA-0026.dwg

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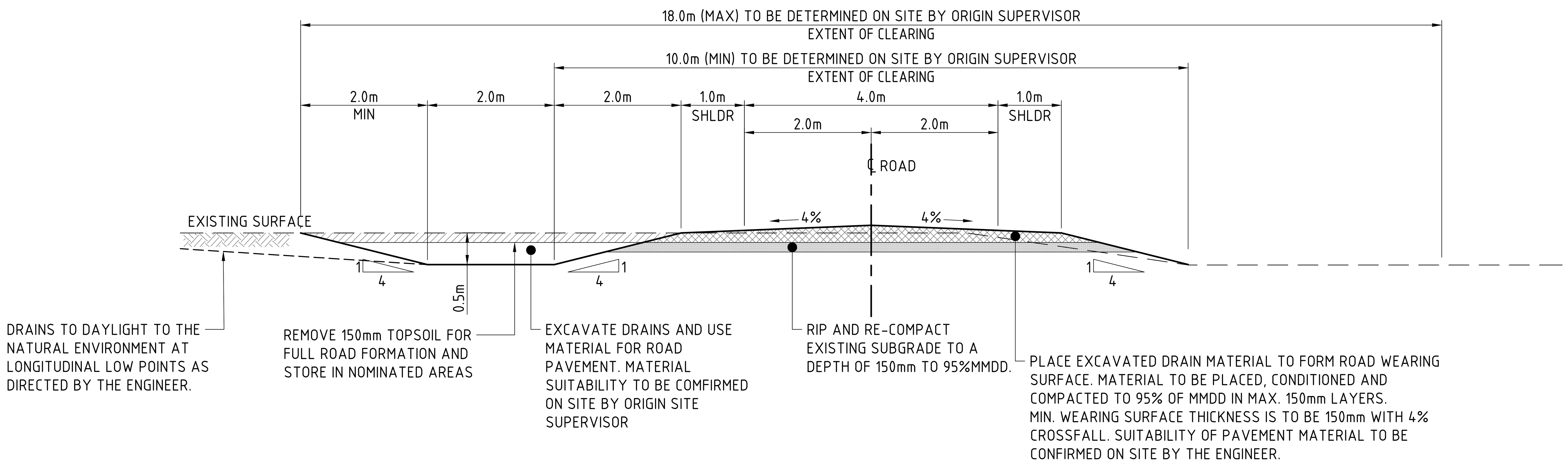

TYPICAL CROSS SECTION - ACCESS ROAD

SCALE (m) 0 0.2 0.4 0.6 0.8 1.0 1:20 (A1)

NOTES:

1. ALL UNITS ARE IN MILLIMETRES (mm) UNLESS NOTED OTHERWISE.
2. ENSURE THAT TABLE DRAINS ARE FREE DRAINING.
3. GROUND CONDITIONS AND SUITABLE MATERIALS TO BE CONFIRMED ON SITE BY SUPERINTENDENT.
4. CLEARED VEGETATION TO BE STORED ALONGSIDE NEW ROAD FOR FUTURE REHABILITATION.
5. REFER TO SPECIFICATION FOR COMPACTION REQUIREMENTS.
6. STRIPPED TOPSOIL TO BE STORED IN BERMS ALONGSIDE ROAD.
7. REFER TO SPECIFICATION FOR GENERAL REQUIREMENTS.
8. THE CONTRACTOR IS TO NOTIFY THE ORIGIN SUPERVISOR IF AREAS OF SOFT GROUND ARE ENCOUNTERED OR IF THE SPECIFICATION CANNOT BE ACHIEVED.
9. CLEAR, STRIP 150mm TOPSOIL AND STOCKPILE IN NOMINATED BUFFER ZONE TO ESTABLISH BORROW PITS.
10. THIS DRAWING MAY BE USED FOR TEMPORARY ACCESS APPLICATION TO NT ROADS.
11. TYPICAL CROSS SECTION DESIGNED IN ACCORDANCE WITH NORTHERN TERRITORY STANDARD DRAWING C(S)3003.

ISSUED FOR CONSTRUCTION

DRAWING NO.	REFERENCE DRAWING TITLE	REV	DATE	REVISION DESCRIPTION	DRAWN	DWG CHECK	DESIGN	ENG DES CHECK	OE DRAFT SUPER	OE PROJECT APPROVAL
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		1	11.04.19	REISSUED FOR CONSTRUCTION	CRD	PCM	PCM	JMJ		
NT-2050-20-DA-0023	GENERAL ARRANGEMENT PLAN	0	20.03.19	ISSUED FOR CONSTRUCTION	CRD	PCM	PCM	JMJ		

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Fax: (07) 3369 7840

	BY	DATE
DRAWN	CRD	20.03.2019
DWG CHECK	PCM	20.03.2019
DESIGN	PCM	20.03.2019
ENG DES CHECK	JMJ	20.03.2019
ORIGIN DRAFT. SUPER.		
ORIGIN PROJECT APPROVAL		

TITLE
BEETALOO EXPLORATION DRILL CAMPAIGN
VELKERRI 76 S2-1
DESIGN DETAILS

PROJECT NO.

MOD NO.

SCALE 1:1000 @ A1

DRAWING NO. NT-2050-20-DD-0023

REVISION 0

CADFILE NT-2050-20-DD-0023.dwg

A1

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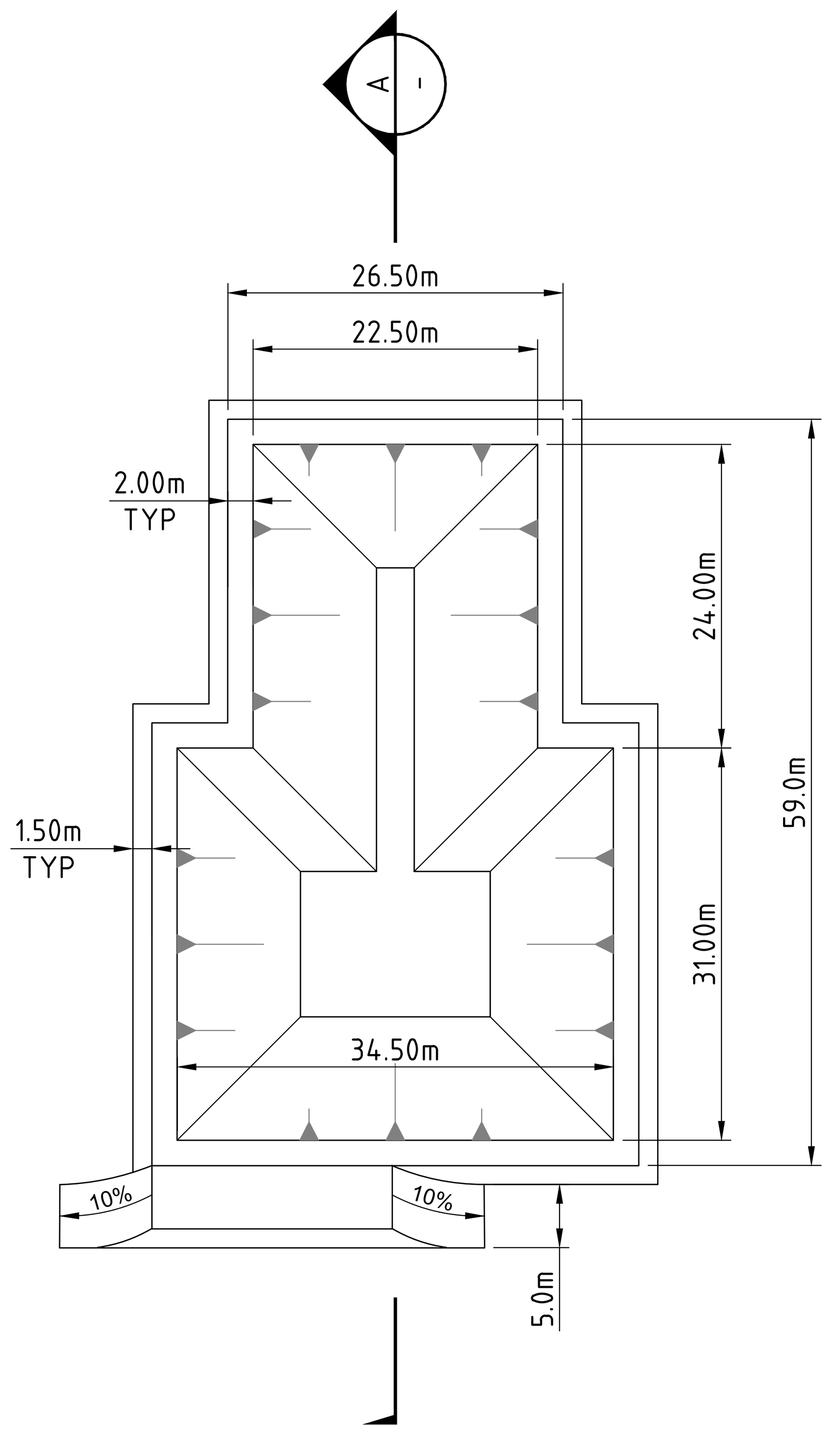
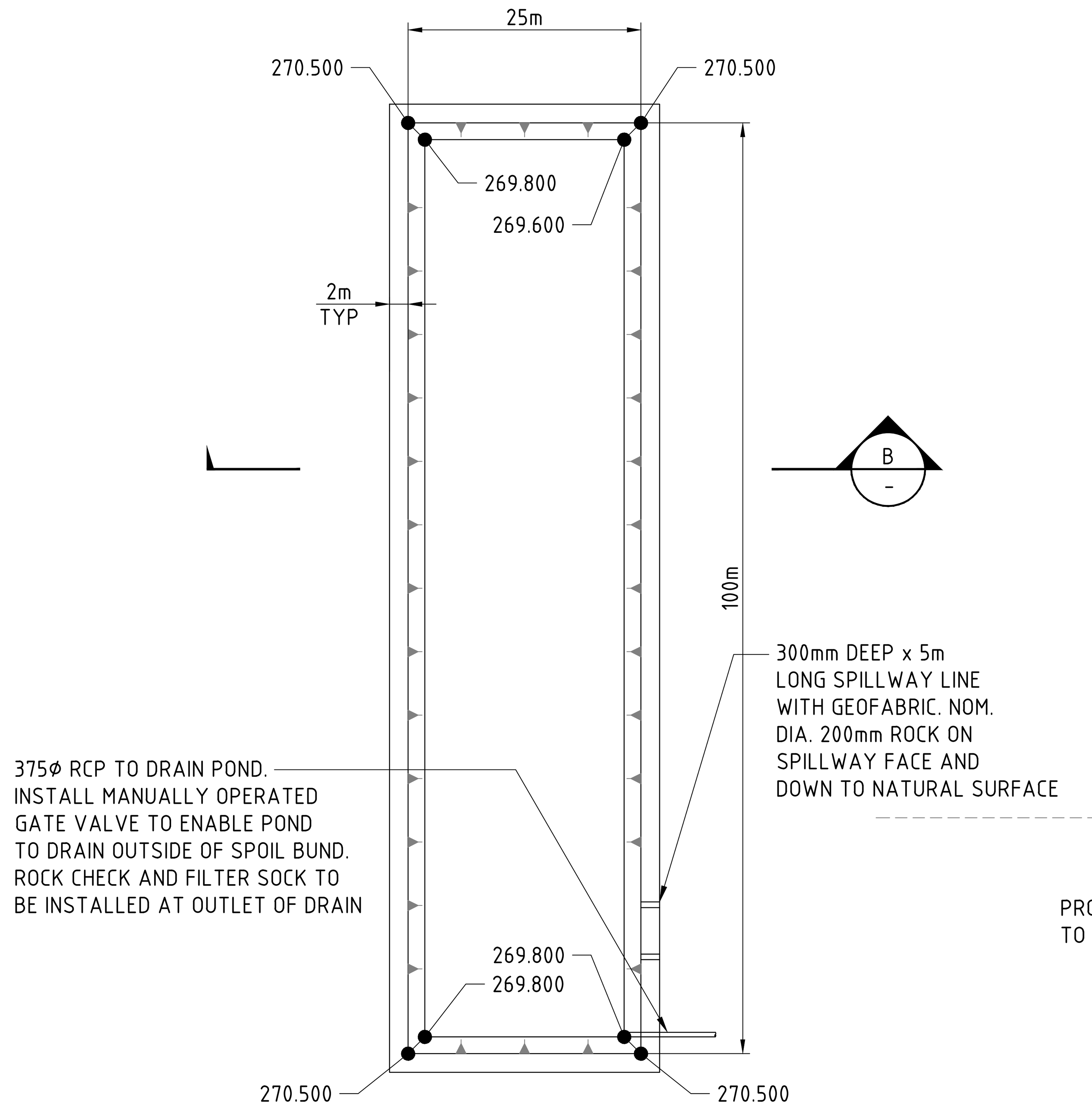


PLAN - MUD SUMP

Scale N.T.S.



PLAN - SECONDARY CONTAINMENT

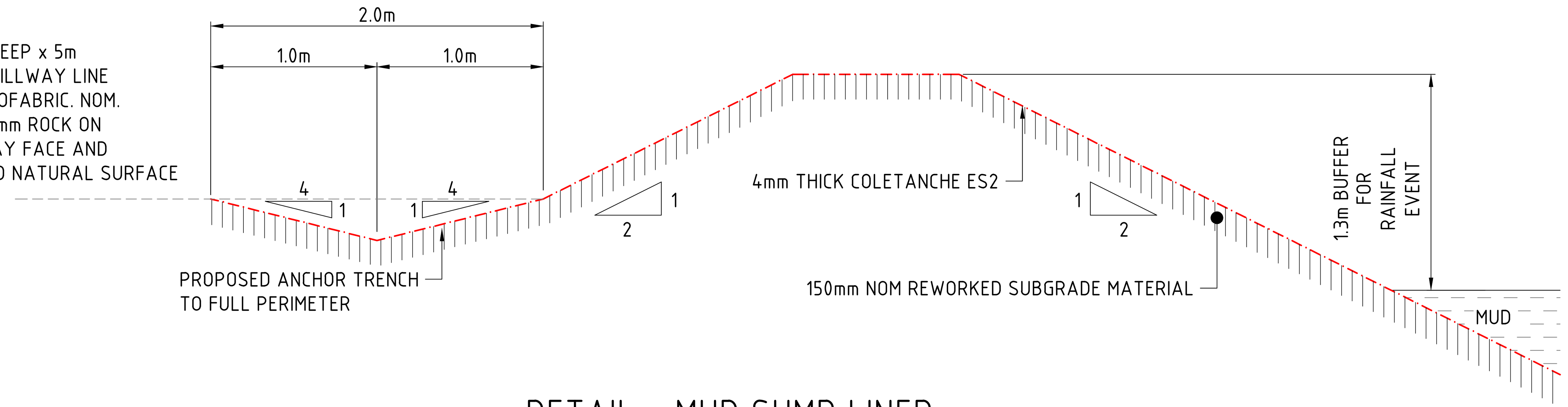
Scale N.T.S.

NOTES:

1. ALL UNITS ARE IN MILLIMETRES (mm) UNLESS NOTED OTHERWISE.
2. GROUND CONDITIONS AND SUITABLE MATERIALS TO BE CONFIRMED ON SITE BY SUPERINTENDENT.
3. REFER TO SPECIFICATION FOR COMPACTION REQUIREMENTS.
4. REFER TO SPECIFICATION FOR GENERAL REQUIREMENTS.
5. THE CONTRACTOR IS TO NOTIFY THE ORIGIN SUPERVISOR IF AREAS OF SOFT GROUND ARE ENCOUNTERED OR IF THE SPECIFICATION CANNOT BE ACHIEVED.
6. REFER TO DRAWING NT-2050-20-DA-0023 FOR SETOUT DETAILS OF MUD SUMP.
7. FAUNA LADDERS TO BE INSTALLED TO MUD SUMP.
8. CONTRACTOR TO PROVIDE CATTLE PANELS FOR FENCING AROUND SUMP WHERE DEPTH IS GREATER THAN 1.5m.
9. FENCE OR BARRICADE TO BE INSTALLED AT SUMP LOAD OUT LOCATION TO ENSURE VEHICLES DO NOT COMPROMISE SUMP WALL/ENTER SUM.
10. MUD SUMP VEHICLE OFFLOAD AREA TO BE COMPACTED TO 200 KPa

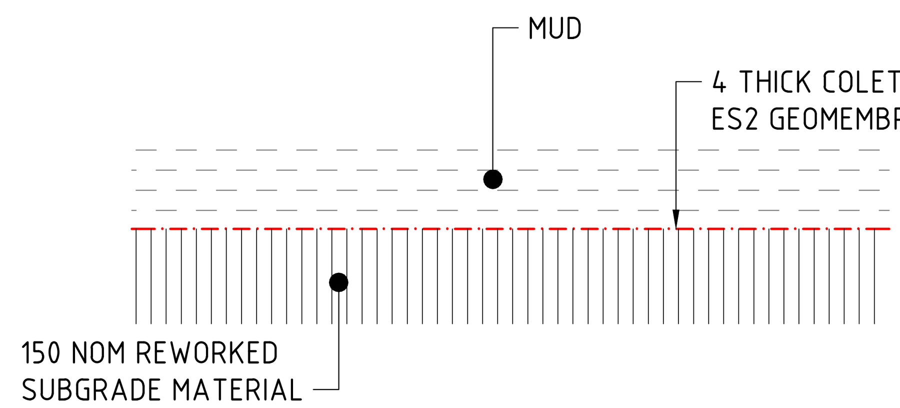
NOTES:

1. GEOSYNTHETICS ARE DRAWN EXAGGERATED FOR CLARITY.



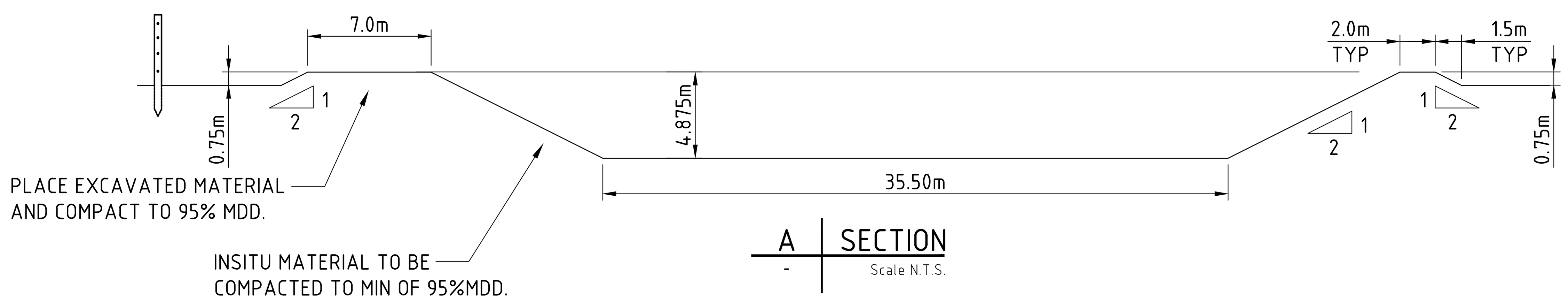
DETAIL - MUD SUMP LINER

Scale N.T.S.

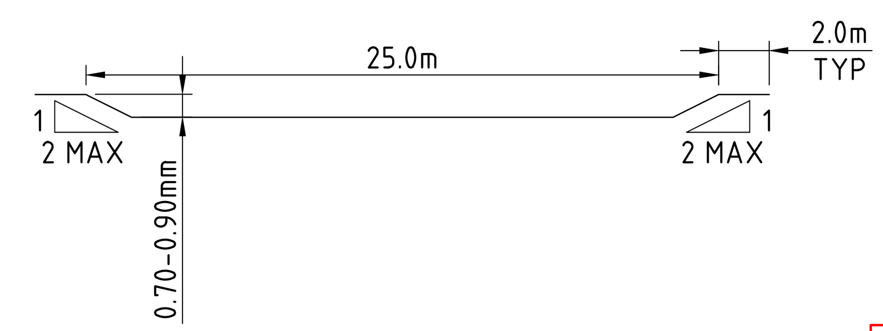


DETAIL - BASE LINER

Scale N.T.S.



A | SECTION
- Scale N.T.S.



B | SECTION
- Scale N.T.S.

ISSUED FOR CONSTRUCTION

DRAWING NO.	REFERENCE DRAWING TITLE	REV	DATE	REVISION DESCRIPTION	DRAWN	DWG CHECK	DESIGN	ENG DES CHECK
NT-2050-20-DA-0022	GENERAL ARRANGEMENT PLAN	1	16.04.19	REISSUED FOR CONSTRUCTION	CRD	PCM	PCM	JMJ
		0	11.04.19	ISSUED FOR CONSTRUCTION	CRD	PCM	PCM	JMJ

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	BY	DATE
DRAWN	CRD	20.03.2019
DWG CHECK	PCM	20.03.2019
DESIGN	PCM	20.03.2019
ENG DES CHECK	JMJ	20.03.2019
ORIGIN DRAFT. SUPER.		
ORIGIN PROJECT APPROVAL		

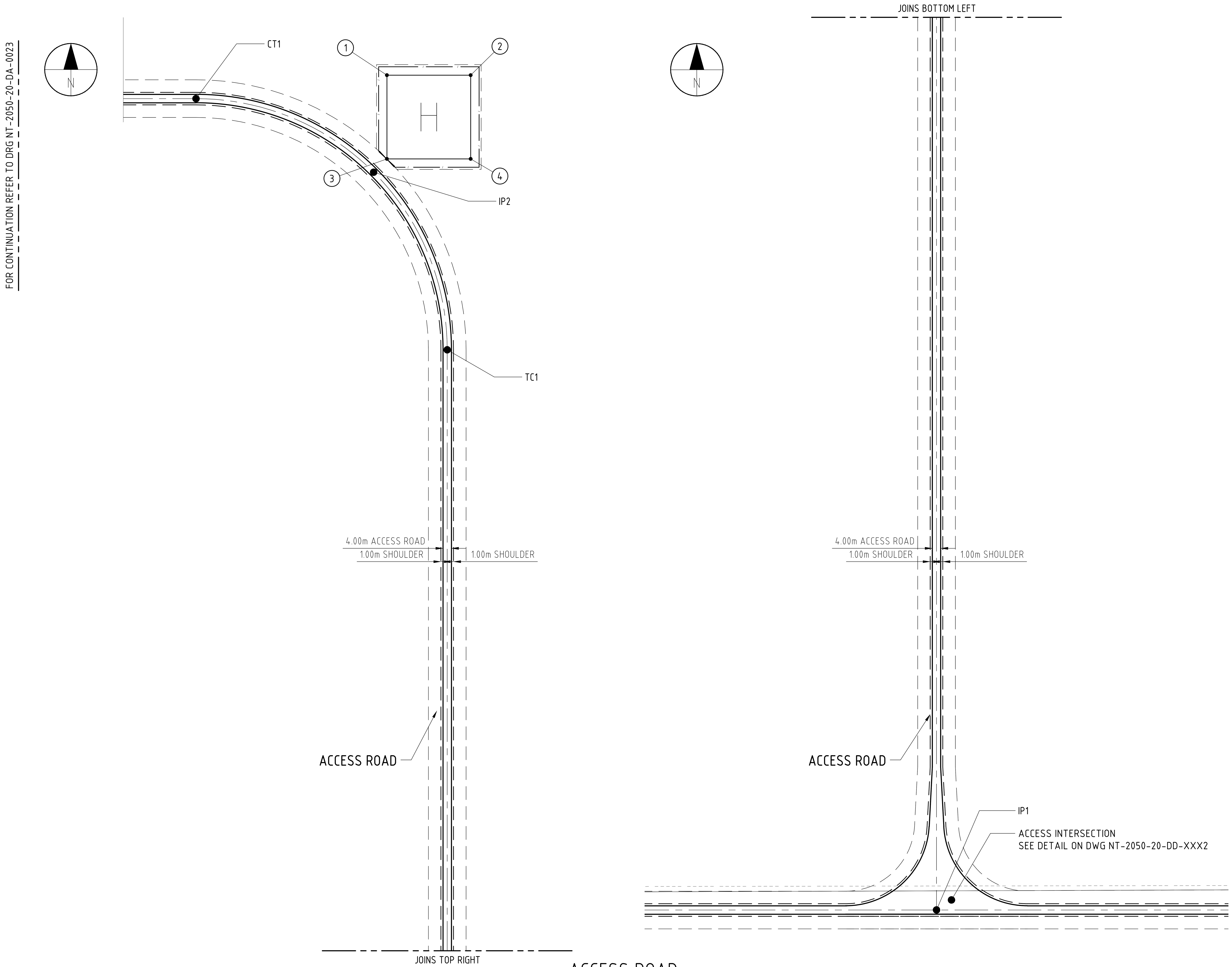
TITLE
BEETALOO EXPLORATION DRILL CAMPAIGN
VELKERRI 76 S2-1
MUD SUMP DETAILS

PROJECT NO. | MOD NO. | SCALE 1:1000 @ A1

DRAWING NO. NT-2050-20-DD-0031 | REVISION 1 | A1

CADFILE NT-2050-20-DD-0031.dwg

Thu, 18 Apr 2019 - 1:51pm   P:\604X\60480548\5. CAD\20-SHEETS\VELKERRI 76 S2-1\NT-2050-20-DD-0031.DWG   Dudley, Calvin



ACCESS ROAD

LEGEND

EXISTING

- CONTOURS

PROPOSED

- ACCESS ROAD CENTERLINE
- EDGE OF PAVEMENT
- EDGE OF SHOULDER
- EDGE OF FOOTPATH
- EXTENT OF CLEARING - (EXTENT OF FIRE BREAK)
- EDGE OF FENCELINE

NOTES:

1. ALL DIMENSIONS ARE IN METRES UNLESS NOTED OTHERWISE.
2. ALL WORKS TO BE CARRIED OUT IN ACCORDANCE WITH THE APPROVED MANAGEMENT PLAN REQUIREMENTS.
3. NO CONSTRUCTION WORKS ARE TO BE CARRIED OUT OUTSIDE THE APPROVED WORK CORRIDOR BOUNDARIES.
4. CONSTRUCTION FACILITY AREA LOCATIONS TO BE APPROVED BY THE ORIGIN SUPERVISOR PRIOR TO WORKS COMMENCING.
5. THE CONTRACTOR IS TO LIAISE WITH SERVICE PROVIDERS AND THE RELEVANT AUTHORITIES TO ENSURE ALL CONSTRUCTION WORKS ARE CARRIED OUT IN ACCORDANCE WITH SERVICE PROVIDERS AND RELEVANT AUTHORITIES REQUIREMENTS.
6. NO SERVICES WERE PRESENT OR PROVIDED BY DBYD AT THE TIME OF DESIGN AND ARE THEREFORE NOT SHOWN, HOWEVER THE CONTRACTOR IS RESPONSIBLE FOR CONDUCTING A SEARCH PRIOR TO WORKS BEING CARRIED OUT. ANY DAMAGE TO EXISTING SERVICES IS TO BE RE-INSTATED AT THE CONTRACTORS EXPENSE.
7. SIGNAGE TO BE INSTALLED PRIOR TO ROAD USE.
8. LOCATION OF INTERSECTION IS TO BE CONFIRMED BY CONTRACTOR ON SITE.
9. TRAFFIC ROAD SIGNAGE TO COMPLY WITH AS1743 AND NORTHERN TERRITORY GUIDELINES.
10. REFER TO DRG. NT-2050-20-DD-0023 FOR ROAD PAVEMENT DETAILS.
11. FINISH SURFACE LEVELS ARE TO FOLLOW EXISTING SURFACE LEVELS AS NEAR AS POSSIBLE AND TO THE GRADES SPECIFIED ON THE DRAWINGS.
12. TABLE DRAINS ARE TO BE CUT ALONG THE LENGTH OF THE ROAD AND ALL ROAD PAVEMENTS ARE TO HAVE A 4% CROSSFALL IN ACCORDANCE WITH THE ROAD CROSS-SECTION DETAILED ON DRG. NT-2050-20-DD-0023.
13. FOR CONTINUATION OF ROAD SETOUT REFER TO DRG. NT-2050-20-DA-0023.

PRELIMINARY

NOT FOR CONSTRUCTION

SCALE (m) 0 10 20 30 40 50 1:1000 (A1)

DRAWING NO.	REFERENCE DRAWING TITLE	REV	DATE	REVISION DESCRIPTION	DRAWN	DWG CHECK	DESIGN	ENG DES CHECK	DE DRAFT SUPER	DE PROJECT APPROVAL
NT-2050-20-DA-XXX2	PAD INTERSECTION DETAIL									
NT-2050-20-DA-0023	GENERAL ARRANGEMENT PLAN	A	21.03.2019	PRELIMINARY ISSUE	CD	-	-	-	-	-

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PROJECT 60480548 BEETALOO EXPLORATION
DRAWING OFFICE DARWIN
PROJECT APPROVALS - OTHERS

origin

Origin Energy Ltd
ABN 30 000 051 696
GPO Box 148
Brisbane Qld. 4001
Ph: (07) 3858 0600
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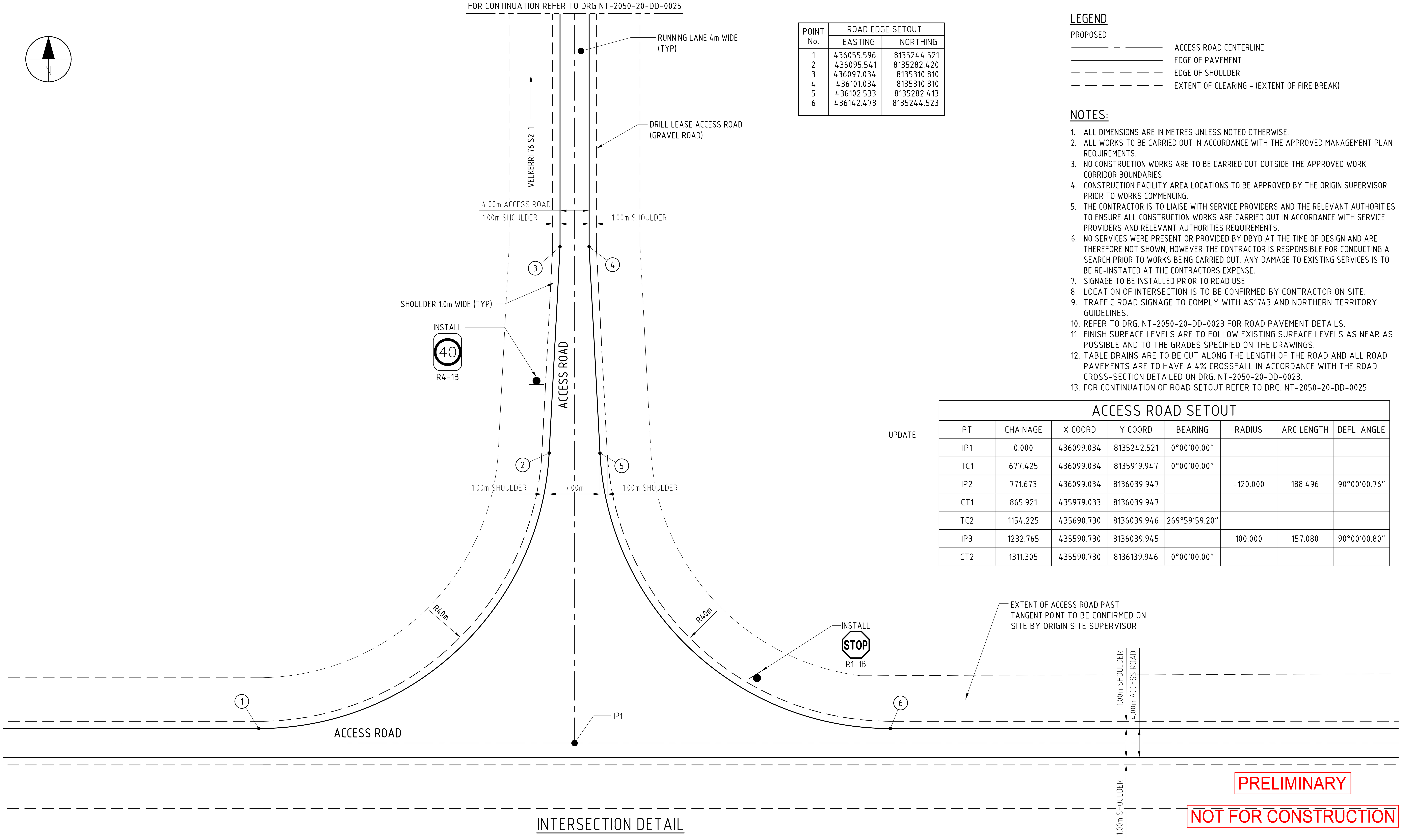
	BY	DATE
DRAWN	CD	
DWG CHECK	-	
DESIGN	-	
ENG DES CHECK	-	
ORIGIN DRAFT. SUPER.	-	
ORIGIN PROJECT APPROVAL	-	

TITLE
BEETALOO EXPLORATION DRILL CAMPAIGN
VELKERRI 76 S2-1
DRILL PAD, ACCOMODATION CAMP AND WATER TANK
ACCESS ROAD

PROJECT NO.
MOD NO.
SCALE 1:1000 @ A1
DRAWING NO. NT-2050-20-DD-0025
REVISION A
CADFILE NT-2050-20-DD-0025.dwg
A1

Thu, 18 Apr 2019 - 1:51pm P:\604X\60480548\5. CAD\20-SHEETS\VELKERRI 76 S2-1\NT-2050-20-DD-0025.DWG Dudley, Calvin



POINT No.	ROAD EDGE SETOUT	
	EASTING	NORTHING
1	436055.596	8135244.521
2	436095.541	8135282.420
3	436097.034	8135310.810
4	436101.034	8135310.810
5	436102.533	8135282.413
6	436142.478	8135244.523

LEGEND

PROPOSED

- ACCESS ROAD CENTERLINE
- EDGE OF PAVEMENT
- EDGE OF SHOULDER
- EXTENT OF CLEARING - (EXTENT OF FIRE BREAK)

NOTES:

1. ALL DIMENSIONS ARE IN METRES UNLESS NOTED OTHERWISE.
2. ALL WORKS TO BE CARRIED OUT IN ACCORDANCE WITH THE APPROVED MANAGEMENT PLAN REQUIREMENTS.
3. NO CONSTRUCTION WORKS ARE TO BE CARRIED OUT OUTSIDE THE APPROVED WORK CORRIDOR BOUNDARIES.
4. CONSTRUCTION FACILITY AREA LOCATIONS TO BE APPROVED BY THE ORIGIN SUPERVISOR PRIOR TO WORKS COMMENCING.
5. THE CONTRACTOR IS TO LIAISE WITH SERVICE PROVIDERS AND THE RELEVANT AUTHORITIES TO ENSURE ALL CONSTRUCTION WORKS ARE CARRIED OUT IN ACCORDANCE WITH SERVICE PROVIDERS AND RELEVANT AUTHORITIES REQUIREMENTS.
6. NO SERVICES WERE PRESENT OR PROVIDED BY DBYD AT THE TIME OF DESIGN AND ARE THEREFORE NOT SHOWN, HOWEVER THE CONTRACTOR IS RESPONSIBLE FOR CONDUCTING A SEARCH PRIOR TO WORKS BEING CARRIED OUT. ANY DAMAGE TO EXISTING SERVICES IS TO BE RE-INSTATED AT THE CONTRACTORS EXPENSE.
7. SIGNAGE TO BE INSTALLED PRIOR TO ROAD USE.
8. LOCATION OF INTERSECTION IS TO BE CONFIRMED BY CONTRACTOR ON SITE.
9. TRAFFIC ROAD SIGNAGE TO COMPLY WITH AS1743 AND NORTHERN TERRITORY GUIDELINES.
10. REFER TO DRG. NT-2050-20-DD-0023 FOR ROAD PAVEMENT DETAILS.
11. FINISH SURFACE LEVELS ARE TO FOLLOW EXISTING SURFACE LEVELS AS NEAR AS POSSIBLE AND TO THE GRADES SPECIFIED ON THE DRAWINGS.
12. TABLE DRAINS ARE TO BE CUT ALONG THE LENGTH OF THE ROAD AND ALL ROAD PAVEMENTS ARE TO HAVE A 4% CROSSFALL IN ACCORDANCE WITH THE ROAD CROSS-SECTION DETAILED ON DRG. NT-2050-20-DD-0023.
13. FOR CONTINUATION OF ROAD SETOUT REFER TO DRG. NT-2050-20-DD-0025.

ACCESS ROAD SETOUT

PT	CHAINAGE	X COORD	Y COORD	BEARING	RADIUS	ARC LENGTH	DEFL. ANGLE
IP1	0.000	436099.034	8135242.521	0°00'00.00"			
TC1	677.425	436099.034	8135919.947	0°00'00.00"			
IP2	771.673	436099.034	8136039.947		-120.000	188.496	90°00'00.76"
CT1	865.921	435979.033	8136039.947				
TC2	1154.225	435690.730	8136039.946	269°59'59.20"			
IP3	1232.765	435590.730	8136039.945		100.000	157.080	90°00'00.80"
CT2	1311.305	435590.730	8136139.946	0°00'00.00"			

INTERSECTION DETAIL

0 2.5 5.0 7.5 10.0 12.5
SCALE (m) 1:250 (A1)

0 10 20 30 40 50
SCALE (m) 1:1000 (A1)

DRAWING NO.	REFERENCE DRAWING TITLE	REV	DATE	REVISION DESCRIPTION	DRAWN	DWG CHECK	DESIGN	ENG DES CHECK	OE DRAFT SUPER	OE PROJECT APPROVAL
NT-2050-20-DD-0023	DESIGN DETAILS									
NT-2050-20-DD-0025	ACCESS ROAD	A	21.03.2019	PRELIMINARY ISSUE	CD	-	-	-	-	-

APPROVALS

PREPARED FOR ORIGIN BY:

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ORIGIN PROJECT APPROVAL	-	— . — . —

TITLE
BEETALOO EXPLORATION DRILL CAMPAIGN
VELKERRI 76 S2-1
DRILL PAD, ACCOMODATION CAMP AND WATER TANK
PAD INTERSECTION DETAIL

PROJECT NO.
MOD NO.
SCALE 1:1000 @ A1
DRAWING NO. NT-2050-20-DD-0032
REVISION A
CADFILE NT-2050-20-DD-0032.dwg
A1

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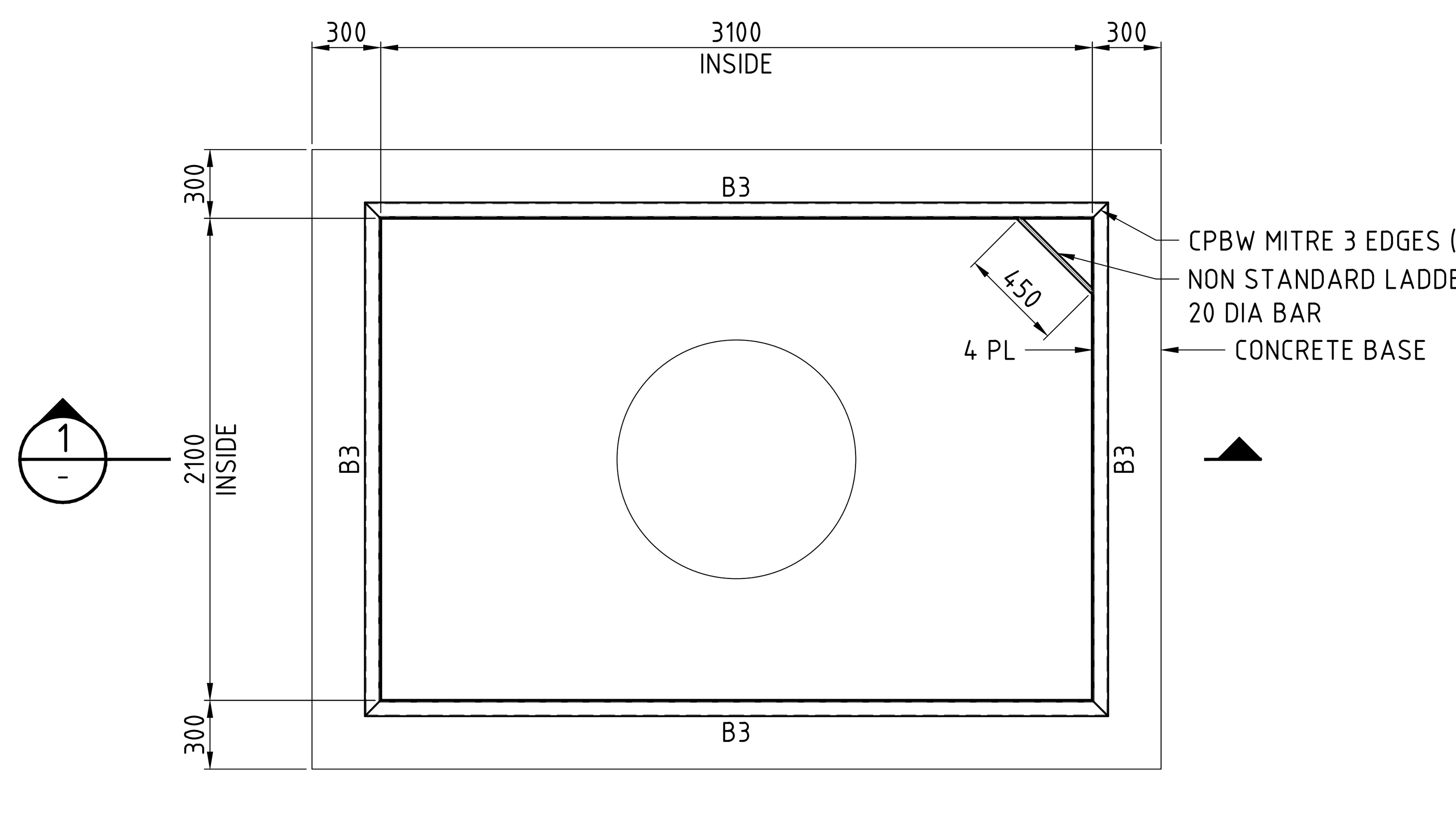
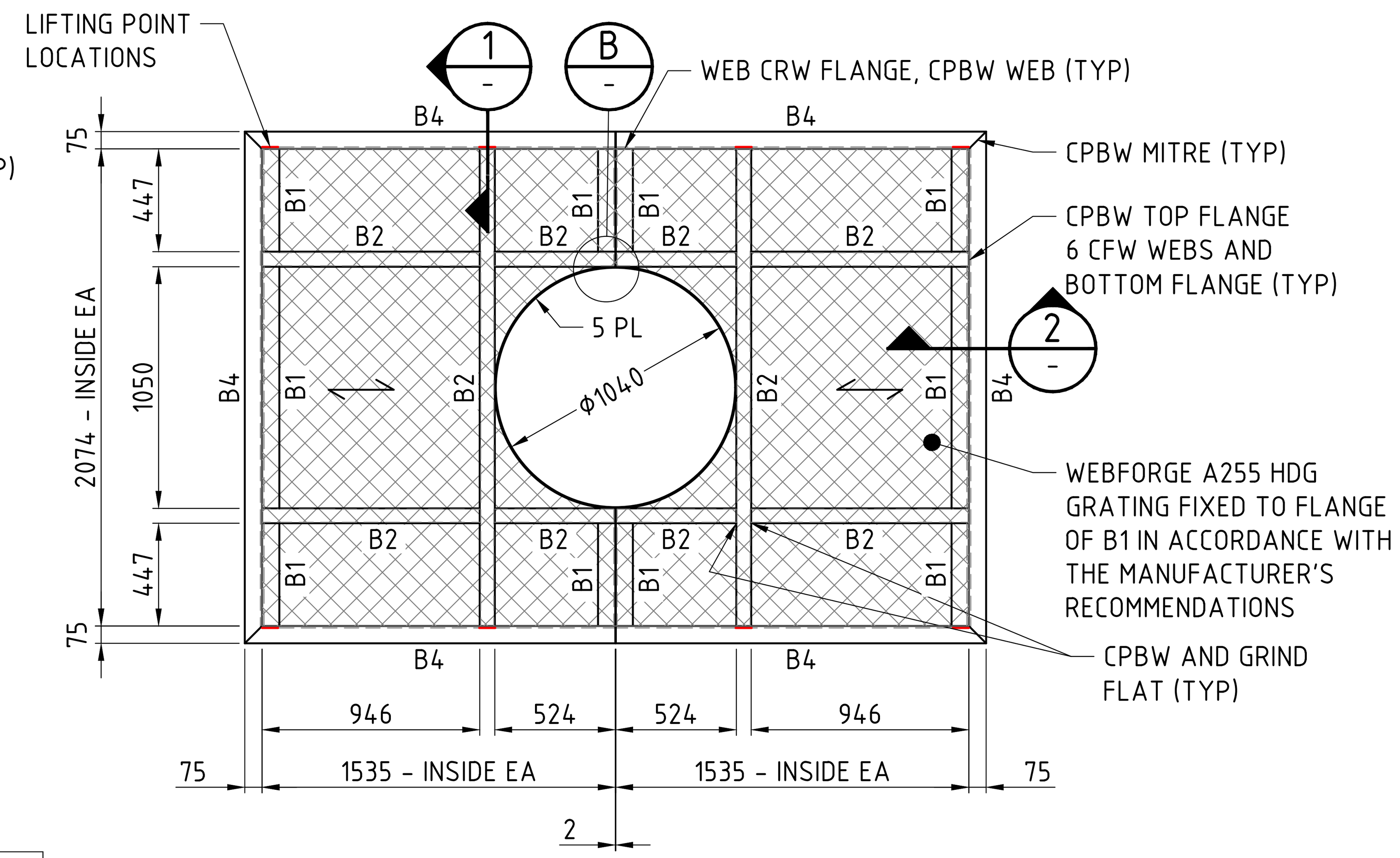
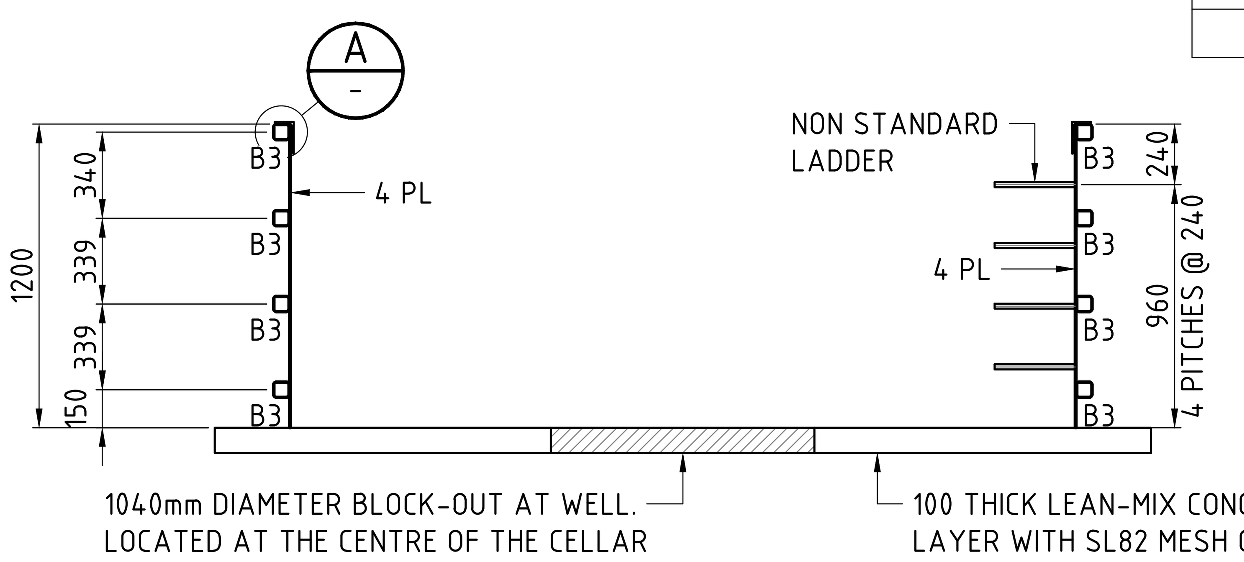


CELLAR PLAN
SCALE 1:25

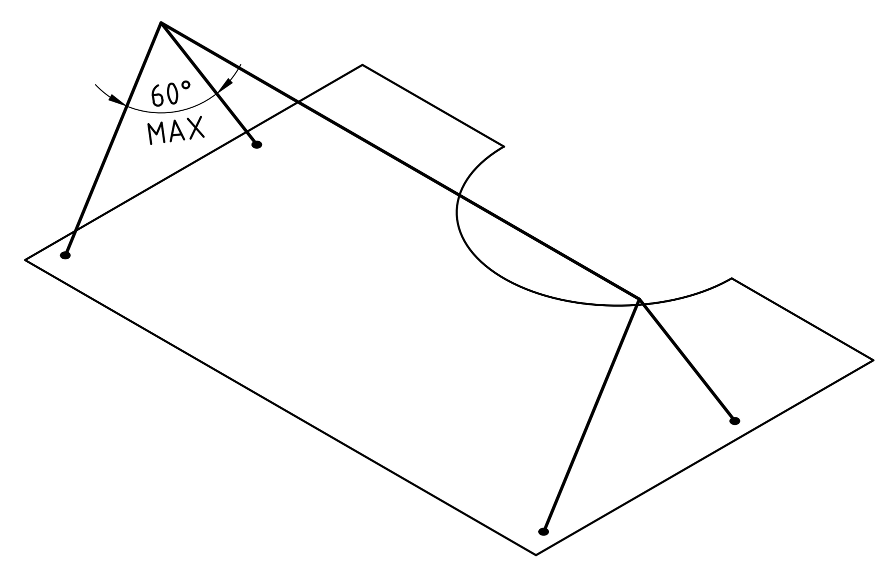


CELLAR COVER PLAN
SCALE 1:25
GRATING SPAN DIRECTION

MEMBER SCHEDULE	
MARK	SIZE
B1	75x8 EA
B2	65x4 SHS
B3	65x4 SHS
B4	125x75x8 UA



SECTION 1
SCALE 1:25



LIFTING DIAGRAM

LIFTING NOTES

- DESIGN ASSUMES A DYNAMIC IMPACT FACTOR Kd=1.2 AND FACTOR OF SAFETY (FOS) OF 3.0
- SLING ANGLE MUST BE 60 DEGREES MAXIMUM AT THE HOOK.
- LIFTING BEAM SHALL HAVE WWL200kg STAMPED INTO FLANGE

GENERAL NOTES

- THE FOOTINGS HAVE BEEN DESIGNED FOR A SAFE BEARING PRESSURE OF 50 kPa.
- THE FOOTING DEPTH SHALL BE CHECKED BY THE SUPERINTENDENT AFTER EXCAVATION, AND THE DEPTH MAY BE VARIED FROM THAT DETAILED ON THE DRAWINGS DEPENDING ON THE EXACT LOCATION OF THE LOAD BEARING STRATA.
- FILL UNDER BUILDING FLOOR SLABS:
  GRANULAR MATERIAL COMPACTED TO A DRY DENSITY RATIO NOT LESS THAN 98% (STANDARD COMPACTION).
- FILL UNDER PAVEMENT SLABS:
  GRANULAR MATERIAL TO A MIN. THICKNESS OF 50mm UNO ALL FILL AND TOP 150mm OF SUBGRADE COMPACTED TO A DRY DENSITY RATIO NOT LESS THAN 98% (STANDARD COMPACTION).
- DESIGN LIVE LOADS HAVE BEEN CALCULATED IN ACCORDANCE WITH A.S. 1170 PART 1 & A.S. 1657.
- DESIGN LIVE LOAD SURCHAGE ON SOIL 5 kPa
- THESE DRAWINGS SHALL BE READ IN CONJUNCTION WITH THE ARCHITECTS AND OTHER ENGINEERS DRAWINGS, AND ALL DIMENSIONS AND DETAILS SHALL BE CHECKED WITH THEIR DRAWINGS AND ON SITE.
- TRADE NAMES HAVE BEEN USED ONLY TO ESTABLISH A BASIC REQUIREMENT AND ANY SATISFACTORY EQUIVALENT MAY BE SUBMITTED FOR REVIEW.
- ALL DIMENSIONS OF EXISTING STRUCTURES SHALL BE CHECKED PRIOR TO FABRICATION AND ERECTION.
- DURING CONSTRUCTION THE CONTRACTOR SHALL BE RESPONSIBLE FOR MAINTAINING THE STRUCTURE AND EXCAVATIONS IN A STABLE CONDITION, AND ENSURING NO PART SHALL BE OVERSTRESSED UNDER CONSTRUCTION ACTIVITY.

CONCRETE NOTES

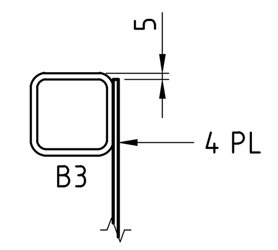
- CONCRETE, CONCRETE WORK, AND STEEL REINFORCEMENT SHALL CONFORM TO A.S. 3600, CONCRETE STRUCTURES.
- THE PROPORTION OF FLY ASH SHALL BE 25% BY WEIGHT OF THE TOTAL COMBINED WEIGHT OF FLY ASH AND CEMENT.
- MAXIMUM SLUMP OF CONCRETE = 80±15mm UNO.
- MAXIMUM NOMINAL SIZE OF AGGREGATE = 20mm.
- PLACE 2.N12 REINFORCING BARS X 1000 LONG IN TOP REINF. LAYER DIAGONALLY ACROSS ALL RE-ENTRANT CORNERS AND OPENINGS.
- REINFORCEMENT SHOWN ON DRAWINGS IS REPRESENTED DIAGRAMMATICALLY AND NOT NECESSARILY IN TRUE PROJECTION.
- ALL REINFORCEMENT HOOKS AND COGS SHALL BE STANDARD UNLESS SHOWN OR NOTED OTHERWISE ON THE DRAWINGS.
- ALL REINFORCING STEEL SHALL BE ACRS (AUSTRALIAN CERTIFICATION AUTHORITY FOR REINFORCING AND STRUCTURAL STEEL) CERTIFIED.

STEELWORK NOTES

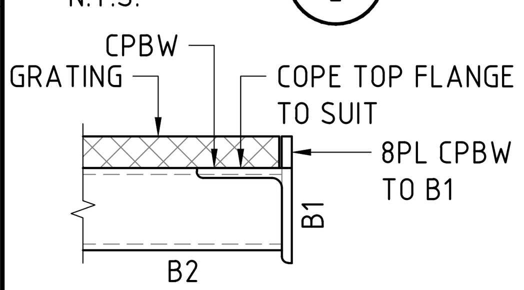
- ALL STEELWORK SHALL CONFORM TO A.S. 4100, STEEL STRUCTURES.
- STEEL GRADES: 300 UNO.
  SHS - 350.
  PLATES - 250.
- FABRICATION SHALL BE CARRIED OUT BY WELDERS WHO ARE QUALIFIED IN ACCORDANCE WITH THE REQUIREMENTS OF A.S./NZS 1554.1.
- THE BOLTING PROCEDURE ADOPTED UNLESS NOTED OTHERWISE IS 8.8/S IN ACCORDANCE WITH THE AUSTRALIAN INSTITUTE OF STEEL CONSTRUCTION - MANUAL OF STANDARDISED STRUCTURAL CONNECTIONS.
- ALL BOLTS OR FASTENERS SHALL BE MARKED WITH THE MANUFACTURERS BRAND, AND COMPLY WITH THE FOLLOWING :
  - BOLTS DENOTED 4.6/S ARE COMMERCIAL BOLTS OF STRENGTH GRADE 4.6 TO A.S. 1111 - SNUG TIGHT.
  - BOLTS DENOTED 8.8/S, 8.8/TF, OR 8.8/TB ARE HIGH STRENGTH STRUCTURAL BOLTS OF STRENGTH GRADE 8.8 TO A.S. 1252.
- BOLTS SHALL BE M20 8.8/S UNO.
- GRADE 8.8 BOLTS SHALL NOT BE WELDED, INCLUDING TACK WELDS FOR CAGING.
- PLATES IN STRUCTURAL STEEL CONNECTIONS SHALL BE 10mm THICK UNO
- MINIMUM CONNECTIONS SHALL BE 10PL. 2/M20 8.8/S BOLTS UNO.
- ALL BOLTS (INCLUDING MASONRY ANCHORS) SHALL BE HOT DIPPED GALVANISED.
- ALL WELDS SHALL BE 6 CFW UNLESS NOTED OTHERWISE.
- ALL WELDS SHALL BE CATEGORY S.P. AS SPECIFIED IN A.S. 1554, UNO.
- ELECTRODES SHALL BE B-G49X OR B-T49X UNO.
- ALL RHS AND CHS MEMBERS SHALL HAVE 5 PL. SEAL PLATES AT ENDS UNO.
- PROTECTIVE COATING SHALL BE EITHER
  - ALL STEELWORK SSHALL BE BLAST CLEANED TO CLASS 2½ AS SPECIFIED IN AS 1627.4 WITH SURFACE ROUGHNESS OF 75 MICRONS
  - 2 COATS OF IMMERSION GRADE EPOXY TO DRY FILM THICKNESS 400 MICRONS (EACH COAT).

  OR

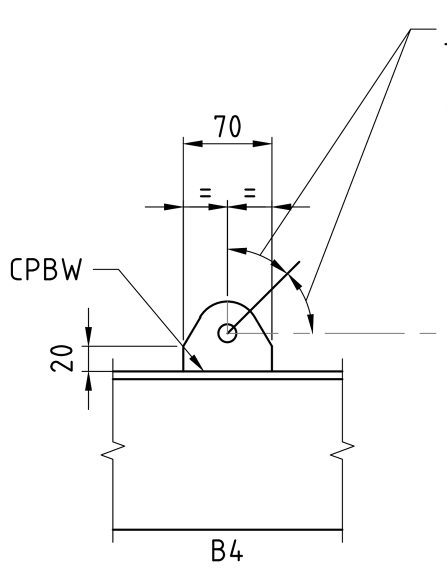
  - HOT DIP GALVANISED TO AS4680
- SHOP DRAWINGS SHALL BE SUBMITTED BEFORE COMMENCEMENT OF FABRICATION. GRADE OF SANDBLASTING, PAINT BRAND, TYPE, FILM THICKNESS AND WELD CATEGORY SHALL BE NOTED ON THESE DRAWINGS.
- ALL MEMBER CENTROIDS AT CONNECTIONS SHALL INTERSECT AT A POINT UNO GAUGE LINES MAY BE USED IN LIEU OF CENTROIDS FOR BOLTED END CONNECTIONS OF ANGLES.
- ALL STRUCTURAL STEEL SHALL BE ACRS (AUSTRALASIAN CERTIFICATION AUTHORITY FOR REINFORCING AND STRUCTURAL STEEL) CERTIFIED.



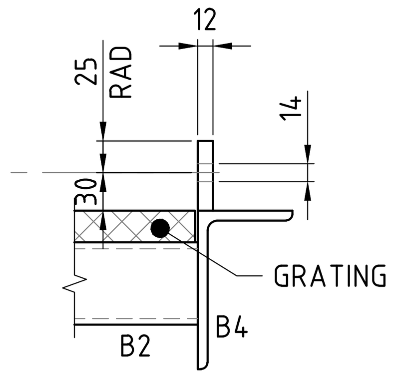
DETAIL A
N.T.S.



DETAIL B
N.T.S.



LIFTING POINT
N.T.S.



SECTION 1
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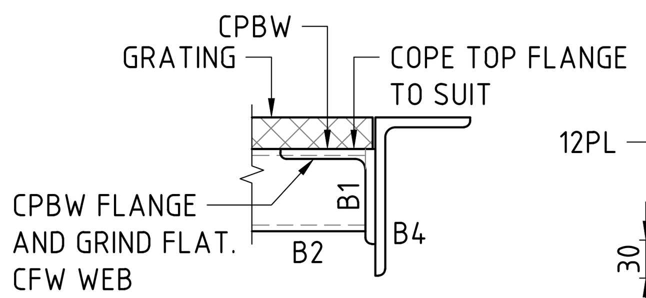
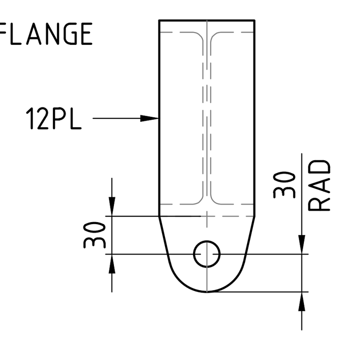
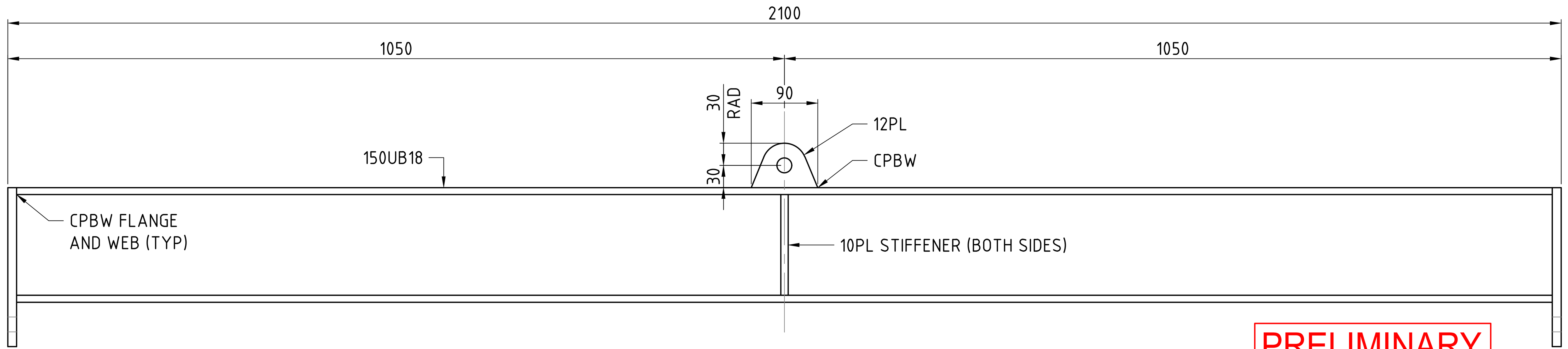


SECTION 2
N.T.S.



END ELEVATION
LIFTING BEAM
N.T.S.



LIFTING BEAM
N.T.S.

PRELIMINARY

NOT FOR CONSTRUCTION

REV	DATE	REVISION DESCRIPTION
A	21.03.2019	PRELIMINARY ISSUE

DRAWING NO. | REFERENCE DRAWING TITLE | DRAWN | DWG CHECK | DESIGN | ENG DES CHECK | OE DRAFT SUPER | OE PROJECT APPROVAL | APPROVALS

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O.E. DRAFT. SUPER.	-	- . - . -
O.E. PROJECT APPROVAL	-	- . - . -

TITLE
BEETALOO EXPLORATION DRILL CAMPAIGN
VELKERRI 76 S2-1
DRILLING CELLAR DETAILS

PROJECT NO. | MOD NO. | SCALE 1:25 @ A1
DRAWING NO. NT-2050-20-DD-0027
REVISION A
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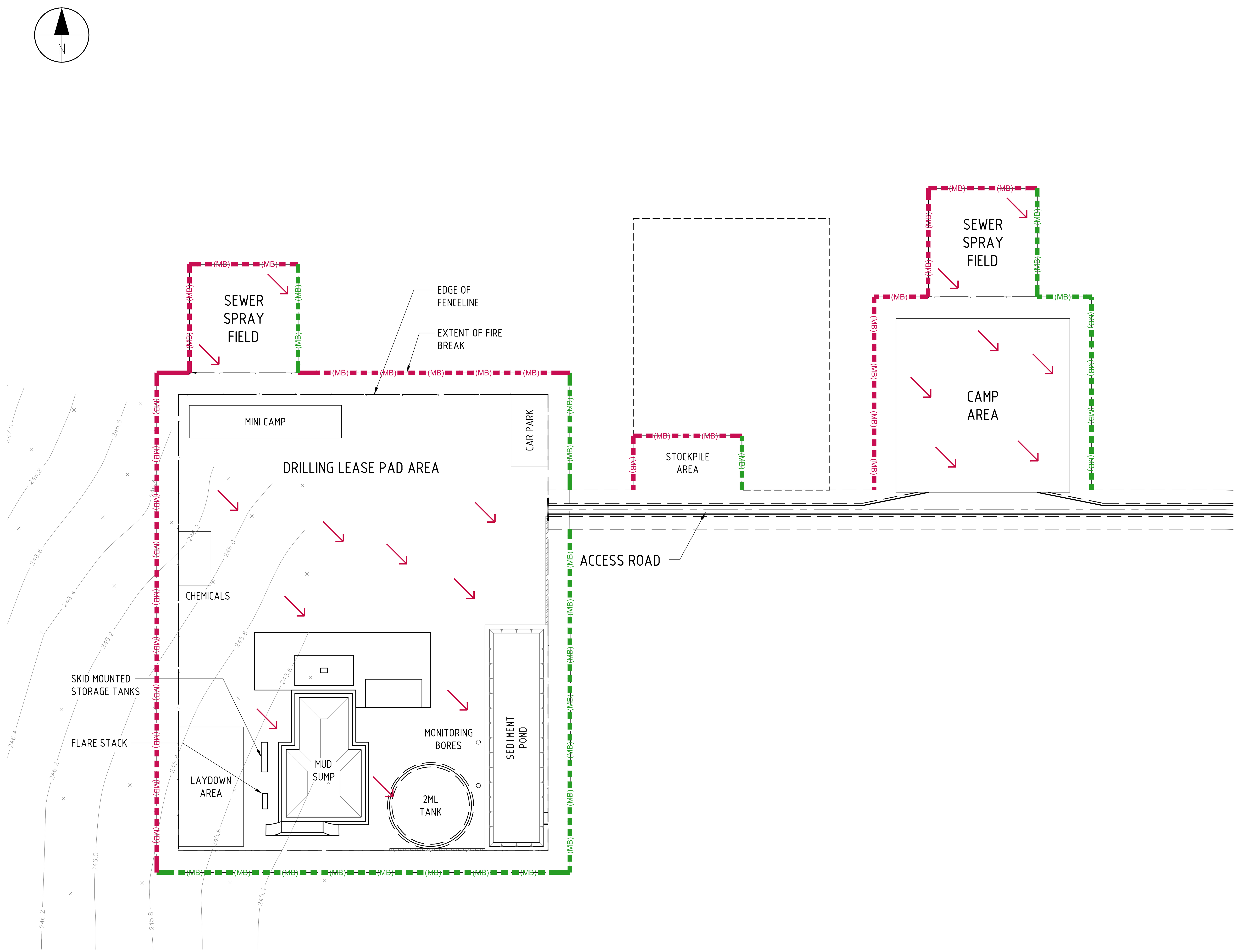

LEGEND

EXISTING

CONTOURS

PROPOSED

(MB) TOPSOIL BERM (DIRTY WATER)

(MB) TOPSOIL BERM (CLEAN WATER)

FLOW DIRETION

U-SHAPED SEDIMENT TRAP

NOTES:

1. ALL WORKS TO BE IN ACCORDANCE WITH THE INTERNATIONAL EROSION CONTROL ASSOCIATION (IECA) GUIDELINES.
2. TOPSOIL STRIPPING DEPTH ASSESSMENT MUST BE UNDERTAKEN IN ACCORDANCE WITH THE BEETALOO TOPSOIL STRIPPING TECHNICAL INSTRUCTION (NT-2050-15-TI-0001) AND AMELIORATION RATES AGREED WITH THE ORIGIN SUPERVISOR. THE EXPECTED NOMINAL TOPSOIL DEPTH FOR THE SITE IS 150mm, FINAL STRIP DEPTH TO BE CONFIRMED IN THE FIELD.
3. MAINTENANCE OF ESC DEVICES:
   - THE CONTRACTOR SHALL INSPECT ALL ENVIRONMENTAL DEVICES ON A REGULAR BASIS. ANY RECTIFICATION OF DAMAGE TO THE ENVIRONMENTAL CONTROL DEVICES OR CLEANING OUT OF THE DEVICES IS TO BE CARRIED OUT BY THE CONTRACTOR AS REQUIRED.
   - REGULAR MAINTENANCE SHALL BE UNDERTAKEN UNTIL SUFFICIENT GROUND COVER IS ESTABLISHED TO PROVIDE STABILISATION TO ALL DISTURBED AREAS.
4. TOPSOIL BERM DIMENSIONS IN ACCORDANCE WITH IECA FIGURE 1 ON STANDARD DRAWING MB-01.
5. ALL ESC DEVICES WILL BE DESIGN AND INSTALLED IN ACCORDANCE WITH THE NT LAND CLEARANCE GUIDELINES.
6. THE CONTRACTOR MUST SUBMIT AN EROSION AND SEDIMENT CONTROL PLAN WHICH WILL BE APPROVED BY ORIGIN PRIOR TO MOBILISATION.

EROSION AND SEDIMENT CONTROL PLAN

PRELIMINARY

NOT FOR CONSTRUCTION

SCALE (m) 0 10 20 30 40 50 1:1000 (A1)

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-	-	A	21.03.2019	PRELIMINARY ISSUE	CD	-	-	-	-	-

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ORIGIN PROJECT APPROVAL	-	— . — . —

TITLE
BEETALOO EXPLORATION DRILL CAMPAIGN
VELKERRI 76 S2-1
DRILL PAD, ACCOMODATION CAMP AND WATER TANK
EROSION AND SEDIMENT CONTROL PLAN

PROJECT NO.
MOD NO.
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CADFILE NT-2050-15-MP-0022.dwg
REVISION A
A1

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143, avenue de Verdun
92130 Issy-les-Moulineaux
France
www.coletanche.com

Prepared: 12/06/2018
Cancels and replaces. 15/01/2018
Code : 1876901
Manufacture source Courchelettes (59-France)
Technical ref: FT AXTER ES2 ASTM

PRODUCT DATA SHEET

COLETANCHE ES 2

DESCRIPTION

COLETANCHE ES 2 is an SBS elastomeric modified bituminous geomembrane.

USE

Moderate level of mechanical resistance, for use an environmental protection and groundworks waterproofing, in particular :
- To cover landfill,
- Hydraulic ponds,
- Containment of Industrial liquid wastes,
- Canals ,
- Contamined land.

Product use must be validated by Axter

APPLICATION METHOD

By torch welding or other similar technique

STORAGE

Rolls must not be stored directly on the ground. Provide suitable supports (blocks, slides, wooden planks) with a minimum height of 35 cm to be placed under the ends of the mandrel.

COMPOSITION

(indicative)

Reinforcement (g/m²) :	Glass mat	50
Reinforcement (g/m²) :	Non-woven geotextile	250
Binder (g/m²) :	Elastomeric SBS	4300
Surface finish (g/m²) :	Sand	250
Under surface finish (g/m²) :	Polyester antiroot film	15

CHARACTERISTICS

		STANDARD	UNITS	AVERAGE	Minimum
Dimensions	Length	-	*m*	80	79
	Width		*m*	5.10	5.01
Thickness (on finished product)		*ASTM D 5199*	mm	4.00	*3.60*
Surface mass		*ASTM D 3776*	kg/m²	4.85	*4.30*
Resistance to tearing	Longitudinal	*ASTM D 4073*	N	825	*619*
	Cross direction			700	*525*
Tensile properties : maximum tensile strength	Longitudinal	*ASTM D 7275*	kN/m	27	*20.3*
	Cross direction			24	*15*
Tensile properties : elongation	Longitudinal		%	50	*35*
	Cross direction			50	*35*
Static Puncture		*ASTM D 4833*	N	530	*477*
Flexibility at low temperature	Longitudinal	*ASTM D 5147*	°C	-20	-15
	Cross direction			-20	-15
Water permeability (liquid tightness)		*ASTM E 96*	*m/s*	6.10^{-14}	<
Gas permeability (gas tightness)		*ASTM D 1434-82*	*m^3/(m².j.atm)*	2.10^{-4}	<

NOTE: AXTER COLETANCHE INC. may modify the composition and/or utilisation of its products without prior notice. Consequently orders will be filled according to the latest specification.

GENERAL

1. ALL WORK EXCLUDING WORK ASSOCIATED WITH LINER SUPPLY AND INSTALLATION SHALL BE COMPLETED IN ACCORDANCE WITH 'ORIGIN' TECHNICAL SPECIFICATION Q-4522-20-TS-0001: POND EARTHWORKS AND WITH PROJECT SPECIFIC DRAWINGS, PROJECT STANDARD DRAWINGS AND OTHER CONTRACT DOCUMENTATION AS APPLICABLE.
2. ALL WORK ASSOCIATED WITH LINER SUPPLY AND INSTALLATION SHALL BE COMPLETED IN ACCORDANCE WITH 'ORIGIN' TECHNICAL SPECIFICATION Q-4522-20-TS-0002 AND Q-4522-20-TS-0003.
3. THE CONTRACTOR SHALL TAKE OUT ALL APPROPRIATE LOCAL GOVERNMENT AND OTHER AUTHORITY PERMITS PRIOR TO COMMENCING WORK.
4. THE CONTRACTOR SHALL ASCERTAIN THE EXACT LOCATION OF ALL EXISTING SERVICES ON AND ADJACENT TO THE SITE OF THE WORK PRIOR TO COMMENCING THE WORK AND SHALL BE RESPONSIBLE FOR THE COST OF RECTIFICATION OF ANY DAMAGES TO THE EXISTING SERVICES OCCASIONED DURING THE WORK. LOCATIONS OF EXISTING SERVICES IF AND WHERE SHOWN ON THE DRAWINGS ARE APPROXIMATE ONLY. DRAWINGS MAY NOT INDICATE ALL EXISTING SERVICES.
5. THE CONTRACTOR SHALL PROGRAMME WORK AND INCORPORATE APPROPRIATE MEASURES TO MINIMISE DISTURBANCE TO OTHERS BY DUST, NOISE, FLOODING, SERVICES DISCONNECTIONS AND THE LIKE.
6. NOTWITHSTANDING THE EXTENT OF FILLING AND EXCAVATION WORK SHOWN ON THE DRAWINGS, NOTED IN THE SPECIFICATION OR NOTED IN OTHER CONTRACT DOCUMENTS, THE EXTENT OF THE WORK SHALL BE CONFIRMED WITH THE SUPERINTENDENT PRIOR TO COMMENCEMENT OF THE WORK.
7. THE CONTRACTOR SHALL MAINTAIN THE SITE FREE OF RUBBISH AND EXCESS MATERIALS AND SHALL STACK AND/OR STOCKPILE CONSTRUCTION MATERIALS IN A SUITABLE MANNER AS APPLICABLE FOR EACH OF THE INDIVIDUAL MATERIALS.

ENVIRONMENTAL AND SEDIMENT CONTROL NOTES

1. THE CONTRACTOR SHALL AVOID DISTURBANCE OF ENVIRONMENTALLY SENSITIVE AREAS. UNLESS NOTED OTHERWISE IN THE CONTRACT DOCUMENTS, THE CONTRACTOR SHALL INSTALL TEMPORARY FENCING (STAR PICKETS WITH 2 STRANDS OF PLAIN WIRE AND FLAGGING TO SUIT) ALONG THE BOUNDS OF ENVIRONMENTAL BUFFERS. THERE SHALL BE NO ENTRY INTO ENVIRONMENTAL BUFFER AREAS (BEYOND THE FENCED BOUNDS) UNLESS OTHERWISE APPROVED FOR BY THE SUPERINTENDENT.
2. THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE DESIGN, INSTALLATION AND MAINTENANCE OF ALL TEMPORARY EROSION AND SEDIMENT CONTROL DEVICES/MEASURES INCLUDING CUT OFF DRAINS AND BUNDS, REQUIRED DURING THE COURSE OF THE WORK AND UP UNTIL THE WORK IS TAKEN OFF MAINTENANCE.
3. A COPY OF THE PROPOSED EROSION AND SEDIMENT CONTROL PLAN, PREPARED IN ACCORDANCE WITH OTHER CONTRACT DOCUMENTATION, SHALL BE SUBMITTED TO THE SUPERINTENDENT PRIOR TO THE COMMENCEMENT OF WORK ON THE SITE.
4. THE CONTRACTOR SHALL INSTALL ALL SEDIMENT CONTROL DEVICES/MEASURES PRIOR TO COMMENCEMENT OF THE WORK PROPER. DURING THE COURSE OF THE WORK, THE CONTRACTOR SHALL INSTALL FURTHER SEDIMENT CONTROL DEVICES/MEASURES INCLUDING CUT OFF DRAINS AND BUNDS, DEEMED NECESSARY TO CONTROL SEDIMENT RUNOFF.
5. THE CONTRACTOR SHALL INSPECT ALL EROSION AND SEDIMENT CONTROL DEVICES/MEASURES FOR DAMAGE FOLLOWING EACH RAINFALL EVENT. DAMAGED DEVICES/MEASURES SHALL BE REMOVED AND REPLACED, SEDIMENT SHALL BE REMOVED AND ALL ERODED AREAS MADE GOOD.
6. ALL EROSION AND SEDIMENT CONTROL DEVICES/MEASURES SHALL BE CLEANED OUT PRIOR TO SEDIMENT VOLUME REACHING 50% OF THE CONTROL DEVICE/MEASURE CAPACITY.

POND EARTHWORKS

1. EARTHWORKS SHALL GENERALLY BE COMPLETED IN ACCORDANCE WITH 'ORIGIN' TECHNICAL SPECIFICATION Q-4522-20-TS-0001: POND EARTHWORKS AND WITH PROJECT SPECIFIC DRAWINGS, PROJECT STANDARD DRAWINGS AND OTHER CONTRACT DOCUMENTATION AS APPLICABLE.
2. TOPSOIL SHALL BE STRIPPED TO A DEPTH OF 150mm ACROSS THE EXTENTS OF THE WORK AND STOCKPILED FOR REUSE WHERE DIRECTED BY THE SUPERINTENDENT.
3. COMPACTION TESTING SHALL BE COMPLETED IN ACCORDANCE WITH THE SPECIFICATION.
4. THE PREPARED SURFACE/SURFACES TO BE LINED SHALL BE MAINTAINED (MOISTURE CONTENT AND LEVEL OF COMPACTION) UNTIL IMMEDIATELY PRIOR TO LINER INSTALLATION. WHERE INSTALLATION OF THE LINER IS DELAYED DUE TO ANY CAUSE WHATSOEVER AND/OR THE PREPARED SURFACE/SURFACES ARE SUBJECT TO ELEMENTS OF THE WEATHER WHICH RESULTS IN CHANGES IN THE MOISTURE CONTENT, COMPACTION AND INTEGRITY OF THE SURFACE/SURFACES, THE SURFACE/SURFACES SHALL BE REWORKED IMMEDIATELY PRIOR TO THE INSTALLATION OF THE LINER TO ACHIEVE THE SPECIFIED REQUIREMENTS FOR MOISTURE CONTENT, LEVEL OF COMPACTION AND SURFACE INTEGRITY.

TOPSOIL REINSTATEMENT AND AMENDMENT

1. TOPSOIL SHALL BE PLACED TO ALL DISTURBED AREAS EXCLUDING AREAS OCCUPIED BY PAVEMENTS, SPILLWAYS AND CAPPING MATERIAL OR AS DIRECTED BY THE SUPERINTENDENT.
2. FINISHED EARTHWORKS SURFACES TO RECEIVE TOPSOIL SHALL BE PREPARED IN ACCORDANCE WITH REQUIREMENTS STATED HEREIN.
   - 2.1. FINISHED EARTHWORKS SURFACES (SUBGRADE) TO BE TOPSOILED SHALL BE RIPPED/TYNED TO DEPTHS OF 150mm.
   - 2.2. GYPSUM SHALL BE SPREAD AT THE RATE OF 50 t/Ha (5 kg/m2) AND SHALL BE THOROUGHLY WORKED AND MIXED INTO THE LOOSENED MATERIAL/MATERIALS VIA TWO (2) PASSES OF A TWO (2) WAY DISC PLOW MINIMUM OR VIA ROTARY HOE.
   - 2.3. FOLLOWING MIXING, THE MATERIAL SHALL BE RESHAPED TO THE PROFILES REQUIRED OF THE FINISHED EARTHWORKS AND SHALL BE COMPACTED TO 95% MINIMUM OF THE MAXIMUM DRY DENSITY FOR THE MATERIAL - STANDARD COMPACTIVE EFFORT.
3. TOPSOIL WORK AND ASSOCIATED SUBGRADE AMENDMENT SHALL BE COMPLETED IMMEDIATELY FOLLOWING THE TRIMMING OF EARTHWORKS.
4. TOPSOIL SHALL BE PLACED TO A DEPTH OF 150mm.
5. TOPSOIL SHALL BE AMENDED BY THE INCLUSION OF 10 t/ha FEEDLOT MANURE, 100 kg/ha UREA AND 2 t/ha GYPSUM OR AS DIRECTED BY THE SUPERINTENDENT BASED ON SOIL ASSESSMENT.
6. GRASS SEED OF THE SPECIES AND MIX COMPOSITION AS DETERMINED BY ORIGIN ENERGY SHALL BE SOWN INTO THE TOPSOIL.

BITUMINOUS GEOMEMBRANE LINER PRODUCT DATA

1. DESCRIPTION - BGM IS AN SBS ELASTOMERIC MODIFIED BITUMINOUS GEOMEMBRANE.
2. USE - EXTREME LEVEL OF MECHANICAL RESISTANCE, FOR USE AS ENVIRONMENTAL PROTECTION AND GROUNDWORKS WATERPROOFING (AGGRESSIVE MATERIALS, REINFORCED PRECAUTIONS)
   - -RAILWAYS, DIRECTLY UNDER BALLAST
   - -DAMS
3. PRODUCT USE MUST BE VALIDATED BY THE MANUFACTURER.
4. APPLICATION METHOD - TORCHED.
5. STORAGE - ROLLS MUST NOT BE STORED DIRECTLY ON THE GROUND. THEY MUST BE LAID SUPPORTED ON CONCRETE BLOCKS, TRESTLES OR TIMBER BEAMS, MIN 35cm HEIGHT, PLACED UNDER MANDREL ENDS.

COMPOSITION	
GLASS MAT	50 g/m²
NON-WOVEN GEOTEXTILE	400 g/m²
ELASTOMERIC SBS	5400 g/m²
SAND	200 g/m²
POLYESTER ANTIROOT FILM	15 g/m²

CHARACTERISTICS		STANDARD	UNITS	VALUES	TOLERANCE MIN	TOLERANCE MAX
DIMENSIONS	LENGTH		m	54	≥	
DIMENSIONS	WIDTH	-	m	5.01	≥	
THICKNESS (ON FINISHED PRODUCT)		ASTM D 5199	mm	5.60	5.32	6.16
SURFACE MASS		ASTM D 3776	kg/m²	6.40	6.10	7
RESISTANCE TO TEARING	LONGITUDINAL			1225	919	
RESISTANCE TO TEARING	CROSS DIRECTION	ASTM D 4073	N	1025	769	
TENSILE PROPERTIES : MAXIMUM TENSILE STRENGTH	LONGITUDINAL			39	29	
TENSILE PROPERTIES : MAXIMUM TENSILE STRENGTH	CROSS DIRECTION		kN/m	31	23	
TENSILE PROPERTIES : ELONGATION	LONGITUDINAL	ASTM D 7275		60	48	
TENSILE PROPERTIES : ELONGATION	CROSS DIRECTION		%	60	48	
TENSILE PROPERTIES : MAXIMUM TENSILE STRENGTH	LONGITUDINAL			32	24	
TENSILE PROPERTIES : MAXIMUM TENSILE STRENGTH	CROSS DIRECTION		kN/m	28	21	
TENSILE PROPERTIES : ELONGATION	LONGITUDINAL	ASTM D 4595		90	60	
TENSILE PROPERTIES : ELONGATION	CROSS DIRECTION		%	90	60	
STATIC PUNCTURE		ASTM D 4833	N	650	585	
FLEXIBILITY AT LOW TEMPERATURE	SURFACE			-20		
FLEXIBILITY AT LOW TEMPERATURE	UNDER SURFACE	ASTM D 5147	°C	-20		
WATER PERMEABILITY (LIQUID TIGHTNESS)		ASTM E 96	m/s	6.10^{-14}		
GAS PERMEABILITY (GAS TIGHTNESS)		ASTM D 1434-82	m³/(m².j.atm)	$< 2,3.10^{-14}$		

BITUMINOUS GEOMEMBRANE LINER INSTALLATION

1. BITUMINOUS GEOMEMBRANE INSTALLATION SHALL BE PERFORMED IN ACCORDANCE TO THE MANUFACTURER'S RECOMMENDATION. IF RECOMMENDATIONS ARE IN CONFLICT WITH DESIGN, THE CONTRACTOR TO NOTIFY THE PRINCIPAL IN WRITING FOR CLARIFICATION.
2. THE CONTRACTOR SHALL MONITOR AND ACCEPT RESPONSIBILITY FOR THE QUALITY OF MATERIALS PLACED INTO THE WORK. THE PRINCIPAL WILL REJECT MATERIALS INCORPORATED INTO WORK THAT FAIL TO COMPLY WITH SPECIFIED REQUIREMENTS. THE CONTRACTOR SHALL REMOVE REJECTED MATERIALS FROM THE WORK AND REPLACE WITH MATERIALS OF THE SPECIFIED QUALITY.
3. MEASUREMENT SHALL BE MADE OF THE TOTAL SURFACE AREA IN SQUARE METRES COVERED BY BITUMINOUS GEOMEMBRANE. FINAL QUANTITIES WILL BE BASED ON AS-BUILT CONDITIONS. CONTRACTOR SHOULD MAKE ALLOWANCE FOR BITUMINOUS GEOMEMBRANE IN ANCHOR TRENCHES, DRAINAGE TRENCHES, AND OVERLAPS; HOWEVER, NO ALLOWANCE WILL BE MADE FOR WASTE OR MATERIALS USED FOR THE CONVENIENCE OF THE CONTRACTOR.
4. ROLLS SHALL NOT BE DRAGGED, LIFTED BY ONE END, OR DROPPED. A MANDREL OF SUFFICIENT STRENGTH TO SUPPORT THE FULL WEIGHT OF A ROLL WITHOUT SIGNIFICANT BENDING, SHALL BE USED FOR ALL HANDLING ACTIVITIES. THE DIAMETER OF THE MANDREL SHALL BE SMALL ENOUGH TO BE EASILY INSERTED THROUGH THE CORE OF THE ROLL. CHAINS SHALL BE USED TO LINK THE ENDS OF THE MANDREL TO THE ENDS OF A SPREADER BAR. THE SPREADER BAR SHALL BE WIDE ENOUGH TO PREVENT THE CHAINS FROM RUBBING AGAINST THE ENDS OF THE ROLL. ALTERNATIVELY, A STINGER BAR PROTRUDING FROM THE END OF A FORKLIFT OR OTHER EQUIPMENT MAY BE USED. THE STINGER BAR SHALL BE AT LEAST THREE-FOURTHS THE LENGTH OF THE CORE AND ALSO MUST BE CAPABLE OF SUPPORTING THE FULL WEIGHT OF THE ROLL WITHOUT SIGNIFICANT BENDING.
5. THE LINER SHALL BE PLACED IN A RELAXED STATE SUCH THAT THE MATERIAL CAN RESPOND TO THERMAL CHANGES WITHOUT EXCESSIVE BUCKLING, WRINKLING OR TENSIONING.
6. ONLY THE QUANTITY OF BITUMINOUS GEOMEMBRANE THAT WILL BE ANCHORED AND SEAMED TOGETHER IN ONE DAY SHALL BE DEPLOYED.

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BGM INSTALLATION (CONTINUED)

7. THE PROCEDURES AND EQUIPMENT USED SHALL NOT ELONGATE, WRINKLE, SCRATCH, OR OTHERWISE DAMAGE THE BITUMINOUS GEOMEMBRANE, OTHER GEOSYNTHETIC LAYERS, OR THE UNDERLYING SUBGRADE. BITUMINOUS GEOMEMBRANE DAMAGED DURING INSTALLATION SHALL BE REPLACED OR REPAIRED, AT THE CONTRACTORS EXPENSE AND AT THE PRINCIPAL'S DISCRETION. ADEQUATE BALLAST (I.E., SAND BAGS OR OTHER) SHALL BE PLACED ON THE BITUMINOUS GEOMEMBRANE, WITHOUT DAMAGING THE BITUMINOUS GEOMEMBRANE, TO PREVENT UPLIFT BY WIND. NO EQUIPMENT SHALL BE OPERATED ON THE TOP SURFACE OF THE BITUMINOUS GEOMEMBRANE WITHOUT PERMISSION FROM THE PRINCIPAL. THE METHODS USED TO DEPLOY, BACKFILL, AND BALLAST (TEMPORARY OR PERMANENT) OVER THE BITUMINOUS GEOMEMBRANE SHALL MINIMIZE WRINKLES AND TENSILE STRESSES IN THE BITUMINOUS GEOMEMBRANE. THE BITUMINOUS GEOMEMBRANE SHALL HAVE ADEQUATE SLACK TO PREVENT THE CREATION OF TENSILE STRESS.
8. IN GENERAL, SEAMS SHALL BE ORIENTATED PARALLEL TO THE LINE OF MAXIMUM SLOPE. NO HORIZONTAL WELDS ALONG SLOPES OR WITHIN 1 METRE OF SLOPE TRANSITIONS UNLESS APPROVED BY THE PRINCIPAL. IN CORNERS AND ODD SHAPED GEOMETRIC LOCATIONS, THE TOTAL LENGTH OF THE FIELD SEAM SHALL BE MINIMIZED. SEAMS SHALL NOT BE LOCATED AT LOW POINTS IN THE SUBGRADE UNLESS GEOMETRY REQUIRES SEAMING AT SUCH LOCATIONS AS APPROVED BY THE PRINCIPAL.
9. QUADRUPLE POINT LOCATIONS DUE TO ALIGNED STRIP ENDS ARE NOT ALLOWED. TRIPLE POINT LOCATIONS WILL BE COVERED WITH AN ADDITIONAL BITUMINOUS GEOMEMBRANE.
10. THE BITUMINOUS GEOMEMBRANE SHALL NOT BE ALLOWED TO "BRIDGE OVER" VOIDS OR LOW AREAS IN THE SUBGRADE. THE BITUMINOUS GEOMEMBRANE SHALL REST IN INTIMATE CONTACT WITH THE SUBGRADE.
11. THE SUBGRADE UNDER THE BITUMINOUS GEOMEMBRANE SHALL CONFORM THE TECHNICAL SPECIFICATIONS.
12. TEMPORARY BALLASTING SUCH AS SAND BAGS OR TYRES SHALL BE PLACED ON THE LINER TO PREVENT WIND DAMAGE OR BRIDGING DURING AND AFTER INSTALLATION. IT SHOULD BE NOTED THAT THIS TEMPORARY BALLASTING SHALL BE OF A SUITABLE CONSTRUCTION TO PREVENT AGAINST DAMAGE OF THE LINER. THE CONTRACTOR SHALL BE REQUIRED TO ENSURE THAT THE SPACING OF THESE SAND BAGS/TYRES ARE APPROPRIATELY DESIGNED (THIS COULD INCLUDE TYING THE SAND BAGS/TYRES TOGETHER IN A HORIZONTAL AND VERTICAL DIRECTION) TO PREVENT AGAINST UPLIFT AND ANY POTENTIAL DAMAGE OF THE LINER. ANY LINER MATERIAL THAT HAS BEEN DAMAGED AS THE RESULT OF WIND OR BRIDGING, IN THE OPINION OF THE PRINCIPAL, SHALL BE REMOVED AND REPLACED AT THE CONTRACTOR'S EXPENSE.
13. ALL PERSONNEL WORKING ON THE LINER SURFACE SHALL WEAR SOFT-SOLED SHOES, AND SHALL NOT ENGAGE IN ANY ACTIVITY WHICH MAY DAMAGE THE LINER.
14. BITUMINOUS GEOMEMBRANE SHALL NOT BE DEPLOYED OR FIELD-SEAMED IN THE PRESENCE OF SIGNIFICANT RAIN, IN AREAS OF PONDED WATER, OR IN THE PRESENCE OF WIND IN EXCESS OF 55 KM/HOUR. UNLESS AUTHORIZED BY THE PRINCIPAL, NO PLACEMENT OR SEAMING SHALL BE ATTEMPTED AT AMBIENT TEMPERATURES BELOW -25 DEGREES C (-13 DEGREES F) OR ABOVE 40 DEGREES C (104 DEGREES F). AMBIENT TEMPERATURE SHALL BE MEASURED AT A HEIGHT NO GREATER THAN 150 MM 6 INCHES ABOVE THE GROUND OR BITUMINOUS GEOMEMBRANE SURFACE. IN MARGINAL CONDITIONS, SEAMING SHALL CEASE UNLESS DESTRUCTIVE FIELD SEAM TESTS, CONDUCTED BY THE QC LABORATORY, CONFIRM THAT SEAM PROPERTIES MEET THE DESIGN REQUIREMENTS.
15. THE CONTRACTOR SHALL NOMINATE A MASTER WELDING SUPERVISOR BEFORE COMMENCING WORK AND SHALL DEMONSTRATE THAT THE MASTER WELDING SUPERVISOR HAS A PROVEN BACKGROUND IN INSTALLATION OF SIMILAR SYSTEMS AND MATERIALS SIMILAR TO THOSE SPECIFIED. ALL PERSONNEL EMPLOYED IN WELDING SHALL BE COMPETENT AND EXPERIENCED IN THE USE OF THE EQUIPMENT. THE CONTRACTOR SHALL ULTIMATELY BE RESPONSIBLE FOR ENSURING THE QUALITY ASSURANCE PROGRAMME IS FOLLOWED.
16. THE CONTRACTOR SHALL BE RESPONSIBLE AND SHALL PROVIDE SUFFICIENT RESOURCES FOR FIELD HANDLING, DEPLOYING, SEAMING, TEMPORARILY RESTRAINING (AGAINST WIND), AND OTHER ASPECTS OF THE DEPLOYMENT AND INSTALLATION OF THE BITUMINOUS GEOMEMBRANE. NO SEAMING SHALL BE PERFORMED UNLESS A MASTER WELDING SUPERVISOR IS PRESENT ON-SITE.
17. EVERY WORKER PERFORMING WELDING OF THE BITUMINOUS GEOMEMBRANE WILL NEED TO DEMONSTRATE A CONDABRI VERIFICATION OF COMPETENCE (VOC) PRIOR TO UNDERTAKING WORKS ON THE FIELD. THE CONDABRI VOC CERTIFICATION AND TESTING WILL BE ADMINISTERED BY THE LEVEL 1 CQC. TRIAL WELD TEST SAMPLES SHALL SUBMITTED TO A THIRD PARTY INDEPENDENT LABORATORY FOR DESTRUCTIVE TESTING.
18. DESTRUCTIVE TESTING SHALL BE COMPLETED IN ACCORDANCE TO ASTM D 7056 AND ASTM D 3019. NON-DESTRUCTIVE AIR LANCE TESTING SHALL BE COMPLETED IN ACCORDANCE TO ASTM D 4437.
19. CONNECTIONS TO ADJOINING STRUCTURES SHALL BE MADE IN ACCORDANCE WITH THE DETAILS SHOWN ON THE CONSTRUCTION DRAWINGS. CONNECTIONS SHALL BE AT LEAST EQUIVALENT IN STRENGTH TO THE NORMAL LAP JOINTS AND THE SECURITY OF CONTAINMENT SHALL NOT BE DIMINISHED. LOCAL STRESSES IN THE LINER AT CONNECTIONS SHALL BE MINIMISED.
20. ANCHOR TRENCHES SHALL BE EXCAVATED IN ACCORDANCE WITH THE DETAILS ON THE CONSTRUCTION DRAWINGS. THE ANCHOR TRENCHES SHALL BE KEPT WELL DRAINED TO AVOID SOFTENING DURING RAIN PERIODS AND MAINTAINED SO AS TO NOT DRY, DESICCATE AND CRACK.
21. IN ACCORDANCE WITH Q-4522-20-TS-0001, THE CONTRACTOR SHALL SEEK APPROVAL FROM THE PRINCIPAL PRIOR TO THE COMMENCEMENT OF ANCHOR TRENCH BACKFILLING. ONCE THE ANCHOR TRENCH IS READY TO BE BACKFILLED, IT SHALL BE BACKFILLED IN EARLY MORNING WHEN THE LINER IS AT MAXIMUM CONTRACTION. BACKFILLING SHALL BE CARRIED OUT IN A PLANNED, LOGICAL SEQUENCE TO AVOID OVERSTRESSING OF THE LINER AND MINIMIZE EXPOSURE WET WEATHER DAMAGE.
22. ANCHOR TRENCH SHALL BE BACKFILLED WITH FLOWABLE CONCRETE STABILIZED SAND (5% CEMENTICIOUS) AND MIX DESIGN SHALL BE SUBMITTED FOR APPROVAL.
23. A LEVEL 1 CQC IS REQUIRED DURING ALL LINER INSTALLATION, LINER REPAIRS, AND QUALITY/COMPLIANCE TESTING. MATERIAL TESTING SHALL BE CARRIED OUT AT RANDOMLY CHOSEN LOCATIONS, IN ACCORDANCE WITH SPECIFIED TESTING REQUIREMENTS AND FREQUENCIES, AND/OR AT LOCATIONS SELECTED BY THE PRINCIPAL.
24. ALL AREAS FOUND TO BE DEFECTIVE SHALL BE REPAIRED AT THE EXPENSE OF THE CONTRACTOR. THE PRINCIPAL SHALL BE NOTIFIED OF DEFECTIVE AREAS PRIOR TO THE REPAIR TAKING PLACE.
25. THE CONTRACTOR SHALL ENSURE A PLAN IS MARKED UP SHOWING THE LOCATIONS OF REPAIRS MADE AND THE TYPE OF REPAIR MADE. THE CONTRACTOR SHALL SUBMIT A MARKED UP DRAWING SHOWING THE LOCATIONS OF THE REPAIRS TO THE PRINCIPAL FOR REVIEW AND APPROVAL.
26. THE ENTIRE SURFACE OF EVERY SHEET OF LINER MATERIAL SHALL BE INSPECTED BY THE CONTRACTOR DURING PLACING TO IDENTIFY ANY TEARS, ABRASIONS, INDENTATIONS, CRACKS, THIN AREAS, OR OTHER DEFECTS.
27. ANY DEFECTS SUCH AS HOLES, TEARS, BLISTERS, LAMINATION, UNDISPERSED RAW MATERIALS OR VISIBLE NON-UNIFORMITY OR CONTAMINATION BY FOREIGN MATTER WHICH IN THE OPINION OF THE PRINCIPAL IS DETRIMENTAL TO THE LONG SERVICE LIFE REQUIRED OF THE LINER, SHALL BE GROUNDS FOR REJECTION OF THE LINER MATERIAL.
28. WHERE ADDITIONAL FAULTS ARE FOUND, THE PRINCIPAL RESERVES THE RIGHT TO REJECT THE ROLL. THE CONTRACTOR SHALL REPLACE ANY REJECTED ROLLS AND REPAIR ANY DEFECTS TO THE PRINCIPAL'S SATISFACTION AT THE CONTRACTOR'S EXPENSE.

BGM INSTALLATION (CONTINUED)

29. FOLLOWING INSTALLATION OF THE LINER, A DETAILED VISUAL INSPECTION OF THE PRIMARY LINER SURFACE SHALL BE PERFORMED BY THE PRINCIPAL (ACCOMPANIED BY THE CONTRACTOR), TO IDENTIFY ANY DEFECTS IN THE LINER SURFACE CAUSED DURING INSTALLATION. PRIOR TO PERFORMING THE SURVEY, A SURVEY GRID SHALL BE DETERMINED TO ENSURE THAT THE VISUAL SURVEY IS PERFORMED ACROSS 100-PERCENT OF THE LINER SURFACE.
30. ALL LINER WELD SEAMS SHALL BE SUBJECTED TO BOTH NON-DESTRUCTIVE AND DESTRUCTIVE TESTING. DESTRUCTIVE FIELD TESTING WILL BE AT THE INTERVALS LISTED AND ANY LOCATION CHOSEN BY THE PRINCIPAL. THE REPRESENTATIVE SAMPLES OF FIELD SEAMS SHALL BE TAKEN FOR LABORATORY TESTING BY AN INDEPENDENT, APPROPRIATELY QUALIFIED TESTING LABORATORY. WELD AND MATERIAL STRENGTH REQUIREMENTS TO COMPLY WITH MANUFACTURERS RECOMMENDATIONS.
31. NON-DESTRUCTIVE AND DESTRUCTIVE TESTING SHALL BE OBSERVED BY THE LEVEL 1 CQC/LIS.
32. TRIAL WELDS TESTING SHALL BE CARRIED OUT THE SAME AS DESTRUCTIVE TESTING TRIAL WELDS.
33. TRIAL WELDS TO BE COMPLETED AT BEGINNING OF PROJECT. WELD TO BE CONDUCTED BY MASTER WELDING SUPERVISOR AND SHALL BE SENT TO LABORATORY FOR TESTING.
34. JOINT MUST BE CENTERED IN THE SAMPLE. THE SAMPLE MUST BE AT LEAST 350mm FOR 5 TESTS TO BE CARRIED OUT ON THE SAME SAMPLE. EACH SAMPLE MUST BE CLEARLY IDENTIFIED.
35. NON-DESTRUCTIVE FIELD WELD TESTS SHALL BE CARRIED OUT ON ALL WELDED SEAMS. A FAILED TEST IS ANY LOCATION OF WELDED SEAM THAT HAS LESS THAN 150mm OF CROSS SECTIONAL WIDTH.
36. DESTRUCTIVE TESTS SHALL BE CARRIED OUT AT AN INTERVAL OF EVERY 1000 METRES OF WELDED SEAMS. A PASSING TEST IS EQUAL OR GREATER THAN 90% OF MATERIAL STRENGTH AND FAILURE OF SAMPLE OUTSIDE OF WELD.
37. THE CONTRACTOR SHALL DEPLOY THE BITUMINOUS GEOMEMBRANE PANELS IN GENERAL ACCORDANCE WITH THE LAYOUT DRAWING SPECIFIED. THE LAYOUT DRAWINGS MUST BE APPROVED BY THE PRINCIPAL OR LEVEL 1 CQA PRIOR TO INSTALLATION OF ANY LINER.
38. A BITUMINOUS GEOMEMBRANE FIELD PANEL IS A ROLL OR A PORTION OF ROLL CUT IN THE FIELD. EACH FIELD PANEL SHALL BE GIVEN A UNIQUE IDENTIFICATION CODE (NUMBER OR LETTER-NUMBER). THIS IDENTIFICATION CODE SHALL BE AGREED UPON BY THE LEVEL CQA AND CONTRACTOR.
39. FIELD PANELS SHALL BE INSTALLED IN ACCORDANCE TO THE PRINCIPAL APPROVED WORK METHOD STATEMENT.
40. PANELS SHALL BE SEAMED IN ACCORDANCE WITH THE BITUMINOUS GEOMEMBRANE MANUFACTURER'S RECOMMENDATIONS. IN CORNERS AND ODD-SHAPED GEOMETRIC LOCATIONS, THE NUMBER OF FIELD SEAMS SHALL BE MINIMIZED. SEAMING SHALL EXTEND TO THE OUTSIDE EDGE OF PANELS. THE SEAM AREA SHALL BE FREE OF MOISTURE, DUST, DIRT, AND FOREIGN MATERIAL AT THE TIME OF SEAMING. THE PANELS SHALL OVERLAP A MINIMUM 200mm FOR SEAMING. ENDS AND OVERLAPS MUST BE WELDED ON A HOMOGENEOUS AND CONTINUOUS BASIS, LEAVING A 6mm BITUMEN BEAD ALONG THE SEAM.
41. SEAMS SHALL BE WELDED USING PROPANE TORCHES. THE TORCH-WELDS MUST BE APPROVED ACCORDING TO THE MANUFACTURER'S RECOMMENDATIONS AND PRINCIPAL.
42. BITUMINOUS GEOMEMBRANE TO BE WELDED TO CONCRETE AT INSTALLATION AREAS BY HEATING THE CONCRETE SURFACE AND THE BGM, THEN ROLLING WITH A SMALL ROLLER AND APPLYING HIGH PRESSURE. CONCRETE SURFACE SHALL BE PREPARED BY APPLYING 300 g/m² OF COLD PRIMER (SAMIPRIME KS-P OR APPROVED EQUAL) 24 HOURS PRIOR TO WELDING.
43. ONE QC SAMPLE, 500 MM IN LENGTH, FOR THE ENTIRE WIDTH OF A ROLL, SHALL BE OBTAINED FOR EVERY 9,000 SQUARE METERS 100,000 SQUARE FEET OF MATERIAL DELIVERED TO THE SITE. SAMPLES SHALL NOT BE OBTAINED FROM THE FIRST METRE OF THE ROLL. THE SAMPLES SHALL BE IDENTIFIED BY MANUFACTURER'S NAME, PRODUCT IDENTIFICATION, LOT AND ROLL/PANEL NUMBER. THE DATE, A UNIQUE SAMPLE NUMBER, AND THE MACHINE DIRECTION SHALL ALSO BE NOTED.
44. ANY PORTION OF THE LINER WITH A FLAW OR THAT FAILS A NON-DESTRUCTIVE OR DESTRUCTIVE TEST SHALL BE REPAIRED BY ONE OF THE FOLLOWING METHODS:
   - 44.1. PATCHING OR CAPPING FOR HOLES, DEFECTS OR TEARS USED TO REPAIR LARGE HOLES, TEARS, LARGE PANEL DEFECTS, AND DESTRUCTIVE SAMPLE LOCATIONS THAT ARE LESS THAN 2M2 (TOTAL AREA). PATCHES AND REPAIRS ARE TO BE OVERLAID WITH A STRIP OF NEW MATERIAL AND SEAMED (CAP STRIPPED). STRIP SHALL HAVE ROUNDED CORNERS AND EXTEND A MINIMUM OF 200 MM BEYOND THE EDGE OF THE REPAIR OR DEFECT AREA. AFTER REPAIRS ARE COMPLETED, THE REPAIRED SEAM SHALL BE NON-DESTRUCTIVELY TESTED.
   - 44.2. REMOVAL AND REPLACE - USED TO REPLACE AREAS WITH LARGE DEFECTS WHERE THE PRECEDING METHODS ARE NOT APPROPRIATE. ALSO USED TO REMOVE EXCESS MATERIAL (WRINKLES) FROM THE INSTALLED LINER.
   - 44.3. ONCE THE REPAIR HAS BEEN COMPLETED, FURTHER NON-DESTRUCTIVE OR DESTRUCTIVE TESTING SHALL BE CARRIED OUT.
45. FULL RECORDS OF LINER TESTING AND INSPECTION SHALL BE SUBMITTED PROGRESSIVELY TO THE PRINCIPAL, AS THE WORK PROCEEDS. FINAL COMPLETION WILL NOT BE CERTIFIED UNTIL ALL RECORDS HAVE BEEN SUBMITTED AND APPROVED BY THE PRINCIPAL.
   - 45.1. RECORDS SHALL INCLUDE, BUT NOT LIMITED TO, THE FOLLOWING:
   - 45.2. CONTRACTOR'S AS-BUILT PANEL LAYOUT DRAWING SHOWING PANEL NUMBERS AND JOINT NUMBERS, TO BE MARKED UP PROGRESSIVELY WITH THE ROLL NUMBER USED FOR EACH PANEL, AND WITH THE LOCATIONS OF SAMPLES TAKEN FOR DESTRUCTIVE TESTING;
   - 45.3. MANUFACTURER'S ROLL PRODUCTION TEST REPORTS FOR ALL ROLLS USED IN THE WORK;
   - 45.4. SUBGRADE CERTIFICATION REPORTS;
   - 45.5. DAILY TEST REPORTS REFERENCED TO JOINT NUMBERS ;
   - 45.6. DAILY TEST WELD FIELD TEST REPORTS REFERENCED TO JOINT NUMBERS, EQUIPMENT IDENTIFICATION, AND OPERATOR, AND INCLUDING WEATHER AND TEMPERATURE CONDITIONS AND ANY ADJUSTMENTS TO EQUIPMENT CONTROLS;
   - 45.7. NON-DESTRUCTIVE AND DESTRUCTIVE TEST FIELD REPORT AND RECORD OF SUBMISSION FOR LABORATORY TESTING REFERENCED TO JOINT NUMBER;
   - 45.8. LABORATORY TEST REPORTS TO BE AVAILABLE WITHIN TWO WEEKS OF TESTING; AND
   - 45.9. RECORD DRAWING INDICATING LINER SEAM LOCATIONS, DESTRUCTIVE TEST LOCATIONS, CAP STRIP LOCATIONS, PATCHES AND ALL REPAIRS FOR THE LINER SYSTEM.

BITUMINOUS GEOMEMBRANE LINER BALLAST ANCHORS

1. BALLAST ANCHORS SHALL BE SOIL ANCHOR PENETRATOR PE18SQ (OR ENGINEER APPROVED EQUIVALENT).
2. BALLAST ANCHOR SPACING INTERVALS ALONG BATTER (AS PER DETAIL 1, Q-4522-20-DH-0003).
   - 2.1. POINT A - EVERY 5 METRES (NEAREST SEAM OVERLAP).
   - 2.2. POINT B AND C - EVERY 5 METRES (NEAREST SEAM OVERLAP.)
3. BITUMSEAL SHALL BE USED BETWEEN THE BALLAST PLATE AND BITUMINOUS GEOMEMBRANE LINER.
4. BALLAST ANCHOR LOCATE AT ANCHOR POINT A (CREST OF DAM) SHALL BE PAINTED WITH HIGH VISIBILITY SAFETY PAINT.

DRAWING NO.	REFERENCE DRAWING TITLE	REV	DATE	REVISION DESCRIPTION	DRAWN	DWG CHECK	DESIGN	ENG DES CHECK	DE DRAFT SUPER	DE PROJECT APPROVAL
		0	14/07/2017	ISSUED FOR CONSTRUCTION	[signature]	MD	BF	[signature]	[signature]	[signature]

APPROVALS

PREPARED FOR ORIGIN BY: MWH | AUSTRALIA PACIFIC LNG

PROJECT: [signature] | DRAWING OFFICE: MD

PROJECT APPROVALS - OTHERS

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	BY	DATE
DRAWN	RW	29/09/2016
DWG CHECK	MD	17.07.17
DESIGN	BF	17.07.17
ENG DES CHECK	[signature]	17/7/17
ORIGIN DRAFT. SUPER.	[signature]	Oct 6, 2018
ORIGIN PROJECT APPROVAL	[signature]	Oct 6, 2018

TITLE: CONDABRI CENTRAL
BRINE POND 7
GENERAL NOTES STANDARD CIVIL DRAWING

PROJECT NO. 83503552
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Appendix B: Land Condition Assessment

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Origin
27-Jun-2019

Land Condition Assessment

Velkerri 76 S2 and Kyalla 117 N2 Exploration Program

Land Condition Assessment

Velkerri 76 S2 and Kyalla 117 N2 Exploration Program

Client: Origin

ABN: 66 007 845 338

Prepared by

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Quality Information

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Date	27-Jun-2019
Prepared by	Alana Court
Reviewed by	Abe Francis

Revision History

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			Name/Position	**Signature**
0	20-Sep-2018	August 2018 Land Condition Assessment	Alana Court Principal Scientist	
1	5-Mar-2019	Revised for 2019 program	Alana Court Principal Scientist	
2	16-May-2019	Revision 2 for 2019 program	Alana Court Principal Scientist	
3	27-June-2019	Update following DENR comments regarding recently released *Weed Management Planning Guide: Onshore Petroleum Projects June 2019*	Alana Court Principal Scientist	

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Table of Acronyms

Acronym	Meaning
°C	Degrees Celsius
%	Percentage
AAPA	Aboriginal Areas Protection Authority
ALA	Atlas of Living Australia
AS	Australian Standard
BOM	Bureau of Meteorology
CLA	Cambrian Limestone Aquifer
Cth	Commonwealth
DoH	Department of Health (NT)
DotEE	Department of the Environment and Energy (Cmwlth)
DENR	Department of Environment and Natural Resources (NT)
DPIR	Department of Primary Industries and Resource (NT)
DLPE	Department of Lands, Planning and the Environment (NT)
EPA	Environment Protection Authority (NT)
EP##	Exploration Permit (e.g. EP76, EP98 and EP117)
EMP	Environmental Management Plan
EPBC	Environmental Protection and Biodiversity Conservation
ESCP	Erosion and Sediment Control Plan
GPS	Global Positioning Device
Ha	hectare
IBA	Important Bird Area
ILUA	Indigenous Land Use Agreement
Km	Kilometre
km^2	Square Kilometres
km/hr	Kilometre per hour
LCA	Land Condition Assessment
m	metre
MD	Measured Depth
MNES	Matters of National Environmental Significance
mm	millimetre
NLC	Northern Land Council
NT	Northern Territory
OHS	Occupational Health and Safety
RWA	Restricted Work Area
TO	Traditional Owner
TPWC Act	*Territory Parks and Wildlife Conservation Act*

Acronym	Meaning
WMP	Weed Management Plan
WoNS	Weed of National Significance

1.0 Introduction

1.1 Purpose of this Report

AECOM Australia Pty Ltd (AECOM) conducted a land condition assessment (LCA) to support Origin Energy's (Origin) application to the Northern Territory Department of Environment and Natural Resources (DENR) for an Environmental Management Plan (EMP) for various exploration activities.

The purpose of the LCA was to gather baseline information to provide an environmental condition assessment to support the proposed exploration activities to be carried out by Origin at two proposed lease sites during 2019/2020.

1.2 Project Boundary

Origin are proposing to undertake a series of activities required to expand their exploration program in the Beetaloo Basin. Origin are targeting two sites for the 2019/2020 exploration program, Velkerri 76 S2 and Kyalla 117 N2. The location and proposed disturbance area are presented in Table 1 and Figure 1.

Table 1 Proposed Lease Area for Exploration Activities and Disturbance Area

Exploration Permit	Name	Station	Zone*	Easting	Northing	Disturbance Area (ha)
EP76	Velkerri 76 S2-1	Amungee Mungee	53	435488	8136321	7.2~
EP117	Kyalla 117 N2-1	Hayfield/Shenandoah	53	356175	8137500	9.8~
EP117	Stuart Highway Intersection	Hayfield/Shenandoah	53	332371	8135170	0.5
EP117	Gravel Pit 1	Hayfield/Shenandoah	53	339883	8135005	1.0
EP117	Gravel Pit 2	Hayfield/Shenandoah	53	360366	8135138	1.0
EP117	Gravel Pit 3	Hayfield/Shenandoah	53	362841	8135102	1.0
EP117	Gravel Pit 4 and access track	Hayfield/Shenandoah	53	397906	8136039	1.5
EP117	Gravel Pit 5 and access track	Hayfield/Shenandoah	53	403386	8135809	1.0
EP117	Gravel Pit 6 and access track	Hayfield/Shenandoah	53	405049	8135927	1.0
EP76	Gravel Pit 7	Amungee Mungee	53	435749	8135306	0.5
Total Disturbance Area (Ha)						**24.5 ha**

** Universal Transverse Mercator (UTM) geographic coordinate system is Geocentric Datum of Australia (GDA) 94.*
~Includes well pad, camp lease, stockpile laydown and access track turnin.

For the purpose of this assessment, the project boundaries were defined as the areas which may be affected by the proposed exploration activities, including:

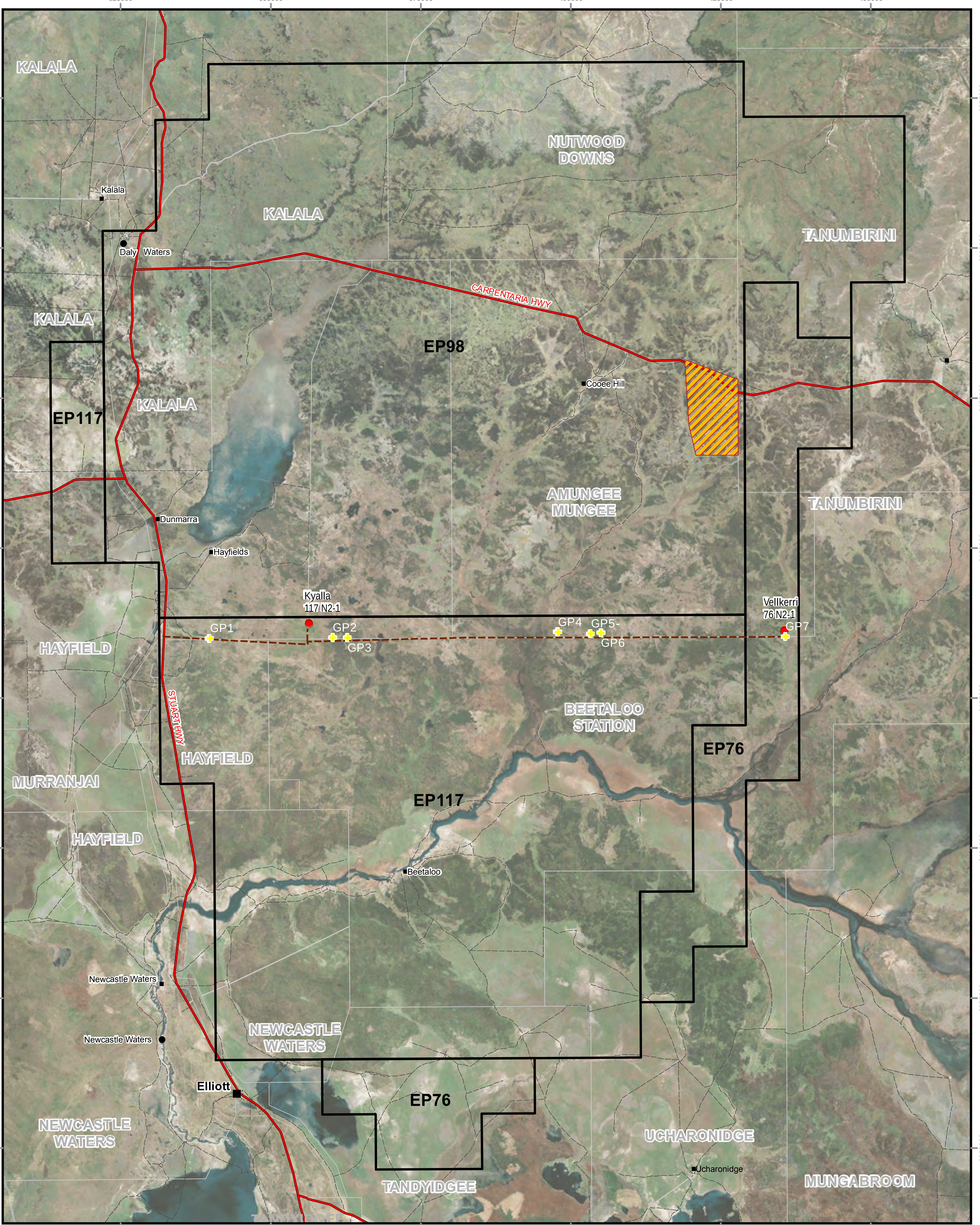
- Construction of a 5.5-ha lease pad at Kyalla 117 N2 and Velkerri 76 S2.
- Construction of a 1.2-ha camp pad at Kyalla 117 N2 and Velkerri 76 S2.
- Construction of a 0.2-ha stockpile area at Kyalla 117 N2 and Velkerri 76 S2.

- Construction of a 0.25-ha helipad and 1-ha wet weather storage area at the Velkerri 76 S2.
- Construct a 650 m long x 8 m wide (0.52-ha) lease pad turn in to Kyalla 117 N2 connecting the proposed lease pad to the existing access track.
- Construct a 1,100 m long x 8 m wide (0.88-ha) lease pad turn in to Velkerri 76 S2 connecting the proposed lease pad to the existing access track.
- Minor intersection upgrade works at the intersection with the Stuart Highway of approximately 0.5-ha in accordance with approved Road Agency approval (2018-0186-D2) and Permit to Work within NT Government Road Reserve.
- Utilise approximately 107 km of existing access track.
- Obtain gravels, as required, for construction of drill pads and sections of the access track at up to seven proposed borrow pits (7 gravel pits up to 1 to 2.1 ha).
- All other activities ancillary to the drilling, stimulation and well testing of an exploration well.

1.3 Scope of works

The scope of work for the LCA involved:

- a review of historical data and reports prepared during the previous Beetaloo onshore oil and gas exploration programs
- a search of the Commonwealth Department of the Environment and Energy (DoTEE) Protected Matters database (27 August 2018)
- a search of the NT Natural Resource Management InfoNet Database (flora and fauna database) (4 September 2018)
- a search of the Atlas of Living Australia (ALA) database for flora and fauna records (2014 and 2016)
- completion of LCA field survey of the proposed exploration lease areas drilling program.
- Preparation of this report.



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GEOCENTRIC DATUM OF AUSTRALIA 94

0 5 10 20

Kilometers

1:570,000 (when printed at A3)

LEGEND

- Proposed Wells 2018
- Homestead
- Place Name
- Populated Place
- Gravel Pits
- Highway
- Tracks
- Access Routes
- Cadastre
- Permit Areas
- Bullwaddy Conservation Reserve

LOCATION

Data sources:
Permit Area, Cadastre - NT Gov 2019.
Places, Vegetation - Aust Gov 2019
Highways, Roads, Drainage -

ORIGIN ENERGY RESOURCES LIMITED
2019 Environmental Management Plan

Site Location

PROJECT ID	60480548
CREATED BY	jace.emberg
LAST MODIFIED	20-May-2019
VERSION	1

Figure 1

Filename: \\audwn1fp001\Projects\604x\60480548\4. Tech Work Area\4.99 GIS\02_MXDs\LCA\Site_Location.mxd

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2.0 Assessment Method

2.1 Desktop Review

The existing data collected between 2005 and 2016 for the permit areas was mapped based on image interpretation, with ground-truthing of the proposed exploration areas being completed during the field assessment (refer Section 2.2). This information was reviewed prior to the field work to identify the following:

- terrestrial vegetation types and flora and fauna species occurring within the region and with potential to occur within the project area, using existing documents and aerial / satellite imagery.
- terrestrial Commonwealth or Territory listed threatened species or communities identified within the region and with potential to occur within the project area.
- matters of national environmental significance or other matters protected by the Environment Protection and Biodiversity Conservation Act (EPBC Act) that are likely to occur within the project area.
- existing weeds or feral animals listed under the EPBC Act, *Weeds Management Act* or the *Territory Parks and Wildlife Conservation Act* and with potential to occur within the project area.

Table 2 provides a chronological list of reports previously compiled for the exploration permit area between 2004 and 2016, in relation to environmental approvals and management support for petroleum exploration activities in the Beetaloo Basin, NT.

The extent of work undertaken since 2004 has enabled a good understanding of the natural and cultural environment, which has been used in assessing the proposed exploration areas within the Permit Area.

Table 2 Summary of existing Environmental Assessments and Reports for the Beetaloo Basin (2004 to 2018)

Date	Report
Sweetpea Petroleum	
Jul- Aug 2004	Baseline land condition assessment
	Site database established
Jul 2005	Exploration EMP finalised and approved
Petrohunter Australia (Partner to Sweetpea)	
Dec 2006	Baseline vegetation assessment
Apr 2007	Drill site assessments
Apr 2007	Annual report
Jun 2007	Update of the existing EMP to include the new Exploration Permit areas
Jul 2007	Drill Site maps
Jul 2007	Supplemental Environmental Management Plan, Drilling Program 2007, Beetaloo Basin, NT
Jul 2007	Soil erosion assessment
Jul 2007	Groundwater quality
July 2007	Emergency Maps
Jul 2007	Environment & Heritage Induction Materials
Aug 2007	Site-based Drilling EMP
Falcon Oil and Gas	
Dec 2010	Drill site condition assessments

Date	Report
Jan 2011	Archaeological survey
March 2011	Site-specific drilling EMP
2011	Falcon Shenandoah 1 Stimulation and Testing Groundwater Monitoring
2011/2012	Shenandoah 1 Re-Entry Environment Plan (EP)
July 2012	EP99 Archaeological Survey, Beetaloo Basin
2013	EP99 Seismic Exploration Environmental Management Plan
2013	Sweetpea 2006 Closeout Environmental Survey
Origin	
2015 and 2016	Beetaloo Basin Environmental and Heritage Assessment and preparation of Approval documentation.
October 2018	Land Condition Assessment

2.2 Field assessment and reporting

The LCA of the proposed exploration lease areas, including access tracks, was conducted on 28 to 29 August 2018 by Principal Environmental Scientist, Abe Francis. The survey involved helicopter and pedestrian survey of the proposed exploration lease areas and access tracks and was accompanied by the AECOM Principal Heritage Consultant, Luke Kirkwood and the Department of Environment and Natural Resource (DENR) Regional Weed Officer (Onshore Shale Gas Development), Tahnee Hill.

The LCA used rapid assessment techniques, which allowed for large areas to be surveyed over a relatively small period of time. The helicopter provided a good platform to enable the field team a degree of flexibility by allowing an aerial view of the access tracks and proposed exploration lease areas, as well as the ability to land in otherwise remote locations for ground-truthing.

The primary aim of the LCA was to identify and document site condition prior to the proposed activities occurring in the footprint of the two lease areas and proposed access tracks and inform the preparation of the programs Environmental Management Plan (EMP).

Following the desktop review, AECOM undertook a condition assessment at each of the nominated sites and access tracks to record site-based characteristics, including:

- the presence of drainage lines and the direction of surface flows
- the distance to the nearest sensitive receptors (such as significant vegetation communities or fauna habitats)
- soil characteristics and intactness
- terrestrial vegetation community types (note that the vegetation descriptions would be based on dominant species for each vegetation structural component)
- listed threatened flora species and fauna habitat features, such as hollows, logs and burrows (the fauna habitat quality for each mapped vegetation community type would be assessed)
- incidental fauna sightings
- the presence of weeds and/or feral animals (i.e. indication of scats, tracks, wallows etc.)
- general land use description.

For this assessment, the environmental scouting included a 4-hectare area around the proposed exploration areas, plus an additional 500 m buffer to allow for future flexibility for the proposed Origin exploration activities.

A 250 m buffer each side of an existing access track were scouted to allow for locating camps, gravel pits and water supply bores in the future. Where the access tracks were located on a property boundary, the buffer was 500 m out into the property the track was located on.

It is noted that not all of the nominated areas scouted for the exploration areas and/or access tracks will be affected by site activities, but sufficient size was allowed to provide flexibility in the siting of infrastructure and borrow pits, which in turn can be used to minimise environmental and heritage impacts (e.g. significant tree or habitat avoidance, Sacred Site/archaeological artefact avoidance).

3.0 Land Condition Assessment

The results of the LCA and desktop review has been summarised in the following sections. The area covered during the assessment is shown in Figure 2. During the helicopter survey, two sites proposed for exploration activities were ground-truthed, along with the proposed access tracks (refer Section 1.2). Scoping for the gravel pits was also conducted.

3.1 Climate

The climate of the Origin permit areas can be described as arid to semi-arid, with rainfall decreasing in frequency and quantity from north to south. The climate is monsoon influenced, with a distinctive wet and dry season experienced through the year. The area experiences a wet season during the summer months between October and March, which is dominated by hot and wet conditions. Whilst the dry season during the winter months experiences mild days and cool nights between May to August. September and April are transitional months, with occasional rainfall. The average annual rainfall in the north of the permit area is listed at 680 mm at Daly Waters. The southern portion of the permit area records an average annual rainfall of 535 mm at Newcastle Waters and 608 mm listed at Elliott. Approximately 90% of the rainfall occurs during the Wet Season, and annual totals show moderate variability from year to year.

The maximum rainfall for the permit area occurs during January and February. Daly Waters experience the highest rainfall in the region at this time, with 165 mm during each month, followed by Elliott (133-164 mm during each month) and Newcastle Waters (125-130 mm during each month). July and August experience the least amount of rainfall and are the driest months across all three weather monitoring sites, ranging from one to four mm of rainfall. The annual rainfall pattern within the area is highly variable and becomes increasingly unpredictable the further move away from the coast. Drought conditions are known to occur in the region once every ten years (Holt and Bertram, 1981).

The land condition assessment was undertaken between 28 and 29 August 2018. The timing of the assessment was such that it fell within the dry season. The Daly Water airstrip station recorded a higher than average rainfall of 590 mm between January to April 2018 wet season compared to the mean rainfall from 1939 to 2018 of 482 mm.

The average annual rainfall experienced across the region (which includes the BOM data from Daly Waters Airstrip and Elliot) is shown in Table 3.

Table 3 Annual rainfall 2016-2018

Year	Annual Rainfall (mm)		Months Rain was recorded	
	DW	NW	DW	NW
2016	608	570	12	9
2017	866	607	7	6
2018*	590	270	4	4

DW – Daly Waters Airstrip, NW – Newcastle Waters.

Data sourced from Bureau of Meteorology, Climate Averages for Station 014626 Daly Waters Airstrip recorded from 1939-2018, Station 015131 Elliot recorded from 1949-2018. * note 2018 is only current to date (October 2018)

Due to the timing of the LCA occurring at the end of the dry not all species were able to be identified, however sufficient data was able to be captured to obtain a good understanding of the land condition within the proposed lease areas to help inform required management measures for the protection of the environment.

The proposed lease sites and the short access roads are unlikely to be impacted by the onset of the wet season because they are located outside of the adjacent major flow paths and creeklines within the permit area (refer to Section 3.2).

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LEGEND

- Homestead
- Place Name
- Populated Place
- Highway
- Minor Road
- Tracks
- Access Tracks
- Cadastre
- Permit Areas
- Bullwaddy Conservation Reserve
- Helicopter Transects
- Gravel Pits

LOCATION

Data sources:
Permit Area, Cadastre - NT Gov 2019.
Places, Vegetation - Aust Gov 2019
Highways, Roads, Drainage -

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2019 Environmental Management Plan

Heritage Assessment Transects

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VERSION	1

Figure 2

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3.2 Topography, Surface Water and Drainage

The permit area is located within three main topographic zones. These are primarily made up of black soil plains in the south, laterite plains in the north and small sections of bedrock hills in the south west and north east of the permit areas (Tickell, 2003). The proposed lease areas occur within the lateritic plains. The topography of the two sites have low relief and surface water flow ultimately drains in a south and south westerly direction.

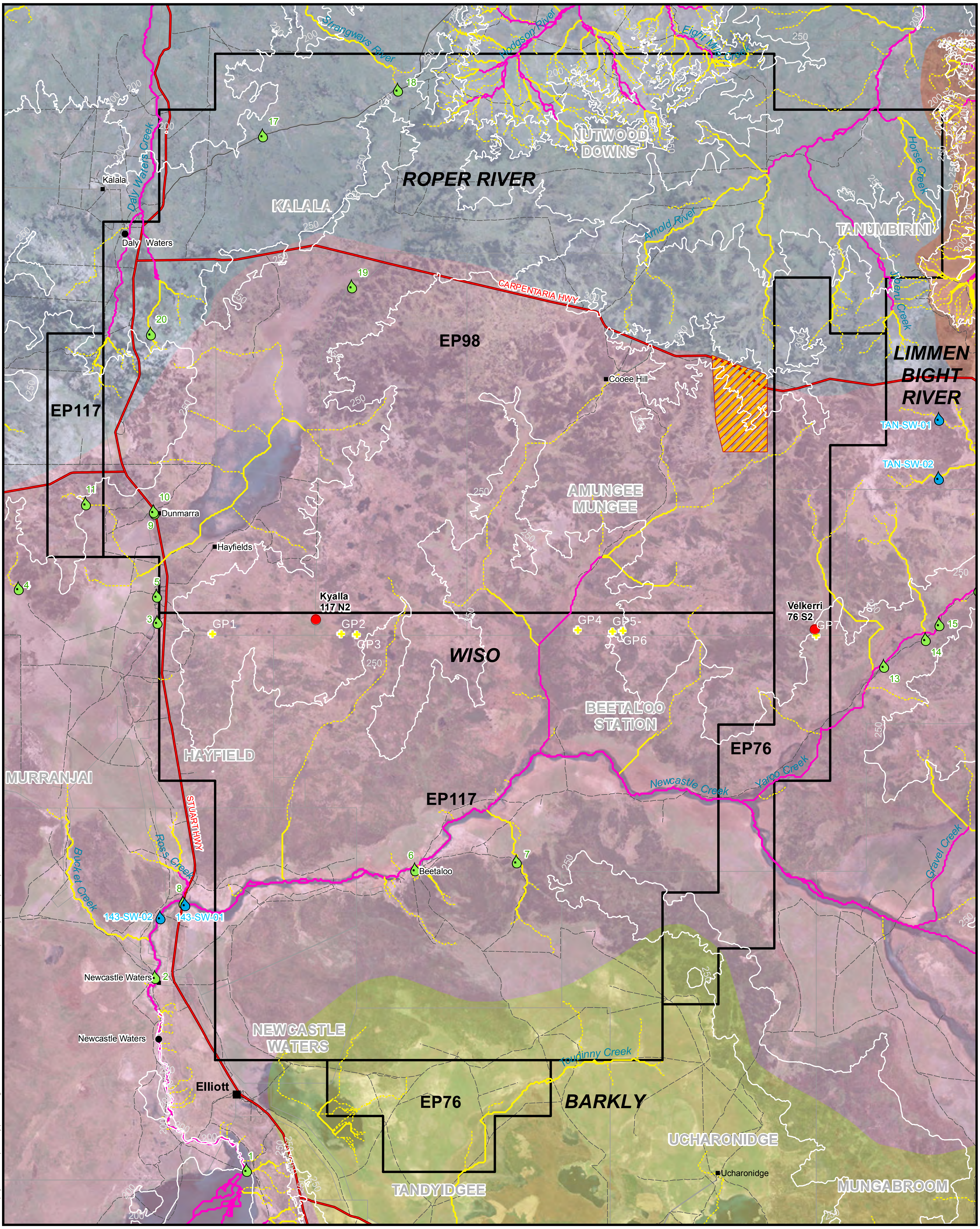
Three main river basins, Roper River Basin to the north, Wiso River Basin in the centre and the Barkly River Basin in the south occur within the exploration permit area (Figure 3). All the proposed lease areas are located within the Wiso River Basin. The Wiso River Basin covers the southern half of EP98 (south of the Carpentaria Highway) and the majority of EP117 and is internally drained by Newcastle Creek and a number of small ephemeral creeks. Newcastle Creek flows into Lake Woods, which is located south of Newcastle Waters Station.

Lake Woods covers an area of inundation of approximately 50,000 ha in normal rainfall years, extending to 80,000 ha in exceptionally wet years, after which it can retain water for several years (AECOM, 2015). Lake Woods is described as a major quasi-permanent surface water body in the region, although some semi-permanent and many ephemeral waterholes are located across the permit area (HLA, 2006b) and is listed as a Site of Conservation Significance by the Department of Environment and Natural Resources (DENR) and is listed on the Directory of Important Wetlands in Australia. Lake Woods is listed as a wetland of national significance in the Directory of Important Wetlands in Australia (DIWA: NT013 Lake Woods). The site meets criteria 1, 2, 3, 4, 5 and includes DIWA wetland types: B1, B6, B10, B13 and B14.

Although Lake Woods is located outside of the Exploration Permit Areas, it is fed principally by surface inflow of Newcastle Creek originating more than 160 km north-east on Amungee Mungee Station (NTG, undated). During the period of inundation, Lake Woods supports over 100,000 waterbirds including internationally significant numbers of Plumed Whistling-Duck. Numerous bird species nest and feed in the diverse wetland habitat, and the conservation group ‘Birdlife International’ nominated Lake Woods as an ‘Important Bird Area’ (IBA). The lake also includes the largest area of lignum swamp in the Northern Territory and in tropical Australia (NTG, undated).

Newcastle Creek (Stream Order 4) and a number of small intermittent streams (Stream Order 1 and 2) are located along the proposed access tracks to Velkerri 76 S2 site (refer Figure 3). The streams only flow for a short period during the wet season, with waterholes forming at the beginning of the dry season. If the wet season is poor, the waterholes will often remain dry, whereas, during heavy wet seasons, large areas of the internal drainage systems are flooded. The stream banks are often lined with a scatter of small trees which highlights them from the surrounding plains.

The two proposed lease pad areas are not located within the major flow pathway of Newcastle Creek and the small intermittent streams. During the wetseason it is likely the region would experience widespread surface flooding, to a depth of 30 cm, which has previously been identified by debris being collected on fence lines (HLA, 2005).



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Kilometers

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LEGEND

- Proposed Well 2018
- Homestead
- Place Name
- Populated Place
- Contours
- Gravel Pits
- Surface Water 2007
- Contours
- Surface Water 2015
- DLRM Surface Water
- Highway
- Minor Road
- Tracks
- Bullwaddy Conservation Reserve
- Cadastre
- Permit Areas

River Basins
- Barkly
- Limmen Bight River
- Roper River
- Wiso

Stream Order

Intermittant Streams
- 1
- 2

Creeks
- 3
- 4

Rivers
- 5
- 6
- 7

LOCATION

Data sources:
Permit Area, Cadastre, Basin - NT Gov 2014,
Places - Aust Gov 2014
Highways, Roads, Drainage - StreetPro 2014

ORIGIN ENERGY RESOURCES LIMITED
Environmental Management Plan 2019

Surface Water and Stream Order of Permit Area

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VERSION	1

Figure 3

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3.3 Land System

Land systems are defined because of their distinct differences from the surrounding areas and by the recurring pattern of geology, topography, soils and vegetation. Land system mapping for the permit area developed is a compilation of the Northern Land Systems (scale 1:250 000) and the Southern Land Systems (scale 1:1 000 000) (Department of Land Resource Management 2013). The data set is made up of the following:

- *Land Systems of the Northern Part of the Northern Territory* is an amalgamation of 16 existing Land System surveys with modifications to some of the original interpretations. This land system dataset is the Northern Territory contribution to Australian Soil Resource Information System (ASRIS) national soils database at scale 1:250,000.
- *Land Systems of the Southern Part of the NT* is a compilation of three existing land system surveys and the Atlas of Australian Soils (scale 1:2,000,000). It covers the southern part (approx 70%) of the Northern Territory. Published maps were made digital and edited to accommodate overlaps, gaps and mismatching boundaries. Where possible, the land system descriptions have been extrapolated into areas covered by the broader scale Atlas mapping.

Using the available information, there are 22 different land systems located within the exploration permit areas. The Velkerri 76 S2 and Kyalla 117 N2 proposed lease area and seven proposed gravel pits all occur within the Beetaloo Land System which is characterised by:

- gently undulating lateritic plains and rises
- lateritic red earths and lateritic podzolic soils
- *Acacia shirleyi* (Lancewood) forest.

3.4 Soils

The dominant soils encountered within the permit area have been derived from ancient rock formations and ancestral soils that were formed during the earlier weathering cycles. The soils are deeply weathered and leached (Orr and Holmes, 1984). The soils in the permit area have been influenced by:

- past wetter conditions that formed relict Tertiary plains which comprise highly leached and lateritic soils
- extensive areas of Post-Tertiary Alluvia on which a variety of mature soils formed
- the dissected hilly country that is dominated by skeletal soils or rocky outcrops
- a range of parent materials of residual soils, ranging from basic volcanic and highly calcareous rocks to granitoid rocks and sandstones (Christian *et al*, 1951).

The lateritic plains, located within the permit area, are classed as very strongly leached soils of the Tertiary land surface. The three main soil types located within the permit area, include:

- **Tertiary Lateritic Red Earths**, which occur on the gently undulating topography. The soil profile can be described as:

  A-Horizon Grey-brown sandy loam

  B-Horizon Reddish brown sandy clay loam

  C-Horizon Red-brown to red light clay, overlying heavy ferruginous gravel and massive laterite

- **Tertiary Lateritic Red Sands**, which occur on gently undulating to undulating topography of the Tertiary Lateritic Plain, formed from sandstones and complex parent materials of the deep sandy soils. The soil profile can be described as:

  A-Horizon Grey-brown to brown sand

  B-Horizon Brown sand

C-Horizon	Red-brown to yellow-brown sand overlying pisolitic ferruginous gravel and massive laterite. Altered colouring of highly siliceous parent sandstone is only evident in the mottled and pallid zones.

- **Tertiary Lateritic Podzolic Soils**, formed on the gently undulating topography over a variety of rocks. These soils are located in the northern section of the Barkly Basin. The soil profile can be described as:

A-Horizon	Grey sand
B-Horizon	Yellowish-grey sand
C-Horizon	Yellow-grey sandy loam with ferruginous gravel overlying massive laterite, mottled and pallid zones.

Geotechnical investigations have confirmed the proposed lease sites consist of red silty sand with some gravel pieces. Although Velkerri 76 S2 test result indicated a higher percentage of gravel content compared to Kyalla 117 N2 both sites should be characterised as red silty sand. The surface soils collected during the field survey indicated the soils were slightly acidic (ph range of 5.0 to 6.2) across the permit area. A dispersion test was also undertaken on the samples which indicated that the soils were non-dispersive and maintained their shape when submerged in water. Results from the soil testing is provided in Appendix A.

There are also small sections of the proposed access track that may traverse through Black soil plain country. Black Soil Plains are located within the Barkly Tablelands, including EP76, the southern part of EP117 and a small section of EP98. The soils usually crack widely in the upper profile upon drying and have a loose, self-mulching surface. The soils are neutral to alkaline, calcareous and commonly have depths to one metre (Fisher, 2001). The cracking clay soils occur mostly on flat or gently undulating plains ('downs') and are associated with the exposure and weathering of sedimentary or basic volcanic rocks. The Black soils also occur on the more recent depositional landscapes in the form of alluvial clays associated with drainage lines and major river systems.

3.4.1 Erosion Susceptibility

Soil erosion susceptibility varies throughout the permit area, dependent upon the soil types, slope and extent of ground disturbance. Apart from the erosive impact of climatic conditions, soil erosion is influenced mainly by the inherent properties of the soils and the processes which occurred during the formation of the landscapes (Aldrick and Wilson, 1992).

Erosion will occur in the permit area if the land is used beyond its capacity, as is seen if land is overstocked or vehicle movements not controlled, for example. The location of proposed lease areas has been examined on the ground, to determine the risk of erosion occurring. Factors considered include the following.

- Soil type – soils with higher clay content are prone to generation of bulldust and are easily eroded by wind and water. Gravelly soils tend to be more robust to disturbance on the scale expected during the exploration program. Both sites reported a soil type of red silty sand.
- Slope – the slope of the site will determine the risk of erosion during rainfall events, with steeply inclined areas a higher risk than small undulations in the landform. All the proposed lease sites were in very flat (low relief) with a slope of <1%. During the program, the crossings of the access track on the small ephemeral streams and Newcastle Creek will require additional controls.
- Aspect – the position of the access track and pads in relation to the direction of the contour should be considered and creation of tracks across (as opposed to parallel with) the contour should be avoided.
- Rainfall – Table 4 present the erosion risk rating based on average monthly rainfall using the rating system provided in the IECA (2008) Table 4.4.2 for Daly Waters. The construction activities for all exploration activities is proposed to be commence following the wet season from April 2019 onwards. Most of the soil disturbance activities will be completed prior to the onset of the wet season in November 2019. As such, based on rainfall during the construction period, the overall risk of erosion is considered very low for the Velkerri 76 S2 and Kyalla 117 N2 sites.

Table 4 Erosion Risk Rating based on average monthly rainfall at Daly Waters

-Item	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	165.4	165.4	120.1	23.6	5.0	5.6	1.5	1.7	4.9	22.5	59.4	110
Erosion Risk*	H	H	H	VL	VL	VL	VL	VL	VL	VL	M	H

** E = Extreme (>225 mm); H = High (100+ to 225 mm); M = Moderate (45+ to 100 mm); L = Low (30+ to 45 mm); VL = Very Low (0 to 30 mm)*

Based on the sites descriptions and the results from the soil samples, the erosion risk for the proposed lease areas is considered None/Slight erosion risk. This was confirmed during the field survey in August 2018 which reported no evidence of erosion within the proposed lease areas.

Certain sections of the proposed access tracks are likely to encounter more erosion susceptible soils, such as the access track to the southern sites and where streams and Newcastle Creek are crossed (refer Section 3.2). Mitigation measures will need to be established to minimise the risk for erosion along the track and are stabilised leading up to the wet season.

Overall, the main issues to be managed in relation to soils during exploration activities in the permit areas include:

- the generation of bull dust along the access tracks. Noting previous observations have indicated bull dust had formed where the surface crust had been disturbed and then subjected to repeated ground disturbance (AECOM 2015). This was primarily in grassland areas.
- The formation erosion gullies along inappropriately placed tracks and fence lines, where a slope was present. Scolding to bedrock has previously been observed in other areas of the permit, as well as pooling of water in areas of compaction and subsidence.

3.5 Biological Environment

3.5.1 Vegetation Communities

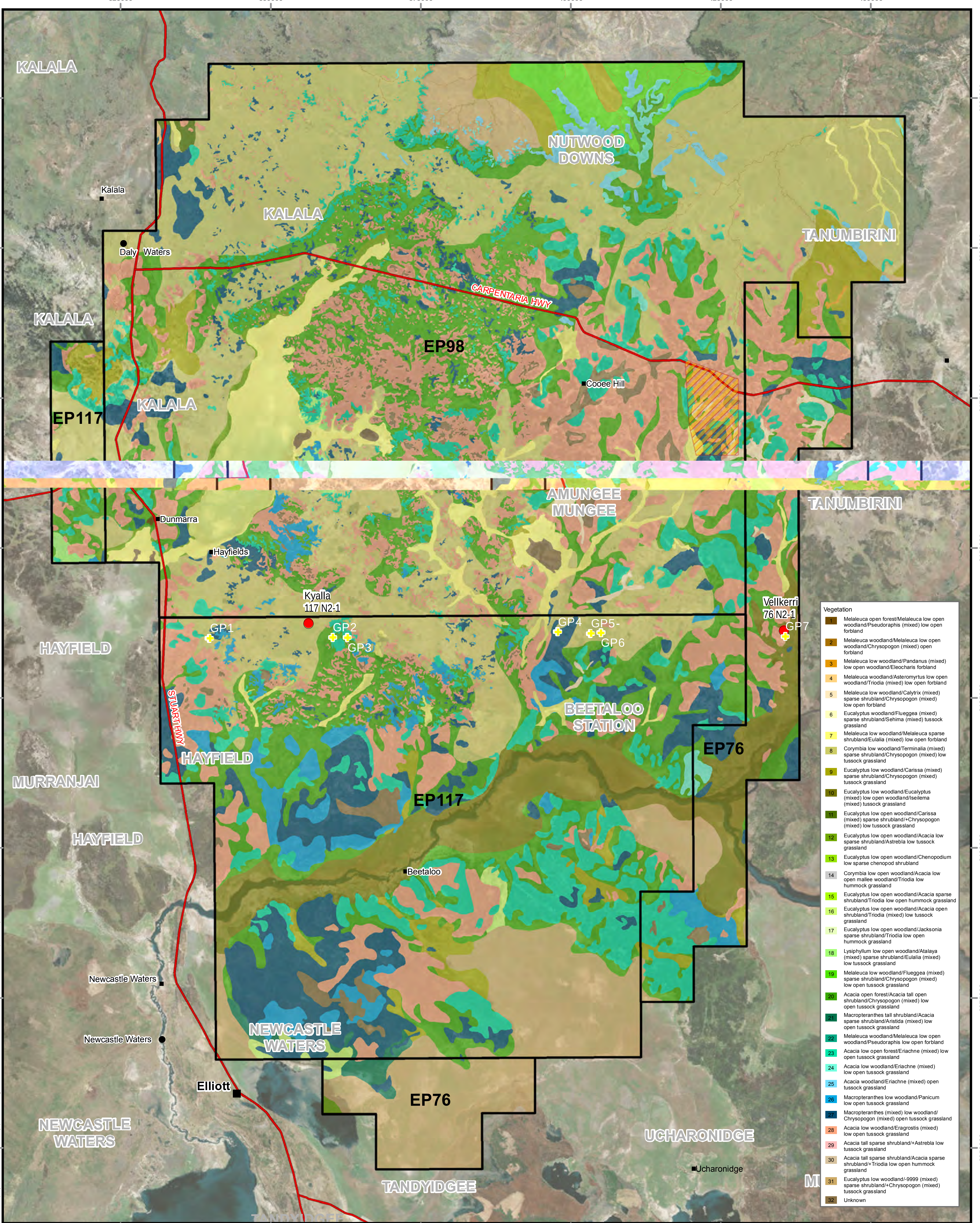
The Interim Biogeographic Regionalisation of Australia is a nationally recognised ecosystem classification system (Environment Australia, 2000). Bioregions are large, geographically distinct ecosystems that are distinguished by broad physical and biological characteristics, which can be further classified into Subregions. These regions and subregions are used as the basis for regional comparisons and conservation of flora and floristic communities.

Of the 85 bioregions mapped nationally, 20 occur within the Northern Territory and only two within the Origin permit areas, the Sturt Plateau bioregion and the Mitchell Grass Downs bioregion. The 2018 proposed lease sites all fall within the Sturt Plateau Bioregion which comprises undulating plains on sandstone, with predominantly neutral sandy red and yellow earth soils. Dominant vegetation associations included extensive areas of Lancewood (*Acacia shirleyi*) - Bullwaddy (*Macropteranthes kekwickii*) vegetation. Land condition in the bioregion is moderate to good but is threatened by impacts from weeds, feral animals, pastoralism and changed fire regimes.

Vegetation communities within the permit areas have been ground-truthed during baseline assessments in 2004, 2006 (HLA, 2006; 2006c), 2010, 2014, 2016 (AECOM, 2011; 2014; 2016) and more recently in August 2018, along with assessments of weeds, habitat, erosion and land condition.

Kyalla 117 N2 vegetation community including the turn-in is described as *Corymbia* spp open woodland with mixed *Terminalia* spp. shrubland over low tussock grassland (*Triodia bitextura*). Whereas, Velkerri 76 S2 vegetation community is described as *Eucalyptus/Corymbia spp.* low open woodland with *Iseilema spp.* mixed tussock grassland. Directly to the west and south of Velkerri 76 S2 there is a large stand of Bullwaddy and Lancewood vegetation community which the proposed access track previously traversed. Following site survey the project has determined that the access track will now be diverted around the Lancewood/Bullwaddy stand to minimise impact on a known sensitive vegetation community.

Figure 4 provides vegetation communities across the entire permit area, while Figure 5 and Figure 6 provides the vegetation communities on the proposed lease sites, Kyalla 117 N2 and Velkerri 76 S2.



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LEGEND

- Proposed Wells 2019
- Homestead
- Place Name
- Populated Place
- Highway
- Permit Areas
- Bullwaddy Conservation Reserve
- Gravel Pits

LOCATION

Data sources:
Permit Area, Cadastre - NT Gov 2019.
Places, Vegetation - Aust Gov 2019
Highways, Roads, Drainage -

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Vegetation Communities

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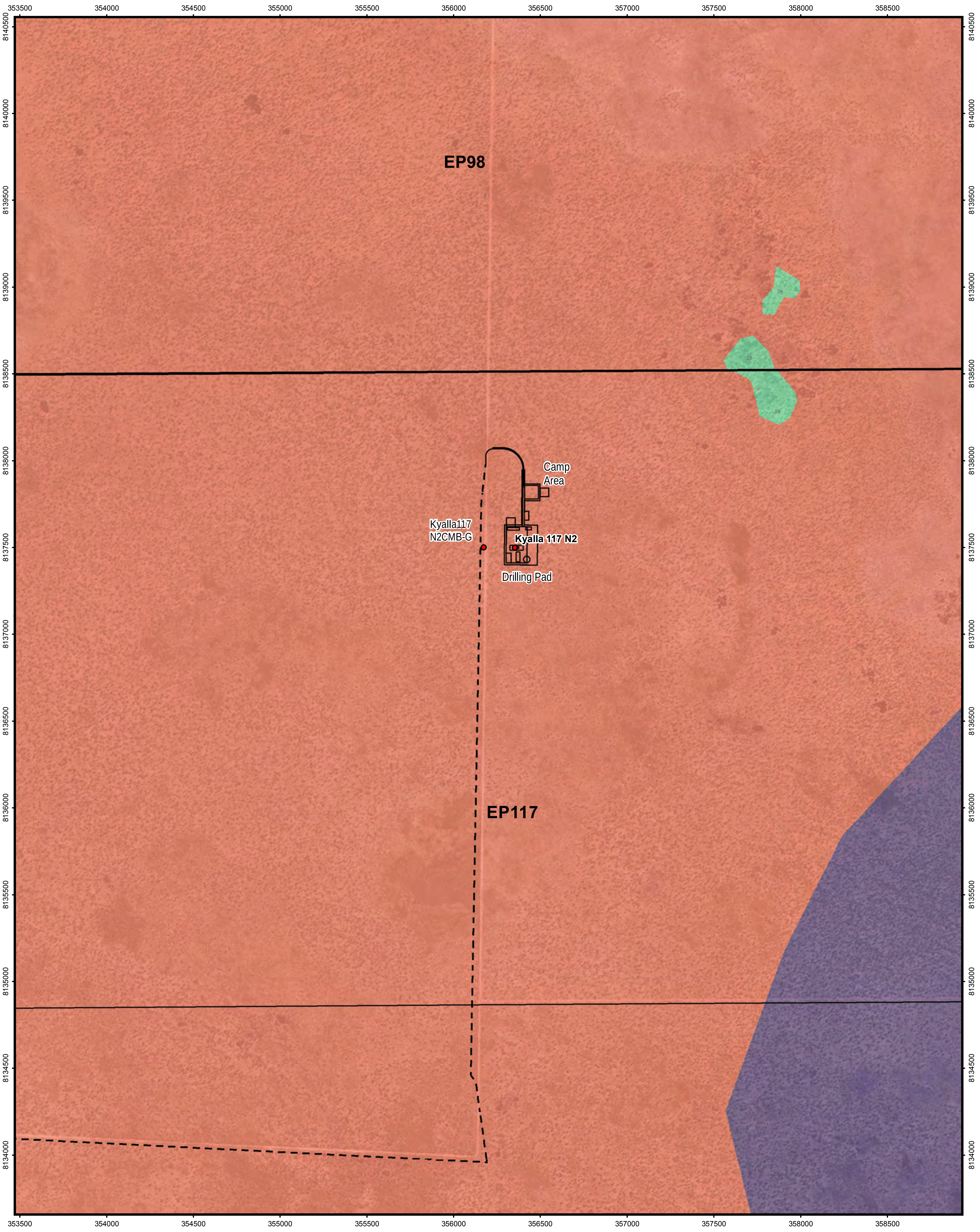
Figure 4

A3 size



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Meters

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LEGEND

- KYA117-N2 CMB-G
- Proposed 2019
- Drill Pad and Services Location
- Permit Areas

Vegetation Community

- Acacia low woodland/Eragrostis (mixed) low open tussock grassland
- Acacia open forest/Acacia tall open shrubland/Chrysopogon (mixed) low open tussock grassland
- Corymbia low woodland/Terminalia (mixed) sparse shrubland/Chrysopogon (mixed) low tussock grassland

LOCATION

Data sources:
Permit Area, Cadastre - NT Gov 2019.
Places, Vegetation - Aust Gov 2019
Highways, Roads, Drainage -

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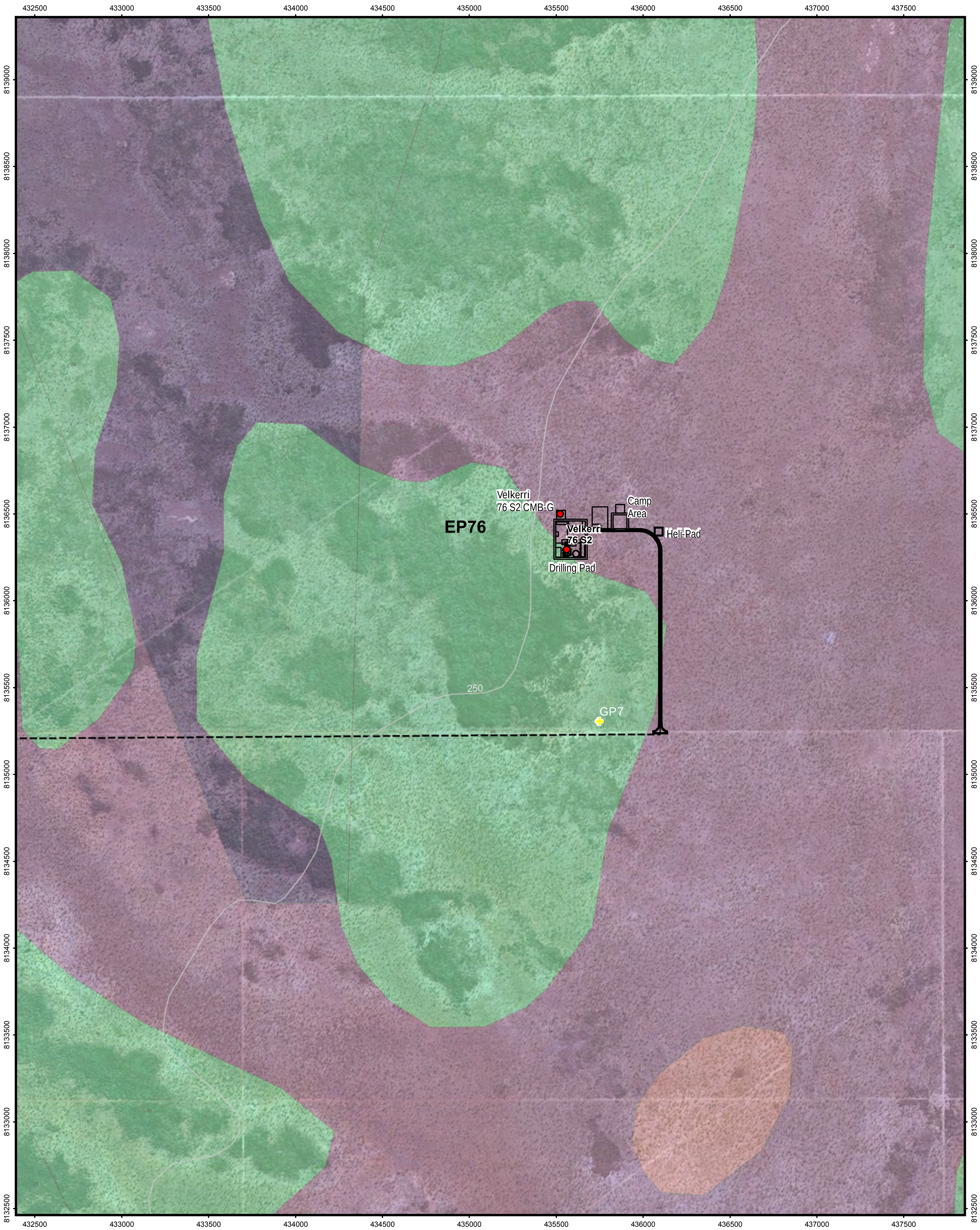
Kyalla 117 N2-1
Vegetation Community

PROJECT ID	60480548
CREATED BY	jace.emberg
LAST MODIFIED	04-Mar-2019
VERSION	1

Figure
5



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Projection: GDA94 MGA Zone 53

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LEGEND

- Velkerri76 S2 CMB-G
- Velkerri76 S2
- Permit Areas
- Tracks
- Contours
- Gravel Pits

Vegetation

- Acacia low woodland/Eragrostis (mixed) low open tussock
- Acacia open forest/Acacia tall open shrubland/Chrysopogon (mixed) low open tussock grassland
- Eucalyptus low woodland/Eucalyptus (mixed) low open woodland/Iseilema (mixed) tussock grassland
- Macropteranthes (mixed) low woodland/Chrysopogon (mixed) open tussock grassland

LOCATION

Data sources:
Permit Area, Cadastre - NT Gov 2019.
Places, Vegetation - Aust Gov 2019
Highways, Roads, Drainage - StreetPro 2019

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Velkerri 76 S2-1

PROJECT ID	60480548
CREATED BY	jace.emberg
LAST MODIFIED	20-May-2019
VERSION	1

Figure
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The approximate 107 km of the existing access track is predominantly surrounded by the same vegetation unit as Kyalla 117 N2, with patches of Bullwaddy and Lancewood, including at the proposed entrance off the Stuart Highway and surrounding some of the Gravel Pits. In addition, there are some areas of minor stands of Melaleuca low open wood and mixed acacia woodlands.

Previous exploration activities in the permit area provided some understanding on how the vegetation communities regenerated following clearing and rehabilitation. The rehabilitation monitoring following previous exploration programs were undertake during 2007 and again in 2013 (HLA, 2007 and 2013). It was noted that in the first year the success of rehabilitation was greatest in communities with grassland understory (primarily due to annual grass growth), whereas woodlands (mainly Lancewood and Bullwaddy) showed low levels of natural regeneration. By 2013, six years after disturbance the origin seismic lines through the Lancewood were such that there was almost no difference in the canopy height to the surrounding Lancewood communities.

The vegetation types described for the identified gravel pit locations are described in Table 5.

Table 5 Gravel Pit Vegetation Description

Gravel Pit	Vegetation Description
GP1	Corymbia low woodland/Terminalia (mixed) sparse shrubland/Chrysopogon (mixed) low tussock grassland
GP2	Acacia open forest/Acacia tall open shrubland/Chrysopogon (mixed) low open tussock grassland
GP3	Acacia open forest/Acacia tall open shrubland/Chrysopogon (mixed) low open tussock grassland
GP4	Macropteranthes (mixed) low woodland/Chrysopogon (mixed) open tussock grassland
GP5	Corymbia low woodland/Terminalia (mixed) sparse shrubland/Chrysopogon (mixed) low tussock grassland
GP6	Corymbia low woodland/Terminalia (mixed) sparse shrubland/Chrysopogon (mixed) low tussock grassland
GP7	Acacia low woodland/Eragrostis (mixed) low open tussock grassland

The vegetation throughout the permit area during the August 2018 survey appeared in very good condition with minimal impacts from grazing, fire and erosion.

3.5.2 Flora

A total of 805 plant species have been recorded within the wider region, during the August 2018 survey 10 dominant flora species were identified at Kyalla 117 N2 and Velkerri 76 S2 (Appendix B). As the survey was conducted during the late dry season, grasses and other annual species were difficult or impossible to identify due to the lack of inflorescence or because they had already died-back.

No Commonwealth or NT threatened plant species were identified as occurring by the Protected Matters Searches (refer Appendix C). One species, the prostrate, herbaceous vine *Ipomoea argillicola*, is listed as Near Threatened under Section 29 of the *Territory Parks and Wildlife Conservation Act 2000* (TPWC Act) and could potentially occur in the project sites, although has not been reported in previous and current surveys. NT flora data base shows that this species has been recorded from the Bullwaddy Conservation Reserve and at locations surrounding the area in previous searches (AECOM, 2015).

The region supports fragmented stands of Bullwaddy, which is listed under the TPWC Act as 'Least Concern', which refers to species that are either widespread or common and cannot be categorised as Critically Endangered, Endangered, Vulnerable, Near Threatened or Data Deficient. However, Bullwaddy is significant in terms of the habitat it provides for a range of native species. The extent of Bullwaddy in the permit area is far more extensive than that indicated by the NT Herbarium records.

3.5.3 Weeds

Weeds remain an increasing threat to the Barkly region's natural assets. This threat is not new and considerable time and effort has already been invested in weed management across the region (Department of Land Resource Management, 2015).

Figure 7 and Table 6 provides a list of weed species that are known to occur or likely to occur within the wider exploration Permit Areas.

This information is based on:

- Mapping data provided by the Weed Management Branch, DENR.
- *Weed Management Planning Guide: Onshore Petroleum Projects* (DENR, June 2019).
- Guidelines for the *Management of the Weeds of Beetaloo 2018* (DLRM et al 2018).
- Department of the Environment and Energy (DotEE) EPBC Act Protected Matters Report database.
- Previous data collected by AECOM in the permit area.

Table 6 NT listed weeds known of likely to occur within the Permit Area

Scientific Name	Common Name	Status	Data Source
Acacia nilotica	Prickly Acacia	Class A and C, WoNS	Weed Management Branch – Mapping data DotEE Protected Matters Report
Alternanthera pungens	Khaki Weed	Class B and C	DLRM databases (DLRM *et al* 2018)
Andropogon gayanus	Gamba Grass	Class A and C, WoNS	Weed Management Branch – Mapping data
Azadirachta indica	Neem	Class B and C	Weed Management Branch – Mapping data
Cenchrus ciliaris	Buffel Grass	Not declared in NT	DotEE Protected Matters Report
Cenchrus echinatus	Mossman River Grass	Class B and C	DLRM databases (DLRM *et al* 2018)
Datura ferox	Fierce Thornapple	Class A and C	DLRM databases (DLRM *et al* 2018)
Hyptis suaveolens	Hyptis	Class B and C	Weed Management Branch – Mapping data DLRM databases (DLRM *et al* 2018)
Jatropha gossypiifolia	Bellyache Bush	Class B and C, WoNS	Weed Management Branch – Mapping data DLRM databases (DLRM *et al* 2018) DotEE Protected Matters Report
Parkinsonia aculeate	Parkinsonia	Class B and C, WONS	Weed Management Branch – Mapping data DLRM databases (DLRM *et al* 2018) DotEE Protected Matters Report

Scientific Name	Common Name	Status	Data Source
Prosopis pallida	Mesquite	Class A and C, WONS	Weed Management Branch – Mapping data DLRM databases (DLRM *et al* 2018)
Sida acuta	Spinyhead sida	Class B and C	Weed Management Branch – Mapping data
Sida cordifolia	Flannel Weed	Class B and C	Weed Management Branch – Mapping data DLRM databases (DLRM *et al* 2018)
Sida rhombifolia	Paddy's Lucerne	Class B and C	DLRM databases (DLRM *et al* 2018)
Tamarix aphylla	Athel pine	Class B and C, WONS	Weed Management Branch – Mapping data
Themeda quadrivalvis	Grader Grass	Class B and C, WoNs	Weed Management Branch – Mapping data
Tribulus terrestris	Caltrop	Class B and C	DLRM databases (DLRM *et al* 2018)
Xanthium occidentale	Noogoora Burr	Class B and C	Weed Management Branch – Mapping data DLRM databases (DLRM *et al* 2018)

Note: Declarations under the Northern Territory Weeds *Management Act 2013*:

- a Class A weed is to be eradicated
- a Class B weed is to have its growth and spread controlled
- a Class C weed is not to be introduced to the NT.

* All Class A and B weeds are also Class C.

They survey undertaken in August 2018 and June 2019 of the proposed exploration lease areas did not identify any weed species. This suggests that the habitat condition in the areas of the proposed sites and surrounding areas were good.

Previous surveys within the Permit Area in 2014, 2015, 2016, 2018 and 2019 of drill sites and access tracks have also found that the proposed areas had a low number of weed species which suggests the habitat condition was fairly high in and around the Permit Area. Specifically, three listed species, *Parkinsonia aculeate* (Parkinsonia), *Hyptis suaveolens* (Hyptis) and *Calotropis procera* (Rubber Bush) have been recorded.

Rubber Bush (Plate 1) was recorded during the follow up survey conducted June 2019. In addition, Wild Passionfruit (*Passiflora foetida*) (Plate 2) and Stylo (*Stylosanthes* sp.) were observed throughout the area but are not listed as weed under NT legislation.

Rubber Bush (Class B and C) has previously been recorded in close proximity to the Beetaloo access track in 2016 and was also noted during the 2019 survey at the start of the Stuart Highway intersection (Plate 1). This was a patch of adult plants with seedpods.

Parkinsonia is considered a Weed of National Significance (WoNS), which are weed species that are the focus of national management programs for restricting their spread and/or eradicating them from parts of Australia. This species was not recorded within the proposed 2019 exploration area.

It is possible that additional species are present but were present in low abundance or difficult to identify due to stage of growth.

Plate 1 Rubber Bush near the Stuart Highway Intersection on Hayfield/Shenandoah

Plate 2 Wild Passionfruit also located near the Stuart Highway Intersection.

These weed species surveyed within the Permit Area and their corresponding Northern Territory *Weeds Management Act 2013* declarations are listed in Table 7.

Table 7 Species found within the permit area

Scientific Name	Common Name	Declaration	Where located
Hyptis suaveolens	Hyptis	Class B and C	Beetaloo access track Access track to Velkerri 98-E1-1 site Stuart Highway
Parkinsonia aculeate	Parkinsonia	Class B and C, WONS	Beetaloo access track
Calotropis procera	Rubber bush	Class B and C	Close proximity to the Beetaloo access track. At beginning of 2019 Access Track near Stuart Highway Intersection

In addition to these 18 species a range of annual grass weeds are known to occur along road corridors throughout the region. Hyptis (Plate 3), and Buffel Grass (*Cenchrus ciliaris*) (Plate 4) were recorded along the Stuart Highway within the NTG Road Reserves. Buffel Grass is of concern due to its invasive nature and ability to alter ecosystem function. Buffel Grass however was introduced and cultivated for livestock feed and is useful in soil stabilisation.

Plate 3 Hyptis at a road side truck stop on the Stuart Highway

Plate 4 Buffel Grass on top of a Table Drain along Stuart Highway

The *Guidelines for the Management of the Weeds of Beetaloo 2018* (DLRM et al 2018), also identifies a number of introduced plants that have previously been recorded within the proposed permit areas and have been identified as problem weeds in one or more locations across Northern Australia. It is noted that these are not listed under the NT *Weeds Management Act* but could be of concern elsewhere in Australia. Understanding the potential weeds likely to occur within the Permit Area is particularly important when proposed activities include transporting machinery and equipment during the construction process.

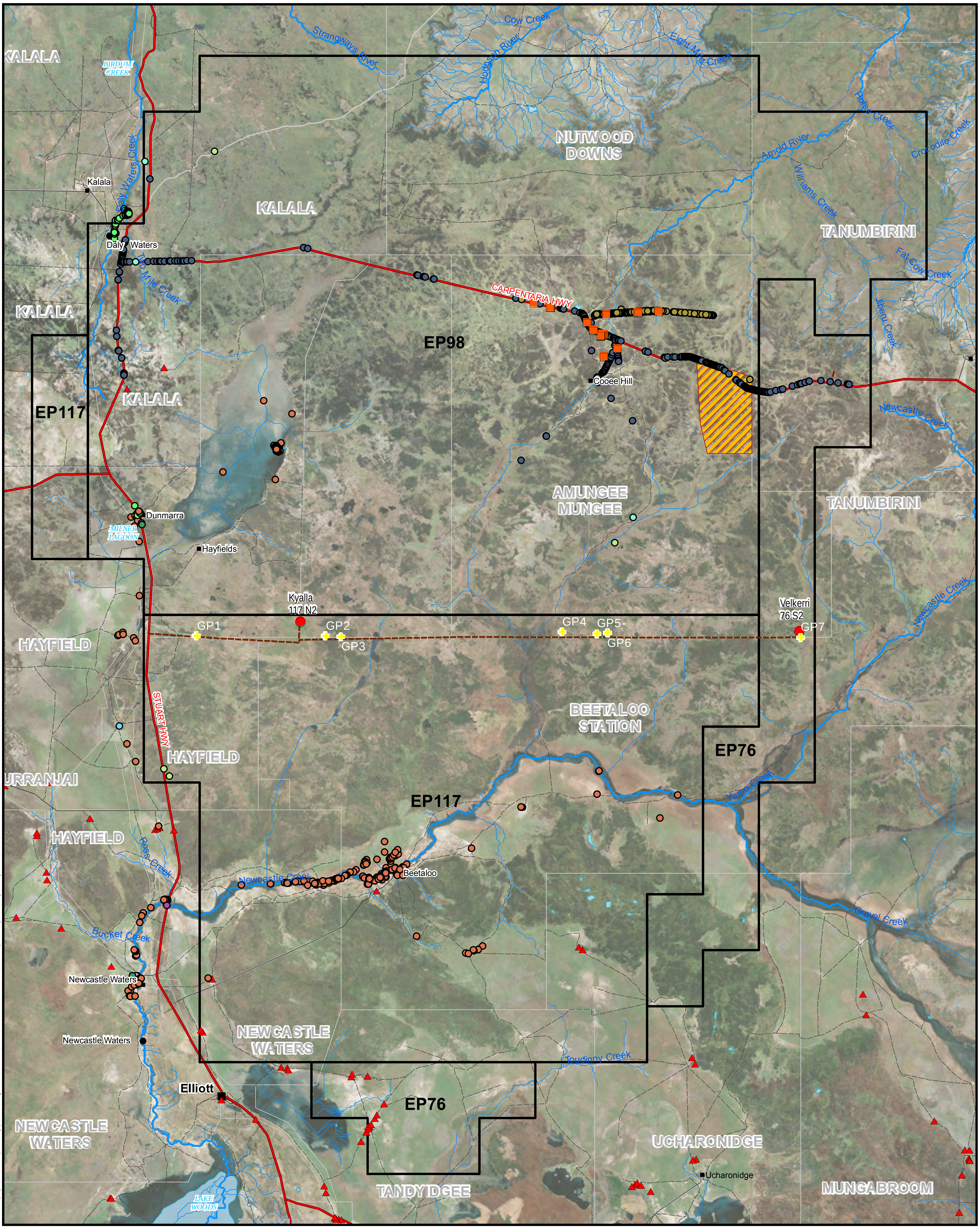
The *Barkly Regional Weed Management Plan* provides additional information on regional weed management priorities and management actions to support landholders in their obligations to manage weeds on their land (DLRM, 2015).

This plan includes a list of alert weed species. These species are not yet naturalised in the region but have the potential to have a high level of impact to the region should they become established. The likelihood of the species naturalising and spreading in the region is perceived to be high (DLRM, 2015).

The alert species identified the *Barkly Regional Weed Management Plan* are listed Table 8. If found the program EMP requires the Weed Management Branch to be contacted for identification and disposal.

Table 8 Alert species identified in the Barkly Region

Scientific Name	Common Name	Declaration
Cenchrus setaceum	Fountain grass	Class B and C
Parthenium hysterophorus	Parthenium	Class A and C, WONS
Cryptostegia grandiflora	Rubber vine	Class A and C, WONS



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LEGEND

- Proposed Wells 2019
- Homestead
- Place Name
- Populated Place
- Major Stream
- Minor Stream
- Access Tracks
- Highway
- Minor Road
- Tracks
- Cadastre
- Permit Areas
- Bullwaddy Conservation Reserve
- Gravel Pits

Weed Name

- Athel pine
- Bellyache bush
- Burr - Noogoora
- Gamba grass
- Grader grass
- Hyptis
- Mesquite
- Neem
- Parkinsonia
- Prickly acacia
- Sida - Flannel weed
- Sida - Spiny head
- Gamba Grass
- Rubberbush

LOCATION

Data sources:
Permit Area, Cadastre - NT Gov 2019.
Places, Vegetation - Aust Gov 2019
Highways, Roads, Drainage - StreetPro 2019

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2019 Environmental Management Plan

Weeds of the Permit Area

PROJECT ID	60480548
CREATED BY	jace.emberg
LAST MODIFIED	20-May-2019
VERSION	1

Figure 7

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3.5.4 Fauna and Habitat

Previous surveys and database searches indicate that the permit areas are an important area for a diverse array of fauna. The NT Fauna database provides records for the following fauna species (excluding migratory birds): 32 species of mammal, 198 species of birds, 96 species of reptiles and 19 species of frogs. Surveys undertaken elsewhere within the region have recorded:

- 78 bird, 33 reptile, 11 mammal and six frog species in the Bullwaddy Conservation Reserve (PWCNT, 2005)
- 148 bird, 47 reptile, 21 mammal and six frog species in the Junction Stock Reserve and nearby Newcastle Waters (Fleming *et al.*, 1983)
- 157 bird species within the project area as determined by a search of the Birds Australia bird atlas database (Birds Australia, 2010).

The proposed exploration sites are all located within similar habitat types consisting primarily of open *Eucalyptus*/*Corymbia* woodland with a tussock grass understorey. There are Bullwaddy/Lancewood communities around the proposed sites and individuals of both species are dispersed throughout. In the wider landscape, including proposed access tracks, additional vegetation types include those associated with drainage lines, grasslands/floodplains and acacia shrublands.

Eucalypt/Corymbia woodland provides habitat for a range of species. The proposed sites had high native grass cover and included numerous species suitable for granivorous birds (seed eaters). Dense leaf litter and numerous logs provide suitable refuge and foraging sites for fauna such as reptiles. Although most of the species found in this vegetation type are widespread in the tropical savannas of the Northern Territory, some such as the threatened Crested Shrike-tit (*Falcunculus frontatus whitei*) are rare and known to utilise this habitat (DoTEE, 2014, Ward, 2008). Many of the sites have a high density of hollow-bearing trees that provide important habitat for many fauna species. Avoiding clearing large hollow-bearing trees will reduce the impact to native wildlife within the permit area.

Savanna grasslands and open woodland provide suitable habitat for species such as Emu (*Dromaius novaehollandiae*) and Australian Bush Turkey (*Ardeotis australis*. Drainage lines and seasonally inundated grasslands may also provide habitat for migratory species during the wet season and are breeding areas for frogs. Limiting disturbances in these areas and avoiding these areas during the wet season would limit impacts on fauna.

3.5.4.1 Threatened Fauna

A search of the DotEE Protected Matters database of nationally significant fauna (PMST), the NT Government fauna database (NRM Infonet), and records from the Atlas of Living Australia (ALA) was undertaken for the proposed lease areas and access tracks. The search results indicate the potential presence of 15 fauna species listed as threatened under the EPBC Act and/or the TPWC Act (Table 9). These included ten birds, eight mammals and two reptiles.

The likelihood assessment of species occurrence is based on the availability of suitable habitat within the permit area, records in the vicinity and distributional data. Therefore many of the threatened and migratory fauna species indicated in databases as ‘occurring’ or ‘likely to occur’ have been assessed as *unlikely to occur* within the proposed exploration lease areas. As some areas in the proposed lease area have not been subject to intensive survey and some species are very cryptic, a conservative approach has been taken to assess species presence. A full description of each species, their distribution and habitat associations are outlined in Table 9 below.

No core habitat for threatened fauna was identified at the sites. However, some species may possibly occur and are known to occur in the wider landscape. Threatened species that may possibly occur include:

- Gouldian Finch *Erythrura gouldiae* (E-EPBC Act, VU-TPWC Act)
- Crested Shrike-tit (northern) *Falcunculus frontatus whitei* (VU-EPBC Act, NT-TPWC Act)

Research has shown that critical components of suitable habitat for the Gouldian Finch include suitable nesting trees during the breeding season (particularly *E. tintinnans*, *E. brevifolia* or *E. leucophloia*), a water source and a diverse range of favoured annual and perennial grasses (DoE, 2015). No nesting habitat was recorded during the surveys and it is unlikely this species breeds in close vicinity of the sites. During the wet season Gouldian Finches move from breeding habitat on hillsides with suitable trees down to lower lying areas where they forage on perennial grasses such as *Triodia* sp., *Alloteropsis semialata*, and *Chrysopogon fallax* (Palmer *et al*. 2012). Some of the perennial grasses were recorded during recent surveys so potential foraging habitat is present; however, there are limited records in the vicinity of the sites suggesting it is not an important area for this species.

The Crested Shrike-tit lives in dry Eucalypt forests and woodland where it feeds on insects from the canopy and also under bark (Ward, 2008). It has been recorded in wet Melaleuca open woodlands, woodlands dominated by Nutwood (*Terminalia arostrata*), Bloodwoods with flaky bark and ironwood (DoE, 2014, Ward, 2008). In the NT, nesting has been recorded from September through to January and nests are built in terminal branches at the top of trees (Ward *et al*., 2009). The stronghold of this species is north of this location and only one old record exists near Borroloola. Although it is possible this species may be present in the area, it is unlikely to represent an important area for this species and the impact of the proposed activities, given their size, would be small.

The Grey Falcon (*Falco hypoleucus*) is a widespread species listed as Vulnerable in the NT that is considered possibly to be present in the study area. The Painted Honeyeater (*Grantiella picta*) has been known to occur in the study area, however, given it does not breed in the NT it would only be present intermittently for foraging. Based on the field assessment there was no breeding habitat recorded, and depending on grass seed and water availability it is unlikely the study area comprises core habitat for this species.

As records of species may be limited in remote areas the precautionary principle has been applied. There are some species that have been assessed as possibly occurring even though their primary habitat is not found within the proposed sites or access tracks. These include species that are associated with ephemeral wetlands, low lying areas that may be seasonally inundated and creeks. During the wet and early dry season these areas may sustain threated species such as wetland birds (including migratory species) and also the Plains Death Adder (*Acanthopis hawkei*).

Table 9 EPBC and TPWC Listed Threatened Species and Likelihood of Occurrence

Species	Conservation Status		Distribution	Habitat	Likelihood of Occurrence
	EPBC	NT			
Birds					
Calidris ferruginea Curlew Sandpiper	Marine Migratory	VU	In the NT this species occurs around Darwin, north to Melville Island and Cobourg Peninsula, and east and south-east to Gove. It has been recorded inland from Victoria River Downs and around Alice Springs (Higgins & Davies 1996).	Coastal habitats, inland it has been found around lakes, dams and ephemeral/permanent waterholes.	Unlikely (suitable habitat not present at survey sites but potential sporadic in wider landscape)
Erythrotriorchis radiatus Red Goshawk	VU	-	Found across most of Northern Australia, in the NT most records are from the Top End but there are records from central Australia (Pizzey & Knight, 2012).	Red Goshawks occupy a range of habitats, often at ecotones, including coastal and sub-coastal tall open forest, tropical savannahs crossed by wooded or forested watercourses. In the NT, it inhabits tall open forest/woodland as well as tall riparian woodland (Aumann & Baker-Gabb, 1991).	Unlikely (no records and core habitat absent)
Erythrura gouldiae Gouldian Finch	E	VU	Formerly widespread across northern Australia. In the NT they are found in the Top End south past Daly Waters (Palmer *et al*., 2012).	Gouldian Finches occupy different habitat types in the breeding and non-breeding season. Breeding habitat consist of hillsides with suitable nesting trees. In the non-breeding season they are found in lowland drainages to feed on suitable perennial grasses (Dostine & Franklin, 2002).	Possible (sporadic, foraging only, no recent records)
Falcunculus frontatus whitei Crested Shrike-tit (northern)	VU	NT	This species has a very patchy distribution with records from the Victoria River District to Maningrida. Only one record near Borroloola (1930) (Woinarski & Ward, 2012).	Occupies wet and semi-arid melaleuca and eucalypt open woodlands. May be associated with bloodwoods with flaky bark and ironwood (Ward, 2008).	Possible (no records in vicinity although suitable habitat present, very rare)

Species	Conservation Status		Distribution	Habitat	Likelihood of Occurrence
	EPBC	NT			
Falco hypoleucos Grey Falcon	-	VU	This species has a widespread distribution and records for this species exist throughout the NT. However, most records are from arid and semi-arid regions (Pizzey and Knight, 2012).	Grey Falcons inhabit lightly treed inland plains, gibber desserts, sandridges, pastoral lands, timbered watercourses and, occasionally, the driest deserts. (Pizzey and Knight, 2012). Also found also in association with inland drainage systems.	Likely (probably not at proposed lease areas but likely in floodplains across the permit area)
Geophaps smithii Partridge Pigeon	VU	VU	Occurs across the Top End of the NT, declined/disappeared from lower rainfall areas (Woinarski, 2007).	Found predominantly in open eucalypt forest and woodland with grassy understories (Woinarski, 2007).	Unlikely (no records, occurs north of the permit area although some habitat present)
Grantiella picta Painted Honey Eater	VU	VU	This species is found throughout eastern Australia but breeding is known from south-eastern Australia (Pizzey and Knight, 2012). This species is rare.	This species specialises on the fruit of mistletoes although it may also forage on nectar and insects (Garnett *et al.*, 2011). Numerous large tracts of *Acacia shirleyi* with abundant mistletoes were recorded in the vicinity of the Beetaloo sites.	Possible (records from Barkly Tablelands but none in close vicinity, habitat present, foraging only)
Polytelis alexandrae Princess Parrot	VU	VU	Occupies arid lands in Australia where it is patchily distributed (Woinarski, 2007).	Found in sand dune habitat, spinifex with eucalypts, and shrubs such as acacias, hakeas, and eremophilas (Pizzey and Knight, 2012; Woinarski, 2007).	Unlikely (most records from southern arid region, not primary habitat)
Rostratula australias Australian Painted Snipe	CE	VU	In the NT, probably occurs in central and southern area although it also possible occurs in the northern portion of the area (Woinarski *et al*, 2007).	These birds prefer a habitat of recently flooded temporary vegetated wetlands during the non-breeding period and brackish temporary freshwater wetlands with minimum vegetation during breeding periods. Birds usually forage in thick, low vegetated areas during the day (Curtis *et al*, 2012).	Unlikely* (one record, no suitable habitat at drill sites but may be present in the wider landscape during the wet season)
Tyto novvaehollandiae kimberli	VU	VU	Distributed in Northern Australia although not well	This species inhabits tall open eucalypt forest in the NT, especially those associated	Unlikely

Species	Conservation Status		Distribution	Habitat	Likelihood of Occurrence
	EPBC	NT			
Masked Owl (northern)			known. In the NT, occurs from Cobourg south to Katherine and the VRD and east to the McArthur River (DOTE, 2014)	with *E. Miniata* and *E. tetrodonta (*Woinarski, 2007*)*. Also found in riparian and monsoonal forest and rainforest (DOTE, 2014)	(primary habitat absent)
Mammals					
Dasyurus hallucatus Northern Quoll	E	CE	Found throughout most of Northern Australia although now restricted to six main areas (Menkhorst & Knight, 2011). In the NT it is found in the Top End as far southeast as Boroloola (DOTE, 2014). One previous record from Shenandoah Pastoral Lease (unknown date).	Northern Quolls do not have highly specific habitat requirements although the most suitable appear to be rocky habitats (Woinarski, 2007). They occur in a variety of habitats across their range, including open forest and woodland. Daytime den sites provide important shelter. Shelter sites include rocky outcrops, tree hollows, hollow logs, termite mounds, goanna burrows and human dwellings.	Unlikely (no recent records, no core habitat)
Pseudantechinus mimulus Carpentarian Antechinus	–	VU	Found in QLD and the NT. In the NT it has been reported from the Sir Edward Pellew Island group, and Pungalina reserve near Borroloola.	This species is distributed in rocky habitat including sandstone boulders and outcrops with hummock grasses (Woinarski, 2004). In QLD, this species has been recorded on rocky ridges and hill-slopes (Lloyd *et al*., 2013).	Unlikely (one record but no suitable habitat)
Isodon auratus Golden Bandicoot	V	E	This species used to be found across northern, central and western Australia but decline after European settlement (Woinarski, 2007). Now only found on Marchinbar Island in the NT and small area of the NW Kimberley (Fisher and Woinarski, 1994; Woinarski, 2007).	Previously inhabiting a range of arid and semi-arid habitats, in the NT it occupies heathland and shrubland and hummock grasslands on sandstone, vine thickets and grassy woodlands (Menkhorst and Knight, 2011; Woinarski, 2007).	Highly unlikely (only persists in NE Arnhemland)

Species	Conservation Status		Distribution	Habitat	Likelihood of Occurrence
	EPBC	NT			
Macroderma gigas Ghost Bat	VU	NT	The species' current range in northern Australia ranges from relatively arid conditions in the Pilbara region of Western Australia to humid rainforests of northern Queensland. A large colony occurs in a series of gold mine workings at Pine Creek, NT. This species have also been recorded throughout the mainland Top End north of approximately 17º latitude.	The distribution of this species is influenced by the availability of suitable caves and mines for roost sites (NTG, 2018).	Unlikely (no recent records, no suitable cave located near proposed sites)
Macrotis lagotis Greater Bilby	VU	VU	This species occurs in south-western Queensland and in arid north-western Australia (Western Australia and Northern Territory). This species was previously widespread in arid and semi-arid Australia (Pavey, 2009). The most northern records are from Newcastle Waters and Wave Hill (Southgate & Paltridge, 1998).	In the NT, this species is found on sandy soils dominated by spinifex (Pavey, 2009). Low shrubs such as *Acacias* and *Melaleucas* are also common in this habitat. Also hummock grassland associated with low lying drainage systems and alluvial areas.	Unlikely (no recent records, primary habitat limited in permit area)
Saccolaimus saccolaimus nudicluniatus Bare-rumped Sheath-Tailed Bat	CE	DD	Wide distribution from India through south-eastern Asia to the Solomon Islands, including north-eastern Queensland and the NT. The north-eastern Australian populations are described as the subspecies S. s. nudicluniatus, although it is	Previous specimens have been collected from Open *Pandanus* woodland fringing the sedgelands of the South Alligator River in Kakudu National Park (Friend and Braithwaite, 1986). In the NT, it has also been recorded from eucalypt tall open forests (Churchill, 1998)	Unlikely (no records and primary habitat not present)

Species	Conservation Status		Distribution	Habitat	Likelihood of Occurrence
	EPBC	NT			
			not clear whether this should be applied to the NT population (Duncan et al. 1999). There have been very few (<5 confirmed) records since (McKean et al. 1981; Thomson 1991). All confirmed records have been from the Kakadu lowlands.		
Trichosurus vulpecula vulpecula Common Brushtail Possum	–	E	Previously widespread in the NT, this species is now found in isolated locations in the southern NT (Woinarski, 2007).	This species occupies riparian habitat in the vicinity of rocky outcrops or slopes (Kerle *et al*., 1992).	Unlikely (no records in the vicinity of the lease area and no suitable habitat)
Rattus tunneyi Pale Field-rat	–	V	Inhabiting higher rainfall area including the Top End of the NT (Menkhorst and Knight, 2011).	This species favours dense vegetation found along rivers where it occupies burrows in loose colonies (Cole and Woinarski, 2002). However, this species can be found in a variety of habitats including woodlands if a dense understorey of grasses is present (Menkhorst and Knight, 2011)	Unlikely (one record from 1999 in greater area, primary habitat absent)
Reptiles					
Acanthopis hawkei Plains Death Adder	VU	VU	In the NT this species is found in the floodplains of the Adelaide, Mary and Alligator Rivers and the Barkly Tablelands.	Found on flat cracking soils in treeless floodplains where it forages on frogs, reptiles and rats.	Unlikely (no records or suitable habitat)
Varanus Mertensi Mertens Water Monitor	–	V	Distributed throughout coastal and inland waters in northern Australia. In the NT found throughout most of the Top	Semi-aquatic species that inhabits vegetation associated with water such as Pandanus and paperbark. Seldom found far away from water (Mayes, 2006).	Unlikely*(was confirmed during previous surveys along Newcastle

Species	Conservation Status		Distribution	Habitat	Likelihood of Occurrence
	EPBC	NT			
			End. Decrease in NT population attributed to Cane Toads.		Creek, habitat unsuitable at proposed exploration lease sites)

3.5.5 Feral Animals

Feral animals known to occur within the region include:

- Pig (*Sus scrofa*)
- Wild Dog (*Canis lupus familiaris*)
- Feral Cat (*Felis catus*)
- Cane Toad (*Bufo marinus*)
- Horse (*Equus caballus*)
- Donkey (*Equus asinus*)
- Water Buffalo (*Bubalus bubalis*)
- Camel (*Camelus dromedarius*)
- Black Rat (*Rattus rattus*)
- Domestic Cattle (*Bos Taurus*)

During the August 2018 survey evidence of cattle grazing in present or 1-2 years previously was recorded and in previous surveys of the permit area cat tracks were observed as the only non-native species recorded but based on records many species, especially Dogs/Dingo, Pigs and Cane Toads will be present in permit area. The disturbance from cattle within the proposed sites were considered to have resulted in less than 5% damage or no damage at all.

The Cane Toad is known to be present in the permit area and the Commonwealth DoTEE recognises this species as a 'key threatening process' related to their impacts on biodiversity through predation, competition, land degradation and poisoning. In the Northern Territory, the Cane Toad has been implicated in the decline of several species including a large number of reptiles such as the King Brown Snake and water monitors (Smith & Phillips, 2006).

Pest predators such as the Cat are most likely common although their abundance is difficult to assess due to their cryptic nature. Introduced predators such as Cats can impact many vertebrates (e.g. Dickman, 2009 &1996). One of the primary concerns of introduced predators in the site is the impact on EPBC listed species such as reptiles, and ground-dwelling birds. Feral cats are believed to be one of factors that have led to the decline of threatened ground-dwelling bird the Partridge Pigeon (Woinarski *et al*. 2007)

Species could be attracted to the increased activities at the site potentially increasing their abundance in the landscape, and their control should be taken into consideration during the proposed activities on site. It is of key importance during all phases of the project that care is taken to ensure that rubbish is securely contained (i.e. with suitable lids) and removed from the site as soon as possible to discourage attracting any feral animals.

3.5.6 Fire

Fire is a natural occurrence in most Australian ecosystems and plays an important role in their ecology. Fire is generally excluded from Mitchell grasslands by pastoral management in order to maintain forage throughout the dry season (HLA, 2005) whereas fire is more frequent in the Sturt Plateau.

Historically, the majority of dry season fires (June to September) have occurred in the northern half of the permit area, in EP76, EP98 and EP117. At this time of year, the fires are likely to be high intensity (HLA, 2005). Wet season fires (October to May) have occurred within the permit area. These fires are likely to be patchy and of lower intensity, depending on the state of curing of the fuel load.

Bullwaddy and Lancewood communities, which are located throughout the permit area, are fire sensitive and hot fires have the ability to reduce habitat quality for both flora and fauna species. Research suggests that fauna diversity may be impacted by a hot fire, particularly for diurnal reptiles (e.g. Legge *et al*., 2008).

Based on field data, fire disturbance was determined as follows:

- Vekerri 76 S2-1 – Fire Frequency 2-3 years previous, Intensity 1 (minor scars on some trees/shrubs and Height <1m.
- Kyalla 117 N2-1 – Fire Frequency 1-2 years previous, Intensity 4 (some trees and shrubs killed) and Height 1-4 m. It was noted that site appeared to have had a hot fire go through previously with abundance of new Acacia regrowth.

All sites that showed evidence of fire disturbance were showing signs of regrowth and recovery.

3.6 Land Condition Summary

Detailed land condition description and photographs of each of the proposed lease areas (Velkerri 76 S2-1, Kyalla 117 N2-1) are provided in Table 10 and Table 11 below.

Table 10 Velkerri 76 S2 Condition Description

Site ID	Velkerri 76 S2
Location	-16°51' 20.13, 134°23' 39.85
Landform and soil	Plains and rises associated with deeply weathered profiles (laterite) including sand sheets and other depositional products; sandy and earth soils. Trace of cracking clay soils.
Habitat type	*Eucalyptus/Corymbia low woodland*
Vegetation Community	Eucalyptus low woodland/low open tussock grassland This vegetation community is considered regionally extensive and not subjected to extensive clearing.
Dominant flora species	Canopy dominated by *Corymbia dichromophloia*, *Erythrophleum chlorostachys*. Shrub layer including *Eucalyptus sp*. Ground layer species include *Aristida latifolia, Pterocaulon sphacelatum, Triodia bitextura.*
Habitat condition	Good condition with evidence of recent grazing. Large hollow bearing trees and logs were common in the area. The large hollows provide suitable nesting and shelter for numerous fauna species including reptiles, arboreal mammals, and nocturnal birds. The habitat contained moderate refuge opportunities in the form of dense leaf litter, dense grass cover, and woody debris. Good continuous cover adjoining adjacent woodland habitat. No evidence of weeds or feral animals.
Potential Listed Threatened Species	Grey Falcon, Northern Shrike-tit, Plains Death Adder, Gouldian Finch.

Habitat photos at central point of survey site (August 2018)




Additional Habitat Photos across survey site (August 2018)


Table 11 Kyalla 117 N2-1 Condition Description

Site ID	Kyalla 117 N2-1
Location	-16°50' 29.01, 133°39' 0.16
Landform and soil	Plains and rises associated with deeply weathered profiles (laterite) including sand sheets and other depositional products; sandy and earth soils
Habitat type	*Corymbia* low woodland
Vegetation Community	*Corymbia* low woodland/*Terminalia* (mixed) sparse shrubland/*Chrysopogon* (mixed) low tussock grassland This vegetation community is considered regionally extensive and not subjected to extensive clearing.
Dominant flora species	Canopy dominated by *Corymbia dichromophloia, Eucalyptus setosa*. Shrub layer including *Acacia ancistrocarpa, Alphitonia pomaderroides, Brachychiton paradoxus.* Ground layer species include *Triodia bitextura*
Habitat condition	Good condition with evidence of recent grazing. Vegetation appeared to heavily burnt in recent years. No evidence of hollow bearing trees and logs. The habitat contained moderate to high refuge opportunities in the form of dense leaf litter, tussock grass cover, and woody debris. Good continuous cover adjoining adjacent woodland habitat and regionally extenisive. No evidence of weeds or feral animals.
Potential Listed Threatened Species	Grey Falcon, Northern Shrike-tit, Plains Death Adder, Gouldian Finch.

Habitat photos at central point of survey site (August 2018)

Additional Habitat Photos across survey site (August 2018)

4.0 Conclusion

During August 2018, AECOM undertook a land condition assessment of the two proposed exploration lease areas and access tracks to provide a baseline assessment of ecological conditions in support of Origin Energy's application to the Northern Territory Department of Environment and Natural Resources, including the preparation of an Environmental Management Plan (EMP) for various exploration activities. Additional weed survey was conducted during June 2019 to further inform conditions at the site.

The purpose of the LCA was to gather baseline information to provide an environmental condition assessment to support the proposed exploration activities to be carried out by Origin at two proposed lease sites during 2019/2020.

The LCA identified the ecological conditions and documented the site condition prior to Origin commencement of exploration within two of their Permit Areas EP76 and EP117. The information obtained during the initial LCA will assist in determining that at the end of the exploration activities that the lease areas have been rehabilitated back to its natural state.

The proposed exploration program will have a total disturbance of approximately 24.5 ha and will utilise 107 km of existing access tracks.

The desktop review and field survey assisted in identifying the potential environmental risks and impacts to the environment based on the conditions identified on site and has allowed the development of mitigation measures to minimise Origin's impact on the environment.

During the survey of the proposed exploration lease areas, as well as the areas surrounding the proposed access tracks were assessed to be in generally good condition with no to low evidence of weeds, erosion and disturbance from cattle.

The likelihood assessment concluded that no EPBC listed threatened ecological communities or threatened species are likely to be significantly impacted from the proposed exploration program activities.

Overall, the impacts of the vegetation clearing for the proposed lease areas and access tracks are considered minor from a landscape perspective. Surrounding habitat is extensive and most species are mobile and will be able to access surrounding habitat.

The mitigation measures presented in the Drilling and Stimulation EMP would assist in minimising the impacts from Origin's activities on EPBC listed species and communities.

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Appendix A

Soil Test Results

Soil Id	Photo	Soil pH	Soil Colour	Dispersion Test Observations
Kyalla N2-1		5.14	1.5YR 4/6	**Initial Observation** • Sample was fully crumbed when submerged in demineralised water. **Final Observation** • Non-dispersive, particles crumble though water remains clear.
Velkerri S2		5.02	10YR 3/4	**Initial Observation** • Sample was fully crumbed when submerged in demineralised water. **Final Observation** • Non-dispersive, particles crumble though water remains clear.

NOTE:
Initial Observation - observation made when the sample was submerged in water
Final Observation - observation made after 2 hours

Appendix B

Flora Species Record, August 2018

Appendix B Flora Species Record, August 2018

Table 12 Flora Species Recorded, August 2018 Field Survey

Family	Genus	Species
Asteraceae	*Pterocaulon*	*sphacelatum*
Caesalpiniaceae	*Erythrophleum*	*chlorostachys*
Combretaceae	*Terminalia*	*canescens*
		arostrata
	Macropteranthes	*kekwickii*
Euphorbiaceae	*Petalostigma*	*pubescens*
Fabaceae	*Acacia*	*ancistrocarpa*
		shirleyi
		sp.
Myrtaceae	*Corymbia*	*dichromophloia*
		drysdalensis
		ferruginea
Poaceae	*Aristida*	*holathera*
	Chrysopogon	*fallax*
	Enneapogon	*lindleyanus*
	Eragrostis	*spartinoides*
	Eriachne	*aristidea*
		ciliata
		nervosa
		sp.
	Heteropogon	*contortus*
	Sarga	*plumosum*
	Schizachyrium	*fragile*
	Sporobolus	*australasicus*
	Themeda	*triandra*
	Triodia	*bitextura*
		sp.
Rhamnaceae	*Alphitonia*	*pomaderroides*
Sterculiaceae	*Brachychiton*	*paradoxum*

Appendix C

DotEE Protected Matters Search Report

Australian Government
Department of the Environment and Energy

EPBC Act Protected Matters Report

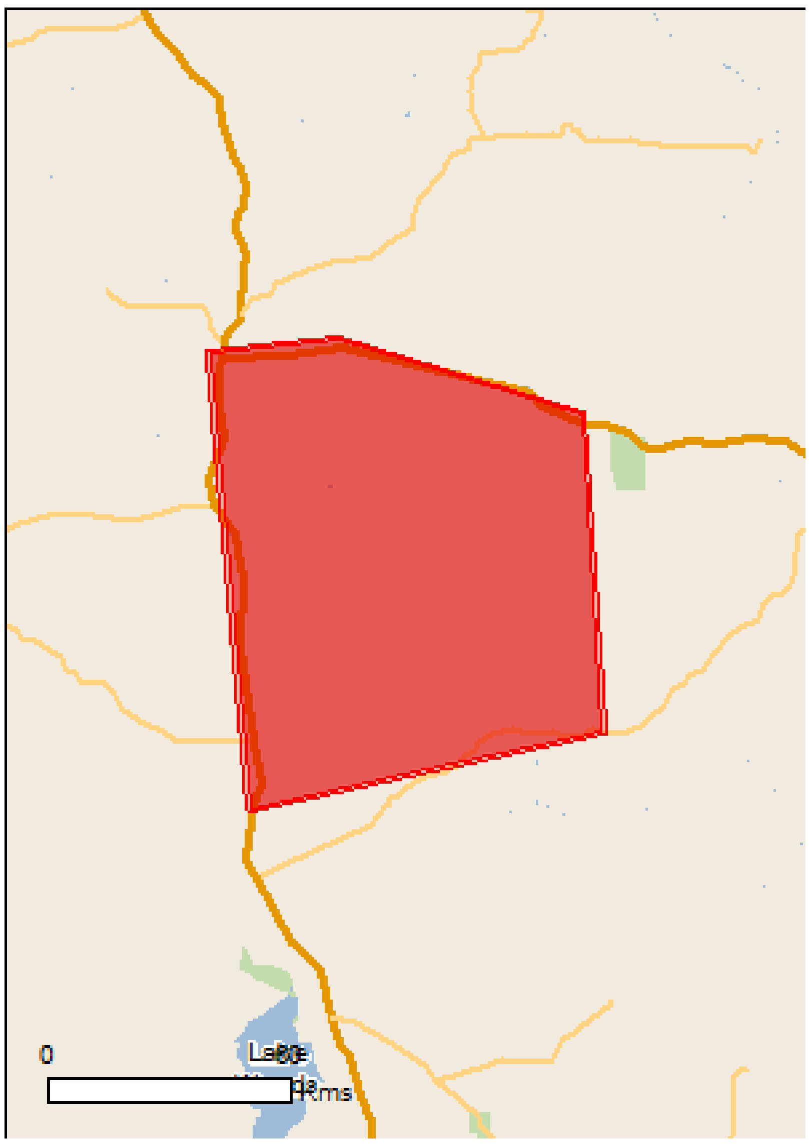
This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

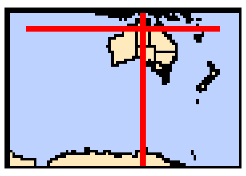
Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

Report created: 27/08/18 10:22:23

- Summary
- Details
  - Matters of NES
  - Other Matters Protected by the EPBC Act
  - Extra Information
- Caveat
- Acknowledgements



Coordinates
Buffer: 1.0Km



Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	None
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	12
Listed Migratory Species:	12

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	None
Commonwealth Heritage Places:	None
Listed Marine Species:	19
Whales and Other Cetaceans:	None
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	1
Regional Forest Agreements:	None
Invasive Species:	15
Nationally Important Wetlands:	None
Key Ecological Features (Marine)	None

Details

Matters of National Environmental Significance

Listed Threatened Species		[Resource Information]
Name	Status	Type of Presence
Birds		
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Erythrotriorchis radiatus Red Goshawk [942]	Vulnerable	Species or species habitat likely to occur within area
Erythrura gouldiae Gouldian Finch [413]	Endangered	Species or species habitat likely to occur within area
Falcunculus frontatus whitei Crested Shrike-tit (northern), Northern Shrike-tit [26013]	Vulnerable	Species or species habitat likely to occur within area
Grantiella picta Painted Honeyeater [470]	Vulnerable	Species or species habitat known to occur within area
Rostratula australis Australian Painted-snipe, Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area
Tyto novaehollandiae kimberli Masked Owl (northern) [26048]	Vulnerable	Species or species habitat may occur within area
Mammals		
Macroderma gigas Ghost Bat [174]	Vulnerable	Species or species habitat likely to occur within area
Macrotis lagotis Greater Bilby [282]	Vulnerable	Species or species habitat likely to occur within area
Saccolaimus saccolaimus nudicluniatus Bare-rumped Sheath-tailed Bat, Bare-rumped Sheathtail Bat [66889]	Vulnerable	Species or species habitat may occur within area
Reptiles		
Acanthophis hawkei Plains Death Adder [83821]	Vulnerable	Species or species habitat likely to occur within area
Elseya lavarackorum Gulf Snapping Turtle [67197]	Endangered	Species or species habitat may occur within area

Listed Migratory Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Migratory Terrestrial Species		
Cecropis daurica Red-rumped Swallow [80610]		Species or species habitat may occur within area
Cuculus optatus Oriental Cuckoo, Horsfield's Cuckoo [86651]		Species or species habitat may occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat may occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Anseranas semipalmata Magpie Goose [978]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea alba Great Egret, White Egret [59541]		Species or species habitat known to occur within area
Ardea ibis Cattle Egret [59542]		Species or species habitat may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area
Chrysococcyx osculans Black-eared Cuckoo [705]		Species or species habitat known to occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat may occur within area
Hirundo daurica Red-rumped Swallow [59480]		Species or species habitat may occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat may occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area
Rostratula benghalensis (sensu lato) Painted Snipe [889]	Endangered*	Species or species habitat likely to occur within area
Reptiles		
Crocodylus johnstoni Freshwater Crocodile, Johnston's Crocodile, Johnston's River Crocodile [1773]		Species or species habitat may occur within area

Extra Information

State and Territory Reserves	[Resource Information]
Name	State
Frew Ponds	NT

Invasive Species	[Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence
Frogs		
Rhinella marina Cane Toad [83218]		Species or species habitat may occur within area
Mammals		
Bos taurus Domestic Cattle [16]		Species or species habitat likely to occur within area
Bubalus bubalis Water Buffalo, Swamp Buffalo [1]		Species or species habitat likely to occur within area
Camelus dromedarius Dromedary, Camel [7]		Species or species habitat likely to occur within area
Canis lupus familiaris Domestic Dog [82654]		Species or species habitat likely to occur within area
Equus caballus Horse [5]		Species or species habitat likely to occur within area
Felis catus Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Rattus rattus Black Rat, Ship Rat [84]		Species or species habitat likely to occur within area
Sus scrofa Pig [6]		Species or species habitat likely to occur within area
Plants		

Name	Status	Type of Presence
Acacia nilotica subsp. indica		
Prickly Acacia [6196]		Species or species habitat may occur within area
Cenchrus ciliaris		
Buffel-grass, Black Buffel-grass [20213]		Species or species habitat likely to occur within area
Jatropha gossypifolia		
Cotton-leaved Physic-Nut, Bellyache Bush, Cotton-leaf Physic Nut, Cotton-leaf Jatropha, Black Physic Nut [7507]		Species or species habitat likely to occur within area
Parkinsonia aculeata		
Parkinsonia, Jerusalem Thorn, Jelly Bean Tree, Horse Bean [12301]		Species or species habitat likely to occur within area
Vachellia nilotica		
Prickly Acacia, Blackthorn, Prickly Mimosa, Black Piquant, Babul [84351]		Species or species habitat likely to occur within area
Reptiles		
Hemidactylus frenatus		
Asian House Gecko [1708]		Species or species habitat likely to occur within area

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc). In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-16.305477 133.356741,-16.297568 133.356741,-16.269886 133.641013,-16.428018 134.180716,-17.098628 134.226035,-17.263941 133.447379,-16.305477 133.356741

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

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Appendix C: Chemical Risk Assessment

AECOM Imagine it. Delivered.

Beetaloo 2019 Campaign EMP
Origin Energy B2 Pty Ltd
24-Apr-2019

Beetaloo 2019 Campaign - Chemical Risk Assessments

Beetaloo 2019 Campaign - Chemical Risk Assessments

Client: Origin Energy B2 Pty Ltd

ABN: 42105431525

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24-Apr-2019

Job No.: 60480548

AECOM in Australia and New Zealand is certified to ISO9001, ISO14001 AS/NZS4801 and OHSAS18001.

Quality Information

Document	Beetaloo 2019 Campaign - Chemical Risk Assessments
Ref	60480548
Date	24-Apr-2019
Prepared by	Cindy Cheung, Tiffany Teo
Reviewed by	Mark Chapman

Revision History

Rev	Revision Date	Details	Authorised	
			Name/Position	Signature
0	24-Apr-2019	Final	Hayden Seear Project Manager	

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1.1.2 Outcome of Tier 2 Screen 2
1.2 Hydraulic Fracture Stimulation Chemical Tracers 2
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1.3.1 Outcome of Tier 1 Screen 2
1.3.2 Outcome of Tier 2 Screen 3

Appendix A
Chemical Risk Assessment Hydraulic Fracture Stimulation Fluid – Hybrid A

Appendix B
Chemical Risk Assessment Hydraulic Fracture Stimulation Fluid – HVFR B

Appendix C
Chemical Risk Assessment Hydraulic Fracture Stimulation Fluid – SW C

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Hydraulic Fracture Stimulation Fluid - Chemical Toxicological Profiles D

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Hydraulic Fracture Stimulation Fluid Tracers Chemical Toxicological Profiles F

Appendix G
Chemical Risk Assessment - Drilling Fluid G

Appendix H
Drilling Fluid – Chemical Toxicological Profiles H

1.0 Background

Chemical risk assessments were performed to assess the potential human health and environmental health effects of the chemicals proposed to be used in the Beetaloo 2019 campaign.

The following fluid systems were assessed:

- Hydraulic fracture stimulation fluids;
- Hydraulic fracture stimulation chemical tracers; and
- Drilling fluids.

The method used for the chemical risk assessment aligned with the guidance provided by the Commonwealth and the methodology adopted for the chemical risk assessment was in general accordance with the following:

- Northern Territory Government, Department of Environmental and Natural Resources, Draft Guideline for the Preparation of an Environmental Management Plan under the Petroleum (Environment) Regulations, 2019 (herein referred to as NT 2019)
- Department of the Environment and Energy, Exposure Draft - Chemical Risk Assessment Guidance Manual: for chemicals associated with coal seam gas extraction, 2017 (herein referred to as DOE 2017)
- National Industrial Chemicals Notification and Assessment Scheme (NICNAS), National Assessment of Chemicals Associated with Coal Seam Gas Extraction in Australia, 2017 (herein referred to as NICNAS 2017)
- enHealth "Environmental Health Risk Assessment, Guidelines for Assessing Human Health Risks from Environmental Hazards", 2012
- National Environment Protection (Assessment of Site Contamination) Measure 1999 (ASC NEPM); Schedule B4, Site-specific health risk assessment methodology, 2013

The chemical risk assessment comprised the following tasks, consistent with the framework presented in NT 2019:

- Hazard assessment. An evaluation of the environmental hazard of the chemical additives in the hydraulic fracturing fluid, based on their environmental persistence, bioaccumulation and aquatic toxicity properties. Chemicals of potential concern are identified for further assessment. An evaluation of human health toxicity is also provided.
- Exposure assessment. The exposure assessment comprises of an evaluation of surface and sub-surface exposure pathways assessment and mass balance calculation to identify the amount of each chemical additive of the hydraulic fracturing fluid.
- Screening and validation processes via Tier 1 and Tier 2 assessments. To determine chemicals known to be of low concern, and identify chemicals for further risk assessment
  - Tier 1: using published information about each chemical proposed to be used in the hydraulic fracturing activity.
  - Tier 2: A quantitative evaluation of the risks using toxicity values and quantitative estimates of chemical intake to provide an estimate of potential human health and environmental risk associated with the hydraulic fracturing activities, based on the identification of complete exposure pathways and hazard identification.

As per the NT Government Guidance (NT 2019), the Tier 1 Screening Assessment included the following information:

1) Name of chemical
2) Chemical purpose
3) Chemical Abstract Services (CAS) number
4) Total mass in kg

5) Approximate down-hole concentration for that chemical expressed in mg/L
6) Appropriate ecotoxicity (aquatic and oral values) data including for acute LC50/EC50 and chronic No Observable Effects Concentration (NOEC) data.
7) Information on the biodegradation and bioaccumulation potential of any organic chemicals

1.1 Hydraulic Fracture Stimulation Fluids

It is understood that three recipes (SW, Hybrid and HVFR) will be used for the 2019 Beetaloo campaign.

1.1.1 Outcome of Tier 1 Screen

Comparison of the chemicals with the assessment criteria indicated that all of the chemicals (with the exception of Hydrotreated light petroleum distillate, CAS# 64742-47-8) were not considered to require a Tier 2 assessment. However some chemicals (14 from SW, 17 from Hybrid 15 from HVFR) were identified to require management in flowback water and addressed in the wastewater management and disposal program due to their volume of use and elevated concentrations that were above ecotoxicity values. It is to be noted that none of these chemicals were identified to be persistent and bioaccumulative.

The Tier 1 screening is provided in **Appendix A**, **Appendix B**, **Appendix C**, the chemical toxicological profiles are provided in **Appendix D**.

1.1.2 Outcome of Tier 2 Screen

A Tier 2 assessment was conducted on Hydrotreated light petroleum distillate, which was classified as a bioaccumulative and toxic substance. As per NICNAS 2017 and DOE 2017 guidance, the Margin of Exposure approach (MOE) was used to assess the health risk to workers. For each occupational activity scenario (i.e. transport and storage, mixing/blending drilling of hydraulic fracturing chemicals, injection of drilling chemicals and cleaning and maintenance), a MoE was derived by comparing the point of departure (e.g No Observed Adverse Effects Level (NOAEL)) for long term health effects from the critical toxicological study to the estimated total human internal dose from all routes of exposure. Based on the calculated MoEs the chemical is of low concern for workers (refer to individual toxicity profile for further detail).

The Tier 2 screening is provided in **Appendix A**, **Appendix B**, **Appendix C**, the chemical toxicological profiles are provided in **Appendix D**.

1.2 Hydraulic Fracture Stimulation Chemical Tracers

It's understood the following chemical tracers may be used for the 2019 Beetaloo campaign – CFT, GFT and WFT.

1.2.1 Outcome of Tier 1 Screen

Comparison of the chemicals with the assessment criteria indicated that all of the chemicals included in the proposed chemical tracers passed the Tier 1 screening.

The Tier 1 screening is provided in **Appendix E**, the chemical toxicological profiles are provided in **Appendix F**.

1.3 Drilling Fluids

It's understood a drilling fluid recipe supplied by Bariod, specifically the 'planned' chemicals (as opposed to the chemicals nominated as 'contingency') will be used for the 2019 Beetaloo campaign.

1.3.1 Outcome of Tier 1 Screen

Comparison of the chemicals with the assessment criteria indicated that all of the chemicals (with the exception of Hydrotreated light petroleum distillate, CAS# 64742-47-8) were not considered to require a Tier 2 assessment.

However some (3) chemicals were identified to require management in flowback water and addressed in the wastewater management and disposal program due to their volume of use and elevated concentrations that were above ecotoxicity values. It is to be noted that none of these chemicals were identified to be persistent and bioaccumulative.

The Tier 1 screening is provided in **Appendix G**, the chemical toxicological profiles are provided in **Appendix H**.

1.3.2 Outcome of Tier 2 Screen

A Tier 2 assessment was conducted on Hydrotreated light petroleum distillate, which was classified as a bioaccumulative and toxic substance. As per NICNAS 2017 and DOE 2017 guidance, the Margin of Exposure approach (MOE) was used to assess the health risk to workers. For each occupational activity scenario (i.e. transport and storage, mixing/blending drilling of hydraulic fracturing chemicals, injection of drilling chemicals and cleaning and maintenance), a MoE was derived by comparing the point of departure (e.g No Observed Adverse Effects Level (NOAEL)) for long term health effects from the critical toxicological study to the estimated total human internal dose from all routes of exposure. Based on the calculated MoEs the chemical is of low concern for workers (refer to individual toxicity profile for further detail).

The Tier 2 screening is provided in **Appendix G**, the chemical toxicological profiles are provided in **Appendix H**.

