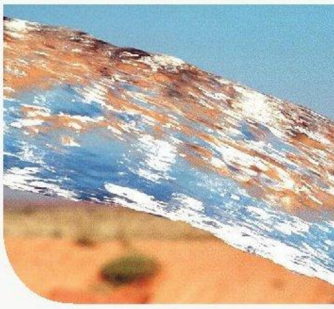
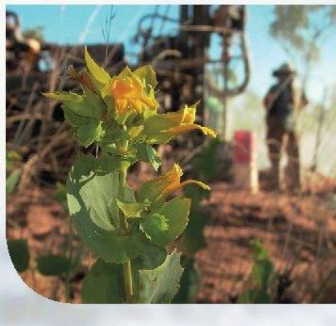
APPENDIX 2:
SURFACE WATER REPORTS





ABRA LEAD-SILVER PROJECT

HYDROLOGY AND SURFACE-WATER ASSESSMENT

REPORT FOR
GALENA MINING LTD

SEPTEMBER 2018

Rockwater
HYDROGEOLOGICAL AND ENVIRONMENTAL CONSULTANTS

Report No. 496-0/18/02rev

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REVISION	AUTHOR	REVIEW	AUTHORISED	ISSUED
0	CC	PHW		29/8/18
1	CC	PHW		13/9/18

1. INTRODUCTION

Galena Mining Ltd is conducting a pre-feasibility study for mining its Abra lead-silver deposit, located 200 km north of Meekatharra in the Jillawarra sub-basin of the Proterozoic Edmund Basin. The project lies on a south-east facing slope. There are two major drainage lines about 200 m south and 400 m east of the project. Also, some of the project's planned infrastructure intersects or lies between two small creeks.

Rockwater Pty Ltd was commissioned by Galena Mining Ltd to prepare a surface water management plan to assess the potential impact of flood flows on surface infrastructure and to determine the bunding and drainage requirements.

Applicable catchments are shown in Figures 1 and 3, together with topographic contours (1 m interval).

The scope of work covered in this report includes the following:

- Identification of catchment areas and natural water courses that could impact the project's surface installations;
- Hydrological analyses to estimate peak flows for 1 in 2, 5, 10, 20, 50 and 100-year ARI rainfalls for the critical storm duration in the relevant catchment areas; and for a 1-in-2000-year rainfall, taken to be the Probable Maximum Precipitation (PMP) event;
- Surface water hydraulic analyses at critical locations and sections in order to examine the impact of the 1 in 100 year ARI peak flow and Probable Maximum Flood; and
- Identifying and providing advice and concept design and recommendations for perimeter bunds and any diversion channels needed to prevent flooding during the 1 in 100 year ARI flow event, and drainage requirements.

1.1. INFORMATION PROVIDED BY GALENA

The following information and data were provided by Galena Mining Ltd:

- The planned layout of the site; and
- 1.0 m-interval topographic contours covering the catchments that could impact on the project.

2. SURFACE WATER HYDROLOGY

The Abra project is elevated well above the surrounding major drainage lines. However, the project's planned infrastructure intersects or lies close to two minor creeks. There are two major catchments (A and B, Fig. 1) with the potential for peak flows to impact the project area and underground mine, and three smaller catchments (C, D and E, Fig. 3) that could impact the project's surface infrastructure.

For this assessment, the methods described in the Australian Rainfall and Runoff 1987 (AR&R, 1987) Guideline and later versions were used. However, recent studies showed that the guideline presented in AR&R 1987 for the Pilbara region tends to over-estimate the peak flows. More recent and less conservative methods were developed for analyses in the Pilbara region (e.g. Flavell 2012, Davies & Yip 2014, and the revised Australian Rainfall and Runoff 2016). However, no strict guidelines were established for this region using the recent methods, and so the results from the AR&R 1987 were assumed to be appropriate for the purpose of this report.

2.1. RAINFALL ANALYSIS

Intensity-Frequency-Duration (IFD) curves for the Abra site were obtained from the Bureau of Meteorology web-site, and are based on the statistical and meteorological analyses given in the AR&R 1987 Guideline (Pilgrim et. al., 1987). The IFD tables and curves are included in Appendix I.

The Probable Maximum Precipitation (PMP) was taken to be a 1-in-2000 year event, with a probability of it occurring in any year of 0.05%. The design rainfall for this event is also included in a table and chart in Appendix I. The Probable Maximum Flood (PMF) would result from a PMP event.

2.2. IDENTIFICATION OF CATCHMENT AREAS

The relevant catchment areas were identified from the 1.0 m interval contour plan (Fig. 1 and Fig. 3) where they would impact on key points on the drainage lines. Note that Catchment B forms part of the larger Catchment A, and Catchment C is a sub-catchment of Catchment D. These areas were used in the peak flow estimation analysis as described in Section 2.6.

2.3. TIME OF CONCENTRATION

The time of concentration is required to estimate the critical storm duration for peak flows in each catchment. This was estimated using Equation 1 for the Pilbara Region of Western Australia as recommended by AR&R 1987 and later editions:

$$t_c = 0.56 \cdot A^{0.38} \qquad \text{Equation 1}$$

Where:

t_c is the time of concentration (hours)

A is the catchment area (km^2)

2.4. RATIONAL METHOD

The Statistical Rational Method, used in peak-flow estimation, is presented in Equation 2.

$$Q_y = 0.278 \cdot C_y \cdot I_{tcy} \cdot A \qquad \text{Equation 2}$$

Where:

Q_y is the peak flow for return period of y years (m^3/s)

0.278 is a dimensionless metric conversion factor

C_y is the runoff coefficient for y years (dimensionless)

I_{tcy} is rainfall intensity (mm/hr)

A is catchment area (km^2)

2.5. FLOOD INDEX METHOD

The Flood Index Method for the Pilbara Region, also used in peak-flow estimation, is presented in Equation 3.

$$Q_5 = 6.73 \times 10^{-4} \cdot \mathrm{A}^{0.72} \cdot \mathrm{P}^{1.51} \quad \text{Equation 3}$$

Where:

Q_5 is the peak discharge for the 5-year ARI flow (m^3/s)
A is the catchment area (km^2)
P is the average annual rainfall (mm)

2.6. HYDROLOGY RESULTS FOR THE MINE, INFRASTRUCTURE AND ACCESS ROAD CATCHMENTS

The characteristics of the catchments which could impact the Abra project are listed in Tables 1 and 2. The nearest Bureau of Meteorology (BoM) station is Tangadee (Stn. 007179), located 45 km east-north-east of Abra. Annual Rainfall (1960 to 2018) averages 269 mm.

Table 1: Major Catchment Characteristics (Fig. 1)

Catchment	Area (km^2)	Length (km)
A	40.5	7.6
B	5.5	4.0

Table 2: Minor Catchment Characteristics (Fig. 3)

Catchment	Area (km^2)	Length (km)
C	0.12	0.7
D	0.74	1.5
E	1.17	2.1

A summary of the design peak flows, as estimated using the Rational and Flood Index Methods, is shown in Table 3. The detailed calculations are presented in Appendix I.

Table 3: Estimated Peak Flows for Each Catchment

Catchment A	ARI (years) / Discharge (m³/s)					
Method:	2	5	10	20	50	100	PMF*
Rational	23.88	52.81	98.22	197.32	361.81	633.25	
Index	22.99	45.11	79.65	136.38	256.59	404.80	
Adopted (average)	**23.43**	**48.96**	**88.93**	**166.85**	**309.20**	**519.03**	**894.55**
Catchment B	ARI (years) / Discharge (m³/s)						
Method:	2	5	10	20	50	100	PMF*
Rational	6.30	13.61	25.00	49.69	89.90	156.06	
Index	5.67	10.72	17.83	28.61	49.75	82.71	
Adopted (average)	**5.98**	**12.16**	**21.42**	**39.15**	**69.82**	**119.38**	**205.76**
Catchment C	ARI (years) / Discharge (m³/s)						
Method:	2	5	10	20	50	100	PMF*
Rational	0.41	0.87	1.59	3.15	5.67	9.80	
Index	0.40	0.69	1.03	1.46	2.19	3.35	
Adopted (average)	**0.40**	**0.78**	**1.31**	**2.31**	**3.93**	**6.58**	**11.33**
Catchment D	ARI (years) / Discharge (m³/s)						
Method:	2	5	10	20	50	100	PMF*
Rational	1.37	2.97	5.46	10.90	19.76	34.31	
Index	1.40	2.54	3.98	5.98	9.61	15.29	
Adopted (average)	**1.38**	**2.75**	**4.72**	**8.44**	**14.68**	**24.80**	**42.74**
Catchment E	ARI (years) / Discharge (m³/s)						
Method:	2	5	10	20	50	100	PMF*
Rational	1.81	3.93	7.24	14.46	26.25	45.64	
Index	1.92	3.52	5.59	8.53	13.95	22.40	
Adopted	**1.86**	**3.72**	**6.41**	**11.49**	**20.10**	**34.02**	**58.63**

** PMF estimated using multiplying factors from CRC-FORGE results*

3. HYDRAULIC ANALYSES

3.1. IMPACT OF MAJOR FLOWS ON THE PROJECT AREA

Flows in catchments A and B (Fig. 1) were analysed to assess whether the 1 in 100 year ARI peak flows and Probable Maximum Flood (PMF) could reach the project area and underground mines.

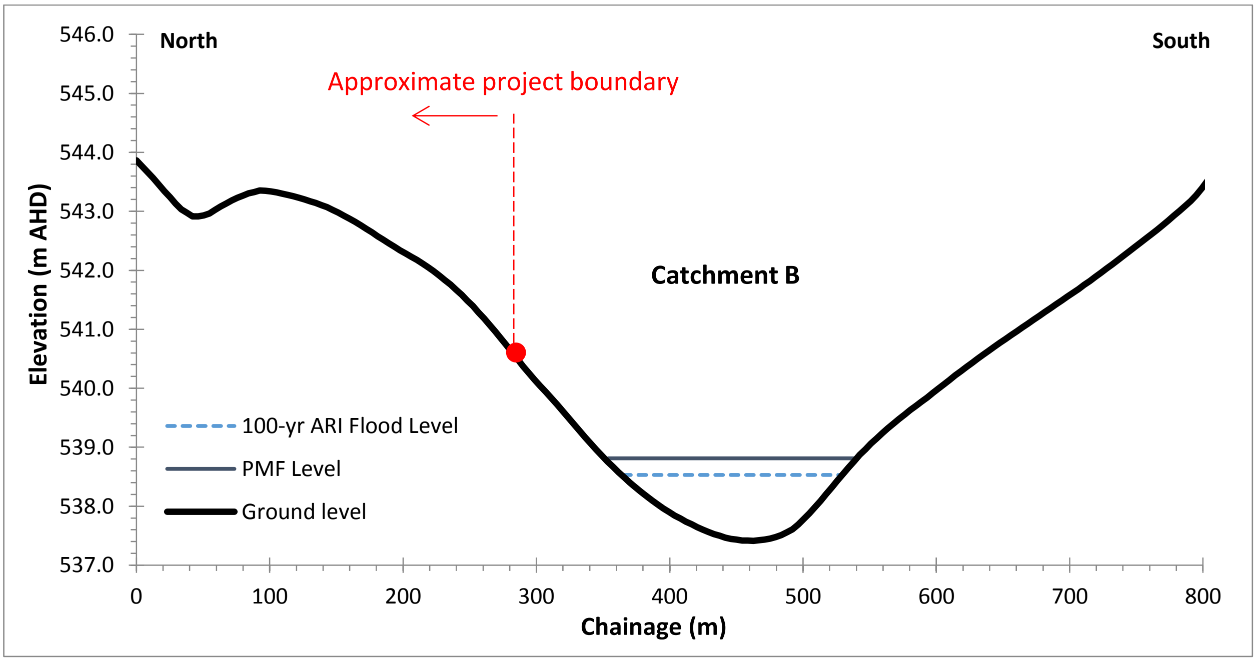
The locations of the major flow paths that could impact the project were identified from aerial photography and the 1 m contour plan (Fig. 1). The extent, velocity and flows within these flow paths were then determined at selected cross-sections where stage-discharge and stage-velocity relationships were calculated using Manning's equation.

Hydraulic analyses were conducted at four cross-sections (cross-sections 1 to 4, Fig. 2) to assess whether the peak flows would reach the project's boundaries. Note: all cross-sections presented in this report are looking downstream from the natural creeks.

3.1.1. CROSS-SECTION 1 – SOUTH OF THE PLANNED MINE

In a 1-in-100 year flood, the peak flood levels from Catchment B, south of the project, would be at about 538.53 m AHD with a width of about 165 m, and the level would be about 0.28 m higher in a Probable Maximum Flood (PMF). These flood levels would have significant flow, depth and extent; however, they should not impact the project area as shown in Text-Figure 1 below.

Text-Figure 1: Cross Section 1 with 100 year ARI flood level and PMF



The maximum depth of the 1-in-100 year flood would be about 1.12 m and the maximum velocity in the order of 1.0 m/s (Table 4).

Table 4: Cross-section 1*, 100-year ARI flood and PMF summary

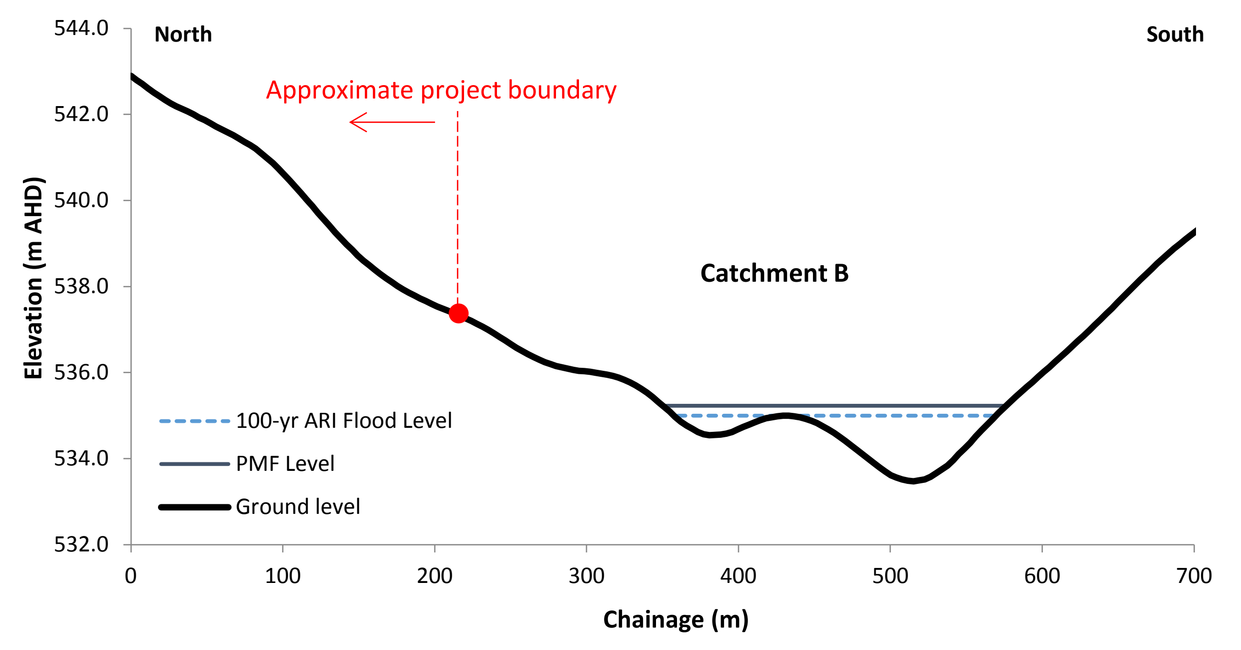
Flood Analysis	Flow (m^3/s)	Flood Level Elevation (m AHD)	Depth (m)	Velocity (m/s)	Extent of Flood Level (m)
100-yr	119	538.53	1.12	1.0	165
PMF	206	538.81	1.40	1.2	185

* Catchment B

3.1.2. CROSS-SECTION 2 – SOUTH-EAST OF THE PLAANNED MINE

In a 1-in-100 year flood, the peak flood levels from Catchment B, south and west of the project, would be at 535.00 m AHD with a width of about 212 m, and the level would be 0.23 m higher in a Probable Maximum Flood (PMF). These flood levels would be of significant flow, depth and extent, however, would not impact the project area as shown in Text-Figure 2 below.

Text-Figure 2: Cross Section 2 with 100 year ARI flood level and PMF



The maximum depth of the 1-in-100 year flood would be about 1.5 m and the maximum velocity in the order of 1.1 m/s (Table 5).

