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Bloomfield Collieries
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Attention: John Hindmarsh

Review of the Flooding Impacts from the Proposed Extension of Mining at the Rixs Creek Colliery

1 Background

Mr John Hindmarsh of Rixs Creek Mine (RXC) requested JP Environmental to review potential flooding impacts from the proposed extension of mining at Rixs Creek Mine after regulatory review of the EIS.

The objective of this study is to:

- Assess the potential impacts from Hunter River flooding on the mining operation and infrastructure;
- Carry out a flood flow assessment of Rixs Creek along the stream reach from just above the New England Highway to just below the southern project boundary.to examine potential impacts from peak flow velocity and water levels on mining, public and private infrastructure along and downstream of the reach; and
- Assess downstream impacts on streams exiting the site where changes to flooding regimes due to proposed mining operations will occur.

2 Methodology

2.1 Hunter River Flooding

There are three main methods of estimating flood peak frequency: (i) flood frequency analysis, (ii) runoff-routing models using design rainfall, and (iii) a regional flood methods.

Flood frequency analysis refers to procedures that use gauged flood data to select and fit a probability model of flood peaks at the site of the gauge. If the site of interest is located near a gauging station, flood frequency analysis is the preferred method, provided the data series is long enough (predictions should not extend beyond the length of the series) and does not have significant missing data that cannot be filled. Runoff-routing models develop a flood hydrograph from either an actual event (recorded rainfall time series) or a design storm. Runoff-routing models and regional flood methods are used where gauged data are inadequate and for ungauged sites. *(The above description is adapted from Bowmans Creek Diversion Flood Hydrology and Geomorphology, Fluvial systems 2009)*.

Regional flood frequency analysis is widely used for flood estimation in Australia for small to medium sized catchments where little or no data are available. It involves the identification of groups (or regions) of hydrologically homogeneous catchments and the application of a regional estimation method in the identified homogeneous region. The particular advantages of regional flood frequency analysis are that it can be used in areas with a sparse data network and short flow records, and that it provides a means by which flood estimates can be made at ungauged sites.

The confluence of Rixs Creek catchment is located some 23.4 km upstream of the river gauge at Singleton operated by DPI Office of Water.

The Singleton gauge record is regularly used for flood frequency analysis studies, and several of these studies are referenced to estimate a 1% AEP flood level near the southern boundary at Rixs Creek Mine due to Hunter River flooding – see Section 3. For the probable maximum flood, an extreme flood was adopted rather than estimating a probable maximum flood (PMF) to examine the impacts of a low probability flood.

The gauge level at Singleton was translated upstream to estimate a water level at the Rixs Creek confluence. In the 1% AEP flood, Rixs Creek acts as a backwater off the river proper and water levels at the Mine boundary can be inferred from the river flood level. Estimated flood levels are mapped in **Figure 1**.

2.2 Rixs Creek Mine Flooding

The proposed mine modification falls predominantly within the Rixs Creek catchment. Smaller areas of Dead Mans Gully (originally described as Un-named Tributary in the EIS) and Station Creek are affected by changes to catchment size. Each of these catchments is ungauged, and because of this, regional flood estimation was the preferred method to calculate the 1% AEP peak flows; and to determine a peak flow for the PMF. This is discussed in more fetial in Section 3.

The HECRAS model was used to estimate water levels and average velocities in the Creek reach of interest. Cross sections for the model were constructed from site specific survey and additional sections were interpolated as required to fill in detail around structure. Tributary lows were added down the modelled reach as catchment areas increased. The flood levels and extents determined by modelling are mapped on **Figure 3**, **Figure 4** and **Figure 5**.

3 Hunter River Flood Levels

3.1 The 1955 Flood at Singleton

Patterson Britton & Partners (2001) noted that the 1955, 1893, 1913, and 1971 floods were "considered to be of 20 year recurrence or rarer, at Singleton ... [and that]. . .In the upper Hunter, the 1955 flood is often regarded as being of similar magnitude to the design 100 year recurrence flood". Downstream at Maitland, the 1955 flood is considered to be rarer than the 100 year ARI event.

Fluvial Systems (2009) prepared a flood frequency analysis for the Singleton gauge. Various distributions were fitted to the Singleton data. The best fit distributions were Generalized Pareto (GP), Log-Pearson III (LPIII) and Generalized Extreme Value (GEV) which gave similar results. Overall, the GP was considered the best fit to the data and gave a 1% AEP flow of 7,923 m^3/s. The report goes on to note:

> *At Singleton, the 1955 flood peaked at 13,123 m^3/s, which is 1.66 times the estimated 100 year ARI event. The flood distribution predicts that the 1955 flood was a 166 year ARI event. Although this should be regarded as a highly uncertain estimate because it is an extrapolation, the evidence points to the 1955 flood event having an ARI greater than 100 years at Singleton in the context of the period from 1913 up to the present day.*

3.2 1% AEP Flood at Singleton

Estimates of the 1% AEP flood at Singleton taken from reference documents are:

Table 1: 1% AEP Flow Estimates for Singleton

Source	Flow (m^3/s)	Method	Document Reference No.
Fluvial Systems 2009	7,923	Generalized Pareto	1
WMAwater 2010	9,390	Not stated.	2
Kuczera 2014	11,100	LPIII Gauged Bayesian Inference	3
Kuczera 2014	6,200	LPIII Gauged +historic. Bayesian Inference	3

The Fluvial Systems estimate has been adopted as the 1% AEP flow, being closest to the average of the above values. This flow would produce a gauge level of approximately 15.2 metres (42.8 mAHD) at the Singleton gauge based on an extrapolation of the current DPI Water rating table for this station. Note that this water level is 0.63 metres above the level commonly accepted value for the 1955 flood at Singleton.

3.3 Probable Maximum Flow (PMF) for Singleton

Webb, McKeown & Associates Pty Ltd (1998)], in a flood study for Maitland City Council, did not determine the probable maximum flood (PMF) discharge along the Hunter River at Maitland. Rather, an 'extreme flood' approximating the PMF, was allowed for. Using this approach, the extreme flood discharge for Singleton has been set at 24,000 m^3/s, compared with 7,936 m^3/s for the modelled 1% AEP event; increasing the flow peak by a factor of 3.

In 2010 WMAwater adopted the same approach to the PMF for the “Hunter River: Branxton to Green Rocks Flood Study” for Maitland City Council.

It is considered reasonable to use the same approach here in lieu of estimating the PMF. The extreme flood value of 24,000 m^3/s would produce a water level at the Singleton gauge of about 16 metres (43.6 mAHD).

3.4 Estimated Water Levels at Rixs Creek Confluence

The two Hunter river gauges closest to Rixs Creek with a suitably long record and having stage data tied to AHD are 210083 Liddell (40 km upstream) and 210001 Singleton (23 km downstream). An analysis of the river gradient between these gauges indicated a relatively narrow range of river gradients (Fluvial Systems 2009). As noted by Fluvial Systems:

> *" local morphology and hydraulics means that the water surface is not likely to be even along this 62.3 km of river, but as a first approximation, the slope of the river surface can be used to predict water surface elevation at Bowmans Creek junction, for the length of common record at Liddell and Singleton. The full (longer) Singleton record can be used by using a single (mean) value of river gradient for days when Liddell data are not available."*

Fluvial Systems (2009) plotted peak daily discharge against mean water surface gradient between Liddell and Singleton gauges and determined a mean gradient of 0.000594 m/m. The water stage levels at the Singleton gauge have been translated upstream to the Rixs Creek confluence based on two assumed river gradients from Singleton.

Estimated water levels at Rixs Creek using various gradients are provided in **Table 2.**

Table 2: Estimated Hunter River Flood Levels at Rixs Creek

Gradient Method	1% AEP Water Level (mAHD)	Extreme Flood water Level (mAHD)
Mean Bed Slope Rixs Creek - Singleton	55.4	56.2
Mean Water Surface Gradient Liddell - Singleton	56.7	57.5

The flood water level values estimated using the mean water surface gradient have been adopted, being more conservative, and are mapped on **Figure 1**. Large areas of floodplain storage, observable on **Figure 1,** provides some cushion against underestimating the size of the Extreme Flood, i.e. large errors in the flood estimation are unlikely to be accompanied by large differences in estimated water height.

4 Rixs Creek Flood Assessment

4.1 The Creek Reach

The reach of interest extends from the New England Highway to the southern project boundary. The Creek passes between the East and West Pits (Pit 2 and Pit 3). Pit 3 is the active mining area, and Pit 2 is a mined out open cut void that has been used for some years as a tailings dam. The Pit 2 tailings dam is no longer used to manage tailings and is being prepared for capping and rehabilitation.

The length of Rixs Creek passing between Pit 2 and Pit 3 extends from the New England Highway to just downstream of the active mining operation, where a creek draining the Singleton Industrial Estate joins from the east. This section of stream is just under than 2.6 kilometres long. Downstream of this, the stream flows away from the mining area for 1.5 kilometres towards the southern Project Boundary.

The 115 metres of Rixs Creek immediately below the New England Highway is a man-made channel installed by the Roads & Maritime Services some time after 1975. This straight section of channel replaced a meander, shortening the stream by some 150 metres of stream. This channel is trapezoidal in shape with a well vegetated stream bed that has two shallow incised low flow channels. The upper left batter and the right batter are 1:1 slopes with no topsoil, medium to light grass cover and show signs of ongoing erosion (scarping). There is no tree coverage on the banks that could stabilise the batters, although trees are colonising the batter toes.

