HASTINGS
Technology Metals Limited

APPENDIX 3-4

Hydrology Assessment

Prepared for:

HASTINGS TECHNOLOGY METALS LIMITED

Yangibana Rare Earth Project, Gascoyne
Preliminary Hydrology Assessment

December 2016

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Executive Summary

JDA Consultant Hydrologists were commissioned by Hastings Technology Metals to assess the hydrology and flood characteristics of the Yangibana Rare Earth Project (the Site) and surrounds to assist with planning of mine infrastructure.

The catchment hydrology and runoff hydraulics were assessed for the 18% to 1% AEP (10, 20, 50, 100, 500 yr ARI) and PMP events. Modelling results were used to map the flood extent, depth, peak levels and flows across the Study Area.

The MIKE21 hydrodynamic model was used construct a catchment model for the Study Area and a detailed hydraulic model for the Site.

The regional catchment model was developed using a 90 m by 90 m DEM (CGIAR-CSI, 2008) with runoff generated using a direct rainfall approach. This model was used to assess flooding on a catchment scale and generate peak flows and runoff hydrographs for the detailed hydraulic model.

The detailed hydraulic model for the Site was developed using a 10m by 10m DEM. This model was used to simulate flooding characteristics in detail to allow for planning of proposed infrastructure.

Model output was used to generate a series of flood maps showing flood extent, depths, water elevation contours and peak flow rates across the Study Area (see Figures 10 to 24).

A surface water assessment of the Yangibana North Mining Area identified that a 2,250 km long diversion channel is required to divert floodwaters from Yangibana Creek tributaries around the proposed Yangibana North pits and back into the Yangibana Creek. Erosion protection and a flood protection bund of this diversion channel is recommended.

The 1% AEP (100 year ARI) flood mapping of the Bald Hill and Frasers Hill Mining Area indicates that flow is maintained with the flow channels, with little breakout of flows. Large sections of this Mining Area are unaffected by flood flows, other than shallow, localised overland runoff, which can be managed.

To assist future planning and culvert design at the southern access road a discharge rate per hectare (L/s/ha) for the 18% to 1% AEP (5, 10, 20, 50,100 yr ARI) and PMP events has been generated. These discharge rates will be used by project engineers to design culvert specifications.

In terms of access from the Copra-Gifford Creek Road into the Site, there are a number of drainage lines that will need to be traversed. Using XP-STORM, a 1D hydraulic model was constructed to produce hydrographs for each river crossing. The road crossings across the haul road and access roads are proposed (by Wave International) to be flush with the natural creek invert (no raised floodways). This will result in periods of closure during storm events, ranging between 0 and 6.4 hours and 0 and 1.2 hours during the 10% AEP (5 year ARI) storm event for light and heavy vehicles respectively. During the 1% AEP (100 year ARI) the closure period has been estimated to be between 0 and 68.4 hours and 0 and 67.3 hours for light and heavy vehicles respectively. Of all crossing assessed the Lyons River crossing (FW2) is likely to be inundated for the longest duration (2.5 days) following events exceeding the 18% AEP (5 yr ARI).

CONTENTS

1. INTRODUCTION 1

2. LITERATURE REVIEW 2
   - 2.1 Department of Agriculture and Food (2012) 2
   - 2.2 DHI (2012) 2
   - 2.3 Landloch (2016) 2
   - 2.4 ARR1987 (IEAust, 1987) 3
   - 2.5 ARR2016 (Ball et al., 2016) 3

3. SITE DESCRIPTION 4
   - 3.1 Location 4
   - 3.2 Proposed Mine Expansion 4
   - 3.3 Topography 4
   - 3.4 Rainfall Data 4
   - 3.5 Regional Hydrology 5

4. REGIONAL HYDROLOGY ASSESSMENT 6
   - 4.1 Rainfall IFD 6
   - 4.2 Probable Maximum Precipitation 6
   - 4.3 Catchment Simulation using Direct Rainfall 7
     - *4.3.1 Catchment Topography 7*
     - *4.3.2 Catchment Roughness 7*
     - *4.3.3 Downstream Boundary Condition 8*
     - *4.3.4 Loss Model 8*
     - *4.3.5 Results of Simulations 8*

5. HYDRAULIC ASSESSMENT & FLOOD MAPPING 9
   - 5.1 Model Description 9
     - *5.1.1 Topography 9*
     - *5.1.2 Boundary Conditions 9*
     - *5.1.3 Roughness 9*
     - *5.1.4 Additional Model Parameters 9*
   - 5.2 Results for Existing Catchment 10

6. SURFACE WATER MITIGATION MEASURES 11
   - 6.1 Yangibana North 11
     - *6.1.1 Diversion Drain 12*
   - 6.2 Access Road/Haul Road Crossings 13
     - *6.2.1 Floodways 13*
     - *6.2.2 Southern Access Road 15*

7. CONCLUSIONS & RECOMMENDATIONS 17

8. REFERENCES 19

LIST OF TABLES

Table 1: Percentage Difference between 1987 and 2013 IFD at Yangibana

Table 2: Rainfall Gauge Information

Table 3: Yangibana IFD Data

Table 4: PMP Total Rainfall Depth (mm)

Table 5: Lyons River Peak Flows at Study Area Upstream Boundary

Table 6: Scour Protection Properties

Table 7: Preliminary Hydraulic Model Results at Floodway Crossings

Table 8: Summary of Time of Closure (hours) for Road Crossings 1 to 7

Table 9: Preliminary Discharge Rate/ha for Southern Access Road

LIST OF FIGURES

1. Location Plan
2. Proposed Mine Infrastructure & Aerial Imagery
3. Site Topography
4. Regional Rainfall Station Locations
5. Edmund and Wanna / Gifford Creek Rainfall Station Annual and Average Monthly Rainfall
6. Lyons River Catchment Plan
7. Lyons River Catchment Topography
8. Yangibana Rainfall Intensity Frequency Duration (IFD)
9. Lyons River Hydrological Model Setup
10. Lyons River Hydrological Model – 1% AEP (100 year ARI) 6 hour duration Flood Depth Mapping
11. Lyons River Hydrological Model – 2% AEP (50 year ARI) 6 hour duration Flood Depth Mapping
12. Lyons River Hydrological Model – 5% AEP (20 year ARI) 6 hour duration Flood Depth Mapping
13. Lyons River Hydrological Model – 10% AEP (10 year ARI) 6 hour duration Flood Depth Mapping
14. Lyons River Hydrological Model – 18% AEP (5 year ARI) 6 hour duration Flood Depth Mapping
15. Lyons River Hydrological Model – PMF Depth Mapping
16. Detailed Hydraulic Model Setup
17. Detailed Hydraulic Model – Mannings n (Roughness) Mapping
18. Detailed Hydraulic Model – 1% AEP (100 year ARI) 6 hour duration Flood Depth Mapping
19. Detailed Hydraulic Model – 2% AEP (50 year ARI) 6 hour duration Flood Depth Mapping
20. Detailed Hydraulic Model – 5% AEP (20 year ARI) 6 hour duration Flood Depth Mapping
21. Detailed Hydraulic Model – 10% AEP (10 year ARI) 6 hour duration Flood Depth Mapping
22. Detailed Hydraulic Model – 18% AEP (5 year ARI) 6 hour duration Flood Depth Mapping
23. Detailed Hydraulic Model – PMF Depth Mapping
24. Yangibana North Site Layout and Surface Water Management Plan
25. Yangibana North – Option 1 Diversion Drain Long Section
26. Floodway Layout
27. Yangibana Mine – Discharge at Southern Access Road

APPENDICES:

A. Floodway Crossing Inundation and Closure Times

B. Yangibana Floodway Layout and Design

1. INTRODUCTION

JDA Consultant Hydrologists were commissioned by Hastings Technology Metals Limited to complete a Preliminary Hydrological Study to support a Detailed Feasibility Study (DFS) for the Yangibana Rare Earth Project in the Gascoyne Region of Western Australia (see Figure 1).

This study will be used to assist planning for the required mine infrastructure which will extend from the access road connection at Cobra-Gifford Creek Road to the Yangibana Project (YPA).

The JDA Scope of Works includes:

- Estimation of catchment runoff rates and hydrographs for the 20%, 10%, 5%, 2% and 1% AEP event rainfall (5, 10, 20, 50 and 100 year ARI events respectively) and probable maximum flood (PMF) for the site and regional catchments;
- Construct a preliminary 2D hydraulic model and simulate flood events for the 20%, 10%, 5%, 2% and 1% AEP event rainfall (5, 10, 20, 50 and 100 year ARI events respectively) and probable maximum flood (PMF) for the project area to determine flood levels, depths, flow rates and velocities.
- Utilising results from 2D modelling determine site specific surface water management and diversion structures and erosion protection measures to mitigate the risk of flooding during the 20%, 10%, 5%, 2% and 1% AEP event rainfall (5, 10, 20, 50 and 100 year ARI events respectively) and probable maximum flood (PMF) within the project region.

2. LITERATURE REVIEW

There are three studies and two guidance documents which provide data and direction for the hydrological assessment at Yangibana.

2.1 Department of Agriculture and Food (2012)

This report by the Department of Agriculture and Food (DAFWA) details an assessment of the Gascoyne River catchment following flood events that occurred in December 2010 and February 2011 which resulted in flooding in Carnarvon. It was thought that the poor vegetation cover within the catchment resulted in greater runoff during these flood events. The report provides some evidence on the role that vegetation groundcover management has in promoting infiltration within the catchment and therefore reducing runoff.

Soil infiltration testing and profiling was conducted at 50 sites throughout the Gascoyne catchment. While vegetated areas had significantly higher infiltration rates, these formed only a small percentage of the landscape.

The study found that large areas of the Gascoyne River catchment are water shedding, with very shallow soils and with limited storage capacity and so in large floods the vegetation cover condition and associated infiltration rates have only a limited impact on runoff rates and volumes. At the soil profile sites, the soils were frequently less than 0.3 m deep, and were usually a sandy loam over clay, hardpan or weathered rock. A total soil water storage of 60 mm was estimated for the profile, significantly less than the rainfall recorded in the storm events over the 2010/2011 summer period.

2.2 DHI (2012)

The DHI study is closely related to the DAFWA study and used a catchment hydrologic model (MIKESHE) to assess catchment condition impact on runoff. A detailed two dimensional (2D) model was developed and calibrated for the Gascoyne River catchment. The model used topography, rainfall, evaporation, soils and land use data. Model processes included infiltration and recharge, soil unsaturated zone storage and drainage, evapotranspiration, overland flow, groundwater and surface water interactions and creek / river flow.

A sensitivity analysis using the model found that runoff was insensitive to hydraulic conductivity, probably as peak rainfall rates for extreme events significantly exceeded possible infiltration rates, favouring runoff over infiltration.

2.3 Landloch (2016)

This study provides a baseline soil assessment for the Yangibana site. It gives a preliminary desktop review of available soil, geology, land systems and geomorphology, describes the field assessment, and presents the results of the field testing and subsequent laboratory testing.

Two main soil types have been identified, being:

- Hill Soil – characterised as dark brown sandy loam with shallow soil depth (0.2 to 0.5 m), overlying decomposing granite. Soil fines content (silt and clay) ranged between 10 and 31%, with a median of 19%. This indicates high fines content.
- Plains Soil – characterised as loamy sand overlying silty loam or clay loam. The sandy loam horizon is shallow (0.2 – 0.3 m). Soil fines content is between 27 and 42% with a median of 36%.

2.4 ARR1987 (IEAust, 1987)

Australian Rainfall and Runoff: A Guide to Flood Estimation (1987) has been the guiding document for the estimation of floods in Australia for the last 30 years. For all areas of Australian it provides information on:

- Rainfall design IFD data;
- Catchment rainfall losses;
- Rainfall temporal and spatial patterns;
- Areal reduction factors (for rainfall for large catchments); and
- Flood estimates.

Over the last four years a revision of the document has been in progress and a draft was recently released; this is discussed below.

2.5 ARR2016 (Ball et al., 2016)

The new revision of Australian Rainfall and Runoff was released in July 2016 for industry comment and incorporates an additional 28 years of data collected since IEAust (1987). Some chapters of the document are still being finalised and not all datasets are currently available for use.

For Yangibana:

- The Study Area is within the Arid region for storm losses – information for this region is not yet available;
- The Study Area is within the Northern Coastal zone for areal reduction factor – equations are available, and these have been applied within the assessment described in this report;
- Temporal patterns are not yet available and are likely to be released in late 2016;
- Revised rainfall IFD data was released in 2013, however the 2 and 1% AEP (50, 100 year ARI) values are being further revised and were released on 25 November 2016 (after modelling completed). A comparison of the 1987 IFD for Yangibana with the 2013 revision is shown in Table 1, and indicates that generally there is a decrease in rainfall depth (ie negative % change), except for shorter duration, more extreme rainfall. Given the 2013 data is being revised, the 1987 IFD has been used in this report.