Table 5: Cross-section 2*, 100-year ARI flood and PMF summary

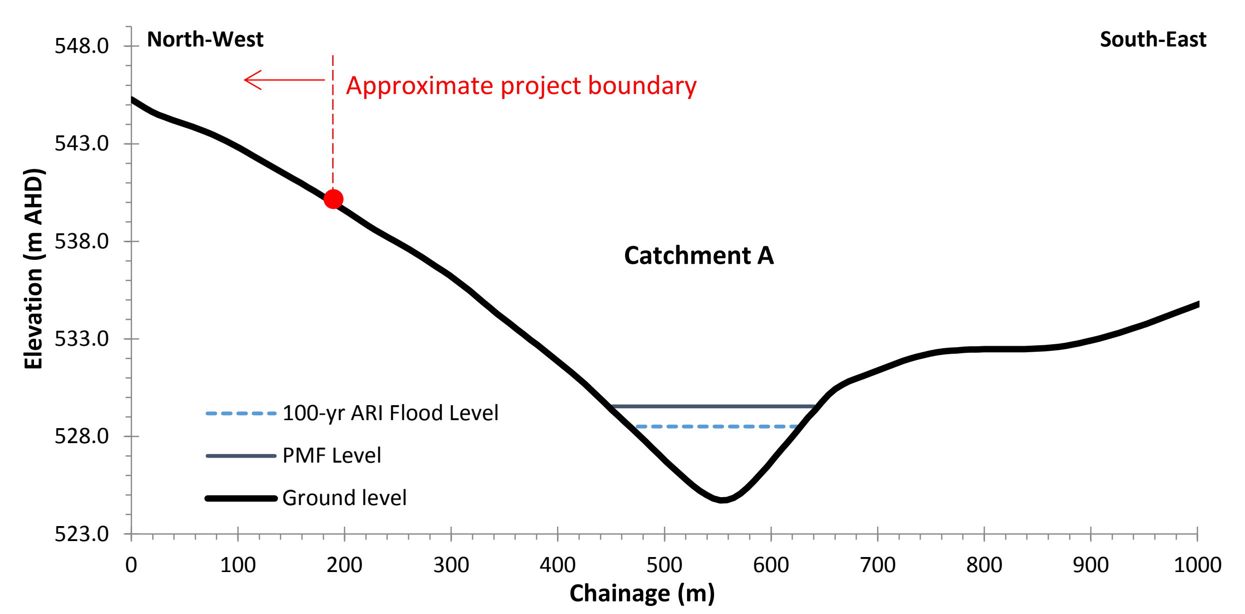
Flood Analysis	Flow (m^3/s)	Flood Level Elevation (m AHD)	Depth (m)	Velocity (m/s)	Extent of Flood Level (m)
100-yr	119	535.00	1.53	1.1	212
PMF	206	535.23	1.76	1.2	224

* Catchment B

3.1.3. CROSS-SECTION 3 – SOUTH-EAST OF THE PLANNED INFRASTRUCTURE

In a 1-in-100 year flood, the peak flood levels from Catchment A, south and east of the infrastructure, would be at 528.51 m AHD with a width of about 152 m, and the level would be 1.04 m higher in a Probable Maximum Flood (PMF). These flood levels would be of significant flow, depth and extent, however, would not impact the project area as shown in Text-Figure 3 below.

Text-Figure 3: Cross Section 3 with 100 year ARI flood level and PMF



The maximum depth of the 1-in-100 year flood would be about 3.78 m and the maximum velocity in the order of 1.5 m/s (Table 6).

Table 6: Cross-section 3*, 100-year ARI flood and PMF summary

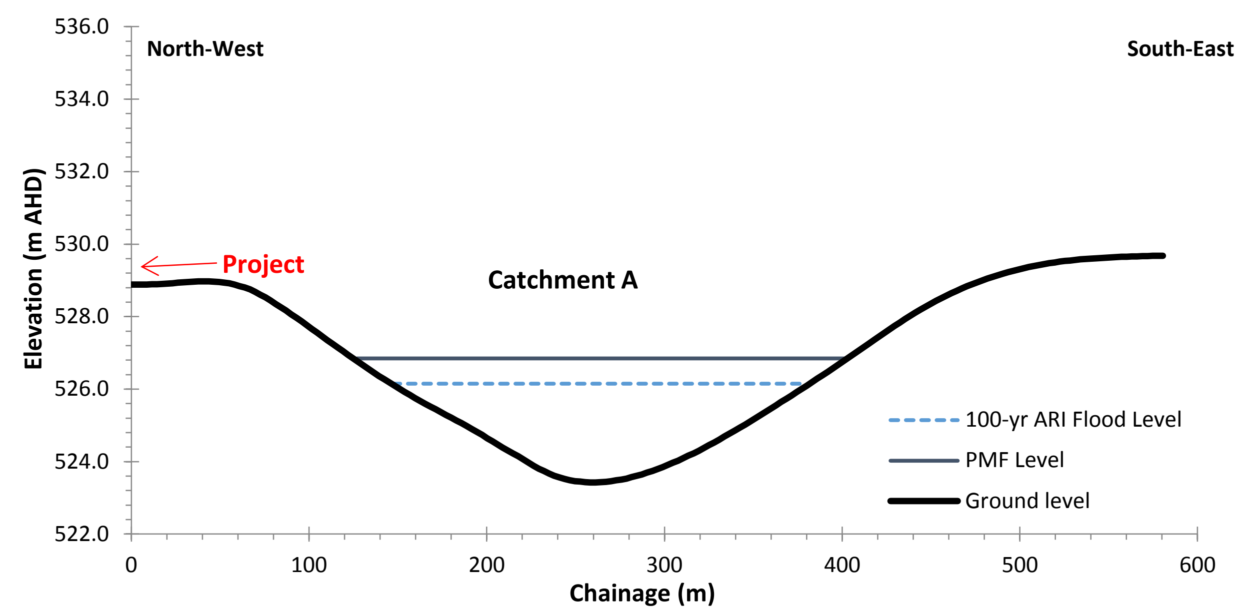
Flood Analysis	Flow (m^3/s)	Flood Level Elevation (m AHD)	Depth (m)	Velocity (m/s)	Extent of Flood Level (m)
100-yr	519	528.51	3.78	1.5	152
PMF	895	529.55	4.82	1.7	190

* Catchment A

3.1.4. CROSS-SECTION 4 –EAST OF THE PLANNED INFRASTRUCTURE

In a 1-in-100 year flood, the peak flood levels from Catchment A, east of the infrastructure, would be at 526.15 m AHD with a width of about 232 m, and the level would be 0.70 m higher in a Probable Maximum Flood (PMF). These flood levels would be of significant flow, depth and extent, however, would not impact the project area as shown in Text-Figure 5: Cross Section 5 with 100 year ARI flood level and PMF below.

Text-Figure 4: Cross Section 4 with 100 year ARI flood level and PMF



The maximum depth of the 1-in-100 year flood would be about 2.73 m and the maximum velocity in the order of 1.4 m/s (Table 7).

Table 7: Cross-section 4*, 100-year ARI flood and PMF summary

Flood Analysis	Flow (m^3/s)	Flood Level Elevation (m AHD)	Depth (m)	Velocity (m/s)	Extent of Flood Level (m)
100-yr	533	526.15	2.73	1.4	300
PMF	918	526.85	3.43	1.6	328

* Catchment A

The above hydraulic analyses show that the peak flows in the major catchments will be substantial, but would not reach the project boundaries and impact the planned mining and infrastructure areas.

3.2. IMPACT OF MINOR FLOWS ON THE SURFACE INFRASTRUCTURE

Flows in the minor catchments which could impact the infrastructure area were also analysed to assess the impact of the 1 in 100 year ARI peak flows and Probable Maximum Flood (PMF) on the surface infrastructure to determine the protective measures required.

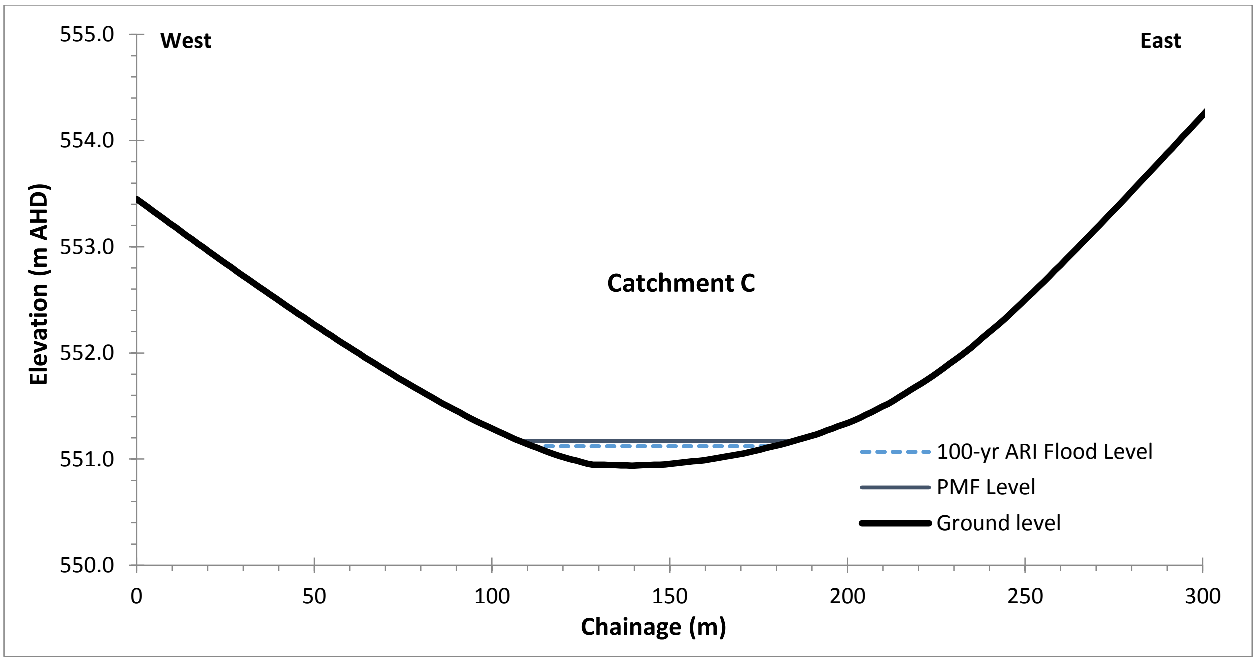
The locations of the minor flow paths that could impact the project's surface infrastructure were identified from aerial photography and the 1 m contour plan (Fig. 3). The planned infrastructure intersects or is very close to two small natural drainage lines that could impact the project during high rainfall events.

Hydraulic analyses were conducted at three critical locations (cross-section 5 to 7, Fig. 3) to assess the impact of the peak flows.

3.2.1. CROSS-SECTION 5 - IMPACT FROM CATCHMENT C

In a 1-in-100 year flood, the peak flood levels from Catchment C would be at about 551.12 m AHD with a width of about 66 m, and the level would be about 0.05 m higher in a Probable Maximum Flood (PMF). These flood levels would be of low flow, depth and velocity; therefore, they should have a limited impact on the project area, as shown in Text-Figure 5: Cross Section 5 with 100 year ARI flood level and PMF below.

Text-Figure 5: Cross Section 5 with 100 year ARI flood level and PMF



The maximum depth of the 1-in-100 year flood would be about 0.18 m and the maximum velocity in the order of 0.8 m/s (Table 8).

Table 8: Cross-section 5*, 100-year ARI flood and PMF summary

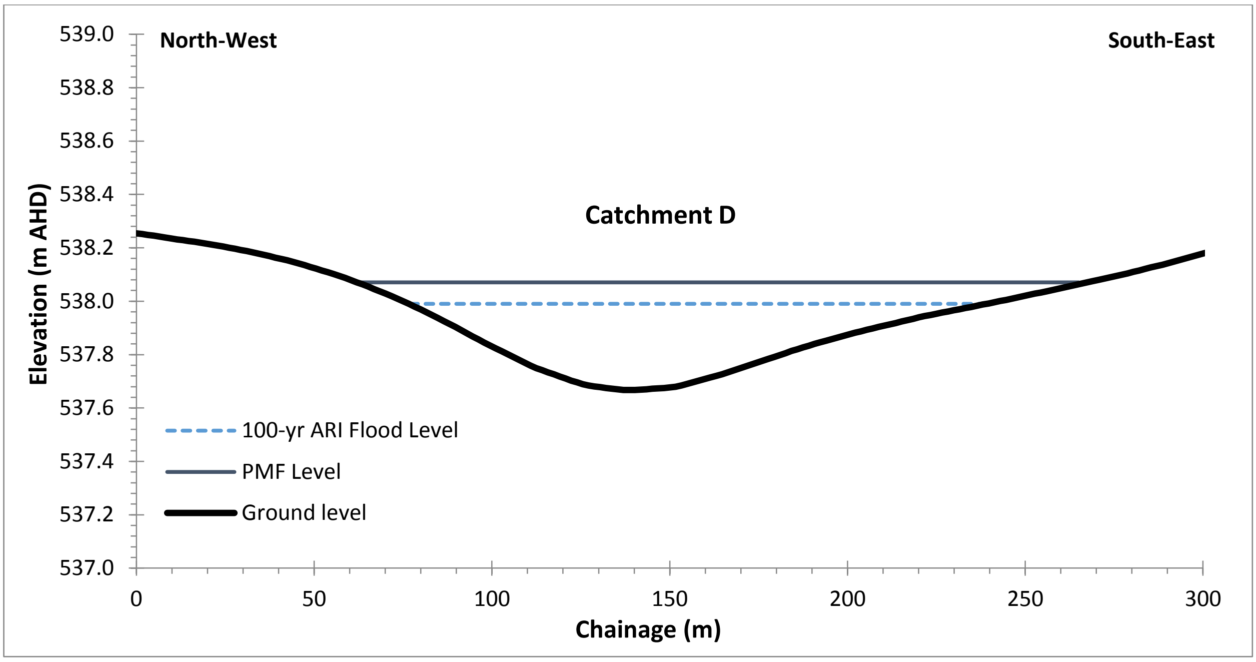
Flood Analysis	Flow (m^3/s)	Flood Level Elevation (m AHD)	Depth (m)	Velocity (m/s)	Extent of Flood Level (m)
100-yr	6.6	551.12	0.18	0.8	66
PMF	11.3	551.17	0.23	1.0	75

* Catchment C

3.2.2. CROSS-SECTION 6 – IMPACT FROM CATCHMENT D

In a 1-in-100 year flood, the peak flood levels from Catchment D would be at 537.99 m AHD with a width of about 161 m, and the level would be 0.08 m higher in a Probable Maximum Flood (PMF). These flood levels would be of significant extent, and could have an impact on the project's infrastructure.

Text-Figure 6: Cross Section 6 with 100 year ARI flood level and PMF



The maximum depth of the 1-in-100 year flood would be about 0.32 m and the maximum velocity in the order of 0.9 m/s (Table 9).

Table 9: Cross-section 6*, 100-year ARI flood and PMF summary

Flood Analysis	Flow (m^3/s)	Flood Level Elevation (m AHD)	Depth (m)	Velocity (m/s)	Extent of Flood Level (m)
100-yr	24.8	537.99	0.32	0.9	161
PMF	42.7	538.07	0.40	1.0	202

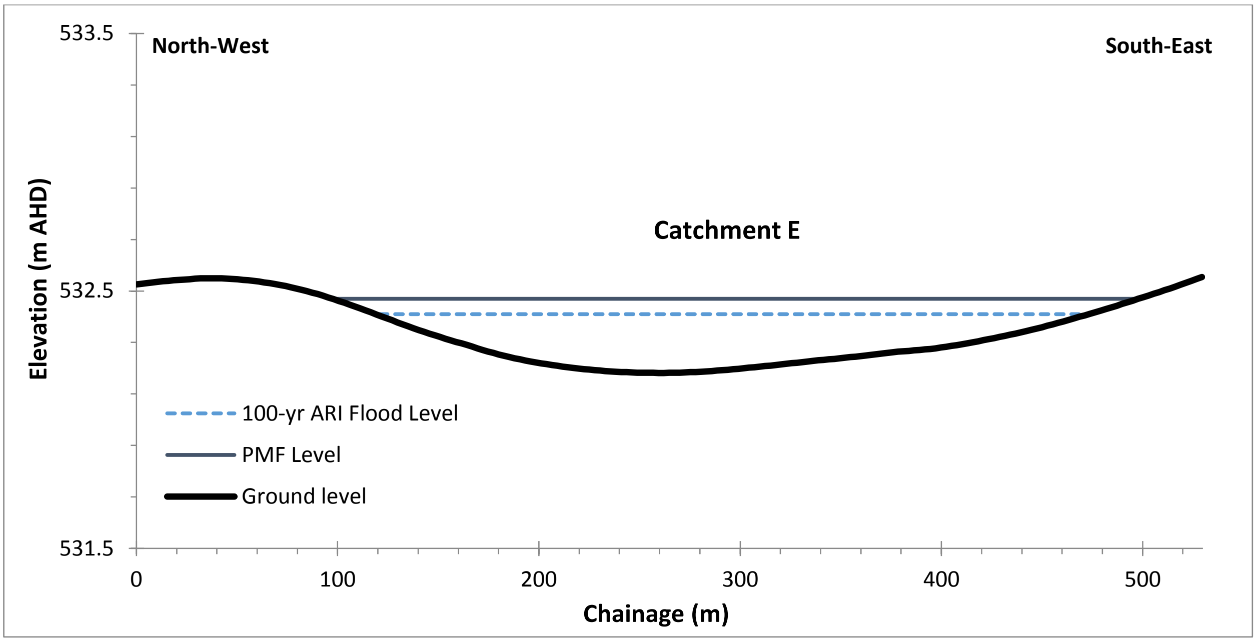
* Catchment D

The peak flows from catchment B could result in scouring and damage to the infrastructure. It is recommended to slightly change the footprint of the tailings storage facility (TSF) and to build a diversion channel (as shown in Figure 4). The diversion channel would reduce the extent of the peak floods and prevent any damage to the infrastructure. The conceptual design and hydraulic analyses for the channel are given in Section 4 of this report.

3.2.3. CROSS-SECTION 7 – IMPACT FROM CATCHMENT E

In a 1-in-100 year flood, the peak flood levels from Catchment E would be at 532.41 m AHD with a width of about 352 m, and the level would be 0.06 m higher in a Probable Maximum Flood (PMF). These flood levels would be of significant flow and extent, and could have an impact on the project's infrastructure, in particular the TSF. It is understood that the airstrip is likely to be relocated elsewhere, and so has not been considered in this analysis.

Text-Figure 7: Cross Section 7 with 100 year ARI flood level and PMF



The maximum depth of the 1-in-100 year flood would be about 0.23 m and the maximum velocity in the order of 0.7 m/s (Table 10).

Table 10: Cross-section 7*, 100-year ARI flood and PMF summary

Flood Analysis	Flow (m^3/s)	Flood Level Elevation (m AHD)	Depth (m)	Velocity (m/s)	Extent of Flood Level (m)
100-yr	34.0	532.41	0.23	0.7	352
PMF	58.6	532.47	0.29	0.8	400

* Catchment E

The peak flows from catchment E would be of shallow depth but of significant width and could have an impact on the infrastructure. It is recommended to change the footprint of the TSF and to dig a drain in the existing creek to limit the extent of the peak flows. The conceptual design and hydraulic analyses for the drain are given in Section 4 of this report, and the realigned TSF is shown in Figure 4.