Appendix A

Chemical Risk Assessment Hydraulic Fracture Stimulation Fluid – Hybrid

Human Health Screening Assessment
Hydraulic Fracture Stimulation Fluid HYBRID Recipe

Chemical Name	CAS Number	Density (kg/L)	Volume of Chemical (L)	Volume Fraction (%v/v)	Chemical Mass in Fluid (kg)	Mass Fraction (% w/w)	Concentration in Injected Fluid (mg/L)	Parent Compound Purpose	Ecotoxicity[1]	Toxicity[2]	Biodegradation[1,3]	Bioaccummulative[1]	Screening	Discussion	Outcome of Tier 2 Assessment[1]
Choline Chloride	67-48-1	1.1	24,720	0.0950%	27,192	0.0973%	1,096	Clay Stabiliser	96-hour fish LC50 value is >100 mg/L 48-hour in vertebrate EC50 is 349 mg/L 72-hour EC50 to Pseudokirchneriella subcapitata is >1,000 mg/L 21-day Daphnia NOEC value is 30.2 mg/L	Based on Chronic: Low	Choline chloride is readily biodegradable and thus it does not meet the screening criteria for persistence.	Not Bioaccumulative (based on a measured log Kow of -3.77 and a calculated BCF of 0.59)	Tier 1 (NICNAS)	A Tier 1 Human Health Assessment for this chemical has been conducted by NICNAS which concluded that this chemical was identified as low concern to human health. A Tier 2 assessment is not required.	NA
Guar gum	9000-30-0	0.7	23,649	0.0909%	16,555	0.0592%	667	Gelling agent	lowest measured ecotoxicity endpoint for fish was reported to be 218 mg/L.	Based on Acute: Low	Guar gum is a naturally occurring polysaccharide which would be expected to readily biodegrade. Thus, it is not expected to meet the screening criteria for persistence	Not Bioaccumulative based on the molecular weight of guar gum (ranges from 200,000 to 300,000 daltons), and it is also water soluble.	Tier 1	The risk was classified as low based on acute data. A Tier 2 assessment is not required.	NA
Hydrochloric acid	7647-01-0	1.152	10,206	0.0392%	11,757	0.0421%	474	Acid	Algae = 0.492 mg/L Daphnia = 0.492 mg/L Fish = 4.92 mg/L Daphnia (chronic) = 62 mg/L	Based on Chronic: Low	N.A.(Inorganic)	N.A. (Inorganic)	Tier 1	The risk was classified as low based on chronic data. A Tier 2 assessment is not required.	NA
Alcohols, C6-12, ethoxylated propoxylated	68937-66-6	0.94	5,253	0.0202%	4,938	0.0177%	199	Surfactant	LC50 (96h) 0.59 mg/L (Pleuronectes platessa) EC50 (48h) 0.14 mg/L (Daphnia magna) EC50 (96h) 0.7 mg/L (Pseudokirchneriella subapitata) NOEC 4.4 mg/L (Pimephales promelas, juvenile)	Based on Chronic: Moderate	Expected to be readily biodegradable based on similar substances	Not Bio accumulative (Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8)	Tier 1 with management	The risk was classified as moderate. The exposure concentration is elevated. However, this chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Ethylene glycol	107-21-1	1.11	3,723	0.0143%	4,132	0.0148%	166	Crosslinker	LC50 for fish = 22800 mg/L LC50 for Daphnia =7800 mg/L NOEC for Algae =100 mg/L	Based on Acute: Low	Readily biodegradable	No based on the measured log Kow of -1.36 and a measured BCF of 10	Tier 1 (NICNAS)	NICNAS has classified this chemical as having low environmental concern. A Tier 2 assessment is not required.	NA
Ulexite	1319-33-1	1.49	3,476	0.0134%	5,175	0.0185%	209	Crosslinker	Chronic endpoints for Boric acid were available for Daphnia (6 mg/L) and Fish (2.1 mg/L).	Based on Chronic: Moderate	N.A.(Inorganic)	N.A. (Inorganic)	Tier 1 with management	The risk was classified as moderate. The exposure concentration is elevated. However, this chemical is an inorganic substance and its ionic species is ubiquitous in environment. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Triethanol amine	102-71-6	1.1245	3,309	0.0127%	3,721	0.0133%	150	Crosslinker	Fish: 96h-LC50 of 11,800 mg/ Daphnia: 24h-EC50 of 1,390 mg/l Daphnia: 21 d NOEC of 16 mg/l Algae:96 h EC50 of 910 mg/l	Based on Chronic: Low	Inherently biodegradable	Not Bio accumulative (Based on an estimated log Kow value of -1.0, and BCF value of <3.9)	Tier 1	The risk was classified as low based on chronic data. A Tier 2 assessment is not required.	NA
Sodium Chloride	7647-14-5	2.165	2,859	0.0110%	6,189	0.0221%	249	Stabiliser	EC50 = 400 to 30000 mg/L EC50 Fish = 1290 mg/L NOEC = 314 mg/L (Daphnia)	Based on Chronic: Low	N.A.(Inorganic)	N.A. (Inorganic)	Tier 1	The risk was classified as low based on chronic data. A Tier 2 assessment is not required.	NA
Sodium polyacrylate	9003-04-7	1.32	2,370	0.0091%	3,128	0.0112%	126		96 hr LC50 for fish is >1000 mg/L NOEC from a chronic early life stage test for the fathead minnow is 56 mg/L 48 hr LC50 for Dapnia magna is >1000 mg/L NOEC for a 21day chronic reproductive test on Daphnia magna is 5.6 mg/L EC10 for Scenedesmus is 180 mg/L	Based on Chronic: Moderate to low	Sodium polyacrylate has limited biodegradation potential and thus meets the screening criteria for persistence.	Bioaccumulation of sodium polyacrylate is unlikely due to the high molecular weight of the polymer.	Tier 1 (NICNAS)	A Tier 1 Human Health Assessment for this chemical has been conducted by NICNAS which concluded that this chemical was identified as low concern to human health. A Tier 2 assessment is not required.	NA
Sodium hydroxide	1310-73-2	1.515	2,059	0.0079%	3,119	0.0112%	126	pH buffer	Measured acute endpoints were available for fish (196 mg/L). Measured chronic endpoint were available for Daphnia (240 mg/L)	Based on Chronic: Low	N.A.(Inorganic)	N.A. (Inorganic)	Tier 1	The risk was classified as low based on chronic data and it is expected to be readily biodegradable and not bioaccummulative. A Tier 2 assessment is not required.	NA
Alcohols, C10-16, ethoxylated propoxylated	69227-22-1	0.94	1,876	0.0072%	1,763	0.0063%	71	Friction Reducer, Surfactant	LC50 (96h) 0.59 mg/L (Pleuronectes platessa EC50 (48h) 0.14 mg/L (Daphnia magna) ErC50 (48h) 0.7 mg/L (Skeletonema costatum) ErC50 (16.9h) > 10 g/L (Pseudomonas putida)	Based on Acute: Very high	Expected to be readily biodegradable based on similar substances	Not Bio accumulative (Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8)	Tier 1 with management	The risk was classified as very high based on acute data. The exposure concentration is elevated. However, this chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Acetic acid	64-19-7	1.05	1,558	0.0060%	1,636	0.0059%	66	Acid	Acute endpoints: Fish = 75 mg/L, Daphnia EC50 = 32 mg/L Chronic endpoints: Daphnia = 150 mg/L	Based on Chronic: Low	Readily biodegradable	Not Bio accumulative (Based on log Kow = -0.136)	Tier 1	The risk was classified as low based on chronic data and it is expected to be readily biodegradable and not bioaccummulative. A Tier 2 assessment is not required.	NA
Diethanolamine	111-42-2	1.1	1,459	0.0056%	1,605	0.0057%	65	Breaker Activiator	Fish 96-h LC50 = 1370 mg/l Invertebrates 48-h EC50 = 55 mg/l Pseudokirchneriella subcapitata 96-h ErC50 = 2.2 mg/l Microorganisms 16-h TTC = 16 mg/l Daphnia magna, the NOEC (21 days) was 0.78 mg/l	Based on Chronic: High	Readily biodegradable	Not Bioaccumulative. Based on a measured log Kow of -2.18 and a calculated BCF of 3.16	Tier 1 with management	The risk was classified as high. However, this chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Tributyl tetradecyl phosphonium chloride	81741-28-8	0.95	736	0.0028%	700	0.0025%	28	Biocide	LC50: (96 hour) 0.46 mg/L (Oncorhynchus mykiss) LC50: (96 hour) 0.06 mg/l (Lepomis macrochirus) LC50: (96 hour) 0.58 mg/l (fish) TLM96: 1.6 mg/l (Crangon crangon) TLM48: 0.025 mg/l (Daphnia magna Modelled acute endpoint: Daphnia is 16.788 mg/L Fish is 1059.2530 mg/L	Based on Acute: Very high	Not available, however it has been observed to biodegrade in sediment.	Not bioaccumulative (Based on an estimated log Kow value of 6.26)	Tier 1 with management	The risk was classified as very high. The exposure concentration is elevated. However, this chemical is not expected to be bioaccummulative and has been observed to biodegrade. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Acrylamide acrylate copolymer	9003-06-9	0.75	730	0.0028%	548	0.0020%	22	Scale Inhibitor	96 hour LC50 for fish = 1 400 mg/L 48 hour EC50 for Daphnia magna = 1 200 mg/L 21 day EC50 for Daphnia magna = 680 mg/L 21 day NOEC for algae = 380 mg/L	Based on Chronic: Low	Polymers are not readily biodegradable, hence they meet the screening criteria for persistence.	Polymers are expected to have very high molecular weights and poor water solubility. They are not expected to be bioavailable.	Tier 1 (NICNAS)	A Tier 1 Human Health Assessment for this chemical has been conducted by NICNAS which concluded that this chemical was identified as low concern to human health. A Tier 2 assessment is not required.	NA

Human Health Screening Assessment
Hydraulic Fracture Stimulation Fluid HYBRID Recipe

Chemical Name	CAS Number	Density (kg/L)	Volume of Chemical (L)	Volume Fraction (%v/v)	Chemical Mass in Fluid (kg)	Mass Fraction (% w/w)	Concentration in Injected Fluid (mg/L)	Parent Compound Purpose	Ecotoxicity[1]	Toxicity[2]	Biodegradation[1,3]	Bioaccummulative[1]	Screening	Discussion	Outcome of Tier 2 Assessment[1]
Sodium bisulfite	7681-38-1	2.44	483	0.0019%	1,179	0.0042%	47	Scale Inhibitor	72h-EC50 = 36.8 mg sodium sulfite/L (alga) NOEC of >8.41 mg sodium sulfite/L (Daphnia)	Based on Chronic: Moderate	N.A.(Inorganic)	N.A. (Inorganic)	Tier 1 with management	The risk was classified as moderate. The exposure concentration is elevated. However, this chemical is an inorganic substance and its ionic species is ubiquitous in environment. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Chlorous acid, sodium salt	7758-19-2	2.47	458	0.0018%	1,131	0.0040%	46	Breaker	LC50 values above 100 mg/l (fish) LC50 48-hour = 0.063 mg/l (daphnia) ECr50 value at 72 h as 1.2 mg/l (algae)	Based on Acute: Very High	No. Not expected to be persistent due to its instability.	No. Based on an estimated log Kow value of 3	Tier 1 with management	The risk was classified as very high based on acute data. However, this chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Disodium octaborate tetrahydrate	12008-41-2	1.874	336	0.0013%	630	0.0023%	25	Crosslinker	Algae: EC10 (3 d) 96.5 mg/L (Pseudokirchneriella subcapitata) Fish: LC50 (96 h) 314.6 mg/L (Pimephales promelas), NOEC (34 d) 25.2 mg/L (Danio rerio) Invertebrates: NOEC (21 d) 42.5 mg/L (Daphnia magna) Microorganism: EC50 (3 h) > 39371 mg/L (activated sludge)	Based on Chronic: Low	N.A.(Inorganic)	N.A. (Inorganic)	Tier 1	The risk was classified as low based on chronic data. A Tier 2 assessment is not required.	NA
Cinnamaldehyde	104-55-2	1.048	332	0.0013%	348	0.0012%	14	Corrosion Inhibitor	Danio rerio (Zebrafish) 96 h LC50 = 3.1 mg/L; Daphnia magna (Water flea) 48 h EC50 = 3.86 mg/L; Pseudokirchneriella subcapitata (Green algae) 72 h EC50 = 4.07 mg/L. 72 h NOEC value = 2.0 mg/L Pseudokirchneriella subcapitata (Green algae)	Based on Chronic: Moderate	N.A.(Inorganic)	N.A. (Inorganic)	Tier 1 with management	The risk was classified as moderate. The exposure concentration is elevated. However, this chemical is an inorganic substance and its ionic species is ubiquitous in environment. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Polyethylene glycol	25322-68-3	1.21	328	0.0013%	397	0.0014%	16	Scale Inhibitor	LC50 = 100 mg/L (fish) LC50 = 1000 mg/L (invertebrates) EC 50 = 15.91 mg/L (algae)	Based on Acute: Moderate	Expected to be readily biodegradable	No based on BCF of 3.2	Tier 1 with management	The risk was classified as moderate. The exposure concentration is slightly elevated. However, this chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Diethylene glycol	111-46-6	1.12	303	0.0012%	339	0.0012%	14	Corrosion Inhibitor	LC 50 = >100 mg/L (fish, invertebrates, algae)	Based on Acute: Low	Readily biodegradable	No based on the estimated BCF of 3	Tier 1	The risk was classified as low based on chronic data and it is expected to be readily biodegradable and not bioaccummulative. A Tier 2 assessment is not required.	NA
Crystalline silica, quartz	14808-60-7	2.6	235	0.0009%	611	0.0022%	25	Crosslinker	no acute toxicity to fish, Daphnia, or algae, though some physical effects were observed with loading rates of greater than or equal to 10 g/L (OECD 2004). Any harmful effects to aquatic ecosystems are therefore not ecotoxicological in nature. No chronic toxicity data were identified.	Based on Acute: Low	N.A.(Inorganic)	N.A. (Inorganic)	Tier 1 with management	The risk was classified as low based on acute data. A Tier 2 assessment is not required.	NA
Methanol	67-56-1	0.791	125	0.0005%	99	0.0004%	4	Corrosion Inhibitor, Surfactant	LC50s ranged from 15,400 to 29,400 mg/L (fish) 24-hour and 48-hour EC50s were > 10,000 mg/L (Daphnia) 28 days NOEC was 446.7 mg/L (fish) 21 days NOEC was 208 mg/L (invertebrates)	Based on Chronic: Low	Readily biodegradable	No based on the Log Kow of -0.74	Tier 1	The risk was classified as low based on chronic data and it is expected to be readily biodegradable and not bioaccummulative. A Tier 2 assessment is not required.	NA
Sodium persulfate	7775-27-1	1.68	116	0.0004%	194	0.0007%	8	Breaker	LC50 fish = 163 to 771 mg/L. EC50 invertebrates = 133 and 519 mg/L EC50 algae = 116 mg/L	Based on Acute: Low	N.A.(Inorganic)	N.A. (Inorganic)	Tier 1	The risk was classified as low based on acute data. A Tier 2 assessment is not required.	NA
Amine oxides, cocoalkyldimethyl	61788-90-7	0.716	103	0.0004%	74	0.0003%	3	Corrosion Inhibitor	LC50/EC50/ErC50 values: 0.60-32 mg/L for fish 0.50-10.8 mg/L for Daphnia magna 0.010-5.30 mg/L for algae NOEC/ EC20: 0.010-1.72 mg/L for algae 0.28 mg/L for Daphnia 0.31 mg/L for fish	Based on Chronic: Very High	Readily biodegradable	No based on the calculated Log Kow of <2.7 and BCF <87	Tier 1 with management	The risk was classified as very high based on chronic data. The exposure concentration is elevated. However, this chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Citric acid	77-92-9	1.542	69	0.0003%	106	0.0004%	4	Corrosion Inhibitor	LC50/EC50 > 100 mg/L (fish, daphnia, algae) 8 day NOEC = 425 mg/L (algae)	Based on Chronic: Low	Readily biodegradable	No based on low log Kow	Tier 1	The risk was classified as low based on chronic data and it is expected to be readily biodegradable and not bioaccummulative. A Tier 2 assessment is not required.	NA
Benzaldehyde	100-52-7	1.0415	47	0.0002%	48	0.0002%	2	Corrosion Inhibitor	Acute LC50 for freshwater fish is 1.07 mg/L, freshwater invertebrates is 16.2 mg/L and EC10 for freshwater algae is 20 mg/L. Chronic NOEC for freshwater fish is 0.12 mg/L.	Based on Chronic: High	Expected to be readily biodegradable	No based on Log Pow of 1.4	Tier 1 with management	The risk was classified as high. However, this chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Ethanol	64-17-5	0.7864	45	0.0002%	35	0.0001%	1	Surfactant	LC50/EC50 > 1000 mg/L (fish, daphnia, algae) NOEC for invertebrates is 9.6 mg/L (10 day reproduction), plants it is 280 mg/L (7 day study)	Based on Chronic: High	Readily biodegradable	No based on calculated logBCF=0.5	Tier 1 (conc < ecotox)	The risk was classified as high based on chronic data. However, the exposure concentration is below the respective LC50/EC50 values and as this chemical is epected to be readily biodegradable, a Tier 2 assessment is not required.	NA
Hydrotreated light petroleum distillate	64742-47-8	0.8	43	0.0002%	35	0.0001%	1	Friction Reducer, Surfactant	96 hr LL50 was 2 to 5 mg/L (fish) 48 hr EL50 was 1.4 mg/L (daphnia) 21 d NOEL = 0.48 mg/L (daphnia)	Based on Chronic: High	Readily biodegradable	Yes based on calculated log BCF values for constituents that range from 2.78 to 4.06, and calculated BCF values of 598 to 11,430 L/kg wet-weight	Tier 2	The risk was classified as high based on chronic data. The substance is expected to be readily biodegradable, but is considered to have a potential to bioaccumulate. Thus, a Tier 2 assessment would be required.	A Tier 2 assessment was conducted using the Margin of Exposure (MOE) approach as per DOE and NICNAS 2017 guidance. Based on the calculated MOEs the chemical is of low concern for workers (refer to individual toxicity profile for further detail).
Fatty acids, tall-oil, ethoxylated	61791-00-2	1.054	23	0.0001%	24	0.0001%	1	Surfactant	96h-LL50 > 100 mg/L (fish) 48h-EL50 = 12.41 mg/L (invertebrates) 72h-EL50 = 39.7 mg/L (algae) 72h-EL10 = 7.08 mg/L (algae)	Based on Acute: High	Readily biodegradable (read across)	No based on low BCF values of < 100 L/kg ww	Tier 1 with management	The risk was classified as high. However, this chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA

Human Health Screening Assessment
Hydraulic Fracture Stimulation Fluid HYBRID Recipe

Chemical Name	CAS Number	Density (kg/L)	Volume of Chemical (L)	Volume Fraction (%v/v)	Chemical Mass in Fluid (kg)	Mass Fraction (% w/w)	Concentration in Injected Fluid (mg/L)	Parent Compound Purpose	Ecotoxicity[1]	Toxicity[2]	Biodegradation[1,3]	Bioaccummulative[1]	Screening	Discussion	Outcome of Tier 2 Assessment[1]
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	0.9	22	0.0001%	20	0.0001%	1	Surfactant	LC50 (96h) 6.7 mg/L (Danio rerio) (similar substance) LC50 (21d) = 0.1 mg/L (Daphnia magna) LC50 (48h) = 2.15 mg/L EC50 (72h) 2.2 mg/L (Scendesmus subspicatus) (similar substance)	Based on Chronic: High	Readily biodegradable (read across)	No Log Kow 3	Tier 1 with management	The risk was classified as high. However, this chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Butyl alcohol	71-36-3	0.81	22	0.0001%	18	0.0001%	1	Surfactant	Fish, LC50 (96h) 1376 mg/l Invertebrates, EC50 (48h) 1328 mg/L) Algae, EC50 (96h) 225 mg/L EC10 (17h) Pseudomonas putida = 2476 mg/L Chronic NOECrepro (21d) = 4.1 mg/L for Daphnia magna	Based on Chronic: Moderate	Readily biodegradable	No based on low log Kow values of 1	Tier 1 (conc < ecotox)	The risk was classified as high based on chronic data. However, the exposure concentration is below the respective LC50/EC50 values and as this chemical is epected to be readily biodegradable, a Tier 2 assessment is not required.	NA
Alcohols, C12-15, ethoxylated	68131-39-5	0.867	20	0.0001%	18	0.0001%	1	Friction Reducer, Surfactant	96 h LC50 Oncorhynchus mykiss was 5 - 7 mg/L Lepomis macrochirus, NOEC (30 days) was 0.11 – 0.33 mg/L. Daphnia magna, EC50 (48 h) was 2.5 mg/L. Daphnia magna, NOEC (21 days) was 0.77 – 1.75 mg/L. Green algae, EC50 (96 h) was 1.4 mg/L. EC50 (3 h) for microorganisms was 140 mg/L.	Based on Chronic: High	Readily biodegradable	No. Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8, it is not expected to be bioaccumulative.	Tier 1 with management	The risk was classified as high. However, this chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Alcohols, C12-16, ethoxylated	68551-12-2	0.97	20	0.00008%	19	0.00007%	1	Corrosion Inhibitor, Surfactant	96 h LC50 Oncorhynchus mykiss was 5 - 7 mg/L Lepomis macrochirus, NOEC (30 days) was 0.11 – 0.33 mg/L. Daphnia magna, EC50 (48 h) was 2.5 mg/L. Daphnia magna, NOEC (21 days) was 0.77 – 1.75 mg/L. Green algae, EC50 (96 h) was 1.4 mg/L. EC50 (3 h) for microorganisms was 140 mg/L.	Based on Chronic: High	Readily biodegradable	No. Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8, it is not expected to be bioaccumulative.	Tier 1 with management	The risk was classified as high. However, this chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Sodium iodide	7681-82-5	3.67	5	0.00002%	19	0.00007%	1	Corrosion Inhibitor	96 hour LC50 for fish is > 860 mg/l 7 days NOEC for fish is 100 mg/L 48hrs-EC50 for Daphnia magna is 1.27 mg/L NOEC for algae is 66 mg/L	Based on Chronic: Low	N.A.(Inorganic)	N.A.(Inorganic)	Tier 1 (NICNAS)	A Tier 1 Human Health Assessment for this chemical has been conducted by NICNAS which concluded that this chemical was identified as low concern to human health. A Tier 2 assessment is not required.	NA
Acrylonitrile	107-13-1	0.806	2	0.00001%	2	0.00001%	0.1	Surfactant	96h LC50 for freshwater fish = 10 - 20 mg/l 96h LC50 for saltwater fish 8.6 mg/l 48h EC50 for Daphnia = 7.6 mg/l 30d NOEC for fish of 0.17 mg/l	Based on Chronic: High	Biodegradable	No based on the low log Pow (0.00-0.30)	Tier 1 with management	The risk was classified as high. However, this chemical is expected to be Biodegradable and not bioaccummulative. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Sodium Sulfate	7757-82-6	2.68	0	0.0000004%	0	0.00000%	0.01	Scale Inhibitor	acute studies all show a toxicity of sodium sulfate higher than 100 mg/l	Based on Acute: Low	N.A.(Inorganic)	N.A.(Inorganic)	Tier 1 (NICNAS)	A Tier 1 Human Health Assessment for this chemical has been conducted by NICNAS which concluded that this chemical was identified as low concern to human health. A Tier 2 assessment is not required.	NA
Glutaraldehyde	111-30-8	1.05	0	0.0000001%	0	0.00000%	0.001	Biocide	96 h acute Bluegill sunfish LC50 = 11.2 mg/L 48 h acute Oyster larvae LC550 = 2.1 mg/L 96 h acute Green crabs LC50 = 465 mg/L 96 h acute Grass shrimp LC50 = 41 mg/L 48 acute Daphnia magna LC50 = 0.35 mg/L 48 acute Daphnia magna LC50 = 16.3 mg/L 21 d reproduct'n Daphnia magna LOEC = 4.3 mg/L, NOEC = 2.1 mg/L 96 h algal growth inhibition Selenastrum capricornutum ILm = 3.9 mg/L (median inhibitory limit) 96 h algal growth inhibition Scenedesmus subspicatus EC50 = 1.0 mg/L Bacterial inhibition Sewage microbes IC50 = 25-34 mg/L	Based on Chronic: Moderate	Readily biodegradable	No based on the Log Pow of -0.01	Tier 1 (conc < ecotox)	The risk was classified as moderate based on chronic data. However, the exposure concentration is below the respective LC50/EC50 values and as this chemical is epected to be readily biodegradable, a Tier 2 assessment is not required.	NA

Notes
1 - Please refer to the individual toxicity profiles for further detail.
2 - Toxicity assessed using Commonwealth of Australia 2013 Ecotoxicity Assessment Guidelines (presented as Table 4 in the Northern Territory Government Draft Guideline for the Preparation of an Environment Management Plan under the Petroleum Regulations (2019))
3- Biodegradation assessed as per Northern Territory Government Draft Guideline for the Preparation of an Environment Management Plan under the Petroleum Regulations (2019) and Australian Government Department of Health National Industrial Chemicals Notification and Assessment Scheme (NICNAS)
BCF - Bioconcentration Factor
NA - Not Applicable
MOE - Margin of Exposure
NICNAS 2017 - National Assessment of Chemicals Associated with Coal Seam Gas Extraction in Australia
DOE 2017 - Draft Risk Assessment Guidance Manual: For Chemicals Associated with Coal Seam Gas Extraction, Australian Government, Department of Energy

Attachment A - Risk Characterisation Calculations

64742-47-8 Distillates (petroleum), hydrotreated light

Adult worker exposure scenario	Total Internal Dose (mg/kg bw/day)	NOAEL (mg/kg bw/day)	Critical effect	MOE (NOAEL / dosage)	Chemical is of concern? (MOE < 100)
Occupational Activity					
Transport and storage	Negligible*	1000	maternal toxicity in rats		No
Mixing/blending drilling of hydraulic fracturing chemicals	0.810			1235	
Injection of drilling chemicals	Negligible*				
Cleaning and maintenance (hydraulic fracturing)	0.162			6173	
Combined exposure Mixing/blending and cleaning and maintenance	**0.972**			1029	

* In the absence of accidents/incidents, repeated occupational exposures during transport and storage, or during injection of mixed/blended chemicals, are negligible.
Similarly, repeated occupational exposures to the chemical via the transport and storage of drilling muds are negligible (NICNAS 2017).

Worker exposure during mixing/blending of chemicals

Dermal Exposure

$$Ederm = \frac{C \times Dease \times SAderm \times Bderm}{BW}$$ (source Equation 1 - NICNAS 2017)

Ederm	Internal dermal dose of the chemical, mg/kg bw/day	0.06	mg/kg bw/day	
C	concentration of the chemical, %	100%	%	default concentration of 1000 g/L (100%) is used. Assumes the chemical is in its pure form and not diluted with other chemicals (NICNAS 2017)
Dease	external dose estimated by EASE model, mg/cm2/day	0.1	mg/cm2/day	Assuming no PPE, the upper limit value of DEASE, 0.1 mg/cm2/day is used (NICNAS 2017)
SAderm	surface area of exposed skin, cm2	840	cm2	US EPA 2011, NICNAS 2017
Bderm	dermal bioavailability, %	10%	%	NICNAS 2017
BW	body weight, kg bw.	70	kg bw	enHealth 2012, NICNAS 2017

Inhalation Exposure

$$Einh = \frac{Fresp \times C \times Demkg \times Vair \times Binh \times t}{BW}$$ (source Equation 2 - NICNAS 2017)

Einh	Internal inhalation dose of the chemical, mg/kg bw/day	0.750	mg/kg bw/day	
Fresp	respirable/inhalable fraction of the chemical, dimensionless	1	dimensionless	assumed to be 1 (NICNAS 2017)
C	concentration of the chemical, %	100%	%	default concentration of 1000 g/L (100%) is used as the concentration of chemical when delivered to site. Assumes the chemical is in its pure form and not diluted with other chemicals (NICNAS 2017)
Demkg	external dose estimated by EMKG-EXPO-TOOL, mg/m3	0.6	mg/m3	NICNAS 2017
Vair	worker ventilation rate, m3/day	22	m3/day	enHealth 2012, NICNAS 2017
Binh	inhalation bioavailability, %	100%	%	NICNAS 2017
t	duration of exposure, h/day	4	h/day	assumed to be four hours, which is an estimate of the duration of manual handling activities that occur during mixing (NICNAS 2017)
BW	body weight, kg bw	70	kg bw	enHealth 2012, NICNAS 2017
t	time	4	hours	NICNAS 2017

Etotal = Ederm + Einh
Etotal = 0.810 mg/kg bw/day

Worker exposure during cleaning and maintenance (drilling)

Dermal Exposure

$$Ederm = \frac{C \times Dease \times SAderm \times Bderm}{BW}$$

Ederm	Internal dermal dose of the chemical, mg/kg bw/day	0.012	mg/kg bw/day	
C	concentration of the chemical, %	10%	%	an assumed concentration of 100 g/L (10%) is used as the concentration of chemical in the final formulation prior to injection
Dease	external dose estimated by EASE model, mg/cm2/day	0.1	mg/cm2/day	Assuming no PPE, the upper limit value of Dease, 0.1 mg/cm2/day, is used (NICNAS 2017).
SAderm	surface area of exposed skin, cm2	840	cm2	for hands (USEPA 2011, NICNAS 2017)
Bderm	dermal bioavailability, %	10%	%	NICNAS 2017
BW	body weight, kg bw.	70	kg bw	enHealth 2012, NICNAS 2017
t	time	8	hours	NICNAS 2017

Inhalation Exposure

$$Einh = \frac{Fresp \times C \times Demkg \times Vair \times Binh \times t}{BW}$$

Einh	Internal inhalation dose of the chemical, mg/kg bw/day	0.150	mg/kg bw/day	
Fresp	respirable/inhalable fraction of the chemical, dimensionless	1	dimensionless	assumed to be 1 (NICNAS 2017)
C	concentration of the chemical, %	10%	%	an assumed concentration of 100 g/L (10%) is used as the concentration of chemical in the final formulation prior to injection
Demkg	external dose estimated by EMKG-EXPO-TOOL, mg/m3	0.6	mg/m3	Assuming no PPE, the upper limit value is used - EMKG-EXPO-TOOL, NICNAS
Vair	worker ventilation rate, m3/day	22	m3/day	enHealth 2012, NICNAS 2017
Binh	inhalation bioavailability, %	100%	%	NICNAS 2017
t	duration of exposure, h/day	8	h/day	assued to be eight hours which is an estimate of the manual handling activities that occur during cleaning and maintenance (NICNAS 2017)
BW	body weight, kg bw	70	kg bw	enHealth 2012, NICNAS 2017

Etotal = Ederm + Einh
Etotal = 0.162 mg/kg bw/day

Appendix B

Chemical Risk Assessment Hydraulic Fracture Stimulation Fluid – HVFR

Human Health Screening Assessment
Hydraulic Fracture Stimulation Fluid HVFR Recipe

Chemical Name	CAS Number	Density (kg/L)	Volume of Chemical (L)	Volume Fraction (%v/v)	Chemical Mass in Fluid (kg)	Mass Fraction (% w/w)	Concentration in Injected Fluid (mg/L)	Parent Compound Purpose	Ecotoxicity[1]	Toxicity[2]	Biodegradation[1,3]	Bioaccummulative[1]	Tier 1 Screening Assessment	Discussion	Outcome of Tier 2 Assessment[1]
Acetic acid	64-19-7	1.05	50	0.0034%	53	0.0033%	38	Acid	Acute endpoints: Fish = 75 mg/L, Daphnia EC50 = 32 mg/L Chronic endpoints: Daphnia = 150 mg/L	Based on Chronic: Low	Readily biodegradable	Not Bio accumulative (Based on log Kow = -0.136)	Tier 1	The risk was classified as low based on chronic data and it is expected to be readily biodegradable and not bioaccummulative. A Tier 2 assessment is not required.	NA
Acrylamide acrylate copolymer	9003-06-9	0.75	39	0.0026%	29	0.0018%	21	Scale Inhibitor	96 hour LC50 for fish = 1 400 mg/L 48 hour EC50 for Daphnia magna = 1 200 mg/L 21 day EC50 for Daphnia magna = 680 mg/L 21 day NOEC for algae = 380 mg/L	Based on Chronic: Low	Polymers are not readily biodegradable, hence they meet the screening criteria for persistence.	Polymers are expected to have very high molecular weights and poor water solubility. They are not expected to be bioavailable.	Tier 1 (NICNAS)	A Tier 1 Human Health Assessment for this chemical has been conducted by NICNAS which concluded that this chemical was identified as low concern to human health. A Tier 2 assessment is not required.	NA
Acrylamide, sodium acrylate polymer	25987-30-8	0.75	265	0.0179%	199	0.0123%	143	Corrosion Inhibitor	LC50 (96h) 0.59 mg/L (Pleuronectes platessa) EC50 (48h) 0.14 mg/L (Daphnia magna) EC50 (96h) 0.7 mg/L (Pseudokirchneriella subapitata) NOEC 4.4 mg/L (Pimephales promelas, juvenile)	96 hour LC50 for fish = 1 400 mg/L 48 hour EC50 for Daphnia magna = 1 200 mg/L 21 day EC50 for Daphnia magna = 680 mg/L 21 day NOEC for algae = 380 mg/L	Based on Chronic: Low	Polymers are not readily biodegradable, hence they meet the screening criteria for persistence.	Tier 1 (NICNAS)	A Tier 1 Human Health Assessment for this chemical has been conducted by NICNAS which concluded that this chemical was identified as low concern to human health. A Tier 2 assessment is not required.	NA
Acrylonitrile	107-13-1	0.806	0	0.0000%	0	0.0000%	0.1	Surfactant	96h LC50 for freshwater fish = 10 - 20 mg/l 96h LC50 for saltwater fish 8.6 mg/l 48h EC50 for Daphnia = 7.6 mg/l 30d NOEC for fish of 0.17 mg/l	Based on Chronic: High	Biodegradable	No based on the low log Pow (0.00-0.30)	Tier 1 with management	The risk was classified as high. However, this chemical is expected to be Biodegradable and not bioaccummulative. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Alcohols, C10-16, ethoxylated propoxylated	69227-22-1	0.94	172	0.0117%	162	0.0100%	116	Friction Reducer, Surfactant	LC50 (96h) 0.59 mg/L (Pleuronectes platessa EC50 (48h) 0.14 mg/L (Daphnia magna) ErC50 (48h) 0.7 mg/L (Skeletonema costatum) ErC50 (16.9h) > 10 g/L (Pseudomonas putida)	Based on Acute: Very high	Expected to be readily biodegradable based on similar substances	Not Bio accumulative (Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8)	Tier 1 with management	The risk was classified as very high based on acute data. The exposure concentration is elevated. However, this chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Alcohols, C12-15, ethoxylated	68131-39-5	0.867	1	0.0001%	1	0.0001%	1	Friction Reducer, Surfactant	96 h LC50 Oncorhynchus mykiss was 5 - 7 mg/L Lepomis macrochirus, NOEC (30 days) was 0.11 – 0.33 mg/L. Daphnia magna, EC50 (48 h) was 2.5 mg/L. Daphnia magna, NOEC (21 days) was 0.77 – 1.75 mg/L. Green algae, EC50 (96 h) was 1.4 mg/L. EC50 (3 h) for microorganisms was 140 mg/L.	Based on Chronic: High	Readily biodegradable	No. Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8, it is not expected to be bioaccumulative.	Tier 1 with management	The risk was classified as high. However, this chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Alcohols, C12-16, ethoxylated	68551-12-2	0.97	1	0.0001%	1	0.0001%	1	Corrosion Inhibitor, Surfactant	96 h LC50 Oncorhynchus mykiss was 5 - 7 mg/L Lepomis macrochirus, NOEC (30 days) was 0.11 – 0.33 mg/L. Daphnia magna, EC50 (48 h) was 2.5 mg/L. Daphnia magna, NOEC (21 days) was 0.77 – 1.75 mg/L. Green algae, EC50 (96 h) was 1.4 mg/L. EC50 (3 h) for microorganisms was 140 mg/L.	Based on Chronic: High	Readily biodegradable	No. Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8, it is not expected to be bioaccumulative.	Tier 1 with management	The risk was classified as high. However, this chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Alcohols, C6-12, ethoxylated propoxylated	68937-66-6	0.94	482	0.0327%	454	0.0281%	326	Surfactant	LC50 (96h) 0.59 mg/L (Pleuronectes platessa) EC50 (48h) 0.14 mg/L (Daphnia magna) EC50 (96h) 0.7 mg/L (Pseudokirchneriella subapitata) NOEC 4.4 mg/L (Pimephales promelas, juvenile)	Based on Chronic: Moderate	Expected to be readily biodegradable based on similar substances	Not Bio accumulative (Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8)	Tier 1 with management	The risk was classified as moderate. The exposure concentration is elevated. However, this chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	0.9	1	0.0001%	1	0.0001%	1	Surfactant	LC50 (96h) 6.7 mg/L (Danio rerio) (similar substance) LC50 (21d) = 0.1 mg/L (Daphnia magna) LC50 (48h) = 2.15 mg/L EC50 (72h) 2.2 mg/L (Scendesmus subspicatus) (similar substance)	Based on Chronic: High	Readily biodegradable (read across)	No based on Log Kow of 3	Tier 1 with management	The risk was classified as high. However, this chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Amine oxides, cocoalkyldimethyl	61788-90-7	0.716	5	0.0003%	4	0.0002%	3	Corrosion Inhibitor	LC50/EC50/ErC50 values: 0.60-32 mg/L for fish 0.50-10.8 mg/L for Daphnia magna 0.010-5.30 mg/L for algae NOEC/ EC20: 0.010-1.72 mg/L for algae 0.28 mg/L for Daphnia 0.31 mg/L for fish	Based on Chronic: Very High	Readily biodegradable	No based on the calculated Log Kow of <2.7 and BCF <87	Tier 1 with management	The risk was classified as very high based on chronic data. The exposure concentration is elevated. However, this chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Benzaldehyde	100-52-7	1.0415	2	0.0002%	2	0.0001%	2	Corrosion Inhibitor	Acute LC50 for freshwater fish is 1.07 mg/L, freshwater invertebrates is 16.2 mg/L and EC10 for freshwater algae is 20 mg/L. Chronic NOEC for freshwater fish is 0.12 mg/L.	Based on Chronic: High	Expected to be readily biodegradable	No based on Log Pow of 1.4	Tier 1 with management	The risk was classified as high. However, this chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Butyl alcohol	71-36-3	0.81	1	0.0001%	1	0.0001%	1	Surfactant	Fish, LC50 (96h) 1376 mg/l Invertebrates, EC50 (48h) 1328 mg/L) Algae, EC50 (96h) 225 mg/L EC10 (17h) Pseudomonas putida = 2476 mg/L Chronic NOECrepro (21d) = 4.1 mg/L for Daphnia magna	Based on Chronic: Moderate	Readily biodegradable	No based on low log Kow values of 1	Tier 1 (conc < ecotox)	The risk was classified as high based on chronic data. However, the exposure concentration is below the respective LC50/EC50 values and as this chemical is epected to be readily biodegradable, a Tier 2 assessment is not required.	NA
Choline Chloride	67-48-1	1.1	1,388	0.0940%	1,527	0.0945%	1098	Clay Stabiliser	96-hour fish LC50 value is >100 mg/L 48-hour in vertebrate EC50 is 349 mg/L 72-hour EC50 to Pseudokirchneriella subcapitata is >1,000 mg/L 21-day Daphnia NOEC value is 30.2 mg/L	Based on Chronic: Low	Choline chloride is readily biodegradable and thus it does not meet the screening criteria for persistence.	Not Bioaccumulative (based on a measured log Kow of -3.77 and a calculated BCF of 0.59)	Tier 1 (NICNAS)	A Tier 1 Human Health Assessment for this chemical has been conducted by NICNAS which concluded that this chemical was identified as low concern to human health. A Tier 2 assessment is not required.	NA
Cinnamaldehyde	104-55-2	1.048	17	0.0011%	17	0.0011%	13	Corrosion Inhibitor	Danio rerio (Zebrafish) 96 h LC50 = 3.1 mg/L; Daphnia magna (Water flea) 48 h EC50 = 3.86 mg/L; Pseudokirchneriella subcapitata (Green algae) 72 h EC50 = 4.07 mg/L. 72 h NOEC value = 2.0 mg/L Pseudokirchneriella subcapitata (Green algae)	Based on Chronic: Moderate	N.A.(Inorganic)	N.A. (Inorganic)	Tier 1 with management	The risk was classified as moderate. The exposure concentration is elevated. However, this chemical is an inorganic substance and its ionic species is ubiquitous in environment. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Citric acid	77-92-9	1.542	3	0.0002%	5	0.0003%	4	Corrosion Inhibitor	LC50/EC50 > 100 mg/L (fish, daphnia, algae) 8 day NOEC = 425 mg/L (algae)	Based on Chronic: Low	Readily biodegradable	No based on low log Kow	Tier 1	The risk was classified as low based on chronic data and it is expected to be readily biodegradable and not bioaccummulative. A Tier 2 assessment is not required.	NA
Diethanolamine	111-42-2	1.1	0	0.0000%	0	0.0000%	0.1	Breaker Activiator	Fish 96-h LC50 = 1370 mg/l Invertebrates 48-h EC50 = 55 mg/l Pseudokirchneriella subcapitata 96-h ErC50 = 2.2 mg/l Microorganisms 16-h TTC = 16 mg/l Daphnia magna, the NOEC (21 days) was 0.78 mg/l	Based on Chronic: High	Readily biodegradable	No. Based on a measured log Kow of -2.18 and a calculated BCF of 3.16	Tier 1 with management	The risk was classified as high. However, this chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA

Human Health Screening Assessment
Hydraulic Fracture Stimulation Fluid HVFR Recipe

Chemical Name	CAS Number	Density (kg/L)	Volume of Chemical (L)	Volume Fraction (%v/v)	Chemical Mass in Fluid (kg)	Mass Fraction (% w/w)	Concentration in Injected Fluid (mg/L)	Parent Compound Purpose	Ecotoxicity[1]	Toxicity[2]	Biodegradation[1,3]	Bioaccummulative[1]	Tier 1 Screening Assessment	Discussion	Outcome of Tier 2 Assessment[1]
Diethylene glycol	111-46-6	1.12	15	0.0010%	17	0.0010%	12	Corrosion Inhibitor	LC 50 = >100 mg/L (fish, invertebrates, algae)	Based on Acute: Low	Readily biodegradable	No based on the estimated BCF of 3	Tier 1	The risk was classified as low based on chronic data and it is expected to be readily biodegradable and not bioaccummulative. A Tier 2 assessment is not required.	NA
Ethanol	64-17-5	0.7864	2	0.0002%	2	0.0001%	1	Surfactant	LC50/EC50 > 1000 mg/L (fish, daphnia, algae) NOEC for invertebrates is 9.6 mg/L (10 day reproduction), plants it is 280 mg/L (7 day study)	Based on Chronic: High	Readily biodegradable	No based on calculated logBCF=0.5	Tier 1 (conc < ecotox)	The risk was classified as high based on chronic data. However, the exposure concentration is below the respective LC50/EC50 values and as this chemical is epected to be readily biodegradable, a Tier 2 assessment is not required.	NA
Ethoxylated branched C13 alcohol	68439-54-3	0.8	18	0.0012%	14	0.0009%	10		96 h LC50 Oncorhynchus mykiss was 5 - 7 mg/L Lepomis macrochirus, NOEC (30 days) was 0.11 – 0.33 mg/L. Daphnia magna, EC50 (48 h) was 2.5 mg/L. Daphnia magna, NOEC (21 days) was 0.77 – 1.75 mg/L. Green algae, EC50 (96 h) was 1.4 mg/L. EC50 (3 h) for microorganisms was 140 mg/L.	Based on Chronic: High	Readily biodegradable	No.	Tier 1 with management	The risk was classified as high. However, this chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Ethylene glycol	107-21-1	1.11	20	0.0014%	22	0.0014%	16	Crosslinker	LC50 for fish = 22800 mg/L LC50 for Daphnia =7800 mg/L NOEC for Algae =100 mg/L	Based on Acute: Low	Readily biodegradable	No based on the measured log Kow of -1.36 and a measured BCF of 10	Tier 1 (NICNAS)	NICNAS has classified this chemical as having low environmental concern. A Tier 2 assessment is not required.	NA
Fatty acids, tall-oil, ethoxylated	61791-00-2	1.054	1	0.0001%	1	0.0001%	1	Surfactant	96h-LL50 > 100 mg/L (fish) 48h-EL50 = 12.41 mg/L (invertebrates) 72h-EL50 = 39.7 mg/L (algae) 72h-EL10 = 7.08 mg/L (algae)	Based on Acute: High	Readily biodegradable (read across)	No based on low BCF values of < 100 L/kg ww	Tier 1 with management	The risk was classified as high. However, this chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Hydrochloric acid	7647-01-0	1.152	510	0.0345%	588	0.0364%	423	Acid	Algae = 0.492 mg/L Daphnia = 0.492 mg/L Fish = 4.92 mg/L Daphnia (chronic) = 62 mg/L	Based on Chronic: Low	N.A.(Inorganic)	N.A. (Inorganic)	Tier 1	The risk was classified as low based on chronic data. A Tier 2 assessment is not required.	NA
Hydrotreated light petroleum distillate	64742-47-8	0.8	223	0.0151%	178	0.0110%	128	Friction Reducer, Surfactant	96 hr LL50 was 2 to 5 mg/L (fish) 48 hr EL50 was 1.4 mg/L (daphnia) 21 d NOEL = 0.48 mg/L (daphnia)	Based on Chronic: High	Readily biodegradable	Yes based on calculated log BCF values for constituents that range from 2.78 to 4.06, and calculated BCF values of 598 to 11,430 L/kg wet-weight	Tier 2	The risk was classified as high based on chronic data. The substance is expected to be readily biodegradable, but is considered to have a potential to bioaccumulate. A Tier 2 assessment is required.	A Tier 2 assessment was conducted using the Margin of Exposure (MOE) approach as per DOE and NICNAS 2017 guidance. Based on the calculated MOEs the chemical is of low concern for workers (refer to individual toxicity profile for further detail).
Methanol	67-56-1	0.791	6	0.0004%	5	0.0003%	4	Corrosion Inhibitor, Surfactant	LC50s ranged from 15,400 to 29,400 mg/L (fish) 24-hour and 48-hour EC50s were > 10,000 mg/L (Daphnia) 28 days NOEC was 446.7 mg/L (fish) 21 days NOEC was 208 mg/L (invertebrates)	Based on Chronic: Low	Readily biodegradable	No based on the Log Kow of -0.74	Tier 1	The risk was classified as low based on chronic data and it is expected to be readily biodegradable and not bioaccummulative. A Tier 2 assessment is not required.	NA
Polyethylene glycol	25322-68-3	1.21	30	0.0020%	36	0.0023%	26	Scale Inhibitor	LC50 = 100 mg/L (fish) LC50 = 1000 mg/L (invertebrates) EC 50 = 15.91 mg/L (algae)	Based on Acute: Moderate	Expected to be readily biodegradable	No based on BCF of 3.2	Tier 1 with management	The risk was classified as moderate. The exposure concentration is elevated. However, this chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Sobitan, mono-9-octadecenoate, (Z)	1338-43-8	1.06	18	0.0012%	19	0.0012%	13	Surfactant	96 h LC50 for fish = 75 mg/L	Based on Acute: Low	Readily biodegradable	No. Based on a calculated BCF of 2.832 and a BAF of 36.4	Tier 1 (conc < ecotox)	The risk was classified as low and the exposure concentration is below the respective EC50 value. A Tier 2 assessment is not required.	NA
Sodium bisulfite	7681-38-1	2.44	27	0.0018%	66	0.0041%	48	Scale Inhibitor	72h-EC50 = 36.8 mg sodium sulfite/L (alga) NOEC of >8.41 mg sodium sulfite/L (Daphnia)	Based on Chronic: Moderate	N.A.(Inorganic)	N.A. (Inorganic)	Tier 1 with management	The risk was classified as moderate. The exposure concentration is elevated. However, this chemical is an inorganic substance and its ionic species is ubiquitous in environment. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Sodium Chloride	7647-14-5	2.165	68	0.0046%	146	0.0091%	105	Stabiliser	EC50 = 400 to 30000 mg/L EC50 Fish = 1290 mg/L NOEC = 314 mg/L (Daphnia)	Based on Chronic: Low	N.A.(Inorganic)	N.A. (Inorganic)	Tier 1	The risk was classified as low based on chronic data. A Tier 2 assessment is not required.	NA
Sodium diacetate	126-96-5	1.01	18	0.0012%	18	0.0011%	13	pH buffer	96 h LC 50 for fish = 184.7 mg/L 48h EC 50 for daphnia > 141 mg/L 72 h EC50 for algae = 164 mg/L	Based on Acute: Low	Readily biodegradable	No. Based on a log Kow of -3.72 and a calculated BCF of 3.16	Tier 1 (NICNAS)	NICNAS has classified this chemical as having low environmental concern. A Tier 2 assessment is not required.	NA
Sodium hydroxide	1310-73-2	1.515	4	0.0003%	6	0.0004%	4	pH buffer	Measured acute endpoints for fish (196 mg/L). Measured chronic endpoint for Daphnia (240 mg/L)	Based on Chronic: Low	N.A.(Inorganic)	N.A. (Inorganic)	Tier 1	The risk was classified as low based on chronic data and it is expected to be readily biodegradable and not bioaccummulative. A Tier 2 assessment is not required.	NA
Sodium iodide	7681-82-5	3.67	0	0.0000%	1	0.0001%	1	Corrosion Inhibitor	96 hour LC50 for fish is > 860 mg/l 7 days NOEC for fish is 100 mg/L 48hrs-EC50 for Daphnia magna is 1.27 mg/L NOEC for algae is 66 mg/L	Based on Chronic: Low	N.A.(Inorganic)	N.A.(Inorganic)	Tier 1 (NICNAS)	A Tier 1 Human Health Assessment for this chemical has been conducted by NICNAS which concluded that this chemical was identified as low concern to human health. A Tier 2 assessment is not required.	NA
Sodium polyacrylate	9003-04-7	1.32	133	0.0090%	176	0.0109%	126	Gelling Agent	96 hr LC50 for fish is >1000 mg/L NOEC from a chronic early life stage test for the fathead minnow is 56 mg/L 48 hr LC50 for Dapnia magna is >1000 mg/L NOEC for a 21day chronic reproductive test on Daphnia magna is 5.6 mg/L EC10 for Scenedesmus is 180 mg/L	Based on Chronic: Moderate to low	Sodium polyacrylate has limited biodegradation potential and thus meets the screening criteria for persistence.	Bioaccumulation of sodium polyacrylate is unlikely due to the high molecular weight of the polymer.	Tier 1 (NICNAS)	A Tier 1 Human Health Assessment for this chemical has been conducted by NICNAS which concluded that this chemical was identified as low concern to human health. A Tier 2 assessment is not required.	NA
Sorbitan monooleate polyoxyethylene derivative	9005-65-6	1.06	18	0.0012%	19	0.0012%	13	Surfactant	EC50 in algae was reported to be 100 mg/L	Based on Acute: Low	Not readily biodegradable	No. Based on a log Kow of -2.03 and a calculated BCF of 3.16	Tier 1 (conc < ecotox)	The risk was classified as low and the exposure concentration is below the respective EC50 value. A Tier 2 assessment is not required.	NA
Tributyl tetradecyl phosphonium chloride	81741-28-8	0.95	41	0.0028%	39	0.0024%	28	Biocide	LC50: (96 hour) 0.46 mg/L (Oncorhynchus mykiss) LC50: (96 hour) 0.06 mg/l (Lepomis macrochirus) LC50: (96 hour) 0.58 mg/l (fish) TLM96: 1.6 mg/l (Crangon crangon) TLM48: 0.025 mg/l (Daphnia magna Modelled acute endpoint: Daphnia is 16.788 mg/L Fish is 1059.2530 mg/L	Based on Acute: Very high	Not available, however it has been observed to biodegrade in sediment.	Not bioaccumulative (Based on an estimated log Kow value of 6.26)	Tier 1 with management	The risk was classified as very high. The exposure concentration is elevated. However, this chemical is not expected to be bioaccummulative and has been observed to biodegrade. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA

Notes
1 - Please refer to the individual toxicity profiles for further detail.
2 - Toxicity assessed using Commonwealth of Australia 2013 Ecotoxicity Assessment Guidelines (presented as Table 4 in the Northern Territory Government Draft Guideline for the Preparation of an Environment Management Plan under the Petroleum Regulations (2019))
3- Biodegradation assessed as per Northern Territory Government Draft Guideline for the Preparation of an Environment Management Plan under the Petroleum Regulations (2019) and Australian Government Department of Health National Industrial Chemicals Notification and Assessment Scheme (NICNAS)
BCF - Bioconcentration Factor
NA - Not Applicable
MOE - Margin of Exposure
NICNAS 2017 - National Assessment of Chemicals Associated with Coal Seam Gas Extraction in Australia
DOE 2017 - Draft Risk Assessment Guidance Manual: For Chemicals Associated with Coal Seam Gas Extraction, Australian Government, Department of Energy

Attachment A - Risk Characterisation Calculations

64742-47-8 Distillates (petroleum), hydrotreated light

Adult worker exposure scenario	Total Internal Dose (mg/kg bw/day)	NOAEL (mg/kg bw/day)	Critical effect	MOE (NOAEL / dosage)	Chemical is of concern? (MOE < 100)
Occupational Activity					
Transport and storage	Negligible*	1000	maternal toxicity in rats		No
Mixing/blending drilling of hydraulic fracturing chemicals	0.810			1235	
Injection of drilling chemicals	Negligible*				
Cleaning and maintenance (hydraulic fracturing)	0.162			6173	
Combined exposure Mixing/blending and cleaning and maintenance	**0.972**			1029	

* In the absence of accidents/incidents, repeated occupational exposures during transport and storage, or during injection of mixed/blended chemicals, are negligible.
Similarly, repeated occupational exposures to the chemical via the transport and storage of drilling muds are negligible (NICNAS 2017).

Worker exposure during mixing/blending of chemicals

Dermal Exposure

$$Ederm = \frac{C \times Dease \times SAderm \times Bderm}{BW}$$ (source Equation 1 - NICNAS 2017)

Ederm	Internal dermal dose of the chemical, mg/kg bw/day	0.06	mg/kg bw/day	
C	concentration of the chemical, %	100%	%	default concentration of 1000 g/L (100%) is used. Assumes the chemical is in its pure form and not diluted with other chemicals (NICNAS 2017)
Dease	external dose estimated by EASE model, mg/cm2/day	0.1	mg/cm2/day	Assuming no PPE, the upper limit value of DEASE, 0.1 mg/cm2/day is used (NICNAS 2017)
SAderm	surface area of exposed skin, cm2	840	cm2	US EPA 2011, NICNAS 2017
Bderm	dermal bioavailability, %	10%	%	NICNAS 2017
BW	body weight, kg bw.	70	kg bw	enHealth 2012, NICNAS 2017

Inhalation Exposure

$$Einh = \frac{Fresp \times C \times Demkg \times Vair \times Binh \times t}{BW}$$ (source Equation 2 - NICNAS 2017)

Einh	Internal inhalation dose of the chemical, mg/kg bw/day	0.750	mg/kg bw/day	
Fresp	respirable/inhalable fraction of the chemical, dimensionless	1	dimensionless	assumed to be 1 (NICNAS 2017)
C	concentration of the chemical, %	100%	%	default concentration of 1000 g/L (100%) is used as the concentration of chemical when delivered to site. Assumes the chemical is in its pure form and not diluted with other chemicals (NICNAS 2017)
Demkg	external dose estimated by EMKG-EXPO-TOOL, mg/m3	0.6	mg/m3	NICNAS 2017
Vair	worker ventilation rate, m3/day	22	m3/day	enHealth 2012, NICNAS 2017
Binh	inhalation bioavailability, %	100%	%	NICNAS 2017
t	duration of exposure, h/day	4	h/day	assumed to be four hours, which is an estimate of the duration of manual handling activities that occur during mixing (NICNAS 2017)
BW	body weight, kg bw	70	kg bw	enHealth 2012, NICNAS 2017
t	time	4	hours	NICNAS 2017

Etotal = Ederm + Einh
Etotal = 0.810 mg/kg bw/day

Worker exposure during cleaning and maintenance (drilling)

Dermal Exposure

$$Ederm = \frac{C \times Dease \times SAderm \times Bderm}{BW}$$

Ederm	Internal dermal dose of the chemical, mg/kg bw/day	0.012	mg/kg bw/day	
C	concentration of the chemical, %	10%	%	an assumed concentration of 100 g/L (10%) is used as the concentration of chemical in the final formulation prior to injection
Dease	external dose estimated by EASE model, mg/cm2/day	0.1	mg/cm2/day	Assuming no PPE, the upper limit value of Dease, 0.1 mg/cm2/day, is used (NICNAS 2017).
SAderm	surface area of exposed skin, cm2	840	cm2	for hands (USEPA 2011, NICNAS 2017)
Bderm	dermal bioavailability, %	10%	%	NICNAS 2017
BW	body weight, kg bw.	70	kg bw	enHealth 2012, NICNAS 2017
t	time	8	hours	NICNAS 2017

Inhalation Exposure

$$Einh = \frac{Fresp \times C \times Demkg \times Vair \times Binh \times t}{BW}$$

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Einh	Internal inhalation dose of the chemical, mg/kg bw/day	0.150	mg/kg bw/day	
Fresp	respirable/inhalable fraction of the chemical, dimensionless	1	dimensionless	assumed to be 1 (NICNAS 2017)
C	concentration of the chemical, %	10%	%	an assumed concentration of 100 g/L (10%) is used as the concentration of chemical in the final formulation prior to injection
Demkg	external dose estimated by EMKG-EXPO-TOOL, mg/m3	0.6	mg/m3	Assuming no PPE, the upper limit value is used - EMKG-EXPO-TOOL, NICNAS
Vair	worker ventilation rate, m3/day	22	m3/day	enHealth 2012, NICNAS 2017
Binh	inhalation bioavailability, %	100%	%	NICNAS 2017
t	duration of exposure, h/day	8	h/day	assued to be eight hours which is an estimate of the manual handling activities that occur during cleaning and maintenance (NICNAS 2017)
BW	body weight, kg bw	70	kg bw	enHealth 2012, NICNAS 2017

Etotal = Ederm + Einh
Etotal = 0.162 mg/kg bw/day

Appendix C

Chemical Risk Assessment Hydraulic Fracture Stimulation Fluid – SW

Human Health Screening Assessment
Hydraulic Fracture Stimulation Fluid SW Recipe

Chemical Name	CAS Number	Density (kg/L)	Volume of Chemical (L)	Volume Fraction (%v/v)	Chemical Mass in Fluid (kg)	Mass Fraction (% w/w)	Concentration in Injected Fluid (mg/L)	Parent Compound Purpose	Ecotoxicity[1]	Toxicity[2]	Biodegradation[1,3]	Bioaccummulative[1]	Screening	Discussion	Outcome of Tier 2 Assessment[1]
Choline Chloride	67-48-1	1.1	24720	0.0848%	27192	0.0869%	977	Clay Stabiliser	96-hour fish LC50 value is >100 mg/L 48-hour in vertebrate EC50 is 349 mg/L 72-hour EC50 to Pseudokirchneriella subcapitata is >1,000 mg/L 21-day Daphnia NOEC value is 30.2 mg/L	Based on Chronic: Low	Choline chloride is readily biodegradable and thus it does not meet the screening criteria for persistence.	Not Bioaccumulative (based on a measured log Kow of -3.77 and a calculated BCF of 0.59)	Tier 1 (NICNAS)	A Tier 1 Human Health Assessment for this chemical has been conducted by NICNAS which concluded that this chemical was identified as low concern to human health. A Tier 2 assessment is not required.	NA
Hydrochloric acid	7647-01-0	1.152	23649	0.0811%	27244	0.0871%	979	Acid	Algae (acute) = 0.492 mg/L Daphnia (acute) = 0.492 mg/L Fish (acute) = 4.92 mg/L Daphnia (chronic) = 62 mg/L	Based on Chronic: Low	N.A.(Inorganic)	N.A. (Inorganic)	Tier 1	The risk was classified as low based on chronic data. A Tier 2 assessment is not required.	NA
Alcohols, C6-12, ethoxylated propoxylated	68937-66-6	0.94	10,206	0.0350%	9,593	0.0307%	345	Surfactant	LC50 (96h) 0.59 mg/L (Pleuronectes platessa) EC50 (48h) 0.14 mg/L (Daphnia magna) EC50 (96h) 0.7 mg/L (Pseudokirchneriella subapitata) NOEC 4.4 mg/L (Pimephales promelas, juvenile)	Based on Chronic: Moderate	Expected to be readily biodegradable based on similar substances	Not Bio accumulative (Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8)	Tier 1 with management	The risk was classified as moderate. The exposure concentration is elevated. This chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Alcohols, C10-16, ethoxylated propoxylated	69227-22-1	0.94	5,253	0.0180%	4,938	0.0158%	177	Friction Reducer, Surfactant	LC50 (96h) 0.59 mg/L (Pleuronectes platessa EC50 (48h) 0.14 mg/L (Daphnia magna) ErC50 (48h) 0.7 mg/L (Skeletonema costatum) ErC50 (16.9h) > 10 g/L (Pseudomonas putida)	Based on Acute: Very high	Expected to be readily biodegradable based on similar substances	Not Bio accumulative (Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8)	Tier 1 with management	The risk was classified as very high based on acute data. The exposure concentration is elevated. This chemical is expected to be readily biodegradable and not bioaccummulative. A Tier 2 assessment is not required. Management of this chemical in flowback water will be addressed in the Wastewater Management Plan.	NA
Sodium polyacrylate	9003-04-7	1.32	3723	0.0128%	4914	0.0157%	177		96 hr LC50 for fish is >1000 mg/L NOEC from a chronic early life stage test for the fathead minnow is 56 mg/L 48 hr LC50 for Dapnia magna is >1000 mg/L NOEC for a 21day chronic reproductive test on Daphnia magna is 5.6 mg/L EC10 for Scenedesmus is 180 mg/L	Based on Chronic: Moderate to low	Sodium polyacrylate has limited biodegradation potential and thus meets the screening criteria for persistence.	Bioaccumulation of sodium polyacrylate is unlikely due to the high molecular weight of the polymer.	Tier 1 (NICNAS)	A Tier 1 Human Health Assessment for this chemical has been conducted by NICNAS which concluded that this chemical was identified as low concern to human health. A Tier 2 assessment is not required.	NA
Sodium Chloride	7647-14-5	2.165	3476	0.0119%	7525	0.0241%	270	Stabiliser	EC50 = 400 to 30000 mg/L EC50 Fish = 1290 mg/L NOEC = 314 mg/L (Daphnia)	Based on Chronic: Low	N.A.(Inorganic)	N.A. (Inorganic)	Tier 1	The risk was classified as low based on chronic data. A Tier 2 assessment is not required.	NA
Acrylamide acrylate copolymer	25987-30-8	0.75	3309	0.0113%	2482	0.0079%	89	Scale Inhibitor	96 hour LC50 for fish = 1 400 mg/L 48 hour EC50 for Daphnia magna = 1 200 mg/L 21 day EC50 for Daphnia magna = 680 mg/L 21 day NOEC for algae = 380 mg/L	Based on Chronic: Low	Polymers are not readily biodegradable, hence they meet the screening criteria for persistence.	Polymers are expected to have very high molecular weights and poor water solubility. They are not expected to be bioavailable.	Tier 1 (NICNAS)	A Tier 1 Human Health Assessment for this chemical has been conducted by NICNAS which concluded that this chemical was identified as low concern to human health. A Tier 2 assessment is not required.	NA
Acetic acid	64-19-7	1.05	2859	0.0098%	3002	0.0096%	108	Acid	Acute endpoints: Fish = 75 mg/L, Daphnia EC50 = 32 mg/L Chronic endpoints: Daphnia = 150 mg/L	Based on Chronic: Low	Readily biodegradable	Not Bio accumulative (Based on log Kow = -0.136)	Tier 1	The risk was classified as low based on chronic data and it is expected to be readily biodegradable and not bioaccummulative. A Tier 2 assessment is not required.	NA
Tributyl tetradecyl phosphonium chloride	81741-28-8	0.95	2370	0.0081%	2251	0.0072%	81	Biocide	LC50: (96 hour) 0.46 mg/L (Oncorhynchus mykiss) LC50: (96 hour) 0.06 mg/l (Lepomis macrochirus) LC50: (96 hour) 0.58 mg/l (fish) TLM96: 1.6 mg/l (Crangon crangon) TLM48: 0.025 mg/l (Daphnia magna Modelled acute endpoint: Daphnia is 16.788 mg/L Fish is 1059.2530 mg/L	Based on Acute: Very high	Not available, however it has been observed to biodegrade in sediment.	Not bioaccumulative (Based on an estimated log Kow value of 6.26)	Tier 1 with management	The risk was classified as very high. The exposure concentration is elevated. However, this chemical is not expected to be bioaccummulative and has been observed to biodegrade. Management of this chemical in flowback water is addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Polyethylene glycol	25322-68-3	1.21	2059	0.0071%	2491	0.0080%	89	Scale Inhibitor	LC50 = 100 mg/L (fish) LC50 = 1000 mg/L (invertebrates) EC 50 = 15.91 mg/L (algae)	Based on Acute: Moderate	Expected to be readily biodegradable	No based on BCF of 3.2	Tier 1 with management	The risk was classified as moderate. The exposure concentration is elevated. This chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water will be addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Sodium bisulfite	7631-90-5	1.348	1876	0.0064%	2529	0.0081%	91	Scale Inhibitor	72h-EC50 = 36.8 mg sodium sulfite/L (alga) NOEC of >8.41 mg sodium sulfite/L (Daphnia)	Based on Chronic: Moderate	N.A.(Inorganic)	N.A. (Inorganic)	Tier 1 with management	The risk was classified as moderate. The exposure concentration is elevated. This chemical is an inorganic substance and its ionic species is ubiquitous in environment. Management of this chemical in flowback water will be addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Ethylene glycol	107-21-1	1.11	1558	0.0053%	1729	0.0055%	62	Crosslinker	LC50 for fish = 22800 mg/L LC50 for Daphnia =7800 mg/L NOEC for Algae =100 mg/L	Based on Acute: Low	Readily biodegradable	No based on the measured log Kow of -1.36 and a measured BCF of 10	Tier 1 (NICNAS)	NICNAS has classified this chemical as having low environmental concern. A Tier 2 assessment is not required.	NA
Cinnamaldehyde	104-55-2	1.048	1459	0.0050%	1529	0.0049%	55	Corrosion Inhibitor	Danio rerio (Zebrafish) 96 h LC50 = 3.1 mg/L; Daphnia magna (Water flea) 48 h EC50 = 3.86 mg/L; Pseudokirchneriella subcapitata (Green algae) 72 h EC50 = 4.07 mg/L. 72 h NOEC value = 2.0 mg/L Pseudokirchneriella subcapitata (Green algae)	Based on Chronic: Moderate	N.A.(Inorganic)	N.A. (Inorganic)	Tier 1 with management	The risk was classified as moderate. The exposure concentration is elevated. This chemical is an inorganic substance and its ionic species is ubiquitous in environment. Management of this chemical in flowback water will be addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Diethylene glycol	111-46-6	1.12	736	0.0025%	825	0.0026%	30	Corrosion Inhibitor	LC 50 = >100 mg/L (fish, invertebrates, algae)	Based on Acute: Low	Readily biodegradable	No based on the estimated BCF of 3	Tier 1	The risk was classified as low based on chronic data and it is expected to be readily biodegradable and not bioaccummulative. A Tier 2 assessment is not required.	NA
Methanol	67-56-1	0.791	730	0.0025%	578	0.0018%	21	Corrosion Inhibitor, Surfactant	LC50s ranged from 15,400 to 29,400 mg/L (fish) 24-hour and 48-hour EC50s were > 10,000 mg/L (Daphnia) 28 days NOEC was 446.7 mg/L (fish) 21 days NOEC was 208 mg/L (invertebrates)	Based on Chronic: Low	Readily biodegradable	No based on the Log Kow of -0.74	Tier 1	The risk was classified as low based on chronic data and it is expected to be readily biodegradable and not bioaccummulative. A Tier 2 assessment is not required.	NA
Amine oxides, cocoalkyldimethyl	61788-90-7	0.716	483	0.0017%	346	0.0011%	12	Corrosion Inhibitor	LC50/EC50/ErC50 values: 0.60-32 mg/L for fish 0.50-10.8 mg/L for Daphnia magna 0.010-5.30 mg/L for algae NOEC/ EC20: 0.010-1.72 mg/L for algae 0.28 mg/L for Daphnia 0.31 mg/L for fish	Based on Chronic: Very High	Readily biodegradable	No based on the calculated Log Kow of <2.7 and BCF <87	Tier 1 with management	The risk was classified as very high based on chronic data. The exposure concentration is elevated. This chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water will be addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Sodium hydroxide	1310-73-2	1.515	458	0.0016%	694	0.0022%	25	pH buffer	Measured acute endpoints for fish (196 mg/L). Measured chronic endpoint for Daphnia (240 mg/L)	Based on Chronic: Low	N.A.(Inorganic)	N.A. (Inorganic)	Tier 1	The risk was classified as low based on chronic data and it is expected to be readily biodegradable and not bioaccummulative. A Tier 2 assessment is not required.	NA
Citric acid	77-92-9	1.542	336	0.0012%	518	0.0017%	19	Corrosion Inhibitor	LC50/EC50 > 100 mg/L (fish, daphnia, algae) 8 day NOEC = 425 mg/L (algae)	Based on Chronic: Low	Readily biodegradable	No based on low log Kow	Tier 1	The risk was classified as low based on chronic data and it is expected to be readily biodegradable and not bioaccummulative. A Tier 2 assessment is not required.	NA
Benzaldehyde	100-52-7	1.0415	332	0.0011%	346	0.0011%	12	Corrosion Inhibitor	Acute LC50 for freshwater fish is 1.07 mg/L, freshwater invertebrates is 16.2 mg/L and EC10 for freshwater algae is 20 mg/L. Chronic NOEC for freshwater fish is 0.12 mg/L.	Based on Chronic: High	Expected to be readily biodegradable	No based on Log Pow of 1.4	Tier 1 with management	The risk was classified as high. This chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water will be addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA

Human Health Screening Assessment
Hydraulic Fracture Stimulation Fluid SW Recipe

Chemical Name	CAS Number	Density (kg/L)	Volume of Chemical (L)	Volume Fraction (%v/v)	Chemical Mass in Fluid (kg)	Mass Fraction (% w/w)	Concentration in Injected Fluid (mg/L)	Parent Compound Purpose	Ecotoxicity[1]	Toxicity[2]	Biodegradation[1,3]	Bioaccummulative[1]	Screening	Discussion	Outcome of Tier 2 Assessment[1]
Ethanol	64-17-5	0.7864	328	0.0011%	258	0.0008%	9	Surfactant	LC50/EC50 > 1000 mg/L (fish, daphnia, algae) NOEC for invertebrates is 9.6 mg/L (10 day reproduction), plants it is 280 mg/L (7 day study)	Based on Chronic: High	Readily biodegradable	No based on calculated logBCF=0.5	Tier 1 (conc < ecotox)	The risk was classified as high based on chronic data. However, the exposure concentration is below the respective LC50/EC50 values and as this chemical is epected to be readily biodegradable, a Tier 2 assessment is not required.	NA
Hydrotreated light petroleum distillate	64742-47-8	0.8	303	0.0010%	242	0.0008%	9	Friction Reducer, Surfactant	96 hr LL50 was 2 to 5 mg/L (fish) 48 hr EL50 was 1.4 mg/L (daphnia) 21 d NOEL = 0.48 mg/L (daphnia)	Based on Chronic: High	Readily biodegradable	Yes based on calculated log BCF values for constituents that range from 2.78 to 4.06, and calculated BCF values of 598 to 11,430 L/kg wet-weight	Tier 2	The risk was classified as high based on chronic data. The substance is expected to be readily biodegradable, but is considered to have a potential to bioaccumulate. A Tier 2 assessment is required.	A Tier 2 assessment was conducted using the Margin of Exposure (MOE) approach as per DOE and NICNAS 2017 guidance. Based on the calculated MOEs the chemical is of low concern for workers (refer to individual toxicity profile for further detail).
Fatty acids, tall-oil, ethoxylated	61791-00-2	1.054	235	0.0008%	248	0.0008%	9	Surfactant	96h-LL50 > 100 mg/L (fish) 48h-EL50 = 12.41 mg/L (invertebrates) 72h-EL50 = 39.7 mg/L (algae) 72h-EL10 = 7.08 mg/L (algae)	Based on Acute: High	Readily biodegradable (read across)	No based on low BCF values of < 100 L/kg ww	Tier 1 with management	The risk was classified as high. This chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water will be addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	0.9	125	0.0004%	112	0.0004%	4	Surfactant	LC50 (96h) 6.7 mg/L (Danio rerio) (similar substance) LC50 (21d) = 0.1 mg/L (Daphnia magna) LC50 (48h) = 2.15 mg/L EC50 (72h) 2.2 mg/L (Scendesmus subspicatus) (similar substance)	Based on Chronic: High	Readily biodegradable (read across)	No Log Kow 3	Tier 1 with management	The risk was classified as high. This chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water will be addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Butyl alcohol	71-36-3	0.81	116	0.0004%	94	0.0003%	3	Surfactant	Fish, LC50 (96h) 1376 mg/l Invertebrates, EC50 (48h) 1328 mg/L) Algae, EC50 (96h) 225 mg/L EC10 (17h) Pseudomonas putida = 2476 mg/L Chronic NOECrepro (21d) = 4.1 mg/L for Daphnia magna	Based on Chronic: Moderate	Readily biodegradable	No based on low log Kow values of 1	Tier 1 (conc < ecotox)	The risk was classified as high based on chronic data. However, the exposure concentration is below the respective LC50/EC50 values and as this chemical is epected to be readily biodegradable, a Tier 2 assessment is not required.	NA
Alcohols, C12-15, ethoxylated	68131-39-5	0.867	103	0.0004%	89	0.0003%	3	Friction Reducer, Surfactant	96 h LC50 Oncorhynchus mykiss was 5 - 7 mg/L Lepomis macrochirus, NOEC (30 days) was 0.11 – 0.33 mg/L. Daphnia magna, EC50 (48 h) was 2.5 mg/L. Daphnia magna, NOEC (21 days) was 0.77 – 1.75 mg/L. Green algae, EC50 (96 h) was 1.4 mg/L. EC50 (3 h) for microorganisms was 140 mg/L.	Based on Chronic: High	Readily biodegradable	No. Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8, it is not expected to be bioaccumulative.	Tier 1 with management	The risk was classified as high. This chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water will be addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Alcohols, C12-16, ethoxylated	68551-12-2	0.97	69	0.0002%	67	0.0002%	2	Corrosion Inhibitor, Surfactant	96 h LC50 Oncorhynchus mykiss was 5 - 7 mg/L Lepomis macrochirus, NOEC (30 days) was 0.11 – 0.33 mg/L. Daphnia magna, EC50 (48 h) was 2.5 mg/L. Daphnia magna, NOEC (21 days) was 0.77 – 1.75 mg/L. Green algae, EC50 (96 h) was 1.4 mg/L. EC50 (3 h) for microorganisms was 140 mg/L.	Based on Chronic: High	Readily biodegradable	No. Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8, it is not expected to be bioaccumulative.	Tier 1 with management	The risk was classified as high. This chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water will be addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Sodium iodide	7681-82-5	3.67	47	0.0002%	171	0.0005%	6	Corrosion Inhibitor	96 hour LC50 for fish is > 860 mg/l 7 days NOEC for fish is 100 mg/L 48hrs-EC50 for Daphnia magna is 1.27 mg/L NOEC for algae is 66 mg/L	Based on Chronic: Low	N.A.(Inorganic)	N.A.(Inorganic)	Tier 1 (NICNAS)	A Tier 1 Human Health Assessment for this chemical has been conducted by NICNAS which concluded that this chemical was identified as low concern to human health. A Tier 2 assessment is not required.	NA
Acrylonitrile	107-13-1	0.806	45	0.0002%	36	0.0001%	1	Surfactant	96h LC50 for freshwater fish = 10 - 20 mg/l 96h LC50 for saltwater fish 8.6 mg/l 48h EC50 for Daphnia = 7.6 mg/l 30d NOEC for fish of 0.17 mg/l	Based on Chronic: High	Biodegradable	No based on the low log Pow (0.00-0.30)	Tier 1 with management	The risk was classified as high. This chemical is expected to be Biodegradable and not bioaccummulative. Management of this chemical in flowback water will be addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Diethanolamine	111-42-2	1.1	43	0.0001%	48	0.0002%	2	Breaker Activiator	Fish 96-h LC50 = 1370 mg/l Invertebrates 48-h EC50 = 55 mg/l Pseudokirchneriella subcapitata 96-h ErC50 = 2.2 mg/l Microorganisms 16-h TTC = 16 mg/l Daphnia magna, the NOEC (21 days) was 0.78 mg/l	Based on Chronic: High	Readily biodegradable	No. Based on a measured log Kow of -2.18 and a calculated BCF of 3.16	Tier 1 with management	The risk was classified as high. This chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water will be addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Glutaraldehyde	111-30-8	1.05	23	0.0001%	24	0.0001%	1	Biocide	96 h acute Bluegill sunfish LC50 = 11.2 mg/L 48 h acute Oyster larvae LC550 = 2.1 mg/L 96 h acute Green crabs LC50 = 465 mg/L 96 h acute Grass shrimp LC50 = 41 mg/L 48 acute Daphnia magna LC50 = 0.35 mg/L 48 acute Daphnia magna LC50 = 16.3 mg/L 21 d reproduct'n Daphnia magna LOEC = 4.3 mg/L, NOEC = 2.1 mg/L 96 h algal growth inhibition Selenastrum capricornutum ILm = 3.9 mg/L (median inhibitory limit) 96 h algal growth inhibition Scenedesmus subspicatus EC50 = 1.0 mg/L Bacterial inhibition Sewage microbes IC50 = 25-34 mg/L	Based on Chronic: Moderate	Readily biodegradable	No based on the Log Pow of -0.01	Tier 1 (conc < ecotox)	The risk was classified as moderate based on chronic data. However, the exposure concentration is below the respective LC50/EC50 values and as this chemical is epected to be readily biodegradable, a Tier 2 assessment is not required.	NA

Notes
1 - Please refer to the individual toxicity profiles for further detail.
2 - Toxicity assessed using Commonwealth of Australia 2013 Ecotoxicity Assessment Guidelines (presented as Table 4 in the Northern Territory Government Draft Guideline for the Preparation of an Environment Management Plan under the Petroleum Regulations (2019))
3- Biodegradation assessed as per Northern Territory Government Draft Guideline for the Preparation of an Environment Management Plan under the Petroleum Regulations (2019) and Australian Government Department of Health National Industrial Chemicals Notification and Assessment Scheme (NICNAS)
BCF - Bioconcentration Factor
NA - Not Applicable
MOE - Margin of Exposure
NICNAS 2017 - National Assessment of Chemicals Associated with Coal Seam Gas Extraction in Australia
DOE 2017 - Draft Risk Assessment Guidance Manual: For Chemicals Associated with Coal Seam Gas Extraction, Australian Government, Department of Energy

Attachment A - Risk Characterisation Calculations

64742-47-8 Distillates (petroleum), hydrotreated light

Adult worker exposure scenario	Total Internal Dose (mg/kg bw/day)	NOAEL (mg/kg bw/day)	Critical effect	MOE (NOAEL / dosage)	Chemical is of concern? (MOE < 100)
Occupational Activity					
Transport and storage	Negligible*	1000	maternal toxicity in rats		No
Mixing/blending drilling of hydraulic fracturing chemicals	0.810			1235	
Injection of drilling chemicals	Negligible*				
Cleaning and maintenance (hydraulic fracturing)	0.162			6173	
Combined exposure Mixing/blending and cleaning and maintenance	**0.972**			1029	

* In the absence of accidents/incidents, repeated occupational exposures during transport and storage, or during injection of mixed/blended chemicals, are negligible.
Similarly, repeated occupational exposures to the chemical via the transport and storage of drilling muds are negligible (NICNAS 2017).

Worker exposure during mixing/blending of chemicals

Dermal Exposure

$$Ederm = \frac{C \times Dease \times SAderm \times Bderm}{BW}$$ (source Equation 1 - NICNAS 2017)

Ederm	Internal dermal dose of the chemical, mg/kg bw/day	0.06	mg/kg bw/day	
C	concentration of the chemical, %	100%	%	default concentration of 1000 g/L (100%) is used. Assumes the chemical is in its pure form and not diluted with other chemicals (NICNAS 2017)
Dease	external dose estimated by EASE model, mg/cm2/day	0.1	mg/cm2/day	Assuming no PPE, the upper limit value of DEASE, 0.1 mg/cm2/day is used (NICNAS 2017)
SAderm	surface area of exposed skin, cm2	840	cm2	US EPA 2011, NICNAS 2017
Bderm	dermal bioavailability, %	10%	%	NICNAS 2017
BW	body weight, kg bw.	70	kg bw	enHealth 2012, NICNAS 2017

Inhalation Exposure

$$Einh = \frac{Fresp \times C \times Demkg \times Vair \times Binh \times t}{BW}$$ (source Equation 2 - NICNAS 2017)

Einh	Internal inhalation dose of the chemical, mg/kg bw/day	0.750	mg/kg bw/day	
Fresp	respirable/inhalable fraction of the chemical, dimensionless	1	dimensionless	assumed to be 1 (NICNAS 2017)
C	concentration of the chemical, %	100%	%	default concentration of 1000 g/L (100%) is used as the concentration of chemical when delivered to site. Assumes the chemical is in its pure form and not diluted with other chemicals (NICNAS 2017)
Demkg	external dose estimated by EMKG-EXPO-TOOL, mg/m3	0.6	mg/m3	NICNAS 2017
Vair	worker ventilation rate, m3/day	22	m3/day	enHealth 2012, NICNAS 2017
Binh	inhalation bioavailability, %	100%	%	NICNAS 2017
t	duration of exposure, h/day	4	h/day	assumed to be four hours, which is an estimate of the duration of manual handling activities that occur during mixing (NICNAS 2017)
BW	body weight, kg bw	70	kg bw	enHealth 2012, NICNAS 2017
t	time	4	hours	NICNAS 2017

Etotal = Ederm + Einh
Etotal = 0.810 mg/kg bw/day

Worker exposure during cleaning and maintenance (drilling)

Dermal Exposure

$$Ederm = \frac{C \times Dease \times SAderm \times Bderm}{BW}$$

Ederm	Internal dermal dose of the chemical, mg/kg bw/day	0.012	mg/kg bw/day	
C	concentration of the chemical, %	10%	%	an assumed concentration of 100 g/L (10%) is used as the concentration of chemical in the final formulation prior to injection
Dease	external dose estimated by EASE model, mg/cm2/day	0.1	mg/cm2/day	Assuming no PPE, the upper limit value of Dease, 0.1 mg/cm2/day, is used (NICNAS 2017).
SAderm	surface area of exposed skin, cm2	840	cm2	for hands (USEPA 2011, NICNAS 2017)
Bderm	dermal bioavailability, %	10%	%	NICNAS 2017
BW	body weight, kg bw.	70	kg bw	enHealth 2012, NICNAS 2017
t	time	8	hours	NICNAS 2017

Inhalation Exposure

$$Einh = \frac{Fresp \times C \times Demkg \times Vair \times Binh \times t}{BW}$$

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Einh	Internal inhalation dose of the chemical, mg/kg bw/day	0.150	mg/kg bw/day	
Fresp	respirable/inhalable fraction of the chemical, dimensionless	1	dimensionless	assumed to be 1 (NICNAS 2017)
C	concentration of the chemical, %	10%	%	an assumed concentration of 100 g/L (10%) is used as the concentration of chemical in the final formulation prior to injection
Demkg	external dose estimated by EMKG-EXPO-TOOL, mg/m3	0.6	mg/m3	Assuming no PPE, the upper limit value is used - EMKG-EXPO-TOOL, NICNAS
Vair	worker ventilation rate, m3/day	22	m3/day	enHealth 2012, NICNAS 2017
Binh	inhalation bioavailability, %	100%	%	NICNAS 2017
t	duration of exposure, h/day	8	h/day	assued to be eight hours which is an estimate of the manual handling activities that occur during cleaning and maintenance (NICNAS 2017)
BW	body weight, kg bw	70	kg bw	enHealth 2012, NICNAS 2017

Etotal = Ederm + Einh
Etotal = 0.162 mg/kg bw/day

Appendix D

Hydraulic Fracture Stimulation Fluid - Chemical Toxicological Profiles

Toxicity Summary - Acetic acid

Chemical and Physical Properties[1,6]	
CAS number	64-19-7
Molecular formula	$C_2H_4O_2$
Product name	Acetic Acid 60%
Molecular weight	60 g/mol
Solubility in water	1000 g/L at 25°C
pH	1.38
Melting point	16.6 °C
Boiling point	117.9 °C
Vapour pressure	1.5 kPa at 20°C
Henrys law constant	0.0101 Pa m^3/mol
Explosive potential	Above 39°C explosive vapour mixtures may be formed. Risk of fire and explosion on contact with strong oxidants.
Flammability potential	Flammable. Flashpoint = 39°C
Colour/Form	Clear colourless liquid with a pungent vinegar smell
Overview	Acetic acid is naturally occurring as the acid in apple cider vinegar and other fruit derived products. Acetic acid is recognised by Food Standards Australia New Zealand (FSANZ) and the US Food and Drug Administration (FDA) as safe as a food additives (e.g. flavouring agent, preservative).
Environmental Fate[1]	
Soil/Water/Air	When released into the environment, acetic acid is not expected to adsorb onto suspended solids or sediments. Acetic acid dissociates in aqueous media to H+ and the acetate anion ($CH_3CO_2^-$). The compound is expected to be present in the dissociated form, where volatilisation is not an important process. Based on the range of expected Koc values, acetic acide is expected to have a very high to moderate mobility in soil. In air acetic acid will exist soley in the vapour phase where it is degraded with photochemically produced hydroxyl radicals with a half-life for this reaction in air of approximately 22 days. Acetic acid is readily biodegradable, and biodegrades rapidly under aerobic and anaerobic conditions. Based on an estimated bioconcentration factor of 3.2, the potential for bioaccumulation is low.

Human Health Toxicity Summary [1,2,5,6]	
Chronic Repeated Dose Toxicity	In a six-month repeat dose oral toxicity study (Lamb and Evard 1919), pigs were initially fed acetic acid at 155 mg/kg bw/day with the dose was raised every 10 to 30 days until a final dose of 380 to 450 mg/kg bw/day was reached after 60 days. There was no mortality and no effects on body weight or acid-base balance noted in this study (REACH 2013). A NOAEL was not established in this study. Repeated intra-gastric administration of the chemical at 3% concentration in animals (unspecified) for six months resulted in chronic inflammation of the oesophageal mucosa (HSDB 2013). Similarly, intra-gastric administration to rats of 3 mL of a 10% solution for 90 days produced a drop in haemoglobin concentration and erythrocyte count (HSDB 2013). In another similar study, pigs were fed daily diets containing the chemical at 0, 240, 720, 960 and 1200 mg/kg bw/day for successive 30-day periods for a total of 150 days (HSDB 2013).There were no significant differences in growth rate, weight gain, early morning urinary ammonia and terminal blood pH between controls and test groups. A NOEL or NOAEL was not indicated by the authors. Based on the available information and taking a conservative approach, the NOAEL in the study is considered to be 1200 mg/kg bw/day, the highest tested dose with no adverse effects. This NOAEL will be used for human health risk assessment. In the only available dermal repeat dose toxicity study (Slaga et al. 1975), acetic acid was applied dermally to mice at doses of 1 to 40 mg/animal, one to three times/week for 32 weeks. Single dermal applications of acetic acid at doses of up to 40 mg/animal did not induce mortality. However, more than one application per week of 10 mg acetic acid or more caused excessive mortality. 33% of mice died when 10 mg acetic acid/animal was applied dermally three times/week and approximately 50% of mice died when 20 mg was applied twice a week. No biochemical or histopathological effects were reported. A LOAEL of 10 mg/animal was suggested by the authors, however it was expressed in terms of ‘mg/animal’ rather than ‘mg/kg bw/day’ and it therefore cannot be adopted. Dermal NOAEL or LOAEL for acetic acid are not available. Repeated oral, inhalation and dermal exposure of humans to pure acetic acid has been reported to have effects on the gastrointestinal tract and to cause digestive disorders including heartburn and constipation, chronic inflammation of the respiratory tract, pharyngitis, catarrhal bronchitis, darkening of skin, skin dermatitis and erosion of the exposed front teeth enamel. In addition, skin on the palms of hands can become dry, cracked and hyperkeratotic. These observed effects were not associated with any systemic findings, suggesting the effects observed could be due to its corrosive action (EC 2012; HSDB 2013).
Carcinogenicity	In a carcinogenicity study (Slaga et al. 1975), acetic acid was tested as the promoter for tumour development in mice. Acetic acid was applied dermally to mice initiated with a carcinogenic agent, dimethylbenz(a)anthracene (DMBA) at doses of 1 to 40 mg/animal, one to three times/week for 32 weeks. Control animals received acetic acid dermally once per week. No further details were provided about the exposure duration. Single dermal application of acetic acid at doses of up to 40 mg/animal did not induce mortality. However, more than one application per week of 10 to 40 mg acetic acid caused excessive mortality. Thirty three per cent of mice died when 10 mg acetic acid/animal was applied dermally three times/week and approximately 50% of mice died when 20 mg was applied twice a week. No biochemical or histopathological effects were reported. Acetic acid did not produce any carcinogenic effects in mice (REACH 2013). In another study, oral administration of the chemical as a 3% solution in rats, three times/week for eight months did not induce tumours in the oesophagus and fore-stomach, although epithelial hyperplasia was observed. When dosed in combination with the known carcinogen, N-nitrososarcosine ethyl ester (positive control), there was an increase in oesophageal/stomach tumour formation (REACH 2013). Based on the limited available data, acetic acid is not likely to be a carcinogen.

Mutagenicity/ Genotoxicity	Acetic acid was not mutagenic in bacterial reverse mutation assays using Salmonella typhimurium strains TA100, TA1535, TA97 and TA98 with and without metabolic activation (Ishidate et al. 1984). Acetic acid was negative in the chromosome aberration assay using Chinese hamster lung fibroblasts at concentrations of up to 1 mg/mL with or without metabolic activation. In one study using Chinese hamster ovary Kl cells, acetic acid induced chromosomal aberrations at the initial pH of 6.0 or below (about 10 to 14 mM of acid) both with and without S9 mix (REACH 2013). However, when the culture medium was neutralised to pH 7.2 with sodium hydroxide, no clastogenic activity was observed. Moreover, pH lower than 6.0 (pH 5.7 or below) were also found to be cytotoxic. Chromosomal aberrations induced at these high concentrations were therefore considered to be artefacts due to acidification of the culture medium. Acetic acid was concluded not to be clastogenic when tested in cultured Chinese hamster K1 cells (REACH 2013; HSDB 2013). It was concluded that acetic acid is not mutagenic.
Reproductive Toxicity	No data available
Developmental Toxicity/Teratogenicity	In two developmental toxicity studies conducted according to the EU Method B.31 (prenatal developmental toxicity study), acetic acid was administered by gavage to pregnant female Wistar rats and CD-1 mice at 16, 74.3, 345, and 1600 mg/kg bw/day during gestation days 6 to 15 (10 consecutive doses) (REACH 2013). In a similar study, the chemical was administered by gavage to female Dutch rabbits at 16, 74.3, 345, and 1600 mg/kg bw/day during gestation days 6 to 18 (13 consecutive doses) (REACH 2013). There were no clearly discernible effects on implantation, maternal survival or foetal survival in any species at any of the doses. The number of abnormalities seen in either soft or skeletal tissues of the test groups did not differ significantly from those occurring spontaneously in the controls. No NOAEL could be established for maternal toxicity or foetal developmental effects. Based on the available data, the chemical does not show developmental toxicity.
Acute Toxicity	Acetic acid was of low acute toxicity in animal tests following oral exposure. The median lethal dose (LD50) observed in two rat studies is greater than 2000 mg/kg bw (REACH2013). In one study, groups of unfasted rats were fed 2239, 2512, 2859, 3100, 3500, 4000, 4467 mg/kg bw sodium acetate and observed for six days (REACH 2013). The acute oral median lethal dose (LD50) of the sodium salt of acetic acid was found to be 3310 mg/kg bw for rats. Acetic acid was of moderate acute toxicity in rabbits following dermal exposure. The LD50 in rabbits was 1060 mg/kg bw (HSDB 2013). Details regarding the concentration of the administered test substance were not provided. The moderate acute dermal toxicity is believed to be due to its local corrosive effects rather than any systemic toxicity. Acetic acid was of low acute toxicity in animal tests following inhalation exposure. In an acute inhalation study, mice were exposed to various concentrations of acetic acid (experimental details and concentration range not provided) (HSDB 2013). Clinical signs of respiratory irritation were evident at concentrations of 2.46 mg/L and higher. Animals exposed to concentrations higher than 11.07 mg/L died within 27 hours of exposure. Surviving mice recovered quickly and showed no abnormalities three days after exposure. The median lethal concentration (LC50) was determined by the Weil's method and was estimated to be 13.8 mg/L in the mouse. Severe health effects have been reported in humans following accidental exposure to acetic acid by different routes, mainly due to the local corrosive effects of the chemical leading to systemic effects (HSDB 2013).

Irritation	Pure acetic acid is corrosive to skin. In animal studies, severe skin burns were reported in guinea pigs following application to intact or abraded skin of patches of 80% solution of the chemical, moderate to severe burns at 50 to 80% solution, mild injury at 50% solution, and no effect at 10% solution (HSDB 2013). In a study with rabbits, the chemical was considered to be slightly irritating at concentrations of 3.3% and 10% (REACH 2013). In another study with rabbits, a concentration of 2.5% of the chemical was not irritating while concentrations of 10 to 25% caused moderate to severe erythema, slight to severe oedema, skin lesions over the application site and eschar formation (REACH 2013). A 10% solution was therefore considered a skin irritant. As part of a study to select the optimum testing conditions for predicting hazard to the human eye, 3%and 10% aqueous acetic acid were tested in rabbit eyes (REACH 2013). Materials were applied directly to the central corneal surface. Irritation was followed for up to 21 days and scored according to the Draize scale. The 3% acetic acid gave moderate irritation and 10% acetic acid was severely irritating or corrosive. In other studies, instillation of 0.5 mL of a 1% acetic acid solution in the eyes of rabbits caused a severe burn (Smyth et al. 1951). Solutions of 5% induced injury in eyes of rabbits which healed by 14 days, while a 10% solution resulted in severe permanent damage (Henschler 1973). Based on the results of the studies pure acetic acid is considered to be corrosive to eyes. In an acute inhalation study in mice, clinical signs of respiratory irritation were evident at concentrations of 2.46 mg/L and higher (see Section A28.5.2.3). Acetic acid vapours were reported to cause damage to nose, throat and lungs in humans (SCOEL 2012). Acetic acid is considered to be a respiratory tract irritant. Chemical burns and eye and nasal irritation have been reported in humans following exposure
Sensitisation	No experimental data were available, however the US National Institute of Occupational Safety and Health (NIOSH) Pocket Guide to Chemical Hazards mentions skin sensitisation as one of the symptoms of acetic acid exposure (NIOSH 2010). A 1994 report (Kivity et al. 1994) describes a late asthmatic response to inhaled glacial acetic acid by an asthma patient. Based on reports of patients with bronchial asthma reacting to acetic acid challenge, it is believed that acetic acid may cause allergic reactions in humans (HSDB 2013). Some researchers consider acetic acid capable of causing a syndrome known as ‘reactive airways dysfunction’, which resembles bronchial asthma. Symptoms include dyspnoea, wheezing, and cough.
Health Effects Summary	Acetic acid has low acute oral and inhalation toxicity but moderate dermal toxicity. LD50 for oral, dermal and inhalation routes were >3100 mg/kg bw, 1060 mg/kg bw and 13.8 mg/L, respectively in laboratory animals. It is corrosive to skin, eyes and respiratory tract. Acetic acid has low repeat dose toxicity by oral and dermal routes. Information on toxicity by the inhalation route is not available. It is not genotoxic or carcinogenic and does not have any developmental effects in animals. Information on effects on fertility is not available. The critical health effect of acetic acid for risk characterisation is its corrosivity.
Key Study/Critical Effect for Screening Criteria	A NOEL or NOAEL was not established in any of the repeat dose studies. Based on the available information and taking a conservative approach, the highest tested dose with no adverse effects in the repeat dose oral study (1200 mg/kg bw/day) was taken as the NOAEL for human health risk assessment.
Ecological Toxicity [2]	
Aquatic Toxicity	Acute endpoints: Fish = 75 mg/L (measured), Daphnia EC50 = 32 mg/L (Dept. Env. (2013a) in LMC, 2012 Chronic endpoints: Daphnia = 150 mg/L (measured)
Determination of PNEC aquatic	PNECaquatic: On the basis of the chronic results for Daphnia, an assessment factor of 10 has been applied to the lowest reported effect concentration of 150 mg/L. The PNECaquatic is determined to be 15 mg/L.

Current Regulatory Controls	
Australian Hazard Classification	Acetic acid is classified as hazardous, with the following risk phrase for human health in the Hazardous Substances Information System (HSIS) (Safe Work Australia 2013): C; R35 (Corrosive, causes severe burns). Mixtures containing the chemical are classified as hazardous with the following risk phrases based on the concentration (Conc) of the chemical in the mixtures: Conc >=90%: C; R35 (Corrosive, causes severe burns) ≥25% Conc <90%: C; R34 (Corrosive, causes burns) ≥10% Conc <25%: Xi; R36/38 (Irritant, Irritating to eyes and skin).
Australian Occupational Exposure Standards	The chemical has an exposure standard of 25 mg/m³ (10 ppm) Time Weighted Average (TWA) and 37 mg/m³ (15 ppm) Short-Term Exposure Limit (STEL) (Safe Work Australia 2013).
International Occupational Exposure Standards	The following exposure standards are identified in Galleria Chemica (2013). Occupational Exposure limit (TWA): 10 to 25 mg/m^3 [China, Canada, Denmark, Germany, Ireland, South Africa, Spain, Sweden, Switzerland, and the US]. An exposure limit (STEL): 15 to 50 mg/m^3 [China, Canada, France, Ireland, Singapore, South Africa, Spain, Sweden, Switzerland, and the US].
Australian Food Standards	Acetic acid is allotted the following International Numbering System of food additives number: INS 260 (Food Standards Australia New Zealand 2013).
Australian Drinking Water Guidelines	No data found
Aquatic Toxicity Guidelines	No data found
PBT Assessment	
P/vP Criteria fulfilled?	No. The acetate ion of acetic acid is readily biodegradable and thus it does not meet the screening criteria for persistence.
B/vB criteria fulfilled?	The log Kow for acetic acid is reported to be -0.136. Acetate is also found in the body and is metabolized as part of the body's biochemical pathways. Thus, acetic acid (specifically, the acetate ion) does not meet the screening criteria for bioaccumulation.
T criteria fulfilled?	No. The NOECs from the chronic aquatic toxicity data on acetic acid are >1 mg/L, hence does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT

References

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Toxicity Summary - Acrylamide polymers: Acrylamide, 2-acrylamido-2-methylpropanesulfonic acid, sodium salt polymer and Polymer of 2-acrylamido-2- ethylpropanesulfonic acid sodium salt and methyl acrylate

Chemical and Physical Properties [2, 3, 4]	
CAS number	38193-60-1, 136793-29-8, 9003-06-9, 25987-30-8
Molecular formula	38193-60-1: $(C_7H_{13}NO_4S.C_3H_5NO.Na)_x$ 136793-29-8: $C_{11}H_{18}NNaO_6S$
Molecular weight	Likely >1000 MW
Solubility in water	No data available.
Melting point	No data available.
Boiling point	No data available.
Vapour pressure	No data available.
Henrys law constant	No data available.
Explosive potential	No data available.
Flammability potential	No data available.
Colour/Form	No data available.
Overview	No studies are available for the Acrylamide polymers. Information for 2-Acrylamido-2-methylpropanesulfonic acid, ammonium salt will be referenced in the following sections. 2-Acrylamido-2-methylpropanesulfonic acid, ammonium salts are generally incorporated into polymers. As such, the fate of the monomer is tied to the polymer and no hydrolysis, movement, biodegradation or bioaccumulation of the polymer is expected. A Tier 1 Human Health Assessment for Acrylamide, 2-acrylamido-2-methylpropanesulfonic acid, sodium salt polymer has been conducted by NICNAS which concluded that this chemical was identified as low concern to human health.
Environmental Fate [2]	
Soil/Water/Air	The polymers are not expected to be readily biodegradable. Biodegradation is limited due to the very high molecular weights and the low water solubilities of the polymers. Due to their high molecular weight, the polymers are not expected to bioaccumulate.
Human Health Toxicity Summary [2]	
Chronic Repeated Dose Toxicity	A repeat dose 28 day oral toxicity study carried out in rats with a 50% aqueous solution of 2-Acrylamido-2-methylpropanesulfonic acid, ammonium salt indicated no treatment related toxic effects.
Carcinogenicity	No information available.
Mutagenicity/ Genotoxicity	2-Acrylamido-2-methylpropanesulfonic acid, ammonium salt did not induce a mutagenic response in bacteria and no clastogenicity was observed when a 50% solution of the notified chemical was tested in albino mice cells in vitro.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	No data available.

Acute Toxicity	Aqueous solutions containing 50% of 2-Acrylamido-2-methylpropanesulfonic acid, ammonium salt exhibited low acute oral and dermal toxicity in rats (LD50 > 5 000 mg/kg, and 2 000 mg/kg respectively).
Irritation	2-Acrylamido-2-methylpropanesulfonic acid, ammonium salt was non-irritant to rabbit skin and a slight eye irritant in rabbits.
Sensitisation	A 50% aqueous solution of 2-Acrylamido-2-methylpropanesulfonic acid, ammonium salt showed minimal sensitisation potential when tested in guinea pigs.
Health Effects Summary	This chemical has been identified by NICNAS to be of low concern to human health.
Key Study/Critical Effect for Screening Criteria	No data available
Ecological Toxicity [2]	
Aquatic Toxicity	Limited information is available. The polymers are expected to be a low concern for toxicity to aquatic organisms. Due to their poor solubility and high molecular weights, they are not expected to be bioavailable. The polymers do not contain any reactive functional groups. Ecotoxicity data for 2-Acrylamido-2-methylpropanesulfonic acid, ammonium salt indicate that it is practically non-toxic to fish, water fleas and algae.
Determination of PNEC aquatic	No PNEC values were calculated.
Current Regulatory Controls[5]	
Australian Hazard Classification	No data available
Australian Occupational Exposure Standards	No data available
International Occupational Exposure Standards	No data available
Australian Food Standards	No data available
Australian Drinking Water Guidelines	Based on health considerations, the concentration of acrylamide in drinking water should not exceed 0.0002 mg/L.
Aquatic Toxicity Guidelines	No data available
PBT Assessment [1, 2]	
P/vP Criteria fulfilled?	The polymers are not readily biodegradable, hence they meet the screening criteria for persistence.
B/vB criteria fulfilled?	The polymers are expected to have very high molecular weights and poor water solubility. They are not expected to be bioavailable, hence the polymers do not meet the criteria for bioaccumulation.
T criteria fulfilled?	There are no aquatic toxicity studies on the polymers. They are expected to have low aquatic toxicity because of their very high molecular weights and poor water solubility. As such, the polymers do not meet the criteria for toxicity.
Overall conclusion	Not PBT substances
Revised	December 2018

References

1. Categorization Results from the Canadian Domestic Substance List, CAS# 38193-60-1

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5. National Health and Medical Research Council, Natural Resources Management Ministerial Council, national Water Quality Management Strategy, Australian Drinking Water Guidelines 6, 2011, Version 3.3 Updated November 2016.

Toxicity Summary - Acrylonitrile

Chemical and Physical Properties [1,2,3,4]	
CAS number	107-13-1
Molecular formula	C3H3N
Molecular weight	53.06
Solubility in water	73 g/L at 20 °C
Melting point	– 88.55 °C
Boiling point	77.3 °C
Vapour pressure	12.4 kPa at 20 °C
Henrys law constant	9.0 Pa $\cdot m^3$/mole at 20 °C
Explosive potential	Sax (1989) presents that acetonitrile forms explosive mixtures with air. The lower explosive limit is 3.05% in volume and the upper explosive limit 17% in volume.
Flammability potential	Acetonitrile is highly flammable, with a lower flammability limit of 4.4% in volume and an upper flammability limit of 16% in volume.
Colour/Form	Volatile, colourless liquid with a sweet ether-like odour
Overview	Acrylonitrile was first prepared in 1893 but had no significant technical or commercial applications until the late 1930s when a synthetic rubber based on a co-polymer of butadiene and acrylonitrile was introduced in Germany (Langvardt, 1984). In USA, projects relating to nitrile rubber received special support during World War II because of their strategic importance and acrylonitrile became established as a monomer of commercial importance. Demand for acrylonitrile began to soar following the introduction of acrylic fibres in 1950. Today, acrylonitrile is an industrial intermediate used predominantly in the production of polymeric materials, with acrylic fibres accounting for 60% and plastics for 25% of world consumption (SRI, 1995). Other uses include the production of adiponitrile and acrylamide monomers and the co-polymerisation with other monomers to produce polymer emulsions, elastomers and nitrile rubber. From the early 1940s to the mid-1960s, acrylonitrile was mainly manufactured by the dehydration of ethylene cyanohydrin produced from ethylene oxide and aqueous hydrocyanic acid. Nowadays, all acrylonitrile is produced by direct catalytic conversion of propene, oxygen (as air) and ammonia (SRI, 1995). Processes based on propane or ethylene have been developed and may become commercially viable in the future where propane or ethylene feedstock is readily available. In 1995, global acrylonitrile capacity amounted to 4.5 million metric tonnes (t) (SRI, 1995).
Environmental Fate [1]	
Soil/Water/Air	Acrylonitrile is readily to fairly degradable in water, soil and in the troposphere. Its toxicity to aquatic vertebrates and invertebrates, algae and aquatic plants is slight to moderate. Bioaccumulation is expected to be slight to negligible. As there are no readily hydrolysable groups on the acrylonitrile molecule, hydrolysis is not expected to be an environmentally significant process. The vapour pressure of acrylonitrile puts it in the category of highly volatile chemicals (Mensink et al., 1995). However, the water solubility is also high. The Henry's Law constant can provide an indication of the volatility characteristics of compounds (Lyman et al., 1982). The characteristics of acrylonitrile indicate that although the volatilisation from aquatic systems is not rapid, it may be a significant removal process in the environment. Therefore, the high vapour pressure is mediated by the high water solubility. The volatilisation half-life of acrylonitrile in a typical pond, river and lake has been estimated at 6, 1.2 and 4.8 days respectively (Howard, 1989). The US EPA has previously suggested that although acrylonitrile is quite volatile, large spillages of the substance could lead to groundwater contamination (DoE, 1993).
Human Health Toxicity Summary [1,2,3]	

Chronic Repeated Dose Toxicity	Repeated-dose toxicity studies involving inhalation, ingestion or subcutaneous or intraperitoneal injection of acrylonitrile for 1-12 months in rats, mice, guinea pigs, rabbits, cats, dogs and monkeys showed a narrow range between lethal and no observed adverse effect levels. The most consistently observed effects were decreased body weight gain, irritation of the respiratory tract, kidney damage and reversible ataxia or paralysis. Retching and vomiting, adrenal hyperplasia, increased liver weight, hyperplasia of the gastric mucosa and biochemical effects such as small reductions in haemoglobin, haematocrit and erythrocyte counts and small increases in alkaline phosphatase were observed in some studies.
Carcinogenicity	The carcinogenic potential of acrylonitrile has been investigated in three strains of rats exposed to 5-80 ppm in air (2 studies), 1-500 ppm in drinking water (5 studies), or 0.1-10 mg/kg by gavage (2 studies). Exposure-related tumours were found in all studies. The most common forms were astrocytomas of the CNS and carcinomas of the zymbal gland, both of which rarely occur spontaneously in experimental animals. Tumours of the mammary gland, tongue, small intestine and forestomach (oral exposure only) were less consistent across studies. A 2-year bioassay in mice, where metabolism via CNEO plays a greater role than in rats, is currently underway within the US National Toxicology Program. Acrylonitrile has also been evaluated by the International Agency for Research on Cancer (IARC). In 1979 and 1987, IARC concluded that there was limited evidence of carcinogenicity of acrylonitrile in humans and sufficient evidence of carcinogenicity in animals and therefore assigned the chemical to group 2A: agents that are probably carcinogenic to humans (IARC, 1979, 1987). In February 1998, all published literature on acrylonitrile was re-evaluated by an IARC working group comprising 30 experts from 12 countries. The group concluded that although additional studies confirmed that acrylonitrile is a potent multi-site carcinogen in rats, the combined epidemiological evidence did not support a credible association between acrylonitrile exposure and cancer. As such, IARC determined that there was inadequate evidence in humans but sufficient evidence in experimental animals for the carcinogenicity of acrylonitrile and re-classified the chemical in group 2B: agents that are possibly carcinogenic to humans (IARC, 1999).
Mutagenicity/ Genotoxicity	The genetic toxicity of acrylonitrile has been investigated in numerous in vitro and in vivo test systems. In vitro, it was weakly positive in several bacterial, fungal and mammalian mutagenicity assays and mammalian and fungal cytogenetic tests, particularly in the presence of metabolic activation. Where CNEO was tested in parallel assays, it was mutagenic in the absence of metabolic activation. In vivo, acrylonitrile tested negative in several dominant lethal, micronucleus and chromosome aberration assays. Studies in Drosophila using various genetic markers gave positive results. In vitro and in vivo assays for DNA binding and unscheduled DNA synthesis yielded negative results in tests using the most reliable techniques. On balance, it appears that acrylonitrile has little affinity for DNA, whereas the metabolite CNEO is a direct-acting mutagen in vitro. It is conceivable that the lack of genotoxicity of acrylonitrile in several in vivo tests is due to limited formation and/or rapid degradation of CNEO in intact mammals.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	In a 3-generation rat study, up to 35 mg/kg/day had no effect on fertility. In sub-acute studies in rats and mice, there was evidence of defective spermatogenesis at oral doses approaching acutely toxic levels, whereas several long-term studies found no abnormalities in male reproductive organs. In developmental toxicity studies in rats, hamsters, and rat embryos exposed in vitro, acrylonitrile showed some potential to cause foetal toxicity, but developmental effects in vivo occurred only at exposure levels associated with marked maternal toxicity.
Acute Toxicity	Acrylonitrile is acutely toxic by all routes of administration. In the rat, the LD50 is 72-186 mg/kg from oral and 148-282 mg/kg from skin exposure, and the 4 h LC50 from inhalation is 138-558 ppm (0.47-1.2 mg/L). The acute toxicity is roughly similar in other species, including mice, guinea pigs, rabbits, cats and dogs. Irrespective of route or test species, a lethal dose causes central nervous system (CNS) excitation followed by paralysis and respiratory arrest. The target organs are the gastrointestinal tract (bleeding), adrenals (haemorrhagic necrosis), brain (oedema) and lungs (oedema).
Irritation	Acrylonitrile is irritating to the skin and eyes. Repeated airborne exposure induces inflammatory and hyperplastic changes in the nasal mucosa, indicating a potential for irritation of the respiratory system.

Sensitisation	A guinea pig maximisation test for skin sensitisation was strongly positive. There are no data on respiratory sensitisation.
Health Effects Summary	Acrylonitrile is acutely toxic to humans by inhalation, in contact with skin and if swallowed. It is also a severe eye irritant and may cause sensitization by skin contact. Repeat dose toxicity studies in animals have shown treatment related changes in the gastrointestinal tract, central nervous system and adrenal gland. There are occasional reports of liver and kidney damage. It is a rodent carcinogen, tumours being observed in the brain, Zymbal gland, gastrointestinal tract and mammary gland. Detailed, recent epidemiological studies do not however provide evidence of human carcinogenicity. Acrylonitrile is an in vitro mutagen, indicating that the mechanism of carcinogenicity may be genotoxic. This is not however supported by the results of in vivo mutagenicity studies. It is concluded that there is a need for active management of the identified risk and further consideration of the risk management measures currently being applied in relation to workers, consumers and the population exposed via the environment.
Key Study/Critical Effect for Screening Criteria	In animals repeated exposure to acrylonitrile results in damage to the gastrointestinal tract, central nervous system and adrenal gland. There are occasional reports of liver and kidney damage. The respiratory tract is also affected following inhalation exposure, based on histopathological changes in the nasal turbinates of rats in the Quast et al.,(1980) two year study. A LO(A)EL of 20 ppm was established in the study, treatment-related nasal changes being evident at this exposure level, and this was used as a starting point in the risk assessment in relation to inhalation exposure. A No Adverse Effect Level (NAEL) of 4 ppm for the inhalation route was been derived from the LO(A)EL of 20 ppm, by application of a safety factor of 5. In relation to oral administration of acrylonitrile, the N(A)OEL is estimated to be 3 ppm (0.25 mg/kg/day) in drinking water, based on the information from the Biodynamics study (1980) study in rats which showed systemic toxicity, probably attributable to metabolic release of cyanide.
Ecological Toxicity [6]	
Aquatic Toxicity	The data set for acrylonitrile includes a wide range of information on short and long term toxicity in fish, Daphnia and other aquatic invertebrates. Acrylonitrile is moderately toxic to fish, with 96-hour LC50 for fresh water fish generally lying in the range of 10 - 20 mg/l (nominal). A recent short term study in the saltwater species Cyprinodon variegatus, carried out in full compliance with current protocols, reported a 96-hour LC50 of 8.6 mg/l. The lowest 48 hour EC50 for Daphnia was 7.6 mg/l. The fish early life stage toxicity test in Pimephales promelas, using flow-through conditions, provided a LOEC/NOEC of 0.34 mg/l, while a 30 day flow through test in mature fish of the same species provided a long-term LC50 of 2.6 mg/l. If the value of 0.34 mg/l is taken as a LOEC, a NOEC may be derived by application of safety factor of 2, giving a NOEC of 0.17 mg/l.
Determination of PNEC aquatic	Applying an assessment factor of 10 to the NOEC (0.17 mg/l) derived from the fish early life stage toxicity test gives a PNEC of 17 µg/l.
Current Regulatory Controls [1,7]	
Australian Hazard Classification	The chemical is classified as hazardous, with the following risk phrases for human health in the Hazardous Chemical Information System (HCIS) (Safe Work Australia): H225 (Highly flammable liquid and vapour) H350 (May cause cancer) H331 (Toxic if inhaled) H311 (Toxic in contact with skin) H301 (Toxic if swallowed) H335 (May cause respiratory irritation) H315 (Causes skin irritation) H318 (Causes serious eye damage) H317 (May cause an allergic skin reaction) H411 (Toxic to aquatic life with long-lasting effects)
Australian Occupational Exposure Standards	The current national occupational exposure standard for acrylonitrile in Australia is 2 ppm (4.3 mg/m3) expressed as an 8 h TWA airborne concentration, Carcinogen Category 2, with a 'skin' notation (NOHSC, 1995a).

International Occupational Exposure Standards	The following exposure standards are identified: 8h TWA: Austria 2 ppm (4.5 mg/m^3) Belgium 2 ppm (4.3 mg/m^3) Denmark 2 ppm (4.0 mg/m^3) Finland 2 ppm (4.3 mg/m^3) France 2 ppm (4.0 mg/m^3) Germany 3 ppm (7.0 mg/m^3) Hungary 0.23 ppm (0.5 mg/m^3) India 2 ppm (4.3 mg/m^3) Ireland 2 ppm (4.5 mg/m^3) Japan 2 ppm (4.3 mg/m^3) Netherlands 4 ppm (9 mg/m^3) Philippines 20 ppm (43 mg/m^3) Poland 5 ppm (10 mg/m^3) Russia 0.23 ppm (0.5 mg/m^3) Spain 2 ppm (4.5 mg/m^3) Sweden 2 ppm (4.5 mg/m^3) Turkey 20 ppm (43 mg/m^3) United Kingdom 2 ppm (4 mg/m^3) USA (NIOSH) 1 ppm (2.2 mg/m^3) USA (OSHA) 2 ppm (4.3 mg/m^3) Short-term exposure limits (STEL): Finland 4 ppm (9 mg/m^3) France 15 ppm (32.5 mg/m^3) Netherlands 10 ppm (22 mg/m^3) Sweden 6 ppm (14 mg/m^3) USA (NIOSH) 10 ppm (22 mg/m^3) USA (OSHA) 10 ppm (22 mg/m^3)
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	A freshwater low reliability trigger value of 160 µg/L was calculated for acetonitrile using an AF of 1000. In the absence of marine data, this was adopted as a marine low reliability trigger value.
PBT Assessment	
P/vP Criteria fulfilled?	No. Acrylonitrile is readily to fairly degradable in water, soil and in the troposphere
B/vB criteria fulfilled?	No. The low log Pow (0.00-0.30) measures for acrylonitrile suggest bioaccumulation will not occur.
T criteria fulfilled?	Yes. Chronic toxicity data <1 mg/L in fish, thus acrylonitrile meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	January 2019

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Toxicity Summary - Alcohols, C10-16, ethoxylated propoxylated

Chemical and Physical Properties[1]	
CAS number	69227-22-1
Molecular formula	No data available.
Molecular weight	No data available.
Solubility in water	Soluble in water
Melting point	-3 °C
Boiling point	No data available.
Vapour pressure	No data available.
Henrys law constant	No data available.
Explosive potential	No data available.
Flammability potential	No data available.
Colour/Form	Yellow liquid, mild odour
Overview	Principle Route of Exposure: Eye or skin contact, inhalation Causes severe eye irritation which may damage tissue. Causes skin irritation. Harmful if swallowed.
Environmental Fate[1]	
Soil/Water/Air	This substance is expected to be readily biodegradable (84% @ 28d) (similar substances). Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8, it is not expected to be bioaccumulative. Mobility in soil: KOC = >4
Human Health Toxicity Summary [1]	
Chronic Repeated Dose Toxicity	No data available to indicate product or components present at greater than 0.1% are chronic health hazards.
Carcinogenicity	Did not show carcinogenic effects in animal experiments (similar substances)
Mutagenicity/ Genotoxicity	In vitro tests did not show mutagenic effects. In vivo tests did not show mutagenic effects. (similar substances)
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Animal testing did not show any effects on fertility.
Acute Toxicity	LD50 Oral: 600 mg/kg (Rat) (similar substance) LD50 Dermal: > 5200 mg/kg (Rabbit) (similar substance) LD50 Inhalation: > 0.22 mg/L (saturated concentration) (Rat) (similar substance)
Irritation	May cause mild respiratory irritation. Causes severe eye irritation which may damage tissue. Causes skin irritation.
Sensitisation	Did not cause sensitization on laboratory animals (guinea pig) (similar substances)
Health Effects Summary	Causes severe eye irritation which may damage tissue. Causes skin irritation. Harmful if swallowed.
Key Study/Critical Effect for Screening Criteria	
Ecological Toxicity [1]	

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Aquatic Toxicity	Toxicity to fish: LC50 (96h) 0.59 mg/L (Pleuronectes platessa) (similar substance) LC50 (96h) 1.6 mg/L (Pimephales promelas) (similar substace) LC50 (96h) 3 mg/L (Brachydanio rerio) (similar substance) Toxicity to invertebrates: EC50 (48h) 0.14 mg/L (Daphnia magna) (similar substance) EC50 (48h) 2 mg/L (Daphnia magna) (similar substance) Toxicity to algae: EC50 (72h) 0.75 mg/L (Pseudokirchnerella subcapitata) (similar substance) ErC50 (48h) 0.7 mg/L (Skeletonema costatum) EC10 9.79 mg/L (Selenastrum capricornutum) (similar substance) ErC50 1.1 mg/L (Scenedesmus subspicatus) (similar substance) Toxicity to microorganisms: ErC50 (16.9h) > 10 g/L (Pseudomonas putida) (similar substance)
Determination of PNEC aquatic	On the basis that the data consists of short term results from three trophic levels, an assessment factor of 1000 has been applied to the lowest reported effect concentration of 0.14 mg/L for Daphnia. The PNEC aquatic is 0.14 µg/L.
Current Regulatory Controls [1]	
Australian Hazard Classification	H302 - Harmful if swallowed H315 - Causes skin irritation H318 - Causes serious eye damage
Australian Occupational Exposure Standards	No data available.
International Occupational Exposure Standards	No data available.
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	No data available.
PBT Assessment	
P/vP Criteria fulfilled?	No. Expected to be readily biodegradable based on similar substances.
B/vB criteria fulfilled?	No. Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8, it is not expected to be bioaccumulative.
T criteria fulfilled?	No. The acute aquatic toxicity of this chemical is >0.01 mg/L. Thus, it is not expected to meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	January 2019

References

1. Redacted

Toxicity Summary - Alcohols, C6-12, ethoxylated propoxylated

Chemical and Physical Properties[1]	
CAS number	68937-66-6
Molecular formula	No data available.
Molecular weight	No data available.
Solubility in water	Soluble in water
Melting point	-3 °C
Boiling point	No data available.
Vapour pressure	No data available.
Henrys law constant	No data available.
Explosive potential	No data available.
Flammability potential	No data available.
Colour/Form	Yellow liquid, mild odour
Overview	Principle Route of Exposure: Eye or skin contact, inhalation Causes severe eye irritation which may damage tissue. Causes skin irritation. Harmful if swallowed.
Environmental Fate[1]	
Soil/Water/Air	This substance is expected to be readily biodegradable (60% @ 28d) (similar substances). Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8, it is not expected to be bioaccumulative. Mobility in soil: KOC = >4
Human Health Toxicity Summary [1]	
Chronic Repeated Dose Toxicity	No data available to indicate product or components present at greater than 0.1% are chronic health hazards.
Carcinogenicity	Did not show carcinogenic effects in animal experiments (similar substances)
Mutagenicity/ Genotoxicity	In vitro tests did not show mutagenic effects. In vivo tests did not show mutagenic effects. (similar substances)
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Animal testing did not show any effects on fertility.
Acute Toxicity	LD50 Oral: 600 mg/kg (Rat) (similar substance) LD50 Dermal: > 5200 mg/kg (Rabbit) (similar substance) LD50 Inhalation: > 0.22 mg/L (saturated concentration) (Rat) (similar substance)
Irritation	May cause mild respiratory irritation. Causes severe eye irritation which may damage tissue. Causes skin irritation.
Sensitisation	Did not cause sensitization on laboratory animals (guinea pig) (similar substances)
Health Effects Summary	Causes severe eye irritation which may damage tissue. Causes skin irritation. Harmful if swallowed.
Key Study/Critical Effect for Screening Criteria	
Ecological Toxicity [1]	

Aquatic Toxicity	Toxicity to fish: LC50 (96h) 0.59 mg/L (Pleuronectes platessa) (similar substance) LC50 (96) 1.4 mg/L (Pimephales promelas) (similar substance) NOEC 4.4 mg/L (Pimephales promelas, juvenile) Toxicity to invertebrates: EC50 (48h) 0.14 mg/L (Daphnia magna) (similar substance) EC50 (48h) 0.39 mg/L (Cerodaphnia dubia) (similar substance) Toxicity to algae: EC50 (72h) 0.75 mg/L (Pseudokirchnerella subcapitata) (similar substance) EC50 (96h) 0.7 mg/L (Pseudokirchneriella subapitata) (similar substance) CD10 8 mg/L (Pseudokirchneriella subapitata) EC10 2 mg/L (Brachionus calyciflorus) Toxicity to microorganisms: EC50 (48h) 0.39 mg/L (Cerodaphnia dubia) (similar substance)
Determination of PNEC aquatic	On the basis that the data consists of short term results from three trophic levels, an assessment factor of 1000 has been applied to the lowest reported effect concentration of 0.14 mg/L for Daphnia. The PNEC aquatic is 0.14 µg/L.
Current Regulatory Controls [1]	
Australian Hazard Classification	H302 - Harmful if swallowed H315 - Causes skin irritation H318 - Causes serious eye damage
Australian Occupational Exposure Standards	No data available.
International Occupational Exposure Standards	No data available.
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	No data available.
PBT Assessment	
P/vP Criteria fulfilled?	No. Expected to be readily biodegradable based on similar substances.
B/vB criteria fulfilled?	No. Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8, it is not expected to be bioaccumulative.
T criteria fulfilled?	Not applicable. Chronic toxicity data >1 mg/L in invertebrates, thus sodium hydroxide does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	January 2019

References

1. Redacted

Toxicity Summary - Ethoxylated of aliphatic alcohols (>C6)

Chemical and Physical Properties [1,2,3]	
CAS number	112-59-4, 3055-93-4, 3055-94-5, 3055-95-6, 3055-97-8, 4536-30-5, 5274-68-0, 25190-05-0, 9002-92-0, 9004-95-9, 9004-98-2, 9005-00-9, 9043-30-5, 31726-34-8, 24938-91-8, 26183-52-8, 26468-86-0, 27252-75-1, 27306-79-2, 31943-12-1, 32128-65-7, 37281-47-3, 37702-39-9, 39587-22-9, 52292-17-8, 61723-78-2, 68439-45-2, 68439-46-3, 68439-49-6, 68439-50-9, 68439-54-3, 61791-13-7, 61791-28-4, 61827-42-7, 64425-86-1, 66455-14-9, 66455-15-0, 69227-20-9, 67254-71-1, 68002-97-1, 68131-39-5, 68131-40-8, 68155-01-1, 68213-23-0, 68526-94-3, 68551-12-2, 97953-22-5, 68920-66-1, 68991-48-0, 78330-21-9
Molecular formula	Unspecified
Molecular weight	Unspecified
Solubility in water	0.1876 - 13.18 mg/L at 25 °C (C12-14 ethoxylated, 1-2.5 EO) (CAS 68131-39-5) 1.69 - 246.7 mg/L at 25 °C (C9-11, ethoxylated (EO < 2.5) (CAS 68439-46-3)
Melting point	7.2 °C at 101.3 kPa (CAS 68131-39-5) -20 °C at 101.3 kPa (CAS 68439-46-3)
Boiling point	271.11 - 516.11 °C (CAS 68131-39-5) 260 °C (CAS 68439-46-3)
Vapour pressure	< 1 Pa at 25 °C (CAS 68131-39-5) 0.004 - 117 Pa at 20 °C (CAS 68439-46-3)
Henrys law constant	No data available.
Explosive potential	Non explosives
Flammability potential	Non flammable
Colour/Form	Organic liquid, colourless to light yellow
Overview	The chemicals in this group are structurally related alcohol ethoxylates (AEs), ethoxylated ethers of aliphatic alcohols, where the alky chain length is six carbons or higher. Ethoxylates of shorter chain alcohols (C<6) do not show the same degree of surfactancy compared to the chemicals in this group. Commercially available AEs generally consist of a mixture of various AE homologues of varying carbon chain lengths and degree of ethoxylation. The chemicals contain a hydrophobic alkyl chain attached via an ether linkage to a hydrophilic ethylene oxide (EO) chain that gives them their characteristic surfactant properties. The hydrophobic alkyl and the hydrophilic EO chains can vary in length depending on method of production and source of the precursor chemicals (HERA, 2009). Although most of chemicals of this group are polymers according to the definition in the Industrial Chemicals (Notification and Assessment) Act (1989), the individually named members do not necessarily meet the polymer of low concern (PLC) criteria as the number-average molecular weight (NAMW) >1000 Da. Lower molecular weight forms of these chemicals (MW <500) are expected to be used in commercial, domestic and cosmetic products. The chemicals are used extensively as non-ionic surfactants in a wide range of cosmetic and domestic products. The chemicals in this group are expected to have similar physicochemical and toxicological properties, which depend on the alkyl chain length and the number of EO units.
Environmental Fate [2,3]	
Soil/Water/Air	Alcohol ethoxylates are readily biodegradable under aerobic conditions and also anaerobically biodegradable (HERA, 2009). The main mechanism of primary biodegradation for the linear and essentially linear AE is the central cleavage of the molecule, leading to the formation of long chain alcohol and polyethylene glycol (HERA, 2009; Marcomini et al., 2000a; Marcomini et al., 2000b). Long chain alcohols themselves are readily biodegradable up to C18 (SIDS, 2006). Abiotic degradation in water, soil, sediment and air is not expected to occur because of the chemical structures of AE homologues. Neither hydrolysis under normal

	environmental conditions (pH range from 4 to 9) nor photolysis in the atmosphere, in water, or when absorbed to soil and sediment surfaces, is to be considered (HERA, 2009). Experimentally determined BCF-values given for pure homologues and summarized in the publication of Tolls et al. (2000) are used as read-across data for the endpoint bioaccumulation in water. It can be stated that bioaccumulation of alcohol ethoxylates is regarded to be negligible as the surfactants will be rapidly metabolised. For more detail see endpoint summary for bioaccumulation. Concerning transport and distribution of the alcohol ethoxylate mixtures a high adsorption of the substances is determined by using QSAR-models. Adsorption onto surfaces is an intrinsic property of alcohol ethoxylates and thus a high Koc-value is expected.
Human Health Toxicity Summary [1]	
Chronic Repeated Dose Toxicity	The chemicals in this group are not expected to cause serious damage to health fr In several 90-day oral feeding studies in rats (similar to OECD TG 407), the NOAEL was established between 50 and 700 mg/kg bw/day (calculated from dietary levels) for group members (CAS Nos. 68439-50-9 and 68131-39-5, ranging from C12–15 with EO7). Effects observed at higher concentrations included reduction in mean body weights, and increases in relative liver and kidney weights. These changes were considered to be adaptive and related to the poor palatability of the test chemicals. No treatment related histopathological changes were reported (SCCS, 2007; HERA 2009; CIR, 2012). Similar effects were seen in longer-term studies. Alcohols, C12-13, ethoxylated (CAS No. 66455-14-9; EO6.5) and alcohols, C14-15, ethoxylated (CAS No. 68951-67-7, EO7, not listed on AICS) were given to rats in one- and two-year chronic feeding studies at levels between 0.1 and 1 %. The NOAEL was established between 50 and 192 mg/kg bw/day (calculated from dietary level). Effects observed at higher levels included reduction in mean body weights, and increase in relative liver and kidney weights. These changes were considered to be adaptive and may be due to poor palatability of the test chemicals. No treatment related lesions were observed (SCCS, 2007; HERA, 2009; CIR, 2012).om repeated oral and dermal exposure. In a 90-day study (OECD TG 411), Fischer rats were exposed to the chemical (C9–11 with 6 EO units, CAS No. 68439-46-3) at 1, 10 or 25 % concentration, 3 days/week. The application site was shaved but not covered. There were no significant treatment related effects at any concentration. Dry and flaky skin was observed in the 10 and 25 % dose groups. Increased relative kidney weights were observed in the 25 % dose groups. However, no histological lesions were observed. The NOAEL was established at 10 %, equivalent to 80 mg/kg bw/day (HERA, 2009).
Carcinogenicity	Based on the data available, the chemicals in this group are not considered to be carcinogenic. Two chemicals, alcohols, C12-13, ethoxylated (CAS No. 66455-14-9; EO6.5) and alcohols, C14-15, ethoxylated (CAS No. 68951-67-7, EO7, not listed on AICS) were administered at up to 1 % in the diet to rats for one and two years, respectively. No treatment related histopathological effects or increased tumour incidences were observed in either study (HERA, 2009; CIR, 2012). The chemicals are synthesised through processes which may result in 1,4-dioxane as an impurity. This impurity is classified as a Carcinogen—Category 3 (R40—Limited evidence of a carcinogenic effect). However, it is reported that cosmetic industry uses additional purification steps to remove the 1,4-dioxane residual in PEG before blending into cosmetic formulations (CIR, 2012).

Mutagenicity/ Genotoxicity	Based on the data available, the chemicals in this group are not considered to be genotoxic. The group members (CAS Nos. 68439-50-9, 68131-39-5 and 64425-86-1) and several analogue chemicals (ranging from C12–18 and EO3–21) produced negative results in several in vitro and in vivo tests for gene mutation and clastogenicity. Negative results were reported in bacterial reverse mutation tests for mutagenicity against Salmonella typhimurium (strains TA98, TA100, TA102, TA104, TA1535, TA1537 and TA1538) and Escherichia coli (strains WP2 and WP2uvrA pKM101), with or without metabolic activation. Negative results were also reported in chromosomal aberration tests in Chinese hamster V79, Chinese hamster ovary, mouse lymphoma and rat liver cell lines (SCCP, 2007; HERA, 2009; CIR, 2012). These chemicals did not induce chromosomal damage in Chinese hamster or Tunstall Wistar rat bone marrow cells after acute oral doses ranged between 250 and 3400 mg/kg bw (HERA, 2009).
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Based on the data available, the chemicals of this group are not considered to cause reproductive or developmental toxicity. In a two-generation reproductive and developmental toxicity study, the chemical (C14-15EO7) was administered in the diet of Charles River CD rats (n=25/sex/group, at doses of 0, 25, 50 or 250 mg/kg bw/day). The NOAEL for reproductive toxicity was established as 250 mg/kg bw/day (or 0.5 % of the diet). No treatment related effects were reported with respect to fertility, gestation, or viability indices or other histopathological parameters. The NOAEL for developmental toxicity was established as 50 mg/kg bw/day based on reduced pup body weights in the second generation at 250 mg/kg bw/day (HERA 2009; CIR, 2012). In a two-generation reproductive and developmental toxicity study, the chemical (C9-11EO6) was applied dermally to Fischer 344 rats (n=30/sex/group, at doses of 0,10, 100 or 250 mg/kg bw/day, 3 times a week except mating periods). No treatment related effects were reported with respect to mating, fertility, gestation, or viability indices and mean gestational length in both generations. No effects on testicular weights or sperm counts were observed in the male rats. The NOAEL for reproductive toxicity was established as 250 mg/kg bw/day. The NOAEL for developmental toxicity was >250 mg/kg bw/day, based on no effects seen in growth and development in the offspring up to the highest dose tested (HERA 2009; CIR, 2012). In a two generation study, the chemical (C12EO6) was administered in the diet of female rabbits at doses of 0, 50, 100 or 200 mg/kg bw/day from gestation days 2 to 16. Ataxia and a slight decrease in body weight were observed at 100 and 200 mg/kg bw/day, indicating maternal toxicity. Nine rabbits in the control group and 31 in the treatment groups died during the study (details not available). There were no treatment related effects on implantations, number of live foetuses and spontaneous abortions. The NOAEL for maternal toxicity was reported as >50 mg/kg bw/day (HERA, 2009). Although certain short chain monoethylene glycol ethers such as 2-ethoxyethanol (CAS No. 110-80-5) are known reproductive toxicants, the ability of the glycol ethers to cause testicular toxicity decreases with increasing chain length, with effects not observed with chain lengths greater than C2 (OECD, 2004).

Acute Toxicity	Based on the available animal (rats, mice and guinea pigs) studies, the chemicals in this group are expected to have low to moderate acute oral toxicity (REACHa-h; OECD, 2005; HERA, 2009; CIR, 2012). The LD50 in rats ranged from 600 mg/kg bw to greater than 20 g/kg bw. Observed sublethal effects for the chemical with the highest toxicity (C15–16 and EO10) included diarrhoea, pilo-erection, ataxia, abnormal posture, difficult laboured breathing, salivation, lacrimation, bloody noses and lethargy. Data from HERA assessment studies show that the chemicals with ethoxylate chains (EO) between 5 and 15 units were more toxic by the oral route than those with less than 4 or greater than 21 units. No relationship between the alcohol chain length and toxicity was observed (HERA, 2009). The chemicals of this group exhibit low acute dermal and inhalation toxicity. The chemicals (C9 to C15 with 3–13 EO units) were of low acute toxicity in rats and rabbits following dermal exposure. The LD50 ranged from 2000 to 5000 mg/kg bw. Sub-clinical effects included wet appearance of the fur, little or no urine, laboured breathing, lethargy, diarrhoea, ataxia, muscle tremours and decreased activity. There was no relationship between the alcohol chain length or number of ethoxylate groups and toxicity. Very high dermal doses of the chemicals (>16000 mg/kg bw) applied dermally for 24 hours in rabbits led to severe skin irritation, ataxia and lung lesions (HERA, 2009; CIR, 2012). In a guideline study (Test Guideline (TG) 403), a single static inhalation exposure to substantially saturated vapour (equivalent to 131.58 ppm - calculated) of C6EO1-2.5 (CAS No. 112-59-4), resulted in no mortality or other signs of inhalation toxicity in Sprague- Dawley (SD) rats (REACHa).
Irritation	The chemicals in this group are reported to be moderate to severe skin irritants in animal studies. The degree of irritation was reported to be dependent on the type of patch (occluded vs semi-occluded), exposure time (ranging from 4 hours up to 4 weeks) and the concentration used. Undiluted chemicals were moderately to severely irritating, 1–10 % was mildly irritating and 0.1 % and 0.5 % were non-irritating. There was also a general trend between the severity of irritation and the degree of ethoxylation. Chemicals with three and less ethoxylate units appeared to be more irritating than chemicals with higher degree of ethoxylation. No trend in irritation potential with respect to the length of carbon chain could be established. Available data indicates that undiluted AEs can produce varying degrees of eye irritation ranging from moderate to severe irritancy. The severity of irritation was found to be concentration dependent, with up to 1 % minimally irritating and concentrations in the range of 1 to 10 % slightly to moderately irritating. In most cases, following exposure, the eyes of the treated animals recovered a few days after exposure. Further tests showed that rinsing the eye 30 seconds after application with tap water may reduce the severity of the effects. No clear relationship could be established between the number of EO units or carbon chain length and eye irritation potency.
Sensitisation	Based on available data, the chemicals in this group are not skin sensitisers.
Health Effects Summary	The chemicals in this group are synthesised from linear alcohols (primary or secondary) or branched alcohols. The commercial AEs may also contain un-reacted alcohol as reaction by-products at about 5 % but with variations between different commercial products (HERA, 2009). Available data on linear and branched chain alcohols show that they have low acute and systemic toxicity and exhibit similar patterns of absorption, metabolism, and excretion to alcohol ethoxylates. They are also shown to have no skin sensitisation potential. A potential for skin and eye irritation exists with alcohols >11 carbon chain length (OECD, 2006; OECD, 2006a).
Key Study/Critical Effect for Screening Criteria	The critical human health effects for risk characterisation are acute oral toxicity and skin and eye irritation. The irritant effects are similar to those produced by other surfactants, and the severity of irritation appears to increase directly with concentration and generally decrease with an increasing number of ethoxylate units.

Ecological Toxicity [2,3]	
Aquatic Toxicity	The 96 h LC50 value for Alcohols, C9-11, ethoxylated with Oncorhynchus mykiss was 5 - 7 mg/L based on nominal concentrations. In the long term toxicity test to Lepomis macrochirus, the NOEC (30 days) was 0.11 – 0.33 mg/L. In the short–term toxicity test to Daphnia magna, the EC50 (48 h) was 2.5 mg/L. In the long term toxicity test to Daphnia magna, the NOEC (21 days) was 0.77 – 1.75 mg/L. In the short–term toxicity test to Pseudokirchneriella subcapitata (green algae), the EC50 (96 h) was 1.4 mg/L. The EC50 (3 h) for microorganisms was 140 mg/L. In a study conducted with two different fish species (bluegill sunfish and fathead minnow) the effects of C14 -15 alcohol ethoxylates (7EO) were determined (Dorn et al., 1995, Shell). In two experiments fish were exposed for 10 d in a laboratory assay and for 30 d in an outdoor stream mesocosm. Effect parameters determined were survival and growth of juvenile bluegills and survival and reproduction of fathead minnows. In the laboratory experiment the NOEC for survival and swimming performance of bluegills and for survival of fathead minnows was 0.16 mg/L. In the stream mesocosm the NOEC for bluegill survival and growth was >0.33 mg/L and for fathead minnow survival 0.28 mg/L. There was an indication of decreased egg laying by fathead minnow in the streams at concentrations of 0.33 mg/L or greater. On the basis of the reported results a worst-case NOEC of 0.16 mg/L is assumed. One publication is available for an alcohol ethoxylate mixture with a chain length of C12 - C13 and approximately 6.5 ethoxy groups (Gillespie et al. 1999). The 21 days flow-through chronic experiment on daphnids is conducted according to the guidelines USEPA-TSCA (U.S. EPA, 1992) and ASTM (1988) and is well documented in the paper. Nevertheless the degree of ethoxylation of the tested mixture described in the paper (6.5 EO) is higher than the degree of ethoxylation described for CAS 68131-39-5 (2.5 EO). The NOEC of 0.77 mg/L for reproduction can be used for read-across.
Determination of PNEC aquatic	A PNECaquatic of 11 µg/L was calculated using the lowest chronic endpoint of NOEC of 0.11 mg/L for Daphnia magna. An assessment factor of 10 was used.
Current Regulatory Controls [1]	
Australian Hazard Classification	No data available.
Australian Occupational Exposure Standards	No specific exposure standards are available.
International Occupational Exposure Standards	No specific exposure standards are available.
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	Trigger values for freshwater (95% species) (ANZECC 2000): Alcohol ethoxyolated sulfate (AES) = 650 µgL^{-1} Alcohol ethoxylated surfactants (AE) = 140 µgL^{-1}
PBT Assessment	
P/vP Criteria fulfilled?	No. These chemicals were found to be readily biodegradable. Thus, it does not meet the screening criteria for persistence.
B/vB criteria fulfilled?	No. Bioaccumulation in organisms is expected to be negligible, due to biotransformation and excretion of alcohol ethoxylates.
T criteria fulfilled?	No. The NOECs from the chronic aquatic toxicity data are >0.01 mg/L, hence does not meet the screening criteria for toxicity.

Overall conclusion	Not PBT
Revised	January 2019

References

1. National Industrial Chemicals Notification and Assessment Scheme (NICNAS). IMAP, Human Health Tier II Assessment for Ethoxylates of aliphatic alcohols (>C6):, Retrieved 2019: https://www.nicnas.gov.au
2. ECHA REACH, Alcohols, C9-11 ethoxylated, < 2.5 EO, Retrieved 2017: https://echa.europa.eu/information-on-chemicals/registered-substances
3. ECHA REACH, Alcohols, C12-15 ethoxylated, Retrieved 2017: https://echa.europa.eu/information-on-chemicals/registered-substances

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Toxicity Summary - Alcohols, C6-12, ethoxylated propoxylated

Chemical and Physical Properties[1]	
CAS number	68937-66-6
Molecular formula	No data available.
Molecular weight	No data available.
Solubility in water	Soluble in water
Melting point	-3 °C
Boiling point	No data available.
Vapour pressure	No data available.
Henrys law constant	No data available.
Explosive potential	No data available.
Flammability potential	No data available.
Colour/Form	Yellow liquid, mild odour
Overview	Principle Route of Exposure: Eye or skin contact, inhalation Causes severe eye irritation which may damage tissue. Causes skin irritation. Harmful if swallowed.
Environmental Fate[1]	
Soil/Water/Air	This substance is expected to be readily biodegradable (60% @ 28d) (similar substances). Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8, it is not expected to be bioaccumulative. Mobility in soil: KOC = >4
Human Health Toxicity Summary [1]	
Chronic Repeated Dose Toxicity	No data available to indicate product or components present at greater than 0.1% are chronic health hazards.
Carcinogenicity	Did not show carcinogenic effects in animal experiments (similar substances)
Mutagenicity/ Genotoxicity	In vitro tests did not show mutagenic effects. In vivo tests did not show mutagenic effects. (similar substances)
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Animal testing did not show any effects on fertility.
Acute Toxicity	LD50 Oral: 600 mg/kg (Rat) (similar substance) LD50 Dermal: > 5200 mg/kg (Rabbit) (similar substance) LD50 Inhalation: > 0.22 mg/L (saturated concentration) (Rat) (similar substance)
Irritation	May cause mild respiratory irritation. Causes severe eye irritation which may damage tissue. Causes skin irritation.
Sensitisation	Did not cause sensitization on laboratory animals (guinea pig) (similar substances)
Health Effects Summary	Causes severe eye irritation which may damage tissue. Causes skin irritation. Harmful if swallowed.
Key Study/Critical Effect for Screening Criteria	
Ecological Toxicity [1]	

Aquatic Toxicity	Toxicity to fish: LC50 (96h) 0.59 mg/L (Pleuronectes platessa) (similar substance) LC50 (96) 1.4 mg/L (Pimephales promelas) (similar substance) NOEC 4.4 mg/L (Pimephales promelas, juvenile) Toxicity to invertebrates: EC50 (48h) 0.14 mg/L (Daphnia magna) (similar substance) EC50 (48h) 0.39 mg/L (Cerodaphnia dubia) (similar substance) Toxicity to algae: EC50 (72h) 0.75 mg/L (Pseudokirchnerella subcapitata) (similar substance) EC50 (96h) 0.7 mg/L (Pseudokirchneriella subapitata) (similar substance) CD10 8 mg/L (Pseudokirchneriella subapitata) EC10 2 mg/L (Brachionus calyciflorus) Toxicity to microorganisms: EC50 (48h) 0.39 mg/L (Cerodaphnia dubia) (similar substance)
Determination of PNEC aquatic	On the basis that the data consists of short term results from three trophic levels, an assessment factor of 1000 has been applied to the lowest reported effect concentration of 0.14 mg/L for Daphnia. The PNEC aquatic is 0.14 µg/L.
Current Regulatory Controls [1]	
Australian Hazard Classification	H302 - Harmful if swallowed H315 - Causes skin irritation H318 - Causes serious eye damage
Australian Occupational Exposure Standards	No data available.
International Occupational Exposure Standards	No data available.
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	No data available.
PBT Assessment	
P/vP Criteria fulfilled?	No. Expected to be readily biodegradable based on similar substances.
B/vB criteria fulfilled?	No. Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8, it is not expected to be bioaccumulative.
T criteria fulfilled?	Not applicable. Chronic toxicity data >1 mg/L in invertebrates, thus sodium hydroxide does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	January 2019

References

1. Redacted

Toxicity Summary - Amides, tall-oil fatty, N,N-bis(hydroxyethyl)

Chemical and Physical Properties [1,2]	
CAS number	68155-20-4
Molecular formula	UVCB
Molecular weight	370 (typical C18 monounsaturated)
Solubility in water	Dispersible
Melting point	<25 °C (liquid)
Boiling point	>300 °C (estimated)
Vapour pressure	$<1.0\times10^{-10}$ (estimated)
Henrys law constant	$<1.0\times10^{-10}$ (estimated)
Explosive potential	No data available.
Flammability potential	No data available.
Colour/Form	Liquid
Overview	Non-confidential information in the IUR indicated that the industrial processing and uses of the chemical include other basic organic chemical manufacturing as surface active agents and intermediates; pesticide and other agricultural chemical manufacturing as surface active agents; soap and cleaning compound manufacturing as surface active agents; support activities for mining as surface active agents; and petrochemical manufacturing as surface active agents. Non-confidential commercial and consumer uses of this chemical include lubricants, greases and fuel additives.
Environmental Fate [1,2]	
Soil/Water/Air	The members of the fatty nitrogen derived amides category are long-chain alkyl substituted amides used in commercial product mixtures. The category consists of three subcategories: Subcategory I, fatty acid amides; Subcategory II, fatty alkanolamides; and Subcategory III, fatty acid reaction products with amines. For the purpose of this discussion only, a one-member Subcategory, Subcategory IV, which contains CASRN, 61790-63-4, has been considered as part of Subcategory II. The components of Subcategory I are solids possessing low vapor pressure and low water solubility. The substances in Subcategory II contain solids and liquids with negligible to low vapor pressure and tend to be dispersible in water. The substances in Subcategory III also contain solids and liquids possessing negligible to low vapor pressure that tend to be dispersible in water. The fatty acid amides (Subcategory I) and the fatty acid reaction products with amines (Subcategory III) are expected to possess low mobility in soil. The fatty alkanolamides (Subcategory II) are expected to possess moderate to high mobility in soil. Volatilization is low to moderate for the fatty acid amides and low for the fatty alkanolamides and the fatty acid reaction products with amines. The rate of hydrolysis is considered negligible for all category members. The rate of atmospheric photooxidation is considered moderate to rapid for members of each subcategory; however, this is not expected to be an important environmental fate process since these substances are not expected to exist in the vapor phase in the atmosphere. The overall weight of evidence suggests that the members of the fatty nitrogen derived amides category should possess low persistence (P1) and low bioaccumulation potential (B1) with the exception of two members of subcategory III. Fatty acids, tall-oil, reaction products with tetraethylenepentamine and fatty acids, tall-oil, reaction products with polyethylenepolyamines are expected to possess low persistence (P1), but moderate bioaccumulation potential (B2).
Human Health Toxicity Summary [1, 2, 3]	

Chronic Repeated Dose Toxicity	Based on read-across from CAS 120-40-1, an oral repeated dose toxicity study reported NOEL = 0.1% which corresponds to 50 mg/kg/day. No rats died as a result of being treated with the test substance. Two males treated with diet containing 1.0% test substance were euthanized on Days 23 and 58 because of weight loss and respiratory distress. Extensive lung abscess formation was seen at autopsy and bronchopneumonia was confirmed histologically. Growth was inhibited significantly in males and females at and above the 0.5% dietary concentration. Food intake was reduced at all dietary levels except 0.1%, and was attributed to an effect of the test substance on palatability of the diet. The rats in the palatability study showed exclusive preference to the control feed than the treated feed, virtually no test diet was consumed at any dietary levels incorporated. Hematological examination revealed statistically significant reductions in hemoglobin levels and red cell counts in females at the 2.0 and 1.0% dietary concentration and in hemoglobin levels in males at the 2.0% level. Examination of the femoral bone marrow smears showed not deviation from normality. Serum chemistry revealed significantly high serum levels of glutamic-oxaloacetic transaminase in females at the 0.5% level and higher, but only at the 0.5% level in males. Urinalysis was comparable across all groups for males and females. Gross examinations were unremarkable. Statistically significant increases in relative kidney weight in all test groups except at 0.1% in females and at 2.0 and 1.0% in males; and increases in relative liver weight in females at 2.0 and 1.0% were seen. These were attributed to the decreases in body weight. Types and incidence of pathological lesions seen histologically were comparable in control and test groups. Gonads were examined histologically, thus this study meets SIDS requirements for a reproductive screen.
Carcinogenicity	Not regarded as carcinogenic.
Mutagenicity/ Genotoxicity	Based on read-across from CAS 120-40-1, the test substance did not induce reverse mutations in the tested strains of Salmonella typhimurium in the presence or absence of S-9 activation.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Based on read-across from CAS 68603-42-9, the results from a developmental toxicity study showed that repeated oral administration of COMPERLAN KD to pregnant rats on day 6 through 15 of gestation, caused no symptoms of cumulative toxicity up to a dose level of 1000 mg/kg/day. With the exception of salivation and propulsion of the head during the dose administration, there were no treatment-related effects. Also, COMPERLAN KD does not reveal any embryotoxic or teratogenic potential at dose levels up to 1000 mg/kg/day (author of the report).
Acute Toxicity	Acute oral and dermal toxicities of CASRN 68140-00-1 in rat and rabbit, respectively, are low. Based on read-across from CAS 68140-00-1, an oral acute toxicity test on rats reported LD50 > 5 g/kg. All animals survived the 8-day observation period and no adverse effects were observed. With respect to the determined LD50 value, it is assumed that the LD50 value for female rats also exceeds the limit dose of > 2000 mg/kg body weight. In a dermal acute toxicity test on rabbits, LD50 > 2 g/kg was reported. All animals survived. All animals appeared normal through day 14. Two females that had abraded skin lost weight (0.01 and 0.25 kg) over the 14-day post-exposure period. All remaining rabbits gained weight through day 14. Swiss-Webster mice (4 males/dose) were administered “Alkanolamide #1”, identified in the robust summary as CASRN 68144-20-4, via whole body exposure for 3 hours. Doses were 86- 219 mg/m3 (0.086 – 0.219 mg/L). Animals were observed for several days. No mortality was observed. LC50 > 0.219 mg/L
Irritation	The test article produced sensory irritation later in the exposure at low concentrations. Pulmonary irritation also occurred later in these exposures.
Sensitisation	Did not cause sensitization on laboratory animals (similar substances)

Health Effects Summary	Acute oral and dermal toxicities of CASRN 68140-00-1 in rat and rabbit, respectively, are low. CASRNs 142-78-9 and 68140-00-1 were negative for gene mutations in bacteria in vitro. No data are available for the repeated-dose/reproductive/developmental toxicity and genetic toxicity (chromosomal aberrations) endpoints. The repeated-dose/reproductive/developmental toxicity and genetic toxicity (chromosomal aberrations) endpoints are identified as data gaps
Key Study/Critical Effect for Screening Criteria	
Ecological Toxicity [1, 3]	
Aquatic Toxicity	Based on read-across for CAS No: 68603-42-9 Daphnia: EC50 (24-hour): 3.3 mg active matter/l Daphnia: 48-hour LC50 = 2.15 and 2.64 mg/l Based on read-across for CAS No: 112-84-5 The experiment measured the survival and reproduction of Daphnia magna over a 21-day exposure to the test and control substances. Daphnids were cultured in the laboratory using Elendt M7 medium and a daily feeding regiment of green algal cells (Chlorella vulgaris). Four experimental groups: control (Elendt M7 medium), solvent control (0.1 ml methanol/l), 33 µg/l, and 100 µg/l (nominal concentrations) were used in a static-renewal exposure system. All test solutions were prepared with Elendt M7 medium. Replicate test vessels consisted of 4 oz glass bottles containing 100 ml of test solution. There were 10 replicates per experimental group. On the day of test initiation, neonate daphnids were removed from cultures and placed in a crystallizing dish containing Elendt M7 medium. One daphnid was placed in each replicate test vessel, and each vessel was randomly placed in the testing area. Light intensity was not measured, but ambient laboratory lighting was provided with a photoperiod of 16 hours light/8 hours dark. Each day, test solutions were renewed, and the daphnids were fed 1.7 x 10(5) cells/ml of Chlorella vulgaris. Adult survival and reproduction was assessed each day and neonates were removed daily. The pH, dissolved oxygen (DO) and total hardness (as mg/l CaCO(3)) were measured on test days 0, 1, every Tuesday and Friday and on day 21. Means and ranges for temperature, water pH, DO and total hardness were 19.7 °C (14.5 - 25.0 °C), 7.6 (7.2 - 8.1), 8.2 mg/l (4.5 - 9.3 mg/l) and 245 mg/l (234 - 256 mg/l) as CaCO(3), respectively. Concentrations of the test substance in exposure solutions were measured on test days 0, 1, 5, 9, 12, 16 and 19 in both the old and the new solutions. Effect concentrations were based on mean measured concentrations. 21 d NOEC = 0.08 mg/L
Determination of PNEC aquatic	Applying an assessment factor of 1000 to the NOEC (0.08 mg/l) gives a PNEC of 0.08 µg/l.
Current Regulatory Controls	
Australian Hazard Classification	No data available.
Australian Occupational Exposure Standards	No data available.
International Occupational Exposure Standards	No data available.
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	No data available.
PBT Assessment	
P/vP Criteria fulfilled?	No. Expected to be readily biodegradable based on similar substances.

B/vB criteria fulfilled?	No. Based on BAF = 108 and log Kow of 3 (estimated)
T criteria fulfilled?	No. Acute toxicity data was >1 mg/L.
Overall conclusion	Not PBT
Revised	January 2019

References

1. OECD, Amides, tall-oil fatty, N,N-bis(hydroxyethyl), Retrieved 2019: http://www.echemportal.org
2. USEPA Hazard Characterization Document, Fatty Nitrogen Derived (FND) Amides Category, September 2010
3. Redacted

Toxicity Summary - Amine oxides, cocoalkyldimethyl

Chemical and Physical Properties	
CAS number	61788-90-7
Molecular formula	CH3.(CH2)R.N(CH3)2:O, where R is 9-17
Molecular weight	237 (70% C12: 30% C14) (molecular weight will vary depending on structure)
Solubility in water	409.5 g/L
Melting point	Average: 130.5
Boiling point	Decomposes before boiling
Vapour pressure	Predicted vapour pressure values are < 4.6E-7 hPa
Henrys law constant	No data available.
Explosive potential	No data available.
Flammability potential	No data available.
Colour/Form	No data available.
Overview	Surfactants known as amine oxides (AO) contain even numbered linear alkyl chains ranging from C8 to C20. Also known as fatty alkyl dimethyl AOs, they are usually produced by reacting alkyl dimethyl amines with hydrogen peroxide in water. The AOs are produced, transported and used in water solutions, typically at a 25-35% activity level. The AOs are produced and used either as single chain length substances (e.g., C12) or as a mixture of different chain lengths (e.g., C12 to C18). All of the substances in this category are surfactants, consisting of a polar “head” (the amine oxide) and a relatively inert, hydrophobic “tail” (the long alkyl substituent). AOs are used in cleaning and personal care products as foam stabilizers, thickeners, emollients, emulsifying and conditioning agents. Primary uses are in liquid hard surface cleaners, laundry and dishwashing detergents, shampoos and hair conditioning products.
Environmental Fate[1]	
Soil/Water/Air	AOs are highly water soluble (C10-16 AO = 409.5g/L). AO is fully biodegradable under both aerobic and anaerobic conditions and is effectively removed during wastewater sewer transport (“pipe loss” >90%) and in biological wastewater treatment (~98%). It has low potential for bioaccumulation (BCF <87 L/kg). These characteristics help to minimize the potential for environmental exposure, and for indirect human exposures via drinking water and/or fish consumption.
Human Health Toxicity Summary [1]	
Chronic Repeated Dose Toxicity	In four repeated-dose studies with rats and mice exposed to AO via oral and dermal routes (all with CAS No 70592-80-2), three dermal studies were designed to assess the effect of repeated exposure on skin at maximum doses of 1.5 mg AO/kg-bw/day. Higher doses were tested in a 90-day dietary study with rabbits. No treatment-related clinical chemistry, hematology and histopathological changes were observed. In these studies, LOAELs ranged from 87 to 150 mg AO/kg bw/day with the highest oral NOAEL below the lowest LOAEL as 80 mg AO/kg bw/day. Signs of toxicity observed in the oral study included suppressed mean body weight gain, lenticular opacities and diarrhoea; in the dermal studies, local dermal irritation was evident.
Carcinogenicity	The carcinogenic potential of amine oxides has been thoroughly investigated in three carcinogenicity studies in rats or mice by dermal, dietary, or drinking water routes. In all cases the substances demonstrated no evidence of a carcinogenic response.

Mutagenicity/ Genotoxicity	In five in vitro bacterial (Salmonella) mutagenicity studies, AO shows no evidence of mutagenicity either with or without S9 metabolic activation at concentrations up to 250 ug/plate (higher concentrations caused cytotoxicity). Three in vivo studies investigated clastogenic effects on a close structural analog of the category, 1-(methyldodecyl)dimethylamine-N-oxide including: a mouse micronucleus, a Chinese hamster micronucleus and a Chinese hamster cytogenetics study. These studies were all negative showing no increase in micronuclei or chromosome aberrations. An in vivo mouse dominant lethal assay showed no evidence of heritable effects. Two AOs (CAS No 1643-20-5 and CAS No 3332-27-2) were negative in an in vitro cell transformation assay tested at concentrations up to 20 ug/ml.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	No evidence of reproductive toxicity or fertility effects was observed in a study in which rats were given dietary doses of AO in the diet over two generations (CAS No 1643-20-5). No macroscopic or histopathological changes were attributable to treatment with the test substance. The maternal NOAEL from this reproductive study was >40 mg AO/kg bw/day, which was the highest dose tested. At all treatment levels, the rate of bodyweight gain for the F1 and F2 offspring was reduced during the lactation period, however, this reduction was not greater than 10%. This effect appeared to be dose-related, but was not statistically significant until after weaning in the mid and high dose levels. This was not considered an adverse effect since the body weight change only reached statistical significance when the rat pups were getting the majority of their calories from solid food (Developmental NOAEL >40 mg/kg bw/day). In three developmental toxicity studies via gavage in rats and rabbits (with CAS No 1643-20-5 & 70592-80-2), effects such as decreased fetal weight or delayed ossification, were most often observed only at maternally toxic doses and were associated with the irritation effects of AO on the gastrointestinal tract. No decreases in litter size, no changes in litter parameters, no malformations or significant differences in skeletal defects were observed at oral doses up to 25 mg/kg bw/day in rats (based on decreased fetal weight at 100 mg/kg bw/day) and >160 mg/kg bw/day in rabbits (the highest dose tested).
Acute Toxicity	In rat oral acute toxicity limit tests, no deaths occurred at single doses of 600 mg C10-16 AO/kg bw or less (for CAS No 70592-80-2). In multi-dose studies, acute oral LD50 values for rats ranged from 846 mg AO/kg bw to 3873 mg AO/kg bw (both values for CAS No 61788-90-7), with several other AO's having rat oral LD50's falling within this range. In single dose acute dermal toxicity limit tests, no deaths occurred at a dose of 520 mg AO/kg bw (CAS No 70592-80-2). This dose was equivalent to 2 mL/kg of a 30% formulation. There were no deaths observed in a rat acute inhalation study to aerosol droplets of a consumer product providing a dose of 0.016 mg AO/L.
Irritation	In a series of studies on rabbits, AO's of varying chain length showed consistent results and all 1) were not irritating to the skin or eyes at low concentrations (1%), 2) were moderately irritating at 5%, and 3) more severely irritating when tested as produced (e.g., ~30% aqueous solutions). In studies that included rinsing, eye irritation effects diminished with rinsing after 30 seconds of exposure and were slight with rinsing after 4 seconds of exposure. In Draize rabbit eye irritation tests using ~30% AO solutions, rabbits experienced severe to moderate irritation. (The maximum concentration of AO is 10% active in consumer products.) Accidental eye exposure in manufacturing employee incidents and consumer incidents established that eye irritation effects of exposure during manufacturing and use of products containing AO and other surfactants are moderate, transient and reversible
Sensitisation	There is no indication of skin sensitization for the AO category based on the available animal and human data.
Health Effects Summary	The chemicals in this category present properties indicating a hazard for human health (skin and eye irritation). However, these hazards do not warrant further work as they are related to reversible, transient and non-lasting effects. Nevertheless, these hazards should be noted by chemical safety professionals and users.
Key Study/Critical Effect for Screening Criteria	Skin and eye irritation.

Ecological Toxicity [1,2,3]	
Aquatic Toxicity	Extensive aquatic toxicity data are available for commercially representative amine oxides (C10 to C18) that are single chain length as well as mixtures. Based on hazard data, freshwater green algae are considered the most sensitive species, for acute and chronic endpoints. Acute toxicity is affected by chain length for fish and invertebrates. Chain length affects hydrophobicity, wherein longer chain-lengths increase the rate of uptake and decrease depuration. All but four supporting AO's have been tested for acute toxicity in fish, daphnia, and algae. The range of acute LC50/EC50/ErC50 values based on a review of the aquatic toxicity data on AO were 0.60-32 mg/L for fish, 0.50-10.8 mg/L for Daphnia magna and 0.010-5.30 mg/L for algae. Chronic toxicity data were normalized to a chain length of 12.9 carbon atoms, as this average chain length represents the largest volume product for North America (CAS No 70952-80-2). Chronic toxicity (NOEC, EC20) for an amine oxide of average chain length of C12.9 ranged as follows for the different trophic levels: 0.010-1.72 mg/L for algae, 0.28 mg/L for Daphnia (flow through) and 0.31 mg/L for fish (flow through). These are based on geometric mean values, and a dataset of 21 chronic toxicity studies. Based on a chronic periphyton microcosm bioassay that included 110 taxa of algae (most sensitive species), a NOEC value of 0.050 mg/L was derived when normalized for a C12.9 amine oxide.
Determination of PNEC aquatic	Chronic toxicity values are reported for fish, aquatic invertebrates, and freshwater algae. Since there is valid chronic toxicity data for three trophic levels, an assessment factor of 10 is used (in accordance with EU guidance). Based on the NOEC for freshwater algae (the most sensitive species), the aquatic PNEC is 0.01 µg/L.
Current Regulatory Controls [4]	
Australian Hazard Classification	No data available.
Australian Occupational Exposure Standards	No data available.
International Occupational Exposure Standards	No data available.
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	No data available.
PBT Assessment	
P/vP Criteria fulfilled?	No. AOs are highly removed by conventional sewage treatment systems and biodegrade rapidly and completely under aerobic and anaerobic conditions.
B/vB criteria fulfilled?	No. BCFWIN predictions using the calculated logKow value of < 2.7 as input parameters (derived for C10-16 AO), calculated bioconcentration factor < 87 for C12-14 AO (The Procter & Gamble Company, 2002C). Thus the potential for bioaccumulation of AOs in aquatic organisms is considered to be low.
T criteria fulfilled?	Yes. Chronic toxicity data < 1 mg/L fish, aquatic invertebrate and/or algae, thus AO does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	January 2019

References

1. OECD (2001) SIDS Initial Assessment Profile for Amine Oxides (AO)

Toxicity Summary - Benzaldehyde

Chemical and Physical Properties[1,2,3]	
CAS number	100-52-7
Molecular formula	C7H6O
Molecular weight	106.12
Solubility in water	6.55 g/L at 25°C
Melting point	-26°C
Boiling point	179.2°C
Vapour pressure	0.130 kPa (0.97 mmHg) at 20°C
Henrys law constant	2.85 Pa.m³.mol-1 @ 25 °C
Explosive potential	Non explosive
Flammability potential	Non flammable
Colour/Form	Colourless or yellow liquid with an almond-like odour.
Overview	Benzaldehyde is a colourless liquid that becomes yellowish with age. It smells a little like almond and has a burning, aromatic taste. Benzaldehyde is very soluble in water. Benzaldehyde occurs naturally in plants. It can be formed in the atmosphere from the reaction of some chemicals with sunlight. It has been detected in air associated with volcanoes. Benzaldehyde is an important commercial chemical that is used to make other chemicals. It is also used as a preservative in cosmetics, personal care products, food and select car detailing products. It is used as a solvent for oils, flavouring, and in synthetic perfumes. It may be a tobacco additive. It was formerly used as an insecticide.
Environmental Fate [2,3]	
Soil/Water/Air	The test substance is readily biodegradable. The test substance was shown to degrade under influence of light with a DT50 of 9.4 hours. In addition under anaerobic conditions complete biodegradation is expected. As the logKow is 1.4, the potential for bioaccumulation and sorption of the test substance is considered to be low. The Henry Constant was calculated to be 2.85 Pa m^3/mol. A calculation with Simple Treat shows that the test substance will degrade in the Sewage Treatment Plant for > 88% with at maximum about 12% to end up in the water compartment.

Human Health Toxicity Summary [1]	
Chronic Repeated Dose Toxicity	Based on the data available, the chemical is not considered to cause serious damage to health from repeated oral and inhalation exposure. In a repeated dose oral toxicity study, Fischer rats (male/female, 10/sex/dose) were administered the chemical by oral gavage at doses of 0, 50, 100, 200, 400 or 800 mg/kg bw/day, five days a week, for 13 weeks. Mortalities and histopathological changes including lesions in the brain (degeneration and necrosis of the cerebellum and necrosis in the hippocampus), renal tubular necrosis, hyperplasia and/or hyperkeratosis of the forestomach, and degeneration of the liver were observed in both sexes at the highest tested dose level. Depressed body weights (26 % lower than controls) were also observed for male rats at this dose. A no observed adverse effect level (NOAEL) of 400 mg/kg bw/day was established (NTP, 1990; OECD, 2002; CIR, 2006; REACH). A similar repeated dose oral toxicity study on B6C3F1 mice (male/female, 10/sex/dose) was also conducted. The mice were administered the chemical by oral gavage at doses of 0, 75, 150, 300, 600 or 1200 mg/kg bw/day, five days a week, for 13 weeks. Within the first week of dosing, 9/10 males and 1/10 females died at the highest tested dose. Mild to moderate renal tubular degeneration in all males was observed in the high dose group and 1/10 males in the 600 mg/kg/day group. Depressed body weights (9 % lower than controls) were also observed for the males at 600 mg/kg bw/day. The NOAEL was determined to be 300 mg/kg bw/day for male mice and 600 mg/kg bw/day for female mice (NTP, 1990; OECD, 2002; CIR, 2006; REACH). In another repeated dose oral toxicity study, similar to OECD TG 408, groups of Osborne–Mendel rats (male/female, five/sex/dose) were fed a powdered diet containing the chemical at concentrations of 1000 ppm for 28 weeks, or 10000 ppm (approximately 500 mg/kg bw/day) daily for 16 weeks. No effects on body weight or haematological parameters and no macroscopic/microscopic changes in selected organs were noted at 10000 ppm (CIR, 2006; REACH). In a repeated dose inhalation toxicity study conducted similarly to OECD TG 412, groups of Sprague Dawley (SD) rats (male/female, 14/sex/dose) were exposed (whole body) to the vapours of the chemical at 0, 500, 750 and 1000 ppm, six hours a day for 14 days. Significant reduction in body weight was observed for all males but only at 1000 ppm for females. Mortalities occurred in the two higher dose groups. All groups exhibited clinical toxicity symptoms including reduced motor activity, hypothermia, respiratory problems and nasal and ocular irritation. With increased concentrations, the severity of nasal and ocular irritation increased. At the two highest doses, the rats displayed aggressive behaviour and central nervous system symptoms (tremors, piloerection, diuresis, seizures and sensitivity to noise). The most prominent histopathological observation was goblet cell metaplasia in the respiratory epithelial lining of the nasal septum, which was found in males at doses 500 and 1000 ppm, but not in females. A no observed adverse effect concentration (NOAEC) could not be determined due to the clinical observations (indicative of neurotoxicity), hypothermia, and goblet cell metaplasia which were seen at concentrations of 500 ppm and above. The lowest observed adverse effect concentration (LOAEC) was reported to be 500 ppm in this study (CIR, 2006; HSDB; REACH). In another repeated dose inhalation toxicity study with limited documentation (non-guideline), rats were exposed to the chemical at 186 ppm (803 mg/m^3), four hours a day, five days a week for two weeks. Respiratory irritation was observed during exposure. No other effects were reported (EC, 2000; OECD 2002).

Carcinogenicity	Although the chemical has been reported to have 'some evidence of carcinogenic activity' in B6C3F1 mice, there was 'no evidence of carcinogenic activity' in Fischer 344 rats receiving 200 or 400 mg/kg bw/day (NTP, 1990). It was further concluded that the increased incidences of pancreatic acinar cell neoplasms in male rats and squamous cell papillomas of the forestomach in mice were probably due to the high concentrations of corn oil (mild irritant and mitogen) used as a vehicle in these studies (US EPA, 2001). The chemical is also considered not to have mutagenic or genotoxic potential (see Genotoxicity). Therefore, the chemical is not considered to have carcinogenic potential. In a combined chronic toxicity–carcinogenicity study (OECD TG 451), groups of eight-week-old Fischer 344 rats (male/female, 50/sex/dose) were administered (gavage) the chemical in corn oil at doses of 200 or 400 mg/kg bw, five days a week for two years. At the highest dose, mortality in male rats was significantly higher than the controls. No dose-related effects on body weight and clinical signs were observed. As squamous cell papillomas of the forestomach were seen in only two female rats in the high dose group and there was a lack of supporting hyperplasia, these were not considered to be due to the administration of the chemical. Significant increases in the incidences of pancreatic acinar cell hyperplasia and tumours were observed in male rats only at the high dose. Unpublished National Toxicology Program (NTP) studies indicated that pancreatic acinar cell tumours found in rats gavaged with corn oil were not autunomous as these tumours failed to transplant. Therefore, based on the facts that these tumours failed to transplant, were present in variable numbers in control animals, and increased only at the high dose, it was concluded that pancreatic acinar cell hyperplasia and tumours were not considered as evidence of carcinogenic activity for the chemical (NTP, 1990; EC, 2000; HSDB; REACH). It was further concluded that the increased incidence of tumours specific to male rats in this study was probably due to the use of corn oil as a vehicle in this study (US EPA, 2001). In the same carcinogenicity study, groups of eight-week-old B6C3F1 mice (male and female, 50/sex/dose) were administered (gavage) the chemical in corn oil at doses of 200 or 400 mg/kg bw (in males), 300 or 600 mg/kg bw (in females), five days a week for two years. Although no significant differences in mean body weights and survival were observed between any groups of mice, effects were noted in the forestomach of mice. The incidences of uncommonly occurring squamous cell papillomas of the forestomach in both exposure groups were significantly greater as compared to the controls (male: vehicle control, 1/50; low dose, 2/50; high dose, 5/50; female: 0/50; 5/50; 6/50). The increased incidences of papillomas were accompanied by significantly increased incidences of focal hyperplasia in the forestomach in both sexes of the 400 mg/kg bw group and in females of the 200 mg/kg bw group, compared with vehicle controls. The NTP considered that the increase in papillomas was due to a concurrent increase in hyperplasia following treatment with the chemical and concluded that there was 'some evidence of carcinogenicity' in mice. It was also concluded male and female mice might have been able to tolerate higher doses (NTP, 1990; REACH).

Mutagenicity/ Genotoxicity	Overall, the data indicate that the chemical has no mutagenic or genotoxic potential. Although there is no mutagenic activity in bacterial systems, the chemical does have weak clastogenic effects in some mammalian cell assays. There are also no in vivo data available. The chemical gave negative results in several in vitro bacterial reverse mutation assays with Salmonella typhimurium at concentrations up to 3333 mg/plate. Induction of chromosomal aberrations was also not observed in Chinese hamster ovary (CHO) cells, treated with the chemical up to 500 mg/mL in the absence of S9 or with up to 1600 ug/mL with S9 (NTP, 1990; REACH). In an in vitro chromosomal aberration assay (OECD TG 473) in the Chinese hamster cell line B241, a significant percentage (13 %; 21/162) of the cells displayed abnormalities following exposure to a concentration of 5.3 nM of the chemical for 24 hours (CIR, 2006). Cytogenetic tests with CHO cells reported an increased number of sister chromatid exchanges at doses of 50 mg/ml and 160 mg/ml in the absence of S9 or at 1600 mg/mL with S9 (NTP, 1990; HSDB; REACH). The chemical gave positive results in a mouse lymphoma forward mutation assay (OECD TG 476) with mouse lymphoma L5178Y cells. The concentrations of the chemical tested in this assay were 0, 50, 100, 200, 400, and 800 mg/mL. Although significant increases in mutant fractions were observed at a dose of 400 mg/mL, the positive response was noted to be close to the cytotoxic dose of 640 mg/ml (HSDB; REACH). Negative results were obtained with the chemicals in an in vivo sex-linked recessive lethal test with Drosophila melanogaster (NTP, 1990; OECD, 2002; HSDB; REACH).
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Although limited data are available, the available information indicates that the chemical does not show specific reproductive or developmental toxicity. Benzyl derivatives, including benzaldehyde, have been reported to produce no evidence of reproductive and developmental toxicity during various studies. It was also stated that as benzyl derivatives generally follow similar metabolic pathways, studies conducted on benzyl derivatives provide adequate evidence for benzaldehyde (US EPA, 2001). As part of reviewing the reproductive toxicity and teratogenicity of benzaldehyde and related compounds (benzyl acetate, benzyl alcohol, and benzoic acid and its salts), the Joint Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) Expert Committee on Food Additives concluded that 'delayed development and reduced foetal and postnatal pup body weights were observed in developmental toxicity studies in rats, mice, hamsters and rabbits, but only at doses that were toxic to the mother' (CIR, 2006). In a poorly-documented one-generation reproductive toxicity study (non-guideline), male and female rats were administered the chemical by oral gavage at doses of 0 or 5 mg/kg bw/day in oil, once every second day for 32 weeks. Dosing commenced at 75 days before breeding with untreated males; two pregnancies per rat were studied, one at 75 days and one at 180 days. The number of gestating females, number of live-born offspring, pup weights at birth and on postnatal days 7 and 21, and pup viability were recorded. The incidences of pregnancy were reported to be lower for treated females compared with controls. All other parameters were reported to be similar between the treatment and control groups. It was concluded that the treatment did not cause a significant change in any of the reproductive parameters measured. (US EPA, 2001; OECD, 2002; CIR, 2006; REACH).

Acute Toxicity	In an acute oral toxicity study conducted similar to the Organisation for Economic Co-operation and Development (OECD) Test Guideline (TG) 401, groups of male Wistar rats were administered (by gavage) the chemical at doses of 0.8, 1.0, 1.1, 1.2, 1.3, 1.5, and 1.8 mL/kg bw and observed twice daily for 14 days. The acute median lethal dose (LD50) was reported to be 1.43 mL/kg bw (1430 mg/kg bw), with a mortality rate of 100 % (10/10) at the highest tested dose. Observed sub-lethal effects included sedation, staggering, weight loss and a rough coat (REACH). In another acute oral toxicity study with limited data, male and female rats were administered the chemical at doses of 1100–1540 mg/kg bw. An LD50 of 1300 mg/kg bw was established (OECD, 2002; REACH). Although limited information is available, the chemical is likely to have low acute dermal toxicity in animal tests following dermal exposure. In an acute dermal toxicity study in rabbits with limited available data, an LD50 of >1250 mg/kg bw was reported (OECD, 2002; HSDB; REACH). Although limited data are available, the available information indicates that the chemical has moderate acute toxicity in animal tests following inhalation exposure and is recommended for classification. In an acute inhalation toxicity study conducted according to OECD TG 436, Wistar rats (male/female) were exposed (nose only) to the vapours of the chemical at 1 and 5 mg/L for four hours and observed up to 14 days. Clinical effects were observed in most animals following exposure at 5 mg/L including lethargy, flat/hunched postures, ventrolateral recumbency, respiratory difficulties and piloerection. Four animals out of six (one male and three females) died following exposure at 5 mg/L. A median lethal concentration (LC50) of <5mg/L was established, based on mortalities at the highest tested dose (REACH). An increased incidence of respiratory symptoms was noted among workers exposed to vapour of the chemical at atmospheric concentrations of >5 mg/m^3 (OECD, 2002).
Irritation	Although limited data are available, the available information indicates that the chemical is not likely to be a skin irritant. In two skin irritation studies (non-guideline) with limited data, the undiluted chemical (500 mg) was applied to the intact or abraded skin of New Zealand White rabbits for 24 hours with observation up to seven days. Although the exact details were not provided, slight skin irritation was observed (EC, 2000). Although limited data are available, the chemical had been reported to be an eye irritant in animal studies. The available information is not sufficient to support a classification. In an eye irritation study (non-guideline), one drop of the undiluted chemical was applied to the conjunctival sac of a rabbit. Observations were made at one, 24 and 48 hours following application. Immediate irritation effects were noted at one hour and within 24 hours, the anterior portion of the cornea was damaged. The cornea was cleared within 48 hours and only erythema of the conjunctiva and nictitating membrane was noted at this stage. Although the rabbit died on the sixth day, the death was not related to the application of the chemical (CIR, 2006; REACH). In another eye irritation study (non-guideline) with limited data, the chemical (100 µL, concentration not stated) was instilled into the eyes of two rabbits and observed for seven days. The chemical was observed to be slightly irritating to the eyes (REACH).

Sensitisation	Although the chemical has produced skin sensitisation reactions in some tests, based on the weight of evidence, the chemical is not likely to be a skin sensitiser. It is also noted that the chemical is rapidly metabolised to benzoic acid in the skin. Clinical reports of allergy to the chemical are rare and benzoic acid has also been reported not to produce sensitisation in clinical trials in humans (CIR, 2006). In a Magnusson-Kligman skin sensitisation test conducted by the US EPA, guinea pigs (10/group) were initially exposed to the chemical intradermally by a 0.1 mL injection of 3 % chemical in paraffin oil followed by topical application to a patch of skin (occluded for 48 hours) of 15 % chemical in petrolatum. The skin was later challenged by a topical application (occluded for 24 hours) of 7 % chemical in petrolatum on a patch of skin. As the chemical failed to induce erythema in either group, the chemical was concluded not to be a skin sensitiser (CIR, 2006). In a skin sensitisation study that compared four testing methods of 32 fragrance materials on Himalayan guinea pigs, the chemical tested positive for allergenicity in the Draize test (DT), the maximisation test (MT) and Freund's complete adjuvant (FCA) test. The guinea pigs were injected intradermally with the chemical at doses of 0.05 mL (0.1 % solution), 0.1 mL (5 % solution) and 0.05 mL (undiluted) for DT, MT and FCA, respectively (EC, 2000; CIR, 2006; REACH). The chemical was reported to be non-sensitising in the open epicutaneous test (OET) for the same study as reported above. The guinea pigs were exposed to the chemical (undiluted, 0.03 , 0.1, 0.3, 1, 3, 10, or 30 %) at a dose of 0.1 mL on an 8 cm2 area of shaved skin on the flank. Applications were repeated once a day for 21 days and the sites were scored for signs of irritation 24 hours following each treatment. The acute minimum irritating concentration was 10 % and after 21 exposures was 3 %. The animals were challenged with 3 % (minimum irritating concentration for day 21) or an unspecified lower concentration on a 2 cm2 area of shaved skin at two weeks post-exposure. The sites were scored at 24, 48 and 72 hours. No sensitisation effects were observed (CIR, 2006; REACH). In a guinea pig skin maximisation test (OECD TG 406), animals were injected intradermally with 2.7 % of the chemical and followed by three epidermal challenges with 2.1, 2.1 and 0.64 % of the chemical. It was noted that only one intradermal induction was performed and no additional topical induction. Also, there were three challenge reactions instead of one. The time between induction and challenge applications was also not stated. No sensitisation effects were observed (REACH).
Health Effects Summary	The critical health effects for risk characterisation include systemic acute effects (acute toxicity from oral and inhalation exposure).
Key Study/Critical Effect for Screening Criteria	The chemical has been reported to possibly cause respiratory failure, depression of the CNS and convulsions at high concentrations (HSDB). A young woman died after ingesting 50–60 ml (700–2000 mg/kg) of the chemical. At autopsy, yellowish-white pulp with a strong odour of bitter almond was found in the stomach. The time between consumption and death was not specified. In another case, a man had to be revived from near death following ingestion of 40 ml of a derivative of the chemical (o-hydroxybenzaldehyde). Based on these two studies, a lethal oral dose of 600–900 mg/kg bw was calculated for the chemical in the absence of prompt treatment (NTP, 1990; EC, 2000; CIR, 2006). In a case study, workers exposed to vapour of the chemical at atmospheric concentrations of >5 mg/m^3 reported an increased incidence of respiratory symptoms (OECD, 2002). In an inhalation toxicity study, human volunteers were exposed to 4.5 ppm (19.5 mg/m^3) of the chemical for one minute. Irritation of the eyes and upper respiratory tract were observed. In an occupational study, workers exposed to the chemical vapour at atmospheric concentrations of >5 mg/m^3 reported symptoms of slight eye irritation and considerable skin irritation (OECD, 2002).

Ecological Toxicity [2,3]	
Aquatic Toxicity	Acute LC50 for freshwater fish is 1.07 mg/L, freshwater invertebrates is 16.2 mg/L and EC10 for freshwater algae is 20 mg/L. Chronic NOEC for freshwater fish is 0.12 mg/L. The overall acute dataset on aquatic organisms yields a lowest LC50 value for fish of 1.07 mg/L and a NOEC of 0.12 mg/L. However, the substance is readily biodegradable and has a low potential for bioaccumulation. Based on the second ATP to CLP the test substance was classified as Chronic category 3 for aquatic toxicity.
Determination of PNEC aquatic	Ecotoxicological data indicate that benzaldehyde is acutely toxic to fish, harmful to daphnia and very slightly toxic to algae. Using an uncertainty factor of 100 on the lowest LC50 to fish a PNEC (Predicted No Effect Concentration) of 10.7 ug/L is calculated, for aquatic organisms.
Current Regulatory Controls [1]	
Australian Hazard Classification	The chemical is classified as hazardous, with the following risk phrases for human health in the Hazardous Substances Information System (HSIS) (Safe Work Australia): Harmful if swallowed, Xn; R22 (Acute toxicity)
Australian Occupational Exposure Standards	No specific exposure standards are available.
International Occupational Exposure Standards	The following exposure standards are identified (Galleria Chemica). The chemical has an exposure standard of 5 mg/m^3 time weighted average (TWA) in Bulgaria, Hungary, Latvia and Russia; 10 mg/m^3 in Poland; and 2 ppm in the USA. Short-term exposure limits (STEL) of 4 ppm in the USA and Canada; 10 mg/m^3 in Hungary; and 40 mg/m^3 in Poland have been reported.
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	No data available.
PBT Assessment	
P/vP Criteria fulfilled?	No. Expected to be readily biodegradable.
B/vB criteria fulfilled?	No. As the Log Pow is 1.4 (Log Pow < 4.5), it is not expected to be bioaccumulative.
T criteria fulfilled?	No. The chronic aquatic toxicity of the chemical is > 0.01 mg/L. Hence the substance does not fulfil the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	January 2019

References

1. National Industrial Chemicals Notification and Assessment Scheme (NICNAS). IMAP, Human Health Tier II Assessment for Benzaldehyde: Retrieved 2019: https://www.nicnas.gov.au
2. ECHA REACH, Benzaldehyde, Retrieved 2019: https://echa.europa.eu/
3. OECD (2002) SIDS Initial Assessment Profile for Benzaldehyde

Toxicity Summary - Butyl alcohol

Chemical and Physical Properties[1,2,3]	
CAS number	71-36-3
Molecular formula	$C4H10O$
Molecular weight	74.12
Solubility in water	77 g/l at 20 °C
Melting point	-89.9 °C
Boiling point	117.6 °C
Vapour pressure	0.56 kPa at 20 °C
Henrys law constant	0.054 Pa m^3/mol
Explosive potential	Non-explosive
Flammability potential	Flammable
Colour/Form	Colourless liquid with a mildly alcoholic odour.
Overview	n-Butyl alcohol is used as a solvent in surface coatings. These can include varnishes, resins, waxes and gums. It is also used in the manufacture of other butyl compounds. n-Butyl alcohol is a product of fermentation. It has also been detected in the volatiles of foods such as cheese, muskmelon and cooked rice. People that work in industries where products containing n-butyl alcohol are used will have the highest exposure. These could include varnishing of automobiles, painting shops and fabric coating. Exposure will happen by eating foods containing n-butyl alcohol and breathing in fumes from cooking certain foods. n-Butyl alcohol can be found in surface water and air. It is often found in indoor air of new construction. It breaks down in air by reaction with radicals. It is expected to evaporate from soil and water surfaces. n-Butyl alcohol that remains in soil or water will be broken down by microorganisms. It is not expected to build up in aquatic organisms.
Environmental Fate[1]	
Soil/Water/Air	Based on level III fugacity modelling, BA will partition 83.5% in air, 5.9% in soil, 10.6% in water, <0.1% in suspended solids, and <0.1% in biota and in sediment. BA degrades in air by reaction with hydroxyl radicals, having a half-life in air of 1.2 to 2.3 days. The volatilization half-life for BA in water is estimated to be 2.4 hours for streams, 3.9 hours for rivers and 126 days for lakes.
Human Health Toxicity Summary [1]	
Chronic Repeated Dose Toxicity	A no observed adverse effect level (NOAEL) of 125 mg/kg bw/day and a lowest observed adverse effect level (LOAEL) of 500 mg/kg bw/day in male and female CD rats was reported based on results from a repeat dose oral study using the chemical (OECD 2001). Groups of male and female rats (30/sex/group) were administered the chemical via gavage at 0, 30, 125 or 500 mg/kg/day for 13 weeks. It was reported that ataxia (impaired muscle coordination) and hypoactivity were observed at the highest dose during the final six weeks of the study. No treatment related effects were reported in the 30 and 125 mg/kg/ bw/day dose groups (OECD 2001). In a non-guideline study, the chemical was applied to the skin of rabbits under occlusive conditions over a period of 21 days. Local effects were reported such as drying of the skin, cracking, wrinkling and exfoliation of the epidermis. However, no systemic toxicity was reported (REACH). In another non-guideline repeat dose dermal study on rabbits, 42 to 55 mL/kg of the chemical applied to the skin of rabbits over four consecutive days resulted in 100 % mortality. However, the same study reported that 30 applications of 20 mL/kg of the chemical over six weeks did not produce any deaths (OECD 2001).

Carcinogenicity	OECD (2001) reported that based on the number of negative mutagenicity and clastogenicity findings, the chemical is not expected to be a carcinogen. A weight of evidence study reported that the chemical is not expected to have carcinogenic potential as it does not contain structural components to support carcinogenicity (REACH, HSDB).
Mutagenicity/ Genotoxicity	The chemical is not expected to be genotoxic. The chemical tested negative in a number of tests for genotoxicity. These included several in vitro tests (OECD Guideline 473: mammalian chromosome aberration test on Chinese hamster lung fibroblasts V79; OECD Guideline 471: bacterial reverse mutation assay on S. typhimurium TA 98, TA 100, TA 98, TA 1535 and TA 1537; OECD Guideline 476: mammalian cell gene mutation test on Chinese hamster lung fibroblasts V79) and in vivo tests (OECD Guideline 474: mouse micronucleus) (OECD 2001, REACH).
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	The chemical is not expected to be toxic to reproduction (OECD 2001). In a non-guideline study, male and female Sprague Dawley (SD) rats were exposed to the chemical via inhalation at 0, 3000 or 6000 ppm for seven hours/day. Female rats were exposed to the chemical throughout gestation, while males were exposed to the chemical for six weeks prior to mating. No harmful effects on fertility or pregnancy rate were reported at any of the dose levels. In another non-guideline study, no testicular toxicity (effect on testes weight or histopathology) was reported in SD male rats that were administered the chemical via oral intubation at 533 mg/kg bw/day over six days (OECD 2001). Any developmental effects were only reported to be observed secondary to maternal toxicity, so the chemical is not expected to be a developmental toxin. OECD (2001) reported that the chemical showed mild foetotoxicity and developmental variations in offspring only at or near the maternally toxic and, in some cases, lethal dose of 8000 ppm. Offspring of female SD rats exposed via inhalation to 0, 3500, 6000 or 8000 ppm of the chemical on gestations days 1 to 19, reported a reduction of foetal weights at 6000 and 8000 ppm and a slight increase in skeletal malformations at 8000 ppm but not at the lower dosage levels. At a maternally toxic dose of 8000 ppm, decreased weight gain, food consumption and dam deaths were reported. The NOAEL for offspring and dams was 3500 ppm as there was a slight decrease in foetal weight at the 6000 ppm dose level. In another 20 day study in male and female SD rats exposed to 0, 3000 or 6000 ppm of the chemical via inhalation, a small number of behavioural and neurochemical variations in offspring at 6000 ppm were reported. No maternal toxicity was reported throughout gestation for females or for six weeks prior to mating for males as a result of maternal or paternal exposure. However, the effects observed in offspring were not regarded as biologically significant by the authors due to inconsistences between dose-response patterns.
Acute Toxicity	The chemical is reported to be slightly acutely toxic via the oral route of exposure. Oral median lethal doses (LD50s) in rats were reported between 790 and 4360 mg/kg bw (OECD 2001). The chemical is reported to have low toxicity via the dermal route of exposure. The lowest LD50 in rabbits was reported to be 3402 mg/kg bw (OECD 2001). The chemical is reported to be of low acute toxicity via the inhalation route of exposure. The median lethal concentration (LC50) in rats was reported to be greater than 5000 ppm (OECD 2001).

Irritation	Based on an inhalation study in mice, it was reported that 1268 ppm (3909 mg/ m³) of the chemical was predicted to be intolerable in humans, 127 ppm (390.9 mg/ m³) would be uncomfortable in humans and 13 ppm (40 mg/ m³) was expected to have no effect on humans (OECD 2001). Moderate irritation was reported in a 24 hour patch test (non-guideline study) where 405 or 500 mg of the chemical was applied to the skin of the rabbits. It was reported that these effects may be due to the chemical's defatting (chemical dissolving of dermal lipids from the skin) and drying characteristics (OECD 2001). Another non-guideline study reported the chemical was a skin irritant in several Vienna white rabbits exposed to 0.5 mL of the chemical for five minutes, one hour or two hours under occlusive conditions. The animals were observed for eight days. The authors concluded that exposure for two hours under occlusive conditions resulted in higher Draize scores and observed superficial necrosis (death of tissue). However, there was no full thickness destruction of the skin (REACH). The chemical was reported to be a severe eye irritant when tested according to OECD Test Guideline (TG) 405 using 0.1 mL of the chemical applied to three New Zealand white rabbits. Severe occular lesions were present at the end of the seven day observation period, indicating severe eye damage and irreversible effects on the eye (REACH). The chemical was reported to be a severe eye irritant in rabbits in non-guideline studies where 1.62 or 20 mg of the chemical was applied into rabbit eyes over a 24 or 72 hour period (OECD 2001). An additional non-guideline study reported severe corneal irritation when 0.005 mL of the chemical was applied into rabbit eyes.
Sensitisation	Based on available repeat dose dermal studies, the chemical is not expected to be a skin sensitiser. OECD (2001) reported that human studies and experience show that the chemical is not likely to be a skin sensitiser.
Health Effects Summary	The critical health effects for risk characterisation include local effects (serious damage to the eyes and respiratory irritation). The chemical also possesses hazardous properties such as skin irritation, harm if ingested and chemical vapours causing drowsiness and dizziness.
Key Study/Critical Effect for Screening Criteria	n-Butyl alcohol was only slightly toxic to experimental animals following acute oral, dermal, or inhalation exposure. The acute oral LD50 values for female rats ranged from 790 to 4360 mg/kg.
Ecological Toxicity [3]	
Aquatic Toxicity	Results on acute aquatic toxicity are available for fish (Pimephales promelas, LC50 (96h) 1376 mg/l), invertebrates (Daphnia magna, EC50 (48h) 1328 mg/L), and algae (Selenastrum capricornutum, EC50 (96h) 225 mg/L). EC10 (17h) as determined for Pseudomonas putida was 2476 mg/L. Furthermore, based on the chronic NOECrepro (21d) of 4.1 mg/L for Daphnia magna butan-1-ol is very likely not harmful to aquatic organisms. Thus, no adverse effects were observed.
Determination of PNEC aquatic	A PNECaqua = 0.082 mg/L can be calculated based on the lowest chronic toxicity value (21 day NOEC = 4.1 mg/L) for aquatic invertebrates (Daphnia) with the assessment factor of 50.
Current Regulatory Controls[4]	
Australian Hazard Classification	The chemical is classified as hazardous with the following risk phrases for human health in the Hazardous Substances Information System (HSIS) Safe Work Australia: Xn; R22 (Harmful if swallowed) Xi; R37/38-41 (Irritating to respiratory system and skin. Risk of serious damage to eyes) R67 (Vapours may cause drowsiness and dizziness)
Australian Occupational Exposure Standards	The chemical has an exposure standard of 152 mg/m³ (50 ppm) Peak limitation Time Weighted Average (Ceiling TWA).

International Occupational Exposure Standards	The following exposure standards were identified (Galleria Chemica): Ceiling TWA: 150- 152 mg/m³ (50 ppm). India, Indonesia, Japan (OEL), Malaysia and USA [National Institute for Occupational Safety and Health (NIOSH)]. Ceiling TWA: 90 mg/m³ (30 ppm). Canada (British Colombia), Estonia, Russia and Sweden. TWA: 150- 154 mg/m³ (50 ppm). Canada (Yukon), Chile, Denmark, Egypt, Iceland, Poland and Switzerland. TWA: 300- 310 mg/m³ (100 ppm). Germany, Greece, Taiwan and USA [Occupational Safety and Health Administration (OSHA)]. TWA: 45- 75 mg/m³ (15-25 ppm). Canada (Alberta, British Colombia, Saskatchewan), Estonia, Hungary, Ireland, Japan [Workplace Exposure Standards (WES) and Working Environment Evaluation Standards (WEES)], Norway and Sweden.
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	No data available.
PBT Assessment	
P/vP Criteria fulfilled?	No. n-Butanol is considered readily biodegradable.
B/vB criteria fulfilled?	No. Due to the low log Pow (1.0), accumulation in organisms is not to be expected.
T criteria fulfilled?	Not applicable. Chronic toxicity data >1 mg/L in invertebrates, thus butyl alcohol does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	January 2019

References

1. NICNAS (2017) Human Health Tier II Assessment for 1-Butanol: Retrieved 2019: https://www.nicnas.gov.au
2. OECD (2005) SIDS Initial Assessment Profile on 1-Butanol
3. ECHA REACH, 1-Butanol, Retrieved 2019: https://echa.europa.eu/

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Toxicity Summary - Chlorous acid, sodium salt

Chemical and Physical Properties [1,2,3]	
CAS number	7758-19-2
Molecular formula	ClHO2.Na
Molecular weight	90.4
Solubility in water	571 g/L at 20 °C
Melting point	234 °C
Boiling point	Decomposes > 170 °C. Poor purity of test substance, accurate value cannot be obtained.
Vapour pressure	1.1 x 10^{-7} Pa at 25°C
Henrys law constant	No data available.
Explosive potential	At normal temperature and pressure, the natural form of chlorine dioxide is unstable, highly reactive (an oxidizing agent) and explosive. It is explosive when its concentration in air exceeds 10% v/v when it is easily detonated by sunlight, heat, contact with mercury or carbon monoxide (O'Neil et al. 2001).
Flammability potential	Non-flammable
Colour/Form	White crystals or crystalline powder, odourless
Overview	The commercial production of sodium chlorite is carried out in two steps: firstly, sodium chlorate is reacted with an acid to generate chlorine dioxide (gas) and secondly, chlorine dioxide is reacted with caustic soda, catalysed by hydrogen peroxide, to form sodium chlorite. The industrial product formed is a solution of 34.5%; the commercial grade is obtained by dilution with water. Chlorine dioxide may also be produced from sodium chlorate. The total amount of sodium chlorite (as 100%) sold on average in the EU Member States (15) for the years 1998-2000 was 11 800 tonnes per year. This includes use as preservatives for liquid cooling and processing systems; food and feed area disinfectants; food or feedstocks; molluscicides; and slimicides and other non-defined biocidal use. The estimated annual total consumption of sodium chlorite in Japan is 4000 tonnes.
Environmental Fate [2]	
Soil/Water/Air	Irradiation of sodium chlorite solutions indicated a photodegradation half-life of about 30 minutes with a steady increase in pH (pH 8 to 12.6) and major products identified as hydroxide, chlorine dioxide and chloride with chlorate and hypochlorite as minor products and trace amounts of chlorine. The radiation dose (9000 j/m^2) needed to produce a 50% reduction in chlorite concentration suggests that the doses (200-250 j/m^2) used for drinking water disinfection would not result in a significant reduction in chlorite concentrations (Cosson and Ernst, 1994; Leitner et al., 1992). It is not considered technically appropriate to perform a ready biodegradation test on sodium chlorite. As ready biodegradation studies measure oxygen consumption or carbon dioxide production, none of these techniques can be used to analyse mineralization of this compound. However, sodium chlorite is expected to be rapidly reduced to sodium chloride in the environment, especially in anaerobic conditions. Due to its extremely low lipophilicity and high instability in water, sodium chlorite and hence chlorine dioxide are not expected to bioaccumulate in fish.

Human Health Toxicity Summary [1,2]	
Chronic Repeated Dose Toxicity	In a study used by the World Health Organization (WHO) to establish a drinking water guideline for chlorite in 1993, rats were administered sodium chlorite at doses of 0, 10, 50, 100, 250 and 500 mg/L (equivalent to 0, 1, 5, 10, 25 and 50 mg/kg bw/day) via drinking water for 30, 60 or 90 days (Heffernan et al. 1979). After 30 days, haematological parameters were depressed indicating slight anaemia at 10 and 25 mg/kg bw/day. These were correcting at 60 days and returned to near normal levels by 90 days. Decreases in erythrocyte glutathione levels were observed at 5 mg/kg bw/day and above, but given the magnitude of variations normally seen in mammals, the toxicological significance of these changes was uncertain. The No Observed Adverse Effect Level (NOAEL) established from this study was 5 mg/kg bw/day. In a 14-day range finding study conducted to OECD TG 407, rats were administered sodium chlorite daily by gavage at doses of 0, 25, 50, 100 or 200 mg/kg bw day (CMA 1992a; Harrington et al. 1995a). At 200 mg/kg bw/day, 3 of 10 animals died. At 100 mg/kg bw/day, changes in haematological parameters were seen and body weight gains were reduced. At 50 mg/kg bw/day, body weights in males were reduced and at both 25 and 50 mg/kg bw/day haematocrits were slightly reduced. A follow-up 90-day study was performed in which rats were administered sodium chlorite daily by gavage at doses of 0, 10, 25 or 80 mg/kg bw day (CMA 1992b; Harrington et al. 1995a). At 80 mg/kg bw/day, four of 30 animals died and surviving animals displayed hypoactivity, piloerection and hunched posture. At 25 mg/kg bw/day, one of 30 animals died. Increased salivation was observed at both doses. Treatment-related haematological changes consisting of reduced erythrocyte counts, reduced associated erythrocyte parameters and morphological changes in erythrocytes were observed at 80 mg/kg bw/day. These were accompanied by increases in absolute and relative spleen weights, histopathological abnormalities in the spleen and evidence of irritation of the gastric mucosa. At 25 mg/kg bw/day, minor clinical signs and occasional histopathological abnormalities in the stomach mucosa were seen. There were no haematological changes considered treatment related at this dose. A NOAEL was established at 10 mg/kg bw/day. Data on repeat dose toxicity were also available from a two-generation reproductive toxicity study in rats conducted to OECD TG 416 (Chlorine Dioxide Panel of the Chemical Manufacturers Association 1996; Gill et al. 2000). This study was used by the WHO to revise an earlier drinking water quality guideline for chlorite and chlorate (WHO 2005). A NOAEL of 35 ppm (approximately 3.9 mg/kg bw/day) was derived based on decreased liver weights in two generations. Repeated dose toxicity studies have also been performed in mice. Mice were treated for 30 days with doses equivalent to 0, 0.19, 1.9 and 19 mg/kg bw/day sodium chlorite in drinking water (Moore and Calabrese 1980). Slight changes in haematological parameters suggestive of effects on erythrocyte cell membranes were seen at 19 mg/kg bw/day. A NOAEL of 1.9 mg/kg bw day was established. Similarly, in more limited studies, mice were administered sodium chlorite in drinking water at doses up to approximately 17 mg/kg bw/day for 30, 90 or 180 days. No effects on water consumption, body weight gain, kidney weights or kidney histology were seen (Connor et al. 1985). Also, no dose-related immunomodulatory effects were seen in a study of immunotoxicity in mice receiving sodium chlorite in drinking water at levels up to 30 mg/L for 28 days (Karrow et al. 2001). In conclusion, several rodent studies of 30 to 90 days' duration have reported haemotoxicity from repeated doses of sodium chlorite. A guideline 90-day repeated dose toxicity study in rats reported reduced erythrocyte counts, reduced associated erythrocyte parameters and morphological changes in erythrocytes at 80 mg/kg bw/day. At lower doses, minor clinical signs and occasional histopathological abnormalities in the stomach mucosa were seen. A NOAEL for repeated dose oral toxicity was established from this 90-day study at 10 mg/kg bw/day.

Carcinogenicity	A limited number of carcinogenicity studies indicated that sodium chlorite is not carcinogenic in laboratory animals. In an oral carcinogenicity study conducted similarly to OECD TG 451, groups of 50 male and 50 female rats were exposed to sodium chlorite in drinking water at concentrations of 0, 300 or 600 mg/L (estimated to be 0, 18 or 32 mg/kg bw/day for males and 0, 28 or 41 mg/kg bw/day for females) for 85 weeks. The original study envisaged an exposure period of 104 weeks, but was stopped at 85 weeks due to infections in all groups. At this time there were no significant changes in organ weights and haematological or clinical chemistry findings between groups. Tumours developed in the testis, uterus, pituitary gland, thyroid gland (males) and adrenal gland (males) of both treated and control rats. However, the incidences of tumours and non-neoplastic lesions in the three groups were not significantly different. There were no findings suggestive of a carcinogenic effect of sodium chlorite (Shimoyama et al., 1985). In another oral carcinogenicity study conducted similarly to OECD TG 451, groups of 50 male and 50 female B6C3F1 mice were exposed to sodium chlorite in drinking water at concentrations of 0, 250 or 500 mg/L (estimated to be 0, 36 and 71 mg/kg bw/day) for 85 weeks (Yokose et al., 1987). After 85 weeks, surviving animals were euthanised and histopathological examinations were performed. Although tumours developed in a variety of organs in all animals including controls, the only significant change was an increase in lung adenomas in highest dose males: 5/43 (12 %) in this group, compared with 0/35 (0 %) in the control group. Based on an absence of dose-related increases in the incidence of lung adenomas and the lack of increased incidence of lung adenocarcinomas, the authors concluded that sodium chlorite had no carcinogenic potential.
Mutagenicity/ Genotoxicity	Sodium chlorite is not mutagenic or genotoxic. In vitro genotoxicity test results for sodium chlorite are not available. In the three in vivo tests that looked at chromosomal damage or sperm head abnormality, sodium chlorite gave negative results for genotoxicity (Meier et al., 1985). In vitro tests using chlorine dioxide have been reported in the literature. Chlorite (and chlorate) ions are produced following dissolution of chlorine dioxide in aqueous media. Therefore, in vitro test results for chlorine dioxide are regarded as relevant to sodium chlorite. Two of the three in vitro tests, the mouse lymphoma forward mutation assay and in vitro transformation of BALB/3T3 cells, were negative for chlorine dioxide, whereas the chromosome aberration frequencies test in Chinese hamster ovary cells was positive (Scopas, 1986a, Scopas, 1986b and Scopas, 1986c). Across all available studies, data suggest that sodium chlorite (and chlorine dioxide) has low genotoxic potential.

Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Based on a series of studies of fertility and sperm parameters in rats, sodium chlorite is not considered to be toxic to the reproductive system. Studies in rats and rabbits did not show any effect of sodium chlorite on development. In a rabbit study conducted according to US EPA guidelines, sodium chlorite was administered via drinking water to groups of 16 pregnant New Zealand White rabbits at concentrations of 0, 200, 600 or 1200 mg/L during gestation days (GD) 7–19 (Harrington et al., 1995b). At 600 and 1200 mg/L, dose-related reductions in water consumption (due to palatability problems), food consumption and body weight gain were observed. No treatment-related abnormalities were observed at maternal necropsy. Overall, data indicate that sodium chlorite does not cause developmental toxicity at doses below those associated with maternal toxicity. In a two-generation reproduction study in rats conducted according to OECD TG 416 (Gill et al. 2000), groups of 30 male and 30 female Sprague-Dawley rats were administered sodium chlorite via drinking water at doses of 0, 35, 70 or 300 ppm (approximately 0, 4, 7.6 or 28.2 mg/kg bw/day for males and 0, 3.9, 8 and 38.7 mg/kg bw/day for females) (Chlorine Dioxide Panel of the Chemical Manufacturers Association 1996; Gill et al. 2000). Dosing was conducted in the parental F0 generation commencing 10 weeks prior to mating, until weaning of the F2 generation. Males were exposed through mating and then sacrificed. Females were exposed through mating, pregnancy and lactation and were sacrificed following weaning of litters. F1 pups were continued on the same treatment regime as the parents. At 14 weeks they were mated to produce the F2 generation. Reductions in food and water consumption and body weight gain were observed for all generations, attributed to unpalatability of the formulated drinking water. At 35 and 70 ppm, minor reductions in several haematological parameters were observed in F1 female pups. These appeared within the range of historical control data and were not regarded as toxicologically significant. At 70 ppm, a reduction in liver weight was also observed in F0 females and F1 males and females. A slight decrease in the maximum response to auditory startle stimulus was also observed in F2 pups. At 300 ppm, reductions in haematological parameters were seen in F1 male and female pups and adults. Reduced liver weights were seen in F0 adult males, F1 adult males and females and F1 pups. Reduced thymus and spleen weights were also seen in both generations. A slight decrease in absolute brain weight was seen in F1 male pups at post-natal day (PND) 11 but not at PND 25. In F2 pups at this dose, there was a slightly lowered incidence of normal righting reflexes and a slight decrease in the maximum response to auditory startle stimulus. Reduced pup body weight at birth and during lactation in F1 and F2 generations were also observed. Delays in preputial separation and vaginal openings were reported for F1 pups. Despite systemic toxicity, the authors reported no treatment-related changes to oestrous cyclicity, sperm motility, sperm morphology, or mating, fertility or gestational indices. Also, there were no treatment-related changes in number of pups born, sex ratios, live birth index or pup survival indices. There were no treatment-related changes in serum T3 or T4 in F1 pups or F1 adults. On the basis of historical data, delays in preputial separation and vaginal openings reported for F1 pups were attributed to reduced body weight rather than a direct treatment-related effect. Similarly, slight decreases in brain weight in male pups were consistent with decreased body weight. The toxicological significance of decreases in auditory startle stimulus response at 70 and 300 ppm was unclear. The magnitude of responses was small compared to known neuroactive chemicals, dose response to the stimulus was weak, there was a lack of corroborative evidence from neuropathology or other test of motor function or arousal, and the decreases in response were not replicated upon later examination of the same animals at PND 60 (Gill et al. 2000). A NOAEL of 35 ppm (approximately 3.9 mg/kg bw/day) with a LOAEL at 70 ppm (approximately 7.6 mg/kg bw/day) were derived based on decreased liver weights.

Acute Toxicity	Sodium chlorite has moderate acute oral toxicity. An acute oral toxicity study in rats, similar to OECD Test Guideline TG 401, derived a lethal median dose (LD50) of 284 mg/kg bw for sodium chlorite. At doses of 250 mg/kg bw and above, the main clinical signs were prostration and cyanosis (Atochem, 1984). Sodium chlorite has high acute dermal toxicity. In a dermal toxicity study in rabbits, conducted according to US EPA test guidelines, various doses of an aqueous slurry (80 %) of sodium chlorite were administered under semi-occlusive dressings to over 10 % of the body surface area for 24 hours. Animals were observed for clinical signs immediately after dosing, at one and four hours and then once daily for 14 days following exposure. Slight depression and dose-related dermal irritation consisting of skin thickening, epidermal scaling, necrosis and sloughing were noted in all animals. The study reported a dermal LD50 of 134 mg/kg bw (Degussa Corporation, 1984).
Irritation	Sodium chlorite is a severe skin irritant. Necrosis was observed in rabbits in the skin irritation studies. In one skin irritation study conducted according to US EPA test guidelines, 0.5 g sodium chlorite powder (80 % pure) was applied to three male and three female New Zealand White rabbits under occlusive conditions for four hours. Dermal responses were assessed at 30–60 minutes on day one, and once daily for 21 days after application. Irritation consisted of erythema (grades 1–3) in all sites at 30–60 minutes and 24 hours after dosing, persisting through day seven at two sites. Oedema (grade one) was observed at one site at 30–60 minutes and at two sites at 48 hours. Other dermal effects included blanching, thickening, necrosis, sloughing, and blackened areas (REACH, 2014). In another study in rabbits, edema cutis and subcutis were observed immediately after patch removal followed by formation of eschar within 24–48h. Dose and other details of the test were not provided (REACH, 2014) A 34.5 % solution of sodium chlorite, applied to rabbit skin for four hours under semi-occlusive conditions, did not elicit any irritation effects. Only one of three animals displayed slight erythema and dryness of the skin (Elf Atochem SA, 1994). In the only eye irritation study available and conducted according to US EPA test guidelines, sodium chlorite was found to be a severe eye irritant. A 31.5 % sodium chlorite solution was applied to the eyes of rabbits. Six of the nine rabbits showed corneal opacity that did not reverse by rinsing the eyes 30 seconds after instillation. All animals showed iris damage and exhibited moderate to severe redness and chemosis which was also not abolished by rinsing. Superficial corneal vascularisation and transient cases of haemorrhaging and adhesion of conjunctivae to cornea were also seen (Atochem, 1985).
Sensitisation	Sodium chlorite is not considered to be a skin sensitiser. A guinea pig maximisation test conducted according to OECD TG 406 reported no clinical signs and no cutaneous reactions upon a challenge application of 1 % sodium chlorite in normal saline. Sodium chlorite was concluded not to be a skin sensitiser (CEFIC sodium chlorite sector group, 2002).
Health Effects Summary	The critical health effects for risk characterisation include acute effects from oral and dermal exposure, and severe skin and eye irritation and repeated dose toxicity from oral exposure.
Key Study/Critical Effect for Screening Criteria	A guideline two-generation reproductive toxicity study in rats also reported haemotoxicity, as well as hepatotoxicity and slight neurobehavioural changes at doses below those associated with no effects in repeated dose studies. The study reported no effects on fertility or development. Accordingly, a NOAEL for hepatotoxicity was established from this 2- generation study at 3.9 mg/kg bw/day. The LOAEL was approximately 7.6 mg/kg bw/day. This NOAEL is used for this human health risk assessment.
Ecological Toxicity [2]	

Aquatic Toxicity	Sodium chlorite, in general, shows low acute toxicity to fish with LC50 values above 100 mg/l for zebrafish, sheepshead minnow and rainbow trout and slightly lower for bluegill sunfish. Due to extremely low lipophilicity and high instability in water, sodium chlorite is not expected to bioaccumulate in fish. Sodium chlorite is more toxic to invertebrates with high toxicity to Daphnia magna (sodium chlorite, LC50 48-hour = 0.063 mg/l) and the crustacean, Mysidopsis bahia (sodium chlorite LC50 96-hour = 0.65 mg/l). However, the mollusc, Crassostrea virginica was much less sensitive (sodium chlorite 96 hours NOEC was 70.6 mg/l and the EC50 (shell growth) was 129 mg/l). The green algae were more sensitive to sodium chlorite than fish or oyster and toxicity increased with time (ECr50 value at 72 hours was recorded as 1.2 mg/l).
Determination of PNEC aquatic	Using an uncertainty factor of 100 on the lowest LC50 to Daphnia a PNEC (Predicted No Effect Concentration) of 0.63 ug/L is calculated, for aquatic organisms.
Current Regulatory Controls[1]	
Australian Hazard Classification	The chemical is not listed on the Hazardous Substances Information System (HSIS) (Safe Work Australia).
Australian Occupational Exposure Standards	There is no specific exposure standard for sodium chlorite. However, the permissible exposure limits for dusts apply: · Time Weighted Average (TWA): 10 mg/m^3 measured as inspirable dust.
International Occupational Exposure Standards	There are no specific exposure standards for sodium chlorite. However, the following exposure standards for particulates are identified (Galleria Chemica 2013). TWA: · 10 mg/m^3 [Canada, Ireland, Spain] · 5 mg/m^3 [US] · 1 mg/m^3 [Latvia].
Australian Food Standards	Sodium chlorite has the following listings in the Australia New Zealand Food Standards Code – Standard 1.3.3 Processing Aids (Food Standards Australia and New Zealand 2013): · As a permitted bleaching agent, washing and peeling agent (maximum level 1 mg/kg available chlorine) · As a permitted processing aid with miscellaneous functions (anti-microbial agent for meat, fish, fruit and vegetables; maximum level is the limit of determination for chlorite, chlorate, chlorous acid and chlorine dioxide).
Australian Drinking Water Guidelines	The National Health and Medical Research Council (NHMRC) Australian Drinking Water Guidelines lists chlorite under microbial, chemical and physical characteristics as a by-product of chlorine dioxide disinfection. The guideline value for chlorite based on health considerations is 0.8 mg/L (NHMRC 2011).
Aquatic Toxicity Guidelines	No data available.
PBT Assessment [3]	
P/vP Criteria fulfilled?	No. Not expected to be persistent due to its instability.
B/vB criteria fulfilled?	No. There is no concern for potential bioaccumulation from chlorine chlorite.
T criteria fulfilled?	Yes. Acutely toxic to aquatic invertebrates.
Overall conclusion	Not PBT
Revised	January 2019

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Toxicity Summary - 2-hydroxy-N,N,N-trimethylethanaminium

Chemical and Physical Properties[1,2,3,4]	
CAS number	67-48-1
Molecular formula	$C_5H_{14}NOCl$
Molecular weight	139.63 g/mole
Solubility in water	Very soluble in water and alcohol
Melting point	247°C
Boiling point	Decomposition upon heating
Vapour pressure	6.57 x 10^{-8} Pa at 25°C
Henrys law constant	2.06*10E-11 Pa*m³/mole at 25°C
Explosive potential	Not explosive
Flammability potential	Combustible. Gives off irritating or toxic fumes (or gases) in a fire.
Colour/Form	white crystalline solid
Overview	Choline chloride is a quaternary amine salt, it dissociates in water into the corresponding positively charged quaternary hydroxyl alkylammonium ion and the negatively charged chloride ion. Choline chloride has neither explosive nor oxidizing properties due to its molecular structure Choline is a dietary component and found in foods as free choline and as esterified forms such as phosphocholine, glycerophosphocholine, sphingomyeline, and phosphatidylcholine. It functions as a precursor for acetylcholine, phospholipids, and the methyl donor betaine and is important for the structural integrity of cell membranes, methyl metabolism, cholinergic neurotransmission, transmembrane signalling, and lipid and cholesterol transport and metabolism. Evidence from animal studies and from human exposure indicates that choline chloride has low toxicity, is not mutagenic and has no developmental toxicity. This is not unexpected in view of its presence in the diet and its production in metabolic processes in the body; it fulfils key roles in nerve transmission, cell membrane integrity, and lipid metabolism. Only limited animal data are available on effects on fertility, but the normal exposure of humans to appreciable amounts of choline chloride both from the diet and formed from normal metabolic processes, would argue against it having any significant adverse effects on fertility. This is supported by the fact that it has been widely used as an animal feed additive for decades with no apparent adverse effects being noted on fertility. A Tier 1 Human Health Assessment for this chemical has been conducted by NICNAS which concluded that this chemical was identified as low concern to human health.
Environmental Fate[1,3,4]	
Soil/Water/Air	Distribution modelling using Mackay Level I indicates water (100 %) to be the main target compartment. The amount in the other compartments is with < 0.0001 % negligible. Choline chloride is readily biodegradable according to OECD-criteria (MITI-I Test; BOD measurements) reaching 93 % degradation within 14 days. Due to the chemical structure hydrolysis can be excluded. In the atmosphere choline chloride will be rapidly degraded according to a half-life time (t½) of about 6.9 hours for hydroxyl-radicals based on a 12 hours day. Due to the measured and calculated logKow of –3.77 and –5.16 both at 25°C, respectively, and a calculated logKoc of 0.37 a bio- or geoaccumulation is not to be expected.

Human Health Toxicity Summary [1,3,4,5]	
Chronic Repeated Dose Toxicity	A 72-week feeding study was conducted to investigate the impact of choline chloride on the liver tumour promoting activity of phenobarbital and DDT in diethylnitroamineinitiated Fischer 344 rats (Shivapurkar *et al.*, 1986). Animals received approximately 500 mg/kg-day choline chloride. Following the end of the exposure period, the animals were kept on the same untreated diet as the control group until study termination at week 103. Histopathology was limited to the liver and organs that developed gross abnormalities. There were no significant differences between treated and control animals on survival rates, body weights, and relative liver weights. Neither was there any increased number of neoplastic liver nodules, hepatocellular carcinomas, lung tumours, leukaemia nor other tumours between treated and control animals. The NOAEL for choline chloride in this study is 500 mg/kg/day In humans, oral administration of 10,000 mg/day choline chloride in a pilot study treating a small number of patients with Alzheimer's disease, resulted in a slight hypotensive effect (Boyd *et al.*, 1977). This dose was regarded as a LOAEL by the Standing Committee on the Scientific Evaluation of Dietary Reference Intake (2000).
Carcinogenicity	No studies were located.
Mutagenicity/ Genotoxicity	Choline chloride was not mutagenic to bacteria in reverse mutation assays (Haworth *et al.*, 1984; JETOC, 1997; Litton Bionetics, 1977). A small, but statistically significant, and dose-related increase in sister chromatid exchanges (SCEs) in Chinese Hamster Ovary (CHO) cells was reported at 50 and 500 µg/ml choline chloride in the absence of S9 only (Bloom *et al.*, 1982). No higher concentrations were examined. These results could not be confirmed in another study using CHO cells at concentrations of choline chloride up to 5,000 µg/ml. (Galloway *et al.*, 1985). In a gene conversion assay with *Saccharomyces cerevisiae* strain D4, choline chloride was negative in the presence and absence of metabolic activation (Litton Bionetics, 1977). No *in vivo* genotoxicity studies were available.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Pregnant female mice were given in their feed 1,250 to 20,000 mg/kg choline chloride during gestational days 1 to 18 (BASF AG, 1966). Maternal body weight gain was reduced in all treated groups except for the 1,250 mg/kg group. Determination of maternal weight gain of dams with embryonic/foetal absorptions showed that there was no All foetuses were resorbed in the 20,000 mg/kg group. Embryonic/foetal lethality of 35% and 69% were seen in the 4,160 and 10,800 mg/kg groups, respectively. No resorptions occurred in the 1,250 mg/kg group. Developmental toxicity was seen in all but the 1,250 mg/kg group. No statistically significant increases in malformations were observed in any dose group. The NOAELs for maternal and developmental toxicity is 1,250 mg/kg/day.
Acute Toxicity	The oral LD50 in rats was reported to be between 3,150 and 5,000 mg/kg (BASF AG, 1963a, 1969).
Irritation	Application of a 70% aqueous solution to the skin of rabbits for 20 hours under occlusive conditions resulted in only minor skin irritation (BASF AG, 1963b). Slight eye irritation was seen in the eyes of rabbits after instillation of a 70% aqueous solution of choline chloride; no effects were seen one day after exposure (BASF AG, 1963c).
Sensitisation	No data are available in animals. In a Human Repeated Insult Patch Test, there was no evidence of dermal sensitization in two hundred subjects given 0.5% (w/v) aqueous solution of choline chloride during the induction phase and 0.2% (w/v) aqueous solution during the challenge phase (Colgate-Palmolive, 2003).
Health Effects Summary	This chemical has been identified by NICNAS to be of low concern to human health.

Key Study/Critical Effect for Screening Criteria	The Standing Committee on the Scientific Evaluation of Dietary Reference Intakes selected hypotension as the critical effect from the study by Boyd *et al.* (1977) when deriving a Tolerable Upper Intake Level. Boyd *et al.* (1977) reported a LOAEL of 10,000 mg/day choline chloride (7,500 mg/day choline). An uncertainty factor of 2 was chosen because of the limited data regarding hypotension and the inter-individual variation in response to cholinergic effects. Thus, the value for the Tolerable Upper Intake Value for repeated exposure of adults to choline is 3,500 mg/day choline. The oral RfD for choline chloride is derived by using the LOAEL of 10,000 mg/day from the Boyd *et al.* (1977) study, which is divided by an uncertainty factor of 2, to obtain a value of 5,000 mg/day or 71 mg/kg/day for a 70 kg person. Oral RfD = 71 mg/kg/day Drinking water guideline value = 248 ppm
Ecological Toxicity [4]	
Aquatic Toxicity	The 96-hour fish LC50 value is >100 mg/L (nominal and measured) in *Oryzias latipes* (MOE Japan, 1999a), and the 48-hour in vertebrate EC50 is 349 mg/L (nominal and measured) in *Daphnia magna* (MOE Japan, 1999b). The 72-hour EC50 to *Pseudokirchneriella subcapitata* is >1,000 mg/L (nominal and measured) based on growth rate; the 72-hour NOEC is 32 mg/L (MOE Japan, 1999c). In a 21-day *Daphnia magna* reproduction test, the nominal and measured NOEC was reported to be 30.2 mg/L (MOE Japan, 1999d).
Determination of PNEC aquatic	PNECaquatic: Experimental results are available for three trophic levels. Acute E(L)C50 values are available for fish (>100 mg/L), invertebrates (349 mg/L), and algae (>1,000 mg/L). Results from chronic studies are available for invertebrates (21-day NOEC = 30.2 mg/L) and algae (72-hour NOEC = 32 mg/L). On the basis that the data consists of chronic studies on two trophic levels, an assessment factor of 10 has been applied to the lowest reported NOEC of 30 mg/L for Daphnia. The PNECaquatic is 3.02 mg/L.
Current Regulatory Controls	
Australian Hazard Classification	No data available
Australian Occupational Exposure Standards	No data available
International Occupational Exposure Standards	No data available
Australian Food Standards	No data available
Australian Drinking Water Guidelines	No data available
Aquatic Toxicity Guidelines	No data available
PBT Assessment [3]	
P/vP Criteria fulfilled?	Choline chloride is readily biodegradable and thus it does not meet the screening criteria for persistence.
B/vB criteria fulfilled?	Based on a measured log Kow of -3.77 and a calculated BCF of 0.59, choline chloride does not meet the screening criteria for bioaccumulation.
T criteria fulfilled?	The chronic toxicity data on choline chloride show NOECs of >0.01 mg/L. Thus, choline chloride does not meet the screening criteria for toxicity.
Overall conclusion	Not a PBT substance (based on screening data).
Revised	December 2018

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Toxicity Summary - Cinnamaldehyde

Chemical and Physical Properties [1,2,3,4]	
CAS number	104-55-2
Molecular formula	C9H8O
Molecular weight	132.16
Solubility in water	2.11 g/L at 22 °C
Melting point	-18 °C
Boiling point	250°C
Vapour pressure	3.85 Pa at 25 °C
Henrys law constant	0.162 Pa.m³.mol-1 at 25 °C
Explosive potential	Non-explosive
Flammability potential	Non-flammable
Colour/Form	Yellowish oily liquid with strong odour of cinnamon
Overview	Cinnamaldehyde is a plant natural product that is present in some essential oils extracted from plants. For large scale applications such as in the flavouring and fragrance industries, this chemical is synthesised.
Environmental Fate [1,3]	
Soil/Water/Air	Cinnamaldehyde is expected to remain in soil, or partition to water and sediment, when released as a result of industrial uses. It is not expected to be persistent in the environment and is expected to undergo rapid and ultimate biodegradation in water. Cinnamaldehyde is not expected to bioaccumulate in aquatic organisms. No evidence has been identified to indicate that Cinnamaldehyde biomagnify through the aquatic food chain. The atmospheric oxidation half-life of cinnamaldehyde was estimated using the level III multimedia model. It was estimated that the substance is not persistent in air medium as the half-life period of cinnamaldehyde in air is only 0.31 days. This indicates that cinnamaldehyde is rapidly phototransformed in air. The Hydrolysis rate constant of Cinnamaldehyde is estimated to be 3.36 x 10-17 cm3/molecule-sec. at half-life of 3.411 days indicating that the substance is slowly hydrolysable.
Human Health Toxicity Summary [2,4]	
Chronic Repeated Dose Toxicity	Cinnamaldehyde is 'generally regarded as safe' for use as a flavour ingredient by the US Food and Drug Administration (US FDA, 2015), reflecting the low level of concern regarding its potential for long-term toxicity via the oral route. Considering the no observed adverse effect levels (NOAELs) of 68–200 mg/kg bw/day, based on 17-week to 2-year rat studies (read across), and no toxicologically significant treatment-related effects reported in various studies, repeated oral exposure to the chemical is not considered to cause serious damage to health. Based on the limited data available, the chemical is not considered to cause serious damage to health by repeated dermal exposure.
Carcinogenicity	Based on the limited data available for cinnamaldehyde and trans-cinnamaldehyde (CAS No. 14371-10-9), the chemical is not expected to have carcinogenic potential. In a two-year carcinogenicity study, groups of F344/N rats and B6C3F1 mice (50 animals/sex/dose) were fed microencapsulated trans-cinnamaldehyde (CAS No. 14371-10-9) by daily gavage at doses of 0, 1000, 2100 or 4100 ppm (equivalent to 0, 50, 100 or 200 mg/kg bw/day). Increased incidences of preputial and prostate gland adenomas and mononuclear cell leukaemia were considered to be within the historical range in controls, or likely to represent biological variations unrelated to exposure to the chemical. No other treatment-related neoplasms or non-neoplastic lesions were reported in either species (Adams et al., 2004; NTP, 2004; REACH; US HPVIS, 2009).

Mutagenicity/ Genotoxicity	The chemical cinnamaldehyde contains an a,b-unsaturated aldehyde group, a common structural alert for genotoxicity due to the ability of the chemical to form DNA adducts. However, based on the available data, the chemical is not considered to be genotoxic. The chemical cinnamaldehyde and the isomer trans-cinnamaldehyde (CAS No. 14371-10-9) were negative for point mutations in almost all strains of Salmonella typhimurium in the Ames test. A positive result was found only with TA100 strain, and in only two out of eleven tests. Evidence of genotoxic activity was also observed in isolated mammalian cells. However, these results were weakly positive and observed at cytotoxic concentrations. A sex-linked recessive lethal test in Drosophila melanogaster demonstrated that systemically-available chemical (administered via injection) could enter germ cells and induce mutations; however, oral dosing did not produce the same effect. Importantly, the reported activity in in vitro and insect studies did not translate into significant genotoxic activity in mammalian systems in vivo.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	The chemical is not expected to have the potential for reproductive or developmental toxicity. Any developmental effects were only observed secondary to maternal toxicity. In a two-generation study in rats (strains not reported), cinnamaldehyde (absolute dose 2 mg—route not specified) was dosed every two days for 223 and 210 days and did not have any effects on body weight gain, reproductive ability, development or viability of offspring (NTP, 2004). Cinnamaldehyde in olive oil was administered to female SD rats via oral gavage at doses of 0, 5, 25 or 250 mg/kg bw/day on gestation days (GD) 7–17. Treatment-related, increased incidence of defective cranial ossification in all dose groups was observed. Renal abnormalities including dilated pelvis and reduced papilla and dilated ureters were observed at low and mid doses, but not at high dose. Offspring at ≥25 mg/kg bw/day had significantly increased instances of reduced ossification of the tympanic bulla. An increase in the incidence of abnormal sternebrae was also reported in the 25 mg/kg bw/day group. However, these effects were not found to be dose-related and may be attributed to a decrease in maternal weight gain that was noted in the mid- and high-dose groups. A LOAEL of 5 mg/kg bw/day for developmental toxicity was reported based on the reduced cranial ossification and kidney variations. A LOAEL of 25 mg/kg bw/day was reported for maternal toxicity based on the reduced weight gain observed in the dams (Adams et al., 2004; NTP, 2004; US HPVIS, 2009; HSDB; REACH). No signs of toxicity were reported in the dams or in the offspring of CD-1 mice after exposure to 1200 mg/kg bw/day during GD 6–13 (cinnamaldehyde) or GD 7–14 (trans-cinnamaldehyde) (NTP, 2004; US HPVIS, 2009; REACH).
Acute Toxicity	Cinnamaldehyde has low acute oral toxicity based on animal studies. The median lethal dose (LD50) in rats is >2000 mg/kg bw. Cinnamaldehyde has moderate acute dermal toxicity based on animal studies, warranting hazard classification. The dermal LD50 in rabbits was in the range of 620–1260 mg/kg bw (Bickers et al., 2005; Cocchiara et al., 2005; FFHBVC, 2005; and US HPVIS, 2009). Albino rabbits (2 animals/dose) were administered a single dose of cinnamaldehyde (0, 0.25, 0.50, 1.0, 2.0 or 4.0 mL/kg bw—equivalent to 0, 263, 525, 1050, 2100 or 4200 mg/kg bw) by application to intact and abraded skin. All animals in the 1.0 mL/kg and higher dose groups died after treatment. The LD50 was reported to be 620 mg/kg bw (Cocchiara et al., 2005; FFHPVC, 2005; US HPVIS, 2009; REACH).
Irritation	Respiratory irritation was assessed in CF-1 female mice by recording their respiratory rate following exposure to nebulised cinnamaldehyde for 1 minute, either through nose-only breathing or via a tracheal cannula. Marked respiratory depression with nose-only inhalation was observed. The ED25 (dose providing a 25 % reduction in respiratory rate) was calculated to be 241 µg/L. No significant effects were observed when inhalation was through the tracheal cannula (Cocchiara et al., 2005). Cinnamaldehyde produced severe irritation in rabbits when applied undiluted, mild irritation in mice and guinea pigs at concentrations of 3–5 %, and was non-irritating to rabbits at 1 % (Bickers et al., 2005). The US EPA considers cinnamaldehyde a strong skin irritant in guinea pigs (no study details provided) (US HPVIS, 2009). Several international agencies have concluded that cinnamaldehyde is an eye irritant (US HPVIS, 2009; REACH), and a number of notifications to the Classification and Labelling Inventory by industry in the European Union have indicated the chemical as irritating to the eyes (ECHA C&L).

Sensitisation	The chemical was considered to be a moderate to strong skin sensitiser based on the positive results in several local lymph node assays (LLNA). The EC3 value (concentration required to provoke a 3-fold increase in lymph node cell proliferative activity compared with controls) was reported to be as low as 0.2 % (SCCS, 2012).
Health Effects Summary	Cinnamaldehyde is a well-recognised and frequently reported consumer contact allergen (SCCNFP, 1999; RIVM, 2009; SCCS, 2012; IFRA, 2013). It is one of eight components of the diagnostic test, the fragrance mix, used by dermatologists to determine if a patient has allergies to common chemicals used in fragrances. It is an established contact allergen in humans according to the Scientific Committee on Consumer Safety (2012), and accounts for 5–36 % of the reactions to the fragrance mix (SCCNFP, 1999). A number of human repeat insult patch tests (HRIPTs) have been undertaken to determine the skin sensitisation potential of cinnamaldehyde in healthy volunteers, as well as groups of subjects suspected of skin allergies to fragrances (SCCNFP, 1999; NTP, 2004; Cocchiara et al., 2005). Although fewer cases of sensitisation were found when the concentration of the chemical was less than 1 %, positive allergic responses have been reported in cases where the administered concentration of cinnamaldehyde was as low as 0.2 % (Cocchiara et al., 2005). Skin irritation effects were generally predominant at concentrations above 3 % cinnamaldehyde, and often impeded the interpretation of results from the patch testing (SCCNFP, 1999; NTP, 2004). Many cases of skin sensitisation have occurred following occupational and consumer exposure to the chemical. Workers in spice manufacturing plants, hairdressing salons and bakeries have reported cases of contact dermatitis that were traced back to cinnamaldehyde. In addition, exposure of consumers to toothpaste, cosmetics and perfumes containing the chemical as a fragrance ingredient have resulted in a number of case studies identifying cinnamaldehyde as an agent responsible for the allergic reactions (see SCCNFP, 1999; NTP, 2004; Cocchiara et al., 2005 for review).
Key Study/Critical Effect for Screening Criteria	The critical health effect for risk characterisation is skin sensitisation. Other observed health effects include systemic acute effects (acute toxicity from dermal exposure) and local effects (eye/skin/respiratory irritation).
Ecological Toxicity [1]	
Aquatic Toxicity	The following data are measured acute toxicity values for cinnamaldehyde: Danio rerio (Zebrafish) EC Directive 92/69/EEC C.1 Acute Toxicity for Fish: 96 h LC50 = 3.1 mg/L; Daphnia magna (Water flea) OECD TG 202: 48 h EC50 = 3.86 mg/L; Pseudokirchneriella subcapitata (Green algae) OECD TG 201: 72 h EC50 = 4.07 mg/L. In the chronic toxicity study, the 72 h NOEC value of 2.0 mg/L was reported for Pseudokirchneriella subcapitata (Green algae) OECD TG 201.
Determination of PNEC aquatic	A PNECaqua = 0.2 mg/L can be calculated based on the chronic toxicity value (72 h NOEC = 2 mg/L) for green algae with the assessment factor of 10.
Current Regulatory Controls[4]	
Australian Hazard Classification	The chemical is not listed in the Hazardous Substances Information System (HSIS) (Safe Work Australia).
Australian Occupational Exposure Standards	No specific exposure standards are available for the chemical.
International Occupational Exposure Standards	The US Temporary Emergency Exposure Limits (TEELs) for cinnamaldehyde are 14, 150 and 670 mg/m^3 (Galleria Chemica).
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	No data available.

PBT Assessment	
P/vP Criteria fulfilled?	Not applicable (inorganic salt, ionic species ubiquitous in environment)
B/vB criteria fulfilled?	Not applicable. Bioaccumulation is not applicable to these inorganic ions; sodium and hydroxide ions are ubiquitous and are present in most water, soil and sediment.
T criteria fulfilled?	Not applicable. Chronic toxicity data >1 mg/L in invertebrates, thus sodium hydroxide does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	January 2019

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2. NICNAS (2017b) Human Health Tier II assessment for 2-Propenal, 3-phenyl-
3. HSDB (n.d.). *Hazardous Substances Data Bank*. Retrieved 2015, from Toxnet, Toxicology Data Network, National Library of Medicine: http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB
4. ECHA REACH, Cinnamaldehyde, Retrieved 2017: https://echa.europa.eu/information-on-chemicals/registered-substances

Toxicity Summary - Citric acid

Chemical and Physical Properties[2,3,5]	
CAS number	77-92-9
Molecular formula	C6-H8-O7
Product name	--
Molecular weight	192.124
Solubility in water	1000000 mg/L
pH	2 to 2.2
Melting point	Decomposition > 175 C
Boiling point	152 to159 C
Vapour pressure	White powder or granules
Henrys law constant	1.7 x10^{-8} mm Hg at 25 deg C
Explosive potential	4.39 x 10^{-09} Pa.m^3/mol
Flammability potential	Dust explosion possible if powder or granular form, mixed with air
Colour/Form	Melts and decomposes in fire, a non-hazardous reaction.
Overview	Citric acid is a water soluble organic solid. It is a natural substance that appears as an intermediate in the basic physiological citric acid or Krebs cycle in every eukaryote cell. Citric acid has been produced for many years in high volumes. It has wide dispersive use, being added to processed food and beverages, used in pharmaceutical preparations and in household cleaners as well as in special technical applications. Citric acid is recognised by Food Standards Australia New Zealand (FSANZ) and the WHO JECFA as safe as a multipurpose food additive. No upper limit of concentrations has been established in food products. This chemical has been identified by NICNAS to be of low concern to human health based on an initial screening approach and thus required no further assessment.
Environmental Fate[2,5]	
Soil/Water/Air	Citric acid is highly mobile in the environment and is extremely soluble in water. The pKa of citric acid is 2.79, indicating that this compound will exist almost entirely in the anion form in the environment. The compound does not sorb to soil or particles in the water column and is readily and rapidly degraded in surface waters and in soil. (OECD, hsdb)

Human Health Toxicity Summary [1,2,4,5]	
Chronic Repeated Dose Toxicity	A 2-year chronic oral study in rats being given 5% or 3% citric acid in feed (approx. 2 resp. 1.2 g/kg/d) found slightly decreased growth in the higher dosage group but no tissue abnormalities in the major organs. From the lower dosage a NOAEL of 1200 mg/kg/d results. Similarly, NOAELs of 1500 mg/kg/d (rabbit) and of 1400 mg/kg/d (dog) have been determined. In general, citric acid is a strong chelating agent, the dietary uptake of which may interfere with biological availability, absorption and excretion of metals. Further, loss of superficial enamel and erosion of teeth as well as local irritation result from frequent ingestion of citric acid in beverages including natural fruit juices; citric acid fumes were reported to apparently affect the teeth of exposed workers. The average daily intake of citric acid from natural sources in the diet and food additives was estimated at about 40 mg/kg for women, 130 mg/kg for infants and 400 mg/kg for individuals on slimming diets; maximum daily intake is reported to reach levels of 500 mg/kg. No formal ADI (acceptable daily intake) level has been specified for citric acid and its common salts by the Joint FAO/WHO Expert Committee on Food Additives nor by the EC Scientific Committee for Food.
Carcinogenicity	Citric acid has not been classified by the IARC.
Mutagenicity/ Genotoxicity	In several in vitro and in vivo tests citric acid was not mutagenic. The substance was not mutagenic either in bacterial tests with Salmonella typhimurium (Ames test, 2 studies) and Escherichia coli, with and without metabolic activation.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	In a two-generation 90 days study with male and female rats fed 1.2 % citric acid no adverse effect on reproductive parameters nor any teratogenicity of dietary citric acid was seen. There were no indications of teratogenic or other adverse effects in three shorter term reproductive studies in rats with dietary dosage of either 5% citric acid (approx. 2.5 g/kg/d) previous, during and after mating (NOEL = 2500 mg/kg/d), or 295 mg/kg/d (route unspecified) during days 6–15 of pregnancy
Acute Toxicity	Citric acid has a low acute toxicity by oral application in both rat (LD50 = 3,000–12,000 mg/kg, 3 different values) and mouse (LD50 = 5,400 mg/kg). General effects comprised physiological disturbances (acidosis and calcium deficiency), while “high” doses caused nervous system effects as well as severe damage to the stomach mucosa.
Irritation	Local effects of citric acid to the skin (rabbit) are reported as slightly irritating in two studies and as not irritating in a third study using a 30% aqueous solution. In an acute eye irritation/corrosion test in rabbits according to OECD 405 citric acid was highly irritating.
Sensitisation	The sensitising potential is low.
Key Study/Critical Effect for Screening Criteria	A 2-year chronic oral study in rats being given 5% or 3% citric acid in feed resulted in a NOAEL of 1200 mg/kg/d. Uncertainty factors: 10 (interspecies variability) and 10 (intraspecies variability). Drinking water guideline = 4.7 ppm
Ecological Toxicity [1,5]	
Aquatic Toxicity	The 96-hour LC50 values for citric acid to fish are from 440 to 1,516 mg/L. The acute toxicity 24 hour EC50 value for invertebrates is 85 mg/L. The 7 day toxic limit concentration (TLC) values for algae range from 300 to 640 mg/L. In an 8 day freshwater static test for the algae Scenedesmus quadricauda, the NOEC is 425 mg/L. In freshwater, citric acid appears to be of low toxicity to aquatic acute test standard organisms, fish, daphnia and algae, with consistent LC50/EC50 values of several hundred milligrams per litre.