TABLE 1: PERCENTAGE DIFFERENCE BETWEEN 1987 AND 2013 IFD AT YANGIBANA

Duration	2 yr ARI	5 yr ARI	10 yr ARI	20 yr ARI	50 yr ARI	100 yr ARI
0.5 hour	-10%	-1%	6%	9%	13%	17%
1 hour	-12%	-4%	3%	5%	9%	13%
2 hours	-11%	-5%	0%	2%	4%	6%
3 hours	-9%	-5%	-1%	-1%	1%	2%
6 hours	-5%	-5%	-3%	-4%	-5%	-5%
12 hours	-2%	-5%	-4%	-7%	-9%	-11%
24 hours	-3%	-5%	-5%	-8%	-11%	-12%
48 hours	-6%	-6%	-4%	-7%	-8%	-10%
72	-5%	-5%	-3%	-5%	-7%	-8%

3. SITE DESCRIPTION

3.1 Location

The site of the proposed Yangibana Rare Earths Project is shown from a regional perspective in Figure 1, with the Study Area as determined by JDA enveloping the proposed mine infrastructure. Figure 2 presents aerial photography showing the propose site in relation to existing creek systems, and vegetation cover. The main access point for the study area is the Cobra-Gifford Creek Road, located at the southern extent of the plot.

Vegetation cover is sparse, with a large percentage of the area being un-vegetated. The greatest concentration of vegetation is within the creek and river channels.

3.2 Proposed Mine Expansion

The proposed Yangibana Rare Earths Project mine layout is presented in Figure 2. There are two pits and associated spoil heaps located in Yangibana Creek to the north west of the Study Area. Other pits, spoil heaps and the bulk of the mine works is located within the Frasers Creek catchment. The main access road crosses the Lyons River within the Study Area (Figure 2).

3.3 Topography

Site topography is shown in Figure 3, with a DEM derived from LiDAR data (CGIAR-CSI, 2008) with elevation varying from 367 mAHD to 309 mAHD. Regional ground elevations generally grade across the Study Area towards the Lyons River.

The Study Area lies to the north of Lyons Rivers (a major tributary of the Gascoyne River) and directly east of Edmund River (tributary of Lyons River).

3.4 Rainfall Data

The study area resides within the Gascoyne region of Western Australia. Rainfall in this region occurs from two types of meteorological event: rare and high intensity rainfall resulting from tropical cyclonic activity, and more frequent, lower intensity rainfall resulting from low pressure systems, localised thunderstorms or tropical upper air disturbances.

In the region there are 13 daily rainfall stations – these are listed in Table 2, and are shown in Figure 4. Average annual rainfall for the region is between 210 and 278 mm. The 2 closes stations are Edmund (#007164) and Wanna / Gifford Creek (#007028). The Wanna / Gifford Creek station closed in 2009, however the Edmund station is still open, although data is missing 2010 to 2014. Annual and average monthly rainfall information for the two stations are shown in Figure 5. The data indicates that rainfall predominantly falls between January and June.

TABLE 2: RAINFALL GAUGE INFORMATION

Station	Station ID	Period Open	Average
Lyons River / Airstrip	006030 / 006112	1906 – 2016	219.9
Eudamullah	006021	1928 – 2013	210.7
Mount Sandiman	006042	1947 – 2003 [1]	271.4
Minnie Creek / Airstrip	006040 / 006104	1900 – 2016	225.8
Edmund	007164	1972 – 2016[1]	278.0
Wanna / Gifford Creek	007028	1946 – 2009	244.9
Mount Phillip	007058	1902 – 2016	226.0
Cobra Station / Airstrip	007111 / 007209	1898 – 2016 [1]	244.8
Mount Augustus	007053	1901 – 2016	234.5
Waldburg	007201	1989 – 2000	274.9
Pingandy	007104	2002 – 2016	249.0
Mount Vernon	007059	1939 – 2016	251.9
Woodlands	007105	1955 – 2015	256.2

Note: 1. Interrupted record

3.5 Regional Hydrology

The Lyons River is a tributary of the Gascoyne River, and discharges westward along the southern boundary of the Study Area (Figure 2). The access road for the project must cross the Lyons River to connect to the Cobra-Gifford Creek Road.

The catchment area of the Lyons River to this crossing location is approximately 11,000 km^2 (Figure 6). The catchment extends approximately 200 km east from the Study Area. Topography of the catchment is shown in Figure 7, based on a 90 m grid DEM sourced from NASA.

There is a flow and level gauging station located approximately 140 km downstream of the Study Area. The total catchment area to the gauging station is approximately 19,600 km^2.

4. REGIONAL HYDROLOGY ASSESSMENT

To assess the impact that the Lyons River would have on the Study Area and what implications for design might be, an assessment of the Lyons River hydrology was made. As discussed in Section 3.5 above, the Lyons River has a large catchment. It is very long, and aerial photography (Figure 6) and topography (Figure 7) show that there are flat areas within the catchment where drainage is poorly defined and significant storage will occur.

Freely available coarse grid (90 m) LiDAR information from NASA (CGIAR-CSI, 2008) was used to simulate the Lyons River Catchment to provide information on flow rates and levels in the Lyons River adjacent to the Study Area. This is referred to as the "Lyons River hydrological model", as described in this chapter.

This model was also used to generate flow hydrographs for a detailed hydraulic model of the Fraser Creek and Yangibana Creek catchments.

4.1 Rainfall IFD

Rainfall Intensity Frequency Duration (IFD) data for Yangibana was calculated using the Bureau of Meteorology CDIRS system 1987 on the BoM website. Data for events from the 1 year to 100 year ARI and durations from 5 minutes to 72 hours is shown in Figure 8 and tabulated in Table 3 below.

These rainfall IFD values are suitable for use at both local scale (Fraser Creek and Yangibana Creek Catchments) and regional scale (Lyons River), with use of appropriate areal reduction factors. Areal reduction factor calculation is consistent with the equations within the recent ARR (Ball et al., 2016).

TABLE 3: YANGIBANA IFD DATA

Duration	AEP (ARI in brackets)						
	63% (1yr)	40% (2yr)	18% (5yr)	10% (10yr)	5% (20yr)	2% (50yr)	1% (100yr)
5 minute	57.1	75.3	103	121	143	173	196
10 minute	43.2	57.0	78.6	92.2	109	133	151
30 minute	25.7	34.0	47.1	55.2	65.6	79.6	90.5
1 hour	16.8	22.4	31.3	37.0	44.2	53.9	61.6
2 hour	10.2	13.7	19.8	23.7	28.7	35.5	41.0
3 hour	7.47	10.1	14.9	18.1	22.1	27.6	32.1
6 hour	4.31	5.93	9.10	11.3	14.0	17.9	21.1
12 hour	2.53	3.51	5.56	6.99	8.80	11.4	13.6
24 hour	1.53	2.13	3.39	4.28	5.41	7.03	8.38
48 hour	0.917	1.27	2.01	2.52	3.18	4.11	4.89
72 hour	0.648	0.897	1.43	1.80	2.26	2.93	3.48

4.2 Probable Maximum Precipitation

To estimate the probable maximum precipitation (PMP), the Generalized Short Duration Method (GSDM) and the Generalised Tropical Storm Method (GTSM) were used for short and long storm durations respectively (BoM, 2003 & 2005). These methods are recommended by Australian Rainfall and Runoff (IEAust, 1987 and Ball et al., 2016) and provide complete information on PMP estimation as presented in Table 4.

The GSDM provides PMP estimates for durations up to 6 hours for catchments up to 1,000 km^2, andspatial distribution patterns apply based on catchment areas.

The GTSMR provides PMP estimates for longer durations (24 to 120 hours) with catchment area is built into the calculations, accounting for spatial scales.

TABLE 4: PMP TOTAL RAINFALL DEPTH (MM)

Duration (hours)	**PMP**	
	Fraser Creek / Yangibana Creek	**Lyons River**
GSDM		
0.5	306	-
1	441	-
3	630	-
6	788	-
GTSMR		
24	-	800
36	-	850
48	-	970
72	-	1190
96	-	1350
120	-	1420

4.3 Catchment Simulation using Direct Rainfall

JDA has used a 2D hydraulic model namely MIKE21 F (flexible mesh) - known as a *"rain on grid"* approach, in which a design storm event is applied to the topographical Digital Elevation Model (DEM) and hydrodynamic equations are used to route flow through the system. This approach best serves the purpose when catchment topography is complex together with natural depression storage areas that will attenuate peak flows, as found within the Lyons River catchment.

The model uses catchment topography, roughness and downstream boundary conditions, along with design storm rainfall and loss model to generate flows and flood depth.

4.3.1 Catchment Topography

The topography used in the hydrological model is based on a 90 m grid DEM from NASA (CGIAR-CSI, 2008) as shown in Figure 9. The data is sufficiently accurate to allow for the modelling of flows from the catchment and flood depths within the catchment.

4.3.2 Catchment Roughness

The roughness of the catchment is determined primarily by vegetation and degree of rock cover. As described in Section 3.1, vegetation cover is sparse across most of the catchment, with greater concentrations of vegetation occurring within the creek and river channels.

Manning's roughness of 0.055 has been applied to the creek and river channels to account for vegetation; the remaining land areas have been assigned a lower value of 0.03.

4.3.3 Downstream Boundary Condition

The downstream boundary of the model is located on the Lyons River, downstream beyond the Site see Figure 9. A Rating Curve approach has been applied to the boundary.

4.3.4 Loss Model

As described in Section 2, the soils of the catchment areas are predominantly shallow sandy loams overlying weathered granite or clayey loams. This limits the capacity for rainfall infiltration into the soil.

ARR1987 (IEAust, 1987) suggests a continuing loss of 3 mm/hr for the loamy soils of the arid interior and wheatbelt regions, while 5 mm/hr is suggested for North West WA (Pilbara) loam soils. To be conservative, a continuing loss of 3 mm/hr has been adopted.

No initial loss has been applied to rainfall, to avoid double counting of storage losses within the 2D topography, which were not factored into ARR1987 for initial losses.

4.3.5 Results of Simulations

The 2D model was run for storm durations between 1 and 72 hours. Flood mapping for the Lyons River catchment are shown in Figures 10 to 14 for the 1% (100 year ARI) to 18% (5 year ARI) events, or 6 hours critical storm duration. Figure 15 shows flood mapping for the PMF. Peak flows in the Lyons River at the upstream boundary of the Site are presented in Table 5.

TABLE 5: LYONS RIVER PEAK FLOWS AT STUDY AREA UPSTREAM BOUNDARY

AEP	Peak Flow (m^3/s)
18% (5 year ARI)	23.6
10% (10 year ARI)	32.0
5% (20 year ARI)	155.1
2% (50 year ARI)	454.8
1% (100 year ARI)	747.2
PMF	47,088

5. HYDRAULIC ASSESSMENT & FLOOD MAPPING

To assess flood conditions that are likely to impact on the proposed mine infrastructure, a detailed hydraulic model was developed for Fraser, Yangibana and Gifford Creeks, as well as the Lyons River adjacent to the Study Area. This model used rainfall on grid for the creek catchments, and includes flow in the Lyons River based on the larger Lyons River hydrological mode described in Chapter 4. The detailed model allows for accurate delineation of flood extent, depth, flow rates and velocities, which will be used to inform mine design.

5.1 Model Description

The MIKE21 FM (Flexible Mesh) hydrodynamic model was used to simulate flooding characteristics within the Study Area.

The MIKE21 FM model comprises a mesh file (topography), a roughness coefficient (resistance), boundary conditions (still water levels), initial water levels and secondary model parameters (simulation parameters, eddy viscosity and wetting/flooding/drying parameters).

5.1.1 Topography

The Flexible Mesh is an unstructured mesh and uses an element-centred finite volume solution technique. Using the LiDAR (CGIAR-CSI, 2008) survey data, a topographical triangular mesh with an elemental area of 25 m^2 was developed for the Fraser, Yangibana and Gifford Creeks, see Figure 16 for model setup. The triangular elemental area was selected as optimal to describe drainage features and rainfall runoff within the Study Area whilst minimising simulation run times.

5.1.2 Boundary Conditions

As described above in Section 4.3.3, a rating curve boundary was used for the downstream boundary condition in the model.

Two boundaries (BND2 & 3, see Figure 16) were used to input Lyons River flow hydrographs from the larger hydrologic model. Three boundaries (BND4, 5, 6) were used to input flow from the Gifford Creek catchment to the south of the model – these flows were also derived from the larger hydrologic model.