There are two culvert crossings downstream from the New England Highway that occupy the stream bed for 65 and 40 metres respectively.

The remainder of the stream bed is relatively undisturbed and recovering from unsustainable agricultural practices that characterised the first half of last century. The stream bed typically consists of reaches of grey silty loam alternating with near horizontal layers of sandstone or jumbled boulders. One section of sandstone bed extended for some 350 metres. There are regular nick points in the rock channel, with shelf drops ranging from 0.2 metres to 0.8 metres, however there are no sills that provide ponding. The banks consist of mainly grey silty clays with sand and a loamy texture.

There are two predominant channel shapes: trapezoidal cross-sections with relatively steep side slopes (mainly the sheet rock beds) and reaches with U-shaped sections. The stream has relatively wide floodplains. The stream reach appears relatively stable.

Except for the channel diversion immediately below the highway, the stream banks and floodplains are densely wooded (mainly casuarina regrowth) and well vegetated, with trunk diameters regularly exceeding 100 mm. There is evidence of bank vegetation encouraging deposition at the bank toe, allowing colonising vegetation to encroach further into the channel, especially in the sections constrained by the rock bed. Woody debris, some large, is collecting in the channel. The total width of the riparian zone generally exceeded 50 metres, often reaching 80 metres, with two pinch points at the culverts installed for mining.

The New England Highway forms the upper bound of the reach. The highway is a major road route (Arterial Road Class 1) and should not be adversely affected by flooding. The Austroads Guide to Road Design Part 5: Drainage, Table 4.3 suggests a design ARI of 50 – 100 years for Cross drainage (culverts & bridges). The RTA Supplement to Austroads Guide to Road Design Part 5 (2008) states that a “major drainage system is normally designed for an ARI of 100 years.” Thus the culvert crossing of the New England Highway should be immune to at least the 1:100 ARI peak flow. The culvert consists of four box sections of dimensions 3m x 3m.

A haul road between West Pit and the Pit 2 tailings dam crosses the creek about 1100 metres downstream of the New England Highway. The culvert consists of a single 2100 mm diameter corrugated steel pipe about 65 metres long below an earthen embankment about 5.5 metres high. The stream bed appears to naturally drop about 2 metres over the length of this culvert. The tailings dam area is expected to be rehabilitated some time between 2020 and 2026, meaning the culvert may continue to operate for up to 10 years after which the affected creek section is proposed to be rehabilitated. This haul road creek crossing is designed to overtop in a 1:100 ARI peak flow and the roadside berms contain a 35 metre gap to allow overflows to pass with minimal constriction. The downstream section of the embankment is rock armoured against these overflows.

A triple 2100 RCP culvert crossing of the creek is located some 1,900 metres downstream of the New England Highway. This location is a disused haul road, and the culvert has been rehabilitated “in place” with the former road crest lowered. There are no roadside berms or other obstructions to the overflow of this crossing.

4.2 Estimation of Peak Flows for Rixs Creek

Regional flood methods are used where gauged data are inadequate and for ungauged sites. Rixs Creek is ungauged, and the Probabalistic Rational Method from ARR 1987 (PRM) was used to determine flood flow peaks. Using the PRM maintains consistency with flood flow peaks estimated for the Rixs Creek Continuation of Mining EIS, which were also determined using the PRM.

The PRM is known to have error, and new methods for regional flood estimation are under development by the Institution of Engineers. Rijal and Rahman (2005) studied a selection of gauged catchments from SE Australia. The study compared the performance of the PRM and a Quantile Regression Technique for catchments ranging in size from 3 to 950 km^2. The errors in the studied methods were based on comparison to peak flow estimates made using standard flood frequency analysis performed on gauged data with record lengths ranging from 24 to 59 years. One of the study findings was that there is a chance of about 10% that the error in design flood estimates will exceed 100% with the Probabilistic Rational Method. The authors warned that "the users of these techniques should be aware of this large error and provision should be made accordingly". Consequently, it was considered appropriate to assess the Creek performance against a flow 100% larger than the 1% AEP flow as well as the Extreme Flood.

Whilst PRM was not intended for use on mined, disturbed or urban catchments it is widely used as an estimation tool on mining and disturbed catchments, for example, see the “Managing Urban Stormwater Soils and Construction - Volume 2E Mines and

Quarries”, (DECC, 2008) and Managing Urban Storm water, Soils and Construction, (Landcom, 2004). It is considered that the flood peaks calculated using PRM are conservative, i.e. the peaks are higher than what is likely to occur in this catchment. The reasons for this assumption are:

- The reconstructed landforms contain larger volumes of surface storage than undisturbed catchments due to sediment management and erosion control requirements, providing some attenuation of peak flows.
- Surface drainage paths for sediment management and erosion control are significantly longer than for undisturbed catchments. This tends to lengthen the time of concentration of the catchment when compared to catchments of similar size, attenuating peak flows.
- The catchments in this and most active mining scenarios are fragmented, outside the bounds of the original catchment, sometimes linked by channels and have longer flow distances than the original catchments – refer Figure 6. This tends to lengthen the time of concentration of the catchment when compared to catchments of similar size, attenuating peak flows.
- Soil storage capacity and infiltration rates for rehabilitated soils in the Hunter coal industry tend to be higher than natural soils, generating less runoff.

The catchment areas used to estimate peak flows are notionally based on the 2026 mining scenario. The 2026 mine plan has the largest catchment area reporting to the study reach during the period of active mining south of the New England Highway – see **Table 5.** Four catchment scenarios for the study reach over the life of Rixs Creek Mine time are presented in **Table 3.** Observations relevant to the data presented in **Table 3** are:

- The catchment areas at all locations moving down the reach for each mining scenario never exceed the areas for the corresponding pre-mining catchment.
- Flood flows from each of the mining scenarios are expected to be less than those for the pre-mining condition because: the catchments are appreciably smaller than the pre-mining and; the mining catchments will tend to produce attenuated peaks compared to pre-mining catchments for reasons outlined in the previous paragraph.

Table 3: Catchment Comparisons for Modelled Reach of Rixs Creek

Scenario	Pre-Mining (ha)	2014 - EIS (ha)	2026 Mining Scenario (ha)	End of Mining (ha)
Ch 9845 **Upstream of New England Highway**	947	599	636	805
Ch. 7230 **Downstream of Operations**	1522	1090	1252	1215
Ch. 5774 **A Point Downstream of the Project Boundary**	1976	1409	1568	1848

The Extreme Flood was set at four times the value of the 1% AEP flow peak. The peak flows estimated for the Creek reach are set out in **Table 4** below.

4.3 Flood Flow Assessment

The HEC-RAS model was used to assess the flood performance of the Creek reach. HEC-RAS was developed by the US Army Corps of Engineers as a river analysis system. This software allows the user to perform one-dimensional steady flow, one and two-dimensional unsteady flow calculations, sediment transport/mobile bed computations, and water temperature/water quality modelling.

Creek cross sections and intermediate bed points were surveyed and photographed in 2013. The reach was photographed to provide a reference when determining stream roughness values – Manning's 'n'. Where required, cross sections were in-filled with synthetic sections from surveyed sections and 1 metre contours. Creek cross sections extended 2.2 kilometres upstream and 5.7 kilometres downstream from the reach of interest.

The Hunter River Flood levels determined using the mean water surface gradient between Liddell and Singleton were used as downstream reach boundary conditions - see **Table 2**.

Flows moving down the reach were adjusted to account for catchment inflows. The locations of the inflows were determined from site inspections and reference to existing and proposed drainage plans. The cross sections and inflow locations used in the HECRAS model are shown on **Figure 2** and set out in **Table 4**. The chainage (Ch.) of each location in the table is the distance upstream in metres, measured from the confluence of Rixs Creek with the Hunter River.

Table 4: Flood Flows used in HECRAS Model

Location	Catchment Area (ha)	1% AEP ARI (m^3/s)	1% AEPI + 100% (m^3/s)	Extreme Flow (m^3/s)
Ch. 9825: **Upstream of New England Highway**	636	20	40	80
Ch. 8,798: **Upstream of Tailings Dam Haul Road Culvert**	673	20.9	42	84
Ch. 8171: **Pit 2 Rehabilitation**	727	22.1	44	88
Ch. 7484: **Pit 3 Rehabilitation**	752	22.4	89	90
Ch. 7230: **Downstream of Operations**	1252	33	67	133
Ch. 5774: **A Point Downstream of the Project Boundary**	1568	40	79	158

5 Flooding in Other Mining Affected Catchments

Two other catchments are affected by the proposed mine plan:

1. Station Creek
2. Dead Mans Gully.

The drainage from the Rixs Creek Project Area into Station Creek catchment flows onto land owned by Bloomfield Group (the owner of Rixs Creek Mine) or associated entities. Bloomfield Group land ownership extends down Station Creek as far as Glennies Creek. The Director Generals Requirements do not require assessment of flooding impacts on lands owned by the proponent.