Determination of PNEC aquatic	$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (440 mg/L), Daphnia (85 mg/L). A TLC value of 300 mg/L was obtained for algae from which no dependable EC50 can be derived. Even though a NOEC was obtained from the algae study, there were no chronic studies conducted on fish or Daphnia. On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 85 mg/L for Daphnia Magna. The $PNEC_{aquatic}$ was calculated to be 0.085 mg/L.
Current Regulatory Controls	
Australian Hazard Classification	
Australian Occupational Exposure Standards	
International Occupational Exposure Standards	
Australian Food Standards	
Australian Drinking Water Guidelines	No data found
Aquatic Toxicity Guidelines	No data found
Australian Hazard Classification	
PBT Assessment[1]	
P/vP Criteria fulfilled?	Citric acid is expected to be readily biodegradable and does not persist in the environment
B/vB criteria fulfilled?	Based on the low Log Kow and widespread natural occurrence, citric acid is not expected to have potential for bioaccumulation.
T criteria fulfilled?	Long term data not available (acute data >0.1 mg/L); potentially not toxic.
Overall conclusion	Not a PBT substance (based on screening data).

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3. IPCS Citric Acid, Retrieved 2015: http://www.inchem.org
4. JECFA http://apps.who.int/ipsc/database/evaluations/chemical.aspx?chemID=4785
5. OECD, Citric Acid, Retrieved 2015: http://www.echemportal.org

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Toxicity Summary - Crystalline silica-cristobalite, crystalline silica-quartz

Chemical and Physical Properties[1,3]	
CAS number	Crystalline Silica (Cristobalite) : 14464-46-1 Crystalline Silica (Quartz): 14808-60-7 Diatomacous Earth (Calcined silica): 91053-39-3
Molecular formula	Crystalline Silica (Cristobalite): SiO_2 Crystalline Silica (Quartz): SiO_2 Diatomacous Earth (Calcined silica): SiO_2
Molecular weight	60.09 g/mol
Solubility in water	Insoluble/negligible
pH	-
Melting point	1713°C (Cristobalite) 1610°C (Quartz)
Boiling point	2230 °C
Vapour pressure	NA
Henrys law constant	NA
Explosive potential	Not explosive
Flammability potential	Not flammable
Colour/Form	Transparent crystals
Overview	Silica is an off-white granule that occurs naturally in various crystalline and amorphous or other non-crystalline forms. Crystalline silica is characterized by silicon dioxide (SiO2) molecules oriented in fixed, periodic patterns to form stable crystals. The primary crystalline form of silica is quartz. Other crystalline forms of silica include cristobalite, tripoli and tridymite. Particle size is a key determinate of silica toxicity, since toxicity is restricted to particles that are small enough to be deposited into the target regions of the respiratory tract. Uncalcined diatomaceous earth typically contains around 1%crystalline silica. When diatomaceous earth is subjected to pressure or is processed ("calcined") at temperatures above 1000°C some of the amorphous silica is converted to crystalline silica in the form of cristobalite. Calcined diatomaceous earth can contain anywhere from 1% to 75% cristobalite.
Environmental Fate [1,2]	
Soil/Water/Air	Crystalline Silica consists of diatomaceous earth, a naturally occurring material. Its primary component, silica, is found in common materials like quartz, sand and agate. The materials are ubiquitous and unlikely to react chemically with any other substance in the environment.

Human Health Toxicity Summary [1,2,3]	
Chronic Repeated Dose Toxicity	A number of animal studies have found that cristobalite is more toxic to the lung than quartz, and more tumorigenic (e.g., King et al. 1953; Wagner et al. 1980). However, several other authors concluded that this is not the case (Bolsaitis and Wallace 1996; Guthrie and Heaney 1995). OSHA (2013) has examined evidence on the comparative toxicity of the silica polymorphs (quartz, cristobalite, and tridymite) and found no difference in toxicity effects between cristobalite and quartz. Furthermore, no difference in toxicity between cristobalite and quartz has been observed in epidemiologic studies (NIOSH 2002). There is no information on the repeat dose oral, inhalation or dermal effect of calcined silica. However, since calcined diatomaceous earth contains varying amounts of crystalline silica in the form of cristobalite, and may also contain small amounts of quartz and tridymite, it is expected that any long-term health hazards associated with diatomaceous earth would mainly be due to the effects of crystalline silica. In humans, the most prevalent effect identified from long term exposure in occupational settings is silicosis, a diffused nodular pulmonary fibrosis (US EPA 1996).
Carcinogenicity	IARC (2012) concluded that there is sufficient evidence in humans for the carcinogenicity of inhaled crystalline silica in the form of quartz or cristobalite from occupational sources. There is sufficient evidence in experimental animals for the carcinogenicity of quartz and cristobalite. The IARC has also concluded that inhaled crystalline silica in the form of cristobalite or quartz from occupational sources is carcinogenic to humans (Group 1) (IARC 2012).
Mutagenicity/ Genotoxicity	Conflicting results have been reported in genotoxicity studies with crystalline quartz or cristobalite, and a direct genotoxic effect for crystalline silica has not been confirmed or ruled out. Studies on genotoxicity of calcined diatomaceous silica are not available.
Reproductive Toxicity Developmental Toxicity/Teratogenicity	No data available.
Acute Toxicity	No data available.
Irritation	No data available. Most acute toxicity studies for quartz or cristobalite were conducted using intratracheal instillation. Single intratracheal instillation of quartz caused inflammatory effects and formation of discrete silicotic nodules in rats, mice and hamsters (IARC 2012; WHO 2000). Other effects like oxidative stress, cellular proliferation and increases in water, protein, and phospholipid content of rat lungs, apoptosis (programmed cell death) and lung cancer were also noted. In general, exposure to high concentrations of dust may cause coughing and mild, temporary irritation (CCOHS 2001).
Sensitisation	No data available. However, based on the structure and physico-chemical properties, the three forms of crystalline silica or the calcined diatomaceous silica are not expected to cause skin sensitisation.
Health Effects Summary	The substances are not skin or eye irritants but acute inhalation of dust may cause discomfort and stress as well as signs of local irritation to nasal, bronchiolar and ocular mucous membranes. Based on the evaluation of the epidemiological data it is concluded that inhalation exposure to crystalline silica results in lung cancer. This conclusion is also supported by animal studies in which inhalation and intratracheal exposure to crystalline silica resulted in lung tumours. The most common types of lung tumour observed in rats were lung adenocarcinomas.
Key Study/Critical Effect for Screening Criteria	Not applicable.

Ecological Toxicity [1,2,3]	
Aquatic Toxicity	Aquatic toxicity studies performed at saturation concentrations of synthetic amorphous silica showed no acute toxicity to fish, Daphnia, or algae, though some physical effects were observed with loading rates of greater than or equal to 10 g/L (OECD 2004). Any harmful effects to aquatic ecosystems are therefore not ecotoxicological in nature. No chronic toxicity data were identified.
Determination of PNEC aquatic	Not applicable.
Current Regulatory Controls [3]	
Australian Hazard Classification	Quartz and cristobalite are listed in the Hazardous Substances Information System (HSIS) (Safe Work Australia 2014a) as hazardous substances. Calcined silica is not listed in the HSIS.
Australian Occupational Exposure Standards	Time Weighted Average (TWA) occupational exposure standard of 0.1 mg/m^3 for quartz and cristobalite are recommended in Australia (Safework Australia 2013). A Short-Term Exposure Limit (STEL) is not recommended for any of the compounds.
International Occupational Exposure Standards	TWA for quartz, cristobalite: Canada: 0.025 mg/m^3 France: 0.05 mg/m^3 Japan: 0.03 mg/m^3 Sweden: 0.05 mg/m^3 US (ACGIH): 0.025 mg/m^3 US (NIOSH): 0.05 mg/m^3 US (OSHA): 0.1 mg/m^3 US: 0.3, 0.9, 1.5, 500 mg/m^3 Temporary Emergency Exposure Limits (TEEL) (Diatomaceous silica, calcined)
Australian Food Standards	No data found.
Australian Drinking Water Guidelines	The Australian Drinking Water Guidelines state: 'To minimise an undesirable scale build up on surfaces, silica (SiO¬2) within drinking water should not exceed 80 mg/L' (National Health and Medical Research Council (NHMRC) 2001).
Aquatic Toxicity Guidelines	No data found.
PBT Assessment [3]	
P/vP Criteria fulfilled?	No. Not applicable, inorganic substance, ubiquitous in environment.
B/vB criteria fulfilled?	No. Not applicable, inorganic substance, ubiquitous in environment.
T criteria fulfilled?	No. Long term data not available (acute data >0.1 mg/L).
Overall conclusion	It is not currently possible to categorise the environmental hazards of metals and other inorganic chemicals according to standard persistence, bioaccumulation and toxicity (PBT) hazard criteria. These criteria were developed for organic chemicals and do not take into account the unique properties of inorganic substances and their behaviour in the environment (UNECE 2007; US EPA 2007). Further assessment of the environmental risks from the use of this chemical is not required as identified by DoEE
Revised	April 2018

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2. OECD-SIDS Initial Targeted Assessment Profile on Quartz and Cristobalite, SIAM 32, 19-21 April 2011.
3. Department of the Environment and Energy 2017 , National assessment of chemicals associated with coal seam gas extraction in Australia, prepared by the National Industrial Chemicals Notification and Assessment Scheme

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Toxicity Summary - Diethanolamine

Chemical and Physical Properties [1,2,4]	
CAS number	111-42-2
Molecular formula	C4H11NO2
Molecular weight	105.14
Solubility in water	1,000 g/L @ 20 °C
Melting point	27 °C at 101.3 kPa
Boiling point	269.9 °C at 101.325 kPa
Vapour pressure	0.0028 hPa (25 °C)
Henrys law constant	3.97 x 10-6 Pa*m^3/mol
Explosive potential	Non explosive
Flammability potential	Non flammable
Colour/Form	Colourless crystals or a white syrupy liquid with a mild ammonical odour.
Overview	2,2'-Iminodiethanol (diethanolamine, DEA) belongs to the ethanolamines group that includes monoethanolamine (MEA), diethanolamine (DEA) and triethanolamine (TEA). Large-scale production of DEA is carried out by the reaction of ethylene oxide and excess ammonia, followed by fractionation of the three ethanolamines (mono-, di- and triethanolamine). Ethanolamines are used widely as intermediates in the production of anionic and non-ionic surfactants, which have become commercially important as detergents, textile and leather chemicals, and emulsifiers. Their uses range from drilling and cutting oils to medicinal soaps and high-quality toiletries. DEA is an important additive of corrosion inhibitors, particularly in coolants for automobile engines. DEA is also employed as an additive in lubricants and in cement/concrete production. Large amounts of DEA are used as such in closed systems for absorptive gas purification to remove weakly acidic components. In the production of detergents, cleaners, fabric softeners and metalworking fluids DEA is used for acid neutralization and to prevent soil deposition. DEA is also used as an intermediate in the production of morpholine, photographic chemicals and polyurethanes. In addition, DEA is used as a building block for agrochemicals.
Environmental Fate [4]	
Soil/Water/Air	The colourless solid DEA is completely miscible with water at ambient temperature and has a negligible vapour pressure of 0.0028 hPa (25 °C). The measured log KOW of -2.18 (25 °C) and the calculated BCF of 3.16 indicate a low potential for bioaccumulation. The Henry's law constant of 3.97 x 10-6 Pa*m^3/mol (uncharged) is considered as an indication for low volatility. The calculated Koc of uncharged DEA is 1 (corrected log Koc = 0). Thus, the potential for adsorption to soil, sediment, and suspended solid may be low. However, binding of the substance to the matrix of soils (and sediments) with high capacities for cation exchange (e.g. clay) cannot be excluded for the charged molecule. The measured pKa value of 8.92 (23 °C) indicates that at environmentally relevant conditions of pH 6 – 8, the molecule will predominantly occur in the charged (cationic) form. At pH values > 9, DEA will predominantly be present as the uncharged species. According to Mackay Level I modelling, uncharged DEA will distribute almost completely into water (99.99 %). DEA is readily biodegradable according to OECD criteria. Potential for anaerobic degradation of DEA was also observed. In the atmosphere, it will be photodegraded by reactions with OH radicals (calculated half-life of the uncharged molecule for a 12-hour day and 1.5E06 OH/cm^3: 2.4 hours = 0.1 day; for a 24-h day and 0.5E06 OH/cm^3: 4.2 hours = 0.2 days). At environmental pH conditions hydrolysis is not expected to be a relevant degradation process due to the absence of hydrolysable groups
Human Health Toxicity Summary [1,2]	

Chronic Repeated Dose Toxicity	In a 90 day oral gavage study conducted similarly to OECD TG 408 in F344 rats, lowest observed adverse effect levels (LOAEL) of 320 and 160 ppm (equivalent to 25 and 14 mg/kg bw/day, respectively) was reported in male and female rats, respectively. These were the lowest doses tested. Mortality was observed in males (2/10 animals) at the highest dose (5000 ppm) before the completion of the study (REACH; OECD, 2008). Signs of toxicity were observed across all dose groups (160 - 2500 ppm), and included tremors, extreme weight loss, abnormal posture and a dose dependent increase in microcytic anaemia. Dose related (≥ 320 ppm in males and ≥ 160 ppm in females) changes in kidney weights were associated with an increase in nephropathy and renal cell necrosis. Dose related (≥ 320 ppm in males and ≥ 630 ppm in females) increase in liver weight was associated with a moderate increase in serum bile acid concentration (REACH; OECD, 2008). Based on treatment-related effects reported with a LOAEL of 32 and 80 mg/kg bw/day in rat and mouse studies, respectively, the chemical is considered to cause serious damage to health from repeated oral exposure. In a 90 day dermal application study conducted similarly to OECD TG 411 in F344 rats, a LOAEL of 32 mg/kg bw/day was reported in male and female rats. Mortality occurred in one male and two female rats administered the highest dose of 500 mg/kg bw/day (REACH; OECD, 2008). Ulceration, inflammation, hyperkeratosis, and acanthosis occurred at all administered doses (32 - 500 mg/kg bw/day). Other signs of toxicity included reductions in body weight gain, anaemia, renal function changes and liver weight increases. Demyelination in the brain, nephropathy and renal tubular necrosis were also observed (REACH; OECD, 2008). In a similar study conducted similarly to OECD TG 411 in B6C3F1 mice, a LOAEL of 80 mg/kg bw/day was reported in male and female mice. Effects on the skin were noted at all doses (80 - 1250 mg/kg bw/day) and consisted of acanthosis at the lower doses and a dose-dependent increase in ulcerations, inflammation and hyperkeratosis at higher dose levels (630 and 1250 mg/kg bw/day in males and females, respectively) (REACH; OECD, 2008). Further signs of toxicity included dose dependent increases in liver and kidney weights. The increase in liver weight was associated with hepatocellular changes consisting of enlarged hepatocytes and, at the higher dose levels, the presence of multinucleated, giant hepatocytes. Liver damage (hepatocellular necrosis) was observed in male mice only (REACH; OECD, 2008). Based on the available data no adverse systemic toxicity was evident. Local effects were observed at a lowest observed adverse effect concentration (LOAEC) of 0.15 mg/L in one study. The available data do not warrant a hazard classification for repeated dose inhalation toxicity. However, a classification for respiratory irritation is warranted. In a 90 day inhalation study conducted according to OECD TG 413 in Wistar rats, a LOAEC of 0.15 mg/L was reported in male and female rats. Local inflammation (focal squamous metaplasia and hyperplasia) was evident in the larynx (0.15 mg/L) and trachea (0.4 mg/L) in a concentration dependent manner (REACH, SIDS, 2008). Marginal increases in liver weight and serum alkaline phosphatase levels occurred at the mid - high doses (0.15 and 0.4 mg/L, respectively), although, no histopathological changes were noted. In females, erosions of the glandular stomach occurred in a dose dependent manner (0.15 mg/L and 0.4 mg/L) (REACH; OECD, 2008). A further study conducted according to OECD TG 413 in male and female Wistar rats using lower doses (0.0015, 0.003 or 0.008 mg/L) showed similar local irritation effects (focal squamous metaplasia) after 90 days of exposure. After 90 days of exposure to the chemical, a group of 10 animals were given three months of recovery. At the end of the recovery period, no treatment related systemic effects were observed, indicating reversibility in the laryngeal epithelium up to the highest dose administered (0.008 mg/L) (REACH, OECD, 2008).

Carcinogenicity	Limited data are available on the carcinogenicity of DEA. A two-year carcinogenicity study was conducted by the United States National Toxicology Program (NTP, 1999). Based on the pattern of occupational and consumer exposure, dermal administration was considered the most appropriate route for the carcinogenicity study in rats and mice. Groups of 50 male F344/N rats were administered dermal doses of 0, 16, 32, or 64 mg/kg bw DEA in ethanol solutions, 5 days per week for 103 weeks. Female rats were administered 0, 8, 16, or 32 mg/kg bw, and male and female B6C3F1 mice were administered 0, 40, 80, or 160 mg/kg bw DEA dermally, 5 days per week for 103 weeks. Mean body weights of treated rats were generally lower than those of the control rats. The only clinical finding attributed to DEA administration was irritation of the skin at the site of application. This effect was dose-related. Exudate, consisting of focal accumulations of serum and cellular debris on the epidermal surface, occurred at significantly increased incidences in 64 mg/kg bw males and in all dosed female groups. In rats, the main histopathological effects were noted in kidneys of female rats with nephropathy, renal tubular epithelial cell necrosis and/or mineralisation, which increased in incidence and/or severity in a dose-dependent manner. The incidence of nephropathy in dosed female groups was significantly greater than that in the vehicle controls; but no such effects were seen in male rats. There was no neoplastic response in the skin or any organ associated with DEA exposure during the two-year study. The incidence of basophilic foci was significantly decreased in all dosed groups of males and females. The incidence of fibroadenoma in mammary glands in female rats occurred with a negative trend, being lower in all dosed groups compared to the historical control range. In mice, mean body weights of treated groups were depressed, more so in female mice than in male mice. The liver was clearly the most affected organ, and female mice were more sensitive than males. Exposure to diethanolamine for two years produced a marked neoplastic response in the liver characterised by significant increases in the incidences and multiplicity of hepatocellular adenomas (males: 31/50, 42/50, 49/50, 45/50 and females: 32/50, 50/50, 48/50, 48/50) and hepatocellular carcinoma (males: 12/50, 17/50, 33/50, 34/50 and females: 5/50, 19/50, 38/50, 42/50) at 0, 40, 80 and 160 mg/kg bw/day, respectively. The microscopic appearance of these liver neoplasms was typical of those usually observed spontaneously in B6C3F1 mice. There was a morphologic continuum from adenoma to carcinoma, with less differentiation and typical trabecular formations in the carcinomas. Increased mortality was noted in female mice and this, along with reduced body weights, was considered to be a consequence of the presence of liver neoplasms. The incidence of hepatoblastomas, uncommon phenotypic variants of hepatocellular carcinoma, was significantly increased in male mice, but not in females. In addition, the incidence of syncytial alteration, a non-neoplastic lesion characterised by the presence of hepatocytes containing multiple (three or more) nuclei, was increased in all groups of dosed mice; this lesion was not present in the controls. Centrilobular cytoplasmic alteration was increased in treated males but was not present in females. There were no neoplasms of the skin in mice. Effects in the kidneys included increased organ weights and increased incidence of tubular epithelial cell necrosis. The incidences of renal tubule adenoma and renal tubule adenoma or carcinoma (combined) occurred with a positive trend in male mice, but renal tubule carcinoma did not follow the same pattern. Detailed evaluation of the renal neoplasms indicated a treatment- and dose-related increase in the incidences of renal tubule adenoma (1/50, 4/50, 6/50 and 6/50) and adenoma or carcinoma (combined) (3/50, 5/50, 6/50 and 8/50 at 0, 40, 80 and 160 mg/kg, respectively). Diethanolamine is eliminated in urine as the parent compound. The data on the mode of action are insufficient to conclude that diethanolamine-induced tumours in mice are relevant for humans and, therefore, based on the available information, diethanolamine is not classified for carcinogenicity.

Mutagenicity/ Genotoxicity	The chemical tested negative in several in vitro (Ames test with and without metabolic activation, reverse mutation assay, cytogenic assay and the mouse lymphoma assay) and in vivo (micronucleus assay and the alkaline elution assay) tests for gene mutation and clastogenicity (NICNAS; OECD, 2008).
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	No reproductive toxicity studies are available for diethanolamine. Repeated dose studies were conducted in F344/N rats and B6C3F1 mice of both sexes for 13 weeks (10/sex/species/dose) to characterise the effects of oral and dermal exposure (NTP, 1992). No reproductive toxicity in male or female rats was reported following dermal administration of the chemical for 13 weeks. There were no morphological effects on male or female reproductive organs or in sperm parameters (NTP, 1992). It is likely that testicular degeneration in a 90-day drinking water study is a direct toxic effect of diethanolamine. However, no effect on the reproductive organs of the female rats was noted. The NOAEL for reproductive effects in males is 630 ppm (48 mg/kg bw/day). In an inhalation study, conducted according to OECD TG 413, male and female Wistar rats were exposed to the chemical via inhalation (0.015, 0.15 or 0.4 mg/L), five times a week for 90 days. Reproductive effects in males were reported at the highest concentration (0.4 mg/L) and these included testicular atrophy and slight atrophy of the prostate. No changes were observed in female rats (OECD, 2008). The effects of diethanolamine on the male reproductive system are indicative of a potential to impair reproductive capability. However, more detailed reproductive toxicity studies are needed to confirm the potential effects on fertility observed in male rats. The current information is insufficient to classify diethanolamine for reproductive toxicity. Developmental effects were tested following exposure of dams to diethanolamine by oral, dermal and inhalation routes. In almost all the rodent studies, developmental effects were seen only at higher doses, at which maternal effects were also noted. In a dermal study in rabbits, the overall incidence of malformation was similar to the incidence seen in control animals. The current data therefore do not allow for a clear delineation of reproductive and developmental toxicity of diethanolamine in experimental animals. Classification of diethanolamine for reproductive and developmental toxicity is, therefore, not recommended at this stage.

Acute Toxicity	The reported oral median lethal dose (LD50) values in rats ranged from 780 - 3540 mg/kg bw (OECD, 2008). In one study male Sprague Dawley (SD) rats administered a single oral dose of aqueous DEA (100 – 6400 mg/kg bw) resulting in 90 % mortality at the highest dose. Doses greater than 100 mg/kg bw resulted in an increase in liver weight. An increase in the relative kidney weight was observed at doses greater than 1600 mg/kg bw. Clinical chemistry changes were reported for the liver at doses greater than 200 mg/kg bw and for the kidney at greater than 400 mg/kg bw (OECD, 2008). The chemical was of low acute toxicity in animal tests following dermal exposure. The median lethal dose (LD50) in rabbits is greater than 12000 mg/kg bw (IUCLID, 2000). The chemical was of low acute toxicity in animal tests following inhalation exposure. The median lethal concentration (LC50) in rats is 6.4 mg/L. The available data do not warrant hazard classification. Acute inhalation exposure to the chemical for 1.5 – 4 hours at concentrations between 30 – 1476 ppm (0.13 - 6.4 mg/L) caused mortality in 5/8 rats after 105 minutes of exposure to 6.4 mg/L. Exposure to 3.35 mg/L (768 ppm) for up to 4 hours resulted in no mortality. It was reported that the exposure was to vapours or aerosols (most likely at the higher concentration). Observed sub-lethal effects included lethargy, increased breathing, increased blood pressure, congestion in the lung and discolouration in the kidney and thymus (REACH; OECD 2008).
Irritation	The chemical on unabraded rabbit skin produced skin irritation after 1 - 15 minutes and marked irritation after 20 hours. Over 72 hours, erythema increased and oedema decreased (REACH). After 20 hours of exposure the mean Draize scores for erythema and oedema formation were 2 and 1.33, respectively. While the Draize scores for erythema and oedema returned to normal after 8 days, severe desquamation of the skin persisted. The chemical is also reported to cause ulceration, inflammation and hyperkeratosis following repeated exposure. In an eye irritation study in Vienna White rabbits, 0.05 mL of the chemical was instilled into the rabbit's eyes and observed for eight days. The chemical caused signs of severe irritation consisting of superficial corrosion, corneal opacity, conjunctival bleeding, conjunctivitis and oedema (OECD, 2008; REACH). Extensive corrosion was evident at the end of the observation period. In a further study, 0.1 g of the chemical was applied into the conjunctival sac of New Zealand White rabbits. This resulted in strong irritation of the cornea, iris and conjunctiva, which did not completely resolve over seven days of observation (OECD, 2008).
Sensitisation	The chemical was not found to induce dermal sensitisation in the Guinea pig maximization test conducted according to OECD Test Guideline (TG) 406 (OECD, 2008).
Health Effects Summary	The critical health effects for risk characterisation include systemic acute effects (acute toxicity by the oral route of exposure) and local effects (skin, eye and respiratory irritation). The chemical may also cause harmful effects following repeated exposure through oral and dermal routes.
Key Study/Critical Effect for Screening Criteria	The lowest observed adverse effect levels (LOAEL) of 320 and 160 ppm (equivalent to 25 and 14 mg/kg bw/day, respectively) were reported in male and female rats, respectively, based on kidney and liver weights in the drinking water study (US NTP, 1992). In mice, the LOAEL was 630 ppm (104 mg/kg bw/day for males and 142 mg/kg bw/day for females) based on liver weight changes. It is reported that the fatal oral dose of the chemical is 20g in humans (HSDB).
Ecological Toxicity [3,4]	

Aquatic Toxicity	The lowest reliable acute toxicity values for aquatic species were as follows: Pimephales promelas (fish) 96-h LC50 = 1370 mg/l (nominal) Daphnia magna (invertebrates) 48-h EC50 = 55 mg/l (nominal) Pseudokirchneriella subcapitata 96-h ErC50 = 2.2 mg/l (nominal) Pseudomonas sp. (microorganisms) 16-h TTC = 16 mg/l (nominal) In a chronic toxicity test on reproduction of the water flea Daphnia magna, the NOEC (21 days) was 0.78 mg/l (nominal, based on analytical verification).
Determination of PNEC aquatic	Using an uncertainty factor of 50 on the lowest NOEC to Daphnia a PNEC (Predicted No Effect Concentration) of 0.02 mg/L is calculated, for aquatic organisms.
Current Regulatory Controls [1]	
Australian Hazard Classification	The chemical is classified as hazardous, with the following risk phrases for human health in the Hazardous Substances Information System (HSIS) (Safe Work Australia): Xn; R22 (Acute toxicity) Xi; R38/41 (Irritation) Xn; R48/22 (Repeated dose toxicity)
Australian Occupational Exposure Standards	The chemical has an exposure standard of 13 mg/m³ (3 ppm) time weighted average (TWA).
International Occupational Exposure Standards	The following exposure standards are identified (Galleria Chemica): An exposure limit (TWA) of 2 - 15 mg/m³ (0.46 – 3 ppm) in different countries such as USA (Alaska, Hawaii), Canada (Yukon), Norway and Switzerland.
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	No data available.
PBT Assessment [4]	
P/vP Criteria fulfilled?	No. DEA is readily biodegradable according to OECD criteria.
B/vB criteria fulfilled?	No. Based on a measured log Kow of -2.18 and a calculated BCF of 3.16, this chemical does not meet the screening criteria for bioaccumulation.
T criteria fulfilled?	No. The chronic aquatic toxicity of the chemical is > 0.01 mg/L. Hence the substance does not fulfil the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	January 2019

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Toxicity Summary - 2,2''-oxydiethanol (Diethylene glycol)

Chemical and Physical Properties[1,2,3,4]	
CAS number	111-46-6
Molecular formula	$C_4H_{10}O_3$
Molecular weight	106.1 g/mol
Solubility in water	Miscible
Melting point	-10°C
Boiling point	245°C
Vapour pressure	It has a low vapour pressure (<0.01 kPa at 25°C).
Henrys law constant	2.0×10^{-9} atm-cu m/mol at 25 °C
Explosive potential	Not explosive
Flammability potential	Combustible
Colour/Form	Odourless, colourless, viscous and hygroscopic liquid with a sharply sweetish taste
Overview	Diethylene glycol (DEG) is produced via a non-catalytic reaction between ethylene oxide and water at high pressure temperature. The resulting crude ethylene glycols (EG) are dried. The water-free glycol mixture is subsequently fractionated by vacuum distillation into mono, di and triethylene glycol. Biodegradation of polyethylene glycols results in chain shortening with concomitant formation of ethylene glycol and diethylene glycol in nature DEG is a widely used chemical in industrial and household applications. It is also used in cosmetics for topical use. DEG is not an approved food additive in Australia. However, DEG is allowable in food in Australia as an impurity in polyethylene glycol (PEG) used as a processing aid or miscellaneous food additive. PEG used for this purpose must contain no more than 0.25% w/w DEG.
Environmental Fate[1,4]	
Soil/Water/Air	EGs emitted to the atmosphere readily undergo hydroxyl radical induced photodegradation, with half-lives ranging from about 2 to 15 hours. Particulate-phase EGs may be physically removed from the atmosphere by wet deposition (SRC, 2003). EGs have limited volatility, decreasing with increasing molecular weight. Level III fugacity modelling and Henry's Law constants ranging from 1.31×10^{-7} to 7.62×10^{-15} atm-m^3/mole indicate that volatilization from water to the atmosphere is limited. EGs are inherently to readily biodegraded in water. Since these substances are resistant to water hydrolysis, abiotic degradative processes in water are not major elimination pathways. Fugacity modelling indicates that EGs have a high affinity for soil as well as water. Low soil/sediment coefficients (Koc = 1 to 10) suggest that these substances are highly mobile in soil, have limited tendency to adsorb onto suspended solids and sediment, and are therefore subject to biodegradative elimination in either soil or water. Overall, the data suggest that EGs do not persist in the environment and that they have limited potential for bioaccumulation.

Human Health Toxicity Summary [1,2,3,4,5]	
Chronic Repeated Dose Toxicity	Two well-conducted studies were identified from which effect levels from long-term oral DEG administration could be derived (OECD, 2004; Health Council of the Netherlands 2007). In these two studies by Gaunt et al. (1976*) using DEG doses in food of 0%-4% (0.3-3.7 g/kg bw/d) for 98 days and 0%-2% (0.05-1.5 g/kg bw/d) for 225 days in Wistar rats (10-15/sex/dose), kidney effects were reported consisting of oxalate crystalluria, increased urine volumes and histopathological evidence of hydropic degeneration and tubular necrosis. For the crystalluria and increased urine volumes, there were inconsistent findings between male and female rats and questionable dose-response relationships. For example, the number of male rats with urinary oxalate crystals was not increased at the highest male dose of 1.2 g/kg bw/d in the 225 day study. In addition, the observed increase in urinary volumes was possibly caused by the osmotic diuretic effect of DEG and the oxalate crystalluria could not be explained in view of oxalic acid being a minor metabolite of DEG in rats. Therefore, the significance of elevated production of oxalate was regarded as unclear (Health Council of the Netherlands, 2007) and was viewed as a biomarker and not an indication of toxicity (OECD, 2004). OECD (2004) identified a LOAEL for kidney effects of 230 mg/kg bw/d from the 225 day study based on increases in urine volume. The NOAEL was 100 mg/kg bw/d. Health Council of the Netherlands (2007) regarded a NOAEL based on renal histopathological findings as more relevant than a NOAEL based on increased urine volumes. From the 98 day study, a LOAEL based on renal hydropic degeneration was established at 1.6 g/kg bw/day with the NOAEL at 300 mg/kg bw/d (Health Council of the Netherlands, 2007).
Carcinogenicity	The International Agency for Research on Cancer (IARC) has not evaluated DEG as a carcinogen. Urinary bladder calculus and tumour responses were recorded in some long-term oral studies in the rat. Bladder tumours were found associated with the formation of oxalate containing bladder stones in a 2-year feeding study by Fitzhugh and Nelson (1946*). On the other hand, Weil et al. (1965*, 1967*) found that DEG did not induce bladder tumours in rats unless a foreign body or lesion was present, such as an oxalate- containing bladder stone or a surgery-induced bladder lesion. These authors concluded that the bladder tumours seen were due to mechanical irritation by oxalate-containing bladder stones rather than the carcinogenic response to DEG. In more recent studies such as Ito et al. (1988*), Masui (1988*) and Hiasa et al. (1990* and 1991*), DEG did not demonstrate any evidence of carcinogenic effects after oral administration. Several studies in mice also showed that DEG is not carcinogenic after dermal application. No information was found in the literature concerning the occurrence of bladder stones in humans after ingestion of DEG. Overall, although some human carcinogenicity information are available, data are insufficient (e.g. lack of a quantitative estimate of DEG exposure and sound methodology) to evaluate the carcinogenic potential of DEG.
Mutagenicity/ Genotoxicity	DEG was shown to be negative in the majority of gene mutation and chromosome aberration studies in vitro. Some indications of chromosomal damage were seen in vivo only at high doses. Taken together, DEG is considered non-genotoxic.

Reproductive Toxicity / Developmental Toxicity/Teratogenicity	In oral studies, adverse effects on fertility were seen in mice and foetal abnormalities occurred in rats and mice. Inhalation and injection studies in rabbits and hamsters also revealed foetal abnormalities and other adverse effects on the foetus. However, reduced fertility was observed only at high doses of DEG, up to 6.1 g/kg bw/d in mice with maternal toxicity. With regard to developmental toxicity, a significant decrease in mean foetal body weight in mice was seen at 10 g/kg bw/d in the presence of maternal toxicity. In addition, at an oral dose of 6.1 g/kg bw/d in a 2-generation study in mice, craniofacial malformations, including exencephaly and cleft palate, and related mortality were observed in the presence of maternal toxicity. In rats, a decreased foetal body weight with increased skeletal variations was seen at 4.5 g/kg bw/d in the presence of maternal toxicity. Foetal malformations were not observed at dose levels up to 8.9 g/kg bw/d. From these studies, the NOAEL for fertility and developmental effects is established at 3.1 g/kg bw/d with a LOAEL of 6.1 g/kg bw/d based on reductions in litters/pair, live pups/litter and live pup weight
Acute Toxicity	In animals, the acute oral, dermal and inhalational toxicity of DEG are low. Oral toxicity is similar for both rats and mice with LD50 values ranging 13-30 g/kg bw across both species. A single study of dermal toxicity in rabbits derived an LD50 value of 12.5 or 13.3 g/kg bw . Acute inhalational toxicity has also been tested in rats and mice. The 4-hour LC50 in rats was 4600 mg/m^3. In humans, mortality and morbidity are high in cases of inadvertent DEG ingestion, with most deaths occurring within the first 2 weeks post exposure. Neurological impairments observed after exposure include encephalopathy, demyelinating neuropathy, optic neuritis, facial paralysis, cerebral oedema and haemorrhages. Acute anuric renal failure with metabolic acidosis and concomitant severe neurological abnormalities progressing to coma and finally death were also noted during severe intoxications after uptake of DEG in patients with burns. A median lethal oral dose of 1.49 g/kg bw DEG (range 0.25-4.9 g/kg bw) was estimated from large-scale intoxication of Haitian children with a paracetamol syrup contaminated with DEG. However, large overlaps in ranges of lethal and non-lethal doses have been observed for adults and children. Accidents in humans following acute DEG exposure have been recorded. A large number of mass poisonings in humans involving substitution of DEG for more expensive, non-toxic, glycols in medicinal preparations have been documented over the past 70 years. Typical features of acute toxicity include neurological impairment, metabolic acidosis and acute renal failure. Early mortality and morbidity are high, with most deaths occurring within the first two weeks following DEG exposure. Humans appear to be 10 times more susceptible to acute oral toxic effects of DEG compared with experimental animals, with median lethal dose of 1490 mg/kg bw in humans compared with > 15000 mg/kg bw in rats (NICNAS, 2009).
Irritation	Overall, available data indicate that DEG causes no or only minimal skin and eye irritation in laboratory animals. Respiratory depression was reported in mice although the characteristics were reported as not typical of a pure airway irritant (OECD, 2004). No other information on respiratory irritation was available. Similar to experimental animals, DEG causes no or only minimal skin irritation in humans. Data for eye irritation in humans were not available.
Sensitisation	DEG does not cause skin sensitisation in guinea pigs. In humans, there is a single case study reporting skin sensitisation 2-4 weeks after a man had started smoking a brand of cigarettes containing DEG. However, overall, available data indicate that DEG is not a skin sensitiser in humans.
Health Effects Summary	The critical health effects for risk characterisation include systemic acute effects (acute toxicity from oral exposure).

Key Study/Critical Effect for Screening Criteria	The effects of diethylene glycol on the liver and kidneys after prolonged oral exposure are considered as the critical effects. Key study is the oral exposure study in rats carried out by Gaunt *et al.* (1976). the NOAEL for hydropic degeneration is 300 mg/kg bw/day (0.4% diethylene glycol in food) in the male rats (Health Council of the Netherlands, 2007). Uncertainty factors: 10 (interspecicies variability); 10 (intraspecies variability); 10 (sub-chronic to chronic) Oral RfD = 300/1000 = 0.3 mg/kg/day Drinking water guidance value = 1.17 mg/L
Ecological Toxicity [1,4]	
Aquatic Toxicity	Fish acute toxicity (measured as LC50 in mg/L) for DEG ranges from >1000 mg/L to 77900 mg/L. The lowest acute toxicity (LC50) to invertebrates (Daphnia) value was >100 mg/L (48hr LC50) . Algal toxicity has been tested for DEG with an EC50 of >1000 mg/L. Chronic toxicity to fish was also tested which resulted in a 7 day LC50 of 61,000 mg/L and chronic toxicity data on pentaEG are available for algae (NOEC – 100 mg/L)
Determination of PNEC aquatic	On the basis that short term results from three trophic levels and long term results from two trophic levels, an assessment factor of 50 has been applied to the lowest reported NOEC for algae (100 mg/L). The PNEC aquatic is 2.0 mg/L.
Current Regulatory Controls [6]	
Australian Hazard Classification	The chemical is classified as hazardous with the following risk phrase for human health in HSIS (Safe Work Australia): Xn; R22 (Harmful if swallowed)
Australian Occupational Exposure Standards	TWA (time weighted average) = 100 mg/m^3 (Safe Work Australia).
International Occupational Exposure Standards	TWA = 101 mg/m^3 [UK] (HSE, 2013).
Australian Food Standards	No data available
Australian Drinking Water Guidelines	No data available
Aquatic Toxicity Guidelines	No data available
PBT Assessment [1,4]	
P/vP Criteria fulfilled?	DEG is readily biodegradable and as such not persistent in the environment.
B/vB criteria fulfilled?	An estimated BCF of 3 suggests the potential for bioconcentration in aquatic organisms is low.
T criteria fulfilled?	The acute aquatic toxicity of DEG is > 0.01 mg/L. Hence the substance does not fulfill the screening criteria for toxic (T).
Overall conclusion	Not a PBT substance (based on screening data).
Revised	December 2018

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Toxicity Summary - Boric acid/sodium tetraborate / boronatrocalcite / boron sodium oxide

Chemical and Physical Properties[1,3,5,8]	
CAS number	Boric Acid: 10043-35-3 Sodium Tetraborate: 1330-43-4 Boronatrocalcite: 1319-33-1 Boron sodium oxide: 12008-41-2
Molecular formula	Boric acid: H_3BO_3 Sodium Tetraborate: $Na_2B_4O_7$ Boronatrocalcite: $CaNaH_{12}(BO_3)5.2H_2O$ Boron sodium oxide: $B_8Na_2O_{13}$
Molecular weight	Boric acid: 61.833 g/mol Sodium Tetraborate: 201.220 g/mol Boronatrocalcite: 405.23 g/mol Boron sodium oxide: 340.47
Solubility in water	Boric acid: 49.20 g/l @ 20± 0.5 °C Sodium Tetraborate: 3.1% at 25 °C Boronatrocalcite: no data found Boron sodium oxide: 223.65 g/L @ 20 °C
pH	Boric acid: 6.1 in a 0.1% (wt) solution Sodium Tetraborate: 9.3 at 20 °C (3% solution) Boronatrocalcite: no data found Boron sodium oxide: no data found
Melting point	Boric Acid: 170.9 °C Sodium Tetraborate: 743 °C Boronatrocalcite: no data found Boron sodium oxide: 813 °C
Boiling point	Boric Acid: 300 C Sodium Tetraborate: 1,575 °C (decomposes) Boronatrocalcite: no data found Boron sodium oxide: no data found
Vapour pressure	Boric acid: 9.9×10^{-6} Pa @ 25 °C Sodium Tetraborate: Negligible at 20 °C Boronatrocalcite: no data found Boron sodium oxide: no data found
Henrys law constant	No data found
Explosive potential	Not explosive
Flammability potential	Not flammable
Colour/Form	Boric Acid: Colourless, transparent crystals or white granules or powder. Sodium Tetraborate: Colourless, monoclinic crystalline salt; also occurs as a white powder. Boronatrocalcite: Silky white rounded crystalline masses or parallel fibres. Boron sodium oxide: Solid white powder. Odourless.

Overview	Limited toxicity data is available for sodium tetraborate (Borax anhydrous) and boronatrocalcite (Ulexite) as such; this toxicity profile includes data on boron and boric acid. Boric acid and borate salts exist naturally in rocks, soil, plants and water as forms of the naturally occurring element boron. Anhydrous Borax is a free flowing mixture of clear, glass-like particles and white granules formed by the crushing of relatively large masses of fused materials. Borax is a salt of boric acid. Borax occurs naturally in evaporite deposits produced by the repeated evaporation of seasonal lakes and has many applications in chemistry, mining and pharmaceuticals. Ulexite is a sodium-calcium-hydroborate and, like other borates, is a structurally complex mineral. It is composed of hydrogen (3.98 %), sodium (5.67 %), calcium (9.89 %), boron (13.34 %), and oxygen (67.12 %) There is a lack of data available in the literature to directly assess the toxicity of the chemical. The major component of the chemical is a borate ion, which is likely to be associated with human health hazards of the chemical. The other constituents are considered to be of low concern to human health (NICNAS, 2013). As the chemical will readily break down in the stomach pH to boric acid (H_3BO_3) following ingestion, the toxicokinetics and toxicity of the chemical will be driven predominantly by borate ions. Boron is a naturally occurring element that is found in the form of borates in the oceans, sedimentary rocks, coal, shale, and some soils. Boron is widely distributed in nature, with concentrations of about 10 mg/kg in the earth's crust (range 5 mg/kg in basalts to 100 mg/kg in shales) and about 4.5 mg/L in the ocean. Borates are used in glass, ceramics, detergents, wood treatment and insulation fiberglass industries. Boric acid and other borates are also used in a range of consumer products including cosmetic and personal care products and also in detergents. Moreover, borates are essential for all plants – their use as fertilizers increases crop yields (including grapes, potatoes, sugar beets, alfalfa and olives) and quality. Boron occurs in foods as borate and boric acid. Boron has not been established to be an essential nutrient for humans and no specific biochemical function for boron has been identified in higher animals or man. There is some evidence that, in humans, boron intake within the usual dietary range may influence the metabolism and utilisation of other nutrients, particularly calcium, and may have a beneficial effect on bone calcification and maintenance.
Environmental Fate[2,4]	
Soil/Water/Air	All of the chemical in this group will transform into boric acid in the aquatic environment. This simple mononuclear boron compound is highly water soluble and is the predominant form of dissolved boron in surface waters. It is a mobile species in the environment and is to be found in all major environmental compartments.

Human Health Toxicity Summary [2,3,4,8,9]	
Chronic Repeated Dose Toxicity	The haematological system and the testes have been identified as the major targets after oral repeat dose exposure to Boric acid. Studies after repeated dermal or inhalation exposure to boric acid are not available. A NOAEL for effects on testes and the blood system of 17.5 mg boron/kg bw/day can be derived (with a LOAEL of 58.5 mg boron/kg bw/day) from two 2-year studies in rats on boric acid. Results obtained with boric acid can be supported by findings obtained from other borates thus indicating that the boron ion is the toxicologically relevant species
Carcinogenicity	Boric acid is not listed as an IARC carcinogen. In long term feeding studies on boric acid and disodium tetraborate decahydrate in both rats and dogs, no carcinogenic effects were observed.
Mutagenicity/ Genotoxicity	Boric acid is not mutagenic either in vitro or in vivo.
Reproductive Toxicity Developmental Toxicity/Teratogenicity	Results from animal experiments demonstrate that boric acid adversely effects fertility and development. Feeding studies in different animal species (rats, mice and dogs) have consistently demonstrated that the male reproductive system is the principle target in experimental animals, although effects on the female reproductive system have also been reported. Testicular damage ranging from mildly inhibited spermiation to complete atrophy has been demonstrated following oral administration of boric acid. Effects on fertility were observed at lower dose levels compared to dose levels, where signs of general toxicity appeared. Based on data from the two-year feeding studies with boric acid and borax in rats, 17.5 mg boron /kg bw/day (equivalent to 100 mg boric acid/kg bw/day)_was derived as a NOAEL for male and female fertility. Developmental effects have been observed in three species, rats, mice and rabbits. The most sensitive species appears to be rats, in which the effects observed at non maternally toxic doses include a reduction in foetal body weight and minor skeletal variations which, with the exception of short rib XIII, had reversed by 21 days post-natal. The NOAEL for developmental effects is 9.6 mg boron/kg bw/day (55 mg boric acid/kg/day).
Acute Toxicity	Boric acid is of low acute toxicity. LD50 oral rat > 3765 mg/kg bw (659 mg boron/kg/bw); LD50 dermal rabbits > 2000 mg/kg bw/day; 4 hour LC50 inhalation rat ≥ 2.03 mg/L.
Irritation	In rabbits, boric acid caused no/mild skin irritation, induced reversible conjunctival redness and chemosis with minor effects on the iris. In rats and mice, boric acid acts as a sensory irritant. The substance may irritate the eyes, nasal mucous membranes, skin and the respiratory tract, and may cause effects on the gastrointestinal tract, liver and kidneys.
Sensitisation	No borate tested has displayed skin sensitisation in Bheuler studies. No evidence of skin sensitisation has been seen in humans exposed occupationally to sodium borates, or in a human patch test with a 3% aqueous boric acid solution.
Health Effects Summary	Borates are of low acute toxicity and low skin irritation potential. It may cause sensory irritant effects on animals and humans with acute exposure. Borates were shown not to be skin sensitisers, genotoxic or carcinogenic. Repeated exposures to boron as boric acid induced effects on fertility (testes), development and the blood system.
Key Study/Critical Effect for Screening Criteria	The critical lowest No Observed Adverse Effect (NOAEL) level for the purposes of risk assessment is 9.6 mg boron/kg bw/day. This NOAEL was the equivalent of 55 mg boric acid/kg bw/day; 38 mg disodium octaborate anhydrate/kg bw/day and 85 mg borax/kg bw/day), from feeding (dietary intake) studies based on developmental effects. Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability); 10 (subacute to chronic). Drinking water guideline for boron: 3.5 ppm

Ecological Toxicity [3,9]	
Aquatic Toxicity	The most sensitive tests report that acute effects on fish are in the range of 10-20 mg-B/L although the quality of these studies was rated low. The lowest daphnid acute value is 133 mg-B/L. Algal and microbial inhibition studies suggest less toxicity: Selenastrum growth was not affected at 93 mg-B/L and activated sludge respiration showed minimal effects at 683 mg/L boric acid (119 mg-B/L). Chronic endpoints for Boric acid were available for Daphnia (6 mg/L) and Fish (2.1 mg/L).
Determination of PNEC aquatic	Canadian Water Quality Guidelines for the Protection of Aquatic Life: Long–term Exposure to Boron is 1.5 mg/L (2009). An assessment factor of 100 has been applied to the lowest reported chronic effect concentration of 2.1 mg/L for Fish. The PNECaquatic is 0.021 mg/L.
Current Regulatory Controls[9]	
Australian Hazard Classification	Boric acid and borax are classified as hazardous for human health in the Hazardous Substances Information System (HSIS) (Safe Work Australia 2013) with the following risk phrases: · Toxic to reproduction (Repr.) Cat. 2; R60 (May impair fertility) · Repr. Cat. 2; R61 (May cause harm to the unborn child) Mixtures containing boric acid and borax are classified as hazardous with the following risk phrases based on the concentration (conc) of the chemicals in the mixtures. · Boric acid: Conc ≥5.5%: Toxic (T); R60; R61 · Borax: Conc ≥8.5%: T; R60; R61.
Australian Occupational Exposure Standards	There are no specific exposure standards for boric acid or disodium octaborate anhydrate. However, the permissible exposure limits (as the time weighted average (TWA)) for dusts apply (10 mg/m^3 measured as inspirable dust) (Safe Work Australia 2013b). The exposure standard for borax is 5 mg/m^3 TWA (Safe Work Australia 2013a).
International Occupational Exposure Standards	The following exposure standards were identified (Galleria Chemica 2013): · Boric acid − Canada 2 mg/m^3 TWA, 6 mg/m^3 Short-term exposure limit (STEL) (borate compounds) − Germany 10 mg/m^3 TWA; 1 mg/m^3 STEL − Spain 10 mg/m^3 TWA (insoluble particles) − US 2 mg/m^3 TWA; 6 mg/m^3 STEL (borate compounds), 5 mg/m^3 TWA (particulates, respirable fraction) · Disodium octaborate anhydrate − Canada 10 mg/m^3 TWA, (insoluble particles) − Spain 10 mg/m^3 TWA (particulates, inhalable fraction) − US 5 mg/m^3 TWA (particulates, respirable fraction) · Borax − Canada 1 to 5 mg/m^3 TWA, 6 mg/m^3 STEL (inorganic borate compounds) − Denmark 1 to 2 mg/m^3 TWA − Germany 0.5 mg/m^3 TWA − Spain 5 mg/m^3 TWA − Sweden and UK 2 mg/m^3 TWA − US 2 mg/m^3 TWA (inorganic borate compounds); 5 to 10 mg/m^3 TWA.
Australian Food Standards	No data found.
Australian Drinking Water Guidelines	No aesthetic or health-related guidance values exist specifically for boric acid, disodium octaborate anhydrate or borax. However, the guidelines note that boron in the environment is likely to be predominantly in the form of boric acid and that based on health considerations, the concentration of boron in drinking water should not exceed 4 mg/L (NHMRC 2011).
Aquatic Toxicity Guidelines	For boron: 90 µg/L (ANZECC 2000 99% Freshwater)
PBT Assessment[9]	
P/vP Criteria fulfilled?	For the purposes of this PBT assessment, the persistent criteria is not considered applicable to this inorganic substance.

B/vB criteria fulfilled?	For the purposes of this PBT assessment, the bioaccumulation criteria is not considered applicable to this inorganic substance.
T criteria fulfilled?	No. The chronic toxicity data is >1 mg/L.
Overall conclusion	Not PBT
Revised	April 2018

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Toxicity Summary - Ethanol

Chemical and Physical Properties[1,2,3]	
CAS number	64-17-5
Molecular formula	C2H6O
Molecular weight	46.07
Solubility in water	1 x 10_3 g/L at 25 °C
Melting point	114.14 °C
Boiling point	78.3 °C
Vapour pressure	57.3 hPa at 20°C
Henrys law constant	0.000252
Explosive potential	Non explosive
Flammability potential	Highly flammable (100%)
Colour/Form	Clear, colourless liquid with a characteristic pleasant odour and burning taste.
Overview	Ethanol, also known as grain alcohol, is a clear, colourless liquid. It has an alcohol odour a burning taste. Ethanol mixes easily with water. Ethanol is present in emissions from plants, fires, volcanoes, animal wastes, insects and natural fermentation of sugars. Ethanol is an important commercial chemical used in alcoholic beverages, which may contain up to 50% ethanol. It is also used as a solvent in cleaners and as a fuel additive. Ethanol is used in the production of other chemicals, pharmaceuticals, perfumes, and cosmetics. It is also used as a fungicide and to regulate plant growth. It is an ingredient in many consumer products, such as cleaners, sprays, inks, mouthwash, perfume and aftershave, and human and veterinary medicines. Ethanol is a food additive.
Environmental Fate[3]	
Soil/Water/Air	Ethanol is stable to hydrolysis but is readily biodegradable (74% after 5 days) and is not likely to bioaccumulate (calculated logBCF=0.5). Ethanol is not persistent in the environment. Fugacity-based modelling shows that ethanol released into the environment will become distributed mainly into air and water. Relative distributions between compartments based on an emission pattern of 1000:100:10 were 57 % in air, 34 % in water, and 9 % in soil. These predictions are supported by the limited data available on prevailing concentrations, which shows that ethanol has been detected in outdoor air and in river water. The total tropospheric half-life of ethanol is estimated to be 10-36 hours, with degradation due to hydroxyl, NOx and SOx radical-mediated photooxidation. As a volatile organic compound in the atmosphere, ethanol is a potential contributor to tropospheric ozone formation under certain conditions, however its photochemical ozone creation potential is considered to be moderate to low (40-45 relative to ethylene as 100).
Human Health Toxicity Summary [1]	

Chronic Repeated Dose Toxicity	Many repeated dose studies of chemical have been conducted in many species, predominantly with the aim of assessing adverse effects associated with the consumption of alcoholic beverages. Consequently, these are mostly conducted through oral exposure and with doses well in excess of those that might be encountered in occupational exposure or consumer products (OECD, 2005), or unintentional public exposures from environmental contamination. Considering the lowest observed adverse effect level (LOAEL) available from a 90-day rat study (3600 mg/kg bw/day), and based on the treatment-related effects reported in various repeated dose toxicity studies, the chemical is not considered to cause serious damage to health from repeated oral exposure, except from exposure to high doses. In a well-conducted repeated dose toxicity study, the chemical was administered (in a liquid diet) to Sprague Dawley (SD) rats at a 1, 2, 3, 4, 5, and 10 % concentration for 90 days. Water consumption in the 10 % group was reduced relative to controls. There were no adverse clinical signs or mortality during the study. Serum liver enzymes were unaffected by treatment and kidney findings were reported to be minimal. A LOAEL was established at 3 % (approximately 3600 mg/kg bw/day), based on dose-related hepatic yellowing, centrilobular steatosis, increased frequency and severity of Mallory bodies (hyaline), and acidophilic degeneration and necrosis. The no observed adverse effect level (NOAEL) was 2 % (approximately 2400 mg/kg bw/day) (OECD, 2005; REACH). In another repeated dose toxicity study conducted in accordance with national test guidelines of USA (EPA OPPTS 870.3100), the chemical was administered in drinking water to Fischer 344 (F344) rats and B6C3F1 mice at a single dose of 5 % concentration for 90 days. Even though male rats showed minor changes in thymus weights, and some slight but inconsistent changes in haematology and clinical chemistry, these effects were not considered adverse. Based on water consumption data, this single dose study established a 5 % nominal NOAEL for male rats (approximately 3250 mg/kg bw/day). Although minor changes in clinical chemistry were also seen in female rats, some female rats (4/10) also exhibited liver nodules (diaphragmatic nodules) and small increases in liver weights. As no NOAEL could be established for female rats, a LOAEL of 4400 mg/kg bw/day was established. For male mice, a LOAEL at 9700 mg/kg bw/day was established, based on increased organ weights (liver, heart, kidney and lung) and decreased sperm counts in the cauda epididymis. Although female mice showed small changes in the length of dioestrus and pro-oestrus, the overall cycle length was unchanged. As biological significance of these changes was unclear, a NOAEL for female mice was established at 5 % (9400 mg/kg bw/day) (OECD, 2005; REACH). As properly conducted studies in animals are not available, there are no valid data on the effects of repeated inhalation exposure to the chemical. However, limited information is presented below to indicate that the chemical is likely to be of low toxicity following repeated inhalation exposure. In a repeated dose toxicity study, SD male rats (10/dose) were exposed to the chemical through inhalation (whole body exposure) continuously at 20 mg/L for three, six, nine, and 26 days. Although initial exposure to the chemical produced a number of transient effects (lethargy, ataxia and intoxication, mild hepatic vacuolisation and changes to clinical chemistry parameters), animals adapted and appeared normal at the end of the study. Induction of metabolic tolerance to the chemical was also indicated as it was noted that the levels of the chemical in the blood of animals exposed for 26 days were much lower than those exposed for shorter periods (REACH). In another repeated dose toxicity study, the chemical was administered through inhalation at 0 or 6300 ppm (1 ppm = 1.92 mg/m³) to SD rats (10/sex/dose) for six hours/day, five days/week, for four weeks (total of 20 days exposure). Additional groups of animals (five/sex/dose) were also included in the study to determine reversibility of effects for a further four weeks following cessation of treatment. There were no treatment-related clinical signs of toxicity and there were also no gross pathological or histological changes reported of the major organs. Body weights, liver enzyme levels, haematology, and clinical chemistry parameters were otherwise normal (REACH).

Carcinogenicity	The International Agency for Research on Cancer (IARC) has concluded that there is sufficient evidence in humans and experimental animals to establish carcinogenicity of alcohol consumption and ethanol, respectively. It was also concluded that there is sufficient evidence in experimental animals to establish carcinogenicity of acetaldehyde (major metabolite of ethanol). Consequently, IARC has classified that 'alcohol consumption is carcinogenic to humans (Group 1)' and that 'ethanol in alcoholic beverages is carcinogenic to humans (Group 1)'. This conclusion was supported by an analysis of the expanded human dataset that carcinogenic effects appeared independent of the type of alcoholic beverage (IARC, 2010; IARC, 2012). As the use of the chemical in alcoholic beverages is not considered in this report, the above assessment of carcinogenicity of alcohol beverages may not be relevant to occupational exposure to the chemical or from using the chemical in consumer products (OECD, 2005). Furthermore, studies in animals conducted mostly through oral exposure at very high doses, exceeding the 'maximum tolerated dose', may be of little relevance when assessing risks associated with occupational exposure or using consumer products containing the chemical (OECD, 2005). Thus, classification is not considered appropriate.
Mutagenicity/ Genotoxicity	Overall, the data indicate that the chemical has no mutagenic or genotoxic potential (OECD, 2005; REACH). The results from numerous bacterial mutation assays of the chemical have generally been negative. A very weak positive effect of the chemical was found in an Escherichia coli DNA repair test but not in Ames tests with Salmonella typhimurium conducted by the same authors. In separate studies, there have been positive results reported in Ames tests, but only at concentrations of the chemical significantly greater than those specified in test guidelines. The chemical is therefore not considered mutagenic in bacteria.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	The chemical does not show specific reproductive or developmental toxicity. Any reproductive and developmental effects were only observed secondary to maternal toxicity. As results of inhalation studies showed no developmental toxicity from chemical exposures even at maternally toxic doses, it can be concluded that deliberate oral consumption of alcoholic beverages is required for any reproductive or developmental toxicity (OECD, 2005).
Acute Toxicity	The chemical has low acute toxicity by oral exposure in animal tests. The median lethal dose (LD50) in rats is >2000 mg/kg bw. Observed sub-lethal effects included central nervous system depression, e.g. inebriation, disturbances of gait, dose-related decreases in responses to painful stimuli, respiratory depression, and coma. Deaths were reported due to cardiorespiratory failure (OECD, 2005; HSDB; REACH). Few studies are available on the dermal toxicity of the chemical. A poorly documented rabbit study reported death in one of four animals following a dose of 20000 mg/kg bw. Although limited data are available, the apparent low dermal toxicity from this study is regarded as consistent with low uptake of ethanol through intact skin. The median lethal dose (LD50) in rats is greater than 2000 mg/kg bw. Observed sub-lethal effects were not reported for the study (OECD, 2005; REACH). The chemical has low acute toxicity by inhalation exposure in animal tests. The lowest reported median lethal concentration (LC50) is 124.7 mg/L/four hours in rats. Observed sub-lethal effects included attempts to escape, reddish-watery eyes, nasal secretions, closing of eyelids, snout wiping, intermittent respiration, loss of pain reflex, abdominal position, and apathy (OECD, 2005; REACH).

Irritation	The chemical is not regarded as irritating to skin. In a skin irritation study conducted in accordance with OECD Test Guideline (TG) 404, the chemical was applied to six New Zealand White rabbits for four hours using exposure chambers. The mean score for erythema was one at 24 hours and remained zero at all other time points (48, 72 hours); the mean score for oedema remained zero at all time points (24, 48, 72 hours). The chemical was concluded not to be irritating to the skin of rabbits. Another skin irritation study in rabbits, where the chemical was applied under occlusion for 24 hours, also showed only very slight skin irritation (OECD, 2005; REACH). The chemical produced irritant effects in several eye irritation studies in rabbits. In an eye irritation study conducted in accordance with US Federal guideline (Fed. Reg. Vol. 38, No. 187, 1973), the chemical (0.1 mL) was applied on the conjuctival sac of one eye of each of three New Zealand White rabbits. Irritation responses were observed at 24, 48 and 72 hours and eight days following application. Mean Draize scores following grading at 24, 48 and 72 hours for three rabbits were 1 for corneal opacity, 0.22 for iritis, 2.45 for conjunctivitis, and 1.89 for chemosis. Mean Draize scores following grading at day eight were 0.67 for corneal opacity, 1.67 for conjunctivitis, and 1.33 for chemosis. While iris lesions were fully reversible by day eight, other eye lesions were not fully reversible at this time. Given the observation period did not extend to 21 days, it is difficult to conclude any findings on the reversibility of the irritation. The average response of 2/3 animals was sufficiently severe in terms of conjunctival effects (>2.5) and chemosis (^{3}2) observed, that classification as an eye irritant is warranted (REACH). In another eye irritation study (OECD TG 405), the chemical (0.1 mL) was applied to the eyes of three rabbits (strain not specified) and observed up to 14 days. Mean Draize scores at 24, 48 and 72 hours were 2.11 for conjunctivitis, 1.33 for chemosis, 0.44 for iritis, and 1.11 for corneal opacity. Although all symptoms subsided by day 14, conjunctivitis was still present at day seven. As positive responses for corneal opacity (mean score >1 for 2/3 animals) and conjunctival redness (mean score >2 for 2/3 animals) were noted in the study, the chemical is considered to be an eye irritant (category 2A) (OECD, 2005; REACH). In an eye irritation study (OECD TG 405), the chemical (0.1 mL) was applied into the lower conjunctival sac of one eye of six New Zealand White rabbits and observed up to 72 hours. Reported average Draize scores at 24, 48 and 72 hours were 2.39 for redness of the conjunctivae, 1.2 for chemosis, 0.28 for iritis, and 1.2 for corneal opacity. As conjuctival redness persisted for 24 hours with a mean score of >2 and corneal opacity was noted with a mean score >1, the chemical is considered to be an eye irritant (category 2A) (OECD, 2005; REACH). In an eye irritation study conducted in accordance with US Federal guideline (Fed. Reg. 28 (119), 5582, 1963), the chemical (0.1 mL) was applied on the lower lid of one eye of six New Zealand White rabbits. The eyes were examined at 24, 48, and 72 hours and at day seven following administration of the chemical. Mean Draize scores following grading at 24, 48 and 72 hours were 1.72 for conjunctivitis, 1.78 for chemosis, 0.83 for iritis, and 1.28 for corneal opacity. While iris lesions were fully reversible at day seven, other eye lesions were not. Mean Draize scores following grading at day seven were 0.83 for conjunctivitis, 0.83 for chemosis, and 1.17 for corneal opacity. As corneal opacity was noted with a mean score >1, the chemical is considered an eye irritant (category 2A). In addition, whilst mean scores for conjunctival redness and chemosis were <2, scores ^{3}2 were noted in four out of six animals (OECD, 2005; REACH).

Sensitisation	The available data indicate that the chemical does not induce skin sensitisation in animals. The chemical, at 75 % concentration, was used as a solvent in a Magnusson and Kligman guinea pig maximisation test of a polyalkalene glycol. Skin reactions were not observed at challenge with the polyalkalene glycol in 75 % ethanol in either the test or negative control animals (OECD, 2005). In a mouse ear swelling test, no increase in ear thickness was observed following a challenge application of the chemical at 95 % (OECD, 2005; REACH). In a mouse local lymph node assay (LLNA) (OECD TG429) the chemical, or diethyl phthalate, were used as vehicles to examine the skin sensitisation potential of four test fragrance materials. The concentration of the chemical in this study varied from 0–100 %. The level of induced T-lymphocyte proliferation was low for the chemical compared with that for fragrance materials known to be mild to moderate skin sensitisers, and comparable with the other negative control vehicle (diethyl phthalate). On the basis of a lack of sensitising potential up to a concentration of 100 %, the test concluded that the chemical is an appropriate vehicle for use in a local lymph node assay (REACH).
Health Effects Summary	While exposure to the chemical through consuming alcoholic beverages is associated with an increased risk of carcinogenicity and reproductive and developmental toxicity, these risks increase in a dose-dependent manner and are not considered relevant at doses relating to occupational exposure and using consumer products containing the substance such as mouthwash. Therefore the critical health effect for risk characterisation from industrial use of the chemical is a local effect: eye irritation.
Key Study/Critical Effect for Screening Criteria	Overall, the most sensitive endpoint for ethanol is repeat dose toxicity. The oral NOAEL was 2,400 mg/kg bw/day. This NOAEL is used in this human health risk assessment.
Ecological Toxicity [2,3]	
Aquatic Toxicity	The aquatic toxicity data in fish, invertebrates, and algae indicate a low order of acute toxicity with LC50/EC50 values greater than 1000 mg/L. The most sensitive species were algae Chlorella vulgaris with a 96hr EC50 of 1000 mg/L and the invertebrate Artemia Salina with a 24hr LC50 of 1833 mg/L. Valid chronic toxicity data are available for two trophic levels. NICNAS (2017) reported a measured chronic endpoint of 7800 mg/L for Daphnia.
Determination of PNEC aquatic	A PNECaqua = 780 mg/L can be calculated based on the chronic toxicity value (NOEC = 7800 mg/L) for aquatic invertebrates (Daphnia) with the assessment factor of 10.
Current Regulatory Controls [1,4]	
Australian Hazard Classification	The chemical is not classified for health hazards on the Hazardous Substances Information System (HSIS) (Safe Work Australia).
Australian Occupational Exposure Standards	The chemical has an exposure standard of 1880 mg/m³ (1000 ppm) time weighted average (TWA).
International Occupational Exposure Standards	The following exposure standards are identified (Galleria Chemica): An exposure limit (TWA) of 960–1920 mg/m³ (500-1000 ppm) in countries such as Canada, Denmark, Germany, Sweden, South Africa, Switzerland, United Kingdom, and the United States of America. An exposure limit (STEL) of 1900–1920 mg/m³ (1000 ppm) in countries such as Canada, Sweden, and Switzerland.

Australian Food Standards	Ethanol has the following listings in the Australia New Zealand Food Standards Code (Food Standards Australia and New Zealand 2013): · as a permitted food additive subject to GMP (ethanol) (Standard 1.3.1 Food additives) · as a generally permitted processing aid (ethyl alcohol) (Standard 1.3.3 Processing aids) · as a permitted component of wine (alcohol) (Standard 2.7.3 Fruit wine and vegetable wine) · as subject to a composition limit in brewed soft drinks (no more than 1.15% alcohol/volume) (Standard 2.6.2 Non-alcoholic beverages and brewed soft drinks) · As subject to a composition limit in: − wine and sparkling wine (no less than 45mL ethanol/L and not to contain added ethanol) − fortified wine (no less than 150 mL ethanol/L and no more than 220 mL ethanol/L) − brandy (must contain no less than 250 mL/L of the spirit distilled at a strength of no more than 830 mL ethanol/L at 20°C (Standard 4.5.1 Wine production requirements).
Australian Drinking Water Guidelines	No aesthetic or health-related guidance values were identified for this chemical in the Australian Drinking Water Guidelines (NHMRC 2011).
Aquatic Toxicity Guidelines	1400 µg/L (95% protection level) (ANZECC & ARMCANZ, 2000)
PBT Assessment [2]	
P/vP Criteria fulfilled?	No. Ethanol is readily biodegradable (74% after 5 days).
B/vB criteria fulfilled?	No. Ethanol is not likely to bioaccumulate (calculated logBCF=0.5).
T criteria fulfilled?	No. Chronic aquatic toxicity (NOEC) >1mg/l, thus ethanol does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	January 2019

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Toxicity Summary - Ethylene glycol

Chemical and Physical Properties [1,2]	
CAS number	107-21-1
Molecular formula	C2H6O2
Molecular weight	62.07 g/mol
Solubility in water	Miscible with water.
pH	No data found
Melting point	-12.69 ºC
Boiling point	197.3 ºC
Vapour pressure	0.092 mm/Hg at 25C
Henrys law constant	Low. 6.00X10-8 atm-cu m/mol at 25 deg C
Explosive potential	Not explosive
Flammability potential	Lower flammable limit of 3.2% by volume; Flashpoint of 232 deg F (111 deg C). Not combustible.
Colour/Form	Colourless odourless liquid
Overview	Ethylene glycol is a clear, colourless, syrupy liquid with a sweet taste but no odour. It has low volatility. It is miscible with water and some other solvents, slightly soluble in ether, but practically insoluble in benzene, chlorinated hydrocarbons, petroleum ethers, and oils. As a small molecular weight alcohol, ethylene glycol readily passes through biological membranes and will be effectively absorbed from the gastrointestinal tract and via inhalation exposure. It is rapidly distributed in body water. The chemical has numerous domestic and commercial uses, and is found in cleaning products, cosmetics, hydraulic brake fluids, anti-freeze agents and corrosion inhibitors. Ethylene glycol has been assessed by NICNAS to be of low environmental concern when used in coal seam gas extraction.
Environmental Fate [1,3,5]	
Soil/Water/Air	Ethylene glycol released to the atmosphere will be degraded by reaction with hydroxyl radicals; the half-life for the compound in this reaction has been estimated at between 0.3 and 3.5 days. No hydrolysis of ethylene glycol is expected in surface waters. The compound has little or no capacity to bind to particulates and will be mobile in soil. The low octanol/water partition coefficient and measured bioconcentration factors indicate low capacity for bioaccumulation Ethylene glycol is readily biodegradable in standard tests using sewage sludge. Rapid degradation has been reported in surface waters (less in salt water than in fresh water), groundwater, and soil.

Human Health Toxicity Summary [1,2,3,4,6,7]	
Chronic Repeated Dose Toxicity	Considering the lowest observed adverse effect levels (LOAELs) available from 13–104 week studies (300–3000 mg/kgbw/d) (ATSDR, 2010), and based on the treatment-related effects reported in various repeated dose toxicity studies, the chemical is not considered to cause serious damage to health from repeated oral exposure. However, there is evidence of cumulative effects, as the nephropathy observed at high doses in acute toxicity studies also occurs after repeated exposure at lower doses. The National Toxicology Program (NTP) conducted a 13 week and a two year study in B6C3F1 mice. In the 13 week study, 10 male and 10 female mice were administered 0, 3200, 6300, 12500, 25000 or 50000 ppm ethylene glycol incorporated into feed. There were no reported deaths and no chemical-related clinical findings were reported. Histopathology showed chemical-related kidney and liver lesions, which were significantly elevated in the 25000 and 50000 ppm male mice. These lesions included nephropathy and centrilobular hepatocellular hyaline degeneration (NTP, 1993). The two year study used 60 male mice dosed with the chemical at 0, 6250, 12500 or 25000 ppm and 60 females dosed at 0, 12500, 25000 or 50000 ppm in feed. The doses in ppm were reported as being equivalent to: males - 0, 1500, 3000 or 6000 mg/kg bw/d and females - 0, 3000, 6000 or 12000 mg/kg bw/d. There were no significant differences in survival although male mice in the high dose (6000 mg/kg bw/d) group had to be housed separately after week 54 due to excessive fighting. Survival of mice was not affected by ethylene glycol administration at all doses. As with the 13 week study, mice did not show any adverse clinical signs. Histopathology showed hepatocellular degeneration in the mid and high dose male and high dose female mice. Pulmonary arterial hyperplasia occurred at a higher incidence in female mice than male mice exposed to the chemical. Some male mice in the high dose group had oxalate-like crystals and/or calculi in the renal system (NTP, 1993). Mice appear to be less sensitive than rats to ethylene glycol. A two-year study conducted in Fischer-344 (F344) rats found that administration of the chemical (40, 200 or 1000 mg/kg bw/d) resulted in excessive mortality in male rats in the high dose group after nine months. All male rats in the high dose group (1000 mg/kg bw/d) were reported dead by 15 months of the study. Survival was significantly reduced in male rats in the 1000 mg/kg bw/d group only. (Cruzan et al., 2004; DePass et al., 1986). Pathology investigation of the male rats concluded that extensive kidney damage was the reason for increased mortality in the 1000 mg/kg bw/d group. The NOAEL for male rats was reported as 200 mg/kg bw/d in this study (DePass et al., 1986). A further study indicates that the Wistar rat strain is more sensitive than the F344 strain. In a 16-week study, 10 male rats of each strain were exposed to the chemical (0, 50, 150, 500 or 1000 mg/kg bw/d) by incorporation in a normal diet. Mortality was reported in two Wistar rats at the highest dose and significant weight loss was observed in Wistar rats administered 500 and 1000 mg/kg bw/d, respectively. Both strains of rats treated with ≥ 500 mg/kg bw/d had increased calcium oxalate crystals in the kidney tubules as well as crystal associated nephropathy; this was reported as being more severe in the Wistar rat strain (Cruzan et al., 2004). Further repeated dose studies conducted in rodents have reported no observed adverse effect levels (NOAELs) in the range of 150–2000 mg/kg bw/d depending on species and strain studied. Overall, repeated oral exposure to ethylene glycol is consistently associated with adverse effects on the kidney such as crystal nephropathy in rodents (ATSDR, 2010).

	In a study conducted according to OECD TG 410, five male Beagle dogs per group were dermally exposed (60 % of the total body surface area) to 0.5, 2.0 or 8 mL/kg bw/d Glysantin G 105 (automotive coolant which contains ≥ 92.5 % ethylene glycol and ≥1.4 % p-tert.-butyl benzoate (PTBBA)) daily for four weeks. Mortality (4/5 animals) was reported at the highest dose (8 mL/kg). Prior to death, animals showed signs of toxicity including staggering gait, vomiting, diarrhoea and reduced food intake. Clinical analysis showed increased creatinine and urea levels and increased incidence of calcium oxalate crystals. Pathology investigation reported oxalate nephrosis, testicular atrophy and uraemic gastroenteritis. Similar pathology findings were reported at the mid dose (2 mL/kg), but only in one animal. No mortality or any further clinical or pathological adverse effects were reported at the mid and lower doses. Further studies conducted comparing pure ethylene glycol to Glysantin G105 showed that the testicular atrophy was associated with the presence of PTBBA in Glysantin G105 and not ethylene glycol (REACH). PTBBA has known testicular toxicity (NICNAS). Mortality was reported in 1/15 rats, 3/15 guinea pigs, 1/3 rabbits, 0/3 dogs and 0/3 monkeys after exposure to 12 mg/m3 of ethylene glycol aerosol for 90 days. Apart from mortality, no specific signs of clinical toxicity were reported. In a further study, no mortality or toxicity was observed in the same range of animal species exposed to either 10 or 57 mg/m3 ethylene glycol. The authors noted that as the exposure was whole body, further oral intake from grooming may have occurred, and therefore a reliable LOAEL could not be established (ATSDR, 2010).
Carcinogenicity	Based on the available data, ethylene glycol is not considered to be a carcinogen. Histopathological investigations showed no evidence of carcinogenicity in studies conducted in various rodent species. No tumours were reported in SD rats administered up to 3000 mg/kg bw/day in the diet for two years, F344 rats administered 1000 mg/kg bw/day in the diet for one year, B6C3F1 mice administered up to 12000 mg/kg bw/day in the diet for two years and CD-1 mice administered up to 1000 mg/kg bw/day in the diet for two years (NTP, 2004; WHO, 2002). A limited number of epidemiological studies have reported that exposure to the chemical does not increase the risk of cancer. Ethylene glycol exposure (inhalation) in 1666 chemical plant employees was not found to increase the odds ratio (OR) for any type of cancer (ATSDR, 2010).
Mutagenicity/ Genotoxicity	Based on the weight of evidence from the available in vitro and in vivo genotoxicity studies the chemical is not considered to be genotoxic. An Ames assay conducted according to OECD TG 471 reported that the chemical did not induce bacterial mutations in Salmonella typhimurium strains TA 1535, TA 1537, TA 98, TA 100 and Escherichia coli WP2 at a concentration up to 5000 □g/plate with or without metabolic activation (REACH). Further in vitro genotoxicity tests conducted with bacterial and mammalian cell lines were all negative for gene mutations and DNA strand breaks respectively (ATSDR, 2010). An in vivo study in mice reported no chromosomal aberrations in Swiss mice exposed to 638 mg/kg bw/day for two days (WHO, 2002). Negative results were found for dominant lethal mutations in F344 rats after administration of up to 1000 mg/kg bw/d ethylene glycol in a 155-day multi-generational study.

Reproductive Toxicity Developmental Toxicity/Teratogenicity	The available data from rat studies suggest that developmental effects were only observed secondary to maternal toxicity, so the chemical does not show specific developmental toxicity. The chemical is not toxic to reproduction. Having reviewed the available data the Centre for the Evaluation of Risks to Human Reproduction (CERHR) expert panel concluded that there are sufficient data to conclude that the chemical is not toxic to reproduction in rats orally exposed to 1000 mg/kg bw/day in diet (NTP, 2004). A study in mice gave negative results at doses up to 2826 mg/kg bw/day via drinking water. The expert panel also concluded that exposure of CD-1 mice to the chemical by the dermal route for 6 hours/d on gestation days (GD) 6-15 resulted in no evidence of developmental toxicity up to a dose of 3549 mg/kg bw/d. Developmental toxicity was also not observed in rabbits exposed orally via gavage on GD 6-19 to doses as high as 2000 mg/kg bw/d. Severe maternal toxicity was observed at the high dose with maternal deaths as well as oxalate crystals in the kidney. Data suggested that oral exposure to high doses of the chemical (≥500 mg/kg bw/d in CD-1 mice and ≥1000 mg/kg bw/d in SD rats) on GD 6-15 causes developmental effects in mice and rats such as axial skeletal malformations, external malformations, reduced body weights and increased post-implantation loss (NTP, 2004). The CERHR expert panel concluded that developmental toxicity may not be attributed directly to the chemical but from the accumulation of glycolic acid, which is a metabolic breakdown product of ethylene glycol. The developmental effects are seen at doses that exceed saturation of glycolic acid metabolism. Observations from rat studies suggest that oral doses resulting in developmental toxicity (1000 mg/kg bw/d) are greater than those associated with maternal and renal toxicity at 500 mg/kg bw/d.
Acute Toxicity	Ethylene glycol has low acute toxicity via oral, inhalation, or dermal exposure. LD50s for the oral administration of ethylene glycol in rats range from 4000 to 10 020 mg/kg body weight, while reported values in guinea-pigs and mice are 6610 mg/kg body weight and 5500–8350 mg/kg body weight, respectively. The minimum lethal oral dose in rats is 3.8 g/kg body weight (Clark et al., 1979). Oral LD50s of 5500 and 1650 mg ethylene glycol/kg body weight have also been reported in dogs and cats, respectively. A dermal LD50 of 10 600 mg/kg body weight has been reported for rabbits. In rats and mice, the lethal concentration following 2-h inhalation exposure has been reported to be >200 mg/m3.
Irritation	The available data show that the chemical is a mild skin irritant in animals. Mild dermal irritation was reported in rabbits and guinea pigs. No dermal effects were reported in female CD-1 mice exposed to 3549 mg/kg bw/day ethylene glycol under occlusive conditions for 6 hours/day on gestation days 6-15 (NTP, 2004; WHO, 2002). The available data indicate that the chemical is a mild eye irritant in animals. In a study conducted in six New Zealand White rabbits, 0.05 mL of the chemical (4 or 40 %) applied to one eye (while the other eye served as a control) at 10 minute intervals for a total of 35 applications in a six hour period was reported to cause chemosis, swelling and conjunctival redness. All eyes exposed to the chemical were reported to be normal on day seven of observation and no evidence of systemic toxicity was reported (REACH).
Sensitisation	The chemical was not found to induce dermal sensitisation when tested according to OECD Test Guideline (TG) 406 (REACH).
Health Effects Summary	Ethylene glycol demonstrates acute oral toxicity, is a mild skin and eye irritant and a respiratory irritant in humans. The chemical is not a skin sensitiser. Consistent adverse effects associated with repeated exposure to ethylene glycol in animals are the kidney effects, characterised by calcium oxalate crystal deposition and consequent renal lesions.

Key Study/Critical Effect for Screening Criteria	The key study chosen for the determination of a drinking water guidance value is the one-year rat feeding study by Wilson et al. (2005). No adverse chronic renal effects from ethylene glycol dosing were seen in animals exposed below 150 mg/kg/day. The oral RfD for ethylene glycol is thus based on the NOAEL of 150 mg/kg/day. Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability) Oral RfD = 150/100 = 1.5 mg/kg/dayDrinking water guideline value = 0.59 ppm
Ecological Toxicity [3,8]	
Aquatic Toxicity	The aquatic toxicity of the 'ethylene glycol and higher glycols' (mono-, di-, tri-, tetra- and pentaethylene glycol) is evaluated as a category. Fish acute toxicity (measured as LC50 in mg/L) has been tested for all category members and ranges from 22800 for EG to greater than 50000 for pentaEG. Toxicity to Daphnia (measured as LC50 in mg/L) is greater than 20,000 for all category members except tetraEG (LC50=7800 mg/L) indicating low toxicity, but the toxicity was not as uniform as in fish. Toxicity evaluations in another invertebrate, brine shrimp (Artemia salina) were imprecise, but appear to be more consistent than the measured Daphnia toxicity values (no toxicity observed at the highest tested dose, 20g/l for EG, 10 g/l for DEG, TEG and tetraEG). Algal toxicity has been tested for EG, DEG, TEG, and PentaEG, and no toxicity was found at concentrations less than or equal to 100 mg/L. As a worst case assumption the limit test concentration of 100 mg/L was used as NOEC value for the PNEC derivation.
Determination of PNEC aquatic	PNECaquatic: An assessment factor of 10 has been applied to the lowest reported effect concentration of 100 mg/L. The PNECaquatic is determined to be 10 mg/L.
Current Regulatory Controls [7]	
Australian Hazard Classification	Xn (Harmful); R22 (Harmful if swallowed) (Safe Work Australia 2013) Acute Toxicity: Harmful if swallowed – Cat 4 (H302) (NICNAS)
Australian Occupational Exposure Standards	Ethylene glycol has an exposure standard of 10 mg/m^3 time weighted average (TWA). A further exposure standard for ethylene glycol (vapour) is 52 mg/m^3 (20 ppm) TWA and a short-term exposure limit (STEL) of 104 mg/m^3 (40 ppm) (Safe Work Australia 2013)
International Occupational Exposure Standards	TWA: 50 mg/m3 (20 ppm) [Belgium, Hungary, UK, Finland] 26 mg/m³ (10 ppm) [Denmark, Iceland, Sweden] 25 to 50 mg/m³ (63 to 125 ppm) [Mexico, Norway] 5 mg/m³ [Russia] STEL: 20 to 40 mg/m3 (50 to 104 ppm) [Belgium, Hungary, UK, Finland, Peru, Sweden] 10 mg/m³ [Russia]
Australian Food Standards	No data found.
Australian Drinking Water Guidelines	No data found
Aquatic Toxicity Guidelines	No data found
PBT Assessment [1,3,5]	
P/vP Criteria fulfilled?	Ethylene glycol is readily biodegradable both aerobically and anaerobically and as such not persistent in the environment.
B/vB criteria fulfilled?	Based on the measured log Kow of -1.36 and a measured BCF of 10, Ethylene glycol is not bioaccumulative.
T criteria fulfilled?	The acute aquatic toxicity of Ethylene glycol is > 0.01 mg/L. Hence the substance does not fulfill the screening criteria for toxic (T)
Overall conclusion	Not a PBT substance (based on screening data).
Revised	April 2018

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Toxicity Summary - Fatty acids, tall-oil, ethoxylated

Chemical and Physical Properties[1]	
CAS number	61791-00-2
Molecular formula	C(18-50)H(34-98)O(3-8)
Molecular weight	UVCB
Solubility in water	No data available.
Melting point	-85 °C at 101.3 kPa
Boiling point	No data available.
Vapour pressure	No data available.
Henrys law constant	No data available.
Explosive potential	Non-explosive (100%)
Flammability potential	Not classified
Colour/Form	Liquid
Overview	This substance is used by consumers, in articles, by professional workers (widespread uses), in formulation or re-packing, at industrial sites and in manufacturing.
Environmental Fate[1]	
Soil/Water/Air	One study investigating the adsorption/desorption behaviour of Fatty acids, tall-oil, ethoxylated (CAS 61791-00-2) is available. The study was performed according to GLP and OECD guideline 121 (BASF 2017). 6 different peaks were observed with log Koc values ranging from < 1.8 to > 5.63. The two main components (> 85%) show log Koc values > 4. Thus, adsorption of Fatty acids, tall-oil, ethoxylated to solid soil is expected. The test with the source substance was conducted according to OECD Guideline 301B, under GLP conditions (BASF 2005). Domestic, non-adapted activated sludge was exposed to the test substance for 28 days at 22°C, and biodegradation was measured by CO2 consumption. After 28 days, the test substance reached a biodegradation of 90 - 100 %. Based on the results for the read-across substance, Fatty acids, tall oil, ethoxylated (EO > 1 < 2.5) (CAS 61791-00-2) is considered to be readily biodegradable. The test substance consists of components with log Kow values in the range of 5 to > 10 (KOWWIN v1.68) indicating a potential for bioaccumulation. But due to rapid environmental biodegradation, metabolisation via enzymatic hydrolysis (monoesters and diesters) as well as sterical hindrance of crossing biological mebranes (high molecular weight of diesters) a relevant uptake and bioaccumulation in aquatic organisms is not expected. This is supported by low BCF values of < 100 L/kg ww (BCFBAF v3.01, Arnot-Gobas, including biotransformation, upper trophic) calculated for different components of the UVCB (mono- and diester EO1 to EO5). Thus, taking all information into account, the test substance is not considered to be bioaccumulative.
Human Health Toxicity Summary [1]	
Chronic Repeated Dose Toxicity	Under the conditions of this Combined Repeated Dose Toxicity Study with the Reproduction/Developmental Toxicity Screening Test, the oral administration by gavage of test substance to Wistar rats revealed no adverse signs of toxicity in male and female animals at a dose level of 1000 mg/kg bw/d. Thus, the no observed adverse effect level (NOAEL) for general systemic toxicity was 1000 mg/kg bw/d for male and female Wistar rats.
Carcinogenicity	No data available.

Mutagenicity/ Genotoxicity	The test substance is not mutagenic in bacteria, as determined in an OECD 471 study. The test substance is not chromosome damaging, as determined in an OECD 487 study. The test substance is not mutagenic in mammalian cells, as determined in an OECD 476 study.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Under the conditions of this Combined Repeated Dose Toxicity Study with the Reproduction/Developmental Toxicity Screening Test, the oral administration by gavage of the test substance to Wistar rats revealed no adverse signs of toxicity in male and female animals at a dose level of 1000 mg/kg bw/d. Thus, the no observed adverse effect level (NOAEL) for general systemic toxicity was 1000 mg/kg bw/d for male and female Wistar rats. The NOAEL for reproductive performance and fertility was set to 1000 mg/kg bw/d for male and female Wistar rats.
Acute Toxicity	In an acute oral toxicity study performed similar to OECD guideline 401 (BASF 1971), three groups of rats consisting of 10 animals/sex/dose were treated by single gavage application with an aqueous solution of the test substance (10000, 8000, 6400 mg/kg bw). The animals were observed for mortality and for clinical symptoms of toxicity over a period of 7 days. At the end of the observation period, the surviving animals were sacrificed for the purpose of necropsy. No mortality occurred at the tested concentrations. At all doses mastication, irregular breathing, redness of the eyes and closed eyes were seen immediately after dosing. The next morning mastication and irregular breathing was observed. On the following days, no clinical sings were observed. Pathological examination revealed hydrometra in 3 animals exposed to 10000 mg/kg bw, 2 animals exposed to 8000 mg/kg bw, and 3 animals exposed to 6400 mg/kg bw. Based on the results obtained under the test conditions of this study, the acute oral LD50 was determined to be > 10000 mg/kg bw. To evaluate the potential acute inhalation toxicity of the test substance an Inhalation Risk Test conducted according to a BASF internal testing method (BASF 1971). The test demonstrates the toxicity of an atmosphere saturated with vapours of the volatile components of a test substance at the temperature chosen for vapour generation (20 °C). Rats were exposed sequentially to the vapours, generated by bubbling 200 l/h air through a substance column of about 5 cm above a fritted glass disc in a glass cylinder. The animals were exposed for 8 hour. The exposure concentration was estimated to be 0.28 mg/L based on evaporated substance. In addition to mortality, clinical signs were recorded and necropsy on surviving animals performed. No mortality occurred and no clinical sign were noted during exposure and observation period. In one animal exposed for 8 hours hydrometra was observed after necropsy. Since no mortality occurred at the concentrations tested an LC50 estimation cannot be made. In another Inhalation Risk Test of similar design, Rats (12 animals) were exposed sequentially to the vapours, generated by bubbling 200 l/h air through a substance column of about 5 cm above a fritted glass disc in a glass cylinder. This time vapours were generated at 20 °C as well as 50 °C. The exposure concentrations were 0.04 mg/L and 0.34 mg/L. Rats were exposed for 8 hour. As in the previous study, no mortality occurred after exposure up to 8 hours. Clinical sings observed in the animals exposed to the vapour generated at 20°C included mild escape attempts when exposure began and at the end of the exposure period slight eye irritation was observed. The next day, the animals were without symptoms. In the animals exposed to the vapour generated at 50 °C escape attempts were noted in the first 60 minutes of exposure. Exposure to the saturated atmosphere caused slight eye irritation. At the end of the exposure period, all clinical signs were resolved. Since no mortality occurred at the concentrations tested an LC50 estimation cannot be made. Based on the inhalation studies, no conclusion on LC50 can be drawn, because the tested concentrations are too low in relation to the classification criteria.

Irritation	The test substance was not irritant or corrosive to the skin in a GLP-compliant OECD 431 and 439 study. The test substance was not irritant to the eyes in a GLP-compliant OECD 492 study. Based on the available information, classification for skin and eye irritation is not warranted, in accordance with EU Classification, Labelling and Packaging of Substances and Mixtures (CLP) Regulation No. (EC) 1272/2008.
Sensitisation	The test substance did not show an indication of skin sensitising potential in an OECD 429 (LLNA) study. However, an earlier Buehler test (OECD 406) did indicate skin sensitising potential of the substance.
Health Effects Summary	Possible sensitiser.
Key Study/Critical Effect for Screening Criteria	
Ecological Toxicity [1]	
Aquatic Toxicity	Short-term toxicity tests with the target substance for all trophic levels (fish, daphnia, algae) are available. The test substance did not indicate to be harmful to freshwater fish (96h-LL50 > 100 mg/L), but showed to be toxic to aquatic invertebrates (48h-EL50 = 12.41 mg/L) and harmful to algae (72h-EL50 = 39.7 mg/L). Hence, aquatic invertebrates were most susceptible to the test substance and this effect value was used for the PNEC derivation. Long-term toxicity data with the source substance are only available for algae. The algal test revealed the substance to be of low toxicity to algae (72h-EL10 = 7.08 mg/L). In addition, data are available for toxicity to microorganisms. A test on respiration inhibition with activated sludge resulted in an 3h-EC10 of > 10000 mg/L indicating that detrimental effects in STPs are not to be expected.
Determination of PNEC aquatic	A PNECaqua = 0.012 mg/L can be calculated based on the lowest acute toxicity value (EL50 = 12.41 mg/L) for aquatic invertebrates (Daphnia) with the assessment factor of 1000.
Current Regulatory Controls	
Australian Hazard Classification	No data available.
Australian Occupational Exposure Standards	No data available.
International Occupational Exposure Standards	No data available.
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	No data available.
PBT Assessment[1]	
P/vP Criteria fulfilled?	No. Based on the results from the read-across substance, Fatty acids, tall oil, ethoxylated (EO > 1 < 2.5) (CAS 61791-00-2) is considered to be readily biodegradable.
B/vB criteria fulfilled?	No. The test substance consists of components with log Kow values in the range of xx to > 10 (KOWWIN v1.68) indicating a potential for bioaccumulation. But due to rapid environmental biodegradation, metabolisation via enzymatic hydrolysis (monoesters and diesters) as well as sterical hindrance of crossing biological membranes (high molecular weight of diesters) a relevant uptake and bioaccumulation in aquatic organisms is not expected. This is supported by low BCF values of < 100 L/kg ww (BCFBAF v3.01, Arnot-Gobas, including biotransformation, upper trophic) calculated for different components of the UVCB (mono- and diester

	EO1 to EO5). Thus, taking all information into account, the test substance is not considered to be B or vB.
T criteria fulfilled?	No. Available short-term and long-term toxicity tests with aquatic organisms resulted in effect values > 1 mg/L. Thus, this substance does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	January 2019

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Toxicity Summary - Glutaraldehyde

Chemical and Physical Properties [1,2,3]	
CAS number	111-30-8
Molecular formula	C5H8O2
Molecular weight	100.11
Solubility in water	Soluble in all proportions in water and ethanol; soluble in benzene and ether.
Melting point	-14°C
Boiling point	188°C
Vapour pressure	2.03×10^{-3} kPa at 25 °C (50% solution)
Henrys law constant	0.011 Pa m^3/mol @ 25 °C
Explosive potential	Non explosive
Flammability potential	Non flammable
Colour/Form	Colourless oily liquid. In the vapour state, glutaraldehyde has a pungent odour, with an odour threshold of 0.04 ppm.
Overview	Glutaraldehyde is manufactured in Germany by BASF and in the USA by Union Carbide Corporation. It is usually sold commercially as a 45% or 50% aqueous solution. Glutaraldehyde has a wide variety of uses throughout the world with its use spread over a number of different industries. It is used primarily as a biocide but it also has wide use as a fixative, and some use as a therapeutic agent. The principal health effects of glutaraldehyde are irritation of the skin, eye and respiratory tract, skin sensitisation and occupational asthma. Exposure data indicated that, in some situations, particularly the health care industry (disinfection), x-ray film processing and the animal health industry (spray use), health concerns may arise where available control measures such as ventilation have not been implemented to minimise exposure. Due to low and intermittent exposure, the public health risk from the industrial use of glutaraldehyde is minimal. For the use of glutaraldehyde in cosmetics, a safety margin of >400 for extensive use indicated low concern.
Environmental Fate[1]	
Soil/Water/Air	Glutaraldehyde is a hydrophilic substance that will be mainly associated with the aquatic compartment, with minor amounts partitioning to the atmosphere, following release to the environment. Hydrolysis is slow, but glutaraldehyde, like other aldehydes, undergoes aerial oxidation in solution. It biodegrades rapidly in aerobic and anaerobic aquatic environments at subcidal concentrations (below 10 mg/L) and will not bioaccumulate. Tropospheric degradation is also rapid.
Human Health Toxicity Summary [1,2,3]	

Chronic Repeated Dose Toxicity	A two-year chronic study was conducted in male and female Fischer 344 rats (NICNAS 1994). Groups of 100 male and 100 female rats were administered 0, 50, 250, or 1000 ppm w/v glutaraldehyde in drinking water (4, 17 and 64 mg/kg bw/day for the males and 6, 25 and 86 mg/kg/day for the females). The mortality rate over the treatment period was 25 to 30% for males and 19 to 23% for females with no dose-related increase. The major cause of death in all rats (control and dose groups) was large granular cell lymphatic leukaemia (LGLL). Small dose-related decreases in absolute body weight and body weight gain occurred at 250 and 1000 ppm in males and at 1000 ppm in females. Dose-related decrease in urine volumes and associated increase in osmolality were observed in higher dose animals. At necropsy at 52, 78 and 104 weeks, the only statistically significant changes in organ weights were for the kidney. Relative kidney weights were increased for males and females at 52 and 78 weeks. A significant dose-related increase in kidney weight relative to final body weight occurred for males and females in the 250 and 1000 ppm groups, including an increase in absolute kidney weight for the female rats. Changes in final body weights and the weights of other organs were minor and / or sporadic and were unlikely to be related to glutaraldehyde exposure. The total leucocyte count was significantly increased at week 104 in males at 250 and 1000 ppm, and in females at 250 ppm only. The variation in counts was large, possibly due to the large monocyte count at 250 and 1000 ppm. Changes in clinical chemistry parameters included decreases in the activities of some enzymes at 250 and 1000 ppm and occasional decreases in total protein, globulin and phosphorous; these were probably due to reduced food consumption and body weight. Gross pathology showed evidence of gastric inflammation, particularly in rats sacrificed at the end of the study, with irritation observed as ulceration, a multifocal colour change and thickening of the mucosa (dose groups not specified). Histologic examination of the tissues revealed squamous epithelial hyperplasia and keratinised cysts and oedema. Based on the observations, a NOAEL of 4 mg/kg bw/day for males and 6 mg/kg bw/day for females was established in this study. For the purpose of human health risk assessment, the lowest NOAEL (4 mg/kg bw/day) established in the two-year chronic study in rats will be used.
Carcinogenicity	In a two-year chronic/carcinogenicity study by Van Miller et al. (2002), groups of 100 male and 100 female Fischer 344 rats were treated with 0, 50, 250, or 1000 ppm w/v glutaraldehyde in drinking water. The mean glutaraldehyde consumption for each of the three groups was 4, 17 and 64 mg/kg bw/day for the males and 6, 25 and 86 mg/kg bw/day for the females. The mortality rate during the study period was 25 to 30% for males and 19 to 23% for females and was not dose-related. Gross pathology showed evidence of gastric inflammation. The main finding of the study was an increased incidence of large granular lymphocytic leukaemia (LGLL) in the spleen and liver of male and female rats in all groups, including the control group. Treated females showed a significantly increased incidence of LGLL and analysis for dose-response trend for the severity of LLGL revealed an increased severity in females at the higher dosages (53% in spleen and 54% in liver versus respectively 20% and 23% in untreated females) while no such observation were made for the males. No other significant oncogenic effects were observed during the study. Occurrence of LGLL was seen in all groups including controls; the incidence of LGLL in the 1000 ppm group was high compared to controls but no clear dose-response relationship was evident, and LGLL mainly affected treated females whereas the incidence in treated males was within the control range (REACH 2013). Historical control data for untreated Fischer 344 rats in NTP studies also indicates that the ranges for this tumour are 10 to 72% in males and 6 to 31% in females (REACH 2013). The control data in the Van Miller et al. study fitted in with the historical control data reported from NTP studies. The variability in control data for LGLL and the wide variation reported in the literature makes a definitive conclusion difficult. Base on this study, glutaraldehyde was considered not to be carcinogenic.

Mutagenicity/ Genotoxicity	Glutaraldehyde has been extensively tested for genetic activity in vitro and in vivo, however there is disagreement in the literature regarding glutaraldehyde's genetic activity (Zeiger et al. 2005). While all in vivo genotoxicity tests with glutaraldehyde gave negative results, mixed results were reported for in vitro mutagenicity tests. Early in vitro tests were negative (Watts 1984), but some recent bacterial assays and tests in mammalian cells indicated that glutaraldehyde could be mutagenic in vitro. A series of reverse mutation assays was carried out with various Salmonella typhimurium strains, with and without metabolic activation (REACH 2013). All assays with TA 100, 1535, 1537 and 98 were negative. Some assays with TA 102 and 104 gave positive results. Tests with Escherichia coli also yielded both positive as well as negative results. Glutaraldehyde induced sister chromatid exchanges in CHO cells with and without S9 metabolic activation in one laboratory, but was negative without S9 and only weakly positive with S9 in the second laboratory (NICNAS 1994). The difference in the results was attributed to slight differences between the data evaluation systems used in the two laboratories. Glutaraldehyde was not mutagenic in any of the in vivo assays such as peripheral blood micronucleus test, rat bone marrow chromosomal aberration assay and the Drosophila melanogaster sex-linked recessive lethal test (NICNAS 1994; REACH 2013). Chromosome aberrations in bone marrow cells were reported in only one out of eight studies using rats and mice, micronuclei were not induced in bone marrow cells of mice, and dominant lethal mutations were not induced in mice. Glutaraldehyde did not induce cell transformation in Syrian hamster embryo cells in vitro (Zeiger et al. 2005). In vivo, inhalation of glutaraldehyde induced cell proliferation in nasal tissue in rats and mice, but did not induce DNA damage at these sites. Based on these observations, it is concluded that glutaraldehyde is not a genotoxin.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Studies on the incidence of miscarriage in pregnant women have shown no difference between those exposed to glutaraldehyde and those not exposed to the chemical. Studies in female rats and mice have resulted in embryotoxicity/foetotoxicity for glutaraldehyde, but only at doses which are maternally toxic. A number of studies have found no evidence of teratogenicity.

Acute Toxicity	Several acute oral toxicity studies with glutaraldehyde have been reported in rats and other species. In one reliable study, administration of 0.2, 0.3, 0.5, 1.0, 1.7 mL/kg bw glutaraldehyde (corresponding to 226, 339, 565, 1130 and 1921 mg/kg bw, respectively) to male/female Wistar rats by gavage gave a median lethal dose (LD50) of 226 mg/kg bw (REACH 2013). Necropsy of animals that died during the observation period revealed congestion of the lungs and the abdominal viscera. In another study in Sprague-Dawley rats, the oral LD50 was 316 mg/kg bw for males and 285 mg/kg bw for females, when 10 mL of 2.15, 3.16, 4.64, 14.7% glutaraldehyde (corresponding to 215, 316, 464 and 1470 mg/kg bw) was administered by oral gavage (REACH 2013). In a separate study using different strengths of glutaraldehyde, Ballantyne (1986) showed that the oral LD50 for glutaraldehyde in rats varied with the concentration of the glutaraldehyde used. By using different concentrations of glutaraldehyde solutions (1% to 50%) and varying the administration volume to maintain a constant dose, oral LD50 in the range 66 to 733 mg/kg bw were obtained. These studies indicate that glutaraldehyde has high acute oral toxicity. Of the 18 acute dermal toxicity studies reported in REACH (2013) dossiers, results from 14 studies indicated LD50 higher than 2000 mg/kg bw. In four other studies, LD50 ranged between 250 and 1432 mg/kg bw. These studies however did not follow international guidelines and have low reliability. Based on these studies, glutaraldehyde is considered to have low acute dermal toxicity. In a well-defined study, 10 male and 10 female Sprague-Dawley rats per dose group were exposed to glutaraldehyde as liquid aerosol at 0.22, 0.31 and 0.63 mg/L for 4 hours (REACH 2013). Exposure was followed by an observation period of 14 days. During the exposure period slight nasal discharge, snout wiping, flank respiration and irregular to intermittent respiration were reported in rats. During the post-exposure period, bloody nasal discharge, red crusts surrounding the nose, whooping or gasping respiration with rasping sounds and a tremulous gait were observed. These symptoms disappeared in the surviving animals within 5 to 9 days post-exposure. Mortalities were noted in all treated groups. The determination of the LC50 values was based on the Probit Analysis. An LC50 of 0.48 mg/L was calculated for both male and female rats. In another acute inhalation study conducted in a similar manner to the above study, Sprague-Dawley rats, 10 rats per sex per dose group, were exposed to 0.1, 0.18, 0.28, 0.39 and 0.44 mg/L glutaraldehyde as liquid aerosol for 4 hours (REACH 2013). During and after exposure, mortality and clinical signs of toxicity were recorded at regular time intervals. The LC50 in this study was established as 0.28 mg/L for females and 0.39 mg/L for males. Based on the above studies, glutaraldehyde is considered to have high acute inhalation toxicity.
Irritation	Glutaraldehyde is corrosive to the skin and eyes of rabbits at high concentrations, with signs of skin irritation evident at 2%, and eye irritation at 0.2%. Exposure to glutaraldehyde vapours in acute inhalational studies resulted in nasal irritation and respiratory difficulties. Joint irritation was seen in rabbits after intra-articular administration.
Sensitisation	The skin sensitisation effect of glutaraldehyde was demonstrated in tests with guinea pigs.
Health Effects Summary	Glutaraldehyde has high acute oral and inhalation toxicity and low to moderate acute dermal toxicity. Based on human and animal data, it is corrosive, the vapours are irritating to the respiratory tract, and it has skin and respiratory sensitisation potential. Glutaraldehyde has high repeat dose oral and inhalation toxicity, with an oral No-Observed-Adverse-Effect Level (NOAEL) of 4 mg/kg bw/day based on changes in liver and kidney weights and clinical chemistry parameters. Glutaraldehyde is not genotoxic or carcinogenic. It did not have any adverse effects on the reproductive system of adult rats or on the development of foetuses. The critical adverse health effects of glutaraldehyde are corrosivity, skin and respiratory tract sensitisation and acute and repeat dose oral and inhalation toxicity.
Key Study/Critical Effect for Screening Criteria	From the hazard characterisation, the critical (most sensitive) adverse health effects for repeated exposures to the chemical are changes in clinical chemistry parameters and relative organ (liver and kidney) weights. Glutaraldehyde has high repeat dose oral toxicity with an oral NOAEL of 4 mg/kg bw/day. This NOAEL is used in this human health risk assessment.
Ecological Toxicity [1,2,3,4]	

Aquatic Toxicity	96 h acute Bluegill sunfish LC50 = 11.2 mg/L 48 h acute Oyster larvae LC550 = 2.1 mg/L 96 h acute Green crabs LC50 = 465 mg/L 96 h acute Grass shrimp LC50 = 41 mg/L 48 acute Daphnia magna LC50 = 0.35 mg/L 48 acute Daphnia magna LC50 = 16.3 mg/L 21 d reproduct'n Daphnia magna LOEC = 4.3 mg/L, NOEC = 2.1 mg/L 96 h algal growth inhibition Selenastrum capricornutum ILm = 3.9 mg/L (median inhibitory limit) 96 h algal growth inhibition Scenedesmus subspicatus EC50 = 1.0 mg/L Bacterial inhibition Sewage microbes IC50 = 25-34 mg/L In summary, the test results indicate that glutaraldehyde is slightly to moderately toxic to aquatic fauna and moderately to highly toxic to algae. In some instances, glutaraldehyde appeared to be rapidly lost from test waters in the laboratory. Such behaviour in aquatic toxicity tests generally means that their results will underestimate the inherent toxicity of a substance. However, the toxicity that will prevail under environmental conditions is likely to be lower than that recorded in the laboratory in view of the rapid degradation that would be expected to occur in natural surface waters.
Determination of PNEC aquatic	As a wide selection of species is available, applying a safety factor of 10 to the NOEC (2.1 mg/L) derived from Daphnia seems most appropriate, giving a PNEC of 2100/10 = 0.21 mg/L for faunal species
Current Regulatory Controls [1,2,4]	
Australian Hazard Classification	Glutaraldehyde is classified as hazardous in the Hazardous Substances Information System (HSIS) with the following risk phrase (Safe Work Australia 2013): · T (Toxic); R23/25 (Toxic by inhalation and if swallowed) · C (Corrosive ; R34 (causes burns) · R42/43 (May cause sensitisation by inhalation and skin contact). Mixtures containing the chemical are classified as hazardous with the following risk phrases based on the concentration (Conc) of the chemical in the mixtures. The risk phrases for this chemical are: · Conc ≥50%: T; R23/25; R34; R42/43 (Toxic; toxic by inhalation and if swallowed; causes burns; may cause sensitisation by inhalation and skin contact) · ≥25% Conc <50%: T; R23; R22; R34; R42/43 (Toxic; toxic by inhalation, harmful if swallowed, causes burns; may cause sensitisation by inhalation and skin contact) · ≥10% Conc <25%: C; R20/22; R34; 42/43 (Corrosive; harmful by inhalation and if swallowed; causes burns; may cause sensitisation by inhalation and skin contact) · ≥2% Conc <10%: Xn; R20/22; R37/38; R41; R42/43 (Harmful; harmful by inhalation and if swallowed; irritating to respiratory system and skin; risk of serious eye damage; may cause sensitisation by inhalation and skin contact) · ≥1% Conc <2%: Xn; R36/37/38 R42/43 (Harmful; Irritating to eyes, respiratory system and skin; may cause sensitisation by inhalation and skin contact) · ≥0.5% Conc <1%: Xi; R36/37/38; R43 (Irritating; irritating to eyes, respiratory system and skin; may cause sensitisation by skin contact)
Australian Occupational Exposure Standards	The chemical has an exposure standard of 0.41 mg/m³, 0.1 ppm; Time Weighted Average (TWA).
International Occupational Exposure Standards	The following exposure standards are identified in Galleria Chemica (2013): · Occupational Exposure limit (TWA) of 0.2 mg/m3 [Canada, China, Denmark, Japan, Korea, UK] · 0.4 mg/m3 TWA [Sweden] · 0.8 mg/m3 TWA [US (NIOSH), Greece]
Australian Food Standards	No Australian food standards relating to the chemical have been identified (Food Standards Australia New Zealand 2013).
Australian Drinking Water Guidelines	No aesthetic or health-related guidance values were identified for this chemical in the Australian Drinking Water Guidelines. (National Health and Medical Research Council (NHMRC) 2011).

Aquatic Toxicity Guidelines	No data available.
PBT Assessment	
P/vP Criteria fulfilled?	No. Readily biodegradable and as such not persistent in the environment.
B/vB criteria fulfilled?	No. As the Log Pow is -0.01 (Log Pow < 4.5), it is not expected to be bioaccumulative.
T criteria fulfilled?	No. Chronic toxicity data >1 mg/L in invertebrates, thus glutaraldehyde does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	January 2019

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Toxicity Summary - Guar gum

Chemical and Physical Properties[1,2,7]	
CAS number	9000-30-0
Molecular formula	NA.
Product name	
Molecular weight	220,000 g/mol
Solubility in water	Completely soluble in water
pH	No data were found.
Melting point	No data were found.
Boiling point	No data were found.
Vapour pressure	solid
Henrys law constant	NA
Explosive potential	NA
Flammability potential	NA
Colour/Form	NA
Overview	Guar gum is a yellowish-white free-flowing powder. It is completely soluble in water and practically insoluble in oils, greases, hydrocarbons, ketones and esters. Water solutions are tasteless, odourless and a pale, translucent grey colour and neutral. The powder has 5 to 8 times the thickening power of starch. Water solution may be converted to a gel by adding a small amount of borox and are stable to heat. Guar gum is extensively used, eg typically used as a protective colloid, stabilizer, thickening and film forming agent for cheese, salad dressing, milk products including ice cream and soups; disintegration agent in tablet formulations; in pharmaceutical jelly formulations; in suspension, emulsions, lotions, creams and toothpastes; in bulk laxatives and appetite depressants; in mining industry as a flocculent, for hydraulic fracturing aid in oil well recovery and as a filtering ages; gelling and waterproofing agent in explosive and in water treatment as a coagulant. Guar gum is approved for use as a food additive by the U.S. Food and Drug Administration and is on the list of substances "generally recognized as safe" (CFR 1974). This chemical has been identified by NICNAS to be of low concern to human health based on an initial screening approach and thus required no further assessment.
Environmental Fate[1]	
Soil/Water/Air	No information was found. Guar gum, being a polysaccharide composed of galactomannan, would be expected to be readily biodegradable

Human Health Toxicity Summary [1,2,3,5,6,7,8,9]	
Chronic Repeated Dose Toxicity	F344 rats and B6C3F1 mice were given diets containing 0, 6,300, 12,500, 25,000, 50,000 or 100,000 ppm guar gum for 13 weeks (NTP, 1982). Mean body weights were decreased in male rats (100,000 ppm group) and in female mice (50,000 and 100,000 ppm). A dose-related decrease in feed consumption was observed for male and female rats; male and female mice were comparable or higher than that of controls. There were no compound-related clinical signs or histopathological effects. F344 rats and B6C3F1 mice were given diets containing 0, 25,000 ppm or 50,000 ppm guar gum for 103 weeks (NTP, 1982). Mean body weights of the high-dose females were lower than those of the controls after week 20 for mice and week 40 for rats. No compound-related clinical signs or adverse effects on survival were observed. Feed consumption by dosed rats and mice of either sex was lower than that of controls. There were no non-neoplastic histopathological effects in either rats or mice that were treatment-related.
Carcinogenicity	F344 rats and B6C3F1 mice were given diets containing 0, 25,000 ppm or 50,000 ppm guar gum for 103 weeks (NTP, 1982). There were increased incidences of adenomas of the pituitary in male rats and pheochromocytomas of the adrenal in female rats that were statistically significant, but these differences were considered to be unrelated to guar gum administration. When pituitary adenomas or carcinomas and when pheochromocytomas or malignant pheochromocytomas are combined, the statistical differences disappear. Hepatocellular carcinomas occurred in treated male mice at incidences that were significantly lower than that in controls. The combined incidence of male mice with either hepatocellular adenomas or carcinomas was also significantly lower in the highdose group. It was concluded that under conditions of this bioassay, guar gum was not carcinogenic for F344 rats or B6C3F1 mice.
Mutagenicity/ Genotoxicity	Guar gum induced no consistent responses in dominant lethal gene tests to suggest that it was mutagenic to the rat. Guar gum was not mutagenic to Salmonella typhimurium TA 1530 or G-46 when tested without metabolic activation; however, it was mutagenic to Saccharomyces cerevisiae D- 3 (Green, 1977). Guar gum also was reported to cause chromosomal aberrations in human embryonic lung cells WI-38 (Green, 1977). No in vivo genotoxicity studies have been conducted on guar gum.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	The developmental effects of guar gum were evaluated in groups of 20 rabbits by daily dermal administration of the test substance for 6 hours/day at dose levels of 0, 2, 10 and 50 mg/kg/day on days 6 through 18 of gestation. The number of early resorptions was significantly increased and the number of viable foetuses was correspondingly decreased at 50 mg/kg/day ($p<0.05$). The NOEL was 2 mg/kg/day. The frequency of foetal malformations and variations in the treated groups was comparable to that of the control group at all dose levels. Female rabbits were given daily (6 hours/day) dermal administration of 0, 2, 10 and 50 mg/kg guar gum during gestational days 6 through 18 (IRDC, 1988). Mortalities included 2 deaths at 50 mg/kg and 1 death at 10 mg/kg. A single animal was killed in extremis. A dose-related increase in dermal irritation (including erythema, edema, and desquamation) was observed in animals receiving 10 and 50 mg/kg. The number of early resorptions was significantly increased and the number of viable fetuses was correspondingly decreased at 50 mg/kg/day ($p<0.05$). The frequency of fetal malformations and variations in the treated groups was comparable to that of the control group at all dose levels. The NOEL for this study is 2 mg/kg/day.
Acute Toxicity	Guar gum has been blamed for causing esophageal obstruction. A death has the use of one guar gum tablet product, which apparently swelled in the esophagus, resulting in complications that caused the fatality. Mildly toxic by ingestion. The oral LD50 is 8,100 mg/kg for mice and 9,400 mg/kg for rats.
Irritation	No data were found.
Sensitisation	Occupational asthma has been reported in subjects of guar gum. A respiratory sensitizer There are reports of respiratory sensitization in workers exposed occupationally to guar gum dusts (Maio, 1986).

Key Study/Critical Effect for Screening Criteria	The key studies for the determination of a drinking water guidance value is the NTP two year chronic bioassays. The LOAELs are based on decreased mean body weights in female mice and rats fed 50,000 ppm guar gum in diet for 103 weeks. The NOAELs for these studies are 25,000 ppm guar gum. Rat: NOAEL (mg/kg/day) = 25,000 ppm * 0.05 = 1,250 mg/kg/day Mouse: NOAEL (mg/kg/day) = 25,000 ppm * 0.13 = 3,250 mg/kg/day Where 0.05 and 0.13 are the fraction of body weight that rats and mice, respectively, consume per day as food (U.S. EPA). The lowest NOAEL of 1,250 mg/kg/day for the rat will be used to derive a drinking water guidance value. Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability) Oral RfD = 1,250/100 = 12.5 mg/kg/day Drinking water guideline = 49 ppm
Ecological Toxicity [1,7]	
Aquatic Toxicity	The lowest measured ecotoxicity endpoint for fish was reported to be 218 mg/L.
Determination of PNEC aquatic	PNECaquatic: On the basis that the data consists of only one short-term result from one trophic level, an assessment factor of 1,000 has been applied to the reported effect concentration of 218 mg/L for Fish. The PNECaquatic is 0.218 mg/L.
Current Regulatory Controls	
Australian Hazard Classification	No data available.
Australian Occupational Exposure Standards	No data available.
International Occupational Exposure Standards	No data available.
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	No data available.
Australian Hazard Classification	No data available.
PBT Assessment	
P/vP Criteria fulfilled?	No biodegradation information was found on guar gum. However, guar gum is a naturally occurring polysaccharide which would be expected to readily biodegrade. Thus, it is not expected to meet the screening criteria for persistence
B/vB criteria fulfilled?	The molecular weight of guar gum ranges from 200,000 to 300,000 daltons, and it is also water soluble. Thus, guar gum is not expected to meet the criteria for bioaccumulation
T criteria fulfilled?	The acute aquatic toxicity of guar gum is >0.1 mg/L. Thus, guar gum is not expected to meet the screening criteria for toxicity
Overall conclusion	Not a PBT substance.

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Toxicity Summary - Hydrochloric acid

Chemical and Physical Properties [1,2]	
CAS number	7647-01-0
Molecular formula	HCl
Molecular weight	36.46 g/mol
Solubility in water	Soluble
Melting point	-114.22 °C
Boiling point	-85.05°C
Vapour pressure	35,424 mm Hg at 25 deg C
Henrys law constant	2.04 x106 mol/L atm
Explosive potential	Reacts with most metals producing explosive hydrogen gas
Flammability potential	Not combustible
Colour/Form	liquid
Overview	CAS Registry number. Since the gas becomes the acid in aqueous systems and volatilization of the gas can occur from aqueous systems, it is often difficult to determine which is being considered in a specific item in the literature. If released to water, hydrogen chloride dissociates readily in water to chloride and hydronium ions, decreasing the pH of the water. The solution in water is a strong acid, it reacts violently with bases and is corrosive. Reacts violently with oxidants forming toxic gas (chlorine). Attacks many metals in the presence of water forming flammable/explosive gas (hydrogen). Hydrochloric acid is one of the most widely used industrial chemicals. Uses include pickling and cleaning metals, food process, and cleaning of industrial equipment.
Environmental Fate [3,4]	
Soil/Water/Air	Hydrochloric acid is readily dissociated in water into hydrated protons and chloride ions. The increase in the concentration of hydrochloric acid in water decreases the pH in the aquatic ecosystem. Generally, the buffer capacity to maintain the pH in the aquatic ecosystem is important and the equilibrium between CO2, HCO3 - and CO3 2- in the aquatic ecosystem is mainly responsible for the buffer capacity of receiving water.

Human Health Toxicity Summary [1,2,3,8]	
Chronic Repeated Dose Toxicity	Frequent contact with aqueous solutions of hydrochloric acid may lead to dermatitis. For repeated dose toxicity, local irritation effects were observed in the groups of 10 ppm and above in a 90-day inhalation study. Rats were fed diets containing 280 to 1,250 mmol/kg hydrochloric acid (10.2 to 45.6 mg/kg) for 7-12 weeks. There was increased water intake in all treated groups. All animals fed diet containing 937 mmol/kg and above for 9 weeks, and half of the animals fed diet containing 900 mmol/kg for 12 weeks died. Also at doses >937 mmol/kg, there was decreased body weight, food consumption, blood pH, femur length, rate of ash in bone (Upton and L'Estrange, 1977). In another study with rats, hydrochloric acid was administered via drinking water at pH 2-3 (study duration not provided). Decreased protein levels in urine and decreased urine volumes were observed in the treatment groups (Clausing and Gottschalk, 1989).
Carcinogenicity	HCl is not classifiable as a human carcinogen. No evidence of treatment related carcinogenicity was observed either in other animal studies performed by inhalation, oral or dermal administration. In three industry-based human case studies conducted in the U.S, no association between hydrogen chloride exposure and cancers of the lung, brain, or kidney was observed. In one U.S study of steel-pickling workers an excess risk for cancer of the lung was identified in workers exposed primarily to hydrochloric acid. Under IARC definitions, HCl is not classifiable as to its carcinogenicity to humans (Group 3).
Mutagenicity/ Genotoxicity	In single studies, HCl induced mutation and chromosomal aberrations in mammalian cells and induced chromosomal aberrations in insects and in plants. It did not induce mutation in bacteria. For genetic toxicity, a negative result has been shown in the Ames test. A positive result, which is considered to be an artefact due to the low pH, has been obtained in a chromosome aberration test using Hamster ovary cells. The effects of low pH in in vitro studies are not a problem in vivo as the proton level is regulated systemically. Hydrochloric acid is not considered to be genotoxic.
Reproductive Toxicity Developmental Toxicity/Teratogenicity	No reliable studies have been reported regarding toxicity to reproduction and development in animals after oral, dermal or inhalation exposure to hydrogen chloride/hydrochloric acid. As protons and chloride ions are normal constituents in the body fluid of animal species, low concentrations of hydrogen chloride gas/mist or solution do not seem to cause adverse effects to animals. The cells of gastric glands secrete hydrochloric acid into the cavity of the stomach. No reliable conclusion could be drawn on the potential reproductive toxicity of hydrogen chloride/hydrochloric acid.

Acute Toxicity	Rapid evaporation of the liquid may cause frostbite. The substance is corrosive to the eyes, the skin and the respiratory tract and can cause serious skin burns and blurred/reduced vision or blindness. Inhalation of high concentrations of the gas may cause pneumonitis and lung oedema, resulting in reactive airways dysfunction syndrome. The effects may be delayed. Exposure to hydrochloric acid can produce burns on the skin and mucous membranes, with severity related to the concentration of the solution. Subsequent ulceration may occur, followed by keloid and retractile scarring. Dental decay, including yellowing, softening and breaking of teeth, and related digestive diseases have been recorded after exposures to hydrochloric acid. Mortality has been observed following ingestion of hydrochloric acid. Female rats orally administered 3.3% hydrochloric acid yielded an acute oral median lethal dose (LD50) in a range from 238 to 277 mg/kg bw (Hoechst 1966). No details of the study were available. In another study in rats, administration of a solution of undisclosed concentration induced stomach ulceration, inflammation of the intestine, discolouration of the liver and hyperaemia of the lung (Monsanto 1976). An LD50 of 700 mg/kg bw was reported. An acute dermal LD50 was established as >5010 mg/kg bw in rabbits however the dose levels administered were not reported (Monsanto 1976). Acute median lethal concentration (LC50) values of 8.3 mg/L and 3.2 mg/L were observed in rats and mice respectively after a 30 minute inhalation exposure to aerosolised hydrochloric acid (Darmer et al. 1974).
Irritation	In a skin irritation test in rabbits performed according to OECD TG 404, 37% hydrochloric acid (0.5 mL) was applied by both semi-occlusion and occlusion (Potokar 1985). The chemical was found to be corrosive under both conditions after one hour exposure. Concentrations >17% also caused corrosion in rabbits. Concentrations >3.3% caused skin irritation to rabbits after application for 5 days. Hydrochloric acid caused mild to severe eye irritation in animal studies. There were no data available for respiratory irritation however; inhalation of hydrochloric acid vapours is expected to cause irritation. In humans, the chemical was determined to be 'irritating to skin' (York et al. 1996).
Sensitisation	May cause dermatitis with frequent contact of aqueous solutions of hydrochloric acid.
Health Effects Summary	Hydrochloric acid has demonstrated acute oral toxicity, corrosive effects to the skin and eye, and irritant effects to the respiratory system. Hydrochloric acid is not a skin sensitiser based on the available studies. Only limited information on the repeated oral toxicity of hydrochloric acid is available. However, as the component ions are normal constituents of the human body (particularly the stomach), only localised effects are expected. No systemic effects from repeated exposures are expected. The chemical is not genotoxic. No evidence of treatment-related carcinogenicity was observed in animal studies performed by inhalation or dermal administration. In humans, no association between hydrogen chloride exposure and tumour incidence was observed. No reliable studies were identified regarding specific toxicity to reproduction and development in animals after exposure to hydrochloric acid/hydrogen chloride. Because protons and chloride ions are normal constituents in the body fluids, low concentrations of hydrochloric acid/hydrogen chloride would not be expected to cause adverse reproductive effects to animals. This conclusion is supported by the 90-day inhalation study of hydrogen chloride where no effects on the gonads of rodents were observed.
Key Study/Critical Effect for Screening Criteria	The Australian drinking water guideline value for pH may apply to hydrochloric acid.

Ecological Toxicity [1,3,4,8]	
Aquatic Toxicity	The measured acute endpoint for: Algae = 0.492 mg/L Daphnia = 0.492 mg/L Fish = 4.92 mg/L The measured chronic endpoint for Daphnia is 62 mg/L
Determination of PNEC aquatic	On the basis that the data consists of short-term and long-term results from three trophic levels, an assessment factor of 10 has been applied to the lowest reported Chronic endpoint of 62 mg/L for Daphnia. The PNECaquatic is 6.2 mg/L.
Current Regulatory Controls [8]	
Australian Hazard Classification	C (Corrosive); R34 (Causes burns) Xi (Irritant); R37 (Irritating to respiratory system).
Australian Occupational Exposure Standards	There are no specific exposure standards for hydrochloric acid. However, the permissible exposure limits for hydrogen chloride gas apply (Safe Work Australia 2013): Time Weighted Average (TWA) of 7.5 mg/m^3 (5 ppm).
International Occupational Exposure Standards	The following exposure standards were identified for hydrogen chloride (Galleria Chemical 2013). TWA: 7 to 8 mg/m^3 (5 ppm) [Austria, Belgium, Denmark, EU, Hungary, Japan, Korea, Mexico, The Netherlands, New Zealand, Norway, Sweden, Turkey] 2 to 5 mg/m^3 (1-2 ppm) [Germany, Poland, Switzerland, UK]. Short Term Exposure Limit (STEL): 15 mg/m^3 (10 ppm) [Austria, Belgium, EU, Hungary]
Australian Food Standards	Hydrochloric acid is an additive permitted in accordance with Good Manufacturing Practice (GMP) in processed foods specified in Schedule 1 of the Australia New Zealand Food Standards Code – Standard 1.3.1 – Food Additives (Food Standards Australia New Zealand 2013).
Australian Drinking Water Guidelines	Hydrochloric acid is listed as an endorsed drinking water treatment chemical in the Australian Drinking Water Guidelines (National Health and Medical Research Council (NHMRC) 2011).
Aquatic Toxicity Guidelines	No data found
PBT Assessment	
P/vP Criteria fulfilled?	Hydrochloric acid is an organic salt that dissociates completely to hydrogen and chloride ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both hydrogen and chloride ions are also ubiquitous and are present in most water, soil and sediment. Thus, the persistent criteria is not considered applicable to this inorganic salt.
B/vB criteria fulfilled?	Hydrogen and chloride ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, hydrochloric acid is not expected to bioaccumulate.
T criteria fulfilled?	No chronic toxicity data exist on hydrochloric acid; however, the acute EC(L)50s are >0.1 mg/L in fish, invertebrates and algae. Thus, hydrochloric acid does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	April 2018

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7. Safe Work Australia Workplace Exposure Standards for Airborne Contaminants, 2013.
8. Department of the Environment and Energy 2017 , National assessment of chemicals associated with coal seam gas extraction in Australia, prepared by the National Industrial Chemicals Notification and Assessment Scheme

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Toxicity Summary - Distillates, Hydrotreated Light

Chemical and Physical Properties [1,2,3,4]	
CAS number	64742-47-8
Molecular formula	C48H94
Molecular weight	Not applicable - unknown or variable composition, complex reaction products or biological materials (UVCB)
Solubility in water	0.009 to 6.45 mg/L (at 25°C)
Melting point	-49 °C
Boiling point	146 to 299 °C
Vapour pressure	1 to 3.7 kPa at 37.8 °C
Henrys law constant	No data found.
Explosive potential	Above 66°C explosive vapour/air mixtures may be formed
Flammability potential	Combustible
Colour/Form	Liquid at room temperature
Overview	Distillates, hydrotreated light (also called deodorised kerosene) is a petroleum substance. The C_9-C_{14} Aliphatic [< 2% Aromatic] Hydrocarbon Solvents Category is comprised of complex aliphatic hydrocarbon solvents that contain >98% aliphatic constituents with carbon numbers in the range of C9-C14 and less than 2% aromatic constituents. The chemical is used as a component of a drilling fluid formulation for coal seam gas extraction.
Environmental Fate[1]	
Soil/Water/Air	Members of the C_9-C_{14} Aliphatic [≤2% aromatics] Hydrocarbon Solvents Category have the potential to volatilize from surface waters, based on Henry's Law constants (HLC) representing volatility for category members that range from 4.76 x 10^4 to 1.67 x 10^6 Pa-m^3/mole (at 25°C). In the air, category members have the potential to rapidly degrade through indirect photolytic processes mediated primarily by hydroxyl radicals (•OH) with calculated degradation half-lives ranging from 0.42 to 1.10 days or 10.8 to 26.4 hours based on a 12-hr day and an •OH concentration of 1.5 x 10^6 •OH/cm^3. These chemicals are unlikely to degrade by hydrolysis as they lack a functional group that is hydrolytically reactive.

Human Health Toxicity Summary [1,2,3]	
Chronic Repeated Dose Toxicity	In a 90-day study conducted in accordance with OECD TG 408, Sprague-Dawley rats were administered deodorized kerosene by gavage at doses of 0, 100, 500 or 1000 mg/kg bw/day (REACH 2013). Microscopic changes, such as incidence of a2µ-globulin, were seen in male kidneys. These effects are not considered relevant to humans. No other treatment-related effects were observed. No Lowest Observed Adverse Effect Level (LOAEL) or No Observed Adverse Effect Level (NOAEL) could be established in this study. Repeated dermal exposures to members of the kerosene/jet fuel category showed minimal systemic effects (API 2010). Animal data on repeat dermal toxicity of kerosene (petroleum) are summarised from REACH (2013) and presented in Table A29.2. The LOAELs and NOAELs are indicated for each study. Prolonged skin exposure to kerosene (petroleum) in rats and rabbits were consistently associated with local irritation. In rabbits only, systemic effects included changes in bodyweight and organ weights. It is expected that deodorized kerosene would have similar effects in the animals. In a 13-week study, rats (strain not specified) were exposed to deodorized kerosene vapour at concentrations of 0, 0.02, 0.048 or 0.10 mg/L for six hours/day, five days/week. No treatment-related effects were reported (REACH 2013).
Carcinogenicity	A study for deodorized kerosene is available in the REACH Dossier (REACH 2013) but was not reported in enough detail to be able to determine the carcinogenicity of the substance. In a study conducted similarly to OECD TG 451, B6C3F1 mice were applied 0, 250 or 500 mg/kg bw/day kerosene (petroleum) in the interscapular region (type of wrapping not specified) for 103 weeks (REACH 2013). At the end of the study, less than 10% decrease in bodyweight gain was observed at the top dose in both sexes. Mortality in females was significantly higher at the two doses compared to controls. Increased incidence and severity of chronic dermatitis was seen in all treatment groups. At the top dose, increased incidence of the following non-neoplastic lesions was reported: amyloid in the liver, kidney, adrenal cortex (males only), spleen; granulocytic hyperplasia in the bone marrow; and hyperplasia of the axillary lymph nodes (females only). The only indication of neoplastic lesions was an increased incidence of malignant lymphomas observed in treated female animals but the values were within the range of historical controls. Under the conditions of the test, kerosene (petroleum) was not carcinogenic. The LOAEL for systemic effects is 250 mg/kg bw/day. The International Agency for Research on Cancer (IARC) concluded that there is inadequate evidence for the carcinogenicity of kerosene (petroleum) in experimental animals and humans, placing the chemical in Group 3 (Not classifiable as to its carcinogenicity to humans) (IARC 1989). Deodorized kerosene is not carcinogenic, based on reading across the information available for kerosene (petroleum).
Mutagenicity/ Genotoxicity	In vitro tests reported deodorized kerosene as negative both with and without metabolic activation in Ames tests conducted in accordance with OECD TG 471 (REACH 2013; OECD 2011) and in chromosomal aberration tests conducted in accordance with OECD TG 473 (OECD 2011, 2012). In an in vivo study, deodorized kerosene was negative in a dominant lethal assay, conducted in accordance with OECD TG 478, in male Swiss mice and Long Evans rats administered 10% deodorized kerosene intraperitoneally (REACH 2013). These studies demonstrate that deodorized kerosene is not genotoxic.

Reproductive Toxicity / Developmental Toxicity/Teratogenicity	C9-C14 aliphatic (≤2% aromatic) hydrocarbon solvents and C14-C20 aliphatic (≤2% aromatic) hydrocarbon solvents are not toxic to fertility (OECD 2011, 2012). Members of the kerosene/jet fuel category are not toxic to fertility (API 2010). Sprague-Dawley rats were administered undiluted kerosene (petroleum) by gavage at doses of 0, 750, 1500 or 3000 mg/kg bw/day in males treated for 70-90 days and 0, 325, 750 or 1500 mg/kg bw/day in females treated for 21 weeks. At 750 and 1500 mg/kg bw/day, increased absolute liver weight was observed in females but with no corresponding changes in clinical chemistry or histopathology. In females only, other effects included perianal dermatitis at 1500 mg/kg bw/day and stomach hyperplasia at 750 and 1500 mg/kg bw/day. These parameters were not measured in males. In males, the study indicated dose dependent decrease in male bodyweight that was linked to nephropathy specific to male rats. Data for this effect were not provided in the study description. There were no treatment related effects on fertility in both sexes (REACH 2013). The NOAEL for systemic effects in females only was 325 mg/kg bw/day. No NOAEL can be established for fertility effects. C9-C14 aliphatic (≤2% aromatic) hydrocarbon solvents and C14-C20 aliphatic (≤2% aromatic) hydrocarbon solvents are not developmental toxicants (OECD 2011, 2012). Members of the kerosene/jet fuel category are not developmental toxicants (API 2010). In a study conducted in accordance with OECD TG 414, Sprague-Dawley rats were administered kerosene (petroleum) by gavage on gestation days (GD) 6 to 15 at doses of 0, 500, 1000, 1500 or 2000 mg/kg bw/day (REACH 2013). Bodyweight gain was decreased at 1500 and 2000 mg/kg bw/day. Foetal weight was decreased at 1500 and 2000 mg/kg bw/day which may be attributed to decreased maternal bodyweight gain. No malformations were reported. The maternal NOAEL is 1000 mg/kg bw/day. In another study, Sprague-Dawley rats were exposed (whole body) to kerosene (petroleum) in air at concentrations of 0, 106 or 364 ppm on GD 6-15. There were no treatment-related effects observed in the dams and offspring (REACH 2013). Deodorized kerosene is not considered a developmental toxicant, based on reading across data available for kerosene (petroleum).
Acute Toxicity	The chemicals have low acute toxicity based on results from animal tests following oral exposure. The median lethal dose (LD50) in rats is >2000 mg/kg bw (OECD, 2011; US EPA, 2011; OECD, 2012a; OECD, 2012b; OECD, 2012c). The chemicals have low acute toxicity based on results from animal tests following dermal exposure. The LD50 in rats and rabbits is >2000 mg/kg bw (OECD, 2011; US EPA, 2011; OECD, 2012a; OECD, 2012b; OECD, 2012c). The chemicals have low acute toxicity based on results from animal tests following inhalation exposure.
Irritation	Semi-occlusive applications of commercial grade deodorized kerosene produced slight irritation in New Zealand White and SPF rabbits in dermal irritation studies conducted in accordance with OECD TG 404. The studies reported the range of erythema and oedema scores to be 0.3-0.9 and 0.2-1.0, respectively, based on Draize scoring at 24, 48 and 72 hours. Deodorized kerosene is slightly irritating to rabbit skin. Several studies conducted similarly to OECD TG 405 showed minimal effects to the eye with the reported range of conjunctival redness score to be 0-0.2 from instillation of undiluted deodorized kerosene in the eyes of New Zealand White and SPF rabbits (OECD 2011). Deodorized kerosene is slightly irritating to rabbit eye.
Sensitisation	The C9-C14 aliphatic (≤2% aromatics) Category members do not cause skin sensitization.

Health Effects Summary	Deodorised kerosene is an aspiration hazard since it has low viscosity and is composed of aliphatic and aromatic hydrocarbons up to 10%. Deodorised kerosene has low acute oral, dermal and inhalation toxicity, and is slightly irritating to the skin and eyes. The substance is not a skin sensitiser, based on reading across data available for kerosene (petroleum). No treatment-related effects were reported in repeated oral and inhalation exposures to deodorised kerosene. Prolonged dermal exposure to kerosene (petroleum) reported local irritation in rats and rabbits, and changes in bodyweight and organ weights in rabbits. It is expected that these effects would be similar for deodorised kerosene. Based on the absence of adverse effects observed in repeat dose toxicity studies, for the purposes of quantifying the health risk to the general worker and public, the highest dose tested in the study conducted in rats (1 000 mg/kg bw/day) is used in this risk assessment. The substance is not genotoxic. It is neither a carcinogen nor a reproductive toxicant, based on reading across data available for kerosene (petroleum).
Key Study/Critical Effect for Screening Criteria	The most appropriate No-Observed-Adverse-Effect Level (NOAEL) for risk assessment is 1 000 mg/kg bw/day based on maternal toxicity (decreased bodyweight gain) at the Lowest- Observed-Adverse-Effect Level (LOAEL) of 1 500 mg/kg bw/day from a developmental toxicity study on kerosene (petroleum).
Ecological Toxicity [2]	
Aquatic Toxicity	Lowest acute endpoint for Daphnia = 0.018 mg/L (modelled)
Determination of PNEC aquatic	Based on the lowest acute endpoint for Daphnia (0.018 mg/L), an assessment factor of 100 has been applied, resulting in a PNECaquatic of 1.80E-04 mg/L.
Current Regulatory Controls [2]	
Australian Hazard Classification	All of the chemicals are classified as hazardous, with the following risk phrase for human health in the Hazardous Substances Information System (HSIS) (Safe Work Australia): Xn; R65 (acute toxicity) Mixtures containing the substance are classified as hazardous with the following risk phrase based on the concentration (Conc) of the substance in the mixtures: Conc ≥10%: Xn; R65 (May cause lung damage if swallowed)
Australian Occupational Exposure Standards	No specific exposure standards are available.
International Occupational Exposure Standards	No specific exposure standards are available for this chemical.
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	Oils and greases (including petrochemicals) for freshwater production: <300[6] µg/L (ANZECC 2000)
PBT Assessment	
P/vP Criteria fulfilled?	No. This chemical is expected to be biodegradable. The ready biodegradability of SHELLSOL NF a solvent naphtha (petroleum), heavy aromatics (consists predominantly of C9 aromatics 25%m/m; C10 aromatics 65%, and indanes 10%) was studied in mineral nutrient medium inoculated with activated sludge (mixed liquor suspended solids 100-101 mg/L, pH 6.9) and incubated for 28 days at 20°C. SHELLSOL NF is readily biodegrade after 28 days but not within the 10 day window.
B/vB criteria fulfilled?	Category members have a potential to bioaccumulate, based on calculated log BCF values for constituents that range from 2.78 to 4.06, and calculated BCF values of 598 to 11,430 L/kg wet-weight, based on the Arnot and Gobas model, that take into account biotransformation of the chemicals in fish tissue. This chemical also has a log Kow of 6.025.

T criteria fulfilled?	Yes. The lowest acute endpoint is <1 mg/L.
Overall conclusion	Not PBT
Revised	January 2019

Human Health Risk Assessment

Occupational Exposure

Table 2 presents the calculated internal doses for adult workers associated with drilling chemical exposure/hydraulic fracturing chemical exposure.

Table 2 Calculated Internal Doses for Adult Workers

Occupational Activity	E_{derm} (mg/kg bw/day)	E_{inh} (mg/kg bw/day)	E_{total} (mg/kg bw/day)
Transport and storage	Negligible*	Negligible*	Negligible*
Mixing/blending drilling of hydraulic fracturing chemicals	0.06	0.750	**0.810**
Injection of drilling chemicals	Negligible*	Negligible*	Negligible*
Cleaning and maintenance (hydraulic fracturing)	0.012	0.150	**0.162**
Combined exposure Mixing/blending and cleaning and maintenance			**0.972**
Transport and storage of drilling muds	Negligible*	Negligible*	Negligible*

Ederm - Internal dose from dermal exposure; Einh – Internal dose from inhalation exposure; Etotal – Total internal dose from all routes.

* In the absence of accidents/incidents, repeated occupational exposures during transport and storage, or during injection of mixed/blended chemicals, are negligible. Similarly, repeated occupational exposures to the chemical via the transport and storage of drilling muds are negligible (NICNAS 2017).

Human Health Risk Characterisation

Uncertainty Factors

Using the Margin of Exposure (MOE) approach, conservative default uncertainty factors for intra- and inter-species variability are assumed to be 10 each. A MOE of less than 100 is considered a concern (NICNAS 2017).

Acute Health Risks

Acute exposure to the chemical is unlikely to result in adverse health effects. In addition, given the low concentration in the drilling fluids, exposure to the chemical via these fluids is of low concern for workers.

Chronic long-term health risks

The critical (most sensitive) adverse health effect is maternal toxicity (decreased bodyweight gain). The NOAEL established for this effect is 1000 mg/kg bw/day from a reproductive toxicity study. There are no adverse effects observed from repeated exposures to the chemical at any dose tested, up to 1000 mg/kg bw/day. This highest no-effect dose is applicable for a general worker. Margins of Exposure (MOE) for adverse health effects from repeated occupational exposures are calculated by comparing the NOAEL with exposures estimated for different occupational activities and combined activities. **Table 3** presents Margin of Exposure calculated for Adult Workers associated with drilling chemical exposure/hydraulic fracturing chemical exposure. Risk characterisation calculations are presented in **Attachment A**.

Table3 Margins of exposure calculated for adult workers

Adult worker exposure scenario	E_{total} (mg/kg bw/day)	NOAEL (mg/kg bw/day)	Critical effect	MOE (NOAEL / E_{total})	Chemical is of concern? (MOE < 100)
Occupational Activity					
Mixing/blending drilling of hydraulic fracturing chemicals	0.810	1000	Maternal toxicity in rats	1235	No
Cleaning and maintenance (hydraulic fracturing)	0.162			6173	
Combined exposure Mixing/blending and cleaning and maintenance	0.972			1029	

Based on uncertainty factors derived for this risk characterisation, the MOEs indicate that the chemical is of low concern for workers from repeated exposures during certain operations.

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Toxicity Summary - Methanol

Chemical and Physical Properties[1,3,4]	
CAS number	67-56-1
Molecular formula	CH4O
Molecular weight	32.04
Solubility in water	1,000 g/L at 20 °C
Melting point	-98 °C
Boiling point	65 °C
Vapour pressure	16.927 kPa at 25 °C
Henrys law constant	0.461 Pa m^3/mol
Explosive potential	Vapour/air mixtures are explosive
Flammability potential	Highly flammable
Colour/Form	Clear colourless liquid
Overview	Methanol occurs naturally in humans, animals and plants. The general population is exposed to methanol mainly through consumption of food and beverages and through use of consumer products such as paints, sealers and adhesives that contain methanol as a solvent.
Environmental Fate [1,3]	
Soil/Water/Air	Air is the main target compartment, based on a fugacity model calculation (Mackay Level III) with about 73 % of environmental methanol distributing to air and 16 % to water. Methanol is degraded in the atmosphere by photochemical, hydroxyl-radical dependent reactions. The estimated elimination half-life is calculated to be about 17-18 days with a rate constant of 0.93 x 10-2 cm3/molecule-sec. Methanol is completely miscible in water and has a low octanol/water partition coefficient. These properties are indicative of high mobility in soil.
Human Health Toxicity Summary [1,2,3]	
Chronic Repeated Dose Toxicity	Considering the no observed adverse effect level (NOAEL) available from a 90-day rat study (500 mg/kg bw/day), the chemical is not considered to cause serious damage to health by repeated oral exposure. In a 20-day inhalation study in monkeys, 3.9 mg/L (3000 mL/m3) was identified as the LOAEL (continuous exposure) where neurotoxic lesions appeared to progress in monkeys (according to NEDO 1987). This exposure concentration correlated with methanol blood levels 80 mg/L and formate levels 30 mg/L. There was no evidence of adverse effects in rats exposed to methanol up to 6.6 mg/L, six hours/day for 28 days, except local nasal irritation and increased relative spleen weights, which were observed only at the middle dose and not considered treatment-related (Andrews et al. 1987). A NOAEL could not be established in this study. In the chronic exposure studies in rats and mice, slight treatment-related decreases in body and organ weights were reported at the highest dose. These are however not considered as ‘adverse’ effects. In monkeys, slight degeneration of the inside nucleus of the thalamus was observed at 0.13 and 1.3 mg/L after seven months or more (NEDO 1987). One monkey at 0.13 mg/L and two at 1.3 mg/L showed slight but clear changes in peroneal nerves indicating damage to peripheral nerves. Some signs of fibrosis at 1.3 mg/L, which were considered borderline. There were mild but significant effects on heart and kidney at 0.13 and 1.3 mg/L. Histologically, a significant increase of Sudan positive granules was noted in the 1.3 mg group without pathological manifestations (e.g. fibrosis). Although the authors considered the lowest dose (0.013 mg/L) as the LOAEL, it was observed that effects at this dose were very mild and reversible and therefore not considered to be adverse effects. Based on these observations, a NOAEL of 0.013 mg/L was established in this study.

Carcinogenicity	The chemical is not likely to be a carcinogen. In a chronic inhalation study, Fisher rats and B6C3F1 mice were exposed to 0.013, 0.13, and 1.3 mg/L methanol for 24 and 18 months, respectively (NEDO 1987). No differences in survival were noted in the treatment groups compared with the control group. There was no evidence of an increase in liver tumours in rats or in the spontaneous liver tumour rate in mice. In the rats, some tumours such as papillary lung adenomas (males only), adrenal phaeochromocytomas (females only) and metastatic (transition) tumours appeared at a somewhat higher incidence in high-dose group rats after week 79 and 104 without clear dose-response relationship. However these tumour incidences were not statistically significantly different from those in the control group. In the mice, there were no appreciable differences from the control in either numbers of animals with tumours or in degree of malignancy observed. Proliferative effects on the astroglia cells were observed in monkeys continuously exposed to 0.013, 0.13 and 1.3 mg/L methanol by the inhalation route (NEDO 1987). These effects however were of a transient nature and disappeared after a six-month recovery period. There were no signs of histological degeneration.
Mutagenicity/ Genotoxicity	Methanol has been examined in numerous in vitro and in vivo test systems, including bacterial, mammalian and fungal test systems. Most in vitro studies did not demonstrate mutagenic activity. A small number of studies gave ambiguous results. All other studies produced negative results consistently. The majority of in vivo assays were negative for mutagenicity and clastogenicity (OECD 2004). Methanol was therefore concluded to be not mutagenic.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	No impairment of fertility or reproductive performance was reported in male and female rats exposed to the chemical, except at very high doses. Male mice had morphological anomalies in spermatozoa after repeated oral dosing at 1000 mg/kg bw/day (blood level > 500 to 1000 mg/L in mice) (OECD 2004). Rodent studies indicate that methanol has developmental toxicity effects. The rodent data on developmental toxicity are relevant for humans despite the known differences in methanol metabolism between the two species. However, rodents are considered adequate models for humans only at levels where formate does not accumulate (NTP 2003). Blood methanol levels associated with serious developmental effects in rodents were in the range associated with formate accumulation (1000 to 2000 mg methanol per litre of blood), which is likely to result in metabolic acidosis, and visual and clinical effects in humans (NTP 2003; OECD 2004). The limited data available in humans do not show an association between reproductive and developmental toxicity and methanol (NTP 2003). Following a review of the developmental toxicity studies, the NTP concluded that there is evidence to suggest that females with low folate levels may be more susceptible to the adverse developmental effects of methanol, but more information was necessary to clarify this issue (NTP 2003). Based on the data available, the chemical is not considered to have reproductive or developmental toxicity in humans.

Acute Toxicity	In rats, mice, rabbits and dogs, the LD50 values after single oral administration range from about 5600 to 14 400 mg/kg bw (EHC 1997). Adverse effects noted in these animals were ataxia, narcosis and coma after high methanol doses. The animals did not exhibit acidosis and ophthalmologic changes typically seen in humans at high lethal and sub-lethal doses In rhesus monkeys, no deaths were reported at doses of 1000 to 2000 mg/kg bw, while animals receiving 3000 to 8000 mg/kg bw died within two days (OECD 2004). Treated animals showed acidosis, and some exhibited semi-coma and ophthalmologic changes. Human data, however, indicate acute oral toxicity at comparatively lower doses of 300 to 1000 mg/kg bw (EHC 1997). The reported median lethal doses (LD50) for experimental animals are 7300 mg/kg bw (mouse), 5628 mg/kg bw (rat), 14 200 mg/kg bw (rabbit) and 7000 mg/kg bw (monkey). The lowest lethal dose (LDLo) for humans ranges from 143 to 428 mg/kg bw (ChemIDplus 2012). There are limited available dermal toxicity studies in animals. In one dermal exposure study all the rats survived after application of 35 000 mg/kg bw methanol to the skin under occlusive conditions, while deaths were reported at 45 000 mg/kg bw (Eulner and Gedicke 1955). In rabbits, a dermal LD50 of 17 000 mg/kg bw was reported although no details of the study were provided (Carnegie-Mellon 1981). Limited data in monkeys indicate that the chemical is toxic via the dermal route (McCord 1931). Humans have been found to be more susceptible to methanol as compared to monkeys. Therefore, acute dermal toxicity with methanol is expected in humans (OECD 2004). The lowest reported dermal LD50 is 17 000 mg/kg bw, which was recorded in rabbits. Median lethal concentrations (LC50) of 87.5 and 128.2 mg/L were reported in rats following six and four hour inhalation exposures to methanol, respectively (BASF 1980a, 1980b). Clinical signs of toxicity were secretions from eyes and nose, laboured breathing, staggering, apathy and narcosis. A similar LC50 value (79 mg/L) was reported for mice following 2.25 hours exposure (Von Burg 1994). In cats, LC50 values after six-hour exposures ranged from 26 to 48 mg/L. A shorter duration of 4.5 hours led to an LC50 of 85.4 mg/L (Von Burg 1994). Studies in Rhesus monkeys indicated lethal concentrations (percent mortality not reported) at 13 mg/L after 18 hour exposure and 52 mg/L after one to four hour exposure (OECD 2004).
Irritation	The chemical is not a skin irritant. The chemical is a slight eye irritant in rabbits. High concentration of methanol vapours may cause irritation of the respiratory tract. In a short-term exposure study (details not available), exposure of rats to an atmosphere saturated with methanol vapours produced severe irritation of mucous membranes and milky corneal opacity (BASF 1975). All animals died after eight hours (BASF 1975).
Sensitisation	The chemical is not a skin sensitiser.
Health Effects Summary	Methanol has low acute oral, dermal and inhalation toxicity in experimental animals but moderate to high acute oral and dermal toxicity in humans. A Lowest Lethal Dose (LDLo) of 143 - 428 mg/kg bw (humans) has been reported. It is not a skin or eye irritant but is expected to be a moderate respiratory irritant, based on its effect on the mucous membrane in rats exposed to methanol vapours and on the effects observed in repeat dose inhalation studies. Tests with guinea pigs indicated that methanol is not a skin sensitiser. The critical effects to human health are acute toxicity from inhalation, skin contact and swallowing, and possible irreversible effects from acute oral exposure. No deaths were reported in Rhesus monkeys dosed at 2 000 mg/kg bw, but treated animals showed acidosis, and some exhibited semi-coma and ophthalmic changes. Human data, however, indicate acute oral toxicity and ophthalmic changes at comparatively lower doses of 300 - 1 000 mg/kg bw. Information on repeated dose toxicity by the dermal route is not available. Methanol was not genotoxic or carcinogenic. Reproductive and developmental toxicity studies did not show any significant effects of relevance to humans.

Key Study/Critical Effect for Screening Criteria	A No-Observed-Adverse-Effect-Concentration (NOAEC) of 0.013 mg/L (13 mg/m3) is used for this risk assessment. This NOAEC is derived from a chronic inhalation study in monkeys, in which degenerative effects in the brain and slight damage to the optic and peripheral nerves were noted at 0.13 mg/L and above. Changes in peroneal nerves were also noted in higher dosed animals, indicating damage to peripheral nerves. An oral No Observed Adverse Effect Level (NOAEL) of 500 mg/kg bw/day was also established in rats in a 90-day oral study based on increased liver enzymes (enzymes not specified) and decreased absolute brain weights at the highest dose. This value is not used in this risk assessment because acute oral data indicate that humans are more sensitive to methanol toxicity than rodents.
Ecological Toxicity [2,3]	
Aquatic Toxicity	In several 96-hour studies in fish in which methanol concentrations were measured during the tests, LC50s ranged from 15,400 to 29,400 mg/L. In the chronic toxicity study to invertebrates, the NOEC was 32,000 mg/L.
Determination of PNEC aquatic	A PNECaqua = 3.20E+03 mg/L can be calculated based on the lowest chronic toxicity value for aquatic invertebrates (Daphnia) with the assessment factor of 10.
Current Regulatory Controls[4]	
Australian Hazard Classification	The chemical is classified as hazardous with the following risk phrases for human health in the Hazardous Substances Information System (HSIS) (Safe Work Australia): T; R23/24/25 (acute toxicity) T; R39/23/24/25 (irreversible effects from acute exposure) Mixtures containing the chemical are classified as hazardous based on the concentration (Conc) of the chemical in the mixtures. The risk phrases for this chemical are: Conc ≥20%: T; R23/24/25; (Toxic: Toxic by inhalation, in contact with skin and if swallowed); R39/23/24/25; (Toxic: danger of very serious irreversible effects through inhalation, in contact with skin and if swallowed) 10% ≤Conc <20%: T; R20/21/22; (Toxic: Harmful by inhalation, in contact with skin and if swallowed); R39/23/24/25; (Toxic: danger of very serious irreversible effects through inhalation, in contact with skin and if swallowed) 3% ≤Conc <10%: Xn; R20/21/22; (Harmful: Harmful by inhalation, in contact with skin and if swallowed); R68/20/21/22; (Harmful: possible risk of irreversible effects through inhalation, in contact with skin and if swallowed).
Australian Occupational Exposure Standards	The chemical has an exposure standard of 262 mg/m³ (200 ppm) Time Weighted Average (TWA) and 328 mg/m³ (250 ppm) Short-Term Exposure Limits (STEL) (Safe Work Australia).

International Occupational Exposure Standards	The following were identified (Galleria Chemica): 250-270 mg/m³ (200 ppm) TWA in USA, Canada, Denmark, United Kingdom, Germany, France, Estonia, Greece, Hungary, South Africa, Spain, Singapore, Taiwan, Sweden, Malta, Malaysia, Latvia, Japan, Indonesia, India, Iceland, Egypt, Ireland, Mexico, Philippines and Switzerland; 250-350 mg/m³ (250-328 ppm) STEL in USA, Canada, United Kingdom, Greece, South Africa, Singapore, Sweden, India, Egypt and Mexico; 50 mg/m³ TWA in Bulgaria; 100 mg/m³ TWA and 300 mg/m³ STEL in Poland; 133 mg/m³ TWA in Netherlands; 25 mg/m³ TWA and 50 mg/m³ STEL in China; 1300 mg/m³ (1000 ppm) STEL in France; and 1040 mg/m³ STEL in Hungary and Switzerland.
Australian Food Standards	No Australian food standards were identified (FSANZ 2013)
Australian Drinking Water Guidelines	No aesthetic or health-related guidance values were identified for methanol in the Australian Drinking Water Guidelines (National Health and Medical Research Council (NHMRC) 2011).
Aquatic Toxicity Guidelines	No data available.
PBT Assessment	
P/vP Criteria fulfilled?	No. Methanol is expected to be readily biodegradable.
B/vB criteria fulfilled?	No. The Log Kow for methanol is -0.82 to -0.64. Thus, methanol does not meet the screening criteria for bioaccumulation.
T criteria fulfilled?	No. The EC50s from the acute aquatic toxicity data on methanol are >1 mg/L, hence does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	January 2019

References

1. NICNAS (2017) Human Health Tier II Assessment for Methanol
2. National Industrial Chemicals Notification and Assessment Scheme (NICNAS, 2017). National assessment of chemicals associated with coal seam gas extraction in Australia. Human health hazards of chemicals associated with coal seam gas extraction in Australia.
3. OECD (2008) SIDS Initial Assessment Profile on Methanol
4. ECHA REACH, Methanol, Retrieved 2017: https://echa.europa.eu/information-on-chemicals/registered-substances
5. IPCS Acetic Acid, Retrieved 2015: http://www.inchem.org

Toxicity Summary - Polyethylene glycol

Chemical and Physical Properties	
CAS number	25322-68-3
Molecular formula	$(C_2H_4O)nH_2O$
Molecular weight	UVCB
Solubility in water	40 g/L @ 30 °C
Melting point	-10 °C at 101.3 kPa
Boiling point	870 °C at 101.3 kPa
Vapour pressure	0 Pa @ 25 °C
Henrys law constant	
Explosive potential	Non explosive
Flammability potential	Non flammable
Colour/Form	Odourless, viscous transparent organic liquid
Overview	Polyethylene glycols, also known as PEGs, are clear, colourless, thick liquids to waxy solids, depending on the molecular weight. The molecular weight of PEGs ranges from 200 to over 6000. Some may have a faint odour and bitter taste. PEGs mix easily with water. PEGs are important commercial chemicals. They are used to make other chemicals, paper coatings, solvents, plasticizers and used in many household products, cosmetics and pharmaceuticals. One formulation, PEG 3500, is used as a laxative. PEGs are also used as food and animal feed additives.
Environmental Fate[1]	
Soil/Water/Air	Koc value of PEG was estimated as 10 L/kg by means of MCI method. This indicates that PEG will have a negligible tendency of sorption to soil and sediment and therefore have rapid migration potential to groundwater. The estimated half-life of the substance indicates that the substance is rapidly hydrolysable.

Human Health Toxicity Summary [1]	
Chronic Repeated Dose Toxicity	The substance PEG exhibits repeated dose toxicity by oral, dermal and inhalation route. A study was designed to investigate the subacute repeated dose toxicity effects of Polyethylene Glycols (PEG 400) in Wistar rats (male/female) by oral route, in an overall study period of 90 days. Dose group (5 animals per group) was fed a solution ofPEG400 equivalent to 0, 2000, 4000, 8000, 16000 or 24000 mg/kg/day in the diet. The control group received no polyethylene glycol. During the study period, body weight as a ratio to the amount of nutrient consumed, body weight, liver weight, kidney weight, micro pathology of liver and kidneys were examined. No effects upon male and female rats were observed when PEG 400 was present in the diet at a level up to 8000 mg/kg/day (8%concentration) for 90 days study period. But at 16000 mg/kg/day it showed effects on organ weight (liver and kidney heavier than that of control rats); and a decrease in weight gain was observed. Thus, from overall conclusion of the study the NOAEL (no observed adverse effect level) for repeated dose oral toxicity was considered to be 8000 mg/kg/day. And the LOAEL (low observed adverse effect level) for subacute repeated dose toxicity was considered to be 16000 mg/kg/day. Rats were exposed to airborne concentrations of 100 mg/m^3 and 1000 mg/m^3 of PEG-200 for periods up to 13 weeks. Toxicological, physiological, hematological, blood chemical, and pathological effects were evaluated during the course of the exposures. No significant lesions observed in this study occurred exclusively in exposed animals and the severity of lesions which were found was not dose-related. It is our impression that there were no PEG 200 induced lesions in rat tissue at the dosage level and exposure/post exposure periods evaluated in this study. Organ:body weight ratios in rats at all concentrations and for the 6- and 13-week exposure periods and the 30-day post exposure period showed no pattern of significance that could be related to PEG 200. The mice organ:body weights for the 6-week·exposure period are unavailable. No pattern of significance could be related to PEG 200 exposure for the 13-week or the 30-day post exposure periods. There were no consistently significant changes in rat blood chemistry at the end of the 6- or 13-week exposures or the 30-day post exposure period. It appears that PEG-200 produced no positive effects in the rodents at the Inn and 1000 mg/m3 PEG 200 concentrations over the 13 weeks of exposure used in this study. Thus it is concluded that the NOAEC value of PEG-200 in rats was observed at dose level of 1000 mg/m^3. The NOAEL value of PEG in rabbit was observed at dose level of 760 mg/kg bw/day. The supporting study indicates the TDLo (TDLo - Lowest published toxic dose) of PEG was observed at a dose concentration of 30 mL/kg (30000 mg/kg) in a 30 days study period where the dosage of PEG was intermittently given to rodent-rabbit by the dermal route(full study is not available). Considering the above results it is concluded that PEG is non-toxic by dermal route.
Carcinogenicity	No data available.
Mutagenicity/ Genotoxicity	PEG was found to be non-genotoxic.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	The one generation reproductive toxicity NOAEL (no observed adverse effect level) of PEG in rat was observed at a dose concentration of 1698.09 mg/kg bw/day. On the basis of this NOAEL value it indicates that PEG does not exhibit toxic effects to rat below the above mention dose.
Acute Toxicity	Acute toxicity of PEG to mouse by the oral route indicates that the substance does not exhibits acute toxicity by the oral route. Similarly the acute values of inhalation also indicate that the substance does not exhibits acute toxicity by the inhalative route. Thus, it can be inferred that the target substance is non-toxic to any of the oral, dermal and inhalation route of exposure.
Irritation	The available studies indicate that the substance PEG is not classified as a skin and eye irritant according to CLP regulation within the dose levels mentioned in the study.
Sensitisation	In the human repeat insult patch test 216 subjects were enrolled and 200 subsequently completed the study. PEG 200 caused some degree of sensitization response in 1 of the 200 subjects. This subject was a 61 year old white woman.

Health Effects Summary	PEG is non acute toxic to oral, dermal and inhalation route, shows no irritation effect to skin and eye, is not genotoxic and is not developmental and reproductive toxic.
Key Study/Critical Effect for Screening Criteria	Oral: In chronic repeated dose toxicity study by polyethylene glycols (PEG) 400 showed no effect upon male and female dogs when present in the diet at a level of 500 mg/kg/day (2% concentration) for one year. Thus NOAELs (no observed adverse effect level) for repeated dose oral toxicity was considered to be 500 mg/kg/day. Inhalation: The NOAEC value of PEG-200 in rats was observed at dose level of 1000 mg/m^3. Dermal: The NOAEL value of PEG in rabbit was observed at dose level of 760 mg/kg bw/day.
Ecological Toxicity [1]	
Aquatic Toxicity	The toxicity values of fish, invertebrates and algae are LC50 = 100 mg/L, LC50 = 1000 mg/L and EC 50 = 15.91 mg/L, respectively.
Determination of PNEC aquatic	Acute LC50 values are reported for fish, aquatic invertebrates, and freshwater algae. Since there is valid acute toxicity data for three trophic levels, an assessment factor of 1000 is used (in accordance with EU guidance). Based on the EC50 for freshwater algae (the most sensitive species in short term tests), the aquatic PNEC is 15.91 µg/L.
Current Regulatory Controls	
Australian Hazard Classification	No data available.
Australian Occupational Exposure Standards	No data available.
International Occupational Exposure Standards	No data available.
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	No data available.
PBT Assessment [1]	
P/vP Criteria fulfilled?	No. PEG is non persistent in nature and so is considered to have rapid biodegradation in the environment.
B/vB criteria fulfilled?	No. The calculated BCF of PEG is 3.2 dimensionless and below the threshold of 2000.
T criteria fulfilled?	No. Acute toxicity data >1 mg/L in fish, invertebrates and algae, thus PEG does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	January 2019

References

1. ECHA REACH European Chemicals Agency Database: http://apps.echa.europa.eu

Toxicity Summary - Sodium bisulfite

Chemical and Physical Properties [1]	
CAS number	7631-90-5
Molecular formula	H2O3S.Na
Molecular weight	104.06
Solubility in water	724 g/L @ 20 °C
Melting point	No data available.
Boiling point	No data available.
Vapour pressure	No data available.
Henrys law constant	No data available.
Explosive potential	No data available.
Flammability potential	No data available.
Colour/Form	No data available.
Overview	Sulfites in aqueous solutions involve complex equilibria among the different species of sulfur oxidation state IV. The composition of their mixture in solutions depends on the pH and temperature. Sulfur dioxide may be produced from sulfites at low pH. At a pH closer to 7, the concentration ratio of bisulfite (HSO_3^-) to sulfur dioxide (SO_2) is very high (Gunnison and Jacobsen, 1987). Sulfites occur naturally in some foods and beverages as a result of fermentation (e.g. in beer and wine). A small percentage of the population (up to 1 %) is sensitive to sulfites (FDA, cited in Grotheer et al., 2005), as sulfur dioxide may be generated from sulfites in the stomach at low pH (Simon, 1986). The sensitivity to sulfur dioxide can cause a wide range of reactions in humans ranging from mild to severe dermatological, pulmonary, gastrointestinal, or cardiovascular symptoms (Grotheer et al., 2005).
Environmental Fate[1]	
Soil/Water/Air	The substance has a very low vapour pressure, and also does not sublime. Therefore, the substance will not be present as a gas and no radical reactions can be expected. According to its chemical properties, hydrolysis is not expected/probable. Photodegradation in water is not relevant because it dissociates rapidly into ions and decomposes in water, and it not susceptible to visible light. The substance is an inorganic compound which does not undergo biodegradation. The substance readiliy dissociates in aqueous solution, as with soil moisture. Bioaccumulation is not to be expected. a low log Kow underlines this statement. Due to the ionic salt-character and other physico-chemical properties (negligible vapour pressure, very high water solubility and decomposition in water), the Henry constant is near to zero. Because of its ionic nature, sodium hydrogensulfite as well as its dissociation products are not volatile from aqueous solutions. Relevant adsorption onto soils, sediments or suspended matter is not expected.

Human Health Toxicity Summary [1]	
Chronic Repeated Dose Toxicity	Based on the data available for sodium metabisulfite, Sulfites are not considered to cause serious damage to health by repeated oral and inhalation exposure. In an 8-week study, SD rats (normal and sulfite oxidase enzyme—which oxidises sulfite to sulfate—deficient) were exposed to sodium metabisulfite (CAS No. 7681-57-4) or a mixture containing sodium metabisulfite and acetaldehyde hydroxysulfonate, in drinking water at doses of 0, 7, 70 or 175 mg/kg bw/day (as SO2). A no observed effect level (NOEL) for sodium metabisulfite was established as 70 mg/kg bw/day (as SO2) for all treated rats (normal and enzyme deficient), based on severe gastric lesions, significant body weight reduction and increased urine excretion with sulfites observed at the highest dose. The NOEL for the mixture was 7 mg/kg bw/day (as SO2) for enzyme-deficient rats, based on severe gastric and hepatic lesions at higher doses. At necropsy, lung oedema was observed in sodium metabisulfite treated, enzyme-deficient rats (Hui et al., 1989 cited in CIR, 2003). Groups of six rats (Sprague Dawley) were exposed to sodium sulfite (CAS No: 7757-83-7) aerosols with a particle size of approximately 1 µm at concentrations of 0.1, 1, 5 or 15 mg/m3 for three days. Mild pulmonary oedema at 5 mg/m3 and irritation of the tracheal epithelium at 15 mg/m^3 were observed (CIR, 2003). In a repeated dose study, eight dogs (beagle) were exposed to 1 mg/m3 of sodium metabisulfite (CAS No: 7681-57-4) aerosols with a mass median aerodynamic diameter (MMAD) of 0.63 µm for 290 days. Severe epithelial changes were observed with hyperplastic foci in the respiratory region of the nasal cavity. An increase in the nonciliated cell numbers in the membranous portion of the trachea of the animals was also observed. No other effects were reported (CIR, 2003).
Carcinogenicity	Based on a 104-week repeated dose toxicity study in rats, with up to 2 % sodium bisulfite in the diet, sodium bisulfite is not considered carcinogenic to rats (OECD, 2001).
Mutagenicity/ Genotoxicity	Based on the data available, Sulfites are not considered to be genotoxic. A mixture of sodium bisulfite (CAS No. 7631-90-5) and sodium sulfite (1:3) was tested at concentrations of 0.05–1 mmol/L in human peripheral lymphocytes. Positive results were obtained for chromosomal aberrations: micronucleus formation, and sister chromatid exchange (WHO, 1999). In an in vitro unscheduled DNA synthesis test with rat hepatocytes (OECD TG 486), and in an in vivo micronucleus test (OECD TG 474), sodium bisulfite (CAS No. 7631-90-5) did not show any evidence of mutagenicity (SCCNFP, 2003). Sodium bisulfite gave both positive and negative results in the mutagenicity testing. The positive results in Salmonella typhimurium strains containing his-G46 and his-D6610 mutations, and in some E.coli strains were suggested to be due to the presence of sulfurous acid under acidic conditions. At a neutral pH and lower concentrations, sodium bisulfite was not mutagenic to these strains. However, sodium bisulfite alone gave negative results in all in vivo studies with mammalian systems (rats and mice) (CIR, 2003).
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Based on the data available, Sulfites are not considered to cause reproductive or developmental toxicity. Pregnant rats (Wistar) were exposed by gavage to sodium bisulfite (CAS No. 7631-90-5) at 0, 1, 5, 24, or 110 mg/kg bw/day on days 6–15 of gestation. The NOAEL for maternal toxicity or embryo foetotoxicity was 110 mg/kg bw/day. A NOAEL of 123 mg/kg bw/day was established in a study with pregnant rabbits (Dutch belted) exposed to sodium metabisulfite (CAS No. 7681-57-4) at 0, 1.23, 5.71, 26.5 or 123 mg/kg bw/day on days 6–18 of gestation. In both these studies, there were no treatment related effects reported on nidation (nesting behaviour), maternal or foetal survival. The number of abnormalities in soft or skeletal tissues of the treated groups were similar to controls (OECD, 2001).

Acute Toxicity	Sodium bisulfite has an oral LD50 of 2000 mg/kg bw in rats (ChemIDplus). Based on the limited data available, sulfites are considered to be of low acute dermal toxicity. The LD50 for sodium metabisulfite in rats is >2000 mg/kg bw. Sulfites exhibit low acute toxicity in animal tests (US EPA, 2007). Based on the limited data available, no conclusion can be made on the acute inhalation toxicity of the chemicals in this group. A group of guinea pigs was exposed (whole body) for one hour to 0.204, 0.395 or 1.152 mg/m^3 of sodium sulfite (CAS No. 7757-83-7) aerosols with a mass median aerodynamic diameter (MMAD) of 0.36 µm. The chemical caused dose-related changes in the lung capacity parameters (bronchoconstriction) with a lowest observed adverse effect concentration (LOAEC) of 0.204 mg/m^3 (Chen et al., 1987 cited in CIR, 2003). Sodium bisulfite are classified as hazardous with the risk phrase 'Contact with acid liberates toxic gas' (Xi; R31) in the Hazardous Substances Information System (HSIS) (Safe Work Australia).
Irritation	No data are available on respiratory tract irritation from a single exposure. A 3-day repeated dose study indicated irritation of the tracheal epithelium in rats from exposure to sodium sulfite (CAS No. 7757-83-7) aerosols at 15 mg/m^3 (CIR, 2003). In acute dermal irritation studies (OECD TG 404) with sodium sulfite, sodium bisulfite and potassium sulfite, no skin irritation was observed in albino rabbits (SCCNFP, 2003). In acute eye irritation studies (OECD TG 405) with sodium sulfite and sodium bisulfite in rabbits, slight to severe effects in the cornea and the iris in most of the exposed animals persisted during the observation periods (eight and 15 days, respectively). Slight to moderate conjunctival effects (erythema and oedema) were also observed up to the end of the observation periods. Due to the persistency of eye effects, especially of increased corneal opacity, both chemicals were considered as severe eye irritants (SCCNFP, 2003).
Sensitisation	Based on the available data, Sulfites are not likely to be skin sensitisers.
Health Effects Summary	Severe eye irritation effects; acute oral toxicity; and the possibility of liberating toxic gas when the chemical is in contact with acids. Sensitivity to sulfites that causes allergic reactions in a small percentage of the population should also be considered.
Key Study/Critical Effect for Screening Criteria	The main critical effects to human health are severe eye irritation and acute oral toxicity. The chemicals in this group will liberate toxic gas when in contact with acid and therefore may cause effects in individuals with a high acid content in the stomach. A small percentage of the population (up to 1 %) are sensitive to sulfites (FDA, cited in Grotheer et al., 2005). Those who have asthma are most at risk to sulfite sensitivity and other forms of sulfite reactions. This sensitivity can cause a wide range of allergic reactions ranging from mild to severe.
Ecological Toxicity [2]	
Aquatic Toxicity	Acute and chronic toxicity data were available for the three main aquatic trophic levels that are considered for classification purposes. Classification is based on the lowest acute and chronic value, referred to as the acute and chronic toxicity reference value (TRV). The lowest acute effect concentration was observed for the alga S. subspicatus (72h-EC50), and was 36.8 mg sodium sulfite/L. Translating this value to HNaSO3 results in an acute TRV of 47.9 mg/L for this substance. For sulfite/disulfite compounds, the lowest chronic value was a NOEC of >8.41 mg sodium sulfite/L for the invertebrate D. magna. Translating this value to HNaSO3 results in a chronic TRV of 10.9 mg/L for this substance, i.e., > 1 mg/L.

Determination of PNEC aquatic	The lowest value for chronic toxicity was and unbounded NOEC of 8.41 mg sodium sulfite/L. Applying the AF of 10 results in a PNECaquatic of 0.84 mg sodium sulfite/L.Translating this value to HNaSO3 gives a PNECaquatic of 1.09 mg test substance/L. As the lowest NOEC-value is an unbounded value (i.e., no effect was noted at the highest test concentration), this value can be considered as a worst-case estimate. Further refinement of the NOEC-value for daphnids could increase the PNECaquatic up to a maximum value of 2.8 mg sodium sulfite/L (i.e., an assessment factor of 10 on the algal 72h-EC10 value), which is equivalent to 3.64 mg test substance/L.
Current Regulatory Controls [1]	
Australian Hazard Classification	Sodium bisulfite is classified as hazardous with the following risk phrases for human health in the Hazardous Substances Information System (HSIS) (Safe Work Australia): Sodium bisulfite (CAS No. 7631-90-5): Xn; R22 (acute toxicity) Xi; R31 (contact with acid liberates toxic gas)
Australian Occupational Exposure Standards	Sodium bisulfite has an exposure standard of 5 mg/m^3 time weighted average (TWA). The exposure standard for sulfur dioxide of 5.2 mg/m^3 (2 ppm) (TWA) is also relevant to uses of these chemicals that may generate sulfur dioxide.
International Occupational Exposure Standards	An exposure limit (OEL, TWA, STEL, PEL or STV) of 5–10 mg/m^3 in different countries such as USA, United Kingdom, Canada, Ireland, Spain, Norway and Switzerland.
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	No data available.
PBT Assessment [2]	
P/vP Criteria fulfilled?	Not applicable (inorganic substance)
B/vB criteria fulfilled?	Not applicable (inorganic substance)
T criteria fulfilled?	Not applicable (inorganic substance)
Overall conclusion	Not PBT
Revised	January 2019

References

1. National Industrial Chemicals Notification and Assessment Scheme (NICNAS). IMAP, Human Health Tier II Assessment for Ethoxylates of aliphatic alcohols (>C6): Retrieved 2019: https://www.nicnas.gov.au
2. ECHA REACH, Sodium hydrogensulfite, Retrieved 2019: https://echa.europa.eu/

Toxicity Summary - Sodium chloride

Chemical and Physical Properties [1,4]	
CAS number	7647-14-5
Molecular formula	NaCl
Molecular weight	58.44 g/mol
Solubility in water	3.57 x 10 5 g/m3 at 25oC
pH	In aqueous solution is neutral
Melting point	1 mm Hg at 865oC
Boiling point	1670 ^{o}C
Vapour pressure	No data found
Henrys law constant	No data found
Explosive potential	Not explosive
Flammability potential	Not flammable
Colour/Form	light brown liquid or colourless crystals
Overview	Sodium, together with potassium is an essential mineral for the regulation of body fluid balance. Sodium is the most abundant cation in the extracellular fluid and sodium salts account for more than 90% of the osmotically active solute in the plasma and interstitial fluid. Consequently, sodium load is the major determinant of extracellular volume. Chloride is also important in maintaining the fluid balance and is an essential component of the gastric and intestinal secretions Sodium chloride occurs naturally as rock salt which comprises 95% to 99% NaCl. It is also widely used in food products. The NHMRC has established dietary guidelines for the intake of sodium per day (adults should consume less than 2300 mg sodium per day). This chemical has been identified by NICNAS to be of low concern to human health based on an initial screening approach and thus required no further assessment.
Environmental Fate [2,3]	
Soil/Water/Air	Due to its high solubility, sodium chloride is highly mobile in the environment. Once dissociated, chloride ions will migrate readily, however sodium ions will sorb to clay-rich materials limiting mobility. If released into the environment, sodium chloride is not likely to sorb to solid particles in the water column, is readily dissociated to form chloride and sodium ions, is not bioaccumulative in aquatic species or the food chain.

Human Health Toxicity Summary [2,3]	
Chronic Repeated Dose Toxicity	High sodium chloride intakes increase calcium excretion and may increase the risk of kidney stone formation. There is evidence for a causal relationship between the consumption of sodium (mainly from common salt) and both blood pressure and the age-related rise in blood pressure. Data suggest that30% of a normotensive population may be salt sensitive. Sodium chloride has been demonstrated to be a gastric tumour promoter in experimental animals and high sodium chloride intakes have been associated with incidence of stomach cancer in human populations with traditional diets of highly concentrated, salted foods.
Carcinogenicity	Not listed with IARC.
Mutagenicity/ Genotoxicity	No data available.
Reproductive Toxicity Developmental Toxicity/Teratogenicity	No data available.
Acute Toxicity	No data available.
Irritation	Although rare, acute toxicity may be caused by ingestion of 500 – 1000 mg sodium chloride/kg body weight. Symptoms include vomiting, ulceration of the gastrointestinal tract, muscle weakness and renal damage, leading to dehydration, metabolic acidosis and severe peripheral and central neural effects.
Sensitisation	No data available.
Health Effects Summary	Sodium is an essential mineral for the regulation of body fluid balance. This chemical has been identified by NICNAS to be of low concern to human health.
Key Study/Critical Effect for Screening Criteria	The Australian drinking water guideline value for sodium and chloride may apply.
Ecological Toxicity [2,3,4]	
Aquatic Toxicity	A large number of studies are available in relation to the aquatic toxicity of sodium chloride with the USEPA ECOTOX database identifying 1712 records. The evaluation of ecological effects of sodium chloride has been evaluated in detail for the assessment of the use of rock salt in the US on roadways during the winter months. The following has been summarised from the US review: The presence of sodium chloride may result in the increased mobilisation of other contaminants (metals, nutrients etc) and a shift in the acid buffering capacity may compromise aquatic ecosystems. Most sensitive species are birds where a safe concentration of 1000 mg/L sodium chloride can be established. Salt tolerance of aquatic species varies significantly with EC50 concentrations ranging from 400 to 30000 mg/L. The measured acute endpoint for Fish was reported at 1290 mg/L. The measured NOEC for Daphnia is 314 mg/L.
Determination of PNEC aquatic	PNECaquatic: On the basis of the chronic results for Daphnia, an assessment factor of 100 has been applied to the lowest reported effect concentration of 314 mg/L. The PNECaquatic is determined to be 3.14 mg/L.
Current Regulatory Controls	
Australian Hazard Classification	No data available
Australian Occupational Exposure Standards	No data available
International Occupational Exposure Standards	No data available
Australian Food Standards	No data available

Australian Drinking Water Guidelines	No data available
Aquatic Toxicity Guidelines	No data available
PBT Assessment [4]	
P/vP Criteria fulfilled?	Sodium chloride is an organic salt that dissociates completely to sodium and chloride ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both sodium and chloride ions are also ubiquitous and are present in most water, soil and sediment. The persistent criteria is not considered applicable to this inorganic salt.
B/vB criteria fulfilled?	Sodium and chloride ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, sodium chloride is not expected to bioaccumulate.
T criteria fulfilled?	The measured chronic toxicity data for sodium chloride was 314 mg/L for Daphnia Thus, sodium chloride does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	April 2018

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1. HSDB (n.d.). *Hazardous Substances Data Bank*. Retrieved 2015, from Toxnet, Toxicology Data Network, National Library of Medicine: http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB
2. UK 2003. Expert Group on Vitamins and Minerals, Risk Assessment - Sodium Chloride
3. US, 2007. Hazard Identification for Human and Ecological Effects of Sodium Chloride Rock Salt. Prepared by the New Hampshire Department of Environmental Services
4. Department of the Environment and Energy 2017 , National assessment of chemicals associated with coal seam gas extraction in Australia, prepared by the National Industrial Chemicals Notification and Assessment Scheme

Toxicity Summary - Sodium hydroxide

Chemical and Physical Properties	
CAS number	1310-73-2
Molecular formula	Na-O-H
Product name	40 g/mol
Molecular weight	1.11E+06 mg/L at 20C
Solubility in water	13
Melting point	318 °C
Boiling point	1388 °C
Vapour pressure	Negligible at 25 deg C
Henrys law constant	No data found.
Explosive potential	No
Flammability potential	No
Colour/Form	Anhydrous (pure) NaOH is a solid – *refer melting point above*. However it is a hygoscopic, ionic solid, and will absorb water from air and is highly soluble
Incompatibility	Avoid contact of solid NaOH with water due to strong exothermic reaction, leather, wood, acids, organic halogen compounds or organic nitro compounds. Carbon monoxide gas can form upon contact with reducing sugars, food and beverage products in enclosed spaces. NAoH is neither explosive, flammable, nor oxidising.
Overview	Vegetable oil refining, regenerating iron exchange resins, organic fusions, peeling of fruits and vegetables in the food industry, etching and electroplating.
Environmental Fate[1]	
Soil/Water/Air	Sodium hydroxide is highly soluble, not volatile and unlikely to materially adsorb to soil and is therefore predominately found in the aquatic environment if released to the environment. NaOH will readily dissociate to be present in the environment as sodium and hydroxyl ions, both being ubiquitous in the environment. NaOH is a strong alkali, so it's dissolution in water may locally raise the pH of the affected environment. The dissolution reaction is also strongly exothermic.

Human Health Toxicity Summary [1,2,,3]	
Chronic Repeated Dose Toxicity	No animal data are available on repeated dose toxicity studies by oral or dermal routes for sodium hydroxide. In a repeat dose inhalation study, twenty seven white rats died within a month, mostly from bronchopneumonia, after being exposed twice weekly to an aerosol of unknown airborne concentration of sodium hydroxide, generated from an aqueous 40% sodium hydroxide solution (NIOSH 1975). When exposed to an aerosol generated from a 20% sodium hydroxide solution, the bronchi were dilated, the epithelial cover was thin and frequently desquamated, and the septa were dilated and cracked. A light round cell infiltration of the sub-mucus membrane tissue was also observed. Few changes occurred in a group of rats exposed to aerosols from 10% sodium hydroxide, but rats exposed to an aerosol of 5% sodium hydroxide had dilation of the bronchi and a slight degeneration of the mucus membrane and thickened strata of lymphadenoid tissue surrounding the bronchi. A NOAEL could not be established in this study. Workers exposed to 0.24 to 1.86 mg/m^3 sodium hydroxide for 2 to 15 minutes reported throat irritation and watery eyes (NIOSH 1975). Based on the observations of the irritant effects on workers exposed to 1 to 40 mg/m^3 sodium hydroxide, it was concluded that 2 mg/m^3 represented a concentration that is 'noticeably but not extensively irritant' (NIOSH 1975). Obstructive airway disease has been reported following chronic occupational exposure to sodium hydroxide mist (IPCS 1996). The patient developed cough, dyspnoea and tachypnoea after a 20-year exposure to sodium hydroxide.
Carcinogenicity	IARC Category 3 - not classifiable as to human carcinogenicity
Mutagenicity/ Genotoxicity	In vitro and vivo genetic toxicity testing reported no evidence of mutagenic activity.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	No valid studies were identified regarding reproduction toxicity after oral, dermal or inhalation exposure to NaOH. Sodium hydroxide is not expected to be systemically available to the body under normal handling and use conditions.
Acute Toxicity	Exposure to the solid or concentrated liquid can cause severe burns to the eyes, skin and gastrointestinal tract which may cause death. An oral LD50 of a 1-10% solution of NaOH in rabbits was 325 mg/kg bw (as 100% NaOH). An oral LD50 of 140 to 340 mg/kg in rats has also been reported (National Research Council 2011), however details of the study are not available. In an acute dermal study, mice were treated dermally with 50% sodium hydroxide, and the treated area was irrigated with water at various intervals (OECD 2002). The mortality of mice was 20, 40, 80 and 71% when they were irrigated at 30 minutes, one hour, two hours or not at all after the application. All animals developed rapidly progressive burns. No mortality or burns were observed when the treated area was irrigated immediately after the application. A 5% aqueous solution of sodium hydroxide produced severe necrosis when applied to the skin of rabbits for four hours (Clayton and Clayton 1993). A dermal LD50 of 1350 mg/kg has been reported in rabbits (National Research Council 2011), however details of the study are not available. Caustic dusts are irritating to the upper respiratory system. Prolonged exposure to high concentrations may cause discomfort and ulceration of nasal passages. Cases of fatality due to ingestion of liquid sodium hydroxide have been reported in humans.
Irritation	Sodium hydroxide is a corrosive irritant to skin, eyes and mucous membranes. A NaOH solution of 8% can be considered corrosive based on animal data. Human data indicate that concentrations of 0.5 to 4% were irritating.
Sensitisation	Sodium hydroxide has no skin sensitisation potential.

Health Effects Summary	An oral LD50 of 325 mg/kg in rats and a dermal LD50 of 1350 mg/kg in rabbits were reported for sodium hydroxide. Lethality has been reported in animals at oral doses of 240 mg/kg bw. Inhalational LC50 is not available. Sodium hydroxide is corrosive to skin, eyes and gastrointestinal and respiratory tracts. Based on human data, concentrations of 0.5 to 4.0% are irritating to the skin, while a concentration of 8.0% is corrosive. Sodium hydroxide is not a skin sensitiser. No animal data were available on repeated dose toxicity by oral or dermal routes for sodium hydroxide. In the single reported repeat dose inhalation study, a NOAEL could not be established. Both in vitro and in vivo genetic toxicity tests indicated no evidence of a mutagenic activity. Information is not available on reproductive and developmental toxicity and carcinogenicity of sodium hydroxide. Due to dissociation into ions which are subject to homeostatic controls in the human body, systemic effects from repeated exposures to sodium hydroxide are not expected. The critical health effect of sodium hydroxide is its corrosive effect.
Key Study/Critical Effect for Screening Criteria	No oral TRV apply. Acute toxicity only (irritant and corrosive), not systemically available in body. The Australian drinking water guideline value for pH may apply to sodium hydroxide.
Ecological Toxicity [1,2,3]	
Aquatic Toxicity	Measured acute endpoints were available for fish (196 mg/L). Measured chronic endpoint were available for Daphnia (240 mg/L)
Determination of PNEC aquatic	An assessment factor of 10 has been applied to the lowest reported NOEC of 240 mg/L for Daphnia. The PNECaquatic is 24 mg/L.
Current Regulatory Controls[4]	
Australian Hazard Classification	C: R35 (Corrosive, causes severe burns)
Australian Occupational Exposure Standards	Sodium hydroxide has an exposure standard of 2 mg/m³, Time Weighted Average (Safe Work Australia 2013).
International Occupational Exposure Standards	Occupational Exposure Limit (OEL) or limit values in working environment of 2 mg/m³ [Argentina, Belgium, Bulgaria, Canada, China, India, Japan and the US (NIOSH 1975)]. Occupational exposure standard: 2 mg/m³ [Korea] Occupational exposure limit values: 0.5 mg/m³ [Latvia] Short Term Exposure Limit (STEL): 2 mg/m³ [UK] US Department of Energy Temporary Emergency Exposure Limits (TEELs) = 0.5 mg/m³ (TEEL-0 and TEEL-1), 5 mg/m³ (TEEL-2) and 50 mg/m³ (TEEL-3).
Australian Food Standards	Processing aids - Generally permitted - permitted for use as acidity regulator (FSANZ 2013). Sodium hydroxide is allotted an International Numbering System (INS) of food additives number: INS 524 (Food Standards Australia New Zealand 2013).
Australian Drinking Water Guidelines	No data found. However, since sodium hydroxide readily dissociates in water into sodium and hydroxyl ions, the Australian Drinking Water Guidelines for sodium state that, based on aesthetic considerations (taste), the concentration of sodium in drinking water should not exceed 180 mg/L (National Health and Medical Research Council (NHMRC) 2011). No health-based guideline value is proposed for sodium.
Aquatic Toxicity Guidelines	No data found.
Occupational Exposure Limits	Peak limitation – 2 mg/m^3
PBT Assessment	
P/vP Criteria fulfilled?	Not applicable (inorganic salt, ionic species ubiquitous in environment)
B/vB criteria fulfilled?	Not applicable. Bioaccumulation is not applicable to these inorganic ions; sodium and hydroxide ions are ubiquitous and are present in most water, soil and sediment.

T criteria fulfilled?	Not applicable. Chronic toxicity data >1 mg/L in invertebrates, thus sodium hydroxide does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT

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3. European Commission (EC) Joint Research Centre (JRC) Institute for Health and Consumer Protection - European Chemical Substances Information System (ESIS), Sodium Hydroxide, Summary Risk Assessment Report, 2008
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Toxicity Summary - Sodium iodide

Chemical and Physical Properties [1,2,3]	
CAS number	7681-82-5
Molecular formula	INa
Molecular weight	149.92
Solubility in water	165 – 1,800 g/L @ 25 °C
Melting point	651 - 659 °C at 101.3 kPa
Boiling point	1,304 °C at 101.3 kPa
Vapour pressure	-1.301 @ 25 °C
Henrys law constant	0.015 Pa.m³.mol-1 @ 25 °C
Explosive potential	Non explosive
Flammability potential	Non flammable
Colour/Form	Solid, colourless cubic crystals, odourless
Overview	Iodides are used by the thyroid gland in hormone production. Iodides have been utilized to treat iodine disorders, hyperthyroidism, bacterial, fungal or protozoal infections and also were traditionally as expectorants because of their stimulatory effects on bronchial secretions. A Tier 1 Human Health Assessment for this chemical has been conducted by NICNAS which concluded that it was low concern to human health.
Environmental Fate [2]	
Soil/Water/Air	Sodium iodide is very stable under ordinary conditions of use and storage. The phototransformation in air is irrelevant to sodium iodide, because few sodium iodide can be distributed in air for the low vapour pressure and high water solubility. Hydrolysis is not a concern to such inorganic substance which can be completely ionized in water phase. sodium iodide will completely dissociate in water giving sodium ion and iodide anion. The sodium iodide is readily absorbed by organisms as Na+ and I-, which are both small (an)ions and well known to not likely to be bioaccumulative. Based on the intrinsic prosperities of sodium iodide, the substance can be expected to have a low potential for adsorption (completely ionized to small ions in water phase). The sodium ion and iodide anion are uniformly distributed in water phase. In the air, these two basic (an)ions is negligible, due to high water solubility and low vapour pressure. To sediment and soil phases, these two (an)ions are mostly distributed in the pore water.
Human Health Toxicity Summary [1]	

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Chronic Repeated Dose Toxicity	The most likely route for human exposure is via digestion, so the dermal and inhalation route are irrelevant in the repeated toxicity assessment. Boyages et al. (1989) compared thyroid status in groups of children 7–15 years of age who resided in two areas of China where drinking-water iodide concentrations were either 462.5 µg/l (n = 120) or 54 µg/l (n =51). Urinary iodine concentrations were 1236 µg/g creatinine in the high-iodine group and 428 µg/g creatinine in the low-iodine group. Although the subjects were all euthyroid, with normal values for serum thyroid hormones and TSH concentrations, TSH concentrations were significantly higher ($P < 0.05$) in the high-iodine group. The high-iodine group had a 65% prevalence of goitre and a 15% prevalence of Grade 2 goitre compared with 15% for goitre and 0% for Grade 2 goitre in the low-iodine group. To transform the measured urinary iodine levels into estimates of iodine intakes, steady state baseline dietary intakes of iodide were assumed to be equivalent to the reported 24 h urinary iodine excretion rates. Assuming a body weight of 40 kg and lean body mass of 85% of body weight, the urinary iodine/creatinine ratios reported by Boyages et al. (1989) can be converted to approximate equivalent intake rates of 1150 µg/day (0.029 mg/kg body weight per day) and 400 µg/day (0.01 mg/kg body weight per day) for the high- and low-iodine groups, respectively. Thus, the NOAEL for this study is considered to be 0.01 mg/kg body weight per day. From the Boyages et al. (1989) study, supported by the studies of Gardner et al. (1988), Paul et al. (1988), and others, a TDI of 0.01 mg/kg body weight, based upon reversible subclinical hypothyroidism, can be established by dividing the NOAEL of 0.01 mg/kg body weight per day by an uncertainty factor of 1.
Carcinogenicity	A chronic toxicity and carcinogenicity study, in which male and female F344/DuCrj rats were administrated iodide (KI) in the drinking water at concentrations of 0, 10, 100 or 1000 ppm for 104 weeks was conducted. In the test, neither focal hyperplasias, adenomas nor carcinomas derived from the follicular epithelium were increased, despite the fact that iodide was administered for 2 yr. It was therefore concluded that long-term treatment of iodide per se does not result in thyroid tumour induction in rats. In contrast, SCCs were observed in the submandibular gland in the 1000 ppm groups of both sexes, along with focal acinar atrophy and/or ductular proliferation, frequently accompanied by squamous metaplasia. Based on the fact that the cell proliferation of these proliferating ductules was higher in cases with metaplasia, and the evidence of a morphological continuum from meta-plasias to squamous cell carcinomas, a histogenetic relationship is suspected, which was also described in previous investigation (Takegawa et al., 1998). Based on these findings, it suggests that excess iodide has a thyroid tumour-promoting effect, but iodide per se does not induce thyroid tumours in rats. In the salivary gland, iodide was suggested to have carcinogenic potential via an epigenetic mechanism, only active at a high dose (1000 ppm in drinking water). The default value of volume of drinking water for rat is well accepted of 10 ml/100g bw·day, and the average body weight for rat is 250g. Based on these the LOAEL for salivary glands for carcinogenicity is proposed to be 100 mg/kg bw·day of iodide by drinking water

Mutagenicity/ Genotoxicity	The mutagenic potential for iodide (in potassium iodide) was studied using the L5178Y mouse (TK+/-) lymphoma assay (Kessler et al., 1980), The established mutagens ethylmethanesulphonate (EMS) and dimethylnitrosamine (DMN)were highly active in this assay, whereas iodide (KI) was inactive. Using the BALB/c 3T3 transformation assay well assessed the transformational capacities of these same agents and the positive mutagen N-ethyl-N-nitro-N-nitrosoguanidine (MNNG). All concentrations of the iodide tested were inactive in this assay it can be concluded that KI did not possess any biologically significant mutagenic cell transforming ability. Another study (J.M. Poul, and P. Sanders, 2004) on genotoxic effects of potassium iodide was conducted in vitro using the alkaline comet assay at concentration of 0.625, 1.25, 2.5, 5 and 10 mM. Additionally in the test cell viability was also measured using the Trypan blue exclusion method and expressed as proportion of total cells. The test results showed that potassium iodide did not induced DNA damage or cytotoxicity in the alkaline comet assay for doses up to 10 mM. In the same study, the chromosome damage effects of potassium iodide were evaluated in vitro using cytokinesis-block micronucleus test at concentration of 0.625, 1.25, 2.5, 5 and 10 mM. Additionally in the test cytotoxicity was also measured by the binucleated (BN) cell ratio between treated and control slides. The test results showed that potassium iodide did not induce chromosome damage or cytotoxicity in the alkaline comet assay for doses up to 10 mM. In an in vivo chromosome aberration test on embryonic hepatocytes, Stable iodine of 10 mg/kg is administered to the rats 7 days after fertilization. Then the embryonic liver was homogenated and the cells in metaphase were stained and checked under metaphase. The chromosome aberration cells were counted respectively for the concentration group and control group. The chromosome aberration rate in the concentration group was compared with that in the control group. The result showed there was no significant difference between iodide dosed group with the control group. Therefore, it can be concluded that the iodide has neither genetic toxicity nor cytotoxicity to mammalian cells.

Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Iodide (KI) was fed to male and female rats before and during breeding, to females only during gestation and lactation, and to their offspring after weaning (day 21 after birth) through to day 90, at levels of 0, 0.025, 0.05 or 0.1% (w/w) of the diet. There was no evidence suggesting that potassium iodide was embryotoxic. Litter size was significantly reduced, but birth weights and external morphology among those born alive were not significantly altered. No change in thyroid weight was observed indicating that these doses were not overtly thyrotoxic. Thyroid hormones were not assessed, however, and it is possible that thyroid function could have been altered in these animals. Nevertheless, the data are consistent with a picture of impaired thyroid function. Several tests of post-weaning behaviour showed effects at the lowest dose, 0.025 % potassium iodide. M-maze errors were increased at this dose and rotorod performance decreased. However, because these effects were not found at the higher doses it appears unlikely that they were related to potassium iodide. At present, these effects can only described as 'false positives'. The only effect on post-weaning behaviour that appeared to be consistently related to potassium iodide exposure was the reduction in nocturnal running-wheel activity found among the tested females. It may be that female cyclicity makes them more sensitive to the influence of chronic moderate iodide exposure than males and this could explain the contrast with the results of an acute test of activity and exploration, the open-field test, on which no consistent iodide-related effects were found. According to REACH guidance “R 10.8 of Guidance on information requirements and chemical safety assessment Chapter R.10: Characterisation of dose [concentration]-response for environment” The NOAEL can be calculated with the equation R 10-7:NOAEL(mg/kg bw day) = NOEC (mg/kg food)/CONV Where NOEC (mg/kg food) is 0.1, and CONV for Rattus norvegicus (> 6 weeks) is 20, and 10 for Rattus norvegicus (≤6 weeks). Therefore under this study the NOAEL for rats is 50 mg/kg bw day (developmental). In another study, twenty-five thyroiditis-prone BB/W rats were prenatally and postnatally exposed to iodine in drinking-water at dosages equivalent to 0, 0.059, or 59 mg/kg body weight per day for about 12 weeks. An increase in the number of lysosomes and lipid droplets was observed in the treated animals, especially in the higher exposure group. However, the test organism is not healty, as well as not enough information in the study, the effects cannot be considered to be dose related. Additionally, old studies were conducted with rabbits hamsters, rats and swine (Arrington LR, et al., 1965) to determine the effects of excess iodine intake. Females were bred to normal males, potassium or sodium iodide was added to the diet during the latter portion of gestation and the females were permitted to litter normally. Observations were made for length of gestation, parturition time, lactation and survival of young. 250 to 1000 ppm iodide fed for 2 to 5 days caused increasing mortality of new born rabbits. Hamsters were not affected by 2500 ppm iodine except for slightly re duced feed intake and decreased weaning weight of the young. Gestation time for rats and hamsters was not affected by iodine. Female rats and rabbits re-bred after removal from dietary iodine produced and nursed litters normally. Swine were not affected by dietary levels of iodine which were toxic to rabbits and rats. In conclusion, the iodide is not reproductive, embryonic toxicity, but the developmental toxicity was showed under concentration of 0.1% in diet, corresponding NOAEL as 50 mg/kg bw day (developmental).

Acute Toxicity	The most relevant study on vertebrates by oral route is a company study (A. Hausner, G. Weise, and A. Hofmann, 1980). In the test the effects of iodide were studied in male and female Wistar rats. 10 male and 10 female in each dose and control groups were administrated with potassium iodide for 14 days at dose of 0 (control), 2000, 2500, 2800 3200, 3600, and 4000 mg/kg body weight mg/kg bw respectively. The key value of LD50 was calculated by Probit-analysis (Fink und Hund 1965). It shows the 24 hour and 7-14 days of LD50 to rats (male/female) was respectively 3118 and 2779 mg/kg bw under test conditions. Therefore the key value which is used in the hazard classification and chemical safety assessment is 3118 mg/kg bw.
Irritation	Iodine has been used for dermal application in human as disinfectant (as Iodine and Povidine Iodine) for long time. The mechanism of disinfecting is oxidizing bactericide by iodine; meanwhile the iodine is reduced to iodide. It means after application of iodine on skin, the iodide is left on skin. In addition, based on information from assessment report of WHO, in a human assay, five patients were applied with potassium iodide in concentrations ranging from 5% to 20% in petrolatum, the reactions were negative. With such evidence, it can be concluded that iodide has no effect to the human skin.
Sensitisation	No adverse effect observed (not sensitising) for skin and respiratory sensitisation.
Health Effects Summary	This chemical has been identified by NICNAS to be of low concern to human health
Key Study/Critical Effect for Screening Criteria	TDI of iodide is 0.01 mg/kg body weight.
Ecological Toxicity [2]	
Aquatic Toxicity	The 96 hours acute toxicity test to Rainbow Trout (Laverock, M.J., M. Stephenson, and C.R. MacDonald, 1995) was conducted according to Protocol to determine the acute lethality of liquid effluents to fish, which was established by Ontario Ministry of the Environment. The results showed that the 96 hour LC50 is over 860 mg/l. The acute toxicity to daphnia of iodide was determined (INERIS Parc Technologique ALATA, 2012) according to OECD test guideline 202 following GLP procedure to give a result of 48hrs-EC50 as 1.27 mg/L (95%CL, 1.19 -1.38 mg/L). There is another data on daphnia acute toxiciy (Laboratoire d'Ecotoxicologie Parc technologique ALATA, 1996) of KI according to method of "French standard", which was similar to OECD test guideline 202, which is 48 hrs- EC50 as 7.5 mg/l. As the study for NaI gives lower tolerance value for daphnia and the test itself is more reliable (Klimisch score 1), the 48 hrs- EC50 of 1.27 mg/l is taken as the key value. One study of acute toxicity of iodide to algae was published in well-known journal "water research" (Bringmann, G., and R. Kuhn, 1980). It was not a standard test and without declaration of GLP compliance, and in the test the 7 days cell multiplication inhibition test was applied to the model organism, Scenedesmus quadricauda (green algae) for iodide, but fulfilled basically scientific principles. The results showed the toxicity threshold (≥3% inhibition of the biomass of green algae) of iodide to green algae is 2370 mg/l.
Determination of PNEC aquatic	PNECaquatic: On the basis of the acute results for Daphnia, an assessment factor of 100 has been applied to the lowest reported effect concentration of 1.27 mg/L. The PNECaquatic is determined to be 1.27 µg/L.
Current Regulatory Controls	
Australian Hazard Classification	No data available.
Australian Occupational Exposure Standards	No data available.

International Occupational Exposure Standards	No data available.
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	No data available.
PBT Assessment [2]	
P/vP Criteria fulfilled?	Not applicable (inorganic salt, ionic species ubiquitous in environment).
B/vB criteria fulfilled?	Not applicable. Bioaccumulation is not applicable to these inorganic ions; sodium and iodide ions are ubiquitous and are present in most water, soil and sediment.
T criteria fulfilled?	Not applicable. Acute toxicity data >0.01 mg/L in invertebrates, thus sodium iodide does not meet the screening criteria for toxicity.
Overall conclusion	Not applicable.
Revised	January 2019

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Toxicity Summary - Sodium Persulfate

Chemical and Physical Properties[1,2,3,4]	
CAS number	7775-27-1
Molecular formula	Na2O8S2
Molecular weight	238
Solubility in water	730 g/l at 25 °C
Melting point	Decomposes at > 180°C
Boiling point	No data available
Vapour pressure	0 Pa at 25 °C (negligible)
Henrys law constant	No data available
Explosive potential	Non-explosive
Flammability potential	Non-flammable
Colour/Form	White crystals or powder
Overview	The persulfates category includes molecules with similar chemical structure and similar physical-chemical properties. Substances of the persulfate category are inorganic salts sharing the persulfate anion moiety. The inorganic substances differ only by the cationic portion of the salt, which is not expected to influence the hazardous properties of the molecule. The anionic part is identical and is expected to display the same environmental, ecotoxicological and toxicological behaviour based on the available data.
Environmental Fate[1,3]	
Soil/Water/Air	Substances of the persulfate category are not stable in the environment. Persulfates are not expected to adsorb to soil due to their dissociation properties, instability (hydrolysis) and high water solubility. They should behave as free ions or decompose into sulfate ions. In soils, upon decomposition, the cation could form more stable sulfate or bisulfate salts. Persulfates are not expected to bioaccumulate in the soil or in aqueous solution. They will decompose into inorganic sulfate or bisulfate.
Human Health Toxicity Summary [1]	
Chronic Repeated Dose Toxicity	The persulfates have low repeat dose toxicity. Twenty-eight-day repeated dose oral (dietary) toxicity studies were conducted in rats with three persulfate salts. The oral doses for the three salts were 0, 100, 316, 1000 ppm (equivalent to 0, 12.6, 41.2, 131.5 mg/kg bw/day for the potasium salt). Tests were performed in male rats only. The no observed adverse effect levels (NOAEL) for sodium and potassium salts were 137 and 131.5 mg /kg bw/day, respectively (the highest doses tested), while the NOAEL for ammonium persulfate was 41 mg/kg bw/day, based on decreased relative adrenal weight at the highest dose (FMC, 1979a; FMC, 1979b; FMC1979c). Another oral (dietary) subchronic toxicity study using sodium persulfate was conducted in rats. Rats (20/sex/group; strain not provided) were fed rodent chow containing 0, 300, 1000 or 3000 ppm sodium persulfate (0, 23, 100 or 225 mg/kg bw/day) for 90 days. On day 48 of the study, the concentration of the group receiving 1000 ppm was increased to 5000 ppm for the remainder of the study. At the two high dose levels body weight was decreased during the last 6 weeks of treatment (FMC 1979e).
Carcinogenicity	Based on the limited data available, there is no evidence of carcinogenicity of any of the persulfate salt. In a non-guideline study, female SENCAR mice were exposed dermally twice weekly to 0.2 mL of a 200 mg/mL solution of ammonium persulfate for 51 weeks. The investigators concluded that ammonium persulfate is neither a tumour promoter nor a complete carcinogen when applied to the skin (Kurokawa et al., 1984).

Mutagenicity/ Genotoxicity	Based on the limited available data, sodium persulfate was not mutagenic. An in vitro unscheduled DNA synthesis test was also negative for sodium persulfate (FMC, 1990d). The ammonium salt was not clastogenic in Chinese hamster fibroblasts in the absence of metabolic activation in a chromosome aberration test (Ishidate et al., 1988). Sodium persulfate was negative in two in vivo genotoxicity studies. Doses of sodium persulfate up to 338 mg/kg injected into mice intraperitoneally did not increase the incidence of micronuclei in bone marrow polychromatic erythrocytes (FMC, 1990c). Sodium persulfate was found to be non-genotoxic when tested up to 820 mg/kg in an in vivo unscheduled DNA synthesis test in rats (FMC, 1991c).
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Based on the limited data available for ammonium persulfate, the sodium persulfate is not toxic to reproduction or development. In a well conducted fertility/developmental study (OECD 421), groups of rats (Crl:CD (SD)IGS BR, 12/sex/group) were administered ammonium persulfate in the diet at doses of 0, 40, 100 and 250 mg/kg bw/day (Weaver, 2004). Animals (both sexes) were dosed two weeks prior to and during mating. Females were administered the substance following mating, throughout gestation and until lactation day 4. In the parental generation group, there were no treatment related clinical signs, effects on body and organ weights or gross lesions. There were no significant adverse effects on the gonads and progression of spermatogenesis, although a non-significant decrease in pregnancy rates was reported at = 100 mg /kg bw/day. On this basis, it was concluded that the NOAEL for fertility indices and reproductive performance was the top dose of 250 mg /kg bw/day. There were no treatment-related clinical signs, mortality or necropsy findings among pups (live birth and viability indices were similar across all groups). There was a slight transient depression in mean pup body weight; however it was not considered adverse. The developmental toxicity NOAEL determined was the highest dose of 250 mg /kg bw/day (Weaver, 2004).
Acute Toxicity	Persulfate salts are considered to have moderate acute toxicity by the oral route. The acute oral median lethal dose (LD50) values for soidum persulfate (in rats) was reported as 895-930 mg/kg bw (Degussa AG, 1979). Clinical signs were ocular and oral discharge, irregular breathing and loss of muscle control. Persulfate salts have low acute dermal toxicity. The acute dermal LD50 was greater than 10,000 mg/kg bw (rabbits) for sodium persulfates (FMC, 1979c). Ocular and nasal discharge and slight irritation were reported in animals dermally exposed to high levels of persulfates (FMC, 1979b). Persulfates have low acute inhalation toxicity. Acute inhalation studies with sodium persulfates performed according to OECD guidelines in rats, indicated median lethal concentration (LC50) values of greater than the maximum attainable concentrations, 5.1 mg/L. Following exposure to high concentrations of persulfates, animals exhibited dyspnoea, respiratory distress and increased nasal, ocular and oral secretion (FMC 1987, FMC, 1979b; FMC 1995).

Irritation	The chemicals are classified as hazardous with the risk phrase 'Irritating to Respiratory system' (Xi; R37) in the HSIS (Safe Work Australia). Groups of male ND4 Swiss Webster mice were exposed, head-only, to sodium persulfate dust for 30 minutes at concentrations of 0.26 to 3.22 mg/L. Mortality was observed in all except the lowest exposure group during the 7-day post-exposure period with clinical signs that included ocular and nasal discharge and decreased respiratory rate. Abnormal gait and whole body tremors were observed in animals exposed to the highest concentration of dust. The concentration of dust which produced a 50 % decrease in respiratory rate (RD50) was 2.25 mg/L, indicating that sodium persulfate was a respiratory system irritant (FMC, 1994). Sodium persulfates were not found to be skin irritants in animal studies. However human observations support the existing classification as skin irritants. Three brief study reports submitted by industry on sodium persulfate showed at most a slight skin irritant potential in rabbits (FMC, 1979d; FMC, 1980). The chemicals are classified as hazardous with the risk phrase 'Irritating to eyes' (Xi; R36) in the HSIS (Safe Work Australia). In a single unpublished study, sodium persulfate was instilled into the eyes of 8 rabbits. Eye irritation was scored by the Draize method at 24, 48 and 72 h. Slight conjunctivitis was noted at 48 h (FMC, 1979c).
Sensitisation	There was evidence of delayed contact hypersensitivity in two maximisation tests (OECD TG 406) using ammonium and sodium persulfate in guinea pigs. All test animals reacted positively following challenge by intradermal injection of 0.1 % ammonium persulfate and 80 % of animals were positive following dermal challenge with 1 % ammonium persulfate 14 days later. The corresponding figures for sodium persulfate were 90 % positive for test animals positive following an (non-standard) intracutaneous challenge and 60 % of the test animals were positive following topical challenge (CIR, 2001; BIBRA International, 1997). Sodium persulfate was not sensitising when applied to the skin of guinea pigs in an unpublished Buehler Test, conducted to guideline standards (FMC, 1990b). In a murine local lymph node assay (LLNA), investigators concluded that both ammonium and sodium persulfate were moderate to strong sensitisers with EC3 values (amount of chemical required to elicit a stimulation index of 3) calculated to be 1.9 % and 0.9 % respectively (Cruz et al., 2009 cited in HSDB).
Health Effects Summary	Although the persulfate salts are harmful by the oral route, potential for acute toxicity was generally not demonstrated via the dermal or inhalation routes. The persulfate salts were irritating to eyes and respiratory system but not skin irritants in animal studies, while studies in humans indicate that persulfates can cause skin irritation. The persulfates are capable of inducing skin and respiratory sensitisation in animals and these are also the major chronic effects observed in humans. Mouse LLNA results for ammonium and sodium persulfate suggest that persulfates are moderate to strong sensitisers. Overall, the main critical effects to human health are skin and respiratory sensitisation and irritation.
Key Study/Critical Effect for Screening Criteria	
Ecological Toxicity [2]	
Aquatic Toxicity	The LC50 values for acute toxicity to fish ranged between 163 to 771 mg/L for sodium persulfate. The acute toxicity EC50 values for invertebrates were between 133 and 519 mg/L for sodium persulfate. In algae, the EC50 for sodium persulfate 116 mg/L.
Determination of PNEC aquatic	A PNECaquatic of 116 µg/L was calculated using the lowest endpoint of EC50 of 116 mg/L for algae. An assessment factor of 1000 was used.
Current Regulatory Controls	

Australian Hazard Classification	No data available.
Australian Occupational Exposure Standards	No data available.
International Occupational Exposure Standards	No data available.
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	No data available.
PBT Assessment	
P/vP Criteria fulfilled?	No. Biodegradation is not applicable to substances of the Persulfate Category, as the substances are inorganic. Upon contact with water or water vapour substances of the persulfate category hydrolyse into cation and persulfate anion. The persulfate anion, independent of the cation, undergoes further decomposition in normal water or acid conditions, readily oxidizing water to oxygen, producing sulphate and hydrogen ions. All final persulfate degradation products are ubiquitous to the environment.
B/vB criteria fulfilled?	No. Persulfates are very soluble in water and are not expected to bioaccumulate in soil or aqueous solutions.
T criteria fulfilled?	Based on measured acute toxicity endpoints of greater than 1 mg/L, sodium persulfate does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	January 2019

References

1. NICNAS (2017) Human Health Tier II Assessment for Persulfates
2. OECD (2005) SIDS Initial Assessment Profile on Persulfates
3. ECHA REACH, Disodium peroxodisulphate, Retrieved 2017: https://echa.europa.eu/information-on-chemicals/registered-substances
4. ICSC Sodium Persulfates, Retrieved 2017: http://www.inchem.org

Toxicity Summary - Sodium sulphate

Toxicity Summary - Sodium sulphate

Chemical and Physical Properties[1,3,4,5]	
CAS number	7757-82-6
Molecular formula	Na2SO4
Product name	142.04 g/mol
Molecular weight	161 g/l at 20 °C
Solubility in water	No data found.
Melting point	884 °C
Boiling point	Decomposition occurs above 884°C.
Vapour pressure	Solid
Henrys law constant	Expected to be extremely low
Explosive potential	No data found.
Flammability potential	No data found.
Colour/Form	Not combustible. Gives off irritating or toxic fumes/gases in a fire.
Overview	Sodium sulfate is widely distributed in nature; it occurs as mineral salts (e.g. thenardite, mirabilite), it is present in almost all fresh and salt waters and sulfate as such is normally present in almost all natural foodstuffs. Both sodium and sulfate ions are among the most common ions found in all living organisms. In mammals, sulfate is an normal metabolite of sulfur-containing amino-acids, it is normally incorporated in a variety of body compounds and it plays an important role in detoxification/ excretion processes due to sulfoconjugation Sodium sulfate has been produced for many years in high volumes for use in detergents, glass and paper manufacture and a variety of smaller industrial uses National Industrial Chemicals Notification and Assessment Scheme (NICNAS) has performed an IMAP environment Tier 1 summary which concluded that sodium sulphate is an inorganic substance comprising ions of low ecotoxicological concern. This chemical is not expected to pose an unreasonable risk to the environment provided that ANZECC water quality guidelines for physical and chemical stressors are not exceeded.
Environmental Fate[1,4,5]	
Soil/Water/Air	Sodium sulphate is a solid inorganic salt well soluble in water. In water solutions it is fully dissociated to sodium and sulfate ions. In anaerobic environments sulfate is biologically reduced to (hydrogen) sulphide by sulfate reducing bacteria, or incorporated into living organisms as source of sulphur, and thereby included in the sulphur cycle. The BCF of sodium sulfate is very low (0.5) and therefore bioconcentration is not expected. Sodium and sulfate ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. However some plants (e.g. corn and *Kochia Scoparia*), are capable of accumulating sulfate to concentrations that are potentially toxic to ruminants.
Human Health Toxicity Summary [1,2,4,5]	
Chronic Repeated Dose Toxicity	Valid oral repeated dose toxicity studies with 21, 28 and 35 day studies in hens and pigs are available. Toxicity was confined to changes in bodyweight, water and feed intake and diarrhoea. These changes occurred only at very high doses of sodium sulfate. In ruminants, high concentrations of sulfate in food may result in the formation of toxic amounts of sulfites by bacterial reduction the rumen, leading to poly-encephalomalacia. The available data do not allow the derivation of a NOAEL. Based on available consumer data, a daily dose of around 25 mg/kg/day is well tolerated by humans

Carcinogenicity	There is no valid oral carcinogenicity study. Limited data from experimental studies support the notion that a substance that is abundantly present in and essential to the body is unlikely to be carcinogenic.
Mutagenicity/ Genotoxicity	Sodium sulfate has been shown to be without effect in the Ames test using various strains of *S. typhimurium* (TA1535, TA1537, TA100, TA98) both with and without S9 activation in a GLP standardised test Based on the natural intra- and extracellular occurrence of the substance it can be concluded that sodium sulfate is highly unlikely to be mutagenic
Reproductive Toxicity	Limited data of poor validity did not provide an indication of toxicity to reproduction.
Developmental Toxicity/Teratogenicity	No data were found.
Acute Toxicity	The acute toxicity (LD50) of sodium sulfate has not been reliably established but is probably far in excess of 5000 mg/kg. In an inhalation study with an aerosol, no adverse effects were found at 10 mg/m3. Also human data indicate a very low acute toxicity of sodium sulfate. Human clinical experience indicates that very high oral doses of sodium sulfate, 300 mg/kg bw up to 20 grams for an adult, are well tolerated, except from (intentionally) causing severe diarrhoea. WHO/FAO did not set an ADI for sodium sulfate. There is no data on acute dermal toxicity, but this is probably of no concern because of total ionisation in solution.
Irritation	Sodium sulfate is not irritating to the skin and slightly irritating to the eyes. Respiratory irritation has never been reported.
Sensitisation	Sodium sulphate is not a skin or respiratory sensitiser
Key Study/Critical Effect for Screening Criteria	The Australian Drinking Water Guidelines for sodium and sulphate may apply to sodium sulphate.
Ecological Toxicity [3,4,5]	
Aquatic Toxicity	Algae were shown to be the most sensitive to sodium sulfate; EC50 120h = 1,900 mg/l. For invertebrates *(Daphnia magna)* the EC50 48h = 4,580 mg/l and fish appeared to be the least sensitive with a LC50 96h = 7,960 mg/l for *Pimephales promelas*. No data were found for long term toxicity. The acute studies all show a toxicity of sodium sulfate higher than 100 mg/l, no bioaccumulation is expected
Determination of PNEC aquatic	An assessment factor of 1000 has been applied to the lowest reported effect concentration of 1900 mg/L for Daphnia. The PNEC aquatic is 1.9 mg/L.
Current Regulatory Controls	
Australian Hazard Classification	The chemical is not listed in the Hazardous Substance Information System (HSIS) (Safe Work Australia 2013).
Australian Occupational Exposure Standards	No data found
International Occupational Exposure Standards	No data found
Australian Food Standards	No data found
Australian Drinking Water Guidelines	The Australian Drinking Water Guideline for sulphate is 250 mg/L (aesthetic) and sodium is 180 mg/L (aesthetic).
Aquatic Toxicity Guidelines	No data found
PBT Assessment	
P/vP Criteria fulfilled?	Sodium sulphate is an inorganic salt that dissociates completely to sodium and sulphate ions in aqueous solutions. The persistent criterion is not considered applicable to this inorganic salt.
B/vB criteria fulfilled?	The BCF of sodium sulfate is very low (0.5) and therefore bioconcentration is not

	expected.
T criteria fulfilled?	The acute aquatic toxicity of sodium sulfate is > 0.01 mg/L. Hence the substance does not fulfill the screening criteria for toxic (T)
Overall conclusion	Not a PBT substance (based on screening data).

References

1. HSDB (n.d.). *Hazardous Substances Data Bank*. Retrieved 2017, from Toxnet, Toxicology Data Network, National Library of Medicine: http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB
2. National Health and Medical Research Council, Natural Resources Management Ministerial Council, national Water Quality Management Strategy, Australian Drinking Water Guidelines 6, 2011, Version 3.3 Updated November 2016.
3. National Industrial Chemicals Notification and Assessment Scheme (NICNAS), IMAP Environment Tier I Summary all tranches, 2016.
4. OECD (2005a) Screening Information Dataset (SIDS) Initial Assessment Report for Sodium Sulfate, CAS Number 7757-82-6, UNEP Publications
5. OECD (2005b) SIDS Initial Assessment Profile for Sodium Sulfate, CAS Number 7757-82-6, UNEP Publications

Toxicity Summary - Tributyl tetradecyl (TTPC)

Chemical and Physical Properties[3]	
CAS number	81741-28-8
Molecular formula	C26-H56P.Cl
Product name	BE9
Molecular weight	435.15 g/mol
Solubility in water	miscible
Melting point	45 °C
Boiling point	439 °C (estimated)
Vapour pressure	Solid
Henrys law constant	1.04 x 10-8 kPa at 25 °C (estimated)
Explosive potential	No data found
Flammability potential	No data found
Colour/Form	No data found
Overview	Limited toxicity information was located for TTPC. TTPC is an antimicrobial biocide that is effective at preventing microbial slime from forming in oilfield sites such as fracturing fluids and water flooding operations. This chemical has been identified by Health Canada to be of negligible risk to birds and aquatic organisms. At high doses TTPC can be toxic to birds and aquatic organisms but due to its use pattern, the potential exposure of these organisms is expected to be minimal and, consequently, risk to these organisms is not of concern.
Environmental Fate[5]	
Soil/Water/Air	In the event of a release of produced/flowback water containing TTPC to the aquatic environment, TTPC would be expected to mix readily as it is very highly soluble in water. The primary route of dissipation is expected to be sorption to sediment and organic matter. Once TTPC has adsorbed onto sediments, it will break down into two other chemicals, (tributyl-(5-hydroxy-pentyl) phosphonium chloride and tributyl-(7-hydroxy-heptyl) phosphonium chloride). TTPC is considered to be moderately persistent to persistent in aerobic aquatic systems and non-persistent in aerobic water. TTPC is not expected to undergo photolysis. Based on its negligible vapour pressure, volatilization of TTPC from moist soil or water surfaces is not expected. TTPC and its transformation products are not expected to bioaccumulate. In the event of a release of produced water containing TTPC to the terrestrial environment, the primary route of dissipation for TTPC is expected to be adsorption to soil particles. TTPC has high soil adsorption coefficients, is highly adsorptive to soil and exhibits limited mobility. It could be expected that biodegradation in soil may occur as it was observed to biodegrade in sediment.
Human Health Toxicity Summary [1,2]	
Chronic Repeated Dose Toxicity	No data were found.
Carcinogenicity	No data were found.

Mutagenicity/ Genotoxicity	No data were available for TTPC. A brief report for TBPB noted that the chemical tested negative in an Ames bacterial mutagenicity assay, a Chinese hamster ovary (CHO) chromosome aberration test and a cell transformation test using Hamster Embryo Cells (HEC) although further details were not provided (Dunn et al. 1982). Therefore, TBPB is not mutagenic under the conditions tested and, on the basis of this limited evidence; it is assumed that TTPC is not genotoxic.
Reproductive Toxicity	No data were found.
Developmental Toxicity/Teratogenicity	No data were found.
Acute Toxicity	An inhalation study (EPA Office of Prevention, Pesticides and Toxic Substances (OPPTS) 870.1300) in rats exposed nose-only to TTPC (particle size 1.7 to 2.1 µm) reported hypoactivity, gasping, irregular respiration, red nasal discharge, ano-genital staining and abdominal distension at 0.05 mg/L (US EPA 2012b). Six of the 10 animals died within three days of a four-hour exposure. Gross necropsy revealed red coloured lungs, distension of stomach and / or intestines and / or mottled liver. The single exposure acute inhalation LC50 for this study was identified as <0.05 mg/L. This study shows that TTPC is highly toxic by the inhalation route in rats. No oral or dermal information was available for TTPC. However, based on analogue data available for THPB, TBPC and TBPB from animal studies, acute toxicity of TTPC by oral and dermal route is likely to be moderate
Irritation	No information was available for TTPC but data were available for the analogues THPB and TBPC.for skin irritation. Overall, the effects observed with the analogues THPB and TBPC, albeit after a 24-hour exposure period compared with the four-hour exposure specified by the equivalent OECD TG, demonstrate the likely corrosive potential of TTPC to the skin. No information was available for TTPC but data were available for the analogues THPB, TBPC and TBPB for eye irritation. The effects observed in all tests with the analogues THPB, TBPC and TBPB demonstrate the likely corrosive potential of TTPC to the eyes. In an inhalation study with TTPC in rats, a red nasal discharge and facial staining was noted (US EPA 2012b). While the information in the study is limited based on the analogues being corrosive to the skin it is likely that the chemicals are also irritant to the respiratory mucosa. TTPC is therefore likely to be a respiratory irritant.
Sensitisation	No data were available for TTPC. TBPC at 0.1% concentration in normal saline solution was determined as not sensitising to the skin following dermal applications (undisclosed induction and one challenge treatment) in guinea pigs (US EPA 1978). TBPC is not a skin sensitiser in guinea pigs and therefore a sensitisation potential for TTPC is not expected. No data were available for respiratory sensitisation.
Health Effects Summary	TTPC demonstrates high acute toxicity by the inhalation route. Based on read across data available from THPB, TBPC and TBPB, the chemical has moderate acute toxicity by oral and dermal routes and is corrosive to the skin and eye and is a respiratory irritant. Data available for TBPC and TBPB indicate that the chemical is not a skin sensitiser or genotoxic, respectively. No repeat dose, carcinogenicity or reproductive toxicity data were available for the chemical or suitable analogues. Chronic exposure may be considered as inappropriate given the nature of TTPC and analogues as direct acting corrosives mediating severe adverse effects at the site of contact. In conclusion, the critical health effect of TTPC is its acute inhalation toxicity.

Key Study/Critical Effect for Screening Criteria	No data are available for determining the critical effect and the LOAEL/NOAEL for an oral reference dose.
Ecological Toxicity [3,4]	
Aquatic Toxicity	LC50: (96 hour) 0.46 mg/L (Oncorhynchus mykiss) LC50: (96 hour) 0.06 mg/l (Lepomis macrochirus) LC50: (96 hour) 0.58 mg/l (fish) TLM96: 1.6 mg/l (Crangon crangon) TLM48: 0.025 mg/l (Daphnia magna) The modelled acute endpoint for Daphnia is 16.788 mg/L and Fish is 1059.2530 mg/L.
Determination of PNEC aquatic	PNECaquatic: On the basis that the modelled data consists of short-term results from two trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 0.025 mg/L for Daphnia. The PNECaquatic is calculated to be 0.000025 mg/L.
Current Regulatory Controls	
Australian Hazard Classification	The chemical is not listed in the Hazardous Substance Information System (HSIS) (Safe Work Australia 2013).
Australian Occupational Exposure Standards	No data found
International Occupational Exposure Standards	No data found
Australian Food Standards	No data found
Australian Drinking Water Guidelines	No data found
Aquatic Toxicity Guidelines	No data found
PBT Assessment[3,4,5]	
P/vP Criteria fulfilled?	No information is available on biodegradation, however it has been observed to biodegrade in sediment.
B/vB criteria fulfilled?	Not Bioaccumulative (Based on an estimated log Kow value of 6.48)
T criteria fulfilled?	No chronic toxicity data are available for TTPC. The lowest modelled acute endpoint of TTPC is 0.025 mg/L for Daphnia. Since this value is <0.1 mg/L, TTPC does meet the screening criteria for toxicity.
Overall conclusion	Inconclusive.

