07

Surface water

7. Surface water

7.1 Introduction

This chapter describes the existing surface water characteristics and potential impacts on surface water resources within and around the proposed Nolans site. A detailed surface water report is provided in Appendix I of the EIS.

Section 5.3 of the TOR for the project provided the following environmental objectives in relation to surface water resources:

> *Water resources will be protected both now and in the future, such that ecological health and land uses, and the health, welfare and amenity of people are maintained.*
>
> *Proposed creek diversion(s) will maintain equivalent ecological functionality of the waterways, and minimise impacts to linked riparian and aquatic ecosystems for the short and long term.*

This chapter addresses the potential impacts on surface water resources within and around the Nolans site for all stages of the project as required in the TOR. Groundwater resources are discussed in Chapter 8 of this EIS.

7.2 Methodology

A summary of the approach to assessment of surface water resources in the study area is described below and more detail is provided in Appendix I.

Key tasks involved in the preparation of the surface water impact assessment included:

- Desktop review to identify data relating to surface water resources within the study area and identify potential surface water monitoring locations
- Site visit in January 2011
- Surface water quality records obtained from the NT DLRM water data portal
- Rainfall-runoff model (XP-RAFTS) to derive flood peak discharge along the two creeks flowing through the proposed mine site (Kerosene Camp Creek and Nolans Creek)
- 2-D rain-on-grid flood modelling to obtain the extent and depth of flooding during a 1 in 1000-year average recurrence interval (ARI) event together with an indication of flow velocity at locations across the Nolans site
- 1-D flood routing model to investigate the hydraulics of the Kerosene Camp Creek diversion (Appendix A of Appendix I).

7.3 Existing environment

This section describes the surface water resources and related features identified in the study area, and discusses the relative value of the features in the local and regional context.

7.3.1 Topography and land use

The proposed Nolans mine site is at the head of the Kerosene Camp Creek valley on the north facing slopes of an east – west trending ridge of the Reynolds Range, and the processing site is situated on the southern slopes of the same ridge. Topographic elevation is 886 m above sea level (m ASL) at Mt Boothby to the east of the mine site, and 1,006 m ASL at Mt Freeling to the west (Figure 1-6). Most of the Kerosene Camp Creek valley floor at the mine site is typically between 650 and 700 m ASL whilst the processing site is at an elevation of about 670 m ASL. Longitudinal gradients along local creeks to the north and south of the ridgeline are typically less than 0.5 percent with steeper gradients of about 10 percent on isolated hills.

The Nolans site, with the exception of the western part of the borefield, lies wholly within Aileron Station, which is currently operating rangeland cattle grazing.

Third party infrastructure in the vicinity of the Nolans site includes:

- APA Group's Amadeus Basin to Darwin gas pipeline which runs south west to north east along the south eastern boundary of the processing plant and is buried to a depth of about 1 m
- The Stuart Highway which runs north – south about 10 kilometres east of the Nolans site but does not cross surface watercourses downstream of the Nolans site and
- Napperby Station / Laramba access road which runs east – west about 12 kilometres south of the processing site and traverses minor surface watercourses downstream of the processing plant.

7.3.2 Rainfall and evaporation

Prevailing winds are from the southeast and mean monthly minimum and maximum temperatures range between 4.9 °C in July and 37.6 °C in January. Mean annual rainfall at Nolans site is about 310 millimetres and mean annual potential evaporation is about 2,400 millimetres.

Annual total rainfall is erratic from year to year and almost 50 per cent of the annual total rainfall can occur within a single month. Most rainfall tends to occur in the summer months and significant events tend to be limited to one or two occurrences each year. The seasonal distribution of rainfall and potential evaporation is shown in Table 7-1 and Table 7-2, respectively. This shows that on average monthly rainfall is about one seventh of the monthly potential evaporation. Whilst the record shows that occasionally rainfall can exceed potential evaporation in very wet months, actual evaporation will closely match rainfall throughout the year and virtually all the rain that does fall will evaporate.

Table 7-1 Mean monthly rainfall (mm)

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Napperby	55	55	39	22	21	11	14	6	7	19	30	40	309
Alice Springs	41	43	31	17	18	13	15	9	8	21	29	37	282
Mine Site	48	73	68	30	11	5	6	1	1	3	35	32	314

Table 7-2 Mean monthly potential evaporation (mm)

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Alice Springs	271	221	210	159	112	87	97	134	178	230	238	259	2196
Mine Site	286	240	235	185	137	91	89	163	200	249	257	265	2396

7.3.3 Surface water drainage

Semi-arid regions such as the area in which the mine is located are typically characterised by conditions in which evaporation closely matches rainfall and virtually all rainfall evaporates during events resulting in almost no surface runoff. This general situation will alter if intense rainfall occurs. Therefore, the occurrence of surface runoff and flows within local creeks is likely to be infrequent and only occur during exceptional rainfall events, such as those associated with the occasional southward extension of a monsoon trough or periodic incursion of north-west cloud bands over the interior of the continent.

Kerosene Camp Creek is an ephemeral creek and flows through the centre of the mine site before joining with a major tributary three kilometres further to the north where after it eventually flows into Woodforde River. Minor tributaries of Kerosene Camp Creek occur upstream of the mine site between the processing site and the mine site and have a combined catchment area of approximately 19.5 km^2 (Figure 7-1). Nolans Creek is a major tributary of Kerosene Camp Creek and has a catchment area of approximately 26 km^2 upstream of the open pit. It flows adjacent to the eastern boundary of the proposed TSF and will pass between WRDs 2 and 6 where after it joins Kerosene Camp Creek (Figure 7-2).

The Woodforde River, into which Kerosene Camp Creek flows, passes through the western margins of the Ti Tree Basin aquifer which is about 20 kilometres downstream of the mine site (Figure 7-1). The aquifer at this location along the Woodforde River is about 60 m below ground level (~550 metres ASL) (NRETAS 2007) and is down gradient of the mine site.

The access road from the Stuart Highway to the mine site crosses the drainage paths from catchments on the upper slopes of the Yalyirimbi Range (Figure 7-3). Drainage continues to flow towards the Southern Basins and Lake Lewis 40 kilometres to the west of the Nolans site. Catchments upstream of the access road are relatively small, typically less than 3 km^2 with one catchment of about 12 km^2 located towards the eastern end of the access road.

The processing site also receives drainage from the upper slopes of the Yalyirimbi Range (Figure 7-2). Due to their small catchment area, channels tend to be ill-defined with runoff likely to be dispersed across the south facing hillslope before combining into distinct creeks which eventually drain into the Southern Basins and Lake Lewis 40 kilometres to the west. Catchments upstream of the processing plant are typically less than 1 km^2 in extent.

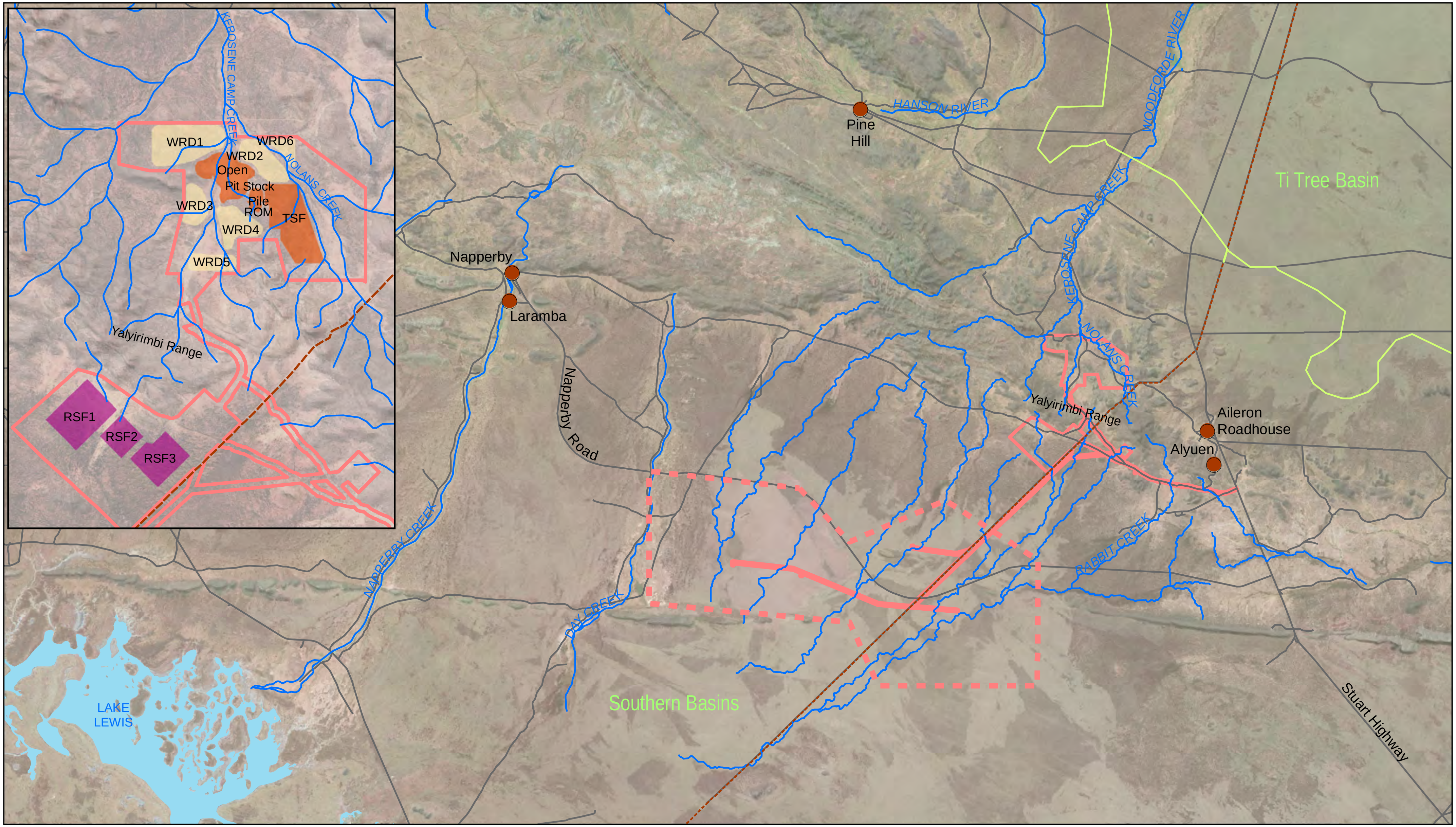
7.3.4 Surface water monitoring

Long-term gauging of flow in watercourses that traverse or flow close to the proposed mine site has been carried out at Arden Soak Bore on the Woodforde River. This gauge is located approximately 26 kilometres downstream of the mine site and includes the runoff from catchments at the mine site.

