Bombora Project
Lake Roe Flood Depth Assessment

Prepared for:

Ramelius Resources

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1. BACKGROUND

The proposed Roe Mining Project is located approximately 100 km due east of Kalgoorlie and about 45 km southwest of Ramelius Resources' Lake Rebecca Project in the Goldfields Region of Western Australia (refer Figure 1.1). The Project is proposed to consist of the Bombora and (potentially) Kopai Crescent open cut pits. Both pits are located in proximity to Lake Roe, with the Kopai Cresent pit footprint extending partially over the lake basin. Both areas are likely to be prone to flooding from water ponding within Lake Roe following large rainfall events.

To reduce the risk of flooding to the pits from runoff within Lake Roe, it is likely that a flood protection levee will be required around the perimeter of the pit areas (at a minimum). The following assessment has been completed to provide estimates of the level of flood protection provided by different flood levee elevations by estimating flood inundation elevations for different flood recurrence intervals.

As part of the assessment to establish the elevation of the flood protection bund, AQ2 completed a 2D flood model to characterise the flood behaviours within the lake and a water balance model to predict the lake's flood levels for different recurrence intervals.

The proposed Bombora Project footprint is located in the southwest corner of Lake Roe. An overview of the proposed Project layout is presented in Figure 1.2. The proposed Project is situated on a sub-area of Lake Roe and comprises three separate open pits—referred to as the North Pit, Central Pit, and South Pit. These pits are located within a low-lying landscape that is prone to inundation during significant rainfall events. A layout plan showing the location and relative position of the pits is provided in Figure 1.3.

Given the location of the Project within a salt lake environment, the design of the flood protection bund may need to consider both overland flow from the external catchment and the storage of rainfall within the local lake sub-area and the greater Lake Roe system.

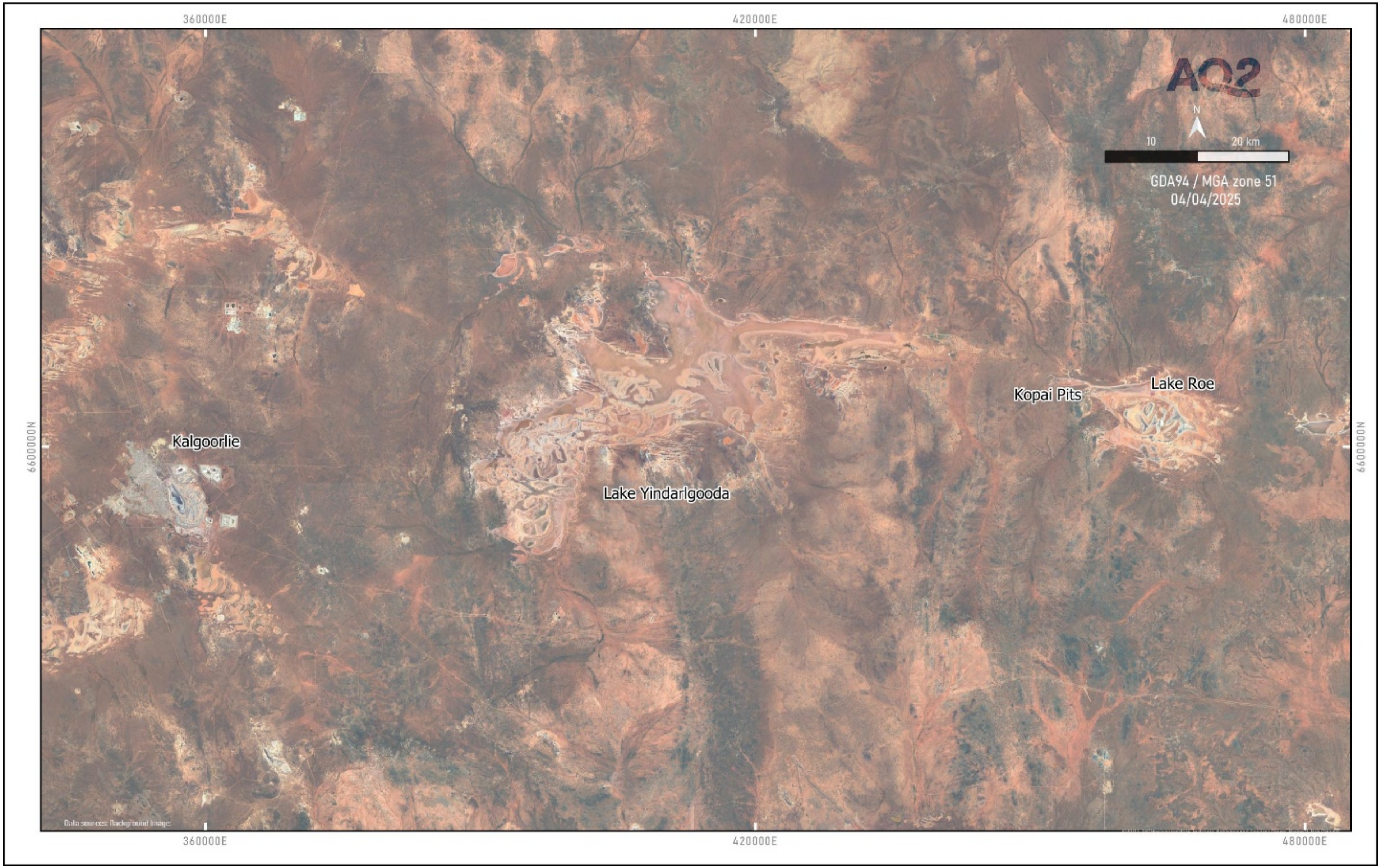
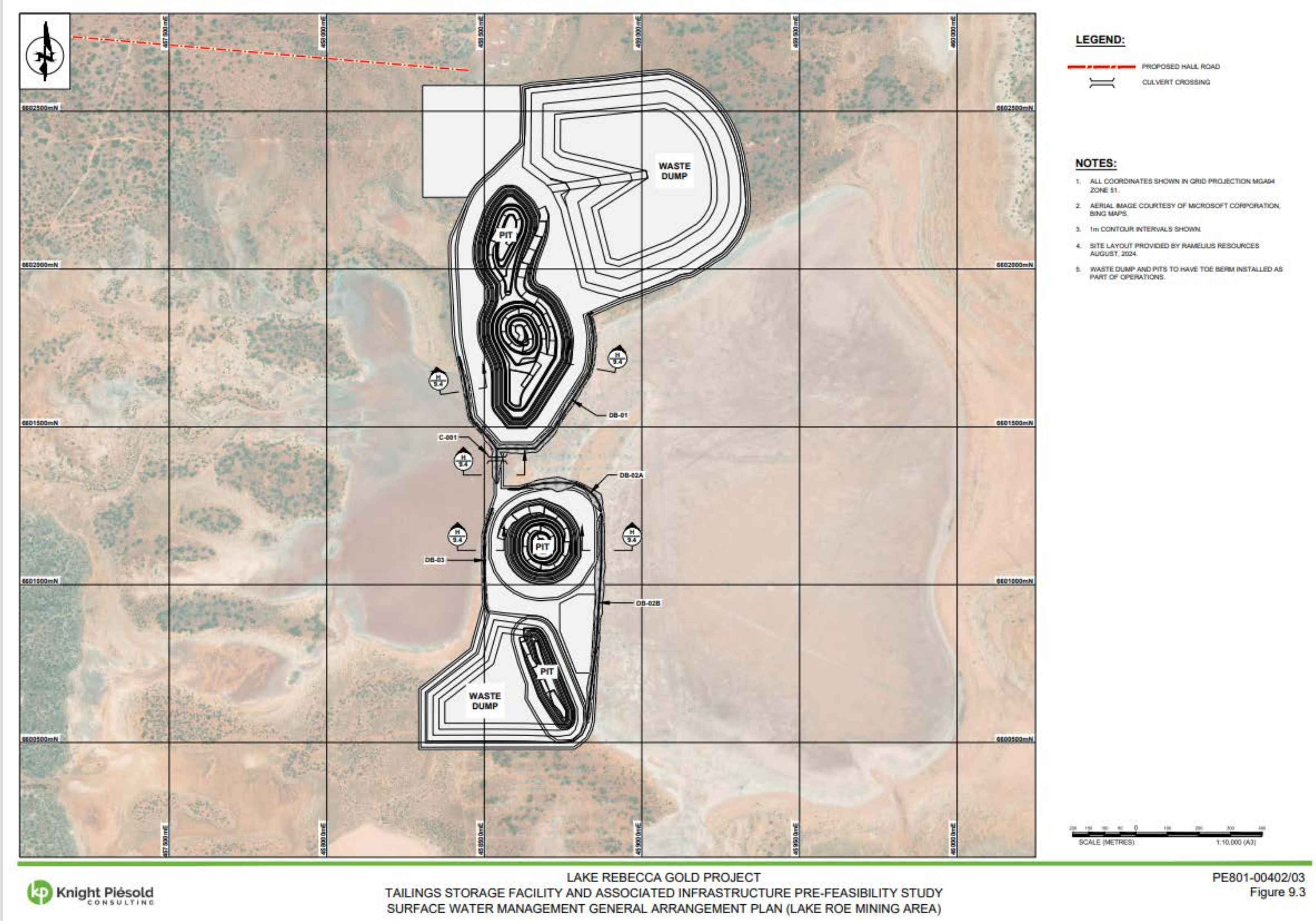


Figure 1.1 Project Location

Figure 1.2 Bombora and Kopai Mine Location



LEGEND:

🟥	PROPOSED HAUL ROAD
⌶	CULVERT CROSSING

NOTES:

1. ALL COORDINATES SHOWN IN GRID PROJECTION MGA94 ZONE 51.
2. AERIAL IMAGE COURTESY OF MICROSOFT CORPORATION, BING MAPS.
3. 1m CONTOUR INTERVALS SHOWN.
4. SITE LAYOUT PROVIDED BY RAMELIUS RESOURCES AUGUST, 2024.
5. WASTE DUMP AND PITS TO HAVE TOE BERM INSTALLED AS PART OF OPERATIONS.

Knight Piésold CONSULTING

LAKE REBECCA GOLD PROJECT
TAILINGS STORAGE FACILITY AND ASSOCIATED INFRASTRUCTURE PRE-FEASIBILITY STUDY
SURFACE WATER MANAGEMENT GENERAL ARRANGEMENT PLAN (LAKE ROE MINING AREA)

PE801-00402/03
Figure 9.3

Figure 1.3 Bombora Mine Layout (Supplied by Knight Piesold)

2. HYDROLOGY OVERVIEW

The area colloquially referred to as Lake Roe is a complex of interconnected smaller lake sub-areas which span approximately 90 km in length (west to east), situated within a broader paleo-drainage system that historically had flowed from northwest to southeast. As the elevation gradient of the paleo-drainage system has reduced with time and the climate dried, the system has become a number of salt lakes which become terminal drainage points under most runoff events.

The region lies within an arid zone characterised by large dryland creek systems and highly variable hydrological conditions which range from prolonged droughts to episodic flood events. These extremes influence the region's physical, chemical, and biological characteristics.

2.1 Climate and Rainfall Measurements

The Project area is classified as a semi-arid climate with dry, hot summers and cool mild winers. As shown in Figure 2.2, there are a number of regional weather stations which collect rainfall data. The location and data availability from each of these weather stations is summarised in Table 2.1.

Table 2.1 Regional Weather Stations

Weather Station	Lake Roe Distance (km)	Direction from Lake Roe	Data Collection Period
Karonie	30	South	1915-1986
Cowarna Downs	40	South-southwest	1968-2020
Kalgoorlie Airport	100	West	1939-2025
Gindalbie	95	Northwest	1918-2025

Cowarna Downs station is the closest station with a medium length of rainfall record (40 years). SILO data from Cowarna Downs station (BOM Station ID 12220) was considered the most representative analogue of the climatic conditions of the Lake Roe area based on proximity and observed data availability for assessments focussed on the medium-term conditions within the lake (such as the calibration of the lake water balance model). The station is situated approximately 40 km south-southwest of Lake Roe, with rainfall records available between 1970s to 2010. A SILO rainfall dataset was obtained between 1970 and October 2024.

It was noted the Cowarna Downs station SILO dataset:

- Likely best represents Lake Roe's rainfall for 1970–2010, when actual measurements were taken at the weather station.
- Rainfall data outside these years would be interpolated from nearby stations and is likely to be less representative of Lake Roe catchment's rainfall.
- Used SILO's interpolation techniques to derive temperature and evaporation values as this was not recorded at the Cowarna Downs station. The nearest station this data was recorded was at Kalgoorlie 110 kms away.

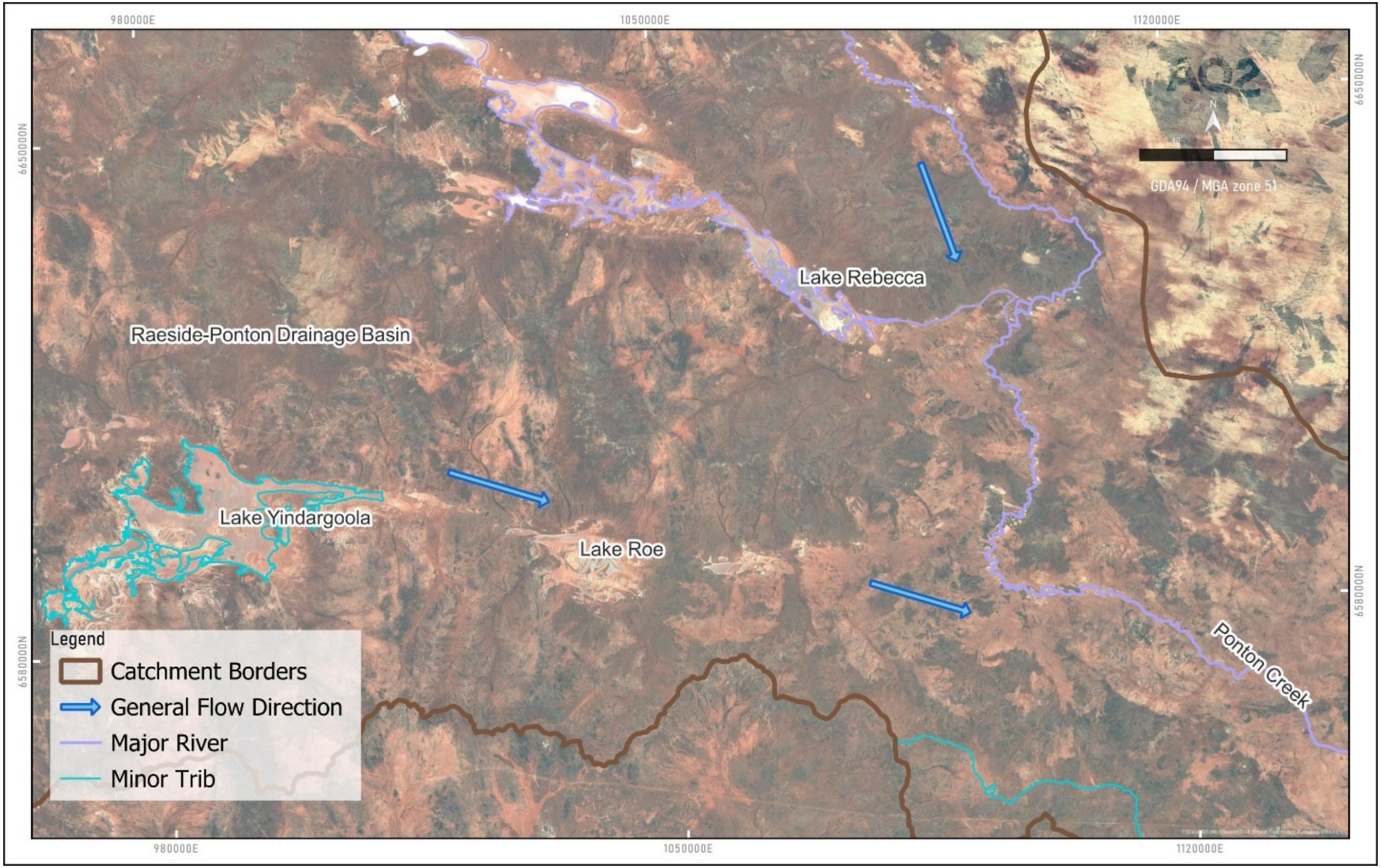


Figure 2.1 Regional Hydrology

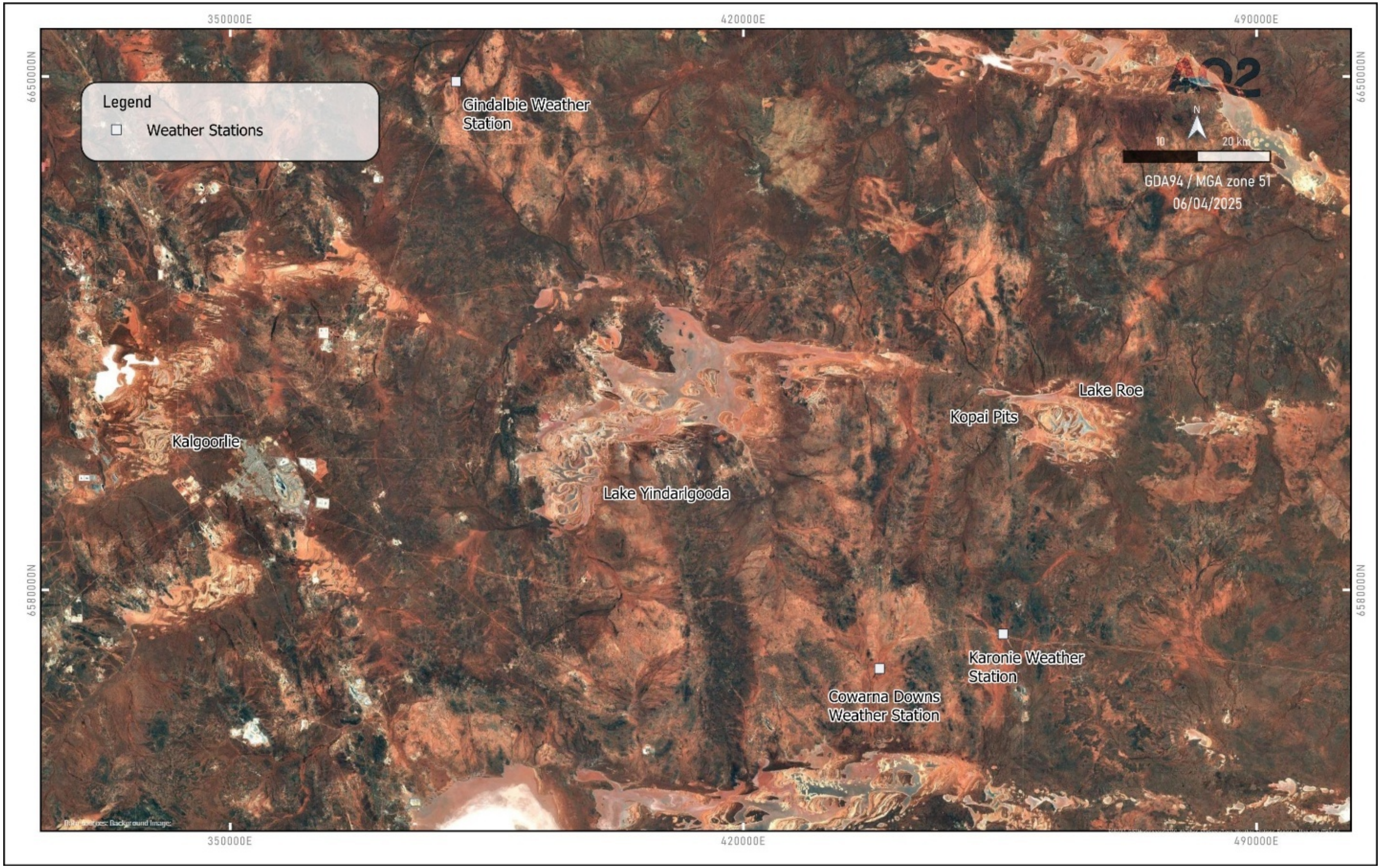


Figure 2.2 Regional Weather Stations

Gindalbie Station (BOM Station ID 12247), located 95 km northwest of Lake Roe, is the closest station with a long-term record to the project, but it was considered too distant to be a realistic reflection of the rainfall which actually fell at Lake Roe in the past. This weather station has recorded rainfall events which are greater in magnitude than rainfall events recorded at either the Karonie or Cowarna Downs weather stations. Given the longer duration rainfall record (and larger rainfall events), the Gindalbie Weather Station rainfall data has been used to derive synthetic rainfall data for use in the lake water balance (discussed further below). Even though the weather station is located ~100km from the lake, there are no topographic/climatic reasons why those rainfall patterns could not occur at Lake Roe.