References

1. Material Safety Data Sheet for Bellacide 350, BWA Water Additives, SDS No. 10794
2. National Information System of the Regional Integrated Pest Management (IPM) Centers, U.S. Department of Agriculture and National Institutes of Food and Agriculture (www.ipmcenters.org).
3. National Industrial Chemicals Notification and Assessment Scheme (NICNAS, 2017). National assessment of chemicals associated with coal seam gas extraction in Australia.
4. Safety Data Sheet for BE-9, Halliburton, 2017
5. Health Canada Pest Management Regulatory Agency, Proposed Registration Decision, Tributyl tetradecyl Phosphonium Chloride and Bellacide 350, July 2018

Toxicity Summary - 2,2`,2"- Nitrilotriethanol

Chemical and Physical Properties [1,2, 3,6]	
CAS number	102-71-6
Molecular formula	C6H15NO3
Molecular weight	149.19 g/mol
Solubility in water	Miscible with water.
pH	10.5
Melting point	17-21.6 °C
Boiling point	153 °C at 0.1007 kPa 192.87 °C at 0.7996 kPa 236.69 °C at 5.01 kPa 320 °C at 101 kPa
Vapour pressure	$3.59x10^{-6}$ mm Hg at 25 °C
Henrys law constant	$7.05x10^{-13}$ atm-cu m/mole at 25 °C
Explosive potential	No data found.
Flammability potential	Combustible, when exposed to heat or flame. Gives off irritating or toxic fumes (or gases) in a fire.
Colour/Form	Pale yellow to colourless viscous liquid with a slight ammonia odour.
Overview	Triethanolamine is a member of the ethanolamines family that combines the properties of amines and alcohols. Triethanolamine is typically supplied as a pale colourless to yellow liquid with an ammonia-like odor. Triethanolamine is primarily used in detergents, personal-care products, and textile finishing. Triethanolamine may also be used as in other applications including adhesives, agricultural products, concrete additives, gas treating processes, rubber, surfactants, photographic chemicals, and urethane foams. Contact with triethanolamine may cause slight to severe eye irritation. Brief contact is essentially nonirritating to the skin, but repeated exposure may cause irritation and burns. Skin contact may cause an allergic skin reaction. At room temperature, exposure to vapour is minimal due to low volatility; single exposure is not likely to be hazardous. This product has very low toxicity if swallowed. Harmful effects are not anticipated from swallowing small amounts, but swallowing larger amounts may cause injury. This product has been toxic to the fetus in laboratory animals at doses toxic to the mother. Findings from a study by the National Toxicology Program suggest an increased incidence of liver tumors in mice, but their relevant to humans is not clear. Triethanolamine is water soluable and biodegradable according to the OECD 301A test for biodegradation. It is not expected to bioaccumulate or persist in the environment. Triethanolimine is practically non-toxic to aquatic organisms on an acute basis. However large releases may increase the pH of aquatic systems to levels that may be toxic to aquatic organisms.

Environmental Fate [1,3,4,6]	
Soil/Water/Air	If released to soil, triethanolamine is expected to have very high mobility based upon an estimated Koc of 7. However, the pKa of triethanolamine is 7.8, indicating that this compound will primarily exist in cation form; and cations generally adsorb to organic carbon and clay more strongly than their neutral counterparts. Volatilization from moist soil surfaces is not expected to be an important fate process based upon an estimated Henry's Law constant of 7.1X10-13 atm-cu m/mole. If released into water, triethanolamine is not expected to adsorb to suspended solids and sediment based upon the estimated Koc. Triethanolamine biodegraded in a biochemical oxygen demand (BOD) test at an initial concn 50 ppm. After 10 days, the ThOD (theoretical oxygen demand) was 70% using acclimated water as seed and sewage as inoculum. Volatilization from water surfaces is not expected to be an important fate process based upon this compound's estimated Henry's Law constant. An estimated BCF of 3 suggests the potential for bioconcentration in aquatic organisms is low. Hydrolysis is not expected to be an important environmental fate process since this compound lacks functional groups that hydrolyze under environmental conditions

Human Health Toxicity Summary [1,2,3,4,5,6]	
Chronic Repeated Dose Toxicity	Fischer 344 rats and B6C3F1 mice were administered 0, 500, 1000, 2000, 4000 or 8000 mg/100 mL triethanolamine in drinking water (NTP 1990). Water consumption was reduced at the top two doses. No other details were provided. In a 91-day study conducted in accordance with OECD TG 408, Cox CD rats were administered 88.5% triethanolamine in the diet at doses of 0, 250, 500 or 1000 mg/kg bw/day (REACH 2013). There were no significant dose-dependent changes in bodyweight, organ weight, histopathology, pathology and haematology. No Lowest Observed Adverse Effect Level (LOAEL) or No Observed Adverse Effect Level (NOAEL) can be established for this study. In a 90-day study, rats (strain not specified) were administered doses of 5 to 2610 mg/kg bw/day triethanolamine in the diet (Smyth et al. 1951). The study reported microscopic lesions and mortality at doses of 730 mg/kg bw/day and above. The authors indicated the NOAEL as 80 mg/kg bw/day. No other details were provided. In 60- and 120-day studies in rats (strain not specified) given 200 to 1800 mg/kg bw/day triethanolamine, effects observed included liver changes at all treatment doses after 60 and 120 days administration, kidney changes at 400 mg/kg bw/day after 60 and 120 days administration, and kidney damage at >800 mg/kg bw/day after 60 and 120 days administration (Kindsvatter 1940). The specific changes in the liver and kidney were not described. No other details were provided. The LOAEL for this study was 200 mg/kg bw/day. Repeated dermal dose toxicity with triethanolamine application was consistently associated with inflammation at the treatment site. Systemic effects included changes in bodyweight and organ to bodyweight ratios. The critical study for determining the effects of repeated dermal exposures to the chemical is the 90-day study cited in REACH (2013) conducted similarly to OECD TG 411. The NOAELs for this study are 125 mg/kg bw/day for males and 250 mg/kg bw/day for females. In an inhalation study, Fischer 344 rats were exposed to 0, 125, 250, 500, 1000 or 2000 mg/m3 triethanolamine for 16 days (NTP 1985b). The effects observed included decreased bodyweight at 2000 mg/m3 for both sexes, increased liver weight in males at 2000 mg/m3, increased kidney weight in males at concentrations ≥500 mg/m3, and increased kidney weight in females at concentrations ≥250 mg/m3. Minimal to slight acute inflammation of the larynx was reportedbut the doses for which this effect was seen were not specified. The LOAECs are 500 mg/m3 in males and 250 mg/m3 in females. The NOAECs are 250 and 125 mg/m3 in males and females, respectively. Wistar rats were exposed through the head and nose to 0, 0.02, 0.1 or 0.5 mg/L aerosolised triethanolamine in a 28-day study conducted in accordance with OECD TG 412 (Gamer et al., 2008). There were no treatment-related effects seen on bodyweight, haematology, clinical chemistry and neurobehavioural parameters. Local effects, such as minimal to moderate focal inflammation in the submucosa of the larynx region, were reported at all treatment concentrations. The LOAEC and NOAEC for systemic effects cannot be established. The LOAEC for local effects is 0.02 mg/L. B6C3F1 mice exposed to 0, 125, 250, 500, 1000 or 2000 mg/m3 triethanolamine for 14 days showed minimal acute inflammation of the laryngeal submucosa (NTP 1985a). The doses for which this effect was seen were not specified.
Carcinogenicity	The International Agency for Research on Cancer (IARC) has classified the chemical as ‘not classifiable as to its carcinogenicity to humans’ (Group 3), based on inadequate evidence for carcinogenicity in humans and experimental animals (IARC, 2000). There was no evidence of carcinogenicity by oral (up to 1000 mg/kg/day for 104 weeks, and up to 3334 mg/kg/day for 82 weeks amongst rats and mice respectively) or dermal routes (dose unknown) in studies of 14-18 months duration using rats and mice. No inhalation data were available.

Mutagenicity/ Genotoxicity	Triethanolamine was not genotoxic in a number of in vitro studies (bacterial reverse mutation, mammalian cell cytogenetics, and unscheduled DNA synthesis). On the basis of the negative results observed in a range of in vitro studies, in vivo genotoxicity is not anticipated.
Reproductive Toxicity Developmental Toxicity/Teratogenicity	Triethanolamine is not considered to be toxic to fertility and not considered to be a developmental toxicant. There were no effects observed in the reproductive organs of the animals treated with the chemical from repeated oral, dermal and inhalation toxicity studies. In a reproduction/developmental toxicity screening test conducted in accordance with OECD TG 421, Wistar rats were administered 0, 100, 300 or 1000 mg/kg bw/day triethanolamine by gavage (REACH 2013). The animals were treated during pre-mating (two weeks for both sexes), mating (maximum of two weeks for both sexes), post-mating (one week in males), and the entire gestation period and four days of lactation in females. There were no parental systemic effects reported in all of the treated animals. Most of the animals treated at the top dose showed transient salivation, which could be attributed to the unpalatability of the chemical or local irritation of the upper digestive tract. There were no effects on fertility observed in any of the treated animals. The parental LOAEL and NOAEL for local effects are 1000 and 300 mg/kg bw/day, respectively. The developmental LOAEL and NOAEL are 1000 and 300 mg/kg bw/day, respectively. The LOAEL and NOAEL for fertility cannot be established. A dye formulation containing 0.15, 1.5 or 2% triethanolamine was applied to the shaved skin of CD-1 rats (Burnett et al. 1976). The application occurred seven times during the gestation period. There were no systemic or local effects observed. No developmental effects were reported.
Acute Toxicity	The chemical was of low acute toxicity in animal tests following oral exposure. The median lethal dose (LD50) in experimental rats studies ranged from is 4190–11300 mg/kg bw triethanolamine. Two studies in mice (strain not specified), two studies in rabbits (strain not specified), and three studies in guinea pigs (strain not specified) reported acute oral LD50s of 5400 to 7800, 2200 to 5200, and 2200 to 8000 mg/kg bw, respectively.Observed sub-lethal effects included agitation, elevated respiration and reduced grooming (NIWL, 2003; CIR, 2011). The chemical was of low acute toxicity in animal tests following dermal exposure. The median lethal dose (LD50) in rabbits is greater than 2000 mg/kg bw. Observed sublethal effects included mild erythema 24 hours after exposure, resolving after 6 –10 days (REACH; CIR, 2011). Due to the low vapour pressure of the chemical, the highest attainable vapour concentration is 1.8 mg/m³. In a study conducted in rats (strain not specified) exposed to the chemical (1.8 mg/m³), no deaths were reported. One out of 12 rats exposed showed signs of chronic bronchitis (REACH).
Irritation	Based on the available data, the chemical is considered a respiratory and eye irritant. In two studies conducted similarly to OECD TG 405 the average Draize scores for corneal opacity, redness of the conjunctivae and chemosis were 1, 2 and 1.75 respectively (REACH). In one study, the corneal opacity in one animal had not fully resolved by day eight of the observation period. However, based on the results seen in the other animals, it is expected that the corneal opacity would fully resolve had the observation period continued for 21 days. The chemical was not irritating to skin in studies that were performed in accordance with OECD Test Guideline (TG) 404 (REACH). In one study, three Vienna White Rabbits were dermally exposed to the chemical (85 % concentration of triethanolamine and 15 % diethanolamine) through a occlusive patch for four hours. Neither oedema nor erythema was observed throughout the observation period (REACH). In animal studies with repeated exposures, the chemical was applied to rabbit ears over 10 open applications, with 10 unoccluded applications to abdominal intact skin, or with three semi-occluded 24-hour applications to abraded skin. These exposures resulted in slight to moderate irritation (CIR, 2013). In a two-year repeated dose dermal study, the chemical caused lesions consisting of acanthosis (thickened skin), ulceration and chronic active inflammation at the application site. In the repeated dose inhalation studies, minimal to slight acute inflammation of the larynx was observed in rats and mice (NTP 1985a, 1985b). In a more recent 28-day inhalation study, minimal to moderate focal inflammation in the submucosa of the larynx was observed in rats (Gamer et al. 2008).

Sensitisation	Triethanolamine is not a skin sensitizer in animals. The negative results observed for the chemical in several guinea pig maximisation tests and one local lymph node assay support a conclusion that the chemical is not a skin sensitiser (REACH; CIR, 2013).
Health Effects Summary	Triethanolamine has low acute oral and dermal toxicity but may cause eye and respiratory irritation. Triethanolamine was non-irritating to the skin in rabbit studies, whilst studies in humans indicate that the chemical can cause skin irritation. The chemical is not a skin sensitiser. The chemical is neither genotoxic, carcinogenic nor a reproductive toxicant.
Key Study/Critical Effect for Screening Criteria	The most appropriate NOAELs for risk assessment, determined from the 90-day repeat dermal dose toxicity study cited in REACH (2013) are 125 (males) and 250 (females) mg/kg bw/day based on systemic effects. Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability); 10 (subchronic to chronic) Oral RfD = 125/1000 = 0.125 mg/kg/day Drinking water guideline value = 0.49 ppm

Ecological Toxicity [1,3, 4,6]	
Aquatic Toxicity	Triethanolamine is of low acute toxicity to fish and aquatic invertebrates. The most sensitive fish species tested was the fathead minnow Pimephales promelas for which a 96h-LC50 of 11,800 mg/l was determined. Triethanolamine was slightly more toxic to Daphnia, which had a 24h-EC50 of 1,390 mg/l. In a 21 day reproduction test with Daphnia magna, a NOEC of 16 mg/l and an EC50 of 2,038 mg/l were determined in a semi-static test (concentrations measured twice during the test). Triethanolamine appears to be more toxic to algal species. Toxicity tests have been carried out at both constant pH and allowing the pH to increase with increasing triethanolamine concentration. In two cases triethanolamine appears to be more toxic when the test is carried out allowing the pH to increase. In one case, using the green algae Scenedesmus quadricauda, the 7-8 day toxicity threshold (defined as the concentration which just caused an effect of cell multiplication of around 3% compared with controls - can be considered as a NOEC) for triethanolamine was found to be much lower at constant pH (toxicity threshold = 1.8 mg/l) than when the pH was allowed to vary (toxicity threshold = 715 mg/l). The EC50 was reported as 910 mg/l for Scenedesmus subspicatus (algae) for 96 hour exposure under test conditions where the test media was neutralised.
Determination of PNEC aquatic	PNECaquatic: On the basis that the data consists of short-term and long-term results from three trophic levels, an assessment factor of 10 has been applied to the lowest reported NOEC of1.8 mg/L for Scenedesmus quadricauda mg/L for invertebrates. The PNECaquatic is 0.18 mg/L.
Current Regulatory Controls [2]	
Australian Hazard Classification	Triethanolamine is listed on the Hazardous Substances Information System (HSIS) (Safe Work Australia 2013) with a recommended Exposure Standard.
Australian Occupational Exposure Standards	Time Weighted Average (TWA) of 5 mg/m^3 (Safe Work Australia 2013).
International Occupational Exposure Standards	TWA: 5 mg/m^3 [Belgium, Finland, Iceland, New Zealand, Peru] 0.5 mg/m^3 [Denmark].
Australian Food Standards	Triethanolamine is listed as a permitted processing aid in bleaching agents, washing and peeling agents, water used as an ingredient in other foods, and miscellaneous functions under the conditions of Good Manufacturing Practice (GMP) (Food Standards Australia New Zealand 2013).
Australian Drinking Water Guidelines	No data found
Aquatic Toxicity Guidelines	No data found
PBT Assessment [1,3,4,6]	
P/vP Criteria fulfilled?	There are conflicting findings from standard ready biodegradability tests regarding the rate of biodegradation of triethanolamine. Some studies indicate relative rapid biodegradation, whereas some closed bottle studies indicate slow biodegradation under the test conditions (OECD 1995). However, the chemical is inherently biodegradable. The results of a test using OECD test guideline 302B showed that 89% of the chemical is degraded after 14 days (OECD 1995). Thus, Triethanolamine is categorised as Persistent.
B/vB criteria fulfilled?	Based on the measured log Kow of -1.0 and a measured BCF of <3.9 L/kg in fish, triethanolamine has low bioaccumulation potential and is considered not bioaccumulative.
T criteria fulfilled?	The acute aquatic toxicity of triethanolamine is > 0.01 mg/L. Hence the substance does not fulfill the screening criteria for toxic (T)
Overall conclusion	Not a PBT substance (based on screening data). Further assessment of the environmental risks from the use of this chemical is not required as identified by DoEE.
Revised	April 2018

References

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2. National Industrial Chemicals Notification and Assessment Scheme (NICNAS), 2014. Inventory Multi-Tiered Assessment and Prioitisation (IMAP), Human Health Tier II Assessment for Ethanol, 2,2',2''- nitrilotris-, CAS Number 102-71-6.
3. OECD (1995) SIDS Initial Assessment Report for Triethanolamine, CAS Number 102-71-6
4. DOW Product Safety Assessment Triethanolamine, 2014
5. International Agency for Research on Cancer (IARC) – Summaries & Evaluations, Triethanolamine, 2000
6. Department of the Environment and Energy 2017 , National assessment of chemicals associated with coal seam gas extraction in Australia, prepared by the National Industrial Chemicals Notification and Assessment Scheme

Appendix E

Chemical Risk Assessment Hydraulic Fracture Stimulation Fluid – Tracers

Human Health Screening Assessment
Chemical Tracers

Tracer Name	Concentration in Injected Fluid (mg/L)	Ecotoxicity	Toxicity	Persistence	Bioaccummulative	Screening	Discussion
CFT (20 chemicals)	0.75	Algae EC50 = 33.1 mg/L Fish LC50 = 44.6 mg/L Daphnia EC50 > 100 mg/L Algae EC10 = 3.4 mg/L Fish NOEC 28 d = 120 mg/L Daphnia NOEC 21 d = 25 mg/L	Based on chronic: Low	Expected to be readily biodegradable	No based on calculated log Kow of 1.87	Tier 1	The risk was classified as low based on chronic data. A Tier 2 assessment would not be required.
GFT (15 chemicals)	1.35	Fish 96h LC50 > 100 mg/L Invertebrates 48h EC50 > 0.1 mg/L Microorganism 3h EC50 > 100 mg/L Fish 96h NOEC = 1000 mg/L	Based on chronic: Low	Not readily biodegradable	Yes based on calculated log Kow of > 4.5	Tier 1 with management	The risk was classified as low based on chronic data. It is not expected to be readily biodegradable and is bioaccummulative. Management of this chemical in flowback water will be addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.
WFT (1 chemical)	200,000 – 250,000	LC50 fish (96 h) > 120 mg/L EC50 daphnia (48h) > 125 mg/L EC50 plants (48h) > 125 mg/L	Based on acute: Low	Not readily biodegradable	No based on log Kow of -10.7	Tier 1 with management	The risk was classified as low based on acute data. The exposure concentration is markedly elevated. It is not expected to be readily biodegradable however, it is not bioaccummulative. Management of this chemical in flowback water will be addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.
WFT (1 chemical)	200,000 – 250,000	Fish 96 h LC50 = 87 mg/L Daphnia 48 h EC50 = 182 mg/L Algae ErC50 > 100 mg/L	Based on acute: Low	Expected to be readily biodegradable	No based on log Kow of 0.07	Tier 1 with management	The risk was classified as low based on acute data. The exposure concentration is markedly elevated. It is expected to be readily biodegradable and is not bioaccummulative. Management of this chemical in flowback water will be addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.

Appendix F

Hydraulic Fracture Stimulation Fluid Tracers Chemical Toxicological Profiles

Toxicity Summary - Water SoluableTracers (CFTs) - Benzoic acid used as analogue data

Chemical and Physical Properties[1]	
CAS number	20 chemicals (proprietary)
Molecular formula	Proprietary
Molecular weight	Proprietary
Solubility in water	Proprietary
Melting point	Proprietary
Boiling point	Proprietary
Vapour pressure	Proprietary
Henrys law constant	No data available.
Explosive potential	Non-flammable
Flammability potential	Non explosive
Colour/Form	A white crystalline powder with a pleasant odour.
Overview	CFTs are organic compounds.
Environmental Fate[1,2,3]	
Soil/Water/Air	If released to air, the vapor pressure indicates benzoic acid will exist solely as a vapor in the atmosphere. Vapor-phase benzoic acid will be degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals; the half-life for this reaction in air is estimated to be 9 days. Benzoic acid absorbs light at wavelengths >290 nm and, therefore, may be susceptible to direct photolysis by sunlight. If released to soil, benzoic acid is expected to have very high mobility based upon an estimated Koc of 15 (log Kow of 1.87). The pKa of benzoic acid is 4.20, indicating that this compound will exist almost entirely in the anion form in the environment and anions generally do not adsorb more strongly to soils containing organic carbon and clay than their neutral counterparts. Volatilization from moist soil is not expected because the compound exists as an anion and anions do not volatilize. Benzoic acid is not expected to volatilize from dry soil surfaces based upon its vapor pressure. If released into water, benzoic acid is not expected to adsorb to suspended solids and sediment based upon the estimated Koc. Biodegradation half-lives of 0.85 and 3.6 days using inoculum from a polluted river and a reservoir, respectively, suggest that biodegradation may be an important fate process in water. Measured BCF values of <10, 14, and 21 were reported for Golden ide (Leuciscus idus melanotus)(1), trout(2), and mosquito fish (Gambusia affinis)(3), respectively. This BCF range suggests the potential for bioconcentration in aquatic organisms is low.

Human Health Toxicity Summary [1]	
Chronic Repeated Dose Toxicity	Based on the weight of evidence the chemical is not considered to cause serious damage to health by repeated oral exposure (no observed adverse effect level (NOAEL) of 825 mg/kg bw/d). Effects observed at > 1000 mg/kg bw/d included increased mortality, reduced weight gain, and liver and kidney effects (OECD, 2004). Available animal data suggest that the chemical is not likely to cause serious damage to health via repeated dermal exposure. No treatment-related effects in rabbits at doses of up to 2500 mg/kg bw/d applied 5 d/wk for 3 weeks (OECD, 2004). Available animal data suggest that the chemical is not likely to cause serious damage to health via repeated inhalation exposure. The only available rat study for this chemical reported 2/20 mortalities at 1.2 mg/L 6 h/d (5 d/wk over 4 wk). Local reddish discharge around the nostrils and inflammatory cell infiltrates and interstitial fibrosis of the lung secondary to local irritant effects were also observed at ³ 0.25 mg/L. On the basis of systemic effects, the NOAEC is considered to be > 0.25 mg/L 6 h/d (ECHA, 2011).
Carcinogenicity	Based on the available data, the chemical is not considered carcinogenic. The chemical was not carcinogenic (NOAEL 500 mg/kg bw/d) in a lifetime 3-generation study in rats when given with the diet at doses up to 500 mg/kg bw/d. No increase in the lifetime tumour incidence, clinical abnormalities or histopathological changes were observed (OECD, 2004). A lifelong study using male/female Swiss Albino mice given the chemical (2 %) continuously in drinking water showed no carcinogenic effect (such as effect on survival or incidence of tumours) (CICAD, 2000).
Mutagenicity/ Genotoxicity	Based on the weight of the evidence of the in vitro and in vivo genotoxicity data, the chemical is not considered mutagenic or clastogenic. In vitro data using the reverse mutation assays with various strains of Salmonella typhimurium (with and without metabolic activation) and sister chromatid exchange assays (except one equivocal result) were negative. Weak genotoxic effects or equivocal results were observed in most of the chromosome aberration assays in three mammalian cell lines and two of the recombination assays in Bacillus subtilis (no further information available, only summary given) (REACH). No genotoxicity was observed in the in vivo cytogenetic, micronucleus, or other assays at either somatic or germ cell level (OECD, 2004).
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	No evidence of reproductive or developmental toxicity was observed for the chemical.

Acute Toxicity	The chemical is of low acute toxicity in animal tests following oral exposure. The median lethal dose (LD50) in rats and mice is greater than 2000 mg/kg bw/d. LD50 in rats ranged from 1700-3040 mg/kg bw/d and in mouse ranged from 1940-2370 mg/kg bw/d. However, the studies that reported the lower LD50s were all pre-guideline studies and no further information was available to critically assess the data. LD50s reported in two reliable studies were 2250 mg/kg bw/d (mice) and 2565 mg/kg bw/d (rats) (OECD, 2004). The chemical is of low acute toxicity in animal tests following oral exposure. The median lethal dose (LD50) in rats and mice is greater than 2000 mg/kg bw/d. LD50 in rats ranged from 1700-3040 mg/kg bw/d and in mouse ranged from 1940-2370 mg/kg bw/d. However, the studies that reported the lower LD50s were all pre-guideline studies and no further information was available to critically assess the data. LD50s reported in two reliable studies were 2250 mg/kg bw/d (mice) and 2565 mg/kg bw/d (rats) (OECD, 2004). The chemical exhibits low acute toxicity in animal tests as evidenced by reported dermal LD50 (median lethal concentration) in rats of greater than 2000 mg/kg bw (OECD, 2004). The chemical exhibits low acute toxicity in animal tests following inhalation exposure. No mortalities or toxic effects were observed in rats and mice with the reported median lethal concentration (LC50) > 12.2 mg/L/4-h (ECHA, 2011; OECD, 2004).
Irritation	Inhalation toxicity of the chemical was evaluated in one rat study (0, 0.025, 0.25 and 1.2 mg/L, 6 h/d 5 d/wk over 4 weeks) using fine benzoic acid dust (see Repeat dose toxicity - Inhalation). A reddish discharge around the nostrils was seen in the mid and high dose groups. An increased incidence and intensity of interstitial inflammatory cell infiltrate and interstitial fibrosis (indicating upper respiratory tract irritation) was noted at all doses. Observed histopathological changes were most likely due to a persistent irritating effect of the test substance on the lung. No changes in gross pathology were noted (REACH). The chemical was irritating (erythema and swelling of the ear lobe) in the guinea pig ear swelling test at ³ 1%, particularly when dissolved in ethanol, although it was not found irritating in the rabbit (OECD, 2004). The chemical was highly irritating in rabbit eyes, causing irreversible corneal opacity and chemosis in 2/3 animals, and increasing conjunctival redness severity with white/grey discoloration after 2-day observation. A Draize score of 35 was given based on the effects (REACH). In another rabbit study an irritation score of 65.0/110 was noted. No further details were available from this study (OECD, 2004).
Sensitisation	The negative results seen for the chemical from several skin sensitisation animal studies including guinea pig maximisation test (GPMT), Buehler test and local lymph node assay (LLNA) support a conclusion that the chemical is not a skin sensitiser (REACH). The chemical did not induce sensitisation in healthy volunteers although some allergic reactions were noted in 34/537 patients with suspected contact dermatitis (at 2 %) (SCCP, 2005) and 9/121 patients with dermatoses and 10/57 patients with chronic urticaria (at 5 %) (ECHA, 2011).
Health Effects Summary	The critical health effects associated with the chemical (but not the salts) are skin, eye and respiratory tract irritation. However, no systemic effects were seen with benzoic acid. The salts are expected to exist almost entirely as the benzoate ion under normal physiological conditions and will not have the local irritant properties that arise from the acidity of benzoic acid. Therefore, it is unlikely that any systemic effects will be observed with the salts of benzoic acid.
Key Study/Critical Effect for Screening Criteria	The critical lowest No Observed Adverse Effect (NOAEL) level for the purposes of risk assessment is 825 mg/kg bw/day from the repeated chronic oral toxicity study.

Ecological Toxicity [2]	
Aquatic Toxicity	Studies on three trophic levels are available with the lowest EC50 found in algae (33.1 mg/L). In this study the concentrations decreased significantly over the exposure period of 72 hours. The LC50 for fish is 44.6 mg/L and for daphnia an EC50 of > 100 mg/L was derived. The EC10 from the algae study is 3.4 mg/L, which is much lower than the NOEC for fish (120 mg/L in a 28 day study) and daphnia (25 mg/L in 21 day reproduction test).
Determination of PNEC aquatic	Long-term data was available for a fish, invertebrate and algae. An assessment factor of 10 was used on the lowest NOEC of 3.4 mg/L for algae for a resulting PNEC of 0.34 mg/L.
Current Regulatory Controls[1]	
Australian Hazard Classification	The chemical is not listed on the Hazardous Substances Information System (HSIS) (Safe Work Australia).
Australian Occupational Exposure Standards	No specific exposure standards are available.
International Occupational Exposure Standards	The following exposure standards are identified (Galleria Chemica): An exposure limit (TWA) of 5–10 mg/m^3 in different countries such as USA (California, Tennessee), Canada and England.
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	No data available.
PBT Assessment	
P/vP Criteria fulfilled?	Benzoic acid is readily biodegradable and as such not persistent in the environment.
B/vB criteria fulfilled?	Based on the measured BCF values of <10 to 21 and a log Kow of 1.87 benzoic acid is not expected to be bioaccumulative.
T criteria fulfilled?	The acute aquatic toxicity of this chemical is >0.01 mg/L. Thus, it is not expected to meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	April 2019

References

Redacted

Toxicity Summary - Gas Phase Frac Tracers (GFTs)

Chemical and Physical Properties[1,2,3]	
CAS number	15 chemicals (proprietary).
Molecular formula	Proprietary
Molecular weight	Proprietary
Solubility in water	Proprietary
Melting point	Proprietary
Boiling point	Proprietary
Vapour pressure	Proprietary
Henrys law constant	No data available
Explosive potential	Non explosive
Flammability potential	Non-flammable
Colour/Form	Colourless, odourless liquid
Overview	GFTs are chemically inactive, nontoxic, and non-flammable compounds that are found in the atmosphere at very low levels. They are chemical inert, have no biological effects and are very safe. GFTs present no known danger to humans if inhaled or ingested.
Environmental Fate[1]	
Soil/Water/Air	GFTs as a class are extremely stable. They are not susceptible to hydrolysis, and not affected by light (including UV).
Human Health Toxicity Summary [1,2,3]	
Chronic Repeated Dose Toxicity	Two-week repeat dose preliminary inhalation toxicity (rat at a target concentration of 10,000 ppm (10%), no treatment-related effects were noted for clinical signs, body weight, food consumption, water consumption, macroscopic pathology or organ weights. 90 day inhalation study in rats: no treatment-related effects were observed in this study in which rats were exposed to 5,000 ppm, 15,000 ppm, and 50,000 ppm of the test material for 6 hours per day, 5 days per week for a total of 13 weeks. These results indicate that the toxicity of the test material following repeated inhalation exposure is very low and suggest that the gas can be treated as a simple asphyxiant.
Carcinogenicity	Chromosomal aberration test in cultured mammalian cells: non-clastogenic
Mutagenicity/ Genotoxicity	Bacterial mutation assay salmonella typhimurium (strains ta 1535, ta 1537, ta 1538, ta 98 and ta 100): negative.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	No data available.

Acute Toxicity	Inhalation 4-hour LC50 : > 800,000 ppm in rats Effects observed in animals by inhalation include decreased growth rate, pulmonary changes, irregular respiration, increased urine volume and creatinine, reversible pathological changes in the kidneys, and increased urinary fluoride concentration. One study showed no arrhythmogenic effects in dogs at a concentration of 20 %, while another study did show some arrhythmogenic effects in both guinea pigs and dogs. Long-term inhalation exposures resulted in an initial decrease in growth rate, but no other adverse changes were noted. No animal test reports are available to define carcinogenic, developmental, or reproductive hazards. The compound does not produce genetic damage in bacterial cell cultures but has not been tested in animals. Acute inhalation toxicity study (rat): the 4-hour LC50 is above 110,000 ppm. These results suggest that on an acute inhalation basis the test material can be considered as a simple asphyxiant.
Irritation	Non-irritating
Sensitisation	Not sensitising
Health Effects Summary	The chemicals have been used in various medical applications, both in trials and in routine use, in human subjects, for some forty years, indicating these materials have zero toxicity to humans.
Key Study/Critical Effect for Screening Criteria	
Ecological Toxicity [1]	
Aquatic Toxicity	Fish 96h LC50 > 100 mg/L Invertebrates 48h EC50 > 0.1 mg/L Microorganism 3h EC50 > 100 mg/L Pimephales promelas (fathead minnow) 96 h NOEC = 1000 mg/L
Determination of PNEC aquatic	$PNEC_{aquatic}$ has not been calculated. The substance exhibits no toxicity.
Current Regulatory Controls	
Australian Hazard Classification	No data available.
Australian Occupational Exposure Standards	No data available.
International Occupational Exposure Standards	No data available.
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	No data available.
PBT Assessment	
P/vP Criteria fulfilled?	Yes, GFTs are not biodegradable. However, they are volatile and are quickly removed from the environment.
B/vB criteria fulfilled?	The estimated Log Kow is generally > 4.5 (EPI Suite), thus it is expected to be bioaccumulative.
T criteria fulfilled?	No. Fish 96 h NOEC = 1000 mg/L. Thus, it is not expected to meet the screening criteria for toxicity.
Overall conclusion	Not PBT

Revised	April 2019

References

Redacted

AECOM Imagine it Delivered

Toxicity Summary - Water Flow Assurance Tracer (WFT)

Chemical and Physical Properties[1,2,3,4]	
CAS number	One chemical (proprietary)
Molecular formula	Proprietary
Molecular weight	Proprietary
Solubility in water	Proprietary
Melting point	Proprietary
Boiling point	Proprietary
Vapour pressure	Proprietary
Henrys law constant	Proprietary
Explosive potential	Non-explosive (100%)
Flammability potential	Non-flammable (100%)
Colour/Form	Bright, odourless, orange-yellow powder
Overview	This chemical is used as a food, drug, and cosmetic colorant. It is used to colour confectionary, bakery goods, animal feeds, aqueous drug solutions, toothpastes, bath salts, hair rinses, and printing inks for use in and on foods, drugs, and cosmetics and on food, drug, and cosmetic packaging materials.
Environmental Fate[2]	
Soil/Water/Air	This chemical's production as a dye for wool, silks and as a colorant in food, drugs and cosmetics may result in its release to the environment through various waste streams. If released to air, this chemical will exist solely in the particulate phase in the atmosphere since it is a salt and will be non-volatile. Particulate-phase this chemical will be removed from the atmosphere by wet or dry deposition. This chemical may be susceptible to direct photolysis by sunlight; after exposure to sunlight, This chemical in distilled water exhibited a first order rate constant of 2.31×10^{-3} per day, corresponding to a half-life of 300 days. If released to soil, this chemical is expected to be mobile since this compound is expected to exist almost entirely in anion form in the environment and anions generally do not adsorb more strongly to soils containing organic carbon and clay than their neutral counterparts. Volatilization from moist soil surfaces is not expected to be an important fate process because the compound exists as an anion and anions do not volatilize. If released into water, this chemical is not expected to adsorb to suspended solids and sediment based upon this compound's ionic nature in the environment. This chemical passed through pilot scale treatment activated sludge processes relatively unchanged, indicating that biodegradation is not expected to be an important environmental fate process. This chemical will exist almost entirely in the anion form at pH values of 5 to 9 and therefore volatilization from water surfaces is not expected to be an important fate process. Measured BCF values of <0.29 and <3.0 in carp suggests bioconcentration in aquatic organisms is low. Hydrolysis is not expected to be an important environmental fate process since this compound lacks functional groups that hydrolyse under environmental conditions.

Human Health Toxicity Summary [1,2,3,4]	
Chronic Repeated Dose Toxicity	Two separate but concurrent studies in rats given 0%, 0.1%, 1% or 2% in the diet or 0% or 5% in the diet for between 113 and 125 weeks showed decreases in body weight in females at 1% in the diet and in males (12.2% decrease) and females (16.9% decrease) at 5% in the diet, but there were no effects at 2% in the diet. The FAO/WHO Expert Committee on Food Additives concluded that 2% in the diet, equal to 984 mg/kg bw per day, was the NOAEL for this study. During a 2-year study in Fischer 344 rats given This chemical in the drinking water at a concentration of 0%, 1% or 2%, statistically significant increases in mesothelioma in the abdominal cavity in males and endometrial stromal polyps in females in the 1% concentration groups were reported. The incidences of these tumours were not dose dependent, and the authors noted that the incidences were within the historical control range for these tumours in this rat strain.
Carcinogenicity	A 104-week carcinogenicity study in mice given 0%, 0.5%, 1.5% or 5% This chemical in the diet showed no effects other than reductions in body weight at various time points in both sexes at 5% in the diet and slight, but statistically significant, increases in feed consumption in males at 5% in the diet. Although the authors considered the NOAEL to be the highest dose tested, the FAO/WHO Expert Committee on Food Additives concluded that 1.5% in the diet, equal to 2173 mg/kg bw per day, was the NOAEL for this study, on the basis of a body weight reduction concurrent with an increase in feed consumption at the higher dose in males.
Mutagenicity/ Genotoxicity	The FAO/WHO Expert Committee on Food Additives concluded that the overall weight of evidence indicates that this chemical is not genotoxic.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Reproductive and developmental parameters were assessed in the rat chronic toxicity studies that included an in utero exposure phase. No significant effects on reproduction or body weights of the offspring were observed. The FAO/WHO Expert Committee on Food Additives concluded that 5% in the diet, equal to 2641 mg/kg bw per day, the highest dose tested, was the NOAEL for reproductive end-points in this study. No reproductive effects were observed in two developmental neurotoxicity studies. Also, no effects on reproductive parameters were observed in several other developmental neurotoxicity studies in rats using a mixture of colours, including This chemical, as the test substance. Two developmental toxicity studies were available in rats, one with dietary administration and one with drinking-water administration of This chemical during gestation days 0–19; these showed no adverse effects at doses up to 1000 mg/kg bw per day.
Acute Toxicity	In reports submitted to the World Health Organization, the acute oral LD50 in mice was reported to be 12,750 mg/kg bw [National Institute of Hygienic Sciences of Japan, 1964]. In rats, the LD50 by intraperitoneal injection was reported to be 2,000 mg/kg bw and the LD50 by intravenous injection was reported to be 1,000 mg/kg bw [Deutsche Forschungsgemeinschaft, 1957].
Irritation	No irritating effects were observed both for skin and for eye.
Sensitisation	The results of the available tests about the evaluation of dermal effects on human showed no sensitizing effects.
Health Effects Summary	A number of case reports have been published showing intolerance or hypersensitivity reactions to This chemical. Although some of these reactions have been shown to be quite severe, their prevalence appears to be very low (0.12% in the general population).
Key Study/Critical Effect for Screening Criteria	An average daily intake (ADI) of 0-10 mg/kg bw per day was assigned by JECFA in 2016.

Ecological Toxicity [1]	
Aquatic Toxicity	Acute short-term administration on fish: LC50 fish (96 h) > 120 mg/L Acute short-term administration on invertebrates: Both of the acute toxicity to Daphnia magna studies does not show any toxic effects. EC50(48h) > 125 mg/L Acute short-term administration on aquatic plants: Both of the acute toxicity to aquatic plants studies does not show any toxic effects. EC50(48h) > 125 mg/L
Determination of PNEC aquatic	On the basis of the three acute toxicity data points, an assessment factor of 1000 has been applied to the lowest reported effect concentration of 120 mg/L. The PNECaquatic is determined to be 0.12 mg/L.
Current Regulatory Controls[3,4]	
Australian Hazard Classification	This chemical is a permitted food colour in both Australia and New Zealand.
Australian Occupational Exposure Standards	No data available.
International Occupational Exposure Standards	This chemical is a certified colour additive approved by the FDA in the United States to colour food, drugs and cosmetics.
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	No data available.
PBT Assessment	
P/vP Criteria fulfilled?	Not readily biodegradable. Thus, it is expected to meet the screening criteria for persistence.
B/vB criteria fulfilled?	As the estimated Log Pow is -10.7 (Log Pow < 4.5), it is not expected to be bioaccumulative.
T criteria fulfilled?	The acute aquatic toxicity of this chemical is >0.01 mg/L. Thus, it is not expected to meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	April 2019

References

Redacted

Toxicity Summary - Water Flow Assurance Tracer (WFT)

Chemical and Physical Properties[3,4,8,9]	
CAS number	One chemical (proprietary)
Molecular formula	Proprietary
Product name	--
Molecular weight	Proprietary
Solubility in water	Proprietary
pH	6.9
Melting point	Proprietary
Boiling point	Proprietary
Vapour pressure	Odourless white crystals or crystalline powder
Henrys law constant	Proprietary
Explosive potential	Proprietary
Flammability potential	Combustible. Gives off irritating of toxic fumes in a fire.
Colour/Form	No data found
Overview	This WFT is a naturally occurring substance in various plant species. The use in food is the predominant way of human exposure and of exposure of the environment. It is generally recognised as safe (GRAS) as a food additive by the US FDA.
Environmental Fate[4,8,9]	
Soil/Water/Air	If released to air, a vapor pressure of 9.0X10-7 mm Hg at 25 deg C indicates this chemical will exist in both the vapor and particulate phases in the atmosphere. In vapor-phase the chemical will be degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals; the half-life for this reaction in air is estimated to be 20 hours. If released to soil, this chemical is expected to have low to no mobility based upon Koc values of 741 and 7762 determined in silt and sandy loam soils. An approximated Koc of 71 suggests high mobility in sand which contains no clay and very low organic carbon content. Volatilization from moist soil surfaces is not expected to be an important fate process based upon an estimated Henry's Law constant of 1.1X10-11 atm-cu m/mole. Various biodegradation studies have found this chemical to be readily biodegradable. If released into water, this chemical is expected to adsorb to suspended solids and sediment based upon the Koc. Volatilization from water surfaces is not expected to be an important fate process based upon this compound's estimated Henry's Law constant. An estimated BCF of 3 (log Kow of -0.07) suggests the potential for bioconcentration in aquatic organisms is low. The hydrolysis half-life of this chemical in water is reported to be >1 year. Degradation in natural water can occur through photodegradation and biodegradation.

Human Health Toxicity Summary [1,2,3,5,6,7,8,9]	
Chronic Repeated Dose Toxicity	This chemical was tested for carcinogenicity in five studies in rats by oral administration. In two of these studies, no significant difference in the incidence of tumours at any site was found. The other three studies were found to be inadequate for evaluation. Studies on oral and intraperitoneal administration of this chemical to mice were found to be inadequate for evaluation. In one study, decaffeinated coffee to which this chemical was added was tested by oral administration to rats; overall, no increase in tumours at any site was observed as compared to appropriate controls. Administration of this chemical in combination with known carcinogens resulted in decreased incidences of lung tumours in mice treated with urethane, of mammary tumours in rats treated with diethylstilboestrol and of skin tumours in mice treated with either ultra-violet light or cigarette-smoke condensate. This chemical did not influence the incidence of bladder tumours induced in rats by N-nitroso-N-butyl(4-hydroxybutyl)amine in three experiments or of pancreatic tumours induced in rats by 4-hydroxyaminoquinoline-1-oxide in another study. Nawrot et al. (2003) concluded in their review of the effects of this chemical on human health that “for the healthy adult population, moderate daily this chemical intake at a dose level up to 400 mg/day (equivalent to 6 mg/kg body weight/day in a 65-kg person) is not associated with adverse effects such as general toxicity, cardiovascular effects, effects on bone status and calcium balance (with consumption of adequate calcium), changes in adult behaviour, increased incidence of cancer and effects on male fertility.” It was indicated that habitual daily use of this chemical at greater than 500-600 mg/day (8.3 - 10 mg/kg) could be considered a health risk. For women, this chemical intake greater than 400 mg/day (6.7 mg/kg) “may increase the risk of detrusor instability (unstable bladder) development in women”.
Carcinogenicity	IARC evaluates that this chemical is not classifiable as to its carcinogenicity to humans (group 3).
Mutagenicity/ Genotoxicity	The potential for this chemical to induce genotoxicity has been evaluated in both in vitro an in vivo studies, with in vitro studies indicating both genotoxic and non-genotoxic results; in vivo studies have shown that, overall, this chemical is not genotoxic .
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	This chemical has been shown to cause adverse reproductive and developmental effects in mice, rats, rabbits and monkeys. Testicular atrophy was observed at high dose levels in rats. Reproductive studies in mice showed no effect on pregnancy but there was a decrease in litter size at birth. Teratogenic effects were usually associated with high, single, daily doses that were also associated with other signs of maternal toxicity. High daily levels given as divided doses were less toxic to the conceptus that when given as a single dose. Reduced fetal body weight was observed in rats. A reversible delay in ossification of the sternum was observed in rats at a relative low dose given by gavage. With administration in drinking-water, similar effects were seen, but at higher doses. One epidemiological study revealed no effect of this chemical on the sex ratio of their children. In lymphocytes of normal, this chemical-exposed people, chromosomal aberrations were not observed. An increased frequency of micronucleated blood cells was observed in otherwise healthy splenectomized people exposed to this chemical. Urine of this chemical-exposed persons was not mutagenic to Salmonella typhimurium.
Acute Toxicity	After oral application the LD50 for rats (10 animals/group/sex) was found to be 261-383 mg/kg bw; as clinical symptoms of toxicity, dyspnoea and staggering were seen after oral intake. In further reports the oral LD50 for rats was reported to be 200-400 mg/kg bw and for mice 185 mg/kg bw. The inhalation of the substance by rats as an aerosol for a period of 4 h resulted in an LC50-value of ca. 4.94 mg/l. Irregular and accelerated respiration were noted in this study. The LD50 for dermal application was >2000 mg/kg bw; no clinical symptoms of toxicity were observed. In animals studies this chemical showed moderate toxicity after oral uptake and inhalation and a low acute toxicity after dermal treatment .

Irritation	The undiluted substance was not irritating to the eyes of rabbits. Mean irritation indices were 0.9 (corneal opacity), 0 (iritis), 1.6 (conjunctival erythema) and 0.6 (conjunctival edema). The strongest signs of irritation were observed in 3/3 animals within the first 24h. By day 8 only one animal showed slight corneal opacity and conjunctival redness. The substance in a 50% aqueous dilution was not irritating to the skin of rabbits (Irritation index was 0) (OECD guideline 404 and 405). This chemical is not irritating to skin and eyes.
Sensitisation	No data available.
Key Study/Critical Effect for Screening Criteria	The American College of Obstetricians and Gynaecologists (2010) concluded that moderate chemical consumption (<200 mg/day) does not appear to be a major contributing factor in miscarriage or preterm birth. Thus, the acceptable daily intake of this chemical will be set at 200 mg/person/day for the derivation of a drinking water guidance value. Assuming that humans consume 2 litres of water a day, the drinking water guidance value for this chemical is determined to be 100 mg/L.
Ecological Toxicity [8,9]	
Aquatic Toxicity	Acute toxicity guideline studies have been conducted in fish, invertebrates and algae (OECD, 2002a,b; ECHA REACH database). A 96-hour LC50 in Leuciscus idus was reported to be 87 mg/L; the 48-hour EC50 in Daphnia magna was reported to be 182 mg/L. and the ErC50 in Scenedesmus subspicatus was reported to be >100 mg/L. .
Determination of PNEC aquatic	Based on the lowest acute toxicity value of 87 mg/L in fish and an assessment factor of 1,000, a PNECaquatic is determined to be 0.087 mg/L
Current Regulatory Controls	
Australian Hazard Classification	No data found
Australian Occupational Exposure Standards	No data found
International Occupational Exposure Standards	No data found
Australian Food Standards	No data found
Australian Drinking Water Guidelines	No data found
Aquatic Toxicity Guidelines	No data found
Australian Hazard Classification	No data found
Australian Occupational Exposure Standards	No data found
PBT Assessment	
P/vP Criteria fulfilled?	This chemical is expected to be readily biodegradable and thus would not be expected to meet the screening criteria for persistence.
B/vB criteria fulfilled?	This chemical is water-soluble and bioaccumulation is not expected according to the log Kow (0.07). Thus, this chemical is not likely to meet the screening criteria for bioaccumulation.
T criteria fulfilled?	Long term data not available (acute data >0.1 mg/L); potentially not toxic.
Overall conclusion	Not a PBT substance (based on screening data).

References

Redacted

Appendix G

Chemical Risk Assessment - Drilling Fluid

Human Health Screening Assessment
Planned Drilling Muds

Chemical Name	CAS Number	Concentration in Injected Fluid (mg/L)	Ecotoxicity[1]	Toxicity[2]	Biodegradation[1,3]	Bioaccummulative[1]	Screening	Discussion	Outcome of Tier 2 Assessment[1]
Smectite	12199-37-0	10	96 hr Oncorhynchus mykiss (Rainbow Trout) LC50 = 19000 mg/L	Based on acute: Low	N.A.(Inorganic)	N.A. (Inorganic)	Tier 1	The risk was classified as low based on acute data. A Tier 2 assessment is not required.	NA
Quartz/Cristobite	14808-60-7	10	acute data >10 g/L	Based on acute: Low	N.A.(Inorganic)	N.A. (Inorganic)	Tier 1	The risk was classified as low based on acute data. A Tier 2 assessment is not required.	NA
Plagioclase Feldspar/Kaolinite	1332-58-7	10	Daphnia pulex (water flea) 24- and 48-h LC50 >1.1 g/L P. trilineatum 12-h LC50 = 170 mg/L O. fasciatus 12-h LC50 = 710 mg/L	Based on acute: Low	N.A.(Inorganic)	N.A. (Inorganic)	Tier 1	The risk was classified as low based on acute data. A Tier 2 assessment is not required.	NA
Sodium hydroxide	1310-73-2	0.3	Measured acute endpoints for fish = 196 mg/L Measured chronic endpoint for Daphnia = 240 mg/L	Based on acute: Low	N.A.(Inorganic)	N.A. (Inorganic)	Tier 1	The risk was classified as low based on acute data. A Tier 2 assessment is not required.	NA
Glutaraldehyde	111-30-8	0.3	96 h acute Bluegill sunfish LC50 = 11.2 mg/L 48 h acute Oyster larvae LC550 = 2.1 mg/L 96 h acute Green crabs LC50 = 465 mg/L 96 h acute Grass shrimp LC50 = 41 mg/L 48 acute Daphnia magna LC50 = 0.35 mg/L 48 acute Daphnia magna LC50 = 16.3 mg/L 21 d reproduct'n Daphnia magna LOEC = 4.3 mg/L, NOEC = 2.1 mg/L 96 h algal growth inhibition Selenastrum capricornutum ILm = 3.9 mg/L (median inhibitory limit) 96 h algal growth inhibition Scenedesmus subspicatus EC50 = 1.0 mg/L Bacterial inhibition Sewage microbes IC50 = 25-34 mg/L	Based on chronic: Moderate	Readily biodegradable	No based on the Log Pow of -0.01	Tier 1 (conc < ecotox)	The risk was classified as moderate based on chronic data. The potential exposure concentration is below the respective LC50/EC50 values. This chemical is expected to be readily biodegradable. A Tier 2 assessment would not be required.	NA
Methanol	67-56-1	0.3	Acute LC50s = 15,400 to 29,400 mg/L Invertebrates, chronic NOEC = 32,000 mg/L.	Based on acute: Low	Readily biodegradable	No based on the Log Kow of -0.74	Tier 1	The risk was classified as low based on acute data. A Tier 2 assessment is not required.	NA
Sodium Carbonate	497-19-8	0.3	96-hour LC50 Bluegill sunfish (Lepomis macrochirus) = 300 mg/L 96-hour LC50 to mosquitofish (Gambusia affinis) = 740 mg/L 48-hour EC50 to the invertebrate Ceriodaphnia cf. dubia = 200 to 227 mg/L	Based on acute: Low	N.A.(Inorganic)	N.A. (Inorganic)	Tier 1	The risk was classified as low based on acute data. A Tier 2 assessment is not required.	NA
Ethanol, 2,2'-oxybis-, reaction products with ammonia, morpholine derivatives residues	68909-77-3	1	Leuciscus idus, Fish LC50 (96 h) = 681.2 mg/L Daphnia EC50 = 122 mg/L Green alga ErC50 (72h) = 45 mg/L Microorganism > 1000 mg/L	Based on acute: Low	Not readily biodegradable.	No based on the Log Pow of 0.565	Tier 1 with management	The risk was classified as low based on acute data. It is not expected to be readily biodegradable however it is not a bioaccummulative substance. Management of this chemical in flowback water will be addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Nitrilotriacetic acid	5064-31-3	1	Fish 96 h LC50 = 98 - 487 mg/L Fish NOEC = 54 mg/L Invertebrates NOEC = 9.3 mg/L	Based on chronic: Moderate	Readily biodegradable	No based on the Log Pow of -13.2	Tier 1 (conc < ecotox)	The risk was classified as moderate based on chronic data. The potential exposure concentration is below the respective LC50/EC50 values. This chemical is expected to be readily biodegradable and not bioaccummulative. ATier 2 assessment is not required.	NA
Sodium Chloride	7647-14-5	60	acute endpoint for Fish = 1290 mg/L NOEC for Daphnia = 314 mg/L	Based on chronic: Low	N.A.(Inorganic)	N.A. (Inorganic)	Tier 1	The risk was classified as low based on chronic data. A Tier 2 assessment is not required.	NA
Citric Acid, monohydrate	77-92-9	1	96 h LC50 fish = 440 to 1,516 mg/L 24 h EC50 value for invertebrates is 85 mg/L 7 d toxic limit concentration values for algae = 300 to 640 mg/L 8 d freshwater static test for the algae Scenedesmus quadricauda, NOEC = 425 mg/L	Based on chronic: Low	Expected to be readily biodegradable	Not bioaccumulative	Tier 1	The risk was classified as low based on chronic data and it is expected to be readily biodegradable and not bioaccummulative. A Tier 2 assessment is not required.	NA
Sodium Bicarbonate	144-55-8	0.5	21 d Daphnia NOEC = 576 mg/L	Based on chronic: Low	N.A.(Inorganic)	N.A. (Inorganic)	Tier 1	The risk was classified as low based on chronic data. A Tier 2 assessment is not required.	NA
Xanthan Gum	11138-66-2	1.5	Acute Fish (measured) = 420 mg/L	Based on acute: Low	Expected to be readily biodegradable	Not bioaccumulative	Tier 1	The risk was classified as low based on acute data. A Tier 2 assessment is not required.	NA
Glyoxal <1%	107-22-2	1.5	96 h-LC50 fish = 215 mg/L Invertebrates EC50 > 100 mg/L NOEC fish = 119 mg/L (a.i.)	Based on chronic: Low	Expected to be readily biodegradable	Not bioaccumulative	Tier 1	The risk was classified as low based on chronic data and it is expected to be readily biodegradable and not bioaccummulative. A Tier 2 assessment is not required.	NA
Poly Anionic Cellulose	9004-32-4	1.5	96 h LC50 for Brachydanio rerio is >2,500 mg/L 48 h LC50 for Daphnia magna is >5,000 mg/L; 96 h EC50 for Selenastrum capricornutum is 500 mg/L	Based on acute: Low	Not readily biodegradable	Not bioaccumulative	Tier 1	The risk was classified as low based on acute data. It is not expected to be readily biodegradable however it is not expected to be bioaccummulative. A Tier 2 assessment is not required.	NA
Potassium Chloride	7447-40-7	18	96 h LC50 in Pimephales promelas = 880 mg/L 48 h LC50 Lepomis macrochirus, Oncorhyncusmykiss and Ictalurus punctatus = 720 - 2010 mg/L 48 h EC50 Daphnia magna and Ceriodaphnia dubia were 660 and 630 mg/L respectively NOEC for Daphnia is 373 mg/L	Based on chronic: Low	N.A.(Inorganic)	N.A. (Inorganic)	Tier 1	The risk was classified as low based on chronic data. A Tier 2 assessment is not required.	NA
Starch	9005-25-8	4	Crassostrea virginica 96 h = 1000 mg/L Orthopristis chrysoptera 96 h = 5000 mg/L Bairdiella chrysoura 96 h = 5000 mg/L	Based on acute: Low	Expected to be readily biodegradable	Not bioaccumulative	Tier 1	The risk was classified as low based on acute data and it is expected to be readily biodegradable and not bioaccummulative. A Tier 2 assessment is not required.	NA

Human Health Screening Assessment
Planned Drilling Muds

Chemical Name	CAS Number	Concentration in Injected Fluid (mg/L)	Ecotoxicity[1]	Toxicity[2]	Biodegradation[1,3]	Bioaccummulative[1]	Screening	Discussion	Outcome of Tier 2 Assessment[1]
Tetrahydro-3,5-dimethyl-1,3,5-thiadiazine-2-thione	533-74-4	4	Daphnia magna (Water flea), 48 h, static, EC50 = 0.3 mg/L Salmo gairdneri (Rainbow trout), 96 h, static, LC50 = 0.16 mg/L Ankistrodesmus bribaianus (Green alga), 72 h, static, EC50 = 1.08 mg/L Colinus virginianus (Bobwhite quail), 21 d, LD50 = 415 mg/kg bw Colinus virginianus (Bobwhite quail), 25 weeks, NOEL = 100 mg/kg food	Based on acute: Very high	Expected to be readily biodegradable	Not bioaccumulative	Tier 1 with management	The risk was classified as very high and the potential exposure concentration is markedly elevated. This chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water will be addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
2-Propenoic acid, sodium salt, polymer with 2-propena	25085-02-3	1.5	There are no aquatic toxicity studies on the polymer. It is expected to have low concern for aquatic toxicity because of its very high molecular weight and poor water solubility. As such, the polymer does not meet the critera for toxicity.	Assumed to be low	Not readily biodegradable	Not bioaccumulative	Tier 1	The risk was classified as low. It is not expected to be readily biodegradable however it is not a bioaccumulative substance. A Tier 2 assessment is not required.	NA
Distillates, hydrotreated light	64742-47-8	1.5	Lowest acute endpoint for Daphnia = 0.018 mg/L (modelled)	Based on acute: Very high	Readily biodegradable	Yes based on calculated log BCF values for constituents that range from 2.78 to 4.06, and calculated BCF values of 598 to 11,430 L/kg wet-weight	Tier 2	The risk was classified as high based on chronic data. The substance is expected to be readily biodegradable, but is considered to have a potential to bioaccumulate. A Tier 2 assessment is required.	A Tier 2 assessment was conducted using the Margin of Exposure (MOE) approach as per DOE and NICNAS 2017 guidance. Based on the calculated MOEs the chemical is of low concern for workers (refer to individual toxicity profile for further detail).
Alcohol, C11-14, ethoxylated	78330-21-9	1.5	96 h LC50, Oncorhynchus mykiss = 5 - 7 mg/L 30 d Lepomis macrochirus, NOEC = 0.11 – 0.33 mg/L. 48 h EC50 Daphnia magna = 2.5 mg/L. 21 d NOEC Daphnia magna = 0.77 – 1.75 mg/L. 96 h EC50 (green algae) = 1.4 mg/L EC50 (3 h) for microorganisms = 140 mg/L	Based on chronic: High	Readily biodegradable	Not bioaccumulative	Tier 1 with management	The risk was classified as high. This chemical is expected to be readily biodegradable and not bioaccummulative. Management of this chemical in flowback water will be addressed in the Wastewater Management Plan. A Tier 2 assessment is not required.	NA
Sodium erythorbate	6381-77-7	0.2	96 h LC50 Fish > 100 mg/L 48 h EC50 Daphnia magna = 84 - 100 mg/L 72 h NOEC alga = 20 mg/L	Based on acute: Low	Not readily biodegradable	Not bioaccumulative	Tier 1	The risk was classified as low. It is not expected to be readily biodegradable however it is not a bioaccumulative substance. A Tier 2 assessment is not required.	NA

Notes
1 - Please refer to the individual toxicity profiles for further detail.
2 - Toxicity assessed using Commonwealth of Australia 2013 Ecotoxicity Assessment Guidelines (presented as Table 4 in the Northern Territory Government Draft Guideline for the Preparation of an Environment Management Plan under the Petroleum Regulations (2019))
3- Biodegradation assessed as per Northern Territory Government Draft Guideline for the Preparation of an Environment Management Plan under the Petroleum Regulations (2019) and Australian Government Department of Health National Industrial Chemicals Notification and Assessment Scheme (NICNAS)
BCF - Bioconcentration Factor
NA - Not Applicable
MOE - Margin of Exposure
NICNAS 2017 - National Assessment of Chemicals Associated with Coal Seam Gas Extraction in Australia
DOE 2017 - Draft Risk Assessment Guidance Manual: For Chemicals Associated with Coal Seam Gas Extraction, Australian Government, Department of Energy

Attachment A - Risk Characterisation Calculations

64742-47-8 Distillates (petroleum), hydrotreated light

Drilling Muds - Adult worker exposure scenario	Total Internal Dose (mg/kg bw/day)	NOAEL (mg/kg bw/day)	Critical effect	MOE (NOAEL / dosage)	Chemical is of concern? (MOE < 100)
Haliburton Frac Recipes					
Occupational Activity					
Transport and storage	Negligible*	1000	maternal toxicity in rats		No
Mixing/blending drilling of hydraulic fracturing chemicals	0.810			1235	
Injection of drilling chemicals	Negligible*				
Cleaning and maintenance (hydraulic fracturing)	0.162			6173	
Combined exposure Mixing/blending and cleaning and maintenance	**0.972**			1029	

* In the absence of accidents/incidents, repeated occupational exposures during transport and storage, or during injection of mixed/blended chemicals, are negligible.
Similarly, repeated occupational exposures to the chemical via the transport and storage of drilling muds are negligible (NICNAS 2017).

Worker exposure during mixing/blending of chemicals

Dermal Exposure

$$Ederm = \frac{C \times Dease \times SAderm \times Bderm}{BW}$$ (source Equation 1 - NICNAS 2017)

Ederm	Internal dermal dose of the chemical, mg/kg bw/day	0.06	mg/kg bw/day	
C	concentration of the chemical, %	100%	%	default concentration of 1000 g/L (100%) is used. Assumes the chemical is in its pure form and not diluted with other chemicals (NICNAS 2017)
Dease	external dose estimated by EASE model, mg/cm2/day	0.1	mg/cm2/day	Assuming no PPE, the upper limit value of DEASE, 0.1 mg/cm2/day is used (NICNAS 2017)
SAderm	surface area of exposed skin, cm2	840	cm2	US EPA 2011, NICNAS 2017
Bderm	dermal bioavailability, %	10%	%	NICNAS 2017
BW	body weight, kg bw.	70	kg bw	enHealth 2012, NICNAS 2017

Inhalation Exposure

$$Einh = \frac{Fresp \times C \times Demkg \times Vair \times Binh \times t}{BW}$$ (source Equation 2 - NICNAS 2017)

Einh	Internal inhalation dose of the chemical, mg/kg bw/day	0.750	mg/kg bw/day	
Fresp	respirable/inhalable fraction of the chemical, dimensionless	1	dimensionless	assumed to be 1 (NICNAS 2017)
C	concentration of the chemical, %	100%	%	default concentration of 1000 g/L (100%) is used as the concentration of chemical when delivered to site. Assumes the chemical is in its pure form and not diluted with other chemicals (NICNAS 2017)
Demkg	external dose estimated by EMKG-EXPO-TOOL, mg/m3	0.6	mg/m3	NICNAS 2017
Vair	worker ventilation rate, m3/day	22	m3/day	enHealth 2012, NICNAS 2017
Binh	inhalation bioavailability, %	100%	%	NICNAS 2017
t	duration of exposure, h/day	4	h/day	assumed to be four hours, which is an estimate of the duration of manual handling activities that occur during mixing (NICNAS 2017)
BW	body weight, kg bw	70	kg bw	enHealth 2012, NICNAS 2017
t	time	4	hours	NICNAS 2017

Etotal = Ederm + Einh
Etotal = 0.810 mg/kg bw/day

Worker exposure during cleaning and maintenance (drilling)

Dermal Exposure

$$Ederm = \frac{C \times Dease \times SAderm \times Bderm}{BW}$$

Ederm	Internal dermal dose of the chemical, mg/kg bw/day	0.012	mg/kg bw/day	
C	concentration of the chemical, %	10%	%	an assumed concentration of 100 g/L (10%) is used as the concentration of chemical in the final formulation prior to injection
Dease	external dose estimated by EASE model, mg/cm2/day	0.1	mg/cm2/day	Assuming no PPE, the upper limit value of Dease, 0.1 mg/cm2/day, is used (NICNAS 2017).
SAderm	surface area of exposed skin, cm2	840	cm2	for hands (USEPA 2011, NICNAS 2017)
Bderm	dermal bioavailability, %	10%	%	NICNAS 2017
BW	body weight, kg bw.	70	kg bw	enHealth 2012, NICNAS 2017
t	time	8	hours	NICNAS 2017

Inhalation Exposure

$$Einh = \frac{Fresp \times C \times Demkg \times Vair \times Binh \times t}{BW}$$

Einh	Internal inhalation dose of the chemical, mg/kg bw/day	0.150	mg/kg bw/day	
Fresp	respirable/inhalable fraction of the chemical, dimensionless	1	dimensionless	assumed to be 1 (NICNAS 2017)
C	concentration of the chemical, %	10%	%	an assumed concentration of 100 g/L (10%) is used as the concentration of chemical in the final formulation prior to injection
Demkg	external dose estimated by EMKG-EXPO-TOOL, mg/m3	0.6	mg/m3	Assuming no PPE, the upper limit value is used - EMKG-EXPO-TOOL, NICNAS
Vair	worker ventilation rate, m3/day	22	m3/day	enHealth 2012, NICNAS 2017
Binh	inhalation bioavailability, %	100%	%	NICNAS 2017
t	duration of exposure, h/day	8	h/day	assued to be eight hours which is an estimate of the manual handling activities that occur during cleaning and maintenance (NICNAS 2017)
BW	body weight, kg bw	70	kg bw	enHealth 2012, NICNAS 2017

Etotal = Ederm + Einh
Etotal = 0.162 mg/kg bw/day

Appendix H

Drilling Fluid – Chemical Toxicological Profiles

AECOM Imagine it Delivered

Toxicity Summary - 2-Propenoic acid, polymer with sodium phosphinate and 2-Propenoic acid, sodium salt, polymer with 2-propenamide

Chemical and Physical Properties[1,2,3]	
CAS number	129898-01-7 25085-02-3
Molecular formula	(C3H4O2.H3O2P.Na)x.xNa (C3H5NO.C3H4O2.Na)x
Molecular weight	Likely >1000 MW
Solubility in water	No data available.
Melting point	No data available.
Boiling point	No data available.
Vapour pressure	No data available.
Henrys law constant	No data available.
Explosive potential	No data available.
Flammability potential	No data available.
Colour/Form	No data available.
Overview	No studies are available. The polymer is not expected to be readily biodegradable. Biodegradation is limited due to the very high molecular weight and the low water solubility of the polymer. Due to its high molecular weight, the polymer is not expected to bioaccumulate. This chemical has been identified by NICNAS to be of low concern to human health and thus required no further assessment.
Environmental Fate[2]	
Soil/Water/Air	The polymer is not expected to be readily biodegradable. Biodegradation is limited due to the very high molecular weight and the low water solubility of the polymer. Due to its high molecular weight, the polymer is not expected to bioaccumulate.
Human Health Toxicity Summary	
Chronic Repeated Dose Toxicity	No data available.
Carcinogenicity	No data available.
Mutagenicity/ Genotoxicity	No data available.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	No data available.
Acute Toxicity	No data available.
Irritation	No data available.
Sensitisation	No data available.
Health Effects Summary	This chemical has been identified by NICNAS to be of low concern to human health.

Key Study/Critical Effect for Screening Criteria	No data available.
Ecological Toxicity[2]	
Aquatic Toxicity	Limited information is available. The polymer is expected to be a low concern for toxicity to aquatic organisms. Due to its poor solubility and high molecular weight, it is not expected to be bioavailable. It does not contain any reactive functional groups.
Determination of PNEC aquatic	No PNEC values were calculated.
Current Regulatory Controls	
Australian Hazard Classification	No data available.
Australian Occupational Exposure Standards	No data available.
International Occupational Exposure Standards	No data available.
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	No data available.
PBT Assessment	
P/vP Criteria fulfilled?	The polymer is not readily biodegradable, hence it meets the screening criteria for persistence.
B/vB criteria fulfilled?	The polymer is expected to have a very high molecular weight and poor water solubility. It is not expected to be bioavailable, hence this polymer does not meet the criteria for bioaccumulation.
T criteria fulfilled?	There are no aquatic toxicity studies on the polymer. It is expected to have low concern for aquatic toxicity because of its very high molecular weight and poor water solubility. As such, the polymer does not meet the critera for toxicity.
Overall conclusion	Not PBT
Revised	April 2019

References

1. National Industrial Chemicals Notification and Assessment Scheme (NICNAS). IMAP, Human Health Tier 1 Assessment. Retrieved 2019: https://www.nicnas.gov.au
2. Categorization Results from the Canadian Domestic Substance List, 2-Propenoic acid, polymer with sodium phosphinate
3. U.S National Library of Medicine, Toxicology Data Network, ChemIDplus, CAS#38193-60-1. Accessed 2017 at https://chem.nlm.nih.gov/chemidplus/rn/38193-60-1

Toxicity Summary - Ethoxylated of aliphatic alcohols (>C6)

Chemical and Physical Properties [1,2,3]	
CAS number	112-59-4, 3055-93-4, 3055-94-5, 3055-95-6, 3055-97-8, 4536-30-5, 5274-68-0, 25190-05-0, 9002-92-0, 9004-95-9, 9004-98-2, 9005-00-9, 9043-30-5, 31726-34-8, 24938-91-8, 26183-52-8, 26468-86-0, 27252-75-1, 27306-79-2, 31943-12-1, 32128-65-7, 37281-47-3, 37702-39-9, 39587-22-9, 52292-17-8, 61723-78-2, 68439-45-2, 68439-46-3, 68439-49-6, 68439-50-9, 68439-54-3, 61791-13-7, 61791-28-4, 61827-42-7, 64425-86-1, 66455-14-9, 66455-15-0, 69227-20-9, 67254-71-1, 68002-97-1, 68131-39-5, 68131-40-8, 68155-01-1, 68213-23-0, 68526-94-3, 68551-12-2, 97953-22-5, 68920-66-1, 68991-48-0
Molecular formula	Unspecified
Molecular weight	Unspecified
Solubility in water	0.1876 - 13.18 mg/L at 25 °C (C12-14 ethoxylated, 1-2.5 EO) (CAS 68131-39-5) 1.69 - 246.7 mg/L at 25 °C (C9-11, ethoxylated (EO < 2.5) (CAS 68439-46-3)
Melting point	7.2 °C at 101.3 kPa (CAS 68131-39-5) -20 °C at 101.3 kPa (CAS 68439-46-3)
Boiling point	271.11 - 516.11 °C (CAS 68131-39-5) 260 °C (CAS 68439-46-3)
Vapour pressure	< 1 Pa at 25 °C (CAS 68131-39-5) 0.004 - 117 Pa at 20 °C (CAS 68439-46-3)
Henrys law constant	No data available.
Explosive potential	Non explosives
Flammability potential	Non flammable
Colour/Form	Organic liquid, colourless to light yellow
Overview	The chemicals in this group are structurally related alcohol ethoxylates (AEs), ethoxylated ethers of aliphatic alcohols, where the alky chain length is six carbons or higher. Ethoxylates of shorter chain alcohols (C<6) do not show the same degree of surfactancy compared to the chemicals in this group. Commercially available AEs generally consist of a mixture of various AE homologues of varying carbon chain lengths and degree of ethoxylation. The chemicals contain a hydrophobic alkyl chain attached via an ether linkage to a hydrophilic ethylene oxide (EO) chain that gives them their characteristic surfactant properties. The hydrophobic alkyl and the hydrophilic EO chains can vary in length depending on method of production and source of the precursor chemicals (HERA, 2009). Although most of chemicals of this group are polymers according to the definition in the Industrial Chemicals (Notification and Assessment) Act (1989), the individually named members do not necessarily meet the polymer of low concern (PLC) criteria as the number-average molecular weight (NAMW) >1000 Da. Lower molecular weight forms of these chemicals (MW <500) are expected to be used in commercial, domestic and cosmetic products. The chemicals are used extensively as non-ionic surfactants in a wide range of cosmetic and domestic products. The chemicals in this group are expected to have similar physicochemical and toxicological properties, which depend on the alkyl chain length and the number of EO units.
Environmental Fate [2,3]	
Soil/Water/Air	Alcohol ethoxylates are readily biodegradable under aerobic conditions and also anaerobically biodegradable (HERA, 2009). The main mechanism of primary biodegradation for the linear and essentially linear AE is the central cleavage of the molecule, leading to the formation of long chain alcohol and polyethylene glycol (HERA, 2009; Marcomini et al., 2000a; Marcomini et al., 2000b). Long chain alcohols themselves are readily biodegradable up to C18 (SIDS, 2006). Abiotic degradation in water, soil, sediment and air is not expected to occur because of the chemical structures of AE homologues. Neither hydrolysis under normal

	environmental conditions (pH range from 4 to 9) nor photolysis in the atmosphere, in water, or when absorbed to soil and sediment surfaces, is to be considered (HERA, 2009). Experimentally determined BCF-values given for pure homologues and summarized in the publication of Tolls et al. (2000) are used as read-across data for the endpoint bioaccumulation in water. It can be stated that bioaccumulation of alcohol ethoxylates is regarded to be negligible as the surfactants will be rapidly metabolised. For more detail see endpoint summary for bioaccumulation. Concerning transport and distribution of the alcohol ethoxylate mixtures a high adsorption of the substances is determined by using QSAR-models. Adsorption onto surfaces is an intrinsic property of alcohol ethoxylates and thus a high Koc-value is expected.
Human Health Toxicity Summary [1]	
Chronic Repeated Dose Toxicity	The chemicals in this group are not expected to cause serious damage to health fr In several 90-day oral feeding studies in rats (similar to OECD TG 407), the NOAEL was established between 50 and 700 mg/kg bw/day (calculated from dietary levels) for group members (CAS Nos. 68439-50-9 and 68131-39-5, ranging from C12–15 with EO7). Effects observed at higher concentrations included reduction in mean body weights, and increases in relative liver and kidney weights. These changes were considered to be adaptive and related to the poor palatability of the test chemicals. No treatment related histopathological changes were reported (SCCS, 2007; HERA 2009; CIR, 2012). Similar effects were seen in longer-term studies. Alcohols, C12-13, ethoxylated (CAS No. 66455-14-9; EO6.5) and alcohols, C14-15, ethoxylated (CAS No. 68951-67-7, EO7, not listed on AICS) were given to rats in one- and two-year chronic feeding studies at levels between 0.1 and 1 %. The NOAEL was established between 50 and 192 mg/kg bw/day (calculated from dietary level). Effects observed at higher levels included reduction in mean body weights, and increase in relative liver and kidney weights. These changes were considered to be adaptive and may be due to poor palatability of the test chemicals. No treatment related lesions were observed (SCCS, 2007; HERA, 2009; CIR, 2012).om repeated oral and dermal exposure. In a 90-day study (OECD TG 411), Fischer rats were exposed to the chemical (C9–11 with 6 EO units, CAS No. 68439-46-3) at 1, 10 or 25 % concentration, 3 days/week. The application site was shaved but not covered. There were no significant treatment related effects at any concentration. Dry and flaky skin was observed in the 10 and 25 % dose groups. Increased relative kidney weights were observed in the 25 % dose groups. However, no histological lesions were observed. The NOAEL was established at 10 %, equivalent to 80 mg/kg bw/day (HERA, 2009).
Carcinogenicity	Based on the data available, the chemicals in this group are not considered to be carcinogenic. Two chemicals, alcohols, C12-13, ethoxylated (CAS No. 66455-14-9; EO6.5) and alcohols, C14-15, ethoxylated (CAS No. 68951-67-7, EO7, not listed on AICS) were administered at up to 1 % in the diet to rats for one and two years, respectively. No treatment related histopathological effects or increased tumour incidences were observed in either study (HERA, 2009; CIR, 2012). The chemicals are synthesised through processes which may result in 1,4-dioxane as an impurity. This impurity is classified as a Carcinogen—Category 3 (R40—Limited evidence of a carcinogenic effect). However, it is reported that cosmetic industry uses additional purification steps to remove the 1,4-dioxane residual in PEG before blending into cosmetic formulations (CIR, 2012).

Mutagenicity/ Genotoxicity	Based on the data available, the chemicals in this group are not considered to be genotoxic. The group members (CAS Nos. 68439-50-9, 68131-39-5 and 64425-86-1) and several analogue chemicals (ranging from C12–18 and EO3–21) produced negative results in several in vitro and in vivo tests for gene mutation and clastogenicity. Negative results were reported in bacterial reverse mutation tests for mutagenicity against Salmonella typhimurium (strains TA98, TA100, TA102, TA104, TA1535, TA1537 and TA1538) and Escherichia coli (strains WP2 and WP2uvrA pKM101), with or without metabolic activation. Negative results were also reported in chromosomal aberration tests in Chinese hamster V79, Chinese hamster ovary, mouse lymphoma and rat liver cell lines (SCCP, 2007; HERA, 2009; CIR, 2012). These chemicals did not induce chromosomal damage in Chinese hamster or Tunstall Wistar rat bone marrow cells after acute oral doses ranged between 250 and 3400 mg/kg bw (HERA, 2009).
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Based on the data available, the chemicals of this group are not considered to cause reproductive or developmental toxicity. In a two-generation reproductive and developmental toxicity study, the chemical (C14-15EO7) was administered in the diet of Charles River CD rats (n=25/sex/group, at doses of 0, 25, 50 or 250 mg/kg bw/day). The NOAEL for reproductive toxicity was established as 250 mg/kg bw/day (or 0.5 % of the diet). No treatment related effects were reported with respect to fertility, gestation, or viability indices or other histopathological parameters. The NOAEL for developmental toxicity was established as 50 mg/kg bw/day based on reduced pup body weights in the second generation at 250 mg/kg bw/day (HERA 2009; CIR, 2012). In a two-generation reproductive and developmental toxicity study, the chemical (C9-11EO6) was applied dermally to Fischer 344 rats (n=30/sex/group, at doses of 0,10, 100 or 250 mg/kg bw/day, 3 times a week except mating periods). No treatment related effects were reported with respect to mating, fertility, gestation, or viability indices and mean gestational length in both generations. No effects on testicular weights or sperm counts were observed in the male rats. The NOAEL for reproductive toxicity was established as 250 mg/kg bw/day. The NOAEL for developmental toxicity was >250 mg/kg bw/day, based on no effects seen in growth and development in the offspring up to the highest dose tested (HERA 2009; CIR, 2012). In a two generation study, the chemical (C12EO6) was administered in the diet of female rabbits at doses of 0, 50, 100 or 200 mg/kg bw/day from gestation days 2 to 16. Ataxia and a slight decrease in body weight were observed at 100 and 200 mg/kg bw/day, indicating maternal toxicity. Nine rabbits in the control group and 31 in the treatment groups died during the study (details not available). There were no treatment related effects on implantations, number of live foetuses and spontaneous abortions. The NOAEL for maternal toxicity was reported as >50 mg/kg bw/day (HERA, 2009). Although certain short chain monoethylene glycol ethers such as 2-ethoxyethanol (CAS No. 110-80-5) are known reproductive toxicants, the ability of the glycol ethers to cause testicular toxicity decreases with increasing chain length, with effects not observed with chain lengths greater than C2 (OECD, 2004).

Acute Toxicity	Based on the available animal (rats, mice and guinea pigs) studies, the chemicals in this group are expected to have low to moderate acute oral toxicity (REACHa-h; OECD, 2005; HERA, 2009; CIR, 2012). The LD50 in rats ranged from 600 mg/kg bw to greater than 20 g/kg bw. Observed sublethal effects for the chemical with the highest toxicity (C15–16 and EO10) included diarrhoea, pilo-erection, ataxia, abnormal posture, difficult laboured breathing, salivation, lacrimation, bloody noses and lethargy. Data from HERA assessment studies show that the chemicals with ethoxylate chains (EO) between 5 and 15 units were more toxic by the oral route than those with less than 4 or greater than 21 units. No relationship between the alcohol chain length and toxicity was observed (HERA, 2009). The chemicals of this group exhibit low acute dermal and inhalation toxicity. The chemicals (C9 to C15 with 3–13 EO units) were of low acute toxicity in rats and rabbits following dermal exposure. The LD50 ranged from 2000 to 5000 mg/kg bw. Sub-clinical effects included wet appearance of the fur, little or no urine, laboured breathing, lethargy, diarrhoea, ataxia, muscle tremours and decreased activity. There was no relationship between the alcohol chain length or number of ethoxylate groups and toxicity. Very high dermal doses of the chemicals (>16000 mg/kg bw) applied dermally for 24 hours in rabbits led to severe skin irritation, ataxia and lung lesions (HERA, 2009; CIR, 2012). In a guideline study (Test Guideline (TG) 403), a single static inhalation exposure to substantially saturated vapour (equivalent to 131.58 ppm - calculated) of C6EO1-2.5 (CAS No. 112-59-4), resulted in no mortality or other signs of inhalation toxicity in Sprague- Dawley (SD) rats (REACHa).
Irritation	The chemicals in this group are reported to be moderate to severe skin irritants in animal studies. The degree of irritation was reported to be dependent on the type of patch (occluded vs semi-occluded), exposure time (ranging from 4 hours up to 4 weeks) and the concentration used. Undiluted chemicals were moderately to severely irritating, 1–10 % was mildly irritating and 0.1 % and 0.5 % were non-irritating. There was also a general trend between the severity of irritation and the degree of ethoxylation. Chemicals with three and less ethoxylate units appeared to be more irritating than chemicals with higher degree of ethoxylation. No trend in irritation potential with respect to the length of carbon chain could be established. Available data indicates that undiluted AEs can produce varying degrees of eye irritation ranging from moderate to severe irritancy. The severity of irritation was found to be concentration dependent, with up to 1 % minimally irritating and concentrations in the range of 1 to 10 % slightly to moderately irritating. In most cases, following exposure, the eyes of the treated animals recovered a few days after exposure. Further tests showed that rinsing the eye 30 seconds after application with tap water may reduce the severity of the effects. No clear relationship could be established between the number of EO units or carbon chain length and eye irritation potency.
Sensitisation	Based on available data, the chemicals in this group are not skin sensitisers.
Health Effects Summary	The chemicals in this group are synthesised from linear alcohols (primary or secondary) or branched alcohols. The commercial AEs may also contain un-reacted alcohol as reaction by-products at about 5 % but with variations between different commercial products (HERA, 2009). Available data on linear and branched chain alcohols show that they have low acute and systemic toxicity and exhibit similar patterns of absorption, metabolism, and excretion to alcohol ethoxylates. They are also shown to have no skin sensitisation potential. A potential for skin and eye irritation exists with alcohols >11 carbon chain length (OECD, 2006; OECD, 2006a).
Key Study/Critical Effect for Screening Criteria	The critical human health effects for risk characterisation are acute oral toxicity and skin and eye irritation. The irritant effects are similar to those produced by other surfactants, and the severity of irritation appears to increase directly with concentration and generally decrease with an increasing number of ethoxylate units.

Ecological Toxicity [2,3]	
Aquatic Toxicity	The 96 h LC50 value for Alcohols, C9-11, ethoxylated with Oncorhynchus mykiss was 5 - 7 mg/L based on nominal concentrations. In the long term toxicity test to Lepomis macrochirus, the NOEC (30 days) was 0.11 – 0.33 mg/L. In the short–term toxicity test to Daphnia magna, the EC50 (48 h) was 2.5 mg/L. In the long term toxicity test to Daphnia magna, the NOEC (21 days) was 0.77 – 1.75 mg/L. In the short–term toxicity test to Pseudokirchneriella subcapitata (green algae), the EC50 (96 h) was 1.4 mg/L. The EC50 (3 h) for microorganisms was 140 mg/L. In a study conducted with two different fish species (bluegill sunfish and fathead minnow) the effects of C14 -15 alcohol ethoxylates (7EO) were determined (Dorn et al., 1995, Shell). In two experiments fish were exposed for 10 d in a laboratory assay and for 30 d in an outdoor stream mesocosm. Effect parameters determined were survival and growth of juvenile bluegills and survival and reproduction of fathead minnows. In the laboratory experiment the NOEC for survival and swimming performance of bluegills and for survival of fathead minnows was 0.16 mg/L. In the stream mesocosm the NOEC for bluegill survival and growth was >0.33 mg/L and for fathead minnow survival 0.28 mg/L. There was an indication of decreased egg laying by fathead minnow in the streams at concentrations of 0.33 mg/L or greater. On the basis of the reported results a worst-case NOEC of 0.16 mg/L is assumed. One publication is available for an alcohol ethoxylate mixture with a chain length of C12 - C13 and approximately 6.5 ethoxy groups (Gillespie et al. 1999). The 21 days flow-through chronic experiment on daphnids is conducted according to the guidelines USEPA-TSCA (U.S. EPA, 1992) and ASTM (1988) and is well documented in the paper. Nevertheless the degree of ethoxylation of the tested mixture described in the paper (6.5 EO) is higher than the degree of ethoxylation described for CAS 68131-39-5 (2.5 EO). The NOEC of 0.77 mg/L for reproduction can be used for read-across.
Determination of PNEC aquatic	A PNECaquatic of 11 µg/L was calculated using the lowest chronic endpoint of NOEC of 0.11 mg/L for Daphnia magna. An assessment factor of 10 was used.
Current Regulatory Controls [1]	
Australian Hazard Classification	No data available.
Australian Occupational Exposure Standards	No specific exposure standards are available.
International Occupational Exposure Standards	No specific exposure standards are available.
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	Trigger values for freshwater (95% species) (ANZECC 2000): Alcohol ethoxyolated sulfate (AES) = 650 μgL^{-1} Alcohol ethoxylated surfactants (AE) = 140 μgL^{-1}
PBT Assessment	
P/vP Criteria fulfilled?	No. These chemicals were found to be readily biodegradable. Thus, it does not meet the screening criteria for persistence.
B/vB criteria fulfilled?	No. Bioaccumulation in organisms is expected to be negligible, due to biotransformation and excretion of alcohol ethoxylates.
T criteria fulfilled?	No. The NOECs from the chronic aquatic toxicity data are >0.01 mg/L, hence does not meet the screening criteria for toxicity.

Overall conclusion	Not PBT
Revised	January 2019

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Toxicity Summary - Cellulose, carboxymethyl ether, sodium salt

Chemical and Physical Properties[1,2]	
CAS number	9004-32-4
Molecular formula	No data available.
Molecular weight	No data available.
Solubility in water	No data available.
Melting point	No data available.
Boiling point	No data available.
Vapour pressure	No data available.
Henrys law constant	No data available.
Explosive potential	No data available.
Flammability potential	No data available.
Colour/Form	White odourless hygroscopic granules or powder.
Overview	Sodium carboxycellulose is the sodium salt of carboxymethylcellulose. Carboxymethyl cellulose is a cellulose derivative with carboxymethyl groups (-CH2COOH) bound to some of the hydroxyl groups of the glucopyranose monomers that make up the cellulose backbone. Sodium carboxycellulase is a listed as GRAS (Generally Regarded as Safe) by the U.S. Food and Drug Administration (FDA GRAS database). It is an approved food additive in the EU (EC, 1995) and may be added to all foodstuffs following quantum satis principle, except in products for the dietary management of metabolic disorders, where the limit of use is 10 g/L or kg (EC, 1999). The Joint FAO/WHO Expert Committee on Food Additives has determined an Acceptable Daily Intake (ADI) for sodium carboxymethyl cellulose of “Not Specified” (no upper limit) (JECFA, 1989). A Tier 1 Human Health Assessment for this chemical has been conducted by NICNAS which concluded that it was low concern to human health.
Environmental Fate[1]	
Soil/Water/Air	Carboxymethyl cellulose (DS 0.7) showed 25% biodegradation after 28 days in a OECD 301A test. Thus, sodium carboxymethyl cellulose is not readily biodegradable. Other studies have also shown partial degradation of carboxymethyl cellulose in ready and inherent biodegradability tests.
Human Health Toxicity Summary	
Chronic Repeated Dose Toxicity	No data available.
Carcinogenicity	No data available.
Mutagenicity/ Genotoxicity	No data available.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	No data available.
Acute Toxicity	No data available.

Irritation	No data available.
Sensitisation	No data available.
Health Effects Summary	No data available.
Key Study/Critical Effect for Screening Criteria	No data are available for determining the critical effect and the LOAEL/NOAEL for an oral reference dose.
Ecological Toxicity [1]	
Aquatic Toxicity	Carboxymethyl cellulose has been tested in several acute aquatic toxicity tests. The 96-hour LC50 for Brachydanio rerio is >2,500 mg/L; the 48-hour LC50 for Daphnia magna is >5,000 mg/L; and the 96-hour EC50 for Selenastrum capricornutum is 500 mg/L.
Determination of PNEC aquatic	PNECaquatic: Experimental results are available for three trophic levels. Acute E(L)C50 values are available for fish (>2,500 mg/L), Daphnia (>5,000 mg/L), and algae (>500 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 500 mg/L for algae. The PNECaquatic is 0.5 mg/L.
Current Regulatory Controls[4]	
Australian Hazard Classification	No data available.
Australian Occupational Exposure Standards	No data available.
International Occupational Exposure Standards	No data available.
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	No data available.
PBT Assessment	
P/vP Criteria fulfilled?	Sodium carboxymethyl cellulose is a water-soluble semisynthetic polymer and is not readily biodegradable. Thus, it meets the screening criteria for persistence.
B/vB criteria fulfilled?	Sodium carboxymethyl cellulose is a water-soluble semisynthetic polymer and is expected to have a molecular weight of >1,000 which limits its bioavailability to aquatic organisms. Thus, it is not expected to bioaccumulate.
T criteria fulfilled?	The acute EC(L)50 of sodium carboxymethylcellulose is >0.1 mg/L in fish, invertebrates and algae. Thus, it does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	April 2019

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Toxicity Summary - Citric acid

Chemical and Physical Properties[2,3,5]	
CAS number	77-92-9
Molecular formula	C6-H8-O7
Product name	--
Molecular weight	192.124
Solubility in water	1000000 mg/L
pH	2 to 2.2
Melting point	Decomposition > 175 C
Boiling point	152 to159 C
Vapour pressure	White powder or granules
Henrys law constant	1.7 $x10^{-8}$ mm Hg at 25 deg C
Explosive potential	4.39 x 10^{-09} $Pa.m^3/mol$
Flammability potential	Dust explosion possible if powder or granular form, mixed with air
Colour/Form	Melts and decomposes in fire, a non-hazardous reaction.
Overview	Citric acid is a water soluble organic solid. It is a natural substance that appears as an intermediate in the basic physiological citric acid or Krebs cycle in every eukaryote cell. Citric acid has been produced for many years in high volumes. It has wide dispersive use, being added to processed food and beverages, used in pharmaceutical preparations and in household cleaners as well as in special technical applications. Citric acid is recognised by Food Standards Australia New Zealand (FSANZ) and the WHO JECFA as safe as a multipurpose food additive. No upper limit of concentrations has been established in food products. This chemical has been identified by NICNAS to be of low concern to human health based on an initial screening approach and thus required no further assessment.
Environmental Fate[2,5]	
Soil/Water/Air	Citric acid is highly mobile in the environment and is extremely soluble in water. The pKa of citric acid is 2.79, indicating that this compound will exist almost entirely in the anion form in the environment. The compound does not sorb to soil or particles in the water column and is readily and rapidly degraded in surface waters and in soil. (OECD, hsdb)

Human Health Toxicity Summary [1,2,4,5]	
Chronic Repeated Dose Toxicity	A 2-year chronic oral study in rats being given 5% or 3% citric acid in feed (approx. 2 resp. 1.2 g/kg/d) found slightly decreased growth in the higher dosage group but no tissue abnormalities in the major organs. From the lower dosage a NOAEL of 1200 mg/kg/d results. Similarly, NOAELs of 1500 mg/kg/d (rabbit) and of 1400 mg/kg/d (dog) have been determined. In general, citric acid is a strong chelating agent, the dietary uptake of which may interfere with biological availability, absorption and excretion of metals. Further, loss of superficial enamel and erosion of teeth as well as local irritation result from frequent ingestion of citric acid in beverages including natural fruit juices; citric acid fumes were reported to apparently affect the teeth of exposed workers. The average daily intake of citric acid from natural sources in the diet and food additives was estimated at about 40 mg/kg for women, 130 mg/kg for infants and 400 mg/kg for individuals on slimming diets; maximum daily intake is reported to reach levels of 500 mg/kg. No formal ADI (acceptable daily intake) level has been specified for citric acid and its common salts by the Joint FAO/WHO Expert Committee on Food Additives nor by the EC Scientific Committee for Food.
Carcinogenicity	Citric acid has not been classified by the IARC.
Mutagenicity/ Genotoxicity	In several in vitro and in vivo tests citric acid was not mutagenic. The substance was not mutagenic either in bacterial tests with Salmonella typhimurium (Ames test, 2 studies) and Escherichia coli, with and without metabolic activation.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	In a two-generation 90 days study with male and female rats fed 1.2 % citric acid no adverse effect on reproductive parameters nor any teratogenicity of dietary citric acid was seen. There were no indications of teratogenic or other adverse effects in three shorter term reproductive studies in rats with dietary dosage of either 5% citric acid (approx. 2.5 g/kg/d) previous, during and after mating (NOEL = 2500 mg/kg/d), or 295 mg/kg/d (route unspecified) during days 6–15 of pregnancy
Acute Toxicity	Citric acid has a low acute toxicity by oral application in both rat (LD50 = 3,000–12,000 mg/kg, 3 different values) and mouse (LD50 = 5,400 mg/kg). General effects comprised physiological disturbances (acidosis and calcium deficiency), while “high” doses caused nervous system effects as well as severe damage to the stomach mucosa.
Irritation	Local effects of citric acid to the skin (rabbit) are reported as slightly irritating in two studies and as not irritating in a third study using a 30% aqueous solution. In an acute eye irritation/corrosion test in rabbits according to OECD 405 citric acid was highly irritating.
Sensitisation	The sensitising potential is low.
Key Study/Critical Effect for Screening Criteria	A 2-year chronic oral study in rats being given 5% or 3% citric acid in feed resulted in a NOAEL of 1200 mg/kg/d. Uncertainty factors: 10 (interspecies variability) and 10 (intraspecies variability). Drinking water guideline = 4.7 ppm
Ecological Toxicity [1,5]	
Aquatic Toxicity	The 96-hour LC50 values for citric acid to fish are from 440 to 1,516 mg/L. The acute toxicity 24 hour EC50 value for invertebrates is 85 mg/L. The 7 day toxic limit concentration (TLC) values for algae range from 300 to 640 mg/L. In an 8 day freshwater static test for the algae Scenedesmus quadricauda, the NOEC is 425 mg/L. In freshwater, citric acid appears to be of low toxicity to aquatic acute test standard organisms, fish, daphnia and algae, with consistent LC50/EC50 values of several hundred milligrams per litre.

Determination of PNEC aquatic	$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (440 mg/L), Daphnia (85 mg/L). A TLC value of 300 mg/L was obtained for algae from which no dependable EC50 can be derived. Even though a NOEC was obtained from the algae study, there were no chronic studies conducted on fish or Daphnia. On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 85 mg/L for Daphnia Magna. The $PNEC_{aquatic}$ was calculated to be 0.085 mg/L.
Current Regulatory Controls	
Australian Hazard Classification	No data found
Australian Occupational Exposure Standards	No data found
International Occupational Exposure Standards	No data found
Australian Food Standards	No data found
Australian Drinking Water Guidelines	No data found
Aquatic Toxicity Guidelines	No data found
Australian Hazard Classification	No data found
PBT Assessment[1]	
P/vP Criteria fulfilled?	Citric acid is expected to be readily biodegradable and does not persist in the environment
B/vB criteria fulfilled?	Based on the low Log Kow and widespread natural occurrence, citric acid is not expected to have potential for bioaccumulation.
T criteria fulfilled?	Long term data not available (acute data >0.1 mg/L); potentially not toxic.
Overall conclusion	Not a PBT substance (based on screening data).

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Toxicity Summary - Crystalline silica-cristobalite, crystalline silica-quartz, tridymite

Chemical and Physical Properties[1,3]	
CAS number	Crystalline Silica (Cristobalite) : 14464-46-1 Crystalline Silica (Quartz): 14808-60-7 Diatomacous Earth (Calcined silica): 91053-39-3 Tridymite: 15468-32-3
Molecular formula	Crystalline Silica (Cristobalite): SiO_2 Crystalline Silica (Quartz): SiO_2 Diatomacous Earth (Calcined silica): SiO_2
Molecular weight	60.09 g/mol
Solubility in water	Insoluble/negligible
pH	-
Melting point	1713°C (Cristobalite) 1610°C (Quartz)
Boiling point	2230 °C
Vapour pressure	NA
Henrys law constant	NA
Explosive potential	Not explosive
Flammability potential	Not flammable
Colour/Form	Transparent crystals
Overview	Silica is an off-white granule that occurs naturally in various crystalline and amorphous or other non-crystalline forms. Crystalline silica is characterized by silicon dioxide (SiO2) molecules oriented in fixed, periodic patterns to form stable crystals. The primary crystalline form of silica is quartz. Other crystalline forms of silica include cristobalite, tripoli and tridymite. Particle size is a key determinate of silica toxicity, since toxicity is restricted to particles that are small enough to be deposited into the target regions of the respiratory tract. Uncalcined diatomaceous earth typically contains around 1%crystalline silica. When diatomaceous earth is subjected to pressure or is processed ("calcined") at temperatures above 1000°C some of the amorphous silica is converted to crystalline silica in the form of cristobalite. Calcined diatomaceous earth can contain anywhere from 1% to 75% cristobalite.
Environmental Fate [1,2]	
Soil/Water/Air	Crystalline Silica consists of diatomaceous earth, a naturally occurring material. Its primary component, silica, is found in common materials like quartz, sand and agate. The materials are ubiquitous and unlikely to react chemically with any other substance in the environment.

Human Health Toxicity Summary [1,2,3]	
Chronic Repeated Dose Toxicity	A number of animal studies have found that cristobalite is more toxic to the lung than quartz, and more tumorigenic (e.g., King et al. 1953; Wagner et al. 1980). However, several other authors concluded that this is not the case (Bolsaitis and Wallace 1996; Guthrie and Heaney 1995). OSHA (2013) has examined evidence on the comparative toxicity of the silica polymorphs (quartz, cristobalite, and tridymite) and found no difference in toxicity effects between cristobalite and quartz. Furthermore, no difference in toxicity between cristobalite and quartz has been observed in epidemiologic studies (NIOSH 2002). There is no information on the repeat dose oral, inhalation or dermal effect of calcined silica. However, since calcined diatomaceous earth contains varying amounts of crystalline silica in the form of cristobalite, and may also contain small amounts of quartz and tridymite, it is expected that any long-term health hazards associated with diatomaceous earth would mainly be due to the effects of crystalline silica. In humans, the most prevalent effect identified from long term exposure in occupational settings is silicosis, a diffused nodular pulmonary fibrosis (US EPA 1996).
Carcinogenicity	IARC (2012) concluded that there is sufficient evidence in humans for the carcinogenicity of inhaled crystalline silica in the form of quartz or cristobalite from occupational sources. There is sufficient evidence in experimental animals for the carcinogenicity of quartz and cristobalite. The IARC has also concluded that inhaled crystalline silica in the form of cristobalite or quartz from occupational sources is carcinogenic to humans (Group 1) (IARC 2012).
Mutagenicity/ Genotoxicity	Conflicting results have been reported in genotoxicity studies with crystalline quartz or cristobalite, and a direct genotoxic effect for crystalline silica has not been confirmed or ruled out. Studies on genotoxicity of calcined diatomaceous silica are not available.
Reproductive Toxicity Developmental Toxicity/Teratogenicity	No data available.
Acute Toxicity	No data available.
Irritation	No data available. Most acute toxicity studies for quartz or cristobalite were conducted using intratracheal instillation. Single intratracheal instillation of quartz caused inflammatory effects and formation of discrete silicotic nodules in rats, mice and hamsters (IARC 2012; WHO 2000). Other effects like oxidative stress, cellular proliferation and increases in water, protein, and phospholipid content of rat lungs, apoptosis (programmed cell death) and lung cancer were also noted. In general, exposure to high concentrations of dust may cause coughing and mild, temporary irritation (CCOHS 2001).
Sensitisation	No data available. However, based on the structure and physico-chemical properties, the three forms of crystalline silica or the calcined diatomaceous silica are not expected to cause skin sensitisation.
Health Effects Summary	The substances are not skin or eye irritants but acute inhalation of dust may cause discomfort and stress as well as signs of local irritation to nasal, bronchiolar and ocular mucous membranes. Based on the evaluation of the epidemiological data it is concluded that inhalation exposure to crystalline silica results in lung cancer. This conclusion is also supported by animal studies in which inhalation and intratracheal exposure to crystalline silica resulted in lung tumours. The most common types of lung tumour observed in rats were lung adenocarcinomas.
Key Study/Critical Effect for Screening Criteria	Not applicable.

Ecological Toxicity [1,2,3]	
Aquatic Toxicity	Aquatic toxicity studies performed at saturation concentrations of synthetic amorphous silica showed no acute toxicity to fish, Daphnia, or algae, though some physical effects were observed with loading rates of greater than or equal to 10 g/L (OECD 2004). Any harmful effects to aquatic ecosystems are therefore not ecotoxicological in nature. No chronic toxicity data were identified.
Determination of PNEC aquatic	Not applicable.
Current Regulatory Controls [3]	
Australian Hazard Classification	Quartz and cristobalite are listed in the Hazardous Substances Information System (HSIS) (Safe Work Australia 2014a) as hazardous substances. Calcined silica is not listed in the HSIS.
Australian Occupational Exposure Standards	Time Weighted Average (TWA) occupational exposure standard of 0.1 mg/m^3 for quartz and cristobalite are recommended in Australia (Safework Australia 2013). A Short-Term Exposure Limit (STEL) is not recommended for any of the compounds.
International Occupational Exposure Standards	TWA for quartz, cristobalite: Canada: 0.025 mg/m^3 France: 0.05 mg/m^3 Japan: 0.03 mg/m^3 Sweden: 0.05 mg/m^3 US (ACGIH): 0.025 mg/m^3 US (NIOSH): 0.05 mg/m^3 US (OSHA): 0.1 mg/m^3 US: 0.3, 0.9, 1.5, 500 mg/m^3 Temporary Emergency Exposure Limits (TEEL) (Diatomaceous silica, calcined)
Australian Food Standards	No data found.
Australian Drinking Water Guidelines	The Australian Drinking Water Guidelines state: 'To minimise an undesirable scale build up on surfaces, silica (SiO¬2) within drinking water should not exceed 80 mg/L' (National Health and Medical Research Council (NHMRC) 2001).
Aquatic Toxicity Guidelines	No data found.
PBT Assessment [3]	
P/vP Criteria fulfilled?	No. Not applicable, inorganic substance, ubiquitous in environment.
B/vB criteria fulfilled?	No. Not applicable, inorganic substance, ubiquitous in environment.
T criteria fulfilled?	No. Long term data not available (acute data >0.1 mg/L).
Overall conclusion	It is not currently possible to categorise the environmental hazards of metals and other inorganic chemicals according to standard persistence, bioaccumulation and toxicity (PBT) hazard criteria. These criteria were developed for organic chemicals and do not take into account the unique properties of inorganic substances and their behaviour in the environment (UNECE 2007; US EPA 2007). Further assessment of the environmental risks from the use of this chemical is not required as identified by DoEE
Revised	April 2018

References

1. HSDB. Hazardous Substances Data Bank. Retrieved 2015, from Toxnet, Toxicology Data Network, National Library of Medicine: http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB
2. OECD-SIDS Initial Targeted Assessment Profile on Quartz and Cristobalite, SIAM 32, 19-21 April 2011.
3. Department of the Environment and Energy 2017 , National assessment of chemicals associated with coal seam gas extraction in Australia, prepared by the National Industrial Chemicals Notification and Assessment Scheme

Toxicity Summary - Distillates, Hydrotreated Light

Chemical and Physical Properties [1,2,3,4]	
CAS number	64742-47-8
Molecular formula	C48H94
Molecular weight	Not applicable - unknown or variable composition, complex reaction products or biological materials (UVCB)
Solubility in water	0.009 to 6.45 mg/L (at 25°C)
Melting point	-49 °C
Boiling point	146 to 299 °C
Vapour pressure	1 to 3.7 kPa at 37.8 °C
Henrys law constant	No data found.
Explosive potential	Above 66°C explosive vapour/air mixtures may be formed
Flammability potential	Combustible
Colour/Form	Liquid at room temperature
Overview	Distillates, hydrotreated light (also called deodorised kerosene) is a petroleum substance. The C_9-C_{14} Aliphatic [< 2% Aromatic] Hydrocarbon Solvents Category is comprised of complex aliphatic hydrocarbon solvents that contain >98% aliphatic constituents with carbon numbers in the range of C9-C14 and less than 2% aromatic constituents. The chemical is used as a component of a drilling fluid formulation for coal seam gas extraction.
Environmental Fate[1]	
Soil/Water/Air	Members of the C_9-C_{14} Aliphatic [≤2% aromatics] Hydrocarbon Solvents Category have the potential to volatilize from surface waters, based on Henry's Law constants (HLC) representing volatility for category members that range from 4.76 x 10^4 to 1.67 x 10^6 Pa-m^3/mole (at 25°C). In the air, category members have the potential to rapidly degrade through indirect photolytic processes mediated primarily by hydroxyl radicals (•OH) with calculated degradation half-lives ranging from 0.42 to 1.10 days or 10.8 to 26.4 hours based on a 12-hr day and an •OH concentration of 1.5 x 10^6 •OH/cm^3. These chemicals are unlikely to degrade by hydrolysis as they lack a functional group that is hydrolytically reactive.

Human Health Toxicity Summary [1,2,3]	
Chronic Repeated Dose Toxicity	In a 90-day study conducted in accordance with OECD TG 408, Sprague-Dawley rats were administered deodorized kerosene by gavage at doses of 0, 100, 500 or 1000 mg/kg bw/day (REACH 2013). Microscopic changes, such as incidence of a2μ-globulin, were seen in male kidneys. These effects are not considered relevant to humans. No other treatment-related effects were observed. No Lowest Observed Adverse Effect Level (LOAEL) or No Observed Adverse Effect Level (NOAEL) could be established in this study. Repeated dermal exposures to members of the kerosene/jet fuel category showed minimal systemic effects (API 2010). Animal data on repeat dermal toxicity of kerosene (petroleum) are summarised from REACH (2013) and presented in Table A29.2. The LOAELs and NOAELs are indicated for each study. Prolonged skin exposure to kerosene (petroleum) in rats and rabbits were consistently associated with local irritation. In rabbits only, systemic effects included changes in bodyweight and organ weights. It is expected that deodorized kerosene would have similar effects in the animals. In a 13-week study, rats (strain not specified) were exposed to deodorized kerosene vapour at concentrations of 0, 0.02, 0.048 or 0.10 mg/L for six hours/day, five days/week. No treatment-related effects were reported (REACH 2013).
Carcinogenicity	A study for deodorized kerosene is available in the REACH Dossier (REACH 2013) but was not reported in enough detail to be able to determine the carcinogenicity of the substance. In a study conducted similarly to OECD TG 451, B6C3F1 mice were applied 0, 250 or 500 mg/kg bw/day kerosene (petroleum) in the interscapular region (type of wrapping not specified) for 103 weeks (REACH 2013). At the end of the study, less than 10% decrease in bodyweight gain was observed at the top dose in both sexes. Mortality in females was significantly higher at the two doses compared to controls. Increased incidence and severity of chronic dermatitis was seen in all treatment groups. At the top dose, increased incidence of the following non-neoplastic lesions was reported: amyloid in the liver, kidney, adrenal cortex (males only), spleen; granulocytic hyperplasia in the bone marrow; and hyperplasia of the axillary lymph nodes (females only). The only indication of neoplastic lesions was an increased incidence of malignant lymphomas observed in treated female animals but the values were within the range of historical controls. Under the conditions of the test, kerosene (petroleum) was not carcinogenic. The LOAEL for systemic effects is 250 mg/kg bw/day. The International Agency for Research on Cancer (IARC) concluded that there is inadequate evidence for the carcinogenicity of kerosene (petroleum) in experimental animals and humans, placing the chemical in Group 3 (Not classifiable as to its carcinogenicity to humans) (IARC 1989). Deodorized kerosene is not carcinogenic, based on reading across the information available for kerosene (petroleum).
Mutagenicity/ Genotoxicity	In vitro tests reported deodorized kerosene as negative both with and without metabolic activation in Ames tests conducted in accordance with OECD TG 471 (REACH 2013; OECD 2011) and in chromosomal aberration tests conducted in accordance with OECD TG 473 (OECD 2011, 2012). In an in vivo study, deodorized kerosene was negative in a dominant lethal assay, conducted in accordance with OECD TG 478, in male Swiss mice and Long Evans rats administered 10% deodorized kerosene intraperitoneally (REACH 2013). These studies demonstrate that deodorized kerosene is not genotoxic.

Reproductive Toxicity / Developmental Toxicity/Teratogenicity	C9-C14 aliphatic (≤2% aromatic) hydrocarbon solvents and C14-C20 aliphatic (≤2% aromatic) hydrocarbon solvents are not toxic to fertility (OECD 2011, 2012). Members of the kerosene/jet fuel category are not toxic to fertility (API 2010). Sprague-Dawley rats were administered undiluted kerosene (petroleum) by gavage at doses of 0, 750, 1500 or 3000 mg/kg bw/day in males treated for 70-90 days and 0, 325, 750 or 1500 mg/kg bw/day in females treated for 21 weeks. At 750 and 1500 mg/kg bw/day, increased absolute liver weight was observed in females but with no corresponding changes in clinical chemistry or histopathology. In females only, other effects included perianal dermatitis at 1500 mg/kg bw/day and stomach hyperplasia at 750 and 1500 mg/kg bw/day. These parameters were not measured in males. In males, the study indicated dose dependent decrease in male bodyweight that was linked to nephropathy specific to male rats. Data for this effect were not provided in the study description. There were no treatment related effects on fertility in both sexes (REACH 2013). The NOAEL for systemic effects in females only was 325 mg/kg bw/day. No NOAEL can be established for fertility effects. C9-C14 aliphatic (≤2% aromatic) hydrocarbon solvents and C14-C20 aliphatic (≤2% aromatic) hydrocarbon solvents are not developmental toxicants (OECD 2011, 2012). Members of the kerosene/jet fuel category are not developmental toxicants (API 2010). In a study conducted in accordance with OECD TG 414, Sprague-Dawley rats were administered kerosene (petroleum) by gavage on gestation days (GD) 6 to 15 at doses of 0, 500, 1000, 1500 or 2000 mg/kg bw/day (REACH 2013). Bodyweight gain was decreased at 1500 and 2000 mg/kg bw/day. Foetal weight was decreased at 1500 and 2000 mg/kg bw/day which may be attributed to decreased maternal bodyweight gain. No malformations were reported. The maternal NOAEL is 1000 mg/kg bw/day. In another study, Sprague-Dawley rats were exposed (whole body) to kerosene (petroleum) in air at concentrations of 0, 106 or 364 ppm on GD 6-15. There were no treatment-related effects observed in the dams and offspring (REACH 2013). Deodorized kerosene is not considered a developmental toxicant, based on reading across data available for kerosene (petroleum).
Acute Toxicity	The chemicals have low acute toxicity based on results from animal tests following oral exposure. The median lethal dose (LD50) in rats is >2000 mg/kg bw (OECD, 2011; US EPA, 2011; OECD, 2012a; OECD, 2012b; OECD, 2012c). The chemicals have low acute toxicity based on results from animal tests following dermal exposure. The LD50 in rats and rabbits is >2000 mg/kg bw (OECD, 2011; US EPA, 2011; OECD, 2012a; OECD, 2012b; OECD, 2012c). The chemicals have low acute toxicity based on results from animal tests following inhalation exposure.
Irritation	Semi-occlusive applications of commercial grade deodorized kerosene produced slight irritation in New Zealand White and SPF rabbits in dermal irritation studies conducted in accordance with OECD TG 404. The studies reported the range of erythema and oedema scores to be 0.3-0.9 and 0.2-1.0, respectively, based on Draize scoring at 24, 48 and 72 hours. Deodorized kerosene is slightly irritating to rabbit skin. Several studies conducted similarly to OECD TG 405 showed minimal effects to the eye with the reported range of conjunctival redness score to be 0-0.2 from instillation of undiluted deodorized kerosene in the eyes of New Zealand White and SPF rabbits (OECD 2011). Deodorized kerosene is slightly irritating to rabbit eye.
Sensitisation	The C9-C14 aliphatic (≤2% aromatics) Category members do not cause skin sensitization.

Health Effects Summary	Deodorised kerosene is an aspiration hazard since it has low viscosity and is composed of aliphatic and aromatic hydrocarbons up to 10%. Deodorised kerosene has low acute oral, dermal and inhalation toxicity, and is slightly irritating to the skin and eyes. The substance is not a skin sensitiser, based on reading across data available for kerosene (petroleum). No treatment-related effects were reported in repeated oral and inhalation exposures to deodorised kerosene. Prolonged dermal exposure to kerosene (petroleum) reported local irritation in rats and rabbits, and changes in bodyweight and organ weights in rabbits. It is expected that these effects would be similar for deodorised kerosene. Based on the absence of adverse effects observed in repeat dose toxicity studies, for the purposes of quantifying the health risk to the general worker and public, the highest dose tested in the study conducted in rats (1 000 mg/kg bw/day) is used in this risk assessment. The substance is not genotoxic. It is neither a carcinogen nor a reproductive toxicant, based on reading across data available for kerosene (petroleum).
Key Study/Critical Effect for Screening Criteria	The most appropriate No-Observed-Adverse-Effect Level (NOAEL) for risk assessment is 1 000 mg/kg bw/day based on maternal toxicity (decreased bodyweight gain) at the Lowest- Observed-Adverse-Effect Level (LOAEL) of 1 500 mg/kg bw/day from a developmental toxicity study on kerosene (petroleum).
Ecological Toxicity [2]	
Aquatic Toxicity	Lowest acute endpoint for Daphnia = 0.018 mg/L (modelled)
Determination of PNEC aquatic	Based on the lowest acute endpoint for Daphnia (0.018 mg/L), an assessment factor of 100 has been applied, resulting in a PNECaquatic of 1.80E-04 mg/L.
Current Regulatory Controls [2]	
Australian Hazard Classification	All of the chemicals are classified as hazardous, with the following risk phrase for human health in the Hazardous Substances Information System (HSIS) (Safe Work Australia): Xn; R65 (acute toxicity) Mixtures containing the substance are classified as hazardous with the following risk phrase based on the concentration (Conc) of the substance in the mixtures: Conc ≥10%: Xn; R65 (May cause lung damage if swallowed)
Australian Occupational Exposure Standards	No specific exposure standards are available.
International Occupational Exposure Standards	No specific exposure standards are available for this chemical.
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	Oils and greases (including petrochemicals) for freshwater production: <300[6] µg/L (ANZECC 2000)
PBT Assessment	
P/vP Criteria fulfilled?	No. This chemical is expected to be biodegradable. The ready biodegradability of SHELLSOL NF a solvent naphtha (petroleum), heavy aromatics (consists predominantly of C9 aromatics 25%m/m; C10 aromatics 65%, and indanes 10%) was studied in mineral nutrient medium inoculated with activated sludge (mixed liquor suspended solids 100-101 mg/L, pH 6.9) and incubated for 28 days at 20°C. SHELLSOL NF is readily biodegrade after 28 days but not within the 10 day window.
B/vB criteria fulfilled?	Category members have a potential to bioaccumulate, based on calculated log BCF values for constituents that range from 2.78 to 4.06, and calculated BCF values of 598 to 11,430 L/kg wet-weight, based on the Arnot and Gobas model, that take into account biotransformation of the chemicals in fish tissue. This chemical also has a log Kow of 6.025.

T criteria fulfilled?	Yes. The lowest acute endpoint is <1 mg/L.
Overall conclusion	Not PBT
Revised	January 2019

Human Health Risk Assessment

Occupational Exposure

Table 2 presents the calculated internal doses for adult workers associated with drilling chemical exposure/hydraulic fracturing chemical exposure.

Table 2 Calculated Internal Doses for Adult Workers

Occupational Activity	E_{derm} (mg/kg bw/day)	E_{inh} (mg/kg bw/day)	E_{total} (mg/kg bw/day)
Transport and storage	Negligible*	Negligible*	Negligible*
Mixing/blending drilling of hydraulic fracturing chemicals	0.06	0.750	**0.810**
Injection of drilling chemicals	Negligible*	Negligible*	Negligible*
Cleaning and maintenance (hydraulic fracturing)	0.012	0.150	**0.162**
Combined exposure Mixing/blending and cleaning and maintenance			**0.972**
Transport and storage of drilling muds	Negligible*	Negligible*	Negligible*

Ederm - Internal dose from dermal exposure; Einh – Internal dose from inhalation exposure; Etotal – Total internal dose from all routes.

* In the absence of accidents/incidents, repeated occupational exposures during transport and storage, or during injection of mixed/blended chemicals, are negligible. Similarly, repeated occupational exposures to the chemical via the transport and storage of drilling muds are negligible (NICNAS 2017).

Human Health Risk Characterisation

Uncertainty Factors

Using the Margin of Exposure (MOE) approach, conservative default uncertainty factors for intra- and inter-species variability are assumed to be 10 each. A MOE of less than 100 is considered a concern (NICNAS 2017).

Acute Health Risks

Acute exposure to the chemical is unlikely to result in adverse health effects. In addition, given the low concentration in the drilling fluids, exposure to the chemical via these fluids is of low concern for workers.

Chronic long-term health risks

The critical (most sensitive) adverse health effect is maternal toxicity (decreased bodyweight gain). The NOAEL established for this effect is 1000 mg/kg bw/day from a reproductive toxicity study. There are no adverse effects observed from repeated exposures to the chemical at any dose tested, up to 1000 mg/kg bw/day. This highest no-effect dose is applicable for a general worker. Margins of Exposure (MOE) for adverse health effects from repeated occupational exposures are calculated by comparing the NOAEL with exposures estimated for different occupational activities and combined activities. **Table 3** presents Margin of Exposure calculated for Adult Workers associated with drilling chemical exposure/hydraulic fracturing chemical exposure. Risk characterisation calculations are presented in **Attachment A**.

Table3 Margins of exposure calculated for adult workers

<table>
<tr><th>Adult worker exposure scenario</th><th>E_{total} (mg/kg bw/day)</th><th>NOAEL (mg/kg bw/day)</th><th>Critical effect</th><th>MOE (NOAEL / E_{total})</th><th>Chemical is of concern? (MOE < 100)</th></tr>
<tr><td colspan="6">Occupational Activity</td></tr>
<tr><td>Mixing/blending drilling of hydraulic fracturing chemicals</td><td>0.810</td><td rowspan="3">1000</td><td rowspan="3">Maternal toxicity in rats</td><td>1235</td><td rowspan="3">No</td></tr>
<tr><td>Cleaning and maintenance (hydraulic fracturing)</td><td>0.162</td><td>6173</td></tr>
<tr><td>Combined exposure
Mixing/blending and cleaning and maintenance</td><td>0.972</td><td>1029</td></tr>
</table>

Based on uncertainty factors derived for this risk characterisation, the MOEs indicate that the chemical is of low concern for workers from repeated exposures during certain operations.

References

1. OECD (2012) SIDS Initial Assessment Profile on C_9-C_{14} Aliphatic [≤2% aromatic] Hydrocarbon Solvents Category. Available at: http://webnet.oecd.org/HPV/UI/SIDS_Details.aspx?id=476560b6-e2b7-4466-9c52-0b278c8b71a7
2. National Industrial Chemicals Notification and Assessment Scheme (NICNAS, 2017). National assessment of chemicals associated with coal seam gas extraction in Australia. Human health hazards of chemicals associated with coal seam gas extraction in Australia.
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4. ECHA REACH, Distillates (petroleum), hydrotreated light, Retrieved 2017: https://echa.europa.eu/information-on-chemicals/registered-substances
5. ICSC Distillates (petroleum), hydrotreated light, Retrieved 2017: http://www.inchem.org
6. ANZECC (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality for protection for aquatic ecosystems

AECOM Imagine it Delivered

Toxicity Summary - Ethanol, 2,2'-oxybis-, reaction products with ammonia, morpholine derivatives residues

Chemical and Physical Properties[1]	
CAS number	68909-77-3
Molecular formula	C36H78N6O14
Molecular weight	UVCB
Solubility in water	100 g/L at 20 °C
Melting point	-20 °C at 101.3 kPa
Boiling point	223 °C at 101.3 kPa
Vapour pressure	0.55 - 20 Pa at 20 - 25 °C
Henrys law constant	No data available
Explosive potential	Non-explosive (100%)
Flammability potential	Not classified (50%), Non-flammable (50%)
Colour/Form	Liquid
Overview	The residuum from the reaction of diethylene glycol and ammonia. It consists predominantly of morpholine-based derivatives such as [(aminoethoxy)ethyl]morpholine, [(hydroxyethoxy)ethyl]morpholine, 3-morpholinone, and 4,4'-(oxydi-2,1-ethanediyl)bis[morpholine].
Environmental Fate[1]	
Soil/Water/Air	The substance is hydrolytically stable at pH 4, 7 and 9 at 25°C. Adsorption to solid soil phase is not to be expected. Based on the assessment of the components, it can be concluded that the mixture will not evaporate into the atmosphere. The substance is not readily biodegradable. Based on the low log Kow, the substance will have a low potential for bioaccumulation. Over time, the mixture will preferentially distribute into the compartment water.
Human Health Toxicity Summary[1]	
Chronic Repeated Dose Toxicity	No adverse effects were observed in male and female rats in a 28 days and a 90 days repeated dose toxicity test conducted according to OECD 407 and OECD 408 respectively (Calvert Laboratories, Inc., 2011 and Envigo Research Limited, 2018) in which animals were exposed orally (gavage) to 0, 100, 500 or 1000 mg/kg bw/d (28 days study) and to 0, 10, 100 or 1000 mg/kg bw/d (90 days study). In both studies, an NOAEL of 1000 mg/kg bw was determined.
Carcinogenicity	No data available.
Mutagenicity/ Genotoxicity	In an in vivo micronucleus test on mouse bone marrow erythrocytes (BioReliance, 2010), performed according to OECD guideline 474, the animals were exposed orally (via gavage) with 500, 1000, 2000 mg/kg. This did not induce a statistically positive increase in micronuclei in the hemopoietic cells of the mouse bone marrow at the time intervals evaluated under the experimental condition of this assay. No toxicity was observed. Vehicle and positive controls were valid.

Reproductive Toxicity / Developmental Toxicity/Teratogenicity	A Reproductive / Development Toxicity Screening Testing in Rats was performed according to OECD guideline 421 (Calvert Laboratories, Inc., 2011, Klimisch 1). In this GLP-compliant study, male and female Sprague-Dawley rats (10 animals/sex/dose) were exposed to 1000 mg/kg bw/day. Control animals received concurrent vehicle (water). The rats were exposed on a daily basis, starting two weeks prior to cohabitation until the day before the scheduled euthanasia (minimum of 4 weeks) for males and starting for a minimum of 15 days prior to cohabitation, during cohabitation and from presumed gestation days 0 through day 19 of gestation for females. One female animal was found dead on lactation day 2. All other females survived until scheduled sacrifice. No treatment-related effects were observed in clinical signs, mortality, body weight (gain), food consumption, gross pathology, organ weights or histopathology in the parental animals. There was no treatment-related effect on reproductive performance or in reproductive parameters like for instance number of gravid animals, corpora lutea per dam, total implantations, litter viability or foetal sex ratios. The incidence of neonates born alive/found dead, stillborn or missing between lactation days 0 -4 was comparable among study groups. No treatment-related malformations were observed for neonates. The body weight of neonates was statistically significantly increased with an unknown biological significance for this finding. A NOAEL of 1000 mg/kg bw/day was established.
Acute Toxicity	The oral LD50 in male and female Sprague-Dawley rats was determined to be 5000 mg/kg bw in a reliable, key study conducted similarly to OECD guideline 420 (Calvert Laboratories, Inc., 2010). Calvert Laboratories Inc (2010) determined acute dermal toxicity in 10 male / female rats following a GLP-compliant study performed equivalent to OECD guideline 402 (key study, Klimisch 1). Only one dose was tested (2000 mg/kg bw). No mortality was observed. Shortly after exposure, local erythema and oedema effects were observed in both males and females. The effects seemed to be reversible in males and 1 female. In the 4 other females, necrosis and slouching appeared.
Irritation	The skin irritation potential of the test substance is investigated in a key, reliable study performed according to OECD guideline 404 (Allen, 1994; Klimisch 2) in 3 rabbits. Semi-occlusive patches were removed from shaved test sites after exposure periods of 3 min, 1h, and 4h to 0.5mL of the test substance. The Draize scoring system was used to evaluate the results. No erythema/eschar formation and no oedema formation is observed after 3 min and 1 hour exposure. After 4 hours of exposure, very slight erythema in all 3 animals and very slight oedema in 2 animals was observed, but this was fully reversible within 24 - 48 hrs. Calvert Laboratories, Inc. (2010) investigated the eye irritation potential of the test substance in a key, reliable study performed according to EU method B.5 (Klimisch 1) in 3 rabbits. The treated eyes (with 0.1mL test substance) will remain unrinsed for at least 24 hours after instillation. The 24-, 48- and 72-hours scores will be added separately for each animal and each total divided by 3 to yield the individual mean scores for each animal. Based on the data and according to the criterial of the CLP regulation, the test substance is classified as irritant to the eyes (category 2).
Sensitisation	Based on a guinea pig maximization study, performed according to the OECD guideline 406 (Allen, 1996; Klimisch 2), the test substance is considered not sensitising to the skin.
Health Effects Summary	This chemical may cause skin and eye irritation.
Key Study/Critical Effect for Screening Criteria	The critical lowest No Observed Adverse Effect (NOAEL) level for the purposes of risk assessment is 1000 mg/kg bw/day from the 90 day repeated oral toxicity study.
Ecological Toxicity [1]	

Aquatic Toxicity	In a static test following the procedures of the German national standard DIN 38412 using Leuciscus idus as test species a LC50 (96 h) of 681.2 mg/L (nominal) was determined [BASF AG, 1988; Study No. 10F0118/885140]. In conclusion, the substance is with high probability not acutely harmful to fish. The EC50 of the test item on daphnids was found to be greater than 122 mg/L (measured value) in a GLP guideline study according to OECD 202 [BASF SE, 2010; Study No. 50E0396/09E012]. Therefore, the test substance is with high probability acutely not harmful to aquatic invertebrates. A study was performed to assess the effect of the test item on the growth of the green alga Pseudokirchneriella subcapitata. The method followed that described in the OECD Guidelines for Testing of Chemicals (2006) No 201, "Freshwater Alga and Cyanobacteria, Growth Inhibition Test" referenced as Method C.3 of Commission Regulation (EC) No 440/2008. The effect of the test item on the growth of Pseudokirchneriella subcapitata has been investigated over a 72-Hour period. the ErC50(72h) of the test item is 45 mg/L for Pseudokirchneriella subcapitata. The toxicity to microorganisms was determined in a GLP short-term respiration test according to OECD guideline 209 using activated sludge from a municipal sewage treatment plant. After 180 minutes no inhibition effect on the respiration rate at the highest test concentration (1000 mg/L) was observed [BASF 2010; Study No. 08G0396/09G004]. Therefore, it can be concluded that inhibition of the degradation activity of activated sludge is not anticipated when introduced in appropriately low concentrations.
Determination of PNEC aquatic	The available short-term aquatic tests covering the three trophic levels (fish, daphnids, algae) showed the lowest L(E)C50 to be 45 mg/L in algae. An assessment factor of 1000 was used for a resulting PNEC for of 0.045 mg/L.
Current Regulatory Controls[4]	
Australian Hazard Classification	No data available.
Australian Occupational Exposure Standards	No data available.
International Occupational Exposure Standards	No data available.
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	No data available.
PBT Assessment[1]	
P/vP Criteria fulfilled?	Not readily biodegradable. Thus, it is expected to meet the screening criteria for persistence.
B/vB criteria fulfilled?	As the Log Pow is 0.565 at 20 °C (Log Pow < 4.5), it is not expected to be bioaccumulative.
T criteria fulfilled?	The acute aquatic toxicity of this chemical is >0.1 mg/L. Thus, it is not expected to meet the screening criteria for toxicity
Overall conclusion	Not PBT
Revised	March 2019

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Toxicity Summary - Glutaraldehyde

Chemical and Physical Properties [1,2,3]	
CAS number	111-30-8
Molecular formula	C5H8O2
Molecular weight	100.11
Solubility in water	Soluble in all proportions in water and ethanol; soluble in benzene and ether.
Melting point	-14°C
Boiling point	188°C
Vapour pressure	2.03 x 10^{-3} kPa at 25 °C (50% solution)
Henrys law constant	0.011 Pa m^3/mol @ 25 °C
Explosive potential	Non explosive
Flammability potential	Non flammable
Colour/Form	Colourless oily liquid. In the vapour state, glutaraldehyde has a pungent odour, with an odour threshold of 0.04 ppm.
Overview	Glutaraldehyde is manufactured in Germany by BASF and in the USA by Union Carbide Corporation. It is usually sold commercially as a 45% or 50% aqueous solution. Glutaraldehyde has a wide variety of uses throughout the world with its use spread over a number of different industries. It is used primarily as a biocide but it also has wide use as a fixative, and some use as a therapeutic agent. The principal health effects of glutaraldehyde are irritation of the skin, eye and respiratory tract, skin sensitisation and occupational asthma. Exposure data indicated that, in some situations, particularly the health care industry (disinfection), x-ray film processing and the animal health industry (spray use), health concerns may arise where available control measures such as ventilation have not been implemented to minimise exposure. Due to low and intermittent exposure, the public health risk from the industrial use of glutaraldehyde is minimal. For the use of glutaraldehyde in cosmetics, a safety margin of >400 for extensive use indicated low concern.
Environmental Fate[1]	
Soil/Water/Air	Glutaraldehyde is a hydrophilic substance that will be mainly associated with the aquatic compartment, with minor amounts partitioning to the atmosphere, following release to the environment. Hydrolysis is slow, but glutaraldehyde, like other aldehydes, undergoes aerial oxidation in solution. It biodegrades rapidly in aerobic and anaerobic aquatic environments at subcidal concentrations (below 10 mg/L) and will not bioaccumulate. Tropospheric degradation is also rapid.
Human Health Toxicity Summary [1,2,3]	

Chronic Repeated Dose Toxicity	A two-year chronic study was conducted in male and female Fischer 344 rats (NICNAS 1994). Groups of 100 male and 100 female rats were administered 0, 50, 250, or 1000 ppm w/v glutaraldehyde in drinking water (4, 17 and 64 mg/kg bw/day for the males and 6, 25 and 86 mg/kg/day for the females). The mortality rate over the treatment period was 25 to 30% for males and 19 to 23% for females with no dose-related increase. The major cause of death in all rats (control and dose groups) was large granular cell lymphatic leukaemia (LGLL). Small dose-related decreases in absolute body weight and body weight gain occurred at 250 and 1000 ppm in males and at 1000 ppm in females. Dose-related decrease in urine volumes and associated increase in osmolality were observed in higher dose animals. At necropsy at 52, 78 and 104 weeks, the only statistically significant changes in organ weights were for the kidney. Relative kidney weights were increased for males and females at 52 and 78 weeks. A significant dose-related increase in kidney weight relative to final body weight occurred for males and females in the 250 and 1000 ppm groups, including an increase in absolute kidney weight for the female rats. Changes in final body weights and the weights of other organs were minor and / or sporadic and were unlikely to be related to glutaraldehyde exposure. The total leucocyte count was significantly increased at week 104 in males at 250 and 1000 ppm, and in females at 250 ppm only. The variation in counts was large, possibly due to the large monocyte count at 250 and 1000 ppm. Changes in clinical chemistry parameters included decreases in the activities of some enzymes at 250 and 1000 ppm and occasional decreases in total protein, globulin and phosphorous; these were probably due to reduced food consumption and body weight. Gross pathology showed evidence of gastric inflammation, particularly in rats sacrificed at the end of the study, with irritation observed as ulceration, a multifocal colour change and thickening of the mucosa (dose groups not specified). Histologic examination of the tissues revealed squamous epithelial hyperplasia and keratinised cysts and oedema. Based on the observations, a NOAEL of 4 mg/kg bw/day for males and 6 mg/kg bw/day for females was established in this study. For the purpose of human health risk assessment, the lowest NOAEL (4 mg/kg bw/day) established in the two-year chronic study in rats will be used.
Carcinogenicity	In a two-year chronic/carcinogenicity study by Van Miller et al. (2002), groups of 100 male and 100 female Fischer 344 rats were treated with 0, 50, 250, or 1000 ppm w/v glutaraldehyde in drinking water. The mean glutaraldehyde consumption for each of the three groups was 4, 17 and 64 mg/kg bw/day for the males and 6, 25 and 86 mg/kg bw/day for the females. The mortality rate during the study period was 25 to 30% for males and 19 to 23% for females and was not dose-related. Gross pathology showed evidence of gastric inflammation. The main finding of the study was an increased incidence of large granular lymphocytic leukaemia (LGLL) in the spleen and liver of male and female rats in all groups, including the control group. Treated females showed a significantly increased incidence of LGLL and analysis for dose-response trend for the severity of LLGL revealed an increased severity in females at the higher dosages (53% in spleen and 54% in liver versus respectively 20% and 23% in untreated females) while no such observation were made for the males. No other significant oncogenic effects were observed during the study. Occurrence of LGLL was seen in all groups including controls; the incidence of LGLL in the 1000 ppm group was high compared to controls but no clear dose-response relationship was evident, and LGLL mainly affected treated females whereas the incidence in treated males was within the control range (REACH 2013). Historical control data for untreated Fischer 344 rats in NTP studies also indicates that the ranges for this tumour are 10 to 72% in males and 6 to 31% in females (REACH 2013). The control data in the Van Miller et al. study fitted in with the historical control data reported from NTP studies. The variability in control data for LGLL and the wide variation reported in the literature makes a definitive conclusion difficult. Base on this study, glutaraldehyde was considered not to be carcinogenic.

Mutagenicity/ Genotoxicity	Glutaraldehyde has been extensively tested for genetic activity in vitro and in vivo, however there is disagreement in the literature regarding glutaraldehyde's genetic activity (Zeiger et al. 2005). While all in vivo genotoxicity tests with glutaraldehyde gave negative results, mixed results were reported for in vitro mutagenicity tests. Early in vitro tests were negative (Watts 1984), but some recent bacterial assays and tests in mammalian cells indicated that glutaraldehyde could be mutagenic in vitro. A series of reverse mutation assays was carried out with various Salmonella typhimurium strains, with and without metabolic activation (REACH 2013). All assays with TA 100, 1535, 1537 and 98 were negative. Some assays with TA 102 and 104 gave positive results. Tests with Escherichia coli also yielded both positive as well as negative results. Glutaraldehyde induced sister chromatid exchanges in CHO cells with and without S9 metabolic activation in one laboratory, but was negative without S9 and only weakly positive with S9 in the second laboratory (NICNAS 1994). The difference in the results was attributed to slight differences between the data evaluation systems used in the two laboratories. Glutaraldehyde was not mutagenic in any of the in vivo assays such as peripheral blood micronucleus test, rat bone marrow chromosomal aberration assay and the Drosophila melanogaster sex-linked recessive lethal test (NICNAS 1994; REACH 2013). Chromosome aberrations in bone marrow cells were reported in only one out of eight studies using rats and mice, micronuclei were not induced in bone marrow cells of mice, and dominant lethal mutations were not induced in mice. Glutaraldehyde did not induce cell transformation in Syrian hamster embryo cells in vitro (Zeiger et al. 2005). In vivo, inhalation of glutaraldehyde induced cell proliferation in nasal tissue in rats and mice, but did not induce DNA damage at these sites. Based on these observations, it is concluded that glutaraldehyde is not a genotoxin.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Studies on the incidence of miscarriage in pregnant women have shown no difference between those exposed to glutaraldehyde and those not exposed to the chemical. Studies in female rats and mice have resulted in embryotoxicity/foetotoxicity for glutaraldehyde, but only at doses which are maternally toxic. A number of studies have found no evidence of teratogenicity.

Acute Toxicity	Several acute oral toxicity studies with glutaraldehyde have been reported in rats and other species. In one reliable study, administration of 0.2, 0.3, 0.5, 1.0, 1.7 mL/kg bw glutaraldehyde (corresponding to 226, 339, 565, 1130 and 1921 mg/kg bw, respectively) to male/female Wistar rats by gavage gave a median lethal dose (LD50) of 226 mg/kg bw (REACH 2013). Necropsy of animals that died during the observation period revealed congestion of the lungs and the abdominal viscera. In another study in Sprague-Dawley rats, the oral LD50 was 316 mg/kg bw for males and 285 mg/kg bw for females, when 10 mL of 2.15, 3.16, 4.64, 14.7% glutaraldehyde (corresponding to 215, 316, 464 and 1470 mg/kg bw) was administered by oral gavage (REACH 2013). In a separate study using different strengths of glutaraldehyde, Ballantyne (1986) showed that the oral LD50 for glutaraldehyde in rats varied with the concentration of the glutaraldehyde used. By using different concentrations of glutaraldehyde solutions (1% to 50%) and varying the administration volume to maintain a constant dose, oral LD50 in the range 66 to 733 mg/kg bw were obtained. These studies indicate that glutaraldehyde has high acute oral toxicity. Of the 18 acute dermal toxicity studies reported in REACH (2013) dossiers, results from 14 studies indicated LD50 higher than 2000 mg/kg bw. In four other studies, LD50 ranged between 250 and 1432 mg/kg bw. These studies however did not follow international guidelines and have low reliability. Based on these studies, glutaraldehyde is considered to have low acute dermal toxicity. In a well-defined study, 10 male and 10 female Sprague-Dawley rats per dose group were exposed to glutaraldehyde as liquid aerosol at 0.22, 0.31 and 0.63 mg/L for 4 hours (REACH 2013). Exposure was followed by an observation period of 14 days. During the exposure period slight nasal discharge, snout wiping, flank respiration and irregular to intermittent respiration were reported in rats. During the post-exposure period, bloody nasal discharge, red crusts surrounding the nose, whooping or gasping respiration with rasping sounds and a tremulous gait were observed. These symptoms disappeared in the surviving animals within 5 to 9 days post-exposure. Mortalities were noted in all treated groups. The determination of the LC50 values was based on the Probit Analysis. An LC50 of 0.48 mg/L was calculated for both male and female rats. In another acute inhalation study conducted in a similar manner to the above study, Sprague-Dawley rats, 10 rats per sex per dose group, were exposed to 0.1, 0.18, 0.28, 0.39 and 0.44 mg/L glutaraldehyde as liquid aerosol for 4 hours (REACH 2013). During and after exposure, mortality and clinical signs of toxicity were recorded at regular time intervals. The LC50 in this study was established as 0.28 mg/L for females and 0.39 mg/L for males. Based on the above studies, glutaraldehyde is considered to have high acute inhalation toxicity.
Irritation	Glutaraldehyde is corrosive to the skin and eyes of rabbits at high concentrations, with signs of skin irritation evident at 2%, and eye irritation at 0.2%. Exposure to glutaraldehyde vapours in acute inhalational studies resulted in nasal irritation and respiratory difficulties. Joint irritation was seen in rabbits after intra-articular administration.
Sensitisation	The skin sensitisation effect of glutaraldehyde was demonstrated in tests with guinea pigs.
Health Effects Summary	Glutaraldehyde has high acute oral and inhalation toxicity and low to moderate acute dermal toxicity. Based on human and animal data, it is corrosive, the vapours are irritating to the respiratory tract, and it has skin and respiratory sensitisation potential. Glutaraldehyde has high repeat dose oral and inhalation toxicity, with an oral No-Observed-Adverse-Effect Level (NOAEL) of 4 mg/kg bw/day based on changes in liver and kidney weights and clinical chemistry parameters. Glutaraldehyde is not genotoxic or carcinogenic. It did not have any adverse effects on the reproductive system of adult rats or on the development of foetuses. The critical adverse health effects of glutaraldehyde are corrosivity, skin and respiratory tract sensitisation and acute and repeat dose oral and inhalation toxicity.
Key Study/Critical Effect for Screening Criteria	From the hazard characterisation, the critical (most sensitive) adverse health effects for repeated exposures to the chemical are changes in clinical chemistry parameters and relative organ (liver and kidney) weights. Glutaraldehyde has high repeat dose oral toxicity with an oral NOAEL of 4 mg/kg bw/day. This NOAEL is used in this human health risk assessment.
Ecological Toxicity [1,2,3,4]	

Aquatic Toxicity	96 h acute Bluegill sunfish LC50 = 11.2 mg/L 48 h acute Oyster larvae LC550 = 2.1 mg/L 96 h acute Green crabs LC50 = 465 mg/L 96 h acute Grass shrimp LC50 = 41 mg/L 48 acute Daphnia magna LC50 = 0.35 mg/L 48 acute Daphnia magna LC50 = 16.3 mg/L 21 d reproduct'n Daphnia magna LOEC = 4.3 mg/L, NOEC = 2.1 mg/L 96 h algal growth inhibition Selenastrum capricornutum ILm = 3.9 mg/L (median inhibitory limit) 96 h algal growth inhibition Scenedesmus subspicatus EC50 = 1.0 mg/L Bacterial inhibition Sewage microbes IC50 = 25-34 mg/L In summary, the test results indicate that glutaraldehyde is slightly to moderately toxic to aquatic fauna and moderately to highly toxic to algae. In some instances, glutaraldehyde appeared to be rapidly lost from test waters in the laboratory. Such behaviour in aquatic toxicity tests generally means that their results will underestimate the inherent toxicity of a substance. However, the toxicity that will prevail under environmental conditions is likely to be lower than that recorded in the laboratory in view of the rapid degradation that would be expected to occur in natural surface waters.
Determination of PNEC aquatic	As a wide selection of species is available, applying a safety factor of 10 to the NOEC (2.1 mg/L) derived from Daphnia seems most appropriate, giving a PNEC of 2100/10 = 0.21 mg/L for faunal species
Current Regulatory Controls [1,2,4]	
Australian Hazard Classification	Glutaraldehyde is classified as hazardous in the Hazardous Substances Information System (HSIS) with the following risk phrase (Safe Work Australia 2013): · T (Toxic); R23/25 (Toxic by inhalation and if swallowed) · C (Corrosive ; R34 (causes burns) · R42/43 (May cause sensitisation by inhalation and skin contact). Mixtures containing the chemical are classified as hazardous with the following risk phrases based on the concentration (Conc) of the chemical in the mixtures. The risk phrases for this chemical are: · Conc ≥50%: T; R23/25; R34; R42/43 (Toxic; toxic by inhalation and if swallowed; causes burns; may cause sensitisation by inhalation and skin contact) · ≥25% Conc <50%: T; R23; R22; R34; R42/43 (Toxic; toxic by inhalation, harmful if swallowed, causes burns; may cause sensitisation by inhalation and skin contact) · ≥10% Conc <25%: C; R20/22; R34; 42/43 (Corrosive; harmful by inhalation and if swallowed; causes burns; may cause sensitisation by inhalation and skin contact) · ≥2% Conc <10%: Xn; R20/22; R37/38; R41; R42/43 (Harmful; harmful by inhalation and if swallowed; irritating to respiratory system and skin; risk of serious eye damage; may cause sensitisation by inhalation and skin contact) · ≥1% Conc <2%: Xn; R36/37/38 R42/43 (Harmful; Irritating to eyes, respiratory system and skin; may cause sensitisation by inhalation and skin contact) · ≥0.5% Conc <1%: Xi; R36/37/38; R43 (Irritating; irritating to eyes, respiratory system and skin; may cause sensitisation by skin contact)
Australian Occupational Exposure Standards	The chemical has an exposure standard of 0.41 mg/m³, 0.1 ppm; Time Weighted Average (TWA).
International Occupational Exposure Standards	The following exposure standards are identified in Galleria Chemica (2013): · Occupational Exposure limit (TWA) of 0.2 mg/m3 [Canada, China, Denmark, Japan, Korea, UK] · 0.4 mg/m3 TWA [Sweden] · 0.8 mg/m3 TWA [US (NIOSH), Greece]
Australian Food Standards	No Australian food standards relating to the chemical have been identified (Food Standards Australia New Zealand 2013).
Australian Drinking Water Guidelines	No aesthetic or health-related guidance values were identified for this chemical in the Australian Drinking Water Guidelines. (National Health and Medical Research Council (NHMRC) 2011).

Aquatic Toxicity Guidelines	No data available.
PBT Assessment	
P/vP Criteria fulfilled?	No. Readily biodegradable and as such not persistent in the environment.
B/vB criteria fulfilled?	No. As the Log Pow is -0.01 (Log Pow < 4.5), it is not expected to be bioaccumulative.
T criteria fulfilled?	No. Chronic toxicity data >1 mg/L in invertebrates, thus glutaraldehyde does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	January 2019

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Toxicity Summary - Glyoxal (Ethanedial)

Chemical and Physical Properties[1,2,3]	
CAS number	107-22-2
Molecular formula	C2H2O2
Molecular weight	58.04
Solubility in water	600 g/L at 25 °C
Melting point	15 °C
Boiling point	50.4 °C
Vapour pressure	29.33 kPa at 20 °C
Henrys law constant	No data available.
Explosive potential	Non explosive
Flammability potential	Not classified
Colour/Form	Light yellow liquid with a mild odour at ambient temperatures; yellow crystals at 15 °C.
Overview	Glyoxal is generally available as an aqueous solution, typically containing 30-50% glyoxal in which hydrated oligomers are present. This chemical is used as a chemical intermediate in the production of pharmaceuticals and dyestuffs, as a cross-linking agent in the production of polymers, as a biocide, and as a disinfecting agent. Due to microbial activity as well as non-enzymatic autoxidation of oil or browning reactions of saccharides, glyoxal is frequently detected in fermented food and beverages. It is found in beer, wine and tea.
Environmental Fate[1]	
Soil/Water/Air	Glyoxal's production and use as a crosslinking agent in permanent-press fabrics, textiles, organic synthesis, glues, and biocides may result in its release to the environment through various waste streams. Glyoxal is also released to the environment from the combustion of wood, automobile exhaust, and the atmospheric degradation of aromatic and olefinic hydrocarbons. It may also be produced as a disinfection byproduct during the treatment of drinking water. Glyoxal is also endogenously produced by a variety of enzyme-independent pathways. If released to air, an extrapolated vapor pressure of 255 mm Hg at 25 deg C indicates glyoxal will exist solely in the vapor-phase. Vapor-phase glyoxal is degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals; the half-life for this reaction in air is estimated to be 34 hours. Glyoxal also undergoes direct photolysis, with an estimated atmospheric lifetime of 5 hours. If released to soil, glyoxal is expected to have very high mobility based upon an estimated Koc of 1. Volatilization from moist soil surfaces is not expected to be an important fate process based upon a Henry's Law constant of 3.33X10-9 atm-cu m/mole. The potential for volatilization of glyoxal from dry soil surfaces may exist based upon the extrapolated vapor pressure of this compound. Screening studies using sewage seed have indicated that glyoxal is readily biodegradable. If released into water, glyoxal is not expected to adsorb to suspended solids and sediment based upon the estimated Koc. Volatilization from water surfaces is not expected to be an important fate process based upon this compound's Henry's Law constant. Photolysis in sunlit surface waters is expected to be an important fate process because glyoxal absorbs light greater than 290 nm and undergoes direct photolysis in the atmosphere. Glyoxal is not expected to undergo hydrolysis in the environment due to the lack of hydrolyzable functional groups. An estimated BCF of 3 suggests the potential for bioconcentration in aquatic organisms is low.

Human Health Toxicity Summary [1]	
Chronic Repeated Dose Toxicity	From an oral 28 day repeat dose toxicity test conducted in accordance with OECD TG 407 a NOAEL was established at 40 mg/kg bw/day (active substance), based on dose-related changes in body weight gain at higher doses. A single inhalation toxicity study in rats revealed no systemic toxicity even at the highest dose of 0.4 mg/m^3.
Carcinogenicity	Results from several carcinogenicity studies, tumour initiation/promotion studies and in vitro cell transformation assays show that ethanedial is not carcinogenic.
Mutagenicity/ Genotoxicity	Ethanedial was shown to be mutagenic in both bacterial and mammalian cells in vitro. Unscheduled DNA synthesis was reported in one study in mice in vivo, but only within the pyloric sphincter and liver and not in more remote organs.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Available data on ethanedial and an analogue of ethanedial present in aqueous solutions suggest no effects on fertility or developmental toxicity in the absence of material toxicity.
Acute Toxicity	Ethanedial is moderately toxic via the oral and inhalation routes. In a guideline study in rats, an oral LD50 for a 40% ethanedial aqueous solution was reported at 3300 mg/kg bw. This corresponds to 1320 mg/kg bw/day for the active ingredient. An LC50 for inhalation toxicity was established at 2.44 g/L (active ingredient). Ethanedial is therefore considered to be of low dermal toxicity.
Irritation	Animal studies indicate that ethanedial is a skin and eye irritant
Sensitisation	Based on both animal and human studies, ethanedial is also considered a skin sensitiser.
Health Effects Summary	Ethanedial is moderately toxic via the oral and inhalation routes. In a guideline study in rats, an acute oral median lethal dose (LD50) for a 40% ethanedial aqueous solution was reported at 3 300 mg/kg bw. This corresponds to 1 320 mg/kg bw day for the active ingredient. A median lethal concentration (LC50) for inhalation toxicity was established at 2.44 g/L (active ingredient). Ethanedial is of low dermal toxicity. Animal studies indicate that ethanedial is a skin and eye irritant. From both animal and human studies, ethanedial is also a skin sensitiser.
Key Study/Critical Effect for Screening Criteria	A single repeat dose inhalation toxicity study in rats revealed no systemic toxicity even at the highest dose of 10 mg/m^3. From an oral 28-day repeat dose toxicity test conducted in accordance with OECD TG 407, a No-Observed-Adverse-Effect Level (NOAEL) was established at 40 mg/kg bw/day (active substance), based on dose related changes in body weight gain at higher doses. An adjustment factor of three is applied for inadequate duration of this study, as the no-effect dose was derived from a 28 day study. Consequently, for the purposes of quantifying the health risk of the chemical, an adjusted NOAEL of 13.3 mg/kg bw/day is used in this risk assessment.
Ecological Toxicity [1,2,3]	
Aquatic Toxicity	215 mg/L 96 h-LC50 fish. The result of the key study on freshwater invertebrates (BASF, 1988) indicates no acute toxicity of glyoxal (40% in aqueous solution) to Daphnia magna. The EC50 value is above 100 mg/L even when it is considered that no analytical monitoring was performed since glyoxal was shown to be stable at least for this 48-h period. In a GLP guideline study following OECD 210, the chronic treatment of early-life-stages of fish with the test item (Glyoxal 40%) under flow-through conditions resulted in no substance-related effects. Referring to the nominal concentrations of the active substance glyoxal, the NOEC was 119 mg a.i./L (BASF, 2009).
Determination of PNEC aquatic	An assessment factor of 100 has been applied to the reported LC50 of 215 mg/L for fish. The PNECaquatic is 2.15 mg/L.

Current Regulatory Controls[4]	
Australian Hazard Classification	Ethanedial is classified as hazardous for human health in the Hazardous Substances Information System (HSIS) with the following risk phrases (Safe Work Australia 2013): • Muta. Cat. 3 (Mutagenic Substances, Category 3) • R68 (Possible risk of irreversible effects) • Xn; R20 (Harmful by inhalation) • Xi; R36/38 (Irritating to eyes and skin) • R43 (May cause sensitisation by skin contact)
Australian Occupational Exposure Standards	No specific exposure standards were available.
International Occupational Exposure Standards	The following exposure standards are identified (Galleria Chemica 2013). Time Weighted Average (TWA): • 0.1 mg/m³ [Belgium, Columbia, Canada (Alberta, British Columbia, Saskatchewan), • Italy, Nicaragua, Portugal, Spain, United States of America] • 0.5 mg/m³ (0.2 ppm) [Denmark]. • Short Term Exposure Limit (STEL): • 0.3 mg/m³ [Canada (Saskatchewan)].
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No aesthetic or health-related guidance values were identified for this chemical in the Australian Drinking Water Guidelines (National Health and Medical Research Council (NHMRC) 2011).
Aquatic Toxicity Guidelines	No data available.
PBT Assessment[1,2]	
P/vP Criteria fulfilled?	Expected to be readily biodegradable and as such not persistent in the environment.
B/vB criteria fulfilled?	As the Log Pow is 0.85 (Log Pow < 4.5), it is not expected to be bioaccumulative.
T criteria fulfilled?	The acute aquatic toxicity of this chemical is >0.01 mg/L. Thus, it is not expected to meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	April 2019

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Toxicity Summary - Kaolin

Chemical and Physical Properties[1,2,4,5]	
CAS number	1332-58-7
Molecular formula	H2Al2Si2O8 H2O
Molecular weight	258 (approx)
Solubility in water	Insoluble
Melting point	No data available.
Boiling point	No data available.
Vapour pressure	No data available.
Henrys law constant	No data available.
Explosive potential	No data available.
Flammability potential	Not combustible
Colour/Form	White, greyish-white, or slightly coloured
Overview	Kaolin is a mixture of different minerals. Its main component is kaolinite and it frequently contains quartz, mica, feldspar, illite and montmorlilonite. Kaolinite composition is tiny sheets of triclinic crystals with pseudohexagonal morphology. It is formed by rock weathering. Kaolin is used in paper production, in paints, rubber, plastic, ceramic, chemical, pharmaceutical and cosmetic industries. It has a high fusion point and is the most refractory of all clays. A Tier 1 Human Health Assessment for this chemical has been conducted by NICNAS which concluded that it was low concern to human health.
Environmental Fate[4]	
Soil/Water/Air	Kaolin is a natural component of the soil and occurs widely in ambient air. It has a density of 2.1–2.6 g/cm^3. The cation exchange capacity of kaolinite is considerably less than that of montmorillonite, in the order of 2–10 meq/100 g, depending on the particle size, but the rate of the exchange reaction is rapid, almost instantaneous (Grim, 1968). Kaolinite adsorbs small molecular substances such as lecithin, quinoline, paraquat, and diquat, but also proteins, polyacrylonitrile, bacteria, and viruses (McLaren et al., 1958; Mortensen, 1961; Weber et al., 1965; Steel & Anderson, 1972; Wallace et al., 1975; Adamis & Timár, 1980; Schiffenbauer & Stotzky, 1982; Lipson & Stotzky, 1983). The adsorbed material can be easily removed from the particles because adsorption is limited to the surface of the particles (planes, edges), unlike the case with montmorillonite, where the adsorbed molecules are also bound between the layers (Weber et al., 1965). Upon heating, kaolinite starts to lose water at approximately 400 °C, and the dehydration approaches completeness at approximately 525 °C (Grim, 1968). The dehydration depends on the particle size and crystallinity.
Human Health Toxicity Summary [1,4]	
Chronic Repeated Dose Toxicity	Long-term exposure to kaolin may lead to a relatively benign pneumoconiosis, known as kaolinosis. Deterioration of lung function has been observed only in cases with prominent radiological alterations. Based on data from China clay workers in the United Kingdom, it can be very roughly estimated that kaolin is at least an order of magnitude less potent than quartz.
Carcinogenicity	A4; Not classifiable as a human carcinogen

Mutagenicity/ Genotoxicity	Recently, manufactured nano/microparticles such as fullerenes (C60), carbon black (CB) and ceramic fiber are being widely used because of their desirable properties in industrial, medical and cosmetic fields. However, there are few data on these particles in mammalian mutagenesis and carcinogenesis. To examine genotoxic effects by C60, CB and kaolin, an in vitro micronuclei (MN) test was conducted with human lung cancer cell line, A549 cells. In addition, DNA damage and mutations were analyzed by in vivo assay systems using male C57BL/6J or gpt delta transgenic mice which were intratracheally instilled with single or multiple doses of 0.2 mg per animal of particles. In in vitro genotoxic analysis, increased MN frequencies were observed in A549 cells treated with C60, CB and kaolin in a dose-dependent manner. These three nano/microparticles also induced DNA damage in the lungs of C57BL/6J mice measured by comet assay. Moreover, single or multiple instillations of C60 and kaolin, increased either or both of gpt and Spi- mutant frequencies in the lungs of gpt delta transgenic mice. Mutation spectra analysis showed transversions were predominant, and more than 60% of the base substitutions occurred at G:C base pairs in the gpt genes. The G:C to C:G transversion was commonly increased by these particle instillations. Manufactured nano/microparticles, CB, C60 and kaolin, were shown to be genotoxic in in vitro and in vivo assay systems.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	No data available.
Acute Toxicity	Occupationally inhaled kaolin produced chronic pulmonary fibrosis. In an acute oral study in which 120 rats were fed doses of Kaolin ranging from 100 to 210 g/kg. Fourteen rats were controls. Kaolin was inert and nonstatic except for the danger of bowel obstruction resulting in perforation. The clinical signs were listlessness, anorexia, oliguria, hypothermia, and dyspnea. These were a pathological reaction from over distension of the alimentary canal by an inert solid. The number of fatalities and the incidence and advance of bowel obstruction along the small intestine were dose related. The dose that killed 50% of the rats by bowel obstruction was 149 g/kg.
Irritation	Causes moderate eye irritation. May cause irritation of the respiratory system
Sensitisation	No data available.
Health Effects Summary	Kaolin is toxic to a variety of mammalian cells in vitro, and it produces transient inflammation in the lungs of experimental animals after intratracheal instillation.
Key Study/Critical Effect for Screening Criteria	No data available.

Ecological Toxicity [4]	
Aquatic Toxicity	The 24- and 48-h LC50 values for kaolinite toxicity to the water flea (Daphnia pulex) were >1.1 g/litre (Lee, 1976). Georgia kaolin caused <10% mortality of sea urchin (Strongylocentrosus purpuratus), Japanese clam (Tapes japonica), hermit crab (Pagurus hirsutiusculus), isopod (Sphaeroma pentodon), mud snail (Nassarius obsoletus), blue mussel (Mytilus edulis), and tunicates (Molgula manhattensis and Styela montereyensis) within 5–12 days. The 200-h LC10 values for coast mussel (Mytilus californianus), black-spotted bay shrimp (Crangon nigromaculata), migrant prawn (Palaemon macrodactylus), dungeness crab (Cancer magister), and the polychaete Neanthes succinea were 26, 16, 24, 10, and 9 g/litre, respectively. The 100-h LC10 values for the tunicate Ascidia ceratodes, amphipod Anisogammarus confervicolus, and shiner perch (Cymatogaster aggregata) were 7, 38, and 1 g/litre, respectively (McFarland & Peddicord, 1980). No effect on the hatching success or egg development rate of four marine fish species — red seabream (Pagrus major), black porgy (Acanthopagrus schlegeli), striped knifefish (Oplegnathus fasciatus), and threeline grunt (Parapristipoma trilineatum) — was observed at kaolinite concentrations up to 10 g/litre for 24 h. Larvae were more sensitive to kaolinite: the 12-h LC50 values were 170 and 710 mg/litre for P. trilineatum and O. fasciatus, respectively; mortality was also observed for P. major at concentrations of 1000 mg/litre and above (Isono et al., 1998).
Determination of PNEC aquatic	Kaolin has low toxicity to aquatic species, a large number of which have been tested. As such, $PNEC_{aquatic}$ has not been determined.
Current Regulatory Controls[2,3]	
Australian Hazard Classification	No hazard classification according to GHS criteria
Australian Occupational Exposure Standards	TWA: 10 mg/m^3
International Occupational Exposure Standards	TLV: (respirable fraction): 2 mg/m^3, as TWA
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	No data available.
PBT Assessment	
P/vP Criteria fulfilled?	Not applicable (inorganic salt, ionic species ubiquitous in environment)
B/vB criteria fulfilled?	Not applicable. Bioaccumulation is not applicable to these inorganic ions.
T criteria fulfilled?	Not applicable. Acute toxicity data >1 mg/L in water flea, thus Kaolin does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	April 2019

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Toxicity Summary - Methanol

Chemical and Physical Properties[1,3,4]	
CAS number	67-56-1
Molecular formula	CH4O
Molecular weight	32.04
Solubility in water	1,000 g/L at 20 °C
Melting point	-98 °C
Boiling point	65 °C
Vapour pressure	16.927 kPa at 25 °C
Henrys law constant	0.461 Pa m^3/mol
Explosive potential	Vapour/air mixtures are explosive
Flammability potential	Highly flammable
Colour/Form	Clear colourless liquid
Overview	Methanol occurs naturally in humans, animals and plants. The general population is exposed to methanol mainly through consumption of food and beverages and through use of consumer products such as paints, sealers and adhesives that contain methanol as a solvent.
Environmental Fate [1,3]	
Soil/Water/Air	Air is the main target compartment, based on a fugacity model calculation (Mackay Level III) with about 73 % of environmental methanol distributing to air and 16 % to water. Methanol is degraded in the atmosphere by photochemical, hydroxyl-radical dependent reactions. The estimated elimination half-life is calculated to be about 17-18 days with a rate constant of 0.93 x 10-2 cm3/molecule-sec. Methanol is completely miscible in water and has a low octanol/water partition coefficient. These properties are indicative of high mobility in soil.
Human Health Toxicity Summary [1,2,3]	
Chronic Repeated Dose Toxicity	Considering the no observed adverse effect level (NOAEL) available from a 90-day rat study (500 mg/kg bw/day), the chemical is not considered to cause serious damage to health by repeated oral exposure. In a 20-day inhalation study in monkeys, 3.9 mg/L (3000 mL/m3) was identified as the LOAEL (continuous exposure) where neurotoxic lesions appeared to progress in monkeys (according to NEDO 1987). This exposure concentration correlated with methanol blood levels 80 mg/L and formate levels 30 mg/L. There was no evidence of adverse effects in rats exposed to methanol up to 6.6 mg/L, six hours/day for 28 days, except local nasal irritation and increased relative spleen weights, which were observed only at the middle dose and not considered treatment-related (Andrews et al. 1987). A NOAEL could not be established in this study. In the chronic exposure studies in rats and mice, slight treatment-related decreases in body and organ weights were reported at the highest dose. These are however not considered as ‘adverse’ effects. In monkeys, slight degeneration of the inside nucleus of the thalamus was observed at 0.13 and 1.3 mg/L after seven months or more (NEDO 1987). One monkey at 0.13 mg/L and two at 1.3 mg/L showed slight but clear changes in peroneal nerves indicating damage to peripheral nerves. Some signs of fibrosis at 1.3 mg/L, which were considered borderline. There were mild but significant effects on heart and kidney at 0.13 and 1.3 mg/L. Histologically, a significant increase of Sudan positive granules was noted in the 1.3 mg group without pathological manifestations (e.g. fibrosis). Although the authors considered the lowest dose (0.013 mg/L) as the LOAEL, it was observed that effects at this dose were very mild and reversible and therefore not considered to be adverse effects. Based on these observations, a NOAEL of 0.013 mg/L was established in this study.

Carcinogenicity	The chemical is not likely to be a carcinogen. In a chronic inhalation study, Fisher rats and B6C3F1 mice were exposed to 0.013, 0.13, and 1.3 mg/L methanol for 24 and 18 months, respectively (NEDO 1987). No differences in survival were noted in the treatment groups compared with the control group. There was no evidence of an increase in liver tumours in rats or in the spontaneous liver tumour rate in mice. In the rats, some tumours such as papillary lung adenomas (males only), adrenal phaeochromocytomas (females only) and metastatic (transition) tumours appeared at a somewhat higher incidence in high-dose group rats after week 79 and 104 without clear dose-response relationship. However these tumour incidences were not statistically significantly different from those in the control group. In the mice, there were no appreciable differences from the control in either numbers of animals with tumours or in degree of malignancy observed. Proliferative effects on the astroglia cells were observed in monkeys continuously exposed to 0.013, 0.13 and 1.3 mg/L methanol by the inhalation route (NEDO 1987). These effects however were of a transient nature and disappeared after a six-month recovery period. There were no signs of histological degeneration.
Mutagenicity/ Genotoxicity	Methanol has been examined in numerous in vitro and in vivo test systems, including bacterial, mammalian and fungal test systems. Most in vitro studies did not demonstrate mutagenic activity. A small number of studies gave ambiguous results. All other studies produced negative results consistently. The majority of in vivo assays were negative for mutagenicity and clastogenicity (OECD 2004). Methanol was therefore concluded to be not mutagenic.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	No impairment of fertility or reproductive performance was reported in male and female rats exposed to the chemical, except at very high doses. Male mice had morphological anomalies in spermatozoa after repeated oral dosing at 1000 mg/kg bw/day (blood level > 500 to 1000 mg/L in mice) (OECD 2004). Rodent studies indicate that methanol has developmental toxicity effects. The rodent data on developmental toxicity are relevant for humans despite the known differences in methanol metabolism between the two species. However, rodents are considered adequate models for humans only at levels where formate does not accumulate (NTP 2003). Blood methanol levels associated with serious developmental effects in rodents were in the range associated with formate accumulation (1000 to 2000 mg methanol per litre of blood), which is likely to result in metabolic acidosis, and visual and clinical effects in humans (NTP 2003; OECD 2004). The limited data available in humans do not show an association between reproductive and developmental toxicity and methanol (NTP 2003). Following a review of the developmental toxicity studies, the NTP concluded that there is evidence to suggest that females with low folate levels may be more susceptible to the adverse developmental effects of methanol, but more information was necessary to clarify this issue (NTP 2003). Based on the data available, the chemical is not considered to have reproductive or developmental toxicity in humans.

Acute Toxicity	In rats, mice, rabbits and dogs, the LD50 values after single oral administration range from about 5600 to 14 400 mg/kg bw (EHC 1997). Adverse effects noted in these animals were ataxia, narcosis and coma after high methanol doses. The animals did not exhibit acidosis and ophthalmologic changes typically seen in humans at high lethal and sub-lethal doses In rhesus monkeys, no deaths were reported at doses of 1000 to 2000 mg/kg bw, while animals receiving 3000 to 8000 mg/kg bw died within two days (OECD 2004). Treated animals showed acidosis, and some exhibited semi-coma and ophthalmologic changes. Human data, however, indicate acute oral toxicity at comparatively lower doses of 300 to 1000 mg/kg bw (EHC 1997). The reported median lethal doses (LD50) for experimental animals are 7300 mg/kg bw (mouse), 5628 mg/kg bw (rat), 14 200 mg/kg bw (rabbit) and 7000 mg/kg bw (monkey). The lowest lethal dose (LDLo) for humans ranges from 143 to 428 mg/kg bw (ChemIDplus 2012). There are limited available dermal toxicity studies in animals. In one dermal exposure study all the rats survived after application of 35 000 mg/kg bw methanol to the skin under occlusive conditions, while deaths were reported at 45 000 mg/kg bw (Eulner and Gedicke 1955). In rabbits, a dermal LD50 of 17 000 mg/kg bw was reported although no details of the study were provided (Carnegie-Mellon 1981). Limited data in monkeys indicate that the chemical is toxic via the dermal route (McCord 1931). Humans have been found to be more susceptible to methanol as compared to monkeys. Therefore, acute dermal toxicity with methanol is expected in humans (OECD 2004). The lowest reported dermal LD50 is 17 000 mg/kg bw, which was recorded in rabbits. Median lethal concentrations (LC50) of 87.5 and 128.2 mg/L were reported in rats following six and four hour inhalation exposures to methanol, respectively (BASF 1980a, 1980b). Clinical signs of toxicity were secretions from eyes and nose, laboured breathing, staggering, apathy and narcosis. A similar LC50 value (79 mg/L) was reported for mice following 2.25 hours exposure (Von Burg 1994). In cats, LC50 values after six-hour exposures ranged from 26 to 48 mg/L. A shorter duration of 4.5 hours led to an LC50 of 85.4 mg/L (Von Burg 1994). Studies in Rhesus monkeys indicated lethal concentrations (percent mortality not reported) at 13 mg/L after 18 hour exposure and 52 mg/L after one to four hour exposure (OECD 2004).
Irritation	The chemical is not a skin irritant. The chemical is a slight eye irritant in rabbits. High concentration of methanol vapours may cause irritation of the respiratory tract. In a short-term exposure study (details not available), exposure of rats to an atmosphere saturated with methanol vapours produced severe irritation of mucous membranes and milky corneal opacity (BASF 1975). All animals died after eight hours (BASF 1975).
Sensitisation	The chemical is not a skin sensitiser.
Health Effects Summary	Methanol has low acute oral, dermal and inhalation toxicity in experimental animals but moderate to high acute oral and dermal toxicity in humans. A Lowest Lethal Dose (LDLo) of 143 - 428 mg/kg bw (humans) has been reported. It is not a skin or eye irritant but is expected to be a moderate respiratory irritant, based on its effect on the mucous membrane in rats exposed to methanol vapours and on the effects observed in repeat dose inhalation studies. Tests with guinea pigs indicated that methanol is not a skin sensitiser. The critical effects to human health are acute toxicity from inhalation, skin contact and swallowing, and possible irreversible effects from acute oral exposure. No deaths were reported in Rhesus monkeys dosed at 2 000 mg/kg bw, but treated animals showed acidosis, and some exhibited semi-coma and ophthalmic changes. Human data, however, indicate acute oral toxicity and ophthalmic changes at comparatively lower doses of 300 - 1 000 mg/kg bw. Information on repeated dose toxicity by the dermal route is not available. Methanol was not genotoxic or carcinogenic. Reproductive and developmental toxicity studies did not show any significant effects of relevance to humans.

Key Study/Critical Effect for Screening Criteria	A No-Observed-Adverse-Effect-Concentration (NOAEC) of 0.013 mg/L (13 mg/m3) is used for this risk assessment. This NOAEC is derived from a chronic inhalation study in monkeys, in which degenerative effects in the brain and slight damage to the optic and peripheral nerves were noted at 0.13 mg/L and above. Changes in peroneal nerves were also noted in higher dosed animals, indicating damage to peripheral nerves. An oral No Observed Adverse Effect Level (NOAEL) of 500 mg/kg bw/day was also established in rats in a 90-day oral study based on increased liver enzymes (enzymes not specified) and decreased absolute brain weights at the highest dose. This value is not used in this risk assessment because acute oral data indicate that humans are more sensitive to methanol toxicity than rodents.
Ecological Toxicity [2,3]	
Aquatic Toxicity	In several 96-hour studies in fish in which methanol concentrations were measured during the tests, LC50s ranged from 15,400 to 29,400 mg/L. In the chronic toxicity study to invertebrates, the NOEC was 32,000 mg/L.
Determination of PNEC aquatic	A PNECaqua = 3.20E+03 mg/L can be calculated based on the lowest chronic toxicity value for aquatic invertebrates (Daphnia) with the assessment factor of 10.
Current Regulatory Controls[4]	
Australian Hazard Classification	The chemical is classified as hazardous with the following risk phrases for human health in the Hazardous Substances Information System (HSIS) (Safe Work Australia): T; R23/24/25 (acute toxicity) T; R39/23/24/25 (irreversible effects from acute exposure) Mixtures containing the chemical are classified as hazardous based on the concentration (Conc) of the chemical in the mixtures. The risk phrases for this chemical are: Conc ≥20%: T; R23/24/25; (Toxic: Toxic by inhalation, in contact with skin and if swallowed); R39/23/24/25; (Toxic: danger of very serious irreversible effects through inhalation, in contact with skin and if swallowed) 10% ≤Conc <20%: T; R20/21/22; (Toxic: Harmful by inhalation, in contact with skin and if swallowed); R39/23/24/25; (Toxic: danger of very serious irreversible effects through inhalation, in contact with skin and if swallowed) 3% ≤Conc <10%: Xn; R20/21/22; (Harmful: Harmful by inhalation, in contact with skin and if swallowed); R68/20/21/22; (Harmful: possible risk of irreversible effects through inhalation, in contact with skin and if swallowed).
Australian Occupational Exposure Standards	The chemical has an exposure standard of 262 mg/m³ (200 ppm) Time Weighted Average (TWA) and 328 mg/m³ (250 ppm) Short-Term Exposure Limits (STEL) (Safe Work Australia).

International Occupational Exposure Standards	The following were identified (Galleria Chemica): 250-270 mg/m³ (200 ppm) TWA in USA, Canada, Denmark, United Kingdom, Germany, France, Estonia, Greece, Hungary, South Africa, Spain, Singapore, Taiwan, Sweden, Malta, Malaysia, Latvia, Japan, Indonesia, India, Iceland, Egypt, Ireland, Mexico, Philippines and Switzerland; 250-350 mg/m³ (250-328 ppm) STEL in USA, Canada, United Kingdom, Greece, South Africa, Singapore, Sweden, India, Egypt and Mexico; 50 mg/m³ TWA in Bulgaria; 100 mg/m³ TWA and 300 mg/m³ STEL in Poland; 133 mg/m³ TWA in Netherlands; 25 mg/m³ TWA and 50 mg/m³ STEL in China; 1300 mg/m³ (1000 ppm) STEL in France; and 1040 mg/m³ STEL in Hungary and Switzerland.
Australian Food Standards	No Australian food standards were identified (FSANZ 2013)
Australian Drinking Water Guidelines	No aesthetic or health-related guidance values were identified for methanol in the Australian Drinking Water Guidelines (National Health and Medical Research Council (NHMRC) 2011).
Aquatic Toxicity Guidelines	No data available.
PBT Assessment	
P/vP Criteria fulfilled?	No. Methanol is expected to be readily biodegradable.
B/vB criteria fulfilled?	No. The Log Kow for methanol is -0.82 to -0.64. Thus, methanol does not meet the screening criteria for bioaccumulation.
T criteria fulfilled?	No. The EC50s from the acute aquatic toxicity data on methanol are >1 mg/L, hence does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	January 2019

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Toxicity Summary - Potassium chloride

Chemical and Physical Properties [1,2,3,8,9,10]	
CAS number	7447-40-7
Molecular formula	KCl
Molecular weight	74.55 g/mol
Solubility in water	34.20 at 20 °C
pH	7
Melting point	771.00 °C
Boiling point	1500 °C
Vapour pressure	No data found
Henrys law constant	No data found
Explosive potential	Not explosive
Flammability potential	Not flammable
Colour/Form	White crystals or crystalline powder
Overview	Potassium is an essential element in the body. It is the main intracellular cation with 98% of total body potassium located within the cells. It is mainly used in fertilisers, medicine, lethal injections, scientific applications, feedstock, food processing and as a sodium substitute in table salt. Potassium chloride is an essential element with homeostatic physiological processes regulating levels in the body. In cases of increased exposure to high levels of potassium significant health effects in people with kidney disease or other conditions, such as heart disease may result. Potassium chloride as an inorganic salt is not subjected to further degradation processes in the environment once it dissociates into its respective ions. In water, potassium chloride is highly water soluble, and readily undergoes dissociation. In soil, transport and leaching of potassium and chloride ions is affected by the clay minerals (type and content), pH, and organic matter. This chemical has been identified by NICNAS to be of low concern to human health based on an initial screening approach and thus required no further assessment.
Environmental Fate [1,3,8,9]	
Soil/Water/Air	KCl is a solid inorganic salt that is highly soluble in water (342 g/L at 20° C). Potassium chloride fully dissociates in aqueous solutions to K+ and Cl- ions. Cl, either as an inorganic salt or as K+ and Cl- ions, is ubiquitous in the environment. There is no potential for bioaccumulation or bioconcentration. Potassium and chloride ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated.

Human Health Toxicity Summary [1,3,8,9]	
Chronic Repeated Dose Toxicity	Fourteen female rats were given KCl in their drinking water (approximately 5,250 mg/kg/day) for 105 days. Ten rats were sacrificed after 105 days of exposure for examination of the heart, kidneys and the adrenals; four rats (recovery group) were kept for an additional month. KCl exposure resulted in decreased heart weight, increased kidney weight, and enlargement of part of the adrenals. All changes were reversible within one month of exposure (Bacchus, 1951).F344/Slc male rats were given 0, 110, 450 or 1,820 mg/kg/day KCl in feed for two years. At the end of the study, survival rates were 48%, 64%, 58% and 84% in the controls, 110, 45 and 1,820 mg/kg/day groups. Nephritis was reported to be predominant in all groups, including the controls. The only treatment-related effect observed was gastritis(inflammation of the stomach lining). The incidence of gastritis and ulcers were 6%, 18%, 18% and 30% in the controls, 110, 450 and 1,820 mg/kg/day groups (Imai *et al.*, 1968). Male and female Wistar rats were fed diets containing 0 or 3% KCl over a total period of 30 months: Examination after 13 weeks (10 rats/sex/group), after 18 months (15 rats/sex/group) and after 30 months (50 rats/sex /group). Due to the reduction of feed intake the mean test substance intake and mean body weight decreased in time. After 30 months of treatment, there was hypertrophy of the zona glomerulosa in the adrenals (24/50 treated rats versus 4/50 in controls); and cystitis in the urinary bladder (males: 3/59; females 3/50) and single epithelial hyperplasia of the bladder (males 3/50; females 2/50) (Lina *et al.*, 1994; Lina and Kuijpers, 2004).
Carcinogenicity	Potassium chloride has not been evaluated and is not listed by the IARC as a carcinogen. In a long-term study, male rats (50 per group) were fed potassium chloride in the diet at levels of 110, 450 or 1820 mg/kg bw/day for 2 years. No carcinogenic effects were observed in male rats.
Mutagenicity/ Genotoxicity	No gene mutation ns were reported in bacterial tests, with and without metabolic activation. However, high concentrations of potassium chloride showed positive results in a range of genotoxic screening assays using mammalian cells in culture. The action of potassium chloride in culture seems to be an indirect effect therefore further *in vivo* studies were not considered necessary.
Reproductive Toxicity Developmental Toxicity/Teratogenicity	A developmental study revealed no foetotoxic or teratogenic effects of potassium chloridel in doses up to 235 mg/kg/day (mice) and 310 mg/kg/day (rats). No fertility study has been located. Further human and ecological assessment was not recommended by the OECD SIDS.
Acute Toxicity	Potassium chloride is an essential element with homeostatic physiological processes regulating levels in the body. In cases of increased exposure to high levels of potassium significant health effects in people with kidney disease or other conditions, such as heart disease may result. Adverse health effects due to consumption of potassium from drinking water are unlikely to occur in healthy individuals. Acute effects are rare in humans although under particular circumstances severe effects may occur. Lethal effects were observed in a 2 month old baby fed 15,000 mg potassium chloride for 2 days and in another case report where an adult woman had ingested slow released potassium chloride tablets (35, 000 mg). The most common form of ingestion is through drinking water. It is not considered necessary to establish a health-based guideline value for potassium in drinking water due to its lack of toxicity.
Irritation	Slight skin and eye irritant. A threshold concentration for skin irritancy of 60% was seen when potassium chloride in aqueous solution was in contact with skin of human volunteers. The threshold concentration when applied to broken skin was 5%.
Sensitisation	No data found.
Health Effects Summary	This chemical has been identified by NICNAS to be of low concern to human health and it is listed by the US Food and Drug Administration (FDA) as a Generally Recognised as Safe (GRAS) substance.

Key Study/Critical Effect for Screening Criteria	In a two-year rat feeding study, there was an increased incidence of gastritis and ulcers at dose levels of >110 mg/kg/day (Imai *et al.*, 1968). There was no NOAEL. Thus, the LOAEL for this study is 110 mg/kgday. Since the gastritis and ulcers are the result of a localized irritation effect of the test substance (site of contact) in the gastrointestinal tract, an uncertainty factor for interspecies variability is deemed unnecessary. For systemic effects, the NOAEL for the two-year rat feeding study is considered to be 1,820 mg/kg/day, the highest dose tested. Uncertainty factors: 10 (intraspecies variability); 10 (interspecies variability); 1 (intraspecies variability) Oral Reference Dose = 1,820/100 = 18.2 mg/kg/day Drinking water guideline: 71 ppm
Ecological Toxicity [1,3,8,9,10]	
Aquatic Toxicity	In a guideline study, the 96-hour LC50 in *Pimephales promelas* was reported to be 880 mg/L (Mount *et al.*, 1997). The 48-hour LC50 values from two studies on *Lepomis macrochirus* (Patrick *et al.*, 1968; Trama, 1954), and one study each on *Oncorhyncusmykiss* and *Ictalurus punctatus* (Waller *et al.*, 1993) ranged from 720 to 2,010 mg/L. In a guideline study, the 48-hour EC50s in *Daphnia magna* and *Ceriodaphnia dubia* were 660 and 630 mg/L, respectively (Mount *et al.*, 1997; ECHA REACH database). The 48-hour EC50 in *Daphnia magna* in another study was also reported to be 177 mg/L (Biesinger and Christensen, 1972).The toxicity of KCl has been investigated in one algae species (*Nitzschia linearis*), showing 120 hour-EC50 (growth rate) of 1,337 mg/L (Patrick *et al.*, 1968). The 72-hour EC50 to *Scenedesmus subspicatus* is >100 mg/L (growth rate), with a NOEC of >100 mg/L (ECHA REACH database). In a fish early-life-stage test with the fathead minnow (*Pimephales promelas*), the 7-day NOEC is 500 mg/L (ECHA REACH database). A long term (21-day) study has been performed on *Daphnia magna* where effects on reproduction were investigated for several metals. A 16% impairment of reproduction (LOEC) was observed at a concentration of 53 mg/L of K +, equal to KCl concentration of 101 mg/L (Biesinger and Christensen, 1972). The measured NOEC for Daphnia is 373 mg/L
Determination of PNEC aquatic	PNECaquatic: On the basis of the chronic results for Daphnia, an assessment factor of 100 has been applied to the lowest reported effect concentration of 373 mg/L. The PNECaquatic is determined to be 3.73 mg/L.
Current Regulatory Controls	
Australian Hazard Classification	No data available
Australian Occupational Exposure Standards	No data available
International Occupational Exposure Standards	No data available
Australian Food Standards	No data available
Australian Drinking Water Guidelines	No data available
Aquatic Toxicity Guidelines	No data available
PBT Assessment [1,8,9,10]	
P/vP Criteria fulfilled?	Potassium chloride is an organic salt that dissociates completely to potassium and chloride ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both potassium and chloride ions are also ubiquitous and are present in most water, soil and sediment. For the purposes of this PBT assessment, the persistent criteria is not considered applicable to this inorganic salt.
B/vB criteria fulfilled?	Potassium and chloride ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, potassium chloride is not expected to bioaccumulate.

T criteria fulfilled?	The measured chronic toxicity data for potassium chloride was 373 mg/L for Daphnia. Thus, potassium chloride does not meet the screening criteria for toxicity
Overall conclusion	Not PBT
Revised	April 2018

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Toxicity Summary - Smectite

Chemical and Physical Properties[1,2,3]	
CAS number	12199-37-0
Molecular formula	No data available.
Molecular weight	No data available.
Solubility in water	No data available.
Melting point	No data available.
Boiling point	No data available.
Vapour pressure	No data available.
Henrys law constant	No data available.
Explosive potential	No data available.
Flammability potential	No data available.
Colour/Form	Off-white to tan fine flakes or powder
Overview	Smectites commonly result from the weathering of basic rocks. Smectite formation is favoured by level to gently sloping terranes that are poorly drained, mildly alkaline (such as in marine environments), and have the high Si and Mg potentials (Borchardt, 1977). Other factors that favour the formation of smectites include the availability of Ca and the paucity of K (Deer and others, 1975). Poor drainage is necessary because otherwise water can leach away ions (e.g. Mg) freed in the alteration reactions. Smetites are used in the industry as fillers, carriers, absorbents and a component in drilling fluids (Grim, 1962). A Tier 1 Human Health Assessment for this chemical has been conducted by NICNAS which concluded that it was low concern to human health.
Environmental Fate[4*]	
Soil/Water/Air	Limited data is available for smectite, read across data has been obtained from bentonite. Bentonite is a rock formed of highly colloidal and plastic clays composed mainly of montmorillonite, a clay mineral of the smectite group, and is produced by in situ devitrification of volcanic ash. Bentonite's production and use in domestic products, cat litter, construction materials, ceramics, pharmaceuticals, beer and wine production and cosmetics may result in its release to the environment through various waste streams. Its use in drilling muds, in agricultural practice as a carrier and an animal feed binder will result in its direct release to the environment. Bentonite is a colloidal native hydrated aluminum silicate (clay) found in midwest of USA and in Canada. Occupational exposure to bentonite may occur through inhalation of dust and dermal contact with this compound at workplaces where bentonite is produced or used. Use data indicate that the general population may be exposed to bentonite via ingestion of and dermal contact with consumer products containing bentonite.
Human Health Toxicity Summary[4*]	
Chronic Repeated Dose Toxicity	Mice maintained on diets containing bentonite displayed slightly reduced growth rates. Mice treated with higher doses showed minimal growth and fatty livers and fibrosis of the liver and benign hepatomas. Bentonite increased the susceptibility of mice to pulmonary infection.
Carcinogenicity	No adequate studies are available on the carcinogenicity of bentonite.

Mutagenicity/ Genotoxicity	The genotoxic potential of bentonite particles (diameter < 10 um) with an a-quartz content of up to 6% and different chemical modifications (alkaline, acidic, organic) was investigated. Human lung fibroblasts (IMR90) were incubated for 36 hr, 48 hr, or 72 hr with bentonite particles in concentrations ranging from 1 to 15 ug/sq cm. Genotoxicity was assessed using the micronucleus (MN) assay and kinetochore analysis. The generation of reactive oxygen species (ROS) caused by bentonite particles via Fenton-like mechanisms was measured acellularly using electron spin resonance (ESR) technique and intracellularly by applying an iron chelator. The results show that bentonite-induced genotoxic effects in human lung fibroblasts are weak. The formation of micronuclei was only slightly increased after exposure of IMR90 cells to an acidic sample of bentonite dust with a quartz content of 4-5% for 36 hr (15 ug/sq cm), 48 hr (5 ug/sq cm), and 72 hr (1 ug/sq cm), to an alkaline sample with a quartz content of 5% for 48 hr and 72 hr (15 ug/sq cm), and to an acidic bentonite sample with 1% quartz for 72 hr (1 ug/sq cm). Native (untreated) and organic activated bentonite particles did not show genotoxic effects in most of the experiments. Also, bentonite particles with a quartz content < 1% were negative in the micronucleus assay. Generation of ROS measured by ESR was dependent on the content of transition metals in the sample but not on the quartz content or the chemical modification. Reduction of MN after addition of the iron chelator 2,2'-dipyridyl showed that ROS formation also occurs intracellularly. It was concluded that the genotoxic potential of bentonite particles is generally low but can be altered by the content of quartz and available transition metals.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Limited studies did not demonstrate developmental toxicity in rats after oral exposure to bentonite.
Acute Toxicity	Single intratracheal injection into rodents of bentonite and montmorillonite with low quartz content caused dose and particle side dependent effects, as well as transient local inflammation, which included oedema and increased lung weight. Single intratracheal exposures of rats to bentonite caused storage foci in the lungs. After intratracheal exposure of rats to this material with high quartz content, fibrosis is noted.
Irritation	The powder may contain large amounts of free silica which can produce pneumoconiosis with chronic inhalation.
Sensitisation	No data available.
Health Effects Summary	The substance can be absorbed into the body by inhalation. The substance is mildly irritating to the eyes and skin. The substance may have effects on the lungs. This may result in fibrosis.
Key Study/Critical Effect for Screening Criteria	No study available.
Ecological Toxicity [4*]	
Aquatic Toxicity	The 96-h LC50 for rainbow trout (Oncorhynchus mykiss) of Wyoming bentonite, used as a viscosifier in drilling fluids, was 19 g/litre (Sprague & Logan, 1979).
Determination of PNEC aquatic	PNEC has not been calculated.
Current Regulatory Controls	
Australian Hazard Classification	No data available.
Australian Occupational Exposure Standards	No data available.
International Occupational Exposure Standards	No data available.
Australian Food Standards	No data available.

Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	No data available.
PBT Assessment[4]	
P/vP Criteria fulfilled?	No data available for Smectite. Information on bentonite reported that Biodegradation of bentonite appears to be minimal.
B/vB criteria fulfilled?	No, bioaccumulation appear minimal for montmorillonite compounds
T criteria fulfilled?	No, read across data from bentonite reported 96h LC50 for fish was > 1 mg/L. Thus, it is not expected to meet the toxicity criteria.
Overall conclusion	Not PBT
Revised	April 2019

* No data available for Smectite. Toxicity data for Bentonite is presented as a surrogate.

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Toxicity Summary - Sodium bicarbonate

Chemical and Physical Properties [1,2,4,5,6]	
CAS number	144-55-8
Molecular formula	NaHCO3
Molecular weight	84.01
Solubility in water	96 g/L (at 20 °C)
Melting point	Decomposes when heated over 50 °C
Boiling point	Decomposes
Vapour pressure	Negligible, ionizable inorganic compound
Henrys law constant	No data available
Explosive potential	No data available
Flammability potential	No data available
Colour/Form	white, odourless, crystalline powder
Overview	Sodium bicarbonate is classified by the U.S. Food and Drug Administration (FDA) as a 'Generally Recognised as Safe' (GRAS) ingredient in food with no other limitation than current good manufacturing practice (FDA, 1978; FDA, 1983). In the EU it is approved as a food additive (EU, 2000) and a feed ingredient (EU, 1998).In Australia it is recognised by Food Standards Australia New Zealand (FSANZ) as a food additive. Sodium bicarbonate is used as animal feed additive, human food additive and it is used in pharmaceuticals. It is also used for the production of other chemicals and used in cosmetics and detergents and other household cleaning products. A Tier 1 Human Health Assessment for this chemical has been conducted by NICNAS which concluded that it was low concern to human health.
Environmental Fate[3]	
Soil/Water/Air	The high water solubility and low vapour pressure indicate that sodium bicarbonate will be found predominantly in the aquatic environment. Sodium bicarbonate is present in the environment as sodium and bicarbonate ions, which implies that it will not adsorb on particulate matter or surfaces and will not accumulate in living tissues.
Human Health Toxicity Summary [2,3]	
Chronic Repeated Dose Toxicity	There are no directly relevant studies on repeated dose exposure, however, knowledge of prior use and available literature does not indicate any adverse effects of long-term use of exposure via any route. In humans there is a long history of sodium bicarbonate used as an antacid in doses up to 4 g without adverse effects of long-term use, although it is recommended not to use high doses of pure sodium bicarbonate instead of antacids. In addition, sodium bicarbonate is an important extracellular buffer in vertebrates and is therefore readily regulated in the body.
Carcinogenicity	As with other sodium salts, high doses of sodium bicarbonate promote carcinoma formation in rat urinary bladder after pre-exposure to initiator or BBN. However, when rats were only exposed to sodium bicarbonate no carcinogenic effect on the urinary bladder was found. Based on the available information there are no indications that sodium bicarbonate has carcinogenic effects.
Mutagenicity/ Genotoxicity	*In vitro* bacterial and mammalian cell tests showed no evidence of genotoxic activity.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Sodium bicarbonate did not induce developmental effects when administered orally at the following doses: 580 mg/kg bw (mice), 340 mg/kg bw (rats) and 330 mg/kg bw (rabbits). Furthermore the substance will usually not reach the foetus when the exposure to sodium bicarbonate is sufficiently low, as it does not become systemically available.

Acute Toxicity	Acute oral ingestion by the patients may result in a ruptured stomach due to excessive gas development. Acute or chronic excessive oral ingestion may cause metabolic alkalosis, cyanosis and hypernatraemia. These conditions are usually reversible, and will not cause adverse effects.
Irritation	Sodium bicarbonate is a minimal or mild ocular and skin irritant
Sensitisation	No data available
Health Effects Summary	This chemical has been identified by NICNAS to be of low concern to human health.
Key Study/Critical Effect for Screening Criteria	The Australian drinking water screening value for sodium (180 ppm, aethestic) and pH may apply to sodium bicarbonate.
Ecological Toxicity [3]	
Aquatic Toxicity	In a 96-hr acute flow-through test with rainbow trout (Oncorhynchus mykiss) a NOEC of 2,300 mg/l and a LC50 of 7,700 mg/l were determined. The test was conducted under GLP conditions and according to FIFRA Guideline Reference number 72-1. In a 96-hr acute flow-through test with bluegill sunfish (Lepomis macrochirus) a NOEC of 5,200 mg/l and a LC50 of 7,100 mg/l were determined. The test was conducted under GLP conditions and according to FIFRA Guideline Reference number 72-1. In a 48-hr acute flow-through test with Daphnia magna a NOEC of 3,100 mg/l and a LC50 of 4,100 mg/l were determine. The test was conducted under GLP conditions and according to FIFRA Guideline Reference number 72-2. A (chronic) reproduction test with Daphnia magna was carried out. Test solutions were prepared to contain the appropriate concentrations of salts to yield a total hardness of170 mg/l $CaCO_3$. At the tested concentration $NaHCO_3$ of 576 mg/l the survival was 100% and the cumulative number of offspring per female did not significantly differ from the control. This demonstrates that the 21-day Daphnia magna NOEC is higher than 576 mg/l. Standard toxicity tests with algae or aquatic plants have not been found, but test medium for acute algae tests contain 50 mg/l sodium bicarbonate. Glass slides were exposed to a portion of a small stream with an addition of sodium bicarbonate to a concentration of 45 mg/l for a period of 63 days. An increasing algal standing crop compared to the controls was found. Except for a small increase of Cyanophycea species, no shift in species was determined.
Determination of PNEC aquatic	It is not considered useful to calculate a PNEC for sodium bicarbonate because factors such as the buffer capacity, the natural pH, and the fluctuation of the pH are very specific for a certain ecosystem. Based on the information above, a PNECaquatic was not derived for sodium bicarbonate.
Current Regulatory Controls[4]	
Australian Hazard Classification	No data available
Australian Occupational Exposure Standards	No data available
International Occupational Exposure Standards	No data available
Australian Food Standards	No data available
Australian Drinking Water Guidelines	No data available
Aquatic Toxicity Guidelines	No data available
PBT Assessment	
P/vP Criteria fulfilled?	Sodium bicarbonate is an inorganic salt that is present in the environment as sodium and bicarbonate ions. Biodegradation is not applicable to these inorganic ions. Thus, the persistent criterion is not considered applicable to this inorganic salt.
B/vB criteria fulfilled?	Sodium and bicarbonate ions are essential to all living organisms and its

	extracellular concentrations are actively regulated. Thus, sodium bicarbonate is not expected to bioaccumulate.
T criteria fulfilled?	The 21 d chronic NOEC is 576 mg/L for Daphnia. Thus, sodium bicarbonate does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	March 2019

References

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Toxicity Summary - Sodium carbonate

Chemical and Physical Properties[1,2,3,4,6]	
CAS number	497-19-8
Molecular formula	Na_2CO_3
Molecular weight	105.99 g/mol
Solubility in water	215 g/l at 20 °C
Melting point	851 °C
Boiling point	Decomposition
Vapour pressure	No data found
Henrys law constant	No data found
Explosive potential	It reacts violently with acids and reacts with magnesium, phosphorous pentoxide causing explosion hazard
Flammability potential	Reacts with fluorine causing fire hazard
Colour/Form	White powder
Overview	Sodium carbonate has been reviewed in the OECD-SIDS program (OECD, 2002a,b).Sodium carbonate is a strong alkaline compound with a pH of 11.6 for a 0.1M aqueous solution. The pKa of carbonate (CO3 2-) is 10.33, which means that at a pH of 10.33 both carbonate and bicarbonate are present in equal amounts. In water, sodium carbonate dissociates into sodium ion (Na+) and carbonate (CO3 2-). The carbonate ions will react with water, resulting in the formation of bicarbonate and hydroxide, until equilibrium is established. Sodium carbonate is used in many countries (e.g. U.S. and EU) as a food additive. It is regarded as a 'Generally Recognised as Safe' (GRAS) substance in food with no limitation other than current good manufacturing practice. Sodium carbon is extensively used across a range of industries and processes such as in the manufacturing of sodium salts, glass, soap/detergents and aluminium
Environmental Fate[1,2,3,4]	
Soil/Water/Air	The high water solubility and low vapor pressure indicate that sodium carbonate will be found predominantly in the aquatic environment. In water, sodium carbonate dissociates into sodium (Na+) and carbonate (CO3 2-) and both ions will not adsorb on particulate matter or surfaces and will not accumulate in living tissues.
Human Health Toxicity Summary[1]	
Chronic Repeated Dose Toxicity	No chronic oral and dermal data are available. Due to the biological importance of the products formed by the stomach acid (biocarbonate and carbon dioxide), systemic toxicity is not expected. In rats, histopathological changes of the respiratory tract and the lungs were seen following repeated inhalation exposure to sodium carbonate (70 mg/m^3 aqueous sodium cabonate at pH 11.6 for 3.5 months) and potassium carbonate (0.4 mg/L potassium carbonate at pH 9.9 for 21days). These effects were considered local responses to the high alkalinity of this group of chemicals (OECD, 2002; REACHa; REACHb).
Carcinogenicity	No data are available. Based on the available data from carcinogenicity studies with related substances (sodium bicarbonate and potassium bicarbonate), the chemicals in this group are not considered carcinogenic (OECD, 2002; REACHa; REACHb). Carbonate ions are neutralised under physiological conditions to form bicarbonate ions and/or carbon dioxide, which are major products of all human metabolic activities; therefore, systemic toxicity is not expected.

Mutagenicity/ Genotoxicity	Based on the available data, this chemical is not considered to be genotoxic (OECD, 2002; REACHa; REACHb). Carbonate ions are neutralised under physiological conditions to form bicarbonate ions and/or carbon dioxide, which are major products of all human metabolic activities; therefore, systemic toxicity is not expected.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Based on the limited information available, this chemical does not show specific reproductive or developmental toxicity (OECD, 2002; REACHa; REACHb). Carbonate ions are neutralised under physiological conditions to form bicarbonate ions and/or carbon dioxide, which are major products of all human metabolic activities; therefore, systemic toxicity is not expected.
Acute Toxicity	In animal tests, this chemical was of low acute toxicity following oral exposure. The median lethal dose (LD50) was >2000 mg/kg bw in rats (OECD, 2002; REACHa; REACHb).The majority of the animals that died following acute oral exposure to sodium carbonate at concentrations up to 2600 mg/kg/bw showed oral or nasal discharge, lesions in the liver, mottled lungs, mottled or pale kidneys and a red or partly gas-filled gastro-intestinal tract. In animal tests, this chemical was of low acute toxicity following dermal exposure. The median lethal dose (LD50) was >2000 mg/kg bw in rats (OECD, 2002; REACHa; REACHb). No systemic effects were observed following dermal exposure to sodium carbonate. Local severe skin irritation (severe erythema and oedema) was seen at the application site (OECD, 2002; REACHa; REACHb). In animal tests, this chemical was of low acute toxicity following inhalation exposure. The median lethal dose (LC50) was >2000 mg/m^3 in rats (OECD, 2002; REACH, a & b). Signs of respiratory impairment including dyspnoea, wheezing, excessive salivation and a distended abdomen were observed immediately after inhalation exposure to sodium carbonate of up to 2300 mg/m^3. Excessive salivation, repeated swallowing and a lack of appetite were observed 2–5 hours after exposure. Animals that died had lesions in the anterior trachea, posterior pharynx and larynx, along with an accumulation of mucus, vesiculation and mucosal oedema (REACHa).
Irritation	Sodium carbonate is classified as hazardous with the risk phrase 'Irritating to eyes' (Xi; R36) in HSIS (Safe Work Australia). However, in several eye irritation studies in rabbits, sodium carbonate was found to be severely irritating to the eyes, with effects including conjunctivitis, marked corneal opacity and iritis, which persisted for seven days (REACHa; REACHb). The available data support an amendment to the current HSIS eye irritation classification for sodium carbonate.
Sensitisation	Based on the limited data available, sodium carbonate is not considered to be skin sensitisers (OECD, 2002; REACHa; REACHb). No structural flags for sensitisation are present.
Health Effects Summary	The critical health effects for risk characterisation include serious eye damage and respiratory irritation because of the high basicity of the chemicals in this group. Skin irritation and corrosion of eyes and mucous membranes are also of concern where long-term exposure to the solid or concentrated solutions may occur. These effects are particularly relevant to domestic use of the chemicals.
Key Study/Critical Effect for Screening Criteria	The Australian drinking water screening value for sodium (180 ppm, aesthetic) and pH may apply to sodium carbonate.
Ecological Toxicity [1,2,3,4]	
Aquatic Toxicity	The acute 96-hour LC50 to three sizes of Bluegill sunfish (*Lepomis macrochirus*) exposed to sodium carbonate is 300 mg/L for all sizes. The acute 96-hour LC50 to mosquitofish (*Gambusia affinis*) is 740 mg/L. The acute 48-hour EC50 value to the invertebrate *Ceriodaphnia* cf. *dubia* is from 200 to 227 mg/L.
Determination of PNEC aquatic	PNECaquatic: Experimental results are available for two trophic levels. Acute E(L)C50 values are available for fish (300 mg/L) and *Ceriodaphnia* (200 mg/L). On the basis that the data consists of short-term results from two trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 200 mg/L for Daphnia. The PNECaquatic is 0.2 mg/L.

Current Regulatory Controls[1]	
Australian Hazard Classification	Sodium carbonate is classified as hazardous, with the following risk phrases for human health in the Hazardous Substances Information System (HSIS) (Safe Work Australia): 'Xi; R36 (Irritating to eyes)'.
Australian Occupational Exposure Standards	Sodium carbonate has an exposure standard of 7.5 mg/m^3 (5 ppm) time weighted average (TWA) and 15 mg/m^3 (10 ppm) short-term exposure limit (STEL) (Safework Australia).
International Occupational Exposure Standards	Occupational exposure standard limits for sodium and potassium carbonate recommended by other countries are provided below (Galleria Chemica, 2013): US Dept of Energy (DOE) Temporary Emergency Exposure Limits (TEELs): Sodium carbonate: TEEL-0 = 10 mg/m^3 , TEEL-1 = 30 mg/m^3 , TEEL-2 = 50 mg/m^3, TEEL-3 = 500 mg/m^3 No other country has an occupational exposure limit specifically for sodium and potassium carbonate, although many countries have assigned a generic TWA exposure limits of 10 mg/m^3 (inhalable dust), and 3 mg/m^3 (respirable dust) for particles not otherwise classified (PNOC).
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	No data available.
PBT Assessment[4,6]	
P/vP Criteria fulfilled?	Not applicable, inorganic substance, ubiquitous in environment.
B/vB criteria fulfilled?	Not applicable. Bioaccumulation is not applicable to these inorganic ions.
T criteria fulfilled?	No chronic toxicity data exist; however, the acute EC(L)50s are >0.1 mg/L. Thus, does not meet the screening criteria for toxicity
Overall conclusion	Not PBT
Revised	March 2019

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Toxicity Summary - Sodium chloride

Chemical and Physical Properties [1,4]	
CAS number	7647-14-5
Molecular formula	NaCl
Molecular weight	58.44 g/mol
Solubility in water	3.57 x 10 5 g/m3 at 25oC
pH	In aqueous solution is neutral
Melting point	1 mm Hg at 865oC
Boiling point	1670 °C
Vapour pressure	No data found
Henrys law constant	No data found
Explosive potential	Not explosive
Flammability potential	Not flammable
Colour/Form	light brown liquid or colourless crystals
Overview	Sodium, together with potassium is an essential mineral for the regulation of body fluid balance. Sodium is the most abundant cation in the extracellular fluid and sodium salts account for more than 90% of the osmotically active solute in the plasma and interstitial fluid. Consequently, sodium load is the major determinant of extracellular volume. Chloride is also important in maintaining the fluid balance and is an essential component of the gastric and intestinal secretions Sodium chloride occurs naturally as rock salt which comprises 95% to 99% NaCl. It is also widely used in food products. The NHMRC has established dietary guidelines for the intake of sodium per day (adults should consume less than 2300 mg sodium per day). This chemical has been identified by NICNAS to be of low concern to human health based on an initial screening approach and thus required no further assessment.
Environmental Fate [2,3]	
Soil/Water/Air	Due to its high solubility, sodium chloride is highly mobile in the environment. Once dissociated, chloride ions will migrate readily, however sodium ions will sorb to clay-rich materials limiting mobility. If released into the environment, sodium chloride is not likely to sorb to solid particles in the water column, is readily dissociated to form chloride and sodium ions, is not bioaccumulative in aquatic species or the food chain.

Human Health Toxicity Summary [2,3]	
Chronic Repeated Dose Toxicity	High sodium chloride intakes increase calcium excretion and may increase the risk of kidney stone formation. There is evidence for a causal relationship between the consumption of sodium (mainly from common salt) and both blood pressure and the age-related rise in blood pressure. Data suggest that30% of a normotensive population may be salt sensitive. Sodium chloride has been demonstrated to be a gastric tumour promoter in experimental animals and high sodium chloride intakes have been associated with incidence of stomach cancer in human populations with traditional diets of highly concentrated, salted foods.
Carcinogenicity	Not listed with IARC.
Mutagenicity/ Genotoxicity	No data available.
Reproductive Toxicity Developmental Toxicity/Teratogenicity	No data available.
Acute Toxicity	No data available.
Irritation	Although rare, acute toxicity may be caused by ingestion of 500 – 1000 mg sodium chloride/kg body weight. Symptoms include vomiting, ulceration of the gastrointestinal tract, muscle weakness and renal damage, leading to dehydration, metabolic acidosis and severe peripheral and central neural effects.
Sensitisation	No data available.
Health Effects Summary	Sodium is an essential mineral for the regulation of body fluid balance. This chemical has been identified by NICNAS to be of low concern to human health.
Key Study/Critical Effect for Screening Criteria	The Australian drinking water guideline value for sodium and chloride may apply.
Ecological Toxicity [2,3,4]	
Aquatic Toxicity	A large number of studies are available in relation to the aquatic toxicity of sodium chloride with the USEPA ECOTOX database identifying 1712 records. The evaluation of ecological effects of sodium chloride has been evaluated in detail for the assessment of the use of rock salt in the US on roadways during the winter months. The following has been summarised from the US review: The presence of sodium chloride may result in the increased mobilisation of other contaminants (metals, nutrients etc) and a shift in the acid buffering capacity may compromise aquatic ecosystems. Most sensitive species are birds where a safe concentration of 1000 mg/L sodium chloride can be established. Salt tolerance of aquatic species varies significantly with EC50 concentrations ranging from 400 to 30000 mg/L. The measured acute endpoint for Fish was reported at 1290 mg/L. The measured NOEC for Daphnia is 314 mg/L.
Determination of PNEC aquatic	PNECaquatic: On the basis of the chronic results for Daphnia, an assessment factor of 100 has been applied to the lowest reported effect concentration of 314 mg/L. The PNECaquatic is determined to be 3.14 mg/L.
Current Regulatory Controls	
Australian Hazard Classification	No data available
Australian Occupational Exposure Standards	No data available
International Occupational Exposure Standards	No data available
Australian Food Standards	No data available

Australian Drinking Water Guidelines	No data available
Aquatic Toxicity Guidelines	No data available
PBT Assessment [4]	
P/vP Criteria fulfilled?	Sodium chloride is an organic salt that dissociates completely to sodium and chloride ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both sodium and chloride ions are also ubiquitous and are present in most water, soil and sediment. The persistent criteria is not considered applicable to this inorganic salt.
B/vB criteria fulfilled?	Sodium and chloride ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, sodium chloride is not expected to bioaccumulate.
T criteria fulfilled?	The measured chronic toxicity data for sodium chloride was 314 mg/L for Daphnia Thus, sodium chloride does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	April 2018

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Toxicity Summary - Sodium Erythorbate

Chemical and Physical Properties[1,2]	
CAS number	6381-77-7
Molecular formula	C6H7NaO6
Molecular weight	199.13
Solubility in water	Soluble; 146 g/L at 20 °C and pH 6
Melting point	160 °C at 101.3 kPa
Boiling point	No data available.
Vapour pressure	No data available.
Henrys law constant	No data available.
Explosive potential	No data available.
Flammability potential	Non-flammable (100%)
Colour/Form	White, free-flowing crystals
Overview	Sodium erythorbate is a synthetic antioxidant used in food and cosmetic formulations. Foliar application of sodium erythorbate sprays and dusts are used to control young tree decline in citrus trees and to reduce ozone damage to Thompson seedless grapes. It is also used in hydraulic fracturing mixtures to prevent precipitation of metal oxides (iron control). This chemical has been identified by NICNAS to be of low concern to human health based on an initial screening approach and thus required no further assessment.
Environmental Fate[1]	
Soil/Water/Air	The chemical is not expected to be readily biodegradable. The chemical achieved 56% degradation in 28 days according to test guidelines OECD 301E. However, the degradation after 28 d was not yet finished as a plateau is not yet visible in the degradation curve; thus, a further degradation of the product seems to be possible.
Human Health Toxicity Summary[1]	
Chronic Repeated Dose Toxicity	Male 6-week-old F344 rats were given doses of 5% Sodium Erythorbate in feed for 168 days. Parameters of urinary excretion were investigated and the urinary bladder epithelium was examined using light and scanning electron microscopy at weeks 8, 16, and 24. The urine of rats fed Sodium Erythorbate had increased pH, elevated content of crystals and sodium, and decreased osmolality; however, no morphological alterations such as hyperplasia were detected in the mucosa. The urine values and urinary bladder mucosa were similar to controls at doses below 5 g/kg/day.

Carcinogenicity	F344/DuCrj rats of both sexes (6-week-old) were given 1.25% or 2.5% Sodium Erythorbate in drinking water for 104 weeks and untreated water for 8 additional weeks. Rats of the control group were given untreated water only. Each group consisted of 52 male and 50 female rats. Cumulative consumption of Sodium Erythorbate by male rats was 217 g/rat (1.25%) and 430 g/rat (2.5%). Consumption by females was 206 g/rat (1.25%) and 583 g/rat (2.5%). Body weight of rats given 2.5% Sodium Erythorbate was reduced by 8.5% for males and 15.5% for females at weeks 88 and 85, respectively, compared to controls. Body weight gain was normal in rats of the low dose group. All male treated and control rats (except two of the high-dose group) had testicular interstitial cell tumours. Various tumours occurred in 80% of control males, 69% of males given the low dose, and 78% of males given the high dose. A 6-18% incidence of leukaemia, pheochromocytoma, mammary fibroadenoma, and mesothelioma was observed. Of the females of the control, 1.25%, and 2.5% dose groups, 94%, 88%, and 78% had tumours, respectively. Twenty to 43% of females (all groups) had leukaemia, mammary fibroadenoma, endometrial stromal polyp and/or pituitary adenoma. Females given 2.5% Sodium Erythorbate had significantly fewer tumours than control females. The pattern of occurrence of the various types of tumours was similar among the groups. Sodium Erythorbate did not enhance the development of rare spontaneous tumours or transform benign tumours (e.g., solid adenoma of the thyroid) to carcinomas. The investigators concluded that Sodium Erythorbate was not carcinogenic in F344 rats.
Mutagenicity/ Genotoxicity	Sodium Erythorbate (99.8% pure; 5.0 mg/plate) was non-mutagenic in S. typhimurium strains TA92, TA94, TA98, TA100, TA1535, and TA1537 with and without S9 activation. Sodium Erythorbate (0.25 mg/mL plate) was also negative in the chromosomal aberration assay using Chinese hamster fibroblasts; Sodium Erythorbate did not induce the formation of polyploid cells after 48 hours, and caused 1 % chromosomal breaks after 24 hours.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Sodium erythorbate did not cause maternal or fetal toxicity when administered to female rats and mice during gestation by oral intubation at dosages up to 1,030 mg/kg/day. Developmental toxicity did not occur after pregnant rats were given up to 5% sodium erythorbate in feed during a 13-week teratogenesis study. It produced negative results in the Ames test, the host-mediated assay using S. typhimurium, chromosomal aberration tests using Chinese hamster ovary fibroblasts, the dominant lethal test using rats, and the B. subtilis rec assay.
Acute Toxicity	Sodium erythorbate powder was applied to the intact and abraded skin of six rabbits as a single 2 g/kg dose. A substantial amount of residual compound was observed 24 hours after dosing. No erythema, edema, or other signs of dermal irritation were observed at five of six test sites. One rabbit (abraded skin) had slight (1+) erythema at 24 hours that cleared by 48 hours.
Irritation	Sodium erythorbate powder did not cause signs of dermal irritation when applied to the intact and abraded skin of rabbits. Instillation of sodium erythorbate powder to the conjunctival sac of rabbits caused slight and transient reddening of the conjunctiva that cleared within 24 hours.
Sensitisation	In a dermal sensitization study (according to OECD 429) with Sodium erythorbate (5, 10, 25% w/w in propylene glycol), young adult female CBA/Ca (CBA/CaOlaHsd) mice (4/group) were tested using the local lymph node assay (LLNA). In this study, Sodium erythorbate was not considered a potential skin sensitizer.
Health Effects Summary	Sodium erythorbate did not show signs of toxicity, carcinogenicity, mutagenicity, irritation and sensitisation in the studies reported. This chemical has been identified by NICNAS to be of low concern to human health.
Key Study/Critical Effect for Screening Criteria	The Australian drinking water guideline value for sodium may apply.

Ecological Toxicity [1,2]	
Aquatic Toxicity	The acute toxicity of the sodium erythorbate to the freshwater fish rainbow trout (Oncorhynchus myldss) has been investigated and gave a 96-Hour LC50 of greater than 100 mg/L (semi-static). The acute toxicity of sodium erythorbate to Daphnia magna gave an EC50 (48 h) of 84 - 100 mg/L. The effect of the test item on the growth of Pseudokirchneriella subcapitata has been investigated over a 72-Hour period. The EC50 (72 h) was 160 mg/L while the NOEC (72 h) was 20 mg/L.
Determination of PNEC aquatic	A PNECaquatic of 84 µg/L was calculated using the lowest endpoint of EC50 of 84 mg/L for Daphnia magna. An assessment factor of 1000 was used.
Current Regulatory Controls[4]	
Australian Hazard Classification	No data available.
Australian Occupational Exposure Standards	No data available.
International Occupational Exposure Standards	No data available.
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	No data available.
PBT Assessment	
P/vP Criteria fulfilled?	Could potentially be persistent as it is not readily biodegradable.
B/vB criteria fulfilled?	No. The Log Pow is -3.29 (Log Pow < 4.5) which does not meet the screening criteria for bioaccumulation.
T criteria fulfilled?	No. Based on measured acute toxicity endpoints of greater than 1 mg/L Sodium erythorbate does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	April 2019

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Toxicity Summary - Sodium hydroxide

Chemical and Physical Properties	
CAS number	1310-73-2
Molecular formula	Na-O-H
Product name	40 g/mol
Molecular weight	1.11E+06 mg/L at 20C
Solubility in water	13
Melting point	318 °C
Boiling point	1388 °C
Vapour pressure	Negligible at 25 deg C
Henrys law constant	No data found.
Explosive potential	No
Flammability potential	No
Colour/Form	Anhydrous (pure) NaOH is a solid – *refer melting point above*. However it is a hygoscopic, ionic solid, and will absorb water from air and is highly soluble
Incompatibility	Avoid contact of solid NaOH with water due to strong exothermic reaction, leather, wood, acids, organic halogen compounds or organic nitro compounds. Carbon monoxide gas can form upon contact with reducing sugars, food and beverage products in enclosed spaces. NAoH is neither explosive, flammable, nor oxidising.
Overview	Vegetable oil refining, regenerating iron exchange resins, organic fusions, peeling of fruits and vegetables in the food industry, etching and electroplating.
Environmental Fate[1]	
Soil/Water/Air	Sodium hydroxide is highly soluble, not volatile and unlikely to materially adsorb to soil and is therefore predominately found in the aquatic environment if released to the environment. NaOH will readily dissociate to be present in the environment as sodium and hydroxyl ions, both being ubiquitous in the environment. NaOH is a strong alkali, so it's dissolution in water may locally raise the pH of the affected environment. The dissolution reaction is also strongly exothermic.

Human Health Toxicity Summary [1,2,,3]	
Chronic Repeated Dose Toxicity	No animal data are available on repeated dose toxicity studies by oral or dermal routes for sodium hydroxide. In a repeat dose inhalation study, twenty seven white rats died within a month, mostly from bronchopneumonia, after being exposed twice weekly to an aerosol of unknown airborne concentration of sodium hydroxide, generated from an aqueous 40% sodium hydroxide solution (NIOSH 1975). When exposed to an aerosol generated from a 20% sodium hydroxide solution, the bronchi were dilated, the epithelial cover was thin and frequently desquamated, and the septa were dilated and cracked. A light round cell infiltration of the sub-mucus membrane tissue was also observed. Few changes occurred in a group of rats exposed to aerosols from 10% sodium hydroxide, but rats exposed to an aerosol of 5% sodium hydroxide had dilation of the bronchi and a slight degeneration of the mucus membrane and thickened strata of lymphadenoid tissue surrounding the bronchi. A NOAEL could not be established in this study. Workers exposed to 0.24 to 1.86 mg/m^3 sodium hydroxide for 2 to 15 minutes reported throat irritation and watery eyes (NIOSH 1975). Based on the observations of the irritant effects on workers exposed to 1 to 40 mg/m^3 sodium hydroxide, it was concluded that 2 mg/m^3 represented a concentration that is ‘noticeably but not extensively irritant’ (NIOSH 1975). Obstructive airway disease has been reported following chronic occupational exposure to sodium hydroxide mist (IPCS 1996). The patient developed cough, dyspnoea and tachypnoea after a 20-year exposure to sodium hydroxide.
Carcinogenicity	IARC Category 3 - not classifiable as to human carcinogenicity
Mutagenicity/ Genotoxicity	In vitro and vivo genetic toxicity testing reported no evidence of mutagenic activity.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	No valid studies were identified regarding reproduction toxicity after oral, dermal or inhalation exposure to NaOH. Sodium hydroxide is not expected to be systemically available to the body under normal handling and use conditions.
Acute Toxicity	Exposure to the solid or concentrated liquid can cause severe burns to the eyes, skin and gastrointestinal tract which may cause death. An oral LD50 of a 1-10% solution of NaOH in rabbits was 325 mg/kg bw (as 100% NaOH). An oral LD50 of 140 to 340 mg/kg in rats has also been reported (National Research Council 2011), however details of the study are not available. In an acute dermal study, mice were treated dermally with 50% sodium hydroxide, and the treated area was irrigated with water at various intervals (OECD 2002). The mortality of mice was 20, 40, 80 and 71% when they were irrigated at 30 minutes, one hour, two hours or not at all after the application. All animals developed rapidly progressive burns. No mortality or burns were observed when the treated area was irrigated immediately after the application. A 5% aqueous solution of sodium hydroxide produced severe necrosis when applied to the skin of rabbits for four hours (Clayton and Clayton 1993). A dermal LD50 of 1350 mg/kg has been reported in rabbits (National Research Council 2011), however details of the study are not available. Caustic dusts are irritating to the upper respiratory system. Prolonged exposure to high concentrations may cause discomfort and ulceration of nasal passages. Cases of fatality due to ingestion of liquid sodium hydroxide have been reported in humans.
Irritation	Sodium hydroxide is a corrosive irritant to skin, eyes and mucous membranes. A NaOH solution of 8% can be considered corrosive based on animal data. Human data indicate that concentrations of 0.5 to 4% were irritating.
Sensitisation	Sodium hydroxide has no skin sensitisation potential.

Health Effects Summary	An oral LD50 of 325 mg/kg in rats and a dermal LD50 of 1350 mg/kg in rabbits were reported for sodium hydroxide. Lethality has been reported in animals at oral doses of 240 mg/kg bw. Inhalational LC50 is not available. Sodium hydroxide is corrosive to skin, eyes and gastrointestinal and respiratory tracts. Based on human data, concentrations of 0.5 to 4.0% are irritating to the skin, while a concentration of 8.0% is corrosive. Sodium hydroxide is not a skin sensitiser. No animal data were available on repeated dose toxicity by oral or dermal routes for sodium hydroxide. In the single reported repeat dose inhalation study, a NOAEL could not be established. Both in vitro and in vivo genetic toxicity tests indicated no evidence of a mutagenic activity. Information is not available on reproductive and developmental toxicity and carcinogenicity of sodium hydroxide. Due to dissociation into ions which are subject to homeostatic controls in the human body, systemic effects from repeated exposures to sodium hydroxide are not expected. The critical health effect of sodium hydroxide is its corrosive effect.
Key Study/Critical Effect for Screening Criteria	No oral TRV apply. Acute toxicity only (irritant and corrosive), not systemically available in body. The Australian drinking water guideline value for pH may apply to sodium hydroxide.
Ecological Toxicity [1,2,3]	
Aquatic Toxicity	Measured acute endpoints were available for fish (196 mg/L). Measured chronic endpoint were available for Daphnia (240 mg/L)
Determination of PNEC aquatic	An assessment factor of 10 has been applied to the lowest reported NOEC of 240 mg/L for Daphnia. The PNECaquatic is 24 mg/L.
Current Regulatory Controls[4]	
Australian Hazard Classification	C: R35 (Corrosive, causes severe burns)
Australian Occupational Exposure Standards	Sodium hydroxide has an exposure standard of 2 mg/m³, Time Weighted Average (Safe Work Australia 2013).
International Occupational Exposure Standards	Occupational Exposure Limit (OEL) or limit values in working environment of 2 mg/m³ [Argentina, Belgium, Bulgaria, Canada, China, India, Japan and the US (NIOSH 1975)]. Occupational exposure standard: 2 mg/m³ [Korea] Occupational exposure limit values: 0.5 mg/m³ [Latvia] Short Term Exposure Limit (STEL): 2 mg/m³ [UK] US Department of Energy Temporary Emergency Exposure Limits (TEELs) = 0.5 mg/m³ (TEEL-0 and TEEL-1), 5 mg/m³ (TEEL-2) and 50 mg/m³ (TEEL-3).
Australian Food Standards	Processing aids - Generally permitted - permitted for use as acidity regulator (FSANZ 2013). Sodium hydroxide is allotted an International Numbering System (INS) of food additives number: INS 524 (Food Standards Australia New Zealand 2013).
Australian Drinking Water Guidelines	No data found. However, since sodium hydroxide readily dissociates in water into sodium and hydroxyl ions, the Australian Drinking Water Guidelines for sodium state that, based on aesthetic considerations (taste), the concentration of sodium in drinking water should not exceed 180 mg/L (National Health and Medical Research Council (NHMRC) 2011). No health-based guideline value is proposed for sodium.
Aquatic Toxicity Guidelines	No data found.
Occupational Exposure Limits	Peak limitation – 2 mg/m³
PBT Assessment	
P/vP Criteria fulfilled?	Not applicable (inorganic salt, ionic species ubiquitous in environment)
B/vB criteria fulfilled?	Not applicable. Bioaccumulation is not applicable to these inorganic ions; sodium and hydroxide ions are ubiquitous and are present in most water, soil and sediment.

T criteria fulfilled?	Not applicable. Chronic toxicity data >1 mg/L in invertebrates, thus sodium hydroxide does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT

References

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2. HSDB (n.d.). *Hazardous Substances Data Bank*. Retrieved March 2015, from Toxnet, Toxicology Data Network, National Library of Medicine: http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB
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AECOM Imagine it Delivered

Toxicity Summary - Starch

Chemical and Physical Properties[1,2,4,6]	
CAS number	9005-25-8
Molecular formula	(C6H10O5)n
Molecular weight	UVCB
Solubility in water	In cold water, starch absorbs water reversibly and swells slightly. In hot water, irreversible swelling occurs, producing gelatisation.
Melting point	No data available.
Boiling point	No data available.
Vapour pressure	No data available.
Henrys law constant	No data available.
Explosive potential	Combustible
Flammability potential	No data available.
Colour/Form	White powder, tasteless and has no smell
Overview	Starch is a high –polymeric carbohydrate material primarily composed of amylopectin and amylose. It is usually derived from cereal grains such as corn, wheat and sorghum and from roots and tubers such as potatoes and tapioca. It includes starch which has been pregelatinized by heating in the presence of water. This chemical has been identified by NICNAS to be of low concern to human health and thus required no further assessment.
Environmental Fate[7]	
Soil/Water/Air	Based on information from NICNAS (2006): In a ready biodegradation test, the notified polymer (Potato Starch Modified) showed an 86.87% degradation during a Modified Sturm Test (OECD Test Guideline 301B) indicating that it was readily biodegradable. The test was verified using a sodium benzoate standard which showed 93.77% degradation at the end of the study. In addition a toxicity control consisting of a mixture of the test substance and sodium benzoate showed 83.49% degradation at the end of the study period, indicating that the test material did not inhibit the microbial activity. The notified polymer does potentially contain cationic and anionic functional groups, however based on the typical dissociation constants for the functionalities and their ratio within the polymer it is expected to have a net anionic charge throughout most of the environmental pH range, becoming slightly cationic only at the low end of the range. In landfill and the sewer, the notified chemical is expected to be relatively readily degraded by biotic and abiotic pathways to ultimately yield water and oxides of carbon and nitrogen and salts of chlorine and sodium. Any incineration of the notified polymer would result in its destruction and the formation of carbon dioxide and water and ash containing salts of chlorine and sodium. The notified polymer has a high molecular weight not expected to bioaccumulate.

Human Health Toxicity Summary[2,3]	
Chronic Repeated Dose Toxicity	A long-term study was carried out on the effects of inoculating 1.5 g of starch powder into the peritoneal cavity of rats. After an initial considerable inflammatory reaction, the intense vascular reaction subsided, leaving firm adhesions that were still present in animals sacrificed at 18 months (Ell90). Feeding of unmodified cornstarch and potato starch to groups of rats at dietary levels up to 30% (equivalent to 27.4-33.6 g/kg bw/d) in a 2-year test and 10% (food intake not indicated) in a 3-generation test did not result in distinct toxicologically significant effects (Gro74). Rats fed a cooked diet containing 62% unmodified maize starch (equivalent to 51.1 g/kg bw/d*) for 2 years also did not show significant toxicological effects, including reproductive effects over 3 generations (Tru79). Slight growth retardation was seen in rats exposed for 4 weeks to raw potato starch at a dietary level of 40% (equivalent to 46.0-52.8 g/kg bw/d) (Fer73).
Carcinogenicity	Not classifiable as a human carcinogen (A4)
Mutagenicity/ Genotoxicity	There were no indications for significant toxicity, carcinogenicity or reproduction toxicity of starch in rats fed 27.4-52.8 g/kg bw/day.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	There were no indications for significant toxicity, carcinogenicity or reproduction toxicity of starch in rats fed 27.4-52.8 g/kg bw/day.
Acute Toxicity	Toxicity of starch given orally to albino rats were studied. Experiments were performed upon CBL albino rats weighing 140 ± 15 (mean ± S.D.). Starch was given daily for 14 consecutive days in total daily oral doses of 36, 72, 120 and 168 g/kg and in animals which did not succumb to gastric rupture in doses gradually increasing to 204, 240 and 288 g/kg. Gastric rupture appeared in 50 – 75% of rats given starch in amounts of 168 g/kg and over. Of the survivors of gastric rupture, 5% died of pneumonia and 20% from bowel obstruction during the 14 days of starch administration. Doses of one tenth body weight and above produced some inhibition of growth, doses of one fifth body weight and above increased the susceptibility to pneumonia and bowel obstruction owing to the inability of the animal to evacuate the starch calculi. It was noted that doses of this order could not readily be taken by humans and smaller doses had insignificant toxicity. Acute respiratory effects after exposure to dust from the refining process of potato starch have been described (personal sampling: 3.9-56.0 mg/m^3, total dust). The responsible agent could not be identified although the authors suspected endotoxin to be the causative agent (Hol94). Millers and bakers occupationally exposed to grain and flour dusts (personal sampling: 1.1-14.3 mg/m^3, total dust) showed significantly higher incidences of coughing and chronic bronchitis compared to a non-exposed reference group (Mas95, Mas96). A dose-response relationship was observed between dust exposure levels and chronic respiratory symptoms (Mas95). Although flour is a complex product that is mainly made up of starch (70%) and gluten (12%), it may also contain mite dust and endotoxins. The causative role of starch in the observed respiratory symptoms is therefore not clear. The intraperitoneal LD50 of starch in mice is 6600 mg/kg (ACG99).
Irritation	Skin contact with a total dose of 300 µg of starch, intermittently applied over a 3-day period, resulted in a mild erythema and slight oedema of the skin in humans (ACG99).
Sensitisation	No data available.
Health Effects Summary	This chemical has been identified by NICNAS to be of low concern to human health.
Key Study/Critical Effect for Screening Criteria	The intraperitoneal LD50 of starch in mice is 6600 mg/kg (ACG99).

