TECTONIC RESOURCES NL

PHILLIPS RIVER GOLD PROJECT

Trilogy Notice of Intent: Surface Hydrology Assessment

April 2005

JDA Consultant Hydrologists

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1. INTRODUCTION

JDA Consultant Hydrologists were commissioned by Tectonic Resources NL to describe the surface hydrology of the Trilogy Project site and recommend surface drainage controls appropriate to the proposed mine infrastructure as part of the preparation of the Notice of Intent for the project.

The Trilogy Project is a mining only operation with the ore intended to be transported to the RAV 8 processing plant, located 25 kilometres east of Ravensthorpe on the South Coast Highway.

The objectives of this study are as follows;

- ❒ Identify surface runoff catchments and drainage routes
- ❒ Identify peak flows for existing conditions
- ❒ Assess proposed infrastructure layout and recommend drainage controls were necessary

2. CATCHMENT DESCRIPTION

2.1 Location

The Trilogy site is located approximately 27 km south-east of Ravensthorpe on the Hopetoun - Ravensthorpe Road. The proposed development is within Myamba Farm, with farming intended to continue in the other parts of the farm during mining.

2.2 Climate

The climate at Trilogy is similar to Ravensthorpe and is characterised by consistent rainfall throughout the year with a mean annual rainfall of approximately 430 mm per year (Table 1). Class A pan evaporation for Ravensthorpe of 1987 mm is approximately 4 times mean annual rainfall (Luke *et. al.,* 1988).

Table 1. Climatological summary for Ravensthorpe for data 1901 to 2003

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Mean Daily Maximum Temperature	29.2	28.4	26.6	23.7	20.0	17.2	16.2	17.1	19.5	22.3	24.8	27.3	
Mean Daily Minimum Temperature	14.0	14.5	13.5	11.8	9.6	7.9	6.8	6.6	7.5	8.9	10.9	12.7	
Mean Monthly Rainfall (mm)	22.8	25.3	31.2	32.8	45.0	44.0	47.1	44.9	41.5	38.1	29.6	22.3	**427.7**
Monthly Rainfall 2003	5.8	34.8	70.9	37.5	33.0	18.2	55.1	56.0	33.7	29.2	45.9	20.8	440.9

Source: Bureau of Meteorology

2.3 Soils

Soils across the Trilogy site are generally characterised by a thin (5 cm) gravelly loam topsoil overlying light to heavy clays. Outback Ecology (2004) indicates the topsoils have good physical properties making the soils stable, but stripping and re-spreading of the topsoils will break down some of the structural stability. The underlying clays are much less stable and prone to slaking and dispersion during wetting. The site is considered to be susceptible to erosion from constructed landforms (Outback Ecology, 2004).

2.4 Topography

The topography of the area is characterised by low hills with very gentle slopes (2 to 3%). Stream channels within the landscape are widely spaced forming an integrated network of convergent creeks (Figure 1).

Maximum elevation is the in the north of the Trilogy site at approximately 90 m AHD, falling to 80 m AHD at the southern end of site.

2.5 Surface Drainage Features

Surface drainage is north to south from the ranges towards the Southern Ocean. The main drainage arteries in the immediate Trilogy area are the Phillips River, Steere River and Jerdacuttup River. The Phillips and Steere Rivers discharge to Culham Inlet just north-west of Hopetoun, while Jerdacuttup River discharges to Jerdacuttup Lakes to the east of Hopetoun (Figure 1).

The proposed Trilogy Project drains south by Kuliba Creek, a tributary of the Steere River. Kuliba creek intersects the Steere River on the west side of Ravensthorpe-Hopetoun Rd, approximately 8 km south-west of the Study Area.

3. RUNOFF ESTIMATES: EXISTING CATCHMENT

3.1 Sub-Catchments

There are 2 sub-catchments of Kuliba Creek identified within the Study Area as shown in Figure 2. The estimated area for these sub-catchments is presented in Table 2 below.

Table 2: Estimated Area of Sub-Catchments

Sub-Catchment	Estimated Area (ha)	% Cleared
A	98	95
B	224	95
Total	322	95

3.2 Land Use

The Study Area occurs on cleared farmland (Myamba Farm) with only isolated pockets of perennial vegetation remaining. The area is closely grazed with pasture cover varying seasonally. A number of existing farm dams used for stock watering intercept the flow of the creeks.

3.3 Estimated Peak Flows

Due to the lack of gauged flow data on the Steere River and its tributaries, the Rational Method of flood estimation was adopted to estimated peak flows as recommended in Australian Rainfall and Runoff (AR&R, 2000). The Rational Method provides peak flow estimates up to the 50 year Average Recurrence Interval (ARI). For the 100 year ARI, the peak flow was estimated by extrapolation. The extrapolation to the 100 yr ARI is based on a linear extension of the line between the 20 yr and 50 yr ARI.

The Trilogy Site is within the Wheatbelt Zone for flood estimation (AR&R, 2000). Based on the catchment characteristics of the Study Area, equations for loamy soils 75-100% cleared were adopted (AR&R, 2000). Analysis of rainfall intensity and duration (Figure 3) was carried out using procedures described in Book 2 of AR&R (2000).

Data sheets for flood estimation for each sub-catchment are included as Appendix A, with calculated flows presented in Table 3. The flood frequency curves showing the peak discharge for both sub-catchments are plotted as Figure 4.

Table 3: Estimates of Flow Peaks

Creek[1]	Flow Peaks (m^3/s)	
	50 year ARI	100 year ARI
A	5.8	8.0
B	10.3	17.5

Notes:

1. Creek is annotated in accordance with its associated sub-catchment name.

The accuracy of the Rational Method in predicting floods on ungauged catchments, such as the Steere River, is only known for the 10 year ARI. For this event we can be 68% sure that the true value is between half and twice the estimated value (AR&R, 2000). Rarer flood estimates are less certain, but can still be considered the best estimates available.

4. PROPOSED MINES & INFRASTRUCTURE

4.1 Site Access & Layout

Access to the Trilogy site is from Ravensthorpe-Hopetoun Road to the west of the site. The general layout of the site includes an open cut pit, waste dump and a water storage facility to store/evaporate dewatering discharge from the open cut pit (Figure 5). Associated with the pit is a Run of Mine (ROM) pad where the ore is stockpiled for haulage to RAV8.

4.2 Roads

The main access road is approximately 1.4 km in length and connects the Trilogy Site to Hopetoun-Ravensthorpe Rd. The road surface will be all weather to ensure haulage from the site to RAV8 remains uninterrupted. The road will have a proposed running width of 11m with 1:3 side batters.

There are no other roads currently marked out on Figure 5, but minor service roads will be required to allow access to all infrastructure including the water storage facility.

4.3 Pit & Waste Dump

The development includes an open cut pit and associated waste dump. The pit covers an area of 3.81 ha and the waste dump 8.01 ha. The waste dump is located on the north-west side of the pit adjacent to the ROM pad (Figure 5). The ROM pad covers an area of approximately 1.69 ha.

4.4 Water Storage Facility

The water storage facility is located 300 m south-west of the pit and covers an area of 9.72 ha. The facility is designed to contain dewatering discharge from the pit and has a large surface area to facilitate evaporation.

5. RUNOFF ESTIMATES: DURING MINING OPERATIONS

5.1 Sub-catchments

Based on the proposed mine site layout the sub-catchment areas and level of clearing will change due the construction of infrastructure, namely Trilogy pit, the waste dump, ROM pad and Water Storage Facility. Infrastructure planned around the open pit is minor and only occupies 0.1 ha (fuel and magazine) with much of the infrastructure in place at the farmhouse. Roads are largely existing and just need to be upgraded.

Tectonic NL propose to re-vegetate a number of corridors along the main access road and creek A, a total area of between 5 and 10 hectares. We would not expect the vegetation to mature enough in the life of the mine to have a significant effect on the runoff rate.

As the catchments are already heavily cleared, the change in clearing from mining will be only minor. Table 4 shows the revised sub-catchment characteristics indicative of the proposed mine site layout.

Table 4. Sub-catchment characteristics during mining operations

Sub-Catchment	Estimated Area (ha)	% Cleared
A	98	85
B	221	95
Total	319	92

5.2 Estimated Peak Flows

Peak flows have been estimated based on the revised sub-catchment characteristics and are presented in Table 5. Mainstream length and slope used in the revised sub-catchment calculation remain unchanged from the existing sub-catchment calculations.

Table 5: Estimates of peak flows during mining operations

Sub-Catchment No.	Flow Peaks (m^3/s)	
	50 year ARI	100 year ARI
A	5.8	8.0
B	10.3	17.5

6. RELEVANT DESIGN CRITERIA

The Department of Minerals and Energy (1998) Guidelines for environmental approval of mining projects in WA includes the following specific requirements relevant to this report.

Existing Environment – Hydrology (page 23)

- “Brief summary of surface and sub-surface flows as they relate to the project and facilities including any flood potential…”
- “To assist the assessment of flood impact, a contour plan encompassing the area of operations and up to a minimum of 500 metres around the operation is required. This contour plan should have a maximum contour interval of 5 metres with a 2 metre interval being preferred.”

Existing Environment – Climate (page 23)

- “The NOI should contain climatic information necessary to adequately assess and manage all significant environmental effects emanating from the project. Minimum drainage design should be based on the 100 year return rainfall event.”

Environmental Impact Assessment and the Management Commitments – Land Clearing (page 26)

- “The impact of land clearing and vegetation removal on soil erosion, salinity and hydrology should be assessed and described….”
- “Land management and drainage strategies should be considered along with factors like the areas shape and profile, water control…”

Environmental Impact Assessment and the Management Commitments – Water (page 26)

- “Impacts on local water resource and other users”
- “Dewatering requirements, drainage controls and impact on regional drainage”.

JDA understands that all other NOI requirements will be addressed seperately to this report.

7. SURFACE WATER CONTROLS

7.1 General

An outlay of the proposed surface water control treatments as described below are presented in Figure 6. The aim will be to optimise flood control and surface water resources. As the area is already heavily cleared the additional runoff generated by the construction of the mine infrastructure should be minor. Additional runoff can be attenuated on site and used within the mine operation, while seeking to maintain environmental flows in the creeks at existing rates as far as possible.

7.2 Diversion of Creek A for the Dewatering Storage Facility

The proposed dewatering storage facility is located on the creek line of Creek A. We estimate for the developed catchment the flow Creek A at this location would be 7 m^3/s for the 100 yr ARI. A trapezoidal open drain with the dimensions shown in Table 6 would be able to contain this flow around the storage facility. We recommend a more detailed analysis of catchment runoff prior to the construction of the diversion.

Table 6. Estimated open drain dimensions for Creek A diversion

Base width (m)	Depth (m)	Side Batter (v:h)	Mainstream average grade	Roughness 'n'
0.5	2.0	1:3	1:160	0.06

In order to achieve sufficient grade in the drain the diversion should commence approximately 250 m north of the water storage facility as shown in Figure 6.

7.3 Roads

Road drainage around the Trilogy Site will need to be managed by incorporating road side drains into road designs. With the road drain flows can be controlled by use of energy dissipaters, drop structures and sediment controls.

The main access road will cross Creek A approximately 350 west of the pit. The crossing is immediately upstream of the location where the proposed diversion of Creek A around the dewatering storage facility should commence. The 100 yr ARI flow in Creek A at this crossing during mining operations is estimated to be 7 m^3/s. Assuming a 15 m long culvert at a grade of 1:100 (v:h) an indicative pipe size of two 1200 x 1800 mm box culverts is required to convey this flow. As with the diversion drain we recommend a more detailed analysis of catchment runoff prior to construction of the crossing.

7.4 Runoff Erosion Controls

Due to the physical characteristics of the soil identified by Outback Ecology (2004) runoff erosion controls will be required for all cleared areas, including the waste dump and ROM pad which cover areas of 8.01 and 1.70 ha respectively. The additional runoff from these areas will need to be managed to ensure erosion of the surrounding landscape does not occur.

7.5 Flood Mitigation and Ponding Controls

To prevent flooding of infrastructure and unwanted ponding of stormwater around the pit, waste dump and dewatering storage facility, appropriate water control bunds and drains should be incorporated in to the designs of these structures.

7.5.1 Trilogy Pit

The pit is located at the top of the boundary between sub-catchment A and B and as such surface flows towards the pit should be relatively minor. Due to the proximity of the waste dump, additional runoff from the dump will need to be managed and directed away from Trilogy Pit to Creek A and B. Appropriate water control bunds and drains should be installed around the pit to prevent any surface flows from entering the pit.

7.5.2 Waste Dump

The waste dump is located at the boundary between sub-catchment A and B and as such surface flows towards the pit will be minor. Appropriate water control bunds and drains should be installed to prevent any erosion from surface flows around the base of the facility.

7.5.3 Water Storage Facility

The proposed location of the water storage facility is in the path of the existing creekline of sub-catchment A. As discussed in Section 7.2 the creek should be diverted around the facility via an open drain.

With the diversion in place a small area of runoff may collect and pond against the northern bank of the facility. A Cut-off (trapezoidal open) drain should be constructed along this margin to direct the flow west past the top of the storage facility and south connecting with Creek A. Indicative dimensions for the drain are provided in Table 7.

Table 7. Estimated Cut-off drain dimensions for ponding protection of dewatering storage facility

Base width (m)	Depth (m)	Side Batter (v:h)	Mainstream average grade	Roughness ‘n’
0.5	1.5	1:3	1:350	0.06

The drain size has been estimated to accommodate a 100 year ARI flow of 3 m^3/s.

8. CONCLUSIONS

- The Trilogy Project is a mining only development with the ore transported north to the RAV8 plant for processing.
- There are 2 sub-catchments of Kuliba Creek within the Study Area which are tributaries of the Steere River.
- Peak flows have been estimated for each sub-catchment based on the Rational Method described in Australian Rainfall & Runoff (2000).
- Due to the lack of gauged data for rivers in the Esperance Coast area, the peak flows are indicative only.
- The diversion of Creek A is necessary for construction of the dewatering storage facility.
- A road crossing is required where the Main Access Rd crosses Creek A.
- A Cut-off drain is required to prevent stormwater runoff ponding at the northern bank of the dewatering storage facility.
- Pipe and drain sizes provided in this report should be checked for capacity prior to construction.

9. REFERENCES

Luke, G., Burke, K., O'Brien, T. (1988) *Evaporation Data For Western Australia. Technical Report 65*. Western Australian Department of Agriculture.

McDonald, R., Isbell, R., Speight, J., Walker, J. and Hopkins, S. (1998) *Australian Soil and Land Survey Field Handbook*. Second Edition. Department of Primary Industries and Energy and CSIRO Australia.

Outback Ecology (2004) *Phillips River Gold Project Tectonic Resources NL – Kundip and Trilogy Projects: Topsoil characterisation at Kundip and Trilogy and recommendations for rehabilitation*. Report to Tectonic Resources NL.

Public Works Department Western Australia (1982) *Streamflow Records of Western Australia to 1982. Volume 1 Basins 601-612*. Water Resources Branch, Public Works Department of Western Australia.

The Institution of Engineers Australia (2000) *Australian Rainfall & Runoff. Volume 1: A Guide to Flood Estimation.* The Institution of Engineers Australia.

The Institution of Engineers Australia (1987) *Australian Rainfall & Runoff. Volume 2: A Guide to Flood Estimation.* The Institution of Engineers Australia.

