9.4 Hydrological Processes and Inland Water Quality (Surface Water)

9.4.1 EPA Objective

The EPA's objective with regards to hydrological processes for surface water is:

- To maintain the hydrological regimes of surface water so that existing and potential uses, including ecosystem maintenance, are protected.

The EPA's objective with regards to inland water quality for surface water is:

- To maintain the quality of surface water, sediment and biota so that the environmental values, both ecological and social are protected.

9.4.2 Relevant Legislation and Policy

The WA *Rights in Water and Irrigation Act 1914* (RIWI Act) makes provision for the regulation, management, use and protection of water resources, and for related purposes. Surface waters within and around the Project Areas are ephemeral and not considered suitable for drinking water supply, stock watering or irrigation, and therefore there are no specific licensing requirements relating to surface water for the Project, under the RIWI Act.

The EPA has developed a number of policies relevant to the protection of surface waters in WA. These include EPA (2004a) *Position Statement No. 4: Environmental Protection of Wetlands, Pert*h, EPA (2004b) *Position Statement No 5: Environmental Protection and Ecological Sustainability of the Rangelands in Western Australia*, and EPA policies.

The DoW has developed a number of operational policies and guidance. The policy most relevant to surface water management is DoW (2009) *Operational Policy No. 1.02 – Policy on water conservation/ efficiency plans*, Perth, Western Australia.

The Australian and New Zealand Environment Conservation Council (ANZECC) and the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) have developed the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000). The main objective of these guidelines is:

> "to provide an authoritative guide for setting water quality objectives required to sustain current, or likely future, environmental values [uses] for natural and semi-natural water resources in Australia and New Zealand."

The water quality guidelines were prepared as part of Australia's National Water Quality Management Strategy (NWQMS). They are based around the protection of various environmental values (or uses) of surface waters. Environmental values that apply to surface waters within and around the Project Area are:

- aquatic ecosystems;
- cultural and spiritual values.

Surface water that is captured within the Project Area would be considered 'industrial water' and retained for use by the Project. No water quality guidelines are provided for industrial water within the ANZECC/ARMCANZ guidelines.

Associated with each environmental value are trigger values for substances that might affect water quality. If these values are exceeded they may be used to trigger an investigation or initiate a management response. Where two or more agreed environmental values apply to a water body, the more conservative, or stringent of the associated guidelines would be selected as the water quality objective.

Once the environmental values to be protected have been selected, the level of environmental protection or water quality necessary to maintain each value is determined. Management goals that describe how this will be achieved can then be developed following consultation with relevant stakeholders.

9.4.3 Studies and Investigations

A Surface Water Study for the original project was undertaken by BHP Billiton between 2009 and 2011. Cameco commissioned URS to undertake a review of this work and update it where appropriate for the revised Project (URS 2015a). An assessment of the overall site water balance was also undertaken for the Project (URS 2015b). The surface water report and water balance study are presented in Appendix H1 and Appendix H2 respectively.

9.4.3.1 Surface Water Study

The overall objectives of the surface water study were to characterise the existing surface water environment; assess potential changes to the surface water environment resulting from the proposed Project; and identify mitigation and management strategies to minimise potential changes to surface water hydrology. This study included:

- characterisation of the baseline hydrological regime, including stream flows, flood patterns, water chemistry, and water quantity and quality;
- analysis of rainfall data to inform project design elements necessary to manage storm rainfall events;
- assessment of the changes to the hydrological regimes including, water levels, water chemistry, stream flows, flood patterns, and water quantity and quality, as a result of implementation of the Project, under a range of climatic scenarios including probable maximum precipitation (PMP);
- calculating the duration of flooding within the development envelope under pre-construction, mining and post closure conditions; and.
- assessment of potential erosion and sediment transport within the Project envelope before disturbance, during operation and post closure.

Baseline Site Investigations

As part of the surface water study undertaken by URS for BHPB between 2009 and 2011, several site investigations were undertaken to support both the surface water and groundwater studies. The following site investigations were undertaken:

- reconnaissance survey (March 2009) with a walkover of the development envelope and local reaches of the Yeelirrie Catchment;
- infiltration tests conducted in June 2009 (winter) and January 2010 (summer);
- soil sampling (in June 2009 and January 2010); and
- opportunistic surface water sampling during two rainfall events in 2009 and 2010.

Baseline Surface Water Hydrology and Drainage Characterisation

Characterisation of the baseline surface water flows within the study area was based on:

- the results of a literature review;
- available topographic data to delineate the local catchments, inform drainage patterns and channel characteristics;
- analysis of available datasets from both historical records and recent site investigations including land system information from the Department of Agriculture & Food Western Australia (AgWA 1994 & 1998); and
- review of rainfall data and development of design rainfall data for the Yeelirrie (Playa) Catchment and the Lake Miranda Catchment for selected Average Recurrence Interval (ARI) events (1, 2, 5, 10, 20, 50, 100 and 1,000 years).

From this, hydrological modelling was undertaken to simulate the rainfall-runoff, surface water drainage and flow characteristics of the study area for a range of rainfall events.

Baseline Flood Characterisation and Simulations

The baseline hydraulic flood model was used to characterise the surface water flow along the main flow paths of the Lake Miranda and Yeelirrie Playa Catchments and determine the:

- extents of flooding for selected ARI events;
- depths of flood water for selected ARI events;
- natural attenuation of flood waters;
- flow velocities; and
- potential surface water flows out of the Lake Miranda Catchment.

Baseline Interactions between Surface Water and Groundwater

The interaction between surface water and groundwater was described by investigating the:

- observed water table responses to rainfall and flooding;
- surface water flux actually reaching the water table (recharge) and its predictability based on recently monitored ARI events;
- depth to the water table, groundwater salinity and position within the catchment; and
- comparing the observed recharge rises to local stratigraphy to determine whether event-based recharges are significant to event-based groundwater flow.

Environmental Change Assessment during Operations

Hydrological modelling was undertaken to assess the changes between the baseline hydrology and the modelled hydrological conditions resulting from the proposed Project.

To prevent the inflow from surface water runoff into the mine site area, Cameco is proposing to construct a surface water diversion bund to divert surface water runoff and stream flow around the active mining area during operations. The diversion bund, designed to protect against a 1,000-year ARI flood event, will be constructed in two stages in order to minimise the amount of precipitation and surface water runoff that would collect within the mine area and require management.

The baseline hydraulic flood model was adapted to incorporate key elements of the proposed Project infrastructure that potentially influence the surface water environment.

Hydraulic flood modelling was undertaken on the Lake Miranda Catchment to predict the effects of the surface water diversion bund on surface water flows during 1-, 5-, 20-, 100- and 1,000- year ARI events. The predictive assessments of changes to flood depths, extents and velocity of flow were undertaken at three different scales, with a hydraulic flood model developed for each:

- Regional Scale: Lake Miranda Catchment outside of the surface water diversion bund.
- Local Scale: Yeelirrie Playa Catchment outside of the surface water diversion bund.
- Minesite Scale: Area inside the surface water diversion bund forming the predominant disturbance footprint.

Changes to erosion and sediment characteristics were examined. Changes to surface water and groundwater interactions as a result of the Project were also investigated.

Change Assessment after Mine Closure

Changes to surface hydrology after mine closure were assessed based on the following closure concepts:

- Backfill of the pit area and build-up of the proposed disturbance area of the mine site to a 1:100 year ARI flood level. The area above this level would be shaped to be free draining.
- The diversion bunds would be removed and the northern watercourse would be reinstated by means of a channel along the northern side of the mine backfill area, with a capacity to convey the 1:100 year ARI flood flow without overtopping the site.
- Small areas on the northern upstream side of the surface water diversion bund will be filled to ensure hydraulic smoothness.

The change in flood characteristics from baseline conditions due to the post-closure landform were modelled and focussed on change in flood water depth / levels around the mine site; and change in flow velocities.

Changes to erosion and sediment characteristics post-closure were assessed. Changes to surface water and groundwater interactions, including alterations to groundwater recharge post-closure were also investigated.

Further detail on the methodology for the Surface Water Study is presented in URS (2015a) (Appendix H1). Further information on groundwater is provided in Section 9.5.

9.4.3.2 Project Water Balance

The ESD requires Cameco to assess the overall site water balance and management of affected surface water to ensure onsite containment. A water balance model was developed for the original project by URS in 2011. This was updated for Cameco's Project in 2015. The key components of the water balance model are:

- climate inputs (rainfall and evaporation);
- water demand.
- water supply
- water storage and distribution; and
- water recycling.

From the water balance model, a proposed Water Management Strategy (WMS) was developed. The WMS was tested under a range of climatic conditions (Monte Carlo simulations) based on historical data.

Further detail on the methodology for the Water Balance Study is presented in URS (2015b) (Appendix H2) and Section 6.6.

9.4.4 Existing Environment

The climate and surface water environment of the study area is described in detail in URS (2015a; Appendix H2) and summarised below.

9.4.4.1 Climate

There are no permanent surface water features in the region and rainfall is the primary source of surface water within the study area. The average annual rainfall for Yeelirrie Homestead is 238 mm with a minimum annual rainfall of 43 mm and a maximum annual rainfall of 507 mm (BoM 2015). The rainfall frequency and total annual rainfall is widely variable with a dependability of only 40%. Yeelirrie receives 61% of mean annual rainfall in the summer months (November to April) and the remainder during winter, generally at low intensity, producing limited surface water runoff.

Summer rains are normally of high intensity, caused by localised thunderstorm activity or much larger weather systems associated with tropical lows and cyclones. Cyclones and associated rain-bearing lows are the source of the majority of extreme rainfall events that are likely to generate surface runoff within the Yeelirrie Catchment. Data from the Bureau of Meteorology (BoM) indicates that 13 cyclones have passed within 200 km of Yeelirrie Homestead between 1970 and 2000.

No evaporation data is available from the BoM Yeelirrie Meteorological station. In the absence of evaporation data at Yeelirrie, long term SILO synthetic rainfall and evaporation data were generated for the Yeelirrie Catchment. Mean annual pan evaporation is estimated to be about 2,260 mm. Mean annual rainfall at Yeelirrie is about 10% of the mean annual pan evaporation.

Design rainfall

Design rainfall events were estimated to support the baseline surface water assessments within the Lake Miranda Catchment. Design rainfall quantities were estimated for a range of ARI events (1- to 1,000-year ARI) and Probable Maximum Precipitation (PMP). Design rainfall for selected ARIs is presented in Table 9-38.