4. RECOMMENDED PROTECTIVE MEASURES

4.1. CONSTRUCTION OF A DRAIN

As highlighted in Section 3.2.3, peak flows from Catchment E could have an impact on the TSF, even with the footprint realigned. A drain is recommended to enhance the natural drainage line (Fig. 4).

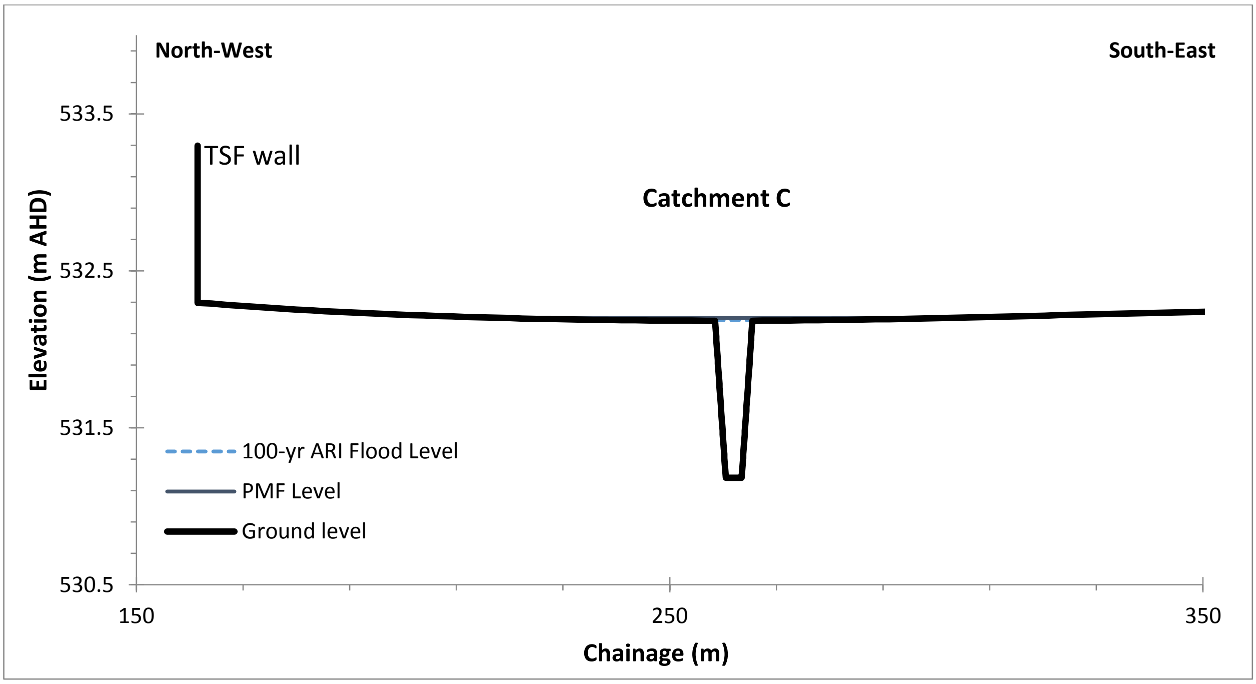
The recommended dimensions for the drain are presented in Table 11. Cross-section 8 (Text-Figure 8) is at the same location as cross-section 7 presented above to compare the estimated peak flood levels with and without the proposed drain.

Table 11: Proposed drain dimensions

Drain Bank Slope	Drain Bed Width (m)*	Drain Depth (m)*
1:2	3.0	1.0

**These values are indicative and should be considered as minimum requirements.*

Text-Figure 8: Cross Section 8 - Proposed drain with peak flood levels



With the proposed drain design, the 1-in-100 year flood would remain within the drain and the maximum velocity would be in the order of 5.5 m/s. The Probable Maximum Flood would be only 0.02 m above the drain with a width of 82 m. Table 12 summarises the 100-year flood characteristics with and without the proposed drain.

Table 12: 100-year flood comparison with and without proposed drain

Cross Section	Ground level (m AHD)	Drain Base (m AHD)	100-year ARI Flood Elevation (m AHD)	100-year ARI Flood Velocity (m/s)	100-year ARI Flood Width (m)
7*	532.18	No drain	532.42	0.7	360
8*	532.18	531.18	532.18	5.5	7

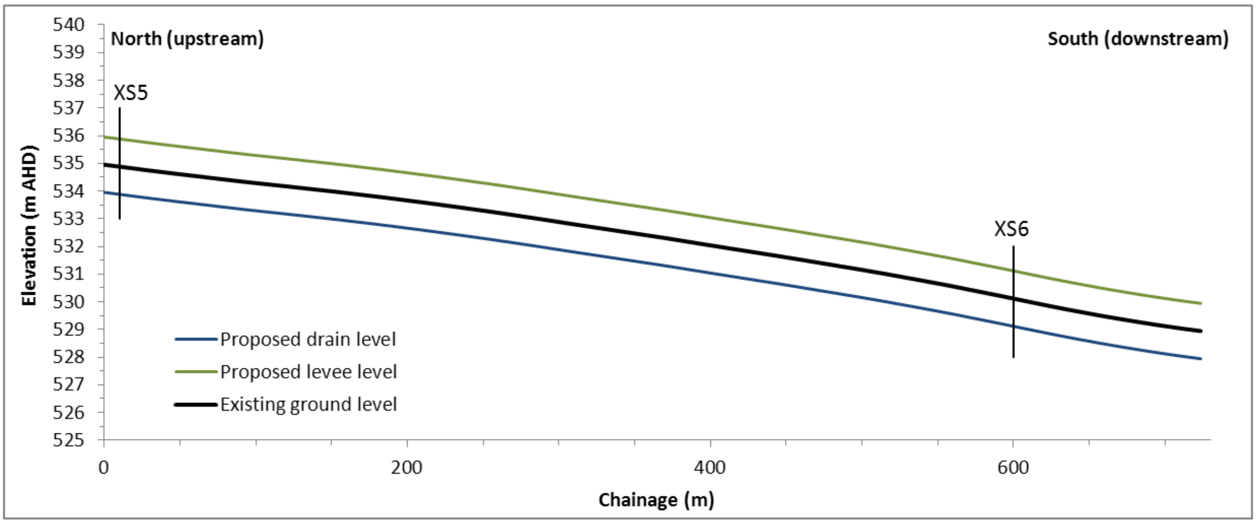
* Catchment E

4.2. RECOMMENDED DIVERSION CHANNEL

A diversion channel is also recommended to divert the natural creek and prevent the peak floods from Catchment D from impacting the northern side of the TSF. The proposed diversion channel is shown in Figure 4.

A conceptual long-section of the diversion channel is presented in Text-Figure 9 below.

Text-Figure 9: Conceptual long-section of Diversion Channel



Excavation of a drain will be required in conjunction with a levee to form the channel: the excavated material can be used for construction of the levee. The recommended dimensions for the drain and the levee forming the diversion channel are given in Table 13.

Table 13: Proposed diversion channel dimensions

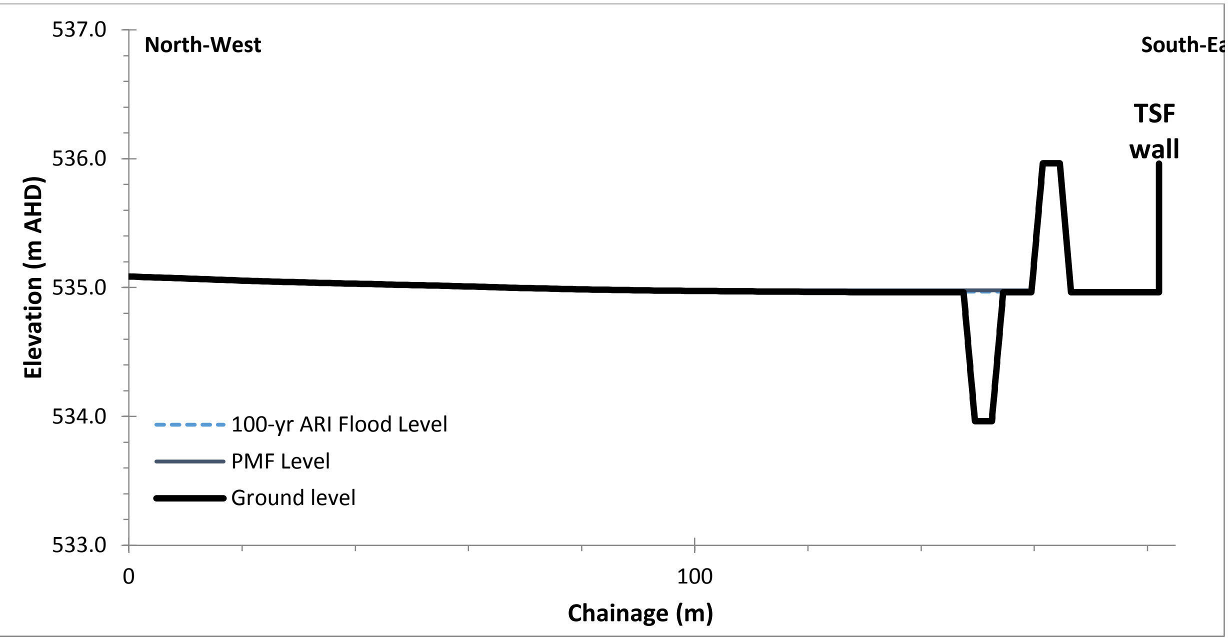
Drain/Levee Bank Slope	Drain Bed/Top of Levee Width (m)*	Drain Depth/Levee Height (m)*	Cross-sections
1:2	3.0	1.0	9 & 10

*These values are indicative and should be considered as minimum requirements

Cross-sections 9 and 10 below (Text-Figures 10 and 11) show the flood levels at the upstream and downstream ends of the proposed diversion channel.

4.2.1. HYDRAULIC ANALYSES – UPSTREAM END OF THE PROPOSED DIVERSION CHANNEL

Text-Figure 10: Cross Section 9 - Proposed diversion channel with peak flood levels



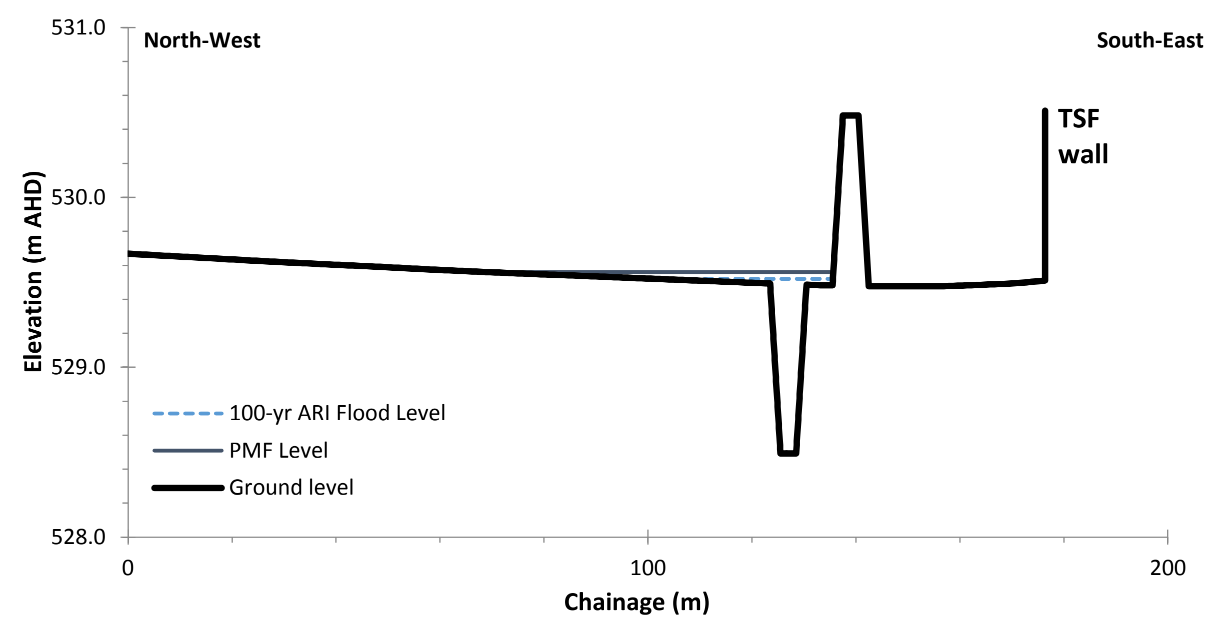
In the 1-in-100 year flood, the maximum level would be about 0.01 m above the drain, the maximum velocity in the order of 3.9 m/s (100-year flood comparison with and without proposed drain), and the Probable Maximum Flood would be 0.01 m higher.

Table 14: Cross-section 9, proposed drain/levee concept design and 100-year flood summary

Corresponding long-section chainage (m)	Flow (m^3/s)	Existing ground level (m AHD)	Proposed levee level (m AHD)	Proposed drain level (m AHD)	100-year ARI Flood Elevation (m AHD)	100-year ARI Flood Velocity (m/s)
0	26.6	534.96	535.96	533.96	534.97	3.9

4.2.2. HYDRAULIC ANALYSES – DOWNSTREAM END OF THE PROPOSED DIVERSION CHANNEL

Text-Figure 11: Cross Section 10 - Proposed diversion channel with peak flood levels



In the 1-in-100 year flood, the maximum level would be about 0.04 m above the drain, the maximum velocity in the order of 3.9 m/s (100-year flood comparison with and without proposed drain), and the Probable Maximum Flood would be 0.04 m higher.

Table 15: Cross-section 10, proposed drain/levee concept design and 100-year flood summary

Corresponding long-section chainage (m)	Flow (m^3/s)	Existing ground level (m AHD)	Proposed levee level (m AHD)	Proposed drain level (m AHD)	100-year ARI Flood Elevation (m AHD)	100-year ARI Flood Velocity (m/s)
600	29.0	529.48	530.48	528.48	529.52	3.9

The above analyses show the construction of a diversion channel would efficiently divert the natural creek away from the TSF wall. Also, it would significantly reduce the depths and widths of the peak flood levels.

For information purposes, a cross-section of a typical levee and drain system is provided in Appendix C.

5. SUMMARY OF FLOOD MANAGEMENT REQUIREMENTS

The Abra lead-silver deposit is located near major drainage lines (Fig. 1), in an area subject to high flood flows. However, it is located well above these major creeks, and the hydraulic analyses presented in this report indicate that the peak flows resulting from these catchments would not impact on the project area and underground mine.

However, the planned infrastructure, in particular the TSF, intersects or is close to two minor drainage lines which flow northwards (Fig. 3). High rainfall events could result in flooding and potential damage to the TSF walls.

Where recommended, the levees and drains have been designed to control the width of the flows.

Drainage from Catchment C would intersect an edge of the processing plant. However, given the small size of the catchment, the flood flows would be minor and dissipate rapidly. A small bund and drain can be constructed to control flows and protect the plant.

Drainage from Catchment D intersects the planned south-western wall of the TSF. Changing the TSF orientation is recommended (as shown in Figure 4); and a diversion channel together with a small levee will be required to protect and divert flows around the TSF.

Drainage from Catchment E will pass close to the south-eastern wall of the TSF. The 100-year ARI peak flow would cover a significant width and could impact the wall of the TSF. The excavation of a drain is recommended to contain runoff and to limit the extent of the flood flows (Fig. 4).