A summary of the Cowarna Downs station SILO dataset is as follows:

- Long-term average annual rainfall of 260.7 mm.
- Annual average Class A pan evaporation rate of 2,420 mm and an annual average Morton's shallow lake evaporation rate of 1,560 mm (from SILO interpolation at Cowarna Downs).
- Long-term average maximum temperature of 26 °C.
- Monthly average rainfall, Class A pan evaporation, Morton's shallow lake evaporation, maximum and minimum temperature (1970–2024) as shown in Figure 2.3.
- Daily rainfall sequence as shown in Figure 2.4.

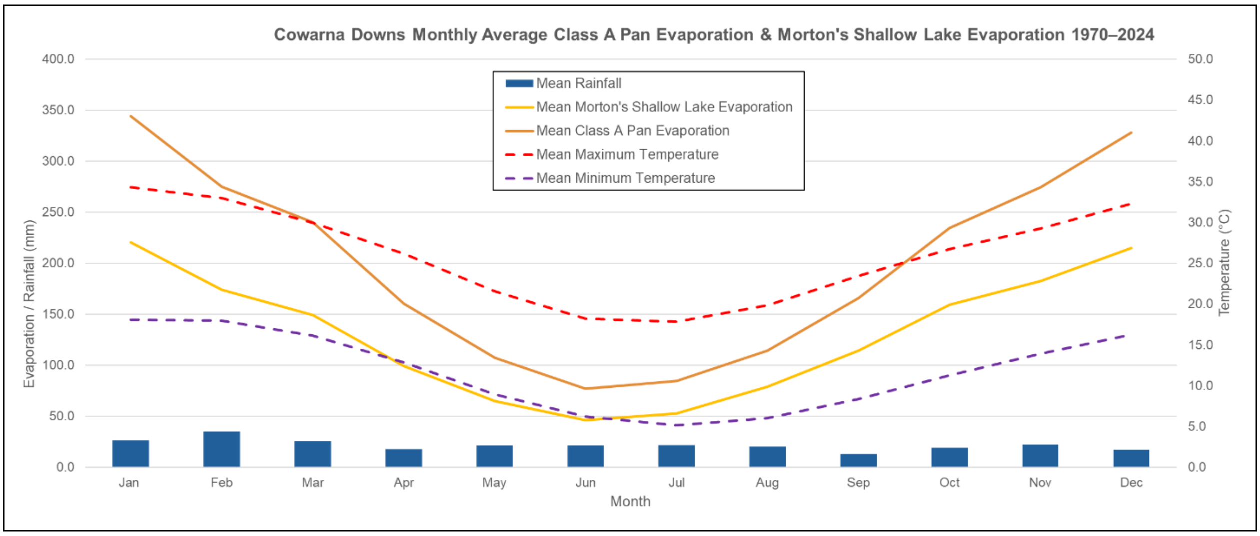


Figure 2.3 Cowarna Downs Monthly Average Climate Characteristics (1970–2024)

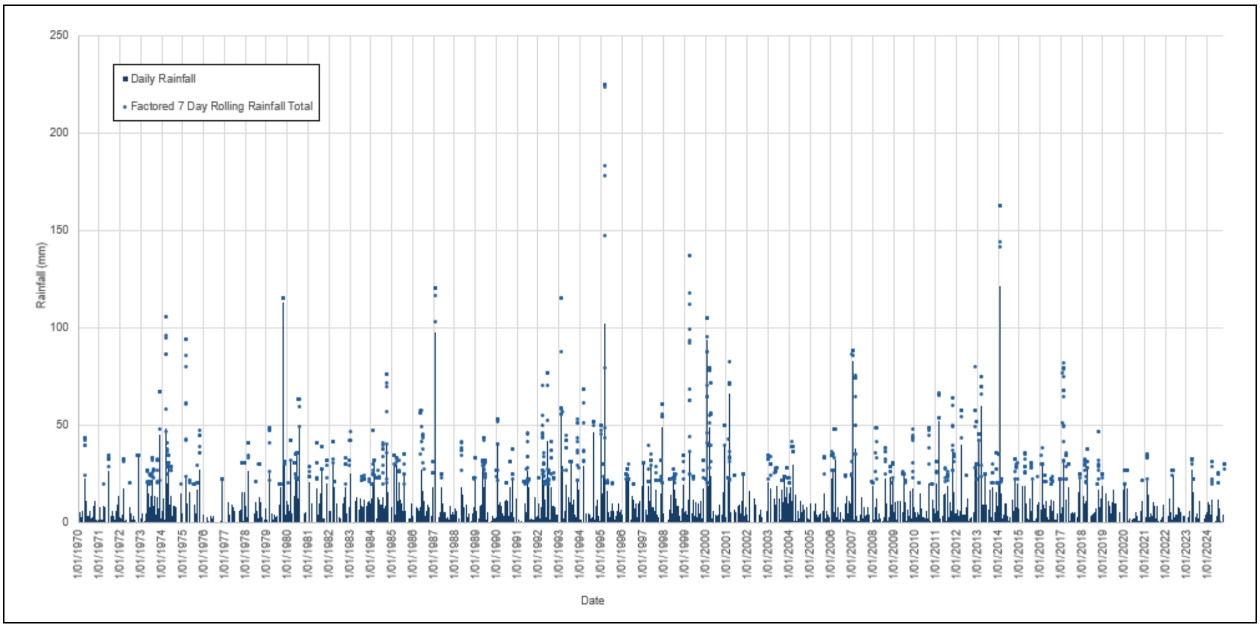


Figure 2.4 Cowarna Downs Rainfall Metrics (1970–2024)

2.2 Design Rainfall

2.2.1 Probability Terminology

Australian Rainfall and Runoff (ARR) (Ball, et. Al 2019) recommends the use of Annual Exceedance Probability (AEP) defining flood probability, so has been adopted throughout this report. AEP is defined as the probability or likelihood of an event occurring or being exceeded within any given year, usually expressed as a percentage. This new terminology supersedes the Annual Recurrence Interval (ARI) terminology adopted in the earlier revision of ARR (Institution of Engineers, Australia 1987). The relationship between ARI and AEP is defined below.

$$AEP = 1 - \exp\left(\frac{-1}{ARI}\right)$$

For example, a 1 in 100 ARI event would occur on average once every 100 years and has 1% change of occurring in particular year (i.e. 1% AEP), while a 1 in 50 ARI event has 2% chance of occurring (2% AEP).

The likelihood of a flood event exceeding an AEP design criterion over the operational lifetime of the Bombora operation (in the order of 10 years) was calculated. The exceedance probability is computed using the following equation (as per ARR):

$$p = 1 - \exp\left(-\frac{L}{Y}\right)$$

Where:

Y = the return period of a given flood event (ARI)
L = the design life in years
P = the exceedance probability during the design life

The likelihood of an event (rainfall or flooding event) exceeding different AEP magnitudes over 10 years is summarised in Table 2.2. Note that there is still a 10% probability of an event exceeding a 1% AEP magnitude occurring over a 10-year project life.

Table 2.2 Exceedance Probability

Mine Life (years)	Probability of Exceedance (%) for AEP							
	39.4% (2yr ARI)	18.1% (5yr ARI)	10% (10yr ARI)	5% (20yr ARI)	2% (50yr ARI)	1% (100yr ARI)	500yr	1000yr
10	99%	86%	63%	39%	18%	10%	2%	1%

2.2.2 Intensity-Frequency-Duration Data

Intensity-Frequency-Duration (IFD) data for the Project was extracted from the BoM website from the 2016 datasets. The 2016 IFD data is presented in Table 2 . Given the flooding mechanism of most concern for this project is inundation caused by storage of runoff volume within Lake Roe, longer duration rainfall events are likely to be the most relevant for the assessments. Throughout this report, the 72-hour rainfall event has been used for the assessments. The 1% AEP rainfall depth from a 72-hour event is predicted to be 191 mm.

Table 2 Intensity - Frequency - Duration Rainfall Data

Duration	63.20%	50%	20%	10%	5%	2%	1%	0.2%	0.1%
9 hour	24	28.5	44.2	56.6	70.2	90.3	108	158	158
12 hour	26	30.8	48.1	61.8	76.9	99.2	119	174	204
18 hour	28.8	34.2	53.8	69.5	87.1	113	135	198	232
24 hour	30.8	36.7	57.9	75.2	94.8	123	147	216	253
30 hour	32.3	38.5	61	79.6	101	131	157	227	264
36 hour	33.5	39.9	63.6	83.2	106	137	165	237	275
48 hour	35.3	42.1	67.5	88.7	113	147	176	254	295
72 hour	37.6	44.9	72.5	95.7	123	159	191	279	325
96 hour	39	46.7	75.6	99.9	128	166	199	295	345
120 hour	40.1	48	77.6	103	131	170	203	304	356

2.2.3 Probable Maximum Precipitation (PMP)

As part of this study, an assessment has been completed that considers the risk of flooding/within the lake sub-areas during a PMP event. Consistent with the other flood events which have been considered in this study, the PMP event used for this study is the 72-hour rainfall event.

The BoM has developed several methods for estimating the PMP rainfall depth depending on storm duration for the Project region. To determine the appropriate PMP rainfall intensity for the site, two methods were reviewed: the GTSMR (Generalised Tropical Storm Methodology for Regions) and the (GSAM Generalised Short-Duration Method) . This was necessary as the mine site is located within the transition zone between the GTSMR and GSAM regions. Calculations were carried out using both approaches, including the GSAM summer and autumn scenarios. Both methods were completed with the rainfall depths from the GTSMR considered the most appropriate for this assessment, as they were significantly larger and more consistent with the rainfall depths for rare rainfall events estimated by the IFD curves. A summary of the PMP rainfall depths for a point location and for a catchment-wide application (considering a reduction in average rainfall depth over a large catchment) are summarised in Table 2.3.

Table 2.3 Probable Maximum Precipitation

ARI	72hr Rainfall (mm)
PMP (Point Location)	1215
PMP (1500 km^2)	650

2.2.4 Lake Roe Inflow Catchment

Lake Roe commands a 1,300 km^2 catchment draining predominantly from the north and south of the lake (refer Figure 2.5). Within this catchment are a number of drainage lines, with these drainage lines contribute runoff to different sub-areas of the lake. The hydrological response within the lake is influenced by the size of the catchment to each lake sub-area and the relative storage capacity of each of the sub-areas.

To the west of the catchment area that has been defined for Lake Roe for this assessment lies another chain of salt lakes. For this assessment, it is assumed that runoff from catchments reporting to this chain of salts lakes terminates at the salt lakes and does not contribute runoff through the paleo-drainage system to Lake Roe under any magnitude runoff event. The likelihood of this occurring has not been assessed for this project, but would require much more extensive detailed terrain data to do so.

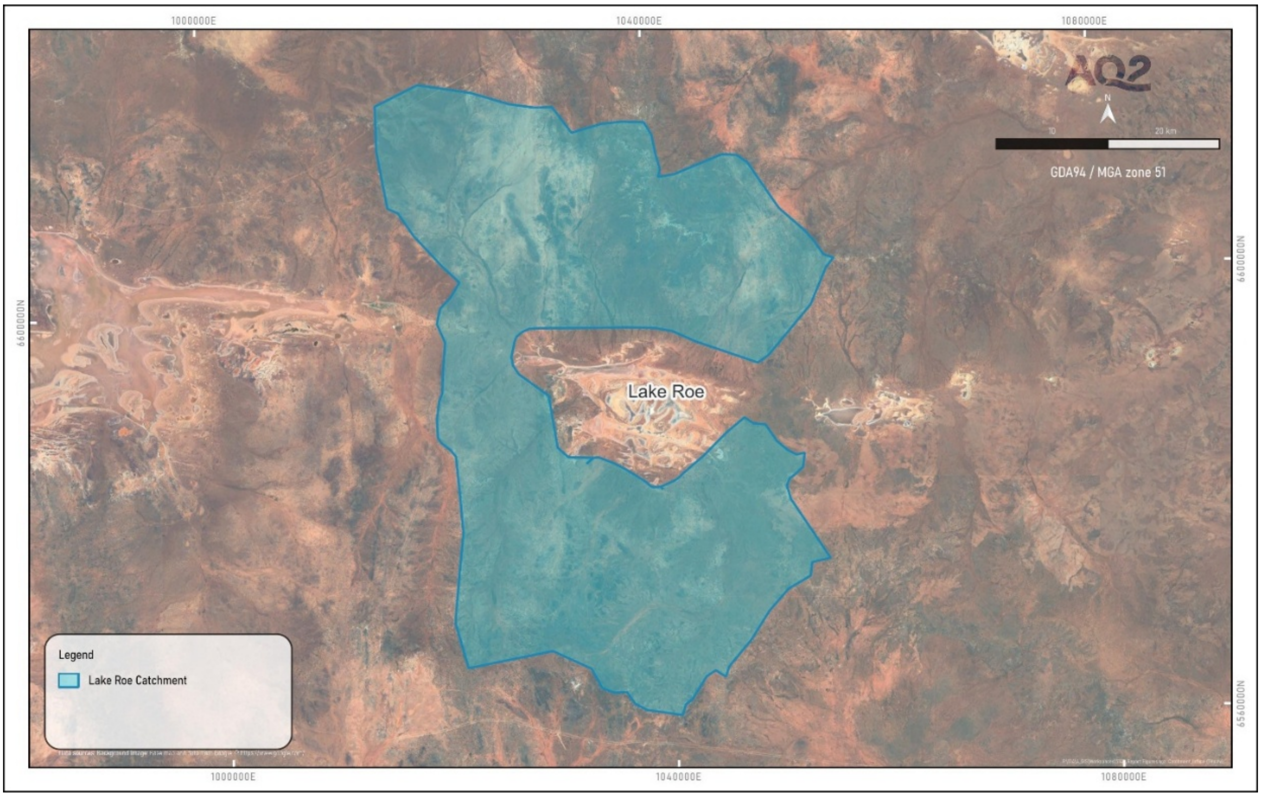


Figure 2.5 Lake Roe Adopted Full Catchment Area

3. LAKE HYDRAULIC CONCEPTUALISATION

The flow behaviour within Lake Roe between different lake sub-areas has been assessed to assist in determining how to prepare a lake water balance model for the project. The conceptualisation has been completed on the following basis:

- Define catchment areas for the main drainages reporting to different parts of the lake.
- Define runoff hydrographs for flood events reporting to the lake from the sub-catchment areas for a design storm event using a hydrological model (RORB).
- Simulate the hydraulics of the flow through the lake sub-areas to characterise how the lake sub-areas become connected, where local saddles between the sub-areas constrain flow between the lake sub-areas. This has been achieved by simulating the sub-catchment inflow hydrographs within a 2D hydraulic flood model.
- Estimate water level inundation within Lake Roe for a single design rainfall event (in particular close to the Bombora Project area), assuming the lake is dry at the commencement of the design storm event.

The approach to the above points is summarised in more detail in the sections below, with the observations used to develop the lake water balance model (discussed in Section 4). The lake water balance model is required as the flood frequency due to the storage of runoff within the lake requires consideration of antecedent rainfall conditions and different duration events. For example, does the 1% AEP wettest year result in a higher level of flooding than a 1% AEP 72-hour event, or are two 10% AEP events in quick succession equally as likely as a 1% AEP event and result in a higher flood elevation.

3.1 Sub-Catchment Definition

Using a combination of detailed 1m LiDAR elevation data, publicly available elevation data and aerial photography information, catchment areas for the main drainage lines reporting to Lake Roe were defined. The sub-catchment areas defined for Lake Roe are shown in Figure 3.1.

Figure 3.1 Lake Roe Sub-Catchment Areas

3.2 Catchment Runoff Estimation

The runoff behaviour from the sub-catchments to the lake has been simulated by preparing a RORB hydrology model to quantify runoff volumes and rates using the following steps:

- RORB hydrology models were developed for a representative large and small sub-catchment to estimate flow hydrographs and runoff volumes forthe20% AEP, 1% AEP and PMP rainfall events from different sized catchments. Catchments B and I (refer Figure 3.1) were selected for the RORB models to represent a large and small catchment respectively.
- A separate single design rainfall hyetograph (rainfall intensity temporal pattern during a storm) was selected for a 72-hour storm event for each of the 20% AEP, 1% AEP and PMP rainfall events using ARR defined design temporal patterns.
    - As recommended by the latest ARR guidance, the design IFD rainfall depths used to define the 20% AEP and 1% AEP events were increased by a factor of 20% to reflect the input of climate change on rainfall depths (on the basis of the IFDs being derived from historic rainfall data and to reflect projections of impacts to future rainfall depths). No factors were applied to the PMP rainfall depths to account for climate change. The Long-Term (2080 period) Medium RCP4.5 model projection was used as the basis for selection of the climate change multiplier.
- Rainfall losses were applied to the design hydrographs within the RORB model. The following losses were adopted:
    - 20% AEP and 1% AEP – Runoff Coefficient 35% (based on Flavell 2012b).
    - PMP - Continuing Loss 3mm/hr (as per ARR 2019 Guidelines, Book 8 Section 4.3.4.3.).
    - The adopted Runoff Coefficients include an allowance for increased rainfall losses due to the impact of climate change (due to drier soil conditions). The adopted runoff coefficients stated above for the 20% AEP and 1% AEP events have been reduced by 10% from ARR recommended regional values to reflect this. No changes to the PMP values were applied to account for climate change.
- The key parameters within the RORB models (Kc and m), which assist in defining the attenuation of runoff through the drainage lines were adopted as follows:
    - Kc was calculated using equation 7.6.25 from chapter 6.2.1.5 of Book 7 of Australian Rainfall and Runoff (ARR, 2019) for the arid interior . The calculated Kc value for Catchment B was 6.27, the Kc value for Catchment I was 3.15.
    - The exponent “m” is the RORB parameter that describes the nonlinearity of a catchment’s storage routing. The standard value used for ungauged catchments of 0.8 was adopted (Laurenson et al 2010).
- The resulting runoff hydrographs (runoff rate with time) from Catchment B (large catchment) and Catchment I (small catchment) were used as the basis to estimate runoff hydrographs for the other sub-catchments. The other sub-catchments were classified as either large or small, and hydrographs defined by scaling the flow rate based on their relative catchment size to Catchments B and I (as applicable).

Note that the exact storm and hydrograph selected are largely unimportant for this assessment for the following reasons:

- The rainfall hyetograph and runoff hydrographs that were defined are used within the 2D flood model (discussed below), which in turn is used to characterise the flow characteristics within the Lake Roe sub-areas. The 2D flood model is not directly used to define the flood levels.
- The adopted rainfall loss model adopted was an initial loss - proportional loss model. All rainfall hyetographs result in the same volume of water running off the sub-catchment areas.
- Similarly, the choice of model Kc and m values is largely unimportant for this assessment.

Further note that the adoption of the climate change multipliers which were applied to rainfall and rainfall loss inputs were conservatively chosen from 2080 climate change projections.

3.3 Flood Modelling Setup

The flood response within Lake Roe was simulated by creating a 2D flood model using the Hydrologic Engineering Center's River Analysis System (HEC-RAS) Version 6.7 Beta (USACE 2025). The 2D model was developed to predict inundation extents resulting from the 20%, 1% AEP and PMP rainfall events, with only the 1% and PMP results shown in this section for brevity.

The basis for the 2D model is the 1m LiDAR elevation data provided to AQ2 by Ramelius Resources on 26 February 2025. Figure 3.2 shows the provided terrain data and the 2D model domain applied.

The general 2D model build details are as follows, with a model setup shown spatially in Figure 3.3:

- A computational mesh spacing of 100 m x 100 m was applied to the 2D flow area.
- A refined mesh spacing of 20 m x 20 m was applied at the location of the lake -sub areas.
- A roughness coefficient of 0.06 was adopted across the model domain as a representative/ average roughness coefficient across the full model domain.
- Nineteen inflow boundaries (A–S) were established around the model boundary, with each boundary corresponding to a delineated catchment as discussed above and shown in Figure 3.1.
- An outflow boundary condition was applied to the eastern edge of Lake Roe, corresponding to a low point in a saddle which may allow outflow of water from the lake to the downstream paleo-drainage system (should the lake water level rise high enough).
- A 72-hour rain-on-grid storm was incorporated into the HEC-RAS model to simulate the direct rainfall across the area within the model domain. The same storm hyetograph and rainfall losses as defined for the RORB model were applied.
- An adaptive times step was assigned using a maximum Courant Number of 2.0.
- A simulation period of 168 hours (7-days) was applied to the model to allow sufficient time for the runoff from the upstream catchments to reach Lake Roe, drain through the lake network and redistribute the runoff between the lake sub-areas.

