



Description of the Existing Environment

Appendix 01

Imperial Oil & Gas A Pty Ltd

EP 167/168

IMA1-5

Prepared For

Imperial Oil & Gas A Pty Ltd

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Prepared For

Imperial Oil & Gas A Pty Ltd

Prepared By

inGauge Energy Australia
 Level 4, 301 Coronation Drive, Milton, QLD 4064
 E: admin@ingauge.com.au
 ABN: 51 164 429 190

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1 Description of the Environment

1.1 Project Area

The Project Area encompasses a total area of 2,355 km², representing approximately 9% of the total exploration area of EP 167 and EP 168. Its approximate dimensions are 57 km east-west and 54 km north-south. The proposed maximum total disturbance is approximately 222 ha, representing ~0.1% of the Project Area.

The following subsections describe the existing environment of the Project Area and environs. The information presented in this appendix uses the NT EPA's *Environmental Factors and Objectives* [NT EPA, 2022B] and the Source-Pathway-Receptor conceptual site model in *Guidelines on Conceptual Site Models* to focus the risk assessment of the Activity [NT EPA, 2013].

The *Terrestrial Ecosystems Baseline Report: Strategic Regional Environmental and Baseline Assessment for the Beetaloo Sub-basin* (SREBA Report [L YOUNG et al., 2022]) includes the assessment of water and biodiversity resources to inform land-use planning and the collection of baseline data to provide a reference point for ongoing monitoring [DEPWS, 2022]. The Project Area is within the Beetaloo SREBA Study Area (Figure 1.2—1). Relevant baseline information from the SREBA studies has also been used to describe the environmental factors in the Project Area in this EMP.

The environmental baseline assessment for the Project Area also uses the CSIRO land systems (LS) mapping methodology, which provides detailed descriptions for a range of environmental attributes in each discrete LS area or group of areas with a recurring pattern of topography, soils, and vegetation based on geomorphology. The framework for the principles and practice of land system mapping was first described by CSIRO soil scientists [C.S CHRISTIAN et al., 1953] involving the then revolutionary concept of using air photographs as an analogue model of the land resource to identify broad scale recurring patterns of land units, and then determining their characteristics by stereoscopic aerial photo examination and field transect sampling. It was further developed by the Division of Land Research and Regional Survey that merged into Rangeland Research in arid zones of northern Australia, at Katherine and Alice Springs, in the subsequent decades. CSIRO Land Research Surveys land system mapping [M. A RANDAL, 1966] integrates environmental features resulting from the interactions of geology, landform, and hydrology, which influence the distribution of markedly different soil types and, hence, vegetation species across the landscape.

The land system framework broadly recognises that geomorphic factors in a landscape result in distinct erosion, deposition and stable areas based on proximal elevation and hydrology. The land systems in the Project Area provide a useful and an important first-pass in selecting sites for well pads and access tracks because of the civil engineering requirements for soil stability and hydrology; and excluding LS areas with unsuitable soil types and hydrology.

The framework also enables sampling, based on LS grouping, to validate baseline information from georeferenced imagery acquired during the 2021 baseline field survey for each of the nine land systems mapped in the Project Area where disturbance may occur. It also provides a useful method for monitoring rehabilitation on long, narrow (4 m wide) seismic survey lines (SSL) using stratified

sampling, to ensure specific LS are sampled adequately and helps obtain precise estimates of rehabilitation trajectories of SSL in each land system. This technique is a probability sampling method, also known as stratified sampling.

1.2 Climate

The Project Area is west of Larrimah in the Northern Territory. Imperial A has used Bureau of Meteorology (BOM) data from weather station 14612 (Larrimah) in its climate analysis. The Larrimah BOM station has 72 years of daily rainfall data (1952 to present); however, the collection of rainfall data in Larrimah began in the 1880's [BOM, 2023].

1.2.1 Temperature

The mean daily minimum temperatures for Larrimah range between 12.3 and 24.5°C, and the maximum mean daily temperatures range between 29.3 and 37.9°C, as presented in Table 1.2—1.

Table 1.2—1: Larrimah Average Monthly Temperatures

Temperatures	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Mean Max (°C)	35.3	34.4	34.0	33.8	31.7	29.3	29.4	31.8	35.1	37.3	37.9	36.8	33.9
Mean Min (°C)	24.0	23.7	22.5	19.8	16.3	13.0	12.3	14.1	18.4	22.2	24.3	24.5	19.6

1.2.2 Evaporation

Imperial A has used SILO Data Drill Lake evaporation data for the calculation of evaporation in the Project Area. Monthly evaporation depth totals have been listed for the 10th, 50th and 90th percentiles (P10, P50 and P90) (Table 1.2—2). Percentiles are based on 120 years of SILO Data Drill Lake evaporation data [SILO, 2021].

The average annual evaporation for Larrimah is approximately 2,024 mm, which exceeds the annual rainfall even in the wettest years.

Given that the highest rainfall months for the Project Area are December, January, and February, Imperial A has used the sum of the P10 lake evaporation for December, January, and February, being 466 mm. As such, Imperial A has used a more conservative 90-day evaporation rate of 450 mm when calculating freeboard requirements to cater for 1 in 1,000-year rainfall events.

Table 1.2—2: Larrimah Average Monthly Evaporation

Evaporation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
P10 (mm)	161	130	151	144	132	111	122	152	177	202	196	176	1,852
P50 (mm)	187	160	175	158	139	117	129	156	182	213	208	199	2,024
P90 (mm)	204	184	197	172	149	125	135	162	190	223	218	219	2,178

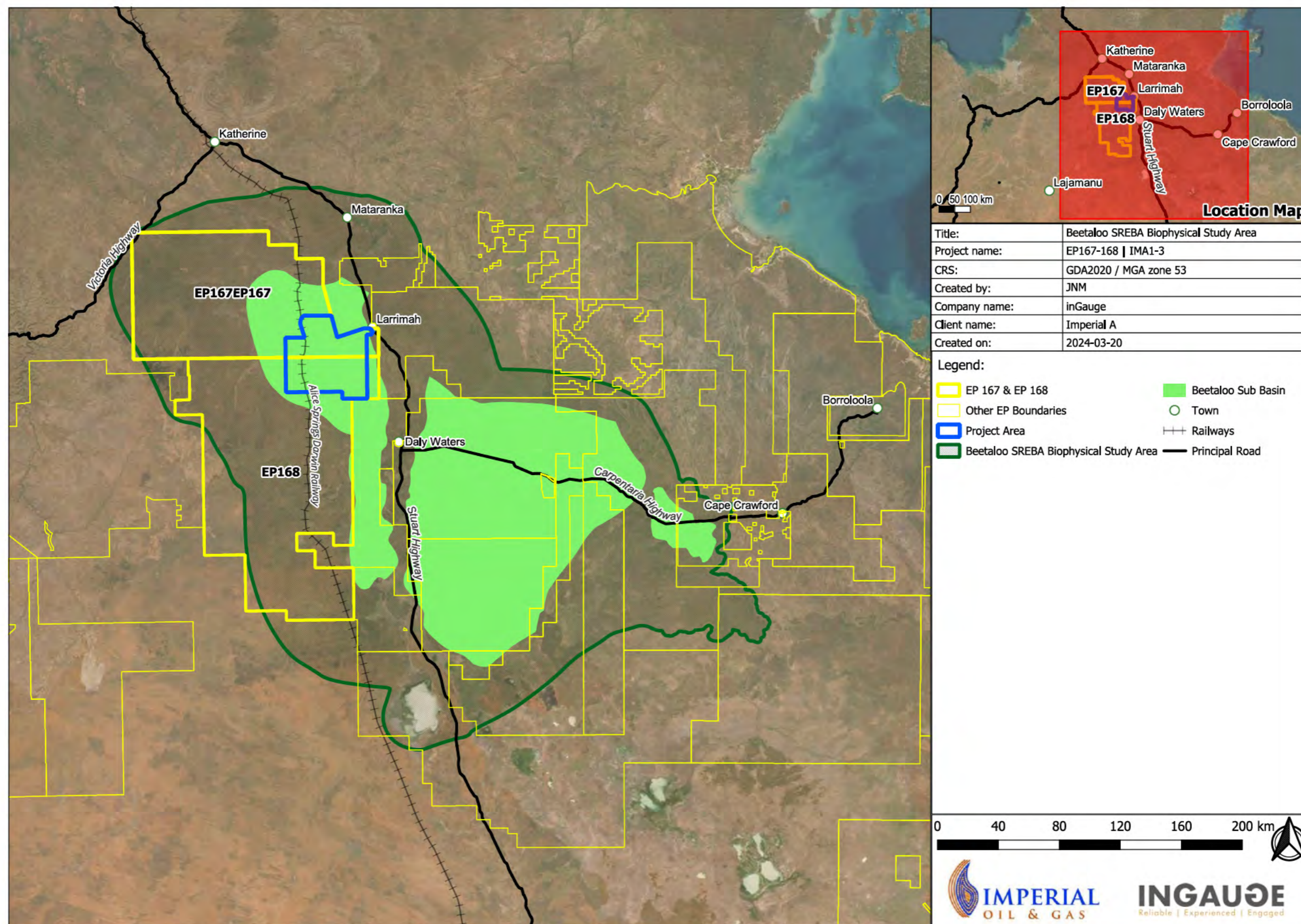


Figure 1.2—1: Beetaloo SREBA Study Area and Project Area

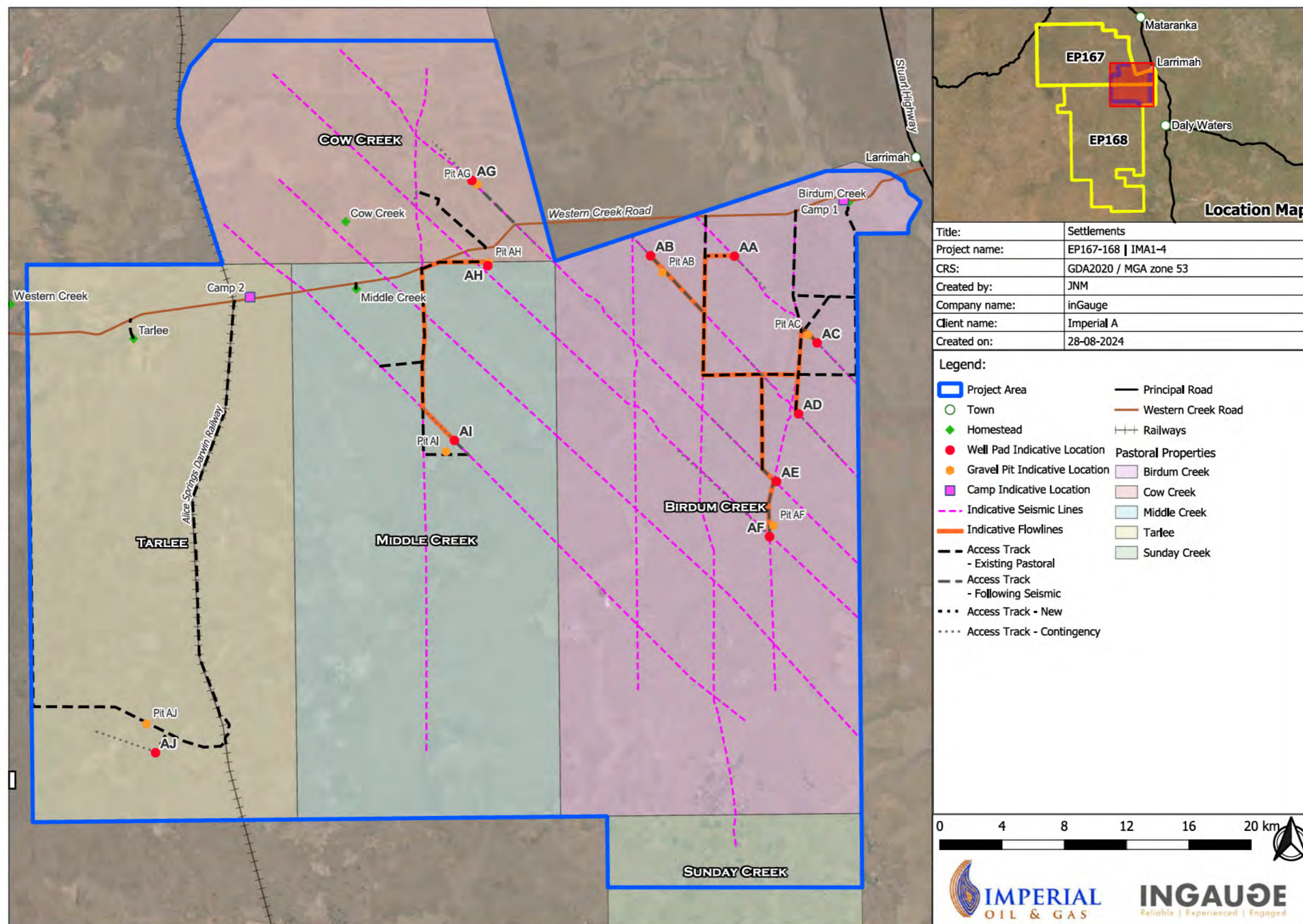


Figure 1.2—2: Pastoral Stations and Dwellings in the Project Area

1.3 Rainfall

Imperial A has evaluated average monthly rainfall, average daily rainfall, and 1 in 1,000-year events when assessing rainfall risks for this EMP. These elements are discussed below.

1.3.1 Average Monthly Rainfall

The Project Area experiences a tropical savannah climate within the humid zone with a distinct Wet and Dry Season and an average annual rainfall total of approximately 850 mm. Generally, approximately 85% of the total annual rainfall in the Project Area occurs between December and March **Figure 1.3—1**. These rainfall events may cause localised stream flooding, determined by the rainfall's volume, duration, spatial distribution, and soil moisture content. In contrast, the local Larrimah Dry Season between April-May and September-October experiences little or no rain. This is the optimal seasonal window for civil works and rig moves in the Project Area as reflected in the Project Schedule in Section 3 of the EMP.

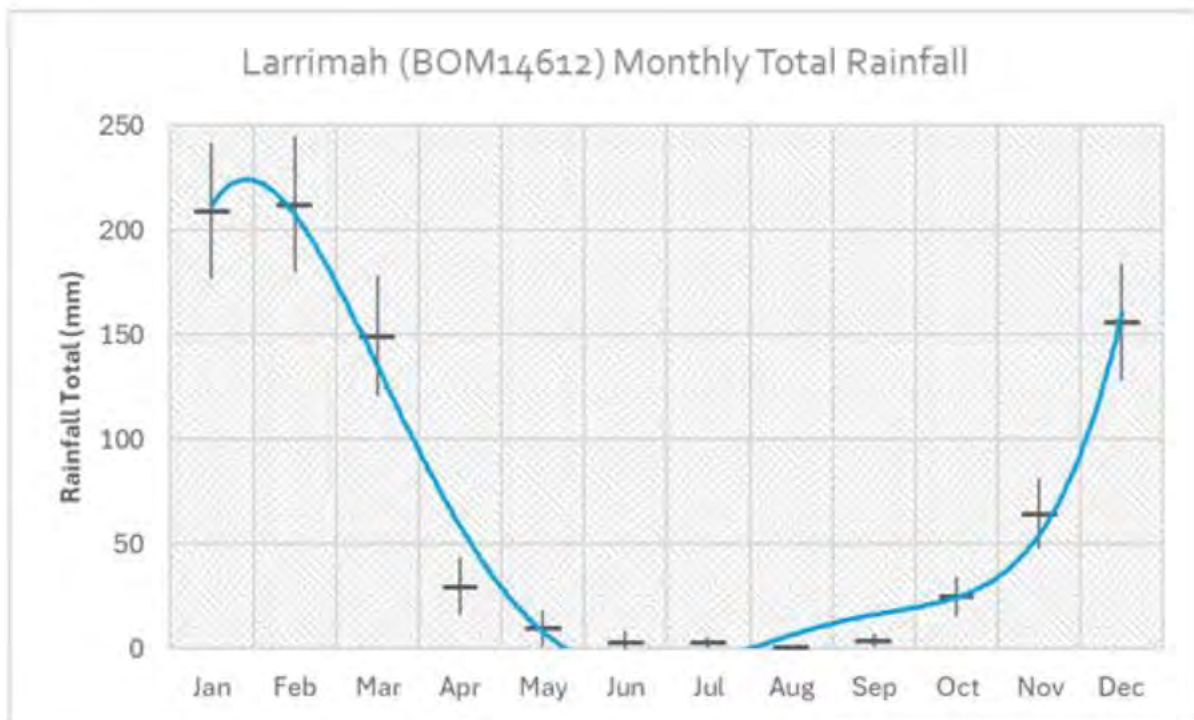


Figure 1.3—1: Larrimah Total Monthly Rainfall Average ± 95% Confidence Limits

1.3.2 Extreme Rainfall Analysis

Annual 90-day and 4-day maximum rainfall recorded at Larrimah since daily rainfall records began in 1953 were computed to provide respective annual exceedance probabilities. The results of this analysis are presented in Figure 1.3—2.

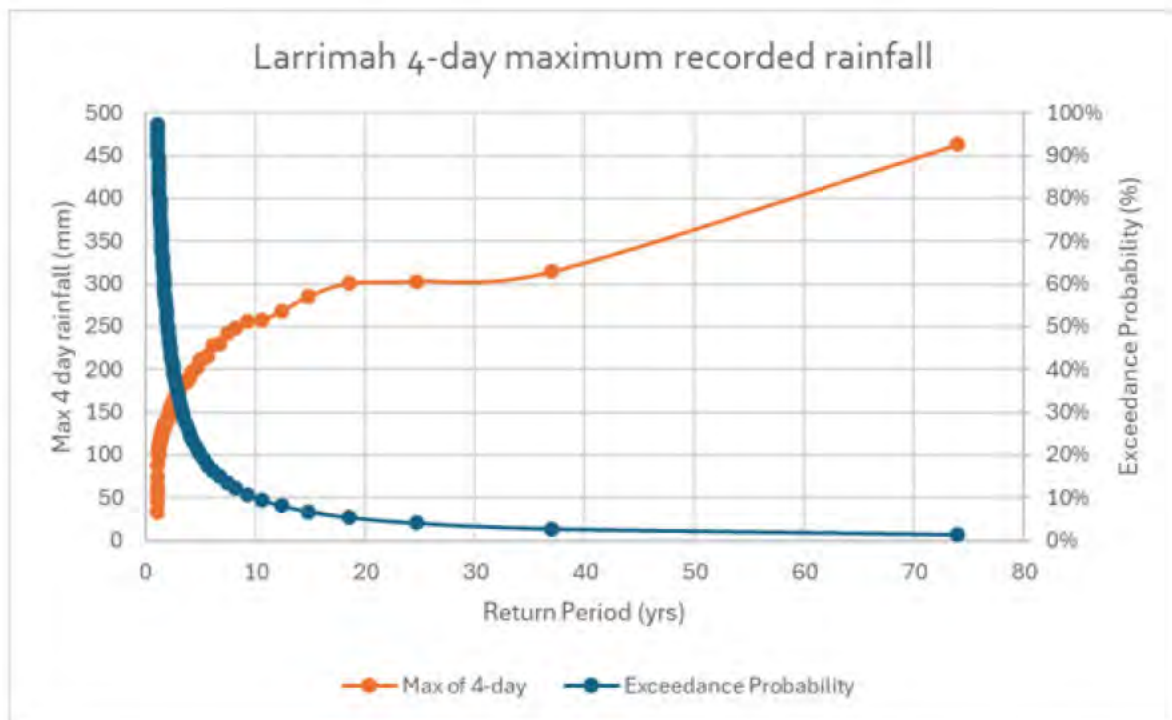
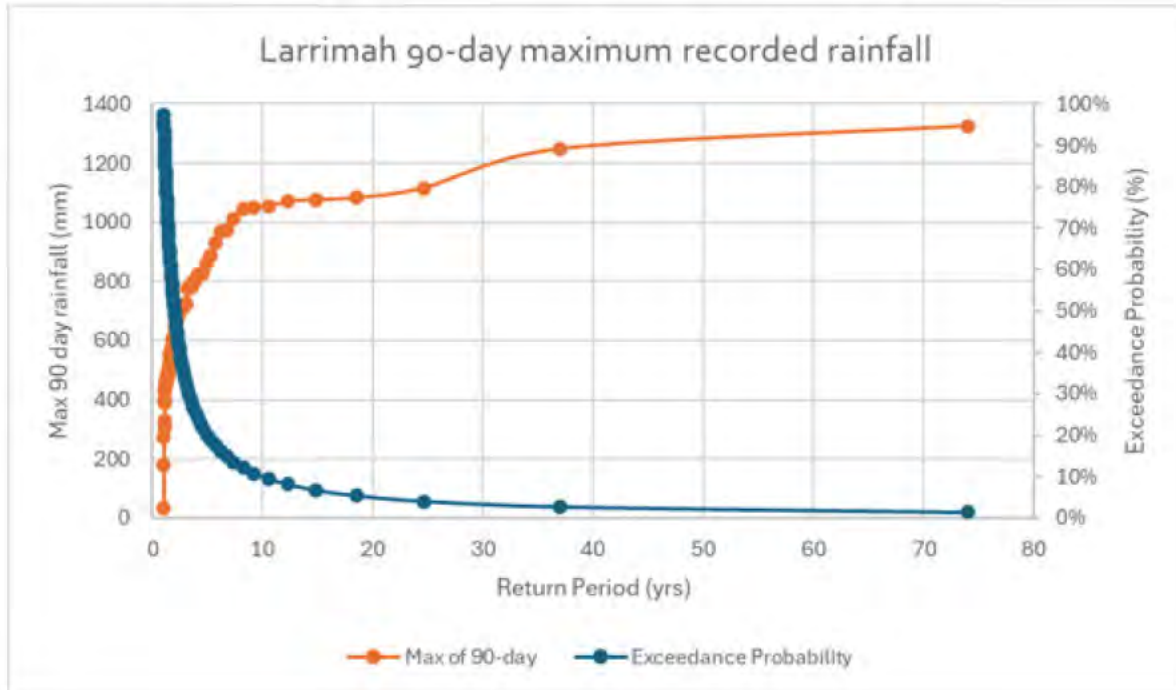


Figure 1.3—2: Larrimah Maximum 90-day and 4-day Rainfall Annual Exceedance Probabilities Since 1953

1.3.3 Wet Season

Consistent with industry-accepted methodology associated with practices such as dam risk assessments (which calculate the Wet season based on your geographical location), three months was determined to be an applicable period to model a 1 in 1,000-year rainfall event.

The highest three-month rainfall periods for Larrimah were used, and a Log Pearson III distribution was fitted to the data. This analysis allowed us to extrapolate the 1,000-year, three-month duration Wet season.

Larrimah's highest predicted 1:1,000-year total rainfall in three months in the Wet Season is 1,575 mm. However, upper 10% confidence bounds show that it could be up to 1,735 mm (Figure 1.3—3). These calculations do not allow for any evaporation. The average annual evaporation for Larrimah is approximately 2,024 mm, which exceeds the annual rainfall even in the wettest years.

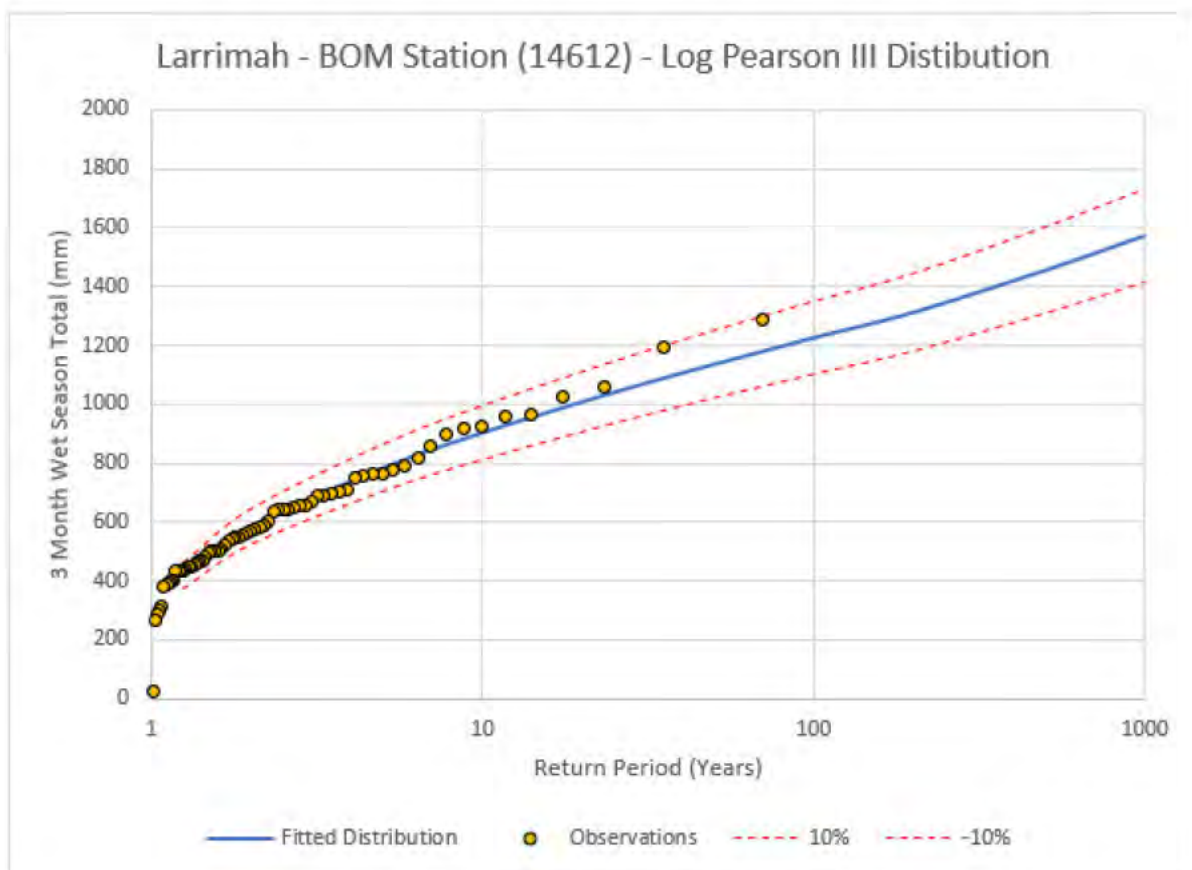


Figure 1.3—3: One in 1000 Year Rainfall Events - Wet Season

Given that the highest rainfall months for the Project Area are December, January, and February, Imperial A has used the sum of the P₁₀ lake evaporation for these months, being 466 mm, and has adopted a more conservative P₁₀ 90-day evaporation of 450 mm when calculating the freeboard requirements to cater for 1:1,000-year rainfall events.

Based on the upper P10 rainfall event and P10 evaporation for the wettest months, a design Wet Season freeboard of 1.3 m is proposed for all open pits and unattended open-top tanks to minimise the risk of overtopping.

1.3.4 Dry Season

Due to limitations with the Log Pearson III Distribution method, it is not feasible to use it to predict 1 in 1,000 rainfall events over the Dry Season. Since the collection of rainfall data in Larrimah began in the 1880s, almost one-quarter of all Dry Seasons have had no recorded rainfall, which skews the remaining data.

Therefore, another method is required to estimate Dry Season 1 in 1,000-year events. The maximum 1-week rainfall total for each year during the Dry Season was collated for Larrimah. These points were then plotted against a logarithmic probability scale from 0 to 100%, with a line of best-fit passing through the data. This is illustrated in Figure 1.3—4.

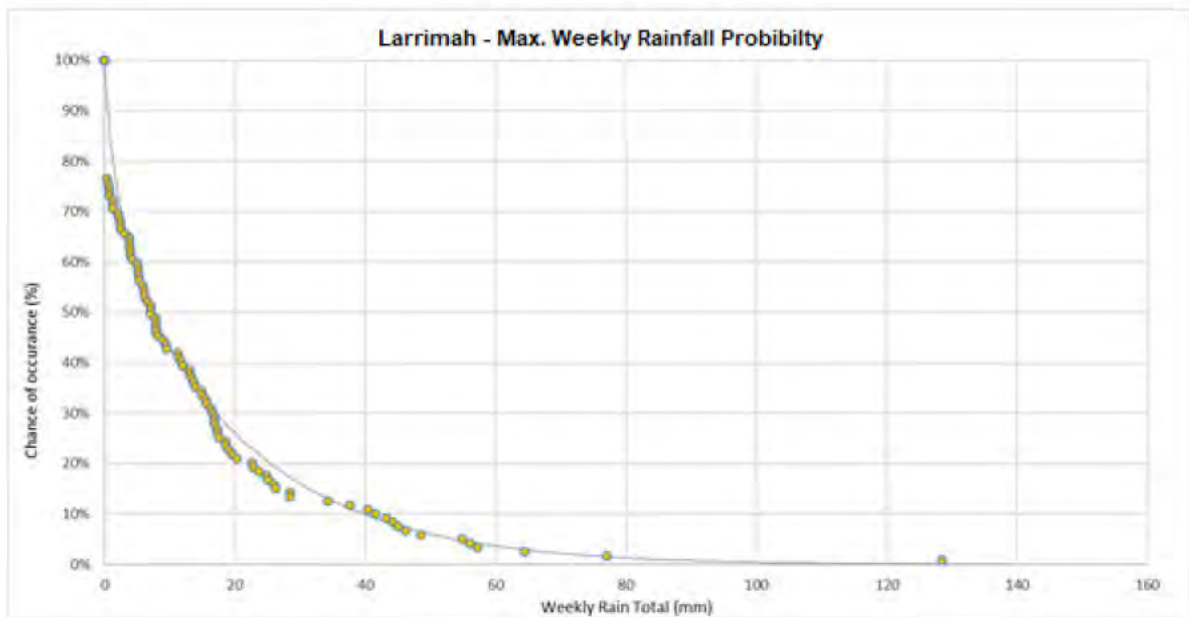


Figure 1.3—4: Total Weekly Rainfall Probability Estimate – Dry Season

Using the trendlines, it is possible to estimate the maximum Dry Season weekly rain total associated with a probability of 0.1% (1:1,000); for Larrimah as 130 mm.

1.4 Bioregions

The Project Area is in the north-western sector of the approximately 98,500 km² Sturt Plateau bioregion. Bioregions are a broad classification based on climate, soils, landform and topography, catchment, native vegetation types, and species information. The Sturt Plateau is in the savannah zone of northern Australia.

Savannahs function as tree-grass systems from an ecosystem function viewpoint and as savannahs from a region-scale land cover viewpoint. Savannah is a mixed physiognomy of grasses and woody plants in any geographical area, naturally occurring at landscape or regional scale' [M HILL et al., 2010].

The soils in the Project Area at the locations of well pads and access tracks are predominantly neutral, non-swelling, sandy clay red and yellow earths dominated by deep Red Kandosols, which support the vast savannah tussock grassland of much of the Sturt Plateau [DEPWS, 2022].

1.5 Geology

The Project Area is situated in the western Beetaloo Sub-basin which comprises a thick sequence of stacked sedimentary basins ranging from the Mesoproterozoic to Cretaceous age. The prospective organic-rich shale gas reservoirs of the Mesoproterozoic lower Kyalla Formation and the Amungee Member of the Velkerri Formation form part of the upper section of the Roper Group, which is estimated to be approximately 3,500 m thick in the deeper section of the Project Area and thins to the west. This sequence consists of predominantly mudstones and sandstones.

The Roper Group in the Project Area is unconformably overlain by a Neoproterozoic sequence which includes the Bukalara Sandstone and Hayfield Mudstone. The Bukalara Sandstone aquifer is the water supply for this project and is typically 100 m thick and between 150 – 350 m BGL across the Project Area. The Neoproterozoic sequence is unconformably overlain by the Cambrian and Devonian age Daly Basin, which includes a thick sequence of the Antrum Plateau Volcanics (APV) and Tindall Limestone. The Daly Basin is covered by a thin sequence of Cretaceous age mudstone and sandstones of the Carpentaria Basin and younger surface alluvial deposits.

Along the eastern and northern portion of the Project Area, the target aquifer, the Bukalara Sandstone is present directly below the APV. On a regional scale, the overlying APV is considered to act as an aquitard or an aquiclude to any underlying and overlying aquifers [S. Tickell, 2022]. Along the eastern portion of the Project Area in particular, the APV can also act as a localised aquifer within fractures or small isolated sandstone lens. The average top of the basalt in the Project Area is approximately 68 m below ground level, based on the DENR's Statement of Bores in the area (Table 1.11—1), with a measured thickness of approximately ~140 m.

Immediately west of Larrimah along the western side of the Birdum Creek fault, encompassing the Project Area, the Cambrian Limestone Aquifer (CLA) has been eroded (not present) or elevated above the water table due to geological uplift from the APV basalt suite and is therefore absent as an aquifer

across a significant portion of the Project Area (see **Figure 1.10—7**) [S. Tickell, 2022]. The Birdum Creek Fault penetrates the Cambrian limestone sequence and the underlying Antrim Plateau Volcanics. The vertical displacement along the fault is in the order of 200 m in the Larrimah region [D. Yin Foo, 2002]. The CLA is present approximately at the rail line in the west.

The planned exploration and appraisal wells are targeting the organic-rich shales in the Amungee Member in the Velkerri Formation. These organic-rich shales are generally divided into three to four target shales termed the A, Intra-A/B, B and C Shales from oldest to youngest. The proposed wells will likely initially focus completions within the B Shale reservoir; however, the A, Intra-A/B and C Shales may become future targets for completions. The top of the target sequence averages >1400 mBGL across the Project Area (**Table 1.11—4**), with the B Shale varying from 1,000 – 1,800 m BGL.

The target shale reservoirs of the Velkerri Formation Amungee Member are isolated from the shallow CLA by a thick sequence of low permeability units (mudstones, tight sandstones and volcanics) within the Wyworrie Member (upper Velkerri Formation), Kyalla Formation, Hayfield Mudstone and APV. These low permeability units separate the target shale reservoirs from the shallow aquifers by 1,000 – 1,500 m in the Project Area and form a geomechanical and permeability barrier to the shallow aquifer units above.

1.6 Topography

The Project Area is in the Elsey Creek catchment system in the Barkly Tablelands on the northwest of the Sturt Plateau. Migration of the drainages is evident across the Sturt Plateau as their relict paths (paleochannels) and flood plains are often signified by shallow cracking clays. Of note in the Project Area is the evolution of the Elsey Creek catchment system, which has captured Western Creek, formerly a major tributary of the Dry River [D. YIN FOO, 2002]. The Project Area is situated on a geologically uplifted plateau terrain with little local relief and exceptionally flat, as evident in the geomorphological mapping for the area (**Figure 1.6—1**), at the top of the Elsey Creek catchment (6,784 km²), which flows north. It is covered by ~37 m thick indurated clay, siltstone, which support savannah vegetation of tussock grasses and open forest.

The elevation range is approximately 54 m from a low point in the northeast corner of the Project Area on the Western Creek Road at Birdum Creek, crossing west of Larrimah. This creek crossing is situated at ~160 m AHD and, during major flood events, will likely be impassable for short periods. The Project Area extends to an approximate height of ~210 m AHD in the southwest. The Project Area covers approximately 35% of the total Elsey Creek catchment.

Elsey Creek catchment has an elevation range of 144 m, from a maximum of 278 m AHD to a minimum elevation of 134 m AHD at Warlock Ponds. The catchment has a long-term river flow gauging station downstream at Warlock Ponds, approximately 68 km due north of the Project Area (see **Figure 1.10—2**). The data from this station provides useful historical hydrological information for characterising the highly seasonal nature of catchment flow and its annual change in the Project Area.

Given the flat plateau topography of much of the landscape in the Project Area, the inaccuracy and coarse precision of the Shuttle Radar Topography Mission (SRTM) data means that flood mapping is more error-prone than in other areas and interpretation requires additional precaution in selecting proposed disturbance sites such as well pads, flowlines and new access tracks.

The rail line, located primarily in the Banjo land system (LS) in the west and the Stuart Highway to the east, are aligned N-S. These transport corridors are at similar elevations of roughly 200 m AHD in this Project Area. This provides a useful east-west flood level benchmark and validation tool for assessing flood risk in the Project Area. It reflects the broad and unusually flat tableland topography across the Project Area. It also highlights the need for careful site selection for well pads and associated new access tracks for stable soil load bearing foundation and to avoid/mitigate potential flood inundation and channel flow paths.

The Project Area is characterised by active but limited drainage networks confined primarily to the relict floodplains and paleochannel flow paths in three LS units: the Larrimah LS, the Mering LS and Western LS. These mapped units encompass the drainage system in this part of the Elsey Creek catchment, east of the rail line in the Project Area. During Dry Season, they retract, leaving occasional shallow ephemeral pools/soaks known as 'flood out' country in the Project Area in the Larrimah LS. Ground disturbance in these three LS is avoided.

Mound-building termite (*Tumulitermes hastilis*) colonies are a conspicuous topographic feature in the heavier Kandasol soils, in which the well pads are located, in the Project Area. The mounds are constructed of enriched clay-sand, usually up to 50 cm high. Their absence in areas subject to periodic flood inundation provides a useful landscape indicator.

[REDACTED]

[REDACTED] Ground disturbance in the Mering LS will be avoided. The observed areas in the Mering LS hold significant habitat and archaeological values, which include:

- [REDACTED]
- [REDACTED]
- [REDACTED]
- [REDACTED]

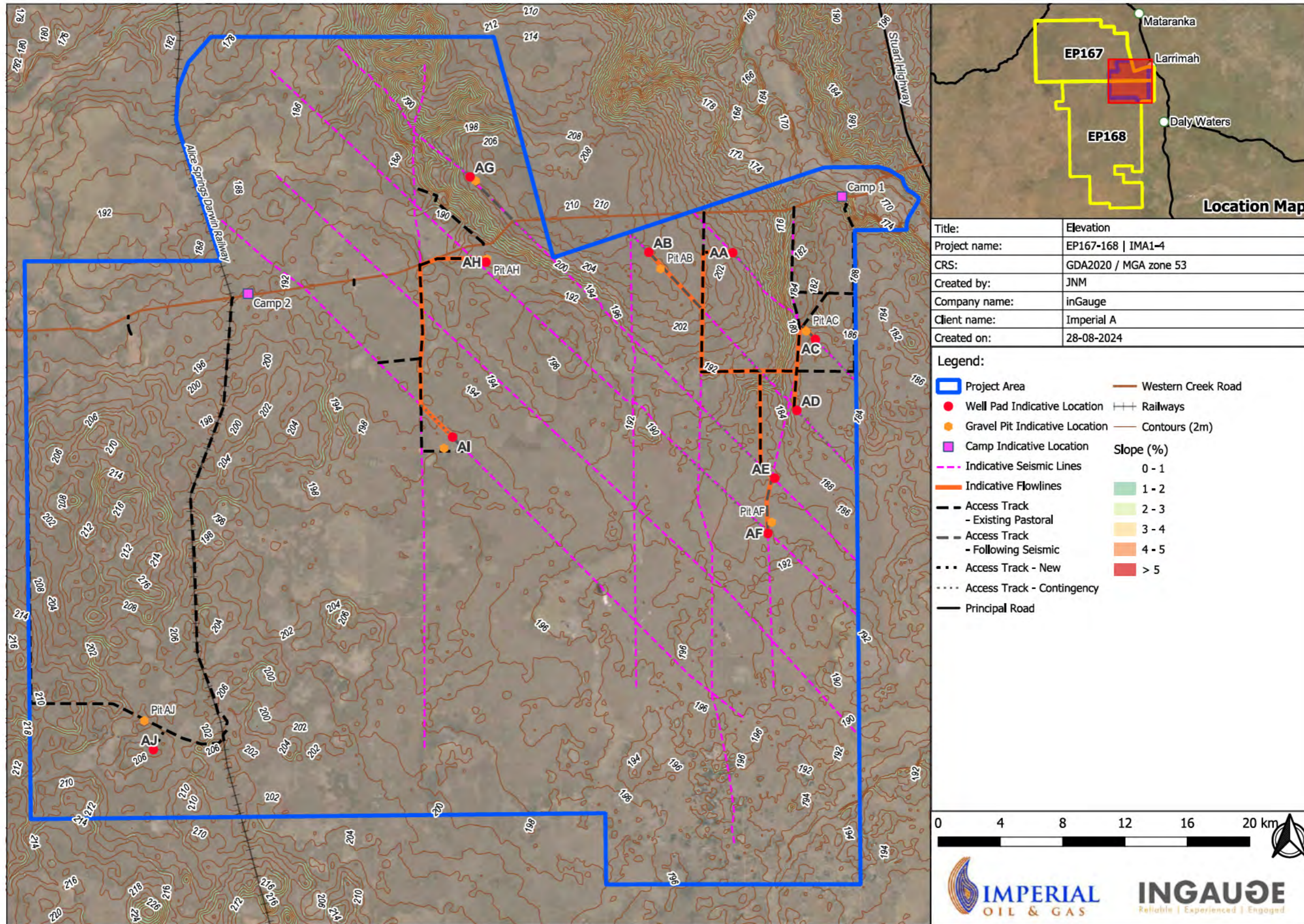


Figure 1.6—1: Ground Elevation Relative to AHD in Project Area

1.7 Land Systems

Land systems (LS) are distinct areas or groups of areas with a recurring pattern of topography, soils, and vegetation based on geomorphology. LS mapping integrates environmental features resulting from the interactions of geology, landform, and hydrology, which influence the distribution of markedly different soil types and, hence, vegetation species across the landscape. The framework broadly recognises that geomorphic factors in a landscape result in distinct erosion, deposition and stable areas within a landscape based on proximal elevation and hydrology. This controls the soil type in a LS area and related environmental covariates.

1.7.1 Land System Framework

The LS mapping provides a systematic framework for describing baseline habitat types within a region such as the Project Area and is a useful tool for assisting site selection evaluation for new access tracks, flowlines, and well pads [M. A RANDAL, 1966]. It provides a useful and an important initial site selection screening for well pads and access tracks because of the civil engineering requirements for soil stability and hydrology; and excluding areas that are unsuitable.

LS categorisation also provides a method for stratified sampling of georeferenced imagery to validate environmental baseline information across the Project Area. This sampling methodology can also be useful for monitoring and demonstrating vegetation recovery along narrow linear corridors, such as seismic survey lines (SSL), that traverse the landscape. Nine land systems have been identified in the Project Area and excerpts of the summary of descriptions of each of the LS (Randal, 1966), are presented in Table 1.7—1.

1.7.2 Land System Ground Truthing

Table 1.9—2 provides a selection of georeferenced imagery acquired during the baseline survey on the different LS intersected by the SSL corridors. The imagery confirms:

- LS mapping is consistent with the relevant LS landscape descriptions, soil types and vegetation.
- LS mapping is a useful tool in evaluating site suitability and potential impacts in the Project Area.

As noted, the Project Area is situated on a geologically uplifted plateau terrain with little local relief and is exceptionally flat. The subtle difference in elevation between the different LS mapped in the Project Area reflects the hydrology and ongoing erosional processes at the top of the Elsey Creek catchment. The significant difference in soil types, landscape descriptions, and associated vegetation species in the different LS, provides a useful indicator and guide in assessing risk and suitability of proposed high disturbance areas, including well pad location, access track and flowline paths.

The most elevated LS unit in the Project Area is found in the Sturt LS (218 m AHD) abutting the Bullwaddy LS (210 m-200 m AHD) in the southwest. The Sturt LS consists of level to undulating plains on the Sturt Plateau. The Bullwaddy LS consists of plains and rises associated with deeply weathered laterite profiles, which occur at the boundary with the more elevated (>10 m) Sturt LS to the

southwest. This weathering process results in mixed soils in the unit, consisting of rudosols topographically grading to lithosols, gravelly earths, deep loamy red earths, and finally, black soils at the lowest elevation in ephemeral soak mapped in the unit. The lithic erosional processes continue eastward into the vertosol 'floodout country' of the Larrimah LS (195 m AHD), discussed below.

1.7.3 Land System Selection for Infrastructure

The three LSs in the Project Area, considered 'stable' in terms of pedological development and elevation in the catchment area, in which well pads and other long-term disturbance areas such as new access tracks, are to be located are as follows:

- **Forrest LS (~205 m AHD)** to the east, which consists of gently sloping sandy surfaced plains of deep sandy-clay Red Kandosols, with few indistinct drainage depressions and sandy and earth soils on open mixed woodland, tussock grass savannah. Eight of the nine proposed well pad locations are in this land system.
- **Brolga LS (205 m AHD)** to the west, which consists of almost level plains of deep sandy Red Kandosols, with few infilled sink holes terminating in the Cretaceous sediments overlying the APV basalt, including sand sheets and sandy and earth soils on open mixed woodland, tussock grass savannah. One well pad is proposed in this land system.
- **Bullwaddy LS (205 m AHD)** in the southwest near the rail line which consists of soils grading from shallow Leptic Rudosols through to gravelly Red and Brown Kandosols and deep loamy Red Kandosols.

The three LSs in the Project Area, considered 'erosional' or 'depositional', in terms of pedological development and elevation in the catchment area, will be avoided for well pads and other long-term disturbance areas such as new access tracks and flowlines are as follows:

- **Larrimah LS (195 m AHD)** in the central and southern sectors, which consists of relict flood plains of brown and grey vertosols that are level to gently undulating clay plains ('black soil' plains) and cracking clay soils dominated by monoculture stands of *Eucalyptus microtheca*. This species is commonly found fringing seasonally dry watercourses, swamps, lakes, and low-lying areas subject to temporary inundation. The Larrimah LS functions hydrologically in the flat landscape at the top of the Elsey Creek catchment as sediment deposition zone and the relict paleochannel in the northeastern portion of this LS acts as 'floodout country'. During high flow events, the Larrimah LS will overflow to the Mering LS. No infrastructure will be sited in the Larrimah LS.
- **Mering LS (180 m – 190 m AHD)** in the northeastern sector, which consists chiefly of tenosols comprised of shallow gravelly earths and sands that have been leached of clay through erosion. The Mering LS functions as a channel system and drainage path from the Larrimah LS to the southwest during flooding periods. No infrastructure will be sited in the Mering LS.
- **Western LS (190 m AHD)** in the eastern and southern sectors consists of alluvial floodplains, swamps, drainage depressions and active flood plains of cracking clay associated, respectively with the Birdum Creek and Sunday Creek catchment drainage lines. No infrastructure will be sited in the Western LS.

The seven LSs in the Project Area intercepted by the SSL are Banjo (188 m AHD), Mering (190 m AHD), Forrest (205 m AHD), Western (190 m AHD), Brolga (205 m AHD), Larrimah (195 m AHD) and Bullwaddy (205 m AHD). **Figure 1.7—1** shows the land systems of the Project Area.

Table 1.7—1: Description of Land Systems in the Project Area

Geo Zone	Land System	Class	Class Description	Landform	Area (ha)	% of Project Area
Sturt Plateau	Banjo	Lateritic Plains and Rises	Plains and rises associated with deeply weathered profiles (laterite), including sand sheets and other deposited products, and sandy and earth soils.	Gently undulating to almost level plains	52,071.10	22
Sturt Plateau	Brolga	Lateritic Plains and Rises	Plains and rises associated with deeply weathered profiles (laterite), including sand sheets and other deposited products, and sandy and earth soils.	Almost level plains with few infilled sinkholes	58,014.94	25
Sturt Plateau	Bulwaddy	Lateritic Plains and Rises	Plains and rises associated with deeply weathered profiles (laterite), including sand sheets and other deposited products, and sandy and earth soils.	Generally, undulating rises, comprising frequent rises and associated slopes, almost level with residual plains and closed clay depressions	33,608.89	14
Sturt Plateau	Eley	Lateritic Plains and Rises	Plains and rises associated with deeply weathered profiles (laterite), including sand sheets and other deposited products, and sandy and earth soils.	Gently undulating to almost level plains characterised by large, closed depressions	33.23	>1
Sturt Plateau	Forrest	Lateritic Plains and Rises	Plains and rises associated with deeply weathered profiles (laterite) including sand sheets and other deposited products; sandy and earth soils.	Gently sloping sandy surfaced plains with few indistinct drainage depressions	52,241.13	22
Sturt Plateau	Larrimah	Clay Plains	Level to gently undulating clay plains (black soil plains); cracking clay soils.	Relict flood plains	22,237.24	9
Sturt Plateau	Mering	Lateritic Plains and Rises	Plains and rises associated with deeply weathered profiles (laterite), including sand sheets and other deposited products, and sandy and earth soils.	Undulating low gravelly crests and slopes with isolated ridges	11,358.19	5
Sturt Plateau	Sturt	Lateritic Plains and Rises	Plains and rises associated with deeply weathered profiles (laterite), including sand sheets and other deposited products, and sandy and earth soils.	Level to undulating plains on the Sturt Plateau	3,622.79	2
Sturt Plateau	Western	Alluvial floodplains	Alluvial floodplains, swamps, drainage depressions and alluvial fans; sandy, silty and clay soils on Quaternary alluvium.	Active flood plains	2,310.13	1
Total					235,497.64	100%

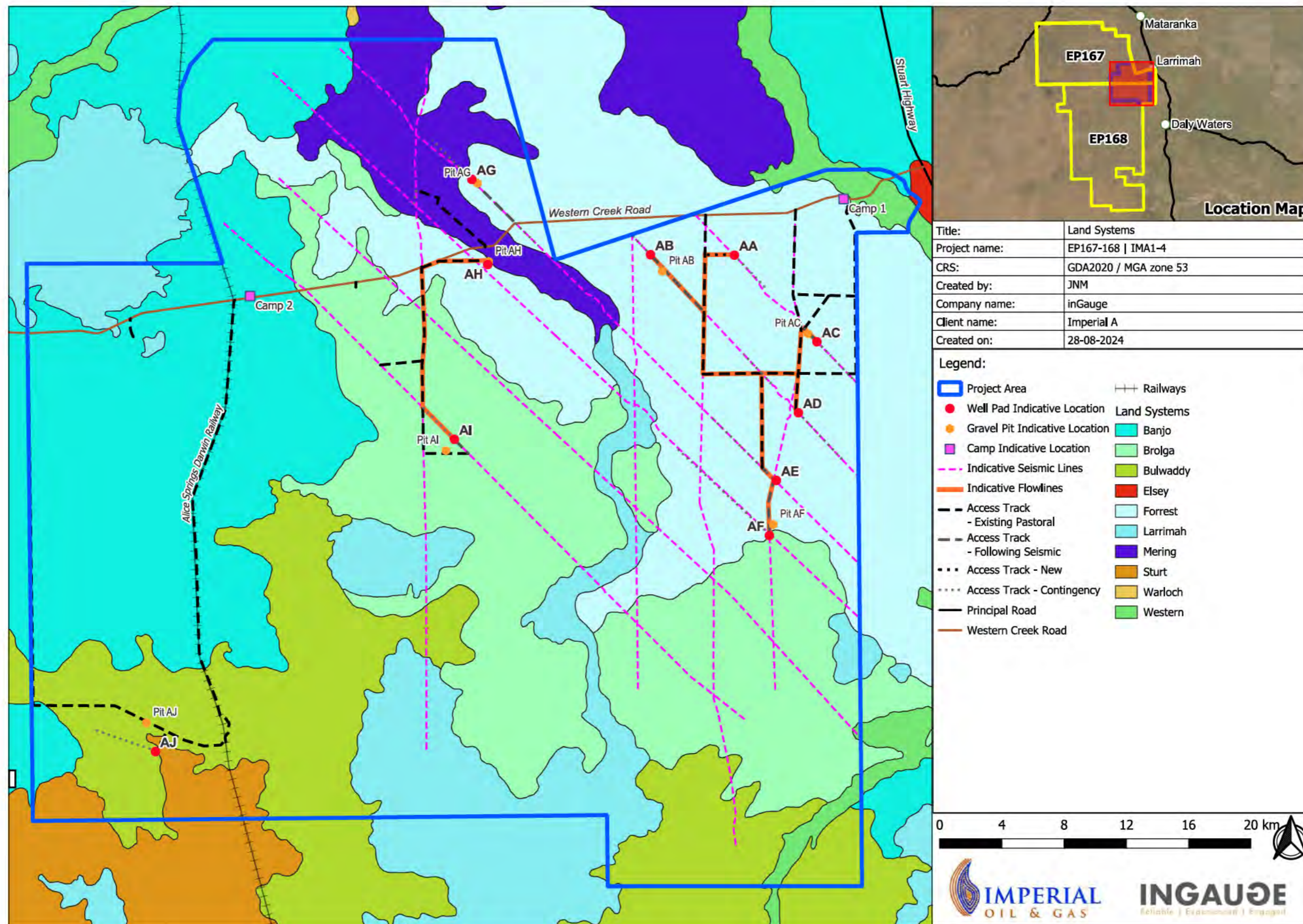


Figure 1.7—1: Land Systems of the Project Area

1.8 Soils

The Activity is located in an area generally described as plains and rises associated with deeply weathered profiles (laterite), including sand sheets and other depositional products, sandy and earth soils [DEPWS, 2022]. Pedological development of soils occurring in the Elsey Creek catchment broadly reflects erosional and depositional processes occurring in sediments transported from higher elevations in the area. Soil types align closely with the land system units, as is evident in the georeferenced imagery in the Project Area (see **Table 1.9—2**).

Soil mapping in the environs of the Project Area broadly reflects topographic and ground elevation features, as evident in **Figure 1.8—1**. The soil lithology and groundwater zones across the Project Area, taken from the DENR *Statement of Bores*, are summarised in **Table 1.11—1**.

The surface Cretaceous soil consists of a sandy indurated clay soil surface layer and highly siliceous laterite siltstone, siltstone horizon, with an average thickness of 37 m across the Project Area. The presence of this thick Cretaceous soil significantly limits meteoric (rainfall) recharge by potential vertical infiltration in the Project area. It also greatly limits any contamination of groundwater from potential spills and precludes the presence of potential GDE vegetation associated with groundwater. In areas where sinkholes occur (see **Section 1.10.8**), the lateritic material has been dissolved or altered, creating either voids or compartments filled with unconsolidated material. Regional water table lowering during the late Cenozoic era (Quaternary <2.5 mya) and the collapse of the overlying beds into the low-density zones within the Cretaceous sediment caused the formation of sinkholes. Some sinkholes may be due to the collapse of the voids in the underlying CLA, but these are further north and far from the rail line [C TWIDALE, 1987].

1.8.1 Soils and Land Systems

The key mapped soil types in the Project Area and associated LS are listed below in terms of pedological development and stability.

- **Rudosols** – occur in erosion areas and are young soils with little time pedologically to modify from parent lateritic material that occurs at the rise in the Bullwaddy LS on the boundary of the Sturt LS. They are usually thin and gravelly in this laterite material.
- **Lithosols** – occur in erosion areas and are found in the Bullwaddy LS. Lithosols are thin skeletal soils lacking well-defined horizons consisting of weathered rock fragments and represent a grading from parent rudosols at higher elevations in this area.
- **Tenosols** – occur in erosion areas and are found in the northern section of the Project Area in the Mering LS. These are shallow gravelly earths and sands and broadly reflect the floodout erosional processes occurring in Mering LS, in this segment of the Elsey Creek catchment.
- **Red Kandasols** – occur in stable areas and are comprise ferruginous kaolinitic regolith typical of the ferruginous plains. It is pale red in colour and dominated by clay loam to light clay in surface horizons and light to medium clay in lower horizons [C EDGOOSE, 2003]. Nine proposed well pad locations are located on the Red Kandasol soil type in the Forrest LS and Brolga LS. Kandasol is also found in the Bullwaddy LS where well pad AJ is located. Kandasol

is non-swelling, sandy clay that supports the savannah tussock grassland of much of the Sturt Plateau bioregion [DEPWS, 2022]. The soils result from prolonged, intense, deep weathering of parent rock material high in iron and/or aluminium oxides and kaolin clay, giving them their characteristic non-swelling profile and red kandosol colour. Subsoil horizons are generally weak to non-structured reddish clay loams and medium clays. Red Kandosols are susceptible to erosion on slope areas, especially during heavy rainfall, thus the need for site-specific erosion and sediment controls. Their clay content can vary significantly, as is evident in the georeferenced imagery for the different LS containing this soil type. They are not prone to salinisation.

- **Vertosols** - are restricted to low-lying areas, generally below 190 m AHD. They occur in deposition areas on floodplains and drainages in the Project Area in the Larrimah LS- cracking clay plains, also known as 'downs'; and Western LS-alluvial plains comprise material largely derived from the 'Downs'. Mitchell grass and Flinders grass on cracking clay plains characterise these areas [C EDGOOSE, 2003]. They are cracking clay soils (referred to colloquially as 'black soil country') and are smectite-dominated medium to heavy clay profiles with common chert and ferruginous fragments and rare tiny sand lenses. Particularly in the marginal areas, the cracking clay plains are gilgaied and contain remnants of the ferruginous plains [C EDGOOSE, 2003]. They have a heavy clay texture throughout the profile, display strong cracking when dry, and shrink and swell considerably during the wetting and drying phases. Vertosols are prone to salinisation and can have high natural salt levels (depending on the parent material and landscape practices), particularly at lower elevations [P. MEYER, 2023].

