



FORRESTANIA NICKEL PROJECT
NEW MORNING PIT

SURFACE WATER ASSESSMENT

REPORT FOR
WESTERN AREAS LIMITED

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Rockwater
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REVISION	AUTHOR	REVIEW	AUTHORISED	ISSUED
Draft	JG	PHW	JRP	27/11/18

1. INTRODUCTION

1.1. BACKGROUND

Western Areas NL (Western Areas) is planning the development of the New Morning nickel-sulphide deposit, located at the Forrestania project, about 110 km south-east of Hyden in the southern Yilgarn region of Western Australia.

Rockwater was engaged to carry out a surface-water hydrological and hydraulic analysis for the proposed infrastructure footprint of the New Morning deposit and the nearby declared rare flora (DRF) populations (Figure 1). This report presents the results of a surface-water hydrology and hydraulics study to investigate whether there would be any significant impact from rainfall and/or run-off events on the proposed mine infrastructure. It also includes any actions to prevent or limit damage to drainage lines that apparently sustain populations of DRF populations, and to minimise flooding that could increase the potential for the spread of dieback (there are reported to be significant populations of DRF with dieback, to the east of New Morning).

1.2. PROJECT DESCRIPTION

This surface-water management report is for mining approval purposes. It includes hydrological and hydraulic analysis of relevant catchment areas and natural creeks that could impact the pit, DRF vegetation and mine infrastructure. Where warranted, preliminary concept design of diversion drains and protective levees are included. Design recommendations are carried out in accordance with regulatory compliance requirements.

1.3. SCOPE OF WORK

The scope and deliverables of this report include the following:

- Identify creeks and delineate catchment areas that could impact the planned New Morning pit, planned waste dump, leach pad, workshop and proposed haul road diversion (new haul road).
- Hydrological analysis using relevant Australian Rainfall and Runoff Guidelines to estimate peak flows of return periods from 1 in 1 year to 1 in 100-year ARI and the PMF (1-in-2000 year ARI).
- Surface-water hydraulic analysis at relevant selected cross sections to estimate the extent, velocity and depths of flows, and comment on their potential impact on the proposed works associated with New Morning Project.
- Conceptual preliminary design of diversion channels and protective levees for the pit and infrastructure and waterway crossings at the proposed road alignment.
- Assessment of impacts of the proposed work on the mine and infrastructure and potential impacts of the new haul road on the Declared Rare Fauna (DRF) areas.
- Preparation of a draft report and concept sketches.

1.4. INFORMATION PROVIDED BY WESTERN AREAS LIMITED

The following information and data were provided by Western Areas Limited:

- Detailed 1.0 m topographical survey data covering the project area.
- GIS datasets showing the footprint of the New Morning Pit, Planned Waste Dump, Leach Pad, Workshop, existing road network (to be demolished) and the proposed new haul road alignment (shapefile and CAD format).
- GIS dataset showing DRF populations (shapefile format).

2. HYDROLOGY

The new haul road is generally aligned on a ridge that sheds water to the west and east. The creeks and waterways that could potentially impact the proposed pit, waste dump, leach pad and workshop typically flow from east to west. The creeks and associated catchments were delineated using the 1.0 m topographical survey data from 2015, provided by Western Areas NL.

2.1. CATCHMENT CHARACTERISTICS

Catchment characteristics of the local creeks identified to potentially impact the planned mining of New Morning pit are presented in Table 1. These creeks and catchments are shown in Figure 2.

Table 1: Catchment characteristics

Catchment	Area (km^2)	Length (km)	Slope (m/km)	Average Annual Rainfall (mm)	Clearing (%)
A	0.61	1.00	18.13	343	75
B	1.09	1.10	24.00	343	75
C	0.90	1.20	21.82	343	75
D	0.44	0.90	23.33	343	75
E	2.34	3.50	14.07	343	75
F	2.91	2.60	11.36	343	75
G	0.11	0.50	20.00	343	75

2.2. PEAK FLOW ESTIMATION

The latest publication of Australian Rainfall and Runoff (ARR) (2016) does not provide methods to estimate peak flows from ungauged catchments for the Arid region in which the New Morning Project lies. In the absence of further guidance from ARR2016, the design peak flows for each catchment in this study were estimated using the Wheatbelt region rational and index flood methods as provided by ARR in 1987. These methods have been found to give a good indication of actual flows and were previously adopted for the design of the Spotted Quoll and Flying Fox mines.

The results using both methods are presented in Table 2, with the maximum value selected as the adopted design peak flow for each design interval.

The Probable Maximum Flood (PMF), assumed to be equivalent to the 1-in-2000 year ARI peak flow, was calculated by applying the Probable Maximum Precipitation (PMP) depths derived using the software CRC-FORGE which adopts the Rainfall Growth Estimation method.

Table 2: Estimated and adopted design peak flows

Catchment	ARR1987 Wheatbelt Region	Average Recurrence Interval (Years)						
		2	5	10	20	50	100	2000
A	Rational (m^3/s)	0.30	0.63	1.13	2.01	3.52	4.75	7.81
	Index (m^3/s)	0.28	0.55	0.98	1.69	3.13	3.35	8.12
	Adopted (m^3/s)	**0.30**	**0.63**	**1.13**	**2.01**	**3.52**	**4.75**	**8.12**
B	Rational (m^3/s)	0.44	0.94	1.68	2.97	5.17	6.95	11.43
	Index (m^3/s)	0.39	0.79	1.38	2.40	4.44	4.74	10.88
	Adopted (m^3/s)	**0.44**	**0.94**	**1.68**	**2.97**	**5.17**	**6.95**	**11.43**
C	Rational (m^3/s)	0.37	0.80	1.42	2.52	4.39	5.91	9.71
	Index (m^3/s)	0.35	0.70	1.23	2.14	3.96	4.23	9.88
	Adopted (m^3/s)	**0.37**	**0.80**	**1.42**	**2.52**	**4.39**	**5.91**	**9.88**
D	Rational (m^3/s)	0.24	0.51	0.92	1.64	2.88	3.90	6.40
	Index (m^3/s)	0.23	0.46	0.80	1.39	2.58	2.75	6.88
	Adopted (m^3/s)	**0.24**	**0.51**	**0.92**	**1.64**	**2.88**	**3.90**	**6.88**
E	Rational (m^3/s)	0.54	1.14	2.02	3.57	6.16	8.25	13.58
	Index (m^3/s)	0.62	1.24	2.19	3.79	7.02	7.50	15.91
	Adopted (m^3/s)	**0.62**	**1.24**	**2.19**	**3.79**	**7.02**	**8.25**	**15.91**
F	Rational (m^3/s)	0.71	1.48	2.62	4.63	7.99	10.70	17.60
	Index (m^3/s)	0.71	1.42	2.49	4.32	8.00	8.54	17.71
	Adopted (m^3/s)	**0.71**	**1.48**	**2.62**	**4.63**	**8.00**	**10.70**	**17.71**
G	Rational (m^3/s)	0.10	0.22	0.39	0.71	1.26	1.71	2.81
	Index (m^3/s)	0.10	0.20	0.35	0.61	1.12	1.20	3.37
	Adopted (m^3/s)	**0.10**	**0.22**	**0.39**	**0.71**	**1.26**	**1.71**	**3.37**

3. HYDRAULICS

The alignment of flow paths that could impact the pits and infrastructure were identified from aerial photography and the 1.0 m topographical survey. The extent, velocity and discharge within these flow paths were then determined at selected cross-sections where stage-discharge and stage-velocity relationships were calculated using Manning's equation (Equation 1).

$$V = \frac{1}{n} \cdot \left(\frac{A}{P} \right)^{2/3} \cdot (S)^{1/2}$$

Equation 1

Where:

n *is a dimensionless roughness coefficient*
A *is the wetted waterway area (m^2)*
P *is the wetted perimeter (m)*
S *is the hydraulic gradient (m/m)*

The continuity Equation 2 was used to estimate flow Q (m^3/s):

$$Q = A \cdot V$$

Equation 2

Where:

A *is the waterway area in (m^2)*

V *is the velocity (m/s)*

The value for the roughness coefficient "n" in Equation 3 at each cross-section was estimated using observations from aerial photography, and the slopes were estimated from the topographic contours.

The purpose of this analysis was to assess whether the 1-in-100 year and 1-in-2000 year ARI peak flows would adversely impact the pit and infrastructure, and to provide information for the concept design of protective measures, if required.

A list of cross-sections hydraulically analysed is presented in Table 3. The locations of these cross-sections are shown in Figure 3.

