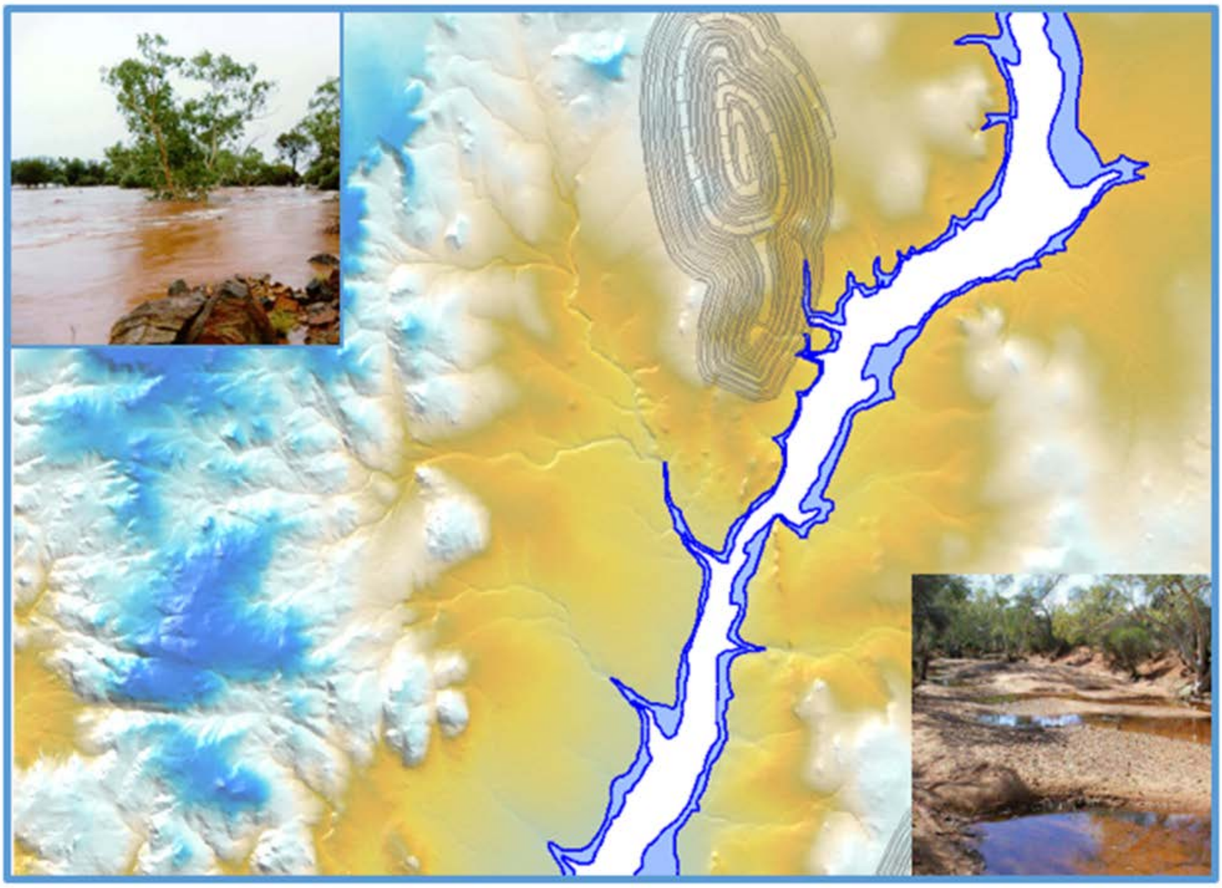
Mt Keith Satellite Pits
Environmental Impact Assessment
Hydrology Processes and Inland Water

BHP - NICKEL WEST



MWES CONSULTING

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EXECUTIVE SUMMARY

SURFACE WATER

The project is located in the upper catchment of Jones Creek, where minor flows of several hours duration can typically be expected one to three times per year. For the large majority of creek flow events, there is no potential interaction between the flood water and proposed major landforms (pits and dump). The potential for interaction only occurs in small areas at the margins of extreme flood levels which will occur briefly (less than one hour) and rarely (less than once in 50 years). A small amount of permanent bunding will securely isolate the SMW pit void from high-stage creek flow. The small incursions of the WRD onto the Jones Creek extreme flood zone are in areas of low stream velocity.

Catchment scale volumetric impacts have been evaluated and found to be minor. Flow frequency and duration will be practically unaffected and total catchment discharge reduction will be approximately proportional to the catchment area reduction. Modelling shows that in most years that large scale catchment-wide flow occurs, the total annual yield greatly exceeds the capacity of the terminal Claypan such that the frequency of filling the Claypan will be barely diminished by the development.

Risks from materials handling are mitigated by the fact that the ore is generally low grade and relatively low in sulphide and trace metals. Waste rock constitutes the bulk of material movement and has very low levels of mineralisation and the majority has high mechanical and chemical stability (“competence”). The potential for ecological impacts from additional dissolved trace element load from all potential sources is considered to be low, provided appropriate operational practises are maintained.

Measures have been designed to control additional sediment load to the creek system. These include permanent clean stormwater diversions and operational drains and traps to control sediment. Effective operation of the control structures will be critical to minimising the impact. Operational monitoring of the physical and chemical characteristics stream pool water and sediment quality will provide a robust and direct form of feedback on performance.

Road alignments have been adjusted to minimise impacts where possible and are not problematic from a hydrological perspective. Surface gradients along and across the proposed routes are generally low. Some relatively minor drainage measures, cut slope cladding and road surface profile modifications cladding are detailed.

SURFACE WATER POTENTIAL IMPACTS

1. Quantity of flow in Jones Creek
    - Reduced catchment flow and yield due to retention of stormwater in pit voids and dumps
    - Capture of creek flow by the pit voids
2. Water Quality in Jones Creek
    - Improper containment of sediment laden stormwater run-off during operations
    - Point source contamination from haul road creek crossings
    - Post-closure sediment load from waste rock dumps
    - Post-closure discharge from pit lakes
3. Mt Keith Haul Road
    - Erosion and run-off shadowing

SURFACE WATER IMPACTS MITIGATION

Avoidance

Re-design of the SMW pit to a smaller footprint such that Jones Creek diversion is not necessary
Exclusion of disturbance to 60+ metres from Jones Creek with the exception of two crossings
Proposed layout is designed to lie outside the flood zones
Haul route to Mt Keith directly departs from the Jones Creek catchment

Minimisation

Compact overall site footprint
Single large waste rock landform limits footprint
Clean water diversion drains impose volumetric limits on stormwater intercepted by the disturbed area
Creek crossings by natural surface level flood-ways

Management

Disturbed area drains and first flush check dams
Peak flood flow exclusion bund at pit perimeter
Clay bunds to prevent ingress of stormwater to the waste rock dump from upstream
Rock cladding of erosion-prone slopes graded for haul road construction (breakaways and creek-crossings)
Operational procedures to minimise tyre tracking of oxide waste through creek crossing in wet weather
Mt Keith road design detail to eliminate stormwater capture, erosion and shadowing

Rehabilitation

Prioritise low-erosion objectives over revegetation in design of waste rock dump profile and capping

SURFACE WATER RESIDUAL IMPACTS MANAGEMENT

Jones Creek water and sediment quality - operational monitoring results compared to baseline
Jones Creek catchment yield - operational flow monitoring

GROUNDWATER

Groundwater is relatively scarce in the project area. The largest aquifer present is the is the regolith-zone over the SMW dunite ultramafic which will be largely drained and mined out by the SMW pit. The host greenstone belt rocks also contain an array of minor narrow, steep and localised aquifers associated with geological contacts and structural features. Water level data indicates a degree of interconnection between these features and this array is likely to be continuous for 10’s of kilometres north and south of the MKSO site.

Groundwater modelling shows that drawdown of 5 metres will extend up to several hundred metres beyond the pit crest. In the baseline condition minor aquifers are typically submerged (confined) by 20 metres such that , at maximum project drawdown, they will remain fully saturated, and hence practically unimpacted, well within the 5-metre drawdown contour extent.

Mature eucalypts in Jones Creek adjacent to the SMW Pit and other vegetation are not considered vulnerable to drawdown impacts since baseline water levels are normally at least 15 metres below the creek bed level and pit dewatering will not affect soil/rock moisture in the overlying profile.

After closure, the Goliath pit will partially refill to form a very deep pit lake and minor discharge zone from the surrounding country rock. Ongoing evaporative losses mean the pit lake salinity will continue to increase.

The backfilled SMW void will refill to a level close to the original static water level over about 50 years and long term water quality is expected to be minimally impacted.

Under normal climatic conditions, dewatering rates will be less than operational water requirements creating a modest water supply deficit. Several low impact options to address this deficit are detailed. The viability of the four existing water supplies to the Mt Keith Concentrator has been assessed. It is expected that the borefields will continue to deliver the additional 10 years water supply without substantial modification and that the extension will not create any different environmental outcomes.

GROUNDWATER POTENTIAL IMPACTS

1. SMW pit drawdown impacts on biological receptors
2. Post closure pit lake discharge to surface drainage
3. Impacts from deleterious water quality in the post-closure pit lake

GROUNDWATER IMPACTS MITIGATION

Minimisation

Groundwater abstraction for dewatering - limit groundwater supply development in the area

Rehabilitation

Backfilling the SMW pit will allow full recovery of groundwater levels

GROUNDWATER RESIDUAL IMPACTS MANAGEMENT

Groundwater level monitoring – confirm predicted extent of drawdown cone from dewatering

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1. INTRODUCTION

Major components of the proposed development include:

- Haul road 15 km north to Mt Keith tenements
- Stage 1 Goliath Pit, 205 M tonnes mined FY20-23 with waste to waste rock dump (WRD)
- Six Mile Well (SMW) pit, 227 M tonnes mined FY23-27 with waste to (WRD)
- Stage 2 Goliath Pit, 362 M tonnes mined FY26-31 with waste to SMW and WRD
- Site haul roads, stockpiles, workshop, office etc.

2. BASELINE SURFACE HYDROLOGY

Climatic data presented here is largely sourced from the Australian Bureau of Meteorology (BoM) website. General climatic statistics presented here are based on those from Wiluna (BoM station 013012) which is located 100 km north of the site and Leinster Aero (#012314) 50 km to the south. Rainfall data for closer BoM stations was also reviewed.

Long term rainfall averages are slightly higher at Wiluna than some of the closer stations such as Yakabindie Homestead (BoM #12088). The BoM pan evaporation data for Wiluna are inconsistent with wider regional data and values from the BoM regional grid are used here, however the sensitivity of the impacts assessment to any local variations is low.

Rainfall intensity, duration and frequency data are those obtained from the BoM “New IFDs (2013)” and are calculated based on a grid which takes account of local topographic effects.

2.1 Climate

Mt Keith’s climate is semi-arid region with cool winters and hot summers. The seasonal range in mean daily minimum temperature is 5 to 23°C and in maximum temperature is 19 to 38°C.

Wind strengths are generally moderate, averaging between 8 to 12 km/hr over most of the year. The prevailing wind direction is from the east to southeast over most of the year. Stronger westerly winds occur in spring, with September average afternoon strengths exceeding 40 km/hr on an average of 1 day per month.

High temperatures and low humidity throughout much of the year produce an average pan evaporation of about 3,200 mm, and average evaporation exceeds average rainfall in all months of the year. The long term average rainfall for the area is about 235 mm.

2.2 Rainfall

Average monthly rainfall is reasonably consistent from December to July (25 to 35 mm) and from August to November (10 to 20 mm). The average number of rain days per year (> 1 mm) is about 32. High intensity rains occur more commonly in summer, caused by localised thunderstorm activity or much larger weather systems associated with cyclones and tropical lows, however high intensity rain can also occur in association with winter weather patterns. Low rainfall intensity and low rainfall totals occur most consistently in the months of September to November.

BoM data indicate that the region has an average annual tropical cyclone frequency of between 0.1 and 0.2. Rainfall intensity-frequency duration relationships for the site are shown in Table 1. For frequencies of up to 100 years (annual exceedance probability 1%) the data are obtained from the BoM website IFD calculator. Probable maximum precipitation (PMP) is calculated using the BoM Generalised Tropical Storm Method.

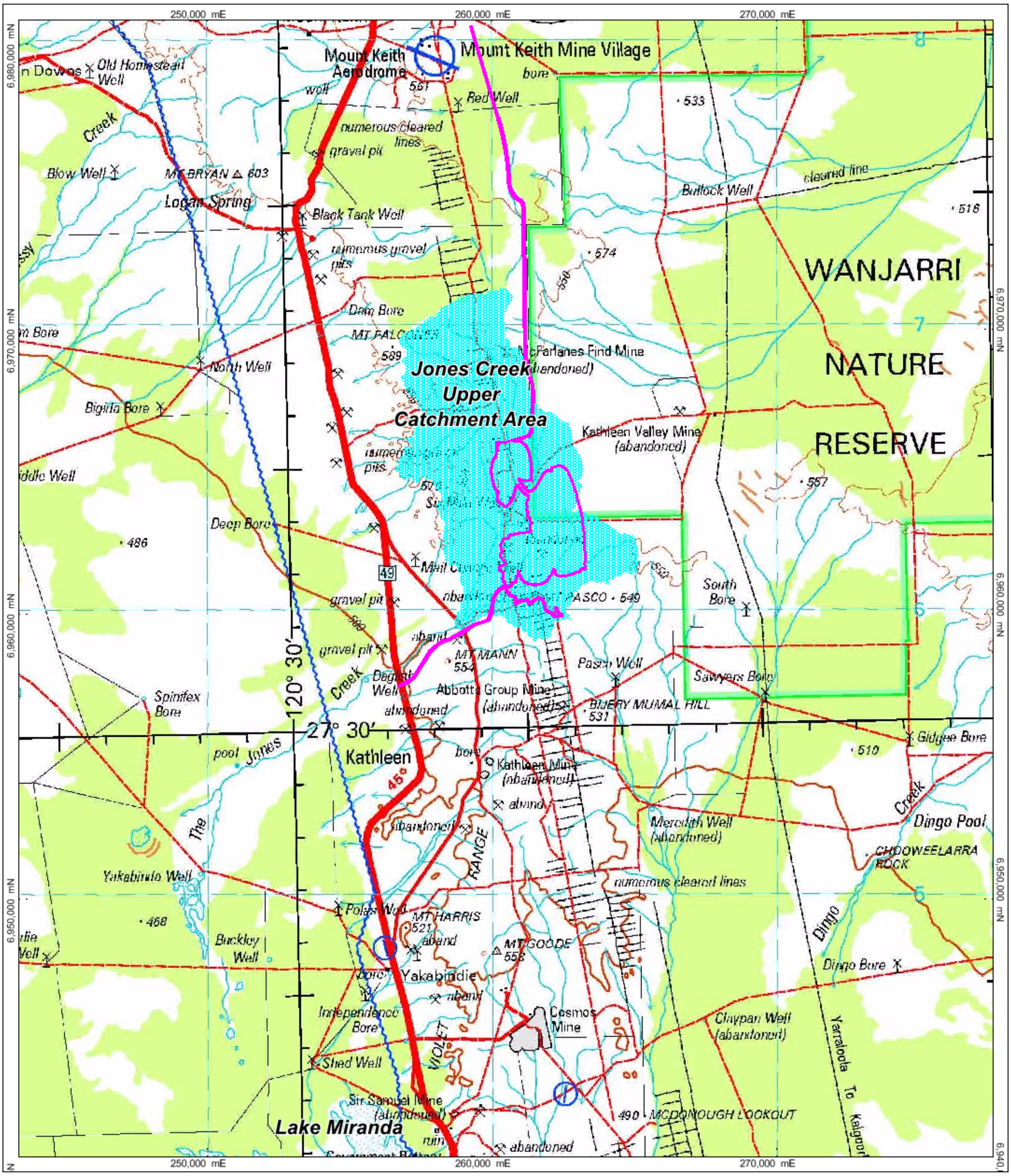
Table 1 – Rainfall Intensity Frequency and Duration (mm) and Probable Maximum Precipitation

	Annual Exceedance Probability							**PMP**
Duration	**1EY**	**50%**	**20%**	**10%**	**5%**	**2%**	**1%**	
5 min	3.9	4.7	7.4	9.5	11.8	15.1	18	
10 min	6	7.2	11.4	14.7	18.2	23.3	27.7	
15 min	7.4	8.9	14.1	18.1	22.4	28.7	34.1	
30 min	9.9	11.9	18.9	24.3	30.1	38.6	45.9	
1 hour	12.7	15.2	24	30.8	38.2	49.1	58.6	
2 hours	15.9	19	29.7	38.1	47.2	60.8	72.6	
3 hours	18.1	21.6	33.7	43.1	53.4	68.7	81.9	
6 hours	22.8	27.1	42.1	53.7	66.3	84.8	100.7	
12 hours	28.7	34.3	53.2	67.6	82.9	105.1	123.9	
24 hours	35.8	42.9	66.7	84.3	102.8	129.1	150.8	832
2 days	43.1	51.8	80.7	101.6	123.1	153.4	177.9	1201
3 days	46.7	56.3	87.6	110.1	133.2	165.4	191.3	1515
4 days	48.8	58.7	91.4	114.8	138.8	172	198.8	1695
5 days	50	60.1	93.5	117.4	141.9	175.8	203.1	1786
7 days	51.1	61.4	95.3	119.6	144.5	179	206.7	

2.3 Regional Hydrology

The project is located in the Lake Miranda catchment (Figure1). The north-east side of the main valley is formed by the Barr Smith Range, in which are located the existing and proposed satellite pits. The upper slopes of the Range are sparsely vegetated, rocky and relatively steep (by regional standards). From the catchment divide at altitude 550 -580m m AHD down to about 515 m AHD, drainage line gradients are typically 1-4%. The short ephemeral creeks which drain the sides of the Range flood out onto the sedimentary deposits on the lower slopes of the valley. These minor lateral tributary creeks mostly terminate several kilometres short of the valley floor in vegetated distributary alluvial fans (flood-outs). Jones Creek drains the largest catchment of the Barr Smith Range and includes a well defined creek-bed which crosses the lower valley alluvial slopes and discharges to a Claypan near the valley axis.

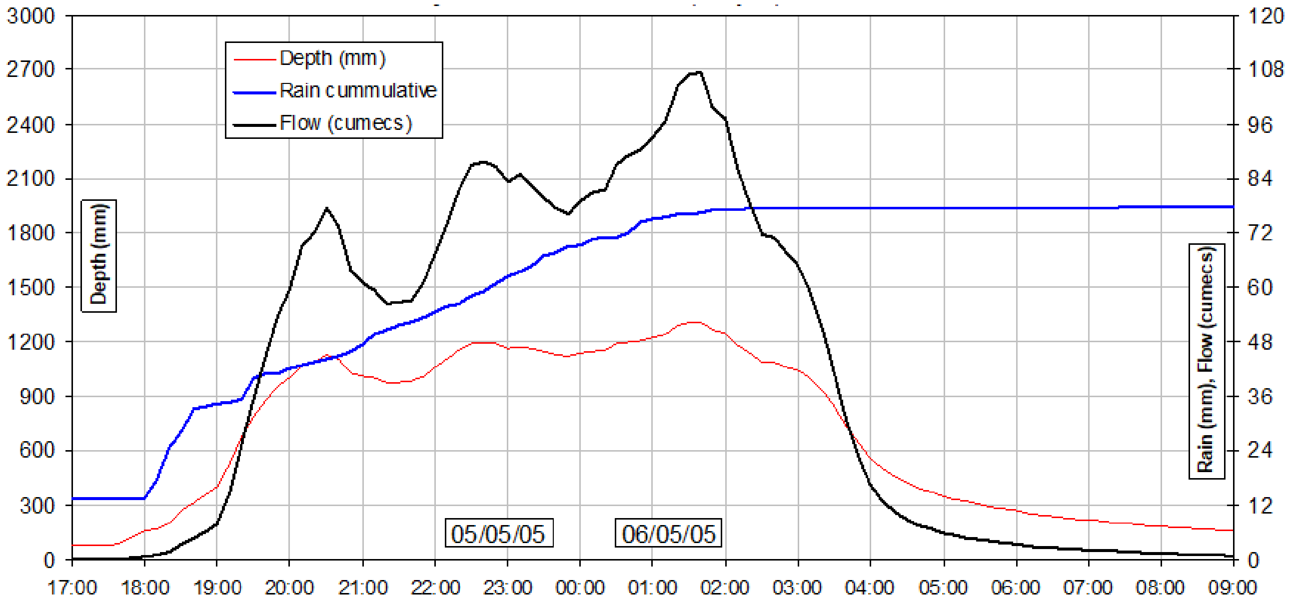
Figure 1 – Project Area and Regional Catchment Features



2.4 Jones Creek

The satellite pits development is located in the mid-upper reaches of Jones Creek at an altitude of about 520-560 m AHD. In this area the Creek is incised quite deeply into the Barr-Smith Range and the catchment is relatively efficient in terms of yielding stormwater run-off to the main stream. Surface gradients are relatively steep by regional standards, due to presence of a sequence of low strike ridges within the upper catchment. The rocky nature of the terrain with little alluvial or residual soil cover and sparse low vegetation further enhances the tendency for the catchment to shed rather than store water. This tendency is evidenced by the dense array of well defined and well incised minor tributaries and the relatively broad and coarse gravel bearing main-stream. The tendency is also reflected in the flash-flooding type of creek flows generated by the catchment. An example of the rapid ascension and recession of the creek hydrograph was captured by monitoring equipment at the main highway road bridge in May 2005. A total of 78 mm of rainfall was recorded over 72 hours (1 in 4 year frequency) which included 56 mm over 6 hours (1:10 year frequency). Monitoring of measured rainfall rate, flow depth and calculated flow rate is shown in Figure 2, with the flow event lasting less than 12 hours.

Figure 2 – Jones Creek Highway Crossing - May 2005 Flow Event



The local and regional context dictates that for most flow events, the large majority of water discharging from Jones Creek originates in the upper steep, rocky and poorly vegetated portion of the Jones Creek catchment.

2.5 Regional Stormwater Run-off Model

The physical environment and parameters relevant to stormwater run-off are described in Flavell (2011). Streamflow data from the relatively steep and rocky (by regional standards) Newton Dam catchment at Kambalda was modelled using RORB to determine runoff characteristics which were then adjusted to local conditions based on comparison of differences in climate, soil and vegetation.

Twelve local catchments were then selected with a variety of sizes/shapes, giving critical storm durations in the range 1 to 6 hours. RORB models were constructed for each of the 12 local catchments using the adjusted runoff coefficients. The models were run for simulation of design storms of various frequencies. Multiple regression analysis of the 2, 5, 10, 20, 50 and 100-year ARI design flood estimates and catchment characteristics was undertaken to derive equations for estimating design flow rates for the area as follows:

$$Q_2 = 0.16\,(AS_e^{0.5})^{0.82}\,(L^2/A)^{-0.35} \qquad (1)$$

$$Q_5 = 0.49\,(AS_e^{0.5})^{0.84}\,(L^2/A)^{-0.33} \qquad (2)$$

$$Q_{10} = 0.91\,(AS_e^{0.5})^{0.84}\,(L^2/A)^{-0.34} \qquad (3)$$

$$Q_{20} = 1.48\,(AS_e^{0.5})^{0.85}(L^2/A)^{-0.33} \qquad (4)$$

$$Q_{50} = 2.50\,(AS_e^{0.5})^{0.82}\,(L^2/A)^{-0.36} \qquad (5)$$

$$Q_{100} = 3.37\,(AS_e^{0.5})^{0.83}\,(L^2/A)^{-0.35} \qquad (6)$$

Where: A = catchment area (km2)
L = mainstream length (km)
Se = equivalent uniform slope (m/km)
Qn = n year flood estimate (m3/sec)
And for $L^2/A < 1.0$, it should be replaced with A/L^2

These equations constitute the Mt Keith Regional Flood Flow Estimation Method (MKRFFEM)

2.6 Peak Flow Rates for Jones Creek

Runoff modeling was undertaken using the RORB model and reported by Flavell (2011). Peak flow rates were calculated in site specific RORB models and using the regional peak flow methodology described above. The baseline site specific catchment model (Figure 3) shows:

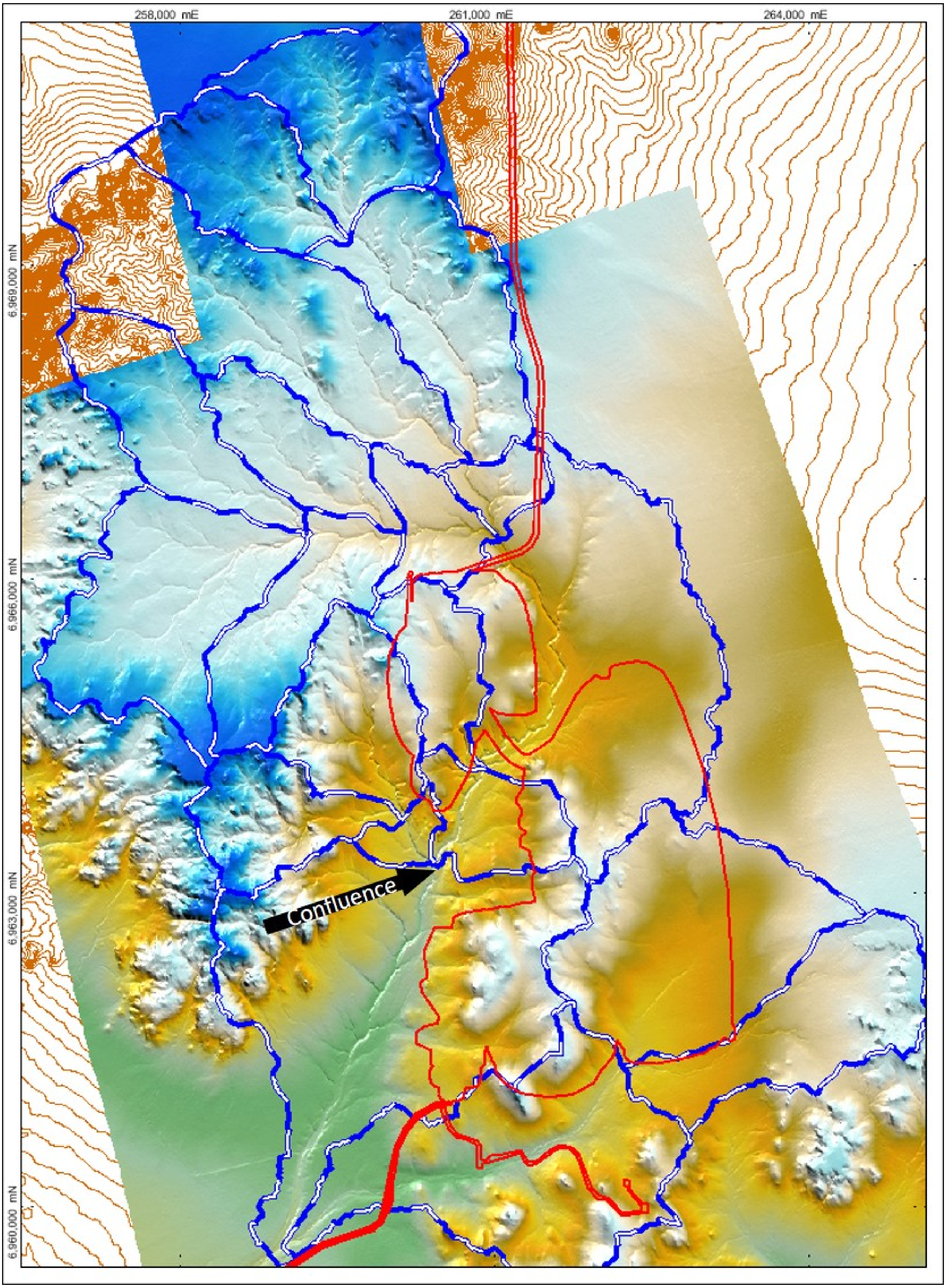
- 20 sub-catchments used in run-off modelling
- Confluence of upstream and western tributary streams
- Proposed disturbance area
- Topographical features
- 5 metre DEM as colour- fill

The peak flow rate estimation was further informed by observations relating to historical extreme flow events. In particular, the flow event of 24th January 1990 was observed, photographed and back-analysed, (Rockwater, 1990, 1991, Peck, 1992). The calculated peak flow rates are tabulated below

Table 2 – Mainstream Peak Flow Rates

Catchment	Method	A	Se	L	Average Recurrence Interval (years)						
		km^2	m/km	km	2	5	10	20	50	100	1000
					Flow rate (cumecs)						
Upstream of Site	RORB				3.5	11.9	22.6	37.8	53	72.8	160
Upstream of Site	MKRFFEM	28.2	3.9	8.7	3.1	10.3	19.0	32.6	47.3	67.0	
Western Tributary	MKRFFEM				1.1	3.6	6.6	11.1	17.3	23.9	52.5
Confluence	Summation				4.6	15.5	29.2	48.9	70.3	96.7	212.5

Figure 3 – Jones Creek RORB Runoff Model Catchments

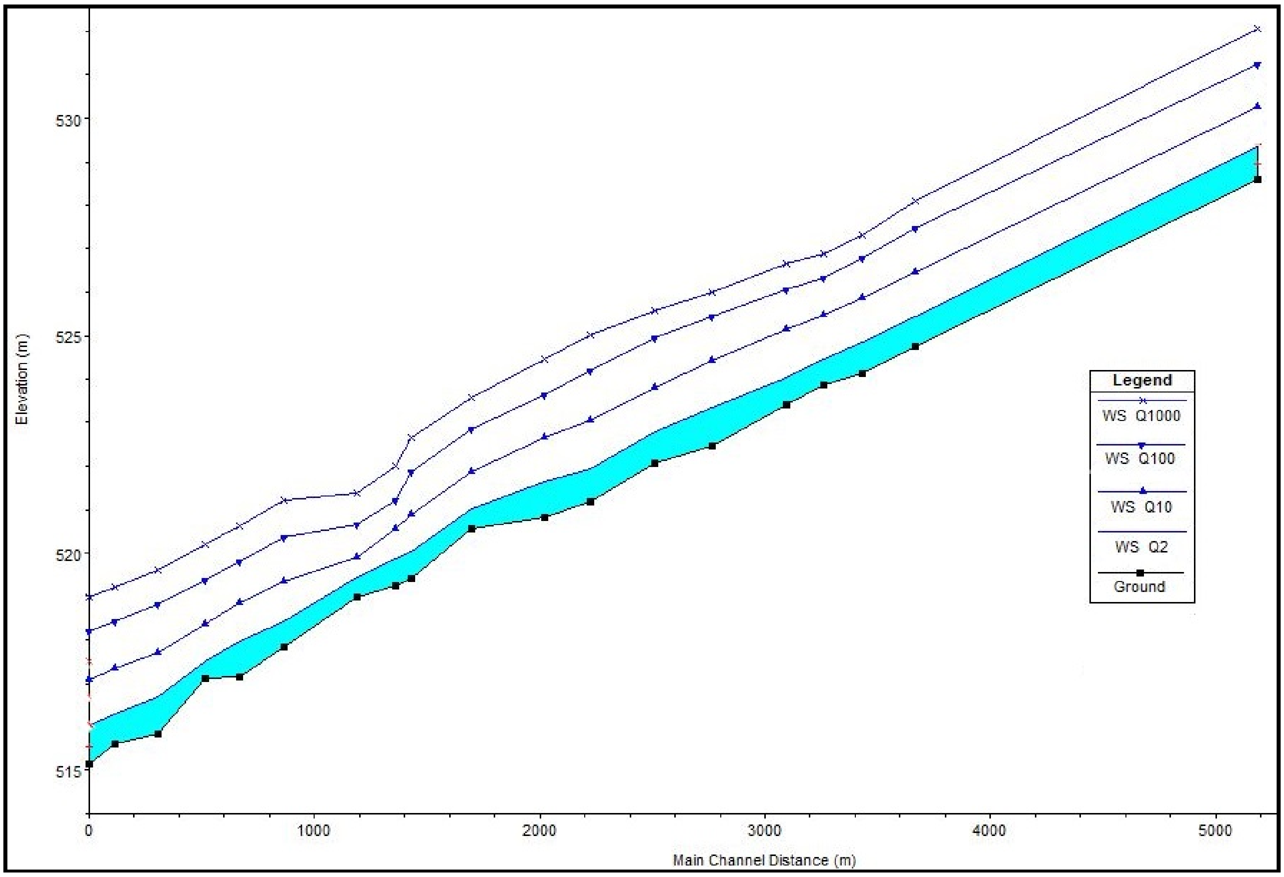


2.7 Peak Flood Levels

A HEC-RAS (US Army Corps of Engineers, 1997) hydraulic model was developed that encompassed the mainstream reach through the site (Flavell, 2011). The model comprises 19 cross sections from downstream channel centre at 6,962,254 mN (cross section 1) to upstream channel centre at 6,966,103 mN (cross section 19).