Direct rainfall was applied to the model mesh. A range of storm durations were modelled for each AEP event to determine the critical duration, producing peak water levels and flow rates.

The loss model described above in Section 4.3.4 was also used for the detailed hydraulic model.

5.1.3 Roughness

A roughness map was developed covering the same area as the topographic grid. Manning's n roughness values as described in Section 4.3.2 were applied to the detailed model. Figure 17 shows the distribution of roughness within the detailed model.

5.1.4 Additional Model Parameters

The following secondary model parameters were adopted based on JDA experience:

- Drying depth (0.001 m)
- Flooding Depth (0.002 m)
- Wetting Depth (0.0021 m)

- 0.2 minimum time step
- Eddy viscosity calculated using the Smagorinsky formulation with constant value of 0.28.

Wetting, flooding and drying depths affect the rate of propagation of a flood wave across a floodplain, but do not impact significantly on flood water levels.

5.2 Results for Existing Catchment

MIKE21FM 2D modelling results for the existing catchment are shown in Figures 18 to 23 for the 1% (100 year ARI) to 18% (5 year ARI) and PMF events respectively. Each plot shows flood depth and flood extent, with flood water surface elevation shown at a number of tag points and maximum discharge and velocities at selected cross-sections along the main floodways. The plots have been separated into three subplots to show areas of interest in detail.

6. SURFACE WATER MITIGATION MEASURES

Utilising the methodologies discussed within Sections 4 and 5, the impact of regional and local flood waters on the proposed mine infrastructure has been assessed. Based on this assessment a combination of diversion channels, floodways and culverts is required to mitigate impacts associated with surface water flows in the Study Area.

For the purposes of this study the surface water management areas have been divided into the following sub-areas;

- Bald Hill and Frasers Mining Area
- Yangibana North Mining Area
- Access Road/Haul Road Crossings

Proposed surface water management options for each sub-area are discussed below.

6.1 Bald Hill and Frasers Mining Area

The Bald Hill and Frasers Mining Area layout and local surface water drainage features are presented in Figures 18 to 23. The mining area footprint for this area is located within the tributaries of Frasers Creek. Both the Bald Hill and Frasers Pits sit almost directly on the upper reaches of these tributaries, as such local drainage is away from the site. No notable drainage paths are located within the processing plant and there is only minor risk from tributaries to the north and south of the processing plant, flooding extents of these tributaries during events up to the PMP are presented in Figures 18 to 23.

The haul road corridor to the south of Bald Hill traverses the alignment of a small drainage system and also crosses a more significant drainage path, indicated by FW4 (see Figure 26), which has a 1% AEP (100 yr ARI) discharge of 129 m^3/s. Surface water management requirements at this crossing have been considered and are discussed in Section 6.3.

Based on supplied information and the 18% to 1% AEP (5 to 100 year ARI) flood mapping there is no direct flood risk to the Bald Hill and Frasers Mining Area. Flows are generally maintained with the flow channels, with little breakout of flows. Large sections of the Mining Area are unaffected by flood flows, other than shallow, localised overland runoff, which can be managed. However, this preliminary assessment is highly dependent upon the current extent of the processing plant and associated mining area. In the event that the infrastructure footprint was modified the flooding risk should be re-evaluated using existing hydraulic modelling.

6.2 Yangibana North

The Yangibana North mining area (North and West pits) and local surface water drainage features are depicted in Figures 24. The Yangibana North footprint is located in the upper reaches of Yangibana Creek within a number of minor tributaries. Surface water flows in the area are largely in south-west direction within ephemeral drainage lines which all ultimately discharge into the Lyons River. Diversion of these drainage networks is required to protect the integrity of proposed waste dumps and to prevent flooding of the open pits. To aid in future discussions and planning two diversion channel routes were explored; both are discussed in below.

6.2.1 Diversion Drain

Utilising floodmaps and peak flows generated in 2D hydraulic modelling (MIKE21), proposed layout and LiDAR-sourced topography two diversion channel alignments were considered to determine a suitable diversion route. Both alignment options are discussed below:

- **Option 1** – This diversion channel commences at point A (see Figure 24) and extends in a south-easterly direction adjacent to the pits northern boundary for a distance of 900 m, it then follows the haul road till it meets the Yangibana Creek where it discharges (see Figure 24).
- **Option 2** - This diversion channel commences at point A (see Figure 24) and traverses in a north-west direction adjacent to the pits northern perimeter for a distance of 1,100 m, at this point the channel heads south-west along the pits western perimeter for 500 m and then continues down gradient for 450 m before discharging into Yangibana Creek at point C (see Figure 24).

Based on cut and fill analysis option 2 was considered to be the most suitable route. Figure 25 shows the proposed alignment, LiDAR-sourced topography along the diversion drain, the proposed drain invert and the estimated 1% (100 yr ARI) water level profile. Also shown are upstream and downstream typical drain cross-sections. A uniform grade drain invert profile from point A to the outlet point C has been assumed between the upstream (i.e. 329.9 mAHD) and downstream (i.e. 326.2 mAHD) point identified in the long-section (Figure 25). The diversion drain profile may be revised at detailed design stage.

Figure 25 shows that the maximum cut (below natural surface) required to achieve the minimum grade (0.1%) is likely to be between 9 - 11m for a length of 500 m. Minor incisions are required for the remainder of the drain invert. The estimated total cut volume for the entire drainage alignment is 449,200 m^3.

The diversion drain was designed as a 21 m wide standard trapezoidal drain with 1:6 sloped batters and uniform grade based on LiDAR elevations. Narrower drains (e.g. 5 m) are possible but may require increased scour and overtopping protection. A Manning (n) roughness coefficient of 0.03 was used. Potentially steeper side slopes of the diversion drain may be acceptable; geotechnical advice will be required to confirm final achievable side slopes.

The diversion drain should be constructed before commencement of any mining operation in order to protect the flooding of the open pit mine from flooding.

A diversion bund approximately 2m high (crest 331.4 mAHD) will be required to protect the open pits. This elevation will provide 0.5 m of freeboard for the 1% AEP. The flood protection bund should be sized, designed and constructed according to a site-specific detailed geo-technical assessment that will identify adequate materials to be used for the safe diversion of flood waters.

The results of the analysis indicate flow velocities within the proposed diversion drain will be up to 1.5 m/s for the 1% AEP (100 yr ARI) which is likely to result in erosion of the channel and subsequent sedimentation downstream. JDA recommends that rip-rap protection be provided at least at the over the first 20 m discharge outlet (point C) using facing class rock at a thickness of 0.5 m, as outlined in Table 6. If rip-rap is readily available and it is considered to be cost effective a scour control layer is also recommended for the batter slopes of the drain.

TABLE 6: SCOUR PROTECTION PROPERTIES

Velocity (m/s)	Class of Rock Protection	Section Thickness
<2	None	-
2.0-2.6	Facing	0.5
2.6-2.9	Light	0.75
2.9-3.9	¼	1.0
3.9-4.5	½	1.25
4.5-5.1	1.0	1.6

Note that rip-rap specifications should be confirmed by a geotechnical engineer.

6.3 Access Road/Haul Road Crossings

6.3.1 Floodways

Flood waters from Yangibana Creek, Fraser Creek, Lyon River and Gifford Creek traverse either the main access road (FW1A, 1B, 2, 3, 4 – see Figure 26) or the haul road (FW 5, 6 & 7 – see Figure 26). It was proposed by Wave International (Wave) that at all floodways (except FW2) would be constructed flush with the natural creek invert (i.e. not a raised floodway). Appendix B details the proposed floodway design (supplied by Wave) for all floodway sections.

With the exception of FW2 (Lyons River), road crossing flood serviceability criteria and closure period was assessed using the XP-STORM 1D model (calibrated to 2D) to produce flood level hydrographs. Water level hydrographs for the 18% to 1% AEP (2 to 100 year ARI) events are plotted with the MRWA design guidelines (MRWA, 2006) for light and heavy vehicles in Appendix A. Due to the size of FW2's contributing catchment the serviceability at this crossing was assessed using the regional 2D hydrological model as this method allowed for the incorporation of catchment storage. Notably, when compared to the hydrographs produced using XP-STORM, the resulting hydrographs for FW2 are relatively coarse. This is a consequence of the 90 m x 90 m LIDAR grid used to model flows within this catchment. JDA suggests results are re-assessed at a later stage if a more refined LIDAR (CGIAR-CSI, 2008) data set becomes available.

Table 7 presents preliminary peak discharge and flow velocities at each FW crossing whilst Table 8 contains cumulative time of closure for inundation during different ARI's.

Results of the serviceability assessment suggest all crossings, accept FW2 (Lyons River) will be inundated for a period of less than 1 day during all modelled ARI events. The Lyons River crossing (FW2) is likely to be inundated for a significant period of time greater than 2.5 days following all events greater than the 18% AEP (5 yr ARI). As FW2 is located at the entry to the site closure of this crossing is likely to prevent access to the mine site for both light and heavy vehicles. As discussed above the duration of inundation at FW2 can be refined to greater detail if a LIDAR dataset of increased density becomes available.

6.3.1.1 Erosion Protection Measures

The results of the analysis indicate flow velocities at FW2 and FW6 are in excess of 1.9 m/s in events greater than the 5% AEP (20 yr ARI). JDA recommends that at these velocities rip-rap protection be provided upslope and downslope of the floodways and along floodway batters at the specifications outlined in Table 6. If rip-rap is readily available and it is considered to be cost effective a scour control layer is also recommended at all floodways.

TABLE 7: PRELIMINARY HYDRAULIC MODEL RESULTS AT FLOODWAY CROSSINGS

Crossing	18% AEP (5yr ARI)		10% AEP (10yr ARI)		5% AEP (20yr ARI)		2% AEP (50yr ARI)		1% AEP (100yr ARI)	
	Peak Q (m^3/s)	Max Velocity (m/s)	Peak Q (m^3/s)	Max Velocity (m/s)	Peak Q (m^3/s)	Max Velocity (m/s)	Peak Q (m^3/s)	Max Velocity (m/s)	Peak Q (m^3/s)	Max Velocity (m/s)
Floodway Crossing 1A	30.2	0.6	74.3	1.2	66.2	0.9	82.4	1.1	114.5	1.2
Floodway Crossing 1B	30.2	0.6	74.3	1.2	66.2	0.9	82.4	1.1	114.5	1.2
Floodway Crossing 2	23.6	0.7	32.0	0.8	155.1	1.9	454.8	2.6	747.2	2.7
Floodway Crossing 3	63.5	0.8	85.2	0.8	108.5	0.8	130.4	1.0	159.1	1.2
Floodway Crossing 4	54.7	0.8	74	0.9	98.1	1.0	107.4	1.1	129.7	1.1
Floodway Crossing 5	56.2	1.0	76.3	1.1	99.8	1.2	113.9	1.2	136.7	1.3
Floodway Crossing 6	94.7	1.6	125.7	1.7	163.6	1.9	185.5	1.9	221.9	2.0
Floodway Crossing 7	53.9	1.1	74.3	1.2	99.1	1.2	114.3	1.3	138.1	1.4

TABLE 8: SUMMARY OF TIME OF CLOSURE (HOURS) FOR ROAD CROSSINGS 1 TO 7

Vehicle Type	ARI				
	18% AEP (5yr ARI)	10% AEP (10yr ARI)	5% AEP (20yr ARI)	2% AEP (50yr ARI)	1% AEP (100yr ARI)
Floodway Crossing 1A					
Light	0	0	0	3.8	6.4
Heavy	0	0	0	0	0
Floodway Crossing 1B					
Light	0	0	0	0	0
Heavy	0	0	0	0	0
Floodway Crossing 2	6.4	61.3	67.2	67.3	68.4
Light					
Heavy	1.2	44.8	71.9	58.3	67.3
Floodway Crossing 3					
Light	1.7	2.5	3.7	5.5	6.6
Heavy	0	0	0	0	0
Floodway Crossing 4					
Light	0.2	1.3	1.9	2.4	3.5
Heavy	0	0	0	0	0
Floodway Crossing 5					
Light	0	0	1.1	1.8	2.2
Heavy	0	0	0	0	0
Floodway Crossing 6					
Light	5.1	6.3	7.0	8.5	9.4
Heavy	0	0	0	0	0
Floodway Crossing 7					
Light	0	1.2	2.3	2.9	4.6
Heavy	0	0	0	0	0

Note: allowable flood heights for light vehicles = 0.2 m and for heavy vehicles = 0.5 m

6.3.2 Southern Access Road

The southern access road is a 7.5 km stretch of proposed access road running in a north-west direction from Cobra/Gifford Creek Road towards the Study Area (parallel with Gifford Creek). The current alignment has the road crossing a number of minor ephemeral drainage courses (see Figure 27) which ultimately feed Gifford Creek. To prevent obstruction of surface water flows and sheetflow to Gifford Creek we recommend culverts be distributed in a relatively a uniform fashion along this access road (see Figure 27).