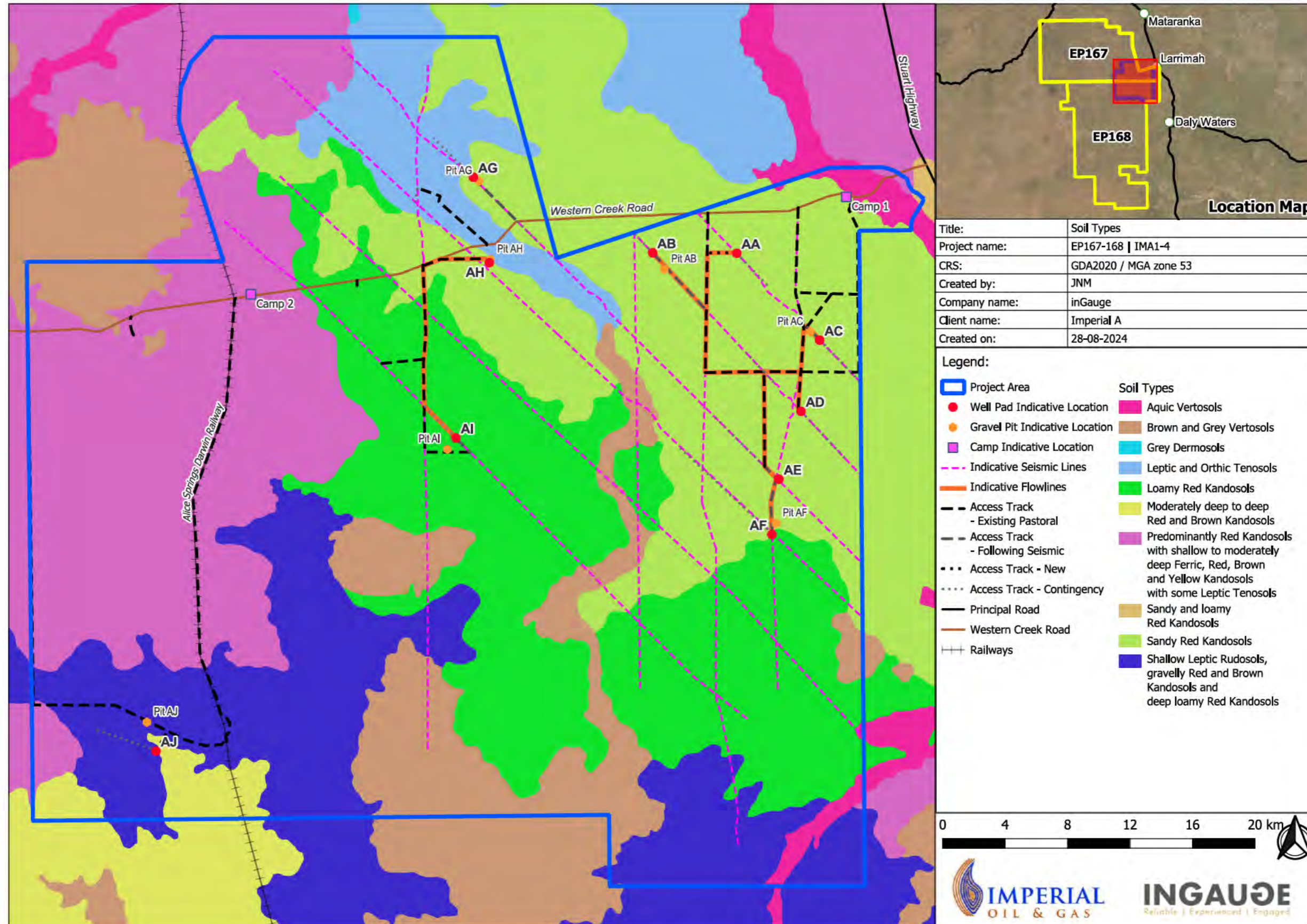


Figure 1.8—1: Soil Types of the Project Area

1.9 Vegetation

Australian tropical savannah typically consists of three strata:

- An overstorey dominated by evergreen Eucalyptus and Bloodwood tree species.
- A mid-storey of pantropical semi- to fully deciduous tree and shrub species.
- An understorey dominated by annual and perennial tussock grasses.

Although biomass tends to be modest compared with the temperate woodlands and forests of southern Australia, owing to their extensive area, these savannahs store about one-third of Australia's terrestrial carbon [M HILL et al., 2010].

The eastern portion of the Project Area is mapped in SREBA Veg 100 as open eucalypt woodland on sandy loam associated with the Forrest LS, and the western portion (Brolga LS) as eucalypt open woodland in run-on areas associated with the loamy red Kandasol soil type (Figure 1.8—1). The adjoining Larrimah LS provides the depositional area for soil arising from erosion higher in the landscape and the hydrological system for accumulation, pooling and movement of surface water down the Elsey Creek catchment system towards the northeast as described below.

An ecologist will inspect the final selected well pad locations prior to any disturbance to avoid potential localised rill/gully erosion in run-on areas. Erosion control measures (e.g., low-profile diversion bunds; progressive rehabilitation) for surface infrastructure such as well pads and buried flowlines are an important element of construction and operation in these locations.

1.9.1 Trees and Land System

As noted in Section 1.8, land system mapping integrates environmental features resulting from the interactions of geology, landform, and hydrology, which influence the distribution of markedly different soil types and, hence, vegetation across the landscape. The LS mapping provides details on associated soil types and associated vegetation [M. A. RANDAL, 1966]. The LS units and associated indicator vegetation species largely reflect elevation differences and associated soil type in the tableland topography of the upper Elsey Creek catchment in which the Project Area is located (Figure 1.6—1). The nine LS in the Project Area and associated elevation, soil type and vegetation are summarised in Table 1.9—1. The Forrest, Brolga and Bullwaddy LS are proposed well pad locations. Other LS intersect the proposed SSL corridors. Key woodland species vary between the different LSs and reflect the soil type and hydrology present. For example:

- LS with Kandasol soils (Forrest, Brolga, Banjo, Sturt) are considered stable areas. They consist of bloodwoods, mixed eucalypts and red-flowering kurrajong.
- LS with vertosol soils (Larrimah LS and Western LS) are considered depositional areas. They are associated with distinct vegetation such as Coolibah (*E.microtheca*) and Mistletoe, which provide important habitat for some listed threatened fauna potentially in the Project Area. Mistletoe occurs in mature riparian vegetation near soaks, low-lying flood plains and waterways in the Larrimah LS and Western LS in the Project Area. Table 1.9—2 provides a

selection of georeferenced imagery acquired during the baseline survey on the different LS intersected by the SSL corridors. The imagery confirms:








- LS mapping is consistent with the relevant LS landscape descriptions, soil types and vegetation.
- LS mapping is a useful tool in evaluating site suitability and potential impacts in the Project Area.

Table 1.9—1: Project Area Land Systems and Associated Vegetation

Land System	AHD	Landscape	Soil Type	Vegetation
Forest	~>200	Lateritic Plains	Sandy Red Kandosols	Mid-high open woodland of <i>C. ferruginea</i> , <i>C. terminalis</i> , <i>E. tetradonta</i> , <i>Erythrophleum chlorostachys</i> over <i>Plectrachne pungens</i> , <i>Chrysopogon latifolius</i> , <i>Sehima nervosum</i> .
Brolga	~>200	Lateritic Plains	Loamy Red Kandosols	Mid-high open woodland of <i>C. ferruginea</i> , <i>E. tetradonta</i> , <i>E. miniata</i> , <i>C. terminalis</i> , <i>Erythrophleum chlorostachys</i> over <i>Plectrachne pungens</i> , <i>Sehima nervosum</i> , <i>Themeda australis</i> .
Bulwaddy	210-200	Lateritic Plains and Rises	Rudosol Lithosol Kandosols Vertosols	Mid-high open woodland of <i>E. patellaris</i> , <i>C. ferruginea</i> , <i>C. dichromophloia</i> , <i>Erythrophleum chlorostachys</i> , <i>C. terminalis</i> over <i>Sorghum plumosum</i> , <i>Sehima nervosum</i> , <i>Chrysopogon latifolius</i> .
Sturt	218	Level to undulating plains	Deep Red and Brown Kandosols	Mid-high open woodland of <i>E. patellaris</i> , <i>E. argillacea</i> , <i>Erythrophleum chlorostachys</i> , <i>C. terminalis</i> , <i>C. confertiflora</i> over a dense grass cover (<i>Chrysopogon latifolius</i> , <i>Sehima nervosum</i> , <i>Sorghum plumosum</i>).
Banjo	200	Lateritic Plains	Red Kandosols	Mid-high open woodland of <i>E. patellaris</i> , <i>C. terminalis</i> , <i>C. ferruginea</i> , <i>Erythrophleum chlorostachys</i> , <i>C. dichromophloia</i> over <i>Chrysopogon latifolius</i> , <i>Themeda australis</i> , <i>Sehima nervosum</i> .
Mering	190-180 200	Lateritic Plains Rises	Leptic and Orthic Tenosols	Very variable, mid-high open woodland of <i>C. ferruginea</i> , <i>C. terminalis</i> , <i>E. patellaris</i> over <i>Triodia bitextura</i> ,

Land System	AHD	Landscape	Soil Type	Vegetation
				<i>Chrysopogon latifolius</i> , <i>Sorghum plumosum</i> .
Larrimah	195	Relict flood plains	Brown and Grey Vertosols	Tall sparse shrubland of <i>Carissa lanceolata</i> , <i>Ventilago viminalis</i> , <i>Terminalia volucris</i> with scattered trees (<i>Lysiphyllum cunninghamii</i> , <i>Atalaya hemiglauca</i> , <i>E. microtheca</i>) over <i>Aristida</i> spp, <i>Sorghum</i> sp, <i>Astrebla squarrosa</i> .
Western	190	Alluvial floodplains	Aquic Vertosols	Low open woodland of <i>E. microtheca</i> , <i>Lysiphyllum cunninghamii</i> , <i>Excoecaria parvifolia</i> , <i>C. terminalis</i> , <i>C. grandifolia</i> over <i>Sorghum plumosum</i> , <i>Aristida latifolia</i> , <i>Dichanthium fecundum</i> .
Eley	166	Lateritic plains and rises	Sandy and loamy Red Kandasols	Mixed eucalypt woodland

Table 1.9—2: Land System Georeferenced Imagery in Project Area

Forrest		
		
Brolga		
		
Bulwaddy		
		
Banjo		
		

Mering



Larrimah



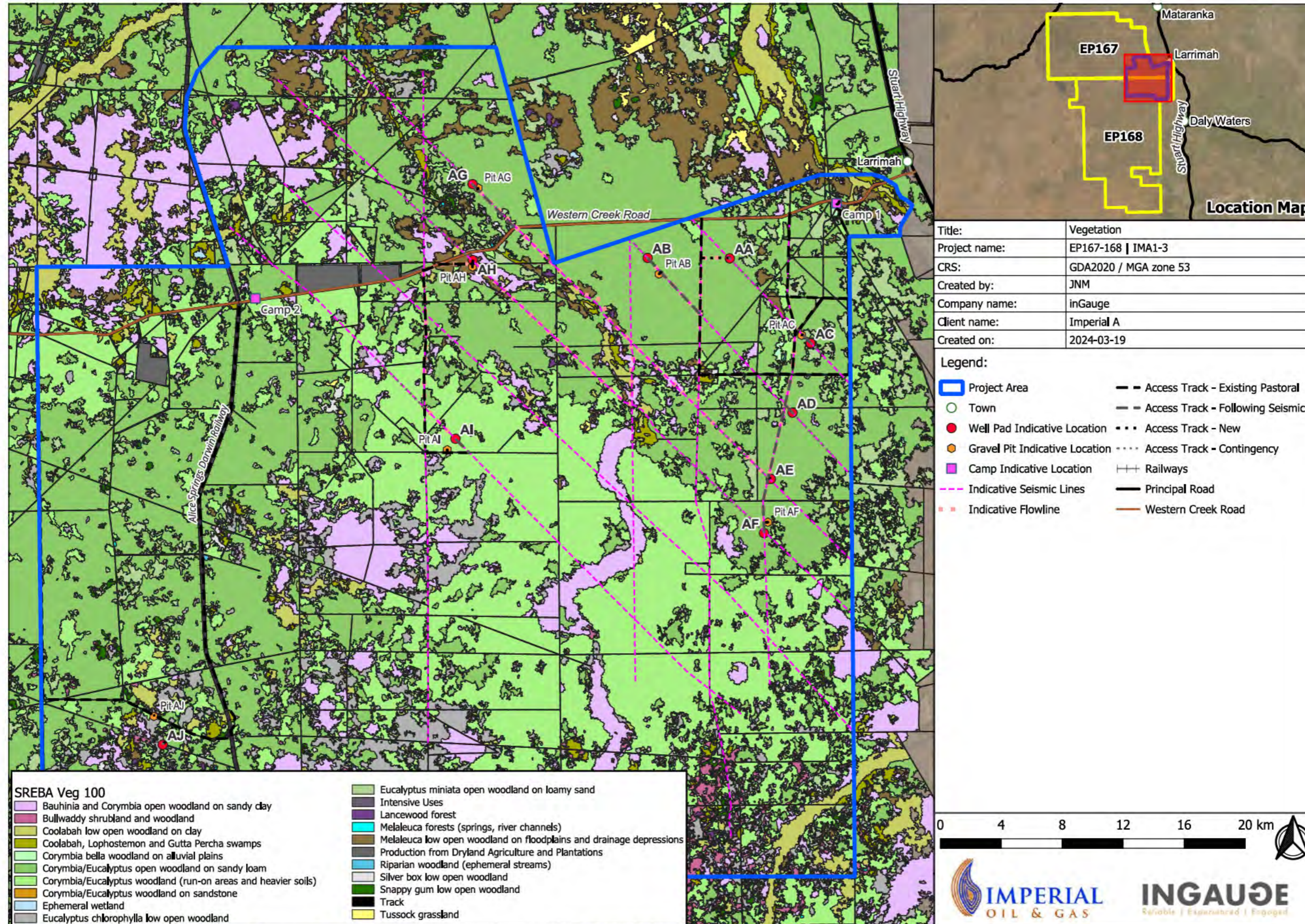


Figure 1.9—1: Vegetation Mapping in Project Area

1.9.2 Grasses and Land Systems

The Sturt Plateau savannah understorey is dominated by tussock grassland on Kandasol, Tenosol, and Vertosol soils, including in the Project Area [DEPWS, 2022]. This vegetation is characterised by large perennial tussock grasses, broad-leaved and lilioid herbs in the inter-tussock spaces, and a sparse presence of woody plants. In localised areas of sustained higher soil moisture, such as portions of the Larrimah LS, such as ephemeral topographic depressions (soakages), forbs may dominate over tussock grasses.

Tussock grasses have modular growth forms that grow as single plants in clumps, tufts, or bunches rather than forming a continuous lawn or meadow. When mature, these grasses are deep-rooted (~2 m) and structurally capable of breaking up the large, high-energy drops of rain in intense, short-duration rainstorms, which are characteristic of summer convectional storm events in the Bioregion. The tussock grass vegetation also provides critical soil stability and erosion control, particularly in the run-on areas in the west of the Project Area during high rainfall events.

The cracking clay plains, also known as 'downs', are the most widespread feature of the Larrimah LS and support the most favourable pasture (because of tolerance to grazing) of Mitchell grasses and Flinders grasses in the region [C EDGOOSE, 2003]. Tussock species identified in the key land systems of interest illustrate the distinctive difference in grass species distribution governed by soil type and hydrology.

- **Forrest LS** – Sandy Kandasols in gently sloping plains: *Chrysopogon latifolius* (Ribbon grass), *Plectrachne pungens*, *Sehima nervosum*.
- **Brolga LS** – Loamy Kandasols on nearly level plains: *Themeda australis* (Kangaroo grass), *Plectrachne pungens*, *Sehima nervosum*.
- **Bullwaddy LS** – Loamy Kandasols on plains and rises: *Sorghum plumosum*, *Sehima nervosum*, *Chrysopogon latifolius*.
- **Larrimah LS** – Vertosols in floodplains and floodout: *Astrebla spp* (Mitchell grass), *Aristida spp* (Feathertop), *Sorghum spp*.
- **Mering LS** – Tenosols (sandy shallow soils): *Triodia bitextura* (Spinifex) *Chrysopogon latifolius* (Ribbon grass), *Plectrachne pungens*, *Sorghum plumosum*.

The tussock grass vegetation is seasonally fire-prone due to the curing of the annual grasses during the Dry Season. The Project Area is burned regularly (see Figure 1.20—1), particularly in the Forrest LS and Brolga LS, where tussock grass is thickest and most prone to bushfire. It is also noted that the Larrimah LS in the Project Area was burned in 2022 after the baseline georeferenced imagery was acquired (Figure 1.20—1). Savannah tussock grasses are considered resilient perennial vegetation with seasonally synchronous seed production and are relatively unproblematic to rehabilitate in the Project Area's deep loam/sandy clay Red Kandasol soil, provided erosion control is managed. This hardiness is evidenced by the Sturt Plateau savannah's recovery after drought, frequent bushfires, and overgrazing effects.

Ground-dwelling termites and ants are important components of savannah tussock grass ecosystems in the Beetaloo, not only because they constitute a significant part of the animal biomass but also because of their role in soil processes and function [DEPWS et al., 2022].

- Mound-building termite (*Tumulitermes hastilis*) colonies are a conspicuous topographic feature in the heavier kandosol soils of the Forrest LS, Brolga LS and Bullwaddy LS, in which the well pads are located, in the Project Area. Their presence reflects the absence of flood inundation and reflects the pedological stability of the three LS in which well pads are proposed.
- Ant biodiversity is incredibly high in the Sturt Plateau. Of the 748 ant species now known from the Beetaloo region, the highest diversity was found in savannah tussock grass woodland and woodland on rocky flats [DEPWS et al., 2022].

1.9.3 Riparian Vegetation and Land Systems

No high-value surface aquatic ecosystems and sites were mapped in the Project Area in the Beetaloo SREBA Report. The Roper River Discharge Zone (RDZ) southern boundary (refer to **Figure 1.10—2**) occurs approximately ~65 km north of the Project Area [DEPWS et al., 2022]. The RDZ is where groundwater in the Roper River flow path discharges to the surface near Mataranka and is considered to have outstanding values.

There is limited riparian vegetation present in the Project Area due to the very flat topography and limited drainage network on this broad tableland landscape (refer to **Figure 1.6—1**). This is largely confined to the Larrimah LS, which acts as 'flood out black soil country' with the presence of vertosol soil groups, generally below 190 m AHD, and is self-evident in the georeferenced imagery for this LS in the Project Area. The patch size of some of the riparian vegetation associated with permanent soaks in the Larrimah LS are relatively large, intact, and likely to support a variety of bird populations. Riparian vegetation of different species also occurs to a more limited extent in the Mering LS and Western LS.

Soaks with standing water in the Project Area during the Dry Season are largely confined to the Larrimah LS. The soaks are fringed with Eucalypts and Melaleucas, commonly including *Corymbia terminalis* (inland bloodwood), *Eucalyptus microtheca* (Coolibah), *Melaleuca minutifolia* and parasitic mistletoe species, which are an important foodplant for the Painted Honeyeater (*Grantiella picta*), which may be present in the area. Mature Coolibah often have a range of small to large hollows. *Ventilago viminalis* and the deciduous rosewood tree *Terminalia volucris*, which blooms heavily in the Dry Season, are likely important species for honeyeaters. These species are also recorded only in the Larrimah LS in the Project Area.

Habitat values associated with riparian vegetation habitats on drainage lines and depressions in the Larrimah LS, and to a more limited extent in portions of the sandier Mering LS, include:

- Provides water and supports flowering and seeding vegetation, which supports insect and fish populations, as well as prey of aquatic species, invertebrates, and small vertebrates for amphibians, mammals, birds, and reptiles.
- Riparian vegetation provides refuge, sheltered movement corridors for fauna and shade for creeks and pools.
- Riparian woodlands have some hollows, which are important for hollow-dependent animals (e.g., parrots, bats, finches).
- Mistletoe was common in the limited floodplain soak areas on the Larrimah LS within the Project Area. Given the abundance of mistletoe, the woodlands associated with these areas provide potential habitat for Painted Honeyeater (*Grantiella picta*).

- May provide suitable habitat for Crested Shrike-tit (northern) (*Falcunculus frontatus whitei*), Pictorella mannikin (*Heteromunia pectoralis*) and Grey Falcon (*Falco hypoleucos*).
- Whilst not considered optimal, the hollows within the riparian vegetation around these wetlands/soaks may also provide breeding habitat for Gouldian finch (*Erythrura gouldiae*).
- Floodplains in the Larrimah LS, Mering LS, Western LS may provide suitable habitat during the Wet Season for migratory wetland species such as Great Egret (*Ardea alba*), Cattle Egret (*Ardea ibis*) and Oriental Pratincole (*Glareola maldivarum*).

1.10 Surface Water

1.10.1 Catchment Systems

The Project Area is in the top of the Elsey Creek catchment, which includes Birdum Creek. During heavy rain events, surface water flows in a north-easterly direction from this region of the Sturt Plateau to the Roper River and then into the Upper Gulf. Elsey Creek joins the Roper River east of Mataranka, within the Elsey National Park, approximately 90 km to the northeast of the Project Area. No high-value surface aquatic ecosystems and sites were mapped in the Project Area in the Beetaloo SREBA Report [DEPWS et al., 2022].

1.10.2 Flooding

The flat terrain of the Project Area and the high storage capacity of flood out areas of the landscape, such as the Larrimah LS, results in a relatively low contribution (less than 10%) of rainfall to overland flow and eventual streamflow. Wet Season stream flows are generally event-based [D. YIN FOO et al., 2000]. Overland flow forms the major component of Project Area runoff that reaches the creek line network, which, in the Project Area is the Larrimah LS and Mering LS. Overland flow may occur after soil saturation is reached and during intense storm events when the flood out area in the Larrimah LS flows to the Mering LS downstream. Flash flooding may occur during high-intensity rainfall periods, primarily from December to March inclusive. Flash floods are characterised by the transportation of large amounts of sediments and organic matter from the surrounding landscape to flood out areas.

Runoff as sheet flow from lithic slopes under intense storm conditions may also be initiated under these rainfall conditions in the Brolga LS. Due to the scale of the low-relief land, significant volumes of run-on water may travel down sheet flow pathways to reach the drainage channels in the Larrimah LS and Mering LS within the Project Area. In the Project Area, run-on water from the preceding Wet Season attenuates rapidly, and by the end of April, flow in the catchment has ceased.

An Annual Exceedance Probability (AEP) is the probability of a flood event occurring in any year. It is denoted as either a percentage, such as a 1% or a 1 in 100-year event. Predictive indicative flood modelling (AEP-100 years) for the Project Area is shown in Figure 1.10—1. A Log Pearson III distribution was used to calculate a 1 in 100-year rainfall event for the Project Area. A steady-state rainfall simulation was then developed over the catchment area using TUFLOW and the SRTM data to calculate peak flood depths and flow rates using the rainfall values from this event.

Of significance in the flood predictions is that at the northeast corner of the Project Area in the Mering LS, Western Creek Road crosses Birdum Creek at an elevation of ~160 m AHD. This area is predicted to flood under high rainfall conditions. However, as noted below, analysis of the hydrology of the catchment indicates that this is likely to be for short duration (hours to days).

1.10.3 Roper River Discharge Zone

The Roper River Discharge Zone's (RDZ) southern boundary (see **Figure 1.10—2**) occurs approximately ~65 km north of the Project Area [DEPWS et al., 2022]. The RDZ is where groundwater in the Roper flow path, mostly sourced from groundwater originating in the Cambrian Limestone Aquifer (CLA), discharges to the surface in the vicinity of Mataranka and is considered to have outstanding values [S. TICKELL, 2022].

- Estimated annual discharge of 63,2000 – 252,000 ML from the Roper flowpath of the CLA through creek beds, springs, and shallow diffuse discharge, which sustains permanent water flow in the upper Roper River.
- The highest aquatic biodiversity value in the Beetaloo SREBA study area, including high species richness of fish and all aquatic taxa, the highest number of unique aquatic species and the presence of threatened species, including a significant population of the Gulf Snapping Turtle, and distinct genetic lineages of some aquatic taxa.
- Most of the groundwater-dependent vegetation communities in the study area (particularly those with high or moderate confidence), including *Melaleuca* forests (springs, river channels), Monsoon Forest and thicket and *Corymbia bella* woodland on alluvial plains.
- A breeding locality for the threatened Red Goshawk.
- High social and economic value associated with the Mataranka Thermal Pools.

As noted, the Project Area is in a geologically uplifted area known as Antrim Plateau Volcanics (APV). As a result, the CLA is not present in the APV vicinity in the Project Area as shown in **Figure 1.10—7**. Consequently, the potential risk from the Activity to groundwater discharge in the RDZ is considered most unlikely.

1.10.4 Elsey Creek Catchment Hydrology

The Project Area is in the Barkly Tablelands on the northwest of the Sturt Plateau. It is situated on a geologically uplifted plateau terrain with little local relief and is exceptionally flat, as evident in the geomorphological mapping for the area (**Figure 1.6—1**), at the top of the Elsey Creek catchment (6,784 km²), which flows north. It is covered by ~37 m thick sandy clay loam soils on stable areas and vertosols in deposition areas, and which support savannah vegetation of tussock grasses and open forest. Given the very flat terrain of the Project Area and lack of well-formed channel beds at this higher catchment elevation, an understanding of the seasonal hydrological characteristics of the Elsey Creek catchment is an important component of site selection and informing overall Activity risk assessment.

Elsy Creek catchment is 6,784 km², with an elevation range of 144 m from a maximum of 278 m AHD to a minimum elevation of 134 m AHD at Warlock Ponds. The Project Area lies within approximately 35% of the total Elsey Creek catchment (Figure 1.10—2). The longest stream length in the Elsey Creek catchment is 205 km, giving a computed average catchment slope of ~ 0.07% or a rise, on average, of ~ 700 mm in 1 km. These low slopes are not visually apparent in the landscape.

Elsy Creek catchment has a long-term river flow gauging station at Warlock Ponds¹, approximately 68 km due north of the Project Area. Measured stream flow is highly episodic, with only 10 years in the last 57 years exceeding 200 m³/sec. Stream height ranges from 0 m to 7 m in height.

Approximately 95% of the Elsey Creek catchment's annual stream flow occurs in the months of January to March. This is reflected in the rapid attenuation to negligible or nil average daily stream flow during onset of the Dry Season, as shown in Figure 1.10—3. The average total annual flow from the Elsey Creek catchment is 140 GL, but annual stream flow data shows this has varied significantly between years, reflecting the inter-annual pulse nature of rainfall and stream flow events in this landscape, as shown in Figure 1.10—4.

Less than threshold Wet Season rainfalls (approximately 600 mm annually) in the sub-catchments of Elsey Creek contribute only to accumulation in:

- Low-lying swampy areas within the main drainage paths of the tributary creek systems that intercept the Project Area in the Larrimah LS and Mering LS.
- Ephemeral soaks that occur sporadically in the Brolga LS.

The catchment rainfall run-off relationship is evident in the significantly high correlation coefficient ($r = 0.72$) between annual total rainfall recorded in the Project Area and Elsey Creek catchment discharge, as shown in Figure 1.10—5. In low rainfall years, no discharge may occur, and run-off accumulates in the soaks present across the Larrimah LS. Minimal flow is predicted when total annual rainfall is less than 600 mm in the Project Area, principally because of the storage capacity of the low-lying floodout country in the Larrimah LS, before flowing to the Mering LS will occur.

In the Project Area, the low-lying rainfall accumulation areas have been delineated in the field survey and mapped in proximity to the nine proposed seismic survey corridors, flowlines, and 10 well pad locations, as shown in Figure 1.10—7. The low-laying areas are chiefly associated with the Larrimah LS and Mering LS in the Project Area and will be avoided in land disturbance.

This annual Wet Season threshold, before saturation and significant run-off occur, highlights the efficacy of the tussock savannah ecosystem for providing significant and rapid infiltration capacity during a very short Wet Season period each year. However, under the annual average rainfall of ~850 mm, the corresponding average Elsey Creek catchment total annual flow is ~ 140 GL.

¹ [Hydrologic Reference Stations: Water Information: Bureau of Meteorology \(bom.gov.au\)](https://www.bom.gov.au)

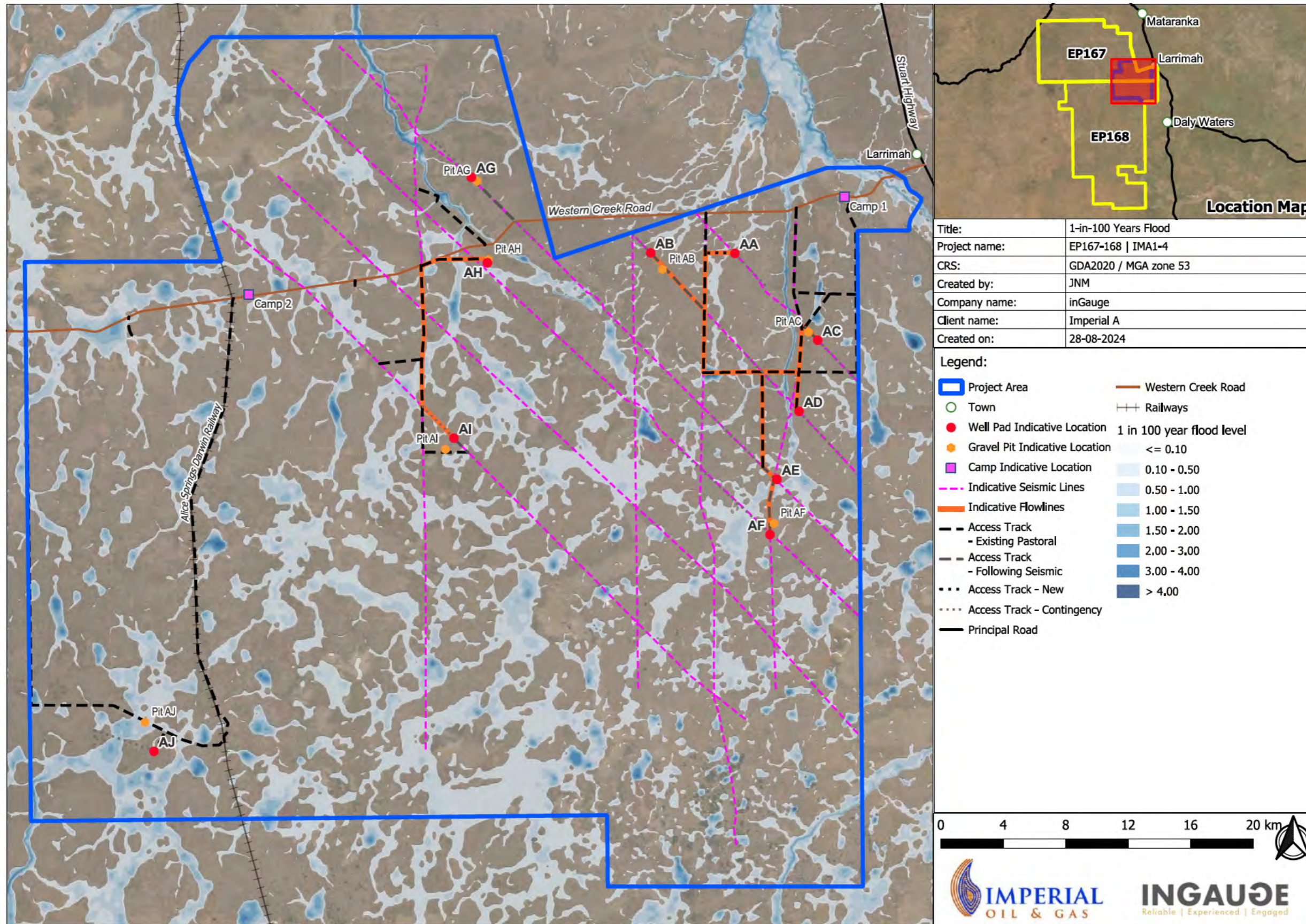


Figure 1.10—1: Predictive Indicative Flood Modelling (AEP-100 yrs) for the Project Area

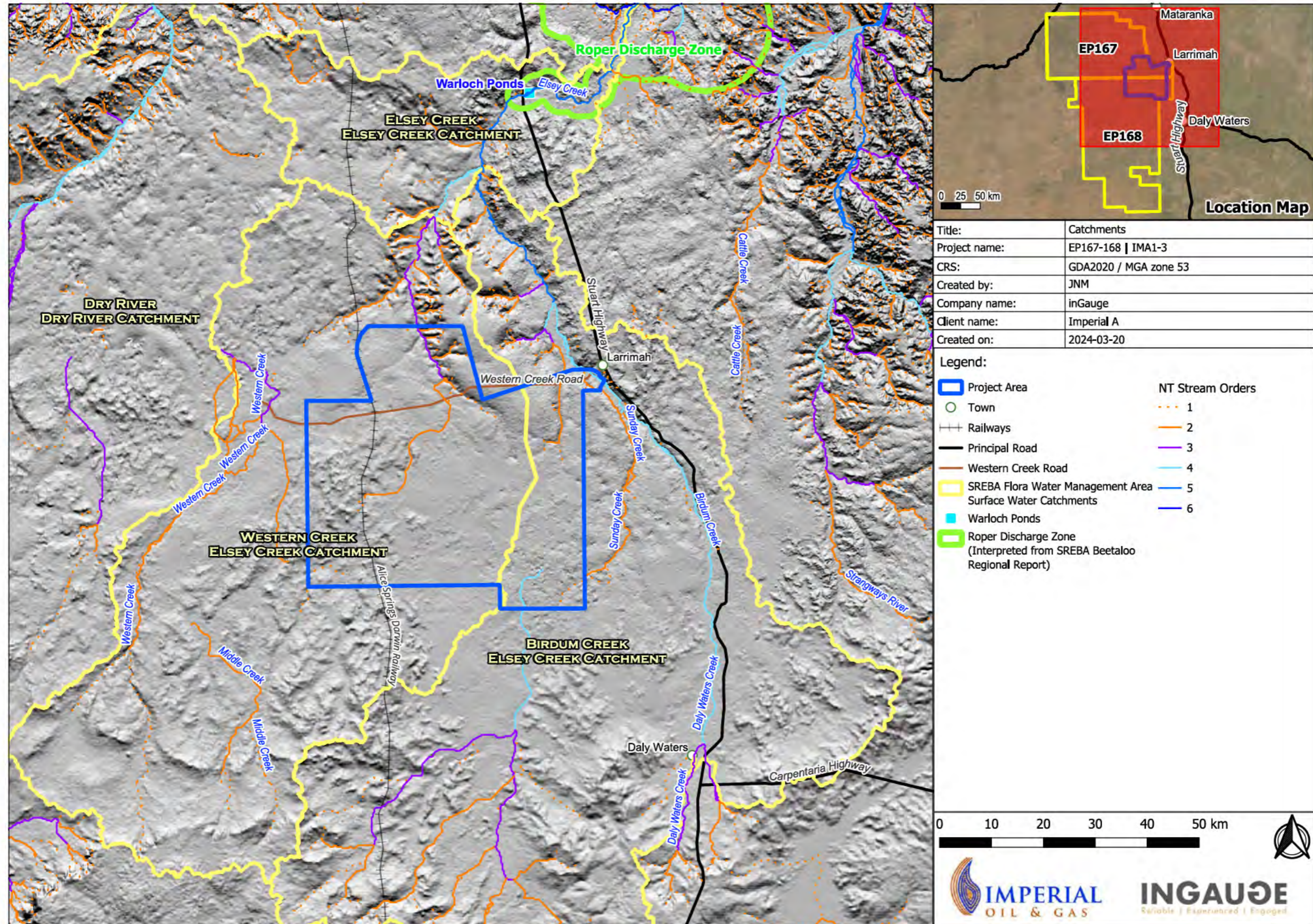


Figure 1.10—2: Project Area in Elsey Creek Catchment and Roper Discharge Zone

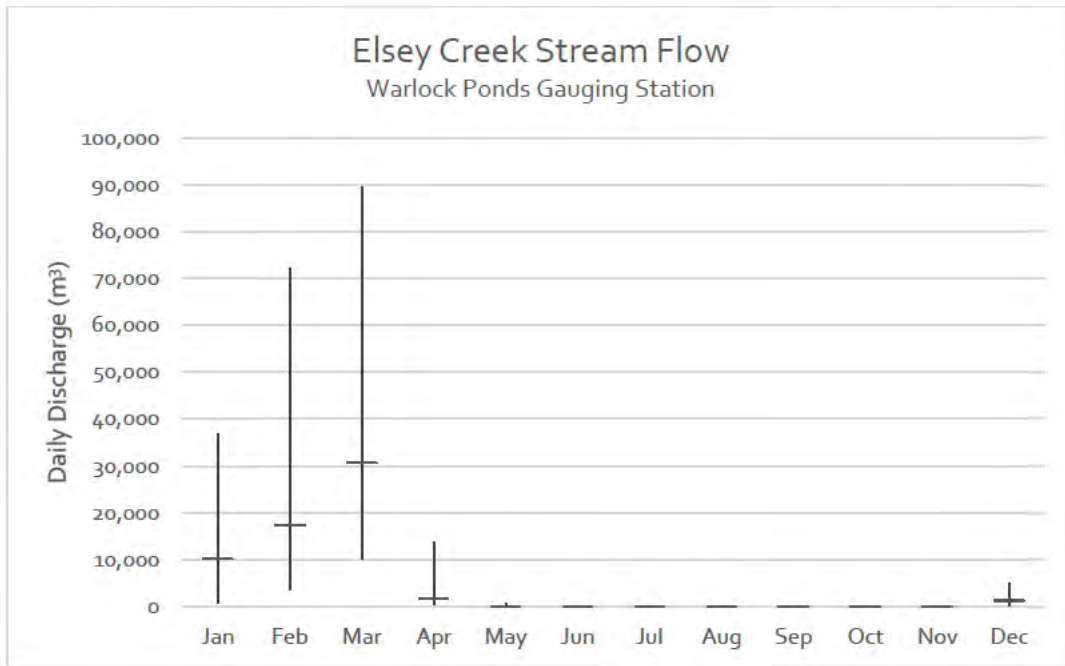


Figure 1.10—3: Monthly Stream Flow at Warlock Ponds - Median and Quartile Range

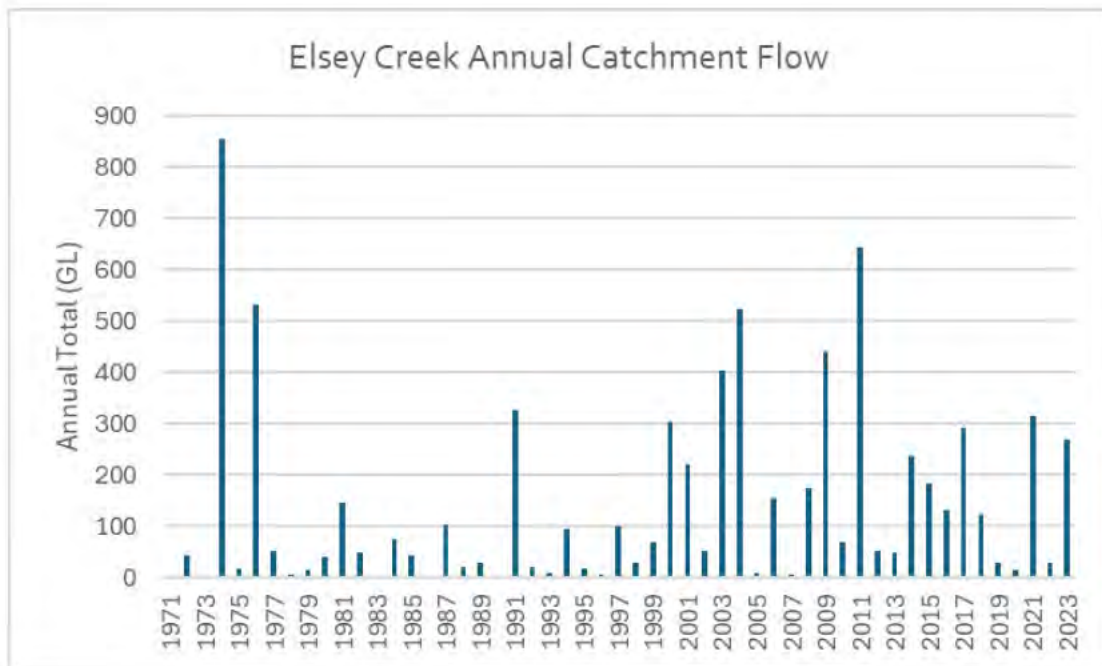


Figure 1.10—4: Eley Creek Annual Catchment Flow

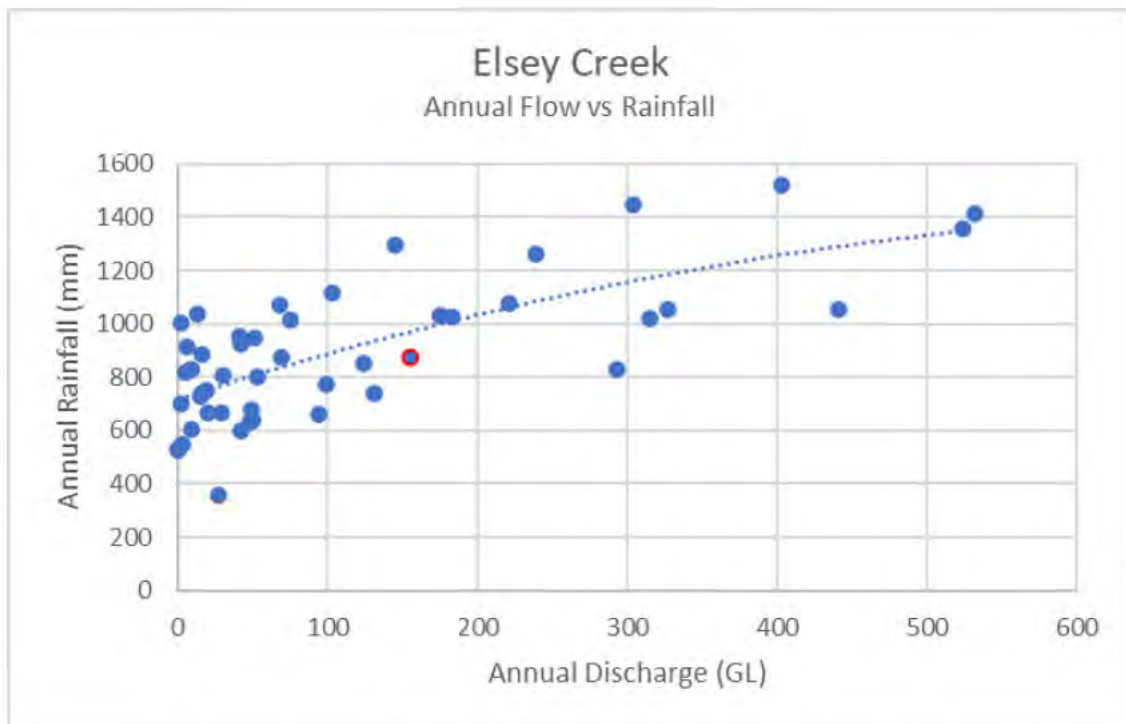


Figure 1.10—5: Elsey Creek Annual Flow vs Total Annual Rainfall

($r = 0.72$; \circ = average annual rainfall and catchment runoff)

1.10.5 Streams and Flood Plain

The distribution of northern Australian riverine communities generally follows a topographic sequence related to the landform elevation [S. Capon et al., 2016]. Capon found a notable shift in community richness around a specific elevation within most catchments, which coincides with a change from erosional zones to stable zones and depositional zones. Although the relative elevation differences across the Project Area are relatively small, the same geomorphic zones are identified in the relevant LS. Elsey Creek catchment water flow in the Project Area is towards the northeast. It is characterised by:

- Erosion zones on the Bullwaddy LS where it abuts the more elevated Sturt LS in the southwest of the Project Area and is characterised by the presence of Rudosols, Lithosols; and 'run-on' areas in the Brolga LS in southwest of the Project Area.
- Deposition zones in the level relict floodplains of the Larrimah LS are characterised by Vertosol soils. demonstrated by the presence of smectite-dominated medium to heavy clay profiles (cracking clay black soil country or 'downs'). Any surface water accumulations retract during the Dry Season, leaving occasional shallow ephemeral pools/soaks in the northeast of the Larrimah LS in the Project Area. These were identified and mapped during the Project Area survey. Vertosols also occur in the alluvial floodplains of Western LS
- Stable zones on Kandasol soils in the Forrest LS, Brolga LS and Bullwaddy LS
- Active drainage networks and coarse, unstable Tenosol sediments in the sandy gravels of the Mering LS to the northeast. The mapped Stream Order 1 and 2 waterways have no

discernible beds, banks, or channels but rather generally delineate the very flat topography and limited drainage network in the low-lying 'flood out' country (see **Figure 1.10—2**).

The Elsey Creek catchment rainfall run-off relationship (**Section 1.10.4**) showed minimal flow is predicted when total annual rainfall is less than 600 mm in the Project Area. Rainfall of 600 mm is also considered the annual minimum to support savannah grasslands in the NT.

The low-lying Larrimah LS of black soil floodout country has significant storage capacity and is 'recharged' during these events. The Larrimah LS provides the only permanent water source in the Project Area during the Dry Season. Overflow to the downstream Mering LS likely only occurs during high rainfall events once the area is saturated.

1.10.6 Sub-Catchment Drainage Network

Drainage, stream orders, GDEs, and sinkholes of the Project Area are shown in **Figure 1.10—7**. The primary drainage lines of the Elsey Creek catchment with respect to the Project Area are in the Larrimah LS and Mering LS. The drainage lines include:

- Middle Creek in the north, which leads into Western Creek before it joins Elsey Creek to the northeast of the Project Area. This portion of the Middle Creek sub-catchment is located in the Larrimah LS and includes a few Stream Order (SO) 1 drainage lines commencing at the highest elevations, a Stream Order 2 that bisects much of the western Project Area heading northeast in the Larrimah LS, connecting to Stream Order 3 at lower elevations in the Mering LS in the northern Project Area heading north. Georeferenced imagery of the higher order streams is provided in **Figure 1.10—6**.
- The top of a sub-catchment of Birdum Creek in the east of the Project Area in the Western LS. In this drainage line, ephemeral soaks are present at elevations below 190 m AHD. This portion of the Birdum Creek sub-catchment includes several Stream Order 1 drainage lines commencing at the highest elevations, a Stream Order 2 that bisects the southeastern part of the Project Area heading north (see **Figure 1.10—6 – ID#6**). This leads to Stream Order 3 at lower elevations outside and to the east of Project Area. This tributary then joins the main channel of Birdum Creek which runs north parallel and adjacent to the Stuart Highway east of the Project Area before joining Elsey Creek.
- At the northeast corner of the Project Area in the Mering LS, Western Creek Road crosses Birdum Creek at an elevation of ~160 m AHD. This area is predicted to flood under high rainfall conditions (see **Figure 1.10—1**).
- Sunday Creek in the south in the Western LS and outside the Project Area. This leads into Birdum Creek, where there are no mapped drainage lines in the Project Area.
- Western Creek sub-catchment in the west – draining to the Larrimah LS.

In the southeast of the Project Area, a dry flood plain and a permanent pool were mapped at the top of the catchment at Sunday Creek below an elevation of approximately 188 m AHD in the Western LS which is comprised of alluvial floodplains. Pools and flood plains at low points in the landscape in the vicinity of the seismic corridors were also mapped across the Project Area associated with the Larrimah LS and Mering LS.

1.10.7 Streams on Seismic Corridors - Georeferenced Imagery

Selected georeferenced imagery from the field survey, relating to stream areas nearby crossings for proposed seismic lines is mapped in **Figure 1.10—6** and a description of the morphology and vegetation presented in **Table 1.10—2**. Imagery is provided in **Figure 1.10—6**.

The imagery shows that in the Project Area:

- Stream Order (3) occurs in the North of the Project Area in the Mering LS. It is the most significant watercourse of Project Area and has very low to almost no-defined banks and sandy substrate.
- Stream Order (2) in the Project Area have no defined bed or banks. They consist of low-lying drainage areas in the landscape. Overland flow would be concentrated through these areas in the wet seasons.
- Riparian vegetation is associated with floodout country in Larrimah LS with no defined stream order.

Given the extremely flat terrain and absence of defined creek morphology in the mapped stream orders in the Project Area, it is considered most unlikely that disturbance of the streams will occur during the seismic survey operations. The streams consist of low-lying drainage areas in the landscape with no defined banks or stream beds and absence of associated riparian vegetation. Overland flow would be concentrated through these areas in the rainy period of the Wet Season. The pastoralists have made use of these lower stream orders to harvest and store run-off in farm dams in several locations across the Project Area as is evident in **Figure 1.10—6**.

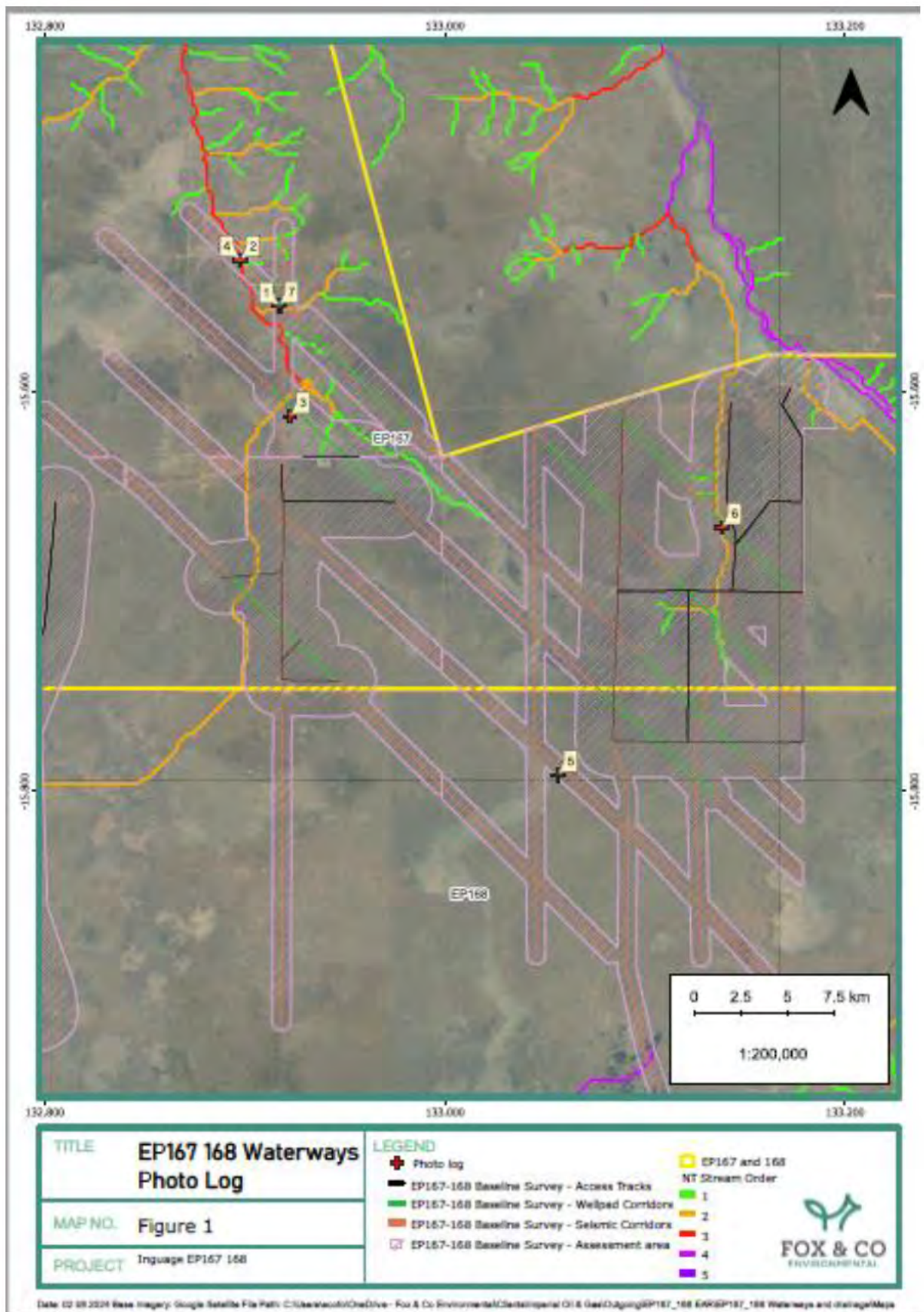
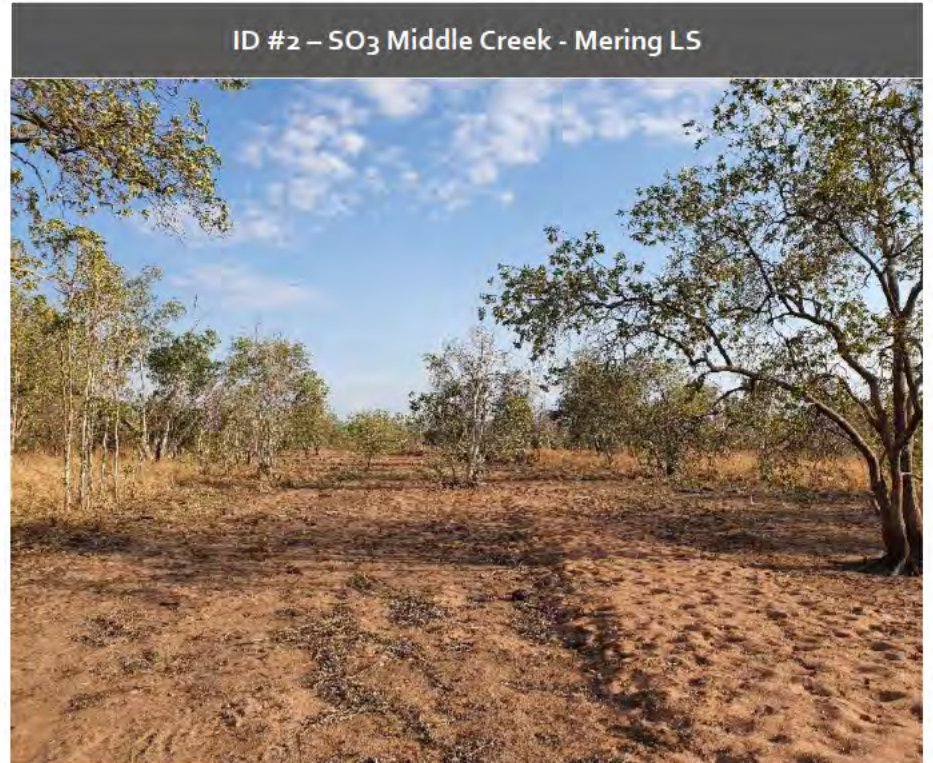


Figure 1.10—6: Georeferenced Imagery Locations for Stream Areas on Seismic Lines

Table 1.10—1: Georeferenced Imagery for Stream Areas on Seismic Lines

Photo ID #	Longitude	Latitude	Stream Morphology and Vegetation
1	132.9173	- 15.5575	Amber waterway. SO ₂ . No defined bed or banks. Consists of low-lying drainage areas in the landscape. Overland flow would be concentrated through these areas in the wet seasons. In the Mering LS.
2	132.8976	- 15.5344	Red waterway. SO ₃ . Main watercourse of Project Area although has very low to almost no-defined banks. Sandy substrate. In the Mering LS.
3	132.9225	- 15.6126	Close to mapped SO ₂ . Rather than defined watercourse, the area is a low-lying drainage feature that has very shallow pools where water persists late into the Dry Season. In the Forrest LS.
4	132.8976	- 15.5344	Red Waterway. SO ₃ . In the Mering LS.
5	133.0563	- 15.7918	Example of low-lying ephemeral floodout. In the Larrimah LS.
6	133.1383	- 15.6681	Mapped SO ₂ (amber) waterway. Like the other mapped waterways, they do not have defined bed or banks but rather are low drainage lines in the landscape that have the occasional very shallow pool that holds water a little later in the dry season. In the Forrest LS.
7	132.9168	-15.5572	Amber waterway. SO ₂ . No defined bed or banks. Consists of low-lying drainage areas in the landscape. Overland flow would be concentrated through these areas in the wet seasons. In the Mering LS.