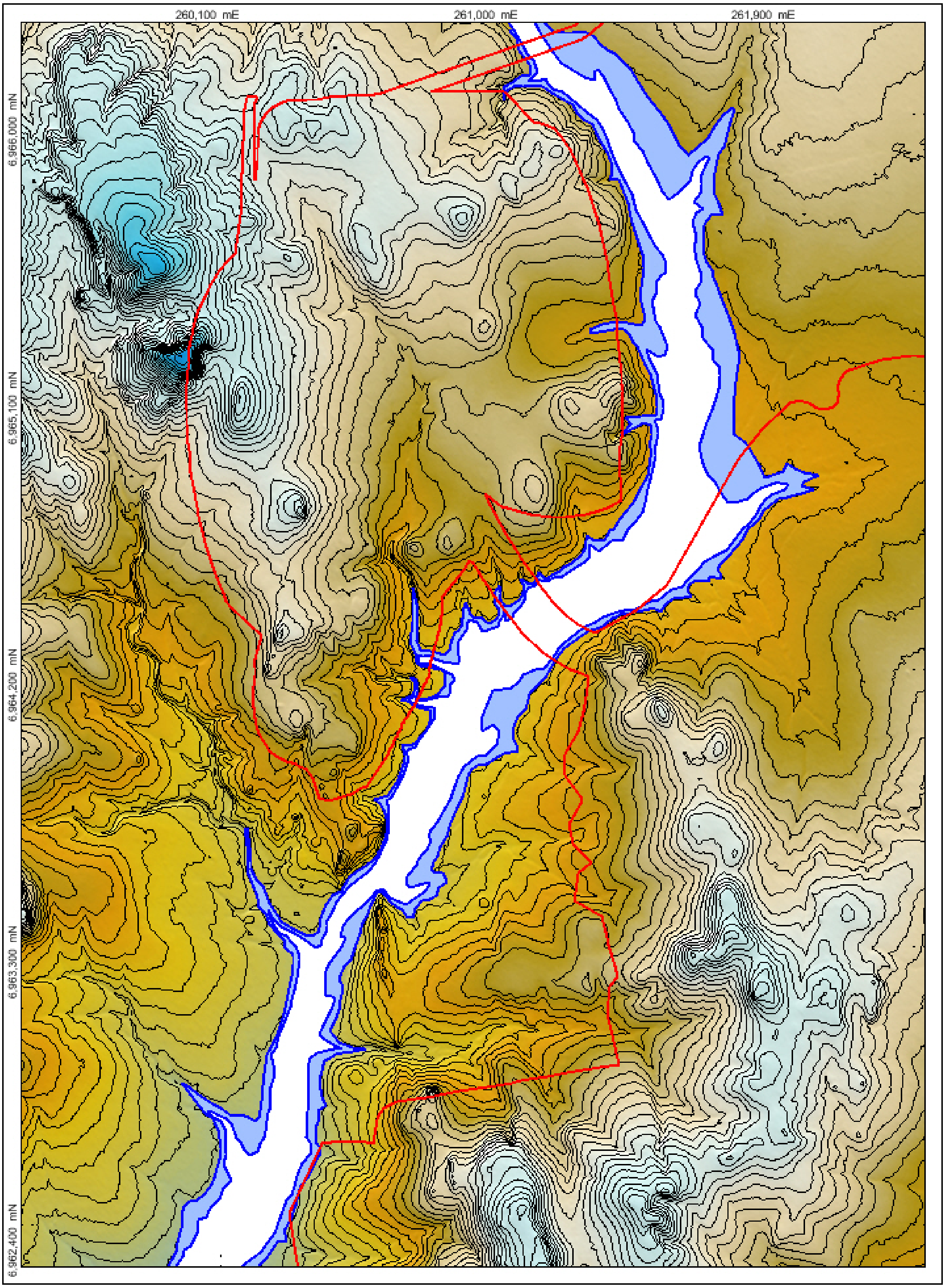
The design flows defined above were applied to the model and the water surface profiles and velocities determined. The longitudinal profile showing the cross section points and water surface profiles for the 1:2, 1:10, 1:100 and 1:1000 year ARI events is shown on Figure 4.

Figure 4 – Jones Creek Peak flood level profiles



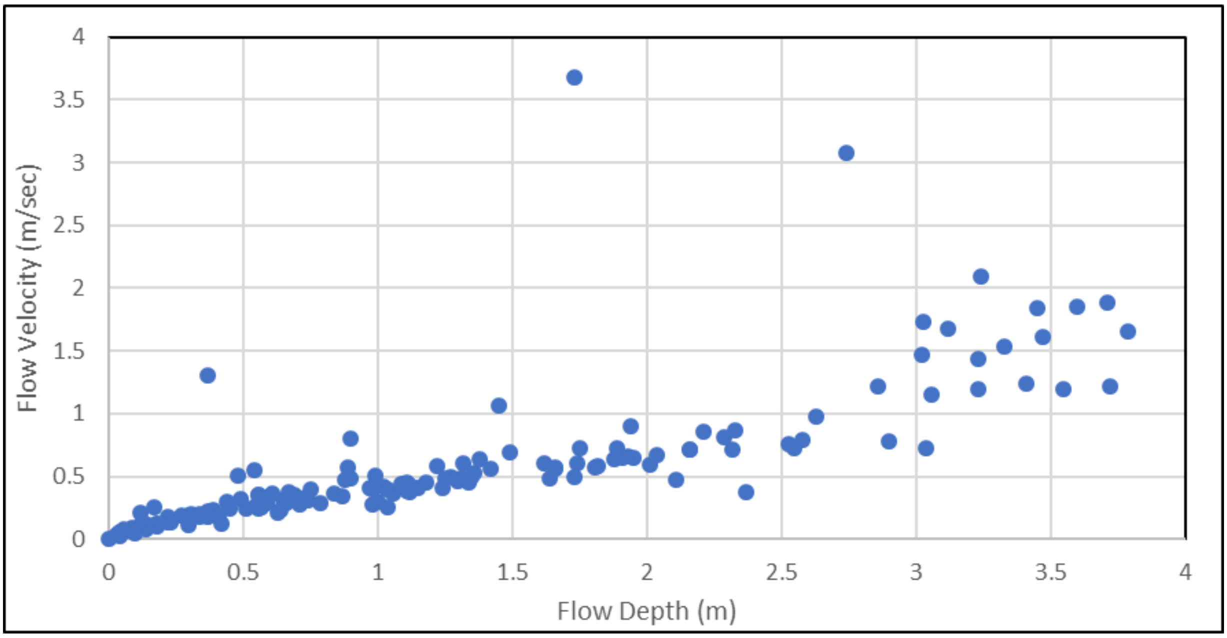
The extent of the 1:100 year (white) and 1:1000 year (blue) flood events are shown in Figure 5. Apart from the two Jones Creek crossings there are only minor projected incursions of the proposed disturbed area into the extreme flood zone. In these areas controls may be required to manage interactions and impacts as discussed in subsequent sections below.

Figure 5 – Peak Food Levels for 1:100 and 1:1000 Year Events



Model simulations of flow velocity for the extreme (1:1000 year ARI) peak flow case, are shown plotted against flow depth on Figure 6. Each point represents a portion of the flow section on each of the 19 cross sections included in the model.

Figure 6 – Jones Creek Model Simulated Flow Velocity



Channel flow velocity for the extreme peak level (1:1000 year ARI) is mostly in the range 1-2 m/sec in the main channel (5-10 metres wide), declining to about 0.5 m/sec immediately outside the main channel (flow depths < 2 metres). Flow velocity is less than 0.2 m/sec at the margins of the peak flood wave where water depth is less than 0.3 m.

Flow velocity outliers with channel velocity up to 3.6 m/sec occur on cross sections 7-9. These sections are located south of the six-mile pit, on a relatively steep and rocky reach where the flow rate increases by input from the western tributary.

2.8 Catchment Yield Model

Jones Creek is reported anecdotally to flow from moderate to high intensity rainfall of 25 mm or more. Methods described in Pilgrim (1987) for peak flow calculations indicate ongoing losses for relevant catchment type/regions are in the range 3-5 mm/h.

Automated rainfall, channel flow depth and flow velocity instrumentation was operated for a period at the Old Highway crossing located 3km upstream from the current Highway bridge. The site has a catchment area of 55 sq km. One substantial flow event was recorded in May 2005 as described above (Figure 2) . A total of 78 mm was recorded in the single pluviometer, between 00:50 on 4/5/05 and 13:10 on 6/5/05. The rainfall total included 5.2 mm over 5 hours prior to 9am on the 4/5/05, 1mm on the night of the 4th and 71.4 mm over 9 hours on the night of the 5th. The catchment was dry prior to these events with little rainfall over the preceding six months. Peak rainfall intensity and the corresponding average recurrence intervals for the event are as follows:

- 9.3 mm/hr over 6 hours, ARI = 1 in 12 years (critical duration for peak flow)
- 7.9 mm/hr over 9 hours, ARI = 1 in 15 years (duration of the event)
- 3.0 mm/hr over 24 hours, ARI = 1 in 6 years

Flow velocity and depth were recorded at the channel centre on the old highway causeway crossing. The observed flow depth and velocity data were used to calibrate a HEC-RAS model rating curve for the cross section. The model was also constrained by the hydraulic parameters developed for the HEC-RAS models used in the peak flow assessment (Flavell, 2011) . The monitoring data and rating curve allowed the following determinations:

- The 6.5 hour delay from peak rainfall intensity to peak flow rate is consistent with critical duration estimates from previous modelling results
- The peak flow rate for the critical duration 32 cumecs is consistent with peak flow modelling results for the 1 in 12 year ARI
- Calculated total discharge for the event of 700,000 kL amounts to a runoff coefficient of 18% for the 55 sq km catchment

Catchment yield was simulated using a simple one-day time-step model. The model uses a 100-year CLIGEN generated synthetic climate record (Landloch, 2007 – Development of Concave Waste Dump Batter Profiles – Mt Keith Mine). Daily rainfall total and event duration (hours) where used in the model. The model includes initial and ongoing rainfall losses and catchment storage depletion by evapotranspiration.

The adopted parameters were based on local observations, anecdotal evidence and regionally derived parameters. The initial loss term (catchment storage = 30mm) and catchment storage depletion by evaporation at 2mm/d imply the creek flows after 30 mm of intense rain and that the upper catchment dries out within 15 days. The ongoing loss rate (4 mm/hr) is based on ARR guidance of 3-5 mm/hour (Australian Rainfall and Runoff, Institution of Engineers Australia. 1997) and by calibration to the May 2005 event for which the model correctly produces total runoff volume. The adopted parameters are conservative with respect to yield estimation (conservatively low for catchment yield impacts assessment).

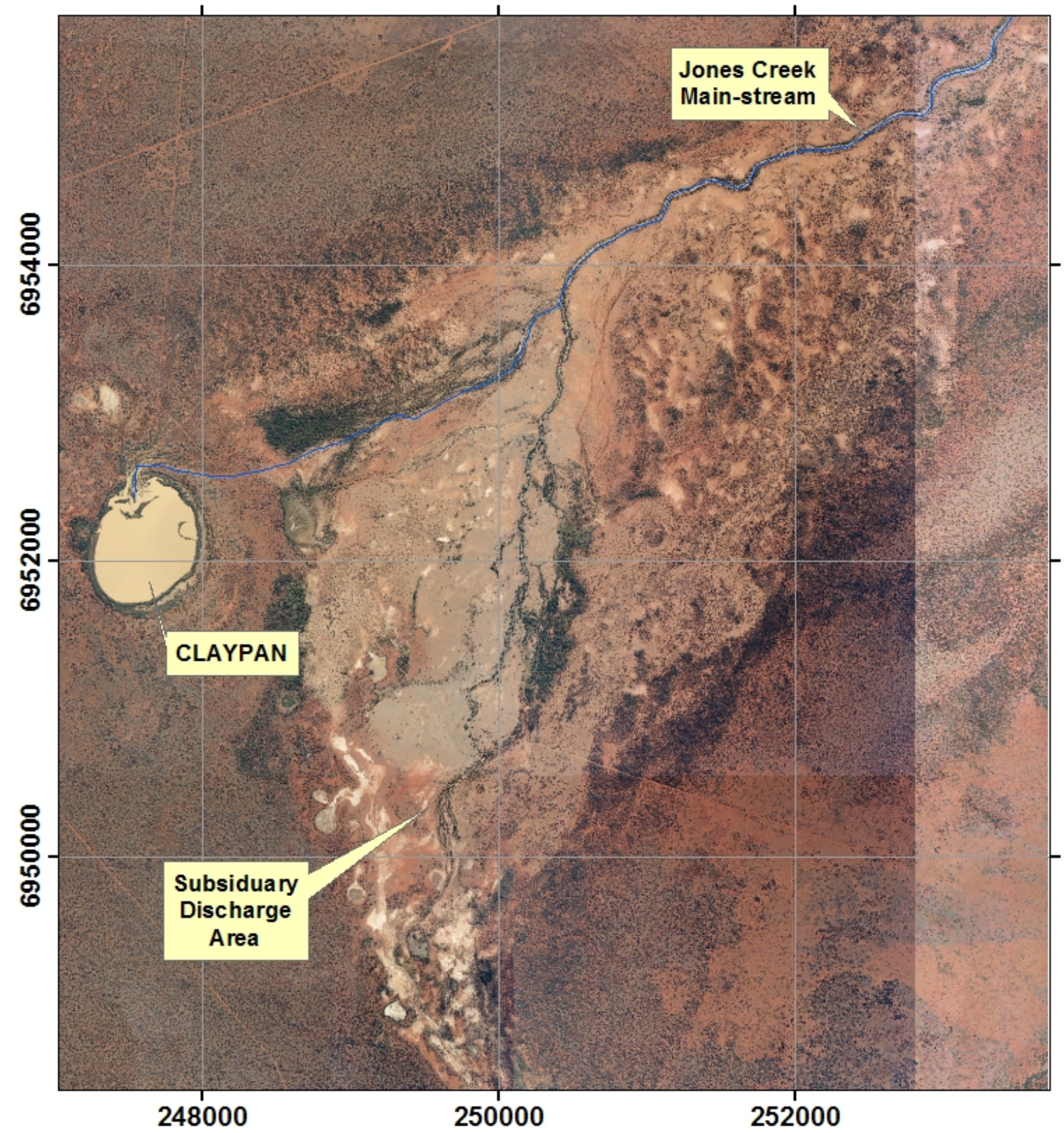
Modelling of the baseline 64.1 sq km catchment area produces a 100-year runoff record with the following characteristics:

• Flow days (whole creek to claypan)	81 per 100 years
• Flow events (ie separated by > 1 day)	76 per 100 years
• Years in which Claypan flooded	49 per 100 years
• Median annual yield in flow years	1168 ML/a
• Probability of fill to 1.25 m depth	36 % in any year
• Probability of fill to 0.5 m depth	43 % in any year

2.9 The Jones Creek Discharge Area and Terminal Claypan

The downstream Clay-pan is part of the broader flood out area which forms at the terminus of the Creek in the valley floor. Aerial photographs show that high flow distribution of the stream flow starts about 7 km upstream from the Clay-pan where there is overbank discharge to the south. The creek bifurcates 3 km upstream of the Clay-pan, with the subsidiary channel discharging to a heavily wooded area and collection of minor clay-pans (Figure 7).

Figure 7– Jones Creek discharge area and terminal Clay-pan



The partitioning of flows in the discharge area may be dynamic and subject to slight variations in sedimentation. However, the main Claypan elevation is about 2.5 m lower than the elevation in the subsidiary discharge area whilst both are at a downstream distance of about 3 km from the creek bifurcation. This indicates that, for low to moderate flow events the large majority of volume reports to the main Clay-pan, with southern discharge only at very high water levels and/or after the Clay-pan fills and water levels back up the main channel.

The Claypan holds water and sustains a fresh-brackish water ecosystem for several months after stream flow events which is unusual in the Northern Goldfields. The low water salinity and unusually long “hydro-period” defines its potential significance as a habitat or ecological water resource. The potential impacts of the development on the Clay-pan arise from the reduction in catchment area due to the excavation of pits (zero run-off) and construction of waste dumps (practically zero run-off). During extreme rainfall events the Clay-pan fills to overflowing negating any effect of reduced catchment yield. For the more common low –medium intensity rainfall/runoff events, the reduced catchment yield will reduce the volume in storage in the Clay-pan. It is for these smaller and more common (nominally 1 in 2 year to 1 in 5 year average recurrence interval events) that the potential impacts of catchment area reduction will be greatest.

After a flow event, storage in the Clay-pan is gradually depleted by evaporation and seepage so that any reduction in catchment yield will reduce the initial and average depth of water in the Clay-pan and therefore the duration (hydro-period) of inundation. Potential impacts on environmental receptors can be gauged in context of these hydrological impacts.

In May 2011 the volume in storage in the Claypan was investigated at a time of substantial inundation of vegetation at the margins after rains in February 2011. The Clay-pan floor was found to be very flat with most of the area at a water depth of 1.55 m and the 1 metre depth contour located within about 10 metres of the edge of vegetation around the edge. The total surface area in May 2011 was measured at 0.48 sq km and the volume in storage calculated 630,000 kL. The storage versus depth relationship is shown in Figure 8

Figure 8 – Claypan Storage Curve

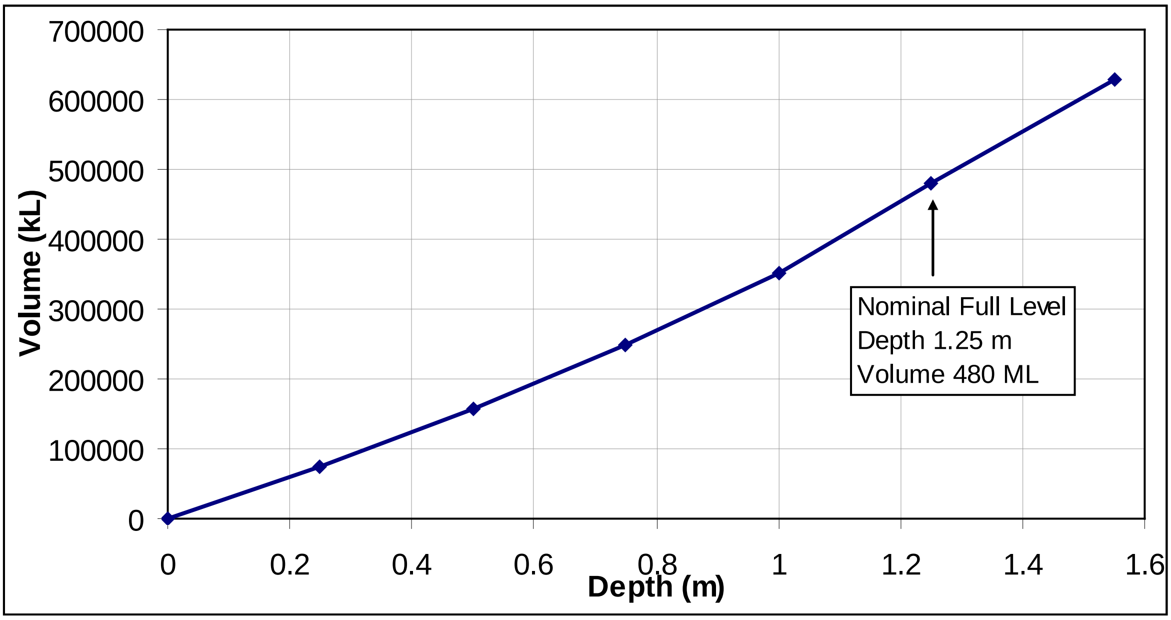
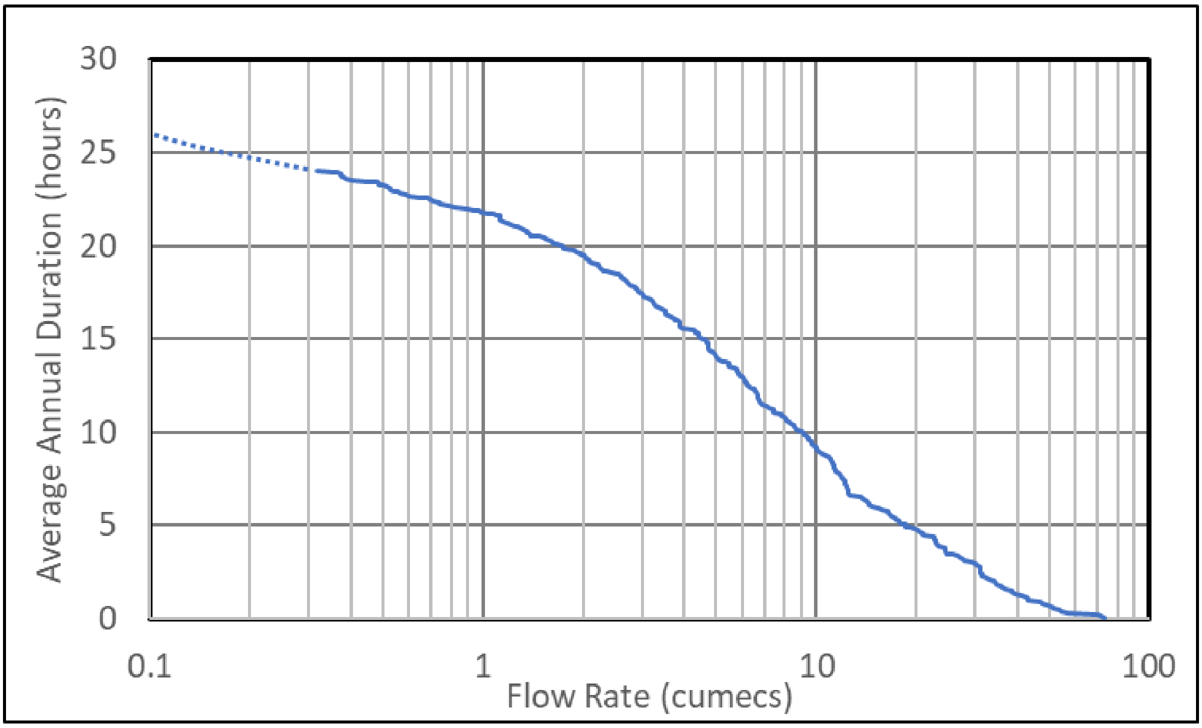


Figure 7 shows the Clay-pan from 2006 imagery with the Clay-pan “full” in the sense that water coverage is to limits of vegetation. The surface area is 0.42 sq. km. Using 2011 depth measurements the typical “full” depth is about 1.25 metres – ie full to limits of vegetation. At this level the volume in storage is about 480,000 kL.

2.10 The Upper Catchment Creek Hydrograph

The 100-year, one-day time step whole catchment yield model described above, was adjusted to provide an estimate of flow duration statistics in the upper catchment (disturbance area). Loss parameters were adjusted to reflect the upper catchment differences (catchment storage = 25 mm, storage depletion = 1 mm/d and ongoing loss 2 mm/hour) These parameters provide a conservative (high) estimate of flow duration as a basis for consideration of operational impacts assessment and to provide conservatism. The duration for individual flows was estimated on an hourly basis as the duration of the rainfall event plus 4 hours (when rainfall minus losses exceeds threshold for flow) which is based on observed hydrographs and unit hydrographs for similar “peaky” catchments. The model results are summarised in Figure 9 which shows the average duration (hours per year) for which a given flow rate is exceeded.

Figure 9 - Flow Rate Duration-Frequency in Jones Creek Upper Catchment



For example, a flow rate of 1 cumec would be exceeded for an average of 21 hours whilst a flow rate of 10 cumecs would be exceeded for an average of 9 hours per year. Other relevant statistics from the 100 year simulation are as follows:

Total number of flow events:	345
Average duration:	8 hours
Maximum duration:	18 hours
Maximum number of consecutive flow days:	4

The greater estimated frequency of flows (compared to the whole catchment model Section 2.9) reflects the following factors:

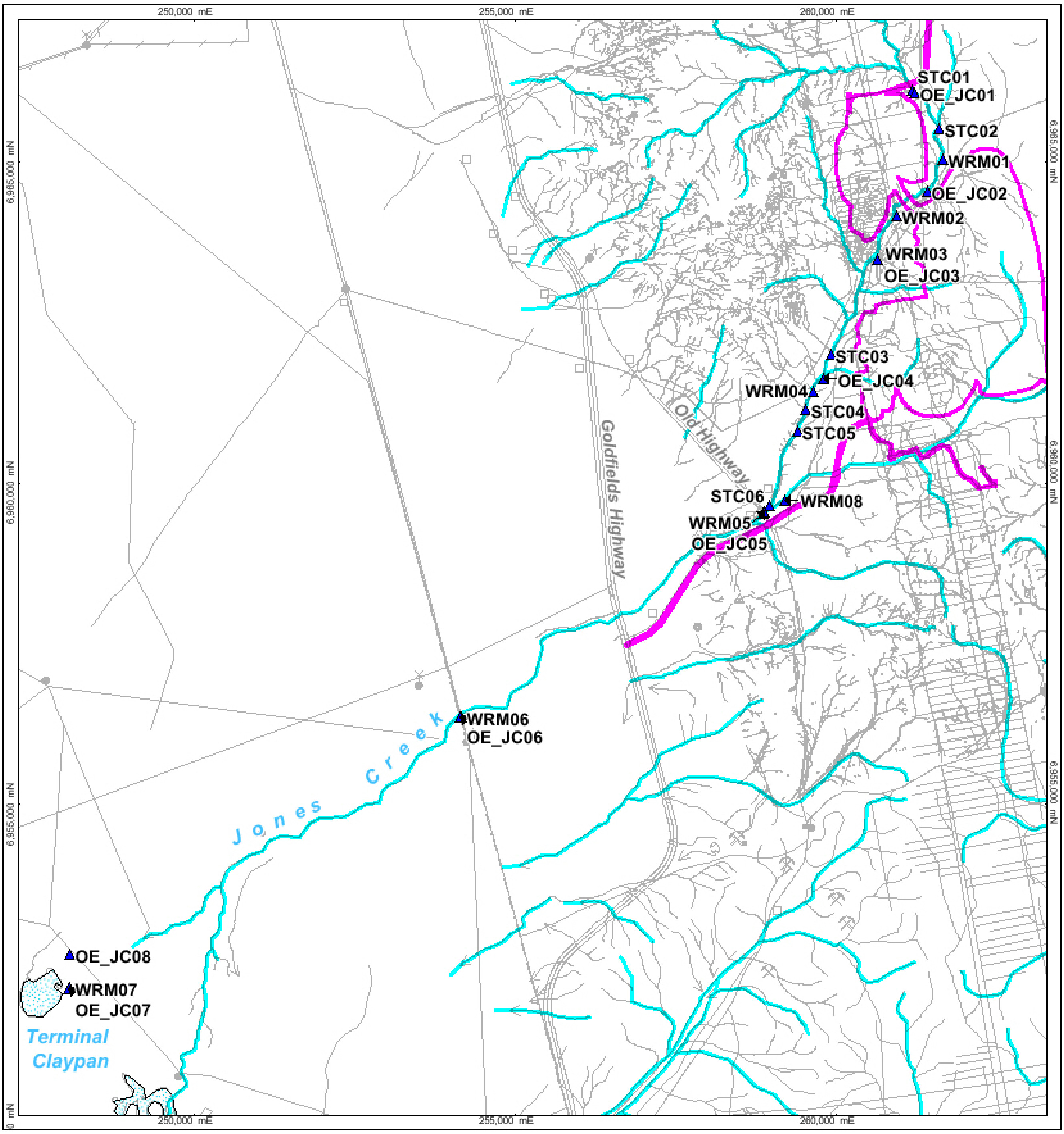
- Small flows may be limited to the upper catchment and not result in discharge to the Claypan
- The shorter hourly basis appropriate to the upper catchment captures more brief and smaller flows
- In context of impacts assessment, model loss parameters used in the yield simulation are conservatively high and in the flow duration simulation parameters are conservatively low

2.11 Baseline Water Quality

Flow modelling and monitoring have shown the “flashy” nature of stream flows in Jones Creek, with typical flow events having a duration measured in hours. The brief and infrequent flow events combined with the remote location have limited the opportunities for stormwater runoff sampling. These factors also confound the definition of baseline flow water quality with complexity relating the high variability of runoff patterns during particular flow events as well as the large range in duration and rainfall patterns between flow events.

Baseline surface water quality sampling has been from residual ponds after flow events and three programs have been undertaken. Locations are shown in Figure 10.

Figure 10 – Surface Water Sample Locations



Streamtec (1992) samples are locations STC01-06 on Figure 10. Sampling from stagnant pools one month after a flow event showed low salinity (40-121 mg/L) and low turbidity. Concentrations of most trace metals (cadmium, copper, nickel and lead) were mostly below detection levels, noting however the relatively high copper detection limit (20 µg/L). High iron and manganese concentrations were ascribed to natural leaching from sediments in anoxic conditions.

Further stream pool sampling was undertaken on 18-20 May 2005 (Wetland Research and Management, September 2005) after the flow event of 5 May described above. The sample locations are prefixed “WRM on Figure 10. Stream pool salinity was less than 100 mg/L. Nutrient levels were found to be elevated presumably due to pastoral impacts, with total nitrogen, (up to 2.4 mg/L), nitrate (up to 1.9 mg/L) and total phosphorus (up to 0.06 mg/L) exceeding ANZECC (2000) trigger levels. Arsenic, cadmium, chromium mercury, lead and selenium concentrations were at undetectable to extremely low levels. Copper, nickel and zinc were consistently detectable and copper concentrations at 3-7 µg/L, exceeded the ANZECC (2000) 80% protection trigger level of 2.5 µg/L.

Two rounds of water sampling were undertaken at six creek sites and 1 claypan site in early 2011, (Outback Ecology, 2011) about 6 and 8 weeks after creek flows. Locations are shown on Figure 10 with prefix "OE_". Results were consistent with the previous sampling. The creek samples were non-turbid and of less than 170 mg/L salinity. Nutrients were again found to be elevated with total nitrogen in the range 0.6-2.1 mg/L and total phosphorous up to 0.06 mg/L in stream sediments and up to 0.19 in the claypan samples. Of the broad range of trace analytes assessed, only aluminium, barium, copper iron and nickel were routinely detectable. Stream pool copper concentrations were up to 13 µg/L and 7 of 10 samples exceeded the ANZECC (2000) 80% protection trigger level of 2.5 µg/L. The claypan samples were fresh but turbid, one of two samples slightly exceeded the copper trigger level and both samples (1.13 and 1.63 mg/L), exceeded the 80% protection trigger value of 0.15 mg/L for aluminium.

2.12 Baseline Stream Sediment Characteristics

Due to the complexity of factors impacting on stream water quality, additional control on surface water impacts assessment can be achieved by reference to baseline stream sediment characteristics, which can potentially provide a more robust indicator of impacts.

Descriptive and quantitative assessment of the stream sediment at four sample reach sites and at the terminal clay pan was undertaken by SKM (May 2005) including:

- General description and photographic records
- Survey and description of the channel profile
- Sampling for grain size analysis and chemical composition

Particle size distribution (PSD) curves for sediments from each of the four creek transects were similar. Three samples from within the main channel classed as medium-grained sand with more than 85% sand sized particles and up to 1.2% clay sized particles. The two claypan PSD samples classed as very fine silt with 17-25% clay content.

Chemical analysis of the sub-106 micron fraction (As, Cd, Cr, Cu, Hg, Ni, Pb, Zn) showed total metals concentrations to be generally well below the sediment quality guideline low trigger value for aquatic ecosystems (ANZECC, 2000). Nickel and chromium concentrations were close to the lower trigger value and substantially below the upper trigger value, at typical concentrations for soils associated with un-mineralised greenstone belt rocks of the WA Goldfields.

Sediment samples taken in 2011 were from overbank positions at the locations shown on Figure 10 (Outback Ecology, 2011) and were not subject to size-fractionation. The elemental composition results were similar to the 2005 results with most of the potentially soluble and toxicologically relevant metals being at very low concentrations compared to ANZECC trigger levels except chromium and nickel. Chromium concentrations ranged from 26-210 mg/kg, mostly between the ANZECC low and high trigger values (80 and 370 mg/kg) while nickel concentrations were in the range 4-36 mg/kg, generally lower than the 2005 samples and mostly below the low and high ANZECC trigger values (21 and 52 mg/kg).

3. BASELINE HYDROGEOLOGY – REGIONAL SETTING

3.1 Background

The hydrogeological impact assessment is well constrained by experience at nearby Mt Keith and Leinster, where operating and closed mines are located in similar up-lying strike ridge country with similar host/ore rock sequences. In common, groundwater occurrence is enhanced by the weathering of the dunite (adcumulate) ultramafic ore with partial silica replacement in the regolith zone, creating a porous vuggy material, typically at depths of 40-60 metres. The aquifers are of limited lateral and vertical extent and surrounding rocks are of very low permeability. The typical dewatering history for these mines involves a higher rate of pumping to deplete the localised “reservoir” which then stabilising at low ongoing rates. Drawdown extent is localised to less than 1 km from the pit perimeter due to the absence of extensive interconnected aquifers.