Table 3: Cross-sections and features impacted

Cross Section	Impact
XS_1	New Morning Pit
XS_2	Leach Pad
XS_3	Leach Pad (Alternative Diversion Option)
XS_4	Waste Dump (Creek Approaching Waste Dump)
XS_5	New Morning Pit (Creek Approaching Pit)

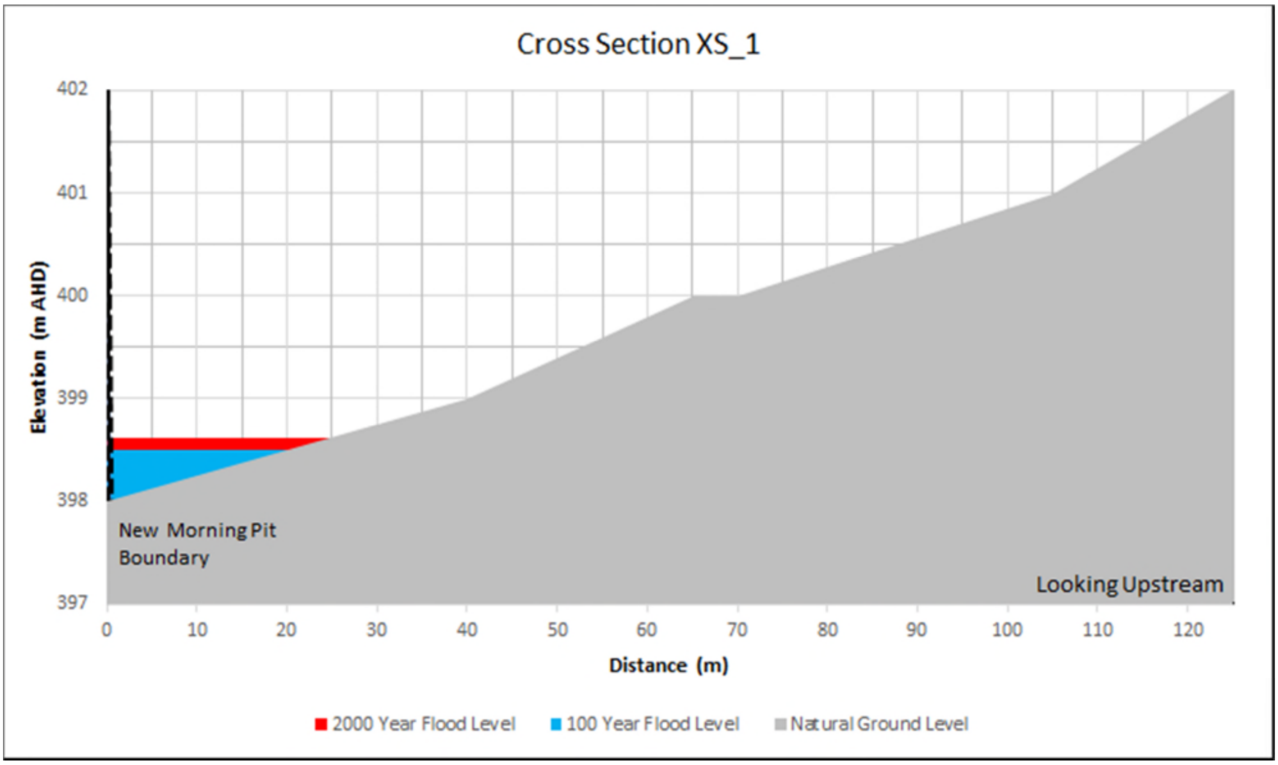
3.1. HYDRAULIC RESULTS

The hydraulic results, including flood levels and flow velocities at each cross section for the 1-in-100 and 1-in-2000 year ARI flood events are presented in Table 4. The results for the more-frequent storm events are included in Appendix A.

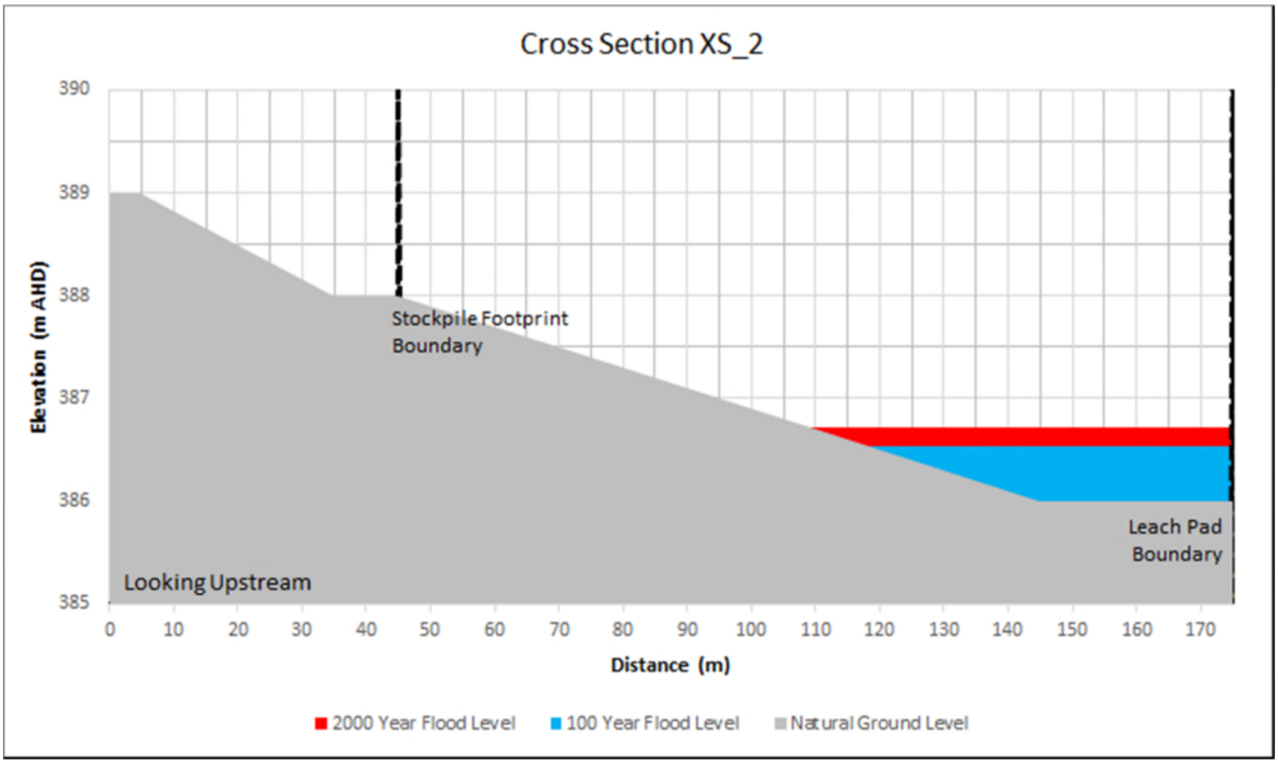
Table 4: Hydraulic results

Cross Section	Contributing Catchment	Impact Mine Pit and Infrastructure	Hydraulic Results	1-in-100 Year	1-in-2000 Year
XS_1	D	New Morning Pit (Diversion Option)	Peak Flow (m^3/s)	3.90	6.88
			Flood Level (m AHD)	398.49	398.61
			Maximum Depth (m)	0.49	0.61
			Velocity (m/s)	0.76	0.88
XS_2	D, E and F	Leach Pad (Diversion Option)	Peak Flow (m^3/s)	22.85	40.50
			Flood Level (m AHD)	386.53	386.72
			Maximum Depth (m)	0.53	0.72
			Velocity (m/s)	1.02	1.20
XS_3	D, E and F	Leach Pad (Alternative Diversion Option)	Peak Flow (m^3/s)	22.85	40.50
			Flood Level (m AHD)	389.56	389.76
			Maximum Depth (m)	0.56	0.76
			Velocity (m/s)	1.04	1.22
XS_4	C	Waste Dump (Creek Approaching Waste Dump)	Peak Flow (m^3/s)	5.91	9.88
			Flood Level (m AHD)	394.29	394.37
			Maximum Depth (m)	0.29	0.37
			Velocity (m/s)	0.62	0.71
XS_5	D	New Morning Pit (Creek Approaching Pit)	Peak Flow (m^3/s)	3.90	6.88
			Flood Level (m AHD)	400.36	400.44
			Maximum Depth (m)	0.36	0.44
			Velocity (m/s)	0.59	0.67

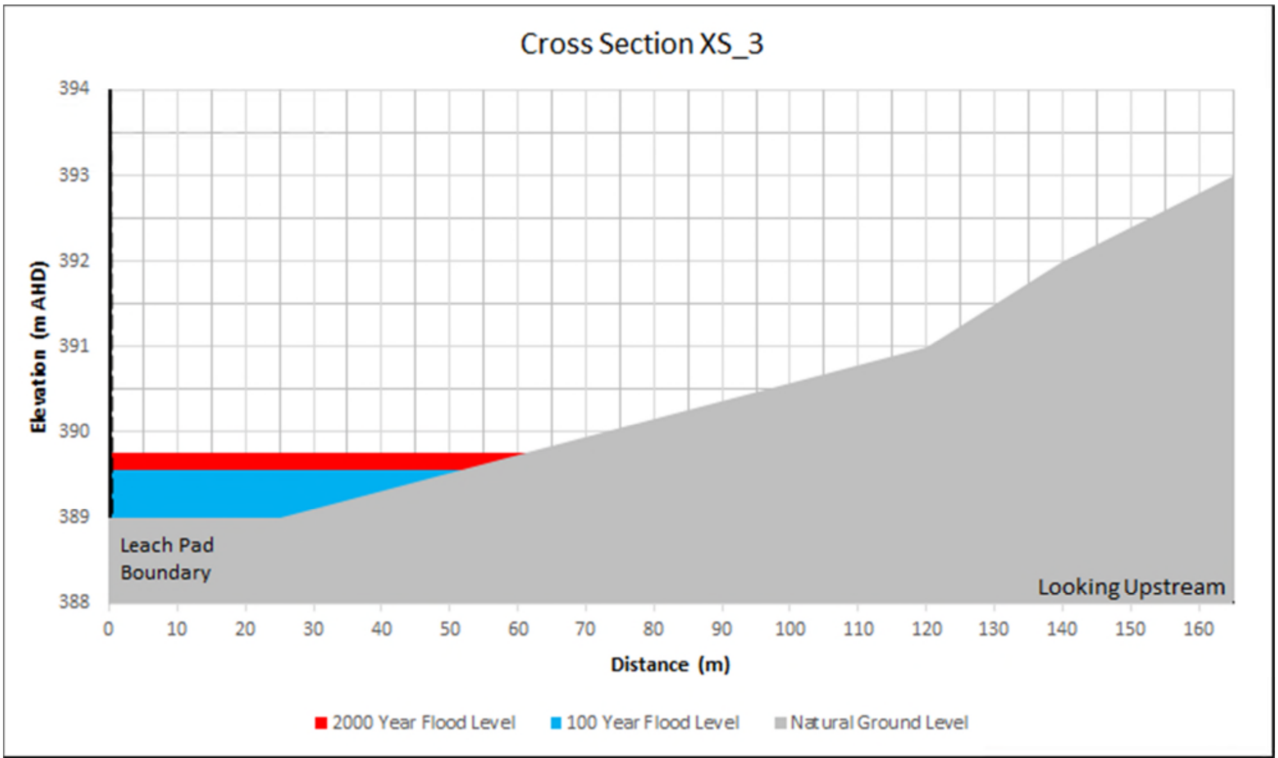
The results showing the extent and depths of flows at the cross-section locations relative to the proposed pits and infrastructure boundaries are shown in Text-Figures 1 to 5. All cross-sections are presented as looking upstream.