Table 1.10—2: Georeferenced Imagery of Stream Morphology and Vegetation in Project Area



ID # 7 SO₂ Middle Creek – Mering LS



Middle Creek – Mering LS



1.10.8 Sinkholes

Sinkholes are pipe-like features that form when soil and rock collapse into subsurface cavities, leaving an open hole or a depression at the surface. Open sinkholes can provide pathways for rapid recharge to aquifers in the Cambrian Limestone Aquifer (CLA). This recharge component is poorly understood and hard to model, particularly as the distribution of sinkholes is not fully known in the Beetaloo. Areas above the western lobe of the Beetaloo Sub-basin are more prone to sinkhole development than the eastern lobe [S. TICKELL, 2022].

Most sinkholes in the region have evolved wholly within the surface Cretaceous material which has an average thickness of ~59 m across the Project Area (see Section o). It is comprised of highly siliceous laterite siltstone, which has been dissolved or altered, creating either voids or compartments filled with unconsolidated material. Regional water table lowering during the late Cenozoic era (Quaternary <2.5 mya) and the collapse of the overlying beds into the low-density zones within the Cretaceous sediment caused the formation of sinkholes [C TWIDALE, 1987]. Litter derived from a Eucalyptus-dominated woodland facilitated iron mobilisation. Biogenic agents may have accelerated the weathering of the silica, silicates and iron oxides of which the country rock and laterite are largely composed.

Sinkholes also occur within and at the margins of old drainage lines. Some sinkholes may be due to the collapse of the voids in the underlying CLA where present, but these are further north and far from the rail line [C TWIDALE, 1987].

Sinkholes that have been identified in and near the Project Area have been mapped in Figure 1.10—7. Infilled sinkholes are associated with the Larrimah LS (vertosols) and the Brolga LS. However, as noted previously, the CLA is not present in the Antrim Plateau Volcanics (APV) basalt uplift area, defined by the APV boundary mapped in Figure 1.10—7. Any sinkholes that may be present within the APV boundary of the Project Area, terminate in the Cretaceous strata overlying the basalt, and can have no connection with the CLA because it is absent in this area due to uplift. One sinkhole was identified in the Bullwaddy LS in the southwest near the rail line and well pad AJ where the CLA occurs.

Mapped sinkholes in the Project Area are distant from well pads. All well pads in the Project Area are in areas where any sinkholes that may be present (mapped or unmapped) terminate in the Cretaceous sediments because:

- Well pads AA -AI inclusive are situated on the APV basalt, and the CLA is absent in that region.
- Well pad AJ in the southwest is located above the CLA but separated vertically by more than 40 m of clay siltstone and sandy soil as evident in the nearby RN35145 water bore and the Tarlee S3 Well Completion Report. Connectivity of sinkholes with the CLA in this location is therefore considered remote.
- Doline (sinkhole) mapping was conducted prior to the Darwin – Alice Springs rail line construction. No karstic geohazards were identified in the vicinity of the rail corridor traversing this region [C TWIDALE, 1987].

1.10.9 Springs

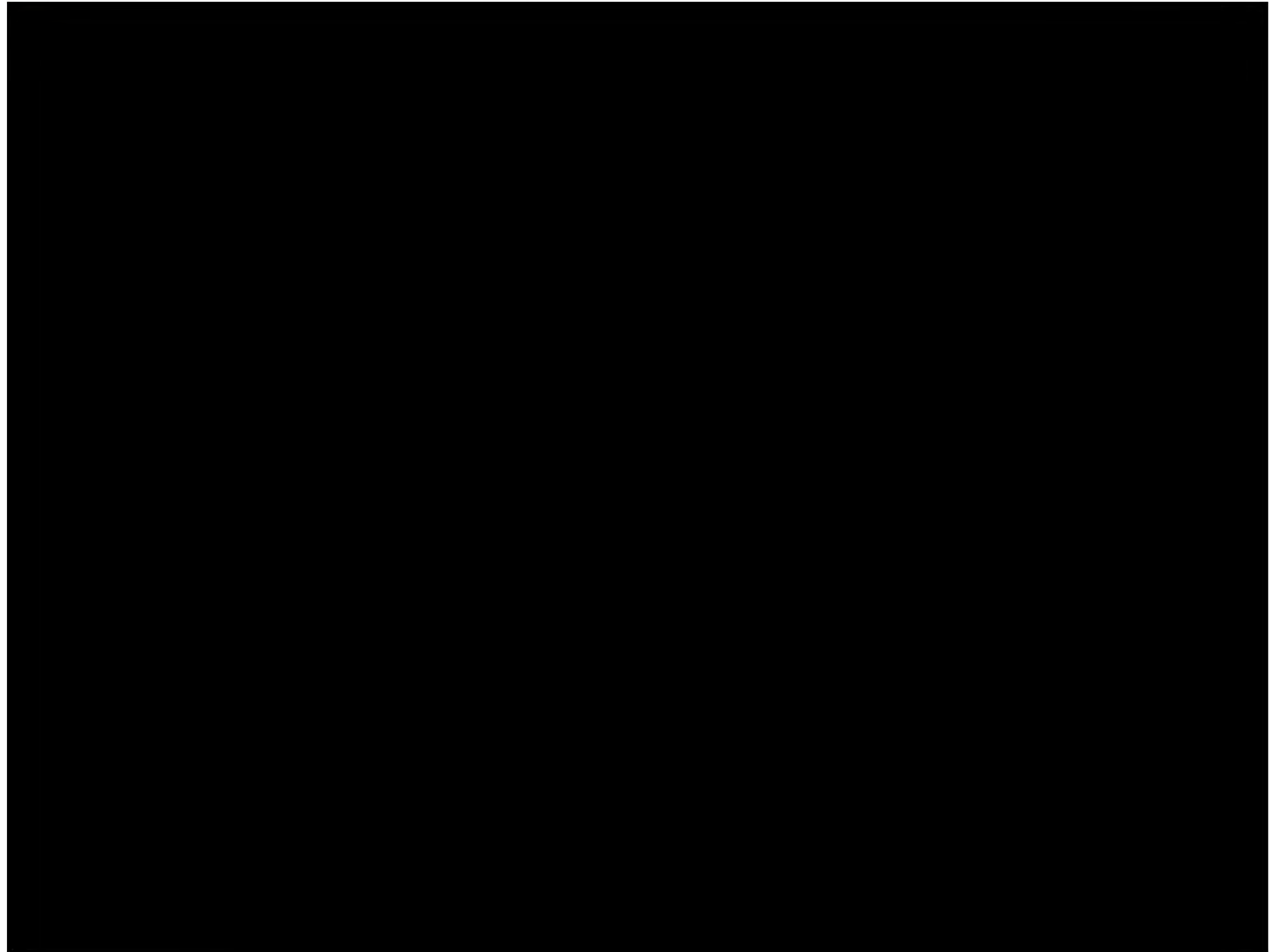
Analysis of the springs spatial layer of the Natural Resource Maps shows no springs within the Project Area [DEPWS, 2022]. This is to be expected, given the flat nature of the terrain; the Project Area relative elevation range in the catchment; and the soil stratigraphy in the Project Area.

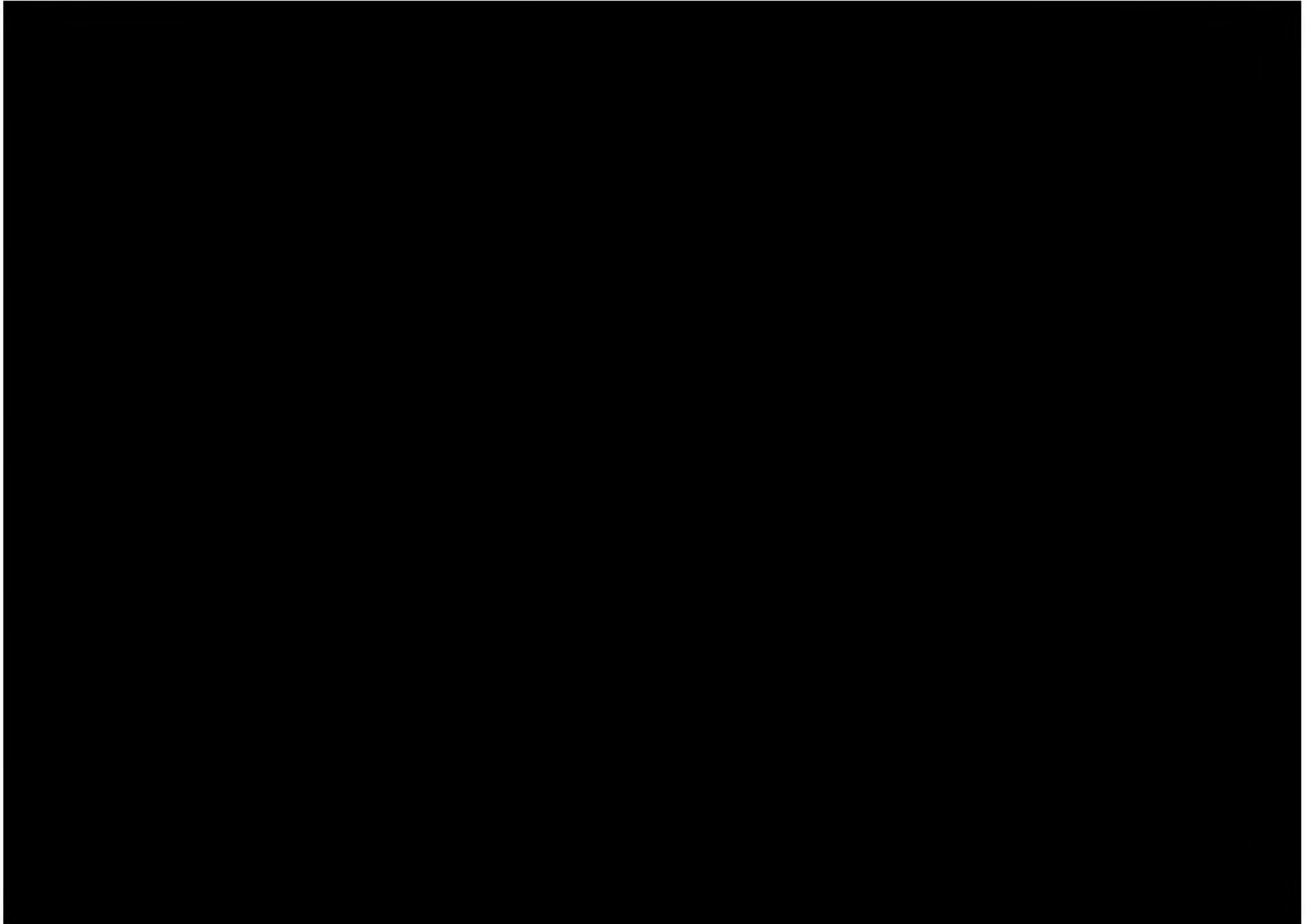
As noted previously, the CLA is also not present in the Project Area where uplift from the underlying APV basalt has occurred. Access to the fractured basalt aquifers by pastoral bores in this region is very limited; standing water level is relatively consistent at 44m bgl (± 5 m); and surface connectivity with the underlying APV basalt horizon is likely to be a highly restricted potential pathway. The average top of the APV basalt across the Project Area is ~ 68 m bgl, with a measured thickness of approximately ~140 m.

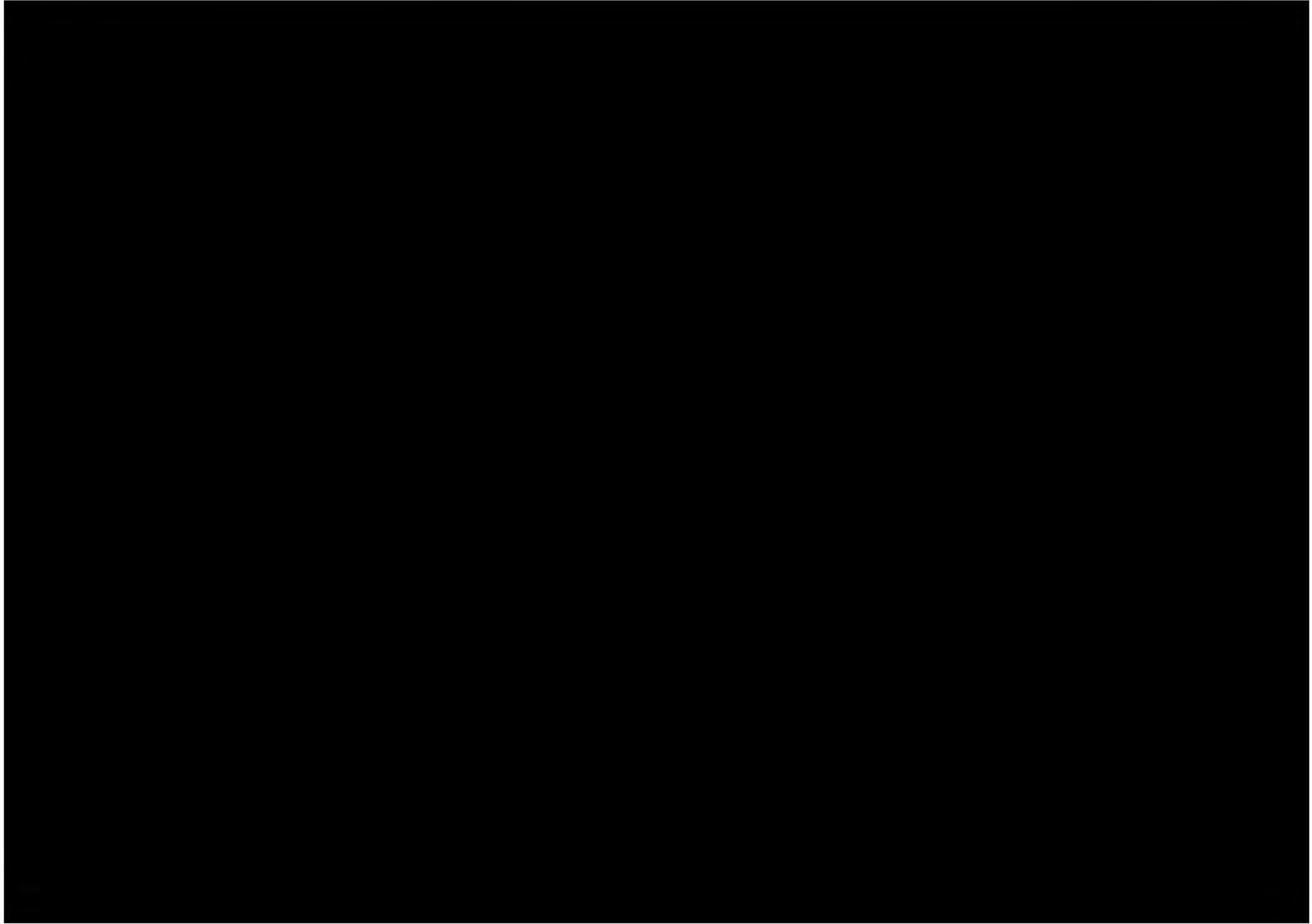
1.10.10 Soaks and Waterholes

An eleven-day aerial survey of the seismic line corridors was conducted with ecologists and archaeologists from 3rd to 13th November 2021. There were 82 landings made along ten seismic lines, ten well corridors and access tracks. Soaks and waterholes with standing water were mapped in and near the survey corridors. Permanent and ephemeral soaks and waterholes formed in shallow closed claypan depressions, and less frequently pools, are an important resource feature in the flat topography of the Project Area. As noted previously, these features are largely confined to the Larrimah LS in the Project Area. Small shallow ephemeral soaks have also been mapped in the field survey (Figure 1.10—7) in the Forrest LS, Brolga LS and Bullwaddy LS. They are entirely fed by meteoric (rain run-off) input and serve as important refuge water sources for local fauna (including cattle and aerial fauna), often within up to a 5 km radius on a landscape scale, during the onset and variable duration of the long and mostly arid Dry Season, April to October inclusive.

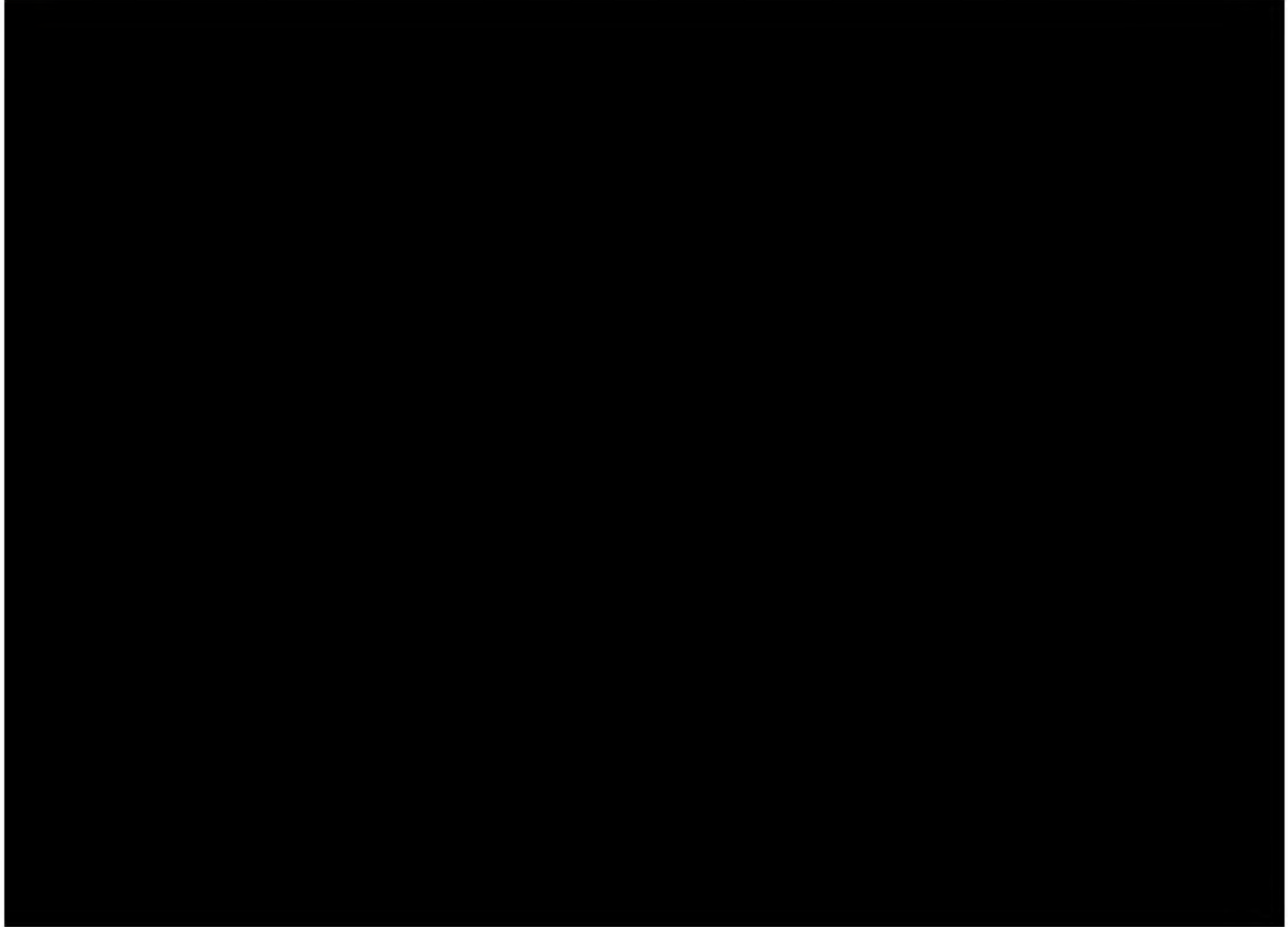
A review of available water quality data for these surface water features across the Sturt Plateau in the Beetaloo showed that pH may vary from 7.5 – 9, reflecting the range of photosynthetic activity in this ponded rainwater. Electrical conductivity (EC) varied from 35-135 μ S/cm, reflecting that the source of water for these features is entirely rainwater [ECOZ ENVIRONMENTAL CONSULTANTS, 2016; P. MEYER, 2023]. Groundwater EC in the Project Area is at least an order of magnitude higher.











Ground surface visibility estimates for the survey were classified as 'good' in this flat open landscape where significant features, such as soaks, were relatively easy to identify from the air in proximity to the survey that was flown on each proposed seismic line corridor (Appendix 01.01 – this appendix includes example photographs). The total rainfall in the previous 210 days was only 8.9 mm, which underscores the aridity of the region. This was just prior to the beginning of the onset of the Wet Season for 2021. During the survey, 65 mm of rain was recorded at nearby Larrimah.

The survey identified and captured georeferenced imagery for each of the LS in the Project Area. Some of these images have been compiled for each LS in Table 1.9—2 and validate the descriptions provided for each LS unit in terms of landscape, soils and vegetation species [C.S CHRISTIAN et al., 1954].

Of the ephemeral soaks identified near the proposed SSL, 12 of 20 still had standing water at this late stage of the Dry Season and were confined to the Larrimah LS, as evident in the georeferenced baseline imagery. A summary of the surface water body features is shown in Table 1.10—3 and mapped in Figure 1.10—7.

Table 1.10—3: Water Body Features Mapped in the Vicinity of Project Area

Surface Water Feature	Status	Number of Sites Identified
Flood Plain	Standing Water	1
Flood Plain	Dry	4
Permanent Pool	Standing Water	1
Permanent Pool in Waterway	Standing Water	1
Ephemeral Soak	Dry	8
Ephemeral Soak	Wet	12

1.10.11 Infiltration

As noted previously, the measured standing groundwater level (SWL) across the Project Area is relatively consistent at 44 m bgl (± 5 m) and reflects the extremely flat terrain. Isolated fractured basalt aquifers occur within the APV basalt in this region, and stock bores tap such limited aquifers in the Project Area (Table 1.11—1). Because a sandy clay soil horizon of Cretaceous material (average thickness 37 m) is present across the Project Area, surface connectivity with the underlying APV basalt horizon, which is considered a regional aquitard, is likely to be a highly restricted potential pathway for surface infiltration. The results of the Darcy infiltration modelling (see Appendix 06.01) conservatively assumed that water is available in the surface to act as a driving head (i.e., a consistent leak). The results indicate water will take approximately 80 years to move through the initial 50 m (clay/siltstone).

The average top of the APV basalt across the Project Area is ~ 68 m bgl, with a measured thickness of approximately ~140 m. On a regional scale this basalt formation is considered to act as an aquitard or an aquiclude to any underlying aquifers [S. TICKELL, 2022].

Because the CLA is not extant in the Project Area, and thick basalt aquitard is present, the possibility of surface connectivity, including sink holes and soak holes, with the deeper and more substantive regional Bukalara Sandstone aquifer is remote within the mapped boundaries of the APV on which the proposed well pads are located. Well pad AJ in the southwest is located above the CLA but separated vertically by more than 40 m of indurated clay siltstone and sandy soil, as evident in the nearby RN35145 water bore and the Tarlee S3 Well Completion Report. Geohazard surveys were also conducted prior to constructing the nearby rail line corridor to ensure it avoided karstic sinkhole country [C TWIDALE, 1987]. The connectivity of sinkholes with the CLA in this location is therefore considered remote.

1.11 Hydrogeology

1.11.1 Cambrian Limestone Aquifer

The CLA is contained in a vast limestone marine reef that was formed during the mid Cambrian era (540-485 MYA). The Cambrian Limestone is remarkably flat across the Beetaloo, as observed in its elevation, derived from drilling logs at Tarlee-1 in the Project Area and ~200 km away in the southeastern Beetaloo basin at Tanumbirini-1. The top is located at approximately 170 m AHD in both areas, overlaid by Cretaceous siltstone and laterised sediments. The CLA contains the widespread fractured and karstic aquifers that are utilised for stock and domestic purposes across the Beetaloo [S. TICKELL, 2022], where it is present.

However, immediately west of Larrimah, including the eastern half of the Project Area where most of the Activity is proposed, the CLA has been uplifted and eroded (not present) or is above the water table along the western side of the Birdum Creek fault [S. TICKELL, 2022; D. YIN FOO et al., 2000]. This is mapped as the APV in Figure 1.10—7. Its absence from Birdum, Middle and Cow Creek water bore data from relevant Water Bore Statements summarised in

The CLA is not existent in most of the Project Area except in the west near the rail line. This lack of accessible groundwater and surface water in the eastern Project Area means that many pastoral bores target groundwater in the underlying APV.

Table 1.11—1: Hydro Stratigraphy from Water Bore Statements in Project Area

Pastoral Station	Sand-clay	Mixed Limestone Chert	Basalt Top	Top of Screen	Standing Water Level	Project Area	Water Bore Log
Western Creek	31	31-83		52	49	E	RNo26367
Birdum Creek	42	-	42	118	37	E	RNo36919
Middle Creek	33	-	33	70	35	N	RNo36506
Cow Creek	42	-	42	40	31	W	RNo33135
Middle Creek	39	-	39	55	46	W	RNo35147
Middle Creek	42	42-136	136	127	50	W	RNo35137
Middle Creek	33	33-112	112	129	52	S	RNo35138
Sunday Creek	30	30-60	69	145	50	S	RNo35136
Average (m)	37	-	68	92	44		

1.11.2 Antrim Plateau Volcanics

Isolated fractured rock aquifers occur within the Kalkarindji suite basalt, represented by the APV in this region. The average depth of the top of the APV is approximately 40 m bgl, with a measured thickness of approximately ~140 m in the Project Area. Stock bores tap such basalt aquifers in the Project Area, screening at depths from 40-70m bgl (Table 1.11—1). Standing water level across the Project Area is relatively consistent at 44 m bgl (\pm 5 m).

Bores intersecting the weathered surface of the basalt, in some instances, may yield about 0.3 L/s, while fractures will usually yield 1 to 2 L/s (Yin Foo & Matthews, 2002). However, there is a high rate of unsuccessful bores drilled in the basalt. Water quality is highly variable (fresh to saline), which limits supply from this sequence for stock or domestic purposes (DEPWS, 2022). Bores in the area report an average electrical conductivity (EC) of 910 μ S/cm (TDS 550 mg/l) and a range of 400–1,840 μ S/cm (TDS 240 – 1,100 mg/l). Groundwater quality results from DEPWS observation bore in the APV basalt near the Project Area are shown in Figure 1.11—1. On a regional scale, this APV basalt formation is considered to act as an aquitard or an aquiclude to any underlying aquifers [S. TICKELL, 2022].

1.11.3 Unnamed Sandstone

This formation has a more restricted distribution than the regional Bukalara Sandstone, with which it has often been confused. Tarlee-1 is the only petroleum well to intersect the Unnamed Sandstone in the Project Area. The lithographic log at Tarlee 1 intercepted a 44 m thick interval immediately below the basalt at ~180 m bgl. This sandstone has also been intersected in water bores surrounding the Project Area (Figure 1.11—1).

Aeromagnetic imaging across the Project Area shows a series of magnetic lineations striking NW-SE, which reportedly line up the presence of the Unnamed Sandstone [S. TICKELL, 2022]. This lineament is likely related to a variation in the thickness of volcanics associated with flood basalts that filled an aeolian dune system during the regional Antrim Plateau Volcanics event 59 MA.

At RNo41445 near Larrizona Station, northwest of the Project Area, the formation was intersected from 194 to 247 m. The bore was screened across the overlying Unnamed Sandstone and Bukalara Sandstone, and pump tested at 16 L/s. It is considered likely to be an intermediate-scale, fractured and porous aquifer with good prospects as an alternative water supply to the CLA in this region [S. TICKELL, 2022]. Where the Unnamed Sandstone unit directly overlies Bukalara Sandstone, it should be treated as one fully connected aquifer. Water chemistry results from drilling and pumping tests at RNo41445 indicate that the CLA and Sturt Plateau Bukalara Aquifer are distinct from one another. Similar water qualities between water-bearing zones of the basalt and the underlying Sturt Plateau Bukalara Aquifer may indicate some degree of vertical flow and/or solute transport [M SHORT, 2021].

Where the Unnamed Sandstone unit directly overlies the siltstone-rich Cox Formation (Hayfield Mudstone), as observed in the central area of the western Beetaloo Sub-basin (Figure 1.11—1), it is likely that the sandstone unit only occurs as a local to intermediate-scale aquifer. However, it is currently unknown how laterally continuous the Unnamed Sandstone unit is, and further investigation would be required to understand this aspect to determine if it should be treated as a regional-scale aquifer.

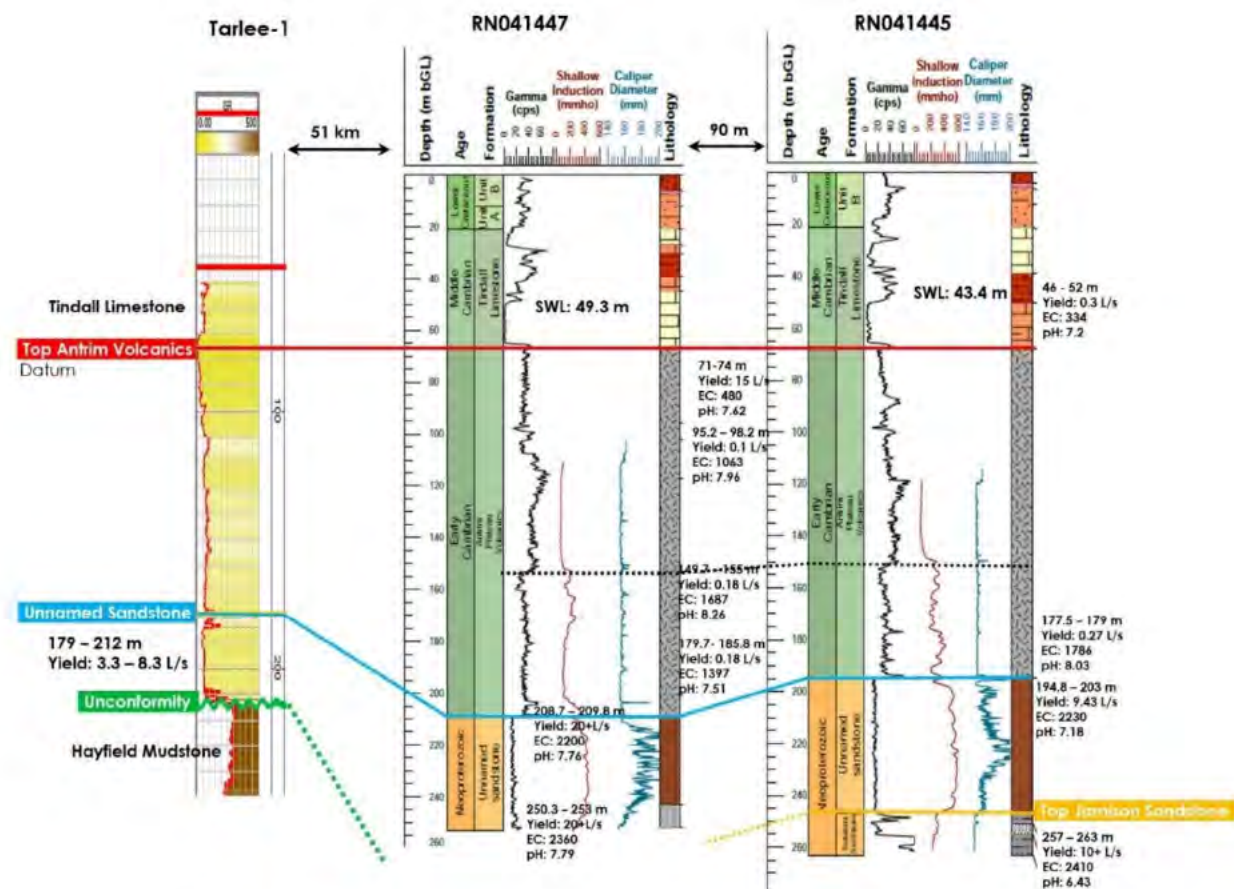


Figure 1.11—1: Unnamed Sandstone Hydrogeological Results in Project Area

1.11.4 Bukalara Sandstone

Below the APV basalt is the target aquifer for the Project, the Bukalara Sandstone (Figure 1.11—2 and Figure 1.11—3). The Bukalara Sandstone (also previously referred to as Jamison Sandstone) outcrops or is found beneath the APV basalt along the eastern side of the Daly and Georgina basins on Nutwood Downs and Mallapunyah Springs, where it forms a fractured rock aquifer [S. TICKELL, 2022]. The Bukalara Sandstone is confined by the basalt, and parts of the Cox Formation (Hayfield Mudstone) in the Project Area. No surface discharge sites related to this aquifer are known. There is one existing water bore (RNo31397) in the project area that intercepts this aquifer and is located ~17 km NW of the indicative AH well pad. The modelled drawdown at this bore is 0.2 m under the maximum drawdown scenario.

This interval has been intersected in five exploration wells in EP 167 and EP 168, with the top of the Bukalara Sandstone ranging from 150 to 370 m (Figure 1.11—3) and can exceed 100m thick. The top was encountered at Tarlee S3 in the west of the Project Area at 280 m bgl. At RNo31397 in the northwest of the Project Area (Figure), it was encountered at 221 mbgl and had a completion yield of 4 L/s. RNo41448 near Larrizona Station to the northwest of the Project Area and had a production rate of 18 L/s airlifted from the formation between 253 to 257 m [S. TICKELL, 2022].

A DEPWS Bukalara observation bore, RNo41445, on Western Creek Road near the northwestern boundary of the Project Area was constructed for hydrogeological investigation of the Bukalara sequence (see Figure 1.11—3) and installation of a groundwater level logger for baseline monitoring. The aquifer production zone was completed as a 150 mm diameter open hole from a depth of 180 m – 250 m bgl and recorded at > 20 L/s, with brackish (3,760 µS/cm) and slightly alkaline (pH 8.1) water quality [M SHORT, 2021]. Due to elevated salinity, it is not considered potable or usable for irrigation but is suitable for cattle. Groundwater quality results from DEPWS observation bore in the Bukalara near the Project Area are shown in Table 1.11—3

The estimated total confined storage of the Bukalara Aquifer is conservatively estimated to be 120,00 ML [AUSTRALASIAN GROUNDWATER & ENVIRONMENTAL CONSULTANTS, 2022]. The total Activity water consumption (inclusive of 2024-2029) is conservatively estimated to be ~ 410.9 ML, which is 0.3% of the estimated Bukalara storage volume. The Activity's duration is potentially up to 5 years. Groundwater utilised by Imperial A will adhere to the provisions of the existing GWEL (Licence – JS10363), which was granted under the *Water Act, 1992 (NT)*. The GWEL allows up to 250 ML/year from the Bukalara Sandstone Aquifer (also referred to as the Jamison Sandstone Aquifer) for the Activity until May 2033.

1.11.5 EPBC Act Water Trigger

On 15 December 2023, the *EPBC Act - Water Trigger* was amended to include consideration of likely significant impacts on water resources in relation to all types of unconventional gas, for example, shale and tight gas-related developments. This means that actions relating to all types of unconventional gas developments with the potential to significantly impact water resources may need to be referred under the EPBC Act. The Department of Climate Change, Energy, the Environment and Water's *Significant Impact Guidelines 1.3 (SIG 1.3): Coal Seam Gas and Large Coal*

Mining Developments— Impacts on Water Resources provide detail about the assessment of impact criteria for the Water Trigger significant impact assessment (SIA) [DCCEEW, 2022]. In *SIG 1.3*:

“An action is likely to have a significant impact on a water resource if there is a real or a not remote chance or possibility that it will directly or indirectly result in a change to:

- *the hydrology of a water resource, or*
- *the water quality of a water resource*

that is of sufficient scale or intensity to reduce the current or future utility of the water resource for third-party users, including environmental and other public benefit outcomes, or to create a material risk of such reduction in utility occurring.”

An SIA for the *EPBC Act Water Trigger* has been completed in conformance with the relevant assessment impact criteria. The Activity’s water extraction was modelled to provide predicted drawdown contours in the Bukalara Sandstone [AUSTRALASIAN GROUNDWATER & ENVIRONMENTAL CONSULTANTS, 2022]. This was done for the purposes of the GWEL application.

A maximum drawdown of 2 m was detected 1 km away in DEPWS observation bore RNo41448 during constant rate pump test, as shown in **Figure 1.11—2**, in which a water level logger has been deployed and provides useful validation to predicted Activity drawdown modelling for the Bukalara [M SHORT, 2021].

The closest proposed extraction bore to the registered Bukalara bore is well pad AG which is located about 17 km southeast from RNo31397 (**Figure 1.11—2**). The proposed maximum monthly extraction rate at any single bore does not exceed 57 ML/month (21 L/s). This extraction rate is comparable with the one applied during the constant rate test. As the registered Bukalara bores are much further away from the proposed extraction bore locations, it is highly unlikely that greater drawdown will be observed in the registered bores than recorded in RNo41448 during the pumping test. Eight scenarios were modelled with a number having a 0.1 m contour extending outside the Project Area. A median drawdown modelling scenario is shown in **Figure 1.11—2**. For all modelling scenarios, the drawdown contours were less than 1m at 1km distance from the well pads as recommended in SREBA report [L YOUNG et al., 2022].

Baseline and ongoing groundwater monitoring will be reported for the listed 67 analytes, including groundwater level, in compliance with *the Code* at each constructed well pad. The closest existing bore accessing the Bukalara Sandstone (RNo31397) is located about 17 km northwest of the Project Area proposed well pad AH, as shown in **Figure 1.11—2**. Assessment of the proposed action in accordance with the Water Trigger *SIG 1.3* for potential impact on the water resources in the Project Area for ‘Project attributable impacts’ (see summary in **Table 1.11—2**) concluded that the proposed action is not likely to have a significant impact on the water resource and therefore does not need to be referred under the *EPBC Act*.

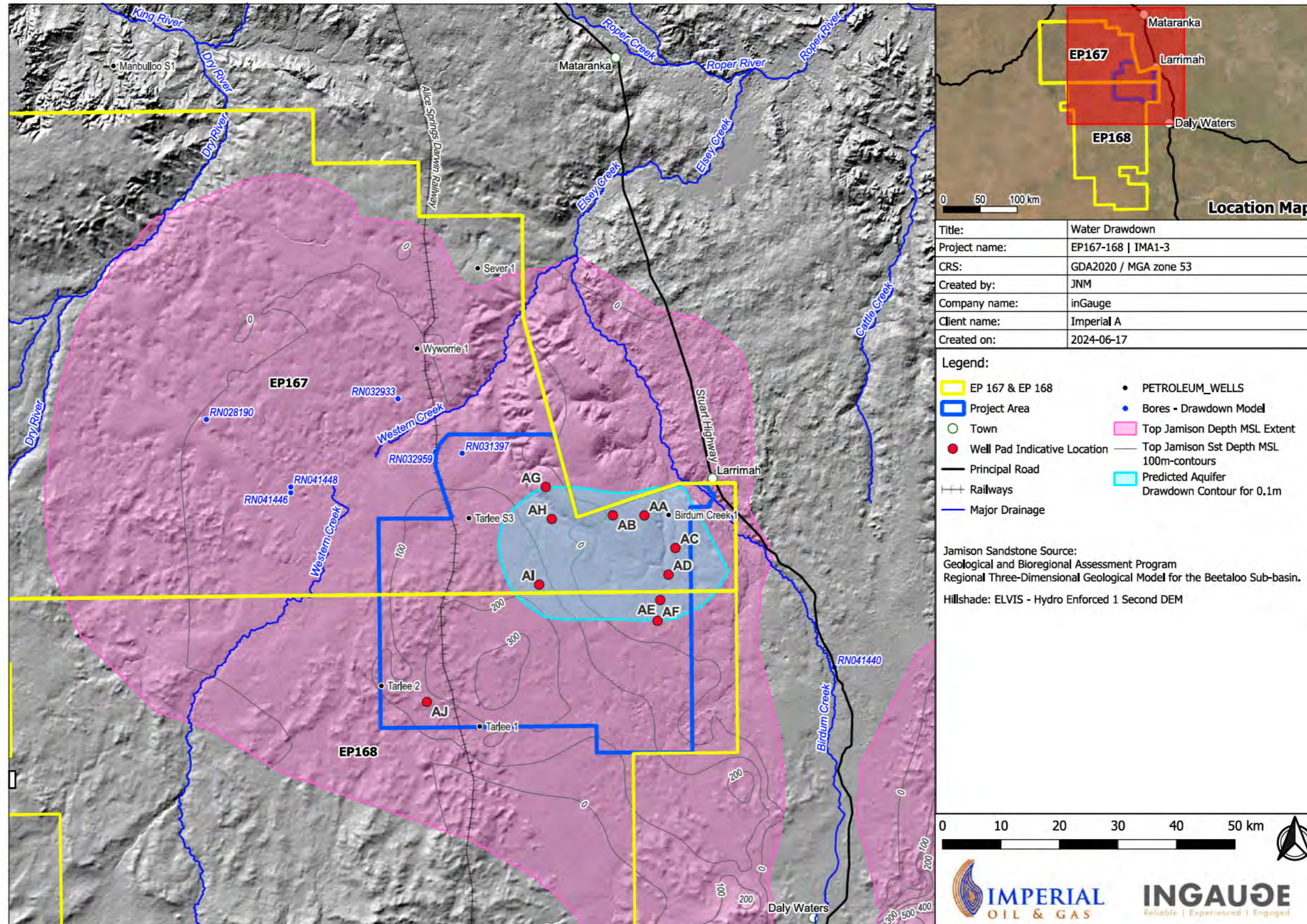


Figure 1.11—2: Bukalara (Jamison) Aquifer and 0.1 m Predicted Activity Drawdown Contour Boundary

Table 1.11—2: Summary of Impact Criteria Assessment for SIG1.3 Water Trigger

#	Impact	Overview	Outcome
1	Lead to a long-term change in the hydrology of the water resource	The Activity water extraction was modelled to provide predicted drawdown contours for the Bukalara Sandstone. For all modelling scenarios, the drawdown contours were less than 0.15 m at the Project Area boundaries and mostly within 5 km of the proposed array of nine well pads, as shown in Figure 1.11—2. For all modelling scenarios, the drawdown contours were less than 1m at 1km distance from the well pads as recommended in SREBA report [L YOUNG et al., 2022].	Will not have a significant impact.
2	Lead to a long-term change in the water quality of the water resource	Aquifer protection is a key objective of the Activity and is achieved by isolation, containment, integrity, and monitoring in all relevant aspects of the Activity. The integrity of the petroleum well isolation is confirmed and managed via Well Barrier Integrity Validation Reporting (WBIV), as required under the WOMP. No PBT chemicals that could have a lasting effect will be used in the Activity. Groundwater monitoring (baseline and ongoing) of the Bukalara will be conducted and reported at each well pad in compliance with <i>the Code</i> .	Will not have a significant impact.
3	Value of the water resource for provisioning services (use by other industries and use as drinking water)	Groundwater in the Bukalara in the Project Area is brackish and therefore not considered potable nor usable for irrigation, but it is suitable for cattle and for use in the hydraulic fracturing of shale.	Will not have a significant impact.
4	Value of the water resource for regulating services (such as the climate or the stabilisation of coastal systems)	The Bukalara Sandstone is confined by the APV basalt in the Project Area. No surface discharge sites related to this aquifer are known. No existing water bores in the Project Area intercept this aquifer.	Will not have a significant impact.
5	Value of the water resource for cultural services (including recreation and tourism, science, and education)	Baseline and ongoing groundwater monitoring of the Bukalara will be reported for the listed 67 analytes, including groundwater level, in compliance with <i>the Code</i> at each constructed well pad.	Will not have a significant impact.
6	Value of the water resource for supporting services (e.g. maintenance of ecosystem function)	The Project Area is situated on a geologically uplifted plateau terrain due to the underlying Antrim Plateau Volcanics (APV) and, therefore, is located outside the Cambrian Limestone Aquifer (CLA) east of the rail line. The Bukalara Sandstone is confined by the APV basalt in the Project Area. No surface discharge sites related to this aquifer are known.	Will not have a significant impact.
7	The significance of impacts on potentially connected hydrological systems	The RDZ is where CLA groundwater in the Roper flow path discharges to the surface south of Mataranka and is considered to have 'outstanding environmental values. The southern boundary of the RDZ occurs approximately ~65 km north of the Project Area and is shown Figure 1.10—2. Project-attributable impacts to the RDZ hydrological system are, therefore, remote because the CLA is not present in the Project Area.	Will not have a significant impact.
8	The significance of impacts of Activity timing on the water resource	Activity timing will focus on the Dry Season for civil and drilling operations. Because the Bukalara Sandstone is confined by the APV basalt in the Project Area and remote from the recharge area, seasonal variations in the aquifer are improbable.	Will not have a significant impact.
9	The significance of impacts in Activity scale on the water resource	No existing water bores in the Project Area intercepts this aquifer. The estimated total confined storage of the Bukalara Aquifer is 119,905 ML. The Activity's total water consumption (inclusive 2024-2029) is ~ 410.9 ML, which is 0.3% of the conservatively estimated Bukalara storage volume. The project duration is potentially for up to 5 years. Groundwater utilised by Imperial A will adhere to the provisions of the existing GWEL (Licence - JS10363), which was granted under the <i>Water Act 1992 (NT)</i> .	Will not have a significant impact.
10	The significance of cumulative impacts on the water resource	The closest existing bore accessing the Bukalara Sandstone is located about 17 km northwest of proposed well pads AH. The Activity water extraction predicted drawdown contours for all modelling scenarios were less than 0.15m at the Project Area boundaries and less than 1m at 1km from the well pads. Groundwater in the Bukalara in the Project Area is brackish and therefore not considered potable nor usable for irrigation but is suitable for cattle and for use in hydraulic fracturing of shale.	Will not have a significant impact.
11	The significance of regional scale impacts on surface water flows associated with the localised development	The Project Area has little local topographic relief and is exceptionally flat. It is situated at the top of the Elsey Creek catchment and is covered by ~37 m thick sandy clay loam soils, which support savannah vegetation of tussock grasses and open forest. There are very few mapped Stream Order 1 and 2 ephemeral waterways and one Stream Order 3 (Middle Creek) within the Project Area. These areas will be avoided with suitable buffers in compliance with <i>Land Clearing Guidelines (LCG)</i> . The Activity does not propose to release any water to the environment produced from operations. Well pads are designed to bypass potential overland flow in the very flat tussock grassland savanna landscape. Stormwater accumulations at well pads will be managed in settling basins. A total of up to nine well pads, each approximately 7 ha in area, each with associated groundwater monitoring and extraction bores in compliance with <i>the Code</i> , are proposed in the disturbance footprint.	Will not have a significant impact.
12	The significance of regional scale impacts on the water table associated with the localised development	In the Project Area, limited existing stock water bores tap fractured basalt at the top of the APV, which is approximately 40 m bgl, screening at depths from 40-70 m bgl. Standing water level across the Project Area is relatively consistent at 44 m bgl (± 5 m). Below the APV basalt is the target aquifer for the Project, the Bukalara Sandstone. This aquifer is confined by the APV basalt in the Project Area. The average top of the basalt in the Project Area is at approximately 68 m below ground level with a measured thickness of approximately ~140 m. On a regional scale, this APV basalt formation is considered to act as an aquitard or an aquiclude to any underlying aquifers [S TICKELL, 2022]. Consequently, groundwater above the APV in the Project Area is isolated from the Bukalara Sandstone.	Will not have a significant impact.

1.11.6 Ground Water Quality

In the SREBA Report, except for aesthetic guidelines, no township on the Sturt Plateau exceeds Australian drinking water health guidelines within the SREBA study area. Aesthetic guidelines are not considered as a risk to human health; they only indicate water palatability for the community. Poor palatability in some locations has led to community complaints received and investigated by Power and Water. However, hardness, chloride, sodium, TDS, and EC were significantly higher than in most other regional townships. Water quality reported at limited existing bores in the Project Area is highly variable (fresh to saline). A regional surface and groundwater characterisation report for EP 167 and 168 was prepared for the previous operators, providing general characteristics of this region, a 26,000 km² exploration permit area [ECOZ ENVIRONMENTAL CONSULTANTS, 2016].

A range of key physical and chemical analytes of the two potential groundwater sources in the Project Area is summarised from Short's *Sturt Plateau 2020 Drilling and Pumping Test Program* in Table 1.11—3 [M SHORT, 2021]. It also includes analysis from a bore (RNo41440) where the CLA is present to the southeast of the Project Area and east of Birdum Creek fault for comparative purposes with the CLA intercepted in RNo41445 northwest of Project Area, near the rail line, as shown in Figure 1.11—2.

Water samples collected by the previous operator of EP 167 and 168 during the 2014-15 petroleum exploration drilling program from the Bukalara Sandstone had a measured EC of approximately 2,200 µS/cm [ECOZ ENVIRONMENTAL CONSULTANTS, 2016]. Short reported that the Bukalara aquifer production zone at RNo41445 was completed as a 150 mm diameter open hole from a depth of 180 m – 250 m bgl and recorded at >20 L/s, with brackish (3,930 µS/cm) and slightly alkaline (pH 8.5) water quality. Due to elevated salinity, it is not considered potable or usable for irrigation but is suitable for cattle [M SHORT, 2021]. Hydrogeological results from boreholes that intersected the Unnamed Sandstone and Bukalara Sandstone in the Project Area are shown in Figure 1.11—2 and Figure 1.11—3, respectively. Groundwater quality in the CLA is also reported in this region in RNo41445. It is considered potable and significantly different from the CLA bore (RNo41440) east of the Stuart Highway, as shown in Table 1.11—3.

Table 1.11—3: Water Quality Range of Aquifer Units in Proximity to Project Area [M. Short, 2021]

Analyte	Units	APV Basalt (RNo41447)	Bukalara (RNo41445)	CLA (RNo41445)	CLA (RNo41440)
Conductivity	(µS/cm)	1680-3580	3730-3930	513	1980-2090
Salinity	mg/L	1015-1494	2005-2133	405	1394-1534
Chloride	mg/L	306-924	958-1040	16	317-346
Sodium	mg/L	195-632	647-693	14.7	216-251
Bicarbonate	mg/L	86-242	187-205	272	457-516
Potassium	mg/L	2.9-15.1	9.8-10.3	4	33-35
Calcium	mg/L	42-58	55-63	57	85-103
Magnesium	mg/L	3-45	10-11	22	62-64

1.11.7 Aquifer Protection

From an aquifer protection perspective, the key formations in the Project Area are the APV basalt, possibly the Unnamed Sandstone, the Bukalara Sandstone, and the top of the Velkerri Formation shale targets for hydraulic fracturing. A summary of the depths of the tops of these formations from ground level is provided in Table 1.11—4. These data were derived from exploration wells drilled in the Project Area in the past.

The hydrostratigraphy demonstrates that the limited and isolated fractured basalt is covered by an average soil thickness of 59 m across the Project Area. It consists of Cretaceous sediments of laterised ferruginous siltstone, as noted in Water Bore Statements and Well Completion Reports, in the Project Area. The basalt below is also an aquiclude, with an average thickness of ~140 m, preventing any potential surface infiltration to the confined regional Bukalara Sandstone aquifer. The base of the Bukalara Sandstone is separated from the top of the target Velkerri Formation shale for hydraulic fracturing by more than 1,000 m, which exceeds the minimum Code requirement of 600 m.

Table 1.11—4: Key Formation Depths in Project Area for Aquifer Protection

Key Formations	Tarlee S3 Depth (mGL)	Tarlee 1 Depth (mGL)	Birdum Ck 1 Depth (mGL)	Average Depth (mGL)
Basalt - Top	58	72	48	59
Unnamed Ss - Top	n/a	180	n/a	n/a
Unnamed Ss - Base	n/a	212	n/a	n/a
Bukalara - Top	277	373	150	266
Bukalara - Base	374	485	246	368
C/B* Shale - Top	1,315	1,236*	1,640	1,430

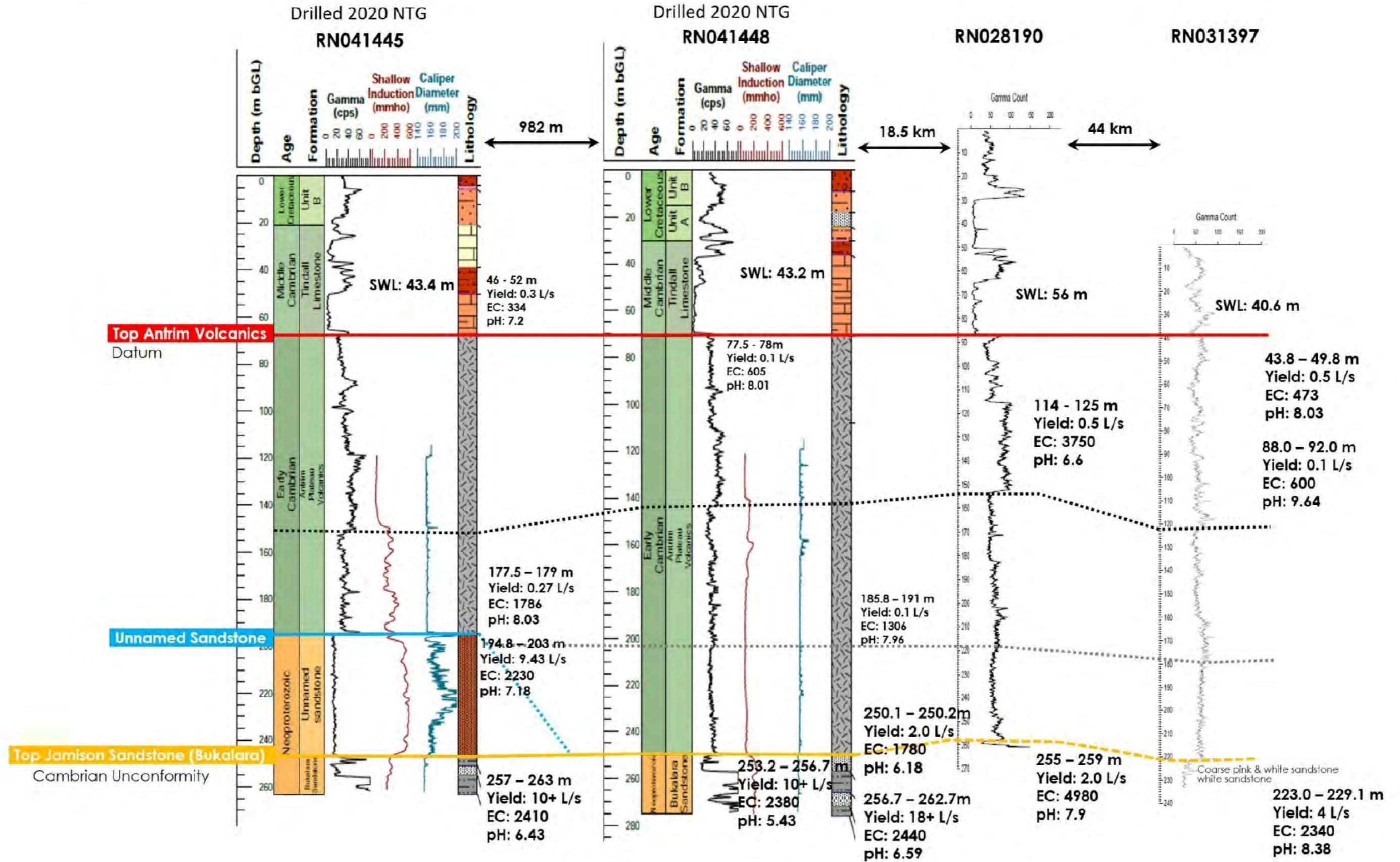


Figure 1.11—3: Bukalara Sandstone Hydrogeological Results in Project Area

1.12 Site Selection Planning to Avoid Significant Habitat

As noted in **Section 1.9.3**, there is limited riparian vegetation present in the Project Area due to the very flat topography and limited drainage network on this broad tableland landscape (refer to **Figure 1.6—1**) and the long and arid Dry Season with high temperatures and evaporation rates. Consequently, permanent and ephemeral soaks and waterholes formed in shallow claypan depressions, and less frequently pools, are an important limited resource feature for all macrofauna in the flat topography of the Project Area. This is largely confined to the Larrimah LS, which acts as ‘flood out black soil country’ with the presence of vertosol soil groups, generally below 190 m AHD, and is self-evident in the georeferenced imagery for this LS in the Project Area. The patch size of some of the riparian vegetation associated with permanent soaks in the Larrimah LS is relatively large, intact, and likely to support a variety of bird populations and other associated macrofauna. Riparian vegetation of different species also occurs to a more limited extent in the Mering LS. Examples of the habitat in each of these land systems are shown in **Table 1.12—1**. There are no other areas within the survey area for the seismic line corridors that have permanent surface water.