Table 9-38: Design rainfall for selected ARIs (mm)

ARI (year)	Rainfall Duration (hrs)					
	1	6	12	24	48	72
Yeelirrie (Playa) Catchment						
1	12.5	20.8	25.2	31.2	37.4	40.3
5	15.6	29.9	39.5	49.7	63.6	71.8
20	22.5	46.2	63.1	79.9	104.8	116.8
100	36.0	78.5	107.0	139.2	177.8	198.8
1,000	NC	NC	NC	197.4	242.9	257.7
PMP	NC	NC	NC	650	860	1,030
Lake Miranda Catchment						
20	20.9	43.0	59.7	76.7	100.9	114.0
100	34.1	75.2	103.0	134.5	173.9	194.6
1,000	NC	NC	NC	193.5	239.4	254.5
PMP	NC	NC	NC	560	740	900

Note: For selected events the design rainfall have not been calculated (NC) as these are non-critical events and therefore not required.

9.4.4.2 Regional Drainage Characteristics

The Project is located within the Lake Miranda Catchment (7.560 km^2) which is a closed drainage area for typical rainfall events. During extreme rainfall events sufficient runoff may be generated for flood waters to fill Lake Miranda and flow across a low topographic saddle east into Lake Darlot. Lake Darlot is part of the larger Lake Carey Catchment (114,000 km^2) which is a surface runoff catchment within the Salt Lake Basin (441,000 km^2) of the Western Plateau Division. The regional drainage catchments are shown on Figure 9-20.

Figure 9-20: Regional drainage basins

9.4.4.3 Catchment Characteristics

The Yeelirrie Study Area has a gentle relief with the exception of sand dunes and granite breakaways. The total elevation range within the catchment is approximately 100 m from about 480 m AHD in the centre of the catchment near the Yeelirrie Homestead, to a maximum of about 580 m AHD on the granite breakaways, which mark the divide between the catchments. The topographic relief within the proposed Project Area is in the order of about 20 m.

The Yeelirrie catchment (upstream of the Yeelirrie Playa) drains to the southeast into Lake Miranda (Figure 9-21). The Yeelirrie catchment is further divided into a number of sub-catchments (Figure 9-22). The Project is located in the valley floor of the Yeelirrie Playa catchment drainage line on the confluence of two main drainage lines which drain the Yeelirrie Playa catchment upstream of the mine site with a total catchment area of 2,915 km^2. The northern drainage line which passes along part of the northern side of the pit drains sub-catchments A1-4 (2,449 km^2). The southern drainage line which is mostly south of the pit, drains sub-catchment B (466 km^2). Sub-catchment C (222 km^2) drains into the Yeelirrie Playa drainage line along the length of the proposed mine site, both north and south.

There are no known hydrological records for the study area, such as stream flow measurements or gauged run-off events. There is also no known record of a major flood in the main valley, although sheet-flooding has been observed nearby at the Yeelirrie Homestead. The hydrology of the study area has been described in several technical reports, predominantly hydrological studies for the Yeelirrie feasibility and environmental impact assessment studies from 1976 to 1982.

Surface runoff within the Yeelirrie Catchment occurs only occasionally following intense rainfall. Sheet runoff may shed from the upper margins of the catchments, flow rapidly to the central drainage line and generate short-lived stream flow. Typically, the stream flow terminates in playas (including clay pans). On the larger playas, water may remain for several weeks following large rainfall events (Western Mining Corporation 1978).

Surface water infiltration into the ground depends on a number of factors including rainfall intensity, duration, frequency, hydraulic conductivity of the soil and moisture characteristics during and between rainfall events. Recharge responses to rainfall during have been noted following the review of six climatic events since 2010. Typically, the infiltration rate was noted to be high where sandy soils are present in areas of low relief and where calcrete (and related “crab holes”) are present in low-lying areas where runoff accumulates. Infiltration was also higher in areas that are subject to inundation even if the underlying soils are clayey (e.g. clay pans). These areas accumulate clay and silt from the runoff, and salt derived from natural sources within the catchment.

Groundwater may also influence surface water where the water table is close to or above the ground surface. Evaporation draws salt from the water table where it accumulates at the surface along with salt derived from runoff. Salt lakes such as Lake Miranda and other smaller features in the Albion Downs area are examples of this.

Springs resulting from conditions where the water table is above the surface can also affect the surface water quality due to the accumulation of salt and other naturally-occurring solutes. There is only one spring in the region, Palm Springs located 54 km east southeast of the Project.

Also present are small rock holes and pools which fill after rainfall and evaporate shortly afterwards. These occur on granitic outcrops to the northeast and southwest of Yeelirrie Homestead and have cultural significance.