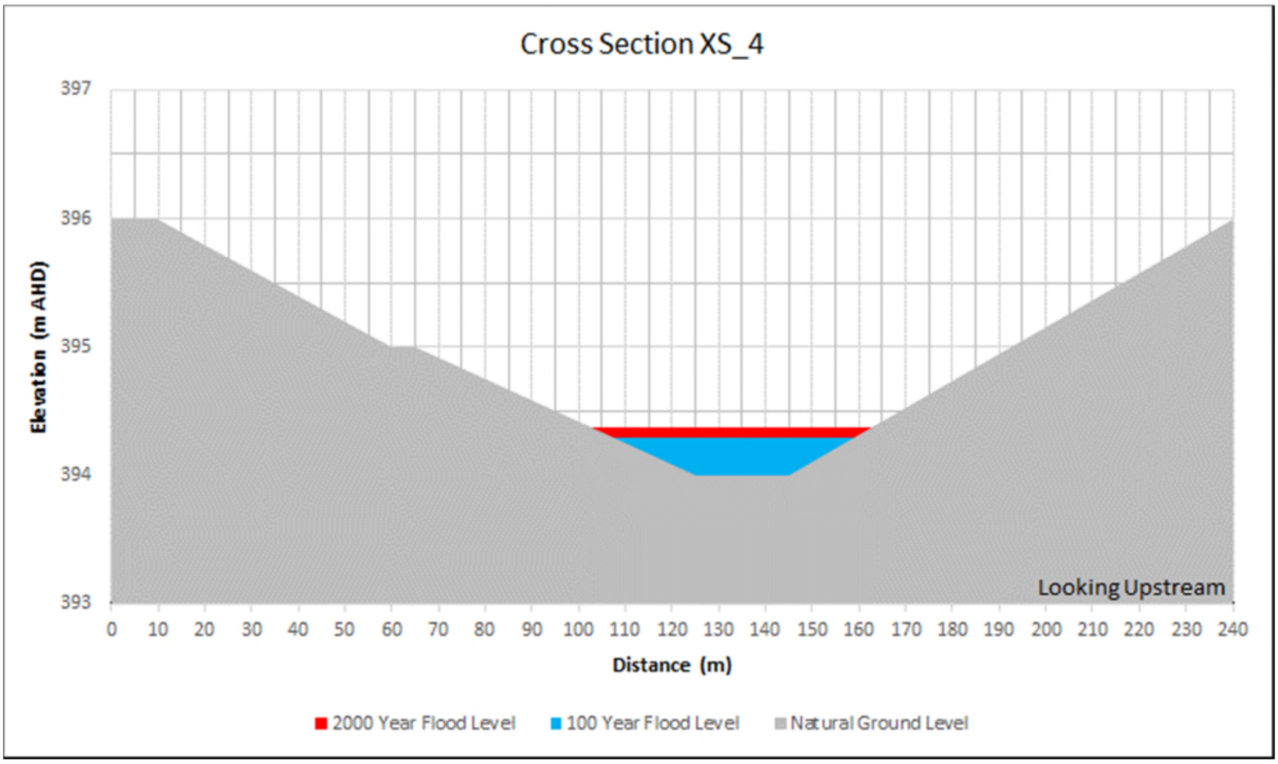
Text-Figures 1 : 1-in-100 and 1-in-2000 year ARI flood levels at cross section XS_1



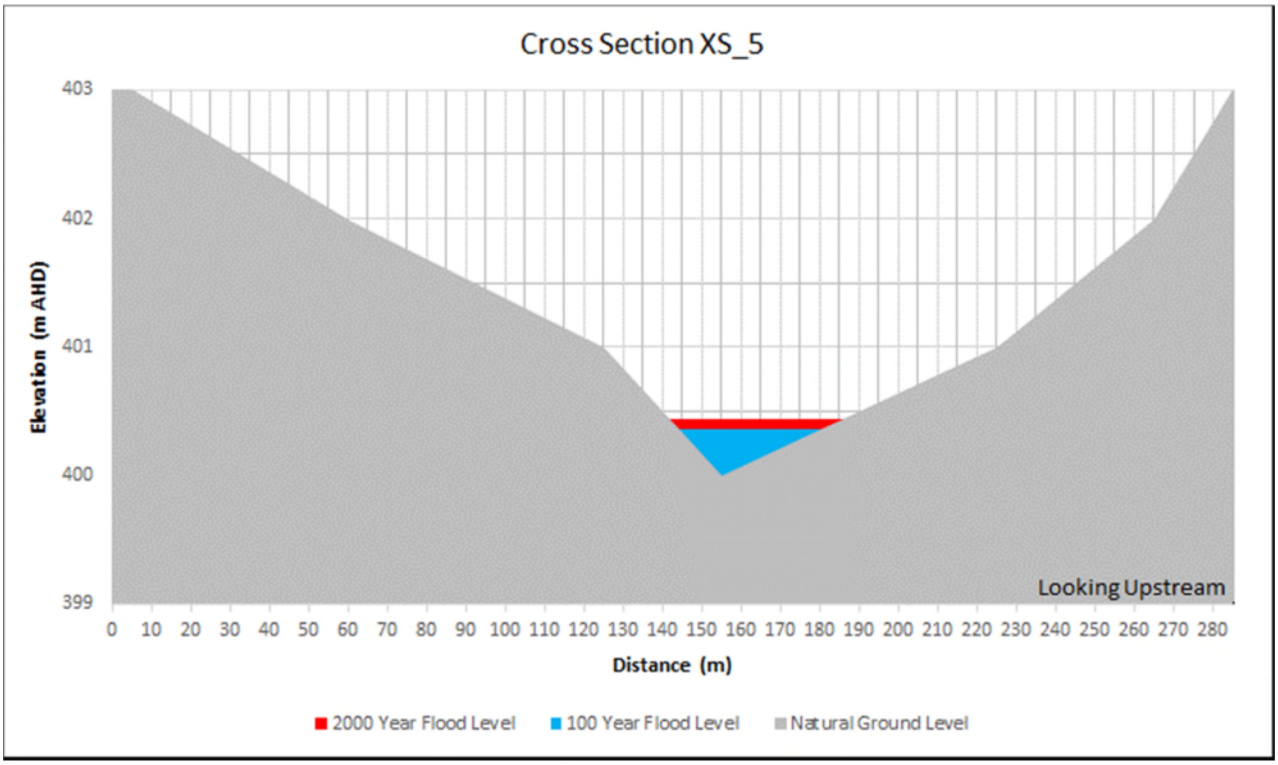
Text-Figures 2 : 1-in-100 and 1-in-2000 year ARI flood levels at cross section XS_2



Text-Figures 3 : 1-in-100 and 1-in-2000 year ARI flood levels at cross section XS_3



Text-Figures 4 : 1-in-100 and 1-in-2000 year ARI flood levels at cross section XS_4



Text-Figures 5 : 1-in-100 and 1-in-2000 year ARI flood levels at cross section XS_5

3.2. NEW MORNING PIT

The eastern boundary of New Morning Pit is impacted by Catchment D which would directly discharge into the pit and therefore a diversion drain system is required. Two recommended design concepts are presented in Sections 3.6.1 and 3.6.2 below.

At all the other boundaries of the New Morning Pit the ground surface naturally slopes away from the pit, and therefore flood protection measures are not required.

3.3. LEACH PAD

Assuming the diversion drain concept presented in Section 3.6.1 is adopted, the surface-water runoff from Catchments D, E and F will combine to squeeze through between the northern boundary of the Leach Pad and the southern boundary of the stockpile footprint. The concept diversion drains at the boundary between the Leach Pad and stockpile boundaries are also presented in Section 3.6.1.

If it is not practicable to construct a diversion drain system described in Section 3.6.1, an alternative option to divert the combined flows around the south-eastern corner of the Leach Pad is recommended and described in Section 3.6.2. There are, however, several constraints associated with this option.

3.4. WORKSHOP

Surface water runoff from the relatively small Catchment G could potentially impact the Workshop. If it is not feasible to relocate the Workshop footprint slightly to the south to avoid the drainage path, the option of a flow path diversion system to the north of it is recommended, as presented in Section 3.6.3.

