Appendix Es

Codrilla Surface Water Assessment – Revised Report

CODRILLA COAL MINE SURFACE WATER IMPACT ASSESSMENT

BOWEN BASIN JOINT VENTURE

June 2011

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For and on behalf of
WRM Water & Environment Pty Ltd

David Newton
Director

EXECUTIVE SUMMARY

Introduction

McCollum Environmental Management Services is preparing an Environmental Impact Statement (EIS) for the Codrilla Project; a proposed coal mine located about 125km south-west of Mackay. As part of the EIS, WRM Water & Environment was requested to undertake a flood study and water balance to determine the impact of the proposed mining operations on flooding behaviour and streamflow in Devlin Creek, and its tributaries draining the project area.

Drainage Characteristics

The proposed Codrilla mining operations are located on flat land on the northern side of the Devlin Creek main channel. Devlin Creek is a tributary of the Isaac River. In the area of interest, Devlin Creek has an incised channel and a wide floodplain. The proposed mining operations are also located near Swampy Creek, which is a tributary of Devlin Creek. The Swampy Creek floodplain in the vicinity of the proposed mining operations has a flow capacity in excess of the Probable Maximum Flood discharge for Devlin Creek and will not impact on the proposed mine operations.

Water Quality

Most water quality parameter levels in Devlin Creek (both upstream and downstream of the mining lease) are lower than in the Isaac River. Median pH at all sample locations in the vicinity of the project is within the range of the Regional Guideline Values, but median pH in Swampy Creek is lower than Devlin Creek and the Isaac River. Median turbidity and TSS in Swampy Creek are higher than Devlin Creek. Median Total Nitrogen and Total Phosphorus concentrations at all sites are well in excess of the Regional Guideline Values. 95th percentile concentrations for the majority of metals in Devlin Creek are below the Release Contaminant Trigger Levels. Metals with levels in Devlin Creek naturally above the Release Contaminant Trigger levels include aluminium, uranium, zinc and iron.

Flood Impacts of the Proposed Mine

Hydrologic and hydraulic modelling of the Devlin Creek catchment was undertaken to determine the impact of the proposed Codrilla Project on Devlin Creek flood levels and velocities. The estimated design flood discharges for the Devlin Creek catchment at the proposed site are as follows:

- The 2 year Average Recurrence Interval (ARI) flood event: 70m^3/s;
- The 10 year ARI flood event: 204m^3/s;
- The 100 year ARI flood event: 525m^3/s;
- The 2,000 year ARI flood event: 1078m^3/s; and
- The Probable Maximum Flood (PMF) event: 3483m^3/s.

The results of the hydraulic modelling showed the following:

- The 2 year ARI design flood event is mostly contained within the Devlin Creek main channel and does not impact on the proposed mine footprint.
- The 10 year, 100 year and 2,000 year ARI design flood events will not impact on the eastern pit and overburden dump footprints of the proposed mine. However, the

proposed mine infrastructure area on the eastern side of Fitzroy Developmental Road is subject to partial backwater flooding during all events of 100 year ARI and larger.

- The western end of the open cut pit footprint is subject to partial backwater flooding during all events of 10 year ARI and larger. For the 100 year ARI flood event the maximum inundation depth within the pit footprint is approximately 1.4m.
- Flood plain velocities in the vicinity of the western pit and overburden dump range from approximately 0.1m/s to 0.9m/s for the 2 year to 2,000 year ARI flood events. Channel velocities in an unnamed tributary of Devlin Creek in the vicinity of the western pit and overburden dump range from approximately 0.5m/s to 1.1m/s for the 2 year to 2,000 year ARI flood events.
- Devlin Creek channel velocities range from approximately 0.8m/s to 2.5m/s upstream of Fitzroy Developmental Road and approximately 0.9m/s to 2.0m/s downstream of Fitzroy Developmental Road for the 2 year to 2,000 year ARI flood events.
- The PMF levels range from approximately 0.5m to a maximum of 1.5m higher than the 2,000 year ARI flood event. The PMF will inundate part of the western and eastern pit footprints as well as part of the eastern mine infrastructure area.

Two levees will be constructed to prevent flooding of the western pit footprint and the eastern mine infrastructure. The levee crest elevations will be set at the 2,000 year ARI flood level plus 0.5m (for the western levee this is between 180.1m AHD and 182.3m AHD, and for the eastern levee this is between 174.1m AHD and 175.7m AHD).

The proposed levee was included in the hydraulic model and the results showed the following impacts:

- The proposed levees prevent the inundation of the western pit and overburden dump and proposed mine infrastructure.
- The 2 year ARI design flood does not impact on the proposed mine. Therefore there is no change in flood depths resulting form the construction of the levees.
- There are no significant changes to flood depths for the 10 year ARI design flood resulting from the construction of the proposed levees. Any increases in flood level are limited to 0.1m.
- There are minor increases in flood depths for the 100 year ARI design flood resulting from the construction of the proposed levees. The flood depths have increased by a maximum of 0.2m and are concentrated near the upstream side of the western levee.
- There are localised increases in flood depth for the 2,000 year ARI design flood resulting from the construction of the proposed levees. The majority of the increases are less than 0.4m however, there is a small area immediately upstream of the proposed western levee where flood depths have increased by more than 0.4m.
- There is no significant change in flood velocities in Devlin Creek for the 2 year, 10 year, 100 year and 2,000 year ARI design floods as a result of the proposed levee. There are some increases in flood velocities (up to 0.5m/s for the 2,000 year ARI flood event) adjacent to the proposed levees.

<u>Site Water Management System and Site Water Balance</u>

The proposed mine operations will significantly change the drainage characteristics of the minor gullies crossing the mining area. Runoff from undisturbed areas will generally be diverted around the operational areas where possible. Runoff from disturbed areas will be captured in the site water management system.

Runoff collected in the pits will be pumped to one of three environmental dams for later reuse for dust suppression or in the Coal Handling and Preparation Plant (CHPP). During mining of the East Pit, additional pit water storage capacity is to be provided in a temporary pit water storage to be constructed by excavating ahead of mining within the proposed West Pit mining area. The temporary dam will be decommissioned before the West Pit advances to within close proximity. During mining of the West Pit, excess pit water would be stored in the East Pit void.

The environmental dams have been sized using a water balance model to ensure that under historical conditions it would be possible to contain all pit and plant runoff without discharge. Under the high runoff scenario, the temporary pit water storage volume required to achieve this is 2600ML.

If water quality and receiving water conditions allow, excess water could potentially be released from the site via controlled discharges from water storages. However historical simulation water balance modelling indicates that this should not be necessary if the water management system is implemented as proposed. When operated in this way, the risk of discharge from sediment dams over the project life is low. This approach is consistent with the intent of current drafts of DERM's Model Environmental Authority Conditions for Coal Mines in the Fitzroy Basin and the Manual for Assessing Hazard Categories of Dams. During dry periods, when the yield from the site water management system is low, water will need to be imported to meet supply shortfalls.

<u>Impacts of the Proposed Project on Local Drainage Characteristics</u>

The proposed water management system will have a significant impact on flows in the very small tributaries leaving the site. However, the impact on flows in the watercourses further downstream will be much smaller. In Devlin Creek, just downstream of the Swampy Creek confluence, the modelled median annual flow is predicted to be reduced by 7.0% in 2015 and by 10.8% when the mine footprint is largest.

<u>Surface Water Monitoring</u>

A surface water monitoring program will be implemented for the Codrilla Project to demonstrate the effectiveness of site water management in ensuring that mining operations do not have an adverse impact on the environmental values of receiving waters. The surface water monitoring program will include monitoring of flows in Devlin Creek, as well as water quality upstream and downstream of the mine along Devlin Creek and Swampy Creek.

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McCollum Environmental Management Services is preparing an Environmental Impact Statement (EIS) for the Codrilla Project, a proposed coal mine located about 125km south-west of Mackay. As part of the EIS, WRM Water & Environment was requested to undertake a flood study and water balance to determine the impact of the proposed mining operations on flooding behaviour in Devlin Creek and its tributaries, that drain the area of interest. Figure 1.1 shows the location of the proposed Codrilla Project.

To undertake the flood study, a TUFLOW two dimensional hydraulic model was developed of Devlin Creek and its floodplain for existing conditions and with the proposed mine infrastructure in place. This report presents the methodology and results of the flood study and water balance, provides an overview of surface water resources in the vicinity of the project and defines potential surface water impacts of the Codrilla Project. This report supersedes the previous version of the report (Revision 3, 13 September 2010) which was originally submitted with the EIS. This revision incorporates updated water balance modelling to include recent climate data, as well as changes to the mine plan.

This report is structured as follows.

- Section 2 describes the characteristics of the Devlin Creek catchment and the local drainage characteristics of the channel and floodplain in the vicinity of the proposed mining operations as well as potential impacts of the mining operations.
- Section 3 describes the climatic conditions of the Devlin Creek catchment, including rainfall and evaporation patterns and available streamflow data.
- Section 4 describes the surface water quality of the Devlin Creek catchment, upstream and downstream of the proposed mining lease boundary.
- Section 5 discusses the existing water use entitlements in the Devlin Creek catchment.
- Section 6 presents the methodology and results of the hydrological modelling undertaken to determine design flood discharges for the Devlin Creek catchment.
- Section 7 presents the methodology and results of the hydraulic modelling undertaken to determine design flood levels, flood extents and flood velocities for existing and proposed mine conditions.
- Section 8 presents the methodology and results of the water balance modelling undertaken to assess the performance of the proposed water management system in controlling runoff from disturbed areas.
- Section 9 outlines a surface water monitoring plan.
- Section 10 summarises the findings of the study.
- Section 11 is a list of references.
- Appendix A provides surface water quality sampling results.
- Appendix B provides maps that show the existing conditions and changes in velocities at the study area for the range of flood events investigated.

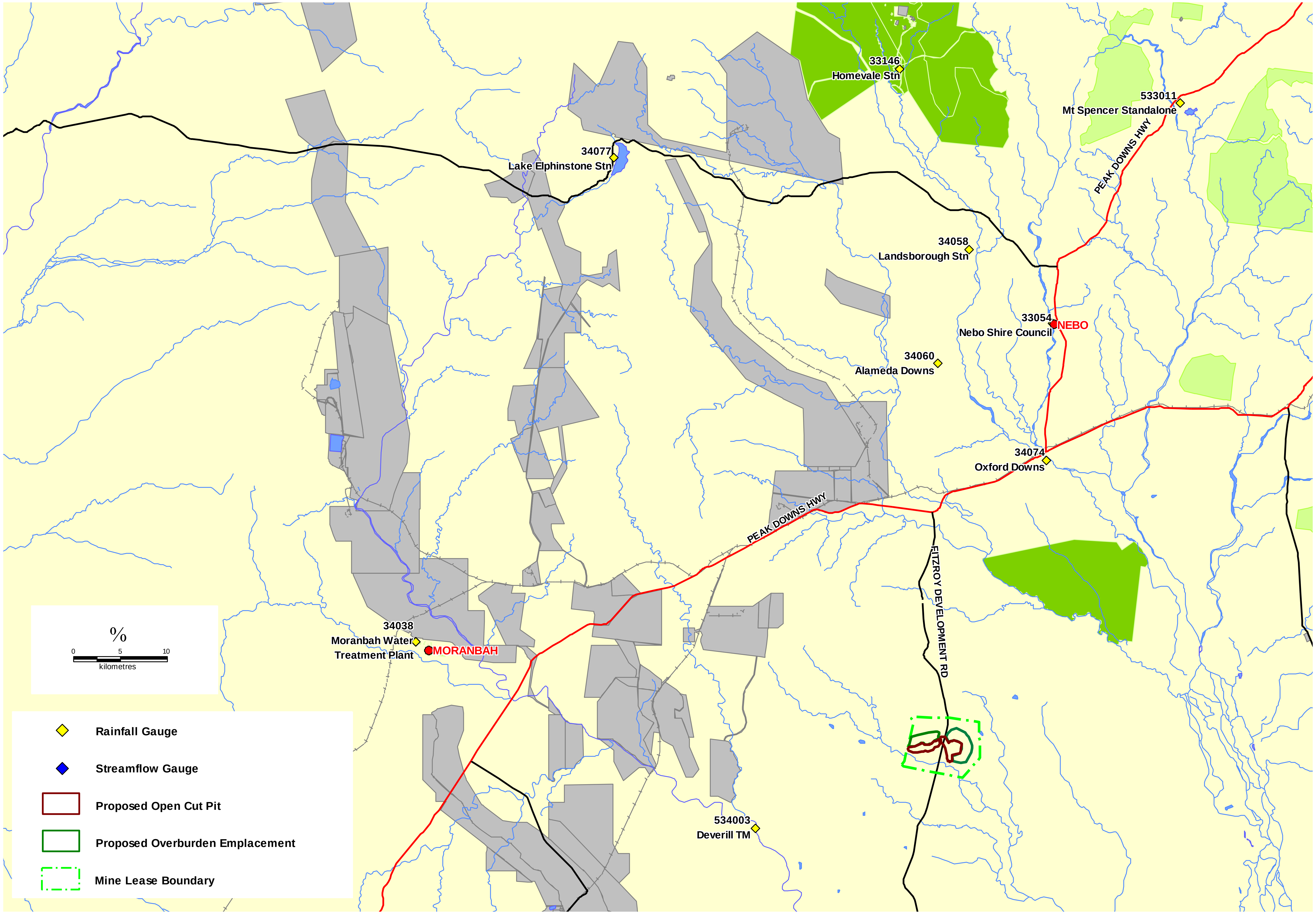

Figure 1.1 Codrilla Coal Mine Project Locality

2 DRAINAGE NETWORK

2.1 EXISTING DRAINAGE NETWORK

2.1.1 Catchment Characteristics

Figure 2.1 shows the proposed location of Codrilla Project mining operations. The site is located on flat land on the northern side of Devlin Creek, to the west of its south-flowing tributary Swampy Creek. Devlin Creek flows in a south-easterly direction adjacent to the proposed mine and discharges to the Isaac River approximately 38km to the south-east. Devlin Creek has a total catchment area of over 1,200km^2 of which, approximately 260km^2 is upstream of the Codrilla Project's eastern mining tenement boundary.

The Devlin Creek catchment incorporates a number of tributaries, including Swampy Creek, Bundarra Creek, Birdies Gully, Duck Creek, Scrubby Creek, and South Creek. A significant proportion of the catchment has been cleared for grazing, with some areas of remnant vegetation remaining in the upper catchment. The Moorvale Mine is located in the upper headwaters of Devlin Creek.

The flow characteristics of the catchments shown in Figure 2.1 are summarised in Table 2.1 below. The median annual flow has been estimated based on the results of a catchment modelling using the Australian Water Balance Model (AWBM) (Boughton, 2003). The model was calibrated to streamflow observations at the Devlin Creek @ Bombandy streamflow gauge operated by DERM between 1971 and 1988 (see Figure 1.1). The catchment area to this gauge is 1,026km^2. The median annual runoff over the modelled period is approximately 23.6mm/a, or 4.2% of median annual rainfall (mean annual runoff is 5.6% of mean annual rainfall).

Table 2.1 Local (Pre Mine) Catchment Characteristics

Reporting Point	Description of Location	Catchment Area (km^2)	Median Annual Flow (ML/a)
A	Devlin Creek @ Lease Boundary	261.2	6,173
B	Trib of Swampy Creek @ Lease Boundary	22.4	528
C	Trib of Swampy Creek @ Lease Boundary	5.8	137
D	Trib of Swampy Creek @ Lease Boundary	5.42	128
E	Swampy Creek D/S of minor Trib (B, C, D)	145.1	3,430
F	Devlin Creek D/S of Swampy Creek	437.9	10,350

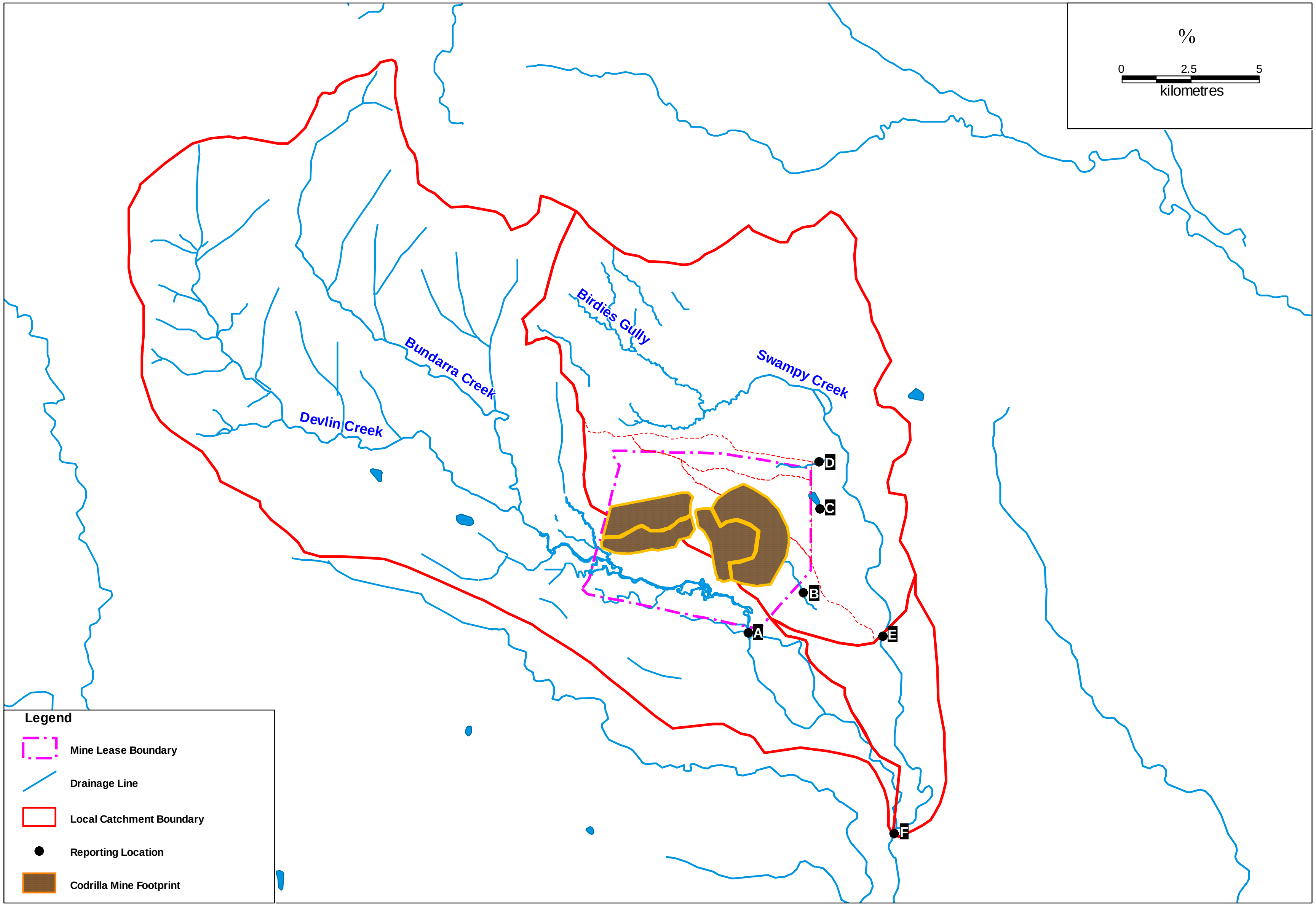

Figure 2.1 Local Drainage Network

2.1.2 Devlin Creek Channel and Floodplain Characteristics

Devlin Creek in the area of interest consists of an incised main channel across a very wide, flat floodplain. Numerous old meander bends which have been cut off from the current channel alignment are evident at various locations along the creek. The Devlin Creek channel has a base width of about 5 to 10m and is about 3 to 5m deep. The banks of the creek are quite steep ranging from approximately 1V:2H to 1V:3H. The banks are vegetated with a mixture of large mature eucalypts and grasses. In some locations along Devlin Creek, erosion of the banks is evident as is large woody debris. Figure 2.2 shows a photograph of the Devlin Creek channel in the vicinity of the Fitzroy Developmental Road crossing (close to the proposed mining operations) taken in May 2009.

Figure 2.2 Devlin Creek Channel in the Vicinity of the Fitzroy Developmental Road Crossing

2.1.3 Swampy Creek Channel and Floodplain Characteristics

Swampy Creek is a tributary of Devlin Creek that joins Devlin Creek some 9km south-east of the Codrilla Mine Lease. Swampy Creek has a catchment area of approximately 100km^2 adjacent to the proposed mine. It drains in a southerly direction approximately 3km to the north-east of the proposed eastern overburden dump. Swampy Creek discharges into Devlin Creek approximately 9km to the south-east of the proposed mining operations. The location of Swampy Creek relative to the proposed mine is shown in Figures 1.1 and 2.1.

Figure 2.3 shows a cross section of Swampy Creek taken from the edge of the eastern overburden dump to the mining lease boundary. The location of the cross section is shown in Figure 2.1. The cross section of Swampy Creek in this location has an area of approximately 12,500m^2 to the ground level at the eastern boundary of the proposed overburden dump (171.7m AHD). Using Manning's equation, with an adopted bed slope of 0.1% and an 'n' value of 0.05, the Swampy Creek channel and floodplain in this location has a flow capacity of approximately 16,800 m^3/s. This is significantly higher than the calculated Devlin Creek Probable Maximum Flood discharge, which is about 3,500m^3/s. Swampy Creek has a smaller catchment than Devlin Creek in the vicinity of the mine, hence flooding from Swampy Creek will not impact on the proposed mine workings.

2.1.4 Site Drainage Characteristics

Due to the very flat topography of the Devlin Creek floodplain, flow paths for local stormwater drainage are poorly defined. The approximate boundaries of local catchments draining the area of proposed mining operations are shown in Figure 2.1. However, there are no well defined watercourses across the floodplain. The flood and drainage behaviour of site runoff will be controlled by the design of proposed stormwater flow paths to be undertaken as part of infrastructure design.

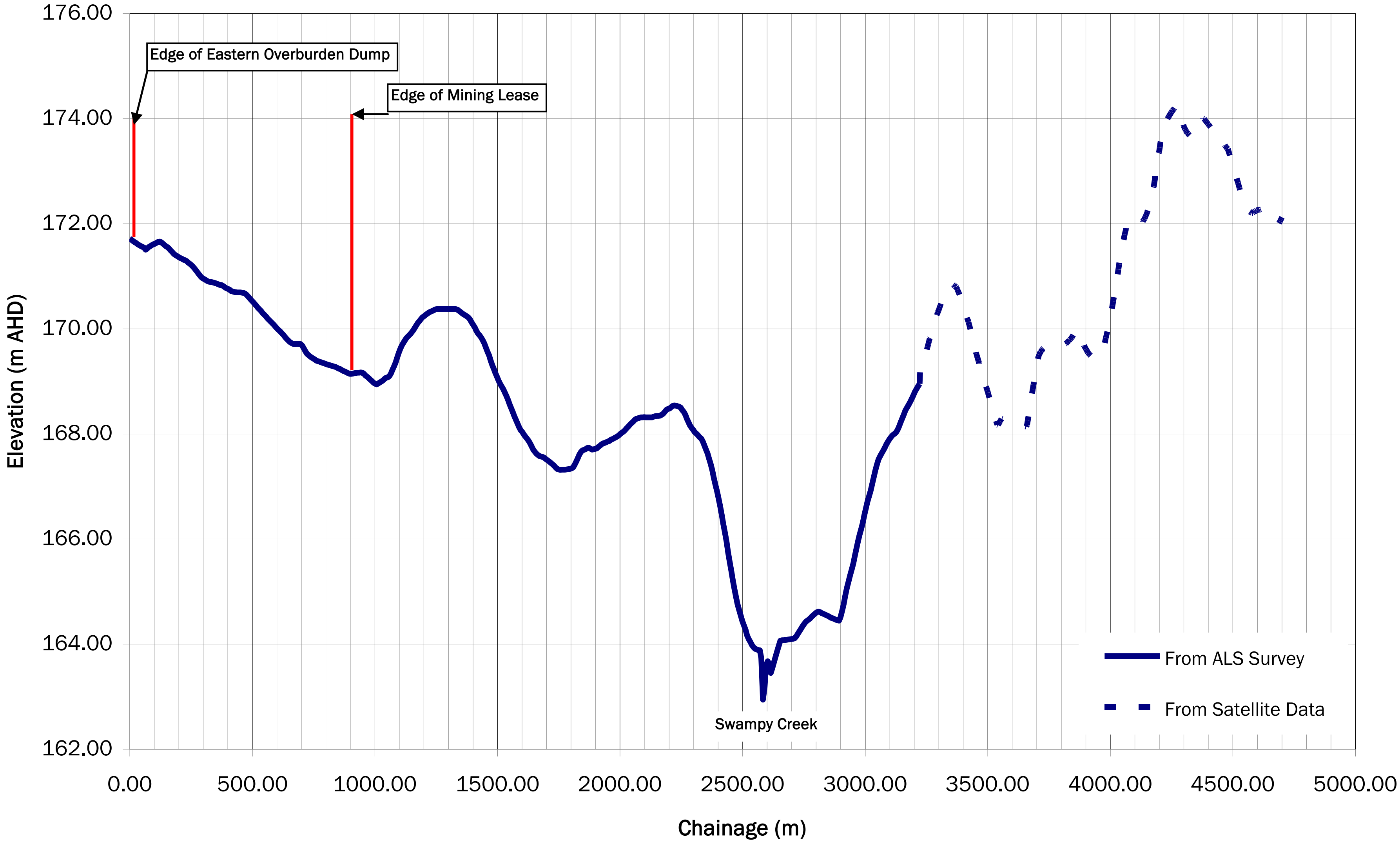

Figure 2.3 Cross Section of Swampy Creek Channel & Floodplain in the vicinity of the Eastern Overburden Dump

2.2 IMPACTS OF MINING OPERATIONS

The proposed locations of the open cut pits and overburden emplacements for the Codrilla Project are outside the banks of the Devlin Creek and Swampy Creek main channels. Hence, the proposed mine operations will not affect the geomorphology or frequent flow behaviour of Devlin Creek or Swampy Creek. Mine infrastructure is located above the Swampy Creek floodplain at an elevation significantly higher than the elevation of the main channel and therefore will not affect flood depths and flow velocities during rare flood events. However, mine infrastructure will be located on the Devlin Creek floodplain and will potentially affect flood depths and flow velocities during flood events where flows exceed the main channel capacity. Details of the hydrologic and hydraulic modelling that assess the impacts of the proposed development on flood behaviour along Devlin Creek are presented in subsequent sections of this report.

Proposed haul road crossings of waterways will include culverts capable of passing the 2 year ARI flood event and will be designed to ensure minimal impact on larger flood events. These haul road crossings will have small local upstream impacts and detailed flood modelling has not been undertaken as part of this impact assessment.

The proposed development may obstruct flow paths for local stormwater runoff, which are poorly defined due to the very flat topography of the Devlin Creek floodplain. Potential impacts on local runoff will be addressed in the design of stormwater management infrastructure on the site.

It is proposed to return the open cut pits to natural surface level (apart from the small final void areas) at the cessation of mining activities.

3 CLIMATIC CONDITIONS

3.1 RAINFALL & EVAPORATION

Table 3.1 shows summary details of rainfall recording stations in the vicinity of the Devlin Creek catchment. Note that none of these stations are located within the Devlin Creek catchment. The locations of the various stations are shown in Figure 1.1.

Table 3.1 Details of Rainfall Stations in the Area of Interest

Station No.	Station Name	Type	Elevation (m)	Lat. (°S)	Long. (°E)	Distance from Site (km)	Opened	Closed	Owner
33054	Nebo Shire Council	Daily	195	-21.6889	148.6881	45km NE	30-03-1870		BOM
33146	Homevale Stn	Daily	280	-21.4447	148.5306	72km N	30/08/1970	29/06/1998	BOM
33146	Homevale Stn	Pluvio	280	-21.4447	148.5306	72km N	24/10/1970	29/06/1998	BOM
34038	Moranbah Water Treatment Plant	Daily	240	-21.9947	148.0308	58km NW	30/03/1972		BOM
34058	Landsborough Stn	Daily	300	-21.6181	148.6019	53km N	1/01/1966		BOM
34060	Alameda Downs	Daily	250	-21.7278	148.5697	41km N	30/08/1972		BOM
34074	Oxford Downs	Daily	180	-21.8208	148.6825	32km NE	1/01/1895		BOM
34077	Lake Elphinstone Stn	Daily	350	-21.5297	148.2353	72km NW	1/01/1973		BOM
533011	Mt Spencer Standalone	Pluvio		-21.4778	148.8206	73km NE	3/04/1985		NRW
534003	Deverill TM	Pluvio	200	-22.1742	148.3811	22km SW	1/08/1995		BOM

Table 3.2 shows mean monthly rainfalls for the two rainfall stations with the longest period of record, Nebo Shire Council (Station No. 33054) and Oxford Downs (Station No. 34074). Results are shown for a “water year”, commencing in October. The mean annual rainfall recorded at Nebo over a period of 139 years is about 750 mm. The mean annual rainfall at Oxford Downs, 32 km from the mine site is about 640 mm. Note that Oxford Downs has significant periods of missing data.

The closest meteorological station recording evaporation is located at the Moranbah Water Treatment Plant (Station No. 34074), located some 58 km to the north-west of the proposed mine site. Mean monthly evaporation (based on a Class A evaporation pan) is also shown in Table 3.2. Mean annual evaporation is 2346 mm, which is substantially higher than rainfall.

Figure 3.1 shows the annual distribution of monthly rainfall and evaporation in the vicinity of the mine site. Mean evaporation exceeds mean rainfall in every month of the year.

Table 3.2 Mean Monthly Rainfall and Evaporation in the Area of Interest

Month	Mean Monthly Rainfall (mm)		Mean Monthly Evaporation (mm)
	Nebo Shire Council (33054) [139 years data]	Oxford Downs (34074) [64 years data]	Moranbah WWTP (34038) [24 years data]
October	31.2	32.7	251.1
November	55.0	57.6	258.0
December	96.9	97.3	269.7
January	139.0	113.9	254.2
February	135.9	102.3	210.0
March	106.8	76.3	217.0
April	47.3	38.9	174.0
May	34.8	32.3	133.3
June	39.5	33.9	108.0
July	27.8	20.2	117.8
August	17.9	19.3	151.9
September	19.8	16.5	201.0
Total	**751.9**	**641.2**	**2346.0**

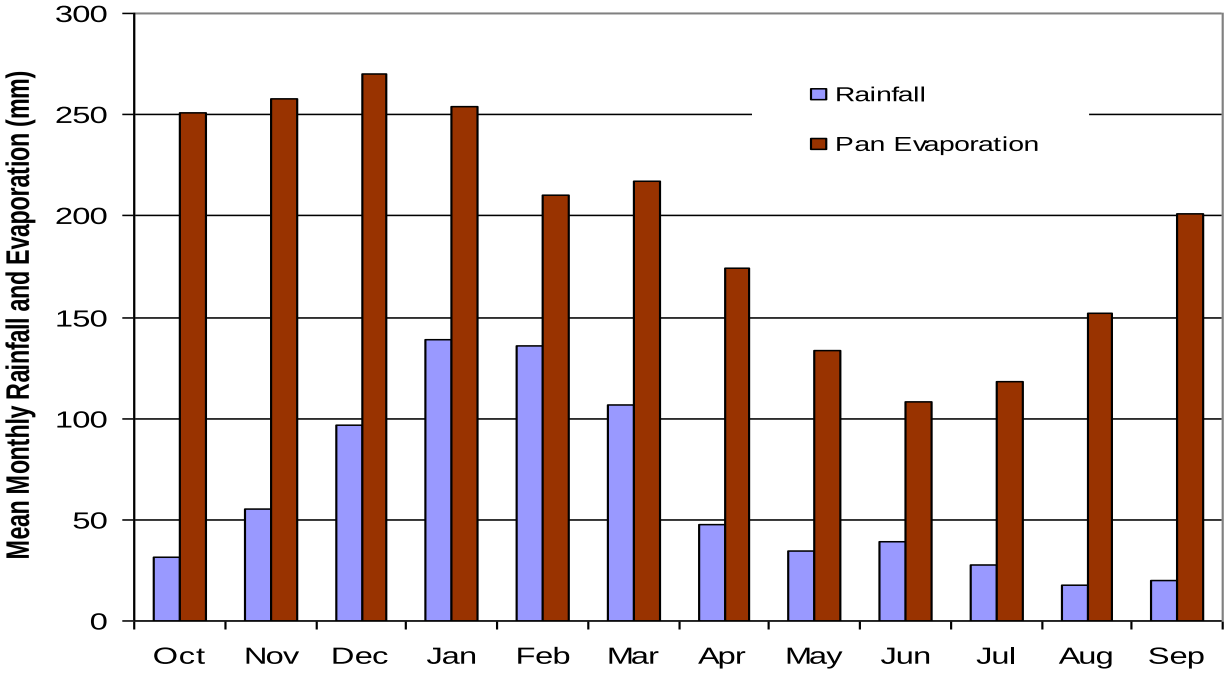

Figure 3.1 Distribution of Monthly Rainfall (Nebo Shire Council) and Evaporation (Moranbah Water Treatment Plant)

3.2 2010/11 WET SEASON RAINFALLS

The 2010/11 wet season resulted in significant rainfall over the area of interest. Review of recorded daily rainfalls at Oxford Downs indicates that:

- Calendar 2010 was the wettest year on record (49 years of complete data available) with a total annual rainfall of 1,324 mm.