Catchment changes over the life of the project are set out in **Table** 5. Catchment areas for Dead Mans Gully gradually decrease over the life of the project, reflecting mining activity moving into the upper reaches of the catchment. The Dead Mans Gully catchment will always be less than the pre-mining catchment area. Flood peaks into this catchment from the Project Area will decrease in line with catchment reductions. The diverted catchment areas for Dead Mans Gully in 2014 and 2042 are shown on **Figure 7**.

Table 5: Summary of Catchment Change for the Life of the Project

Year	Rixs Creek (ha)	Change (ha)	Station Creek (ha)	Change (ha)	Dead Mans Gully (ha)	Change (ha)	Mining Area (ha)	Check Total (ha)	Total Loss
1990	2,562	0	2,413	0	1,402	0	0	6,378	0%
2014	1,986	-576	2,305	-108	1,321	-82	766	6,378	12%
2017	2,036	-526	2,305	-108	1,319	-83	717	6,378	11%
2020	2,122	-456	2,427	14	1,351	-52	478	6,378	7%
2023	2,113	-465	2,435	22	1,311	-91	518	6,378	8%
2026	2,171	-407	2,435	21	1,272	-131	501	6,378	8%
2042	2,444	-134	2,447	33	1,260	-142	227	6,378	4%

6 Results and Impacts

6.1 Hunter River Flooding

Flooding in the Hunter River does not impact on the operation of Rixs Creek mine. The estimated 1% AEP Flood and Extreme Flood levels for the Hunter River at the confluence of Rixs Creek are considered to be conservative estimates. The influence of flooding in the Hunter River on flood water levels in Rixs Creek does not extend any further upstream than Ch. 6800, about 175 metres from the toe of the nearest rehabilitated slope and about 500 metres along the Creek bed into the project Area. Sensitivity runs indicate that if the Extreme Flood level were 1 metre higher, the impact is unchanged.

6.2 Rixs Creek Flooding – Impacts Inside the Project Area

Table 7, **Table 8** and **Table 9** are appended to this letter. These tables summarise depths and average velocities along the Creek reach based on the peak flows set out in **Table 4**.

The flood extents arising from the modelled peak flows are mapped in **Figure 3**, **Figure 4** and **Figure 5**. Figure 4 and Figure 5 superimpose the lesser flood from the previous Figure to demonstrate the increased area of inundation due to the flood of interest. Where water levels are not influenced by structures placed within the stream, the Extreme Flood is contained within the floodplain. Due to catchment sizes being the same or lower, the extent of flooding in areas unaffected by introduced structures is at most the same, but expected to be less than if the catchment were undisturbed.

Average flow velocities on the floodplains for the 1% AEP flood are all less than 1.2 m/s. For the Upper Limit 1% AEP flood, 91% of average velocities are less than 1.2 m/s and the highest average value is 1.6 m/s. In the Extreme Flood, 80% of average velocities are less than 1.2 m/s and the highest average value is 2.2 m/s. The creek floodplains generally have dense tree cover and the minor areas without trees are well grassed. The soils would be well bound by the root systems and should withstand the short term flood velocities.

Elevated water levels at the culvert at Ch. 7900 do not encroach upon rehabilitated mined land. The culvert embankment overflows during the 1% AEP Upper Limit Flood and the Extreme Flood with water depths up to 0.8 metres. This has potential to cause erosion at this structure.

Elevated water levels at the 2100 mm diameter culvert crossing to the Pit 2 tailings dam causes the culvert embankment to overflow during each of the modelled flood scenarios with overflow depths ranging from 0.3 to 1.2 metres. This has potential to cause erosion at this structure.

Upstream of the 2100 mm diameter culvert crossing to the Pit 2 tailings dam, water inflows at the Pit 2 tailings dam are likely to occur under each flow scenario modelled. The potential inflow points are indicated by flow "arrows" shown on **Figure 3**, **Figure 4** and **Figure 5**. The existing berms along the edge of the active mining area provide protection for the 1% AEP Upper Limit Flood. Under the Extreme Flood scenario, water inflows to Pit 3 are likely to occur at low points in berms around the perimeter of the open cut. The estimated depths of overflows are set out in . Areas of the active mine and the decommissioned Pit 2 tailings dam will be subject to inundation. The assessment of the integrity of the berms against flood water did not form part of the scope of this study.

Inundation of the active pit will impose an adverse economic impact on Rixs Creek Mine. Inundation of the tailings dam and the open cut will adversely impact the mine water management system, increasing the volume of saline water to be contained and disposed of. The potential volume of inflows into the tailings dam has not been determined, however logic dictates that there is a risk that some water may flow back to Rixs Creek once the flood level subsides.

Under the Extreme Flood scenario, one sediment trap is submerged. The affected dam is located on the left (eastern) bank at Ch. 7910 just upstream of the triple 2100 culvert and adjacent to the toe of the mature rehabilitation. This rehabilitation is mature and the dam is no longer required to operate as a sediment dam. The dam submerged by the headwaters of the culvert, and the average velocity on the floodplain in the vicinity of the sediment trap is 0.41 m/s. Erosion of the dam embankment is considered unlikely. No sediment traps or dams are impacted under any of the other modelled scenarios.

Table 6: Estimated Inflow Depths

Location & Destination	1% AEP ARI (m)	1% AEPI + 100% - (m)	Extreme Flood (m)
Ch. 9300 **Pit 2 Tailings Dam**	0.3	0.7	1.2
Ch. 9200 **Pit 2 Tailings Dam**	1.3	1.7	2.2
Ch. 8733 **Pit 2 Tailings Dam**	n/a	n/a	0.1
Ch. 9200 **Pit 3**	n/a	n/a	0.2
Ch. 8950 **Pit 3**	n/a	n/a	0.2

Water approaches but does not reach the toe of the Pit 3 rehabilitation on the right (western) bank around Ch. 8300 in the1% AEPI+100% Flood and the Extreme Flood Scenario. In each case the average velocity is less than 0.51 m/s, and erosion is considered unlikely.

6.3 Rixs Creek Flooding – Impacts Outside Project Area

6.3.1 New England Highway

The Rixs Creek culvert crossing beneath the New England Highway has the capacity to convey the Extreme Flood. The modelled maximum water level from the Extreme Flood is about 0.8 metres below the crown of the culvert and more than 2 metres below the road shoulder. RTA (Roads & Maritime) road design standards only require this culvert to convey the 1:100 ARI flood.

The catchment area reporting to the culvert beneath the New England Highway is always less than the pre-mining catchment over the life of the project. The impact of the project is a decrease in flood peak flows at the existing New England Highway culvert when compared to the pre-mining catchment.

6.3.2 Rixs Creek Downstream of Mining Operations

The Rixs Creek catchment area flowing off the Project Area is always less than the pre-mining catchment over the life of the project - **Table 5**. The overall impact of the project is a decrease in flood peak flows in Rixs Creek when compared to the pre-mining condition. No downstream landholders are impacted by increased flood peaks.

6.3.2 Dead Mans Gully Downstream of Mining Operations

The Dead Mans Gully catchment area flowing off the Project Area is always less than the pre-mining catchment over the life of the project - **Table** 5. The overall impact of the project is a decrease in flood peak flows in Dead Mans Gully when compared to the pre-mining condition. No downstream landholders are impacted by increased flood peaks.

6 Mitigation of Impacts

There are no increases to flood peaks due to the project on private property or on public infrastructure. No mitigation is required.

Overtopping of the two culverts in the reach of Rixs Creek between Pits 2 and 3 has the potential to cause localised erosion. The current upstream and downstream channels at each culvert are not eroded and the embankment faces show no evidence of erosion. The short term and infrequent nature of the overtopping events would warrant no more than repairs if the culverts overflow during the life of the operation and damage does occur.

Inundation of the open cut due to elevated flood levels at the culvert crossing to Pit 2 tailings dam will impose economic and environmental costs on Rixs Creek Mine. The level of protection provided against flood inflows is an economic decision for the mine operator, likely to be determined by insurance requirements. Standard practice in the local mining appears to be to adopt a protection standard of 1:100 AEP against flooding.

Inundation of the Pit 3 tailings dam due to elevated flood levels at the culvert crossing to Pit 3 tailings dam will impose economic and environmental costs on Rixs Creek

Mine. The failure to prevent inflows and subsequent outflows at the tailings dam in events up to the 1:100 AEP flood would be considered by the Environment Protection Authority as not complying with the Hunter River Salinity Trading Scheme, and prosecution would be likely. It would seem prudent for Rixs Creek Mine to prevent inflows to the Pit 2 decommissioned tailings dam from Rixs Creek for floods up to and including the 1% AEP flood in Rixs Creek.

Mitigation of the inundation impacts due to the may be achieved in several ways. Suggested actions include:

- Lowering the level of the road embankment the culvert crossing to Pit 2 tailings dam would eliminate risk to the open cut and require minimal work to protect the tailings dam. The embankment level would need to be lowered by about a metre. Modelling indicates that increasing the number of culvert barrels is relatively ineffective, e.g. increasing to 3 barrels would reduce headwater levels by 0.3 metres.
- Create a continuous embankment between Rixs Creek and the Pit 2 tailings dam to 71 mAHD. The majority of the required embankments are already in place and only short lengths embankment up to 2 metres (generally less than 1 metre) in height would be required. Constructing the berms from selected mine spoil using track rolling by the dump trucks would be adequate, providing that a sufficient width of berm is provided. Selected mine spoil would need to be predominantly fines with rocks exceeding 0.25 metres removed. Alternately, the outer face of the rehabilitated emplacement could be constructed to 71 mAHD.