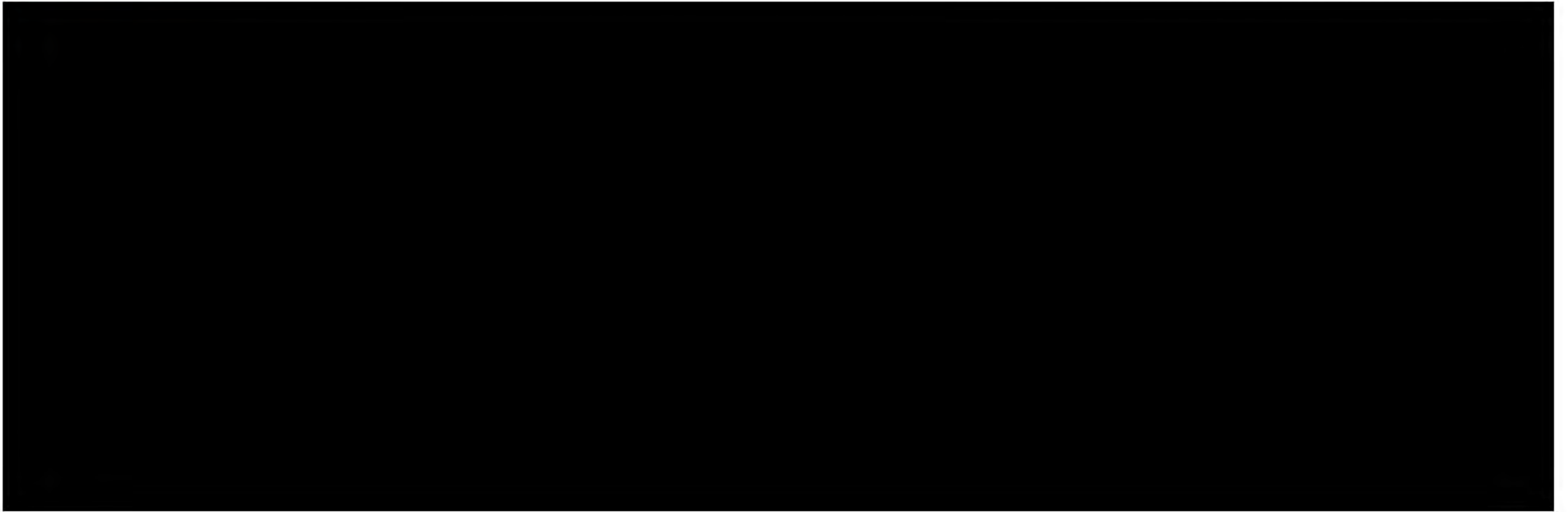
Table 1.12—1: Water Resource and Riparian Vegetation in Larrimah and Mering (RHC) Land Systems



As previously noted, the Project Area is characterised by very flat terrain with minimal vertical relief, which supports open savannah vegetation of tussock grasses and open forest; a lack of any well-formed channel beds at this higher catchment elevation; and depauperate topographic features such as rocky outcrops, cliffs, caves, gorges that are known to provide habitat niches for specific threatened species that may potentially occur and other macrofauna. [REDACTED]

[REDACTED]. Ground disturbance in the Mering LS will be avoided. No other elevated topographic features have been identified across the Project Area.

The land systems in the Project Area (see Figure 1.7—1) provide a useful and an important initial analysis in selecting sites for well pads and access tracks/flowlines because of the civil engineering requirements for soil stability and hydrology; and excluding LS areas with unsuitable soil types (see Figure 1.8—1) and hydrology. No surface infrastructure is proposed in land systems that have been identified as unsuitable and the mitigations measures and controls described in Appendix 03 for the seismic lines traversing these areas will not result in significant or long-lasting disturbance to vegetation; nor impact the hydrology of these areas.



1.12.1 Wildlife Movement Corridors – Planning and Design

The Project Area extends across three pastoral stations and is bounded on the west by the Railway Line and on the east by the Stuart Highway. Western Creek Road is the only arterial public gravel road that traverses (E-W) the Project Area. The Western Creek Road is unsealed and supports large seasonal volumes of stock movement.

The Project Area is traversed by numerous fencelines and pastoral access tracks, contains water bores and is used to graze cattle. There is potential for vehicle collisions with cattle and wildlife within the Project Area. This risk has been considered and mitigated in the Risk Assessment (**Appendix 04**).

The Project Area is characterised by very flat terrain with minimal vertical relief, which supports open savannah vegetation of tussock grasses and open forest; a lack of any well-formed channel beds; and depauperate topographic features such as rocky outcrops, cliffs, caves, gorges that are known to provide habitat niches for specific threatened species that may potentially occur and other macrofauna.

The streams in the Project Area consist of low-lying drainage areas in the landscape with no defined banks or stream beds and absence of associated riparian vegetation. Overland flow would be concentrated through these areas in the rainy period of the Wet Season. The pastoralists have made use of these lower stream orders to harvest and store run-off in farm dams in several locations across the Project Area as is evident in **Figure 1.10—6**.

The Larrimah LS provides the only permanent water source in the Project Area during the Dry Season. This factor means that most wildlife macrofauna movements are likely highly restricted to this land system in the Dry Season when operations are active. This land system is avoided in the selection of traffic corridors.

Existing pastoral access tracks throughout the EP will be repurposed for the Activity as a priority to reduce the amount of land clearing required. Aside from seismic activities, all access tracks in the Project Area need to be 6 m wide for the Activity. The access tracks are designed in accordance with the details provided in **Appendix 05** Erosion and Sediment Control Plan. The dimensions include drainage shoulders and provide good visibility in this open savannah to identify cattle and other wildlife. This is evident in the examples of existing movement corridors existing on the Project Area shown in **Table 1.12—3**.

The limited stock watering bores are also a clustering point for cattle. These have been identified and mapped in **Figure 1.10—7**.

For the seismic program six truck movements per week are anticipated at the beginning and end of the 4 months acquisition program. The civil well pad construction, drilling, hydraulic fracturing and extended production phases occur sequentially with civils nominally commencing when the Dry Season is underway. The major trucking movements are associated with the beginning and end (mobilisation/demobilisation) of each phase. In Northern Australian onshore petroleum operations, there is significant economic imperative to ensure that the drilling rig, hydraulic fracturing rig and completions rig can demobilise from site prior to onset of the monsoonal rain season. As previously noted, the absence of surface water during the Dry Season in or near well pad access corridors across the Project Area will further limit potential interaction with wildlife.

Table 1.12—3 Selected Existing Movement Corridors in the Project Area



1.13 Listed Threatened Species

A threatened species assessment was conducted for the Project Area, by Fox & Co in 2021 [FOX & CO ENVIRONMENTAL, 2021]. It included a desktop review of potential threatened species and habitats in the Project Area of the following databases:

- Commonwealth Department of Agriculture, Water and the Environment (DAWE) protected matters search tool (PMST).
- The Atlas of Living Australia (ALA).
- Birdlife Australia's Birdata.
- Northern Territory Government, Department of Environment, Parks and Water Security (DEPWS) NR Maps.
- CSIRO land systems mapping, including for hydrology-related vegetation species and permanent water bodies in the Project Area.

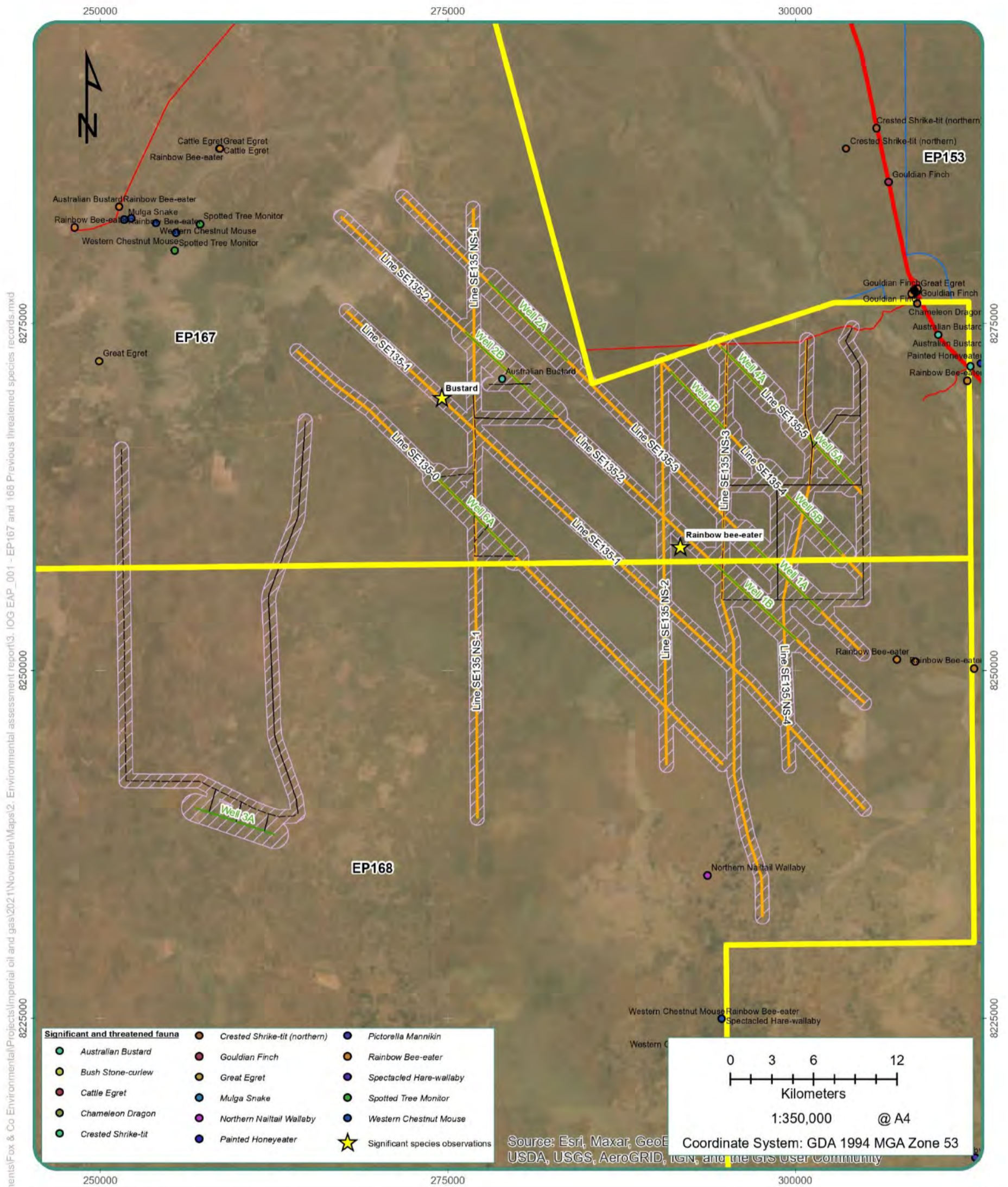
A Protected Matters Search Tool report (PMST) was performed on a study area of a 50 km radius around the Project Area boundary, on 21 August 2024. This search identified 20 listed threatened species and 15 listed migratory species that have the potential to occur in the study area. Due to the absence of suitable habitats not all threatened species identified in the PMST search are expected to occur within the study area.

The potential threatened species are listed in **Table 1.13—1**, and the potential migratory listed species are detailed in **Table 1.14—1**. No threatened flora has been identified in desktop searches nor previously recorded in the Project Area during the survey by Fox and Co in 2021 [FOX & CO ENVIRONMENTAL, 2021]. A map of locations of previous significant and threatened species on EP167/EP168 is provided in **Figure 1.13—1****Error! Reference source not found.**. The key areas identified for potential habitat for threatened species is in the Larrimah LS, Mering LS and Western LS. The Larrimah LS and Western LS contain the only permanent water bodies in the area part from shallow ephemeral soaks (closed clay depressions) in the Project Area. These LS areas will not be disturbed by the Activity.

Table 1.13—1: Threatened Species Identified in the Project Area and Their Likelihood of Occurrence

#	Scientific Name	Common Name	Class	Threatened Category	Likelihood of Occurrence
1	<i>Tiliqua scincoides intermedia</i>	Northern Blue-tongued Skink	Reptile	Critically Endangered	High
2	<i>Varanus mitchelli</i>	Mitchell's Water Monitor	Reptile	Critically Endangered	High
3	<i>Varanus mertensi</i>	Mertens' Water Monitor	Reptile	Endangered	High
4	<i>Elseya lavarackorum*</i>	Gulf Snapping Turtle	Reptile	Endangered	Low
5	<i>Erythrura gouldiae</i>	Gouldian Finch	Bird	Endangered	High
6	<i>Erythrotriorchis radiatus</i>	Red Goshawk	Bird	Endangered	Moderate
7	<i>Rostratula australis*</i>	Australian Painted Snipe	Bird	Endangered	Low
8	<i>Falcunculus frontatus whitei</i>	Northern Shrike-tit	Bird	Vulnerable	High
9	<i>Falco hypoleucos</i>	Grey Falcon	Bird	Vulnerable	High
10	<i>Grantiella picta</i>	Painted Honeyeater	Bird	Vulnerable	High
11	<i>Calidris acuminata</i>	Sharp-tailed Sandpiper	Bird	Vulnerable	Low
12	<i>Tyto novaehollandiae kimberli</i>	Masked Owl (Northern)	Bird	Vulnerable	Moderate
13	<i>Calidris ferruginea*</i>	Curlew Sandpiper	Bird	Critically Endangered	Low
14	<i>Saccolaimus nudicluniatus</i>	Bare-rumped Sheath-tail Bat	Mammal	Vulnerable	Moderate
15	<i>Trichosurus vulpecula arnhemensis</i>	Northern Brushtail Possum	Mammal	Vulnerable	High
16	<i>Macroderma gigas*</i>	Ghost Bat	Mammal	Vulnerable	Moderate
17	<i>Phascogale pirata</i>	Northern Brush-tailed Phascogale	Mammal	Vulnerable	Low
18	<i>Dasyurus hallucatus*</i>	Northern Quoll	Mammal	Endangered	Moderate
19	<i>Macrotis Lagotis*</i>	Greater Bilby	Mammal	Vulnerable	Low
20	<i>Pristis pristis*</i>	Freshwater Sawfish	Shark	Vulnerable	Low

*Indicates species that were excluded from SIA due to lack of records and/or suitable habitat in the Project Area



<p>TITLE: EP167 and 168 Previous threatened species records</p>		<p>LEGEND</p> <ul style="list-style-type: none"> Populated places EP167 and 168 Exploration title granted Roads Principal Road Secondary Road Minor Road EP167-168 Baseline Survey - Access Tracks EP167-168 Baseline Survey - Wellpad Corridors EP167-168 Baseline Survey - Seismic Corridors EP167-168 Baseline Survey - Assessment area 	
<p>MAP NO: Figure 3</p>			
<p>PROJECT: EP167 and 168 November 2021 Environmental Assessment Report</p>			

Date: 18/11/2021

Data Source:

Figure 1.13—1: Previous Significant and Threatened Species Records on EP167/EP168

1.14 Listed Migratory Species

The listed migratory fauna species that could potentially occur within 50 km of the Project Area are identified in Table 1.14—1.

Table 1.14—1: Migratory Species Potentially Occurring Within Project Area

#	Scientific Name	Common Name	Threatened Category	Likelihood of Occurrence
1	<i>Apus pacificus</i>	Fork-tailed Swift	Migratory	Moderate
2	<i>Calidris melanotos</i>	Pectoral Sandpiper	Migratory	Low
3	<i>Calidris acuminata</i>	Sharp-tailed Sandpiper	Vulnerable	Low
4	<i>Cuculus optatus</i>	Oriental Cuckoo	Migratory	Low
5	<i>Pristis pristis</i>	Freshwater Sawfish	Vulnerable	Low
6	<i>Glareola maldivarum</i>	Oriental Pratincole	Migratory	High
7	<i>Hirundo rustica</i>	Barn Swallow	Migratory	Low
8	<i>Charadrius veredus</i>	Oriental Plover	Migratory	Moderate
9	<i>Crocodylus porosus</i>	Saltwater Crocodile	Migratory	Low
10	<i>Motacilla flava</i>	Yellow Wagtail	Migratory	Moderate
11	<i>Motacilla cinerea</i>	Grey Wagtail	Migratory	Low
12	<i>Cecropis daurica</i>	Red-rumped Swallow	Migratory	Moderate
13	<i>Actitis hypoleucos</i>	Common Sandpiper	Migratory	Low
14	<i>Calidris ferruginea</i>	Curlew Sandpiper	Critically Endangered	Low
15	<i>Pandion haliaetus</i>	Osprey	Migratory	Moderate

1.15 Significant Impact Assessments (SIA)

As a result of the recent EPBC Threatened Species amendments, Imperial A has conducted a Significant Impact Assessment (SIA), required for Matters of National Environmental Significance (MNES) for EPBC-listed threatened species that may occur in the Project Area, a summary of these impact assessments is presented below for the potentially resident threatened species.

Of the 20 listed threatened species (Table 1.13—1), six species were excluded from the SIA due to having no prior records in the region and/or there being no suitable habitat in the Project Area for the

species to survive. This lack of records in the area is primarily due to a lack of permanent suitable water bodies in the Project Area; hence, the Gulf Snapping Turtle, Freshwater Sawfish, Curlew Sandpiper, Painted Snipe were excluded from further assessment. Additionally, the Northern quoll and Ghost Bat was also excluded from the SIA as no records reported in the region and rocky escarpments used as niche habitat by the species do not exist in the Project Area [FOX & CO ENVIRONMENTAL, 2021].

These six exclusions reduced the potential threatened species in the Project Area to 14; the SIA concluded that none of the fauna species that have the potential to occur in the Project Area will be significantly impacted by the proposed Activity. The likelihood of occurrence (LoO) of these species has been assessed using criteria in Table 1.15—1. Among the 14 listed threatened fauna species assessed that have the potential to occur in the Project Area, two are currently listed as Critically Endangered, three as Endangered and nine as Vulnerable.

Table 1.15—1: Likelihood of Occurrence (LoO) Assessment

Likelihood of Occurrence	Descriptor	Suitable Habitat	Records
High	Species likely to occur.	Core habitat available.	Recent proximate records.
Medium	Species may occur but with evidence lowering their likelihood.	Some habitat is available but there is an absence of permanent surface water or other key habitat factors	Occurs within the species' known distribution; species has not been recorded within, or adjacent to, the Project Area.
Low	Species unlikely to occur based on available data.	No core habitat available.	No recent proximate records: species has not been recorded within, or adjacent to, the Proposal Area.

Seven of the 14 listed threatened species assessed for these criteria, eight were considered to have a High LoO potential to occur in the Project Area. Three species had a Moderate LoO potential. The remaining three species were considered to have Low LoO. The absence of surface water across much of the Project Area during the extended Dry Season (average ~200 days) is likely a significant limiting and controlling factor for macrofauna residency in the Project Area. As discussed, the Larrimah LS and Mering LS are considered the key core habitat areas for potential listed species in the Project Area. No ground disturbance is proposed in these units. The discussion below provides detail of the eight species with a High LoO.

1.16 Threatened Species with a High Likelihood of Occurrence

The following Significant Impact Assessments (SIA) were undertaken in accordance with the *Matters of National Environmental Significance, Significant Impact Guidelines (1.1)*, Department of

Environment [DAWE, 2013] (Table 1.15—1) on the species identified as having a high likelihood of occurrence in the Project Area (Table 1.16—1).

Table 1.16—1: Threatened Species Identified to have a High Likelihood of Occurrence in the Project Area

Scientific Name	Common Name	EPBC Act ¹	Likelihood of Occurrence
<i>Erythrura gouldiae</i>	Gouldian Finch	E	High Potential to Occur Possible foraging habitat in open grassy woodland and ephemeral soaks providing water source. Limited suitable breeding habitat within Project Area. Absence of surface water in much of the Project Area during the Dry Season is a limiting factor. SREBA records [L YOUNG et al., 2022] proximate to Project Area.
<i>Falcunculus frontatus whitei</i>	Northern Crested Shrike-Tit	V	High Potential to Occur Suitable habitat exists and there are previous records in Project Area and Beetaloo SREBA study.
<i>Falco hypoleucos</i>	Grey Falcon	V	High Potential to Occur Limited preferred habitat for nesting in tall trees along waterways exists in the Project Area. There are previous records in the greater EP 167/168 EP.
<i>Grantiella picta</i>	Painted Honeyeater	V	High Potential to Occur Suitable habitat exists and there are previous records in Project Area including Beetaloo SREBA study.
<i>Trichosurus vulpecula arnhemensis</i>	Northern Brushtail Possum	V	High Potential to Occur Suitable habitat exists, there are potential SREBA study records within the surrounding area toward Mataranka township (genetic testing required to confirm).
<i>Tiliqua scincoides intermedia</i>	Northern blue-tongue skink	CE	High Potential to Occur Suitable habitat occurs and there are previous records within the Project Area. Possible foraging habitat in open grassy woodland and ephemeral soaks providing water source.
<i>Varanus mertensi</i>	Merten's Water Monitor	E	High Potential to Occur Suitable habitat exists and there are previous records in Project Area including Beetaloo SREBA study.
<i>Varanus mitchell</i>	Mitchell's Water Monitor	CE	High Potential to Occur Suitable habitat exists and there are previous records in Project Area including Beetaloo SREBA study.

1.16.1 Gouldian Finch (*Erythrura gouldiae*) (EPBC Act – E)

Gouldian finches are found in northern Australia from Cape York Peninsula to northwest Queensland and the north of the Northern Territory to the Kimberley Region of Western Australia. They inhabit open woodlands dominated by Eucalyptus trees and support a ground cover of Sorghum and other grasses. Often found in vegetation along watercourses.

Critical components of suitable core habitat for the Gouldian Finch include the presence of favoured annual and perennial grasses (especially Sorghum), a nearby source of surface water and, in the breeding season, unburnt hollow-bearing Eucalyptus trees (especially *E. tintinnans*, *E. brevifolia* and *E. leucophloia*). Its breeding habitat is usually confined to ridges and rocky foothills, probably due to the presence of Sorghum grasses and surface water. None of these landscape habitats or eucalypt species are reported in the LS described in the Project Area.

Gouldian finches feed almost exclusively on grass seed and depend on a relatively small number of grass species that seed at different times throughout the year [MORCOMBE, 2004]. Gouldian Finches were reported in the SREBA study in the vicinity of the Project Area at waterholes to the north and southeast but outside the Project Area, and outside the eastern Project Area boundary, near the Stuart Highway in the vicinity of Birdum Creek in the Western LS. Table 1.16—2 provides a SIA for the Gouldian finch.

Table 1.16—2: Significant Impact Assessment for the Gouldian Finch

Impact Criteria	Assessment
An action is LIKELY to have a significant impact on an endangered species if there is a real chance or possibility that it will:	
Lead to a long-term decrease in the size of a population.	The proposed Activity's construction and operation will not lead to a long-term decrease in the size of the Gouldian finch population, given the flat plateau terrain in the Project Area and limited sub-optimal breeding habitat and limited waterholes confined to the Larrimah LS. These are mapped and the Larrimah LS is avoided in the Activity. The absence of surface water in most of the Project Area during the Dry Season is also a significant limiting factor. Will not have a Significant Impact.
Reduce the species' area of occupancy.	Riparian vegetation consisting of <i>E. brevifolia</i> , <i>E. dichromophloia</i> , <i>E. tintinnans</i> , or <i>E. leucophloia</i> is present as narrow (usually 1 tree wide along banks) in highly restricted soaks and a single Stream Order 3 drainage line in the Project Area. This is in the Mering LS which will not be disturbed. Any riparian areas identified during ecologist field survey undertaken prior to clearing, will be avoided with suitable buffers, in compliance with the <i>Land Clearing Guidelines (LCG)</i> [DEPWS, 2021A]. Given the avoidance of potential roosting Gouldian finch habitat, the Activity is not expected to significantly reduce this species' potential area of occupancy. Will not have a Significant Impact.
Fragment an existing population into two or more populations.	The Activity clearing is localised and/or narrow linear in nature and, so it would not fragment an existing population into two or more populations. Will not have a Significant Impact.
Adversely affect habitat critical to the survival of a species.	Potential breeding habitat (riparian woodland with hollows), which is highly restricted within the Project Area, will be avoided, and therefore, the Activity will not significantly affect habitat critical to the survival of this species. Final site inspection prior to clearing to be undertaken by an ecologist to avoid riparian woodland with mature hollow trees in ground disturbance areas. Will not have a Significant Impact.
Disrupt the breeding cycle of a population.	Potential breeding habitat within the Project Area is avoided (riparian woodland with hollows) and therefore the Activity will not disrupt the breeding cycle of a population. Will not have a Significant Impact.
Modify, destroy, remove, isolate, or decrease the availability or quality of habitat to the extent that the species is likely to decline.	The Activity layout has been designed to minimise impacts to potential habitat (riparian woodland) in the landscape. Therefore, the Activity will not modify, destroy, remove, isolate, or decrease the availability or quality of habitat to the extent that the species is likely to decline. Will not have a Significant Impact.
Result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat.	Historically, an air-sac mite was investigated for its role in causing population declines. However, although the mite was often identified in sick birds, its role in causing the poor condition (rather than being a secondary consequence of birds being in poor condition because of other factors) remained unclear. The Activity will not increase the extent of these known invasive species. The Activity is not expected to result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat. Will not have a Significant Impact.
Introduce diseases that may cause the species to decline.	No diseases are listed as a current threat to Gouldian finch. The Project is not expected to introduce a disease that may cause the species to decline. Will not have a Significant Impact.
Interfere with the recovery of the species.	Vegetation changes through altered fire regimes and grazing by introduced herbivores are the factors most likely to have caused past declines and to potentially be preventing recovery in Gouldian finch populations. The Activity is unlikely to interfere with the recovery of the species. Will not have a Significant Impact.

1.16.2 Northern Shrike-Tit (*Falcunculus frontatus whitei*) (EPBC Act – V)

The Northern Shrike-tit (northern) occurs in the Kimberley region of Western Australia and the north of the Northern Territory as far east as the Queensland border. It is generally found in open eucalypt woodlands dominated by Bloodwood, Darwin Box and Roughleaf Cabbage Gum along forested gullies and waterways in drier areas. Recent records for shrike-tits in the Katherine region come from open mixed eucalypt woodland habitat with a grassy understorey on heavy soils that are shallowly inundated for much of the wet season [L YOUNG et al., 2022]. This type of habitat is largely confined to the Larrimah LS in the Project Area. Northern Shrike-tits forage unobtrusively in the canopy of trees, feeding on various invertebrates, including cicadas, katydids, tree crickets, spiders, and beetle larvae.

The species prefer brushy, semi-open habitats where they can find suitable prey. The subspecies is monogamous, resident and territorial. Breeding occurs over the Wet Season, with nest building commencing in September or October. It has been recorded in areas with grassy and shrubby understoreys. Seasonally waterlogged areas, confined to the Larrimah LS in the Project Area, may attract the species. The species were detected near the Project Area during the SREBA survey [L YOUNG et al., 2022]. A SIA for the Northern shrike-tit is presented in Table 1.16—3.

Table 1.16—3: Significant Impact Assessment for the Northern Shrike-tit

Impact Criteria	Assessment
An action is LIKELY to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:	
Lead to a long-term decrease in the size of an important population of a species.	The proposed Activity's construction and operation will not lead to a long-term decrease in the size of the Northern Shrike-tit population, given the flat plateau terrain in the Project Area and limited sub-optimal breeding habitat, such as forested gullies, waterways, and waterholes. Persistent surface water is confined to the Larrimah LS. These are mapped and the Larrimah LS is avoided in the Activity. Will not have a Significant Impact.
Reduce the area of occupancy of an important population.	Given the widespread foraging and predatory nature of this species and the avoidance of disturbance of limited forested gullies, ephemeral waterways, waterholes, and riparian vegetation in the flat plateau terrain in the Project Area, the Activity is not expected to reduce the area of occupancy of an important population. Will not have a Significant Impact.
Fragment an existing important population into two or more populations.	Given the territorial nature of this species, the avoidance of land systems with isolated locations of potential food resources, and limited records in the Project Area, the Activity is not expected to fragment an existing important population into two or more populations. Will not have a Significant Impact.
Adversely affect habitat critical to the survival of a species.	Given the lack of records, avoidance of riparian vegetation, and the clearing of other remnant vegetation for the Activity is not expected to impact Northern Shrike-tit foraging habitat. Will not have a Significant Impact.
Disrupt the breeding cycle of an important population.	Given the limited records, avoidance of riparian vegetation and clearing of other remnant vegetation for the Activity are not expected to impact the Northern Shrike-tit nesting habitat. Will not have a Significant Impact.

1.16.3 Grey Falcon (*Falco hypoleucos*) (EPBC Act – V)

The Grey Falcon is a predator, mainly of smaller bird species, and occurs in low densities, usually as pairs, in arid and semi-arid open woodland in Central and northern Australia. Here they frequent timbered lowland plains, particularly acacia shrublands that are crossed by tree-lined water courses. Their nests are usually in the slender, sloping, topmost branches of one of the taller eucalypts in the region, such as Coolibah, which are limited to the Larrimah LS in the Project Area.

Grey falcons have been observed hunting in treeless areas, in tussock grassland and in open woodland, especially in winter [DEPWS, 2021B]. No Grey falcons were reported in the Project Area in the SREBA study but they are cryptic species [L YOUNG et al., 2022]. A hotspot breeding locality was identified ~65 km north of the Project Area in the Roper Discharge Zone Outstanding Environmental Values Area. The SIA is presented in Table 1.16—4.

Table 1.16—4: Significant Impact Assessment for the Grey Falcon

Impact Criteria	Assessment
An action is LIKELY to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:	
Lead to a long-term decrease in the size of an important population of a species.	Some suitable habitat exists in the Project Area and Grey falcon species has been reported in the greater EP167/EP168 area. Breeding locality identified ~65 km north of Project Area in the Roper Discharge Zone Outstanding Environmental Values Area [L YOUNG et al., 2022]. Considering the lack of records and avoidance of land systems containing potential available nesting habitat, the Activity is not expected to lead to a long-term decrease in the size of an important population. Will not have a Significant Impact.
Reduce the area of occupancy of an important population.	Given the widespread nature of this species and limited records in the Project Area, the Activity is not expected to reduce the area of occupancy of an important population. Will not have a Significant Impact.
Fragment an existing important population into two or more populations.	Given the widespread nature of this species and limited records in the Project Area, the Activity is not expected to fragment an existing important population into two or more populations. Will not have a Significant Impact.
Adversely affect habitat critical to the survival of a species.	Given the lack of records, avoidance of riparian vegetation, clearing of other remnant vegetation for the Activity is not expected to impact Grey Falcon potential roosting or foraging habitat. Will not have a Significant Impact.
Disrupt the breeding cycle of an important population.	Given the limited records, avoidance of riparian vegetation, clearing of other remnant vegetation for the Project is not expected to impact Grey Falcon nesting habitat. Final site inspection prior to clearing to be undertaken by an ecologist to avoid mature hollow trees. Will not have a Significant Impact.
Modify, destroy, remove, or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.	Given the limited number of records, avoidance of riparian vegetation, clearing of other remnant vegetation for the Activity to the extent that the Activity may modify, destroy, remove, isolate, or decrease the availability or quality of habitat to the extent that the species is likely to decline is not considered significant. Will not have a Significant Impact.
Result in invasive species that are harmful to vulnerable species becoming established in the vulnerable species' habitat.	In the absence of specific studies on Grey Falcons, it is generally considered the threat of predation by feral cats to be the highest threat. The Activity is unlikely to result in a spread of an invasive species that are harmful to Grey Falcons becoming established. Will not have a Significant Impact.
Introduce disease that may cause the species to decline.	No diseases are listed as a current threat to Grey Falcons. Will not have a Significant Impact.
Interfere substantially with the recovery of the species.	The Activity is not expected to interfere substantially with the recovery of the species. Will not have a Significant Impact.

1.16.4 Painted Honeyeater (*Grantiella picta*) (EPBC Act – V)

The Painted Honeyeater is sparsely distributed from southeast Australia to northwest Queensland and the eastern Northern Territory. The species is a specialist feeder on mistletoe fruit in eucalypt forests/woodlands and riparian woodlands that consist of a variety of communities, such as black box and river red gum, box-ironbark-yellow gum woodlands, Acacia-dominated woodlands, paperbarks, and Callitris-dominated woodlands.

The Painted Honeyeater's diet consists primarily of mistletoe fruit, and their reproductive biology is centred around the fruiting season of mistletoe. Hence, the species prefer woodlands, which contain a higher number of mature trees, as these host a higher density of mistletoe. Mistletoe occurs in mature riparian vegetation near soaks, low-lying flood plains, and waterholes in the Larrimah LS and Western LS in the Project Area. These LS areas are avoided in the proposed ground disturbance with suitable buffers compliant with LCG. The SIA for the Painted honeyeater is detailed in [Error! Not a valid bookmark self-reference.](#) Table 1.16—5.

[Error! Not a valid bookmark self-reference.](#) Table 1.16—5: Significant Impact Assessment for the Painted Honeyeater

Impact Criteria	Assessment
An action is LIKELY to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:	
Lead to a long-term decrease in the size of a population.	The proposed Activity's construction and operation will not lead to a long-term decrease in the size of the Painted Honeyeater population, given the highly localised and limited occurrence of the Painted Honeyeater foodplant, mistletoe, which is confined to ephemeral soaks, waterholes, persistent waterways, and floodplain areas in the Larrimah LS. These are mapped and the Larrimah LS is avoided in the Activity. Will not have a Significant Impact.
Reduce the area of occupancy of the species.	Given the highly localised suitable feeding habitat within the Project Area, avoidance of these areas in proposed disturbance, and overall moderate potential of a localized and minor population within the Project Area, it is not expected that the Project will significantly reduce the area of the occupancy of this species. Will not have a Significant Impact.
Fragment an existing population into two or more populations.	No known populations are within the Project Area, so the Activity is not fragmenting an existing population into two or more populations. Will not have a Significant Impact.
Adversely affect habitat critical to the survival of a species.	The proposed Activity's construction and operation will not lead to a long-term decrease in the size of the Painted Honeyeater population, given the flat plateau terrain in the Project Area and limited sub-optimal feeding habitat, such as forested gullies, waterways, and waterholes which are restricted to the Larrimah LS which is avoided. Will not have a Significant Impact.
Disrupt the breeding cycle of a population.	Populations within the Project Area are unlikely to be significant given the highly limited and localised foodplant source which is restricted to the Larrimah LS which is avoided. Therefore, the Activity will not disrupt the breeding cycle of a population. Will not have a Significant Impact.
Modify, destroy, remove, isolate, or decrease the availability or quality of habitat to the extent that the species is likely to decline.	The Activity will not modify, destroy, remove, isolate, or decrease the availability or quality of habitat to the extent that the species is likely to decline. Will not have a Significant Impact.
Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat.	The Activity is not expected to result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat. Will not have a Significant Impact.
Introduce diseases that may cause the species to decline.	No diseases are listed as a current threat to the Painted Honeyeater. The Activity is not expected to introduce a disease that may cause the species to decline. Will not have a Significant Impact.
Interfere with the recovery of the species.	Painted honeyeater occurrence will be limited to riparian and low-lying areas where foodplant is present, and therefore, the Activity is unlikely to interfere with the recovery of the species. Will not have a Significant Impact.

1.16.5 Northern Brushtail Possum (*Trichosurus vulpecula arnhemensis*)

The Northern Brushtail Possum occurs discontinuously from the Gulf of Carpentaria hinterland near Borroloola, Northern Territory, west to the Kimberley, Western Australia. The species occurs primarily in tall eucalypt, open forests with large hollow-bearing trees, particularly where the understorey includes fruit-bearing shrubs [DAWE, 2022]. Altered fire regimes have been identified as a key driver of shrub loss in the savannas of northern Australia, reducing food resources and habitat quality for species such as the Northern Brushtail Possum. The clearing of large hollow-bearing trees is also of particular concern, as the Northern Brushtail Possum is dependent on these for nesting (Kerle 1985).

In the Study Area, the Northern Brushtail Possum's distribution overlaps with the Common Brushtail Possum (*Trichosurus vulpecula vulpecula*) and the historical distributional boundary between the two sub-species is poorly understood. The SREBA report suggests the Beetaloo region is the distributional range limit for both sub-species, with the Northern sub-species occurring in the Top End and the Common sub-species occurring to the south. The two sub-species were once widely distributed across the Northern Territory but suffered severe declines following European Settlement [DEPWS, 2021C]. In the monsoonal tropics the Northern Brushtail diet mostly comprises fruits, flowers and foliage including a range of mistletoe species as well as *Erythrophleum chlorostachys* (Cooktown Ironwood) [KERLE J, 1985].

The SREBA study identified Brushtail Possums on camera traps and nocturnal surveys. The closest record to EP 167/168 occurred in the Mataranka vicinity. Without genetic testing, the SREBA study was not able to determine if the species encountered were the Northern or Common Brushtail Possum; however, the Mataranka record was assumed to be the Northern Brushtail Possum (genetic studies are required to confirm). The Northern Brushtail Possum is threatened by intense wildfires, predation by feral cats, habitat modification from introduced weed species and habitat loss [DAWE, 2022]. The SIA for the Northern Brushtail Possum is presented in Table 1.16—6.

Table 1.16—6: Significant Impact Assessment for the Northern Brushtail Possum

Impact Criteria	Assessment
An action is LIKELY to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:	
Lead to a long-term decrease in the size of a population.	The Activity will not lead to a long-term decrease in the size of the Northern Brushtail Possum population given the modest total potential disturbance footprint of ~260 ha (~0.01% of the ~26,000 km ² of the total area of EP 167/EP168) in the broad savannah tussock grass plateau landscape. Will not have a Significant Impact.
Reduce the area of occupancy of the species.	The proposed Activity construction and operation will not lead to a long-term decrease in the size of the Northern Brushtail Possum population given the modest total potential disturbance footprint of ~260 ha (~0.01% of the ~26,000 km ² of the total area of EP 167/EP168). Will not have a Significant Impact.
Adversely affects habitat critical to the survival of a species.	The Project Area contains potential suitable habitat for both the Common Brushtail and, potentially, the overlapping Northern Brushtail Possum population. The open savannah is regularly burned by pastoralists. The Northern Brushtail Possum is reported to be found in higher abundance where shrub density is high; these areas likely provide refuge from predation by feral cats as well as important food resources such as mistletoe species [KERLE J, 1985; A STOBO-WILSON et al., 2019]. In the flat Project Area, this niche habitat, including mistletoe species, is found near permanent surface water areas. Persistent surface water is confined to the Larrimah LS. These are mapped and the Larrimah LS is avoided in the Activity. Will not have a Significant Impact.
Disrupt the breeding cycle of a population.	Will not have a Significant Impact.
Modify, destroy, remove, isolate, or decrease the availability or quality of habitat to the extent that the species is likely to decline.	The Northern Brushtail Possum is reported to be found in higher abundance where shrub density is high; these areas likely provide refuge from predation by feral cats as well as important food resources such as mistletoe species [KERLE J, 1985; A STOBO-WILSON et al., 2019]. In the flat open savanna of the Project Area this niche habitat, including mistletoe species, is found near permanent surface water areas. Persistent surface water is confined to the Larrimah LS. These are mapped and the Larrimah LS is avoided in the Activity. Will not have a Significant Impact.
Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat.	Invasive grasses provide a fuel load which is up to five times greater than native species and probably making movement and suitable vegetated habitat for the subspecies more difficult where invasive grasses occur [KERLE J, 1985; A STOBO-WILSON et al., 2019]. The Weed Management Plan mitigates Activity attributable introduction and spread of potential invasive weed species. Will not have a Significant Impact.
Interfere with the recovery of the species.	Key threats to the Northern Brushtail Possum (especially introduced predators, interacting with changed fire regimes and land use) operate across its entire range, and it is likely that the population is continuing to decline due to these ongoing threats. The Activity will not alter fire regimes or significantly affect land use in the Project Area. Disturbance of potential key habitat is avoided. Will not have a Significant Impact.

1.16.6 Northern Blue-tongued Skink (*Tiliqua scincoides intermedia*) (EPBC Act – CE)

The Northern blue-tongued skink (*Tiliqua scincoides intermedia*) is listed as Critically Endangered under the EPBC Act [DCCEEW, 2023]. In the absence of cane toads (*Rhinella marina*), Northern blue-tongue skinks are regularly encountered, abundant, and occur in a wide variety of geomorphologies and habitats. They have been detected previously in the Project Area [FOX & CO ENVIRONMENTAL, 2021]. The greatest threat to the long-term persistence of the Northern blue-tongue skink is the invasive and toxic cane toad. No Critical Habitat, as defined under section 207A of the EPBC Act, has been identified or included in the register of Critical Habitat for the Northern blue-tongue skink. Despite the extended arid season experienced in the Project Area, the persistent presence of surface water in the Larrimah LS does present a potential risk for cane toads to establish a breeding population in the area. The SIA for the Northern blue-tongue skink is presented in Table 1.16—7.

Table 1.16—7: Significant Impact Assessment for the Northern Blue-tongue Skink

Impact Criteria	Assessment
An action is LIKELY to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:	
Lead to a long-term decrease in the size of a population.	The Activity will not lead to a long-term decrease in the size of the Northern blue-tongue skink population given the modest total potential disturbance footprint of ~260 ha (~0.01% of the ~26,000 km ² of the total area of EP 167/EP168) in the broad savannah tussock grass plateau landscape. Will not have a Significant Impact.
Reduce the area of occupancy of the species.	The proposed Activity construction and operation will not lead to a long-term decrease in the size of the Northern blue-tongue skink population given the modest total potential disturbance footprint of ~260 ha (~0.01% of the ~26,000 km ² of the total area of EP 167/EP168). Will not have a Significant Impact.
Adversely affects habitat critical to the survival of a species.	The Project Area contains very limited core habitat, as listed, for the Northern blue-tongue skink population. If present, it has been avoided: <ul style="list-style-type: none"> • Riparian vegetation. • Well-vegetated creeks and drainage lines. • Well-vegetated swamps, soaks, and springs. • Dense thickets within floodplains, grasslands, shrublands, savannas and woodlands. • Shady thickets in rocky ranges and gorges. Will not have a Significant Impact.
Disrupt the breeding cycle of a population.	The Activity will not disrupt the breeding cycle of a population. Will not have a Significant Impact.
Modify, destroy, remove, isolate, or decrease the availability or quality of habitat to the extent that the species is likely to decline.	The Activity will not modify, destroy, remove, isolate, or decrease the availability or quality of habitat to the extent that the species is likely to decline. Key habitat areas such as riparian vegetation, soaks, drainage lines and rocky outcrops have been mapped and will be avoided. Will not have a Significant Impact.
Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat.	The Activity is not expected to result in the introduction of cane toads to the area due to biosecurity controls. The extended Dry Season, high aridity and temperature, and absence of permanent surface water in much of the Project Area will limit cane toad spread in the Project Area. Will not have a Significant Impact.
Interfere with the recovery of the species.	Cane toads, a key threat to the Northern blue-tongue skink, cannot survive for more than three days during dry conditions that normally prevail in Project Area without access to water. Cane toads were detected patchily at dams, leaking cattle troughs and tanks along the southern transects of the Beetaloo Basin but not along the long northern transect in Beetaloo SREBA study. Cane toads have been identified in the region for more than a decade and in the Project Area (Fox, 2021). The extended Dry Season, high aridity and temperature, and absence of permanent surface water in most of the Project Area will significantly limit cane toad potential invasive success in the proposed disturbance areas. Will not have a Significant Impact.

1.16.7 Water Monitors

Mertens' Water Monitor (*Varanus mertensi*) and Mitchell's Water Monitor (*Varanus mitchelli*) are semiaquatic and occupy coastal and inland rivers, margins of watercourses and swamps and lagoons. Given the similarity of the species, they have been assessed together in the SIA provided in **Table 1.16—8**. Both species are adept at climbing and will rest in hollows and underneath bark on trees. In the Northern Territory, both species have declined following the spread of the cane toad. *Varanus mertensi* was detected at four sites and *Varanus mitchelli* at one site in the SREBA Beetaloo study. Conservation and management effort for these monitors is best aimed at trying to maintain the presence of these species in toad-invaded areas.

Table 1.16—8: Significant Impact Assessment for the Mertens' and Mitchell's Water Monitor

Impact Criteria	Assessment
An action is LIKELY to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:	
Lead to a long-term decrease in the size of a population.	The Activity will not lead to a long-term decrease in the size of the Water Monitor population. Cane toads have been recorded in the in the Project Area/Larrimah for more than a decade, so the risk of a new introduction is negated. Will not have a Significant Impact.
Reduce the area of occupancy of the species.	The Activity will not lead to a long-term decrease in the size of the Water Monitor population as the only potential habitat in the Project Area is in the Larrimah LS where no ground disturbance will occur. Will not have a Significant Impact.
Fragment an existing population into two or more populations.	The Activity will not lead to a long-term decrease in the size of the Water Monitor population as the only potential habitat in the Project Area is in the Larrimah LS where no ground disturbance will occur. Will not have a Significant Impact.
Adversely affect habitat critical to the survival of a species.	The Activity will not lead to a long-term decrease in the size of the Water Monitor population as the only potential habitat in the Project Area is in the Larrimah LS where no ground disturbance will occur. Will not have a Significant Impact.
Disrupt the breeding cycle of a population.	Will not have a Significant Impact.
Modify, destroy, remove, isolate, or decrease the availability or quality of habitat to the extent that the species is likely to decline.	The Activity will not lead to a long-term decrease in the size of the Water Monitor population as the only potential habitat in the Project Area is in the Larrimah LS where no ground disturbance will occur. Will not have a Significant Impact.
Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat.	Cane toads have been recorded in the in the Project Area/Larrimah for more than a decade, so the risk of a new introduction is negated. Will not have a Significant Impact.
Interfere with the recovery of the species.	Given the scarcity of records for the two species in the Project Area and the lack of permanent water required for their survival, The Activity is not expected to interfere with the recovery of these species. Will not have a Significant Impact.

1.16.8 Threatening Process Impact Conclusion

None of the 14 listed threatened fauna species assessed, including those with a High LoO, that have the potential to occur in the Project Area are likely to be significantly impacted by the proposed Activity. Avoidance is the guiding principle to mitigate potential impacts on all flora and fauna, particularly for MNES within the Project Area. Avoidance is achieved by the following:

- The use of the LS framework to identify and avoid mapped LS associated with key threatened species potential key habitat. This habitat is chiefly constrained to the Larrimah LS, Mering LS and Western LS.
- The limited scale and relatively small ground disturbance area proposed for clearing is represents less than 0.1% of the Project Area.
- Final siting of well pads and flowline installation will occur prior to clearing, with a qualified ecologist to avoid significant habitat trees, such as large landscape trees with significant hollows for potential roost sites, should they occur.
- The Project Area is located on a geologically uplifted 'plateau terrain' known as the Antrim Plateau Volcanics (APV), which reflects the broad and unusually flat tableland topography at the top of the Elsey Creek catchment. Consequently, surface features such as creek lines and ridges are absent across much of the Project Area, significantly limiting suitable habitat for many listed species.
- As a result of geological uplifting, the CLA is absent in the Project Area; fractured basalt in the APV is a limited groundwater source and is found at depths greater than 40 m bgl. This significantly constrains the presence of potential GDE.

1.17 Pest Species and Weeds

The invasive and toxic cane toad (*Rhinella marina*) has been reported in the Elsey Creek National Park and at Mataranka since as early as 2002. Although they were not detected during the environmental survey conducted at the end of the Dry Season in 2021, they are likely to be present in the Project Area, given their ability to be invasive in aquatic systems during wet periods. They have been detected previously in the Project Area [FOX & CO ENVIRONMENTAL, 2021].

The absence of permanent surface water across much of the Project Area, including at proposed surface infrastructure sites, coupled with high temperatures and evaporation during the extended arid Dry Season will significantly constrain the spread of cane toads beyond permanent water bodies. The risk of new translocations/introductions of the cane toad to the Project Area is therefore considered low due of the Project Activity. Their potential impact on threatened species and carnivorous fauna in general is discussed in **Section 1.15**.

The observed weed locations identified during the November 2021 survey are presented in **Appendix 09** (Weed Management Plan) and summarised in **Table 1.17—1**. The DEPWS Natural Resource Maps database was also used to identify all introduced flora species that have previously been recorded within the tenement area associated with the proposed Activity. Introduced weed species in the Beetaloo SREBA study were mostly associated with areas of higher productivity, such as run-on areas

with heavier soils, drainage depressions, riparian areas, springs, floodplains, and wetlands [DEPWS, 2022]. In the Project Area this landscape is most likely associated with land systems at low elevation such as the Larrimah LS, Western LS and Mering LS.

During the 2021 Dry-Wet Season baseline field survey, *Sida acuta* (Spinyhead Sida), which is a Class B declared weed in the Northern Territory, was recorded in drainage lines along Western Creek/Larrimah Road and in some other drainage features in the Larrimah LS within the Project Area.

Proposed weed monitoring for the Project is described in Appendix 09.

Table 1.17—1: Known Weed Species to Occur in EP 167/168 (based on 2019 and 2021 surveys)

Scientific Name	Common Name	NT Class	WoNS	Recorded in 2021 Survey
<i>Sida acuta</i>	Spinyhead Sida / Sida	B	No	Yes - Recorded in drainage lines along Western Creek/Larrimah Road and additional drainage features within the Project Area. Spinyhead Sida will be managed using chemical or non-chemical methods detailed in the <i>Northern Territory Weed Management Handbook</i> [NORTHERN TERRITORY GOVERNMENT, 2021].
<i>Mimosa pigra</i>	Mimosa	A	Yes	No
<i>Cenchrus pedicellatus</i>	Annual Mission Grass	/	/	No
<i>Azadirachta indica</i>	Neem	B	No	No
<i>Calotropis procera</i>	Rubber Bush	B	No	No
<i>Jatropha gossypifolia</i>	Bellyache bush	A / B	Yes	No
<i>Andropogon gayanus</i>	Gamba grass	A / B	Yes	No
<i>Themeda quadrivalvis</i>	Grader grass	B	No	No

1.18 Air Quality

Baseline air quality monitoring results for an array of SREBA air quality monitoring stations deployed in the Beetaloo region at the end of the Dry Season in October and November 2022 are reported in

the SREBA [DEPWS, 2022]. Due to the location's remote nature, measuring particulate matter in accordance with the relevant Australian Standards was not practicable.

The measurements were carried out using a light scattering, portable particle sensor with a low power demand that does not require samples to be taken and does not have excessive maintenance requirements. The monitoring results at Mataranka and Manbulloo, north of Project Area for October – November 2022 are shown in Table 1.17—1 together with the NEPM standards.

The measured average concentration at Mataranka for PM₁₀ (Particulate Matter ≤ 10 µm) for October – November 2022 was 39 µg/m³, which exceeds the NEPM PM₁₀ standard of 25 µg/m³. The measured maximum 24-hour PM₁₀ concentration was 156 µg/m³, which also exceeds the NEPM PM₁₀ standard of 50 µg/m³. This air quality index is considered very poor.

However, measured average concentration at Manbulloo for PM_{2.5} (Particulate Matter ≤ 2.5 µm), which is of more concern to human and animal health as this particle size can reach deep into the lungs, was 54 µg/m³ for October – November 2022, compared with the NEPM annual average standard of 8 µg/m³, and the measured maximum 24-hour PM_{2.5} concentration of 195 µg/m³, corresponds with the current daily NEPM limit of 25 µg/m³. This air quality index is considered 'very poor', and precautions should be taken to minimise exposure.

The report notes that the maximum 24-hour average PM₁₀ and PM_{2.5} concentrations regularly exceed the NEPM standards across the NT due to seasonal conditions and bushfires. The PM_{2.5} to PM₁₀ ratio is unusually high compared with international figures and most likely reflects the high smoke levels that arise during bushfires and burn-offs. Much of the Project Area is regularly burnt (1-2 years), as shown in the most recent fire frequency mapping for the Project Area discussed further in Section 1.19. The primary sources of air pollutants arising from the Activity are:

- Management of sand for HF at well pads.
- Dust from construction works and bare earth areas.
- Activity road traffic.
- Gaseous emissions from onsite equipment and machinery.
- Gas flaring.

Table 1.18—1: SREBA Study PM₁₀ and PM_{2.5} Concentrations and NEPM Limits

Concentration	(Avg Oct-Nov)	(24- hr max)	NEPM (Annual avg)	NEPM (Daily Limit)
PM ₁₀ (Mataranka)	39	156	25 µg/m ³	50 µg/m ³
PM _{2.5} (Manbulloo)	54	195	8 µg/m ³ *	25 µg/m ³ **

* Reducing to 7 µg/m³ in 2025.

**Reducing to 20 µg/m³ in 2025.

A Methane Emissions Monitoring Plan is available in Appendix 10. Imperial A is committed to undertaking a 6-monthly leak detection at the well pad as per Part D (5) of the Code.

1.19 Fire

The Project Area is generally an open grassland savannah that is lightly timbered. The Project Area has been increasingly utilised for cattle grazing, and therefore many new fence lines and fire breaks have been constructed in the Project Area. As a part of grazing management practices towards the end of the Dry Season, paddocks are burned regularly to reduce fuel load and to promote new pasture growth through the following Wet Season. Much of the Project Area is regularly burnt (1-2 years), as shown in the most recent fire mapping for the Project Area (Figure 1.20—1). The Larrimah LS in the Project Area was burned in 2022, which was after the environmental baseline survey georeferenced imagery was acquired in late 2021.

Imperial A's Fire Management Plan was developed as part of the Exploration Program and is provided in Appendix 08. Mapping obtained from the Northern Australia Fire Information website [NAFI, 2021] details fire frequency in the Project Area.

1.20 Historical and Natural Heritage

A search of the *NT Heritage Register* [DTFHC, 2021] for EP 167/168 was conducted, and no recorded NT heritage items or places are present in the Project Area. A search of the *EPBC PMST* database [EPBC, 2021] showed no World Heritage Properties or National Heritage Places registered within 5 km of the Project Area.

An aerial/ground archaeological survey in the Project Area was conducted along the proposed seismic and well pad corridors, constrained by focusing on the seismic corridors, 1 km wide for the seismic lines, and 4 km wide for the well sites. The archaeological report from this survey is attached to this EMP as Appendix 01.01.

[REDACTED]

AAPA Authority Certificate C2022/092 is in place that covers the works being carried out under this EMP. Traditional Owner representatives will be on-site during all first disturbance works under this EMP.