Flow records show that flow events are relatively infrequent with only 25 per cent of days during the 41-year record having a total daily flow greater than 3 Ml (arbitrarily selected discharge of 0.03 m^3/s) and thus even fewer days with larger flow volumes.

The occurrence of surface runoff is most likely in months during the summer season, December to March (refer Figure 7-4). Records at Arden Soak Bore suggest that only one or two flow events can be expected in most years. The maximum recorded flow at Arden Soak Bore (Figure 7-5) is 206 m^3/s (January 2010) during which flow was recorded over a period of just three days indicating the relatively ‘flash’ response and short duration of flow events for drainage systems in this region.

Anecdotal evidence suggests that surface runoff infiltrates to the alluvium of creek channels where after it will form shallow groundwater flow moving down gradient along the creek channel.



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0 2.5 5 7.5 10

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

LEGEND

- Outstations and Communities
- Groundwater basin boundary
- Gas pipeline
- Waterways
- Roads
- Project Areas
- Borefield Area
- Waterbodies

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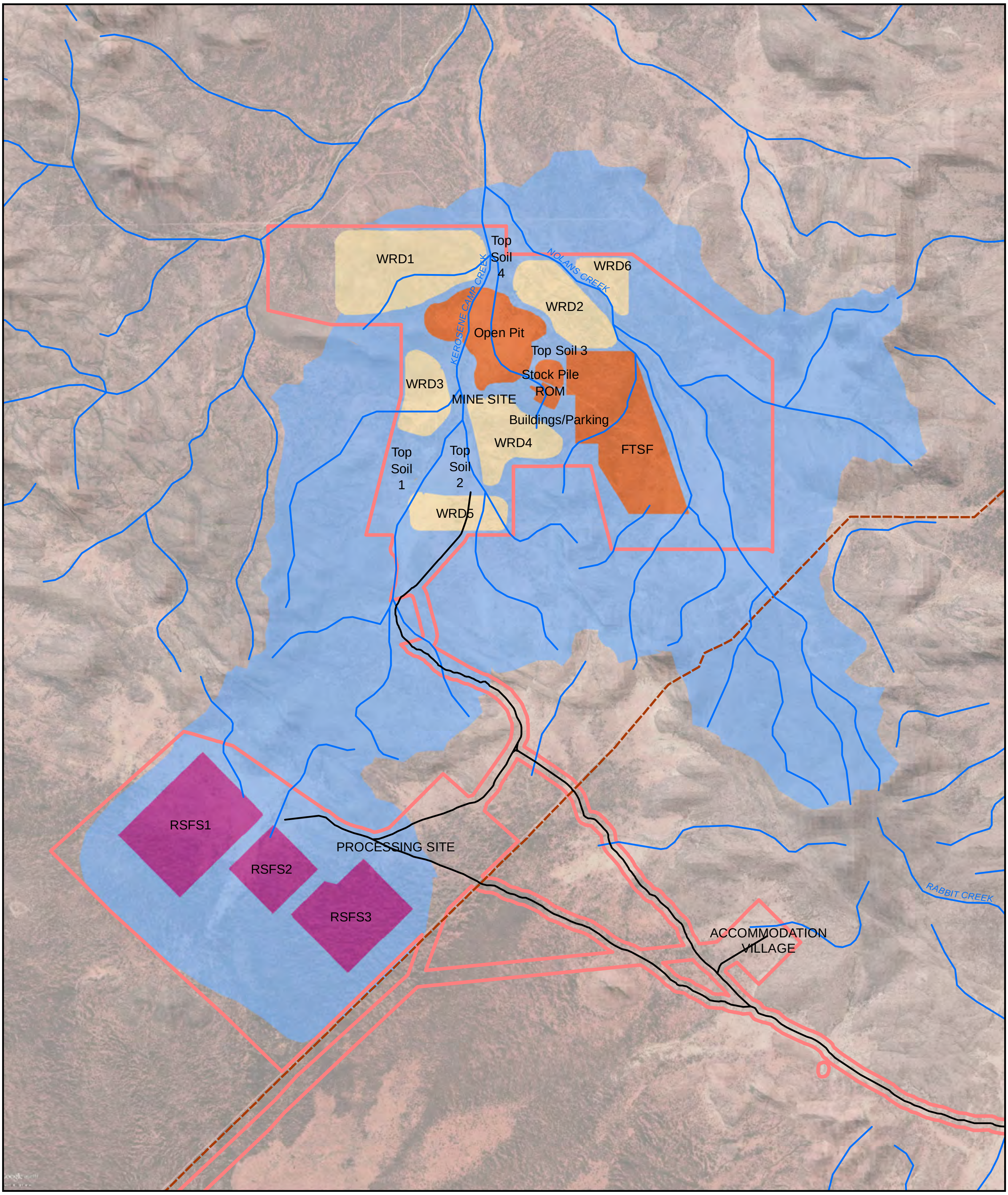
Surface water drainage network

Figure 7-1

G:\43\22301\GIS\Maps\4322301_574_SurfaceDrainageNetwork.mxd

Level 5 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: GA - Roads, Placenames, Placenames, Lakes, Imagery (2015). ESRI - Shaded Relief (2009). ARL - Project Areas (2015). GHD - Waterways, Outstations and Communities (2016). Created by: CM



LEGEND

- Access Road
- Waterways
- Gas Pipeline
- Project Areas

Water Type

- Clean
- Ore Contact
- Process
- Sediment

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0 0.5 1 1.5 2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

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Date 13 Apr 2016

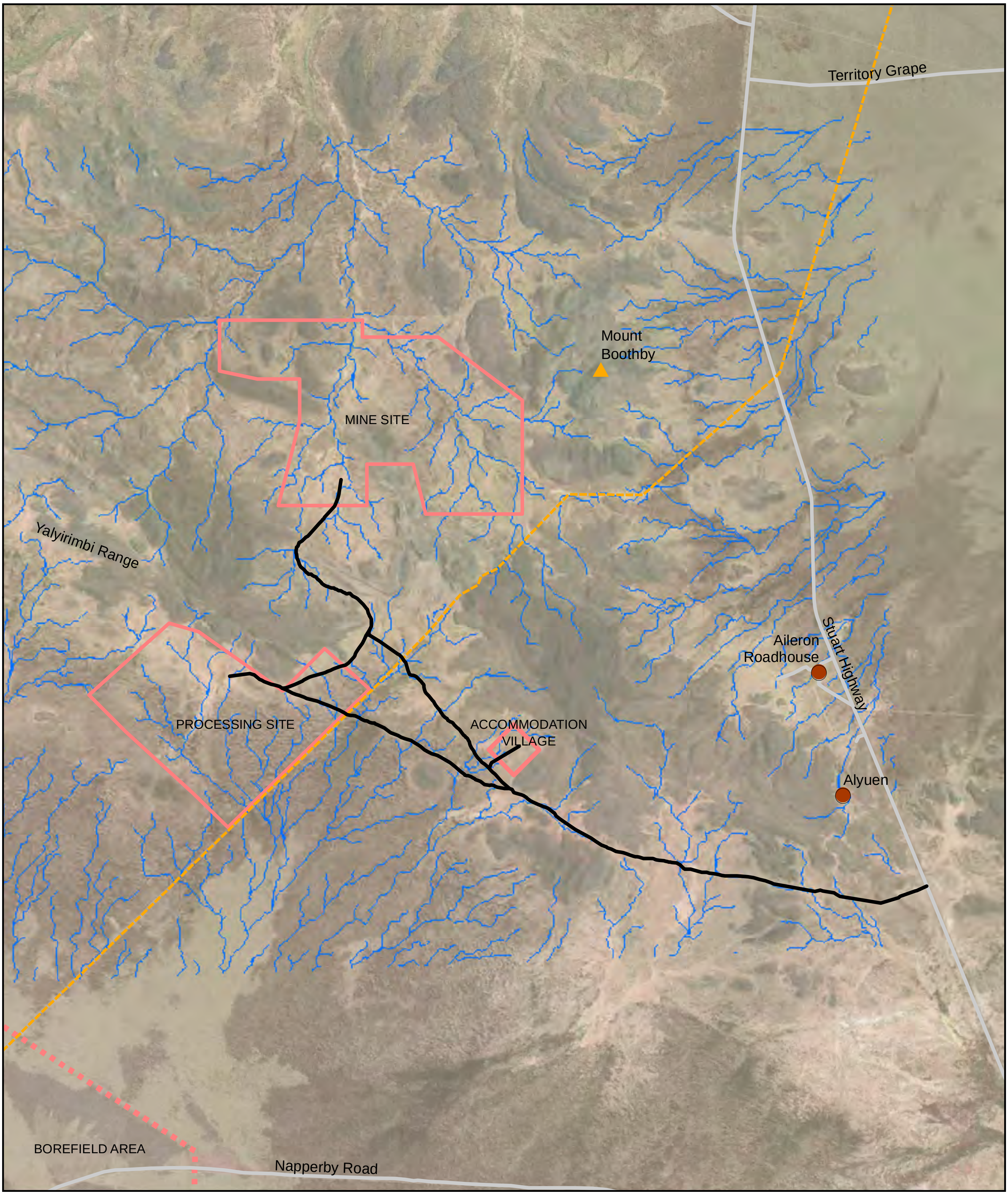
Surface drainage network at the mine site and processing site

