ENGENY
WATER MANAGEMENT

WARATAH COAL

Mine Site Creek Diversion and Flooding

Galilee Coal Project SEIS Technical Report

November 2012

M1700_005

www.engeny.com.au
P: 07 3221 7174 I F: 07 3236 2399
Lvl 11, 344 Queen st Brisbane QLD 4000 I PO Box 10183 Brisbane QLD 4000

WARATAH COAL
MINE SITE CREEK DIVERSION AND FLOODING

ENGENY
WATER MANAGEMENT

DISCLAIMER

This report has been prepared on behalf of and for the exclusive use of Waratah Coal and is subject to and issued in accordance with Waratah Coal instruction to Engeny Water Management (Engeny). The content of this report was based on previous information and studies supplied by Waratah Coal.

Engeny accepts no liability or responsibility whatsoever for it in respect of any use of or reliance upon this report by any third party. Copying this report without the permission of Waratah Coal. or Engeny is not permitted.

M1700_005 SEIS Water Management					
M:\Projects\M1700_Waratah Coal\M1700_005 SEIS Water Management\Documents\Revisions					
REV	**DESCRIPTION**	**AUTHOR**	**REVIEWER**	**APPROVED BY**	**DATE**
Rev 0	Client Issue	Ben Kiernan	Andrew Vitale	Andrew Vitale	3 August 2012
Rev 1	Final	Ben Kiernan	Andrew Vitale	Andrew Vitale	8 August 2012
Rev 2	CG Amendments	Ben Kiernan	Andrew Vitale	Andrew Vitale	2 November 2012
Signatures		B.Ki	AVitale	AVitale	

WARATAH COAL
MINE SITE CREEK DIVERSION AND FLOODING

CONTENTS

Appendices

WARATAH COAL
MINE SITE CREEK DIVERSION AND FLOODING

List of Tables

List of Figures

Abbreviations

ACARP – Australian Coal Association Research Program

AHD – Australian Height Datum

ALS – Aerial Laser Scanning

ARF – Areal Reduction Factors

ARI – Average Recurrence Interval

BOM – Bureau of Meteorology

CHPP – Coal Handling and Preparation Plant

DEHP – Department of Environment and Heritage Protection

DEM – Digital Elevation Model

DERM – Department of Environment and Resource Management

DNRM – Department of Natural Resources and Mines

EIS – Environmental Impact Statement

EPC – Exploration Permit Coal

IDC – Index of Diversion Condition

IFD – Intensity Frequency Duration

MGA – Map Grid of Australia

Mtpa – Million Tonnes Per Annum

MIA – Mine Industrial Area

MLA – Mining Lease Application

SEIS – Supplementary Environmental Impact Statement

RL – Reduced Level

ROM – Run of Mine

1. INTRODUCTION

Waratah Coal has commissioned Engeny Water Management (Engeny) to undertake an assessment of the flood impacts associated with the Galilee Coal Project mine site (hereafter referred to as the project). This report provides conceptual level assessment of the project creek diversion and flooding requirements to support the submission of the SEIS and address stakeholder concerns raised during the EIS public consultation process. It builds on the previous baseline hydrological and flood assessment undertaken as part of the EIS (Engeny, 2011).

1.1 Background

Waratah Coal proposes to mine 1.4 billion tonnes of raw coal from existing tenements (EPC 1040 and EPC1079) approximately 30 km north of Alpha within the Galilee Basin. The annual ROM coal production will be 56 Mtpa to produce 40 Mtpa of saleable export steaming coal to international markets. The processed coal will be transported by a new standard gauge railway system approximately 453 km in length that runs from the project site to the existing Port of Abbot Point.