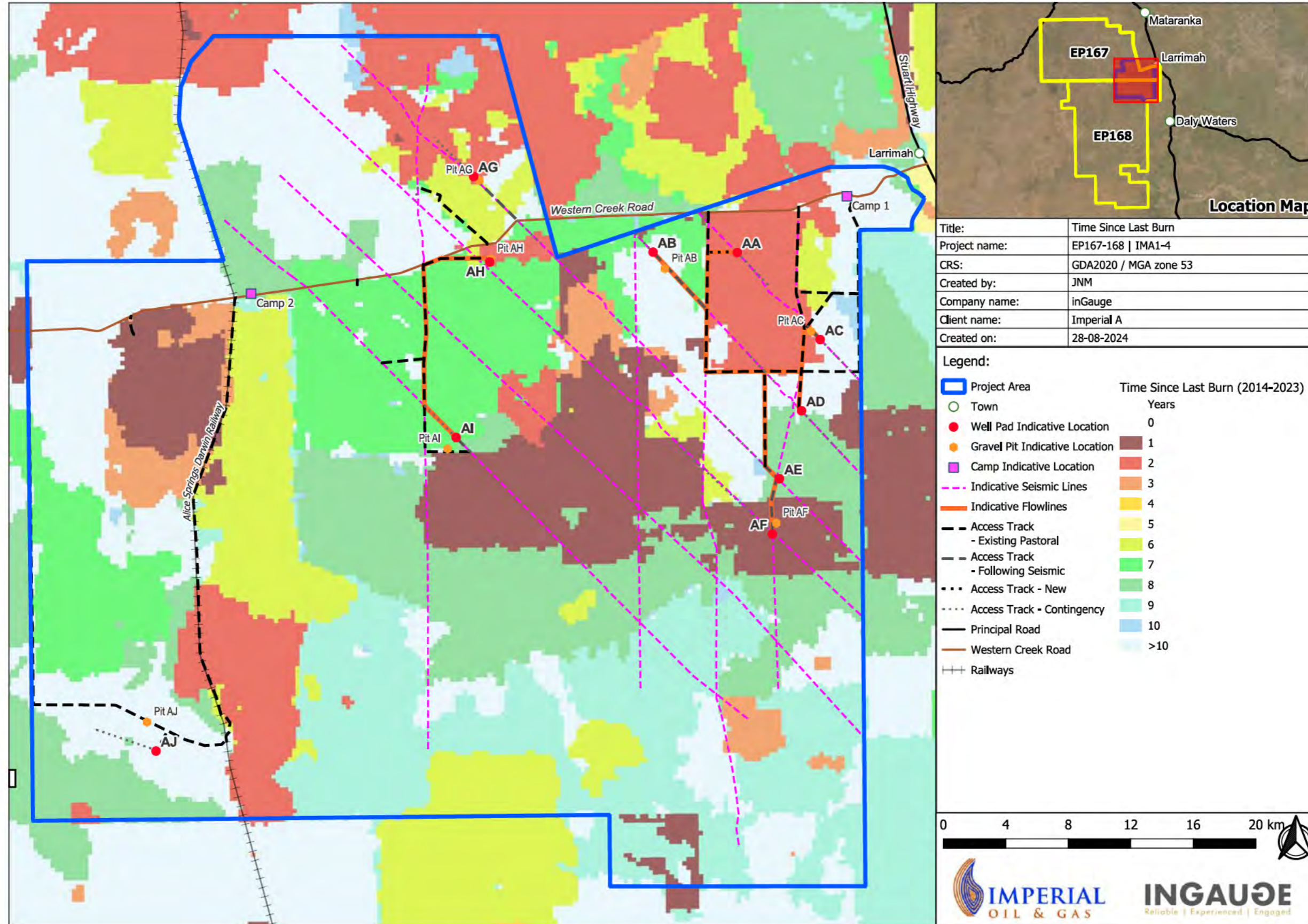


Figure 1.20—1: Time Since Last Burn Across the Project Area (2014-2023)

1.21 Protected Areas

There are no Parks, World Heritage Properties, National Heritage Places, Wetlands of International Importance or conservation areas or Sites of Conservation significance within the Project Area. The closest of these features is the Elsey National Park and the associated Mataranka thermal pools located within the RDZ, approximately 60 km to the Northeast of the Project Area. **Figure 1.21—1** shows the Protected Areas in the vicinity of the Project Area. There is a listed threatened ecological community (TEC) mapped in the 50 km buffer around the Project Area, the Arnhem Plateau Sandstone Shrubland Complex; however, there are no anticipated impacts on this TEC from the Activity.

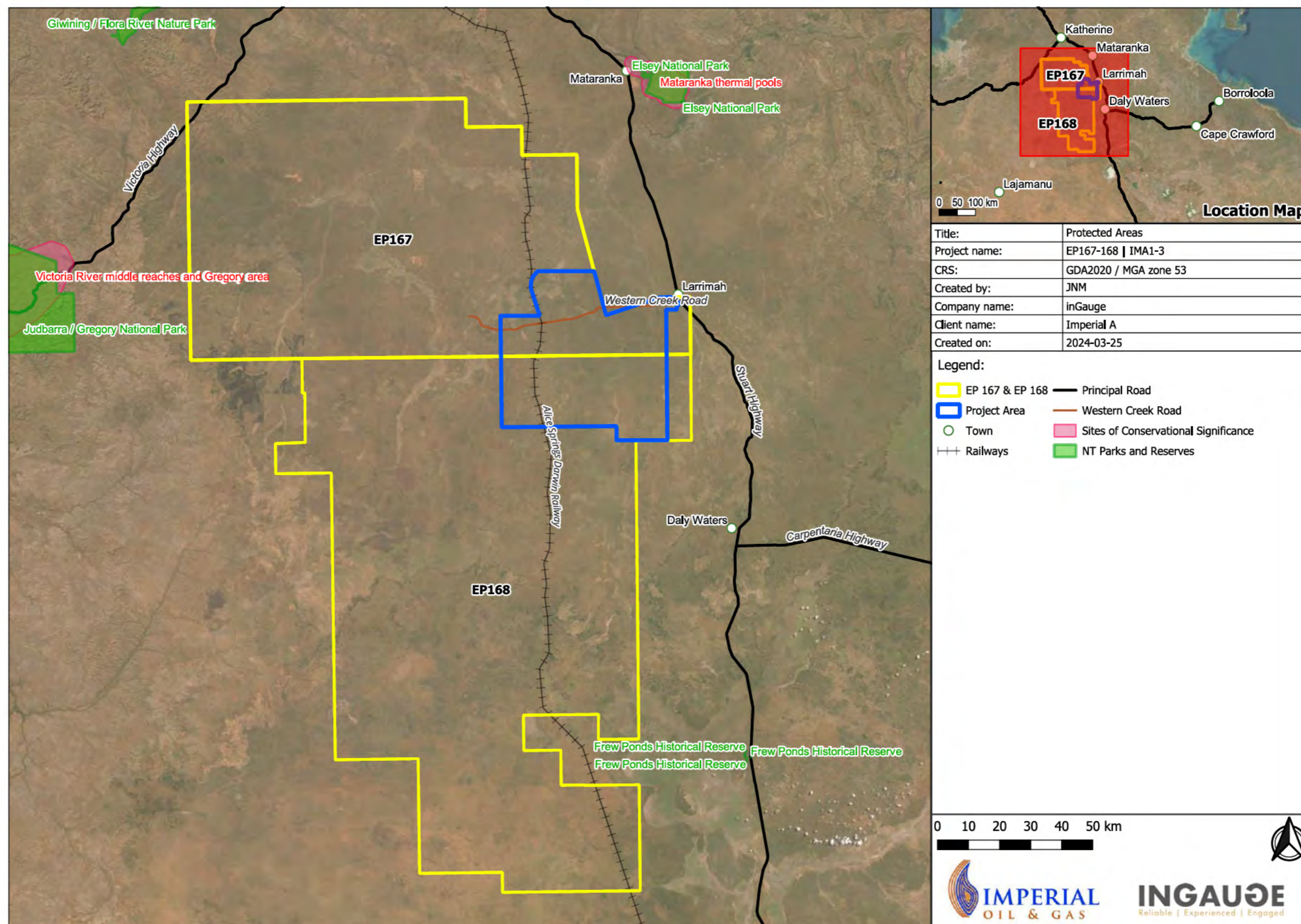


Figure 1.21—1: Protected Areas of the of the Region

1.22 Socioeconomic Environment

There are no settlements within the Project Area. The closest settlement Larrimah, is approximately 2 km east of the Project Area boundary and 5.4 km east of the proposed Camp 1 location. The nearest other settlements are Mataranka, 76 km to the north on the Stuart Highway, and Daly Waters, 93 km to the south on the Stuart Highway. Crossing through the western side of the Project Area is the Adelaide to Darwin rail corridor, and to the east is the Amadeus Gas Pipeline (Figure 1.22—1 and Figure 1.22—2).

The closest homesteads are Cow Creek, 3.5 km from the nearest seismic corridor, and Middle Creek, 4.2 km from the nearest seismic corridor (Figure 1.22—1). The distance from Larrimah to the nearest seismic/well pad corridor is 11.9 km. Note the seismic corridors may be narrowed in final ground-truthing prior to ground disturbance, which may increase the distances to these homesteads. Figure 1.22—1 shows the settlements in the region of the Project Area. Well pad AJ in the Bullwaddy LS in the southwest of the Project Area is ~4km from the rail line. The well pad is screened from the rail by the more elevated Sturt LS, which abuts the Bullwaddy LS to the southwest, as shown in Figure 1.7—1.

There are no sensitive receptors per the definitions listed in Table 3.5 of the *Northern Territory Noise Management Framework Guideline Version 0.1* [NT EPA, 2018] within 3 km of any well pad movement corridor. The EP 167 and 168 area is mainly used for pastoral grazing as directed under the *NT Pastoral Land Act* [DIPL et al., 1992]. The deed of agreement of informed consent and access to the land is facilitated through the *NT Petroleum Regulations* [DITT, 2020].

The Stakeholder Engagement Management Plan (Appendix 12) and the environmental controls provided in the environmental risk assessment (Appendix 04), set out the specific arrangements for ensuring that engagement with local pastoral stations and communities as well as the wider region are open and ongoing during the exploration activities.

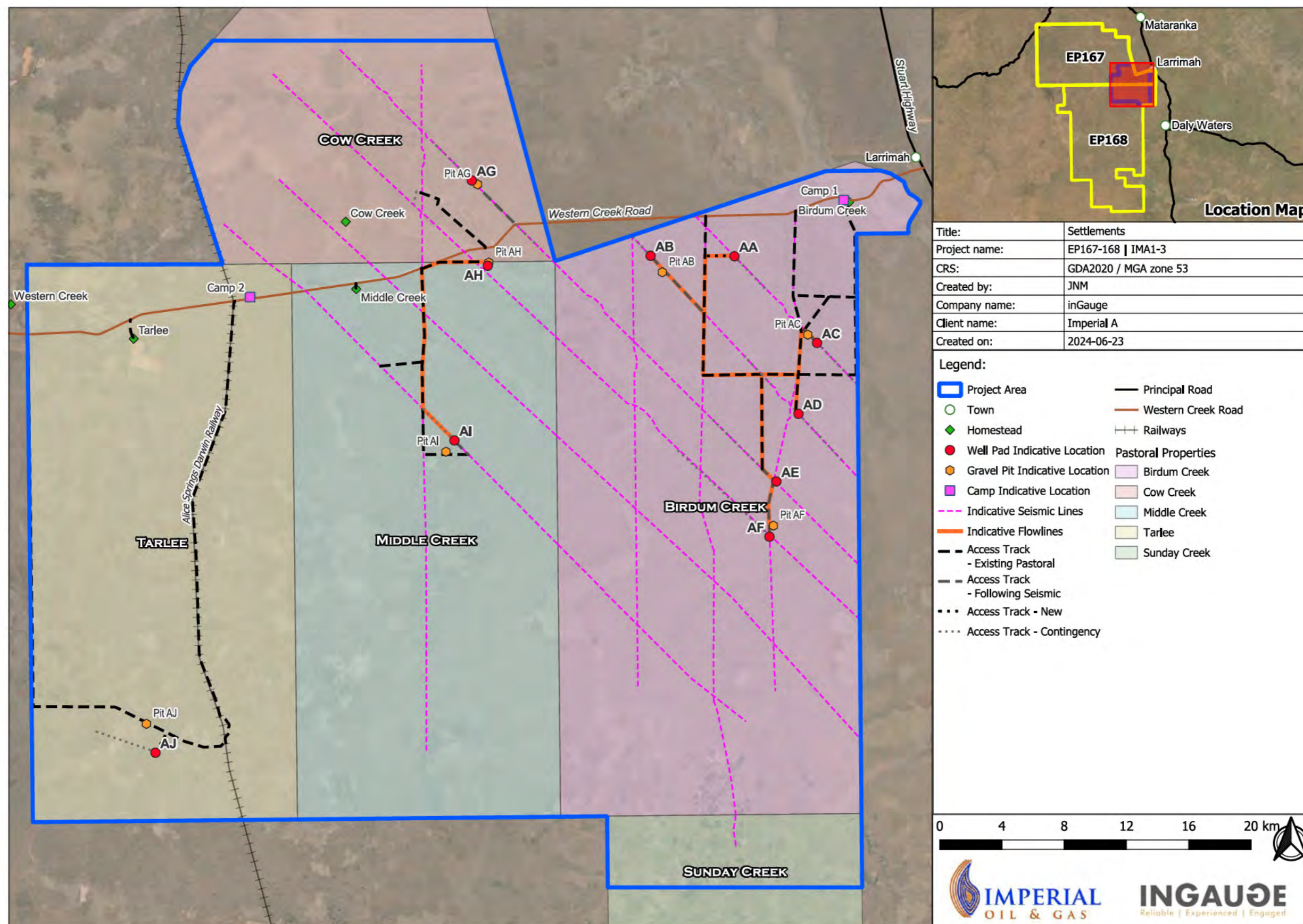


Figure 1.22—1: Project Area within the Socioeconomic Environment

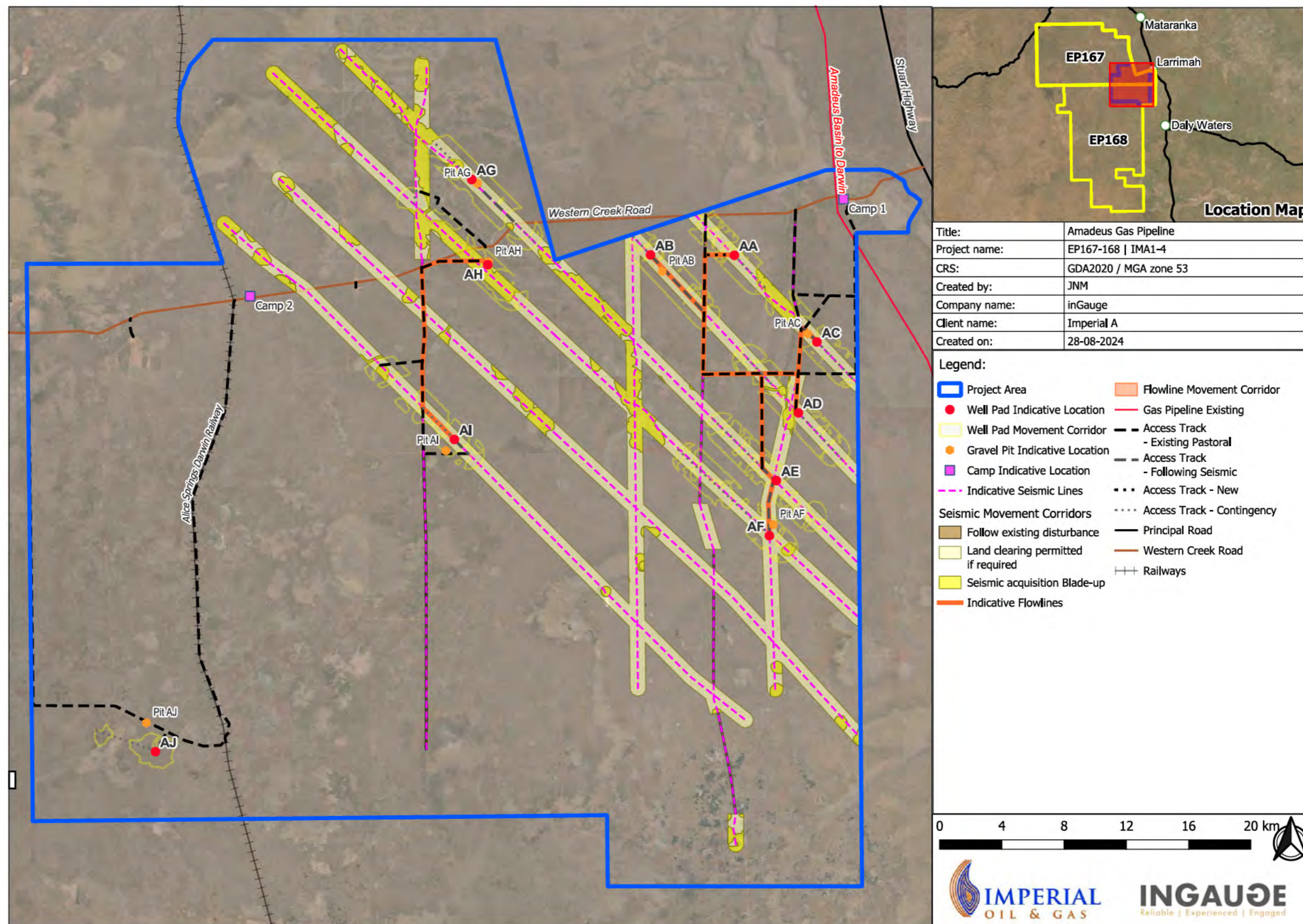


Figure 1.22—2: Project Area and Amadeus Gas Pipeline

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Appendices

1.22.1 Appendix 01.01 - Archaeological Report



Archaeological Report

Appendix 01.01

Imperial Oil & Gas A Pty Ltd

EP 167/168

IMA1-5

**ISLANDS OF REFUGIA: IMPERIAL EP167 AND
EP168 SEISMIC LINES, WELL CORRIDORS AND
ACCESS TRACKS AERIAL ARCHAEOLOGICAL
SURVEY, WESTERN BEETALOO BASIN,
NORTHERN TERRITORY**



Abridged report for Imperial Oil and Gas A Pty Ltd

Dr. Silvano Jung
Principal
Ellengowan Enterprises – archaeological consultant
ABN: 47 208 214 348

April 2023



EXECUTIVE SUMMARY

Imperial Oil and Gas A Pty Ltd are proposing to conduct a seismic and gas Well site survey on their Exploration Permits (EP) 167 and 168, just west of Larrimah in the Northern Territory. Ten seismic lines, which varied in length between 15 and 52 km long, and ten gas Well sites, were to be surveyed. In total the survey distance was 780 km long, including access tracks and covered up to 134² kms in the gas Well corridors. An archaeological heritage assessment of the proposed works was required to comply with the Northern Territory *Heritage Act (2011)*. An archaeological survey, in conjunction with an environmental survey was conducted, which discovered nine archaeological sites along the seismic lines.

[REDACTED]

No archaeological material was found in the proposed gas Well site corridors. The list below is of the nine archaeological sites recorded. Two mitigation options are suggested to eliminate the risk to cultural heritage sites on the EP167 and EP-168 seismic surveys.

[REDACTED]

Summary of recommendations:

- Mitigation schedule of sites (cells in red indicate a direct impact on sites):

No	Site ID	Site Type	Individual site type	GPS Grid Reference (Centroid) Datum: GDA 94, Zone: 53L		Description	Significance	Recommendation
			Artefacts (n.)	Easting	Northing			
1								
2								
3								
4								
5								

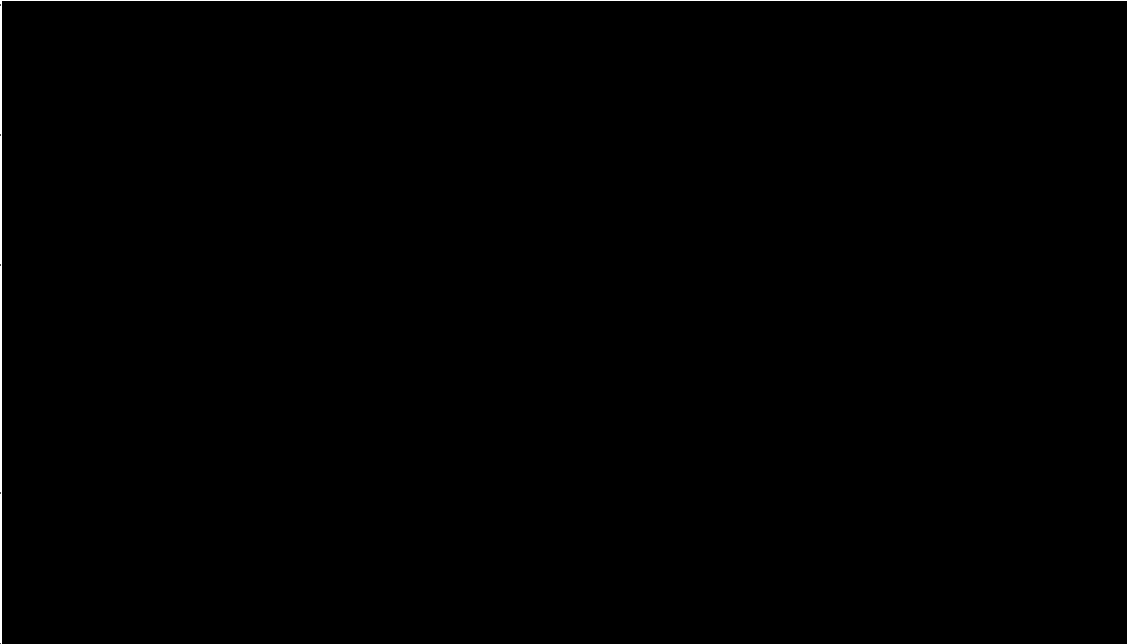
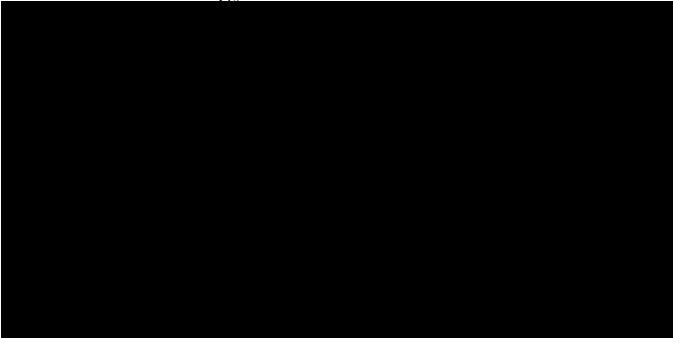
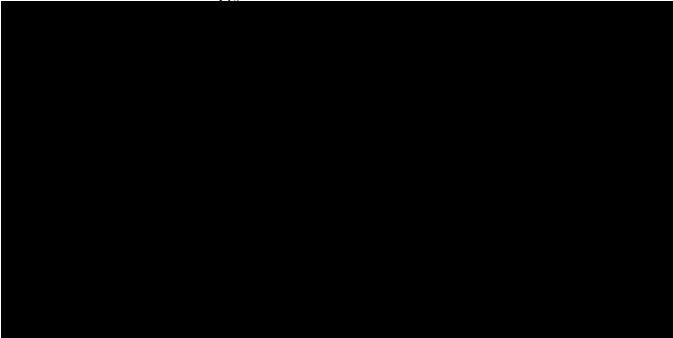
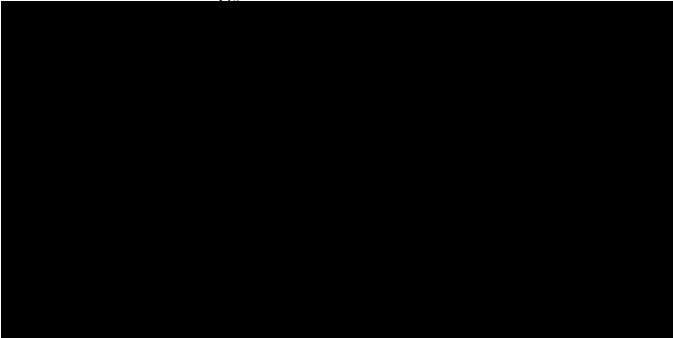
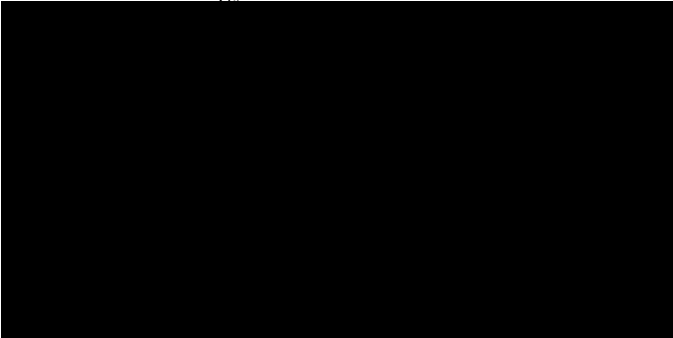
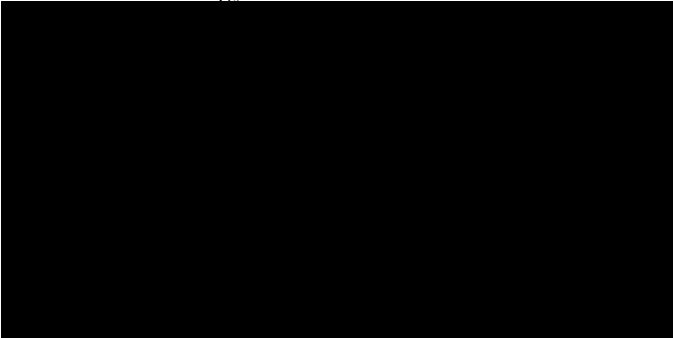
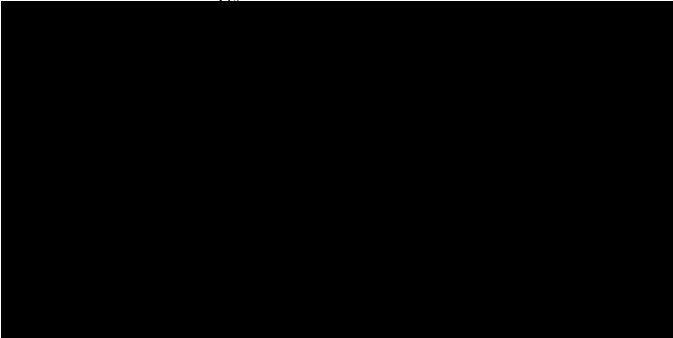
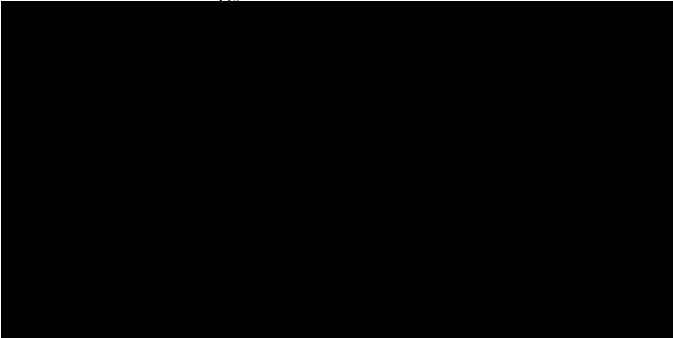
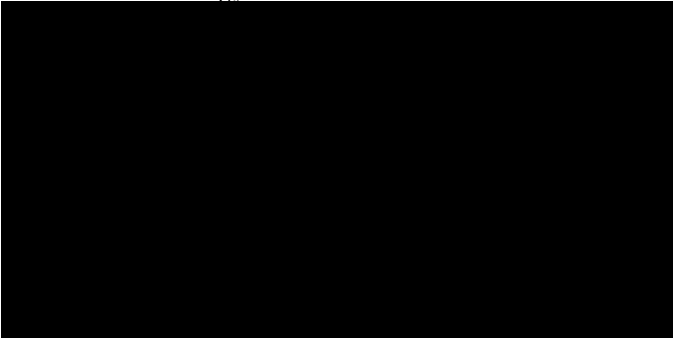
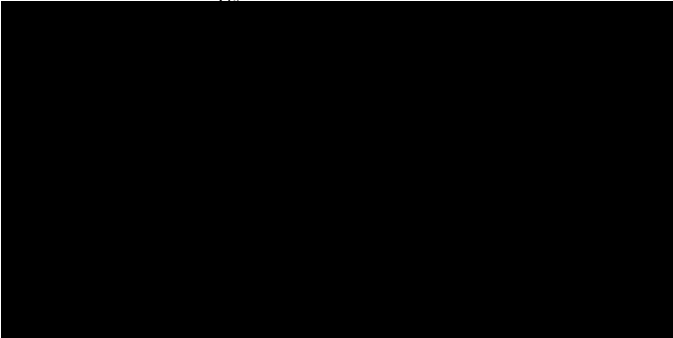
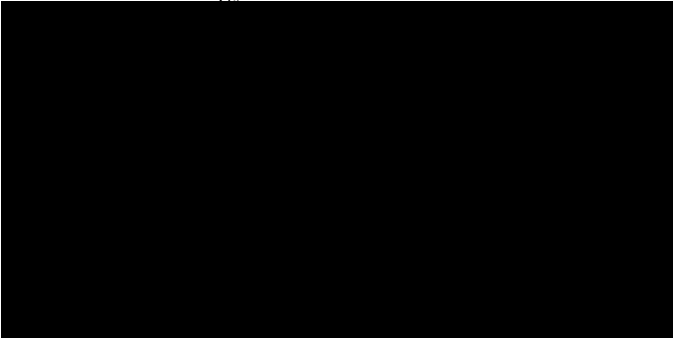
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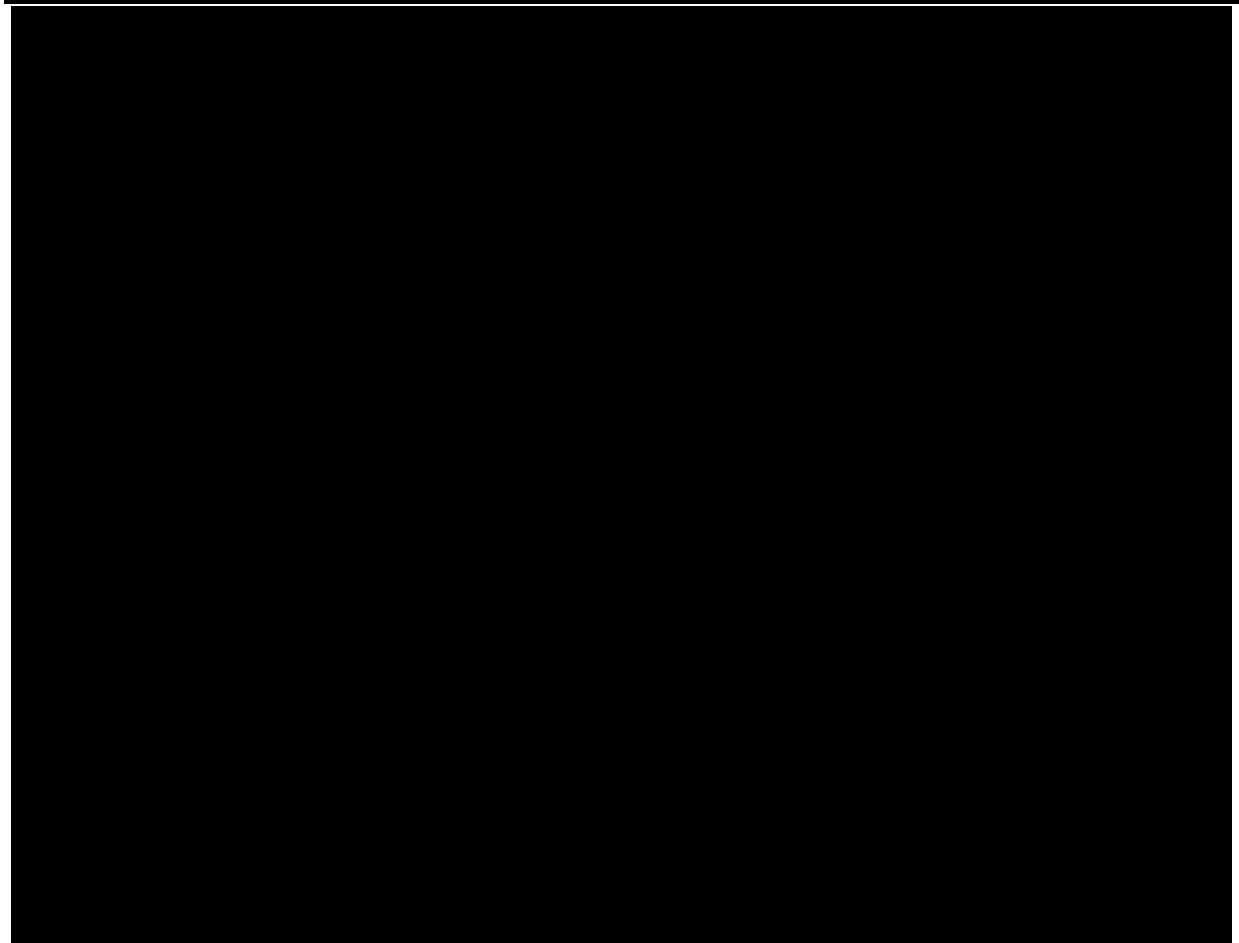
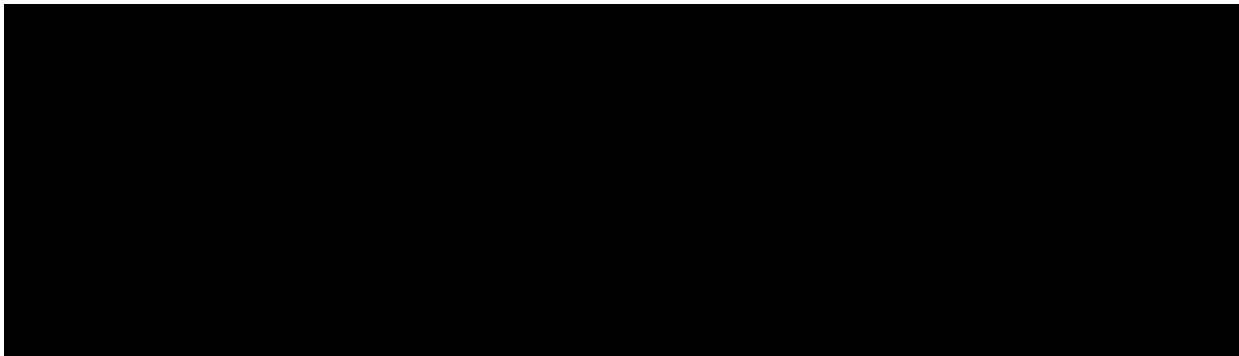
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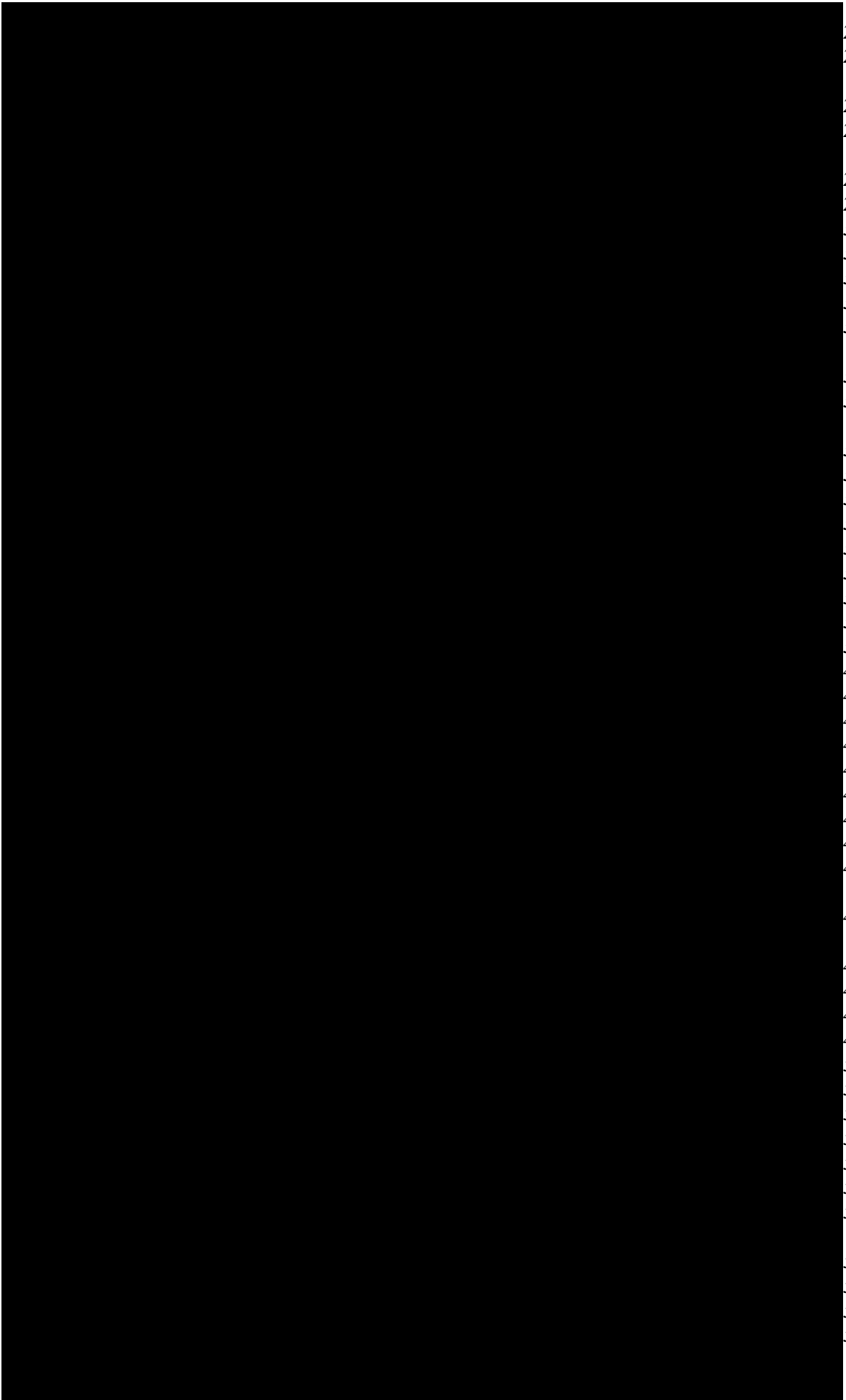
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1.0 INTRODUCTION

1.1 Background and consultancy brief

Imperial Oil and Gas A Ltd Pty (Imperial Energy) are proposing to build 375.83 kms of seismic survey lines, divided between ten lines, each within a one kilometre corridor. In addition to the seismic lines, ten Well sites are to be surveyed, which are spaced in a linear configuration measuring between six to eight kilometres along seismic lines. The Well corridors are, however, four kilometres wide and cover approximately 145² km. These corridors will allow the placement of the Well anywhere within the corridor, depending on local condition restraints and engineering requirements. These Well corridors have a boundary length totaling approximately 185 km. There is also a total of 217 km of access tracks, with a one-kilometre corridor in the works programme. A total survey distance of 783 km was required.

The survey area and access tracks cover four pastoral stations, Cow Creek, Middle Creek, Birdum Creek and Tarlee Stations, which are encompassed by Exploration Permit 167 and 168 on the western Beetaloo Basin, just west of Larrimah in the Northern Territory. An aerial archaeological survey was required to assess the impact of the proposed works, on archaeological sites, or objects.

An eleven-day aerial survey was conducted from 3 to 13 November 2021 together with ecologists Paul Fox and Laura Steiniger (Fox and Co). Our pilot was Blake Leigh-Smith, and our aircraft was a Robinson R44 (VH-WDI) helicopter. The consultancy brief was specifically to:

- Identify any prescribed archaeological objects or places as defined under the Northern Territory *Heritage Act (2011)*, and any archaeological sites located within the entire survey area.
- Assess the nature, distribution and significance of these objects or places and discuss possible constraints to the works posed by the presence of archaeological and historic sites and an indication of what sites are likely to be the most sensitive in this respect.
- Present a final report including a summary of survey results, determination of significance of sites and the likely impact of the proposed development, and recommendations regarding management strategies or mitigation procedures as appropriate under the Northern Territory *Heritage Act (2011)*.

The results of the fieldwork identified nine archaeological sites in what appeared to be a pattern in their distribution. All sites, consisting of [REDACTED], were found in association [REDACTED]. The sites were found to have well-defined boundaries that will enable the seismic survey to circumvent them, avoiding any threat to the archaeological resource. No archaeological material was found on the proposed Well sites and [REDACTED]. None were found within the access tracks corridors themselves.

The following describes the archaeological sites and details the mitigation strategy, which is site avoidance and deviation. Seismic lines going straight through them will directly impact some archaeological sites. Site avoidance, however, is not just to protect the archaeological resource, but also to avoid any impacts on the waterholes themselves, as they are a significant environmental refugia for both humans and wildlife, quite literally islands in an otherwise waterless terrain.

1.2 Location of the study areas and brief environmental description

The survey area is just to the west of the township of Larrimah, on the western Beetaloo Basin, 500 km south of Darwin in the Northern Territory (Figure 1). The survey area's foot print extends west of Birdum Creek to a distance of 54 km along the Larrimah/Western Creek Road and from north-south it spans approximately 51 km, over four pastoral stations: Cows Creek, Middle Creek, Birdum Creek and Tarlee (Alick, et al. 2016).

These survey distances are broken down per seismic line with their concomitant Well site. These are shown in the list below and mapped in Figure 2:

Total flight distance: 783km	
•	Line SE135 NS-1 = 44.00km
•	Line SE135 NS-2 = 29.20km
•	Line SE135 N-3 = 41.63km
•	Line SE135 N-4 = 31.00km
•	Line SE135-0 = 43km
•	Well 6A Corridor = 20.00km (16 ² km)
•	Line SE135-1 = 52km
•	Line SE135-2 = 52km
•	Well 1B Corridor = 20.60km (16.7 ² km)
•	Well 2B Corridor = 21.30km (17.4 ² km)
•	Line SE135-3 = 47km
•	Well 1A Corridor = 20.00km (16.00 ² km)
•	Well 2A Corridor = 20.00km (16.00 ² km)
•	Line SE135-4 = 21.0km
•	Well 4B Corridor = 16.00km (12.00 ² km)
•	Well 5B Corridor = 20.00km (16.00 ² km)
•	Line SE135-5 = 15km
•	Well 4A Corridor = 14.60km (10.60 ² km)
•	Well 5A Corridor = 16.00km (12.00 ² km)
•	Well 3A = 06.00km
•	Well 3A Corridor = 16km (12 ² km)
Total access track distance: 217km	
1.	Tarlee Station = 66km
2.	Middle Creek Station Access track = 9 km
3.	Birdum Creek Station = 72km
4.	Larrimah/Western Creek Road = 70km

The environment is flat with open woodland with vegetation consisting of *Corymbia opaca* (bloodwoods), *Erythrophleum chlorostachys* (Iron Woods), *E. argillacea* (Grey Box), *Brachychiton megaphyllus* (Red Flowering Currajong) *E. grandifolia* (Cabbage Gum), *E. miniata* (Darwin Woollybutt) and *E. bigalerita* (White Wood). Forest types include lancewood and bullwaddy, particularly to the south of the survey area. Soil types range from laterite to cracking black soil plains and some white bargo soils (bull dust) to the south.

The only nearby major water way is Birdum Creek, which is to the east and outside of the survey area. There are major waterholes, such as the Mering Mering Waterhole and the Blue or Teenyoung Waterhole, but these are to the north and west of the Larrimah/Western Creek Road, also outside of the survey area. The southern area is also characterised by sinkholes and limestone outcrops. Granite and quartz outcrops also occur, but further north towards the Western Creek Road.

The survey recorded numerous unknown waterholes of various sizes, whose distribution was throughout the survey area. Some of the waterholes occurred in limestone areas and contained clear water.



Figure 1. Location map of Imperial Energy's EP167/168 study area, just west of Larrimah (After Google Earth).

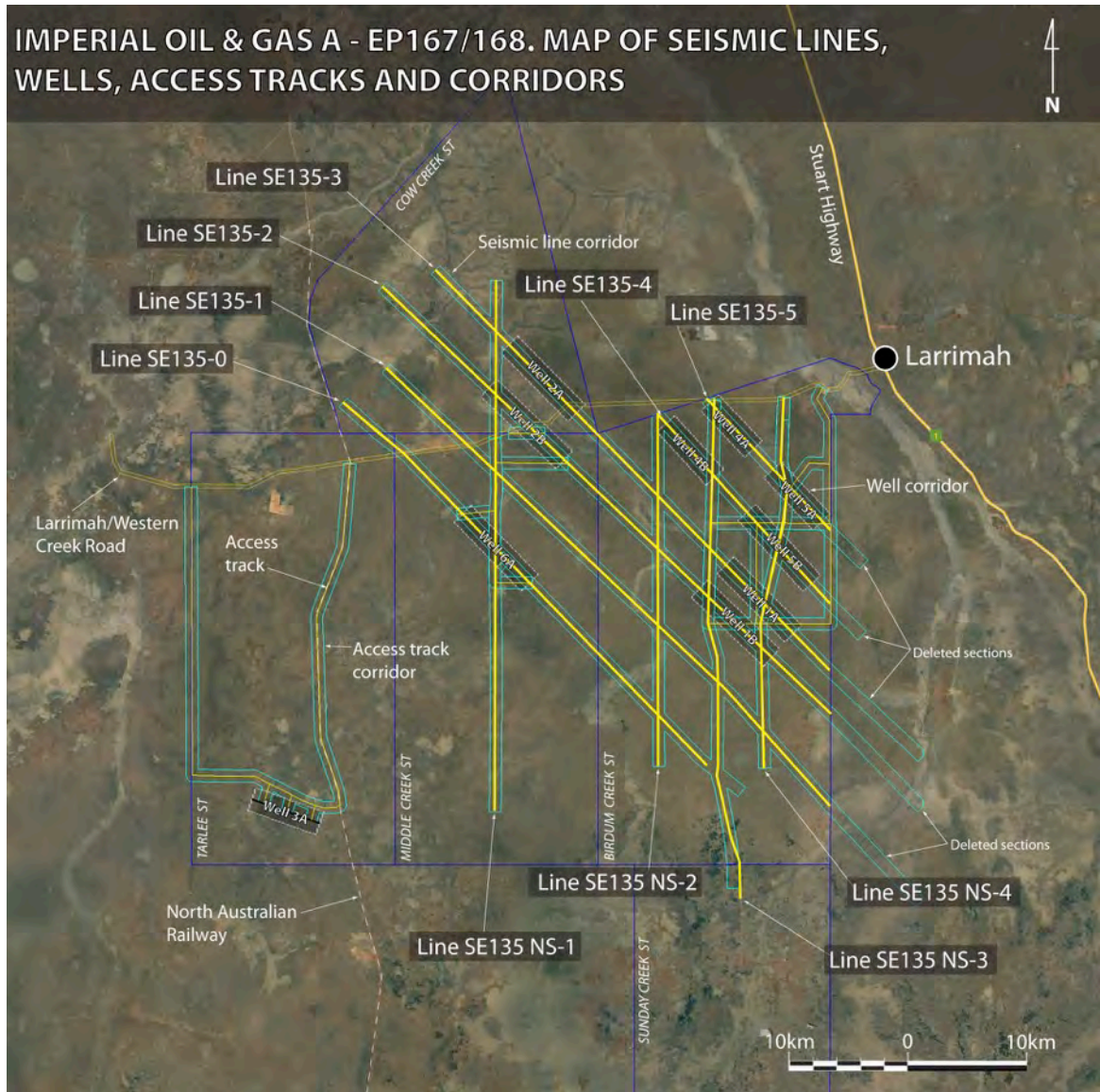


Figure 2. Location of the study area, showing seismic lines, proposed well sites and access tracks (After Google Earth).

The geology of the survey area is shown in Figure 3, with the geological units listed below. Raw material types for artefact manufacture certainly occur in the survey area.

- Cza – Alluvium, some black soil and sandy soil.
- Czs – sand, sandy and loamy soils, gravel, some lateritic material.
- Klm – quartz sandstone, siltstone, claystone.
- Ti – Limestone, some chert, fossiliferous.

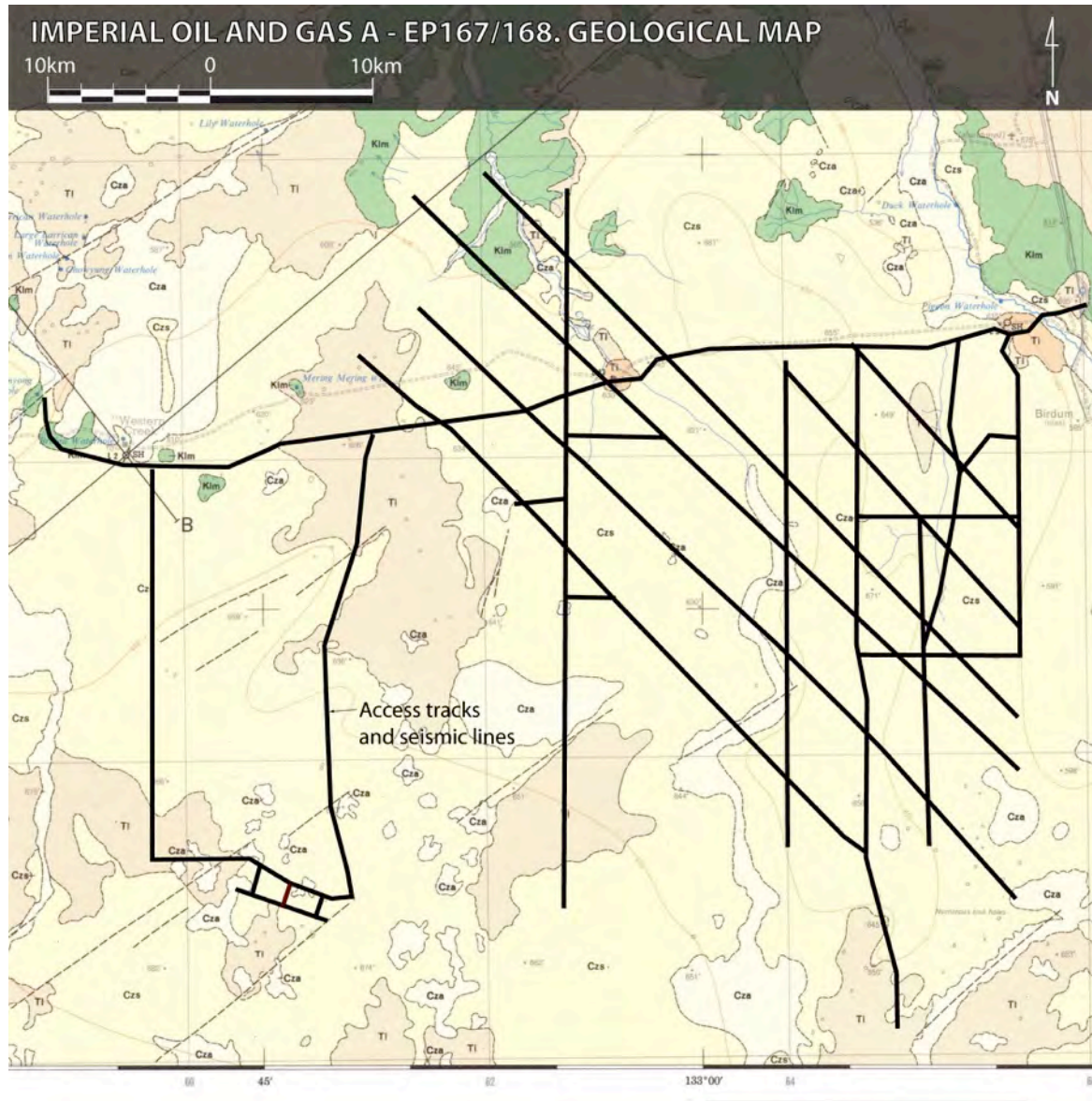


Figure 3. Geology map of the survey area with overlaid seismic survey lines and access tracks (After LARRIMAH SD5313. Geoscience Australia. 1: 250 000 Geological Map, 1st edition 1969. <http://scanned-maps.geoscience.gov.au/250dpi/sd5313.jpg>. Accessed 17 November 2021).

2.0 HERITAGE LEGISLATIVE FRAMEWORK

2.1. Northern Territory legislation

There are two kinds of heritage sites protected under the Northern Territory *Heritage Act (2011)*, hereafter referred to as the *Act*, declared and prescribed places and objects. The Act places legal constraints on owners of private property, local government and the Crown:

- Places or objects listed on the Northern Territory Heritage Register are declared heritage places and objects that are protected under section 33 of the *Act*, and
- Prescribed archaeological places and objects, which may or may not be declared, are protected under sections 29 and 39 of the *Act*.

It is an offence under the *Act* to damage, destroy, alter or carry out work of any sort on declared or prescribed sites without the written consent of the Minister or Minister's delegate. If considered appropriate, the Heritage Branch may on occasion utilise the discretion available in the *Act* to give permission for small-scale disturbance (such as the relocation of isolated stone artefacts) without the need for a formal application. The discretion is allowed under s148 of the *Act*, which in effect says that a heritage officer (such as an archaeologist) may undertake actions (or authorize actions), not construed as an offence.

2.1.1 Declared heritage places and objects

Categories, which describe the status of each site on the Northern Territory Heritage Register database, are listed in Table 1.

Table 1. Site status on the Northern Territory Heritage Register database

Status	Description
D	Declared heritage place.
NR	Not recommended. HC* determined that the place did not meet heritage assessment criteria and did not hold sufficient value to warrant declaration under the <i>Act</i> .
RF	Refused by the Minister. HC* recommended for declaration and Minister refused to do so.
P	Proposed. HC* has determined that the place warrants declaration under the <i>Act</i> but has not yet made its recommendations to the minister.
RV	Revoked. Declaration as a heritage place pursuant to Section 26(1) of the <i>Act</i> is revoked.
N	Nominated. HC* has yet to complete its assessment of the heritage value of the place.

*Heritage Council

The Northern Territory Heritage Register contains places that possess special significance for the Northern Territory and have been recognized for a wide range of natural and cultural values. As a result it includes places that have been deemed significant because of their environmental and/or cultural characteristics. For the purposes of the current report, only places of historic or archaeological significance have been included. A search of the register indicates that the proposed works programme for Imperial Oil and Gas A on EP167 and EP168, will not impact on any sites listed in the Heritage Register.

2.1.2 Prescribed archaeological places and objects

Most archaeological places and objects are listed in the *Heritage Conservation Regulations* (1999) as prescribed places and objects. The Heritage Branch, Community Participation and Inclusion, Department of Territory Families, Housing and Communities, hold the Archaeological Sites Register. Included in this register are the protected prescribed sites that consist of all archaeological sites and objects pertaining to the past occupation by Aboriginal people. Any historic sites listed on this register do not indicate that these sites are protected or hold legal significance under the Northern Territory *Heritage Act 2011*.

2.2. Constraints

2.2.1 Ground Integrity (GI)

Assessing ground surface integrity provides an indicator of whether or not the landscape under study has been modified, and if so the degree of disturbance encountered. It then becomes possible to gauge the degree to which modification has influenced the environmental context within which artefacts and/or places of cultural and/or scientific interest are located. Ground surface integrity must also be assessed from the perspective of the current legislation.

The *Aboriginal Cultural Heritage Act 2003* (in Queensland, but equally applicable to the Northern Territory) provides a definition for GI that includes the removal of native vegetation as inferring the ground has been subjected to ‘significant ground disturbance’. Under these criteria of modification, therefore, the *Act* assumes that archaeological integrity and significance is greatly reduced, is negligible, or even extinguished completely.

Contrary to this however, archaeologists are continually finding evidence that important cultural heritage material and/or places regularly survive not only land clearing activities but also invasive farming techniques such as ploughing.

Combined with this is the fact that, regardless of levels of GI, significant Aboriginal objects and/or significant Aboriginal areas can be defined on entirely cultural grounds, by Traditional Owners, not requiring any assessment of ground surface integrity.

Levels of GI are determined using a percentage range between 0-100% where 0% indicates all GI is gone, and 100% represents excellent preservation of the original context. Zero – 0%; Poor – 1-25%; Moderate- 26-50 %; Fair – 51-75 %; Good – 76-85%; Excellent 86-100%.

2.2.2 Ground Surface Visibility (GSV)

Assessments of ground surface visibility provide an indication of how much of the ground surface can actually be seen.

Ground surface visibility (GSV) is most commonly inhibited by vegetation but other inhibitors may include concrete, gravel and bitumen. Levels are determined using a percentage scale similar to that used for the calculation of Ground Integrity (GI), in that 0% represents zero visibility and 100% represents maximum visibility (bare ground). Zero – 0%; Poor – 1-25%; Moderate – 26-50 %; Fair – 51-75 %; Good – 76-85%; Excellent – 86-100%. The better the visibility, the more potential there is for locating cultural/archaeological material.

3.0 PREVIOUS RESEARCH

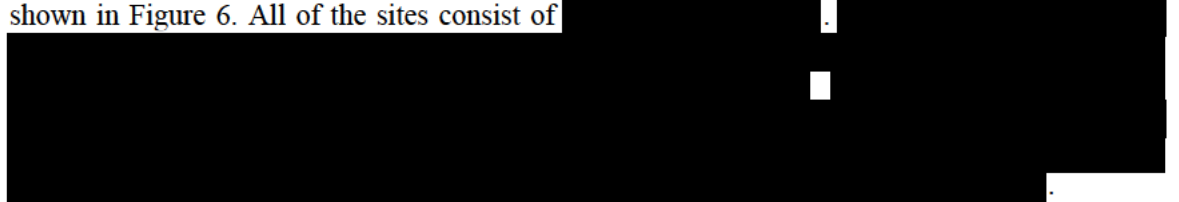
3.1 Literature review

The study area occurs within the traditional lands of the Yangman people (Fig. 4). Merlan's (1994) study of the Yangman speakers relate to people living in Katherine, but indicate that the language, hence stories about country, was in decline, or obsolete:

I had been inquiring whether anyone knew the Yangman language, and Bobby was recommended to me as Yangman by some Bunjarri people. This interested me, partly because Yangman identity is hardly cited by any Aborigines in Katherine nowadays, with the exception of members of the family, mentioned above, who have a specific and locally well-known paternal link to a place associated with that identity on the Dry River. On the other hand, welfare censuses show that the Yangman identity was still given as their won in the late 1960s by a number of (mainly elderly) people in Katherine (eight in all). Following their deaths (and even though several had children who were members of their families in which there had been multiple marriages and were therefore sets of part-siblings), the Yangman identity has not been reproduced in Katherine: it, like Dagoman identity, has become obsolete in town (Merlan, 1994:27).