Figure 7-2

G:\43\22301\GIS\Maps\4322301_573_SurfaceWaterType_Fig7-2.mxd

Level 5, 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: GA - Roads, Waterways, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 11/02/2016). ARL - Project Areas (2015). GHD - XPRafts Model (2016). Created by: CM



LEGEND

- Mountain
- Outstations and Communities
- Roads
- Access Track
- Gas Pipeline
- Natural drainage
- Project Areas

1:125,000 @ A4

0 1 2 3 4

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

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Access road drainage network

Figure 7-3

G:\43\22301\GIS\Maps\4322301_575_AccessRoadNaturalDrainage.mxd

Level 5, 66 Smith Street Darwin NT 0800 Australia **T** 61 8 8982 0100 **F** 61 8 8981 1075 **E** drwmail@ghd.com **W** www.ghd.com

Data source: GA - Roads, Placenames, Placenames, Lakes, Images (2015). ESRI - Shaded Relief (2009). ARL - Project Areas (2015). GHD - Natural drainage (2016). Created by: CM

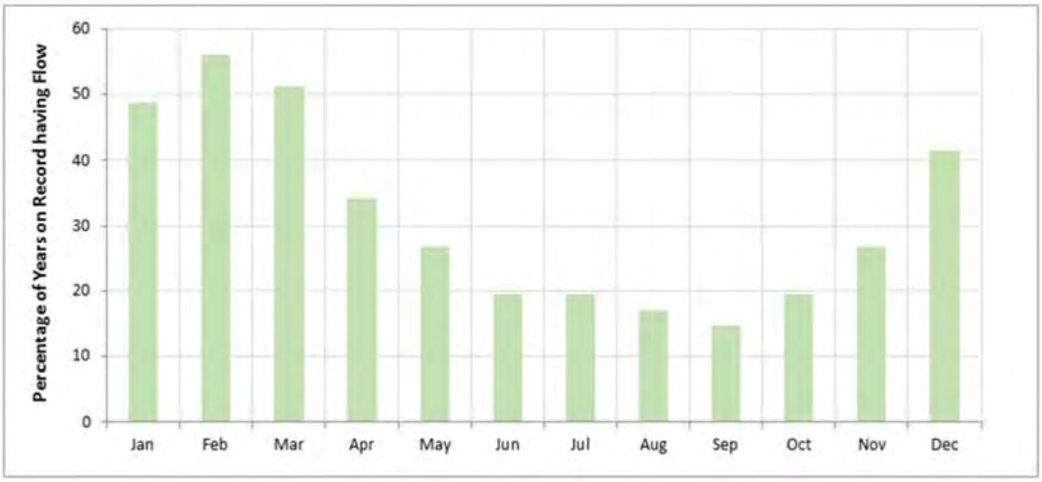


Figure 7-4 Occurrence of flow at Arden Soak Bore on Woodforde River

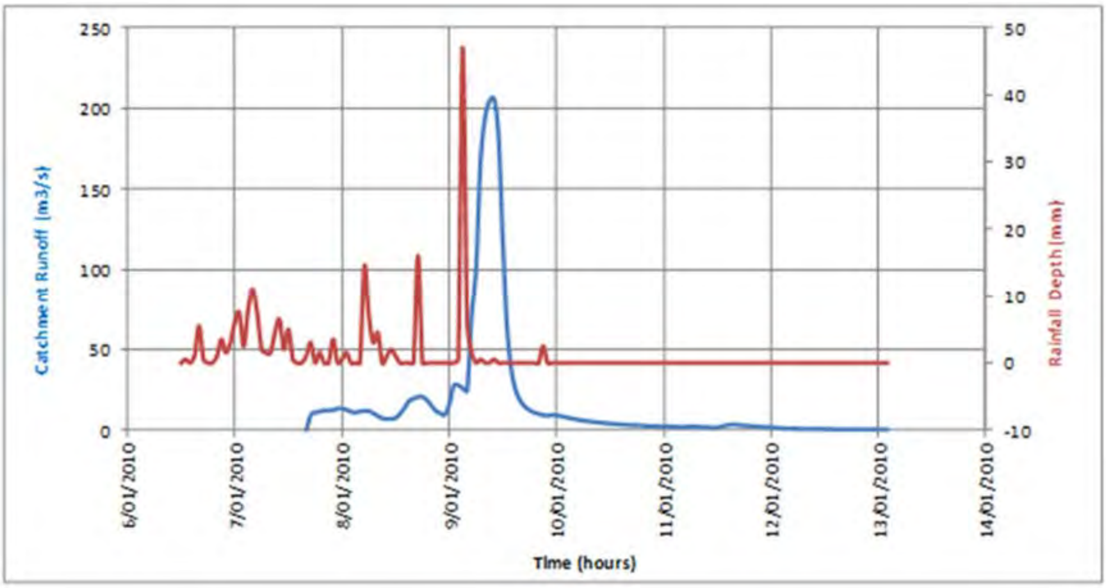


Figure 7-5 Maximum recorded flow at Arden Soak Bore on Woodforde River

7.3.5 Geomorphology

Creeks flowing through the mine site are generally straight with gentle bends and grades of approximately 1 in 400 (0.25 per cent).

The existing channel of Kerosene Camp Creek has bankfull widths in the order of 10 to 15 metres and depths in the range of 1 to 2 metres. The channel invert typically consists of a relatively featureless bed of sand with some gravel. In cross-section, the channel is symmetrical and relatively simplistic in form with limited evidence of features such as pools, bars or benches. Banks are composed of alluvially deposited sand and silt and are vegetated with low grasses and scattered shrubs and trees. Bedrock occasionally outcrops in the banks and bed providing some control on channel form and bed levels.

Nolans Creek is set within a terraced valley with the contemporary valley floor extending up to approximately 100 metres. The inset floodplains typically bound either side of the channel, with the surrounding terrace surfaces rising 1 to 2 metres above the floodplains. Based on bank exposures the floodplains are likely to be dominantly composed of silty sand. The floodplain surfaces are largely vegetated with low shrubs and are dissected by shallow flood channels.

7.3.6 Surface and groundwater interaction

The groundwater characteristics of the region within which the Nolans site is located are described in Chapter 8 of this EIS.

Regionally, the mine site is located near the southern margin of the Ti Tree Basin (Figure 7-1). Groundwater is approximately 15 metres below the ground surface at the mine site location. The processing plant is located on the northern margin of the Whitcherry Basin which is one of a series of interconnected basins termed the 'Southern Basins' that drain westward and toward Lake Lewis, 40 kilometres southwest of the processing plant (Figure 7-1). The Ti Tree and the Southern Basins are considered to connect at the eastern margin of the Southern Basins near the Stuart Highway in an area termed 'The Margins'. The Margins area is considered to be a subtle groundwater divide with water flowing north of the divide to the Ti-Tree Basin and south of the divide to the Southern Basins. The Yalyirimbi Range ridgeline between the mine site and processing site is the surface water divide between the Ti Tree and Southern Basins.

The ephemeral nature of creeks indicates no sustained support of surface flow from groundwater. In addition, the large disparity between evaporation and rainfall throughout the year suggests that recharge of aquifers is limited to periods of intense rainfall which are infrequent (once or twice a year) and relatively short lived.

The local aquifer at the mine site is thought to approximately correspond to the geographical extent of the ore body which is surrounded by much lower permeability basement rocks that act as an aquitard (Appendix K). It is expected that, due to the porous nature of soils in the area and the surface outcropping of the ore (apatite), this local aquifer will be recharged directly from surface infiltration during infrequent rainfall events and by leakage through the overlying creek bed when Kerosene Camp Creek is flowing.