The mine will consist of a combination of open cut mining and longwall underground mining. Open cut operations will involve dragline and truck and shovel operations producing 20 Mtpa ROM with coal delivered to the CHPP via heavy vehicle access roads. The underground mines will operate via continuous mines and longwall shearers producing 36 Mtpa ROM delivered to the CHPP via a conveyor system. The CHPP will be capable of producing 40 Mtpa of product coal which will be stockpiled adjacent to the CHPP for train load out. Co-disposal of coarse rejects and tailings will be utilised with disposal in the tailings dam and box cut spoil areas. Additional mine infrastructure will include:

- Mine infrastructure area consisting of administration buildings, parking areas workshop and lay down areas;
- Vehicle equipment and wash down facilities;
- A 2,000 person accommodation village and wastewater treatment plant;
- Light vehicle access roads and site access roads;
- Raw water storage for CHPP vacuum pumps, potable water supply and fire fighting;
- Environmental control dams, sediment dams, pit dewatering and underground dewatering dams and flood protection levees;
- Rail loop and train load out facilities.

The proposed mine infrastructure layout is included in Appendix A.

1.2 Scope of Works

This report has been prepared to describe the existing flood behaviour of the mine and mitigation measures to protect mine infrastructure and people without impacting downstream properties. The study has been undertaken to address government and specific stakeholder concerns raised during the EIS public consultation. The following scope of works has been adopted to address these concerns:

- Undertake a desktop geomorphic assessment of the creeks that will be impacted by the proposed mine operations to understand the behaviour, processes and physical condition of the creeks.
- Revise the hydrologic analysis undertaken as part of the *Mine Development Flood Assessment* (Engeny, 2011) to account for the recent large rainfall events experienced in 2011 and include the 1000 year ARI rainfall event.
- Develop a hydraulic model to understand existing flood behaviour including inundation area, flood depths, flood velocity, stream power, shear stress and existing channel flow capacities.
- Undertake a concept design for the diversion of Lagoon, Malcolm and Saltbush Creeks based on the results of the geomorphic assessment. Utilise hydraulic modelling to assess the performance of the proposed creek diversions in accordance with ACARP and DERM watercourse diversion guidelines.
- Utilise hydraulic modelling to determine the flood behaviour of extreme rainfall events up to the 1000 year ARI event and provide concept design of flood protection levees for open cut pits and key mine infrastructure.
- Assess the impacts to the existing flood behaviour as a result of watercourse diversion and flood protection levees.
- Provide recommendations for management of establishment and long term performance of the creek diversions.
- Develop a creek monitoring program for the creek diversions through all phases of mine life.

1.3 Study Area

The project tenements (EPC 1040 and part of EPC 1079) cover an approximate area of 1,055 km² and are located in the south-east parts of the Barcaldine Regional Council, local authority in Queensland. The contributing catchment covers an approximate area of 1,316 km² and typically drains in a north-easterly direction through the tenement areas. The majority of the tenement areas drain to the Belyando and Burdekin River basin via Lagoon Creek while the western edge of EPC 1079 drains to the Cooper Creek basin. The existing land use within the project catchments are primarily defined as rural production with some conservation and natural environments.

The maximum elevation within the contributing catchment area is approximately 620 mAHD along the western boundary of the catchment and 520 mAHD along the southern boundary of the catchment. The minimum elevation of the catchment is approximately 315 mAHD directly downstream of the MLA.

The climate zone in the vicinity of the mine site is classified as Grassland (BOM, 2012), which has hot dry summers and warm dry winters. The average annual rainfall in region is 532 mm (Alpha Post Office) with a clearly defined wet and dry season. The tenement areas have both minor and major creeks flowing through them. These include Tallarenha, Beta, Saltbush, Malcolm and Lagoon Creeks. These creeks systems are typically ephemeral and can experience expansive flooding after sustained periods of heavy rain.

2. METHODOLOGY

The methodology for flood assessment and concept design of creek diversions has been undertaken in accordance with relevant legislation and industry standards. This has been done to minimise residual risk to the surface water environment as a result of the project. Table 2.1 summarises the revised risk assessment for creek diversions that was undertaken as part of the EIS.