Dated: 13 September 2018

Rockwater Pty Ltd

C Corthier
Engineering Geologist

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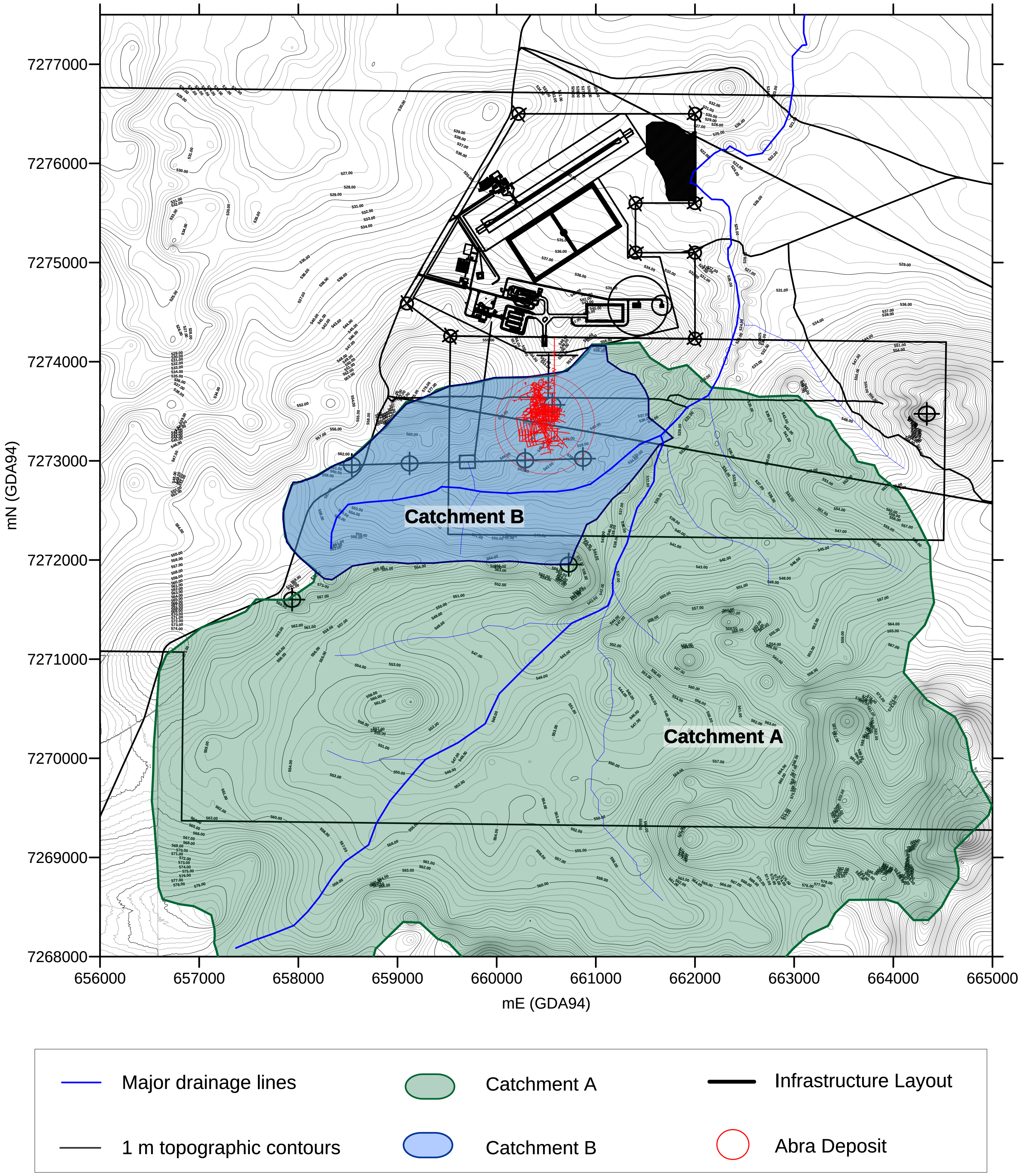
FIGURES

FIGURE 1



major catchments.srf

CLIENT: Galena Mining

PROJECT: Abra Silver-lead Deposit

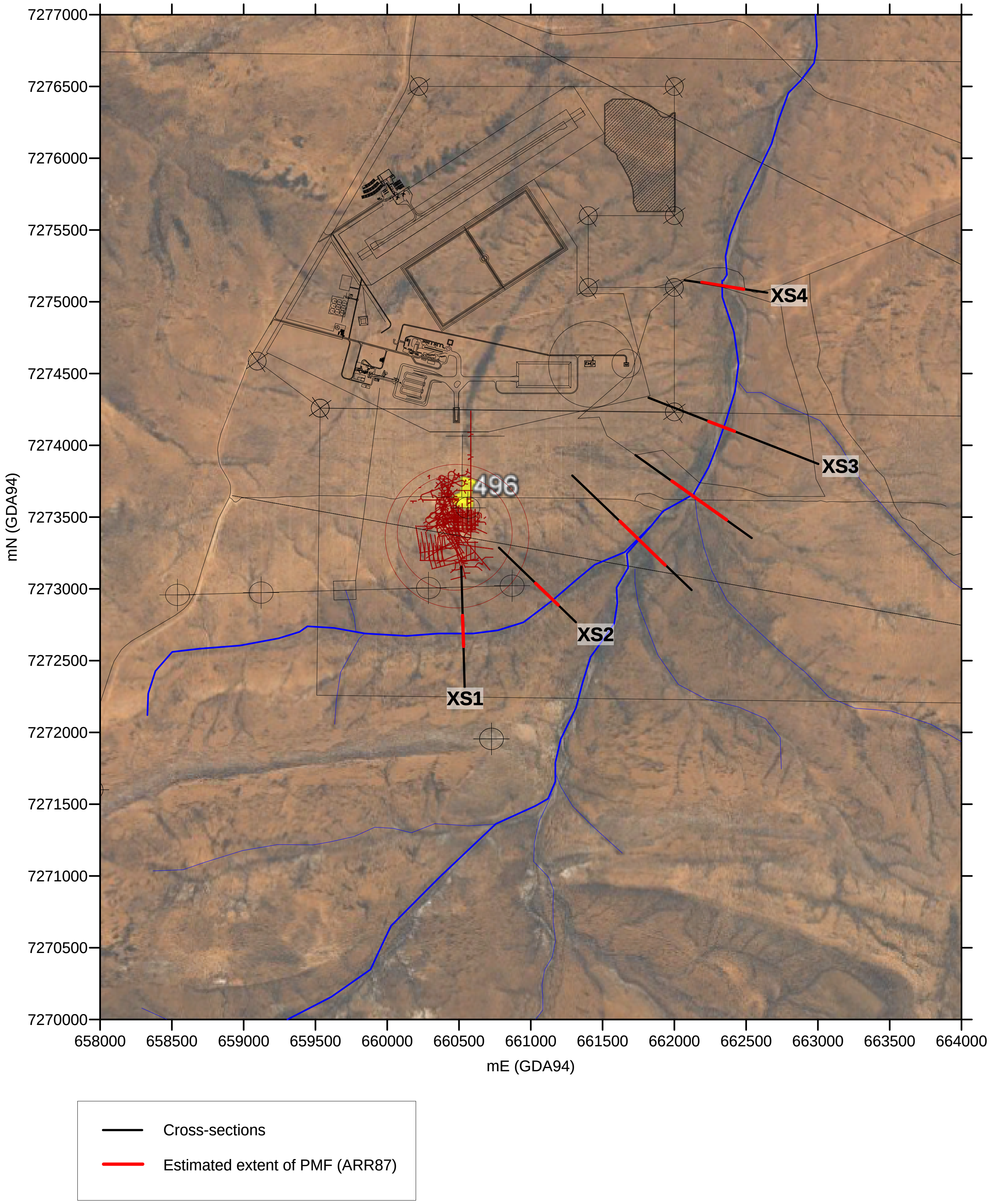
DATE: September 2018

Dwg No: 496-0/18/2-1

PROJECT AREA & MAJOR CATCHMENTS

Rockwater PROPRIETARY LIMITED

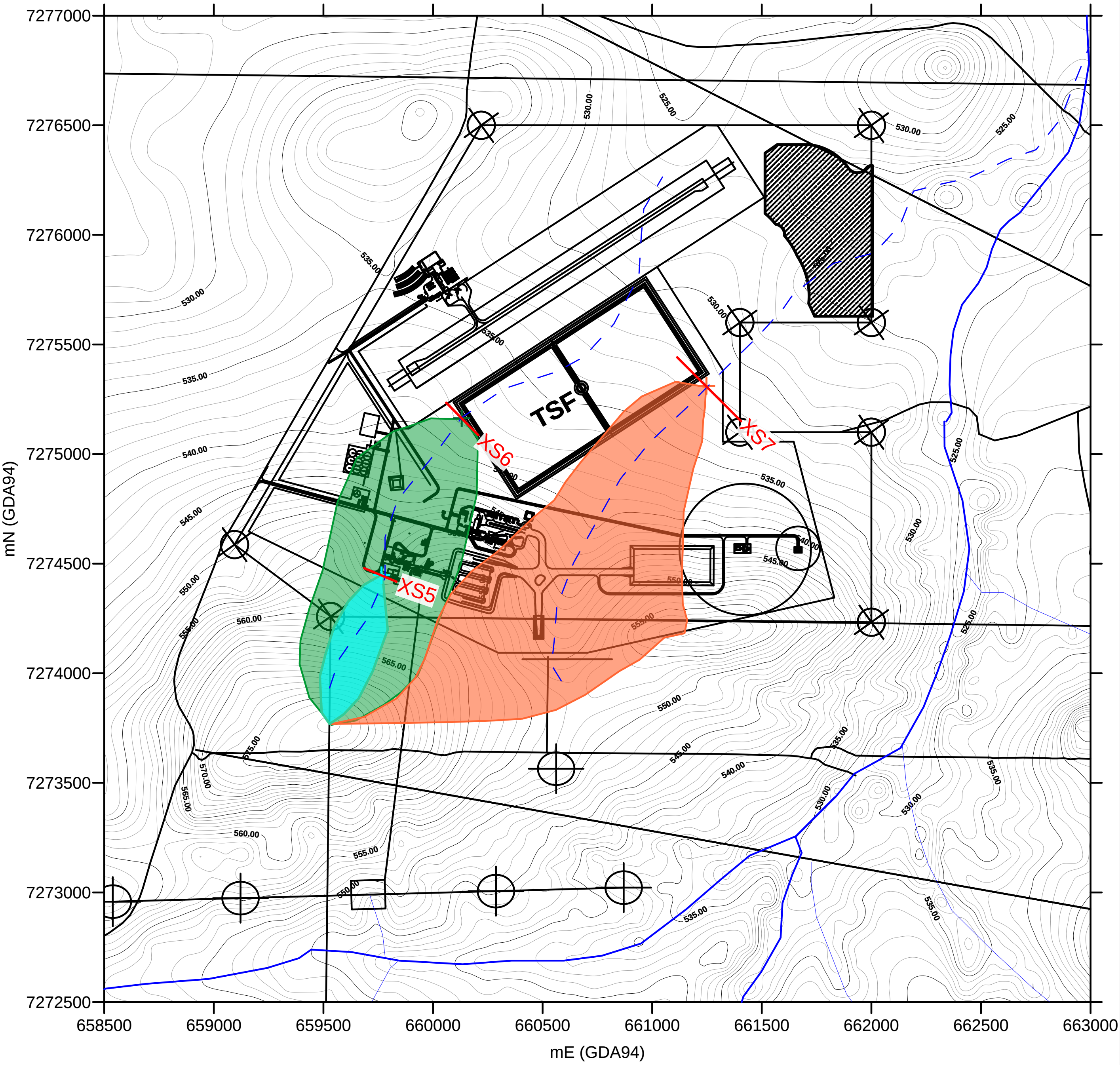
FIGURE 2



cross-sections.srf

CLIENT: Galena Mining PROJECT: Abra Silver-lead Deposit DATE: September 2018 Dwg No: 496-0/18/2-2	CROSS-SECTIONS & FLOOD EXTENT FROM MAJOR CREEKS Rockwater PROPRIETARY LIMITED

FIGURE 3

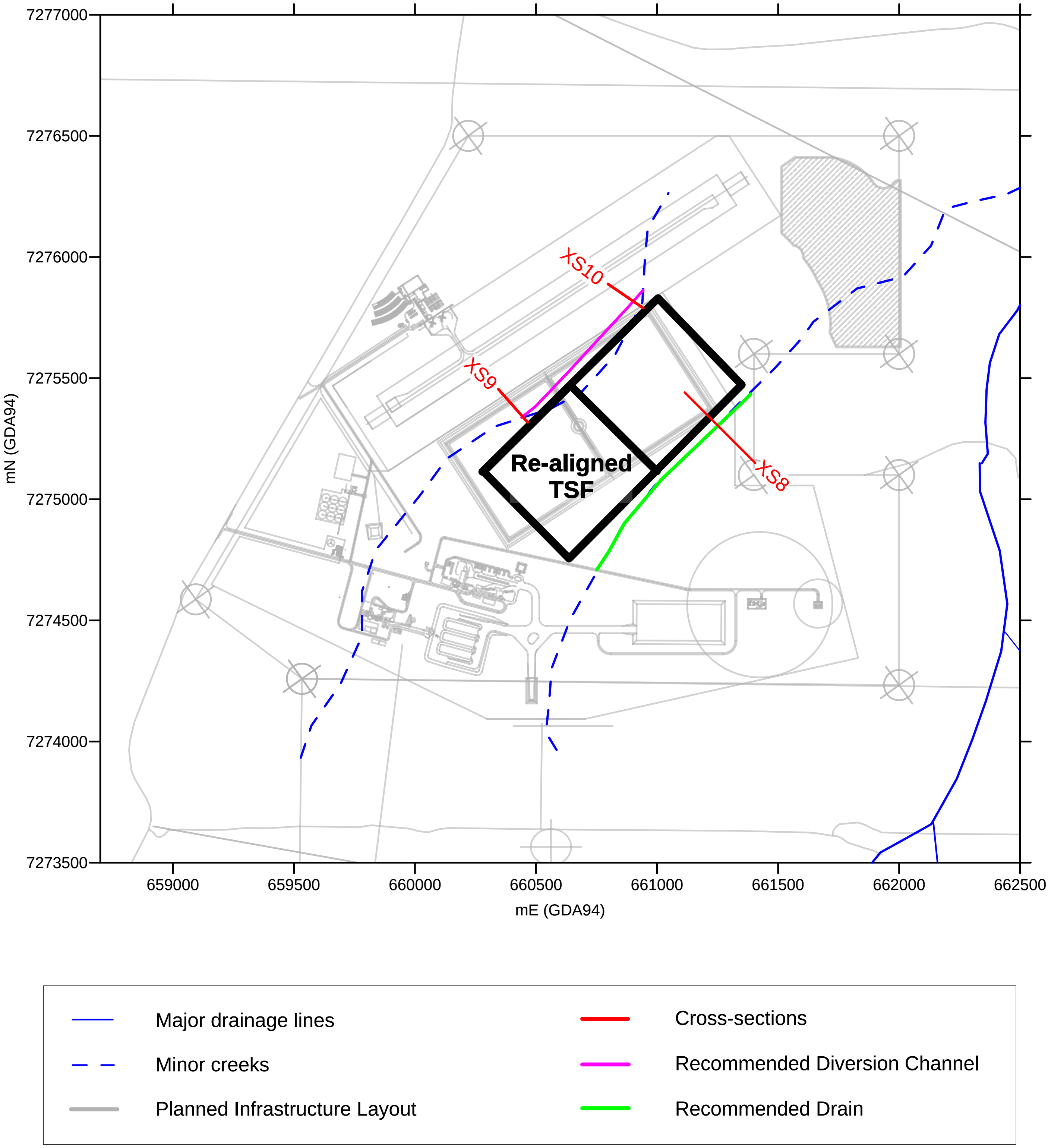


Major drainage lines
Minor creeks
1 m topographic contours
Catchment C
Catchment D
Catchment E
Infrastructure Layout
Cross-sections

minor catchments.srf

CLIENT: Galena Mining PROJECT: Abra Silver-lead Deposit DATE: September 2018 Dwg No: 496-0/18/2-3	LAYOUT PLAN & MINOR CATCHMENTS Rockwater PROPRIETARY LIMITED

FIGURE 4



Protective measures.srf

CLIENT: Galena Mining

PROJECT: Abra Silver-lead Deposit

DATE: September 2018

Dwg No: 496-0/18/2-4

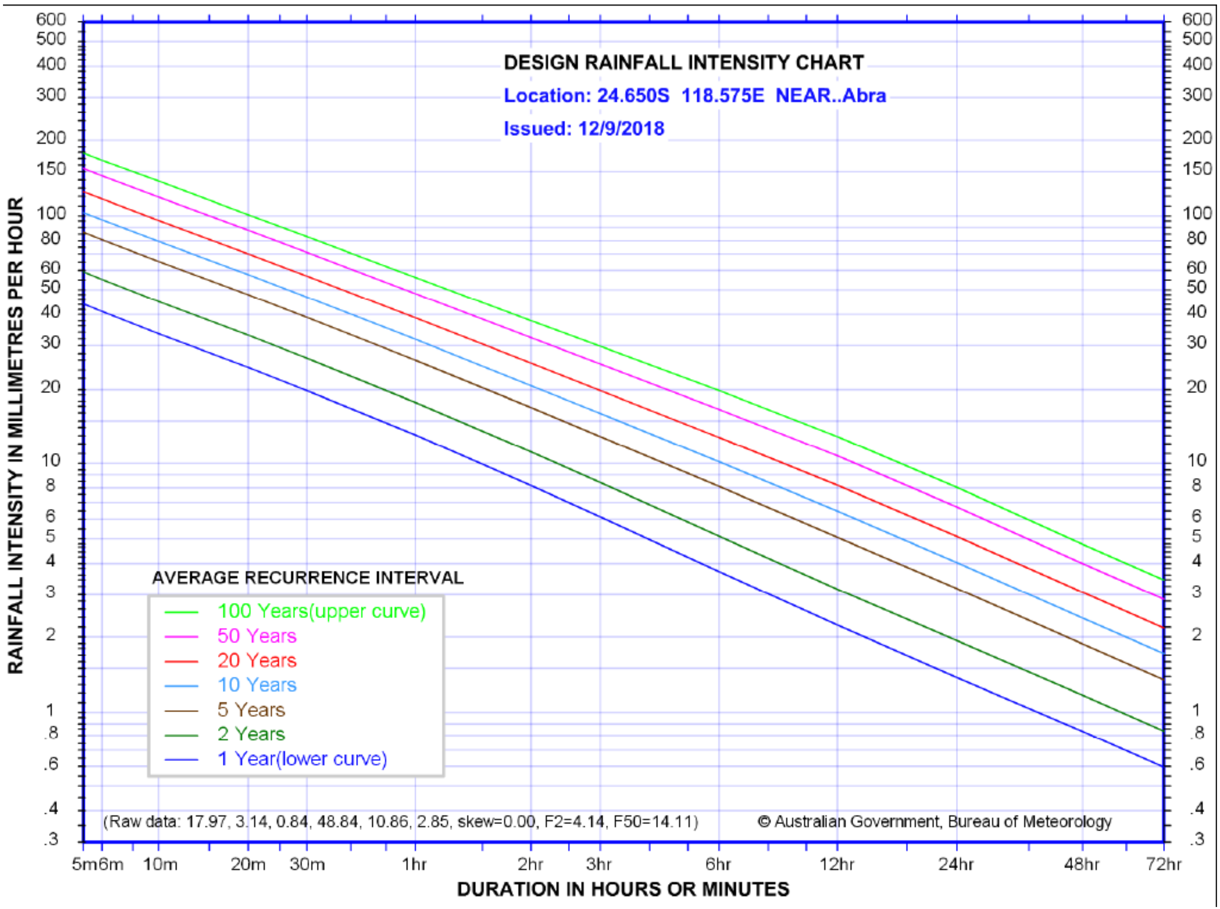
PROTECTIVE MEASURES

Rockwater PROPRIETARY LIMITED

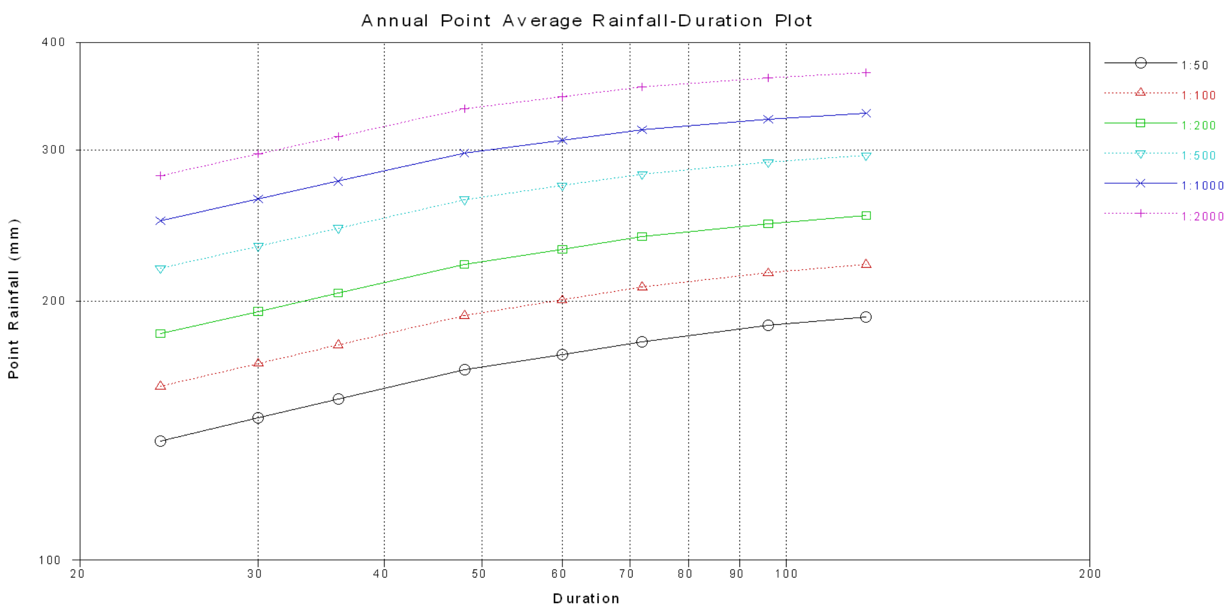
APPENDIX A: HYDROLOGY CHARTS AND CALCULATIONS