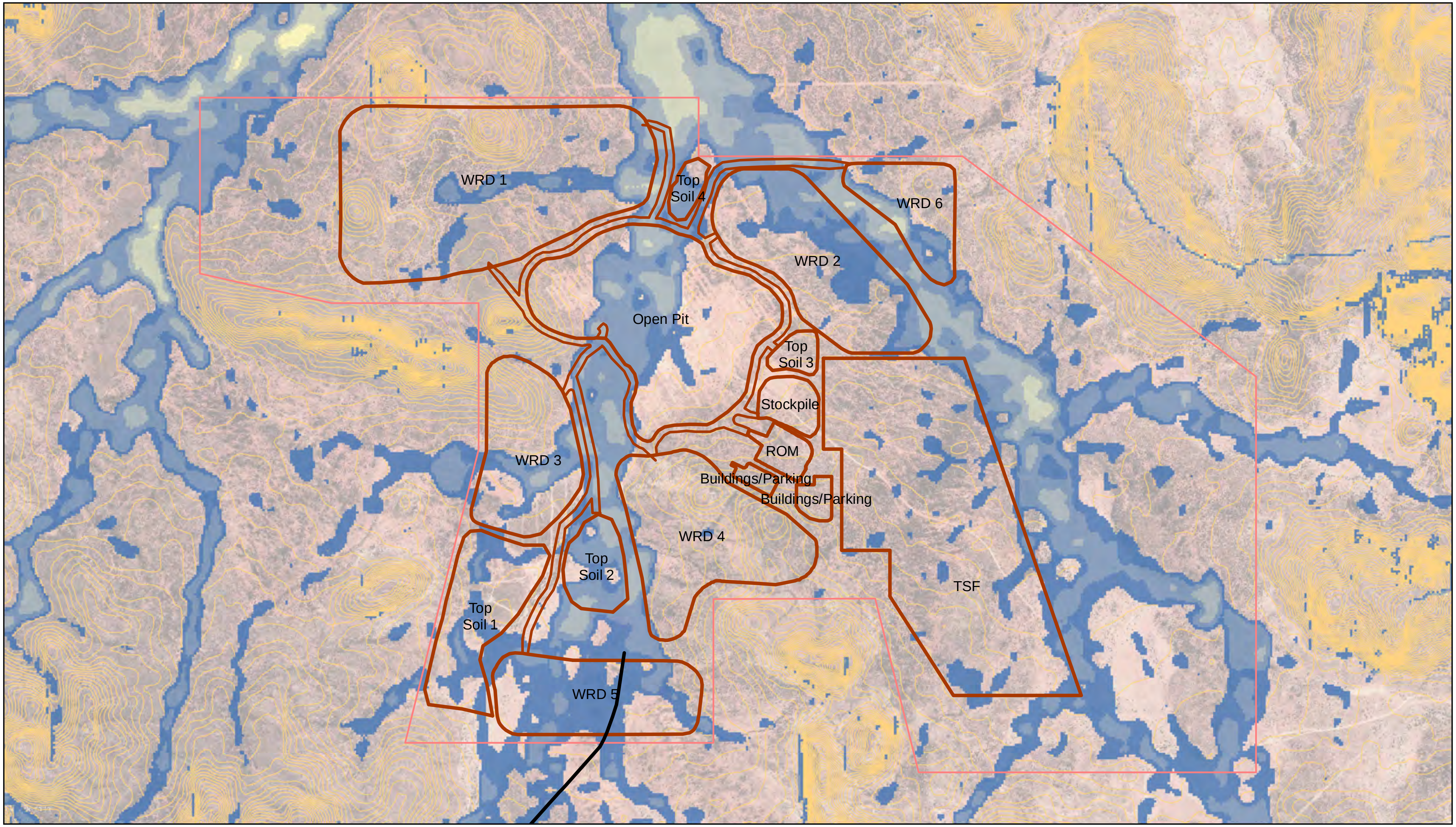
7.3.7 Flood risk

Flow events are infrequent and the probability of the mine site experiencing flood events with annual recurrence intervals of between 10 and 1,000 years during the 43-year LOM can be summarised as follows:

- 1 in 10-year ARI flood event has a 99 per cent probability of occurring during the LOM
- 1 in 50-year ARI flood event has a 58 per cent probability of occurring during the LOM
- 1 in 100-year ARI flood event has a 35 per cent probability of occurring during the LOM
- 1 in 1,000-year ARI flood event has a 4 percent probability of occurring during the LOM.

The lateral extent, depth, and velocity of flooding for existing site conditions (pre-mining) is shown in Figure 7-6 and Figure 7-7, and a summary of indicative flood depth and velocity at significant locations is provided in Table 7-3. Flood peak discharge along the two creeks flowing through the proposed mine site (Kerosene Camp Creek and Nolans Creek) has been obtained from hydrological modelling described in Appendix I.

Estimates of flood peak discharge assume a 4.5 hour storm rainfall event which is equivalent to the time of concentration for catchments draining to the downstream boundary of the proposed mine site. It is recognised that the critical storm duration will vary across the site and therefore more detailed modelling will be required during the design stage.



1:35,000 @ A4

0 250 500 750 1,000

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

LEGEND

- Access Roads
- Haul Roads
- 2m Contours
- Infrastructure
- Mine Site Boundary

Pre-Mining Flood Depth (m)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 4.0 - 4.5

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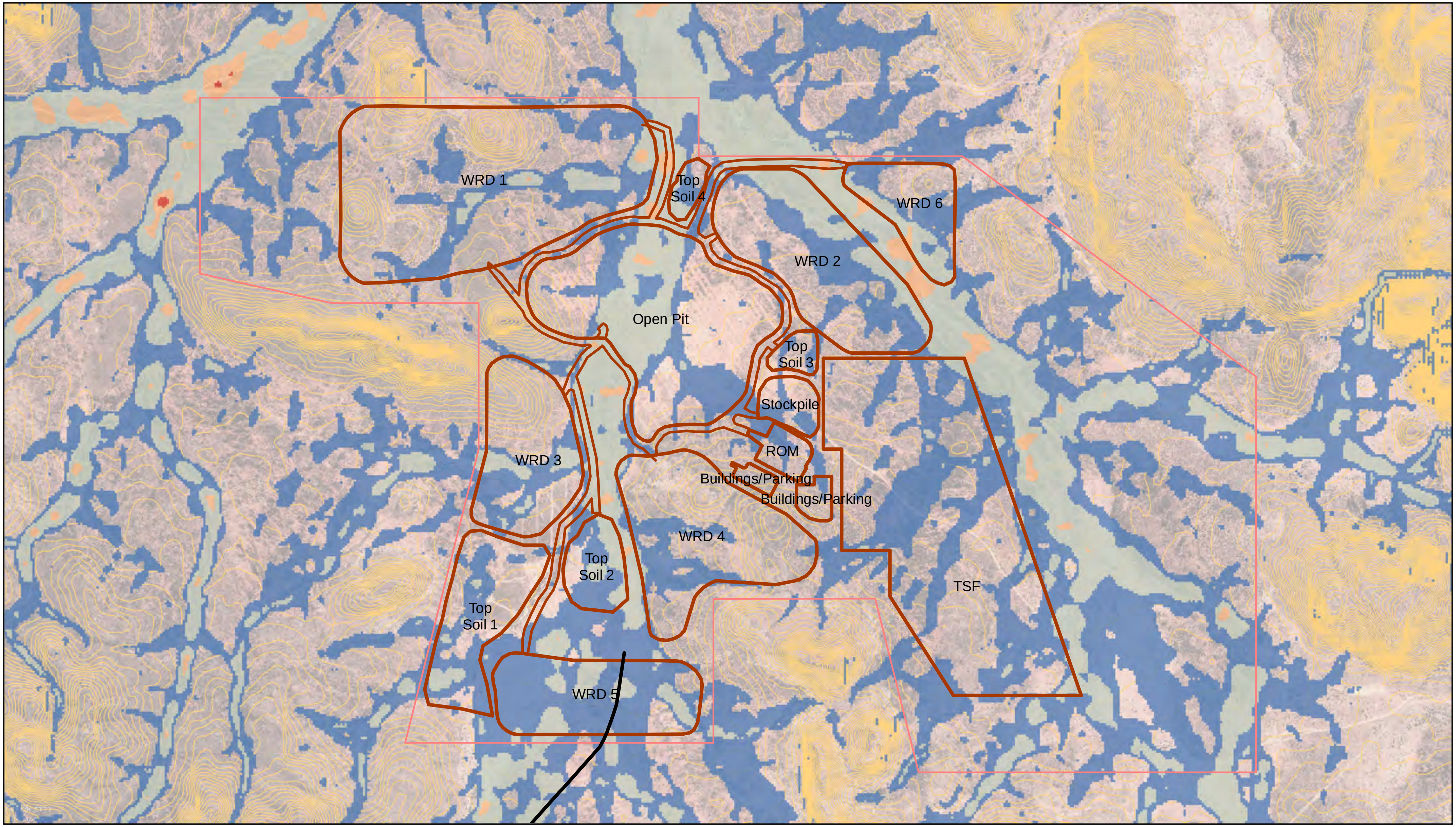
Flood depth for 1 in 1000 year ARI design storm event - pre-mining Figure 7-6

G:\43\22301\GIS\Maps\4322301_022_FloodDepthPreMine.mxd

Level 5 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: Google Earth Pro - Imagery (Date extracted: 29/04/2015). ARL - Proposed Haul Roads, Existing Creek Channels, Proposed Infrastructure (2015). CSIRO - 2m Contours (derived from SRTM) (2015). GHD - Flood Data (2016). Created by: CM



1:35,000 @ A4

0 250 500 750 1,000

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

LEGEND

- Access Roads
- Haul Roads
- 2m Contours
- Proposed Infrastructure
- Mine Site Boundary

Pre-Mining Flood Velocity (m/s)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0