Table 2.1: Revised Creek Diversion Impact Assessment

Impact	Existing Risk Rating (Waratah Coal EIS, 2011)	Revised Mitigation Measures	Revised Mitigation Rating
Erosion and sedimentation of waterways as a result of creek diversions	High	Creek diversion concept design has been undertaken to comply with industry standards which have been developed to limit erosion and sediment accretion. A monitoring program has been developed to assess and manage the long term performance of the proposed creek diversions.	Low
Disruption to flow connectivity and geomorphic processes	High	The creeks proposed to be diverted will maintain existing connectivity with the diversions discharging back into the existing active channel prior to reaching the downstream MLA boundary. A desktop geomorphic assessment of the creeks to be diverted has been undertaken to determine the current geomorphic process and features which have been incorporated into the concept design.	Low

2.1 Project Requirements

A 25 year production schedule has been developed to provide 20 Mtpa ROM from the open cut pits. Excavation for three of the four pits will commence in year 1 of operations. Malcolm Creek currently discharges in a westerly direction through the MLA over the future open cut pits OC1 South and OC2 South. As a result the diversion of Malcolm Creek is required prior to year 1 to access coal reserves within these pits. The construction of this diversion will occur in conjunction with the mine infrastructure corridor which runs from west to east. This will allow establishment time for the diversion prior to the first wet season of operation.

The proposed CHPP and rail loop are located between the existing active channels of Lagoon Creek and Saltbush Creek. As a consequence Lagoon Creek will be required to be diverted into the active channel of Saltbush Creek to protect CHPP infrastructure. The construction of these diversions will occur prior to year one of operation in conjunction with the CHPP and rail loop construction.

In addition to the diversion of active creek channels flood protection levees will also be provided to prevent open cut pit inundation and protect critical mine infrastructure. These levels will be set at the 1000 year ARI flood level, plus 500 mm freeboard in accordance with the *Manual for Assessing Hazard Categories and Hydraulic Performance of Dams* (DERM, 2012).

2.2 Relevant Legislation and Guidelines

2.2.1 Water Act 2000

The *Water Act 2000* is the primary statutory document that establishes a system for planning, allocating and use of water within Queensland. The Act is administered by DNRM and specifies requirements for works impacting the bed or banks of a watercourse. Consequently the proposed creek diversions may require licensing through the application of a Riverine Protection Permit prior to construction.

2.2.2 Environmental Protection Act 1994

The *Environmental Protection Act 1994*, administered by DEHP is the overarching legislation defining the identification of environmental values through the *Environmental Protection (Water) Act 2009.* The proposed creek diversions have been designed and will be operated to minimise environmental impact downstream to maintain existing environmental values. The Act also controls the use of regulated structures such as levees through the *Manual for Assessing Hazard Categories and Hydraulic Performance of Dams* (DERM, 2012).

2.2.3 Sustainable Planning Act 2009

The *Sustainable Planning Act 2009* seeks to achieve sustainable planning outcomes through managing the process by which development takes place, managing the effects of development on the environment and continuing the coordination and integration of local, regional and state planning. Construction of the creek diversions and levees may require a planning approval for excavation and fill under the Act.

2.2.4 Regulated Dams Manual

The *Manual for Assessing Hazard Categories and Hydraulic Performance of Dams* (DERM, 2012) sets out requirements for hazard category assessment and certification of the design of dams and other land-based containment structures, constructed as part of environmentally relevant activities under the *Environmental Protection Act* 1994. The

Manual has been used to determine the hydrologic design requirements associated with the proposed flood protection levees.

2.2.5 ACARP Watercourse Diversion Guidelines

The desktop geomorphic assessment and concept design of the proposed creek diversions has been undertaken in accordance with the following ACARP guidelines:

- *Maintenance of Geomorphic Processes in Bowen River Diversions – Stage 1* (ACARP, 2000);
- *Monitoring and Evaluation Program for Bowen River Basin River Diversions – Stage 2* (ID&A, 2001);
- *Bowen Basin River Diversions Design and Rehabilitation Criteria – Stage 3* (Fisher Stewart, 2002).

Although these reports are based on research undertaken for creek diversions within the Bowen Basin they are considered the most relevant standards to adopt for the project.

2.2.6 DERM Watercourse Diversion Guidelines

The guideline, *Watercourse Diversions – Central Queensland Mining Industry* (DERM, 2011) outlines the design criteria against which a future creek diversion license application will be assessed. These criteria have been modified from the existing ACARP guidelines. This guideline has been used to assess the hydraulic performance of the creek diversion concept design.