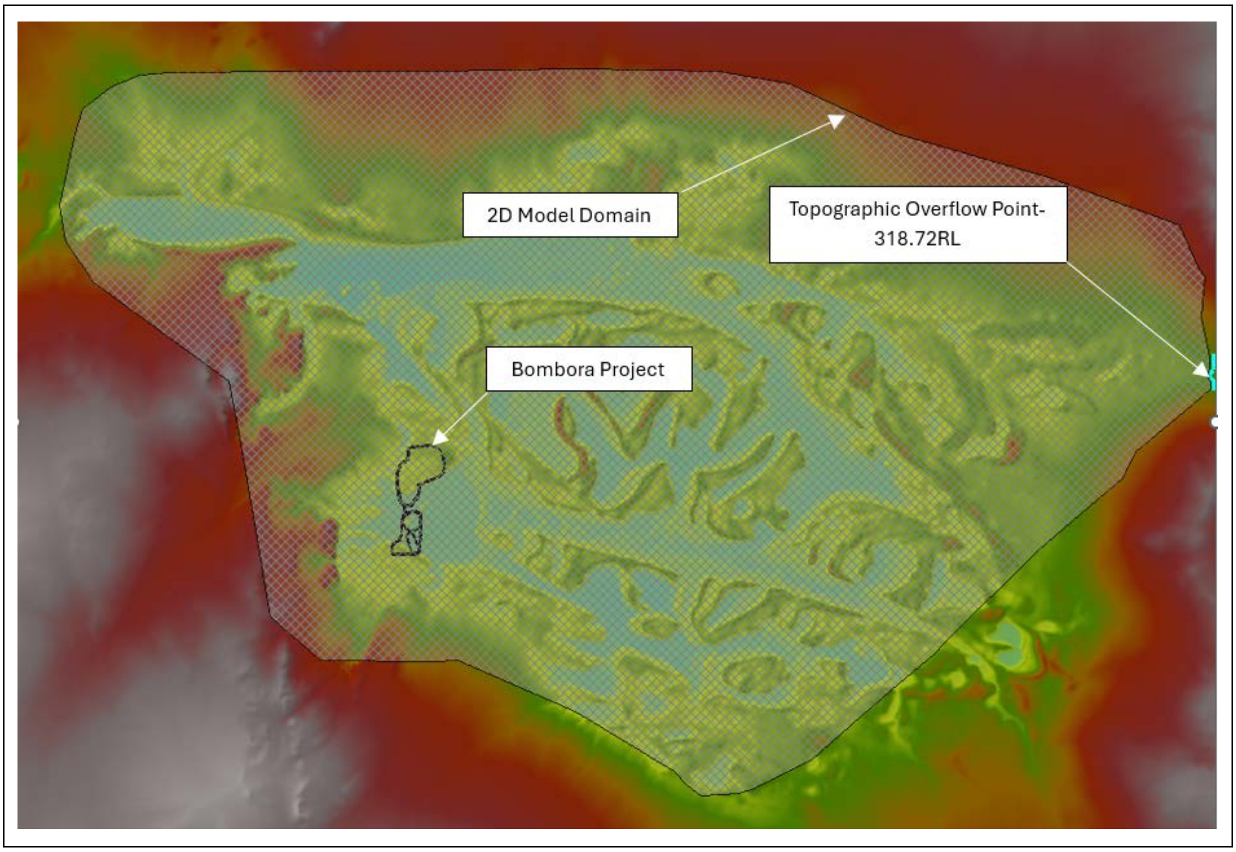


Figure 3.2 Model Terrain Data

Figure 3.3 2D Model Setup

3.4 Flood Modelling Results and Observations

Results from the flood modelling exercises are shown in the following figures:

- Figure 3.4 – the predicted maximum flood depths from the adopted 1% AEP rainfall event. Note that these maps represent the maximum flood depths predicted throughout the simulation period for each model grid cell.
- Figure 3.5 – the predicted maximum water surface elevation from the adopted 1% AEP rainfall event across the simulation period for each model grid cell across the lake.
- Figure 3.6 – the predicted maximum flood depths from the adopted PMP rainfall event across the simulation period for each model grid cell across the lake.
- Figure 3.7 – the predicted maximum water surface elevation from the adopted PMP rainfall event across the simulation period for each model grid cell across the lake.

The following key observations were made from the 1% AEP flood modelling results:

- The runoff volume from this event was large enough for most of the lake sub-areas to become hydraulically connected. As such, over time, the water surface elevation across the majority of the lake area becomes the same.
    - Note that following the 20% AEP event the main sub-areas of the lake also are predicted to become connected, and therefore it has been assumed that for all large runoff events there will be sufficient runoff to connect all of the main lake sub-areas together.
- Reviewing the results as the lake fills during simulation period, it was clear that intermediate high-points between lake sub-areas need to be overtopped before water can be transferred through the lake system. The runoff from the larger catchments (such as H, K and R) fill the lake sub-areas which they immediately report before runoff spills over and reports to central parts of the lake. In smaller, more frequent runoff events than those simulated, there may be insufficient runoff for inundation to spill to the central lake sub-areas,
- The predicted flood elevation from the 1% AEP 72-hour rainfall event is 314.5 mRL across the major lake sub-areas (including those adjacent to Bombora).
    - The lake sub-area in the northwest corner of Lake Roe is marginally higher than the other lake sub-areas. This is because a relatively large catchment reports to a relatively small storage volume in this sub-area, and the outflow to the remainder of the lake is hydraulically constrained. The energy loss required to transfer runoff from this sub-area to the main lake area results in a WSE elevation of 314.6 mRL, some 0.1 m above the flood level in the remainder of the lake. This should be considered when reviewing any potential flood protection levees for the Kopai Crescent Project.
    - Note that as discussed earlier in the report, the response from the 1% AEP 72-hour rainfall event does not necessarily represent the 1% AEP flood depth (which is estimated by the water balance model).
- This inundation level is below the water surface elevation required for Lake Roe water to overtop to the east, and therefore all runoff is contained within the Lake Roe footprint.

The following key observations were made from the PMP flood modelling results:

- A significantly larger portion of the lake area is inundated by the runoff, and a single large lake would form.
- The predicted water level in the lake from the PMP rainfall event is 319.1 mRL.
- The lake overtops to the east at this water level, which is 0.4 m above the overflow point (318.7 mRL).
- The elevation of the lake overflow point will somewhat control the maximum flood level which is possible in Lake Roe. If larger volumes of water report to the lake, additional water will flow to the east and away from the lake.

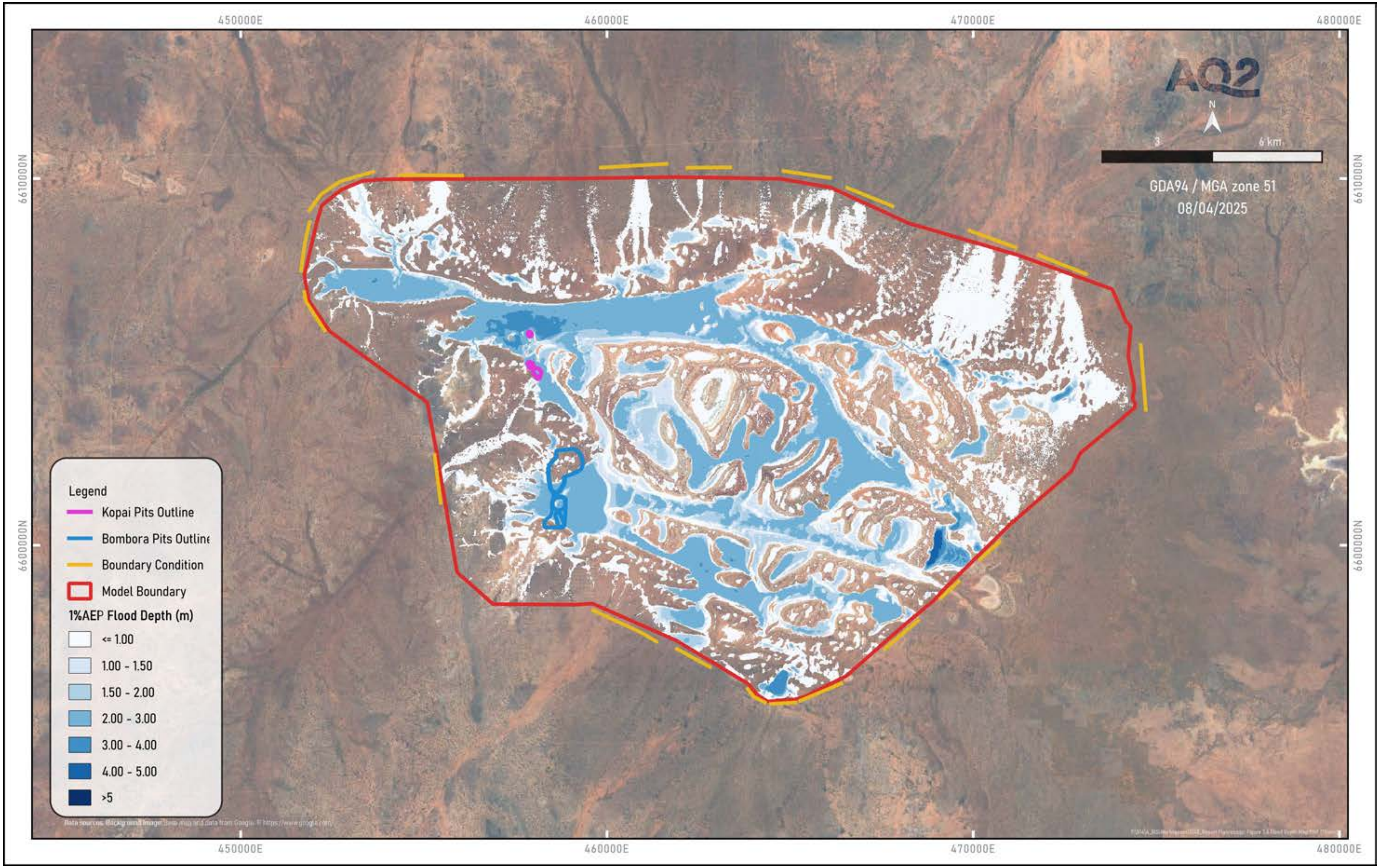
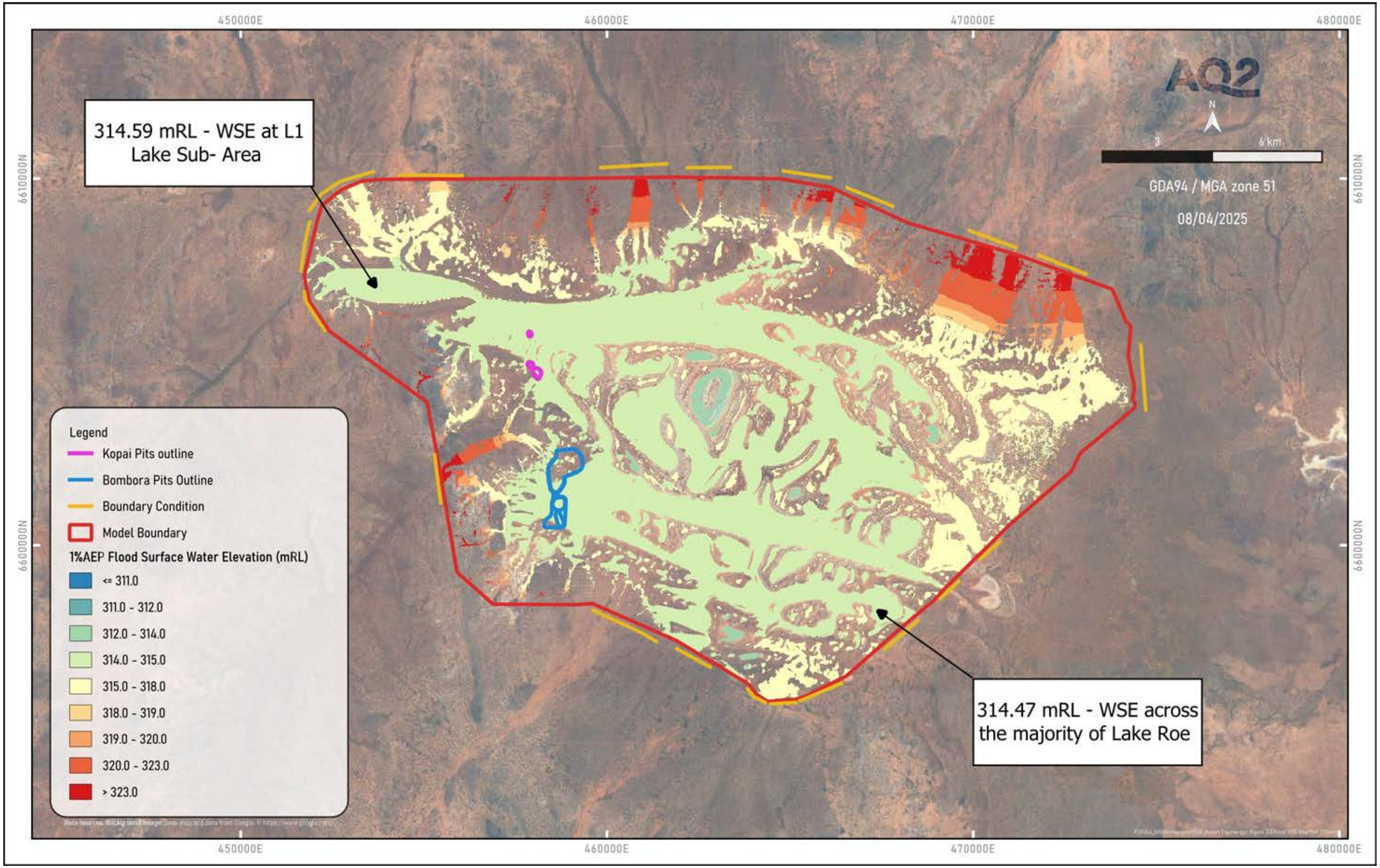


Figure 3.4 Maximum Flood Depth Map (1% AEP Rainfall Event)



314.59 mRL - WSE at L1 Lake Sub- Area

314.47 mRL - WSE across the majority of Lake Roe

Figure 3.5 Maximum Flood WSE Map (1% AEP Rainfall Event)

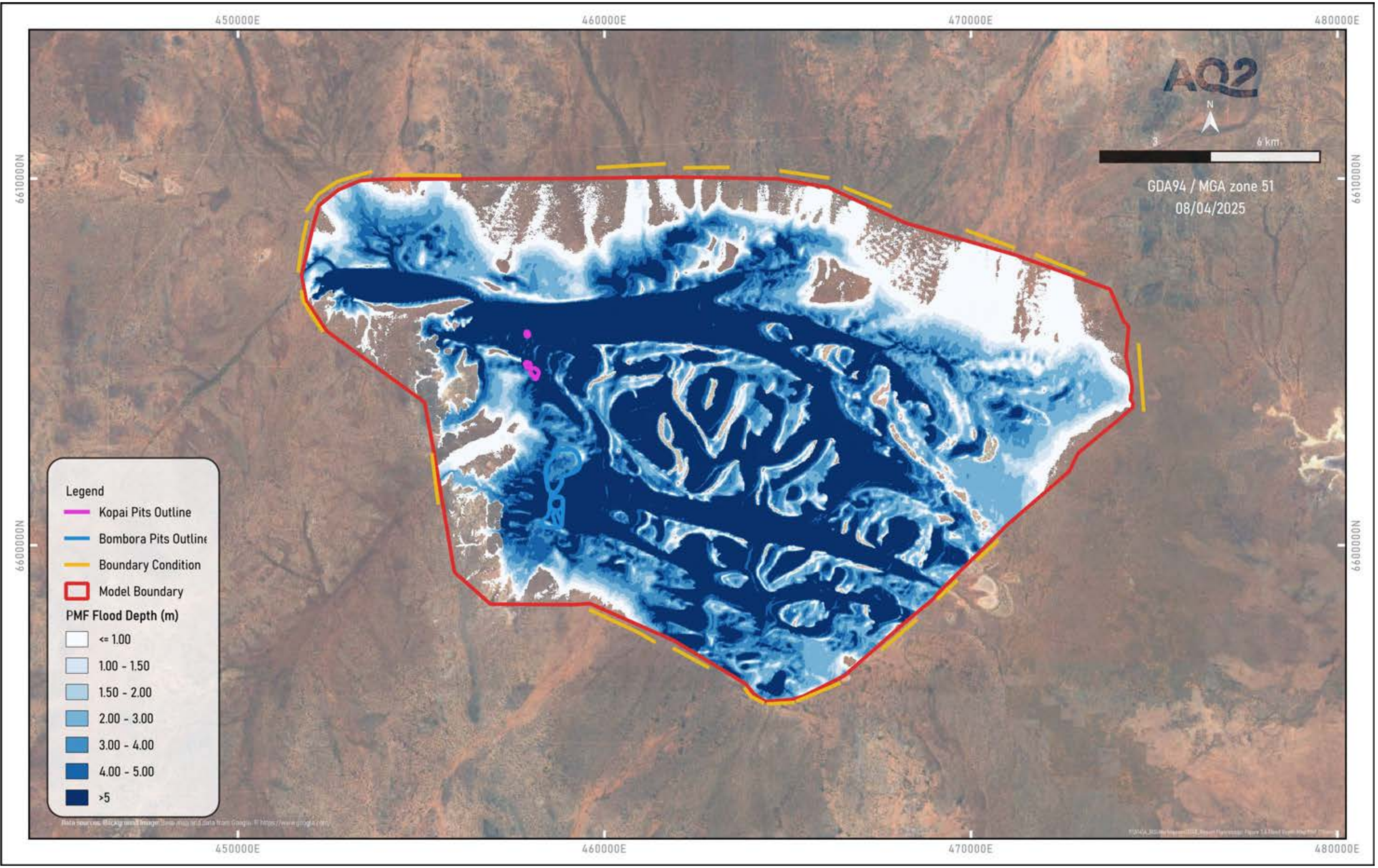


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Figure 3.6 Maximum Flood Depth Map (PMP Rainfall Event)

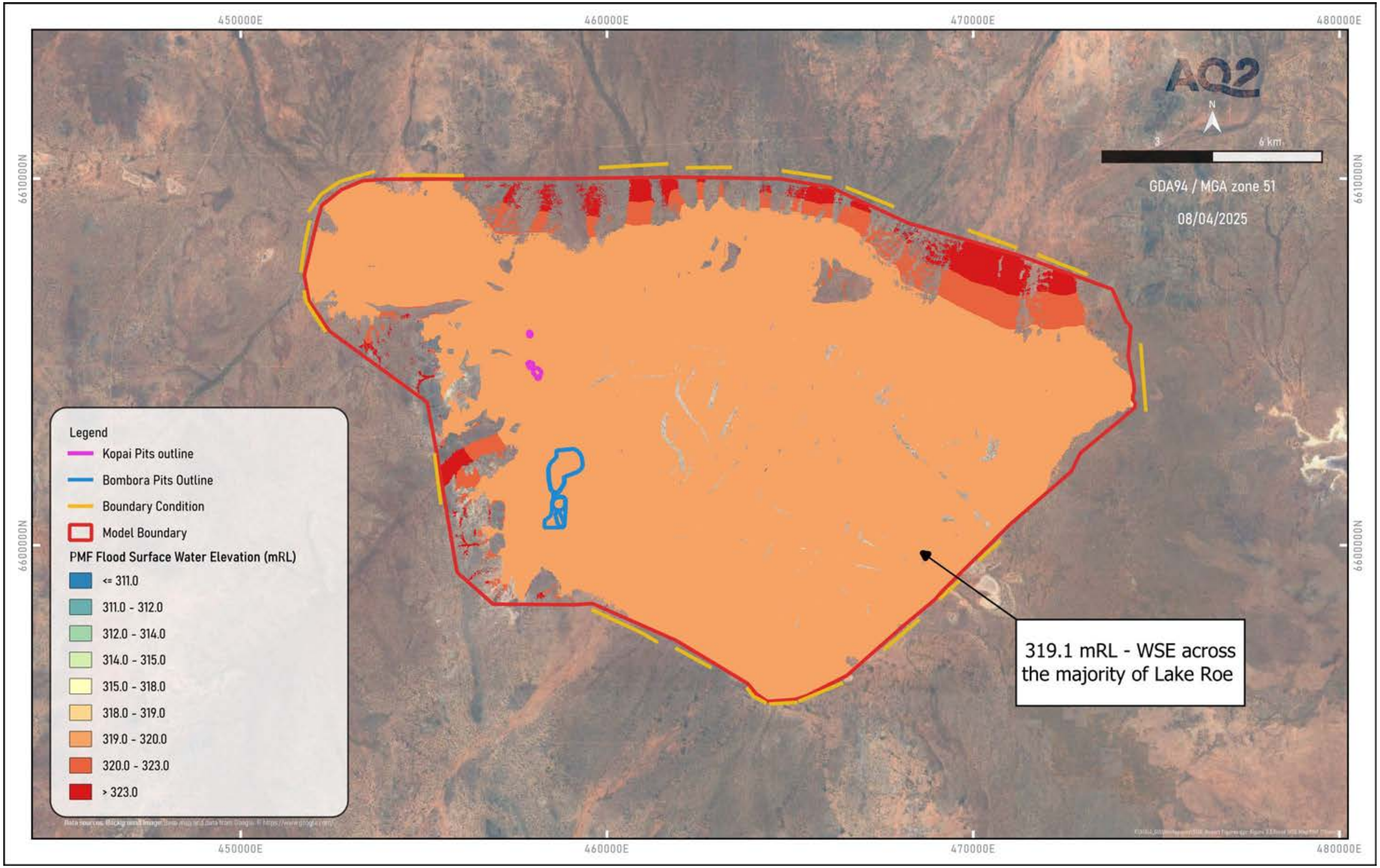


Figure 3.7 Maximum Flood WSE Map (PMP Rainfall Event)