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

IFD Curves:



CRC Forge Results:



AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **PILBARA**

LOCATION: Abra

CATCHMENT: A

Pilbara Region

Catchment Characteristics	A (km^2)	L (km)	S_e (m/km)	P (mm)
	40.5	7.6	6	269

RATIONAL METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	40.5	-	7980	km^2
L =	10	-	194	km
S_e =	1.43	-	3.77	m/km
P =	230	-	400	mm

$Q_Y = 0.278 C_Y . I_{tc,Y} . A$ ………… **(1.1)**

$t_c = 0.56A^{0.38}$ ………… **(1.29)**

$t_c =$ 2.29 Hrs

$C_2 = 3.07\text{x}10^{-1}L^{-0.20}$ ………… **(1.30)**

$C_2 =$ 0.205

Frequency Factors (C_Y/C_{10})

	ARI (years)					
	2	5	10	20	50	*100*
C_Y/C_2	1.00	1.46	2.21	3.60	5.20	*7.76*

100 year ARI extrapolated using the logarithmic trend-line

Therefore:

	ARI (years)					
	2	5	10	20	50	100
C_Y	0.20	0.30	0.45	0.74	1.06	1.59

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **PILBARA**

LOCATION: Abra

CATCHMENT: A

RATIONAL METHOD:
CONTINUES

DETERMINE AVERAGE RAINFALL INTENSITY FOR DESIGN DURATION

t_c = 2.29 hours

Use IFD curves

Duration	ARI (Years) [mm/hr]					
(hours)	2	5	10	20	50	100
2.29	10.4	15.7	19.3	23.8	30.2	35.4

Calculate peak discharge using equation (1.1)

Discharge	ARI (Years)					
(m^3/s)	2	5	10	20	50	100
Q	23.9	52.8	98.2	197.3	361.8	633.3

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **PILBARA**

LOCATION: Abra

CATCHMENT: A

INDEX FLOOD METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	40.5	-	49600	km^2
L =	10	-	498	km
S_e =	0.88	-	3.77	m/km
P =	230	-	400	mm

$Q_5 = 6.73 \times 10^{-4} A^{0.72} P^{1.51}$ .... **(1.31)**

Q_5 = 45.1 m^3/s

Frequency Factors (Q_Y/Q_5) interpolated for Catchment A

	ARI (years)					
40.5 km^2	2	5	10	20	50	*100*
Q_Y/Q_5	0.51	1.00	1.77	3.02	5.69	*8.97*

100 year ARI extrapolated using the power trend-line

Therefore the peak discharge

Discharge	ARI (Years)					
(m^3/s)	2	5	10	20	50	100
Q	22.99	45.11	79.65	136.38	256.59	404.80

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **PILBARA**

LOCATION: Abra

CATCHMENT: A

SUMMARY OF RATIONAL AND INDEX METHODS:

Pilbara Region

Catchment A	ARI (years) / Discharge (m^3/s)						
Method:	2	5	10	20	50	100	PMF*
Rational	23.88	52.81	98.22	197.32	361.81	633.25	
Index	22.99	45.11	79.65	136.38	256.59	404.80	
Adopted (average)	**23.43**	**48.96**	**88.93**	**166.85**	**309.20**	**519.03**	**894.55**

*PMF estimated using multiplying factors from CRC-FORGE results

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **PILBARA**

LOCATION: Abra

CATCHMENT: B

Pilbara Region

	A (km^2)	L (km)	S_e (m/km)	P (mm)
Catchment Characteristics	5.5	4.0	7	269

RATIONAL METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	40.5	-	7980	km^2
L =	10	-	194	km
S_e =	1.43	-	3.77	m/km
P =	230	-	400	mm

$Q_Y = 0.278C_Y.I_{tc,Y}.A$ ………… **(1.1)**

$t_c = 0.56A^{0.38}$ ………… **(1.29)**

$t_c =$ 1.07 Hrs

$C_2 = 3.07\times10^{-1}L^{-0.20}$ ………… **(1.30)**

$C_2 =$ 0.233

Frequency Factors (C_Y/C_2)

	ARI (years)					
	2	5	10	20	50	*100*
C_Y/C_2	1.00	1.46	2.21	3.60	5.20	*7.76*

100 year ARI extrapolated using the logarithmic trend-line

Therefore:

	ARI (years)					
	2	5	10	20	50	100
C_Y	0.23	0.34	0.51	0.84	1.21	1.81

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **PILBARA**

LOCATION: Abra

CATCHMENT: B

RATIONAL METHOD:
CONTINUES

DETERMINE AVERAGE RAINFALL INTENSITY FOR DESIGN DURATION

t_c = 1.07 hours

Use IFD curves

Duration (hours)	ARI (Years) [mm/hr]					
	2	5	10	20	50	100
1.07	17.7	26.2	31.8	38.8	48.6	56.5

Calculate peak discharge using equation (1.1)

Discharge (m^3/s)	ARI (Years)					
	2	5	10	20	50	100
Q	6.30	13.61	25.00	49.69	89.90	156.06

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **PILBARA**

LOCATION: Abra

CATCHMENT: B

INDEX FLOOD METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	40.5	-	49600	km^2
L =	10	-	498	km
S_e =	0.88	-	3.77	m/km
P =	230	-	400	mm

$Q_5 = 6.73 \times 10^{-4} A^{0.72} P^{1.51}$ .... **(1.31)**

$Q_5 =$ 10.7 m^3/s

Frequency Factors (Q_Y/Q_5) interpolated for Catchment A

	ARI (years)					
5.5 km^2	2	5	10	20	50	*100*
Q_Y/Q_5	0.53	1.00	1.66	2.67	4.64	7.72

100 year ARI extrapolated using the power trend-line

Therefore the peak discharge

Discharge	ARI (Years)					
(m^3/s)	2	5	10	20	50	100
Q	5.67	10.72	17.83	28.61	49.75	96.15

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **PILBARA**

LOCATION: Abra

CATCHMENT: B

SUMMARY OF RATIONAL AND INDEX METHODS:

Pilbara Region

Catchment B	ARI (years) / Discharge (m^3/s)						
Method:	2	5	10	20	50	100	PMF*
Rational	6.30	13.61	25.00	49.69	89.90	156.06	
Index	5.67	10.72	17.83	28.61	49.75	82.71	
Adopted (average)	**5.98**	**12.16**	**21.42**	**39.15**	**69.82**	**119.38**	**205.76**

*PMF estimated using multiplying factors from CRC-FORGE results

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **PILBARA**

LOCATION: Abra

CATCHMENT: C

Pilbara Region

	A (km^2)	L (km)	S_e (m/km)	P (mm)
Catchment Characteristics	0.123	0.71	39	269

RATIONAL METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	40.5	-	7980	km^2
L =	10	-	194	km
S_e =	1.43	-	3.77	m/km
P =	230	-	400	mm

$Q_Y = 0.278 C_Y . I_{tc,Y} . A$ ………… **(1.1)**

$t_c = 0.56 A^{0.38}$ ………… **(1.29)**

$t_c =$ 0.25 Hrs

$C_2 = 3.07 \times 10^{-1} L^{-0.20}$ ………… **(1.30)**

$C_2 =$ 0.329

Frequency Factors (C_Y/C_{10})

	ARI (years)					
	2	5	10	20	50	*100*
C_Y/C_2	1.00	1.46	2.21	3.60	5.20	*7.76*

100 year ARI extrapolated using the logarithmic trend-line

Therefore:

	ARI (years)					
	2	5	10	20	50	100
C_Y	0.33	0.48	0.73	1.18	1.71	2.55

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **PILBARA**

LOCATION: Abra

CATCHMENT: C

RATIONAL METHOD:
CONTINUES

DETERMINE AVERAGE RAINFALL INTENSITY FOR DESIGN DURATION

t_c = 0.25 hours

Use IFD curves

Duration	ARI (Years) [mm/hr]					
(hours)	2	5	10	20	50	100
0.25	36.2	53.0	63.9	77.8	97.0	112.3

Calculate peak discharge using equation (1.1)

Discharge	ARI (Years)					
(m^3/s)	2	5	10	20	50	100
Q	0.41	0.87	1.59	3.15	5.67	9.80

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **PILBARA**

LOCATION: Abra

CATCHMENT: C

INDEX FLOOD METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	40.5	-	49600	km^2
L =	10	-	498	km
S_e =	0.88	-	3.77	m/km
P =	230	-	400	mm

$Q_5 = 6.73x10^{-4} A^{0.72} P^{1.51}$ .... **(1.31)**

Q_5 = 0.69 m^3/s

Frequency Factors (Q_Y/Q_5) interpolated for Catchment C

	ARI (years)					
0.123 km^2	2	5	10	20	50	*100*
Q_Y/Q_5	0.57	1.00	1.49	2.11	3.15	*4.83*

100 year ARI extrapolated using the power trend-line

Therefore the peak discharge

Discharge	ARI (Years)					
(m^3/s)	2	5	10	20	50	100
Q	0.40	0.69	1.03	1.46	2.19	3.35

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **PILBARA**

LOCATION: Abra

CATCHMENT: C

SUMMARY OF RATIONAL AND INDEX METHODS:

Pilbara Region

Catchment C	ARI (years) / Discharge (m^3/s)						
Method:	2	5	10	20	50	100	PMF*
Rational	0.41	0.87	1.59	3.15	5.67	9.80	
Index	0.40	0.69	1.03	1.46	2.19	3.35	
Adopted (average)	**0.40**	**0.78**	**1.31**	**2.31**	**3.93**	**6.58**	**11.33**

*PMF estimated using multiplying factors from CRC-FORGE results

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **PILBARA**

LOCATION: Abra

CATCHMENT: D

Pilbara Region

Catchment Characteristics	A (km^2)	L (km)	S_e (m/km)	P (mm)
	0.744	1.50	27	269

RATIONAL METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	40.5	-	7980	km^2
L =	10	-	194	km
S_e =	1.43	-	3.77	m/km
P =	230	-	400	mm

$Q_Y = 0.278 C_Y . I_{tc,Y} . A$ .... **(1.1)**

$t_c = 0.56 A^{0.38}$ .... **(1.29)**

$t_c =$ 0.50 Hrs

$C_2 = 3.07 \times 10^{-1} L^{-0.20}$ .... **(1.30)**

$C_2 =$ 0.283

Frequency Factors (C_Y/C_{10})

	ARI (years)					
	2	5	10	20	50	*100*
C_Y/C_2	1.00	1.46	2.21	3.60	5.20	*7.76*

100 year ARI extrapolated using the logarithmic trend-line

Therefore:

	ARI (years)					
	2	5	10	20	50	100
C_Y	0.28	0.41	0.63	1.02	1.47	2.20

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **PILBARA**

LOCATION: Abra

CATCHMENT: D

RATIONAL METHOD:
CONTINUES

DETERMINE AVERAGE RAINFALL INTENSITY FOR DESIGN DURATION

t_c = 0.50 hours

Use IFD curves

Duration	ARI (Years) [mm/hr]					
(hours)	2	5	10	20	50	100
0.50	23.4	34.7	42.2	51.7	64.9	75.5

Calculate peak discharge using equation (1.1)

Discharge	ARI (Years)					
(m^3/s)	2	5	10	20	50	100
Q	1.37	2.97	5.46	10.90	19.76	34.31

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **PILBARA**

LOCATION: Abra

CATCHMENT: D

INDEX FLOOD METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	40.5	-	49600	km^2
L =	10	-	498	km
S_e =	0.88	-	3.77	m/km
P =	230	-	400	mm

$Q_5 = 6.73 \times 10^{-4} A^{0.72} P^{1.51}$ .... **(1.31)**

$Q_5 =$ 2.54 m^3/s

Frequency Factors (Q_Y/Q_5) interpolated for Catchment D

	ARI (years)					
0.744 km^2	2	5	10	20	50	*100*
Q_Y/Q_5	0.55	1.00	1.57	2.36	3.79	*6.02*

100 year ARI extrapolated using the power trend-line

Therefore the peak discharge

Discharge	ARI (Years)					
(m^3/s)	2	5	10	20	50	100
Q	1.40	2.54	3.98	5.98	9.61	15.29

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **PILBARA**

LOCATION: Abra

CATCHMENT: D

SUMMARY OF RATIONAL AND INDEX METHODS:

Pilbara Region

Catchment D	ARI (years) / Discharge (m³/s)						
Method:	2	5	10	20	50	100	PMF*
Rational	1.37	2.97	5.46	10.90	19.76	34.31	
Index	1.40	2.54	3.98	5.98	9.61	15.29	
Adopted (average)	**1.38**	**2.75**	**4.72**	**8.44**	**14.68**	**24.80**	**42.74**

*PMF estimated using multiplying factors from CRC-FORGE results

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **PILBARA**

LOCATION: Abra

CATCHMENT: E

Pilbara Region

	A	L	S_e	P
Catchment	(km^2)	(km)	(m/km)	(mm)
Characteristics	1.17	2.10	13	269

RATIONAL METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	40.5	-	7980	km^2
L =	10	-	194	km
S_e =	1.43	-	3.77	m/km
P =	230	-	400	mm

$Q_Y = 0.278C_Y.I_{tc,Y}.A$ ………… **(1.1)**

$t_c = 0.56A^{0.38}$ ………… **(1.29)**

$t_c =$ 0.59 Hrs

$C_2 = 3.07 \times 10^{-1} L^{-0.20}$ ………… **(1.30)**

$C_2 =$ 0.265

Frequency Factors (C_Y/C_{10})

	ARI (years)					
	2	5	10	20	50	*100*
C_Y/C_2	1.00	1.46	2.21	3.60	5.20	*7.76*

100 year ARI extrapolated using the logarithmic trend-line

Therefore:

	ARI (years)					
	2	5	10	20	50	100
C_Y	0.26	0.39	0.58	0.95	1.38	2.05

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **PILBARA**

LOCATION: Abra

CATCHMENT: E

RATIONAL METHOD:
CONTINUES

DETERMINE AVERAGE RAINFALL INTENSITY FOR DESIGN DURATION

t_c = 0.59 hours

Use IFD curves

Duration	ARI (Years) [mm/hr]					
(hours)	2	5	10	20	50	100
0.59	21.0	31.2	38.1	46.6	58.6	68.3

Calculate peak discharge using equation (1.1)

Discharge	ARI (Years)					
(m^3/s)	2	5	10	20	50	100
Q	1.8	3.9	7.2	14.5	26.3	45.6

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **PILBARA**

LOCATION: Abra

CATCHMENT: E

INDEX FLOOD METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	40.5	-	49600	km^2
L =	10	-	498	km
S_e =	0.88	-	3.77	m/km
P =	230	-	400	mm

$Q_5 = 6.73 x 10^{-4} A^{0.72} P^{1.51}$ .... **(1.31)**

$Q_5 =$ 3.52 m^3/s

Frequency Factors (Q_Y/Q_5) interpolated for Catchment E

	ARI (years)					
1.17 km^2	2	5	10	20	50	*100*
Q_Y/Q_5	0.55	1.00	1.59	2.42	3.97	*6.37*

100 year ARI extrapolated using the power trend-line

Therefore the peak discharge

Discharge	ARI (Years)					
(m^3/s)	2	5	10	20	50	100
Q	1.92	3.52	5.59	8.53	13.95	22.40

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **PILBARA**

LOCATION: Abra

CATCHMENT: E

SUMMARY OF RATIONAL AND INDEX METHODS:

Pilbara Region

Catchment E	ARI (years) / Discharge (m³/s)						
Method:	2	5	10	20	50	100	PMF*
Rational	1.81	3.93	7.24	14.46	26.25	45.64	
Index	1.92	3.52	5.59	8.53	13.95	22.40	
Adopted	**1.86**	**3.72**	**6.41**	**11.49**	**20.10**	**34.02**	**58.63**