3.5. PLANNED WASTE DUMP

The surface water flow from Catchment B and Catchment C is intercepted by the Planned Waste Dump and will require diversion along the infrastructures northern and western boundary. A recommended concept design is presented in Section 3.6.3.

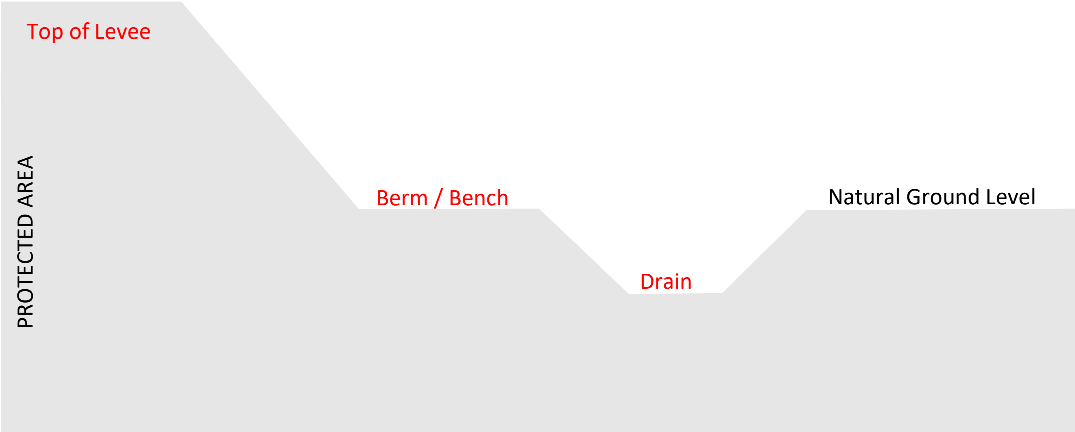
Additionally, a nominal drain and levee system as presented in Section 3.6.4 is required between the Planned Waste Dump and New Morning Pit, to drain local runoff.

3.6. DIVERSION DRAIN CONCEPTS

In general, the proposed New Morning Pit, mine infrastructure layout, and Planned Haul Road alignment will not adversely impact the natural surface water regime to impact the identified Declared Rare Flora (DRF) population footprint.

As discussed in previous sections, diversion drain systems are required to manage and protect the pit and various infrastructure from flooding. The drainage systems proposed below are practical concepts aimed at providing minimal environmental impact and minimal alteration to the natural flood regime.

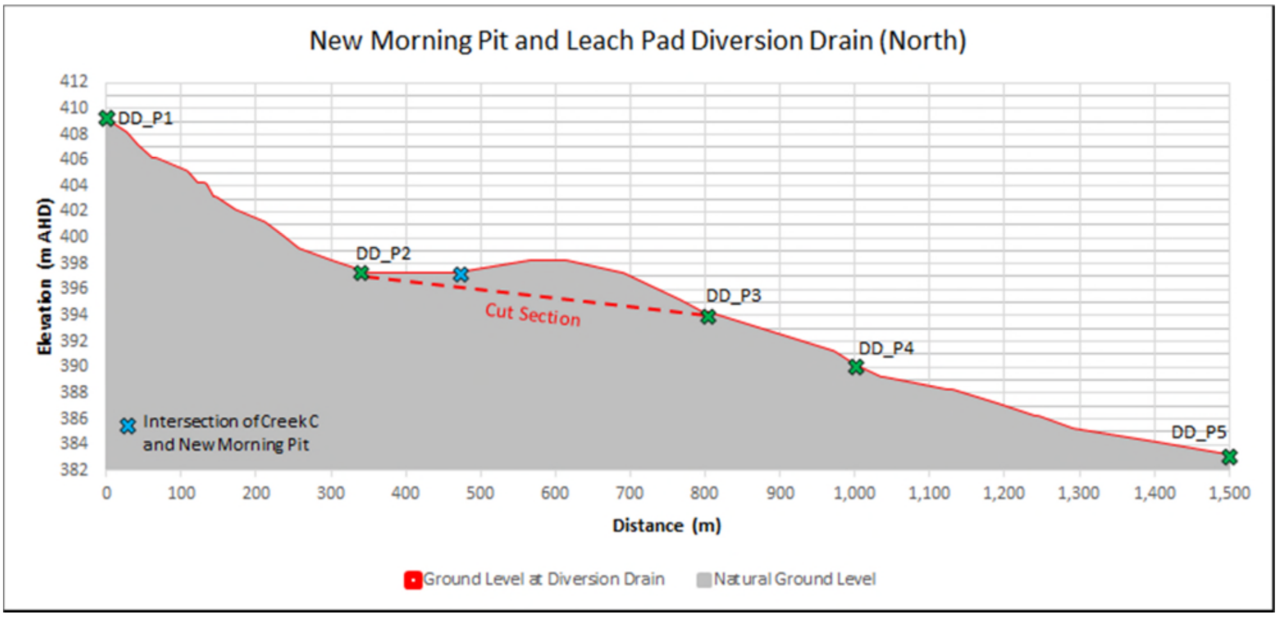
It is important to note that the recommendations in this section are conceptual only and will require site-specific adjustments and considerations during the detail design phase. A typical conceptual cross-section of the diversion drains and levee system is shown in Text-Figure 6.



Text-Figures 6 : Typical concept cross-section of drain and levee sytem

3.6.1. NEW MORNING PIT AND LEACH PAD DIVERSION DRAINS

A drain and levee system, as shown in Figure 3, is recommended from DD_P1, DD_P2 to DD_P3 in order to divert and prevent the 1-in-100 year ARI peak flow of 5.91 m^3/s generated by Catchment D from entering the New Morning Pit. This diversion drain is to join a larger drain which terminates at DD_P5 to convey and divert the combined runoff from Catchments D, E and F. The long-section of this proposed conceptual design along the eastern perimeter of the pit from locations DD_P1, DD_P2, DD_P3, DD_L4 to DD_P5 is presented in Text-Figure 7.



Text-Figures 7 : New Morning Pit and Leach Pad diversion drain DD_P1-DD_P2-DD_P3-DD_L4-DD_P5 concept long section

Based on the current footprint of the New Morning Pit boundary, there is sufficient bed gradient over 1500 m, commencing from approximately 409.00 m AHD at DD_P1 to 383.00 m AHD at DD_P5, to construct this diversion drain.

- A 480 m long cut section, to a maximum depth of approximately 2.0 m is required from DD_P2 to DD_P3.
- A 1.0 m high levee, from the drain bed level is required from DD_P1, DD_P2, DD_P3, and DD_L4 to DD_P5 to protect the new Morning Pit and Leach Pad from the 1-in-100 year ARI combined peak

flow of 22.85 m^3/s. This will also provide flood immunity with freeboard for the combined 40.50 m^3/s peak flow generated by the 1-in-2000 year ARI storm event.

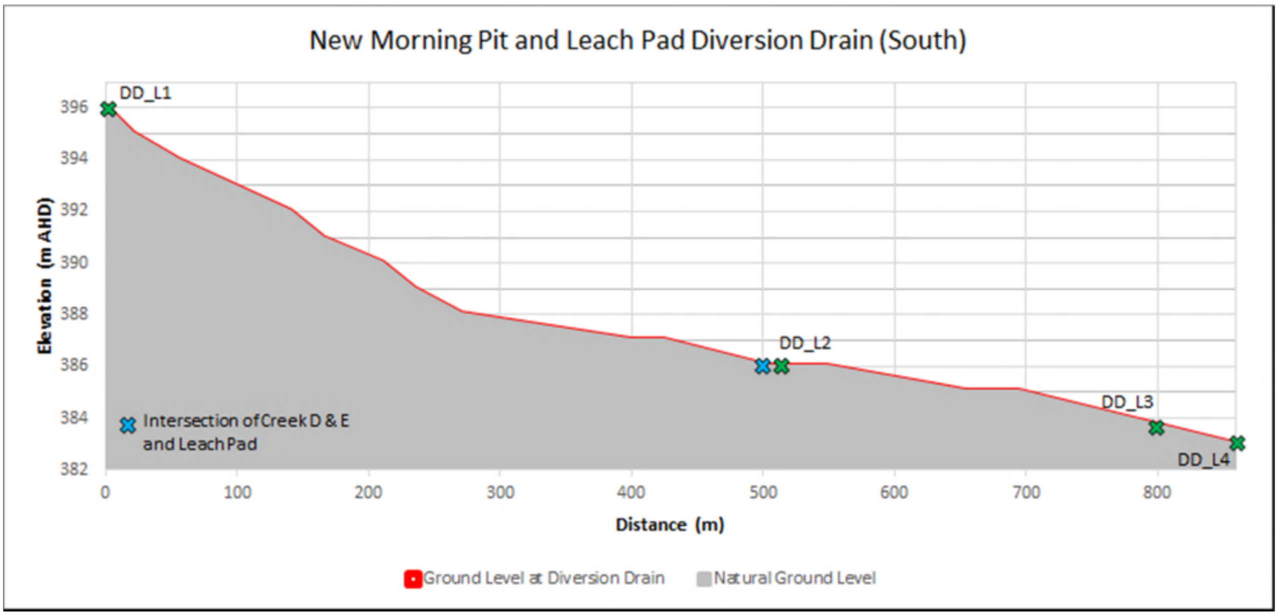
During the rare flood events, flow paths can spread out at ground level; however, a nominal drain size for the more-frequent flow is required.

Details of the required dimensions for this northern section drain are presented in Table 5.