Ecological Toxicity[7]	
Aquatic Toxicity	Based on QSAR modelling: Crassostrea virginica 96 h = 1000 mg/L Orthopristis chrysoptera 96 h = 5000 mg/L Bairdiella chrysoura 96 h = 5000 mg/L
Determination of PNEC aquatic	Based on the lack of ecotoxicity data, PNECaquatic was not determined.
Current Regulatory Controls[2,4]	
Australian Hazard Classification	No data available.
Australian Occupational Exposure Standards	TWA = 10 mg/m^3
International Occupational Exposure Standards	TLV: 10 mg/m^3, as TWA The current administrative occupational exposure limit (MAC) for starch in the Netherlands is 10 mg/m^3, 8-hour TWA, equal to the occupational exposure limit for nuisance dust.
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	No data available.
PBT Assessment	
P/vP Criteria fulfilled?	No. This substance is expected to be readily biodegradable.
B/vB criteria fulfilled?	No. This substance is not expected to be bioaccumulative.
T criteria fulfilled?	Based on QSAR modelling, this substance is not expected to meet the toxicity criteria.
Overall conclusion	Not PBT
Revised	April 2019

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AECOM Imagine it Delivered

Toxicity Summary - Tetrahydro-3,5-dimethyl-1,3,5-thiadiazine-2-thione

Chemical and Physical Properties[1,2,3,5]	
CAS number	533-74-4
Molecular formula	C5H10N2S2
Molecular weight	162.28
Solubility in water	3.5 g/l at 20 °C at pH 5, pH 7and pH 9
Melting point	103.2 – 105.2 °C
Boiling point	No data available.
Vapour pressure	5.8 x 10-6 Pa at 20 °C (extrapolated)
Henrys law constant	2.66X10-10 atm-cu m/mole
Explosive potential	No data available.
Flammability potential	No data available.
Colour/Form	Off-white to yellowish solid of sulphurous odour
Overview	Dazomet (Tetrahydro-3,5-dimethyl-1,3,5-thiadiazine-2-thione) is a soil fumigant effective for the control of nematodes, insects, germinating weeds and soil fungi. Dazomet is strongly phytotoxic, acting by virtue of the chemical release of methylisothiocyanate (MITC).
Environmental Fate[1]	
Soil/Water/Air	Dazomet's production may result in its release to the environment through various waste streams; its use as a soil sterilant, nematicide, fungicide, slimicide in pulp and paper manufacture, and as a preservative in adhesives and glues will result in its direct release to the environment. If released to air, a vapour pressure of 2.80X10-6 mm Hg at 20 deg C indicates dazomet will exist in both the vapour and particulate phases in the atmosphere. Vapour-phase dazomet will be degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals; the half-life for this reaction in air is estimated to be 1.4 hours. Particulate-phase dazomet will be removed from the atmosphere by wet or dry deposition; hydrolysis of this compound during rain events or in clouds may occur. It has been suggested that dazomet may also undergo direct photolytic degradation and this process may contribute to atmospheric removal. If released to soil, dazomet is expected to have high mobility based upon an estimated Koc of 52; however it is expected to hydrolyse before extensive leaching occurs. Volatilization from moist soil surfaces is not expected to be an important fate process based upon a Henry's Law constant of 2.66X10-10 atm-cu m/mole. When dazomet is applied to soil, either to the surface or incorporated, it quickly hydrolyzes in the presence of moisture. The major degradate is methyl isothiocyanate, but formaldehyde, monomethylamine, hydrogen sulfide and (in acid soils) carbon disulfide, are also formed. The half-life of dazomet in soil has been reported as less than 1 day (pH >5). The rate of disappearance was found to be the same in both unamended and sterilized soils and in different soil types, indicating that chemical hydrolysis and not biodegradation is the primary removal process. Dazomet is not expected to volatilize from dry soil surfaces based upon its vapour pressure. If released into water, dazomet is not expected to adsorb to suspended solids and sediment based upon the estimated Koc. Volatilization from water surfaces is not expected to be an important fate process based upon this compound's Henry's Law constant. In water, dazomet is expected to undergo hydrolysis rapidly, forming methyl isothiocyanate and formaldehyde. Half-lives of 3.6, 2.4, 2.8, and 4.0 hours have been reported at pH values of 4.4, 5.7, 7.0, and 8.0, respectively. In salt water (0.15 M), a half-life of 6.1 hours was reported. An estimated BCF of 2.4 suggests the potential for bioconcentration in aquatic organisms is low.

Human Health Toxicity Summary[1]	
Chronic Repeated Dose Toxicity	In a 78 week study, mice were given dazomet in the diet at 0, 20, 80 and 320 ppm. Compound intakes were estimated as follows: males - 0, 4, 16 and 68 mg/kg/d; females - 0, 6, 22 and 93 mg/kg/d. Survival was not affected and there were no noteworthy clinical signs, or bodyweight or food consumption changes. There was a significant elevation of liver weight at the high dose and an increased number of mid-dose and high dose animals with liver discolouration, liver masses and centrilobular lipid deposition. At the high dose, females showed a slightly increased incidence of hepatocellular adenomas (3, 0, 1 and 7 females, out of 50, in the control, low dose, mid dose and high dose groups, respectively) and a significantly increased incidence of basophilic foci. Increased splenic haemosiderin deposition and extramedullary haematopoiesis were noted at the mid dose (males) and high dose. Three/60 females from each dose group had malignant lymphoma at one or more sites; because of the low incidence, lack of a dose-response, and lack of any effect in males, it was not considered to be directly compound-related. The NOEL was 20 ppm (about 4 mg/kg/d in males, 6 mg/kg/d in females).
Carcinogenicity	Rat studies showed no clear evidence of any carcinogenic effect of dazomet. In mice, there was a slight increase in hepatocellular adenomas (not carcinomas) following 78 weeks of treatment at the high dose (320 ppm). There was also an increase in malignant lymphoma in females, but because of the low incidence, the lack of effect in males and the lack of any dose-response, it was not considered to be directly compound-related. The lack of a carcinogenic effect of dazomet is consistent with the data for MITC.
Mutagenicity/ Genotoxicity	An acceptable package of mutagenicity tests has been conducted covering all three end points. The results are the genotoxicity tests are not clear cut. While the majority of tests gave negative results, there were sufficient positive results to indicate some genotoxic potential of dazomet. In summary, there were positive results in one gene mutation assay (HGPRT locus in Chinese hamster ovary cells), equivocal results in another gene mutation assay (TK locus in mouse lymphoma L5178Y cells), and positive results in two chromosome aberration assays (both in vitro assays in mouse lymphoma L5178Y cells), in one in vitro assay for of unscheduled DNA synthesis in primary rat hepatocytes and in one in vitro assay of sister chromatid exchange. In all cases, the positive findings were relatively weak. There were no positive in vivo studies and there was a trend for results to only be positive (or to be stronger) in the absence of metabolic activation than in its presence. This suggests that unchanged dazomet has greater genotoxic potential than the metabolites of dazomet. The unscheduled DNA synthesis assay was the only assay which gave results suggesting that the metabolites of dazomet may have some genotoxic potential, even if only weak.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Dazomet was fed to rats at 0, 5, 30 and 180 ppm for at least 70 days prior to mating, throughout mating and lactation, during production of F_1a and F_1b litters. Selected F_1a pups were maintained on compound-containing diets post-weaning to produce F_2 litters. Hepatotoxicity was observed in both generations, mainly at the high dose, but to some extent at the mid dose. Liver weights were increased and there was an increased severity of liver fatty change. Some serum enzyme and serum protein changes also indicated effects on the liver. There was no impairment of mating or reproductive performance and no adverse effect on reproductive organs or pup development. The NOEL with respect to reproductive function in rats was 180 ppm (about 18 mg/kg/d), while that for systemic toxicity was 5 ppm (about 0.5 mg/kg/d). An oral (gavage) developmental study was conducted in rats at dazomet doses of 0, 3, 10 and 30 mg/kg/d. Food intake and body weight and also uterine weights were reduced at the high dose and to a lesser extent at the mid dose. There was a higher incidence of runts at 10 mg/kg and above, however, without a clear dose-response relationship. There was no evidence of teratogenic effects. The NOEL for maternal and foetal effects was 3 mg/kg/d.
Acute Toxicity	Dazomet is of moderate acute oral toxicity. The oral LD50 values for dazomet from two different studies in rats were about 600 - 900 mg/kg for males and 400 - 550 mg/kg for females. The LD50 of dazomet, given subcutaneously to mice, was 248 mg/kg. The LD50 of dazomet, given subcutaneously to rats, was 470 and 550 mg/kg in males and females, respectively. The dermal LD50 of dazomet in rats was greater than 2000 mg/kg. Symptoms associated with acute dazomet toxicity were shaking, salivation, tonic convulsions, trembling, dyspnoea and lassitude.

Irritation	In two studies, the introduction of 39 or 50 mg dazomet into the eye of rabbits caused slight irritation (moderate conjunctival erythema and slight oedema). Results of two acute dermal irritation studies employing 50% aqueous preparations of dazomet in rabbits were reported. No irritation was observed in the study employing a 4 h exposure period. After a 20 h exposure period, moderate erythema and oedema were observed. Application of the EUP, Basamid Granular (2 g coated on a cottonwool carrier), to the rabbit ear for 20 h caused slight inflammation.
Sensitisation	Skin sensitisation was not observed in two studies following the application of dazomet or Basamid Granular to the guinea pig. No justification was given for the doses / concentrations used in one of these studies and positive control compounds were not tested in these studies.
Health Effects Summary	Dazomet has moderate to low acute oral, dermal and inhalational toxicity. It appears that the toxicity of dazomet is somewhat greater by the oral route than by the dermal and inhalational routes. Dazomet is only a slight dermal and ocular irritant.
Key Study/Critical Effect for Screening Criteria	An ADI of 0.005 mg/kg/d is calculated based on a NOEL of 0.5 mg/kg (established in a 1-year dietary dog study and a 2-year dietary rat reproductive study) and a safety factor of 100.
Ecological Toxicity [1,2,3]	
Aquatic Toxicity	Daphnia magna (Water flea), 48 h, static, EC50 = 0.3 mg/L Salmo gairdneri (Rainbow trout), 96 h, static, LC50 = 0.16 mg/L Ankistrodesmus bribaianus (Green alga), 72 h, static, EC50 = 1.08 mg/L Colinus virginianus (Bobwhite quail), 21 d, LD50 = 415 mg/kg bw Colinus virginianus (Bobwhite quail), 25 weeks, NOEL = 100 mg/kg food
Determination of PNEC aquatic	An assessment factor of 10 has been applied to the lowest reported LC50 of 0.16 mg/L for Rainbow trout. The PNECaquatic is 0.016 mg/L.
Current Regulatory Controls[4]	
Australian Hazard Classification	Acute toxicity – category 4 Eye irritation – category 2 Hazardous to the aquatic environment (acute) – category 1 Hazardous to the aquatic environment (chronic) – category 1
Australian Occupational Exposure Standards	No data available.
International Occupational Exposure Standards	No data available.
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	No data available.
PBT Assessment[1,3,5]	
P/vP Criteria fulfilled?	The half-life of dazomet in soil has been reported as less than 1 day (half-life in soil < 6 months). Thus, it is not expected to be persistent.
B/vB criteria fulfilled?	As the Log Pow is 0.63 at 20 °C (Log Pow < 4.5) and estimated BCF is 2.4, it is not expected to be bioaccumulative.
T criteria fulfilled?	The acute aquatic toxicity of this chemical is >0.01 mg/L. Thus, it is not expected to meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	April 2019

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AECOM Imagine it Delivered

Toxicity Summary - Trisodium Nitrilotriacetate

Chemical and Physical Properties[1,2,3]	
CAS number	5064-31-3
Molecular formula	C6H9NO6.3Na
Molecular weight	257.0
Solubility in water	640 g/l at 20 °C
Melting point	410 °C with decomposition above 200 °C
Boiling point	No data available
Vapour pressure	No data available
Henrys law constant	No data available
Explosive potential	Non-explosive (100%)
Flammability potential	Non-flammable (100%)
Colour/Form	colourless crystalline powder
Overview	The chemicals in this group are known as nitrilotriacetic acid (NTA) and its trisodium and tripotassium salts, trisodium nitrilotriacetate (trisodium NTA) and tripotassium nitrilotriacetate (tripotassium NTA). The trisodium salt also occurs as its monohydrate form (trisodium nitrilotriacetate monohydrate; CAS No. 18662-53-8). The chemical NTA is an aminocarboxylic acid with three functional carboxylate groups. The chemical forms water-soluble complexes with multivalent metal ions. The chemical NTA and trisodium NTA dissociate to form a common moiety, nitrilotriacetate ion. Thus the systemic toxicity of these chemicals is similar (Health Canada, 2010; SCCS 2010). Tripotassium NTA is considered to be functionally similar to trisodium NTA. The chemicals, NTA and trisodium NTA are used to soften water and to remove traces of heavy metals. These chemicals are commonly used as chelating and sequestering agents, and as builders in detergent and cleaning formulations for domestic and commercial use (EU RAR, 2008; SCCS, 2010).
Environmental Fate[1]	
Soil/Water/Air	Trisodium NTA was tested for ready biodegradability according to OECD 301 E (BASF, 1983b,c), OECD 301 F (in addition to a combined CO2/DOC test, see Strotmann et al., 1995), and Sturm Test (BASF, 1983d), and in a die away test (Takahashi et al, 1997) as well as for inherent biodegradability according to OECD 302 B (BASF, 1983a). These tests resulted in 75 -100 % degradation after 7 to 28 days with lag phases ranging between 1 and 16 days. According to results from ready biodegradation tests, trisodium NTA can be regarded as readily biodegradable. In accordance with column 2 of REACH Annex IX, trisodium NTA has a log octanol-water partition coefficient of -13.2 at pH 7, is highly water-soluble, and is unlikely, due to its polar nature, to be taken up by fish gills or across other biological membranes. Due to the ionic structure of the substance a relevant adsorption of trisodium NTA onto the organic fraction of soils, sediments or suspended solids is not expected. However, interaction with the mineral phase may be possible. This assumption is in line with available study results (Dunlap et al., 1971; Bolton et al., 1993) which demonstrate that trisodium NTA is neither strongly sorbed by loam, clay-loam and sandy soils or marine surface sediments (Kp sediment-water = 1.6 l/kg).

Human Health Toxicity Summary[1]	
Chronic Repeated Dose Toxicity	The available data suggest that the chemicals have harmful effects following repeated oral dosing, based on results from animal tests. However, the effects were not sufficient to warrant hazard classification. In a 4-week study, Charles River and Fischer 344 (F344/N) (five or ten animals/group) rats were fed either 0 % or 1.5 % NTA in the diet. Effects observed included reduced growth, increased relative kidney weight, urinary calcium, haematuria and hydronephrosis. A lowest observed adverse effect level (LOAEL) of 1.5 % NTA (equivalent to 750 mg/kg bw/day) was reported (EU RAR, 2008; Health Canada, 2010). In a 10-week study in male Sprague Dawley (SD) rats, trisodium NTA was administered to the rats in drinking water at 0 %, 0.01 %, 0.1 % or 1 % (equivalent to 0, 10, 100 or 1000 mg/kg bw/day). Increased kidney weights were observed in the rats treated at 0.1 % (100 mg/kg bw/day) and marked vacuolisation of the renal tubules was observed at 1 % trisodium NTA (1000 mg/kg bw/day dose) group. A LOAEL of 100 mg/kg bw/day (0.1 % trisodium NTA) was reported (EU RAR, 2008; Health Canada, 2010; SCCS, 2010). Trisodium NTA was administered to male SD rats by gavage at 0, 0.73 or 7.3 mmol/day (equivalent to 0, 187 or 1876 mg/kg bw/day) for 30 days. Cytoplasmic vacuolisation, focal haemorrhage, necrosis, erosion and hyperplasia of the epithelium of the proximal convoluted tubules were observed in all treated animals. An oral LOAEL of 0.73 mmol/day (187 mg/kg bw/day) was reported (EU RAR, 2008; Health Canada, 2010; SCCS, 2010; REACHb). In a 90-day study in rats (strain not reported), NTA was administered to male rats at 0, 100, 1000 or 5000 mg/L in drinking water. All treated animals showed reduced serum potassium levels (EU RAR, 2008; Health Canada, 2010). In two different studies (28-days and 91-days), New Zealand White (NZW) rabbits (six/group) were treated with either 0 or 2.5 % trisodium NTA on intact or abraded skin. No treatment-related effects were observed with or without abrasion (EU RAR, 2008; Health Canada, 2010; SCCS, 2010; REACHa & b). In a 4-week repeated dose inhalation toxicity study, NTA was administered in SD rats, trueblood albino guinea pigs and cynomolgus monkeys at 0, 10, 213 or 343 mg/m^3 concentrations for 6 hours/day by whole body exposure. No respiratory irritation or discomfort was observed at the highest tested concentration. The only treatment-related effects included diarrhoea in monkeys and dyspnoea in rats and guinea pigs. The no observed adverse effect concentration (NOAEC) of 213 mg/m^3 and the lowest observed adverse effect concentration (LOAEC) of 343 mg/m^3 were reported (EU RAR, 2008; Health Canada, 2010; REACHa & b). In another study, male albino rats were treated with NTA at 0, 2, 20, 200 or 2000 mg/m^3 concentrations for 6 hours/day for four consecutive days by inhalation exposure. All animals in the 2000 mg/m^3 showed signs of nasal, respiratory and eye irritation, which were fully reversed on day 14 (EU RAR, 2008; Health Canada, 2010).

Carcinogenicity	Trisodium NTA is classified as hazardous with hazard catergory 'Carcinogenicity – Category 2' and hazard statement 'Suspected of causing cancer' (H351) in the HCIS (Safe Work Australia). The available data support the classification for trisodium NTA. Additionally, the classification for carcinogenicity is considered appropriate for NTA. The International Agency for Research on Cancer (IARC) has classified NTA and its salts as 'Possibly carcinogenic to humans' (Group 2B), based on inadequate evidence for carcinogenicity in humans, but sufficient evidence for carcinogenicity in animal tests (IARC, 1990; IARC, 1995). In two-year carcinogenicity studies in Charles River (CD) rats and B6C3F1 mice, oral administration of Na3NTA induced benign and malignant tumours of the urinary system in both male and female rats at 80–100 mg/kg bw/day and haematopoietic tumours in male mice at 500–600 mg/kg bw. Trisodium NTA was reported to induce renal tubular adenomas and adenocarcinomas in male rats when administered orally (IARC, 1990; IARC, 1995; EU RAR, 2008; Health Canada, 2010; SCCS, 2010; REACHa & b).
Mutagenicity/ Genotoxicity	Based on the weight of evidence from the available in vitro and in vivo genotoxicity studies, the chemicals are not considered to be genotoxic. Several in vitro and in vivo micronucleus tests for gene mutation and clastogenicity were negative, although several positive results were reported (IARC, 1990; IARC, 1995; EU RAR, 2008; Health Canada, 2010; SCCS, 2010; REACHa & b).
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Based on the available information, the chemicals do not cause specific reproductive or developmental toxicity. In different two-generation reproductive and developmental toxicity studies, oral administration of up to 0.5 % trisodium NTA (equivalent to 450 mg/kg bw/day) in the diet of Charles River rats, up to 250 mg/kg bw/day trisodium NTA by gavage in pregnant NZW rabbits, and up to 0.2 % NTA (equivalent to 570 mg/kg bw/day) in drinking water in Naval Medical Research Institute (NMRI) mice, caused no significant maternal, embryonic or foetal effects. No effect on neonatal development was seen in any of the above studies (NTP, 1977; IARC, 1995; EU RAR, 2008; Health Canada, 2010; SCCS, 2010; HSDB; REACHa & b). In a developmental study, female NZW rabbits (groups of 20) were treated by gavage with trisodium NTA in drinking water at 0, 2.5, 25, 100 or 250 mg/kg bw/day during gestation days 7–16. All animals were sacrificed on day 28 of gestation. No treatment-related effects were observed (EU RAR, 2008; Health Canada, 2010; SCCS, 2010; REACHa & b). A study was conducted in pregnant NMRI albino mice (10 animals/group) treated with 0 or 0.2 % trisodium NTA (equivalent to 0 or 570 mg/kg bw/day) in drinking water on 6–18 days of gestation. No significant differences in maternal weight gains and no developmental effects were observed (EU RAR, 2008; Health Canada, 2010; SCCS, 2010; REACHa & b).

Acute Toxicity	Trisodium NTA is classified as hazardous with hazard category 'Acute Toxicity – category 4' and hazard statement 'Harmful if swallowed' (H302) in the HCIS (Safe Work Australia). The available data (median lethal dose—LD50 of 1470 mg/kg bw in female rats and 750 mg/kg bw in monkeys) support this classification. Reported signs of toxicity include ataxia, tremors, hypopnoea, hypothermia, hypoactivity, prostration, staggering, twitching, opisthotonus, tonic convulsion, apathy, salivation and dyspnoea. Available data for NTA indicate an LD50 >6400 mg/kg in rats. The chemicals have low acute toxicity based on results from an animal test in rabbits following dermal exposure. In an acute dermal toxicity study, a 25 % aqueous solution of trisodium NTA monohydrate was applied occlusively to intact skin of rabbits (one animal/sex/dose) at 1000, 1580, 2510, 3980, 6310 or 10000 mg/kg bw. Mild muscle weakness and reduction in activity and appetite were seen in the higher dose groups. No local symptoms or muscular uncoordination were reported. An LD50 of >10,000 mg/kg bw was reported (EU RAR, 2008; REACHa & b). The chemicals have low acute toxicity based on results from animal tests following inhalation exposure. A median lethal concentration (LC50) in rats of >5.0 mg/L was reported for NTA (EU RAR, 2008; Health Canada, 2010; SCCS, 2010).
Irritation	Trisodium NTA is slightly irritating to the animal skin. The effects were not sufficient to warrant a hazard classification. Trisodium NTA is classified as hazardous with hazard category 'Eye Irritation – category 2A' and hazard statement 'Causes serious eye irritation' (H319) in HCIS (Safe Work Australia). The available data support this classification. In an eye irritation study in rabbits, trisodium NTA was found to be irritating. Conjunctivitis and marked corneal effects were observed at 24, 48 and 72 hours after application (ECHA, 2006). Effects were not reversible within the 7-day period. In a study, albino rabbits had considerable discomfort immediately after application of 100 mg of trisodium NTA monohydrate. Effects observed one hour after application included copious discharge, oedema with partial eversion of the lids, moderate redness and congestion with obscure iris. Discharge and oedema reduced on washing the eyes with saline solution after 24 hours. Complete reversal oedema occurred but mild redness and slight corneal dullness were observed on days 5 to 7 (EU RAR, 2008; Health Canada, 2010; SCCS, 2010; REACHb). In another study conducted according to OECD Test Guideline (TG) 405, trisodium NTA (0.1 mL of 38 % solution) applied to the conjunctival sac of three albino rabbits caused slight eye irritation. The average scores for conjunctival redness and chemosis after 24 hours were 2.0 and 0.7, respectively. The conjunctival redness score was 0.1 after 48 hours and no chemosis was present. The conjunctival redness was reversible within 8 days after application. No effects on the cornea and iris were reported (EU RAR, 2008; Health Canada, 2010; SCCS, 2010; REACHb).
Sensitisation	Based on the available data, the chemicals are not considered to be skin sensitisers.
Health Effects Summary	The critical health effects for risk characterisation include systemic long-term effects (carcinogenicity) for all three chemicals, and systemic acute effects (acute toxicity from oral exposure) and local effects (eye irritation) for trisodium NTA and tripotassium NTA only.
Key Study/Critical Effect for Screening Criteria	The Australian Drinking Water Guideline for NTA is 0.2 mg/L.

Ecological Toxicity[4]	
Aquatic Toxicity	Tests on acute toxicity to fish resulted in 96-hour LC50 values in the range of 98 – 487 mg/l. In a generation-cycle test over 224 days on Pimephales promelas (Arthur et al., 1974), there were no observable differences in survival, spawning activity, and egg hatchability at the highest tested concentration of 54 mg/l trisodium NTA (the active test substance was Ca- or Mg-NTA). Based in this study, the NOEC for fish is determined to 54 mg/L. All tests on acute toxicity to invertebrates showed effects only when the trisodium NTA concentration exceeded the stoichiometric metal levels of the medium. It is expected that effects are caused by the uncomplexed agent. This is supported by the increased effect values in hard water. In long-term tests, the most sensitive organism was the amphipod Gammarus pseudo limnaeus. In a generation-cycle test over 21 weeks exposure, the lowest tested concentration without significant effects was 9.3 mg/l trisodium NTA. Based in this study, the NOEC for invertebrates is determined to 9.3 mg/l. At this concentration, NTA is mainly complexed with Ca and Mg.
Determination of PNEC aquatic	Reliable long-term data was available for a fish, invertebrate and algae. The lowest NOEC of 9.3 mg/L was a result for testing with Gammarus pseudolimnaeus (Arthur et al. 1974). An assessment factor of 10 was used for a resulting PNEC for intermittent releases of 0.93 mg/L.
Current Regulatory Controls[1]	
Australian Hazard Classification	Trisodium NTA is classified as hazardous, with the following risk phrases for human health in the Hazardous Chemicals Information System (HCIS) (Safe Work Australia): Acute toxicity – category 4; H302 (Harmful if swallowed) Eye irritation – category 2; H319 (Causes serious eye irritation) Carcinogenicity – category 2; H351 (Suspected of causing cancer).
Australian Occupational Exposure Standards	The chemical NTA has an Australian drinking water guideline value of 0.2 mg/L (NHMRC, 2011; FSANZ).
International Occupational Exposure Standards	The following exposure standards are identified (Galleria Chemica; Protective Action Criteria (PAC)): Temporary Emergency exposure limits (TEELs) defined by the US Department of Energy (DOE): TEEL-1= 3.7 - 9.2 mg/m^3; TEEL-2= 40 - 100 mg/m^3; TEEL-3= 220 - 110 mg/m^3.
Australian Food Standards	The chemical NTA has an Australian drinking water guideline value of 0.2 mg/L (NHMRC, 2011; FSANZ).
Australian Drinking Water Guidelines	The chemical NTA has an Australian drinking water guideline value of 0.2 mg/L (NHMRC, 2011; FSANZ).
Aquatic Toxicity Guidelines	No data available.
PBT Assessment	
P/vP Criteria fulfilled?	NTA is readily biodegradable and as such not persistent in the environment.
B/vB criteria fulfilled?	Trisodium NTA has a log octanol-water partition coefficient of -13.2 at pH 7, is highly water-soluble. Thus, it is not expected to be bioaccumulative.
T criteria fulfilled?	The acute aquatic toxicity of NTA is > 0.01 mg/L. Hence the substance does not fulfil the screening criteria for toxic (T)

Overall conclusion	Not PBT
Revised	March 2019

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Toxicity Summary - Xanthan Gum

Chemical and Physical Properties[1,3]	
CAS number	11138-66-2
Molecular formula	Unspecified
Molecular weight	high-molecular weight (of the order of 1000 kDa)
Solubility in water	Water-soluble
Melting point	No data available.
Boiling point	No data available.
Vapour pressure	No data available.
Henrys law constant	No data available.
Explosive potential	No data available.
Flammability potential	No data available.
Colour/Form	No data available.
Overview	Xanthan gum is a high molecular weight anionic polysaccharide secreted by the bacteria *Xanthomonas compestris*. It is used as a stabilizer and thickener for foods, pharmaceuticals, and cosmetics, for rheology control in water-based systems, and in oil and gas drilling. Xanthan gum is used for controlling the viscosity of drilling muds (DoE 2014). This chemical has been identified by NICNAS to be of low concern to human health based on an initial screening approach and thus required no further assessment.
Environmental Fate[1]	
Soil/Water/Air	Xanthan gum is expected to exhibit similar behaviour to that of guar gum because the two compounds are chemically similar. Thus, it is expected to adsorb strongly to soil and sediment and there is limited potential for it to reach surface waters via dissolved runoff and / or to leach into ground water. Volatilisation from soils and water is not considered to be a likely transport process in the environment (US EPA 2005). Xanthan gum is expected to readily undergo microbial biodegradation in the environment (on the bases that it is polysaccharide and expected to be readily biodegradable), and the potential to bioaccumulate in organisms is considered to be low.

Human Health Toxicity Summary[2]	
Chronic Repeated Dose Toxicity	Groups of 30 male and 30 female Charles River CD strain rats were fed diets for 104 weeks supplying O, 0.25, 0.5, or 1.0 g/kg b.w./day xanthan gum. No abnormalities which could be attributed to ingestion of these experimental diets were found with regard to survival, body-weight gain, food consumption, behaviour, or appearance. Ophthalmic and haematologic examination yielded normal results. Analysis of blood for glucose, SGOT, and prothrombin time showed no abnormalities in test groups. Organ weights were within normal limits and no lesions attributable to xanthan gum were found on gross and histopathological examination (Woodard et al., 1973). Xanthan gum was administered in the diet at levels supplying 0, 0.25, 0.37, or 1.0 g/kg b.w./day to groups of 4 male and 4 female beagle dogs for 107 weeks. No effects attributable to administration of the gum were seen in the treated animals with regard to survival, food intake, body-weight gain, electrocardiograms, blood pressure, heart rate, body temperature, or ophthalmic and neurological examinations. Haemoglobin, total and differential white cell counts, coagulation and prothrombin times, thrombocyte counts, serum alkaline phosphatase, blood urea nitrogen, blood glucose, SGOT, and SPGT were the same in control and treated animals. Urine pH, glucose concentrations, and sediment contents were comparable between test and control groups, but there was a dose-related increase in urine SG and a more frequent appearance of urinary albumin in dogs consuming 1.0 g/kg b.w./day of gum than in the other groups. Stool consistency was normal at the 0.37 g/kg level, but stools were loose at the top-dose level. The weight of the faeces showed a dose-related increase, as would be expected from feeding a non-absorbed hydrophilic gum at high-dose levels. The increased urinary SG is consistent with physiological adjustment for the extra water excreted in the faeces. Examination of the appearance and weights of organs and histopathological examinations failed to detect any adverse effects of treatment with xanthan gum at any dose level (Woodward et al.,1973).
Carcinogenicity	No data available.
Mutagenicity/ Genotoxicity	No data available.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	A three-generation reproduction study was carried out using groups of 10 male and 20 female rats in the first generation and 20 male and 20 female rats in subsequent generations. Dosage levels of 0, 0.25, and 0.5 g/kg/day were administered in the diet. Criteria evaluated were survival, body weight, general appearance, behaviour, the number of litters produced, number of live births and still births, physical condition of the young, weight at birth and weaning, and survival of the young. Females that had fewer than two litters were examined to determine whether there was foetal resorption. Malformations in offspring were recorded and gross and micropathological examinations were made on the offspring of the second and third generations. No adverse effects attributable to xanthan gum were found in this study (Woodard et al., 1973).
Acute Toxicity	A study was carried out on an unspecified number of rats fed diets containing 7.5 or 10% xanthan gum for 99-110 days. No adverse effects were observed in extensive investigatins on these animals (Booth et al., 1963). In a 91-day feeding study, a reduced rate of weight gain was found in groups of rats receiving 7.5 or 15% xanthan gum in the diet. Diets containing 3 or 6% gum did not reduce weight gain. No significant alterations in haemoglobin, red or white cell counts, or organ weights were observed in these rats. Histological examination of tissues from rats at the 15% level showed no pathological effects. At the highest-dose level the animals produced abnormally large faecal pellets, but diarrhoea did not occur. A paired-feeding test was used to compare the growth of rats ingesting a diet containing 7.5% xanthan gum and comparable rats restricted to the same intake of control diet. No differences in weight gain were found at the end of 18 days, indicating the absence of a growth-inhibiting factor (Booth et al.,1963). Groups of 3 male and 3 female beagle dogs were fed diets supplying 0, 0.25, or 0.5 g/kg b.w./day xanthan gum for 12 weeks. Animals in the high-dose group had softer stools than normal, but no diarrhoea. Growth was slightly retarded in the males and the serum cholesterol level was lowered in both sexes of the high-dose group. No other adverse effects were seen. The no-adverse-effect-level in this test was considered to be 0.25 g/kg b.w./day (USDA, 1964).

Irritation	Daily application of a 1% solution for 15 days to rat skin produced no signs of irritation. Daily application of a 1% solution for five days to rabbit conjunctiva produced no signs of irritation.
Sensitisation	Intradermal challenge tests in guinea-pigs did not produce evidence of sensitization (Hendrickson & Booth, sine data).
Health Effects Summary	A mild skin and eye irritant
Key Study/Critical Effect for Screening Criteria	The Joint FAO/WHO Expert Committee on Food Additives allocated an Acceptable Daily Intake (ADI) of "not specified".
Ecological Toxicity [1,2,3]	
Aquatic Toxicity	Acute Fish (measured) = 420 mg/L
Determination of PNEC aquatic	Based on acute fish toxicity of 420 mg/L, an assessment factor of 1000 was used for a resulting PNEC of 0.42 mg/L.
Current Regulatory Controls	
Australian Hazard Classification	No data available.
Australian Occupational Exposure Standards	No data available.
International Occupational Exposure Standards	No data available.
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	No data available.
PBT Assessment	
P/vP Criteria fulfilled?	No biodegradation information was found on xanthan gum. However, xantham gum is a naturally occurring polysaccharide which would be expected to readily biodegrade. Thus, it is not expected to meet the screening criteria for persistence
B/vB criteria fulfilled?	Xantham gum is not expected to meet the criteria for bioaccumulation.
T criteria fulfilled?	Not applicable. Acute toxicity data >1 mg/L in fish, thus xanthan gum does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	March 2019

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Appendix D: Spill Management Plan

BEETALOO EXPLORATION PROGRAM
Spill Management Plan

Review record

Rev	Date	Reason for issue	Authors	Consolidator	Approver
0	18/04/2019	Issued for review	MK	LF	EW
1	26/07/2019	Updated to meet final CoP	Mk	SM	EW

Review due: 18/05/2019

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1. Purpose

This spill Management Plan (SPMP) is designed to outline the measures as to how the risks of spills associated with Origin Energy's Beetaloo Basin exploration activities will be managed. The exploration activities covered under this SPMP include:

- The Kyalla 117 N2 exploration well
- The Velkerri 76 S2 exploration well.

This Plan has been developed in accordance with the Code of Practice: Onshore Petroleum Activities in the Northern Territory (referred to herein as the Code of Practice).

2. Key Legislation

Key legislation and documents consulted in the development of this plan are provided below. A full list of applicable legislation is provided in the corresponding management plans.

- **Code of Practice: Onshore Petroleum Activities in the Northern Territory:** Mandatory code of practice legislating the management of chemicals and wastewater onsite, including the use of secondary containment, lined tanks and spill management plan,
- **Transport of Dangerous Goods by road and Rail (National Uniform Legislation) Act 2010:** covers the transportation of goods by road in the NT. This also covers licences for vehicles and drivers carrying dangerous goods.
- **Workplace Health and safety (National Uniform Legislation) Act 2011;** covers the storage and handling of chemicals on site.
- **Waste Management and Pollution Control Act 1998:** Covers the requirements for the transportation and disposal of waste within the NT. This includes the requirements for contractors, vehicles and facilities managing listed wastes to be licenced.

3. Chemicals and Wastewater Description

Chemicals and Wastewater stored onsite includes:

- Chemicals used for drilling
- Waste drilling fluids
- Chemicals used for stimulation
- Flowback Wastewater
- Completions and well suspension fluid s
- Condensate and oil
- Diesel and fuels
- General equipment maintenance chemicals (hydraulic oils, degreasers etc.)

The full list of chemicals and wastewater stored onsite, including their volume and location are provided in appendix A.

4. Spill Failure Scenarios

Potential spill scenarios associated with exploration activities are summarised in Table 3. These scenarios include:

- Spills from chemical and wastewater handling and storage activities onsite
- Spills from chemical and wastewater during transportation (offsite)
- Tank, drilling sump and containment vessel overflows and structural failures

The loss of containment due to the failure of well barriers is covered under the Well Operations Management Plan (WOMP).

Table 1 Spill Scenario summary table

Spill Scenario	Activity duration	Mechanisms	Location	Quality	Quantity	Key management controls	Monitoring	Receptors
Spills from chemical and wastewater handling and storage activities onsite	•Drilling – 45 days •Stimulation- 30 days •Well testing- 12 months	•Container rupture •Spill during chemical handling and mixing	•Chemicals storage area • Drilling rig •Stimulation spread •Drilling sumps •Flowback storage tanks •well testing equipment	•Saline drilling fluids Saline flowback •Chemicals listed in appendix A	<1000L <1000L <100L	•Designated storage areas with appropriate segregation of incompatible chemicals •Secondary containment to be deployed under high risk spill/ leak storage and handling areas •Spill kits available •Routine inspection of chemical stores •Sites are manned during operations •wastewater management plan	Routine inspection of chemical stores, sumps and tanks during operations Tank leak detection	Retained onsite.
Loss of containment during transfer onsite (leakage from pipes, hoses, fittings etc)	•Drilling 45 days •Stimulation 30 days •Well testing 12 months	Coupling, valve, hosing and equipment failure,	Chemical mixing and transfer areas on the drill rig, mixing hoppers and wastewater storages.	•Saline drilling fluids and wastewater. •Chemicals listed in Appendix A.	<5000L	•Secondary containment to be deployed under high risk spill/ leak storage and handling areas •Spill kits available •Routine inspection of chemical stores •Sites are manned during operations •Wastewater management plan	Routine inspection of all chemical handling areas, including wastewater transfer points and chemical mixing areas.	Retained onsite.
Spills from chemical and wastewater during transportation (offsite)	•Drilling chemical transfer- 1-5 days of bulk chemical transfer generally pre-drilling. •Stimulation chemical transfer 2-3 truckloads of chemicals per week for ~6 weeks •Wastewater disposal over 3 weeks- up to 100 truck movements total over the duration.	•Transport spill •Traffic accident (total or partial release)	Offsite along highway	•Various chemicals as listed in Appendix A •Saline wastewater.	<1000L for transport spill <50,000L for total loss of B-triple carrying flowback.	•All transport companies to be appropriately licenced to transport chemicals and waste (Dangerous goods and Waste Management and Pollution control Act) including the requirement to detect and respond to spills. •Wastewater management plan	Performance of contractors to be monitored as a part of transportation contractors.	•Chemical transport between Darwin/ south Australia and Queensland/ and Daly Waters. •Wastewater transportation between Daly Waters and Queensland Via Tennant Creek.
Tank, drilling sump and containment vessel overflows and structural failures	•Duration of all activities plus ongoing wastewater storage which may be extended beyond 12 months to allow for ongoing evaporation of fluids.	Overfilling of a sump and Flowback tank Structural failure of embankment or tank wall	Sumps and Tanks on lease	Saline wastewater with TDS >50,000mg/l	>10,000L	•Lease pads bunded during the storage of flowback •Enclosed tanks used during wet seasons operations Open tanks with 1:1000ARI freeboard •Tanks constructed to Australian Standards Routine tank and sump inspections	Routine tank and sump level and structural integrity (visual) inspections.	Retained on lease pad within bund.

5. Potential Receptors

A description of the environment, including environmental and cultural sensitivities, with the potential to be impacted by a spill is provided in each of the EMP's. The location of activities is remote Figure 1 illustrates the separation distance from sensitive receptors such as:

- Watercourses
- Communities
- Homesteads
- Heritage places
- Vegetation communities; and
- Protected areas

Maps regarding sacred sites and restricted work areas are also applicable and will be provided to work crews to ensure awareness of these features.

6. Risk Assessment

The risk of spills associated with all drilling, stimulation and well testing activities is covered under following EMP's

- Kyalla 117 N2 Drilling, Stimulation and Well Testing EMP NT-2050-MP-15- 023
- Velkerri 76 S2 Drilling Stimulation and Well Testing EMP NT-2050-MP-15-032

7. Control Measures

Controls measures to manage spills associated with exploration activities are provided in the Environmental Management Plans and summarised in Table 3. The key management controls include:

- Contractors are required to develop spill management plans to comply with the requirements of this plan.
- A Wastewater Management Plan (WWMP) has been developed and implemented governing how wastewater will be managed onsite.
- All flowback, completion fluids, chemicals, oil and fuel storage will be equipped with secondary containment (or dual liners), as per the codes of practice
- Drilling and flare pits will be lined, with enough freeboard to manage a 1:1000ARI wet season
- Tanks will be designed, installed and operated as per the WWMP.
- Where flowback is being stored on a lease pad, the lease pad shall be earthen bunded to prevent release to surrounding areas in the case of a catastrophic failure.
- Well sites are designed and constructed to prevent spills of hazardous chemicals; this includes
    - compacting the lease pad surface to prevent infiltration
    - provision of chemical segregation areas
- Monitoring to detect spills will be undertaken in accordance with section 9
- Procedures will be developed by contractors designed to detect, remediate and report any spills. This includes:
    - Chemical handling procedures
    - Chemical storage and handling Inspection procedures
    - Spill prevention, detection and response procedures
- the transport of hydraulic fracturing chemicals and wastewater during the wet season will be avoided, unless a site specific risk assessment indicates the risk is equal to or below a moderate.
- effective spill clean-up material readily available at each work site and on all mobile service trucks or vehicles, where hydrocarbons and chemicals are stored and / or used
- Inspection reports and maintenance records of secondary containment shall be kept and available for review upon request.
- Spill response mock up drills to be completed as a part of routine emergency response

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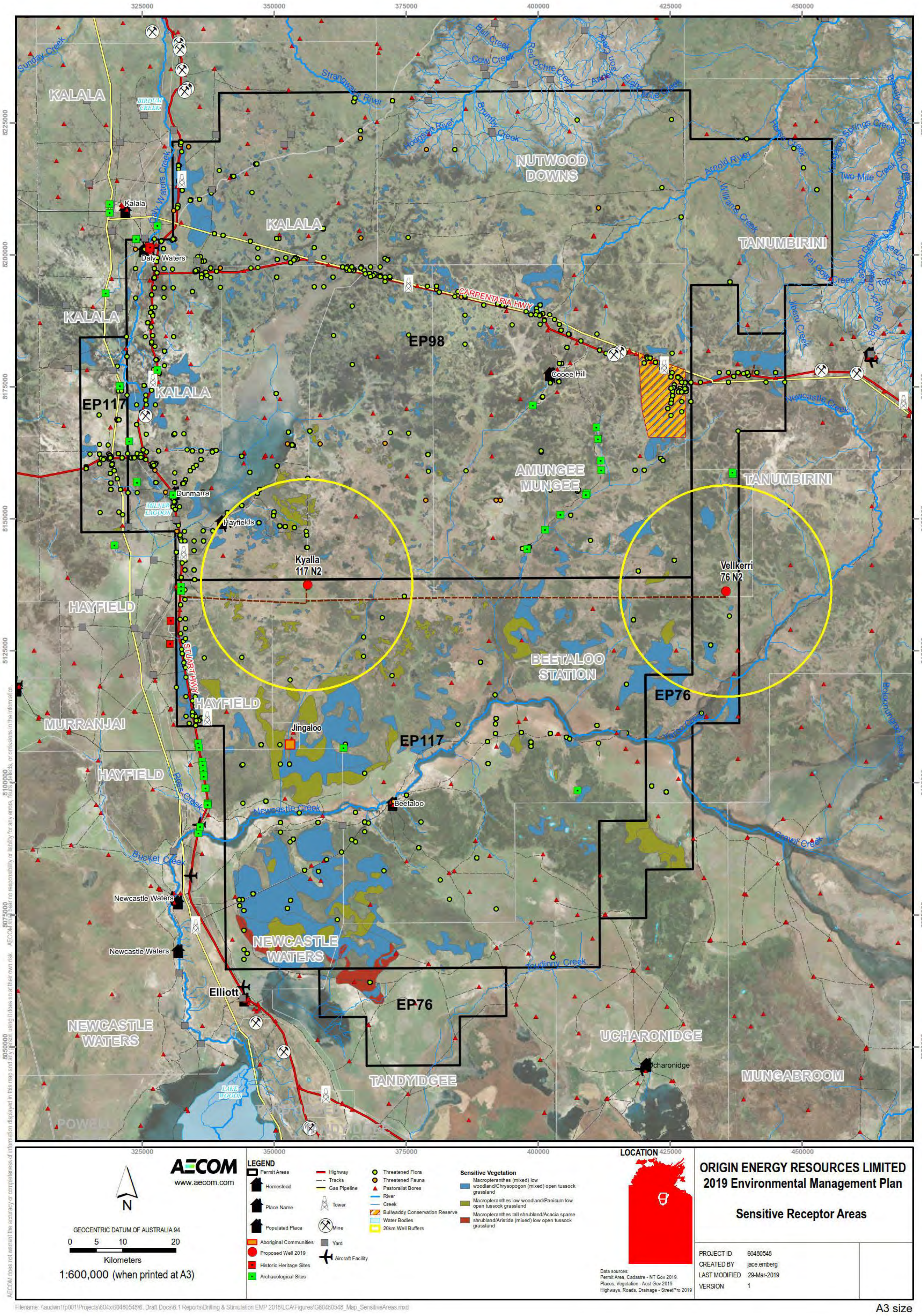

Figure 1 Location of activities and potential receptors

8. Spill Response and management

The following section provides an overview of the response to spills during drilling, stimulation and well testing activities. Where the spill is the result of an emergency situation that is still active, the Beetaloo Exploration Emergency Response Plan (NT-2050-15-MP-024) will take precedence over this plan

8.1 Rapid spill Assessment

When a spill occurs, the on-site Supervisor will carry out a rapid assessment to determine the potential hazards and the type and location of emergency assistance required. This assessment shall include the following:

- Determine the physical (volume and state) and location of the spill
- Determine the appropriate spill category and type of response as per section 12.1.
- Assess the hazard of the material spilled, including any potential hazards associated with chemical mixing (such as oxidising and reducing agents);
- Determine the safety hazard to immediate response personnel and whether additional resources (such as emergency services or specialised equipment or advice) are required to managed the spill safely;
- Determine spill movement, factors affecting the movement (i.e. impending weather, topography, drainage lines etc.) and spill response priorities as per Table 2 (people, communities, environmental and cultural heritage).

Table 2 Spill response priorities

Spill PRIORITY	RESPONSE CONSIDERATIONS
People and communities	• Evacuate and muster (if deemed necessary). • Account for all people and determine missing persons. • Stop unauthorised access. • Provide a technical resource to the Emergency Services (if required). • Protect community and pastoralists
Environment and sacred sites	• For emergencies that are safe to manage, onsite personnel will respond with available resources to limit the extent of the impact to the environment or a protected site. • For larger incidents, or where it is unsafe for onsite personnel to respond, trained people will be mobilised to control and contain the emergency to minimise the impact to the environment or protected site.
Regulators	• Notify Regulators as per incident reporting requirements
Assets	• Monitor automatic shutdown of the equipment or part thereof, or initiate manual shutdowns where it is safe to do so. • Mobilise Emergency Services to intervene.
Reputation	• Notify neighbours (if required).

8.2 Spill containment and clean up procedures

Generic spill containment clean-up procedures must be developed and implemented by each drilling, stimulation and well testing contractor aligning with the requirements of this plan. These procedures shall be adapted (where appropriate) to consider the site and chemical specific hazards associated with each spill event.

The procedures shall consider the following generic spill containment and response procedure:

- Move all people out of harm's way.
- Alert others near-by
- Assess the situation – determine what substances are involved, the potential receptors (people and the environment) and if additional support is required. The substance must be known prior to taking any action (refer to MSDS).
- If applicable; remove any possible risk escalating factors (e.g. ignition hazards in case of flammable/combustible spills); approach from up-wind to reduce fume risks, isolate the spill source (close containment valve, similar). Ensure appropriate controls requirements are met –e.g. PPE, first aid support, etc. - prior to conducting spill clean-up.

- If it is safe to do so; stop the source of the leak (if possible) and contain the spill using onsite equipment to prevent from leaving site or entering a waterway or sensitive feature
- Recover free liquid and contaminated material as soon as practicable to mitigate infiltration. Material recovery should consider the benefit of recovery versus the additional impact that recovery of all contaminated material could cause as per the National Environment Protection (Assessment of Site Contamination) Measure
- Prevent people, livestock and wildlife access to hazardous material through fencing or other barriers.
- Store contaminated material in a manner to minimise the risk of additional contamination.
- For level 2 spills and higher, the Project Manager shall be notified as soon as it is safe to do so, but within 24 hours.
- Project Manager to ensure appropriate external (DPIR/DENR) incident reporting requirements are actioned in accordance with the impact of the spill.
- For level 2 spills and higher, Origin Project Manager to seek expertise as to whether additional testing and remediation is required upon completion of the initial containment and clean up. This consideration will be undertaken in in accordance with the National Environment Protection (Assessment of Site Contamination) Measure
- Upon rectification of a reportable spill, an incident investigation shall be completed as per the Petroleum (Environment) Regulations. This shall include the root cause of the incident, actions taken to mitigate the impact and ongoing monitoring and maintenance required to ensure the site is stable and non-polluting.

8.3 Contaminated Material Disposal

- During a spill clean-up, the storage of contaminated material must be undertaken in a manner that minimises additional contamination
- Offsite disposal must be undertaken in accordance with the NT Waste Management and Pollution Control Act 1998.
- All listed waste transportation shall be undertaken by licenced contractors, be tracked and disposed of at approved waste management facilities.

9. Monitoring and inspections

The monitoring and inspection programs to identify spills is summarised in Table 3.

Table 3 Spill monitoring and inspections

Monitoring Program	Frequency	Methodology	Purpose	Minimum volume of leak
Tank and sump level monitoring (when wastewater is stored onsite)	During operations: Daily All other times: Weekly during Dry season Daily during the wet season	Level dip/ visual assessment	Prevent the overtopping of tanks	10's of litres.
Tank leak detection (when wastewater is stored onsite)	Continuous	Instrument	Detect the migration of fluid through primary containment	10's of Litres
Chemical storage areas (when chemical stored onsite)	Daily during operations Weekly all other times	Visual	Detection of leaks	Litres
Tank structural integrity (when wastewater is stored onsite(	Weekly	Visual inspection	Detect potential structural weakness	N/A

10. Roles and Responsibilities

The critical roles and responsibilities set out in Table 4 are for the main members of the Spill Response Group. This team represents the core group of resources that will lead a spill response with the support of the broader Origin Energy Team.

Table 4 Roles and responsibilities

Position	Role & Responsibility
Project Manager	Ultimately accountable for the implementation of the spill management Plan. Role, or delegate, will liaise with Origin Environment Specialists to determine remediation requirements and external reporting obligations.
On-Site Supervisor	Responsible for the initial response to a spill. This role will be delegated to the well site representative or nominated contractor in charge of a work program. Role will undertake the initial spill assessment, engage emergency services (if required) and co-ordinate immediate spill clean-up operations associations to minimise the potential impacts to people, places and the environment.
Environment/ HSE Lead	Report Spill to Regulatory Authorities. Provide expertise on clean up requirements and ongoing monitoring and management requirements. Interface with government and regulatory bodies for communication and consents
Emergency Response Lead	Provide specialist technical advice (Emergency Response) to support spill management activities

11. Implementation

All contractors engaged to perform drilling, stimulation and well testing will be required to comply with this plan. A bridging SPMP will be developed be each contractor summarising the activities to be undertaken to comply with this plan and the NT Code of Practice.

12. Spill Reporting

12.1 Spill Rating

Table 5 provides a summary of the spill classification based upon the volume and location of spill. The hazards of the potential spill to people and the environment should be assessed independently, to ensure incident specific hazards are considered in the spill response. This table provides guidance as to the likely spill scenarios that may trigger the different incident reporting requirements. The spill tiers include:

- **Level 1:** Spills that can be contained within the well site and can be cleaned up by the operator without involvement of external organisations. Most Tier 1 spills are likely to be less than 200L and would include diesel spills during fuel transfer, oil spillage during routine maintenance or small wastewater spills during well testing. Clean up time is generally less than 1 day. These spills will most likely be classified as recordable incidents as per section 12.Spill Reporting
- **Level 2:** Spills that have not been completely contained within the site boundary and/or may require additional resources to clean-up. Clean up time is generally less than a week. Level 2 spills are typically reportable incidents as defined in section 12 and may also require notification under the WMPCA.
- **Level 3 :** Severe spills that cannot be contained by the operator and requires substantial additional resources to manage the spill. Clean up time is generally greater than a week. Level 3 spills are reportable incidents.

Table 5 Spill Tier Levels

		Spill (L)		
		20-200L	200-2,500 L	>2,500 L
Receiving environment	Bund or contained impervious area	**Not reportable***	**Not reportable***	**Not reportable***
	Onsite *(lease pad, camp pad, hardstand, road or work area)* compacted or sealed surface**	**Not reportable***	**Level 1**	**Level 2**
	Offsite permeable surfaces- areas adjacent to lease pads, camp pads, roads where spills have moved beyond the approved activity area. **	**Level 1**	**Level 2**	**Level 3**
	Sensitive environmental or cultural feature (such as a waterway, drainage lines, wetland, high valued habitat and sacred site) or where the spill has, or has the potential to, cause material or serious environmental harm **	**Level 2**	**Level 2**	**Level 3**

Notes:

* *Non-reportable spills must be recorded in Origin's OCIS (and made available for review by Contractor), with monthly reviews.*

** *spills of Dangerous goods or wastes offsite may need to be reported under NT Dangerous Goods Act or Waste Management and Pollution control Act 1998.*

12.2 Incident Reporting

12.2.1 Reportable Environmental Incident Reporting

The Petroleum (Environment) Regulations define a reportable incident as an incident arising from a regulated activity that has caused, or has the potential to cause, material environmental harm or serious environmental harm as defined under the Petroleum Act. This is applicable to a spill that has occurred during the conduct of activities covered under this plan that is typically a potential level 2 or 3 type spill as defined in Table 5.

An interest holder must notify (this may be oral or in writing) DPIR of a reportable incident as soon as practicable but no later than two-hours after the first occurrence of the incident or after the time the interest holder becomes aware of the incident.

DPIR can be notified through the DPIR Operations Term Emergency number 1300 935 250.
Any verbal report to DPIR must be followed up by a written report from the Project Manager within three days in accordance with the Petroleum (Environment) Regulations.

12.2.2 Recordable incidents

The Petroleum (Environment) Regulations define a recordable incident as an incident arising from a regulated activity that:

I. Has resulted in an environmental impact or environmental risk not specified in the current plan for the activity; or

II. Has resulted in a contravention of an environmental performance standard specified in the current plan for the activity; or

III. Is inconsistent with an environmental outcome specified in the current plan for the activity; and

IV. Is not a reportable incident.

These tpes of spills are typically a level 1 type spill as defined in Table 5.
An interest holder must notify (this may be oral or in writing) DPIR of a recordable incident as soon as practicable but no later than 15-days after the reporting period (agreed period or each 90-day period after the day on which the EMP is approved).

12.2.3 Waste Management and Pollution Control Act incident reporting

In accordance with the NT Waste management and Pollution Control Act 1998 (WMPC Act), the operator has a duty to notify of pollution incidents causing or threatening to cause pollutions as soon as practicable, but no less than 24 hours after becoming aware of the incident.

A notifiable incident is defined as an incident that causes, or is threatening or may threaten to cause, pollution resulting in material environmental harm or serious environmental harm.
A notification must include:
(a) the incident causing or threatening to cause pollution;
(b) the place where the incident occurred;
(c) the date and time of the incident;
(d) how the pollution has occurred, is occurring or may occur;
(e) the attempts made to prevent, reduce, control, rectify or clean up the pollution or resultant environmental harm caused or threatening to be caused by the incident; and
(f) the identity of the person notifying

The notification shall be made to the NT EPA Pollution Hotline 1800 064 567.

Appendix A Chemical volumes and storage areas

Material Name	Volume	Unit	Storage Area
Acetic Acid - 60%	3,000	L	Stimulation chemical storage area
BE-9 Biocide	17,000	L	Stimulation chemical storage area
Caustic Soda Liquid	15,000	L	Stimulation chemical storage area
DCA-11001 Breaker Activator	5,000	L	Stimulation chemical storage area
DCA-13002 Breaker	300	kg	Stimulation chemical storage area
DCA-13003 Breaker	10,000	L	Stimulation chemical storage area
DCA-16001 Clay Stabiliser	42,000	L	Stimulation chemical storage area
DCA-17001 Corrosion Inhibitor	1000	L	Stimulation chemical storage area
DCA-19001 Crosslinker	600	kg	Stimulation chemical storage area
DCA-19002 Crosslinker	10,000	L	Stimulation chemical storage area
DCA-23001 Friction Reducer	5,000	kg	Stimulation chemical storage area
DCA-23003 Friction Reducer	18,000	L	Stimulation chemical storage area
DCA-25005 Gelling Agent	35,000	kg	Stimulation chemical storage area
DCA-30001 Scale Inhibitor	15,000	L	Stimulation chemical storage area
DCA-32002 Surfactant	15,000	L	Stimulation chemical storage area
DCA-32014 Surfactant	200	L	Stimulation chemical storage area
FE-2 Buffer	200	kg	Stimulation chemical storage area
Hydrochloric Acid - 32%	50,000	L	Stimulation chemical storage area
100 Mesh Sand	91,000	kg	Stimulation chemical storage area
40/70 Sand	1,650,000	kg	Stimulation chemical storage area
30/50 Sand	610,000	kg	Stimulation chemical storage area
Sodium Chloride	15,000	kg	Completion chemical storage area
ALDACIDE G	500	L	Completion chemical storage area
OXYGON	100	kg	Completion chemical storage area
BARACOR 100	2,000	L	Completion chemical storage area
CON-DET	50	kg	Drilling chemical Storage
SAPP	50	kg	Drilling chemical Storage
Bentonite	3,000	kg	Drilling chemical Storage
Caustic Soda	1,400	kg	Drilling chemical Storage
EZ MUD DP or EZ MUD Liquid	,2000	kg	Drilling chemical Storage
ALDACIDE G	336	kg	Drilling chemical Storage
STOPPIT	1,000	kg	Drilling chemical Storage
Soda Ash	350	kg	Drilling chemical Storage
BARACOR 100	250	kg	Drilling chemical Storage
Sodium Chloride (Flossy Salt)	96,000	kg	Drilling chemical Storage
Barite	500	kg	Drilling chemical Storage
BARACARB	500	kg	Drilling chemical Storage
Citric Acid	500	kg	Drilling chemical Storage
BARADEFOAM HP	500	kg	Drilling chemical Storage
Sodium Bicarbonate	500	kg	Drilling chemical Storage
PERFORMATROL	500	kg	Drilling chemical Storage
SOURSCAV	500	kg	Drilling chemical Storage

Material Name	Volume	Unit	Storage Area
DRIL-N-SLIDE	500	kg	Drilling chemical Storage
STEELSEAL	500	kg	Drilling chemical Storage
BARAZAN D or BARAZAN D PLUS	4,150	kg	Drilling chemical Storage
PAC L	2,300	kg	Drilling chemical Storage
Potassium Chloride	22,500	kg	Drilling chemical Storage
GEM CP/GP	500	kg	Drilling chemical Storage
QUIK-FREE	500	kg	Drilling chemical Storage
BAROFIBRE, BAROFIBRE Superfine and BAROFIBRE COARSE	500	kg	Drilling chemical Storage
BaraBlend-657	500	kg	Drilling chemical Storage
N-DRIL HT PLUS	500	kg	Drilling chemical Storage
DEXTRID LTE	4,600	kg	Drilling chemical Storage
BARABUF	500	kg	Drilling chemical Storage
BORE-HIB	500	kg	Drilling chemical Storage
BDF 933 or BaraLube W-933	864	kg	Drilling chemical Storage
BAROLIFT	500	kg	Drilling chemical Storage
OXYGON	500	kg	Drilling chemical Storage
ENVIRO-THIN	500	kg	Drilling chemical Storage
Lime	500	kg	Drilling chemical Storage
BDF 677	4,770	kg	Drilling chemical Storage
BDF 988	3,390	kg	Drilling chemical Storage
Waste Drilling Fluids	2,500	m3	Drilling mud sump
Completion fluids	1.4	ML	Drilling sump/ onsite tank
Condensate	160	KL	Condensate storage area
Diesel	100	KL	Diesel storage tanks
Hydraulic oil	1000	L	Workshop
Engine oil	1000	L	Workshop
Degreasers	100	L	Workshop
Flowback	2-5	ML	Flowback tanks

Appendix E: Wastewater Management Plan

THE BEETALOO EXPLORATION PROJECT
Wastewater Management Plan

Review record

Rev	Date	Reason for issue	Author	Reviewer	Approver
0	15/06/2019	Released for use	MK	LF	EW
1	26/07/2019	Revised to align with final CoP	Mk	SM	EW

Review due: 18/05/2021

Beetaloo Exploration WWMP

NT-2050-15-MP-028

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Review due: 18/05/2021

Beetaloo Exploration WWMP

NT-2050-15-MP-028

Review due: 18/05/2021

1. Introduction

This Wastewater Management Plan (WWMP) has been prepared to support Origin's Beetaloo exploration program. The WWMP is a mandatory requirement prepared in accordance with the Code of Practice for Petroleum Activities in the northern Territory (referred to herein as "the CoP").

This plan is designed to provide the management strategy for how wastewater will be managed across Origin's Beetaloo exploration project.

The plan will reference the related sections within each various EMP to avoid duplication. The current Environmental Management Plan's (EMP's) covered by this plan are:

- NT-2050-15-MP-025 Origin Energy Beetaloo Kyalla 117 N2 Drilling, Stimulation and Well Testing Environmental Management Plan
- NT-2050-15-MP-032 Origin Energy Beetaloo Velkerri 76 S2 Drilling, stimulation and Well Testing Environmental Management plan

2. Description of activity.

Wastewater, as defined in the CoP, includes the following:

- Drilling fluid, drill cuttings and cement returns
- Flowback fluid: Generated during the well testing phase.
- Completion fluids, kill fluids and well suspension fluids

Wastewater is produced through the following activities:

- **Drilling**: waste drilling fluids are generated as a result of drilling activities. Drilling fluids primary objective is to provide primary well barrier during well construction (unless underbalance drilling is preferred drilling technique) where bottom hole hydrostatic pressure exerted by drilling fluids is used to overbalance formation pore pressure. Drilling fluids are also used to cool the bit and assist in transporting formation cuttings to surface (rock such as shale, mudstone, siltstone etc.). Excess cement when cementing a casing string and waste drill fluids and cuttings are stored in a lined mud sump, tested and either disposed of onsite or disposed of offsite at a licensed waste facility.
- **Stimulation and well testing:** After the completion of hydraulic fracture stimulation, the exploration well is "flowed back" to remove all recoverable injected fluid from the formation. Flowback wastewater is stored in onsite tanks, evaporated and then disposed of offsite at a licenced facility.
- **Completion activities:** Completion fluids, such as kill fluids or well suspension fluids, are used to supress the formation pressure within the reservoir. The use of these fluids is a form of well control and may need to be removed from the well and disposed of where well interventions are required (i.e. the well may be suspended with fluid post drilling, with the fluid removed prior to completion and stimulation activities

3. Waste Management Framework

Wastewater will be managed with the objective of achieving optimal environmental outcomes and in accordance with the following hierarchy principals:

1. **Avoid:** eliminate the generation of waste through design modification
2. **Reduce**: reduce unnecessary resource use or substitute a less resource intensive product or service.
3. **Re-use**: reuse a waste without further processing
4. **Recycle**: recover resources from a waste
5. **Treatment:** treat the waste to reduce the hazard of the waste prior to disposal
6. **Disposal**: disposal of waste if there is no viable alternative.

It is recognised that the options for avoiding, reducing or re-using wastewater generated during exploration are limited. This is largely restricted to:

- Maximising the re-use and recycling of drilling fluids during operations; and

- minimising the use of suspension fluids by minimising re-entry activities (i.e. multiple entries into a well requiring fluid to be unloaded.

The amount of cuttings produced during the drilling activity is dictated by the regional stratigraphy (target zone depth) and lateral length of the horizontal well, whereas the volume of the flowback is a function of stimulation design and number of stages completed during stimulation. There is however an ability to minimise the volume of waste disposed of offsite, through careful waste management and treatment.

4. Wastewater Risk Assessment

The risks associated with wastewater are covered in the risk assessments within each of the Environmental Management Plans.

Detailed assessments of the site-specific risk associated with the disposal of drilling fluids and muds as per condition C.4.1.2 of the Codes of Practice, will be undertaken upon completion of drilling activities.

5. Wastewater management overview

A summary of how each wastewater stream is managed to optimise the environmental outcomes is provided in Table 1. An individual description of each wastewater stream is provided in the following section.

5.1 Drilling Fluid and Cuttings

Approximately 2400 m3 of drilling fluids, muds and cuttings will be generated as a result of drilling of each exploration well. Drilling fluids and wastes are saline, polymer/bentonite based which are stored in line sumps onsite. The primary contaminants associated with drilling fluids and wastes are likely to be from chlorides.   All drilling fluids are water based muds (WBM) without metal or hydrocarbon presence contained.

Drilling fluids and muds will be managed in accordance with the following:

- All fluids, muds and cuttings stored in engineered lined Coletanche sumps.
- Sumps will be designed with a 1:1000 ARI freeboard calculated in accordance with the methodology outlined in Appendix C
- The Maximum Water Level will be clearly marked on the side of the sump.
- All lease pads will be fenced to prevent livestock and fauna ingress into open sumps.
- Liquids will be transferred to lined wastewater storage tanks from the sump upon completion of activity to allow the muds and cuttings contained in lined sump to dry out with liquids evaporated in lined wastewater storage tanks.
- Liquids will be evaporated and any residual liquids will be transported to a licenced interstate disposal facility (Westrex, Jackson Queensland) with the appropriate interstate waste transport consignment authority as per the National Environmental Protection (Movement of Controlled Waste between States and Territories) Measure 1998 (NEPM) as implemented under the NT Waste management and Pollution Control Act and Queensland environmental Protection Act 1994..
- Leachability testing of drill cuttings and muds will be undertaken in accordance with Table 10 of the Code of Practice.
- A disposal option assessment will be completed by a suitably qualified person (as outlined in section C.4.1.2), with onsite disposal to land only undertaken where environmental harm will not result from the disposal activities.

5.2 Produced water and Flowback Management

All produce water and flowback fluids will be stored in accordance with the NT Code of Practice for Petroleum Activities.

The volume of flowback generated from the activity is dependent on the number of stages of stimulated, with approximately 20% to 80% fluid recovery expected (based on US ranges). For Origin stage 2 activities, it is anticipated that approximately 7.5ML of flowback from the stimulation will be generated from each exploration well, with a final offsite disposal figure of between 3- 4ML. Flowback is anticipated to be saline, with a summary of the anticipated quality provided in Appendix A- Table 5.

Management controls for flowback implemented during the program include:

- No disposal of flowback wastewater to surface water
- Wastewater stored in above ground tanks
- Tanks to be double lined with built in leak detection.
- All wastewater to be stored in enclosed tanks
- The site will have enough enclosed storage to deal with the total volume of wastewater stored at any time.
- Appropriate venting of enclosed tanks to prevent the build-up of explosive gasses
- Tank designs and placement will consider environmental factors, such as wind loading, temperature bushfires and structural integrity.
- All working evaporation tanks operated in the wet season will have a minimum freeboard to allow for a 1 in 1000 year average recurrence intensity wet or dry season (depending on which season operations are undertaken in) as calculated in Appendix C;
- When wastewater storage volumes have been reduced onsite and enclosed tank availability permits, enclosed tanks may be converted to open evaporation treatment tanks (noting the requirement to have enough enclosed storage to manage all wastewater onsite at any time)
- The freeboard requirements will be clearly marked on each of the tanks as the Maximum Water Level (MWL).
- All wastewater on location over the wet season, must be able to be transferred into enclosed tanks within 72hours of becoming aware of a significant rainfall event. This transfer must be completed at least 8 hours prior to the predicted commencement of the significant rainfall event. The determination of a significant rainfall event is provided in section 7
- Storage tanks that are connected will be designed to prevent uncontrolled release from multiple tanks.
- Tanks are to be designed and constructed to the relevant Australian Standard (including AS1554.1 and AS3990) with a quality assurance and quality control (QA/QC) plan and installation procedures implemented by the contractor.
- Tanks will be designed to prevent the ingress of stock and fauna, with each exploration site fenced to prevent stock, fauna and public access.
- Where drilling sumps are left open with drilling waste and are unattended, fencing and fauna ladders
- Mechanical evaporators to be used to reduce the volume of flowback. Evaporators will be positioned in a manner to avoid offsite drift and have automated wind direction and speed cut-offs.
- Monitoring of pond levels will be undertaken daily, with management response criteria implemented to prevent tank overtopping. This includes shutting in operations where freeboard requirements cannot be met.
- Flowback fluid will be evaporated down to as small a volume as physically possible. Residual flowback liquids will be evaporated and transported to an licenced interstate disposal facility (such as, Westrex, Jackson Queensland) with the appropriate interstate waste transport consignment authority as per the National Environmental Protection (Movement of Controlled Waste between States and Territories) Measure 1998 (NEPM) as implemented under the NT Waste management and Pollution Control Act and Queensland environmental Protection Act 1994.

- When the tanks are decommissioned the associated residual solids, brines and liners are removed and disposed of at an appropriately licensed waste disposal facility by a licenced contractor as per NT Waste Management and Pollution Control Act.
- Daily inspections of all wastewater storages will be implemented during operations.

5.3 Completion fluids (suspension and kill fluids)

Weighted completion fluids (suspension and kill fluids) may be used to maintain well control/ suppress formation pressure. Completion fluids are likely to have an elevated salinity, with sodium and potassium-based salts being the main compounds.

It is anticipated that up to 0.5-1ML of completion fluids could be produced, with fluids stored in the drill sump or tanks (depending on whether tanks have been installed on site at the stage). The fluids will be evaporated and any residual transported offsite for final disposal at a licenced facility.

Table 1: Wastewater management summary

Wastewater	Quantity Produced	Properties	Hazards	Storage	Handling	Operational controls	Routine Inspections	Monitoring	Final Management	Final disposal volume	Alternative Management Options considered
Flowback	7.5 ML	Saline (Electrical Conductivity >50,000us/cm) with elevated, sodium, chloride, boron, barium and hydrocarbons as per Appendix A.	High salinity wastewater representing a hazard to groundwater, surface water and soils from Chloride dominated salts if released into the environment	•Stored onsite in double lined above ground enclosed tanks and double lined working evaporation Tanks with leak detection. •All tanks have been sized with regards to the 1:1000 average recurrence interval rainfall event as per Appendix C. maximum water levels (MWL) to be clearly marked on each tank	•Transferred to storage facilities from onsite separators or directly from the well as required under B.4.13.2 (k) of the CoP. •Secondary containment used under all pumps and connections	•Storage volumes of ponds to be monitored daily during operations • Evaporators to be strategically located on or within the boundaries of the pond with drift prevention controls (automated wind direction and speed cut offs) •All wastewater to be transferred into enclosed storage when a significant rainfall event is predicted as per section 7).	•Storage facilities and handling areas inspected Daily during operations •Visual inspections of tanks completed weekly	As per section 8.	Evaporated onsite using fractionating evaporators to reduce final volumes. Trucked offsite to a licenced waste disposal facility (Westrex in QLD) in accordance with NT Waste Management and Pollution Control Act waste consignment authority approval.	3.6ML	•Due to the saline nature of the material, limited re-use or recycling options exist during exploration. •Treatment using Reverse Osmosis or other mechanical filtration has been considered; salinity and scaling constraint posed by wastewater restricted the use of conventional water treatment •request for proposal (RFP) has been released to identify additional technologies for a potential future trial
Drilling Fluids	2400m3	Saline (KCL and NaCl) polymer/bentonite based drilling fluids with formation cuttings.	KCL and NaCL may represent a hazard in residual drilling muds and cuttings if not segregated prior to disposal. Formation cuttings may contain low level of hydrocarbons, which are likely to be degraded quickly in the open sump.	•Stored onsite in lined drilling sumps with sufficient freeboard to accommodate a 1:1000 average recurrence interval rainfall event as per Appendix C. •maximum water levels (MWL) to be clearly marked on each tank and sump	•Transferred directly from rig via the shakers into the sump. • Fluid stored in lined tanks as per CoP.	•Storage volumes of sumps to be monitored daily • material to be dried out after completion of activity, with fluids evaporated in a separate tank. • Material to be tested prior to determining final disposal requirements	• sump level to be monitored daily during operations •Sump liner and embankments to be inspected weekly during operations	As per section 8.	•Fluids will be segregated from muds upon completion of activity and evaporated. •Fluids to be transported to a licenced waste disposal facility (Westrex in QLD) in accordance with NT Waste Management and Pollution Control Act and related interstate waste consignment authority approval. •Final disposal solution of muds and cuttings to be determine through onsite characterisation and risk assessment by third party. •For onsite disposal, Muds and cuttings to be mixed, buried and covered onsite. •For offsite disposal, material will be transported to a licenced waste disposal facility (Westrex in QLD) in accordance with NT Waste Management and Pollution Control Act and related interstate waste consignment authority approval.	750m^3	There are no other viable options currently available in addition to what has currently been considered (offsite and onsite disposal).

Wastewater	Quantity Produced	Properties	Hazards	Storage	Handling	Operational controls	Routine Inspections	Monitoring	Final Management	Final disposal volume	Alternative Management Options considered
Completion, suspension and kill fluids	0.5-1ML	KCL or NaCl based fluids with a TDS >50,000us/cm	High salinity wastewater representing a hazard to groundwater, surface water and soils from chloride dominated salts if released into the environment	• Stored onsite in double lined above ground enclosed tanks and Evaporation Tanks with leak detection. •All tanks have been sized with regards to the 1:1000 average recurrence interval rainfall event as per Appendix C. • maximum water levels (MWL) to be clearly marked on each tank and sump	•Transferred to flowback storage facilities directly from well •Secondary containment used under all pumps and connections	•Storage volumes of ponds to be monitored daily during operations • Evaporators to be strategically located on or within the boundaries of the pond with drift prevention controls (automated wind direction and speed cut offs) •All wastewater to be transferred into enclosed storage when a significant rainfall event is predicted as per section7)..	•Storage facilities and handling areas inspected Daily during operations •Visual inspections of tanks completed weekly	As per section 8.	Stored in flowback tanks. Evaporated onsite using fractionating evaporators to reduce final volumes. Trucked offsite to a licenced waste disposal facility (Westrex in QLD) in accordance with NT Waste Management and Pollution Control Act waste consignment authority approval.	0.5ML	•Due to the saline nature of the material, limited re-use or recycling options exist during exploration. •Treatment using reverse osmosis or other mechanical filtration has been considered; salinity and scaling constrain the use of conventional water treatment •request for proposal (RFP) has been released to identify additional technologies for a potential future trial

6. Waste Transportation and Disposal

All wastewater transport providers will be licenced under the NT Waste Management and Pollution Control Act.

All wastewater will be transported interstate to a licenced waste storage and treatment facility. Westrex at Jackson Queensland is the current default option for wastewater disposal, with other interstate disposal locations available. The transportation of wastewater between states/territories, will require an Interstate waste transport consignment authority as per the National Environmental Protection (Movement of Controlled Waste Between States and Territories) Measure 1998 (NEPM) as implemented under the NT Waste Management and Pollution Control Act and relevant accepting state/territory (such as the Queensland Environmental Protection Act 1994).

All wastewater storage and treatment facilities will be licenced as per the relevant accepting state/territory (such as the Queensland Environmental Protection Act 1994).

7. Significant rainfall events

The 7 day Bureau of Meteorology 4 day total rain forecast (http://www.bom.gov.au/jsp/watl/rainfall/pme.jsp) shall be reviewed daily to identify periods of significant rainfall. Significant rainfall is defined in this WWMP is for an event where greater than 300mm of total rainfall is predicted over a 4 day period. This type of rainfall level is consistent with that from a significant rainfall event; such as a monsoonal trough, tropical low or a cyclone.

Commencement time to transfer the flowback fluid will be selected to ensure that it is completed at least 8 hours prior to the predicted commencement of the significant rainfall event.

8. Fauna interactions

The risk of interactions of fauna, including birds, with wastewater storages is anticipated to be low based on the following:

- All wastewater is saline, reducing the palatability of wastewater. Literature confirms fauna are unwilling to drink high saline water, reducing the potential exposure to wastewater.
- Noise from flaring and equipment likely to deter bird and bat activity during well testing activities (the main period water is stored onsite)
- Site is fenced to prevent livestock and fauna access to site- mud sump to have cattle panels with mesh installed when not operational
- Wastewater tanks have vertical walls with no clear access points for fauna
- Wastewater tanks do not contain tailings beaches or perches, reducing the ability for most birds to land and drink from tanks
- Site will be manned during well testing operations

Specific monitoring of fauna interactions with wastewater storages will be undertaken in accordance with Table 2. Where ongoing fauna mortalities are clearly associated with wastewater storage activities, fauna deterrents shall be utilised to prevent future exposure (such as bird deterrents, netting, increased fencing). Ongoing bird or fauna mortality is defined as >7 carcasses per week for 2 consecutive weeks or >1 endangered fauna species.

9. Wastewater Monitoring Program

A wastewater sampling program will be implemented to characterise the quality of the wastewater during flowback activities. The monitoring program is summarised in Table 2 below.

Table 2: Minimum Monitoring Requirements

Monitoring Program	Location	Monitoring Requirements	Frequency
Flowback characterisation	Post separator- prior to entering storage tanks	Electrical Conductivity, pH, temperature and volume of Flowback	Daily for the first 30 days, and weekly thereafter
		Testing samples of Flowback for Analytes listed in Appendix 1	Weekly until the EC level stabilises (<10% change over 4

Monitoring Program	Location	Monitoring Requirements	Frequency
			weeks) and then monthly until practical completion of flowback activities
Stimulation fluid- pre-injection	Post blender, prior to injection	Testing sample of Stimulation Fluid for Analytes listed in Appendix 1	1 sample Pre-injection for each stimulation fluid utilised
Flowback Storage Tanks	Each storage tank	Testing samples of Flowback for Analytes listed in Appendix 1	6 monthly
	Each Storage	Level, estimated evaporation rates	Daily
Drilling Material	Determined by suitably qualified person	Testing samples of drilling cuttings for analytes listed in Table 10 of the Codes of Practice, Naturally Occurring Radiation Material (NORMs) and volume	Prior to disposal
Fauna interactions	Wastewater tanks and surrounding lease area	1. Ad hoc Bird and fauna observations and photos to be taken around wastewater tanks 2. Wastewater tank inspection for bird carcasses 3. Inspections around area adjacent to lease (within 50m of boundary) 4. Carcasses present during tank emptying	1. Continuous 2. Daily 3. Weekly 4. During final decommissioning

9.1 Sampling Methodology

- Water samples will be collected in accordance with the methodology outlined in Table 3.
- All samples will be collected by appropriately qualified personnel, with all meters calibrated in accordance with the manufacturer's instructions.
- Samples will be collected in laboratory supplied sampling containers and placed in chilled eskies and transported under chain of custody (COC) procedures.
- Analysis will be performed by laboratories with National Association of Testing Authorities (NATA) accredited analysis methodology.
- Each sample will have a unique identifier that would be cross referenced to the monitoring location and time of sampling. Due to the remote location, samples will be couriered to the laboratory to minimise sample holding time violations.

Table 3 Monitoring program methodologies

Program	Sampling Methodology
Drilling sump characterisation	• National Environment Protection (Assessment of Site Contamination) Measure • AS4482.1- 2005 guide to the investigation and sampling of sites with potentially contaminated soil
Flow back and drilling fluid monitoring	• *Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000* (ANZECC Guidelines). • AS/NZ5667.1: 1998. *Water Quality Sampling Part 1: Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples*

10. Wastewater storage management response criteria

To minimise the risk of overtopping a tank or sump, the criteria outlined in Table 4 will be implemented when hydraulic fracturing wastewater is stored onsite.

Table 4 Wastewater storage management response criteria

Monitoring program	Criteria Description	Criteria	Criteria Response
Wastewater tank level monitoring	Enclosed storage level exceedance	The total volume of hydraulic fracturing wastewater stored onsite exceeds the available closed/covered tank storage capacity	Flowback activities to cease, unless authorised by DENR to continue operations. Origin to provide written notification to DENR within 48 hours of of exceedance, along with the proposed plan to return back into
Drilling sump level monitoring	Drilling sump storage level exceedance	The total volume of drilling wastewater exceeds the freeboard capacity of the drilling sump, with no additional storage available within other onsite tanks.	Drilling wastewater disposal activities to cease, unless authorised by DENR to continue operations. Origin to provide written notification to DENR within 48 hours of exceedance, along with the proposed plan to return back into compliance

11. Determine significant rainfall event

The 7-day Bureau of Meteorology 4-day total rain forecast (http://www.bom.gov.au/jsp/watl/rainfall/pme.jsp) shall be reviewed daily to identify periods of significant rainfall. Significant rainfall is defined in this WWMP is for an event where greater than 300mm of total rainfall is predicted over a 4-day period. This type of rainfall level is consistent with that from a significant rainfall event; such as a monsoonal trough, tropical low or a cyclone.

Commencement time to transfer the flowback fluid will be selected to ensure that it is completed at least 8 hours prior to the predicted commencement of the significant rainfall event.

12. Waste transportation and disposal

All wastewater transport providers will be licenced under the NT *Waste Management and Pollution Control Act*.

All wastewater will be transported interstate to a licenced waste storage and treatment facility. Westrex at Jackson Queensland is the current default option for wastewater disposal, with other interstate disposal locations available. The transportation of wastewater between states/territories, will require an Interstate waste transport consignment authority as per the National Environmental Protection (Movement of Controlled Waste Between States and Territories) Measure 1998 (NEPM) as implemented under the *NT Waste Management and Pollution Control Act* and relevant accepting state/territory (such as the Queensland *Environmental Protection Act* 1994).

All wastewater storage and treatment facilities will be licenced as per the relevant accepting state/territory (such as the Queensland *Environmental Protection Act* 1994).

13. Waste Tracking and Reporting

The movement of wastewater will be tracked in accordance with the following:

i. Volumes of wastewater produced from the well;

ii. Volumes of wastewater transferred into each tank;

iii. Estimates for evaporation rates from each tank updated weekly;

iv. Volumes of wastewater reused: and

vi. Volumes of water removed from site (whether by vehicle or pipeline).

- Wastewater tracking will be documented and available upon request
- Offsite wastewater tracking must be in accordance with tracking requirements of listed wastes as per the *Waste Management and Pollution Control Act,* the National Environmental Protection (Movement of Controlled Waste Between States and Territories) Measure 1998 (NEPM) and (where relevant) the *Radiation Protection Act.*
- Wastewater tracking documentation must be reported to the Minister at least annually in the annual environmental report for the relevant EMP.

14. Performance Criteria

The following measurement criteria have been developed to demonstrate the risks associated with wastewater storage are reduced as low as reasonably practicable.:

- Zero wastewater tank overtopping events
- Zero offsite releases of wastewater
- Zero onsite spills of wastewater >5,000L
- Zero wastewater transport spills

15. Incident Reporting

The reporting of incidents shall comply with the *Petroleum (Environment) Regulations* and *Waste Management and Pollution Control Act* and Waste Management and Pollution Act 1998.

15.1 Reportable Environmental Incident Reporting

The Petroleum (Environment) Regulations define a reportable incident as an incident arising from a regulated activity that has caused, or has the potential to cause, material environmental harm or serious environmental harm as defined under the Petroleum Act.

An interest holder must notify (this may be oral or in writing) DPIR of a reportable incident as soon as practicable but no later than two-hours after the first occurrence of the incident or after the time the interest holder becomes aware of the incident.

DPIR can be notified through the DPIR Operations Term Emergency number 1300 935 250.

Any verbal report to DPIR must be followed up by a written report from the Project Manager within three days in accordance with the Petroleum (Environment) Regulations.

15.2 Recordable incidents

The Petroleum (Environment) Regulations define a recordable incident as an incident arising from a regulated activity that:

I. Has resulted in an environmental impact or environmental risk not specified in the current plan for the activity; or

II. Has resulted in a contravention of an environmental performance standard specified in the current plan for the activity; or

III. Is inconsistent with an environmental outcome specified in the current plan for the activity; and

IV. Is not a reportable incident.

An interest holder must notify (this may be oral or in writing) DPIR of a recordable incident as soon as practicable but no later than 15-days after the reporting period (agreed period or each 90-day period after the day on which the EMP is approved).

15.3 Waste Management and Pollution Control Act incident reporting

Where an incident occurs while carrying out an activity outside of petroleum tenure (such as a spill of chemical or wastewater) the incident reporting requirements of the NT Waste management and Pollution Control Act 1998 apply.

In accordance with the WMPC Act, the operator has a duty to notify of incidents causing or threatening to cause pollutions as soon as practicable, but no less than 24 hours after becoming aware of the incident.

A notifiable incident is defined as an incident that causes, or is threatening or may threaten to cause, pollution resulting in material environmental harm or serious environmental harm.

A notification must include:
(a) the incident causing or threatening to cause pollution;
(b) the place where the incident occurred;
(c) the date and time of the incident;
(d) how the pollution has occurred, is occurring or may occur;
(e) the attempts made to prevent, reduce, control, rectify or clean up the pollution or resultant environmental harm caused or threatening to be caused by the incident; and
(f) the identity of the person notifying

The notification shall be made to the NT EPA Pollution Hotline 1800 064 567.

16. Emergency Response

An Emergency Response Plan (NT-2050-15-MP019) has been developed covering the proposed activities within the EMP. The ERP provides a broad framework for managing potential emergency incidents to minimise the potential risk to human safety and the environment. The ERP should be referenced for any emergency response activities.

Spills must be reported to the Minister in accordance with the requirements of spill management plan (NT-2050-15-MP-027 and Reportable and Recordable incidents of the Petroleum (Environment) Regulations.

Appendix A Amungee Nw-1 flowback characteristic summary

Table 5 Anticipated flowback quality based on Amungee NW 1 flowback results.

Parameter	Flow back levels
BTEX compounds	BTEX levels are anticipated to be low ranging between 2 and 15 µg/L.
Total nitrogen (as N)	Maximum value of 62.1mg/l observed within flow back.
Salinity (TDS)	Saline with total dissolved solids level exceeding 49,000mg/L
pH	Slightly acidic with a median value of 6.74
Major ions	Predominantly Na and Cl dominated. Bicarbonate present at levels consistent with stimulation fluid.
Dissolved metals	Barium and Boron are the main metal elements anticipated to be present at elevated levels. Maximum levels of 80.1 mg/L for Barium and 54.5mg/l for Boron were recorded during the Amungee NW 1 flowback . Lower level of other metals such ash Arsenic and Manganese were observed, with maximum concentration of 0.084mg/l and 3.09 mg/L respectively .
Polycyclic Aromatic Hydrocarbons	Expected to be below detection level
Petroleum Hydrocarbons	All fractions of TPH are anticipated to be elevated.
Phenolic Compounds	Low level of phenolic compounds expected, with only Phenol (max 4µg/L) and 3-&4- methylphenol (max 11.3ug/L)
Radionuclides	Maximum Gross Alpha Activity and Gross Beta Activity of 12.4Bq/L and 18.3Bq/L were recorded in the Flowback of offset wells. The primary component being Radium-226.

Appendix B Wastewater monitoring analyte list

Parameter	Reporting Units	Limit of Reporting	Method
Physical Parameters			
Electrical Conductivity (EC)	us/cm	1	Field
Total Dissolved Solids (TDS)	mg/L	10	APHA 2540C
Total Suspended Solids (TSS)	mg/L	5	APHA 2540C
pH		0.1	Field
Sodium Adsorption Ratio	ratio	0.01	APHA 4500 Ca, Mg, Ca, NA
Temperature	°C	0.1	Field
Nutrients			
Nitrate	mg/L	0.01	APHA VC13
Nitrite	mg/L	0.01	APHA 4500 NO2
Total Nitrogen	mg/L	0.1	APHA 4500 NORG
Total Kjeldahl Nitrogen	mg/L	0.1	APHA NORG/TKN
Ammonia	mg/L	0.01	APHA NH4
Reactive Phosphorous	mg/L	0.01	APHA 4500P
Total Phosphorous	mg/L	0.01	APHA 4500P
Anions			
Sulfate	mg/L	1	APHA 4500-SO4-C
Chloride	mg/L	1	APHA 4500-Cl-C
Carbonate	mg/L	1	APHA 2320 B
Bicarbonate (as CaCO3 equivalent)	mg/L	1	APHA 2310 B
Bicarbonate Alkalanity (as CaCO3 equivalent)	mg/L	1	APHA 2320 B
Hydroxide Alkalinity (as CaCO3 equivalent)	mg/L	0.01	APHA 2320 B
Total Alkalinity (as CaCO3 equivalent)	mg/L	0.01	APHA 2320 B
Fluoride	mg/L	0.1	APHA 4500 F-C
Bromide	mg/L	0.01	APHA 4110B
Major Cations			
Sodium	mg/L	1	APHA 4500 Na
Magnesium	mg/L	1	APHA 4500 Mg
Potassium	mg/L	1	APHA 4500 K
Calcium	mg/L	1	APHA 4500 Ca

Parameter	Reporting Units	Limit of Reporting	Method
Metals and Metalloids (total and dissolved)			
Aluminium	mg/L	0.001	USEPA 6010 ICP/AES
Antimony	mg/L	0.001	USEPA 6010 ICP/AES
Arsenic	mg/L	0.001	USEPA 6010 ICP/AES
Barium	mg/L	0.001	USEPA 6010 ICP/AES
Beryllium	mg/L	0.001	USEPA 6010 ICP/AES
Boron	mg/L	0.001	USEPA 6010 ICP/AES
Bromide	mg/L	0.001	USEPA 6010 ICP/AES
Cadmium	mg/L	0.001	USEPA 6010 ICP/AES
Chromium	mg/L	0.001	USEPA 6010 ICP/AES
copper	mg/L	0.001	USEPA 6010 ICP/AES
iron	mg/L	0.001	USEPA 6010 ICP/AES
Lead	mg/L	0.001	USEPA 6010 ICP/AES
Manganese	mg/L	0.001	USEPA 6010 ICP/AES
Mercury	mg/L	0.001	USEPA 6010 ICP/AES
Molybdenum	mg/L	0.001	USEPA 6010 ICP/AES
nickel	mg/L	0.001	USEPA 6010 ICP/AES
Selenium	mg/L	0.001	USEPA 6010 ICP/AES
Silica	mg/L	0.1	USEPA 6010 ICP/AES
Silver	mg/L	0.001	USEPA 6010 ICP/AES
Strontium	mg/L	0.001	USEPA 6010 ICP/AES
Thorium	mg/L	0.001	USEPA 6010 ICP/AES
Tin	mg/L	0.001	USEPA 6010 ICP/AES
Uranium	mg/L	0.001	USEPA 6010 ICP/AES
Vanadium	mg/L	0.001	USEPA 6010 ICP/AES
Zinc	mg/L	0.001	USEPA 6010 ICP/AES
Naturally Occuring Radioactive Material.			
alpha radiation	Bq/L	0.05	ASTM D7283-06
beta radiation	Bq/L	0.05	ASTM D7283-06
BTEX			
Benzene	µg/L	1	USEPA 5030/8260 HS or P&T/GC/MS
Toluene	µg/L	2	USEPA 5030/8260 HS or P&T/GC/MS
Ethylbenzene	µg/L	2	USEPA 5030/8260 HS or P&T/GC/MS
M and P Xylene	µg/L	2	USEPA 5030/8260 HS or P&T/GC/MS

Parameter	Reporting Units	Limit of Reporting	Method
O Xylene	µg/L	2	USEPA 5030/8260 HS or P&T/GC/MS
Total Xylene	µg/L	2	USEPA 5030/8260 HS or P&T/GC/MS
Hydrocarbons			
TRH C6 - C10	µg/L	20	USEPA 5030/8260 HS or P&T/GC/MS
TRH C6 - C10 less BTEX	µg/L	20	USEPA 5030/8260 HS or P&T/GC/MS
TRH >C10 - C16	µg/L	100	USEPA 5030/8260 HS or P&T/GC/MS
TRH >C10 - C16 less Napthalene	µg/L	100	USEPA 5030/8260 HS or P&T/GC/MS
TRH >C16 - C34	µg/L	100	USEPA 5030/8260 HS or P&T/GC/MS
TRH >C34 - C40	µg/L	100	USEPA 5030/8260 HS or P&T/GC/MS
Total TRH C6 - C40	µg/L	100	USEPA 5030/8260 HS or P&T/GC/MS
Polycyclic Aromatic Hydrocarbons			
3-Methylcholanthrene	mg/L	0.001	USEPA 3510/8270 GC/MS
7, 12-Dimethylbenz(a)anthracene	mg/L	0.001	USEPA 3510/8270 GC/MS
Acenaphthene	mg/L	0.001	USEPA 3510/8270 GC/MS
Acenaphthylene	mg/L	0.001	USEPA 3510/8270 GC/MS
Anthracene	mg/L	0.001	USEPA 3510/8270 GC/MS
Benzo (a) pyrene	mg/L	0.0005	USEPA 3510/8270 GC/MS
Benzo (b) fluoranthene	mg/L	0.001	USEPA 3510/8270 GC/MS
Benzo (ghi) perylene	mg/L	0.001	USEPA 3510/8270 GC/MS
Benzo (k) fluoranthene	mg/L	0.001	USEPA 3510/8270 GC/MS
Benzo (a) anthracene	mg/L	0.001	USEPA 3510/8270 GC/MS
Chrysene	mg/L	0.001	USEPA 3510/8270 GC/MS
Dibenz (ah) anthracene	mg/L	0.001	USEPA 3510/8270 GC/MS
Fluoranthene	mg/L	0.001	USEPA 3510/8270 GC/MS
Fluorene	mg/L	0.001	USEPA 3510/8270 GC/MS
Indeno (1,2,3-cd) pyrene	mg/L	0.001	USEPA 3510/8270 GC/MS
Napthalene	mg/L	0.001	USEPA 3510/8270 GC/MS
Phenanthrene	mg/L	0.001	USEPA 3510/8270 GC/MS
Pyrene	mg/L	0.001	USEPA 3510/8270 GC/MS

Parameter	Reporting Units	Limit of Reporting	Method
Carcinogenic PAHs (benzo[a}pyrene equivalents	mg/L	0.001	USEPA 3510/8270 GC/MS
Total PAH	mg/L	0.0005	USEPA 3510/8270 GC/MS
Volatile Organic Compounds			
2,3,4,6-Tetrachlorophenol	µg/L	1	USEPA 3510/8270 GC/MS
2,4,5-Trichlorophenol	µg/L	1	USEPA 3510/8270 GC/MS
2,4,6-Trichlorophenol	µg/L	1	USEPA 3510/8270 GC/MS
2,4-Dichlorophenol	µg/L	1	USEPA 3510/8270 GC/MS
2,4-Dimethylphenol	µg/L	1	USEPA 3510/8270 GC/MS
2,4-Dinitrophenol	µg/L	1	USEPA 3510/8270 GC/MS
2,6-Dichlorophenol	µg/L	1	USEPA 3510/8270 GC/MS
2-Chlorophenol	µg/L	1	USEPA 3510/8270 GC/MS
2-Methyl-4,6-dinitrophenol	µg/L	1	USEPA 3510/8270 GC/MS
2-Nitrophenol	µg/L	1	USEPA 3510/8270 GC/MS
4-Chloro-3-methylphenol	µg/L	1	USEPA 3510/8270 GC/MS
4-Nitrophenol	µg/L	1	USEPA 3510/8270 GC/MS
Dinoseb	µg/L	1	USEPA 3510/8270 GC/MS
Formaldehyde	µg/L	1	USEPA 3510/8270 GC/MS
Hexachlorophene	µg/L	1	USEPA 3510/8270 GC/MS
m- and p-Cresol	µg/L	1	USEPA 3510/8270 GC/MS
Pentachlorophenol	µg/L	1	USEPA 3510/8270 GC/MS
Phenol	µg/L	1	USEPA 3510/8270 GC/MS
Organic Carbon			
Dissolved Organic Carbon	mg/L	1	APHA 5310 B
Total Organic Carbon	mg/L	1	APHA 5310 B

Appendix C 1:1000 ARI Calculation

Monthly rainfall totals were analysed from the Scientific Information for Land Owners (SILO) data for to interpolate rainfall data from 1900 to the present day. Consistent with industry accepted methodology associated with practices (such as dam risk assessments which calculates the wet season based on your geographical location) a 3 month time period was determined applicable.

The highest 3 month rainfall period during the wet and dry seasons was predicted for every year from 1900 till 2018. These values were then used to fit a Log Pearson III distribution to the data to allow us to extrapolate to the 1000 year, 3 month duration wet season (1) and 3 month dry season (figure 2). This method is consistent with the *Australian Rainfall & Runoff* methodologies. The median 1 in 1000 year 3 month wet season is 1289mm and 3 month dry season is 300mm. These figure does not include any evaporation and are therefore considered extremely conservative.

Based on the assessment, a 1300mm wet season and 300mm dry season freeboard will be applied to all open sumps and tanks.

Figure 1 Log Pearson determination of 1:1000 Wet Season ARI.

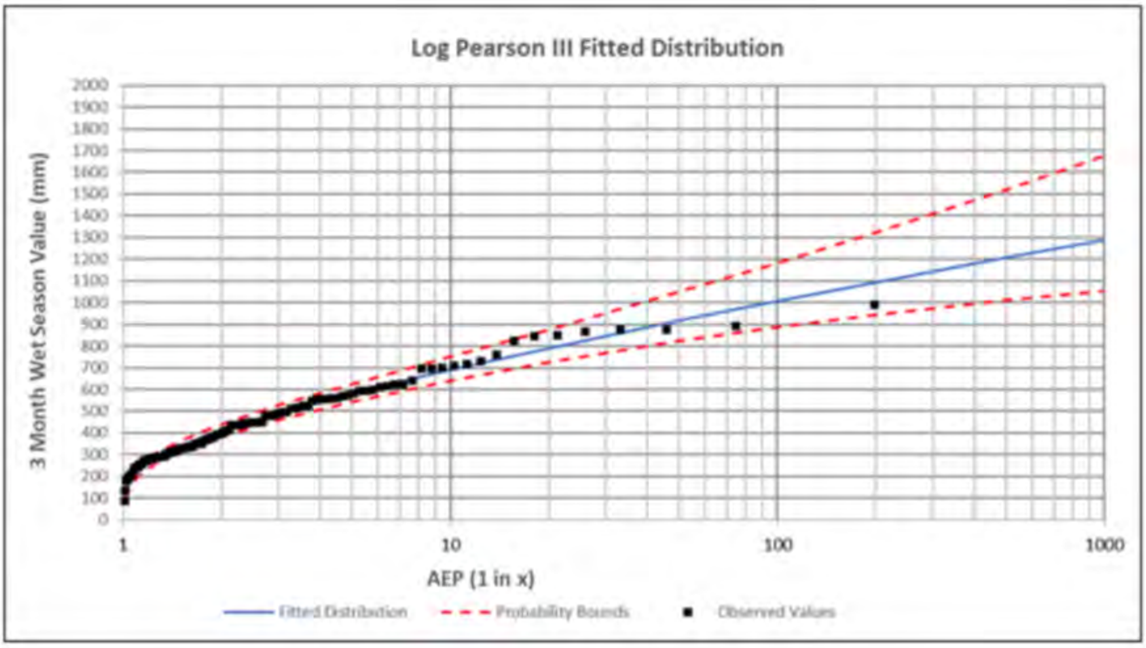
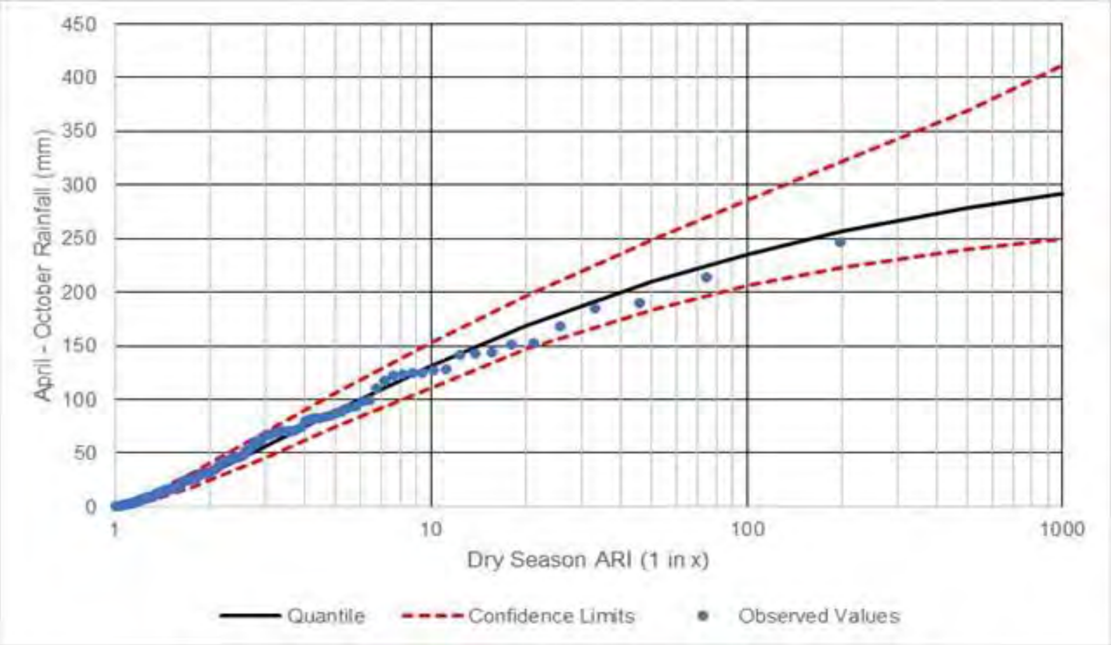


Figure 2 Log Pearson determination of 1:1000 Dry Season ARI.



Appendix F: Water extraction licence statement of reason

Water Extraction Licence Decision

Application

1. The following application (**Application**) for a licence to take water from a bore was lodged in accordance with section 60 of the *Water Act 1992* (**Act**) by Origin Energy B2 Pty Ltd (**Applicant**):

Applicant:	Origin Energy B2 Pty Ltd (ABN 42 105431525)
Date Licence applied for:	15 March 2019
Licence applied for:	Licence to take water from a bore under section 60 of the *Water Act*
Purpose for which Licence is sought:	Petroleum activities
Maximum quantity of water proposed to be taken annually for each beneficial use: Petroleum Activities	 175 ML p.a.
Land from which water will be taken:	NT Portion 1079 (8240 Carpentaria Hwy, Arnold), NT Portion 7027 (4500 Carpentaria Hwy, Birdum).
Land on which water will be used:	NT Portion 702 (16965 Carpentaria Hwy, Pamayu), NT Portion 1079 (8240 Carpentaria Hwy, Arnold), NT Portion 7026 (14981 Stuart Hwy, Birdum), NT Portion 7027 (4500 Carpentaria Hwy, Birdum).
Bores from which water will be taken	 RN040895
Water Source:	Gum Ridge Formation
Water Control District:	Daly Roper Beetaloo Water Control District
Declared Water Allocation Plan:	No declared plan

Decision

2. In accordance with sections 60 and 71C of the Act, I have decided to grant the following licence for the reasons given below (**Licence**):

Applicant:	Origin Energy B2 Pty Ltd (ABN 42 105431525)
Date Licence applied for:	15 March 2019
Licence applied for:	Licence to take water from a bore under section 60 of the *Water Act*
Purpose for which Licence is sought:	Petroleum activities
Maximum quantity of water proposed to be taken annually for each beneficial use: Petroleum Activities	 175 ML p.a.
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Bores from which water will be taken	 RN040895
Water Source:	Gum Ridge Formation
Water Control District:	Daly Roper Beetaloo Water Control District
Declared Water Allocation Plan:	No declared plan

Reasons for Decision

Procedural requirements

3. I am satisfied that all substantive procedural requirements relating to the making of the Application have been met. This includes that:

(a) the Application was duly made in the approved form and includes all information required under the Act and the Water Regulations 1992

(b) the Applicant is a legal entity

and

(c) the Applicant has the authority to access the land from which water is proposed to be taken under the Licence and on which the water will be used (**Land**).

4. Section 71B(1) of the Act provides that within 30 days after lodgement of an application to which Part 6A of the Act applies, the Controller must give notice of the Controller's intention to make a water extraction licence decision (**NOI**).

5. As the Application was accepted for lodgement on 20 March 2019, the NOI was required to be given by 19 April 2019. Accordingly, the NOI was published in the NT News on 22 March 2019 and in the Katherine Times on 27 March 2019.

6. Section 71B(2) of the Act requires a copy of the NOI to be published in a newspaper circulating throughout the Territory and provides that the NOI may also be published in a newspaper circulating in the general locality to which the application relates. To that extent, the NOI was published in the NT News and in the Katherine Times. A copy of the NOI as it appeared in the NT News and in the Katherine Times is provided at Attachment A.

7. The NOI complies with the requirements established by section 71B of the Act in relation to the content of the notice.[1]

Provision of NOI to the owners and occupiers of adjacent land

8. Section 71B(6) of the Act requires the Controller to give a copy of the NOI to owners and occupiers of land immediately adjacent to:
   (a) the land from which the water will be taken

   and

   (b) the land on which the water will be used.

9. All owners and occupiers of land immediately adjacent to the Land which is the subject of the Application were identified by mapping tool NR Maps.

10. A copy of the NOI was sent to each owner and occupier of land adjacent to the Land.

11. The letters referred to in paragraph 10 were sent within 30 days of the lodgement of the Application.

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[1] Section 71B (3) of the Act sets out the general information that must be included in the NOI and s. 71B(4) requires the NOI to include an invitation to make written comments about an application to the Controller within 30 days after publication of the notice. The NOI includes all of that information.

12. Following the 30 day public consultation period the department became aware that land adjacent to the Land was the subject of a native title determination and that native title holders, who are also recognised as occupiers of the adjacent land, were not provided a copy of the NOI. Consequently, the native title holders, via the Northern Land Council, were provided a copy of the NOI on 14 May 2019.

13. Notwithstanding that the letter to the native title holders was sent outside the 30 day period specified in the Act, it is not considered that the delay would have any effect on the validity of a decision to grant the Licence or the Licence itself. That is because the native title holders were given 30 days in which to respond to the NOI and any response received has been taken into account in this assessment.

Responses to NOI

14. In response to the NOI, nine responses were received. A discussion about each response to the NOI is included below from paragraph 79.

Decision-maker

15. In accordance with section 18 of the Act, I was appointed the Controller of Water Resources (Controller) on 19 December 2016. That appointment remains current and there are no limitations on the terms of my appointment that would prevent me from deciding the Application.

16. Further, I am not aware of any personal or professional matter which may prevent me from deciding the Application.

ASSESSMENT UNDERTAKEN, EVIDENCE USED AND ADVICE

Assessment of relevant factors under s 90(1) of the Act

17. Section 90(1) of the Act provides that in making a water extraction licence decision I must take into account any of the factors specified in that section that are relevant to the decision.

18. My decision about the Application is a water extraction licence decision.

19. The following is an assessment of this Application against each of the individual factors specified in section 90(1) of the Act:

(a) the availability of water in the area in question;

20. The Applicant's proposed activity is located in the Daly Roper Beetaloo Water Control District **(District)** declared under section 22 of the Act.

21. The Land overlies the Gum Ridge Formation in the northern Georgina Basin and is outside of a water allocation plan area.

22. Availability of water from the area, in the absence of a declared plan, is informed by the Northern Territory Water Allocation Planning Framework (**Framework**). A copy of the Framework is provided in Attachment B.

23. The Framework is a written policy that has guided water allocation in the Territory for many years. The Application falls within the Arid Zone of the Northern Territory. In the Arid Zone, the Framework relevantly states there will be no deleterious change in ground water discharges to dependent ecosystems, and total extraction over a period of at least 100 years will not exceed 80 per cent of the total aquifer storage at start of extraction. It further provides that if current or projected consumptive use exceeds 80 per cent or ground water discharges to ground water dependent ecosystems are impacted, no new water extraction licences will be granted unless there is scientific evidence supporting the grant.

24. The Georgina Basin Groundwater Assessment: Daly Waters to Tennant Creek, Technical Report 17/2017[2] (Georgina Basin Report), reports the volume of ground water held in storage in the Gum Ridge Formation is estimated to be between 1,766,000 GL (gigalitres) and 3,532,000 GL.

25. In accordance with the Framework, total extraction over a period of at least 100 years should not exceed between 1,412,800 and 2,825,600 GL.

26. There is one water extraction licence in the Gum Ridge Formation, which authorises a total maximum extraction of 967.5 ML from the licensed period of May 2019 to December 2023.

27. The Application proposes to extract 175 ML per year for 3 years which equates to a total extraction for the term of the licence of 525 ML.

28. The total amount of ground water taken under a water extraction licence from May 2019 to December 2023 if this licence is granted would be 1,492.5 ML; significantly less than the estimated water available for extraction under the Framework.

29. With respect to ground water dependent ecosystems; ground water discharges from the Gum Ridge Formation are associated with the ground water dependent ecosystems of Bitter Springs and Rainbow Springs. Modelling activities undertaken by the department, as described in paragraph 37-42, conclude that the proposed extraction would have no change in reliability of spring flows at Bitter Springs or Rainbow Springs.

30. Based on the above information it appears sufficient water is available to meet the requirements of the Applicant.

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[2] Tickell, S.J. and Bruwer, Q, (2017) Georgina Basin Groundwater Assessment: Daly Waters to Tennant Creek, Technical Report 17/2017 (Version 2, April 2019), Northern Territory Department of Environment and Natural Resources. Northern Territory Government, Australia.

(b) the existing and likely future demand for water for domestic purposes in the area in question;

31. Land owners and occupiers have certain prevailing statutory rights under the Act to take water for domestic purposes. The demand for water in the District in the exercise of these statutory rights must be taken into account when determining the amount of water available to be taken for other purposes under water extraction licences.

32. The total land area of where water may be taken and where water may be used is around 13,000 square kilometres and is largely surrounded by pastoral leases. The Land is in a remote location via the Carpentaria Highway, south east of Daly Waters.

33. The Georgina Basin Report indicates there is limited demand for ground water for domestic water. Around 300 ML of water per year is estimated for domestic water use including around 100 ML for 25 homesteads and 200 ML from the Gum Ridge Formation for the township of Elliot.

34. Due to the remote location and pastoral land use in the area future domestic demand is unlikely to change significantly.

35. The existing and likely future demand for water for domestic purposes is therefore insignificant in comparison to volume of water available from the Gum Ridge Formation in accordance with the Framework.

36. In accordance with the definition of a petroleum activity, water used for domestic purposes by petroleum activity employees, contractors and associated workers is included as an ancillary use. For this reason, domestic water use associated with the petroleum activity, is included in the Application volume.

(c) any adverse effects likely to be created as a result of activities under the permit, licence or consent on the supply of water to which any person other than the applicant is entitled under this Act;

37. To assess whether the Applicant's maximum volume of water proposed to be taken would have an effect on the supply of water to which any person other than the Applicant is entitled, the department used the integrated Daly Roper ground water and surface water model (**Model**). The Model outputs were analysed to measure impacts by assessing the change in reliability of surface water flows and ground water discharge (or spring flows) and the reduction in ground water level.

38. Reliability of surface water flows were analysed at indicator sites located at Elsey National Park and Red Rock on the Roper River. The assessment indicated there would be no change in reliability of surface water flows at the specified indicator sites.

39. Spring flow (as a measure of ground water discharge) was assessed at two key sites: Bitter Springs and Rainbow Springs. The analysis determined there would be no change in reliability of spring flows at Bitter Springs or Rainbow Springs.

40. Ground water levels were assessed at eight registered bore locations at varying proximity for each of the nominated extraction points. A maximum reduction in ground water level of 0.12 metres after 58 years of continuous extraction was estimated at registered bores located 1.08 km from the nominated extraction point. This modelled impact on ground water level is significantly less than one metre reduction in ground water level specified in the Inquiry Report as "excessive".

41. A copy of the Water Assessment Report detailing the analysis of the Model outputs can be found in Attachment C.

42. In summary, the water assessment indicates there will be no change in the reliability of surface water flows at the indicator sites and an insignificant reduction in ground water level. Therefore it is unlikely, that the proposed extraction of water will have any adverse effect on the quantity of water to which any person other than the applicant is entitled under the Act.

43. Any potential for an adverse effect could be monitored into the future by licence conditions which:

- limit the Applicant's water usage
- require the Applicant to report on its water usage
- require the Applicant to monitor ground water level prior to extracting water and verify modelled estimates of ground water level draw down
- prohibit the extraction of ground water within one kilometre of bores used for the purpose of stock and domestic use
- report any contraventions of the terms and conditions of the licence.

44. Impacts on water quality, of stock and domestic users including the township of Elliot, will be monitored in association with the environment management plan required under the Petroleum (Environment) Regulations 2016 and the department's Preliminary Guideline: Groundwater Monitoring Bores for Exploration Petroleum Wells in the Beetaloo Sub-basin (refer Attachment D).

(d) the quantity or quality of water to which the applicant is or may be entitled from other sources;

45. There is no other water source in the vicinity of the Applicant's Land that could provide the necessary quantity and quality of water for the Applicant's petroleum activities.

(e) the designated beneficial uses of the water and the quality criteria pertaining to the beneficial uses;

46. The quality criteria that apply to the water are outlined in Gazette Notice G15, 10 April 2019. Under section 22A of the Act the declared beneficial uses of all surface water from all natural waterways and all ground water located in the District are:
    - Agriculture
    - Aquaculture
    - Public water supply
    - Environment
    - Cultural
    - Industry
    - Rural stock and domestic
    - Mining activity
    - Petroleum activity.

    Petroleum activity is the listed beneficial use in the proposed Licence, consistent with the Applicant's business activity, and is listed in the section 22A declaration.

47. Further, under section 73(1), the objectives described in Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia, 2018 to be the objectives that apply in relation to the water in the District, according the beneficial use of the water. These objectives will be monitored in association with the environment management plan required under the Petroleum (Environment) Regulations 2016 and the department's Preliminary Guideline: Groundwater Monitoring Bores for Exploration Petroleum Wells in the Beetaloo Sub-basin (refer Attachment D).

(g) existing or proposed facilities on, or in the area of, the land in question for the retention, recovery or release of drainage water, whether surface or sub-surface drainage water;

48. There are no known existing facilities on, or in the area of, the Land, for the retention, recovery, or release of surface or sub-surface drainage water.

49. The Applicant's proposed development will generate waste water through fracture stimulation flow back fluid, drilling mud, cuttings, drill fluid and domestic grade sewage from the camp site.

50. Waste management will be addressed in the Applicant's environment management plan and is also subject to regulation under the *Waste Management and Pollution Control Act 1998.* Environment management plans must be approved by the Minister for Environment and Natural Resources before activities commence.

51. To address any associated risks special conditions in the licence are included that limit the extraction water unless an approved environment management plan is in place.

(h) the adverse effects, if any, likely to be created by such drainage water resulting from activities under the licence on the quality of any other water or on the use or potential use of any other land;

52. The Applicant has indicated the waste water is likely to be stored temporarily on site before being transported offsite for treatment and disposal at a licensed waste handling facility.

53. Such matters will be addressed under an environment management plan and is also subject to regulation under the *Waste Management and Pollution Control Act 1998.*

54. Additionally, the Inquiry Report, Recommendation 7.17 states that any discharge of any onshore shale gas fracturing waste water (treated or untreated) to either drainage lines, waterways, temporary stream systems or waterways be prohibited. Under section 16 of the Act a discharge of this nature would be an offence unless permitted in a waste discharge licence. A waste discharge licence permitting such an activity would be contrary to the government's acceptance of the Inquiry Report. The Water Amendment Bill 2019, has been passed in Parliament to amend the Act to fulfil several key recommendations of the Inquiry Report, including enforcing recommendation 7.17 of the Inquiry Report.

55. To address any associated risks special conditions in the licence are included that limit the extraction of water unless an approved environment management plan is in place.

(j) the provisions under the Planning Act 1999 relating to the development or use of land in the area in question;

56. Under the Northern Territory Planning Scheme (**NTPS**), the Applicant's Land is zoned NOZONE (No NT Planning Scheme zone applies).

57. Clause 10.2 of the NTPS (Clearing of Native Vegetation) states that the clause does not apply if the clearing is required or controlled under any Act in force in the Territory. Land clearing is a regulated activity under the Petroleum (Environment) Regulations 2016 and managed under an environment management plan.

58. Planning controls relating to land in the immediate locality of the Applicant's Land have also been considered. From searches using mapping tool NR Maps it is evident that all adjacent properties are zoned NOZONE. Further, no proposed change to the zoning of the local area has been identified which may have the effect of impacting the supply of ground water for users such as the Applicant. Therefore this factor is not relevant to my decision.

(k) other factors the Controller considers should be taken into account or that the Controller is required to take into account under any other law in force in the Territory.

Bores

59. The Applicant proposes to take water from one registered water bore. Additional bores are yet to be drilled.

60. The construction of the bore, was undertaken in association with the Applicant's environment management plan, NT EP 117 Water Bore Monitoring Program, approved by the Minister for Primary Industry and Resources on 10 December 2018, variation approved on 12 February 2019.

61. The environment management plan required the bores to be constructed in accordance with Minimum Construction Requirements for Water Bores in Australia, Edition 3. Mandatory requirement 11.1 of the standard requires that multiple aquifer bores must be sealed between the aquifers and permeable zones to prevent intermixing flow, and contamination of the aquifers.

62. A review of the statement of bore and gamma log undertaken by the department indicated the positioning of the cement plug did not isolate the aquifers of the Anthony Lagoon Formation and the Gum Ridge Formation. This is contrary to the requirements of the environment management plan and the Application which means any water extracted under a licence could not be directly attributed to the Gum Ridge Formation. It also means water would be extracted from the incorrect water source.

63. No water has yet been extracted from the bore and is working to rectify the bore construction. This work will be regulated under a bore work permit that has been issued to the Applicant.

64. To address the risks associated with the construction of the bores special licence conditions are included that requires the licence holder to demonstrate the bores are constructed in accordance with the Minimum Construction Requirements for Water Bores in Australia (Edition 3) prior to extracting ground water.

Final Report of the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory

65. An independent Scientific Inquiry into Hydraulic Fracturing of Onshore Unconventional Reservoirs in the Northern Territory was commissioned to investigate the environmental, social and economic risks and impacts of hydraulic fracturing of onshore unconventional gas reservoirs and associated activities. This led to the publication of the Final Report of the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory in March 2018 (Inquiry Report). On 17 April 2018, the government accepted all 135 recommendations of the Inquiry Report. The government has developed an implementation plan that responds to the recommendations https://hydraulicfracturing.nt.gov.au/implementation-plan.

66. Recommendation 15.1 requires a strategic regional environment baseline assessment (SREBA) be undertaken prior to the granting of any further production approvals. Recommendation 7.19 and 7.20 require the SREBA to take into account ground water dependent ecosystems in the Roper River and identify and characterise all subterranean aquatic ecosystems, with a particular emphasis on the Roper River region.

67. The SREBA will be managed under an approved environment management plan in accordance with the Petroleum (Environment) Regulations 2016. This water extraction licence decision relates to ground water for exploration activities and should be made independently of the recommendations regarding the SREBA.

68. Recommendation 7.8 and 7.11 in the Inquiry Report are directly related to this licence decision.

69. Recommendation 7.8 requires that measures are mandated to ensure that any onshore shale gas development does not cause unacceptable local drawdown of aquifers. It states that the extraction of water from water bores to supply water for hydraulic fracturing be prohibited within 1km of existing or proposed groundwater bores (that are used for domestic or stock use). The Inquiry Report establishes a drawdown in excess of 1m as excessive. Recommendation 7.8 also states that gas companies be required, at their expense, to monitor drawdown in local water supply bores.

70. Recommendation 7.11 provides a list of items in order to minimise the risk of ground water contamination from leaky gas wells the majority of which will be regulated under an environment management plan. The item relevant to the licence decision, states that a minimum offset distance of at least 1km between water supply bores and well pads must be adopted unless site-specific information is available to support a lesser distance.

71. These recommendations are addressed in special licence conditions that:

- limit the Applicant's water use
- require the Applicant to report on its water use
- require the Applicant to monitor ground water level prior to extracting water and verify modelled estimates of ground water level draw down
- prohibit the extraction of ground water within one kilometre of bores used for the purpose of stock and domestic use
- report any contraventions of the terms and conditions of the licence
- have an approved environment management plan in place.

Ground water dependant ecosystems

72. The Potential for Groundwater Use by Vegetation in the Australian Arid Zone[3] provides a technical study on ground water dependent ecosystems predominately in the Ti Tree Basin, which may be applied to this area. This study indicates that terrestrial ground water dependent ecosystems generally access water to depths of 15 – 20 metres below ground level. The standing water level of the target aquifer ranges from 44 – 65 metres below ground level which is outside the reaches of terrestrial ground water dependent ecosystems.

Licence period

73. In accordance the Act, a water extraction licence may be granted for a period, not exceeding ten years, as is specified in the licence. However I may grant a licence for a period exceeding ten years, where, in the opinion of the Minister, there are special circumstances that justify it under the Act.

74. The Minister has not provided advice regarding special circumstances that justify granting a licence for more than 10 years.

75. The Applicant has indicated a licence term expiring 31 December 2021.

Prioritising Water Extraction Licence Applications Policy

76. In accordance with the policy Prioritising Water Extraction Licence Applications, applications for new or increased water extraction licences are processed on a first in first served basis sequenced in order of the date and time of lodgement of the application for each water resources area within a water control district.

77. This Application is the only outstanding application lodged with the department for processing in the area of the Gum Ridge Formation and therefore has priority over any other application in this water resource area.

78. The following factors are not relevant to my decision:
    - *Section 90(1) (ab)* - Section 22B (4) of the Act provides that water resource management in a water control district is to be in accordance with a declared water allocation plan. There is no declared plan area in which the Applicant's Land is located.
    - *Section 90(1) (f)* - there is currently no such agreement.

[3] Cook, P.G. and Eamus, D, The Potential for Groundwater use by Vegetation in the Australian Arid Zone, March 2018,

Comments received in response to NOI or from third parties generally

79. As previously stated, nine comments were received in response to the NOI.

80. I am required to consider each response provided within the statutory timeframe for comment when deciding to grant the Application.

81. In the following table is a summary of the issues raised (which extracts the key text from the submission) and the response.

Name of person responding	Owner or occupier of Adjacent land?	Summary of issues raised in submission	Consideration of issues raised
Jacqui Cannon of Consolidated Pastoral Company	Yes	The submission raises the issues of the use of water and the effects on food producers. The submission states that: "...Water should be taken first wherever possible from the water that is a by-product from mining and after this, from depths not accessed by food producers now and that will not be accessed by food producers in the future..." "...Water taken should not be from water sources that interacts with water used now and in the future by food producers..."	This response raises issues which are extraneous to my decision. However indicate concern regarding the availability and protection of water resources which are relevant and need to be weighed in my decision against the other matters that would support the grant of the decision. Matters relating to water availability have been considered in paragraphs 20-30 and 45. The impact on other water uses has been considered in paragraphs 37-44. The Application has been assessed in accordance with the prioritising water extraction licence applications policy detailed in paragraphs 76-77.

Justin Tutty	No	The submission raises issues regarding the appropriate assessment of on-shore gas activities, the implementation of the recommendations of the *Final Report of the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (Inquiry Report)* and the protection of ground water dependent ecosystems. The submission states that: "…pre-emptive allocation related to fracking are neither being pursued nor processed in good faith…" "...is an attempt to evade appropriate assessment of on-shore gas exploitation." "…the recommendations of the Pepper Inquiry require any fracking approvals to be grounded in SREBA – strategic regional assessments that must include a survey of groundwater dependant ecosystems…" "… this proponent is racing against reform, attempting to weight an eventual assessment with the inevitability of approvals granted without the benefit of the imminent regional assessment…"	This response raises issues which are relevant and need to be weighed in my decision against the other matters that would support the grant of the decision. The *Final Report Scientific Inquiry into Hydraulic Fracturing in the Northern Territory* and the recommendations from this report and the issues relating to the SREBA have been considered as addressed above in paragraphs 65 - 71. Ground water dependent ecosystems are relevant to the considerations and been considered in paragraphs 23, 29 and 72.

Amelia Telford of Seed Indigenous Youth Climate Network	No	The submission raises concerns with limited information available and consultation periods and concern about the potential damages of fracking. The submission states that: "...the lack of information regarding this water licence, the lack of consultation and inaccessible process for comment from those most likely to be impacted that is our main concern..." "...without being provided with adequate information, time and resources, many of these communities are unable to have their concerns heard and questions answered" "...request additional time, including a consultation period and process, is allowed for Traditional Owners, Aboriginal communities and appropriate cultural authorities for the area impacted by this licence..."	This response raises issues which are relevant and need to be weighed in my decision against the other matters that would support the grant of the decision. The *Water Act 1992* specifies the public notice and consultation requirements when making a water extraction licence decision. The Act also specifies the content of such notices. The publishing of the notice and consultation periods provided were in accordance with the requirements of the Act The public viewing at the Office is consistent with current practices. Extensive public consultation was undertaken in the preparation of the *Final Report Scientific Inquiry into Hydraulic Fracturing in the Northern Territory* and the recommendations from this report have been considered as addressed above in paragraphs 65 - 71.

Raymond Dixon, Thelma Dixon, Shannon Dixon, Annette Kingston, Regina Kingston, Johnny Devlin, Susan Kingston of Protect Country NT	No	The submission raises concerns relating to the protection of water resources, the impact of water extraction and water availability. The submission states that: "…We are concerned about the amount of water that Origin Energy is applying to take for its exploration program because of the impacts it could have on our water security, and the health of our communities, culture and environment…" "…as Aboriginal custodians we have land rights, but what good are they if we don't have rights to control and protect our water? It is the foundation for all life and our culture…" "…stop new extraction for dangerous and wasteful fracking…"	This response raises issues which are relevant and need to be weighed in my decision against the other matters that would support the grant of the decision. The availability of water in this area has been substantively addressed above in assessing factor 90(1)(a) in paragraph 20 - 30 Any adverse effects likely to be created has been substantively addressed above in assessing factor 90(1)(c) in paragraph 37 - 44 The environmental assessment of on-shore gas activities are undertaken in accordance with the Petroleum (Environment) Regulations 2016.
Naomi Hogan of Lock the Gate Alliance	No	The submission raises issues regarding limited information available to the public and consultation periods and future activities by the Applicant. The submission states that: "…we are concerned there is limited information available to the public on the aquifer that will be targeted, the number of bores that will be	This response raises issues which are relevant and need to be weighed in my decision against the other matters that would support the grant of the decision. The *Water Act 1992* specifies the public notice and consultation requirements when making a water extraction licence decision. The Act also specifies the content of such notices. The publishing of the notice and

		required, and the number of fracking wells that will be services by this water…" "… Clear information should be available about what Origin intends to do with the water and more hydrological information should have been made available…" and "many landholders in the NT are remote and cannot easily access offices in Alice Springs, Katherine or Darwin…" "…Future activities if approved for Origin would involve hundreds of fracking wells, requiring massive volumes of water..." and "…the risks and impacts involved in this process are only going to escalate…" "…call on the Department to re-advertise the Origin water licence application…"	consultation periods provided were in accordance with the requirements of the Act The public viewing at the Office is consistent with current practices. Extensive public consultation was undertaken in the preparation of the *Final Report Scientific Inquiry into Hydraulic Fracturing in the Northern Territory* and the recommendations from this report have been considered as addressed above in paragraphs 65 - 71. The water extraction licence decision relates to the Application. Should the Applicant wish to increase extraction beyond the maximum extraction limit volume of 175 ML p.a., a new application will need to be submitted and assessed in accordance with the Act.
Heidi Jennings	No	The submission raises issues regarding making decisions pending legislative amendments, *Final Report of the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory* (Final Report), and water availability. The submission states that: "... Legislation Amendments and Bills are currently still in the process of being rectified.	This response raises issues which are relevant and need to be weighed in my decision against the other matters that would support the grant of the decision. The *Water Act 1992* specifies the processes that must be undertaken when making a water extraction licence decision. These processes mean that the Controller is not able to refuse a water extraction licence

		This water extraction license should not be accepted at this point in time…" "… The Fracking Inquiry suggested for further investigations on the ground water dependent ecosystems. The 135 recommendations were to be implemented, prior to the Industry being developed in the NT…" "…granting of licenses should only occur when the industry ensures there is no evidence, worldwide, that hydraulic fracturing or UCG, will not affect the quality or quantity of the water, the environment, or cause any systemic activity. There is inadequate evidence to safely enable any high-risk activities to the NT water…" "…Water tables and Aquifer levels are dropping severely and Recharge is unlikely due to a lack of rainfall. Alice Springs area is in drought and has had little rainfall…" "…The basic human right to clean water is being compromised…"	application and must make a decision within a specified timeframe. In making a decision other factors relevant to the decision are taken into account. To that extent it would be premature to consider legislation amendments that have not yet been settled by the government. The recommendations of the *Final Report Scientific Inquiry into Hydraulic Fracturing in the Northern Territory* have been considered as well as Baseline Testing under the SREBA as detailed in paragraphs 65 - 71 The resource information has been substantively addressed above in assessing factor 90(1)(a) in paragraphs 20 - 30. Any adverse effects likely to be created has been substantively addressed above in assessing factor 90(1)(c) in paragraphs 37 - 44.

Pauline Cass of Protect NT Inc.	No	This submission raises concerns regarding the timing of the application with respect to pending amendments to the Water Act 1992, the cumulative impacts of water extraction in the region, triggers for water restrictions, and the information available on the Water Licensing Portal. The submission states that: "... Origin have jumped the gun by applying for a water extraction licence before the new amendments to the Water Act (NT) have been implemented, thereby avoiding the restrictions and penalty increases the new Water Act would place on their activities. For this alone, this application must be denied..." "...The Pepper Inquiry's "Recommendation 14.19" states that, "Cumulative impacts of petroleum and other activities in the region must be considered by a decision-maker..." "... We are also concerned that there are still no water restriction triggers in the Water Act (NT) to protect our groundwater resources during times of drought. The Northern Territory has experienced its driest wet season which has left many of our aquifers at depleted levels. With our changing	This response raises issues which are relevant and need to be weighed in my decision against the other matters that would support the grant of the decision. The *Water Act 1992* specifies the processes that must be undertaken when making a water extraction licence decision. These processes mean that the Controller is not able to refuse a water extraction licence application and must make a decision within a specified timeframe. In making a decision other factors relevant to the decision are taken into account. To that extent it would be premature to consider legislation amendments that have not yet been settled by the government. The recommendations of the *Final Report Scientific Inquiry into Hydraulic Fracturing in the Northern Territory* have been considered as well as Baseline Testing under the SREBA as detailed in paragraphs 65 - 71 The resource information has been substantively addressed above in assessing factor 90(1)(a) in paragraphs 20 - 30. The Water Licensing Portal displays the details contained within the notice of intent to

		climate, drought restrictions must be included in water licences…" "… People need and have a right to more information regarding applications than what is currently provided in the Water Licensing Portal…"	make a water extraction licence decision. Once a decision is made, further information becomes available relating to the licence granted including the statement of decision.
Graeme Sawyer of Protect Country Alliance NT	No	This submission raises concerns regarding baseline data being available on a public register and the availability of information and consultation periods. The submission also raised questions regarding the sustainable year published without a time period and the target aquifer for water extraction. The submission states that: "… we object to the allocation of this water Licence…" and "….request that the water licence application is readvertised. Updated, corrected and more detailed information should be provided to the public…" "… Why was the figure representing the sustainable yield published without a time period	This response raises issues which are relevant and need to be weighed in my decision against the other matters that would support the grant of the decision. The *Water Act 1992* specifies the public notice and consultation requirements when making a water extraction licence decision. The Act also specifies the content of such notices. The publishing of the notice and consultation periods provided were in accordance with the requirements of the Act The department's Water Data Portal provides public access to water quality and quantity data which is updated every month and water quality statistics updated every quarter. Further, Government is developing an online portal to enable timely public reporting and ongoing monitoring associated with Inquiry

		component…" and "…To publish a figure as a yield without a time element is misleading…" "…Can you also explain the changed figures on page 44 of the 2017 Tickell and Brewer report…" "… In the spirit of the fracking inquiry recommendations, the supporting documents and baseline data should be held on a public register…" "… We have strong concerns about the way in which the information was presented in the ad and the lack of information available on the online portal…" "… It is critical that the department gets the processes correct from the outset, as the risks and impacts involved in this process are only going to escalate…"	report as addressed above in paragraphs 65 - 67 The 2017 Tickell and Brewer report contained a typographical error in one section. When this was identified the report was immediately corrected. The resource information has been substantively addressed above in assessing factor 90(1)(a) in paragraphs 20 - 30.
Marion Scrymgour of Northern Land Council (NLC) (representing native title holders)	Occupier	This submission does not object to the grant of the water extraction licence, however raises broader concerns relating to the potential issuing of multiple water extraction licences throughout and adjacent to the Beetaloo Basin. The submission states that: "…With the onshore gas industry in its infancy within the Beetaloo Basin region, it is timely to	This response raises issues which are relevant and need to be weighed in my decision against the other matters that would support the grant of the decision. The integrated Daly Roper surface water and ground water assessment model uses historical water extraction data and climatic conditions to predict the impact of proposed water extraction into the future. The model

		reflect on how groundwater extraction and use could potentially impact on Indigenous people and sites that are significant to them…" "…Groundwater can be a subsurface feature of sacred sites, and example of which is the springs around Mataranka and the associated swamp habitats/environments…" "…The issuing of water extraction licences also has potential to impact on the management of Strategic Indigenous Water Resources…" "…NLC believes a great deal of work needs to be undertaken prior to the granting of further water extraction licences in the region so that accurate baseline data can be obtained…" "…Further water extraction licences should be made reference to groundwater modelling that included consideration of the cumulative impacts…" and "…account for the potential impacts of climate change…"	considers cumulative impact of all water extraction and is used to predict impacts relating to ground water discharge in springs in the Mataranka area including Bitter Springs and Rainbow Springs as addressed in paragraph 29 and 37 - 44. The comment relating to Strategic Water Reserves is extraneous to the issues I need to consider. The Northern Territory Government has made steps to legislate Strategic Aboriginal Water Reserves. This will apply when a water allocation plan is in place. Water allocation planning will be undertaken for areas of the Beetaloo basin as outlined in the recommendations of the *Final Report of the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory*.

82. Other than the responses to the NOI, there has been no contact with any third party in relation to the Application.

Conditions of Licence

83. The conditions of the Licence reflect my decision and the discussion above.

JOANNE TOWNSEND
CONTROLLER OF WATER RESOURCES
11 June 2019

DOCUMENTS PROVIDED WITH THIS DECISION

Attachment	Description
A.	NOI as it appeared in the NT News and in the Katherine Times
B.	Northern Territory Water Allocation Planning Framework
C.	Water Assessment Report
D.	Preliminary Guideline: Groundwater Monitoring Bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin

Notices

General Notices

DEPARTMENT OF **ENVIRONMENT AND NATURAL RESOURCES**

Notice of intention to make a water extraction licence decision (Pursuant to section 71B of the Water Act)

The Controller of Water Resources hereby gives notice that a decision is to be made regarding an application for a grant of a new water extraction licence under section 60 of the Water Act for the proposed beneficial use - petroleum activities, associated with petroleum exploration permit 76, 98 and 117.

The source of extraction for the application in Table 1 is the Gum Ridge Formation for which the estimated sustainable yield is not yet determined but is in the range of 1,412,800 to 2,825,600 gigalitres. The total quantity of water that may be taken from this groundwater resource under existing water extraction licences is 0 ML/year. The total quantity of water that currently is taken from the water resource under water extraction licences is 0 ML/year.

Table 1

Name	Property where water is taken	Property where water is used	Registered bore number	Maximum annual extraction (ML/year)
Origin Energy B2 Pty Ltd	NT Portion 1079 NT Portion 7027	NT Portion 702 NT Portion 1079 NT Portion 7026 NT Portion 7027	RN040895	175

Comments regarding this application should be made in writing by **COB 26 April 2019** to the Controller of Water Resources, PO Box 496, Palmerston NT 0831 or email water.licensing@nt.gov.au

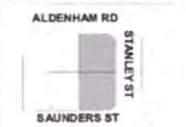
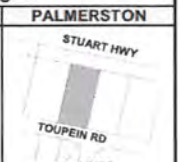
Further information is available at www.waterresources.nt.gov.au/licenceportal

www.nt.gov.au/water

NORTHERN TERRITORY GOVERNMENT

APPLICATIONS LODGED FOR ASSESSMENT UNDER THE *PLANNING ACT*

DEVELOPMENT APPLICATIONS

DARWIN		PALMERSTON
 Lots 1515 & 1516, 7 & 5 Searcy Street Lot 7118 47 Cavenagh Street Town of Darwin Darwin City Changes to the car parking area associated with an existing commercial development (Woolworths) MasterPlan SA P/L	 Lots 12103 & 12104 Town of Nightcliff 7 & 5 Stanley Street Muirhead Subdivision to create two lots (boundary realignment) and amendments to the setback plan approved through DP16/0052A Earl James and Associates	 Lot 7058 Town of Palmerston 19 Toupein Road Yarrawonga Change of use from showroom sales and warehouse to leisure and recreation (shed 2) Tribal Dragon Martial Arts

CLOSING DATE FOR SUBMISSIONS FRIDAY 5th APRIL 2019 4:00 PM CST (or 12 MIDNIGHT CST if lodged online at: www.ntlis.nt.gov.au/planning)

Applications may be inspected at Development Assessment Services, First Floor, Energy House, 18-20 Cavenagh Street, Darwin or viewed online through the Planning Notices online: www.ntlis.nt.gov.au/planning

Submissions must be lodged by the closing date indicated in order to be considered by the consent authority. Submissions in relation to an application must be in writing and include the name and postal address of the author and may be made publicly available in full.

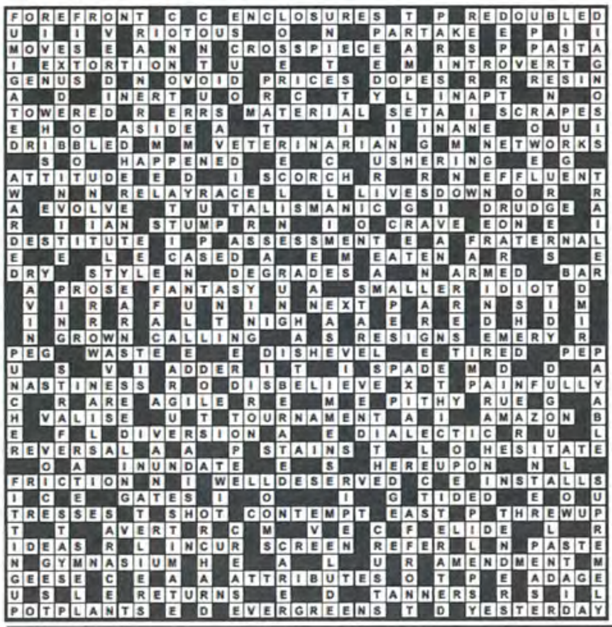
Submissions may be lodged with Development Assessment Services, Department of Infrastructure, Planning and Logistics, GPO Box 1680, Darwin NT 0801, hand delivered to First Floor, Energy House, 18-20 Cavenagh Street, Darwin or lodged online through Planning Notices online: www.ntlis.nt.gov.au/planning

For enquiries phone: 8999 6046 or fax 8980 0700 website: www.ntlis.nt.gov.au/planning

DEPARTMENT OF INFRASTRUCTURE, PLANNING AND LOGISTICS

NORTHERN TERRITORY GOVERNMENT

MEGA MONDAY CROSSWORD SOLUTION



Legal Notices

Form 88B
Rule 88.09

NOTICE OF INTENDED APPLICATION FOR PROBATE

In the Supreme Court of the Northern Territory of Australia.

After 14 days from publication of this notice an application for probate of the Will dated 20 February 2015 of **JANINA SZYC** late of Tiwi Gardens Aged Care, Tiwi in the Northern Territory of Australia, formerly of 59 Jingili Terrace, Jingili in the aforesaid Territory, Retired Hospital Worker, deceased, will be made by **DAVID PIOTR SZYC.**

Creditors are required to send particulars of their claims upon her estate to **WARD KELLER, Lawyers,** GPO Box 330, Darwin, NT, 0801.

NOTICE OF LOST TITLE

Would anyone holding or knowing the whereabouts of certificate of title Volume 736 Folio 733 Lot 1350 Town of Tennant Creek (8 Griggs Street Tennant Creek) registered in the name of Outback Stores Pty Ltd (ACN 120 661 234), please contact, Coralie at Bowden McCormack Lawyers + Advisers Suite 4 Level 1 Northgate Plaza 101 Mitchell Street Darwin or GPO Box 2644 Darwin NT 0801 Email conveyancer@bowden-mccormack.com.au Phone 08 89 416355. Fax: 08 89 416366.

NOTICE OF LOST TITLE

Would anyone holding or knowing the whereabouts of the duplicate certificate as to title **Title Volume 696 Folio 238 for Section 03278 Hundred of Glyde** In the name of: **Coolalinga Holdings Pty Ltd (ACN 085 321 455) as Trustee for the Coolalinga Property Trust** please contact **Darwin Family Law, Level 3/9 Cavenagh Street Darwin NT on 89461666.**

NOTICE OF LOST TITLE

Would anyone holding or knowing the whereabouts of the duplicate certificate of title comprised in **Volume 008 Folio 056 Lot 291 Townsite of Southport** in the name of: **William Eddrup Adcock,** please contact **Carmen Jap at Minter Ellison Lawyers, GPO Box 1134, Darwin NT 0801 or 08 8901 5941.**

Katherine Times

Connect with Classifieds

Phone: 1300 050 909
Email: classifieds.kathtimes@fairfaxmedia.com.au

Positions Vacant

RoperGulf
REGIONAL COUNCIL
SUSTAINABLE - VIABLE - VIBRANT

Located in a stunning part of the Northern Territory, Roper Gulf Region offers a unique lifestyle. The Regional Council covers an area approximately the size of Victoria and is serviced by five major river systems. Career opportunities with the Roper Gulf Regional Council include

Position Title: CDP Senior Employment Consultant

Location: Katherine

Position Type: Casual

Salary Range: Level 5 indicative $64,676.63 to $71,391.16 per annum based on 38 hours per week, (negotiated based on qualifications and experience) plus 25% casual loading

Closing Date: Midnight on Sunday, 14 April 2019

End Date: 30 June 2019

Application Requirements: RGRC Job Application Form, statement addressing the selection criteria and resume/CV sent to recruitment@ropergulf.nt.gov.au

COUNCIL RESIDENTS ENCOURAGED TO APPLY

The Roper Gulf Regional Council has a friendly, progressive and professional work environment with fantastic working conditions that include the following benefits, 6 weeks annual leave + 17.5% loading (pro-rata for part time employees), 10 days personal leave, tax benefits (relating to Zone A), travel allowances and ongoing professional development and training.

www.ropergulf.nt.gov.au

Public Notices

Katherine Umpires Association
Annual General Meeting
Knotts Crossing Resort
Wednesday 3rd April at 7.00 PM
All Welcome
Contact: Daryl Grabek 0400 448 513

HELEN SUMMERS OPTOMETRIST

Helen Summers will be consulting in Katherine on **4th & 5th of April,**
Gorge Health, 11 Second Street Katherine.
Helen Summers offers Professional Eye examinations and assessments for Contact Lenses, Pre & Post Laser treatments as well as Reading and Learning Development
Preferred Medibank Supplier

Please phone 8995 9595 for an appointment

Public Notices

GREEN Snaps Nature Photography Competition. Entries for Green Snaps close on 4 May. The 2019 theme is 'New Life in the NT Environment'. Download an entry form from Katherine Start Page www.webpage-nt.com. Call 0408 440 696 for more information.

Public Notices

APPLICATIONS LODGED FOR ASSESSMENT UNDER THE *PLANNING ACT*

DEVELOPMENT APPLICATIONS

KATHERINE

N.T. Portion 6606
187 Lansdowne Road, Lansdowne
N.T. Portion 07154
180 Quarry Road, Lansdowne
Subdivision and consolidation to create two lots
Earl James and Associates

N.T. Portion 4739
595 Gorge Road, Lansdowne
Restaurant within a defined flood area
Carolyn Grace

CLOSING DATE FOR SUBMISSIONS WEDNESDAY 3rd APRIL 2019 4:00 PM CST (or 12 MIDNIGHT CST if lodged online at: www.ntlis.nt.gov.au/planning)

Applications may be inspected at Development Assessment Services, Katherine Government Centre, 5 First Street, Katherine or viewed online through the Planning Notices Online: www.ntlis.nt.gov.au/planning

Submissions **must** be lodged by the closing date indicated in order to be considered by the consent authority. Submissions in relation to an application must be in writing and include the name and postal address of the author and may be made publicly available in full.

Submissions may be lodged with Development Assessment Services, Department of Infrastructure, Planning and Logistics, PO Box 2390, Katherine NT 0851, hand delivered to Katherine Government Centre, 5 First Street, Katherine or lodged online through Planning Notices Online: www.ntlis.nt.gov.au/planning

For enquiries phone: 8973 8926 or fax: 8973 8944 website: www.ntlis.nt.gov.au/planning

DEPARTMENT OF INFRASTRUCTURE, PLANNING AND LOGISTICS

NORTHERN TERRITORY GOVERNMENT

Public Notices

DEPARTMENT OF **ENVIRONMENT AND NATURAL RESOURCES**

Notice of intention to make a water extraction licence decision (Pursuant to section 71B of the Water Act)

The Controller of Water Resources hereby gives notice that a decision is to be made regarding an application for a grant of a new water extraction licence under section 60 of the Water Act for the proposed beneficial use - petroleum activities, associated with petroleum exploration permit 76, 98 and 117.

The source of extraction for the application in Table 1 is the Gum Ridge Formation for which the estimated sustainable yield is not yet determined but is in the range of 1,412,800 to 2,825,600 gigalitres. The total quantity of water that may be taken from this groundwater resource under existing water extraction licences is 0 ML/year. The total quantity of water that currently is taken from the water resource under water extraction licences is 0 ML/year.

Table 1

Name	Property where water is taken	Property where water is used	Registered bore number	Maximum annual extraction (ML/year)
Origin Energy B2 Pty Ltd	NT Portion 1079 NT Portion 7027	NT Portion 702 NT Portion 1079 NT Portion 7026 NT Portion 7027	RN040895	175

Comments regarding this application should be made in writing by **COB 26 April 2019** to the Controller of Water Resources, PO Box 496, Palmerston NT 0831 or email water.licensing@nt.gov.au

Further information is available at www.waterresources.nt.gov.au/licenceportal

www.nt.gov.au/water

NORTHERN TERRITORY GOVERNMENT

APPLICATION LODGED FOR ASSESSMENT UNDER THE *PLANNING ACT*

EXCEPTIONAL DEVELOPMENT APPLICATION

1st ADVERTISEMENT

The Minister for Infrastructure, Planning and Logistics has received an application for an Exceptional Development Permit for the purpose of Fuel Depot on NT Portion 5437 (40) Emungalan Road, Emungalan

The land is within Zone LI (Light Industry) of the Northern Territory Planning Scheme and the development of the site for Fuel Depot would otherwise be prohibited

CLOSING DATE FOR SUBMISSIONS WEDNESDAY 10 APRIL 2019 4:00PM CST

Applications may be inspected at Development Assessment Services, Katherine Government Centre, 5 First Street, Katherine or viewed online through the Planning Notices Online: www.ntlis.nt.gov.au/planning

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For enquiries phone: 8973 8926 or fax: 8973 8944 website: www.ntlis.nt.gov.

DEPARTMENT OF INFRASTRUCTURE, PLANNING AND LOGISTICS

NORTHERN TERRITORY GOVERNMENT

Work Wanted

OLD car batteries radiators, hot water services solar panels, airconditioners, copper brass. Will pickup. Phone 0432 058 936

Adult Services

Eliza
New to Katherine
Sensual Massage
Friendly
Mature Gentleman Welcome
0403 647 543

DEPARTMENT OF
ENVIRONMENT AND NATURAL RESOURCES

Northern Territory Water Allocation Planning Framework

All available scientific research directly related to environmental and other public benefit requirements for the water resource will be applied in setting water allocations for non-consumptive use as the first priority, with allocations for consumptive use made subsequently within the remaining available water resource.

In the absence of directly related research, contingent allocations are made for environmental and other public benefit water provisions and consumptive use. These are explained below.

Top End (northern one third of the Northern Territory)

Rivers
At least 80 per cent of flow at any time in any part of a river is allocated as water for environmental and other public benefit water provision, and extraction for consumptive uses will not exceed the threshold level equivalent to 20 per cent of flow at any time in any part of a river.

In the event that current and/ or projected consumptive use exceeds the 20 per cent threshold level, new surface water Licences will not be granted unless supported by directly related scientific research into environmental other public benefit requirements.

Aquifers
At least 80 per cent of annual recharge is allocated as water for environmental and other public benefit water provision, and extraction for consumptive uses will not exceed the threshold level equivalent to 20 per cent of annual recharge.

In the event that current and/ or projected consumptive use exceeds the 20 per cent threshold level, new groundwater Licences will not be granted unless supported by either directly related scientific research into groundwater dependent ecosystem/ cultural requirements, or in the absence of such research, hydrological modelling confirming that total groundwater discharge will not be reduced by more than 20 per cent.

Arid Zone (southern two thirds of the Northern Territory)

Rivers
At least 95 per cent of flow at any time in any part of a river is allocated as environmental and other public benefit water provision, and extraction for consumptive uses will not exceed the threshold level equivalent to five per cent of flow at any time in any part of a river.

In the event that current and/ or projected consumptive use exceeds the threshold levels of five per cent for river flow, new surface water Licences will not be granted unless supported by directly related scientific research into environmental other public benefit requirements.

Aquifers

There will be no deleterious change in groundwater discharges to dependent ecosystems, and total extraction over a period of at least 100 years will not exceed 80 per cent of the total aquifer storage at start of extraction.

In the event that current and/ or projected consumptive use exceeds the threshold levels of 80 per cent of the consumptive pool for aquifers, or groundwater discharges to groundwater dependent ecosystems are impacted, new groundwater Licences will not be granted unless supported by directly related scientific research into groundwater dependent ecosystem/cultural requirements.

Water Assessment Report to Water Licensing and Regulation Branch

1. References

TRIM Record Number : LRM2019/0036-0008~0001
Title : Modelling and analysis request - Origin

2. Information Provided

Appendix 1 contains the revised version of the request received from the Water Licencing and Regulation Branch. Subsequent communication with licencing staff clarified the Origin GWEL pumping scenarios as follows:

Scenario 2

Bore	Rate	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
RN040895	ML/Month	0.0	6.4	11.0	5.3	6.0	11.0	13.0	14.3	13.3	4.7	0.3	0.0
RN_Site2	ML/Month	0.0	0.0	0.0	0.0	6.0	11.7	11.7	7.7	9.7	14.0	19.0	10.0

Scenario 3

Bore	Rate	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
RN040895	ML/Month	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	46.5	41.1	0.0
RN_Site2	ML/Month	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	46.5	41.1	0.0

Scenario 2 and 3 are two combinations of maximum annual pumping of 175 ML/y

3. Metadata

3.1 Model Versions

Four scenarios were run with the updated Roper model (M11-G3).

A new version of the model is generated with each pumping scenario application. These were named as:

i. **ORIGIN_SC0 modified_Rech_03_G.fem** for modelling natural flow;
ii. **ORIGIN _SC1_ modified_Rech_03_G.fem** for current use scenario; and
iii. **ORIGIN_SC2 modified_Rech_03_G.fem** and **ORIGIN _SC3 modified_Rech_03_G.fem** for the two Origin pumping scenarios, above.

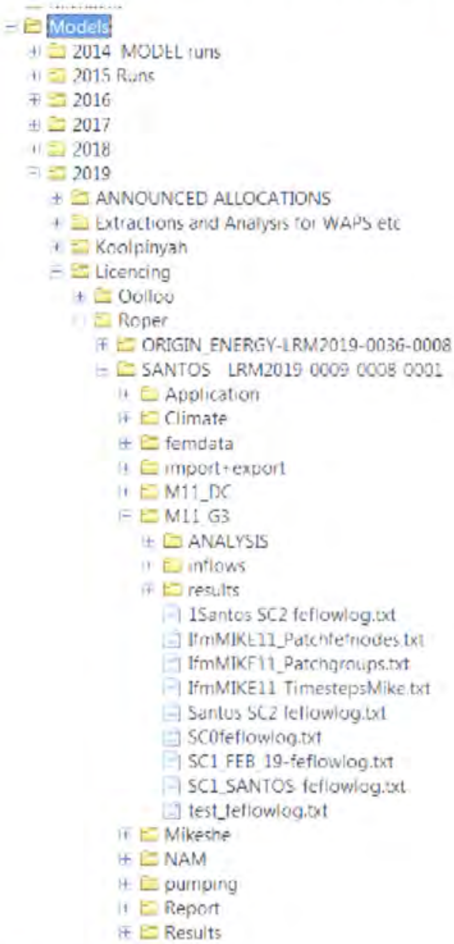
The resultant outputs were compared to the natural (no-pumping) scenario output for impact assessment.

It should be noted that climate data used was identical to that used for the 2018 Announced Allocations and thus was current until March 2018.

3.2 Filenames

All files used for the modelling reside in the Departmental network drive: spatial ([\\pgb-bas01\BAS_DATA](\\pgb-bas01\BAS_DATA)) under the following path:

> :\Working\Water_Resources\Models\2019\Licencing\Roper\ORIGIN_ENERGY-LRM2019-0036-0008



3.3 Input Files

All input files may be located in the folders above

The pumping files particular to this licence application may be found in the **pumping** sub-folder.

3.4 Date of model run

The model runs commenced in March (SC0 and SC1) and May (SC2 and SC3) 2019.

4. Statement of model uncertainty

The Roper groundwater model used in this process is considered an adequate basis to guide licensing decisions. The output should be treated with the understanding and acceptance of the limitations associated with the modelling process.

An analysis of model calibration is provided in Knapton (2006) and a three part documentation of the Roper Model (Knapton, 2009) which cover the groundwater, surface water and connected models. In the analysis, the author identifies the model's sensitivities to the various hydraulic parameterisation. However, this analysis is qualitative, and any resulting uncertainty is not quantified. The author identifies inherent sources of uncertainty which include the variability in spatial distribution of recharge and the difficulty in quantifying it as well as the empirical nature of soil property data, vegetation water use and ground elevation data. These all contribute to the uncertainty in the final output from the model.

A broad based review by Middlemis (2015) provides peer assessment that this model applies best practice approaches to model conceptualisation, development and calibration. Although it is recognised that this model's construction pre-dates the Australian Groundwater Modelling Guidelines (Barnett et al, 2012), it is considered to have *"overall good compliance with the guideline principles"* (Middlemis, 2015).

The estimation of the various inputs and model parameters contributes to a level of uncertainty in the final output. However, it is envisaged that model outputs will be refined over time as groundwater system knowledge, and the quality and completeness of input data improves.

5. Model output summary

Two pumping scenarios to represent the possible options for extraction at bores RN040895 and Site 2 were modelled. These scenarios are named SC2 and SC3.

For the purpose of the licence assessment, the Roper model output was interrogated for:

(a) Resultant impact on flows at these following key indicator sites on the Roper River:

i. Elsey National Park (near flow gauge G9030176); and

ii. Red Rock (near flow gauge G9030250).

(b) There are no registered bores screened within the Gum Ridge Formation aquifer located within a 10 km radius of either pumping bores. Potential drawdown impacts were assessed at approximate radial distances (based on nearest model node) of

i. 1 km (north, south, east and west)

ii. 10 km (north, south, east and west)

(c) Resultant impact on flows at these following key spring discharge sites as represented in the model

iii. Rainbow Springs

iv. Bitter Springs

The model output will be stored in the folder named results (use link) for a period of no less than 6 months after a decision is made. Subsequently, it will be deleted. The output can be regenerated if so required.

6. Model output Analysis

(a) Resultant impact on flows at the key indicator sites of Elsey National Park (G9030176) and Red Rock (G9030250).

The analysis of the model's river flow output is undertaken in the spreadsheet: *Analysis of Flow for Origin_Energy_Application-LRM2019-0036-0008.xlsx* located here (use link).

The analysis determines that there is **no change** in reliability of surface water flow at the indicator sites are as provided in Table 1 below.

TABLE 1 Change in Reliability of Surface water flow

	Change in Reliability	
Location	**SC2**	**SC3**
Elsey National Park (G9030176)	nil	nil
Red Rock (G9030250)	nil	nil

(b) Drawdown impacts due to proposed pumping.

The analysis of the model's hydraulic head data output is undertaken in the spreadsheet: *Drawdowns.xlsx* located here (use link). The licence application proposed three years of pumping. The modelled scenarios SC2 and SC3 represented 58 years of continuous pumping.

The estimated drawdown at approximately 1 and 10 km under Modelled Scenario SC2, relative to Modelled Scenario SC1 (current conditions), are provided in Table 2 below.

TABLE 2 Estimated drawdown due to pumping under Modelled Scenario SC2

Distance from pumping bore (direction)	Model node number	Estimated drawdown (m) after three years of pumping	Modelled drawdown (m) after 58 years consecutive pumping
RN040895			
1.06 km (north)	48759	0.003	0.007
1.11 km (south)	46725	0.003	0.007
1.09 km (east)	47941	0.003	0.007
1.06 km (west)	50349	0.003	0.007
10.27 km (north)	49101	0.001	0.004
10.17 km (south)	47750	0.001	0.004
10.14 km (east)	45892	0.001	0.004
10.87 km (west)	45749	0.001	0.004
Site 2			
1.08 km (north)	51298	0.064	0.112
1.18 km (south)	47444	0.055	0.103
1.08 km (east)	52708	0.064	0.113
1.20 km (west)	51422	0.056	0.103
9.95 km (north)	45948	0.000	0.025
10.08 km (south)	45985	0.000	0.022
10.15 km (east)	50802	0.000	0.024
10.35 km (west)	47065	0.000	0.022

The estimated drawdown at approximately 1 and 10 km under Modelled Scenario SC3, relative to Modelled Scenario SC1 (current conditions), are provided in Table 3 below.

TABLE 3 Estimated drawdown due to pumping under Modelled Scenario SC3

Distance from pumping bore (direction)	Model node number	Estimated drawdown (m) after three years of pumping	Modelled drawdown (m) after 58 years consecutive pumping
RN040895			
1.06 km (north)	48759	0.006	0.010
1.11 km (south)	46725	0.007	0.010
1.09 km (east)	47941	0.006	0.010
1.06 km (west)	50349	0.006	0.010
10.27 km (north)	49101	0.001	0.004
10.17 km (south)	47750	0.001	0.004
10.14 km (east)	45892	0.001	0.004
10.87 km (west)	45749	0.001	0.004
Site 2			
1.08 km (north)	51298	0.079	0.126
1.18 km (south)	47444	0.067	0.114
1.08 km (east)	52708	0.079	0.127
1.20 km (west)	51422	0.070	0.116
9.95 km (north)	45948	0.000	0.025
10.08 km (south)	45985	0.000	0.022
10.15 km (east)	50802	0.000	0.023
10.35 km (west)	47065	0.000	0.021

(c) Resultant impact on flows at two key spring discharge sites as represented in the model.

The analysis of the model's springflow output is undertaken in the spreadsheet:

md_WORKING_Altered Spring Flows_ORIGIN Application.xlsx
located here (use link)

The analysis determines that there is **no change** in reliability of springflow as provided in Table 4 below.

TABLE 4 Change in Reliability of Springflow at two key sites

Bitter Springs	Existing Licences	SC2	SC3
Restricted Years 1/1/1988-31/12/2017	0	0	0
Unrestricted Years	30	30	30
Reliability	100%	100%	100%

Rainbow Springs	Existing Licences	SC2	SC3
Restricted Years 1/1/1988-31/12/2017	0	0	0
Unrestricted Years	30	30	30
Reliability	100%	100%	100%

7. Water Management Context

The licence application is within the Gum Ridge Formation in the northern Georgina Basin. There is no Water Allocation Plan current in this area. At this location, the ESY is presumed to be based on application of the NT Water Allocation Framework policy for the Arid Zone.

Tickell and Bruwer (2017) reports the volume of groundwater held in storage in the Gum Ridge Formation across the Georgina Basin is estimated to be between the limits as provided in the table below:

Minimum groundwater volume (GL)	Maximum groundwater volume (GL)
1,766,000	3,532,000

8. References

Barnett, B., Townley, L.R., Post, V., Evans, R.E., Hunt, R.J., Peeters, L., Richardson, S., Werner, A.D., Knapton, A. and Boronkay, A. (2012). Australian Groundwater Modelling Guidelines. Waterlines report 82, National Water Commission, Canberra. URL: http://archive.nwc.gov.au/library/waterlines/82.

Knapton, A., 2006, Regional Groundwater Modelling Of the Cambrian Limestone Aquifer System Of the Wiso, Georgina and Daly Basins, Water Resources Report 29/2006, Land and Water Division, Department of Natural Resources, Environment and the Arts, Alice Springs.

Knapton, A., 2009, Gulf Water Study : An Integrated Surface – Groundwater Model Of The Roper River Catchment, Northern Territory, Part A - Coupled Surface – Groundwater model, Water Resources Report number 15/2009, Department of Natural Resources, Environment, The Arts & Sport, Darwin.

Knapton, A., 2009, Gulf Water Study : An Integrated Surface – Groundwater Model Of The Roper River Catchment, Northern Territory, Part B – MIKE11 Surface Water Model, Water Resources Report number 31/2009, Department of Natural Resources, Environment, The Arts & Sport, Darwin.

Knapton, A., 2009, Gulf Water Study : An Integrated Surface – Groundwater Model Of The Roper River Catchment, Northern Territory, Part C – FEFLOW Groundwater Model, Water Resources Report number 32/2009, Department of Natural Resources, Environment, The Arts & Sport, Darwin.

Middlemis, H. (2015). Roper Basin Modelling Methodology Review, Report D0853, Prepared by Hydrogeologic Pty Ltd for Northern Territory Department of Land Resource Management, April 2015.

Tickell, S. J. and Bruwer, Q. (2017) Georgina Basin Groundwater Assessment: Daly Waters to Tennant Creek, Technical Report 17/2017, Northern Territory Department of Environment and Natural Resources. Northern Territory Government, Australia.

(d) Appendix 1 - Licence Assessment Modelling and Analysis Request

NORTHERN TERRITORY GOVERNMENT

DEPARTMENT OF ENVIRONMENT AND

Site 2
Easting:435488.000Northing:8136321.000
Latitude:-16 ° 51 ' 20.13525 "Longitude:134 ° 23 ' 39.84654 "
Grid Convergence:0 ° -10 ' 32.18 "Point Scale:0.99965146

LICENSING ASSESSMENT MODELLING A
WATE

1. Request

Undertake modelling and analysis to determine what if any impact the ground water take from the Gum Ridge Formation Aquifer.

2. Licence application

This request for modelling and analysis supports the processing of:

- a new groundwater extraction licence with a maximum entitlement of 175 ML p.a. (based on a May-April water accounting year) from the Gum Ridge Formation Aquifer

3. Data provided

The following information is provided for modelling and analysis purposes.

- Application for a groundwater extraction licence including the Water Use Plan and proposed extraction schedule for 2019-2022.

4. Background information

To summarise information contained within the application:

- Proposed extraction is from RN040895 (Site 1) and a proposed bore with approximate location 435488E, 8136321N Zone 53 (Site 2).
- Proposed extraction from two separate sites within NT Portion 7027 and NT Portion 1079
- Proposed 10 future bore locations targeting the Gum Ridge Formation. *As the applicant is not committing to the use of these bores and the bores have not been constructed, further analysis or consideration of extraction from these sites are not relevant from a licensing perspective.*
- Maximum monthly use from the three bores is 90 ML;
- Combined maximum annual entitlement of 175 ML.

PROPOSED PUMPING SCHEDULE 2019			
Month	Extraction from Site 1 – RN040895 (ML)	Extraction from Site 2 - 435488E, 8136321N Zone 53	Total volume (ML)
Jan	0	0	0
Feb	0	0	0
Mar	0	0	0

Apr	0	0	0
May	10	0	10
Jun	10	0	10
Jul	2	19	21
Aug	6	15	21
Sep	19	4	23
Oct	14	5	19
Nov	1	20	21
Dec	0	14	14
Total	*62*	*77*	*139*

PROPOSED PUMPING SCHEDULE 2020			
Month	Extraction from Site 1 – RN040895 (ML)	Extraction from Site 2 - 435488E, 8136321N Zone 53	Total volume (ML)
Jan	0	0	0
Feb	19	0	19
Mar	13	0	13
Apr	4	0	4
May	4	0	4
Jun	19	20	39
Jul	16	12	28
Aug	16	4	20
Sep	0	4	4
Oct	0	16	16
Nov	0	16	16
Dec	0	16	16

Total	*91*	*88*	*179*

PROPOSED PUMPING SCHEDULE 2021			
Month	Extraction from Site 1 – RN040895 (ML)	Extraction from Site 2 - 435488E, 8136321N Zone 53	Total volume (ML)
Jan	0	0	0
Feb	0	0	0
Mar	20	0	20
Apr	12	0	12
May	4	18	22
Jun	4	15	19
Jul	21	4	25
Aug	21	4	25
Sep	21	21	42
Oct	0	21	21
Nov	0	21	21
Dec	0	0	0
Total	*103*	*104*	*207*

5. Modelling scenarios

The application requests for flexibility in extracting 90 ML in any month, limited to a maximum annual extraction of 175 ML (if referring to a May-April water year). Modelling will need to reflect the projected extraction from the two different sites listed in the table above. Suggest extraction is projected using a 50% split between bore RN040895 and coordinates: 435488E, 8136321N Zone 53, over the driest months Oct/Nov.

Additionally another modelling scenario will need to reflect the proposed pumping schedule, as detailed in the table above.

6. Licensing Assessment Report

A modelling and analysis report prepared by Water Assessments Branch in consultation with the Planning and Engagement Branch is required by: **5 April 2019**

The report should be prepared in consultation with the Water Planning and Engagement Branch

This report should include:

- A summary of the model outputs
- Estimated total sustainable yield of the subject water resource
- Interpretation on how the analysis of model outputs relates to the NT Water Allocation Planning Framework (NTWAPF)
- Reliability and draw down effect. Noting that the Hydraulic Fracturing Inquiry recommendations describe more than 1 metre drawdown as excessive
- Effect encompassing all relevant groundwater and surface water systems to predict any impacts on downstream users
- Should there be any adverse effects, suggestions for alternative proposals that will fit into the NTWAPF
- Any other information you deem relevant.

Copies of data output and analysis files and the final reports should be saved in TRM file: LRM2019/0036-0013.

REQUESTING OFFICER JO CHALLIS 21 MARCH 2019

DEPARTMENT OF
ENVIRONMENT AND NATURAL RESOURCES

Preliminary Guideline: Groundwater Monitoring Bores for Exploration Petroleum Wells in the Beetaloo Sub-basin

1. Purpose and Scope

This preliminary guidance provides information on the expectations of the Department of Environment and Natural Resources (DENR) in relation to the layout, construction and operation of "multi-level observation bores" associated with onshore petroleum wells during the exploration phase of onshore gas development in the Beetaloo Sub-basin.

It is expected that principles in this preliminary guideline will be incorporated into Codes of Practice for the Northern Territory Onshore Petroleum Industry currently being developed by the Northern Territory Government. The requirements in this initial guidance, and subsequently under the Codes, may evolve following a period of operational experience during the exploration phase of the industry and as baseline understanding of the hydrogeological systems improves.

This preliminary guidance will be revised prior to any application to production-level activity.

This preliminary guidance was developed for the Beetaloo Sub-basin and additional guidance will be developed as required to account for different hydrogeology and environmental conditions in other gas basins. Additional guidance will also be developed for conventional petroleum activities.

The guideline relates specifically to monitoring bores established for the purpose of meeting recommendations 7.11 and 7.13 of the *Final Report of the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory, 2018* (the Report), noting that water bores may be established for a range of other purposes.

2. Background

Groundwater monitoring bores must be established to detect any contamination of groundwater as a result of leaky gas wells or onsite spills, in order to meet the recommendations of the Report, specifically:

Recommendation 7.11 (in part)

That prior to the grant of any further exploration approvals, in order to minimise the risk of groundwater contamination from leaky gas wells:

- *Where a well is hydraulically fractured, monitoring of groundwater be undertaken around each well pad to detect any groundwater contamination using multi-level observation bores to ensure full coverage of the horizon, of any aquifer(s) containing water of sufficient quality to be of value for environmental or consumptive use;*
- *All existing well pads are to be equipped with multilevel observation bores;*
- *As a minimum, electrical conductivity data from each level of the monitor bore array should be measured and results electronically transmitted from the well pad site to the regulator as soon as they are available.*
- *Other water quality indicators, as determined by the regulator, should be measured quarterly, with the results publicly disclosed online a soon as reasonably practical from the date of sampling.*

Recommendation 7.13

Upon a gas company undertaking any exploration activity or production activity, monitoring of the groundwater must be implemented around each well pad to detect any groundwater contamination, adopting the monitoring outlined in Recommendation 7.11. If contamination is detected, remediation must commence immediately.

The rationale for these recommendations is further described in the Report (sections 7.6.1 and 7.6.3) and this detail has informed the guideline, notably:

The Panel's view is that monitoring of key water quality indicators in the groundwater in close proximity (that is within 10-20 m) to each planned well or well pad is essential, and that this monitoring should commence prior to any well drilling, with subsequent monitoring being particularly focussed on the hydraulic fracturing stages. To this end, multi-level monitoring bores must be installed in advance (at least six months) prior to the drilling of a gas well and designed to ensure full vertical coverage of any aquifer(s) currently supplying, or potentially being able to supply, water for environmental or consumptive (stock or domestic) uses. The bore array must have a level of vertical resolution at least sufficient to be able to identify whether a leak of fluid or gas is occurring in the top, middle or bottom zones of an aquifer. At a minimum, electrical conductivity should be measured in real-time as an indicator providing 'early warning' of contamination, with the results telemetered from the site to the regulator and made available to the public. The use of telemetry for other parameters should be reviewed every five years or as technological improvements become available. Additionally, other water quality indicators determined by the regulator must be measured quarterly, with the results made publicly available within one month of sampling. The combination of continuous and randomised spot monitoring should continue for three years, after which time its fitness for purpose should be reviewed by the regulator.

If the electrical conductivity or other measurements suggest that a leak has occurred, or is occurring, more detailed investigations must commence immediately, with remediation to be initiated as soon as practicable. Parameter values for setting action thresholds should be determined from the data collected during the SREBA, and reviewed periodically by the regulator.

The text above specifically refers to the installation and monitoring of all new exploration wells. However, there are already a number of explorations wells (including the Amungee NW-1H well) that exist. The Panel recommends that these wells also require the installation of multilevel bores prior to the approval of either first time or repeat hydraulic fracturing activity.

In developing the guidance, a precautionary approach has been applied at this early stage of shale gas exploration in the Northern Territory, which reflects the Inquiry Report and is appropriate given the lack of comprehensive scientific knowledge and extensive data regarding the stratigraphy and water quality of the Cambrian limestone aquifers across the Beetaloo Sub-basin. The guideline has been developed to ensure that scientific information on the stratigraphy and water quality of aquifer units that may be present at each petroleum exploration well site is established prior to the drilling of petroleum wells. This information will further inform the design of petroleum wells to ensure application of best available techniques to isolate and protect identified aquifer units at each site. Implementation of the guideline will also provide a large amount of spatial information about water quality of these important regional aquifers over time. It has also been developed to ensure that a robust groundwater monitoring system is developed to meet the recommendations and intent of the Inquiry, without being excessively onerous for industry in the exploration phase.

The primary water quality indicator recommended by the Inquiry Panel is electrical conductivity (E.C.). A review of ground water quality data across the Beetaloo Sub-basin from data sets with a broad spatial distribution and spanning several years indicates that E.C. is highly variable spatially, and perhaps temporally depending on location. Consequently, monitoring of E.C., and its constituents (e.g. Total Dissolved Solids and Chloride) needs to be site-specific to provide a meaningful baseline.

3. Summary of aquifer unit monitoring requirements

Three main configurations of CLA (Cambrian limestone aquifers) are recognised overlying the Beetaloo Sub-Basin (Figure 1). These can be used as a preliminary guide for planning groundwater monitoring at well sites.

Each configuration is described below.

1. Aquifers in both the Anthony Lagoon and Gum Ridge Formations (or equivalents) are present: The depth to the base of the CLA sequence should be greatest in this zone. Each formation should be monitored with separate monitoring bores. Along the margins of this zone the Anthony Lagoon Formation may lie above the water table and so will not contain any aquifers. In such cases only the Gum Ridge Formation needs to be monitored.
2. Only the Gum Ridge Formation (or equivalent) is present: This formation should be monitored.
3. No aquifers present: This occurs mainly west of Larrimah where the Tindall Limestone (a Gum Ridge Fm. equivalent) lies above the water table. In such situations the uppermost aquifer in the Kalkarindiji Suite should be monitored. This formation occurs directly beneath the Tindall Limestone.

The water supply bore for the exploration well should be drilled to the base of the Gum Ridge Formation (or equivalent). Together with down-hole logs such as gamma and caliper this will enable more accurate identification of aquifers in the CLA sequence. The detailed design of the monitoring program at each well site is likely to be specific to that site, so consultation with DENR Water Assessment Branch is recommended following the drilling of the water supply bore.

The guide above indicates that a minimum of one and a maximum of two aquifer units would be monitored at each site, unless site-specific data clearly indicates no groundwater is present.

Where no groundwater is encountered at the proposed well pad site during the drilling of the water supply bore, the results should be provided to DENR Water Assessment Branch. In this circumstance, an exemption for the requirement to install groundwater monitoring bores at the proposed exploration well pad will be considered by DENR providing there has been an adequate attempt to locate groundwater.

Table 1 below provides a summary of requirements which are detailed in sections 4 to 6.

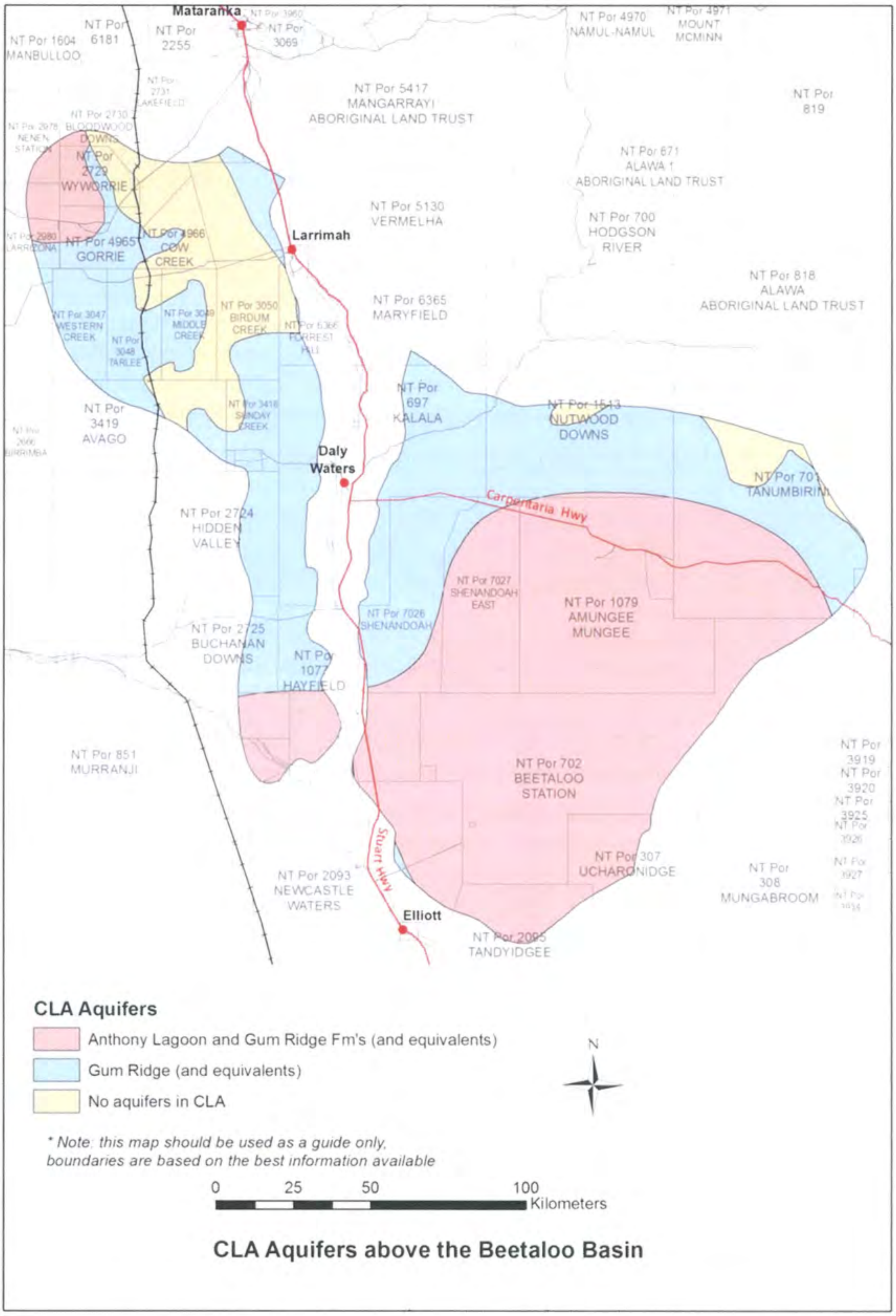


Figure 1 Indicative spatial location of Cambrian Limestone Aquifer units above the Beetaloo Basin

Table 1 – Monitoring bore requirements summary for petroleum exploration wells in the Beetaloo sub-Basin (see sections 4 to 6 for more detail)

Monitoring bore array type	Bore levels required	Possible Beetaloo solution	Location	When required
Control monitoring bore array. *Note this may include the production bore if water is to be sourced at the well site location.*	1 bore for each discrete aquifer unit, which is screened near the top, middle and bottom of the vertical extent of that unit	1 bore screened near the top, middle and bottom of the Anthony Lagoon formation at well sites where it is determined to occur; **and** 1 bore screened near the top, middle and bottom of the Gum Ridge formation; **or** 1 bore screened in the uppermost aquifer in the Kalkarindiji Suite where the Tindall limestone lies above the water table (ref. Sec. 2.3)	Within 100m up-gradient of the well pad	6 months prior to drilling, and preferably to include both wet season and dry season samples. In circumstances, which lie outside of the control of the operator, where six months monitoring data from the control bore is not achievable before drilling, it must at minimum provide six months of data prior to hydraulic fracturing activities
Impact monitoring bore array	1 bore for each discrete aquifer unit, which is screened near the top, middle and bottom of the vertical extent of that unit	As above	Within 20m down-gradient of the petroleum well. Where multiple exploration wells on a well pad are proposed then a single array, 20m down-gradient of the well head-series	At completion of well drilling and prior to hydraulic fracturing of the well. *It is acknowledged that installing this bore array prior to drilling the well may not be possible due to safety reasons.*

4. Layout of groundwater monitoring bores

The minimum requirements for monitoring bores in relation to detecting "leaky wells" is based on Before-After-Control-Impact (BACI) environmental monitoring design. BACI designs are an effective method to evaluate natural and human-induced perturbations of environmental variables (e.g. groundwater quality) when treatment sites cannot be randomly chosen, as is the case in this application. Groundwater monitoring bores to detect potential Impact from "leaky wells" should be located so that any contamination is detected as soon as possible, in a time frame that allows an effective remediation response. Groundwater flow gradients in the Cambrian Limestone Aquifer (CLA) are likely to be low in most parts of the Beetaloo Basin, and DENR believes that monitoring in close proximity (20m) of each well is essential for this purpose. If multiple exploration wells are planned for a single pad, DENR believes that monitoring within 20m downstream of the most proximate well in the series is sufficient.

An appropriate BACI design has been determined to be as follows (also see Figure 2 for a diagrammatic representation):

1. A **Control monitoring bore array** (one or two depending on the discrete aquifer units present at the site), located up-gradient and within 100m of the planned or existing location of the petroleum well pad. This should be installed at least six months prior to drilling of the well and will provide site-specific, baseline ground water quality information. Wherever possible, pre-drilling data should include both wet season and dry season sampling. In circumstances, which lie outside of the control of the operator, where six months monitoring data from the control bore is not achievable before drilling, it **must** provide at minimum six months of data prior to hydraulic fracturing activities. The site-specific aquifer system information derived from drilling the Control monitoring bore array will also inform the subsequent design of the Impact monitoring bore array. It will also provide a basis for understanding natural trends that may occur at the site and therefore help differentiate between background and project-attributable changes over extended timeframes. The control array may also provide useful information about the spatial extent of impacts if a severe perturbation is detected in the impact array.

2. An **Impact monitoring bore array**, screened at similar depths to the **Control monitoring bore array,** 20m down-gradient of the location of the petroleum well. It is acknowledged that installing this bore array prior to drilling the well may not be possible due to safety reasons. Therefore the array may be installed after completion of drilling the petroleum well but must be installed and sampled prior to hydraulic fracturing. Where multiple exploration wells are proposed on a single well pad, either as part of a single drilling campaign or a later infill campaign, then a **single impact monitoring bore array** must be installed and sampled prior to hydraulic fracturing of any well in the series. This bore array must be located within 20m down gradient of the first well in the proposed **series.** and wherever possible this should be at the downgradient end of the series

   Where subsurface geohazards are encountered during the drilling of the exploration petroleum well that may present elevated risks to the installation of an Impact monitoring bore array within 20m of the well, the location of the impact monitoring bore array may be varied on a case-by-case basis with approval from DENR.

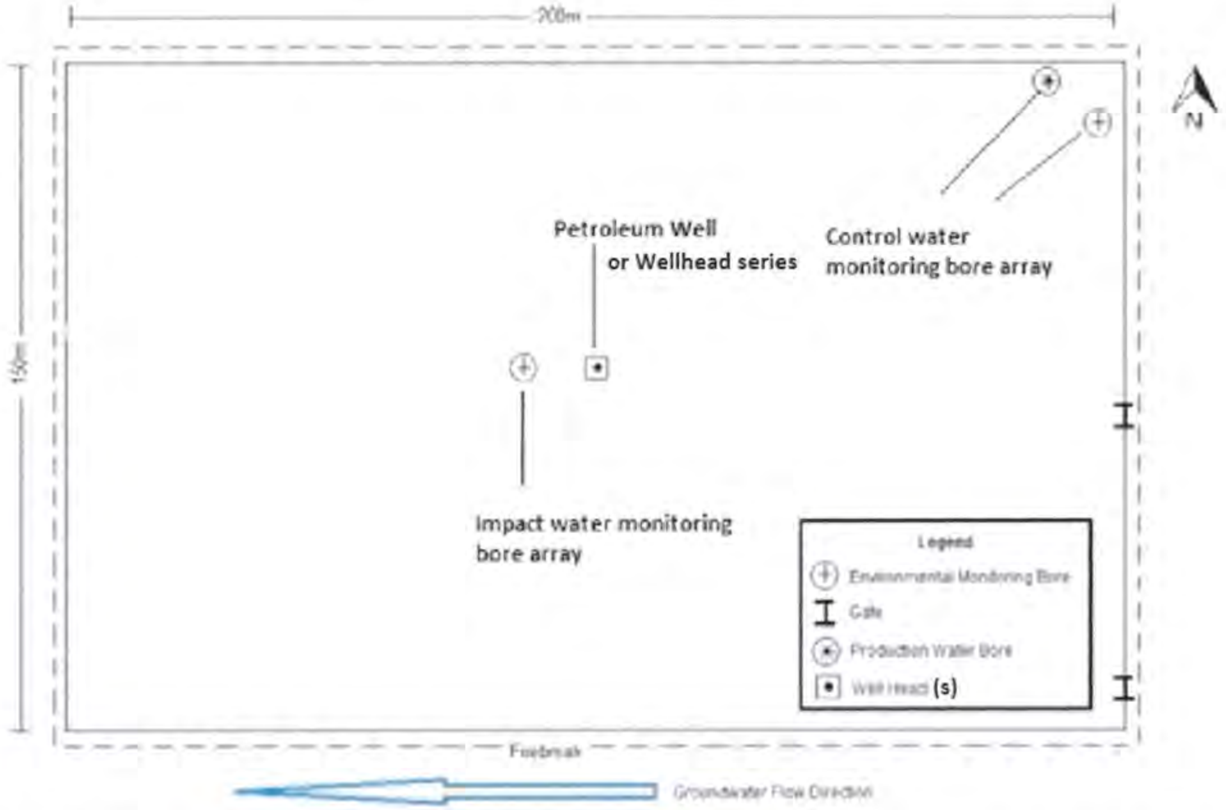


Figure 2: Indicative environmental groundwater monitoring bore layout on a petroleum well pad. Groundwater flow (gradient) direction in this example is from R-L of layout.

5. Design of monitoring bores

Monitoring bores should be established and screened to sample water in each aquifer unit (i.e. each non-interconnected formation) "currently supplying, or potentially being able to supply, water for environmental or consumptive (stock or domestic) uses". The spatial variability of presently recognised aquifer units above the Beetaloo Sub-Basin are outlined in Figure 1. The design of the monitoring program at each well site is likely to be specific to that site, so consultation with DENR Water Assessment Branch regarding number of aquifer units and suitable screening depths is recommended following the drilling of the water supply bore. If water is not to be sourced at the well site, the first Control monitoring bore should be drilled to the base of the deepest recognised aquifer unit to provide the required stratigraphy data.

The appropriate number of bores and screening depths for each monitoring bore array will be site-dependent. Each Control monitoring bore and corresponding Impact monitoring bore should be screened at similar depths in the distinct aquifer units at that site. To provide vertical coverage of the aquifer unit that it samples, each monitoring bore should be screened near the top, middle and bottom of the vertical extent of that aquifer unit (or continuously as appropriate). DENR recognises that is overly onerous, and increases environmental risks, to require separate monitoring bores to be established at each sampling depth within each aquifer unit. Rather, an integrated sample should be collected from each Control monitoring bore and Impact monitoring bore <u>for each aquifer unit</u> in a way that maximises the probability of detecting any leak. Should a leak be detected, other techniques will be applied to determine the source level within the aquifer unit.

Where two monitoring bores are required in a monitoring bore array, the bores should be placed approximately 10m apart in a line approximately perpendicular to the flow gradient. In the unlikely event that three monitoring bores were required in a monitoring bore array, two bores should be placed as per the two-bore scenario, with an additional bore placed downgradient and 10m from the other two bores. It is acknowledged that this will result in the third bore being approximately 28m from the petroleum well.

Bores must be constructed in accordance with Minimum Construction Requirements for Water Bores in Australia, 2012 (https://www.adia.com.au/documents/item/290).

An accurate drilling and lithological log of rock strata should be kept for all operations on the drill site. A clean representative sample of the rock formations intersected should be collected at all changes of strata and at a maximum drill depth intervals of three metres. Samples should be laid out in an orderly sequence for inspection and a report log provided to DENR for each bore hole. It should be noted that r11 of the *Water Regulation* also provides information regarding samples required to be taken and shared by licensed water bore drillers. Results of any down-hole logs such as gamma and caliper should also be provided to DENR, as discussed in Sec. 2.

It is recommended that where possible, bores should be fitted with locks, to minimise risk of malicious interference with the monitoring program.

6. Sampling frequency

As baseline levels of some analytes are likely to vary seasonally it is important that baseline groundwater monitoring is conducted throughout the year, noting that there may be access constraints for periods during the wet season. It is suggested that sampling frequency is initially high (e.g. every 4 weeks) until the extent of natural variation is determined at the **Control monitoring bore array** shown in Figure 2, and statistically robust confidence intervals for the suite of analytes to be measured at that site and within the aquifer zone(s) of interest are established. The Report requires quarterly sampling for parameters other than E.C. for at least three years.

DENR considers that in this preliminary stage of exploration, and to meet the intent of the Report, a **Control monitoring bore array** should be established in time to allow at least six months of sampling prior to the drilling of the gas well, and that sampling should encompass the likely major extent of natural variation between late dry season and late wet season periods.

The **Impact monitoring bore array** must be installed and sampled prior to stimulating the well, noting that more than one pre-impact sample period is desirable.

7. Sampling methodology

Samples should generally be taken in accordance with protocols detailed in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality field sampling program (www.waterquality.gov.au/anz-guidelines/monitoring/field-sampling-program). It is expected that sampling protocols would be detailed in the relevant Environment Management Plan (EMP) and made available to DENR for review.

The EMP must include water sampling procedures including the following components:

1. Water sampling must be undertaken by suitably qualified and trained personnel
2. Prior to sampling a water bore, wherever practicable, the volume of stagnant water within the bore casing must be calculated. Water quality samples must only be collected after:
   a) three times the volume of stagnant water in the bore casing and the discharge piping (including a sufficient additional volume to account for any error in volume calculations) have been discharged; and
   b) when the field water quality parameters (e.g. E.C.) have stabilised, indicating the bore is producing formation water.
3. Water quality samples must have a unique identification number that can be cross-referenced to the monitoring location and time of sampling.

4. Sample preservation measures are to be documented and comply with analytical laboratory requirements and relevant standards (e.g. AS/NZS 5667.1:1998).
5. Sample integrity must be maintained through the use of chain of custody procedures and documentation in accordance with section 3.7 of *Monitoring and Sampling Manual 2009 — Environmental Protection (Water) Policy 2009 (Department of Environment and Heritage Protection, 2013).*
6. Sample analysis should be undertaken by a laboratory that is NATA approved for that analysis.

A survey benchmark relative to Australian Height Datum (AHD) should be established at each well pad monitoring bore, accurate to ±10 cm, to accurately determine depth to water table during each sampling event.

The Analytical Suite to be assessed is listed below in Table 2. A review of the suite of analytes to be tested may be requested by the seline has been established for the monitoring bores.

Analytes of particular interest include **Total Dissolved Solids**, **Chloride**, and **Electrical Conductivity** (E.C.) as a proxy, because drilling fluids, hydraulic fracturing fluids, well suspension fluids and produced formation fluids may have orders of magnitude (100s~1000s) higher concentrations of Chloride than background values in potable waters. In addition, Strontium and Barium are typically elevated in produced water from unconventional shale gas reservoirs and serve among others as additional useful tracers. Dissolved methane is important to monitor as a baseline and over the longer term.

Groundwater pressure monitoring on a continuous basis also provides an indicator of well-integrity failure, particularly during the well-stimulation phase when the differential pressure between the aquifer and well annulus is extremely high, and thus a breach of well-integrity would be instantaneously detected. The use of this parameter as a useful reactive monitoring tool will be examined with industry during this exploration phase.

Table 2 – Required analytes

General	Anions	Cations and Metals		Petroleum
pH	**Chloride**	Calcium	Arsenic	TRH
Electrical conductivity*	Fluoride	Chromium	**Barium**	PAH Suite
Total Dissolved Solids	Sulphate	Copper	Boron	BTEX
Total Suspended Solids	Nitrate	Iron	Cadmium	Diss. Methane
Alkalinity	Nitrite	Lead	Lithium	Diss. Ethane
Gross Alpha		Magnesium	Selenium	Diss. Propane
Gross Beta		Manganese	Silica	
Water level**		Mercury	**Strontium**	
Groundwater pressure***		Potassium	Sodium	
		Silver	Zinc	

*Recommendation 7.11 requires that electrical conductivity (E.C.) should be measured in real-time as an indicator providing 'early warning' of contamination, with the results telemetered from the site to the regulator and made available to the public. It is recognised by DENR that this may be difficult to implement in the first stages of exploration, but proponents should provide a plan and timetable to meet this requirement, preferable before hydraulic fracturing occurs.

**A survey benchmark relative to Australian Height Datum (AHD) should be established at each well pad monitoring bore, accurate to ±10 cm or better, to accurately determine water table elevation.

***This indicator has been suggested by industry and collection of this data is encouraged in order to test validity and applicability.

8. Data Management

Laboratory reports should be provided to the regulator as soon as practicable after each sampling occasion. Sampling, chain of custody and results data should also be provided in ESdat format (or another format if previously agreed with the regulator).

Further detail regarding reporting and publication mechanisms will be developed in consultation with industry, including appropriate units, file formats and data transfer protocols. This will encompass the detailed recommendations of the Report such as real time data transfer, data portals and public release of data.

Appendix G: Water Monitoring Suites

Table 42: Groundwater monitoring suite extracted from the Code of Practice for Onshore Petroleum Activities in the northern Territory.

Table 6: Minimum suite of analytes for groundwater monitoring.

General	LOR	Cations and Metals	LOR
pH	0.01 pH units	Calcium	1 mg/L
Electrical conductivity	1 µS/cm	Chromium	0.001 mg/L
Total Dissolved Solids	10 mg/L	Copper	0.001 mg/L
Total Suspended Solids	1 mg/L	Iron	0.05 mg/L
Alkalinity	1 mg/L	Lead	0.001 mg/L
Gross Alpha	0.05 Bq/L	Magnesium	1 mg/L
Gross Beta	0.1 Bq/L	Manganese	0.001 mg/L
Water level	±10 cm (AHD)	Mercury	0.0001 mg/L
Groundwater pressure		Potassium	1 mg/L
Anions		Silver	0.001 mg/L
Chloride	1 mg/L	Arsenic	0.001 mg/L
Fluoride	0.1 mg/L	Barium	0.001 mg/L
Sulfate	1 mg/L	Boron	0.05 mg/L
Nitrate	0.01 mg/L	Cadmium	0.0001 mg/L
Nitrite	0.01 mg/L	Lithium	0.001 mg/L
Petroleum		Selenium	0.01 mg/L
TRH	100 µg/L	Silica	0.1 mg/L
PAH Suite	0.5 µg//L	Strontium	0.001 mg/L
BTEX	1 µg/L	Sodium	1 mg/L
Diss. Methane	10 µg/L	Zinc	0.005 mg/L
Diss. Ethane	10 µg/L		
Diss. Propane	10 µg/L		

Table 43: Wastewater characterisation suite.

Parameter	Reporting Units	Limit of Reporting	Method
Physical Parameters			
Dissolved oxygen (DO)	mg/L	0.1	Field
Electrical Conductivity (EC)	us/cm	1	Field
Total Dissolved Solids (TDS)	mg/L	10	APHA 2540C

Parameter	Reporting Units	Limit of Reporting	Method
Total Suspended Solids (TSS)	mg/L	5	APHA 2540C
pH		0.1	Field
Sodium Adsorption Ratio	ratio	0.01	APHA 4500
Temperature	°C	0.1	Field
Nutrients			
Nitrate	mg/L	0.01	APHA VC13
Nitrite	mg/L	0.01	APHA 4500 NO2
Total Nitrogen	mg/L	0.1	APHA 4500 NORG
total Kjeldahl Nitrogen	mg/L	0.1	APHA NORG/TKN
Ammonia	mg/L	0.01	APHA NH4
Reactive Phosphorous	mg/L	0.01	APHA 4500P
Total Phosphorous	mg/L	0.01	APHA 4500P
Anions			
Sulphate	mg/L	1	APHA 4500-SO4-C
Chloride	mg/L	1	APHA 4500-Cl-C
Carbonate	mg/L	1	APHA 2320 B
Bicarbonate (as CaCO3 equivalent)	mg/L	1	APHA 2310 B
Bicarbonate Alkalinity (as CaCO3 equivalent)	mg/L	1	APHA 2320 B
Hydroxide Alkalinity (as CaCO3 equivalent)	mg/L	0.01	APHA 2320 B
Total Alkalinity (as CaCO3 equivalent)	mg/L	0.01	APHA 2320 B
Fluoride	mg/L	0.1	APHA 4500 F-C
Bromide	mg/L	0.01	APHA 4110B
Total Cyanide	mg/L	0.004	APHA 4500 CN-0
Major Cations			
Sodium	mg/L	1	APHA 4500 Na
Magnesium	mg/L	1	APHA 4500 Mg
Potassium	mg/L	1	APHA 4500 K
Calcium	mg/L	1	APHA 4500 Ca
Metals and Metalloids (total and dissolved)			
Aluminium	mg/L	0.001	USEPA 6010 ICP/AES
Antimony	mg/L	0.001	USEPA 6010 ICP/AES
Arsenic	mg/L	0.001	USEPA 6010 ICP/AES
Barium	mg/L	0.001	USEPA 6010 ICP/AES

Parameter	Reporting Units	Limit of Reporting	Method
Beryllium	mg/L	0.001	USEPA 6010 ICP/AES
Boron	mg/L	0.001	USEPA 6010 ICP/AES
Bromide	mg/L	0.001	USEPA 6010 ICP/AES
Cadmium	mg/L	0.001	USEPA 6010 ICP/AES
Chromium	mg/L	0.001	USEPA 6010 ICP/AES
Copper	mg/L	0.001	USEPA 6010 ICP/AES
Iron	mg/L	0.001	USEPA 6010 ICP/AES
Lead	mg/L	0.001	USEPA 6010 ICP/AES
Manganese	mg/L	0.001	USEPA 6010 ICP/AES
Mercury	mg/L	0.001	USEPA 6010 ICP/AES
Molybdenum	mg/L	0.001	USEPA 6010 ICP/AES
Nickel	mg/L	0.001	USEPA 6010 ICP/AES
Selenium	mg/L	0.001	USEPA 6010 ICP/AES
Silica	mg/L	0.1	USEPA 6010 ICP/AES
Silver	mg/L	0.001	USEPA 6010 ICP/AES
Strontium	mg/L	0.001	USEPA 6010 ICP/AES
Thorium	mg/L	0.001	USEPA 6010 ICP/AES
Tin	mg/L	0.001	USEPA 6010 ICP/AES
Uranium	mg/L	0.001	USEPA 6010 ICP/AES
Vanadium	mg/L	0.001	USEPA 6010 ICP/AES
Zinc	mg/L	0.001	USEPA 6010 ICP/AES
Naturally Occuring Radioactive Material.			
alpha radiation	Bq/L	0.05	ASTM D7283-06
beta radiation	Bq/L	0.05	ASTM D7283-06
BTEX			
Benzene	mg/L	0.001	USEPA 5030/8260 HS or P&T/GC/MS
Toluene	mg/L	0.001	USEPA 5030/8260 HS or P&T/GC/MS
Ethylbenzene	mg/L	0.001	USEPA 5030/8260 HS or P&T/GC/MS
M and p Xylene	mg/L	0.001	USEPA 5030/8260 HS or P&T/GC/MS
O Xylene	mg/L	0.001	USEPA 5030/8260 HS or P&T/GC/MS
Total Xylene	mg/L	0.001	USEPA 5030/8260 HS or P&T/GC/MS
Hydrocarbons			
TRH C6 - C10	mg/L	0.02	USEPA 5030/8260 HS or P&T/GC/MS

Parameter	Reporting Units	Limit of Reporting	Method
TRH C6 - C10 less BTEX	mg/L	0.02	USEPA 5030/8260 HS or P&T/GC/MS
TRH >C10 - C16	mg/L	0.02	USEPA 5030/8260 HS or P&T/GC/MS
TRH >C10 - C16 less Naphthalene	mg/L	0.02	USEPA 5030/8260 HS or P&T/GC/MS
TRH >C16 - C34	mg/L	0.01	USEPA 5030/8260 HS or P&T/GC/MS
TRH >C34 - C40	mg/L	0.01	USEPA 5030/8260 HS or P&T/GC/MS
Total TRH C6 - C40	mg/L	0.01	USEPA 5030/8260 HS or P&T/GC/MS
Polycyclic Aromatic Hydrocarbons			
3-Methylcholanthrene	mg/L	0.001	USEPA 3510/8270 GC/MS
7, 12-Dimethylbenz(a)anthracene	mg/L	0.001	USEPA 3510/8270 GC/MS
Acenaphthene	mg/L	0.001	USEPA 3510/8270 GC/MS
Acenaphthylene	mg/L	0.001	USEPA 3510/8270 GC/MS
Anthracene	mg/L	0.001	USEPA 3510/8270 GC/MS
Benzo (a) pyrene	mg/L	0.001	USEPA 3510/8270 GC/MS
Benzo (b) fluoranthene	mg/L	0.001	USEPA 3510/8270 GC/MS
Benzo (ghi) perylene	mg/L	0.001	USEPA 3510/8270 GC/MS
Benzo (k) fluoranthene	mg/L	0.001	USEPA 3510/8270 GC/MS
Benzo (a) anthracene	mg/L	0.001	USEPA 3510/8270 GC/MS
Chrysene	mg/L	0.001	USEPA 3510/8270 GC/MS
Dibenz (ah) anthracene	mg/L	0.001	USEPA 3510/8270 GC/MS
Fluoranthene	mg/L	0.001	USEPA 3510/8270 GC/MS
Fluorene	mg/L	0.001	USEPA 3510/8270 GC/MS
Indeno (1,2,3-cd) pyrene	mg/L	0.001	USEPA 3510/8270 GC/MS
Naphthalene	mg/L	0.001	USEPA 3510/8270 GC/MS
Phenanthrene	mg/L	0.001	USEPA 3510/8270 GC/MS
Pyrene	mg/L	0.001	USEPA 3510/8270 GC/MS
Carcinogenic PAHs (benzo[a}pyrene equivalents	mg/L	0.001	USEPA 3510/8270 GC/MS
Total PAH	mg/L	0.001	USEPA 3510/8270 GC/MS
Volatile Organic Compounds			
2,3,4,6-Tetrachlorophenol	mg/L	0.005	USEPA 3510/8270 GC/MS
2,4,5-Trichlorophenol	mg/L	0.005	USEPA 3510/8270 GC/MS
2,4,6-Trichlorophenol	mg/L	0.005	USEPA 3510/8270 GC/MS
2,4-Dichlorophenol	mg/L	0.005	USEPA 3510/8270 GC/MS

Parameter	Reporting Units	Limit of Reporting	Method
2,4-Dimethylphenol	mg/L	0.005	USEPA 3510/8270 GC/MS
2,4-Dinitrophenol	mg/L	0.005	USEPA 3510/8270 GC/MS
2,6-Dichlorophenol	mg/L	0.005	USEPA 3510/8270 GC/MS
2-Chlorophenol	mg/L	0.005	USEPA 3510/8270 GC/MS
2-Methyl-4,6-dinitrophenol	mg/L	0.005	USEPA 3510/8270 GC/MS
2-Nitrophenol	mg/L	0.005	USEPA 3510/8270 GC/MS
4-Chloro-3-methylphenol	mg/L	0.005	USEPA 3510/8270 GC/MS
4-Nitrophenol	mg/L	0.005	USEPA 3510/8270 GC/MS
Dinoseb	mg/L	0.005	USEPA 3510/8270 GC/MS
Formaldehyde	mg/L	0.001	USEPA 3510/8270 GC/MS
Hexachlorophene	mg/L	0.005	USEPA 3510/8270 GC/MS
m- and p-Cresol	mg/L	0.005	USEPA 3510/8270 GC/MS
Pentachlorophenol	mg/L	0.005	USEPA 3510/8270 GC/MS
Phenol	mg/L	0.005	USEPA 3510/8270 GC/MS
Organic Carbon			
Dissolved Organic Carbon	mg/L	1	APHA 5310 B
Total Organic Carbon	mg/L	1	APHA 5310 B

Appendix H: Heritage Assessment

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27 June 2019

Matthew Hanson
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Dear Matthew

Aboriginal & Historic Heritage Assessment: 2018 Exploration Lease Areas

1.0 Introduction

AECOM Australia Pty Ltd (AECOM) was commissioned by Origin Energy Resources Limited (Origin) to conduct a heritage assessment of the proposed exploration lease areas known as Kyalla 117 N2-1 and Velkerri 76 S2-1 located within the Beetaloo Basin, Northern Territory.

The assessment consisted of the following:

- A 5.5-ha area around the proposed lease sites including an additional 500 m buffer to allow for future flexibility.
- A 1-ha camp pad.
- A 0.5-ha helipad at the Velkerri 76 S2-1.
- 650 m long x 8 m wide (0.52-ha) lease pad turn in to Kyalla 117 N2-1 connecting the proposed lease pad to the existing access track.
- 1,100 m long x 8 m wide (0.88-ha) lease pad turn in to Velkerri 76 S2-1 connecting the proposed lease pad to the existing access track.

This report details the results specific to the archaeological inspection of Kyalla 117 N2-1 and Velkerri 76 S2-1. A separate anthropological survey was conducted by AAPA representatives and the respective Traditional Owners.

2.0 Existing Data Sources

Information on the location of heritage sites within the study area was obtained from:

- a review of Native Title claims and Indigenous Land Use Agreements over the proposed activity areas
- a review of existing Northern Territory Heritage Register managed by the NT Heritage Branch
- a review of the Sacred Sites Register maintained by the Aboriginal Areas Protection Authority
- a review of past archaeological survey reports and assessments undertaken within the local area.

Relevant legislation is summarised in Appendix A.

2.1 Native Title

Native Title exists in parts of the determination area as detailed in Table 1.

Table 1 Native Title & ILUA Agreements

Type	Bore	Name	Summary
Native Title	Kyalla 117 N2-1	NTD21/2010 Shenandoah Pastoral Lease	Native Title exists in parts of the determination area and is held by the Kinbininggu and Bamarrngganja groups
	Velkerri 76 S2-1	NTD17/2010 Amungee Mungee Pastoral Lease	Native title exists in parts of the determination area and is held by The Karranjini group; the Bamarrnganja group

The Native Title Petroleum Exploration Agreement between Permit Holder and the NLC includes clauses for the protection of Sacred Sites, objects and sensitive areas related to Aboriginal activities in the area, including cultural, hunting and foraging activities. Site clearance will occur prior to any on ground activities. The Native Title Agreement also includes clauses for the protection of the environment and rehabilitation.

2.2 Australian Heritage Database

A search of the Australia Heritage Database identified that no statutory listed heritage places within the proposed impact areas.

2.3 NT Heritage Register

A search of the Northern Territory Heritage Register identified no heritage places or artefacts within the proposed impact areas.

2.4 Aboriginal Areas Protection Authority

AAPA clearance surveys by AAPA anthropologist and traditional owners were completed and an Authority Certificate issued to Origin for the proposed exploration works within nine exploration activity locations, including Kyalla 117 N2 and Velkerri 76 S2. The clearance certificate issued for Origin's exploration program includes:

- AAPA RA2019/41 (C2019/039) – EP117, EP76 and EP98 within Part NT Portions 701, 702, 1077, 1079, 1513, 5416, 7027 and 7026.

Origin has committed to comply with conditions as prescribed by AAPA certificate for the duration of the program.

2.5 Previous Archaeological Investigations

The majority of archaeological investigations near the study area have been predominately associated with either linear infrastructure in an alignment parallel to the Stuart Highway or natural gas exploration activities associated with the Beetaloo Basin. Of the assessments of relevance to the study area, the majority of sites identified are artefact scatters composed of raw material commonly found in the immediate area (quartz, silcrete and quartzite).

Table 2 provides a summary of previous archaeological investigations undertaken in the local area.

Table 2 Previous Archaeological Assessments in the Local Area

Researchers	Assessment Type	Locality	Key Findings
Smith, 1986	Excavation	Lake Woods	Insitu artefacts dated to 6,000 years.
Hermes, 1986	Survey	Amadeus Basin to Katherine	Large scale survey for a proposed natural gas pipeline targeting areas of major cultural sensitivity from Daly Waters to Katherine. Thirty-two sites were identified with the majority being artefact scatters associated with watercourses.
Quaternary Archaeological Surveys, 1998	Survey	Stuart Highway to Mataranka Homestead	Large scale survey for a fibre optic cable corridor. Three isolated artefacts and one historic heritage site identified.
Heritage Surveys, 1999	Survey	Daly Waters to McArthur River	Nine archaeological sites identified including rockshelters and artefact scatters.
HLA-Envirosciences Pty Ltd, 2006a, 2006b, 2006c, 2006d, 2007	Survey	Beetaloo Basin	Several archaeological sites identified across the exploration permits including artefact scatters, isolated artefacts and stone cairns.
AECOM Australia Pty Ltd, n.d., 2011, 2012a, 2012b	Survey	Beetaloo Basin	Several archaeological sites identified as part of seismic line clearance including large artefact scatters (>1 km), quarry sites and isolated artefacts.
AECOM Australia Pty Ltd, 2014	Survey	Beetaloo Basin	One isolated artefact identified as part of an exploration drilling program clearance.
AECOM Australia Pty Ltd, 2016	Survey	Beetaloo Basin	One isolated artefact identified on Newcastle Waters firebreak

3.0 Heritage Assessment

A heritage assessment involving field survey was undertaken by AECOM archaeologist, Luke Kirkwood for the proposal area on 28 to 29 August 2017. The archaeological inspection involved helicopter and pedestrian survey of the proposed exploration area and access tracks.

At arrival at each inspection target, the helicopter would make a series of passes to assist in the identification of landforms/ecological features of interest to the heritage survey. Upon landing, survey would target these areas, or in cases where no landform/ecological features were identified, general survey would be undertaken targeting areas of surface ground exposure (Figure 1 and Figure 2).

During the inspection notes were taken on landform, ground surface visibility and areas of exposure. The aim of the inspection was to identify any surface expressions of Aboriginal archaeological and cultural heritage values within the proposal area. Photographic records were taken at each proposed disturbance location.

Results of the inspection are provided in Table 3. Appendix C provides details on ground surface visibility classes and subsurface archaeological potential assessment. Plate 1 to Plate 4 present the general context shots of the proposed exploration lease area.

Table 3 Exploration Lease Area Inspection Results

Location	Easting (mE)[a]	Northing (mN)[a]	GSV[b]	GSI[c]	Surface Archaeology	Subsurface Potential	Impact Potential
Kyalla 117 N2-1	356175	8137500	Fair	High	None identified	Low	Low to No Impact
Velkerri 76 S2-1	435488	8136321	Good	High	None identified	Low	Low to No Impact

a GDA94 Zone 53; b GSV = Ground Surface Visibility; c GSI = Ground Surface Integrity

	
Plate 1 Kyalla 117 N2-1 general context shot	**Plate 2 Kyalla 117 N2-1 aerial context shot**
	
Plate 3 Velkerri 76 S2-1 general context shot	**Plate 4 Velkerri 76 S2-1 aerial context shot**

4.0 Identified Archaeological Heritage

No culturally sensitive landforms or archaeological heritage was identified during the survey of the proposed lease sites.

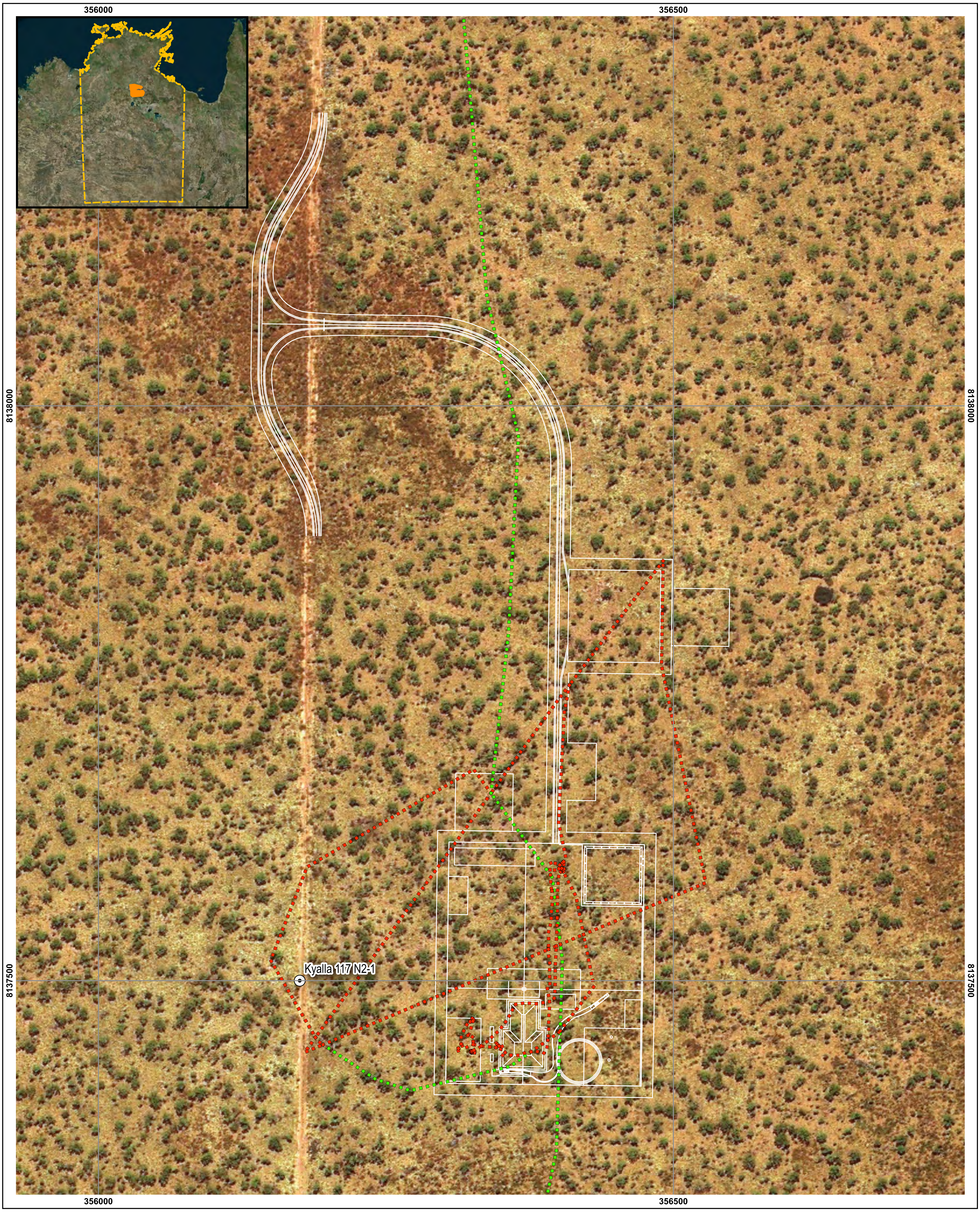
5.0 Key Findings and Recommendations

The key findings of this heritage assessment are:

- A review of existing heritage data and reports for the study area indicate that no previously recorded heritage sites will be impacted by the proposed works.
- AAPA clearance surveys by AAPA anthropologist and Traditional Owners have been completed and AAPA Certificate issued to Origin for their current exploration program.
- Inspection of the proposed exploration lease areas identified no archaeological heritage values (Aboriginal, historical or Macassan)

On the basis of the above findings, the following recommendations are made:

- An unexpected heritage finds stop works procedure is to be implemented for the duration of the project (Appendix D).
- Induction of staff on site is to include reference to the wider area having Indigenous heritage values and the stop works procedure.



LEGEND

Survey Transects 2018

Helicopter

Pedestrian

AECOM
www.aecom.com

0 20 40 60 80 100 m

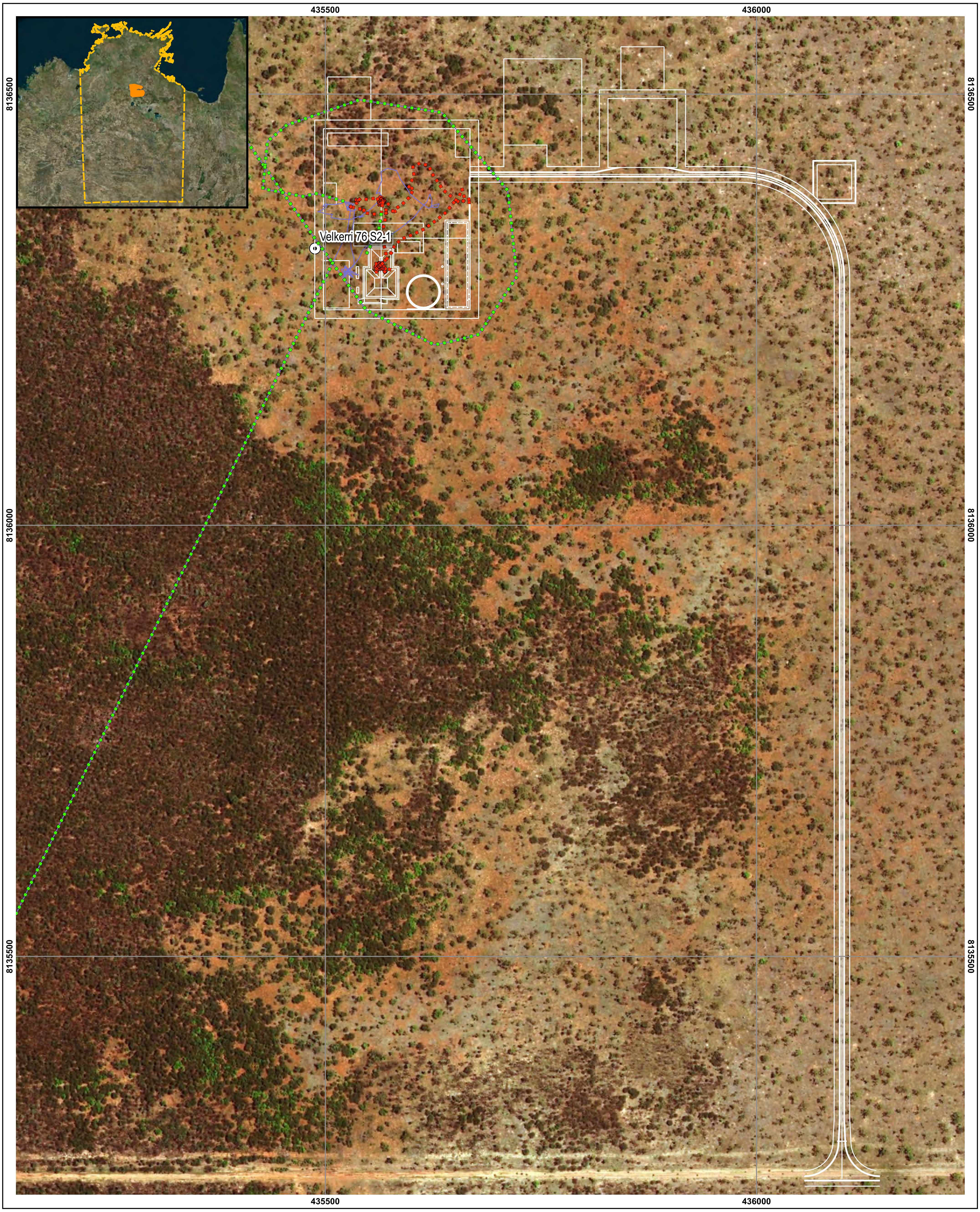
1:3,000 (when printed at A3)

Data Sources:
Origin Energy
Bing Virtual Earth

ORIGIN ENERGY RESOURCES LIMITED
Heritage Assessment
Kyalla 117 N2-1

PROJECT ID	60480548
CREATED BY	LK
LAST MODIFIED	24-4-2019
VERSION	1

Figure F1



LEGEND

Survey Transects 2018

Helicopter

Pedestrian

AECOM
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0 20 40 60 80 100 m

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ORIGIN ENERGY RESOURCES LIMITED
Heritage Assessment
Velkerri 76 S2-1

Data Sources:
Origin Energy
Bing Virtual Earth

PROJECT ID	60480548
CREATED BY	LK
LAST MODIFIED	24-4-2019
VERSION	1

Figure F2

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Yours faithfully

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Appendix A - Legislation

Commonwealth Legislation

Environment Protection and Biodiversity Conservation Act

The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) took effect on the 16 July 2000 (NSW Department of Urban Affairs and Planning, 2000). Under section 26 of the EPBC Act it is stated that:

> *A person must not take on Commonwealth land an action that has, will have or is likely to have a significant impact on the environment.*

Under section 28 of the EPBC Act it is stated that:

> *The Commonwealth or a Commonwealth agency must not take inside or outside the Australian jurisdiction an action that has, will have or is likely to have a significant impact on the environment inside or outside the Australian jurisdiction.*

An action is defined as a project, development, undertaking, activity, series of activities, or alteration. An action will also require approval if:

> *It is undertaken on Commonwealth land and will have or is likely to have a significant impact;*
>
> *It is undertaken outside Commonwealth land and will have or is likely to have a significant impact on the environment on Commonwealth land; and*
>
> *It is undertaken by the Commonwealth and will have or is likely to have a significant impact.*

The EPBC Act defines 'environment' as both natural and cultural environments and therefore includes Aboriginal and historic heritage items. Under the Act, protected heritage items are listed on the National Heritage List (items of significance to the nation) or the Commonwealth Heritage List (items belonging to the Commonwealth or its agencies). These two lists replaced the Register of the National Estate (RNE) which is no longer a statutory list.

Aboriginal and Torres Strait Islander Heritage Protection Act 1984

The *Aboriginal and Torres Strait Islander Heritage Protection Act 1984* (the ATSIHP Act) provides for the preservation and protection of places, areas and objects of particular significance to Indigenous Australians. The stated purpose of the ATSIHP Act is the 'preservation and protection from injury or desecration of areas and objects in Australia and in Australian waters, being areas and objects that are of particular significance to Aboriginals in accordance with Aboriginal tradition' (section 4).

Under the Act, 'Aboriginal tradition' is defined as "the body of traditions, observances, customs and beliefs of Aboriginals generally or of a particular community or group of Aboriginals, and includes any such traditions, observances, customs or beliefs relating to particular persons, areas, objects or relationships" (Section 3). A 'significant Aboriginal area' is an area of land or water in Australia that is of 'particular significance to Aboriginals in accordance with Aboriginal tradition' (Section 3). A 'significant Aboriginal object', on the other hand, refers to an object (including Aboriginal remains) of like significance.

For the purposes of the Act, an area or object is considered to be injured or desecrated if:

- In the case of an area:
  - it is used or treated in a manner inconsistent with Aboriginal tradition;
  - the use or significance of the area in accordance with Aboriginal tradition is adversely affected;
  - passage through, or over, or entry upon, the area by any person occurs in a manner inconsistent with
  - Aboriginal tradition;
- In the case of an object:
  - it is used or treated in a manner inconsistent with Aboriginal tradition.

The ATSIHP Act can override state and territory laws in situations where a state or territory has approved an activity, but the Commonwealth Minister prevents the activity from occurring by making a declaration to protect an area or object. However, the Minister can only make a decision after receiving a legally valid application under the ATSIHP Act and, in the case of long term protection, after considering a report on the matter. Before making a declaration to protect an area or object in a state or territory, the Commonwealth Minister must consult the appropriate Minister of that state or territory (section 13).

Native Title Act 1993

The *Native Title Act 1993* provides for the recognition and protection of native title for Indigenous peoples. The Act recognises native title for land over which native title has not been extinguished and where persons able to establish native title are able to prove continuous use, occupation or other classes of behaviour and actions consistent with a traditional cultural possession of those lands. It also makes provision for Indigenous Land Use Agreements (ILUA) to be formed.

Northern Territory Legislation

Northern Territory Aboriginal Sacred Sites Act 1989

The *Northern Territory Aboriginal Sacred Sites Act* 1989 was established to provide a system that protects sacred sites whilst providing for the development of land.

The Aboriginal Areas Protection Authority (AAPA) is a statutory authority established under the Sacred Sites Act and is responsible for overseeing the protection of sacred sites on land and sea across the whole of Australia's Northern Territory.

The Act establishes the protection of Aboriginal sacred sites through:

- Sacred site avoidance surveys and issuing authority certificates for any development proposals.
- Giving the public information about existing sacred sites through abstracts of Authority records and access to the registers the Authority maintains.
- Establishing and maintaining a Register of Sacred Sites
- Manages the rights of traditional custodians to access Sacred Sites.

The Act also establishes a range of offences and associated penalties that are aimed at protecting sacred sites. It is an offence to desecrate or disturb a site without the approval of the relevant custodians. A register of known sites exists to assist in identifying the likelihood of disturbance and potential need to obtain approval. The Act also establishes a duty-of-care to notify the AAPA of any potential disturbance to Aboriginal sacred sites.

Heritage Act 2011

The *Heritage Act 2011* provides for the protection of both natural and cultural heritage (Aboriginal, historical and Macassan heritage) within the Northern Territory. The Act establishes the Heritage Council (consisting of eleven members) and the NT Heritage Register. It sets the process by which places become heritage places and allows for interim protection of places.

It is an offence to remove or damage heritage places or objects or to mislead or obstruct heritage officers regarding the provision of requested information or entry to works, vehicles or premises that are likely to have been involved in an offence against the Heritage Act. Compliance with the requirements of the Act must be adhered to at all times.

Appendix B – AAPA Clearance Certificate

Removed from public document at AAPA request

Appendix C – Archaeological Assessment Criteria

Table C1 Ground Surface Visibility (GSV) Rating Scheme

GSV rating	Percentage GSV
No ground surface visibility	0%
Very poor	1-10%
Poor	11-30%
Fair	31-50%
Good	51-70%
Very good	71-90%
Excellent	91-100%

Table C2 Ground Surface Integrity (GSI) Rating Scheme

GSI rating	Definition
Low	Ground surface has been subjected to significant disturbance (e.g. earthworks, excavation). Little to no integrity remains.
Moderate	Ground surface has been subject to moderate disturbance (e.g. native vegetation clearance) but retains a reasonable degree of integrity.
High	An unmodified or minimally modified ground surface.

Table C3 Definitions for Subsurface Archaeological Potential

Subsurface Archaeological Potential	Definition
Low	Areas in which subsurface archaeological materials are unlikely to occur. This may be due to unfavourable environmental conditions and/or prior disturbance(s).
Moderate	Areas in which subsurface archaeological materials may occur. Reasonable environmental conditions exist though high artefact counts/densities are unlikely. Subsurface evidence likely to be the product of random discard events as opposed to repeated or extensive activity by Aboriginal people in antiquity.
High	Areas known or highly likely to contain subsurface archaeological materials. Presence of archaeological materials typically reflects optimal environmental conditions and little to no prior landscape disturbance. High artefact counts/densities are likely.

Table C4 Impact Potential Ranking for Aboriginal Objects

Impact Potential	Definition	Management Action
No Impact	Aboriginal objects will not be affected by the proposed activity.	No action required
Low Impact	Unlikely to disturb, destroy, damage or deface an Aboriginal object or objects.	No action required
Moderate Impact	Reasonable potential to disturb, destroy, damage or deface an Aboriginal object or objects.	Avoid area if possible. If avoidance not an option, test excavate area to determine nature and extent of potential archaeological deposits
High Impact	Will, or is highly likely to, disturb, destroy, damage or deface an Aboriginal object or objects.	Avoid area if possible. If avoidance not an option, test excavate area to determine nature and extent of potential archaeological deposits

Appendix D – Unexpected Heritage Finds Procedure

Integrated Gas

UNEXPECTED HERITAGE FINDS PROCEDURE
Beetaloo Asset (Northern Territory)

This documents details the Unexpected Heritage Finds Procedure for the Beetaloo Exploration Program.

Revision	Date	Description	Originator	Checked	Approved
A	31/03/2019	Unexpected Heritage Finds Procedure	Luke Kirkwood/Alana Court		
0					

Review due: 31/03/2019

THE THREE WHATS

What can go wrong?
What could cause it to go wrong?
What can I do to prevent it?

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1. Purpose

The purpose of this procedure is to set out the actions to be undertaken by Origin staff and contractor if a suspected find of Aboriginal and non-Aboriginal cultural heritage is made during civil construction activities.

2. Scope

This procedure covers the requirements associated with:

- The identification of cultural heritage artefacts or areas within the Beetaloo Permit Area.
- The assessment of the risk and control measures to be taken if a suspected Indigenous and non-Indigenous cultural heritage find is discovered; including investigation, notification, recording and reporting, means of communication, measures to avoid cultural heritage and dispute resolution.

It applies to all fieldwork conducted in the Beetaloo Basin.

3. Responsibility

These personnel are responsible for the following activities:

Indigenous Community Manager	Procedure issue and maintenance
Managers / Superintendents / Supervisors	Implementation of this procedure
All Employees / Contractors	Complying with this procedure

4. Requirements

The following management measures are recommended for unexpected heritage finds and are to be included as part of daily toolbox discussions.

4.1 Action in Event of Unexpected Discovery

1. If suspected previously unrecorded cultural heritage is uncovered during project work, work in the immediate vicinity of the find must stop and the area is to be flagged off with suitable markers (star pickets, flagging or barrier mesh).
2. The project work crew may continue work at least 100 m from the site of the find (or other distance approved by the relevant Heritage specialist, providing that at all times the cultural heritage duty of care is observed.

4.2 Recording and Reporting

3. The project work crew must record the suspected find on the Appropriate Forms. This will include GPS location and should include photographs of the suspected find.
4. The project crew must not disturb the suspected find in any way; for example, touch painted art, or collect/relocate the suspected find as this may be illegal and may reduce the scientific and cultural value of the cultural heritage.
5. The immediate supervisor of the project work crew must notify the relevant Heritage Specialist for the area –

    o

   and advise them of the nature of the suspected find.

4.3 Measures to Avoid Harm to Aboriginal Cultural Heritage

Aboriginal finds can include the following:

- Stone artefacts (sharp edged rocks that have identifiable features demonstrating evidence of human modification. See attached information sheet)
- Scarred Trees (trees with symmetrical scars that might demonstrate evidence of removal of bark for use in coolamons, shields and huts. See attached information sheet)
- Grindstones (Large sandstone items (either fixed in bedrock or mobile) that have manmade grooves in them demonstrating use. See attached information sheet)
- Stone Axes (heavy hatchet head like stone items, typically with the leading edge sharpened. See attached information sheet)
- Bone, Shell and Charcoal (potential historical food waste dumps (also known as Middens). See attached information sheet)

Subsurface works may typically encounter shell, charcoal and bone which will appear as lens from a centimetre to several metres in depth.

Prior to surface works, civil construction team should be aware of potential for surface finds of artefacts and avoid impacts to scarred trees.