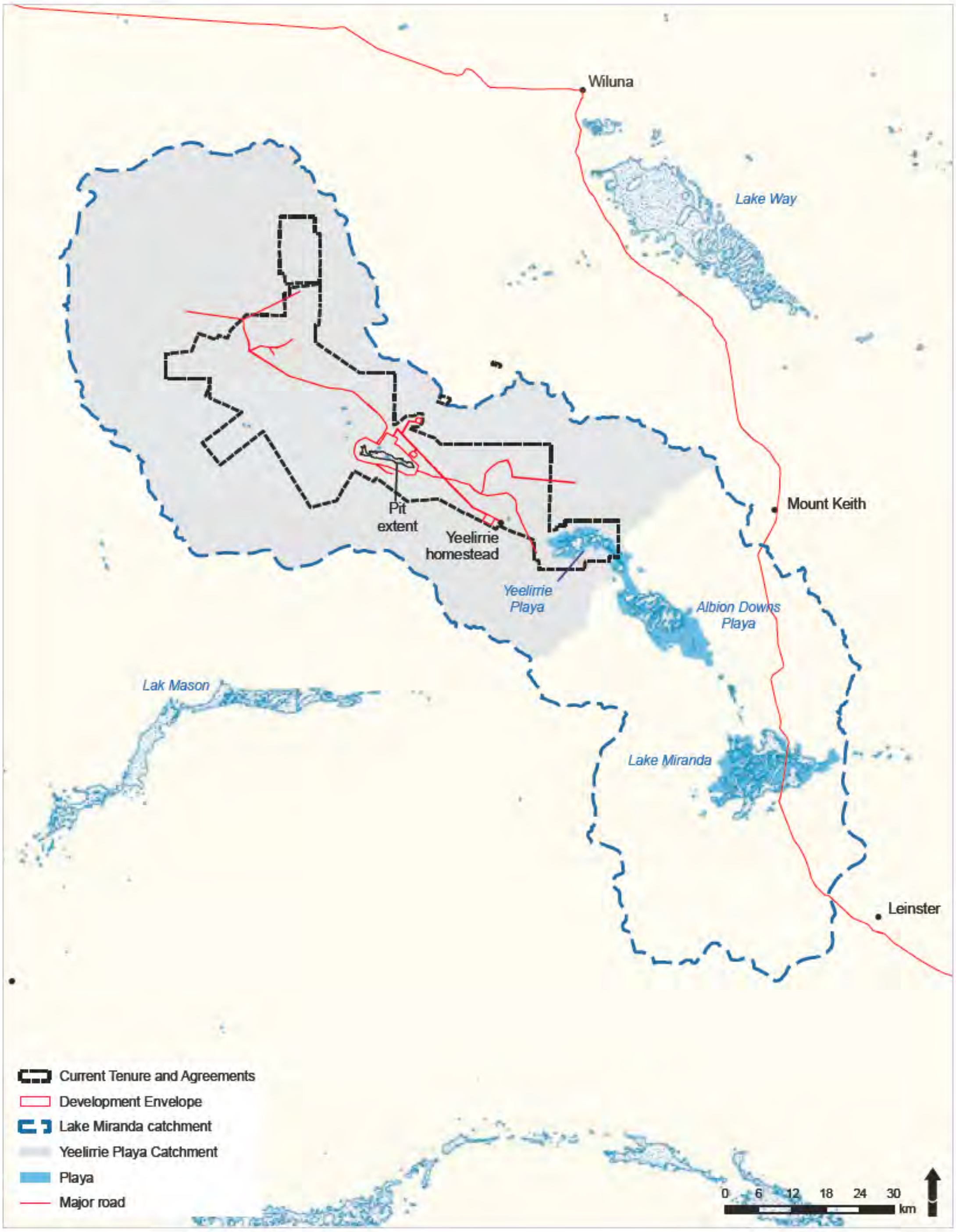


Figure 9-21: Lake Miranda catchment drainage

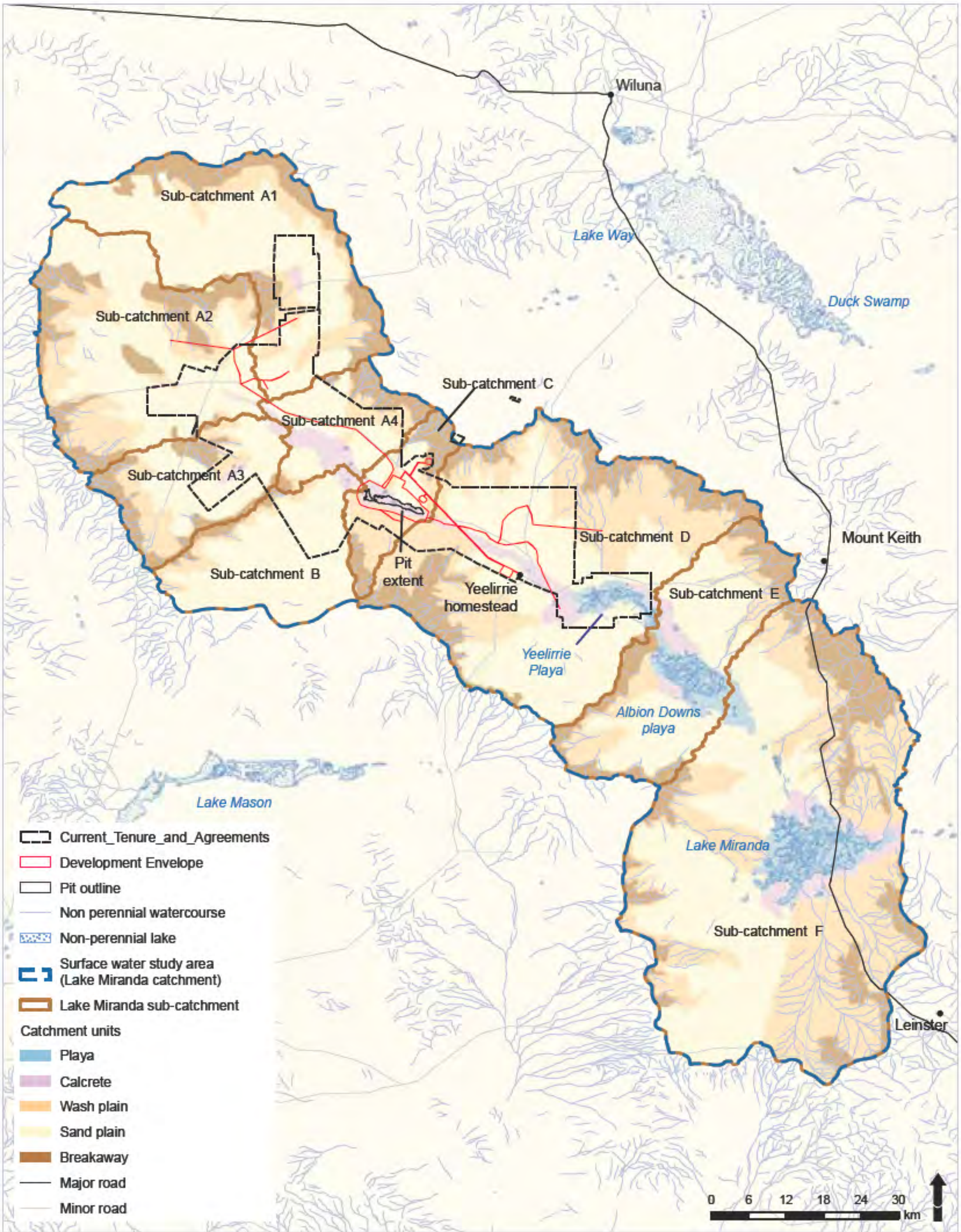


Figure 9-22: Lake Miranda catchment and sub-catchments

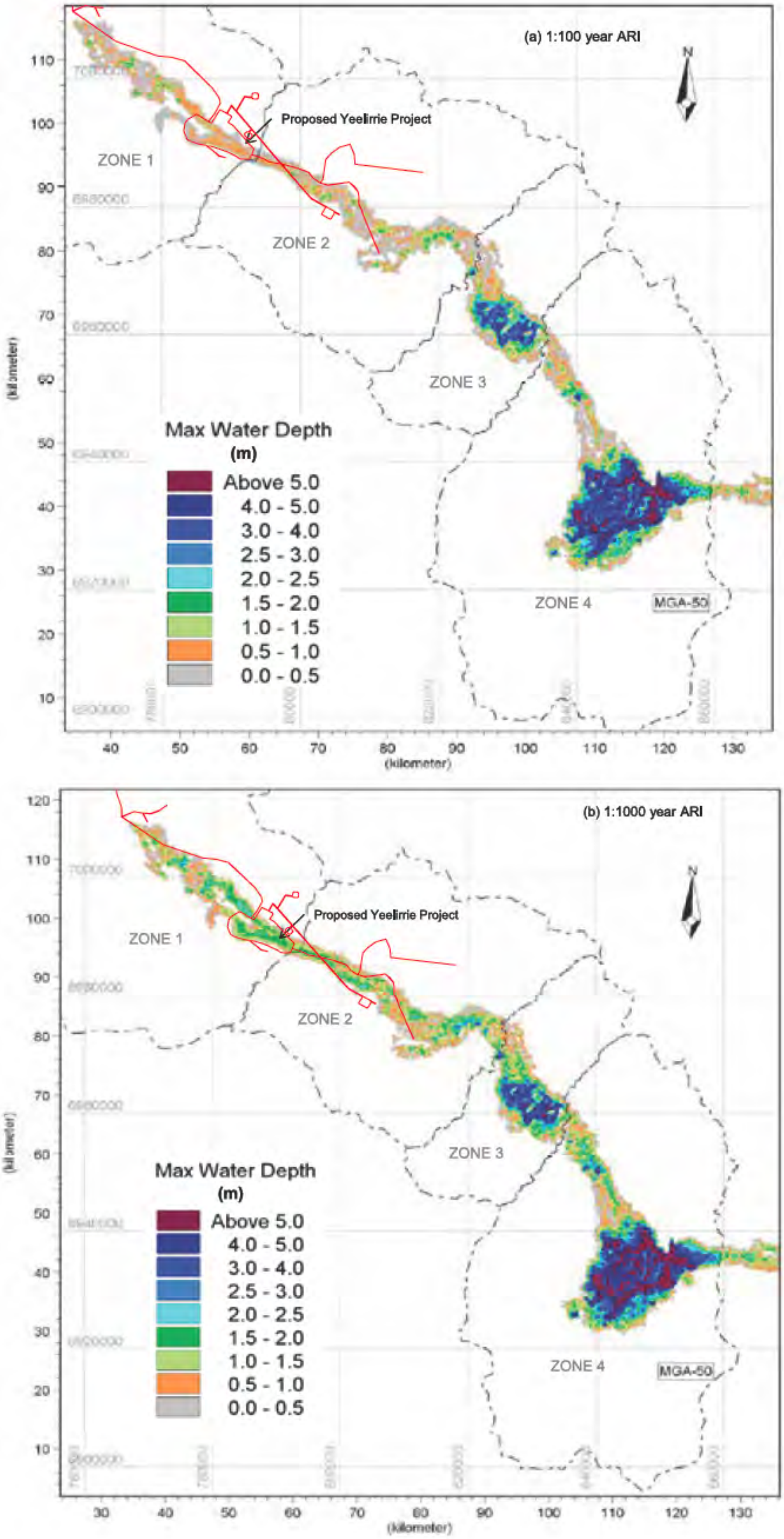


Figure 9-23: Regional baseline flood maps maximum water depths

Baseline Flood Simulations

The hydrological modelling of baseline conditions indicates:

- Rainfall events smaller than 1:20 year ARI generate localised sheet flow runoff. No interconnected flows are predicted to occur within the catchment valley.
- Larger rainfall events (1:20 to 1:100 year ARI) generate interconnected runoff in the valley floor throughout the Lake Miranda catchment terminating in the playas.
- Extreme rainfall events (1:100 year ARI and greater) generate runoff throughout the Lake Miranda catchment, with Lake Miranda spilling over into the Lake Carey catchment.

Simulated maximum flood water depths in the Lake Miranda catchment are presented in Table 9-39 and shown in Figure 9-23.

Table 9-39: Simulated baseline maximum water depths in the Lake Miranda catchment

Zone	Simulated Maximum Flood Water Depths (m)		Cyclonic Rainfall
	ARI Rainfall Event		
	100-year	1,000-year	Trixie (1975)
1	6	3.5	1.8
2	3.5	4.3	2.6
3	5.5	6.3	2.7
4	8.2	9.4	2.9

Simulated peak flood depths in the Yeelirrie Playa catchment indicate a maximum flood depth of 3.4 m for Zone 1 and 3.7 m for Zone 2.

Table 9-40 shows the baseline simulated maximum flood depths on the watercourse reaches immediately upstream and downstream of the proposed Project Area and on the Yeelirrie Playa. Stream flows along the main channel and into the Yeelirrie Playa start to occur during the 20 year ARI event. The maximum flood depths occur where the stream flow slows and pools at low points along the main valley floor flow paths.

Table 9-40: Simulated baseline maximum flood water depths on selected watercourse reaches

Event ARI (years)	Simulated Maximum Flood Water Depths (m)		
	Upstream Reaches	Downstream Reaches	Yeelirrie Playa
1	<0.1	<0.1	<0.1
5	0.1 – 0.25	0.25 – 0.5	0.25 – 0.5
20	0.25 – 0.5	0.5 – 0.75	0.5 – 0.75
100	0.75 – 1.0	0.75 – 1.0	0.75 – 1.0
1,000	2.0 – 2.5	1.5 – 2.0	1.5 – 2.0

Simulated regional baseline maximum flow velocities range up to 1 m/s. However, due to the natural attenuation in the catchment area, the simulated flow velocities have relatively little variation across the catchment.

Surface Water Quality

Opportunistic surface water sampling was completed during two rainfall events that occurred on 24 June 2009 (9.2 mm) and 21 – 22 March 2010 (42.6 mm). Due to the lack of physical access from isolated flooding during the rainfall events, only six surface water samples were collected from the following locations:

- SW4: Upstream Central Valley Playa Land System
- SW3: Northern Flank – Wash Plain Land System
- SW6: Northern Flank – Downstream Wash Plain Shedding to Yeelirrie Playa
- SW2: Southern Flank – Downstream Breakaway Land System
- SW5: Yeelirrie Playa
- SW1: Outskirts Albion Downs Playa

Surface water sampling results are provided in Table 9-41.

Table 9-41: Indicative surface water quality parameters

Parameter	Units	SW4	SW3	SW6	SW2	SW5	SW1
Physical Parameters							
TDS	mg/L	23	<5	123	824	16,800	4,130
Selected Ions							
Na	mg/L	1	<1	2	45	119	26
Cl	mg/L	<1	<1	1	61	97	13
SO_4	mg/L	3	<1	2	11	10	2
Total Alkalinity (as $CaCO_3$)	mg/L	5	4	2	27	314	56
Selected Metals (Dissolved)							
Al	mg/L	0.11	0.28	0.04	-	6.28	-
Fe	mg/L	0.07	0.27	<0.05	<0.05	1.43	3.66
Mn	mg/L	0.04	0.014	0.05	-	0.079	-
Zn	mg/L	0.03	<0.005	0.07	<0.005	0.020	0.012
Sr	mg/L	0.01	0.002	0.005	0.022	0.022	0.006
V	mg/L	<0.01	<0.01	<0.01	<0.01	0.080	<0.01

The data from the available surface water samples (measured in the short-term after rainfall) indicate the surface water is fresh, with relatively low concentrations of chloride, sodium, sulphate and bicarbonate. Samples collected from the Yeelirrie Playa and Albion Downs Playa had comparatively high levels of total dissolved solids (TDS) of 16,800 and 4,130 mg/L, respectively. The measured TDS concentrations, however, are known to include suspended sediments.

The measured chloride concentrations of < 1 to 1 mg/L occur within the upper catchment reaches of watercourses and align with low TDS measurements. These measurements may reflect both low chloride contents in rainfall and limited dissolution and mobilisation, of stored salts either on the surface or in shallow soils.

Measured chloride concentrations in the vicinity of the Yeelirrie and Albion Downs Playas, are indicative of fresh waters at the time of sampling. However, the measured chloride concentrations are not aligned with the TDS concentrations. This indicates there is likely to be evaporation concentration processes and dissolution of stored salts that influence the salinity of infiltrates reporting to the water table.

9.4.5 Potential Impacts

9.4.5.1 Surface Water Impacts

Surface water diversion

To prevent the inflow of surface water runoff into the proposed mine site area, a surface water diversion bund would be constructed to divert surface water runoff and stream flow around the active mining area during the operations. The diversion bund, which has been designed to protect the mine site from a 1,000 year ARI flood event, will be constructed in two stages to minimise the amount of runoff and rainfall that would collect within the mine area and require management (Figure 9-24 and Figure 9-25). The baseline streamflow paths (northern and southern channel) would be partially blocked due to the construction of the surface water diversion bund. Therefore, a diversion channel would be required to drain the flood waters from the northern watercourse, around the minesite and into a combined watercourse (which approximately aligns with the existing southern watercourse) along the western and southern perimeters of the mine, protected by a surface water diversion bund.