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Flood velocity for 1 in 1000 year ARI design storm event - pre-mining Figure 7-7

G:\43\22301\GIS\Maps\4322301_576_FloodVelPreMine.mxd

Level 5 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: Google Earth Pro - Imagery (Date extracted: 29/04/2015). ARL - Proposed Haul Roads, Existing Creek Channels, Proposed Infrastructure (2015). CSIRO - 2m Contours (derived from SRTM) (2015). GHD - Flood Data (2016). Created by: CM

Table 7-3 Design flood characteristics – pre-mining

Creek	Location	Upstream Area (km^2)	1 in 1,000-year ARI – 4.5 hr flood event [a]	
			Velocity (m/s)	Depth (m)
Nolans	Upstream mine site boundary	26.3	0.9	1.3
Nolans	Downstream mine site boundary	28.2	0.6	1.3
Kerosene Camp	Upstream mine site boundary	12.3	0.3	0.2
Kerosene Camp	Proposed diversion inlet	20.4	0.8	1.0
Kerosene Camp	Downstream mine site boundary	25.8	0.7	1.6
Kerosene Camp	Downstream of confluence of Kerosene Camp Creek and Nolans Creek	58.7	0.7	1.7
Tributary of Kerosene Camp	Proposed diversion outlet	46.0	0.7	1.8

Notes: [a] storm duration corresponds to the time of concentration at mine site boundary

7.3.8 Water quality

The character of surface water quality is influenced by land use and the mineral composition of soils and near-surface geology. The absence of a sustained base flow contribution to watercourses is likely to limit the influence of deeper bedrock geology on surface water quality.

Baseline ambient water quality of surface water systems (when they flow) has been determined from the results of water monitoring. Surface water quality records are available from the DLRM water data portal. This data is limited to just two locations in the vicinity of the mine site, namely Arden Soak Bore (G0280010) which is on the Woodforde River 26 kilometres downstream of the mine site, and Allungra Waterhole (G0280004) which is on a different river system 42 kilometres to the east of the mine site. These records are limited to just a few individual samples taken in February and March 2011.

The available records include salinity, pH, dissolved oxygen, temperature and turbidity.

The water sampled in the Woodforde River was fresh but very turbid, neutral in pH and with sufficient dissolved oxygen to support aquatic life. Conditions at the mine site (which is a smaller catchment) may exhibit higher salinity and turbidity due to the lower volume of flow and thus its smaller dilution capacity.

7.3.9 Existing water users

Environmental water use is constrained by the sporadic nature of rainfall and surface runoff. Vegetation and fauna are either capable of surviving in between rainfall events or are able to access shallow groundwater. Depth to groundwater is generally greater than the reach of root systems, except along watercourses where the channel alluvium provides access to shallow groundwater, particularly along the Woodforde River downstream of the mine site.

Lake Lewis and its surrounds is a declared Site of Conservation Significance (SOCS) with a rating of National Significance. The processing site is located in the catchment of the Southern Basins, which drains toward Lake Lewis 40 kilometres to the south-west.

7.4 Project water balance

Water storage facilities should be designed to handle and control required inflows and outflows including unpredictable fluctuations due to exceptional storm inflow. Consideration of such inflows and outflows in a water balance will help identify storage requirements and minimise the risk of uncontrolled overflow and thus structural failure.

A monthly water balance has been carried out to identify whether the Nolans Project is likely to be in water deficit or surplus regarding its water supply requirements.

Available water resources will include water sourced from the borefield (located in the Southern Basins aquifer southwest of processing site), pit dewatering, tailings water that will be recycled from the TSF, and infrequent and short-lived water available from stormwater management ponds.

Open pit dewatering rates have been estimated by groundwater modelling which is reported in Chapter 8.

Project water demands (Figure 7-8) comprise the requirements for ore processing (crushing, beneficiation and processing plants), dust suppression along haul roads and at the ROM pad, together with potable water demands for the site.

7.4.1 Project water use

The overall site raw water demand is projected to peak at 4,777 ML/y. This includes a demand for process water of 4,418 ML/y, potable water 91.5 ML/y and dust suppression 267 ML/y.

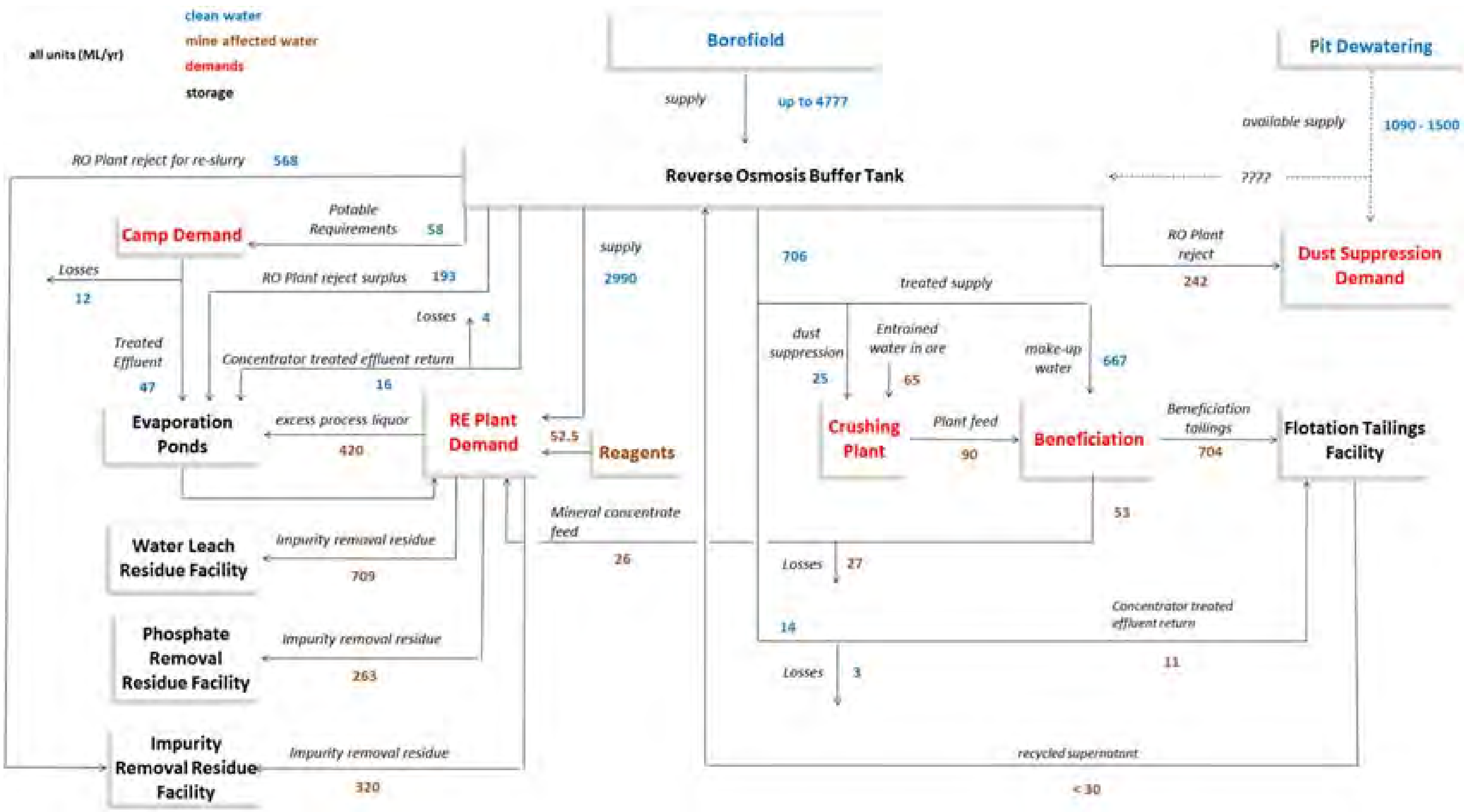


Figure 7-8 Schematic of project water demands (ML/yr) adapted from Lycopodium (2014)

The results of a mine site water balance are summarised in Table 7-4, based on the following:

- Seven mine development stages corresponding to the open pit development stages
- Monthly rainfall and evaporation comparable to conditions during an average year
- Estimation of recycled supernatant water from the TSF based on a slurry inflow of 0.45 Mtpa, which is assumed to correspond with mine development Stage 6 when the maximum quantity of material is mined. Quantities of recycled water for other mine development stages have been pro-rated from this maximum value by means of the relative quantity of mined material (Appendix D of Appendix I)
- Estimation of runoff within the open pit assumes a conservative rainfall loss of 90 percent from evaporation and seepage
- Groundwater inflow of up to 46 L/s depending on the pit water level (Appendix E of Appendix I)
- Pro-rating of the peak processing water demand (4,510 ML/yr) to provide estimates of water demand during other mine development stages. This has been achieved using estimates of the quantity of material mined in each development stage
- De-watering maintains a dry pit floor throughout the year, and
- Recycling of the water captured in sediment ponds at WRDs is assumed to be impractical due to the infrequent nature of surface runoff events.

The water balance for the processing site is excluded, as it comprises a closed system of incident rainfall 314 mm/yr and evaporation 2196 mm/yr only, with no transfers of water or catchment and groundwater inflow.