Procedure

If an object of potential Aboriginal cultural heritage value is uncovered:

1. All work to cease within 10 metres of the suspected find, and the area to be cordoned off using temporary fencing.
2. Site Supervisor is to be immediately notified who will then engage a qualified Heritage Advisor to assess the find and recommend any necessary management measures.
3. Once notified, the relevant Heritage specialists will provide further directions for managing the suspected find, in accordance with legislative requirements and the relevant Cultural Heritage Management Plans where applicable.
4. This may include flagging the discovery, deviating project work around the suspected find or relocating the work front to a new location removed from the suspected find.
5. If the find is determined to be Aboriginal heritage, the Site Supervisor or Heritage Advisor to notify the relevant Heritage Department.
6. Work is not to recommence in the vicinity of the find until direction is provided by the Heritage Department.
7. If the project work cannot deviate around the suspected find for technical or economic reasons and it is necessary to excavate, relocate, remove or harm the suspected find, it will be necessary for Origin to seek the advice and consent of the Traditional Owners for the area as to whether the suspected find is aboriginal cultural heritage, and whether Origin can excavate, relocate, remove or harm the find. If this action is required then there could be considerable delay (one day to several weeks).

4.4 Historical Cultural Heritage

Historic finds can include the following:

- Glass (Coloured glass, bottles (complete or fragmentary etc.)
- Metal (identifiable metallic objects such as cutlery, buckles, farming equipment, woodworking and metal equipment etc.)
- Ceramic (Plates, cups, ink wells, pipes, etc.)
- Wood (identifiable human manufactured wooden items)
- Stone (identifiable human manufactured stone items)
- Bone, Shell and Charcoal (potential historical food waste dumps)

Procedure

The following management measures are recommended for unexpected historic finds:

1. All work to cease within 10 metres of the suspected find, and the area to be cordoned off using temporary fencing.
2. Site Supervisor is to be immediately notified who will then engage a qualified Heritage Advisor to assess the find and recommend any necessary management measures.
3. Once notified, the relevant Heritage specialists will provide further directions for managing the suspected find, in accordance with legislative requirements and the relevant Cultural Heritage Management Plans where applicable.
4. If the find is determined to be of heritage importance, work is not to recommence in the vicinity of the find until direction is provided from the relevant Heritage Department.

4.5 Discovery of Human Remains

If any suspected human remains are discovered during any activity works, they must be initially assumed under the provisions of the relevant *Coroners Act* to be a crime scene and treated accordingly. The following procedure is to be applied:

1. All activity in the vicinity must cease and the Site Supervisor to be notified immediately.
2. The Police must be notified immediately of the discovery by the Site Supervisor or appointed supervisor in charge of the works area.
3. The remains must be left in place and protected from harm or damage with a minimum of at least a 50m buffer. It is important to use best judgement and restrict all movement in the immediate vicinity around the discovery until directed otherwise by the Police as this could contaminate a potential crime scene. Likewise do not set up temporary fencing unless directed by the Police.
4. If the appointed expert investigating the find under the relevant *Coroners Act* believes that there is reasonable grounds to believe the remains to be:
   a. a crime scene, the Police will provide direction on the management of the discovery
   b. Aboriginal ancestral remains or historical remains, the relevant Director Heritage Branch, Department of Tourism and Culture, is to be contacted on (08) 8999 5039 (Darwin office) or (08) 8951 9247 (Alice Springs office) or email heritage@nt.gov.au.

4.6 Aboriginal Heritage Awareness Training

1. Origin staff / contractors conducting project work that may have the potential to harm aboriginal or historic cultural heritage must be aware of their duty to take all reasonable and practicable measures to ensure the project work does not harm any cultural heritage.
2. In addition all Origin staff / contractors undertaking earth disturbance activities that have the potential to harm heritage sites and artefacts shall undergo Cultural Heritage Identification Training to provide them with basic knowledge on the scientific characteristics of Aboriginal heritage and artefacts.
3. Origin staff / contractors must be made aware of the conditions set out in the AAPA Certificate (AAPA C2019/014) and the obligations of all persons (who enter on, or carry out works or use land on which there is a sacred site) under Part IV of the *Northern Territory Aboriginal Sacred Sites Act 1989*.

5. Records

The following records should be kept and maintained in order to demonstrate compliance with the requirements of this procedure:

- Appropriate Forms
- Information Sheets
- Staff Training records.

6. Definitions

Archaeological places or objects e	Archaeological places or objects exist within or in the vicinity of the Origin Permit Areas. All such materials are protected under the Northern Territory Heritage Act.

Aboriginal Cultural Heritage	Has the same meaning as in the relevant Aboriginal Cultural Heritage legislation. It includes pre-settlement and post-settlement significant aboriginal areas and significant aboriginal objects.
Aboriginal Heritage Awareness Training	Training may consist of any of: • Briefings on relevant Aboriginal Cultural Heritage • Briefings on particular arrangements with aboriginal parties • Identification of aboriginal heritage artefacts • Awareness sessions run for Origin staff by traditional owner groups
Burial Sites	Possibility of burial sites located within the Permit Area. Under the Northern Territory Criminal Code it is an offence to interfere with remains of a deceased person. Northern Territory Heritage Act it is an offence to interfere withthe remains of a deceased Aboriginal person without authorization under that Act.
Cultural Heritage Duty of Care	Has the same meaning as defined in Aboriginal Cultural Heritage legislation guidelines applicable to the relevant State in which activities are occurring.
Find	Means a significant Aboriginal object or, evidence of archaeological or historic significance of Aboriginal occupation of an area or Aboriginal human remains, found in the course of undertaking an activity covered by the guidelines.
Traditional Owners	A descendant of the tribe or ethnic group that occupied a particular region before European settlement, as recognised by Australian law.

7. References

1. Aboriginal Cultural Heritage legislation applicable to the Northern Territory
2. Aboriginal Areas Protection Authority Certificate
3. OEUP-1000-PRO-NCH-002 Unexpected Aboriginal Cultural Heritage Find (Traditional Owner Representative Present)
4. OEUP-1000-GDL-NCH-001 The Discovery Management & Handling of Human Remains

8. Appendices

Appendix A Cultural Heritage Audit Checklist (OEUP-1000-FRM-NCH-003)

9. Document information and history

DOCUMENT CUSTODIAN GROUP

Title	Name/s

DOCUMENT AUTHOR

Position	Name
Heritage Consultant	Luke Kirkwood

Appendix A Cultural Heritage Audit Checklist

Cultural Heritage Audit Checklist
OEUP-1000-FRM-NCH-003

Purpose	To ensure the appropriate management of cultural heritage has been undertaken, recorded & maintained in accordance with Origin Energy's procedures, directives, Government statutory requirements & Cultural Heritage Management Plans.
Reference	This form should be used in conjunction with the "Unexpected Aboriginal Cultural Heritage Find (Traditional Owner Representative Not Present)" (OEUP-1000-PRO-NCH-003) and/or the "Unexpected Aboriginal Cultural Heritage Find (Traditional Owner Representative Present)" (OEUP-1000-PRO-NCH-002) procedures.
Records	This document, once completed, will be kept as a record by the Native Title & Cultural Heritage (NTCH) unit and a copy to be retained on Site.
Notes for use:	1. Form to be completed & signed by a Supervisor or a representative from a Traditional Owner group. 2. Form to be reviewed & counter signed by Cultural Heritage Team Leader.

Section 1 - Audit Checklist

Task	Requirement	Compliance Notes	Status
1.	There is evidence that in the event of a suspected find the work crew stopped work in the immediate area of the suspected find while the suspected find was investigated.		
2.	There is evidence that the Appropriate Forms have been completed in the event of a suspected find.		
3.	There is evidence that copies of the Appropriate Forms are maintained by Origin's field based Cultural Heritage Team Leader.		
4.	There is evidence that the project work crew referred any suspected finds to Origin's Heritage specialist.		
5.	There is evidence that in the event that a suspected find could not be avoided, consent to remove / relocate / harm the find was obtained in accordance with statutory requirements and any relevant Cultural Heritage Management Plans.		
6.	There is evidence that Origin staff / contractors have undertaken Heritage Awareness training and/or Heritage Identification training.		

OK - Evidence of requirement in place	NC - Non-conformance
IO - Improvement Opportunity	NA - Not applicable at this site

Section 2 - Approvals

Signature: .... Date: ....
Name: .... Position: Supervisor and/or Traditional Owner Representative

Signature: .... Date: ....
Name: .... Position: Cultural Heritage Team Leader

Released on 18/01/2012 - Revision 0 - Status Approved - Process Owner is Indigenous Communities Manager
Origin Energy Resources Limited: ABN 66 007 845 338
Once printed, this is an uncontrolled document unless issued and stamped Controlled Copy or issued under a transmittal.

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Appendix I: Stakeholder Engagement Plan

BEETALOO EXPLORATION PROJECT

Early Stage Stakeholder Engagement Plan

Abbreviations/Acronyms

Abbreviation/Acronym	Description
ABC	Australian Broadcasting Corporation
ABS	Australian Bureau of Statistics
SEIFA	ABS Socio-Economic Indexes for Areas
BA	Beetaloo Asset
BESSEP	Beetaloo Early Stage Stakeholder Engagement Plan
BESCG	Beetaloo Early Stage Stakeholder Coordination Group
CAAMA	Central Australian Aboriginal Media Association
COFMP	Community Observation and Feedback Management Procedure
COAG	Council of Australian Governments
CSO	Civic Society Organisation
DME	(NT) Department of Mines and Energy
EGM IG	Executive General Manager Integrated Gas
EAA	(NT) Environmental Assessment Act
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EPA	(NT) Environmental Protection Authority
ESD	Ecological Sustainable Development
GM B&GA	General Manager Beetaloo and Growth Assets
IAP2	International Association for Public Participation's
LAGs	Local Aboriginal Groups
LGA	Local Government Authority
NGO	Non-government Organisation
NLC	Northern Land Council
NOI	Notice of Intent
NT	Northern Territory
NTG	Northern Territory Government
NT Inquiry	Scientific Inquiry into Hydraulic Fracturing in the Northern Territory
SLTO	Social Licence to Operate
SREBA	Strategic Regional Environmental Baseline Assessment
TEABBA	Top End Aboriginal Bush Broadcasting Association
TOs	Aboriginal Traditional Owners

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1 EXECUTIVE SUMMARY

Origin Energy (Origin) recognises that early and on-going engagement with stakeholders is fundamental to conducting itself in an open and responsive way to secure a 'social license to operate'. This Beetaloo Early Stage Stakeholder Engagement Plan (**BESSEP**) covers Origin's proposed stakeholder engagement activity for the Beetaloo Exploration Project **(BEP)** for calendar years 2019-20. It provides an overview of the BEP, its key stakeholders and their concerns, how they interact with Origin, and the expected engagement activities and accountabilities of BEP and Origin personnel.

The BEP early stage work comprises the installation of nine (9) hydrocarbon exploration wells (permitted under the NT Petroleum Act) over five (5) operating years, within Petroleum Exploration Permits 76, 98 and 117 (EP76, EP98 and EP117); in total covering 18,500 km^2 in the Barkly Region.

The BESSEP is designed to be a 'living' document, to be constantly reviewed and evolve during the life of the BEP to reflect information gained through stakeholder engagement, evolving BEP activities and changes in stakeholder perceptions, priorities and concerns. This BESSEP has been developed in the context of Origin's *Values, Policies and Directives,* as well as relevant NT legislative and regulatory requirements, International Financial Corporation (**IFC**) standards, and the Exploration Agreements between Origin, Native Title claimants/holders in the project area and their representative body - the Northern Land Council.

As the BEP early stage work progresses, the BESSEP will require continuously updated internal and external key messages and communication plans, particularly at project gateway points. Should early stage activities (exploration and appraisal) prove successful, a development stage SEP having greater emphasis on broader stakeholders at NT and Commonwealth level will be needed, anticipated by reference in this BESSEP.

An Origin internal coordination group, the Beetaloo Stakeholder Engagement Coordination Group (**BSECG**) - established for the duration of early stage work -, is designed to facilitate broad internal understanding and accountability for BEP stakeholder work and consistency in key messages for both internal and external stakeholders. All key messages and formal engagement activities within the BESSEP are discussed and agreed by the General Manager, Beetaloo and Growth Assets; the Executive General Manager Integrated Gas and the Executive General Manager, Corporate Affairs.

The BSECG meets regularly, involving representatives from Origin's functional teams that have contact with external stakeholders, including Beetaloo and Growth Assets, Corporate and External Affairs, Investor Relations, Health, Safety and Environment, People and Culture, Procurement and Security. BEP stakeholder activities are conducted according to Origin's engagement principles (Free, Prior, and Informed) and make use of existing systems and procedures - such as Origin's Community Complaints and Feedback Management Procedure (**CCFMP**). These provide for an accessible record of engagement on BEP issues, as well as guiding any complaints assessment and resolution.

A comprehensive understanding of stakeholders' early concerns and expectations has emerged as a result of discussions and inquires to date; these include direct economic effects, social and cultural heritage impact, community health and safety, and potential effects on water and regional development. These and other concerns that may arise in the future will play a major role in shaping stakeholder engagement focus and activities.

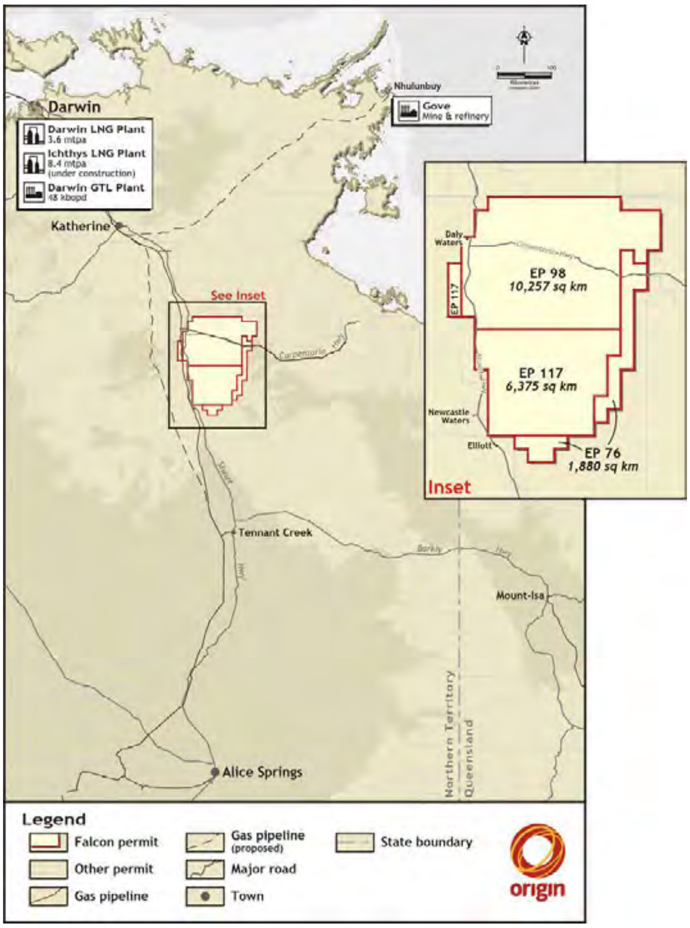
The relationships between stakeholders, the team responsible for delivering the BEP and other functional teams within Origin have been mapped. Inter-team integration and coordination is vital for consistent stakeholder engagement. The BSECG also discusses, agrees and allocates accountabilities for specific issues and roles to specific BEP and Origin functional teams. To this end, initial stakeholder relationship accountabilities have been mapped and are presented in the BESSEP**.**

2 INTRODUCTION

2.1 BEETALOO EXPLORATION PROJECT

Centred 620 kilometres south-east of Darwin (see Figure 1), the Beetaloo Basin underlies an area of approximately 35,260 km2, of which Origin's and Falcon Oil and Gas joint venture exploration licences aggregate 18,500 km2 (52.5%). The basin is considered highly prospective for shale gas and associated liquids. Results and analysis to date suggests that the physical characteristics and properties of the source rocks and play fairway are conducive to successful unconventional development.

Figure 1: Location of exploration permit(s) tenure



2.2 THE FARM-IN AGREEMENT AND PROJECT SCOPE

Origin together with Falcon Oil and Gas Australia Limited (Falcon) are the tenement holders for three (3) (hydrocarbons) exploration permits in the Beetaloo Basin. Origin holds a seventy (70) per cent interest in the three (3) permits and Falcon holds a thirty (30) per cent interest.

2.3 THE EXPLORATION PERMIT COMMITMENTS

The exploration permit holders are required to deliver nine (9) exploratory wells over five years. Prior to a moratorium introduced in September 2016, Origin had delivered four (4) exploratory wells, comprising three (3) non-stimulated vertical wells and one (1) horizontal stimulated well.

In April 2018, after a fifteen (15) month inquiry[1] (the NT Inquiry) involving a panel of eleven (11) subject matter experts led by The Hon Justice Rachael Pepper, the NT Government (NTG) lifted the moratorium. Resumption of exploration activities is contingent, however, on the efficient and effective implementation by the NTG of the NT Inquiry recommendations relating to exploration activities. It is envisaged, that if the NTG implements the required pre-exploration recommendations (approximately 35 of 135 total recommendations) in a timely manner, Origin will be able to resume permitted exploration activities in 2019.

2.4 BEETALOO EARLY STAGE STAKEHOLDER ENGAGEMENT PLAN

2.4.1 Scope

Stakeholder engagement seeks to ensure affected stakeholders gain an understanding of the impacts of a proposal, in this case the Beetaloo Exploration Project (BEP), of proposed mitigation measures and benefits, and that they have an opportunity to communicate feedback to Origin. For this to occur effectively, engagement methods need to be fit for purpose and appropriate to relevant stakeholders including consideration of literacy, culture, gender, age and language. This is particularly important in the NT when engaging with Aboriginal communities, who make up a majority of affected people in remote regions of the NT such as Beetaloo. Origin is particular conscious of Aboriginal cultural protocols, language and associated sensitivities.

This BESSEP covers stakeholder work for early stage[2] (exploration) activities, whilst creating a framework for escalating and broader stakeholder engagement should the exploration work prove successful. The plan will need to be further developed for any future development project. As it stands, it addresses the activities and accountabilities of Origin (the Operator) and all operator engaged personnel who may interact with BEP stakeholders.

In compiling the plan, Origin was guided by the International Finance Corporation definition of stakeholders as *“persons or groups who are directly or indirectly affected by a project, as well as those who may have interests in a project and / or the ability to influence its outcome, either positively or negatively”*. Similarly, consistent with the BEP being still at early stage exploration, communities are defined as *“the host communities being the inhabitants of the immediate and surrounding area that may be affected in some way by project activities”*. On this basis Origin believes that its host Traditional Owners, host Pastoral leaseholders, employees, contractors and local and regional community groups are its primary stakeholders. Other stakeholders include community hubs and towns in the Barkly region, local and NT governments and government agencies, NT residents more broadly, Civil Society Organisations (**CSOs**), special interest groups, media, academic commentators and other businesses.

While the BESSEP seeks to cover the broadest group of interested parties, Origin believes that working closely in a participatory manner with directly impacted stakeholders - those who share non-exclusive access to the land associated with the permit area and hold decision making authority for that land - are primary. Origin will listen, seek to understand and respond to the interests and concerns of other stakeholders, while remaining respectful of local concerns and customs as it evaluates the potential of the Beetaloo and NT other natural gas basins.

Origin provides relevant information to stakeholders and encourages those who are interested to ask questions and provide feedback on perceived and potential impacts, particularly on local communities and the environment. Origin will respond to reasonable requests by providing additional information, by incorporating appropriate suggestions into management and mitigation plans and, where possible, by modifying aspects of the BEP design and activity. Origin proactively engages with responsible Civic Society Organsations (CSOs) to help make its public consultation as broad-based as possible.

---

[1] Scientific Inquiry into Hydraulic Fracturing in the Northern Territory, commissioned by the NTG

[2] The term ‘Early Stage’ is used deliberately to avoid cross-confusion with technical stage gate terminology.

3 BACKGROUND

Origin's internal BESSEP has been developed in the context of relevant NT and Commonwealth Government legislative and regulatory requirements, exploration access agreements with Traditional Native Title Holders / Owners and pastoral leaseholders, and in accordance with Origin's Values, Policies and Directives. An understanding of social and socioeconomic context is central to the way Origin and the BEP seek to operate. In particular, Origin aligns its SEP work to the NT EPA's expectations for how early and effective stakeholder engagement is conducted and demonstrated to satisfy NT *Environmental Assessment Act* considerations. The NT EPA recommends alignment to the International Association for Public Participation's (IAP2) Quality Assurance Standard for Community and Stakeholder Engagement; and this BESSEP is written accordingly.

3.1 RELEVENT LAWS AND REGULATIONS

Applicable NT and Commonwealth Government Laws and Regulations are outlined below;

NT Legislation

- Petroleum Act 2016, Petroleum (Environment) Regulations 2016 and Schedule of Onshore Petroleum Exploration and Production Requirements 2016
- Petroleum (Prospecting and Mining) Regulations 2001
- Aboriginal Land Act 2013
- Biological Control Act 2016
- Bushfires Management Act 2016 (and associated Regulations)
- Control of Roads Act 2018
- Dangerous Goods Act 2012 (and associated Regulations)
- Environmental Assessment Act 2013 (and associated Regulations)
- Environmental Offences and Penalties Act 2011
- Fire and Emergency Act 2016
- Heritage Act 2016 (and associated Regulations)
- Natural Environment Protection Council (Northern Territory) Act
- Northern Territory Aboriginal Sacred Sites Act 2013 (and associated Regulations)
- Pastoral Land Act 2016 (and associated Regulations)
- Plant Health Act 2015
- Public and Environmental Health Act 2016 (and associated Regulations)
- Public Health (General Sanitation, Mosquito Prevention, Rat Exclusion and Prevention) Regulations 1988
- Soil Conservation and Land Utilisation Act 2016
- Territory Parks and Wildlife Conservation Act 2014 (TPWC Act) (and associated Regulations)
- Waste Management and Pollution Control Act 2016 (and associated Regulations)
- Water Act 2016
- Weeds Management Act 2013
- Work Health and Safety (National Uniform Legislation) Act 2014

Commonwealth Legislation

- Aboriginal and Torres Strait Islander Heritage Protection Act 1984
- Aboriginal Land Rights (Northern Territory) Act 1976
- Australian Heritage Council Act 2003
- Environment Protection and Biodiversity Conservation Act 1999
- National Environment Protection Council Act 1994
- National Greenhouse and Energy Reporting Act 2007
- Native Title Act 1993

Codes of Practice and Relevant Guidelines

Codes of Practice

- Codes of Practice for Small On-Site Sewage and Sullage Treatment Systems and the Disposal or reuse of Sewage Effluent (NT Department of Health, 2014)
- Petroleum Act S21E (and Stakeholder Engagement Guidelines Land Access)

Guidelines

- AS1940 The Storage and Handling of Flammable and Combustible Liquids, 2004
- Best Practice Erosion and Sediment Control (International Erosion Control Association, 2008)
- Bores, Drilling and Dams
- Guideline for the Preparation of an Environmental Management Plan (NT EPA, 2015)
- Northern Territory Natural Resource Management Plan 2016-2020 (Territory Natural Resource Management, 2016)
- ISO19011 Guidelines for auditing management systems, 2018
- Leading Practice Sustainable Development Program for the Mining Industry (Australian Government, 2016)
- Minimum Construction Requirements for Water Bores in Australia (National Water Commission, 2012)
- Northern Territory Land Clearing Guidelines (NRETAS, 2010)
- Northern Territory Noise Management Framework Guideline (NT EPA, 2018)
- Weed Management Planning Guide - Onshore Shale Gas Development Projects (DENR, 2018)

3.2 ORIGINS VALUES, POLICIES AND CORE PROCESSES

The BEP uses a suite of Origin management documents that provide information about how it manages its business, assets and operations. The BESSEP interfaces with the relevant core process documents listed below.

- HSE Management System
- Cultural Heritage Management System;
- Core Process - Safe Control of Work
- Core Process - Manage Assets;
- Core Process - Management of Change

3.3 EXPLORATION ACCESS AGREEMENTS

Origin aims to formalise its interactions, obligations and commitments with local and land connected groups through specific agreements, in the case of the BEP these include;

- Tripartite Deeds and Exploration Agreements with Native Title Holders
- Compensation and Access Agreements with host pastoral leaseholders

3.4 ORIGIN AND BEP ENGAGEMENT PRINCIPLES

Origin's BEP stakeholder engagement is based on the following overarching objectives and principles:

- The objective of stakeholder engagement is to secure support for the exploration program from host communities and other stakeholders.
- Full transparency in all stakeholder engagement, activities and payments, consistent with the societal expectations and Origin's policy on bribery and corruption.
- Ongoing provision of clear, factual and accurate information in an open and transparent manner to relevant stakeholders, consistent with the concept of free, prior and informed consultation.
- Where appropriate, Origin formalises and dignifies its engagement with stakeholder institutions through agreements that set out mutual expectations and obligations.
- Engagement and agreements adhere to the principles of good governance and balanced representation.
- Through formal and informal dialogue, Origin provides sufficient opportunities for stakeholders to raise issues, to make suggestions and to voice their concerns and expectations of the BEP
- Origin helps relevant stakeholders understand the information provided, seeks their feedback and lets them know how their discussion and contributions are considered.
- Engagement occurs on the basis of mutual respect, ensuring through induction training that BEP personnel and contractors understand what this means and behave accordingly.
- Origin responds in a timely way to stakeholder feedback, concerns, complaints and requests, and
- Constructive relationships between Origin, BEP and influential stakeholders are managed through personal contact assigned to specific Origin and BEP staff.

In particular, the BEP conforms to the principle of free, prior and informed consent for affected Aboriginal stakeholders, based on transparent communication and relationship building. Free, prior and informed consent at the BEP means affected Native Title holders are consulted about proposed work and given opportunities to discuss and influence the way that work and decisions that may affect them are conducted. Consent does not mean every Aboriginal stakeholder must agree to what is being proposed; rather, it means that Origin has ensured and complied with a thorough process of consultation and participation in decision-making with the Native Title holders has been followed, recognised in formal Agreements. These Agreements ensure that potential negative effects of Origin's activities are avoided or minimised, and that fair and positive contributions to Native Title holders and community development are made.

3.4 DEFINED AREAS OF INFLUENCE

Origin defines its BEP 'Areas of Influence' as follows;

- **Direct 'Area of Influence'** is the immediate footprint of physical infrastructure and associated works inside the exploration permit area.
- **Indirect 'Area of Influence'** is the Barkly Region, involving real and perceived community interests and concerns including direct economic effects, social and cultural heritage impact, community health and safety, and potential impacts on water and regional development.
- **Combined 'Area of Influence'** is the NT overall.

3.5 SUSTAINABLE AND REGIONAL DEVELOPMENT APPROACH

Origin in pursuing its business objectives aims to also generate sustainable, long-term benefits to directly affected community groups, to the Barkly region generally and more broadly into the rest of the NT. To enable successful long-term development, Origin has incorporated sustainable development principles in its management approach, aligned with the NTG's policy aim of ecologically sustainable development (ESD) of natural resources. ESD is defined, in the Council of Australian Governments (COAG) endorsed National Strategy for ESD as *"using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life now*.".

Sustainable development in the BEP context means operating in a way that leaves no negative liabilities for current and future residents in the Areas of Influence, while seeking to ensure any development generates an equitable distribution of benefit across various legitimate stakeholders. The conversion of a substantial proportion of in-situ natural capital into social and human capital in a way that is deemed fair by a majority of stakeholders is key. Beyond royalty payments to the NT Government (as owner of the natural resource), and payments to Native Title holders (host Traditional Owners) (as per Exploration Access Agreements) and host pastoralists (as per Access and Compensation Agreements); Origin seeks to maximise broad-based local participation in education, training, employment and enterprise opportunities engendered by its presence. The broader objective of training, employment and enterprise may only be progressed post exploration success.

Origin's sustainable development focal points are 'people', 'environment', 'communities' and the 'health and safety' of all those who participate in, or are affected by, the activities of its assets. At granular levels, Origin applies materiality and risk assessments and stakeholder priority analysis to all decision making. This business-driven approach leads to the most effective possible management and mitigation of potential adverse impacts; and it requires Origin to work in partnership with others who have the necessary knowledge and skills to maximise the creation of enduring value for BEP investors, employees and the people of the NT.

4 SOCIAL AND SOCIOECONOMIC CONTEXT

There are particular social difficulties associated with the NT's sparsely populated regions, its long distances, harsh climates, and for Aboriginal people, the many different language and cultural groups and a history of relationships with governments and operators of development proposals. These require special consideration when planning engagement with Aboriginal stakeholders. Origin adheres to the Aboriginal engagement principles recommended by the NT Environmental Protection Agency (EPA), set out in Appendix II and those required under the Aboriginal Land Rights Act and the Native Title Act.

The BEP is located within the Barkly and Roper Gulf Local Government Areas (LGA) in the central interior of the NT, midway between the towns of Katherine and Tennant Creek, straddling the Stuart Highway – Carpentaria Highway junction, and the North Australian railway line and gas pipelines running north to Darwin and east to the Eastern Australian pipeline network.

4.1 SOCIOECONOMIC CHARACTERISTICS OF THE BEP AREA OF INFLUENCE

A preliminary socioeconomic study of the BEP Direct and Indirect Areas of Influence was completed in January 2018 by Coffey Services as part of the NT Inquiry[3].

Three local government areas fall within the study area. Of these, the Katherine LAGs area has the highest employment, education and income levels, closely reflecting NT norms for many key socioeconomic indicators. Roper Gulf LGA (administrative centre at Daly Waters) and Barkly LGA (Newcastle Waters and Elliott) are substantially disadvantaged by comparison to the NT overall, and especially in terms of educational involvement and average level of schooling attained.

Population trends in the region are difficult to properly measure because of the transient nature of many regional communities. Changes in Australian Bureau of Statistics (ABS) statistical geography between census years is an extra complication. While the data show that the LGAs experienced overall growth across census years, it appears that the population of the Katherine urban centre has slightly decreased in the past two decades. Katherine LGA has a population age distribution similar to the NT overall,

[3] Beetaloo sub-basin Social Impact Assessment Case Study, 17 January 2018. Coffey Services Australia Pty Limited

whereas Roper-Gulf LGA and Barkly LGA both have younger populations, with median ages below that of the NT and Australia.

All three LGAs have high proportions of Aboriginal people within their populations. The LGAs with higher percentages of Aboriginal people also have the highest levels of socioeconomic disadvantage, including the key areas of education, employment and income. The Katherine LGA has the smallest proportion of reported Aboriginal persons (25%), generally greater income, higher levels of human capital and a more skilled labour catchment, meaning it could be better positioned to participate in economic opportunities associated with any future developments.

All three LGAs have unemployment rates higher than that of the NT generally. Roper-Gulf LGA has the highest unemployment rate, followed closely by the Barkly LGA. Aboriginal unemployment across the entire study area is much higher than the NT generally.

Housing and transport infrastructure are not well developed in the region, and the extent to which Origin and the BEP engages with civic infrastructure will be an element of the BEP's community engagement.

The region has a history of resource extraction and agriculture dominated industry, and this is an integral aspect of the region's sociocultural identity and legacy.

Table 1: Table of Socio-Economic Indicators – LGAs by Comparison

Socioeconomic Indicator	Katherine LGA	Roper-Gulf LGA	Barkly LGA	NT Overall
Population	9,187	6,121	6,823	211,945
Median Age	31	24	27	31
% Aboriginal	25.5	81.8	69.1	26.8
Median Weekly Total Household Income	1,534	1,126	1,158	1,674
% of persons who completed at least year 12 or equivalent	36.8	18.2	20.5	39.9
% of Aboriginal persons who completed at least year 12 or equivalent	13.7	11.5	7.7	N/A
Unemployment Rate %	6.0	18.8	10.6	5.3
Aboriginal Unemployment Rate %	26.2	26.2	23.1	N/A
Median Rent ($/Week)	200	50	50	225
% of households who qualify as being under rental stress	6.2	2.5	5.8	9.0

Table 2: Table of Relative Socio-Economic Conditions

ABS Socio-Economic Indexes for Areas (SEIFA) 2011 – Summary Selected LGAs[4]

[4] Australian Bureau of Statistics (2011e), Census of Population and Housing: Socio-Economic Indexes for Areas (SEIFA) 2011

Local Government Area	*Index of Relative Socio-Economic Advantage and Disadvantage*		*Index of Relative Socio-Economic Disadvantage*		*Index of Economic Resources*		*Index of Education and Occupation*	
	Score	Decile	Score	Decile	Score	Decile	Score	Decile
Katherine LGA	944	4 (40%)	940	3 (30%)	920	2 (20%)	974	7 (70%)
Roper-Gulf LGA	650	1 (10%)	578	1 (10%)	588	1 (10%)	854	1 (10%)
Barkly LGA	738	1 (10%)	680	1 (10%)	712	1 (10%)	923	3 (30%)

Note: BEP LAGs are evaluated relative to all LGAs in Australia. Score = A lower score indicates that an area is relatively disadvantaged compared to an area with a higher score. Scores are an ordinal measure. Scores are standardised so that the average equals 1000 and the standard deviation is 100. Decile = All areas are ordered from lowest to highest score and assigned a number from 1 to 10. A Decile of 1 means that the LGA falls into the bottom 10% of LGAs. The total set of LGAs is divided into ten equal sized groups.

Knowledge base work as part of the the Strategic Regional Environmental Baseline Assessment (SREBA) to be undertaken as part of the NT Inquiry can and should be used to guide and inform future socioeconomic support programmes - should the project achieve exploration success and proceed to a development.

4.2 LOCAL COMMUNITIES

Three small population hubs, too small to be called towns, are located in the BEP Direct Area of Influence. The location of host community hubs and pastoral stations is shown in Figure 3and brief descriptions of key stakeholder groups follow.

Figure 3: Origin's Exploration Permits, Host Community Hubs and Pastoral Stations

Daly Waters is 620 kilometres south of Darwin and three kilometres west of the Stuart Highway, comprising an airfield, a general store and humble housing supporting a resident population of approximately 20 people. The name Daly Waters was given to a series of natural springs by John McDouall Stuart during his third attempt to cross Australia from south to north, in 1861-2. Stuart named the springs after the new Governor of South Australia, Sir Dominick Daly. The Overland Telegraph Line reached Daly Waters from the north and connected to Tennant Creek in 1872. Daly Rivers Airfield was a centre for the London to Sydney air race in 1926, a refuelling stop for early Qantas lights to Singapore, a World War II Airforce base and more recently an operational base for joint military manoeuvres. Although the airfield was closed to commercial traffic in 1965, the original Qantas hangar still stands, housing exhibits of photographs and equipment from the area's aviation past.

Local Traditional Owners are the Jingili people who believe the dreaming tracks of the emu and the sun travelled through what is now Daly Waters to the southern parts of the NT. They gained legally recognised native title rights over both the townsite and ten surrounding pastoral leases covering an area of 30,000 square kilometres (11,583 square miles) in 2009.

Elliott is located close to the halfway point between Darwin and Alice Springs on the Stuart Highway. It has a population of 355 people, many being Jingili people. The township is situated at the site of Number 8 Bore on Newcastle Waters cattle station, the site of an Australian Army camp during World War II and is named after Army Captain R.D (Snow) Elliott MBE.

5 BEP STAKEHOLDER ENGAGEMENT STRATEGY

5.1 BEP STAKEHOLDER ENGAGEMENT OBJECTIVES

The BEP stakeholder engagement goals are to:

- Identify BEP stakeholders;
- Understand and anticipate BEP stakeholder concerns and opportunities for shared outcomes
- Communicate proactively with BEP stakeholders about proposed and current BEP activities, using consistent key messages;
- Achieve BEP objectives while respecting the concerns and issues of relevant stakeholders as they relate to potential BEP impacts;
- Align engagement and messaging consistent with BEP activities, and any subsequent design, construction, operations and activities;
- Develop, implement and maintain constructive relationships with relevant BEP stakeholders, striving for mutual understanding, respect and collaboration;
- Establish and maintain coordinated, internal processes for BEP stakeholder engagement and issues management;
- Share information and feedback across the BEP team, and where appropriate, report back to relevant BEP stakeholders; and
- Tailor language, format, materials and activities to specific BEP stakeholders.

5.2 DEVELOPMENT OF COMMUNICATION PLANS AND KEY MESSAGES

The BESSEP requires that internal and external communication plans and key messages are developed for each major activity associated with the design and delivery of the BEP.

Figure 2: Cascading of Engagement and Communication Plans and Key Messages

5.3 STAKEHOLDER ENGAGEMENT PROCESS

This section describes the process that BEP follows in undertaking stakeholder engagement activities. It includes:

- The strategic imperatives and tools for stakeholder engagement activities;

- A process for coordinating stakeholder engagement activities across Origin and BEP functions;
- A procedure for managing BEP-related complaints, grievances and feedback, and
- A basis for monitoring and evaluating stakeholder engagement activities.

5.4 STRATEGIC IMPERATIVES FOR STAKEHOLDER ENGAGEMENT

This BESSEP is based on the principles and objectives set out in Section 3.4, including that engagement activity should be:

- Free (free of coercion and intimidation);
- Prior (timely disclosure of information), and
- Informed (relevant, understandable and accessible information).

BEP stakeholder engagement makes use of Origin's CCFMP (see *Appendix A*), and other management systems and core processes where relevant. These provide for an accessible record of BEP engagement on stakeholder issues and concerns, as well as guiding community group complaints assessment and resolution.

5.5 ENGAGEMENT TOOLS

The BEP adopts and continuously refines engagement techniques to suit the circumstances and the social norms of particular stakeholders. For example, when engaging with host Traditional Owners and local communities in the BEP Areas of Influence, cultural issues and education levels are carefully considered. Information and consultation sessions use clear, non-technical language; are based on consistent key messages, and specifically seek questions and comments.

Participatory tools and methodologies such as workshops and group sessions are also employed where appropriate to increase stakeholder involvement and ask about suggested alternative ways of doing things, especially if there is controversy or complexity and a need to build a consensus around possible solutions. Specific tools can be used to engage sub-groups including different cultural groups, women, elders, small business owners, and youth. The selection of tailored engagement practices is based on the:

- Number and interest of stakeholders;
- Location and venue of the engagement;
- Social and legal complexity of the issue to be discussed;
- Significance of potential effects, and
- Desired outcomes of engagement.

The type of engagement for each targeted stakeholder group will change as the BEP progresses, however stakeholder groups that are directly and materially affected by a particular component of the BEP are regarded as the most important to be properly informed and involved in decisions that affect them. Three complementary components, described below, typically provide the basis for stakeholder engagement.

5.5.1 Sharing Information

- Newsletter - used for providing regular feedback and updates to a broad range of stakeholders.
- Community Notice Boards - used for announcing upcoming activity and general updates at local and regional centres, catalysing 'word of mouth' cascade.
- Mass Media - local newspaper and radio, TV, Social Media - announcing upcoming activity and general updates
- Origin BEP Website - (www.originenergy.com.au/beetaloo) for sharing information with stakeholders who have internet access.

5.5.2 Direct Dialogue

- Face to face meetings for direct discussions with individuals and small groups for the exchange of specific information relevant to them.
- Site visits and specific presentations for the delivery of key messages and specific studies, reports or data at specific BEP milestones.
- Public meetings for regular updates and discussion with local community groups (e.g. at Traditional Owner, local and regional public meetings)

5.5.3 Collecting and Compiling Stakeholder Input

Information gained through stakeholder engagement is diarised and compiled for analysis through Origin's information management system. This also allows for information sharing with relevant stakeholders (with appropriate levels of confidentiality protection). Examples of information venues include:

- Individual Meetings - direct discussions with individuals or small groups, allowing the sharing of specific information with select people and small groups.
- Groups Sessions - to collect data and feedback on specific decisions or activities (such as Sacred Site Clearance Surveys), or for regularly meeting with groups of community leaders or special interest groups such as local Regional Economic Development Sessions Committees, CSOs, women, elders and youth groups.
- Studies and Surveys - for background and baseline information or collection of opinions or perspectives of sampled populations or different stakeholder groups.

5.5.4 Communication and Engagement Tools

Communication and engagement tools and materials for different stakeholder groups are summarised in Table 3 and Table 4. Importantly, desired outcomes for all engagements are considered when selecting appropriate engagement methods. For example, host Traditional Owners, host pastoral leaseholders and the NT government are key stakeholders with which good working relationships are continuously maintained, so working with them to develop integrated regional development plans aligned to the BEP is important, rather than adopting a 'for information' approach.

6 STAKEHOLDER IDENTIFICATION

Under the IFC definition, stakeholders can include locally affected community groups and individuals, their formal and informal representatives, provincial and local government authorities, politicians, religious leaders, civic society organisations and groups with special interests, the academic community and other businesses"[5]

Two important considerations influence how the BEP categorises its stakeholders, identified according to whether they:

- May be directly and/or indirectly affected by BEP activities or infrastructure
- Are indirectly affected and have the potential to influence BEP design and/or operations.

A high-level list of BEP stakeholder groups is provided in Table 3 and Table 4.

Table 3: Summary of Directly Affected Stakeholder Groups

Directly-Affected BEP Stakeholder Groups	
Directly Affected Community Groups	**Preferred Engagement Methods**

[5] International Finance Corporation. 2007. "Stakeholder Engagement - Good Practice Handbook for Companies Doing Business in Emerging Markets".

Directly-Affected BEP Stakeholder Groups	
Host Traditional Owners (Native Title Holders / Claimants for the shared land of Origin's Exploration Permits tenure)	On-country meetings, face-to-face meetings, ground and aerial surveys including group sessions, workshops, other local working groups (Cultural Heritage monitors), local disclosure materials (e.g. storyboards and brochures etc.) Site visits, and email and hard copy communications with the Local Aboriginal Group (LAG) representative - the Northern Land Council
Host Pastoral Leaseholders (holding pastoral leases for the shared land area of Origin's Exploration Permits tenure)	Face to face individual meetings, Site visits, email communication
NT Government	Regular face-to-face meetings, email and hard copy communications
BEP and Origin	
Origin employees - Contractors and contractor personnel	Internal communications - email, website, individual and group / team meetings / discussions, intranet social media (Workplace), monthly Head of IG address
Origin Suppliers Supply chain partners (transport authorities, transport companies) Other service providers and partners	Individual discussions, questionnaires, group sessions and workshops, supplier development programme

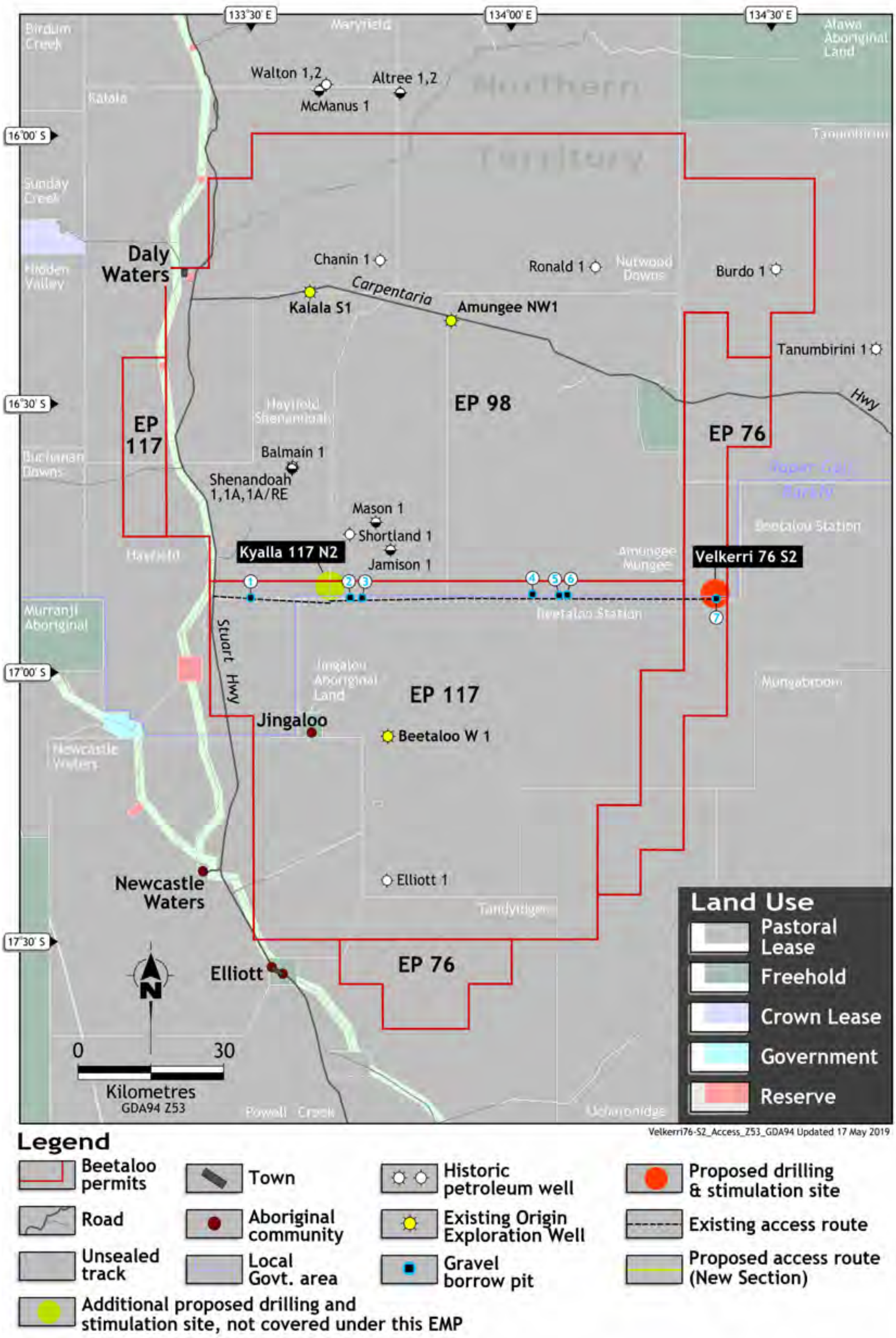
Table 4: Other BEP Stakeholder Groups

Other BEP Stakeholder Groups	
Other Groups	**Preferred Engagement Methods**
Barkly region community residents (Daly Waters, Elliot, Katherine, Tennant Creek, Borroloola)	Local government and regional meetings, individual meetings, surveys, group sessions / discussions and workshops, other local working groups, local disclosure materials (e.g. newsletter, brochures etc.) Regional Shows, Open Days, community development programmes (as partners). Site visits
Other TOs from the Roper and Barkly regions and Aboriginal Peoples from elsewhere in the NT	On-country meetings, face-to-face meetings, local disclosure materials (e.g. storyboards and brochures etc.) Site visits, and email and hard copy communications with the Local Aboriginal Group (LAG) representative - the Northern Land Council
Media (print, radio, TV) Social media channels (LinkedIn, Facebook, and Twitter)	Interviews, press releases/newspaper articles, website, fact sheets
Industry	
NT Industry Associations and other extractive companies	Individual meetings, presentations at meetings, surveys, group sessions and workshops, local disclosure materials (e.g. newsletter, brochures etc. Site tours

6.1 DESCRIPTIONS OF BEP KEY STAKEHOLDERS

The location of host community hubs and pastoral stations is shown in Figure 3and brief descriptions of key stakeholder groups follow.

Figure 3: Origin's Exploration Permits, Host Community Hubs and Pastoral Stations



6.1.1 Local Aboriginal Groups and Host Traditional Owners

Four (4) native title claims and three (3) determined native title areas intersect with Origin's exploration tenements. Origin works with all of them as land-connected Aboriginal peoples. The Local Aboriginal Groups (LAGs) and host Traditional Owners have appointed the Northern Land Council (NLC) as their representative, and legally binding Exploration Access Agreements and Tripartite Deeds are in place detailing the terms and conditions associated with Exploration Permits 76, 98 and 117. Origin also works with the NLC and LAGs to ensure that sacred site avoidance and clearance is undertaken prior to commencing each year's work activities, and to ensure work conditions and instructions are relevant to the most up to date information and regulations. Custodians may vary according to where proposed work activities are to take place.

6.1.2 Other Traditional Owners and NT Aboriginal Peoples

There are a number of Aboriginal communities and groups located away from Origin's tenements that have an interest in the BEP. Origin seeks the NLC's assistance (as the Statutory Representative body in the NT) to work with these groups in order to listen, communicate and engage with a broad cross section of the NT's Aboriginal and Torres Strait Island peoples.

6.1.3 Host Pastoralist Leaseholders

Nine (9) pastoral leases have non-exclusive tenure rights that intersect with Origin's Exploration Permits 76, 98 and 117.

To date, Origin has signed Compensation and Access Agreements for single-year activities with four (4) of these pastoral property owners.

6.1.4 Other Barkly and Roper Gulf Pastoralists

Other pastoral leaseholders located within the Barkly Regional and Roper Gulf LGAs are potentially in-directly affected by Origin's BEP. Origin engages with these leaseholders through the Northern Territory Cattlemen's Association and the two respective LGA Councils, and directly if requested.

6.1.5 Northern Territory Government

The NT Government's representative and administrative functions are important stakeholders in the BEP. Various government departments, such as the Environmental Protection Authority (EPA), Department of Environment and Natural Resources (DENR) and the Department of Primary Industry and Resources (DPIR), have important regulatory roles to play, requiring detailed formal procedural contact and documentation. Less formal engagement is also important, to provide constant up-to-date information and forward-looking indication of regulatory workflows.

6.1.6 Commonwealth Government

The Commonwealth Government is an important BEP stakeholder, particularly in the context of national interest considerations, which will increase if and when the project develops beyond early stage exploration. For historical and on-going NT dependency reasons, various Commonwealth authorities and regulators play are larger role in NT matters than they do in State jurisdictions, particular regarding greenhouse and energy matters, Native Title and land rights; and water, environment and biodiversity.

6.1.7 Regional Residents and Local Government Authorities

Residents of surrounding regions, towns and townships, such as the Roper Gulf, Katherine and Tennant Creek, have a strong indirect interest in the BEP. Given the nature of the NT, with long distances and a sparse population base, many services and potential employees will be drawn from places 100s km away. Regular engagement with local and regional councils should be consistent and ongoing.

6.1.8 Employees and contractors

Employees and contractors are important in three ways:

- as directly affected people who need timely and correct BEP information to make decisions about their and their family's daily lives and future;
- as 'role models' whose behaviour, demeanour and visible respect during interactions with other stakeholders, and particularly traditional owner and pastoral community members, are the single most important factor determining how the BEP is regarded by others, and
- as conduits of information to broader stakeholder groups, usually in face to face situations, this is often reported as the most credible form of communication exchange.

Accordingly, it is vital that internal communications with employees and contractors is well balanced, covering what is important for them to know, and in a way that effectively communicates the key issues. Employee communication works best when (1) it is face-to-face; (2) it is between a manager and direct report; and (3) it is delivered in the language of the recipient. Hence, pre-start and 'tool box' meetings are very effective places for information exchange with employees and contractors. This can be assisted by providing key message fact sheets to managers, superintendents and supervisors, and asking them to pass these on verbally to their work crews. Newsletters and regular fact sheets on important matters should also be available in crib rooms, notice boards, mess areas and the seat pockets of work vehicles. All contractors are provided with the same communication streams that Origin employees receive, and Tier 1 contractors have written into their contacts the level of information cascade expected to their work crews and sub-contractors.

6.1.9 Unions

While the workforce at the BEP is non-unionised, the principle of choice is maintained by Origin and various employee unions are a recognised stakeholder.

6.1.10 NT Training and Education Institutions

The ability of the BEP to locate and employ qualified NT-based employees is very dependent on the education and training NT residents can access. In the event of exploration success and the approval of a commercial development, this will become particularly important, hence keeping NT Training and Education providers informed of potential future trades and professionals demand is an important requirement.

6.1.11 Barkly and NT Businesses

Origin has a proven strategy of maximising local service and supply, for early stage work at the BEP to date this has largely been confined to civils, hospitality, logistics and transport services. In the event of exploration success and commercial development, this could escalate. Engagement with chambers of commerce, industry associations and local and Aboriginal businesses is a critical component of the BESSEP. Given the socioeconomic and geographic characteristics of the BEP Areas of Influence.

6.1.12 Civic Society Organisations (CSOs)

CSOs have the potential to positively or negatively influence BEP outcomes. While most do not have any formal role in BEP permitting, they have the ability to influence those stakeholders having a formal role. CSOs include organisations that have existed in NT and Australia for many years, such as NGOs, religious organisations and more recently smaller localised environmental protection alliances.

Contrasting to activist groups and their local alliances, other supportive and neutral CSOs are critically important for the BEP. These include emergency and service organisations such as the Royal Flying Doctor Service and Careflight, who are a vital part of the BEP's operational support. Engaging with these organisations on a proactive and regular basis is an important element in the BESSEP.

6.1.13 NT Industry Associations and Extractive Businesses

Disseminating the relevant facts about the BEP, and working to 'raise the performance' of all extractive and resource operators, is optimally approached through industry associations.

6.1.14 Media

Media sources in Barkly Region and the NT include:

- Television
- Print - the main local newspapers are the NT News and Katherine Times. The NT News is produced daily, and the Katherine Times is produced weekly. Both newspapers are circulated throughout the Barkly, where they are widely accessible and read.
- Social Media - with the increasing coverage of mobile phone use, social media applications such as Facebook and Twitter are becoming more prevalent in all parts of the Barkly Region.
- Radio – CAAMA, TEABBA and the ABC all broadcast into the Barkly region.

Social Media is frequently unbalanced with little reference to fact, and a proactive approach to media management, using existing media contacts and the provision of Origin generated community stories, is required to generate positive sharing of mutual benefit opportunities.

7 KEY BEP STAKEHOLDER ISSUES, CONCERNS AND MESSAGES

A comprehensive and dynamic understanding of stakeholder concerns and expectations allows the BEP to identify and implement stakeholder engagement activities that support BEP objectives. Already a number of specific stakeholder concerns and expectations have emerged as a result of participatory discussions (see Table 5). These and other concerns and expectations that arise in the future will play a major role in shaping stakeholder engagement focus and activities. The process of identifying, recording and responding to feedback from stakeholders will be ongoing and expand in the event that the BEP progresses to full evaluation and development.

Table 5: Key Stakeholder Group Issues and Concerns

Type of Potential Issue	Stakeholder Concern	Stakeholder groups that have expressed this type of interest
Economic and Infrastructure	Demand for employment opportunities for local people. Interest in the creation of business opportunities for local, regional and NT based companies	Darwin Major Business Group Chamber of Commerce and Industry Manufacturers Council NT Indigenous Business Network Industry Capability Network Katherine Mining and Services Association Regional Economic Development Committees Local Government NT Government NT Cattlemens Association
Social and Cultural Heritage Impact	Concerns regarding impact of the BEP on cultural heritage	Traditional Owners Anti-development activists NT Inquiry members
Compensation	Requests for compensation above and beyond productive land valuations	Pastoralists legal representation
Community Health and Safety	Concerns about potential effect on water quality and quantity (detailed below)	All Territorians

Type of Potential Issue	Stakeholder Concern	Stakeholder groups that have expressed this type of interest
Education	Adequate provision of kindergarten, education and vocational training facilities and programs as demand for qualified personnel increases.	Supporters of industry and those interested in ensuring that there is adequate provision for training and preparing Territorians for future job and business opportunities
Water	Effect of ground and other water sources during hydraulic fracture and ongoing operations.	Traditional Owners, other community members and special interest advocacy groups.
Regional Development	Improvements in road and telecommunications infrastructure	NT and local government authorities Barkly pastoralists Barkly Traditional Owners Barkly community members generally NT Cattlemens Association
Lower power prices	Possible interest in a fixed price formula for Power and Water / Jacana Energy customers from Beetaloo Basin natural gas (rather than introduction of a Gas Reservation Policy)	Darwin business owners
Business Opportunities	Interest in securing service, material and labour supply contracts and other sub-contracting opportunities. Interest in the provision of security services.	Established business people Traditional Owners Pastoralists Existing suppliers Members of the NT Parliament Local Government Councillors Regional Economic Development Committees
Road Traffic	Concern about increased heavy truck use on Stuart Highway and Carpentaria Highway	Road users and transport operators
Social/Environmental Advocacy Interest	Interest in challenging the BEP on the grounds of perception or real social, visual and/or environmental effects.	Local, regional and Darwin based advocacy groups with links to national and international NGOs; partisan academics; and some Unions

7.1 ISSUES MANAGEMENT

Constructively responding to stakeholder issues that arise during BEP activity is a key component of successful stakeholder engagement,specifically:

- Anticipating and planning for potential issues at all stages of the BEP activities;
- Responding to stakeholders about their issues, setting out roles and responsibilities, and coordinating and communicating response measures;
- Differentiating between BEP-specific and/or immediate response issues, and Origin-wide issues that require higher level response;
- Communicating the issues management process to BEP team members;

- Assigning issues accountabilities to BEP and Origin functions and staff;
- Coordinating issues response activities and keeping relevant stakeholders advised of mitigation steps that are both underway and planned;
- Managing any community observation and feedback at a local level, wherever possible, and
- Tracking and reporting on the progress of issues resolution.

7.2 KEY MESSAGES

The language and format of engagement with different stakeholder groups is tailored to their circumstance, and their needs and norms of communication. However, it is vital that there is consistency in the content of what is being communicated. Each stakeholder group should be receiving the same information, or subsets of information, relevant to their own circumstance and engagement objective.

8.1 ANALYSIS PROCESS

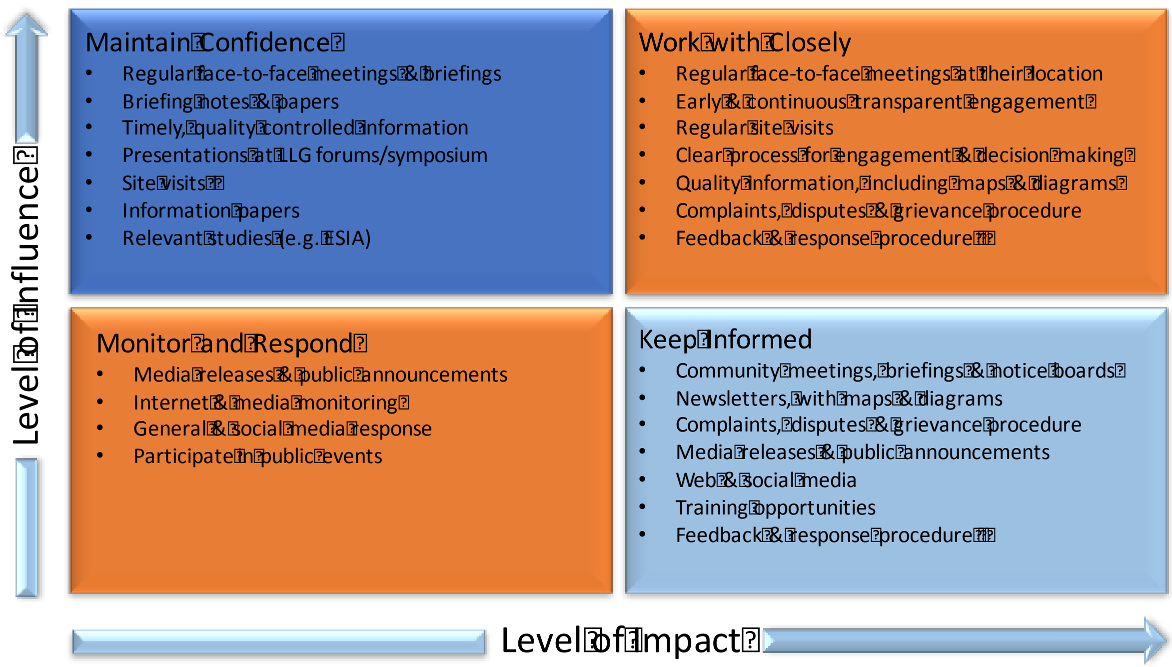
Complementary to social risk assessment, BEP stakeholders are prioritised using an influence/impact matrix.

Influence the stakeholder's ability to influence the approval, rejection or progress of the BEP

Impact the impact physically (i.e. location) of preferred BEP design options or the impact of the investigation / preferred option on the stakeholder's workload and their involvement in decision making (e.g. approvals and reviews).

Use of an influence/impact matrix enables stakeholders to be mapped into four strategic areas: *Work with closely; Maintain confidence; Keep informed;* and *Monitor and respond*

Figure 4: Stakeholder Influence/impact Matrix



7.1.1 Work With Closely

Key activities for these stakeholders include:

- Public events/open days;
- Focus group discussions;
- Phone calls as required;
- Select individual face-to-face meetings and briefings, at their location;
- Government meetings;
- Early and continuous transparent communications;
- Regular site visits;
- Regular community and township visits;
- Newsletter/information sheets;
- Quality information, topic specific, including maps and diagrams;
- Clear processes for engagement and decision making;
- Training, where appropriate; and
- An established and accessible complaints process, and Feedback and response procedure.

Although concerns and disagreement are normal, a clear process based on Origin's CCFMP will be developed in situations where inflexibility sets in and agreement between stakeholders is not occurring. Most concerns can be resolved by face-to-face discussion; however, some escalate to disagreement and dispute, at which point independent fact checking is usually called for. If there is still no resolution, then the parties can agree to third party mediation.

7.1.2 Maintain Confidence

Key activities for these stakeholders include:

- Specific face-to-face meetings and briefings;
- Public events/open days
- Newsletter/information sheets;
- Briefing notes and papers;
- Timely, quality controlled information;
- Presentations;
- Site visits;
- Specific information papers as required;
- Access to relevant studies (Feasibility study, ESIA)

7.1.3 Keep Informed

. Key activities include:

- Community meetings, briefings and notice boards;
- Newsletters, with maps and diagrams;
- Access to complaints and grievance process;
- Media releases and public announcements;
- Web and social media;
- Training opportunities, and
- Feedback and response procedure.

7.1.4 Monitor and Respond

Key activities include:

- Media releases and public announcements;

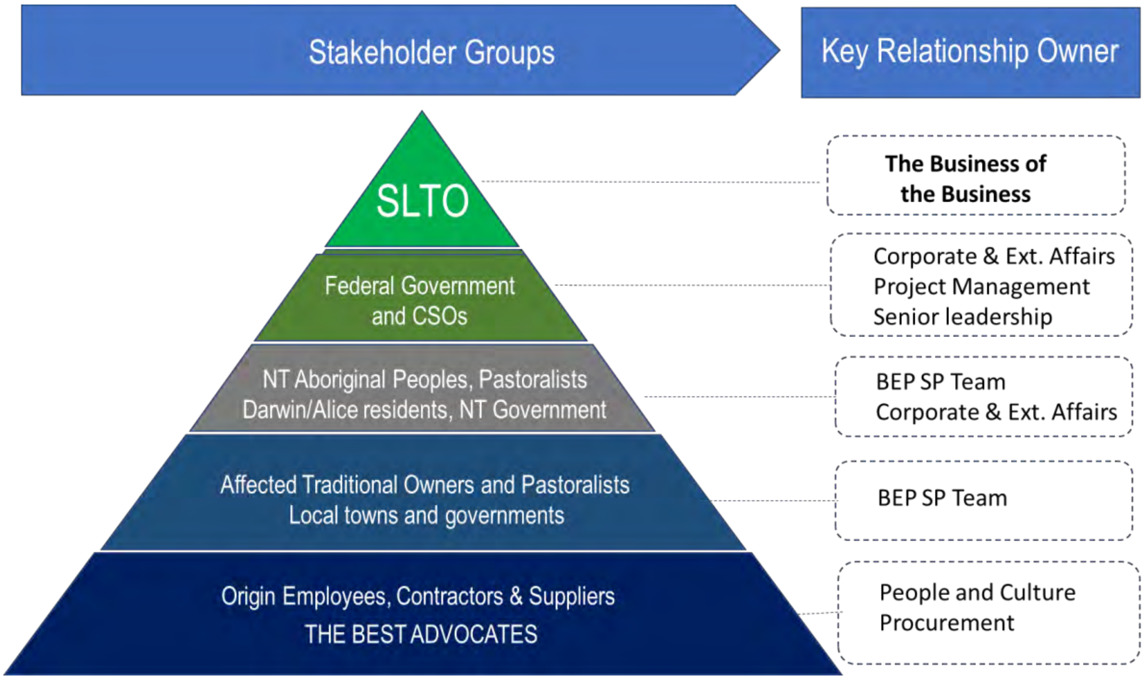
- General and social media; internet monitoring;
- Feedback and response procedure, and
- Participation in major events organised by the BEP

8 COORDINATION OF STAKEHOLDER ENGAGEMENT

9.1 STAKEHOLDER AND BEP FUNCTIONAL RELATIONSHIPS

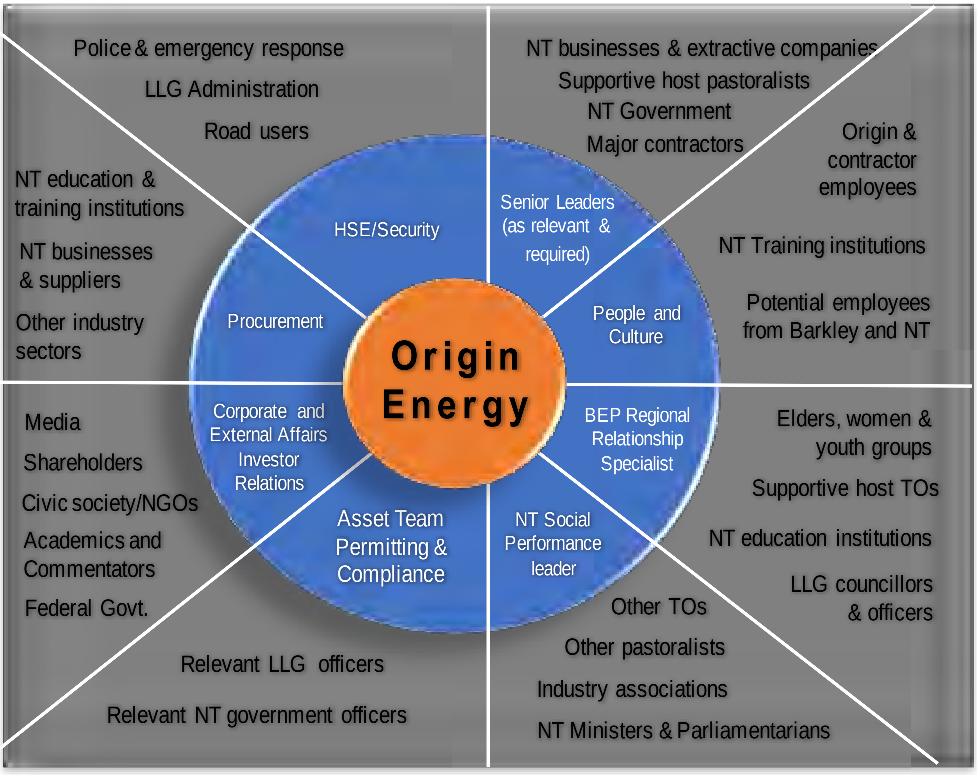
Given the complexity of stakeholder interests and expectations, successful stakeholder engagement requires information sharing and coordination among Origin's various functional teams and leaders. Figure 5 shows the high-level accountability by Origin/BEP's functional teams for managing stakeholders.

Figure 5: BEP Stakeholder Engagement Pyramid



Inter-team integration and coordination is vital for consistent stakeholder engagement; Figure 6 shows in more detail specific BEP stakeholder management accountabilities. Although the map indicates the BEP stakeholders with which specific functions are most likely to interact, certain communication processes may target all interested and affected stakeholders collectively.

Figure 6: BEP Stakeholder Functional Team Relationships



9.2 STAKEHOLDER ENGAGEMENT COORDINATION

The BESCG[6], chaired by the GM Beetaloo and Growth Assets, will play a bridging role to coordinate Origin and BEP decisions related to stakeholder engagement, accountabilities and activities, in accordance with the following principles:

- Organising meetings to discuss and agree current and proposed BEP stakeholder engagement approaches.
- Providing strategic input into stakeholder engagement planning for BEP issues.
- Coordinating consistent key messages to be used by BEP and Origin functional teams in their BEP stakeholder engagement activities.
- Ensuring that BEP stakeholder issues are recorded and reviewed, and that they receive an appropriate and timely response to expressed issues.
- Considering BEP stakeholder responses and other information, and make recommendations to help the BEP achieve its over-arching stakeholder engagement goals.
- Participating in managing and resolving complex issues, complaints and recommendations that may arise during the BEP.
- Helping develop overarching reports on BEP progress for key BEP stakeholders.
- Sustaining relationships and maintaining continuity when there are personnel changes - both within the BEP and Origin, and within BEP stakeholder groups.
- Passing information gained from BEP stakeholders back to BEP leaders.

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[6] *The BESSCG initially includes the GMB&GA, Corporate Affairs Manager Northern Australia; Communications and External Relations Manager, BEP Project Manager; Investor Relations Manager; Procurement Leads; Regional Relationship Specialist; and HSE Leads*

- Ensuring that BEP stakeholder engagement commitments are practical and functional, have received the appropriate internal approval, and do not conflict with any other BEP commitments or be detrimental to the BEP and Origin's business interests and other stakeholders.
- Ensuring BEP stakeholder engagement is documented for internal and external reporting and approval purposes.

9 DATA COLLECTION AND MANAGEMENT

Stakeholder data management is a key component of effective stakeholder engagement. A fit-for-purpose data management system be maintained by Origin to manage the information generated through its stakeholder engagement. The data management system supports the storage and analysis of data provided by stakeholders, along with associated social and environmental data. This system will be used for BEP stakeholder engagement purposes.

A vital element of SEP output is feedback to stakeholders themselves. Origin ensures feedback is provided to all stakeholder participants it engages with through processes that have been agreed. Usually this takes of the form of suitable collated material that provides confidentiality to any individuals.

10 EFFECTIVENESS REVIEW

Origin will monitor the effectiveness of BEP stakeholder engagement activities. Monitoring measures have been developed (Table 6) and will be included in the monthly BESCG meetings.

Table 6: SEP Effectiveness Review Measures

Topic/Aspects	Methods	Accountability	Timeframe
Complaints, observations and feedback specific to BEP stakeholder matters	Origin will review its Community feedback register for BEP-specific complaints *closed* and those *unresolved* per period (and dynamically as they occur). - Number of BEP complaints opened in the month. - Month tracking of complaint progress. - Number of complaints closed in the month. - Type of complaints Origin will ensure that the BEP team provides feedback to the stakeholder and other relevant bodies on the type of complaints received, how they are being addressed and outcomes achieved.	Corporate Affairs Manager Nth Aust.	Monthly
Informal Community Sentiment	Origin's BEP Regional Relationship Specialist (RRS) and Field Supervisor (FS) note comments made during their day to day interactions with community members and other BEP stakeholders. Positive and negative comments, and other sentiments and queries on the BEP will be noted.	BEP RRS, FS and other BEP team members	Monthly Whenever interactions occur

Topic/Aspects	Methods	Accountability	Timeframe
Formal Stakeholder Feedback	Origin will specifically seek formal commentary on matters relating to the BEP from stakeholders in standing committees, such as the Regional Economic Development Committees, Town and Regional Councils, and from *Community Engagement Forum Members (Darwin, Katherine, Tennant Creek, Alice Springs, Borrroloola, Nhulunbuy, Palmerston and Rural Darwin) – to be established quarterly from Q2 2020*	Corporate Affairs Manager Nth Aust.	Quarterly

11 BIBLIOGRAPHY

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International association for public participation (IAP2) (2015) Quality Assurance Standard for Community and Stakeholder Engagement

International Council on Mining and Metals (2015) *Good Practice Guide Indigenous Peoples and Mining* 2nd Edition, ICMM, London

NT EPA (2018 in draft) Guidance for Proponents – Stakeholder Engagement

Appendix J Stakeholder Engagement Log

Date	Originator of communication	Company of contact	Person of contact	Contact type	Summary of contact	Copy of contact or information provided (if written)	Does it trigger merit review?	A statement of the interest holders response to stakeholder	Change to EMP required ?	Details of changes the interest holder has made as a result of the stakeholder engagement
				9 (1) f	9(1)c	9 (1)b. 9 (1)c	9 (1)d	9 (1) e		9 (1)g
02/07/2018	*interest holder*	*Bullwaddy Pastoral*	*Adrian Brown*	*written*	*Notification of Origins Beetaloo exploration project- commencing Monday 9 July 2018*	*Appendix K part B page 2-3 and Appendix I*	*No*	*NA*	*NA*	*NA*
20/08/2018	*interest holder*	*Bullwaddy Pastoral*	*Adrian Brown*	*Written*	*Letter to commence discussions for land access, including provision of draft work program, potential well locations access routes and other associated infrastructure.*	*Appendix K, Part B page 4*	*No*	*NA*	*NA*	*NA*
22/08/2018	*interest holder*	*Bullwaddy Pastoral*	*Adrian Brown*	*Written and Verbal*	*Summary of phone conversation and follow up provision of map for proposed activities, timeline, draft preliminary works agreement, ecological and cultural heritage scouting access*	*Appendix K, Part B page 5-9*	*No*	*NA*	*NA*	*NA*
22/08/2019	*interest holder*	*Bullwaddy Pastoral*	*Adrian Brown*	*Written*	*Letter to commence discussion on preliminary activities (including scouting, environmental monitoring maintenance etc.) and provision of draft access and compensation agreement. Draft access agreement includes description of activity, summary of key risks and controls (well integrity, impairments to aquifers and organic status, rehabilitation, soil erosion, biosecurity, fire, waste, environmental monitoring*	*Appendix K, Part B page 10-65*	*No*	*NA*	*NA*	*NA*
11/03/2019	*interest holder*	*Hayfield Shenandoah Station*	*Val Dyer*	*Written*	*Written correspondence between Pastoralist adding in access track to Amungee boundary as a part of compensation agreement.*	*Appendix K, Part B page 300-301*	*No*	*NA*	*NA*	*NA*
14/03/2019	*Stakeholder*	*Origin Energy*	*David Armstrong*	*Written*	*Written correspondence between Pastoralist and Origin confirming additional variation added to agreement*	*Appendix K, Part B page 302*	*No*	*NA*	*NA*	*NA*
17/05/2019	*interest holder*	*Bullwaddy Pastoral and BBRC Capital*	*Emanate legal*	*Written*	*Provision of Weed Management Plan and traffic Management Plan addressing weed and ttraffic related risks*	*Appendix K, Part B page 304-477*	*No*	*NA*	*NA*	*NA*

Date	Originator of communication	Company of contact	Person of contact	Contact type	Summary of contact	Copy of contact or information provided (if written)	Does it trigger merit review?	A statement of the interest holders response to stakeholder	Change to EMP required ?	Details of changes the interest holder has made as a result of the stakeholder engagement
22/05/2019	interest holder	Bullwaddy Pastoral and BBRC Capital	Emanate legal	Written	Provision of the draft Velkerri 76 S2 civil construction Environmental Management Plan in its entirety. This includes a comprehensive description of all activities, potential impacts to the pastoralists activities and all environmental risks.	Appendix K, Part B page 69-70, EMP Appendix K, Part B Page 477-1161	No	NA	NA	NA
23-244/5/2019	interest holder	Bullwaddy Pastoral and BBRC Capital	Emanate legal	Meeting/ Written	Meeting with BBRC and Bullwaddy Pastoral representative to discuss program, including stakeholder engagement and environemntal controls to key risks.	Appendix K, Part B page 303, Story Boards presented Appendix K, Part B Page 268- 280	No	NA	NA	NA
29/05/2019	stakeholder	Origin Energy	KWM	Written	Emanate responding to Origin Energy Correspondence regarding Review of EMP's	Appendix K, Part B page 71-73	No	NA	NA	NA
31/05/2019	interest holder	Bullwaddy Pastoral and BBRC Capital	Emanate legal	Written	Origin Energy responding to Emanate correspondence regarding review of EMP's	Appendix K, Part B page 74-75	No	NA	NA	NA
03/06/2019	stakeholder	Origin Energy	KWM	Written	Emanate responding to Origin Energy Correspondence regarding Review of EMP's	Appendix K, Part B page 76-77	No	NA	NA	NA
05/06/2019	interest holder	Bullwaddy Pastoral and BBRC Capital	Emanate legal	Written	Origin Energy responding to Emanate correspondence regarding review of EMP's	Appendix K, Part B page 78-79	No	NA	NA	NA
09/06/2019	stakeholder	Origin Energy	KWM	Written	Request for cloudGMS hydrogeology report	Appendix K, Part B page 80	No	NA	NA	NA
09/07/2019	interested	Bullwaddy Pastoral and BBRC Capital	Emanate legal	Written	Origin responding to stakeholder request for hydrogeological report and stakeholder engagement comments.	Appendix K, Part B page 81	No	NA	NA	NA
09/07/2019	stakeholder	Origin Energy	KWM	Written	Stakeholder responding to Origin email regarding status of comments from stakeholder review of civil EMP. Stakeholder outlined comments were pending and provide general comments on EMP in regards to Petroleum (Environment) Regulations	Appendix K, Part B page 82-84	No	NA	NA	NA

Date	Originator of communication	Company of contact	Person of contact	Contact type	Summary of contact	Copy of contact or information provided (if written)	Does it trigger merit review?	A statement of the interest holders response to stakeholder	Change to EMP required ?	Details of changes the interest holder has made as a result of the stakeholder engagement
10/07/2019	*interest holder*	*Bullwaddy Pastoral and BBRC Capital*	*Emanate legal*	*Written*	*Origin Energy provision of Cloud GMS report*	*Appendix K, Part B page 85-144*	*No*	*NA*	*NA*	*NA*
10/07/2019	*stakeholder*	*Origin Energy*	*KWM*	*Written*	*Emanate indicating third party review comments received*	*Appendix K, Part B page 145*	*No*	*NA*	*NA*	*NA*
10/07/2019	*stakeholder*	*Origin Energy*	*KWM*	*Written*	*Emanate providing third party review comments of EMP. Comments were largely focus of hydraulic fracturing- which was not the subject of this EMP. Comments were also received regarding the adequacy of groundwater monitoring program, which is out of Origin's control being mandated through the codes of Practice and Preliminary guideline for groundwater monitoring*	*Appendix K, Part B page 146-169*	*No*	*Yes*	*Yes*	*Administration changes made to EMP including: 1. Provision of additional, zoomed in map suites of all proposed activity areas. 2. Additional information regarding potential pastoralists impacts into risk assessment and environmental risk management summary tables 3. provision of updated Land Condition Assessment to address inconsistencies in locations caused by NLC/AAPA data error*
12/07/2019	*interest holder*	*Bullwaddy Pastoral and BBRC Capital*	*Emanate legal*	*Written*	*Origin provide response to comments from Emanate. This included the commitment to provide additional maps and submit an additional EMP covering Stimulation activities.*	*Appendix K, Part B Page 170-172*	*No*	*NA*	*NA*	*NA*
10/07/2018	*Interest holder*	*NLC*	*Greg Macdonald*	*Written*	*Origin request to obtain site clearances for its proposed 2018/19 exploration program. This request included a description of the proposed activities, estimated duration and summary of key environmental considerations and risk controls.*	*Appendix K, Part B Page 173-186*	*No*	*NA*	*NA*	*NA*
17/07/2018	*Interest holder*	*NLC*	*Greg Macdonald*	*Written*	*Origin provided additional information regarding maps and proposed site locations.*	*Appendix K, Part B Page 187-191*	*No*	*NA*	*NA*	*NA*

Date	Originator of communication	Company of contact	Person of contact	Contact type	Summary of contact	Copy of contact or information provided (if written)	Does it trigger merit review?	A statement of the interest holders response to stakeholder	Change to EMP required ?	Details of changes the interest holder has made as a result of the stakeholder engagement
03/09/2019	*Interest holder*	*NLC*	*Greg Macdonald*	*Meeting*	*Meeting to discuss up coming site clearances and scope amendment by Origin. Additional information on lese pad layout and revised site list include. Location in proximity to Jingaloo community Kyalla W2-1 removed from scope*		*No*	*NA*	*NA*	*NA*
04/09/2018	*Interest holder*	*NLC*	*Greg Macdonald*	*Meeting*	*Revised work program spatial information sent to NLC outlining variation to site clearance scope. Additional information on lese pad layout and revised site list included*	*Appendix K, Part B Page 198-199*	*No*	*No*	*Yes*	*Location in proximity to Jingaloo community Kyalla W2-1 removed from scope*
16/11/2019	*stakeholder*	*Origin Energy*	*Stephanie Stonier*	*Written*	*NC Conditions of Work Report to Operator _Origin_181115 received. Report summarised clearance activities, identified restricted work areas and conditions of work.*	*Appendix K, Part B Page 200-250*	*No*	*Yes*	*Yes*	*Identified restricted work areas and conditions of work add to the emp where relevant.*
03/04/2019-10/04/2019	*Interest Holder*	*NLC/TO*	*NLC/TO*	*Meeting*	*x6 on country meetings in Elliot with Native Title family groups regarding NLC Cleared Areas CA3 (Amungee NW1H (existing well site location), CA5 (Kyalla 117) and CA10 (Velkerri 76). Wednesday 8 May 2019, X1 meeting in Darwin with Native Title family for NLC Cleared Areas from Sacred Site Clearance and Avoidance Survey in response to Origin's WPS - All meeting included overview of the proposed work program and the environmental controls to address environmental risks. Origin used Story boards to present and discuss key aspects regarding the environment and its protection*	*Appendix K, Part B Page 268- 280*	*No*	*NA*	*NA*	*NA*
23/01/2019	*Interest Holder*	*AAPA*	*AAPA*	*Written*	*Electronic application AAPA to Amend AAPA Certificate 2018/103 to include drilling, well testing and hydraulic fracturing activities*	*Appendix K, Part B Page 262-264*	*No*	*NA*	*NA*	*NA*
18/02/2019	*Interest Holder*	*AAPA*	*AAPA*	*Written*	*Email confirmation of wording within AAPA certificate 2018/13 variation application*	*Appendix K, Part B Page 261*	*No*	*NA*	*NA*	*NA*

Date	Originator of communication	Company of contact	Person of contact	Contact type	Summary of contact	Copy of contact or information provided (if written)	Does it trigger merit review?	A statement of the interest holders response to stakeholder	Change to EMP required ?	Details of changes the interest holder has made as a result of the stakeholder engagement
18/02/2019	*stakeholder*	*Origin Energy*	*Stephanie Stonier*	*Written*	*Email requesting information associated with AAPA certificate amendment 2018/103 to include hydraulic fracture activities.*	*Appendix K, Part B Page 260*	*No*	*NA*	*NA*	*NA*
19/02/2019	*Interest Holder*	*AAPA*	*AAPA*	*Written*	*Email providing information requested from AAPA including exploration agreement with custodians and anthropological reports*	*Appendix K, Part B Page Pages 259*	*No*	*NA*	*NA*	*NA*
19/02/2019	*stakeholder*	*Origin Energy*	*Stephanie Stonier*	*Written*	*AAPA email to Origin confirming receipt of information.*	*Appendix K, Part B Pages 259-260*	*No*	*NA*	*NA*	*NA*
07/03/2019	*Interest Holder*	*AAPA*	*AAPA*	*Written*	*AAPA issuing or AAPA certificate C2019/014 covering all drilling, stimulation and well testing activities. Please note, no constraint identifed within the AAPA certificate (such as use of borrow pit identified) related to the Velekrri 76 S2 site.*	*Appendix K, Part B page 280- 290*	*No*	*Yes*	*Yes*	*Identified restricted work areas and conditions of work add to the emp where relevant.*
23/04/2019	*stakeholder*	*Origin Energy*	*Stephanie Stonier*	*Written*	*Electronic application to ammend certification C2019/014*	*Appendix K, Part B Page 265-267*	*No*	*NA*	*NA*	*NA*
23/04/2019	*Interest Holder*	*AAPA*	*AAPA*	*Written*	*Email confirmation of variation lodged for AAPA certificate C2019/014 to updated Gravel pit locations resulting from a report error*	*Appendix K, Part B Page Pages 254*	*No*	*NA*	*NA*	*NA*
24/04/2019	*stakeholder*	*Origin Energy*	*Stephanie Stonier*	*Written*	*Updated GIS coordinate re-issued by AAPA due to GIS discrepancy with NLC data.*	*Appendix K, Part B Page 251-253*	*No*	*Yes*	*Yes*	*Gravel pit location amended through EMP to reflect correct locations*
09/05/2019	*Stakeholder*	*Origin Energy*	*Stephanie Stonier*	*Written*	*AAPA issuing of AAPA cerftficate C2019/039*	*Appendix K, Part B Pages 291-299*	*No*	*Yes*	*Yes*	*Gravel pit location amended through EMP to reflect correct locations*

Date	Originator of communication	Company of contact	Person of contact	Contact type	Summary of contact	Copy of contact or information provided (if written)	Does it trigger merit review?	A statement of the interest holders response to stakeholder	Change to EMP required ?	Details of changes the interest holder has made as a result of the stakeholder engagement
16/07/2019	Interest Holder	Bullwaddy Pastoral and BBRC Capital	Emanate Legal	Written	Email and Amungee Mungee Station Stakeholder Engagement Pack	Appendix K, Part B Pages 1161 - 1263	No	NA	No	
06/09/2019	Stakeholder	Origin Energy	KWM	Written	Stakeholder provides Origin stakeholder's expert reports	Appendix K, Part B Pages 1264 - 1341	No	NA	No	
06/09/2019	Interest Holder	Bullwaddy Pastoral and BBRC Capital	Emanate Legal	Written	Email chain between KWM and Emanate Legal responding to stakeholder's concerns about specific environmental impacts, risks and outcomes identified by stakeholder	Appendix K, Part B Pages 1342 - 1351	No	Yes	No	
09/09/2019	Stakeholder	Origin Energy	KWM	Written	Email from stakeholder responding to Origin's comments about specific environmental impacts, risks and outcomes identified by stakeholder	Appendix K, Part B Pages 1352 - 1357	No	NA	No	
20/09/2019	Interest Holder	Bullwaddy Pastoral and BBRC Capital	Emanate Legal	Written	Email and Origin response to Amungee export review	Appendix K, Part B Pages 1358 - 1433	No	Yes	Yes	Additional information included in the EMP covering Origin's response to contamination Section 3.15, 6.5.1, 6.5.2,6.5.3. Additional information also provided in the hydrogeology section 4.1.6 and seismicity section (4.1.4).

Appendix K Stakeholder Engagement Summary and Evidence

Part A- Stakeholder Compliance summary

Section 7(2)(a)	Document and Content	Date Provided

(i) "the regulated activity the interest holder proposes to carry out"	**Letter from Origin to Adrian Brown (on behalf of Amungee)**
	
	• Includes a table outlining the regulated activities Origin proposes to perform for Velkerri Well 76, including:
	  o Drilling of 1-3 new wells;
	  o Construction of a new well pad;
	  o Drilling of 3-4 new water bores (1-2 extraction and 2 monitoring);
	  o Construction of a drilling camp; and
	  o Construction of a new access road.
	• Includes a timetable outlining the work program Origin proposes to undertake.
		22 August 2018

	Draft Pastoral Land Access and Compensation Agreement
	
	• Item 1 of Schedule 2 (P30 – 33) lists the Agreed Petroleum Activities which include all activities and works reasonably associated with the construction and operation of one exploration well and includes the following activities:
	  o Gates, grids, fences and access points;
	  o Existing access roads;
	  o New access track(s);
	  o Petroleum exploration well;
	  o Rig laydown area;
	  o Laydown area;
	  o Water bore;
	  o Campsite; and
	  o Scouting, surveys and soil and water sampling activities.
	• Item 3 of Schedule 2 (P34) list the indicative duration of the Agreed Petroleum Activities.
		20 November 2018

	Beetaloo Basin Exploration Project – Weed Management Plan (**Appendix O**)	17 May 2019

	• Lists the primary activities subject to the Weed Management Plan as being (P5): o Access track construction, use and maintenance; o Exploration lease pad construction, use and maintenance; o Gravel pit construction and maintenance; o Drilling, stimulating, completing and maintaining petroleum exploration wells; and • Routine access, maintenance and monitoring of all exploration areas subject to this plan.	
	Trafficwerx NT Traffic Management Plan • Provides that a temporary site access road will be constructed as a regulated activity (P2-3), including project dates, hours of work, duration and traffic management plans.	17 May 2019
	Origin Drilling For Shale Gas Poster • Explains that the exploration program for future activities will include drilling of both vertical and horizontal wells. Provides a description of the steps involved in drilling horizontal wells.	24 May 2019
	Stakeholder Engagement Pack – Velkerri 76 S2 – Amungee Mungee Station • Section 2 describes the regulated activities as being the activities associated with the drilling, stimulation and well testing of the proposed Velkerri 76 S2 exploration well which include (P2 and P3): o Installation of an additional two groundwater extraction and groundwater monitoring bores o Access to the following nominated, precleared areas covered under the previous civil construction and water bore EMPs: ▪ exploration well lease pad (4.5 ha) and wet weather laydown yard (1 ha) ▪ temporary camp lease pad (1.2 ha) ▪ helipad (0.5ha) ▪ stockpile area (0.2ha) ▪ 4 gravel pits and associated access tracks (6.4ha) o The drilling of the Velkerri 76 S2-1 horizontal exploration well including: ▪ Drilling of a vertical well 2000-3000m below ground level ▪ Drilling of a horizontal well section up to 3000m o Hydraulic fracture stimulation of a horizontal exploration well ▪ Stimulation of up to 20 stages	16 July 2019

	o Exploration well completion and testing
	    ▪ up to 12 months of well testing
	    ▪ up to 16ML of flowback stored in enclosed tank
	    ▪ use of evaporation tanks to reduce the volume of wastewater
	o Exploration well suspension and decommissioning
	o Construction and operation of a temporary camp
	o Asset maintenance and monitoring works
	o Site decommissioning and rehabilitation
	o All activities ancillary to the above.
	• A detailed description of the regulated activities and their mitigation measures/controls are summarised between P2 and P36.	

(ii) "the location (or locations) where it is proposed to carry out the activity"	**Email from Origin to Adrian Brown** • An Origin representative offers to arrange a sit down meeting with Adrian Brown of Bullwaddy Pastoral Co Pty Limited, part owner of Amungee Mungee Station, to go through the well location selection process and ranking.	2 July 2018
	Letter from Origin to Adrian Brown (as representative for joint owners of Amungee Mungee Station) • Includes a map of potential well location clearance areas, coordinates of new wells and proximity requirements of supporting facilities. • The work programme timeline attached to the letter allowed the landholder to gain an understanding of the impacts on its operations of Origin's early phase works and the later fracking and stimulation phase.	22 August 2018
	Draft Pastoral Land Access and Compensation Agreement • Identifies the affected Pastoral Property (NT Portion 1079, Vol 786 Folio 762) activities to be undertaken on (P1). • Item 2 of Schedule 2 states the access tracks and well site are shown in the plans attached to Annexure D of the agreement. No plans are attached to Annexure D (P34).	20 November 2018
	Beetaloo Basin Exploration Project – Weed Management Plan (**Appendix O**) • Includes maps of the proposed exploration activities and locations of current weed growth and of high weed risk in relation to proposed well locations (high-aerial view) (P4, 10 – 12).	17 May 2019

	Trafficwerx NT Traffic Management Plan • Includes multiple detailed diagrams outlining the construction areas of the proposed access roads in relation to the Stuart Highway (Appendix C – P46 to 52, Appendix K P68). • Provides for the specific location of the proposed access road along the Stuart Highway (P1).	17 May 2019
	Origin Groundwater Monitoring Poster • Includes a map of proposed Phase 1 exploration wells and proximity to Origin's monitored water bores.	24 May 2019
	Origin Beetaloo Exploration Project Poster • Includes a map of Origin EP98, EP117 and EP76 locations.	24 May 2019
	Origin 2019 Work Program Poster (**Appendix L**) • Includes a map of EP98, EP117 and EP76 and the location of each Phase 1 exploration well in broader EP98, EP117 and EP76 area. • Includes a map of the drilling surface location in proximity to the Stuart Highway.	24 May 2019
	Stakeholder Engagement Pack – Velkerri 76 S2 – Amungee Mungee Station • Section 2: o P3 - Table 1 (proposed infrastructure location and disturbance area); o P4 - Figure 2 (location of proposed activities within Origin's exploration tenure); o P1 - Figure 3 (site location map); o P8 – Figure 6 (example drilling rig set up in the Beetaloo); o P11 – Figure 7 (hydraulic fracture stimulation spread); and o P15 – Figure 9 (sample well test schematic). • Section 3:	16 July 2019

	o P37 - Table 6 (Velkerri 76 S2 Condition Description) provides coordinates. • Appendix B included plans of the regulated activities on Amungee Mungee Station (see P61 onwards).	
(iii) "the anticipated environmental impacts and environmental risks of the activity" **AND** **(iv)** "the proposed environmental outcomes in relation to the activity"	**Stakeholder Engagement Pack – Velkerri 76 S2 – Amungee Mungee Station** • Section 4: o Includes an outline of Origin's risk management approach (P38). o Includes information about Origin's Risk Rating Toolkit (P39) and Risk Matrix (P40). o Includes detailed tables of environmental impacts, risks and outcomes of the regulated activities for specific environmental aspects, including: ▪ Soils (P41 – Table 7); ▪ Surface water (P42 – Table 8); ▪ Groundwater (P43 – Table 9); ▪ Vegetation, Flora, Fauna and Habitat (P44 – Table 10); ▪ Weeds (P 45 – Table 11); ▪ Waste Management (P46 – Table 12); ▪ Air Quality (Dust and Emissions) (P47 – Table 13); ▪ Lighting, noise, vibration and visual amenity (P48 – Table 14); ▪ Bushfires (P49 – Table 15); ▪ Cultural heritage and sacred sites (P50 – Table 16); ▪ Social Environment (P51 – Table 17); and ▪ Traffic (P52 – Table 18). o Appendix C includes Origin's environmental risk assessment (see P62 onwards).	16 July 2019
	Beetaloo Basin Exploration Project – Weed Management Plan (**Appendix O**) • The purpose of the Plan is to ensure the risk of weed introduction and spread, resulting from the regulated activities performed by Origin, are mitigated to protect (among other things) the environmental interests of the Territory (P4). • Considers the risk of weed spreading and introduction with evidence from previous weed management surveys conducted on the land (P9 - 17 – incl. Table 4).	17 May 2019
	Trafficwerx NT Traffic Management Plan	17 May 2019

	• Includes references to the anticipated environmental impacts or environmental risks of access track construction and other traffic-environment aspects in describing environmental management processes and outcomes.	
	Email from Scott Singleton (King & Wood Mallesons) to Nicholas Taylor (Emanate Legal) • Responds to email from Nicholas Taylor (Emanate Legal) on 2 September 2019. Provides clarification (by reference to the Stakeholder Engagement Pack sent to Amungee Mungee on 16 July 2019) on how a range of environmental impacts and risks associated with the regulated activities will be controlled, including: o Mobilisation of fluids toward the surface of the land, activated by faults; o Fault reactivation and structural integrity of the subsurface; o Generation of earthquakes or seismic activity as a result of drilling and/or hydraulic stimulation of the well; o Fluid or chemical spills; o Drilling or stimulation of the well within 895m of any faults within the subsurface; o Groundwater contamination; o Pastoral activities on the land; and o The removal, repair and replacement of structures and improvements on land.	6 September 2019
	Origin Response to Amungee hydrogeological expert report • Document details Origin's response to Amungee Mungee's hydrogeological expert report, prepared by Paul Whincup. • Origin's response includes detail on the control of environmental risks and impacts associated with the regulated activities including: o Impacts on groundwater and surface water flow; o Contamination of groundwater and surface water; o Activation and reactivation of faults; and o Seismic activity and earthquakes.	

(v) "the possible consequences of carrying out the activity to the stakeholder's rights or activities"	**Beetaloo Basin Exploration Project – Weed Management Plan** (**Appendix O**) • The plan details the risk mitigation measures to be implemented to control / prevent weed spread. The plan demonstrates how risk of week spread will be managed to ensure there is no consequence in this regard to the stakeholders' rights and activities.	17 May 2019
	Trafficwerx NT Traffic Management Plan • The plan sets out the scope of work to establish a temporary site access road during construction. The location of the access track across the plaintiffs' property is detailed (P2). • The plan includes information about project dates and what times of day traffic management will be in place (P3). • Discussion about how traffic impacts will be managed are discussed in relation to fumes, volatile substances, noise, air quality (P13). • There are maps referencing the access road works proposed to be undertaken which outline impacts to traffic on the Stuart Highway (P46-52).	17 May 2019

	Stakeholder Engagement Pack – Velkerri 76 S2 – Amungee Mungee Station
	• Table 19 (P53) provides a detailed summary of potential consequences and control measures of the carrying out of the regulated activities Amungee Mungee's rights and activities, including:
	  • Reduction in grazing area;
	  • Restricted access to well lease pads during activity duration;
	  • Traffic along access track;
	  • Temporary access restrictions during rig mobilisations and heavy transport operations;
	  • Interference with stock;
	  • Contamination of soils from activities;
	  • Impact to organic certification;
	  • Pastoral bores rates and/or quality;
		16 July 2019

	• Noxious weeds; • Dust; • Increased emissions from flares and wells; • Interaction with stock; and • Pastoral visual amenity.	
	Email from Scott Singleton (King & Wood Mallesons) to Nicholas Taylor (Emanate Legal) (Appendix L) • Responds to email from Nicholas Taylor (Emanate Legal) on 2 September 2019. Provides clarification (by reference to the Stakeholder Engagement Pack sent to Amungee Mungee on 16 July 2019) on how a range of environmental impacts and risks associated with the regulated activities will be controlled, including: o Mobilisation of fluids toward the surface of the land, activated by faults; o Fault reactivation and structural integrity of the subsurface; o Generation of earthquakes or seismic activity as a result of drilling and/or hydraulic stimulation of the well; o Fluid or chemical spills; o Drilling or stimulation of the well within 895m of any faults within the subsurface; o Groundwater contamination; o Pastoral activities on the land; and o The removal, repair and replacement of structures and improvements on land.	6 September 2019
	Origin Response to Amungee hydrogeological expert report (Appendix L) • Document details Origin's response to Amungee Mungee's hydrogeological expert report, prepared by Paul Whincup. • Origin's response provides detail of the possible consequences of the regulated activities on Amungee's activities and how these consequences will be controlled or mitigated including: o Impacts on groundwater and surface water flow (having consequences for Amungee's water management);	23/09/2019

	o Contamination of groundwater and surface water; o Activation and reactivation of faults (with the potential for contaminants to flow the surface); and o Earthquakes.	

Part B- Stakeholder Engagement Detailed Information

Information redacted to protect privacy and commercial in confidence information

Appendix L: Community Engagement Log

Engagement item	Date of engagement
Darwin show Origin representative attended industry booth. Origin provided educational material in the form of story boards covering its proposed exploration activities, including an overview of shale exploration and hydraulic fracturing activities. Origin representatives also answered community questions about the Beetaloo exploration project and potential future job opportunities.	**25/07/2019**
Katherine Show Origin representative attended industry booth. Origin provided educational material in the form of story boards covering its proposed exploration activities, including an overview of shale exploration and hydraulic fracturing activities. Origin representatives also answered community questions about the Beetaloo exploration project and potential future job opportunities.	**19/07/2019**
Tennant Creek show Origin representative attended industry booth. Origin provided educational material in the form of story boards covering its proposed exploration activities, including an overview of shale exploration and hydraulic fracturing activities. Origin representatives also answered community questions about the Beetaloo exploration project and potential future job opportunities.	**12/07/2019**
Beetaloo "Meet the buyer" event with NT business in Tennant Creek Origin presented an overview of the Beetaloo exploration project, including local procurement opportunities to local business representatives. 1 on 1 meetings were held with local businesses to further understand capabilities.	**11/07/2019**
Beetaloo "Meet the buyer" event with NT business in Alice Springs Origin presented an overview of the Beetaloo exploration project, including local procurement opportunities to local business representatives. 1 on 1 meetings were held with local businesses to further understand capabilities.	**09/07/2019**
Full council meeting of the Northern Land Council Origin representatives presented an overview of the Beetaloo Exploration Project to the NLC council.	**17/06/2019**
Beetaloo "Meet the buyer" event with NT business in Darwin Origin presented an overview of the Beetaloo exploration project, including local procurement opportunities to local business representatives. Origin's tier 1 contractors (such as Drillers and completion providers) also presented an outline of their scope and opportunities. 1 on 1 meetings were held with local businesses to further understand capabilities.	**06/06/2019**
Katherine mining services association conference Origin presented to the conference an overview and update on the Beetaloo Exploration Project.	**16/05/2019**
Darwin Port users Group	**04/04/2019**

Engagement item	Date of engagement
Origin presented to the group an overview and update on the Beetaloo Exploration Project.	
GHD Beetaloo discussion Provided an update of the Beetaloo exploration project	**03/04/2019**
NT Cattleman's Association annual conference Origin representative attended the conference	**28/03/2019**
Meeting with the Alice Spring Chamber of Commerce annual conference Origin representative presented an overview and update of the Beetaloo exploration project and future business opportunities.	**18/03/2019**
NT Inquiry Community Business Reference Meeting Origin representative presented an overview and update of the Beetaloo exploration project	**12/03/2019**
Meeting with the Industry Capability Network Discussed the future Beetaloo exploration program and future opportunities	**22/03/2019**
NT Economic Recovery Summit Origin representative presented an overview and update of the Beetaloo exploration project and future business opportunities.	**27/02/2019**
Indigenous Business Network Board Origin representative presented an overview and update of the Beetaloo exploration project and future potential indigenous employment and business opportunities.	**15/02/2019**
Energy Club NT Origin representative presented an overview and update of the Beetaloo exploration project, an update of the Us shale trip and future business opportunities.	**13/02/2019**
Industry Capability Network Origin provided an update to the Beetaloo exploration project and answered questions on the project.	**01/02/2019**
Roper Gulf regional Council Meeting to discuss overview of the Beetaloo Exploration project and forward plans	**19-Dec-18**
Geological and Bioregional Assessment Workshop- CSIRO, DENR, DIPR, Santos, Pangea and Central Petroleum Origin presented information : • Origin's tenure • Geology of the region	**04-05/12/2018**

Engagement item	Date of engagement
• proposed forward exploration activities	
Roper Gulf Regional Council Origin provided an update on the Beetaloo Exploration Project.	**19-Oct-18**
NT Government Department of Business Innovation and Trade Origin provided an overview of the forward Beetaloo exploration project.	**13-Oct-18**
Geological and Bioregional Assessment Meeting Discussion regarding the geology and hydrogeology of the Beetaloo Basin **Beetaloo industry operators meeting with CSIRO, DENR, Santos and Pangea** General discussion on Origin's Beetaloo exploration project Discussion of water and wastewater management in the Beetaloo	**11-Oct-18**
Beetaloo industry operators meeting with CSIRO, DENR, Santos and Pangea General discussion on Origin's Beetaloo exploration project Discussion of methane emission monitoring and management in the Beetaloo	**10-Oct-18**
Barkly Regional Council Provided update on the Beetaloo Exploration project	**27-Sep-18**
Barkly Regional Economic Development Committee Provided of the Beetaloo Exploration project	**27-Sep-18**
	25-Sep-20
Charles Darwin University Meeting in Alice Springs to provide a project update and discuss training options for trades	**13-Sep-18**
Darwin Major Business Group Meeting Provided of the Beetaloo Exploration project	**06-Sep-18**
Meeting with Northern Land Council Meeting to discuss Beetaloo sacred sites clearance survey for future exploration work.	**03-Sep-19**
Geological and Bioregional Assessments first User Panel meeting Provided updated of Beetaloo exploration project and discussed forward GBA program	
Darwin show Origin representative manning the APPEA booth providing an overview of the Beetaloo exploration project	**26-Jul-19**

Engagement item	Date of engagement
Katherine show Origin representative manning the APPEA booth providing an overview of the Beetaloo exploration project	**20-Jul-19**
CSIRO Meeting to discuss Beetaloo project overview and proposed background methane monitoring program across Origin's tenure	**16-Jul-19**
Tennant Creek Show Origin representative manning the APPEA booth providing an overview of the Beetaloo exploration project	**13-Jul-19**
Alice Springs Show Origin representative manning the APPEA booth providing an overview of the Beetaloo exploration project	**06-Jul-18**
Northern Land council meeting to discuss the update on sacred site clearances for the proposed 2019 potential locations for exploration activities	
Engineers Australia Young Pipelines and Young Engineers Australia Origin presented information : • Origin's tenure • Geology of the region • proposed forward exploration activities	**28-Jun-19**
NT Department of Primary industry and Resources and Department of Environment and Natural Resources Discussing regarding the Inquiry recommendations and implementation strategy.	**27-Jun-18**
GHD Origin provided GHD an overview of the future Beetaloo exploration program	**24/05/2018 and 25/06/2018**
NT Department of Primary industry and Resources and Department of Environment and Natural Resources Discussing regarding the Inquiry recommendations and implementation strategy.	**25-May-18**
NT Department of Primary industry and Resources and Department of Environment and Natural Resources Discussing regarding the Inquiry recommendations and implementation strategy.	**18-May-18**
Meeting with the NT Government Delegation at the APPEA conference update on the potential forward Beetaloo exploration project	**16-May-18**

Engagement item	Date of engagement
NT Daly Waters Camp Draft Origin sponsored and attended event	**05/05/2018**
NT Department of Primary industry and Resources Discussing regarding the Inquiry recommendations and implementation strategy.	**03/05/2018**
Northern Territory Cattleman's Association Origin representatives attended NTCA	**23-Mar-18**
Alice Springs Chamber of Commerce Alice Springs Regional Mining conference Origin representatives attended NTCA	**19-Mar-18**

Appendix M Origin Poster Series

2019 Work Program

This year's work program consists of two exploration wells to evaluate liquids rich gas potential.

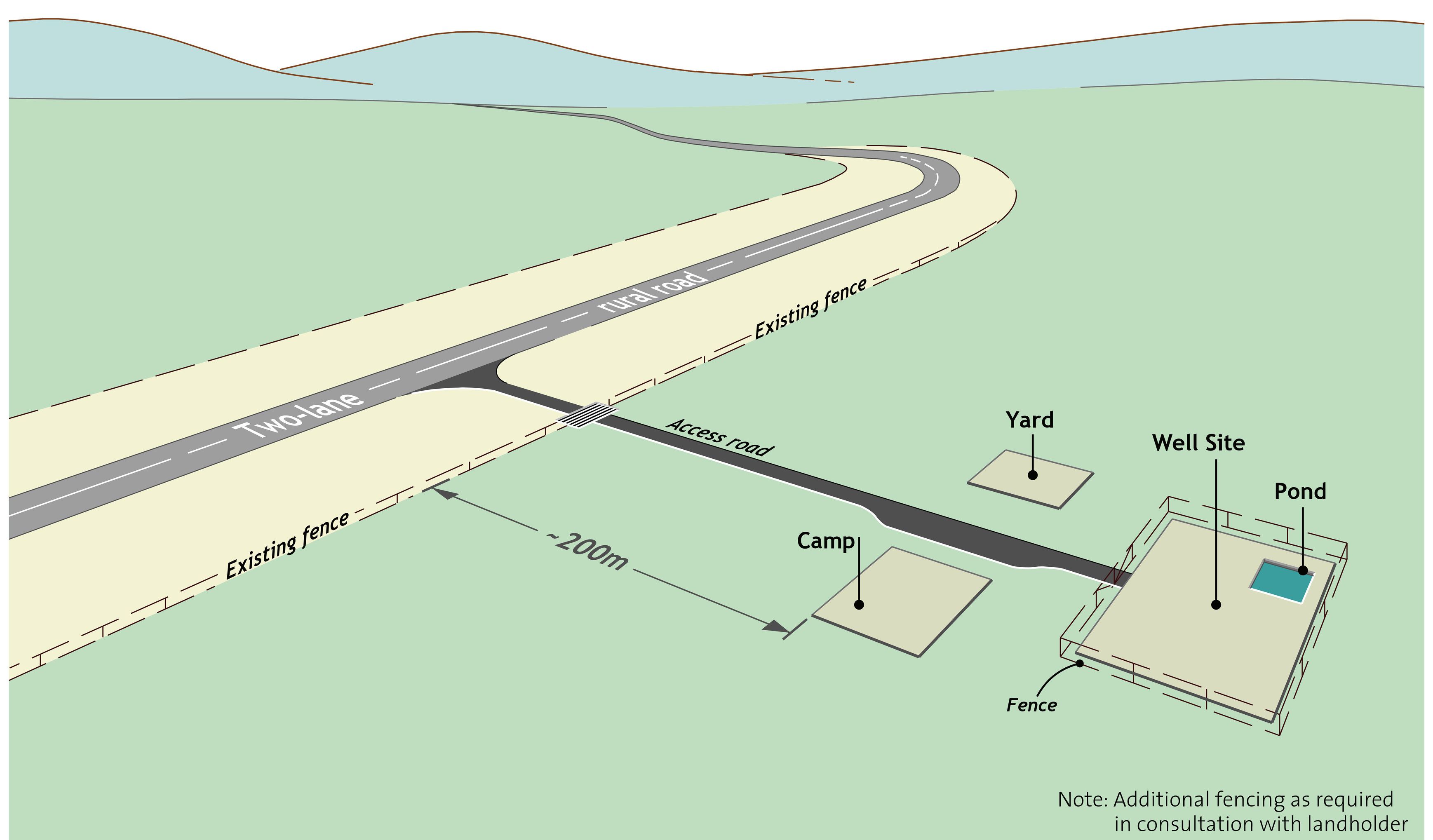
EP 76 Drill and fracture stimulate the Velkerri 76 well

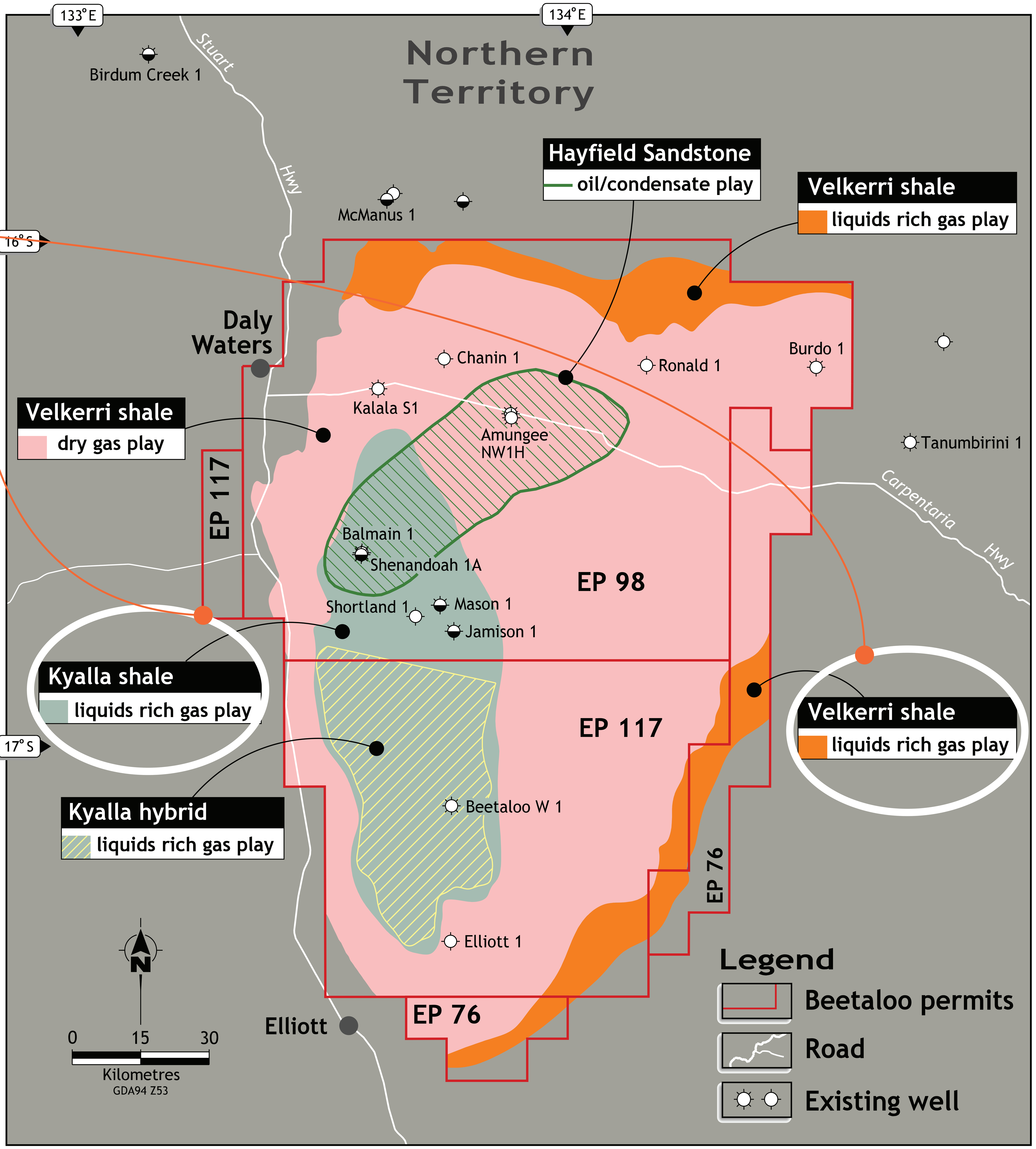
EP 117 Drill and fracture stimulate the Kyalla 117 well

Native Title Holders and custodians together with the Northern Land Council (NLC) completed sacred site clearance and avoidance surveys for this work in September 2018.

Geological studies will continue in other exploration permit areas.

Drilling surface location layout





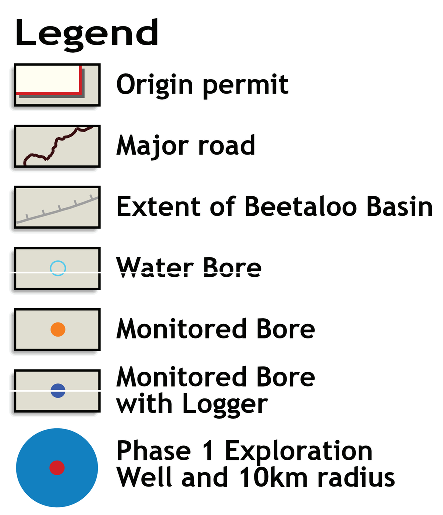
Amungee NW-1 & NW-1H
(Drilling & Environmental Controls)

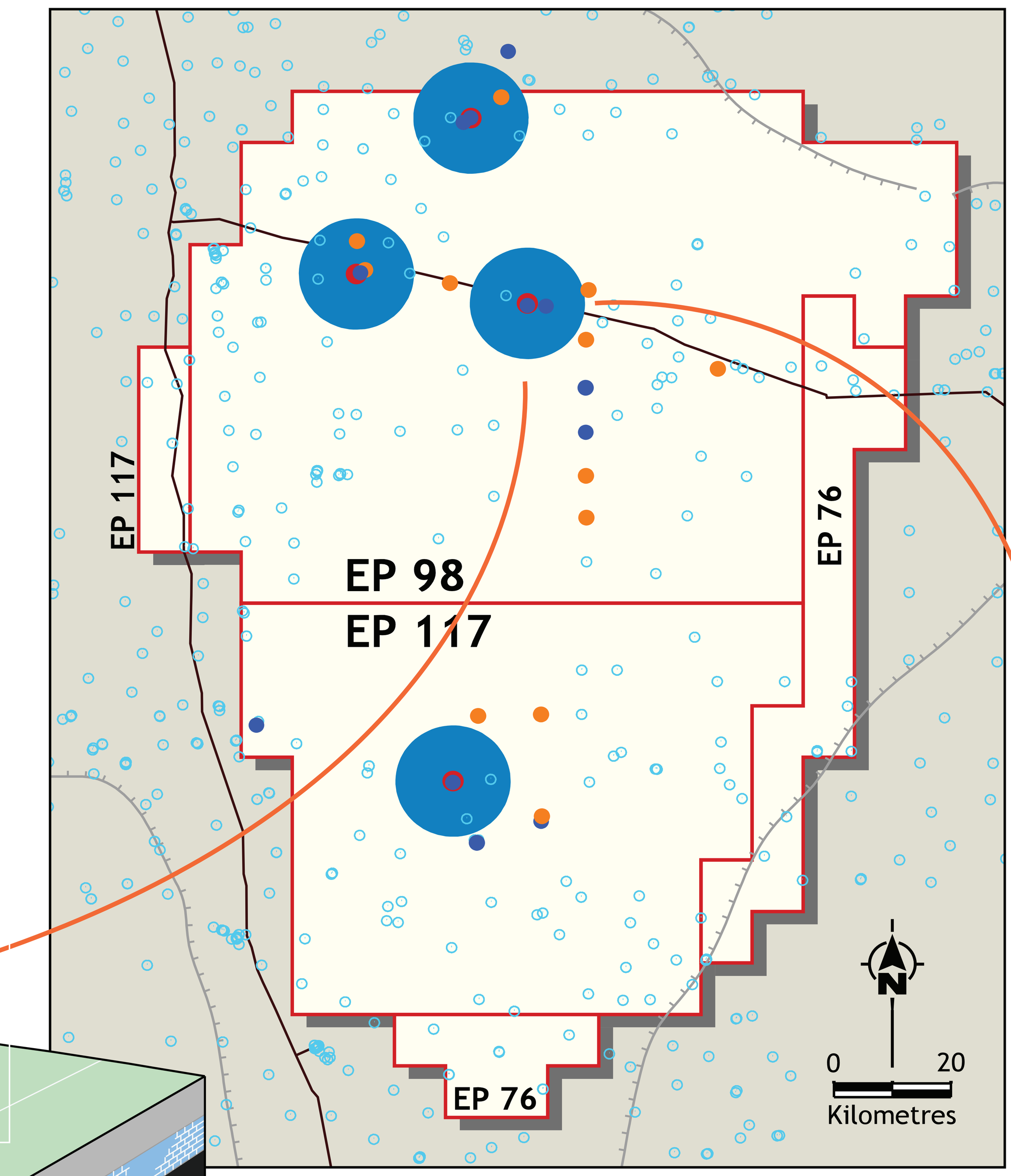
The Amungee NW-1 / NW-1H well is in the in centre of Exploration Permit 98 (EP98) in the northern Beetaloo Sub-Basin, just south of the Carpentaria Highway and around 60 km east of Daly Waters.

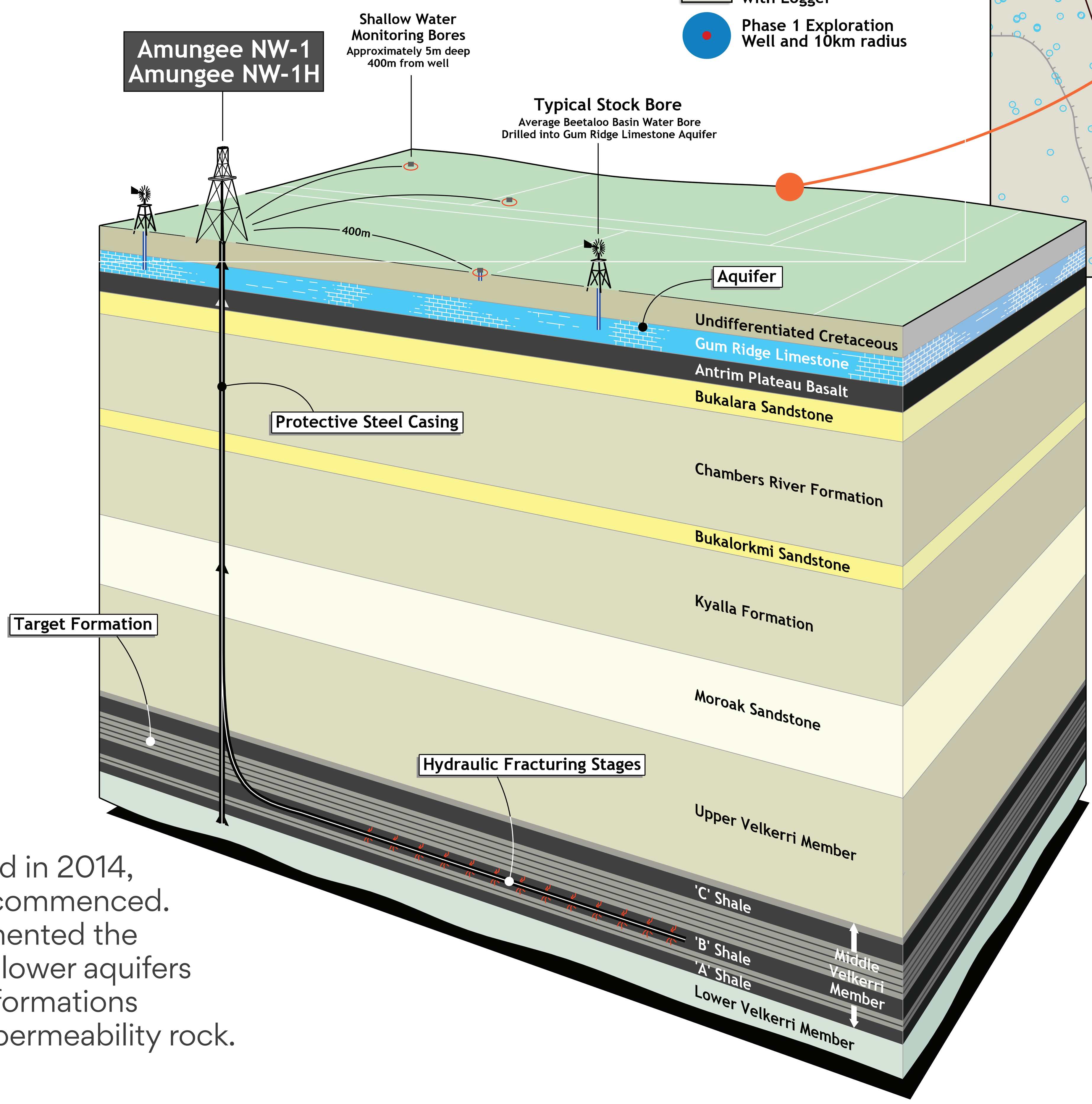
Amungee is the first horizontal well to be drilled in Origin's exploration program in the Beetaloo sub-basin and the first to be fracture stimulated, within existing regulations and with consent of the pastoralist and Traditional Owners.

The vertical stage of the well (NW-1) was successfully drilled in September 2015 to a depth of around 2,600 metres. The horizontal section (NW-1H), around 1,100 metres long, was drilled and fracture stimulated in 2016.

Subsequent production testing over a 57-day period confirmed the wells ability to flow gas, returning an average of 1.1 million cubic feet of gas per day.



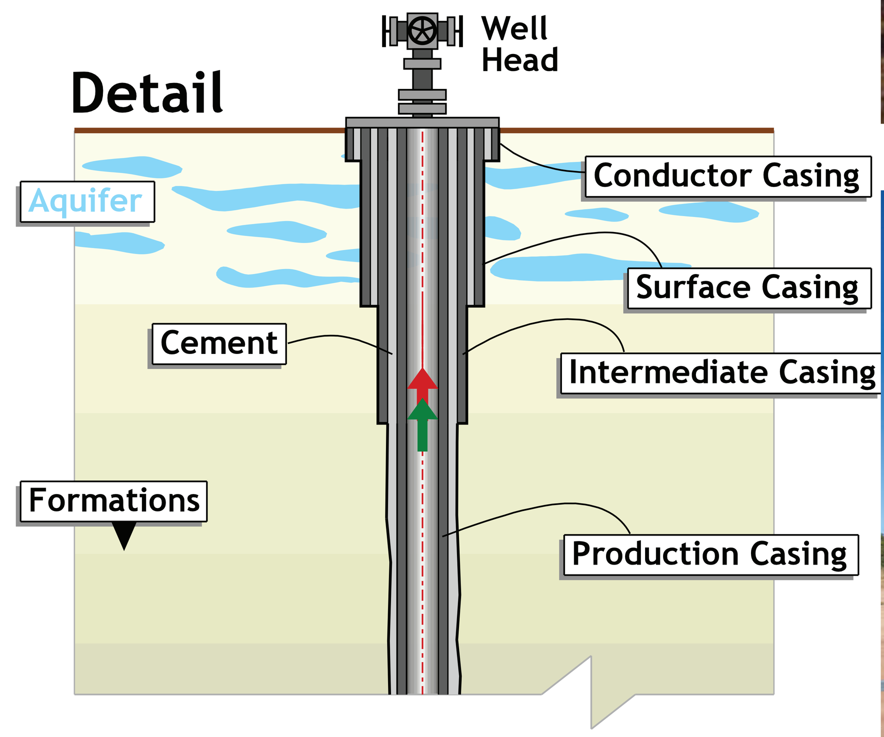




Groundwater monitoring

Groundwater monitoring is a regulatory requirement that allows us to detect any potential groundwater impacts that may occur from exploration activities. It also improves our understanding of the natural variability of water volumes and quality, and broader hydrogeological system in the Beetaloo sub-Basin.

Groundwater monitoring commenced in 2014, before current exploration activities commenced. A formal monitoring plan was implemented the following year - focussing on the shallower aquifers which are separated from the target formations containing gas by over 1.5km of low permeability rock.



This monitoring has found there no evidence of any impact from current exploration activities.

- Groundwater levels have remained stable in the shallower Cretaceous and Cambrian Limestone aquifers;
- The Cenozoic perched aquifer closest to surface responds strongly to rainfall, but water levels recede quickly suggesting a limited storage volume;
- Little or no hydrocarbons have been detected in bore sampling. Only one location found dissolved methane in trace concentrations
- All water sampled is suitable for stock use

Beetaloo Basin Gas

origin

Our exploration program is evaluating both dry gas and liquids rich wet gas in the Velkerri and shallower Kyalla shale formations. Each play has different characteristics.

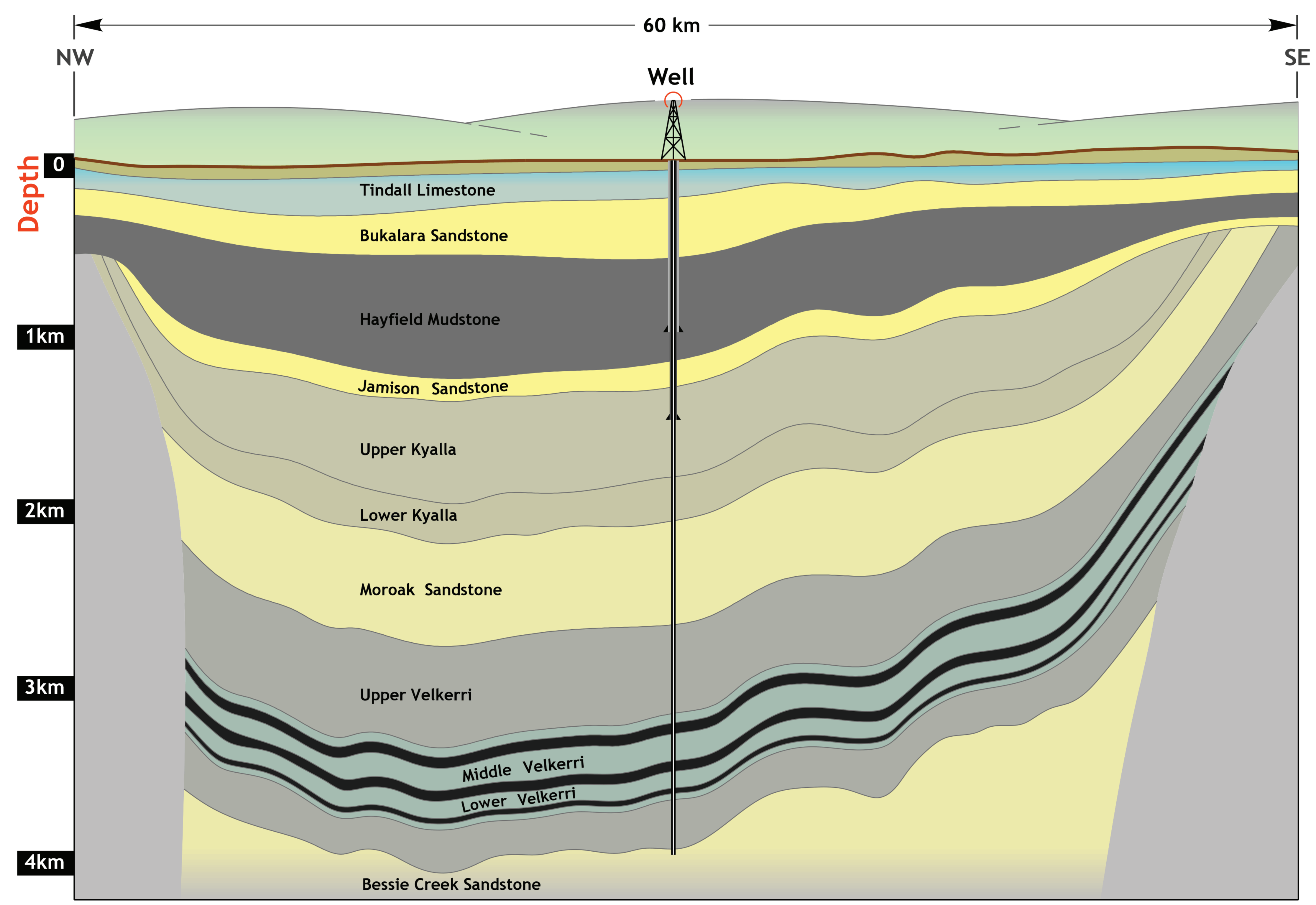
A Billion Years In The Making

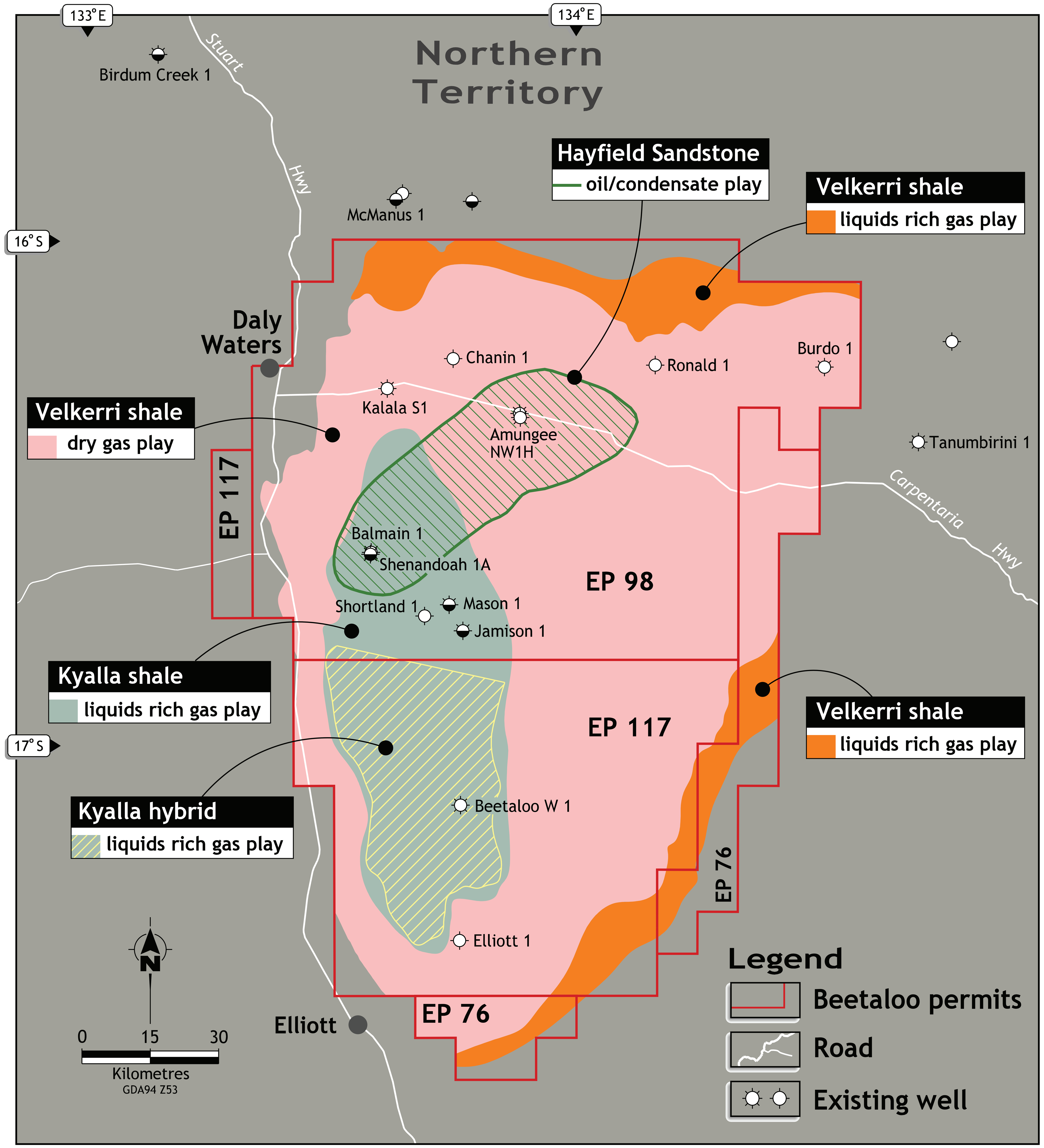
The Beetaloo Basin is 1.4 billion years old - much older than the dinosaurs that roamed the earth between 150 to 200 million years ago.

It's the Proterozoic age, continents are yet to form and the Top End is part of a vast tropical sea.

The Earth's atmosphere is around 3% oxygen and complex life like plants and animals are yet to evolve. Micro-organisms like algae are the main life form. As they die they settle on the ocean floor.

The right combination of depth and temperature then combines to creates the shale rocks we now know as the Velkerri formation, trapping vast reserves of natural gas around two and a half kilometers below surface.





Beetaloo Exploration Project

Origin, together with joint venture partner Falcon Oil and Gas, is exploring for gas in the Northern Territory's Beetaloo Basin.

The Resource Potential

Our exploration project in the Beetaloo Basin is a multi-year, nine well shale gas project that started in mid-2014.

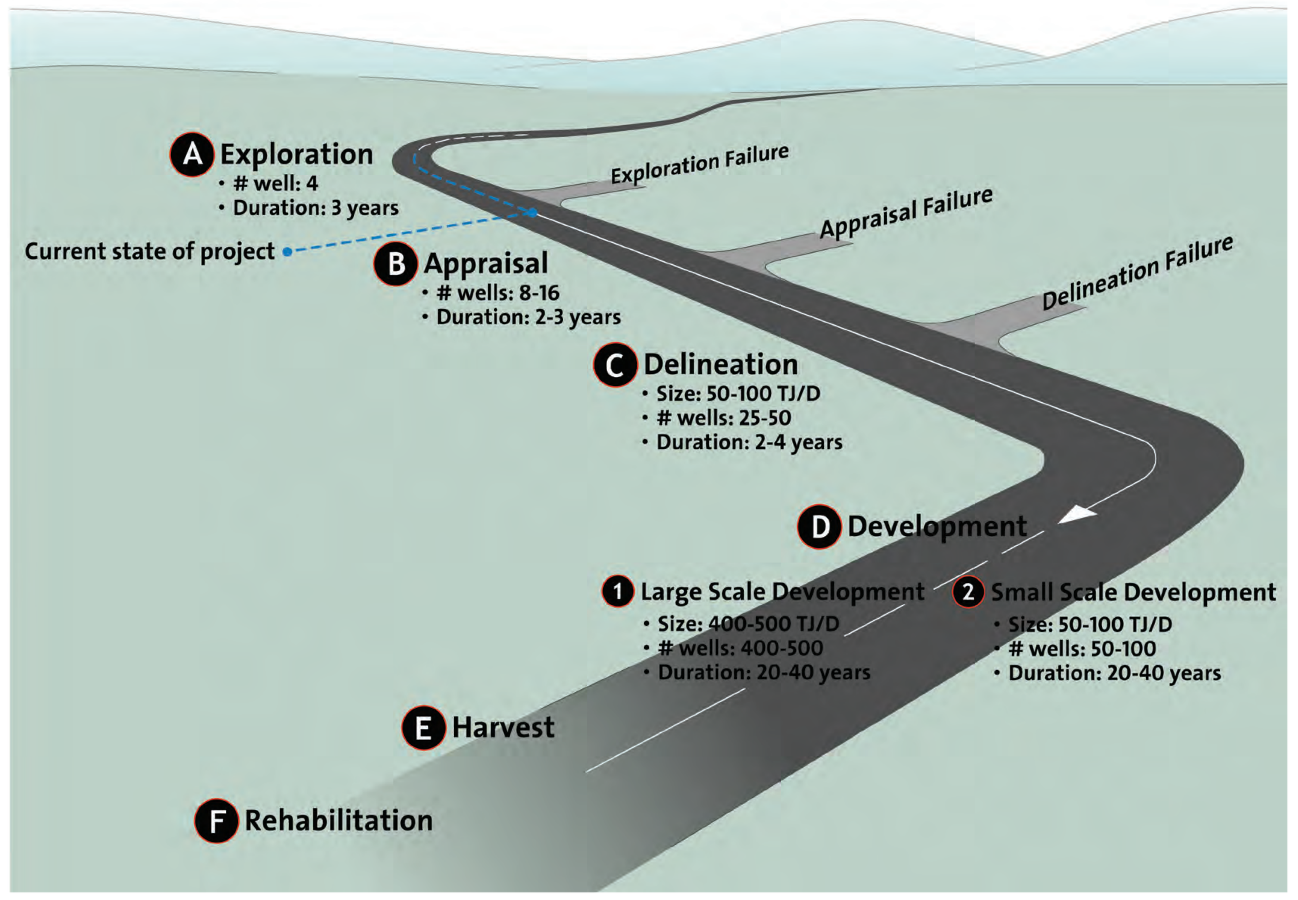
So far, we've drilled four wells. All within regulations and with the consent of the pastoralists and Native Title holders. We plan to drill two more this year (2019).

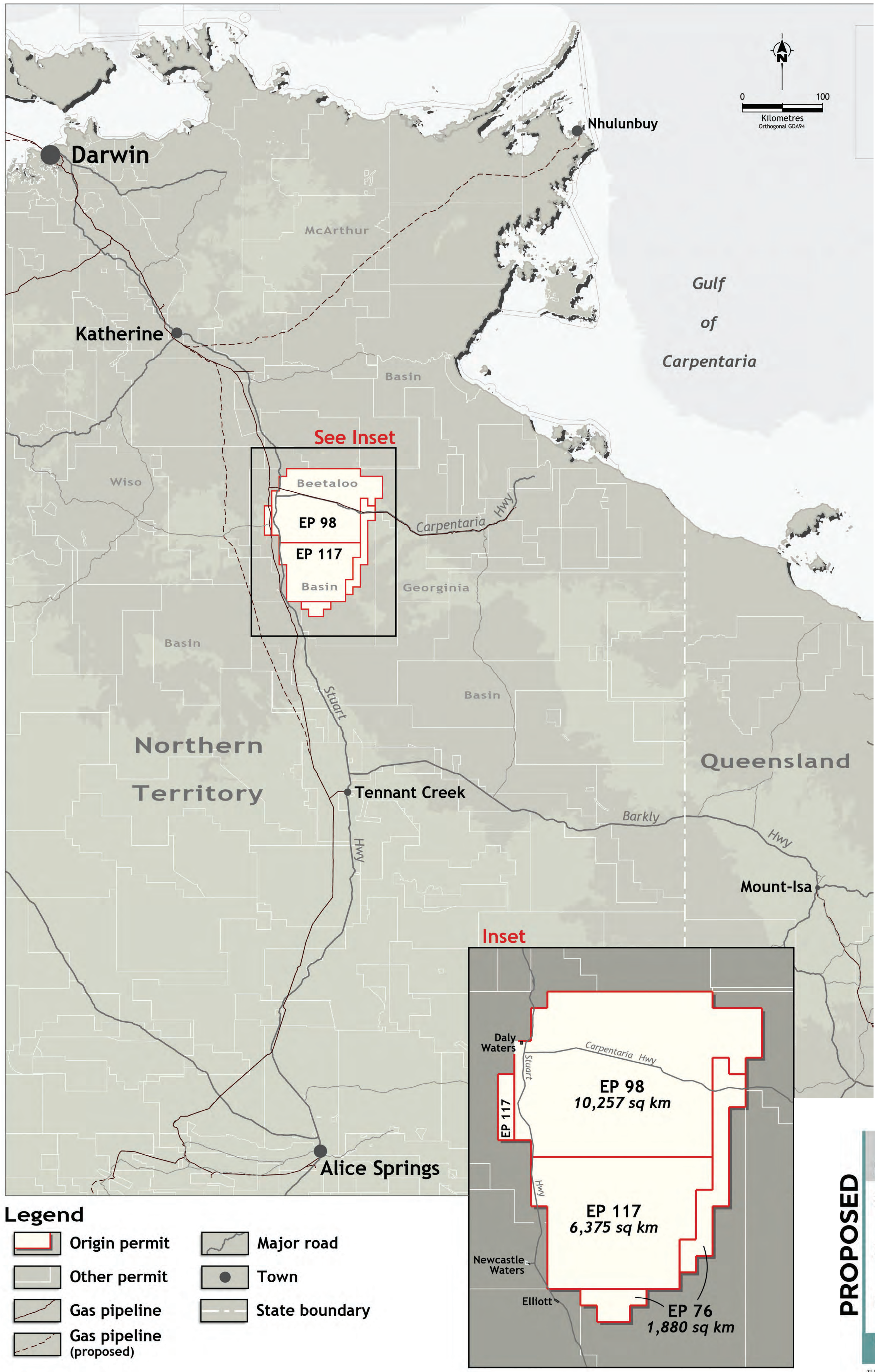
We think there's a very large gas resource underneath the ground with outstanding potential.

We estimate our project could have as much as 61 trillion cubic feet of gas, with 6.6 trillion cubic feet of that already recognised as a contingent resource.

Just how big is this? The Inpex project is 12 trillion cubic feet and the Mereenie gas fields have produced around 240 billion cubic feet since the mid 1980's.

The Road Ahead





The Benefits

If successful, and development goes ahead, the project means:

- more work for and jobs with local companies, including Aboriginal companies
- the opportunity to supply goods and services to the project
- financial payment for host pastoralists and Native Title holders
- taxes and royalties – providing government with more money that can go to improving community services, infrastructure and telecommunications
- energy security (delivering gas to the Eastern Australia)

Our Permit Commitments

PROPOSED

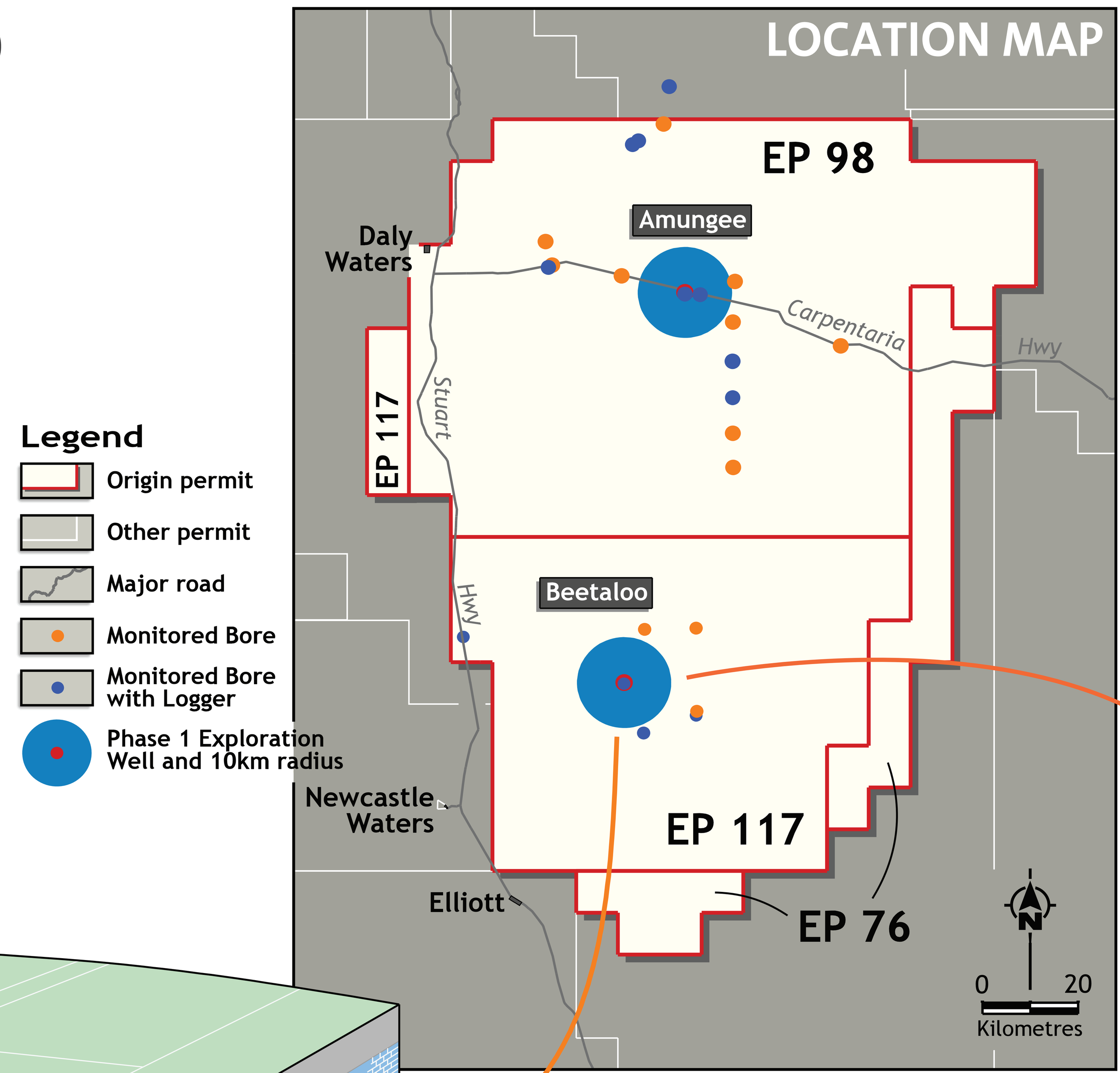
EP	2014	2015	2016	Moratorium 2017-2018	2019-2020	2021-2022
98	Geological and geophysical studies	2 vertical wells, 1 horizontal well	1 HFS horizontal well		Geological and geophysical studies	Geological and geophysical studies
117	Geological and geophysical studies	Geological and geophysical studies	1 vertical well		1 vertical pilot / evaluation well 1 HFS horizontal well	1 HFS horizontal well
76	Geological and geophysical studies	Geological and geophysical studies	Geological and geophysical studies		1 vertical pilot / evaluation well 1 HFS horizontal well	1 HFS horizontal well
Permit Year	1	2	3	4		5

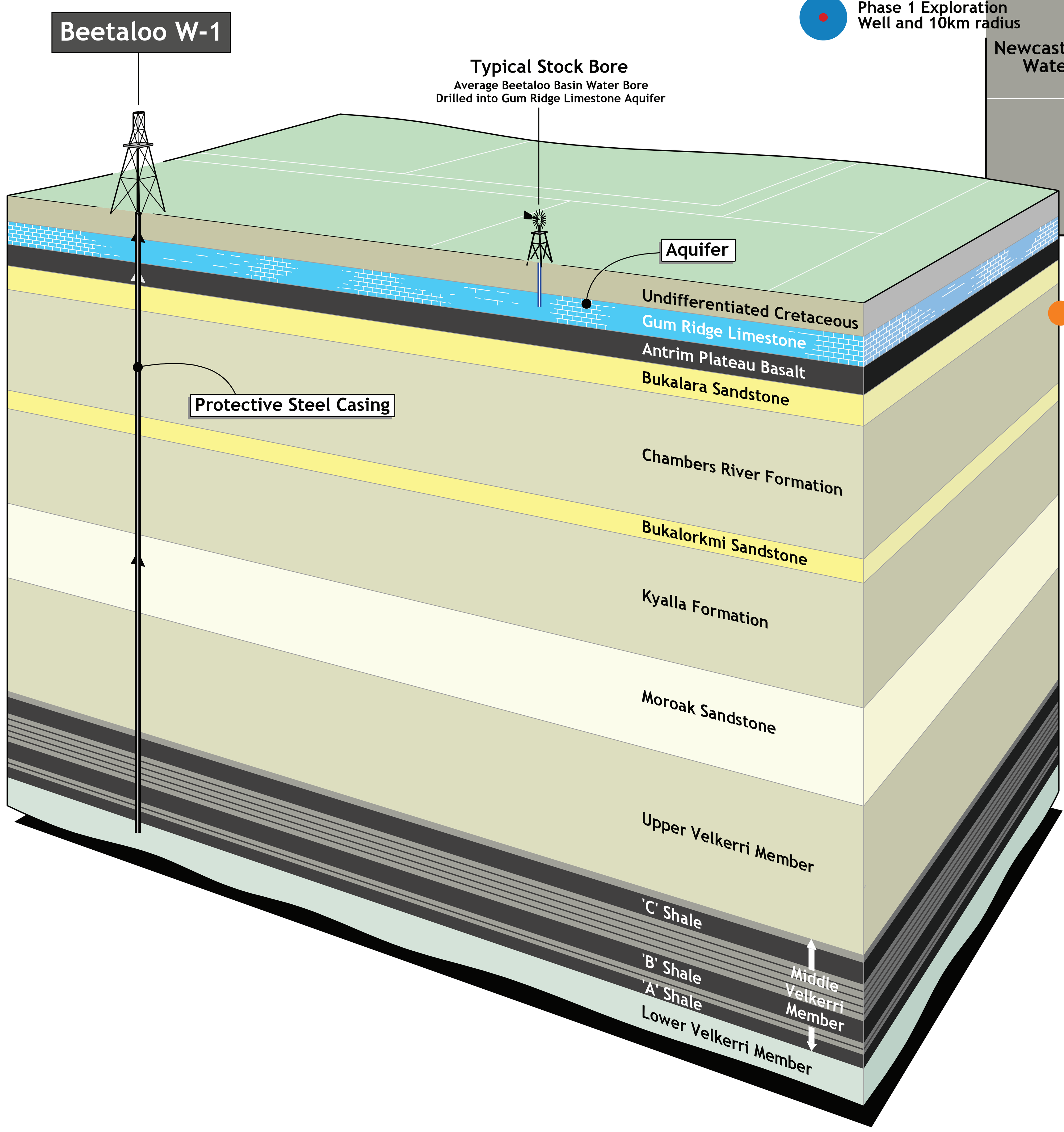
*HFS
Hydraulic Fracture Stimulation   4 March 2019

Beetaloo W1
(Drilling & Environmental Controls)

The Beetaloo W-1 well is in the centre of Exploration Permit 117 (EP117) in the southern Beetaloo Sub-Basin, east of the Stuart Highway and around 54 km northeast of Elliott.

The vertical well was successfully drilled in July 2016 to a depth of around 3,100 metres within the lower Velkerri formation. The well was cased and suspended in September that year.





Groundwater monitoring

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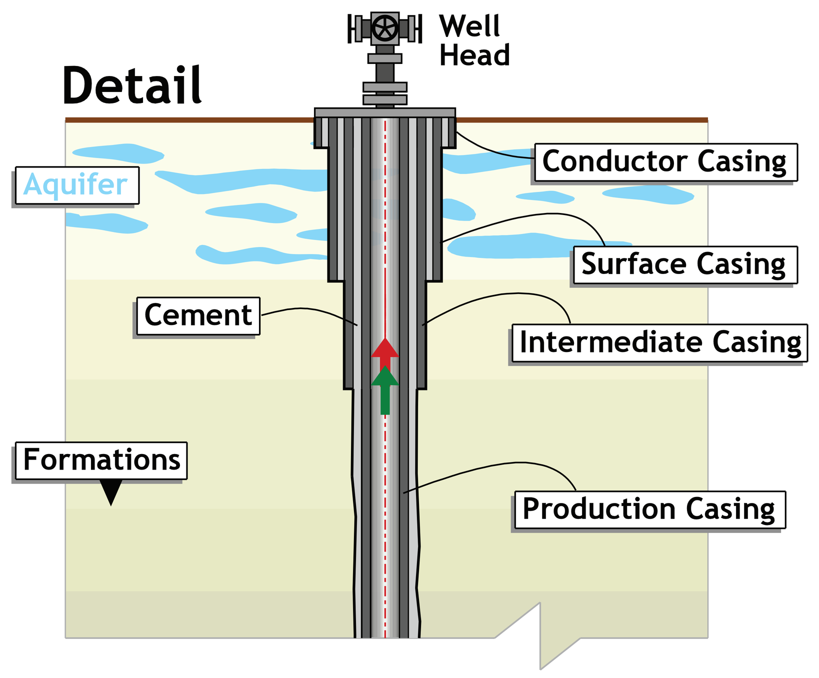
Groundwater monitoring commenced in 2014, before current exploration activities commenced. A formal monitoring plan was implemented the following year - focussing on the shallower aquifers which are separated from the target formations containing gas by over 1.5km of low permeability rock.



This monitoring has found there no evidence of any impact from current exploration activities.

- Groundwater levels have remained stable in the shallower Cretaceous and Cambrian Limestone aquifers;
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- Little or no hydrocarbons have been detected in bore sampling. Only one location found dissolved methane in trace concentrations
- All water sampled is suitable for stock use

Conventional and Unconventional

Conventional and Unconventional are industry terms used to define where gas is found underground and how it's extracted.

It's the same gas (natural gas reserves are mostly methane with some propane, butane and light condensates) - the main difference is how it occurs in nature today.

Conventional gas has typically migrated from where it formed millions of years ago to a sandstone reservoir where it's trapped between porous grains under a denser layer of rock that acts as a cap or seal.

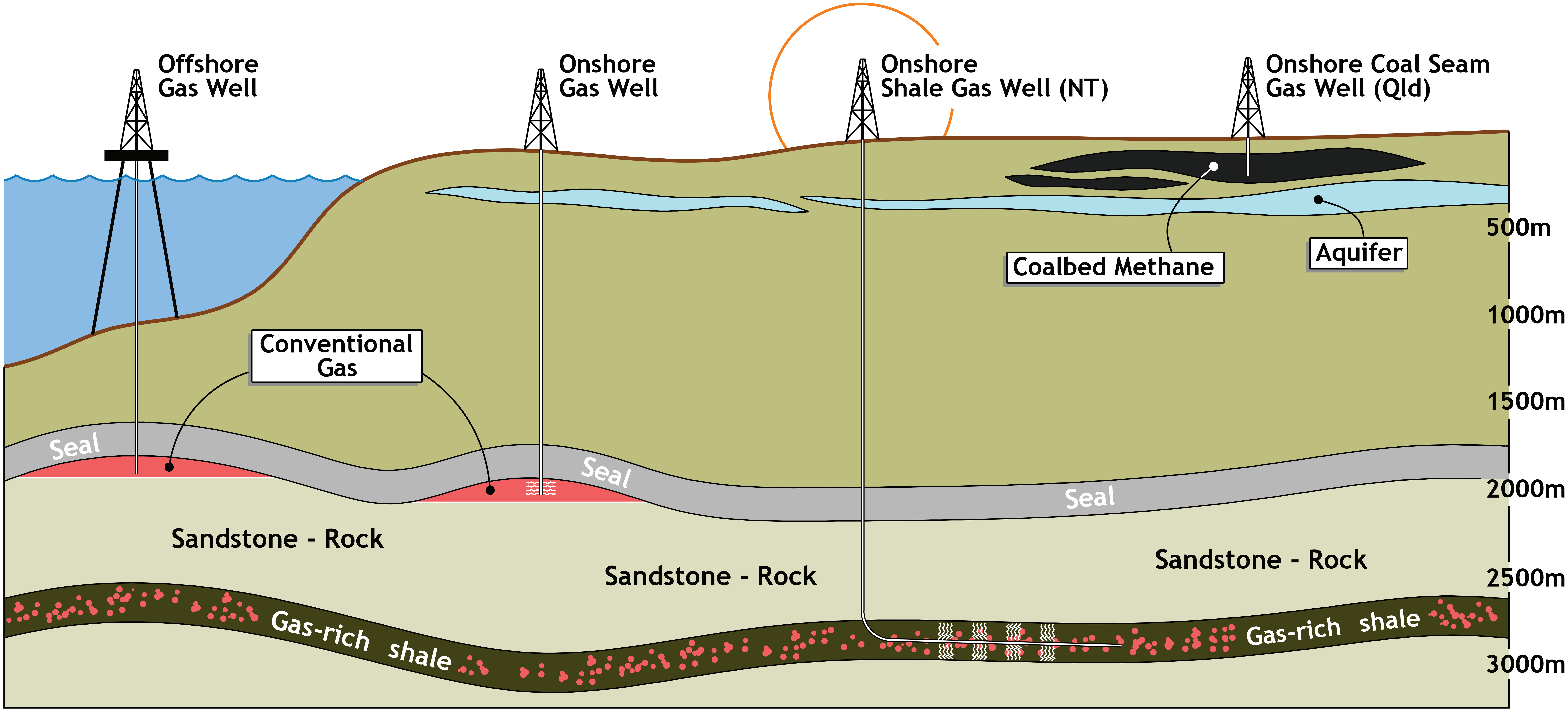
Unconventional gas is typically extracted from where it formed, in coal seams or shale formations that can be less porous and are sometimes described as tighter.

Extracting gas from either source can require a range of different techniques and processes.

It's a common misunderstanding that conventional reserves do not require fracture stimulation and unconventional reserves do.

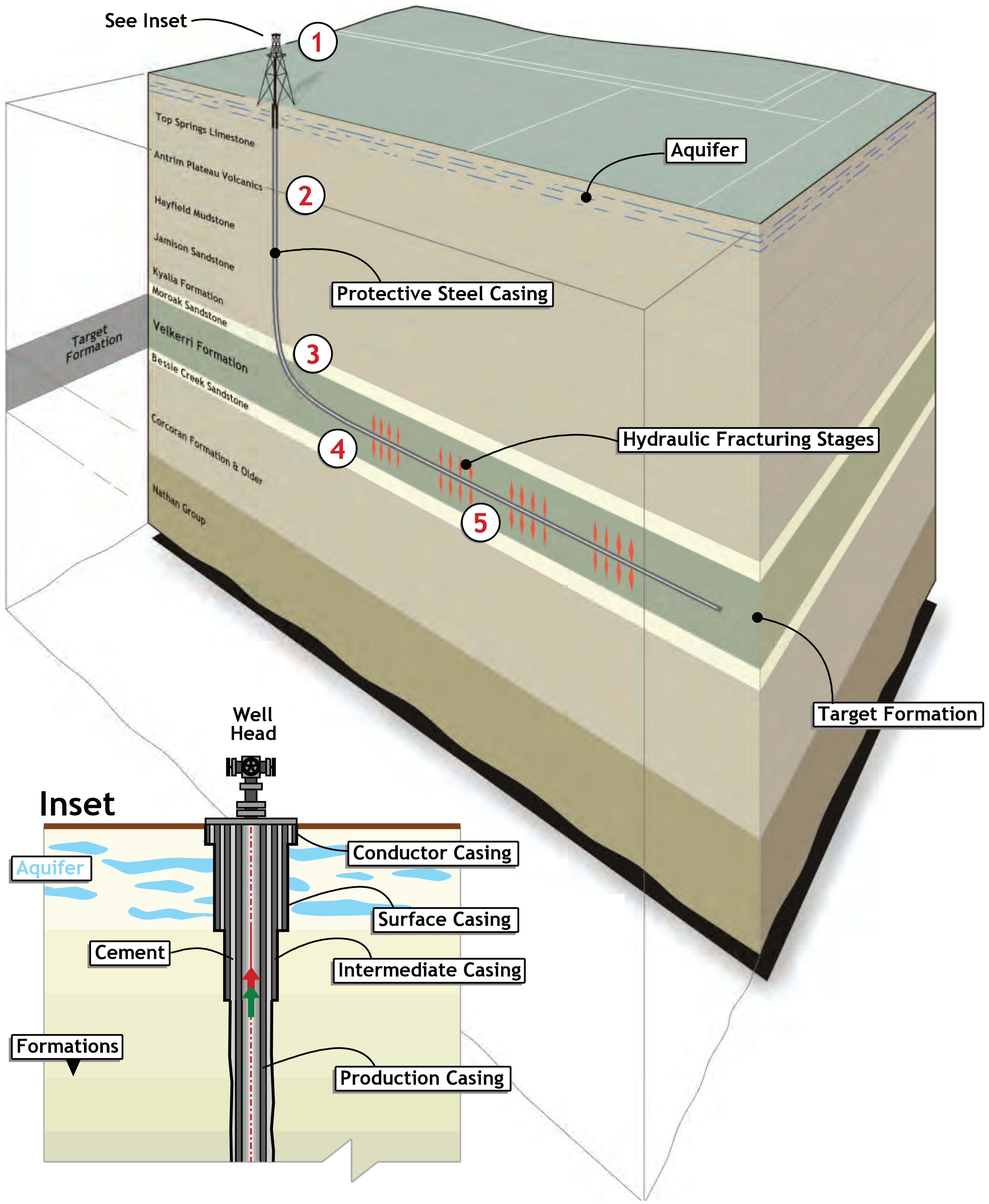
For example, around a third of conventional wells in the Mereenie field near Alice Springs have been fracked.

Less than a quarter of Origin's unconventional coal seam gas wells in Queensland are fracked.



Drilling For Shale Gas

Our exploration program includes drilling both vertical and horizontal wells that target the underground shale rock formations in the Beetaloo Basin.



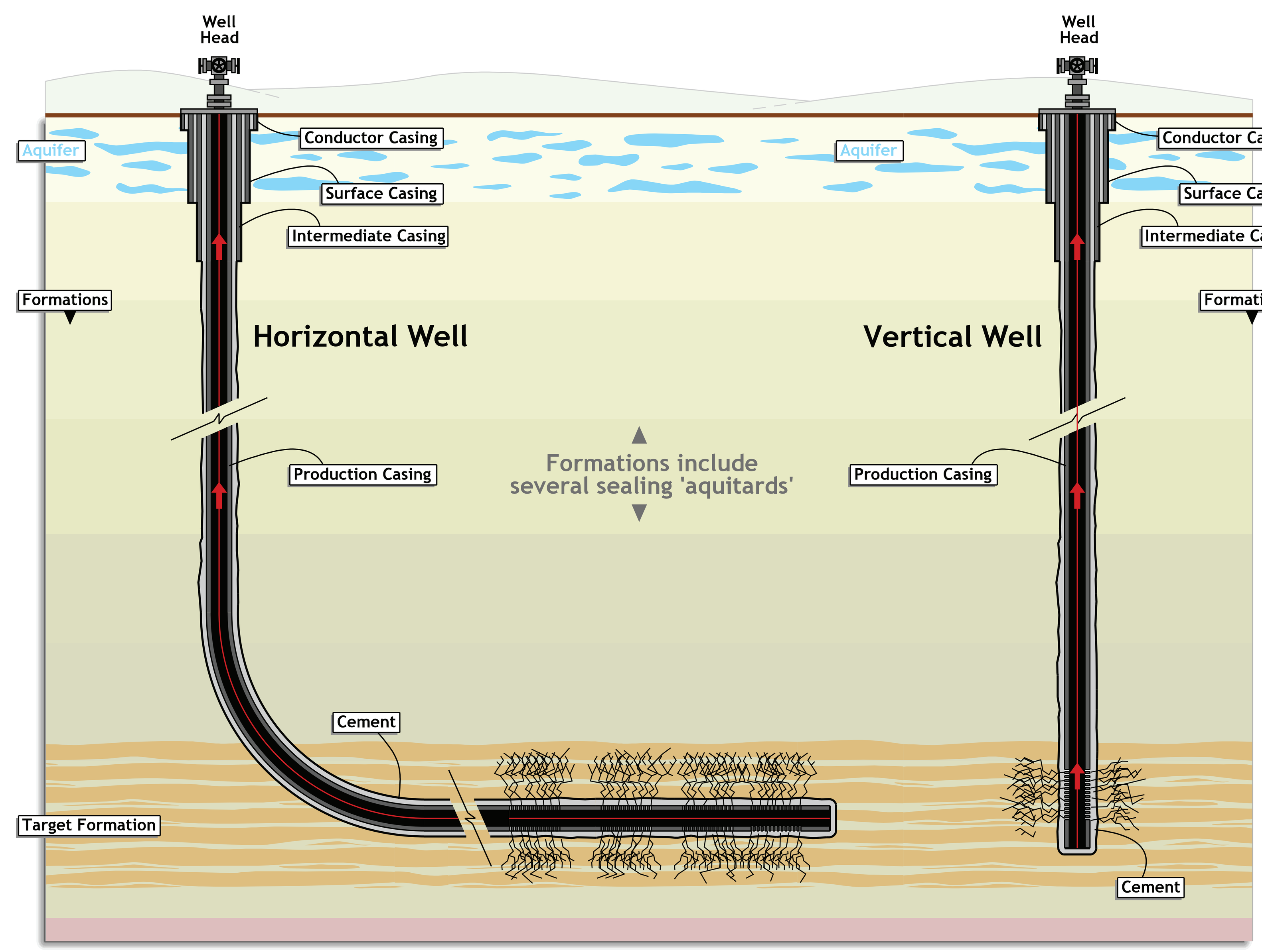
Long Reach Horizontal Drilling

Steps in Horizontal Drilling:

1. Negotiate and agree access, obtain approval and bring in drilling rig and equipment
2. Drill vertical section of well using conventional methods
3. Drill kick-off (curved) section, with the use of a downhole motor mounted directly above the bit, in order to make the turn from vertical to horizontal. Downhole instruments called MWD (measuring while drilling) packages transmit sensor readings upward, allowing operators at the surface to build the angle
4. Drill horizontal wellbore, still using MWD to hold the angle and direction
5. Case off the well with steel casing and cement to allow for completion and fracture stimulation, preparing the well for production

Vertical Wells and Long Reach Horizontal Wells

- Origin will drill both vertical and horizontal wells during the Exploration Phase/s
- Vertical wells allow a more cost effective assessment of the potential for gas and liquids in the target zones and provide some information on production capability
- Horizontal wells will be required to assess the potential for economic gas and liquid recovery rates
- Horizontal wells are most likely to be required for field development



Groundwater Monitoring

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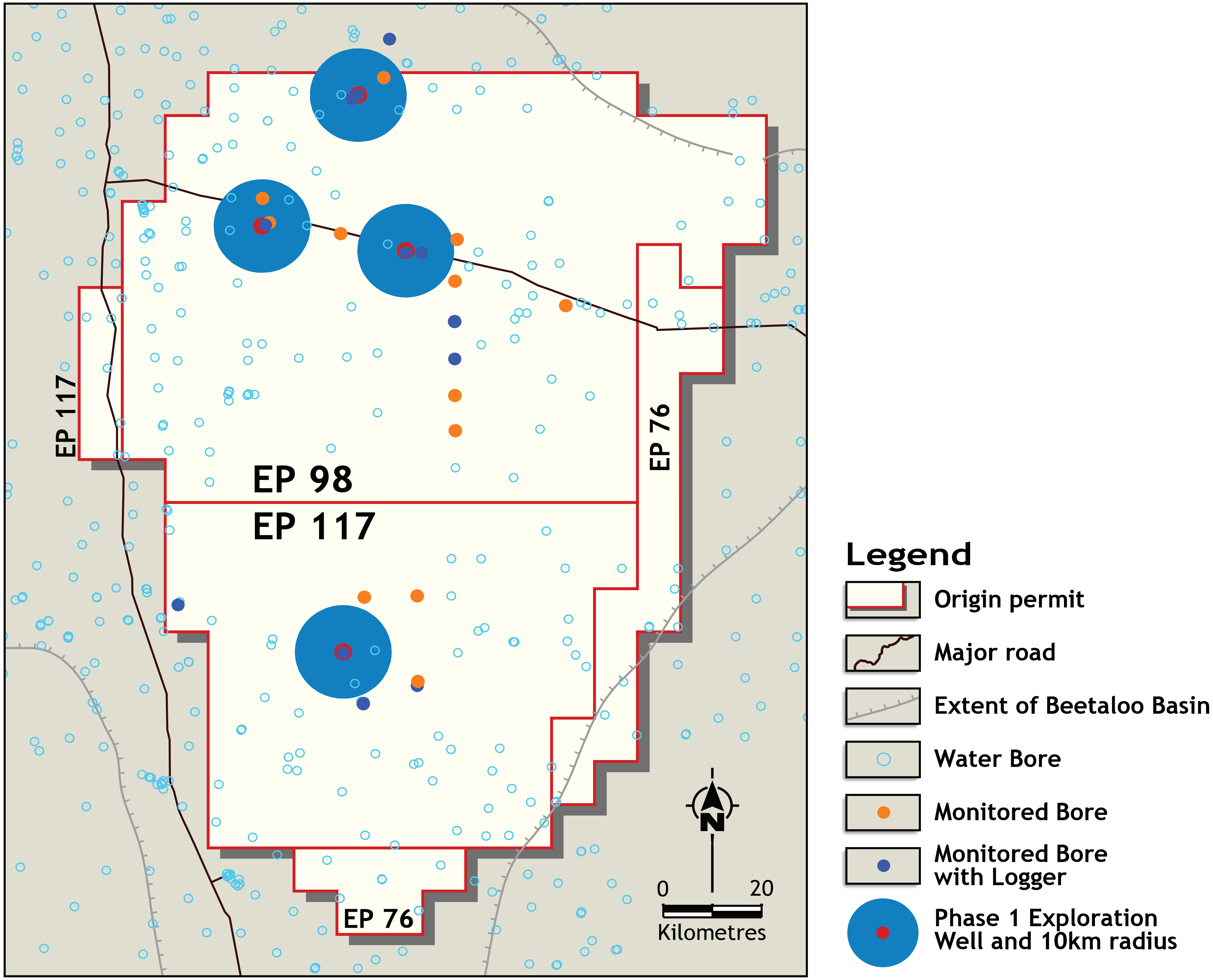


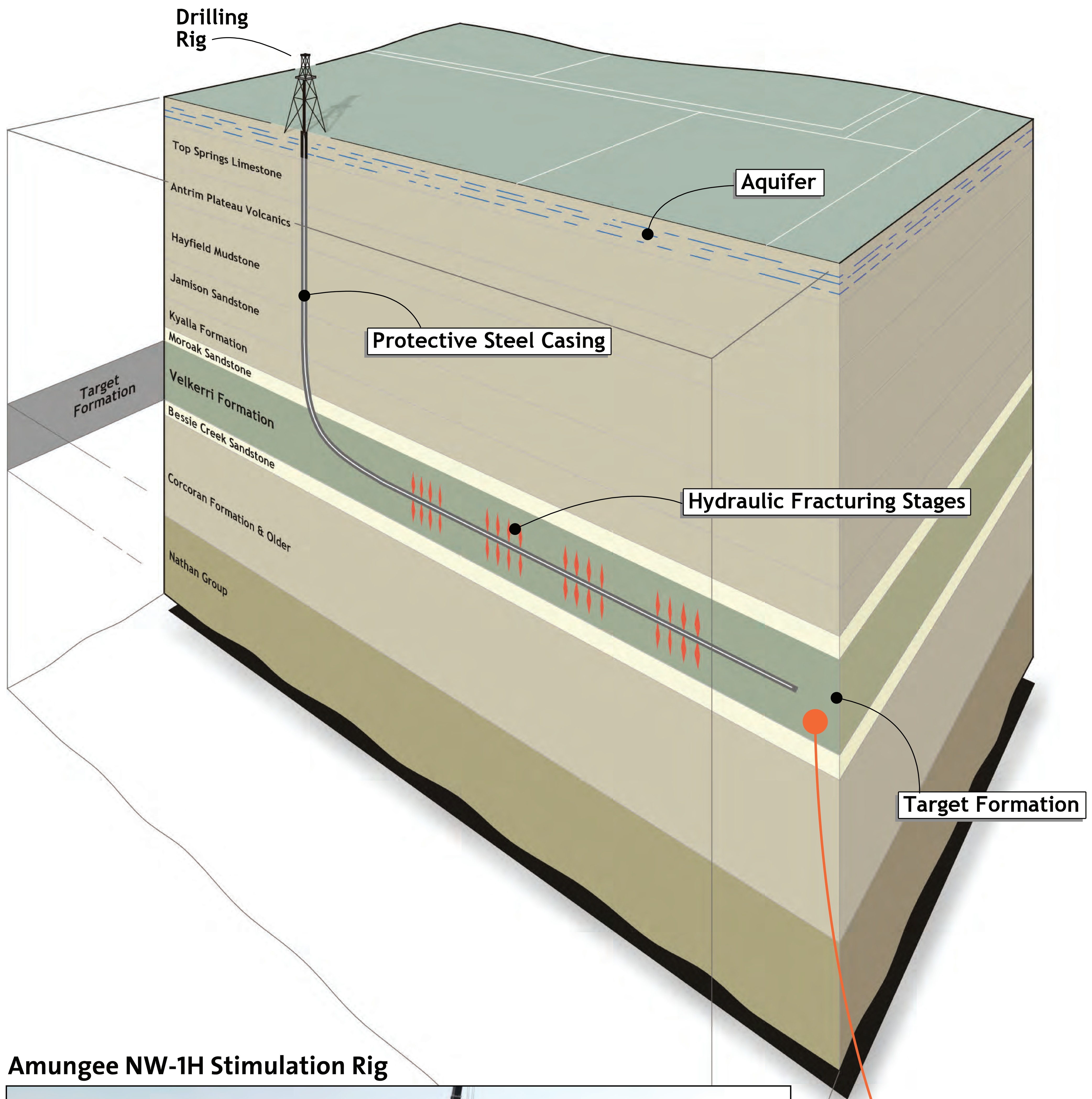
Hydraulic Fracture Stimulation (Fracking)

Fracking is the technical process designed to release the gas trapped in the dense shale rocks deep underground.

It involves pumping water mixed with sand and some chemical additives in low concentrations under pressure to fracture the shale, creating tiny pathways in the rock that allow the gas to flow into the well and be brought to the surface.

Key facts about fracking in the Beetaloo

- Distance offers important protection – there's over 2 kilometres between the shallower aquifers and the deeper rocks where gas is found.
- Both zones are effectively sealed off by several thick geological layers in between called aquatards.
- It's not physically possible for a fracture to extend upwards into the aquifer. Because of the distance, and because the amount of energy and pressure used in fracking isn't enough to connect and create pathways outside of the rock formation where gas is found.
- Any natural vertical fractures or old abandoned bores are extremely unlikely to provide a pathway for fracking fluids to reach a fresh water zone due to the greater weight (what's called hydrostatic head pressure) pushing down from above.
- Seismic work allows us to map the geology and avoid any large structures or faults.



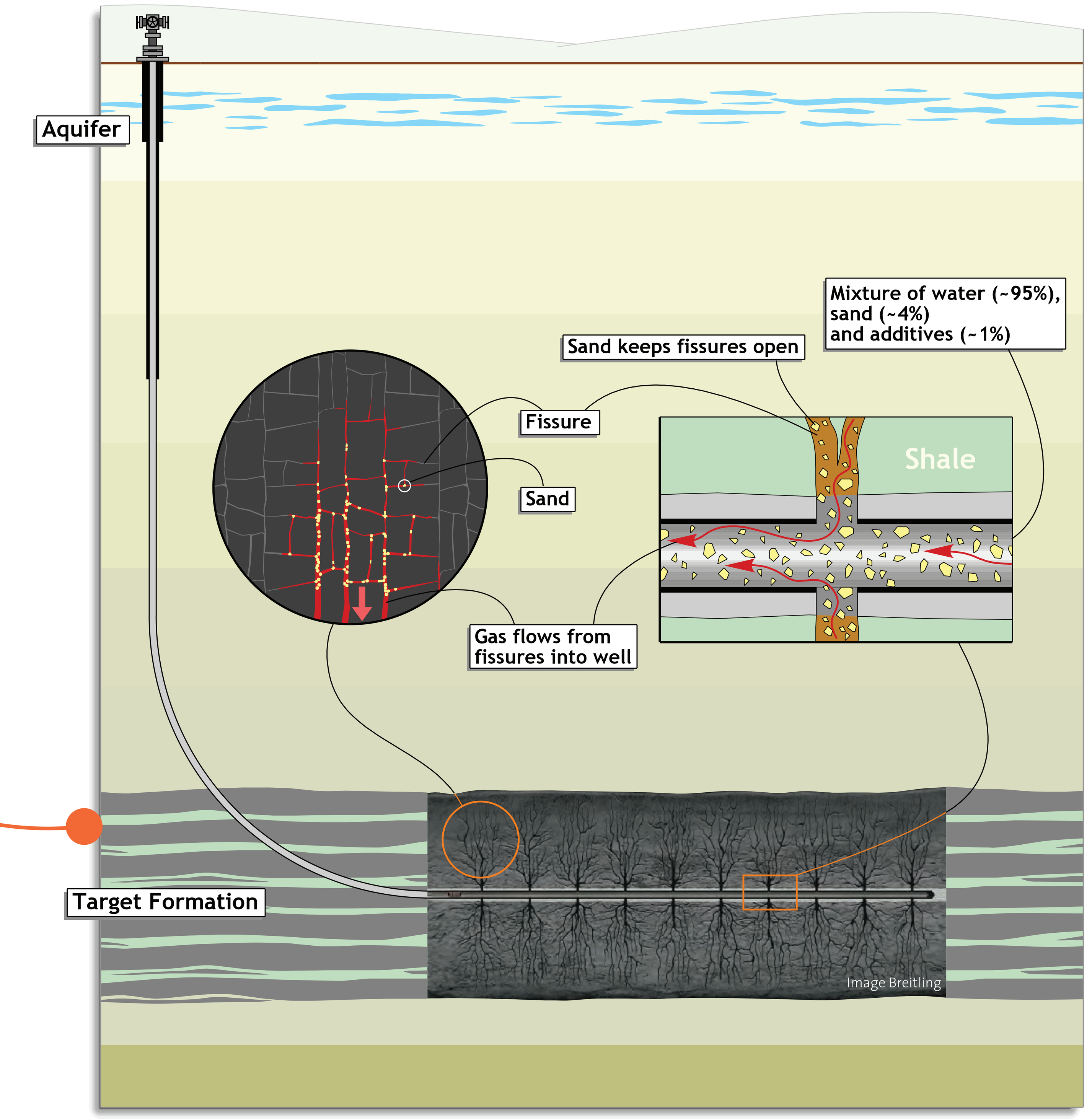
Amungee NW-1H Stimulation Rig

Protecting groundwater

We understand how important groundwater resources are to Traditional Owners, pastoralists and the community.

Both engineered and natural geological barriers isolate and protect underground water sources.

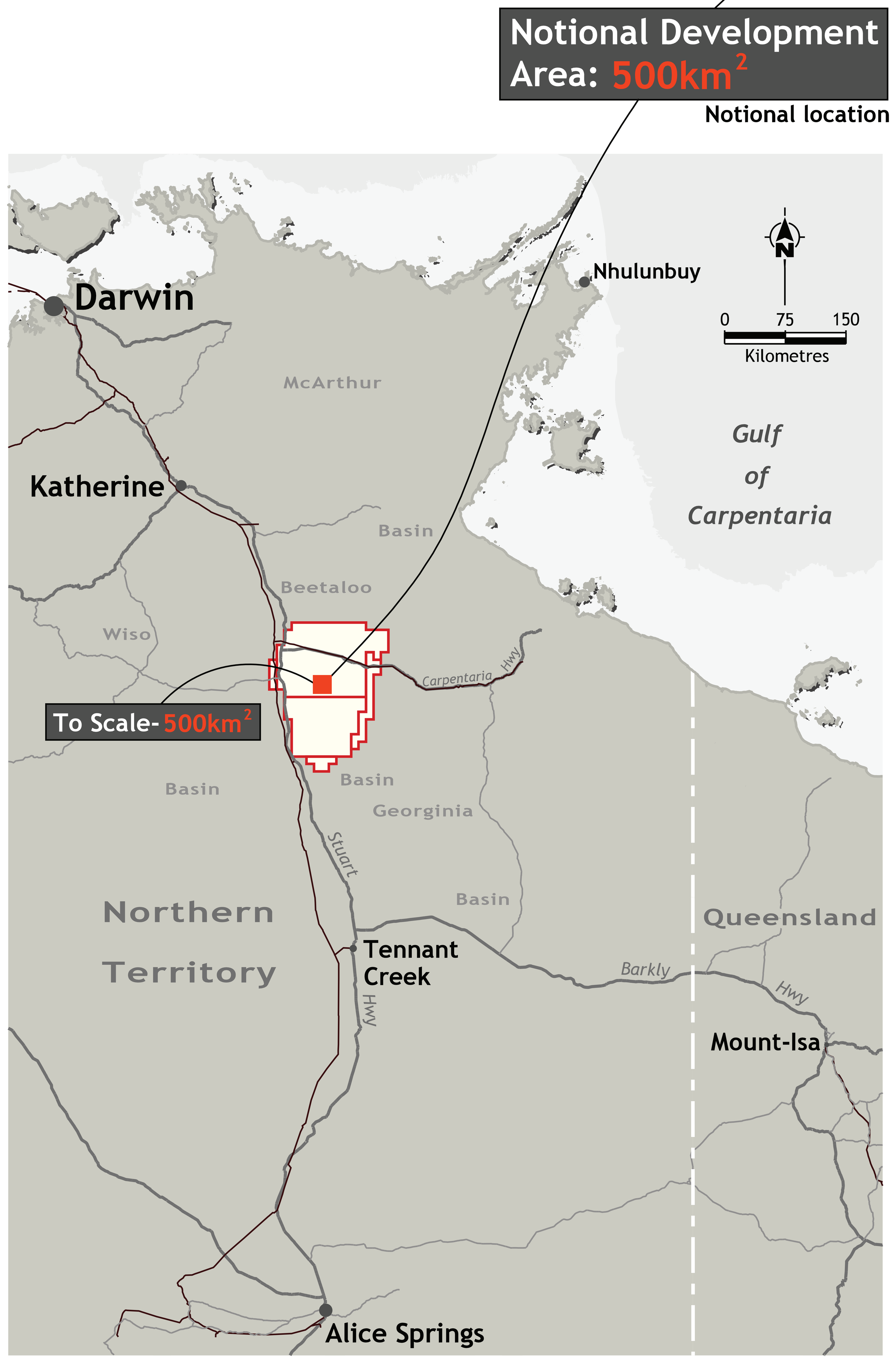
Multiple controls are put in place to protect the environment and groundwater. If these controls aren't successfully met when we drill - we don't frack.

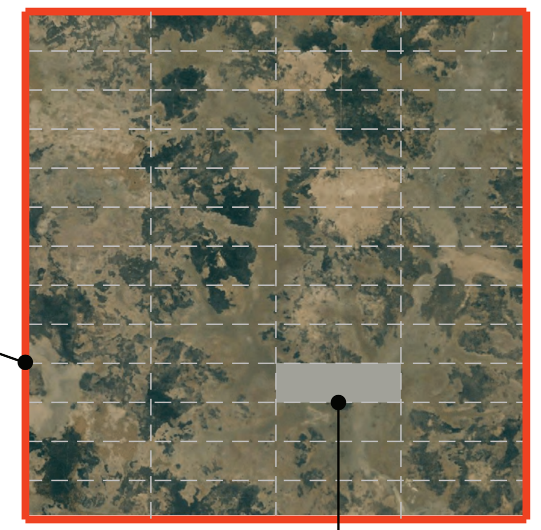


Minimising Above Ground Impacts

Multi -pad drilling and horizontal wells have a small surface footprint – minimising disruption to pastoral operations.

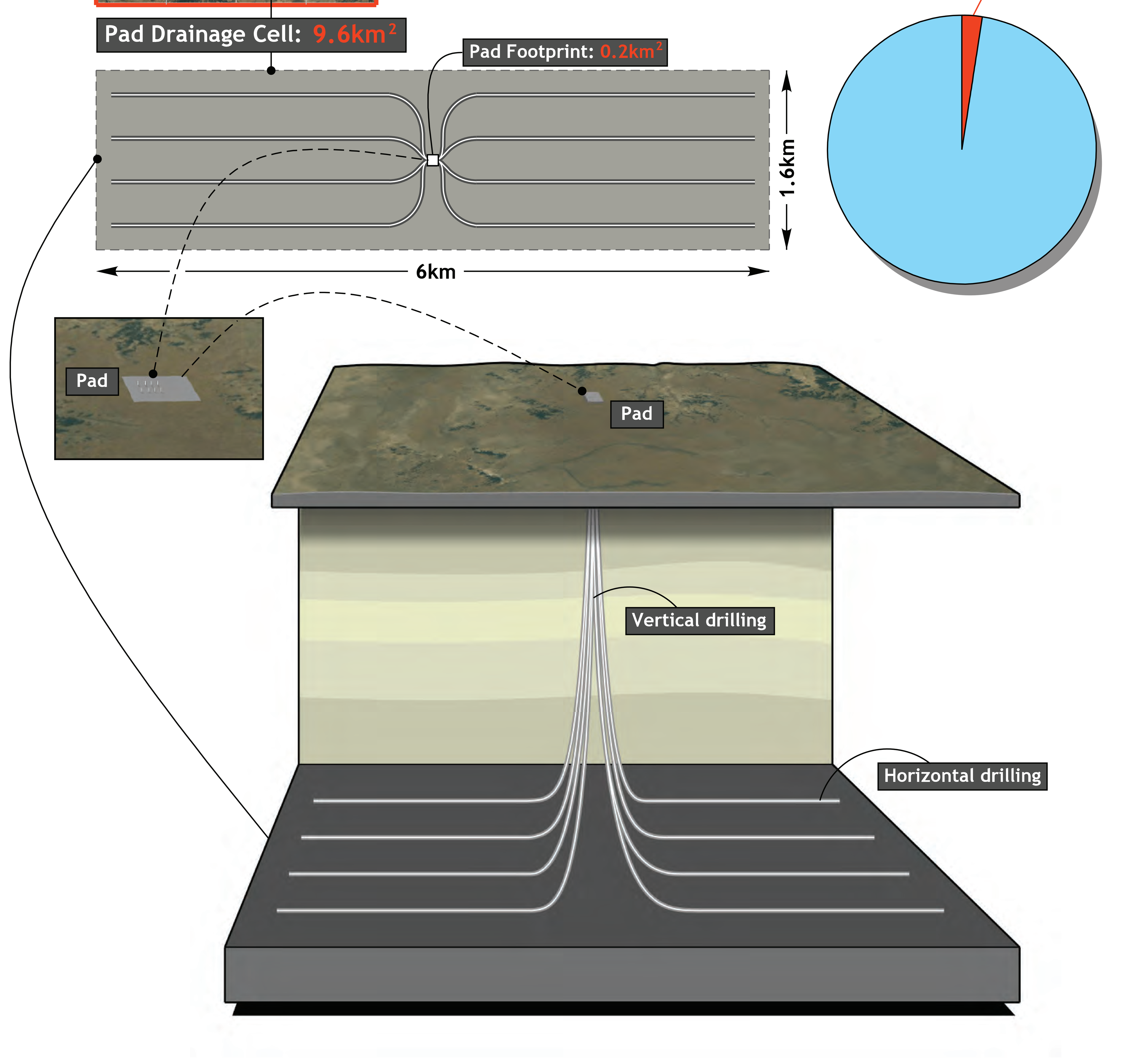
- In our submission to the NT Scientific Inquiry we described the surface footprint for large scale development scenario being no more than 10 square kilometres.
- This is based on multi-pad well design, and related surface infrastructure taking up no more than 2 per cent of a 500 square km land area.
- As further context, this total development area would occur on a handful of pastoral leases.





Preliminary estimates

	Dimensions per pad	Area per pad
Pad footprint	140m x 140m	.02km²
Pipeline right of away footprint per pad	3km x 30m	.09km²
Road footprint per pad	3km x 10m	.03km²
Total surface area footprint per pad	-	.10km²
Total subsurface drainage area per pad	6km x 1.6km	9.6km²



Well Integrity

Engineering standards, steel and cement ensure the drilling and fracking of gas wells do not create a pathway between the underground layers of rock or deteriorate over time.

Built Strong - To Last The Test Of Time

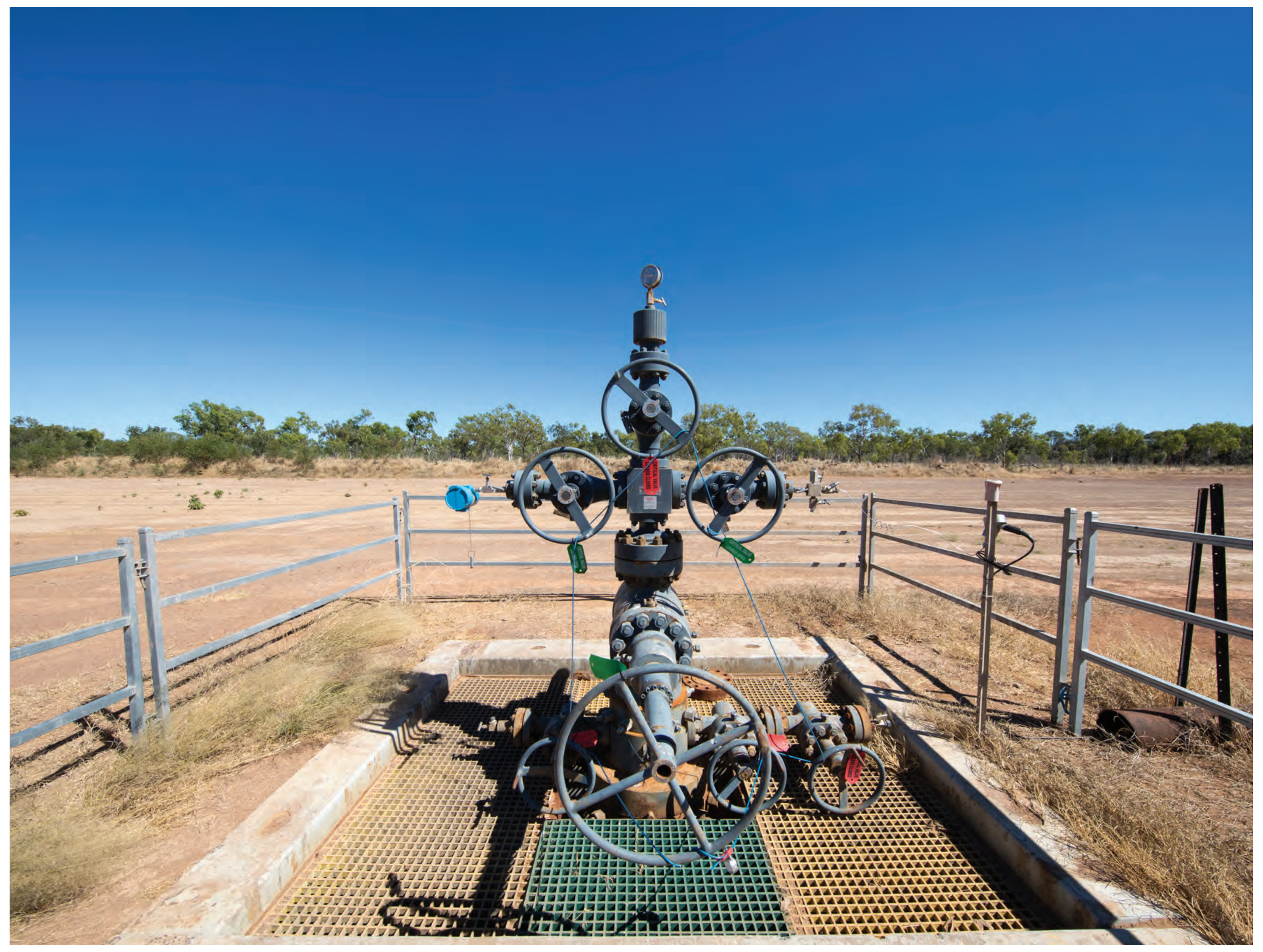
A gas well has three main parts – the steel casing, the above ground well head, and cement which is engineered to be as strong as the rock that it will live in.

Casing and cement hold the hole open and protect or prevent any cross flow between the surrounding underground formations. The cement is pumped down the inside and back up the outside of the casing.

An x-ray device sent down the well (a technique called logging) combined with pressure testing confirm the quality of the job.

The casing is designed to ensure its strong enough to withstand the most extreme loads it could be subjected to.

Added to this is a program of regulatory control and oversight, and the requirement to appropriately decommission every well at the end of its operational life.



Engineering Standards And Performance Data

	Category	Description	Risk
	1	Shallow surface casing + top of production casing cement below over pressured hydrocarbon reservoir	High
	2	Shallow surface casing + top of production casing cement below under pressured hydrocarbon reservoir	
	3	Shallow surface casing + top of production casing cement above top of gas	
	4	Shallow surface casing + top of production casing cement above surface casing shoe	
	5	Deep surface casing + top of production casing cement below under pressured hydrocarbon reservoir	
Origin's minimum design requirement for a producing well	6	Deep surface casing + top of production casing cement above top of gas	
Origin's minimum design requirement for a P&A well	7	Deep surface casing + top of production casing cement above surface casing shoe	
	8	Deep surface casing + 1 intermediate casing + top of production casing cement below top of gas	
Origin's Beetaloo wells	9	Shallow surface casing + 1 intermediate casing + top of production casing cement above casing shoe	
	10	Deep surface casing + 1 intermediate casing + top of production casing cement above top of gas	
	11	Deep surface casing + 1 intermediate casing + top of production casing cement above casing shoe	
	12	Deep surface casing + 2 intermediate casing strings + top of production casing cement above casing shoe	Low

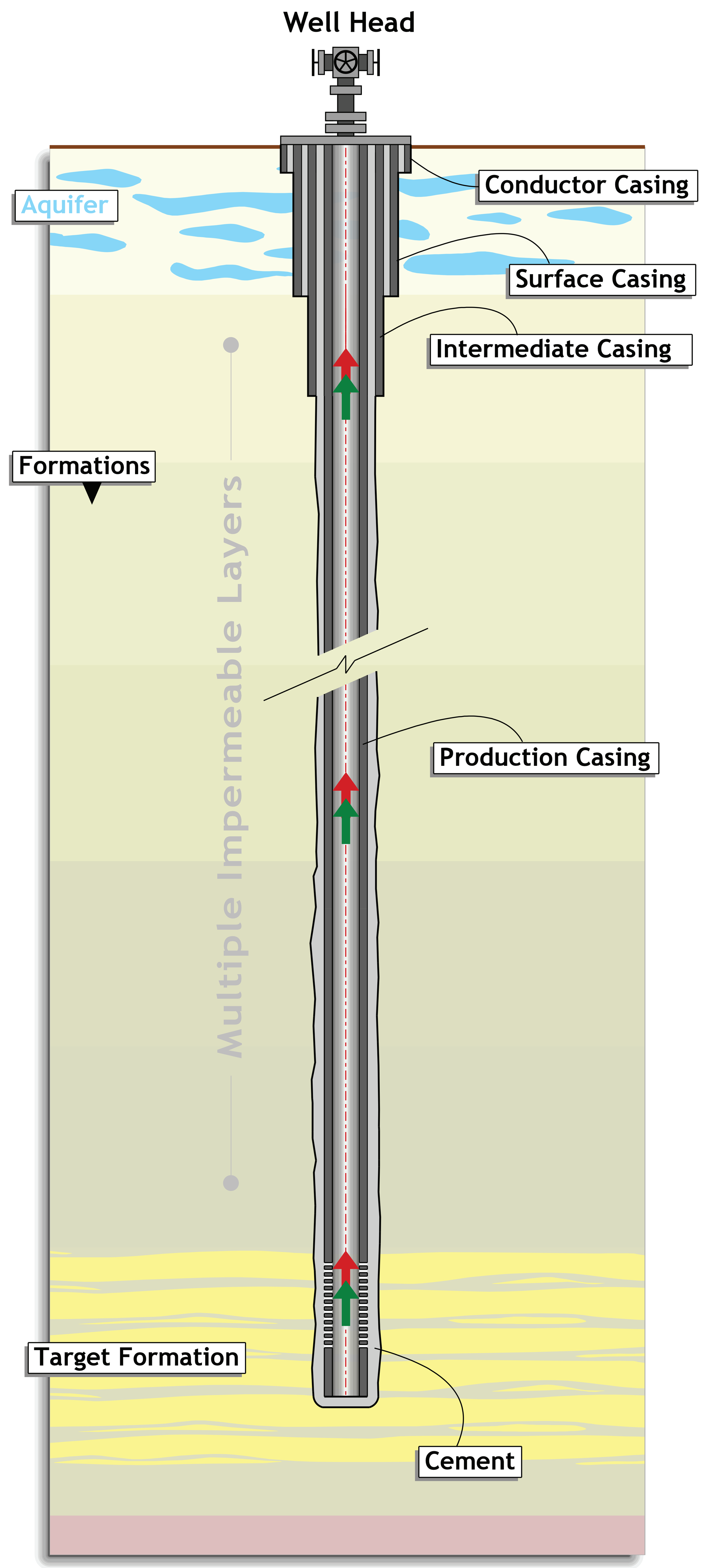
(a) Vertical and deviated wells

CATEGORY	ORIGINAL WELL COUNT	POTENTIAL BARRIER FAILURES	POTENTIAL BARRIER FAILURES %	CATASTROPHIC BARRIER FAILURES	CATASTROPHIC BARRIER FAILURES %	AVG COMPLETION DATE	P&A WELL COUNT	CURRENT WELL COUNT	ORIGINAL AVG SURFACE CASING DEPTH (FT)	ORIGINAL AVG TOP OF PRODUCTION CEMENT (FT)
Category 1	166	100	60.24%	3	1.81%	1979	57	15	253	7,334
Category 2	621	219	35.27%	5	0.81%	1983	138	301	306	6,566
Category 3	46	16	34.78%	1	2.17%	1987	14	31	321	4,008
Category 4	7	0	0.00%	0	0.00%	1982	1	15	222	125
Category 5	8,789	77	0.88%	1	0.01%	1995	782	6,140	559	6,111
Category 6	5,433	6	0.11%	0	0.00%	2007	105	7,181	712	2,816
Category 7	1,766	0	0.00%	0	0.00%	2009	8	2,040	719	534
TOTAL	16,828	418	2.48%	10	0.06%		1,105	15,723		
D&A	147									

(b) Horizontal wells

CATEGORY	ORIGINAL WELL COUNT	POTENTIAL BARRIER FAILURES	POTENTIAL BARRIER FAILURES %	CATASTROPHIC BARRIER FAILURES	CATASTROPHIC BARRIER FAILURES %	AVG COMPLETION DATE	P&A WELL COUNT	CURRENT WELL COUNT	ORIGINAL AVG SURFACE CASING DEPTH (FT)	ORIGINAL AVG TOP OF PRODUCTION CEMENT (FT)
Category 1	0	0	0.00%	0	0.00%	NA	0	0	NA	NA
Category 2	0	0	0.00%	0	0.00%	NA	0	0	NA	NA
Category 3	0	0	0.00%	0	0.00%	NA	0	0	NA	NA
Category 4	0	0	0.00%	0	0.00%	NA	0	0	NA	NA
Category 5	0	0	0.00%	0	0.00%	NA	0	0	NA	NA
Category 6	269	0	0.00%	0	0.00%	2012	1	268	789	2,153
Category 7	704	0	0.00%	0	0.00%	2012	2	702	929	442
TOTAL	973	0	0.00%	0	0.00%		3	970		
D&A	0									

Well Construction - Protecting Aquifers



About Origin

Many Australians know Origin as one of the country's largest electricity retailers. We also have significant interests in power generation and natural gas production. This includes exploring for natural gas reserves to develop as future energy sources. Where we find that it makes good sense to produce the gas, we develop and deliver it to our customers in Australia and overseas.

How We Operate

We know we have to get energy right. For our customers. For our communities. For the planet.

Relationships are built on trust and doing what we say what will do. We realise every community is different and that locals know the areas where we work far better than we do.

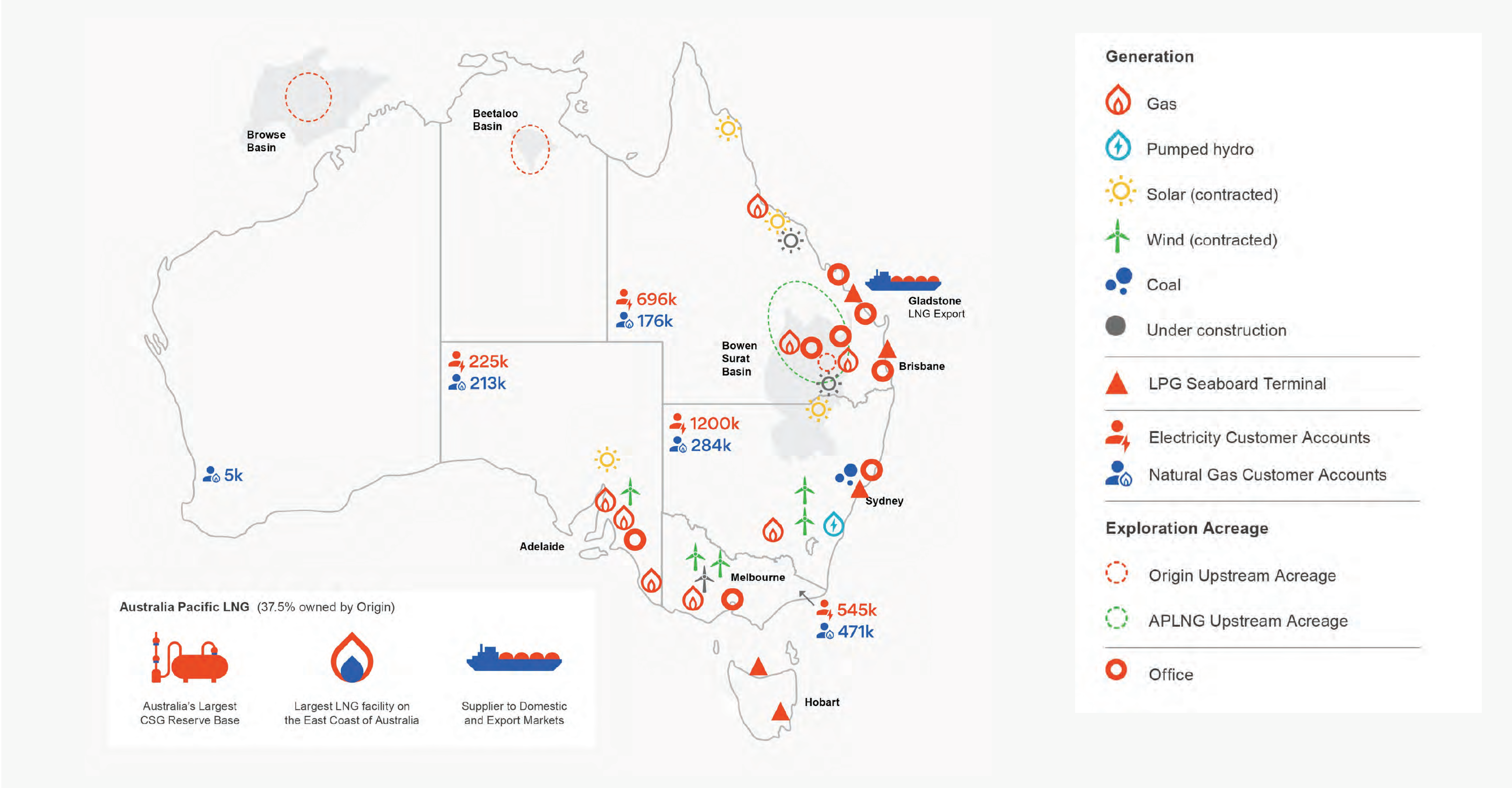
We promise to talk with you about our plans and listen, to help better guide our decision making.

Co-existence is a proven reality in other parts of the country today.

We will always look for ways we can work together to create shared benefit for all Territorians.