Table 5: Minimum drain dimensions for New Morning Pit diversion drain (North)

Start Drain	End Drain	Section Length (m)	Bed to Top of Levee Depth (m)	Section Width (m)
DD_P1	DD_P2	320	1.0	5.0
DD_P2	DD_P3	480	1.0	15.0
DD_P3	DD_P4	200	1.0	15.0
DD_P4	DD_P5	500	1.0	30.0

A diversion drain (south) commencing at DD_L1 and running across the northern boundary of the Leach Pad before terminating at DD_L4 is required to confine the combined diverted flow from Catchments D, E and F through the proposed drain channel between the stockpile footprint and the Leach Pad. The long-section of the proposed conceptual diversion drain from locations DD_L1, DD_L2, and DD_L3 to DD_P4 is presented in Text-Figure 8.



Text-Figures 8 : New Morning Pit and Leach Pad diversion drain from DD_L1-DD_L2-DD_L4 conceptual long section

Based on the current footprint of the Leach Pad boundary, there is sufficient bed gradient over 850 m, commencing from approximately 396.00 m AHD at DD_P1 to 383.00 m AHD at DD_P5, to construct this diversion drain.

- No cut sections are required for this southern-side diversion drain.
- A 1.0 m high levee, from the drain bed level, is required from DD_L1, DD_L2, and DD_L3 to DD_P4 to protect the new Morning Pit and Leach Pad from the 1-in-100 year ARI combined peak flow of 22.85 m^3/s. This levee will also provide flood immunity with freeboard for the combined 40.50 m^3/s peak flow generated by the 1-in-2000 year ARI storm event.

- The section from DD_L2 to DD_L3 of this southern drain levee and the section from approximately DD_P4 to DD_P5 of the northern drain levee is to form a 30 m drain (flow path). The bed level of the drain at this section can be located on natural ground.

Details of the required dimensions of the southern section of the drain are presented in Table 6.

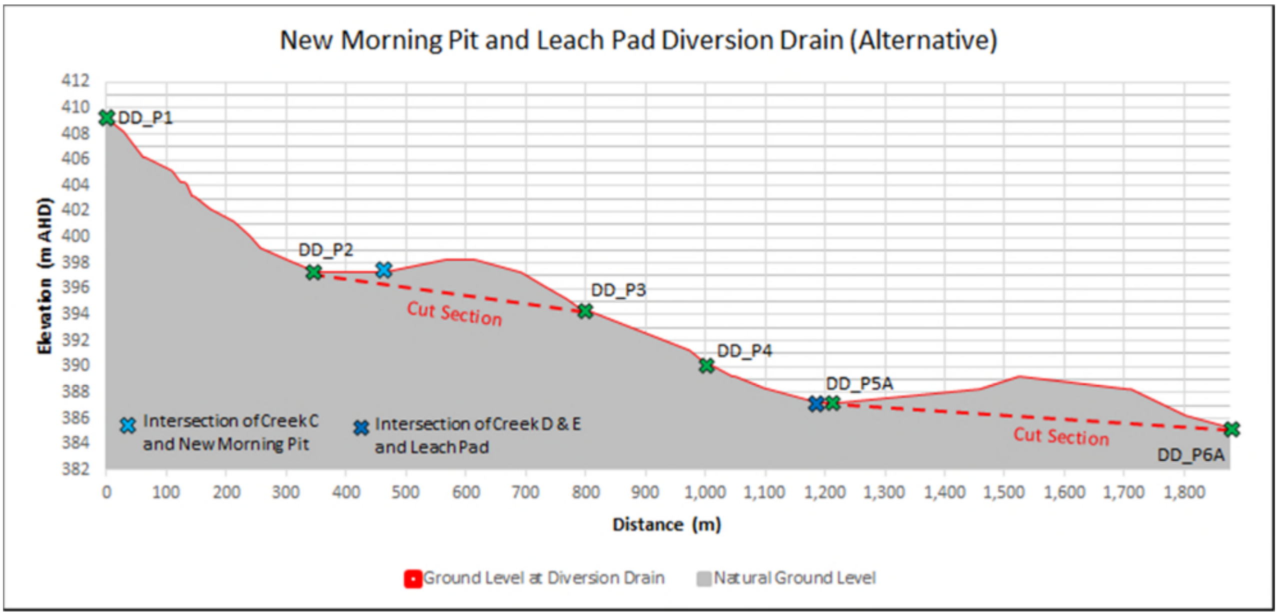
Table 6: Minimum drain dimensions for New Morning Pit diversion drain (South)

Start Drain	End Drain	Section Length (m)	Bed to Top of Bund Depth (m)	Section Width (m)
DD_L1	DD_L2	500	1.0	5.0
DD_L2	DD_L3	300	1.0	30.0
DD_L3	DD_L4	50	1.0	Grade

This option is preferred, based on the assumption that there is sufficient area between the stockpile and Leach Pad to allow the space to be used as a diversion drain and that there are no other practical constraints. If a drain at this location is not possible, the alternative option presented in Section 3.6.2 is recommended.

3.6.2. NEW MORNING PIT AND LEACH PAD DIVERSION DRAINS (ALTERNATIVE OPTION)

If it is not feasible to construct a drain between the Leach Pad the stockpile as recommended in Section 3.6.1, an alternative is to divert the combined flow from Catchments D, E and F around the eastern and southern corner of the Leach Pad (Cross-Section 3). The long-section of this proposed alternative diversion drain from locations DD_P1, DD_P2, DD_P3, DD_L4, DD_P5A to DD_P6A is presented in Text-Figure 9.



Text-Figures 9 : New Morning Pit and Leach Pad alternative diversion drain from DD_P1- DD_P2-DD_P3-DD_L4-DD_P5A-DD_L6A conceptual long section

The dimensions of this option are similar to the northern diversion drain described in Section 3.6.1 from DD_P1, DD_P2, DD_P3 to DD_P4. The differences are from DD_P2 to DD_P3 and DD_P5A to DD_P6A where cut sections are required to create sufficient grade to drain runoff on the southern side of the Leach Pad into the main creek. Based on the current footprint of the Leach Pad, there is sufficient bed gradient over the entire 1850 m, from approximately 409.00 m AHD at DD_P1 to 385.00 m AHD at DD_P6A, to construct this alternative diversion drain.

Two cut sections will be required for this alternative diversion drain:

- A 480 m long cut section, to a maximum depth of approximately 2.0 m is required from DD_P2 to DD_P3.
- A 650 m long cut section, to a maximum depth of approximately 3.0 m is required from DD_P5A to DD_P6A.

A 1.0 m high levee, from the drain bed level is required from DD_P1, DD_P2, DD_P3, DD_L4, DD_P5A to DD_P6A to protect the new Morning Pit and Leach Pad from the 1-in-100 year ARI combined peak flow of 22.85 m^3/s. This levee will also provide flood immunity with freeboard for the combined 40.50 m^3/s peak flow generated by the 1-in-2000 year ARI storm event.

Details of the required minimum drain dimensions of this alternative option are presented in Table 7.

Table 7: Minimum drain dimensions for New Morning Pit alternative diversion drain

Start Drain	End Drain	Section Length (m)	Bed to Top of Bund Depth (m)	Section Width (m)
DD_P1	DD_P2	320	1.0	5.0
DD_P2	DD_P3	480	1.0	15.0
DD_P3	DD_P4	200	1.0	15.0
DD_P4	DD_P5A	200	1.0	30.0
DD_P5A	DD_P6A	650	1.0	30.0

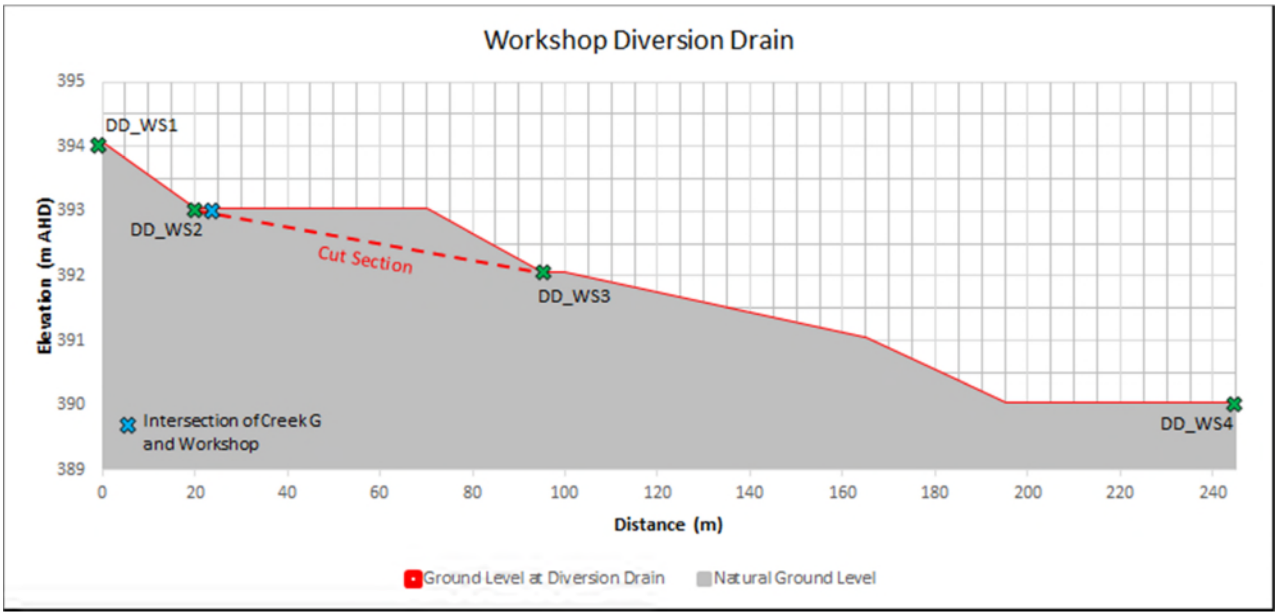
If this option is preferred, minimisation of excavation could possibly be achieved by making adjustments to the configuration, location and orientation of the Leach Pad during the detail design phase.