To assist future planning and culvert design the contributing catchment area was modelled using MIKE21 to generate a total discharge at the access road cross section for the broader catchment envelope; see Figure 27. A maximum discharge for the 18% to 1% AEP (5, 10, 20, 50,100 yr ARI) and PMP events were generated and converted into a discharge rate per hectare (L/s/ha) to aid culvert design at a later stage. The discharge rate for each ARI event are presented in Table 9.

TABLE 9: PRELIMINARY DISCHARGE RATE/HA FOR SOUTHERN ACCESS ROAD

AEP	Peak Flow at Access Road (m^3/s)	Discharge Rate (L/s/ha)
18% (5 year ARI)	28.4	35.6
10% (10 year ARI)	43.1	54.2
5% (20 year ARI)	57.7	72.5
2% (50 year ARI)	60.1	75.4
1% (100 year ARI)	88.5	111.2
PMP	275.8	346.5

In general, JDA recommends the drainage control plan along the southern access road be based on the following concepts:

- Ensuring culverts are adequately sized to convey adopted design flows beneath the access roads while avoiding adverse impacts on local watercourses. MRWA (2006) guidelines suggest regional road networks convey the 10% AEP (10 year ARI) flood discharge; and
- Minimising erosion of the proposed hydraulic structures up and down slope of the road.

The proposed surface water management design should comprise the following components:

- A series of corrugated or concrete culverts of varying diameters to convey flood waters under the access roads back into the natural watercourse (Gifford Creek).
- A number of minor diversion channels constructed adjacent to the road to intercept runoff from the upslope catchments and direct flow along the road to pass through the culverts at selected locations. All channels should be aligned with a grade sufficient to ensure flow velocities would prevent pooling of water along the channels. A minimum channel slope of 0.1% is recommended.

7. CONCLUSIONS & RECOMMENDATIONS

In summary, JDA has provided an assessment of surface water management around the Yangibana site. Peak flows for the 18% to 1% AEP (5, 10, 20, 50, 100 year ARI) events and the PMP were estimated for the proposed Yangibana Mining Project and for the Lyon River Catchment using a two dimensional (2D) hydrodynamic flood model (MIKE21FM) rain on grid approach.

The two-dimensional (2D) hydrodynamic flood model, MIKE21 FM, was developed to provide hydraulic assessment of flood depth, elevation, discharge flow rates and velocities. The 2D hydraulic model shows the proposed layout of Yangibana North is located within the tributary of Yangibana Creek. The 2D model results also shows that the for all events of up to 1% AEP (100 year ARI) there is likely to be overflow discharging to the existing open pit mine.

Using XP-STORM, a 1D hydraulic model was constructed to produce hydrographs for each river crossing. The road crossings across the haul road and access roads are proposed (by Wave International) to be flush with the natural creek invert (no raised floodways). This will result in periods of closure during storm events, ranging between 0 and 6.4 hours and 0 and 1.2 hours during the (5 year ARI) storm event for light and heavy vehicles respectively. During the 1% AEP (100 year ARI) the closure period has been estimated to be between 0 and 68.4 hours and 0 and 67.3 hours for light and heavy vehicles respectively. Of all the crossings the Lyons River crossing (FW2) is likely to be inundated for the longest duration (2.5 days) following events greater than the 18% AEP (5 yr ARI).

Based on the hydraulic analysis (see Figures 18 to 25) the following comments and associated surface water management recommendations are made:

1. A diversion 2,250 km long diversion channel be constructed from point A to C (Figure 24) to divert channel flows from Yangibana tributary around the Yangibana North pits and back into the Yangibana Creek. Scour protection is recommended (as a minimum) at the outlet of the proposed Yangibana North diversion drain. A flood protection bund is required at the inlet of the diversion channel.
2. To assist future planning and culvert design at the southern access road a discharge rate per hectare (L/s/ha) for the 18% to 1% AEP (5, 10, 20, 50,100 yr ARI) and PMP events were generated. These discharge rates will be used by the project engineers to design culvert specifications.
3. The Lyons River crossing (FW2) is likely to be inundated for a significant period of time (>2.5 days) following all events greater than the 18% AEP (5 yr ARI). As FW2 is located at the entry to the site this is likely to prevent access to the mine site for both light and heavy vehicles.
4. In the event that a more refined LIDAR data set becomes available the serviceability/closure time at FW2 should be updated accordingly.

Once a detailed site layout is provided JDA recommend detailed design of surface water structures in and around the process plant, pits and waste dumps to prevent 'sediment laden/contaminated' runoff transported off-site into downstream environments (i.e. Lyons River). All conceptual designs and specifications should be based on the 1% AEP (100 year ARI) design event and around the proposed mining plan and mine infrastructure layout (to be provided by Hastings). These works should be completed as part of a detailed Surface Water Management Plan (SWMP).

Recommended work to be completed as part of, or in parallel to, the SWMP development will include:

- Assessment of sediment management requirements to minimise the risk of sediment discharge from the developed area, based on the physical properties of the surface soil samples collected during the site visit.

- Provision of any surface water and hydrological information and assessments required to supplement other related environmental impact assessments of the proposed mine development.

In order to complete the required work components the following data and information are required:

- Proposed mine plans, including pit shell designs and extents (over time), proposed locations for mine infrastructure such as waste dumps, ROM pad, other mine infrastructure areas (office, workshops, accommodation) and access and haul roads.

- Proposed mine closure plans, including details of rehabilitation requirements and areas to be rehabilitated. Final pit shell designs will be required to define the locations of abandonment/safety bunds based on DMP guidelines, if these are not already included in the mine closure plan.

- Any available data and information from existing geotechnical investigations carried out on site (from test pits) to support design studies and construction specifications for surface water management infrastructure.

8. REFERENCES

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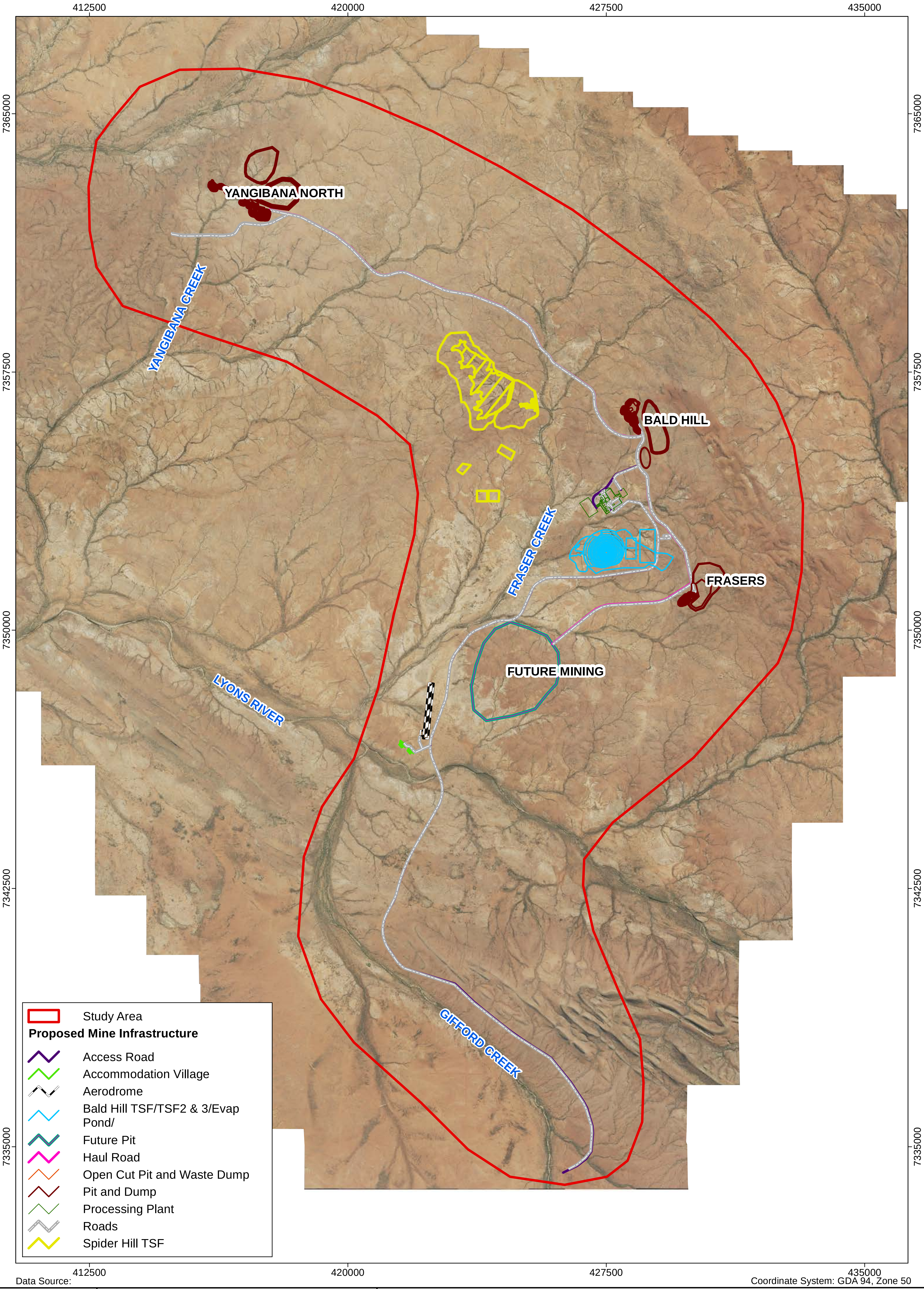
Figures

Note: Due to size restrictions the figures associated with this report could not be included. Contact Lara Jefferson for a copy of all figures – lara.jefferson@enperitus.com



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JDA

Job No. J6297

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0 1,000 2,000 3,000 4,000 Metres

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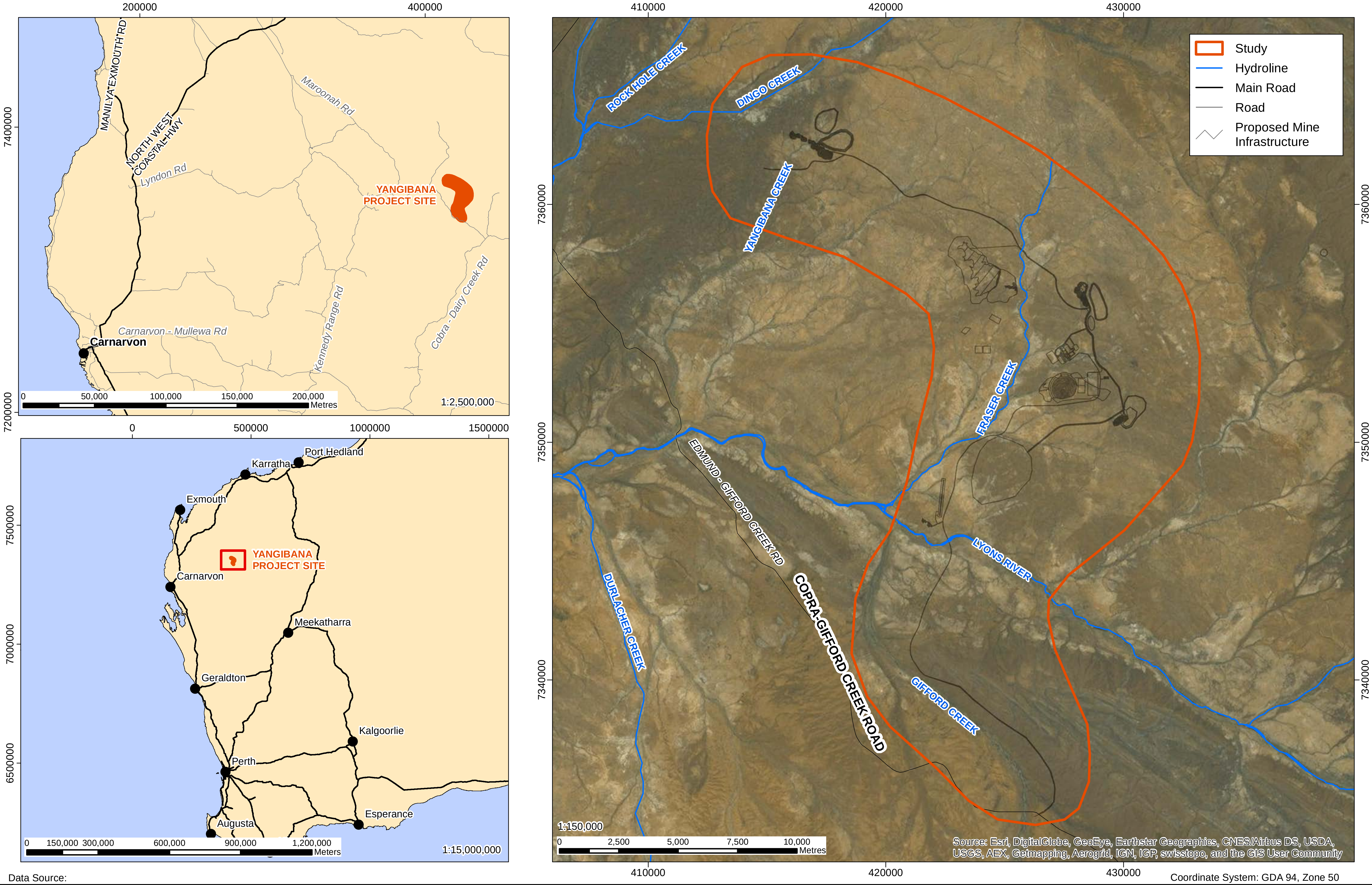
Hastings Technology Metals Limited