- The 2010/2011 wet season (Dec/Jan/Feb) had a total rainfall of 853 mm, which was the third-wettest on record (1,214mm was recorded in 1990/91 and 1,044 mm in 1917/18).
- December 2010 was the wettest December on record, with a total rainfall of 529 mm. The second-wettest December occurred in 1990 with 458 mm of rainfall.

3.3 STREAMFLOW

Figure 1.1 shows the location of the stream flow gauge on Devlin Creek. The Bombandy gauging station (Station No. 130412A) is located approximately 27km south-east (downstream) of the proposed mining operations and was operated by the QLD Department of Environment and Resource Management between 1971 and 1988. Currently, there are no operating stream flow gauges within the Devlin Creek catchment. The catchment area of Devlin Creek to Bombandy is approximately 1023km^2.

Table 3.3 shows the annual recorded runoff volume at the Bombandy streamflow gauge for the period of record, as well as total annual rainfall taken as the mean of recorded annual rainfalls at the four closest stations to the Devlin Creek catchment:

- Nebo Shire Council (No. 33054),
- Landsborough Station (No. 34058),
- Alameda Downs (No. 34060), and
- Oxford Downs (No. 34074).

Table 3.3 Annual Rainfall and Runoff Volumes for Devlin Creek Catchment

Year Commencing	Annual Rainfall (mm)	Annual Runoff Volume at Bombandy	
		(ML)	(mm)
Oct-71	913	21246	17.7
Oct-72	592	17216	14.3
Oct-73	1349	171397	142.5
Oct-74	1065	29185	24.3
Oct-75	1289	68130	56.6
Oct-76	1190	27221	22.6
Oct-77	1071	50666	42.1
Oct-78	1130	65253	54.2
Oct-79	753	2358	2.0
Oct-80	929	17695	14.7
Oct-81	784	1210	1.0
Oct-82	952	78063	64.9
Oct-83	1085	1305	1.1
Oct-84	906	3144	2.6
Oct-85	857	10136	8.4
Oct-86	607	730	0.6
Oct-87	1321	19179	15.9
Mean	**988**	**34361**	**29**

[a] Mean of annual rainfall at Station No.s 33054, 34058, 34060 and 34074.
* Data missing from some stations

4 SURFACE WATER QUALITY

4.1 ENVIRONMENTAL VALUES & WATER QUALITY OBJECTIVES

The downstream receiving waters do not include potable or irrigation water supply systems, or National Parks within 100km of the site. Existing downstream water use is restricted to domestic and agricultural use for stock watering.

The waterways located within and downstream of the Codrilla Project Mining Lease are not included in Schedule 1 of the Environmental Protection (Water) Policy 2009 (EPP Water). The environmental values listed in Part 3 Section 6 of the EPP Water that are to be protected are therefore the:

- biological integrity of an aquatic ecosystem that is adversely affected by human activity to a relatively small but measurable degree;
- suitability of the water for agricultural and recreational use; and
- cultural and spiritual values of the water.

The indicators and water quality guidelines relevant to the above environmental values are listed in the Queensland Water Quality (QWQ) Guidelines and ANZECC (2000). The conditions of waterways located in the vicinity of the Codrilla Project mining lease are classified as Level 2; slightly to moderately disturbed ecosystems under the QWQ Guidelines (DERM, 2009a).

4.2 WATER QUALITY DATA

There is limited information currently available on surface water quality in the area of interest. Table 4.1 shows water quality data recorded at 4 locations (shown in Figure 4.1):

- Swampy Creek at Valkyrie Road (located about 5.5km north-east of the mining lease);
- Devlin Creek at Fitzroy Developmental Road (within the mining lease);
- Devlin Creek at Bombandy (DERM Stn. No. 130412A) (located about 27km south-east (downstream) of the mining lease); and
- Isaac River at Fitzroy-Developmental Road (located about 38km south-south-east of the mining lease).

Although based on a limited number of samples, this data provides an indication of typical water quality parameters for Devlin Creek, both upstream and downstream of the mining lease. The data has also been compared with Regional Guideline Values (DERM, 2009a) and Release Contaminant Trigger Levels (DERM, 2009b). Appendix A shows the full water quality sampling results for all four locations. The following is of note:

- Generally, parameter levels in Devlin Creek (both upstream and downstream of the mining lease) are lower than in the Isaac River, with the exception of dissolved oxygen, total nitrogen, boron, copper, zinc and iron.
- Median pH at all locations is within the range of the Regional Guideline Values.

- Median pH in Swampy Creek is lower than Devlin Creek and the Isaac River.
- Median turbidity and TSS in Swampy Creek are higher than Devlin Creek.
- Median Total Nitrogen and Total Phosphorus concentrations at all sites are well in excess of the Regional Guideline Values.
- 95^{th} percentile concentrations for the majority of metals in Devlin Creek are below the Release Contaminant Trigger Levels. Metals with levels in Devlin Creek naturally above the Release Contaminant Trigger levels include aluminium, uranium, zinc and iron.

Figure 4.2 shows the relationship between Electrical Conductivity (EC) and a qualitative assessment of stream discharge in Devlin and Swampy Creeks and the Isaac River. In Devlin Creek, EC can be significantly elevated during low-flow periods but drops below 200 μS/cm at medium and higher flows. Swampy Creek EC values display a similar pattern, although the EC values at low flows are much lower than in Devlin Creek. The variation of EC with flow in the Isaac River is less pronounced, although no low flow samples were available at the monitoring site.

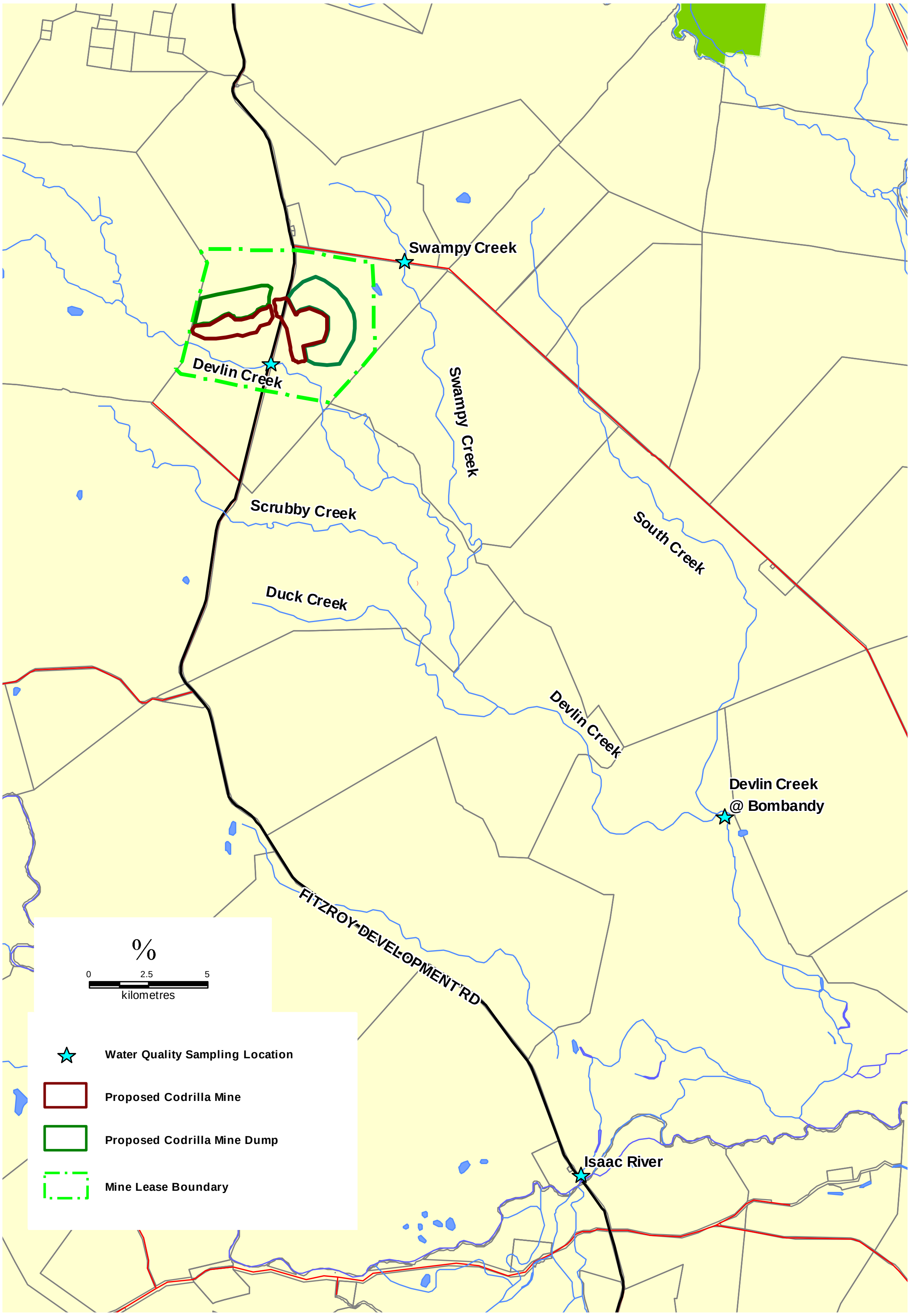

Figure 4.1 Location of Water Quality Sampling Sites

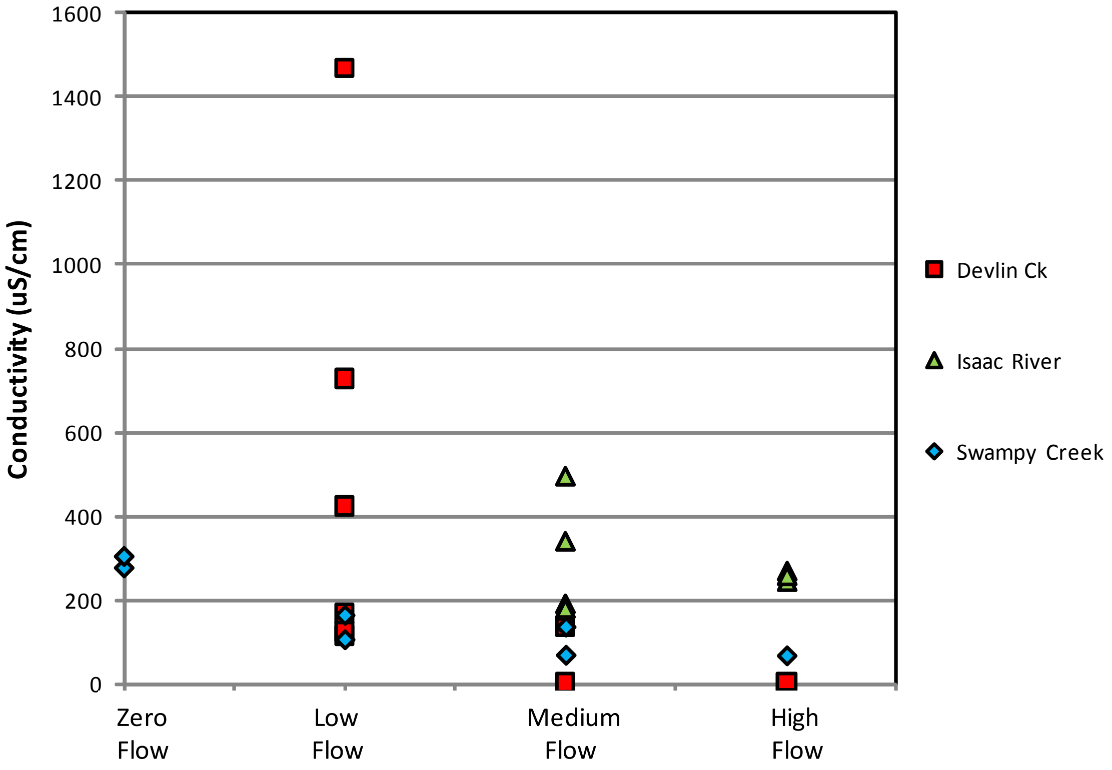

Figure 4.2 Variation in Electrical Conductivity with Discharge

Table 4.1 Recorded Water Quality Data, Swampy Creek, Devlin Creek & Isaac River

Parameter	Units	Swampy Creek (at Valkyrie Road)[1]		Devlin Creek (at Fitzroy Development Road)[1]		Devlin Creek (at Bombandy)[2]		Issac River[1]		Regional Guideline Values[3]
		Median Water Quality								
pH	pH Units	6.7	(7)	7.4	(9)	7.2	(21)	7.5	(7)	6.5-7.5
Temperature	° C	26.6	(4)	26.1	(4)	24.5	(16)	27.0	(3)	-
Conductivity	µS/cm	136	(7)	136	(9)	155.0	(21)	258	(7)	720
Turbidity	NTU	493	(7)	106	(9)	85.0	(4)[6]	>1000	(7)	25
Dissolved Oxygen	mg/L	5.1	(7)	5.0	(9)	NA	-	4.8	(7)	90-110 (%)
Hardness	mg/L	37	(7)	39	(9)	47.0	(18)	63	(7)	-
Total Suspended Solids	mg/L	172	(7)	70	(9)	64.0	(14)	400	(7)	-
Total Nitrogen	mg/L	1.35	(7)	1.45	(9)	NA	-	1.23	(7)	0.25
Total Phosphorus	mg/L	0.1	(7)	0.1	(8)	NA	-	0.21	(6)	0.03
Sulphate	mg/L	<2.0	(7)	3.0	(9)	3.9	(8)[6]	8.0	(7)	-
Fluoride	mg/L	<2.0	(7)	<0.1	(9)	0.1	(14)	0.1	(7)	-
		95th Percentile Water Quality								**Release Contaminant Trigger Levels[4]**
Aluminium [5]	µg/L	1947	(7)	841	(9)	NA	-	850	(7)	100.0
Antimony [5]	µg/L	<5	(7)	<5	(9)	NA	-	<5	(7)	-
Arsenic [5]	µg/L	5	(7)	3	(9)	NA	-	<4	(7)	13.0
Beryllium [5]	µg/L	<5	(7)	<5	(9)	NA	-	<1	(7)	-
Boron [5]	µg/L	191	(7)	118	(9)	60	(4)[7]	110	(7)	370.0
Cadmium [5]	µg/L	<5	(7)	<5	(9)	NA	-	<0.2	(7)	0.2
Chromium [5]	µg/L	<5	(7)	<5	(9)	NA	-	<2	(7)	1.0
Cobalt [5]	µg/L	<5	(7)	<5	(9)	NA	-	<7	(7)	90.0
Copper [5]	µg/L	5	(4)	7.5	(7)	NA	-	6.6	(5)	-
Lead [5]	µg/L	<5	(7)	<5	(9)	NA	-	<5	(7)	10.0
Manganese [5]	µg/L	81	(7)	70	(9)	NA	-	261	(7)	1900.0
Molybdenum [5]	µg/L	<5	(7)	<5	(9)	NA	-	<5	(7)	34.0
Nickel [5]	µg/L	3.8	(7)	<5	(9)	NA	-	8.7	(7)	11.0
Selenium [5]	µg/L	<5	(7)	<5	(9)	NA	-	<5	(7)	10.0
Uranium [5]	µg/L	5.5	(7)	<6	(9)	NA	-	14	(7)	1.0
Vanadium [5]	µg/L	<5	(7)	<6	(9)	NA	-	<13	(7)	10.0
Zinc [5]	µg/L	37	(7)	75	(9)	NA	-	29	(7)	8.0
Iron [5]	µg/L	915	(7)	588	(9)	3900	(5)[7]	948	(7)	300.0
Mercury [5]	µg/L	0.2	(7)	0.2	(9)	NA	-	<0.1	(7)	0.2

1. Samples from 2010/2011
2. Historical Samples 1971- 1988
3. Taken from DERM Queensland Water Quality Guidelines (2009)
4. Taken from DERM Final Model Water Conditions for Coal Mines in the Fitzroy Basin
5. Dissolved
6. Mean Value
7. Maximum Value

(#) – Number of Samples

5 EXISTING WATER USE ENTITLEMENTS

Advice from the Queensland Government Department of Environment and Resource Management (DERM) indicates that there are no current water licences and/or development permits on Devlin Creek. This indicates that there are currently no formal water use entitlements along Devlin Creek. However, DERM provided advice that the owners of Lot 9 on KL119 (located about 23km south-east of the proposed mining lease) hold a permit to source water from Devlin Creek for stock and domestic supply. It is also possible that other landholders and livestock may access small volumes of water from Devlin Creek on an informal basis.

The proposed open cut pit extent will not affect in-bank flows along Devlin Creek. The total pit catchment area is approximately 6.5km^2 which is less that 3% of the catchment area of Devlin Creek to Fitzroy Developmental Road. Hence, the proposed development will have no measurable impact on the quantity of water available to downstream users.

6 ESTIMATION OF DEVLIN CREEK DESIGN DISCHARGES

6.1 OVERVIEW

Devlin Creek flood discharges were estimated for a range of design storm events including the 2 year, 10 year, 100 year and 2,000 year Average Recurrence Interval (ARI) events using the URBS runoff-routing model. Discharges were also estimated for the Probable Maximum Flood (PMF). Recorded streamflow data for Devlin Creek is available at Bombandy. However, the catchment at this location is more than 5 times larger than the Devlin Creek catchment adjacent to the proposed mine infrastructure and hence this data is not well suited to model calibration at the mine site. The results of the URBS model were checked against design flood discharges obtained using the Rational Method, as well as the results of a flood frequency analysis at Bombandy. Details of the hydrologic modelling methodology and results are provided in the following sections.

6.2 MODEL DESCRIPTION

URBS is a networked (i.e. sub-catchment based) runoff-routing model that estimates flood hydrographs by routing rainfall excess through a module representing the catchment storage. In URBS, the storages are arranged to represent the drainage network of the catchment. The distributed nature of storage within the catchment is represented by a separate series of concentrated storages for the main stream and for major tributaries to provide a degree of physical realism. Full details of the URBS model and its features are given in the URBS User Manual (Carroll, 2007).

URBS is widely used in Australia for flood hydrograph estimation and is the preferred hydrologic model for flood forecasting adopted by the Bureau of Meteorology.

6.3 MODEL CONFIGURATION

Figure 6.1 shows the adopted configuration of the Devlin Creek URBS model. The model covers the Devlin Creek catchment to the downstream mining lease boundary (231km^2). It consists of 15 sub-catchments. Table 6.1 shows the areas for each sub-catchment used in the model.

Table 6.1 Devlin Creek URBS Model Sub-Catchment Areas

Sub-Catchment No	Area (km^2)	Sub-Catchment No	Area (km^2)
1	20.1	9	2.7
2	32.1	10	3.1
3	27.7	11	9.6
4	21.5	12	7.9
5	25.5	13	6.3
6	16.0	14	4.8
7	32.5	15	17.1
8	4.3		

6.4 DESIGN RAINFALL DEPTHS & PROBABLE MAXIMUM PRECIPITATION

The URBS model uses design rainfall intensity-frequency duration data from Australian Rainfall and Runoff (ARR) (IEAust, 1998) for the 2, 10 and 100 year ARI design events. Rainfall depths for the 2,000 year ARI event were estimated using the CRC-Forge method (Hargraves, c2004). Probable Maximum Precipitation depths were estimated using the Generalised Short Duration Method (GSDM) for storm durations up to 6 hours (BoM, 2003a) and the Generalised Tropical Storm Method Revised (GTSMR) for storm durations between 12 hours and 72 hours (BoM, 2003b). The adopted rainfall depths for the Devlin Creek catchment are shown in Table 6.2.

Table 6.2 Devlin Creek Catchment Rainfall Depths

Storm Duration (hrs)	Rainfall Depths (mm)				
	2 Year	10 Year	100 Year	2,000 Year	PMP
3	52.1	73.2	109.4	200.5	490.0
6	62.2	90.5	139.9	245.4	630.0
9	67.9	101.1	158.6	273.2	705.0
12	73.7	111.9	177.8	301.1	780.0
18	81.6	126.1	203.9	349.0	900.0
24	89.6	140.4	230.3	386.6	1020.0
36	97.9	156.2	260.6	435.5	1230.0
48	106.2	171.9	290.9	484.3	1430.0
72	111.5	185.4	321.5	561.0	1790.0

The ARR temporal patterns were applied for the 2, 10 and 100 year ARI design events and the BoM GSDM and GTSMR temporal patterns were applied for the 2,000 year ARI and PMP events.

6.5 AREAL REDUCTION FACTORS

Areal Reduction Factors (ARFs) obtained from the Queensland Extreme Rainfall Estimation Project (EREP) (Hargraves c.2004) were applied to the 2, 10 and 100 year ARI rainfall depths. ARFs were not applied to the 2,000 year ARI or PMP rainfall depths as an ARF is included in the rainfall estimation process. The adopted ARFs are shown in Table 6.3.

Table 6.3 Devlin Creek Catchment Areal Reduction Factors

Storm Duration (hrs)	ARF
3	0.900
6	0.925
9	0.931
12	0.938
18	0.944
24	0.950
36	0.950
48	0.950
72	0.950

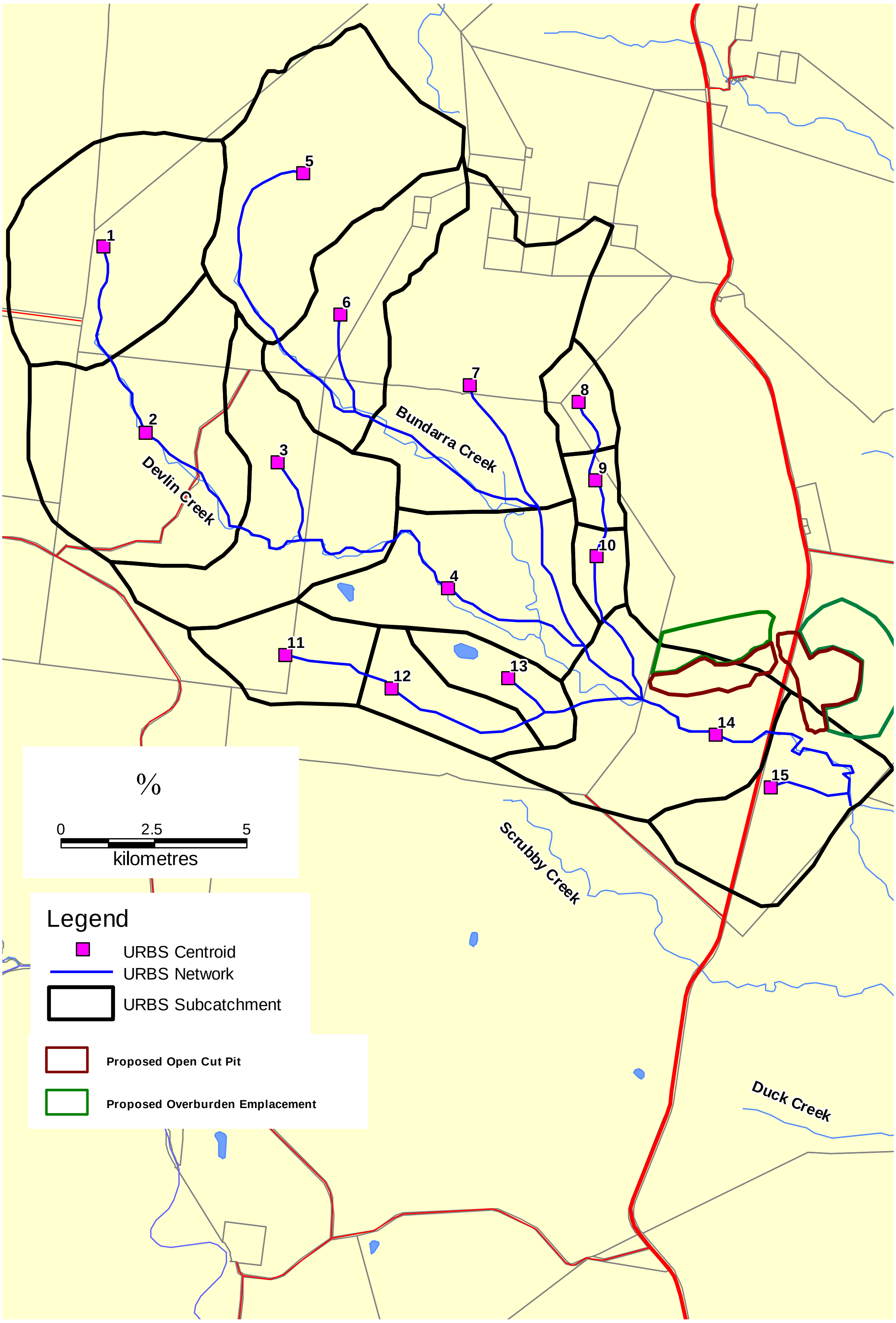

Figure 6.1 Devlin Creek URBS Model Configuration

6.6 MODEL CALIBRATION

6.6.1 Methodology

No suitable rainfall or streamflow data was available for the calibration of the URBS model in the vicinity of the Codrilla Project.

URBS model parameters were initially selected based on a similar previous study undertaken by WRM for the Bee Creek catchment, located between 16 and 20km to the north of the Codrilla site. The Bee Creek model was calibrated to 4 historical flood events. The estimates of design discharges obtained for Devlin Creek using the Bee Creek model parameters were then checked against independent design discharge estimates obtained from the Rational Method and from flood frequency analysis of recorded streamflow data at Bombandy.

Details of the Rational Method and flood frequency analyses, as well as the adopted URBS model parameters and estimated design discharges are provided below.

6.6.2 Rational Method Discharge

The 100 year ARI design discharge for the Devlin Creek catchment to the downstream lease boundary was estimated using the Main Roads Department Rational Method as recommended in Australian Rainfall and Runoff (IEAust, 1987).

Table 6.4 shows the adopted Rational Method parameters to calculate the 100 year ARI discharge for the Devlin Creek catchment at the location of interest.

Table 6.4 Devlin Creek Rational Method Parameters

Rational Method Parameters	
Catchment Area (km^2)	231
Hydraulic Radius (m)	1.47
Average Manning's n	0.05
Stream Length (km)	32
Slope (%)	0.1
Time of Concentration (hours)	19.2
100 Yr ARI Rainfall Intensity at t_c (mm/hr)	12.4
100 Yr ARI Runoff Coefficient (C)	0.66
100 Yr ARI Discharge (m^3/s)	**524**

6.6.3 Flood Frequency Analysis

The methodology recommended in Australian Rainfall and Runoff (IEAust, 1987) was used to fit a Log-Pearson Type III distribution to an annual series of recorded peak flood discharges for Devlin Creek at Bombandy (130412A). Table 6.5 shows recorded peak annual flood discharges at Bombandy. The flood frequency analysis (FFA) results, including the 5% and 95% confidence limits for a range of design discharges are given in Table 6.6. Figure 6.2 shows the plot of the historical peak flows together with the adopted flood frequency distribution. The following is of note with regards to the flood frequency analysis:

- The annual data is for water years (October – September).
- No recorded annual peak series data was available for Bombandy prior to 1971 or after 1988. Hence the flood frequency distribution is based on 17 years of data. As such, the uncertainty in the estimates for large events, such as the 100 year is high.

The estimated 100 year ARI discharge at Bombandy is 552m³/s, which is similar to the Rational Method estimate of 524m³/s at the downstream Codrilla lease boundary, even though the catchment area to Bombandy is about 5 times larger. This apparent inconsistency may reflect the high level of uncertainty in the FFA results due to the short period of recorded data, or the characteristics of the catchment were overbank storage volumes are very large, which significantly reduce peak discharges during large flood events.

Table 6.5 Recorded Peak Flood Discharges, Devlin Creek at Bombandy

Water Year	Peak Discharge (m^3/s)
1971/72	57
1972/73	59
1973/74	230
1974/75	99
1975/76	111
1976/77	80
1977/78	196
1978/79	214
1979/80	16
1980/81	55
1981/82	13
1982/83	151
1983/84	16
1984/85	28
1985/86	44
1986/87	6
1987/88	270

Table 6.6 Flood Frequency Analysis, Devlin Creek at Bombandy

ARI Years	Estimated Peak Discharge (m^3/s)		
	95% Confidence Limit	Estimated Value	5% Confidence Limit
2	40	65	107
10	145	237	388
100	209	552	1458

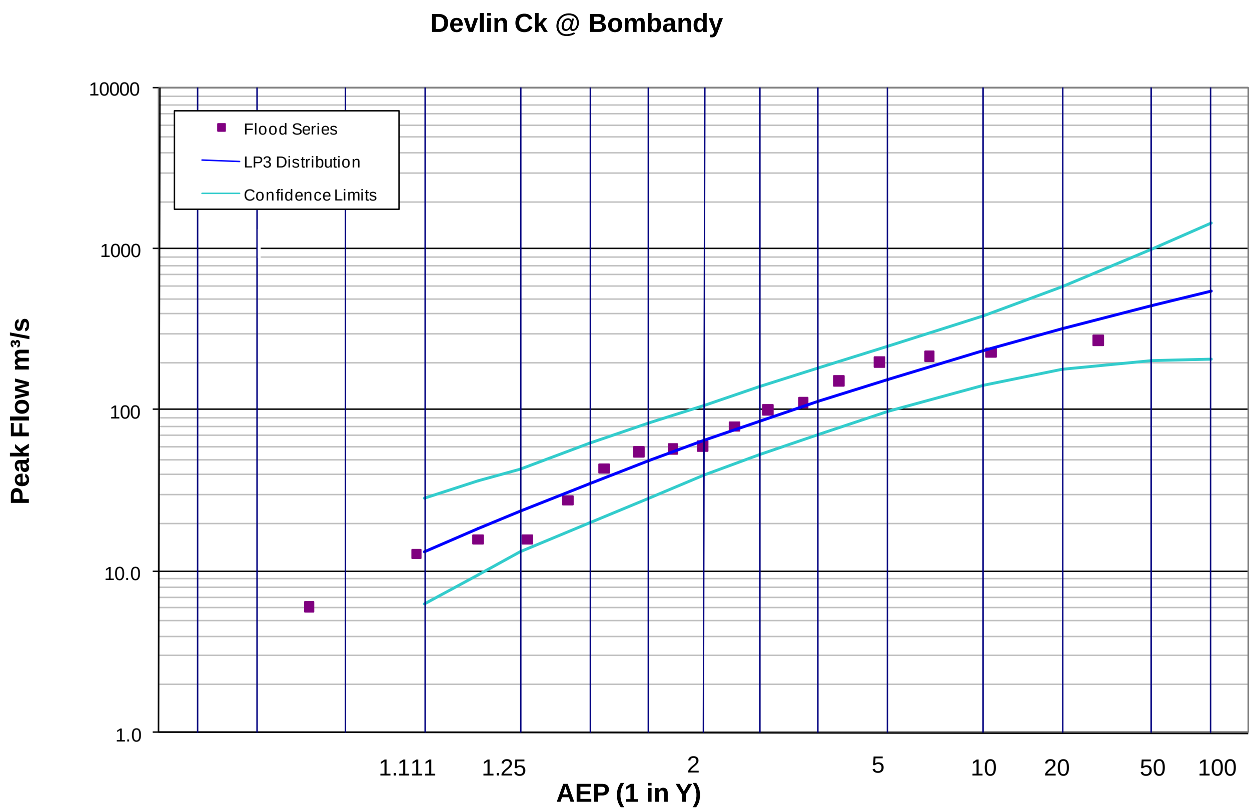

Figure 6.2 Flood Frequency Distribution, Devlin Creek at Bombandy

6.6.4 URBS Model Parameters

The adopted URBS parameters are shown in Table 6.7.

Table 6.7 Adopted URBS Model Global Parameters

Parameters	Value
Channel Lag Parameter – α	0.35
Catchment Lag Parameter – β	3.0
Catchment Non-Linearity Factor – m	0.8

The adopted initial and continuing losses for the various events, shown in Table 6.8, were selected to approximately match the URBS model discharges to the Rational Method discharge estimate and the FFA results.

Table 6.8 Adopted URBS Model Losses

Design Event (ARI Years)	Initial Loss (mm)	Continuing Loss (mm/hr)
2	60	2.5
10	40	2.5
100	20	2.5
2,000	20	2.5
PMP	0	0.0

6.7 ADOPTED DESIGN DISCHARGES

Table 6.9 shows the estimated peak design discharges at the downstream lease boundary. Matching the URBS model discharges to the FFA results for the larger catchment to Bombandy should provide a conservative estimation of design discharges at the Codrilla Project Site.