Diversion of natural surface water drainage lines will alter the baseline hydrology during a significant flood event. However, the modelling indicates that water would not flow within the catchment as a connected watercourse, unless a storm event in excess of a 20 year ARI occurred. The modelling predicts that for the duration of the mine operation, and up to a (hypothetical) 1,000-year ARI event, the surface water diversion bund would:

- prevent external catchment surface water from draining into the proposed Project mine site area, and
- prevent the surface water runoff that collects interior of the surface water diversion bund from discharging uncontrolled outside the bund into the natural environment.

Hydrological changes outside the diversion bund

The modelling indicates that outside the surface water diversion bund the predicted changes resulting from a (hypothetical) flood event include a temporary:

- increase in the water depth immediately upstream of the mine due to ponding;
- increase in the stream flow velocity of water draining around the western and southern perimeter of the mine area (through the proposed diversion channel and between the minesite and southern valley slope);
- increase in the baseline water depth and flow volume immediately downstream of the mine area due to retardation of stream flow upstream of the mine site.

Changes to inundation and water depths

Simulated flood water depths and differences from the baseline are shown in Table 9-42.

Changes to flow velocities

The simulated stream flow velocities along the valley floor are variable and comparatively low (< 1 m/s). This is as a result of the wide and flat valley floor with intermittent attenuation in local depressions, clay pans and playas. There are predicted to be only subtle changes in stream flow velocities for events greater than a 20-year ARI. The simulated differences in stream flow velocity as a result of the Project are not considered significant.

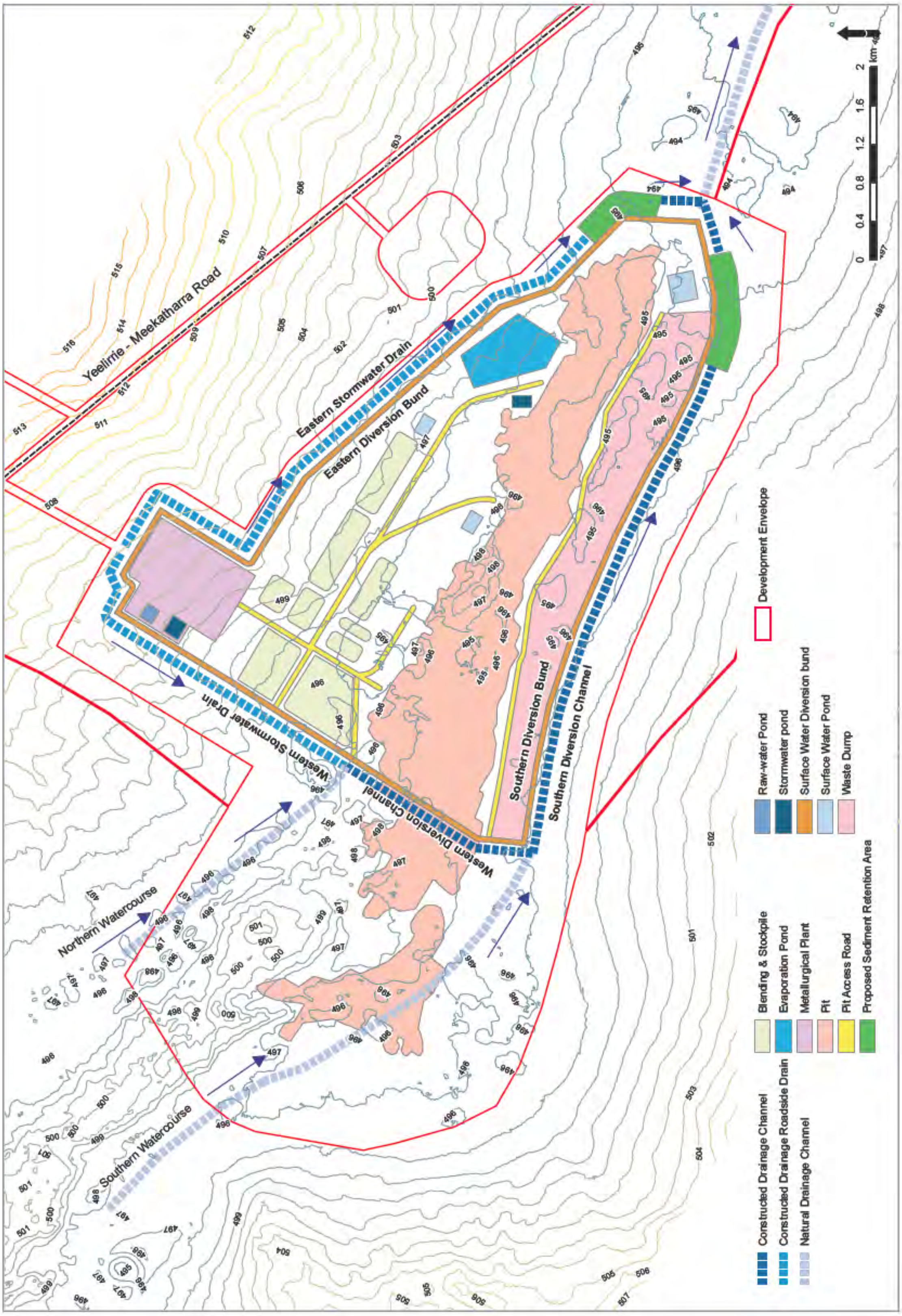


Figure 9-24: Conceptual diversion bund layout Stage 1 (year 1 to 7)

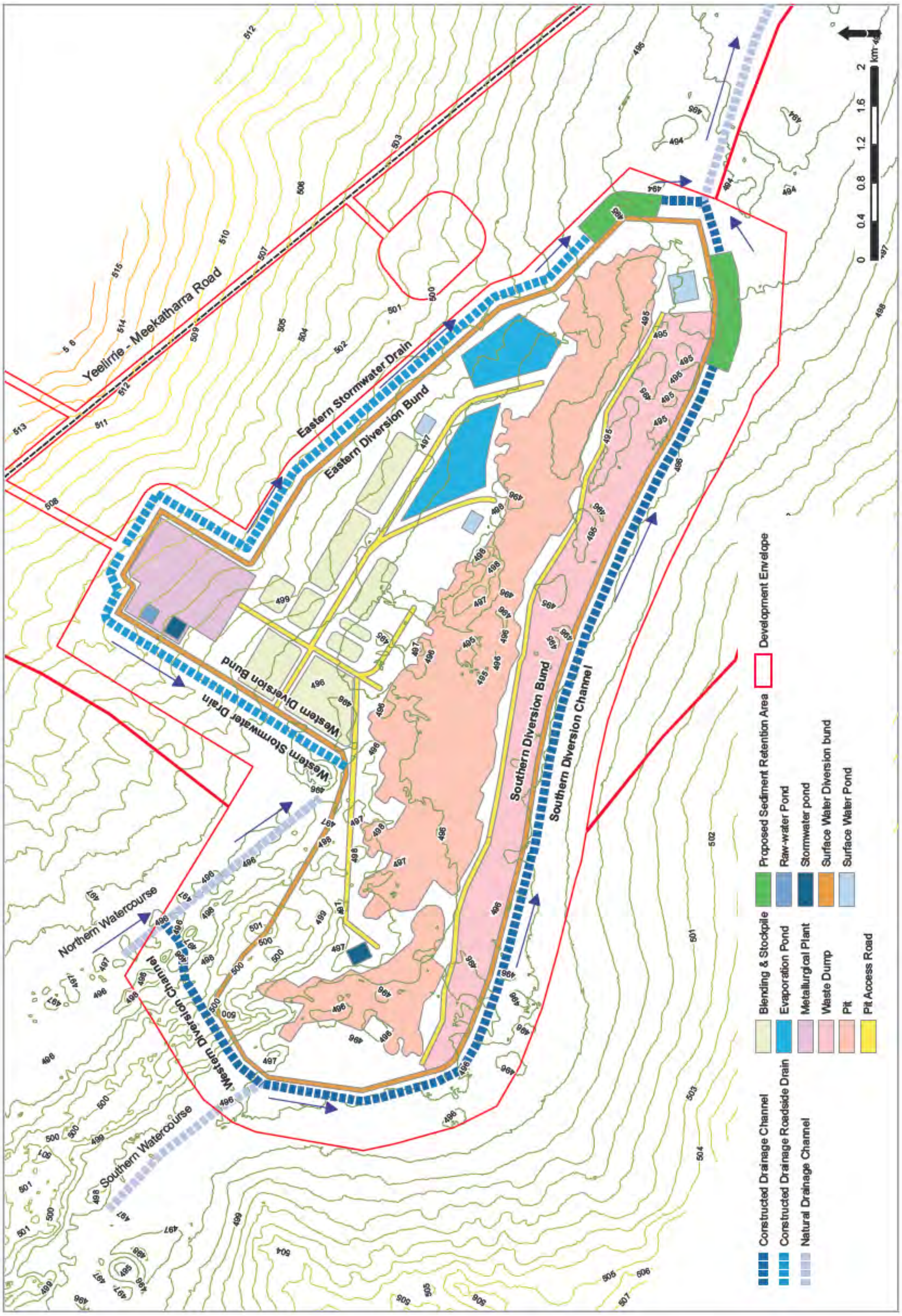


Figure 9-25: Conceptual diversion bund layout Stage 2 (year 8 to 22)

Table 9-42: Simulated flood water depths and differences from baseline

Event ARI	Simulated Maximum Flood Water Depths (m)			Simulated Maximum Difference from Baseline (m)		
	Upstream Reaches	Downstream Reaches	Yeelirrie Playa	Upstream Reaches	Downstream Reaches	Yeelirrie Playa
Stage 2 – Year 8-22 Yeelirrie Playa Catchment Model						
1	0.1	<0.1	0.5	0.1	-0.1 – 0.1	-0.1 – 0.1
5	0.5	0.25 – 0.5	0.25 – 0.5	0.25	-0.1 – 0.1	-0.1 – 0.1
20	0.5 – 0.75	0.50 – 0.75	0.50 – 0.75	0.5	-0.1 – 0.1	-0.1 – 0.1
100	1.5 – 2.0	1.0 – 1.5	1.0 – 1.5	1.25	0.25 – 0.5	0.25 – 0.5
1,000	4.5 – 5.0	1.5 – 2.0	2.0 – 2.5	2.5	-0.1 – 0.1	-0.1 – 0.1

Changes to streamflow hydroperiods

The altered hydrology is predicted to change the surface water availability on watercourse reaches upstream and downstream of the surface water diversion bund. The attenuation of flood waters on the upstream reaches of the surface water diversion bund may increase the hydroperiods for stream flow. Six sites were selected as points of interest and the Yeelirrie Playa hydraulic model was used to simulate flood depths at these locations.