4. LAKE WATER BALANCE

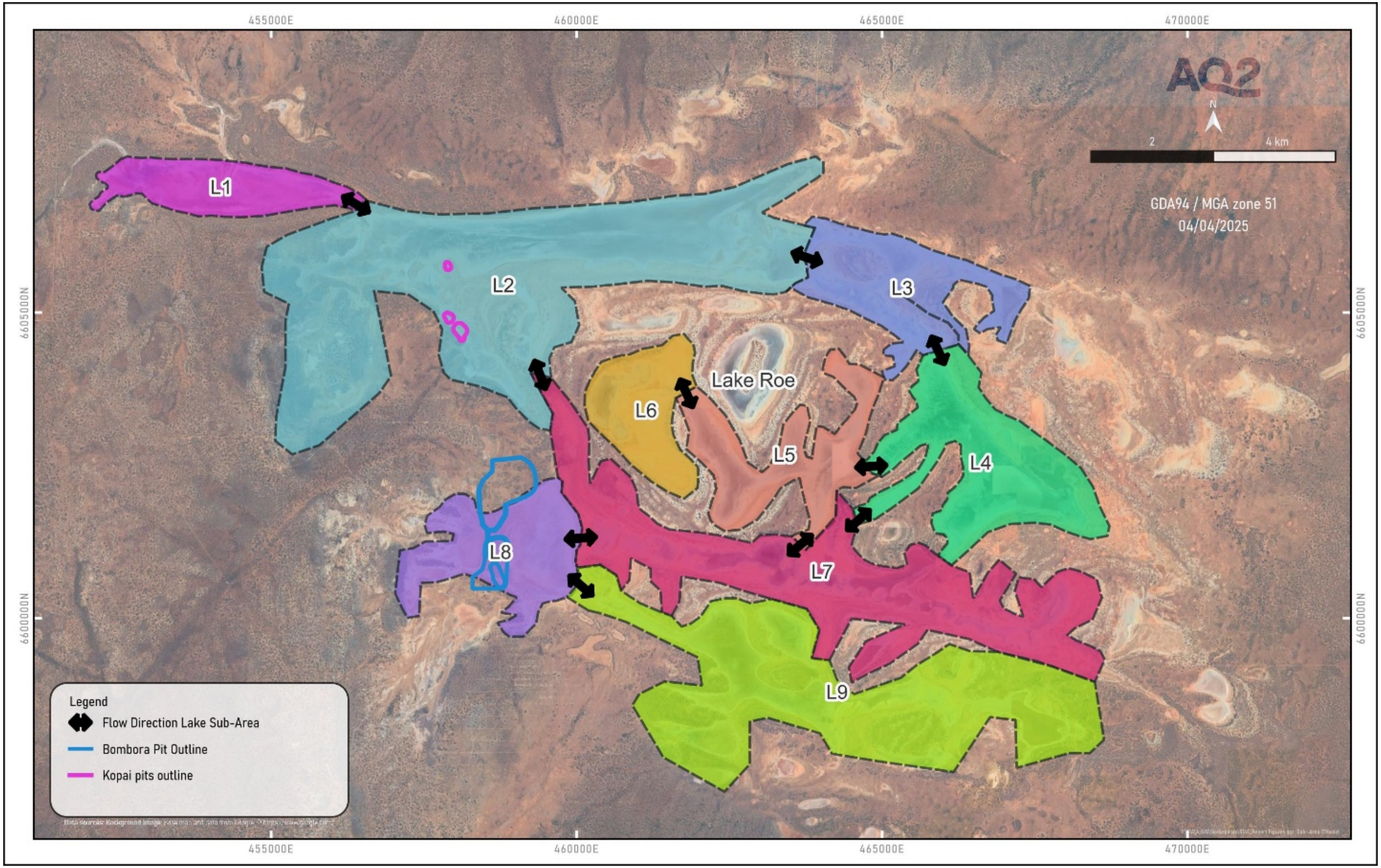
A water balance for Lake Roe has been completed to produce a simulated time series of lake water levels which could be used to allow the recurrence interval of flood levels within Lake Roe to be estimated. The water balance assessment has used the following approach:

- Using the observations from the 2D flood model, Lake Roe has been divided into 9 separate lake sub-areas (refer Figure 4.1).
- The water balance model simulates runoff reporting to each of these sub-areas and the subsequent recession of water from them.
- The water balance was coarsely calibrated to approximate observations of lake flooding from aerial imagery.
- The calibrated water balance model was run with a long-term synthetic rainfall data series (1,000-year duration) derived from rainfall data observed from a nearby weather station.
- A flood frequency analysis was completed of the resultant annual maximum flood level predictions in Lake Roe to provide an estimate of the flood levels at different recurrence intervals.

4.1 Water Balance Inputs and Assumptions

The water balance is summarised as follows:

- Lake Roe has been split into 9 different sub-areas based on the position of localised low points, catchment inflows and bounding low saddles between the sub-areas.
- For each sub-area, the following specific information has been derived:
  - Lake sub-area stage/volume/area relationship (from the provided LiDAR data).
  - Surface water catchment area draining the to the sub-area.
  - Elevation of the saddles which sperate the sub-area from adjacent sub-areas.
  - The approximate area of the “lakebed” which has been defined with different rainfall loss characteristics compared to the broader catchment area reporting to the sub-area.
- The water balance calculations are completed at constant time intervals using the following fundamental equation:
  - Inflow – Outflow = Change in Storage Volume
- The time interval for calculations is 6 hours. This interval is required for model stability given the large volumes of water that are moving through the model.
- At each calculation time interval, the model calculates the water level and inundation area within each sub-area based on the stored water volume at that time-step. The water level and inundation area drive other calculations within the water balance.
- The sub-area water level is used to drive the logic related to the distribution of runoff across the lake between different sub-areas. Once the storage volume within a given sub-area rises above the elevation of any of its bounding saddles, the model simulates water transfer to the adjacent sub-area(s). A portion of the water above the saddle point is transferred during successive time steps to keep the model stable (consistent with the calculation timestep).
- The inundation area of the lake is used to drive the following processes:
  - Direct rainfall on the lake surface (the model assumes 100% of rainfall on the inundation area reports to the lake).
  - Area over which evaporation losses occur from the lake surface.
  - Area over which infiltration losses occur from the lake.



Data sources: Background image: Base map and data from Google ©https://www.google.com/

Figure 4.1 Water Balance Overview

4.1.1 Satellite Imagery Assessment

The Lake Roe inundation extents and frequency were estimated between 1993 and 2024 using satellite data, specifically true colour imagery and Normalized Difference Water Index (NDWI) data from Sentinel, Landsat and Google Earth. Data availability and aerial image quality varied considerably throughout the 1990 to 2024 study period. The inundation extents were compared to the Digital Elevation Model (DEM) of the lake to estimate ponding depths with time.

Confidence in the estimated inundated depths (from observed satellite imagery) varies, but is typically low, and the date of recorded imagery may not coincide with the date of the actual peak inundation extent. Frequent Sentinel data between 2017 and 2024 provides the most reliable period for analyses. Between 2013 and 2017, Landsat (satellite) data are inconsistent with some gaps due to Lake Roe's eastern area falling on a different tile without imagery and satellite imagery strips (Landsat 7) giving an incomplete picture. Pre-2013, imagery from Landsat is less frequent, with data pre-2008 missing for extended periods and/or has insufficient resolution to confidently interpret. Notably, there is a Landsat data gap from late 2011 to early 2013, meaning that any lake inundation due to rainfall events during 2012 are not estimated.

The following observations were made at Lake Roe during the satellite imagery assessment:

- Catchment runoff responses causing at least some inundation in Lake Roe were generally observed when rainfall exceeded approximately 25 mm.
- In small inundation events where widespread flooding across the full lake is not prevalent (i.e., following rainfall depths in the order of 25 mm), the water levels Pan A were estimated. Appendix A presents the estimates of inundation water levels from satellite observations within salt pans B and D for reference.
- Visible widespread inundation across constituent salt pans was typically observed when a rainfall event occurred over multiple days, with total rainfall over the event exceeding 50 mm.

4.1.2 Parameter Selections

Based on the observations from the satellite imagery and the model calibration exercise, the runoff parameters shown which (subjectively) best approximate the observations are summarised in Table 4.1. A plot of the observed lake water levels and the model predictions of lake water levels are presented in Figure 4.2.

Table 4.1 Water Balance Rainfall Loss Parameters

Parameter	Catchment		
	Lake Catchment	Dry Lakebed	Inundated Lake Area
Initial Loss	50 mm	25 mm	0 mm
Runoff Coefficient	25%	70%	100%
Initial Loss Recovery	5 mm/d	2.5 mm/d	0 mm/d

The calibration exercise showed that runoff behaviour was reasonably well predicted by the model, particularly during the 2005 to 2017 period, noting:

- The inherent uncertainty in the estimations of water levels in the lake from the satellite imagery given the flatness of the lake beds and the difficulty in distinguishing between salt and water on the lake bed.
- The SILO rainfall record for Cowarna Downs includes interpolated rainfall data post 2010. When SILO interpolates rainfall data in areas where weather stations are sparse and rainfall is spatially highly

variable, the interpolates tends to show rainfall occurring more frequently but with fewer large rainfall events, which is potentially why the model couldn't match the observed inundation depths post-2017.

- To simplify the calibration assessment, a stage-volume curve for the full lake was developed and used to convert the full volume within the lake (i.e., the sum of the water storage in all sub-areas) into a water level, assuming the same water level occurs across the lake. During smaller flow events, all of the lake sub-areas may not be hydraulically connected and the water level in each sub-area may be different.
- The calibration is based on water levels. The stage-volume curve for the lake is such that a relatively small amount of runoff volume is required to cause inundation up to RL312.5m, such that it is harder to replicate the lower inundation depths.

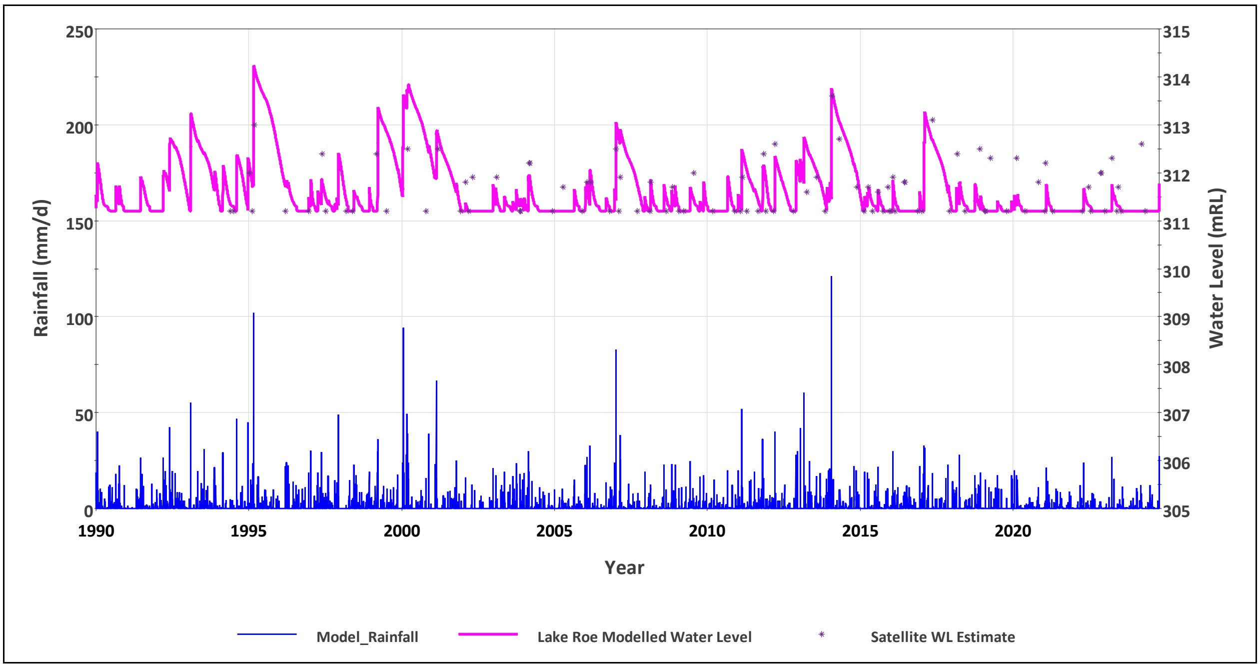


Figure 4.2 Calibrated Water Level Predictions vs Estimated Water Levels from Satellite Observations

4.2 Long-Term Synthetic Rainfall Water Balance Model

4.2.1 Introduction

A long-term water balance was run, with the purpose of developing this model to provide water balance results using a longer rainfall record which would be able to simulate the potential inundation depths from large, rare rainfall events considering antecedent rainfall conditions (and therefore antecedent water stored in the lake sub-areas). Although the expected life expectancy of the Bombora project is in the order of 10 years, The long-term model was run using a 1,000 year rainfall sequence, even though the project life for Bombora is in the order of 10 years. This is because any 10-year rainfall sequence within the record is as equally likely to occur as any other 10-year period.

4.2.2 Synthetic Rainfall Record

The synthetic rainfall generator programmed into the GoldSim model is based on historic daily rainfall records from Gindalbie Rainfall Station. Rainfall records sourced from the Bureau of Meteorology (BOM) between 1918 and 2024 were used. The BOM rainfall dataset was incomplete over this period, with missing data patched using the online SILO enhanced climate database service to provide a continuous record. The output from SILO is formed using records from nearby weather stations.

The 106 years of daily rainfall data was used as an input to the eWater program Stochastic Climate Library (SCL). The SCL uses historic rainfall data as an input and produces a synthetic rainfall data set for the required duration, which is a statistical fit to observed rainfall. For this project, 1,000 years of daily rainfall was produced by the program.

The synthetic daily rainfall data time series that was produced for the model is not reproduced within this report for brevity; a comparison of the summary statistics for the Gindalbie data and the synthetic rainfall data generated are shown in Table 4.2.

Table 4.2 Input Rainfall Data Summary Statistics (Annual)

Annual Statistic	Annual Rainfall Depth – Gindalbie	Annual Rainfall Depth – Synthetic
Median	218mm	223mm
Mean	235mm	235mm
Maximum	674mm	960mm
Minimum	48mm	12mm
90th Percentile	402mm	384mm
75th Percentile	291mm	296mm
25th Percentile	161mm	152mm
10th Percentile	96mm	100mm

Within the GoldSim model, the synthetic rainfall dataset has been increased to account for climate change, consistent with the approach adopted within the 2D modelling. As per ARR guidelines (Ball, et. al, 2019) the rainfall records have been increased by a factor of 20% to account for increases in rainfall depths during large rainfall events as predicted by Long Term (2080 period) medium Representative Concentration Pathways 4.5 (RCP4.5). The 2080 projection period has been adopted conservatively for climate change impacts to rainfall, as the project is likely to have been completed well in advance of 2080.

4.2.3 Rainfall Loss Parameters

The rainfall loss parameters derived in the calibration model were adopted for long-term water balance model. However, a factor to reflect the impact of climate change on likely runoff rates was applied. Although rainfall depths are predicted to increase with climate change, increased temperatures (and therefore evaporation) and periods between rainfall events within the WA arid interior region are predicted to result in an increase in rainfall losses during rainfall events. The applied ROCs within the model were reduced by 10% to reflect the impact of climate change on runoff generation.

4.2.4 Model Results

The results from the long-term synthetic rainfall model run are shown in Figure 4.3. The results indicate the following:

- Widespread inundation only occurs when the flood depths within the lake exceed the elevation of the saddle points between lake sub-areas. These saddle points are typically between RL312.5m and RL313m.
- Inundation of the lake with more than approximately 3m of water above the lowest point in the lake (i.e., a flood level exceeding RL314m) happens about once every ~50 years.
- Flooding exceeding RL315m is predicted to occur about 5 times over the 1,000-year period (i.e., once every 200 years)

- Prolonged inundation (lasting multiple years) happens rarely, but continuous ponding of up to 4 years has been predicted to occur on occasion in the model. Sustained ponding requires multiple large runoff events to occur in close succession.
- The greatest inundation level predicted (RL317m) would result in 5.8m of flood depth at the deepest point of the lake. On the basis of a typical recession rate of 10mm/d, it would take in the order of 1.6 years for the lake to recede to a completely dry state (if no further rainfall were to occur in that period).

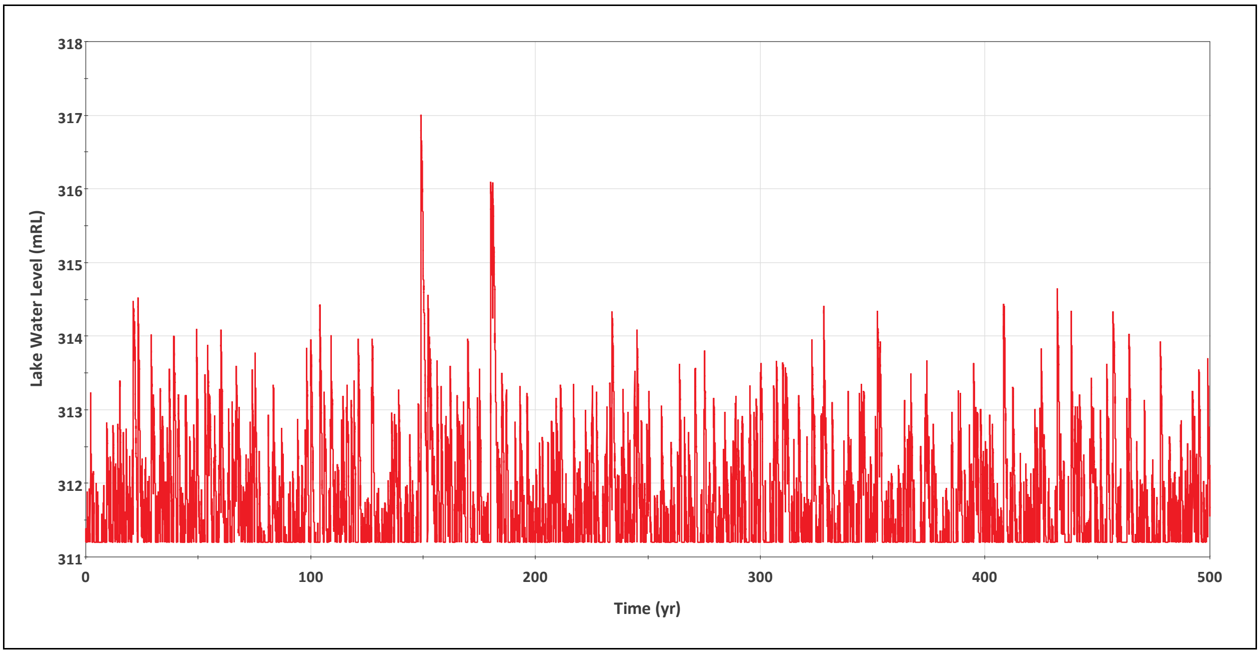


Figure 4.3 Long-Term Model Results (Year 0 to Year 500)

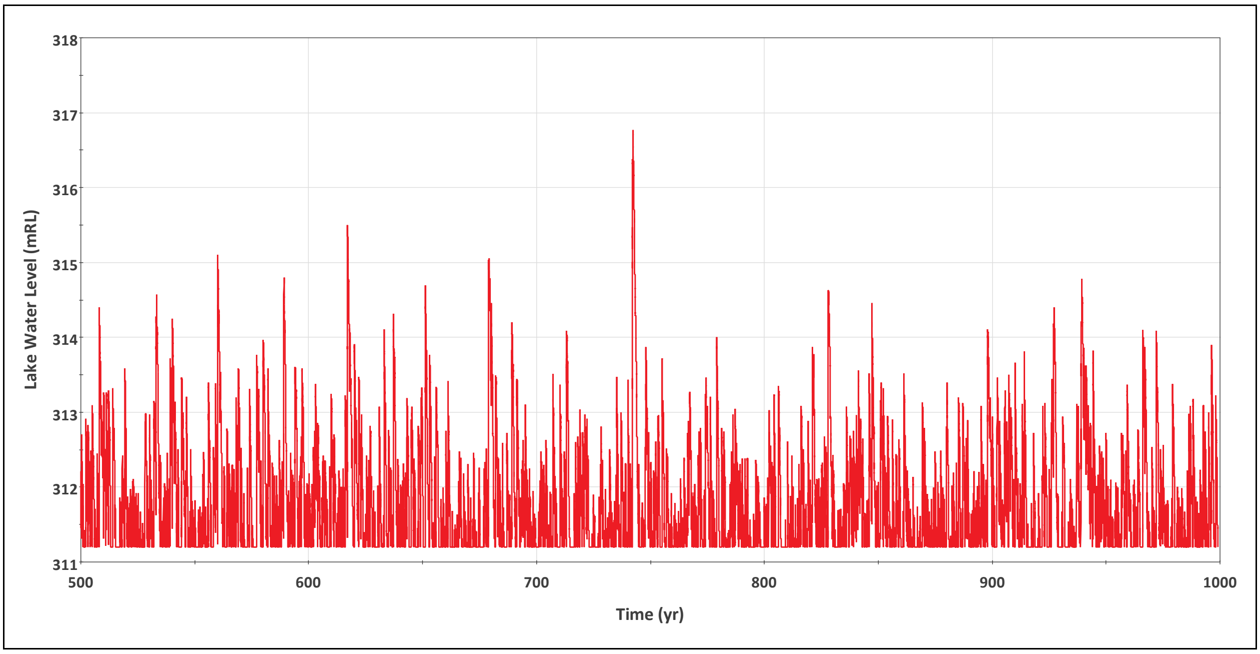


Figure 4.4 Long-Term Model Results (Year 500 to Year 1000)

4.2.5 Flood Frequency Analysis

An annual maximum lake water level series was developed from the long-term water balance model assuming a water year spanning from October to October. The annual maximum series was used in the Flike software to complete a FFA of lake water level.