Yangibana Rare Earths Project

Figure 2: Proposed Mine Infrastructure and Aerial Imagery



Data Source:

Coordinate System: GDA 94, Zone 50

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Job No. J6297
Scale @ A3

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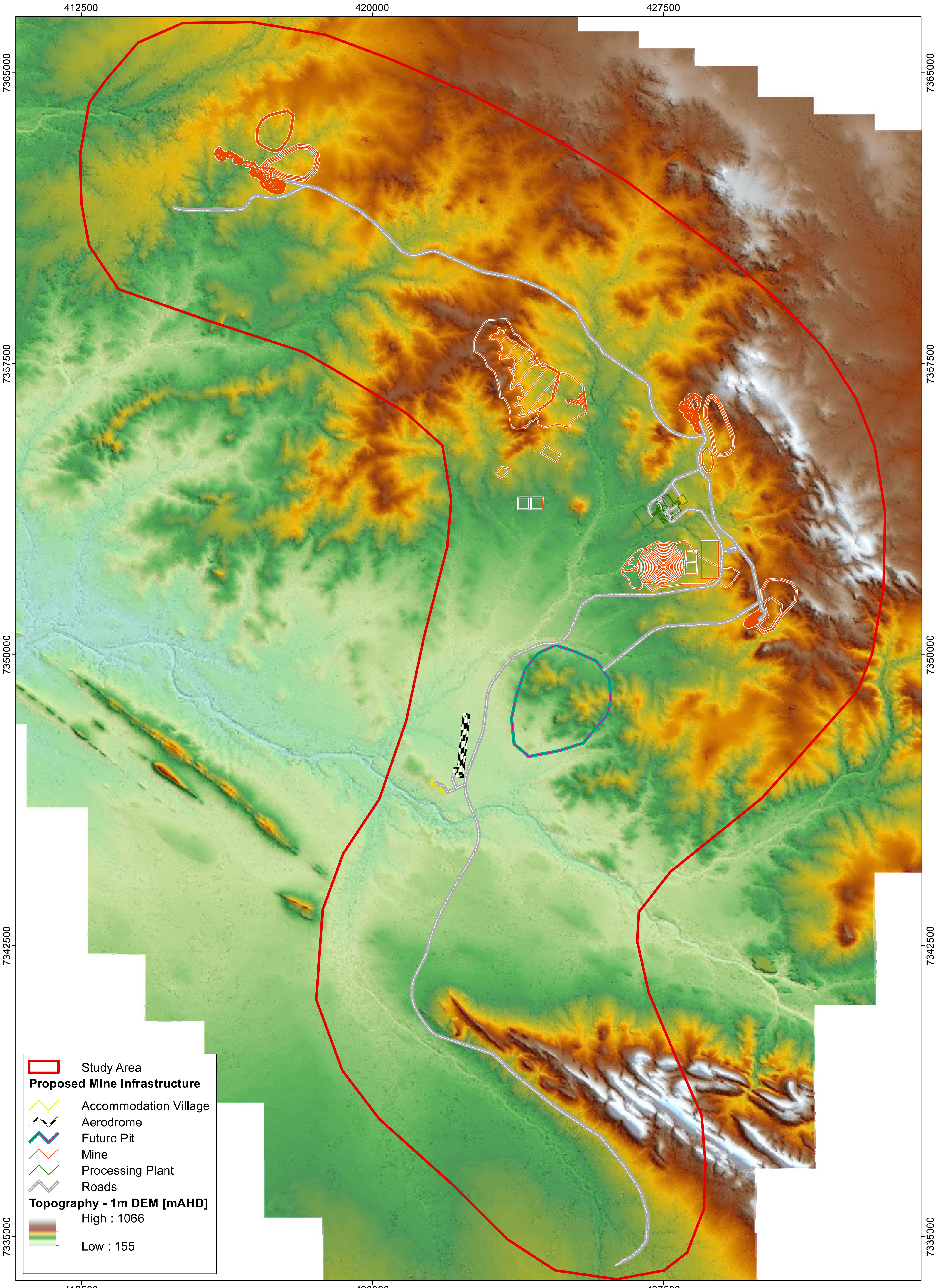
Yangibana Rare Earths Project
Figure 1: Location Plan



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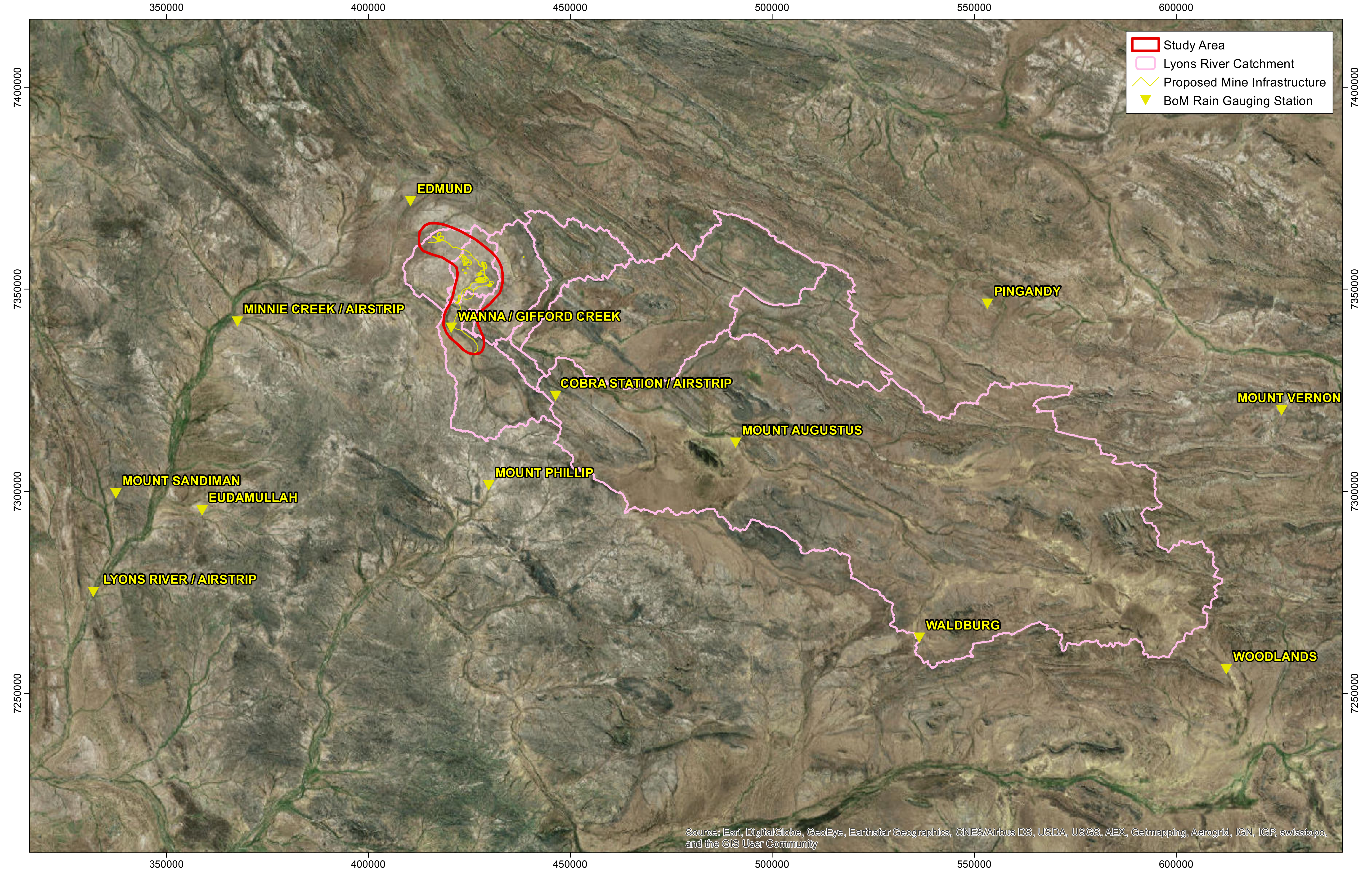
Yangibana Rare Earths Project