8 Conclusion and Recommendations

There are threats from inundation to the Pit 2 tailings dam from Rixs Creek under all flood scenarios modelled and this requires a response from the mine operator. The Pit 3 open cut is currently protected from flooding up to the 1% AEP Upper Limit Flood, however the integrity of the existing berms has not been considered as part of this study.

The recommended actions are to:

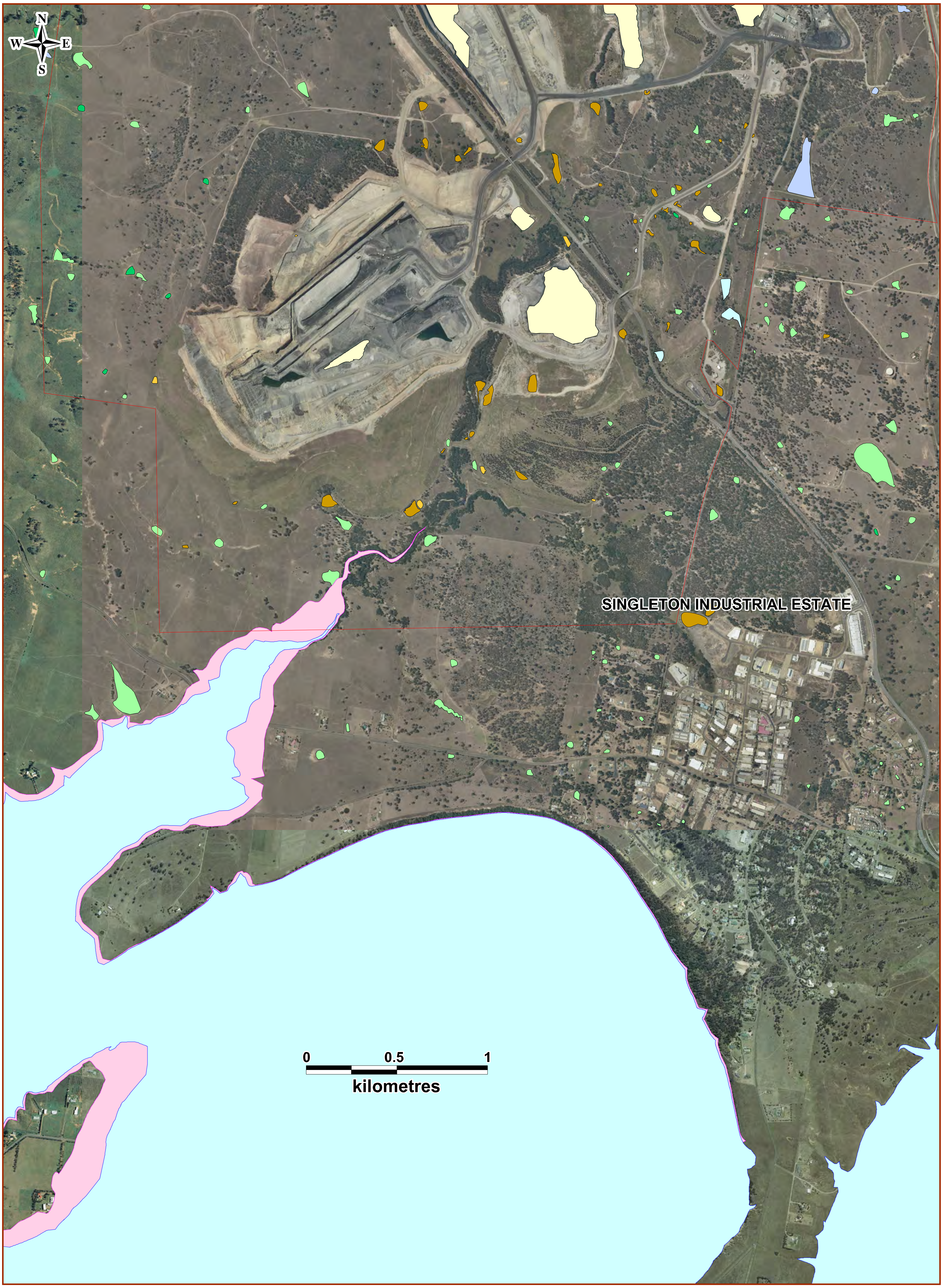
- Protect the open cut and the Pit 2 tailings dam from inflows due to the 1% AEP Upper Limit flood in Rixs Creek. The nature of the protective actions is up to the mine operator.
- Incorporate review of flood protection measures into the design systems of the mine, specifically for Pit 3 along Rixs Creek. The purpose is to ensure containment berms are of adequate height and integrity to withstand the 1% AEP Upper Limit flood in Rixs Creek
- Review the integrity and height of existing berms along the perimeter of Pit 3, upstream of the culvert crossing to Pit 2 tailings dam.
- Ensure that the minimum 35 metre floodway width at the culvert crossing to Pit 2 tailings dam is maintained.

For future proofing, it may be prudent to allow for later modification of freeboard to meet the flood estimation standards being developed for the latest version of Australian Rainfall and Runoff so required.

Should you need further assistance with this matter, please do not hesitate to contact me.

Yours Sincerely,

John Pola
Managing Director



Flood Extent

- 1% AEP Flood
- Extreme Flood
- Project Area

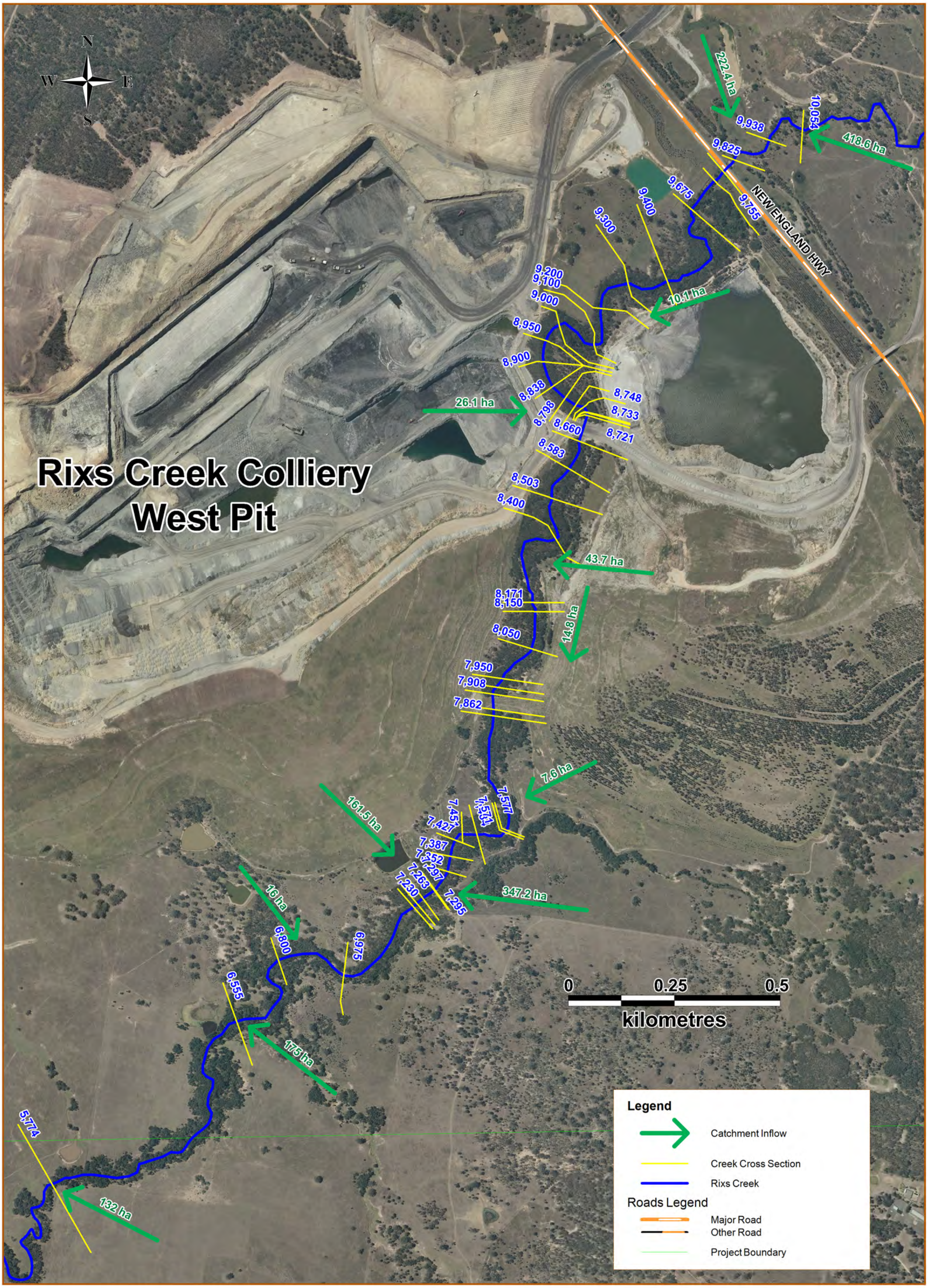
Dams By Purpose

- Clean
- Sediment
- Containment
- Diversion
- Erosion Control
- Rural
- Soil Conservation