At the three sites upstream of the surface water diversion bund, the simulated hydroperiods during Stage 1 showed no significant change from baseline. During Stage 2 of the Project (years 8-22) the simulated hydroperiods were extended by more than 200 hours for a 20 year ARI event and more than 500 hours during a 100 year ARI event. This indicates that the surface water diversion bund resulted in flood waters backing up, upstream of the bund which causes attenuation of flows. At sites downstream of the proposed Project, there were no changes in simulated hydroperiods during Stage 1 and minor changes during Stage 2.

Changes to erosion and sedimentation characteristics

Based on the predicted changes in stream flow velocities along the valley floor, changes to erosion and sedimentation characteristics as a result of the Project were assessed. During more frequent flow events (up to 20 year ARI) the catchment runoff drains to the valley floor and ponds locally in valley depressions. As there is little stream flow there is little to no sediment transportation along the valley floor and therefore no changes in the erosion and sedimentation characteristics predicted as a result of the Project.

During the less frequent and more extreme events that result in stream flow along the valley floor there is the potential for change in the erosion and sedimentation characteristics of the catchment as a result of the Project. The predicted ponding of surface water flows upstream of the Project as a result of the flood bunds is expected to result in sediment deposition, although it is not considered to be significant. The resultant overall change to downstream sediment loads is also considered to be insignificant.

Model predictions for the more extreme events indicate that the streamflow velocities along the southern flood protection bund could reach up to 2 m/s and may result in localised erosion along this stretch of the bund. The eroded sediments are expected to drop out downstream of the Project in areas where stream flows start to pond, or once stream flows are reduced after the rainfall event (e.g. in valley floor depressions and playas).

Maximum water depths and difference from baseline for 20-, 100-year and 1,000-year ARI events are presented in Figure 9-26, Figure 9-27 and Figure 9-28.

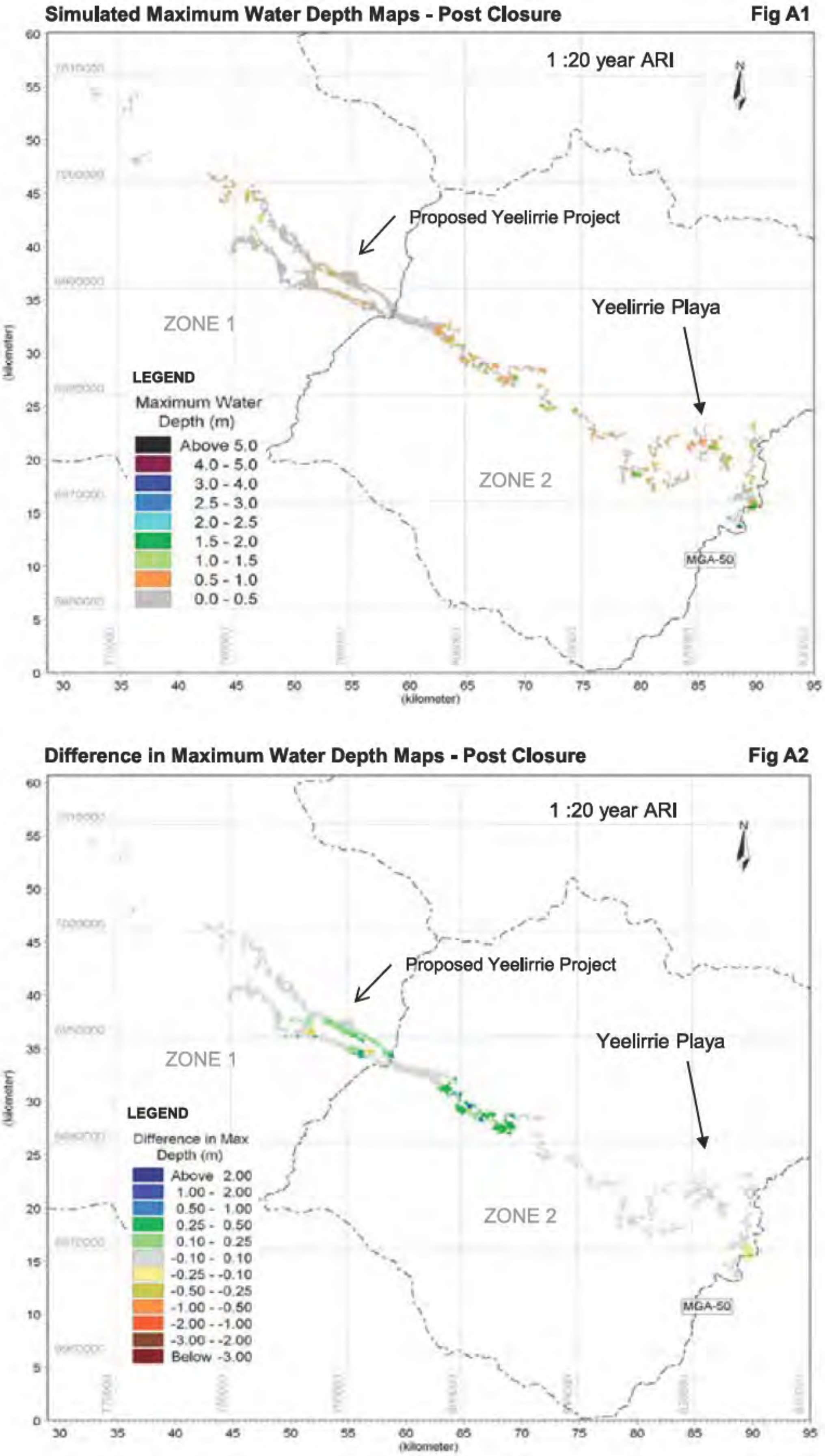
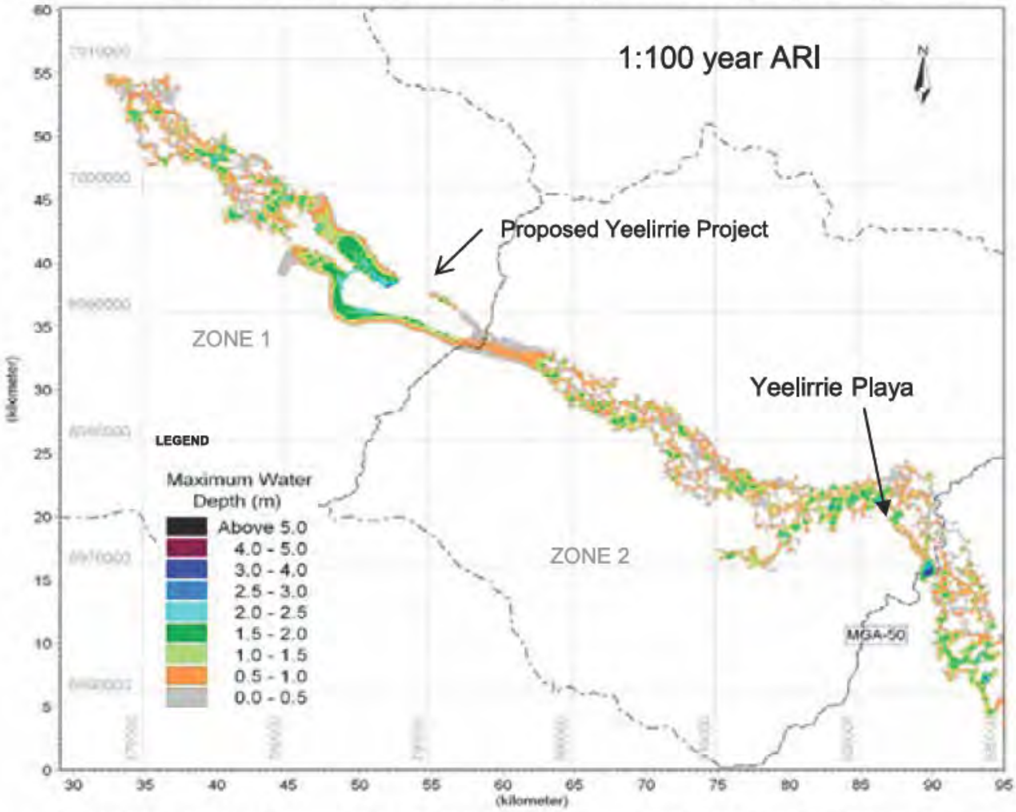


Figure 9-26: Maximum water depths and difference from baseline for 20 year ARI events

Simulated Maximum Water Depths During Mine Operations Stage 2 (Developed Scenario)



Simulated Change in Maximum Water Depths During Mine Operations Stage 2 (Developed minus Baseline)

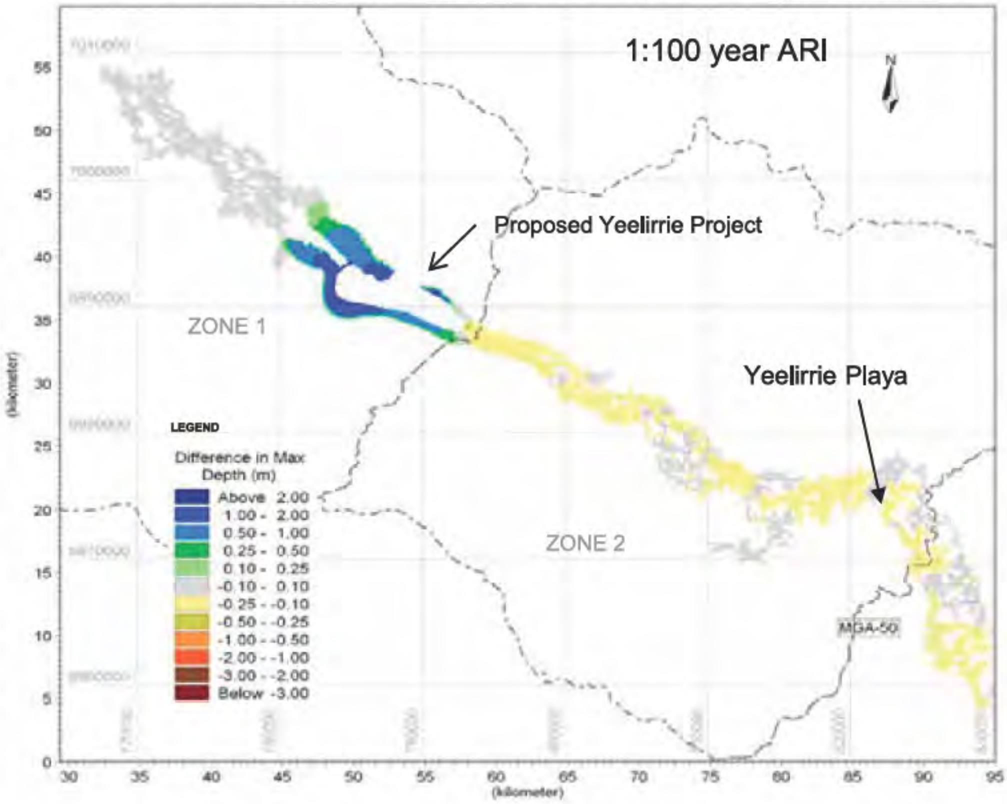


Figure 9-27: Maximum water depths and difference from baseline for 100 year ARI events