3.6.3. WORKSHOP DIVERSION DRAIN

A nominal drain system is required to divert the runoff generated by Catchment G and to protect the infrastructure. The long-section of the proposed diversion drain from location DD_WS1, DD_ WS2, DD_ WS3 to DD_WS4 is presented in Text-Figure 10.

There is sufficient bed gradient over 245 m, commencing from approximately 394.00 m AHD at DD_WS1 to 390.00 m AHD at DD_WS4 to construct this diversion drain.

- A 75 m long cut section, to a maximum depth of approximately 1.0 m is required from DD_WS2 to DD_WS3.
- A levee, 1 .0 m high from the drain bed level, is required from DD_WS1, DD_ WS2, and DD_ WS3 to DD_WS4 to protect the Workshop from the 1-in-100 year ARI combined peak flow of 1.71 m^3/s. This levee will also provide flood immunity with freeboard for the combined 3.37 m^3/s peak flow generated by the 1-in-2000 year ARI storm event.



Text-Figures 10 : Workshop diversion drain from DD_WS1-DD_WS2-DD_WS3-DD_WS4 conceptual long section

Details of the required minimum dimensions of this drain are presented in Table 8.

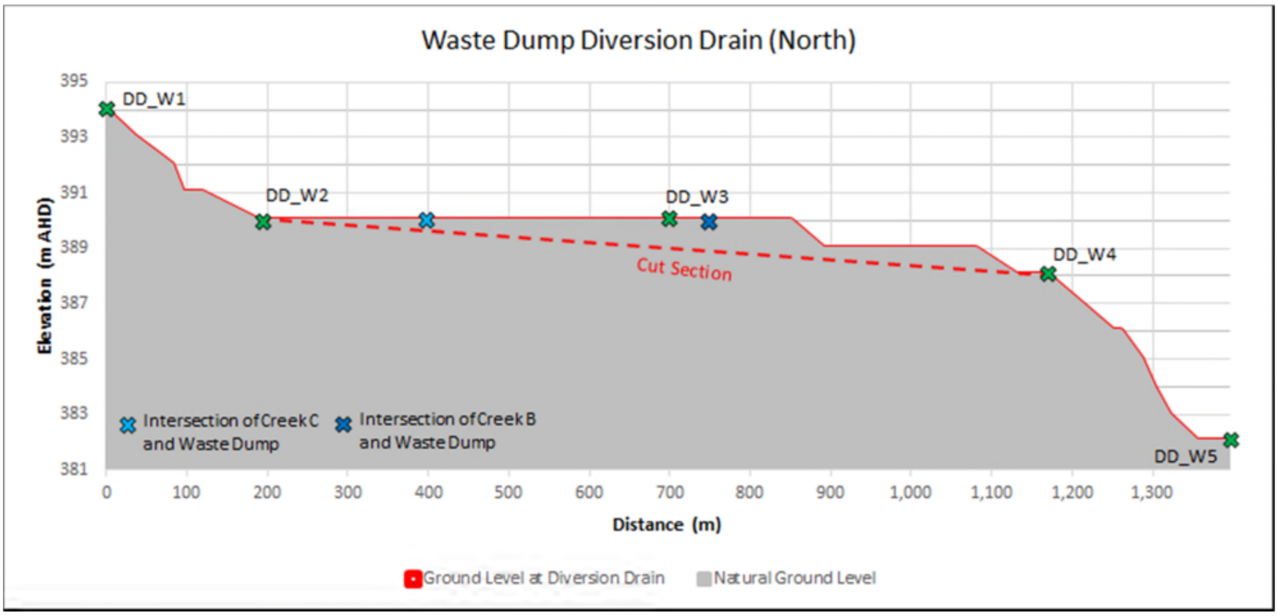
Table 8: Minimum drain dimensions for New Morning Pit alternative diversion drain

Start Drain	End Drain	Section Length (m)	Bed to Top of Bund Depth (m)	Section Width (m)
DD_WS1	DD_WS2	20	1.0	5.0
DD_WS2	DD_WS3	75	1.0	5.0
DD_WS3	DD_WS4	150	1.0	5.0

If possible, it is recommended that the current Workshop footprint be relocated approximately 50 m south to avoid the flow path from Catchment G. This adjustment will move the Workshop to higher ground to be sufficiently elevated from potential flood risks. This alternative option is preferred and will require only typical non-engineered precautionary flood protection measures.

3.6.4. WASTE DUMP DIVERSION DRAINS

The surface water runoff from Catchments B and C will flow directly to the northern and north-eastern boundary of the Planned Waste Dump. Based on the current layout footprint, a drain and levee system is required to divert the flow to the western boundary of the Waste Dump and to back into the main creek of Catchment C. The long-section of the proposed diversion drain from locations DD_W1, DD_ W2, DD_ W3, DD_ W4 to DD_W5 is presented in Text-Figure 11.



Text-Figures 11 : Waste Dump North diversion drain from DD_W1- DD_W2-DD_W3-DD_W4-DD_W5 conceptual long section

There is sufficient bed gradient over 1400 m, commencing from approximately 394.00 m AHD at DD_W1 to 382.00 m AHD at DD_W5, to construct this diversion drain.

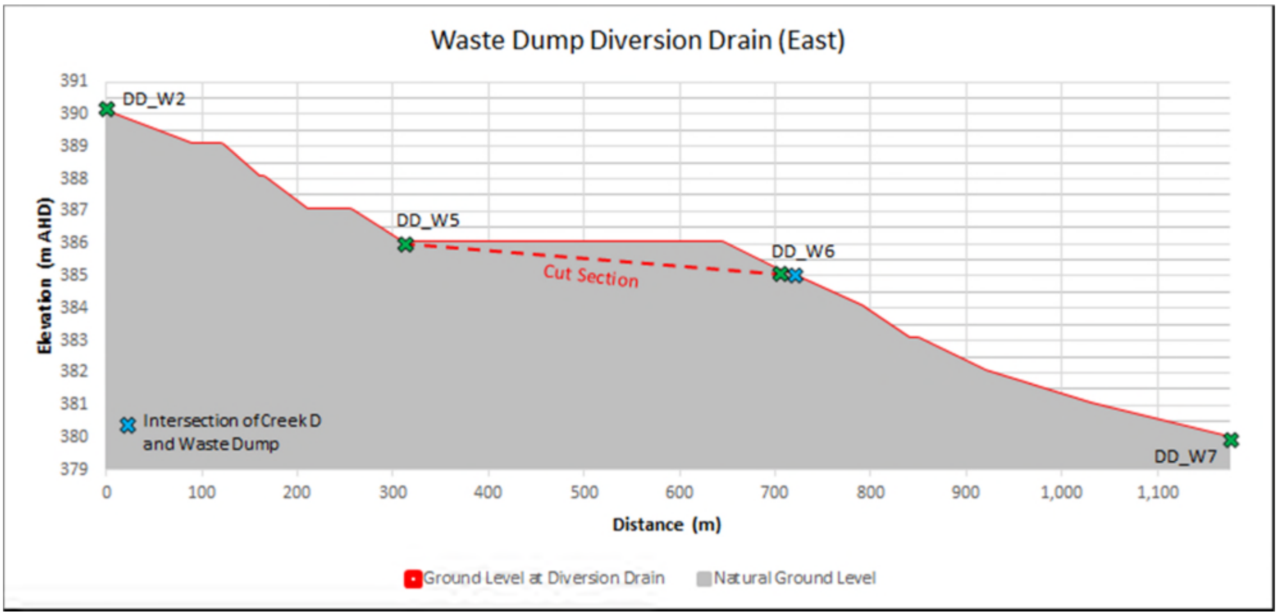
- A 970 m long cut section, to a maximum depth of approximately 1.5 m is required from DD_W2 to DD_W4.
- A 1.0 m high levee, from the drain bed level is required from DD_W1, DD_ W2, DD_ W3, DD_W4 to DD_W5 to protect the toe of the Planned Waste Dump from the 1-in-100 year ARI combined peak flow of 12.86 m^3/s. This levee will also provide flood immunity with freeboard for the combined 21.31 m^3/s peak flow generated by the 1-in-2000 year ARI storm event.

Details of the required minimum dimensions of this drain are presented in Table 9.

Table 9: Minimum drain dimensions for New Morning Pit alternative diversion drain

Start Drain	End Drain	Section Length (m)	Bed to Top of Bund Depth (m)	Section Width (m)
DD_W1	DD_W2	200	1.0	5.0
DD_W2	DD_W3	500	1.5	20.0
DD_W3	DD_W4	470	2.0	20.0
DD_W4	DD_W5	230	1.0	20.0

The topography between the New Morning Pit and the Planned Waste Dump naturally slopes east to west. To drain the local runoff away from the toe of the eastern boundary of the waste dump, a nominal drain and levee system is recommended. The long-section of the proposed diversion drain from location DD_W2, DD_W5, DD_ W6 to DD_W7 is presented in Text-Figure 12.