A Log-Pearson Type III curve was fitted to the modelled data, with the assessment censoring all water levels below a ~1 in 10-year (10%) AEP flood event. Although the curve provided a reasonable fit to the observed flood level data, it was noticed that there appears to be a step change in the flood elevation data between 1 in 100-year AEP event and the 1 in 200-year AEP event.

A summary of the FFA results is provided in Table 4.3, which indicates both the Expected (best estimate) Flood Depths and the 90th Percentile Confidence Level Flood Depths. The results indicate that a 1 in 100-year AEP (1%) flood depth in the lake is predicted to be 315.08 mRL. This compares with the 1% AEP 2D model flood estimate of 314.5 mRL from a 72-hr storm event.

Table 4.3 FFA Results – Flood Depth Recurrence Interval

AEP (1 in Y)	Expected Flood Depth (mRL)	90%-ile Flood Depth (mRL)
5	312.85	313
10	313.51	313.6
20	314.06	314.2
50	314.67	314.9
100	315.08	315.3
200	315.46	315.7
500	315.92	316.2
1000	316.24	316.6

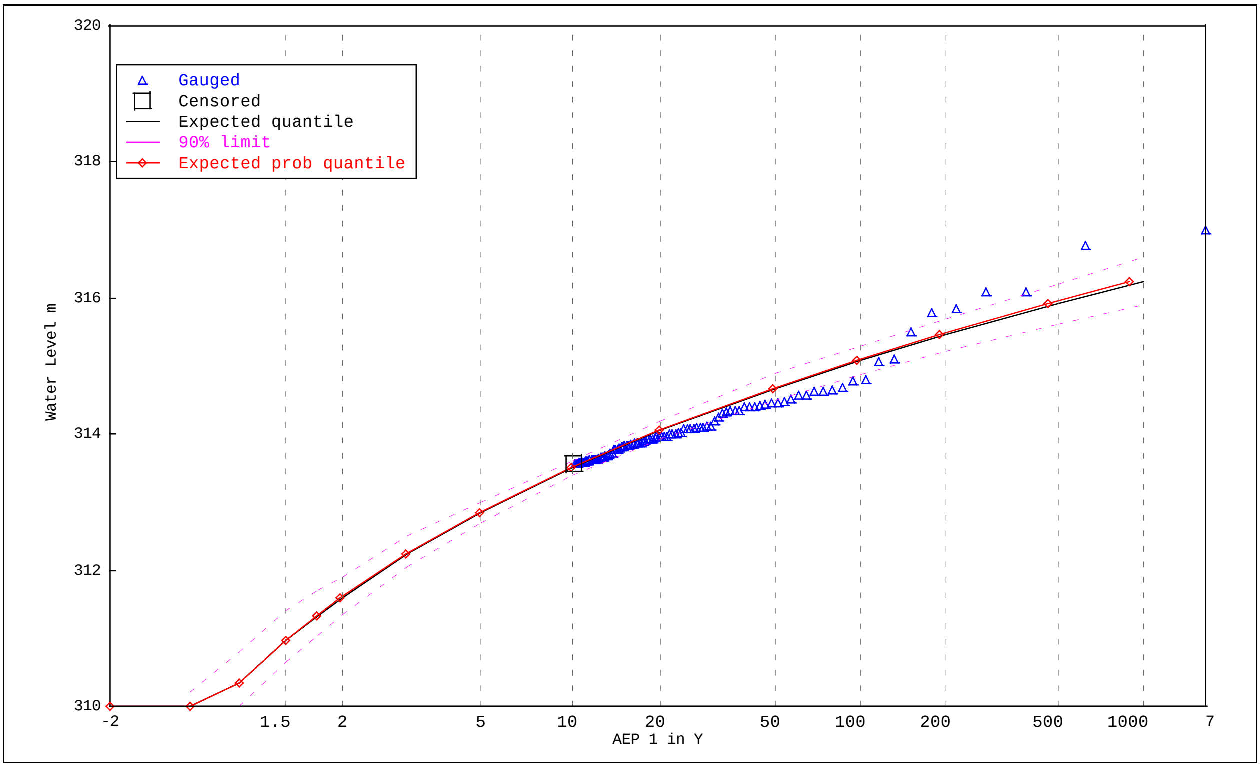


Figure 4.5 Flood Frequency Analysis – Log Pearson Type III

4.2.6 Flood Protection Requirements

The flood protection design requirements for the open cut pit at Bombora (and for Kopai Crescent) should be based on the level of risk which is acceptable to the project during operation of the mine. On the basis that the project is likely to have a low tolerance to risk and the probability of different events over the project life span (refer Table 2.2) it is recommended that the 1% AEP flood depth be used as the basis for sizing flood levee protection around the pit. From the FFA completed, the 1% AEP flood depth within the lake is predicted to be in the order of 315.1 mRL.

The operational flood protection levee crest elevation should also include freeboard to account for factors including uncertainty in the hydrological assessment, potential waves on the lake surface and prevailing winds pushing water to one side of the lake. A nominal 1 m freeboard is recommended on top of the estimated 1% AEP flood level estimated by the FFA. Therefore, the recommended crest elevation for the operational flood protection levee is 316.1mRL.

For reference, the lake inundation elevation following a PMP rainfall event was estimated to be 319.1 mRL.

An overview of the proposed pit layouts is provided in Figure 4.6, showing three separate open cut pits (Northern, Central and Southern pits). Ground elevation profiles for each of the perimeter pit crests are plotted in Figure 4.7 to Figure 4.9, along with the 1% AEP flood level and the proposed pit flood levee elevation (including the freeboard allowance). To achieve a flood protection levee of 316.1 mRL would require in the order of 4 m of fill across the proposed development area which is within the lakebed.

As discussed in Section 3.4, the 2D hydraulic flood model indicates that water levels in lake sub-area L1 are higher than in the remaining lake sub-areas because of the rate of water transfer required from L1 to L2 and the restrictive channel which connections the two lake sub-areas. As such, we recommend that the flood protection levee crest elevation for Kopai Cresent mine area is 0.1 m higher at 316.2 mRL, if this project were to be considered in the future.

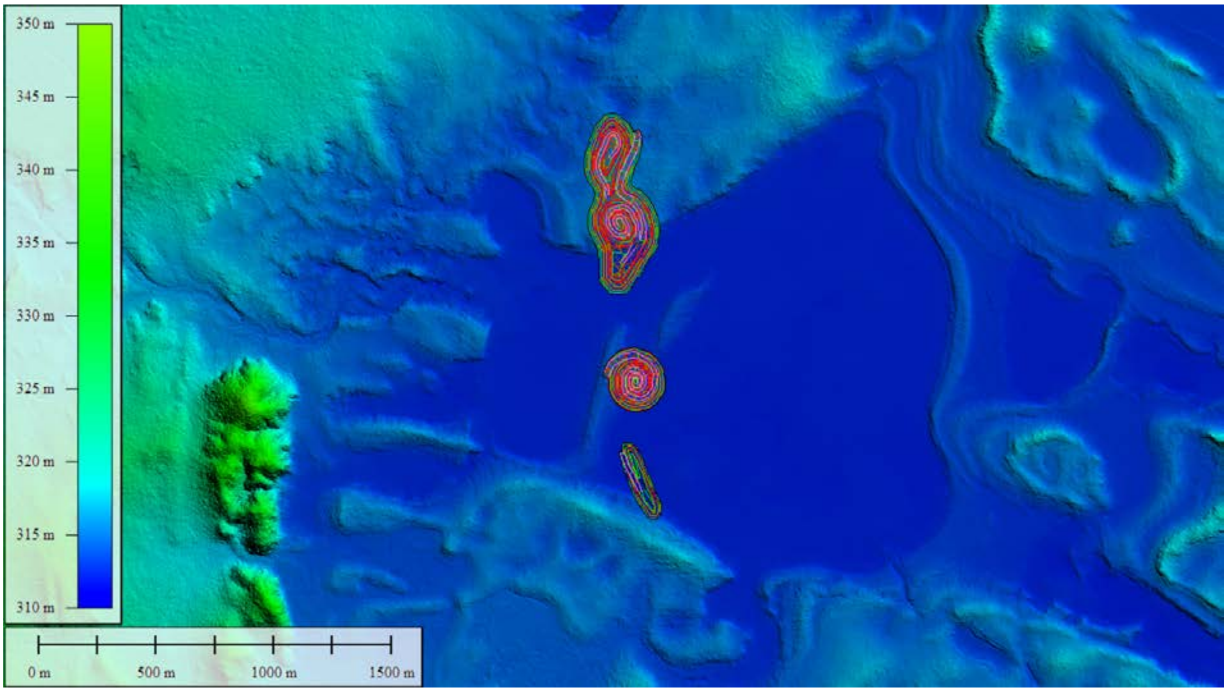


Figure 4.6 Bombora Pit Footprints

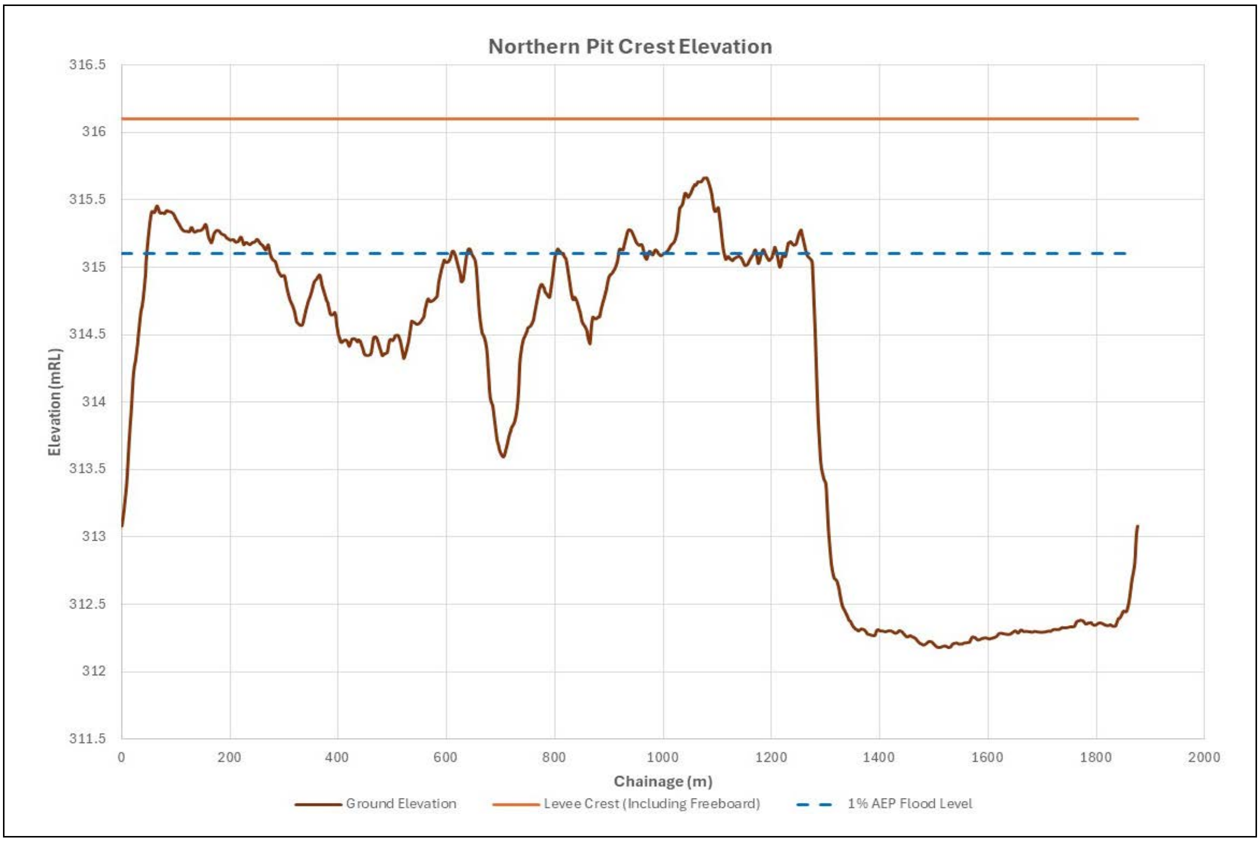


Figure 4.7 Northern Pit - Flood Levee Crest

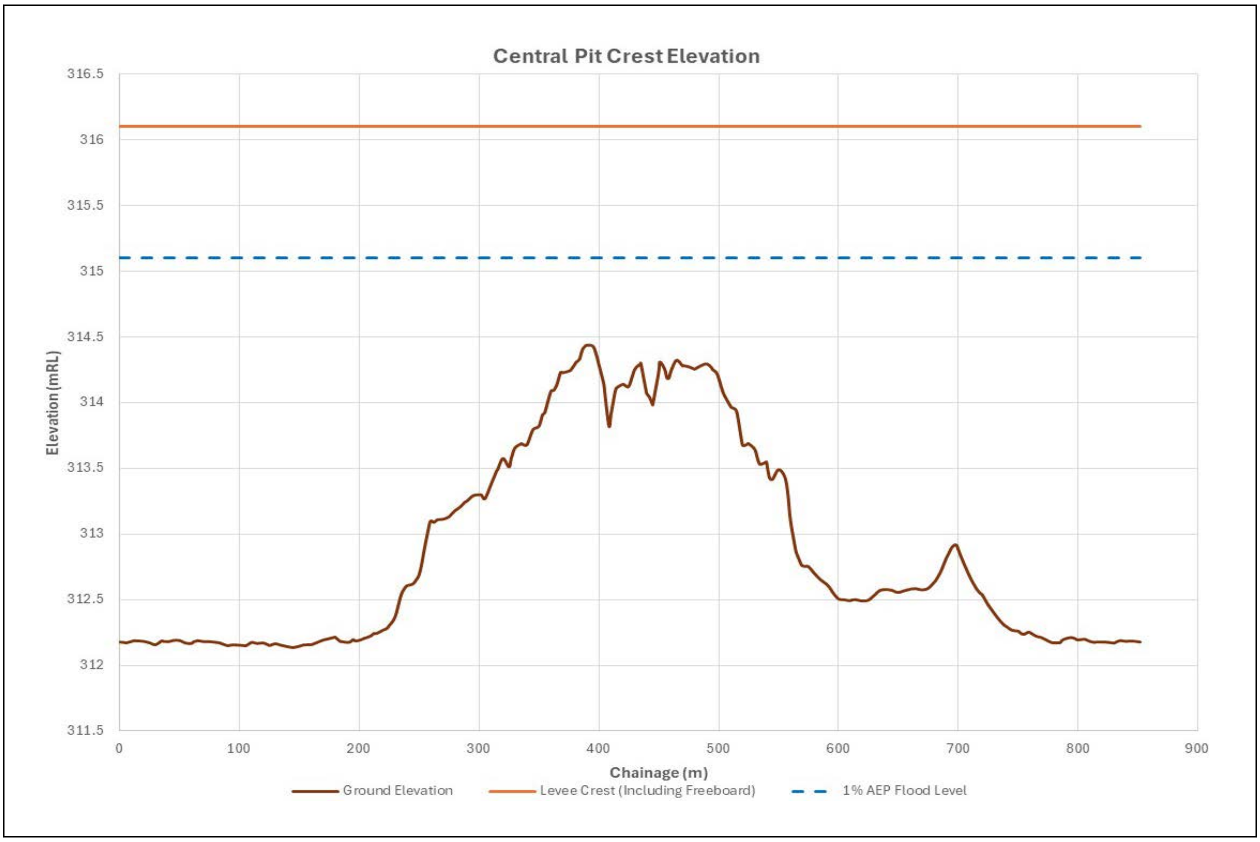


Figure 4.8 Central Pit - Flood Levee Crest

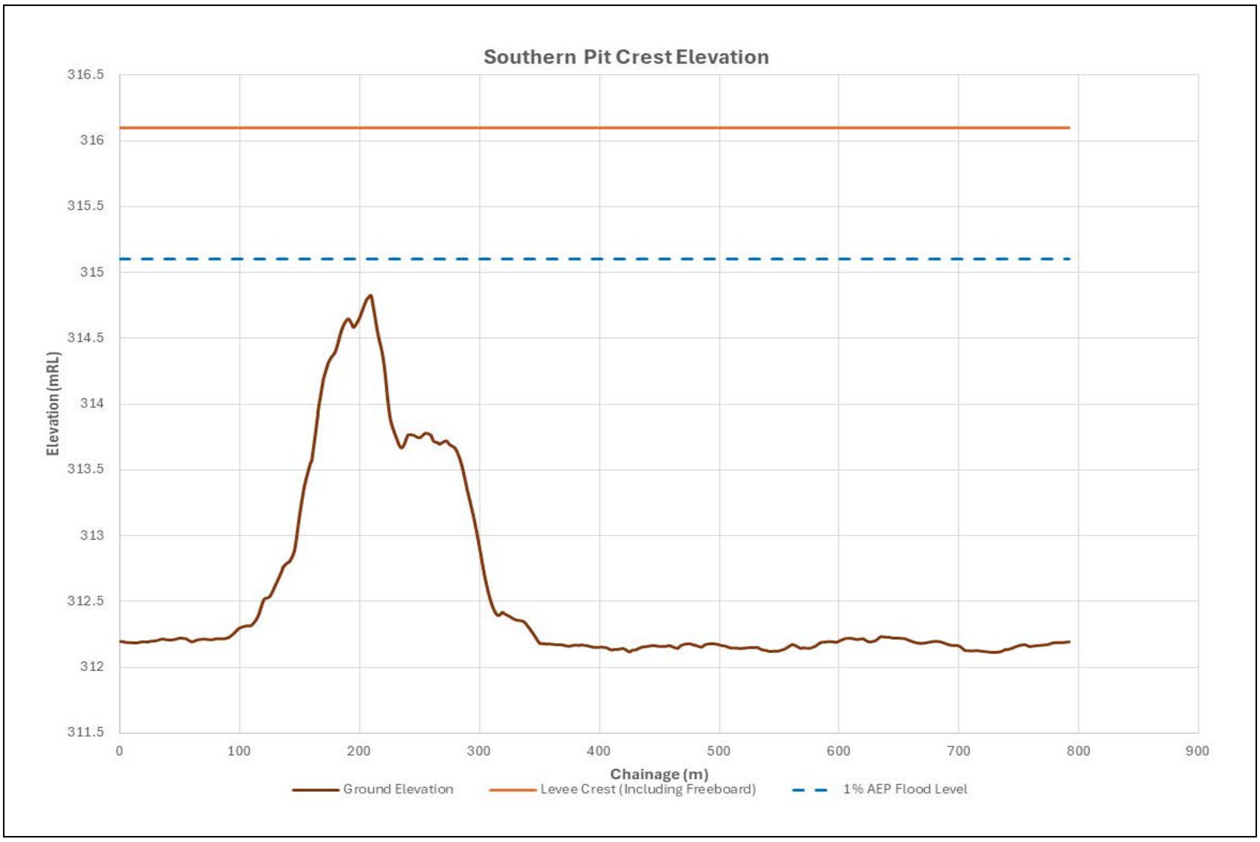


Figure 4.9 Southern Pit - Flood Levee Crest

4.3 Water Balance Limitations

The following main limitations should be noted with respect to the water balance approach:

- Calibration of the model assumed that the rainfall measurements at Cowarna Downs were representation of rainfall patterns at Lake Roe. The SILO Cowarna Downs data is interpolated between 2010 and 2024, such that the rainfall during that period is less likely to be representative. This is likely the reason for the model not being able to replicate water level observations during this period.
- The model assumes that rainfall intensity is even across the full catchment area of Lake Roe. Given the large catchment area reporting to the lake, this is unlikely to occur during a real storm. Some catchment areas would receive more rain than others.
- The logic within the model simplifies what is a complicated hydrological process and adopts common rainfall loss parameters across all catchments, even though it is likely that the runoff responses from different catchments would differ.
- The "observed" lake inundation levels were based on a subjective assessment of satellite images and NDWI data derived from the satellites. It is difficult to estimate the extent of inundation within the lake accurately from these images and observed inundation levels do not generally coincide with when the peak water levels in the lake would have occurred. It is assumed that the observed water level at a point in the lake represents the water level across the full lake extent (even though this is unlikely at shallow inundation depths).
- The response to a rainfall event within the water balance is immediate, whereas in reality, runoff from the catchment may continue to drain to the lake for a number of days after the rainfall event.
- Any impacts of increased salinity within the ponded lake water on evaporation loss rates has not been accounted for within the model.