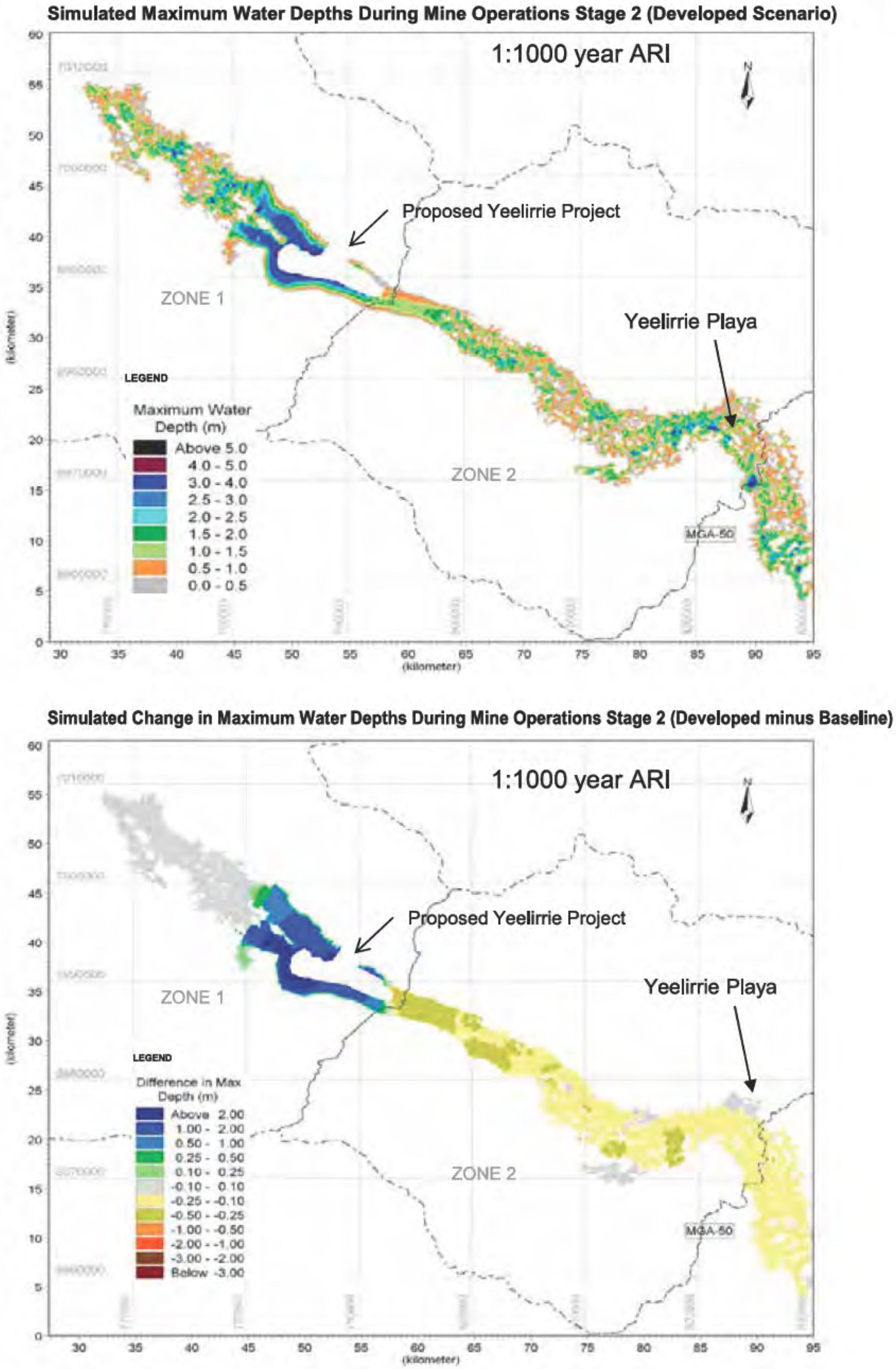


Figure 9-28: Maximum water depths and difference from baseline for 1000 year ARI events

Hydrological changes inside the diversion bund

Stormwater runoff will be captured in stormwater ponds located within the minesite. The ponds will be designed to capture runoff from a 20 year ARI event. If however the rainfall exceeds design capacity, the stormwater pond would be discharged to other storage facilities including the Evaporation Pond, the tailings storage facilities and ultimately into inactive pits. The capacity of the minesite to contain excess water under 1:20, 1:100 and 1:1,000 year ARI rainfall events has been assessed.

The assessment indicates that providing the far eastern section of the flood protection bund is of sufficient height (i.e. 3 m high) and engineered to retain flood waters on site (and keep external floodwaters out) the minesite is able to contain the in-bund stormwater runoff for a 1:1,000 year ARI rainfall event. Therefore, the minesite is expected to operate as a no-discharge site. However, depending on the development stage of the mine, there will be operational requirements to manage and discharge excess water.

Hydrological changes on mine closure

Details on proposed mine closure are provided in Section 9.12. Following mine closure and removal of the diversion bund, the simulated maximum water depths and difference from the baseline maximum water depth for the 1:20, 1:100, 1:1,000 year ARI rainfall events and PMP are shown in Figure 9-29 to Figure 9-32. The simulations show that:

- For the 1:20 year ARI event there is no significant change from baseline. The backfilled pit area would not be subject to inundation.
- The significance for the 1:100 year ARI event is assessed based on Figure 9-30. The difference in maximum water depth is due to a shift in flow path from the baseline location and therefore does not indicate additional ponding.
- For the 1:100 year ARI event the localised increase in flood water depths around the post-closure minesite are a little more significant, especially in the northern watercourse. However, a significant part of the water depth rise is due to the flow constriction of the flow through the northern water course channel. The backfilled pit area would not be subject to inundation.
- The significance for the 1:1,000 year ARI event is assessed based on Figure 9-31. The inundation of the backfilled area occurs during the peak flow period of the flood event and will recede as soon as the flood hydrograph recedes. During this relatively short period of inundation infiltration into the closed landform would potentially occur.
- For the 1:1,000 year ARI event the localised increase in flood water depths around the post-closure minesite appears more significant in both the north and south watercourses. However, a significant part of the water depth rise is due to the constriction of the flow through the northern water course channel. This change is considered relatively small and limited to the immediate vicinity of the post-closure landform. Changes upstream and downstream of the post-closure landform are considered insignificant. Under the 1,1000 year ARI scenario, the post-closure backfilled pit area would be subject to inundation for the duration of the event and surface water would potentially infiltrate the closed landform.
- The significance for the PMP event is assessed based on Fig 9-32. The assessed significance is based on the relatively small change compared to baseline conditions under this most extreme and unlikely event.
- For the PMP event the localised increase in flood water depths around the post-closure landform appears more significant immediately upstream of the minesite. This is due to the constriction of the flow through the site. A predicted flood level change of less than 0.5 m in a limited area upstream of the minesite is predicted and not significant. Under the PMP scenario, the backfilled pit would be subject to significant inundation for the duration of the event and surface water would potentially infiltrate the closed landform.

- The areas and extend of temporary pooling are shown on the difference in maximum water depth maps for each of the flow events. This indicates the maximum extend of the change in water depth at the time of peak discharge. The increase in water level should not be interpreted as pooling as although the water depth has increased, the water is flowing as indicated by the flow velocity figures (not shown). The areas indicate a temporary increase in water depth compared to baseline (green and blue is pooling).

9.4.5.2 Water Balance

Water balance modelling was undertaken for the Yeelirrie Project to validate the performance of the Project Water Management Strategy (WMS). The methodology and key assumptions for the water balance assessment are outlined in URS (2015b) (Appendix H2). The water balance for the Project is summarised below. A schematic figure of the water balance model is presented in Figure 9-33.

The modelling indicates that peak water supply demand during mining will be 8,750 kL/day and required for years 4 to 18. Water supply for the Project will be obtained from the following sources:

- groundwater dewatering / abstraction (to Raw Water Pond 2 [RWP2]);
- brackish wellfields (to Raw Water Pond 1 [RWP1]);
- saline wellfields (to RWP2);
- pit floor dewatering (to RWP2); and
- stormwater runoff (collected at 7 stormwater ponds located at natural low points within each of the sub-catchments within the mine site[1]).

The TDS concentration of water from the TSF is expected to reach 350,900 mg/L and therefore only about 10% (853 kL/day) of the decant water from the TSF can be reused in the processing plant. The remaining water will be sent to the Evaporation Pond to be evaporated as part of the brine management strategy. The Evaporation Pond will be constructed with multiple cells and have a surface area of 50 ha. The salt in the Evaporation Pond will be removed and transferred to the TSF to maintain the salinity of the pond below 200 g/L.

During high rainfall events, transfer of water from the TSF to the Evaporation Pond will cease with excess water retained on the TSF, or pumped to an open pit for temporary storage. In this event, abstraction from the borefields would cease until excess water was used.

Groundwater dewatering will flow to Raw Water Pond 2 (RWP2) and is estimated to be 18,610 ML throughout the LoM.

Based on the brackish water demand and proposed operating rules (e.g. maintaining four-day operational storage for Raw Water Pond 1 [RWP1] which has 10 ML capacity) the model estimated that between 980 and 1,110 ML/year (16,860 – 16,920 ML) of brackish water will be required throughout the life of mine (LoM).

Based on the saline water demand and proposed operating rules (e.g. maintaining four-day operational storage for RWP2 which has 25 ML capacity) it is estimated that 510 to 1,280 ML/year (16,100 – 16,480 ML) of saline water will be required throughout the LoM.

The water balance assessment indicated that the proposed WMS is adequate to contain mine water onsite.