Text-Figures 12 : Waste Dump East diversion drain from DD_W2-DD_W5-DD_W6-DD_W7 conceptual long section

Text-Figure 12 shows adequate bed gradient over 1100 m, commencing from approximately 390.00 m AHD at DD_W2 to 390.00 m AHD at DD_W7 to construct this nominal drain and levee system.

- A 380 m long cut section, to a maximum depth of approximately 2.0 m is required from DD_W5 to DD_WS6.
- A levee, 1.0 m high from the drain bed level, is required from DD_W2, to DD_W5, DD_ W6 and DD_W7 to protect the toe of the waste dump from scour caused by the local runoff.

Details of the required minimum dimensions of this drain are presented in Table 10.

Table 10: Minimum drain dimensions for the Waste Dump east diversion drain

Start Drain	End Drain	Section Length (m)	Bed to Top of Bund Depth (m)	Section Width (m)
DD_W2	DD_W5	320	1.0	5.0
DD_W5	DD_W6	380	1.0	5.0
DD_W6	DD_W7	470	1.0	5.0

If possible, it is recommended that the current configuration of the Planned Waste Dump footprint be appropriately adjusted at the detailed design stage to minimise cut sections and earthworks associated with the required diversion drains.

3.7. NEW HAUL ROAD

The new proposed mine haul road network crosses Catchment A creek and the upper reach of Catchment E. These locations, named FWC_1 and FWC_2, are shown in Figure 3 and are listed in

Table 11, together with the associated creek crossings that will be needed.

Table 11: Road floodway and culvert crossing locations

Location	Crossing	Recommended Floodway Length (m)	Drainage Culvert	Notes
FWC_1	Catchment A	20	Nominal	The floodway will remain serviceable up to the 1-in-100 year ARI flood event
FWC_2	Catchment E (20%)	20	Nominal	

The peak flows at these crossings are relatively low and slow, and therefore it is expected that any concerns relating to serviceability and vulnerability of the road network are likely to be associated with drainage, rather than damage from flooding.

At the detailed design stage, it is recommended that a simple floodway be constructed at these crossings, to accommodate the adopted vertical road profile. The option of using graded rocks or nominal culverts with these floodways should be considered, in order to ensure adequate drainage to prevent road-formation damage and bogging of heavy vehicles.

The governing criteria in designing the length of floodway and treatment at these crossings should be drainage for regularly-occurring storm events, not serviceability and immunity for large flood events, which will be rare.

3.8. IMPACT ON DECLARED RARE FLORA (DRF) POPULATION

As shown in the layout plan in Figure 1, the proposed New Morning Pit and infrastructure are located downstream and therefore will not impact the footprint indicating the DRF population. The proposed diversion drains (see Figure 3) recommended to manage and mitigate flooding of the mine pit and infrastructure are also located downstream and will not impact the DRF population area.

The proposed new haul road alignment will slightly cut-off approximately 20% of flow from Catchment E at FWC_2, but this will be addressed by constructing the floodway and culvert system recommended in Section 3.7.

Therefore, the proposed New Morning Pit, mine infrastructure and haul road will have negligible impact on, or change the natural surface water flow regime associated with, the Declared Rare Flora population, and therefore no remedial works are required.

4. CONCLUSION

The recommendations and preliminary concept design to manage the surface water associated with the New Morning Pit, mine infrastructure, and new haul road - presented herein - are considered to be sufficiently detailed for mining approval and regulatory compliance requirements. These concepts are to be appropriately adjusted and validated with site-specific considerations at the detailed design stage.

Dated: 27 November 2018

Rockwater Pty Ltd

J Goh
Senior Hydrologist

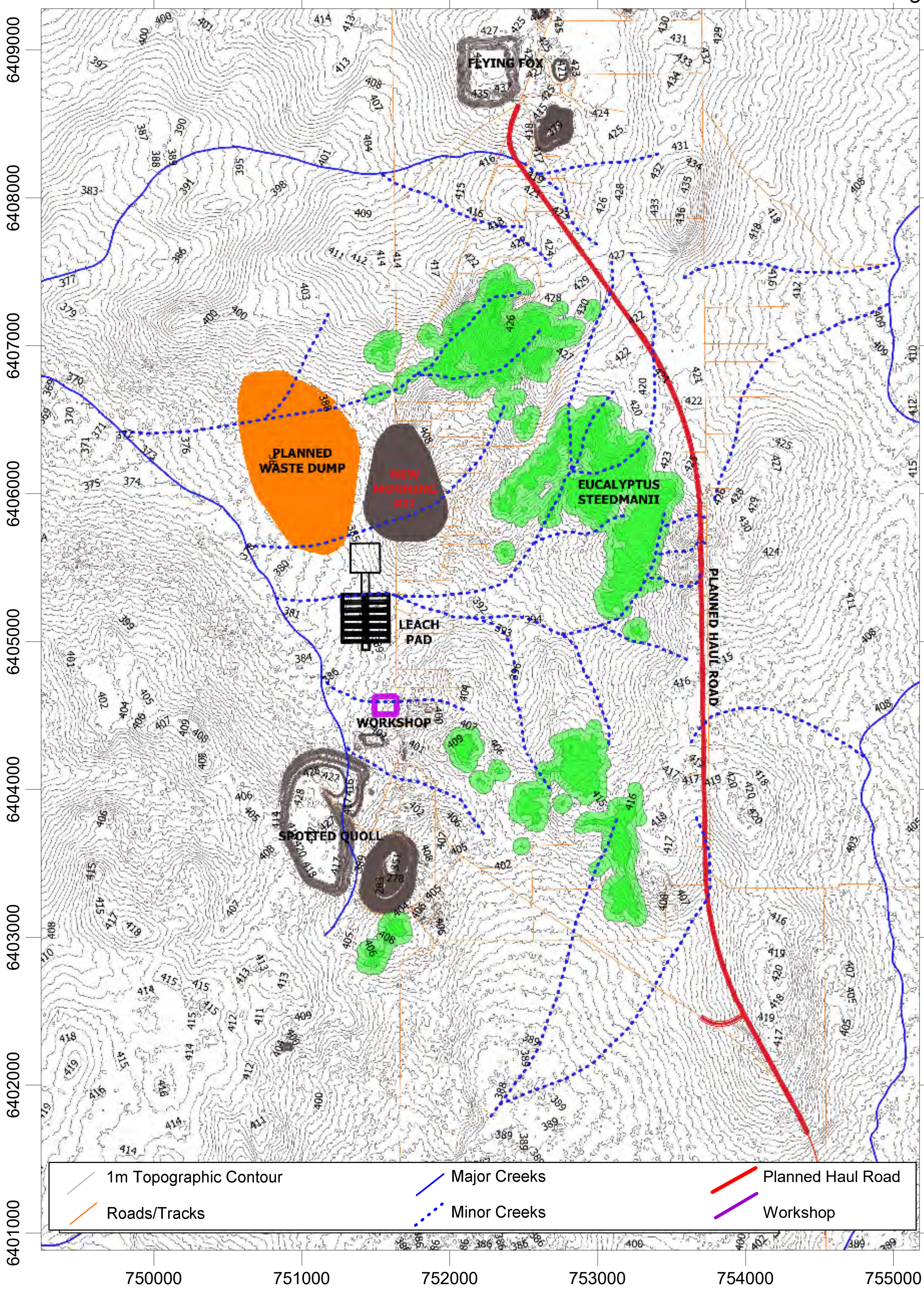
P Wharton
Principal

REFERENCE

Australian Rainfall and Runoff, 1987, A Guide to Flood Estimation, Volume 1. The Institution of Engineers, Australia, Canberra.

FIGURES

Figure 1



I:/298-7-3/Surfer/Fig 1 - Layout Plan.srf

CLIENT:	Western Areas Ltd
PROJECT:	New Morning Surface Water Assessment
DATE:	November 2018
Dwg. No:	298.7.3/18/1-1