- A constant seepage loss rate has been applied within the model. Potentially, the rate of seepage may be elevated at higher inundation depths due to increased pressure (depth) head at the lakebed and the likelihood of higher permeability sediments along the banks of the lake.

4.4 Summary

AQ2 has completed a flood assessment of Lake Roe to define flood risks and flood protection requirements for the Bombora Project. AQ2 completed the flood assessment by conducting the following steps:

- Defining catchment areas for Lake Roe.
- Developing hydrological models for three representative catchment areas reporting to Lake Roe to develop representative hydrographs for inflow to the lake for 20%, 1% and PMP rainfall events. Nominal rainfall hyetographs were used to develop the hydrographs on the basis that the peak flow rate estimated within the hydrograph was less important than the volume of water reporting to the lake.
- Scaling the representative hydrographs by catchment area to develop hydrographs for all catchments reporting to the lake.
- Running a 2D flood model for the lake area for 20%, 1% and PMP rainfall events. Each of these model runs was completed for a single design rainfall event.
- Using the 2D flood model to identify flow behaviours within the lake to conceptualise the development of a water balance model for the lake.
- Develop a water balance model for the lake, which involved:
    - Dividing the lake into 9 separate sub-lake areas, each separated from other lake sub-areas but with its own dedicated stage/volume/area curve.
    - Developing a “calibration” rainfall sequence and a long-term synthetic rainfall sequence for use in the model.
    - Reviewing satellite images to estimate past flood levels to allow calibration of the model.
    - Using lake seepage loss estimates which were made during previous assessments to estimates losses from through the lakebed following inundation events.
    - Sourcing SILO evaporation data which should be representative of evaporative losses from a shallow lake.
    - Creating a rainfall loss function to simulate volumetric runoff from the catchments to the lake following the simulated rainfall sequences. The parameters defining the rainfall loss function were selected to ensure that the “calibration” model run approximated the inundation extents estimated from the satellite imagery.
    - Running the model with the calibrated rainfall loss parameters to produce predictions of runoff over a 1,000-year period.
- Using the peak water level predictions from the model to complete a flood frequency analysis which provided estimates of flood levels within the lake at different recurrence intervals.
- Providing recommended flood levee crest elevations to protect the Bombora pit areas.

To provide protection to the pit from a 1% AEP flood event (which has a 10% chance of occurring over a 10-year mine life), a flood levee crest of 316.1mRL (including a 1m freeboard) is recommended.

5. REFERENCES

Bureau of Meteorology (BOM) 2016. Design Rainfall Data System [Online Resource: http://www.bom.gov.au/water/designRainfalls/revised-ifd

Flavell, D. 2012, "Design flood estimation in Western Australia", Australian Journal of Water Resources

Australian Rainfall and Runoff (ARR) 2019, Book 8: Estimation of Very Rare to Extreme Floods, Chapter 4.3.4.3

Knight Piesold-Lake Rebecca Gold Project Tailings Storage Facility and Associated Infrastructure Pre-Feasibility Study Surface Water General Arrangement Plan (Lake Roe Mining Area). Report Number: PE801-00402/03. Figure 9.3.

APPENDIX A
LAKE ROE HYDRAULIC BEHAVIOUR DESK STUDY

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Memo

To	Helen Chernoff	Company	Ramelius Resources
From	Shirley Field	Job No.	514C
Date	09/12/2024	Doc No.	010b
Subject	Lake Roe Hydraulic Behaviour Desk Study		

Dear Helen,

Please find below our assessment of the ponding behaviour in the vicinity of the proposed Roe Mining Project.

1. BACKGROUND

Ramelius Resources' proposed Roe Mining Project is located in the Goldfields Region of Western Australia, approximately 100 km due east of Kalgoorlie and circa 45 km southwest of the Rebecca Gold Project. The Project is proposed to consist of the Bombora open-cut pits and underground mine, and Kopai Crescent open-cut pits. Both proposed mining areas are proximal to Lake Roe, with the pit footprint extending partially over the Lake Roe basin.

As part of the assessment for potential pit dewatering requirements, Ramelius has asked AQ2 to complete following:

- Characterise the ponding within Lake Roe with respect to frequency and duration of inundation.
- Estimate potential seepage rates from the lake to the underlying groundwater during ponding events.

To understand the hydrological behaviour at Lake Roe, the following was completed:

- Climate characteristics such as daily rainfall, evaporation, and temperature data were defined.
- Inundation events were identified from satellite imagery between 1993 and 2024.
- Inundation events and rainfall records were correlated to identify the climate drivers for inundation.
- Areas which are prone inundation were identified.
- Seepage analysis for the salt pans for different inundation events.
- Potential discharge location(s) for surplus dewatering were assessed, by estimating the rate at which ponded water can lose water to evaporation at different locations.

In addition to this assessment, the following additional works are being completed and will be reported separately:

- Dewatering inflow assessment to the proposed mine pits.
- 2D flood model of Lake Roe to simulate ponding locations and flood distribution throughout Lake Roe from different runoff events.
- A Lake Roe water balance model to estimate flood levels for different design recurrence intervals.

2. CLIMATE

Nearby rainfall, evaporation and temperature climate data were assessed to aid in characterising Lake Roe's hydrological behaviour. The climate data used for this analysis was obtained from the Scientific Information for Land Owners project (SILO) (Jeffrey et al. 2001), as it provides temporally complete daily climate parameters from 1889 to the present, for any location in Australia to the closest 0.05° latitude/longitude (decimal degrees). SILO compiles all valid data for the input location and spatially interpolates, patches, and calculates long-term averages from nearby raw observational data to provide a complete dataset.

SILO data from Cowarna Downs station (BOM Station ID 12220) was considered the most representative analogue of the climatic conditions of the Lake Roe area based on proximity and observed data availability. The station is situated 40 km southwest of Lake Roe's centre (refer Figure 2.1), with rainfall records available between 1970s to 2010. A SILO rainfall dataset was obtained between 1970 and October 2024.

It was noted the Cowarna Downs station SILO dataset:

- Likely best represents Lake Roe's rainfall for 1970–2010, when actual measurements were taken at the weather station.
- Rainfall data outside these years would be interpolated from nearby stations and is likely to be less representative of Lake Roe catchment's rainfall.
- Used SILO's interpolation techniques to derive temperature and evaporation values as this was not recorded at the Cowarna Downs station. The nearest station this data was recorded was at Kalgoorlie 110 kms away.

The closest long-term weather station to the Lake Roe Project Area where rainfall has been recorded is Karonie weather station (BOM Station ID 12041), located approximately south-south-west 25 km away from Lake Roe's centre point; however, there are no observed data from 1990s onwards. Gindalbie station (BOM Station ID 12247), located 95 km northwest, has the largest timespan of observed data, but it was considered too distant to be a realistic analogue of Lake Roe's weather conditions. This weather station had recorded rainfall peaks which were greater in magnitude than Karonie and Cowarna Downs.

A summary of the Cowarna Downs station SILO dataset is as follows:

- Grid reference for the Cowarna Downs station location: -31.00933 degrees south and 122.35564 degrees east.
- Spanned period of 1970s to October 2024.
- Long-term average annual rainfall of 260.7 mm.
- Annual average Class A pan evaporation rate of 2,420 mm and an annual average Morton's shallow lake evaporation rate of 1,560 mm (from SILO interpolation at Cowarna Downs).
- Long-term average maximum temperature of 26 °C.
- Monthly average rainfall, Class A pan evaporation, Morton's shallow lake evaporation, maximum and minimum temperature (1970–2024) as shown in Figure 2.3.

The installation of a weather station at the site would be useful to provide site specific data for rainfall, evaporation and wind speed and direction.

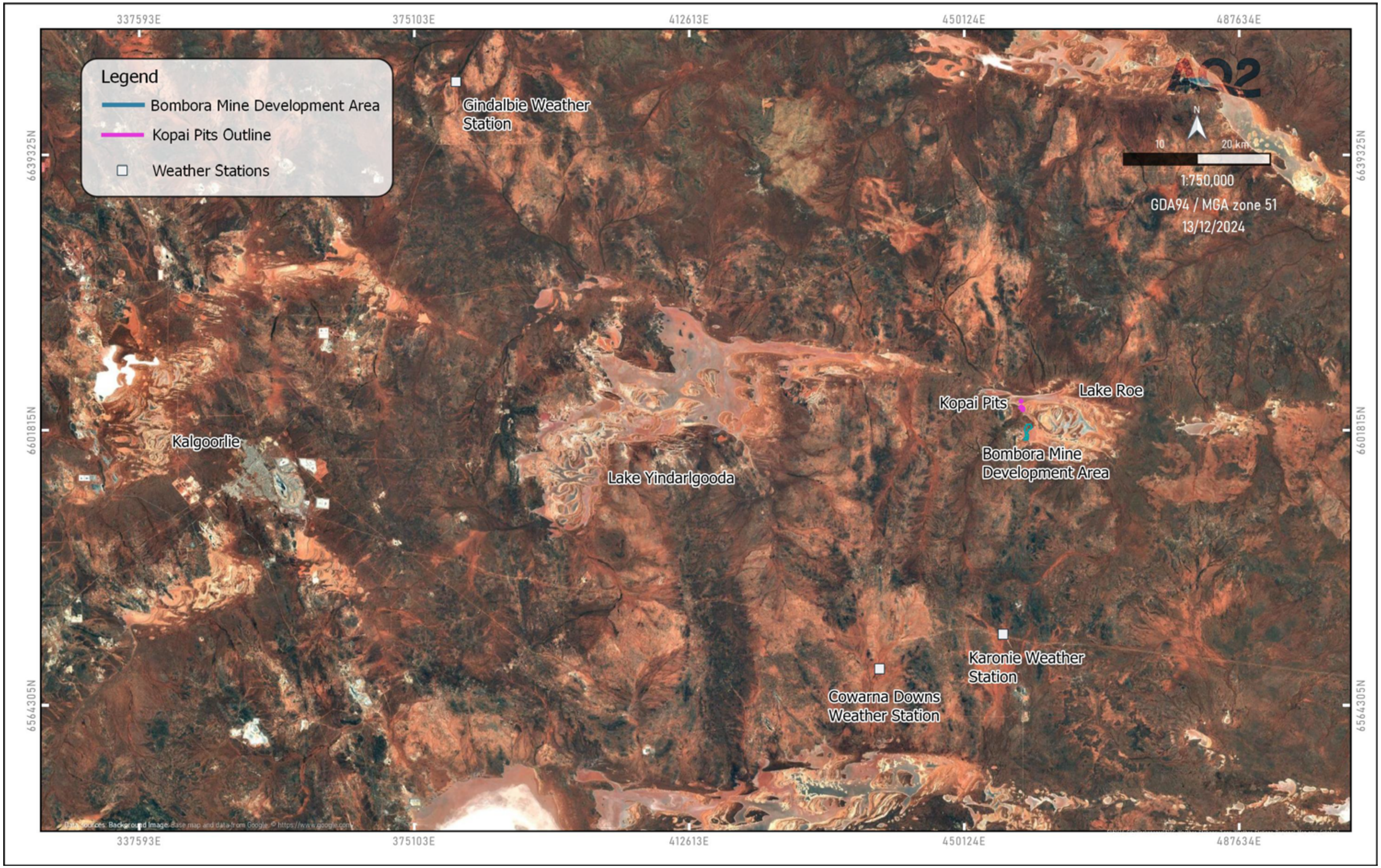


Figure 2.1 Regional Map of the Eastern Goldfields, including Lake Roe, Cowarna Downs, and Kalgoorlie

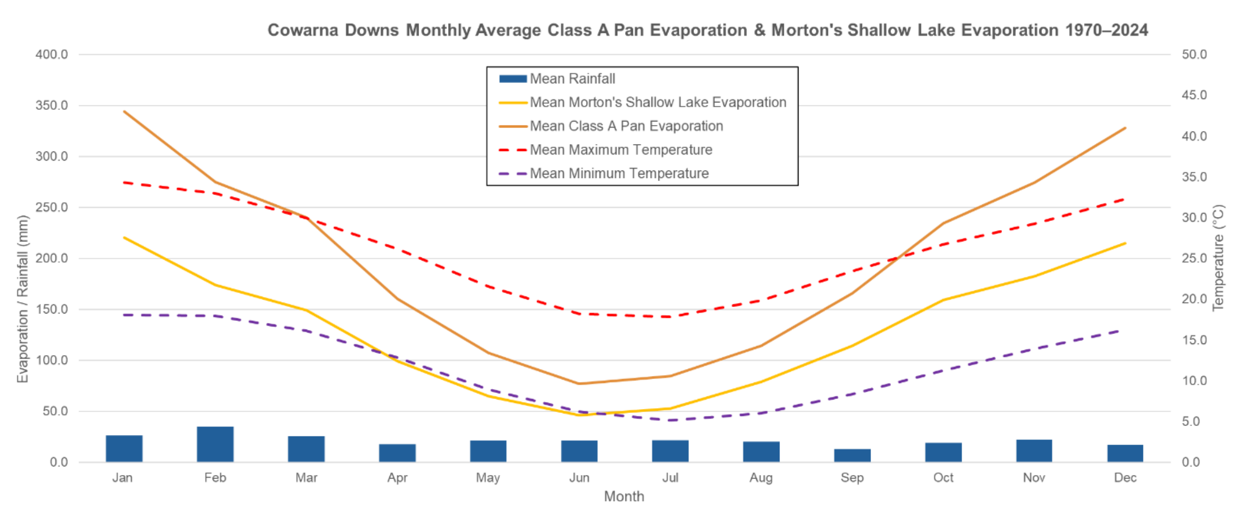


Figure 2.2 Cowarna Downs Monthly Average Climate Characteristics (1970–2024)

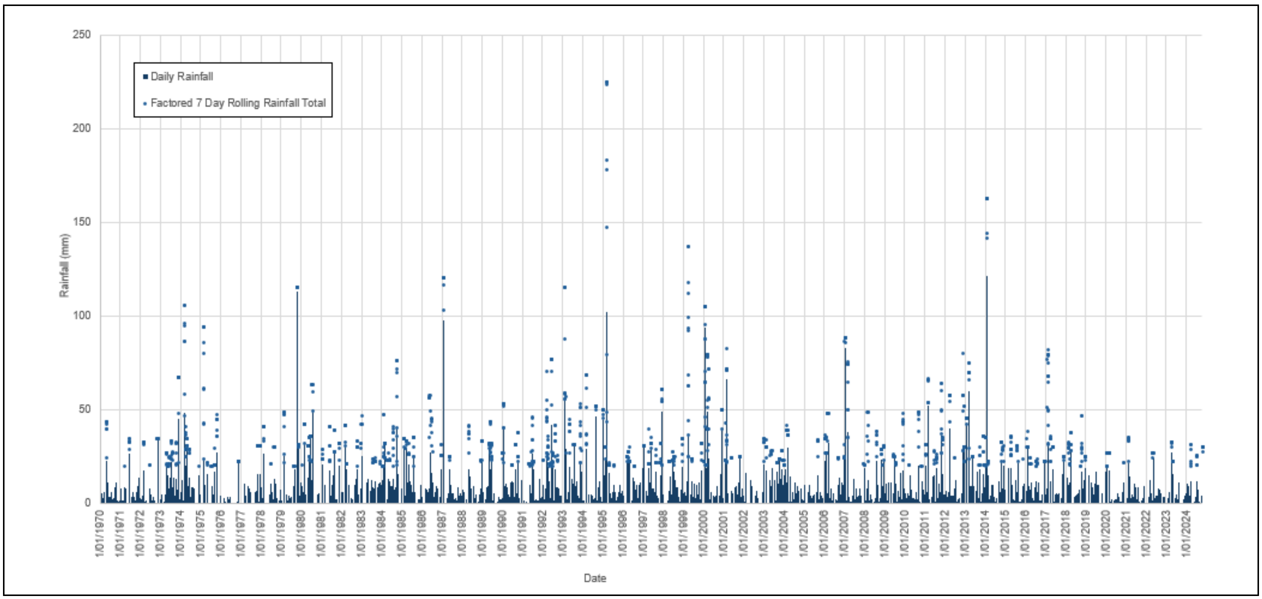


Figure 2.3 Cowarna Downs Rainfall Metrics (1970–2024)

3. SATELLITE IMAGERY ASSESSMENT

The Lake Roe inundation extents and frequency were estimated between 1993 and 2024 using satellite data, specifically true colour imagery and Normalized Difference Water Index (NDWI) data from Sentinel, Landsat and Google Earth. Data availability and aerial image quality varied considerably throughout the 1990 to 2024 study period. The inundation extents were compared to the Digital Elevation Model (DEM) of the lake to estimate ponding depths with time.

As shown in Figure 3.1, Lake Roe consists of a series of small salt pans that appear to be separated by (relatively) high points, some of which appear to be sand dunes, based on assessment of aerial imagery and LiDAR surface elevation data. Each of the small salt pans have a local low point where water may pool.

Figure 3.1 denotes the nominal names used within this study for some salt pans relevant to the assessment. The main catchment reporting to the lake comes from the western side of the lake, with other, smaller catchments reporting to the lake around the lake perimeter. Following large enough inflow events, the individual salt pans may become hydraulically connected.

Confidence in the estimated inundated depths (from observed satellite imagery) varies, and the date of recorded imagery may not coincide with the date of the actual peak inundation extent. Frequent Sentinel data between 2017 and 2024 provides the most reliable period for analyses. Between 2013 and 2017, Landsat (satellite) data are inconsistent with some gaps due to Lake Roe's eastern area falling on a different tile without imagery and satellite imagery strips (Landsat 7) giving an incomplete picture. Pre-2013, imagery from Landsat is less frequent, with data pre-2008 missing for extended periods and/or has insufficient resolution to confidently interpret. Notably, there is a Landsat data gap from late 2011 to early 2013, meaning that any lake inundation due to rainfall events during 2012 are not estimated.

3.1 Inundation Observations

The following observations were made at Lake Roe during the satellite imagery assessment:

- Catchment runoff responses causing at least some inundation in Lake Roe were generally observed when rainfall exceeded approximately 25 mm.
- In small inundation events where widespread flooding across the full lake is not prevalent (i.e., following rainfall depths in the order of 25 mm), the water levels Pan A were estimated. Appendix A presents the estimates of inundation water levels from satellite observations within salt pans B and D for reference.
- Visible widespread inundation across constituent salt pans was typically observed when a rainfall event occurred over multiple days, with total rainfall over the event exceeding 50 mm. Widespread inundation due to a large, singular rainfall day event could not be concluded as there were not any events where daily rainfall exceeded 50 mm within the rainfall data, notwithstanding this may be possible.
- The magnitude of inundation (water level) can vary between constituent salt pans; however, when widespread inundation is observed, the timing of the inundation is generally consistent across the lake.
- Rainfall in early 1995 and 2014 presents the largest rainfall events within the observation period, and these correlated with observations of large inundation events.
- Inundation responses in Lake Roe were generally observed 1 to 3 days after initial rainfall was recorded (noting that satellite observations are not available on a daily basis).

There is a level of uncertainty when correlating satellite observations and rainfall recorded at Cowarna Downs given the distance between the weather station and the lake. Rainfall is highly temporally and spatially variable in the Goldfields and it is likely the rainfall that occurs within the Lake Roe catchment differs from that recorded at Cowarna Downs. Larger events are likely to be more widespread than smaller events, but there is still likely to be a difference between the rainfall recorded at Cowarna Downs and the effective rainfall on the Lake Roe catchment (given the size of the Lake Roe and the Lake Roe, it is likely that rainfall will be variable over the catchment and lake as well). Given the limited spatial availability of rainfall records in the Goldfields, Cowarna Downs is still considered to best represent the rainfall that may have occurred within the Lake Roe catchment.