1. The stormwater runoff ponds were not represented in the GoldSim model for the reasons outlined in URS (2015b).

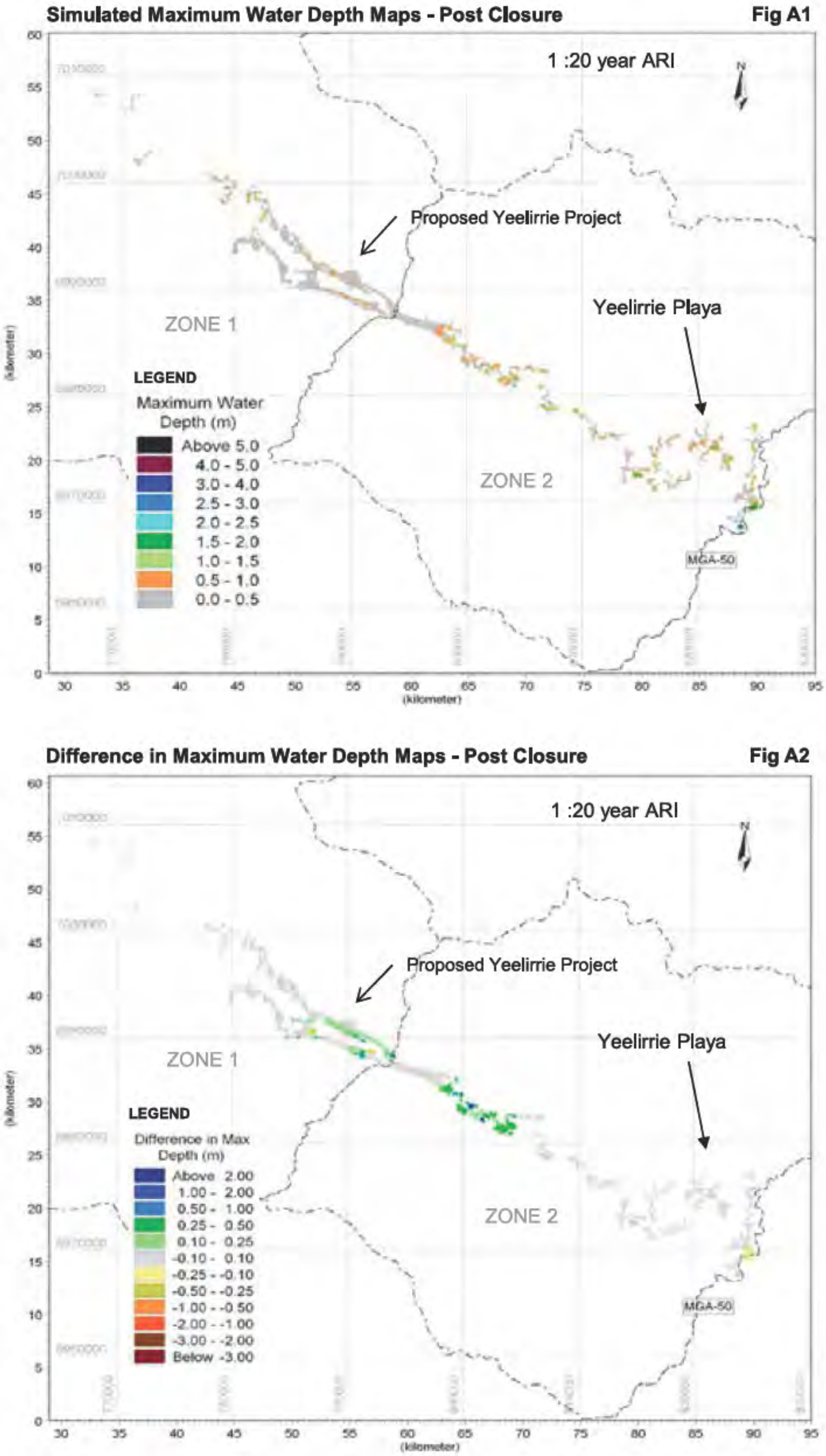


Figure 9-29: Basecase conceptual landform design difference in maximum water depths from baseline (20-year ARI)

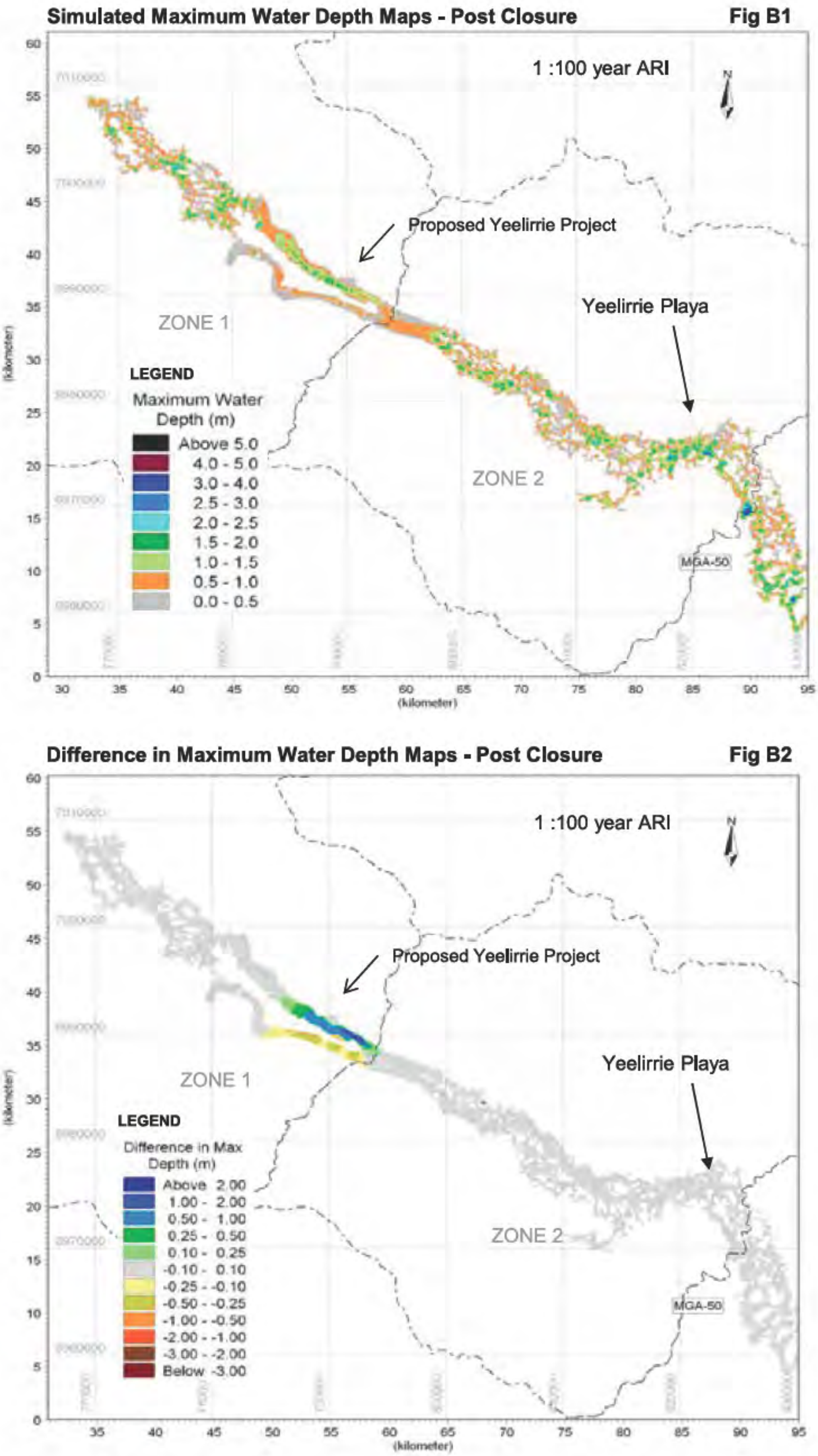


Figure 9-30: Basecase Conceptual Landform Design Difference in Maximum Water Depths from Baseline 100 yr ARI

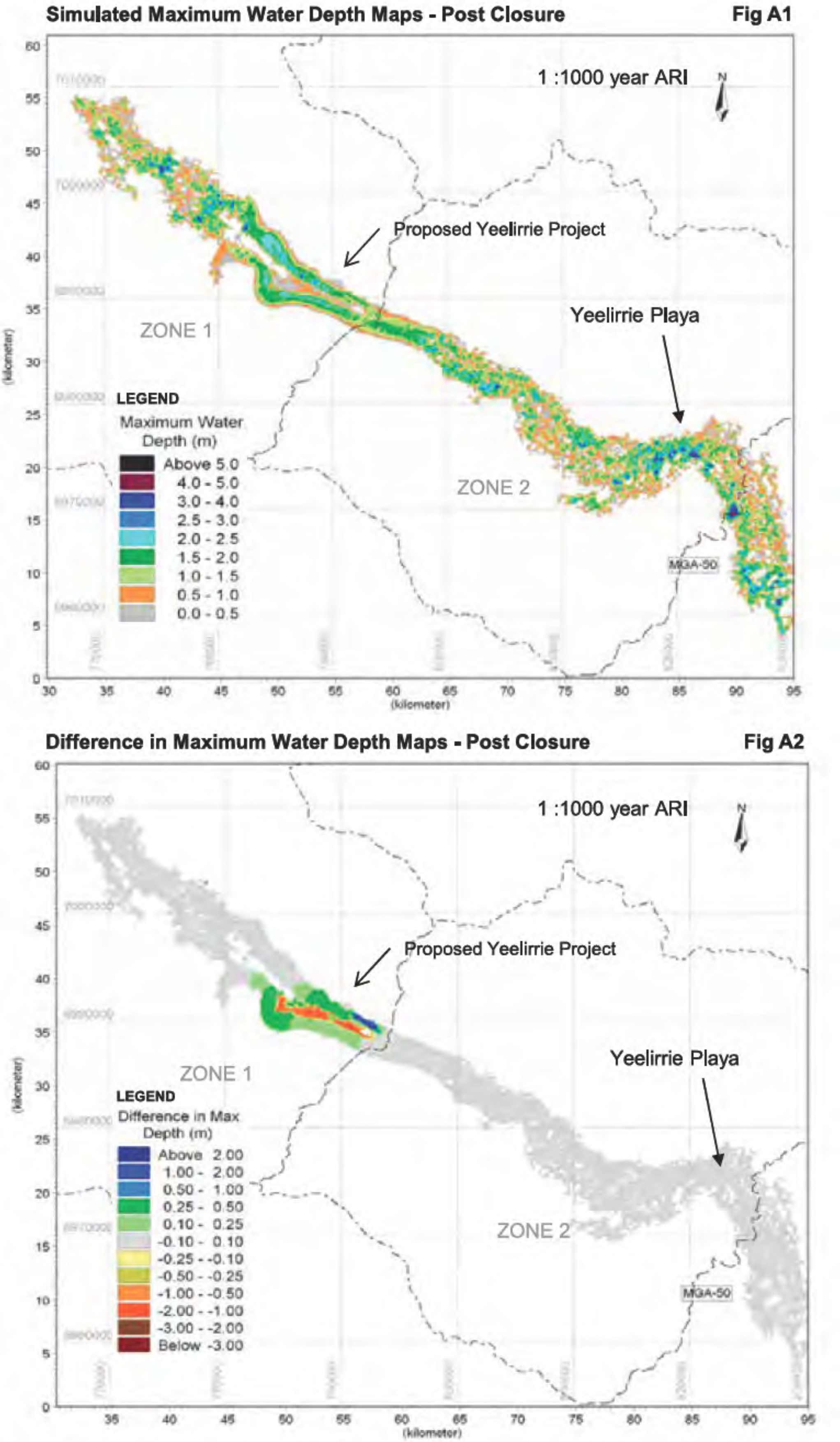


Figure 9-31: Basecase Conceptual Landform Design Difference in Max Water Depths from Baseline 1000 yr ARI