JP Environmental

Surface Water Study for Rixs Creek Continuation of Mining

Figure 1: Hunter River Flood Extents



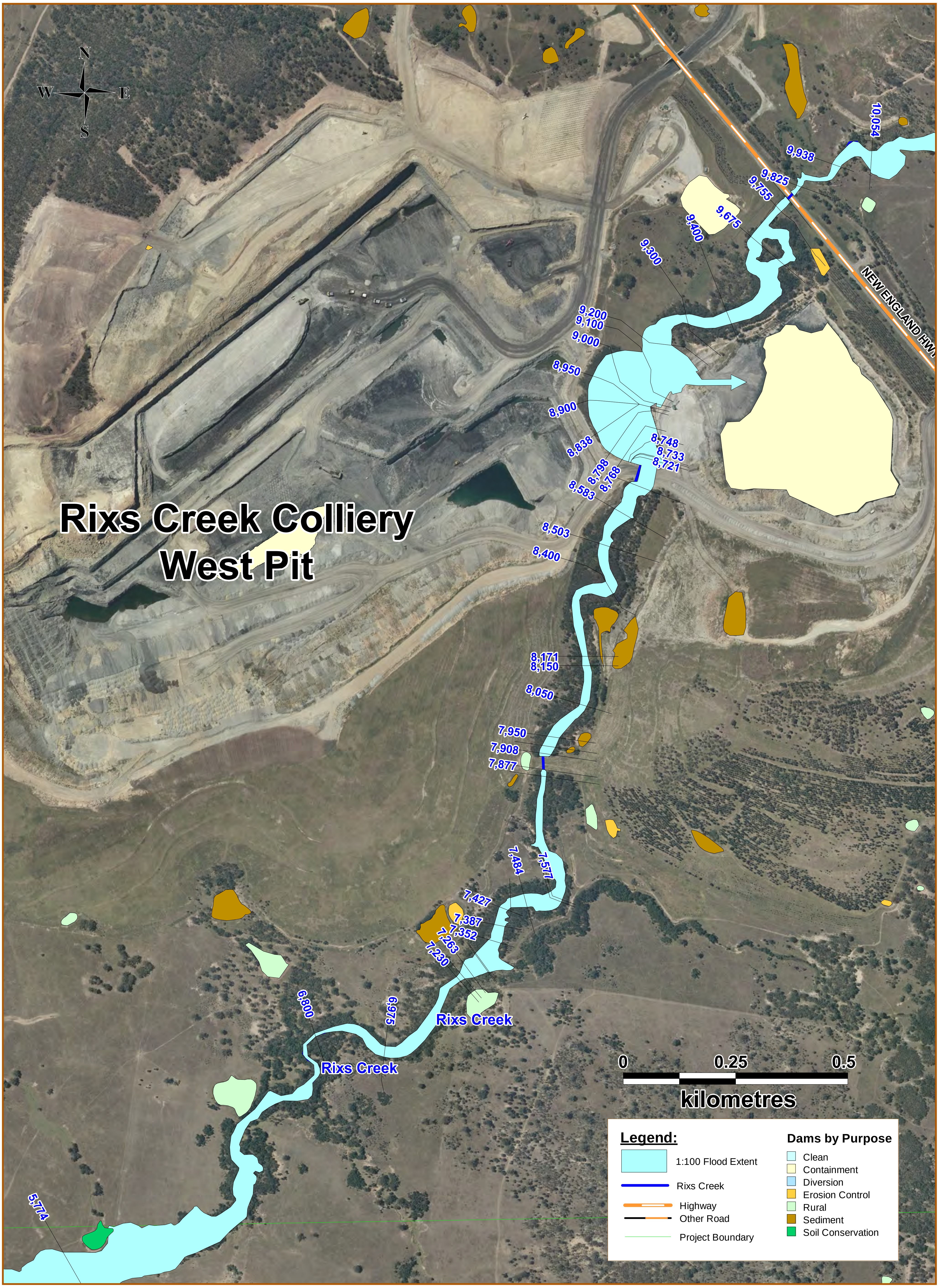
JP ENVIRONMENTAL

• RIX'S CREEK •

Catcment Inflows and Cross Sections

Location:	RXC	Date:	20160307	Project:	RXC SIA
Projection:	MGA Z56	Plan By:	JPP	Layout:	A3
Contour Interval:	5m	Version:	01	Our Ref:	13037

Figure 2



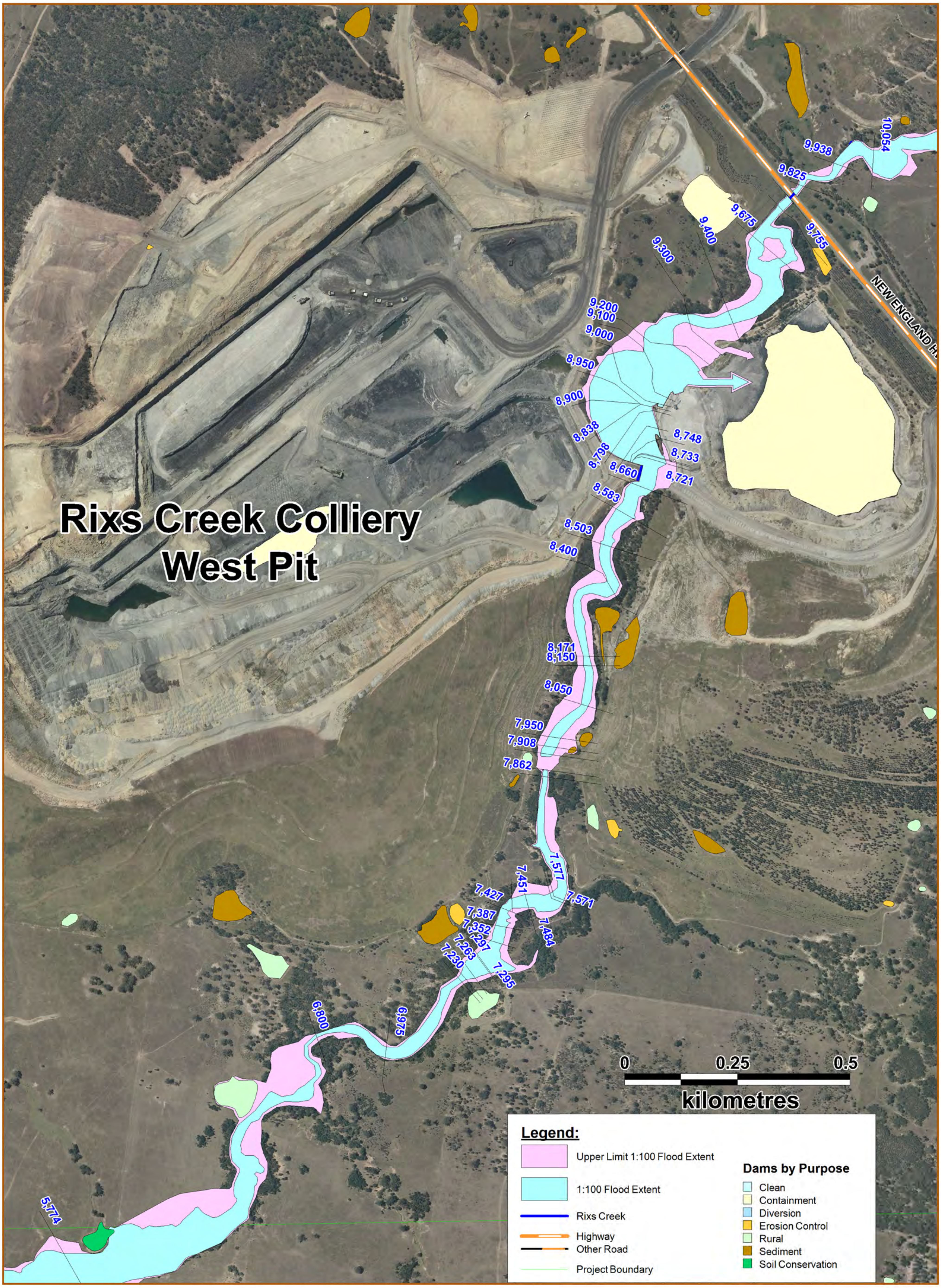
JP ENVIRONMENTAL

• RIX'S CREEK •

Rixs Creek Flood Extent 1% AEP

Location:	RXC	Date:	20160307	Project:	RXC SIA
Projection:	MGA Z56	Plan By:	JPP	Layout:	A3
Contour Interval:	5m	Version:	01	Our Ref:	13037