Due to the high degree of geological, geographic and mine plan similarity between the satellite pits and the Mt Keith pit (and to a lesser degree Leinster pits), a comparative discussion of the specific discussion of hydrogeology and dewatering is relevant. Particular differences between Mt Keith/NDS1 and Leinster ore-bodies include:

- Leinster ore-bodies have areas of massive nickel sulphide ore in additional to the lower grade disseminated sulphide ore which occurs at Mt Keith/NDS1.
- Late phase talc alteration is more intense at the northern sites than at Leinster

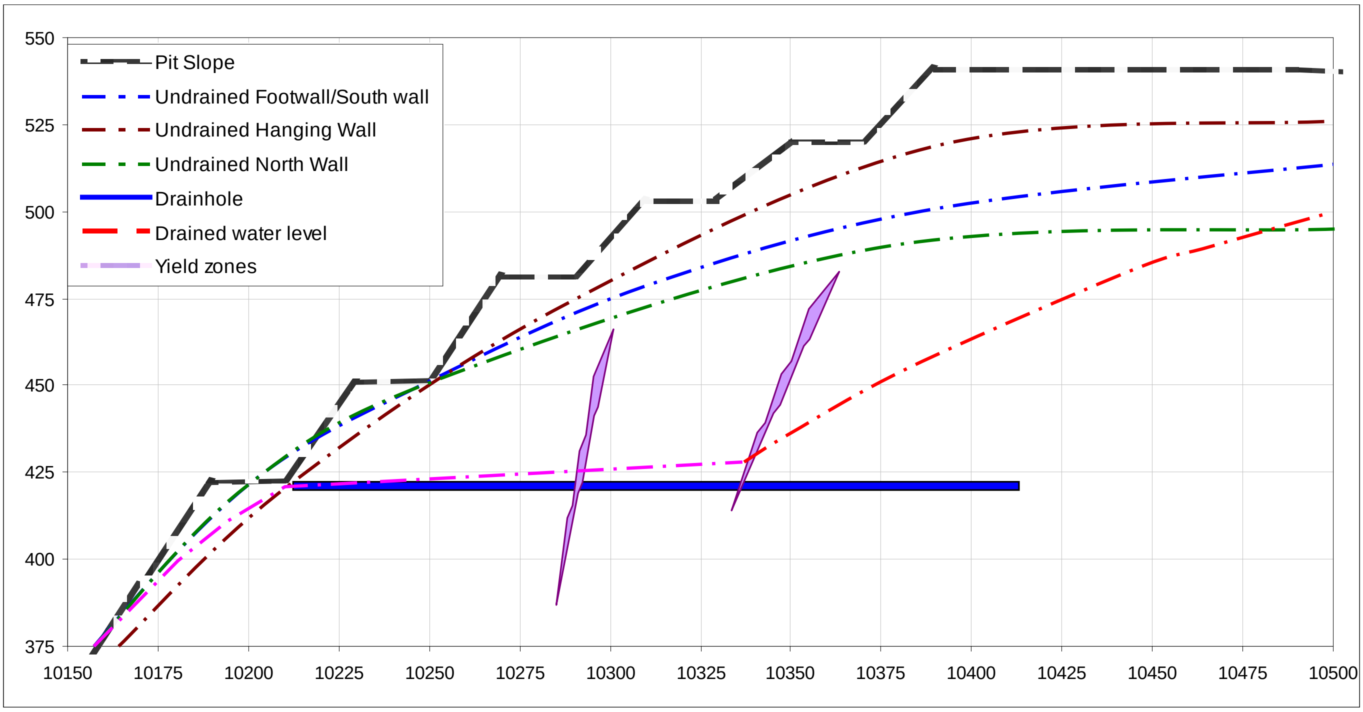
3.2 Mt Keith Pit

After higher rates of pumping in the first two years of the mine operation (1994-1996), the groundwater inflow rate has been about 12 L/sec. Total groundwater inflow has not changed substantially with various staged increases in the pit size. Stormwater pumpage from the pit catchment is additional with significant runoff occurring during months with a rainfall total of greater than 15 mm.

The hydrogeology is very similar to that of the proposed development. The Archean ultramafic unit and flanking volcanics and volcaniclastic sediments into which the pit slopes are mined have practically zero primary porosity or permeability. Groundwater occurrence is limited to secondary features including the weathered zone and structural/lithological discontinuities. Weathered zone groundwater occurs mainly in the saprock interface between weathered and fresh rock. The saprock zone (and overlying saprolite aquitard) can be considered a very low permeability, relatively high storativity unconfined aquifer which is more or less continuous around the pit, with a nominal thickness of about 20 m and typical depth range of between 30 and 70 m BGL.

Natural groundwater levels were at about 520-525m AHD or about 20 metres BGL Piezometers located within or near the pit show the extreme localization of drawdown effects from pit dewatering. Beyond the pit crests on the east and west sides, drawdown is negligible from a geotechnical perspective (less than 5 metres). Drawdown of up to 5-10 m is more extensive along strike to the north and south – up to several hundred metres. The maximum depth to water is about 50 metres in the upper pit slopes. The water table and the pit slopes converge in the lower pit slopes. The configuration of the water table near the pit slopes is shown in Figure 11. The limited radial extent of drawdown induced by dewatering of the Mt Keith pit has led to the use of horizontal drain holes to depressurise the rock mass within the pit crest limits.

Figure 11 –Water Level Profiles in the Mt Keith Pit Slopes



The mineralogy of the low grade nickel sulphide ore delivered to the MKO concentrator is described by Grguric, (2003). The ultramafic ore comprises mainly high magnesium olivine parent rock type, comprising magnesium silicate hydroxides, hydroxides, carbonates and hydrotalcite. Sulphides are present at relatively low concentrations.

For the range of ore types, the neutralisation capacity and long term trace element solubility effects of sulphuric acid dosing on tailings were evaluated in detail by Graeme Campbell Associates (GCA, May 2001). Acid consumption tests demonstrated very high residual acid neutralising capacity (ANC) being in the range 580-610 kg H2SO4 /tonne. Acid addition rates up to 25-30kg H2SO4/tonne to ground ore was found to result in minor depletion of the reserves of alkalinity and negligible changes to minor ion chemistry. It was concluded that:

“when subjected to alternating cycles of wetting and drying, alkaline and low salinity conditions prevail, due to buffering by gangue phases the solubility of minor-elements during weathering is very low”

The regional study of mine voids undertaken by Waters and Rivers Commission (Johnson and Wright, 2003) included a case study of the Mt Keith pit. The hydrological isolation of the pit void was noted. The limited quantities of pyritic chert in the walls of the ultimate pit :

“*suggests there will be no problems with acid mine drainage*”.

It was concluded that the pit lake will become more saline over time but will not impact any regional groundwater resource.

3.3 Leinster Harmony and Eleven Mile Pit Lakes

Dewatering at the Leinster Nickel Operation’s Harmony pit was stopped in mid-2005 and pit flooding recommenced soon after. The recovery of water level in the pit has been monitored. Water level recovery was initially rapid due to low evaporation rates from the small deep pit lake. Water level recovery has since slowed as the pit lake area and surface evaporation has increased. The numerical model of the pit lake water level has proven accurate in describing the water level recovery. This shows the result which is typical for regional pits located in up-lying country, that there is no potential for these pits to fill to a level at which water can impact either surface or groundwater.

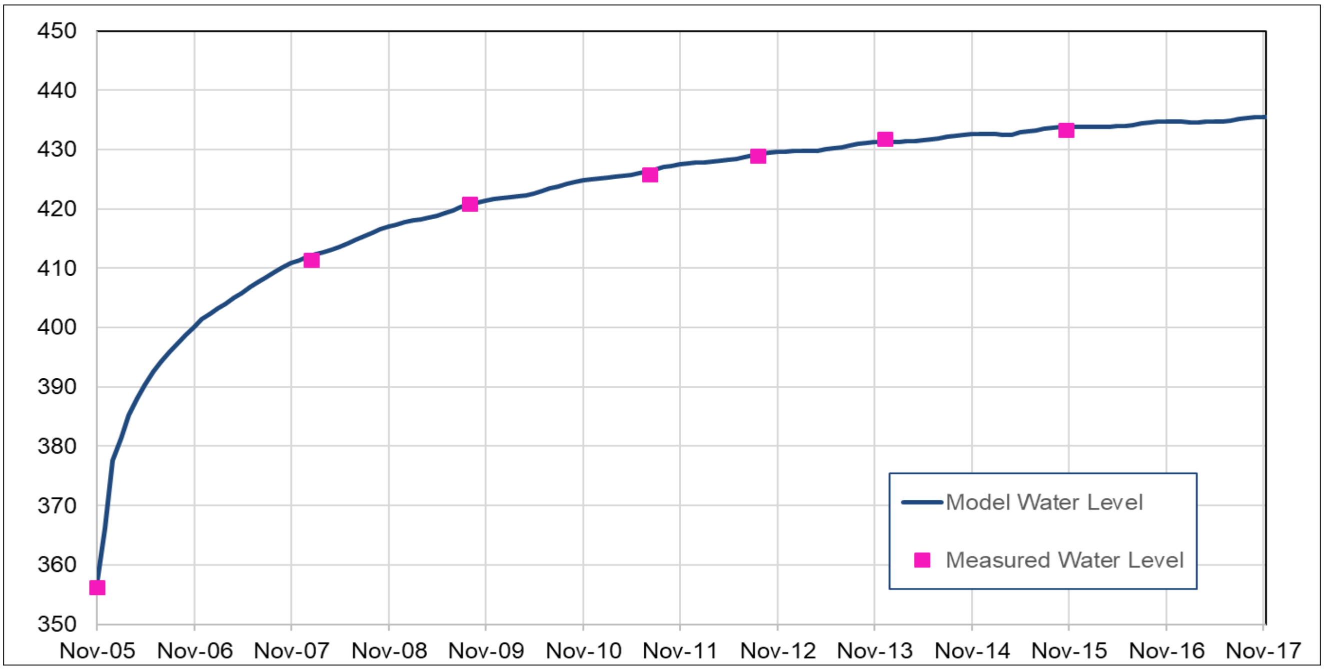
The pit lake was sampled in October 2009, four years after closure. Ten surface samples showed consistent results. The difference between the chemistry of groundwater pumped at the late stages of mining (2004) and the 2009 pit lake water are summarised below:

- Salinity – 2009 pit lake salinity was at 6000 mg/L about double the groundwater salinity
- pH – increased from 7.6 to 8.1
- Nickel - increased from 3 to 7 mg/L
- Boron - increased slightly from 1 to 1.3 mg/L
- Cobalt - increased slightly to 0.025 mg/L
- Iron – increased slightly to 0.03 mg/L
- Zinc – increase slightly to 0.05 mg/L
- Arsenic, cadmium, chromium, lead – remaining at very low concentrations

Depth profiles of the pit lake salinity showed that no stratification had developed in the pit lake

Dewatering at the Eleven Mile Well pit was stopped in early 2005 and pit flooding recommenced soon after. Water level recovery at the Eleven Mile Well Pit has been more rapid than at Harmony due to the smaller volume of the pit. The monitoring hydrograph demonstrates a similar trend to that at the Harmony pit - a continuously diminishing rate of water level recovery and gradual stabilisation of water levels. As for the Harmony Pit the water level model has proven accurate in simulating the rise of pit water levels (Figure 12).

Figure 12 - Post-Closure Water Level Recovery in the 11 Mile Well Pit



The pit lake water quality was sampled in 2007 and 2009. Salinity increased but there was little change in the trace element chemistry of the pit lake water over that period. The difference between the chemistry of groundwater pumped at the late stages of mining and the 2009 pit lake water are listed below:

- Salinity – increased from 2150 to 3200 mg/L
- pH – increased from 7.8 to 8.1
- Nickel - increased from less than 0.005 mg/L to 0.7 mg/L
- Boron – stable at about 1.3 mg/L
- Arsenic, cadmium, chromium, cobalt, lead, selenium, zinc – remaining at very low concentrations

Depth profiles of the pit lake salinity in 2007 and 2009 showed that no stratification had developed in the pit lake.

Groundwater chemistry and its evolution in the Leinster pit lakes is unremarkable and reflects the chemistry of the inflowing groundwater, with some solute enrichment by evaporation. Acidity has not built up in the pits and concentrations of most metals remain at very low levels, with some enrichment associated with evaporative concentration. Wall rock impacts on pit lake chemistry are limited to some additional alkalinity and possibly minor additional dissolved nickel. Wall rock impacts are expected to decline as the water level rises above the areas of nickel sulphides exposed in the base of the pit. Dissolved nickel concentrations will continue to rise due to evaporative concentration and ongoing release, but at a diminishing rate of increase.

4. Mt Keith Satellite Pits Project Hydrogeological Investigations

4.1 Background

The hydrogeology of the area has been evaluated in several phases commencing with the Dominion Mining Feasibility Study (1990). The latest hydrogeological drilling was undertaken in February 2017 and included 34 new monitor bores and the redevelopment (and re-naming) of 19 historical bores – these 53 holes are prefixed SMW or GOL.

Figure 14 shows the locations of all hydrogeological drill sites and the currently proposed northern SMW and southern Goliath pit outlines. Drill-hole details are summarised in Appendix 1. Key references include:

- Coffey Partners, 1990
- Coffey Partners, 1991
- Woodward Clyde,1995
- Hydro-Resources, 1997
- MWES, 2017

4.2 Geology

The geology is typical of Archaean greenstone belts of the Yilgarn Craton comprising a faulted and folded NNW-striking, near-vertical layered sequence of high grade metamorphic sediments and volcanics and early felsic intrusives (Figure 16). Ultramafics are mostly peridotite-rich (high aluminum, fixed silica and low porosity). Nickel sulphide mineralisation is associated with lozenges of adcumulate ultramafic or dunite (olivine rich, low aluminium, silica leaching and high porosity upon weathering). The major host rock is mapped as porphyritic felsic and includes dacite and andesite. The Six Mile Well pit geological setting is more complex than the Goliath Pit, with a cross-cutting fault truncating the southwest side of the host ultramafic and layers of metasediments and basalt in the host rock sequence.

There is little alluvial or soil cover. The regolith profile is relatively shallow being truncated by surface erosion. Thinner weathering occurs over the felsic-intermediate rock types with maximum thickness (highly weathered materials up to 60 metres thick) over the dunite bodies where the profile comprises:

- Oxide ferruginous – clay altered, local hard pan and nodular iron
- Oxide silica-carbonate – complete oxidation, serpentinite, irregular silicification and carbonate alteration
- Supergene – partial oxidation towards top, serpentine bleached and porous

At SMW, the dunite pod has dimensions of 1500 x 400 m and is nearly vertical. The upper ferruginous oxide is up to 10 m thick. The oxide zone rich in secondary silica-carbonate is patchy depending on original parent rock type as above. The base of Supergene (oxide and transitional material) is at a depth of 90 m to 170 m (360-440 m RL).

The Goliath ultramafic package is smaller, and wedge shaped with the footwall sub-vertical and hanging wall dipping to the west. There is a very thin regolith transition zone (oxide-sulphide) with base of oxidation at 30-70 metres depth.

4.3 Environmental Geochemistry

Investigations into the geochemical characteristics of host rocks and low grade nickel ore were reported by Graeme Campbell and Associates (2005). The criteria for potentially acid forming material were established based on:

- Sulphide-S: sulphide sulphur content
- NAPP: net acid producing potential
- ANC: acid neutralising capacity
- MPA: maximum potential acidity (calculated by assuming complete oxidation of sulphide-S)
- NAPP: net acid producing potential (calculated as MPA-ANC)

The criteria for potentially acid forming (PAF) classification being either:

- Sulphide-S ≥ 0.3 %, and any positive-NAPP value
- Sulphide-S ≥ 0.3 %, and a negative-NAPP value with ANC/MPA < 2.0

In general, it was concluded that:

" waste rocks have meagre abundances of sulphide-minerals dispersed throughout a groundmass with moderate-high capacity to consume acid… accordingly the waste bedrocks are classified as non-acid forming".

A notable exception was identified as the volcanic sediments unit which forms a portion of the Chert/Shale (Figure 16) . Samples of the volcanic sediment unit contained total-S in the range 2 - 16%, and despite high ANC the material was classified as potentially acid forming (PAF). The sulphidic material occurs in thin bands and very low volumes in both pits. The situation is similar to the Mt Keith where large scale mining and co-disposal with high ANC material limit the potential for acid leachate at any significant scale. The slight residual risk can be controlled by using routine operating procedures from Mt Keith, which ensure that high S material is identified during drill and blast cycles and then managed during excavation and WRD emplacement.

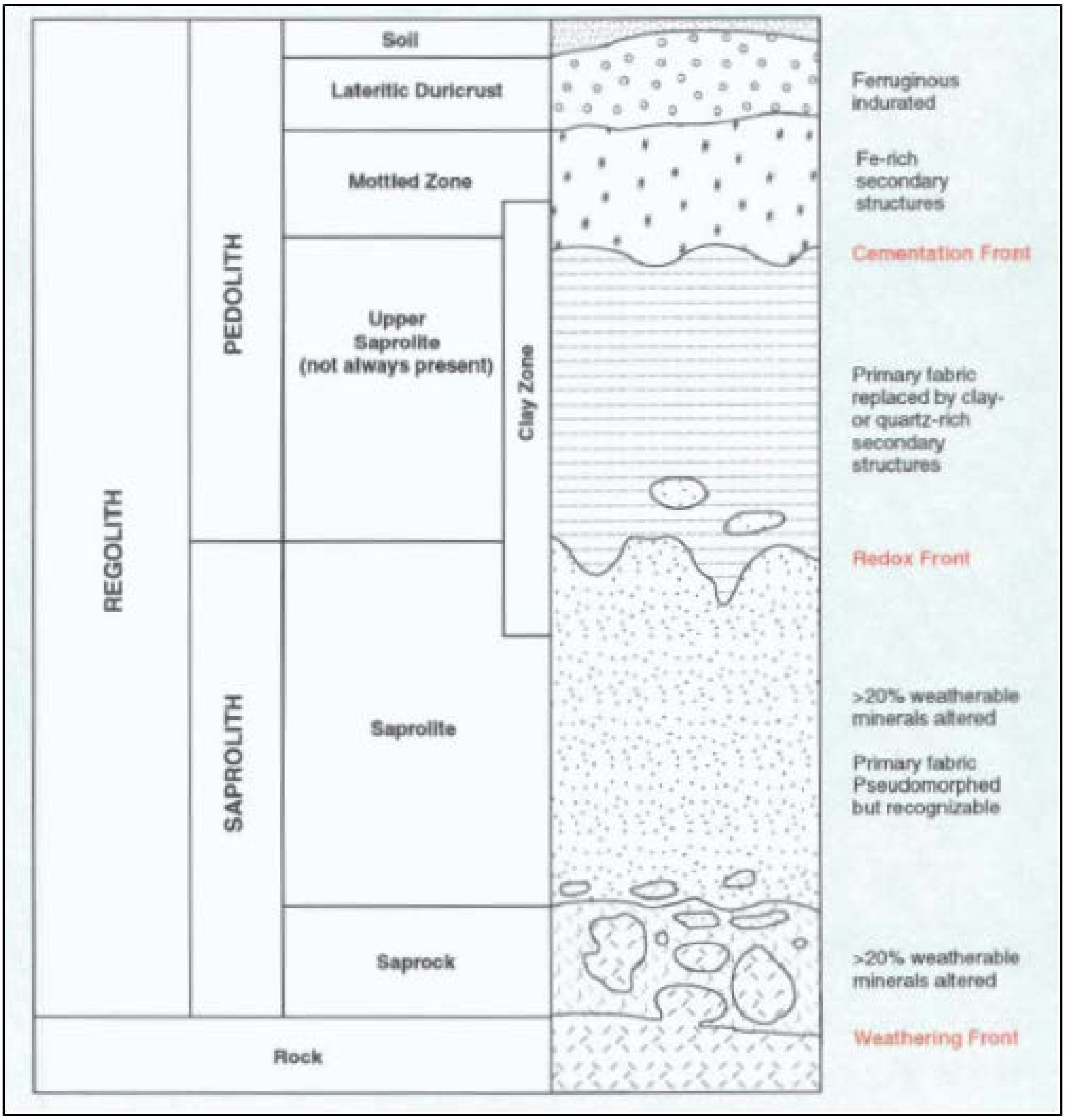
Note that, subsequent to the geochemical assessment (part of the 2005 impacts assessment), Nickel West have developed improved processing of high talc content ores. This change has resulted in more low grade material being classified as ore, resulting in a further reduction in the mineralisation of material emplaced in the WRD.

In addition to site specific investigations, the project is well informed on environmental geochemistry by conditions at Mt Keith, where the same geological formations have very similar lithology, mineralogy and geochemistry. The potential for leaching of deleterious trace elements from un-oxidised orebody materials at Mt Keith is evaluated in detail in GCA (2001) which shows that aggressive acid leaching of ore materials does not generate high metals concentrations. This is confirmed by the absence of anomalous trace elements concentrations in tailings liquor and groundwater seepage from the tailings facility. Mt Keith host rocks are poorly to un-mineralised, inert, high carbonate volcanic rocks with very much lower potential to generate leachate than ore rocks. Waste materials from both the weathered and primary zones were analysed by GCA (2000), confirming their non-acid forming status, together with low concentrations of environmentally significant elements.

Mt Keith experience of waste rock management confirms site specific assessment that the large majority of un-weathered waste rock is "competent" in the sense the waste dumps formed form this material are mechanically and geochemically stable and do not present a particular risk to surface or groundwater.

The regolith or weathering profile imposes approximately horizontal layered variability which presents particular risks and opportunities for environmental management. The general profile is shown in Figure 13.

Figure 13 – Regolith Profile



Upper cemented materials are mined as caprock which is a suitable capping material, Clayey saprolite has a high water storage capacity suitable for revegetation, but can be prone to dis-aggregation and erosion and hence must be excluded from long term outer dump faces. Lower saprolite and saprock are transitional in properties between saprolite and parent rock.

Figure 14 – Bore Locations

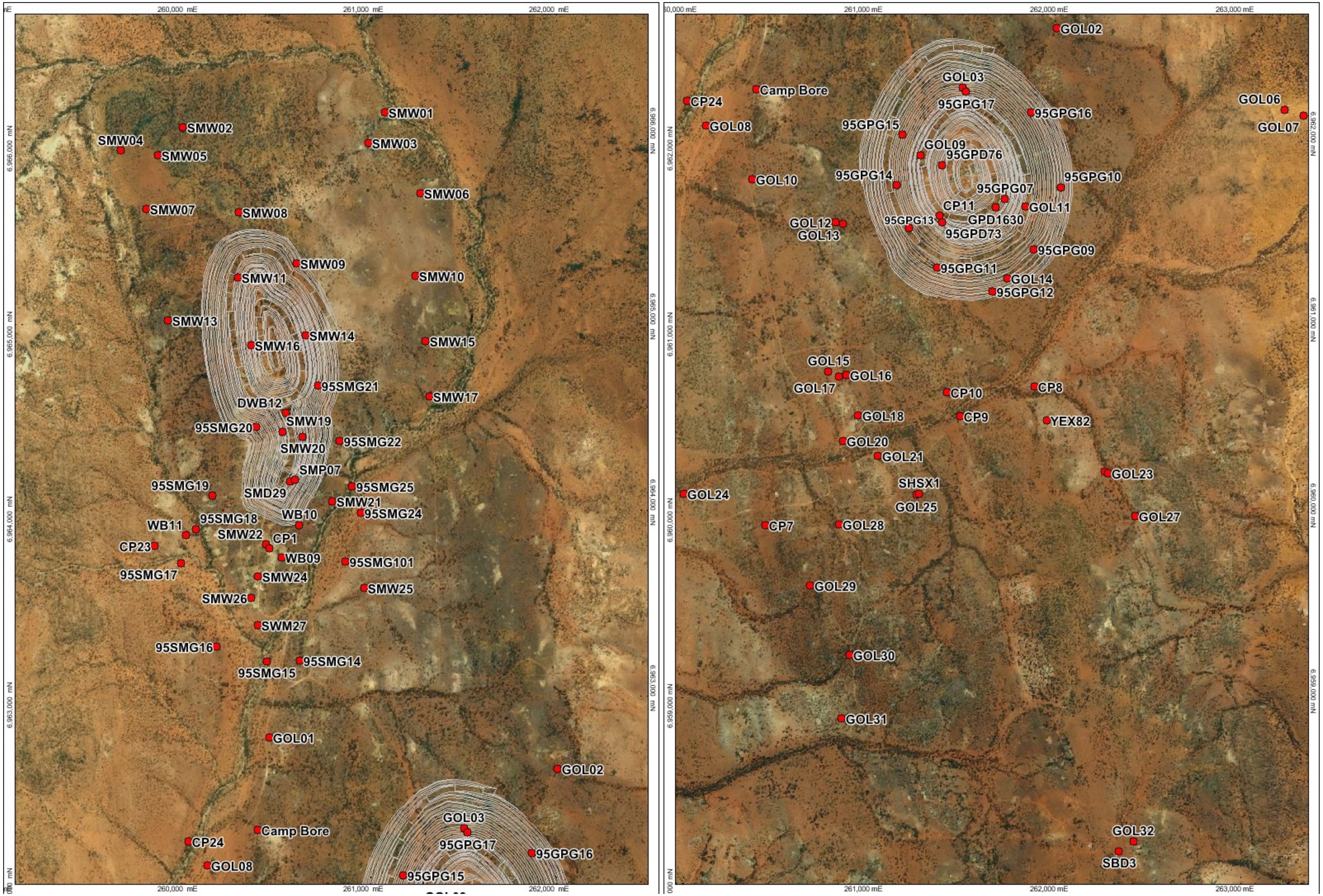


Figure 15 – Water Level (metres AHD)

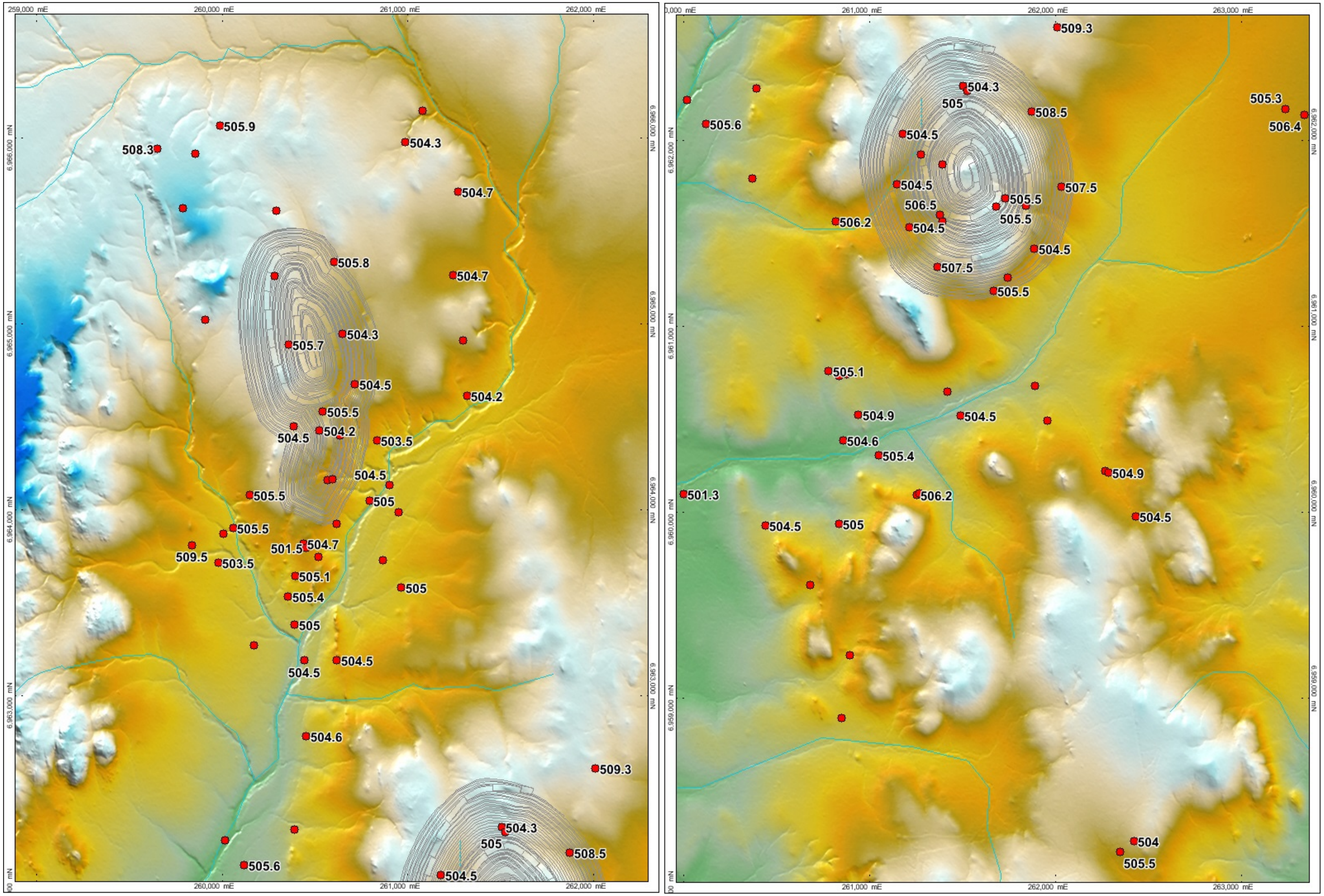


Figure 16 – Groundwater Yield (L/sec)

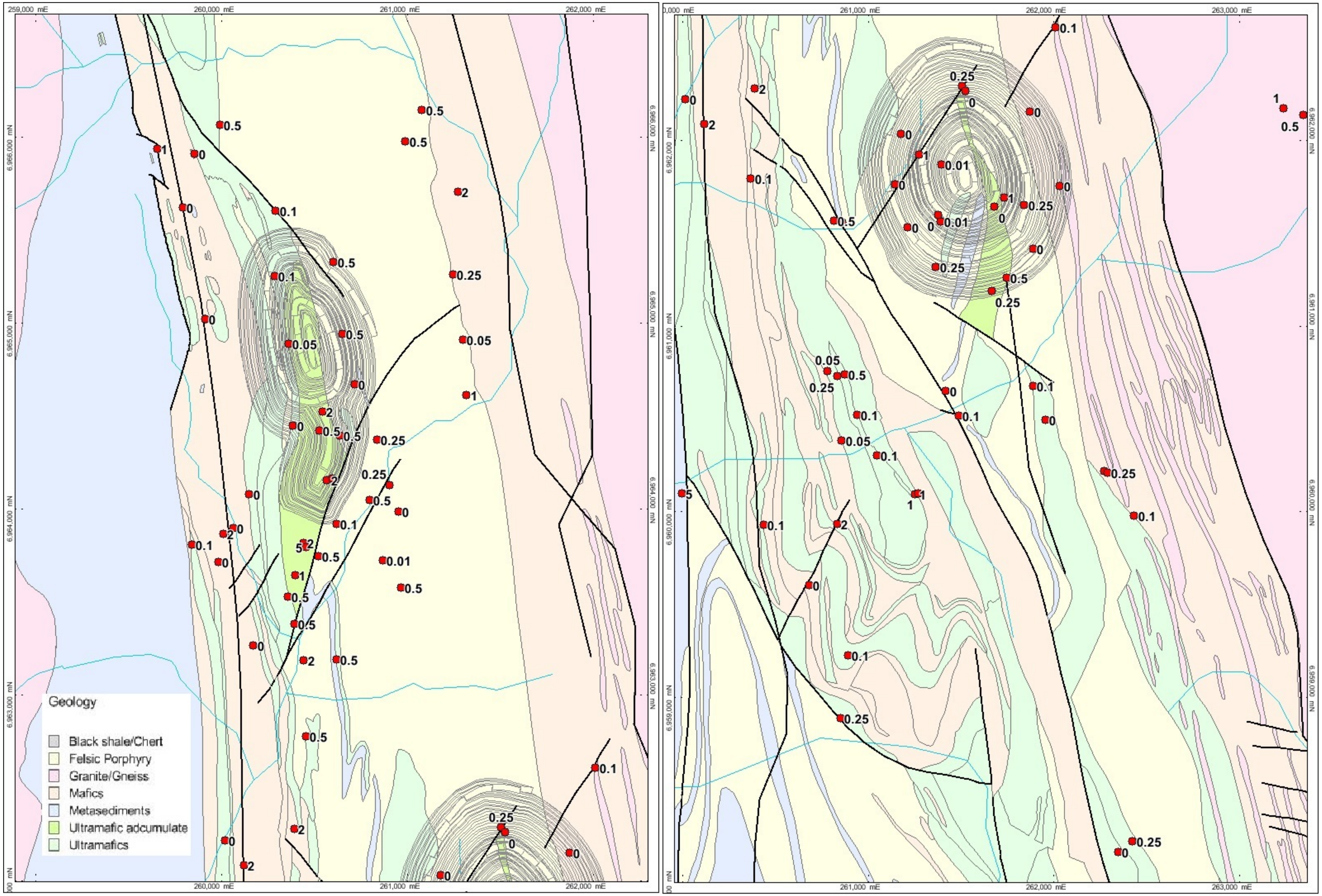


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Figure 17 – Groundwater Salinity (EC uS/cm)