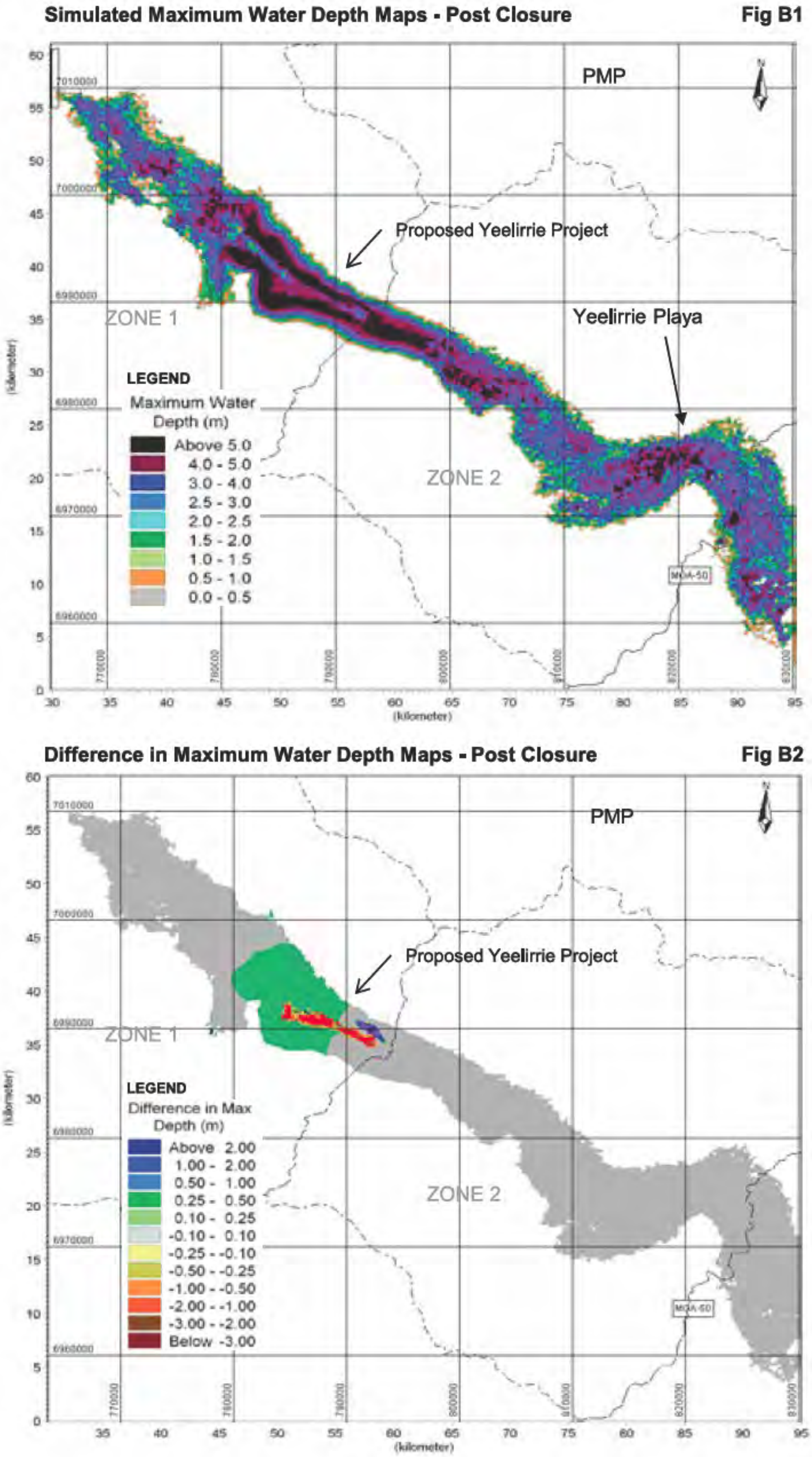


Figure 9-32: Basecase Conceptual Landform Design Difference in Max Water Depths from Baseline PMP

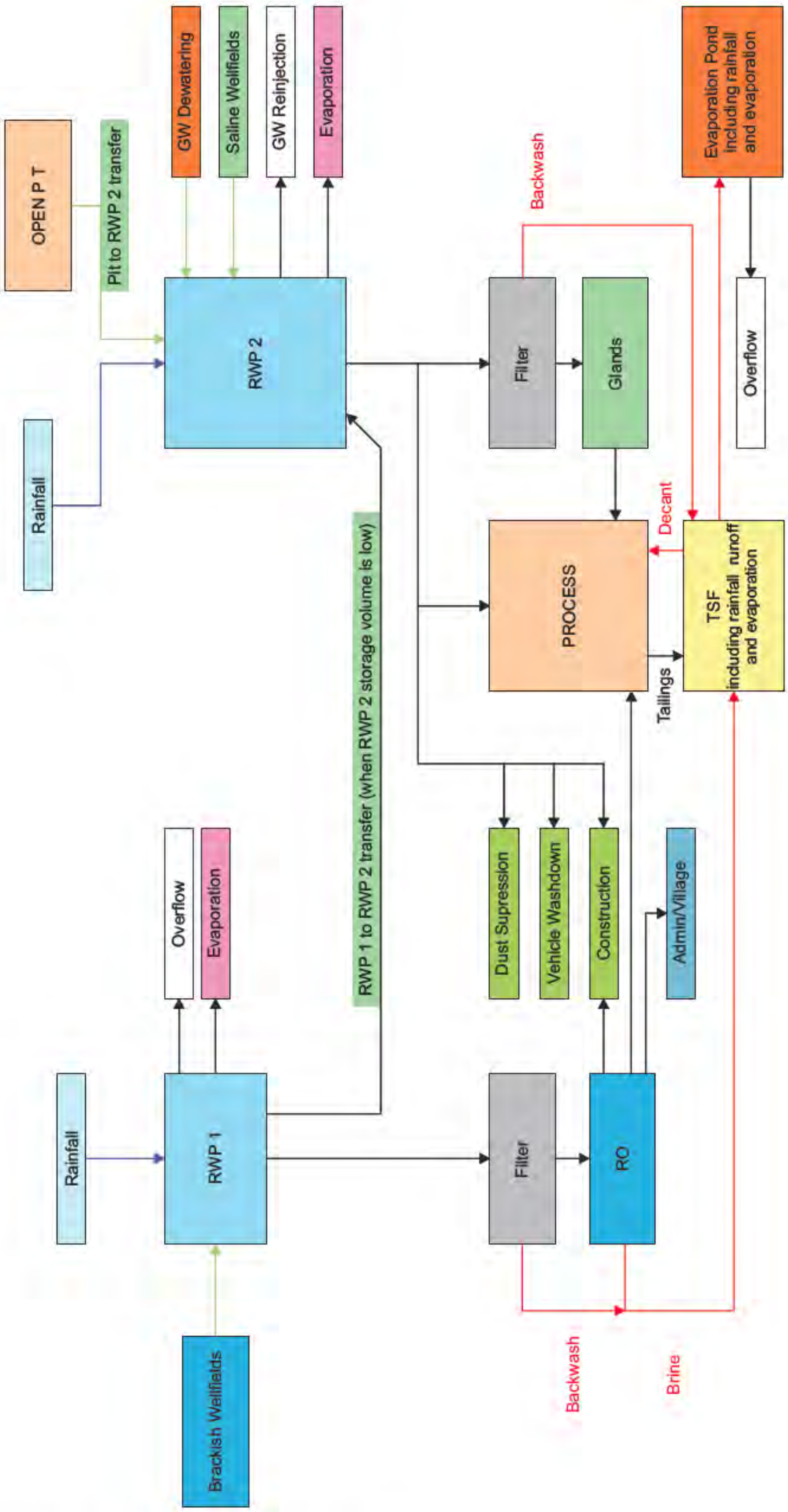


Figure 9-33: Water balance model schematic

9.4.6 Management

Avoid and Minimise

Cameco will develop and implement a Surface Water Management Plan to minimise the impacts on surface water and ensure no release of contaminants to the environment.

The proposed Project would be developed in two stages chiefly to minimise the development foot print and disturbance area, as well as minimise the volume of surface water runoff inside the bund that requires management.

Cameco will construct the surface water diversion bund and diversion channels as showing in Figure 9-24 and Figure 9-25.

To manage and mitigate the potential sediment in the diversion channels, the Project allows for the construction of sedimentation basins at the downstream (eastern) ends of the diversion channel. These basins will slow down the surface water flows in the diversion channels thereby dropping out the suspended sediments before discharging into the surface water environment downstream.

The surface water diversion bund has been designed to protect the mine site and retain floodwater within the bund, from a 1-in-1,000 year ARI flood event. Therefore the site has been designed to operate as a 'no release' site.

Stormwater runoff will be captured in a series of stormwater ponds located within the mine site designed to capture a 1-in-20 year ARI event. If however, rainfall exceeds design capacity, the stormwater would be directed to inactive pits.

The ROM pad and other stockpile areas would be compacted to control seepage and would be graded so that runoff and seepage would be directed to a storm water runoff pond. Water captured in the ponds would be used to supplement the water supply for the processing plant.

Storage areas for process chemicals and liquors will be sealed and bunded to ensure that and process spills can be contained and easily cleaned up.

Rehabilitate

On closure, all mineralised material will be processed or placed back into the open pit which will be backfilled and an engineered cover constructed over the in-pit TSF. Surface water drainage patterns will be reinstated around the final landform.

9.4.7 Commitments

Cameco commits to development and implementation of a Surface Water Management Plan.

9.4.8 Outcomes

Taking into account the Project design and proposed management measures to be implemented, Cameco believes that the Proposal will meet the EPA's objectives with regards to Hydrological Processes and Inland Water Quality (Surface Water).