Figure 3



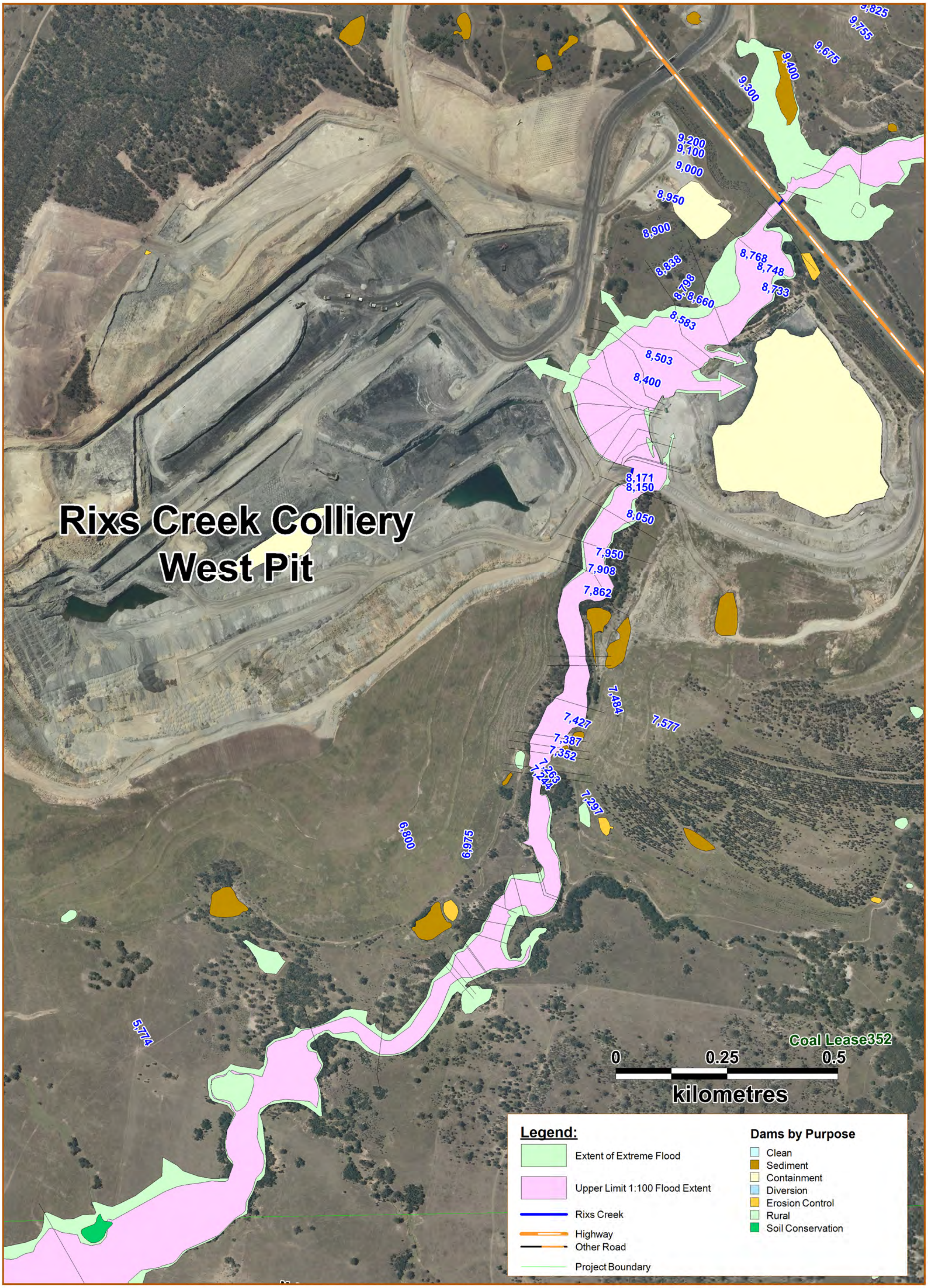
JP ENVIRONMENTAL

• RIX'S CREEK •

Rixs Creek Flood Extent: 1% AEP Upper Limit

Location:	RXC	Date:	20160307	Project:	RXC SIA
Projection:	MGA Z56	Plan By:	JPP	Layout:	A3
Contour Interval:	5m	Version:	01	Our Ref:	13037

Figure 4



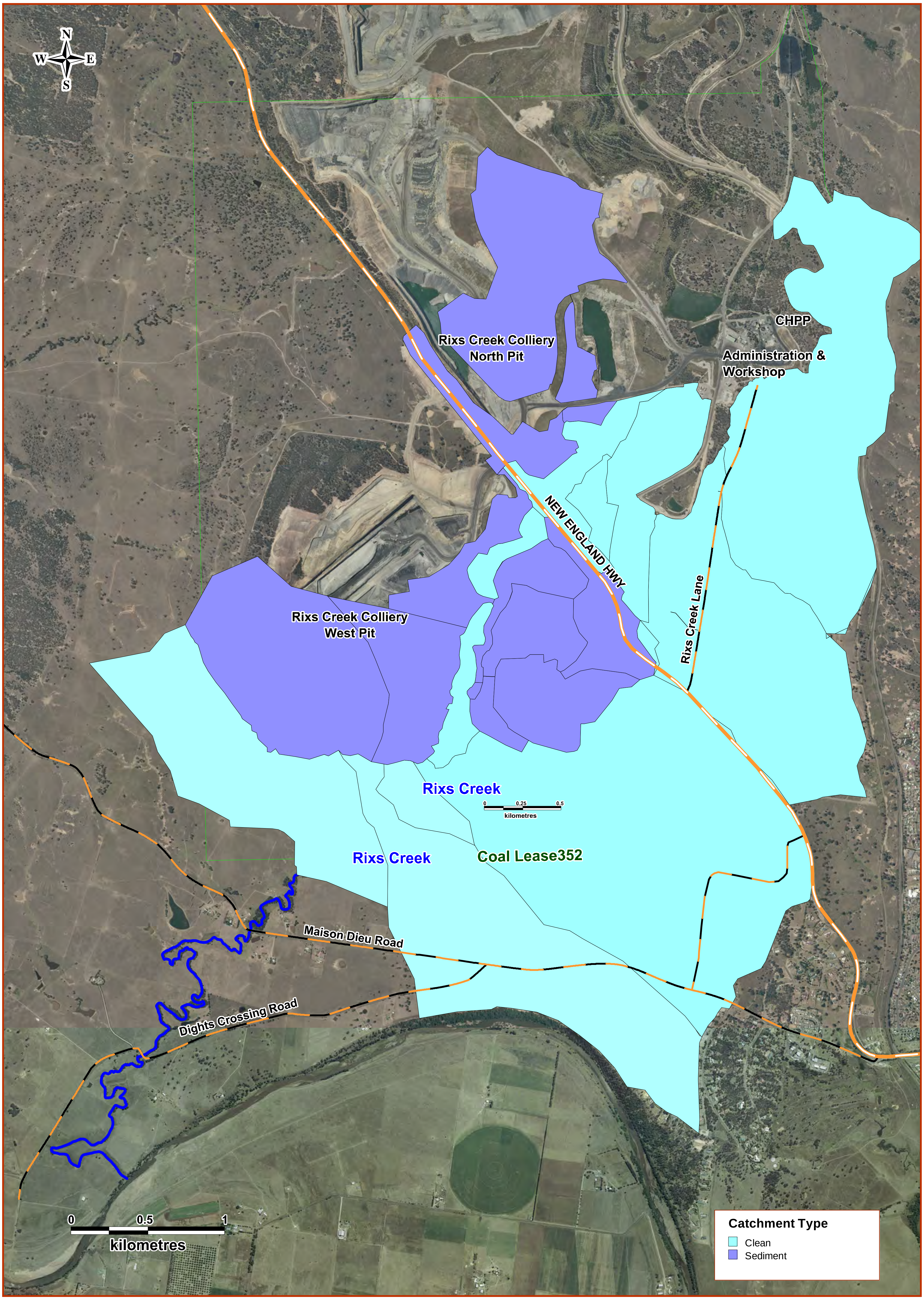
JP ENVIRONMENTAL

• RIX'S CREEK •

Rixs Creek Flood Extent: Extreme Flood

Location:	RXC	Date:	20160307	Project:	RXC SIA
Projection:	MGA Z56	Plan By:	JPP	Layout:	A3
Contour Interval:	5m	Version:	01	Our Ref:	13037