Table 6.9 Adopted Devlin Creek Design Discharges at Downstream Lease Boundary

Design Event (ARI Years)	Design Discharge (m^3/s)	Critical Duration (hours)
2	70	36
10	204	18
100	525	12
2,000	1078	18
PMP	3483	12

7 ASSESSMENT OF DEVLIN CREEK FLOOD IMPACTS

7.1 MODELLING OVERVIEW

A significant proportion of flood discharges along Devlin Creek flow across the floodplain and not within the main channel. To effectively simulate the movement of water across the floodplain, a TUFLOW two dimensional hydrodynamic model (WBM, 2008) of the Devlin Creek floodplain was developed. The model was used to estimate the 2 year, 10 year, 100 year and the 2,000 year ARI design flood levels, flood extents and flood velocities along Devlin Creek in vicinity of the proposed mining lease for both existing and developed conditions. The TUFLOW model was also used to assess the flood behaviour of the Probable Maximum Flood.

TUFLOW estimates flood levels on a fixed grid pattern by solving the full two-dimensional depth averaged momentum and continuity equations for free surface flow. The model automatically calculates breakout points and flow directions within the study area. It is also capable of linking with a one-dimensional model (ESTRY) to ensure accurate simulation of both in-bank and overbank flows. For this study, all structures and channels were modelled within the 2D domain.

No calibration data was available for the model. During a site visit in May 2009, anecdotal evidence was obtained relating to a water level over Fitzroy Developmental Road for an event that occurred in January or February 2008. There is no subdaily rainfall data available for the events in January and February 2008 and therefore it was not possible to estimate discharges or flood levels to compare against the anecdotal information.

7.2 TUFLOW MODEL CONFIGURATION

7.2.1 Existing Conditions Configuration

Figure 7.1 shows the spatial extent of the TUFLOW model for existing conditions for Devlin Creek in the vicinity of the proposed mining lease. The modelled study area covers approximately 2,800 ha and includes the Devlin Creek channel and overbank areas both upstream and downstream of the proposed disturbed areas. A 5m grid size and a 2 second time step were adopted for the two dimensional model area.

Ground level data was obtained from Airborne Laser Survey (ALS), due to the large area of the floodplain model. The ALS data was used to create a digital terrain model of the area. The ALS data was also used to define the Devlin Creek bed geometry, which was integrated into the TUFLOW model to ensure that the channel characteristics were properly defined and channel conveyance was maintained.

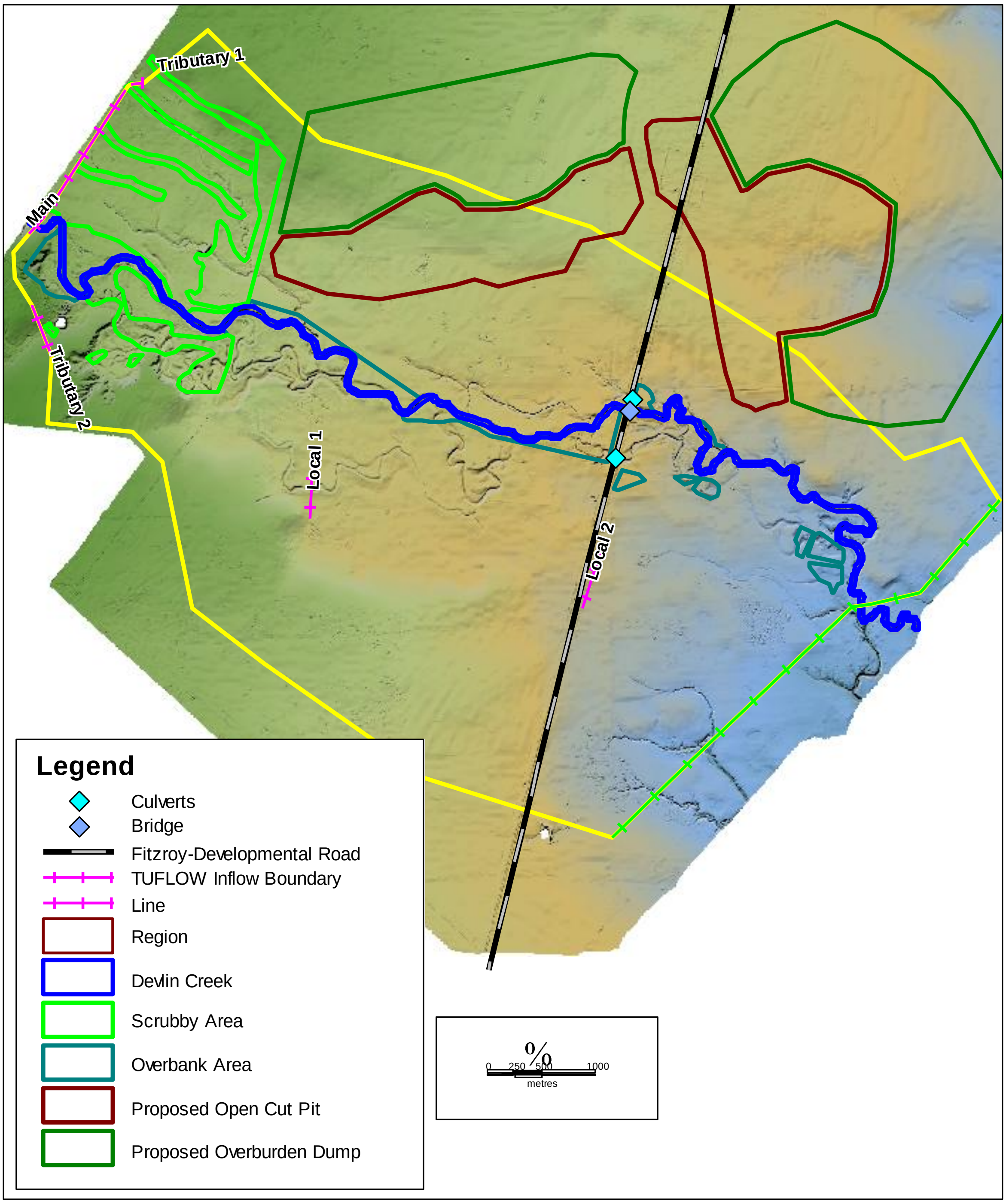

Figure 7.1 TUFLOW Model Configuration

7.2.2 Adopted Manning's 'n' Values

The TUFLOW model uses Manning's 'n' values to represent hydraulic resistance (notionally channel or floodplain roughness). In the absence of calibration data for the hydraulic model, Manning's 'n' values were selected based on typical published values (for example, those of Chow, 1959). The adopted Manning's n values are given in Table 7.1 and their extents are shown in Figure 7.1.

Table 7.1 Adopted Manning's 'n' values

Location	Adopted Manning's 'n'
Floodplain Area	0.040
River Channel	0.050
Overbank Area	0.045
Scrubby Area	0.070

7.2.3 Inflow and Outflow Boundaries

Figure 7.1 shows the locations of the inflow and outflow boundaries used in the TUFLOW model. Four inflow boundaries and one outflow boundary were used to convey water through the model. Table 7.2 shows the adopted peak design discharges at each of the inflow boundaries. The flood hydrographs (flow versus time relationship) were taken from the URBS model output.

A "TUFLOW" generated rating curve was adopted for the downstream boundary. An adopted hydraulic gradient of 0.1% (1m/1000m) was applied to the boundary based on the slope of the channel at the downstream end.

Table 7.2 Adopted Design Discharges at Inflow Boundaries

ARI (Years)	Discharge (m^3/s)				
	Main	Tributary 1	Tributary 2	Local 1	Local 2
2	54	6	11	10	8
10	157	15	30	31	23
100	320	28	58	61	45
2,000	810	67	140	141	104
PMF	2744	232	479	497	366

7.2.4 Existing Hydraulic Structures

Three hydraulic structures were included in the base model; the Fitzroy Developmental Road Bridge over Devlin Creek and two sets of existing drainage culverts underneath Fitzroy Developmental Road to the north and south of the bridge as shown in Figure 7.1. The Fitzroy Developmental Road Bridge was included as a 2D layered flow constriction within the 2D domain. This allowed for the different flow constrictions as flow passed the bridge that would be experienced as water levels changed over the course of an event. The culverts were included as 1D structures within the 2D domain. Table 7.3 shows the adopted configuration of these culverts.

Table 7.3 Fitzroy Developmental Road Culvert Data

Culvert Properties	Northern Culverts	Southern Culverts
U/S Invert Level	173.22m AHD	173.4m AHD
D/S Invert Level	173.12m AHD	173.4m AHD
Culvert Size	2.1m x 1.5m	1.20m x 0.90m
Number of Barrels	5	5

7.3 EXISTING FLOOD LEVELS

Figure 7.2, Figure 7.3, Figure 7.4 and Figure 7.5 show the 2 year, 10 year, 100 year and 2,000 year ARI design flood extents and depths for Devlin Creek in the vicinity of the proposed mine under existing conditions. The location of the proposed mine footprint and associated mine infrastructure is shown in Figure 2.1, Section 2. Figures B1 to B4 in Appendix B show the 2 year, 10 year, 100 year and 2,000 ARI design velocities in Devlin Creek, respectively. The following is of note.

- The 2 year ARI design flood is mostly contained within the Devlin Creek main channel and does not impact on the proposed mine footprint.
- The 10 year, 100 year and 2,000 year ARI design floods do not impact on the eastern pit and overburden dump of the proposed mine. However, proposed mine infrastructure on the eastern side of Fitzroy Developmental Road is subject to partial backwater flooding during all events of 100 year ARI and larger.
- The western end of the open cut pit is subject to partial backwater flooding during all events of 10 year ARI and larger. For the 100 year ARI flood event the maximum inundation depth within the pit footprint is approximately 1.4m.
- Flood plain velocities in the vicinity of the western pit and overburden dump range from approximately 0.1m/s to 0.9m/s for the 2 year to 2,000 year ARI flood events. Channel velocities in an unnamed tributary of Devlin Creek in the vicinity of the western pit and overburden dump range from approximately 0.5m/s to 1.1m/s for the 2 year to 2,000 year ARI flood events.
- Devlin Creek channel velocities range from approximately 0.8m/s to 2.5m/s upstream of Fitzroy Developmental Road and approximately 0.9m/s to 2.0m/s downstream of Fitzroy Developmental Road for the 2 year to 2,000 year ARI flood events.

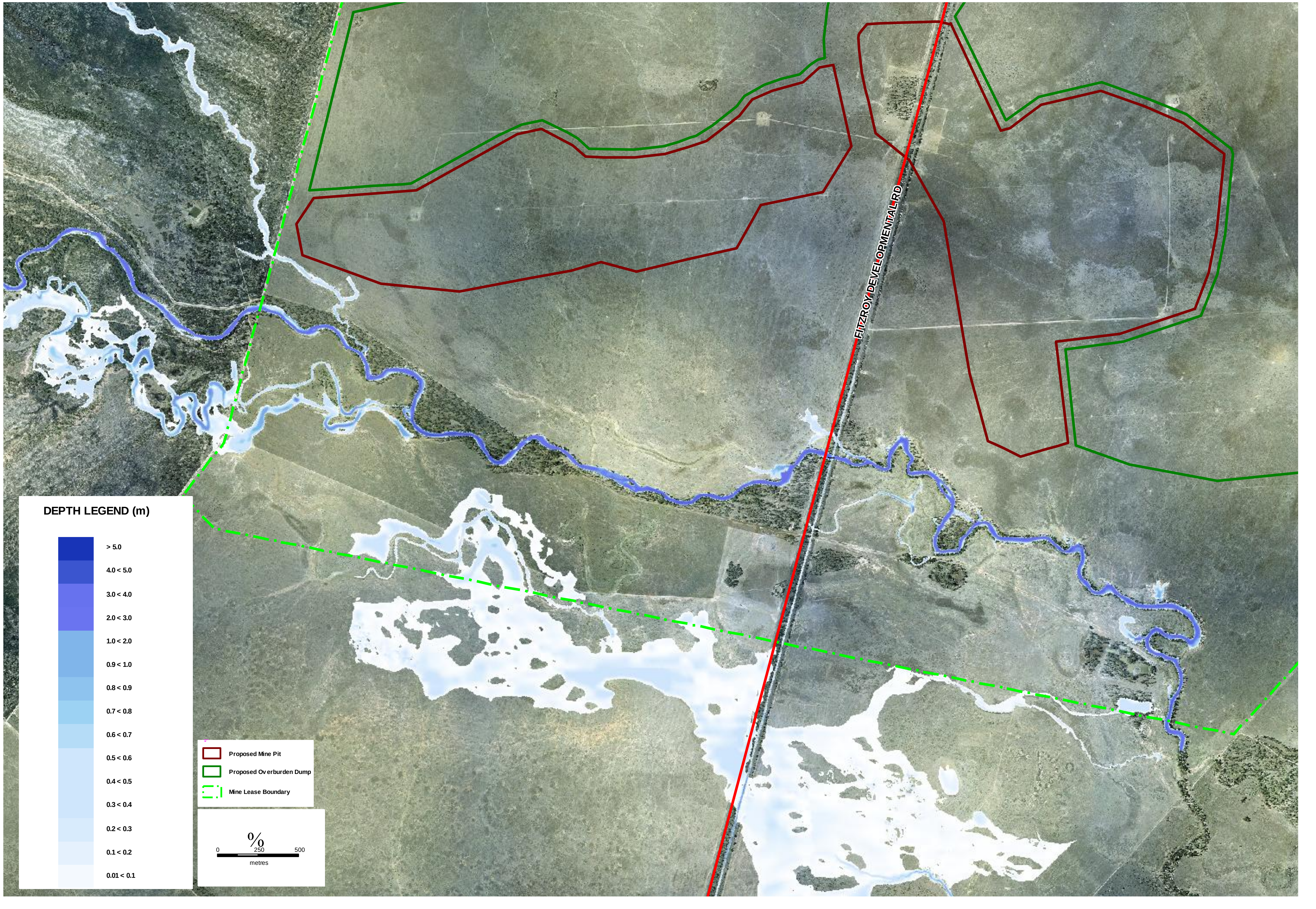

Figure 7.2 2 Year ARI Flood Depths, Devlin Creek

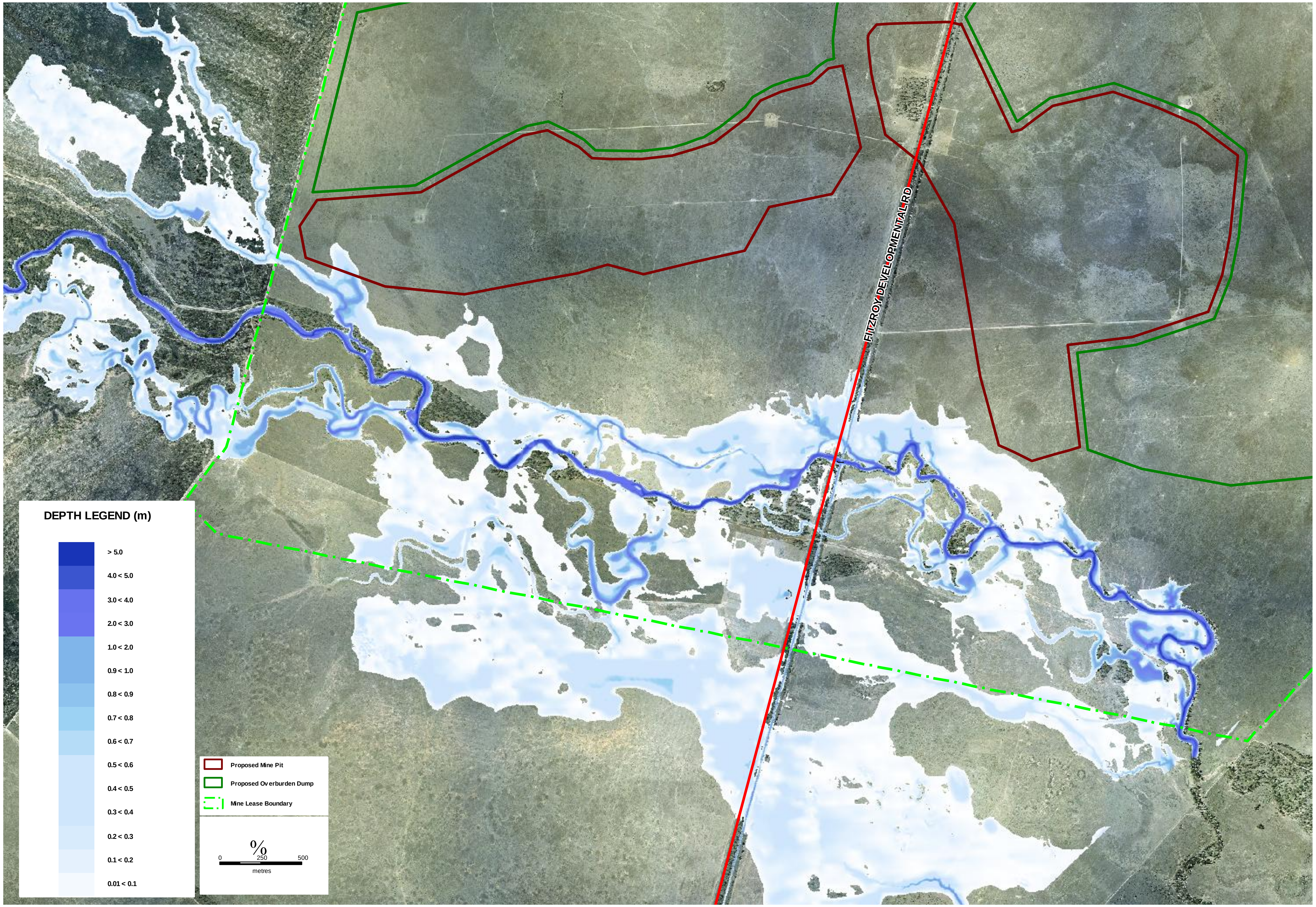

Figure 7.3 10 Year ARI Flood Depths, Devlin Creek

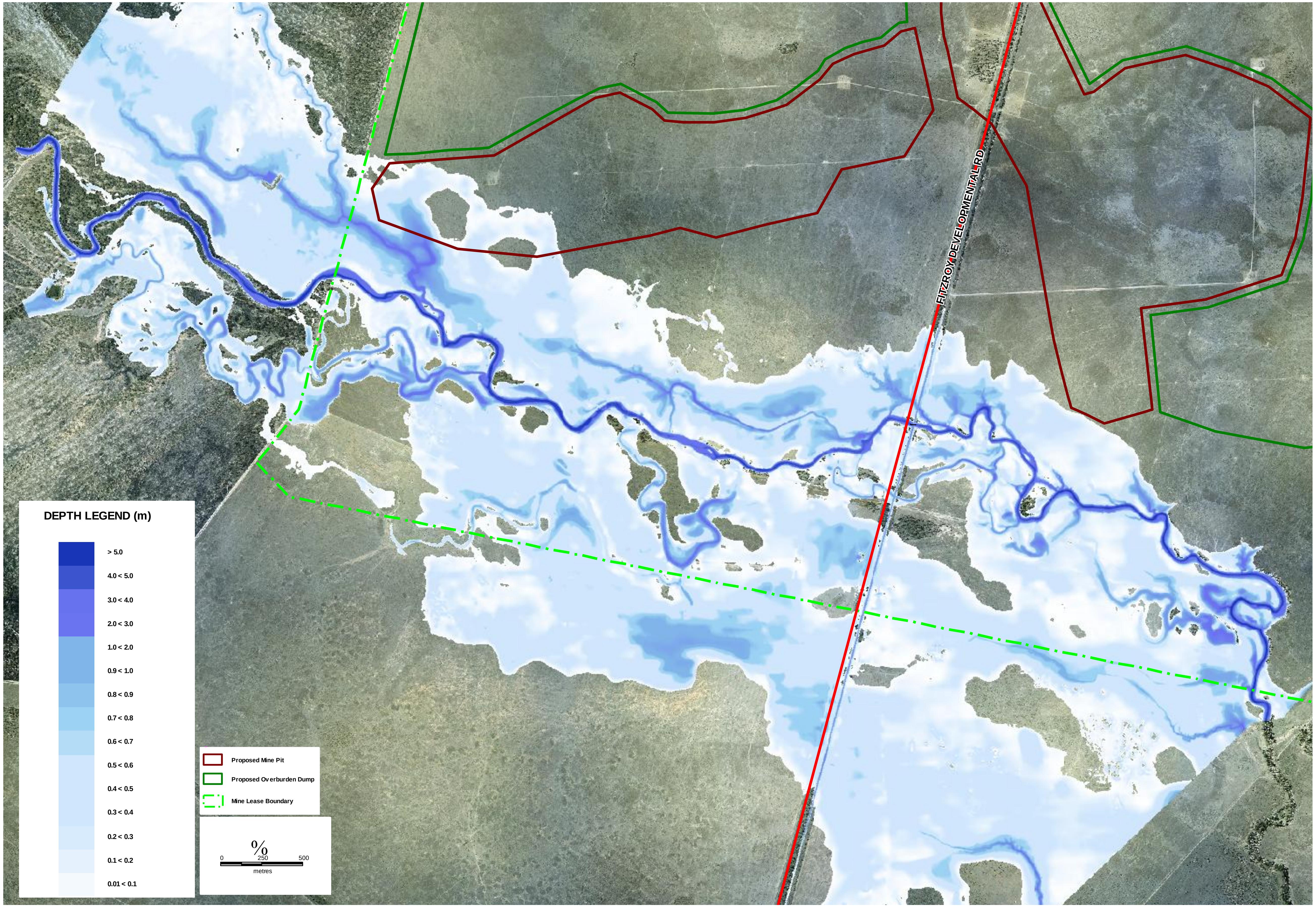

Figure 7.4 100 Year ARI Flood Depths, Devlin Creek

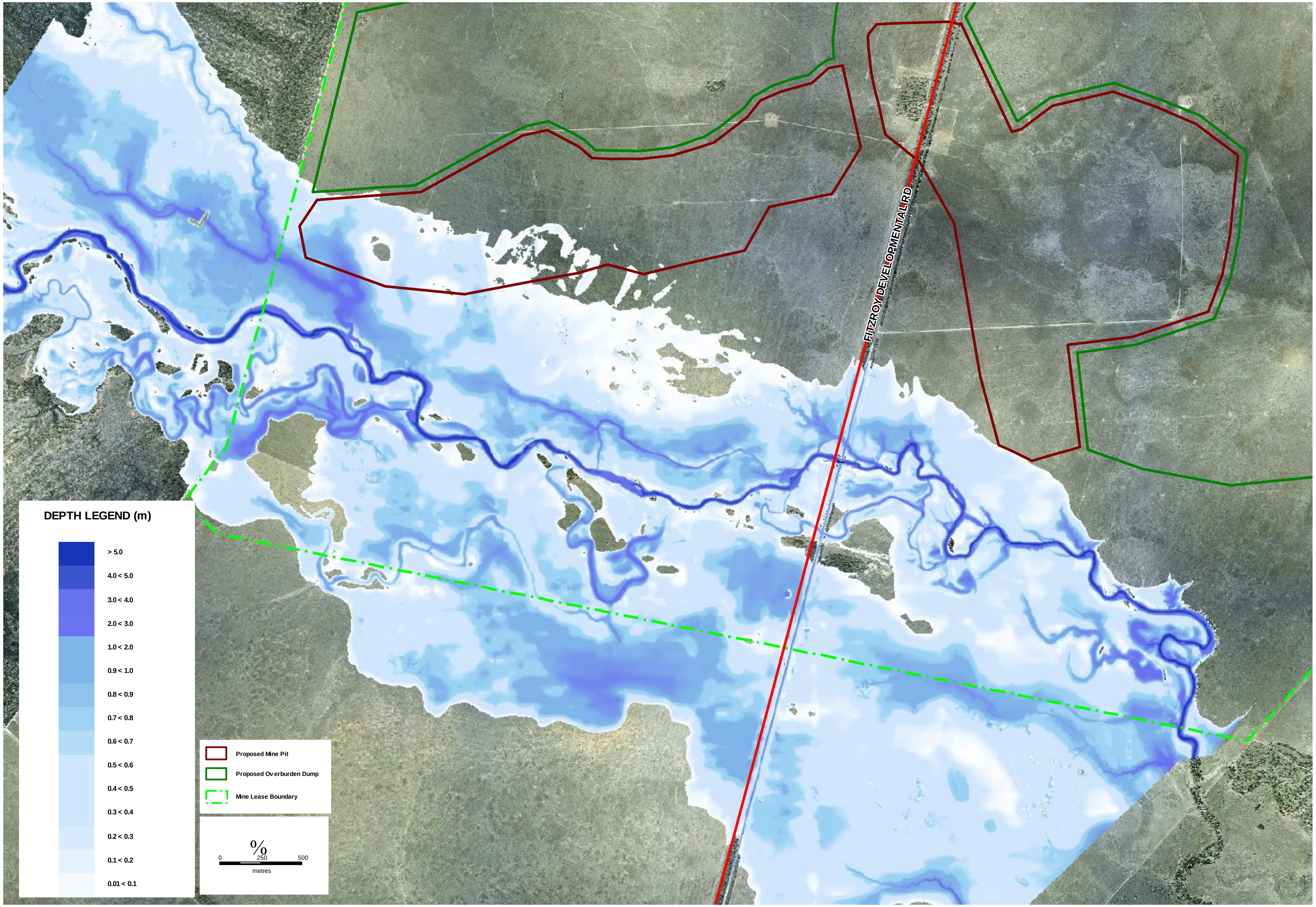

Figure 7.5 2,000 Year ARI Flood Depths, Devlin Creek

7.4 FLOOD IMPACTS OF THE PROPOSED MINE

Due to the very flat topography of the Devlin Creek floodplain, flow paths for local stormwater drainage are poorly defined. The flood and drainage behaviour of site runoff will be controlled by the design of proposed stormwater flow paths to be undertaken as part of infrastructure design.

Flood modelling results for Devlin Creek under existing conditions show that part of the western pit and some eastern mine infrastructure may be subject to some flood inundation for larger and extreme flood events.

A levee will be constructed to prevent flooding of the western pit and overburden dump and the eastern mine infrastructure. The levees were included in the TUFLOW model as Z-shape lines. The location of the levees is shown in Figures 7.6 to 7.9. The required elevation of the levee crests will be the 2,000 year ARI flood level plus 0.5m (about 180.1m AHD to 182.3m AHD for the western levee and 174.1m AHD to 175.7m AHD).The height of the levee crests above ground level is generally of the order of 0.7m, with a maximum height of about 7m in a topographical depression near the western levee.

Figure 7.6, Figure 7.7, Figure 7.8 and Figure 7.9 show the change in the 2 year, 10 year, 100 year and 2,000 year ARI design flood depths for Devlin Creek under proposed mining conditions, including the construction of a levee to protect the proposed mine infrastructure. Table 7.5 shows the change in flood depths at various locations in the vicinity of the proposed levees. Figures B5 – B8 in Appendix B show the change in flood velocities for the 2 year, 10 year, 100 year and 2,000 year ARI design floods in Devlin Creek, respectively. The following is of note:

- The proposed levees prevent the inundation of the western pit and overburden dump and proposed mine infrastructure.
- The 2 year ARI design flood does not impact on the proposed mine. Therefore there is no change in flood depths resulting form the construction of the levees.
- There are no significant changes to flood depths for the 10 year ARI design flood resulting from the construction of the proposed levee. Any increases in flood level are limited to 0.1m.
- There are minor increases in flood depths for the 100 year ARI design flood resulting from the construction of the proposed levees. The flood depths have increased by a maximum of 0.2m and are concentrated near the upstream side of the western levee.
- There are localised increases in flood depth for the 2,000 year ARI design flood resulting from the construction of the proposed levees. The majority of the increases are less than 0.4m however, there is a small area immediately upstream of the proposed western levee where flood depths have increased by over 0.4m.
- There is no significant change in flood velocities in Devlin Creek for the 2 year, 10 year, 100 year and 2,000 year ARI design floods as a result of the proposed levee. There are some increases in flood velocities (up to 0.5m/s for the 2,000 year ARI flood event) in the area surrounding the proposed levees.
- The flood impacts of the proposed mine are isolated to the area immediately adjacent to the proposed open cut pits. The development will have no impact on regional flooding in waterways downstream of the mining lease.