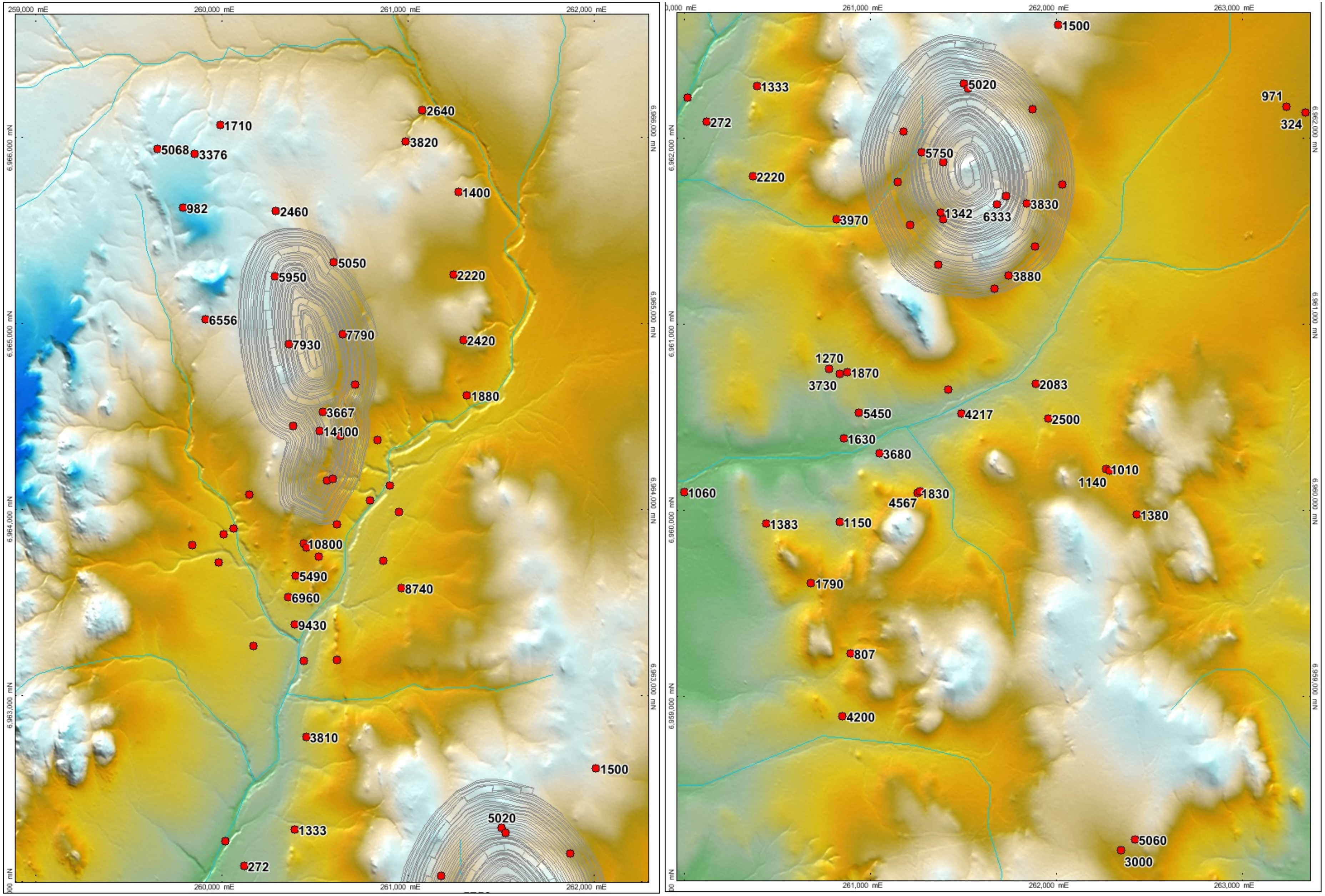
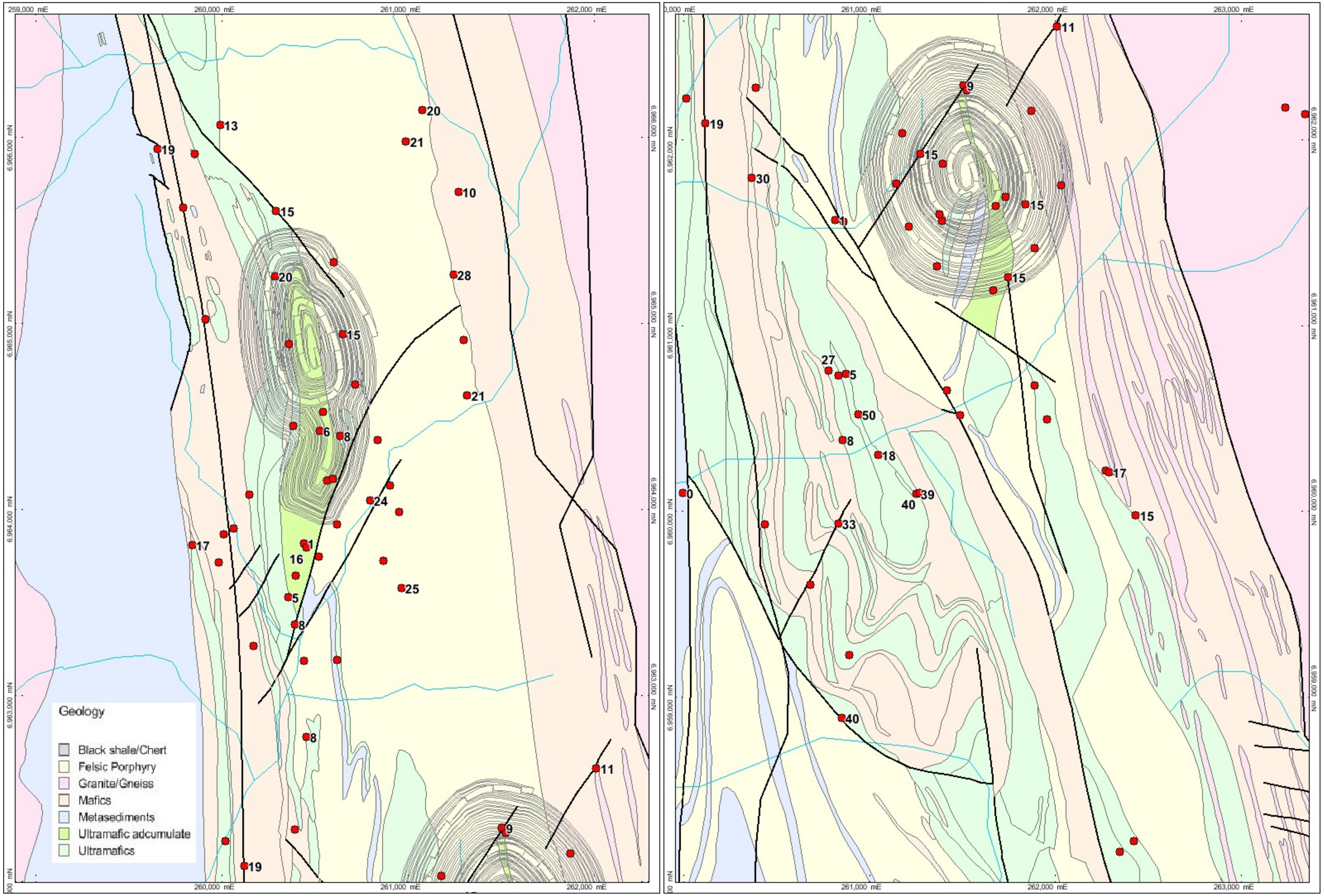


Figure 18 – Aquifer Submergence (depth from water table to aquifer top, metres)



4.4 Groundwater Occurrence

Groundwater is relatively scarce in the local region. There is no laterally continuous regolith horizon aquifer due to elevation, depth to water table and erosional denudation. Most of the bedrock lithology's have practically no primary or secondary porosity and drilling across a majority of the area generates no groundwater yield.

The yield of hydrogeological drill-holes and bores is shown in Figure 16. Note that these are not representative of the typical rockmass conditions across the area, rather the results are strongly biased toward localised higher yielding zones due to targeting of features such as faults, lineaments and lithological contacts. From the 95 drill-holes listed in Appendix 1, 24 recorded no groundwater yield, the median yield was 0.25 L/sec and the average 0.5 L/sec. Reviewing the distribution of drilling and the lithology from which yields were obtained (Appendix 1) the following patterns are evident:

- To the south and west of Goliath Pit, yields were variable and obtained mainly from fresh ultramafics
- In and near Goliath Pit yields were generally very low
- In and near SMW Pit moderate yields were obtained from saprock ultramafic
- In the SMW Pit (west) hanging wall basalt and metasediments there was very low yield
- Minor yields were obtained from structural targets near the felsic/basalt contact east of the SMW Pit

At the site-wide scale, the oxide zone over the dunite ultramafic pod at SMW constitutes the most extensive aquifer, where high permeability and porosity occurs in the oxide silica-carbonate zone which extends to about 50 metres BGL. On a regional scale this is a small and localised "caprock aquifer". Permeability and porosity diminishes with depth and degree of weathering below the main aquifer zone. Low to moderate permeability may also occur to a depth of 60 metres and in highly weathered materials formed in other ultramafic lithology's. No extensive aquifer has been found associated with the Goliath ore-body.

Other groundwater occurrences are isolated fractured rock aquifers occurring at structurally controlled locations within the pit areas and beyond. The fracture zone permeability may range up to moderate- high values, however the fault zones have low porosity and limited lateral extent, which means that storativity is 2 or more orders of magnitude lower than that held on the main SMW regolith aquifer.

4.5 Water levels and Aquifer Submergence

Water levels across the project area are shown on Figure 15. The water levels are based on measurements taken at the end of the 2017 drill campaign. At sites where no value is posted water levels remained depressed for months after drilling and development - an indication of very low rockmass permeability at that site.

Water levels are relatively flat across the area, particularly on the ultramafic bodies with many values in the range 504-505 m AHD. There is a slight hydraulic gradient south down Jones Creek away from the SMW pit.

Depth to the water table varies from a minimum of about 15 metres near the southwest corner of the mapped area. In the bed of Jones Creek through the SMW pit, the depth to water is at least 16-17 metres. Outside of the creek beds the depth to the water table is typically in the range 25-35 metres. At such depths, it is considered that groundwater does not sustain surface vegetation.

Water level measurements from recent investigations were consistent with the earlier measurements to within 0.5 metres. Due to the depth to water table and limited recharge potential, natural groundwater level fluctuations are likely to be minor and not relevant to the dewatering and impact assessment.

The drilling records defined the top of the zone of groundwater yield in each bore (Appendix 1). This can be termed "top of aquifer", although the very low yields encountered in many bores do not warrant classification as an aquifer. The vertical offset between the water level and the "aquifer top" at each site is posted on Figure 18 as the "aquifer submergence" which can also be termed "aquifer confinement". This represents the thickness of saturated low permeability confining materials overlying the aquifer. Aquifer confinement is important in determining drawdown response to pumping (dewatering). If the particular "aquifer" zone is also a biological habitat for stygofauna then the submergence or confinement has particular importance in determining the sensitivity to drawdown. For example, an aquifer zone/habitat with a submergence of 20 metres (confined aquifer) would be insensitive to drawdown of up to 20 metres, whereas a habitat zone with zero submergence (unconfined or water table aquifer) is immediately impacted (partially depleted) by any drawdown.

At most bores the groundwater yield was obtained from a well-confined zone with submergence typically in the range 15-40 metres. The SMW dunite ultramafic is unconfined or semi-confined with submergence typically less than 10 metres.

4.6 Groundwater Quality

Baseline groundwater quality samples were taken at the end of the development of each of the bores in the 2017 drill program for a total of 50 samples. The salinity (measured as electrical conductivity or EC in units of micro-Siemens/cm) of recent and historical samples is posted on Figure 17.

The majority of sites show brackish groundwater with EC in the range 1000-5000 uS/cm and a notably high degree of local variability of groundwater salinity. Bores intersecting the SMW dunite ultramafic aquifer have higher salinity - mostly in the range 5000-10000 uS/cm.

Comprehensive analytical results are presented in Appendix 2. The following notes apply:

- Samples from sites GOL06, SMW04, SMW05, SMW13 showed unrealistically low EC. These sites had very low yield and the samples are supposed to be affected by imported drilling water and hence unrepresentative (field EC values are shown on Figure 17
- Groundwater is neutral to slightly alkaline and of sodium chloride type
- Concentrations of dissolved cadmium, chromium, lead, selenium and zinc were mostly below detection limits
- Concentrations of most other trace components were also at very low levels
- Elevated boron concentrations are widespread and particularly associated with the SMW ultramafic at up to 4.7 mg/L
- Nickel (and to a lesser extent chromium) concentrations are slightly elevated on the SMW dunite with nine samples having an average dissolved nickel of 0.11 mg/L and average total nickel of 0.19 mg/L
- Nutrient levels are unremarkable, with moderate nitrate concentrations typical of arid regions of Australia and with low phosphate concentrations
- Trace element chemistry meets the guideline values for livestock supplies
- Salinity is generally suitable for livestock supplies although some higher values exceed recommended long term supply guidelines for cattle

As mining progresses, the main aquifer will be gradually depleted and groundwater originating from deeper more isolated fracture systems will constitute an increasing proportion of pit pumpage (during periods of dry weather). The groundwater salinity is expected to gradually increase after the first two years of mining, then stabilise with pumping rates.

4.7 Test Pumping, Trial Mining and Packer Tests

The 1990 investigation program included a 10 day pumping test on the southern portion of the SMW deposit with a constant rate of 9.6 L/sec from two bores (Coffey Partners, 1990). Drawdown and recovery patterns showed that the aquifer was highly permeable but of limited lateral extent. This confirms the prognosis based on geological context and mining experience in the region. The pumping test results show a specific yield of about 3.5% for the silica-carbonate weathered dunite material at the centre of the ultramafic body. The results indicate a total storage of about 100 ML within the highly porous central and shallow part of the aquifer. The dewatering prognosis is for abstraction of about 10 L/sec over 6 months to deplete the main storage, with gradually declining groundwater yield to the pit thereafter (Nickel West, April 2006)

Note that the dewatering estimate for the SMW pit excludes additional abstraction from the northern lobe of the SMW pit. It is expected that an additional but lesser silica-carbonate aquifer caprock aquifer will be encountered in this area and additional abstraction of up to 50% may be expected from there.

In 1990 a bulk sampling shaft on the SMW deposit was constructed through the main water bearing zone to 87 m. Dewatering of the shaft was achieved by pumping at 3.6 L/sec.

Coffey Partners reported little indication of substantial groundwater occurrence in the area of the proposed Goliath pit. A single production bore was drilled (CP21) and tested and a sustainable rate of less than 1 L/sec was estimated. Follow up exploration drilling by Woodward Clyde in 1995 confirmed low permeability in the area.

The deeper (sub-regolith) rock mass permeability was investigated at both deposits as part of the 2010 drilling program. At Goliath testing included 17 intervals within three holes. Water take was generally very low at Goliath, with only one tested interval yielding greater than 1 lugeon (1 L/min/metre/1000 kPa). At SMW testing included 29 intervals within six holes. Water take was generally low with some exceptions, mostly at isolated fracture zones which have little significance to overall dewatering volumes. A greater continuity of permeability occurred at the centre of the SMW North deposit indicating substantial groundwater in storage, however the geological context shows that the extent of the aquifer is limited.

4.8 Conceptual Hydrogeological Model

The MKSP development area includes a small semi-confined (low submergence) aquifer in the form of the SMW dunite caprock aquifer.

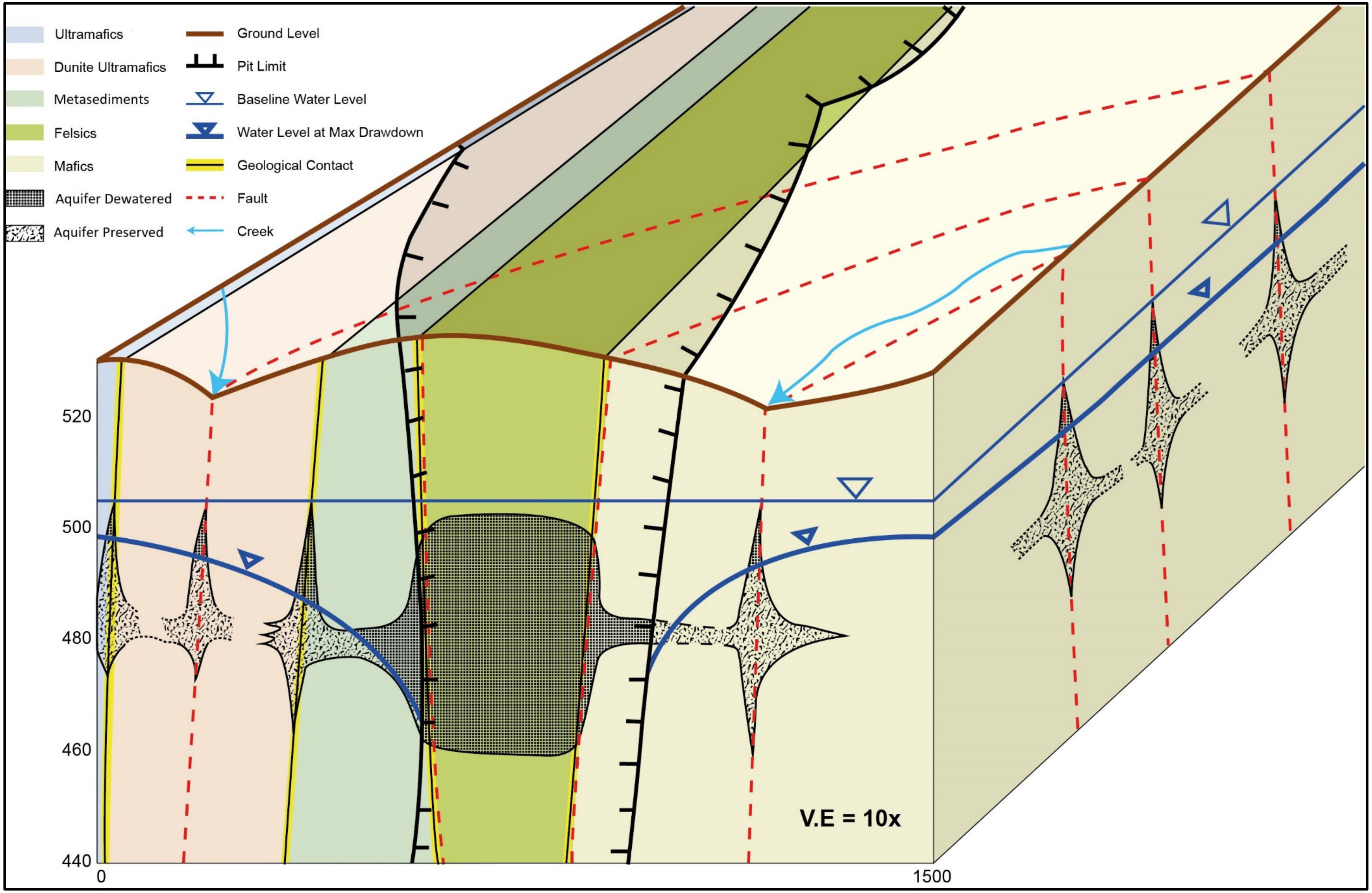
In addition, the greenstone belt geological sequence hosts a generally sparsely distributed network of discrete minor confined aquifers – typically as steep, narrow linear structural zones. Water level data indicates a degree of interconnection between these features. Geological mapping and hydrogeological experience from Leinster to the south and Mt Keith to the north indicates that the distributed array of permeable fracture is likely to be continuous for 10’s of kilometres north and south of the MKSO site.

Depth to the water table varies from a minimum of about 15 -35 metres. At such depths, it is considered that surface vegetation is not groundwater dependent. The further vertical confinement of the aquifers (ie depth of aquifer top below the water table) and the degree of variability of groundwater yield and salinity in drillholes further supports the interpretation of low interconnectivity of surface and groundwater.

Figure 19 shows a stylised representation of the cross-section through the SMW pit including the pre-development water levels. Maximum drawdown induced by dewatering (as simulated by groundwater flow modelling detailed below) is also shown.

The development of the groundwater flow model used to simulate dewatering drawdown in described as part of the hydrogeological impacts assessment below.

Figure 19 - Hydrogeological Setting and Dewatering Drawdown Effect



5. SURFACE WATER IMPACTS ASSESSMENT AND CONTROLS

5.1 Key Risks

1. Quantity of flow in Jones Creek
    - Reduced catchment flow and yield due to retention of stormwater in pit voids and dumps
    - Capture of creek flow by the pit voids
2. Water Quality in Jones Creek
    - Improper containment of sediment laden stormwater run-off during operations
    - Point source contamination from haul road creek crossings
    - Post-closure sediment load from waste rock dumps
    - Post-closure discharge from pit lakes
3. Mt Keith Haul Road
    - Erosion and run-off shadowing

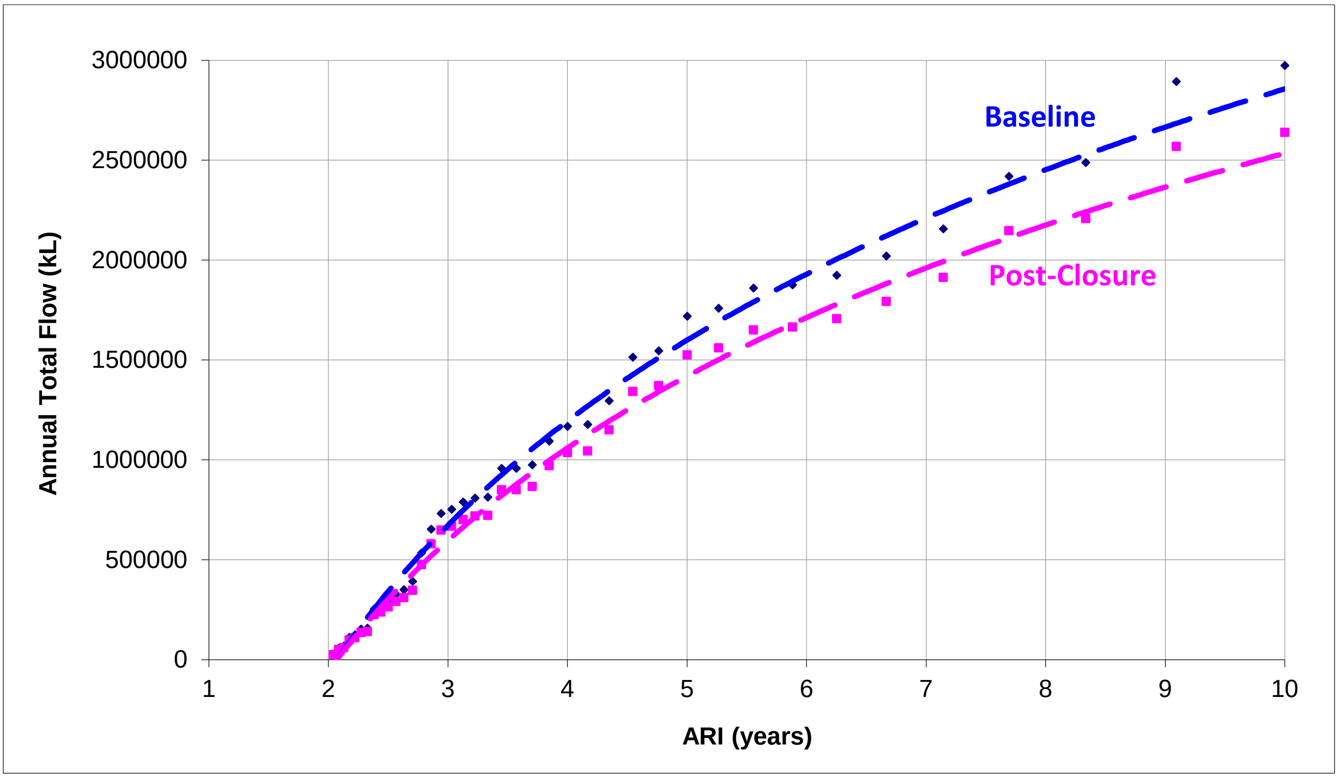
Key risks which are beyond the scope this report include chemical contamination from specific operation point sources such as fuel farms, workshops, chemical storages, etc.

5.2 Catchment Yield

The pit voids will retain all incident run-off and the waste rock dump run-off will be restricted by design. The catchment model described in Section 2.8 was used to determine the impacts of the reduced catchment area on creek flow frequency and magnitude. The baseline catchment area was reduced from 61.8 to 56.9 sq km.

The total annual flow volume for the 49 years in which flow occurs, are plotted against the average return interval for the 100-year rainfall sequence in Figure 20. The baseline and post-closure development scenarios are shown.

Figure 20 - Baseline and Post-Closure Annual Yield Frequency



The impacts on key volumetric parameters are summarised in Table 3:

Table 3 – Impacts on Streamflow and Catchment Yield

PARAMETER	Baseline	Post-Closure
Flow Days	81	81
Flow Events (separated by more than 1 day)	76	76
Years in which flow occurred	49	49
Median total annual flow in flow years (ML)	1168	1036
Probability of fill to more than 1.25 m depth (%)	36	35
Probability of fill to more than 0.5 m depth (%)	43	42

The model shows that the 100-year sequence of rainfall generates the same sequence of slightly smaller creek flows. There is a slight reduction in the frequency of flows above a given threshold – eg a 1% reduction in the annual probability of total flows exceeding the full capacity of the claypan (about 500,000 kL). There is a greater reduction in the frequency of very large annual streamflow totals, eg the average recurrence interval for an annual total of 2,500,000 kL declines from 12% (1:8 year) to 10% (1:10 year).

Due to the relatively high rainfall magnitude/intensity threshold before large scale runoff occurs in the catchment and due to the small volumetric capacity of the Claypan relative to typical flows, the frequency of filling is not substantially affected by the proposed development. Flows will continue to occur at a frequency 1:2 years and the median annual flow (in flow years), whilst reduced by 11%, remains more than double the full volume capacity of the Claypan. On this basis, no active controls are required to manage this impact.

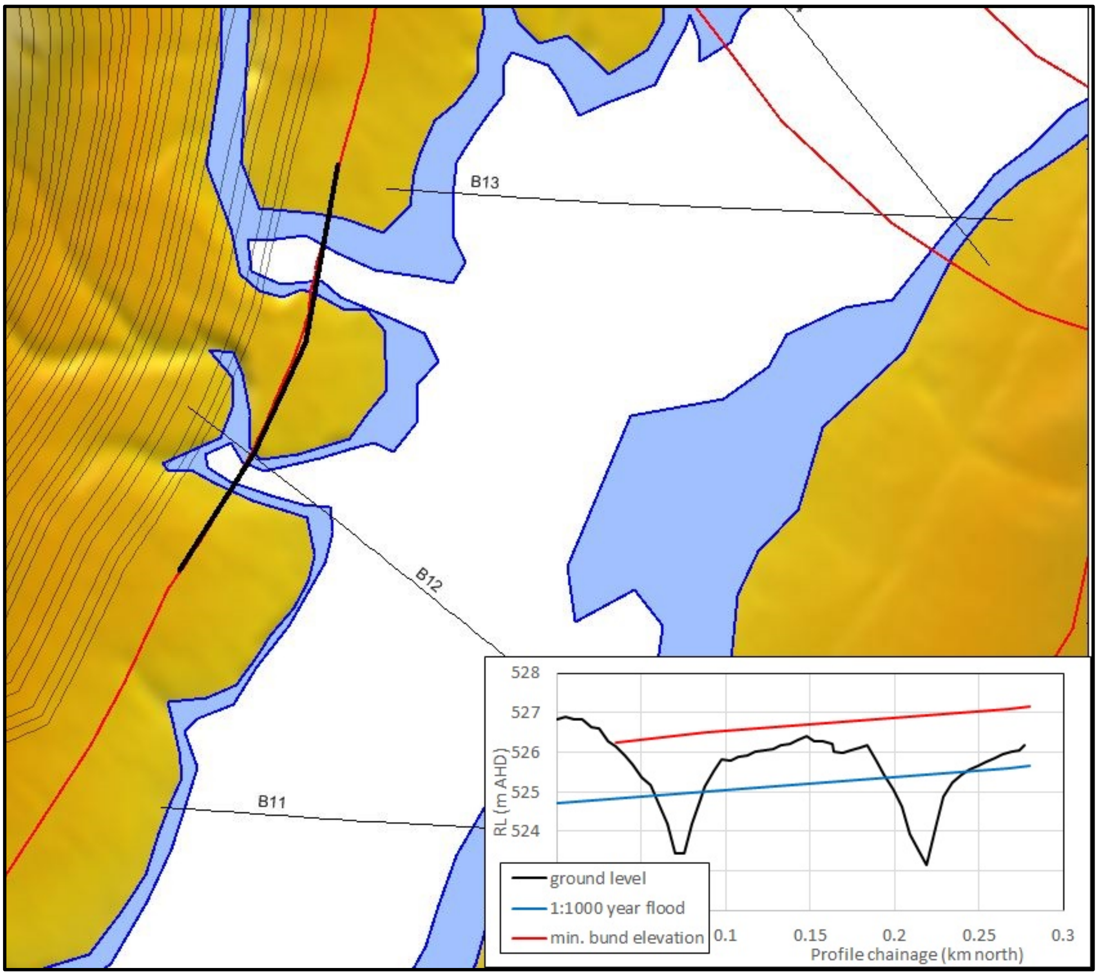
5.3 Creek Flow and Pit Voids

Modelling of rainfall-runoff and peak flood levels in Jones Creek is described in Section 2.7. The estimated 1:100 year and 1:1000 year average return interval flood levels are shown in Figure 5, along with the limits of the area of disturbance associated with the development.

The baseline plan shows some incursion of the 1:100 year flood zone into the disturbance area immediately south of the southern creek crossing, on the west side of creek at the south east corner of SMW pit. It is necessary to eliminate any possibility of creek flood flow entering the pits during operations to ensure a safe work place. In addition, the closure design must ensure that peak flow is not "captured" by the pit to avoid loss of through-flow to the downstream catchment.

Figure 21 shows detail in the area of the incursion, including the 1:100 year flood extent (white), the 1:1000 year flood extent (blue), the hydraulic flood model cross section lines (B11-B13), the limits of the disturbance and the limits of the pit. The disturbance area line is also the location of the pit abandonment bund, a standard operational and post-closure feature mandated by Department of Mines and Petroleum guidelines (DMP, 1997). Figure 21 shows the surface profile along the limit of disturbance/bund alignment. The profile shows that the DMP standard 2 m high bundwall construction would be above the 1:100 year flood level. Hydraulic modeling shows that stream flow velocities will be less than 0.5 m/sec at the bund wall and will not pose a severe erosion risk.

Figure 21 – Jones Creek Peak Flood Extent near the SMW Pit



To ensure adequate safety factor and integrity of the bundwall in this location, additional controls are proposed as follows:

- Additional bund elevation to 1.5 metres above the 1:1000 year ARI flood level
- Compacted coarse rock cladding to ensure long term integrity

5.4 Operational Sediment Containment

The objective is suitable separation and containment of "dirty" stormwater - in particular, stormwater containing mining related particulates which pose a risk to the downstream environment. The mined ore and waste are relatively benign in geochemical terms, however potential impact pathways include:

- Mobilisation of fine-grained ore (especially from the ROM pad area) as creek sediment with the potential to deleteriously impact the water chemistry in creek pools over weeks and months after flow events
- Erosion and re-mobilisation of clay particles originating from clayey saprolite waste rock with the potential to deleteriously impact the physical properties of creek sediments, eg discolouration and clogging of natural coarse creek bed sediments

The proposed major control measures are shown on Figure 22. These relate mining and materials handling at the landform scale and exclude localised drainage and containment relating to specific localised "high risk" potential contaminant point sources (eg workshops) where higher levels of control and containment will need to be specified in detailed design.