Figure 5



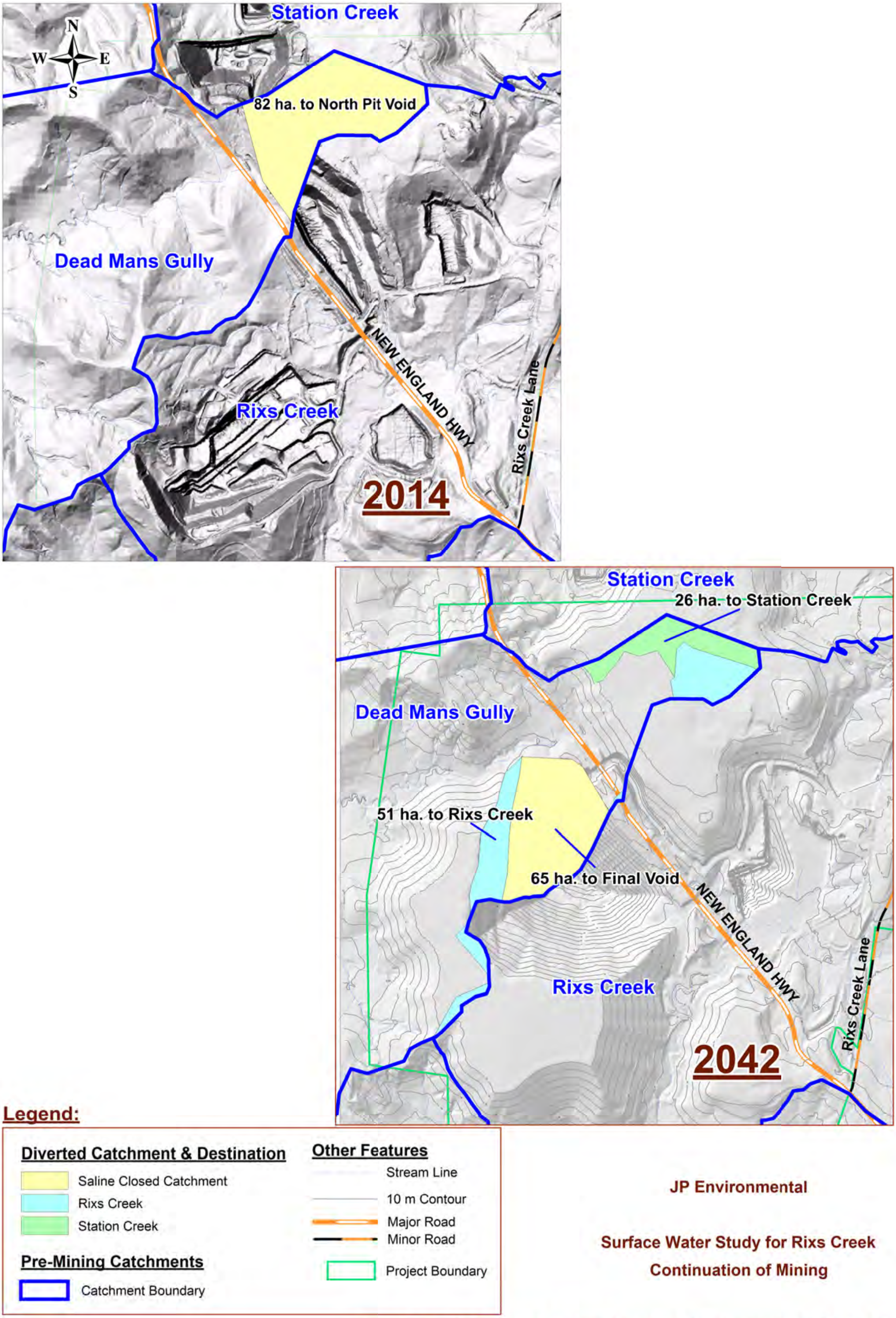
JP ENVIRONMENTAL

RIX'S CREEK

Rixs Creek Catchments in 2026

Location:	RXC	Date:	20160307	Project:	RXC SIA
Projection:	MGA Z56	Plan By:	JPP	Layout:	A3
Contour Interval:	5m	Version:	01	Our Ref:	13037

Figure 6



JP Environmental

Surface Water Study for Rixs Creek Continuation of Mining

Figure 7: Dead Mans Gully Diverted Catchment 2014 & 2042

Table 7: Model Results – ARR87 - 1-%

River Station	Q Total	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Vel Left	Vel Right	Flow Area	Froude # Chl
	(m3/s)	(m)	(m)	(m)	(m/m)	(m/s)	(m/s)	(m/s)	(m2)	
10054	14.5	73.96	73.1	73.99	0.001313	0.86	0.62	0.33	22.18	0.19
9938	20	73.31	72.49	73.4	0.004831	1.41	0.44	0.57	15.5	0.39
9825	20	72.14	72.14	72.53	0.013098	2.75	0.66	0.65	7.35	0.98
9787.1	Culv									
9787	20	72.1		72.14	0.00032	0.86			23.19	0.23
9755	20	72.09		72.12	0.000759	0.72			27.93	0.2
9675	20	72.01		72.03	0.001488	0.64	0.05	0.04	31.99	0.23
9400	20.1	71.02	70.76	71.09	0.013952	1.35	1.14	0.43	17.7	0.5
9300	20.2	70.49		70.53	0.002956	0.59	0.97		24.38	0.28
9200	20.2	70.49		70.49	0.000087	0.13	0.26	0.1	88.96	0.04
9100	20.2	70.47		70.47	0.000697	0.41	0.36	0.31	59.91	0.13
9000	20.3	70.4		70.4	0.000728	0.48	0.3	0.28	64.51	0.13
8950	20.3	70.35		70.36	0.000935	0.53	0.3	0.38	55.48	0.15
8900	20.3	70.32		70.33	0.000543	0.49	0.27	0.3	66.54	0.13
8838	20.3	70.29		70.3	0.000384	0.46	0.25	0.31	63.96	0.11
8798	20.9	70.28		70.29	0.000131	0.51	0.19	0.24	82.51	0.11
8768	20.9	70.28		70.29	0.000105	0.43	0.19	0.23	89.02	0.09
8733	20.9	70.28		70.28	0.000014	0.12	0.11	0.1	180.79	0.02
8731	20.9	70.28		70.28	0.000011	0.11	0.1	0.09	192.37	0.02
8721	20.9	70.28	66.45	70.28	0.000017	0.11	0.11	0.13	182.19	0.02
8718	Culv									
8659.83	20.9	67.77	65.86	67.79	0.000217	0.55	0.14	0.17	40.37	0.12
8645	20.9	67.72		67.77	0.0051	1.03	0.6		21.42	0.31
8583	20.9	67.39		67.46	0.004882	1.31	0.56	0.53	19.52	0.3
8503	20.9	66.97		67.06	0.005263	1.42	0.48	0.5	18.46	0.32
8450	20.9	65.77	65.77	66.34	0.0637	3.32			6.29	1
8400	20.9	65.05	64.57	65.13	0.001939	1.25	0.06	0.06	16.77	0.46
8350	20.9	64.97	64.42	65.03	0.001622	1.15	0.1	0.1	18.34	0.4
8300	20.9	64.9		64.96	0.001323	1.05	0.12	0.12	20.37	0.35
8171	22.1	64.03	64.03	64.4	0.04651	2.71			8.15	1.01
8150	22.1	63.84	63.03	63.9	0.006691	1.14			19.34	0.35
8050	22.1	63.4		63.49	0.002827	1.33	0.3	0.3	17.3	0.36
7950	22.1	63.33		63.36	0.000585	0.66	0.12	0.12	34.29	0.17

River Station	Q Total	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Vel Left	Vel Right	Flow Area	Froude # Chl
	(m3/s)	(m)	(m)	(m)	(m/m)	(m/s)	(m/s)	(m/s)	(m2)	
7925	22.1	63.3		63.33	0.002665	0.72			30.82	0.19
7910	22.1	63.29	61.97	63.32	0.000386	0.72			30.75	0.19
7908	Culv									
7877	22.1	62.62	62.35	62.78	0.005142	1.79			12.37	0.62
7862	22.1	62.3	62.28	62.61	0.027378	2.5			8.85	0.97
7577	22.1	61.64		61.66	0.001091	0.71	0.12	0.17	33.44	0.18
7571	22.1	61.56		61.58	0.000793	0.62	0.08	0.12	37.58	0.15
7484	22.4	61.38		61.45	0.003496	1.2	0.33	0.34	20.83	0.29
7451	22.4	61.04		61.21	0.018664	1.86		0.28	12.09	0.54
7422	22.4	60.94		61	0.004106	1.13	0.4	0.38	22.76	0.27
7387	22.4	60.87		60.9	0.00134	1.03	0.49	0.37	41.06	0.22
7352	22.4	60.88		60.88	0.000167	0.23			97.86	0.08
7297	22.4	60.84		60.86	0.000631	0.68	0.16	0.27	36.43	0.2
7295	22.4	60.85		60.86	0.00026	0.51	0.13	0.19	51.73	0.13
7263	22.4	60.7		60.82	0.013286	1.56		0.39	14.4	0.4
7244	22.4	60.38		60.52	0.018532	1.7			13.19	0.46
7230	33.4	59.97		60.21	0.024365	2.17		0.7	15.62	0.55
6975	33.4	58.68		58.76	0.002371	1.21	0.43	0.43	29.81	0.29
6800	33.4	56.82	56.82	57.48	0.082666	3.6			9.27	1
5774	33.4	56.76	54.21	56.76	0.000072	0.3	0.25	0.16	127.4	0.06