LAYOUT PLAN

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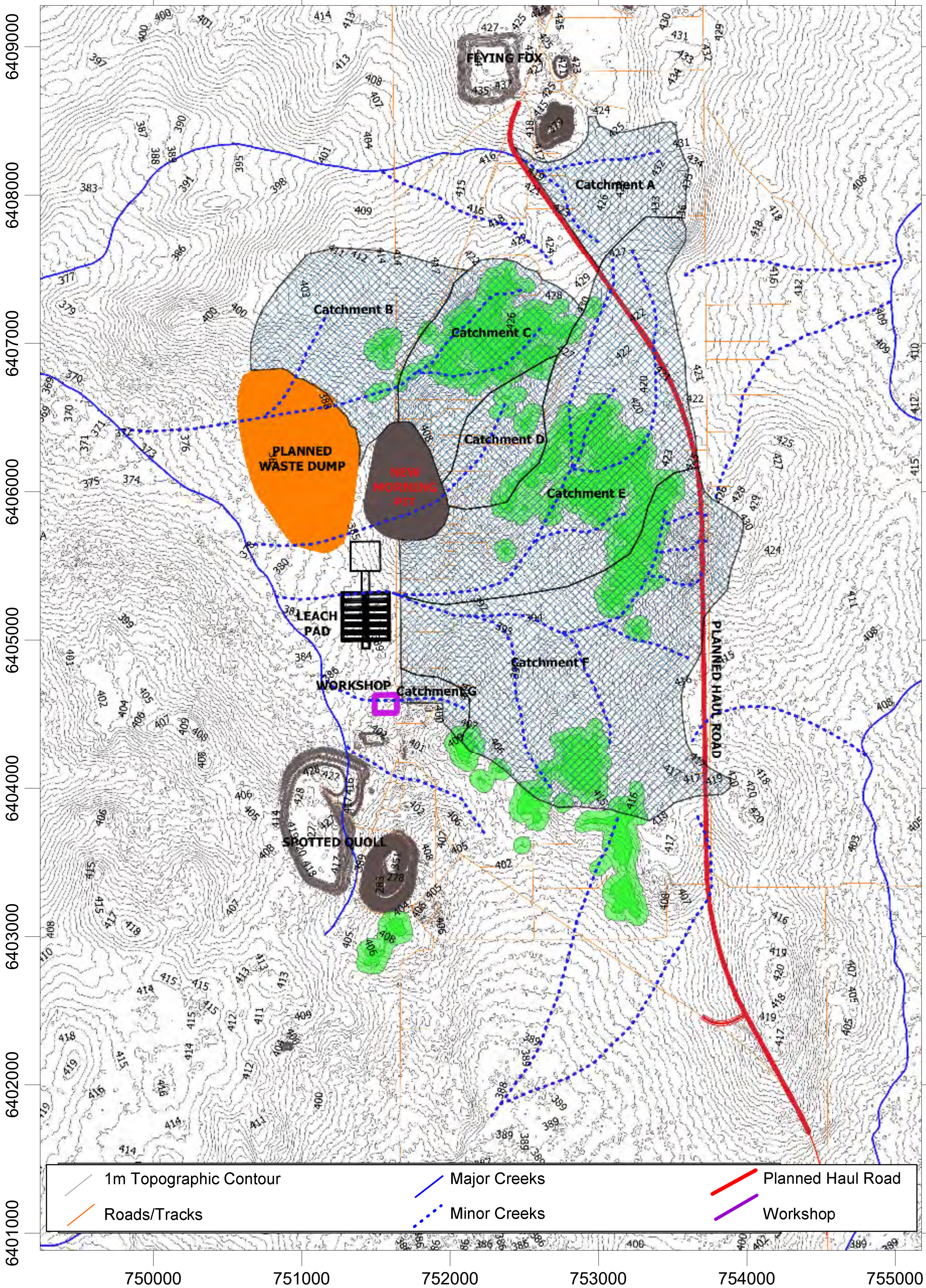
Figure 2



I:/298-7-3/Surfer/Fig 2 - Catchment Plan.srf

CLIENT:	Western Areas Ltd
PROJECT:	New Morning Surface Water Assessment
DATE:	November 2018
Dwg. No:	298.7.3/18/1-2

CATCHMENT PLAN

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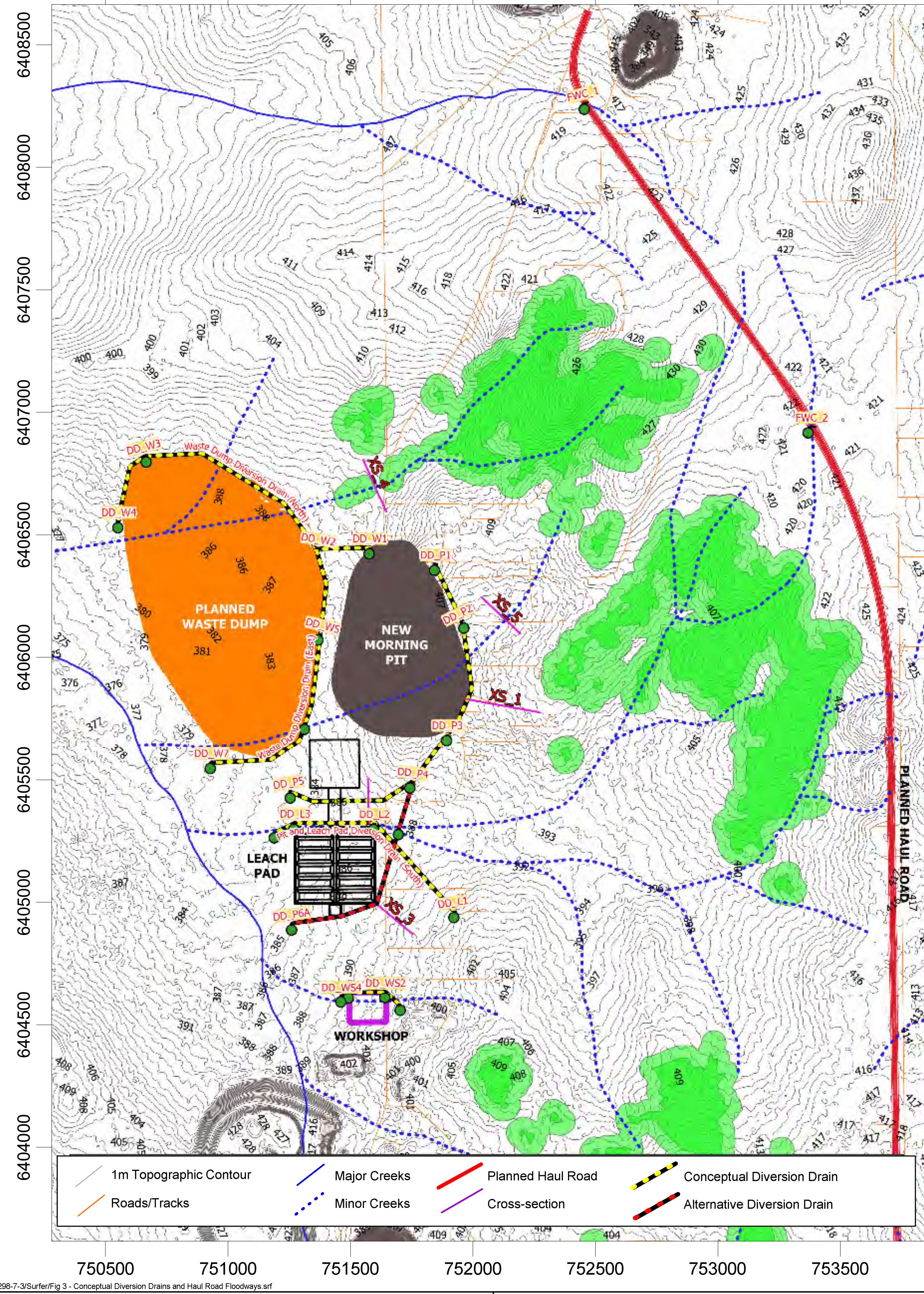
Figure 3



I:/298-7-3/Surfer/Fig 3 - Conceptual Diversion Drains and Haul Road Floodways.srf

CLIENT: Western Areas Ltd

PROJECT: New Morning Surface Water Assessment

DATE: November 2018

Dwg. No: 298.7.3/18/1-3

CONCEPTUAL DIVERSION DRAINS AND HAUL ROAD FLOODWAYS

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APPENDIX A: HYDRAULIC RESULTS

HYDRAULIC RESULTS

Cross Section	Slope (m/m)	Manning's n	ARI (years)	2	5	10	20	50	100	2000
XS_1	0.014	0.06	Peak Flow (m^3/s)	0.24	0.51	0.92	1.64	2.88	3.90	6.88
			Flood Level (m AHD)	398.17	398.23	398.29	398.36	398.44	398.49	398.61
			Maximum Depth (m)	0.17	0.23	0.29	0.36	0.44	0.49	0.61
			Velocity (m/s)	0.38	0.46	0.53	0.61	0.71	0.76	0.88
			Channel Area (m^2)	0.63	1.11	1.73	2.67	4.07	5.10	7.82
XS_2	0.012	0.06	Peak Flow (m^3/s)	1.57	3.23	5.73	10.06	17.90	22.85	40.50
			Flood Level (m AHD)	386.11	386.17	386.24	386.34	386.46	386.53	386.72
			Maximum Depth (m)	0.11	0.17	0.24	0.34	0.46	0.53	0.72
			Velocity (m/s)	0.41	0.53	0.65	0.79	0.94	1.02	1.20
			Channel Area (m^2)	3.81	6.04	8.80	12.81	18.98	22.49	33.61
XS_3	0.012	0.06	Peak Flow (m^3/s)	1.57	3.23	5.73	10.06	17.90	22.85	40.50
			Flood Level (m AHD)	389.13	389.19	389.26	389.36	389.49	389.56	389.76
			Maximum Depth (m)	0.13	0.19	0.26	0.36	0.49	0.56	0.76
			Velocity (m/s)	0.43	0.56	0.67	0.81	0.96	1.04	1.22
			Channel Area (m^2)	3.63	5.81	8.50	12.45	18.56	22.04	33.11
XS_4	0.012	0.06	Peak Flow (m^3/s)	0.37	0.80	1.42	2.52	4.39	5.91	9.88
			Flood Level (m AHD)	394.07	394.10	394.14	394.19	394.25	394.29	394.37
			Maximum Depth (m)	0.07	0.10	0.14	0.19	0.25	0.29	0.37
			Velocity (m/s)	0.27	0.34	0.41	0.49	0.57	0.62	0.71
			Channel Area (m^2)	1.38	2.32	3.46	5.19	7.74	9.61	13.99
XS_5	0.012	0.06	Peak Flow (m^3/s)	0.24	0.51	0.92	1.64	2.88	3.90	6.88
			Flood Level (m AHD)	400.13	400.17	400.21	400.26	400.32	400.36	400.44
			Maximum Depth (m)	0.13	0.17	0.21	0.26	0.32	0.36	0.44
			Velocity (m/s)	0.29	0.35	0.41	0.47	0.54	0.59	0.67
			Channel Area (m^2)	0.82	1.45	2.25	3.48	5.31	6.67	10.20