FIGURES

Data Source: Ravensthorpe SI51-05, Geoscience Australia, Commonwealth of Australia (2004)

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Scale approx 1 : 250 000

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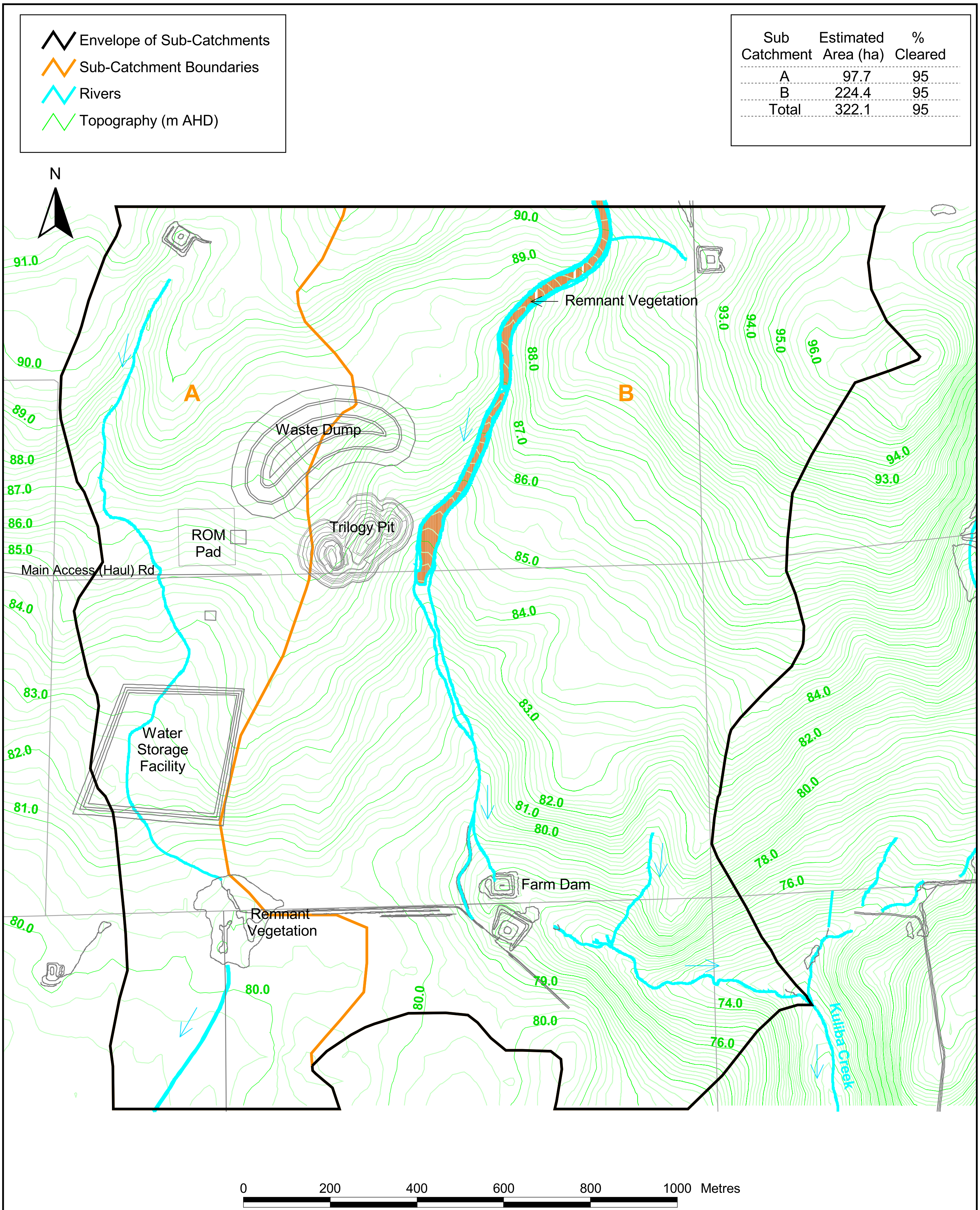
Trilogy NOI: Surface Hydrology Assessment

Figure 1: Trilogy Project Location Plan



Sub Catchment	Estimated Area (ha)	% Cleared
A	97.7	95
B	224.4	95
Total	322.1	95

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Job No. J3319

Scale 1:12000

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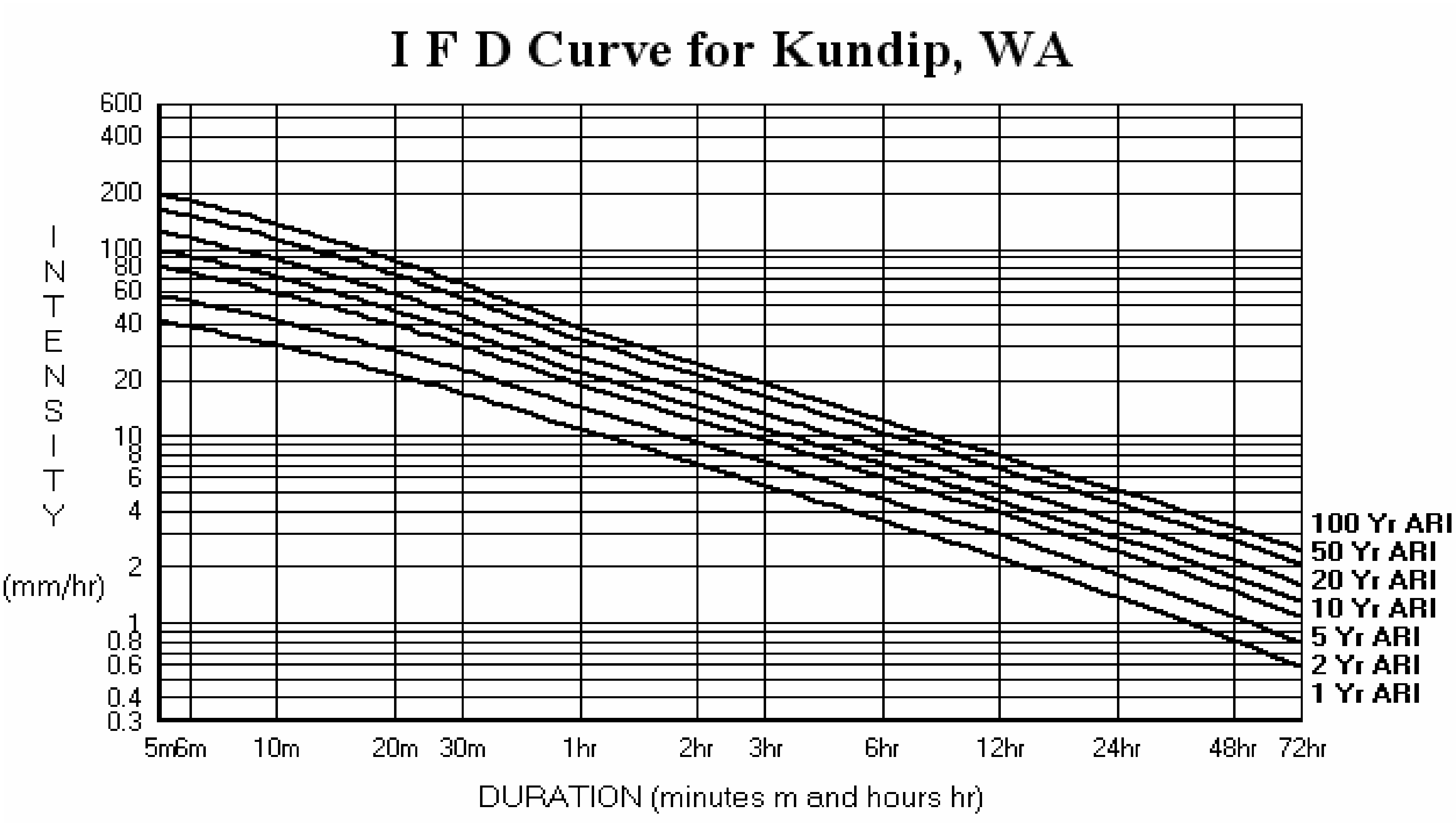
Trilogy NOI : Surface Hydrology Assessment

Figure 2: Surface Drainage Catchment Plan



Data Source: AusIFD Version 2.0

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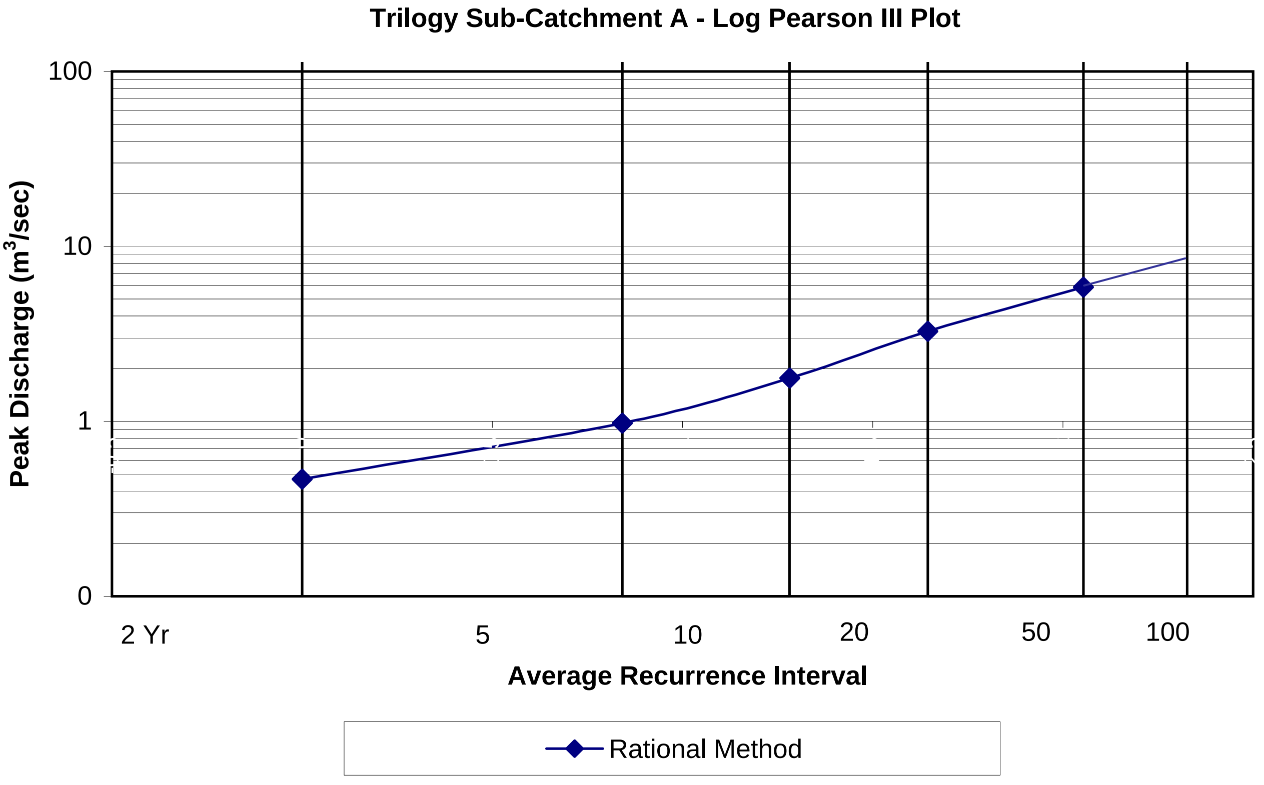
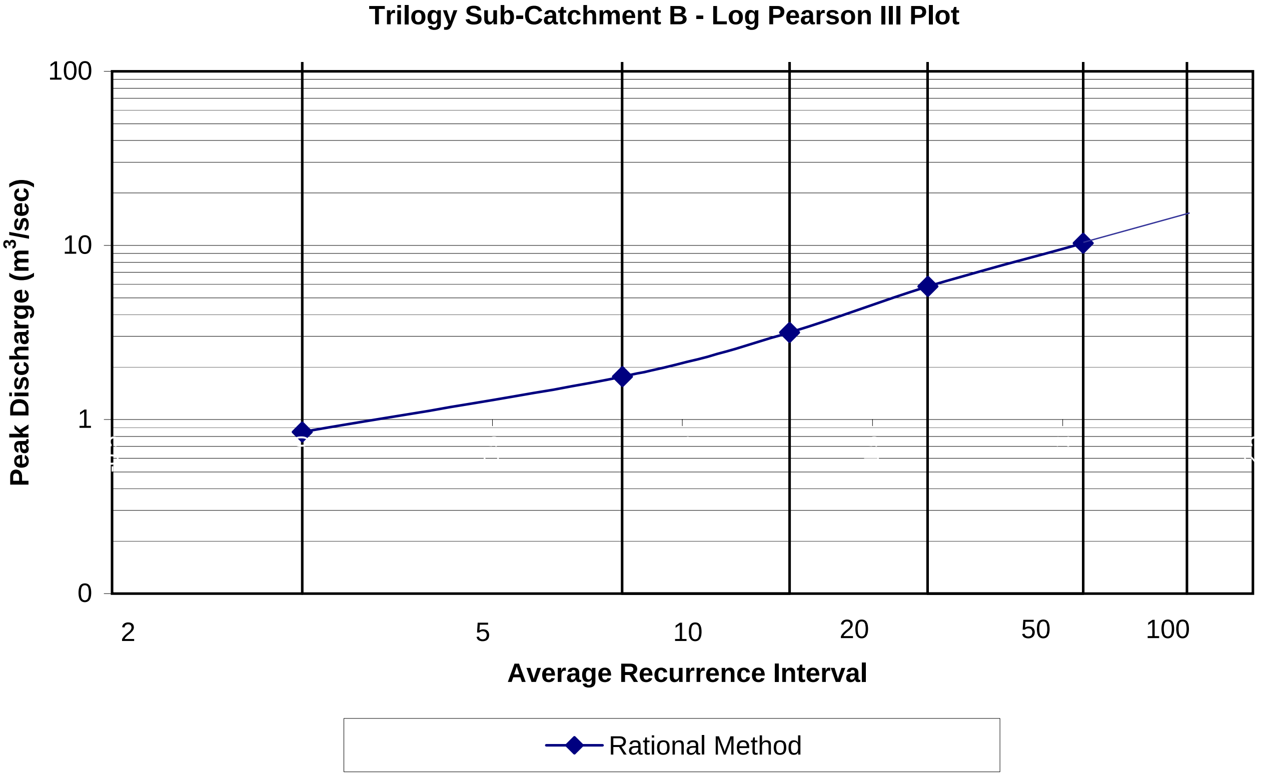
Trilogy NOI: Surface Hydrology Assessment