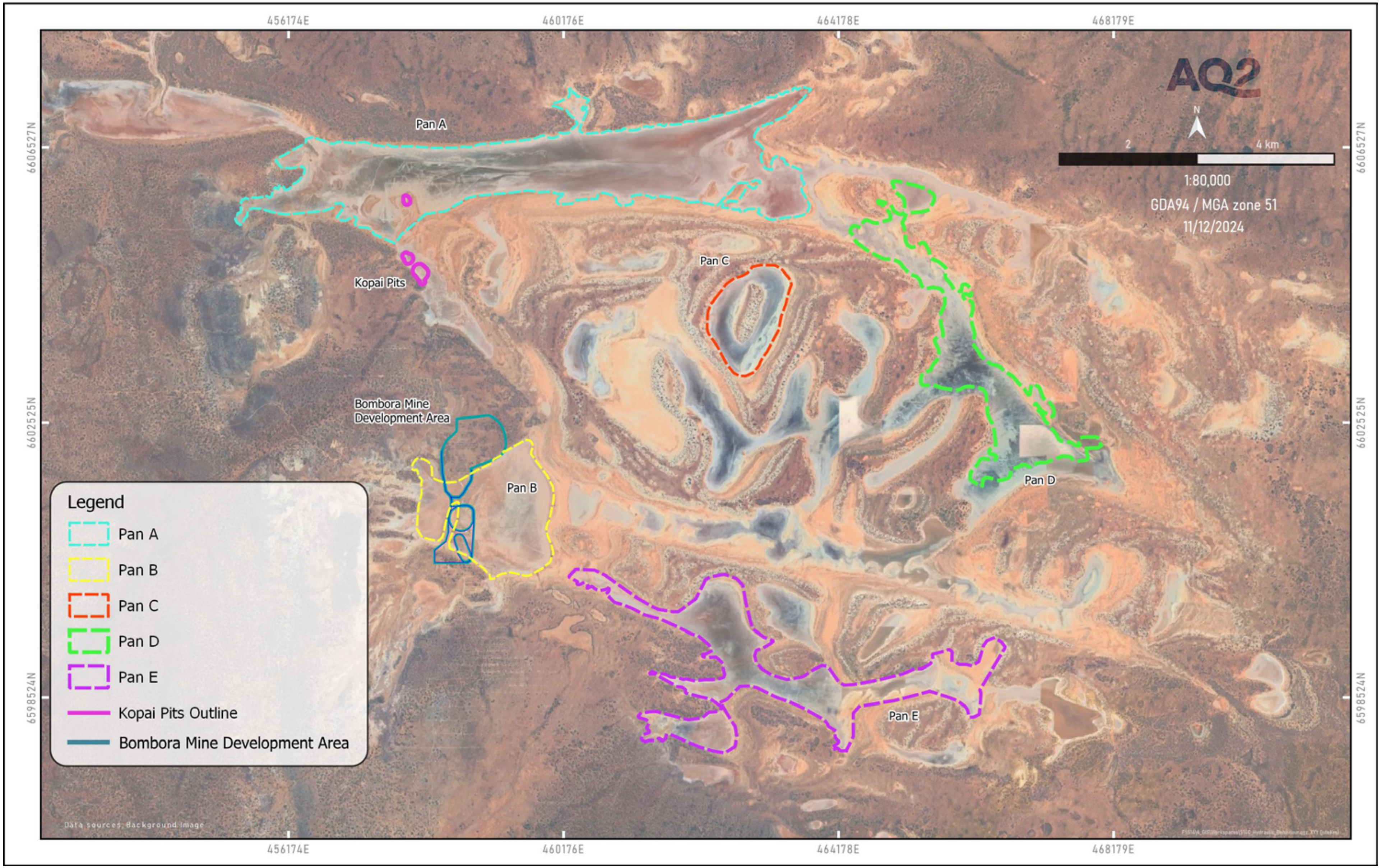


Figure 3.1 Lake Roe Study Area

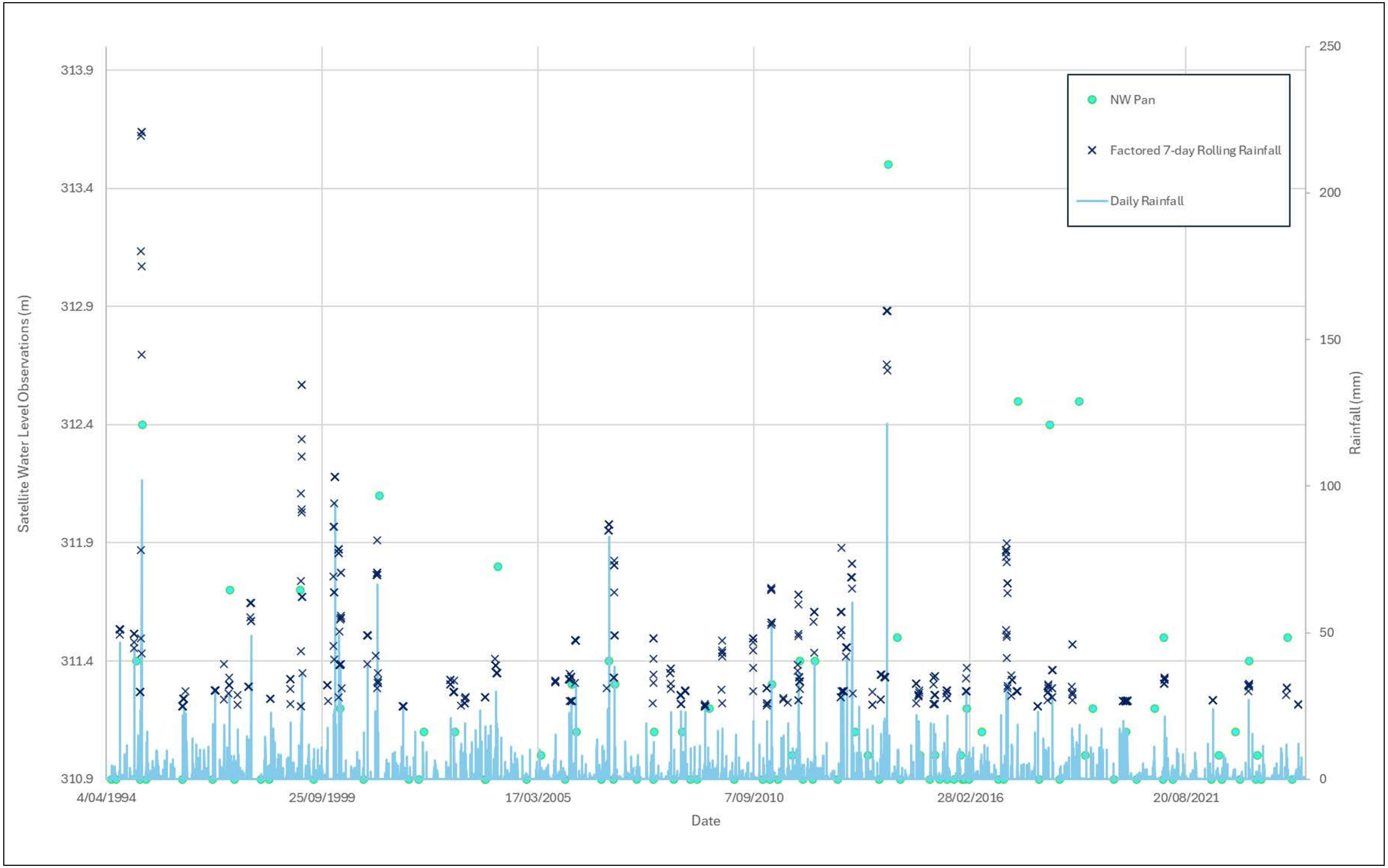


Figure 3.2 Lake Roe Inundation Depths (Pan A) vs Rainfall Data

3.2 Correlations to Intensity–Frequency–Duration (IFD) data

The observed rainfall events since 1993 were correlated with the available Bureau of Meteorology (BoM) intensity–frequency–duration (IFD) data for Cowarna Downs. The 63.2% AEP event (which approximates a large rainfall event which you would expect would happen every year) rainfall depths over 1–3 days of 31.1–38 mm (refer Table 3.1) correlates with the rainfall that results in smaller inundation events observed at Lake Roe in most years.

Larger, rarer rainfall events recorded typically since 1992 at Cowarna Downs (32 years inclusively), seemed to have occurred more frequently than the IFD data would suggest. This is shown in Figure 3.3, where factored rolling rainfall totals from the Cowarna Downs rainfall record are compared to the IFD curves. The plot indicates that, for example, there were 5 x 24-hr (1,440 minutes) duration rainfall events which exceeded the 5% AEP curve where it would be expected that ~2 events of this magnitude may occur in a 32 year period (noting the IFD curves presented do not account for climate change and are typically 10-15% less than what current climate conditions would suggest).

In the last 32 years, there were also 5-6 large inundation events observed in satellite imagery (equating to a 15-20% probability of occurring in a given year). Based on the IFD data, it would be expected that large inundation events would require more than 60 mm of rainfall to occur, which is close to what has been estimated from the inundation estimations (50 mm).

Table 3.1 Cowarna Downs intensity–frequency–duration (IFD) data

Duration	Duration in min	Annual Exceedance Probability (AEP)						
		63.20%	50%	20%	10%	5%	2%	1%
24-hour	1,440	31.1	37	58.6	76.2	96.1	125	150
30-hour	1,800	32.6	38.9	61.8	80.8	102	133	160
36-hour	2,160	33.8	40.4	64.5	84.5	107	140	168
48-hour	2,880	35.7	42.6	68.5	90.2	115	150	180
72-hour	4,320	38	45.5	73.7	97.5	125	163	195
96-hour	5,760	39.5	47.3	76.9	102	131	170	204
120-hour	7,200	40.5	48.6	79	105	134	174	209
144-hour	8,640	41.4	49.7	80.5	106	136	177	212
168-hour	10,080	42.1	50.5	81.6	108	137	178	213

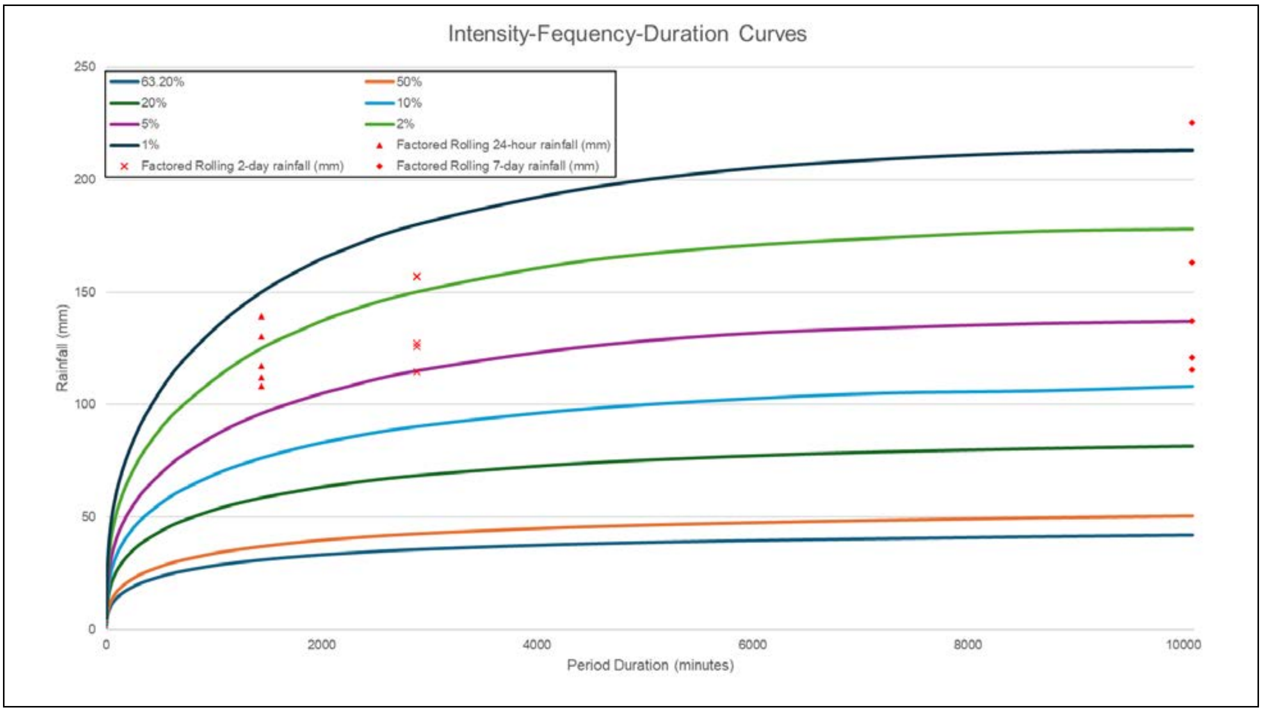


Figure 3.3 Cowarna Downs Intensity–Frequency–Duration (IFD) and Rolling Rainfall Data

4. SEEPAGE ASSESSMENT

Water level recession curves at Lake Roe were predicted following inundation events using a 1D water balance calculation and compared to the observed recession of standing water in the lake from the satellite imagery assessment. As shown in Figure 4.1, Figure 4.2 and Figure 4.3, three key inundation events were identified for assessment in years 1995, 2014 and 2017. The assessment was used to assess the potential seepage from the lake to the subsurface. During the circa 32 years period examined, Lake Roe hosted standing water for various lengths of time (typically in the order of months) after large rainfall events. The water level recession observed from satellite aerial imagery within Lake Roe is assumed to be driven by evaporation and (potentially) seepage into or from the subsurface; Figure 4.4, Figure 4.5 and Figure 4.6 show aerial true colour imagery of the May 2017 flood event's recession

The completed assessment is summarised as follows:

- A stage vs area relationship was derived for different salt pans from the provided LiDAR data.
- Satellite imagery was reviewed to identify periods of significant inundation within the salt pans, nominally years 1995, 2014 and 2017 were chosen as the best data for assessment.
- The inundation area within the salt pans was estimated during period that the lake level recedes when satellite imagery was available (typically in the order of weekly images, but many were unable to be used due to clouds, poor quality etc.).
- The stage area relationship was used to derive estimates of lake water levels with time during the recession period.
- A 1D water level balance calculation was completed using the following formula:

$$Water\ Level = Water\ Level_{Previous} \mp Rainfall - Evaporation - \ Seepage$$

- The daily 1D water balance calculation used the following:
    - The water balance was set to start at the peak lake water observed following the rainfall event.
    - Daily evaporation losses from the lake in the 1D water balance calculation have been predicted using Morton's shallow lake evaporation estimates sourced from the SILO database for the site. These evaporation estimates vary on a daily basis based on meteorological observations.

  - If a small rain event occurred during the water level recession period, the depth of rainfall was added to the running water level total. This assumed that no catchment runoff reported to the lake, with only incident rainfall on the lake surface reporting to the lake. If large rainfall events did occur during the recession, then the observations weren't used as the additional inflow would not be accounted for in the method prescribed above.
  - A nominal seepage loss rate was applied and adjusted such that the modelled recession approximates the observed recession.

The seepage rate that enables water level predictions to approximate the observed recession of standing water within Lake Roe is approximately 3 mm/day. Noting:

- It was difficult to interpret when Lake Roe was completely dry in the satellite imagery due to image quality, partial (or full) cloud cover and the frequency of imagery capture. The appearance of a salt crust on the lake floor in satellite photography was determined not to be a reliable indicator of the entire lake system being fully dry, as, on occasions, these observations concurred with periods where NDWI imagery indicates standing water.
- It is interpreted that groundwater does not contribute to inflow into the Lake Roe, and surface water recession / periodic standing water within the claypan(s) is solely accounted for by evaporative losses and seepage.
- There is a degree of uncertainty in the evaporation losses applied and in the estimation of lake inundation depths. Additionally, there is uncertainty in what the rainfall which falls on the lake is compared to what was measured at Cowarna Downs.

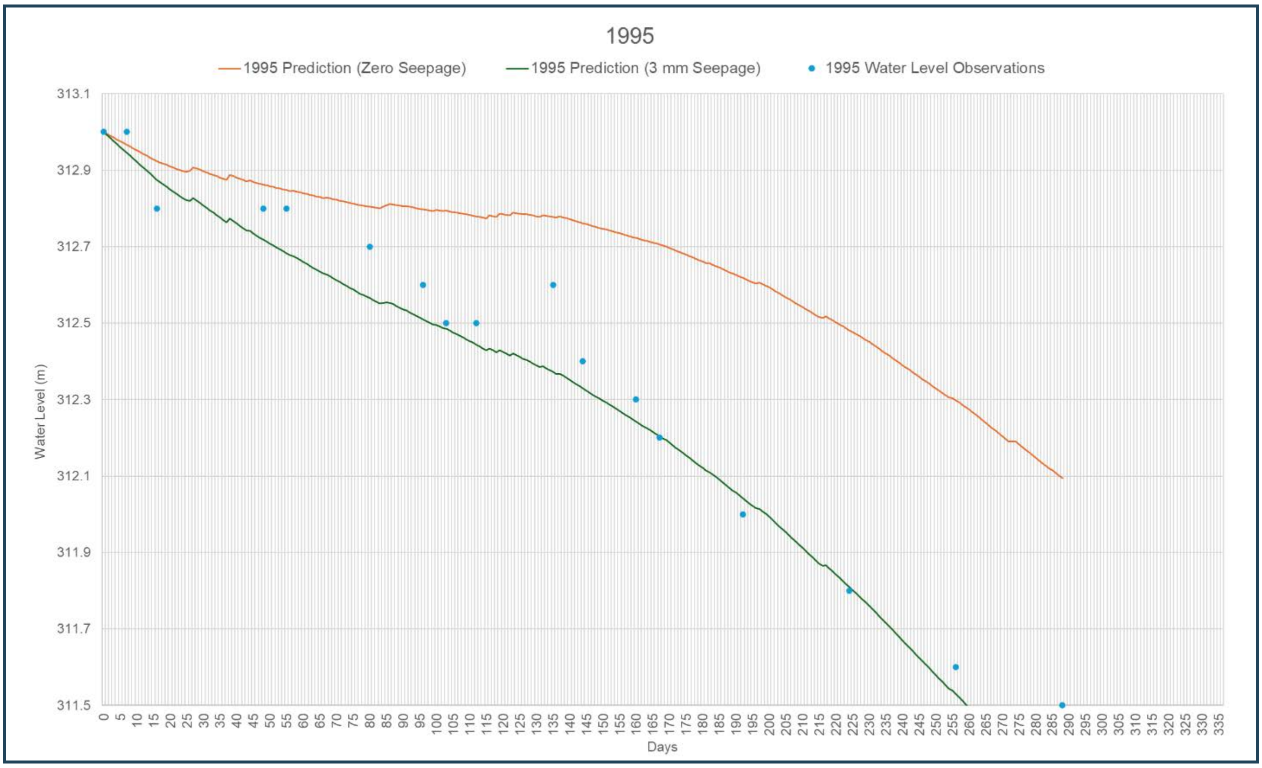


Figure 4.1 Observed vs Predicted Flood Recession Curves (March 1995)

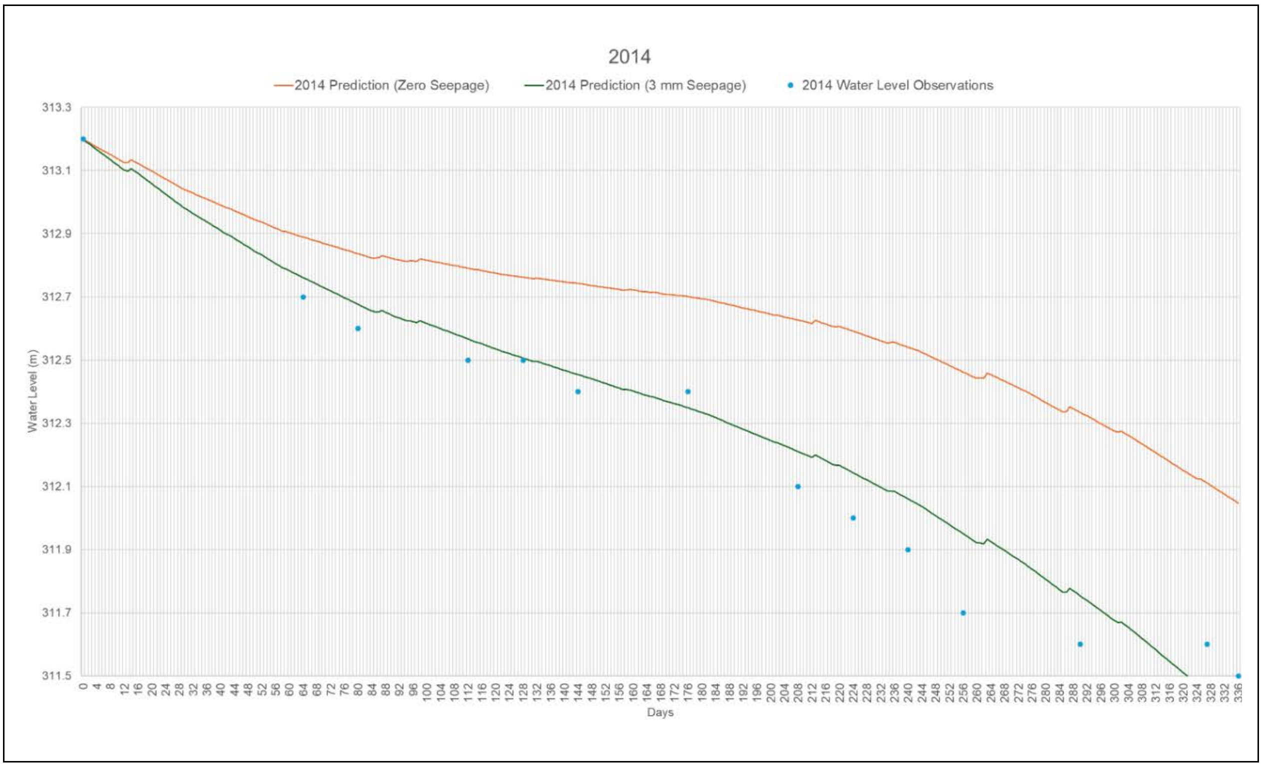


Figure 4.2 Observed vs Predicted Flood Recession Curves (January 2014)