Table 7-4 Site water balance for average rainfall year

Component	Stage 1 (ML/yr)	Stage 2 (ML/yr)	Stage 3 (ML/yr)	Stage 4 (ML/yr)	Stage 5 (ML/yr)	Stage 6 (ML/yr)	Stage 7 (ML/yr)
Open pit rainfall inflow	32	101	139	191	262	335	385
Open pit groundwater inflow	1088	1243	1243	1391	1451	1461	1461
Open pit rainfall losses	-28	-91	-125	-172	-236	-301	-346
Open pit de-watering requirement [B]	-1091	-1253	-1257	-1410	-1477	-1495	-1500
Recycling of the TSF supernatant water[A]	2.7	6.1	3.3	9.4	25.7	30.0	12.4
Process water demand (excluding dust suppression)[C]	405	884	479	1399	3792	4418	1841
Dewater + recycle –	689	376	782	20	-2289	-2893	-328

Component	Stage 1 (ML/yr)	Stage 2 (ML/yr)	Stage 3 (ML/yr)	Stage 4 (ML/yr)	Stage 5 (ML/yr)	Stage 6 (ML/yr)	Stage 7 (ML/yr)
process demand							
Water deficit (excluding dust suppression)	0	0	0	0	2289	2893	328

Notes: source: [A] pro-rated and based on % reclaim from 'Nolans Project Tailings Storage Facilities Engineering Cost Study, Lycopodium, February 2014' [B] Appendix E of Appendix I {rainfall + groundwater inflow – losses} C Section 1.1.1 of Appendix I.

A comparison of the project process water demand with available on-site water resources indicates a potential surplus of water due to pit dewatering during the first four stages of mine development and a potential deficit in the supply of water demands thereafter.

Surplus water will be pumped to a turkey nest pond located at the mine site from where it will be recycled to augment project water supply, whilst deficits in demand will be met by groundwater supply from the borefield.

7.5 Assessment of potential impacts on surface water resources

7.5.1 Overview

The risk of an impact will occur if all three elements of a 'source – pathway – receptor' are present. In this instance the source – receptor of impact is

- Mine affected runoff from the mine site or processing site impacting on downstream receptors e.g. drainage lines or infrastructure e.g. access roads
- Upstream catchment flood water impacting on the mine site or processing site infrastructure or roads
- mine site or processing site construction impacting on normal flows or flood flows in downstream creeks and waterways (due to "removal" of catchment area of the mine from the normal/natural catchments)
- access road construction impacting on normal flows or flood flows across the landscape and in drainage channels.

In terms of surface runoff, the pathway can be:

- Sheet flow
- Channel flow
- Near-surface flow within the channel bed (groundwater pathways are discussed in Chapter 8).

Receptors may include:

- Third party infrastructure
- Water supplies
- Locations with environmental or heritage value
- Nolans site infrastructure

The level of risk posed to surface water resources by each source of impact was assessed using standard qualitative risk assessment procedures, which have been described in Chapter 5 and Appendix F. These risks are described in more detail below.

The elimination of risk is achieved by removing a source, pathway or receptor. If this proves impractical then a risk is managed by the implementation of project controls which are outlined below and dealt with in more detail in the water management sub plan contained within the Environmental Management Plan (Appendix X).

7.5.2 Separation of clean and mine affected water

Potential impact

Significant areas of catchment occur upstream of the mine site boundary comprising 16 km^2 within Kerosene Camp Creek catchment, 26 km^2 within Nolans Creek catchment and 16 km^2 within catchments upstream of the access road and processing plant (Figure 7-9). Due to natural flow paths, runoff that originates from upstream catchments will pass through the mine site and processing site and could therefore increase the volume of mine affected water.

If left undiverted, the open pit has the potential to capture 31 % of the runoff in Kerosene Camp Creek based on relative catchment areas upstream of the pit (19.5 km^2) and at the confluence of Kerosene Camp Creek with a major tributary of Kerosene Camp Creek (63 km^2) (Figure 7-9).

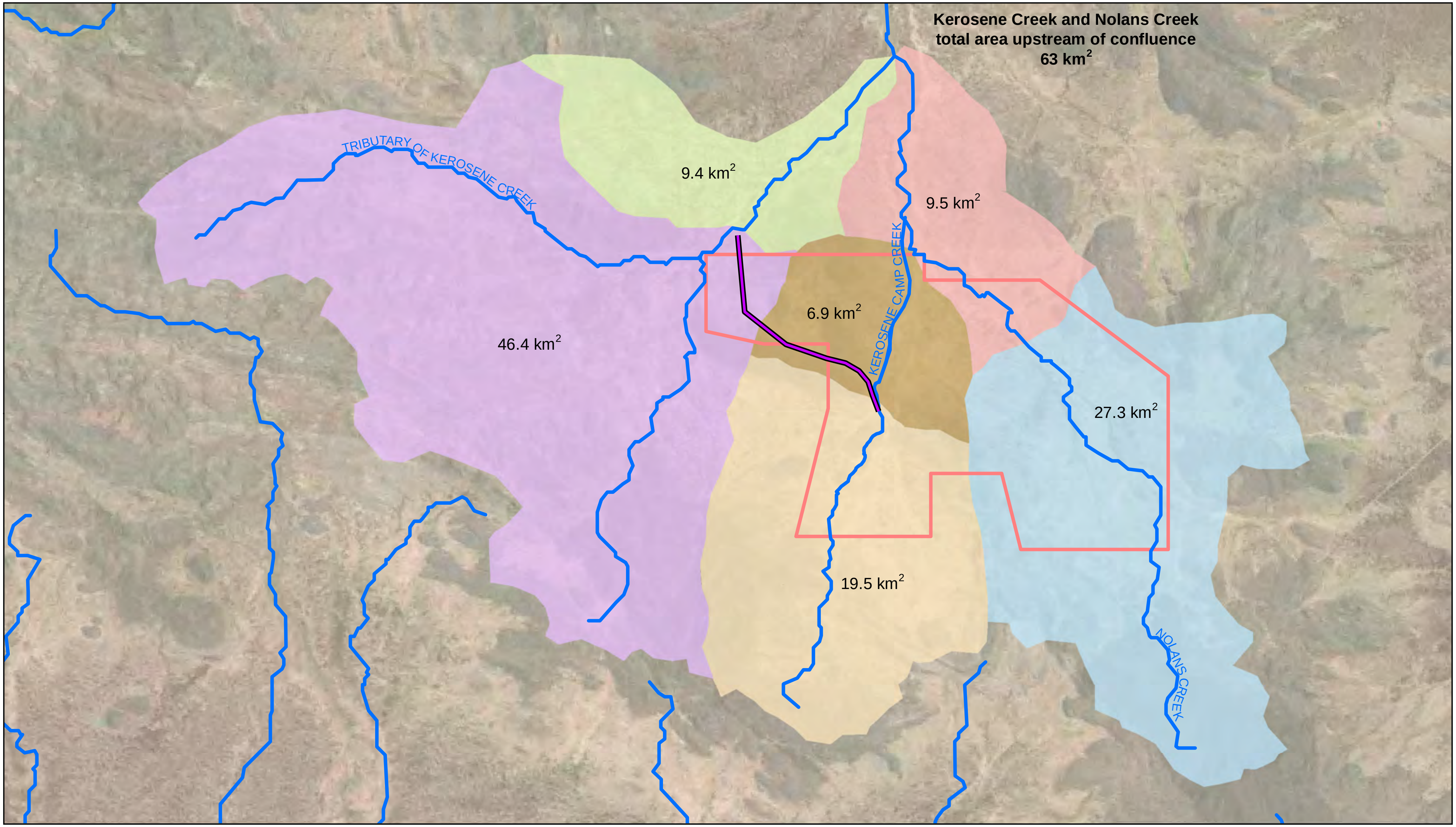
A proposed diversion of Kerosene Camp Creek will cause a change in the direction of flow within Kerosene Camp Creek. An options study (appended to Appendix A of Appendix I) suggests that this will cause an increase in water depth during a 100-year ARI flow event of 1.5 m immediately upstream of the diversion inlet and reduce the flow velocity and shear stress. Additional preliminary modelling suggests the water level upstream of the diversion inlet would increase by a further 0.2 m during a 1 in 1,000-year ARI flow event.

The Kerosene Camp Creek diversion outlet will also cause an increase of 30 percent in the catchment area contributing flow to a major tributary of Kerosene Camp Creek that will cause flows in this receiving watercourse to increase by a similar amount. The design study also suggests that the diverted flow will have flow energies and erosion and sediment transport potential similar to existing conditions in the receiving channel. As a result, the additional flow discharge from the diversion is not expected to have a significant impact on the morphology of the receiving channel (Appendix I).

Controls

Areas adjacent to the creek diversion will need to be protected against over-bank flow by means of a flood protection levee along the approach channel. The final longitudinal profile for the diversion channel will be designed to achieve flow conveyance and sediment transport in the approaches to the diversion that are close to existing conditions within Kerosene Camp Creek.

The diversion of clean water runoff around the processing site will be achieved by means of flood protection bunds and shallow drainage ditches. Conceptual designs are included in the Environmental Management Plan (Appendix X).