Figure 3: Trilogy IFD Curve





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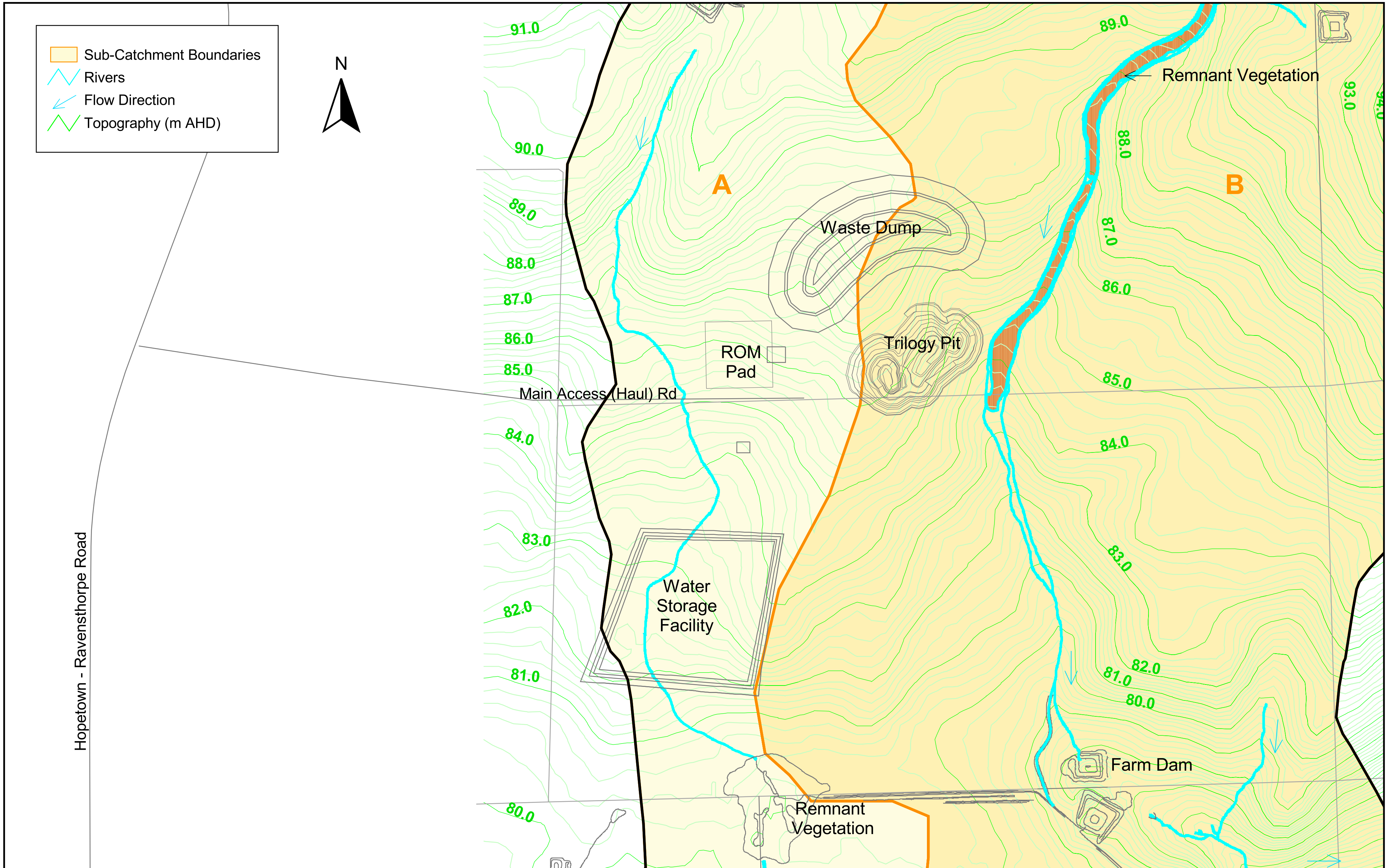
Phillips River Gold Project: Trilogy NOI - Surface Hydrology Assessment

Figure 4: Sub-catchment A and B flood frequency curves



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Scale 1:10000

0 200 400 600 800 1000 Metres

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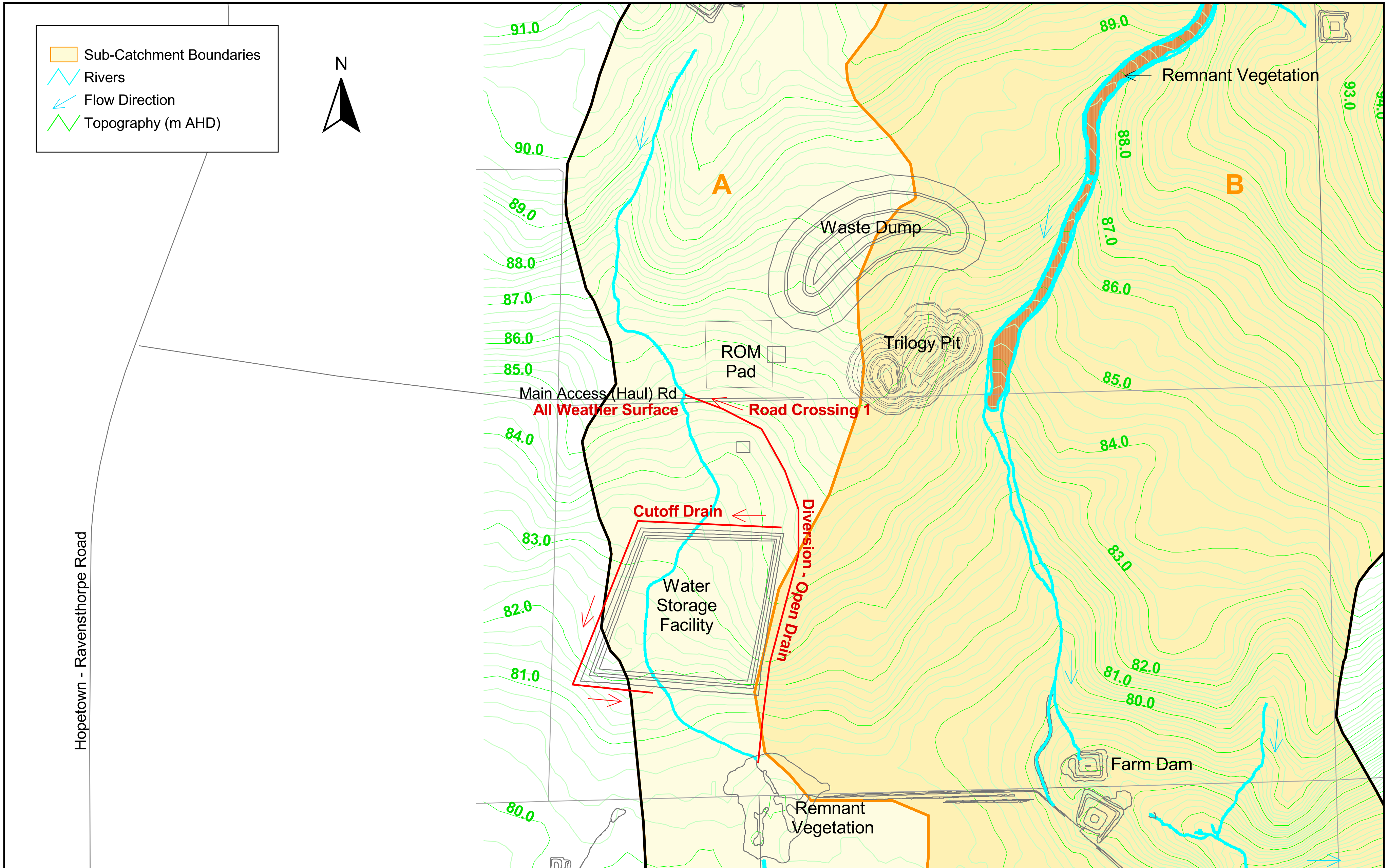
Trilogy NOI : Surface Hydrology Assessment

Figure 5: Proposed Site Layout Plan



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Job No. J3319

Scale 1:10000

0 200 400 600 800 1000 Metres

Tectonic Resources NL

Trilogy NOI : Surface Hydrology Assessment

Figure 6: Surface Water Control Treatments

APPENDIX A

Flood Estimation Data Sheets

ESTIMATION OF PEAK FLOW RATES

M Yan, JDA Consultant Hydrologists 12 June 2000
Methods are from Australian Rainfall & Runoff - Volume 1 (1987).
Password = FLOW

JDA Consultant Hydrologists

WHEATBELT

Select appropriate catchment: Loamy soil catchments 75-100% cleared

User to enter

Trilogy Subcatchment 1

RATIONAL METHOD FOR THE WHEATBELT

1

Catchment area	0.977	km^2
Mainstream length	2.4	km
Slope	4.083	m/km
Catchment cleared	95	%

C_{10} = 0.240   C10=3.46*10-1*L-0.42

t_c = 45.2 mins, 0.8 hours   tc=0.76A $^{0.38}$

ARI (yrs)	2	5	10	20	50	
C_y/C_{10}	0.41	0.65	1.00	1.54	2.20	
I_{tc} values	17.50	23.10	27.20	32.70	40.80	mm/hr ***(via IFD)***
$Q_y = 0.278\, C_{10}*(C_y/C_{10})\, I_{tc}\, A$ **Q =**	**0.47**	**0.98**	**1.77**	**3.28**	**5.84**	m^3/s

INDEX FLOOD METHOD FOR THE WHEATBELT

Catchment area	0.977	km^2
Annual average precipitation	425	mm
Catchment cleared	95	%

Q_5 = 1.022   Q5 = 2.77*10-6 A0.52 P 2.12

ARI (yrs)	2	5	10	20	50	
(Q_y/Q_5)	0.48	1.00	1.84	3.23	6.10	
$Q_y = Q_5*(Q_y/Q_5)$ **Q =**	**0.49**	**1.02**	**1.88**	**3.30**	**6.23**	m^3/s

ESTIMATION OF PEAK FLOW RATES

M Yan, JDA Consultant Hydrologists 12 June 2000

Methods are from Australian Rainfall & Runoff - Volume 1 (1987).

Password = FLOW

JDA Consultant Hydrologists

WHEATBELT

Select appropriate catchment: Loamy soil catchments 75-100% cleared

User to enter

Trilogy Subcatchment 2

RATIONAL METHOD FOR THE WHEATBELT

1

Catchment area	2.244	km^2
Mainstream length	2.64	km
Slope	7.2	m/km
Catchment cleared	95	%

C_{10} = 0.230 C10=3.46*10-1*L-0.42

t_c = 62.0 mins tc=0.76A [0.38]

1.0 hours

ARI (yrs)	2	5	10	20	50	
C_y/C_{10}	0.41	0.65	1.00	1.54	2.20	
I_{tc} values	14.40	18.90	22.00	26.30	32.60	mm/hr ***(via IFD)***
$Q_y = 0.278\ C_{10}*(C_y/C_{10})\ I_{tc}\ A$ **Q =**	**0.85**	**1.76**	**3.16**	**5.81**	**10.30**	**m^3/s**

INDEX FLOOD METHOD FOR THE WHEATBELT

Catchment area	2.244	km^2
Annual average precipitation	425	mm
Catchment cleared	95	%

Q_5 = 1.575 Q5 = 2.77*10-6 A0.52 P 2.12

ARI (yrs)	2	5	10	20	50	
(Q_y/Q_5)	0.48	1.00	1.84	3.23	6.10	
$Q_y = Q_5*(Q_y/Q_5)$ **Q =**	**0.76**	**1.57**	**2.90**	**5.09**	**9.61**	**m^3/s**

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July 2005

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JDA Consultant Hydrologists has been commissioned by Tectonic Resources NL to describe the surface hydrology of the Kundip Project site and recommend surface drainage controls appropriate to the proposed mine infrastructure as part of the preparation of the Notice of Intent for the project.

Kundip is located between Ravensthorpe and Hopetoun within the Shire of Ravensthorpe. The Kundip Project is a mining only operation with the ore intended to be transported to the RAV 8 processing plant, located 25 kilometres east of Ravensthorpe on the South Coast Highway.

The objectives of this study are as follows;

- Identify surface runoff catchments and drainage routes
- Estimate peak flows for existing conditions
- Assess proposed infrastructure layout and recommend surface water controls where necessary

2. PHYSICAL SETTING

2.1 Location

The Kundip Project Area is largely contained within sub-catchments of the Steere River as shown in Figure 2. These sub-catchments are referred to as the 'Kundip Site' in this report. Tributaries from the sub-catchments flow west to the Steere River, with the main river channel crossing under Ravensthorpe-Hopetoun Rd 200 m south of the Kundip site.

A portion of the Kundip mining leases are within the Jerdacuttup River catchment which drains to Jerdacuttup Lakes. The majority of disturbance will be within the Steere River Catchment.

2.2 Climate

The climate at Kundip is similar to Ravensthorpe and is characterised by consistent rainfall throughout the year with a mean annual rainfall of approximately 430 mm per year (Table 1). Class A pan evaporation for Ravensthorpe of 1987 mm is approximately 4 times mean annual rainfall (Luke *et. al.,* 1988).

Table 1. Climatological summary for Ravensthorpe for data 1901 to 2003

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
Mean Daily Maximum Temperature	29.2	28.4	26.6	23.7	20.0	17.2	16.2	17.1	19.5	22.3	24.8	27.3	
Mean Daily Minimum Temperature	14.0	14.5	13.5	11.8	9.6	7.9	6.8	6.6	7.5	8.9	10.9	12.7	
Mean Monthly Rainfall (mm)	22.8	25.3	31.2	32.8	45.0	44.0	47.1	44.9	41.5	38.1	29.6	22.3	**427.7**
Monthly Rainfall 2003	5.8	34.8	70.9	37.5	33.0	18.2	55.1	56.0	33.7	29.2	45.9	20.8	440.9

Source: Bureau of Meteorology

2.3 Soils

Soils across the Kundip site are generally characterised as gravelly loam topsoils overlying light to heavy clays. Outback Ecology (2004) indicates the topsoils have good physical properties making the soils stable. The underlying clays are much less stable and prone to slaking and dispersion during wetting.

2.4 Topography

The topography of the Kundip Site is characterised by moderate slopes (5 to 10%). Stream channels within the landscape are moderately spaced forming an integrated network of convergent creeks (Figure 1).

The divide between the Steere River sub-catchments and Jerdacuttup River catchment to the east varies in elevation between 160 and 230 m AHD. The Steere River main channel falls from 145 to 117 m AHD north to south over a distance of 2.75 km adjacent to the Kundip Site (Figure 2).

2.5 Surface Drainage Features

Regionally, surface drainage is north to south from the Ravensthorpe Range towards the Southern Ocean. The main drainage arteries in the immediate Kundip area are the Phillips River, Steere River and Jerdacuttup River (Figure 1). The Phillips and Steere Rivers discharge to Culham Inlet 8 km north-west of Hopetoun, while Jerdacuttup River discharges to Jerdacuttup Lakes 12 km east of Hopetoun.

Historic mining at the Kundip Site has left a legacy of open pits and spoil heaps which create local surface drainage anomalies. These anomalies are too numerous to describe at the scale appropriate for this report.

2.6 Elverton Tailings Plume

The abandoned Elverton Mine and associated tailings dam are located at the northern boundary of the Steere River catchment (Figure 1). The tailings have been left unprotected and have progressively eroded to form an active sediment plume in the Steere River, extending downstream to the Kundip Site, which is being monitored by Department of Environment (DoE, 2004).

The mobile sediment plume is likely to encroach on Steere River culverts constructed along the main access road for Kundip. Unless regular maintenance is performed, creek flow will probably be over the floodway at shallow depth rather than through the culverts.

3. RUNOFF ESTIMATES: EXISTING CATCHMENT

3.1 Sub-Catchments

Surface drainage across the Kundip Site is generally south-west towards the Steere River, with 11 sub-catchments of the Steere River identified as shown in Figure 2. The existing physical characteristics of each sub-catchment are presented in Table 2 below.

Table 2: Sub-catchment characteristics: existing condition

Sub-Catchment	Estimated Area (ha)	% Cleared
1	22.1	15
2	16.7	15
3	49.3	18
4	28.2	5
5	91.8	15
6	11.4	17
7	177	9
8	2.2	10
9	10.9	15
10	5.4	6
11	81.7	10
Total	**496.7**	**12**

Table 3. Sub-catchment 7 characteristics: existing condition

Sub-Catchment	Estimated Area (ha)	% Cleared
7a	43.3	7
7b	59.2	9
7c	28.0	6
7d	21.1	20
7e	25.4	10
Total	**177.0**	**9**
7a & 7b	102.5	8

3.2 Land Use

As indicated in Table 2, currently the Study Area is largely uncleared and supports a range of native vegetation which varies from Mallee open forest to woodland.

Evidence of previous mining activity includes mine shafts and old diggings along with 3 small open pits that have been abandoned at the northern side of the Study Area, namely: Western Gem Pit, Two Boys Pit, and Kaolin Pit. In one of the abandoned areas around Flag Deposit, the surface soils are heavily disturbed, in particular around the creekline at the western end of the deposit (Outback Ecology, 2004).

3.3 Estimated Peak Flows

Due to the lack of gauged flow data on the Steere River, the Rational Method of flood estimation was adopted as recommended in Australian Rainfall and Runoff (AR&R, 2000). The Rational Method provides peak flow estimates up to the 50 year Average Recurrence Interval (ARI). For the 100 year ARI, the peak flow was estimated by extrapolation. The extrapolation to the 100 yr ARI is based on a linear extension between the 50 yr and 100 yr ARI using a ratio of 1.4. As an example the flood frequency curve showing the peak discharge for the existing catchment 7 is plotted as Figure 4. The ratio of Q100/Q50 is 3.90 ÷ 2.83 = 1.4 for sub-catchment 7.