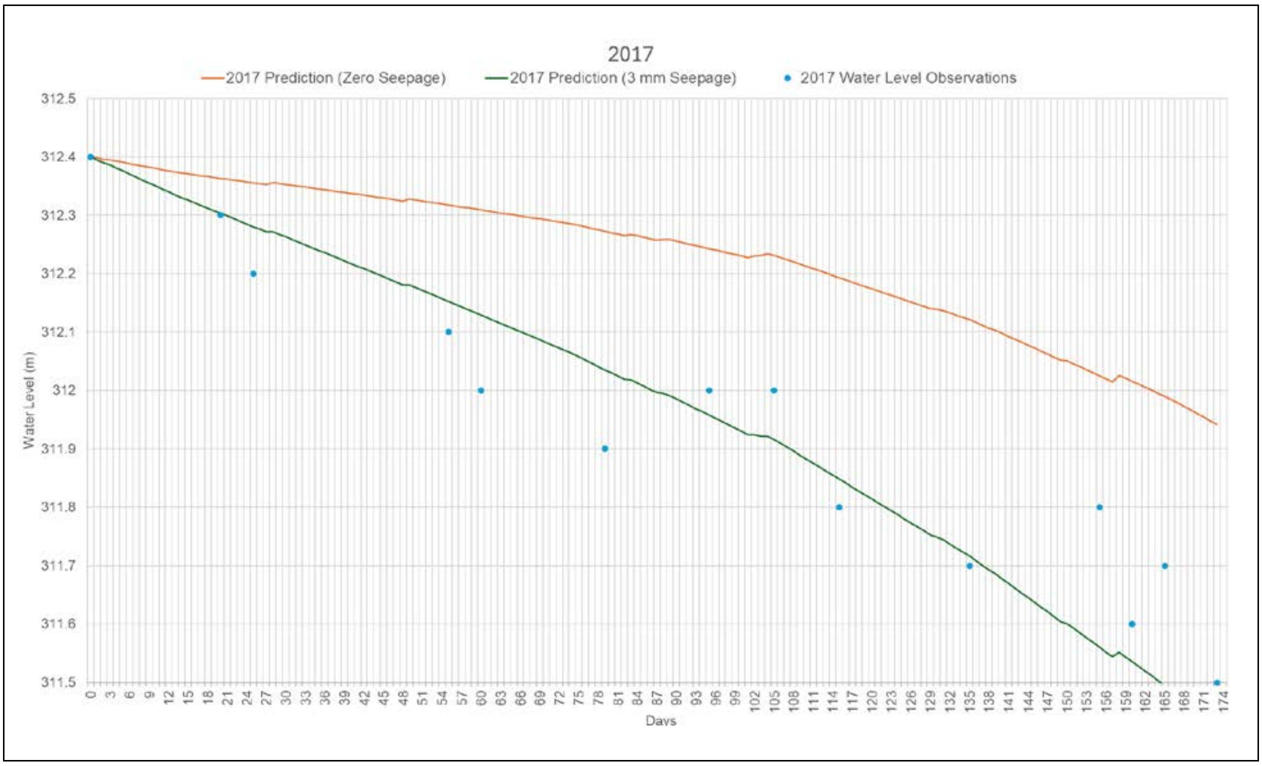


Figure 4.3 Observed vs Predicted Flood Recession Curves (May 2017)

Figure 4.4 True colour imagery for May 2017 flood event's peak inundation on 18 May 2017

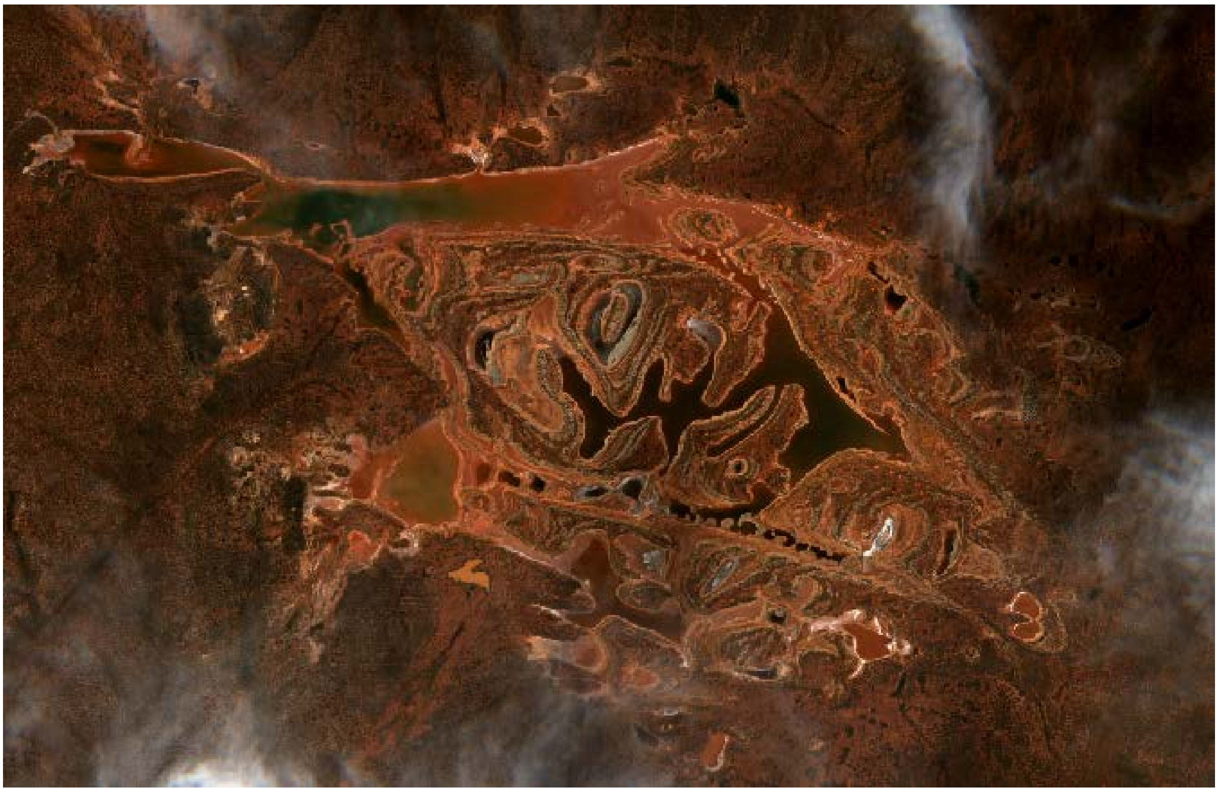


Figure 4.5 True colour imagery for May 2017 flood event's partial recession on 07 June 2017

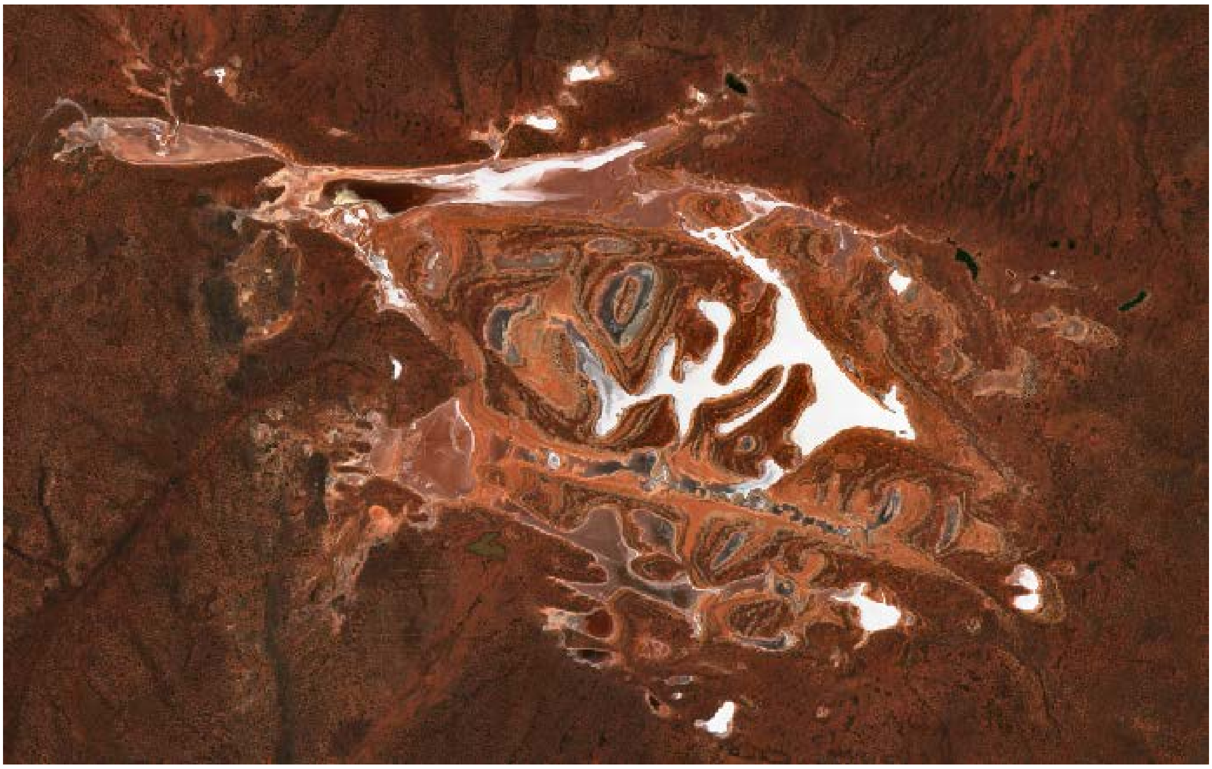


Figure 4.6 True colour imagery for 30 October 2017 flood event – recession

5. POTENTIAL DEWATERING DISCHARGE LOCATIONS

A number of potential locations to receive surplus dewatering have been identified and are shown in Figure 3.1. These locations have chiefly been identified for their proximity to the project area. For each of the potential receiving salt pans, the following has been estimated using the DTM/aerial imagery:

- Maximum storage/inundation elevation – it is assumed that any salt pan could only be filled to either:
    - 0.5 m below the vegetated shoreline of the salt pan.
    - 0.2 m minimum below the point at which the salt pan overtops to the adjacent salt pan (to confine the impact to a single pan).
- Maximum inundation surface area of the salt pan at the maximum inundation elevation.
- Maximum inundation storage volume of the salt pan at the maximum inundation elevation.
- Evaporative loss from the maximum lake surface based on Morton's Shallow Lake Evaporation rate in July, with a nominal reduction in this evaporation rate of 30% adopted to approximate the impact the salinity of the dewatering discharge may have on the evaporation rates.
    - Note that higher evaporation losses would occur during other months, such that the estimates of loss rates are conservative. If there is sufficient balancing storage in the salt pan, the annual average evaporation rate could be applied (rather than the July evaporation rate).

A summary of these characteristics for each salt pan is provided in Table 3.2. The assessment assumes no ponded rainfall within the lake. The advantages / disadvantages of the identified discharge locations are as follows:

- Option A (Pan A) – This pan is close to the proposed Kopai Pit development and provides a large area for storage/evaporation of surplus dewatering. The main disadvantage of this option is that the largest surface water catchments to Lake Roe discharge into this salt pan, and there is the potential that accumulated salt will flow into the downstream pans during large runoff events (i.e., the impact won't be contained to the one pan). Additionally, the discharge of dewatering to this lake may result in recirculation to the Roe Pits, given their proximity to the lake.

- Option B (Pan B) – This pan is close to Bombora Pit development and would contain the surplus discharge to a smaller area compared to Option A. Similar to Option A though, the southwest pan commands a significant upstream catchment, and there is therefore the potential for accumulated salts to be transported to salt pans to the east. Additionally, the discharge of dewatering to this lake may result in recirculation to the Bombora Pits, given their proximity to the lake likely via the Lake Roe N-S fracture zone
- Option C (Pan C) – There is a number of salt pans which appear to be hydraulically isolated from the remainder of Lake Roe by sand dunes, including a roundly shaped pan, the smallest of the four options. Additionally, a cluster of pans situated between Pan B and Pan D have been discounted due to limited volume, all individually smaller than Pan C. These are located further away from the mining areas than Option A and B but may allow impact to be localised to pan. The choice of pan could be based on the rate of dewatering that needs to be managed, with different potential evaporative losses achievable at each pan based on their available surface area. Pan C has been nominally assessed for this option.
- Option D (Pan D) – Pan D could be filled to a depth of approximately 312 mRL (refer Figure 3.1), which is 0.2 m below the elevation of the saddle which separates Pan A and Pan D, to isolate impacts from discharge to this pan. Option D is the pan most isolated and furthest from both the Bombora Mine Development area and Kopai Pits. Option D is the main pan at the most downstream part of Lake Roe.
- Option E (Pan E) – An initial review of Pan E was completed but a comparison of lake shore elevations to the overflow point between consecutive salt pans indicated that it wouldn't be feasible to discharge to one salt pan and fill multiple areas. As such, the available evaporation area for Pan E was too small to consider further.

Environmentally, Option C is the preferred option for discharge as it would isolate the impact of dewatering discharge to the isolation Pan C (subject to confirmation that Pan C has no environmental value which differs from the rest of the lake). However, Option C provides the lowest potential for ongoing loss from the ponded water due to evaporation.

If impact containment is not a priority for the dewatering discharge, Option A may be preferred as it has the highest likelihood of accumulated salt being washed downstream into other parts of the lake during runoff events.

Discharge to Pan D is the furthest discharge option so may be the highest capital cost for discharge, but the benefit is the ponded water is furthest from the mine voids so has the lowest chance of recirculation into the pits.

Further assessments of discharge locations should consider the likely magnitude and duration of discharges to the lake, as well as the potential storage volume in each of the considered discharge locations. A water balance of the pan area could be completed, considering the stage/volume/area relationship of each of the pan options, to predict how each of the pans may fill with time.

Table 5.1 Dewatering Discharge Options

Target	Invert RL	Shoreline RL	Overflow Point RL	Max Inundation RL	Area (km^2)	Loss Potential m^3/day	Loss Potential l/s
Option A	310.9	313	312.2	312.0	7.1	8,500	98
Option B	311.6	312.6	312.4	312.1	2.5	3,000	35
Option C	310.7	313.5	313.6	313.0	1.1	1,000	16
Option D	311.5	313	312.2	312.0	3.1	3,700	43

6. SUMMARY

AQ2 has completed an assessment of available climate data sources for Lake Roe area, a satellite imagery assessment of inundation and other hydraulic behaviour, estimations of potential discharge volumes, and a seepage assessment. Key findings are as follows:

- Pan A, adjacent to Kopai Pits, has been observed to hold runoff in most years. Significant inundation is observed to occur in the order of once every 5 years.
- Following significant inundation events, the lake may hold water for months.
- Seepage rate analyses indicate that in the order of 3 mm/day of seepage may occur from the lake bed when it is inundated.
- Five locations were considered for the discharge of surplus water from the project. Environmentally, Pan C is considered the most favourable, as it would confine the discharge to a single part of the lake. However, Pan C has the smallest surface area and therefore the lowest potential to lose discharged water via evaporation (in the order of 15-20L/s).
- Option D is furthest from the project area and allows for the containment of discharge in the most downstream part of the chain of salt pans that make up the Lake Roe system.
- Further assessment work should be completed on the discharge options when surplus water magnitudes and duration of discharge are estimated.

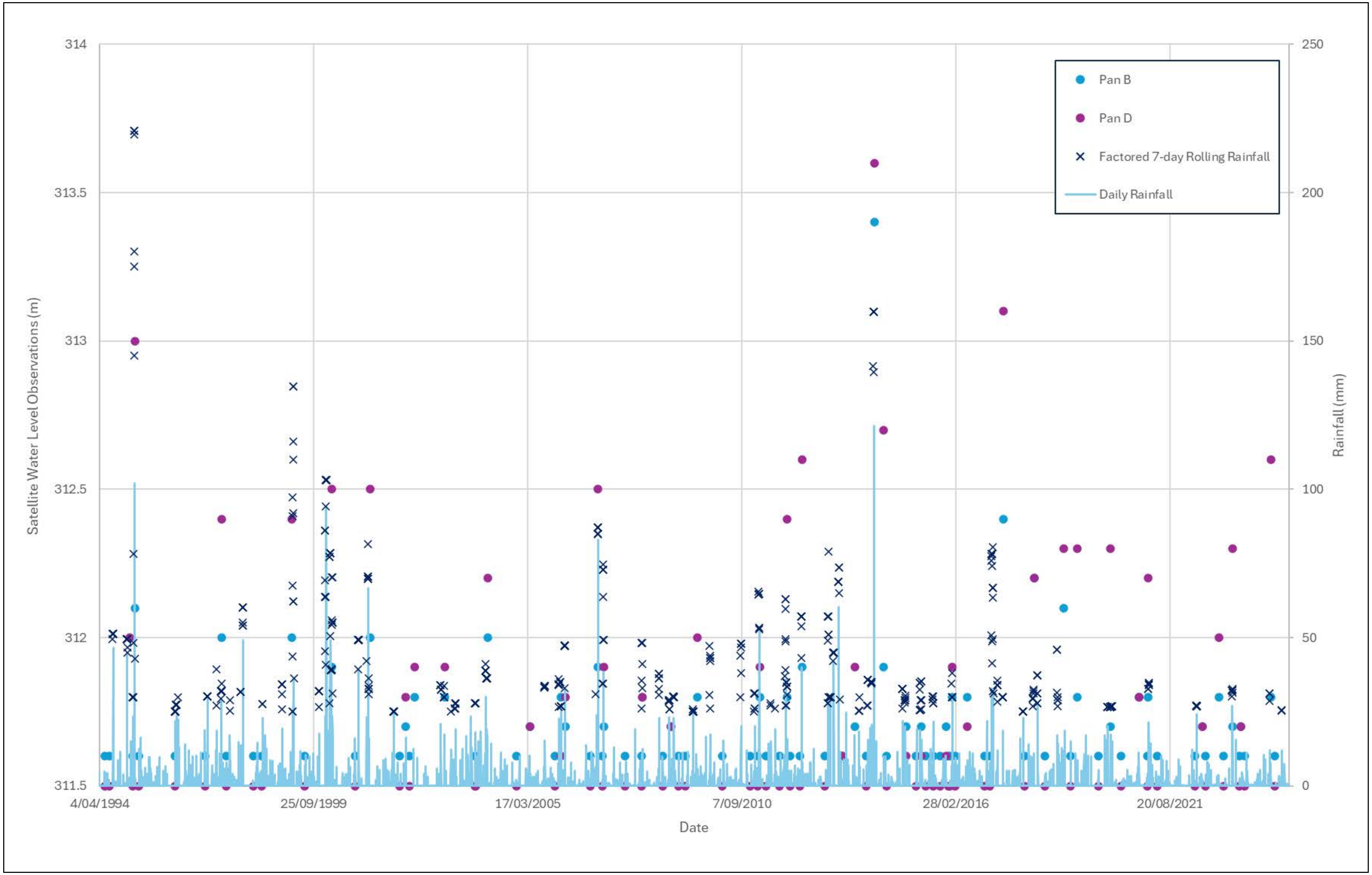
We trust that this assessment meets your requirements. Please contact us should you require further information.

Best wishes,

Shirley-Rose Field	Mark Nicholls
Water Resources Engineer	Consulting Water Resources Engineer

Author: SF/JS (06/12/2024)
Checked: MN (06/12/2024)
Reviewed: MN (06/12/2024)

Attached: Lake Roe Inundation Depths (Pans B and D)



Lake Roe Inundation depths (Pans B and D)