First contacts with the Yangman were probably through the exploration parties of Gregory and Stuart between 1855-56 and subsequently with the establishment of the overland telegraph in the 1870s. From an historical perspective, Larrimah is famous for being the rail terminus of the line from Darwin (Harvey, 1987; Fig. 5).

Previous archaeological studies in the area of EP167 and EP168 include investigations for the rail line from Darwin to Alice Springs (Kinhill, 1995). Other studies relate to the Amadeus Basin to Darwin gas pipeline (Hermes, 1986) and the RAAF base at Tindal (Baker, 1983). Five specific archaeological sites were recorded close to the survey area and these are listed in Table 2 and shown in Figure 6. All of the sites consist of



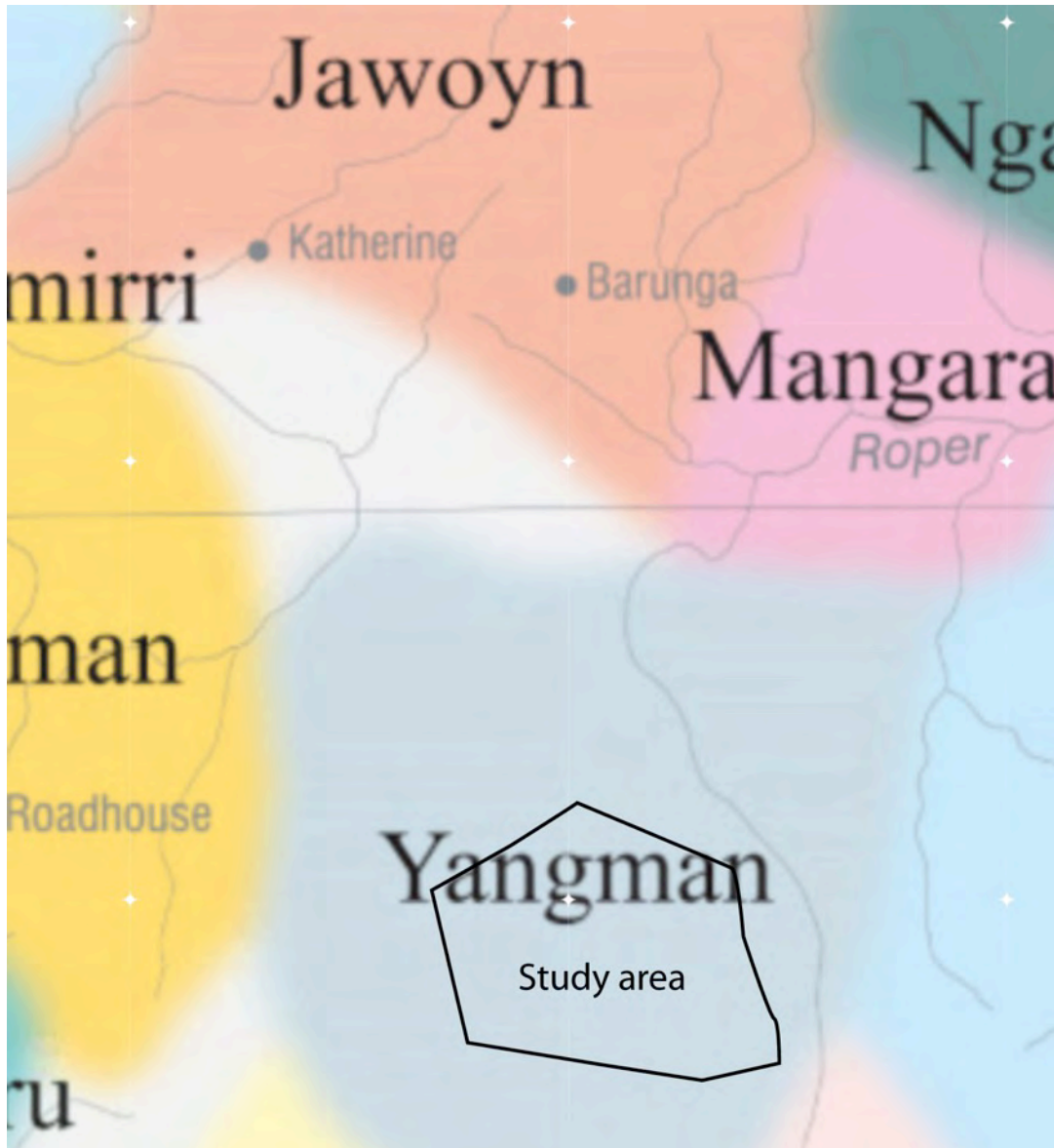


Figure 4. Tindale Map (After AIATSIS. URL: <https://aiatsis.gov.au/explore/map-indigenous-australia>. Accessed 16 November 2021).

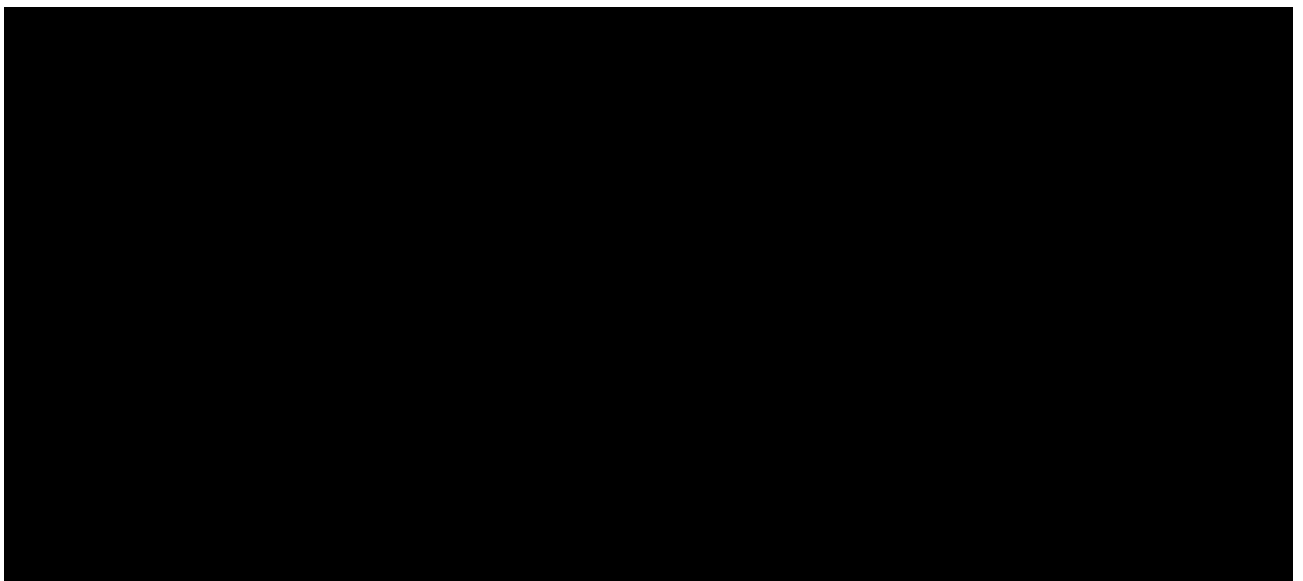
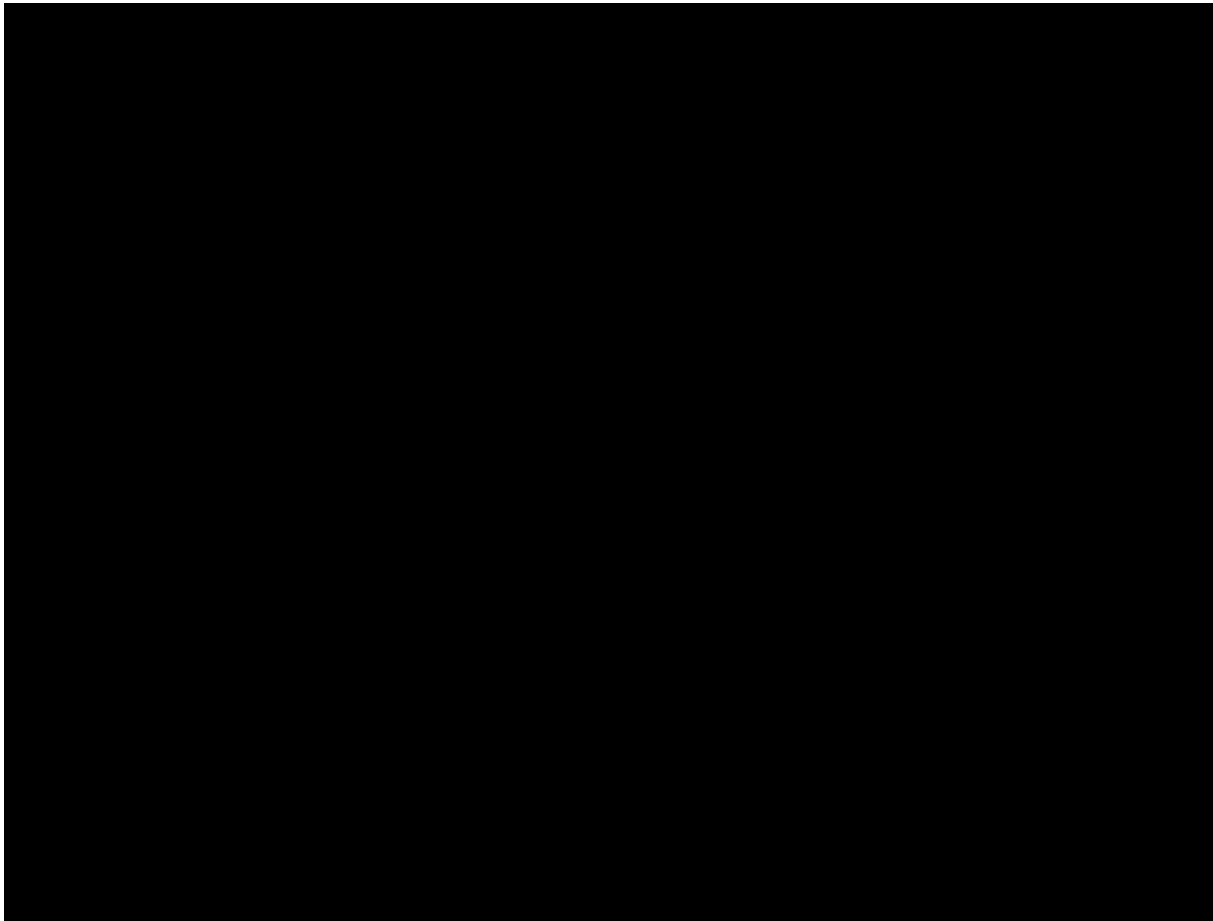




Figure 5. Photo number: PH0546/0029. Title: Birdum. (1940). Alexander Fleetwood Collection, Picture NT. Retrieved November 26, 2021, from <https://hdl.handle.net/10070/720139>.



4.0 METHODS

4.1 Survey method

Archaeological survey methods are often based on sampling strategies. These strategies can be 'purposive', where specific areas are targeted, or 'probabilistic', where decisions are made to survey without any prior knowledge or predictive model of what heritage resources might exist in the landscape to be surveyed. Cultural heritage survey strategies generally involve transects across project areas chosen at random (probabilistic) to avoid possible bias in the results, or transects within particular areas (purposive) known to potentially contain Aboriginal cultural heritage or contain sites that were identified in previous research or surveys.

The purposive survey method was used in this survey utilised aerial resources to assay likely habitation areas. [REDACTED]

[REDACTED] A short pedestrian survey was conducted along each of the survey lines from the helicopter landing zones (LZs). Some were brief to quickly assess sites, while other pedestrian transects were longer at sites of high probability to contain archaeological material. [REDACTED] were photographed and some [REDACTED] and a GPS grid reference was recorded. [REDACTED] were defined by polygons to delineate their boundaries, although site polygons may be extended to [REDACTED] including areas that were archaeologically sterile. Previously recorded sites were relocated to confirm their locations with current GPS accuracy, as the GPS coordinates for sites recorded pre-2000 were still being dithered. Boundaries were also determined for them to identify their extent and density.

The aircraft was to fly along the centre of seismic lines at a height of approximately 200 ft (60.96 m) at a speed of approximately 50 - 70 knots (92.6 km/h to 129.64 km/h). The height afforded good views to either side of the centre line up to 500 m. At well corridors, whose width was 4 km, the outside boundary of the corridor was also flown, turning to the left, which enable both observers on the left hand side of the aircraft to have a clear view. This method was effective in [REDACTED]. Landings were also made outside of the target sites as a control to test the survey method.

4.1.1 Identification of archaeological material

Stone artefacts, including tools and debitage, the by-product of manufacture, are identified on the following criteria after McCarthy (1976), Holdaway and Stern (2004):

- Bulb of percussion
- Eralure scar (on the ventral surface)
- Point of force application (PFA) and associated ring crack
- Termination types (e.g. feathered, stepped, hinged, plunge)
- Flake scars (dorsal scars and ridges)
- Cores (identified by the presence of negative flake scars)
- Hammer stones (identified by the presence of end-crushing on pebble stones)
- Retouch (reworking of flake margins)
- Raw material type
- Grinding stones (very smooth wear on upper surface)

List of artefact type abbreviations:

- Ad – Adze
- An – Anvil
- Bl – Blade

- Co – core
- Cf – Core fragment
- Ct – Core tool
- F – flake
- Fp – flake piece
- Gs – Grindstone/Grinding plate
- Gh – Grinding hollow
- Hs – Hammer stone
- M – Manuport
- Mp – Multi platform core
- Rtf – retouched flake
- S – Scraper
- Sp – Single platform core
- Ts – Top stone
- X – Axe/wasted cobble
- Z – Other e.g., ceremonial

List of artefact raw material abbreviations:

- B – Basalt
- C – Chert
- Ch – Chalcedony
- G – Greywacke
- Gr – Granite
- Hs – Hornsfel
- Im – Indurated mudstone
- J – Jasper
- SS – Sandstone
- S – Silcrete
- Q – Quartz
- Qz – Quartzite

4.1.2 *Definition of archaeological sites*

4.1.2.1 *Historical Sites*

Historical sites in north Australia are those that have physical evidence of European and non-European activities. These range from Macassan sites to military sites of WWII. The Macassan sites are afforded automatic protection under the *Act*. WWII sites, however, are only protected under the *Act* once they have undergone a nomination process. Both Macassan, WWII and other historic sites, such as Chinese mining areas, the Overland Telegraph Line (OTL), the North Australian Railway etc., may overlap with Aboriginal heritage sites.

4.1.2.2 *Aboriginal Heritage Sites*

Aboriginal archaeological sites can be classified by seven main types: 1) stone knapping sites, including quarries, 2) background scatters, including isoliths, 3) stone arrangements, such as mounds, walls, fish traps or stone motifs, 4) shell middens, 5) burials, 6) scarred trees and 7) rock art sites.

Burke and Smith (2004:63) define an archaeological site as ‘any place that contains the physical evidence of past human activity. Australia, however, has what has been referred to as a background scatter of stone artefacts, which refers to low-density artefact scatters that either represent singular knapping events (‘dinner-time’ camps or ‘hunting camps’), or larger sites that have been buried or disturbed. To differentiate this site type from larger sites that may contain

thousands of artefacts, the term Archaeological Site (AS) is used to describe home-camps or quarries i.e., places where people have been returning to for millennia, as opposed to sites that have very low artefact densities that represent sporadic visits i.e., background scatters (BS).

5.0 RESULTS

5.1 Archaeology

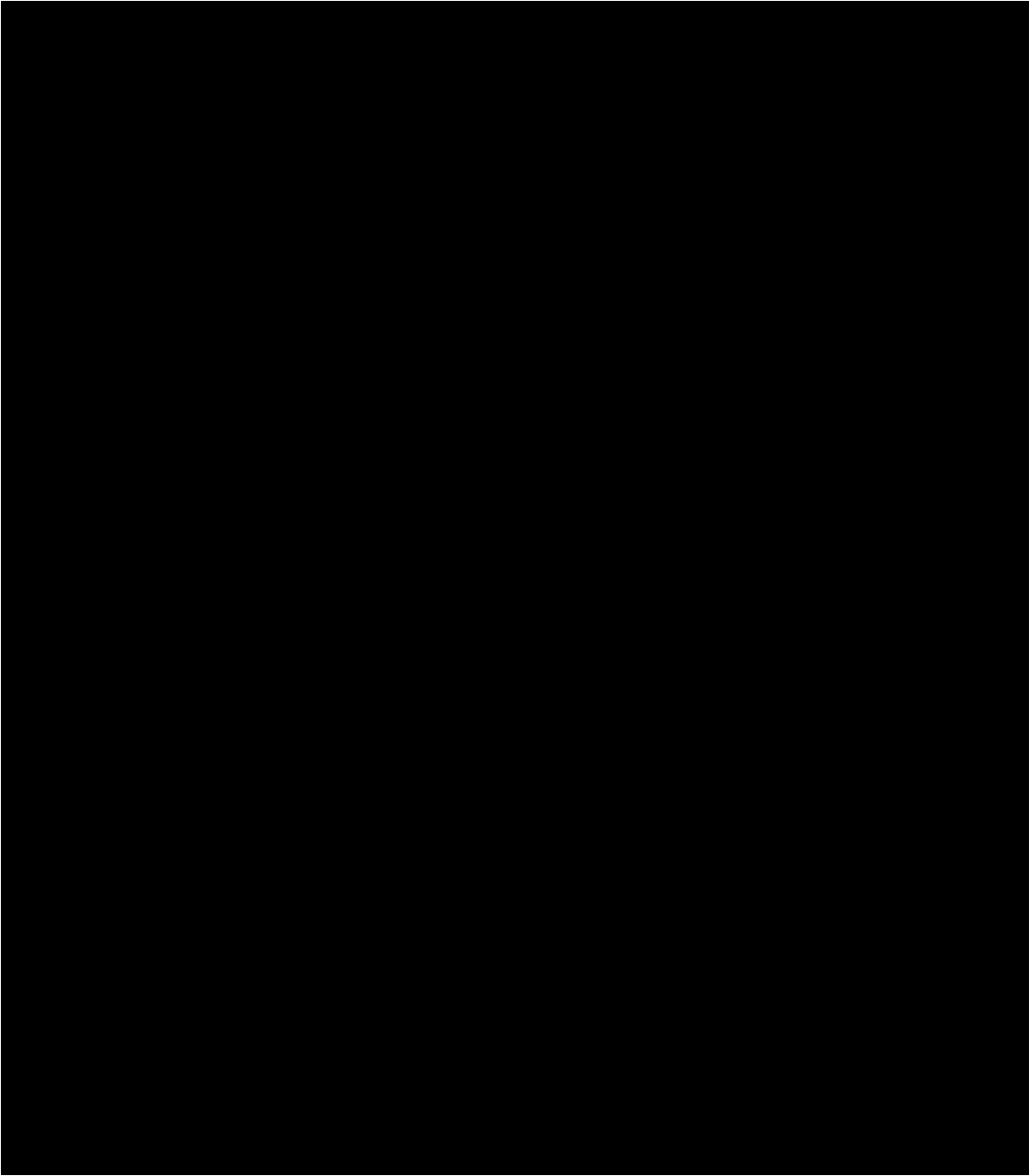
Eighty-two landings were made along ten seismic lines, ten Well corridors and access tracks (Fig. 7).

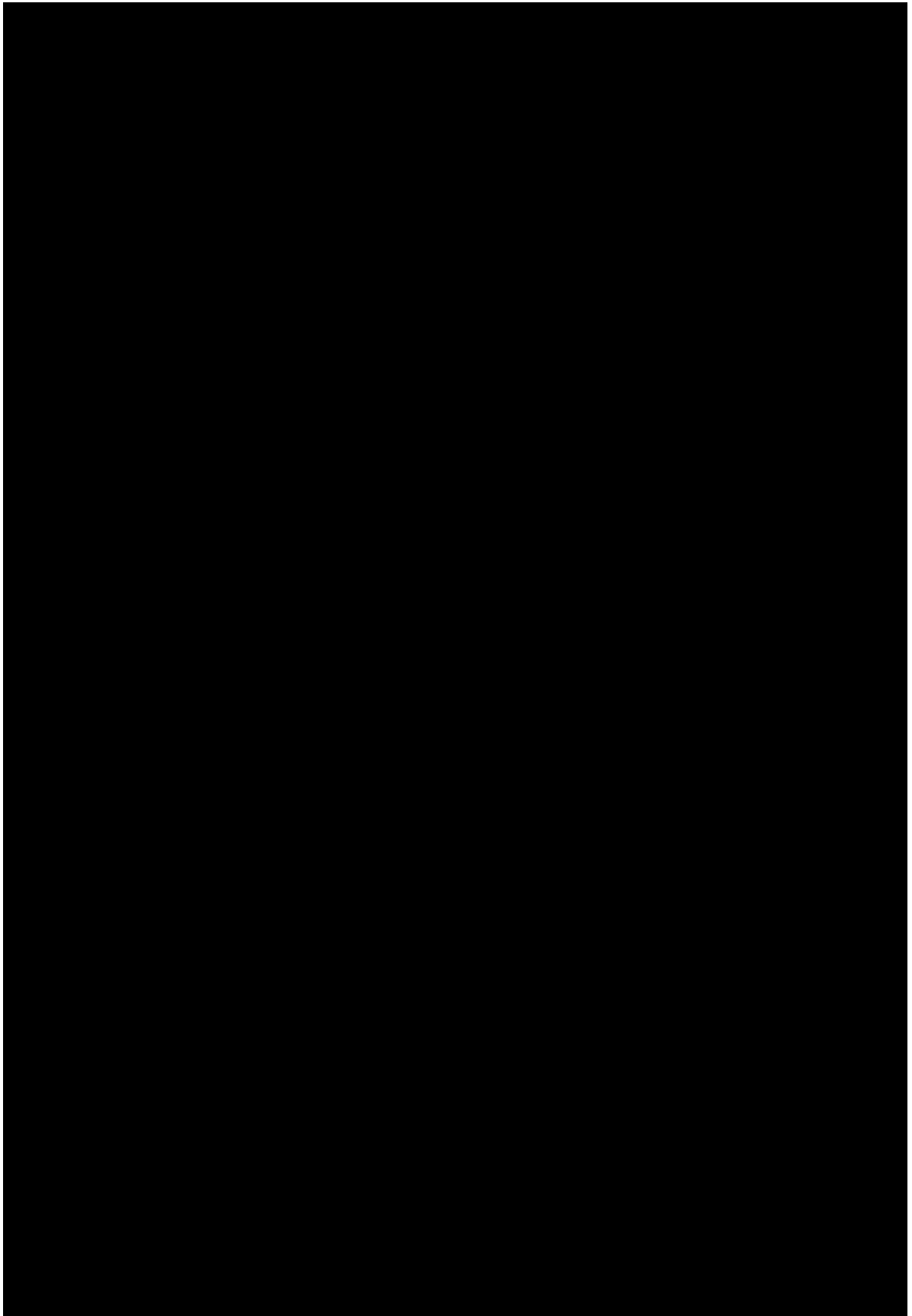
. No archaeological material was found on the well corridors



five sinkholes were recorded, but none had archaeological material. The main pattern in the distribution of sites was

. The majority of the survey area was of flat, featureless open woodland.





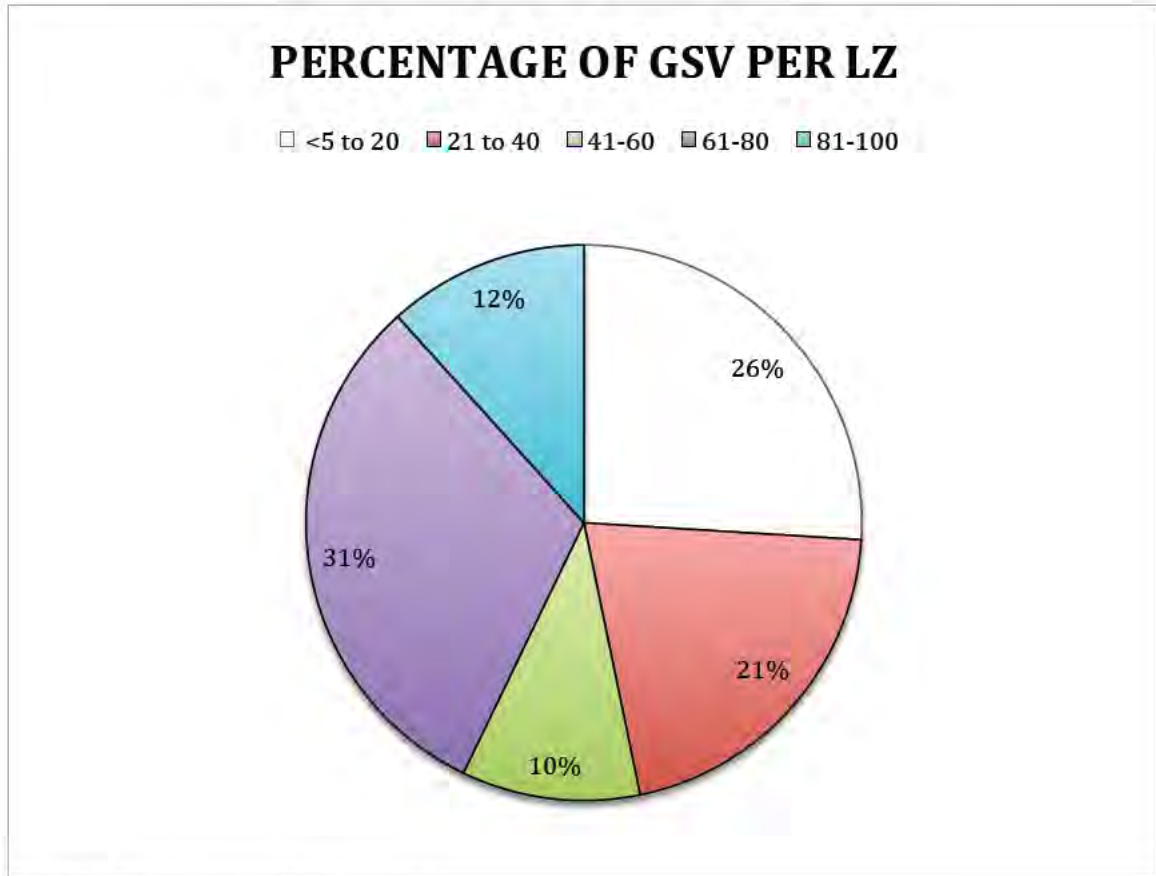


Figure 9. Percentage of GSV per LZ.

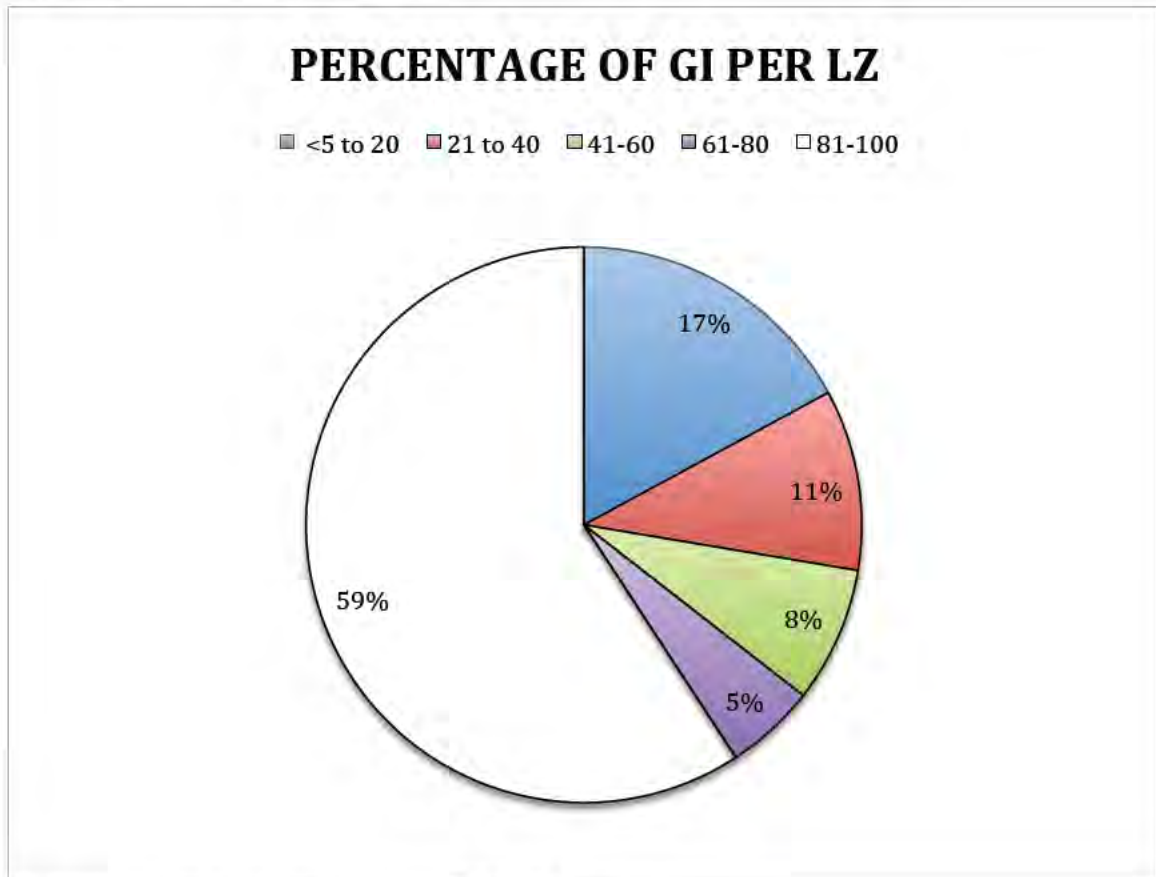
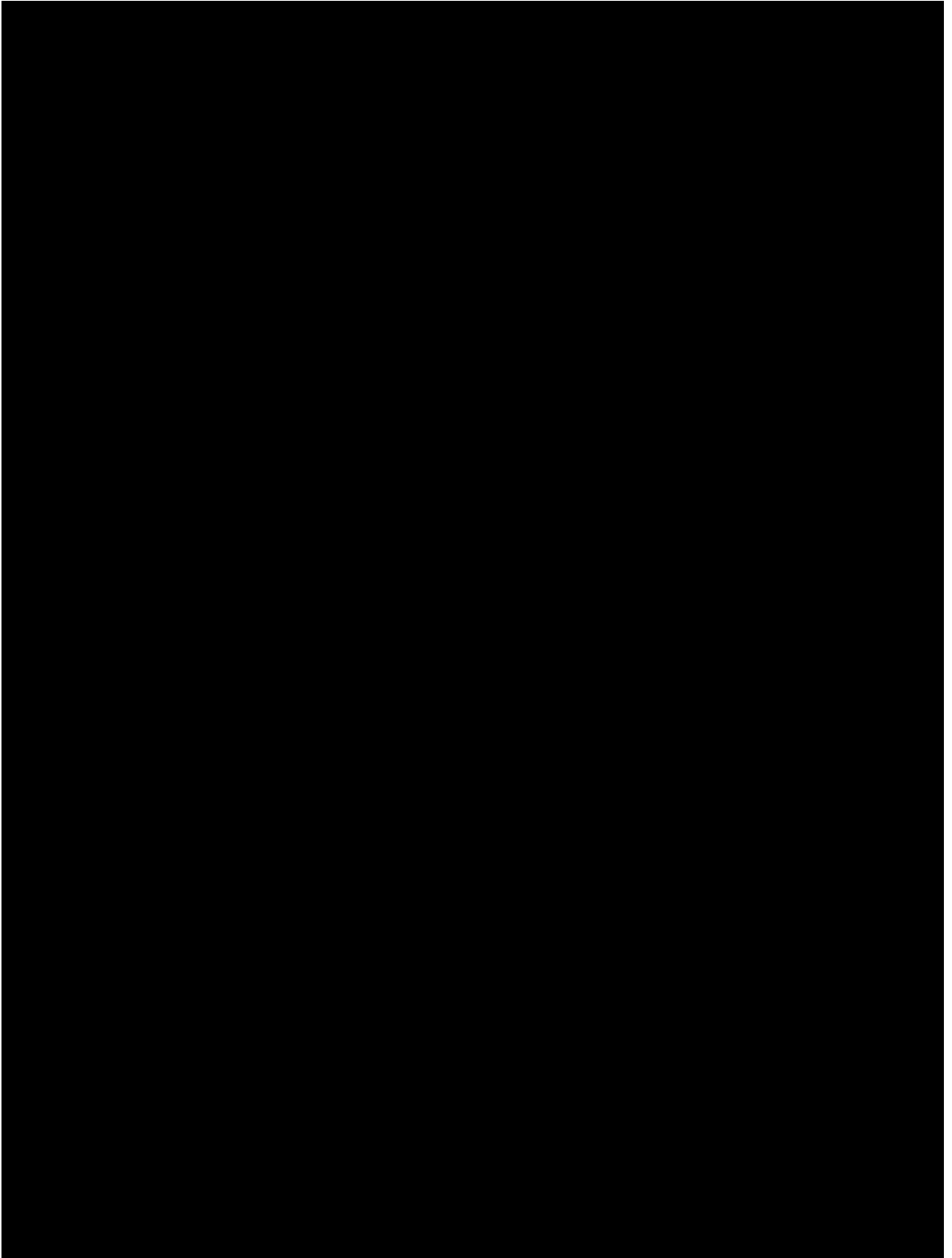
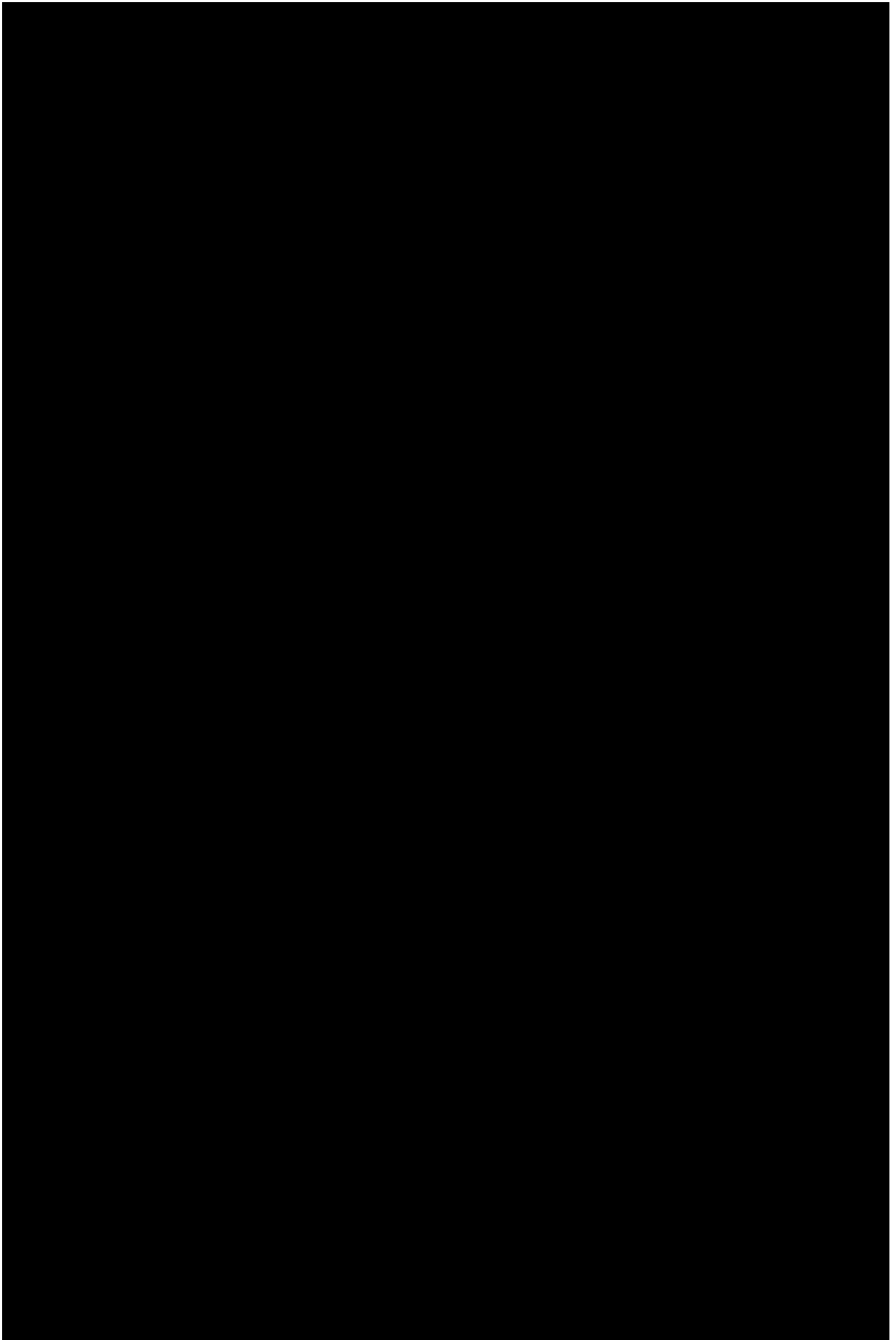
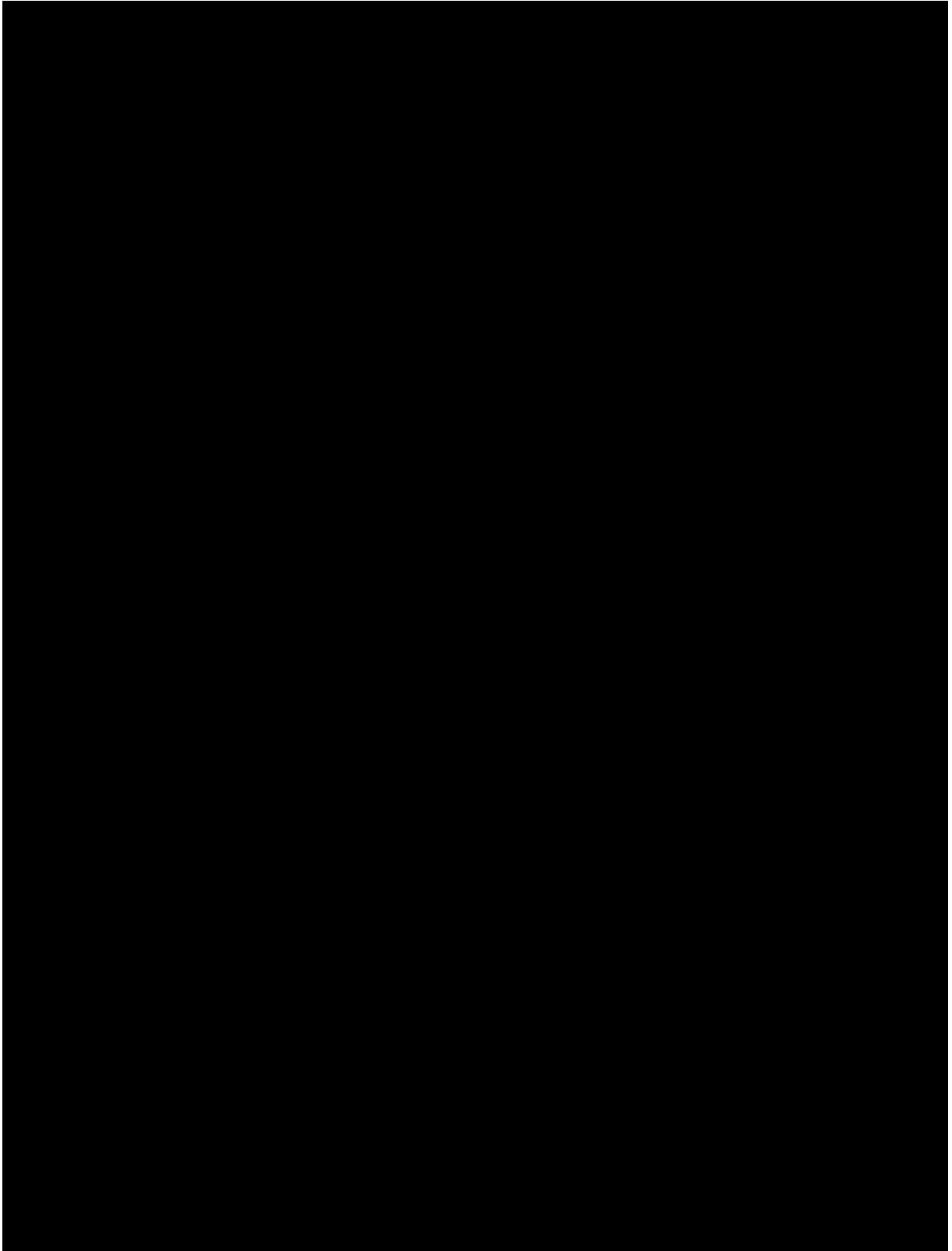
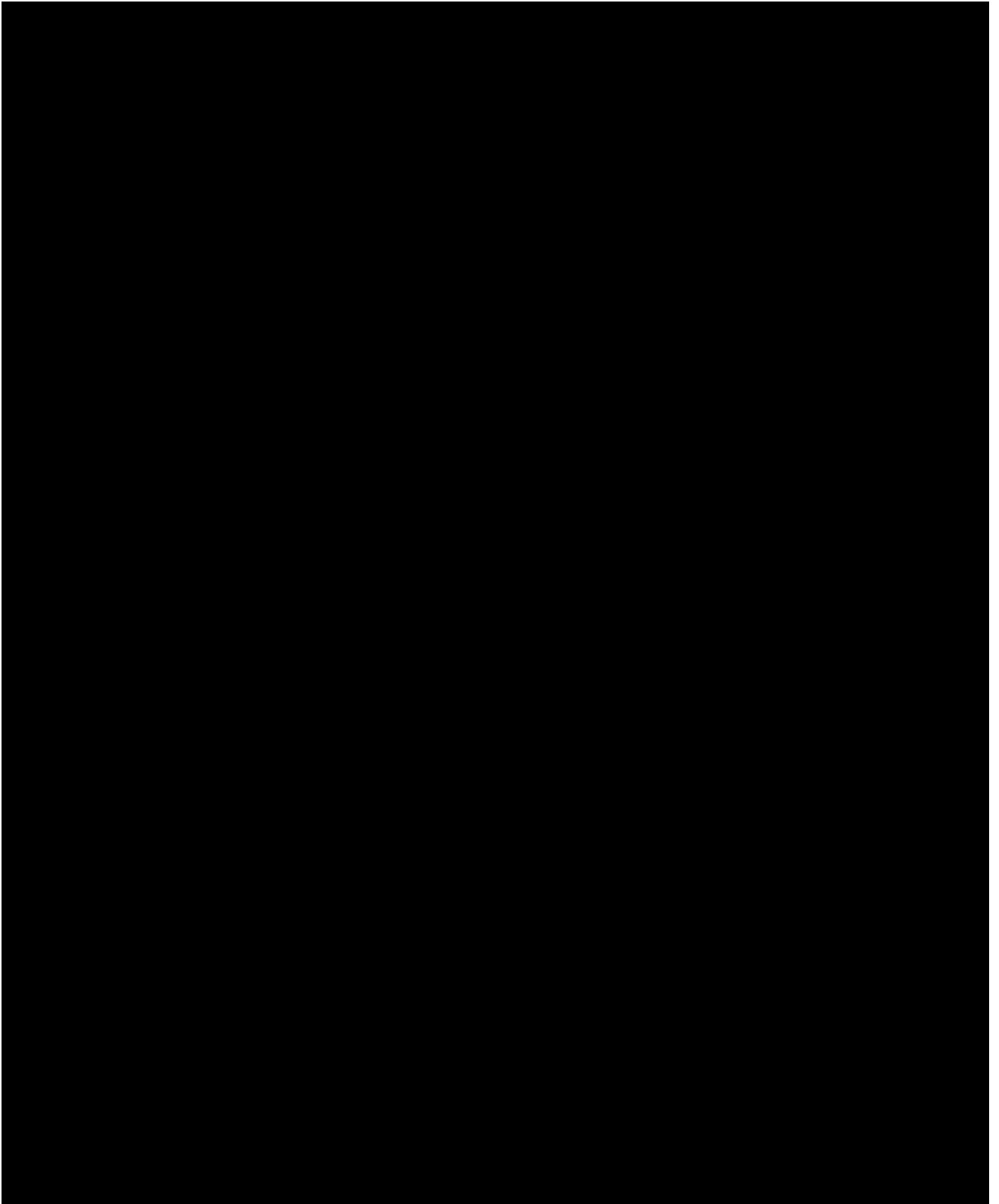


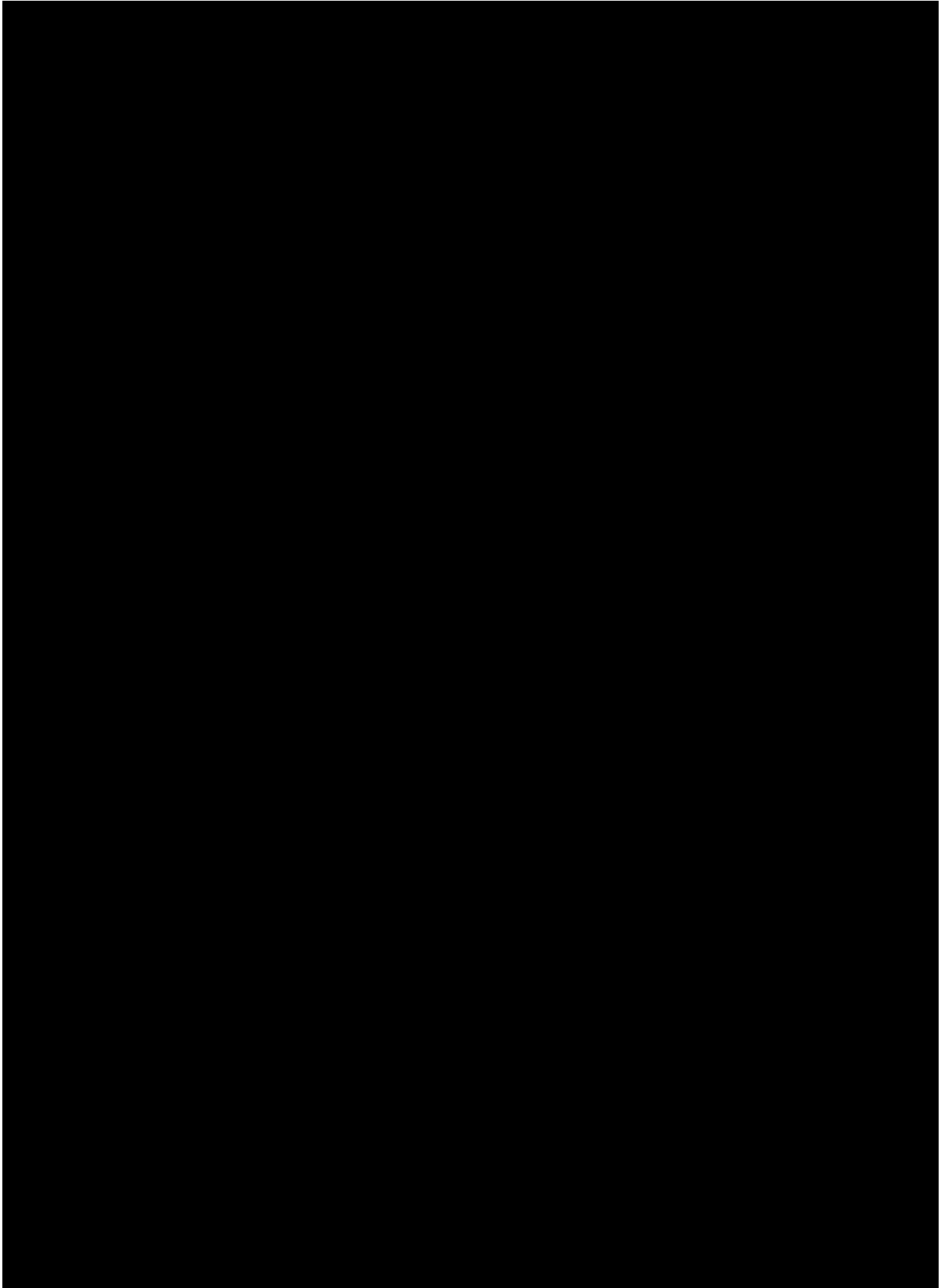
Figure 10. Pie chart of percentage of GI per LZ.