Proposed landform scale control measures include:

- Clean stormwater drains diverting stormwater flow from un-impacted areas around the site
    - North from NW corner of the SMP pit. Length: 800 m, fall : 550 - 540 m, maximum depth: 2 m
    - South from NW corner of the SMP. Length: 200 m, fall : 545 - 539 m, maximum depth: 0.5 m
    - North around the WRD toe : Length: 1300 m, fall : 531 - 527 m, maximum depth: 1.0 metres
    - South around the WRD toe : Length: 1200 m, fall : 530 - 529 m, maximum depth: 1.0 metres

- Dirty water drains directing stormwater from disturbed areas to silt traps
    - Stockpile area: Length: 1400 m, fall : 540 - 530 m, maximum depth: 2.0 metres

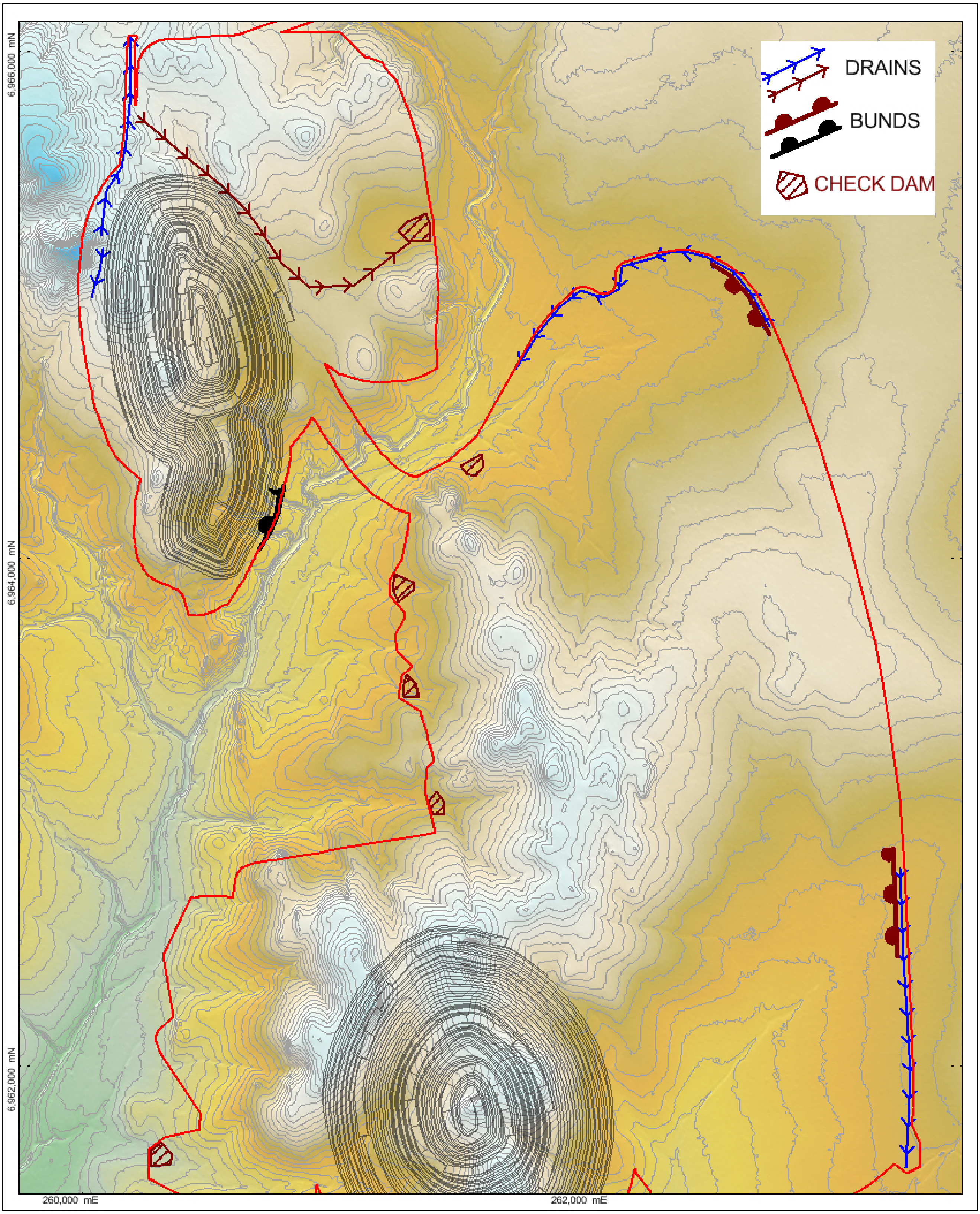
- Clay bunds to prevent stormwater flow down creek-lines blocked by the WRD
    - Northeast and southeast of WRD toe - dump side of main drains

- Coarse dumping on outer surface of WRD to be non-erodible/competent rock

- Flood exclusion bund – southeast side of SMW pit as discussed above

- Silt traps/check dams/rock pads to limit sediment mobilization on selected flow paths
    - small semi-porous embankments (<2.5 metre-high) across key drainage lines
    - unlined, no recovery pumps, water detention not retention
    - partial backfill with loose coarse crushed rock (d_{50} ~ 200mm) of high size uniformity
    - First flush storage capacity with overflow for ongoing run-off
    - Containment for volume equivalent of 4 mm run-off depth across sub-catchment

Figure 22 - Major Stormwater Control Structures



Silt trap locations are preliminary and to be revised based on needs identified from detailed stock-pile and dump sequencing. Key areas for coverage are potential high sediment source areas, including steep concentrated flow paths from areas where oxide material will be stored and exposed continuously over periods of months to years.

The proposed containment capacity (“first-flush” depth) relates to the relatively large scale and low concentration (diffuse) contaminant source, in particular to practically un-mineralised fine-grained waste rock particles. During rainfall events, re-mobilisation of sediment is heavily weighted to the early run-off from higher frequency and higher intensity rain events (ie first-flush effect). The target event for containment is the 1:2 year frequency, 30 minute duration rain event occurring on a dry (un-flushed) catchment - a rainfall total of 12 mm (Table 1). Based on run-off loss models (Flavell, 2011) the run-off coefficient for such an event is about 10%. Allowing for the smaller and steeper nature of the selected catchment, the recommended containment capacity for the diffuse sources described above is 4 mm. A portion of the storage should be provided as void space in the back-filled rock pad, to minimize through-flow of sediment.

As an example of silt trap sizing, a 30 hectare catchment requires a total water containment volume of 1200 kL, for a typical site on a 2% slope and with partial backfill indicative embankment dimensions are 2.0 m high x 50 metres wide.

5.5 Jones Creek Crossings

The southern crossing is on the haul route for all waste rock from the Six Mile Pit to the waste rock dump. When the pre-strip of the Six-Mile Pit is being mined, the majority of the haul fleet will be using this route. Ore from the Goliath pit will be trucked across the southern crossing to the ROM pad. The northern crossing will be used to convey all ore from the ROM pad to the Mt Keith concentrator.

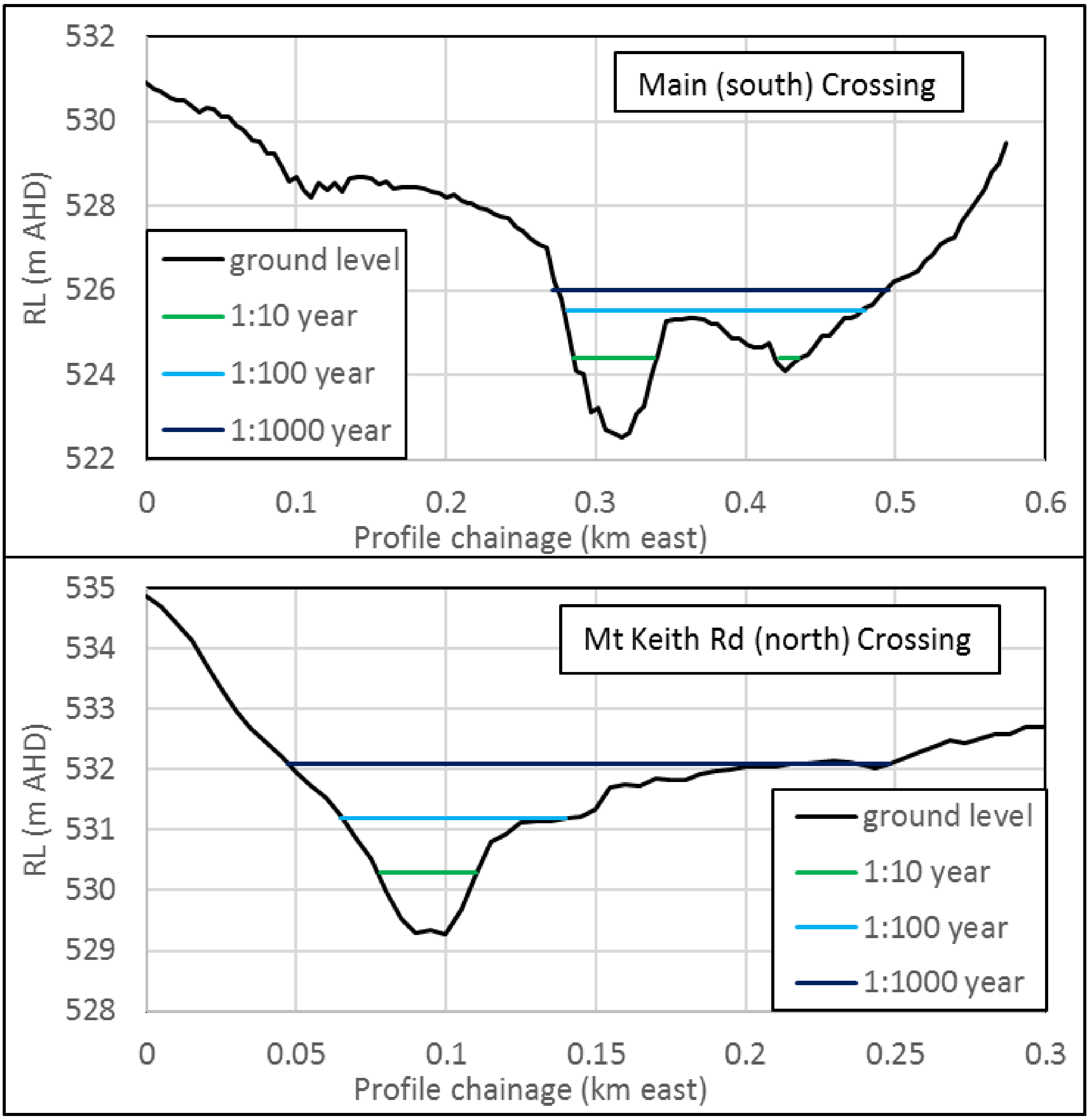
Potential impacts from the haul road crossings relate to Jones Creek water quality, particularly excessive additional sediment load. Mechanisms for introducing additional sediment load include:

- Construction of crossing – bank cutting to achieve acceptable gradients (max 8% slope)
- Erosion of bank cuttings during flow events
- Erosion of road material during flow events
- Flood remobilization of material spilled onto the roadway

The frequency of creek flow events at the haul road crossings is discussed and quantified in Section 2.10. The annual average is for 3 flows of duration 8 hours, with the majority of the flow duration being at a relatively low flow rate (less than 5 cumecs).

The surface profiles and major flood elevations are shown in Figure 23.

Figure 23 – Jones Creek Crossing Profiles



These demonstrate the following:

- The slope of the natural ground surface exceeds 8% over a maximum of about 30 metres horizontally (main crossing - west side). This means that very minor bank cut-backs will be required to achieve suitable grade
- More common high flow events (1:10 year average frequency) impact short sections of roadway (less than 50 metres)

Considering the low frequency and short duration of flow events, a creek bed level floodway is the appropriate creek-bed crossing. The creek crossings will have the following features:

- Minimum build up of road surface above natural creek level in mainstream
- Bed level concrete slab through main channel (up to 20 m long)
- Rock gabion protection buried to bed level on upstream and downstream side of slab
- Coarse rock armouring of the bank cut sections up to the 1:100 year flood
- Best operational practice to minimize vehicle tracking of clayey oxide material during wet periods including:
    - Construction of roads with appropriate compatible materials
    - Road drain and surface maintenance to avoid build up of sediment on roadways
    - Wheel wash as appropriate

5.6 Sediment Load from the Waste Rock Dumps

The majority of the project waste rock will be coarse competent rock. Experience from Mt Keith and Leinster shows that this material is not prone to erosion at slope angles up to the coarse-dumped angle of repose (~36º). Clayey saprolite may be erosion-prone at low slope angles (<10º). This material presents a low risk of geochemical contamination, but has the potential to cause discolouration of creek bed sediments and clogging of the naturally coarse-grained sediments in the creek bed.

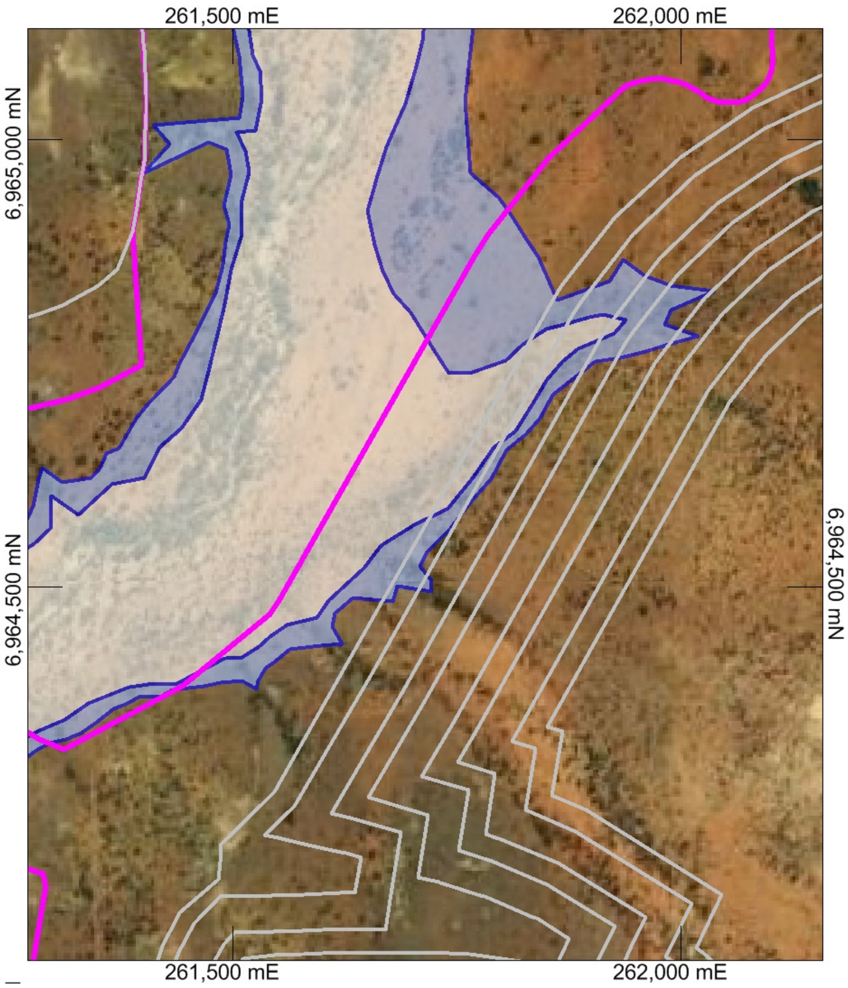
Mt Keith Operations have in place mine planning procedures for the encapsulation of clayey material within competent rock. Considering the low proportion of clayey saprolite in the project waste and that it is generated early in each of the three stages of mining, the existing Mt Keith encapsulation requirements for saprolite will be easily achievable.

There is an overlap of the extreme flood area with the waste dump landform near it's northeast corner. Detail is shown in Figure 24 including the limit of the disturbance area, the flood areas (white = 100 year and blue = 100 year) and the coarse dump plan crest and berm lines, including four 20 metre high berms and three 40 metre wide benches. The coarse dump toe is set back 100 metres from on the disturbance area for the waste dump landform to allow for push-down to the final closure landform and a buffer zone. The risk of erosion form the dump is mitigated by the following factors:

- The flood zone incursion on the waste dump is far from the creek main channel
- Stream flow velocities at the margins are low-moderate (< 0.5 m/sec)
- Inundation will occur rarely and for brief periods

Further control will include coarse rock amour of the exposed toe segment (500 metres) to a height which exceeds the 100 year peak flood level (529 m AHD).

Figure 24 – Flood Zone Incursion onto the Waste Rock Dump Footprint



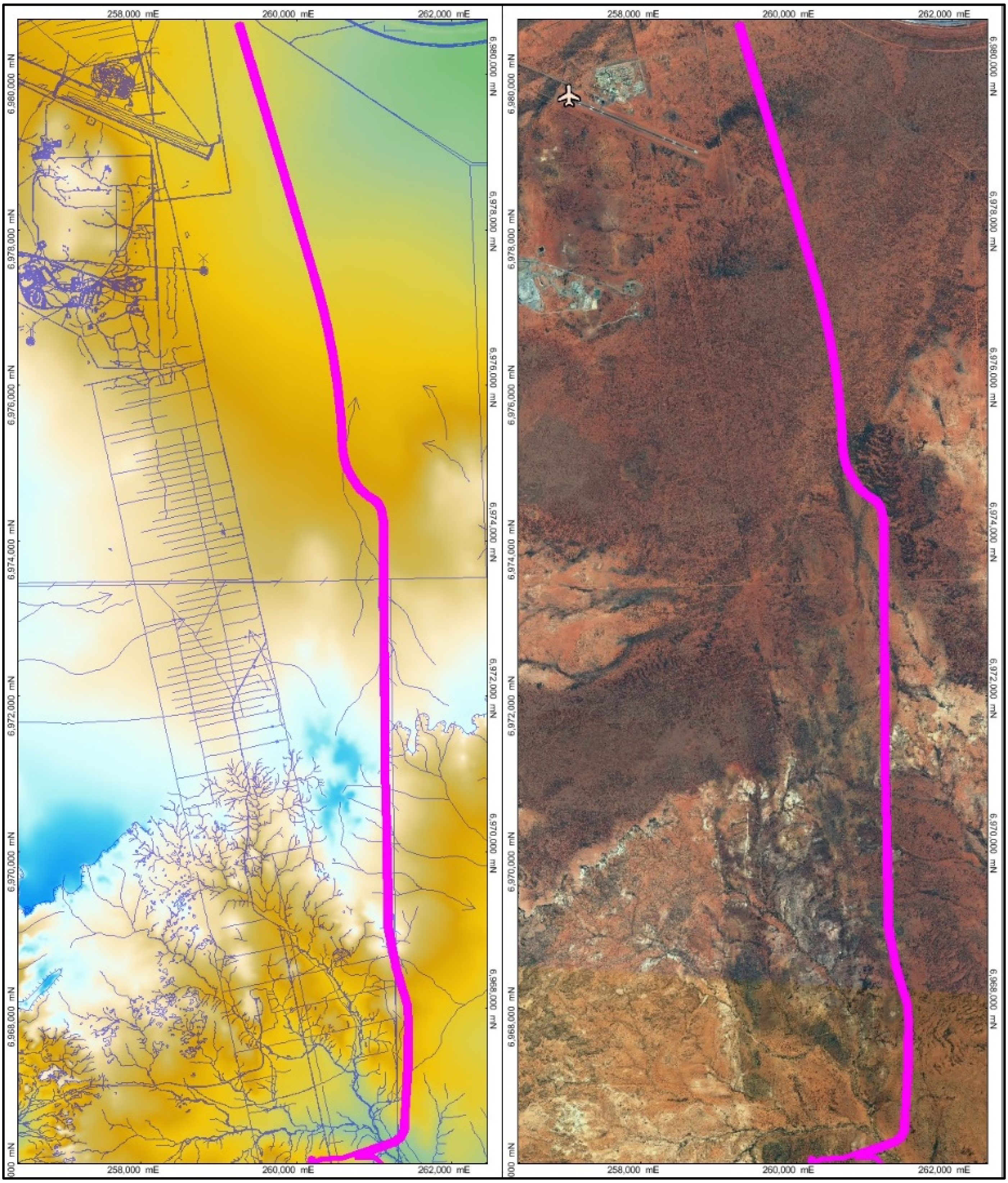
5.7 Post Closure Discharge from the Pit Lakes

The post-closure pit lake is addressed in the hydrogeological context in Section 6.3, including modelling of the post-closure pit lake water level. As for all mine pits in the Goldfields region, provided external surface water inflows are excluded, there is no risk of pit water levels approaching the pit crest and discharging to the natural environment as a surface water flow.

5.8 Mt Keith Haul Road

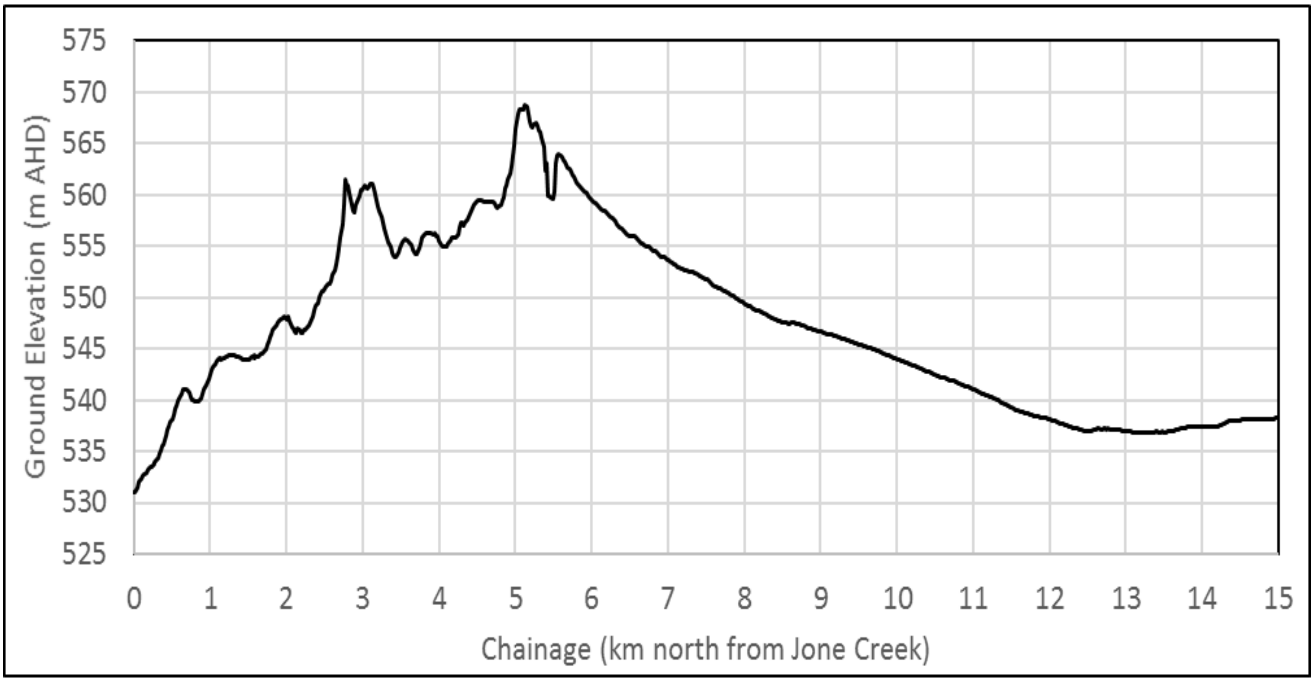
The route is shown on Figure 25, along with existing topography overlying a colour-fill DEM and alternatively overlying aerial imagery.

Figure 25 – Mt Keith Haul Road Route



Total distance from the Jones Creek crossing to the northern end of the project disturbance area (located between the Mt Keith WRD and TSF) is 15 km. The profile of surface elevation along the route is shown in Figure 26.

Figure 26 – Mt Keith Haul Road Route Surface Profile



From chainage zero at Jones Creek the general route features and gradients are as follows:

0-1.2 km:	Ascend directly, traverse at high level, cross ridge line and exit Jones Creek catchment. Route gradient up to 2% and mostly low transverse gradients
1.2-6.4 km:	Oblique ascent / high level traverse in east- draining catchment, crossing one lateral spur several minor drainage lines, then the route enters the flatter Mt Keith catchment. The route gradient is mostly less than 2%. There are short steeper sections of 4-8% gradient within chainage ranges 2.7 - 2.9 km (crossing the spur) and 4.9 - 5.6 km (ascending the minor breakaway). Lateral gradients 0-2% to the east.
6.4-15 km:	Gradual decent of the south slope of the Mt Keith valley, route turning from direct descent to oblique descent to valley floor traverse. No incised channel drainage features. Route-line gradients less than 1% and lateral gradient to the east at less than 0.5 %.

Specific drainage features are summarised in Table 4. Catchment parameters and peak flow rates relate to flood estimation methods described in Section 2.5

Table 4 – Specific Drainage Features on the Haul Route

East	North	Chainage (m north from Jones Creek)	Feature	Catchment		
				Area (km^2)	Slope, (m/km)	Peak flow (100 year) (m^3/sec)
261180	6969460	3440	Creek	0.135	14	1.3
261170	6969720	3710	Creek	0.376	14	3
261170	6970130	4100	Minor Cr	No incised channel		
261160	6970250	4240	Minor Cr	No incised channel		
261160	6970470	4450	Minor Cr	No incised channel		
261150	6970820	4810	Creek	0.161	34	2.2
261130	6972460	6460	Swale	No incised channel		
261130	6972840	6840	Broad Swale	No incised channel		
261130	6973280	7290	Flood-out	No incised channel		
260610	6975100	9310	Flood-out	No incised channel		

In general, the route poses relatively minor drainage challenges and the potential impacts are mitigated by the following factors:

- Surface gradients are low to very low
- Drainage lines are only slightly incised and have small catchment areas
- Vegetation density is generally moderately low

The haul road design is presented in GHD (August 2017), where the base case is for a low crown profile with finished road surface close to the natural ground surface. This will minimize environment impact, drainage structures and fill volumes. The design uses floodways to convey stormwater at the listed tabulated crossings.

The following residual risks and control measures to be included in detailed design:

1. Breakaways - Grading exposes clay saprolite which may be to prone to erosion. Competent rock cladding of erosive material (clay saprolite) exposed in cuttings and in table drains on steeper sections, particularly within breakaways at 6,969,850 – 6,970,050 mN and 6,970,950 – 6,971,500 mN

2. Long slope-parallel sections - Erosion in the lateral table drain. Adequately close spacing of diversion drains, in particular 6,971,500-6,972,500mN

3. Oblique floodway crossings - Roadway capturing drainage. Additional sub-basecourse fill to raise the road profile on the down-slope size of the floodway

4. Contour-parallel sections - Vegetation “shadowing”. Eliminate windrows in areas where overland flow needs to be maintained including swales, floodways (specific drainage features) and other areas where vegetation appears to enhanced by overland flow perpendicular to the roadway, in particular at 6,979,400 mN - 6,979,700 mN

6. IMPACTS ON GROUNDWATER AND THE PIT VOIDS

6.1 Key Risks

Groundwater levels will be maintained at the base of each pit whilst there is active mining and dewatering will result in a cone of drawdown in the water table around the pits. After mining is complete, water levels will then gradually rise to equilibrium levels. The SMW pit will be completely backfilled such that the long term equilibrium water levels will return close to the baseline condition. The post-closure Goliath pit will remain a permanent void. The baseline evaluation informs the hydrogeological risk assessment as follows:

- Operational drawdown from the SMW pit will be comparable to the Mt Keith pit, extending of order 100's of metres beyond the pit crest
- After closure and back-filling the drawdown cone will gradually refill
- There is potential for changed water quality in the backfill and for movement of the impacted water laterally away from the backfilled pit (though-flow)
- There are no aquifers at the Goliath Pit, drawdown extent will be limited. Dry conditions and absence of any pathway or receptor for groundwater impacts negates the requirement of drawdown modelling
- A small lake will develop at the base of the Goliath void

Key hydrogeological risks are as follows:

1. SMW pit drawdown impacts on biological receptors
2. Post closure pit lake discharge to surface drainage
3. Impacts from deleterious water quality in the post-closure pit lake

This report is limited to a description physical and chemical impacts, whilst biological implications of those impacts are not considered here.

6.2 Six Mile Well Pit Drawdown Extent

6.2.1 Groundwater Model Set-Up and Boundaries

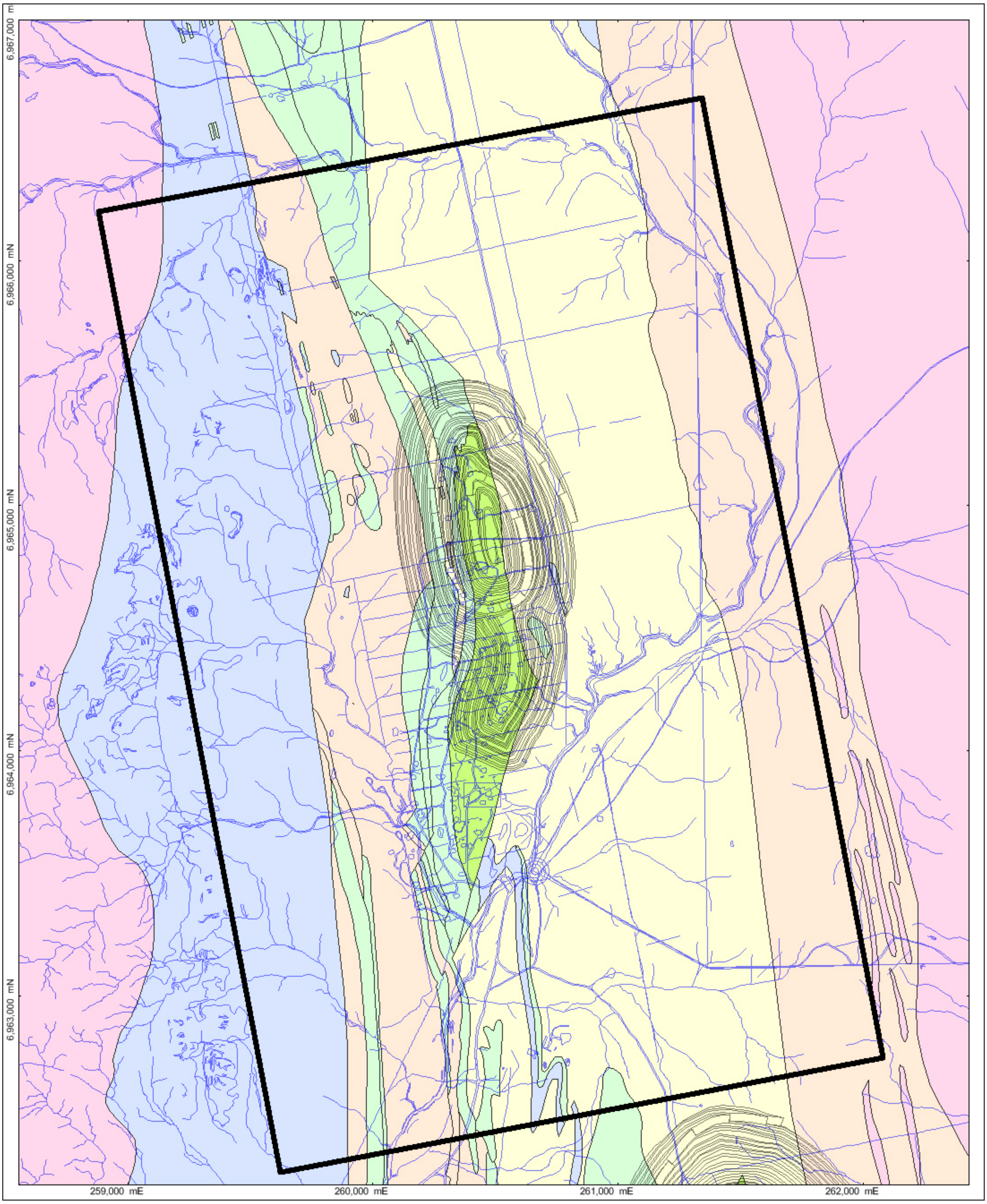
A groundwater flow model was developed to evaluate the pumping requirements and the extent of drawdown around the SMW pit. The conceptual model is based on that developed and calibrated for the existing Mt Keith pit for geotechnical purposes. A four-layer model was used, where:

Layer 1 – Ground surface to base of complete oxidation - saprolite
Layer 2 – Base of transitional altered/weathered– saprock including main aquifer on dunite (adcumulate)
Layer 3 - Slightly weathered bedrock
Layer 4 – Fresh bedrock

The base of Layers 1 and 2 are imported geological surfaces defined from the high-density mineral resource drill pattern. Layer 3 was assigned a uniform thickness of 50 metres based on vertical continuity of water occurrence in groundwater investigation holes. The base Layer 4 was set at a constant elevation of 250 m RL, a depth of 250-300 metres, from below which little groundwater is likely to be sourced. The base elevations of Layers 1, 2 and 3 were then adjusted/smoothed to ensure hydraulic continuity.

The model is constructed on a 100 x 100 m spaced rectangular grid extending 4 km north south and 2.5 km east west. Spatial extent is greater than the expected maximum limits of drawdown based on experience at Mt Keith where the drawdown cone is extremely steep, particularly across strike (east-west). The model is aligned with the local grid and the general strike direction of the bedrock formation at about 11 degrees west of north. lateral extent of the SMW pit model is shown in Figure 27.

Figure 27 – Groundwater Model Domain



Hydraulic boundaries are as follows:

- Northern constant head boundary located 1 km north of the pit boundary and aligning with the west-east reach of Jones Creek crossing the mafic belt
- Southern constant head boundary located 1.4 km south of the pit where mafic belt is crossed by Jones Creek
- Rainfall recharge is applied at a regionally uniform rate
- Mixed type boundaries located on the west and east sides of the model representing the maximum cross-strike extent of substantial drawdown
- No flow boundaries at the remaining margins and at the base of Layer 4

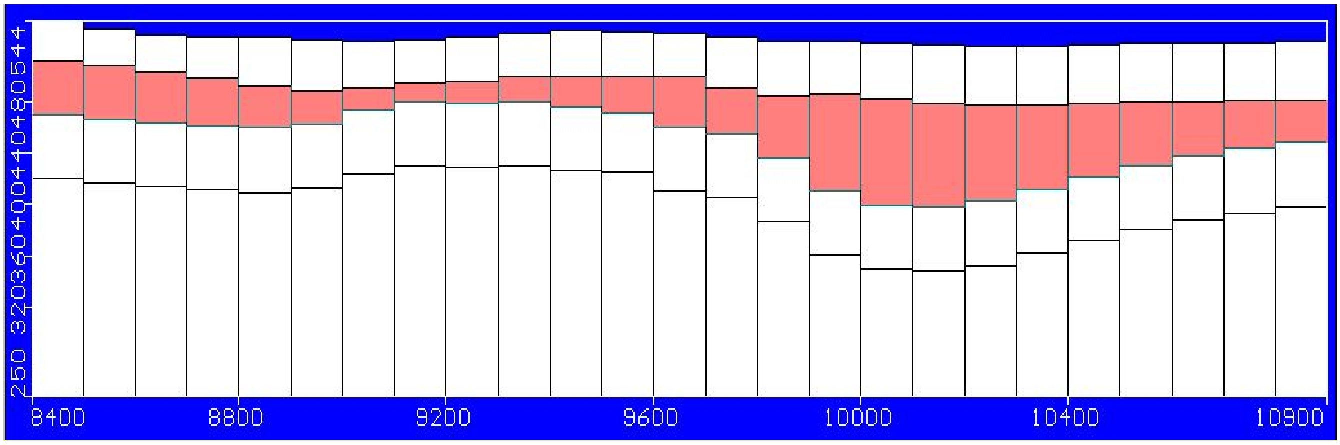
The elevation and conductance of the source boundaries at the model limit were adjusted during calibration and the overall water balance was checked during simulation to ensure that the contribution of water from outside the model domain remained a small component.