Table 7.4 Change in Flood Depth, Various Locations around the Proposed Levees

Location	Ground Elevation (m AHD)	Event											
		2 Year ARI			10 Year ARI			100 Year ARI			2,000 Year ARI		
		Existing Flood Depth (m)	Developed Flood Depth (m)	Difference (m)	Existing Flood Depth (m)	Developed Flood Depth (m)	Difference (m)	Existing Flood Depth (m)	Developed Flood Depth (m)	Difference (m)	Existing Flood Depth (m)	Developed Flood Depth (m)	Difference (m)
A	178.97	0.45	0.45	0.00	1.00	1.01	0.01	1.99	2.11	0.12	2.38	2.60	0.22
B	178.64	0.16	0.16	0.00	1.21	1.22	0.01	2.03	2.05	0.02	2.34	2.37	0.03
C	176.42	-	-	-	0.74	0.74	0.00	1.48	1.48	0.00	1.74	1.74	0.00
D	172.14	3.11	3.11	0.00	3.95	3.95	0.00	4.06	4.06	0.00	4.15	4.15	0.00
E	174.86	-	-	-	-	-	-	0.16	0.16	0.00	0.29	0.29	0.00
F	170.30	2.92	2.92	0.00	4.00	4.00	0.00	4.30	4.30	0.00	4.41	4.41	0.00
G	173.58	-	-	-	0.10	0.11	0.01	0.25	0.25	0.00	0.32	0.32	0.00

- Not inundated

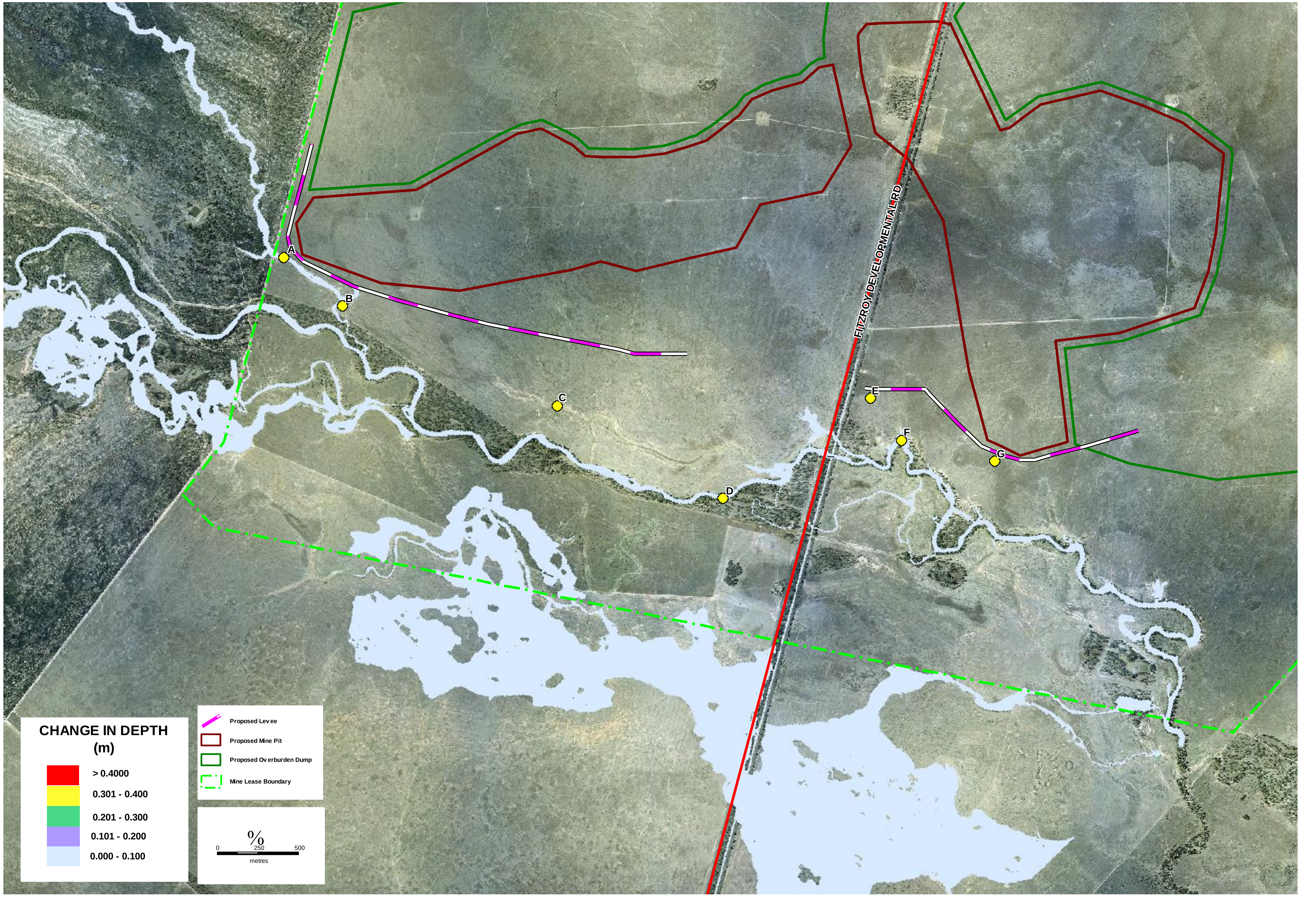

Figure 7.6 Change in Flood Depth, 2 Year ARI, Devlin Creek

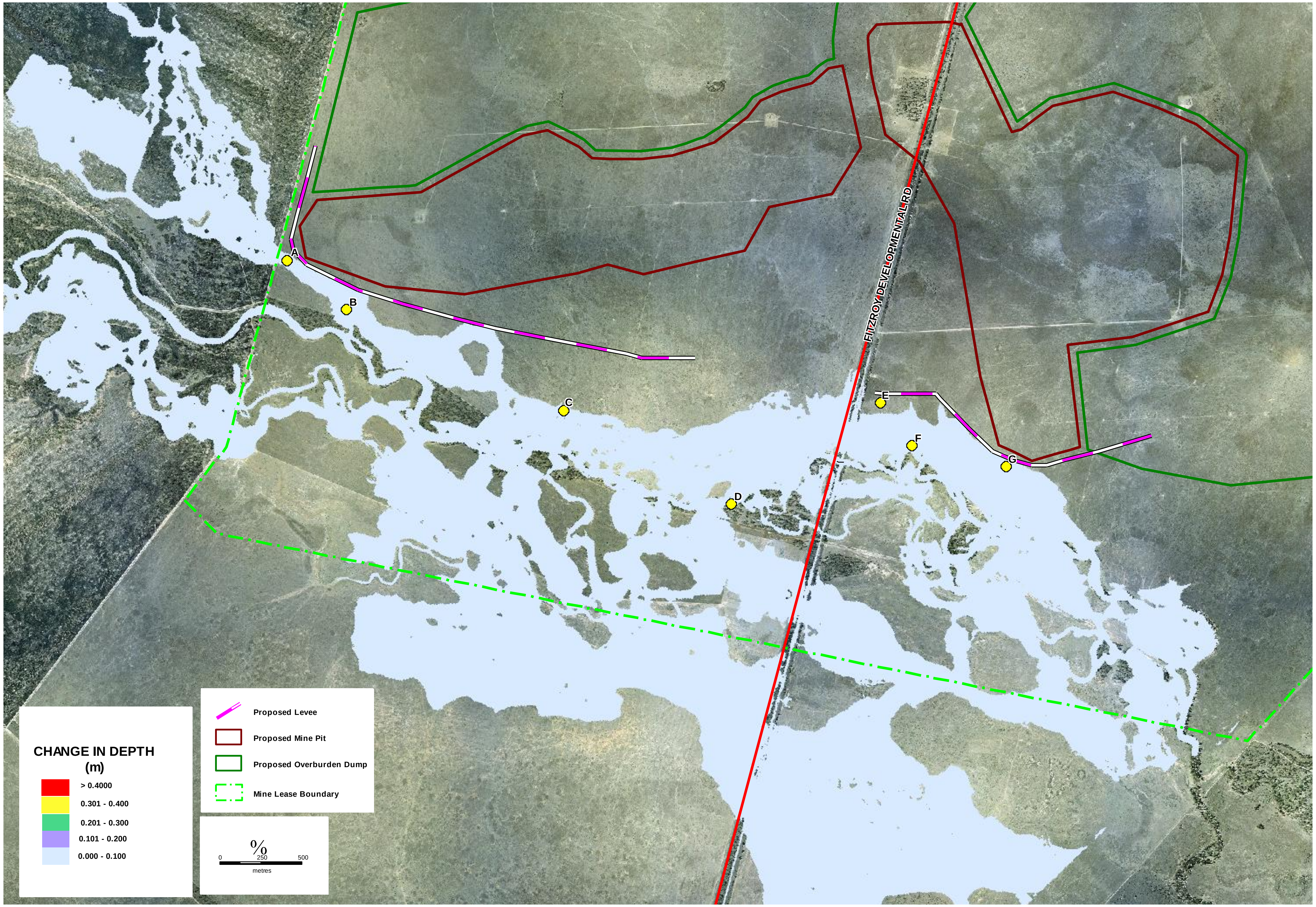

Figure 7.7 Change in Flood Depth, 10 Year ARI, Devlin Creek

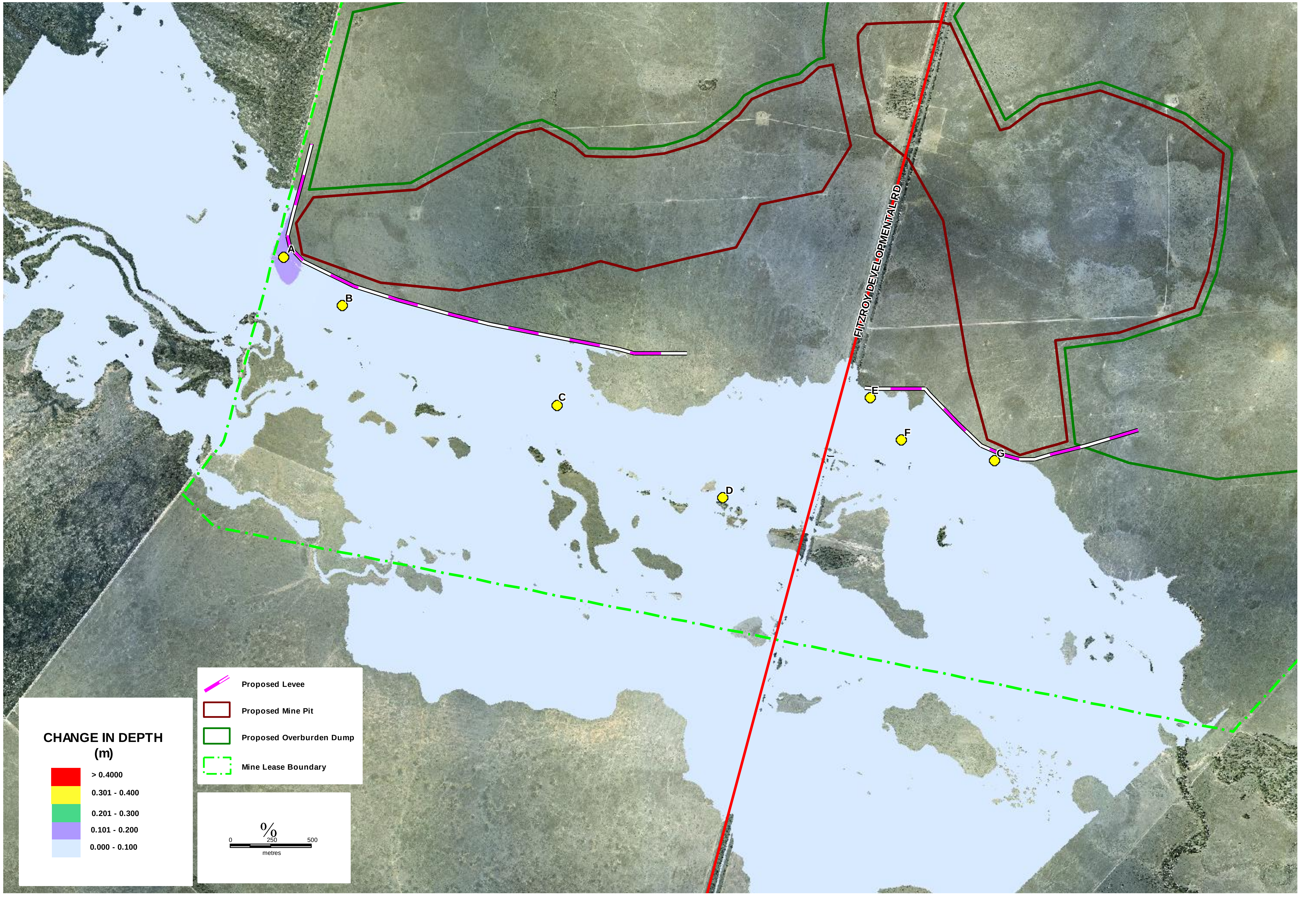

Figure 7.8 Change in Flood Depth, 100 Year ARI, Devlin Creek

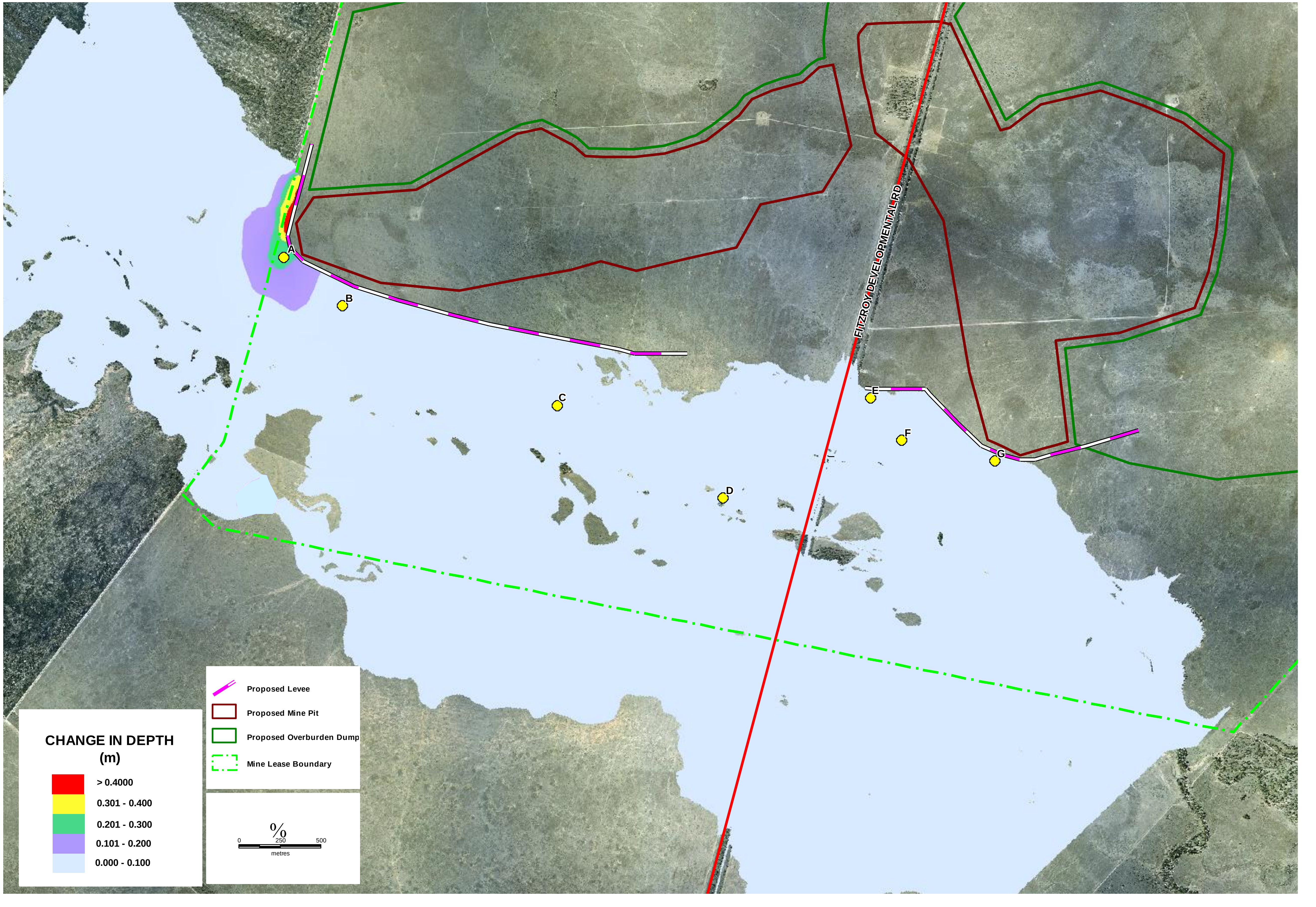

Figure 7.9 Change in Flood Depth, 2,000 Year ARI, Devlin Creek

7.5 PROBABLE MAXIMUM FLOOD

Figure7.10 shows the Probable Maximum Flood (PMF) levels along Devlin Creek adjacent to the proposed mine. PMF levels range from approximately 0.5m higher than the 2,000 year ARI flood levels to a maximum of 1.5m higher than the 2,000 year ARI flood levels.

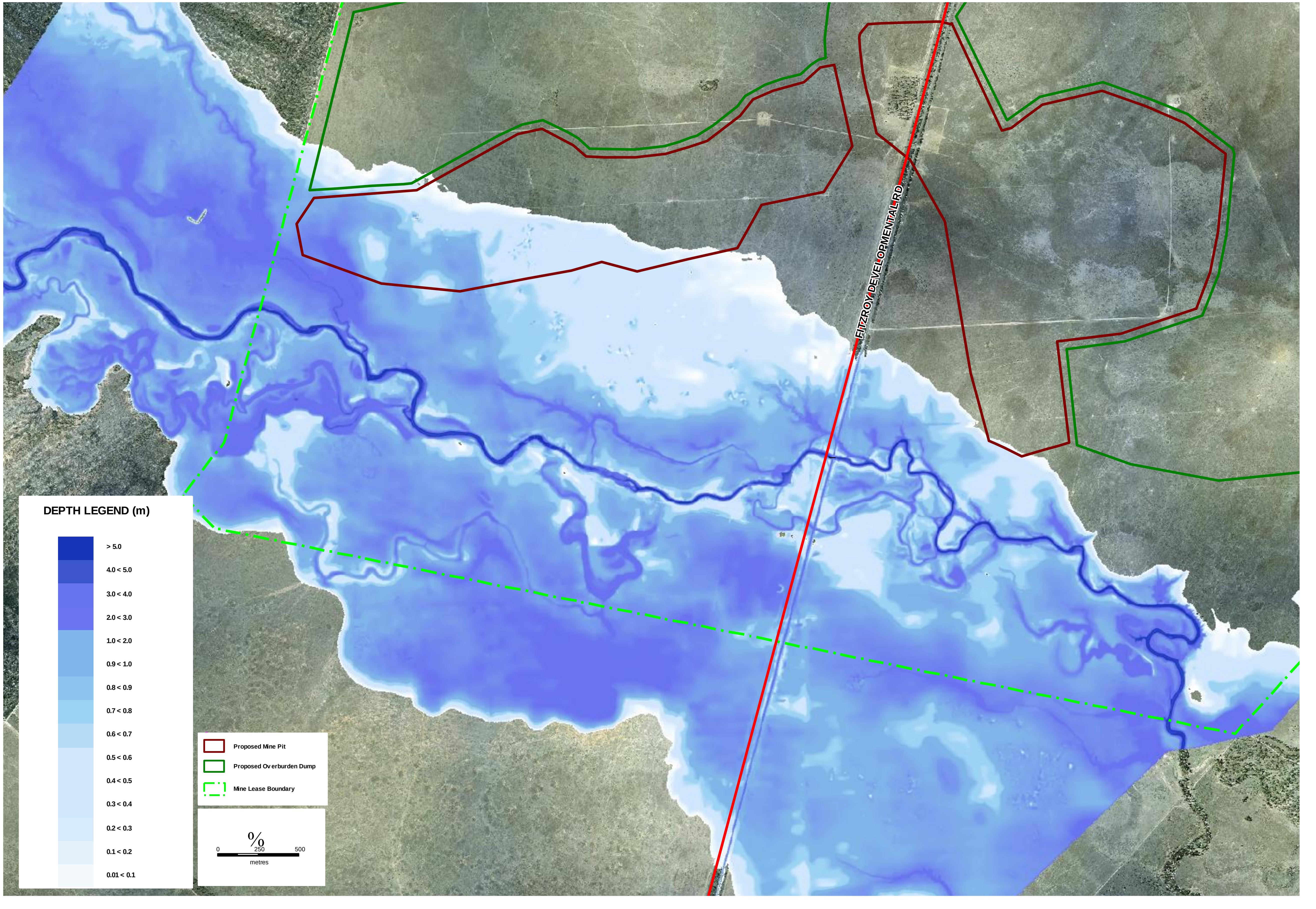

Figure 7.10 Probable Maximum Flood Depths, Devlin Creek

8 SITE WATER BALANCE

8.1 OVERVIEW

The proposed operations will significantly change the characteristics of the minor drainage paths crossing the mining area. A water management system has been devised for the project to separate clean water runoff from surface water that is affected by mining operations. A site water balance modelling study has been undertaken to confirm the effectiveness of the system in limiting off site discharge, and to quantify the impacts on drainage behaviour. A daily timestep GoldSIM model of the site catchments and water management system was developed to make this assessment on the basis of historical climate data.

It is important to understand how the system will perform under the wettest and driest sequences of historical climate record. The model was run for 98 fourteen-year sequences spanning the period 1900 to 2010 (the first being 1900-1913, and the last being 1997-2010). Each sequence represented the mining operation, notionally operating from Jan 2013 to December 2026.

Due to the potential uncertainties in the catchment runoff characteristics, two model cases were used in the assessment:

- High runoff (runoff parameters were selected such that they tend to overestimate catchment runoff). These parameters were used to demonstrate the water management system can reliably contain site runoff even when conservative assumptions are adopted.
- Low runoff (runoff parameters were selected such that they represent the “best estimate” of catchment runoff). These parameters were used to quantify the impact of the project on downstream flows, and for investigating the potential for site water yield to supplement water supplies.

8.2 MODELLED STAGING OF MINE PLAN

The Project has been modelled in five stages, which represent the evolution of the mine layout over time:

- Stage 1 2013 to 2014 (Eastern Pit only) – Macarthur Coal Stage 2 (Year 2)
- Stage 2 2015 to 2020 (Eastern Pit only) – Macarthur Coal Stage 4 (Years 5-6)
- Stage 3 2021 to 2022 (Eastern Pit only) – Macarthur Coal Stage 6 (Years 9-10)
- Stage 4 2023 (Western Pit only) – Macarthur Coal Stage 7 (Year 11)
- Stage 5 2024 to 2027 (Western Pit only) – Macarthur Coal Stage 8 (Years 12-14)

The conceptual water management system layouts at each stage of the project are shown in Figure 8.1 to Figure 8.5. The system is also shown schematically in the diagram in Figure 8.6.

The WMS comprises 2 discrete systems:

1. A pit water system – which captures pit water and runoff from other areas where there is a risk of relatively poor quality runoff. Water is pumped to the environmental dams and then to the Process Water Dam for reuse. Water captured in the Pit Water system is used in preference to the other water sources to reduce the risk of discharge.
2. A sediment dam water system – water captured in the sediment dams is returned to a separate Process Water Dam for reuse.

The following is of note:

- The model does not specifically model the co-disposal system. The CHPP demand is the make-up requirement net of co-disposal return water
- Runoff from undisturbed areas will generally be diverted around the operational areas where possible. Runoff from disturbed areas will be captured in the site water management system.
- If storage water quality and receiving water conditions allow, excess water could potentially be discharged from the site in a controlled manner (but this is has not been modelled).
- During exceptionally wet periods later in the mine life, excess water can be temporarily stored in the Eastern Pit Void.
- Early in the mine life, a temporary pit water dam (ED4) will be provided in the future Western Pit mining area. The dam will receive excess pit water from the Eastern Pit, which is relatively large. The dam will be located to ensure that the Western Pit can be safely mined while the dam is being operated and decommissioned.

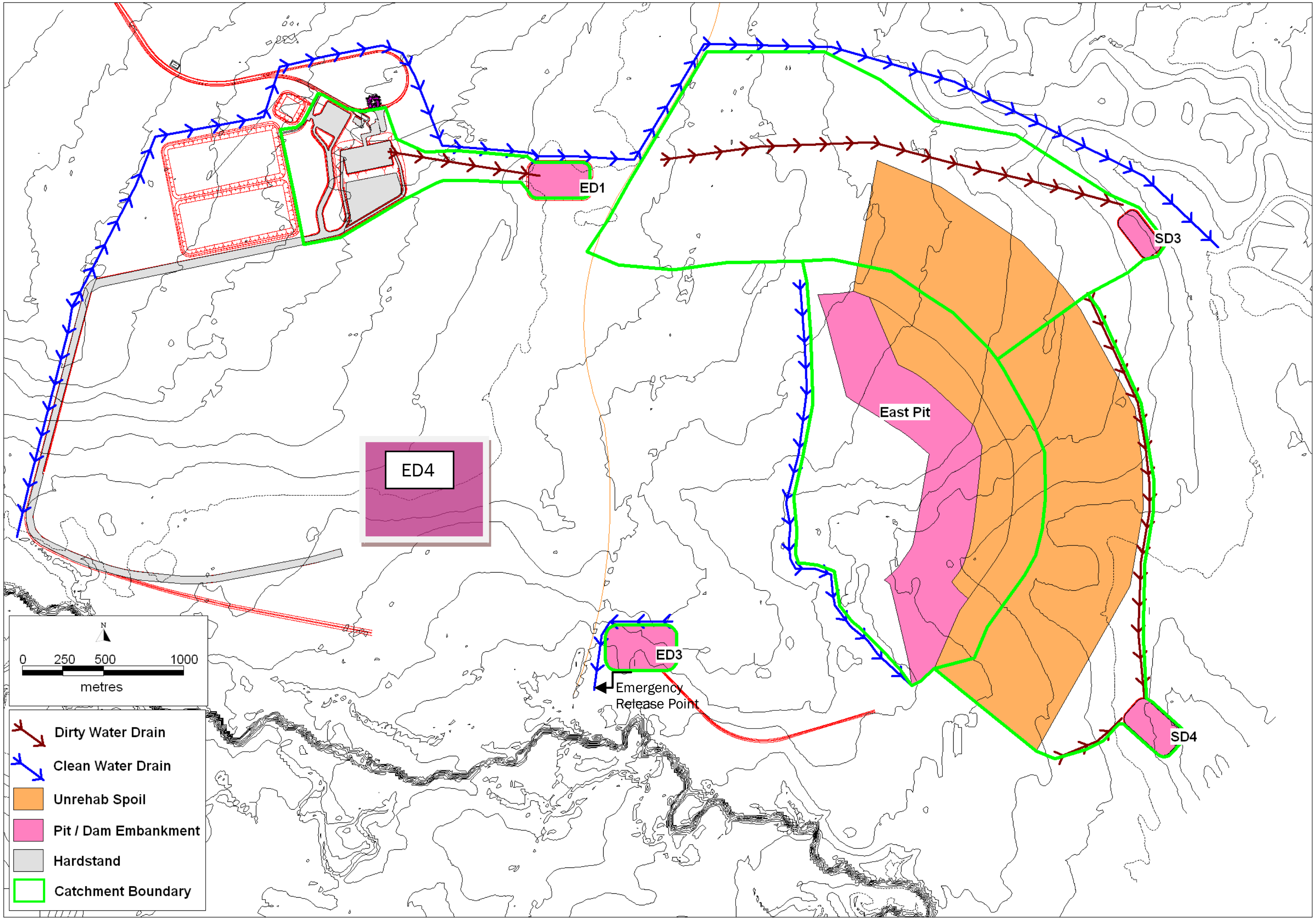

Figure 8.1 Codrilla Coal Project, Stage 1 (2013 to 2014)

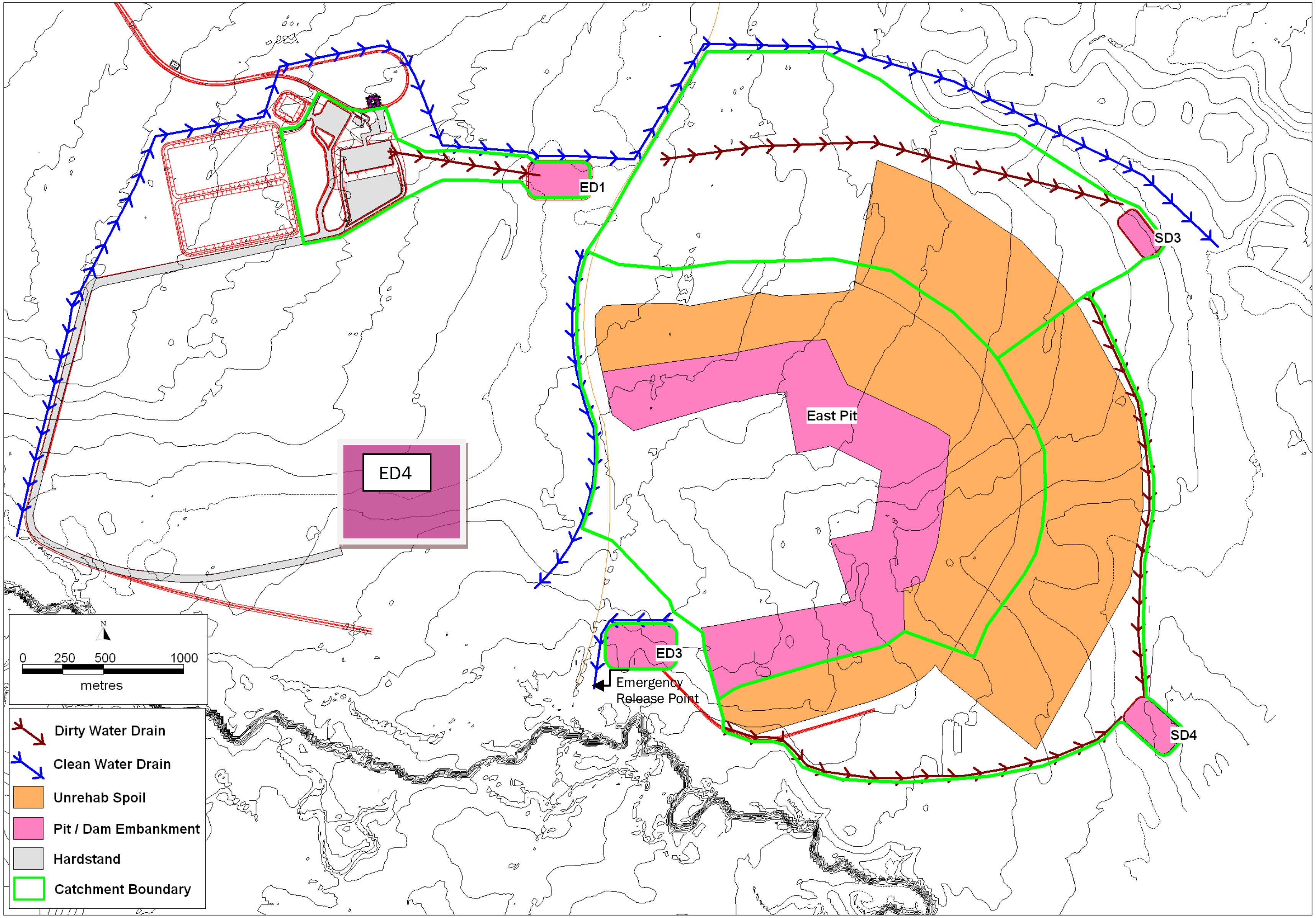

Figure 8.2 Codrilla Coal Project, Stage 2 (2015 to 2020)

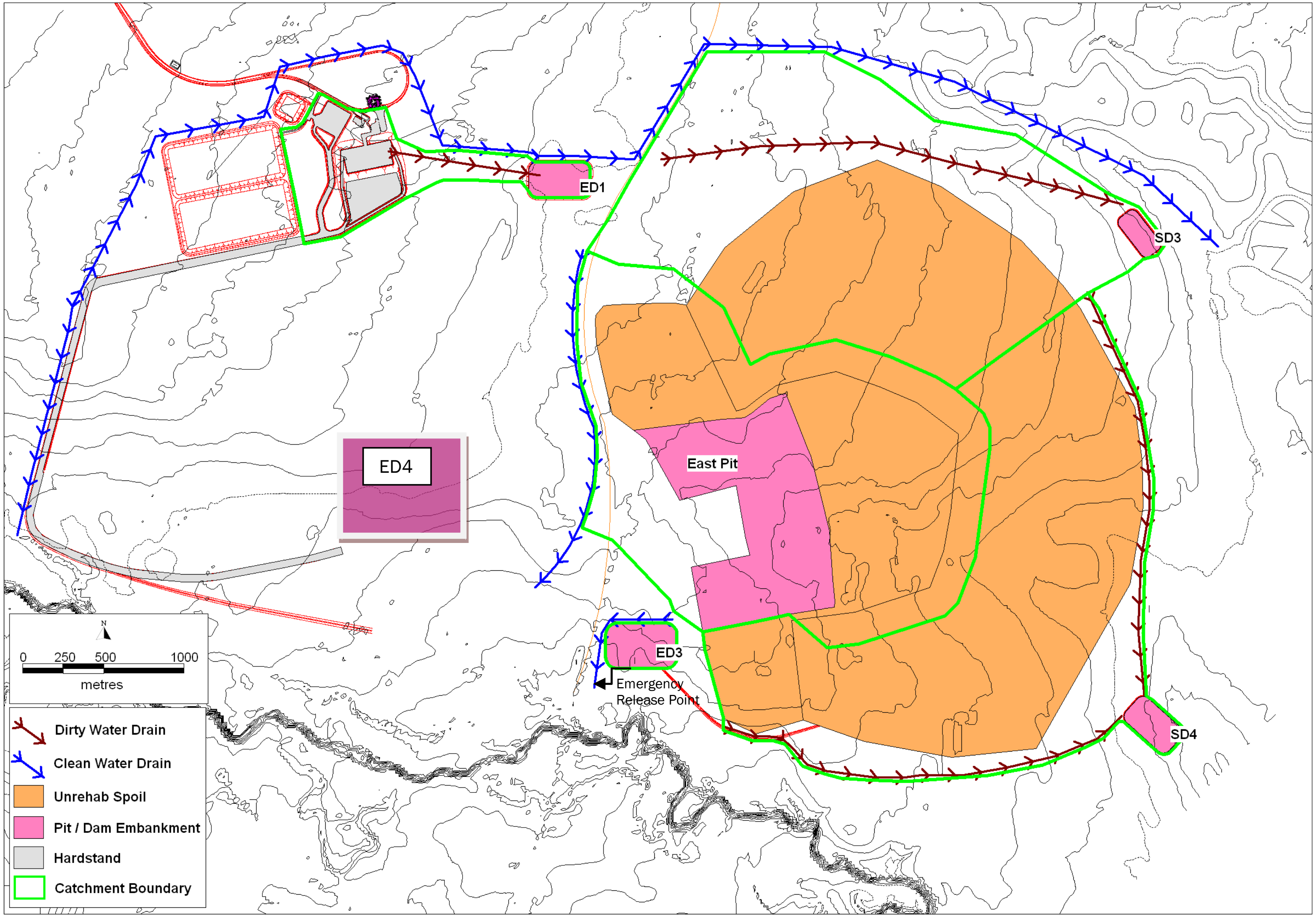

Figure 8.3 Codrilla Coal Project, Stage 3 (2021 to 2022)