The Kundip Site is within the Wheatbelt Zone for flood estimation (AR&R, 2000). Based on the catchment characteristics of the Study Area, equations for loamy and lateritic soils were adopted (AR&R, 2000). Analysis of rainfall intensity and duration (Figure 3) was carried out using procedures described in Book 2 of AR&R (2000).

Data sheets for flood estimation for each sub-catchment are include as Appendix A, with calculated flows presented in Tables 4 & 5.

Table 4: Peak flow estimates: existing condition

Sub-Catchment No.	Flow Peaks (m^3/s)	
	50 year ARI	100 year ARI
1	0.9	1.3
2	0.9	1.3
3	1.4	2.0
4	0.9	1.3
5	1.9	2.7
6	0.6	0.8
7	2.8	3.9
8	0.2	0.3
9	0.6	0.8
10	0.3	0.4
11	1.8	2.5
Steere River[1]	19.8	28.0

Note 1: Steere River Flow is calculated at the downstream end of the Kundip Site where catchment 11 tributary meets Steere River

Table 5: Peak flow estimates sub catchment 7: existing condition

Sub-Catchment No.	Flow Peaks (m^3/s)	
	50 year ARI	100 year ARI
7a	1.2	1.7
7b	1.7	2.4
7c	1.0	1.4
7d	1.3	1.8
7e	1.3	1.8
7a & 7b	2.9	4.1

The accuracy of the Rational Method in predicting floods on ungauged catchments, such as the Steere River, is only known for the 10 year ARI. For this event we can be 68% sure that the true value is between half and twice the estimated value (AR&R, 2000). Rarer flood estimates have a greater uncertainty associated with them.

4. PROPOSED MINES & INFRASTRUCTURE

4.1 Site Access & Layout

Access to the Kundip site is from Ravensthorpe-Hopetoun Road to the west of the site. The general layout of the site includes site offices and workshops, five open cut pits (three with potential for underground declines), two waste dumps and a surface water storage dam. Associated with the pits are Run of Mine (ROM) pads were the ore is stockpiled for haulage to RAV 8.

4.2 Roads

The main access road from the Ravensthorpe – Hopetoun is approximately 2.7 kms in length and connects to the existing gazetted road number 8432 at the eastern lease boundary (Figure 5). The haulage road extends east and then north to the RAV 8 mine where the ore from the Kundip mine will be processed. The other roads within the site can be seen in Figure 5. The main linkages are the offices/workshop and pits to the main access road and haulage road.

All the roads will have a proposed running width of 11m with 1:3 side batters.

4.3 Offices & Workshop

The offices and workshop are proposed to be located at the western end of the site approximately 300 m south off the main access road. Incorporated into the workshop area will be a fuel storage facility and a parking area suitable for heavy earthmoving vehicles.

4.4 Pits & Waste Dumps

The development includes 5 open cut pits and 2 waste dumps (Figure 5).

Hillsborough Pit: An open cut pit. ROM pad shared with Kaolin Pit

Kaolin Pit: An open cut pit. ROM pad adjacent

Maydon Pit: An open cut with proposed underground decline at base of pit. ROM pad adjacent

Flag Pit: An open cut pit with proposed underground decline at base of pit. ROM pad adjacent.

Try Again Pit: An open cut pit with proposed underground access from the Flag Area. ROM pad shared with Flag Area.

Waste Dump No 1: Located in the centre of the development covering an area of approximately 11 ha.

Waste Dump No 2: Located at the northern end of the development covering an area of approximately 18 ha

4.5 Flag Pit Flood Protection

The proposed location of Flag Pit overlays the junction of sub-catchment creeks 7a and 7b. To provide flood protection for the Flag Area it is necessary to construct new infrastructure to control these two creeks.

A dam exists just north of the proposed Flag Pit on the creek line marked as sub-catchment 7a in Figure 2. For flood protection of the Flag Area JDA understands that Tectonic Resources NL are intending to commission the design of a new dam upstream of the existing dam, along with a diversion structure and open drain to divert creek 7b west into the dam.

The new dam will have an overflow spillway on the western embankment with overflow discharging to the west via a channel cut through the catchment divide into the adjacent sub-catchment 7d creek. Creeks 7a and 7b will therefore be blocked upstream of the Flag Area with flow from both creeks controlled within the new dam and spillway to creek 7d.

The primary purpose of the new dam will be flood control to prevent inundation of Flag Pit. Mine water supply will be the secondary function.

5. RUNOFF ESTIMATES: DURING MINING OPERATIONS

5.1 Sub-catchments

Based on the proposed mine site layout the sub-catchment areas and level of clearing will change due the construction of infrastructure.

Generally the level of clearing in all sub-catchments will increase during mining. Some sub-catchment areas will be reduced due to internal drainage within pits. Diversion of runoff around the infrastructure, particularly pits, will occur which will cross sub-catchment boundaries.

Table 6 presents sub-catchment characteristics during mining operations indicating revised catchment areas and percentage cleared to the confluence with Steere River. Total catchment area reduces due to internal drainage within bunds around the pits.

Table 7, which includes Flag Pit, shows catchment characteristics for sub-catchment 7 during mining operations. The catchment areas described in Table 7 for sub-catchment 7a and 7b are upstream of the proposed flood control diversions (see Chapter 7).

Table 6. Sub-catchment characteristics: during mining operations

Sub-Catchment	Estimated Area (ha)	% Cleared
1	22.1	30
2	16.7	15
3	48.9	50
4	27.3	12
5	67.7	25
6	11.4	17
7	164.0	29
8	2.2	10
9	10.9	15
10	5.4	6
11	81.7	10
Total	**458.3**	**21**

Table 7. Sub-catchment 7 characteristics: during mining operations

Sub-Catchment	Estimated Area (ha)	% Cleared
7a (to proposed dam)	41.1	52
7b (to diversion)	48.4	25
7c	28.0	2
7d	21.1	25
7e	25.4	10
Total	**164**	**29**
7a & 7b	89.5	29

5.2 Estimated Peak Flows

Peak flows have been estimated based on the revised sub-catchment characteristics and are presented in Tables 8 & 9.

Table 8: Peak flow estimates: during mining operations

Sub-Catchment No.	Flow Peaks (m^3/s)	
	50 year ARI	100 year ARI
1	1.0	1.4
2	0.9	1.3
3	1.9	2.9
4	0.9	1.3
5	1.8	2.4
6	0.6	0.9
7	3.0	4.2
8	0.2	0.3
9	0.6	0.9
10	0.3	0.5
11	1.8	2.7

Table 9: Peak flow estimates sub-catchment 7: during mining operations

Sub-Catchment No.	Flow Peaks (m^3/s)	
	50 year ARI	100 year ARI
7a (to proposed dam)	4.0	5.6
7b (to diversion)	2.0	2.8
7c	1.1	1.7
7d	1.4	2.1
7e	1.0	1.5
7a & 7b	5.6	8.4

Using the Rational Method of calculation for peak flow estimates the effect of totally clearing an uncleared catchment increases estimated runoff by a factor of 2.6. There is some uncertainty regarding this factor, but other studies in the South-West of WA have concluded a factor of between 2 and 4.

A similar increase in annual runoff can be expected. The increased flow rates will need to be managed to ensure mine site safety from flood risk and to protect the environment from increased flooding and erosion.

6. RELEVANT DESIGN CRITERIA

The Department of Minerals and Energy (1998) Guidelines for environmental approval of mining projects in WA includes the following specific requirements relevant to this report.

Existing Environment – Hydrology (page 23)

- “Brief summary of surface and sub-surface flows as they relate to the project and facilities including any flood potential…”
- “To assist the assessment of flood impact, a contour plan encompassing the area of operations and up to a minimum of 500 metres around the operation is required. This contour plan should have a maximum contour interval of 5 metres with a 2 metre interval being preferred.”

Existing Environment – Climate (page 23)

- “The NOI should contain climatic information necessary to adequately assess and manage all significant environmental effects emanating from the project. Minimum drainage design should be based on the 100 year return rainfall event.”

Environmental Impact Assessment and the Management Commitments – Land Clearing (page 26)

- “The impact of land clearing and vegetation removal on soil erosion, salinity and hydrology should be assessed and described….”
- “Land management and drainage strategies should be considered along with factors like the areas shape and profile, water control…”

Environmental Impact Assessment and the Management Commitments – Water (page 26)

- “Impacts on local water resource and other users”
- “Dewatering requirements, drainage controls and impact on regional drainage”.

JDA understand that all other NOI requirements will be addressed seperately to this report.

7. SURFACE WATER CONTROLS

7.1 General

An outlay of the proposed surface water control treatments as described below are presented in Figure 6. The aim is to optimise flood control and surface water resources. Clearly mining operations will generate additional surface runoff associated with clearing of vegetation. This additional runoff can be used by the mine operation, while seeking to maintain environmental flows in the creeks at existing rates as far as possible.

7.2 Flag Pit Flood Control

Flag pit is located at the junction of Creek 7a and 7b. It is proposed to dam both creeks 7a and 7b upstream of the Flag Area, diverting flood events from catchments 7a and 7b by gravity into catchment 7d to the west. A diversion structure and open drain to divert creek 7b into 7a is shown on Figure 6 and Figure 7(open drain No 2). The proposed dam on Creek 7a will have a spillway and overflow channel to the west through the catchment divide discharging into creek 7d.

Downstream of the diversions on creeks 7a and 7b will be a sump and pump-back facility installed to capture run-off occurring between these structures and Flag Pit bund.

Chapter 6 guidelines suggest 100 year ARI design criterion as a minimum for flood control. This has been confirmed by Department of Industry and Resources (Ian Misich *pers. comm.*). JDA recommends flood control for Flag Pit should be based on a higher than 100 year ARI design criterion. To achieve this we have adopted a factor of safety of approximately 2 applied to 100 year ARI flood estimates.

Based on Table 9 the design of the diversion from creek 7b to 7a (open drain 2) should therefore be based on 6 m^3/s, and the dam spillway from creek 7a to 7b should be based on 18 m^3/s. Table 10 presents indicative dimensions for these diversion drains assuming a Manning's Roughness Co-efficient of 0.06 and side batters of 1:3.

Table 10. Dimensions of open drains

Diversion Drain No.	Design Flow (m^3/s)	Base width (m)	Side Batter (v:h)	Mainstream average grade (v:h)	Roughness 'n'	Flow Depth (m)
1	0.8	0.5	1:3	1:200	0.06	0.7
2	6	5	1:3	1:250	0.06	1.0
3	0.4	0.5	1:3	1:300	0.06	0.6
4	0.3	0.3	1:3	1:15	0.06	0.3
5	3.5	0.5	1:3	1:20	0.06	0.8
6	0.5	0.5	1:3	1:42	0.06	0.4
Dam Spillway	18	15	1:3	1:230	0.06	1.0

7.3 Offices & Workshops

Approximately 2 ha would need to be cleared to accommodate the buildings, service carpark and fuel storage area associated with the offices and workshops. Drainage from this area will need to be managed using sediment traps, hydrocarbon traps and erosion controls.

Due to the topography of the proposed site a small catchment will flow towards the site from the east. This flow can be controlled by an open drain built along the eastern boundary of the site directing the water north to creek 5. The catchment area contributing flow is approximately 3 ha. The estimated 100 year ARI peak flow from this area is 0.14 m^3/s. A channel of dimensions 0.3 m base width, 0.5 m depth at a minimum grade of 1:200 will convey this flow assuming 0.06 Manning's roughness coefficient. Management of groundwater seepage (through-flow) along the uphill side (east) of the cleared site may also be required. We consider the drainage structures incorporated into the road along the south of the site will intercept any surface flows from this direction.

7.4 Roads

Road drainage within the Kundip Site will need to be managed by incorporating road side drains into road designs. With the road drains flows can be controlled by use of energy dissipaters, drop structures and sediment controls. Any existing roads with erosion damage that Tectonic Resources NL intends to utilise should be resurfaced with erosion control structures installed to stabilise the road.

7.4.1 Road Crossings

Road crossings are required where the proposed roads intersect creeklines. This will impact on a number of internal roads which cross Creeks 5 and 7 where minor crossings will be required.

Major road crossings occur where;

1. Crossing 1: Main access road crosses Steere River (Figure 6). Table 4 shows a 100 year ARI flow for Steere River of 28 m^3/s. It is proposed the crossing consist of a bank of low flow culverts and a floodway. Note that maintenance will be required to prevent the culverts from becoming blocked by the active sediment plume from the Elverton Tailings upstream.
2. Crossing 2: Main access road crosses Creek 5 (Figure 6). The Creek 5 catchment upstream of the road crossing will be altered by the construction of Kaolin and Hillsborough Pit reducing the area of runoff, but clearing will increase the runoff rate of remaining areas. From Table 8 the 100 year ARI flow for Creek 5 is estimated to be 2.40 m^3/s. The culvert should be sized to accommodate this flow. Assuming inlet control three 1200 x 600 mm box culverts can carry this flow.
3. Crossing 3: The service roads cross Open Drain No 2 (Creek 7b diversion). Creek 7b will be diverted to sub-catchment 7a via the proposed Open Drain No 2. The design flow in the Open Drain No 2 diversion is 6 m^3/s. The culvert should be sized to accommodate this flow. Assuming inlet flow control, three 1350 mm diameter culverts can convey this flow.

7.5 Runoff Erosion Controls

Due to the physical characteristics of the soil identified by Outback Ecology (2004) runoff erosion controls will be required for all cleared areas. We recommend these controls be considered at the design stage of the infrastructure.

It is also worth noting the Waste Dumps cover an area of approximately 11 and 18 ha respectively. The additional runoff from the dumps will need to be managed to ensure erosion of the surrounding landscape does not occur. Where runoff from the Waste Dumps is concentrated detention basins should be constructed to attenuate peak flows from each catchment to pre-developments rates.

7.6 Pit and Waste Dump Flood Mitigation and Ponding Controls

Due to the particular importance of flood mitigation and ponding controls for the Pits and Waste Dumps they are discussed separately below. The proposed mine site layout will allow adequate spacing between the pits, waste dumps and other infrastructure (roads) to enable construction of drainage structures. The discussion below outlines the required drainage management plan for the pits and waste dumps. Refer to Table 10 for estimated dimensions of open drains discussed.

Hillsborough Pit

Drainage Design Considerations: The pit is situated mid slope on a relatively steep part of the sub-catchment of Creek 5. The pit extends close to the catchment boundary and as such surface flows towards the pit should be minor and not require any special controls.

Flood Mitigation Controls: Appropriate control bunds should be installed around the pit to prevent any surface water flows entering in the pit.

Ponding Controls: The natural surface grade around the pit will prevent any surface flows from ponding against the pit control bunds.

Kaolin Pit

Drainage Design Considerations: The pit is situated across the sub-catchment boundary of Creek 3 and 5. Some surface flows are expected towards the north east corner of the pit from higher in the catchment of Creek 3.

Flood Mitigation Controls: Appropriate control bunds should be installed around the pit to prevent any surface water flows entering in the pit. As Waste Dump No 2 develops, drains will be required to ensure runoff from the Waste Dump does not flow towards Kaolin Pit. This drainage can be directed west to Creek 3 (Open drain 5, Figure 6 and 9).

Ponding Controls: A drain should be constructed along the eastern pit boundary to prevent ponding against the abandonment bund (Open drain 4, Figure 6 and 8). Runoff should be directed south along the eastern boundary of the abandonment bund to Creek 5.

Maydon Pit

Drainage Design Considerations: The pit is situated close to the sub-catchment boundaries of 5, 7a and 7d.

Flood Mitigation Controls: Appropriate control bunds should be installed around the pit to prevent any surface water flows entering in the pit.

Ponding Controls: An open drain should be constructed to prevent surface water ponding along the abandonment bund at the southern end of the pit (Open drain 3, Figure 6 and 8). The drain will direct flows west towards creek 5.