2.3 Previous Reports

This report has been prepared utilising data or results provided in the following previous reports which were prepared as part of the EIS or feasibility studies for the project:

- *Mine Development Flood Assessment* (Engeny, 2011) – This report was prepared for submission with the EIS. This report outlined the existing flood behaviour of all creeks traversing the site using hydraulic modelling based on a 25 m DEM;
- *China First – Surface Water Assessment* (E3 Consulting, 2010) – This report outlines the existing surface water quality, identifies possible impacts and mitigation measures associated with the proposed mine, rail and port. The relevant sections relating to the mine have been used to assist in the desktop geomorphic review.

2.4 Project Data

2.4.1 Topographic Data

A 2 m DEM was developed from ALS survey undertaken by Fugro Spatial Solutions in 2010 with a 250 mm vertical accuracy in the vicinity of mine infrastructure and proposed creek diversions. This DEM has been utilised to define the topography within the hydraulic modelling area. A 25 m DEM provided by DERM was used to facilitate catchment mapping outside of the ALS capture area.

2.4.2 Stream Gauging Data

A review of the DNRM's stream flow gauging database has indicated that no stream gauge gauging stations located on Lagoon Creek. A stream gauging station is located at Violet Grove on Native Companion Creek (Gauge ID 120305A). Data was obtained from DNRM for the full 45 years of gauge operation.

2.4.3 Aerial Imagery

Aerial imagery of the MLA was obtained from Waratah Coal with a 2.5 m resolution. Additional imagery outside of the MLA was obtained from Google Earth. Images were used to determine surface roughness throughout the study areas within the hydraulic model, as well as determine channel routing roughness parameters in the hydrologic model.

2.4.4 Land Use Mapping

Land use data for the study area has been based on review of the Geoscience Australia Native Vegetation Mapping 250K Topographic Dataset and aerial imagery. These datasets were used as the basis for development of catchment parameters as part of the hydrologic and hydraulic modelling works.

2.4.5 Mine Infrastructure

The mine infrastructure layout was provided by Waratah Coal in electronic format to detail the location of open cut pits, underground mines and all associated infrastructure.

3. EXISTING GEOMORPHIC CONDITION

Based on the definition of a watercourse under the *Water Act 2000* there are expected to be a total of six watercourses traversing the area of the MLA that will be impacted as a part of mine operations. These watercourses include:

- Beta Creek – to remain on current alignment with management to overcome impacts of underground mining subsidence;
- Tallarenha Creek – to remain on natural course;
- Saltbush Creek – Capacity to be increased to cater for Lagoon Creek diversion;
- Malcolm Creek – proposed to be diverted;
- Lagoon Creek – proposed to be diverted into the original alignment of Saltbush Creek with increased capacity;
- Spring Creek – to remain on current alignment with management to overcome impacts of underground mining subsidence.

The geology of the Galilee Basin is characterised by the Late Carboniferous to Early Permian volcanic rocks of the Drummond Basin overlain by Triassic sediments including sandstone, siltstone and shale. These formations result in highly ephemeral streams with significant lateral movement of creek centrelines over time. This is evidenced by the remnant channels within the floodplains. The low lying reaches of these creeks act as large sediment stores resulting from erosion in the uplands. These large sediment stores typically limit active channel capacity to less than the 2 year ARI event. The existing geomorphic conditions for the creeks to be diverted are summarised in Table 3.1.

Table 3.1: Existing Creek Classification

Creek Name	Existing Length (m)[1]	Average Slope (m/m)	Entrenchment Ratio	Sinuosity	Meander Radius (m)[2]
Malcolm	21,100	0.002	2.7	1.4	200
Saltbush	9,600	0.001	1.2	1.2	350
Lagoon	18,700	0.001	2.9	1.5	280

These existing characteristics have been identified in order to be replicated in the concept design of the creek diversions to achieve a design representative of the natural watercourses. The following Sections provide a qualitative assessment of the existing geomorphic condition of the creeks to be diverted as part of mine operations.

[1] Denotes existing length of main active channel to be diverted.
[2] Meander radius assumed at 2.7 x bank-full width (Leopold & Wolman, 1960).