Figure 3: Site Topography



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Job No. J6297

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N

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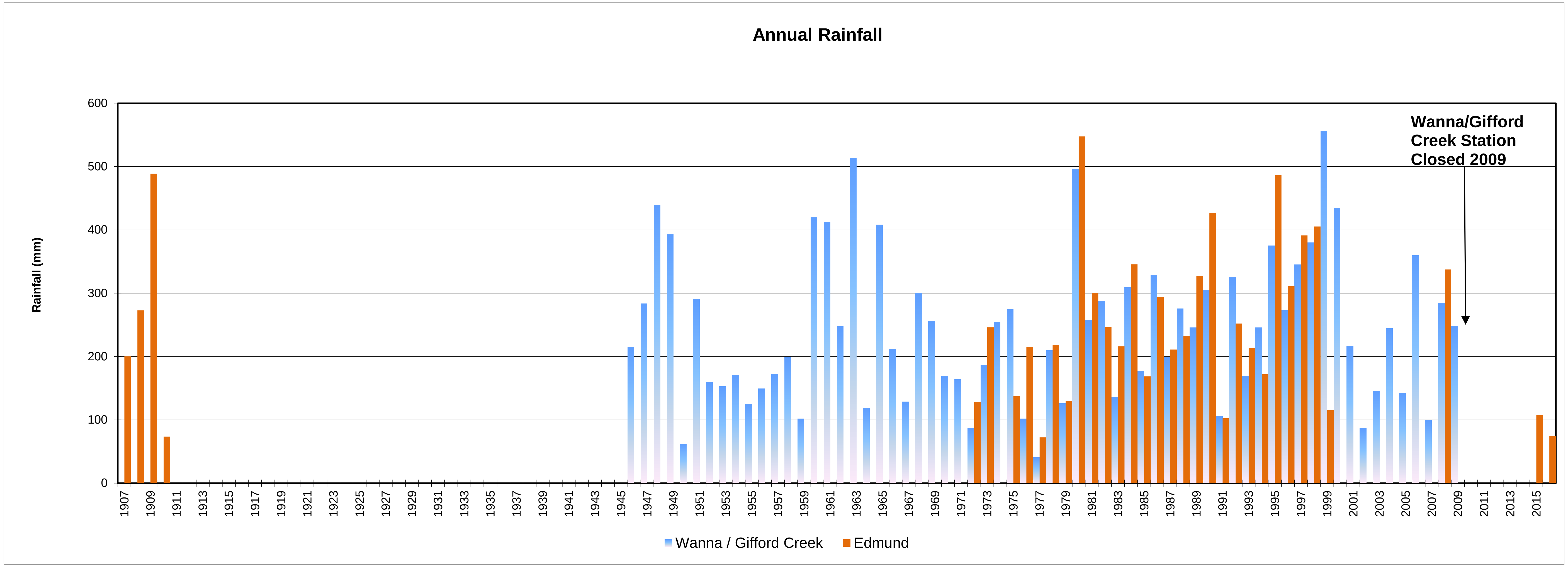
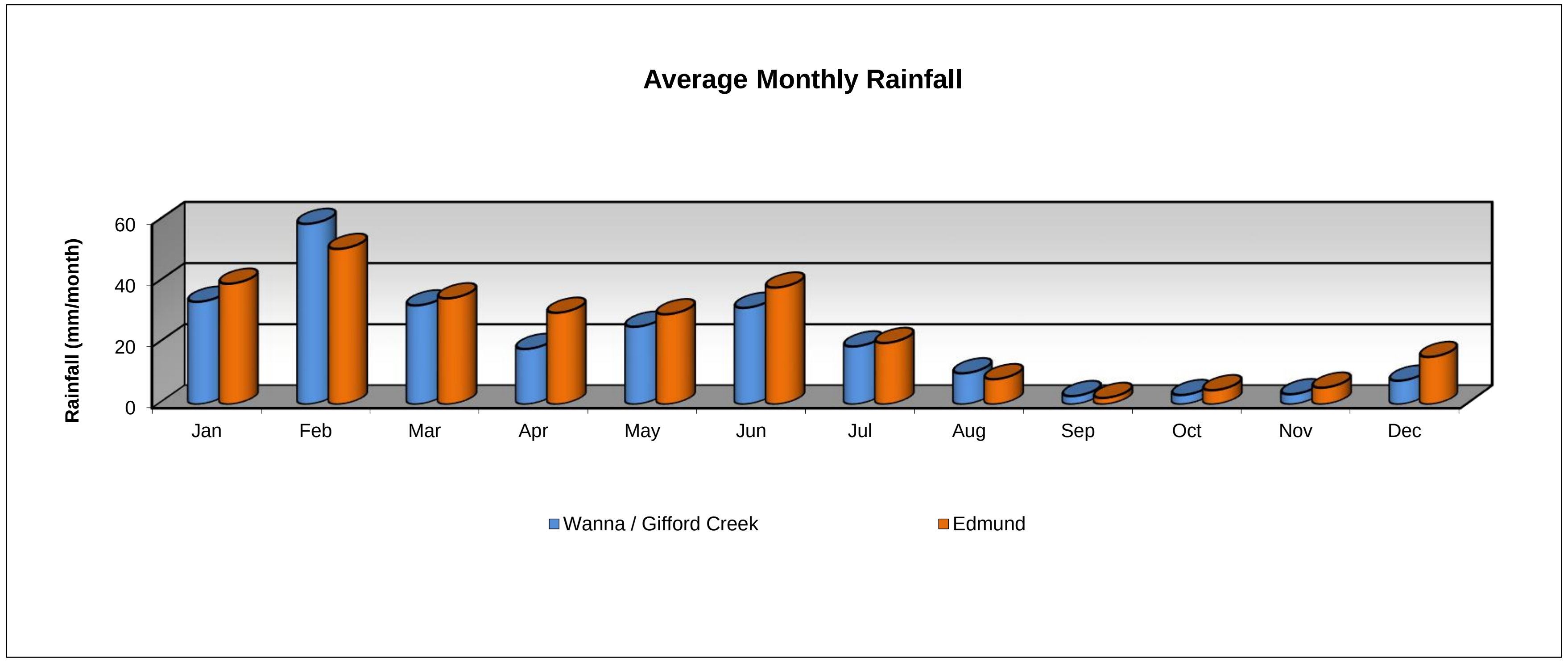
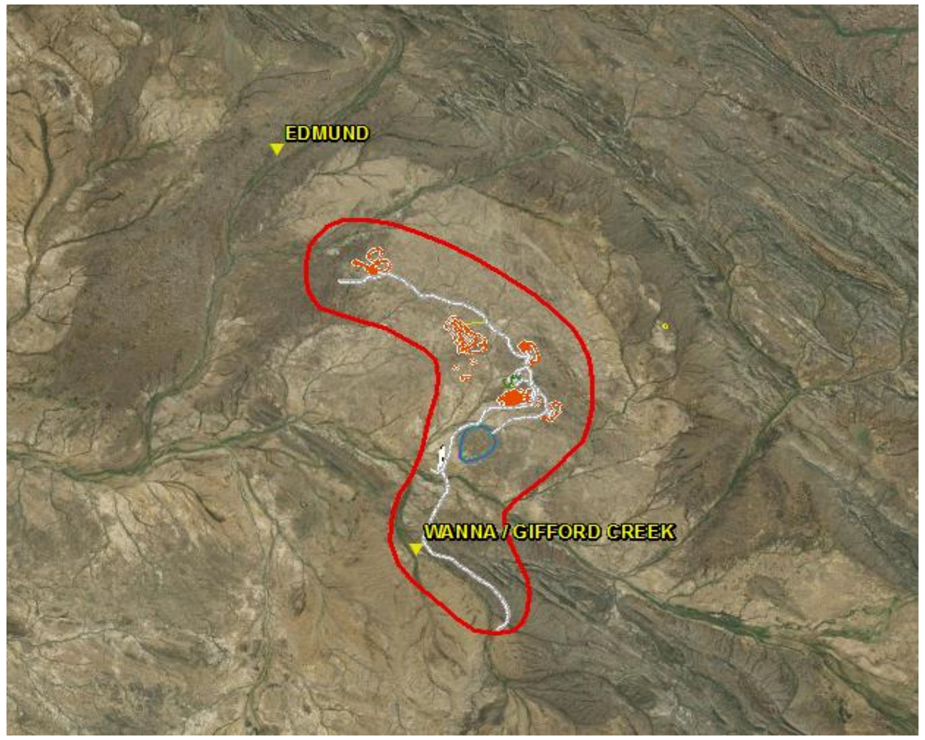
Figure 4: Regional Rainfall Station Locations







Data Source: Gifford Creek/Wanna Rain Gauging Station ID: 7028 and Edmund Rain Gauging Sation ID: 7164 (Bureau of Meteorology, 2016);

Job No. J6297

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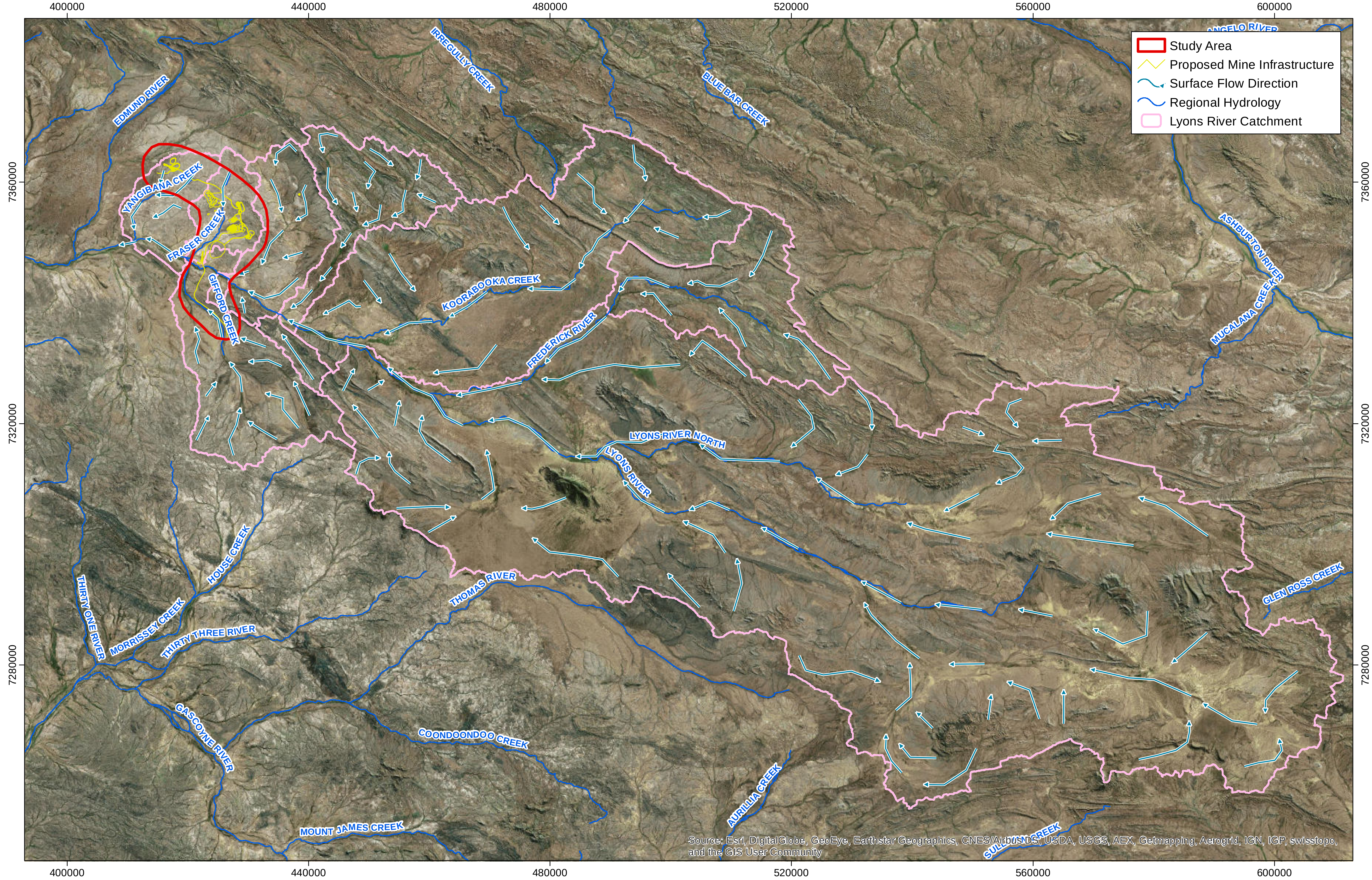
Figure 5: Edmund and Wanna / Gifford Creek Rainfall Station Annual and Average Monthly Rainfall



Data Source: Australian Hydrological Geospatial Fabric (GeoFabric) V3.0 (Bureau of Meteorology, 2016);

Coordinate System: GDA 94, Zone 50

JDA

Job No. J6297

Scale: 1:600,000@A3

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Figure 6: Lyons River Catchment Mapping Plan