Flag Pit

Drainage Design Considerations: The Flag Pit is located in a valley at the junction of Creek 7a and Creek 7b. The catchment area draining to this junction is significant and a creek diversion of both creeks is required to prevent flooding of the pit.

Flood Mitigation Controls: Appropriate water control bunds should be installed around the pit to prevent any surface water flows entering in the pit. It is proposed to divert large flows from both creeks west to sub-catchment 7d via an open drain and spillway arrangement (Open drain 2 and spillway, Figure 6 and 7). The dam will store minor runoff events which can be opportunistically used for mine operations. The dam sizing is discussed further in Section 7.7.

A sump will be required at the lowest point on the north side of the Flag Area to collect runoff from the small area downstream of the diversions. The water collecting in the sump can then be pumped back to the storage dam on creek 7a.

Ponding Controls: Ponding controls will be required at the northern edge of the pit. The sump and pump back scheme will accommodate this area as discussed above. An open drain will be required to prevent surface flows from the southern side of the pit ponding against the abandonment bund. The flows will be directed west to creek 7b downstream of the pit.

Try Again Pit

Drainage Design Considerations: The pit is situated across the sub-catchment boundaries of Creeks 7b and 7c. The topography falls away from the pit.

Flood Mitigation Controls: Appropriate control bunds should be installed around the pit to prevent any surface water flows entering in the pit.

Ponding Controls: Ponding controls will be required to prevent surface flows ponding against the abandonment bund on the southern side of the pit. The flows will be directed west to creek 7b downstream of the pit via an open drain (Figures 6 and 9).

Waste Dump No 1

Drainage Design Considerations: Waste Dump No 1 encompasses an area of 11 ha within sub-catchment 7a and overlays the creekline, cutting off the upper reach of the creek. As a result runoff will pond against at the north east side of the dump. The design of the waste dump is assumed to direct the runoff from the dump into creek 7a.

Flood Mitigation Controls: The Waste Dump spans the width of Catchment 7a with topography falling from the dump along the north and south long sides and the western side. Appropriate control bunds should be installed around the dump to prevent any surface water flows reaching the toe of the dump.

Ponding Controls: Water is expected to collect along the north east side of the Waste Dump. There should be sufficient grade to construct an open drain to direct the flow into the top end of Creek 7b (Open drain 1, Figure 6 and 7).

Waste Dump No 2

Drainage Design Considerations: Waste Dump No 2 encompasses a large area of the upper part of sub-catchment 3.

Flood Mitigation Controls: The runoff from the waste dump will need to be controlled along the southern boundary to prevent any flows to Kaolin Pit. The flows can be directed west via an open drain to discharge into creek 3 downstream of the dump (Open Drain 5, Figure 6 and 9). The increased flow in Creek 3 from the Waste Dump runoff should be attenuated to pre-mining levels by a detention basin.

Appropriate water control bunds should be installed around the dump to prevent any surface water flows reaching the toe of the dump.

Ponding Controls: An open drain to the east of the waste dump (open drain 4) will prevent ponding from occurring by discharging the water south past Kaolin pit to creek 5.

7.7 Surface Water Supply

The primary purpose of the dam above Flag Pit is to provide flood control, but the water stored within the dam could be used opportunistically to meet part of the mine water supply.

The dam concept design as supplied to JDA by Coffey Geosciences Pty Ltd has an approximate capacity of 12 000 m^3 below the spillway level.

With an annual average rainfall of 430 mm/yr and an expected average runoff coefficient on an annual basis of between 2 and 10%, we estimate the average annual runoff to the proposed dam to be between 3000 and 20 000 m^3/yr. Allowing for dam evaporation of approximately 70% of Class A pan or 1391 mm annually, we expect a large proportion of the storage will be lost to evaporation if left in storage. It may be several years after dam construction before a wet year fills this size of dam. As such it would probably be more efficient to use the stored water on an opportunistic basis rather than at a constant rate to minimise evaporation loses.

It is not possible to provide firmer estimates of the water resource potential as the runoff volumes are sensitive to the runoff coefficient, of which there is some uncertainty.

8. CONCLUSIONS

- The Kundip Project is a mining only development with the ore transported north to the RAV 8 plant for processing.
- The proposed development area is within the catchment of the Steere River.
- There are 11 sub-catchments within the Study Area which are tributaries of the Steere River.
- Peak flows have been estimated for each sub-catchment based on the rational method described in Australian Rainfall & Runoff (2000).
- Due to the lack of gauged data for rivers in the Esperance Coast area, the peak flows are indicative only.
- The diversion of creek 7b and 7a into 7d is required to prevent flooding of the Flag pit.
- Road crossings are required where the Main Access Rd crosses Steere River, Creek 5 and the service road crosses creek 7b diversion.

9. RECOMMENDATIONS

Based on the preliminary investigations presented in this report we recommend the following;

- Flood estimates contained in this report should be reviewed as the site planning progresses.

10. REFERENCES

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Janicke, S. (2004) *The Downstream Impact of Mine Site Tailings entering the Upper Steere River at Elverton.* Department of Environment, Albany report.

FIGURES

Data Source: Ravensthorpe SI51-05, Geoscience Australia, Commonwealth of Australia (2004)

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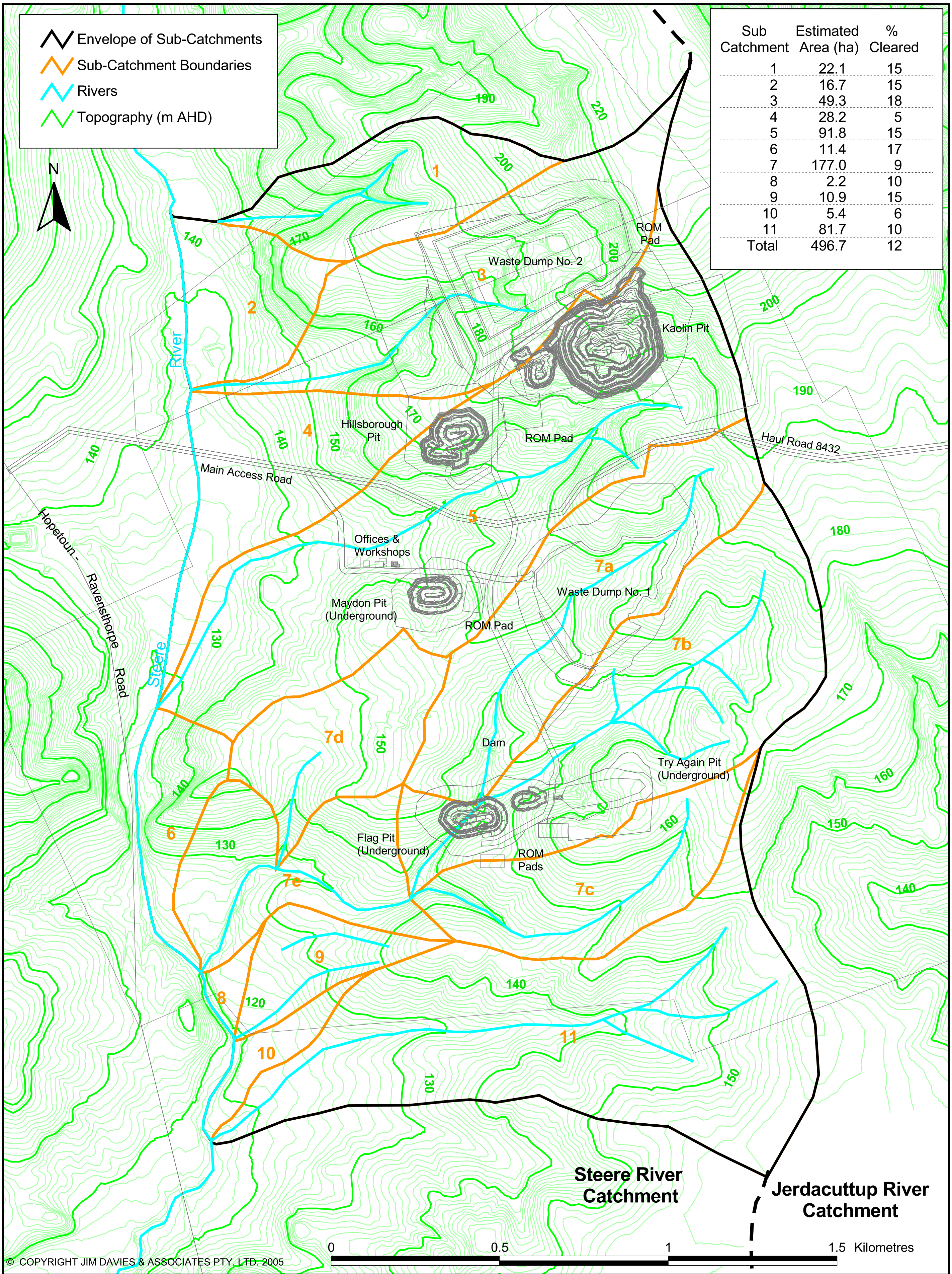
Kundip NOI: Surface Hydrology Assessment
Figure 1: Kundip Project Location Plan



Sub Catchment	Estimated Area (ha)	% Cleared
1	22.1	15
2	16.7	15
3	49.3	18
4	28.2	5
5	91.8	15
6	11.4	17
7	177.0	9
8	2.2	10
9	10.9	15
10	5.4	6
11	81.7	10
Total	496.7	12

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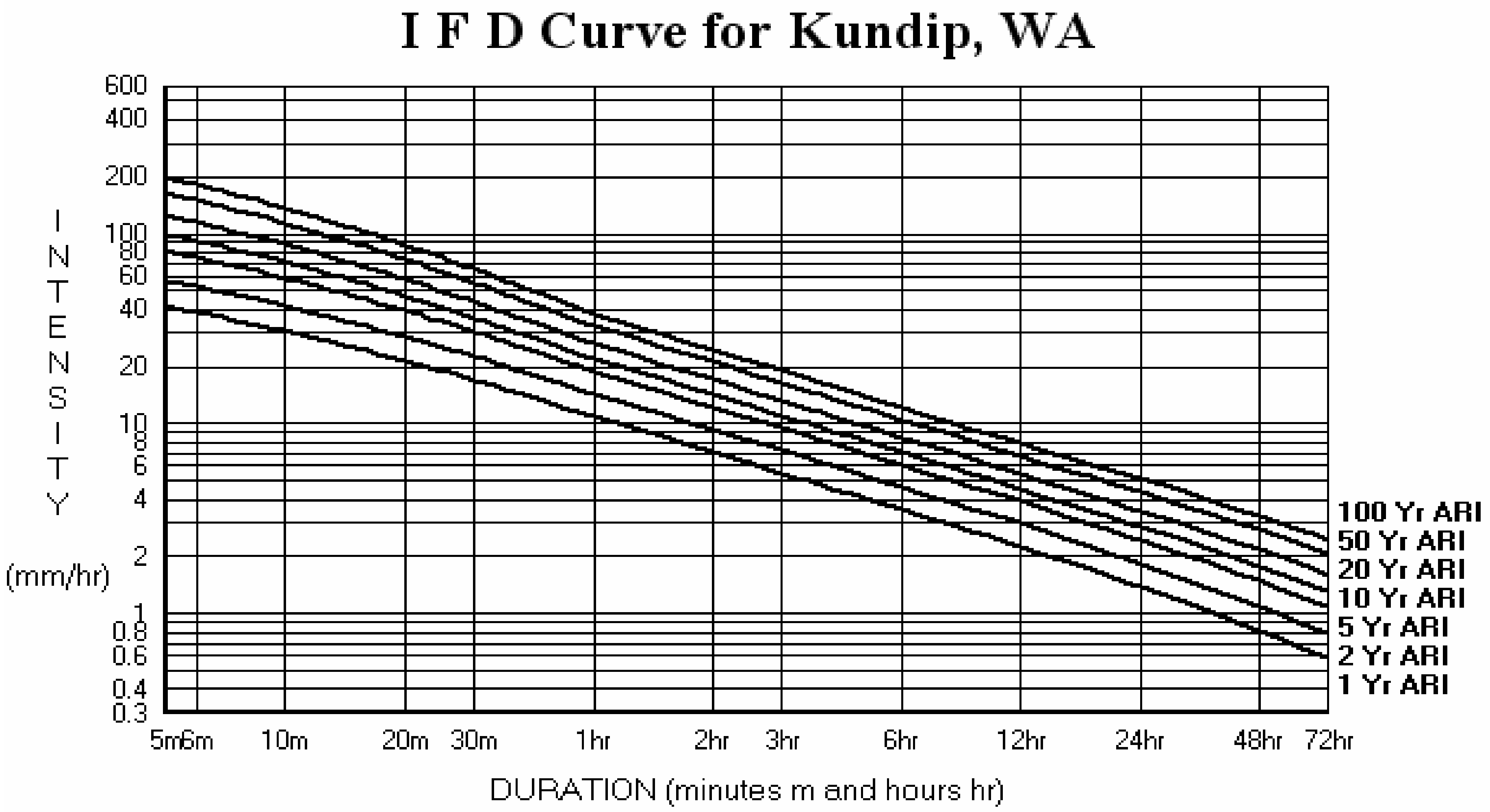
Kundip NOI : Surface Hydrology Assessment

Figure 2: Surface Drainage Catchment Plan



Data Source: AusIFD version 2.0

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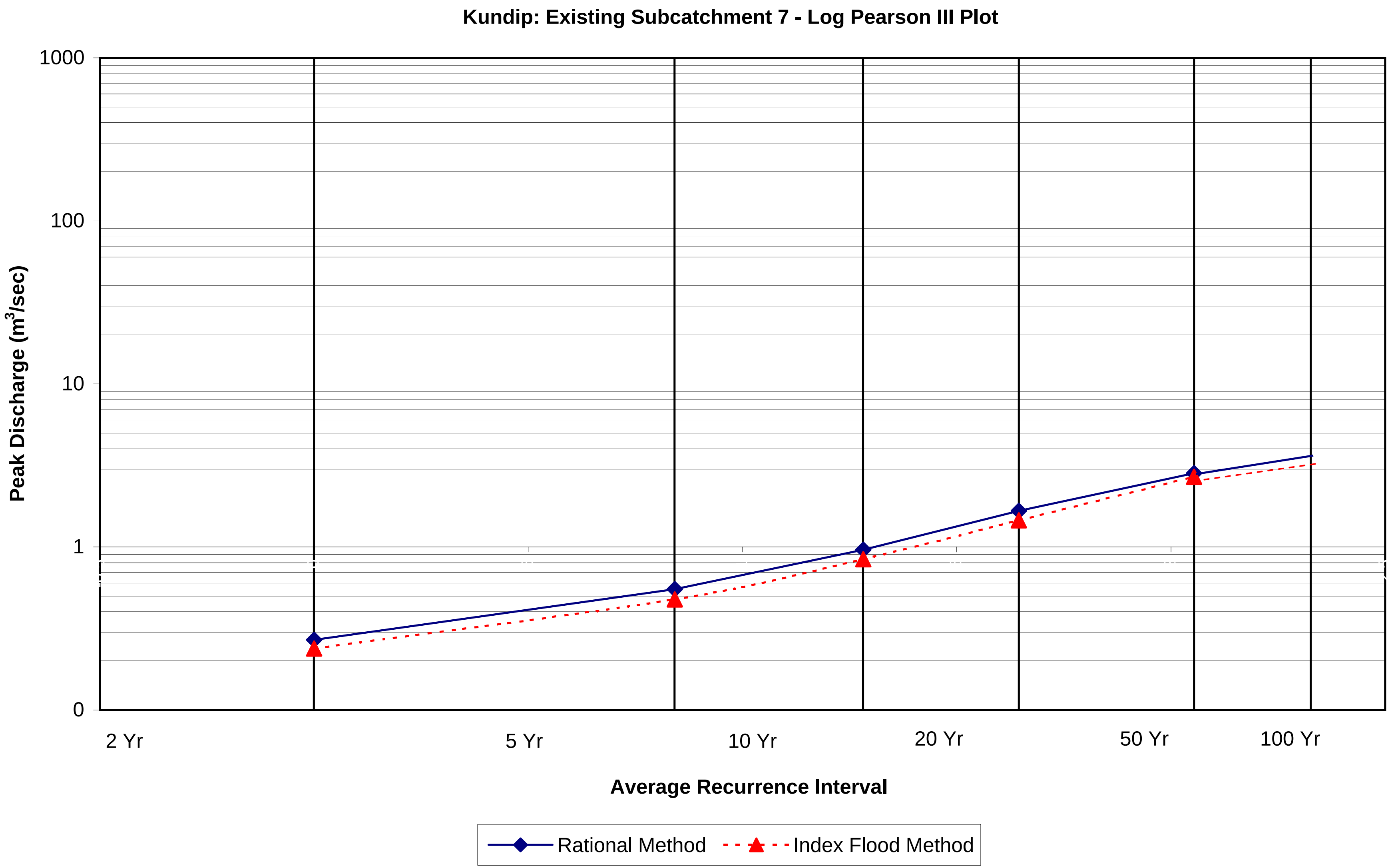
Kundip NOI: Surface Hydrology Assessment