*PMF estimated using multiplying factors from CRC-FORGE results

APPENDIX B: HYDRAULIC ANALYSES

Manning's Formula: $$Q = \frac{1}{n}\left(\frac{A}{P}\right)^{2/3} S^{1/2}$$

Cross-section 1 (Catchment B)

Stage	Top Length (m)	A (m2)	P (m)	Manning's n	Slope (m/m)	V (m/s)	Q (m3/s)
537.4	0.0	0.0	0.0	0.06	0.0058	0.00	0.0
538.0	113.6	45.4	113.6	0.06	0.0058	0.69	31.3
538.1	126.2	57.8	126.2	0.06	0.0058	0.75	43.6
538.2	130.4	71.0	130.4	0.06	0.0058	0.85	60.1
538.3	138.8	84.9	138.8	0.06	0.0058	0.92	77.7
538.4	147.2	99.7	147.2	0.06	0.0058	0.98	97.7
538.5	159.8	116.0	159.9	0.06	0.0058	1.03	119.1
538.6	168.2	132.6	168.3	0.06	0.0058	1.08	143.9
538.7	176.7	150.2	176.7	0.06	0.0058	1.14	171.2
538.8	185.1	168.5	185.1	0.06	0.0058	1.19	201.2
538.9	193.5	187.7	193.5	0.06	0.0058	1.25	233.8
539.0	201.9	207.8	201.9	0.06	0.0058	1.30	269.2

Cross-section 2 (Catchment B)

Stage	Top Length (m)	A (m2)	P (m)	Manning's n	Slope (m/m)	V (m/s)	Q (m3/s)
533.5	0.0	0.0	0.0	0.06	0.0065	0.00	0.0
534.0	56.0	19.2	56.0	0.06	0.0065	0.66	12.7
534.5	82.1	55.3	82.2	0.06	0.0065	1.03	57.1
535.0	209.1	127.7	209.1	0.06	0.0065	0.97	123.5
535.1	216.5	149.2	216.6	0.06	0.0065	1.05	156.4
535.2	220.3	170.7	220.3	0.06	0.0065	1.13	193.4
535.3	224.0	193.7	224.1	0.06	0.0065	1.22	236.1
535.4	231.5	217.2	231.5	0.06	0.0065	1.29	279.5
535.5	238.9	241.2	239.0	0.06	0.0065	1.35	326.0

Cross-section 3 (Catchment A)

Stage	Top Length (m)	A (m2)	P (m)	Manning's n	Slope (m/m)	V (m/s)	Q (m3/s)
524.7	0.0	0.0	0.0	0.06	0.0025	0.00	0.0
525.0	25.4	6.0	25.4	0.06	0.0025	0.32	1.9
526.0	63.5	57.4	63.5	0.06	0.0025	0.78	44.8
526.5	88.9	98.8	88.9	0.06	0.0025	0.89	88.3
527.0	101.6	147.3	101.7	0.06	0.0025	1.07	157.1
527.5	120.6	207.7	120.7	0.06	0.0025	1.20	248.5
528.0	133.3	273.5	133.4	0.06	0.0025	1.34	367.8
528.5	152.3	351.0	152.5	0.06	0.0025	1.45	509.8
528.6	158.7	365.2	158.9	0.06	0.0025	1.45	530.0
528.7	158.7	381.0	158.9	0.06	0.0025	1.49	568.9
528.8	165.0	400.5	165.2	0.06	0.0025	1.50	602.2
528.9	165.0	417.0	165.2	0.06	0.0025	1.54	644.1
529.0	171.4	432.4	171.6	0.06	0.0025	1.54	667.3
529.1	177.7	453.0	177.9	0.06	0.0025	1.55	703.8
529.2	177.7	470.8	177.9	0.06	0.0025	1.59	750.4
529.3	177.7	488.5	177.9	0.06	0.0025	1.63	798.2
529.4	190.4	508.7	190.7	0.06	0.0025	1.60	815.4
529.5	190.4	527.7	190.7	0.06	0.0025	1.64	866.9
529.6	190.4	546.8	190.7	0.06	0.0025	1.68	919.6
529.7	190.4	565.8	190.7	0.06	0.0025	1.72	973.6

Cross-section 4 (Catchment A)

Stage	Top Length (m)	A (m2)	P (m)	Manning's n	Slope (m/m)	V (m/s)	Q (m3/s)
523.4	0.0	0.0	0.0	0.06	0.0038	0.00	0.0
524.0	81.3	31.7	81.3	0.06	0.0038	0.55	17.3
524.5	119.0	83.4	119.0	0.06	0.0038	0.80	67.1
525.0	153.8	153.0	153.9	0.06	0.0038	1.02	155.6
525.5	188.7	240.0	188.7	0.06	0.0038	1.20	287.6
526.0	220.6	344.6	220.7	0.06	0.0038	1.37	473.4
526.1	229.3	367.8	229.4	0.06	0.0038	1.40	514.3
526.2	238.0	391.2	238.1	0.06	0.0038	1.42	556.0
526.3	243.8	415.4	243.9	0.06	0.0038	1.46	604.6
526.4	249.6	440.2	249.7	0.06	0.0038	1.49	655.6
526.5	255.4	465.6	255.5	0.06	0.0038	1.52	709.0
526.6	261.2	491.6	261.3	0.06	0.0038	1.56	764.7
526.7	267.0	518.3	267.1	0.06	0.0038	1.59	822.8
526.8	272.8	545.5	272.9	0.06	0.0038	1.62	883.4
526.9	278.6	573.3	278.7	0.06	0.0038	1.65	946.4
527.0	284.4	601.8	284.5	0.06	0.0038	1.68	1011.9

Cross-section 5 (Catchment C)

Stage	Top Length (m)	A (m2)	P (m)	Manning's n	Slope (m/m)	V (m/s)	Q (m3/s)
550.9	0.0	0.0	0.0	0.06	0.039	0.00	0.0
551.0	39.2	1.7	39.2	0.06	0.039	0.40	0.7
551.1	61.1	6.9	61.1	0.06	0.039	0.77	5.3
551.2	79.9	14.2	79.9	0.06	0.039	1.04	14.8
551.3	95.5	23.2	95.5	0.06	0.039	1.28	29.7
551.4	109.6	33.7	109.6	0.06	0.039	1.50	50.5

Cross-section 6 (Catchment D)

Stage	Top Length (m)	A (m2)	P (m)	Manning's n	Slope (m/m)	V (m/s)	Q (m3/s)
537.67	0.0	0.0	0.0	0.06	0.0273	0.00	0.0
537.7	32.6	0.8	32.6	0.06	0.0273	0.22	0.2
537.8	75.0	6.4	75.0	0.06	0.0273	0.54	3.4
537.9	115.8	16.1	115.8	0.06	0.0273	0.74	11.9
538.0	166.3	30.3	166.3	0.06	0.0273	0.88	26.8
538.1	220.1	49.7	220.1	0.06	0.0273	1.02	50.8
538.2	277.2	74.7	277.2	0.06	0.0273	1.15	85.8

Cross-section 7 (Catchment E)

Stage	Top Length (m)	A (m2)	P (m)	Manning's n	Slope (m/m)	V (m/s)	Q (m3/s)
532.18	0.0	0.0	0.0	0.06	0.020	0.00	0.0
532.2	82.1	1.0	82.1	0.06	0.020	0.12	0.1
532.3	251.5	18.8	251.5	0.06	0.020	0.42	7.8
532.4	344.1	49.2	344.1	0.06	0.020	0.64	31.7
532.5	423.6	87.7	423.6	0.06	0.020	0.83	72.4

Cross-section 8 (Catchment E)

In drain							
Stage	Top Length (m)	A (m2)	P (m)	Manning's n	Slope (m/m)	V (m/s)	Q (m3/s)
531.18	0.0	0.0	0.0	0.02	0.020	0.00	0.0
531.2	3.0	0.1	3.0	0.02	0.020	0.49	0.0
531.3	3.4	0.4	3.4	0.02	0.020	1.63	0.6
531.4	3.8	0.7	3.9	0.02	0.020	2.36	1.8
531.5	4.2	1.2	4.3	0.02	0.020	2.93	3.4
531.6	4.6	1.6	4.8	0.02	0.020	3.41	5.5
531.7	5.0	2.1	5.2	0.02	0.020	3.83	8.0
531.8	5.4	2.6	5.7	0.02	0.020	4.22	11.0
531.9	5.8	3.2	6.1	0.02	0.020	4.57	14.6
532.0	6.2	3.8	6.6	0.02	0.020	4.90	18.6
532.1	6.6	4.4	7.0	0.02	0.020	5.21	23.1
532.18	6.9	5.0	7.4	0.02	0.020	5.45	27.2

Above drain				
Stage	Conveyance K	Manning's n	Channel slope (m/m)	Q (m3/s)
532.185	239.8	0.06	0.020	33.9
532.19	321.8	0.06	0.020	45.5
532.195	398.8	0.06	0.020	56.4
532.20	472.0	0.06	0.020	66.7

Cross-section 9 (Catchment D)

In drain							
Stage	**Top Length (m)**	**A (m2)**	**P (m)**	**Manning's n**	**Slope (m/m)**	**V (m/s)**	**Q (m3/s)**
533.96	0.0	0.0	0.0	0.02	0.010	0.00	0.0
534.0	3.1	0.1	3.1	0.02	0.010	0.55	0.1
534.1	3.5	0.4	3.6	0.02	0.010	1.27	0.6
534.2	3.9	0.8	4.0	0.02	0.010	1.77	1.4
534.3	4.3	1.2	4.5	0.02	0.010	2.17	2.7
534.4	4.7	1.7	4.9	0.02	0.010	2.51	4.2
534.5	5.1	2.2	5.3	0.02	0.010	2.81	6.1
534.6	5.5	2.7	5.8	0.02	0.010	3.08	8.4
534.7	5.9	3.3	6.2	0.02	0.010	3.33	11.0
534.8	6.3	3.9	6.7	0.02	0.010	3.56	13.9
534.9	6.7	4.6	7.1	0.02	0.010	3.78	17.3
534.96	6.9	5.0	7.4	0.02	0.010	3.93	19.5

Above drain				
Stage	**Conveyance K**	**Manning's n**	**Channel slope (m/m)**	**Q (m3/s)**
534.965	229.2	0.06	0.010	23.4
534.97	303.9	0.06	0.010	31.0
534.98	429.8	0.06	0.010	43.9
534.99	529.7	0.06	0.010	54.1
535.00	615.4	0.06	0.010	62.8
535.10	1352.6	0.06	0.010	138.1

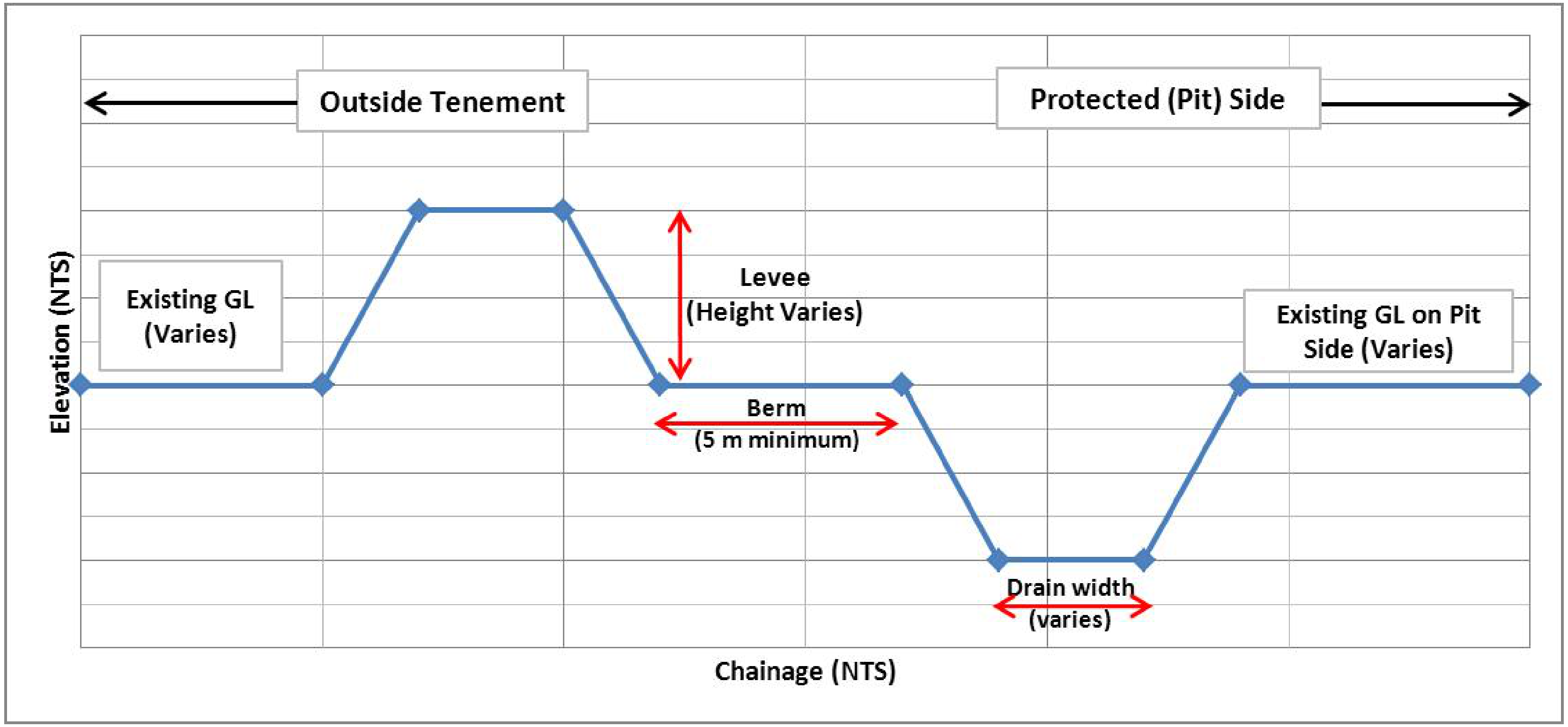
Cross-section 10 (Catchment D)

In drain							
Stage	**Top Length (m)**	**A (m2)**	**P (m)**	**Manning's n**	**Slope (m/m)**	**V (m/s)**	**Q (m3/s)**
528.48	0.0	0.0	0.0	0.02	0.010	0.00	0.0
528.5	3.0	0.0	3.0	0.02	0.010	0.21	0.0
528.6	3.4	0.3	3.4	0.02	0.010	1.11	0.4
528.7	3.8	0.7	3.9	0.02	0.010	1.64	1.2
528.8	4.2	1.1	4.3	0.02	0.010	2.06	2.3
528.9	4.6	1.6	4.8	0.02	0.010	2.41	3.8
529.0	5.0	2.0	5.2	0.02	0.010	2.72	5.6
529.1	5.4	2.6	5.7	0.02	0.010	3.00	7.7
529.2	5.8	3.1	6.1	0.02	0.010	3.26	10.2
529.3	6.2	3.7	6.6	0.02	0.010	3.50	13.1
529.4	6.6	4.4	7.0	0.02	0.010	3.72	16.3
529.48	6.9	4.9	7.4	0.02	0.010	3.91	19.3

Above drain				
Stage	**Conveyance K**	**Manning's n**	**Channel slope (m/m)**	**Q (m3/s)**
529.5	227.1	0.06	0.010	23.2
529.52	306.7	0.06	0.010	31.3
529.56	522.4	0.06	0.010	53.3
529.60	757.5	0.06	0.010	77.3
529.70	1268.4	0.06	0.010	129.5

APPENDIX C: CROSS-SECTION OF A TYPICAL DIVERSION CHANNEL

Appendix C



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CLIENT: Galena Mining

PROJECT: Abra Silver-lead Deposit

DATE: September 2018

DWG NO: 496-0/18-02/App C

Typical Cross-Section Drain/Levee System

Rockwater PROPRIETARY LIMITED

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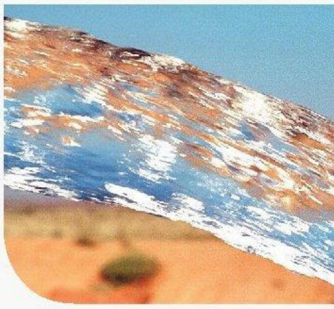
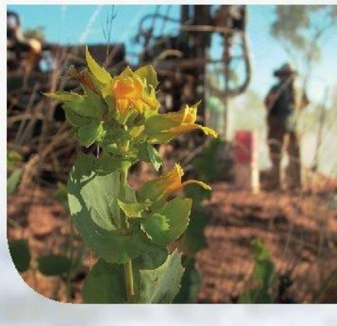
ABRA LEAD-SILVER PROJECT

HYDROLOGY AND SURFACE-WATER ASSESSMENT ADDENDUM



REPORT FOR
GALENA MINING LTD



FEBRUARY 2019

Report No. 496-0/19/01

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REVISION	AUTHOR	REVIEW	AUTHORISED	ISSUED
0	CC/PHW	JG		11/2/19

1. INTRODUCTION

Galena Mining Ltd is conducting a pre-feasibility study for mining its Abra lead-silver deposit, located 200 km north of Meekatharra in the Jillawarra sub-basin of the Proterozoic Edmund Basin. The project lies on a south-east facing slope. There are two major drainage lines about 200 m south and 400 m east of the project. Also, some of the project's planned infrastructure intersects or lies between two small creeks.

Rockwater Pty Ltd was commissioned by Galena Mining Ltd to prepare a surface water management plan to assess the potential impact of flood flows on surface infrastructure and to determine the bunding and drainage requirements. The results were presented in a report (Rockwater, 2018).

The Tangadee Road crosses a major tributary of the Ethel River (5 Mile Creek), 4 km north-east of the Abra Deposit (Fig. 1). The road will be used as the main access to the air-strip, and so Rockwater was asked to investigate the hydrology and hydraulics of the creek at the road crossing, and to make recommendations for construction of the crossing to maintain trafficability after rainfalls. This Addendum to the 2018 surface water management plan presents the results of the investigation, and should be read in conjunction with that report (Rockwater, 2018).