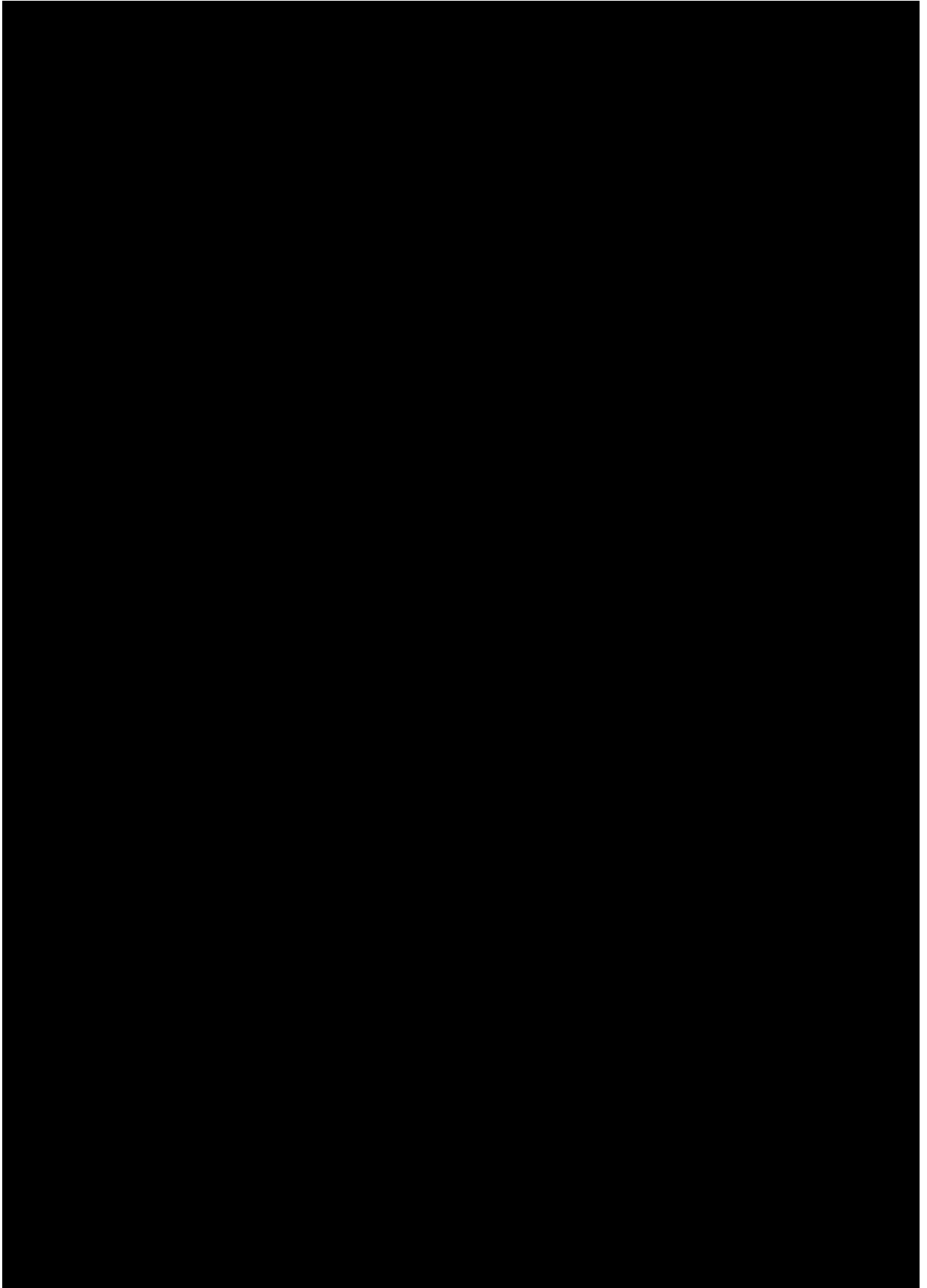


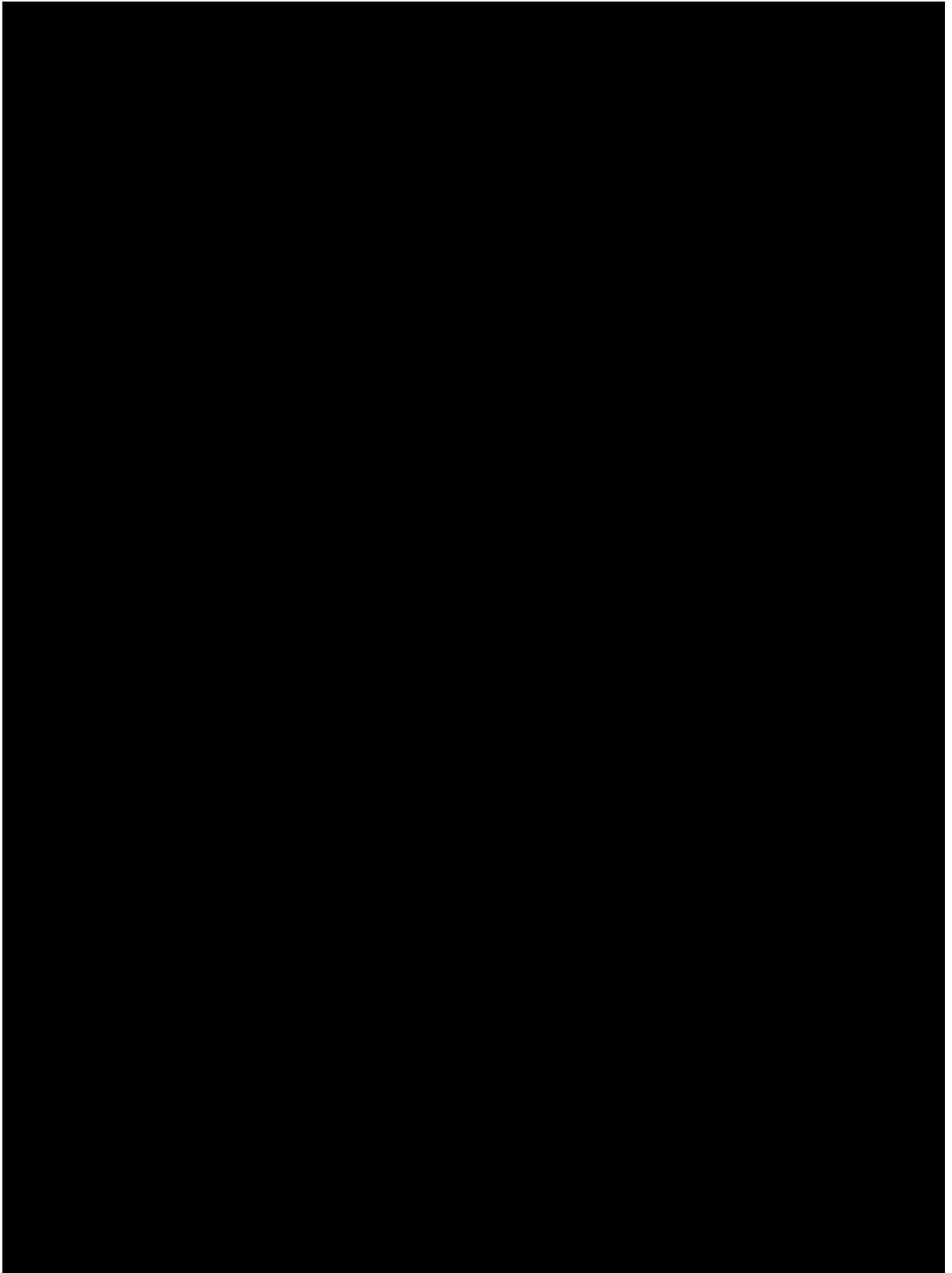


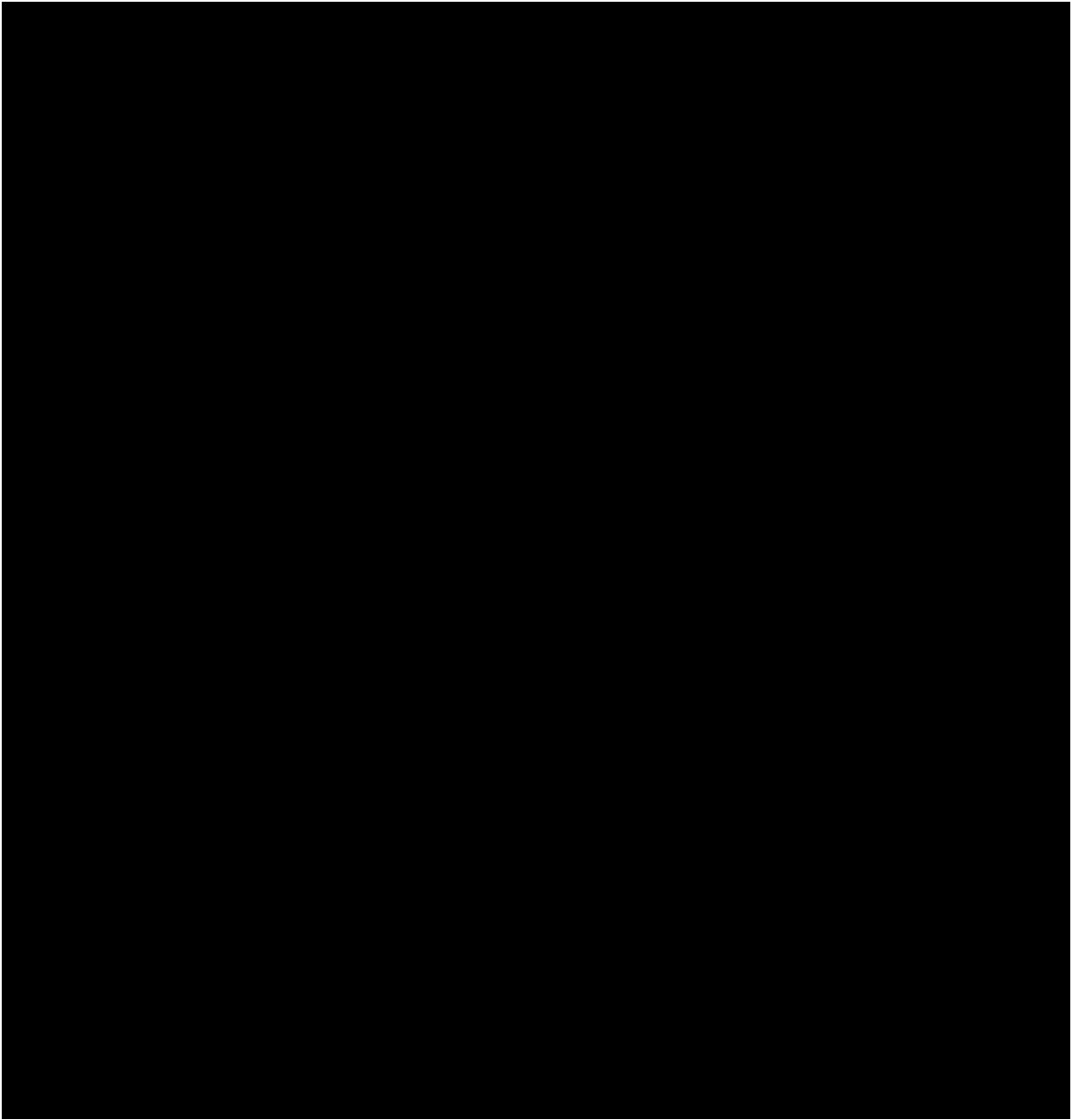


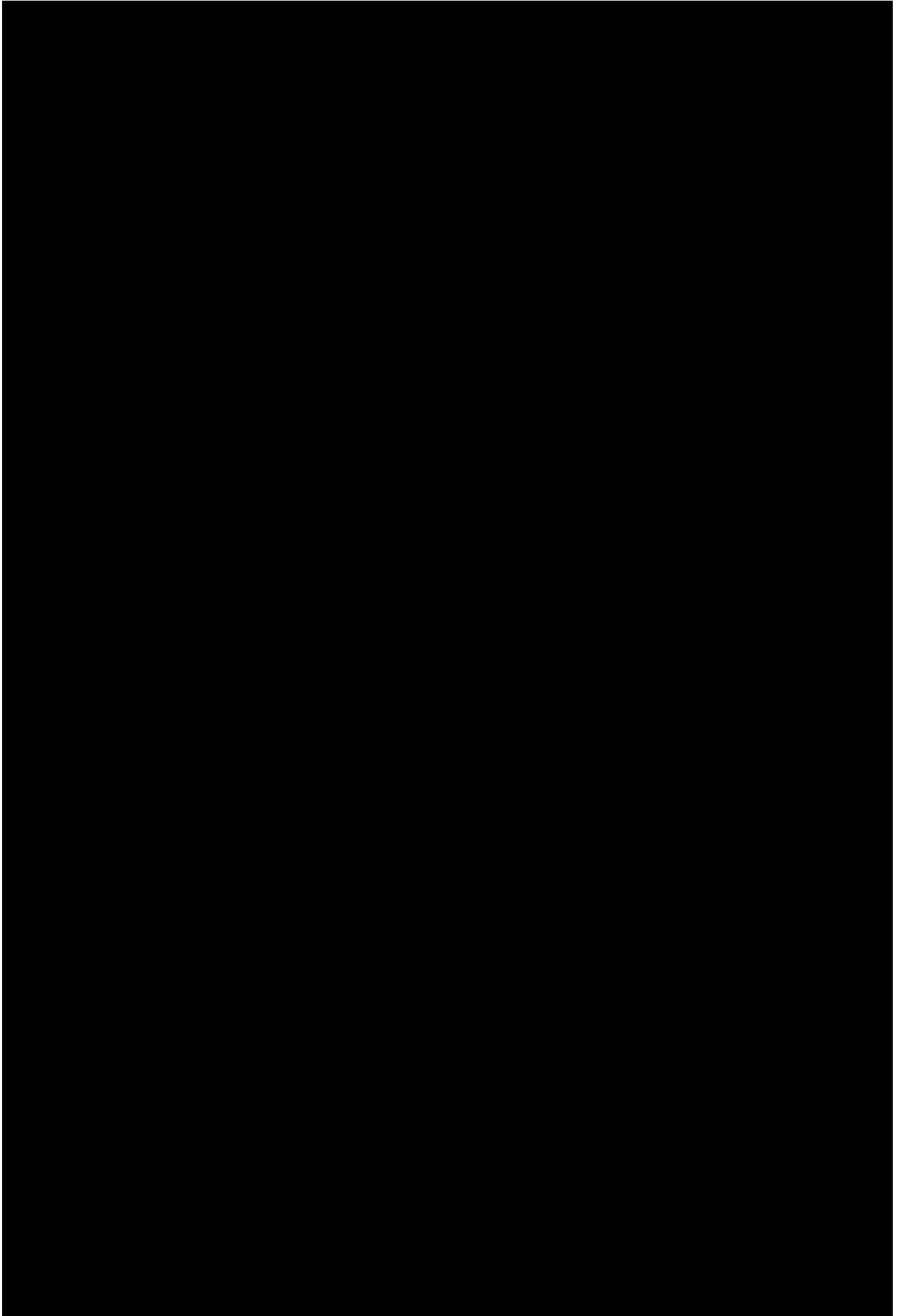


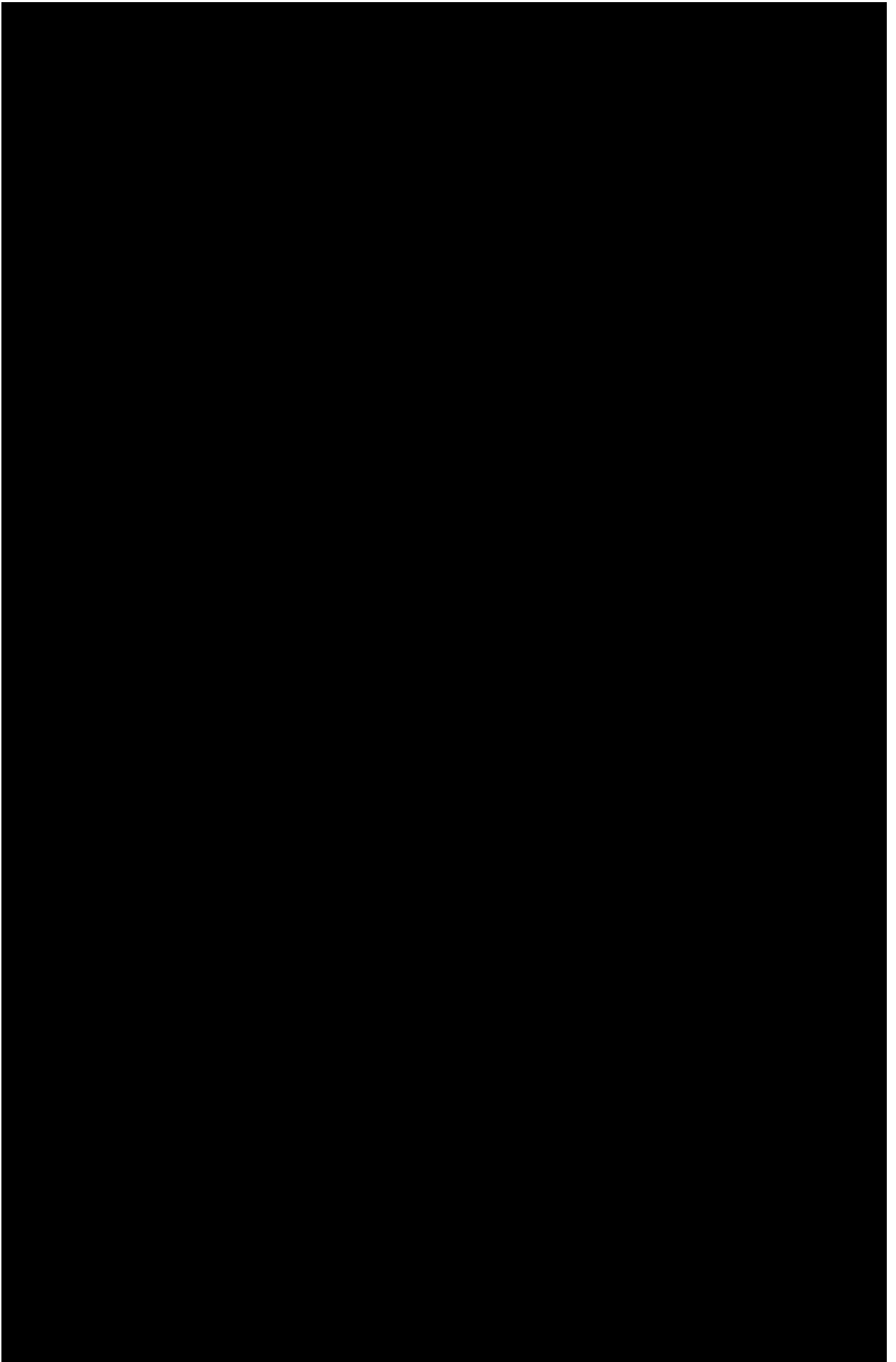


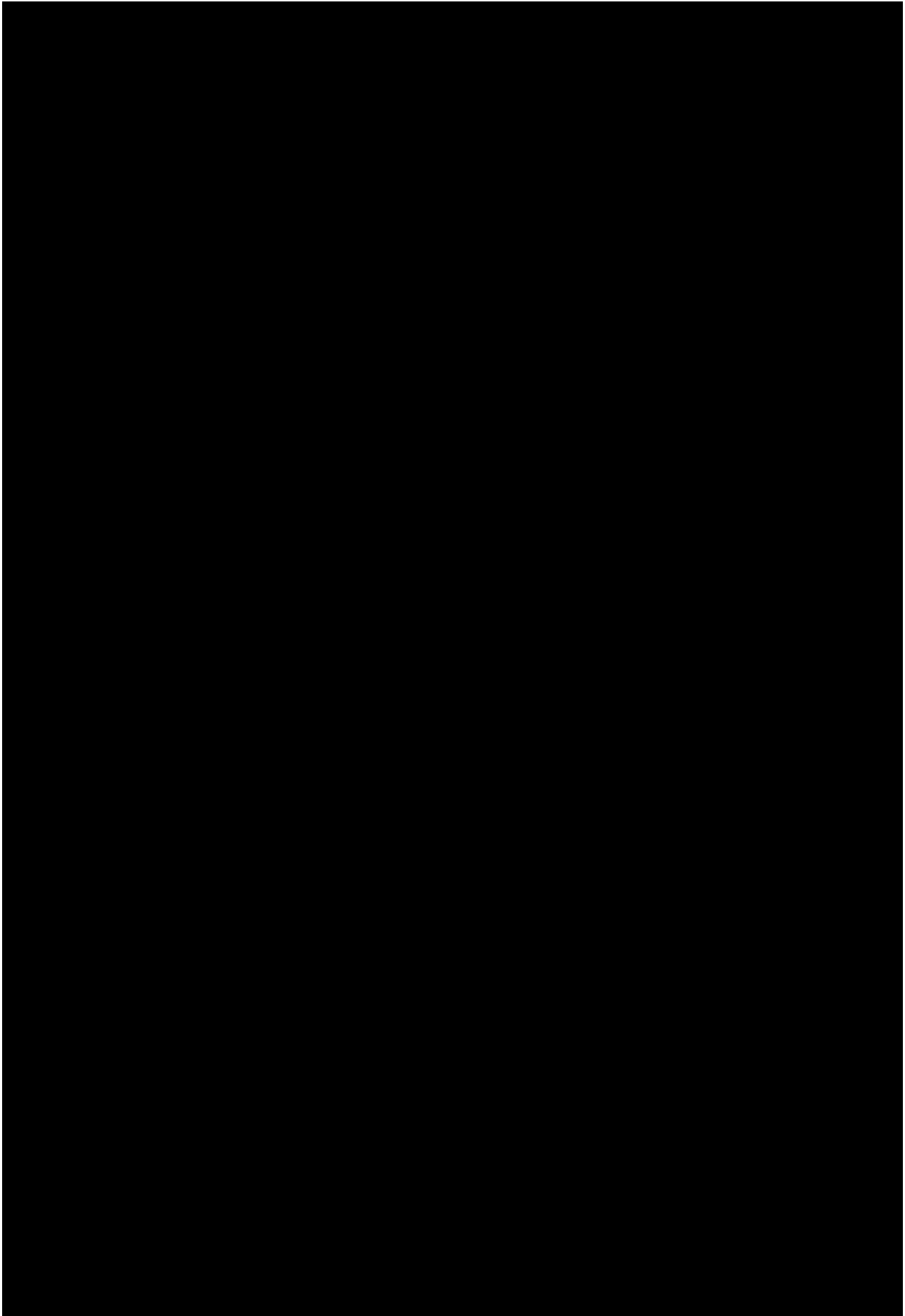


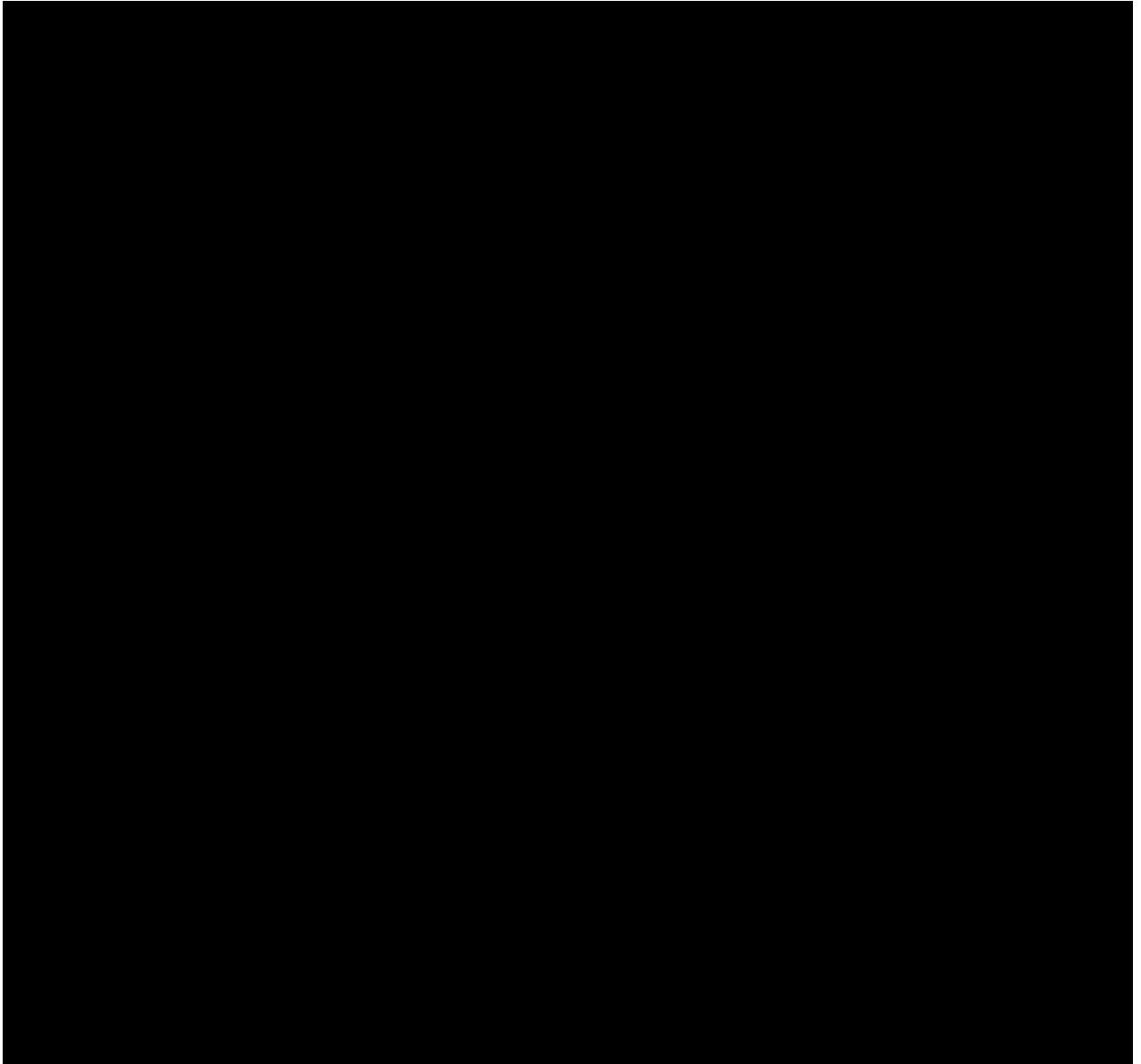


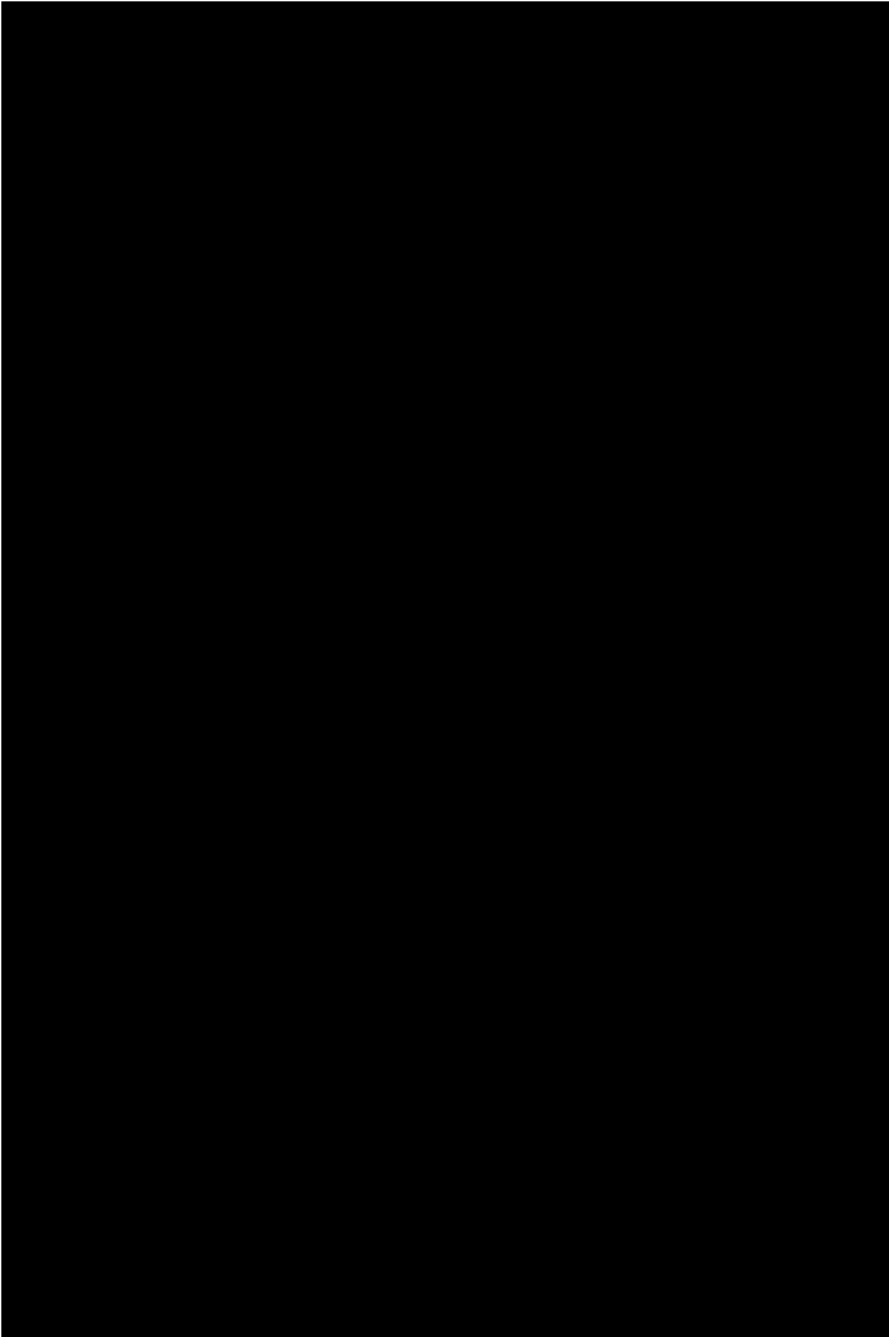


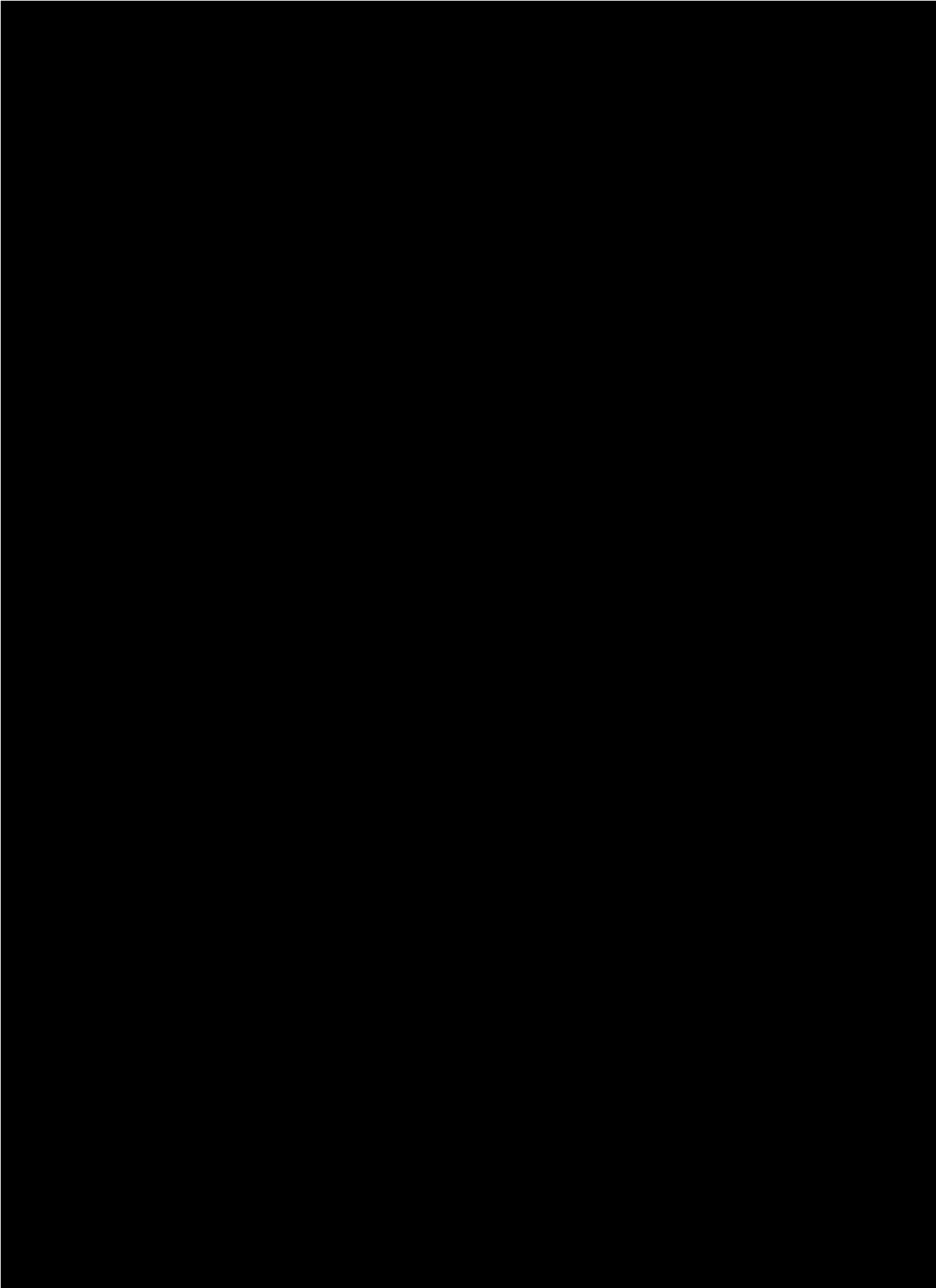


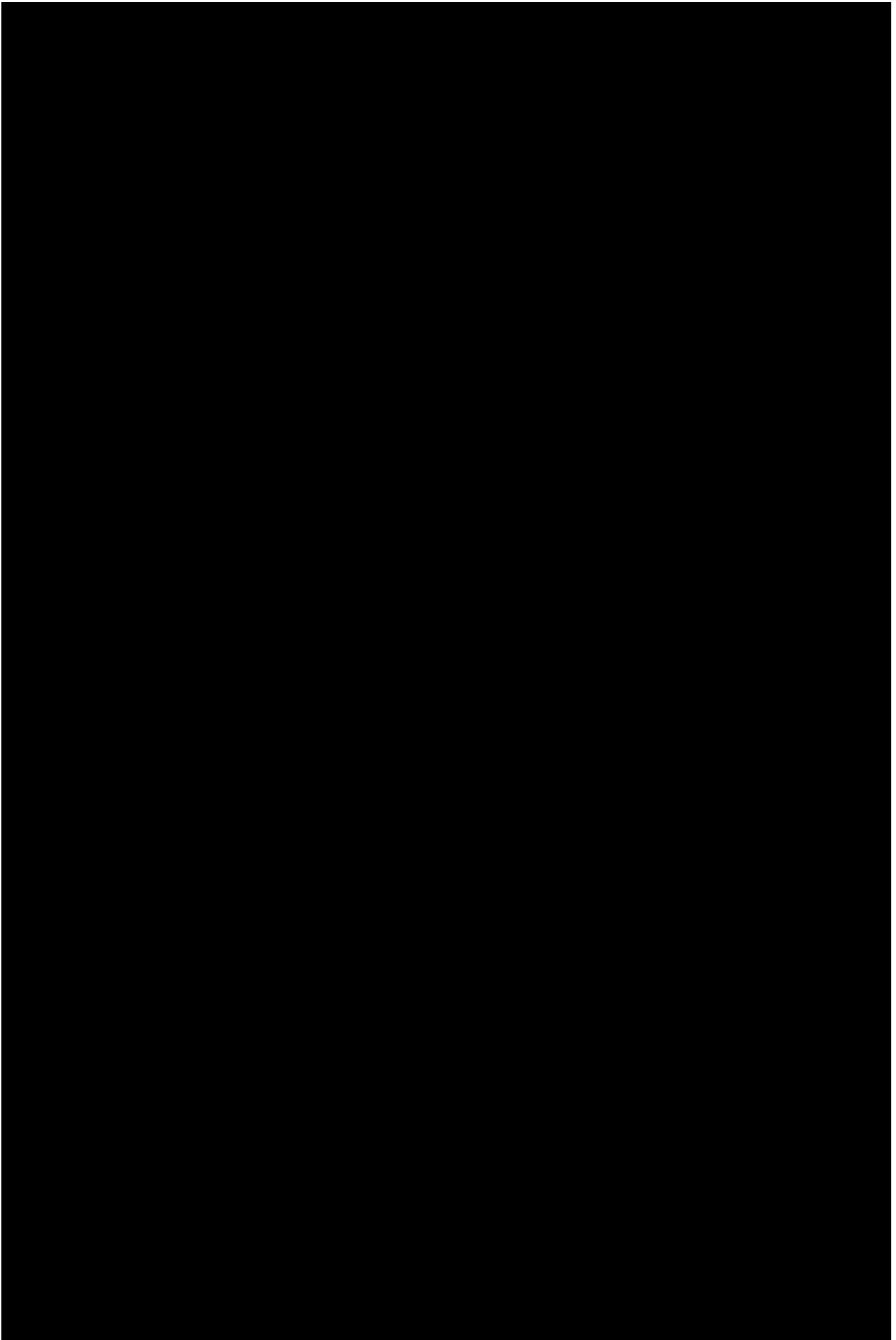


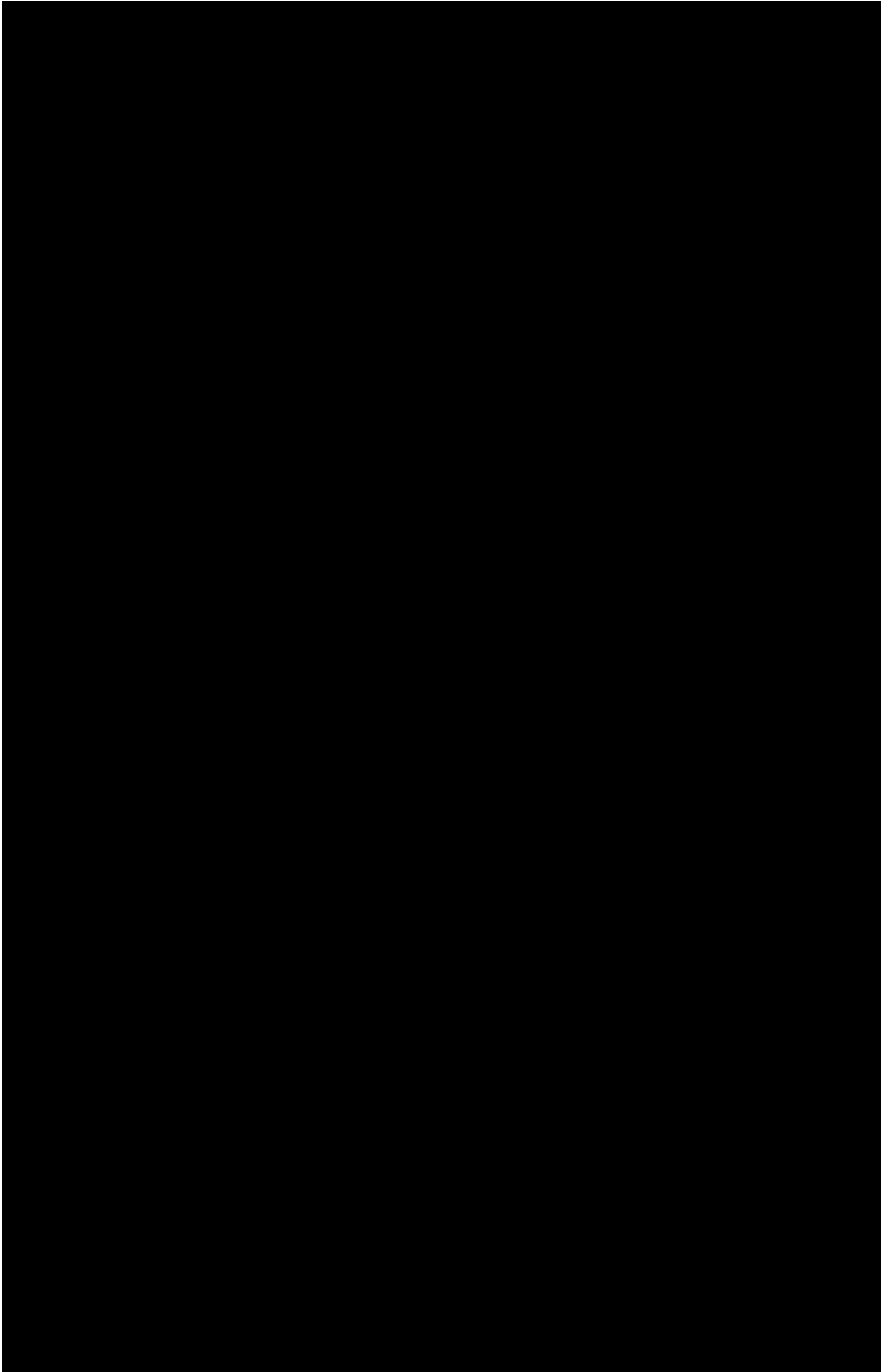


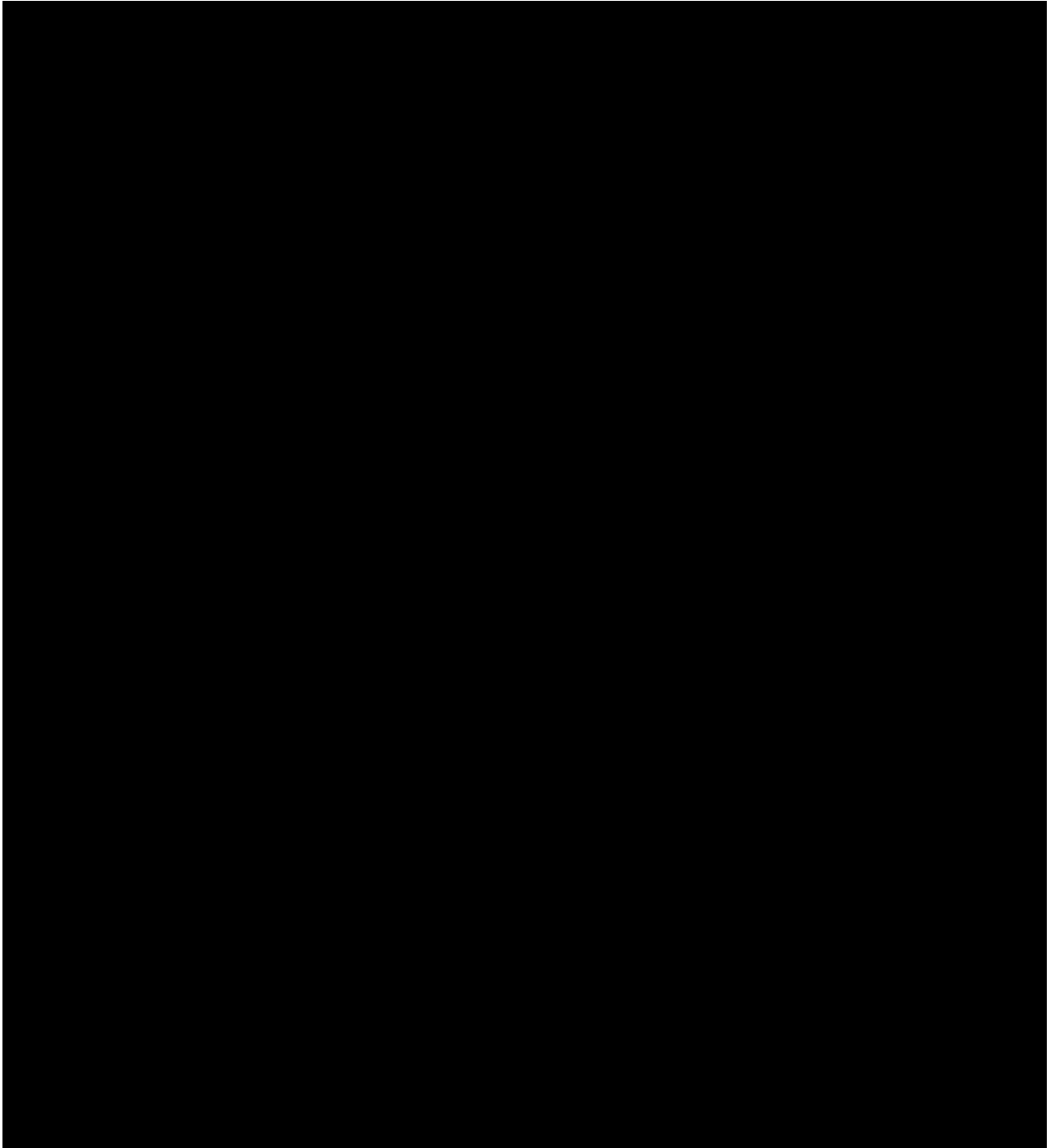


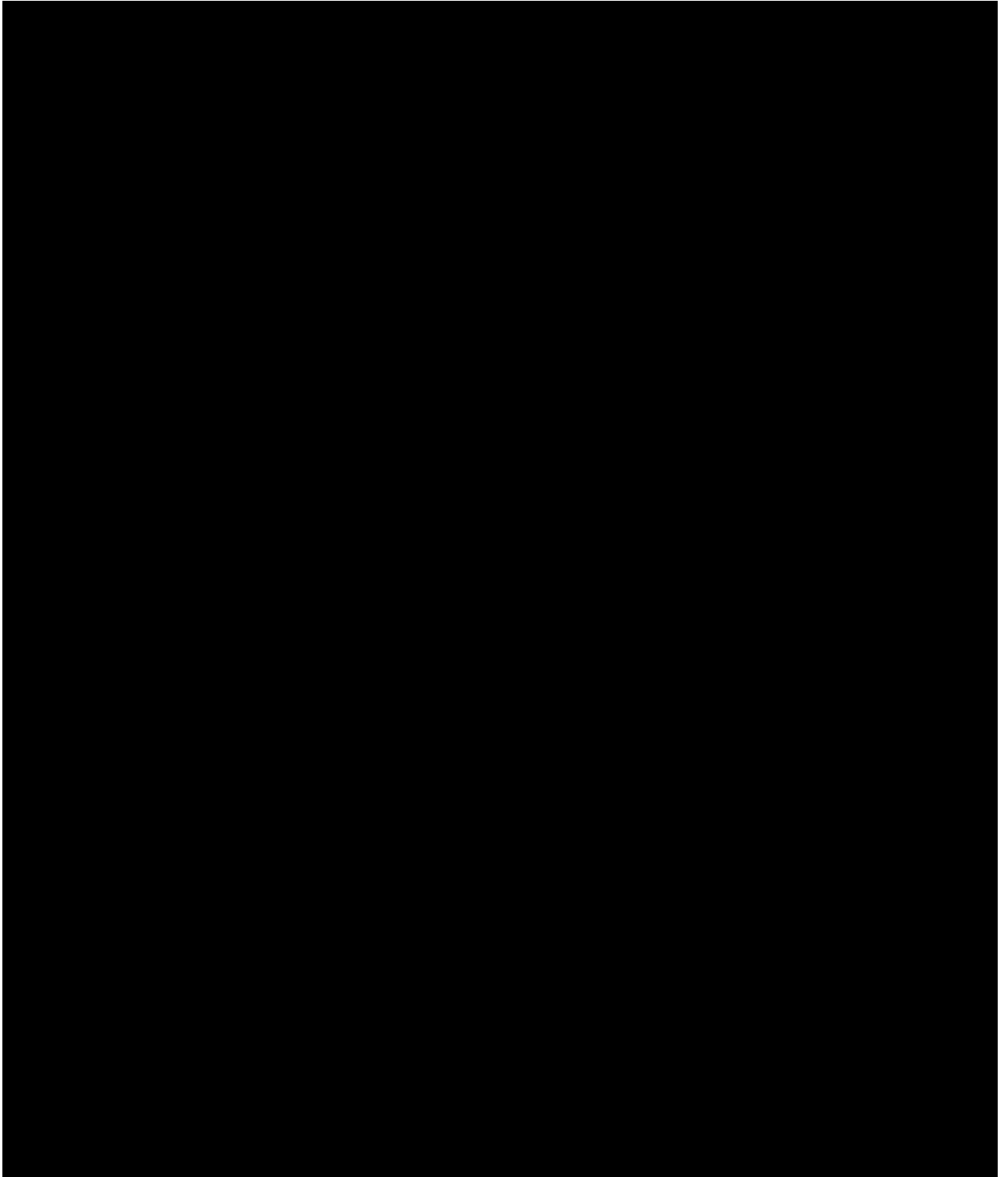


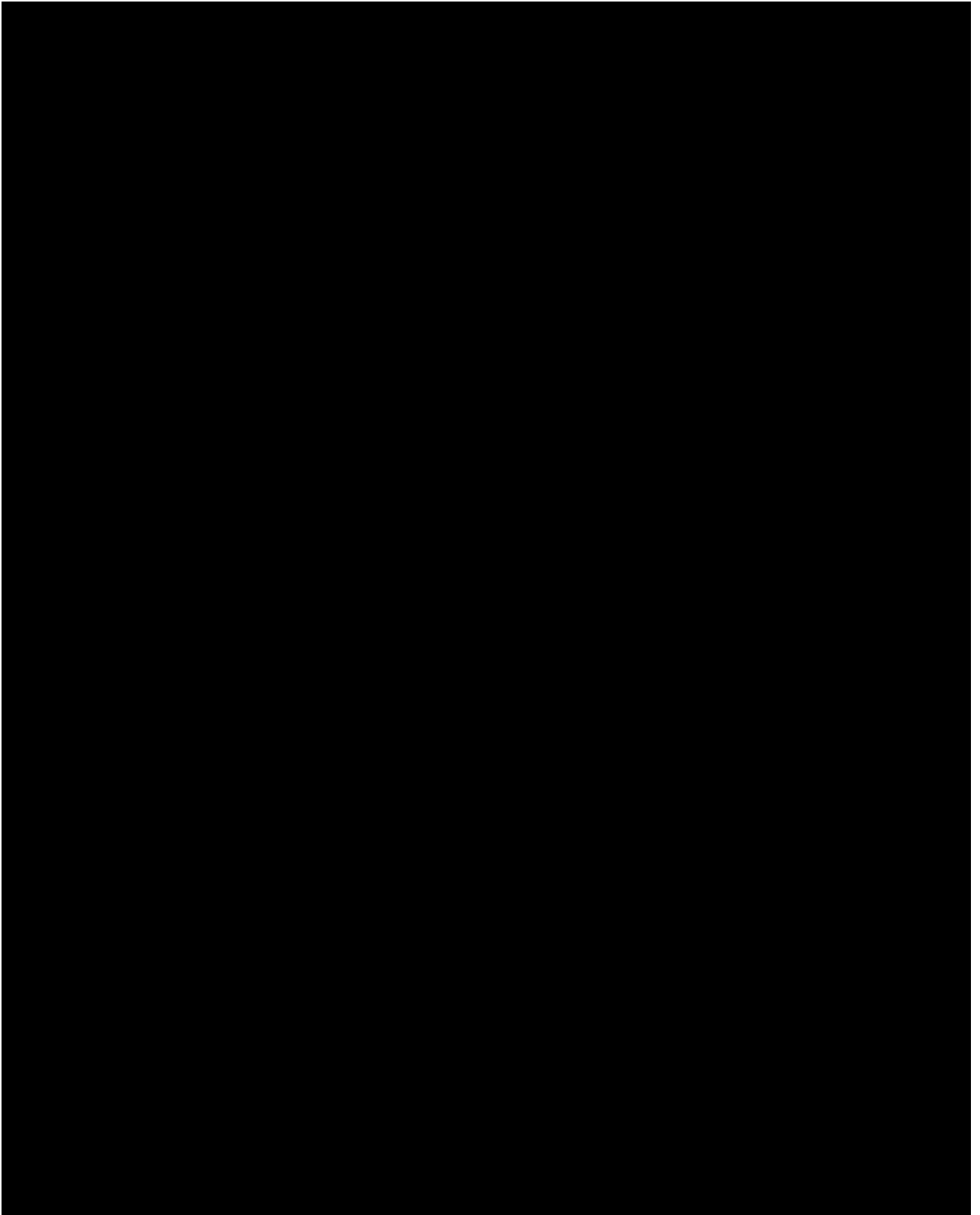


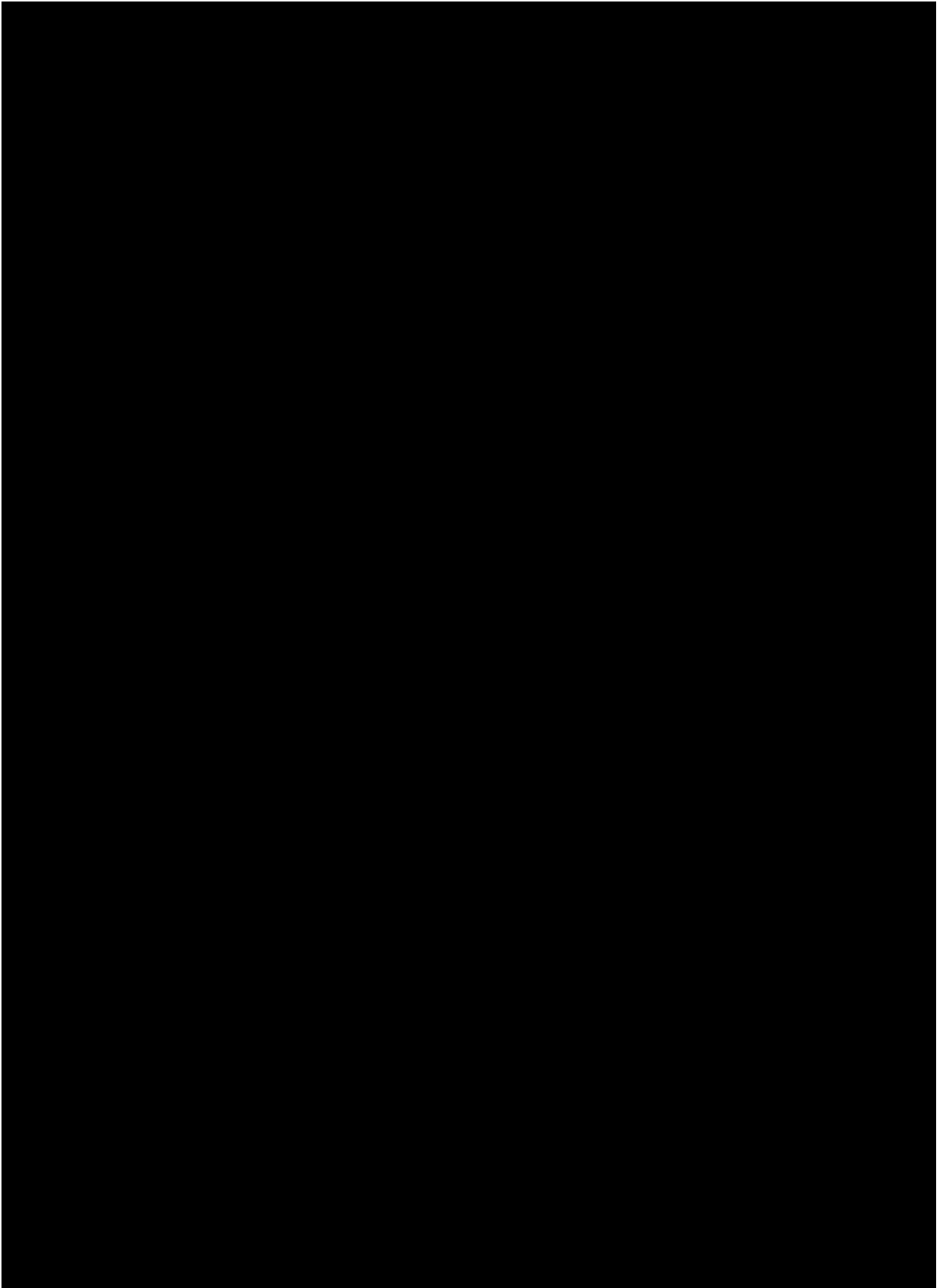


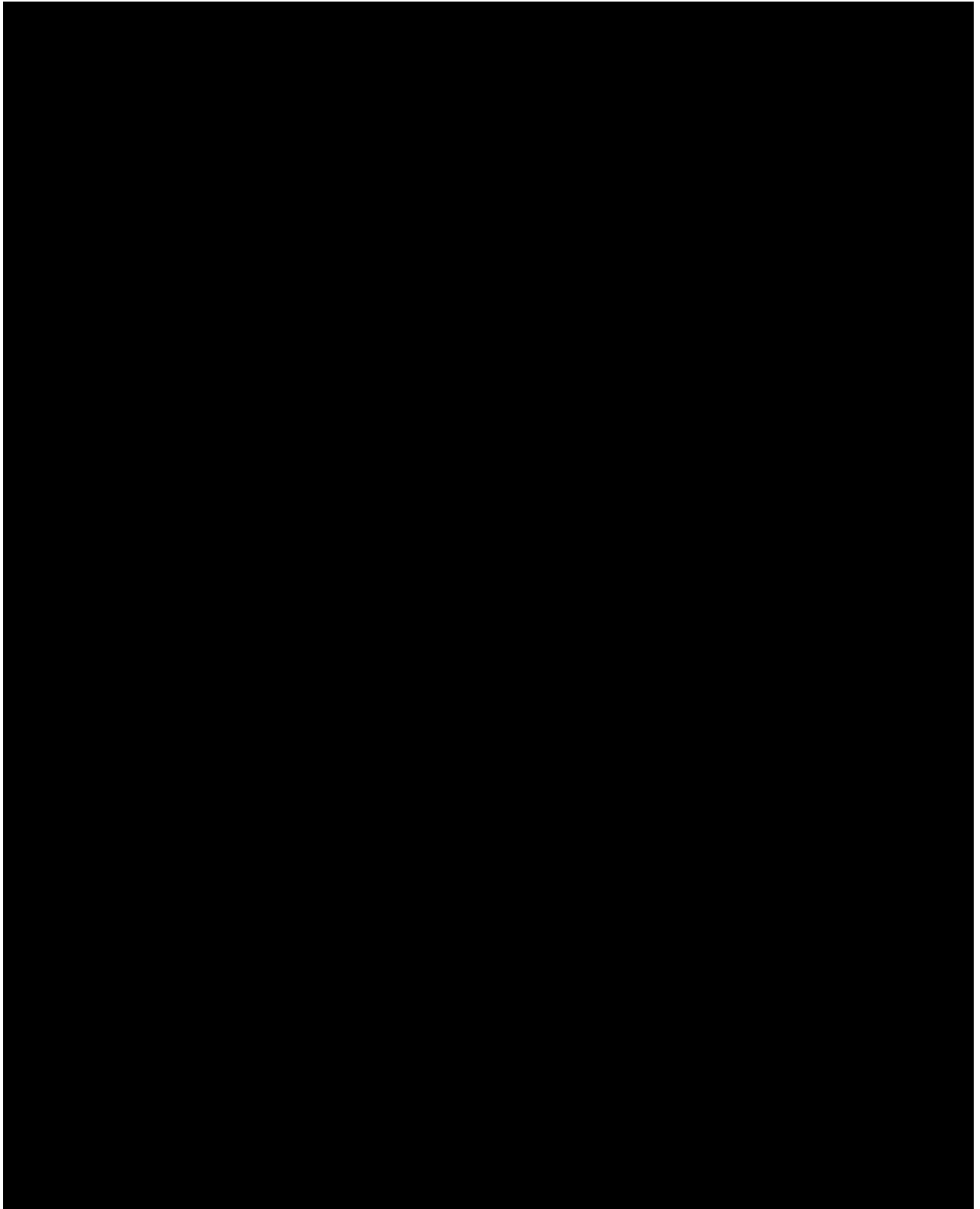


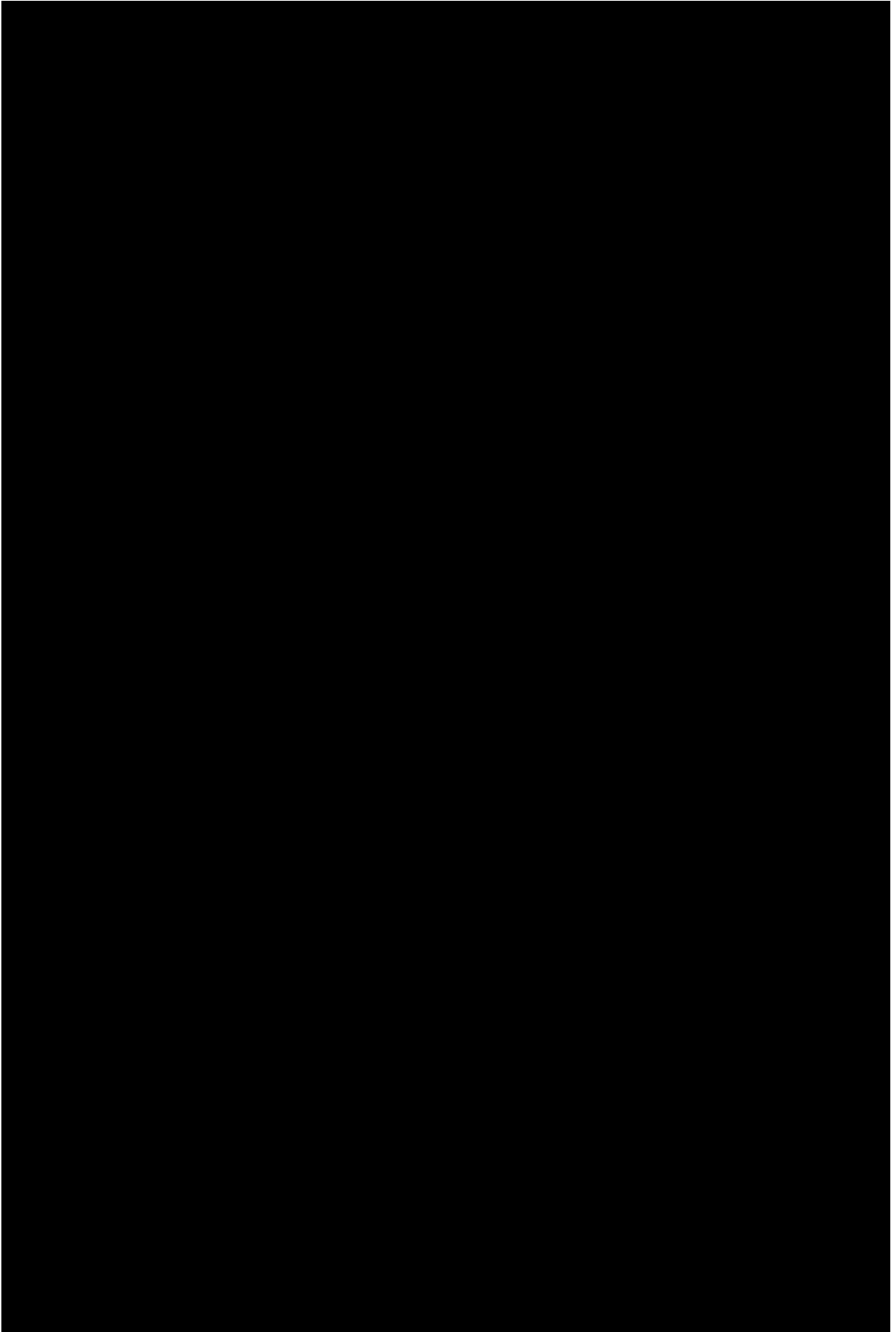


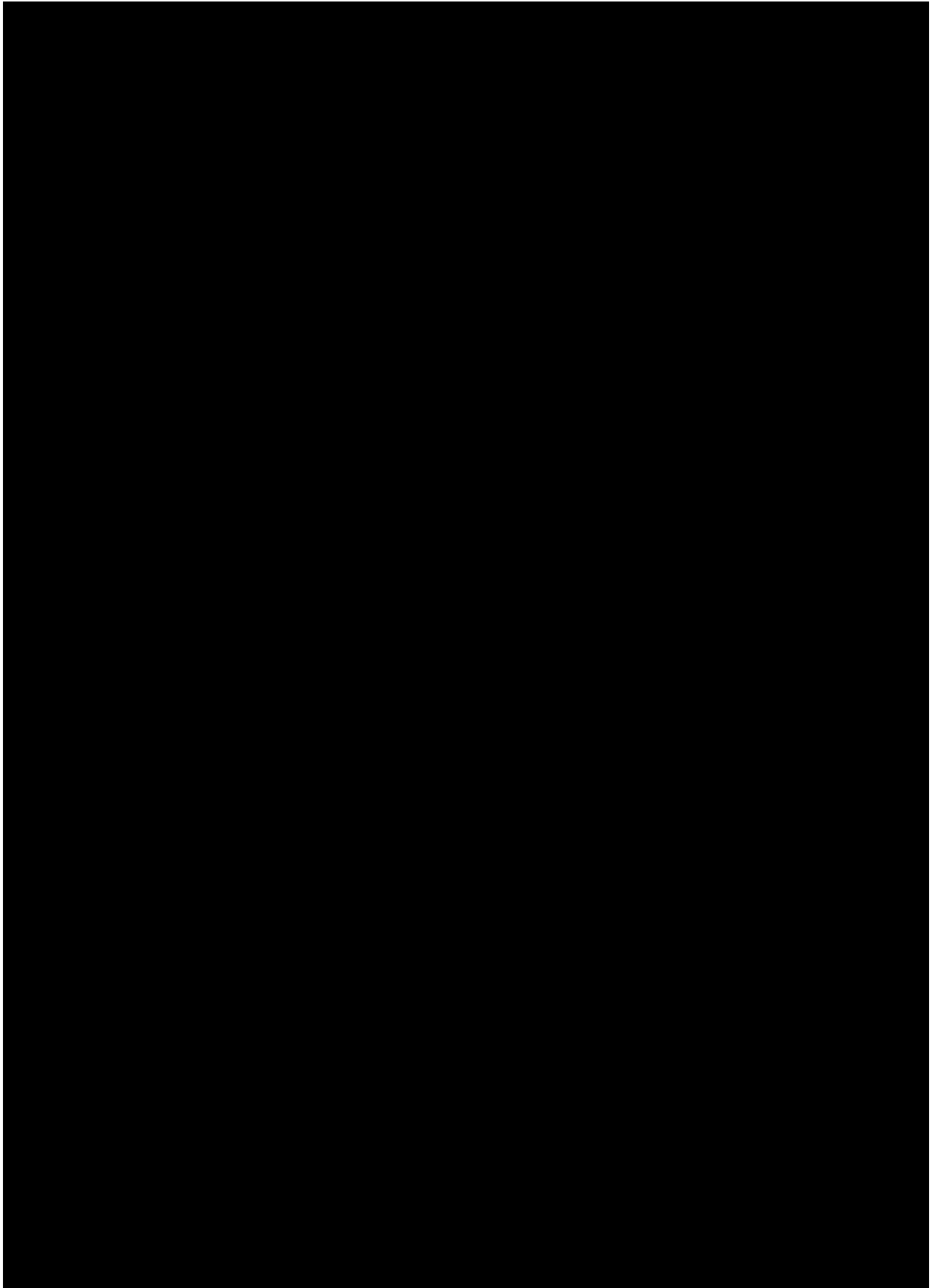


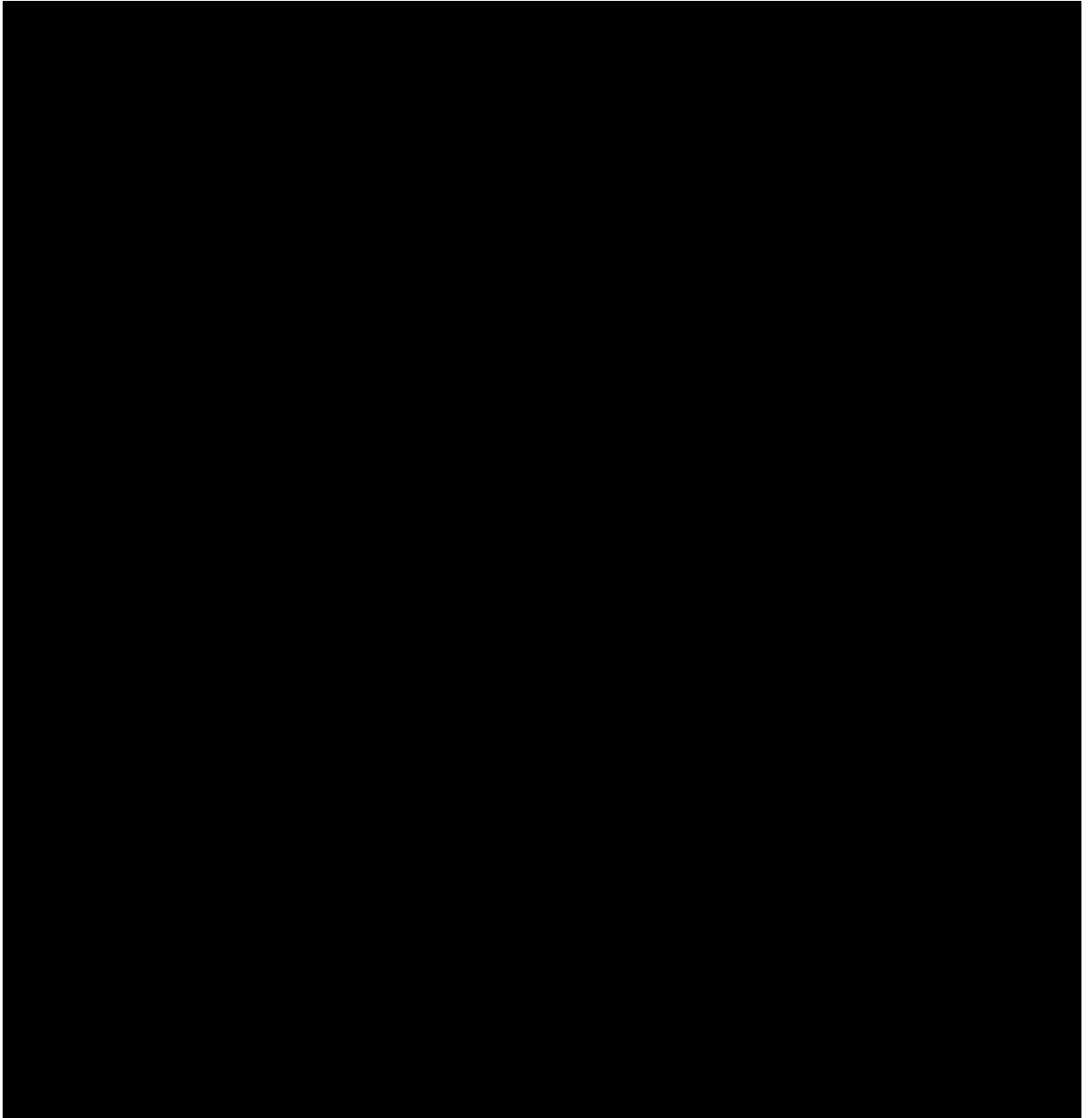


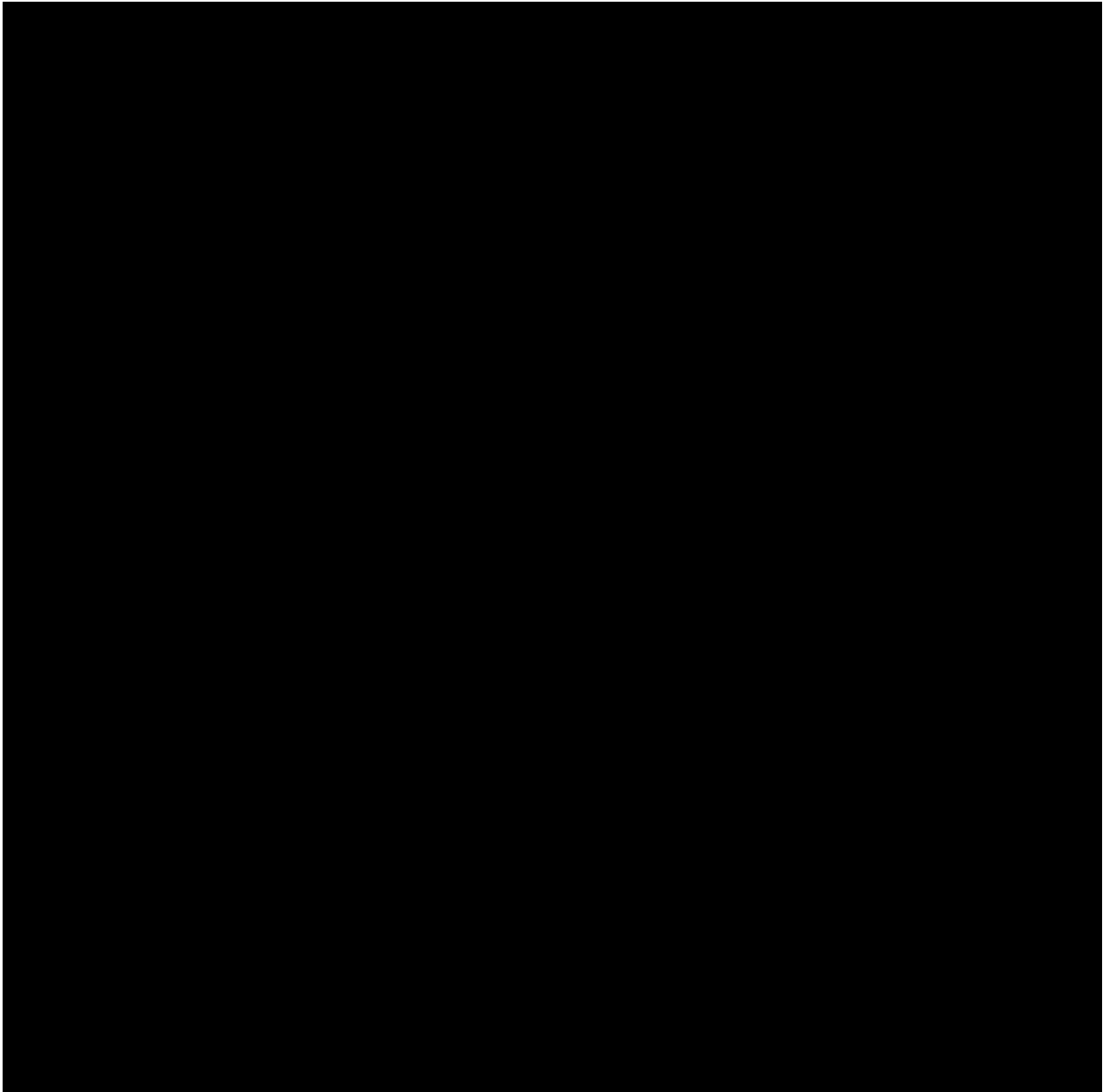


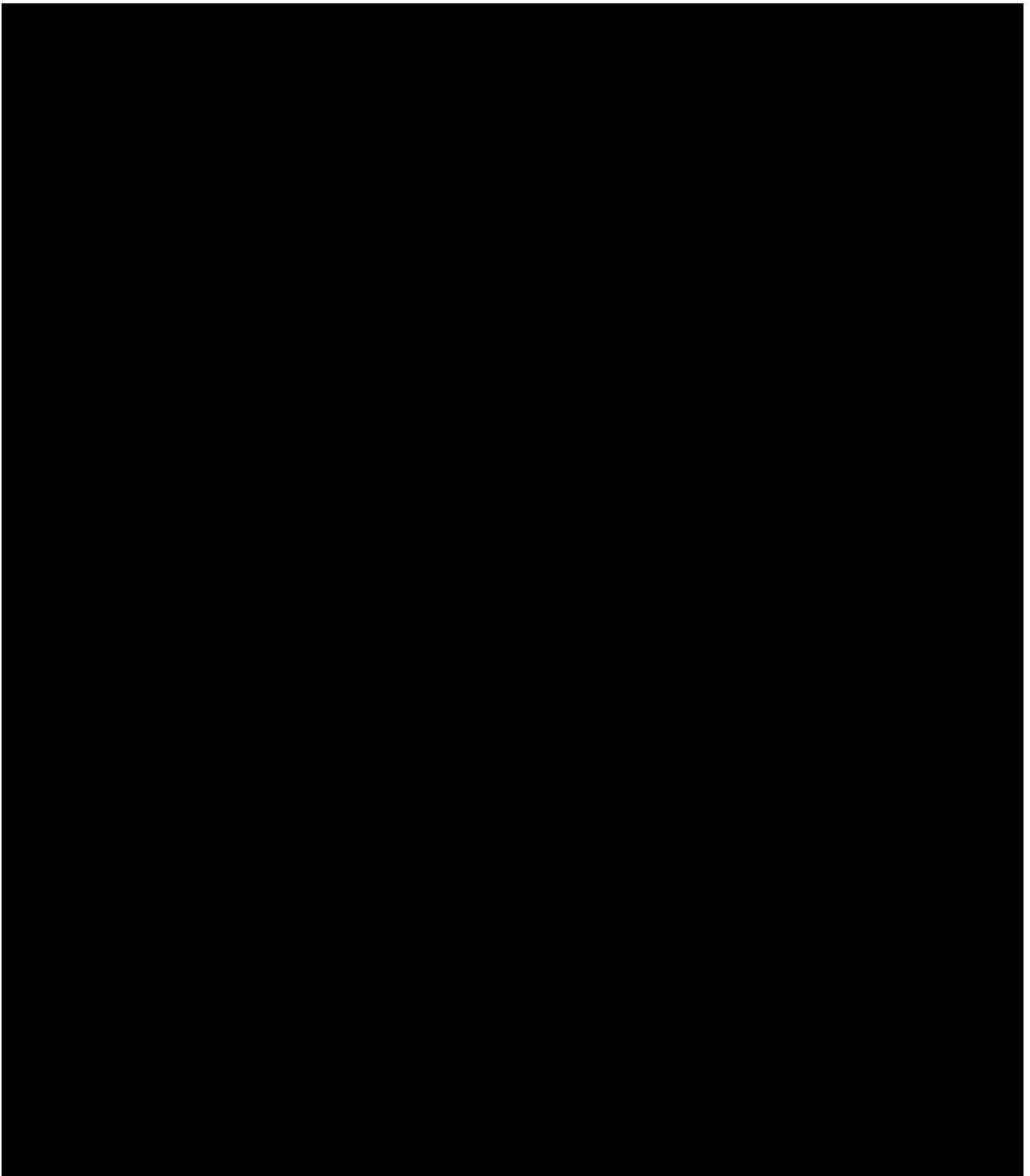


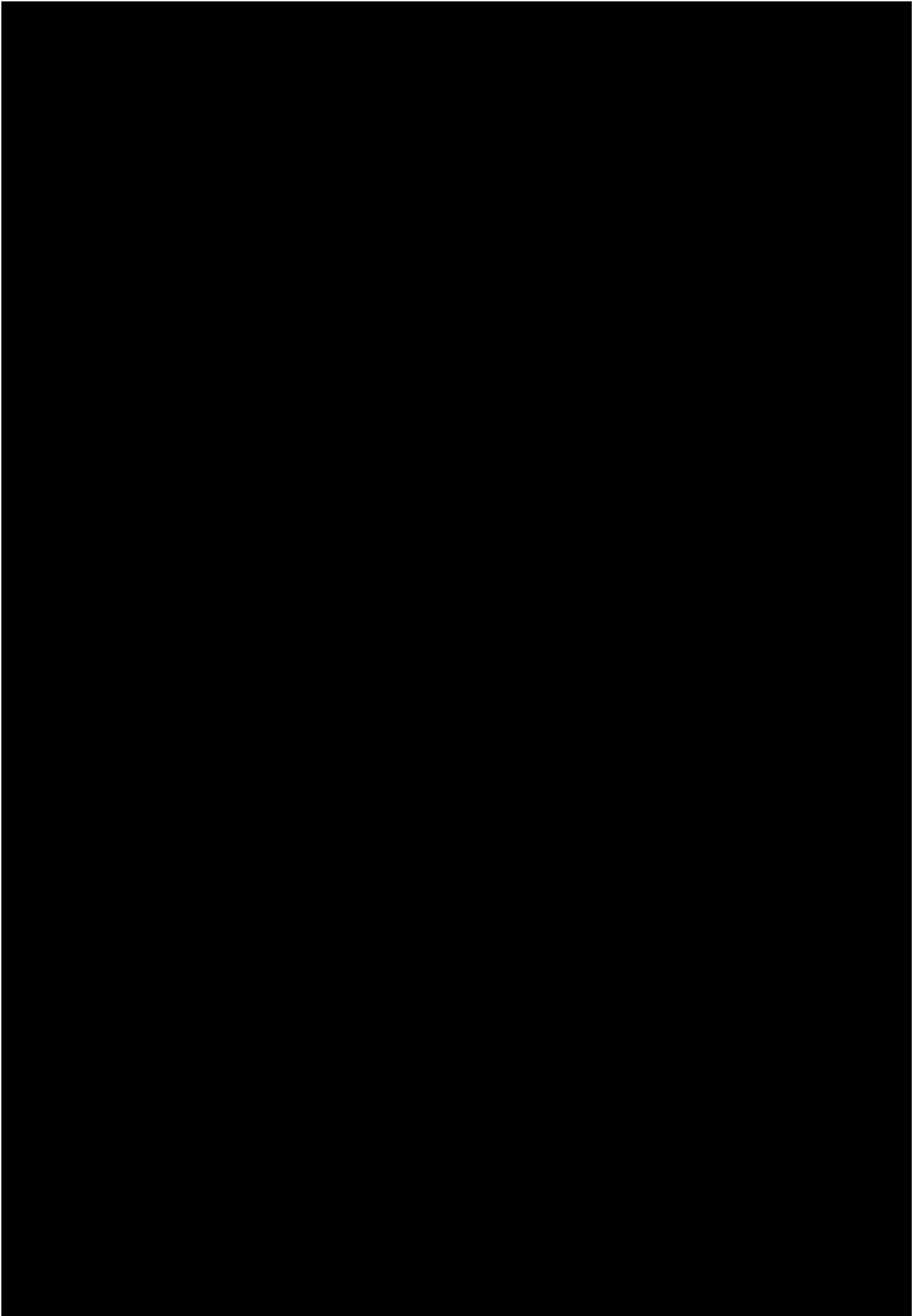


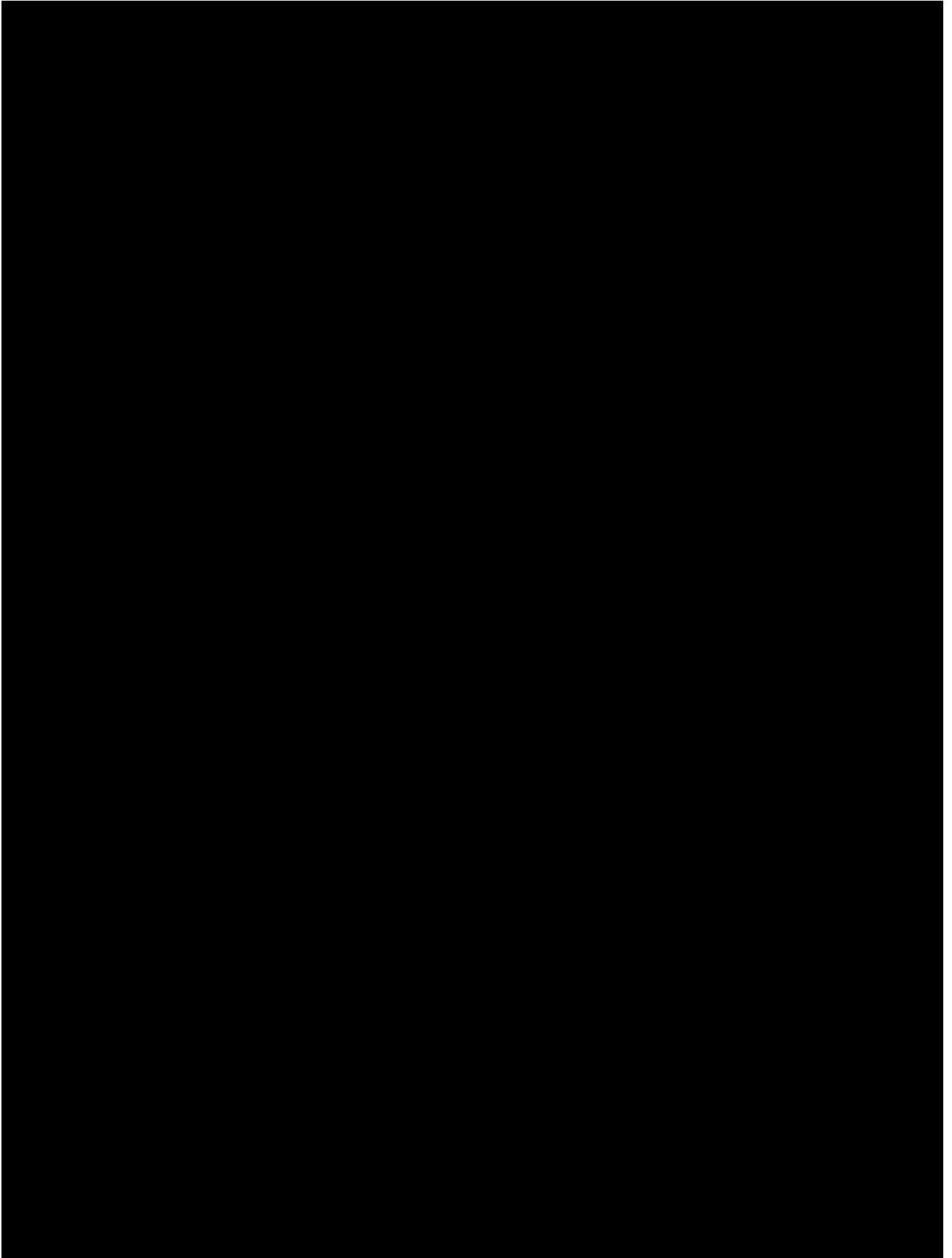


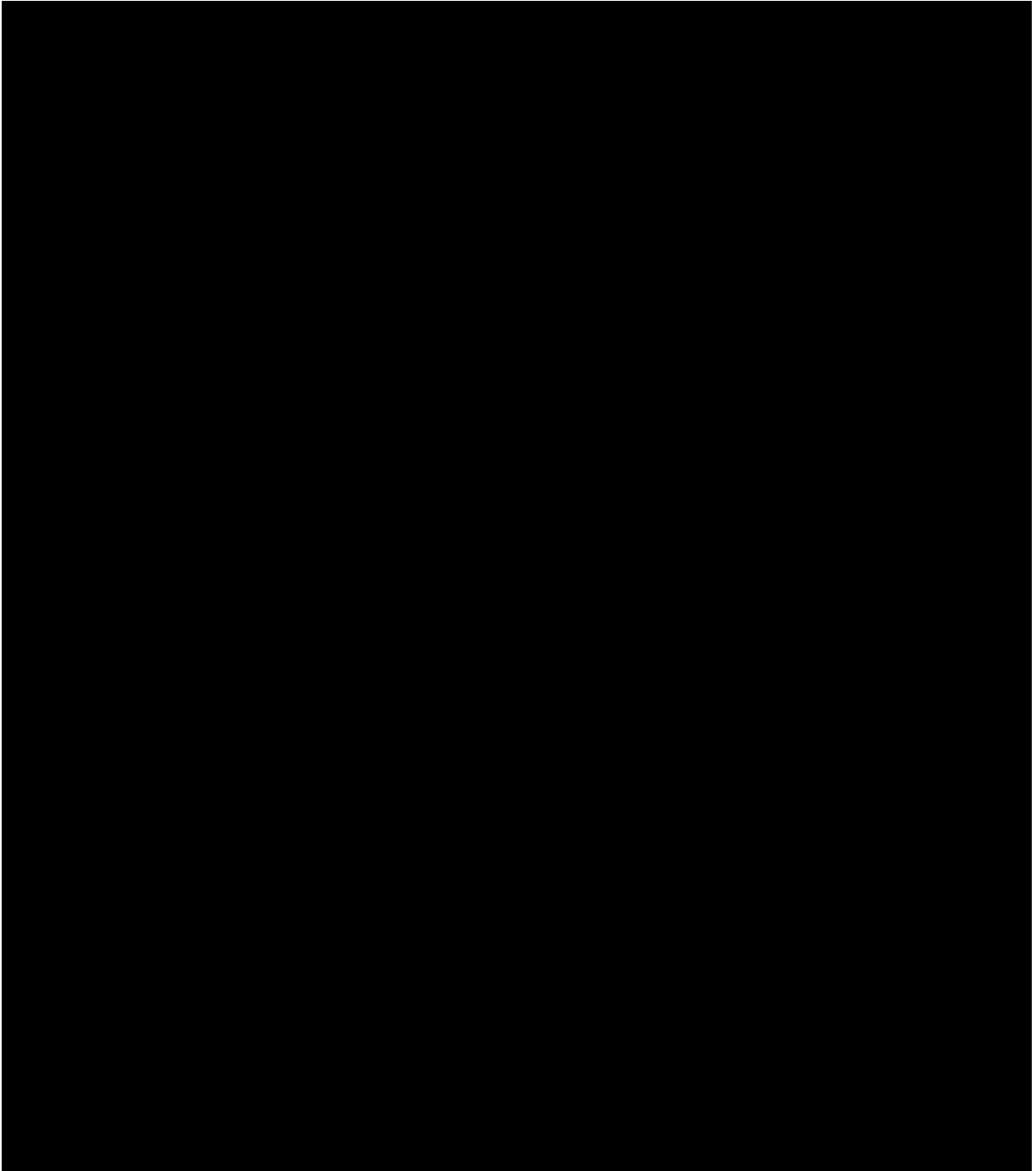


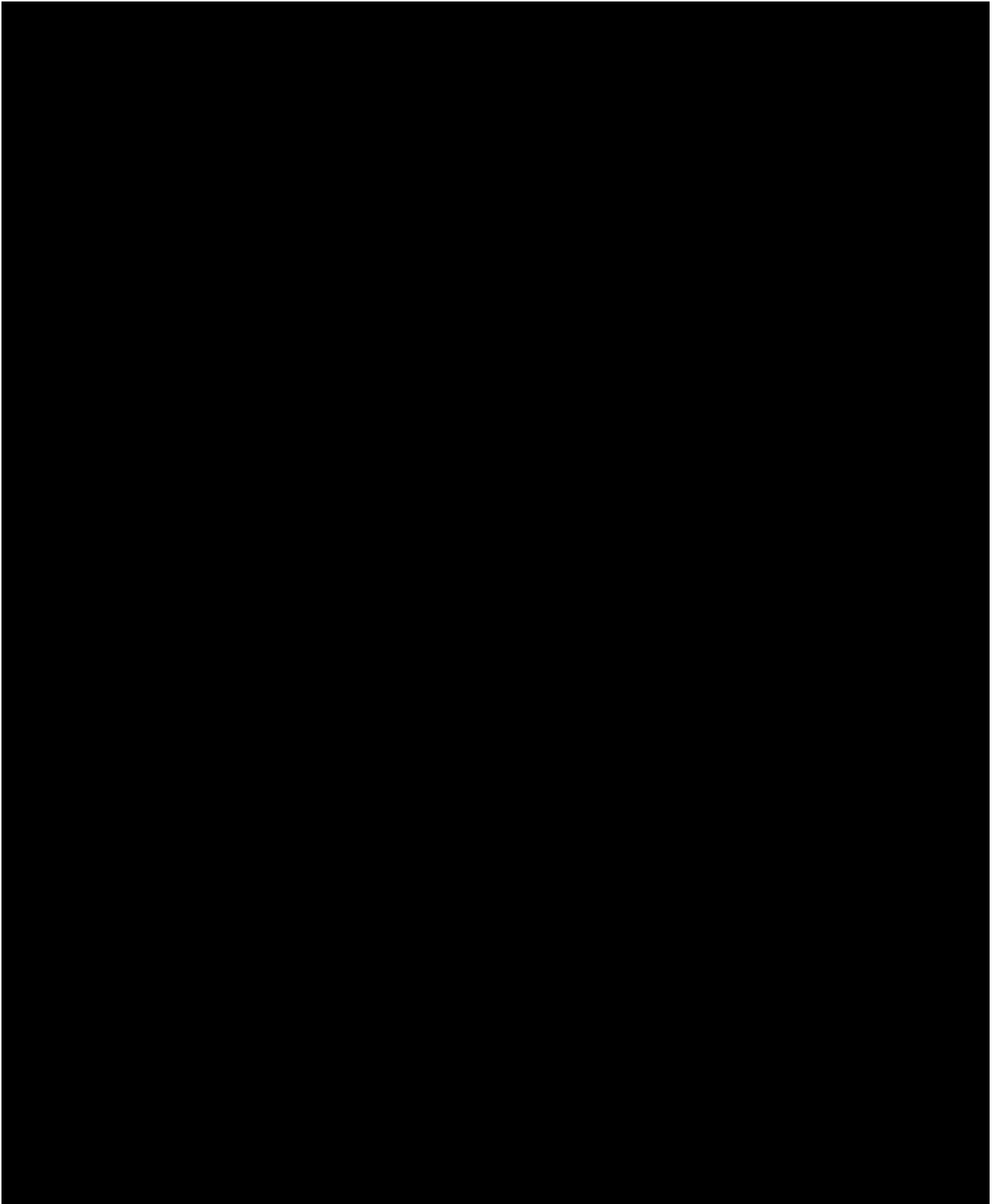


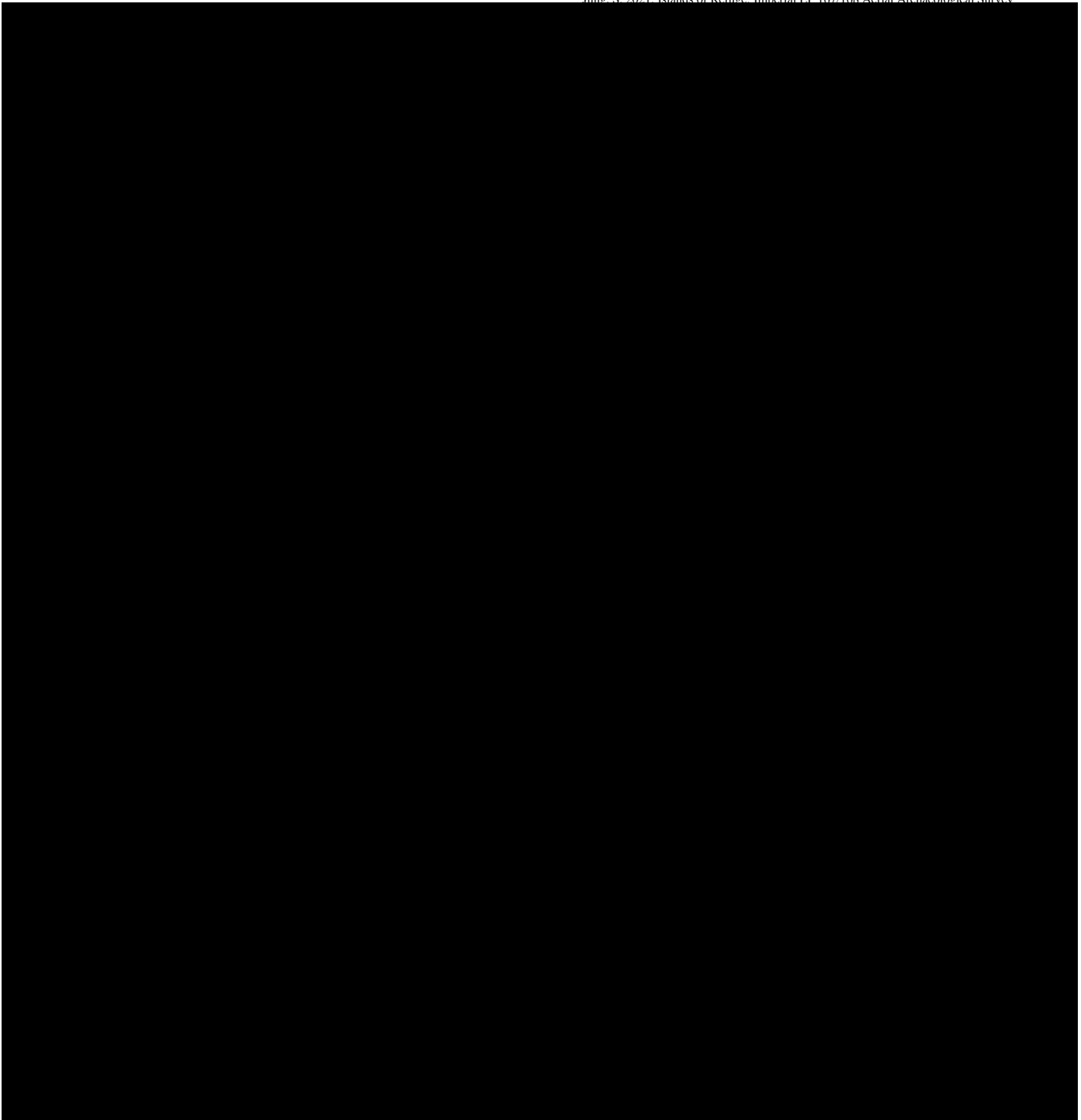


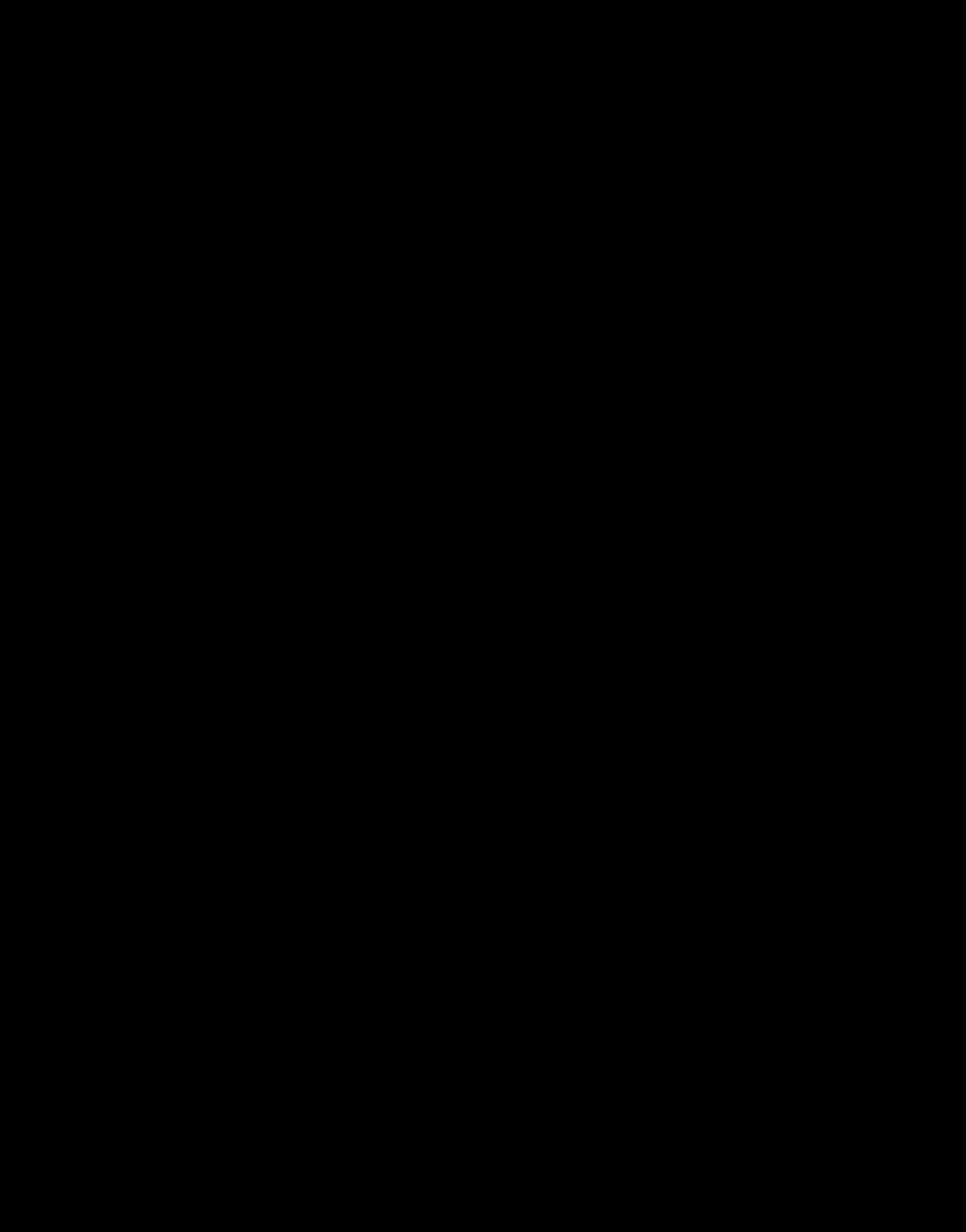


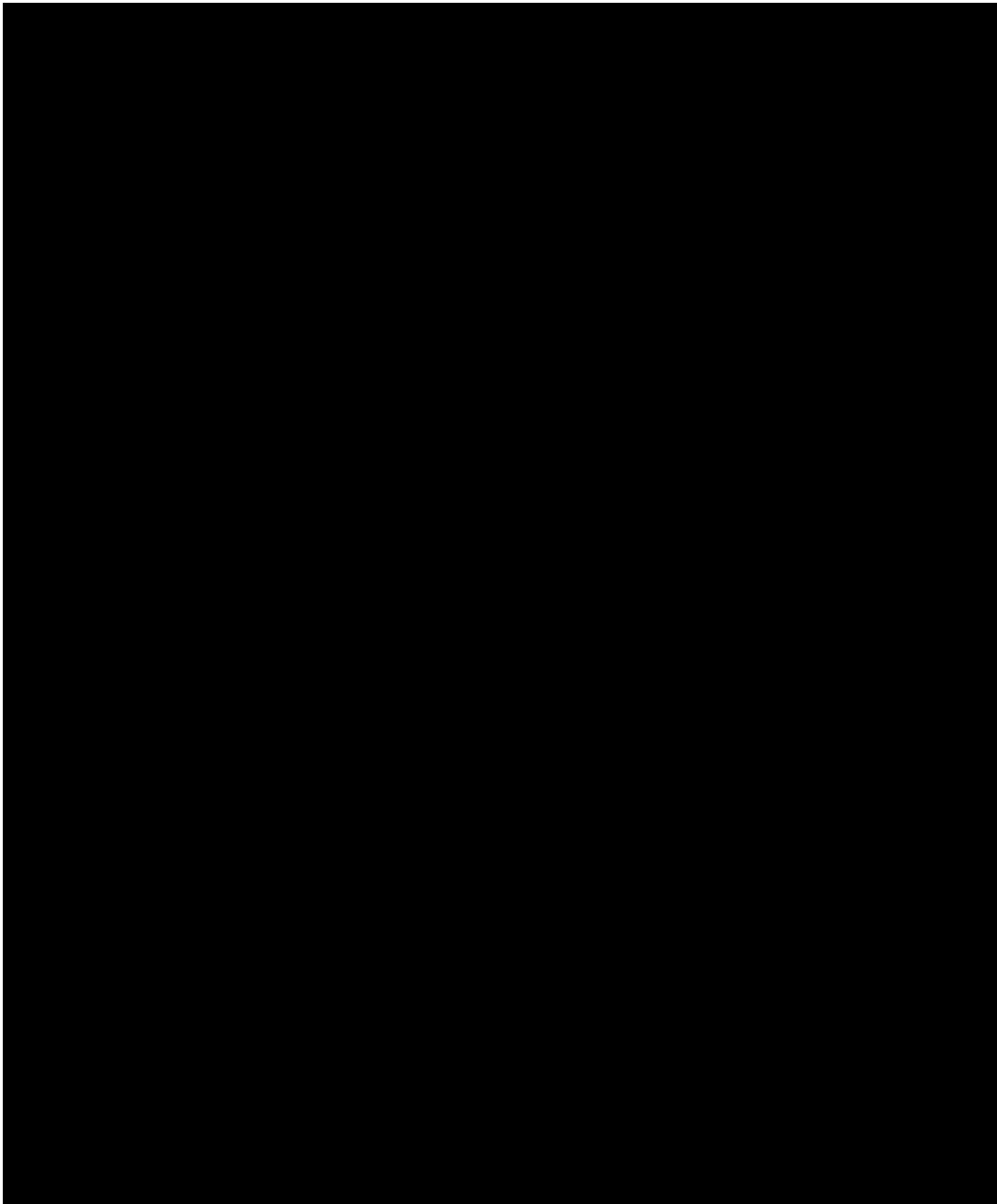


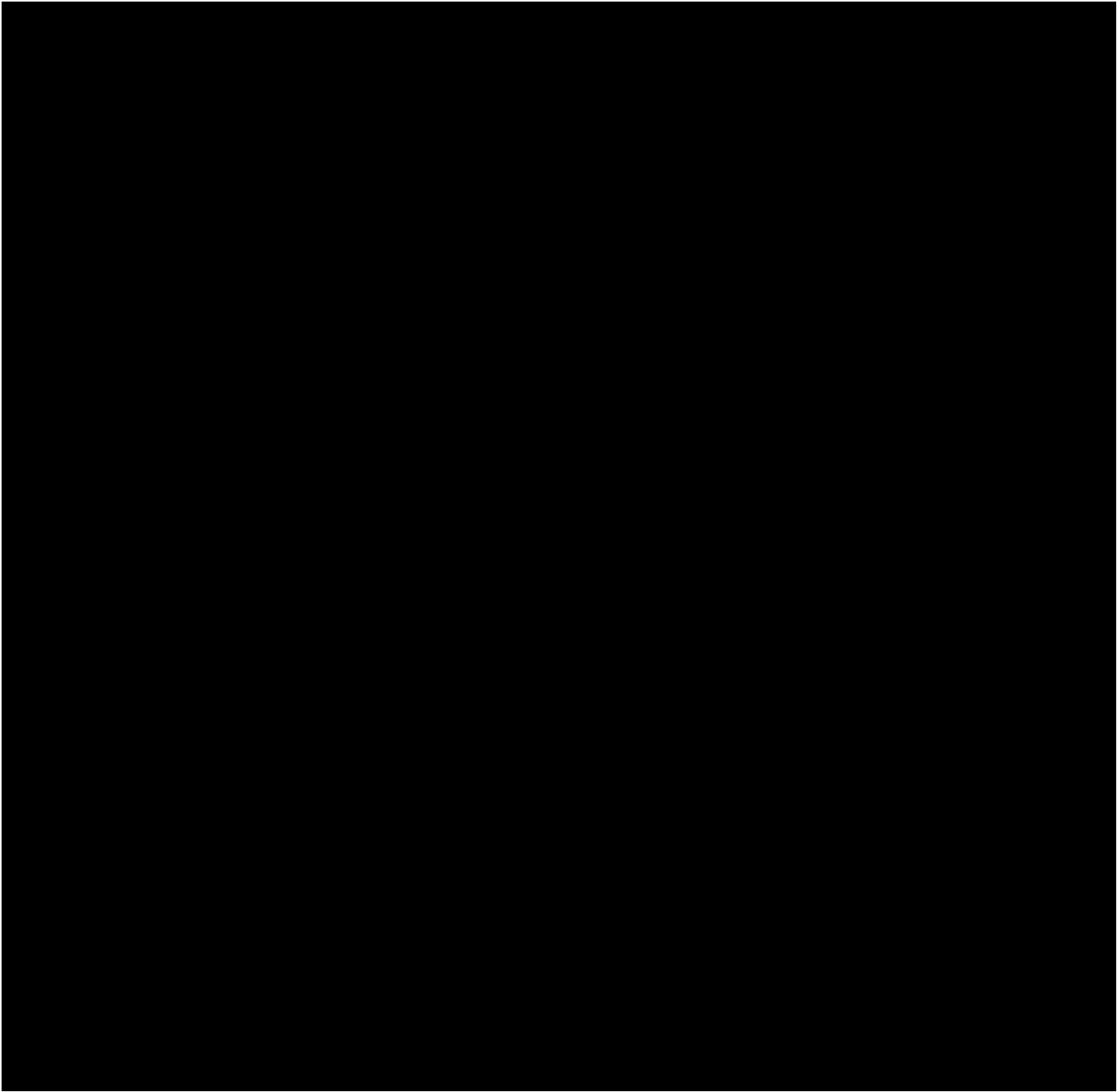


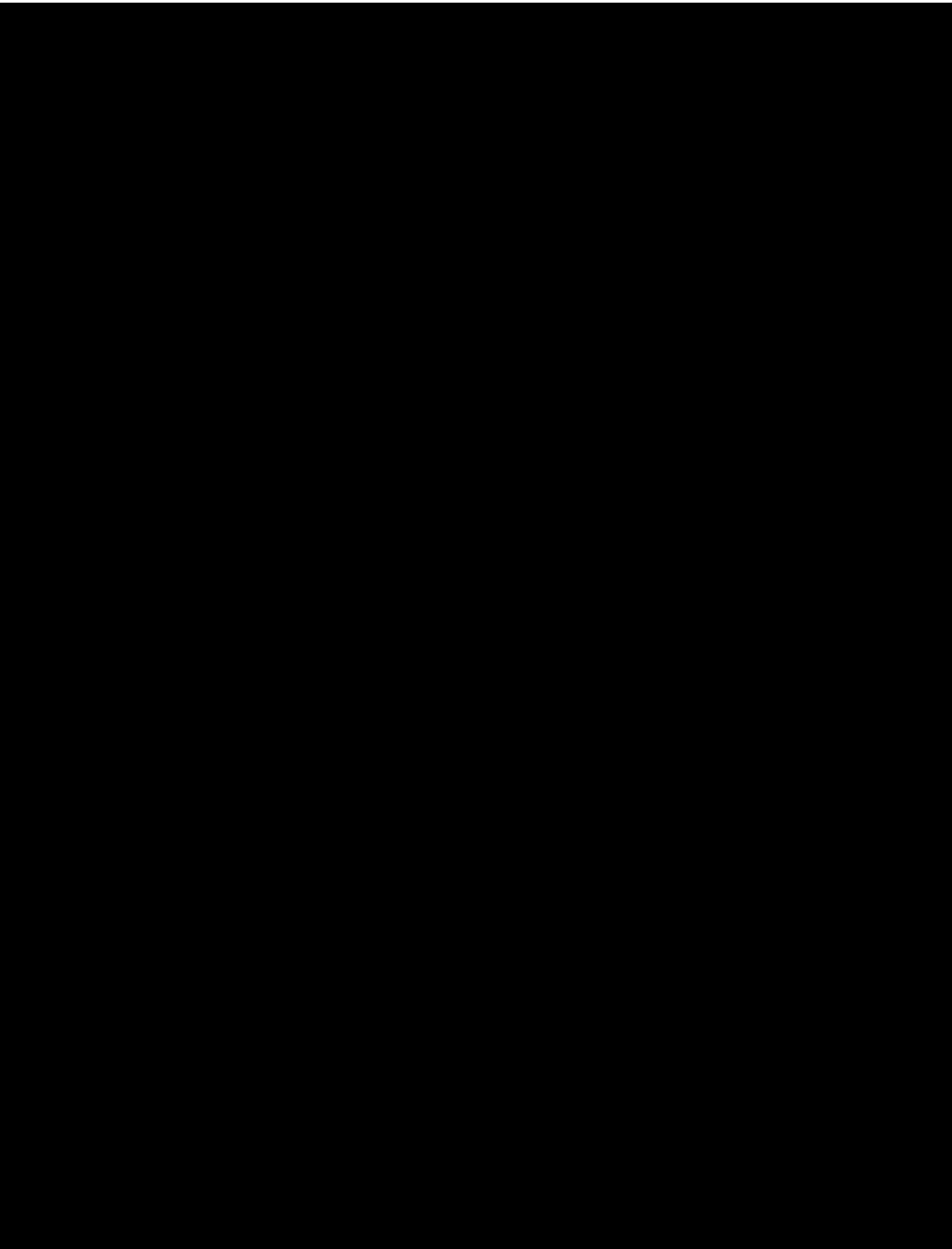


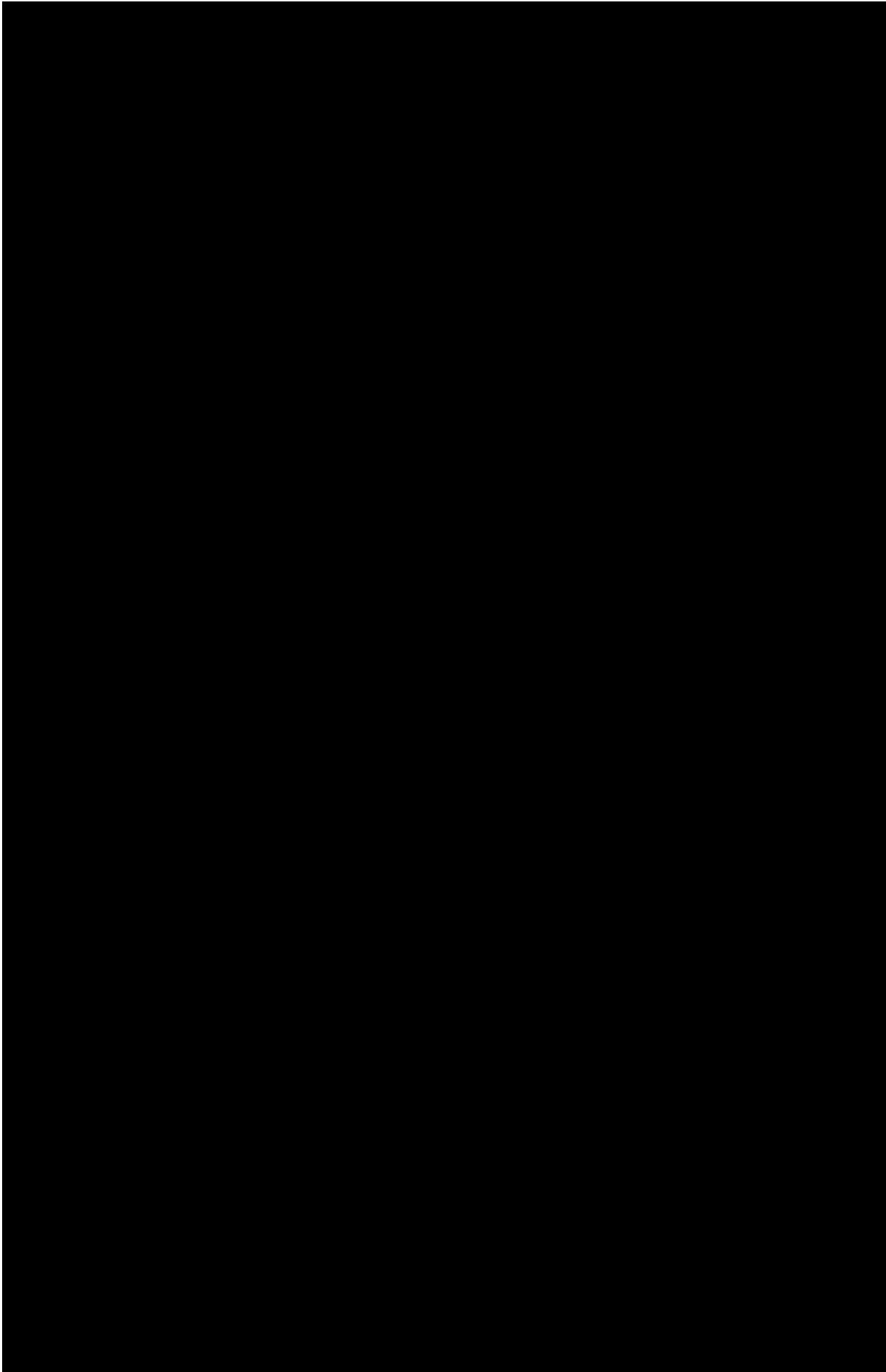


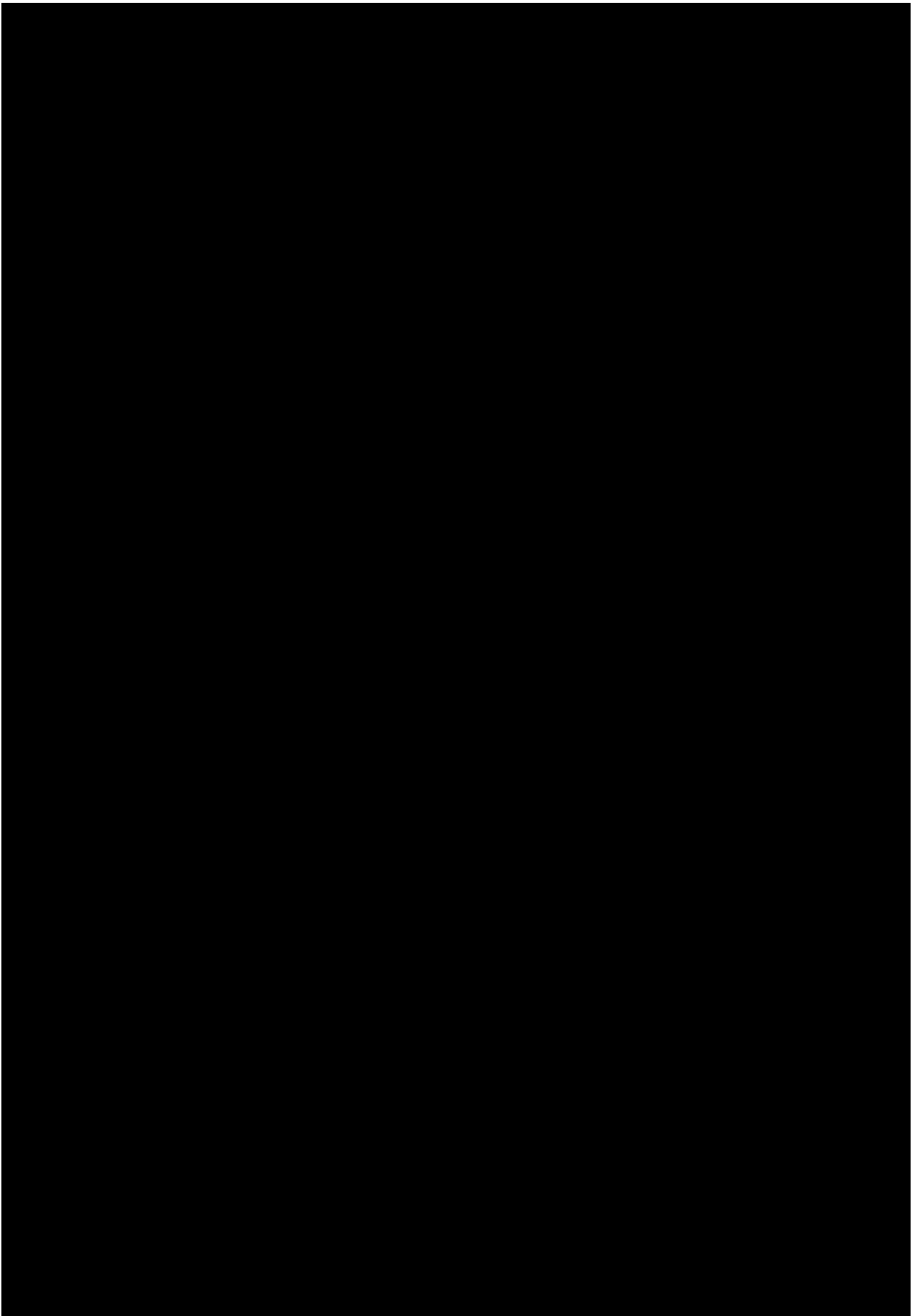












6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The proposed seismic line, well corridors and accesses tracks work programme by Imperial Oil and Gas A over several pastoral stations west of Larrimah necessitated an aerial survey, spanning over 700 km. An archaeological assessment was required to determine the programme's impact, if any, on archaeological sites and objects. This will reduce and mitigate the risk to those sites in order for the work programme to comply with the Northern Territory *Heritage Act (2011)*.

archaeology illustrates Aboriginal people had an intimate knowledge of where to find resources in the environment and to repeatedly return

The survey was constrained by focusing on the works corridors, only 1 km wide for the seismic lines, and 4 km wide for the well sites.

The following two recommendations arise from this report, which will best mitigate the impact of the in EP167 and EP168 on .

6.2 Recommendations

6.2.1 Recommendation 1: Site Avoidance

- The majority of archaeological sites can be avoided as they are confined to geographically small areas mainly and not on the planned route. Site polygons provide the boundaries for these restricted work areas. The polygon waypoints are listed in Appendix 2.

6.2.2 Recommendation 2: Deviation of the seismic lines

- . The line on the former comes within 5 m of the site's northern boundary and is in the construction corridor. The line should deviate around the site to the north. It should deviate around the site polygon in either direction.

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