Figure 3: Kundip Intensity Frequency Duration (IFD) Curve



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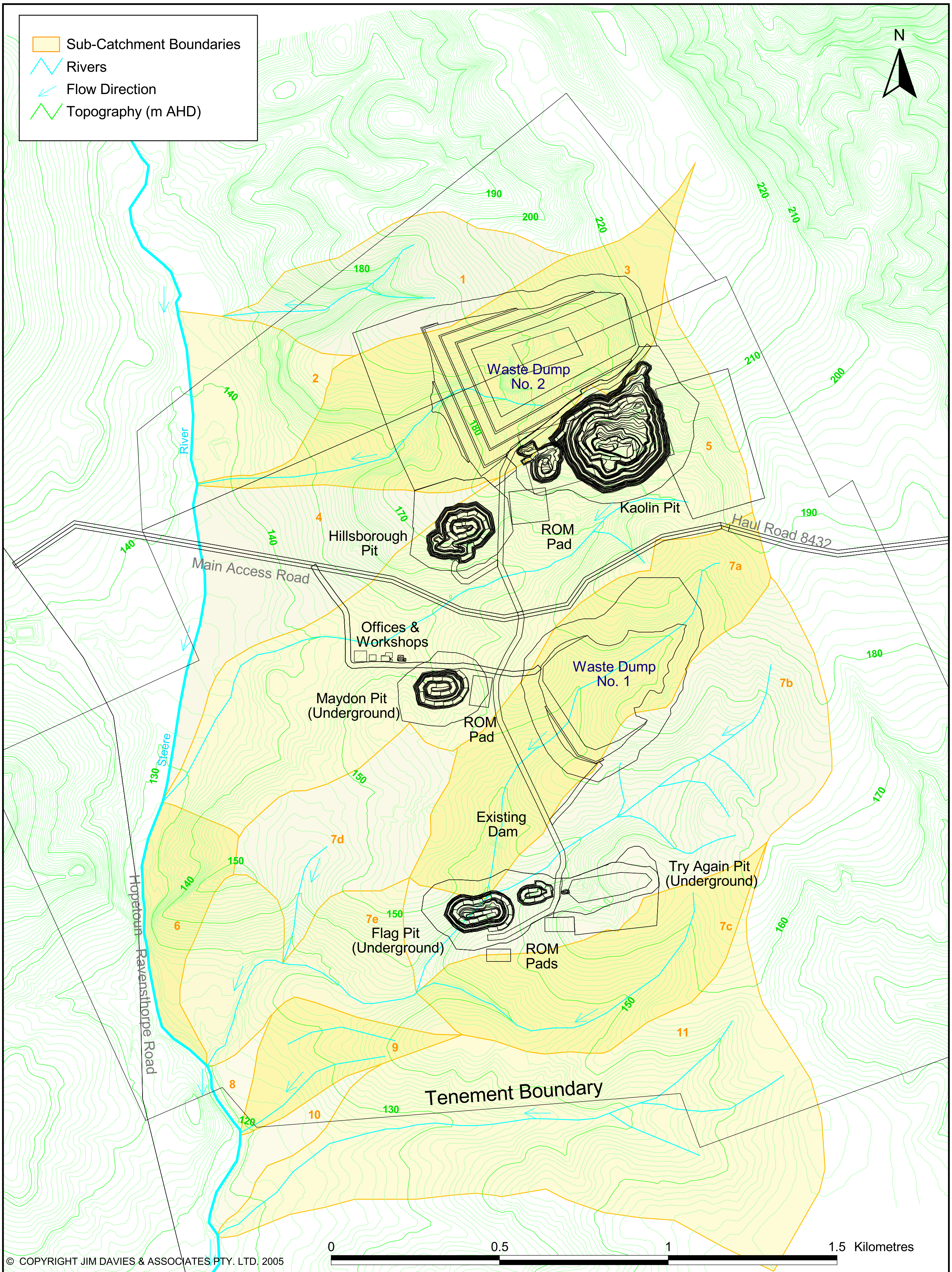
Kundip NOI: Surface Hydrology Assessment

Figure 4: Flood Frequency Curves



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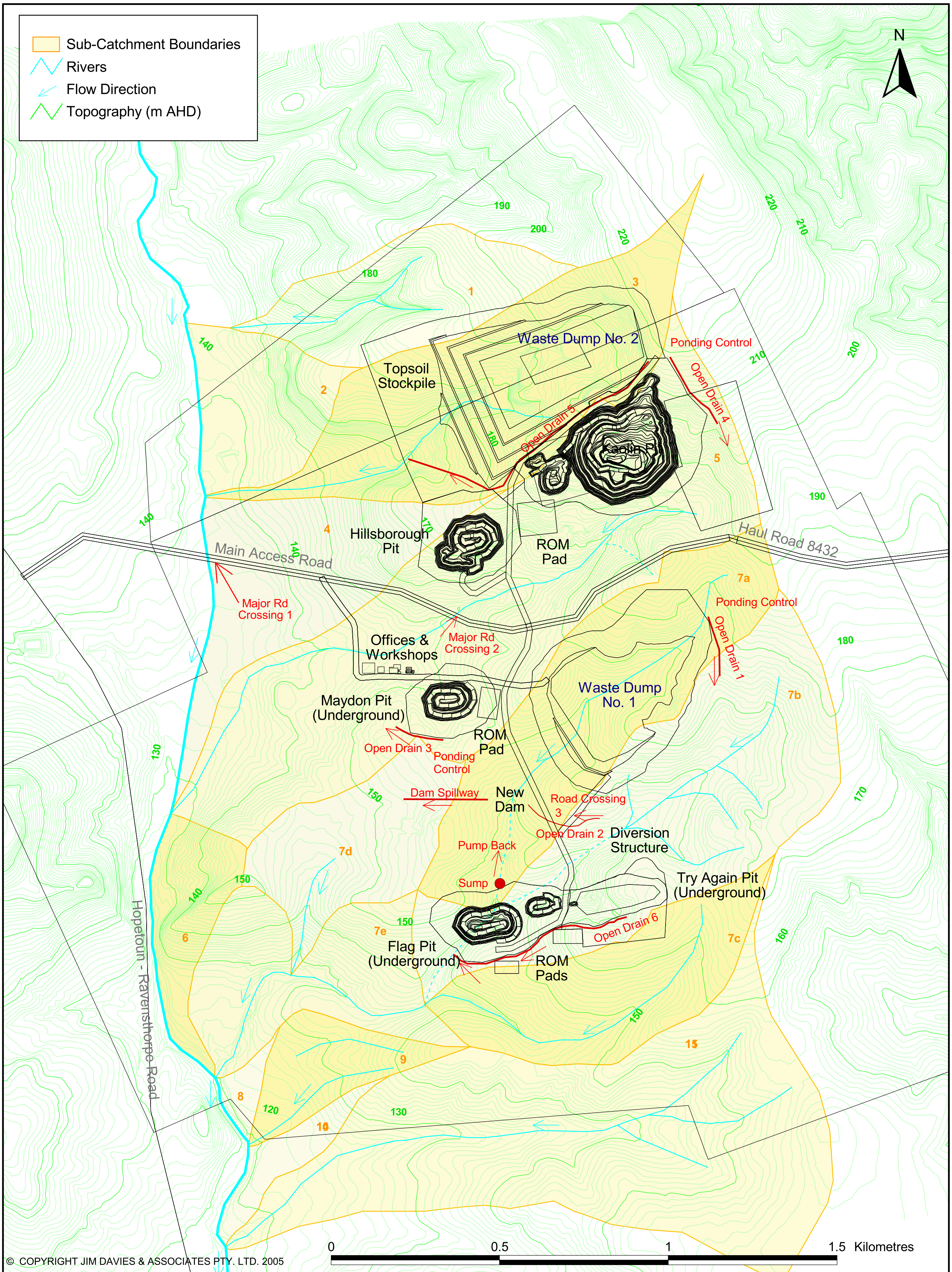
Kundip NOI : Surface Hydrology Assessment

Figure 5: Proposed Site Layout Plan



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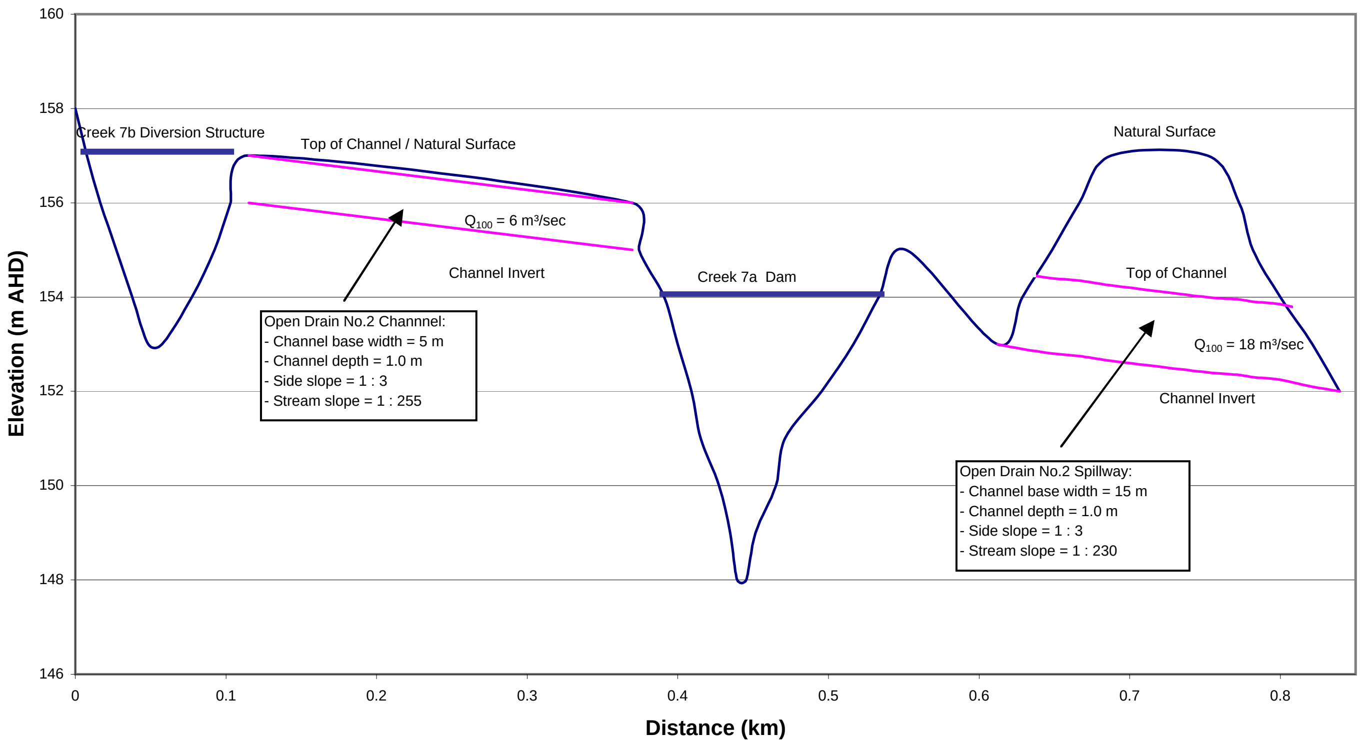
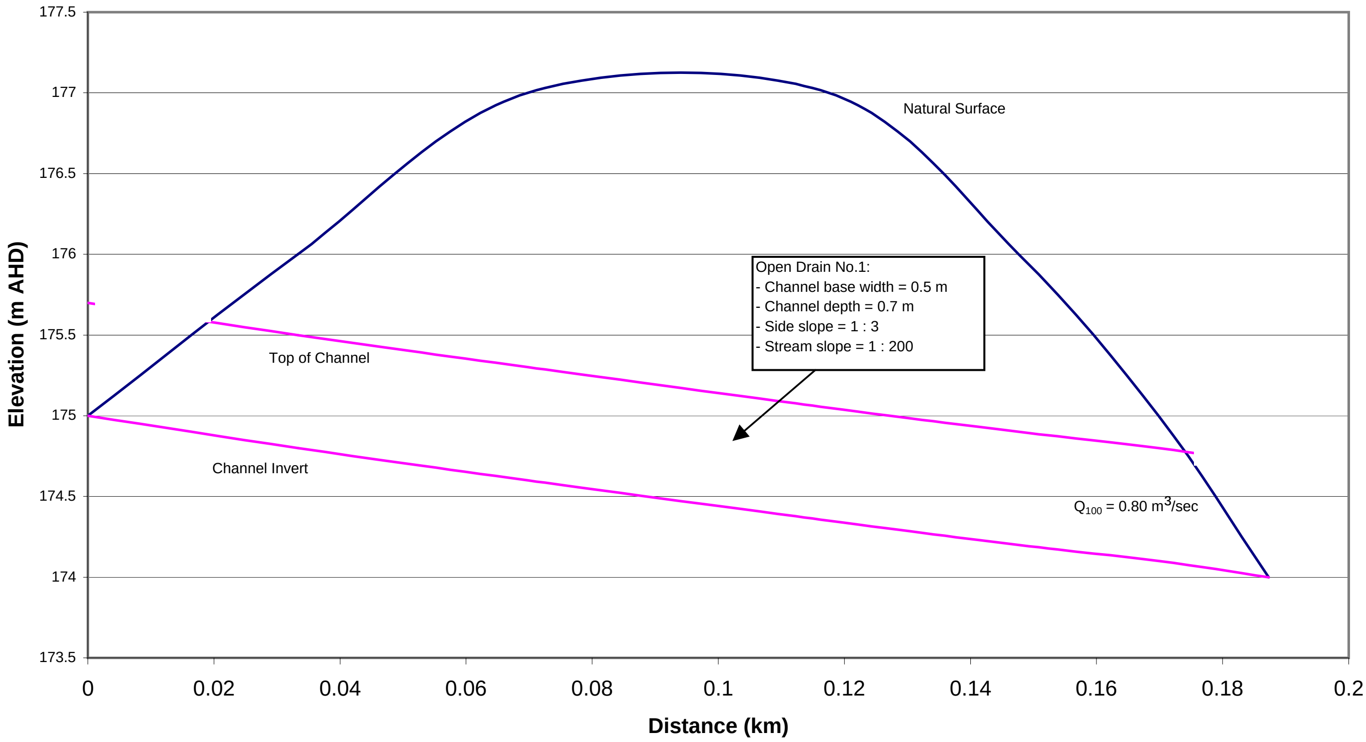
Kundip NOI : Surface Hydrology Assessment