Gas wells on Qld grazing lands

Where We Operate



One Of Australia's Leading Energy Companies

Australia's Leading Energy Retailer

4.1 million gas, electricity and LPG customer accounts

Ensuring Domestic Gas Supply

Delivering around 30% of all gas on the east coast with APLNG

Growing Renewable Supply

Targeted to make up more than 25% of our generation mix by 2020

Powering Australia

7,000 MW of gas, coal and renewable generation and storage across the east coast

Appendix N Drilling, Stimulation, Completion and Testing Program Risk Assessment

Ref	Environmental Factor	Risk Description	Risk Source	Unmitigated consequence	Risk mitigation Measures		Residual Risk Rating			Residual Risk Statement	Effectiveness of Treatment	Scientific uncertainty	Uncertainty Ranking
					Codes of Practice	Site specific risk mitigation measures	Consequenc	Likelihood	Risk Rating				
1	**Groundwater**	Changes in aquifer quality from subsurface (drilling and stimulation) activities impacting a receptor (groundwater user or GDE).	Contamination from drilling fluids. Drilling fluids used to drill through the Cambrian Limestone Aquifer (CLA) are water-based with clay inhibition in the form of KCl. This may result in temporary elevated levels of chlorides in the CLA immediately adjacent to the well bore during the drilling of the top hole section of the well. (Path 1)	Moderate	B.4.10- Drilling fluids B.4.17 Groundwater monitoring	Source: • Drilling fluids used to drill through CLA are low toxic, water-based with addition of salt in the form of potassium chloride for clay inhibition. • Drilling Fluid Safety Data Sheets and used volumes to be provided to DENR/DPIR. Pathway: • Impacted area likely to be localised around the immediate vicinity of well bore Receptor: • No landholder extraction bores within 11.4km.	1	3	L		**Effective**	Origin has extensive experience in drilling conventional and unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report Beetaloo Sub-Basin. - CSIRO regional baseline monitoring program. - Control and impact monitoring bores as per Preliminary Guidelines: Groundwater Monitoring bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin.	Low
2			Cross flow of formation through inappropriate well barrier design. (Path 1)	Serious	B.4.3 Well design and barriers B.4.2 Aquifer Isolation B.4.7 Primary cementing B.4.17 Groundwater monitoring	Source: • Well constructed with multiple casing barriers and specifically-engineered cement in place to protect aquifers. • Well design and Well Barrier Integrity Validation report approved by DPIR as part of Well Operations Management Plan (WOMP). • Well Barrier Integrity Validated (WBIV) during well construction. Pathway: •Any impacted area likely to be localised. Receptor: •No landholder bores within 11.4km.	3	1	L		**Effective**	Origin has extensive experience in drilling conventional and unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). -Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report Beetaloo Sub-Basin. - CSIRO regional baseline monitoring program. - Control and impact monitoring bores as per Preliminary Guidelines: Groundwater Monitoring bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin.	Low
3			Crossflow through fracture growth into aquifer from stimulation activities allowing the migration of fluid and gas. (Path 2)	Serious	B.4.13 Hydraulic Stimulation and Flowback Operations B.4.17 Groundwater monitoring	Source: • Geomechanical data collected to understand fracture gradients. • Geomechanical modelling to ensure the appropriate fracture barriers are in place to contain the fracture propagation. • Risk assessment completed prior to stimulation to determine fracture growth. • Real time pressure monitoring to determine if a fracture has propagated outside the design operating envelope. Pathway: • Overlying sequences have a higher fracturing pressure reducing the risk of fracture migration out of the target shale. • Pressure monitoring during stimulation to identify anomalies indicating fluid loss aquifers. • Well designed with multiple well barriers in place to protect aquifers. Receptor: • 1400m separation distance between Velkerri formation and the Gum Ridge Aquifer. • No landholder bores within 11.4km. • Groundwater monitoring bores installed within 20m down gradient of each stimulated well.	3	1	L		**Effective**	Origin has extensive experience in drilling conventional and unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report. - Preliminary guidelines: Groundwater monitoring bores for exploration petroleum wells in the Beetaloo Sub-Basin. - 9500km of 2D seismic data used to screen for faults - Wireline logging during drilling to detect major unconformities. - CSIRO regional baseline monitoring program. - Control and impact monitoring bores as per Preliminary Guidelines: Groundwater Monitoring bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin.	Low
4			Stimulation activity induces seismic activity that enables cross formational flow between shallow aquifers. (Path 5)	Moderate	B.4.13 Hydraulic Stimulation and Flowback Operations B.4.17 Groundwater monitoring	Source: • Stimulation is not linked to major seismic events (reinjection of wastewater is generally recognised as the main cause). No reinjection of wastewater proposed. • Stimulation stages deployment will be away from geohazards to reduce the loss of fluids into any encountered faults. Pathway: • No significant faults within proximity of activity. • Any faults encountered during drilling will be assessed to determine risk of stimulating. Receptor: • 1400m separation distance between Velkerri formation and the Gum Ridge Aquifer. •No landholder bores within 11.4km.	2	1	L		**Effective**	Origin has extensive experience in stimulating unconventional petroleum wells across Australia. - US Geological Survey data. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report.	Low

Ref	Environmental Factor	Risk Description	Risk Source	Unmitigated consequence	Risk mitigation Measures		Residual Risk Rating			Residual Risk Statement	Effectiveness of Treatment	Scientific uncertainty	Uncertainty Ranking
					Codes of Practice	Site specific risk mitigation measures	Consequence	Likelihood	Risk Rating				
5			Migration via fractures intersecting with offset wells or intersecting an existing geohazard. (Path 2 & 5)	Moderate	B.4.13 Hydraulic Stimulation and Flowback Operations B.4.3 Well design and barriers B.4.17 Groundwater monitoring	Source: • Fracture modelling undertaken to determine maximum fracture growth. • Fluid injected into a shale formation Pathway: • No significant faults within proximity of activity. • Any faults encountered during drilling will be assessed to determine risk of stimulating. • Closest exploration well 35 km (Arnold arch S-1:well is abandoned). Receptor: • No landholder bores within 11.4km. • Regional groundwater monitoring.	2	1	L		Effective	Origin has extensive experience in drilling and stimulating unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report. - 9500km of 2D seismic data used to screen for faults. - Wireline logging during drilling to detect major unconformities. - CSIRO regional baseline monitoring program. - Control and impact monitoring bores as per	Low
6			Leakage of either flowback, produced water, or hydrocarbons (liquid and gaseous) from suspended or abandoned wells. (Path1)	Moderate	B.4.1 Well Integrity Management B.4.2 Aquifer Isolation B.4.3 Well design and barriers B.4.15 Well suspension and decommissioning B.4.17 Groundwater monitoring D.5.5 Leak Remediation and Notification	Source: • Multiple cement and steel casing barriers constructed to protect aquifers. • Well design and construction reports submitted to DPIR. • Integrity of isolation validated and maintained throughout well life. • Well design considers multiple cement and steel casing barriers in place between hydrocarbon-bearing zone and surface. • Well design and Well Barrier Integrity Validation reports submitted to DPIR as part of Well Operations Management Plan (WOMP). • Wells constructed and suspended with barriers in place and verified as per governing code. • Routine well leak detection. • Leaking wells to be remediated as soon as practicable. • Limited gas production time only to extended production test. Pathway: • Impacted area likely to be localised. Receptor: • No landholder bores within 11.4km. • Groundwater monitoring bores installed.	2	2	L		Effective	Origin has extensive experience in drilling, stimulating, maintaining and abandoning unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report. - CSIRO regional baseline monitoring program. - Control and impact monitoring bores as per Preliminary Guidelines: Groundwater Monitoring bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin.	Low
7	**Groundwater**	Contamination of aquifer from surface activities (chemical and waste storage, handling and spills) impacting a receptor (groundwater user or GDE).	Surface contamination from storage and disposal of drilling fluids, additives, muds and cuttings on-site. (Path 3 & 7)	Serious	A.3.8 Containment of Contaminants B.4.13 Hydraulic Stimulation and Flowback Operations C.5.1 Drilling Materials C.4.2 Management of produced water and flowback fluid C.7.2 Spill Management Plan C.8.1 Wastewater Management Plan	Source • Drilling sumps to be lined with an impermeable liner. • Well cellar to be lined to contain drilling fluids with pumps to prevent overflow. • Water levels in drilling sumps to be minimised to reduce hydraulic head. • Inspections of storages to be undertaken weekly to identify potential liner issues. •Spill Management Plan. • Drill cuttings and muds are not expected to contain high NORMS levels- with characterisation of levels undertaken Wastewater tanks and drill sumps to have a 1:1000ARI freeboard. Pathway: • Separation between sump and aquifer anticipated to be 70m, with interbedded clays present. Receptor: • Separation between lease and closest aquifer anticipated to be 70m. • Nearest landholder extraction bore 11.4km. • Impact and control groundwater monitoring bores installed within 20m of exploration wells to detect any potential contamination.	3	1	L		Effective	Origin has extensive experience in drilling and stimulating unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report. - 9500km of 2D seismic data used to screen for faults. - Control and impact monitoring bores as per Preliminary Guidelines: Groundwater Monitoring bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin.	Low
8			Storage, handling and transportation of produced hydrocarbons (condensate). (Path 3)	Serious	A.3.8 Containment of Contaminants B.4.13 Hydraulic Stimulation and Flowback Operations C.4.2 Management of produced water and flowback fluid C.7.1 Wastewater Management Plan C.7.2 Spill Management Plan	Source: •Tanks to be compliant with AS 1940 and double-lined • Weekly inspections to identify any potential leaks. • High risk chemical storage areas to have secondary containment (such as mud shakers, pumps and chemical handling areas). Pathway: • Spill Management Plan implemented. • Separation between chemical storages and closest aquifer anticipated to be over 70m, with interbedded clays likely to limit any contaminant migration. Receptor: • Separation between lease and closest aquifer anticipated to be over 70m. • Nearest landholder extraction bore 11.4km. • Impact and control groundwater monitoring bores installed within 20m of exploration wells to detect any potential contamination. • Spills and leaks to be cleaned up and rectified as soon as possible.	2	2	L		Effective	The regulatory regime legislating the storage, handling and transportation of dangerous goods and combustible liquids within Australia is mature. - Origin has extensive experience in transporting, storing and managing chemicals and fuels associated with unconventional petroleum drilling and stimulation activities. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report.	Low

Ref	Environmental Factor	Risk Description	Risk Source	Unmitigated consequence	Risk mitigation Measures		Residual Risk Rating			Residual Risk Statement	Effectiveness of Treatment	Scientific uncertainty	Uncertainty Ranking
					Codes of Practice	Site specific risk mitigation measures	Consequence	Likelihood	Risk Rating				
9			Surface spills from storage, handling and transportation of flowback water. (Path 3 & 7)	Serious	A.3.8 Containment of Contaminants B.4.13 Hydraulic Stimulation and Flowback Operations C.4.2 Management of produced water and flowback fluid C.7.1 Wastewater Management Plan C.7.2 Spill Management Plan	Source: • Tanks to be double-lined with leak detection. • High risk chemical storage and handling areas to have secondary containment. • Weekly inspections to identify any potential leaks. • Licenced waste transporters to be used. • Secondary containment utilised for storage of on-site chemicals • Lease bunded with each bund. • Spill Management Plan. • NORMS levels are not anticipated to be significant- with characterisation of levels within drilling wastewater and flowback undertaken to validate. • Site contamination assessments undertaken in accordance with NEPM Pathway: • Separation between chemical storages and closest aquifer over 70m, with interbedded clays likely to limit any contaminant migration. • Spill Management Plan implemented. Receptor: • Separation between lease and closest aquifer over 70m. • Nearest landholder extraction bore 11.4km. • Impact and control groundwater monitoring bores installed within 20m of exploration wells to detect any potential contamination. • Spills and leaks to be cleaned up and rectified as soon as possible.	3	1	L		Effective	The regulatory regime legislating the storage, handling and transportation of controlled wastes in the NT and Australia is mature. - Origin has extensive experience in drilling and stimulating unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report.	Low
10			Storage, handling and transportation of chemicals, fuels and wastes. (Path 3)	Serious	A.3.8 Containment of Contaminants C.7.1 Wastewater management plan requirements C.7.2 Spill Management Plan	Source: • All chemical, fuel and waste storage and high risk spill handling areas are to be bunded. • Weekly inspections to identify any potential leaks. • Licenced waste transporters to be used to transport listed wastes. • Chemicals to be transported in accordance with the Australian Dangerous Goods Code and NT Dangerous Goods Act. • Leases to be engineered and compacted with earthen bunding and spill material to be recovered immediately. Pathway: • Separation between chemical stores and closest aquifer over 70m, with interbedded clays likely to limit any potential contaminant migration. • Spill Management Plan implemented. • All transportation of listed wastes and dangerous goods to be undertaken via licenced contractors. Receptor: • Separation between storage areas and closest aquifer over 70m. • Nearest landholder extraction bore 11.4km. • Impact and control groundwater monitoring bores installed around exploration wells to detect any potential contamination. • Area is remote with major urban areas to be avoided during the transportation of dangerous goods and wastes in accordance with the NT Dangerous Goods Act.	2	2	L		Effective	The regulatory regime legislating the storage, handling and transportation of dangerous goods and combustible liquids within Australia is mature. - Origin has extensive experience in transporting, storing and managing chemicals and fuels associated with unconventional petroleum drilling and stimulation activities. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report.	Low
11			Overtopping of drilling sumps and flowback tanks. (Path 7)	Serious	A.3.8 Containment of Contaminants B.4.13 Hydraulic Stimulation and Flowback Operations C.4.2 Management of produced water and flowback fluid C.7.1 Wastewater Management Plan C.7.2 Spill Management Plan	Source: • Wastewater Management Plan. • Spill Management Plan. • Covered tanks to be used during wet season flowback storage. • Open Tank and drilling sump freeboard to be 1:1000 ARI. • Monitoring of tank and sump levels daily when operational. • Leases to be compacted with earthen bunding and spill material to be recovered immediately. • in the event of a major spill, a site assessment in accordance with the National Environmental Protection (Assessment of Site Contamination) Measure, including the assessment of NORMs Pathway: • Spill Management Plan implemented. • Separation between lease pad and closest aquifer over 70m, with interbedded clays likely to limit any potential contaminant migration. Receptor: • Separation between lease and closest aquifer over 70m. • Nearest landholder extraction bore 11.4km. • Impact and control groundwater monitoring bores installed within 20m of exploration wells to detect any potential contamination. • Spills to be cleaned up as soon as possible.	2	1	L		Effective	Origin has extensive experience in managing drilling and stimulation fluids (including flowback) associated with unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report Beetaloo Sub-Basin. - CSIRO regional baseline monitoring program. - Control and impact monitoring bores as per Preliminary Guidelines: Groundwater Monitoring bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin.	Low

Ref	Environmental Factor	Risk Description	Risk Source	Unmitigated consequence	Risk mitigation Measures		Residual Risk Rating			Residual Risk Statement	Effectiveness of Treatment	Scientific uncertainty	Uncertainty Ranking
					Codes of Practice	Site specific risk mitigation measures	Consequence	Likelihood	Risk Rating				
12			Failure of flowback storage tank. (Path4 & 7)	Major	A.3.1 Surface activties mandatory requirements C.4.2 Management of produced water and flowback fluid C.7.2 Spill Management Plan	Source: • Wastewater Management Plan. • Spill Management Plan. • Tanks to be engineered to meet the relevant Australian standards including wind loading and bushfires. • Leases to be compacted with earthen bunding and spill material to be recovered immediately. • in the event of a major spill, a site assessment in accordance with the National Environmental Protection (Assessment of Site Contamination) Measure, including the assessment of NORMs Pathway: • Spill Management Plan implemented. • Separation between lease pad and closest aquifer anticipated to be over70m, with interbedded clays likely to limit any potential contaminant migration. Receptor: • Separation between lease and closest aquifer anticipated to be over 70m. • Nearest landholder extraction bore 11.4km. • Impact and control groundwater monitoring bores installed within 20m of exploration wells to detect any potential contamination. • Spills to be cleaned up as soon as possible.	3	1	L		Effective	Origin has extensive experience in managing drilling and stimulation fluids (including flowback) associated with unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report Beetaloo Sub-Basin. - CSIRO regional baseline monitoring program. - Control and impact monitoring bores as per Preliminary Guidelines: Groundwater Monitoring bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin.	Low
13	Surface Water	Contamination of surface water from surface activities.	Failure of flowback storage tank. (Path4 & 7)	Major	A.3.1 Surface activties mandatory requirements A.3.8 Containment of Contaminants C.4.2 Management of produced water and flowback fluid C.7.1 Wastewater management plan C.7.2 Spill Management Plan	Source: • Wastewater Management Plan. • Spill Management Plan. • Tanks to be engineered to meet the relevant Australian standards including wind loading and bushfires. • Leases to be compacted with earthen bunding and spill material to be recovered immediately. • in the event of a major spill, a site assessment in accordance with the National Environmental Protection (Assessment of Site Contamination) Measure, including the assessment of NORMs Pathway: • Spill Management Plan implemented. • Area is flat with the separation between lease pad and closest major watercourse is ~13km away. • Lease pad bunded preventing off-site release of flowback. Receptor: • Separation between lease pad and closest major watercourse is ~45km. • No major wetlands, with closest ~125km away (Lake Woods).	3	1	L		Effective	Origin has extensive experience in managing drilling and stimulation fluids (including flowback) associated with unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report Beetaloo Sub-Basin. - CSIRO regional baseline monitoring program. - Control and impact monitoring bores as per Preliminary Guidelines: Groundwater Monitoring bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin.	Low
14			Overtopping of drilling sumps and flowback tanks. (Path 4 & 7)	Serious	A.3.8 Containment of Contaminants B.4.13 Hydraulic Stimulation and Flowback Operations C.4.2 Management of produced water and flowback fluid C.7.1 Wastewater Management Plan C.7.2 Spill Management Plan	Source: • Wastewater Management Plan. • Spill Management Plan. • Covered tanks to be used during wet season flowback storage. • Open tank and drilling sump freeboard to be 1:1000 ARI. • Monitoring of tank and sump levels daily when operational. • Leases to be compacted with earthen bunding and spill material to be recovered immediately. • Mud sump to be sized to accommodate anticipated material volume with an appropriate margin of safety. Pathway: • Spill Management Plan implemented. • Area is flat with the separation between lease pad and closest major watercourse is ~13km away. • Lease pad bunded preventing off-site release of wastewater. Receptor: • Separation between lease pad and closest major watercourse is ~45km. • No major wetlands, with closest ~100km away (Lake Woods).	2	2	L		Effective	Origin has extensive experience in managing drilling and stimulation fluids (including flowback) associated with unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report Beetaloo Sub-Basin. - CSIRO regional baseline monitoring program. - Control and impact monitoring bores as per Preliminary Guidelines: Groundwater Monitoring bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin.	Low

Ref	Environmental Factor	Risk Description	Risk Source	Unmitigated consequence	Risk mitigation Measures		Residual Risk Rating			Residual Risk Statement	Effectiveness of Treatment	Scientific uncertainty	Uncertainty Ranking
					Codes of Practice	Site specific risk mitigation measures	Consequenc	Likelihood	Risk Rating				
15			Transportation accident releasing chemical or wastewater (drilling fluid and flowback).	Serious	A.3.8 Containment of Contaminants B.4.13 Hydraulic Stimulation and Flowback Operations C.4.2 Management of produced water and flowback fluid C.7.1 Wastewater Management Plan C.7.2 Spill Management Plan	Source: • Wastewater Management Plan implemented to ensure appropriate wastewater management requirements are implemented as per CoP • Spill Management Plan implemented to prevent, detect and respond to spills Transportation of chemicals, wastewater and fuels to only occur in the wet season where it is safe to do so and a risk assessment indicated the transportation is acceptable, as per Codes of Practice. • All wastes to be transported in accordance with the NT Waste Management and Pollution Control Act. • All dangerous goods to be transported in accordance with the NT Dangerous Goods Act and Australian Dangerous Goods Code. Pathway: • Spill Management Plan implemented. Receptor: • Area is remote with major urban centres to be avoided. • Risk to any receptor is identical to that of normal diesel or petroleum tankers.	3	1	L		Effective	The regulatory regime legislating the storage, handling and transportation of dangerous goods and combustible liquids within Australia is mature. - Origin has extensive experience in transporting chemicals and fuels associated with unconventional petroleum drilling and stimulation activities. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report.	Low
16			Storage and handling of chemicals and fuel. (Path 4)	Moderate	A.3.8 Containment of Contaminants C.7.2 Spill Management Plan	Source: • Wastewater Management Plan. • Spill Management Plan. • All areas where chemicals and fuels are stored will have secondary containment. • Weekly inspections will be implemented and spills rectified as soon as practicable. Pathway: • Spill Management Plan implemented. • Lease pads compacted and earthen bunded to prevent off-site releases. Receptor: • Area is remote with closest receptor approximately 30km away.	1	3	L		Effective	The regulatory regime legislating the storage, handling and transportation of dangerous goods and combustible liquids within Australia is mature. - Origin has extensive experience in transporting, storing and managing chemicals and fuels associated with unconventional petroleum drilling and stimulation activities. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report.	Low
17			Release of stormwater from activities to surface water.	Minor	A.3.1 Surface activties mandatory requirements A.3.4 Erosion and sediment control and hydrology	Source: • Erosion and Sediment Control Plan. • Lease pad located away from watercourses or regional flow paths. • Contaminated stormwater to be retained on-site, treated and disposed off-site at a licenced disposal facility. • Clean stormwater to be reused or released off-site in a manner that reduces the risk of erosion. • Stockpiled debris to be used to discourage water concentration. Pathway: • Lease pad to be earthen bunded. • Erosion and Sediment Control Plan implemented. Receptor: • Area is remote with closest watercourse approximately 45km away.	1	3	L		Effective	The understanding of the risks associated with the release of stormwater from construction sites is mature, with international standards providing guidance to manage the risk. -The NT has a range of technical guidance notes covering soil management, erosion and sediment control including the NT Land Clearing Guidelines.	Low
18			Erosion and sediment releases from lease pads and access tracks.	Moderate	A.3.1 Surface activties mandatory requirements A.3.4 Erosion and sediment control and hydrology	Source: • Erosion and Sediment Control Plan implemented to prevent, detect and respond to erosion and sedimentation. • Lease pad located away from watercourses or regional flow paths. • Land clearing to be undertaken in accordance with the NT Land Clearing Guidelines. • No clearing of vegetation in watercourses proposed. Pathway: • Lease pad to be earthen bunded. • Erosion and Sediment Control Plan implemented to prevent, detect and respond to erosion and sedimentation. Receptor: • Lease pad is located away from watercourses. • Area is remote with closest watercourse approximately 13km away.	1	3	L		Effective	The understanding of the risks associated with the release of stormwater from construction sites is mature, with international standards providing guidance to manage the risk. -The NT has a range of technical guidance notes covering soil management, erosion and sediment control. this includes the NT Land Clearing Guidelines	Low

Ref	Environmental Factor	Risk Description	Risk Source	Unmitigated consequence	Risk mitigation Measures		Residual Risk Rating			Residual Risk Statement	Effectiveness of Treatment	Scientific uncertainty	Uncertainty Ranking
					Codes of Practice	Site specific risk mitigation measures	Consequenc	Likelihood	Risk Rating				
19			Wet season operations- Drilling and stimulation	Serious	A.3.1 Surface activties mandatory requirements A.3.8 Containment of Contaminants C.4.2 Management of produced water and flowback flui C.7.1 Wastewater management plan C.7.2 Spill Management Plan d	•All fuels stored in accordance with AS 1940 •Chemicals storages to be covered to prevent water ingress •Chemical, wastewater and fuel transportation will not be undertaken unless the access track are passable and a specific risk assessment is undertaken that demonstrate the risk of transportation is acceptable (as per the Codes of Practice) •Site to be manned at all time with earth moving equipment and wet weather supplies stored onsite (such as fuels, chemicals and spares) to deal with routine and emergency situations •A wet weather preparedness plan will be developed and implemented outlining the specific risks and controls for wet weather operation •Open working evaporation tanks to have enough freeboard to meet a 1:1000 ARI wet seasons •Enclosed storages will have enough capacity to handle all wastewater stored onsite Site is bunded to prevent offsite releases and overland flow. •Onsite retained stormwater directed to a sediment retention pond prior to release •Wastewater management plan implemented to ensure all controls required to minimise environmental harm are identified and implemented. •Spill management plan implemented to prevent, detect and respond to spills	3	3	M		Effective	Origin has extensive experience in managing drilling and stimulation fluids (including flowback) associated with unconventional petroleum wells across Australia. - codes of practice has impleemtned robust controls to prevent off and onsite contamination resulting from petroleum operations regardless of season	Low
20			Drill sump and flowback tank overtopping.	Serious	A.3.8 Containment of Contaminants C.5.1 Drilling Materials C.4.2 Management of produced water and flowback fluid C.6 Monitoring mandatory requirements C.7.1 Waste management plan C.7.2 Spill Management Plan	Source: • Wastewater Management Plan implemented to ensure the appropriate management of wastewater generated by the activity in accordance with the Code of Practice. • Spill Management Plan implemented to prevent, detect and respond to spills.. • Covered tanks to be used during wet season flowback storage. • Open evaporation tank and drilling sump freeboard to be 1:1000 ARI. • Monitoring of tank and sump levels daily when operational. • Leases to be compacted with earthen bunding and spill material to be recovered immediately. Pathway: • Spill Management Plan implemented. • Lease pad bunded preventing off-site release of wastewater. Receptor: • Lease pad bunded preventing off-site release of wastewater.	2	1	L		Effective	Origin has extensive experience in managing drilling and stimulation fluids (including flowback) associated with unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report Beetaloo Sub-Basin. - CSIRO regional baseline monitoring program. - Control and impact monitoring bores as per Preliminary Guidelines: Groundwater Monitoring bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin.	Low
21			Runoff from sewage treatment irrigation areas.	Minor	A.3.1 Surface activties mandatory requirements A.3.8 Containment of Contaminants	Source: • Irrigation areas located away from watercourses. • Areas designed in accordance with the DOH irrigation guidelines. • Areas appropriately sized to accommodate irrigation volume. Pathway: • Irrigation areas located away from watercourses. Receptor: • Area is remote with closest watercourse approximately 13km away.	1	3	L		Effective	The management of sewerage and greywater is mature with various NT wastewater management guidelines.	Low
22	**Surface Water**	Changes in surface water hydrology resulting vegetation dieback from ponding and diversions away from natural surface systems with environmental and cultural value.	Infrastructure located on regional flow path resulting in changes to surface water flow.	Moderate	A.3.1 Surface activties mandatory requirements A.3.4 Erosion and sediment control and hydrology	Source: • Erosion and Sediment Control Plan implemented to prevent, detect and respond to erosion and sedimentation • Lease pad located away from watercourses or regional flow paths. • Land clearing to be undertaken in accordance with the NT Land Clearing Guidelines. • No clearing of vegetation in watercourses proposed. • Lease pads to be designed to divert stormwater around, without impeding natural surface water flows. • Stockpiled debris to be used to discourage water concentration. Pathway: • Lease pads to be designed to reduce impact on overland flows. Receptor: • Area is remote with closest watercourse approximately 45km away. • The lease area is flat, with water to be diverted around the perimeter of the site.	1	2	L		Effective	Well understood risk with management strategies within the NT Land Clearing Guidelines.	Low

Ref	Environmental Factor	Risk Description	Risk Source	Unmitigated consequence	Risk mitigation Measures		Residual Risk Rating			Residual Risk Statement	Effectiveness of Treatment	Scientific uncertainty	Uncertainty Ranking
					Codes of Practice	Site specific risk mitigation measures	Consequence	Likelihood	Risk Rating				
23			Changes to terrestrial ground surface levels associated with seismic activity.	Moderate	B.4.13 Hydraulic Stimulation and Flowback Operations	Source: • Exploration wells located away form major structural features. • No wastewater injection to be undertaken. • Monitoring of pressure during stimulation to identify if stimulation fluid is entering a open structural feature. Pathway: • No wastewater injection to be undertaken. • Location of well is away from areas with significant faulting. Receptor: • Area is remote with low pollution density.	2	1	L		Effective	- US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report.	Low
24	Water usage	Unsustainable groundwater extraction impacts landholders and groundwater dependent ecosystems.	Over extraction of groundwater for civils, drilling and stimulation activities.	Serious	B.4.17 Groundwater monitoring	Source: • Groundwater extraction for activities to be restricted to the minimum water required. • Exploration well located ~11.4km from closest extraction point. • All water take licenced in accordance with NT Water Act. Pathway: • Drawdown from activity and other users assessed, with impacts to closest receptor determined. Receptor: • Closest receptor is ~11.4km from extraction point. •Continuous flow meters to monitor take and water balance implemented to ensure compliance with WEL GRF10285	3	1	L		Effective	- US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report.	Low
25	Soil	Loss in long-term soil productivity and viability.	Soil compaction from access tracks and leases.	Moderate	A.3.1 Surface activties mandatory requirements	Source: • Land clearing undertaken in accordance with NT Land Clearing Guidelines: • Land Condition Assessment completed. • Lease pads to be stripped of topsoil. • Areas to be rehabilitated to reduce impacts associated with compaction. Pathway: • Areas to be rehabilitated to reduce impacts associated with compaction. Receptor: • Disturbance area is small (less than 0.005% of total tenure area).	2	1	L		Effective	Well understood risk with management strategies within the NT Land Clearing Guidelines.	Low
26			Soil erosion from cleared areas (access tracks, lease pads and camp pads).	Serious	A.3.4 Erosion and sediment control and hydrology	Source: • Land clearing undertaken in accordance with NT Land Clearing Guidelines. • Land Condition Assessment completed. • Areas to be rehabilitated to reduce impacts associated with compaction. • Erosion and Sediment Control Plan implemented. • Stockpiled debris to be used to discourage water concentration. Pathway: • Areas to be rehabilitated to reduce impacts associated with compaction. Receptor: • Disturbance area is small (less than 0.005% of total tenure area).	1	4	M		Effective	The understanding of the risks associated with the release of stormwater from construction sites is mature, with international standards providing guidance to manage the risk. - The NT has a range of technical guidance notes covering soil management, erosion and sediment control including the NT Land Clearing Guidelines.	Low

Ref	Environmental Factor	Risk Description	Risk Source	Unmitigated consequence	Risk mitigation Measures		Residual Risk Rating			Residual Risk Statement	Effectiveness of Treatment	Scientific uncertainty	Uncertainty Ranking
					Codes of Practice	Site specific risk mitigation measures	Consequence	Likelihood	Risk Rating				
27	**Soil**	Soil contamination due to spills and leaks of chemicals, wastes or wastewater.	Spills/leaks from the on-site storing and handling of: - fuels and hydrocarbons - drilling additives - stimulation additives - flowback fluid - solid wastes - storage and transportation of wastes	Serious	A.3.8 Containment of Contaminants C.4.2 Management of produced water and flowback fluid C.7.2 Spill Management Plan	Source: • Wastewater Management Plan implemented to ensure the appropriate management of wastewater generated by the activity in accordance with the Code of Practice. • Spill Management Plan implemented to prevent, detect and respond to spills • All tanks and chemical storage areas to have secondary containment. • Leases to be compacted with earthen bunding and spill material to be recovered immediately. • in the event of a major spill, a site assessment in accordance with the National Environmental Protection (Assessment of Site Contamination) Measure, including the assessment of NORMs Pathway: • Spill Management Plan implemented to prevent, detect and respond to spills. • Lease pad compacted and earthen bunded preventing off-site release of wastewater and chemicals. • All wastes stored and handled in accordance with NT Waste Management and Pollution Control Act. Receptor: • Spill Management Plan to be implemented to prevent, detect and respond to spills • Weekly inspections of secondary containment with any spills rectified as soon as practicable. • All wastes stored and handled in accordance with NT Waste Management and Pollution Control Act.	**1**	**3**	**L**		**Effective**	Origin has extensive experience in transporting, storing and managing drilling and stimulation chemicals (including flowback) associated with unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report Beetaloo Sub-Basin. - CSIRO regional baseline monitoring program. - Control and impact monitoring bores as per Preliminary Guidelines: Groundwater Monitoring bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin.	Low
28			Drill sump and flowback tank overtopping.	Serious	A.3.8 Containment of Contaminants C.5.1 Drilling Materials C.4.2 Management of produced water and flowback fluid C.6 Monitoring mandatory requirements C.7.1 Waste management plan C.7.2 Spill Management Plan	Source: • Wastewater Management Plan implemented to ensure the appropriate management of wastewater generated by the activity in accordance with the Code of Practice. • Spill Management Plan implemented to prevent, detect and respond to spills.. • Covered tanks to be used during wet season flowback storage. • Open evaporation tank and drilling sump freeboard to be 1:1000 ARI. • Monitoring of tank and sump levels daily when operational. • Leases to be compacted with earthen bunding and spill material to be recovered immediately. Pathway: • Spill Management Plan implemented. • Lease pad bunded preventing off-site release of wastewater. Receptor: • Lease pad bunded preventing off-site release of wastewater.	**2**	**1**	**L**		**Effective**	Origin has extensive experience in managing drilling and stimulation fluids (including flowback) associated with unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report Beetaloo Sub-Basin. - CSIRO regional baseline monitoring program. - Control and impact monitoring bores as per Preliminary Guidelines: Groundwater Monitoring bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin.	Low
29			Chemical and waste transportation accident.	Serious	A.3.8 Containment of Contaminants C.7.1 Waste management plan C.7.2 Spill Management Plan	Source: • Wastewater Management Plan implemented to ensure the appropriate management of wastewater generated by the activity in accordance with the Code of Practice. • Spill Management Plan implemented to prevent, detect and respond to spillages.• All wastes to be transported in accordance with the NT Waste Management and Pollution Control Act. • All dangerous goods to be transported in accordance with the NT Dangerous Goods Act and Australian Dangerous Goods Code. Pathway: • Spill Management Plan implemented. • Tanker/truck failure are rare events. Receptor: • Area is remote with major urban centres to be avoided.	**3**	**1**	**L**		**Effective**	The regulatory regime legislating the storage, handling and transportation of controlled wastes in the NT and Australia is mature. - Origin has extensive experience in drilling and stimulating unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report.	Low
30			On-site disposal of drill muds and cuttings.	Serious	B.4.17 Groundwater monitoring C.5.1 Drilling Materials	Source: • Drilling muds are bentonite-based. • Sodium and Chloride levels to be reduced through segregation of drilling fluids from muds. • Drilling muds to be tested and a disposal strategy developed by a suitably qualified third-party in a manner that minimises the risk to the environment. DENR engaged to confirm final disposal strategy. • in the event of a major spill, a site assessment in accordance with the National Environmental Protection (Assessment of Site Contamination) Measure, including the assessment of NORMs Pathway: • Depth to groundwater approximately 70m with interbedded clays separating the lease from the aquifer. Receptor: • Closest landholder bore is 11.4km away.	**2**	**2**	**L**		**Effective**	Origin has extensive experience in managing drilling wastes associated with and unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report. - Various US regulatory authorities provide guidance on drilling waste management.	Low

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					Codes of Practice	Site specific risk mitigation measures	Consequenc	Likelihood	Risk Rating				
31			Failure of a flowback tank.	Major	A.3.1 Surface activties mandatory requirements A.3.8 Containment of Contaminants C.7.1 Wastewater management plan C.7.2 Spill Management Plan	Source: • Wastewater Management Plan implemented to ensure the appropriate management of wastewater generated by the activity in accordance with the Code of Practice. • Spill Management Plan implemented to prevent, detect and respond to spillages. • Tanks to be engineered to meet the relevant Australian standards including wind loading and bushfires. • Leases to be compacted with earthen bunding and spill material to be recovered immediately. Pathway: • Spill Management Plan implemented to prevent, detect and respond to spillages • Lease pad bunded preventing off-site release of flowback. Receptor: • Bunding to minimise the risk of off-site release of fluid in the event of a tank failure. • in the event of a major spill, a site assessment in accordance with the National Environmental Protection (Assessment of Site Contamination) Measure, including the assessment of NORMs	**3**	**1**	**L**		**Effective**	Origin has extensive experience in managing drilling and stimulation fluids (including flowback) associated with unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report. - CSIRO regional baseline monitoring program. - Control and impact monitoring bores as per Preliminary Guidelines: Groundwater Monitoring bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin.	Low
32			Wet season operations- Drilling and stimulation	Serious	A.3.1 Surface activties mandatory requirements A.3.8 Containment of Contaminants C.4.2 Management of produced water and flowback flui C.7.1 Wastewater management plan C.7.2 Spill Management Plan d	•All fuels stored in accordance with AS 1940 •Chemicals storages to be covered to prevent water ingress •Chemical, wastewater and fuel transportation will not be undertaken unless the access track are passable and a specific risk assessment is undertaken that demonstrate the risk of transportation is acceptable (as per the Codes of Practice) •Site to be manned at all time with earth moving equipment and wet weather supplies stored onsite (such as fuels, chemicals and spares) to deal with routine and emergency situations •A wet weather preparedness plan will be developed and implemented outlining the specific risks and controls for wet weather operation •Open working evaporation tanks to have enough freeboard to meet a 1:1000 ARI wet seasons •Enclosed storages will have enough capacity to handle all wastewater stored onsite Site is bunded to prevent offsite releases and overland flow. •Onsite retained stormwater directed to a sediment retention pond prior to release •Wastewater management plan implemented to ensure all controls required to minimise environmental harm are identified and implemented. •Spill management plan implemented to prevent, detect and respond to spills	**3**	**3**	**M**		**Effective**	Origin has extensive experience in managing drilling and stimulation fluids (including flowback) associated with unconventional petroleum wells across Australia. - codes of practice has impleemtned robust controls to prevent off and onsite contamination resulting from petroleum operations regardless of season	Low
33		Soil contamination from the drift of saline wastewater offsite from mechanical evaporation units.	flowback evaporation mist transported offsite during wastewater treatment.	Serious	A.3.1 Surface activties mandatory requirements	• Evaporators to be operated to avoid offsite drift daily monitoring undertaken to ensure no drift from evaporators is identified and corrected • Automatic wind speed and direction cut offs to prevent offsite drift during windy conditions • Flowback tanks located away from boundary, with at least 30m of separation distance.	**2**	**2**	**L**		**Effective**	The use of enhanced evaporators to manage wastewater is a well known technology used through multiple mining and wastewater treatment industries. Evaporators were used successfully on the Amungee Nw 1H well to reduce fluid levels decreasing offsite trucking volumes.	Low
34		Soil contamination from the disposal of greywater and sewerage from camp activities.	Greywater and sewerage disposal (camps).	Minor	C.4.2 Management of flowback water	Source: • All sewerage to be removed off-site in accordance with the NT Waste Management and Pollution Control Act or irrigated as per the NT Health (Treatment of Sewage and Disposal of Effluent and Liquid Waste) Regulations 1974. Pathway: • Irrigation areas to be sized in accordance with the anticipated irrigation volume and quality. Receptor: • Land Condition Assessment.	**1**	**2**	**L**		**Effective**	Risks associated with sewerage and greywater disposal are well known, with technical guidance notes for system design are available within the NT.	Low

Ref	Environmental Factor	Risk Description	Risk Source	Unmitigated consequence	Risk mitigation Measures		Residual Risk Rating			Residual Risk Statement	Effectiveness of Treatment	Scientific uncertainty	Uncertainty Ranking
					Codes of Practice	Site specific risk mitigation measures	Consequenc	Likelihood	Risk Rating				
35	**Terrestrial Flora and fauna**	Disturbance to environmentally sensitive areas and/or high valued habitat areas.	Activity (vehicle and machinery) noise and lighting on well pads and access tracks.	Minor	A.3.1 Surface activties mandatory requirements A.3.3 Noise	Source: • Site location avoids areas of high conservation value as a priority. • Field ecology scouting undertaken as a part of a Land Condition Assessment to prevent impacts to high conservation value areas. • Areas are not considered high conservation value, are not threatened/endangered, with impacts unlikely to result in significant disturbance to threatened/endangered species. Pathway: • no Land clearing proposed Receptor: • Land Condition Assessment confirms the proposed area is regionally abundant and not of high conservation value.	1	3	L		**Effective**	Risks associated with noise on fauna are well understood.	Low
36			Failure of flowback storage tanks.	Major	A.3.1 Surface activties mandatory requirements A.3.8 Containment of Contaminants C.4.2 Management of produced water and flowback fluid C.7.2 Spill Management Plan	Source: • Wastewater Management Plan implemented to ensure the appropriate management of wastewater generated by the activity in accordance with the Code of Practice. • Spill Management Plan implemented to prevent, detect and respond to erosion and sedimentation. • Tanks to be engineered to meet the relevant Australian standards including wind loading and bushfires. • Leases to be compacted with earthen bunding and spill material to be recovered immediately. - Field ecological survey of areas undertaken to avoid areas of high conservation status so areas are not threatened or endangered. Pathway: • Spill Management Plan implemented. • Lease pad bunded preventing off-site release of flowback. Receptor: • Bunding to minimise the risk of off-site release of fluid in the event of a tank failure. • No high conservation areas or endangered flora and fauna within the vicinity of the proposed lease pad likely to be significantly impacted by a release.	3	1	L		**Effective**	Origin has extensive experience in managing drilling and stimulation fluids (including flowback) associated with unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report. - CSIRO regional baseline monitoring program. - Control and impact monitoring bores as per Preliminary Guidelines: Groundwater Monitoring bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin.	Low
37			Introduction and spread of weeds in the area.	Major	A.3.6 Weed management	Source: • Weed Management Plan to be approved by DENR and implemented. • All equipment and vehicles to be washed-down and to have a Biosecurity Declaration Certificate prior to access to site. • Areas of proposed exploration have been surveyed and are deemed to have low weed abundance. • Activity will be restricted to defined lease pads and camp pads. Pathway: • Equipment to be wash-down and certified. • Origin assurance activities to target equipment wash-down certificates to ensure standards are being met. Receptor: • Area is free of weeds and monitoring will be implemented around infrastructure to detect the spread/ introduction of weed species.	2	3	M		**Effective**	Risks associated with weeds are well studied within literature and by the NT DENR. - Field weed surveys will be completed prior to and after construction activities.	Low
39			Accidental ignition of fire from exploration activities (drilling, stimulation, flaring and general access).	Serious	A 3.7 Fire management	Source: • Bushfire management plan implemented to prevent and respond to bushfires. • Bushfire awareness included in site inductions. • Designated smoking areas on-site. • Firefighting equipment to be available to deal with fires. • Fire breaks to be implemented around lease and camp pads. • Appropriate separation distances between flares and surrounding vegetation. • Ignition sources placed outside of the hazardous area. • Intrinsically safe equipment used in hazardous area. • Hazardous area drawing will provide classification of hazardous zones while drilling. Pathway: • Fire breaks to be implemented around lease and camp pads. Receptor: • Activities will comply with landholder and regional bushfire management plans. • Area in the vicinity of Velkerri 76 S2 lease has had recent fire activity, reducing the fuel load.	3	2	M		**Effective**	Risks associated with bushfire are well known, with numerous literature and NT Government management plans and technical guidance notes.	Low

Ref	Environmental Factor	Risk Description	Risk Source	Unmitigated consequence	Risk mitigation Measures		Residual Risk Rating			Residual Risk Statement	Effectiveness of Treatment	Scientific uncertainty	Uncertainty Ranking
					Codes of Practice	Site specific risk mitigation measures	Consequence	Likelihood	Risk Rating				
40			Poor rehabilitation.	Serious	A.3.9 Rehabilitation	• A site specific Rehabilitation Plan will be developed prior to rehabilitation. • The final Rehabilitation Plan will be developed in consultation with the leaseholder and DENR. • Rehabilitation success criteria will be developed with ongoing monitoring undertaken to measure success. • Maintenance will be undertaken periodically to fix any defects.	1	2	L		**Effective**	Risks associated with rehabilitation are well known. Knowledge of rehabilitation within the Beetaloo Basin has been gained, based on previous seismic line rehabilitation programs.	Low
41		Impacts to fauna, including threatened species.	Trapping and drowning of fauna in storage tanks and sumps.	Moderate	C.5.1 Drilling Materials C.4.1 Drilling Fluids	Source: • Tanks walls are raised with minimal risk of animals accessing tanks. • Site manned during operation. Pathway: • Lease pads fenced to prevent stock and wildlife access. Receptor: • Lease pads fenced to prevent stock and wildlife access.	2	2	L		**Effective**	Risks associated with potentially trapping and drowning fauna in storage tanks and sumps are well understood. Origin has extensive experience in managing sumps, ponds and tanks to prevent fauna ingress.	Low
42			Contaminants (chemicals and wastewater) pass through the food chain and bioaccumulate in fauna.	Moderate	A.3.8 Containment of Contaminants C.4.2 Management of produced water and flowback fluid C.7.2 Spill Management Plan	Source: • Wastewater Management Plan implemented to ensure the appropriate management of wastewater in accordance with the Codes of Practice. • Spill Management Plan implemented to prevent, detect and respond to spills • Chemical risk assessments with no chemicals considered above low concern levels when handled in accordance with regulatory requirements and Safety Data Sheets. earthen bunding to prevent off-site release of wastewater and chemicals. Pathway: • Spill Management Plan implemented to prevent, detect and respond to spills • Lease pads fenced. • Lease pad bunded preventing off-site release of chemicals. Receptor: • Bunding to minimise the risk of off-site release of fluid in the event of a tank or storage failure.	2	2	L		**Effective**	A chemical risk assessment and flowback characterisation program for the Amungee NW 1 well ensures all potential chemicals that are persistent, bioaccumulative and toxic at high concentrations are identified and appropriate management strategies implemented. The risks associated with fauna ingestion of chemicals is well known and measures to prevent ingestion (such as fences and separation distances to activity) are deployed as standard practice. Origin has extensive operational experience in drilling and stimulating 1000s of conventional and unconventional petroleum wells with no evidence of impacts on biota from chemicals.	Low
43			Vehicle collisions with fauna – fauna mortality.	Minor	A.3.5 Biodiversity Protection	Source: • Vehicle speed limited to 80km/hr to be reduced around areas of high risk of fauna collision. • Vehicle movements to avoid driving at night. Pathway: • Vehicle speed limits to be reduced around areas of high risk of fauna collision. Receptor: • Vehicle speed limits to be reduced around areas of high risk of fauna collision.	1	3	L		**Effective**	Risks associated with fauna collisions are well known.	Low
44			Activity noise and lighting on well pads and access tracks disturbs fauna.	Minor	A.3.1 Surface activties mandatory requirements A.3.3 Noise	Source: • Site location avoids areas of high conservation value as a priority. • Field ecology scouting undertaken as a part of a Land Condition Assessment to prevent impacts to high conservation value areas. • Areas are not considered high conservation value, are not threatened/endangered, with impacts unlikely to result in fragmentation. Pathway: • Land clearing conducted in accordance with NT Land Clearing Guidelines. • Lighting levels minimised to the level required to complete work safely. Receptor: • Land Condition Assessment confirms the proposed area is regionally abundant and not of high conservation value.	1	3	L		**Effective**	Risks associated with noise and light impacts on flora and fauna are covered extensively in literature.	Low
45			Encouragement of feral animals and other pest species increases leading to competition with native species.	Moderate	A.3.5 Biodiversity Protection	Source: • Camp wastes to be stored in a manner to prevent attracting feral animals. • All food scraps to be removed from site and disposed of at a licenced facility. Pathway: • Camps to be fenced. Receptor: • Camps to be fenced	1	3	L		**Effective**	The risks associated with encouraging feral animals with inadequate waste management are well understood within literature and government policy.	Low

Ref	Environmental Factor	Risk Description	Risk Source	Unmitigated consequence	Risk mitigation Measures		Residual Risk Rating			Residual Risk Statement	Effectiveness of Treatment	Scientific uncertainty	Uncertainty Ranking
					Codes of Practice	Site specific risk mitigation measures	Consequence	Likelihood	Risk Rating				
46			Fragmentation of habitat.	Moderate	A.3.1 Surface activties mandatory requirements A.3.5 Biodiversity Protection	Source: • Site location avoids areas of high conservation value as a priority. • Cleared areas to be clearly marked to avoid confusion. • Field ecology scouting undertaken as a part of Land Condition Assessment to prevent impacts to high conservation value areas. • Areas are not considered high conservation value, are not threatened/endangered, are regionally extensive and impacts are unlikely to result in fragmentation. Pathway: • Land clearing conducted in accordance with NT Land Clearing Guidelines. Receptor: • Land Condition Assessment confirms the proposed area is regionally extensive and not of high conservation value. • Land clearing pressures form other industries are not significant in the area.	1	1	L		Effective	The risks associated with habitat fragmentation are well covered in literature. - NT DENR Vegetation Maps - Field ecological surveys completed across the tenure since 2005, including the subject area.	Low
47			Poor rehabilitation reduces habitat quality.	Serious	A.3.9 Rehabilitation	• A site specific Rehabilitation Plan will be developed prior to rehabilitation. • The Rehabilitation Plan will be developed in consultation with the leaseholder and DENR. • Rehabilitation success criteria will be developed with ongoing monitoring undertaken to measure success. • Maintenance will be undertaken periodically to fix any defects.	2	2	L		Effective	The risks associated with habitat fragmentation are well covered in literature. - NT DENR Vegetation Maps. - Field ecological surveys completed across the tenure since 2005, including the subject area.	Low
48			Accidental ignition of fire from exploration activities (civils, drilling, stimulation, flaring and general access).	Serious	A 3.7 Fire management	Source: • Bushfire management plan implemented to prevent and respond to bushfires. • Bushfire awareness included in site inductions. • Designated smoking areas on-site. • Firefighting equipment to be available to deal with fires. • Fire breaks to be implemented around lease and camp pads. • Appropriate separation distances between flares and surrounding vegetation. • Ignition sources placed outside of the hazardous area. • Intrinsically safe equipment used in hazardous area. • Hazardous area drawing will provide classification of hazardous zones while drilling. Pathway: • Fire breaks to be implemented around lease and camp pads. Receptor: • Activities will comply with landholder and regional bushfire management plans. • Area in the vicinity of Velkerri 76 S2 lease has had recent fire activity, reducing the fuel load.	3	2	M		Effective	Risks associated with bushfire are well known, with numerous literature and NT Government management plans and technical guidance notes.	Low
49	**Cultural Heritage and Sacred Sites**	Disturbance of sacred site or culturally sensitive area	Sites disturbed directly by access track construction or drilling operations.	Serious	A.3.1 Surface activties mandatory requirements	Source: • All areas of the proposed activity to be cleared by NLC. • AAPA certificates for proposed work program have been granted. • The location of infrastructure has considered proximity to sacred sites. Pathway: • Areas of cultural heritage to be avoided during construction. Receptor: • Areas of cultural significance are not within 14km of the proposed area of activity.	3	1	L		Effective	All sites of the proposed activity must have Traditional Owner clearance via the NLC. - AAPA certificates are required for all activities. - Restricted work areas are identified.	Low
50			Accidental ignition by site activities (civil works, drilling, grinding) or site personnel.	Serious	A 3.7 Fire management	Source: • Bushfire management plan implemented to prevent and respond to bushfires. • Bushfire awareness included in site inductions. • Designated smoking areas on-site. • Firefighting equipment to be available to deal with fires. • Fire breaks to be implemented around lease and camp pads. • Appropriate separation distances between flares and surrounding vegetation. • Ignition sources placed outside of the hazardous area. • Intrinsically safe equipment used in hazardous area. • Hazardous area drawing will provide classification of hazardous zones while drilling. Pathway: • Fire breaks to be implemented around lease and camp pads. Receptor: • Activities will comply with landholder and regional bushfire management plans. • Area in the vicinity of Velkerri 76 S2 lease has had recent fire activity, reducing the fuel load.	3	2	M		Effective	Risks associated with bushfire are well known, with numerous literature and NT Government management plans and technical guidance notes.	Low

Ref	Environmental Factor	Risk Description	Risk Source	Unmitigated consequence	Risk mitigation Measures		Residual Risk Rating			Residual Risk Statement	Effectiveness of Treatment	Scientific uncertainty	Uncertainty Ranking
					Codes of Practice	Site specific risk mitigation measures	Consequenc	Likelihood	Risk Rating				
51			Flowback tank structural failure.	Major	A.3.1 Surface activties mandatory requirements A.3.8 Containment of Contaminants C.4.2 Management of produced water and flowback fluid C.7.2 Spill Management Plan	Source: • Wastewater Management Plan implemented to ensure the controls required under the codes of Practice are implemented. • Spill Management Plan implemented to prevent, detect and remediate spills • Tanks to be engineered to meet the relevant Australian standards including wind loading and bushfires. • Leases to be compacted with earthen bunding and off-site release of contaminants to be minimised. • Field cultural heritage and NLC clearance surveys of areas undertaken to avoid areas of cultural significance. Pathway: • Spill Management Plan implemented. • Lease pad bunded preventing off-site release of flowback. Receptor: • Bunding to minimise the risk of off-site release of fluid in the event of a tank failure. • No sacred sites within the vicinity of proposed activity.	**3**	**1**	**L**		**Effective**	Origin has extensive experience in managing drilling and stimulation fluids (including flowback) associated with unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report. - CSIRO regional baseline monitoring program. - Control and impact monitoring bores as per Preliminary Guidelines: Groundwater Monitoring bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin.	Low
52			Personnel unauthorised access to restricted work area.	Serious	A.3.1 Surface activties mandatory requirements	Source: • Restricted work areas are not located in close proximity to explorational activities. • All staff to be inducted covering restricted work areas and cultural heritage. • Access off lease not permitted. Pathway: • Access off lease not permitted. Receptor: • Access off lease not permitted. • No restricted work areas within the vicinity of proposed activity.	**2**	**1**	**L**		**Effective**	All sites of the proposed activity must have Traditional Owner clearance via the NLC. - AAPA certificates are required for all activities. - Restricted work areas are identified .	Low
53	**Community impact**	Loss of visual amenity, experience and sense of place for landholder, community members and tourists.	Industrialisation of landscape.	Moderate	A.3.1 Surface activties mandatory requirements	• Site is located away from major roads and not visible. • Level of clearing for infrastructure is small.	**1**	**1**	**L**		**Effective**	Risks associated with aesthetic changes due to infrastructure construction are well known and not restricted to the petroleum industry.	Low
54			Increased traffic.	Moderate	A.3.1 Surface activties mandatory requirements	• Traffic impact assessment completed assessing the increased traffic levels as negligible: reflective of limited size and scope of activity. • Traffic impacts are expected to small and temporary. • Access route is away from the main homestead. •Capacity of road and level of service will not be impacted materially. •busses used to limit transportation between airport and remote camps- limited Drive In/Drive Out workers- with most Fly in/fly out of Daly Waters.	**2**	**1**	**L**		**Effective**	Risks associated with increased traffic are well known throughout literature and policy.	Low
55			Light emissions activities.	Minor	A.3.1 Surface activties mandatory requirements	• Site is located 100km away from the Stuart Highway and the nearest homestead although a visible hue may be present during flaring. This is likely to be consistent with a small town and only visible during the night.	**1**	**1**	**L**		**Effective**	Risks associated with light emission are well known with various literature and technical guidelines available to mitigate impacts.	Low
56			Influx of workers to region	moderate		• The majority of workers will be Fly in Fly Out and based at remote camps away from communities. • Local hotel accommodation will be used sparingly to avoid competition with tourists. • Workers restricted to lease areas- with no access to surrounding properties authorised.	**2**	**1**	**L**		**Effective**	The limited scope and duration of activities reduces the risk and uncertainty associated with risk. Most workers will be located away from communities, meaning there is unlikely to be a major increase in people.	Low
57			Noise emissions from activities.	Minor	A.3.1 Surface activties mandatory requirements A.3.3 Noise	• Site located 100km away from the Stuart Highway and the nearest homestead so activity is not anticipated to be visible.	**1**	**1**	**L**		**Effective**	Risks associated with noise emission are well known with various literature and NT noise guidelines available to mitigate impacts.	Low
58		Reduction in agriculture productivity.	Introduction and spread of weeds in the area.	Major	A.3.6 Weed management	Source: • Weed Management Plan to be implemented to prevent, detect and respond to weed infestations. • All equipment and vehicles to be washed-down and to have a Biosecurity Declaration Certificate prior to access to site. • Areas of proposed exploration have been surveyed and are deemed to have low weed abundance. Pathway: • Equipment to be washed-down and certified. • Origin assurance activities to target equipment wash-down certificates to ensure standards are being met. Receptor: • Area is free of weeds and monitoring will be implemented around infrastructure to detect the spread/introduction of weed species.	**2**	**3**	**M**		**Effective**	Risks associated with weeds are well studied within literature and by the NT DENR. - Field weed surveys will be completed prior to and after construction activities.	Low

Ref	Environmental Factor	Risk Description	Risk Source	Unmitigated consequence	Risk mitigation Measures		Residual Risk Rating			Residual Risk Statement	Effectiveness of Treatment	Scientific uncertainty	Uncertainty Ranking
					Codes of Practice	Site specific risk mitigation measures	Consequence	Likelihood	Risk Rating				
59			Over extraction of groundwater.	Serious	A.3.2 Well pad specific site selection requirements B.4.17 Groundwater monitoring	Source: • Groundwater extraction for activities to be restricted to the minimum water required and in accordance with Water Extraction Licence conditions • Exploration well located ~11.4km from closest extraction point. • Drawdown from activity and other users assessed, with impacts to closest receptor not anticipated. Receptor: • Closest receptor ~11.4km from extraction point.	1	1	L		Effective	The regional understanding of the CLA is sufficient to understand the risks associated with groundwater extraction. The absence of users and small exploration take reduces the uncertainty of the activity.	Low
60			Impact to surface hydrology reduces water capture.	Moderate	A.3.4 Erosion and sediment control and hydrology A.3.1 Surface activties mandatory requirements	Source: • Lease pads located away form major watercourses or flow paths. • Lease pads designed to not disrupt flow paths, with overland flow diverted around lease. • Infrastructure design in accordance with the NT Land Clearing Guidelines. • Erosion and sediment control plan implemented to prevent, detect and respond to erosion and sedimentation.	1	1	L		Effective	The risks associated with changes in surface hydrology are well known. Guidance notes are available via the NT Land Clearing Guidelines and BPESC to minimise the impact on surface hydrology.	Low
61			Bushfire from accidental ignition by site activities (civil works, drilling, grinding) or personnel.	Serious	A 3.7 Fire management	Source: • Bushfire management plan implemented to prevent and respond to bushfires. • Bushfire awareness included in site inductions. • Designated smoking areas on-site. • Firefighting equipment to be available to deal with fires. • Fire breaks to be implemented around lease and camp pads. • Appropriate separation distances between flares and surrounding vegetation. • Ignition sources placed outside of the hazardous area. • Intrinsically safe equipment used in hazardous area. • Hazardous area drawing will provide classification of hazardous zones while drilling. Pathway: • Fire breaks to be implemented around lease and camp pads. Receptor: • Activities will comply with landholder and regional bushfire management plans. • Area in the vicinity of Velkerri 76 S2 lease has had recent fire activity, reducing the fuel load.	3	2	M		Effective	Risks associated with bushfire are well known, with numerous literature and NT Government management plans and technical guidance notes.	Low
62			Poor rehabilitation of exploration infrastructure.	Serious	A.3.9 Rehabilitation	• A site specific Rehabilitation Plan will be developed prior to rehabilitation. • The Rehabilitation Plan will be developed in consultation with the leaseholder and DENR. • Rehabilitation success criteria will be developed with ongoing monitoring undertaken to measure success. • Maintenance will be undertaken periodically to fix any defects.	2	2	L		Effective	Risks associated with rehabilitation are well known. Knowledge of rehabilitation within the Beetaloo Basin has been gained based on previous seismic line rehabilitation programs.	Low
63			Disruption of agricultural operations, including use of helicopters	Moderate	A.3.1 Surface activties mandatory requirements A.3.3 Noise	• All activities require engagement with leaseholders. • Lease sites are located to avoid disruption to agriculture operations and infrastructure. • Engagement will be undertaken in accordance with NT Petroleum Act. •Traffic levels are anticipated to be small- as per Traffic Impact Assessment. •Helicopter operations to avoid pastoralist homesteads, cattle yards and low level flying. •All helicopter movements to be undertaken in consultation with surrounding pastoralist to avoid impact to operations (such as cattle mustering)	1	1	L		Effective	Origin has extensive experience in co-existing its activities with agricultural users. Consultation with pastoralists is undertaken to ensure impacts on their activities are mitigated.	Low

Ref	Environmental Factor	Risk Description	Risk Source	Unmitigated consequence	Risk mitigation Measures		Residual Risk Rating			Residual Risk Statement	Effectiveness of Treatment	Scientific uncertainty	Uncertainty Ranking
					Codes of Practice	Site specific risk mitigation measures	Consequence	Likelihood	Risk Rating				
64		Safety hazard to pastoralists, community and tourists from increased traffic levels	Increased risk of vehicle accident	Major	A.3.1 Surface activties mandatory requirements	• traffic impact assessment completed • Fatigue management policy implemented • alcohol and drug policy implemented • busses used to transport people from airports to camps- no DIDO from drilling, stimulation and well test workers. • camps located away from major roads with most movements internal between camp lease and drill site • Stuart highway intersection design approved by DIPL with appreciate line of site provided for vehicles to identify turning vehicles.	3	1	L		Effective	The management of traffic related risks are well known throughout industry and the government. The introduction on driver training, fatigue management and alcohol and drug policies is standard across industry	Low
65		Labour competition with local businesses and agricultural procedures.	Exploration activities compete with agricultural industry for resources.	Moderate		• Proposed activity is temporary with no major labour requirements- stakeholders engaged to ensure they know the temporal nature of work. • Local contractors for existing communities will be used where available. • Contracts will be structured to reduce 'boom and bust' cycle (clear understanding of limited scope of work). • All work to be short-term with predominantly skilled workforce sourced regionally/interstate.	1	1	L		Effective	Risks associated with small-scale, limited-duration projects on local economies are well known. The short nature of the projects reduces the risks of 'boom and bust' type cycles.	Low
66	**Air Quality**	Reduction in air quality associated with exploration emissions (civil, Drilling, Stimulating and Well Testing).	Emissions from the combustion of diesel.	Moderate	A.3.1 Surface activties mandatory requirements D.4.1 Baseline assessment	Source: • Low emission equipment to be selected. • All equipment to be maintained in accordance with the manufacturer's recommendations. Pathway: • Site is located away from receptors. Receptor: • No homesteads or communities within 50km	1	1	L		Effective	Risks associated with diesel combustion are well known, both within Australia and Internationally. Methods for estimating emissions are available via the National Pollutant Inventory.	Low
67			Air emissions from flaring.	Moderate	A.3.1 Surface activties mandatory requirements D.4.1 Baseline assessment B.4.13 Hydraulic Stimulation and flowback operations D.5.9 Venting and flaring	Source: • Flare with a 98% combustion efficiency. • Emissions of NOx, CO and TVOC are small and not anticipated to reduce ambient air quality. Pathway: • Vertical flare stack used maximising dispersion. • Site located away from receptors. Receptor: • No homesteads or communities within 50km	1	2	L		Effective	Risks associated with emissions from flares are well known within literature, and Australia and International policy/standards exist (such as NGERS and various US EPA technical guidance notes). Methods for estimating emissions are available via the National Pollutant Inventory.	Low
68			Air emissions from chemical releases during drilling and stimulation activities.	Moderate	A.3.1 Surface activties mandatory requirements B.4.16 Wite materials and fluids management B.4.13 Hydraulic Stimulation and flowback operations	Source: • National Occupational Health and Safety Codes: Code of Practice for the Control of Workplace Hazardous Substances. • Chemical Risk Assessment. • Chemical handling and mixing to reduce particulate emissions. Pathway: • Site is located away from receptors. Receptor: • No homesteads or communities within 50km	1	1	L		Effective	Risks associated with air emissions from petroleum activities are well known, with various risk assessment and emissions estimation technical guidance notes available within Australia and internationally (such as the National Pollutant Inventory and the US EPA).	Low
69		Increased nuisance from dust emissions associated with exploration activities.	Civil construction works, drilling operations, well testing.	Moderate	A.3.1 Surface activties mandatory requirements	Source: • Water trucks will be used to decrease dust emissions. • Reduced speed limits will be adopted in proximity to homesteads. Pathway: • Site is located away from receptors. Receptor: • No homesteads or communities within 50km.	1	2	L		Effective	Origin has extensive experience in managing nuisance emissions of dust during petroleum and construction activities. Strategies for managing dust emissions are well known throughout Australia and the NT.	Low

Ref	Environmental Factor	Risk Description	Risk Source	Unmitigated consequence	Risk mitigation Measures		Residual Risk Rating			Residual Risk Statement	Effectiveness of Treatment	Scientific uncertainty	Uncertainty Ranking
					Codes of Practice	Site specific risk mitigation measures	Consequence	Likelihood	Risk Rating				
70			Bushfire from accidental ignition by site activities (civil works, drilling, grinding) or personnel.	Serious	A 3.7 Fire management	Source: • Bushfire management plan implemented to prevent and respond to bushfires. • Bushfire awareness included in site inductions. • Designated smoking areas on-site. • Firefighting equipment to be available to deal with fires. • Fire breaks to be implemented around lease and camp pads. • Appropriate separation distances between flares and surrounding vegetation. • Ignition sources placed outside of the hazardous area. • Intrinsically safe equipment used in hazardous area. • Hazardous area drawing will provide classification of hazardous zones while drilling. Pathway: • Fire breaks to be implemented around lease and camp pads. Receptor: • Activities will comply with landholder and regional bushfire management plans. • Area in the vicinity of Velkerri 76 S22 lease has had recent fire activity, reducing the fuel load.	**3**	**2**	**M**		**Effective**	Risks associated with bushfire are well known, with numerous literature and NT Government management plans and technical guidance notes.	Low
71	**Greenhouse Gas Emissions**	Unsustainable Greenhouse Gas emissions from the activity.	Combustion of diesel for exploration activities.	Moderate	A.3.1 Surface activties mandatory requirements	Source: • Low emission equipment to be selected. • All equipment to be maintained in accordance with the manufacturer's recommendations. Pathway: • Site is located away from receptors. Receptor: • No homesteads or communities within 50km	**1**	**1**	**L**		**Effective**	The risks associated with Greenhouse Gas generation through diesel combustion are well documented in literature and domestic/international greenhouse policy (such as NGERS and IPCC).	Low
72			Flaring of gas during well testing.	Moderate	B.4.13 Hydraulic Stimulation and flowback operations D.5.9 Venting and flaring	• Venting to be minimised with all venting reported under NGERS. • Flare with a 98% combustion efficiency will be used during drilling and well testing. • Emissions from source rock during drilling are negligible.	**1**	**2**	**L**		**Effective**	The risks associated with Greenhouse Gas generation through the use of flares are well documented in literature and domestic/international greenhouse policy (such as NGERS and IPCC).	Low
73			Uncontrolled release of gas encountered during drilling, stimulation, barrier failure and operator error.	Moderate	B.4.1 Well integrity management B.4.3 Well design and barriers B.4.13 Hydraulic Stimulation and flow back operations D.5.9 Venting and flaring	Source: • Flare to be used during drilling to manage gas ingress. • Drilling overpressure to reduce the inflows of hydrocarbons.	**1**	**2**	**L**		**Effective**	Impacts associated with Greenhouse Gas emissions are well known. Emissions during petroleum activities are estimated using the National Greenhouse and Energy Reporting Scheme (NGERS) estimation techniques.	Low
74			Uncontrolled release of gas from well due to sabotage.	Moderate	D.5.9 Venting and flaring	• Multiple barriers used during well suspension/operation. • Sites manned during operation. • Security cameras. • Routine inspections. • Sites locked. • Valves locked.	**1**	**1**	**L**		**Effective**	The risks associated with Greenhouse Gas generation through the use of flares are well documented in literature and domestic/international greenhouse policy (Such as NGERS and IPCC).	Low
75			Leak of gas from wells.	Moderate	B.4.1 Well integrity management B.4.3 Well design and barriers D.5 Emission detection and management D.5.5 Leak remediation and notification	• Well design considers multiple specifically-engineered cement and steel casing barriers in place between hydrocarbon-bearing zone and surface. • Well design and Well Barrier Integrity Validation reports submitted to DPIR as part of Well Operations Management Plan (WOMP). • Wells constructed and suspended with barriers in place and verified as per governing code. • Routine well leak detection. • Any leaking wells to be remediated as soon as practicable. • Limited gas production time only to extended production test.	**1**	**3**	**L**		**Effective**	The risks associated with Greenhouse Gas generation through leaking infrastructure are well documented in literature and domestic/international greenhouse policy (such as NGERS, US EPA and IPCC).	Low

Ref	Environmental Factor	Risk Description	Risk Source	Unmitigated consequence	Risk mitigation Measures		Residual Risk Rating			Residual Risk Statement	Effectiveness of Treatment	Scientific uncertainty	Uncertainty Ranking
					Codes of Practice	Site specific risk mitigation measures	Consequenc	Likelihood	Risk Rating				
76			Clearing of native vegetation.	Moderate	A.3.1 Surface activties mandatory requirements A.3.5 Biodiversity Protection	Source: • No clearing required. • Site location avoids areas where threatened flora and fauna are predicted. • Field ecology scouting undertaken as a part of a Land Condition Assessment to identify protected flora and fauna. • Significant disturbance to threatened/endangered flora and fauna species is not anticipated. • Material stockpiled surrounding lease and not burnt. Pathway: Guidelines. Receptor: • Land Condition Assessment confirms the proposed area is regionally abundant and not of high conservation value.	1	1	L		Effective	Understanding of Greenhouse Gas emissions from land clearing are well documented within literature. Emission estimates using the Transport Authorities Greenhouse Group Greenhouse Gas Assessment Workbook for Road Projects.	Low
77	Cumulative Risk	Cumulative impacts on groundwater quantify.	Groundwater take from surrounding land users exceeds the natural recharge rate of the Basin.	Serious	Water extraction licences under the NT Water Act	• Groundwater extraction assessments include an estimate of current extraction levels at a regional scale. • No intensive users of groundwater within the region, with stock and domestic being the major usage. • Cumulative impacts considered in the water extraction licence under the NT Water Act. • cumulative impacts assessed under water extract licence GRF10285	2	1	L		Effective	The regional understanding of the CLA is sufficient to understand the risks associated with groundwater extraction. The absence of users and small exploration take reduces the uncertainty of the activity.	Low
78		Cumulative impacts on terrestrial ecology.	Impacts from exploration activities and existing agricultural activities results in impacts to vegetation communities, fragmentation and poses a threat to protected flora and fauna.	Moderate	A.3.1 Surface activties mandatory requirements A.3.2 Well pad site specific site selection A.3.5 Biodiversity Protection	• Area has limited development with no widespread land clearing or other pressures from agriculture or other users. • No valid approved clearing permits present within 50km radius • Activity is limited in scale and will not material decrease availability of habitat across the region. • vegetation communities are extensive with limited petroleum, mining or other threatending proceeses.	2	1	L		Effective	The region has low land clearing pressure with no applications for large scale land clearing present. The level of disturbance proposed is small, with field ecological scouting confirming ecological communities present.	Low
79		Cumulative impacts on amenity.	Exploration activities further reduces amenity (visual, noise, traffic and lighting) through additional landscape modification, dust, noise, light and traffic.	Moderate	A.3.1 Surface activties mandatory requirements A.3.2 Well pad site specific site selection	• Activity is located away from major transportation routes and is not visible from roads. • Flaring may create a visible hue on the horizon consistent with that of a small town. • Traffic volumes are anticipated to be small and well below existing industries. • A Traffic Management Plan covering the intersection upgrade work has been submitted to DPIL for approval . • Low level of development activity within the region, with activity unlikely to cause declines in amenity.	1	1	L		Effective	The region is underdeveloped with the activity located away from major transportation routes, homesteads and communities. The activity is of a small size and unlikely to result in any loss of amenity.	Low
80		Cumulative impacts on surface water quality.	Exploration activities in addition to existing surrounding land use (agriculture) reduces surface water quality.	Moderate	A.3.1 Surface activties mandatory requirements A.3.2 Well pad site specific site selection A.3.4 Erosion and sediment control and hydrology	• Area has limited development with no widespread land clearing pressures from agriculture or other users likely to reduce water quality. • Activity will largely occur on existing disturbed areas with limited additional clearing. • No surface water releases permitted.	1	1	L		Effective	The region is underdeveloped with the activity located away from major flow pathways with limited topographic variation.. The activity is of a small size and unlikely to result in any material increase in sediment loads to surface waters.	Low

Appendix O: Weed Management Plan

BEETALOO BASIN EXPLORATION PROJECT

Weed Management Plan

Review record

Rev	Date	Reason for issue	Author	Reviewer	Approver
0	05/10/2018	Issue for release	A Court	M Kernke	M Hanson
1	29/03/2019	Issue for release	A Court	M Kernke	M Hanson
2	20/05/2019	Minor Update	A Court	M Kernke	M Hanson
2.1	10/09/2019	Minor update	M.Kernke		M.Hanson

Review due: 29/03/2022

Weed Management Plan
NT-2050-15-MP-0016

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Weed Management Plan
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1. Introduction

1.1 Objectives of the WMP

This WMP has been developed to ensure that the risk of weed introduction and spread, resulting from activities associated with Origin Exploration activities are mitigated to protect the economic, community, industry and environmental interests of the Territory.

The plan provides an overview of:

- The project context (Section 2)
- Legal requirements in relation to weed management (Section 3)
- The appointment of a Dedicated Weed Officer (Section 4)
- Identified risks and proposed mitigation measures and management objectives (Section 5 and 6)
- The weed species that are considered likely or known to occur within the Permit Area (Section 6 and 7)
- The Annual Action Plan for those species that are known to occur with the Permit Area (Section 8)
- Control options for species known to occur within the Permit Area (Section 8).
- The monitoring, notification, recording and reporting requirements for the WMP (Sections 9 – 12).

This plan is supported by Appendices that provide guidance on how to identify weed species in the field and collect the necessary data to support the monitoring and reporting requirements of this WMP.

The location of the proposed exploration activities are shown on Figure 1.

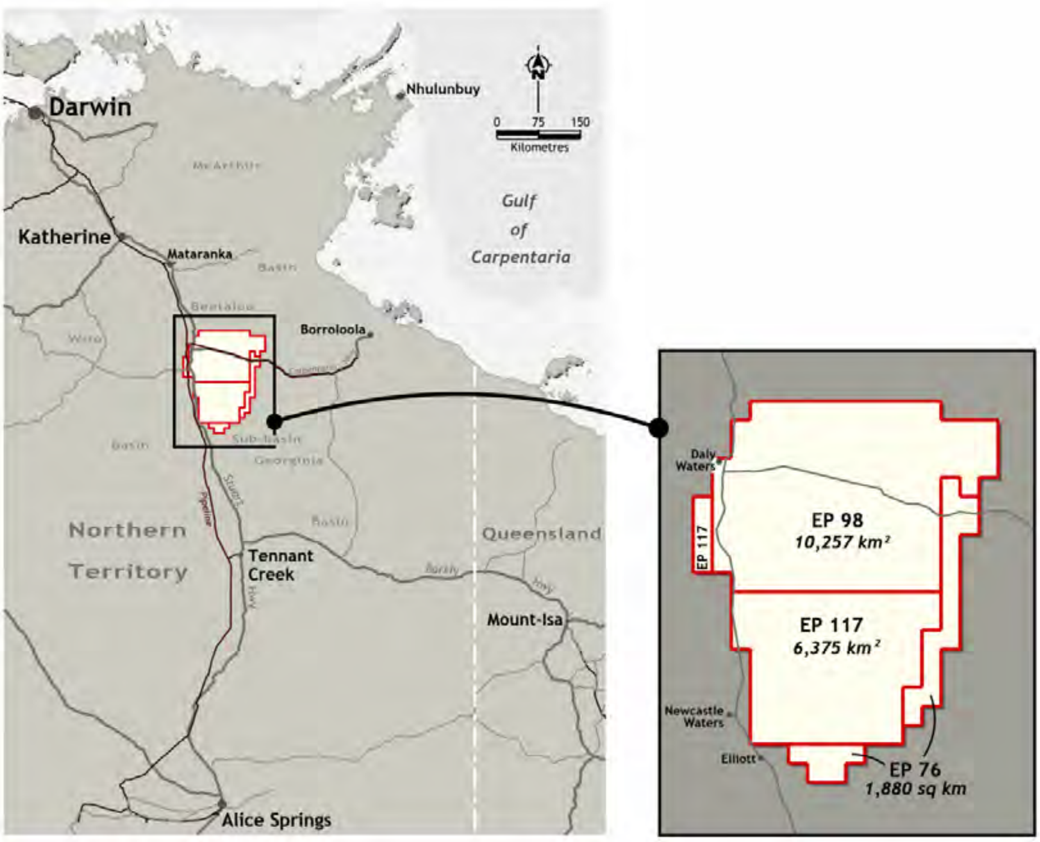

Figure 1 Location of Origin Permit Area

Review due: 29/03/2022

1.2 Intent of the WMP

Weed control is considered to be a significant land management issue in the Northern Territory. This Weed Management Plan (WMP) forms a core component of Origin's overarching environmental management strategy and supports the various project Environmental Management Plan (EMP's).

The movement of rigs, vehicles, machinery and other materials to, from and within the exploration permit area may result in weeds being moved around the pastoral lease, into the lease from surrounding areas or interstate, depending on where the vehicles and materials are sourced from or returned to.

The focus of this WMP is therefore to ensure that infestations are eradicated, or at the very least that existing weed infestations are controlled such that no further weed species colonise the permit area as a result of Origin's activities.

This document is based upon the Weed Management Planning Guide - Onshore Shale Gas Development Projects produced by the Department of Environment and Natural Resources (2018).

2. Project Context

This plan covers all civil, drilling, stimulating, rehabilitation and routine maintenance/monitoring activities undertaken by Origin within permit EP76, EP98 and EP117 as detailed in Table 1. The proposed activities for the 2019/2020 program are highlighted within the table.

Table 1 Coordinates of centroid of proposed exploration lease areas

Exploration Permit	Lease Name	Zone*	Easting	Northing
EP98	Velkerri 98 E1-	53	415515	8180683
EP98	Velkerri 98 N1	53	392292	8189891
EP98	Kyalla 98 W1	53	364955	8177458
EP76	Velkerri 76 S1	53	424362	8113273
EP76	Velkerri 76 S2	53	435488	8136321
EP117	Kyalla 117 N2	53	356175	8137500
EP117	Stuart Highway Intersection	53	332371	8135170
EP117	Velkerri 117 E1	53	428861	8120782
EP117	Kyalla 117 W1	53	368079	8106696

Grey shading are planned sites for 2019/200

** Universal Transverse Mercator (UTM) geographic coordinate system is Geocentric Datum of Australia (GDA) 94.*

The primary activities subject to this WMP are:

- Access track construction, use and maintenance
- Exploration lease pad construction, use and maintenance
- Gravel pit construction and maintenance
- Drilling, stimulating, completing and maintaining petroleum exploration wells
- Routine access, maintenance and monitoring of all exploration areas subject to this plan.

3. Legal Requirements

The following presents the relevant legislation and statutory obligations for the project.

3.1 Northern Territory Petroleum (Environment) Regulations

Petroleum Act 2016, Petroleum (Environment) Regulations 2016 and Code of Practice for Petroleum Activities with in the Northern Territory

The *Petroleum Act 2016* provides legal framework within which persons are encouraged to undertake effective exploration for petroleum and to develop petroleum production so that the optimum value of the resource is returned to the Territory. It regulates the exploration for, and production of petroleum, including environmental protection measures which should be employed during exploration and production activities, including protection of parks and reserves and rehabilitation.

In addition, the Act is supported by the *Petroleum (Environment) Regulations 2016*).

The *Petroleum (Environment) Regulations 2016* requires that regulated activities are carried out in a manner consistent with the principles of ecologically sustainable development, and by which the environmental impacts and environmental risks of the activities are identified and reduced to an acceptable level.

The Code of Practice for Petroleum Activities in the Northern Territory is a mandatory code of practice for the petroleum industry to ensure that petroleum activities in the Northern Territory are managed according to minimum acceptable standards to ensure that risks to the environment can be managed to a level that is as low as reasonably practical (ALARP) and acceptable.

Under these regulations Origin is required to submit an EMP prior to any petroleum exploration or production activity.

EMP's must include:

- potential environmental risks or impacts (in this instance relating to the introduction and spread of weeds);
- appropriate environmental outcomes, environmental performance standards and measurement criteria;
- appropriate implementation strategy and monitoring, recording and reporting arrangements; and
- demonstrate that there has been an appropriate level of engagement with directly affected stakeholders in developing the plan.

This WMP is designed to support and implement the requirements of Origins Project Specific Environmental Management Plans.

3.2 Northern Territory Weeds Management Act

The aim of the *Weeds Management Act (2013)* is 'to protect the Territory's economy, community, industry and environment from the adverse impact of weeds'.

The purpose of the Act, as defined in section 3, is:

- To prevent the spread of weeds in, into and out of the Territory and to ensure that the management of weeds is an integral component of land management in accordance with the Northern Territory Weeds Management Strategy 1996 – 2005 or any other strategy adopted to control weeds in the Territory.
- To ensure there is community consultation in the creation of weed management plans.
- To ensure that there is community responsibility in implementing weed management plans.

The Act identifies declared weeds (those which must be controlled) and provides a framework for weed management. It includes the following weed declaration classes:

Class A – to be eradicated
Class B – growth and spread to be controlled
Class C* – Not to be introduced into the Northern Territory
** All Class A and B weeds are also Class C.*

The Act enables the relevant Minister to approve statutory weed management plans. Management obligations in these plans must be adhered to.

Currently there are statutory management plans for 10 high priority weed species in the Northern Territory.

The WMP must address weeds in accordance with their declaration status and the statutory requirements of any relevant weed management plans.

3.3 Regional Weed Management Plans

Regional Weed Management Plans (RWMP) have been developed for areas of the NT, with the Barkly and the Katherine RWMP overlapping Origin's Beetaloo exploration tenure. the aim of these regional plans is to assist in prioritising weed management by:

- identifying the region's priority weeds and associated pathways of spread to inform management priorities
- identifying landscapes that may need prioritised protection from weed impacts like river corridors or sacred Aboriginal sites
- containing information on alert weeds that are not yet found in the region, but could become major issues if they establish

3.4 Commonwealth Environment Protection Biodiversity Conservation Act

The objectives of the *Environment Protection and Biodiversity Conservation (EPBC) Act* (1999) are, among other things:

- provide for the protection of the environment, especially those aspects of the environment that are matters of national environmental significance; and
- promote ecologically sustainable development through the conservation and ecologically sustainable use of natural resources; and
- promote the conservation of biodiversity; and
- promote a co-operative approach to the protection and management of the environment involving governments, the community, land-holders and indigenous peoples; and
- assist in the co-operative implementation of Australia's international environmental responsibilities.

The *EPBC Act* provides for the identification and listing of key threatening processes. A threatening process is defined as a key threatening process if it threatens or may threaten the survival, abundance or evolutionary development of a native species or ecological community. Key threatening processes include invasive species, such as weeds, which have a major impact on Australia's environment, threatening our unique biodiversity and reducing overall species abundance and diversity (DOTEE 2018).

4. Dedicated Weed Officer

As per recommendation 8.3 of the Scientific Inquiry into Hydraulic Fracturing Stimulation there must be a dedicated Weed Officer for each gas field.

The Weed Officer must have relevant skills and experience and availability to successfully manage weed related issues for the project, including:

- Knowledge of the biology/ecology of local weeds.
- Knowledge of relevant weed management frameworks including Northern Territory legislation and plans, the *EPBC Act*.
- Understanding of existing weed management arrangements being undertaken by landholders.

The Weed Officer is responsible and accountable for delivery of all weed related requirements of the project in accordance with the WMP and the overarching Environmental Management Plan, including:

- Planning and execution of weed monitoring requirements, including baseline weed assessments and ongoing monitoring both during periods of gas related activities as well as during the target identification period of February to May.
- Facilitate training all workers (including contractors) in weed management requirements, with support from the Northern Territory Government Regional Weed Officer - Onshore Shale Gas Development.
- Oversight of implementation of weed control mechanisms including but not limited to wash-downs and proactive weed control programs.
- Ensuring all reporting requirements are met.
- Act as the designated point of contact for and rapidly responding to any weed related complaints and incidents in accordance with the pre-determined strategies in this WMP and additional strategies as required developed in consultation with the Regional Weed Officer - Onshore Shale Gas Development and affected landholders.
- Review and update of WMP's to remain effective in communication with relevant landholders and Regional Weed Officer - Onshore Shale Gas Development in consideration of monitoring results and emerging weed issues for both gas and pastoral operations.

Origin has appointed **Robert Wear, Construction Superintendent** as the dedicated Weed Officer of the Beetaloo Exploration Activities.

5. Weed Species Information

Weed surveys completed in august 2018 indicates the abundance of weeds within the proposed project area is low. *Hyptis suaveolens* (Hyptis), was identified along the access track to the proposed Velkerri 98-E1-1 site, whilst Gamba Grass (*Andropogon gayanus*) is also known to be in the broader region and is used by some Pastoralists in the region for wet season pasture. The pastoral properties using Gamba would be required to control the growth and spread to neighbouring areas (NTG, 2000).

Previous surveys within the permit area completed in 2014, 2015 and 2016 also confirmed the presence of Hyptis in the vicinity of the Carpentaria Highway near Velkerri 98 N1-2 (previously known as Amungee NW-1) site. *Parkinsonia aculeata* (Parkinsonia) and *Calotropis procera* (Rubber Bush) have been previously identified along/in close proximity to the Beetaloo access track. Parkinsonia is considered a Weed of National Significance (WoNS), which are weed species that are the focus of national management programs for the purpose of restricting their spread and/or eradicating them from parts of Australia. These species are specifically presented in Table 2 and Section 9.

Figure 2 illustrates the weeds species confirmed in the region during field surveys, along with other weed species that are known to occur or likely to occur within the wider exploration Permit Areas. This information is based on.

- Origin exploration program weed survey data (2014-2018 results)
- Mapping data provided by the Weed Management Branch, DENR.
- Guidelines for the *Management of the Weeds of Beetaloo 2018* (DLRM et al 2018).
- Barkly and Katherine Regional Weed Management Plans (RWMP)
- Department of the Environment and Energy (DOTEE) EPBC Act Protected Matters Report database.

Table 3 has been separated into priority weeds, RWMP alert species and other species previously identified in the area. Priority weed species are considered higher risk of being introduced or spread through the following criteria:

- Weed species that has been confirmed in the area within the relevant RWMP or through field surveys.
- Weed species listed in a RWMP that is in close proximity to Origin tenure.
- Weed species that are at risk of introduction through the use of machinery sourced from other regions in the NT or from other states.

Alert weed species are identified under the Katherine and Barkley RWMP. These species are not yet naturalised in the region, but have the potential to have a high level of impact to the region should it become established. The likelihood of the species naturalising and spreading in the region is perceived to be high (Department of Land Resource Management 2015).

It is noted that Parthenium (*Parthenium hysterophorus*) is a major problem in rangelands and cropping areas of Queensland and is estimated to cost farmers and graziers more than $22 million a year in reduced production and increased management costs. Vehicle, machinery and material movements from Queensland into the project area present a risk of spread of Parthenium if not managed correctly (Department of Primary Industry and Resources 2016).

Additional mapped locations of weeds within the Barkly and Katherine RWMP are provided in Figure 3 and Figure 4.

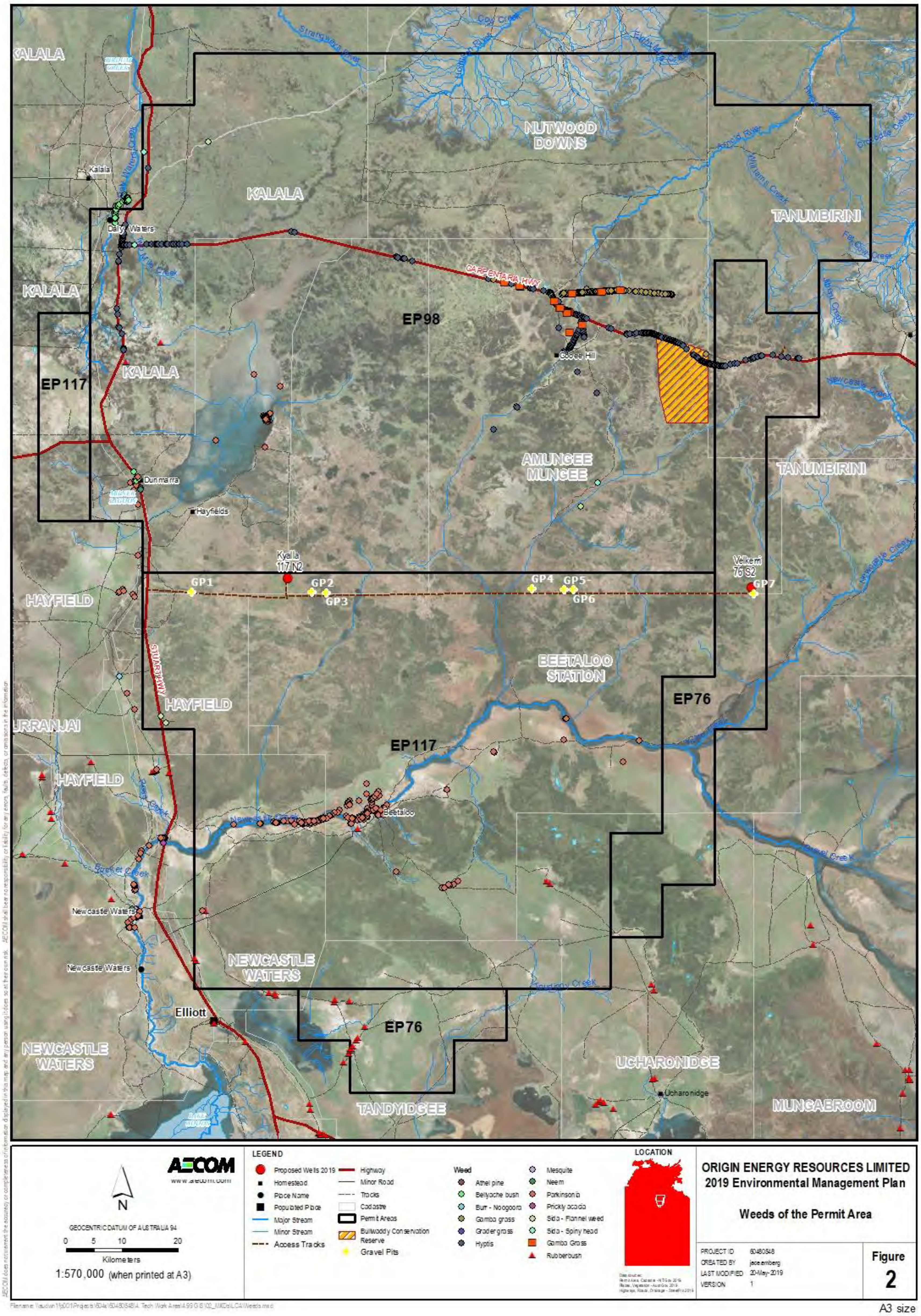

Figure 2 Location of Weeds Species in Permit Areas

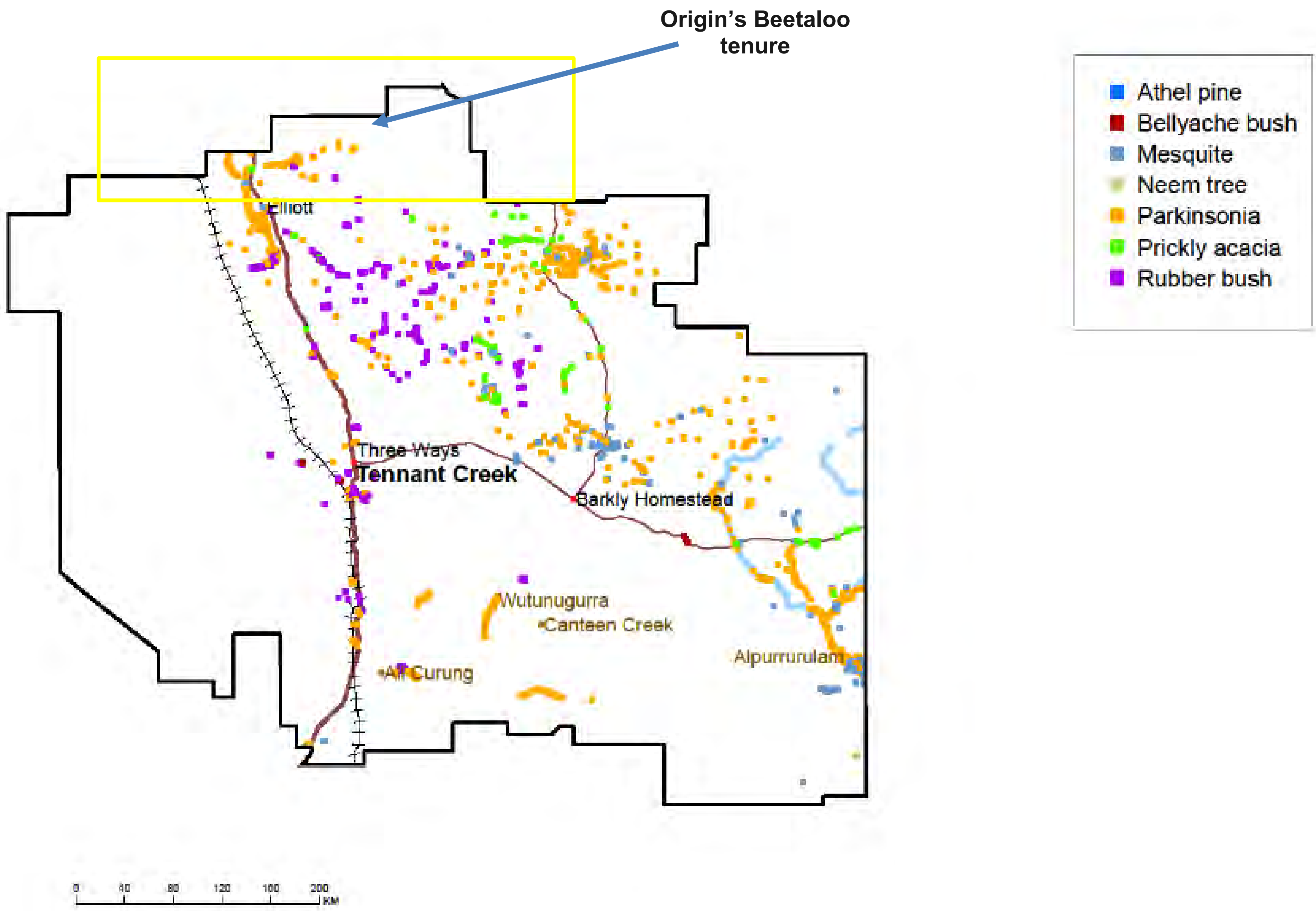

Figure 3 Barkly RWMP mapped priority weed locations

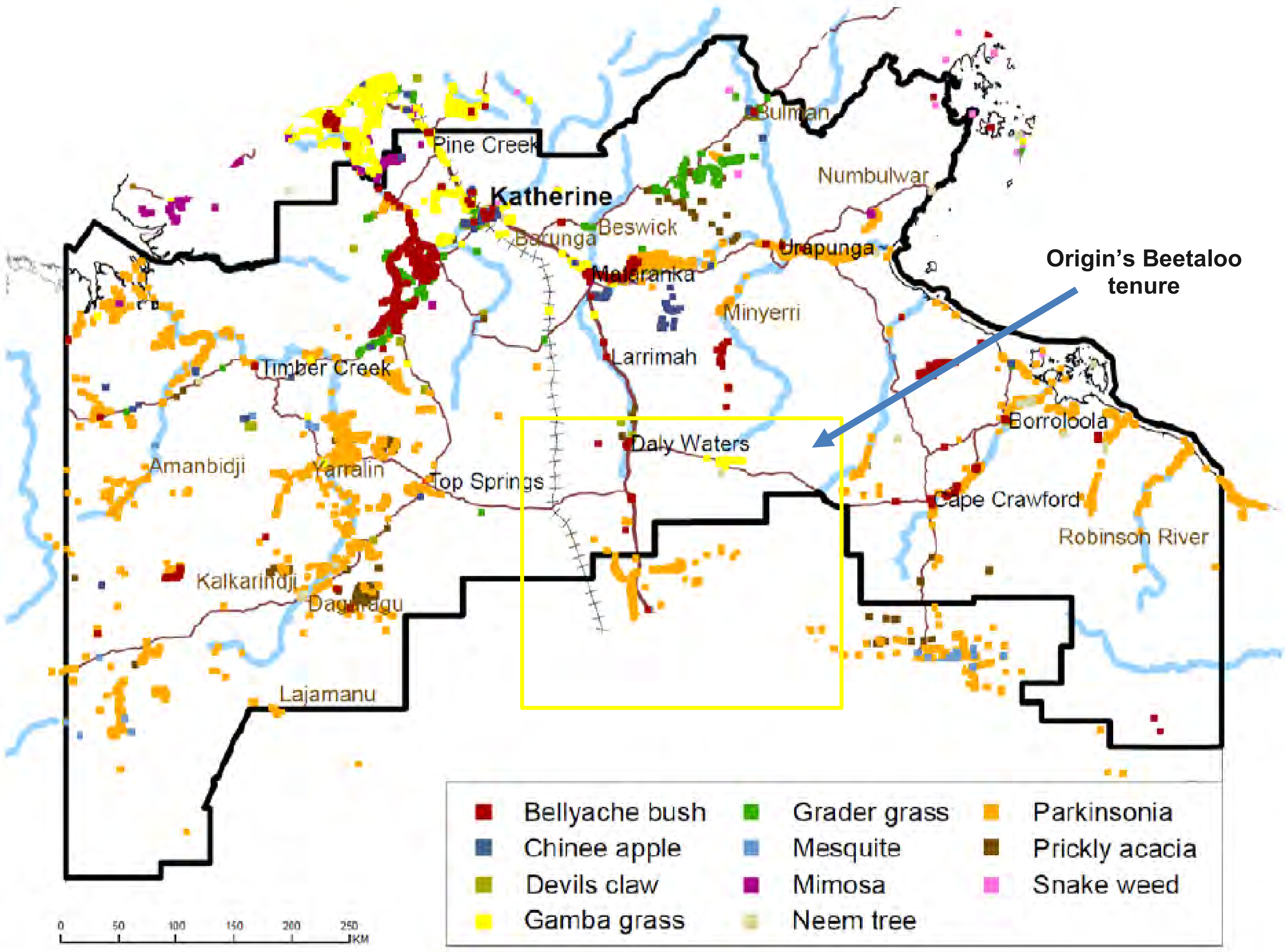

Figure 4 Katherine RWMP mapped priority weeds

Table 2 NT listed weeds known of likely to occur within the Permit Area

Scientific Name	Common Name	Status	Data Source
Priority Weed Species			
Acacia nilotica	Prickly Acacia	Class A, WoNS	Mapped in the exploration lease within the Katherine RWMP
Andropogon gayanus	Gamba Grass	Class A WoNS	Confirmed within exploration lease. High potential introduction through sourcing of equipment from Katherine and Darwin area.
Calotropis procera	Rubber Bush	Class B and C	Mapped in the exploration lease within the Barkly RWMP
Hyptis suaveolens	Hyptis	Class B and C	Confirmed within exploration lease during previous weed Origin surveys
Jatropha gossypiifolia	Bellyache Bush	Class A, WoNS	Mapped in the exploration lease within the Katherine RWMP. Potential introduction through sourcing of equipment from Katherine area.
Parkinsonia aculeata	Parkinsonia	Class B and C, WONS	Confirmed within exploration lease during previous weed Origin surveys and Mapped in the exploration lease within the Katherine RWMP. Potential introduction through sourcing of equipment from Katherine area.
Prosopis pallida	Mesquite	Class A and C, WONS	Mapped in the area surrounding exploration lease within the Katherine and Barkly RWMP
Themeda quadrivalvis	Grader Grass	Class B and C, WoNs	Confirmed within the exploration lease and mapped in the area within the Katherine RWMP. High potential introduction through sourcing of equipment from Katherine area.
Parthenium hysterophorus	Parthenium	Class A and Class C, WoNS	Confirmed by DENR to occur within the exploration lease. Potential introduction through equipment sourced from QLD.
Alert Species under RWMP			
Cenchrus setaceum	Fountain grass	Class B and C	Alert Species within the Barkly Region
Cryptostegia grandiflora	Rubber vine	Class A and C, WONS	Alert Species within the Barkly and Katherine RWMP
Chromolaena odorata	Siam Weed	Class C	Alert Species Katherine RWMP

Scientific Name	Common Name	Status	Data Source
Other species potentially found in region			
Alternanthera pungens	Khaki Weed	Class B and C	DLRM databases (DLRM *et al* 2018)
Azadirachta indica	Neem	Class B and C	Weed Management Branch – Mapping data
Cenchrus ciliaris	Buffel Grass	Not declared in NT	DOTEE Protected Matters Report
Cenchrus echinatus	Mossman River Grass	Class B and C	DLRM databases (DLRM *et al* 2018)
Datura ferox	Fierce Thornapple	Class A and C	DLRM databases (DLRM *et al* 2018)
Sida acuta	Spinyhead sida	Class B and C	Weed Management Branch – Mapping data
Sida cordifolia	Flannel Weed	Class B and C	Weed Management Branch – Mapping data DLRM databases (DLRM *et al* 2018)
Sida rhombifolia	Paddy's Lucerne	Class B and C	DLRM databases (DLRM *et al* 2018)
Xanthium occidentale	Noogoora Burr	Class B and C	Weed Management Branch – Mapping data DLRM databases (DLRM *et al* 2018)

Note: Declarations under the Northern Territory Weeds *Management Act 2013*:

6. Weed Management Mandatory Requirements

6.1 Weed hygiene declarations for vehicles and equipment

1. All vehicles, equipment and loads are to be clean (free of plant matter, seeds, dirt and mud) and have a valid weed hygiene declaration form prior to accessing any pastoralist property
2. Weed hygiene certificates are only to be issued by an authorised inspector that is satisfied that the vehicle is free of plant matter, seeds, dirt, mud animal wastes and any other time that could potentially represent a biosecurity or weeds risk.
3. An authorised inspector is someone who has successfully completed the nationally recognised "AHCBIO201- Inspect and clean machinery for plan, animal and soil material" training course
4. Weed hygiene declarations shall contain:
   a) The identification details of the vehicle or thing inspected.
   b) Odometer reading (where applicable)
   c) Date and location inspected
   d) Name and signature of the authorised inspector issuing the declaration
   e) The organisation with which the inspector issuing the declaration is affiliated
   f) Name and signature of the driver (where applicable)
5. A biosecurity hygiene declaration for a vehicle/equipment remains valid when the vehicle/equipment:
   a) does not travel off sealed/formed roads, or
   b) clean (i.e. free of biosecurity matter including weeds, pests and diseases, and biosecurity carriers) or

c) is located on the same or adjacent property and has not come in contact with any areas with weeds. Areas where it is reasonably expected to come in contact with weeds include the unsealed shoulders of road corridors and known infestation areas as provided in Figure 2.

6. A biosecurity declaration becomes invalid when:
   a) The vehicle or equipment has come into contact with known areas of weed infestations.
   b) The vehicle or equipment has come from a property that is not adjacent to the property to be accessed
   c) It is not known where the vehicle/ equipment has been previously used.

6.2 Weed hygiene declarations for loads and materials.

1. Weed hygiene declarations are to be utilised to satisfy that a load of materials (including hay, seed, sand, gravel, topsoil) is free of or containing a biosecurity matter and carriers. Anyone who is either the seller, supplier or the driver may issue a Weed Hygiene Declaration for a load just as long as they have direct knowledge of the product and the status as weed free or containing a biosecurity matter.
2. Weed declarations are not required for loads moved within areas within the same or adjacent properties that have been determined through baseline weed studies as being weed free.

6.3 Weed washdown facility requirements

1. Cleaning activities should be undertaken at facilities with effective environmental controls to prevent the spread of biosecurity matter.
2. Wash water, mud/ silt, weed material and other contaminants must be bagged and disposed of at a licenced landfill.
3. Where possible, high pressure water spray should be used. This is the preferred method. If this is impractical, (such as at a site location) the minimum requirement is to use a suitable bar or shovel, brooms/ brushes and compressed air to remove contaminants (dry cleaning).

6.4 Equipment sourcing and selection

1. Equipment shall be sourced based on the following prioritisation:
   a) Local equipment, particularly civil construction equipment, shall be sourced as a priority.
   b) Regional equipment (NT) shale be sourced where no local equipment supplier exists
   c) Interstate equipment should be sourced only where local/regional equipment is not available (due to availability or cost constraints). In such cases, additional inspections may be required to ensure vehicles/ equipment are free of weed containing material prior to accessing site.

6.5 Interstate Transportation

All vehicles, equipment and loads moved interstate/territory shall be free of weeds and weed containing material (vegetation, seed, grass, soil, mud etc.) prior to entry into the NT.

All vehicles, equipment and loads travelling from interstate shall have a further inspection prior to access to any pastoral property. If required, additional cleaning shall be undertaken to remove any weeds or weed carrying material.

Where a load/equipment/ vehicle is unclean and is suspected of not being washed prior to entry into the NT, a load must be refused entry into a pastoralist property. The vehicle will require a washdown at an appropriate facility within the state/territory the equipment/vehicle/load originated from.

6.6 Weed management awareness

All staff and contractors shall be made aware of their weed management obligations. This shall be undertaken through:

- Building weed prevention and management requirements into contracts and assessed as a part of work readiness reviews and ongoing assurance activities.
- Inclusion of weed management requirements within site inductions and toolbox talks

7. Weed Introduction and Spread Risks Assessment

As part of the development of the EMP for this project, Origin has undertaken an assessment of the risk of introducing or spreading weeds in the project area. This assessment and the corresponding proposed mitigation measures and management objectives are presented in Table 3 below. Due to the low abundance of weeds within the proposed project area, management controls will primarily focus on preventing the introduction of weed species through appropriate equipment sourcing cleaning and inspection.

Table 3 Risk of weed introduction and spread and corresponding mitigation measures

Environmental Values	Maintain the integrity of significant ecosystems and agricultural productivity		
Management Objectives	Avoid the introduction of weeds Avoid the spread of existing weeds		
Measures Criteria	No introduction or spread of declared weeds resulting from Origins activities.		
Activity	**Potential Risks**		**Management Controls**
	Introduction of new weeds	**Spread of existing weeds**	
Vehicle and equipment movements	Vehicles and equipment sourced from other locations infested with weed species not found in or around Project Area	Traversing of weed infested areas with machinery	- Code of Practice for Petroleum Activities in the Northern Territory Part A- Surface Activities. - Activities will adhere to the guidelines within the NT Weed Management Handbook. - Weed management and control measures to be implemented in alignment with existing landholder biosecurity requirements. - All equipment will have certified equipment wash-down completed prior to entry to the field. Wash-down would occur at Contractors deport or a commercial wash facility prior to mobilisation in a manner that prevents pollution of the surrounding environment. - Machinery to be preferentially sourced locally, with machinery sourced from surrounding areas or Queensland being the 2nd and 3rd preferred option respectively. - Weeds will be actively controlled in cleared/ hardstand areas. - Major equipment moves will be planned from weed-free areas to infested areas and not the other way around. - Ensuring all material imported to or between sites is free of weeds.
Construction of access tracks	Importing materials from areas where weeds are present	Traversing of weed infested areas and creating	- Code of Practice for Petroleum Activities in the Northern Territory Part A- Surface Activities.

Environmental Values	Maintain the integrity of significant ecosystems and agricultural productivity		
Management Objectives	Avoid the introduction of weeds Avoid the spread of existing weeds		
Measures Criteria	No introduction or spread of declared weeds resulting from Origins activities.		
Activity	**Potential Risks**		**Management Controls**
	Introduction of new weeds	**Spread of existing weeds**	
and monitoring bore pads	and creating opportunities for weed species to colonise disturbed areas	opportunities for weed species to colonise disturbed areas	- Activities will adhere to the guidelines within the NT Weed Management Handbook. - Weed management and control measures to be implemented in alignment with existing landholder biosecurity requirements. - All equipment will have certified equipment wash-down completed prior to entry to the field. - Ensure field staff, contractors and machinery operators are familiar with hygiene protocols and weed identification. - Machinery to be preferentially sourced locally, with machinery sourced from surrounding areas or Queensland being the 2nd and 3rd preferred option respectively. - Weeds will be actively controlled in cleared/ hardstand areas. - Stabilise disturbed areas.
Drilling, stimulation and well testing	Introduction of weed species not found in or around EP area.	Traversing of weed infested areas with machinery	- Code of Practice for Petroleum Activities in the Northern Territory Part A- Surface Activities. - Activities will adhere to the guidelines within the NT Weed Management Handbook. - Weed management and control measures to be implemented in alignment with existing landholder biosecurity requirements. - All equipment will have certified equipment wash-down completed prior to entry to the field. Wash-down would occur at Contractors deport or a commercial wash facility prior to mobilisation in a manner that prevents pollution of the surrounding environment. - Ensure field staff, contractors and machinery operators are familiar with hygiene protocols and weed identification. - Weeds will be actively controlled in cleared/ hardstand areas. - Major equipment moves will be planned from weed-free areas to infested areas and not the other way around. - Drilling and stimulation equipment will be restricted to cleared lease areas.

Environmental Values	Maintain the integrity of significant ecosystems and agricultural productivity		
Management Objectives	Avoid the introduction of weeds Avoid the spread of existing weeds		
Measures Criteria	No introduction or spread of declared weeds resulting from Origins activities.		
Activity	**Potential Risks**		**Management Controls**
	Introduction of new weeds	**Spread of existing weeds**	
			- Ensuring all material imported to or between sites is free of weeds.
Operational/ site management	Personnel unable to identify weeds or unaware of weed species present in areas where machinery and equipment is sourced from	Existing weed distribution not known due to: insufficient survey effort, surveys conducted at wrong time of year, surveyors not familiar with / unable to identify declared weed species	- Code of Practice for Petroleum Activities in the Northern Territory Part A- Surface Activities. - Staff members responsible for preventing, identifying and managing weeds to be appropriately trained. - Weed desktop and field-based surveys to be provided to identify existing weed areas. - Pre-and post wet (February to May) inspections and periodic audits will be conducted to identify and report weed outbreaks.
	Insufficient management control to prevent the introduction of weeds	Insufficient management control to prevent the spread of weeds	- Staff members responsible for preventing, identifying and managing weeds to be appropriately trained. - Ensure field staff, contractors and machinery operators are familiar with hygiene protocols and weed identification (Weed identification posters and the NTG Weed Deck will be made available) - Weeds will be actively controlled in cleared/ hardstand areas. - Weed management and control measures to be implemented in alignment with existing landholder biosecurity requirements. - New activities will be planned to address prevention of weed or non-indigenous plant spread.

8. Statutory Weed Management Plans

No statutory weeds have been identified during surveys of the Project Area, however the following plans apply to species that have been found/ could be potential found in the broader region.:

- Weed Management Plan for Athel pine (*Tamarix aphylla*)
- Weed Management Plan for Mesquite (*Prosopis* spp.)
- Weed Management Plan for Prickly Acacia (*Acacia nilotica*)
- Weed Management Plan for Bellyache Bush (*Jatropha gossypiifolia*)

- Weed Management Plan for Neem (*Azadirachta indica*)
- Weed Management Plan for Gamba Grass (*Andropogon gayanus*)
- Weed Management Plan for Grader Grass (*Themeda quadrivalvis*).

The weed management plans detail the legislated obligations of all land owners, land managers and land users in the Northern Territory to eradicate or manage and avoid further spread of the weed species. Conducting land management practices in accordance with the weed management plans will secure compliance with the requirements of the Act (Department of Land Resource Management 2015).

9. Annual Action Plan

An action plan for each of the weed species identified in the Project Area is presented in Table 4. Treatment options as contained in the Northern Territory Weed Management Handbook are presented in Section 9.1 to Section 9.3.

This section will be undated if new weed species are discovered over the life of the program to ensure that statutory requirements with relation to declaration status and relevant weed management plans are addressed (refer to Section 8)

As part of the 2019 Annual Weed Management Action Plan, Origin also commits to undertaking finer detailed weed mapping of all permit area, lease pads, access tracks and gravel pits, as well as any other areas disturbed as part activity.

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Table 4 Annual Weed Management Action Plan

Management objective	- Avoid the introduction of weeds - Avoid the spread of existing weeds			
Weed species	**Survey time/s**	**Treatment time/s**	**Control options**	**Where located**
Hyptis *Hyptis suaveolens*	6 monthly- pre-and post wet season	- Preferred Dec – Mar - Also Nov and April	Refer to section 7.1.	Beetaloo access track Access track to Velkerri 98-E1-1 site
Parkinsonia *Parkinsonia aculeata*	6 monthly- pre-and post wet season	- Preferred Mar – May - Also all year round	Refer to section 7.2.	Beetaloo access track
Rubber Bush *Calotropis procera*	6 monthly- pre-and post wet season	- Preferred October – March - April - July	Refer to section 7.3.	Close proximity to the Beetaloo access track

9.1 Hyptis (*Hyptis suaveolens*) treatment options

Table 5 includes herbicide and non-chemical treatment options for Hyptis *(Hyptis suaveolens) (*Northern Territory Government 2015).

Table 5 Hyptis *(Hyptis suaveolens)* treatment options

Weed Species	Hyptis *(Hyptis suaveolens)*		
Control Methods	**Chemical and concentration**	**Rates**	**Weed growth stage, method and comments**
Herbicides	**2, 4-D amine 625 g/L** Various trade names	320 mL / 100 L	**Seedling or adult (individuals or infestation):** Foliar spray - apply when actively growing.
	Glyphosate 360 g/L Various trade names and formulations	15 mL / 1 L	**Seedling or adult (individuals or infestation):** Foliar spray - apply when actively growing.
Non-chemical applications	- Manually remove all plant material; slash to encourage competition from desirable species.		

Source: Northern Territory Weed Management Handbook (Northern Territory Government 2015).

9.2 Parkinsonia (*Parkinsonia aculeata*) treatment options

Table 6 includes herbicide and non-chemical treatment options for Parkinsonia *(Parkinsonia aculeata)* (Northern Territory Government 2015).

Table 6 Parkinsonia *(Parkinsonia aculeata)* treatment options

Weed Species	Parkinsonia *(Parkinsonia aculeata)*		
Control Methods	**Chemical and concentration**	**Rate**	**Weed growth stage, method and comments**
Herbicides	**Aminopyralid 8 g/L + Triclopyr 300 g/L + Picloram 100 g/L** Grazon™ Extra	350 mL / 100 L or 3 L / ha	**Seedling (individuals and infestation)** Foliar spray – avoid spraying if plants are stressed or bearing pods – Uptake Spraying Oil required Foliar spray – plants up to 2 m or 2 years old - Uptake Spraying Oil required.
	Triclopyr 240 g/L + Picloram 120 g/L Access™	1 L / 60 L (diesel) 1 L / 60 L (diesel)	**Seedling or adult (individuals or infestation)** Basal bark < 5 cm stem diameter Cut stump > 5 cm stem diameter
	Tebuthiuron 200 g/kg	1.5 g / m2	**Seedling or adult (individuals or infestation)** Granulated herbicide - ground applied Do not use within 30 m of desirable trees or apply to continuous area > 0.5 ha. Do not use if fire is eminent. Apply when there is soil moisture or prior to rain.
Non-chemical applications	- Blade-ploughing, stick-raking, bulldozing and chaining can be effective if the root layer is removed from the soil. - Cultivation of pasture or native vegetation after mechanical control will help to prevent re-sprouting and seedling establishment. - Fire destroys seed in the soil surface and can be used as a follow-up to remove seedlings after other control efforts. - Fire may also be used to manage mature trees. Hand grubbing for single plants or small outbreaks, ensure removal of the root system. - Biocontrol options are available with Uu establishing slowly in some areas.		

Source: Northern Territory Weed Management Handbook (Northern Territory Government 2015).

9.3 Rubber bush (*Calotropis procera*) treatment options

Table 7 includes herbicide and non-chemical treatment options for Rubber bush *(Calotropis procera)* (Northern Territory Government 2015).

Table 7 Rubber bush *(Calotropis procera)* treatment options

Weed Species	Rubber bush *(Calotropis procera)*		
Control Methods	**Chemical and concentration**	**Rate**	**Weed growth stage, method and comments**
Herbicides	**Triclopyr 300 g/L + Picloram 100 g/L Conqueror®** **+ Aminopyralid 8 g/L** Grazon™ Extra	750 mL / 100 L (water) 500-750mL / 100 L (water)	**Seedling (individuals or infestation):** Foliar spray. Check label for recommended adjuvant product. More effective on plants <2m as thorough coverage on all leaves is required
	Triclopyr 240 g/L + Picloram 120 g/L Access™	 1 L / 60 L (diesel) 1 L / 10 L (diesel) 1 L / 60 L (diesel)	**Adult (individuals and infestation):** Basal bark < 5cm stem diameter. Spray all stems. Spray to point of runoff. Thin Line up to 5cm stem diameter. Cut stump > 5cm stem diameter.
	Tebuthiuron (200g/kg) Graslan Pending registration. Please check with Weed Management Branch for status confirmation.	1.5-2g/m2	**Seedling or adult:** Application to black clay soils in conjunction with seasonal rainfall. Spread granules according to density of the infestation.
	Fluroxypyr (333g/L) Starane™ Advanced	3 L / 100 L (diesel)	**Adult:** Cut stump method for plants up to 10cm diameter and 3m high.
Non-chemical applications	- This plant is difficult to eradicate as the deep roots survive almost any treatment. - Maintenance of a dense pasture sward will assist in preventing invasion.		

Source: Northern Territory Weed Management Handbook (Northern Territory Government 2015).

10. Notification Procedure

The Regional Weed Officer – Onshore Shale Oil Gas Development at the Weed Management Branch of the DENR should be notified within 48 hours of the discovery of a new weed species in the Project Area.

Initial notification may be verbal, with follow-up written notification provided within seven working days. The notification should include a preliminary species identification and location information. The Regional Weed Officer will advise what further action is required.

It is noted that some species spread rapidly so immediate action may be required to control spread. For example, as stated above *Parthenium (Parthenium hysterophorus) is a Class A (to be eradicated) and Class C (not to be introduced) weed in the Northern Territory as well as being classified as a Weed of National Significance. Early detection is crucial in not allowing this species to spread in the Northern Territory* (Department of Primary Industry and Resources 2016).

In addition, it is noted that under the *Weeds Management Act* that:

'The owner and occupier of land must… within 14 days after becoming aware of a declared weed that has not previously been, or known to have been, present on the land, notify an officer of the presence of the declared weed'.

All weed outbreak incidents will be reported in Origin's OCIS and corrective action initiated.

11. Recording

Records of weed inspections will be maintained by Origin.

Data on weed distribution will be maintained within Origin's GIS and provided to the Weeds Officer at DENR as part of the annual report on performance against the Weed Management Plan, or as requested.

Data will be collected as per the requirements of the Northern Territory Weed Data Collection Manual - Section One Technical Data Description (Weed Management Branch, 2015).

Data will be recorded using the guidelines provided in Appendix A using the data sheet provided in Appendix B (Weed Management Branch, 2015).

The Northern Territory Weed ID Deck (Northern Territory Government 2017) will be referenced to assist with identification of species that have been identified as likely or know to occur in the Permit Area.

Field data will be submitted directly to the Weed Management Branch in a shapefile format or as an Excel spreadsheet, including incidental identification of weeds and following completion of field surveys.

12. Reporting

All weed outbreak incidents will be reported in Origin's OCIS and corrective action initiated.

A report on the performance against this Weed Management Plan will be submitted to DENR on an annual basis.

At a minimum, this should include:

a) Details of activities implemented to address weed spread and introduction risks (e.g. vehicle wash down/ blow down locations, examples of track construction from working from weed free areas into weed infested areas to reduce spread).

b) Details of survey and monitoring events, including dates, personnel, maps and track data.

c) Submission of all weed data collected.

d) Overview of weed control events and success rates (weed control should be captured in detail through the data collection process and submitted as a component of (a)).

13. References

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Appendix A Weed Data Collection Methodology

Field data collection for weed infestations

The following is a guide to efficiently evaluating and recording a weed site in the field.

Each record must identify the person or organisation taking the record, as well as the details explained below.

How to record weed area as a point record

1. Record the species.

When a weed is sighted, move to the area and confirm identification of the weed. If you cannot positively identify the weed record it as "Unknown weed" and take a sample or photograph, do not try to guess. If more than one weed species is present then repeat the process with separate records for each species.

2. Assess the size of the weed patch.

Look across the area of weeds to the furthest weed plant and decide the diameter. Decide if the area is best fits in a circle of either 20, 50 or 100 metres. If it is a single plant or small patch you would choose 20 metres. The size 100 metres extends about as far as you can see on the ground, if the weeds extend out of sight you will need to make another point further on. You may place overlapping circle areas to reflect different densities.

3. Assess the density of weeds within the circle.

Decide how much of the area is covered by weeds. Assign a score from 2 to 5 based on the percentage table below. It will be useful (if possible) to move into the centre of the weed circle. Consider the whole circle size chosen in step 2 deciding on the density score. Area covered should be determined by a 'projected canopy' method.

Density categories

1 = Absent, no weeds of this species in this area.
2 = < 1%, Very few, not many weeds eg: single plant, perhaps with seedlings.
3 = 1 -10%, More than one or two isolated plants but not a lot eg: a few small plants.
4 = 11-50%, A lot, up to half the area covered eg: a tree, dense patches of weeds.
5 = > 50%, Dominant cover is weed, more than half covered eg: thickets, monocultures.

4. Record the location.

Take the GPS location (ideally) from the centre of the circle. If weed seeds may be spread or it is difficult to access the centre it is acceptable to take the reading from the location as close to the centre as practical.

5. Record the treatment.

Record the method you apply a treatment to the weeds, or record 'No Treatment'.
Choose from the list of treatment methods
i.e: No treatment, Unknown, Treated, Foliar spray etc.

How to record weed area as a line (polyline) record

1. Record the species.

When a weed is sighted, move to the area and confirm identification of the weed. If you cannot positively identify the weed record it as “Unknown weed” and take a sample or photograph, do not try to guess. If more than one weed species is present then repeat the process with separate records for each species.

2. Assess the ‘best fit’ width in metres of the linear weed area.

Look along the area of weeds to the furthest weed plant and decide a width that best sums up the width of the infestation from values of 5, 20, 50 or 100 metres. If the width is too variable you may need to make more than one line or consider recording as points or as a polygon.

3. Assess the density of weeds within the line.

For the area of the line, being from start to finish at the designated width, decide the area covered by weeds. Assign a score from 2 to 5 based on the percentage table below. Consider the whole line area when deciding on the density score. Area covered should be determined by a ‘projected canopy’ method.

Density categories
1 = Absent, no weeds of this species in this area.
2 = < 1%, Very few, not many weeds eg: single plant, perhaps with seedlings.
3 = 1 -10%, More than one or two isolated plants but not a lot eg: a few small plants.
4 = 11-50%, A lot, up to half the area covered eg: a tree, dense patches of weeds.
5 = > 50%, Dominant cover is weed, more than half covered eg: thickets, monocultures.

4. Record the location.

Start the GPS track, or line sketch from one end of the linear weed area. Walk or sketch a line as best fit through the middle of the linear weed area and finish at the end point.

5. Record the treatment.

Record the method you apply a treatment to the weeds, or record ‘No Treatment’.
Choose from the list of treatment methods
ie: No treatment, Unknown, Treated, Foliar spray etc.

How to record weed area as a polygon record

1. Record the species.

When a weed is sighted, move to the area and confirm identification of the weed. If you cannot positively identify the weed record it as "Unknown weed" and take a sample or photograph, do not try to guess. If more than one weed species is present then repeat the process with separate records for each species.

2. Assess the extent of the weed area an ensure it can be practically enclosed.

Polygons are good for clearly delineated areas of weeds, you should be able to walk around the edge of the weed area with confidence. Ensure the defined area of weed at a similar density can be delineated before attempting to create the area, you may need more than one polygon. If the area is poorly defined then the point method may be a more useful.

3. Assess the density of weeds within the polygon.

Assess the area covered by weeds for density, you may need to move to several vantage points to get a clear picture. Assign a score from 2 to 5 based on the percentage table below. Consider the whole area within the polygon when deciding on the density score. Area covered should be determined by a 'projected canopy' method.

Density categories
1 = Absent, no weeds of this species in this area.
2 = < 1%, Very few, not many weeds eg: single plant, perhaps with seedlings.
3 = 1 -10%, More than one or two isolated plants but not a lot eg: a few small plants.
4 = 11-50%, A lot, up to half the area covered eg: a tree, dense patches of weeds.
5 = > 50%, Dominant cover is weed, more than half covered eg: thickets, monocultures.

4. Record the location.

Start the GPS track, or polygon sketch from one point of the polygon weed area. It is useful to start from a landmark or flagging tape. Create the polygon edge line by walk a path or sketching along the outer edge of the weed area until you return to the start point. If using a GPS track to create the polygon ensure that you cross your start point so as to close the polygon.

5. Record the treatment.

Record the method you apply a treatment to the weeds in the area, or record 'No Treatment'. Choose from the list of treatment methods

ie: No treatment, Unknown, Treated, Foliar spray etc.

Appendix B Example Weed Data Collection Sheet

RECORDER:					PROJECT:							LOCALITY:		
ORG_NAME:					GPS NAME/MODEL:							RECORDING METHOD :		
SITE_ID	DATE_REC	LAT_G94	LONG_G94	WEED_NAME	SIZE_DIA_M	DENS_CAT	SEEDLINGS	JUVENILES	ADULTS	SEED_PRES	PAST_TREAT	TREATMENT	HERBICIDE	COMMENTS

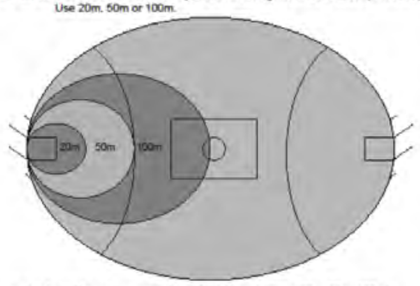
Notes:

Treatment method
Control method applied today as per below.
If none, record 'No treatment'

- Foliar spray
- Residual application
- Basal bark
- Cut stump
- Stem injection
- Aerial spray
- Slashed or cut
- Hand pull

Herbicide	The active ingredient(s) of the herbicide applied today (if any)
GPS waypt	Waypoint ID as entered in the GPS
Weed name	Common name or scientific name for the weed recorded
S (y/n)	Seedlings: Are seedlings visible?
J (y/n)	Juveniles: Are juvenile plants visible?
A (y/n)	Adults: Are there adult plants, or seeds, or evidence of past seeding present?
Seed (y/n)	Seeds: Are seeds visible today? Or plants with seeds or pods?
Treat (y/n)	Treatment: Did you apply treatment to this site?
Comment	Record any notes for yourself here.

Size dia m Size/diameter of the area you are recording information about (in metres). Use 20m, 50m or 100m.



Example of size/diameter compared to a football oval. (Sizes 20m, 50m, 100m)

Dens cat Density of weeds in the assessed area using categories described below

1 = No weeds (absent)	2 = Single plant or very few (<1%)	3 = A few plants (1-10%)
4 = Many weeds, up to half (11 – 50%)	5 = Mostly weeds, more than 50%	6 = Density not assessed

Density category (Dens cat) examples

(extracted from *Northern Territory Weed Data Collection Manual - Section One Technical Data Description.*

Review due: 29/03/2022

Appendix P: Methane Emission Management Plan

MEMP

NT-2050-MP-15- 030

BEETALOO EXPLORATION PROGRAM

Methane Emission Management Plan

Review record

Rev	Date	Reason for issue	Reviewer/s	Consolidator	Approver
0	15/04/2019	Released for use	MK	LF	MH

Review due: 18/05/2021

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1. Purpose

This Methane Emissions Management Plan (MEMP) is designed to outline the measures as to how the risks of methane emissions associated with Origin Energy's Beetaloo Basin exploration activities will be managed. This Plan has been developed in accordance with the Code of Practice for Petroleum Activities in the Northern Territory.

2. Key Legislation

Key legislation and documents consulted in the development of this plan are provided below. A full list of applicable legislation is provided in the corresponding management plans.

- **Code of Practice for Petroleum activities in the Northern Territory:** Mandatory code of practice legislating the management of chemicals and wastewater onsite, including the use of secondary containment, lined tanks and spill management plan,
- **National Greenhouse and Energy Reporting Act 2007:** Regulates the reporting of greenhouse gas emissions, energy production and energy consumption associated with company activities. Data to be supplied annually to the regulator in accordance with emission/energy use guidance manuals.

3. Activity description

The activities undertaken as a part of this MEMP are summarised in Table 1. These activities are restricted to the drilling, stimulation, well testing and ongoing operation of exploration wells. They do not cover any production, compression or pipeline activities as these are currently not proposed.

Table 1 Activity and emission description summary

Activity	Emission Description	Controls	Emission monitoring
Drilling	Methane emissions are small (<1 tonne) and restricted to outgassing of hydrocarbon within intersected shales brought to surface.	•Drilling is overbalanced, preventing gas influx into well bore •Shale formations have negligible permeability with limited influx of gas from target formations	•Due to low emission level, gas is qualitatively monitored in mud stream as a concentration (not flow rate). •Gas desorption data is collected from target reservoir allowing emission estimates.
Stimulation	During stimulation, the well will be overbalanced restricting the flow of hydrocarbons to surface.	•Well is kept overbalanced to prevent gas influx during and after stimulation. •Flowback kept within the formation after each stage.	N/A
Well Testing	Well is unloaded to allow hydrocarbons and fluid to flow to surface. All fluids and hydrocarbons diverted to a separator and then a flare onsite Small emissions (<1 tonne) of methane may be released prior to the onsite of flaring, as the hydrocarbon production rate may not be enough to sustain a flare initially. Small volumes (kg's/day) of methane is entrained within liquid hydrocarbons and flowback fluid and will be released to atmosphere	Well heads are designed in accordance with the NT Code of Practice and API standards to minimise loss of methane containment. methane A reduced emission completion will be utilised- where all gas is sent to a separator and then flared. Personal Gas Detector during all operational visits	•Personal Gas Detector during well testing activities •All flared gas measured using flow meters
Ongoing Well Operations/ suspension	Methane emissions restricted to unplanned leaks from well heads, including surface casing vents.	•Operation staff to carry personal calibrated gas detectors during every routine operational visit to well sites.	•Personal Gas Detector during well testing activities •6 monthly leak detection

Activity	Emission Description	Controls	Emission monitoring
		•Routine wellhead maintenance as per well Integrity Management System •Each well and equipment on a well pad to be inspected every 6 months for leaks using a US EPA Method 21 compliance technique	

4. Equipment Selection and Activity Design

The uncontrolled emissions of natural gas during drilling, stimulation and well testing activities represents a potential hazard to workers and the environment. All equipment will be selected to minimise the emissions during production activities.

- Exploration wells and associated surface infrastructure shall be designed to mitigate leaks in accordance with the relevant standards. These Standards include:
    - ISO 16530-1-2017 Petroleum and natural gas industries- Well Integrity - Life cycle governance
    - API SPEC 5CT 2016 Casing and Tubing
    - API SPEC 16D 2013 Control Systems for Drilling Well Control Equipment and Control Systems for Diverter Equipment
    - API RP 59 2012 Well control operations
    - API SPEC 6A 2016 Wellhead and Christmas Tree equipment
    - NORSOK Standard D-010, Well integrity in drilling and well operations
- Leak detection implemented consistent with Codes of Practice.
- Ongoing well maintenance as per the Well Operations Management Plan.

5. Flowback Activities

5.1 Reduced emission Completion

- A Reduced Emission completions (REC) shall be used to minimise the amount of venting
- A REC for the purpose of the Beetaloo Exploration Project is a separator equipped with a flare.
- Venting shall only be used where the capture or flaring is not possible.
- The recovery or gas and hydrocarbons for sale will be prioritised (where practicable) to minimise flaring.

6. Leak Detection Inspections.

The leak inspection programs will be implemented in accordance with Table 2.

Table 2 Leak detection program

Monitoring Program	Monitoring methodology	Frequency
Routine operational Inspections	Calibrated personal gas detector	During each operational visit
Mandatory inspection	US EPA Method 21	6-monthly

7. Monitoring Methodology

- Mandatory inspections will be completed on all surface infrastructure (vents, flanges, valves, connections, drains, pressure relief vents, etc.) of the exploration well in accordance with the USEPA Method 21 requirements or a vehicle mounted cavity ring-down spectrometer (CRDS).

7.1 Instrument Selection

- A Method 21 detector must be able to detect methane at the minimum detection range of 10 Parts Per Million (PPM), with an +/- accuracy of 50PPM.

- A vehicle mounted CRDS detectors shall have a 10 Parts Per Billion (PPB) minimum detection accuracy with an accuracy of +/- 10PPB
- The instrument shall be intrinsically safe (where used within hazardous areas) and equipped with an electrically driven pump, to ensure that a sample is provided to the detector at a constant flow rate.

7.2 Qualifications

- Inspections must be carried out by a suitably qualified person
- A suitably qualified person is defined as a person that has been specifically trained in leak detection or has at least 3 years industry experience in conducting leak detection activities.

7.3 Calibrations

- Gas detectors must be maintained and calibrated in accordance with the manufacturers instructions. Records of instrument calibration shall be retained.
- A two stage calibration shall be sued, with a Air calibration and a 10PPM by volume CH^4 calibration gas used.
- The instrument response time shall be less than 30 seconds.

7.4 Testing procedure

7.4.1 Method 21

Method 21 inspections are used to survey individual pieces of equipment. These types of inspections require access to the surface of the equipment and are extremely effective at pinpointing leaks. The following procedure is to be followed when conducting method 21 inspections:

1. Ensure gas detector is calibrated and functioning properly
2. Ensure the appropriate permitting is obtained before entry into a hazardous area
3. Place the probe inlet at the surface of the component interface where leakage could occur.
4. Move the probe along the interface periphery while observing the instrument readout. If an increased meter reading is observed, slowly sample the interface where leakage is indicated until the maximum meter reading is obtained.
5. Leave the probe inlet at this maximum reading location for approximately two times the instrument response time (i.e. at least a minute).
6. If the maximum observed meter reading is greater than 500PPM at the surface of a piece of infrastructure, the leak is to be measured again at 150mm immediately above (and downwind) of the leak in an open-air environment
7. The leak shall be classified in accordance with section 7
8. The location of the leak shall be clearly documented and photographs taken (if safe to do so)
9. Any liquid petroleum leaks should also be identified, along with estimates of leak rate and volume released.

7.4.2 Vehicle mounted CRDS

Vehicle mounted CSRDS uses highly sensitive, PPB level detectors to screen clumps of infrastructure for leaks. They are extremely effective at providing a rapid assessment and are used in combination of method 21 assessment to pin point leaks. The following procedure shall be followed when conducting vehicle mounted CRDS inspections:

1. The vehicle shall be driven within 20m up and downwind of the infrastructure at a speed below 20km/hour: it is advisable to drive around a piece of infrastructure in a circular motion to obtain up and down wind in the same pass.
2. where a survey cannot be made within 20m downwind of a piece of infrastructure, a method 21 inspection shall be undertaken.
3. Downwind methane concentrations shall be compared to upwind (background) concentration.
4. Where an emission is identified at 5PPM above background, a method 21 inspection shall be undertaken
5. Where enrichment is recorded below 5PPM, the infrastructure has no material leaks present.

7.5 Leak Classification, Repair and Notification

Each leak shall be classified, repaired and reported in accordance with Table 3. It should be noted, that classification of leaks is only undertaken using a method 21 approach outlined in 7.4.1.

Table 3 Leak classification and remediation summary

Classification	Threshold	Response	Notification	Comments
Minor Leak	>500ppm measured at the surface of the component in accordance with section 6.4.1	All minor leaks must be documented and repaired as soon as practicable, but within 30 days. Where 30 days in unachievable, the reason for the delay and target date for completion must be submitted.	All minor leaks must be documented	A minor leak is an unplanned release that does not occur during commissioning or bringing equipment back into service. These leaks should be corrected immediately as a part of commissioning
Significant Leak	>5000ppm (or 10%of the Lower Explosive Limit) when measured at 150mm above the leak source. Or A Liquid Petroleum (condensate/oil) loss of containment that exceeds 200L. Or The leak is too large or not safe to measure.	1. The activities safety management plan, risk assessment and emergency response requirements must be followed. 2. Remediation work must only commence after a suitable risk assessment has been undertaken (at a level appropriate to the nature of the leak) and the relevant safety procedures are followed including the consideration of all the required Personal Protective Equipment and emergency response material. 3. If safe to do so, the leak source should be isolated and repaired immediately. The response priority must be to make the site safe above all other actions. 4. The leak shall be repaired or made safe as soon as practicable, as follows: i) the leak must be isolated, repaired if possible, contained or otherwise made safe within 72 hours. ii) Where isolation and repair is not possible, an exclusion zone must be established around the leak and appropriate restrictions to on access to the exclusion zone imposed. iii) in the event the 72 hour deadline is unachievable, the reason for the delay and the target date for repair shall be submitted to DPIR before the deadline ahs passed.	In the case of an emergency situation, DPIR must be notified within 24 hours via the emergency response hotline number 1300 935 250. Notification must include the date of identification, nature and level of the leak, infrastructure name, number and location as well as the initial actions to minimise the risk. The land owner or occupier of the property in which these leaks are occurring must be notified in the following circumstances: i) if the leak cannot be repaired immediately; and ii) if the leak is likely to affect any of the land owner's or occupiers facilities or activities. A written close-out report must be submitted within 5 business days of the remediation of the leak, specifying the date of identification, nature and level of leak, location and name of the operating plant, and the rectification actions taken.	A significant leak is an unplanned release that does not occur during commissioning or bringing equipment back into service. These leaks should be corrected immediately as a part of commissioning

Classification	Threshold	Response	Notification	Comments
		5. If it is contended that the risk of immediately repairing the leak exceeds the risk posed by the leak, an extension of the 72-hour deadline may be sought provided that other measures to mitigate the risk are undertaken (eg. ensuring an appropriate exclusion zone has been implemented) 6. For leaks identified on well equipment, higher order controls such as containment by repair must be implemented wherever possible. 7. For leaks identified on well casings or adjacent to the well casing (where a work over rig is necessary to effect repair) it must be determined whether the leak requires immediate repair, or whether the risk can be adequately managed via other control measures until a work over of the well is scheduled for normal operational reasons. The risk assessment to determine the above shall consider the location of the well, likely access to the well from landholders or the general public, and landholder/community concerns in relation to the leak.	If finalising the remediation is delayed more than 7 business days from the identification of the leak an update must be submitted on that day. The final close out report shall be provided when all work is completed.	

8. Reporting

8.1 Flaring and Venting Emissions

- Where natural gas is vented or flared during exploration activities, these emissions shall be measured or estimated using methods consistent with those outline under the National Greenhouse and Energy Reporting (Measurement) Determination 2008. This include:
    - Leaks, venting and flaring during flowback activities
    - Equipment blowdowns, system upsets and accidental releases

8.2 Annual reporting

An annual report will be provided to the Northern Territory Government summarising the following:

1. The records of the stages of flowback activities including:
   i. the date and time of the onset of flowback;
   ii. the date and time of each attempt to route flowback fluid to the separator;
   iii. the date and time of each occurrence in which the operator reverted to the initial flowback stage;
   iv. the date and time of well shut in or connected into adjacent gathering lines;
   v. the date and time that temporary flowback equipment is disconnected.
   vi. the total duration of venting, combustion and flaring over the flowback period.

2. The results of leak detection surveys (in the annual report under the Act) outlining:
   i. the extent of compliance with the leak management plan;
   ii. a summary of monitoring undertaken during the period;
   iii. a summary of minor and significant leaks identified during the reporting period,
   iv. including the date of identification and repair for each leak and those leaks that
   v. could not be repaired; and
   vi. iv. an explanation of why any component could not be repaired and what actions will
   vii. be taken to either decommission the component or otherwise remedy the problem.

Appendix Q: Bushfire Management Plan

BEETALOO BASIN EXPLORATION PROGRAM 2018/2019
Bushfire Management Plan

EP76 & EP117

This document outlines the basic principles for Origin and its Contractors to manage the risk from bushfire, resulting from Exploration activities in the Beetaloo Basin. This BFMP should be read in conjunction with *the relevant Environment Management Plan* and the *Emergency Response Plans for the various Beetaloo activities within Northern Territory*.

Review record

Rev	Date	Reason for issue	Reviewer/s	Consolidator	Approver
0	08/04/2019	BFMP released for approval	A.Court	M.Kernke	M.Hanson
1	04/12/2019	BFMP update in accordance with *Draft Bushfire Management Plan Guide: Onshore Petroleum Projects*	A.Court	M.Kernke	M.Hanson

Review due: 03/06/2020

Bushfire Management Plan
NT-2050-15-MP033

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Review due: 03/06/2020

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1. Introduction

Bushfire management is considered a significant land management activity in the Northern Territory and has been identified as a medium risk in the Origin's Beetaloo Basin Drilling, Stimulation and Well Testing Program Environmental Management Plans (EMP). As such, this Bushfire Management Plan (BFMP) forms a core component of Origin's risk management.

Origin's operational activities within the permit area pose a potential ignition risk as a result of exploration activities from the movement of rigs, vehicles, machinery and from flaring activities within the Permit Area. In addition, there is a potential for external ignition sources which may impact on Origin's operations including nearby pastoral activities and natural occurrences of fire as a result of lightning strikes.

This BFMP has been prepared in accordance with the Northern Territory *Bushfires Management Act 2013* and other relevant legislation.

1.1 Project Context

For the purpose of this BFMP, the project boundaries include all proposed lease areas and access tracks that are part of Origin's proposed exploration activities for 2019/2020.

The primary activities subject to this BFMP are:

- Site preparation and operation of exploration lease areas.
- Drilling, stimulation and well operation, including drilling camp and flaring operations.

The location of the proposed exploration activities are shown on Figure 1.

1.2 Aim and Objective

The aim of this Bushfire Management Plan (BFMP) is to:

- understand and manage risk to reduce the occurrence of, and minimise the impact of bushfires, thereby reducing the threat to life, property, cultural values and the environment;
- increase preparedness by identifying the mitigation measures for the potential impact of unplanned fires on Origin's people, assets and operations;
- comply with the Bushfires Management Act 2016;

- improve collaboration, clarify responsibilities and reduce potential conflicts between staff, contractors, neighbours and Bushfires NT.

The design of the exploration lease area has complied with Northern Territory and local government statutory laws and regulations and designed to meet all relevant and applicable codes and standards, in particular consideration of the Northern Territory *Bushfires Management Act 2013*, the *Code of Practice for Petroleum Activities in the Northern Territory (2019)* and *Australian Standard for the Construction of Buildings in Bushfire Prone Areas (AS3959-2009).*

It is noted that the NT does not have policy or guidelines controlling development in bushfire prone areas, therefore the requirements of AS 3959 are relied on in this instance to guide infrastructure setbacks (asset protection zones) and the assessment of construction standards for bushfire protection.

Site specific Bushfire Management Plan posters have been prepared for the current Kyalla 117 N2 (Appendix A) and Velkerri 117 S2 (Appendix B) operational areas. As Origin progresses its exploration program in the permit areas, additional Site Specific BFMP posters will be prepared

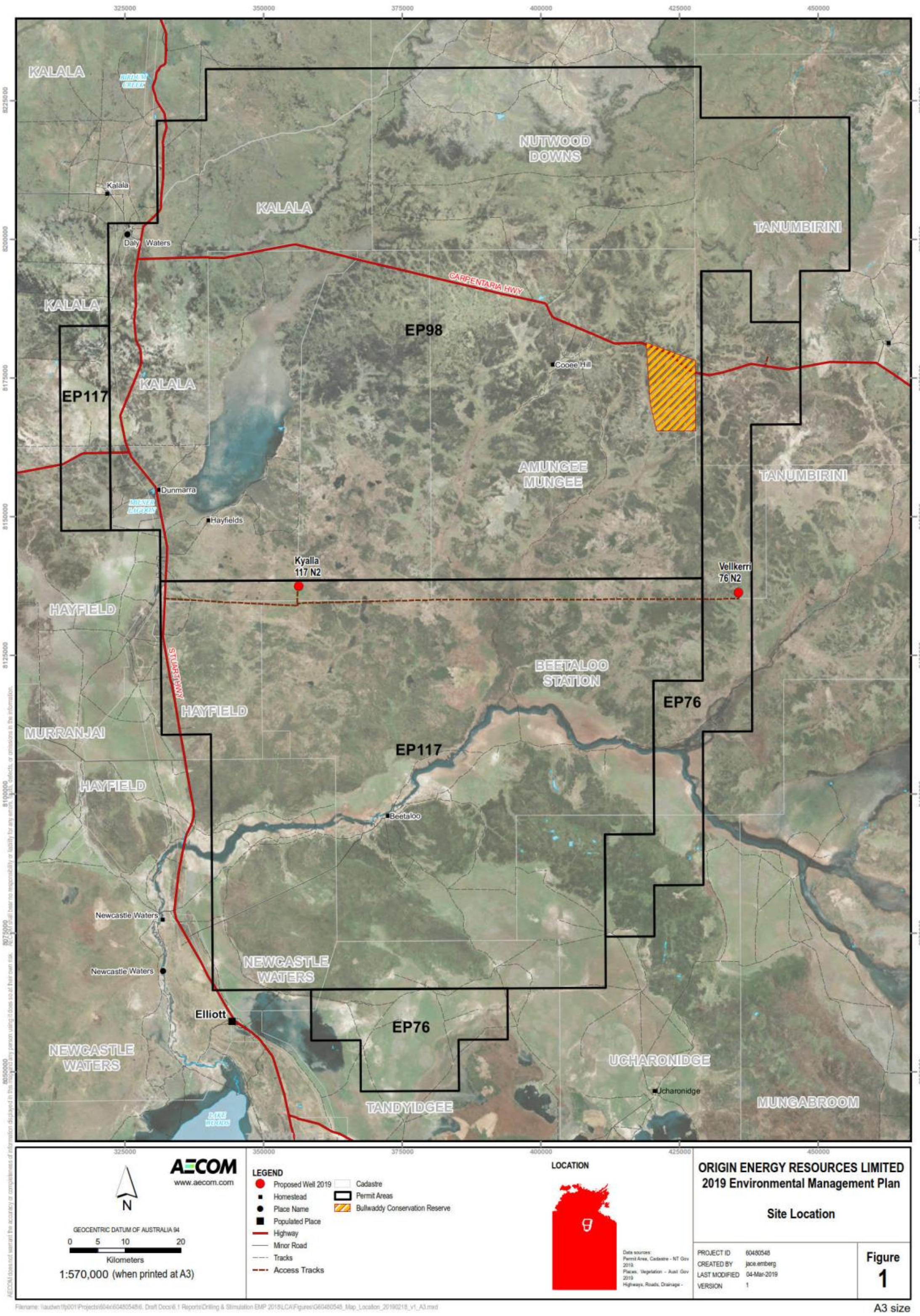


Figure 1 Origin Permit Area and 2019/2020 Exploration

2. Legal and Other Requirements

The following presents the relevant legislation and statutory obligations for the project.

2.1 Northern Territory Petroleum (Environment) Regulations

Petroleum Act 2018, Petroleum (Environment) Regulations 2018 and Schedule of Onshore Petroleum Exploration & Production Requirements 2016

The *Petroleum Act 2016* provides legal framework within which persons are encouraged to undertake effective exploration for petroleum and to develop petroleum production so that the optimum value of the resource is returned to the Territory. It regulates the exploration for, and production of petroleum, including environmental protection measures which should be employed during exploration and production activities, including protection of parks and reserves and rehabilitation.

In addition, the Act is supported by the *Petroleum (Environment) Regulations 2016* and the *Schedule of Onshore Petroleum Exploration and Production Requirements 2016* (Requirements) and the *Code of Practice for Petroleum Activities in the Northern Territory 2019* (Guideline).

The *Petroleum (Environment) Regulations 2016* requires that regulated activities are carried out in a manner consistent with the principles of ecologically sustainable development, and by which the environmental impacts and environmental risks of the activities are identified and reduced to an acceptable level.

Under these regulations Origin is required to submit an EMP prior to any petroleum exploration or production activity.

EMP's must include:

- potential environmental risks or impacts (in this instance relating to the increase in bushfire frequency);
- appropriate environmental outcomes, environmental performance standards and measurement criteria;
- appropriate implementation strategy and monitoring, recording and reporting arrangements; and
- demonstrate that there has been an appropriate level of engagement with directly affected stakeholders in developing the plan.

The Code of Practice requires a fire management plan at the project level to be developed as part of an EMP. As such, this BFMP is designed to support and implement the requirements of Origins *Exploration Program 2019/2020.*

2.2 Northern Territory Bushfires Act (2016)

The purpose of the Bushfires Management Act 2016, as defined in section 3, is:

- *to provide for the protection of life, property and the environment through the mitigation, management and suppression of bushfires, and for related purposes;*

The Act defines the role, powers and authorisation of stakeholders engaged in NT fire management.

2.3 Regional Bushfire Management Plans

Regional Bushfire Management Plans (RBMP) have been developed for areas of the NT. The aim of these regional plans is to assist in identifying and categorising bushfire risk by:

- Identifying the regions risk category; and
- Allocating resources and control/treatments for risk management.

At the time of authoring the project area is partially covered by the Savanna Fire Management Zone RBMP. The Barkley Region currently does not have a RBMP. The land use map and the project area is presented in Figure 2.

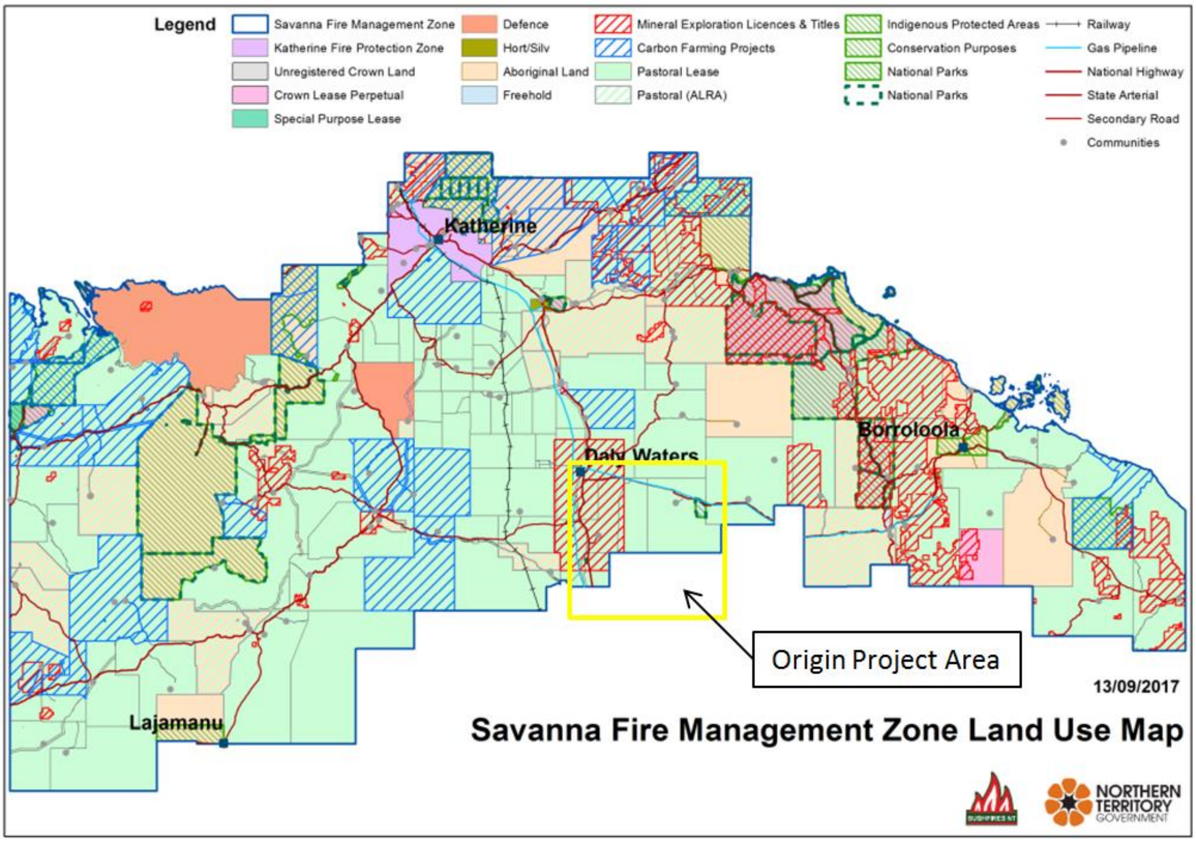


Figure 2 Savanna Fire Management Land Use

3. Origin's Bushfire Management Standards and Guidance

Origin maintains a Bushfire Management Standard to provide overarching guidance to Business Units on bushfire management, asset protection measures and bushfire preparedness. The guidance structure underlying the Bushfire Management Standard is based on three pillars:

- Asset Mitigation
- Landscape Mitigation
- Preparedness and Response.

The Bushfire Management Standard outlines Origin's requirements to protect assets, ensure a safe work environment and meet environmental obligations.

Additional relevant guidance documents include:

- Generic Bushfire Asset Protection Zone (APZ) Guide (Appendix C); and
- IG Bushfire Preparedness Tool (Appendix D).

Although these guidelines are based on Queensland conditions, they provide the minimum requirements to ensure the site and site personnel are prepared to manage bushfire risk. Due to the NT not having specific policies or guidelines controlling developments in bushfire prone areas, this BFMP has considered the requirements of AS 3959 to guide bushland infrastructure setbacks (asset protection zones) and the assessment of construction standards for bushfire protection.

4. Origin's Fire Officer

For the implementation of the BFMP, Origin has appointed **Robert Wear** as the Fire Officer of the Beetaloo Exploration Program 2019/2020. Contact details are as follows:

Name:	Robert Wear
Title:	Construction Superintendent – Beetaloo Exploration
Mobile:	0467 679 003
Satellite Phone:	0147 612 733
Email:	Robert.Wear@upstream.originenergy.com.au

5. Bushfire Hazard Assessment

A bushfire hazard assessment has been completed for the exploration activities at Kyalla 117 N2 and Velkerri 76 S2 as part of the land condition assessment.

The bushfire hazard assessment involved the following tasks:

- Desktop review of available project and available environmental data and reports, as well as Australian Standards and Guidelines for bushfire management.
- A site assessment:
  - Vegetation classification in accordance to the classification system provided in AS3959-2009 Australian Standard for the Construction of Buildings in Bushfire Prone Areas.
  - Determination of the boundary of classified vegetation in relation to the proposed site.
  - Measurement of slope.
  - Recording of site observations of neighbouring properties /areas land use, fire history and existing bushfire management advantages (i.e. water supply, vehicle access).
- Based on results from the site assessment, the Bushfire Attack Level (BAL) calculations for the sites were completed using the Fire Protection Association of Australia Flamesol BAL calculator V4.7 which models the "method 1' BAL assessment procedure in AS3595-2009.

It is noted that BALs are a means of measuring the severity of a building's potential exposure to ember attack, radiant heat and direct flame contact, using increments of radiant heat expressed in kW/m2, and the basis for establishing the requirements for construction to improve protection of site elements to attack by bushfire.

BAL ratings in AS 3959-2009 (from low to high) are BAL-LOW, BAL-12.5, BAL-19, BAL-29, BAL-40 and BAL FZ (flame zone). The BAL rating of a building/infrastructure can be reduced by clearing vegetation; the wider the clearing the lower the BAL rating. BAL-LOW can only be achieved if there is no bushfire hazard vegetation within 100 m of the asset.

6. Site Setting

6.1 Surrounding Land Use

Origin's Beetaloo permit areas are located in the Barkly Region. The closest neighbouring regional towns and communities identified within proximity to Origin's activities include:

- Dunmarra (~100 kms)
- Tennant Creek (~340 kms)
- Elliott (~120 kms)
- Daly Waters (~120 kms)
- Newcastle Waters (~120 kms); and
- Neighbouring pastoral leases of Hayfield, Shenandoah, Amungee Mungee and Beetaloo Stations.

The Kyalla 117 N2 and Velkerri 76 S2 exploration sites are located on two pastoral properties, Hayfield Station and Amungee Mungee Station, respectively. It is not anticipated that civil construction, drilling, stimulation and well testing activities will materially affect cattle grazing in the vicinity of the exploration sites.

The lease pads are positioned in the landscape away from pastoral water infrastructure and are fully fenced, with a fire breaks surrounding the lease pad. Existing access tracks have been upgraded and are maintained to the lease sites.

A range of other land-uses exist in the permit area or in the larger region, including a range of public utilities and facilities. These include the following:

- Tourism – Tourism is an important regional industry with the Stuart Highway being a major thoroughfare for tourists travelling in the area during the dry season. The local townships of Daily Waters, Dunmarra and Elliot provide consumables (food, fuel etc.) and accommodation. A number of heritage areas of importance to regional tourism are located in the broader region, including Elliott, Newcastle Waters and other heritage listed homesteads.
- Road networks – The Stuart Highway and Carpentaria Highway will be used to access the sites. In addition, there are numerous gravel roads connecting properties, and internal property tracks. All properties also have firebreaks on their boundaries and internally.
- Gas pipeline – A gas pipeline runs to the west of the Stuart Highway, along the eastern boundary of EP117 and crosses the boundary of one part of EP98. It also runs parallel with the Carpentaria Highway to the Gulf of Carpentaria, through EP98 and EP76.
- Alice Springs to Darwin Railway – The railway line runs to the west of the gas pipeline and Stuart Highway, and does not cross into any of the permit areas.
- Townships – The townships of Daly Waters and Dunmarra neighbour EP98 to the West.
- Aboriginal Freehold - Jingaloo Community located on EP117 is approximately 45 km SSE of Kyalla 117 N2 and 85 km SW of the Velkerri 76 S2 site.
- Conservation areas – including the Bullwaddy Conservation Reserve, which lies within EP98 and Lake Woods and the Junction Stock Reserve just outside the permit area.
- Heritage – There are seven heritage sites within the exploration permit area and a number of heritage areas of importance to regional tourism located in the broader region, including Elliott, Newcastle Waters and heritage-listed homesteads.
- Archaeological sites – The permit areas have a long history of Aboriginal association and 41 archaeological sites have previously been recorded within the permit areas, as well as registered sacred sites and areas of significance which are shown in the AAPA Abstract of Record.

Separation distances to the nearest environmental and community receptors are illustrated in Figure 3.

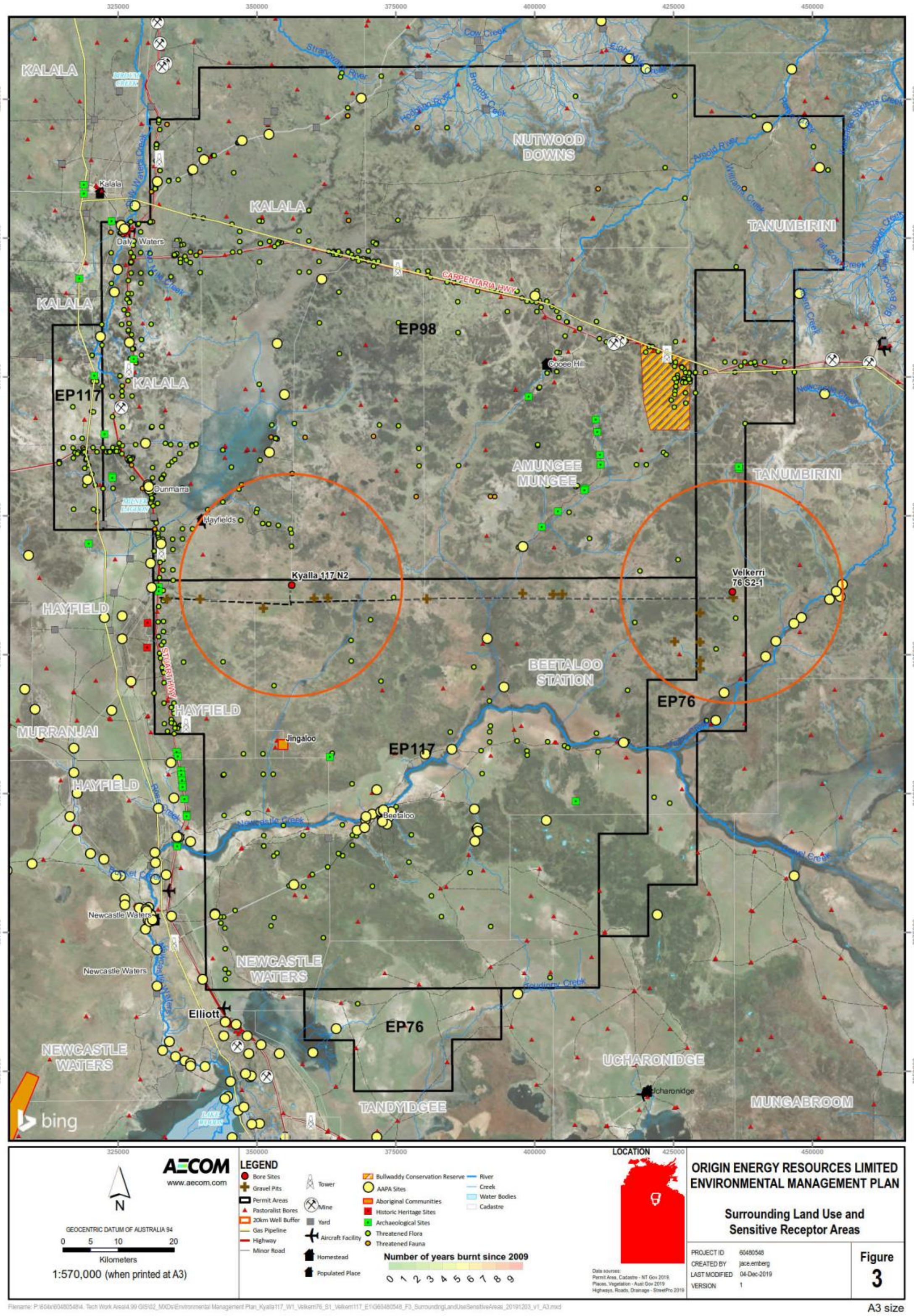


Figure 3 Surrounding Land use and Sensitive Receptors.

6.2 Fire Regime and Fire History

Fire is a natural occurrence in most Australian ecosystems and plays an important role in their ecology. Fire is generally excluded from Mitchell grasslands by pastoral management in order to maintain forage throughout the dry season (HLA, 2005) whereas fire is more frequent in the Sturt Plateau.

Historical, the majority of dry season fires (June to September) have occurred in the northern half of the permit area, in EP76, EP98 and EP117. At this time of year fires are likely to be high intensity (HLA, 2005). Wet season fires (October to May) have also occurred within in the permit area, although these fires are likely to be patchy and of lower intensity, depending on the stat of curing of the fuel load.

Bullwaddy and Lancewood communities, which are located throughout the permit area are fire sensitive and hot fires have the ability to reduce habitat quality for both flora and fauna species. Research suggests that fauna diversity may be impacted by hot fire, particularly for diurnal reptiles (e.g. Legg *et al., 2008).* The Bulwaddy/Lancewood vegetation community located west of Velkerri 76 S2 has value as a fauna refugia habitat. The low fuel loads in this habitat generally restrict spread of fire but the scrub margins are sensitive to fire (Tropical Savannas CRC 2001; Parks and Wildlife 2005).

Fire scar mapping provided on the North Australia and Rangelands Fire Information (NAFI) site for 2009-2019 presented in Figure 4 indicates the project area has a burn frequency of approximately every 3 to 5 years.

Based on field data, fire disturbance was determined at each of the proposed lease areas as follows:

- Velkerri 76 S2-1 – Fire Frequency 2-3 years previous, Intensity 1 (minor scars on some trees/shrubs and Height <1m.
- Kyalla 117 N2-1 – Fire Frequency 1-2 years previous, Intensity 4 (some trees and shrubs killed) and Height 1-4 m. It was noted that site appeared to have had a hot fire go through previously with abundance of new Acacia regrowth.

Since the field survey in August 2018 and Origin's commencement of exploration at the Sites in 2019, no fires have occurred within close proximity to the lease areas. However, Origin have supported Hayfield Station to respond to a wildfire burning to the north of the exploration sites on Hayfield Station near Carpentaria Highway during the year. There was no risk to Origin operated sites from the fires.

6.3 Bushfire Classification

Table 1 presents the site assessment details for Kyalla 117 N2 and Velkerri 76 S2 for the determination of the BAL for the permit area.

Table 1: Bushfire Classification for Kyalla 117 N2 and Velkerri 76 S2

Location	Vegetation Type	Classification[1]	Slope	Fire Sensitive Habitats/Species
Kyalla 117 N2	Open Woodland with grassland understorey (Tussock)	D Scrub	<1%	None identified.
Velkerri 76 S2	Open Woodland with grassland understorey (Tussock)	D Scrub	<1%	None identified within footprint, however Bullwaddy/Lancewood Community located within 100 m of the lease boundary.

1 Vegetation classification in accordance with AS3959 Table 2.3. Overstoreys of open woodland, low open woodland, tall open shrubland and low open shrubland should be classified to the vegetation type on the basis of their understorey.

Based on results from the site assessment, the Bushfire Attack Level (BAL) calculations for the sites were completed using the Fire Protection Association of Australia Flamesol BAL calculator V4.7 which models the "method 1' BAL assessment procedure in AS3595-2009.

See below the workings for determining the BAL:

Step 1 NT Fire Danger Index (FDI)	40
Step 2 Vegetation Classification	Open Woodland with grassland understory (Tussock)
Step 3 Slope	Flat (>1% slope)
Step 4 Distance (m) from vegetation	approximately 50 m to key infrastructure assets on lease pad.

At 50 m from the classified vegetation type of Woodland (upslope and flat land), the relevant Bushfire Attack Level for the proposed lease areas is BAL-12.5. BAL-12.5 is defined as being susceptible from ember attack. It is noted that if distance from classified vegetation type, the BAL would be assessed as Low where there is insufficient risk to warrant any specific construction requirements for the lease area.

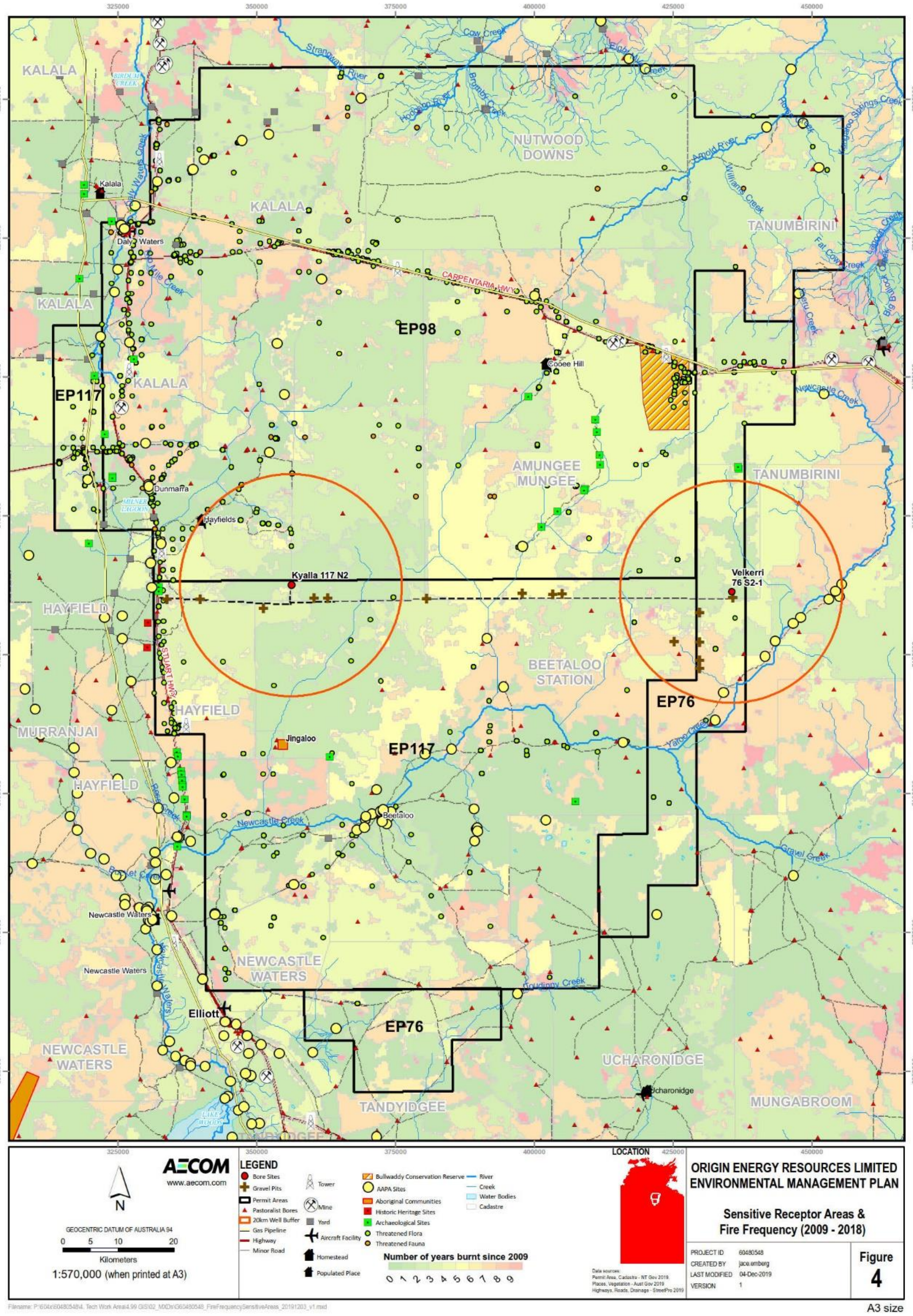


Figure 4 Fire Frequency Map

7. Bushfire Risk Management

7.1 Bushfire Risk

The bushfire risk associated with Origin's operations in the Permit Areas are summarised in Table 2:

Table 2: Bushfire Risk Assessment

<table>
<tr><td>Environmental Values</td><td colspan="3">• Maintain a natural fire regime of the region
• Protection of public, private infrastructure and equipment</td></tr>
<tr><td>Fire Management Objectives</td><td colspan="3">• Minimise the risk of causing bushfires from Origin's activities
• Minimise impacts on environmental habitat and fauna, impacts on stakeholders, impacts on culturally-significant sites, public infrastructure and community lands
• Ensure proper health and safety plan for activities
• Prevent accidental fire risk
• Ensure safe storage of chemicals to prevent fire damage.</td></tr>
<tr><td>Activity</td><td>Environmental impacts and environmental risks</td><td colspan="2">Key control summary</td></tr>
<tr><td>• Civil construction works- access tracks, lease pads and camp pads
• Water Bore drilling
• Drilling, stimulation and well testing (flaring) activities
• Ongoing site access
• Ignition sources from equipment, machinery and plant
• Inappropriate disposal of flammable items, such as cigarettes</td><td>• Vegetation degradation
• Loss of fauna and habitat
• Increased erosion and impacts upon soil and surface water as a result of vegetation loss
• Damage to or loss of public infrastructure, private infrastructure and equipment or community lands
• Damage to or loss of culturally significant sites
• Loss of life</td><td colspan="2">• Site Specific Bushfire Management Plans (Appendix A and Appendix B) implemented to prevent and respond to bushfires for each of Origin's lease area.
• Refer to Section Error! Reference source not found. for Bushfire Risk Mitigation.</td></tr>
<tr><td>Environmental performance standards</td><td colspan="3">• Code of Practice for Petroleum Activities in the Northern Territory Part A - Surface Activities
• Draft Bushfire Management Planning Guide: Onshore Petroleum Projects
• NT Bushfire Management Act
• Origin's Bushfire Management Plan</td></tr>
<tr><td>Measurement criteria</td><td colspan="3">• No uncontrolled fires occurring as a result of Origin's exploration activities</td></tr>
<tr><td>Records</td><td colspan="3">• All incidents of fire to be recorded in Origin's incident reporting tool OCIS</td></tr>
<tr><td>Residual Risk</td><td>Medium</td><td>Scientific Uncertainty</td><td>Low</td></tr>
<tr><td colspan="4">The risk of fire introduction ranked as a 'moderate'. The risk is assessed as a 'severe' consequence, 'highly unlikely' likelihood event. The area is frequented by fire, with risk mitigation measures outlined in the EMP that meet the Petroleum Codes of Practice, NT Bushfire Management Act and Origin's Bushfire Management Plan. Controls above best practice are unlikely to further reduce the risk of introduction of bushfire. Based upon the risk being ranked as a 'moderate' and consistent with standard civil and pastoral activities (regardless of industry), the risk is determined to be ALARP and 'acceptable' in accordance with the rationale within Section Error! Reference source not found. of the EMP, with no further risk reduction warranted.</td></tr>
</table>

7.2 Fire Management Actions

Origin has an overarching bushfire management standard that provides guidance for prevention and management of fire associated with Origin activities. The bushfire management actions are summarised in Table 3. Further information on the determination of APZ is provided in Appendix C and the Bushfire Preparedness Tool in Appendix D and specific site requirements are detailed in the Site Specific BFMP posters presented in Appendix A and Appendix B.

Table 3: Bushfire Risk management control summary

Activity	Fire Management Actions
Site design and layout	- Infrastructure development will consider safety in design and placement to reduce the risk of ignition sources to the extent practicable, including siting of Flares, hazardous material and dangerous goods storage etc.. - Firebreaks and APZ to be utilised for all infrastructure as outlined in the Site Specific BFMP (Appendix A and Appendix B), as well as in the generic requirements detailed in Appendix C and Appendix D. - A 10 m firebreak used around all infrastructure. - Access tracks and roads will serve as firebreaks to limit the spread of fire. - Tanks will have a 20 m APZ applied to mitigate the risk of fire damage. - Flares will be located with at least 25 m separation distance from vegetation to ensure safe operations during fire danger periods. - Firebreaks around exploration wells to be maintained for life of the lease area. - Asset protection zones (APZ) identified based upon fire hazard Index, vegetation type, fuel load and slope as outlined in Appendix A and Appendix B), as well as in the generic requirements detailed in Appendix C and Appendix D.
General Requirements	- Emergency Response Plan implemented to outline the response requirements in case of an emergency, such as bushfire emergencies. - Staff members responsible for managing bushfire risk to be competent in the role they perform. - Origin to prevent fire spread from their lease area. If unable to control fire notify Bushfires NT and the neighbouring properties where spread is likely to go (refer to the Pastoral Properties Contact Details in Section 9). - IG Bushfire Preparedness tool (Appendix D) to be utilised daily during periods with a fire danger of severe or greater (see https://securent.nt.gov.au/). - During fire season ensure machinery operators are familiar with bushfire risks, controls and emergency response procedures. - Fire breaks and asset protection zones (APZ) to be maintained, through the following methods – mowing/slashing directly around lease pad, weed spraying. - Coordinate with landholders proactively to direct Hazard Reduction Activities (planned burns /Mosaic burn etc.). - When a Fire Danger Period has been declared, no burning (other than flaring in accordance with this plan) may take place except where a permit to burn has been obtained from a Fire Control Officer or a Fire Warden. - Controls to be detailed in the Site-specific Bushfire Management Plans (such as smoking bans, firebreaks etc.).

	- Fire response equipment to be available and civil equipment (i.e. water trucks) to be available during work campaigns in the event of a fire. - All hazardous material storage areas to be in accordance with the Flammable and Combustible Liquids Regulations and AS 1940.
Camp and General Site Operations	- Designated smoking areas provided. - Fire extinguishers to be fitted to all vehicles and mobile equipment. - No open fires.
Civil construction	- Equipment to be kept free of grasses and other combustible material which may catch fire. - Fire extinguishers to be fitted to all vehicles and mobile equipment. - Contractors to have their own fire management and emergency response plans consistent with Origin's, outlining the strategies and procedures to prevent and respond to bushfires.
Drilling, simulation, completion and well testing, including Flaring	- All produced gas and liquids will be flared onsite. Two flares will be utilised, with a dedicated vertical flare used to manage gas and a horizontal flare used to manage condensate. - All flares will be designed to meet the requirements of the NT Petroleum CoP including: • Continuous ignition systems. • 98% combustion efficiency as per USEPA standards. • 45 m separation distances from sensitive places and combustible material (such as vegetation). - Flaring of condensate is likely to be restricted to 0.5 hours to 1 hour per day. During condensate flaring, a water curtain will be utilised to dampen the flare flame and reduce heat radiation. The water curtain water usage is anticipated to be between 7,500- 15,000L per day for each well. - Establishment of exclusion zones to occur prior to flaring activities. - A risk assessment to be conducted prior to flaring and on each day during a flaring event. - Open flares may require a permit to burn during the Fire Danger Period (generally from July to December) from Bushfires NT.

A standardised layout will be used on all Origin's drilling, stimulation and well test lease pad. An example of the well pad layout is provided below. It is noted that the minimum separation distances have been allowed for in design:

1. A minimum of 100 m distance from accommodation to Flare stack/pit.
2. A minimum of 25 m from the flare stack/pit to the closest access track.
3. A minimum of 45 m distance from from well centre to the flare stack/pit
4. A minimum of 45 m from sensitive places and combustible material (such as vegetation) to the flare stack/pit.

It is also noted that the APZ identified on the site specific BFMP only apply during operations (drilling, stimulation and well test). Once activities have completed, the APZ can recover. It would only require to be reinstated if further exploration activities are determined.

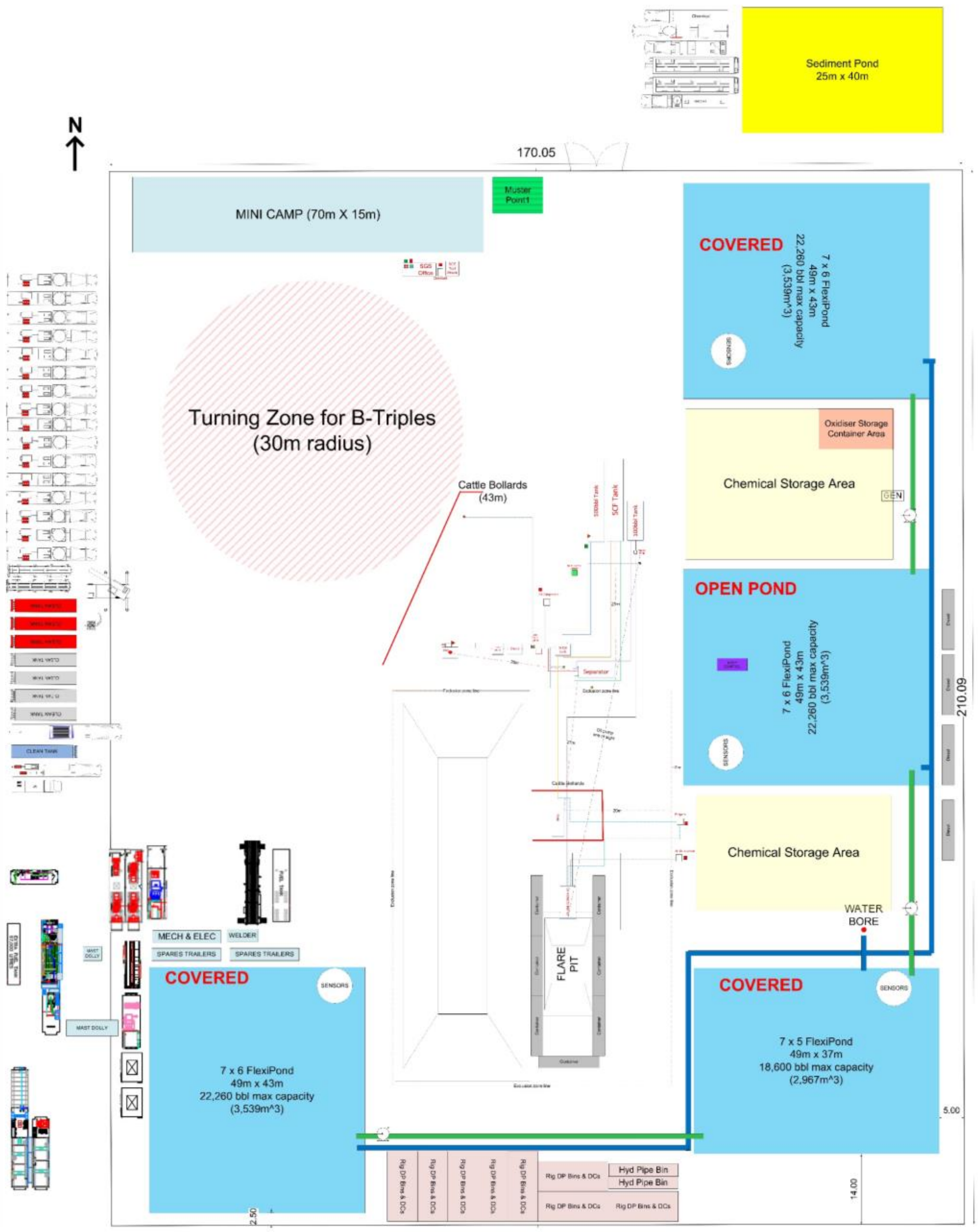


Figure 5 Proposed typical arrange of a Drilling, Stimulation and Well Testing lease pad.

8. Hazard reduction activities

Hazard reduction burns that may be required for APZ vegetation management, will need to be coordinated with the following stakeholders:

- Land holders (Pastoralists)
- Traditional Owners
- Bushfires NT (Regional Fire Services)
- Origin Operations.

9. Communication

9.1 Emergency Response

In the event of a bushfire assessed as impacting Origin sites / designated work areas, the Fire Officer, or delegate, will coordinate response efforts in cooperation with the Emergency Response Team and in accordance with the Emergency Response Plan.

As bush fire risk escalates, Origin's emergency response team will coordinate in the first instance with the Pastoralist whose property is where the fire is occurring. The Origin Fire Officer/Superintendent and the Pastoralist will assess the risk of the fire spreading and determine if require to contact the Savanna Regional Bushfires Committee and Bushfires NT to respond. Engagement with Bushfires NT and the Pastoralist will be required during operations.

Contractors are required to develop Emergency Response Plans which include role competency, appropriate equipment, training and exercising and appropriate documentation relating to the assessed bushfire hazard.

Roles and responsibilities are outlined in the ERP (NT-2050-15-MP0023) and the Site Specific BFMP in Appendix A and B.. Summary of the roles and responsibilities are detailed below.

9.2 Origin Roles and Responsibility

Each management area has been assigned to specific positions within the Exploration team, as follows:

- **Project Manager** – oversees the whole planning and execution of the exploration program and is the person ultimately responsible making all other parties aware of obligations under the BFMP. The Project Manager's role is predominantly office-based.
- **Fire Officer** – person based in the field focussed on the undertaking of operations and construction in accordance with the BFMP. This role is responsible for:
    - Ensuring the APZ have been installed and are functioning.
    - Act as the designated point of contact for and rapidly responding to any fire related incidents, both on and offsite.
    - Liaise with pastoralist to manage on-ground fire-fighting activities.
- **Well-site representatives** – Responsible for Drilling, Stimulation and Well testing operations. This role is responsible for:
  - Ensuring the controls identified in the BFMP are implemented.
  - Undertaking daily reviews of fire danger and implementing IG bushfire preparedness tool.
  - First responder to manage and report fires associated with Origin's activities.
- **Field Personnel** – All staff including Origin and contractors that are working in the Exploration Permit areas. Each person is responsible for day to day management of bushfire related risks.

9.3 Contact Details of Neighbouring Properties

For the successful implementation of the Bushfire Management Plan, Origin is required to engage and collaborate with neighbouring properties to ensure in event of Bushfire. The property name and contact details are provided in Table 4.

Table 4: Pastoral Properties Contact Details.

Pastoral Property	Contact Names	Contact Details
Amungee Mungee	Adrian Brown	(08) 89 711293 Katherine Office +61 427 825159 Direct

Pastoral Property	Contact Names	Contact Details
		(08) 89 759 599 Amungee Homestead UHF 18 VHF 123600
Beetaloo	Scotty and Jane Armstrong	(08) 89 644 613 Office (08) 89 644 711 UHF 16 VHF 123850
Hayfield/Shenandoah	Justin and Sally Dyer Val Dyer	(08) 89 759 920 Hayfield +61 408 802 741 Justin +61 417 836 551 Val UHF 17 VHF 123900
Kalala	Andrew Scott	(08) 89 759 936 Office +61 427 759 938 Ray +61 488 759 944 Tosser
Tanumbirini	Mick Tasker	(08) 89 759 929
Newcastle Waters	Jak Andrews	(08) 89 644 527 (08) 89 644 571 + 61 428 525 895 Jak

9.4 Contact Details of NT Emergency Response

Table 5: External Stakeholders Properties Contact Details.

External Stakeholders	Contact Names	Contact Details
Volunteer Bushfire Brigade	08 875 9936	
National Response Centre	1800 076 251	24/7 contract line
Bushfires NT – Katherine Office	08 8973 8873 08 8973 8871	Troy Munckton
Bushfire NT – Head Quarters	08 8922 0840 Bushfires.nt@nt.gov.au 08 8922 0844	Mark Gardner
NAFI North	http://www.firenorth.org.au/nafi3	
Secure NT (Fire Bans)	https://securent.nt.gov.au/alerts	
Fire incident map	https://www.pfes.nt.gov.au/incident map/	

9.5 Training and Awareness

Contractors will be required to demonstrate they have appropriate systems, procedures and training to manage the bushfire risks covered under this plan.

10. Notification Procedure

10.1 Emergency Notifications

Origin is obliged to inform neighbouring Landholders of fire events (manmade and naturally occurring) where they occur on or within Origin's exploration lease areas, and where there is a potential to effect adjoining properties. All notifications and communication should be undertaken by or at the direction of the Fire Officer.

The Origin National Response Centre is a 24/7 contract line and should be notified of any fires in order to support their planning and tasking activities.

National Response Centre - 1800 076 251

11. Recording

All bushfire incidents, near misses and hazards will be reported through Origin's Incident Management System (OCIS), in accordance with standard incident reporting protocols.

12. Reporting

All bushfire incidents will be reported in Origin's OCIS and corrective action initiated.

13. References

Bushfires NT, 2018. *Savanna Regional Bushfire Management Plan 2018*, Department of Environment and Natural Resources.

Bushfire NT, 2019. *Draft Bushfire Management Planning Guide: Onshore Petroleum Projects*, Department of Environment and Natural Resources.

Northern Territory Fire and Rescue Service, Bushfire Management and Mitigation Publication

Origin Energy Resources Limited. 2018. *IG Bushfire Preparedness Tool.*

Origin Energy Resources Limited. 2018. *Generic Bushfire Asset Protection Zone (APZ) Guide.*

Origin Energy Resources Limited. 2017 *LNG Bushfire Management Standard.*

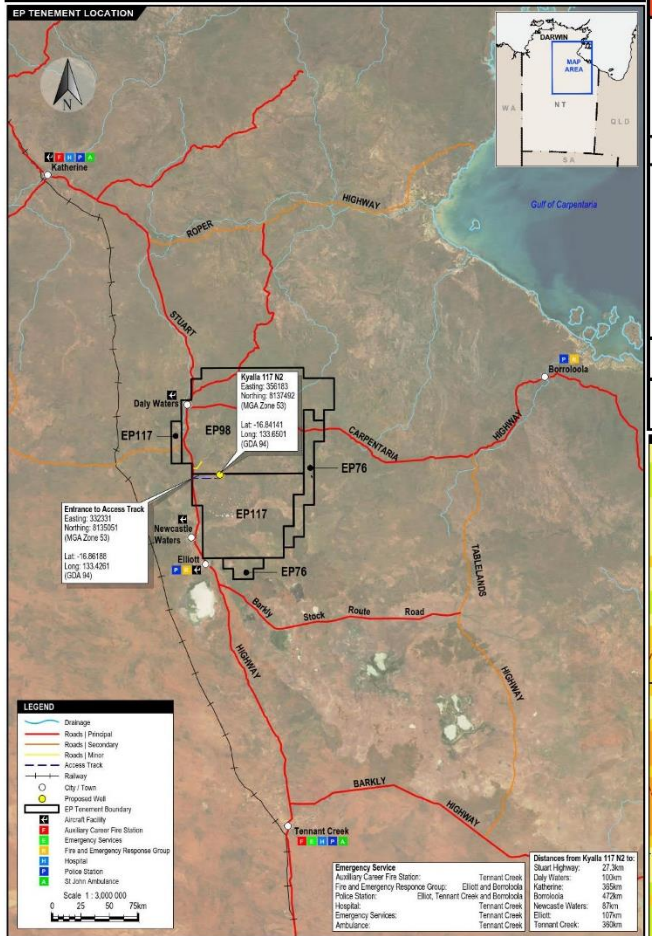
Appendix A Kyalla 117 N2 Site Specific Bushfire Management Plan

Exploration Permit 117

Bushfire Management Plan 2019/2020

Kyalla 117 N2 Lease

Location of Kyalla 117 N2 <<Refer to EP Tenement Location>>	
Property land uses	Gas exploration and cattle grazing
Site fire management aim	To reduce the occurrence of, and minimise the impact of bushfires, thereby reducing the threat to life, property, cultural values and the environment.
Site fire management objectives	Mitigate the potential impact of unplanned fires on Origin's people, assets and operations and neighbouring land uses.



This Site Specific Bushfire Management Plan has been prepared for Origin and its Contractors to manage the risk from bushfire at the Kyalla 117 N2 exploration lease area. This Plan should be read in conjunction with the Overarching *Environmental Management Plan and Emergency Response Plans for Origin's operations in the Beetaloo Basin.*

APPENDIX A Site Specific Management Plan | Version 1 | 4 December 2019

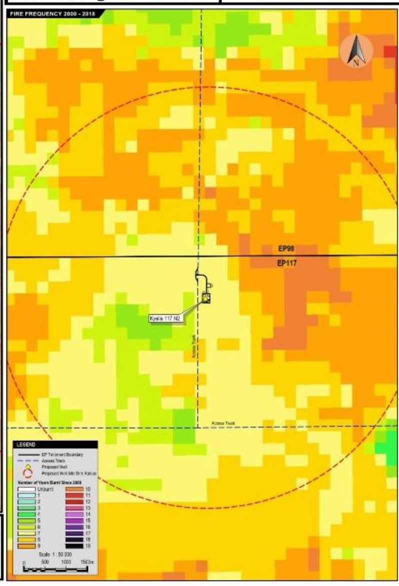
Origin Fire Officer	Contact Details	Name
	mobile : 0467 679 003 Satellite phone : 0147 612 733 Robert.Wear@upstream.originenergy.com.au	**Robert Wear**

Properties	Contact Details		Name
Amungee Mungee Station	(08) 89 711293 Katherine +61 427 825159 Direct (08) 89 759 599 Homestead	UHF 18 VHF 123600	Adrian Brown
Kalala Station	(08) 89 759 936 Office		Andrew Scott
Hayfield Station	(08) 89 759 920 Hayfield +61 408 802 741 Justin +61 417 836 551 Val	UHF 17 VHF 123900	Justin & Sally Dyer
Beetaloo Station	(08) 89 644 613 Office (08) 89 644 711	UHF 16 VHF 123850	Scotty & Jane Armstrong

Offsite Stakeholders	Contact Details	Name
Volunteer Bushfire Brigades	08 8975 9936	
National Response Centre	1800 076 251	24/7 contract line
Emergency	000 or 112 mobile	
Bushfire NT Katherine office	08 8973 8873 08 8973 8871	Troy Munckton
Bushfire NT Head office	08 8922 0840, bushfires.nt@nt.gov.au 08 8922 0844	Mark Gardner
NAFI North	https://www.firenorth.org.au/nafi3/	
Secure NT (Fire Bans)	https://securent.nt.gov.au/alerts	
Fire incident map	https://www.pfes.nt.gov.au/incidentmap/	

Kyalla 117 N2 Fire Management Zones <<refer fire management zones map>>

Bushfire Management Actions	
Infrastructure area	• Remove all vegetation. • Treat emerging vegetation with herbicide. • A permit for open flaring and hot works is required during in a declared fire danger period. • Open flaring and hot works are not permitted on total fire ban days without written approval from a fire control officer or fire warden.
Fire management break	• Maintain a 10 m wide bare earth loop road around the infrastructure area.
Asset Protection Zone (APZ)	• Establish a 40 m wide APZ around the infrastructure area by removing woody understorey vegetation and achieving a grass height of < 100 mm using the methods prescribed in the Origin *Generic bushfire asset protection zone guide*. • Maintain grass cover to a height < 100 mm. • Remove vegetation from the 10 m wide fire break around the infrastructure area. Monitor for grassy weeds and control where appropriate. • Ensure 4 m wide fire access trail around the perimeter of the asset protection zone is trafficable by fire fighting appliances. Monitor for grassy weeds and control where appropriate.
Fire access trails	• Create and maintain 4 m wide access trail around the perimeter of the asset protection zone by grading or spraying.
Neighbouring Property Fire Management Zone	• Annual fire management planning meeting with neighbouring properties. • Neighbour to advise proponent of planned burns.



Bushfire Preparedness – refer to IG Bushfire Preparedness Tool

Preparedness Planning

Mandatory for all Severe, Extreme and Catastrophic FDI days
The following must be reviewed daily. If fire alerts are active or presenting with a know risk (fire in the area), personnel must execute their contingency plans which need to encompass the following:

- ☐ Procedure on identifying and notifying of a bushfire.
- ☐ Critical equipment to be removed / isolated/ shut down.
- ☐ Safe evacuation routes from site and muster points.
- ☐ Communication methods:
  - ✓ Team channels and / or phone numbers
  - ✓ Area channels and/or phone numbers
- ☐ Closest 'Safe Havens' (Community or Origin permanent sites).

Monitoring

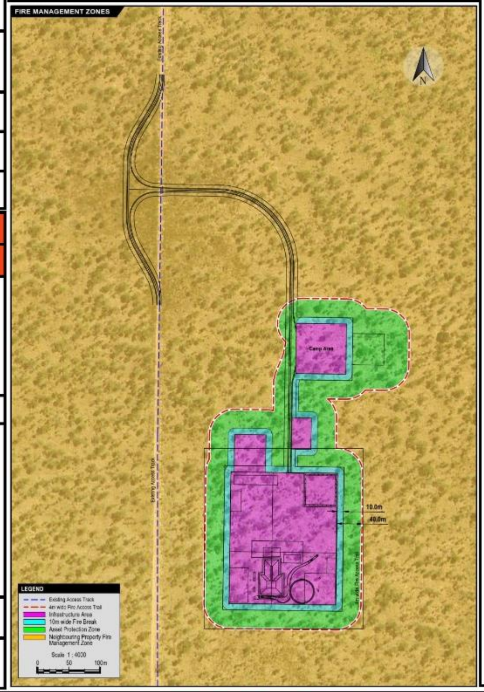
- ☐ Provide timely advice on changes in level of fire risk as available.
- ☐ Monitor team and area common channels for bushfire early warning.
- ☐ Update changes in work location.

Bushfire First Responder Checklist

The following sequence must be followed by the first person responding to a fire:

1. Danger – Remove yourself and others from danger is safe to do so.

2. Alarm – Raise the alarm either on common radio channel or other agreed process.



3. Gather Information –

- ☐ **Location** – Direction from known reference points, (e.g. roads and Origin infrastructure such as well numbers).
- ☐ **Impacts (actual and potential)** – Life, property and the environment.
- ☐ **Fire Characteristics** – Grass or woodlands, flame height, fire front and direction of travel.
- ☐ **Weather** – Wind strength and direction.
- ☐ **Response in Progress** – What response is underway and by who (Origin, Pastoralist or Emergency Services).
- ☐ **Response required** – Origin and / or Pastoralist and / or Emergency Services.
- ☐ **Access** – Safe access and egress routes.

4. Notify Pastoralists – Refer to Property Contacts.

5. Notify Emergency Services – Call "000" or "112" (some mobiles)

6. Notify Origin – Supervisor or superintendent.

7. Respond – If trained in Origin Fire Management (FM1 or FM2).

8. Handover – To the Origin On-Scene Commander (ODC) or QFES on arrival.

9. Support – Provide ongoing support to the response as required.

Annual Works Calendar

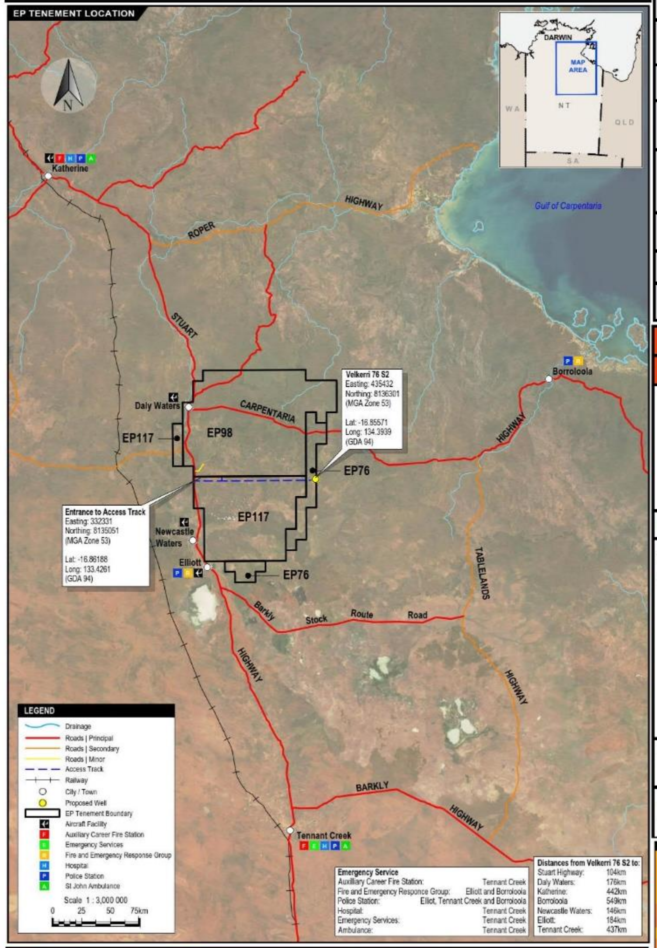
Month	Bushfire Risk	Action	Month	Bushfire Risk	Action
Jan	Low	• No fire management activity	July	High	• Monitor NAFI and visual scan horizon for smoke. • Liaise with neighbour regarding bushfires. • IG bushfire preparedness tool to be utilised daily during periods of fire danger of severe or greater.
Feb	Low	• Manage vegetation onsite including weeds	Aug	High	• Monitor NAFI and visual scan horizon for smoke. • Liaise with neighbour regarding bushfires. • IG bushfire preparedness tool to be utilised daily during periods of fire danger of severe or greater.
Mar	Low	• Planning meeting with neighbour. • Manage vegetation onsite including weeds • Manage fire break and fire access trail.	Sept	High	• Monitor NAFI and visual scan horizon for smoke. • Liaise with neighbour regarding bushfires. • IG bushfire preparedness tool to be utilised daily during periods of fire danger of severe or greater.
Apr	Low	• Manage vegetation onsite including weeds.	Oct	High	• Monitor NAFI and visual scan horizon for smoke. • Liaise with neighbour regarding bushfires. • IG bushfire preparedness tool to be utilised daily during periods of fire danger of severe or greater.
May	Low	• Manage vegetation onsite including weeds.	Nov	Medium	• Monitor NAFI. • Liaise with neighbour regarding bushfires. • IG bushfire preparedness tool to be utilised daily during periods of fire danger of severe or greater.
June	Medium	• Monitor NAFI. • Liaise with neighbour regarding bushfires. • IG bushfire preparedness tool to be utilised daily during periods of fire danger of severe or greater.	Dec	Low	• No fire management activity.

Appendix B Velkerri 76 S2 Site Specific Bushfire Management Plan

Exploration Permit 117
Bushfire Management Plan 2019/2020
Velkerri 76 S2 Lease

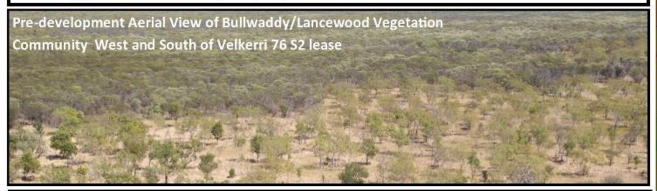
Location of Velkerri 76 S2 <<Refer to EP Tenement Location>>	
Property land uses	Gas exploration and cattle grazing
Site fire management aim	To reduce the occurrence of, and minimise the impact of bushfires, thereby reducing the threat to life, property, cultural values and the environment.
Site fire management objectives	Mitigate the potential impact of unplanned fires on Origin's people, assets and operations and neighbouring land uses.

EP TENEMENT LOCATION



Fire Management Risks

- Ignitions (humans and lightening) on or off site resulting in harm to workers and loss of equipment.
- Fire scar mapping indicates the exploration area burns approximately every 2 years.
- Bullwaddy and Lancewood vegetation communities occur to the south and west of the infrastructure area and are fire sensitive. Hot fires have the ability to reduce habitat quality for both flora and fauna species which utilise these vegetation communities.
- Spread of high fuel load grassy weeds could increase fire intensity, e.g. gamba, grader and buffel grass, adjacent infrastructure areas and access tracks.


Pre-development Aerial View of Bullwaddy/Lancewood Vegetation Community West and South of Velkerri 76 S2 lease

This Site Specific Bushfire Management Plan has been prepared for Origin and its Contractors to manage the risk from bushfire at the Velkerri 76 S2 exploration lease area. This Plan should be read in conjunction with the Overarching *Environmental Management Plan and Emergency Response Plans for Origin's operations in the Beetaloo Basin.*

APPENDIX B Site Specific Management Plan | Version 1 | 4 December 2019

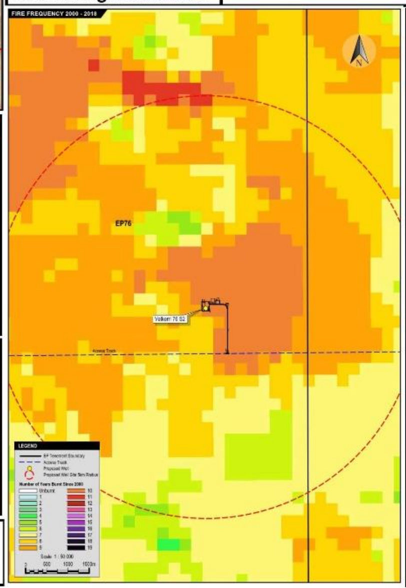
	Contact Details	Name
Origin Fire Officer	mobile : 0467 679 003 Satellite phone : 0147 612 733 Robert.Wear@upstream.originenergy.com.au	**Robert Wear**

Properties	Contact Details		Name
Amungee Mungee Station	(08) 89 711293 Katherine +61 427 825159 Direct (08) 89 759 599 Homestead	UHF 18 VHF 123600	Adrian Brown
Tanumbirini Station	(08) 89 759 929 Office		Mick Tasker
Beetaloo Station	(08) 89 644 613 Office (08) 89 644 711	UHF 16 VHF 123850	Scotty & Jane Armstrong

Offsite Stakeholders	Contact Details	Name
Volunteer Bushfire Brigades	08 8975 9936	
National Response Centre	1800 076 251	24/7 contract line
Emergency	000 or 112 mobile	
Bushfire NT Katherine office	08 8973 8873 08 8973 8871	Troy Munckton
Bushfire NT Head office	08 8922 0840, bushfires.nt@nt.gov.au 08 8922 0844	Mark Gardner
NAFI North	https://www.firenorth.org.au/nafi3/	
Secure NT (Fire Bans)	https://securent.nt.gov.au/alerts	
Fire incident map	https://www.pfes.nt.gov.au/incidentmap/	

Velkerri 76 S2 Fire Management Zones <<refer fire management zones map>>	
Bushfire Management Actions	
Infrastructure area	• Remove all vegetation. • Treat emerging vegetation with herbicide. • A permit for open flaring and hot works is required during in a declared fire danger period. • Open flaring and hot works are not permitted on total fire ban days without written approval from a fire control officer or fire warden.
Fire management break	• Maintain a 10 m wide bare earth loop road around the infrastructure area.
Asset Protection Zone (APZ)	• Establish a 40 m wide APZ around the infrastructure area by removing woody understorey vegetation and achieving a grass height of < 100 mm using the methods prescribed in the Origin *Generic bushfire asset protection zone guide* during operations only. • Maintain grass cover to a height < 100 mm. • Remove vegetation from the 10 m wide fire break around the infrastructure area. Monitor for grassy weeds and control where appropriate. • Ensure 4 m wide fire access trail around the perimeter of the asset protection zone is trafficable by fire fighting appliances. Monitor for grassy weeds and control where appropriate.
Fire access trails	• Create and maintain 4 m wide access trail around the perimeter of the asset protection zone by grading or spraying.
Neighbouring Property Fire Management Zone	• Annual fire management planning meeting with neighbouring properties. • Neighbour to advise proponent of planned burns.

FIRE FREQUENCY 2000 - 2019



Bushfire Preparedness – refer to IG Bushfire Preparedness Tool

Preparedness Planning

Mandatory for all Severe, Extreme and Catastrophic FDI days
The following must be reviewed daily. If fire alerts are active or presenting with a know risk (fire in the area), personnel must execute their contingency plans which need to encompass the following:

- ☐ Procedure on identifying and notifying of a bushfire.
- ☐ Critical equipment to be removed / isolated/ shut down.
- ☐ Safe evacuation routes from site and muster points.
- ☐ Communication methods:
  - ✓ Team channels and / or phone numbers
  - ✓ Area channels and/or phone numbers
- ☐ Closest 'Safe Havens' (Community or Origin permanent sites).

Monitoring

- ☐ Provide timely advice on changes in level of fire risk as available.
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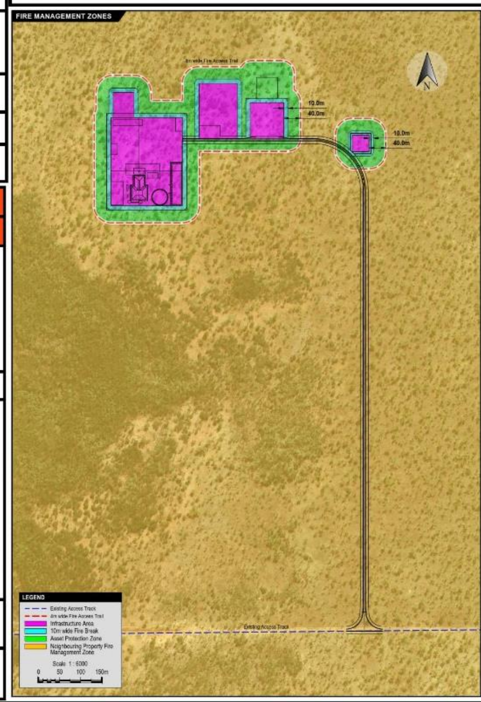
FIRE MANAGEMENT ZONES



3. Gather Information –

- ☐ **Location** – Direction from known reference points, (e.g. roads and Origin infrastructure such as well numbers).
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June	Medium	• Monitor NAFI. • Liaise with neighbour regarding bushfires. • IG bushfire preparedness tool to be utilised daily during periods of fire danger of severe or greater.	Dec	Low	• No fire management activity.

Appendix C Generic Bushfire Asset Protection Zone Guide

ORIGIN LNG BUSHFIRE MANAGEMENT
GENERIC BUSHFIRE ASSET PROTECTION ZONE (APZ) GUIDE

APZ Implementation Plan

1 Identify the Asset Type as per the table

- If on the list move to Step 2
- If not on the list refer to Supervisor or Emergency Response & Security advisor
- If a permanent manned site ensure that a site specific bushfire assessment (Method 2) has been conducted

2 Determine the vegetation type surrounding the Asset

- If able to identify as either Grassland or Bushland move to Step 3
- If unsure use the bushland (higher) value or clarify with Supervisor, Environmental Advisor or Emergency Response & Security Advisor

3 Determine the slope under the vegetation that is within 100 m of the Asset

- If the area under the vegetation is greater than 5 degrees downslope, refer to supervisor to determine what additional mitigations may be required (refer to diagram A)
- If the area under the vegetation is flat or slopes up going outwards from asset, move to Step 4 (refer to diagram B or C)

4 Are there any environmental, site, landowner or heritage constraints preventing you from manageinging the area?

- No constraints, move to Step 5
- If yes or unsure refer to Supervisor, or to relevant function for advice e.g. Environment, Land Relations or Cultural Heritage

5 Manage APZ

- Ensure regularly maintained and manage as per required standard (grass height no higher than 150 mm)
- Where APZ distances cannot be achieved refer to Supervisor or Emergency Response & Security Advisor to determine other mitigation options

More information – the LNG Bushfire Management Framework can be accessed through the bushfire source page *http://source.originenergy.com.au/Business/lng/safety/emergency/Pages/BushfireMgmt.aspx*

For more information on the assessment method used, please refer to the Origin Bushfire Standard.

Version 1, effective date: 24 October 2014

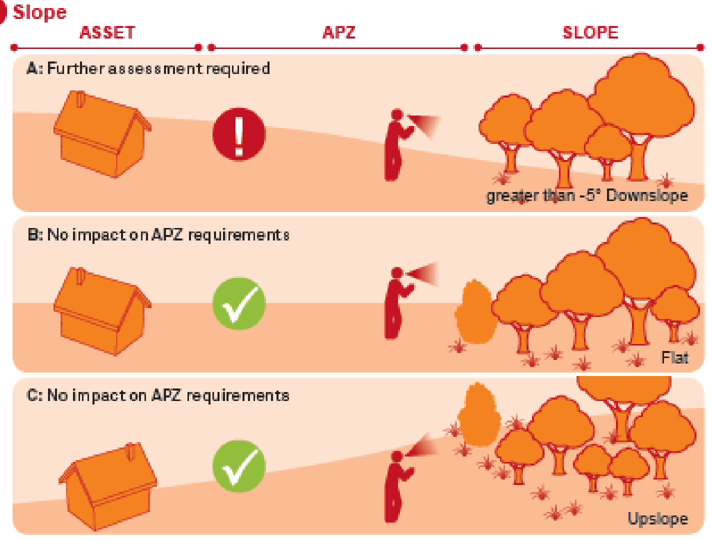
1 APZ per asset type

Site Type	Asset/Infrastructure Type	Vegetation Surrounding Site and Management Required Around Site (in Metres)	
		Grassland	Bushland
Manned Sites	Mobile camps	40	50
	Site Offices/Worksites	40	50
	Homesteads	40	50
	Drill Rigs	40	50
Unmanned Sites	Well Sites	30	40
	Kiosks (HV)	30	40
	Sheds	25	35
	Stock yards	25	35
	Communications towers	20	30
	Lay down yards	20	30
	Water Reinjection sites	20	30
	Lined ponds	10	20
	Pump stations	10	20
	Water gathering stations	10	20
	Water transfer stations	10	20
	High Point Vents	10	20
	Low Point Drains	5	10
	Valve Pits (plastic)	5	10
	Valve Pits (concrete)	1	2
	Regional and shallow water monitoring bores	N/A	N/A

2

Grassland includes everything from sparse native grassland to grassland dominated by exotic species for grazing purposes.
Bushland includes forests, woodlands, scrubs and shrubland.

3 Slope



Slope influences the rate of spread of a fire in that a fire spreads quicker upslope from the fuel (vegetation), approximately doubling its rate of spread for every 10 degrees increase in slope.

4 Constraints

APZ's may only be managed if the land is free from environmental, land heritage and community constraints. This may include:

- Environmental, cultural heritage or historic heritage features
- Land owner agreements
- Other permits and approvals

5 Methods for Managing APZ's

The requirement for an APZ is a managed area where regrowth or grass is managed to a height no higher than 150 mm. The APZ requirements can be achieved by any of the following methods:

- Mowing/Slashing
- Stick Raking
- Weed Spraying
- An approved planned burn

Note: 50 mm is an approximate minimum height for fire to carry.

Where APZ requirements cannot be achieved there are a number of other strategies that can be used to mitigate the assets bushfire risk including:

1. Reducing the fuel loads within the surrounding area and its ability to spread can be achieved through the following methods:

- Annual Hazard Reduction Burning Program
- Firebreak construction and annual maintenance programs
- Stock Grazing

2. Scheduling/Planning should be managed where possible to avoid activities in high risk sites during bushfire periods, in accordance with the Origin LNG Bushfire Preparedness Tool.

3. Response Planning should be conducted for mobile activities (e.g. drilling) during the declared fire season to include:

- Reference to the daily use of the Origin LNG Bushfire Preparedness Tool
- Location of first response fire fighting equipment
- Closest places of safety (method 2 assessed site or town)
- Documented and exercises site evacuation procedures

Appendix D IG Bushfire Preparedness Tool

IG BUSHFIRE PREPAREDNESS TOOL

The following is to be conducted daily during the QLD Fire Season (typically Sep – Jan) and any other forecasted or actual period with a Fire Danger Index (FDI) of Severe of greater.

1. Review Daily Fire Danger Rating
2. Review Fire Danger Matrix Actions Required
3. Determine Site Risk Level – Applies to Mobile Sites Only
4. Determine Restrictions for Mobilising to Site – Applies to Mobile Sites Only
5. Daily Toolbox Planning and Monitoring Routine
6. Bushfire First Responder Checklist

1 DAILY FIRE DANGER RATING

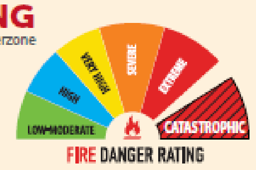
Visit Rural Fire Qld home page then the Origin Weatherzone service:

https://www.ruralfire.qld.gov.au/Pages/FDR.aspx

http://energy.weatherzone.com.au/

Login: ops@originenergy.com.au

Password: originenergyweather1



2 IG FIRE DANGER MATRIX

	WHAT DOES IT MEAN	ALL PERMANENT SITES Method 2 assessed and Asset Protection Zone Maintained	ALL MOBILE SITES AND TEAMS E.G. DRILLING, FSG, SCOUTING, GATHERING Mobile and Non Permanent Sites
Low – Moderate FDI 0 - 11	• The key elements of weather conditions to monitor are sudden drops in relative humidity and an increase in wind strength and temperature. These factors have a direct effect on fire behavior. Be aware of ignition factors of fire and reduce the risk.	• Ensure that all feasible fire related risks are identified and controlled on the site risk register and that defined processes and safety critical activities can be performed safely in times of elevated Fire Danger Rating.	• Ensure individuals are provided with the required resources and tools to be contactable and kept informed on the latest information, updates on weather, fire warnings or incidents in the region that they intend to travel through, visit or work in.
High FDI 12 - 24	• If a fire starts, it is likely to be controlled in these conditions. • Embers can be blown ahead of fires, resulting in spot fires ahead of main fires. This rating presents a minimal risk to life and property (QFRS 2009).	• **Fire Danger Monitoring and Awareness** – Site Management to have a system for the sourcing and communicating (prior to start of shift) weather conditions and Fire Danger Ratings and the ability to notify of any changes all affected employees, visitors and contractors. • **Readiness to Respond** – Review bushfire plans / procedures and check readiness levels.	• **Work Planning** – JSA's are to include an assessment of Bushfire risks. • **Fire Danger Monitoring and Awareness** – Site Management to have a system for the sourcing and communication (prior to start of shift) of weather conditions and Fire Danger Ratings and the ability to notify of any changes to all affected employees, visitors and contractors. • **Readiness to Respond** – Review bushfire plans / procedures and check readiness levels.
Very High FDI 25 - 49	• Fires in these conditions can be difficult to control, with embers being blown ahead of fires, creating spot fires up to 2 km ahead of the fire front. This rating presents a low chance of injury or death (QFRS 2009).	• **Work Planning** – TRA / JSA's are to include an assessment of Bushfire risks. • **Fire Danger Monitoring and Awareness** – Site Management to have a system for the sourcing and communicating (prior to start of shift) weather conditions and Fire Danger Ratings and the ability to notify of any changes all affected employees, visitors and contractors. • **Site Access** – Ensure risks such as access to and from site are considered at different levels of Fire Danger Rating and addressed in the site risk register / site procedures.	• **Work Planning** – JSA's are to include an assessment of Bushfire risks. • **Fire Danger Monitoring and Awareness** – Site Management to have a system for the sourcing and communicating (prior to start of shift) of weather conditions and Fire Danger Ratings and the ability to notify of any changes to all affected employees, visitors and contractors. • **Site Access** – Ensure risks such as access to and from site are considered at different levels of Fire Danger Rating and addressed in the site risk register / site procedures.
Severe FDI 50 - 74	• These are hot, dry and possibly windy conditions for a bush or grass fire. • If a fire starts and takes hold, it will be hard for fire fighters to bring under control. • Fires in these conditions become fast moving and uncontrollable. Embers can be expected to be blown ahead of fires, with the possibility of these embers creating spot fires up to 4 km ahead of the fire front.	• **Work Planning** – Task or activity risk registers / JSA's / SWMS are to be used to mitigate ignition sources and exposure to bushfire. • **Worker Location Monitoring** – Locations and movements of all staff are to be recorded. • **Site Preparation** – Prepare for ember attack by covering / removing exposed combustible material. • **Non Essential Tasks** – All non essential tasks should be delayed, re-scheduled, cancelled or suitably risk assessed and controlled. • **Hot Works** – No Hot works to be undertaken (apart from controlled flaring). Hot works in construction sites (i.e. GPF areas can continue with hot works but need to be under a hot work permit considering proximity to vegetation and with a downwind fire spotter. • **"Stay or Go"** – from site to be undertaken in consultation with supervisor / management (refer to tool over page).	• **Fire Danger Monitoring and Awareness** – Site Management to have a system for the sourcing and communication (prior to start of shift) of weather conditions and Fire Danger Ratings and the ability to notify of any changes to all affected employees, visitors and contractors. • **Essential Tasks** – Task or activity risk registers / JSA's / SWMS are to be used to mitigate ignition sources and exposure to bushfire. Undertaking new tasks must be approved by line management as potential consequences should be considered as Critical for high exposure activities. • **Non Essential Tasks** – All non essential tasks should be delayed, re-scheduled, cancelled or suitably risk assessed and controlled. • **Hot Works** – No Hot works to be undertaken in the field, less controlled flaring. Any required hot works undertaken require a hot works permit and significant precaution implemented. • **Remote Workers** – where only UHF coverage is available, secondary communications / monitoring must be made available e.g. satellite communications, SPOT devices and increase scheduled reporting. • **"Stay or Go"** – from site to be undertaken in consultation with supervisor / management (refer to tool over page). • **Fire threat Updates** - broadcast regular fire updates to workforce across common channels.
Extreme FDI 75 - 99	• These are very hot, dry and windy conditions for a bush or grass fire, flames will be higher than roof tops. • Spot fires will start and move quickly. • Fires in these conditions become fast moving and uncontrollable. Embers can be expected to be blown ahead of fires, with the possibility of these embers creating spot fires up to 6 km ahead of the fire front. • Rural Fire Queensland suggests that chance of avoiding death or injury in these conditions is unlikely when opting to stay to defend assets (QRFS 2009).	• **Work Planning** – Task or activity risk registers / JSA's / SWMS are to be used to mitigate ignition sources and exposure to bushfire. • **Fire Danger Monitoring and Awareness** – Site Management to have a system for the sourcing and communication of weather conditions and Fire Danger Ratings and the ability to notify of any changes to all affected employees, visitors and contractors. • **Readiness to Respond** – Identify in readiness for a fire event which safe places of refuge and evacuation routes are the preferred options given the conditions. • **Non Essential Tasks** – Tasks with the potential to create an ignition source of fuels should be re-scheduled or cancelled. • **Essential Tasks** – (e.g. Safety Critical Tasks) – Should be risk assessed and appropriate mitigations in place to prevent and manage a fire should a fire eventuate.	• **Work Planning** – If already on location, immediately leave the high risk area. If fire alerts are active or present with a known risk (fire in the area), personnel must execute their contingency plans. • **Readiness to Respond** – Identify readiness for a fire event which safe places of refuge and evacuation routes are the preferred options given the conditions. • **Non Essential tasks** – All non safety-critical tasks must be cancelled. • **Journey Management** – Cancel or delay all planned travel to or through the high risk areas. • **Hot Works** – No Hot works to be undertaken in the field, less controlled flaring. • **Flaring** – Only occur after each site has been risk assessed with local stakeholders, and suitable controls are in place such as Asset Protection Zone (APZ) or a fire watch, in situ fire tender, and trained fire crews. • Working in Communication 'black spots' – To be deferred until the threat level reduces to below Severe. • **Remote Workers** – Where only UHF coverage is available, secondary communications / monitoring must be made available e.g. satellite communications, SPOT devices and increase scheduled reporting. • **"Stay or Go"** – From site to be undertaken in consultation with supervisor / management (refer to tool over page). • **Fire threat Updates** – broadcast regular fire updates to workforce across common channels.
Catastrophic FDI 100+	• These are the worst conditions for a bush or grass fire. • If a fire starts and takes hold, it will be extremely difficult to control and will take significant fire fighting resources and cooler conditions to bring it under control. • Fires in these conditions become fast moving and uncontrollable. Embers can be expected to be blown ahead of fires, with the possibility of these embers creating spotfires up to 20 km ahead of the fire front. Rural Fire Queensland suggests that chance of avoiding death or injury in these conditions is unlikely when opting to stay to defend assets (QRFS 2009). • The safest place to be is away from bushfires and bushfire prone areas.	• **Work Planning** – All tasks that could pose a bushfire threat must be cancelled unless they are safety critical and are controlled within specific procedures. • **Readiness to Respond** – Management to remain informed and regularly check the latest information updates on weather, fire warnings or incidents in their region. • **Hot Works** – No Hot works to be undertaken in the field, less controlled flaring. • **Journey Management** – Cancel or delay all planned travel to or through the high risk areas.	

Indicates a probable Total Fire Ban based on these conditions.

Indicates NO HOT WORKS to be performed (less controlled flaring) – Check local district information. Essential hot works at Permanent sites can be performed with a Hot Works Permit using significant precautions.

(Sourced from, AFAC Capgemini and MDP Fire Danger Rating Matrix) • Version 1, effective date: 1 July 2014

3 MOBILE SITE RISK LEVEL

Risk level is determined by three or more aspects in the same category of the highest risk level.

ASPECT	LOW RISK	MEDIUM RISK	HIGH RISK
Site	• Large cleared area Asset Protection Zones (APZ's) around the site of a minimum distance.	• Large cleared Asset Protection Zones (APZ's) around the site not necessarily of the minimum distance	• Minimal cleared Asset Protection Zones (APZ's) around the site, not of the minimum distance
Access	• Multiple routes in and out of site and in different directions.	• At least two routes in and out and in different directions available.	• Single point of entry into and out of the site.
Communications	• Multiple means of communications available including mobile phone, Internet, UHF, Digital Radio or Satellite Phone.	• At least two means of communications with at least one being very reliable.	• Only one means of communications and/ or communications may be unreliable or non-existent.
Fuel Sources and Loads	• Low density and/or high in moisture content e.g. grasslands	• Medium density and/or some degree of moisture content. e.g. well spaced scrubland or woodland.	• High density and/or very dry. e.g. dense scrubland or woodland.
Slope	• Flat or Similar with no large slopes within immediate vicinity of work site	• Mostly Flat with large slopes around the vicinity of the worksite	• Undulating or hilly area both on site and in the immediate vicinity of the work site
Firefighting Response/ Safe Havens	• Fire fighting resources within 15 minutes or access to an Origin Permanent Site (Method 2 assessed safe haven) within 15 minutes	• Fire fighting resources > 60 minutes away or access to an • Origin Permanent Site (Method 2 assessed safe haven) within 45 minutes	• No reasonable access to fire fighting resources or an Origin Permanent Site (Method 2 assessed safe haven)

4 MOBILISING TO SITE

2 + 3

This section provides guidance on "Mobilising to Sites". **Note:** Refer to matrix on next page for details on "Take Fire Precautions" and "Full Assessment".

FDR	LOW RISK	MEDIUM RISK	HIGH RISK
LOW-MODERATE	Mobilise to Site	Mobilise to Site	Mobilise to Site
HIGH	Mobilise to Site	Mobilise to Site	Take Precautions
VERY HIGH	Mobilise to Site	Mobilise to Site	Take Precautions
SEVERE	Mobilise to Site	Take Precautions	Do Not Mobilise
EXTREME	Take Precautions	Take Precautions	Do Not Mobilise
CATASTROPHIC	Do Not Mobilise	Do Not Mobilise	Do Not Mobilise

EVACUATING FROM SITE

2 + 3

This section provides guidance for when it is appropriate to "Evacuate from sites" based on Fire Danger Index (FDI) and the category of the particular site. **Note:** Refer to matrix on next page for details on "Take Fire Precautions" and "Full Assessment".

FDR	LOW RISK	MEDIUM RISK	HIGH RISK
LOW-MODERATE	Continue Work	Continue Work	Continue Work
HIGH	Continue Work	Continue Work	Take Precautions
VERY HIGH	Continue Work	Continue Work	Take Precautions
SEVERE	Continue Work	Take Precautions	Abandon site / Evacuate if time permits
EXTREME	Take Precautions	Take Precautions	Abandon site / Evacuate if time permits
CATASTROPHIC	Abandon site / Evacuate if time permits	Abandon site / Evacuate if time permits	Abandon site / Evacuate if time permits

5 DAILY TOOLBOX PLANNING AND MONITORING ROUTINE

Preparedness Planning

(Mandatory for all Severe, Extreme and Catastrophic FDI days)

The following must be reviewed daily. If fire alerts are active or presented with a known risk (fire in the area), personnel must execute their contingency plans which needs to encompass the following:

- ☐ Procedure on identifying and notifying of a bushfire
- ☐ Critical equipment to be removed / isolated / shut down.
- ☐ Safe evacuation routes from site(s) and muster points.
- ☐ Communications methods:
  - ✔ Team channels and / or phone numbers
  - ✔ Area channels and / or phone numbers
- ☐ Closest "Safe Havens" (Community or Origin Permanent Sites).

Monitoring Routine

- ☐ Provide timely advice on changes in level of fire risk as available.
- ☐ Monitor team and area common channels for bushfire early warning.
- ☐ Update changes in work location.

6 BUSHFIRE FIRST RESPONDER CHECKLIST

The following sequence must be followed by the first person responding to a fire:

1. **Danger** – Remove yourself and others from danger if safe to do so.
2. **Alarm** – Raise the Alarm either on common radio channel or other agreed process.
3. **Gather Information**
   - ☐ **Location** – Direction from known reference points e.g. roads and Origin Infrastructure such as well numbers).
   - ☐ **Impacts (actual and potential)** – Life, property and the environment.
   - ☐ **Fire Characteristics** – Grass or woodlands, flame height, fire front and direction of travel.
   - ☐ **Weather** – Wind strength and direction.
   - ☐ **Response in Progress** – What response is underway and by who (Origin, Landowners or Emergency Services)
   - ☐ **Response Required** – Origin and / or Emergency Services.
   - ☐ **Access** – Safe access and egress routes.
4. **Notify Emergency Services** – Call "000" or "112" (Some mobiles)
5. **Notify Origin** – Supervisor or Superintendent
6. **Respond** – If trained in Origin Fire Management (FM1 or FM2)
7. **Handover** – to the Origin On-Scene Commander (OSC) or QFES on arrival.
8. **Support** – Provide ongoing support to the response as required.

Appendix R: Emergency Response Plan

Emergency Response Plan
NT-2050-15-MP-0024

Integrated Gas

EMERGENCY RESPONSE PLAN
Beetaloo Asset (Northern Territory)

This documents details the Emergency Response Plan for the Beetaloo Asset in a manned and unmanned status.

Revision	Date	Description	Originator	Checked	Approved
0	29/04/2019	Issued for use	L Fulford	B Baldwin M Hanson Ed Wong	T Boyes
1	19/07/2019	Update based on DENR feedback	L Fulford	M Hanson	T Boyes
2	03/12/2019	Update based on DENR feedback	L Fulford	M Kernke	L Fulford

Review due: 01/05/2020

THE THREE WHATS

What can go wrong?
What could cause it to go wrong?
What can I do to prevent it?

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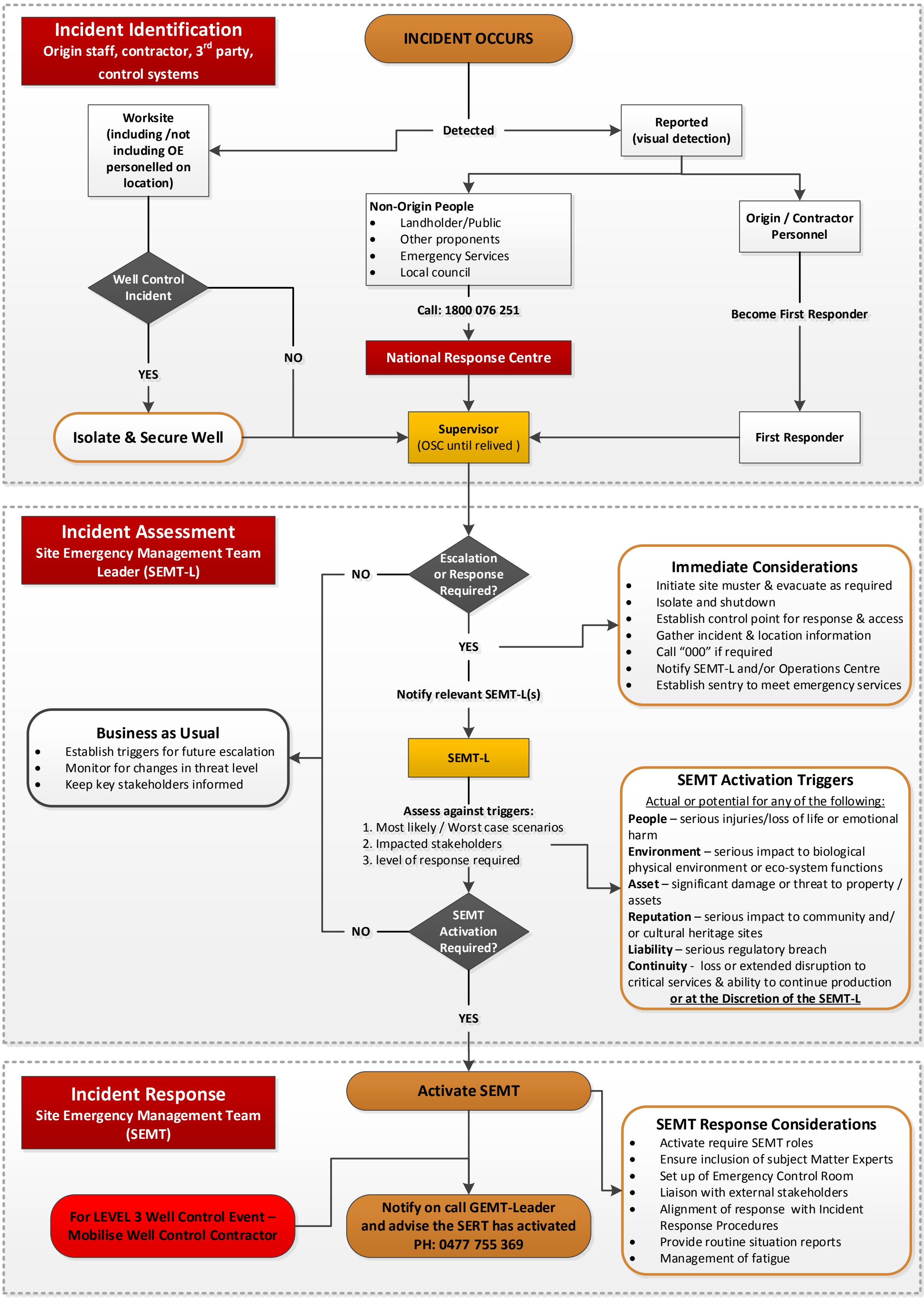
1. Site Emergency Response Plan (SERP) activation immediate actions

When a site level emergency is declared, this plan will be activated and escalated where appropriate.

Table 1: Activation immediate actions

Triggers for Activation			
Site Emergency Response Team activations (actual or potential) for impacts of any of the following and/or at the discretion of the Person in Charge (PIC).			
People	Serious temporary injury/illness or worse to any person		☐
Environment	Moderate effects on biological physical environment and serious short term effect to eco-system functions		☐
Asset	Serious damage or loss to production, property and/or infrastructure		☐
Reputation	Serious impact to community or cultural heritage		☐
Liability	Serious breach of law or regulation		☐
1 – Isolate and Evacuate			
Muster	Account for all personnel (upwind) whilst assessing the situation		☐
Isolate	Either through Emergency Shutdown Devices (ESD's) or remotely		☐
Evacuate	If required evacuate to designated evacuation points either upwind or at a safe distance as determined by event type or respective response guideline		☐
Control	Establish control points to coordinate response and restrict access		☐
Meeting Points	Nominate predetermined Emergency Services meeting points or establish meeting points near known landmarks or road intersections and establish sentry to meet Emergency Services upon their arrival		☐
2 – Communicate and Escalate			
Confirm	Confirm details of the emergency (type of emergency, injuries, contained or uncontained etc.) and response required.		☐
Activate	Activate ERT, SEMT, brief GEMT-L, contact Emergency Services, communicate with other Stakeholders		☐
Escalate	Consider likely impacts		☐
Impacts (actual & potential)	Most likely	What is realistically likely to happen and who / what is impacted?	☐
	Worst case	How bad could it really get and then who / what is impacted?	
SEMT-Leader: Brief On-Call GEMT Leader **0477 755 369** on situation, response and triggers for further activation.			☐
3 – Respond			
• Continually reassess situation	• Appoint OSC		☐
• Designate communication channels	• Establish exclusion zones		☐
• Activate appropriate resources	• Develop SMEACS briefing		☐
• Apply Incident Response Guidelines	• Provide regular updates		☐
4 – Response Management			
Personnel	Appropriate personnel in the ERT, SEMT and from outside resources		☐
Resources	Appropriate resources available to manage the incident		☐
Tools	Appropriate tools available for the ERT, SEMT, OSC and other responders		☐

Figure 1: Detection, Assessment, Response Flowchart



2. Introduction

This Emergency Response Plan (ERP) encompasses all Growth Asset's activities within the Beetaloo Asset and will be activated to manage emergency events at site.

Locations / site specific information may be recorded either in a contractors emergency response plan (ERP), bridging document, or through another means of providing emergency information, e.g Emergency Response Notification (ERN) form.

The Site Emergency Response Plan (SERP) is designed to direct and guide the On Scene Commander (OSC) and Emergency Response Team (ERT) (if nominated) to respond effectively to site level emergencies and return the site to normal operations.

Further support is provided through the Origin Emergency Response Framework via the Group Emergency Management Plan (GEMP 6522903) and Crisis Management Plan (CMP ORG-RMS-PLA-001).

2.1 Purpose

The purpose of this plan is to describe how to effectively manage site emergencies for the Beetaloo Asset whilst in a manned and unmanned condition.

The plan will:

- Briefly describe the Origin emergency response structure
- Explain the notification and escalation paths for an emergency
- Identify key people and explain what they will do during an emergency
- Describe important information about site infrastructure including:
  - Location
  - Geographic area
  - Isolation points (if applicable)
  - Exclusion zones (if applicable)
  - Other technical information
- Provide tools and templates to use during an emergency.

2.2 Scope

This Plan supports normal manned operations and response to unmanned locations. Unmanned relates to periodic contractor service visits and occasional small team visits.

This plan applies to all employees, contractors and visitors to the following Beetaloo Asset locations and activities:

- Asset Locations details as described in Section 3.
- Activities included in scope are:
  - General travel activities (Walking, Land transport).
  - Non/minimum risk activities such as visual inspections, routine low risk maintenance and monitoring tasks.
  - Accompanying or guiding contractors who are engaged in the above mentioned activities.
  - Laydown yards within tenure.
  - Construction Work (such as access tracks, lease builds, site earthworks, remediation)
  - Drilling, well completion, intervention or abandonment activities.
  - Transport to and from work areas (not including chartered flights to Airfield)

This plan excludes:

- Chartered flights to airfield and commercial flights to Darwin
- Third Line Logistics Freight and Haulage from Depots to Laydown Yards
- Accommodation in commercial establishments outside of the work areas identified in Section 3.

2.3 Compliance with Civil Legislation and Australian Standards

This plan meets the requirements as identified by legislation for emergency response plans including:

Australian Standards, Codes, Guidelines and Commonwealth Legislation

- Work Health and Safety Act 2011.
- Work Health and Safety Regulations 2011.
- Environment Protection and Biodiversity Conservation Act 1999.
- Australian Dangerous Goods Code.
- National Environment Protection (Assessment of Site Contamination) Measure (NEPM) 1999 as amended 2013.

Northern Territory

- Work Health and Safety (National Uniform Legislation) Act 2016.
- Work Health and Safety (National Uniform Legislation) Regulations 2017.
- Petroleum Act 2018.
- Petroleum Regulations 2013.
- Petroleum (Environment) Regulations 2018.
- Code of Practice for Petroleum Activities in the Northern Territory
- Bushfire Management Act 2016.
- Bushfire Management (General) Regulations 2018.
- Dangerous Goods Act 2012.
- Dangerous Goods Regulations 2018.
- Transport of Dangerous Goods by Road and Rail (National Uniform Legislation) Act and Regulations.
- Waste Management and Pollution Control Act 2016.
- Northern Territory Contaminated Land Guideline (June 2017).

2.4 Operator Details

Origin Energy B2 Limited (“Origin”)

Level 25

180 Ann Street, Brisbane, QLD, 4000

2.5 Definition of a Site Emergency

An emergency is defined as an unplanned event within a specific site, facility, field or area, accidentally or deliberately caused, which requires a response to normalise the activity and which may result in an incident such as:

- Injury to people
- A near miss

- Loss of control of any health, safety environment or community related incident as part of the operation
- Damage to the environment
- An uncontrolled release of a substance to air, land and water
- Loss of reputation
- Loss of business
- Loss or damage to product or assets
- Loss of production
- The potential for any of the above

2.6 Project, Construction and Mobile Work Group ER Philosophy.

These teams will have the ability to provide a basic response to: incipient fires, minor spills and basic medical emergencies, in order to preserve life, contain incidents (if able) and reduce the impact on our people, the community, environment and assets.

Section 4, Appendix B and Appendix G identify where increased response capability has been introduced to mitigate the consequences of specific incident types, e,g, Loss of Well Control. Depending on the magnitude of the scenario event, escalation could also include emergency services.

2.7 Site Emergency Management Team Activation/Escalation

This Site Emergency Response Plan (SERP) is activated for emergencies that cause or have the potential to cause SERIOUS or greater consequences. Consequence classification is based on Origins Risk Management Directive ORG- RMS-DIR-001

The Site Emergency Management Team Leader (SEMT-L) or On Scene Comander (OSC) has the authority to activate this SERP. Notification must occur to the Group Emergency Management Team (GEMT) Leader, however escalation and activation of the GEMT is determined by the GEMT on call leader. Escalation to the GEMT is conducted by ringing the GEMT-L on call phone [redacted]. The Origin Emergency Management Structure Escalation Chart shows the different escalation levels between the SERT, GEMT and Crisis Management Team (CMT).

Under certain circumstances the GEMT may be activated without the activation of the SERP / SERT. If required the GEMT-L may then require the activation of SERP's / SERT's to manage an incident/s.

2.8 Document Hierarchy

The Document Hierarchy for Origin Emergency response is identified in Figure 2 below.

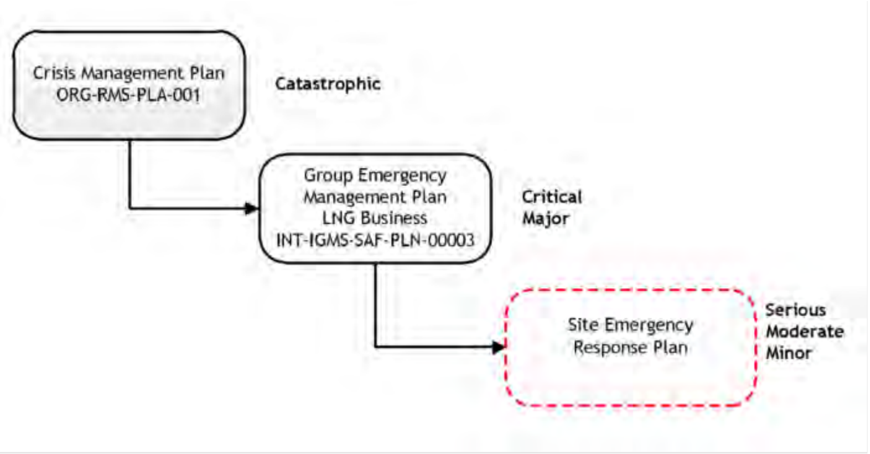


Figure 2 Hierarchy of Emergency Response documentation

2.8.1 Document Hierarchy for Principal Contractors

The relationship of Origin Emergency Response documentation for the Beetaloo Project, in conjunction with Contractor Emergency Response documentation is demonstrated in Figure 3 below.

Emergency Management - Overview

Emergency Response System Framework – Activity Specific

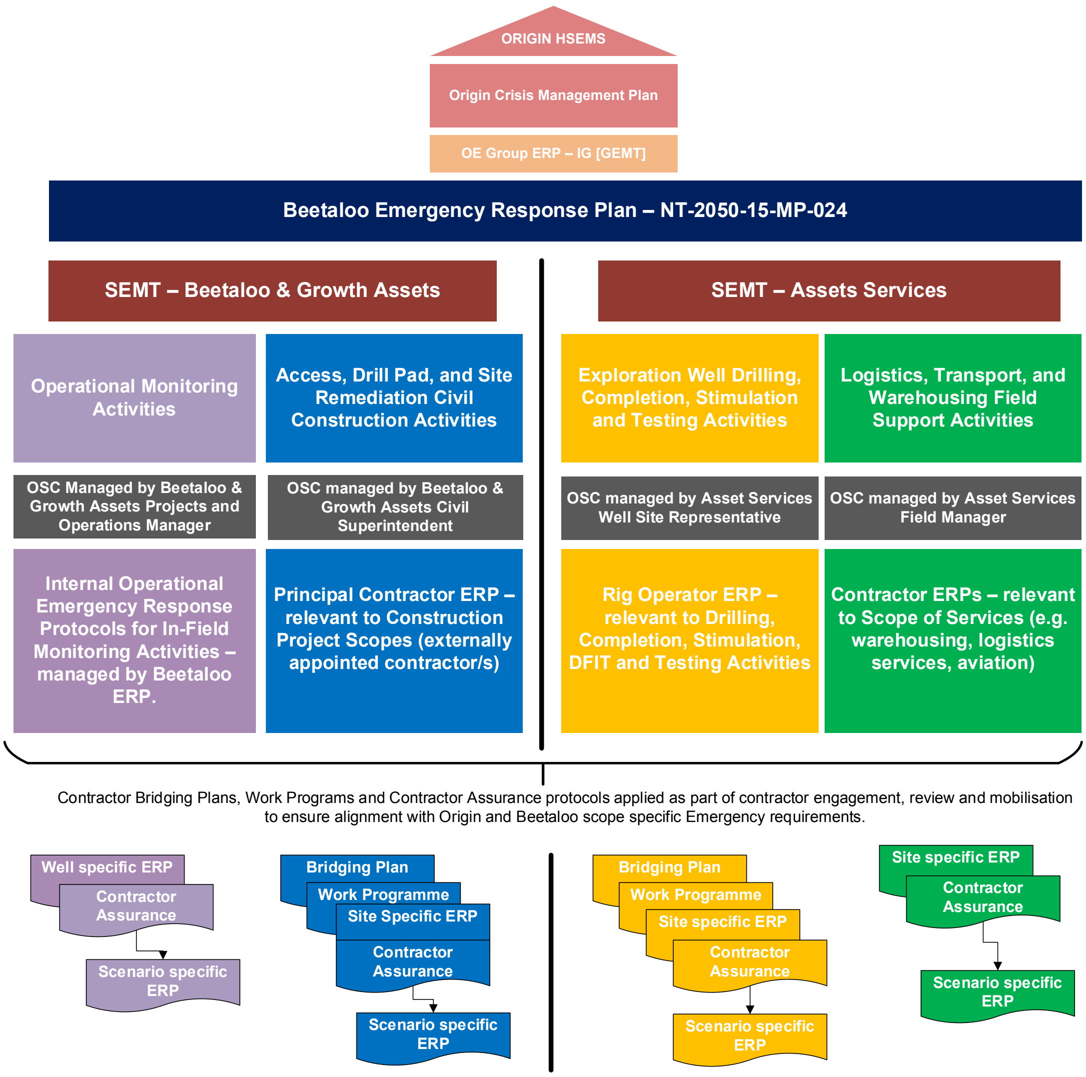


Figure 3 – Hierarchy of Emergency Response documentation

2.8.2 Emergency Management Structure

Figure 4 below identifies the Command and Control and escalation pathway for emergencies. Figure 3 identifies the escalation pathways for each component in Beetaloo & Growth Assets including Asset Services.

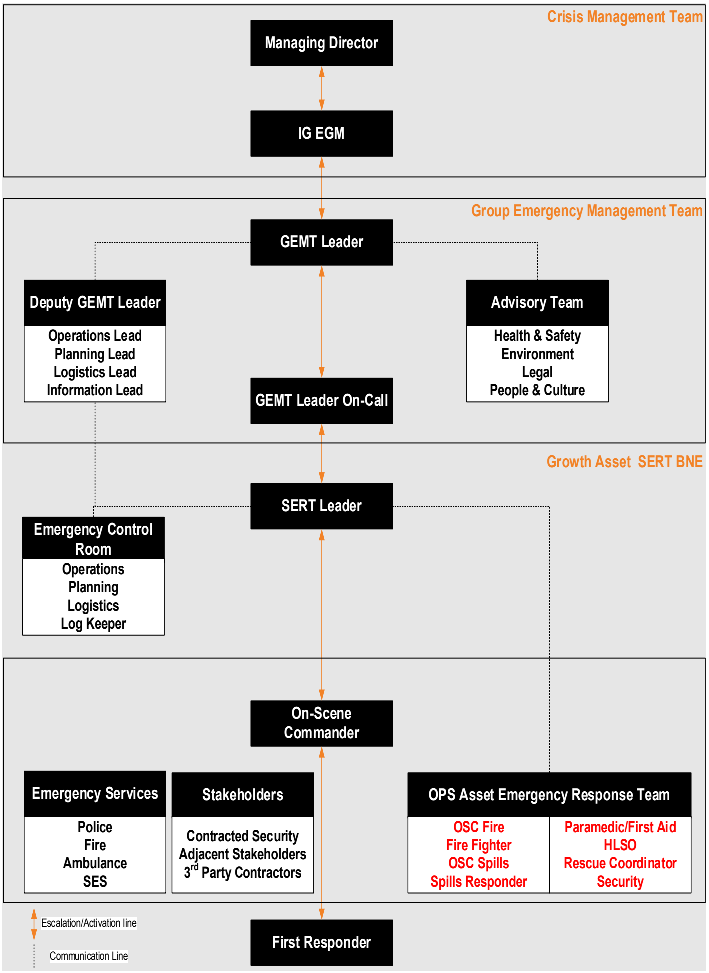


Figure 4 – Emergency Management Structure

3. Beetaloo Asset Locations and Field Activities

The Integrated Gas Growth Asset Business conducts operations in the Northern Territory (NT) at Beetaloo. The activities conducted in this scope include the following areas:

3.1.1 Drilling, Hydraulic Fracturing Stimulation (HFS), Completion and Well Testing Activities

Works are executed by Rig contractors, and are supervised by an Origin Wellsite Representative (company representative) who at times may additionally undertake rigless operations. Contractors undertaking these scopes of work operate under their own Safety Management System and Emergency Response Plans at designated locations identified within this Emergency Response Plan.

Additionally, these activities are supported by the IG Asset Services Emergency Response Plan CDN/ID 19601361 (where deemed applicable).

IG Field Management is executed through the Asset Services Field Managers located within project areas during project duration, details of these are provided within Contacts list within Appendix A.

3.1.2 Civil construction and related activities

Works such as establishing lay down areas, construction of access tracks, are usually executed by contractors operating under their own Safety Management System and Emergency Response Plans at various Beetaloo locations which are bridged to Origin Energy requirements. Beetaloo Field Management is executed through the Beetaloo & Growth Assets Projects & Operations Manager and the Beetaloo & Growth Assets Civil Superintendent whom is located within the project areas during project duration.

3.1.3 Commissioning

Works relating to commissioning of infrastructure are executed by contractors for electrical facilities and Rig Contractors for hydrocarbons as per Contractor Safe Systems of Work.

3.1.4 Projects

Works may be executed at varying locations to expand or support capability improvement to Origin Assets at Beetaloo including water monitoring bores, helicopter landing sites, or communication equipment. These Projects are usually delivered by contractors operating under their own Safety Management System and Emergency Response Plans bridged to Origin Energy requirements.

3.1.5 Field Support (logistics)

Where applicable, mobile camps will be executed by Principal Contractors. Warehousing and laydown activities will be managed by specific location ERP for the activity.

3.1.6 Existing well inspection monitoring

Well inspection monitoring activities are undertaken by local contractors working directly for Origin, these contractors report through the Beetaloo & Growth Assets Projects & Operations Manager and Beetaloo & Growth Assets Civil Superintendent located within project areas during project duration. The process undertaken for existing wells is detailed within Appendix B.

3.2 Field Sites / Locations

Site specific details, include location, proximity to emergency services and townships can be found within Appendix C. The maps below identify the location of the Beetaloo Project as well as specific Site locations referenced within this plan.

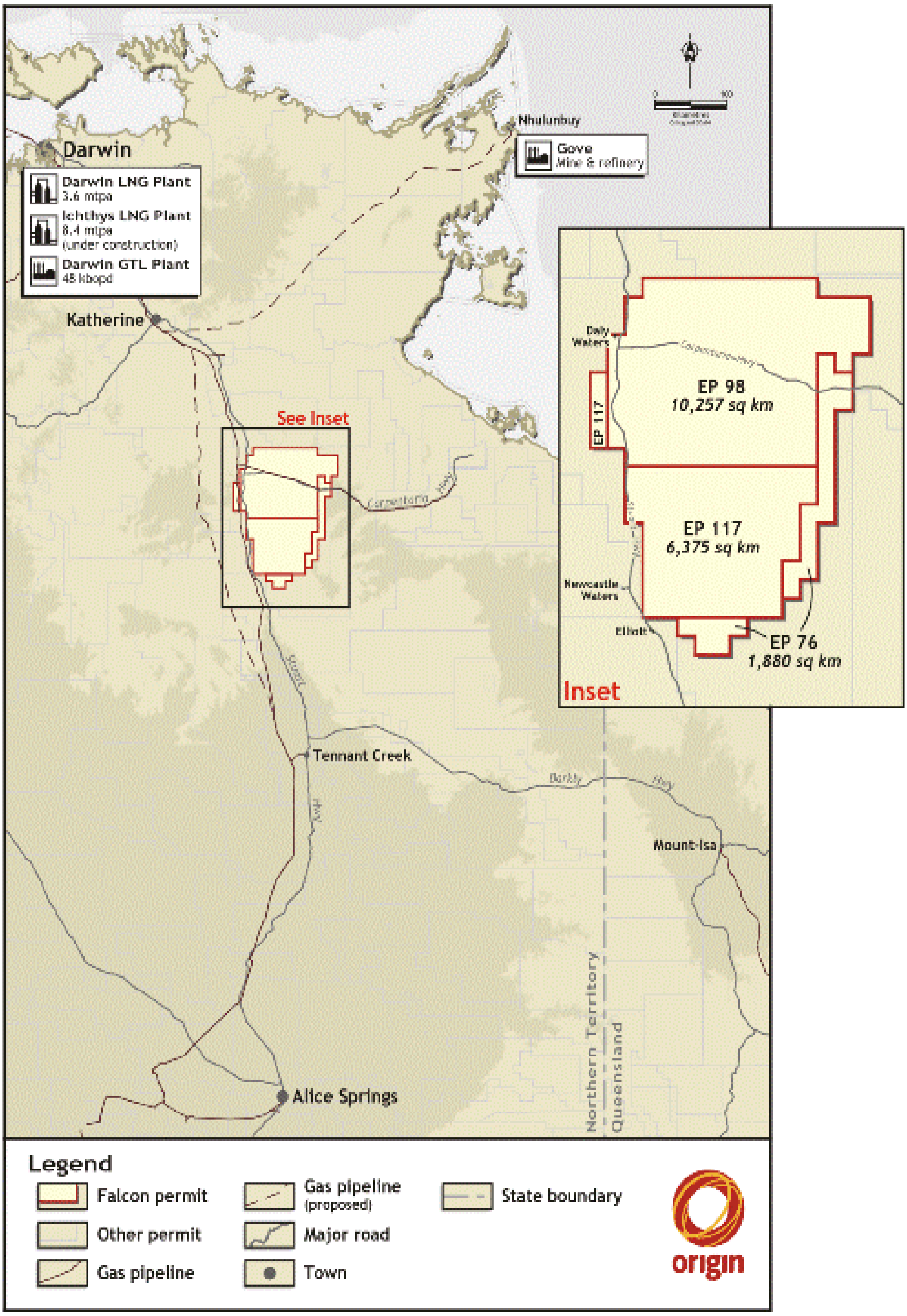


Figure 5: Location of Beetaloo Asset within Northern Territory

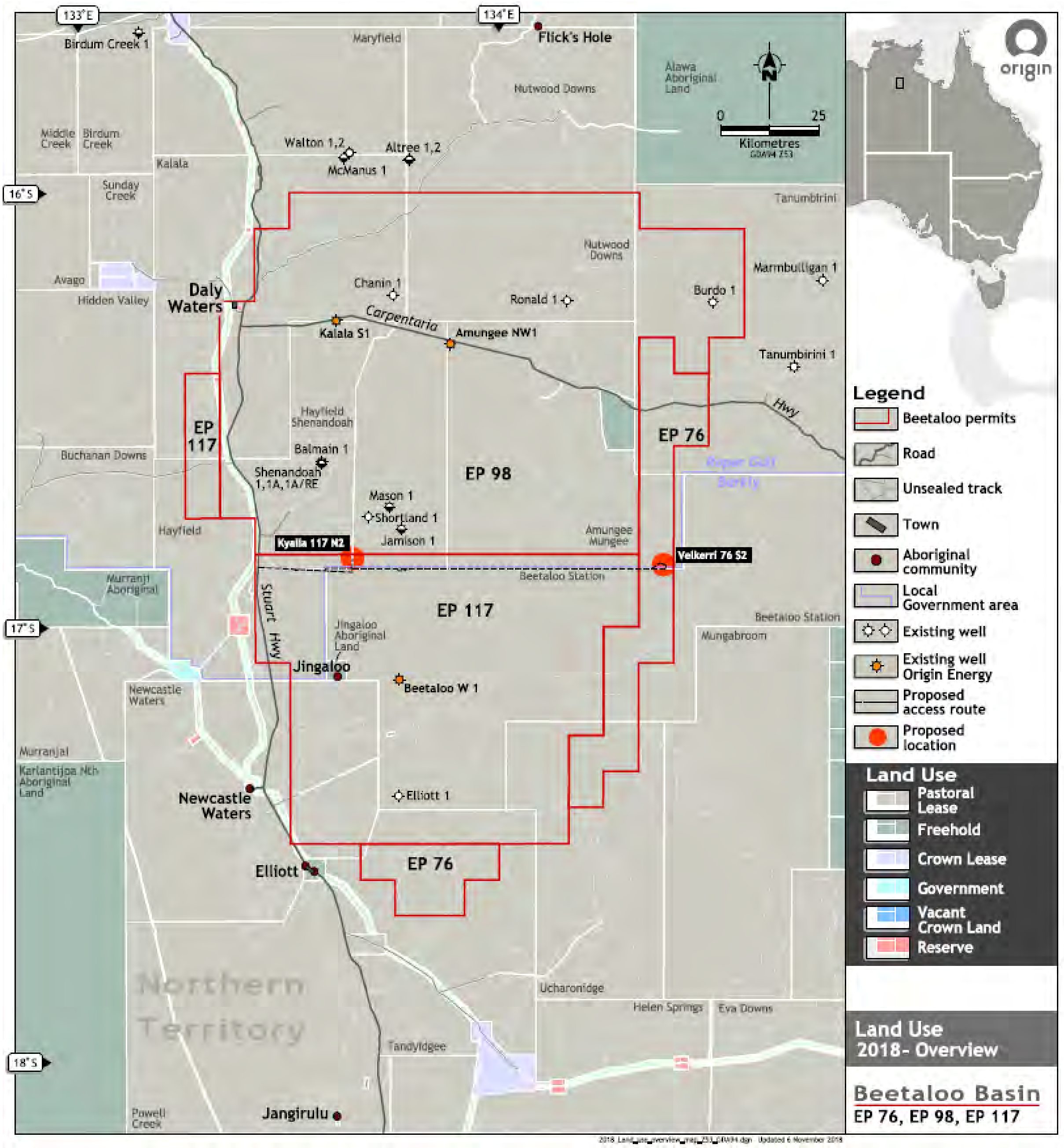


Figure 6 – Current Drilled and proposed wells locations

4. Emergency Scenario Responses

If an incident occurs, the designated Person in Charge as determined by the Beetaloo Safety Management Plan – NT-2050-15-MP-001 (Field Supervisor) will nominate an OSC and also which Origin business unit SEMT-L will be initiated. These aspect is indicated within Figure 3.