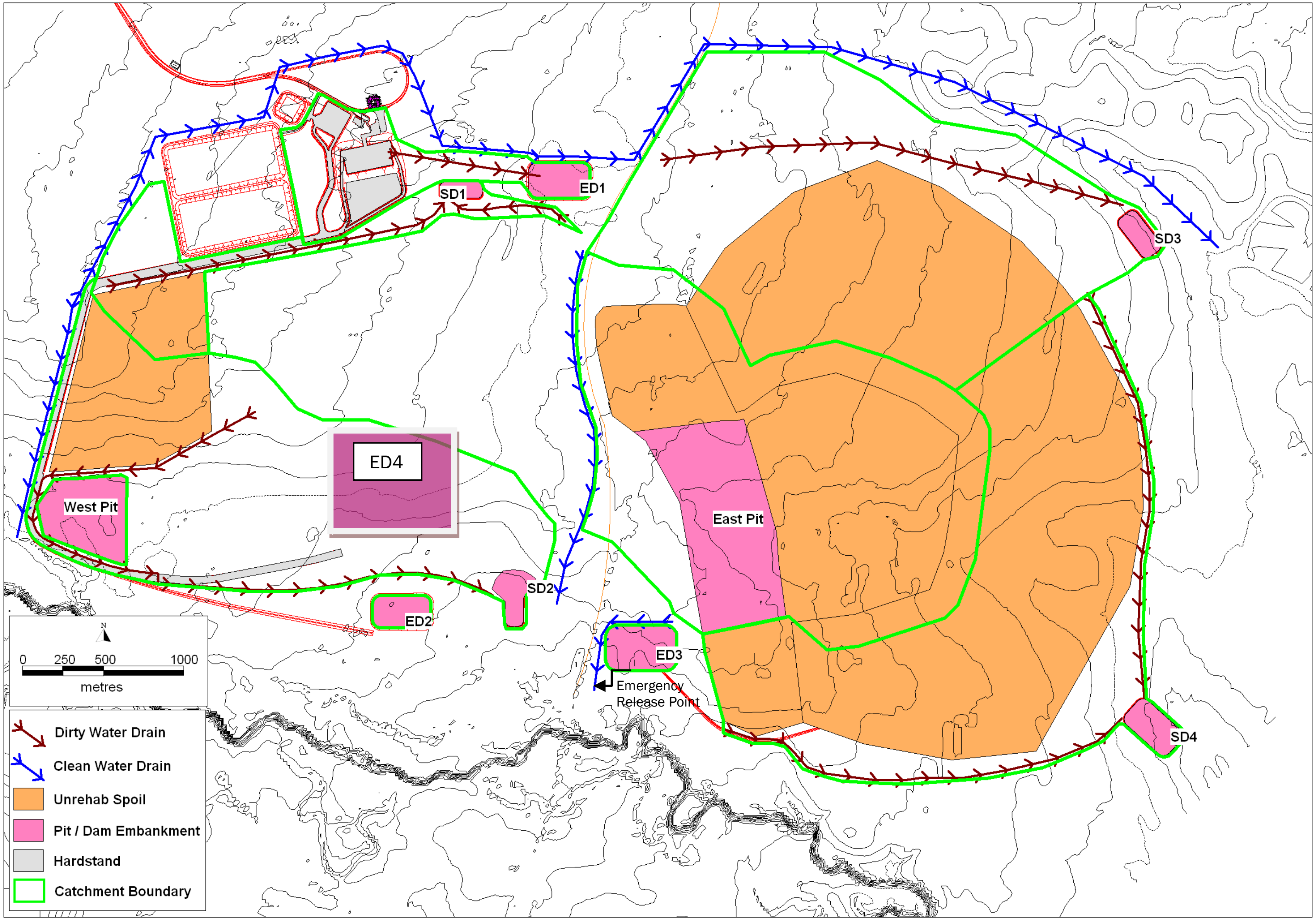

Figure 8.4 Codrilla Coal Project, Stage 4 (2023)

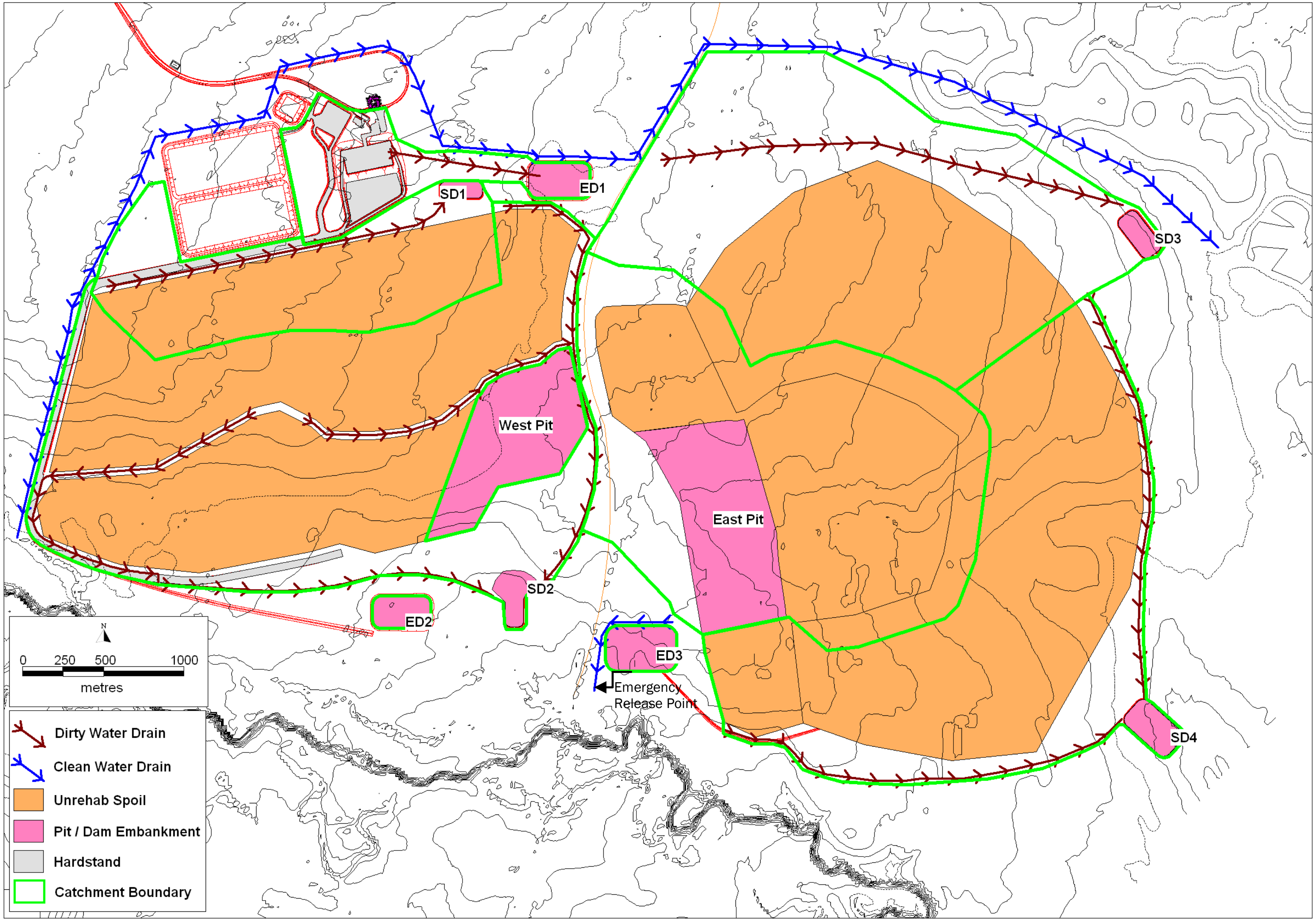

Figure 8.5 Codrilla Coal Project, Stage 5 (2024 to 2027)

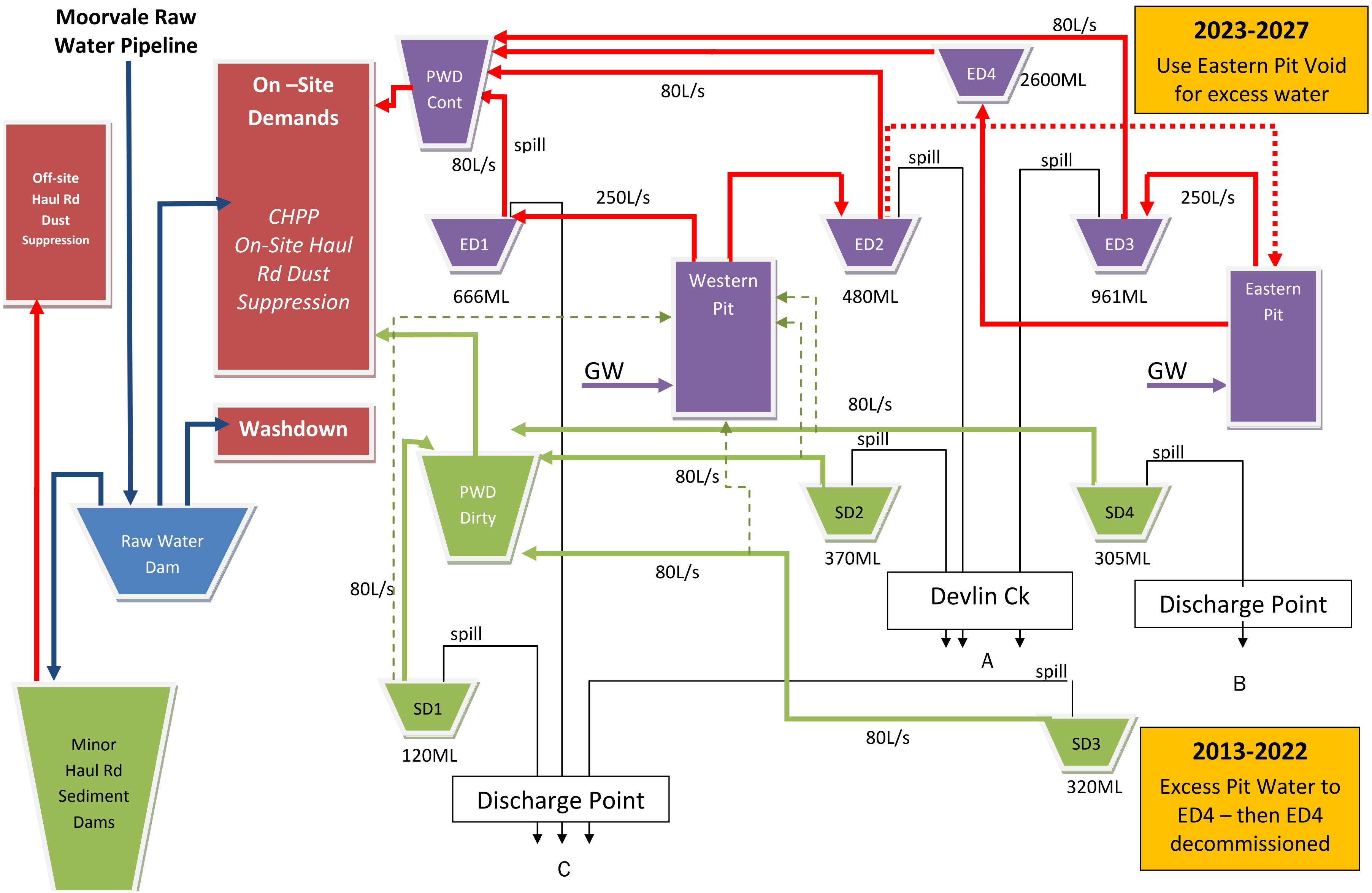

Figure 8.6 WMS Schematic Diagram

8.3 CATCHMENT AREAS

Each dam captures runoff from various catchment types. Catchments across the site were characterised into the following types:

- Undisturbed;
- Unrehabilitated spoil;
- Pit Floor;
- Hardstand Areas.

The areas reporting to each of the dams will change as the site develops. The breakup of catchment types at the end of the project life (Stage 5) are summarised in Table 8.1. The total catchment areas for each stage of mine production are given in Table 8.2.

Table 8.1 Site Catchment Areas and Types (Stage 5)

Storage	Catchment Area (ha)				
	Undisturbed	Unrehabilitated Spoil	Pit Floor	Hardstand	TOTAL
SD1	38.2	115.9	2.5	6.6	163.2
SD2	123.5	362.4	5.5	15.8	507.2
SD3	237.5	196.6	4.1	0.0	438.2
SD4	80.1	328	7.0	0.0	415.1
ED1	44.6	0.0	8.2	20.7	73.5
ED2	0.0	0.0	7.0	0.0	7.0
ED3	0.0	0.0	11.9	0.0	11.9
ED4	0.0	0.0	7.0	0.0	7.0
East Pit	72.7	284.3	71.3	0.0	428.3
West Pit	0.0	0.0	57.6	0.0	57.6
Sediment Return Water Dam	0.0	0.0	7.0	0.0	7.0
Pit Return Water Dam	0.0	0.0	7.0	0.0	7.0

Table 8.2 Total Catchment Areas

Storage	Total Catchment Area (ha)				
	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
SD1	0.0	0.0	0.0	78.6	163.3
SD2	0.0	0.0	0.0	337.1	507.2
SD3	353.5	353.5	438.2	438.2	438.2
SD4	216.1	329.5	415.1	415.1	415.1
ED1	73.5	73.5	73.5	73.5	73.5
ED2	0.0	0.0	0.0	7.0	7.0
ED3	11.9	11.9	11.9	11.9	11.9
ED4	7.0	7.0	7.0	7.0	0.0
East Pit	287.6	598.8	428.4	428.3	428.3
West Pit	0.0	0.0	0.0	23.7	57.6
Sediment Return Water Dam	7.0	7.0	7.0	7.0	7.0
Pit Return Water Dam	7.0	7.0	7.0	7.0	7.0

8.4 CLIMATE DATA AND RAINFALL-RUNOFF MODEL

In the absence of long-term records for the project area - site-specific climate data (daily rainfall, Morton's lake evaporation and Potential Evapotranspiration calculated using the FAO Penman-Monteith formula) for the model was obtained from DERM's Data Drill service.

> The Data Drill *"accesses grids of data derived by interpolating the Bureau of Meteorology's station records. Interpolations are calculated by splining and kriging techniques. The data in the Data Drill are all synthetic; there are no original meteorological station data left in the calculated grid fields. However, the Data Drill does have the advantage of being available for any set of coordinates in Australia" (Jeffrey et al., 2001).*

Catchment runoff was modelled using the AWBM rainfall-runoff model (Boughton, 2003). For undisturbed areas, the AWBM was calibrated to streamflow observations at the Devlin Creek at Bombandy streamflow gauge operated by DERM between 1971 and 1988 downstream of the site (see Figure 4.1). The catchment area to this gauge is 1,026km^2. The median annual runoff over the modelled period is approximately 23.6mm/a, or 4.2% of median annual rainfall (mean annual runoff is 5.6% of mean annual rainfall).

AWBM parameters for other catchment types were derived from previous modelling experience, and were generally selected to be consistent with the parameters adopted in the latest update of the Moorvale and Coppabella Mine water balance models.

Table 8.3 AWBM Model Calibration Results – Devlin Creek at Bombandy

Description	Recorded 1971-88	Calculated 1971-88
Total Number of Days	6,336	6,336
Number of Flow Days	981	994
Mean Annual Runoff Co-efficient (%)	5.6	5.7

Table 8.4 Adopted AWBM Model Parameters – Low Runoff

Model Parameter	Undisturbed	Unrehabilitated Spoil	Pit Floor	Hardstand
A1	0.02	0.02	0.1	0.1
A2	0.195	0.195	0.9	0.9
BFI	0.00	0.00	0	0.9
C1	10.0	10.0	12	8
C2	40	40	38	13.5
C3	420	420	0	0
K_{base}	0.00	0.00	1	0
K_{surf}	0.16	0.16	0	0.1
Median Annual Runoff (mm/a)	24	24	68	151
Mean Annual Runoff ((mm/a)	55	55	119	199

Table 8.5 Adopted AWBM Model Parameters – High Runoff

Model Parameter	Undisturbed	Unrehabilitated Spoil	Pit Floor	Hardstand
A1	0.02	0.1	0.1	0.1
A2	0.195	0.9	0.9	0.9
BFI	0.00	0.9	0	0.9
C1	5	12	12	8
C2	20	21	38	13.5
C3	210	0	0	0
K_{base}	0.00	0.7	1	0
K_{surf}	0.16	0.16	0	0.1
Median Annual Runoff (mm/a)	39	114	68	151
Mean Annual Runoff (mm/a)	83	163	119	199

8.5 PIT GROUNDWATER INFLOWS

Pit groundwater inflow estimates were obtained from the AGE groundwater report addendum (AGE, 2011, P10.) The report presents simulated pit seepage derived from numerical groundwater modelling of the intersected aquifers. The report notes that these are likely to be conservative overestimates of groundwater seepage rates. The results are presented in Figure 8.7 below.

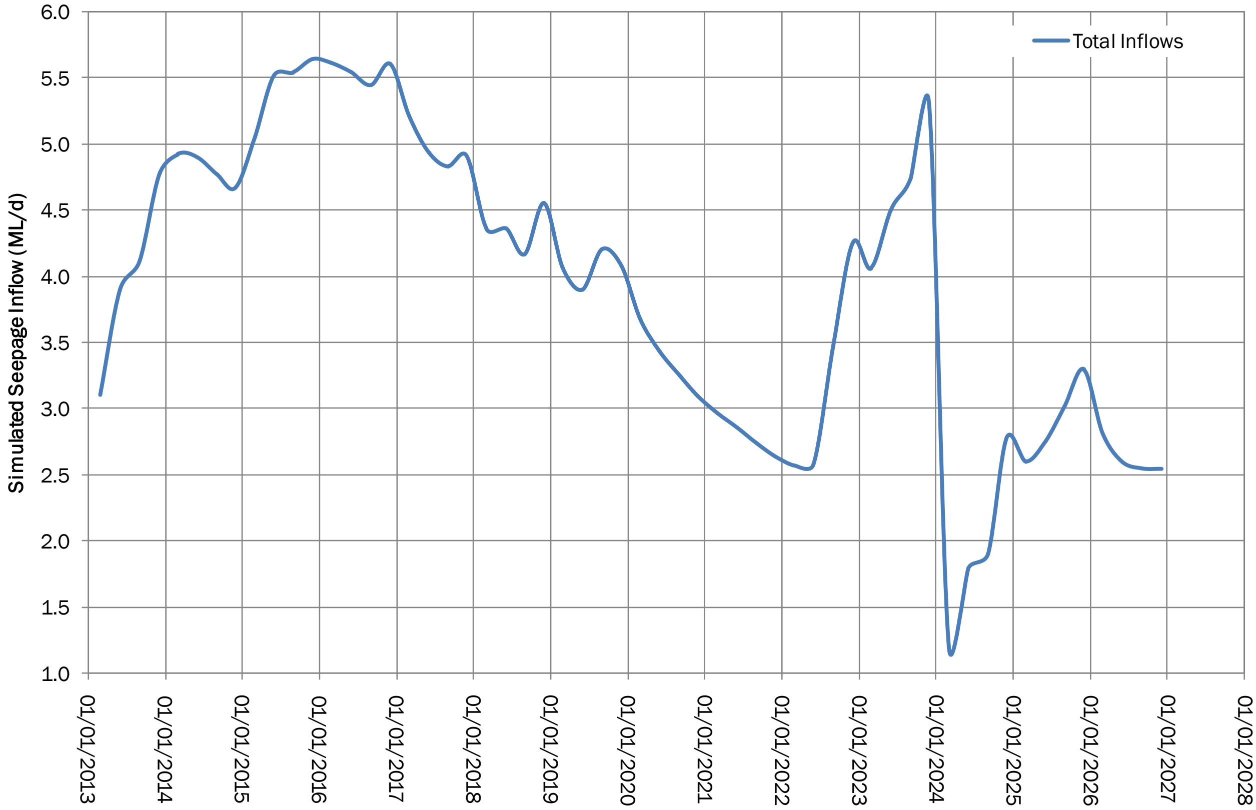

Figure 8.7 Simulated Groundwater Seepage (after AGE, 2010)

The AGE report (AGE, 2010) noted that in-pit groundwater inflows will be smaller due to losses from evaporation and coal extraction on the basis of the following conceptual model:

Inflow = Simulated Seepage
- Evaporation Rate (mm/d)*(500m length of face * 14m height of face)
- entrained loses to mining (1.61ML/d))

This model was incorporated into the GoldSim Model – as shown In Figure 8.8 below. Despite losses to evaporation and coal extraction, this results in some significant groundwater inflows when seepage rates are highest.

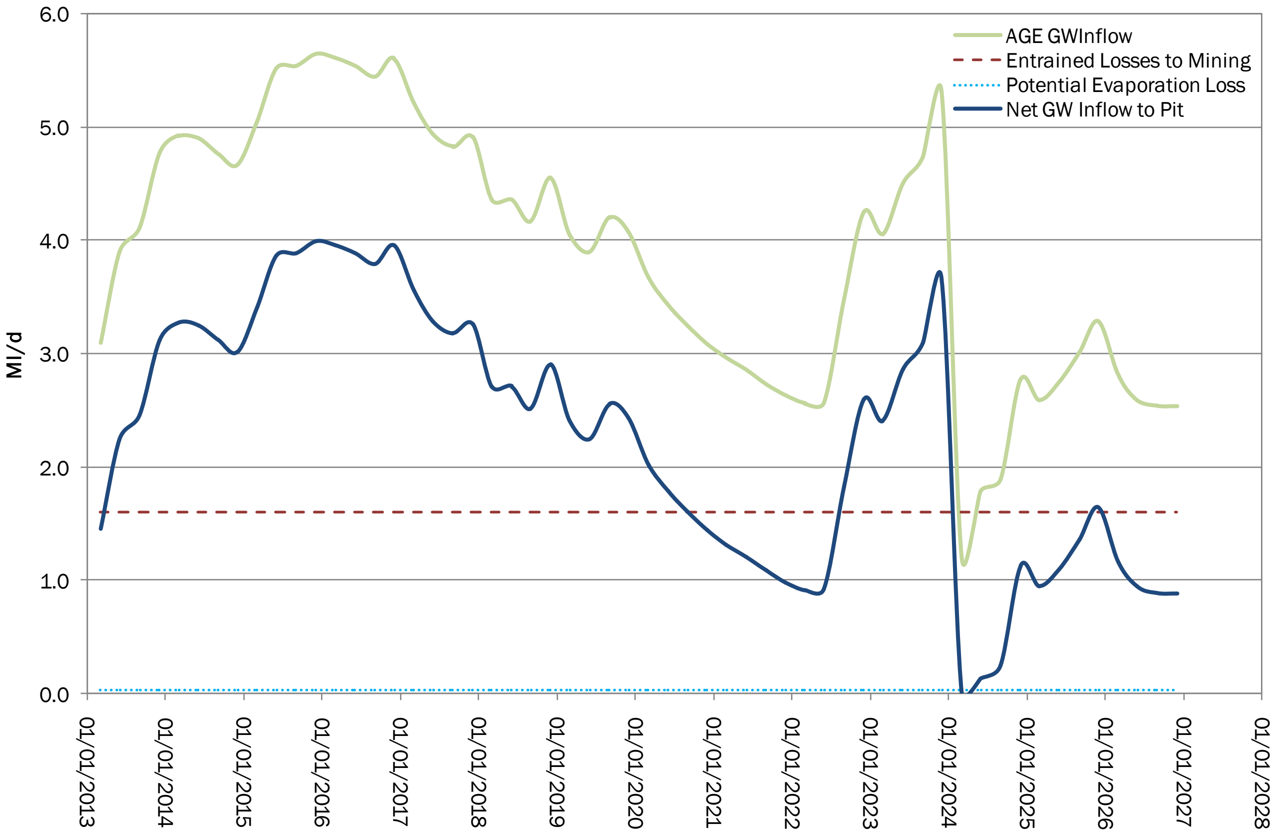

Figure 8.8 Net Pit Groundwater Inflow

8.6 ENVIRONMENTAL DAM AND SEDIMENT DAM SIZES

The capacities of the site water management dams are summarised in the table below. Sediment Dams have been sized to contain runoff from a 10 year ARI 24 hour rainfall event (with a volumetric runoff coefficient of 0.5).

Table 8.6 Dam Capacities

Sediment Dam	Capacity (ML)	Environmental Dam	Capacity (ML)
SD1	120	**ED1**	666
SD2	370	**ED2**	480
SD3	320	**ED3**	961
SD4	305	**ED4**	2600

With the exception of ED1, all environmental dams will have minimal external catchment.

8.7 OPERATING RULES

8.7.1 Pit Water System

Each of the environmental dams is to be operated such that a minimum operating freeboard is maintained under normal operating conditions. A conservative operational freeboard allowance (the runoff from the 100 year ARI 3 month wet season rainfall with a runoff coefficient of 1) was adopted for operation of the dams. The freeboard allowances are summarised in Table 8.7.

Table 8.7 Pit Water Management System Operating Volumes (ML)

Volume Component	ED1	ED2	ED3	ED4	Pit Return Water Dam
Total Capacity	666	480	961	2600	150
Operational Freeboard Allowance	412	61	103	61	91
Max Operational Volume (MOV)	254	419	858	2539	59

The following operating rules were applied to the pit dewatering system:

- Any water accumulating in the pits is immediately pumped to an environmental dam.

West Pit

- If the ED1 MOV is not exceeded - pump to ED1 until the MOV is reached;
- If the ED1 MOV is exceeded – pump to ED2;
- If the ED2 MOV is exceeded – cease pumping.

Pit dewatering capacity has been assumed to be 200L/s for each pump (i.e. a total of 400L/s).

East Pit

- If the ED1 MOV is not exceeded - pump to ED1 until the MOV is reached;
- If the ED4 MOV is not exceeded - pump to ED4 until the MOV is reached;
- If the ED1 MOV is exceeded – pump to ED3;
- If the ED3 MOV is exceeded – cease pumping.

Pit dewatering capacity has been assumed to be 200L/s for each pump (i.e. a total of 600L/s). All other pumps have been modelled as having a capacity of 80L/s. The incoming raw water pipeline from Moorvale was assumed to have a capacity of 76L/s.

8.7.2 Sediment Dam Collection System

Discharge water quality from sediment dams at other similar nearby operations can usually be expected to be within the licensed water quality discharge limits. However, Macarthur Coal wishes to limit the risk of discharge occurring without significant receiving water flows. To achieve this, excess sediment dam water will be pumped to the plant area for reuse or to the Eastern Pit void (once mining there ceases at the end of Stage 3).

The following operating rules were applied to the Sediment Dam collection system:

- Each sediment dam is to be operated such that as soon as water accumulates in them it is returned to the plant area for reuse;
- If the Sediment Return Water Dam MOV is not exceeded - pump to Sediment Return Water Dam until the MOV is reached;
- If the Sediment Return Water Dam MOV is exceeded – cease pumping. If East Pit void is available, pump to East Pit void.

All pumps have been modelled as having a capacity of 80L/s (except pumps to PWD from SD2 and SD4 which have a capacity of 120L/s).

The operational water volumes for the sediment water collection system are summarised below.

Table 8.8 Sediment Water Management System Operating Volumes (ML)

Volume Component	SD1	SD2	SD3	SD4	Sediment Return Water Dam
Catchment Area (ha)	163.3	507.2	438.2	415.1	
Total Capacity	120	370	320	305	60
Operational Freeboard Allowance	0	0	0	0	35

8.8 SITE WATER DEMANDS

Most water demands can use water captured in either the pit water management system or sediment dam water. Dust suppression water demands will vary over the mine life due to the disturbed area increasing and climatic variability. The basis of the demand estimates is summarised in Table 8.9 below, note that:

- The dust suppression demand is averaged over the 13 year simulation.
- The total average demand of 2,187ML/a (based on a total of 28,431ML over the project life) is less than the final demand of approximately 2,296 ML/a near project end.

Table 8.9 Demand Summary

Item	Average Demand (ML/a)	Basis of Estimate
Vehicle washdown	90 (constant)	Drawn from raw water supplies only.
CHPP	896 (constant)	Based on 128m^3/h in DRA report 7,000 h/a (assumes 60% co-disposal recovery). Note this estimate includes ROM dust suppression requirements.
Out of Pit Overburden Dust Suppression	333 (varies)	**Nil if rainfall >5mm/d, Otherwise Area X 4mm/d** Dust modelling indicates that additional suppression may be required on the out of pit overburden dumps. However, dust suppression requirements are not well understood. For the purpose of the water balance model, an application rate of 2mm/d was applied to the last 500mx1000m of overburden dump.
Haul Road Dust Suppression	958 (varies)	In mine haul roads will be approximately 30m wide.
Internal Haul Roads		
Out-of-Pit Haul Roads	233 (varies)	**Nil if rainfall >5mm/d, Otherwise Area X 4mm/d** We have assumed out-of-pit haul roads will be 5km long for each pit.
In-Pit Haul Roads	44 (varies)	**Nil if rainfall >5mm/d, Otherwise Area X 2mm/d, Adopt** We have assumed in-pit haul roads will be 3km long each.
External Haul Road		
To Moorvale (varies)	682	**Nil if rainfall >5mm/d, Otherwise Area X 4mm/d, Adopt** Area extracted from the Lambert and Rehbein Drawings * 80%.

The areas adopted for the application of dust suppression water at each stage of mining is summarised in the table below.

Table 8.10 Areas adopted for dust suppression demand estimates

		Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
External Haul Road	Area (m^2)	511,000	511,000	511,000	511,000	511,000
Out of Pit Haul Road	Length (km)	10	10	10	5	5
	Area (m^2)	110,000	110,000	189,200	220,000	220,000
In Pit Haul Road	Length (km)	3	3	3	3	3
	Area (m^2)	66,000	66,000	66,000	66,000	66,000
Out of Pit Overburden	Area (m^2)	500,000	500,000	500,000	500,000	500,000

8.9 MODEL RESULTS

8.9.1 Pit Water Management System Performance

An example of the behaviour of the system is shown in Figure 8.9, which shows ED1 during the critical wet period commencing in 1982 under the high runoff scenario.

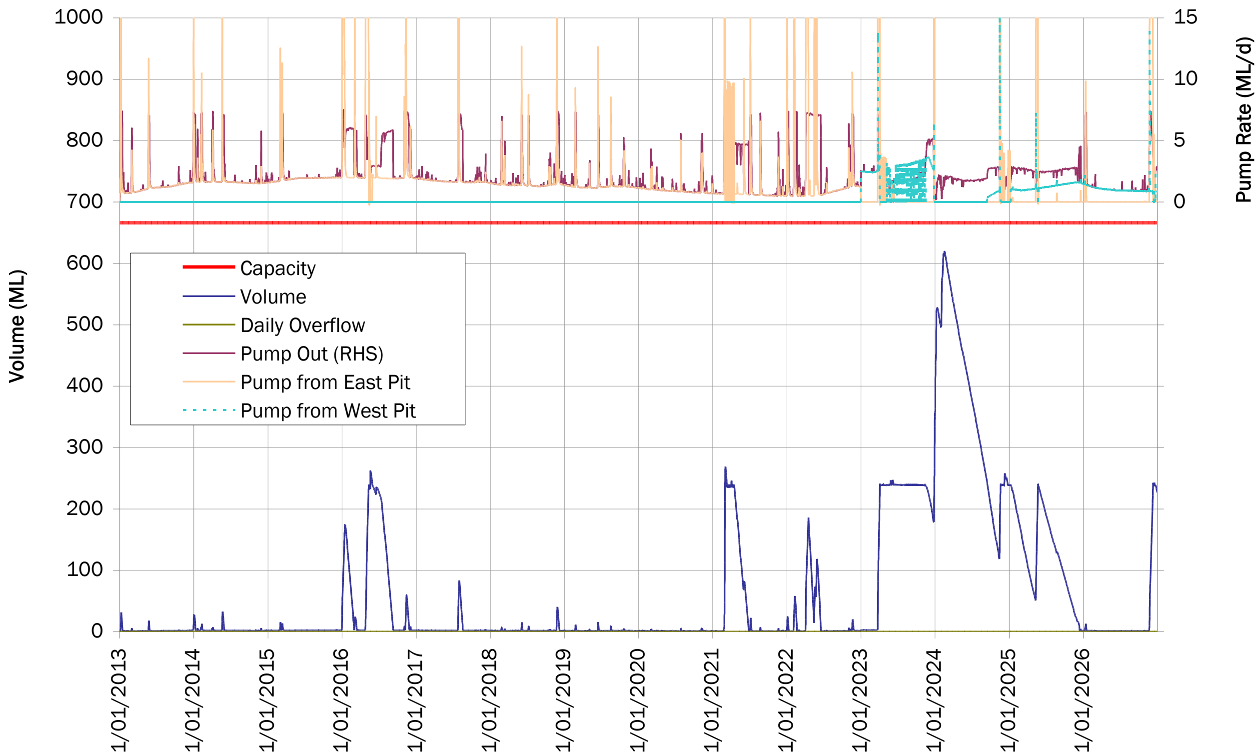

Figure 8.9 ED1 Behaviour – Project Commencing 1982 (High Runoff)

The results show that under the modelled historical conditions, the proposed pit water management system would not have discharged. The maximum stored water volumes are well within the total dam capacities. This is illustrated in Figure 8.10, below, which shows the probability of exceedance for the stored volume in each of the Environmental Dams, and Table 8.11, which compares the maximum modelled volumes to the storage capacities.