Figure 6: Surface Water Control Treatments



7a. Flag Pit Creek Diversion Long-Section



7b. Waste Dump No.1 Diversion Long-Section

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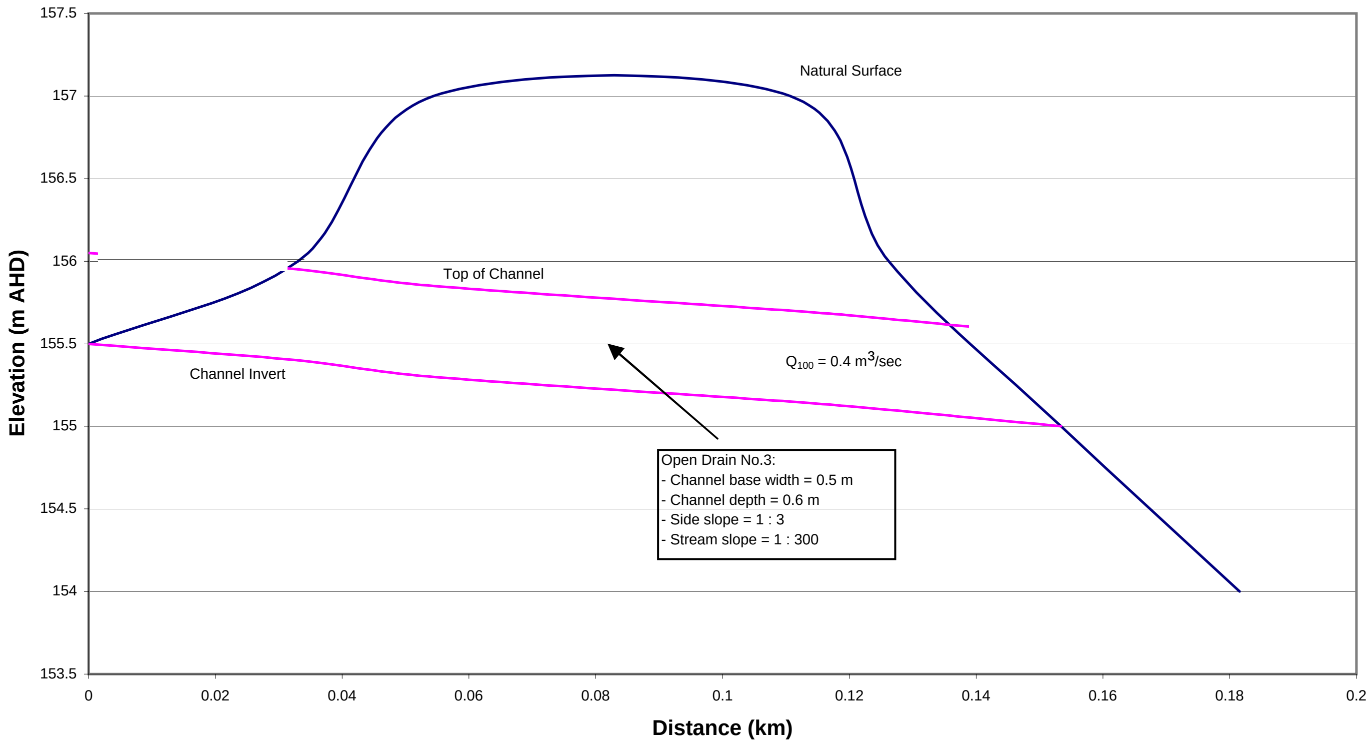
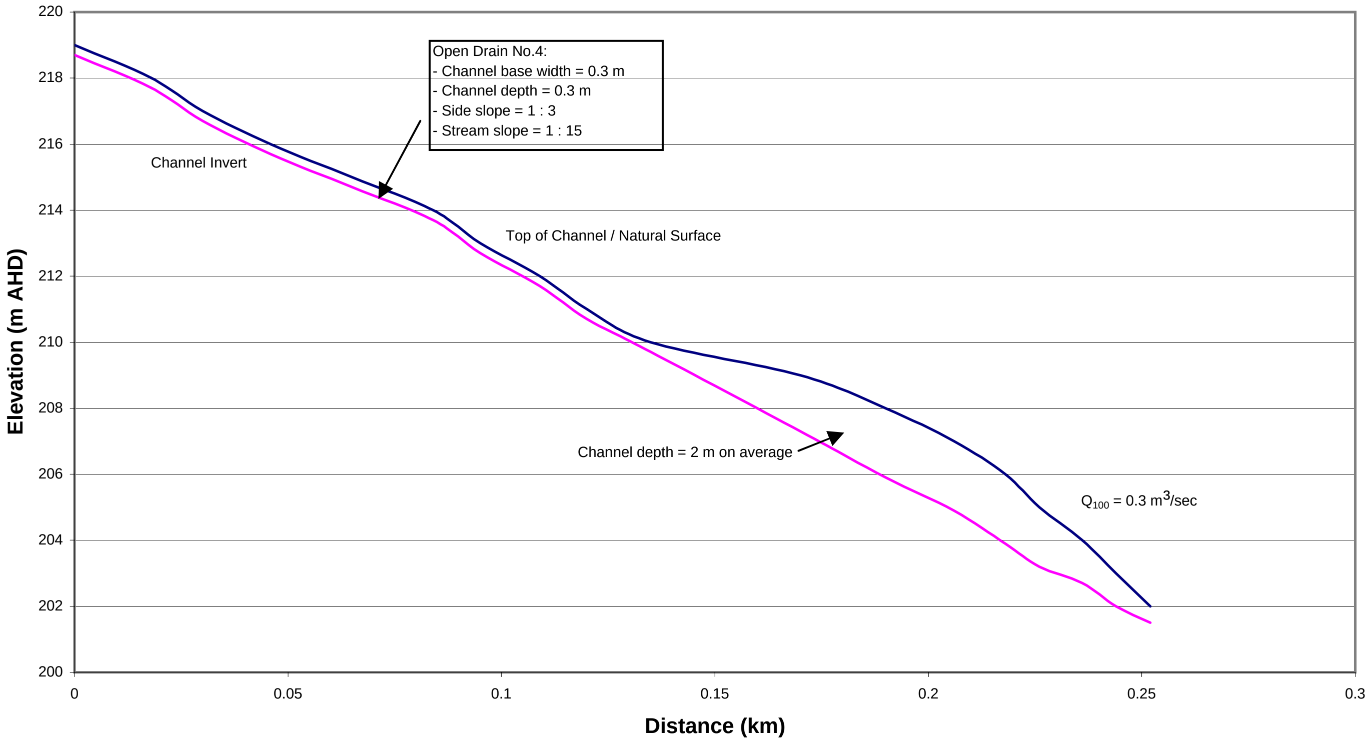
Kundip NOI: Surface Hydrology Assessment

Figure 7: Flag Pit Creek and Waste Dump No.1 Diversion Long Section



8a. Maydon Pit Ponding Control Long-Section



8b. Kaolin Pit Ponding Control Long-Section

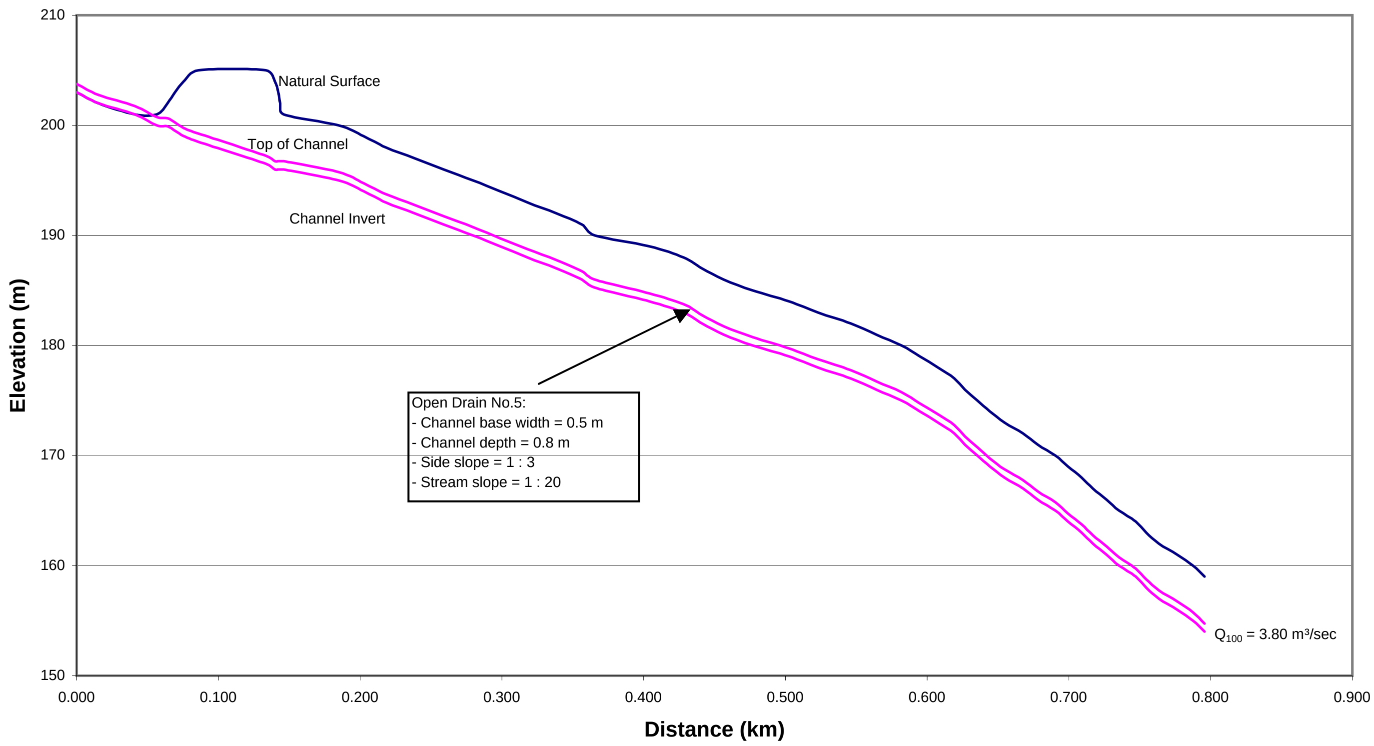
JDA Consultant Hydrologists

Job No. J3319

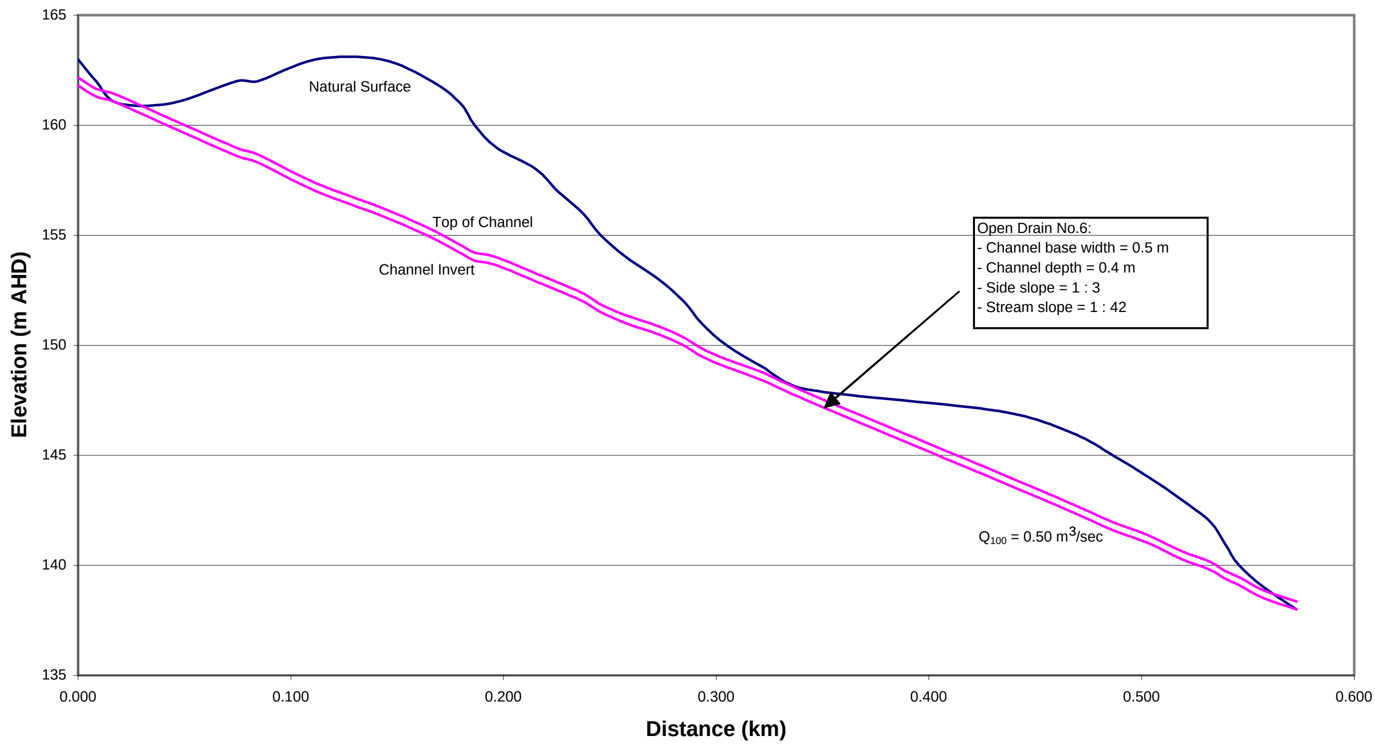
Tectonic Resources NL

Kundip NOI: Surface Hydrology Assessment

Figure 8: Maydon Pit and Kaolin Pit Ponding Control Long Section



9a. Waste Dump No.2 Runoff Interception Drain



9b. Flag Pit & Try Again Pit Southern Boundary Ponding Control Long-section

JDA Consultant Hydrologists	Job No. J3319	Tectonic Resources NL Kundip NOI: Surface Hydrology Assessment **Figure 9: Waste Dump No.2 Runoff Interception Drain and Flag Pit & Try Again Pit Southern Boundary Ponding Control Long Section**