The designated SEMT-L will liaise with the Associated contractor (and Contract Owner) and notify the On-Call GEMT Leader (if deemed required). If an emergency event exceeds the contractors capability, i.e. Loss of well control, then Origin Beetaloo Asset will assume management of the incident and delegate management to internal Origin expertise, i.e Asset Services, Drilling & Completions team. The Integrated Gas Asset Services team will then determine if external support is required.

Category	Response Procedures
GENERAL	▪ Evacuation and Alarms ▪ First Responder – Immediate Action Checklist ▪ Activate Emergency Shutdown Device ▪ Shift Change Over Checklist ▪ Termination of Emergency
FIRE	▪ Fire – (Plant, Building/Storage / Accommodation (Including mobile camps), Electrical) ▪ Bushfire
PERSONAL SAFETY	▪ Medical Emergency ▪ Vehicle Accident ▪ Missing Overdue worker ▪ Lone Worker ▪ Snakebite ▪ Rescue from Height ▪ Rescue from Confined space ▪ Rescue from Heights ▪ Communicable Disease ▪ Electrical Shock ▪ Man Down ▪ Aviation
ENVIRONMENT	▪ Environment Related Incident (Earthquake) ▪ Environment – Weather Related Incident – Storm and Lightning ▪ Loss of Containment / Spill ▪ Flood
FACILITY & EQUIPMENT	▪ Major Structural / Mechanical Damage ▪ HV / LV Electrical Fault
HAZMAT	▪ Diesel ▪ Nitrogen ▪ Loss of Well Control level 1 or 2
SECURITY	▪ Protest / Trespass ▪ Bomb Threat ▪ Armed Intruder ▪ Lockdown

4.1 Scenario Flip Charts

The Emergency Scenario Flip Charts (CDN 3676134) provide an easy to understand detailed response to identified emergency situations and also provide additional scenarios that may not be mentioned. Appendix G contains four main responses from the Flip Charts for ease of reference being: 1.) Bushfire 2.) Flood 3.) Spill and 4.) Loss of Well Control.

4.2 Contractor Scenarios

For some undertakings, for example a Well control event, Origin will delegate its responsibility to a Contractor, or Sub-Contractor with suitable emergency response capability as Origin will have limited/if any field presence at times.

It will be the responsibility of the contractor to provide an initial emergency response and coordinate the emergency event. If an Origin employee is involved in an emergency event at a site under the control of a contractor it is expected that the Origin employee will conform to the contractors response requirements and support the contractor if willing and competent to do so.

Notification of the event will follow normal reporting processes within the business unit. The activation of the GEMT may be required for an incident involving the contractor. While an Origin SEMT-L may be required to coordinate Origin aspects at the incident site, in support of the contractor, contractor management will more likely occur through a nominated Origin contact (i.e.Contract Owner) who will liaise with the contractor emergency management team.

Depending on location of works the contractor may be able to call upon other nearby parties or State Emergency Services for assistance in responding or handling the incident; however the contractor retains responsibility for managing the emergency event.

4.3 Well Monitoring and Control

Appendix B contains all information pertaining to the monitoring of remote wells, well control and classification of well control incidents. A loss of Well Control is considered a Major Accident Event (MAE) which, while rare, requires additional controls and engineering assessments to mitigate potential consequences.

4.3.1 Potential Major Accident Events

A Major Accident Event is an *uncontrolled incident, including fire, explosion or release of dangerous substance with the potential to lead to multiple fatalities or major environmental damage* (potential for critical or catastrophic consequence as per Origin Risk Matrix).

If the Business Unit undertaking the work has the potential for a Major Accident Event to occur these will be identified in the Business Unit Safety Management Plan (SMP) or Safety Case.

For more information refer to MAE hazard assessment and risk reduction (ALARP & SFAIRP requirements) procedure (CDN/ID: 7983063) or contact the Process Safety Advisor at Origin (details in contact list).

5. Campaign specific ERP arrangements

5.1 Roles

The following roles and responsibilities are essential to ensure effective communication within Beetaloo Asset when responding to emergency events.

- First Responder (FR), located at the incident scene and may be a Contractor
- On Scene Commander (OSC) located at the incident scene
- Site Emergency Management Team Leader (SEMT-L), located at either:
  - the Field Emergency Control Room (ECR) ; or
  - The Brisbane ECR, 180 Ann Street, Level 29, Room 29:12

Individuals may undertake multiple roles depending on the nature of the emergency, its duration and complexity. The functional roles that will assist the SEMT-L are listed below and known as the Site Emergency Management Team (SEMT).

- Operations
- Planning
- Logistics
- Log Keeper

Additional roles such as Technical Engineering, Travel and Accommodation Services may supplement the SEMT depending on the type of incident.

If the SEMT-L is unable to undertake their responsibilities a competent alternate or delegate SEMT-L must be appointed to ensure the SEMT continues to function.

If required, depending on the nature and severity of the incident, the Group Emergency Management Team (GEMT) may be activated to support the response. The GEMT can be called upon to support such issues as Regulatory notifications, provide additional manning to site, or source assets required to support the site, such as Aviation.

For in-depth information regarding the above positions refer to the Duty cards in the OSC/SEMT toolkits

SEMT and OSC Toolkit (AUS-IGMS-SAF-GDL CDN 6893451)
http://im.originenergy.com.au/otcs/cs.exe/Open/6893451

5.2 Responsibilities

A summary of responsibilities are located below, with contractors found in the PC ERP.

Roles and responsibilities	
Contractor work parties / First Responder	• Respond to the situation as per the contractors emergency response plan. • Actively participate in the risk management process to assist in the development of emergency action plans; • Check the notice boards for any recent updates to information; • Maintain a high level of awareness of actions to be taken in the event of an emergency situation; • Follow instructions from Emergency Controller, Emergency Services personnel, Fire Wardens, First Aiders and other designated emergency personnel as appropriate; and • Prior to commencing any work or entering a work area, sign on to prestart or JRA for the associated activity.
First Aiders	• Ensure their first aid competencies (minimum *Apply First Aid and CPR*) are maintained and advise the PM prior to the expiry; • Provide first aid treatment or assessment as needed, working within their skill level; • Determine need for medical assistance and provide information to Medical personnel or Emergency services as required; • Ensure that first aid kits are maintained and complete and items are in-date; and • Ensure that all treatments provided, regardless of the type or complexities are recorded.
Site Paramedic / Nurse Practioner	• Provide care on site available during the 12 hr work day (on call 24/7 whilst on location) • Ensures that medical response emergency equipment is suitable and located appropriately; • Checks that Emergency action plans are appropriate for the activity/hazards identified; • Test communication and advises of any changes;
Origin work /travel team supervisor **(Person in Charge)** **On Scene Commander**	• Escalate to the Person in Charge, for Beetaloo & Growth Assets managed activities whom is the Beetaloo & Growth Assets Civil Superintendent or delegate, • For Integrated Gas Asset Services (IGAS) managed activities (identified in Figure 3) to the designated Field Manager. • Maintain a log of events • Escalate to Emergency Services, if required. • Act as On Scene Commander (OSC) and manage first response at site level • Ensure that emergency action plans are discussed on a regular basis at Pre-Start / Toolbox meetings, so that all persons under their control are aware of the project emergency procedures; • Ensure that emergency equipment is maintained in good working order (complete, clean and available for immediate use); • Advise the HSE Representative or Person in Charge (e.g Operations/Project Manager/Field Manager) of any operational issues that may impact with or affect the emergency action plans;

	• Ensure that emergency action plans are prominently displayed and available for use by all workers; and • Take role of on-scene commander especially in first response to an emergency incident. During first response, ensure safety of other team members and ensure that emergency situation is communicated to the Emergency Controller.
For Civil and existing infrastructure (exploration wells) activities managed by Beetaloo & Growth Assets Team. **Operations Manager Growth Assets**	• Act as Site Emergency Management Team Leader (SEMT-L) (with respect to taking call from OSC and escalating to Project Manager Provide well monitoring trend analysis as required • Act as journey contact for field teams. • Escalate to GEMT-L as required. • Support field team with emergency service direction/calls as requested
For D&C activities managed by Integrated Gas Asset Services **Asset Services – D&C Field Manager**	• Act as Site Emergency Management Team Leader (SEMT-L) (with respect to taking call from OSC and escalating to D&C Beetaloo Project Manager • Provide well monitoring trend analysis as required • Act as journey contact for field teams. • Escalate to GEMT-L as required. • Support field team with emergency service direction/calls as requested
General Manager Beetaloo & Growth Assets	• Receive call from PIC and support where required. • Participate in Group Emergency Management Team if activated.
General Manager **Asset Services**	• Receive call from PIC and support where required. • Participate in Group Emergency Management Team if activated.

5.3 Communications

The communication flow between contractors (rig), external services and Origin is demonstrated in the flow chart below:

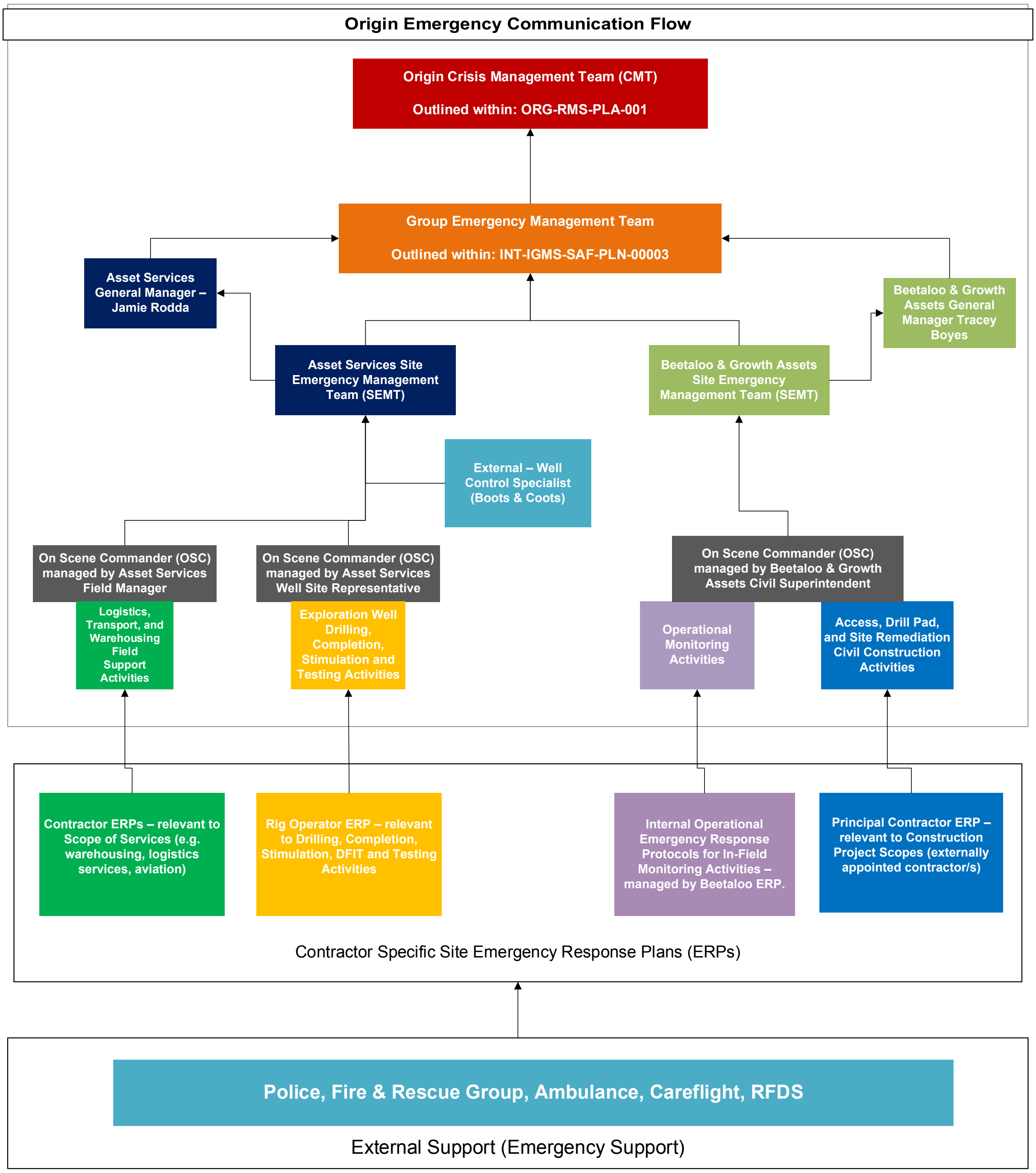


Figure 6: Communication flow

6. Emergency Management and Control

After an emergency is detected, the following emergency management stages will be used to control and contain the incident and return to business as usual.

- Raise the alarm
- Isolate and secure
- Communicate and Escalate
- Respond and Recover

6.1 Raise the alarm

One or more of the following methods can be used to raise the alarm:

- in person
- radio (Digital, UHF, VHF etc)
- phone (mobile, satellite or landline)
- Emergency alarm

6.2 Isolate and Evacuate

- Stop all work and make sure the worksite is safe
  - Secure the well, or impacted area
  - stop vehicle and mobile plant operations
- If you need to abandon vehicles and mobile plant
  - pull over and park in a safe area
  - ensure access and egress to the site is not impeded
  - switch off and leave the keys in the ignition
- Plan a safe route to the muster point and avoid movement through unsafe areas
- Account for all people
- Stand by at the muster point until stood-down or instructed to evacuate

6.3 Communicate and Escalate

- Gather information – where is the emergency, what has happened, who is affected, is anyone missing, where are the safe areas etc
- Advise and update the Site Safety Manager
- Call Emergency Services (police, fire, ambulance) if required
- Identify meeting points for responders (Origin Medical Providers, ERT etc) and Emergency Services
- SEMT activates if required

6.4 Respond and Recover

- Apply first aid to injured people (if safe to do so)
- Activate ERT
- Consider Simultaneous Operations (SIMOPS), advise nearby work groups and if on an IG Asset, the Asset SEMT-L
- Assist Emergency Services
- Follow response procedures

6.5 Meeting Emergency Services

Where Emergency Services such as Ambulance, Police and Fire Services dispatched by road or air, an Origin employee or contractor, whenever possible, will meet the Emergency Service at a designated location and direct them to the incident site.

Meeting points with Emergency Services should be pre-identified if practicable and communicated to the Emergency Services on call out.

6.6 Hazard awareness

Any person arriving at the emergency site (Origin responders, Origin medical providers, Emergency Services) will be made familiar with:

- Hazards generated by the incident (fire, heat radiation, chemical exposure etc)

- Known hazardous areas
- Known safe locations and distances
- Appropriate PPE (if known)

6.7 Shift changeover during an emergency

Shift changeovers are required for continuity of emergency management. The SEMT-L is responsible for change over of personnel involved in the emergency. Effective changeover will be achieved by:

- Staggering changeover times
- Avoiding changeovers during critical periods
- Having changeovers in daylight, where possible
- Briefing incoming personnel

6.8 Termination of emergency and recovery actions

The SEMT-L will declare when the response phase will stop and determine the recovery strategy and resources required in consultation with the GEMT-L if GEMT is activated.

All activities required to terminate an emergency and conduct recovery operations are located in Paragraph 8 of this document.

7. Post Emergency Actions

The following post emergency actions must occur in order to ensure the Asset, and Business as a whole, successfully learns from the incident and returns to pre-incident state operations.

7.1 After Action Review

A debrief or After Action Review (AAR) is to be held after each emergency in accordance with the After Action Review Procedure CDN 8189619 and using the After Action Review Form CDN 13853829. An AAR is designed to discuss strengths and weaknesses and necessary improvements for this plan and related procedures. All AAR's shall be entered in to OCIS along with any action items identified within the corresponding Incident tab.

7.2 Incident investigation

All incident investigations should be conducted in accordance with the Integrated Gas Manage Incidents and Learning Core Process found within ProMapp. The following steps should also be considered:

- Secure the incident site, restrict access and do not disturb anything until investigators have finished and handed back control of the site.
- Gather any evidence that may assist the investigations (list of people involved, response logs, situation boards, photographs etc).

The incident reporting system 'Origin Collective Intelligence System' (OCIS) will be used to record all incidents and actions arising from the emergency.

7.3 Recovery Actions

Prior to resuming work, develop a recovery plannthat considers the following:

- Check plant and equipment for structural, physical and electrical/instrumentation integrity
- Ensure all active detection and protection systems are restored
- Replenish emergency response equipment as required
- Replace or return any third party emergency equipment

In addition, consider the following points:

- People who were involved may require counselling, depending on the nature of the incident
- People should be debriefed, with all relevant information captured for a 'lessons learnt'
- Conduct a tool box talk on specific start up activities before restarting work

- Consider the potential for loss of confidence or potential IR issues following the incident or the response to that incident
- Emergency response plans and training may need to be revised before resuming normal activities.

7.4 Post Incident Clean-Up

Post incident clean up must be done using the following guidelines:

- Conduct an initial inspection to identify the extent of equipment and plant damage
- Assess potential decontamination needs (removal of chemicals/oil/foam from plant/equipment, contaminated soil etc.)
- Store all contaminated material in proper containers, pending offsite disposal by licensed hazardous waste contractors
- Repair or replace damaged equipment and plant
- Inspect and test affected equipment
- Attend to commissioning and site reinstatement

8. Training and Capability

IG emergency response competency based training is managed by Organisational Capability. Training is captured in People Central on the Origin Intranet (Source). Managers and supervisors are responsible for identifying and organising training for people required to perform emergency response roles. All personnel must be given specific instructions and training on how to respond to emergencies and in the correct use of emergency equipment available.

Emergency training may be in the form of:

- Competency based training
- Simulated exercises
- Desktop exercises
- Toolboxes
- Practical drills
- Resource and equipment checks

8.1 Drills and Exercises

The Emergency Exercise Planning and Reporting Procedure AUS-1000-SAF-PRO-00010 CDN/ID 3674898 details the minimum requirements for the planning and conduct of exercises.

All drills and exercises require an After Action Review to determine what worked well and what requires improvement. All actions are to be recorded in OCIS and reviewed until close out.

Figure 7 details the Beetaloo Assets annual exercise program.

In addition to this schedule the IG Well Control Standard (INT-1000-35-TS-001) mandates emergency response exercises to be conducted as follows:

- For continuous operations, IG D&C related activities shall conduct two Well Control Emergency response exercises per year to evaluate the effectiveness of the response of all stakeholders
- For projects that are campaign based, a Well Control Emergency Response Exercise shall be held at the start of the campaign involving all stakeholders. Subsequent exercises shall be conducted on a minimum twice annual basis if applicable.

		Jan	Feb	Mar	Apr	May	Jun
			1st Qtr			2nd Qtr	
Shift 1 and 2	Primary	Environmental	Fire	Environmental	Personnel safety	Structural failure	Personnel safety
	Secondary	Personnel safety	Personnel safety	HAZMAT	Security	Personnel safety	Personnel safety

		Jul	Aug	Sep	Oct	Nov	Dec
			3rd Qtr			4th Qtr	
Shift 1 and 2	Primary	Personnel safety	Personnel safety	Security	Structural / Equipment failure - Water	Fire	Personnel safety
	Secondary	Security	Personnel safety	Personnel safety	Environmental	Personnel safety	HAZMAT

Figure 7 – Exercise Schedule

8.2 Training Requirements

The Site ER job task analysis and Site Supervisor/Wellsite Representative job task analysis identifies the minimum requirements for trained personnel for specific roles that comprise the ERT and SEMT. It is the Contractor / Site Manager responsibility to maintain minimum levels of trained staff to meet their sites requirements.

8.3 Training and Competency

- All parties must be familiarised with the contents of this ERP.
- All personnel identified to fulfil emergency response roles within this ERP must be competent
- Minimum one remote first aid trained person per work party or travelling team.

9. Response Resources

The following response resources may aid in the preparation for, and management of, emergencies by the Beetaloo Asset.

9.1 Planning and Preparation

Enabling activities, such as ensuring minimum training and ensuring hardware maintenance, which are required to be carried out to support this plan are detailed in the:

- Beetaloo Basin Groundwater Monitoring Bore Installation Environmental Management Plan,
- Bushfire Management Plan
- Spill Contingency Management Plan
- Civil Construction Environmental Management Plans, and the
- Drilling, Completion, Hydraulic Fracture Stimulation and Well Testing Environmental Management Plan, in conjunction with the requirements of the Origin Integrated Gas HSEMS.

Dependent on workscope the relevant Person in charge (Field Supervisor) is responsible for ensuring that any staff mobilised to conduct work for OE in the Beetaloo Basin have been appropriately briefed, completed appropriate inductions and completed the nominated minimum training as applicable to the work conducted.

9.2 Equipment and Unmanned Phase

During operations, emergency response equipment available at each Site, and their layout, will be detailed and provided within contractor specific ERPs.

Emergency response assistance will be provided by PPP Contracting within an unmanned aspect, this will only involve monitoring the location from a distance to ensure appropriate escalation can occur if required.

9.3 Incident Response Procedures Flip Charts

Emergency Scenario Flip Charts CDN 3676134 are intended to provide further assistance to each role in dealing with various pre–defined emergency scenarios. The charts define the key roles and responsibilities to ensure essential response actions are undertaken. The flip charts can be found in Core Process Manage Incidents and Learning.

9.4 Spill Response

The Beetaloo Spill Management Plan (NT-2050-15-MP-030) provides specific information on how to manage and handle spill response within the Beetaloo Asset (included spills located off tenure). This document should be referenced for all non emergency spill response scenarios. For managing spills, Emergency Scenario Flip Charts CDN 3676134 and Appendix C should be utilised to manage Spills.

9.5 Chemical Response Procedures

The Chemical Response guidelines (QLD-1000-SAF-PRO CDN 4411922) provide specific information for specific chemicals that are used on Origin sites. The guidelines provide information on:

- PPE requirements
- Chemical details and description
- First Aid requirements
- Evacuation considerations
- Fire and spill management

Whilst this document was developed for QLD based Integrated gas sites it can be used on other sites if the same chemicals are present and the SDS lists the same response requirements. Any differences between the Chemical Response Procedures and the SDS must be risk assessed with appropriate controls adopted.

Chemical Response Procedures (CDN 4411922)

9.6 SEMT and OSC Toolkit

The link below identifies forms and procedures that can be used to help the OSC or SEMT in an emergency situation. These include:

SEMT and OSC Toolkit	
Duty Cards	SEMT Duty Cards
Initial Emergency Response Actions for All Incidents	Checklists
OSC Forms	SEMT Forms
OSC Worksheets	SEMT Worksheets
Checklists	ECR Equipment and Layout
Landing of Careflight Helicopter in The Field	ECR Status Boards

SEMT and OSC Toolkit (AUS-IGMS-SAF-GDL- CDN 6893451)

9.7 Bushfire Management

The following link can provide technical advice in developing Bushfire Management processes as it provides access to Prevention and Response resources such as:

- IG Bushfire Standard
- Bushfire Preparedness Tool
- Generic Bushfire Asset Protection Zone (APZ) Guide
- Beetaloo Bushfire Management Plan
- https://www.pfes.nt.gov.au/incidentmap

Bushfire Management Source Bushfire Page Link

9.8 Flood Management

In the preparation and response to a flood event, the following resources have been developed to help the site prepare for and manage a flood response

- Camp Isolation Readiness Check sheet (Appendix H).
- Flood Mapping via OLIMAPS (where available)

Betaloo Assets teams can use the above tools to develop site Specific Flood Plans. The plan should take into consideration:

- Sources of flooding i.e. rivers, dam over flows etc.
- Fixed and temporary assets affected by flooding
- Access roads that are cut off and at what levels.
- Seasonal Preparedness – Activities at a minimum to prepare site for a flood
- Flood Warning or Watch
- Need to isolate equipment affected by flooding
- Flood Recovery requirements

9.9 Security Toolkits

In addition to the Emergency Response Flip Charts (QLD-1000-SAF-PRO- CDN 6893451) the following documentation supports response to different security scenarios:

- IG Security Management Plan CDN 8278592
- Wellsite Safety and Security Level Classification Procedure
- Regional Protest Plan CDN 7654911
- Beetaloo Security Plan xxxx

Security Toolkits Source Security Page

9.10 Aviation Resources

Specific aviation resources can be sourced for use during an emergency. The IG Aviation Management Plan INT-1000-SAF-PLN-00007 can help to develop site specific aviation appropriate emergency response actions for the business unit's area.

Additionally, the Beetaloo Aviation Management plan provides further guidance for specific aviation practices within the Asset.

Further tools can be found at the IG Transport and Aviation Source Page

The plan identifies

- Aviation Tasking Process
- Aviation Bookings (fixed and rotary winged aircraft)
- Landing Site Management including approved Airfields and Helicopter landing site requirements

.

Aviation Management Plan
Integrated Gas Aviation Management Plan

In addition to the aviation management plan the below link provides details on the following:

- Helicopter Landing Sites technical inspection report form

- Helicopter Landing site design plate
- Helicopter Landing Site Officers
- Approved Helicopter Landing Site Register and requirements
- Aerial Firefighting
- Helicopter Landing Site Officer operators manual

Aviation Resources
http://source.originenergy.com.au/Business/Gas/hse/risk/Pages/Transport.aspx

9.10.1 Helicopter Landing Site Officer (HLSO)

If a helicopter is required for an emergency situation a designated / trained Helicopter Landing Site Officer (HLSO) should be sourced (where available) to support ground activities. It is the responsibility of the HLSO to ensure that they are familiar with the landing locations and the requirements associated with the Helicopter Landing Site Officer Operations Procedure – Integrated Gas (CDN/ID 7983075) .

Landing Site Coordinates should be identified in either the Emergency Response Notification (ERN) document that is prefilled by the rig when moving to a new well location or if conducting a Campaign then nominated in the campaign specific bridging document.

9.11 Emergency Control Room

The Emergency Control Room (ECR), manned by the Growth Assets SEMT, is the coordination centre and "communication hub" for Beetaloo Asset based emergency incidents. The ECR must be activated to help assist the affected site oversee the operational emergency response and well-being of personnel involved in, or affected by, the emergency. The Beetaloo Asset ECR is located in 180 Ann Street in room 29:12 and contains appropriate tools, documents and stationery to support a response.

Emergency Control Room ECR Tools

9.12 Emergency Equipment

A detailed list of Beetaloo major ER equipment is located in Appendix XX.

10. Stakeholder Management

An emergency will be coordinated and supported by the SEMT at the ECR and SEMT at site. The bridging document or the ERN will contain site specific contacts that can be contacted in an emergency.

10.1 Group Emergency Management Team (GEMT)

The GEMT provides support to an emergency situation and manages the higher level requirements to assist the SEMT whilst dealing with regulators, media, legal and industry partners. For every activation of the SEMT, the SEMT-L must contact the on call GEMT-L and advise of the situation. The GEMT-L will determine whether the GEMT will be activated. The SEMTL and GEMTL must be familiar with the levels of incident management categories located within the Emergency response Assessment and Escalation procedure (CDN 8629094)

When an incident has escalated to include the GEMT, the SEMT-L, having consulted with the OSC, will communicate regularly with the GEMT Operations Lead to provide updates and make requests for support.

Group Emergency Management Plan (INT-IGMS-SAF-PLN CDN 6522903)

10.2 Emergency Services

First Responders must notify the OSC and in turn the SEMT-L if they call Emergency Services. Once notified, the OSC is responsible for all communications back to the SEMT.

Upon arrival, Emergency Services may take control of the emergency or leave the control to Origin to manage, depending on the type of emergency and the assistance that is required. In most circumstances Emergency Services will require assistance from Origin for local and technical knowledge and for additional resources to manage the incident.

Where Emergency Services take control of the incident it must be remembered that they are not able to command Origin personnel or resources, this command must still be managed by an Origin representative such as the OSC. This same control over the Emergency Services personnel and resources must be managed by the Emergency Services representative, such as the Incident Controller or senior officer.

10.2.1 Emergency Manifest

A hard copy Emergency Manifest, identifying notifiable quantities of hazardous substances, should be located on arrival at permanent field locations in an easily accessible and identifiable place An Emergency Service Manifest template found in Open Text X Templates (and CDN 5362370) can be used to develop the Emergency Manifest.

10.3 Next of Kin

In the event of a death, serious injury or other emergency, involving Origin personnel, advice to relatives about the condition of a person or about the incident will be coordinated by People and Culture (P&C) through the GEMT.

During or after an emergency, the SEMT-L will refer any queries or concerns from relatives to People and Culture. P&C may also activate Employee Assistance Program (EAP) providers to support site personnel or relatives affected by an incident.

Principal Contractors and Contractor companies are responsible for management of next of kin communication in consultation with Police services, and EAP management in accordance with their emergency response plans and relevant State obligations. Where Contractors do not maintain their own EAP provider, P&C may extend EAP services as determined by the GEMT-L and P&C GEMT representative.

10.4 Landowners / Pastoralists

Contact with local landowners can be initiated by the SEMT-L in extreme circumstances; however Land Relations Advisors are to be used in the first instance. When activated, stakeholder communications will be handled by the GEMT and are addressed in the Group Emergency Management Plan (INT-IGMS-SAF-PLN-00004). Refer to Appendix A for contact details.

10.5 Regulatory Notification

A regulatory notifiable incident is an incident or non-compliance with an External Mandatory Obligation or External Voluntary Obligation that requires notification or reporting to a Regulator as prescribed by applicable Laws and Regulations. HSE regulatory notifiable incidents required to be reported to a regulator are listed in Appendix A.1.

Any regulatory incident notification to joint venture parties must follow the contractual arrangements specified in the joint venture agreement.

The Origin Energy joint venture representative must be consulted to determine Origin Energy's contractual obligations for incident notification and reporting.

Any correspondence between Origin Energy and joint venture partners must be conducted through the joint venture representative unless other arrangements have been agreed.

Verbal Notification	Written Notification
Risk Assurance Compliance and Process Safety Team On-call number 0475 813 986	IntegratedGasCompliance@upstream.originenergy.com.au

Integrated Gas management of Regulatory Notifiable Incidents (INT-IGMS-BUS-PRO-00001 CDN/ID 5814101)

10.6 Dealing with Media Enquires

During an emergency event, media attention may occur at the affected site. All communications with the media must be in accordance with the Origin Media Policy (ORG-CGOV-POL-005). If personnel receive an enquiry from a journalist or reporter, whether in person or by phone and are asked about Origin, they should say:

"I am not in a position to comment but if you give me your name and telephone number I will organise for the most appropriate person to call you."

Always ask for:

- the journalist / reporter's name;
- publication / media outlet;
- contact phone number and / or email, and
- publication deadline.

The SEMT-L will advise the GEMT-L on call and External Affairs managers at the earliest opportunity of any media contact or enquiry. Refer to Appendix A – Table 3 for External Affairs contact details.

It is important to remember that there is no such thing as "off the record". Even if you are speaking informally, you could be quoted at any time.

11. Review and update

The ERP will be reviewed and updated as necessary in response to one or more of the following:

- annually
- when major changes have occurred which may affect the Emergency Response coordination or capabilities
- following routine testing of the plan
- after an actual emergency or
- before installing and commissioning new plant and equipment equipment.

During the review, the following aspects are also to be considered:

- lessons learned from an emergency
- changes in legal requirements
- improvements to effectiveness in terms of response strategy, management and communication
- developments in the latest techniques and technology in handling an emergency
- changes to, or movement of people within our organisation
- changes to contact numbers of internal and external organisations

revisions to existing, or availability of, emergency management tools and equipment and resource suppliers and contractors.

12. Associated Documents

Document	Document Reference
Incident Response Procedures	QLD-1000-SAF-PRO-00041
Chemical Response Procedures	QLD-1000-SAF-PRO-00095
SEMT Toolkit	AUS-IGMS-SAF-GDL-00002
Emergency Response Exercise Planning Form	AUS-1000-SAF-FRM-00012
IG Group Emergency Management Plan (GEMP)	INT-IGMS-SAF-PLN-00004
Crisis Management Plan	ORG-RMS-PLA-001
Emergency Response Exercise Planning and Reporting Procedure	AUS-1000-SAF-PRO-00010
Risk Management Policy	ORG-RISK-POL-001
Origin Risk Toolkit	ORG-RSK-TOOL-001

13. Document information and history

DOCUMENT CUSTODIAN GROUP

Title	Name/s
General Manager – Beetaloo & Growth Assets	Tracey Boyes

DOCUMENT AUTHOR

Position	Name
HSE Lead – Growth Assets	Lucas Fulford

STAKEHOLDERS AND OTHER CONTRIBUTORS

Position	Name
Emergency Response and Security SME – HSE, Risk and Compliance (RAC)	Bruce Baldwin
Operations & Projects Manager – Growth Assets	Matthew Hanson
D&C Project Manager – Growth Assets	Ed Wong
Field Manager – Asset Services (Beetaloo)	Troy Beetson
Logistics Manager – Asset Services	Peter Runge
Environmental Specialist – Growth Assets	Matt Kernke

DOCUMENT HISTORY

Rev	Date	Changes made in document	Reviewer/s	Consolidator	Approver
A	25/03/2019	Consolidation of previous Beetaloo campaign ER plans, unmanned ERP to align with Integrated Gas ERP requirements to form Asset ERP.	B Baldwin	L Fulford	
0	29/04/2019	Issued for Use	B Baldwin M Hanson Ed Wong	L Fulford	T Boyes
1	21/06/2019	- Update references around regulatory reporting requirements based on NT regulator DNER feedback. - Update from NT police comments. - Combined wells and lease pad locations into one location in Appendix C for ease of reference.	M Kernke	L Fulford	T Boyes
2	03/12/2019	Update to Police details in Appendix A1	M Kernke	L Fulford	L Fulford

Appendix A Contact lists

External Agencies		
Role	**Name**	**Primary**
Local Emergency Services	Police, Fire, Ambulance	000 (or 112 from mobile)
Hospital	Katherine Hospital	(08) 8973 9211 Kintore Clinic Katherine (08) 8972 1677
Field response contractor / intial inspections	PPP	Gordon Jackson 0456 618 367 Susey Jackson 0487 120 819 Sat Phone 0147157201 Email: triplepcontracting@outlook.com
Remote Well Monitoring Assistance	Cory Giefer Operations Support Manager MPC Kinetic	+61 418 409 354
Bushfires NT	Fire control officer	Katherine (08) 8973 8871
Volunteer Bushfire brigade		(08) 8975 9936
Regional Shire Council	Roper Gulf Shire	08 8972 9000 or 1300 366 208
Regional Shire Council	Barkley Shire	
Police (non-emergency)	Police Link	131 444 Elliott - (08) 8969 2010 Katherine – (08) 8973 8000
Poisons Information Centre	n/a	13 11 26
Bureau of Meteorology	Cyclone Warnings Forecasts & Warnings	1300 659 211 08 8920 3826
NT DPIR's Petroleum Operations Team	after-hours	+61 1300 935 250
NT DNER		08 8973 8871 or 08 8973 8872 or 08 8973 8870 **DENR** Note, also required to notify landholder
NT EPA Pollution Hotline	n/a	1800 064 567
NT WorkSafe	n/a	1800 019 115 ntworksafe@nt.gov.au
Department of Main roads	n/a	1300 654 628
NT power and water	n/a	1800 245 090
Well Control supplier (for lev3)	Boots & Coots Services Well Control and Prevention	24 hr. hotline 1 800 BLOWOUT or + 1 281 931 8884

Origin Beetaloo contacts		
Role	**Name**	**Primary**
Group Emergency Management Team (GEMT) Leader On-Call	[redacted]	[redacted]
Origin IG Compliance	[redacted]	[redacted] @origin.com.au
General Manager – Beetaloo & Growth Assets	Tracey Boyes	[redacted] origin.com.au
Construction Supervisor – Beetaloo & Growth Assets [Weeds officer]	Robert Wear	[redacted] rigin.com.au
Operations & Projects Manager – Beetaloo & Growth Assets	Matthew Hanson	[redacted] origin.com.au
Ed Wong – D&C Project Manager – Beetaloo & Growth Assets	Ed Wong	[redacted] origin.com.au
HSE Lead – Beetaloo & Growth Assets	Lucas Fulford	[redacted] rigin.com.au
Environmental Specialist – Beetaloo & Growth Assets	Matt Kernke	[redacted] origin.com.au
Corporate Affairs - Beetaloo & Growth Assets	Stephanie Stonier	[redacted] origin.com.au
Senior Petroleum Engineer – Beetaloo & Growth Assets	Alex Cote	[redacted] origin.com.au
Senior Project Engineer - Beetaloo & Growth Assets	Mitch Roll	[redacted] origin.com.au
Rig Superintendent – Asset Services	James Boorman	[redacted] origin.com.au
Field Manager – Asset Services (Beetaloo Stage 2 campaign)	Troy Beetson / Josh Fisher	[redacted]
Field HSE Advisor – Asset Services (Beetaloo Stage 2 campaign)	Zeak Cheney / Shaun McGrath	[redacted]
External Affairs Manager - IG → direct media enquires	Chris Zipf Or Tony Hancox	[redacted]
Process Safety SME – HSE RAC - Origin	Liana Bonnette	[redacted] .com.au
Emergency Response and Security Specialist – HSE RAC - Origin	Bruce Baldwin	[redacted] .com.au

For contacting neighbouring properties/pastoralists, all escalation is to be undertaken by the Beetaloo & Growth Assets Project and Operations Manager – Matthew Hanson (or delegate).

Neighbouring Properties			
Property Name	**Contact Name**	**Phone**	**Direct Neighbouring Properties**
Amungee Mungee	Adrian Brown (owner)	(08) 89 711293 Katherine office [redacted] [redacted] [redacted]	Nutwood Downs –North Tanunbirini – East Hayfield – West Beetaloo – South
Beetaloo	Scotty & Jane Armstrong (son-in-law/ manager)	[redacted] [redacted] [redacted]	Amungee Mungee – North Hayfield/Shenandoah – N/W NCW – West NCW – South (Tandi/Uchar)
Sturt Plains Hayfield/Shenandoah	Brad & Lisa Dyer Justin & Sally Dyer (son/policy)	[redacted] [redacted] [redacted]	Buchannan – West Kalala – North Amungee Mungee – East Beetaloo – East NCW – South
Hidden Valley	David & Jenny James	[redacted]	Sunday Creek – North Kalala – East Buchannan – South
Kalala	Ray & Pam Murphy Tosser Murphy (son)	[redacted] [redacted]	Sunday Creek – West Maryfield – North Nutwood Downs – East Hayfield/Shenan – South Hidden Valley - West
Newcastle Waters	Jak Andrews	[redacted]	Hayfield – North Beetaloo – North
Nutwood Downs	Rod & Rayna Dunbar	[redacted]	Kalala – West Amungee Mungee – South
Tanunbirini	Mick Tasker (Manager)	[redacted]	Amungee Mungee - West

A.1. Incident Notification Matrix – Northern Territory

As detailed in the IG Management of HSE Regulatory Notifiable Incidents procedure, incidents that may potentially be notifiable will be escalated via the various field team, through their functional lead (Field Manager / Operations and Projects Manager) and through to the IG RAC & Process Safety team who will provide guidance in interpreting notification requirements and guiding the external authority notification.

Integrated Gas Regulatory Incident Notification Guideline (NT regulatory notification matrix)				
Legislation	**Incident**	**Way report must be given**	**When report must be given**	**Contact Details**
Work Health and Safety (National Uniform Legislation) Act 2011 ***Sections 35 - 39***	A PCBU must notify the regulator as soon as they become aware of a death, serious injury or illness or dangerous incident that arises out of the conduct of the business or undertaking. A *dangerous incident* includes: • Uncontrolled escape, spillage or leakage of a substance, gas or pressurised substance • Uncontrolled implosion, explosion or fire • Electric shock • Fall or release from height of plant, substance or thing • Collapse, overturning, failure or malfunction of, or damage to, any plant/equipment/structure/excavation • In-rush of water, mud or gas in an underground excavation tunnel or interruption of ventilation in said tunnel A serious injury or illness means that results in: • work related injury • immediate hospital treatment as an in-patient • immediate treatment for serious injuries (for example amputation, scalping, a spinal injury, loss of a bodily function or a serious laceration, burn, head injury or eye injury), or • medical treatment within 48 hours of exposure to a substance.	By telephone	Immediately after becoming aware	1800 019 115 Worksafe ntworksafe@nt.gov.au
Schedule of Onshore Petroleum Exploration and Production Requirements 2019	An incident involving death or serious injury (reports shall be in addition to, and not take precedence over reports required by NT WorkSafe) A serious injury is one which requires immediate attention by a medical practitioner	by telephone AND in writing	immediately As soon as practicable	1300 935 250 DPIR Petroleum.Operations@nt.gov.au
	An incident involving serious damage (other than Environmental Harm) including loss, destruction or damage to property exceeding $50k or when any person dies or suffers serious injury	by telephone AND in writing	immediately As soon as practicable	1300 935 250 DPIR Petroleum.Operations@nt.gov.au
	An incident involving or could potentially involve the injury to a person or serious damage to property that is professionally considered to have been caused by an event that is not in the normal or ordinary course of an operation (Potentially Hazardous event)	by telephone AND in writing	immediately As soon as practicable	1300 935 250 DPIR Petroleum.Operations@nt.gov.au
	An incident where damage to property occurs (<$50k) that is not serious damage to property, but which results in a significant loss of structural integrity or load bearing capacity in the property damaged or results in some other significant unsafe condition	by telephone AND in writing	immediately As soon as practicable	1300 935 250 DPIR Petroleum.Operations@nt.gov.au
	An incident that is considered to be an emergency	by telephone	Immediately (after 000)	1300 935 250 DPIR Petroleum.Operations@nt.gov.au

Integrated Gas Regulatory Incident Notification Guideline (NT regulatory notification matrix)				
Legislation	**Incident**	**Way report must be given**	**When report must be given**	**Contact Details**
Petroleum Act 1984 and associated Regulations	**Reportable Incident:** An incident, arising from a regulated activity, that has caused or has the potential to cause material environmental harm or serious environmental harm. *Material environmental harm* means harm that: (a) Is not trivial or negligible in nature; (b) Consists of an environmental nuisance of a high impact or on a wide scale; (c) Results, or is likely to result, in not more than $50k or the prescribed amount (whichever is greater) being spent in taking appropriate action to prevent or minimise the environmental harm or rehabilitate the environment; or (d) Results in actual or potential loss or damage to the value of not more than $50k or the prescribed amount (whichever is greater). *Serious environmental harm* means environmental harm that is more serious than material environmental harm and includes environmental harm that: (a) Is irreversible or otherwise of a high impact or on a wide scale; (b) Damages an aspect of the environment that is of a high conservation value, high cultural value or high community value or is of special significance; (c) Results or is likely to result in more than $50k or the prescribed amount (whichever is greater) being spent in taking appropriate action to prevent or minimise the environmental harm or rehabilitate the environment; or (d) Results in actual or potential loss or damage to the value of more than $50k or the prescribed amount (whichever is greater). **[Note: Applicable for on tenure Spills]**	by telephone OR in writing AND in writing	As soon as practicable (not later than 2 hours after the incident) <24 hours after oral notice (written notification) 3 days after the incident (initial report) 90 days intervals from the date of the initial report (interim reports) 30 days after clean up or rehabilitation (final)	1300 935 250 DPIR Petroleum.Operations@nt.gov.au
	Recordable Incident: An incident that has resulted in an environmental impact or environmental risk not specified in the current plant for the activity; or has resulted in the contravention of an environmental performance standard specified in the current plan for the activity; or is inconsistent with an environmental outcome specified in the current plan for the activity; and is not a reportable incident.	In writing	15 days after each 90 day period after then day on which the environmental management plan is approved.	1300 935 250 DPIR Petroleum.Operations@nt.gov.au
Environmental Protection Biodiversity Conservation Act 1999	Incidents considered to have an impact to Matters of National Environmental Significance	in writing	within 5 business days of becoming aware	Compliance@environment.gov.au
Energy Pipelines Act 1981 and associated Regulations	A reportable incident that involves: • Death or serious injury (or the potential to cause) • Significant damage to a pipeline (or potential to cause) • Immediate investigation	By telephone AND In writing	As soon as practicable As soon as practicable	1300 935 250 DPIR Petroleum.Operations@nt.gov.au
	A significant pipeline accident event that: • Is connected with work carried out on or in relation to a pipeline • Causes, or has the potential to cause human death	By telephone AND in writing	As soon as practicable As soon as practicable	1300 935 250 DPIR Petroleum.Operations@nt.gov.au
Environmental Assessment Act 1982 and associated Regulations	Alteration of action in such a manner that the environmental significance of the proposed action may be changed	in writing	As soon as practicable after the alteration	08 8924 4218 **NT EPA** ntepa@nt.gov.au
Bushfires Management Act 2016 and associated Regulations	Unable to control a fire on the land	All reasonable steps	Following the fact	08 8973 8871 or 08 8973 8872 or 08 8973 8870 **DENR** Note, also required to notify landholder

Integrated Gas Regulatory Incident Notification Guideline (NT regulatory notification matrix)				
Legislation	**Incident**	**Way report must be given**	**When report must be given**	**Contact Details**
Waste Management and Pollution Control Act 1998 and associated Regulations	An incident that causes, or is threatening or may threaten to cause, pollution resulting in material environmental harm or serious environmental harm. Refer to the definition of *material* and *serious environmental harm* provided in *Petroleum Act* section above. *Pollution* means: (a) A contaminant or waste that is emitted, discharged, deposited or disturbed or that escapes, or (b) A contaminant, effect or phenomenon, that is present in the environment as a consequence of an emission, discharge, deposition, escape or disturbance of a contaminant or waste. Note: does not apply to incidents confined within petroleum activities land (including air and water above or below) – see the EMP for the area of petroleum activities land **[Note: Applicable for off tenure Spills]**	by telephone	Within 24 hours of becoming aware	1800 064 567 **NT EPA** Pollution@nt.gov.au
Heritage Act 2011 and associated Regulations	Discovery of archaeological places and objects	In writing	As soon as practicable (within 7 days of discovery)	08 8999 5039 **DTC - Heritage Branch** heritage@nt.gov.au
Weeds Management Act 2001	First becoming aware of a declared weed that has not previously been, or known to have been, present on the land.	Not specified	14 days of becoming aware	08 8999 4567 **DENR** weedinfo@nt.gov.au
Dangerous Goods Act 1998 and associated Regulations	Becoming aware of theft, loss of, or unauthorised interference with explosives.	Not specified	Immediately after becoming aware	Police Assistance Line 131 444

Internal Contacts	
The on-call phone number is 0475 813 986 and is monitored 24/7 by the Integrated Gas Regulatory Compliance Team	*integratedgascompliance@upstream.originenergy.com.au*
a. *Work Health & Safety Incident Notification form*	*http://www.worksafe.nt.gov.au/LawsAndCompliance/Pages/incident-reporting.aspx*
b. *Pollution Report Form*	*https://ntepa.nt.gov.au/waste-pollution/hotline/pollution-report-form* *http://im.originenergy.com.au/otcs/cs.exe/properties/7486053*
c. *Aviation Accident or Incident Notification Form*	*https://www.atsb.gov.au/mandatory/asair-form.aspx?*

Appendix B Well Inspection and Monitoring Protocol

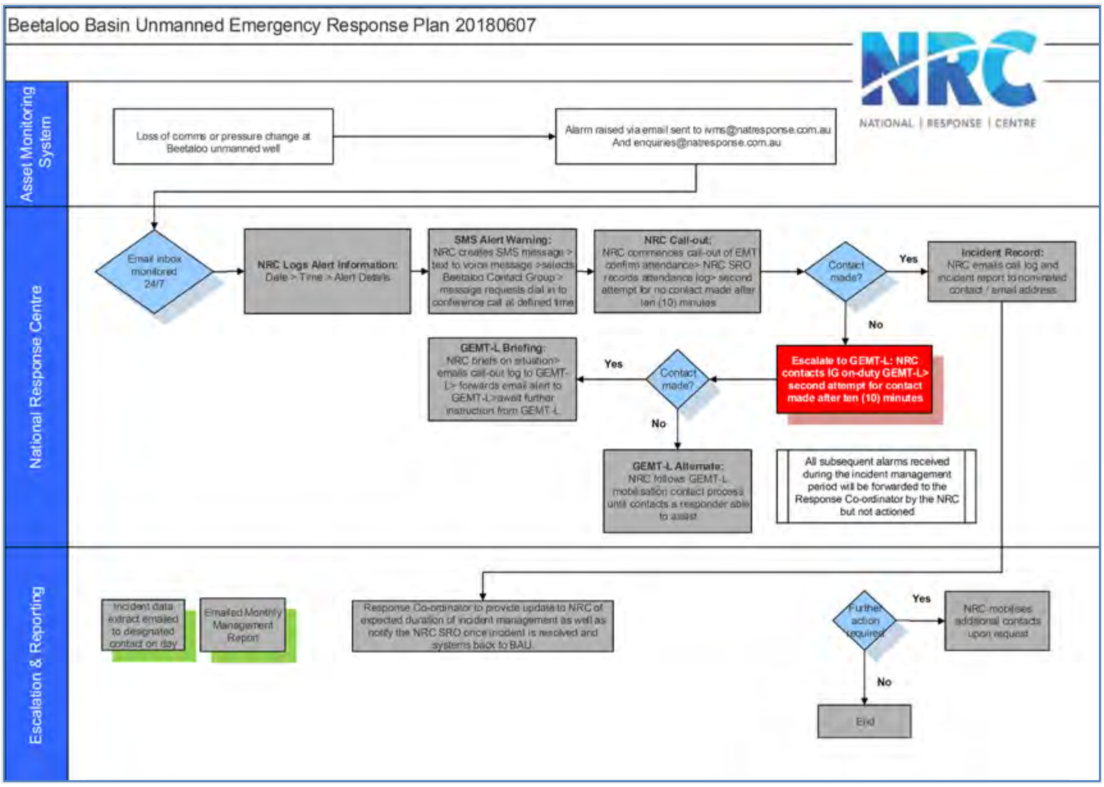
B.1. Well Pressure Remote Monitoring

The Amungee NW-1H well is suspended at surface for monitoring and recording of the reservoir pressure buildup. Real time pressure monitoring exists and a pressure anomaly or loss of communications to site will trigger an email alarm to a minimum of 7 people (listed below) and to a 24/7 monitored email at the Origin's National Response (NRC) centre. The NRC will send a further SMS and text to voice message to the notification list to alert the team of the alarm. The SMS will include time details to call into a conference call number at a set time (nominally 10 minutes time – but to be stated in the message). NRC will start the the conference call however if NRC was unable to contact any one on the list by phone before the call, and no one joins the conference call they escalate to GEMT.

The group on the conference call can then decide if the site requires inspection and agrees on the person (the nominated SERT-L) to deploy Triple P or other services to site. NRC will continue on the conference call maintaining notes of discussions. NRC will follow the below process flow when activated from an alarm.

Conference call number to be used.

1800 062 923
Host PIN 6700 4855 4873
Guest PIN 6700 4855 3024



Current list of people receiving notifications. All people on this list should have this list of people in their contacts to facilitate quick communications.

Role	Name	Primary
Construction Superintendent – Beetaloo & Growth Assets	Robert Wear	+61 467 679 003 sat phone 0147162733
Operations & Project Manager – Beetaloo & Growth Assets	Matthew Hanson	+61 477 748 843

General Manager – Beetaloo & Growth Assets	Tracey Boyes	+61 475 949 668
D&C Project Manager – Asset Services	Ed Wong	+61 475 836 554
Senior Petroleum Engineer – Beetaloo & Growth Assets	Alex Cote	+61 408 612 889
Senior Project Engineer - Beetaloo & Growth Assets	Mitch Roll	+61 423 929 661
HSE Lead – Beetaloo & Growth Assets	Lucas Fulford	+61 477 749 524

If it is determined there is an unexplained pressure change in the well or unrecoverable communications issue then Triple P is deployed to site to assess the situation. The site person shall only deploy to site if it is possible to do so and travel in daylight hours. The requirement is to be at site within 6 hours. This in practice means that they should only be deployed to site if the event occurs before noon. If the event occurs after noon they should notified so as to be on site as early as possible the next morning. Triple P will follow the procedure detailed in the "Well Control" Section B3.

Once on site Triple P will use the satellite phone to call back the person that deployed them to report the situation on site and received further instructions. If the information received from Triple P is that the situation on site is not normal then this triggers an emergency event and Triple P becomes the On Scene Command (OSC) and the Beetaloo & Growth Assets Operations and Project Manager (or the senior person in the group which has responded to the alarm) will be the SERT-L and notifies the General Manager Growth Assets (Tracey Boyes 0475949668).

Other key stakeholders, specifically Stephanie Stonier (0475940931) and any of the alarm monitoring team not already invovled, should then be notified as soon as possilble.

- Triple P
  - Gordon Jackson 0456 618 367
  - Susey Jackson 0487 120 819
  - Sat Phone 0147157201
  - Email triplepcontracting@outlook.com

Well control incidents may require the mobilisation of specialised response contractors.

B.2. Well Control (unmanned)

A specific standard operating procedure has been undertaken for well inspection monitoring where detailed instructions are provided to the worker undertaken the well inspection.

In the event of an uncontrolled release from a wellhead (being observed in the field):

- Move out of harm's way. Find safe upwind location (at least 50 metres away).

  Considerations:
  - Determine wind direction.
  - Always pay attention to Fire, fumes, electrical, ignition and Health Risks.
  - What is the type of Leak and source?
  - Monitor situation visually from distance.
  - Secure site and keep all non-essential personnel and ignition sources away from the hazardous area. (secure location)
- Alert others near-by

- Assess the situation – determine the level of the immediate threat.

If a report is received from any source (for instance tourists travelling along highway see the well on fire) that an incident has occurred then the response for a pressure change in the well, exaclation is to be immediately initiated.

If the responding group are reasonably certain that loss of containment has occurred then Triple P should be sent to site to secure access from the highway and confirm the situation on site and escalation through General Manager – Beetaloo & Growth Assets to GEMT should occur with the recommendation to notify Asset Services to arrange third party Well Control Services to prepare to deploy, or deploy if the report is very credible.

If there is a high level of doubt about the information, Triple P contracting should be deployed to obtained reliable information from site (keeping a safe distance away with any potential ignition source).

Note: After consultation with the Project Manager and/or Well Integrity team representative - and you if are competent, confident – and i**f it is safe** to do so; **contain the incident** by shutting in the well – if flow is through wellbore; then activation of the self actuation UMV may be appropriate; of if escape is evident to be from an annular space, it may be possible to isolate via a manually operated valve.

Well control incidents may require the mobilisaiton of specialised response contractors.

Please refer to Appendix B for Well Inspection and alarm flow chart or NT-2050-35-MN-0001 Amungee NW-1H Remote Pressure Monitoring trouble shooting manual for well integrity monitoring and data transmission details.

B.3. Well Control Incident Classification

In the event that a Well Control Incident exceeds level 1 and 2, the Person in Charge (Wellsite Representative) will activate the SEMT who in turns, notifies the GEMT-L and the involvement of a contracted third party specialist to handle the well control integrity event.

The Well Control specific incident response plan is detailed the Origin Well Control Standard – INT-1000-35-TS-001 and the Asset Services Emergency Response Plan – QLD 1000 SAF PLN CDN/ID 19601361; for well control events these documents are to be followed. The following information is guidance on different levels of well control. Additionally, Appendix G4 gives an basic overview on how Well Control events are managed.

Level 1 **(an uncomplicated kick or a low risk production / well integrity event)**	**Level 2** **(a kick with some complications or a low - moderate risk well integrity event)**	**Level 3** **(complete loss of well control or a moderate - high risk well integrity event)**
Generally, these are events that commonly occur during drilling and workover operations. Additionally covers low risk well integrity events during the production phase. Emergency interfacing is limited due to pressure and flow containment. Personnel and equipment are not threatened, and there are no injuries or fire involved. Thus, the situation can be handled using resources and procedures available on-site (or readily mobilisable in the case of a well integrity event). The situation is managed immediately by the Driller who will keep the rig manager informed of the situation.	A Level 2 event can be defined as an abnormal well control event during drilling and workover operations involving some sort of complication in which: • Well control has NOT been lost at the surface • Resources beyond the normal capabilities of the rig crew or production operations staff may be required • Outside well control consultation, materials, equipment or personnel may be required Includes low - moderate risk production events (e.g. noticeable leak or significant annular pressure). There are no injuries or fires associated with this incident level	A Level 3 emergency denotes a complete loss of well control at surface during drilling and workover operations with no opportunity to restore it using all the resources available on-site. Includes moderate – high risk well integrity events during the production phase. Level 3 Incidents require the SEMT to activate including notification to the GEMT to effectively deal with the situation. External Well Control support (i.e. Boots & Coots, Wild Well Control, Cudd, etc.) must be activated upon confirming that the well is out of control at surface and measures must be immediately taken to protect people, the environment and material assets. These emergencies, although serious at the outset, have the

Caution: Level 1 incidents can escalate quickly to a more serious and threatening level if not handled properly.	since control has not been totally lost. The situation is typically managed by the Rig with the OSC liaising. The SEMT is on Standby but not activated. The incident is generally not sufficiently threatening to activate the GEMT to deal with the situation.	potential to escalate further during control attempts. Such escalation may cause serious structural damage or total loss of the facility, rig, BOP stack and wellhead due to explosion, fire, loss of buoyancy or location subsidence and could affect nearby wells & infrastructure.

Appendix C Site Specific Lease Pads with associated wells

C.1. Location data – Existing Exploration Wells / Lease pads

Permit Area(s)	EP98
Exploration Well name	Kalala South – 1 (Drilled & Suspended Well)
Associated Water Bores	N/A
Well/Lease location (Lat/Long)	16° 17' 37.7" S / 133° 36' 44.3" E
Nearest Town	Daly Waters
Nearest Major Road	Carpentaria Highway
Nearest Airports	Daly Waters: 25 min/25km Elliot: 2hrs / 165 km
Nearest Hospital	Katherine Hospital 3hrs drive
Permit Area(s)	EP117
Exploration Well name	Beetaloo West-1 (Drilled & Suspended Well) (Kyalla 117 W1)
Associated Wells on location	N/A
Well/Lease location (Lat/Long)	17° 7'13.82"S / 133°45'43.63"E
Nearest Town	Elliot
Nearest Major Road	Stuart Highway
Nearest Airport	Daly Waters: 1.5hrs/100km Elliot: 1.75hrs,110km
Nearest Hospital	Katherine Hospital: 4hrs drive
Permit Area(s)	EP98
Exploration Well name	Amungee North West-1H (Velkerri 98 N1) (Drilled & Suspended Well)
Associated wells	VEL 98 N1 – CMB-G (RN40894)
Well/Lease location (Lat/Long)	16°20'51.034"S / 133°53'4.403"E
Nearest Town	Daly Waters
Nearest Major Road	Carptentaria Highway
Nearest Airport	Daly Waters: 1hr /61km Elliot 2.5hrs /202km
Nearest Hospital	Katherine Hospital: 3.5hrs drive

C.2. Location data – Proposed Exploration Wells / Lease pads

Permit Area(s)	EP117
Exploration Well name	Kyalla 117 N2 (To be drilled 2019)
Associated Wells	KYA 117 N2 – CMB - (RN40895) KYA 117 N2 - CMB - AL (RN40896) KYA 117 N2 – CMB - G (RN41132) KYA 117 N2 – IMB - AL (RNxxxxx) - TBC KYA 117 N2 – IMB - G (RNxxxxx) - TBC
Well/Lease location (Lat/Long)	16°50' 29.01"S; 133°39' 0.16"E
Nearest Town	Daly Waters

Nearest Major Road	Stuart Highway
Nearest Airport	Daly Waters: 1hr /92 km Elliot: 1.5hrs /117 km
Nearest Hospital	Katherine Hospital: 4.5hrs drive
Permit Area(s)	EP76
Exploration Well name	Velkerri 76 S2 (To be Drilled 2019)
Associated Wells	VEL76 - S2 – CMB – AL (RN41133) VEL76 – S2 – CMB – G (RN41134) VEL76 - S2 – IMB – AL (RNxxxxx) - TBC VEL76 – S2 – IMB – G (RNxxxxx) - TBC
Well/Lease location (Lat/Long)	16°51' 20.13"S; 134°23' 39.85"E
Nearest Town	Daly Waters
Nearest Major Road	Stuart Highway
Nearest Airports	Daly Waters: 2.5 hr /190 km Elliot: 3.0 hrs /198 km
Nearest Hospital	Katherine Hospital: 5.5 hrs drive

C.3. Campaign specific information

Exploration campaigns have the following specific information, this information is approximate only and should be utilised to provide guidance on approximate personnel data per exploration campaign activity:

C.3.1 Civil activity

Civil	Various Civil contruction activities (Road/track upgrades, lease builds)
Average Personnel #	1-20
Fuel Capacity	Dual walled, self bunded diesel 26.4m3 tank

C.3.2 Drilling activity

Rig	Rig to be contracted for each campaign
Average Personnel #	8-14
Fuel Capacity	Dual walled, self bunded diesel 26.4m3 tank

C.3.3 Hydraulic Fracture Stimulation spread (Fracspread)

Rig name	Fracspread
Average Personnel #	40-60
Fuel Capacity	Dual walled, self bunded diesel 26.4m3 tank

C.3.4 Completion activity specific data

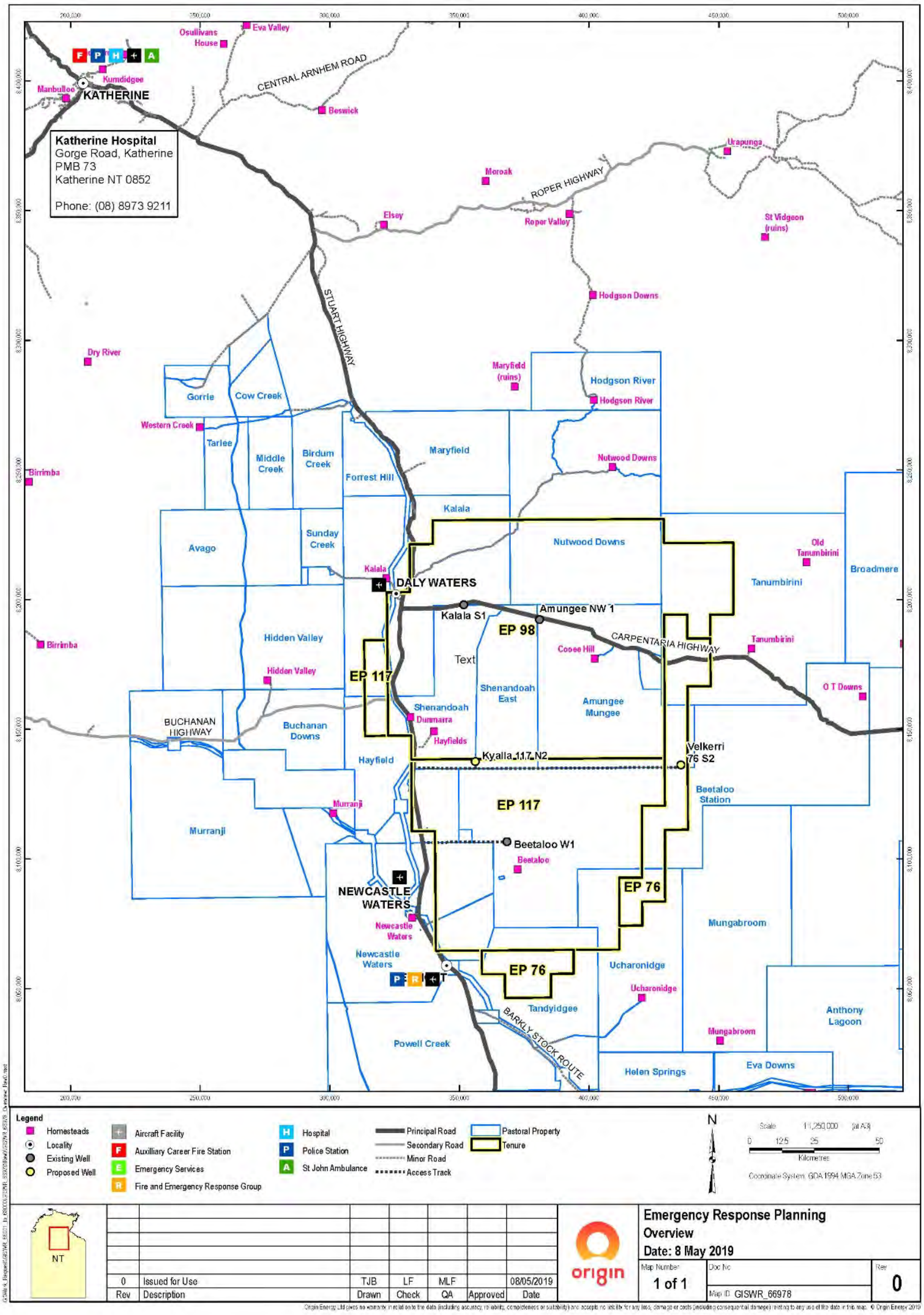
Rig name	Rig to be contracted for each campaign
Average Personnel #	8-12
Fuel Capacity	Dual walled, self bunded diesel 26.4m3 tank

C.3.5 Well Testing spread specific data

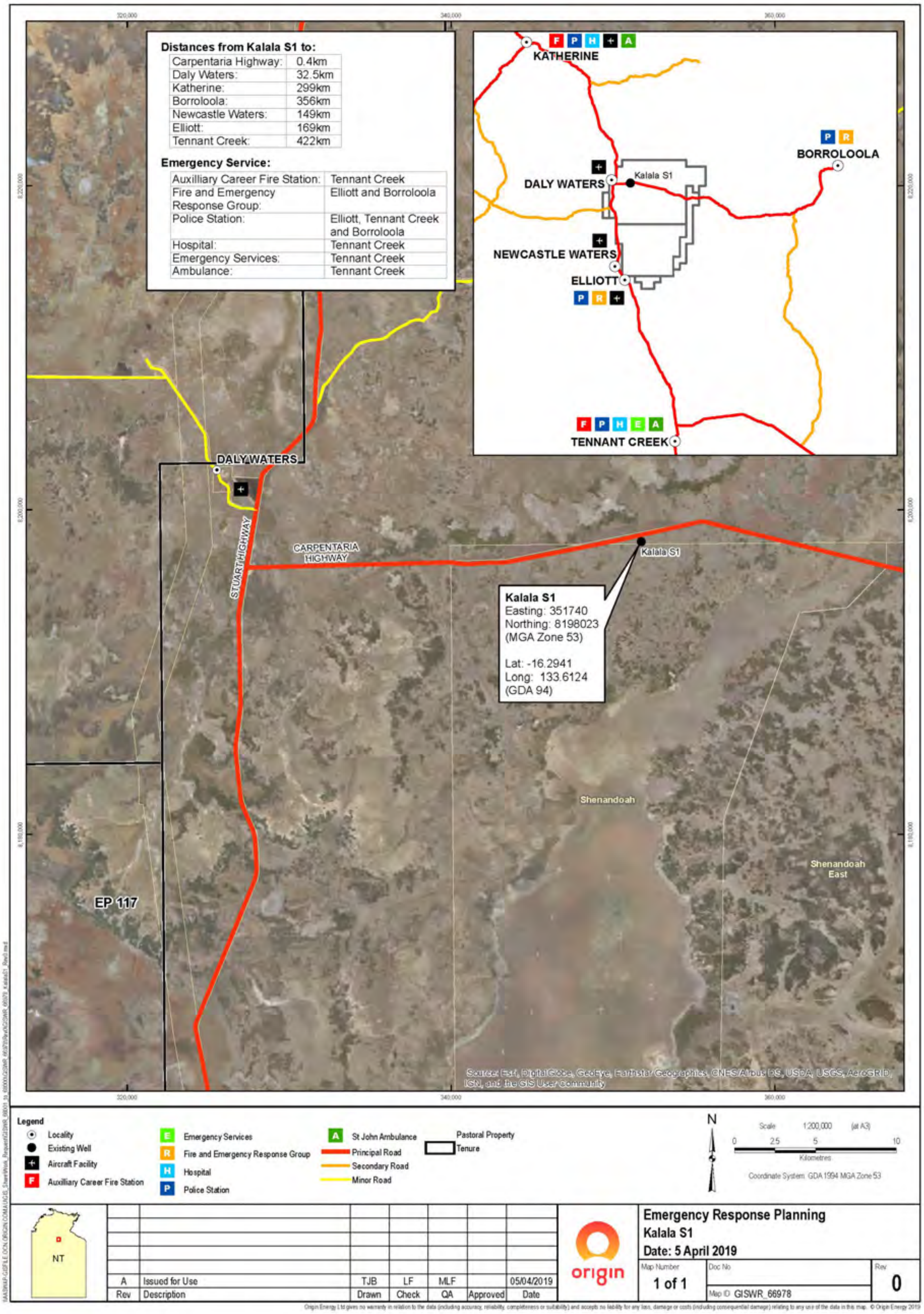
Rig name	Extended Production Test – EPT (Well Test)
Average Personnel #	2-6
Fuel Capacity	Dual walled, self bunded diesel 26.4m3 tank

C.4. Emergency Response Locality maps

Overview maps for all existing and proposed Petroleum Wells



C.4.1 Kalala S1



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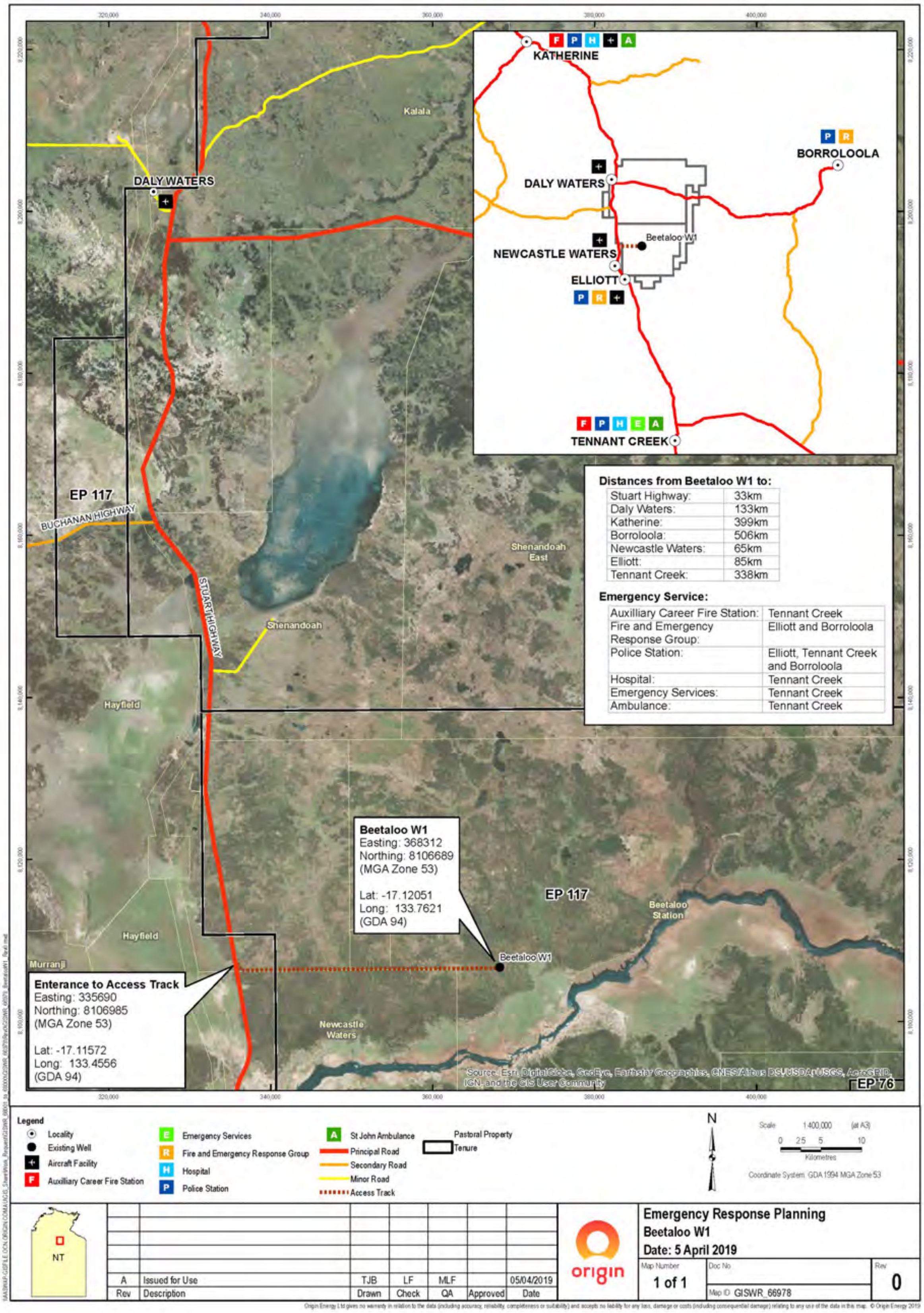
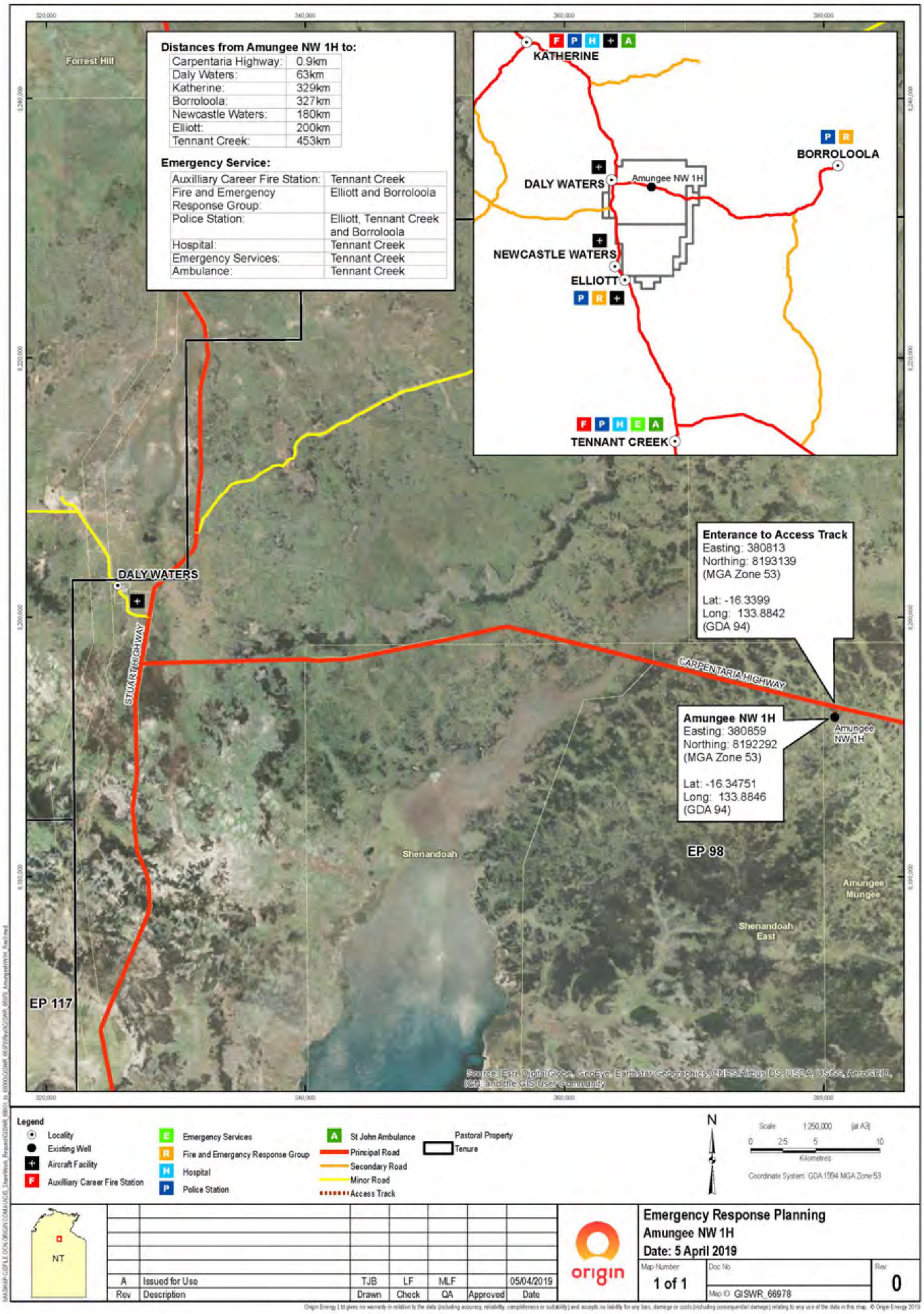
C.4.2 Beetaloo W1



C.4.3 Amungee NW 1H



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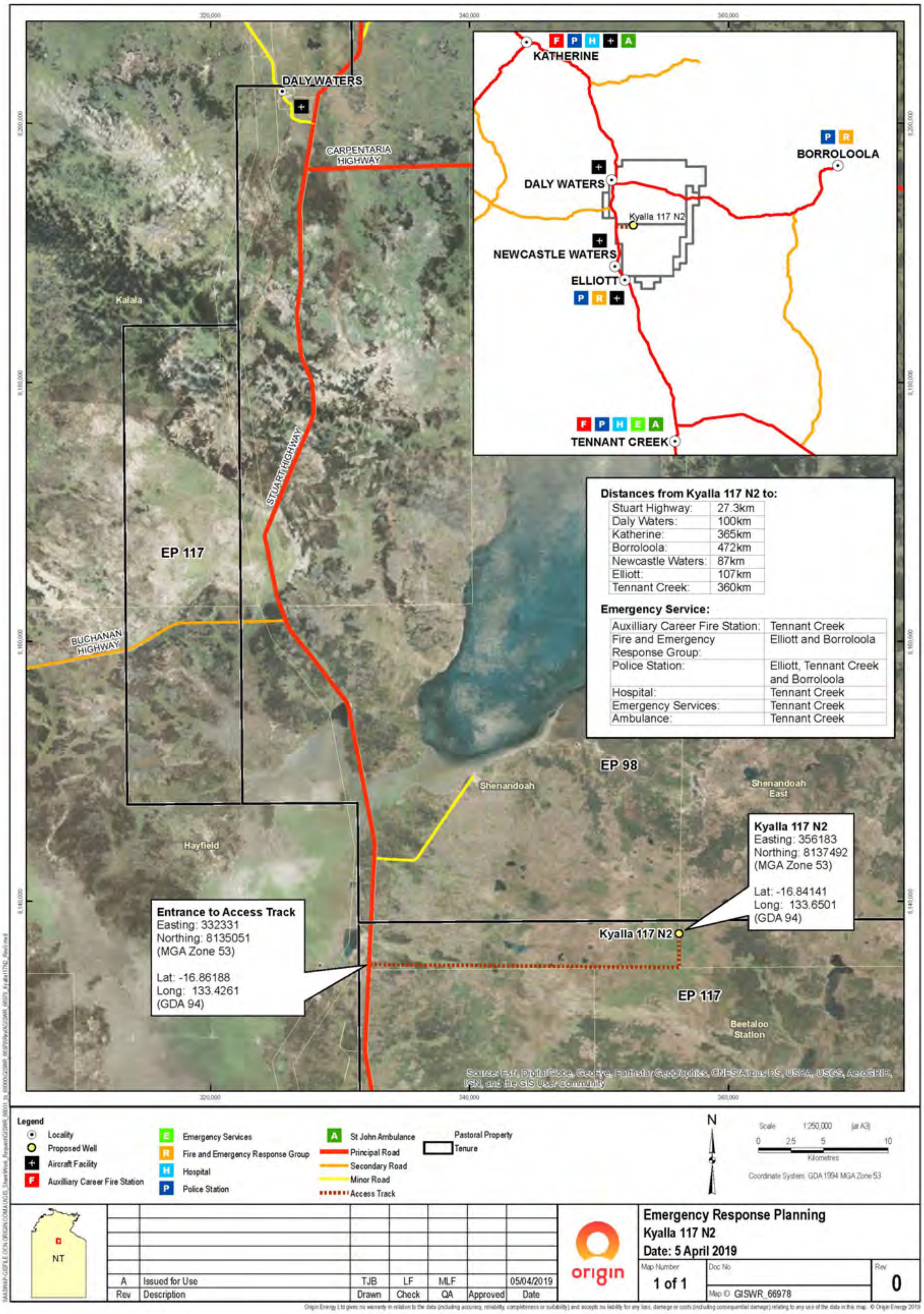
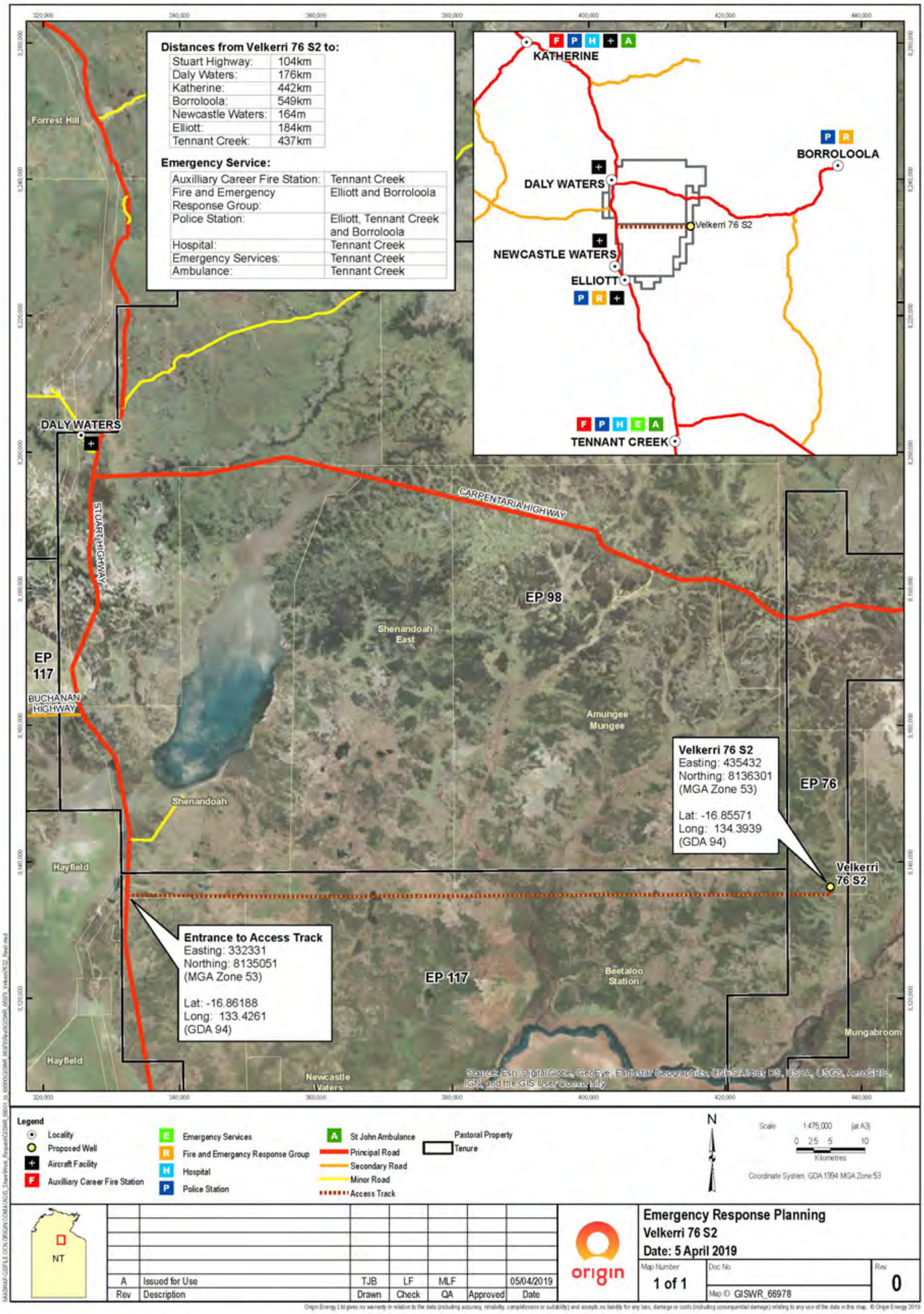
Document Custodian is: General Manager – Beetaloo & Growth Assets

C.4.4 Kyalla 117 N2



C.4.5 Velkerri 76 S2



Appendix D Definitions

Term	Definition
CMP / T	Crisis Management Plan / Team
DPIR	Department of Primary Industry and Resources
DENR	Department of Environment and Natural Resources
EPA	Environmental Protection Agency
SEMT	Site Emergency Management Team
ER/P/T	Emergency Response / Plan / Team
GEMP/T	Group Emergency Management Plan / Team
GEMT-L	Group Emergency Management Team Leader
SEMT-L	Site Emergency Management Team – Leader
OE BU	Origin Energy Business Unit
DA	Development Area
D&C	Drilling and Completions
ECR	Emergency Control Room
ER&S	Emergency Response and Security, Senior Advisor
PC ERT	Primary Contractor Emergency Response Team
PC IMT	Primary Contractor Incident Management Team
FR	First Responder
OE	Origin Energy
OSC	On scene Commander
PC	Primary Contractor

Appendix E Emergency Services Manifest

To be completed within 2 weeks of occupation of Site.

Screen shot of example: Emergency Services Manifest Template.

origin

Integrated Gas

Emergency Services Manifest

Insert Site Name

Purpose	A manifest of notifiable quantities of hazardous substances held at this site facility under section 347 of '*Work Health & Safety Regulation 2011, Queensland*'
Reference	Hazardous Materials Management - LNG Division - 3676149 Risk Management Directive - ORG-RISK-DVE-001
Records	Hard copy to be housed in the locked 'Hazmat' Red box located at the front of the site facility and electronic copy to be available on the Sharepoint H&S team site for monitoring of updates and future audit purposes

Section 1 - General Site Information

Occupier of Facility: Origin Energy Pty Ltd

Site Address: <insert address>
<insert address>
<insert address>

Section 2 - Emergency Contacts

Name	Position	Contact Details			
		Business Hours	Mobile	UHF Radio	After Hours
Upstream Emergency Phone Number (24/7 After Hours) 1800 076 251					

Section 3 - Bulk Storage Locations

Note: Bulk storage includes vessels with a capacity of >500L. Gas tank capacity must be in Water Capacity (L), not gas capacity (m^3).

Location / Equipment ID Number	Type	Capacity	Tank Diameter (Flammable liquids only)	Correct Shipping Name	UN Number	DG Class	Quantity
e.g. T3600-001	*Aboveground tank*	*20,000L*		*Petroleum distillates N.O.S*	*1268*	*3*	*20,000L*

Section 4 - Package and IBC Storage Locations

Note: Packages include containers with a capacity of <500L or IBCs of 1,000L capacity. Cylinder quantities must be in Water Capacity (L), not gas capacity (m^3).

Storage Location	Correct Shipping Name	Package type	UN no.	Class	Max. Qty
e.g. Warehouse	*Hydrochloric Acid*	*Drum*	*1789*	*8*	*3,000L*

Appendix F Site Specific Emergency Response Equipment

To be developed within 2 weeks of site occupation to display the following areas:

- Person in Charge (PIC)
- Muster Areas
- First Aid Treatment Areas
- First Aid Kit locations
- Fixed Fire Extinguishers and Blankets
- Evacuation Routes
- Helicopter Landing Sites
- Emergency Services Meeting Points
- Hazardous / Restricted Areas
- Emergency event PPE Locations
- Spill Kit

Northern Territory – Daly Waters

- Daly Waters Airport

Appendix G Emergency Response Flipcharts

The following scenario responses have been reproduced from the Origin Incident Response Procedures CDN 3676134

Appendix G1 – Bushfire

Appendix G2 – Flood

Appendix G3 – Spill

Appendix G4 – Loss of Containment

G.1. Bushfire

Bushfire

Considerations

1. Is there a need to activate the Emergency Response Team (ERT).
2. Is there adequate fire fighting capability?
3. Is there an adequate water source available?
4. Bushfire - Is based on a region wide fire event where access roads will directly affect evacuation. Refer to Bush Fire Preparedness Tool for response actions, web links (i.e. BOM) and evacuation considerations.

First Responders

1. Raise the Alarm?
2. If there is a casualty provide First Aid (DRSABCD). Continue until either physically unable to do so, relieved or the patient is pronounced deceased by a doctor or paramedic.
3. Refer to the Bush Fire Preparedness Tool.
4. Be vigilant. Watch for flying embers and small fires starting on site.

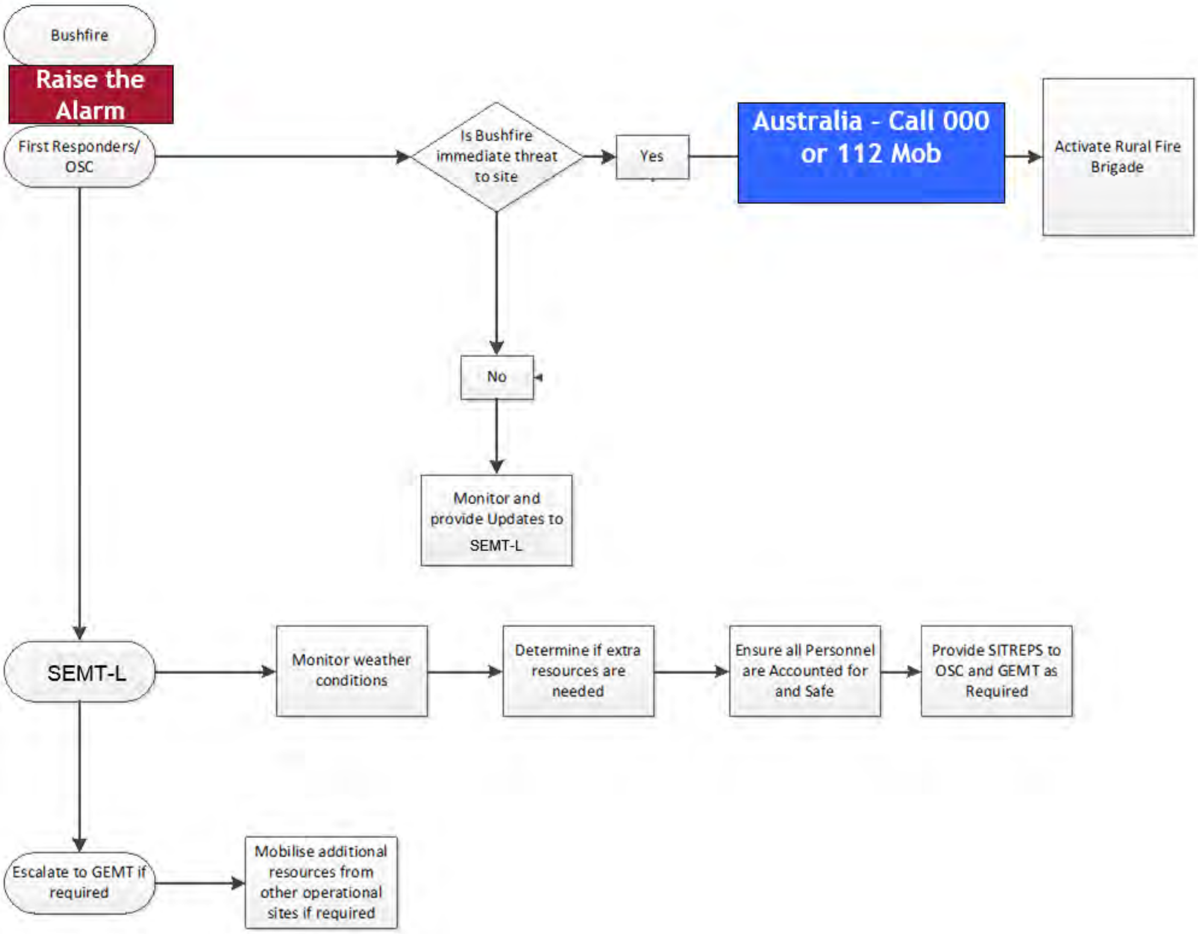
On Scene Commander (OSC)

1. Mitigate Hazards to ensure personnel safety.
2. Contact the Site Emergency Management Team Leader (SEMT-L).
3. Activate Emergency Response Team (ERT) response.
4. Muster personnel and evacuate as required.
5. Contact Emergency Services if required.
6. Prepare for the arrival and briefing of Emergency Services.

Site Emergency Management Team Leader (SEMT-L)

1. Notify Origin Site Representative of emergency in the region.
2. Australia - Call 000 or 112 Mob or Fire Agencies (if available).
3. Identify available fire fighting assets (aerial, ground, mutual aid).
4. Conduct planning for evacuation and determine triggers.
5. Coordinate whole of site actions.
    1. Give preparatory orders for securing the site against the bushfire.
    2. Isolate hazardous energy and make equipment safe.
    3. Provide support to the OSC.
    4. Coordinate Emergency Services.
    5. Ensure isolation of hazardous energy and make safe (e.g. Central Control Room).
    6. Consider mobilization of Civil Maintenance to assist with fire break preparation, asset protection/earthen barriers.
6. Notify Group Emergency Management Team Leader (GEMT-L)?
7. Confirm incident terminated – use Incident Termination Checklist
8. Confirm incident investigation and gathering of facts initiated
9. Mobilise counselling services and support by the Employer Assistance Program (EAP) if required.
10. Don't return to work until all facilities and damage have been declared as safe.

Bushfire


Bushfire
Raise the Alarm
First Responders/ OSC
Is Bushfire immediate threat to site
Yes
Australia - Call 000 or 112 Mob
Activate Rural Fire Brigade
No
Monitor and provide Updates to SEMT-L
SEMT-L
Monitor weather conditions
Determine if extra resources are needed
Ensure all Personnel are Accounted for and Safe
Provide SITREPS to OSC and GEMT as Required
Escalate to GEMT if required
Mobilise additional resources from other operational sites if required

G.2. Flood

Flood

Notification
Level 1
- Once a creek starts to flow over any of the access roads.

Level 2 (Consider Evacuation)
- Creek level reaches 100mm for unsealed roads, or
- Creek level reaches 200mm for sealed roads.

Level 3 (Consider Evacuation and/or Demobilising)
- Creek level reaches 300mm for unsealed roads, or
- Creek level reaches 400mm for sealed roads.
- Consider duration of weather event and prolonged effects on site.

Considerations
Level 1
- Commence prep of site for shut down and evacuation.
- Secure chemicals and toxins.
- Check supplies of food and water.

Level 2
- Non-essential personnel evacuated.
- Track personnel movements and account for all staff at all times.
- Prepare to secure / isolate infrastructure.
- Maintain communications at all times.
- Ensure sufficient food and water available on site if personnel are stranded.

Level 3
- Shut down, secure and evacuate.
- Track personnel movements and account for all staff at all times.

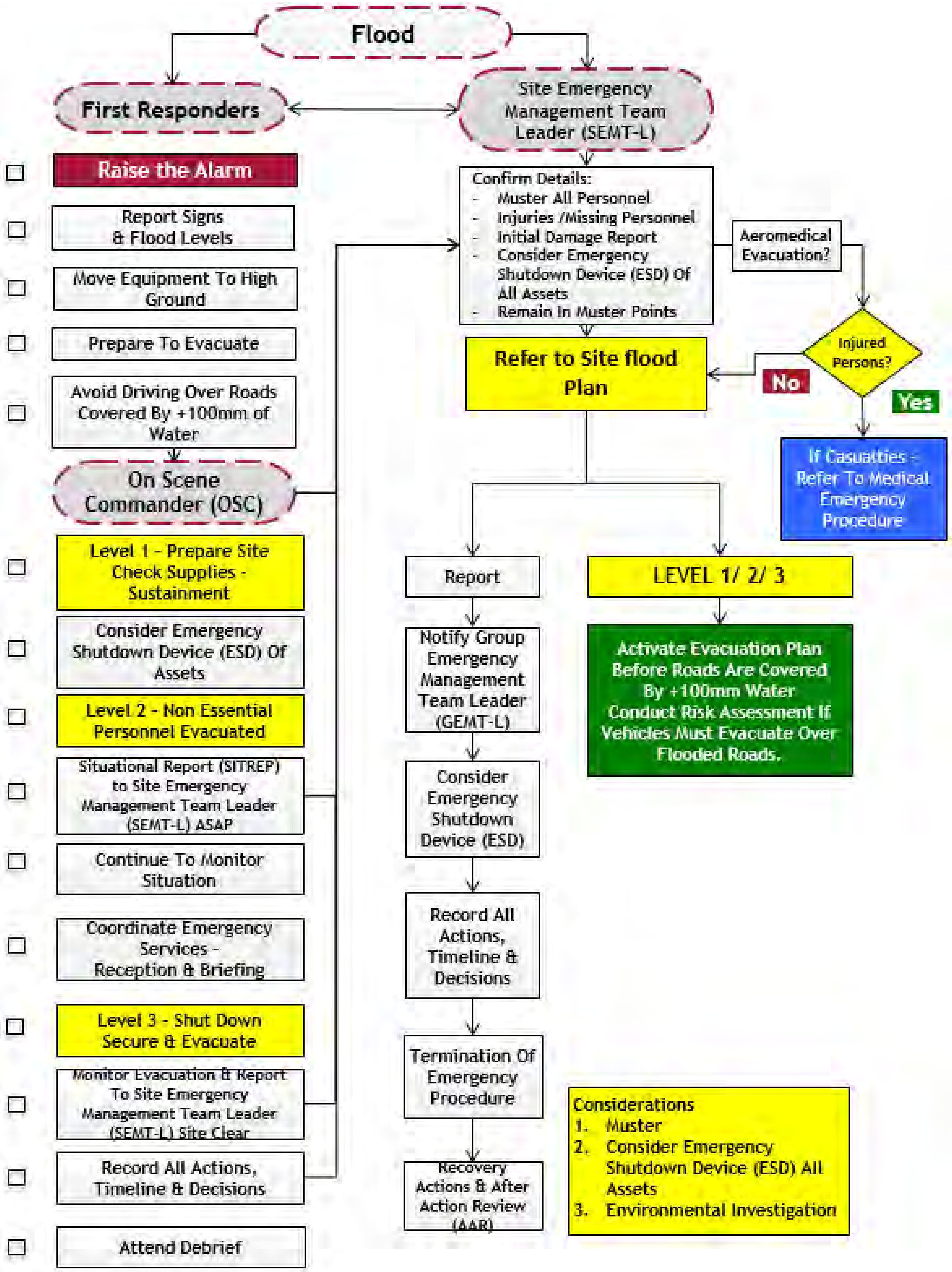
Don't put yourself at risk.

AVOID DRIVING OVER ROADS THAT HAVE MORE THAN 100mm OF WATER OVER THEM.

Driving over flooded roads in an emergency must be risk assessed by the Site Emergency Management Team Leader (SEMT-L).

Prior to Flood Waters Reaching Site:

1. Refer to these tools to identify assets and roads that will flood to certain levels:
   a. Flood Plan,
   b. Flood Mapping, and
   c. Hazard visualiser.
2. Closely monitor weather reports and flood predictions from the Bureau Of Meteorology (BOM).
3. Confirm triggers, evacuation plans and routes. What preparatory actions are required at site? Construction of protective banks takes time and may require additional equipment (plant) to be transported and deployed.
4. Whenever possible, mitigate environmental damage by undertaking appropriate action.
5. Evacuate mobile worksites as early as practicable?.


Flood
First Responders
Site Emergency Management Team Leader (SEMT-L)
Raise the Alarm
Report Signs & Flood Levels
Move Equipment To High Ground
Prepare To Evacuate
Avoid Driving Over Roads Covered By +100mm of Water
On Scene Commander (OSC)
Level 1 - Prepare Site Check Supplies - Sustainment
Consider Emergency Shutdown Device (ESD) Of Assets
Level 2 - Non Essential Personnel Evacuated
Situational Report (SITREP) to Site Emergency Management Team Leader (SEMT-L) ASAP
Continue To Monitor Situation
Coordinate Emergency Services - Reception & Briefing
Level 3 - Shut Down Secure & Evacuate
Monitor Evacuation & Report To Site Emergency Management Team Leader (SEMT-L) Site Clear
Record All Actions, Timeline & Decisions
Attend Debrief
Confirm Details:
- Muster All Personnel
- Injuries /Missing Personnel
- Initial Damage Report
- Consider Emergency Shutdown Device (ESD) Of All Assets
- Remain In Muster Points
Aeromedical Evacuation?
Injured Persons?
No
Yes
Refer to Site flood Plan
If Casualties - Refer To Medical Emergency Procedure
Report
LEVEL 1/ 2/ 3
Notify Group Emergency Management Team Leader (GEMT-L)
Activate Evacuation Plan Before Roads Are Covered By +100mm Water Conduct Risk Assessment If Vehicles Must Evacuate Over Flooded Roads.
Consider Emergency Shutdown Device (ESD)
Record All Actions, Timeline & Decisions
Termination Of Emergency Procedure
Recovery Actions & After Action Review (AAR)
Considerations
1. Muster
2. Consider Emergency Shutdown Device (ESD) All Assets
3. Environmental Investigation

G.3. Spill

Spill

Considerations

1. Activate the Emergency Response Team (ERT).
2. A pollutant spill may be on permeable ground and encompass a wide array of substances, some of which will be toxic and very harmful to the environment.

First Responder

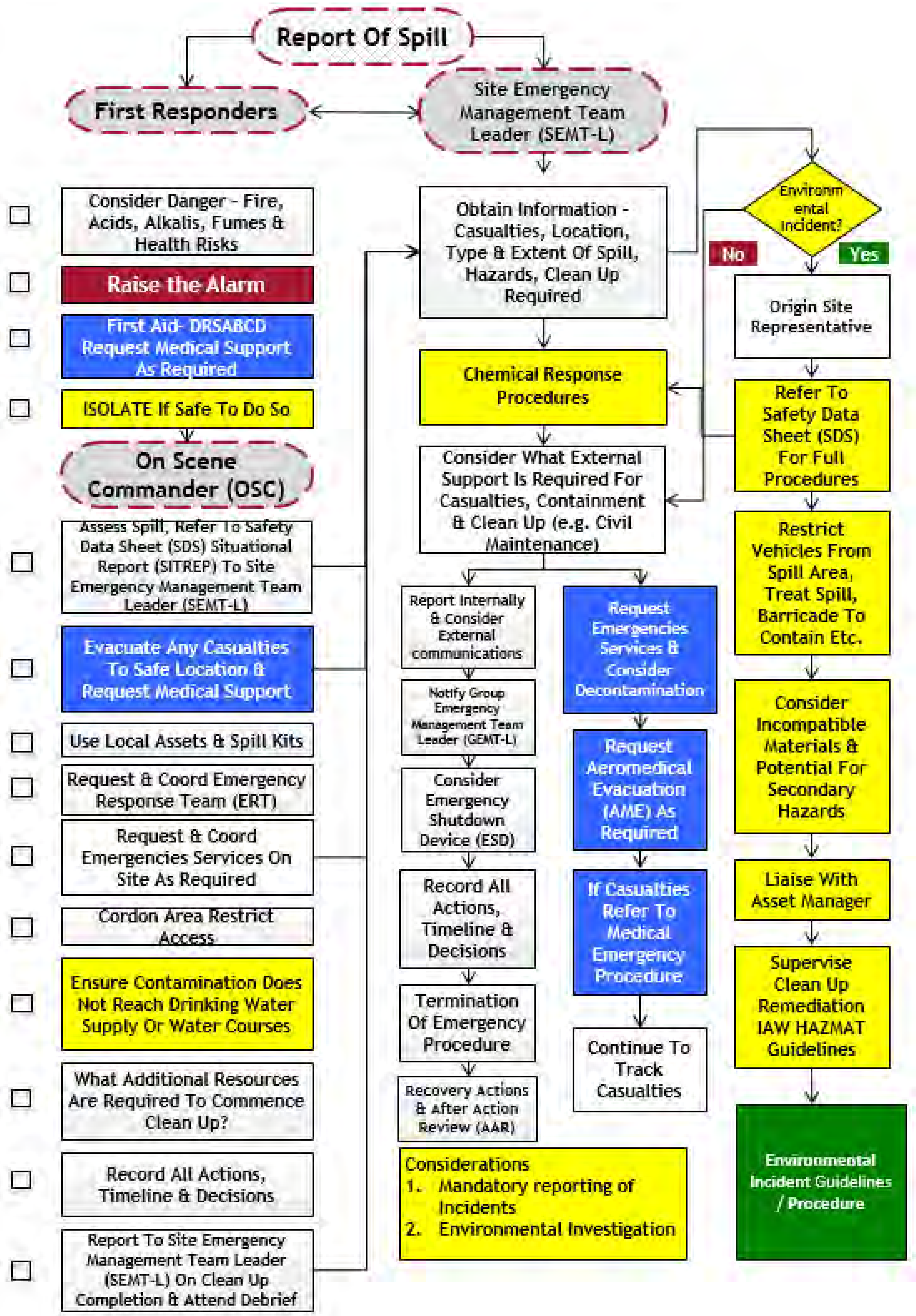
1. Raise the Alarm?
2. Is there a need to activate the Emergency Response Team (ERT)?
3. Always pay attention to fire, fumes, electrical, ignition and other health risks.
4. Activate containment operations immediately to prevent spill from reaching a surface watercourse or ground water.
5. Do not flush the spill down clean drains or other inlets.

On Scene Commander (OSC)

1. Mitigate Hazards to ensure personnel safety.
2. Consider the effects of toxic spills – refer to Safety Data Sheets (SDS).
3. Use appropriate spill kits.
4. Consider type of spill, type of ground and what is the most effective method of containing with the minimum impact on personnel and the environment.
5. Consider how to prevent entry to area and spread of contamination.
6. Engage the Origin Site Representative to help assess the impact and determine appropriate actions for complex or remote incidents.
7. Some chemicals are incompatible and have the potential to increase or alter the hazard – refer to the Chemical Compatibility Chart in the Hazmat section of the site Emergency Response Plan (ERP).
8. For Water Treatment Facilities only - Disposal of diluted material to the ponds is permissible in an emergency but must be approved by the Water Treatment Facility (WTF) Supervisor.

Site Emergency Management Team Leader (SEMT-L)

1. Consider use of Civil Maintenance team for installation of earthen bunds / diversion systems.
2. Consider early engagement with the Origin Site Representative and external agencies through Compliance Team.
3. Consider nature of spill and any decontamination requirements to personnel and or equipment.
4. Consider any logistics that will be required for rapid clean up and /or remediation.
5. Consider advising local land owners and councils as appropriate.
6. Ensure all spills are managed and that environmental impacts are reported correctly within mandated time frames.
7. Consider future prevention measures and better clean up practices.



Report Of Spill
First Responders
Site Emergency Management Team Leader (SEMT-L)
Consider Danger - Fire, Acids, Alkalis, Fumes & Health Risks
Raise the Alarm
First Aid- DRSABCD Request Medical Support As Required
ISOLATE If Safe To Do So
On Scene Commander (OSC)
Assess Spill, Refer To Safety Data Sheet (SDS) Situational Report (SITREP) To Site Emergency Management Team Leader (SEMT-L)
Evacuate Any Casualties To Safe Location & Request Medical Support
Use Local Assets & Spill Kits
Request & Coord Emergency Response Team (ERT)
Request & Coord Emergencies Services On Site As Required
Cordon Area Restrict Access
Ensure Contamination Does Not Reach Drinking Water Supply Or Water Courses
What Additional Resources Are Required To Commence Clean Up?
Record All Actions, Timeline & Decisions
Report To Site Emergency Management Team Leader (SEMT-L) On Clean Up Completion & Attend Debrief
Obtain Information - Casualties, Location, Type & Extent Of Spill, Hazards, Clean Up Required
Chemical Response Procedures
Consider What External Support Is Required For Casualties, Containment & Clean Up (e.g. Civil Maintenance)
Report Internally & Consider External communications
Notify Group Emergency Management Team Leader (GEMT-L)
Consider Emergency Shutdown Device (ESD)
Record All Actions, Timeline & Decisions
Termination Of Emergency Procedure
Recovery Actions & After Action Review (AAR)
Request Emergencies Services & Consider Decontamination
Request Aeromedical Evacuation (AME) As Required
If Casualties Refer To Medical Emergency Procedure
Continue To Track Casualties
Considerations
1. Mandatory reporting of Incidents
2. Environmental Investigation
Environmental Incident?
No
Yes
Origin Site Representative
Refer To Safety Data Sheet (SDS) For Full Procedures
Restrict Vehicles From Spill Area, Treat Spill, Barricade To Contain Etc.
Consider Incompatible Materials & Potential For Secondary Hazards
Liaise With Asset Manager
Supervise Clean Up Remediation IAW HAZMAT Guidelines
Environmental Incident Guidelines / Procedure

G.4. Loss of Well Control

Loss of Well Control

Considerations

1. Activate the Emergency Response Team (ERT).
2. Determine wind direction.
3. Determine leak location; subsurface and and type.
4. Well Control Contractor requirement.
5. Consider Emergency Shutdown Device (ESD) (e.g. Central Control Room (CCR)).

First Responder

1. Raise the Alarm?
2. Always pay attention to Fire, fumes, electrical, ignition and Health Risks.
3. Muster and evacuate.
4. Secure the scene / Cordon off area.
5. Provide full details to On Scene Commander (OSC) and Site Emergency Management Team Leader (SEMT-L) – particularly:
   - Where is it originating from?; and
   - What is the wind direction?

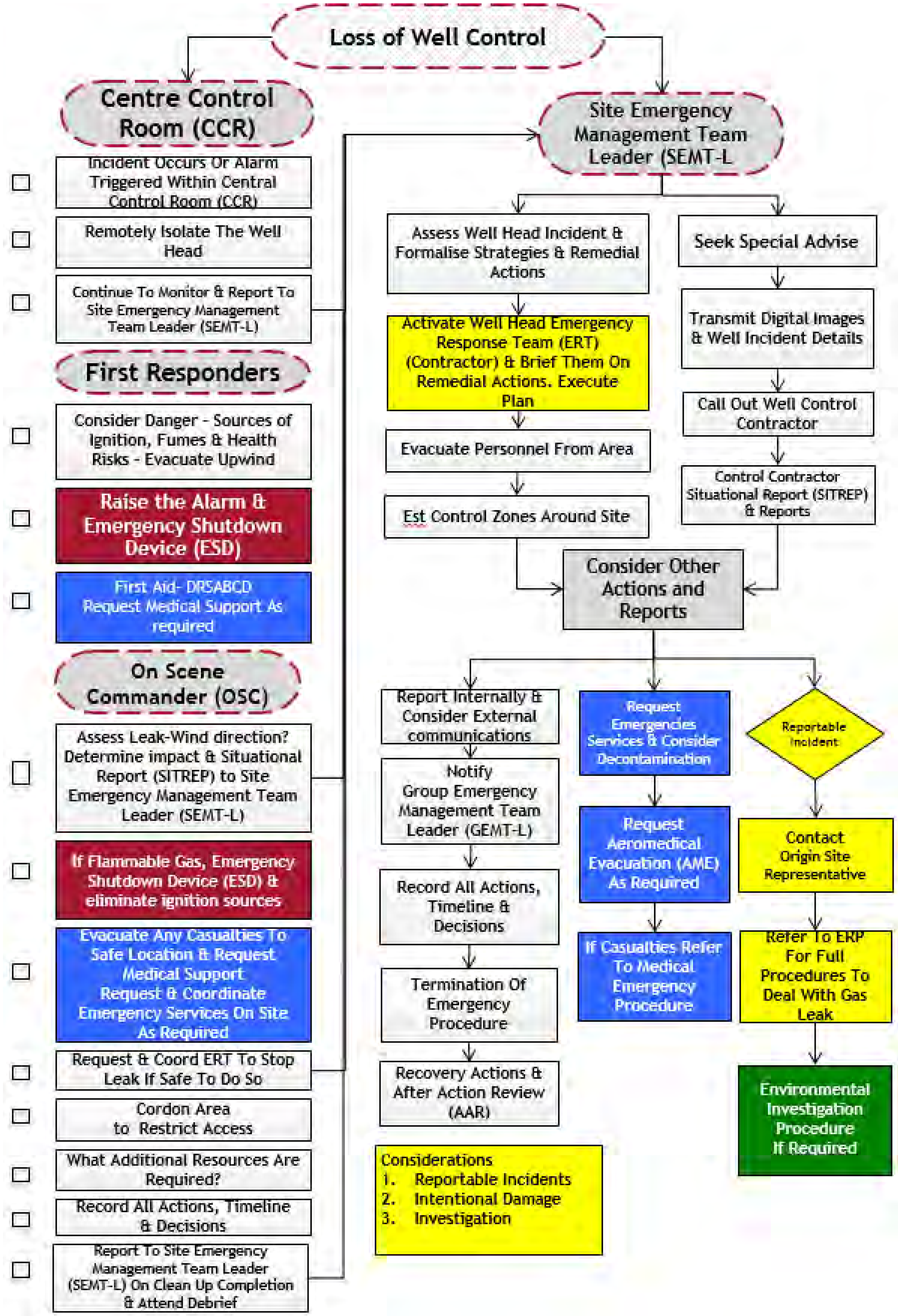
5. Consider ignition sources as vapour could be flammable.

On Scene Commander (OSC)

1. Mitigate Hazards to ensure personnel safety.
2. What is the type of Leak and source? What is the wind direction?
3. Shutdown all potential ignition sources (liaise with Central Control Room (CCR)).
4. Monitor bleed down of leak and keep all non-essential personnel and ignition sources away from the hazardous area.
5. Make a decision whether a full site evacuation is required.

Site Emergency Management Team Leader (SEMT-L)

1. Consider environmental impacts and reporting requirements.
2. Consider early engagement with the Origin Site Representative.
3. Activate and monitor Well Control Contractor deployment and progress.
4. Consider nature of incident and method of repair and recovery to personnel and or equipment.
5. Consider any logistics that will be required for rapid clean up and or remediation.


Loss of Well Control
Centre Control Room (CCR)
Incident Occurs Or Alarm Triggered Within Central Control Room (CCR)
Remotely Isolate The Well Head
Continue To Monitor & Report To Site Emergency Management Team Leader (SEMT-L)
First Responders
Consider Danger - Sources of Ignition, Fumes & Health Risks - Evacuate Upwind
Raise the Alarm & Emergency Shutdown Device (ESD)
First Aid- DRSABCD Request Medical Support As required
On Scene Commander (OSC)
Assess Leak-Wind direction? Determine impact & Situational Report (SITREP) to Site Emergency Management Team Leader (SEMT-L)
If Flammable Gas, Emergency Shutdown Device (ESD) & eliminate ignition sources
Evacuate Any Casualties To Safe Location & Request Medical Support Request & Coordinate Emergency Services On Site As Required
Request & Coord ERT To Stop Leak If Safe To Do So
Cordon Area to Restrict Access
What Additional Resources Are Required?
Record All Actions, Timeline & Decisions
Report To Site Emergency Management Team Leader (SEMT-L) On Clean Up Completion & Attend Debrief
Site Emergency Management Team Leader (SEMT-L
Assess Well Head Incident & Formalise Strategies & Remedial Actions
Activate Well Head Emergency Response Team (ERT) (Contractor) & Brief Them On Remedial Actions. Execute Plan
Evacuate Personnel From Area
Est Control Zones Around Site
Seek Special Advise
Transmit Digital Images & Well Incident Details
Call Out Well Control Contractor
Control Contractor Situational Report (SITREP) & Reports
Consider Other Actions and Reports
Report Internally & Consider External communications
Notify Group Emergency Management Team Leader (GEMT-L)
Record All Actions, Timeline & Decisions
Termination Of Emergency Procedure
Recovery Actions & After Action Review (AAR)
Request Emergencies Services & Consider Decontamination
Request Aeromedical Evacuation (AME) As Required
If Casualties Refer To Medical Emergency Procedure
Reportable Incident
Contact Origin Site Representative
Refer To ERP For Full Procedures To Deal With Gas Leak
Environmental Investigation Procedure If Required
Considerations
1. Reportable Incidents
2. Intentional Damage
3. Investigation

Appendix H Camp Isolation Checklist

Screen shot of Camp Isolation Readiness Checklist. For original version go to: the IG ER&S Flood Source Page

Purpose	This checklist to be used to verify sustainability of camps in preparation for emergency events such as floods.
Reference	Area Flood Preparedness and Response Plans - http://source.originenergy.com.au/Business/lng/safety/emergency/Pages/FloodMgmt.aspx
Records	This checklist will be completed in October each year in preparation for the flood season. Additional requirements for completion will include forecasted severe storm or flood conditions.
Notes for use:	1. To be completed by the Camp Manager. 2. Additional sections critical supply items can be added in Sections 3 & 4 as required.

Date Checklist Completed	Click here to enter a date.	Prepared by	
Camp Name			
Location			
Type of Access	e.g. Dirt/Sealed Road Access or Single Point of access		
Camp Size	e.g. No of beds at full capacity		
Planning Assumptions	e.g. No of beds as the basis for determining supply/sustainment levels		
Camp Fire Fighting System	Choose an item.		

Section 1 - Food

Non Perishable		Perishables	
Current Holdings	Choose an item.	Current Holdings	Choose an item.
Frequency of Delivery	e.g. Twice Weekly - Mon & Thu	Frequency of Delivery	

Section 2 - Water & Waste Water

Water	Days' Supply	Storage Capacity	Current Holdings	Frequency of Delivery
		e.g. 90,000 Lt	Choose an item.	e.g. 2 Weekly - Mon/Thu
Waste Water	Days' Supply	Storage Capacity	Current Holdings	Frequency of Delivery
			Choose an item.	

Section 3 - Fuels & Chemicals

Diesel	Days' Supply	Storage Capacity	Current Holdings	Frequency of Delivery
			Choose an item.	
Other...	Days' Supply	Storage Capacity	Current Holdings	Frequency of Delivery
			Choose an item.	

Section 4 - Other

Linen	Days' Supply	Storage Capacity	Current Holdings	Frequency of Delivery
			Choose an item.	
Other...	Days' Supply	Storage Capacity	Current Holdings	Frequency of Delivery
			Choose an item.	

Section 5 - Exceptions/Comments

Appendix S: Environmental Commitment Register

Obligation Details	Accountability
Layout of the site and exact siting of infrastructure will be informed by the environmental sensitivities and mitigation measures identified in this EMP.	**Project Manager**
Land clearance will not be undertaken as a part of this activity, unless authorised to do so.	**Civil Construction Superintendent**
• The monitoring and maintenance under the erosion and sediment control plan shall be implemented in accordance with the Velkerri civils EMP NT-2050-15-MP-031 .	**Civil Construction Superintendent**
The Spill management plan will be implemented including spill prevention, detection, response and reporting measures.	**Drilling and Completions Lead –**
The wastewater management plan will be implemented including the use of covered tanks, wastewater characterisation, storage monitoring and appropriate disposal.	**Drilling and Completions Lead –**
The bushfire management plan will be implemented to reduce the risk of bushfires. This includes the use of appropriate separation distances between flares and the surrounding vegetation	**Drilling and Completions Lead –**
The Methane emission management plan shall be implemented, including the strategies to prevent, detect, remediate and report potential leaks.	**Drilling and Completions Lead –**
Secondary containment will be implemented for all chemical storage and handling areas	**Drilling and Completions Lead –**
Origin and its sub-contractors will prioritise the use of local labour where such skill sets are available.	**Project Manager**
The weed management plan shall be implemented, including assuring all equipment and vehicles onsite have a valid weed hygiene certificate and routine monitoring is completed. All identified weeds associated with Origin's activities to be treated and managed in consultation with the DENR weeds officer...	**Project Manager/ Civil Construction Superintendent / Drilling and Completions Lead**
The site shall be fenced to prevent fauna and livestock access to wastewater	**Project Manager**
Where monitoring confirms bird or bat mortality associated with onsite wastewater storages, Origin will implement additional controls to prevent such impacts from occurring. This may include netting or bird deterrents as appropriate.	**Drilling and Completions Lead**
The Well Operations Management Plan approved by DPIR will be implemented to ensure the protection of aquifers and the environment. This includes protecting aquifers through the use of multiple cement and casing barriers and performing the specified well integrity verification testing.	**Drilling and Completions Lead**
All Groundwater will be extracted, monitored and recorded in accordance with the Water extraction licence.	**Project Manager/ Civil Construction Superintendent / Drilling and Completions Lead**

Obligation Details	Accountability
All wastes will be transported and disposed of at licenced facilities in accordance with the NT Waste Management and Pollution Control Act 1998.	Project Manager/ Civil Construction Superintendent / Drilling and Completions Lead
Drilling muds and cuttings will be tested in accordance with the Code of Practice for onshore Petroleum Activities in the Northern Territory. Where an independent experts considers onsite disposal of muds and cuttings as being environmentally sound, a report will be submitted to DENR for approval a to the proposed disposal approach and potential risks.	Health Safety and Environment Representative (HSE Representative)
All water bores will be drilled and constructed by an appropriately NT licensed water bore driller and in accordance with the Minimum Construction Requirements for Water bores in Australia 3rd Edition (National Uniform Drillers Licensing Committee, 2012)	Project Manager
Where Origin's activities cause a material impact on the quality and quantity of a stock or domestic bore, Origin will make good such impacts in accordance with section 7.5.2.2 of the Inquiry Report. This may include adjusting pump heights, compensation or where appropriate, re-drilling/modifying the bore into an alternative water source.	Project Manager
Location of the lease areas has considered the minimum offset distance of at least 1km between site activities and pastoral water supply bores.	Project Manager
Each aquifer intersected will be isolated from overlying aquifers with a cemented casing string as per the WOMP.	Drilling and Completions Lead
No material changes in the quality and quantity of aquifers will result from Origin's activities.	Project Manager
Within 28 days of bore completion, a statement of bore (Form 21), with its registered number, will need to be submitted to the Water Resource branch of the Department of Environment and Natural Resources (DENR). This submission shall also contain a copy of the Gamma log.	Project Manager
All water bore cuttings and drilling mud will be disposed of on site in accordance with normal water bore drilling practices. Any contaminated material not suited for on-site disposal will be removed from site and transferred to a licenced waste management facility.	Project Manager/ Civil Construction Superintendent
Surface water will not be used for any activities proposed in this EMP or future operations.	Project Manager
Stormwater flooding across the cleared site will be managed to minimise impacts from erosion and sedimentation.	Project Manager
Records of weed distribution will be maintained within Origin's GIS and if required provided to the Weeds Officer at DENR.	Health Safety and Environment Representative (HSE Representative)
Origin have committed to comply with conditions as prescribed by AAPA for the duration of the program.	Project Manager
Origin has committed resources and time to allow competent and experienced personnel to participate in educational and community information sessions from Darwin in the North, to Alice Springs in the South and across to Borroloola in the East.	Project Manager
Appropriate housekeeping standards will be maintained, and the site will be maintained free of rubbish.	Project Manager/ Civil Construction Superintendent / Drilling and Completions Lead
Camps will be utilised to mitigate the impact on available accommodate and townships.	Project Manager/ Civil Construction

Obligation Details	Accountability
	Superintendent / Drilling and Completions Lead
Wastewater, sewage and sullage generated by the domestic camp activities will be managed by a Department of Health (DoH) approved sewage treatment system or captured and removed from site.	Drilling and Completions Lead
Monitor road conditions to ensure deterioration with possible increase in dust creation, does not occur and undertake road rehabilitation as required.	Project Manager/ Civil Construction Superintendent / Drilling and Completions Lead
At completion, Origin will develop and implement a site specific rehabilitation plan in consultation with DENR to rehabilitate all disturbed areas (unless being transferred to a Pastoralist for beneficial use).	Health Safety and Environment Representative (HSE Representative)
Work instructions summarising the requirements of this EMP shall be prepared and submitted to contractors performing work under this EMP. Origin shall ensure all relevant hold points are enforced and signed off prior to commencing work.	Health Safety and Environment Representative (HSE Representative)

Appendix T Well Operation Management Plan Requirements

B.4.1 Well Integrity Management		
B.4.1.1 Principles		
Monitoring and maintenance is required to preserve the well and its equipment in a suitable condition for their useful life. Well integrity management systems aim to ensure the wells meet operational availability and well integrity goals for the entire well lifecycle, as shown in Figure 1.		
Wells are designed to be operated such that the following are achieved: (a) well integrity is maintained at all times and barriers meet the requirements described in section B.4.3 of this Code; (b) their well integrity is validated through a well integrity testing program; (c) well barrier status is known and technical integrity risks are managed; (d) the well operating envelope is not exceeded; and (e) all materials and equipment installed in a well must maintain well integrity for the lifespan of its intended use.		
B.4.1.2 Mandatory Requirements	**Origin Implementation**	**WOMP Reference**
(a) The interest holder must be able to demonstrate that they have a system or process for managing well integrity throughout the whole well life cycle that complies with ISO 16530- 1:2017 Well integrity - Part 1: Life cycle governance. This system or process must include a well integrity management system.	Well to be designed and constructed as per the Origin Well Design and Delivery Process (WDDP) in conjunction with Origin internal design standards. Wells are managed as per Origin Well Integrity Management Plan (WIMP) and in compliance with ISO 16530-1:2017 Well integrity - Part 1: Life cycle governance Life Cycle Phases include: Basis of Design, Design, Construction, Operation, Intervention & Abandonment Elements covered include: Well integrity (management & policies), risk assessment, organisation structure, well barrier, performance standards, well barrier verification, reporting & documentation, MOC, Continuous improvement/Auditing/Learnings	6.1 Well Design Process 6.2 Casing Design 8 Barrier Analysis 9 Risk Management 12 Well Integrity Management System Appendix G
(b) In order to continue operating a well which has, or is believed to have, a compromised well barrier, a risk assessment must be conducted in line with the	OE standards require dual barriers. Any deviations require a risk assessment to demonstrate ALARP. Remediations	

interest holder's risk assessment process and where required remediation action undertaken.	are to be conducted where required and in accordance to OE well failure model.	
(c) A well integrity testing and validation program must be established for all wells, that includes:		
i. subsurface integrity testing (SIT);	All subsurface barriers are validated during well construction and identified in the Well Acceptance Criteria (WAC). WAC are holding points in the program and must be accepted prior to moving onto the next operation.	
ii. well integrity and well barrier validation requirements in accordance with this Code		
iii. a minimum testing frequency for wells in the operational phase of their lifecycle that is commensurate with well's well integrity risks as per the accepted WOMP; and	Well monitoring will be conducted in accordance to Origin's WIMP. Routine Operational Inspections: During each operational Visit Mandatory Inspections: 6 Monthly	
iv. triggers for well integrity testing based on:	Well integrity barriers are tested when potential failures may be suspected or when known changes to the well barrier/operational envelope have occurred	
a. well integrity monitoring; and		
b. substantive changes to well barriers or well operating envelope.		
(d) Casing and tubing wear due to corrosive fluids and erosion should be assessed throughout the well life cycle and its impact on well integrity.	All produced fluids (gas/liquids) are analysed for corrosive attributes to understand the impact on well integrity for the life cycle of the well. Whilst still in exploration, corrosion coupons are implemented to access the rate of corrosion on the material selection of tubulars and wellheads	

B.4.2 Aquifer protection		
B.4.2.1 Principles		
Protection of aquifers is an integral consideration in petroleum well design.		
Developing a mechanical reactive barrier for a petroleum well involves the following: (a) definition or specification of a barrier; (b) understanding of causes of failure; (c) asking what signals could be monitored to help predict a failure; and (d) asking what signals could be monitored to help detect a failure.		
The protection of aquifers requires the following to be achieved: (a) well-defined stratigraphic definition to the base of the deepest recognised aquifer in the local area prior to drilling; (b) aquifers must be considered during the well design process and interest holders must include the design of aquifer isolation in their WOMP; (c) all aquifers in the area must be isolated from the surface and each other and any hydrocarbon bearing zones using appropriate barriers, in accordance with section B.4.3.2 of this Code; (d) groundwater quality monitoring conducted in accordance with section B.4.17 of this Code; and (e) drilling fluids must be designed to minimise environmental harm, in accordance with section B.4.10.2 of this Code.		
B.4.2.2 Mandatory requirements	**Origin Implementation**	**WOMP Reference**
(a) Casing setting depth must be selected to protect resources including aquifers in accordance with section B.4.3.2 of this Code.	Each identified aquifer is isolated via a casing string and annular cement to surface. Casing points for the top hole are selected to provide isolation of the different aquifers from each other and from the reservoir. Data collected from offset water monitoring bores are utilised to plan casing points for top hole sections.	6.2 Casing Design 6.5 Cementing Programme 10.4 Aquifer Protection 12. Well Integrity Management System
(b) All aquifers, in the area must be isolated from each other and from the surface and any permeable hydrocarbon bearing zones by appropriate well barriers, in accordance with section B.4.3 of this Code.	All identified aquifers are isolated in the top hole sections of the well. Anthony Lagoons (Aquifer) isolated behind conductor casing and cement Gum Ridge (Aquifer) isolated behind surface casing and cement	

	Target hydrocarbon bearing reservoir is isolated behind intermediate and production casing/cement	
(c) Primary cementing design and validation must be carried out in accordance with the interest holder's well operations management plan and in accordance with B.4.7 of this Code.	Cement modelling - lab testing to meet Final cementing program to be prepared Validation metrics outlined in Well Barrier Diagrams	
(d) Monitoring of barriers and casing condition must be carried out in accordance with the interest holder's well operations management plan and in accordance with B.4.1 of this Code.	Barriers are verified during well construction as per the program WACs, this includes mechanical integrity testing of production casing and annular cement verification in the intermediate and production hole sections. On going monitoring of annular pressures conducted as per the OE WIMP.	
(e) If aquifers of environmental value are discovered during drilling that were not identified prior to commencement of drilling notification to the Minister is required under r23 of the PER. This notification should identify whether or not environmental values of the aquifer have been adequately addressed under the EMP and whether or not the EMP requires revision under r17.	Will be complied with if circumstances arise. Control water monitoring bores drilled within 100m of the petroleum bore reduce the likelihood of this occurrence.	

B.4.3 Well design and well barriers		
B.4.3.1 Principles		
Petroleum wells are designed and constructed such that:		
(a) well objectives are met;		
(b) well barriers are designed to prevent unintentional influx, crossflow to other formation layers and outflow to the external environment;		
(c) barrier envelopes are designed such that failure of one barrier should not lead to an uncontrolled release of formation fluids (blowout or cross-flow);		
(d) testing and acceptance requirements specified in the WOMP are satisfied;		
(e) wells can be monitored and maintained to contain and control well fluids, provide structural support and otherwise retain well integrity throughout all reasonably anticipated well construction and production load conditions – which may occur during the life of the well; and		
(f) zonal isolation between different aquifers, and between hydrocarbon bearing zones and aquifers is achieved.		
B.4.3.2 Mandatory requirements	**Origin Implementation**	**WOMP Reference**
Wells must be designed such that:		6.2 Casing Design 6.5 Cementing Programme 6.12 Well Suspension Programme 6.13 Pressure Testing and Well Control 6.15 Well Decommissioning 10.3 Well Control Equipment Appendix B - Well Barriers
(a) casing setting depths and cement isolate aquifers and hydrocarbon bearing zones;	Each identified aquifer is isolated via a casing string and annular cement to surface. Casing points for the top hole are selected to provide isolation of the different aquifers from each other and from the reservoir. Data collected from offset water monitoring bores are utilised to plan casing points for top hole sections. Casing and cement integrity are tested and verified for hole sections that land in the target reservoir formations prior to hydraulic fracturing activity	
(b) unless paragraph (c) applies, they are constructed, maintained and decommissioned in such a manner that it can be demonstrated there are at least two verified well barriers between:		
i. a hydrocarbon bearing zone and aquifers and the surface; and		

ii. deep, saline water bearing formations and aquifers/the surface.	A 4 string well design is implemented for wells in the Velkerri SRR, which provide a minimum of 2 well barriers between hydrocarbon bearing zone, aquifers and the surface	
(c) where one or more of the following circumstances applies, less than two verified barriers may be provided:		
i. during top hole or surface hole drilling where shallow hydrocarbon or water flow risk has been assessed as being negligible;	Regional study and assessment indicate a low risk of shallow hydrocarbon/water flows within the vicinity of the proposed well	
ii. during diverter drilling;	Risk assessed as required	
iii. during well decommissioning when two formations need to be isolated from one another and two barriers are not feasible, and a continuous cement plug extending minimum 50m above to 50m below the interface is placed instead; or	A continuous cement plug may be placed across all shallow aquifers inside the production casing during decommissioning.	
iv. in other circumstances during well life cycle activities when a risk assessment demonstrates that the same level of risk can be achieved as if two verified barriers were in place.	Risk assessed as required	
(d) they are constructed, maintained and decommissioned in such a manner that it can be demonstrated that all aquifers are isolated from each other and the surface by a minimum of one verified well barrier;.	Each operation must meet OE program Well Acceptance Criteria, which prescribe the well barrier elements and validation requirements. The wells are designed in such a manner that annular pressures can be monitored for the life of the well to confirm well integrity	
(e) installation of BOP equipment is provided for;	Wellheads designed for allowance of BOP once top hole section is complete	
(f) well control is maintained during all well activities;	See Well Barrier Diagrams and Risk Assessment	
(g) fit for purpose casing weight and grade are used, having regard to casing corrosion risk and connection suitability;	Mechanical earth models, particularly pore pressure and fracture gradients are utilised in modelling and selecting fit for purpose casing weight and grades for each hole section. Premium connection are implemented for intermediate and production string sections	

(h) specific requirements for well construction materials are included in the design;	Corrosion analysis will be undertaken throughout the exploration phase to characterise the gas composition and analyse corrosion rates. Well operating life is assessed annually and decommissioned early if required.	
(i) minimum casing centralisation standards in section B.4.7.2 of this Code are met;	Once hole section is TD, a well centralisation model is conducted to ensure a minimum of 70% standoff is achieved	
(j) engineered cement slurries and appropriate cement placement techniques are part of the design;	Engineered cement slurries designed accommodate the foreseeable load conditions for the life of the well. Laboratory test/modelling will include at a minimum slurry density, rheology, thickening time, free water, fluid loss (if required), and compressive strength development with time. In addition 3D simulation will be conducted for accurate displacement volume, Rotation of casing while cementing to be conducted to enhance uniform cement sheath in the horizontal wellbore	
(k) petroleum fluids produced from the well do not crossflow to aquifers; and	4 string well design and validated barriers prevent cross flow of petroleum fluids to aquifers	
(l) wherever drilling fluid is being used as a primary barrier, sufficient reserves of drilling fluid and supplies of drilling fluid materials shall be available at the well site for immediate use so that the well can be maintained full of drilling fluid.	Sufficient reserves are kept on location 10% contingency in addition to reserves to accommodate a 1 bbl/m dilution factor and sufficient weight agents on location to increase mud weight by 0.5 ppg for the entire active system	

B.4.5 Working with hydrogen sulfide (H2S)		
The scope of this section B.4.5 covers any well location where H2S is expected to exceed 10 ppm (by volume) in the breathing zone.		
B.4.5.1 Principles		

Hydrogen sulfide (H2S) is classed as a hazardous substance and a dangerous good that is sometimes found in fluids encountered in oil and gas producing and gas processing operations. The interest holder is responsible for ensuring that suitable operational practices are in place to manage the risks associated with H2S.		
H2S management practices include:		
(a) characterisation of the probability and concentration levels of H2S that may be encountered; and		
(b) the safe handling of any H2S encountered during well operations.		
B.4.5.2 Mandatory requirements	**Origin Implementation**	**WOMP Reference**
(a) On detection in exploration wellsor appraisal wells, or where there has been regional evidence of H2S, a review of reservoir and offset well data must be carried out for a well, or campaign of wells in the same reservoir, to determine the probability and concentration levels of H2S.	N/A - H2S not expected	N/A
(b) As hydrogen sulfide is classed as a hazardous substance a risk assessment must be conducted and recorded for all work activities where personnel may be exposed to the substance.		
(c) Prior to operations in an H2S environment, an H2S management plan must be developed that is consistent with API RP49, Recommended Practices For Safe Drilling Of Wells Containing H2S.		
(d) All drilling contractors and service companies involved in well site operations must be notified of predicted H2S levels and temperatures.		
(e) A flare system must be provided to safely collect and burn H2S gas during well control or well test operations. Flare lines must be located as far away from the well as reasonably practicable.		
(f) For operations where H2S is predicted, continuous H2S monitoring equipment shall be installed, which is capable of continuously measuring and displaying the concentration of H2S in ambient air. H2S gas detectors must be available for personnel working in a known high risk zone when H2S is present or predicted in any quantity. A H2S alarm setting of 5 ppm must be used for personal, portable and fixed detectors.		

(g) Personnel are to be provided with personal protective equipment to prevent exposure to H2S if the work area concentration of H2S are expected to exceed or are found to exceed 10 ppm (by volume) 8-hour time weighted average or 15 ppm (by volume) as a short term exposure level . Personnel safety provisions do not apply when the atmospheric concentration of H2S could not exceed 10 ppm (by volume) in the breathing zone.		
(h) For H2S operations, equipment and materials shall be selected on the basis of resistance to sulfide stress cracking and corrosion where the partial pressure of H2S gas exceeds 350 Pa (0.05 psi), or 70 kPa (10 psia) in sour crude systems.		
i. If it is proposed to use a material which is intended for 'non H2S service', a risk assessment and supporting data must be conducted to demonstrate the integrity of equipment or materials over the following timeframes:		
a. during a single temporary exposure to sour reservoir fluids (e.g. circulating out a kick, or if there is a leak in the test string while production testing) or,		
b. in the time between exposure to sour reservoir fluids and completion of evacuation of the well site in the event of uncontrolled total displacement of the well contents by such fluids.		
ii. If operations on a well are suspended then the effects of H2S over the suspension period must be considered.		
(i) Elastomers, packing and other non-ferrous parts exposed to H2S must be resistant at the maximum anticipated temperature of exposure.		
(j) A drilling fluid program must include the use of an H2S scavenger to remove any H2S from the drilling fluid.		
(k) When coring operations are conducted in possible H2S bearing zones, the wearing of breathing equipment and testing for H2S using hand held sensors must be used for the final 10 stands, and must continue while retrieving the inner core barrels, opening the core barrels and examining the cores. Prior to transportation, cores must be sealed and marked to indicate the presence of H2S.		

(l) If H2S in the gas phase is predicted during well test operations, H2S concentration must be monitored at first hydrocarbons to surface and at regular intervals throughout the test.		
(m) If H2S levels exceed original design assumptions or cannot be controlled by the resources available on the rig, then the well must be shut-in. The well must remain shut in until such a time as the level of H2S readiness is increased such that operations can continue safely.		

B.4.6 Casing and tubing		
B.4.6.1 Principles		
The casing program should be configured to accommodate all identified sub-surface hazards and to minimise risk either from cross-flow between formations or the uncontrolled release of well fluids to surface, throughout the life of the well.		
Casing setting depths should be selected to provide an adequate safety margin between the formation fracture pressure and anticipated pressures during well control and casing cementation operations.		
Well casing must be:		
(a) designed, installed, tested and maintained in a way that is consistent with the well integrity management system for the well;		
(b) designed, installed, tested and maintained in a way that is consistent with the well design and barrier requirements set out in section B.4.3 of this Code; and		
(c) designed to consider the required strength, metallurgy (to resist corrosion and erosion), sealing capacity, and **circulation** capacity.		
B.4.6.2 Mandatory requirements	**Origin Implementation**	**WOMP Reference**
(a) Casing and tubing stress analysis must be carried out on all reasonably foreseeable load scenarios that may be imposed on the well. Working stress design must consider both uniaxial and triaxial analysis.	Casing and tubing stress analysis is conducted on all hole sections incorporating axial and triaxial analysis on all foreseeable load scenarios and in accordance to the OE Casing and Tubing Standard.	6.2 Casing Design 6.8 Wellhead Design 6.13 Pressure

(b) Casing, casing connections, wellheads, and valves used in petroleum wells must be designed to withstand the loads, pressures and temperatures that may act on them throughout the entire well life cycle. This includes casing running and cementing, any treatment pressures (e.g. hydraulic stimulation), production or injection pressures, potential well control situations, any potential corrosive conditions (H2S, CO2, etc.), and other factors pertinent to local experience and operational conditions.	Wellhead and tubulars are designed to withstand the anticipated loads experienced for the life cycle of the well. Load cases may include: • casing running • cementing • pressure testing • hydraulic fracturing • production Whilst in exploration, produced fluids are monitored and analysed for potential corrosion. Corrosion coupons will be available to determine the corrosion rate. The well will be abandoned or workover should CO2 be present and causing higher than expected wall loss.	testing and Well Control
(c) Sections B.4.6.2 (a) and (b) do not apply to a conductor pipe.		
(d) Methods of preventing external corrosion that impact well integrity must be applied.	Wells a planned and designed to have cement returned to surface in all annuli. Where reservoirs are discovered to have corrosive fluids CO2 tolerate cement designs can be implemented	
(e) All casing and tubing must be manufactured to the latest edition of API 5CT. The rated capacity of the pipe body and connections must be obtained from the latest edition of API 5CT or the manufacturer’s technical specifications.	All OCTG are to meet API 5CT standards	
(f) Welded joints are permitted in construction of petroleum wells provided they are manufactured in compliance with API 5CT, sections 6, 7, 8, 10, and 13, and Tables C.3/E.3.	N/A - Welded joints not permitted under Origin's Casing and Tubing Standard	
(g) The yield stress of Oil Country Tubing Goods must be de-rated for temperature.	Standard temperature deration has been applied to the design (0.054% per degree)	

(h) When designing casing strings and casing connections for petroleum wells, interest holders must design each well, or similar wells, and the casing string using appropriate design safety factors. Design safety factors used must be specified in the WOMP. A generic worst case design and stress analysis may be adopted to cover multiple wells in a field development targeting the same or a similar reservoir.	All wells are design and constructed to comply with the minimum Safety Design Factors set out in the OE Casing and Tubing Standards • 1.1 for burst • 1.0 for collapse • 1.3 for static tension • 1.6 for dynamic tension • 1.25 for triaxial loads • 1.10 for axial compression	
(i) To verify casing integrity during the well construction process, casing must be pressure tested prior to drilling out for the next hole section (in the case of surface casing or intermediate casing), and prior to stimulation, diagnostic fracture injection test (DFIT), or completion operations commencing (in the case of production casing).	Casing integrity for top hole/intermediate hole sections are verified with a pressure test on plug bump. The production casing is tested to maximum allowable operating pressures. These pressure tests formulate part of the well acceptance criteria's must be met before proceed with the next programmed operation.	
(j) Interest holders must provide DPIR evidence of successful testing of the mechanical integrity of the well through pressure testing prior to hydraulic stimulation or DFIT operations.	Well integrity verification to be submitted to DPIR prior to stimulation/DFIT operations	

	B.4.7 Primary cementing		
	B.4.7.1 Principles		
	Well **cementing** is designed, installed, tested and maintained in a way that is consistent with:		
	(a) the **well integrity** management system (see section B.4.1) for the well, and;		
	(b) well design and barrier requirements set out in section B.4.3 of this Code.		
	Primary cementing of casings and/or **liner** strings is designed to:		
	(a) provide axial support for the casing string to permit further drilling and to provide an anchor for **BOP** equipment;		
	(b) reduce possibilities of casing buckling and/or collapse, particularly in situations where abnormal formation stresses occur;		
	(c) provide a seal across permeable and impermeable formations to prevent undesired flow of formation fluids and crossflow behind casing/liner;		

	(d) provide a seal to protect aquifers from contamination;		
	(e) seal off the bottom of the casing in order to control pressure; and		
	(f) provide corrosion protection, in particular such that corrosion rates of steel with an adequate cement coating are sufficiently low that cement encapsulation of steel is accepted as a permanent barrier.		
	B.4.7.2 Mandatory requirements	**Origin Implementation**	**WOMP Reference**
	(a) The constituents and properties of materials used in primary cementing must be suitable for the intended conditions of use and used in compliance with the relevant safety data sheet requirements.	Proposed slurries will be lab tested to ensure intended conditions are met and used in compliance with the relevant SDS	6.5 Cementing Program 6.15 Well Decommissioning Appendix B - Well Barriers
	(b) The cement slurry density must be designed to maintain well control, prevent gas channelling and achieve the required compressive strength while avoiding losses during cement placement.	Planned cement density will be overbalanced. A lighter cement slurry will be utilised across known loss zones. Slurry displacement modelling will be conducted and spacer train utilised to ensure optimal conditions for cement placement and strength development.	
	(c) Cement laboratory testing procedures must be carried out (as per ISO 10426-2, API RP 10B-2 - Recommended Practice for Testing Well Cements) on representative samples of the mix water, cement and additives to confirm the resulting slurry used for primary cementing meets the requirements of the well design.	Laboratory testing on cement will be carried out in accordance to ISP 10426-2 and API RP 10B-2	
	i. In the case where a number of similar wells are drilled in an area with similar well properties (depths, temperatures, and well design) and well integrity risks, constant cement materials and mix water properties, then a representative lab test is acceptible.		
	ii. The testing, as a minimum, must include slurry density, rheology, thickening time, free water, fluid loss (if required), and compressive strength development with time.		
	(d) The top of cement must be designed in accordance with Table 2.	Cement is planned to be brought to surface in all strings	
	Table 2: Primary cementing criteria		

	Property		
	Planned **Top of Cement**		
	Primary cementing criteria		
	Top of cement (TOC) to comply with barrier requirements set out in section B.4.3 of this part of this **Code** and the following minimum requirements:		
	· Conductor casing string (other than those placed by jetting or driving) **TOC** must be designed to surface.		
	· **TOC** for **surface casing** must be designed to surface.		
	· The **TOC** for any intermediate and **production casing** strings must overlap with the shoe of the previous casing string by a minimum of 200 m (656 ft).		
	· The designed TOC, if not to surface, for any intermediate or production casing strings must be determined such that it has been demonstrated that the length of the cement column will not undermine the primary cementing Principles.		
	· Where interest holders choose not to bring cement to surface, they should consider that after **decommissioning**, two adjacent cement barriers across all aquifers will be required as per B.4.15.2 d) of this **Code.**		
	· The required compressive strength slurry for fracture stimulation must be placed up to at least 150 m (500 ft) measured depth above any zone to be hydraulically fractured.		
	· On **high temperature wells** the **TOC** must be designed to mitigate against **wellhead** growth due to temperature during flow back and production		
	(e) In cases where an approved WOMP specifies that production casing will not be cemented across the production zones, production casing cement must be designed so that the base of the cement is no more than 30 m TVD above the predicted depth of the shallowest production zone.	N/A	

	(f) Unless conducting a green cement pressure test on bump, a minimum 3.5 MPa (500 psi) compressive strength on the tail cement shall be achieved prior to:	Green cement test are planned for the surface/intermediate and production hole section	
	i. pressure testing of casing; or ii. drilling out the shoe track for a subsequent hole section.	For the production casing pressure test in advance of hydraulic fracturing, a minimum of 500 psi CS will be achieved prior to conducting the test	
	(g) Casing centralisation must be designed to achieve a minimum of 70% standoff across the entire cementing interval.	Once hole section is TD, a well centralisation model is conducted to ensure a minimum of 70% standoff is achieved	
	(h) Centraliser selection must suit application (refer to API Technical Report 10TR4 Selection of Centralizers for Primary Cementing Operations).	Centralisers are selected in accordance to API Tech Report 10TR4	
	(i) Casing centralisation simulation must be undertaken for the proposed casing centralisation plan. Simulation for a vertical well must include: i. actual deviation at casing depth; or ii. where the actual deviation is not known, a deviation of three degrees from vertical at casing depth.	Once hole section is TD, a well centralisation model is conducted to ensure a minimum of 70% standoff is achieved	
	(j) Wiper plugs or cementing darts shall be used for production casing to prevent contamination of cement, and to enable plug bump and pressure test of the casing before cement cures.	Wiper plugs are planned as part of the cementing programme	
	(k) There must have be a validation procedure for primary cement jobs which must utilise at least one of the validation methods described in Table 4. If it cannot be verified that zonal isolation is achieved through primary cementing, the interest holder must submit that information,	Cement validation achieved as per below	
Job Type	***Table 4: Validation and evaluation recommendations for primary cement jobs***		
Casing cementation	**Validation Criteria**		

	• Slurry mixed and placed in accordance with approved cementation procedures. • Shoe track volume not over displaced when displacing cement slurry. • Downhole losses not greater than the excess pumped within the cement procedure, and calculated **TOC** using final circulating pressure (FCP) and measured fluid returns achieves the objective(s) identified within the cementation program. • No significant losses or slumping post-placement of cement. • Casing successfully pressure tested. • If drilling out casing, a Formation Integrity Test (FIT) satisfactory after drilling out shoe track.	Primary verification for top hold sections	
	Contingency		
	• Where the validation is inconclusive or not completed, the extension of good quality cement above the shoe, above hydrocarbons or aquifers should be verified by appropriate cement evaluation tools, interpreted by a **competent person**. • **Remedial cementing**/top-up job **cementing** as required.	CBL run planned as primary verification intermediate and production hole sections. Contingent CBL on surface hole.	
Liner cementation	**Validation Criteria**		
	• Slurry mixed and placed in accordance with approved cementation procedures. • Shoe track volume not over displaced when displacing cement slurry. • Downhole losses not greater than the excess pumped within the cement procedure, and calculated **TOC** using final circulating pressure (FCP) and measured fluid returns achieves the objective(s) identified within the cementation program. • No significant losses or slumping post-placement of cement. • Casing successfully pressure tested. • Pressure test of **liner** top **packer** should be performed and recorded to verify zonal isolation. Testing pressures should be no less than 3.5 MPa (500 psi) over the previous casing **leak-off test** at the shoe or inflow tested where practically possible	NA	

	• If drilling out casing, Formation Integrity Test (FIT) satisfactory after drilling out shoe track.		
	Contingency		
	• Where the validation is inconclusive or not completed, the extension of good quality cement above the shoe, above hydrocarbons or above aquifers should be verified by appropriate cement evaluation tools, interpreted by a **competent person**. • If failed pressure test on bump, set **liner** top **packer**, circulate out excess cement and WOC prior to conducting pressure test again. • If failure again, may opt to run a **liner** tie back **packer** on top of the **liner** top and re-test. • **Remedial cementing** if necessary.	NA	
	(l) Wait on cement time prior to slacking off or removing BOPs shall be based on the cement achieving a minimum of 700 kPa (100 psi) compressive strength at the temperature of any potential flow zone in the annulus just cemented. Alternatively, interest holders may use an annulus pack-off or mechanical barrier that is compliant with API Standard 65-2 and tested to verify a pressure seal prior to removing BOPs.	Annulus pack off installed in the annulus and will wait for 100 psi CS on the shoe track before removing BOP	
	(m) when a hydrocarbon bearing zone is intersected during drilling and subsequently cemented, a Cement Bond Log should be performed as a verification of hydraulic isolation from aquifers, the surface and other formations where cross flow is prohibited.	CBL to be conducted on all casing cement jobs for hole sections that penetrate the SRR (intermediate and production casing strings)	

	(n) Calcium chloride or other chloride-based accelerants must not be added to the cement mix unless the free water content of the cement is specified as <2%.	If implemented, will be on top up jobs for surface strings. Free water requirement will be adhered to.	
	(o) A minimum required ultimate compressive strength must be determined for cement slurries to be used across zones which may be hydraulically fracture stimulated.	HFS wells require a minimum 2000 psi unconfined UCS cement slurry	
	(p) For wells that are to be fracture stimulated, including DFIT in a cased section of a well; zonal isolation of the production casing cementation must be validated by a cement bond log which confirms at least 150 m vertical depth of good cement is in place above the any zone to be hydraulically fractured	Planning on cementing to surface, CBL to be conducted from 60deg inclination to surface	

B.4.8 Wellheads		
B.4.8.1 Principles		
The wellhead performs the general functions of:		
(a) supporting casing and completion tubing strings;		
(b) supporting the installation of surface barriers, which include the BOP during the drilling phase, and the Christmas tree during the production phase; and		
(c) providing the arrangement for sealing, testing, monitoring, injecting into, and bleeding off between annuli.		
B.4.8.2 Mandatory requirements	**Origin Implementation**	**WOMP Reference**
(a) Wellhead equipment and running tools must be specified in accordance with API Spec 6A/ISO 10423 and NACE MR0175/ISO 15156.	Wellhead equipment and running tools compliant with API spec 6A, ISO 10423 and NACE MR0175/ISO 15156 for the design life of the well. During exploration, reservoir parameters will be monitored, well design life will be de-rated where required.	6.8 Wellhead Design 6.13 Pressure Testing and Well Control 10.3 Well

(b) Wellhead and Christmas tree pressure ratings must exceed all reasonably expected loads for the entire life of the well. Wellhead product specification level (PSL) and trim must be matched to the fluid properties, pressure and temperature of flowing conditions.	• Temperature Class – U 0ºF to 250ºF • Material Class – AA General Service, Non-sour, Non-corrosive • (A-C Section) Product Specification Level (PSL) – 3 Rated WP 10,000 psi • (D- Section) Product Specification Level (PSL) – 1 Rated WP 5,000 psi • Performance Requirements (PR) – 2 Minimum API cycle testing The wellhead (A & B) sections are isolated from all reservoir fluid contact from a downhole production packer and tubing. Should well conditions change over time, the production tree can be isolated and changed out	Control Equipment
(c) Side outlet valves must be rated to the same pressure as the wellhead they are attached to. Moreover, all components on the hanger and Christmas tree and valves must be rated to the well pressure envelope.	All SOV are rated to the same pressures as the wellhead section they are attached to	
(d) Wellheads must have adequate valve outlets accessible and operational for all annuli to allow for monitoring of annuli in accordance with paragraph B.4.1.2 (c).	Wellhead design with annuli access for the following: • production tubing x production casing annulus • production x intermediate annulus • intermediate x surface annulus • surface x conductor annulus	
(e) Wellheads for high temperature wells must include design for lock down of hangers, rated for the well conditions.	N/A	
(f) Casing to wellhead pressure tests ('P' seal area or equivalent) must not exceed 80% of the collapse rating of the casing.	Casing to wellhead pressure tests are not programmed to exceed 80% of the casing collapse rating.	

(g) Any change of usage of a wellhead (i.e. to incorporate gas lift or re-injection) must be fully risk assessed ensure the compatibility of the existing equipment with the proposed usage.	N/A	

B.4.9 Well Control		
B.4.9.1 Principles		
Well control aims to reduce hazards when conducting petroleum well construction and production operations. The primary purpose of well control is to provide barriers to prevent uncontrolled release of formation fluids to surface or other formations. Well control can be categorised at two levels:		
(a) Primary well control - the maintenance of a hydrostatic pressure of fluid in the well, sufficient to balance the fluid pressure (pore pressure) in the formations drilled. In practice a defined excess hydrostatic pressure is maintained to provide a safe level of 'overbalance' to formation pressure using weighted drilling or kill fluids in most cases. Where a weighted fluid is not used, primary well control is provided by a combination of pressure and flow control equipment.		
(b) Secondary well control - used when the primary well control fails - should there be a loss of hydrostatic pressure or a situation develops where the formation pressure exceeds the hydrostatic pressure, there is the potential for influx of formation fluids into the well. If the well begins to flow, well control equipment will be in place to contain any influx of formation fluid and allow it to be safely circulated out of the well.		
The guiding principle is to maintain at least two well control barriers in place during all well operations as per section B.4.3 of this Code.		
B.4.9.2 Mandatory requirements	**Origin Implementation**	**WOMP Reference**
(a) There must be a well control manual for all phases of a well's lifecycle available for inspection at well sites (as part of or along with safety management system information), detailing requirements for equipment level, kick detection and well control techniques.	Well control documentation to be made available: • OE Well Control standard • Contractor SOPs • Well Control Bridging Document • Beetaloo Safety Management Plan	6.3 Kick Tolerance 6.13 Pressure Testing and Well Control 10.3 Well Control Equipment 14.6 Contractual Provisions / Bridging
(b) During well construction, well control equipment (e.g. BOP stack and wellhead) must be installed for all operations prior to drilling below the surface casing string. Well control equipment can be terminated once the well is decommissioned or cased and suspended after all hydrocarbon zones and aquifers are isolated and barriers established and verified.	Well control equipment will be utilised for all operations subsequent to drilling the conductor section	

(c) A gas detection system must be used on the well site to identify hydrocarbon bearing formations and potential gas influx.	The rig contractor uses a Pason system for gas detection and mud-level monitoring at relevant points around the rig and cellar. Gas detection sensors will also be replicated as part of the mudlogging service.	Document 14.12 Well Control Procedures / Multiple Contractors Appendix B - Well Barrier Diagrams
(d) Well control equipment must be used and operated compliant with API Specifications 16A, 16C and 16D.	All contracting services/well control equipment must meet the minimum requirements of Origin's Well Control Standard. Relevant section - Section 11.1 Well control equipment specification which are compliant with API Spec 16,A, 16C & 16D.	
(e) If undertaking underbalanced drilling or managed pressure drilling activities, well control measures must be in place to counter the absence of weighted drilling fluid as the primary well control method.	N/A	
(f) If undertaking underbalanced drilling or managed pressure drilling activities, Rotary Control Devices must use and operated compliant with API Specification 16RCD and non- return valves must use and operated compliant with API Specification 7NRV.	N/A	
(g) The level of well control equipment required on any operation, and the configuration employed, shall be suitable for the well.	Well control equipment requirements comply with OE Well Control Standard. Drilling, and completion/workover activities - 5Ksi Stimulation activities - 10 Ksi	
(h) Working temperature rating for well control equipment must meet the maximum anticipated continuous exposure temperature for rubber/elastomer components.	Maximum expected temperature is considered 'normal range' and well below the rating of the elastomer components.	
(i) Other than annular BOPs, all well control equipment must be rated to exceed maximum anticipated shut-in surface pressure.	See Well Barrier diagrams, high test pressures are greater than reservoir pressure	
(j) Well control equipment must be function tested and pressure tested in accordance with API Standard 53 at least every 3 weeks.	All contracted well control equipment to be compliant with OE Well Control Standard / API Standard 53	
(k) The surface gas handling system for drilling operations must be fit for purpose and used within operating limitations, that the potential risks of fire and explosion from free gas are identified and managed, and volumes of gas vented or flared are recorded in accordance with Part D of this Code.	Rig surface fluid system rated to 5,000 psi. Poorboy and vacuum degassers installed. Two-phase separator provided through third-party for formation evaluation.	

(l) Methods must be established for early identification of fluid influx (well kick).	Incorporated in Drilling Programme in accordance to: Contractor SOPs Well Control Standard Well Control Bridging Document	
(m) Regular and realistic drills pertaining to on-going or up-coming operations should be conducted to train involved personnel in detection, prevention and recovery of a lost barrier.	All contracted services and well control equipment to be compliant with OE Well Control Standard including regular well control drill requirements	
(n) Prior to drilling below the conductor casing string in exploration wells, or in development wells or appraisal wells in those areas having known shallow gas accumulations, a system shall be installed to safely divert hydrocarbons and other fluids in the event of pressurised fluids occurring below the shoe of the conductor string.	N/A	
(o) Methods must be established that prevent blowouts up the drill pipe in case unexpected subsurface pressures are encountered.	Float Valves / Stab-in Valves, etc to be used in the drill string. FOSV with appropriate X/Os positioned on the floor for use in emergency	
(p) The kick tolerance of the formation being drilled must be known. This may be demonstrated through a Formation Integrity Test or data from offset wells.	Kick tolerance analysis will be conducted for each well. LOT will be conducted on surface, intermediate and production casing and Kick Tolerance calculations updated	

B.4.10 Drilling fluids		
B.4.10.1 Principles		
The primary objectives for drilling and completion fluids are to:		
(a) maintain well integrity and meet well barrier requirements (set out in sections B.4.1 and B.4.3 of this Code respectively);		
(b) optimise hole conditions for the retrieval of quality geological and reservoir data;		
(c) minimise reservoir damage and therefore optimise well productivity; and		
(d) improve drilling performance.		
Containment of drilling fluids and additives must be considered in the well site layout (see section B.4.16) and as part of a spill management plan (section C.7.2).		
B.4.10.2 Mandatory requirements	**Origin Implementation**	**WOMP Reference**

(a) Drilling fluids must be selected and managed to ensure all products used during well operations on petroleum wells are used in accordance with the manufacturer's recommendations and relevant safety data sheets. The name, type and quantity of each chemical used on each well throughout the well construction process must be recorded.	All fluid additives are managed and used in accordance with the manufactures recommendations/SDS. All chemical usage are tracked and documented	6.4 Drilling Fluids Programme 10.4 Aquifer Protection
(b) Drilling fluids shall not contain benzene, toluene, ethylbenzene, or xylene (BTEX) above the levels prescribed in section B.5 of this Code.	Drilling and stimulation fluids/additives are screened for BTEX by an independent NATA certified lab to ensure BTEX levels are below the prescribed levels in Table 8 of section B.5 of the CoP	
(c) Testing of the active drilling fluid must be carried out in accordance with API RP 13B a minimum of twice per day.	Drilling fluids program to specify testing frequency of active drilling fluids and compliant with API RP 13B	
(d) The interest holder must implement a system for accurately monitoring drilling fluids during all drilling operations that: i. allows the determination of drilling fluid volume gains and losses; ii. allows the determination of drilling fluid volumes required to fill the hole on trips; iii. allows the determination of density in/out of the well to ensure the correct weight is being maintained to control the well; and iv. allows the monitoring and recording of gas readings in the return fluid flow once gas bearing strata are intersected.	PVT systems in place measure active fluid levels. Standard operating procedures in place (trip sheets) to monitor trip volumes.) Mud logging engineers on location to measure and record mud densities Redundant gas monitors on location to monitor gas shows in return line	
(e) The drilling fluid handling system and surface gas handling system for drilling operations must allow for the removal of gas from the drilling fluid in accordance with section B.4.9.2. (j).	Poor boy degasser and vacuum degasser system setup with the drilling rig package	
(f) The source of water used for all well operations (drilling, workover and hydraulic fracture stimulation) must be recorded.	Source water used for all regulated well activities will be recorded. Fluid sourced from onsite water bore are equipped with flow meters to actively monitor volumes	
(g) Where use of a non-aqueous drilling fluid is planned, a risk assessment must be carried out to identify all risks associated with the use of non-aqueous drilling fluid and controls put in place. Confirmation must be demonstrated that the rig is suitable for non-aqueous drilling fluid use, including:	N/A	

i. suitable seals and valves and loading/unloading hoses; and		
ii. inclusion in the spill management plan to ensure spills are contained.		
(h) At the end of every well where non-aqueous drilling fluid has been used, a summary must be prepared, reconciling whole quantities of non-aqueous drilling fluid left in the well, returned for storage/refurbishment. This information is to be included in the well completion report.	N/A	
(i) When drilling through local aquifers and until these aquifers are isolated by a minimum of two verified barriers, then:	A non toxic KCL polymer WBM is planned for all top hole section drilling operations	
i. only air, water or water-based drilling fluids are permitted to be used; and		
ii. chemicals or other substances that could leave a residual toxic effect in the aquifer shall not be added to the drilling fluid.		
(j) Where H2S is deemed likely, then:	N/A	
i. the pH of the fluid must be monitored on a regular basis (a decrease in pH may indicate H2S contamination), high pH can be used to hold the sulphides in the mud		
ii. sufficient Zinc Carbonate (ZnCO3), Zinc Oxide or Ironite Sponge must be available to treat a fluid system containing up to 500 ppm (by volume) H2S.		

B.4.11 Air and Gas Drilling Fluids		
B.4.11.1 Principles		
When planning to use air or gas as a drilling fluid, or as a component of a drilling fluid (such as mist, foam, or aerated fluids), the following are required:		
(a) well integrity must be maintained and well barrier requirements met as set out in sections B.4.1 and B.4.3 of this Code, respectively; and		
(b) hazards and risks associated with potentially flammable and/or explosive mixtures of gasses in the well or at the well site must be mitigated to acceptable levels.		
B.4.11.2 Mandatory requirements	**Origin Implementation**	**WOMP Reference**
(a) Compressors and boosters must be located to prevent the ingestion of flammable gasses from drilling activities and fuel stores.	N/A - Not currently in the well construction work scope for Kyalla SRR Wells	N/A

(b) All pressure lines and manifolds must be:		
i. identified with appropriate signage		
ii. positioned so that it does not interfere with vehicular access to the drilling location or cross areas on the drilling location frequented by vehicles and persons		
iii. constructed using hoses, pipes, fittings and connections that have a rating sufficient to withstand the maximum supply pressure		
iv. properly restrained to prevent dangerous movement in the event of coupling or hose failure		
(c) A check valve shall be installed on the delivery line at or near the standpipe.		
(d) The main air or gas supply line shall have at least two valves:		
i. one on the standpipe and accessible from the rig floor		
ii. one located at the compressors and boosters.		
iii. each valve shall be rapid acting, clearly labelled and readily accessible.		
(e) In relation to blooey, diverter or bleed-off lines:		
i. they must only be used during underbalanced driliing.		
ii. where used, they must be run to a pit or tank capable of catching any drill cuttings produced		
iii. they must extend at least 45 metres from the wellhead and shall, where practicable, be laid downwind of the well, or at right angles to the direction of the prevailing wind		
iv. they must include adequate dust suppression to reduce risks to human health and the environment to a level that is as low as reasonably practical and acceptable		
v. reservoir liquids must not be produced to the pit or tank;		
vi. any geological sample catcher installed on a blooey line shall be designed to avoid flashback and to protect persons from dust; and		

vii. a continuous purge of any blooey, diverter or bleed-off diverter line should be conducted using a primary jet during circulation, start-up and shut-down, and when making connections.		
(f) For well control during air drilling operations, all equipment shall be lined-up for a soft shut- in at all times. It is safety critical to avoid a rapid pressure build-up within the well when the well is known to contain hydrocarbons and air.		
(g) Drilling crew from the Assistant Driller and above must be well-control certified and must be trained on soft shutting techniques applicable for underbalanced drilling operations.		
(h) Explosive limits or mist injection shall be established for circulating media that can introduce O2 into the circulating system. If explosive limits are not clearly defined, systems which could introduce O2 should not be used.		
(i) Explosive limits shall be documented and posted next to the O2 monitoring system for all circulating systems that contain O2. Monitoring stations should include the rig floor, inside the substructure next to the BOP stack, and near separation vessels / storage / circulating tanks.		
(j) All gas influxes shall be checked for H2S. If any H2S is detected, the well must be circulated to a kill fluid immediately. The impact of H2S to the flammability limits (e.g., LEL) is unpredictable during reservoir inflow flush production events, therefore, with any detection of H2S air drilling operations shall be terminated.		
(k) Sufficient firefighting equipment and systems must be available at the drilling rig to extinguish an ignition at the wellhead or on the rig floor.		
(l) Enough kill fluid of sufficient density to be able to kill the well in an emergency must be available on site.		
(m) At least one portable gas detector, of a kind acceptable to an Inspector as appointed under the Petroleum Act 1984, must be available for use where air or gas drilling is in progress.		
(n) A downhole float valve must be fitted in the drilling string. Top and bottom kelly cocks must also be installed.		

(o) The rig substructure must be kept adequately ventilated (either by natural ventilation or by fans).		

B.4.12 Well evaluation, logging, testing and coring		
B.4.12.1 Principles		
In petroleum exploration and development, formation evaluation (FE) is used to characterise formation fluids and determine the ability of a well to produce petroleum. Formation evaluation seeks:		
(a) to characterize reservoir properties, including the following:		
i. petrophysical properties;		
ii. formation fluid properties;		
iii. geomechanical properties; and		
(b) to evaluate reservoir productivity.		
Cuttings samples, core samples, fluid samples and other samples from the petroleum well drilling process must be collected, stored and/or distributed according to legislative and regulatory requirements.		
B.4.12.2 Mandatory requirements	**Origin Implementation**	**WOMP Reference**
(a) Equipment must be available to attempt recovery of survey or logging equipment lost down hole.	Fishing equipment has been contracted and will be available onsite	5.5 Evaluation Plan 6.9.1 DFIT Programme 6.11 Well Test Programme
(b) If a radiation source cannot be retrieved from down hole, all relevant information must be submitted in writing and an approval must be sought in relation to disposal of a radiation source under the Radiation Protection Act 2004 (NT).	Will comply if contingency operations are required	
(c) When coring operations are conducted, the testing for gas using hand held sensors at the rig floor must be conducted while retrieving the inner core barrels as well as when opening the core barrel and examining the cores.	Gas detectors are available on the rig floor during coring operations	
(d) Well testing requirements for subsurface open hole tests are as follows:		
i. Well & tool schematic must be prepared and included in the well test program.	Production testing program will comply and address this CoP requirement	
ii. All well test equipment must be located in appropriate hazardous classification areas.	Well testing equipment will be spotted on location in appropriate hazardous classification areas	

iii. Clear and accurate definitions of temperature and pressure ratings must be provided for all surface equipment. Any pressure de-rating due to elevated temperatures must be addressed in the emergency shutdown and monitoring systems.	All surface testing equipment to be appropriately rated to the operating condition (pressure and temperature)	
iv. The line to the testing choke manifold must be rated and pressure tested to the maximum expected surface pressure as calculated from reservoir pressure less the hydrostatic of a gas column to surface plus any kill or surface treatment pressure.	All surface well testing equipment will be designed to have a rated working pressure in excess of the anticipated working pressures	
v. Pressure monitoring capability must be available at the wellhead. During the well test, actual flowing conditions must be recorded and compared to predicted values.	Pressure will be monitored at the wellhead for well testing activities	
vi. The well test surface equipment must be designed, prepared and operated in accordance with API Specification 6A, NACE MR-01-075, ASME B31.3 (Spools & X-Over).	Surface equipment to be designed, prepared and operated in accordance with API Spec 6A, NACE MR-01-75, ASME B31.3	
(e) Extended production testing (EPT) requirements:	Production testing program will comply and address this CoP requirement	
i. A production testing program must include (but is not limited to):		
a. proposed timing and duration;		
b. the equipment proposed to be used for the test including accurate flow measurement device(s);		
c. the well schematic; and		
d. the proposed method of disposal of the petroleum, produced water, flowback fluid or gas produced (see Part C of this Code).		
ii. All well test equipment must be located in appropriate hazardous classification areas.	Well testing equipment will be spotted on location in appropriate hazardous classification areas	
iii. For cased hole testing a pressure test that exceeds the maximum anticipated pressures must be completed to demonstrate mechanical integrity and define a maximum allowable operating pressure (MAOP).	All equipment will be pressure tested to establish a MAOP. The Maximum Allowable Pumping Pressure (M APP) will be set below this value	
iv. For open hole testing a pressure test to the MAOP of the pressure-exposed elements of the system must be completed.		

v. All flowlines, valves and equipment used in a production test must have a rated working pressure in excess of all anticipated pressures and must be tested and operated in accordance with relevant standards.;	All surface well testing equipment will be designed to have a rated working pressure in excess of the anticipated working pressures	
vi. Pressure monitoring capability must be available at the wellhead. During the well test, actual flowing conditions must be recorded and compared to predicted values.	Pressure will be monitored at the wellhead for well testing activities	
vii. The well test surface equipment must be designed, prepared and operated in accordance with API Specification 6A, NACE MR-01-075, ASME B31.3 (Spools & X-Over).	Surface equipment to be designed, prepared and operated in accordance with API Spec 6A, NACE MR-01-75, ASME B31.3	
(f) Diagnostic Fracture Injectivity Testing (DFIT) requirements:		
i. Pressures, rates, and volumes shall be recorded during the DFIT.	Pressure, rates and volumes are to be recorded for a DFIT	
ii. For cased hole DFITs a pressure test that exceeds the maximum anticipated pressures must be completed to demonstrate mechanical integrity and define a MAOP. Refer to B.4.6.3 (c).	All equipment will be pressure tested to establish a MAOP. The Maximum Allowable Pumping Pressure (MAPP) will be set below this value	
iii. For open hole DFITs a pressure test to the MAOP of the pressure-exposed elements of the system must be completed. Refer to B.4.6.3 (c).		

B.4.13 Hydraulic stimulation and flowback operations		
B.4.13.1 Principles		
Hydraulic fracture stimulation and flowback operations are conducted to improve or enable the recovery of hydrocarbons. Hydraulic fracture stimulation and flowback operations must seek the following:		
(a) to maximize the potential for enhanced petroleum recovery from the resource;		
(b) to ensure protection of aquifers is maintained during all operations phases for hydraulic stimulation and flowback;		
(c) to not exceed the well operating envelope and to maintain well barriers;		
(d) to flowback fluids in such a manner as to ensure all recovered flowback fluid is isolated and does not come into contact with aquifers or pollute soil or soil substrate; and		
e) to manage any gas contained within flowback fluids.		
Containment of hydraulic fracturing fluids and additives must be considered in the well site layout (see section B.4.16) and as part of wastewater management and spill management plan (see section C.7).		

B.4.13.2 Mandatory requirements	Origin Implementation	WOMP Reference
(a) Hydraulic fracture stimulation activities must be designed to not impact aquifers.	Prior to HFS activities the mechanical casing integrity if verified, a cement evaluation log is conducted to verify that a minimum of 150m of good cement is in place above the target reservoir. Geological barriers must be in place to constrain the height growth of the hydraulic fracture. Geohazards are assessed and sufficient standoff is implemented where required. For surface operations, chemical storage is bunded to prevent seepage from surface into the aquifer	
(b) Hydraulic fracturing fluid additives must be selected and managed to ensure all products used during well procedures on petroleum wells are used in accordance with the manufacturer's recommendations and relevant safety data sheets.	All fluid additives are managed and used in accordance with the manufactures recommendations/SDS	
(c) In accordance with Schedule 1, Part 2, Clause 6 and Part 3, Clause 11 of the PER, the Implementation Strategy of an EMP for petroleum activities that include hydraulic fracture stimulation must include details of monitoring and reporting of the as-pumped composition of any hydraulic fracturing fluid used. As a minimum, the following must be recorded and reported for each stage (where a stage in this context means all fluids pumped at a particular depth interval):	Pre and post stimulation volumes and additives will be disclosed, containing details of fluid volumes, additives/concentrations and water quality. In addition fluid samples at various stages of the stimulation operations will be sampled and tested for analytes at a NATA certified lab	6.9 Hydraulic Fracture Stimulation Appendix B - Well Barriers Appendix G - Well Acceptance Criteria
a. total volume of hydraulic fracturing fluid pumped,		
b. quality of water used (tested for analytes in section C.8 of this Code. Analyses do not need to be repeated if the same water source is used for multiple stages) and		
c. typical and maximum concentrations of chemicals or other substances used.		
(d) Hydraulic fracturing fluids must not contain benzene, toluene, ethylbenzene, or xylene (BTEX) above the levels prescribed in section.B.5 of this Code.	No fluid additives contain BTEX above the levels prescribed in Section B5 of this Code.	
(e) A WOMP that includes hydraulic fracture stimulation must take into account location and characteristics of known geohazards and any other wells near the well to be hydraulically stimulated.	Geohazard assessments are conducted pre and post well construction. Where potential geohazards are identified risk assessments are conducted and suitable standoffs are implemented to mitigate HFS challenges	

(f) WOMPs must demonstrate that fractures are contained within the proposed stimulation area, containing the target zone(s) and that the stimulated area and target zone(s) are sufficiently separated from aquifers.	Geomechanical models are developed to demonstrate geological stress barriers to contain fracture height growth	
(g) Well integrity must be validated before and after hydraulic fracturing operations.	All HFS wells must meet the pre/post frac WACs to demonstrate well integrity. In addition the well barrier integrity validation reports are submitted to DPIR as to the Well Barrier Integrity Validation Reporting Guideline	
(h) A pressure test that exceeds the maximum anticipated hydraulic fracture stimulation pressures at screen out conditions must be completed to demonstrate mechanical integrity and define a MAOP.	Pressure test Wellhead and production casing to 10ksi.(MAOP) Max allowable pump pressure (MAPP) during HFS will be 9.2ksi	
(i) Pressure communication between casing annuli must be monitored and controlled while conducting hydraulic fracture stimulation.	Wellhead designs allow for monitoring of annuli. Stimulation programs include real time monitoring provisions	
(j) The pressure kickout on the pump units and in-line pressure relief valves (where utilised) must be set below the MAOP.	Pump trips and in line relief valves will be set below 10,000 psi	
(k) All flowback activities must be managed to minimise the release of gas to atmosphere, in accordance with the following requirements:		
i. For exploration wells and appraisal wells and low pressure wells (including those with a low gas to oil ratio), all flowback fluid must be either:	Flowback activities are to be routed through a well completion vessel and/or a separator where gas is separated and sent to be disposed of via a flare.	
a. routed directly to a completion combustion device with a continuous ignition device (e.g. a pilot flame) or,		
b. routed to a well completion vessel and with flowback fluid sent to a separator as soon as the separator will function and then directing the separated gas to a completion combustion device with a continuous ignition device.		
ii. For all development wells undergoing hydraulic fracture stimulation, unless it is not technically feasible to do so, the operator must:	N/A - for Exploration	
a. route all saleable quality gas from the separator to a gas flow line or collection system; or-inject the gas into the well or another well;		
b. use the gas as an onsite fuel source; or use the gas for another useful purpose that a purchased fuel or raw material would serve; or		

c. where technically infeasible, direct the gas to a combustion device with a continuous ignition device		
iii. Despite condition 1 and 2 of this section, venting is only permitted during flowback activities when:	Where gas flows are insufficient to function the separator, venting may be conducted in minor volumes	
a. the gas flow is insufficient to allow the separator to function properly; or		
b. the use of a combustion device creates a fire or safety hazard or where heat emissions may negatively impact the environment		
iv. Where venting is the only technically feasible option for managing produced gas, the technical considerations preventing the use of the recovered gas must be recorded and included in the operator's annual report.		
v. Volumes of gas emitted during the separation flowback stage must be measured using direct measurement as governed under the Commonwealth National Greenhouse and Energy Reporting (Measurement) Determination (2008), and reported in accordance with Part D of this Code.	Volumes of gas produced will be measured, monitored and reported	
(l) Hydraulic fracture stimulation operations should not be conducted in a formation that does not have more than 600 m vertical separation to the nearest aquifer unless the it can be demonstrated that the risks of connectivity with the nearest aquifer is as low as reasonably practicable and acceptable.	Velkerri SRR is prognosed to have >600m vertical separation from the nearest aquifers	

B.4.14 Workover and Intervention		
B.4.14.1 Principles		
Any re-completion or well modification needs to be designed to ensure the well is operated within the maximum expected pressures and load conditions until final decommissioning. Well integrity must be maintained, as set out in section B.4.1 of this Code.		
B.4.14.2 Mandatory requirements	**Origin Implementation**	**WOMP Reference**
(a) Well barrier elements must be in place to intervene on the well during workover and intervention activities. as specified in section B.4.3 of this Code.	Well and wellhead designs allow for well barrier elements to be in place prior to re-entering a well for workover or well intervention activities.	6.14 Well Intervention 12.2 Well Barriers

(b) Fit for purpose well design and construction materials must be used workover and intervention activities as specified in this Code (sections B.4.6, B.4.7, and B.4.8).	Material selection, cement and wellhead designs will be fit for purpose for the well and comply with the NT CoP and OE well construction standards. Reservoir fluids, temperature, pressures, anticipated load conditions are assessed and factor into the design life of the well/well completion	Appendix B - Well Barriers Appendix G - Well Acceptance Criteria
(c) All new barriers or new well operating envelopes must be verified and clearly documented and reported by submission of an updated well barrier integrity validation (WBIV) report to DPIR.	All new barriers will be validated and a WBIV will be submitted to DPIR as per the Well Barrier Integrity Validating Reporting Guideline	
(d) The potential for accumulation of naturally occurring radioactive materials (NORM) in well equipment must be assessed and appropriate measures put in place to reduce risks to the health and safety of people and the environment are put in place.	During exploration NORM will be monitored. Future well interventions will be designed with appropriate measures in place to reduce HSE risk if applicable.	

B.4.15 Well suspension and decommissioning		
B.4.15.1 Principles		
The goal of well decommissioning is to permanently seal the well to prevent the flow of fluids into, out of and along the well at the end of its useful life.		
The decommissioning objectives are to ensure:		
(a) well integrity is maintained at all times, as set out in section B.4.1 of this Code;		
(b) all aquifers are isolated from the surface, each other and from permeable hydrocarbon zones;		
(c) permeable formations containing fluids at different pressure gradients and/or significantly different salinities are isolated from each other to prevent crossflow;		
(d) discrete, permeable hydrocarbon zones are isolated from each other (unless co-mingling of discrete zones is permitted), or a minimum of one well barrier is set above the shallowest co-mingled zone (if co-mingling is permitted);		
(e) all permeable hydrocarbon zones are isolated from the surface; and		
(f) the site is rehabilitated and left safe and free from contaminants as per section A.3.9 of this Code.		
Decommissioning and monitoring of decommissioned wells is conducted through a two stage process as summarized in Table 5.		
The primary considerations for suspension of a petroleum well are to ensure that:		
(a) well integrity is maintained at all times as set out in section B.4.1 of this Code;		
(b) monitoring requirements can be met and that production can readily be resumed; and		
(c) all safety requirements are met.		

<table>
<tr><th>B.4.15.2 Mandatory requirements for decommissioning wells</th><th>Origin Implementation</th><th>WOMP Reference</th></tr>
<tr><td>(a) Decommissioning and monitoring of decommissioned wells must be conducted through a two stage process, as shown in Table 5

Table 5: Two Stage Decommissioning Process
<table>
<tr><th>Stage</th><th>Description</th></tr>
<tr><td>One</td><td>• Interest holder places downhole barriers across all identified hydrocarbon bearing formations and aquifers to be zonally isolated as per section B.4.15.2.
• This includes placing of casing shoe cement plug and any cased hole plugs for permanent zonal isolation in accordance with section B.4.15.3: Cement plug requirements and validation methods..
• A surface cement plug is not placed in the well and the wellhead is not removed at this stage.
• The well is left in a state that casing annuli and casing can be monitored for pressure (i.e. verify well integrity) with all downhole barriers in place.
• Monitoring of pressures at an agreed frequency for duration of 1-6 months, depending on well risk and classification as per approved WOMP.
• Concurrently to the well integrity monitoring, the well pad may be rehabilitated as much as practicable.</td></tr>
<tr><td>Two</td><td>• On successful validation of no well integrity issues, the interest holder completes wellhead removal and surface cement plug placement as per section B.4.15.2.
• These may be rigless activities as required.
• Well status is officially changed to fully decommissioned once requirements of section B.4.15.2 are satisfied.
• Site rehabilitation may be completed.</td></tr>
</table></td>
<td>A 2 stage process is planned for all OE Beetaloo wells.

Stage One: Establish downhole barriers across hydrocarbon zones and aquifers
• Kyalla SRR to be isolated as per NT CoP Table 5: Cement plug requirements and validation methods for well decommissioning - (G) Perforated casing.
• Other potential permeable zones/different pressure regimes to be isolated as per NT CoP Table 5: Cement plug requirements and validation methods for well decommissioning - (B) Cased hole section (unperforated)
• Annular pressures will be monitored on surface for a minimum of 6 months to validate downhole decommissioning barriers

Stage Two: Surface decommissioning
• Aquifers to be isolated as per NT CoP Table 5: Cement plug requirements and validation methods for well decommissioning - Surface cement plug (50m below deepest aquifer/15m below ground level
• Wellhead removal - cut casing 1.5m below ground level and covered with a minimum 30 cm of cement
• Site rehabilitation</td>
<td>6.12 Well Suspension Programme
6.15 Well Decommissioning
Appendix B - Well Barriers
Appendix G - Well Acceptance Criteria</td></tr>
</table>

(b) Cement must be used as the primary sealing material. Cement testing must be carried out as per requirements set out in section B.4.7.2 of this Code.	Cement slurries are tested in accordance to ISO 10426-2 and API RP 10B-2	
(c) Biocide, oxygen scavenger and/or corrosion inhibitor must be used in water-based fluid used for the decommissioning process.	As a minimum biocide, oxygen scavenger / corrosion inhibitors are utilised as suspension fluids during decommissioning	
(d) All aquifers must be isolated: i. from each other and the surface by a minimum of one well barrier; and ii. from any permeable hydrocarbon bearing zones by a minimum of two well barriers.	4 string Velkerri SRR well design enables aquifers to be isolated by a minimum one well barrier (primary cement) and isolate aquifers from hydrocarbon bearing zones by a minimum of two barriers (primary cement + casing strings)	
(e) Cement plugs must conform to the requirements as detailed in section B.4.15.3: Cement plug requirements and validation methods.	The following cement plugs are to be implemented for decommissioning from NT CoP Table 5: Cement plug requirements and validation methods for well decommissioning • (B) Cased hole section (unperforated) • (G) Perforated casing. • (-) Surface Cement Plug Cement plugs to be verified as per B.4.15.2 (G) of the NT CoP	
(f) BOPs and/or the wellhead must not be removed until the cement plug across the surface casing shoe or the plug across the uppermost perforations has been verified.	Wellheads are not planned to be removed until cement barriers above upper most perforations have been verified	
(g) Cement plugs for decommissioning or suspension must be verified as follows:		
i. Off bottom open hole cement plugs are to be verified by tagging the plug with a minimum 2270 kg (5000 lb) drill string weight.	To be applied in suspension/decommissioning of vertical pilot hole section	
ii. For consecutive stacked cement plugs with the first plug set on bottom or solid base (e.g. mechanical packer, other verified cement plug) validation of the top of good quality cement to be carried out by tagging the top plug with a minimum 2270 kg (5000 lb) drill string weight. If using a sacrificial stinger to set open hole plugs, no tag is necessary where no losses are observed during cement placement.	If stacked plugs are implemented with a solid base, verification will be completed via tagging the top plug with a minimum 5000 lb.	

iii. For a cased hole cement plug with the bottom of the plug exposed to open hole validation is to be done by tagging the top plug with a minimum 2270 kg (5000 lb) drill string weight and by pressure testing to 3.5 MPa (500 psi) above the estimated (or previously recorded) leak-off pressure (within the limits of the casing and wellhead pressure ratings).	N/A		
iv. For a cased hole cement plug supported by a pressure tested bridge plug, validation may be by post cement job report and calculations, or by tagging the plug with a minimum 2270 kg (5000 lb) drill string weight.	Where pressure tested mechanical plugs are implemented to support a cement plug, validation will be achieved via successful cement displacement		
v. For an unsupported cased hole cement plug barrier not exposed to open hole below, validation is to be done by tagging the plug with a minimum 2270 kg (5000 lb) drill string weight.	Where cased hole cement plug barriers are placed, validation will be achieved via tagging plug with 5000 lb string weight		
vi. For a final surface cement plug extending from ground level no validation is required. A shallow set plug is not considered a permanent barrier given the very low formation pressures at ground level. Well barriers are to be established with the plugs below the surface cement plug.	Surface cement plugs are not considered a barrier in the Velkerri decommissioning design		
vii. When a sacrificial string is used to place a cement plug, validation may be via a combination of: a. pressure testing to confirm isolation; and b. validation of the conduct of the cement job.	A plugged off packer and tail pipe assembly may be utilised as a base mechanical barrier to support a cement plug. Where this is conducted the sacrificial string must be successfully pressure tested prior to spotting cement		
(h) Prior to wellhead removal, zero pressure on any casing or annulus must be confirmed. Wellheads must be removed, and casing must be cut as per Case: Surface cement plug detailed in B.4.15.3: Cement plug requirements and validation methods.	Prior to wellhead removal, a minimum of 6 months of annuli pressure monitoring is conducted to verify zero pressure is present at surface		
(i) A steel marker plate cut from corrosion resistant alloy or similar grade steel for corrosive environments must be installed after the wellhead has been cut off detailing the following: i. the identifying name of the well or bore;	After the wellhead has been cut and capped, steal marker plate will be installed as per the requirements of B.4.15.2 (i)		

ii. the total depth in metres of the well or bore;		
iii. the date the well or bore was decommissioned; and		
iv. the marker plate shall be covered with soil to ground level.		
(j) Complete and accurate records of the entire decommissioning procedure must be kept, with these records submitted as part of the legislative reporting requirements for the decommissioning of petroleum wells.	Daily drilling/completion reports and well pressure monitoring records are maintained and to be submitted as part of the well completion report in accordance to Section 314 of the Schedule of onshore petroleum exploration and production requirements and Section 76 of the Act	
(k) The potential for accumulation of NORM in well equipment must be assessed and appropriate measures put in place to reduce risks to the health and safety of people and the environment.	On going NORMs monitoring will be conducted. If required, control measures will be implemented to reduced risk to the health and safety of people and the environment	

B.4.16 Site Material and Fluids Management		
B.4.16.1 Principles		
The well site should be laid out to minimise the potential for harm to others and the environment.		
B.4.16.2 Mandatory requirements	**Origin Implementation**	**WOMP Reference**
(a) The well site must be selected and designed in accordance with Part A of this Code.	Well sites are selected and designed in accordance to Part A of the CoP	
(b) The well site must be designed and operated to minimise the risk of causing a fire on the well site or in the surrounding environment.	Well sites are designed and operated to minimise the risks of fire. Fire mitigation plans may include • robust monitoring of seasonal conditions and fuel loads; • maintenance of fire access trails; • maintenance of fire breaks around infrastructure; • appropriate fire control measures on location; • planned well/equipment spacing and stand off to mitigate risk of ignition	6.4 Drilling Fluids Programme 6.9 Hydraulic Fracture Stimulation 6.11 Well Test Program

(c) The well site must be clearly identified in a permanent manner with the well name, well number, major hazards and details of the interest holder.	Each well site will be appropriately signed with the following: • Well name • Details of interest holder • Description Hazards where applicable • Details of PIC where applicable	
(d) The name of the person-in-charge of any active well operations must be displayed in writing at all approaches to the well site.		
(e) The well must be adequately secured to prevent access by wildlife.	The well site will be equipped with stock proof fencing and constructed with earthen berm around the perimeter of the lease to prevent access by wild life. Drilling sumps when not in use will be fenced to prevent fauna access. Wastewater tank height is >2m preventing fauna access.	
(f) The well site must be designed and operated to minimise the potential for releases of contaminants to the environment and the impacts of such a release.	Chemicals and produced fluids are stored in accordance with B.4.16.2(i) The well pad is compacted with an earthen berm around the perimeter to minimise the potential release of contaminants to the environment	
(g) An assessment must be carried out as to whether any materials (solid or liquid) used on, or produced at, a well site could be considered to be, or to contain, hazardous chemicals or those that may cause environmental harm. The outcomes of this assessment must be described in the spill management plan, as outlined in Part C of this Code.	A chemical risk assessment has been conducted on all proposed drilling/stimulation additives and on anticipated flowback composition by an independent third party. Controls measures are documented in the associated spill management plan	
(h) Use, storage and handling of materials on site must be conducted in accordance with section A.3.8 and Part C of this Code, and:		

i. secondary containment must be instituted on areas of the well site where any hazardous chemicals or those that may cause environmental harm are to be stored or handled during all well operations.	**Hazardous Chemicals:** • Stored on location with secondary containment compliant to the section A.3.8 of the CoP **Flowback/Produced fluids management:** • Stored in dual lined enclosed above ground tanks. • Open top tanks with sufficient freeboard will be implemented where flowback fluids are being treated via evaporation. • Freeboard requirements are based on 1:1000 ARI rainfall for the duration the open tank is in operation. Freeboard requirements will be assessed for each well pad location. • Sufficient fluid transfer ability will be on location to transfer fluids out of the open top pond into enclosed storage at least 8 hours prior to any significant storm event • Sufficient covered storage volume available on location at all times to transfer fluid from open tanks to enclosed tanks **Hydrocarbon management:** • Stored in double lined tanks • Disposed of on location via flare	
ii. areas where any hazardous chemicals or those that may cause environmental harm are to be stored or handled must be lined to be sufficiently impervious and able to contain spilled material or waste until it can be removed or treated. This lining may be a geomembrane or a suitably constructed clay liner.	Well sites are designed and constructed with a sufficient quantity of clay to enable spill containment until it can be removed or treated	

B.4.16 Ground Water Monitoring		
B.4.17.1 Principles		

Groundwater is a key environmental receptor in onshore petroleum exploration and development in the Northern Territory. Groundwater monitoring serves as a signal to differentiate natural and human-induced perturbations in the well pad area. Where an impact is detected, further investigation is required and any necessary remediation is undertaken to ensure water quality guidelines are met.

B.4.17.2 Mandatory requirements	**Origin Implementation**	**WOMP Reference**
(a) An accurate understanding must be gained of what aquifers exist at the well site and their depth from surface, and their relationships to each other and other hydro-stratigraphic units during the well design phase.	Desktop studies and assessments regional water bores are conducted, in addition to data collected from water impact monitoring bores drilled within 100m downstream of the petroleum bore are used to identify aquifers	5.6 Ground Water Monitoring
(b) Where there is an intention to hydraulically fracture the well(s) at a well site:		
i. At least six months of local baseline data for water quality indicators of the key aquifers that may be affected by the activity must be acquired:	Control water monitoring bores are planned to be drilled 6 months prior to drilling the petroleum bore. Where this is not achievable (due to circumstances outside the control of the interest holder), bores will be drilled 6 months prior to HFS as approved upon by the regulator. Water quality indicators are monitored as per **Table 6 of CoP:** Minimum suite of analytes for groundwater monitoring	
a) prior to drilling the well(s); or		
b) prior to hydraulic fracturing where six months monitoring data from the control bore is not achievable before drilling due to circumstances that lie outside of the control of the interest holder;		
c) the minimum suite of water quality indicators to be monitored are listed in Table 7, however monitoring of additional water quality indicators may be necessary based on the interest holder's risk assessment conducted for an EMP.		
ii. Electrical conductivity data from the monitoring bore(s) must be measured as soon as practicable after the completion of construction of the monitoring bore (s) until decommissioning of all wells on the well site. Results submitted to the regulator:	Electrical conductivity data will be collected and reported quarterly, a minimum of 6 months prior to stimulation, 3 month post stimulation and annually for the remaining life of the wells on the lease pad	
a) by electronic means from the well site as soon as they are available; or		
b) if the requirement in a) is unachievable to implement in the first stages of exploration, an alternative plan and timetable may be proposed before hydraulic fracturing commences, detailing how electrical conductivity information will be regularly submitted.		

(c) Any guidelines published by the Northern Territory Government from time to time relating to groundwater monitoring parameters, methodologies and frequencies for petroleum operations must be followed. This includes the Preliminary Guideline: Groundwater Monitoring Bores for Exploration Petroleum Wells in the Beetaloo Sub-basin.	OE to comply with all guidelines published by the Northern Territory Government	
(d) Any guidelines published by the Northern Territory Government from time to time relating to reporting and data submission, and groundwater monitoring data standards must be followed.		
(e) In karstic groundwater terrain, which is common in the Northern Territory, a precautionary stratigraphic bore hole (which potentially can be used as a water production bore) to the base of the deepest recognised aquifer may be required at the well pad for an accurate understanding of what aquifers and potential geohazards, if any, exist at the site and their depth from surface.	In regions of karstic groundwater terrain, data collected from control water monitoring bores are utilised to assess aquifers and geohazards around the wellpad region	
(f) Records must be maintained for each well, or group of similar wells, if grouping the wells is appropriate given their similarity.	OE to maintain records for well or group of wells	

B.5 BTEX Limits		
Benzene, toluene, ethylbenzene, or xylene (BTEX) are only permissible in drilling or fracturing fluids, at or below the levels prescribed and when it is either,		
• Naturally occurring in water used to make up the drilling or fracturing fluid • Present as a contaminant in chemicals or other substances used in drilling or stimulation fluids and has no beneficial use		
• Present as a contaminant in chemicals or other substances used in drilling or stimulation fluids and has no beneficial use		
B.5.1.1 Drilling and stimulation fluid chemical additives	**Origin Implementation**	**WOMP Reference**
(a) The combined chemicals or other substances used at their maximum possible concentrations for a particular drilling or stimulation fluid cannot increase BTEX levels of the overall fluid above the BTEX content of the base water of the fluid by more than those levels prescribed in Table 8.	Drilling and stimulation fluids/additives are screened for BTEX by an independent NATA certified lab to ensure BTEX levels are below the prescribed levels in Table 8	6.4 Drilling Fluids Programme 6.9 Hydraulic Fracture Stimulation
Table 8:BTEX Levels in drilling fluids when drilling through local aquifers.		

Compound	Maximum Level (ppb or µg/L)
benzene	1*
toluene	180#
ethylbenzene	80#
xylene	200#

*From Version 3.5 of the Australian Drinking Water Guidelines Paper 6 National Water Quality Management Strategy. National Health and Medical Research Council, National Resource Management Ministerial Council, Commonwealth of Australia, Canberra as updated in August 2011. # Australian and New Zealand Environment Conservation Council Environmental Protection Guidelines (ANZECC 2000) 99% protection level.

B.5.1.2 Recycled produced water and flowback fluid	Origin Implementation	WOMP Reference
(a) Produced water or flowback fluid used in drilling fluids or stimulation fluids must not contain BTEX at levels greater than those expected in water produced (including flowback) from the well being drilled. (b) In the event BTEX levels expected in produced water or flowback fluid from the well being drilled are not known, then the BTEX levels in water used for drilling fluids or stimulation fluid cannot exceed the levels prescribed in Table 9	N/A For the initial exploration drilling/stimulation operations, it is not anticipated that flowback/produced fluids are re-used for drilling/stimulation fluid make up. For future operations where recycled fluid is utilised, BTEX levels are to be monitored and comply with the prescribed maximum levels in the CoP	N/A

Table 9: BTEX Levels in water used for stimulation and drilling fluids.

Compound	Maximum Level (ppb or µg/L)
benzene	600#
toluene	180#
ethylbenzene	80#
xylene	200#

 # Australian and New Zealand Environment Conservation Council Environmental Protection Guidelines (ANZECC 2000)
99% protection level.

B.5.1.3 BTEX levels in drilling fluids when drilling through local aquifers	Origin Implementation	WOMP Reference
(a) Despite sections B.5.1.1 and B.5.1.2 and pursuant to section B.4.10.2 (i) of this Code, drilling fluids used to drill through aquifers and until these aquifers are isolated by a minimum of one verified well barriers cannot contain BTEX levels at the greater of, i. minimum BTEX levels in the local aquifers; or ii. The levels listed in Table 8	Drilling fluids planned for the top hole section are verified to be compliant with the prescribed BTEX level in the CoP	6.4 Drilling Fluids Programme

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Appendix U Public Submission comment summary

Comment number	Date	Comment summary/key points	Origin reply	EMP Changes proposed by Origin
1	8/10/2019	I have recently become aware of your plans to drill 300km South East of Katherine. As you may be aware many areas in the Northern Territory and Australia are in extreme drought. New water extraction for oil and gas fracking - an industry whose pollution will make the problem worse by fuelling a warming climate and more extreme weather, is unacceptable. It is unfair to expose surrounding communities to this, who are already suffering acute health problems relating to climate. Further pollution and waste from fracking will only exacerbate these issues. Your plans are unfair and inhumane. Traditional owners are being excluded from meetings regarding such plans, giving them no say in what will be happening in their community, let alone the chance to suggest strategies that will help protect their environment. I urge you to consider the perspectives of Traditional owners and put a stop to harmful developments. Considering the current position of	1. The impacts associated with hydraulic fracturing, including groundwater contamination, have been rigorously investigated as a part of the NT Scientific Inquiry into Hydraulic Fracturing. The NTG has implemented a range of recommendations, which have been implemented through changes to the NT Water Act and Code of Practice for Onshore Petroleum Activities in the NT. 2. Natural gas is a recognised transition fuel that compliments and facilitates the adoption of low carbon energy sources. 3. Traditional Owner engagement has been completed through the Northern Land Council. The determined Traditional Owners of the area of Origin's activities have given informed consent. This information has been provided in the EMP.	None- The EMP sufficiently addresses these concerns.

Comment number	Date	Comment summary/key points	Origin reply	EMP Changes proposed by Origin
		Australia, and the world in terms of global warming and harmful emissions, fracking is just not acceptable.		
2	30/10/2019	Will destroy songlines and country that they have cared for since time immemorial. Will place peiole and water supplies at risk. Further impacts climate change fracking will reduce the availability of groundwater for traditional owners and local communities as the climate crisis continues and Petroleum companies have failed to properly consult with the region's traditional owners, fracking has begun without true consent of clan/	1. The site and associated activities have obtained NLC clearances with the determined Traditional Owners of the area, with Aboriginal Area Protection Authority (AAPA) certificates granted for all activities. This information was provided in the EMP. 2. The use of groundwater and its potential impact on users has been thoroughly assessed as a part of the Water Extraction Licence. Impacts on current and future users was assessed and not anticipated. The Water Extraction Licence Statement of Reason was provided in the EMP.	None- The EMP sufficiently addresses these concerns.

Comment number	Date	Comment summary/key points	Origin reply	EMP Changes proposed by Origin
		Nations groups in the NT -->cultural genocide.		
3	30/10/2019	To whom it may concern. You lot need to stop now . You know it is risky yet you still want to go ahead with it. You should be charged with crimes against humanity . Stick with conventional gas extraction . I will no longer by any origin product . Shame on you all. Regards Bryan Wilkins .non greeny but concerned grandparent	1. The impacts associated with hydraulic fracturing, including groundwater contamination, have been rigorously investigated as a part of the NT Scientific Inquiry into Hydraulic Fracturing. The inquiry has implemented a range of recommendations, which have been implemented through changes to the NT Water Act and Code of Practice for Onshore Petroleum Activities in the NT.	None- The EMP sufficiently addresses these concerns.
4	30/10/2019	Fails to align with principles of ESD - principle of inter-generational equity, intra-generation equity and polluter pays. Climate change & fugitive emissions. Fails to adequately address scientific uncertainty re current industry knowledge gaps. Lack of details for management and storage for flowback fluids. Lack of information on transferring waste into enclosed tanks in wet season.	1. Flowback management, including transfer details have been adequately addressed in the Wastewater Management Plan and section 3.11 of the EMP. Timelines for when flowback will be managed are provided throughout the EMP, including section 3.11.4 and section 3.28. 2. Fugitive emissions is a category of emissions that includes flaring, venting and leaks. These have been included in section 3.13	Minor- Minor additional information has been added to the EMP and Wastewater management plan to address the comments posed.

Comment number	Date	Comment summary/key points	Origin reply	EMP Changes proposed by Origin
			3. The transfer of wastewater is covered in the wastewater management plan and section 3.11 of the EMP. 4. Origin's activities align with the principles of ESD as outlined through the document. Origin has identified comprehensive controls to ensure the risk to current and future generations is minimised. This includes assessing water take, implementing appropriate well integrity, use of reduced emission completions, implementation of wastewater and spill management plans and ongoing Traditional Owner Engagement 5. Flowback management, including transfer details have been adequately addressed in the Wastewater Management Plan and section 3.11 of the EMP. 6. Natural gas is a recognised transition fuel that compliments and facilitates the adoption of low carbon energy sources. Fugitive emissions have been accounted for in section 3.13 of the EMP.	

Comment number	Date	Comment summary/key points	Origin reply	EMP Changes proposed by Origin
5	31/10/2019	If this project goes ahead it will produce unacceptable levels of climate polluting gases, even if all the fugitive gases are somehow controlled and the wells capped forever. It is known that well integrity is impossible to maintain for the periods required to prevent the levels of fugitive emissions that the fracking industry is reknown for around the globe. Projects like this that contribute enormously to climate change have no social licence, elevate social unrest and cultural diminishment. Regulatory processes are mere red tape and might as well be abolished for they are mere deckchairs on the titanic. The levels of clean water that are expected to wasted for this project and allowed to become polluted by chemicals that are unmanageable in a place that suffers both long dry periods as well as extensive flooding. On all fronts, this project should be rejected: it is expected to contribute to death of humans, native animals, plants, as well as loss of clean water, soil air, quietness, truck-free roads, beautiful sscenery, and a diminshment of society and ancient (yet still current and precious) cultural knowledge and	1. The comments are general in nature, not specific and not based upon sound scientific or factual reasoning. 2. The report attached from Professor Ian Lowe is alarmist and not constrained by reality. The report selects data that aligns with their agenda, rather than the weight of scientific evidence. Leakage rates are extreme and do not represent Australian research completed by CSIRO. The potential size of the resource has also been overstated.	None- The EMP sufficiently addresses these concerns.

Comment number	Date	Comment summary/key points	Origin reply	EMP Changes proposed by Origin
		practices. Allowing projects like this to go ahead will contribute to suicide. The Traditional Custodians have been clear they do not give consent for this project to happen. All who contribute to allowing this and other similar projects to happen contribute to annhilation of our beloved NT and its peoples.		
6	31/10/2010	Not possible to use this mining process without risks of leakage; methane into the atmosphere and chemicals into the subterranean environment. Risk to potable water is unacceptable. Contributes to climate change. You don't have a workforce you need to transition, you don't have infrastructure to decommission, you haven't made a negative impact on the current and future generations. No national offset policy the potential emissions from the natural gas industry.	1. The impacts associated with hydraulic fracturing, including groundwater contamination, have been rigorously investigated as a part of the NT Scientific Inquiry into Hydraulic Fracturing. The NTG has implemented a range of recommendations, which have been implemented through changes to the NT Water Act and Code of Practice for Onshore Petroleum Activities in the NT.	None- The EMP sufficiently addresses these concerns.

Comment number	Date	Comment summary/key points	Origin reply	EMP Changes proposed by Origin
			2. Natural gas is a recognised transition fuel that compliments and facilitates the adoption of low carbon energy sources.	
7	31/10/2019	Even if we are told the chance of contamination is low when we factor in the level damage this contamination could do, displacing entire townships in the NT and ruining NT agriculture. The flow on costs that the NT will have to bare in the future are astronomical. As a born and bred Alice Springs local, I object the proposal from origin and I ask you to please not risk the NT for something as trivial as gas profit. Yours sincerely Ross Grant Brown	The comments are not based upon sound scientific or factual reasoning.	None- The EMP sufficiently addresses these concerns.

Comment number	Date	Comment summary/key points	Origin reply	EMP Changes proposed by Origin
8	31/10/2019	This submission to be lodged as an official objection on the following grounds: 1) The EMP authorises the use of open waste-water storage tanks in direct defiance of recommendation 7.12 from the Fracking Inquiry. 2) There is no information provided on how emissions, including fugitive emissions will be offset as required by recommendation 9.8 from the Fracking Inquiry. 3) Hydraulic stimulation should not be conducted over the wet season because of the high risk of flooding and extreme weather that will be impossible to accurately predict. This risk is simply too great and should operationalise the precautionary principle. 4) The uncertainty around baseline groundwater information, acknowledged by the Fracking Inquiry has not been addressed. No fracking should commence unless this information has been developed by comprehensive and long-term baseline groundwater studies. STOP FRACKING. DON"T FRACK. its not your land to destroy	1- Origin uses a combination of open and enclosed tanks, in compliance with the NT code of Practice for Onshore Petroleum Activities. 2- The implementation of recommendation 9.8 was identified by the inquiry as being required before production, not exploration. Please refer to section 16.3.1 of the final inquiry report (https://frackinginquiry.nt.gov.au/inquiry-reports?a=494302)The comments are not based upon sound scientific or factual reasoning. The risk associated with flooding and wet season operations have been addressed throughout the EMP. 3. Baseline groundwater monitoring data is being collected and is being submitted to the government. This process for collecting data is provided in section 3.26 of the EMP. Origin has collected additional information, such as the installation of groundwater monitoring bores around the lease, to ensure groundwater is protected and any potential impacts detected. The uncertainty around the groundwater resource identified by the inquiry is in regards to a full production scenario- something for which will be addressed in the SREBA and ongoing CSIRO work. The inquiry comment is regarding the potential impacts of a full-scale development..	None- The EMP sufficiently addresses these concerns.

Comment number	Date	Comment summary/key points	Origin reply	EMP Changes proposed by Origin
9	31/10/2019	As per submission 8		None- The EMP sufficiently addresses these concerns.
10	31/10/2019	As per submission 8		None- The EMP sufficiently addresses these concerns.
11	1/11/2019	As per submission 8		None- The EMP sufficiently addresses these concerns.
12	1/11/2019	As per submission 8		None- The EMP sufficiently addresses these concerns.

Comment number	Date	Comment summary/key points	Origin reply	EMP Changes proposed by Origin
13	1/11/2019	As per submission 8		None- The EMP sufficiently addresses these concerns.
14	1/11/2019	Lack of consent and lack of acknowledgement of the concerns and objections of TOs. - Risks associated with hydraulic fracturing activities were not explained in full as part of negotiations for land access. - The failure of the NT Government to enact the recommendation 7.12 enclosed tanks. - The flagrant disregard for the increased risks of operating during the wet season. - Limited attempts to undertake a scientific understanding of the position of this proposed well in relation to the Lake Woods catchment. - The failure of the chemical analysis to expose the harmful chemicals in the patented fracking fluids. - The failure of the risk assessments to consider in detail the drilling through the highly pressurized, deep and salty Moroak aquifer, and the long-term risks. - Origin's activities to attempt to force access onto neighboring cattle stations for exploration works, before improved landholder negotiation rights are in	1. Traditional Owner engagement has been completed through the Northern Land Council. The determined Traditional Owners of the area of Origin's activities have given informed consent. This information has been provided in the EMP. 2. Origin, as illustrated in Appendix K, has complied with the Petroleum (Environment) Regulations. A land access agreement has been signed with the Pastoralist who own the lease for the property. 3. Origin uses a combination of open and enclosed tanks, in compliance with the NT code of Practice for Onshore Petroleum Activities. 4. Wet season operation risks are provided in section 3.22 and Section 6, noting stimulation activities are not proposed to be undertaken in the Wet season. 5. The proximity of the activity in regards to Lake woods has been considered in section 3.2 of the EMP. Lake wood sis approximately 120km from the proposed activity. 6. All chemicals are assessed during the risk assessment- proprietary chemicals are not disclosed to the public, but are assessed.	- Minor additional information has been added to the EMP and Wastewater management plan to address the comments posed.

Comment number	Date	Comment summary/key points	Origin reply	EMP Changes proposed by Origin
		place. - The failure of the NT Government to enact any credible climate position. - There are concerns about the waste transport to Qld. - The failure of the NT Government to properly consider and make meaningful improvements in light of the concerns raised with Origin's Kyalla Drilling and Hydraulic Fracturing 2019 Program EP117 N2 proposal.	7. The formation pressure and chemistry is considered during the design and construction of the well, as discussed in section 3.3 of the EMP. Each formation has a specific risk profile which needs to be considered during the design; not just the Moroak. A Moroak inflow tests was completed on the Elliot-1 and Ronald-1 wells, with the test terminating before flowing to surface. This indicating the reservoir has no hydraulic head (i.e. are not artesian). The fluid is approximately 200000ppm NACL which is approximately 5x the concentration of sea water and of no use for agricultural applications. The absence of hydraulic head and the density of the fluid prevent fluids mixing with surface aquifers. 8. Origin has been in negotiations with the host pastoralists since mid 2018 in regards to his program. Origin has conducted all activities lawfully, through detailed engagement. 9. Waste transportation between states is a standard activity legislated under the National Environmental Protection (Movement of Controlled Waste) Measure. This legislation has been adopted by all States and Territories, and provides the framework for interstate waste transportation. The facility in QLD is	

Comment number	Date	Comment summary/key points	Origin reply	EMP Changes proposed by Origin
			licenced to take the waste, in accordance with the Queensland Environmental Protection Act. Any concerns regarding this facility should be raised with the Queensland EPA. 10. "The failure of the NT Government to properly consider and make meaningful improvements in light of the concerns raised with Origin's Kyalla Drilling and Hydraulic Fracturing 2019 Program EP117 N2 proposal.:- Origin in good faith has addressed all relevant comments. In some cases, comments have not been constrained by fact or reality- this means addressing such comments to the satisfaction of all parties is extremely difficult.	
15	1/11/2019	Emission of greenhouse gases is a very serious environmental issue and in contradiction to recommendation 9.8. The proposal includes handling waste water in a mix of open and enclosed structures - contradicts recommendation 7.12. Uncertainty regards baseline groundwater information has not been addressed and to accord with the spirit of the Fracking Enquiry.	The implementation of recommendation 9.8 was identified by the inquiry as being required before production, not exploration. Please refer to section 16.3.1 of the final inquiry report (https://frackinginquiry.nt.gov.au/inquiry-reports?a=494302) All weeds are to be mapped- with management response on high risk declared weeds.	None- The EMP sufficiently addresses these concerns.

Comment number	Date	Comment summary/key points	Origin reply	EMP Changes proposed by Origin
		The focus on declared weeds means that environmental weeds have not been given the attention they require to manage the potential adverse environmental outcomes of the project - e.g. "buffel".		
16	1/11/2019	As per submission 8		None- The EMP sufficiently addresses these concerns.
17	1/11/2019	Projections from the NT Government are that emissions will peak after 2030, rising from 16.5MT CO2e per annum to a projected 25MT CO2e per annum. Traditional Owners stating that fracking is risky, polluting, invasive, and unnecessary and should not go ahead in the NT.	Traditional Owner engagement has been completed through the Northern Land Council. The determined Traditional Owners of the area of Origin's activities have given infomred consent. This information has been provided in the EMP.	None- The EMP sufficiently addresses these concerns.
18	1/11/2019	All hydraulic fracturing is sub-economic. It is a ponzi scheme and we will end up with terrible destruction. All leak. All pipelines servicing fractured infrastructure leak. All destroy the water; the underground water from the drilling and fracturing, and the surface water from what they do with the water they pump up from deep underground and then leave on the surface in various ways.	The comments are general in nature, not specific and not based upon sound scientific or factual reasoning.	None- The EMP sufficiently addresses these concerns.

Comment number	Date	Comment summary/key points	Origin reply	EMP Changes proposed by Origin
19	1/11/2019	As per submission 8		None- The EMP sufficiently addresses these concerns.
20	1/11/2019	Flow back fluid and waste water management - transferring waste water between tanks; birds landing on tanks; mechanical failure Greenhouse emissions - no offsets; cumulative impacts from emissions; fugitive emissions polluter pays - intergenerational equity; reahb costs Water - additional bores and licencing; recycling of water	1. The risk to birds have been outlined in section 3.11.3. this includes a detailed monitoring program. 2. Wastewater 3. The implementation of recommendation 9.8 was identified by the inquiry as being required before production, not exploration. Please refer to section 16.3.1 of the final inquiry report (https://frackinginquiry.nt.gov.au/inquiry-reports?a=494302)The comments are not based upon sound scientific or factual reasoning. The risk associated with flooding and wet season operations have been addressed throughout the EMP. 4. Discussions surrounding why birds will not consume wastewater has been provided in section 3.11.3 of the EMP. Information on the likely chemical composition has been provided, with the salinity of the effluent likely to be a deterrent. 5. Additional information on the wastewater transfer processes have been added to the EMP. 6. The site will have significant redundant pumping capacity and pump spares to ensure mechanical failures do not impair pumping capacity	- Minor additional information has been added to the EMP and Wastewater management plan to address the comments posed.

Comment number	Date	Comment summary/key points	Origin reply	EMP Changes proposed by Origin
			7. Fugitive emissions is a category of emissions that includes flaring, venting and leaks. These have been included in section 3.13 8. Cumulative GHG emissions from other Origin activities are included in Table 12. This includes emissions from the other Origin location Kyalla 117. 9. The implementation of recommendation 9.8 (GHG offsets) was identified by the inquiry as being required before production, not exploration. Please refer to section 16.3.1 of the final inquiry report (https://frackinginquiry.nt.gov.au/inquiry-reports?a=494302) 10. Development scenario- Natural gas is a well recognised transition fuel that will be critical to ensure the reliability of renewable energy supply. The increase in natural gas emissions has played a large role in reducing the emissions in the US as it displaces coal for power generation. 11. Precautionary principle- Origin has collected additional information, such as the installation of groundwater monitoring bores around the lease, to ensure groundwater is protected and any potential impacts detected. The uncertainty around the groundwater resource identified by the inquiry is in regards to a full production scenario-	

Comment number	Date	Comment summary/key points	Origin reply	EMP Changes proposed by Origin
			something for which will be addressed in the SREBA and ongoing CSIRO work. The inquiry comment isn't specifically for small scale exploration activities. 12. The economic benefits of an onshore gas development are significant, as demonstrated in QLD communities. Comments regarding lack of economic benefits of local communities are not based upon fact and are often (if not entirely) made by people outside of the local communities. 13. Profitability: The purpose of exploration is to determine commercial viability. Comments regarding profitability are not based on facts. 14. Origin is required to have security provisions in place for all wells and disturbance created. This can only be handed back once rehabilitation has occurred. 15. A provision for an a additional 2 bores was added in case the yield of the aquifers in the vicinity of the lease were unable to support the activities. This is not the case and the need for additional bores are unlikely. The number of bores and total take is not related. 16. The "pressure testing activity" is a well integrity check and not hydraulic fracturing.	

Comment number	Date	Comment summary/key points	Origin reply	EMP Changes proposed by Origin
21	1/11/2019	As per submission 8		None- The EMP sufficiently addresses these concerns.
22	1/11/2019	As per submission 8		None- The EMP sufficiently addresses these concerns.
23	1/11/2019	FRACKING SUBSTANCES are harmful to health. The OPEN AIR WASTEWATER TANKS POSE UNACCEPTABLE RISK to the incredible threatened birdlife that visits the site, including the Gouldian Finch. WET SEASON RISKS WITH WASTE ON SITE It is deeply concerning that instead of storing toxic wastewater in enclosed tanks; could cause downstream pollution impacts to Lake Woods,. TRANSPORT RISKS AND TOURISM IMPACTS Origin says they care about cumulative impacts, but have failed to talk to tourism operators about the risks of increased traffic on the Stuart Highway, or to people living downstream from their fracking exploration activities.	1. All chemical substances are harmful to health if used incorrectly. This is referred to as a "hazard". The "risk" of harm to human health is determined through the combination of the hazard and credible exposure pathways. Origin has outlined the various strategies to prevent the hazards to people and the environment. These approaches are enshrined in various chemical handling standards and legislation, as well as the NT Code of Practice for Onshore Petroleum Activities. 2. The storage of flowback fluid is undertaken in accordance with the Code of Practice for Onshore Petroleum Activities within the Northern Territory 3. Transport Risk and Tourism risk- the activity, as outlined in section 3.2, is not	None- The EMP sufficiently addresses these concerns.

Comment number	Date	Comment summary/key points	Origin reply	EMP Changes proposed by Origin
		BUSHFIRE RISKS AND TOTAL FIRE BAN DAYS This area is sensitive to bushfires. Rural Fire Brigades have been calling for gas companies to stop ignition sources and flaring on total fire ban days. Origin must be made to stop all flaring on total fire ban days.	located in proximity to any tourist areas. The site is located 100km form the Stuart highway. The number of heavy vehicle movements required during the activity is provided in section 3.23. The traffic associated with Origin's activities is small and will not impact the aesthetics of the area.	
24	1/11/2019	As per submission 8		None- The EMP sufficiently addresses these concerns.
25	1/11/2019	Please provide a clear conceptual site model identifying all contaminants of concern and their potential human health and environmental impacts.	Conceptual diagrams of the site, including underlying geology and the various activity layouts are provided in figure 5, Figure 8, figure 12, figure 34. Chemical exposure pathways are provided in Table 7.	None- The EMP sufficiently addresses these concerns.
26	1/11/2019	• Failure to properly consult • Failure to consider climate change • Corporate history • Lake woods • Wastewater impacts to birds • Chemical risk assessment	1. Appendix J and K contain all information relating to stakeholder engagement- including court proceedings. 2. Climate change impacts have been considered as a part of the NT Inquiry. Recommendations have been developed to address this issue.	Minor additional information has been added to the EMP and Wastewater management plan to address the comments posed.

Comment number	Date	Comment summary/key points	Origin reply	EMP Changes proposed by Origin
		• Methane levels in groundwater • General risk comments • Traditional Owner engagement • Rehabilitation cost	3. The previous allegations did not result in any breaches in regulation and highlight the lack of validity of the claims against Origin's activities. 4. The comment does not consider the separation distance between the features. This is addressed in section 3.2 of the EMP. 5. Comments regarding risk to birds and fauna have been addressed in section 3.11 of the EMP. The hazard to wildlife has been assessed, with material risks to species having a likelihood of unlikely. 6. Chemical risk assessment- the absence of specific data within a SDS does not mean that the SDS does not contain the appropriate level of information to make an assessment. In fact, the SDS is only one source of information, with international databases on chemicals used for the assessment. 7. This has been addressed in section3.26 and broader CSIRO baseline studies. 8. General comment is not specific. These risks are addressed throughout the document. 9. Origin has obtained Traditional Owner consent with the NLC determined custodians of the land on which the activity is being undertaken on. No Traditional Owner has ever been	

Comment number	Date	Comment summary/key points	Origin reply	EMP Changes proposed by Origin
			excluded from a stakeholder meeting. As provided in Appendix L, the meeting in question was a “meet the buyer” meeting, whereby potential goods and service suppliers were able to meet Origin. These comments are factually incorrect and misleading. 10. Origin is required to have a security bond to cover all rehabilitation costs to provide re-assurance that all activities will be rehabilitated.	
27	1/11/2019	Risks Well integrity Chemicals Corrosion of wells Open air wastewater tanks Amphibians, birdlife Transport impacts and tourism	1. Risks associated with corrosion, high pressure and salinity have been provided in the Well Operations Management Plan (WOMP) overview in Appendix Y of the EMP. Addressing these factors int eh well design is a standard practice. 2. A chemical risk assessment has been undertaken which determined the use of chemicals to be low risk. No information is proved by the comment to justify why chemical use is considered high. 3. The formation pressure and chemistry is considered during the design and construction of the well, as discussed in section 3.3 of the EMP. Each formation has a specific risk profile which needs to be considered during the design; not just the Moroak. A Moroak inflow tests was completed on the Elliot-1 and Ronald-1	Minor additional information has been added to the EMP and Wastewater management plan to address the comments posed.

Comment number	Date	Comment summary/key points	Origin reply	EMP Changes proposed by Origin
			wells, with the test terminating before flowing to surface. This indicating the reservoir has no hydraulic head (i.e. are not artesian). The fluid is approximately 200000ppm NACL which is approximately 5x the concentration of sea water and of no use for agricultural applications. The absence of hydraulic head and the density of the fluid prevent fluids mixing with surface aquifers. 4. The request to the NT Government Regarding the Moroak Sandstone Salinity has no relevance to this EMP. Origin is aware of the salinity of the Moroak and has included this information into the design of the well. 5. Biocides are designed to control bacteria to ensure well integrity. Origin is not proposing to release these to the environment. 6. The likelihood of corrosion and pressure causing saline water and fracking chemicals into the surface aquifers is considered remote. The comment fails to understand generally well design practice as mandated in the code of Practice. 7. Overtopping tanks is a remote risk given the freeboard requirements adopted. Wastewater storages can contain a full 1:1000 ARI cumulative wet season total which does not consider evaporation. Thus,	

Comment number	Date	Comment summary/key points	Origin reply	EMP Changes proposed by Origin
			overtopping is considered extremely remote. 8. Well integrity- wells are designed to account for corrosion and bacterial attack. Biocides and corrosion inhibitors are used during the operation of the well (i.e. before abandonment), to protect the inside of wells from corrosion. The use of the well drilled in 1960's is a poor example, as the industry practice implemented through the Code of Practice offer an order of magnitude greater protection. 9. Corrosion in CSG wells is anticipated during operation of the well (i.e. when the well bore is open to water and gas). Ongoing maintenance of wells is required to protect well integrity during operation. During decommissioning, wells are plugged with cement to isolate each aquifer unit. The steel casing is therefore protected from microbial attack. 10. The comment highlights the hazards associated with the use of chemicals. It fails to understand the likelihood of a failure which is considered in appendix N of the EMP. Chemicals are not to be released into the environment, with prohibition of surface water discharge and reinjection and the requirements for spill management and wastewater management plans.	

Comment number	Date	Comment summary/key points	Origin reply	EMP Changes proposed by Origin
			11. An overview of the Flowback fluid and Wastewater management is provided in section 3.11. Optimal evaporation rates for the site will be determined in the field. It is likely that minimal volume of flowback will be stored in the evaporation ponds to increase wastewater temperature and therefore evaporation. 12. Amphibians- Frogs are unlikely to be attracted to hypersaline water with limited/no literature indicated the contrary. 13. Cane toads- the salinity of the wastewater exceeds the breeding tolerance of Cane toads. 14. Impacts from surfactants in open air tanks to amphibians and birds are likely to be low due to the low concentration within the wastewater stream and rapid (hours to days) breakdown when exposure to UV. Furthermore, surfactants are commonly associated with domestic wastewater which are treated in open storage tanks. Large bird deaths and amphibian mortalities associated with these activities appear to be rare. 15. Discussions regarding bird life are provided in section 3.11.3 16. Transport Risk and Tourism risk- the activity, as outlined in section 3.2, is not located in proximity to any tourist areas.	

Comment number	Date	Comment summary/key points	Origin reply	EMP Changes proposed by Origin
			The site is located 100km form the Stuart highway. The number of heavy vehicle movements required during the activity is provided in section 3.23. The traffic associated with Origin's activities is small and will not impact the aesthetics of the area	
28	1/11/2019	No Social licence	1. Traditional Owner engagement has been completed through the Northern Land Council. The determined Traditional Owners of the area of Origin's activities have given consent. Pastoralist engagement has occurred and access agreements are in place. This information has been provided in the EMP. 2.	None- The EMP sufficiently addresses these concerns.
29	1/11/2019	No Social licence; impacts to waterways, insufficient regulation --> approval process being rushed.	1. Traditional Owner engagement has been completed through the Northern Land Council. The determined Traditional Owners of the area of Origin's activities have given informed consent. This information has been provided in the EMP. 2. The site will be completely bunded, with no wastewater discharged (accidentally or on purpose) to surrounding water ways. 3. The impacts associated with hydraulic fracturing, including groundwater contamination, have been rigorously investigated as a part of the NT Scientific	None- The EMP sufficiently addresses these concerns.

Comment number	Date	Comment summary/key points	Origin reply	EMP Changes proposed by Origin
			Inquiry into Hydraulic Fracturing. The NTG has implemented a range of recommendations, which have been implemented through changes to the NT Water Act and Code of Practice for Onshore Petroleum Activities in the NT. 4. The approval timeframes are regulated and have not been adjusted or fast tracked.	