2. SURFACE WATER HYDROLOGY

2.1. RAINFALL ANALYSIS

Intensity-Frequency-Duration (IFD) curves for the Abra site and the rainfall analysis are given in the main report (Rockwater, 2018). The nearest Bureau of Meteorology (BoM) station is Tangadee (Stn. 007179), located 45 km east-north-east of Abra. Annual Rainfall (1960 to 2018) averages 269 mm.

2.2. CATCHMENT DETAILS

The catchment area for the road crossing (Catchment A) is shown in Fig. 1, and covers an area of 47.8 km^2. Details of the catchment used in the hydrological calculations are as follows:

Catchment Area	47.8 km^2
Catchment Length	10 km
Time of Concentration	2.43 hours
Average annual rainfall	269 mm

2.3. PEAK FLOW ESTIMATION

Two methods recommended in n the Australian Rainfall and Runoff 1987 (AR&R, 1987) Guideline and later versions were used to estimate peak flows. The new 2016 peak flow estimation method gives unrealistic numbers and so was not used.

2.3.1. RATIONAL METHOD

The Statistical Rational Method, used in peak-flow estimation, is presented in Equation 1.

$$Q_y = 0.278 \cdot C_y \cdot I_{tcy} \cdot A$$ **Equation 1**

Where:

Q_y is the peak flow for return period of y years (m^3/s)
0.278 is a dimensionless metric conversion factor
C_y is the runoff coefficient for y years (dimensionless)
I_{tcy} is rainfall intensity (mm/hr)
A is catchment area (km^2)

2.3.2. FLOOD INDEX METHOD

The Flood Index Method for the Pilbara Region, also used in peak-flow estimation, is presented in Equation 2.

$$Q_5 = 6.73 \times 10^{-4} \cdot \mathrm{A}^{0.72} \cdot \mathrm{P}^{1.51}$$ **Equation 2**

Where:

Q_5 is the peak discharge for the 5-year ARI flow (m^3/s)
A is the catchment area (km^2)
P is the average annual rainfall (mm)

2.3.3. DESIGN PEAK FLOWS

A summary of the design peak flows, as estimated using the Rational and Flood Index Methods, is shown in Table 1. The detailed calculations are presented in Appendix I.

Table 1: Estimated Peak Flows

Catchment A	ARI (years) / Discharge (m³/s)						
Method:	2	5	10	20	50	100	PMF*
Rational	22.03	49.20	92.12	186.03	342.62	601.62	
Index	25.83	50.83	90.18	155.26	294.02	512.75	
Adopted	**23.93**	**50.01**	**91.15**	**170.64**	**318.32**	**557.18**	**960.31**

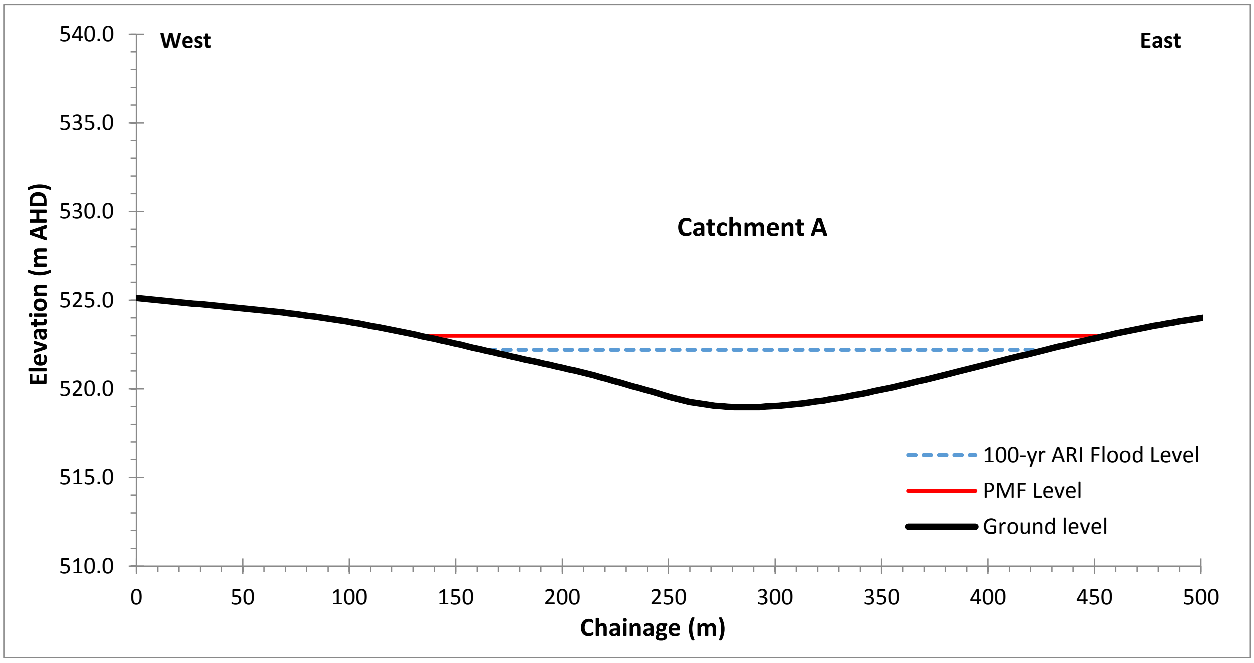
** PMF (probable maximum flood) estimated using multiplying factors from CRC-FORGE results*

3. HYDRAULIC ANALYSES

Hydraulic analyses were conducted to assess the depths, widths and velocities of flood and more-frequent flows at the creek crossing in order to recommend engineering requirements for the crossing. Stage-discharge and stage-velocity relationships were calculated using Manning's equation. The topographic contours along the creek include several "bullseyes" (Fig. 1) that either indicate local holes in the creek bed or errors in the data. These were ignored in the hydraulic analysis for which a constant bed gradient upstream and downstream of the cross-section was assumed.

The analyses indicate that in a 1-in-100 year flood, the peak flood levels at the crossing from Catchment A would be at about 522.2 m AHD with a width of about 263 m, and the level would be about 0.8 m higher in a Probable Maximum Flood (PMF) (Text-Figure 1).

Text-Figure 1: Cross Section with 100 year ARI flood level and PMF



The maximum depth of the 1-in-100 year flood would be about 3.2 m and the maximum velocity in the order of 1.1 m/s (Table 2).

Table 2: Cross-section at road crossing – 100-year ARI flood and PMF summary

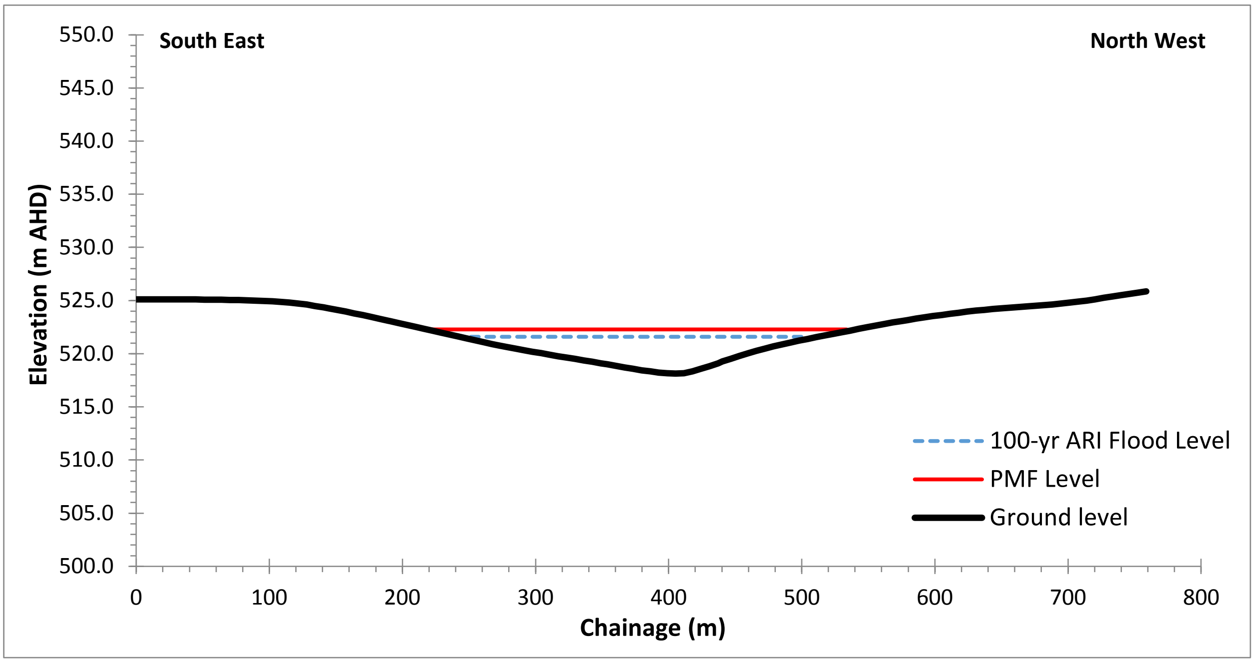
Flood Analysis	Flow (m^3/s)	Flood Level Elevation (m AHD)	Depth (m)	Velocity (m/s)	Extent of Flood Level (m)
100-yr	557	522.2	3.2	1.1	263
PMF	960	523.0	4.0	1.3	319

4. RECOMMENDED CROSSING DESIGN

4.1. EXISTING ROAD CONDITIONS

It is assumed that the existing road is an unformed un-sheeted road following the natural topographic contours as provided.

Text-Figure 2: Long-Section of the existing road at the creek crossing



With the existing road conditions, the road would be closed in every flood event for both light and heavy vehicles. The times of closure in different flood events are presented in Table 3.

Table 3: Closure periods of the existing road

Event	Q (m^3/s)	V (m/s)	Elevation (m AHD)	Depth (m)	Extent (m)	Time of closure (hrs) Light vehicles	Time of closure (hrs) Heavy vehicles
1-in-2 yr	24	0.5	519.0	0.9	80	7.1	5.7
1-in-5 yr	50	0.6	519.4	1.3	100	7.2	6.5
1-in-10 yr	91	0.7	519.8	1.7	140	7.2	6.9
1-in-20 yr	171	0.9	520.2	2.1	160	7.3	7.1
1-in-50 yr	318	1.0	520.9	2.8	210	7.3	7.2
1-in-100 yr	557	1.2	521.6	3.5	260	7.3	7.2

The existing road would operate as an open channel with a natural velocity in the order of 1.0 m/s. While severe scouring is not likely to occur, sediment transport of bedload could require some maintenance.

Depending on the desired serviceability, a floodway-culvert system will likely be required in order to keep the road passable in minor flood events and reduce the time of closure in major flood events. The suggested broad crested weir conceptual design is presented below.

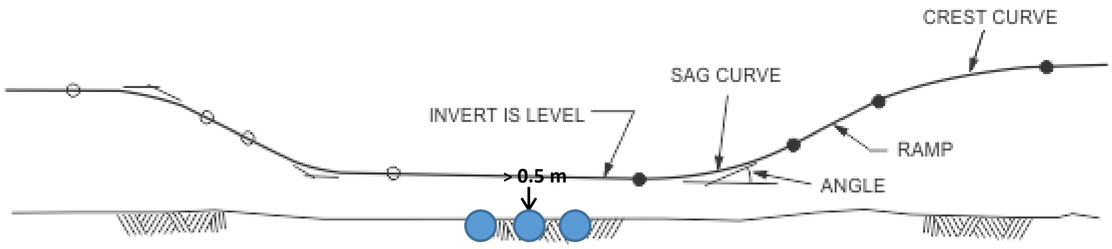
4.2. RECOMMENDATIONS - BROAD CRESTED WEIR

It is recommended that nominal concrete or corrugated steel culverts be installed to drain the normal annual minor flows in order to ensure no bogging at the road embankment and a raised floodway be constructed to pass the rare flood events.

The culverts should be at a minimum of 600mm diameter to avoid obstruction from sediment transportation. The number, size and locations of the culverts are to be decided on site.

The culverts should be placed at the lowest possible level. Also, a minimum of 0.5 m cover above the culverts is required in order to prevent the road-way from failing due to vertical tyre loading of heavy vehicles, as presented in Text-Figure 3 below.

Text-Figure 3: Typical long-section of a floodway (MRWA)



4.2.1. SERVICEABILITY

To be serviceable, the critical depth of the flood flow above the floodway should be no greater than 200 mm for light vehicles and 500 mm for heavy vehicles.

Considering these requirements, the length of the floodway permitting the road to be passable in case of peak flows were calculated using the broad crested weir capacity equation and are shown in Table 4. Note that in the calculations below, the discharge through the culverts is considered nominal and was ignored.

Table 4: Required floodway length for the road to be serviceable in major flood events

		Length of floodway for serviceability (m)	
Flood Event	**Q (m^3/s)**	**Light vehicles (i.e. depth of flow over road = 200mm)**	**Heavy vehicles (i.e. depth of flow over road = 500mm)**
1-in-2 year	24	85	22
1-in-5 year	50	178	45
1-in-10 year	91	324	82
1-in-20 year	171	607	154
1-in-50 year	318	1133	287
1-in-100 year	557	1983	502

4.2.2. CLOSURE PERIODS IN HIGH FLOOD FLOW

Two options are compared in Table 5 below:

- An 85 m length floodway that would allow the road to remain serviceable in the 1-in-2 year flood for light vehicles and the 1-in-10 year flood for heavy vehicles; and
- A 180 m length floodway that would allow light vehicles to cross the creek in the 1-in-5 year flood and heavy vehicles to cross it in the 1-in-20 year flood.

Note that it would probably be more cost-effective to lower the invert level of the floodway rather than shortening the length if the option of lower serviceability is preferred.

Table 5: Closure periods with the two options

Flood Event	Q (m^3/s)	Closure periods (hours) 85 length floodway		Closure periods (hours) 180 length floodway	
		Light vehicles	Heavy vehicles	Light vehicles	Heavy vehicles
1-in-2 year	24	NA	NA	NA	NA
1-in-5 year	50	3.8	NA	NA	NA
1-in-10 year	91	5.4	NA	3.3	NA
1-in-20 year	171	6.3	3.3	5.1	NA
1-in-50 year	318	6.8	5.1	6.1	2.7
1-in-100 year	557	7.0	6.1	6.6	4.7

With both options, the road is likely to be vulnerable to scouring damage in rare flood events and scour protections and/or a scour management plan are required.

4.3. SCOUR PROTECTION RECOMMENDATIONS

Given the low velocity of the 1-in-100 year ARI flow, it is recommended that the protection on the downstream shoulder and batter slope be graded rocks with a maximum diameter of 200-300 mm.

Depending on the planned operational duration of the Abra lead-silver deposit, the probability of actual closure and damage of the floodway should be balanced with the serviceability and cost requirements. Scour protections on the downstream shoulder and batter slope should be considered. However, the floodway could be left unprotected and scour damage during normal overtopping would require minor maintenance and major repair if the unlikely rare flood event occurs.

The risk of damage to the downstream shoulder can be reduced by rounding the shoulder as much as possible, to avoid the generation of negative pressures at the change of flow direction.

If a decision is made not to use scour protection (e.g. graded rocks) on the road, a plan needs to be put in place for a quick repair of the road after damage from scouring.

For information purposes, a typical floodway protection design, as recommended by MRWA for low velocity floods, is presented in Appendix C.

5. CONCLUSIONS

Flood flows from the catchment defined in Figure 1 are likely to be in the form of wide sheet flows. A floodway and nominal drainage culvert system type of waterway structure is probably the most effective way to keep the road passable in minor flood events, and to reduce the time of closure in major flood events. Rockwater recommends that the floodway be designed for a serviceability of 1-in-2 years ARI event.

In the 1-in-100 year ARI flood, the road is likely to be closed for about 7 hours. Residual flow following a flood event could persist for a few days. The risk of scour damage to the road should be taken into considerations in subsequent detailed-design assessments. It is recommended that the floodway be protected by graded rocks with a maximum diameter of 200-300 mm on the downstream shoulder and batter slope.

The floodway should include nominal drainage culverts of at least 600 mm diameter.

All recommendations presented in this report are part of a conceptual design and require adjustments depending on specific site conditions.

Dated: 11 February 2019

Rockwater Pty Ltd

C Corthier
Engineering Geologist

REFERENCES

Pilgrim, D.H., et al, 1987, (AR&R 1987) Australian Rainfall and Runoff. The Institution of Engineers, Australia.