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Analyte	Date	Al mg/L	As mg/L	B mg/L	Ba mg/L	Ca mg/L	Cd mg/L	Cl mg/L	Co mg/L	CN WAD mg/L	Cr mg/L	Cu mg/L	Econd mS/m	Co3 mg/L	HCo3 mg/L	Hg mg/L	Fe mg/L	K mg/L	Mg mg/L	Mn mg/L	Mo mg/L	N_NO3 mg/L	N-NO2 mg/L	N-total mg/L	Na mg/L	Ni mg/L	Pb mg/L	P-total mg/L	Se mg/L	SO4 mg/L	TDS mg/L	V mg/L	Zn mg/L	pH
RAV20	23/9/02	0.008		5.4	0.05	142	<0.005		<0.005		<0.002	<0.002	3270				0.19	195	1630	0.55	<0.010	0.01			8940	0.015	<0.010				31000	<0.005	<0.005	7.8
RAV20	15/9/03												1280									0.01				0.02					7800			8
RAV20	25/3/04					126		14000					4030	120	616			150	1370			0.02			8030	<0.01				2050				8.6
RAV20	11/11/04		<0.010			112	<0.0010		<0.005	<0.01	0.002	<0.005	2930	<2	702		0.016	94.4	1010				<0.02	1.9	5330	0.01	<0.0050	0.02	<0.05	1440	21000			8.1
RAV20	18/3/05	<0.05	<0.05	21	0.23	211	<0.005	72000	<0.05		<0.02	<0.05	13100	180	1040	<0.0005	<0.05	737	7660	0.7	<0.05	0.01			39400	<0.05	<0.005		<0.05		140000	<0.05		8.6
RAVA	17/3/05	<0.05	<0.02	9.6	0.39	138	<0.002	19000	<0.05		<0.02	<0.05	5550	108	1260	<0.0005	<0.05	341	2740	0.06	<0.02	<0.01			10500	<0.02	<0.002		<0.02		45000	<0.05		8.5
RAVB	23/9/02	<0.005		4.9	0.14	138	<0.005		<0.005		<0.002	<0.002	3110				0.56	174	1710	0.26	<0.010	0.01			8130	0.029	<0.010				31000	<0.005	<0.005	7.5
RAVB	11/11/04		<0.010			116	<0.0010		<0.005	<0.01	0.002	<0.005	4770	<2	1400		0.047	234	2210				<0.02	0.92	10600	0.01	<0.0050	0.05	<0.05	2930	35000			7.8
RAVB	10/2/03	<1		5.5	<2	81	<0.05		<0.5		<0.5	<0.5	5300				<0.5	190	1800	<0.5	<1	<0.05			8100	<0.5	<0.5				33000	<5	<0.5	7.9
RAVB	15/9/03					147		15000					4210	<2	1360			177	1870			0.01			8180	0.02				295	30000			7.7
RAVB	25/3/04					111		18000					4820	<2	1440			203	2240			0.01			9780	<0.01				3180				7.8
RAVB	17/3/05	0.019	<0.01	6.7	0.1	105	<0.001	18000	<0.005		<0.002	<0.005	4640	91	1190	<0.0005	<0.005	232	2220	0.21	<0.01	<0.01			10300	0.01	0.003		<0.01		36000	0.006		8.4
RAVC	23/9/02	0.005		4.1	0.022	49	<0.005		<0.005		<0.002	<0.002	3570				0.014	201	2160	<0.005	<0.010	0.01			10200	<0.010	<0.025				37000	<0.005	<0.005	8.6
RAVC	10/2/03	1		51	<2	200	<0.05		<0.5		<0.5	<0.5	20000				<0.5	3300	36000	0.9	<1	<0.05			64000	<0.5	<0.5				360000	<5	0.6	6.8
RAVC	15/9/03					52.6		850					333	<2	256			16.9	87.7			0.01			520	0.03				135	1800			8.3
RAVC	25/3/04					591		60100					12400	108	436			578	5770			0.05			31400	0.02				11400				8.3
RAVC	11/11/04		0.0003			12.3	<0.0001		<0.005	<0.01	0.008	<0.005	19.6	<2	79		0.5	5.4	25.7				<0.02	1.4	113	0.03	0.0005	0.03	<0.05	35.9	140			7.4
RAVD	23/9/02	<0.005		4.5	0.13	133	<0.005		<0.005		<0.002	<0.002	3020				0.12	168	1630	0.076	<0.010	0.02			7890	0.02	<0.010				31000	<0.005	<0.005	8.1
RAVD	20/2/03	<1		<2	5.5	130	<0.05		<0.5		<0.5	<0.5	5100				<0.5	190	1900	3.7	<1	0.19			8900	<0.5	<5				33000	<5	<0.5	8
RAVD	15/9/03					161		9400					2900	<2	982			109	1220			0.01			5310	0.03				161	19000			8.1
RAVD	25/3/04					119		20000					5320	255	1000			223	2320			0.02			10500	0.01				3380				8.4
RAVD	11/11/04		<0.010			118	<0.0010		<0.05	<0.01	<0.02	<0.05	5120	<2	1400		<0.05	239	2210				<0.02	1.7	10200	<0.10	<0.0050	<0.01	<0.50	3150	38000			8.3
RAVD	17/3/05	<0.05	<0.02	8.6	0.11	79	<0.002	22000	<0.05		<0.02	<0.05	5510	264	964	<0.0005	<0.05	310	2880	<0.01	<0.02	<0.01			10700	<0.02	<0.002		<0.02		47000	<0.05		8.9
RAVE	15/9/03					24.4		50					39	<2	140			5.6	12.6			0.17			34.8	0.08				11.8	270			7.5
RAVE	26/3/04					52.2		50					129	<2	372			13.5	32.5			0.01			53.3	0.03				5.3				7.8
RAVE	11/11/04		<0.010			133	<0.0010		<0.005	<0.01	<0.002	0.01	4890	143	442		0.006	216	1880				<0.02	4.9	9880	0.02	<0.0050	0.04	<0.05	2960	36000			8.5
RAVF	23/9/02	<0.005		4.4	0.14	123	<0.005		<0.005		<0.002	<0.002	3050				0.11	178	1670	0.046	<0.010	<0.01			8110	0.013	<0.010				30000	<0.005	<0.005	8.2
RAVF	20/2/03	<1		<2	5	140	<0.05		<0.5		<0.5	<0.5	5100				<0.5	200	1900	0.7	<1	0.07			9100	<0.5	<5				34000	<5	<0.5	8
RAVF	15/9/03												1340									0.02				0.03					8400			8.4
RAVF	25/3/04					107		21000					5490	240	979			236	2490			0.02			11400	<0.01				3540				8.4
RAVF	11/11/04		<0.010			122	<0.0010		<0.05	<0.01	<0.02	<0.05	5460	<2	1380		<0.05	241	2280				<0.02	2.4	10400	<0.10	<0.0050	0.01	<0.50	3220	40000			8.3
RAVF	17/3/05	<0.05	<0.05	16	0.31	152	<0.005	55600	<0.05		<0.02	<0.05	10200	312	1220	<0.0005	<0.05	659	6180	0.1	<0.05	<0.01			25900	<0.05	<0.005		<0.05		100000	<0.05		8.8
RAVG	23/9/02	0.55		3.3	0.16	126	<0.005		<0.005		<0.002	<0.002	3040				0.036	156	1620	0.025	<0.010	0.01			7980	0.031	<0.010				30000	<0.005	<0.005	8.1
RAVG	20/2/03	<1		<2	5	130	<0.05		<0.5		<0.5	<0.5	5700				<0.5	210	2000	0.6	<1	0.09			9800	<0.5	<5				37000	<5	<0.5	8.1
RAVG	15/9/03												1350									0.01				0.03					8300			8.2
RAVG	25/3/04					149		22000					5820	<2	1430			228	2560			0.02			11900	0.02				3680				8.2
RAVG	11/11/04		<0.010			189	<0.0010		<0.05	<0.01	<0.02	<0.05	5580	<2	1430		0.06	225	2520				<0.02	2.1	11600	<0.10	<0.0050	0.01	<0.50	3430	42000			8
RAVG	17/3/05	<0.05	<0.02	9.1	0.37	261	<0.002	39700	<0.05		<0.02	<0.05	8120	118	1430	<0.0005	<0.05	372	4410	0.56	<0.02	<0.01			17500	0.02	<0.002		<0.02		74000	<0.05		8.5
RAVH	23/9/02	<0.005		2.7	0.089	209	<0.005		<0.005		0.002	0.006	3950				0.11	162	2670	0.095	<0.010	0.04			12300	0.027	<0.025				43000	0.007	<0.005	8
RAVH	11/11/04		<0.010			181	<0.0010		<0.05	<0.01	<0.02	<0.05	5160	<2	1360		0.05	179	2100				<0.02	1.5	9920	<0.10	<0.0050	0.03	<0.20	2880	35000			7.9
RAVH	20/2/03	<1		<2	3.6	210	<0.05		<0.5		<0.5	<0.5	6000				<0.5	200	2200	0.8	<1	0.44			11000	<0.5	<5				40000	<5	<0.5	8.3
RAVH	15/9/03												1730									0.01				0.03					11000			8.3
RAVH	25/3/04					146		23000					5860	186	1150			219	2520			0.02			12100	0.01				3630				8.3
RAVH	17/3/05	<0.05	<0.02	10	0.15	81.7	<0.002	29800	<0.05		<0.02	<0.05	6730	132	1740	<0.0005	<0.05	363	3190	0.05	<0.02	0.01			13400	<0.02	<0.002		<0.02		55000	<0.05		8.6
RAVI	23/9/02	0.033		7	0.035	61	<0.005		<0.005		<0.002	0.004	4180				0.098	251	2680	0.012	0.012	0.01			13300	<0.010	<0.025				49000	<0.005	<0.005	8.3
RAVI	20/2/03	1		<2	7.5	80	<0.05		<0.5		<0.5	<0.5	8400				<0.5	280	3300	<0.5	<1	<0.05			16000	<0.5	<0.5				60000	<5	<0.5	8.1
RAVI	15/9/03												2280									0.01				0.03					15000			8.1
RAVI	25/3/04					135		24000					6100	207	1090			231	2590			0.02			12800	0.01				3830				8.3
RAVI	11/11/04		<0.010			131	<0.0010		<0.05	<0.01	<0.02	<0.05	5290	<2	1500		0.05	216	2200				<0.02	2	10800	<0.10	<0.0050	0.02	<0.20	3080	39000			8.2
RAVI	17/3/05	<0.05	<0.02	10	0.14	81.8	<0.002	29800	<0.05		<0.02	<0.05	6750	240	1440	<0.0005	<0.05	382	3370	0.07	<0.02	<0.01			14500	<0.02	<0.002		<0.02		59000	<0.05		8.7
RAVK	23/9/02	<0.005		4.6	0.069	118	<0.005		<0.005		<0.002	0.002	5600				0.19	336	4690	0.016	<0.010	0.01			22600	<0.010	<0.025				89000	<0.005	<0.005	8.1
RAVK	20/2/03	<1		<2	7.5	100	<0.05		<0.5		<0.5	<0.5	7900				<0.5	250	3000	<0.5	<1	<0.05			15000	<0.5	<0.5				54000	<5	<0.5	7.9
RAVK	15/9/03												2900									0.01				0.02					19000			8.2
RAVK	25/3/04					112		25000					6360	<2	1430			247	2690			0.02			13700	0.01				4130				8.2
RAVK	11/11/04		<0.010			106	<0.0010		<0.05	<0.01	<0.02	<0.05	5230	<2	1380		<0.05	206	2020				<0.02	0.96	10500	<0.10	<0.0050	<0.01	<0.20	3130	39000			8.1
RAVK	18/3/05	0.015	<0.01	6.9	0.045	107	<0.001	21000	<0.005		<0.002	<0.005	4880	<2	1240	<0.0005	<0.005	234	2110	0.034	<0.01	0.13			12200	0.02	<0.001		<0.01		39000	0.005		8.3
RAVL	23/9/02	0.14		1.2	0.045	40	<0.005		<0.005		0.004	0.004	539				0.19	24	193	0.28	<0.010	0.11			812	0.038	<0.0025				3700	<0.005	<0.005	7.8
RAVL	20/2/03	<1		<2	5	130	<0.05		<0.5		<0.5	<0.5	5400				<0.5	190	2000	0.6	<1	<0.05			9700	<0.5	<0.5				36000	<5	<0.5	8
RAVL	15/9/03												2900									0.01				0.02					19000			8.5
RAVL	25/3/04					109		26000					6720	225	976			261	2910			0.02			14900	0.01				4380				8.4
RAVL	11/11/04		<0.010			104	<0.0010		<0.05	<0.01	<0.02	<0.05	5650	<2	1520		<0.05	226	2220				<0.02	2.8	11600	<0.10	<0.0050	0.08	<0.20	3360	43000			7
RAVM	23/9/02	0.018		4.3	0.031	116	<0.005		<0.005		<0.002	<0.002	3470				0.9	169	2000	0.27	<0.010	0.01			9880	0.016	<0.025				34000	<0.005	<0.005	7.8
RAVM	15/9/03												1460									0.01				0.02					9000			8.5
RAVM	25/3/04					131		18000					4760	<2	1220			167	2030			0.01			9600	0.01				2900				8.2
RAVM	11/11/04		<0.010			152	<0.0010		<0.005	<0.01	<0.002	<0.005	4790	<2	1140		0.015	194	2070				<0.02	1.1	10300	0.01	<0.0050	0.02	<0.05	2960	35000			8.1
RAVM	18/3/05	<0.05	<0.02	7.7	0.17	144	<0.002	24000	<0.05		<0.02	<0.05	6080	120	1020	<0.0005	<0.05	290	2970	0.2	<0.02	<0.01			12500	0.02	<0.002		<0.02		52000	<0.05		8.6
RAVN	23/9/02	<0.005		5.9	0.26	373	<0.005		<0.005		0.003	<0.002	3500				0.83	154	1930	1	<0.010	0.02			9890	0.05	<0.025				34000	0.012	<0.005	7.9
RAVN	25/3/04					186		17000					4600	<2	1090			150	1830			0.02			9210	0.01				2660				8.2

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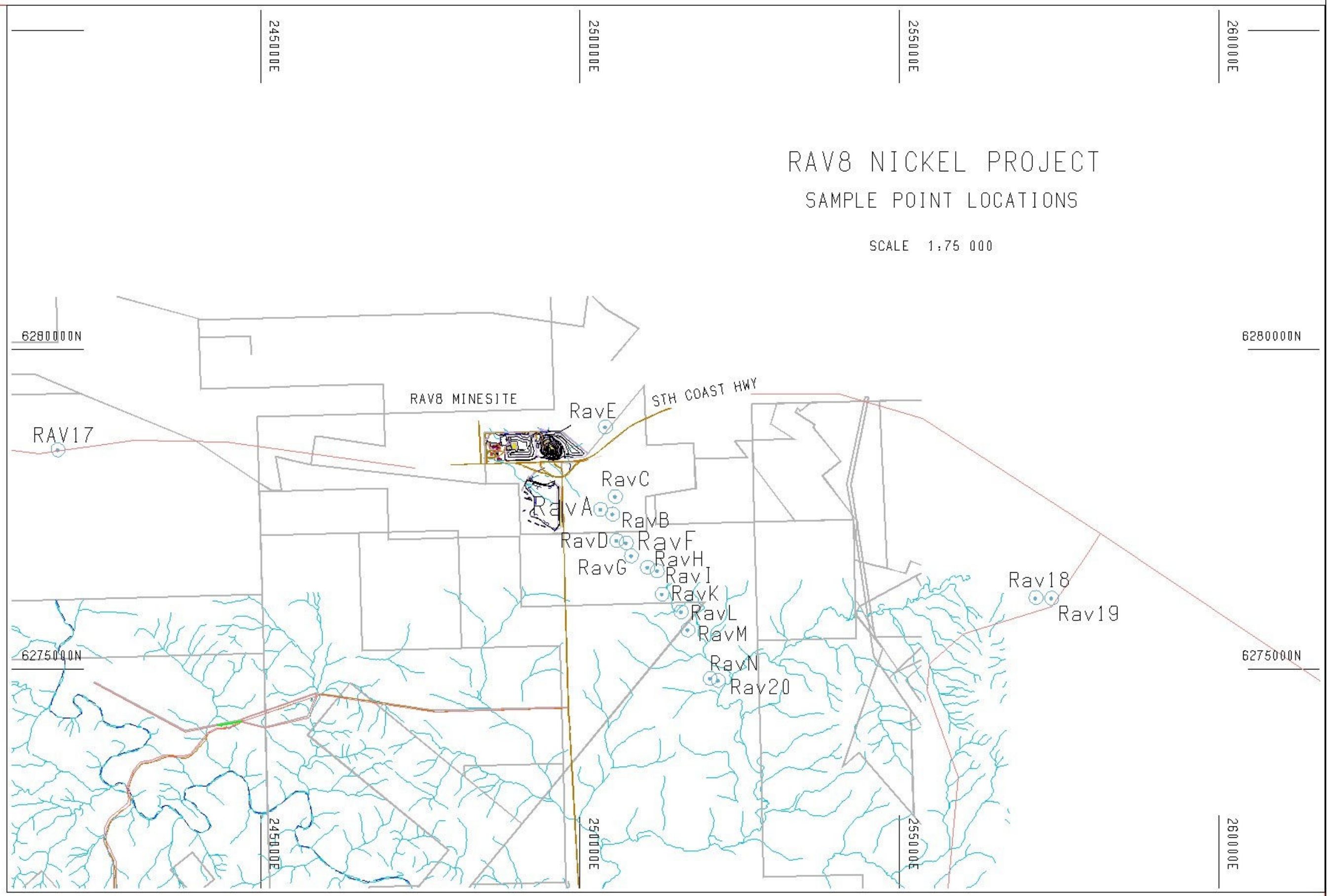

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