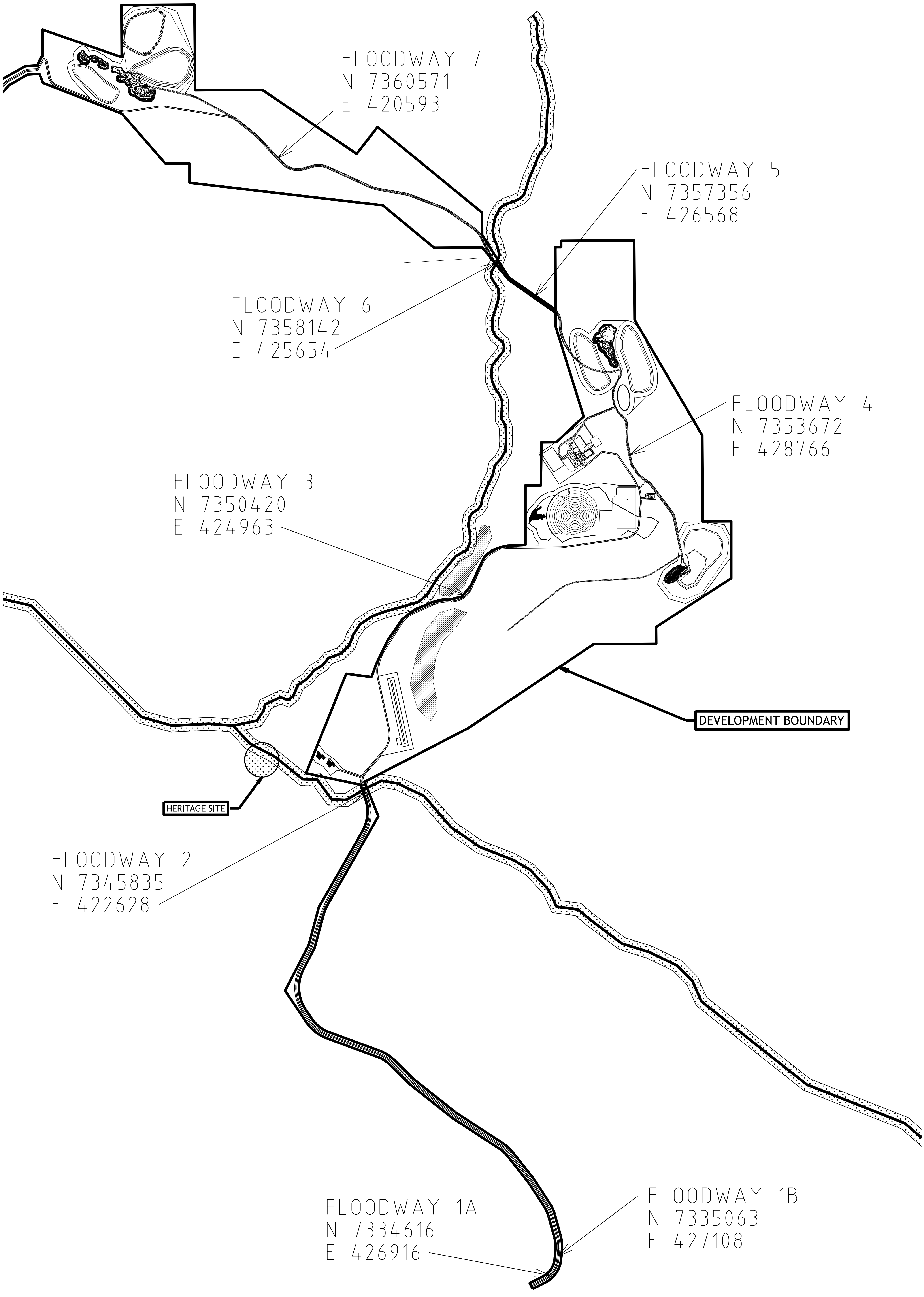
Appendix A

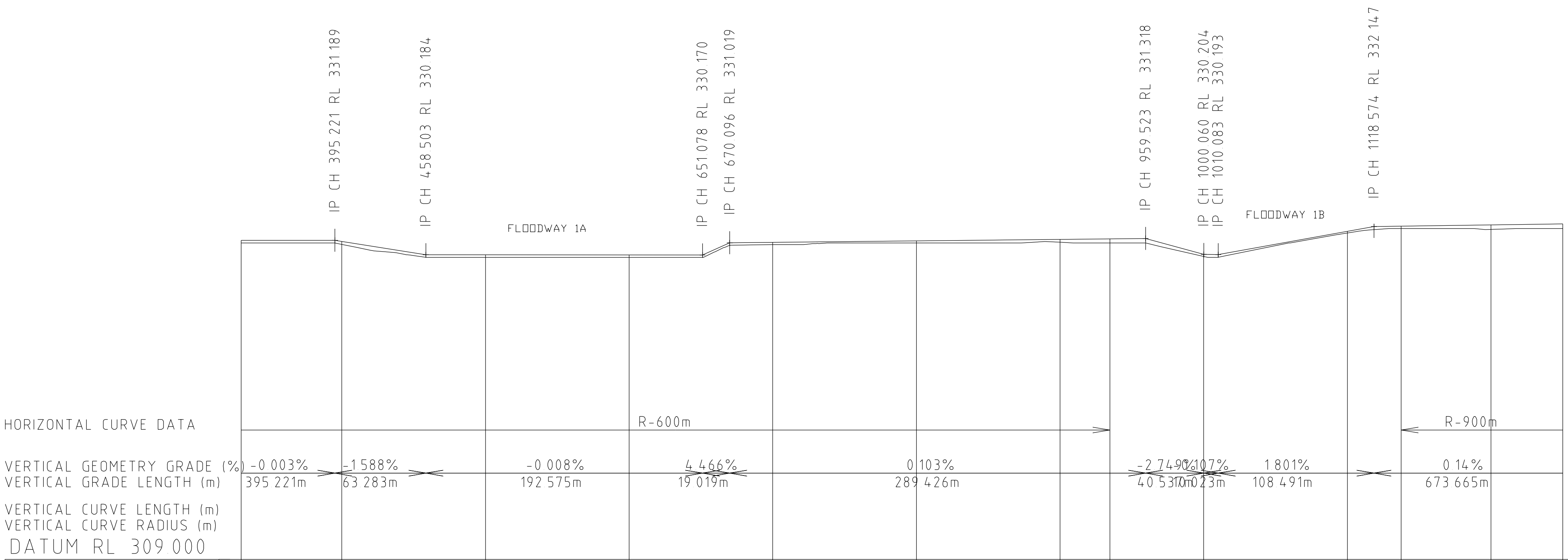
Note: Due to size restrictions the figures associated with this Appendix could not be included. Contact Lara Jefferson for a copy of all figures – lara.jefferson@enperitus.com

Appendix B

Yangibana Floodway Layout and Design

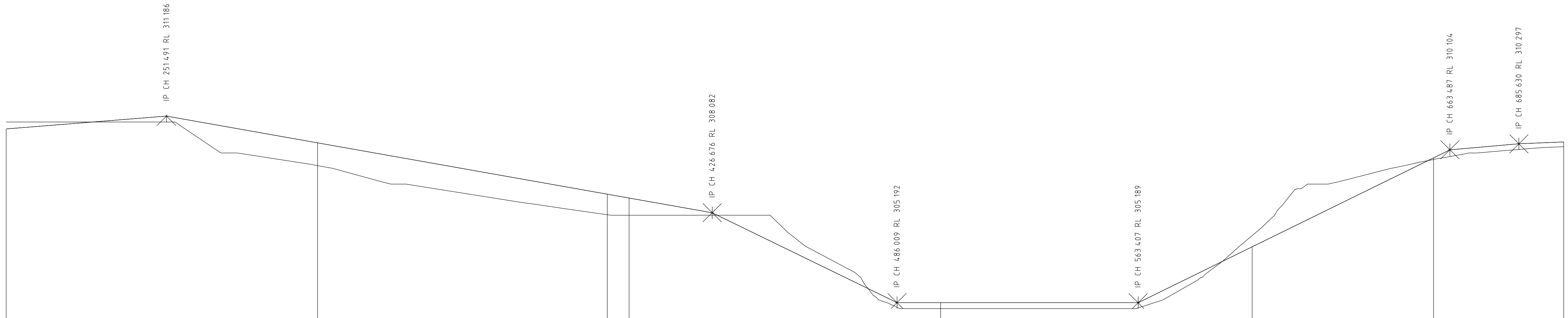
(Wave International, November 2016)


FLOODWAY 7
N 7360571
E 420593
FLOODWAY 5
N 7357356
E 426568
FLOODWAY 6
N 7358142
E 425654
FLOODWAY 4
N 7353672
E 428766
FLOODWAY 3
N 7350420
E 424963
DEVELOPMENT BOUNDARY
HERITAGE SITE
FLOODWAY 2
N 7345835
E 422628
FLOODWAY 1A
N 7334616
E 426916
FLOODWAY 1B
N 7335063
E 427108



SHOULDER LEVELS RHS													
SHOULDER LEVELS LHS													
NAT SURFACE ON ROAD CENTRELINE	331 000	330 903	330 000	330 000	330 886	331 000	331 051	331 000	330 066	331 693	332 000	331 946	332 000
CUT / FILL DEPTH	-0 191	-0 210	-0 181	-0 173	-0 164	-0 153	-0 205	-0 292	-0 139	-0 119	-0 173	-0 315	-0 331
DESIGN LEVELS ON ROAD CENTRELINE	331 191	331 113	330 181	330 173	331 050	331 153	331 256	331 292	330 205	331 812	332 173	332 261	332 331
CHAINAGE	330	400	500	600	700	800	900	934 694	1000	1100	1137 514	1200	1250
SUPER ELEVATION													

LONGITUDINAL SECTION - FLOODWAY 1



HORIZONTAL CURVE DATA: R-1000m; R300m

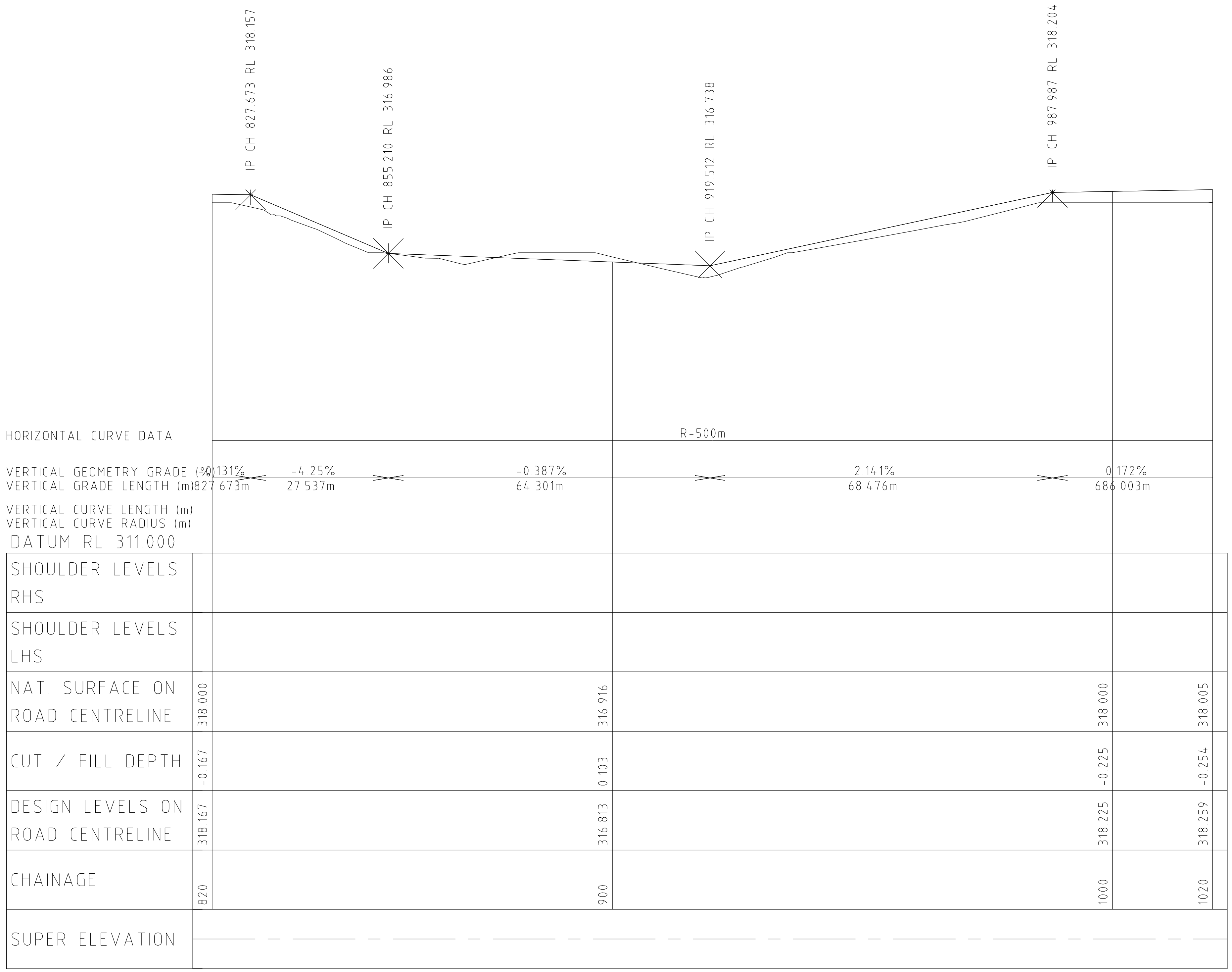
VERTICAL GEOMETRY GRADE (%) / VERTICAL GRADE LENGTH (m):

VERTICAL GEOMETRY GRADE (%)	0.802%	-1.772%	-4.871%	-0.004%	4.912%	0.869%	0.437%
VERTICAL GRADE LENGTH (m)	251.491m	175.185m	59.333m	77.398m	100.08m	22.143m	418.758m

VERTICAL CURVE LENGTH (m)
VERTICAL CURVE RADIUS (m)
DATUM RL 299.000

SHOULDER LEVELS RHS								
SHOULDER LEVELS LHS								
NAT. SURFACE ON ROAD CENTRELINE	311.000	309.597	308.017	308.000	305.000	307.349	309.794	310.204
CUT / FILL DEPTH	0.227	-0.730	-0.661	-0.555	-0.191	0.362	-0.054	-0.156
DESIGN LEVELS ON ROAD CENTRELINE	310.773	310.327	308.678	308.555	305.191	306.986	309.848	310.360
CHAINAGE	200	300	393.009	400	500	600	658.274	700
SUPER ELEVATION								

LONGITUDINAL SECTION - FLOODWAY 2



LONGITUDINAL SECTION - FLOODWAY 3

HORIZONTAL CURVE DATA — R250m; R200m

VERTICAL GEOMETRY GRADE (%) — -0 556%; -1 036%; -1 353%; 0 331%; 2 014%; -0 093%

VERTICAL GRADE LENGTH (m) — 239 965m; 179 722m; 218 498m; 17 837m; 279 885m; 279 361m