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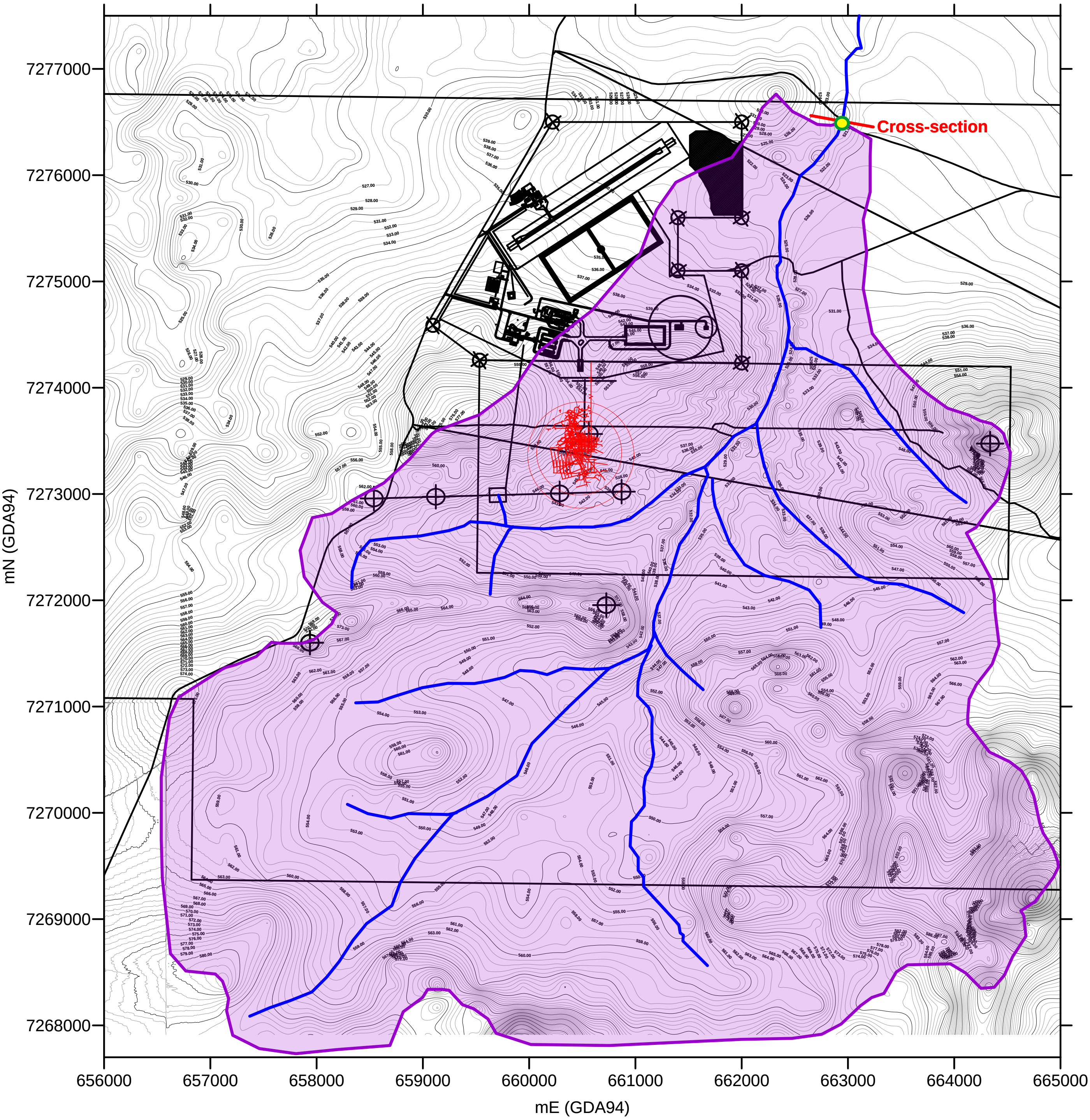
FIGURE

FIGURE 1



Major drainage lines	Catchment A	Infrastructure Layout
1 m topographic contours	Road crossing	Abra Deposit

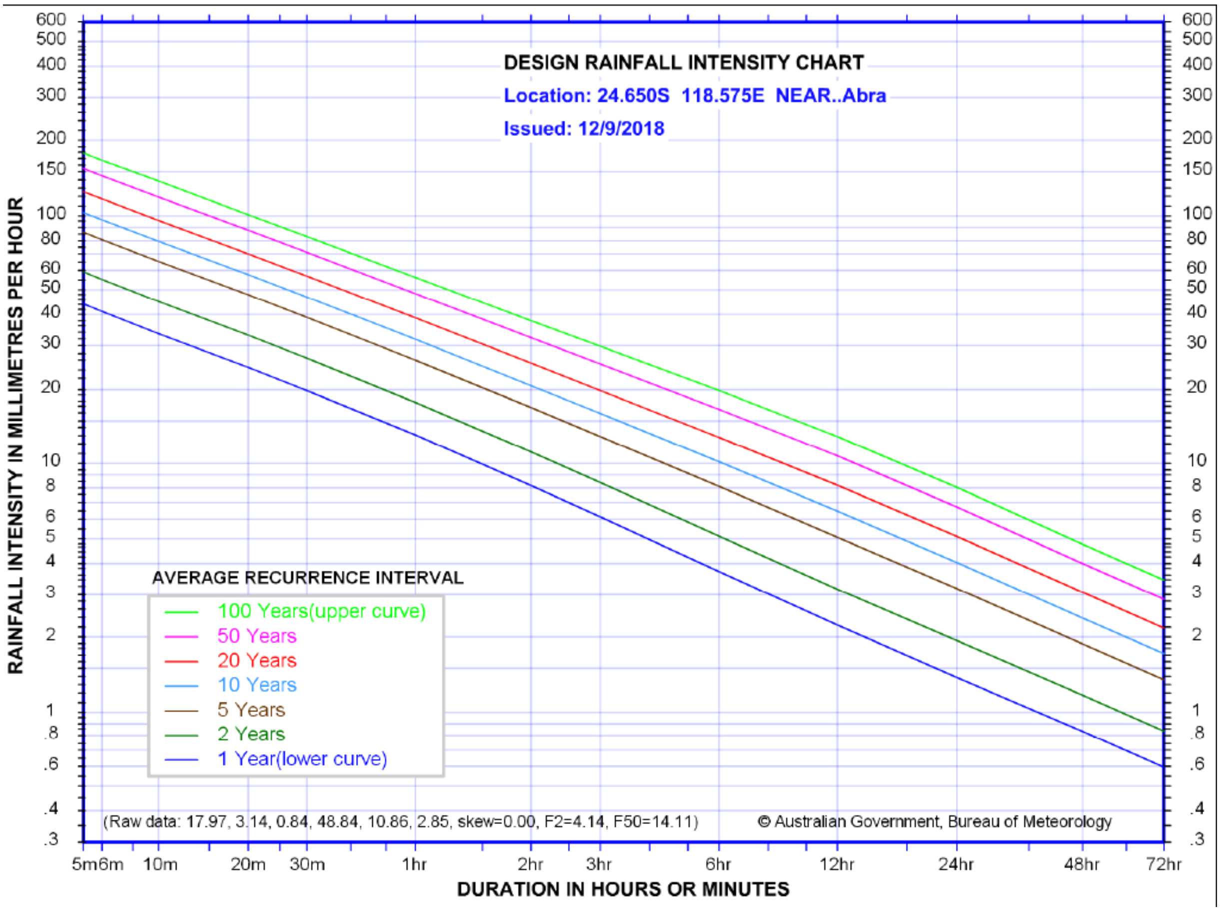
catchment.srf

CLIENT: Galena Mining PROJECT: Abra Silver-lead Deposit DATE: February 2019 Dwg No: 496-0/18/2-1	CATCHMENT & CROSSING LOCATION Rockwater PROPRIETARY LIMITED

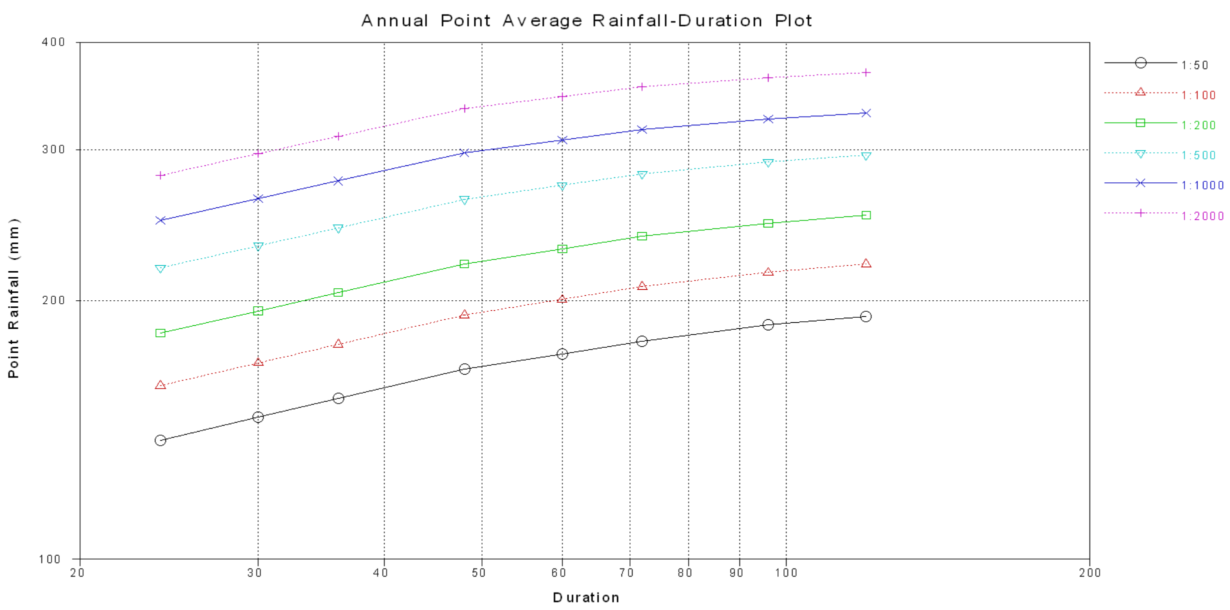
APPENDIX A: HYDROLOGY CHARTS AND CALCULATIONS

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987) RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

IFD Curves:



CRC Forge Results:



AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **PILBARA**

LOCATION: Abra

CATCHMENT: A

Pilbara Region

Catchment Characteristics	A (km^2)	L (km)	S_e (m/km)	P (mm)
	47.8	10	7.6	269

RATIONAL METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	40.5	-	7980	km^2
L =	10	-	194	km
S_e =	1.43	-	3.77	m/km
P =	230	-	400	mm

$Q_Y = 0.278 C_Y . I_{tc,Y} . A$ .... **(1.1)**

$t_c = 0.56A^{0.38}$ .... **(1.29)**

$t_c =$ 2.43 Hrs

$C_2 = 3.07 \times 10^{-1} L^{-0.20}$ .... **(1.30)**

$C_2 =$ 0.194

Frequency Factors (C_Y/C_{10})

	ARI (years)					
	2	5	10	20	50	*100*
C_Y/C_2	1.00	1.46	2.21	3.60	5.20	*7.76*

100 year ARI extrapolated using the logarithmic trend-line

Therefore:

	ARI (years)					
	2	5	10	20	50	100
C_Y	0.19	0.28	0.43	0.70	1.01	1.50

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **PILBARA**

LOCATION: Abra

CATCHMENT: A

RATIONAL METHOD:
CONTINUES

DETERMINE AVERAGE RAINFALL INTENSITY FOR DESIGN DURATION

t_c = 2.43 hours

Use IFD curves

Duration	ARI (Years) [mm/hr]					
(hours)	2	5	10	20	50	100
2.43	8.6	13.1	16.2	20.1	25.6	30.1

Calculate peak discharge using equation (1.1)

Discharge	ARI (Years)					
(m^3/s)	2	5	10	20	50	100
Q	22.0	49.2	92.1	186.0	342.6	601.6

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **PILBARA**

LOCATION: Abra

CATCHMENT: A

INDEX FLOOD METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	40.5	-	49600	km^2
L =	10	-	498	km
S_e =	0.88	-	3.77	m/km
P =	230	-	400	mm

$Q_5 = 6.73 \times 10^{-4} A^{0.72} P^{1.51}$ .... **(1.31)**

$Q_5 =$ 50.8 m^3/s

Frequency Factors (Q_Y/Q_5) interpolated for Catchment A

	ARI (years)					
47.8 km^2	2	5	10	20	50	*100*
Q_Y/Q_5	0.51	1.00	1.77	3.05	5.78	*10.09*

100 year ARI extrapolated using the power trend-line

Therefore the peak discharge

Discharge (m^3/s)	ARI (Years) 2	5	10	20	50	100
Q	25.83	50.83	90.18	155.26	294.02	512.75

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **PILBARA**

LOCATION: Abra

CATCHMENT: A

SUMMARY OF RATIONAL AND INDEX METHODS:

Pilbara Region

Catchment A	ARI (years) / Discharge (m^3/s)						
Method:	2	5	10	20	50	100	PMF*
Rational	22.03	49.20	92.12	186.03	342.62	601.62	
Index	25.83	50.83	90.18	155.26	294.02	512.75	
Adopted	**23.93**	**50.01**	**91.15**	**170.64**	**318.32**	**557.18**	**960.31**

*PMF estimated using multiplying factors from CRC-FORGE results

APPENDIX B: HYDRAULIC ANALYSES

Manning's Formula: $$\mathbf{Q} = \frac{\mathbf{1}}{\mathbf{n}}\left(\frac{\mathbf{A}}{\mathbf{P}}\right)^{2/3} \mathbf{S}^{1/2}$$

Cross-section at crossing (Catchment A)

Stage	Top Length (m)	A (m2)	P (m)	Manning's n	Slope (m/m)	V (m/s)	Q (m3/s)
519.0	0.00	0.00	0.00	0.06	0.002	0.00	0.00
519.5	74.67	27.72	74.68	0.06	0.002	0.39	10.89
520.0	110.52	76.36	110.54	0.06	0.002	0.59	45.39
520.5	143.37	141.99	143.41	0.06	0.002	0.76	107.30
521.0	176.23	223.64	176.28	0.06	0.002	0.89	199.37
521.5	212.07	322.32	212.14	0.06	0.002	1.01	324.05
522.0	247.92	439.16	248.00	0.06	0.002	1.11	488.99
522.2	262.85	490.41	262.94	0.06	0.002	1.15	565.28
522.4	277.79	545.01	277.88	0.06	0.002	1.19	649.64
522.6	289.73	602.13	289.83	0.06	0.002	1.24	745.78
522.8	304.67	661.93	304.77	0.06	0.002	1.28	844.49
523.0	319.60	725.24	319.71	0.06	0.002	1.31	952.48

Road long-section at crossing (Catchment A)

Stage	Top Length (m)	A (m2)	P (m)	Manning's n	Slope (m/m)	V (m/s)	Q (m3/s)
518.1	0.00	0.00	0.00	0.06	0.002	0.00	0.00
518.5	38.24	10.92	38.24	0.06	0.002	0.33	3.60
519.0	76.68	42.96	76.70	0.06	0.002	0.52	22.20
519.5	104.06	91.29	104.09	0.06	0.002	0.70	63.63
520.0	142.50	158.89	142.55	0.06	0.002	0.82	129.94
520.5	187.35	244.03	187.42	0.06	0.002	0.91	221.36
521.0	217.61	347.19	217.69	0.06	0.002	1.04	360.54
521.5	256.05	469.37	256.15	0.06	0.002	1.14	534.68
522.0	294.49	610.70	294.60	0.06	0.002	1.24	755.30
522.5	332.93	768.98	333.05	0.06	0.002	1.33	1021.90

APPENDIX C: TYPICAL FLOODWAY SCOUR PROTECTION DESIGN

CLIENT: Galena Mining

PROJECT: Abra Silver-lead Deposit

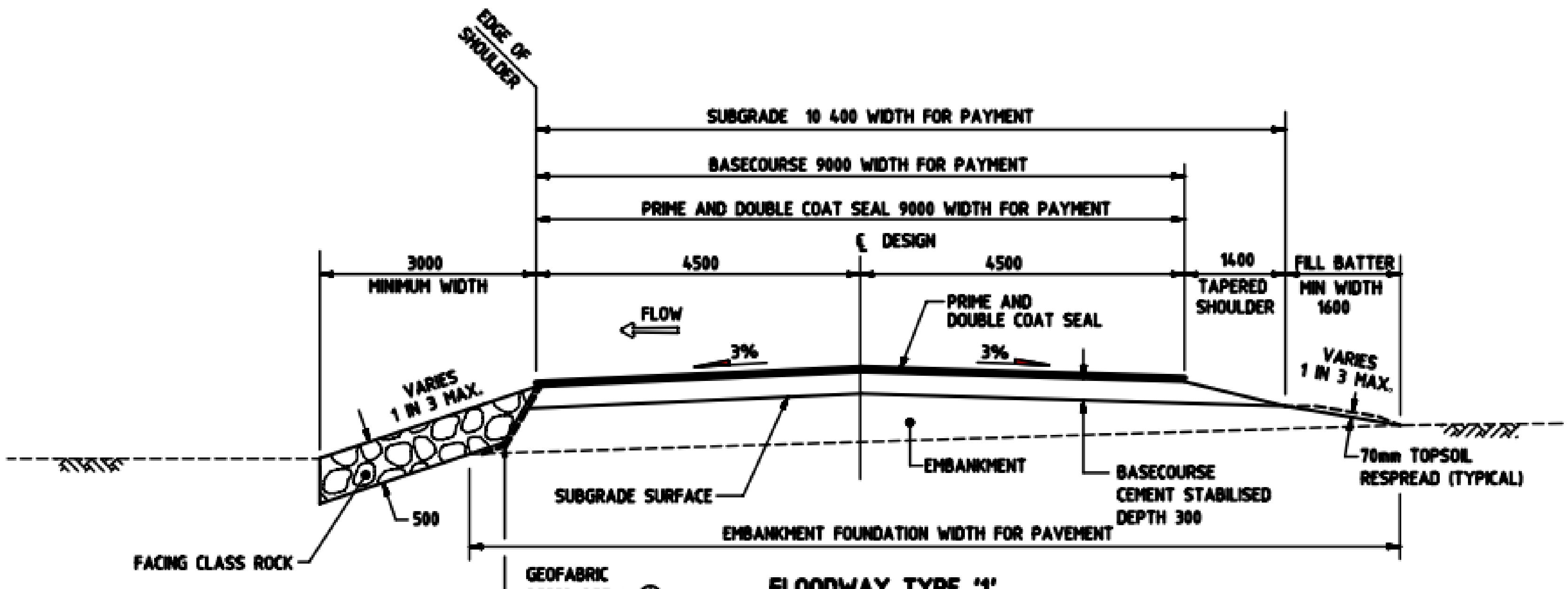
DATE: February 2019

DWG NO: 496-0/19-01/App C

I/496-0/Surfer/18/02/App C/App C-Typical CS of a diversion channel.srf

Typical Floodway Scour Protection Design (MRWA standards)

Appendix C



FLOODWAY TYPE '1'

SCALE 1:50

Rockwater PROPRIETARY LIMITED