6.2.2 Layer Geometry

The ground level is at 520-540 m across much the model area and the baseline water level is at about 504 m . Layer 1 thickens from 10-20 metres in the west and south (unsaturated and inactive) to about 40 metres across much of the pit and greater thickness east of the pit. Layer 2 also thickens to the west and deepens to the west. Typical thickness in the pit area is about 30 m and depth extent from 460-490 m RL. Layer 3 has a thickness of about 50 metres and Layer 4 extends to the base of the model at 250 m RL.

A typical cross section (east-west) through the centre of the model is shown in Figure 28. The highlighted Layer 2 contains the main aquifer. The centre of the pit is located at local grid easting 9600-9800 m East on the section line.

Figure 28 – Groundwater Model - Typical Cross Section



6.2.3 Calibration and Hydraulic Parameters

Initial estimates of hydraulic parameters were constrained by test pumping results and packer tests and by guidance from modelling of similar materials in the Mt Keith pit slopes. The parameters were then adjusted during steady-state and transient calibration.

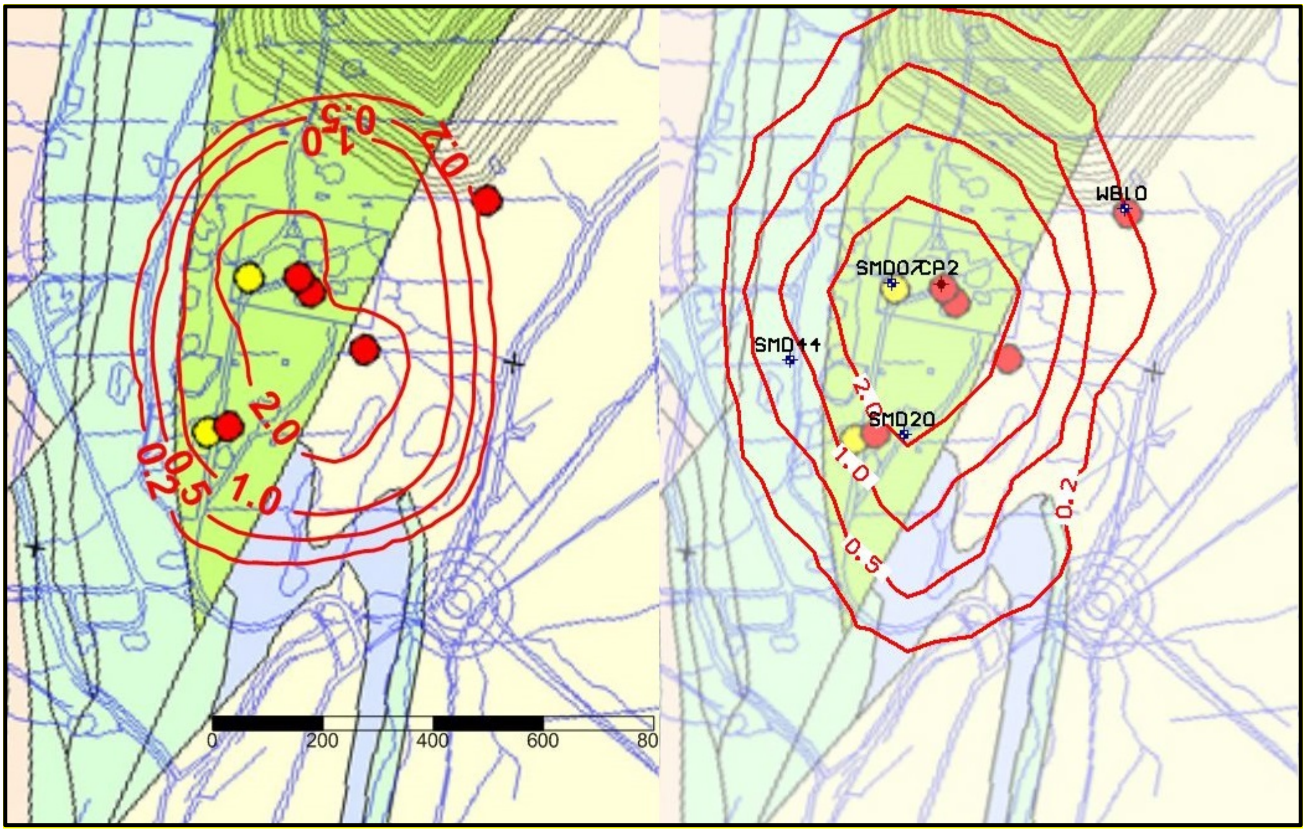
Steady-state calibration was undertaken to develop a set of initial heads which matched the observed heads for use in transient simulation of the pumping test and operational dewatering drawdown. The steady state calibration was primarily achieved by adjusting the recharge rate and downstream constant head elevation. After transient calibration runs, these parameters were further re-adjusted iteratively. The adopted/matched features of the steady sate calibration are as follows:

Up-gradient constant head elevation :	505 m RL
Down-gradient constant head elevation:	499 m RL
Recharge rate (uniform across model):	0.5 mm/year

The configuration generates a north-south water level gradient with water levels at about 504 m in the pit area. These parameters have a relatively minor impact on the transient yield and dewatering simulation, ie the rate of pumpage and extent of drawdown, however the duration of the post closure water level recovery is sensitive to the recharge rate.

After steady-state calibration with the north and south constant head boundaries in place, the lateral mixed type boundaries were set with elevation equal to the steady state level. The lateral margins are flow parallel/ no flow lines in the steady state condition and become a minor source of lateral inflow to the model domain during the dewatering simulation.

Figure 29 – 10 Day Pumping Test Observed and Model Simulated Spatial Drawdown

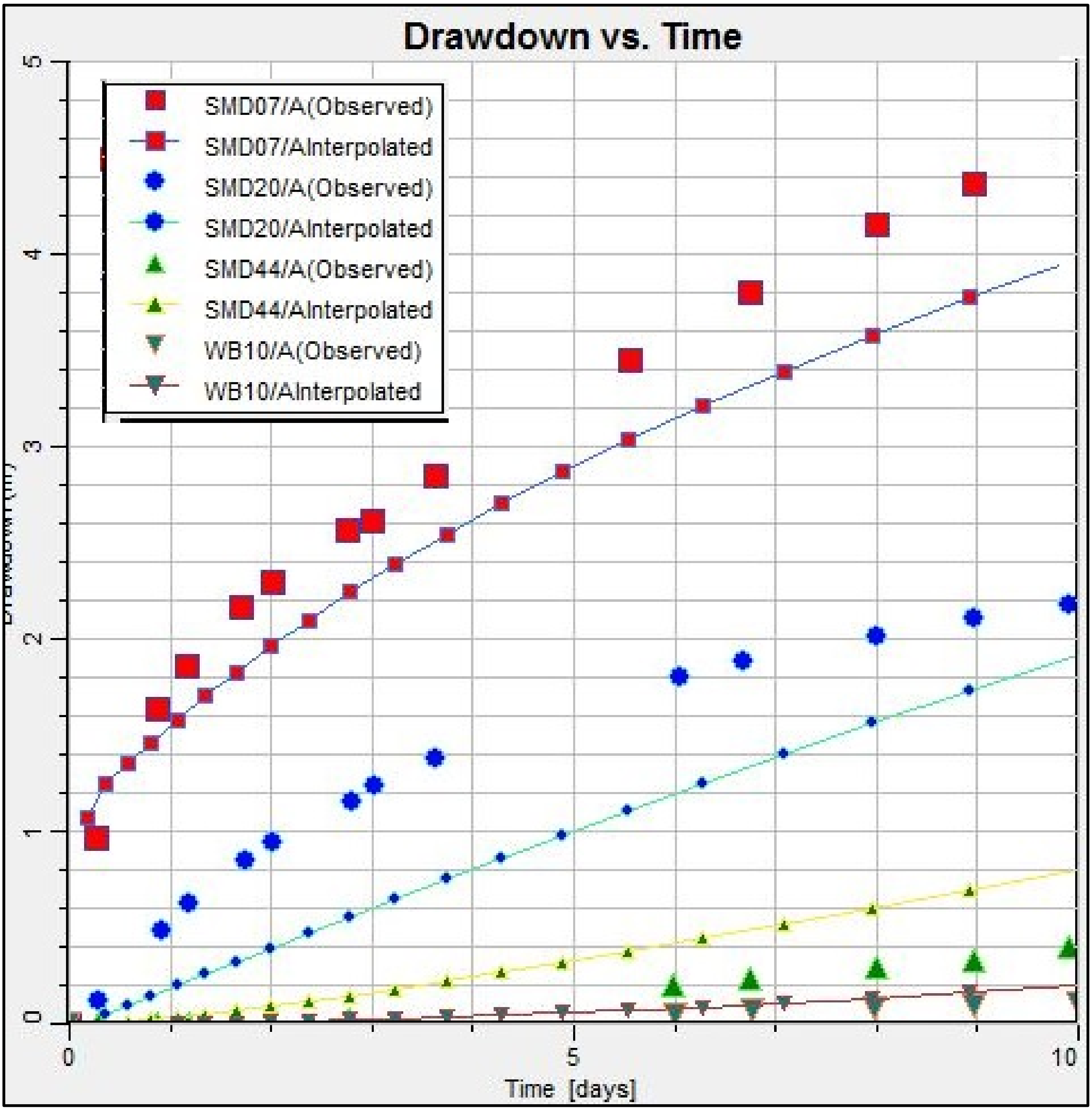


Transient calibration was undertaken using the results of the 10-day pump test reported Coffey Partners (1990). The test involved pumping two adjacent bores located in the dunite aquifer immediately south of the pit at a combined rate of 9.6 L/s with water levels were monitored on an extensive array of bores.

The drawdown cone was analyzed volumetrically which showed that Layer 1 materials with the cone of drawdown responded with a porosity of 3.5 % for the cone of drawdown induced. The remaining model parameters were adjusted to achieve a match between observed and simulated drawdown.

Figure 29 shows the observed (left) and simulated (right) drawdown cone extent after 10 days pumping. The model slightly over-predicts the drawdown extent. The calibration match of the time series drawdown response is shown in Figure 30 for selected bores at locations shown in Figure 29.

Figure 30 – 10 Day Pumping Test Observed and Model Simulated Time-Series Drawdown



Note that the model under-predicts drawdown close to the pump well and over-predicts drawdown at distance. The markedly flat centre and steep edges of the observed drawdown cone are consistent with extreme hydraulic boundary effects imposed by the geological limits of the dunite aquifer. In essence the aquifer is responding as a "tank" rather than as a continuous field. The model does not fully simulate the extreme bounding, hence operational simulation are expected to generate conservatively large drawdown beyond the pit limits.

The calibrated hydraulic parameters are summarised in Table 5.

Table 5 - Groundwater Model Parameters

Layer	Zone	Permeability (m/day)	Porosity
1	Adcumulate	0.01	4%
	Other		2%
2	Adcumulate	2.0	4%
	Ultramafic	0.2	2%
	Other	0.1	
3	Adcumulate	0.1	0.5%
	Ultramafic	0.05	
	Other	0.01	
4	All	0.001	0.1%

The calibration results show a strong weighting of permeability and porosity to the weathered zone of the ultramafic rock type in particular to the adcumulate ultramafic (dunite).

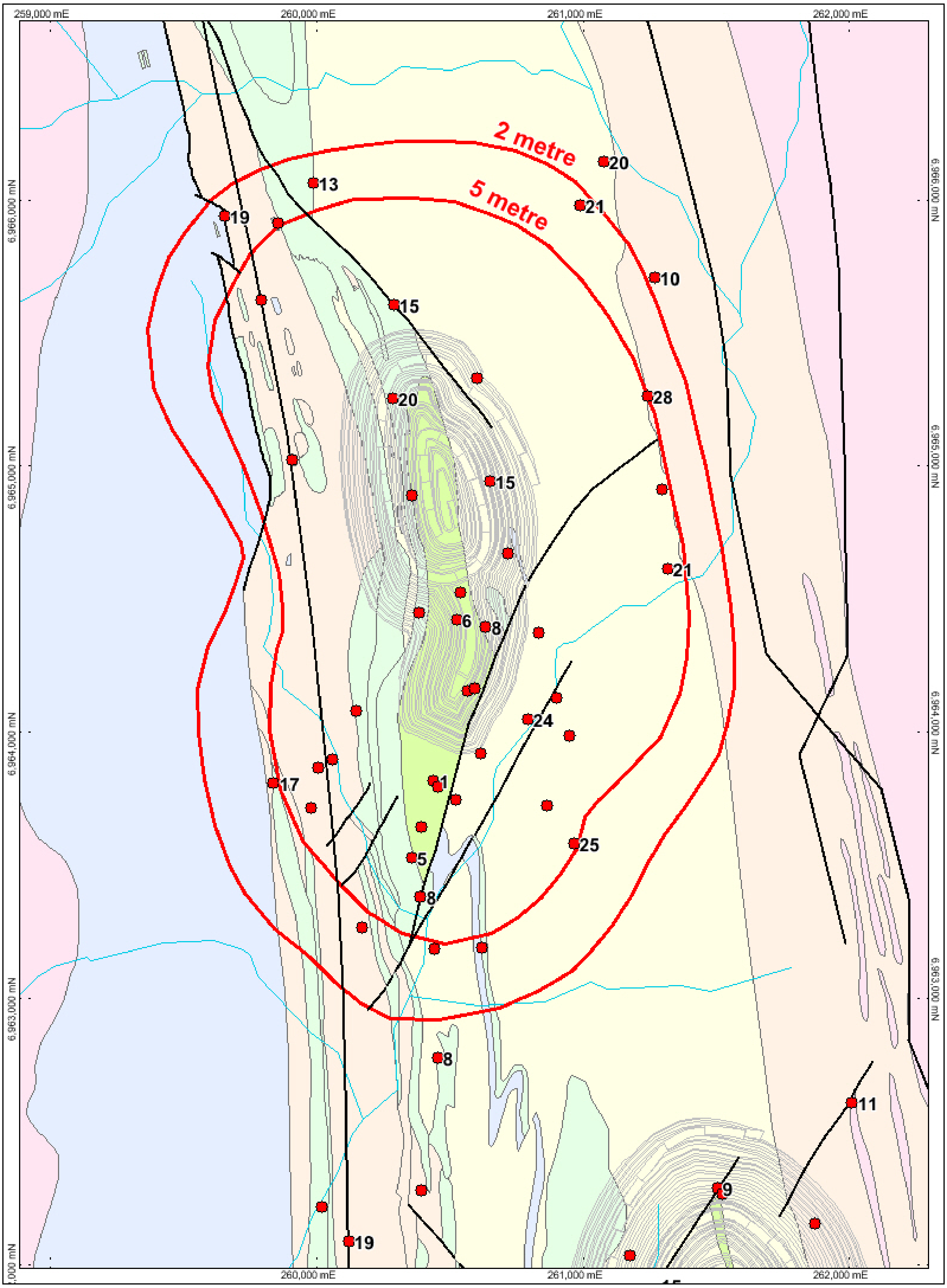
6.2.4 Simulation of Dewatering Drawdown

Drawdown induced by pit dewatering was simulated by setting constant head mixed type boundary cells at the base of the pit. The pit constant head boundaries are set to decline from water table level to near (slightly above) the base of Layer 2 over the scheduled four year mining period, thereby maximising the simulated flow rate and extent of drawdown.

Figure 31 shows the simulated extent of drawdown after four years of mine dewatering as the 5 metre and 2 metre drawdown contours. Posted values are the aquifer submergence or the depth of the top of preamble zone below the water table (Section 4.5).

Dewatering is achieved with abstraction at an average rate of 14 L/sec over 4 years. The 5 metre drawdown cone is predicted to extend 500-700 metres from the pit crest along strike and 300-500 metres across strike. Comparing the drawdown cone to the aquifer submergence (Figure 18) it is clear that the extent of partial aquifer dewatering is less extensive than the 5 metre drawdown cone – ie submergence of less than 5 metres is limited to the extent of the dunite ultramafic which is fully enclosed by the 5 metre contour.

Figure 31 - Model Simulated Dewatering Drawdown and Baseline Aquifer Submergence



Comparing Figures 19 (Conceptual model) and Figure 31, aquifer dewatering is limited to the area where the drawdown exceeds the pre-development submergence – ie where the aquifer becomes unconfined. The extent of any partial aquifer dewatering is less than the extent of the 5-metre drawdown contour.

The dunite aquifer will be largely depleted by dewatering, however the array of minor aquifers in the surrounding country rock will mostly remain fully saturated and hence environmental values will be largely unaffected in these minor aquifers. The rock types and general geological characteristics of the greenstone belt and hence the hydrogeological regime hosting the array of minor aquifers is continuous for several 10's of kilometres to the north and south of the project area.

6.3 The Post Closure Pit Lake Water Level Recovery

The evolution of the backfilled void and pit lake after closure is potentially influenced by the following parameters:

- Pit geometry – volume surface area relationships
- Rate of groundwater inflow and through-flow
- Depth range of aquifers
- Water quality of inflowing groundwater
- Rainfall and evaporation rates
- Chemical interactions between water and wall rock/backfill

Following the methodology used for other pit lakes in the region, models simulating the post-closure water balance were developed to simulate the recovery of water level after closure. Inputs to the model include geometrical parameters, rainfall, runoff groundwater inflow and evaporation.

6.3.1 Goliath Pit Lake

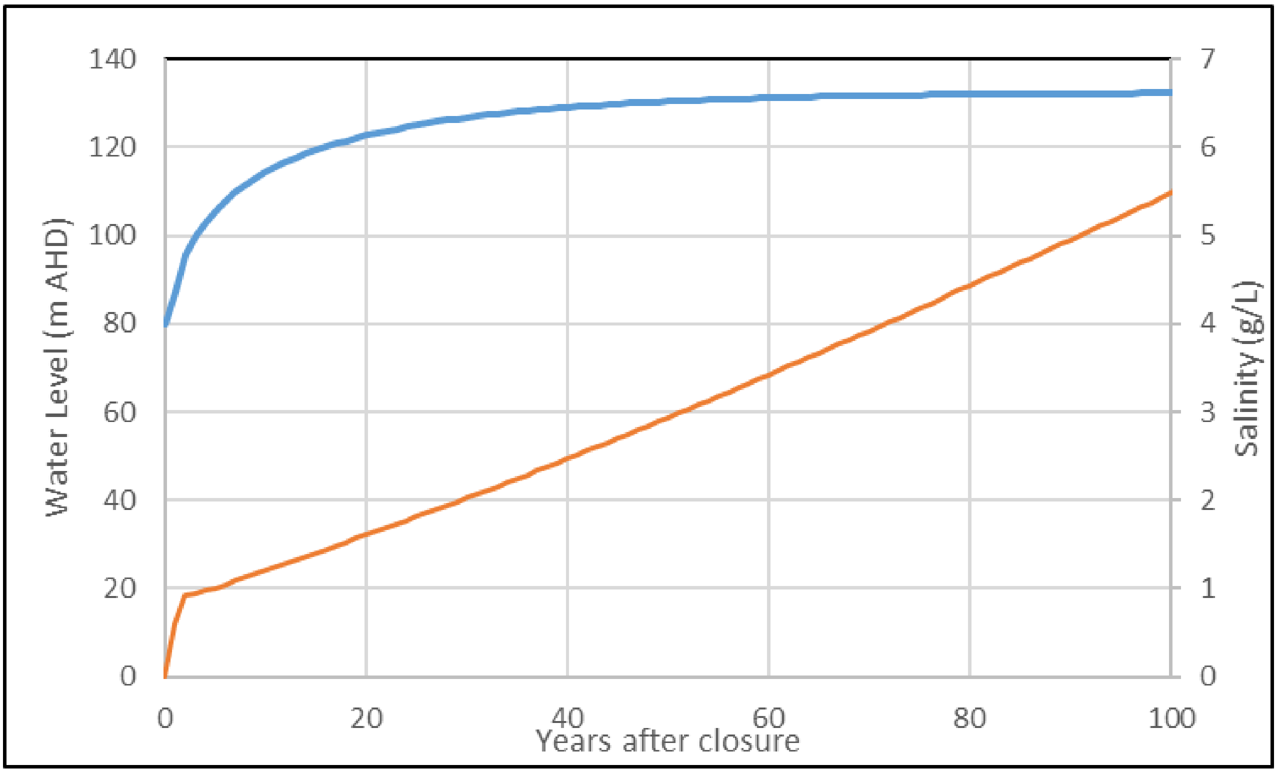
From the hydrogeological appraisals made for dewatering the expected long term groundwater inflow rate for the Goliath Pit is 2 L/sec. The main aquifers (such as are present) are at a depth of less than 100 metres, which means that inflow is unchanged while water levels remain below this depth. The assumed long term groundwater salinity for the Goliath pit is 2000 mg/L for the Goliath pit. Regional groundwater quality and host rock mineralogy/geochemistry dictate that salinity will be the dominant parameter in dictating overall groundwater quality characterisation.

Accretion of rainfall (P) from the pit catchment to the pit lake depends on run-off coefficient from the pit slopes and precipitation directly on the lake surface. Drainage models developed for the Mt Keith pit shows a long term average run-off coefficient of about 40%, with much of the low intensity rainfall resulting in little runoff to the pit. Net evaporation (E) from the pit lake surface differs from the simple subtraction of rainfall from evaporation according to pan factor (0.7 adopted) and the brine factor (will remain close to 1.0 for several hundred years then gradually decreases with increasing salt build up in the pit lake.

The results of the model simulation of water level recovery and salinity build-up are shown in Figure 32.

After completion of mining to the pit floor at 80 m AHD, the water level will gradually stabilise at less than 140 m AHD, leaving a small pit lake with a water level more than 300 metres below the pit crest. Short term fluctuations relating to the most extreme rainfall events will result in relatively minor variations from the long term water level trend line, having a magnitude of no more than 2 metres and duration of several months. Salinity reaches 5.5 g/L after 100 years and continues to rise linearly thereafter. Over thousands of years as salinity increases above 50 g/L then brine factor reductions in pit lake evaporation rate superimpose a very gradual rise in water table level and a very gradual reduction in the rate of salinity increase.

Figure 32 – Goliath Pit Lake Model



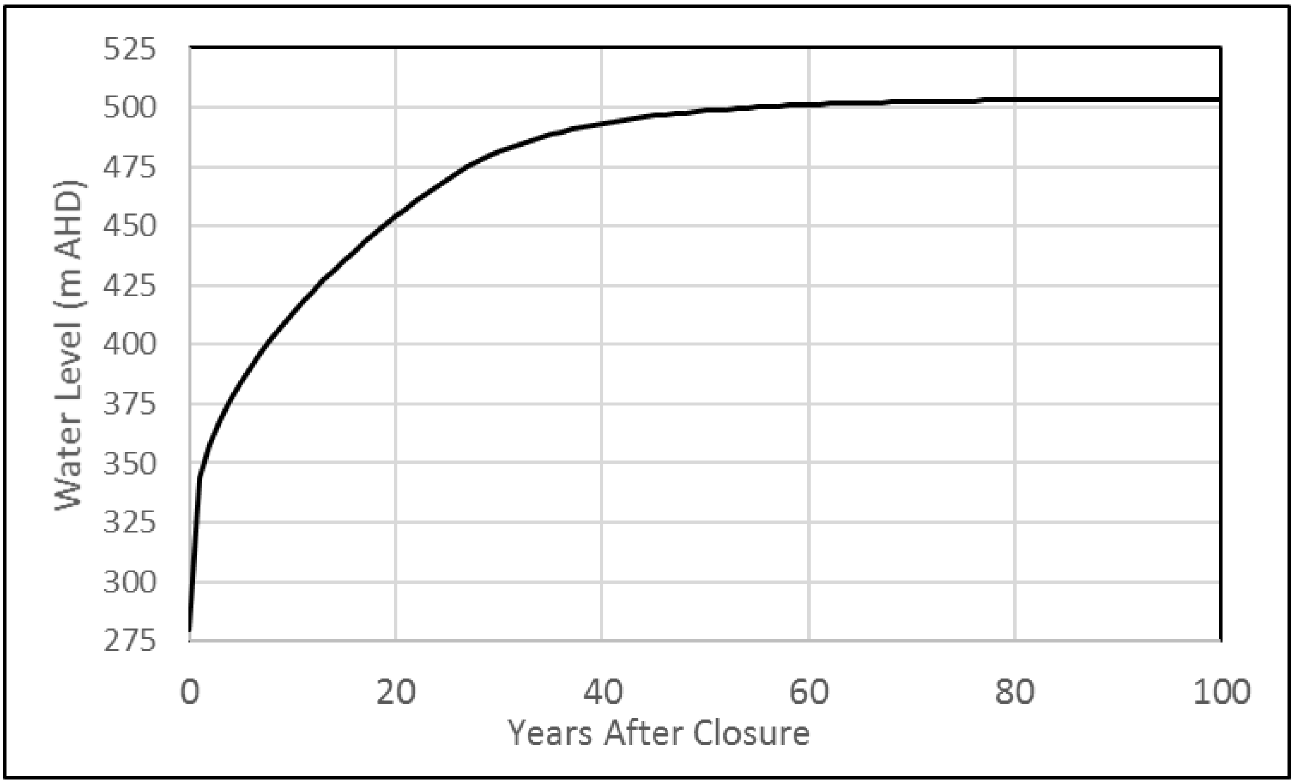
6.3.2 SMW Backfilled Pit

A similar volumetric model to that described above was used. The backfilled pit is not subject to evaporation losses such that groundwater levels will recover, at least to the baseline water table level (503 m AHD). Storage in the backfill is reduced to the residual void space (25%). The maximum (early time) rate of groundwater inflow was based on the results of the numerical flow model. The rate declines linearly after the water level exceeds the base of the main aquifer, to zero at the baseline water level and negative (outflow) at higher water levels.

The final steady-state water level is dependent of the rate of groundwater recharge. The recharge rate through the fill is dependent on run-off and vegetation interception of the final cover. Recharge rates have been estimated based on the assumption of a moderately compacted and gently mounded surface and a low scrub/grass vegetation cover being gradually re-established. Initial recharge rates will be very much higher than baseline conditions, rates will decline as surficial fines are rearranged and vegetation is established but will remain very much greater than baseline conditions (less than 10 mm/year). The assumed recharge rate is 35 mm /annum (15% of rainfall) declining to 12 mm/annum (5 % of rainfall) after 20 years. The early value affects the rate of water level recovery and the later value the final steady rate water level or degree of mounding and additional groundwater through-flow away from the site.

The resulting predicted water level recovery is shown in Figure 33.

Figure 33– SMW Backfilled Void – Simulated Water Level Recovery



The assumed long term recharge rate (5%) results in the steady state water level 0.6 m above the background water level with the additional (increase over baseline) groundwater flux from the backfill of about 0.3 L/sec.

6.4 Chemical Interactions Between Wall Rock, Backfill and Water

Investigations into the geochemical characteristics of host rocks and low grade ore (which occur in small quantities in the pit walls) were reported by Graeme Campbell and Associates (2005). The criteria for potentially acid forming material were established based on:

Sulphide-S: sulphide sulphur content
NAPP: net acid producing potential
ANC: acid neutralising capacity
MPA: maximum potential acidity (calculated by assuming complete oxidation of sulphide-S)
NAPP: net acid producing potential (calculated as MPA-ANC)

The criteria for PAF classification being either:

Sulphide-S ≥ 0.3 %, and any positive-NAPP value
Sulphide-S ≥ 0.3 %, and a negative-NAPP value with ANC/MPA < 2.0

In general, it was concluded that:

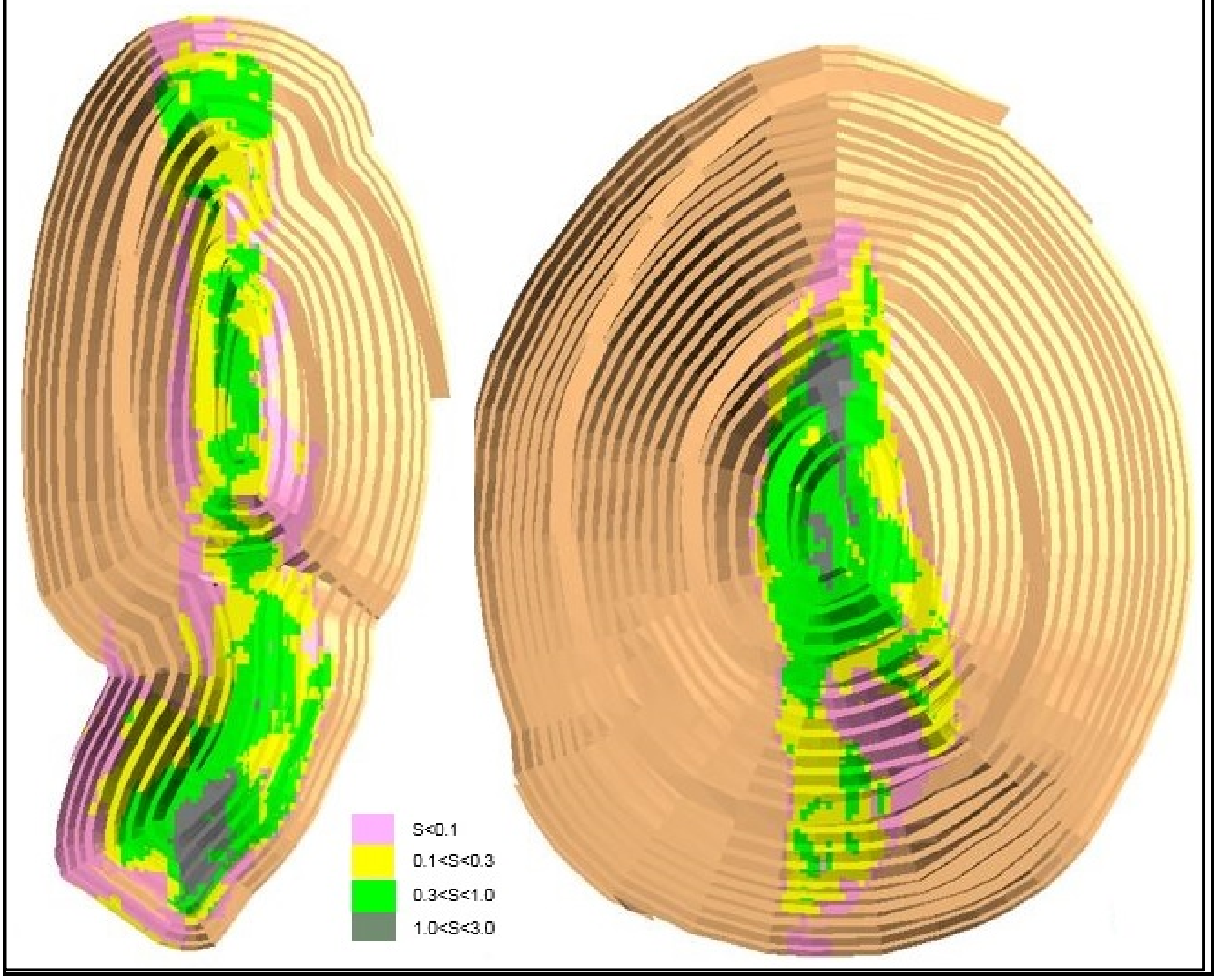
“ waste rocks have meagre abundances of sulphide-minerals dispersed throughout a groundmass with moderate-high capacity to consume acid… accordingly the waste bedrocks are classified as non-acid forming”.

A notable exception was identified as the volcanic sediments unit which forms a portion of the Chert/Shale (Distribution shown in Figure 16). Samples of the volcanic sediment unit contained total-S values of 2 – 16 %, and despite high ANC the material was classified as potentially acid forming (PAF). This material occurs in thin bands and very low volumes in both pits. The situation is similar to the Mt Keith where large scale mining and co-disposal with high ANC material limit the potential for acid leachate at a significant scale. The slight residual risk can be controlled by using routine operating procedures from Mt Keith, which ensure that high S material is identified during drill and blast cycles and then managed during excavation and WRD emplacement.

Note that subsequent to the geochemical assessment (part of the 2005 impacts assessment), Nickel West have developed improved processing of high talc content ores. This change has resulted in more low grade material being classified as ore, resulting in a further reduction in the mineralisation of material emplaced in the WRD.

Figure 34 shows the distribution of total sulphur (including non-reactive sulphate as well as Sulphide-S) in the walls of the final SMW Pit and the Goliath Pits.

Figure 34 - Total Sulphur in the Six Mile Well (left) and Goliath (right) Pit Shells



Larger areas of elevated sulphur are limited to the central ultramafic unit which is exposed in the floor of the pit and in bands at the north and south ends. Routinely measurable sulphur (>0.1%) is largely absent from the larger west and east walls of the pits. At SMW higher sulphur (1-3%) occurs in the southern wall at 370-460 m RL. At Goliath there is a small zone of higher (1-3%) S wall rock deep in the northern side between the 130 and 160 m RL benches and the large majority of >0.3 % S wall rock below 160 m RL.

The limited distribution of elevated sulphide material in the pit walls and the overwhelming high ANC for most wall rocks means that there is no possibility of acidification of the SMW backfill groundwater or the Goliath pit lake.