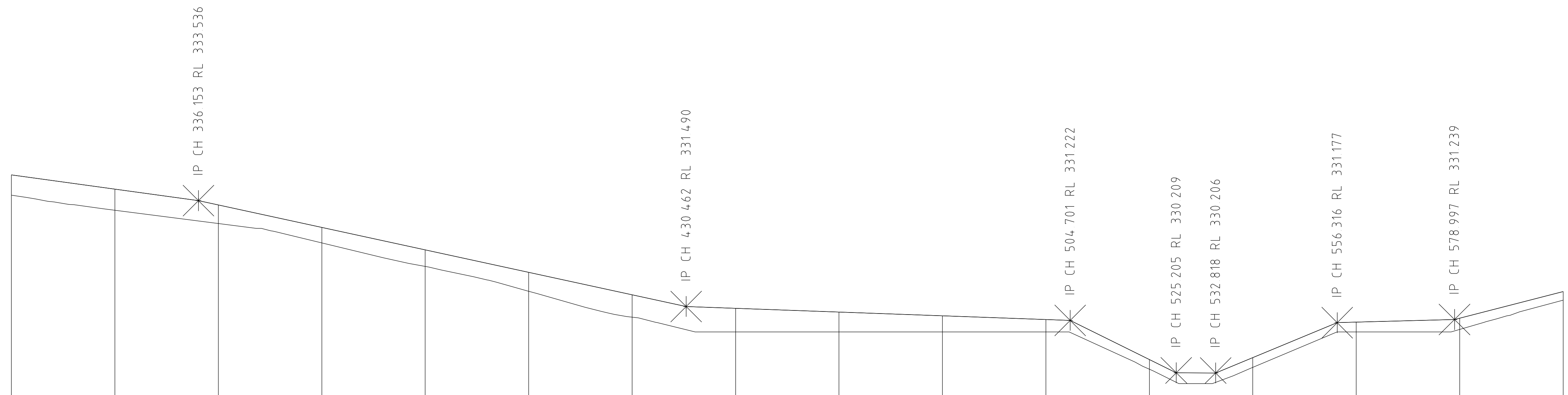
VERTICAL CURVE LENGTH (m)

VERTICAL CURVE RADIUS (m)

DATUM RL 320 000

SHOULDER LEVELS RHS													
SHOULDER LEVELS LHS													
NAT SURFACE ON ROAD CENTRELINE	336 000	335 000	334 381	334 086	332 879	332 624	332 000	331 818	333 729	335 777	336 162	336 485	336 528
CUT / FILL DEPTH	-0 285	-0 442	-0 294	-0 319	-0 563	-0 491	0 238	-0 372	-0 475	-0 440	-0 590	-0 433	-0 352
DESIGN LEVELS ON ROAD CENTRELINE	336 285	335 442	334 675	334 406	333 443	333 115	331 762	332 190	334 203	336 217	336 752	336 918	336 880
CHAINAGE	200	300	373 974	400	475 755	500	600	700	800	900	926 574	959 021	1000
SUPER ELEVATION													

LONGITUDINAL SECTION - FLOODWAY 4



HORIZONTAL CURVE DATA

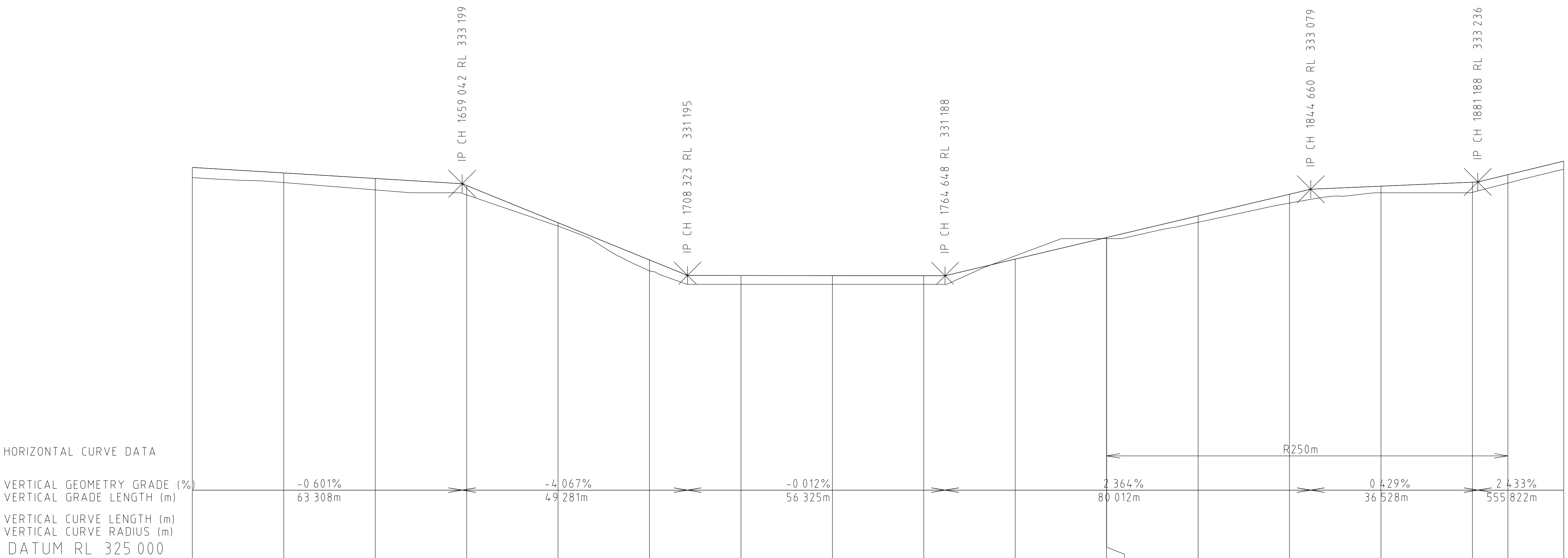
VERTICAL GEOMETRY GRADE (%)	-1 376%	-2 169%	-0 362%	-4 936%	-0 044%	4 131%	0 272%	2 572%
VERTICAL GRADE LENGTH (m)	265 06m	94 308m	74 24m	20 503m	7 613m	23 498m	22 681m	36 392m

VERTICAL CURVE LENGTH (m)
VERTICAL CURVE RADIUS (m)

DATUM RL 324 000

SHOULDER LEVELS RHS																
SHOULDER LEVELS LHS																
NAT. SURFACE ON ROAD CENTRELINE	333 641	333 350	333 094	332 719	332 265	331 784	331 283	331 000	331 000	331 000	331 000	330 279	330 313	331 000	331 048	331 614
CUT / FILL DEPTH	-0 393	-0 408	-0 358	-0 300	-0 320	-0 367	-0 434	-0 456	-0 383	-0 311	-0 239	-0 187	-0 189	-0 187	-0 216	-0 165
DESIGN LEVELS ON ROAD CENTRELINE	334 033	333 758	333 452	333 019	332 585	332 151	331 717	331 456	331 383	331 311	331 239	330 466	330 503	331 187	331 264	331 779
CHAINAGE	300	320	340	360	380	400	420	440	460	480	500	520	540	560	580	600
SUPER ELEVATION																

LONGITUDINAL SECTION - FLOODWAY 5



SHOULDER LEVELS RHS																	
SHOULDER LEVELS LHS																	
NAT. SURFACE ON ROAD CENTRELINE	333.333	333.224	333.063	332.954	332.273	331.293	331.000	331.000	331.000	331.623	332.000	332.000	332.356	332.776	333.000	333.011	333.213	333.512
CUT / FILL DEPTH	-0.221	-0.210	-0.251	-0.206	-0.073	-0.240	-0.193	-0.191	-0.189	0.073	-0.023	-0.024	-0.140	-0.193	-0.145	-0.220	-0.183	-0.182
DESIGN LEVELS ON ROAD CENTRELINE	333.554	333.434	333.313	333.160	332.347	331.533	331.193	331.191	331.189	331.551	332.023	332.024	332.496	332.969	333.145	333.231	333.396	333.694
CHAINAGE	1600	1620	1640	1660	1680	1700	1720	1740	1760	1780	1799.987	1800	1820	1840	1860	1880	1887.77	1900
SUPER ELEVATION																		

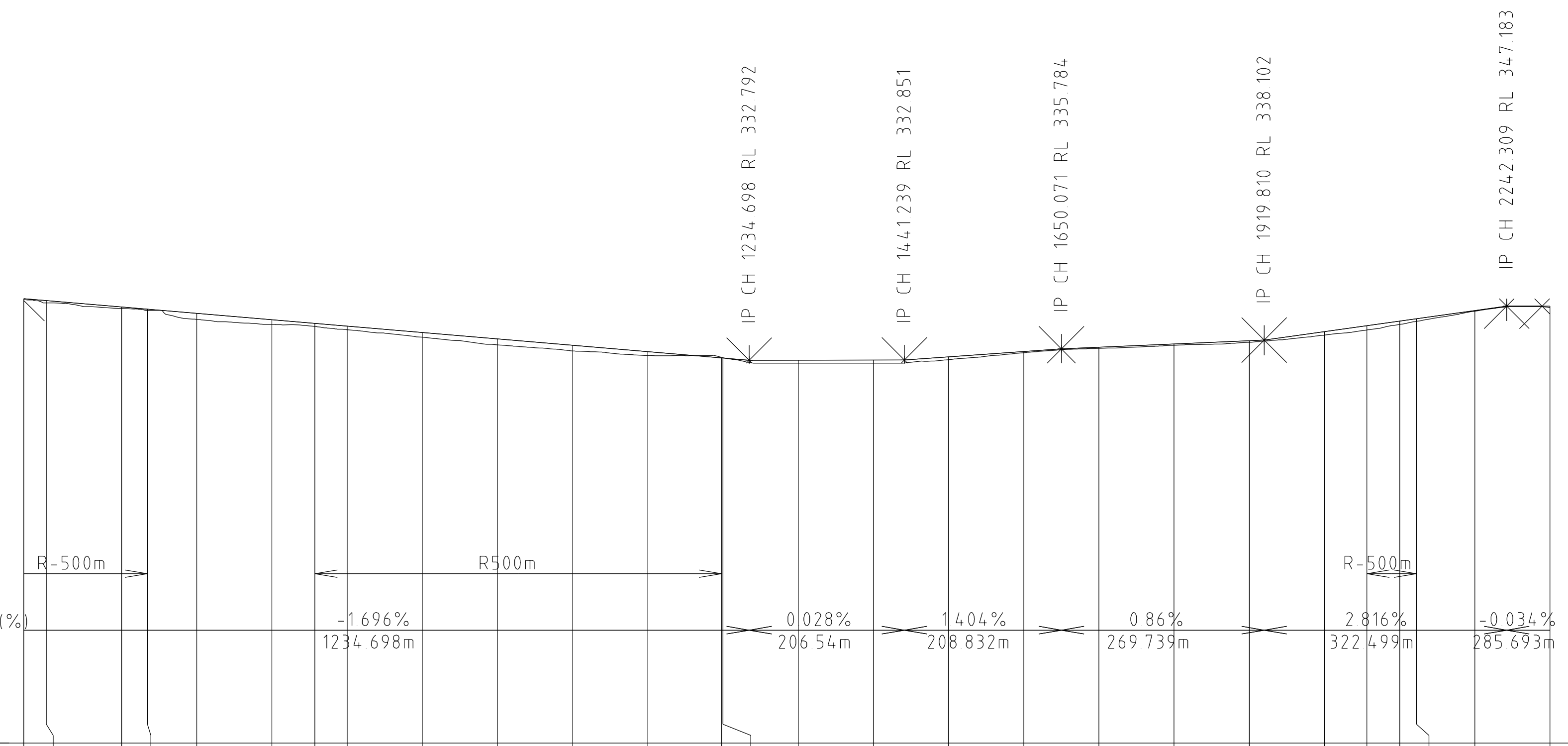
LONGITUDINAL SECTION - FLOODWAY 6

HORIZONTAL CURVE DATA

VERTICAL GEOMETRY GRADE (%)
VERTICAL GRADE LENGTH (m)

VERTICAL CURVE LENGTH (m)
VERTICAL CURVE RADIUS (m)

DATUM RL 231 000



CHAINAGE	SHOULDER LEVELS RHS	SHOULDER LEVELS LHS	NAT SURFACE ON ROAD CENTRELINE	CUT / FILL DEPTH	DESIGN LEVELS ON ROAD CENTRELINE	SUPER ELEVATION
270			348 912	-0 242	349 154	
300			348 000	-0 645	348 645	
400			346 533	-0 416	346 949	
434 373			346 000	-0 366	346 366	
500			343 646	-1 607	345 253	
600			342 273	-1 284	343 557	
656 888			341 747	-0 845	342 592	
700			340 899	-0 962	341 861	
800			338 872	-1 293	340 165	
900			336 852	-1 617	338 469	
1000			335 249	-1 524	336 773	
1100			334 001	-1 076	335 077	
1198 009			333 549	0 135	333 414	
1200			333 457	0 076	333 381	
1300			332 000	-0 811	332 811	
1400			332 000	-0 839	332 839	
1500			332 932	-0 744	333 676	
1600			334 783	-0 298	335 080	
1700			335 916	-0 296	336 213	
1800			336 753	-0 320	337 072	
1900			337 553	-0 379	337 932	
2000			339 440	-0 920	340 360	
2056 301			340 813	-1 132	341 946	
2100			342 290	-0 886	343 176	
2122 557			343 113	-0 699	343 811	
2200			345 810	-0 182	345 992	
2300			346 782	-0 382	347 163	

LONGITUDINAL SECTION - FLOODWAY 7