Table 8.11 Pit Water Management System Performance

	ED1	ED2	ED3	ED4	Pit Return Water Dam
Maximum Storage Volume (ML)	620	405	878	2,540	67
Design Capacity (ML)	666	480	961	2,600	150

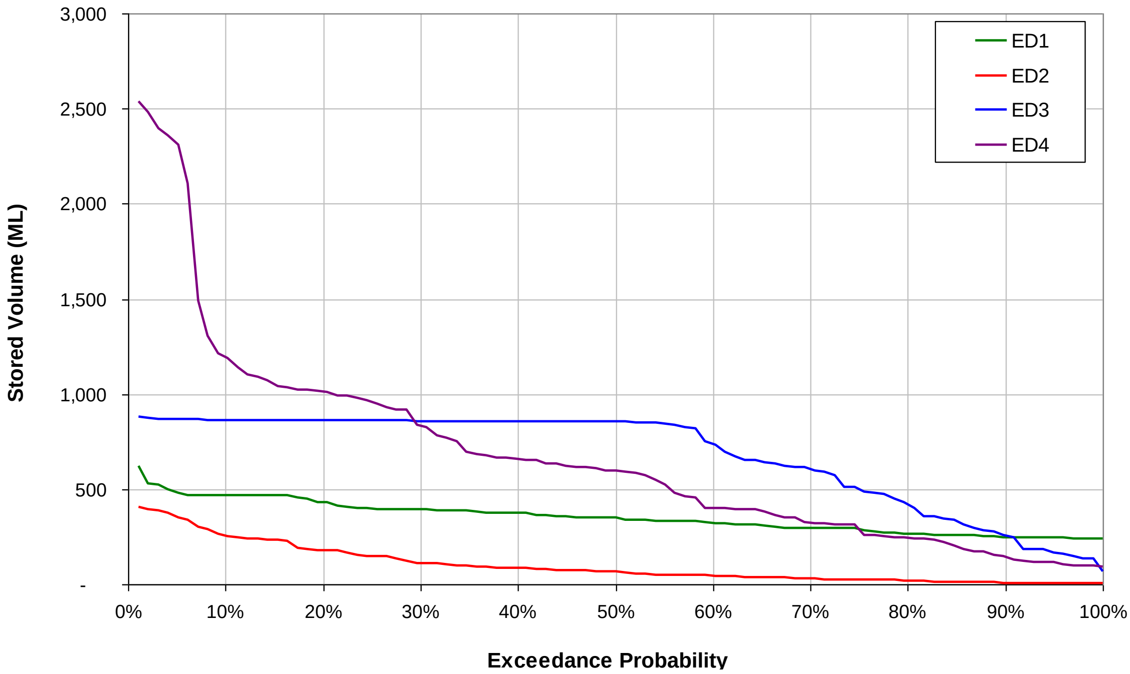

Figure 8.10 Environmental Dam Storage Volume – Probability of exceedance (High Runoff)

Figure 8.11 shows the probability of various stored water volumes occurring in the mine pits. The analysis is based on a simulation from 1900 to 2010. For the East Pit, Stage 2 was modelled, and for the West Pit, Stage 5 was modelled (as these are the critical periods for pit availability – when the pit catchment areas are greatest). The results show that the modelled water management system does not allow large volumes of water to accumulate in West Pit. In East Pit, large volumes of are unavoidable, due to the large pit catchment. However, the high pit dewatering capacity (600L/s) allows the frequency and duration of large stored water volumes to be maintained at manageable levels.

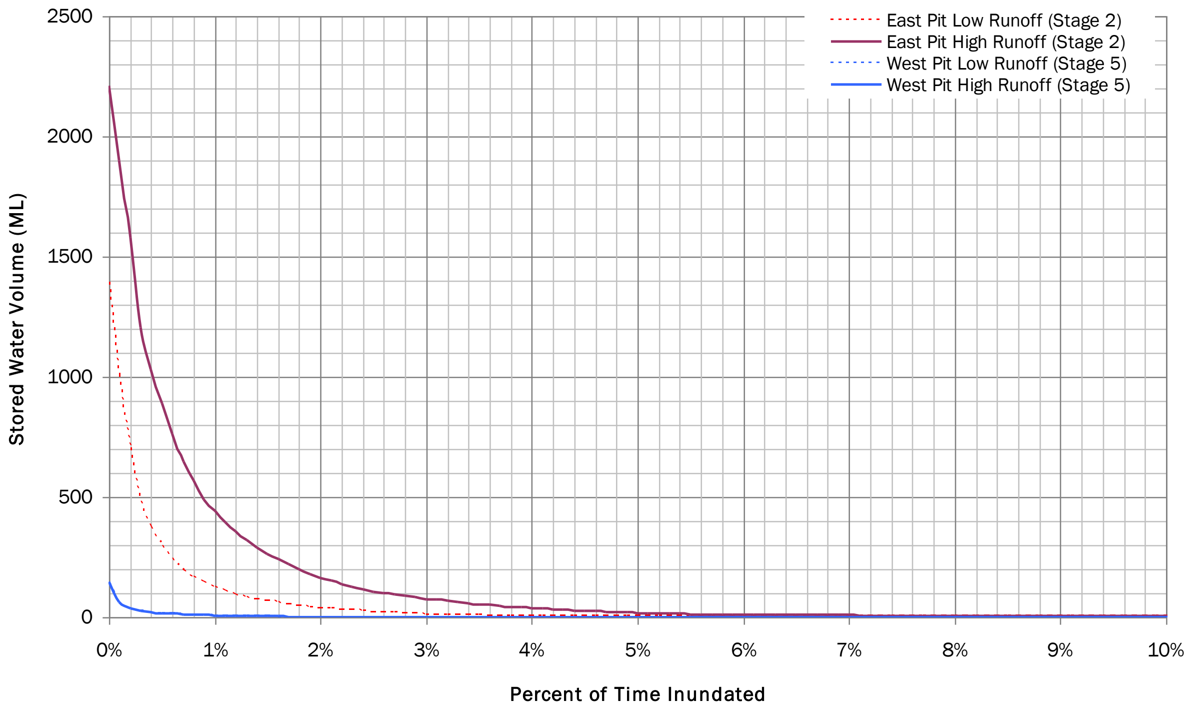

Figure 8.11 In-pit stored water volume

8.9.1 Sediment Dam Collection System Performance

Figure 8.12 shows an example of the behaviour of SD4 during the critical wet period commencing in 1982. The results show that except for periods immediately following rain, the dam is held close to empty.

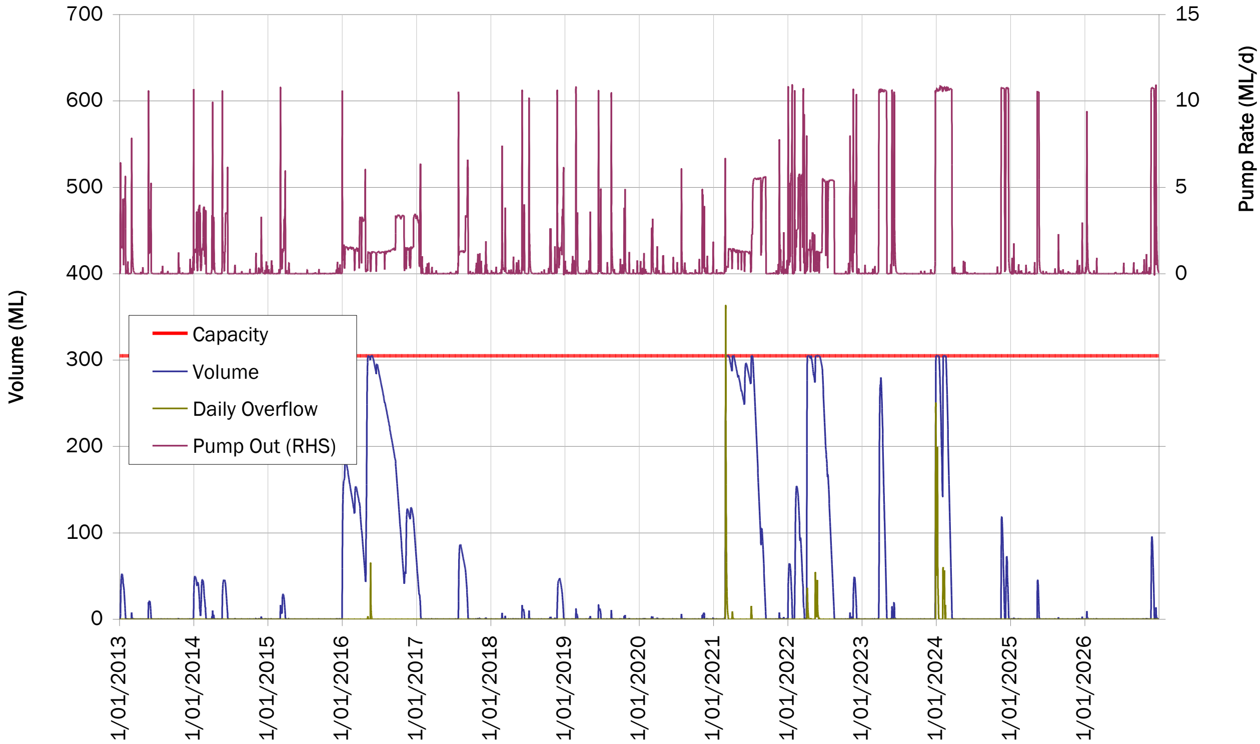

Figure 8.12 Sediment Dam SD4 Behaviour – Project Commencing 1982 (High Runoff)

Figure 8.13 to Figure 8.16 show the frequency of modelled sediment dam spillway discharges over the mine life. Under the low runoff scenario, this occurs less than 3 days per year on average. Under the high runoff scenario, this occurs more often, however, most of the flow days occur in a small number of large events. The median number of discharges per stage is one, and the maximum number of discharges per stage is 5.

Significant volumes of water could accumulate in the Eastern Pit if unused water in excess of site demands is captured (up to 3,400 ML in the worst case 14 year sequence). The Eastern Pit has a maximum capacity of 74,000ML if required. During their operational periods, stored pit water volumes will be kept to minimal through the proposed pit dewatering system. The proposed system should be sufficient to prevent significant interruptions to mining due to pit inundation.

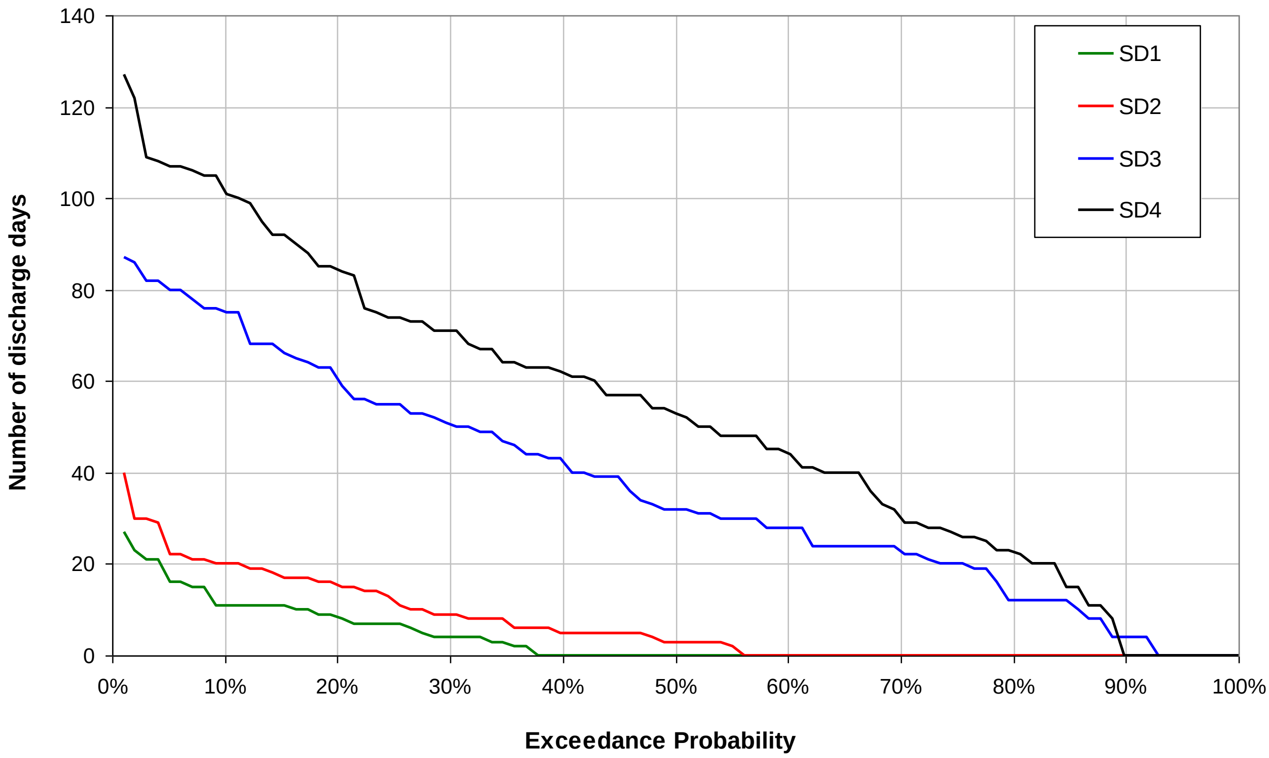

Figure 8.13 Sediment Dams – Number of Discharge Days over 13 Years – High Runoff

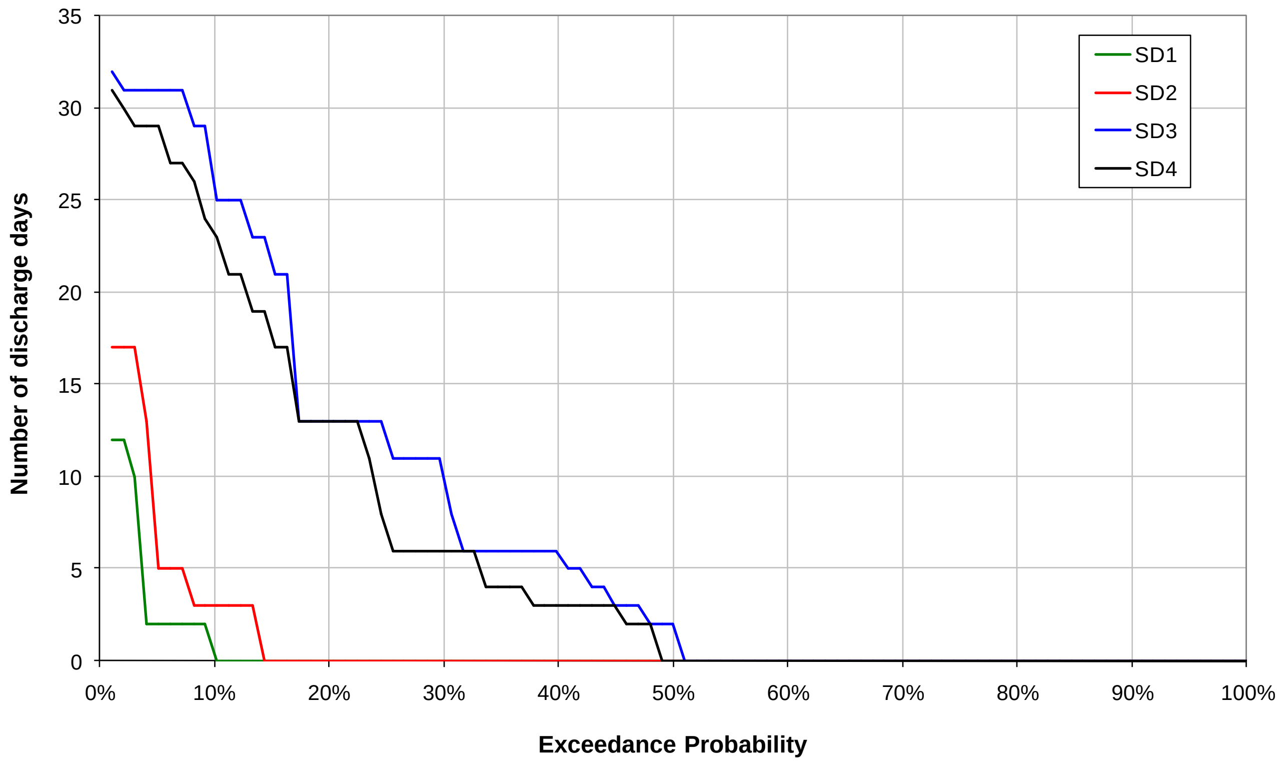

Figure 8.14 Sediment Dams – Number of Discharge Days over 13 Years – Low Runoff

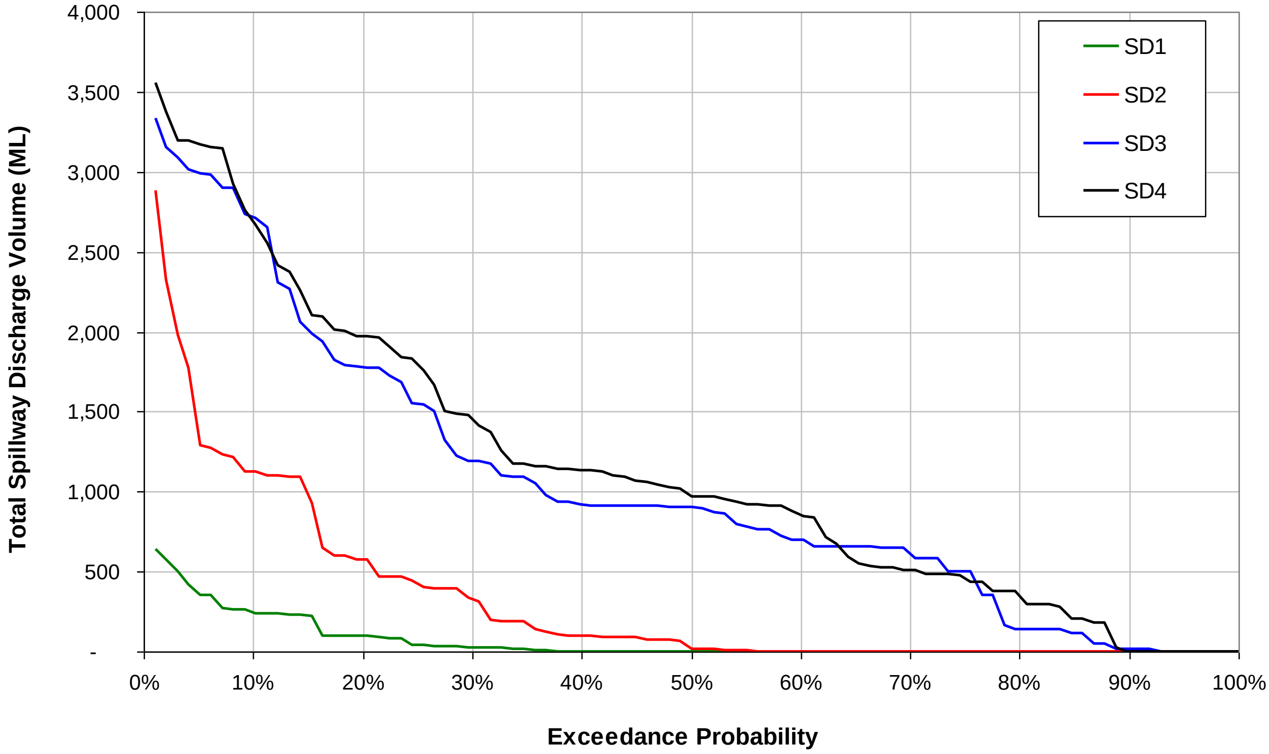

Figure 8.15 Sediment Dam Total Discharge Volume over 13 years – High Runoff

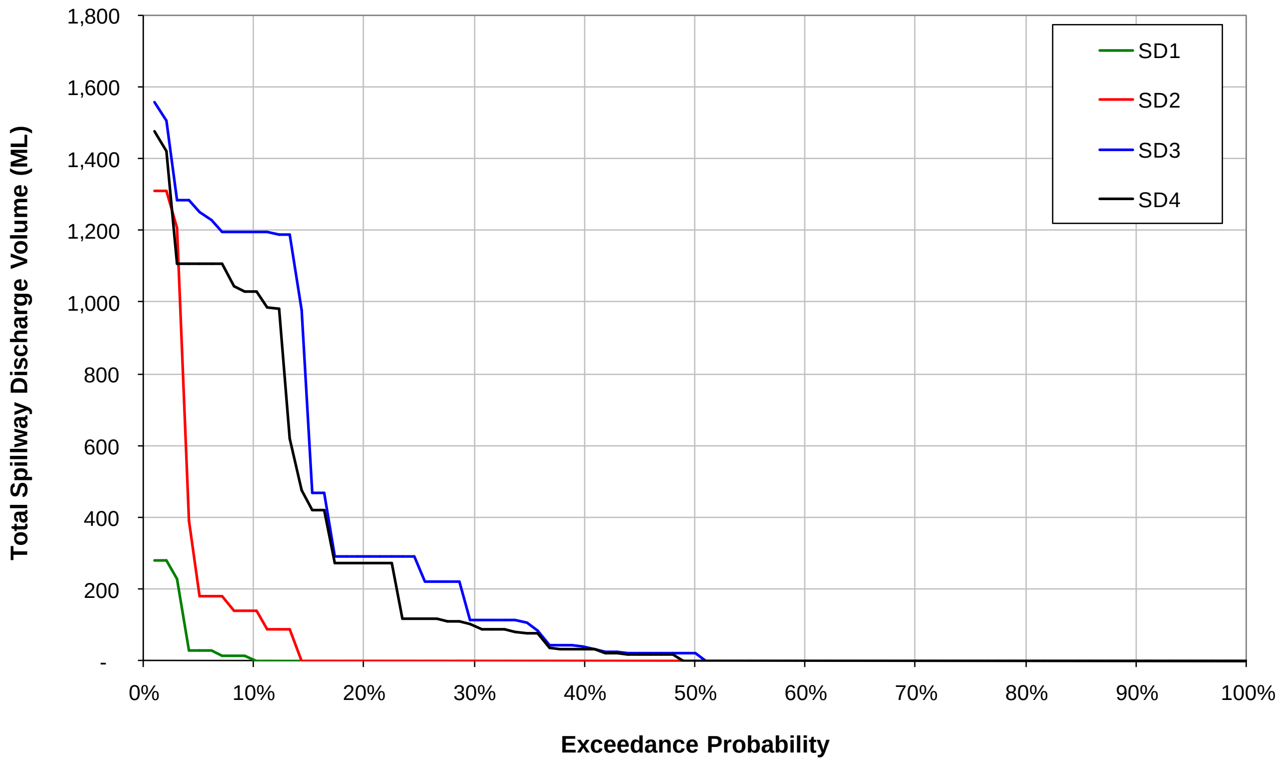

Figure 8.16 Sediment Dam Total Discharge Volume over 13 years – Low Runoff

8.9.2 Overall Site Water Balance

The overall site water balance for the life of the project is summarised in the tables below.

Table 8.12 Total Site Water Balance – Mean of all 14 year sequences - High runoff case

Flow Component	West Pit	East Pit	Environmental Dams	Sediment Dams	Total
	ML	ML	ML	ML	ML
Groundwater Inflow	2,056	9,501	0	0	**11,556**
Catchment Runoff	194	7,339	1,124	13,586	**22,243**
Direct Rainfall	3.6	67.9	1,568	951	**2,590**
Total Inflow	**2,253**	**16,907**	**2,692**	**14,537**	**36,390**
Evaporation	5	80.8	2,341	1058.3	**3,485**
Overflows	0	0	0.0	2,564	**2,564**
Demands	0	0	12,476	5,840	**18,317**
Total Outflow	**5**	**81**	**14,817**	**9,463**	**24,366**
Change in Volume	3	49.8	213	91.6	**357**

Table 8.13 Total Site Water Balance – Mean of all 14 year sequences- Low runoff case

Flow Component	West Pit	East Pit	Environmental Dams	Sediment Dams	Total
	ML	ML	ML	ML	ML
Groundwater Inflow	2,056	9,501	0	0	**11,556**
Catchment Runoff	194	3,422	963	4,721	**9,300**
Direct Rainfall	3.5	40.8	1,465	912	**2,421**
Total Inflow	**2,253**	**12,964**	**2,428**	**5,633**	**23,277**
Evaporation	5	32.8	1,865	601	**2,504**
Overflows	0	0	0.0	489	**489**
Demands	0	0	9,864	2,846	**12,710**
Total Outflow	**5**	**33**	**11,729**	**3,936**	**15,703**
Change in Volume	3	12.2	58	27.6	**101**

8.9.3 Impacts on Flows In Local Catchments

The proposed mine water management system has been sized to contain runoff from disturbed areas for later reuse, with a very low risk of discharge. This is consistent with the intent of current drafts of DERM's Model Environmental Authority Conditions for Coal Mines in the Fitzroy Basin and the Manual for Assessing Hazard Categories of Dams. As a consequence, the Codrilla Project will have a significant impact on flows in the small tributaries that flow through the site. However, the impact on flows in the watercourses just downstream will be much smaller. This is illustrated in Table 8.14, which summarised the impacts of the project at the locations shown in Figure 2.1. At Devlin Creek, just downstream of the Swampy Creek confluence, the modelled median annual flow is predicted to be reduced by 7.0% in 2015 and by 10.8% when the mine footprint is largest. At Reporting Point C, flows will be increased, due to the diversion of undisturbed catchments around the disturbed areas.

Table 8.14 Reduction in flows in local catchments

Reporting Point	Catchment Area (km^2)	Reduction in Median Annual Flow		Description
		2015	2024	
A	261.2	-1.5%	1.7%	Devlin Creek @ Lease Boundary
B	22.4	91.1%	91.1%	Trib of Swampy Creek @ Lease Boundary
C	5.8	-56.9%	-56.9%	Trib of Swampy Creek @ Lease Boundary
D	5.42	9.6%	9.6%	Trib of Swampy Creek @ Lease Boundary
E	145.1	9.5%	15.1%	Swampy Creek D/S of minor Trib (B, C, D)
F	437.9	7.0%	10.8%	Devlin Creek D/S of Swampy Creek

*Flows increase due to clean catchment diversions

8.10 PROVISION FOR EMERGENCY RELEASES

The proposed water management strategy for the Codrilla project is based on no release of water from the mine water management system. However, it is possible that emergency releases may be required under an extreme climate scenario beyond the range of modelled climatic conditions, or if key assumptions or estimates in the water balance modelling, such as the rate of groundwater inflows, are substantially incorrect. Emergency releases, if required, will be undertaken to minimise impacts on receiving water quality by ensuring that discharges occur above the 20th percentile flow in Devlin Creek and that mine water discharges are diluted by a factor of at least 4 to 1.

Figure 8.17 shows the flow frequency curves estimated from recorded streamflow data at 9 gauges in the area of interest, with no-flow days excluded. Table 8.15 below shows the 20th percentile flows (in mm/d) derived from the information shown in Figure 8.17.

The results show that the 20th percentile flow in Devlin Creek is about 0.0014 mm/d, which is the lowest of all streams in the area. Based on the Devlin Creek catchment area to Fitzroy Developmental Road of about 250 km^2, the 20th percentile flow is approximately 4 L/s. In practice, it unlikely that emergency discharges would be less than about 100 L/s. Hence, a minimum stream discharge of 400 L/s would be required to achieve a dilution ratio of 4 to 1.

Water quality will be monitored downstream of the release point to ensure that regional water quality guideline values are not exceeded. Emergency discharges would be immediately ceased if electrical conductivity (a measure of salinity) exceeds the regional guideline value.

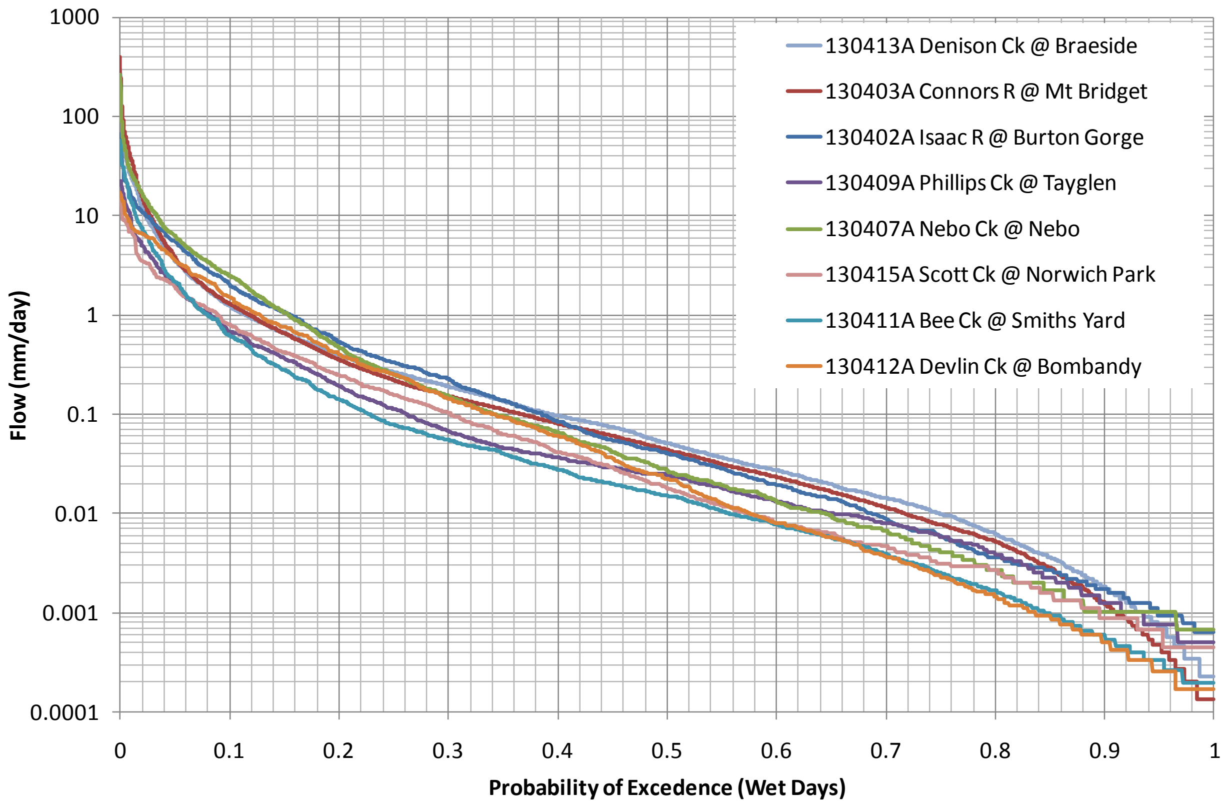

Figure 8.17 Recorded Frequency Curves for 20th Percentile Trigger Flows (mm/d - no-flow days excluded)

Table 8.15 Estimated 20th Percentile Trigger Flows (from DERM streamflow records)

Gauge No.	Gauge Name	Stream	20th percentile flow (ML/d)	20th percentile flow (mm/d)
130411A	Smiths Yard	Bee Ck	2.2	0.0017
130407A	Nebo	Nebo Ck	0.7	0.0027
130410A	Deverill	Isaac	5.9	0.0015
130413A	Braeside	Denison Ck	4.8	0.0063
130402A	Burton Gorge	Isaac	2.0	0.0036
130412A	Bombandy	Devlin Ck	1.5	0.0014
130409A	Tayglen	Phillips Ck	1.3	0.0038
130403A	Mt Bridget	Connors	6.7	0.0052
130415A	Norwich Park	Scott Ck	1.0	0.0027

9 SURFACE WATER MONITORING PLAN

9.1 OVERVIEW

The objective of the surface water monitoring plan for the Codrilla Project is to demonstrate the effectiveness of site water management in ensuring that mining operations do not have an adverse impact on the environmental values of receiving waters. The surface water monitoring program consists of the following components:

- Sampling at fixed locations (using automatic samplers such as pumping or rising stage samplers);
- Additional sampling of receiving waters during and after mine water discharge events (if any); and
- Sampling of onsite mine storages.

9.2 WATER QUALITY MONITORING LOCATIONS

Figure 9.1 shows the existing water quality sampling locations already established for the Codrilla Project. The water quality monitoring program has been designed to provide upstream, source and downstream monitoring in the Devlin Creek catchment as well as onsite storage monitoring. The Devlin Creek catchment is currently monitored at one upstream (Swampy Creek) and one downstream (Devlin Creek at Fitzroy Developmental Road) locations.

The water quality monitoring program will be expanded to include a location upstream of mining disturbance on Devlin Creek, downstream of mining disturbance on Devlin Creek and downstream of the mining lease on Swampy Creek as shown in Figure 9.1. The sampling site at Fitzroy Developmental Road will be moved downstream of the mine water emergency release point. A stream flow monitoring station will be installed at the monitoring site upstream of the mine on Devlin Creek.

Table 9.1 provides a description of the existing and recommended water quality monitoring sites.