After closure, the Goliath pit will partially refill to form a very deep pit lake and minor discharge zone from the generally impermeable country rock. Lake water will initially reflect the chemistry of groundwater, being brackish and with low levels of trace components except for slightly elevated boron. As discussed above, evaporation is the dominant process in controlling changes in water quality and will causing a continuous long term increase in the concentrations of all dissolved constituents and notably increased salinity. Trace element concentrations are unlikely to affect the pit lake water quality categorisation or constrain water use at any time, since increasing salinity will be the dominant constraint.

Groundwater levels in the backfilled SMW void will recover to approach the original static water level after about 50 years. Water levels will then continue to rise and slightly exceed baseline levels (due to increased recharge through the backfill) over about 100 years and long term water quality is expected to be slightly improved. Groundwater is the volumetrically dominant source of water which will re-fill the void, so that void water quality groundwater will reflect the quality of natural groundwater as described above - ie brackish (about 4.5 g/L) and with low levels of trace elements. A very gradual reduction in salinity will occur due to enhanced rainfall recharge through the back-fill.

7. OPERATIONS WATER BALANCE

7.1 The Existing Mt Keith Water Circuit

Mt Keith's current operations include a largely integrated water supply network. Groundwater abstraction for supply is under licence issued under RIWI Act licences issued by Dept. of Water and Environmental Regulation (DEWR) and management conforms to the DWER approved Operating Strategy (Nickel West, March 2016).

The existing Operation has five Groundwater Well licences for a total allocation of 18 GL/a (570 L/sec) and typical annual use is 11 GL (350 L/sec). There are 7 main water supply sources including:

- The Albion Downs Borefield - typical supply 260 L/sec of saline water
- The Caprock and South Lake Way Borefields – typical supply 50 L/sec of sub-potable water
- The Village Borefield - typical supply 5 L/sec of sub-potable water
- Mt Keith Pit Dewatering - typical supply 15 L/sec of saline water
- Cliffs Mine Dewatering - licenced by Nickel West Leinster , typical supply 10 L/sec
- Stormwater Harvesting – highly variable supply averaging about 10 L/sec

Water supplies for the Satellite Pits will be partially integrated with the existing Operation system. Operational management will be as per the existing mine. Nickel West have submitted a revised Operating Strategy for GWL 63902 which will regulate dewatering abstraction at the satellite pits. The document reflects operation practise at the current Mt Keith pit and specifies an annual abstraction limit of 1095 ML or an average of 35 L/sec. The total includes allowances for groundwater and for stormwater which can occasionally be a large sub-total (Nickel West, June 2017).

7.2 Site Water Balance

Dry Weather Demand

Water requirements have been estimated from historical Mt Keith Pit usage as follows:

Local haul road dust suppression	15 L/sec
ROM dust suppression	5 L/sec
Drilling	2 L/sec
Mt Keith Road dust suppression	20 L/sec
Ancillary	3 L/sec
TOTAL	50 L/sec

These are typical dry weather requirements when dust suppression water trucks are operating at normal capacity. Annual averages will be lower, with lower use during occasional rainy periods.

The net increase in demand to the existing integrated Mt Keith water balance requirement is 20 L/sec, since the only additional demand component is the "Mt Keith Road dust suppression" - all other components are simply relocated from the existing Mt Keith Pit to the Satellite Pits. The net increase is partly offset by additional local supplies.

Dewatering Supply

Groundwater modelling indicates that dewatering of the SMW pit will generate a yield of 15 L/sec for about 4 years after which the yield is expected to drop to about 10 L/sec. The Goliath Pit is expected to yield small quantities of groundwater which will not materially impact the dry weather water balance. The higher yield from the SMW pit will be obtained during the first 3 years of the mine schedule, ie during Goliath Stage 1.

Dry Weather Supply Deficit

The dry weather supply deficit for the stand-alone project water balance will initially be 35 L/sec and will increase to 40 L/sec after about 4 years.

From an integrated Mt Keith perspective, the water balance deficit is offset by reduction in water use at the Mt Keith Pit, such that the net deficit is 5-10 L/sec.

7.3 Make-up Water Supply Options

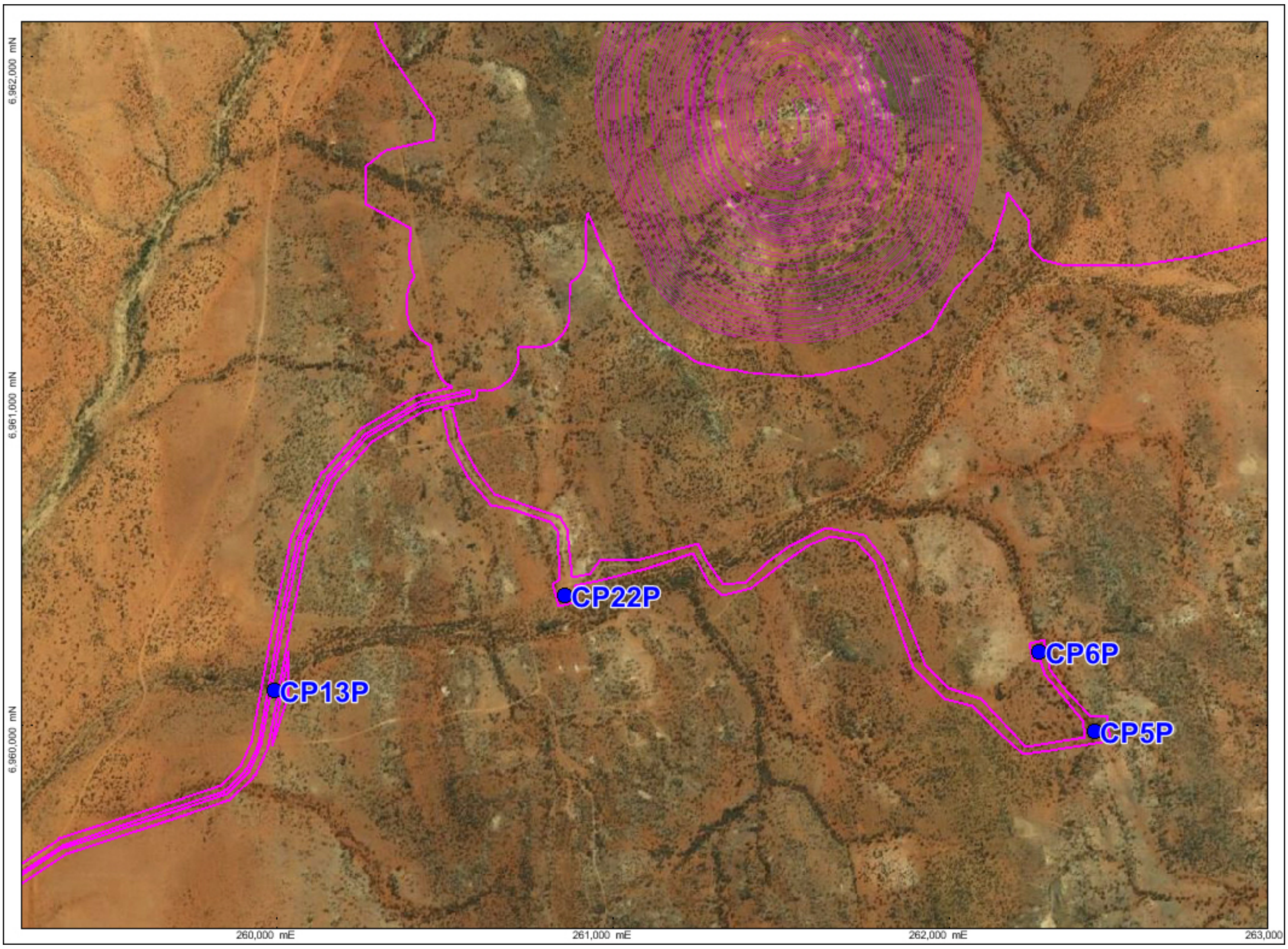
7.3.1 Local Bores

The satellite pits region was explored for groundwater as part of the early 1990's phase of investigation. Low yields were obtained from most drill-holes, however production bores were completed and tested at four locations. These bores intersect minor localised aquifers at the intersection of a structure with a lithological contact. The linear nature and limited extent of the aquifers is evident from the test-pumping results.

The aquifers comprise a single narrow and steeply dipping zone of extent 10's to 100's of metres horizontally and 10's of metres vertically. The fracture zone has moderate permeability, but very limited storage and long term groundwater is yield is derived from leakage to the fracture zone form very low permeability host rocks.

Bore locations are shown on Figure 35.

Figure 35 – Local Water Supply Bores



Pumping test results have been analysed and indicate that a yield of 3 L/sec can be obtained from each of three bores with CP5P and CP6P being so close as to constitute a single site. The local bores have inadequate capacity for the water supply shortfall and can only make a modest contribution to the shortfall. Water quality is good and one or more of these bores could be used as a supply for production of potable water.

7.3.2 Existing Mt Keith Sources

In the context of the existing Mt Keith water balance the project represents a moderate change (relocation of mining demands) and a very small increase in overall water requirement. All supply sources currently available to Mt Keith are sustainable at current abstraction rates in the very long term (MWES, 2016). The additional local water resources (SMW pit dewatering and local bores 10-15 L/sec) will be slightly less than the increase in demand (20 L/sec) for a net demand increase of 5-10 L/sec.

Current supply sources to the Mt Keith Concentrator are detailed below. The two sub-potable borefields have a combined allocation of 4.8 GL/a (150 L/sec) and typical abstraction of 50 L/sec. The South Lake Way borefield capacity was upgraded in 2010.

The Cliffs mine, located near the Mt Keith Village and airport has a long-term dewatering excess of 20 L/sec. Currently the Cliffs mine water is used to make-up the Mt Pit supply deficit however there remains a surplus (about 10 L/sec) which is currently discharged to the Mt Keith TSF. Whilst this excess is partially recovered by decant to the Mt Keith Concentrator the location is favourable for re-directing this supply south for use at the satellite pits.

7.3.3 Southern Borefield

The southern (or Yakabindie") borefield is located 20 km south-southeast of the MKSP site on miscellaneous licence tenements L36/67-81. It was constructed in 1989 as part by previous owners whose project plan included a new nickel concentrator at the project site, rather than transporting ore to Mt Keith for processing. The borefield was designed for a much larger water requirement than the current project.

Nickel West holds GWL 63896 allowing abstraction of 1.5 GL/a (48 L/sec). The borefield was last used to supply water to the Cosmos Mine in 2012 (since closed) , under agreement with Nickel West.

7.4 Mt Keith Concentrator Water Supply

The project will add 10 years of concentrator operation, with satellite pit ore processed from early in FY21 to early FY32. Existing water supplies to the Mt Keith Concentrator will maintain the supply as follows:

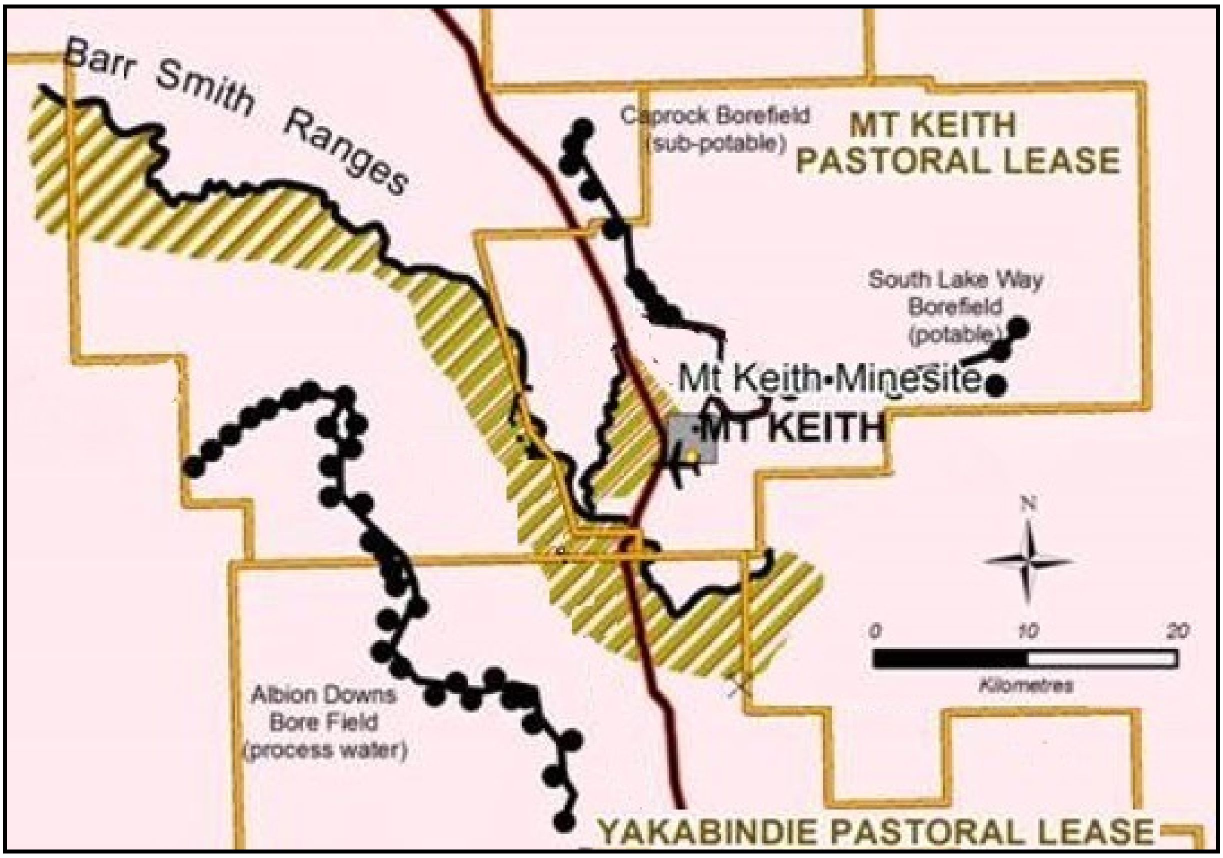
- Process supplies from the Albion Downs Borefield
- Sub-Potable supplies from the Caprock and South Lake Way Borefields
- Village supplies from the Village Borefield
- Additional saline supplies from the Mt Keith Pit and Cliffs Mine
- Minor water harvesting facilities

The general layout of the Mt Keith concentrator water supply borefields is shown below in Figure 36

For the additional complete years of operation of the Mt Keith concentrator (FY22-FY30) the total additional throughput of ore is 99.4 MT of ore and the average rate of throughput is 9.8 MTpa. The milling rate and water intensity of milling are expected to be unchanged from the current operational conditions. The project represents a 10-year continuation of the current Mt Keith water demand situation. Existing supplies from the Mt Keith pit will not be required for mining operations and hence provide a minor net positive to the water supply.

The hydrogeology of the borefields is described in the Groundwater Well Licence Operating Strategy (Nickel West, March 2016) The viability of continuation of the existing water supply sources for an additional 15 years (5 years for the existing Mt Keith pit source and 10 additional years arising from the MKSP project) can be determined from the existing borefields reports, including the annual production summaries and triennial aquifer reviews. The most recent annual production summary includes monitoring results for the period to June 2017 (MWES August 2017). The most recent triennial aquifer reviews complied monitoring results to June 2016 (MWES, November 2016).

Figure 36 – Mt Keith Concentrator Water Supply Borefields

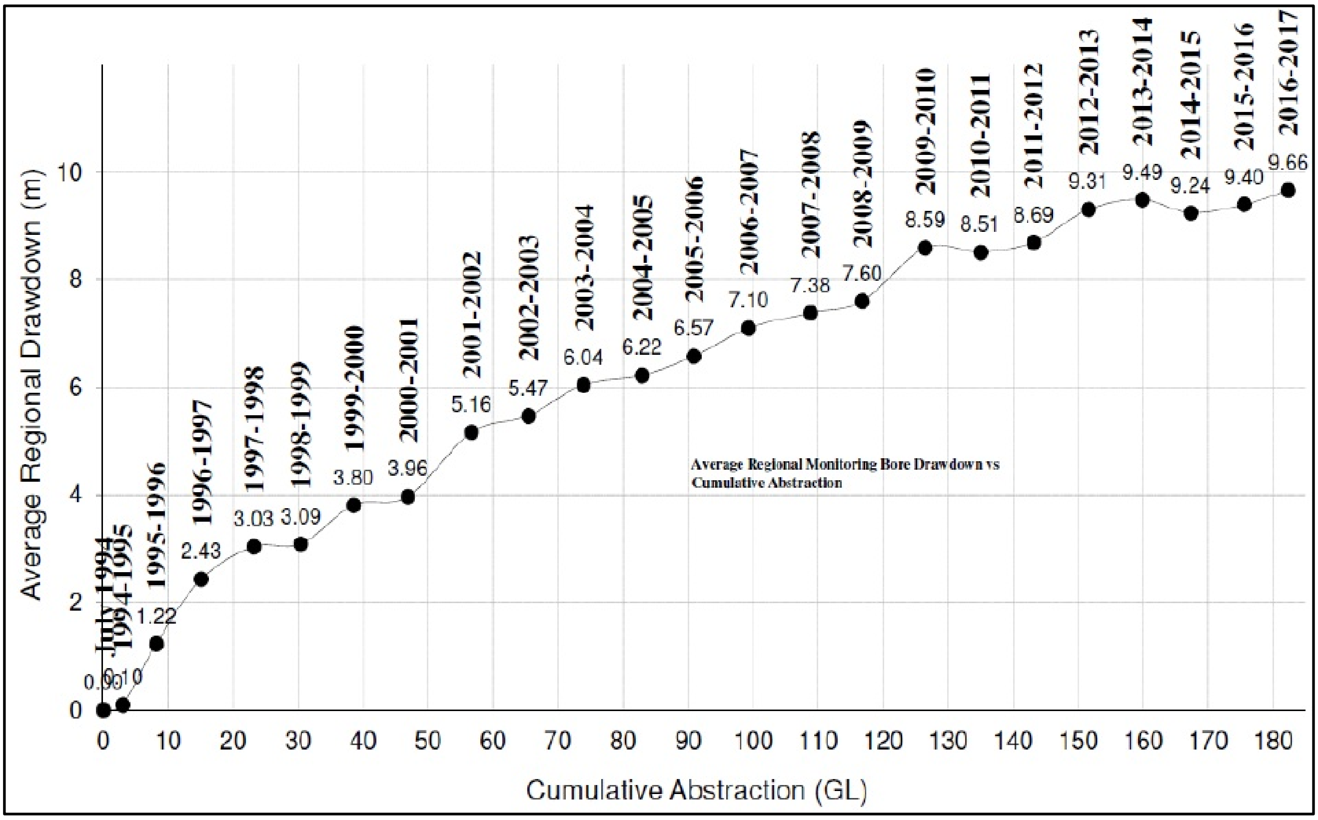


7.4.1 Albion Downs Process Water Supply

The Albion Downs Borefield is located 30-50 km southwest of Mt Keith mine on the Albion Downs and Yakabindie pastoral leases. The borefield is developed on a typical Yilgarn region palaeochannel/Cenozoic basin sedimentary sequence. Production bores are sited at about 1.5 km intervals along the axis of a major regional palaeochannel aquifer, located within the broader Cenozoic sedimentary basin. The borefield comprises 32 production bores which typically produce a total of about 9000 ML/a or about 80% of the water supplied to Mt Keith. Long term monitoring has shown a steady and predictable rate of drawdown. This response is typical of groundwater abstraction from storage in a bounded aquifer system. The steady rate of drawdown over periods of substantial variation in rainfall, indicates that rainfall recharge to the groundwater aquifer is a very small component of groundwater abstraction.

The basin-wide upper aquifer response is demonstrated by the water level response in approximately 50 regional monitoring bores. The average drawdown of the regional bores is used as an indication of the depletion of water stored in the upper aquifer. Figure 37 shows the average of regional monitor bore drawdown is plotted against cumulative abstraction.

Figure 37 – Albion Downs Borefield - Aquifer Drawdown Response



Based on long term average process water requirement of 0.81 kL/tonne of ore processed, the development will require a total of 80 GL from the Albion Downs Borefield. From measured abstraction of 169 GL to June 2015, the total abstraction will rise to about 210 GL by the commencement of satellite pit ore in early FY21 and to 290 GL by the end of the mine life in FY31. The long term drawdown rate of 0.04 m/GL indicates that average regional upper aquifer drawdown will increase from 8.5 m in 2015 to 10.2 m in FY21 and to 13.4 metres by 2031.

The prognosis for borefield operation and impacts from the extended borefield life is not substantially changed from the most recent aquifer review. Basin delineation drilling at the time of the borefield development showed that the typical saturated thickness of the upper aquifer was 15-20 metres. The residual saturated thickness of 7-12 metres (2015 water levels) should allow will allow ongoing supply from the existing borefield at current rates to 2031. Additional water storage in the aquitard, lower aquifer and surrounding host rocks will provide further capacity although possibly at diminishing rates. Ongoing localised trends of rising salinity are likely to continue as brackish-saline water in the upper aquifer is further depleted and saline-hypersaline water from the lower aquifer dominates the overall supply. The impacts on the salinity increases on the quality of the aggregate supply are moderated by the fact that many of the bores already deliver water of stable hypersaline quality.

7.4.2 Caprock Borefield Sub-Potable Supply

The Caprock Borefield comprises a 15 km northern pipeline extending north from the Mt Keith Mine and includes 7 operational production bores. Four southern bores tap separate minor bedrock aquifers and three northern bores tap a short segment of a minor palaeochannel. The borefield has typically supplied 40 % of sub-potable requirements. Typical annual total borefield abstraction of about 650 ML is about 6% of the total groundwater supplied to the operations.

The Borefield is a collection of small isolated aquifers. Drawdown is localised by the limited geological extent of the aquifers and the low yield. Monitoring is therefore focused on local water levels without a regional network of monitor bores. The four southern ultramafic rock hosted Caprock bores are operated by partially dewatering the small localised aquifer to maximize leakage into the “reservoir” from the surrounding low permeability country rock. Pumping water levels are well within the aquifer zone at each bore site. The instantaneous/short term pumping capacity of each bore pump generally exceeds the sustainable capacity of the bore and the bores are operated on rotation (over several months) to allow for water level recovery and seasonal variations in mill demand. The three northern palaeochannel bores exploit a more robust aquifer. Since a very small portion of the palaeochannel has been developed, it can be expected that any localised depletion will be ameliorated by flow along the channel from undeveloped areas; i.e. the limited extent of development of the aquifer means that severe/extensive depletion of the aquifer is not possible.

On this basis it is expected that historical rates of supply from the Caprock borefield can be sustained indefinitely. The borefield is currently licensed by the Department of Water for supply of up to 1500 ML/a GL/a until 2022, this licence having been renewed at least 5 times previously. To meet project requirements would require one further licence renewal for the recent customary duration of 10 years. Provided licence conditions continue to be met, it is anticipated that this renewal would be issued in a routine manner.

7.4.3 South Lake Way Sub-Potable Supply

The South Lake Way Borefield extends 20 km east from the NMK site providing 60% of sub-potable process water to the Concentrator, typically about 1000 ML/a or 9% of the total groundwater supply. The borefield is developed in the upper reaches of a typical Yilgarn region palaeochannel/Cenozoic basin sedimentary sequence. There are eight production bores widely spread along 20 km of the east trending palaeochannel. Bores target the axis of a narrow sand-filled channel deposit at the base of the Cenozoic sediments. Mixed sediments of low-moderate permeability form a shallow (up to 50 m deep) broad (2-3 kilometre width of saturated alluvium) unconfined aquifer overlying the palaeochannel axis. This upper basin provides the bulk of water storage to the borefield. To the west of the TSF bores SLW16 and SLW17 are situated upstream of the main palaeochannel axis and tap fractured bedrock underlying low-permeability and shallow alluvium.

For aquifer resource evaluation, the borefield can be considered as three independent components:

SLW16 and SLW17: located west of the TSF are low yielding bores tapping relatively isolated fractured rock. Similar to southern Caprock bores these are operated at high drawdown with pumping water levels near or within the aquifer zone to maximise yield from surrounding rock. There is little potential for extensive drawdown impact and the historical rates of abstraction should be sustainable indefinitely.

SLW02, SLW03 and SLW04: Located east of the TSF these bores tap alluvial aquifers. Water levels are stable or rising indicating that TSF seepage and rainfall recharge are volumetrically dominant over groundwater abstraction so that maintaining the current rates should be possible.

SLW07, SLW08 and SLW09: The eastern bores are located where the palaeochannel and shallow alluvial sedimentary basin is thicker and broader. The main reservoir is the shallow alluvium. The aquifer response is well defined by the average drawdown in regional monitor bores in a similar manner to the Albion Downs borefield, however drawdown at South Lake Way is very much less than at Albion Downs. Abstraction of 8.6 GL from 1994 to June 2013 had induced a drawdown of 2.4 metres and the long term drawdown trend was 0.21 m/GL. The required yield from the area of about 0.5 GL/a will produce a drawdown rate of about 0.1 metre per year which means that the bores can maintain current supply rates for at least several more decades.

The borefield is currently licensed by the Department of Water for supply of up to 3285 ML/a until 2022, this licence having been renewed at least 5 times previously. To meet project requirements would require one further licence renewal for the recent customary duration of 10 years. Provided licence conditions continue to be met, it is anticipated that this renewal would be issued in a routine manner.

7.4.4 Village Borefield

The Village Borefield comprises seven equipped production bores VB01-VB05, VB10 and VB12, located within 3kms of the Mt Keith Village. Typical annual abstraction is about 150 ML or about 1.3% of the total from the five groundwater licences held by NMK. Bores supply near-potable quality water to the Mt Keith Village where it treated by reverse osmosis fir use as a potable supply.

The bores draw water from minor and relatively isolated fractured ultramafic and granitoid hosted aquifers.. As is common for fractured rock aquifers, the bores are operated with relatively high drawdown - i.e. with pumping water levels below the top of the aquifer zone. This allows a maximum amount of leakage to the aquifer zone from surrounding low permeability bedrock. Since the yield is naturally limited by the rate of seepage from surrounding country rock into the fracture system tapped by the bore, there is no potential for long term depletion and current supplies should be available indefinitely.

The borefield is currently licensed by the Department of Water for supply of up to 275 ML/a GL/a until 2022, this licence having been renewed at least 5 times previously. To meet project requirements would require one further licence renewals for the recent customary duration of 10 years. Provided licence conditions continue to be met, it is anticipated that this renewal would be issued in a routine manner.

8. STORMWATER MANAGEMENT

8.1 Management Objectives and Performance Indicators

The development is located in the regionally unusual and sensitive Jones Creek surface water catchment; hence operations will require a greater focus on stormwater management than is required for existing Mt Keith operations. The primary objectives for design and operation of stormwater controls at the site are:

- Quantity - maintain the existing flow regime and minimise the reduction in clean water yield to the Creek
- Quality - Preserve the stream bed environment by minimising the additional sediment load to the Creek

The objectives will be achieved by appropriate separation of background run-off from impacted stormwater and appropriate control and release of impacted stormwater. Key performance indicators relevant to the management of surface water are as follows:

- No loss of environmental values as a result project related impacts on the flow regime and water quality
- No impacts on third party users

8.2 Risks, Strategy and Management Measures

8.2.1 Pit Flood Protection

On paramount importance is to avoid direct stream flow ingress to the active pits. The overflow of Jones creek or a significant tributary into a mine pit would be dangerous and environmentally unacceptable and must be prevented.

Substantial creek-pit interactions have been prevented by pit design, in particular including the horizontal set-back between Jones Creek and the SMW pit. There remains the potential for pit capture for brief periods at extreme flood levels, the maximum risk is for the capture of a small portion of the total flow for several hours per 100 years. Minor bunding has been detailed to address this residual risk.

8.2.2 Diversion of clean water

The permanent landforms (pits and waste rock dumps) and to a lesser extent temporary features (stockpiles and infrastructure) can result in isolation of portions of the catchment and potentially unnecessary reduction in yield of stormwater to the Creek.

The design layout of these features has been adjusted to minimize this effect and to promote opportunities for clean stormwater to be efficiently routed around the structures. The operational and post-closure diversion of clean water around major project landforms is a key component of the management strategy and will be incorporated into all project and operational revision and modifications.

Key permanent diversion structures include:

- WRD north drain
- WRD south drain
- SMW pit north drain

These final design capacity of the drains should be the 1:10 year peak flow calculated from the Mt Keith Regional Flood Flow Estimation method described above. The drains should include bunding such that peak flows exceeding 1:100 year level remain on the clean side of the drain. The main drains are expected to have low maintenance requirements, however inspections will be required and will be scheduled into normal site EMS and wet weather procedures.

8.2.3 Control of first-flush impacted water

Areas impacted by mining will accumulate materials subject to remobilization by stormwater as potential contaminants. The volumetrically dominant material is oxidised waste rock which may undergo further weathering resulting in the potential for erosional release of fine-grained suspended solids which can clog and dis-color the exiting coarse grained creek sediments.

The primary control is part of the existing Mt Keith dumping procedure, whereby non-competent waste rock is identified in detailed operational mine plans and scheduled for emplacement centrally within or distant from the edges of the WRD toe.

Additional controls include a series of silt traps. Preliminary locations have been established for revision based on needs identified from detailed stock-pile and dump sequencing. Key areas for coverage are potential high sediment source areas, including steep concentrated flow paths from areas where oxide material will be stored and exposed continuously over periods of months to years. The structures are constructed as low gully spanning embankments. A portion of the storage behind the embankment is as void space in a back-filled rock pad, to minimize through-flow of sediment. The silt trap/check dam/rock pad features include:

- small semi-porous embankments (<2.5 metre-high) across key drainage lines
- unlined, no recovery pumps, water detention not retention
- partial backfill with loose coarse crushed rock (d_{50} ~ 200mm) of high size uniformity
- First flush storage capacity with overflow for ongoing run-off
- Containment for volume equivalent of 4 mm run-off depth across sub-catchment

The silt traps will require regular inspections to ensure the original live storage volume is a maintained. Occasional excavation with a loader will be required.

8.2.4 Creek Crossings

Two main haulage creek crossings are planned. Potential impacts from the haul road crossings mainly relate to Jones Creek water quality, particularly excessive additional sediment load. When the particle size distribution of the additional load is exotic to the natural stream bed, impacts would be exacerbated. M
Minor creek flows can typically be expected following 24 hour rainfall totals of 30 mm or typically about once per year. Based on rainfall IFD data the expected flow frequency is slightly more than once per year flow with typical duration of several hours. Continuous flow for between 48 and 72 hours has an expected frequency of about 1:100 years.

Considering the low frequency and duration of flow events, a low level “ford” is the appropriate creek-bed crossing. The following measures should be employed to mitigate excess sediment entrainment by intermittent creek flow events:

- Very coarse rock (d_{50} = 600 mm) armouring of the bank cut sections up to the 1:100 year flood
- Minimum build up of road surface above natural creek level in mainstream
- Initial construction and maintenance (after flow events) to use stockpile of suitably graded material (minimal fines and particle sizing compatible with creek sediments)
- Best operational practice to minimize vehicle tracking of sediment during wet periods including:
    - Cladding of roads with appropriate materials
    - Road drain and surface maintenance to avoid build up of sediment on roadways
    - Wheel wash as appropriate

8.2.5 Mt Keith Haul Road

The haul route is located relatively high in the catchment. There is little inaction with well-defined natural drainage lines, beyond the crossing of Jones Creek at the south end of the route -which is considered above. The main environmental impacts risks are associated with “shadowing” of vegetation from natural stormwater flow. In addition there is the potential for increased natural erosion where the haul road crosses or traverses close to break-aways where erosion prone regolith materials outcrop and may form the substrate to the road. These issues is mainly controlled at the design stage whereby the following measures have been incorporated:

- Route selection – including adjustments to minimize grade, break-away interactions and swale crossings
- Route selection to minimize clearing and bisecting areas of larger vegetation
- Construction of the road crest close to the natural land surface to minimize impedance of sheet surface water flow

8.3 Monitoring Regime

Characterisation of water quality in highly ephemeral water courses can be problematic since quality is highly sensitive to conditions in the catchment between flows, to the pattern of rainfall causing the flow and to the point in time during the event in which samples are taken. Investigations into ore and waste rock geochemistry show little potential for mined materials to impact the solution chemistry of surface water.

Jones Creek has substantial suspended sediment loads due to the natural erosional conditions in the catchment and due to previous disturbances related to wildfire, pastoral and mining industry activities. Project impacts assessment will focus on identifying changes to stream sediment characteristics.

Operational monitoring will comprise two components:

<u>Inspection of control structures</u>

- Diversion drain condition – visual check for silting and erosion, photograph records as required, re-survey of profile and cross-sections as required
- Silt trap condition and storage capacity – visual check for sediment build up, survey of floor elevation as required, re-excavation as necessary
- Creek crossings – routine reporting of sediment build-up. Scrapping and sweeping as required

<u>Environmental monitoring</u>

Impacts to be determined by sediment sampling in the downstream creek bed by reference to the preliminary baseline assessment report (SKM, June 2005).

- Locations – initial six sites identified in baseline report, plus at least 4 additional sites to be selected between the upstream haul road crossing and the upstream SKM site (#1) and 2 sites upstream of the upstream haul road crossing
- Frequency – two rounds prior to project commencement and following substantial flows thereafter
- Survey, photography and description of channel and upstream/downstream reaches
- Particle size distribution from representative integrated “channel” sample and for selected locally representative fine-grained facies
- Geochemical analysis for the two sediment samples – laboratory methodology and analyte list as per SKM (2005) .