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0 500 1,000 1,500 2,000

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

LEGEND

- Diversion Channel
- Waterways
- Mine Site Boundary

Arafura Resources Limited
Nolans Project
Environmental Impact Statement

Job Number	4322301
Revision	A
Date	23 Mar 2016

Kerosene Camp Creek diversion catchments

Figure 7-9

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Data source: Google Earth Pro - Imagery (Date extracted: 29/04/2015). ARL - Proposed Pipelines, Proposed Mine Site, Proposed Diversion Channel Options, Tailings Storage Facility (2015). Created by: CM

7.5.3 Sedimentation and soil erosion

Potential impact

Vegetation clearing and site establishment, including construction of roads will occur during construction of the project including:

- site preparation and topsoil stripping
- excavation of WRD footprints
- creation of top soil stores
- establishment of haul roads and access roads, and construction of cross drainage structures such as culverts and floodways
- construction of processing facilities including tailings and residual storage, and
- construction of the accommodation village.

The construction of project infrastructure and use of heavy machinery in and around existing drainage channels may degrade the structural integrity of the channel edge or deposit material within the channel, thereby impeding or altering existing waterways.

Depending on the carrying capacity of the stream, sediments may be deposited or bank erosion may occur to increase the sediment load in the water to its "carrying capacity".

Whilst creek beds are generally mobile due to the unconsolidated nature of bed material, the relatively shallow gradient of longitudinal profiles limits creek flow velocities to generally less than 1.5 m/s during a 1 in 1,000-year ARI event (Appendix I). This limits the potential for erosion during extreme flood events. Small areas between mine infrastructure have larger gradients and therefore have greater potential for erosion.

Controls

Controls to reduce overland flow-induced erosion are set out in the Environmental Management Plan (Appendix X) and include:

- contouring, such as the creation of a series of benches, swales, furrows or irregularities that cause the precipitation to pond, and infiltrate or evaporate rather than translate into runoff
- construction of water containment structures to hold sediment laden run off and prevent its release to the downstream environment
- vegetation, once established, is probably the most cost-effective erosion control measure.

7.5.4 Construction of linear infrastructure and cross drainage structures

Potential impact

Haul roads and access roads will cross a large number of minor creeks with small upstream catchments.

Construction activities have the potential to cause a reduction in the existing capacity of channels or an increase in channel bed gradient. This could lead to a localised increase in flow velocity during rainfall events, leading to the potential for erosion of creek beds.

Conversely, if channel widths are increased or channel bed gradients reduced this could result in a reduction in the velocity of flow and an increased potential for the deposition of sediment.

To prevent problems associated with erosion or sedimentation at road crossings, changes to the drainage path and flow conveyance capacity of creeks will be minimised where practicable.

Preliminary flood modelling of catchments upstream of proposed haul roads suggests that flood depths and velocities during a 1 in 1,000-year ARI event will not exceed 0.5 m and 1.0 m/s, respectively. Flood depths and flood velocities during more frequent storm events such as a 20-year ARI event would be significantly less.

Controls

Given the limited depth and likely duration of flood flows at roads it is likely that floodways consisting of a localised depression in the elevation of the road formation and reinforcement of the road verge to facilitate the spillage of flow across the depressed section of road; will be the most appropriate method of 'bridging' creeks.

Where creeks are wide, the gradient of creek banks steep, or roads are susceptible to erosion, it will be necessary to use culverts instead of floodways.

7.5.5 Flooding

Potential impact

Preliminary flood modelling of the Nolans site and its upstream catchments has been undertaken to provide an estimate of flood levels and velocity during a 1 in 1,000-year 4.5 hr ARI storm event. Changes in flood levels and flood velocities as a result of mine development have also been assessed (Appendix I) and are summarised for significant locations across the mine site in Table 7-5.

Table 7-5 Design flood characteristics – post-mining

Creek	Location	1 in 1,000-year ARI – 4.5 hr flood event [a]			
		Velocity (m/s)	Depth (m)	Velocity Change [b] (m/s)	Afflux [b] (m)
Nolans	upstream of mine lease boundary	0.9	1.4	0.0	+0.1
Nolans	downstream of mine lease boundary	0.6	1.4	0.0	+0.1
Kerosene Camp	upstream of mine lease boundary	0.2	0.4	-0.1	+0.1
Kerosene Camp	Upstream of proposed diversion inlet	0.3	1.7	-0.5	+0.7
Kerosene Camp	downstream of mine lease boundary	0.5	1.1	-0.2	-0.5
Kerosene Camp	downstream of confluence of Kerosene Camp Creek and Nolans Creek	0.6	1.3	-0.1	-0.4

Notes: [a] storm duration corresponds to the time of concentration at mine site boundary [b] change from pre-mining conditions

Nolans Creek flows along what will be the eastern boundary of the TSF and between the proposed locations for WRDs 2 and 6. The location of Nolans Creek in close proximity to mine infrastructure creates the potential for flooding and erosion. However, due to the shallow gradient of the creek and narrowing of the Nolans Creek floodplain due the WRDs, modelling suggests only a small flood level afflux of 0.1 m and no significant increase in flood flow velocity.

Kerosene Camp Creek enters the mine site adjacent to the proposed WRD 5, and proposed top soil stores in this area further impinge on the Kerosene Camp Creek. However, gradients in this area are relatively shallow and mine development is predicted to cause a small flood level afflux upstream of the mine site boundary of 0.1 m and an insignificant decrease in flood velocity of 0.1 m/s.

The proposed creek diversion will cause an abrupt change in the direction of Kerosene Camp Creek that will result in flow depth immediately upstream of the diversion inlet of about 1.7 m and a slowing of flood water flow by about 0.5 m/s during a 1 in 1,000-year ARI event (for more information see the Diversionreport at Appendix A of Appendix I). This will increase the potential for localised over-bank flooding and spillage from the diversion into the open pit and possibly sedimentation problems upstream of the diversion inlet.

Runoff generated from areas between the open pit, processing site and WRDs represents an additional potential source of water ingress to the open pit with typical flood depths of up to 0.2 m and small localised areas where flood depths reach 0.75 m, and velocities of up to 0.5 m/s.

Controls

The positioning and design of mine infrastructure will take account of the risk of flooding and erosion along existing watercourses and will either position infrastructure outside the 1 in 1,000-year ARI flood extent; or incorporate flood protection measures into flood prone areas. Flood protection measures will include:

- A flood protection levee constructed around the perimeter of the open pit rim to height of 1 m
- A flood protection levee in the approaches to the Kerosene Camp Creek to be constructed to a minimum height of about 2 m and profiling of the diversion inlet to equalise its velocity with that of the existing upstream natural channel
- Provide rock protection to the eastern external embankment of the TSF where flood velocities of to 0.5 m/s can be expected, along the toe of WRDs 2 and 6 adjacent to Nolans Creek (velocities of up to 1.5 m/s), and along the toe of WRDs 3 and 4 (velocities of up to 1 m/s) and WRD 5 and the neighbouring soil store (velocities of up to 2 m/s), and
- Incorporate drains along the western toe of WRD 3, along the southern toe of WRDs 4 and 5, and around the northern, western and southern sides of the TSF, to prevent ingress of runoff from adjacent catchments.

Conceptual designs of water management controls are included in the Environmental Management Plan (Appendix X).

7.5.6 Contaminated water

Contaminated water (by contact with ore and waste rock) will be generated by activities involving the extraction of ore (pit dewatering), its subsequent processing at the mine site (tailings from crushing and beneficiating the ore) and processing site (residue streams), and possibly during hauling of material to WRDs.

Potential impacts - open pit

The open pit will receive groundwater flow during excavation along with incident rainfall, and pit dewatering will be required to maintain dry working conditions. During the first development stage the pit void is at its smallest and the risk of pit overflow is highest should dewatering activities cease. A void space in excess of 4 Mm^3 will be achieved relatively quickly towards the end of stage one and would exceed the average annual volume of inflow from groundwater and incident rainfall.

In addition to the low risk of pit overflow, the low sulfur content, generally low metal toxicant content and low metal and salt leachability of the mined material, further limits the risk of acid mine drainage at the mine site (refer Appendix L of this EIS).

Potential impacts - waste rock dumps

WRDs will occupy a large proportion (590 ha) of the mine site area and will rise to a height of around 50 m. The material to be stored is largely non-acid forming (Appendix L). Detail of the likely water retention capacity of dumps is not available, however given the height and potential void space of stored material, the water retention is likely to be comparable with extreme (1 in 100-year ARI) storm rainfall events (depth of 295 mm) and annual average rainfall (depth of 310 mm). Therefore, the majority of incident rainfall over WRDs will infiltrate and result in negligible surface runoff or return of seepage to the ground surface.

Depending on the properties of material used in the base of the WRDs infiltrating water within the dumps will eventually seep into the underlying ground where it will follow prevailing hydraulic gradients. Following excavation of the pit void and implementation of dewatering activities, hydraulic gradients within the mine site are likely to be directed towards the open pit thereby reducing the potential for migration of mine-affected water to groundwater systems beyond the mine site.

Potential impacts - tailings and residue storage facilities

Due to the prevailing topography of the mine site, uncontrolled overflow from the TSF, should it occur; would discharge contaminated water into Nolans Creek where after, depending on the rate of overflow and the amount and flow of water within Nolans Creek, it could potentially reach the downstream Woodforde River system and the Ti Tree Basin.

Uncontrolled overflow from RSFs at the processing site, should it occur, would enter multiple small watercourses that flow southwards towards the Southern Basins and eventually the project's borefield water supply.