Table 9.1 Existing & Recommended Water Quality Monitoring Sites

Monitoring Point	Location
USSC	Swampy Creek, Upstream of Mining Lease
DCFDR	Devlin Creek downstream of Fitzroy Developmental Rd
USDC	Devlin Creek, Upstream of Mining Lease
DSSC	Swampy Creek, Downstream of Mining Lease
DSDC	Devlin Creek, Downstream of Mining Lease

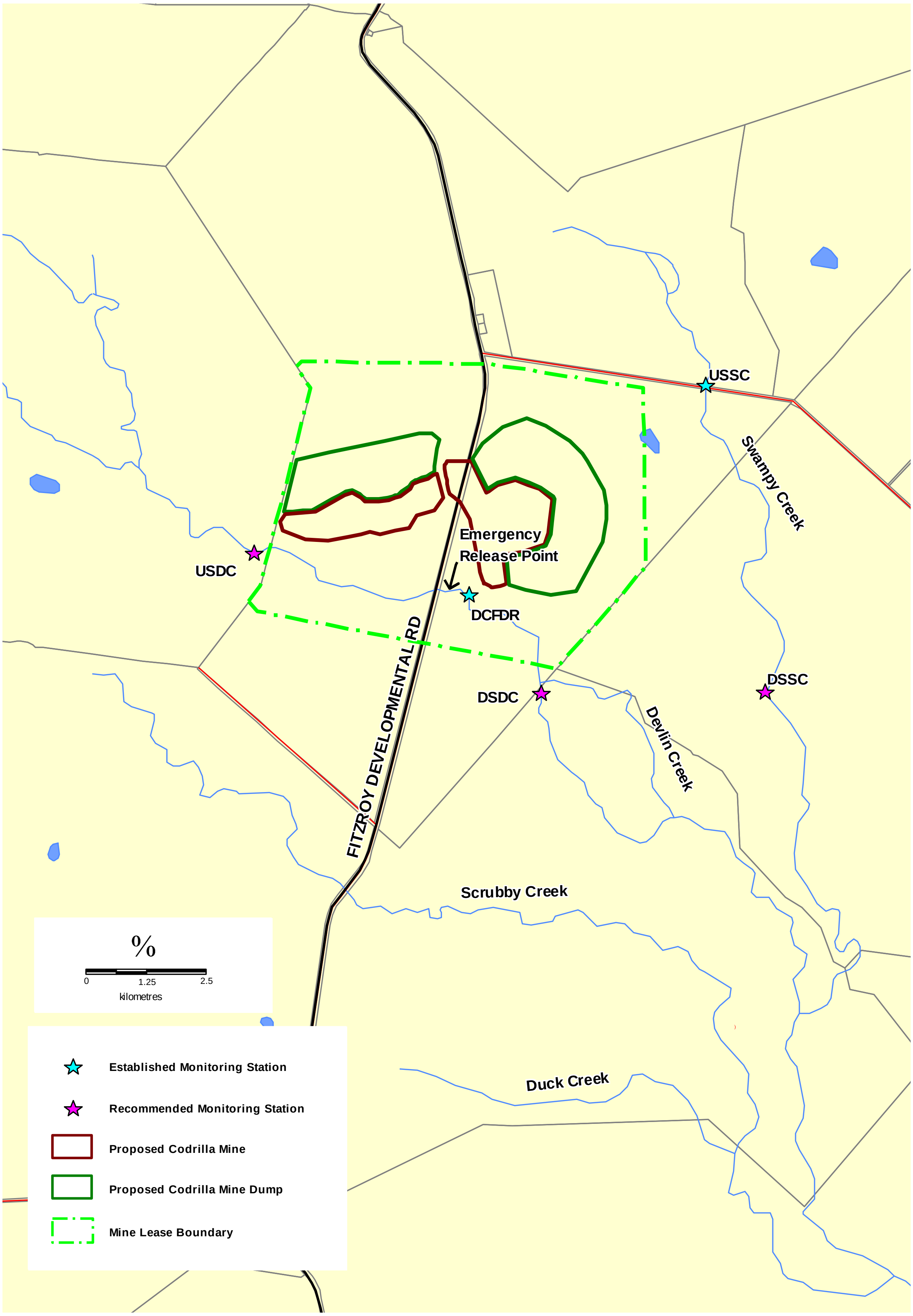

Figure 9.1 Locations of Water Quality Monitoring Stations

9.3 WATER QUALITY MONITORING SCHEDULE

Table 9.2 defines the frequency and parameters to be sampled at each location. Management of water on the mine site will aim to ensure no release of pit water from the site. However, should an event occur where water discharge from the site is required, additional sampling will be undertaken throughout the period when such emergency releases are occurring.

Table 9.3 defines the frequency and parameters to be sampled in the water storages across the mine site. The water quality monitoring program complies with the requirements for a Receiving Environment Monitoring Program (REMP) (DERM, 2009b) and provides regular monitoring of mine site water storages.

Table 9.2 Release Event Water Quality Monitoring Schedule

Location	Parameter	Monitoring Frequency
USSC & USDC	- Water Level - Electrical Conductivity - pH - Turbidity - Suspended Solids - Sulphate - And others listed in Table 3 of DERM 2009b	Continuous (Water level). Automatic sampling during flow events. Additional grab samples daily during release.
All DS Locations	- Electrical Conductivity - pH - Turbidity - Suspended Solids - Sulphate - And other listed in Table 3 of DERM 2009b	Automatic sampling during flow events. Additional grab samples daily during release (the first sample must be taken within 2 hours of commencement of release).

Table 9.3 Storage Monitoring Schedule

Location	Parameter	Monitoring Frequency
All onsite storages	- Water Level - EC - pH - turbidity - TSS	Monthly. Following rainfall events >30mm in 24 hours

Gauge boards (as a minimum) will be used to monitor mine site storage water levels and enable inflows and outflows to be derived. This data will substantially improve the characterisation of catchment runoff and the performance of the minesite water management system. It is recommended that automatic monitoring equipment be installed on key storages.

The event-based sampling will enable quantification of any pollutant loads from the site and their corresponding impact on the water quality of receiving waters. On-site monthly sampling from the water storages allows for any potential problem areas with respect to pollutant generation on-site to be identified in advance ensuring appropriate remedial action can be taken.

10 SUMMARY OF FINDINGS

WRM Water & Environment Pty Ltd was requested to undertake a flood study and water balance study to determine the impact of the proposed Codrilla coal mining operations on flooding and drainage behaviour in Devlin Creek and its tributaries.

<u>Flood Study</u>

To undertake the flood study, a TUFLOW two dimensional hydraulic model was developed of Devlin Creek and its floodplain for existing conditions and with the proposed mine infrastructure in place.

The results of the study are as follows:

- Generally surface water quality in the Devlin Creek catchment is consistent upstream and downstream of the mining lease. Prior to mining, some monitored parameters, such as total suspended solids, total nitrogen, total phosphorus and metals, exceed the Regional Guideline Values for the Central Coast Regions and the Release Contaminant Trigger Levels for Coal Mines in the Fitzroy Basin.
- There are no formal water use entitlements on Devlin Creek, but water from Devlin Creek may be accessed informally for stock and domestic use. Given that the total pit catchment area is approximately 6.5km^2 (or is less that 3% of the catchment area of Devlin Creek to Fitzroy Developmental Road), the proposed development will have no measurable impact on the quantity of water available to downstream users.
- The proposed locations of the open cut pits and overburden emplacements for the Codrilla Project are outside the banks of the Devlin Creek main channel. Hence, the proposed mine will not affect the geomorphology or frequent flow behaviour of Devlin Creek.
- Mine infrastructure will be located on the Devlin Creek floodplain and will potentially affect flood depths and flow velocities during flood events where flows exceed the main Devlin Creek channel capacity.
- The 2 year ARI design flood does not impact on the proposed mine.
- The 10 year, 100 year and 2,000 year ARI design floods do not impact on the eastern pit and overburden dump of the proposed mine. However, proposed eastern mine infrastructure is subject to flooding during all events of 100 year ARI and larger.
- The western end of the open cut pit is subject to partial backwater flooding during all events of 10 year ARI and larger. For the 100 year ARI flood event the maximum inundation depth within the pit footprint is approximately 1.4m
- A levee is required to protect the open cut pit and overburden dump and mine infrastructure from flooding during all events of 10 year ARI and larger.
- The levees will not impact significantly on flood depths for the 10 year and 100 year ARI flood events. Increases in flood level resulting from the construction of the levees for these events are limited to under 0.2m
- The levees will cause localised increases in flood depth for the 2,000 year ARI. Immediately upstream of the levees, flood depths will be increased by over 0.4m.

- The levees will not significantly impact in flood velocities in Devlin Creek for the 2 year, 10 year, 100 year and 2,000 year ARI design floods.
- Probable Maximum Flood levels in Devlin Creek range from approximately 0.5m higher than the 2,000 year ARI flood levels to a maximum of 1.5m higher than the 2,000 year ARI flood levels. As it is proposed that the mine pits will be rehabilitated to natural surface level following cessation of mining activities, hence levee bank protection for the rehabilitated mine pits will not be required.

Site Water Management System and Site Water Balance

The proposed operations will significantly change the characteristics of the minor gullies crossing the mining area. A water management system has been devised for the project, with the following key features:

- Runoff from undisturbed areas will generally be diverted around the operational areas where possible. Runoff from disturbed areas will be captured in the site water management system.
- Runoff entering the pits will be pumped to one of three environmental dams for later reuse for dust suppression or in the Coal Handling and Preparation Plant (CHPP).
- During mining of the East Pit, additional pit water storage capacity is to be provided in a temporary pit water storage to be constructed by excavating ahead of mining within the proposed West Pit mining area. The temporary dam will be decommissioned before the West Pit advances to within close proximity.
- Runoff from out of pit spoil dumps will be captured in one of four sediment dams, and the captured water would be returned to the plant area for reuse.
- If water quality and receiving water conditions allow, excess water could potentially be discharged from the site.

The purpose of the water balance study was to confirm the effectiveness of the system in limiting off site discharge, and to quantify the impacts on the drainage behaviour. A GoldSIM model of the site catchments and water management system was developed to make this assessment on the basis of historical climate data. The AWBM rainfall/runoff model was used to generate a daily time series of catchment runoff.

The results of the study are as follows:

- Under historical conditions it would be possible to contain all pit and plant runoff without discharge if a large enough temporary pit water storage. Under the high runoff scenario, the required storage volume is 2,500ML .
- The risk of discharge from sediment dams is low.
- During mining of the Western Pit, significant volumes of water could accumulate in the Eastern Pit (up to 3,400 ML in the worst case 14 year sequence). The Eastern Pit could potentially store up to 74,000ML of water, if required.
- During dry periods, when the yield from the site water management system is low, water will need to be imported to meet supply shortfalls.
- The proposed water management system will have a significant impact on flows in the very small tributaries leaving the site. However, the impact on flows in the watercourses further downstream will be much smaller. In Devlin Creek, just downstream of the Swampy Creek confluence, the modelled median annual flow is predicted to be reduced by 7.0% in 2015 and by 10.8% when the mine footprint is largest. The impact on flows in the Isaac River downstream would be negligible.

11 REFERENCES

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APPENDIX A

WATER QUALITY SAMPLING RESULTS

Table A1 Historical Water Sampling Results, Devlin Creek at Bombandy

Variable		Count	Minimum	10 Percent	Median	90 Percent	Maximum	Mean	Std Dev	SDate	End Date
100	Stream Water Level	21	-0.74	0.09	0.53	0.99	1.67	0.42	0.55	25/08/1971	13/04/1988
140	Stream Discharge	21	0	0	0	0.068	3.721	0.20	0.81	25/08/1971	13/04/1988
630	Distance below Water Surface	21	0.1	0.1	0.1	0.1	0.1	0.10	0.00	25/08/1971	13/04/1988
2010	Electrical Conductivity @ 25C	21	57	72	155	235	270	152.05	57.02	25/08/1971	13/04/1988
2010.5	Electrical Conductivity @ 25C (Field)	3	55	-	-	-	152	90.67	53.35	5/12/1985	13/04/1988
2030	Turbidity	4	40	-	-	-	100	85.00	30.00	11/06/1983	13/04/1988
2051	Colour - True	1	10	-	-	-	10	10.00	0.00	11/06/1983	11/06/1983
2080.5	Water Temperature (Field)	16	14	16	24.5	28.5	31	23.44	5.03	6/07/1972	13/04/1988
2100	pH	21	6.4	6.9	7.2	7.9	9.2	7.40	0.59	25/08/1971	13/04/1988
2113	Total Alkalinity as CaCO3	17	21	41.6	57	77.2	80	57.00	15.34	25/08/1971	13/04/1988
2123	Alkalinity Hydroxide as OH	9	0	-	-	-	0	0.00	0.00	8/12/1971	4/08/1976
2124	Alkalinity Carbonate as CO3	11	0	0	0.2	0.9	3.9	0.55	1.14	12/12/1973	11/06/1983
2125	Alkalinity Bicarbonate as HCO3	19	25.5	39.6	65	93.6	96	65.71	20.77	25/08/1971	13/04/1988
2132	Hardness as CaCO3 (calculated)	18	13	31.1	47	61.6	66	44.56	13.14	25/08/1971	13/04/1988
2141	Hydrogen as H	11	0	0	0	0	0	0.00	0.00	25/08/1971	29/10/1976
2169	Total Dissolved Solids (calc)	18	34	72.8	97	139.3	140	97.39	27.11	25/08/1971	13/04/1988
2170	Total Dissolved Ions	18	47.3	85.1	129.15	161.69	175.4	122.88	32.85	25/08/1971	13/04/1988
2172	Total Suspended Solids	14	9	16.8	64	249	690	125.50	178.47	26/09/1973	13/04/1988
2302	Calcium as Ca - soluble	19	2	6.4	10	15.2	17	10.17	3.90	25/08/1971	13/04/1988
2311	Chloride as Cl	19	5	7.4	15	29.2	40	16.53	9.15	25/08/1971	13/04/1988
2322	Magnesium as Mg - soluble	19	2	2.56	4.4	6.06	8	4.33	1.47	25/08/1971	13/04/1988
2331	Nitrate as NO3	9	0.2	-	-	-	10	2.58	2.97	8/12/1971	13/04/1988
2381	Potassium as K	13	3.1	4.02	4.7	5.7	6.5	4.65	0.86	26/09/1973	13/04/1988
2391	Sodium as Na	19	5	7.52	14	23	24	14.98	6.33	25/08/1971	13/04/1988
2401	Sulphate as SO4	8	0	-	-	-	7.5	3.91	2.33	8/12/1971	13/04/1988
2551	Boron as B	4	0.03	-	-	-	0.06	0.04	0.02	11/06/1983	13/04/1988
2641	Fluoride as F	14	0.05	0.05	0.1	0.27	0.34	0.14	0.09	25/08/1971	11/06/1983
2682	Iron as Fe - soluble	5	0.1	-	-	-	3.9	1.62	1.51	11/10/1972	13/04/1988
2762	Silica as SiO2 - soluble	15	6	6.4	13	20.2	42	14.40	9.01	26/09/1973	13/04/1988

Table A2 Water Quality Sampling Results, Swampy Creek at Valkyrie Road

CODRILLA PROJECT EIS								
Sample Number		M10R1	M10R4	M10R7	M10R10	M10R12	M10R13	M10R15
Flow		High	Medium	Low	Low	Zero	Zero	Medium
Date Sampled		31/01/2010	5/02/2010	20/02/2010	25/03/2010	18/11/2010	23/11/2010	1/12/2010
Time Sampled		14:41	9:45	7:20	10:00	11:00	11:55	13:53
Sample Identification		SWAMPY CREEK						
PARAMETERS	UNITS							
pH	pH Units	7.29	6.39	6.67	6.54	6.65	8.23	7.9
Temperature**	ºC	26.9	26.8	25.4	26.3			
Conductivity	µS/cm	67.80	135.60	163.10	105.70	275	302	69
Turbidity	NTU	>1000	136.0	59.7	93.6	804	>1000	493
Dissolved Oxygen	mg/L	6.83	3.33	3.19	6.79	4.90	5.13	5.81
Total Suspended Solids[1]	mg/L	262	64	48	30	172	635	246
Biological Oxygen Demand[1]	mg/L	2	<2	<2	<4	17	3	2
Sulphate[1]	mg/L	<2	<2	<2	<0.5	3	3	<2
Fluoride[1]	mg/L	<0.1	<0.1	<0.1	<0.5	0.2	0.2	<0.1
Ortho Phosphate (P)[1]	mg/L	0.119	0.035	0.013	<0.5	<0.005	0.011	0.045
Total Phosphorus (P)[1]	mg/L	0.14	0.11	0.07	<0.1	0.14	0.06	0.09
Nitrate (as N)[1]	mg/L	0.07	<0.01	0.01	<0.5	0.1	0.16	0.01
NOx (as N)[1]	mg/L	0.08	<0.01	0.01	<0.5	0.14	0.16	0.01
Ammonia (as N)[1]	mg/L	0.14	<0.01	0.05	<1	0.02	<0.01	0.01
Total Nitrogen (as N)[1]	mg/L	0.9	1.2	1.1	<2	1.5	2.2	3.4
Hardness (HCO3)[1]	mg/L	9	55	37	20	84	80	13
Petroleum Hydrocarbon (C6-C9)[1]	µg/L	<50	<50	<50	<20			
Petroleum Hydrocarbon (C10-C14)[1]	µg/L	<50	<50	<50	<40			
Petroleum Hydrocarbon (C15-C28)[1]	µg/L	<200	<200	<200	<100			
Petroleum Hydrocarbon (C29-C36)[1]	µg/L	<50	<50	<50	<100			
Sum of TPH C10-C36[1]	µg/L	--	--	--	--			
PARAMETERS TOTAL	UNITS							
Aluminium[1]	µg/L	10200	900	1740	1000	10700	15000	6200
Antimony[1]	µg/L	<5	<5	<5	<5	<5	<5	<5
Arsenic[1]	µg/L	<5	<5	<5	<5	<5	<5	<5
Beryllium[1]	µg/L	1.0	<1	<1	<5	<1	<1	<1
Boron[1]	µg/L	30	40	40	50	90	160	40
Cadmium[1]	µg/L	<0.5	<0.5	<0.5	<5	<0.5	<0.5	<0.5
Chromium[1]	µg/L	16	<5	<5	<5	11	15	7
Cobalt[1]	µg/L	10	<5	<5	<5	10	10	<5
Copper[1]	µg/L	15	<5	<5	<5			
Lead[1]	µg/L	8	<5	<5	7.4	6	7	<5
Manganese[1]	µg/L	526	17	127	40	937	734	180
Molybdenum[1]	µg/L	<5	<5	<5	<5	<5	<5	<5
Nickel[1]	µg/L	13	<5	<5	<5	14	14	6
Selenium[1]	µg/L	<5	<5	<5	<5	<5	<5	<5
Uranium[1]	µg/L	0.5	<0.5	<0.5	<5	0.7	0.8	<0.5
Vanadium[1]	µg/L	30	<10	<10	<5	30	60	20
Zinc[1]	µg/L	30	12	10	23	19	18	10
Iron[1]	µg/L	9340	770	1800	1600	10000	9290	3580
Mercury[1]	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
PARAMETERS FILTERED	UNITS							
Aluminium[1]	µg/L	190	2310	200	89	<10	1100	1000
Antimony[1]	µg/L	<5	<5	<5	<5	<5	<5	<5
Arsenic[1]	µg/L	<1	5	2	<5	1	<1	<1
Beryllium[1]	µg/L	<1	<1	<1	<5	<1	<1	<1
Boron[1]	µg/L	20	40	50	44	200	140	170
Cadmium[1]	µg/L	<0.1	<0.1	<0.1	<5	<0.1	<0.1	<0.1
Chromium[1]	µg/L	<1	<1	<1	<5	<1	<1	2
Cobalt[1]	µg/L	<1	<1	<1	<5	<1	<1	<1
Copper[1]	µg/L	3	1	5	<5			
Lead[1]	µg/L	<1	<1	<1	<5	<1	<1	<1
Manganese[1]	µg/L	21	13	102	8.9	32	<1	10
Molybdenum[1]	µg/L	<1	<1	<1	<5	2	2	1
Nickel[1]	µg/L	1	3	4	<5	3	3	2
Selenium[1]	µg/L	<5	<5	<5	<5	<5	<5	<5
Uranium[1]	µg/L	<5	<5	6	<5	0.4	0.6	<0.1
Vanadium[1]	µg/L	<0.1	<0.1	<0.1	<5	<5	<5	5
Zinc[1]	µg/L	6	10	22	26	30	30	40
Iron[1]	µg/L	100	1050	260	490	<50	<50	600
Mercury[1]	µg/L	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	<0.1

FIELD NOTES

SWAMPY CK 18/11/2010: Creek not flowing, sample taking from large pool of water. Approximately 1.5m below road.

SWAMPY CK 23/11/2010: Creek not flowing, still at same level as 18/11/2010 (1.5m below road). Sample taking from same large pool of water.

SWAMPY CK 01/12/2010: Sample taken from flowing water. Moderate flow approximately 40cm over the road.

SWAMPY CK 21/12/2010: Road closed sign in place. Rang Nebo Police and still weren't able to gain access.

SWAMPY CK 07/01/2011: Road closed sign in place. Rang Nebo Police and still weren't able to gain access.

SWAMPY CK 05/02/2011: Road closed sign in place. Rang Nebo Police and still weren't able to gain access.

SWAMPY CK 31/01/2010: Substantial flow approximately 1m above road.

SWAMPY CK 05/02/2010: Moderate flow approximately 40cm above road.

SWAMPY CK 20/02/2010: Low flow approximately 10cm above road.

SWAMPY CK 25/03/2010: Low flow approximately 5cm above road.

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Table A3 Water Quality Sampling Results, Devlin Creek at Fitzroy Developmental Road

CODRILLA PROJECT EIS										
Sample Number		M10R2	M10R5	M10R8	M10R11	M10R16	M10R17	M11R1	M11R3	M11R5
Flow		High	Medium	Low	Low	Low	Medium	Low	Low	Low
Date Sampled		31/01/2010	5/02/2010	20/02/2010	25/03/2010	1/12/2010	21/12/2010	7/01/2011	5/02/2011	17/03/2011
Time Sampled		15:10	10:18	7:48	10:38	14:20	9:57	8:20	10:17	6:45
Sample Identification		DEVLIN CREEK								
PARAMETERS	UNITS									
pH	pH Units	7.14	6.78	6.96	7.42	7.89	7.67	7.55	7.25	7.95
Temperature**	°C	25.6	27.3	25.6	26.5					
Conductivity	µS/cm	6.1	135.7	424.0	728.0	116	3.1	1470	168.1	124.3
Turbidity	NTU	>1000	529	105	106	620	85	39	39.8	128
Dissolved Oxygen	mg/L	5.02	4.45	4.16	7.71	6.03	5.00	2.94	7.98	7.03
Total Suspended Solids[1]	mg/L	480	70	46	50	177	74	29	22	110
Biological Oxygen Demand[1]	mg/L	5	<2	<2	<4	2		<2	2.4	<2
Sulphate[1]	mg/L	<2	3	6	15	<2	7	5.1	<2	<2
Fluoride[1]	mg/L	<0.1	<0.1	<0.1	<0.5	<0.1	<0.1	0.1	<0.1	<0.1
Ortho Phosphate (P)[1]	mg/L	0.111	0.018	0.069	<0.5	0.048	0.006	0.014	0.020	0.011
Total Phosphorus (P)[1]	mg/L	0.22	0.09	0.12	0.14	0.09	0.08		0.11	0.08
Nitrate (as N)[1]	mg/L	0.28	<0.01	0.09	0.6	0.02	0.05	0.14	0.03	<0.02
NOx (as N)[1]	mg/L	0.29	0.26	0.09	<0.5	0.02		0.15	<0.05	<0.05
Ammonia (as N)[1]	mg/L	0.02	0.05	0.05	<1	0.01	<0.01	0.04	0.03	0.01
Total Nitrogen (as N)[1]	mg/L	1.4	1.5	1.2	<2	2.1	5.8	0.7	1.53	0.8
Hardness (HCO3)[1]	mg/L	16	36	52	57	34	39	85	89	35.6
Petroleum Hydrocarbon (C6-C9)[1]	µg/L	<50	<50	<50	<20		<50	<50	<50	<50
Petroleum Hydrocarbon (C10-C14)[1]	µg/L	<50	<50	<50	<40		<50	<50	<50	<50
Petroleum Hydrocarbon (C15-C28)[1]	µg/L	<200	<200	<200	<100		<200	<200	<200	<200
Petroleum Hydrocarbon (C29-C36)[1]	µg/L	<50	<50	<50	<100		<50	90	50	<50
Sum of TPH C10-C36[1]	µg/L	--	--	--	--		-	90	<200	<200
PARAMETERS TOTAL	UNITS									
Aluminium[1]	µg/L	6140	5760	2070	1300	7200	3870	200	1600	4800
Antimony[1]	µg/L	<5	<5	<5	<5	<5	<5	<5	<5	<5
Arsenic[1]	µg/L	8	<5	<5	<5	<5	<5	2	1	<5
Beryllium[1]	µg/L	2.0	<1	<1	<5	<1	<1	<1	<1	<1
Boron[1]	µg/L	40	50	40	79	40	40	70	70	40
Cadmium[1]	µg/L	<0.5	<0.5	<0.5	<5	<0.5	<0.5	<0.2	<0.2	<0.5
Chromium[1]	µg/L	7	5	<5	<5	7	<5	<1	2	<5
Cobalt[1]	µg/L	16	5	<5	<5	7	<5	<1	<1	1
Copper[1]	µg/L	64	17	6	5.4		14		8	<5
Lead[1]	µg/L	5	<5	<5	5.3	8	<5	<1	<1	<5
Manganese[1]	µg/L	341	148	63	95	376	123	92	34	87
Molybdenum[1]	µg/L	<5	<5	<5	<5	<5	<5	<5	<5	<5
Nickel[1]	µg/L	20	7	<5	<5	10	<5	3	4	<5
Selenium[1]	µg/L	<5	<5	<5	<5	101	<5	2	5	<5
Uranium[1]	µg/L	<0.5	<0.5	<0.5	<5	<0.5	<0.5	<5	0.1	<0.5
Vanadium[1]	µg/L	20	20	<10	6.7	30	<10	<5	<5	<10
Zinc[1]	µg/L	39	35	30	26	18	9	31	49	<5
Iron[1]	µg/L	4840	5710	2380	1200	6840	2810	840	1400	3200
Mercury[1]	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
PARAMETERS FILTERED	UNITS									
Aluminium[1]	µg/L	350	750	890	88	560	180	<50	380	290
Antimony[1]	µg/L	<5	<5	<5	<5	<5	<5	<5	<5	<5
Arsenic[1]	µg/L	<1	4	1	<5	1	1	1	1	1
Beryllium[1]	µg/L	<1	<1	<1	<5	<1	<1	<1	<1	<1
Boron[1]	µg/L	20	50	60	76	130	90	100	70	50
Cadmium[1]	µg/L	<0.1	<0.1	<0.1	<5	<0.1	<0.1	<0.1	<0.2	<0.1
Chromium[1]	µg/L	<1	<1	1	<5	1	<1	<1	<1	<1
Cobalt[1]	µg/L	<1	<1	<1	<5	<1	<1	<1	<1	1
Copper[1]	µg/L	8	4	4	<5		3		4	6
Lead[1]	µg/L	<1	<1	<1	<5	<1	<1	<1	<1	<1
Manganese[1]	µg/L	6	6	8	17	4	12	47	9	85
Molybdenum[1]	µg/L	<1	<1	<1	<5	<1	1	2	<5	<1
Nickel[1]	µg/L	2	<1	3	<5	2	1	2	2	2
Selenium[1]	µg/L	<5	<5	<5	<5	<5	<5	<5	<1	<5
Uranium[1]	µg/L	<5	<5	6	<5	<0.1	0.1	<5	<0.1	<0.1
Vanadium[1]	µg/L	<0.1	<0.1	0.2	<5	6	<5	<5	<5	<5
Zinc[1]	µg/L	15	11	38	31	100	20	29	24	6
Iron[1]	µg/L	140	250	540	290	620	170	210	230	370
Mercury[1]	µg/L	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

FIELD NOTES

DEVLIN CK 18/11/2010: Creek not flowing, no water, no sample taken.
DEVLIN CK 23/11/2010: Creek not flowing, no water, no sample taken.
DEVLIN CK 01/12/2010: Sample taken from flowing water. Low flow approximately 25cm deep.
DEVLIN CK 21/12/2010: Sample taken from flowing water. Moderate flow approximately 80cm deep.
DEVLIN CK 07/01/2011: Sample taken from flowing water. Low flow approximately 20cm deep.
DEVLIN CK 05/02/2011: Sample taken from flowing water. Low flow approximately 30cm deep.
DEVLIN CK 17/03/2011: Sample taken from flowing water. Low flow approximately 30cm deep.

DEVLIN CK 31/01/2010: High Flow approximately 1.5m deep.
DEVLIN CK 05/02/2010: Moderate Flow approximately 50cm deep.
DEVLIN CK 20/02/2010: Low Flow approximately 25cm deep.
DEVLIN CK 25/03/2010: Low Flow approximately 20cm deep.

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Table A4 Water Quality Sampling Results, Isaac River at Fitzroy Developmental Road

CODRILLA PROJECT EIS								
Sample Number		M10R3	M10R6	M10R9	M10R14	M11R2	M11R4	M11R6
Flow		High	High	Medium	Medium	Medium	High	Medium
Date Sampled		31/01/2010	5/02/2010	20/02/2010	23/11/2010	7/01/2011	5/02/2011	17/03/2011
Time Sampled		16:02	11:19	8:35	13:07	9:00	11:09	7:30
Sample Identification		ISAAC RIVER						
PARAMETERS	UNITS							
pH	pH Units	7.28	6.87	6.98	7.9	7.56	7.46	7.76
Temperature**	°C	27.3	27	25.7				
Conductivity	µS/cm	269.00	244.00	191.10	180	340	258	495
Turbidity	NTU	>1000	>1000	>1000	>1000	549	678	>1000
Dissolved Oxygen	mg/L	4.95	0.74	4.72	4.84	4.70	6.68	7.37
Total Suspended Solids[1]	mg/L	160	109	230	474	400	400	1100
Biological Oxygen Demand[1]	mg/L	3	<2	<2	<2	<2	2.6	2.7
Sulphate[1]	mg/L	3	8	8	10	3.4	3.2	20
Fluoride[1]	mg/L	0.2	0.2	<0.1	0.1	<0.1	0.1	0.2
Ortho Phosphate (P)[1]	mg/L	0.141	0.043	0.056	0.044	0.049	0.035	0.015
Total Phosphorus (P)[1]	mg/L	0.32	0.19	0.16	0.09		0.23	0.26
Nitrate (as N)[1]	mg/L	<0.01	<0.01	0.21	0.05	0.08	0.03	0.25
NOx (as N)[1]	mg/L	<0.01	0.15	0.21	0.05	0.1	<0.05	0.25
Ammonia (as N)[1]	mg/L	<0.01	0.12	0.05	0.01	0.06	<0.01	0.01
Total Nitrogen (as N)[1]	mg/L	0.8	1.8	1.2	0.1	1.4	1.23	2
Hardness (HCO3)[1]	mg/L	100	63	40	39	58	150	111.7
Petroleum Hydrocarbon (C6-C9)[1]	µg/L	<50	<50	<50		<50	<50	<50
Petroleum Hydrocarbon (C10-C14)[1]	µg/L	<50	<50	<50		<50	<50	<50
Petroleum Hydrocarbon (C15-C28)[1]	µg/L	<200	<200	<200		<200	<200	<200
Petroleum Hydrocarbon (C29-C36)[1]	µg/L	<50	<50	<50		50	<50	<50
Sum of TPH C10-C36[1]	µg/L	--	--	--		50	<200	<200
PARAMETERS TOTAL	UNITS							
Aluminium[1]	µg/L	10400	16400	10400	22000	2000	11000	14000
Antimony[1]	µg/L	<5	<5	<5	<5	<5	<5	<5
Arsenic[1]	µg/L	6	<5	<5	<5	1	<1	<5
Beryllium[1]	µg/L	<1	<1	<1	1	<1	<1	<1
Boron[1]	µg/L	60	<10	40	90	<50	110	70
Cadmium[1]	µg/L	<0.5	<0.5	<0.5	<0.5	<0.2	<0.2	<0.5
Chromium[1]	µg/L	29	<5	18	28	4	13	17
Cobalt[1]	µg/L	13	<5	9	19	6	6	9
Copper[1]	µg/L	17	10	11			8	12
Lead[1]	µg/L	<5	<5	6	12	5	7	6
Manganese[1]	µg/L	217	<5	291	769	270	220	350
Molybdenum[1]	µg/L	<5	<5	<5	<5	<5	<5	<5
Nickel[1]	µg/L	39	<5	20	34	9	16	21
Selenium[1]	µg/L	<5	<5	<5	<5	<1	5	2
Uranium[1]	µg/L	<0.5	<0.5	0.5	0.9	<5	0.5	<0.5
Vanadium[1]	µg/L	30	<10	30	80	12	22	30
Zinc[1]	µg/L	54	<5	76	53	25	27	37
Iron[1]	µg/L	12100	21600	13500	21000	2900	14000	16000
Mercury[1]	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
PARAMETERS FILTERED	UNITS							
Aluminium[1]	µg/L	90	410	200	500	<50	<50	1000
Antimony[1]	µg/L	<5	<5	<5	<5	<5	<5	<5
Arsenic[1]	µg/L	<1	4	<1	<1	<1	<1	<1
Beryllium[1]	µg/L	<1	<1	<1	<1	<1	<1	<1
Boron[1]	µg/L	50	60	50	110	50	110	60
Cadmium[1]	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1
Chromium[1]	µg/L	2	<1	<1	<1	<1	<1	1
Cobalt[1]	µg/L	<1	<1	<1	<1	<1	<1	7
Copper[1]	µg/L	5	<1	3			1	7
Lead[1]	µg/L	<1	<1	<1	<1	<1	<1	5
Manganese[1]	µg/L	4	3	5	<1	<1	<5	370
Molybdenum[1]	µg/L	<1	<1	<1	<1	<1	<5	<1
Nickel[1]	µg/L	9	1	4	2	3	2	8
Selenium[1]	µg/L	<5	<5	<5	<5	<5	<1	<5
Uranium[1]	µg/L	16	<5	9	<0.1	<5	0.1	0.4
Vanadium[1]	µg/L	<0.1	<0.1	<0.1	<5	<5	<5	13
Zinc[1]	µg/L	17	24	12	30	<5	4	16
Iron[1]	µg/L	100	150	190	80	140	<50	1200
Mercury[1]	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

FIELD NOTES

ISAAC RIVER 18/11/2010: Water over road, unable to access.
ISAAC RIVER 23/11/2010: Sample taken from flowing water. Moderate flow approximately 5m below bridge.
ISAAC RIVER 01/12/2010: Water over road, unable to sample.
ISAAC RIVER 21/12/2010: Water over road, unable to sample.
ISAAC RIVER 07/01/2011: Sample taken from flowing water. Moderate flow approximately 5m below bridge.
ISAAC RIVER 05/02/2011: Sample taken from flowing water. High flow apporximately 2 to 2.5m below bridge.
ISAAC RIVER 17/03/2011: Sample taken from flowing water. Moderate flow approximately 5m below bridge.