Table 8: Model Results – ARR87 - 1-% Upper Limit

River Station	Q Total	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Vel Left	Vel Right	Flow Area	Froude # Chl
	(m3/s)	(m)	(m)	(m)	(m/m)	(m/s)	(m/s)	(m/s)	(m2)	
10054	29	74.31	73.64	74.33	0.000917	0.8	0.63	0.49	52.43	0.16
9938	40	73.75	73.28	73.87	0.004583	1.66	0.98	0.95	29.82	0.39
9825	40	72.64	72.64	73.12	0.009141	3.16	1.67	2.03	13.74	0.89
9787.1	Culv									
9787	40	72.41		72.51	0.001014	1.4			28.62	0.36
9755	40	72.4		72.46	0.001561	1.16	0.44		34.59	0.3
9675	40.1	72.3		72.33	0.001576	0.74	0.62	0.55	65.88	0.23
9400	40.3	71.15	71.1	71.27	0.018324	1.71	1.6	0.74	27.24	0.59
9300	40.3	70.84		70.87	0.001557	0.52	0.81	0.29	50.37	0.21
9200	40.4	70.83		70.84	0.000115	0.19	0.37	0.26	145.48	0.05
9100	40.5	70.81		70.82	0.000403	0.37	0.4	0.37	115.65	0.1
9000	40.5	70.77		70.78	0.0004	0.42	0.38	0.3	125.67	0.1
8950	40.6	70.75		70.75	0.000497	0.46	0.41	0.37	110.85	0.12
8900	40.6	70.73		70.73	0.000369	0.47	0.4	0.38	120.87	0.11
8838	40.5	70.7		70.71	0.000318	0.48	0.39	0.44	116.49	0.11
8798	41.7	70.69		70.7	0.00018	0.67	0.34	0.45	126.6	0.14
8768	41.7	70.69		70.7	0.000154	0.58	0.38	0.48	128.65	0.12
8733	41.7	70.69		70.69	0.000032	0.2	0.34	0.31	214.78	0.03
8731	41.7	70.69		70.69	0.000027	0.19	0.32	0.29	226.63	0.03
8721	41.7	70.69	67.02	70.69	0.000039	0.17	0.32	0.37	215.76	0.03
8718	Culv									
8659.83	41.7	68.28	66.33	68.31	0.000391	0.85	0.36	0.63	55.5	0.17
8645	41.7	68.23		68.29	0.005092	1.21	1.22	0.65	37.06	0.32
8583	41.7	67.87		67.97	0.005277	1.59	1.27	1.15	34.31	0.33
8503	41.7	67.54	66.93	67.61	0.003739	1.42	1.07	0.76	42.09	0.28
8450	41.7	66.79	66.79	67.18	0.022374	2.91	1.82	1.54	17.81	0.65
8400	41.7	66	64.99	66.04	0.000786	0.97	0.45	0.51	54.71	0.24
8350	41.7	65.97	64.86	66.01	0.000609	0.88	0.44	0.5	62.7	0.21
8300	41.7	65.95		65.98	0.000469	0.79	0.4	0.47	71.94	0.18
8171	44.1	65.79		65.85	0.003113	1.04	0.8	0.79	46.44	0.25
8150	44.1	65.81		65.82	0.000381	0.49	0.66	0.51	107.5	0.09
8050	44.1	65.78		65.79	0.000151	0.6	0.52	0.51	110.62	0.1
7950	44.1	65.78		65.78	0.000055	0.38	0.35	0.39	151.28	0.06

7925	44.1	65.78		65.78	0.000147	0.31	0.44	0.37	164.73	0.05
7910	44.1	65.77	62.38	65.78	0.00004	0.42	0.42	0.21	125.18	0.07
7908	Culv									
7877	44.1	63.07		63.33	0.00537	2.24			19.65	0.67
7862	44.1	62.86		63.19	0.015986	2.56			17.22	0.8
7577	44.1	62.21		62.25	0.001219	0.93	0.5	0.52	58.35	0.2
7571	44.1	62.12		62.16	0.001062	0.86	0.47	0.5	60.48	0.18
7484	44.8	61.96		62.02	0.002479	1.23	0.66	0.8	52.65	0.26
7451	44.8	61.45		61.8	0.026626	2.65	1.31	1.26	17.79	0.67
7422	44.8	61.53		61.57	0.002417	1.05	0.65	0.8	57.87	0.22
7387	44.8	61.5		61.52	0.000588	0.81	0.55	0.53	94.97	0.15
7352	44.8	61.5		61.51	0.000125	0.26			172.03	0.07
7297	44.8	61.46		61.49	0.000509	0.81	0.43	0.42	70.75	0.19
7295	44.8	61.47		61.49	0.000251	0.64	0.36	0.36	95.37	0.14
7263	44.8	61.31		61.45	0.011235	1.77	1.59	1.44	29.62	0.39
7244	44.8	60.86	60.26	61.13	0.025595	2.34	1.66	1.5	21.11	0.57
7230	66.7	60.62		60.83	0.016957	2.25	1.89	1.72	34.91	0.48
6975	66.7	59.34		59.45	0.002571	1.56	1	1.23	50.35	0.32
6800	66.7	57.95	57.95	58.32	0.032241	2.89	2.32	1.99	27.11	0.65
5774	66.7	56.91	54.88	56.92	0.000204	0.53	0.42	0.33	148.82	0.1

Table 9: Model Results – ARR 87 Extreme Flood

River Station	Q Total	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Vel Left	Vel Right	Flow Area	Froude # Chl
	(m3/s)	(m)	(m)	(m)	(m/m)	(m/s)	(m/s)	(m/s)	(m2)	
10054	58	74.66	74.16	74.68	0.000664	0.74	0.63	0.49	93.5	0.14
9938	80	74.29	73.86	74.37	0.002702	1.52	0.98	0.95	69.55	0.32
9825	80	73.3	73.3	73.86	0.006832	3.6	1.67	2.03	26.78	0.82
9787.1	Culv									
9787	80	72.72		72.99	0.002973	2.3			34.71	0.58
9755	80.1	72.69		72.86	0.003349	1.87	0.44		48.4	0.45
9675	80.2	72.58	72.12	72.62	0.001947	0.92	0.62	0.55	104.04	0.25
9400	80.5	71.46		71.57	0.009967	1.55	1.6	0.74	59.71	0.46
9300	80.7	71.31		71.34	0.00086	0.54	0.81	0.29	121.72	0.17
9200	80.8	71.3		71.31	0.000122	0.24	0.37	0.26	246.4	0.06
9100	80.9	71.28		71.29	0.000246	0.35	0.4	0.37	212.54	0.08
9000	81	71.26		71.27	0.000282	0.41	0.38	0.3	221.56	0.09
8950	81.1	71.24		71.25	0.000363	0.47	0.41	0.37	196.62	0.1
8900	81.2	71.22		71.23	0.000319	0.51	0.4	0.38	201.2	0.1
8838	81	71.2		71.21	0.000301	0.54	0.39	0.44	193.32	0.11
8798	83.5	71.19		71.2	0.000232	0.86	0.34	0.45	198.19	0.16
8768	83.5	71.18		71.2	0.000223	0.79	0.38	0.48	185.9	0.14
8733	83.5	71.18		71.19	0.000071	0.32	0.34	0.31	256.54	0.05
8731	83.5	71.18		71.19	0.000062	0.31	0.32	0.29	268.66	0.05
8721	83.5	71.18	67.73	71.19	0.000087	0.27	0.32	0.37	257.51	0.04
8718	Culv									
8659.83	83.5	68.79	66.97	68.87	0.000752	1.33	0.36	0.63	77.8	0.24
8645	83.5	68.75		68.85	0.005332	1.51	1.22	0.65	62.21	0.35
8583	83.5	68.32		68.47	0.006945	2.04	1.27	1.15	54.88	0.39
8503	83.5	68	67.47	68.07	0.003335	1.49	1.07	0.76	79.99	0.27
8450	83.5	67.27	67.27	67.67	0.021615	3.3	1.82	1.54	33.89	0.67
8400	83.5	66.39	65.47	66.47	0.001346	1.39	0.45	0.51	85.1	0.31
8350	83.5	66.33	65.33	66.4	0.001122	1.29	0.44	0.5	92.14	0.28
8300	83.5	66.29		66.35	0.000898	1.18	0.4	0.47	103.51	0.25
8171	88.3	65.85		66.04	0.010894	1.99	0.8	0.79	49.12	0.47
8150	88.3	65.9		65.94	0.001276	0.92	0.66	0.51	114.96	0.17
8050	88.3	65.8		65.85	0.000584	1.19	0.52	0.51	112.34	0.2
7950	88.3	65.79		65.81	0.000218	0.75	0.35	0.39	152.25	0.12

7925	88.3	65.79		65.8	0.000578	0.61	0.44	0.37	165.76	0.1
7910	88.3	65.76	62.97	65.8	0.00016	0.84	0.42	0.21	124.88	0.14
7908	Culv									
7877	88.3	63.73		64.12	0.00548	2.75			32.09	0.71
7862	88.3	63.51		63.98	0.014891	3.05			28.92	0.81
7577	88.3	62.78		62.84	0.001566	1.24	0.5	0.52	97.85	0.24
7571	88.3	62.64		62.71	0.001638	1.23	0.47	0.5	94.1	0.23
7484	89.6	62.48		62.54	0.002242	1.34	0.66	0.8	94.26	0.26
7451	89.6	62.05	62.05	62.35	0.018939	2.77	1.31	1.26	44.03	0.6
7422	89.6	62.08	61.34	62.12	0.001989	1.09	0.65	0.8	103.45	0.2
7387	89.6	62.06		62.08	0.000574	0.9	0.55	0.53	158.16	0.16
7352	89.6	62.06		62.06	0.000173	0.36			246.51	0.09
7297	89.6	61.99		62.04	0.000677	1.11	0.43	0.42	112.31	0.23
7295	89.6	62		62.03	0.000369	0.9	0.36	0.36	144.94	0.18
7263	89.6	61.81		61.99	0.011584	2.07	1.59	1.44	49.53	0.41
7244	89.6	61.51		61.73	0.015853	2.28	1.66	1.5	45.18	0.47
7230	133.4	61.33		61.54	0.011815	2.25	1.89	1.72	66.29	0.42
6975	133.4	59.99		60.15	0.003077	2	1	1.23	82.74	0.37
6800	133.4	58.44	58.44	58.87	0.031193	3.29	2.32	1.99	48.36	0.66
5774	133.4	57.84	55.8	57.85	0.000099	0.44	0.42	0.33	332.24	0.07