Climatic conditions that could cause overflow conditions to occur are also likely to result in the generation of flow within downstream creeks. Flow records for the Woodforde River suggest that during exceptional rainfall events surface flow can persist for at least one day. Due to the smaller extent of headwater catchments upstream of the mine and processing sites, the duration of flow in those local creeks is likely to be much shorter. Even so, assuming a moderate flood flow velocity of 0.5 m/s, it is likely to provide sufficient time for contaminated water to reach:

- The tributary of Kerosene Camp Creek (11 kilometres and 6 hours travel time) downstream of the TSF, or
- The edge of the Southern Basins area (10 kilometres and 5.5 hours travel time) downstream of the RSFs.

The migration of contaminated water beyond these distances would take more than one day and would be exposed to high levels of dilution by the ever increasing runoff volume from surrounding catchments.

Should overflow from tailings and residue storage facilities occur during dry conditions then contaminated outflow would seep into the shallow alluvium of adjacent local creeks. Anecdotal evidence suggests that subsurface flow occurs within the alluvium of creeks and this could presumably provide a path for the dispersion of contaminants.

Topographic gradients to the north of the mine site are about 0.2 percent whilst those to the south of the processing site are slightly steeper at 0.3 percent. Thus, an approximate estimate of subsurface flow velocity within the sandy creek beds (hydraulic conductivity 0.001 m/s) is in the region of 100 metres per year and the travel time to reach the tributary of Kerosene Camp Creek and the Southern Basins is therefore in excess of 100 years.

Controls

The mine site lies in the headwaters of the Woodforde River drainage system that flows across the western extension of the Ti Tree Basin. The processing site lies in the headwaters of the Southern Basins and the project's water supply borefield. For this reason, the storage capacity of TSF and RSFs will maintain a negative water balance (i.e. evaporation exceeding water inputs).

The TSF and RSFs will have a design storage capacity that is able to contain a 1 in 100-year ARI average annual rainfall whilst retaining sufficient additional freeboard to accommodate a probable maximum precipitation (PMP) 72-hour storm rainfall event. Water balances have shown that the accumulation of supernatant water can be controlled by natural evaporation, given this design storage capacity.

The storage facilities will also have maximum reporting levels above which water levels will invoke emergency measures to prevent overflow. In addition to evaporation, the supernatant water accumulating in the TSF will be controlled by recycling.

Due to adverse water quality the recycling of supernatant water is not permissible from the RSFs, these being the Water Leach Residue, Phosphate Residue and Impurity Removal Residue facilities.

Additionally, all storage facilities will have low permeability liners and leakage collection systems to reduce the risk of seepage to groundwater.

WRDs will be constructed with an inward sloping top and inward sloping mid-slope bench to trap incident rainfall and promote seepage to internal water storage. Given the relatively high height (50 m) of WRDs and low annual rainfall it is unlikely that internal pore spaces of the dump will become fully saturated where seepage emerging from its base would match infiltration at its surface.

Sediment ponds will be used to capture surface runoff from all mine affected areas to promote evaporation and seepage to ground.

The open pit will require dewatering to allow dry working conditions throughout its operation. Inflow from groundwater, and to a lesser degree incident rainfall, will be pumped to an on-site storage pond for recycling to the concentrator, processing site and/or dust suppression.

Dewatering of the open pit will cause a local drawdown of groundwater levels in the surrounding area. This will cause any seepage of surface water from WRDs and other areas of the mine site to migrate towards the pit, thereby reducing the risk of potential impact on the surface water or groundwater of areas beyond the zone of groundwater drawdown (i.e. more or less coincident with the mine site boundary).

The transfer pipeline between the mine site and processing site will be HDPE. The pipeline will run above ground within a bunded corridor. In the event of leaks or pipe failure, slurry will be captured within the bunded corridor and within event ponds located at significant low points along the eight-kilometre alignment. Specific details of event pond sizing and tiered bund levels will be considered during detailed design.

Additional information

A Failure Impact Assessment study (refer to Appendix J) was undertaken for the TSF to establish the potential risk to downstream residents from a hypothetical dam-break scenario. The risk is specified by a consequence category based on the concept of Population at Risk (PAR) and Potential Lives Lost (PLL).

PAR is the number of people expected to be within the failure impact zone in the event of a dam failure, including both a 'Sunny Day Failure' (pipe failure with no warning and dry downstream creeks) and 'Flood Failure' (breach failure with warning and flow in downstream creeks equivalent to a 1 in 100-year ARI event). At risk is defined as 300 mm of flooding within occupied buildings.

The assessment of PAR and PLL considered the following locations:

- Ti Tree, Waste Transfer Station,
- Pmara Jutunta community, water treatment station.

The assessment excluded site personnel within the model domain. The Stuart Highway is not shown to be inundated by a dam break and road users are therefore not considered to be at risk. Additionally, due to the remoteness of the region, small access tracks and dirt trails within the model domain were assumed unoccupied.

Neither of the above-mentioned occupied locations were shown to be inundated by a dam break flood involving the Sunny Day Failure scenario. The incremental PAR, as caused by a Flood Failure scenario in addition to that caused by natural flooding, is estimated to be less than one. Because the PAR is less than one, there is zero PLL.

The assessment of a consequence category under Australian National Committee on Large Dams (ANCOLD) Consequence Guidelines (2012a) is based on PAR and severity of damages criteria. Knight Piésold (2014) previously assessed the 'severity of damage and loss' for the TSF as having a worst-case impact of 'High'.

Therefore, in the context of a PAR of less than one and a severity of damage and loss of medium, the appropriate ANCOLD consequence category for the TSF is 'Low'.

7.6 Mitigation and monitoring

7.6.1 Mitigation

In addition to the control measures described above in section 7.5, the following administrative controls will be included:

- A water management plan (included in Appendix X) will be implemented including measures to manage flood and stormwater related issues such as:
  - Appropriate consideration of surface water flow in design, placement of infrastructure and construction
  - Proposals to capture surface runoff to small dams for monitoring/sediment control prior to release or recycle
  - Layout of construction ancillary facilities to avoid flood risk areas

  - Amenities and equipment would be located outside high flood hazard areas
  - The extent of works located in high flood risk areas
  - Diversion of overland flow either through or around work areas in a controlled manner
  - Runoff from disturbed areas would be diverted into sediment ponds and not discharged into the natural environment
  - Construction programme will be staged to occur in dry season;
  - Monitoring weather conditions and staging works to avoid periods of heavy rain
  - Developing flood emergency response procedures to remove temporary works during periods of heavy rainfall.
  - Progressive rehabilitation of WRDs to minimise exposed material and dust generation.
- Selection of appropriate ANCOLD risk category and adherence to relevant design standards for the provision of adequate storage capacity and freeboard allowance
- Embankment piezometers and survey pins, regular dam inspections
- Adherence to prescribed maximum operating level and retention of freeboard
- Monitoring program for phreatic levels within Embankment
- Biannual geotechnical inspection of TSF Embankment
- Procedures for spill events and tailings failure or overtopping, including:
  - Above ground pipeline within a bunded corridor
  - Processing plant notification of disruption to flow
  - Flow meters
  - Pressure sensors
  - Shift based visual inspections
  - Design - spray deflectors on welded joints
- Fire and emergency management procedures
- Establish maintenance procedures to ensure all water management equipment is installed and functional.
- An erosion and sediment control plan will be implemented prior to construction including:
  - Use of buffer zones, sediment fences and sediment ponds to arrest the transport of water borne sediment from the site
  - Progressive stabilisation of cleared land as activities are completed, to limit continued exposure of bare soils.
  - Rising stage samplers and gauging stations would be installed and maintained in creeks in and around the mine site to monitor surface flows and water quality in creeks.

7.6.2 Surface water monitoring

Surface water monitoring locations have been selected to meet baseline and ongoing monitoring requirements for the life of the operation and during closure. Details of surface water and water quality monitoring are provided in the Environmental Management Plan (Appendix X).

Surface water monitoring

Surface water monitoring sites for level and water quality will be located along Kerosene Camp Creek, Nolans Creek and headwater tributaries of the Southern Basins. Monitoring will incorporate existing gauges which includes rising stage surface water sampling points and water level gauges.

Bank stabilisation may be required at certain sites; however, the installation of low flow weirs is not recommended. It is considered that the beds at the sites, whilst mobile, provide a relatively consistent cross-section, whereas introducing a low flow structure in the channel may propagate change to the cross-sections through undercutting or sedimentation.

Theoretical rating curves would be required for the channel reaches at each of the surface water monitoring sites to enable conversion of the measured water depths to flow rates established through topographical surveys of the channel reaches and hydraulic modelling. Flow (current) gauging would be undertaken (if practical) to further calibrate the theoretical rating curves. Additional survey may be required, as needed, to establish if there has been any significant change to the channel cross section and/or morphology.

Sediment monitoring

Due to the relatively infrequent nature of streamflow events, sediment sampling would be undertaken to augment water quality sampling. Accumulation of radionuclides, rare earth elements, and other elements in the sediment would provide an indicator of surface water quality. Contaminant progression would be assessed through the distribution and dissipation/accumulation of such elements within the vicinity of and downstream of the mine site and processing site.

The sediment sampling procedure is provided within the Environmental Management Plan (Appendix X) and will include locations along Kerosene Camp Creek and Nolans Creek.

Sediment sampling will be undertaken annually throughout the life of the Project and into closure.

Shallow groundwater monitoring

Nested groundwater monitoring bores will be installed at key locations coinciding with proposed site infrastructure which is identified as a potential source of contamination. In addition, some background monitoring bores will be established. Further details are provided in the Environmental Management Plan (Appendix X).