9. GROUNDWATER MANAGEMENT

Groundwater management is prescribed in the GWL Operating Strategy (Nickel West , June 2017) where all aspects of groundwater management are specified as groundwater well licensing conditions.

9.1 Management Objectives and Performance Indicators

The main groundwater resource in the project area is the regolith aquifer which is formed by weathering/alteration of the ultramafic which hosts the SMW orebody. The aquifer is a small and isolated brackish water resource and mining will result in it's removal and replacement with coarse waste rock backfill.

9.2 Risks, Strategy and Management Measures

There are no major environmental risks relating to groundwater. The evolution of the pit voids after closure is controlled by a number of hydrogeological and geochemical parameters, however it is demonstrated that these water bodies will not pose a threat to any significant groundwater resource. Natural water levels around the pit area are considered to be too deep to be a primary source to existing vegetation such that further drawdown from mine dewatering should not have impacts. Groundwater conditions in pit slopes may be relevant to pit slope stability assessment which further relates to the long term post-closure pit slope evolution – this being potentially relevant to ensuring pit-creek isolation.

The primary objectives for design and operation of groundwater controls at the satellite pits are:

- Confirm the anticipated drawdown response to the extent required for geotechnical (pit slope stability) assessment
- Capture data to support improved assessment of the post-closure pit lake evolution

These objectives will be meet by operational monitoring.

9.3 Monitoring Regime

Consistent with other nearby pits operated by Nickel West, the monitoring regime will include:

- Metering of total abstraction from each of the pits and bores and collation of monthly abstraction by source
- Annual sampling of discharge from each source for determination of water quality
- Groundwater water level monitoring sufficient for dewatering planning and geotechnical requirements

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Appendix 1 – Drill Data Summary

Bore	Previous Name	East	North	GL	RLWL	Depth	AqGeol	ToAgl	ToArl	ToAs	Slota	Slotb	Yield	EC	Report
GOL01		260452	6962778	521.5	504.6	65	FrUM	25	497	8	17	65	0.5	3810	MWES 2017
GOL02		262009	6962609	538.4	509.3	65	FrF/M	40	498	11	17	65	0.1	1500	MWES 2017
GOL03		261503	6962290	544.3	504.3	65		49	495	9	23	65	0.25	5020	MWES 2017
GOL06	YEX162 re-dev.	263235	6962170	529.8	505.3	92							1	971	OE 2011
GOL07	YEX166 re-dev.	263338	6962137	530.7	506.4	100							0.5	324	MWES 2017
GOL08		260119	6962086	518.9	505.6	46	FrM	32	487	19	10	46	2	272	MWES 2017
GOL09		261273	6961925	532.8		65	FrM	48	485	15	23	65	1	5750	MWES 2017
GOL10		260368	6961793	522.0		65	FrUM	49	473	30	11	65	0.1	2220	MWES 2017
GOL11	CP21 redrill	261840	6961649	532.9		65	FrM	43	490	15	23	65	0.25	3830	Coffey 1991b
GOL12	CP53/CP12P re-dev.	260816	6961565	526	506.2	44	SapUM	21	505	1	11	35	0.5	3970	Coffey 1991b
GOL13	95GPG08/YAKB06/CP12 re-dev.	260859	6961556	525.8		63							1	7150	Coffey 1991b
GOL14		261742	6961261	531.0		65	FrM	42	489	15	23	65	0.5	3880	MWES 2017
GOL15	SHNP2 re-dev.	260779	6960760	520.4	505.1	40	FrUM	42	478	27			0.05	1270	HR 1997
GOL16	SHNX4/SHGCN62 re-dev.	260873	6960741	521.2	505.1	44	FrUM	21	500	5			0.5	1870	HR 1997
GOL17	SHGCN60 re-dev.	260835	6960733	520.7	505.0	44							0.25	3730	Willock 2010
GOL18	SHNP1 re-dev.	260939	6960524	520.2	504.9	68	FrF	65	455	50			0.1	5450	HR 1997
GOL20	CP22P re-dev.	260857	6960385	516.5	504.6	63	FrM	20	497	8	12	36	0.05	1630	Coffey 1991b
GOL21	SHSP1 re-dev.	261046	6960306	518.0	505.4	58	FrUM	31	487	18			0.1	3680	HR 1997
GOL22	GOL22/CP6 re-dev.	262267	6960219	526.9		65								1010	Coffey 1991b
GOL23	CP6P re-dev.	262285	6960213	526.9	504.9	62	FrM	40	487	17			0.25	1140	Coffey 1991b
GOL24	CP13P re-dev.	259998	6960098	513.0	501.3	77	FrM	18	509	0			5	1060	Coffey 1991b
GOL25	SHSP2 re-dev.	261252	6960094	526.7	506.2	80	FrUM	60	467	39			1	1830	HR 1997
GOL27	CP5P re-dev.	262430	6959978	529.9	504.5	59	FrF/UM	40	490	15			0.1	1380	HR 1997
GOL28		260833	6959937	520.1	505.0	65	FrUM	48	472	33	17	65	2	1150	MWES 2017
GOL29		260681	6959606	526.5		65	None				17	65	0	1790	MWES 2017
GOL30		260891	6959231	525.4		65	None				17	65	0.1	807	MWES 2017
GOL31		260849	6958892	523.7		65	FrUM	60	464	40	29	65	0.25	4200	MWES 2017

Bore	Previous Name	East	North	GL	RLWL	Depth	AqGeol	ToAgl	ToArl	ToAs	Slota	Slotb	Yield	EC	Report
GOL32	CP54 re-dev.	262422	6958229	533.5	504.0	81.5							0.25	5060	Willock 2010
SMW01		261076	6966147	532.9		66	FrM	48	485	20	30	66	0.5	2640	MWES 2017
SMW02		259988	6966066	542.1	505.9	65	FrF	49	493	13	47	65	0.5	1710	MWES 2017
SMW03		260987	6965978	534.1	504.3	65	SapF	51	483	21	29	65	0.5	3820	MWES 2017
SMW04		259652	6965939	549.3	508.3	64	SapF	60	489	19	58	64	1	5068	MWES 2017
SMW05		259854	6965914	550.2		65	None				47	65	0	3376	MWES 2017
SMW06		261268	6965710	535.3	504.7	65	SapM	40	495	10	25	55	2	1400	MWES 2017
SMW07		259790	6965622	555.1		65	None				29	65	0	982	MWES 2017
SMW08		260289	6965606	540.2		65	FrM	50	490	15	29	65	0.1	2460	MWES 2017
SMW09	N Drill Bore re-dev.	260600	6965330	535.9	505.8	77					47	77	0.5	5050	CL pers comm
SMW10		261242	6965262	530.0	504.7	62	FrM	53	477	28	40	58	0.25	2220	MWES 2017
SMW11		260284	6965255	541.4		65	SapUM	55	486	20	23	65	0.1	5950	MWES 2017
SMW13		259909	6965023	541.3		65	None				17	65	0	6556	MWES 2017
SMW14		260648	6964946	531.9	504.3	65	SapUM	43	489	15	23	65	0.5	7790	MWES 2017
SMW15		261297	6964911	532.7		65	None				29	65	0.05	2420	MWES 2017
SMW16		260357	6964889	537.8	505.7	65	None				23	65	0.05	7930	MWES 2017
SMW17		261316	6964614	526.8	504.2	60	FrM	44	483	21	42	60	1	1880	MWES 2017
SMW19	DWB11 redrill	260524	6964425	534.2	504.2	65	SapUM	36	498	6	23	65	0.5	14100	Coffey 1992
SMW20		260633	6964397	530.8	504.6	65	FrUM	34	497	8	29	65	0.5	5100	MWES 2017
SMW21		260793	6964048	524.5	505.0	65	N.D.	44	481	24	5	47	0.5		MWES 2017
SMW22	CP2redrill	260438	6963818	530.0	504.7	50	SapUM	26	504	1	14	50	2	10800	Coffey 1991
SMW24	CP52 re-dev.	260394	6963644	527.0	505.1	60							1	5490	Willock 2010
SMW25	95SMG23 redrill	260964	6963581	524.8	505.0	65	FrM	45	480	25	17	65	0.5	8740	WC 1995
SMW26	WB12 redrill	260355	6963530	524.5	505.4	50	FrUM	25	500	5	14	50	0.5	6960	Coffey 1991a
SWM27		260390	6963381	522.2	505.0	65	SapUM	25	497	8	17	65	0.5	9430	MWES 2017
95GPD73		261389	6961563	532		200							0.01		WC 1995
95GPD76		261392	6961871	536		200							0.01		WC 1995
95GPG07		261729	6961690	538	505.5	72							1		WC 1995
95GPG09		261886	6961416	530	504.5	80	None						0		WC 1995

Bore	Previous Name	East	North	GL	RLWL	Depth	AqGeol	ToAgl	ToArl	ToAs	Slota	Slotb	Yield	EC	Report
95GPG10		262030	6961752	530	507.5	40	None						0		WC 1995
95GPG11		261363	6961319	534	507.5	66	FrUM						0.25		WC 1995
95GPG12		261664	6961191	531	505.5	70	FrUM						0.25		WC 1995
95GPG13		261213	6961532	529	504.5	42	None						0		WC 1995
95GPG14		261145	6961764	530	504.5	30	None						0		WC 1995
95GPG15		261177	6962033	536	504.5	52	None						0		WC 1995
95GPG16		261870	6962153	532	508.5	36	None						0		WC 1995
95GPG17		261522	6962265	543.5	505.0	66	None						0		WC 1995
95SMG101		260865	6963727	524		470							0.01		WC 1995
95SMG14		260617	6963191	527	504.5	42							0.5		WC 1995
95SMG15		260440	6963188	521	504.5	70							2		WC 1995
95SMG16		260169	6963268	523		20	None						0		WC 1995
95SMG17		259980	6963716	525	503.5	40	None						0		WC 1995
95SMG18		260059	6963900	524	505.5	40	None						0		WC 1995
95SMG19		260147	6964079	531	505.5	90	None						0		WC 1995
95SMG20		260383	6964449	536	504.5	60	None						0		WC 1995
95SMG21		260715	6964673	529	504.5	86	None						0		WC 1995
95SMG22		260834	6964373	526	503.5	84							0.25		WC 1995
95SMG24		260948	6963987	524		60	None						0		WC 1995
95SMG25		260901	6964131	524	504.5	54							0.25		WC 1995
Camp Bore		260390	6962280										2	1333	HR 1997
CP1		260453	6963796	529	501.5	106	SapUM	43	486	16			5		Coffey 1991b
CP10		261417	6960649	521		78	None						0		Coffey 1991b
CP11		261377	6961599	532	506.5	42	None						0	1342	Coffey 1991b
CP23		259837	6963809	526	509.5	61	FrM	33	493	17			0.1		Coffey 1991b
CP24		260017	6962219	515		36	None						0		Coffey 1991b
CP7		260437	6959929	522	504.5	48	None						0.1	1383	Coffey 1991b
CP8		261887	6960679	521		80	None						0.1	2083	Coffey 1991b
CP9		261487	6960519	519	504.5	78	None						0.1	4217	Coffey 1991b

Bore	Previous Name	East	North	GL	RLWL	Depth	AqGeol	ToAgl	ToArl	ToAs	Slota	Slotb	Yield	EC	Report
DWB12		260541	6964526	532	505.5	80							2	3667	Coffey 1991b
GPD1630		261680	6961642	542	505.5		None						0	6333	TW pers comm
SBD3		262345	6958173	532	505.5		None						0	3000	TW pers comm
SHSX1		261268	6960102	515		71	FrUM	58	457	40			1	4567	HR 1997
SMD29		260565	6964158	529		116							2		Coffey 1991a
SMP07		260594	6964164	528		80							1		Coffey 1991a
WB09		260519	6963747	528		60							0.5		Coffey 1991a
WB10		260615	6963922	528		60							0.1		Coffey 1991a
WB11		260007	6963868	525		68	None						2		Coffey 1991a
YEX82		261954	6960494										0	2500	TW pers comm

Table Header Notes

GL	Ground level from DEM nominal +/- 0.5 m
RLWL	water level (m AHD)
Depth	Drilled
AqGeol	Weathering + rock type sap=saprock fr = fresh F= felsic, M=mafic , UM=ultramafic
ToAgl	Top of Aquifer m BGL
ToArl	Top of Aquifer RL (m AHD)
ToAs	Top of Aquifer Submergence below water level
Slota	Top of slotted casing depth (m BGL)
Slotb	Base of slotted casing depth (m BGL)
Yield	Indicative Yield based on drill and development data (L/sec)
EC	Generally laboratory sample result - red highlighted are corrected field EC measurements

Appendix 2 – groundwater chemistry

	Physical and Major Ions							
Analyte	pH Value	EC @ 25°C	Sulfate	Chloride	Calcium	Magnesium	Sodium	Potassium
Unit	pH Unit	µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
LOR	0.01	1	1	1	1	1	1	1
GOL01	7.5	3810	702	843	124	184	456	15
GOL02	7.95	1500	139	204	35	35	241	18
GOL03	7.88	5020	527	1080	48	93	923	30
GOL06	6.14	**89**	15	12	2	1	10	3
GOL07	6.73	324	42	53	10	6	42	4
GOL08	7.26	272	13	26	4	2	55	2
GOL09	7.81	5750	766	1270	24	74	685	23
GOL10	7.97	2220	258	440	50	61	335	14
GOL11	7.98	3830	372	768	34	61	735	28
GOL12	7.84	3970	421	709	16	58	789	24
GOL13	7.86	7150	714	1520	43	169	1340	44
GOL14	8.09	3880	375	708	9	37	813	33
GOL15	8.04	1270	104	160	18	35	216	12
GOL16	7.89	1870	218	286	16	46	330	20
GOL17	8.07	3730	420	754	12	55	768	27
GOL18	7.74	5450	1050	1170	102	129	912	29
GOL20	7.95	1630	151	271	38	78	184	10
GOL21	8.09	3680	373	805	68	140	509	16
GOL22	7.95	1010	60	79	47	38	66	5
GOL23	8.05	1140	63	137	66	62	57	6
GOL24	7.83	1060	86	198	33	33	135	6
GOL25	8.33	1830	229	332	56	64	233	10
GOL27	8.25	1380	96	162	96	55	89	5
GOL28	7.85	1150	150	131	49	65	87	12
GOL29	7.7	1790	224	420	102	36	209	13
GOL30	7.88	807	38	53	68	30	52	5
GOL31	7.88	4200	520	980	66	119	693	30
GOL32	8.35	5060	674	930	13	223	805	25
SMW01	8.2	2640	313	662	76	107	328	17
SMW02	8.31	1710	174	364	47	86	182	10
SMW03	8.07	3820	501	921	130	156	435	21
SMW04	7.68	**477**	21	70	25	18	40	3
SMW05	8	**550**	28	77	30	19	52	6
SMW06	8.02	1400	107	296	48	42	166	11
SMW07	7.15	982	134	180	42	27	104	7
SMW08	7.88	2460	288	569	58	96	318	15
SMW09	8.09	5050	463	1320	185	217	555	22
SMW10	7.99	2220	213	467	70	68	313	16
SMW11	8.09	5950	580	1330	91	394	600	24
SMW13	8.04	**622**	58	97	32	17	66	6
SMW14	8.05	7790	728	1720	259	360	907	35
SMW15	8.3	2420	348	537	36	65	382	18
SMW16	8.4	7930	968	1640	27	164	1530	43
SMW17	8.03	1880	154	422	53	56	230	12
SMW19	7.92	14100	1420	4120	114	823	1940	70
SMW20	8.07	5100	494	1180	96	193	750	30
SMW22	8.24	10800	1320	2930	146	421	1710	78
SMW24	8.02	5490	239	1210	46	126	997	43
SMW25	7.85	8740	758	2390	202	352	1140	41
SMW26	8.61	6960	555	1750	45	201	1240	62

Highlighted values show anomalously low salinity and are considered unrepresentative

	Dissolved Trace Components							
Analyte	Arsenic	Cadmium	Chromium	Copper	Lead	Nickel	Selenium	Zinc
Unit	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
LOR	0.001	0.0001	0.001	0.001	0.001	0.001	0.01	0.005
GOL01	0.002	-0.00005	-0.0005	0.003	-0.0005	0.057	0.01	0.01
GOL02	-0.0005	-0.00005	-0.0005	0.002	-0.0005	0.003	-0.005	-0.0025
GOL03	-0.0005	-0.00005	-0.0005	-0.0005	-0.0005	0.001	-0.005	0.006
GOL06	-0.0005	-0.00005	-0.0005	0.001	-0.0005	-0.0005	-0.005	-0.0025
GOL07	-0.0005	-0.00005	-0.0005	-0.0005	-0.0005	0.002	-0.005	-0.0025
GOL08	-0.0005	-0.00005	0.001	0.005	-0.0005	0.006	-0.005	0.009
GOL09	-0.0005	-0.00005	-0.0005	-0.0005	-0.0005	-0.0005	-0.005	-0.0025
GOL10	0.014	-0.00005	0.001	-0.0005	-0.0005	0.016	-0.005	0.005
GOL11	-0.0005	-0.00005	-0.0005	-0.0005	-0.0005	0.006	-0.005	-0.0025
GOL12	0.045	-0.00005	-0.0005	-0.0005	-0.0005	0.006	-0.005	-0.0025
GOL13	0.015	-0.00005	0.002	0.003	-0.0005	0.001	0.01	-0.0025
GOL14	0.007	-0.00005	0.001	0.001	-0.0005	-0.0005	0.01	-0.0025
GOL15	0.076	-0.00005	0.001	-0.0005	-0.0005	0.004	-0.005	-0.0025
GOL16	0.189	-0.00005	0.001	-0.0005	-0.0005	0.005	-0.005	-0.0025
GOL17	0.292	-0.00005	-0.0005	0.002	-0.0005	0.016	0.01	-0.0025
GOL18	0.001	-0.00005	-0.0005	0.002	-0.0005	0.007	-0.005	0.007
GOL20	0.087	-0.00005	-0.0005	-0.0005	-0.0005	0.004	-0.005	-0.0025
GOL21	0.303	-0.00005	-0.0005	-0.0005	-0.0005	0.057	-0.005	-0.0025
GOL22	0.002	-0.00005	-0.0005	0.012	-0.0005	0.002	-0.005	-0.0025
GOL23	0.001	-0.00005	-0.0005	0.001	0.002	0.002	-0.005	0.007
GOL24	0.066	-0.00005	-0.0005	-0.0005	-0.0005	0.003	-0.005	-0.0025
GOL25	0.035	-0.00005	-0.0005	-0.0005	-0.0005	0.006	-0.005	-0.0025
GOL27	0.002	-0.00005	-0.0005	0.003	0.008	0.002	-0.005	0.01
GOL28	0.03	-0.00005	0.001	0.002	-0.0005	0.005	-0.005	0.006
GOL29	0.004	-0.00005	-0.0005	0.001	-0.0005	0.007	-0.005	-0.0025
GOL30	0.002	-0.00005	-0.0005	0.001	-0.0005	0.002	-0.005	0.007
GOL31	0.264	-0.00005	-0.0005	0.002	-0.0005	0.305	-0.005	0.015
GOL32	0.001	-0.00005	0.021	-0.0005	-0.0005	0.012	0.01	0.006
SMW01	-0.0005	-0.00005	-0.0005	0.002	-0.0005	-0.0005	-0.005	-0.0025
SMW02	0.001	-0.00005	0.075	-0.0005	-0.0005	0.026	-0.005	-0.0025
SMW03	0.002	-0.00005	0.002	-0.0005	-0.0005	0.001	-0.005	-0.0025
SMW04	0.008	-0.00005	0.003	-0.0005	-0.0005	0.003	-0.005	0.012
SMW05	0.004	-0.00005	-0.0005	0.001	-0.0005	0.003	-0.005	-0.0025
SMW06	-0.0005	-0.00005	-0.0005	0.002	-0.0005	0.003	-0.005	0.011
SMW07	0.006	0.0004	-0.0005	0.013	-0.0005	0.018	-0.005	0.006
SMW08	-0.0005	-0.00005	-0.0005	0.001	-0.0005	0.013	-0.005	0.011
SMW09	-0.0005	-0.00005	-0.0005	0.002	-0.0005	0.004	-0.005	0.006
SMW10	-0.0005	-0.00005	0.003	-0.0005	-0.0005	0.003	-0.005	0.024
SMW11	0.003	-0.00005	0.025	0.002	-0.0005	0.087	-0.005	-0.0025
SMW13	0.01	-0.00005	-0.0005	-0.0005	-0.0005	0.004	-0.005	0.006
SMW14	-0.0005	-0.00005	-0.0005	0.001	-0.0005	0.003	-0.005	0.006
SMW15	-0.0005	-0.00005	-0.0005	0.003	-0.0005	0.003	-0.005	-0.0025
SMW16	-0.0005	-0.00005	0.004	0.002	-0.0005	0.087	-0.005	-0.0025
SMW17	-0.0005	-0.00005	-0.0005	-0.0005	-0.0005	0.001	-0.005	0.009
SMW19	0.008	-0.00005	0.008	0.001	-0.0005	0.285	0.01	-0.0025
SMW20	-0.0005	-0.00005	0.026	-0.0005	-0.0005	0.214	-0.005	-0.0025
SMW22	0.003	-0.00005	0.009	-0.0005	-0.0005	0.171	0.01	-0.0025
SMW24	0.006	-0.00005	0.022	0.002	-0.0005	0.045	-0.005	0.012
SMW25	-0.0005	-0.00005	0.011	-0.0005	-0.0005	0.001	-0.005	-0.0025
SMW26	0.014	-0.00005	0.013	-0.0005	-0.0005	0.101	-0.005	-0.0025

Highlighted values show anomalously low salinity and are considered unrepresentative

	Total Trace Components										
Analyte	Arsenic	Barium	Cadmium	Chromium	Copper	Lead	Molybdenum	Nickel	Selenium	Silver	Boron
Unit	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
LOR	0.001	0.001	0.0001	0.001	0.001	0.001	0.001	0.001	0.01	0.001	0.05
GOL01	0.002	0.035	-0.00005	-0.0005	0.004	-0.0005	0.003	0.048	0.01	-0.0005	0.82
GOL02	0.002	0.04	0.0002	0.046	0.074	0.012	0.046	0.054	-0.005	-0.0005	0.68
GOL03	0.001	0.041	-0.00005	0.002	0.003	-0.0005	0.008	0.003	-0.005	-0.0005	2.64
GOL06	0.001	0.012	-0.00005	0.006	0.006	0.003	-0.0005	0.004	-0.005	-0.0005	0.08
GOL07	0.002	0.119	-0.00005	0.035	0.023	0.009	0.001	0.018	-0.005	-0.0005	0.2
GOL08	0.002	0.03	-0.00005	0.027	0.013	0.002	0.001	0.024	-0.005	-0.0005	0.25
GOL09	-0.0005	0.011	-0.00005	0.002	-0.0005	-0.0005	0.017	0.002	-0.005	-0.0005	2.87
GOL10	0.017	0.056	-0.00005	0.009	0.004	-0.0005	0.004	0.023	-0.005	-0.0005	1.06
GOL11	0.002	0.01	-0.00005	0.002	0.018	-0.0005	0.019	0.022	0.01	-0.0005	1.82
GOL12	0.046	0.004	-0.00005	0.002	0.001	-0.0005	0.013	0.009	-0.005	-0.0005	3.14
GOL13	0.016	0.002	-0.00005	0.003	0.002	-0.0005	0.008	0.004	0.01	-0.0005	3.81
GOL14	0.008	0.007	-0.00005	0.004	0.003	-0.0005	0.031	0.005	0.01	-0.0005	3.83
GOL15	0.074	0.05	-0.00005	0.002	0.001	0.002	0.004	0.006	-0.005	-0.0005	0.64
GOL16	0.255	0.006	-0.00005	0.008	0.004	-0.0005	0.004	0.039	-0.005	-0.0005	1.04
GOL17	0.272	0.029	-0.00005	-0.0005	0.002	-0.0005	0.01	0.016	0.01	-0.0005	1.82
GOL18	0.002	0.013	-0.00005	-0.0005	0.002	0.001	0.002	0.008	-0.005	-0.0005	2.73
GOL20	0.083	0.059	-0.00005	0.002	0.001	-0.0005	0.002	0.005	-0.005	-0.0005	0.71
GOL21	0.242	0.021	-0.00005	0.002	0.001	0.001	0.006	0.053	-0.005	-0.0005	1.36
GOL22	0.002	0.011	-0.00005	0.001	0.014	0.001	-0.0005	0.004	-0.005	-0.0005	0.25
GOL23	0.001	0.008	-0.00005	-0.0005	-0.0005	0.003	0.001	0.003	-0.005	-0.0005	0.3
GOL24	0.061	0.013	-0.00005	0.001	-0.0005	-0.0005	0.006	0.004	-0.005	-0.0005	0.34
GOL25	0.029	0.018	-0.00005	-0.0005	-0.0005	-0.0005	0.003	0.007	-0.005	-0.0005	0.79
GOL27	0.002	0.012	-0.00005	0.001	0.003	0.013	0.002	0.004	-0.005	-0.0005	0.3
GOL28	0.029	0.064	-0.00005	0.002	0.003	-0.0005	0.004	0.012	-0.005	-0.0005	0.36
GOL29	0.005	0.083	-0.00005	0.002	0.005	-0.0005	0.013	0.008	-0.005	-0.0005	0.88
GOL30	0.003	0.039	-0.00005	0.002	0.002	-0.0005	0.002	0.006	-0.005	-0.0005	0.28
GOL31	0.246	0.04	-0.00005	0.001	-0.0005	-0.0005	0.002	0.28	-0.005	-0.0005	1.16
GOL32	0.001	0.001	-0.00005	0.024	-0.0005	-0.0005	0.002	0.013	-0.005	-0.0005	2.3
SMW01	0.001	0.026	-0.00005	0.001	0.003	-0.0005	0.005	0.001	-0.005	-0.0005	1.16
SMW02	0.003	0.056	-0.00005	0.096	-0.0005	-0.0005	-0.0005	0.146	-0.005	-0.0005	0.62
SMW03	0.002	0.018	0.0001	0.004	0.004	-0.0005	0.002	0.006	-0.005	-0.0005	1.18
SMW04	0.007	0.027	-0.00005	0.005	0.003	-0.0005	-0.0005	0.006	-0.005	-0.0005	0.16
SMW05	0.004	0.025	-0.00005	0.012	0.018	-0.0005	0.001	0.014	-0.005	-0.0005	0.16
SMW06	-0.0005	0.013	-0.00005	0.002	0.006	-0.0005	0.012	0.008	-0.005	-0.0005	0.68
SMW07	0.006	0.028	0.0004	0.018	0.022	-0.0005	0.006	0.033	-0.005	-0.0005	0.31
SMW08	0.002	0.067	-0.00005	0.017	0.008	0.001	0.002	0.093	-0.005	-0.0005	0.98
SMW09	-0.0005	0.025	-0.00005	0.002	0.004	-0.0005	0.002	0.01	-0.005	-0.0005	1.2
SMW10	-0.0005	0.013	-0.00005	0.006	0.003	-0.0005	0.008	0.01	-0.005	-0.0005	1.1
SMW11	0.003	0.075	-0.00005	0.036	0.004	-0.0005	-0.0005	0.113	-0.005	0.002	0.77
SMW13	0.008	0.03	-0.00005	0.004	0.002	-0.0005	0.002	0.009	-0.005	-0.0005	0.24
SMW14	-0.0005	0.032	-0.00005	0.002	0.002	-0.0005	0.002	0.006	-0.005	-0.0005	1.65
SMW15	-0.0005	0.004	-0.00005	-0.0005	0.003	-0.0005	0.019	0.003	-0.005	-0.0005	1.29
SMW16	0.002	0.033	-0.00005	0.068	0.011	-0.0005	0.002	0.476	-0.005	-0.0005	1.6
SMW17	-0.0005	0.018	-0.00005	0.002	0.002	-0.0005	0.008	0.009	-0.005	-0.0005	0.98
SMW19	0.009	0.019	-0.00005	0.026	0.003	-0.0005	0.003	0.362	-0.005	-0.0005	3.2
SMW20	-0.0005	0.017	-0.00005	0.03	0.003	-0.0005	0.003	0.267	-0.005	-0.0005	1.91
SMW22	0.004	0.016	-0.00005	0.012	0.002	-0.0005	0.007	0.19	-0.005	-0.0005	4.74
SMW24	0.006	0.011	-0.00005	0.024	0.004	-0.0005	0.022	0.053	-0.005	-0.0005	3.38
SMW25	-0.0005	0.032	-0.00005	0.012	0.004	-0.0005	0.004	0.01	-0.005	-0.0005	2.39
SMW26	0.014	0.01	-0.00005	0.064	0.003	-0.0005	0.005	0.212	-0.005	-0.0005	2.92
SMW27	0.009	0.006	-0.00005	0.01	0.003	-0.0005	-0.0005	0.031	-0.005	-0.0005	2.43

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	Nutrients						
Analyte	NH4 as N	NO2 as N	NO3 as N	NO2+NO3 as N	Total Kjeldahl N	Total N	Total P
Unit	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
LOR	0.01	0.01	0.01	0.01	0.1	0.1	0.01
GOL01	0.03	-0.005	0.02	0.02	0.3	0.3	0.04
GOL02	0.07	0.1	35.3	35.4	4.1	39.5	0.21
GOL03	0.05	0.13	17.3	17.4	2.7	20.1	0.06
GOL06	0.25	-0.005	0.83	0.83	0.9	1.7	0.14
GOL07	0.14	-0.005	3.63	3.63	2.5	6.1	0.37
GOL08	0.11	0.04	1.77	1.81	1.2	3	0.26
GOL09	0.1	0.1	19.1	19.2	2.5	21.7	0.15
GOL10	0.04	0.16	13.1	13.3	2	15.3	0.11
GOL11	0.04	0.21	20.5	20.7	2.1	22.8	0.16
GOL12	0.38	0.05	14.2	14.3	2.1	16.4	0.11
GOL13	0.22	0.15	17.8	18	2.8	20.8	0.1
GOL14	0.06	0.08	19.1	19.2	3.7	22.9	0.09
GOL15	0.03	0.02	11.6	11.6	12.4	24	0.08
GOL16	0.04	0.02	23.6	23.6	5	28.6	0.43
GOL17	0.06	0.01	19.7	19.7	2.2	21.9	0.1
GOL18	0.05	-0.005	0.26	0.26	0.2	0.5	0.05
GOL20	0.1	0.09	18.8	18.9	3.1	22	0.43
GOL21	0.04	-0.005	14.9	14.9	1.9	16.8	0.14
GOL22	0.05	-0.005	20.6	20.6	4.8	25.4	0.38
GOL23	0.12	0.04	28.6	28.6	3.9	32.5	0.19
GOL24	0.02	-0.005	8.57	8.57	0.8	9.4	0.53
GOL25	0.2	1.35	4.68	6.03	1.7	7.7	0.24
GOL27	0.05	-0.005	43.2	43.2	4.5	47.7	0.88
GOL28	0.03	0.26	24.3	24.6	2.2	26.8	0.38
GOL29	0.03	-0.005	0.02	0.02	0.5	0.5	0.11
GOL30	0.05	0.08	13.8	13.9	1.7	15.6	0.14
GOL31	0.03	-0.005	0.12	0.12	-0.05	0.1	0.08
GOL32	0.04	-0.005	43	43	4.1	47.1	0.16
SMW01	0.03	0.01	3.91	3.92	0.4	4.3	-0.01
SMW02	0.02	-0.005	8.51	8.51	0.9	9.4	0.13
SMW03	0.03	-0.005	13.2	13.2	1.5	14.7	-0.01
SMW04	0.08	0.57	6.78	7.35	1.2	8.6	-0.01
SMW05	0.04	0.46	5.95	6.41	1.1	7.5	-0.01
SMW06	0.06	0.27	16.9	17.2	1.9	19.1	0.13
SMW07	0.03	0.18	14	14.2	3	17.2	0.11
SMW08	0.05	0.02	7.74	7.76	1.4	9.2	0.09
SMW09	0.04	0.03	18	18	1.9	19.9	-0.01
SMW10	0.06	0.53	16.2	16.7	1.9	18.6	0.02
SMW11	0.04	-0.005	14	14	2.1	16.1	0.02
SMW13	0.05	0.5	5.62	6.12	1.2	7.3	0.04
SMW14	0.05	0.01	23.9	23.9	1.8	25.7	-0.01
SMW15	0.04	0.44	8.02	8.46	2.2	10.7	0.11
SMW16	0.05	0.23	2.58	2.81	0.7	3.5	0.03
SMW17	0.08	0.52	12.2	12.7	1.3	14	-0.01
SMW19	-0.005	0.01	50.2	50.2	5.4	55.6	-0.025
SMW20	0.03	-0.005	12.8	12.8	1.4	14.2	-0.01
SMW22	0.02	0.31	37.1	37.4	3.8	41.2	0.1
SMW24	0.04	-0.005	19.9	19.9	2.5	22.4	-0.01
SMW25	0.03	0.11	15.8	15.9	2	17.9	0.04
SMW26	0.02	-0.005	7.31	7.31	0.7	8	0.04
SMW27	0.1	-0.005	3.25	3.25	0.5	3.8	-0.005

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