ISAAC RIVER 31/01/2010: High flow apporximately 2.5m below bridge.
ISAAC RIVER 05/02/2010: High flow apporximately 3m below bridge.
ISAAC RIVER 20/02/2010: Moderate flow apporximately 5m below bridge.
ISAAC RIVER 25/03/2010: Not required to be sampled.

APPENDIX B

FLOOD VELOCITY MAPS

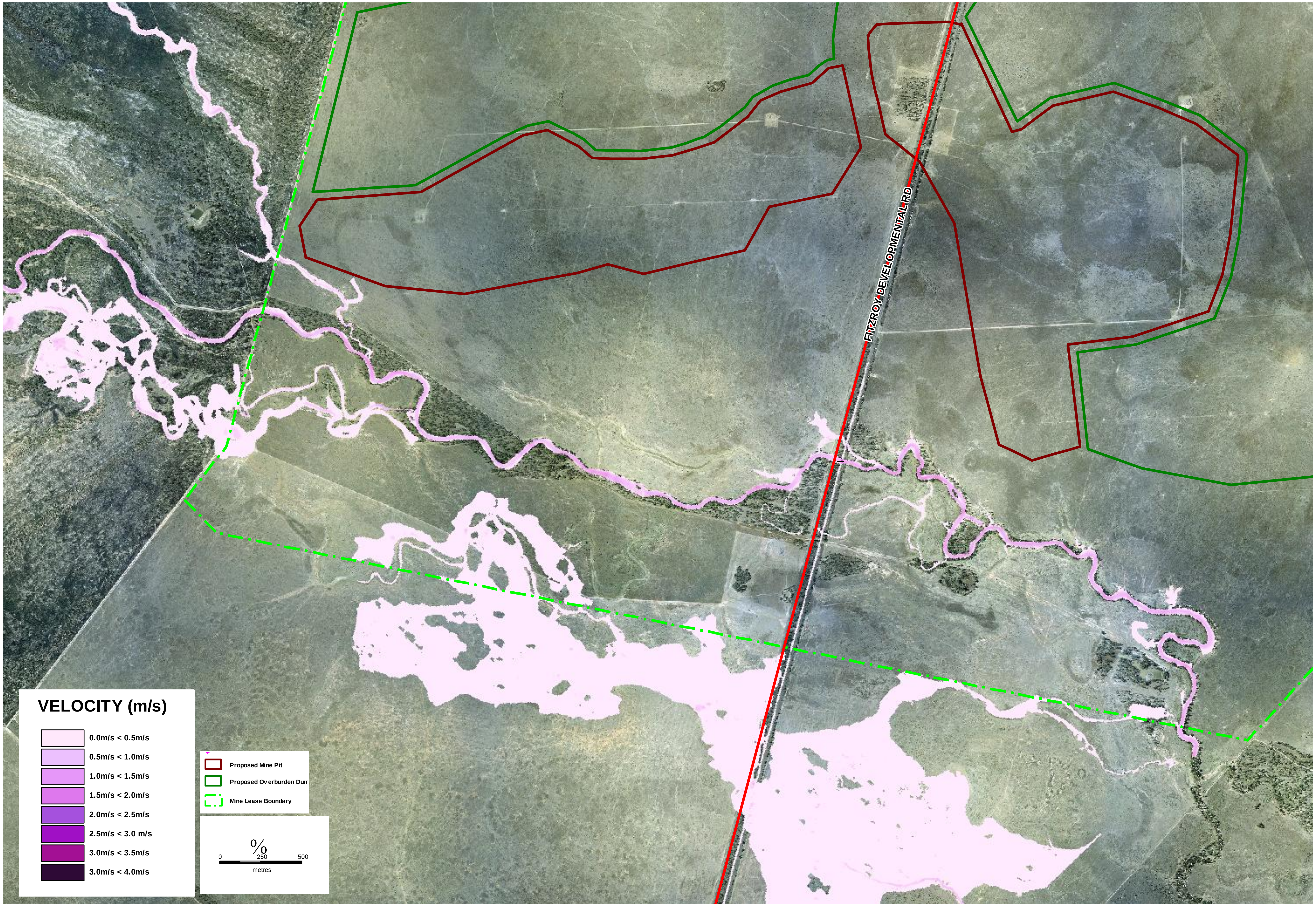

Figure B1 Existing Conditions, 2 Year ARI Flood Velocities, Devlin Creek

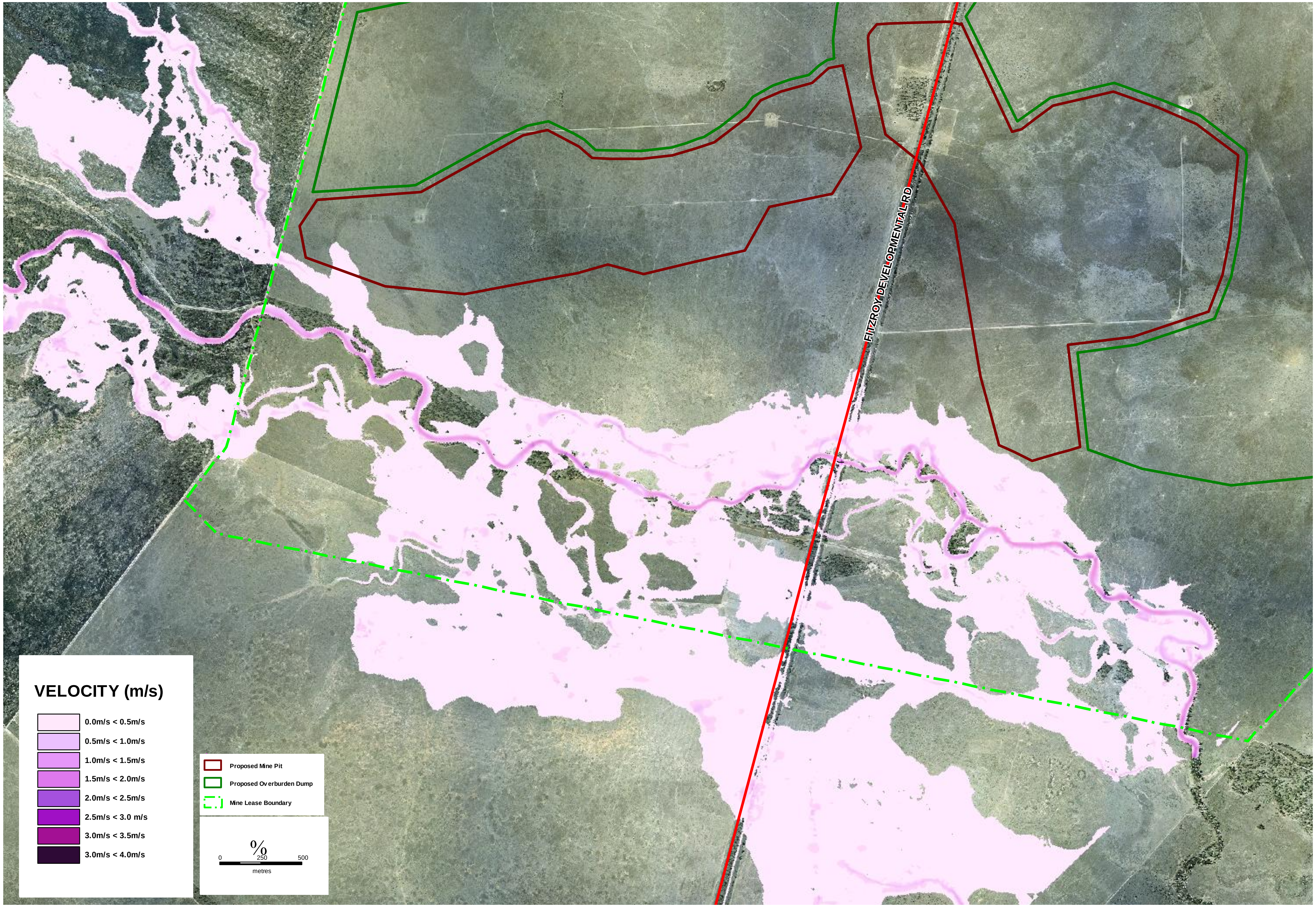

Figure B2 Existing Conditions, 10 Year ARI Flood Velocities, Devlin Creek

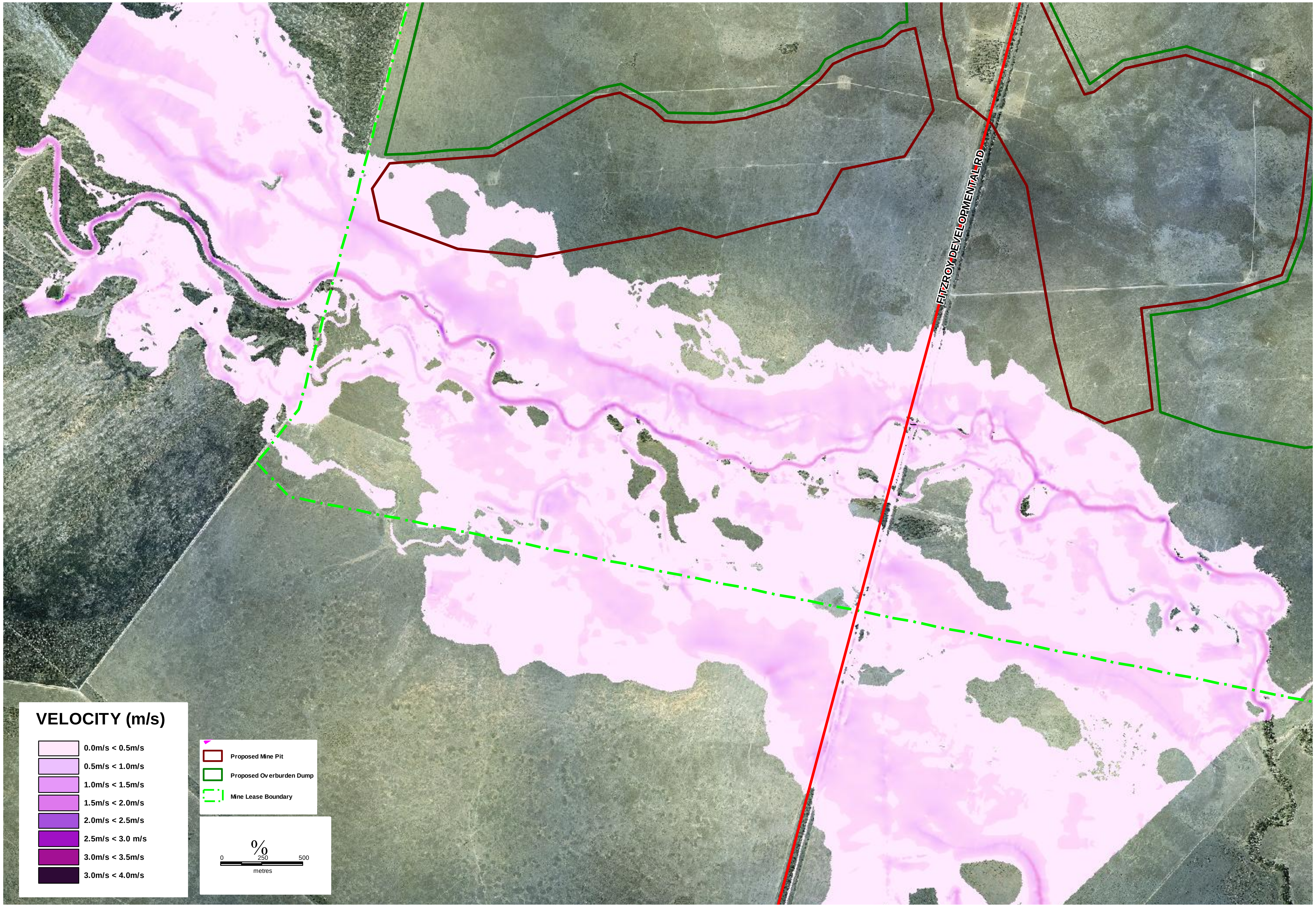

Figure B3 Existing Conditions, 100 year ARI Flood Velocities, Devlin Creek

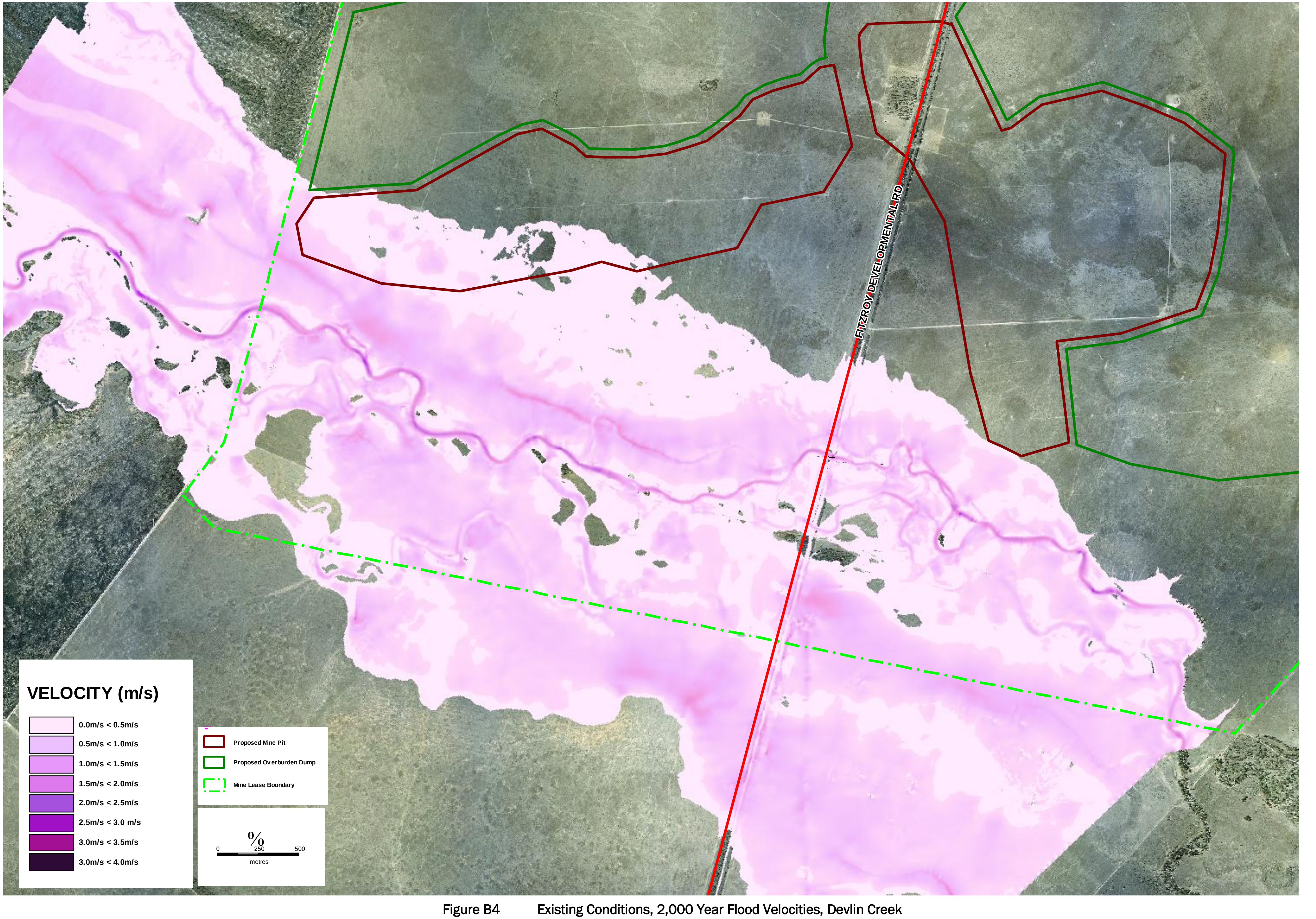

Figure B4 Existing Conditions, 2,000 Year Flood Velocities, Devlin Creek

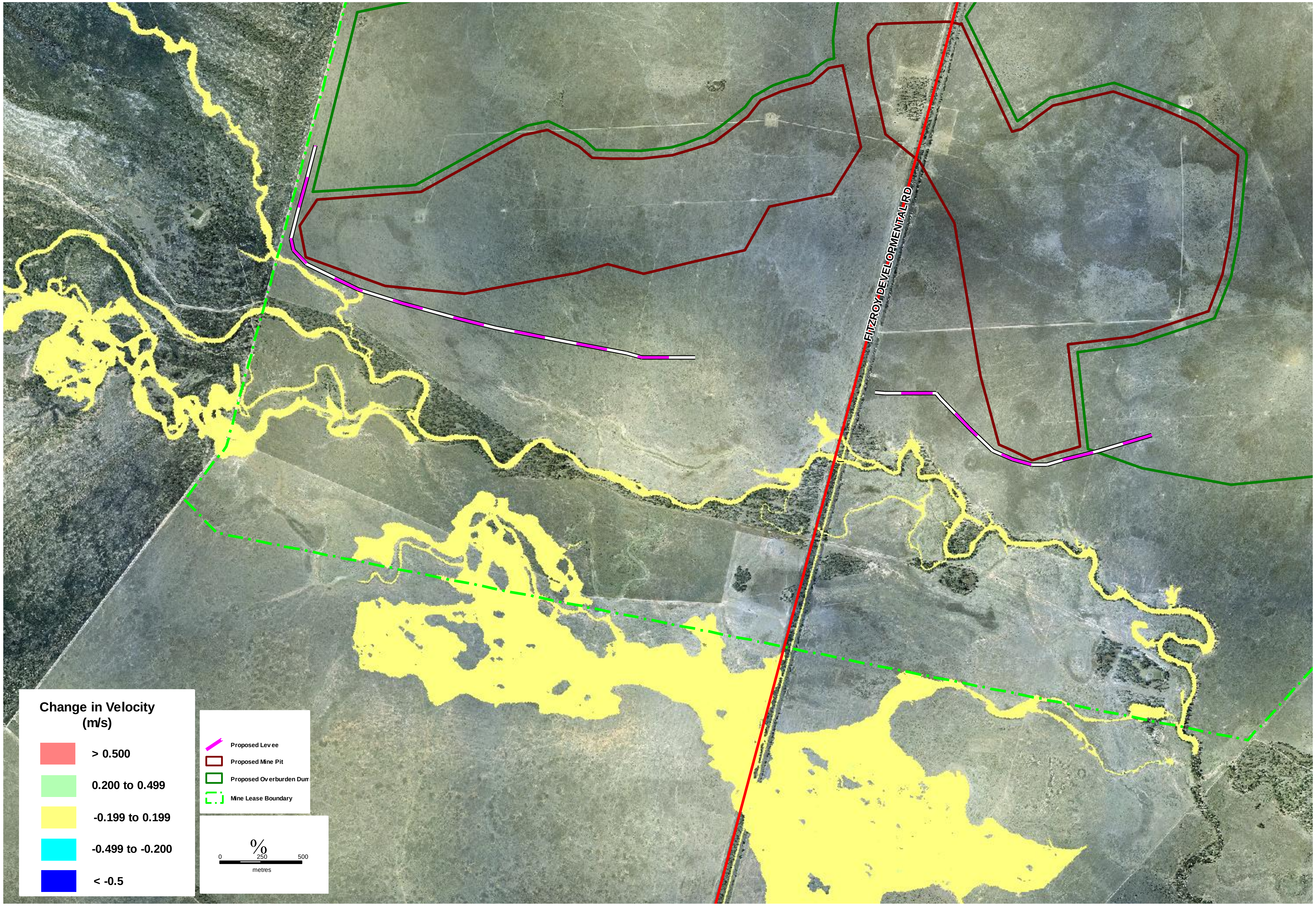

Figure B5 Change in Flood Velocities, 2 year ARI, Devlin Creek

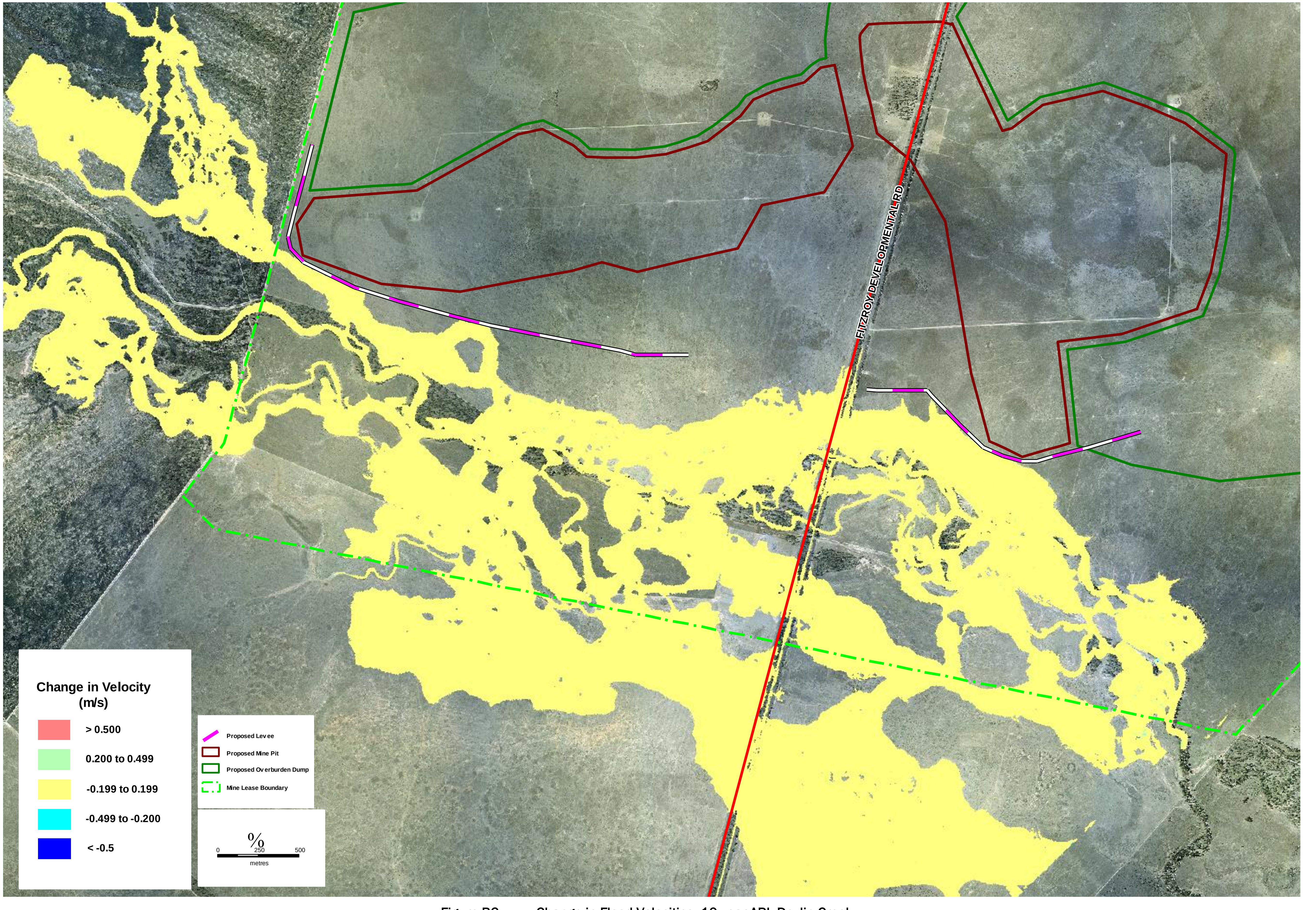

Figure B6 Change in Flood Velocities, 10 year ARI, Devlin Creek

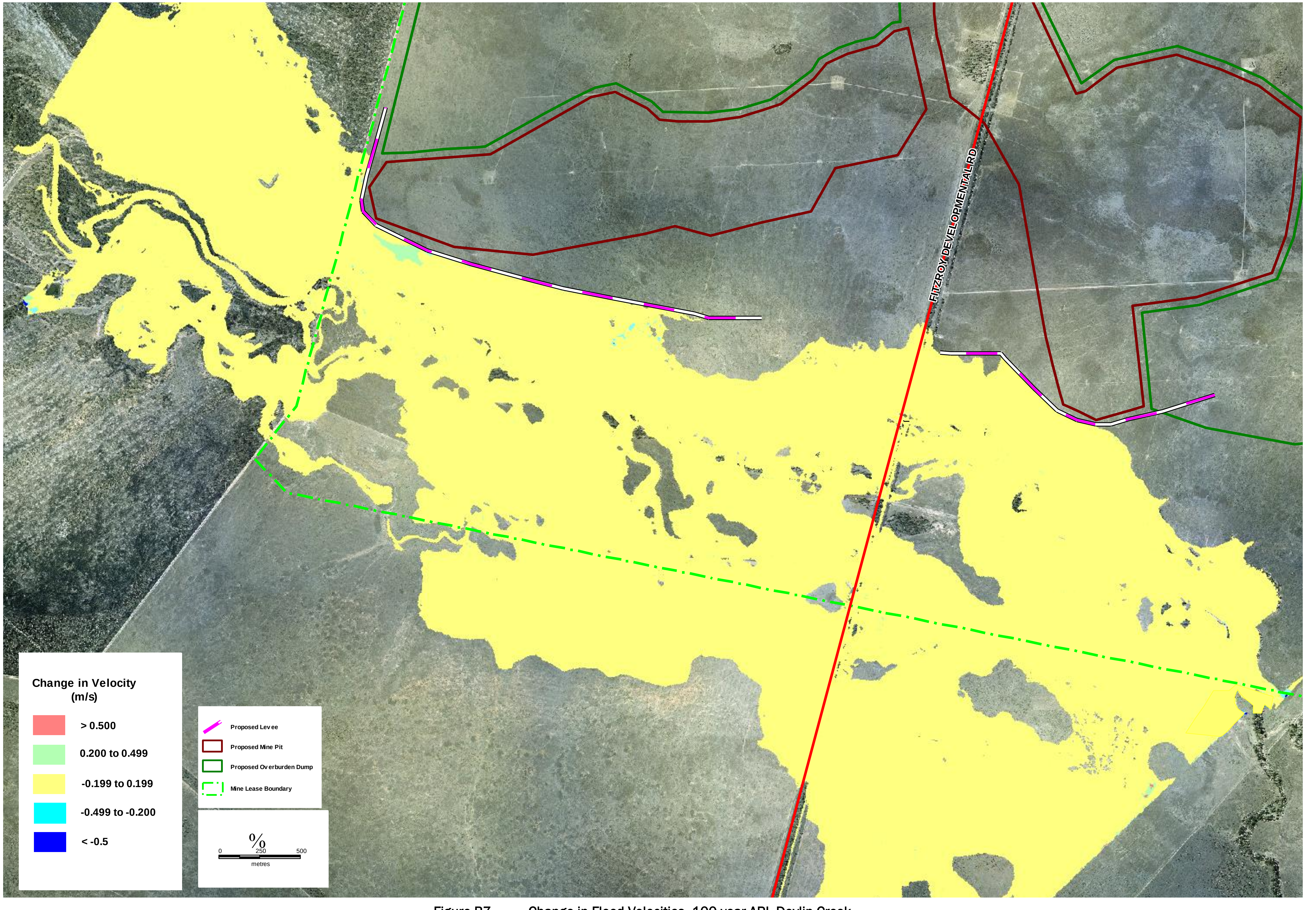

Figure B7 Change in Flood Velocities, 100 year ARI, Devlin Creek

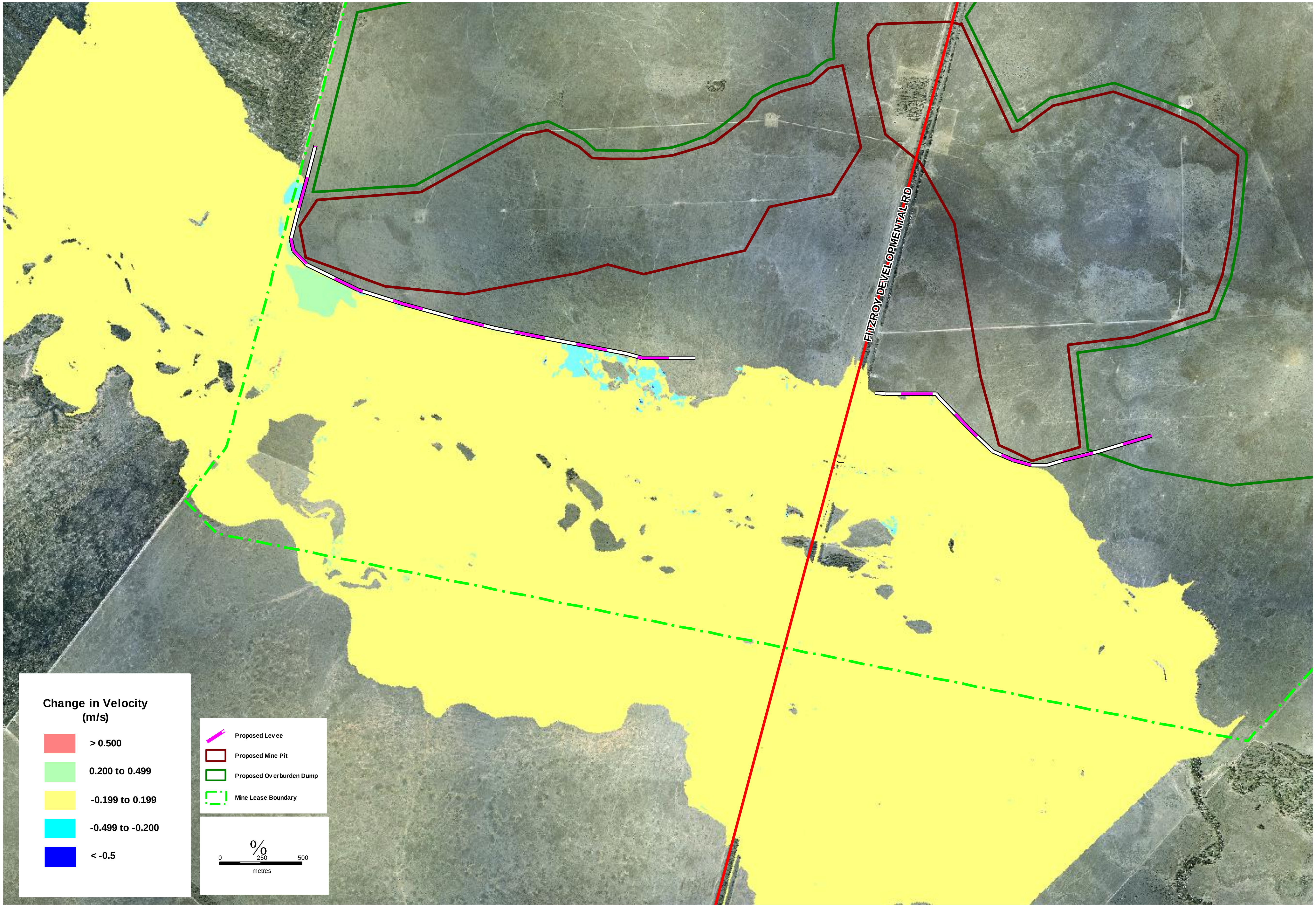

Figure B8 Change in Flood Velocities, 2,000 year ARI, Devlin Creek