3.1 Lagoon Creek

Lagoon Creek is the main creek traversing the MLA with an upstream catchment area of approximately 1,250 km² at the downstream MLA boundary. Lagoon Creek commences at the confluence of Beta Creek and Tallarenha Creek and traverses the mine lease in a south to north direction. The active channel has significant meandering with erosion clearly evident on the outer banks of the meanders. There are a number of pools and riffles which contain small volumes of permanent water during the wet season. There is significant sediment deposition consisting mainly of sand overlying a silty clay substrate (E3 Consulting, 2010). The typical channel form of Lagoon Creek is provided in Figure 3.1.

Figure 3.1 Typical Channel Form - Lagoon Creek

A typical cross section of Lagoon Creek is provided in Figure 3.2. Review of this section indicates presence of benching typically on either side of the active channel as a result of large sediment supply. The typical floodplain width ranges between 500 and 1500 m with the interaction evident between the Saltbush Creek floodplain to the east. Vegetation consisting mainly of large trees is located along the fringes of the in-stream bench with the floodplain consisting predominantly of grasses and understorey vegetation.

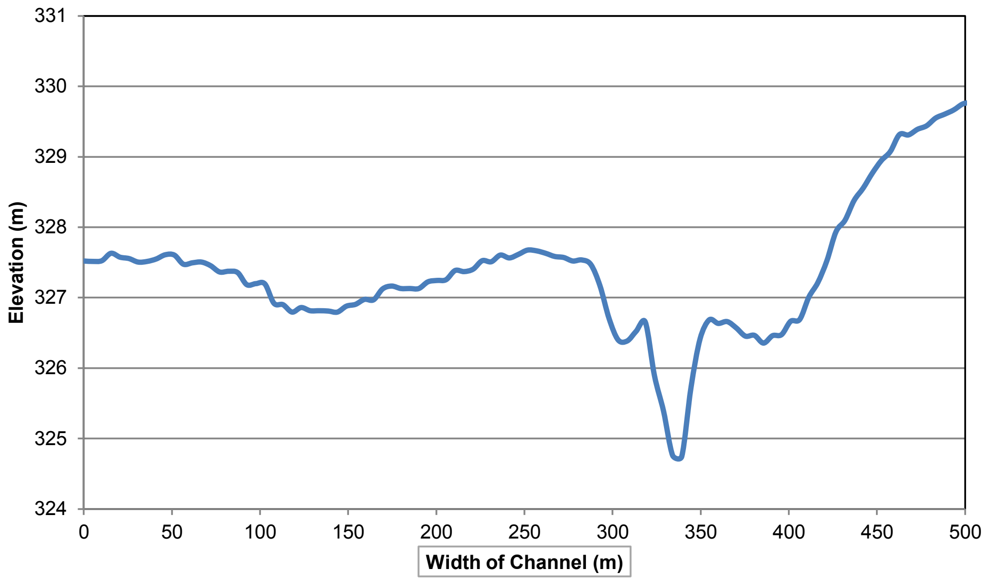


Figure 3.2 Typical Lagoon Creek Cross Section (Looking Downstream)

3.2 Malcolm Creek

Malcolm Creek traverses the site in a west to east direction before merging with Lagoon Creek. The Malcolm Creek catchment covers an area of approximately 660 km² with headwaters located in the mountains to the west of the site. This steep gradient induces significant erosion resulting in a straight deeply incised active channel. This erosion is evident in Figure 3.3 with the incisement of the channel characterised by the steep banks shown in the typical cross section (Figure 3.4). This steeper gradient and higher energy level results in little to no sediment deposition and also prevents the forming of in stream benches due to the continual flow through of sediment.

There is no clearly defined floodplain associated with Malcolm Creek due to its steep nature. There is some minor vegetation consisting of small trees located on the outer edges of the active channel. Malcolm Creek is also highly disturbed with a number of dams and in-stream diversions associated with existing farming activities.

WARATAH COAL
MINE SITE CREEK DIVERSION AND FLOODING

Figure 3.3 Typical Channel Form – Malcolm Creek

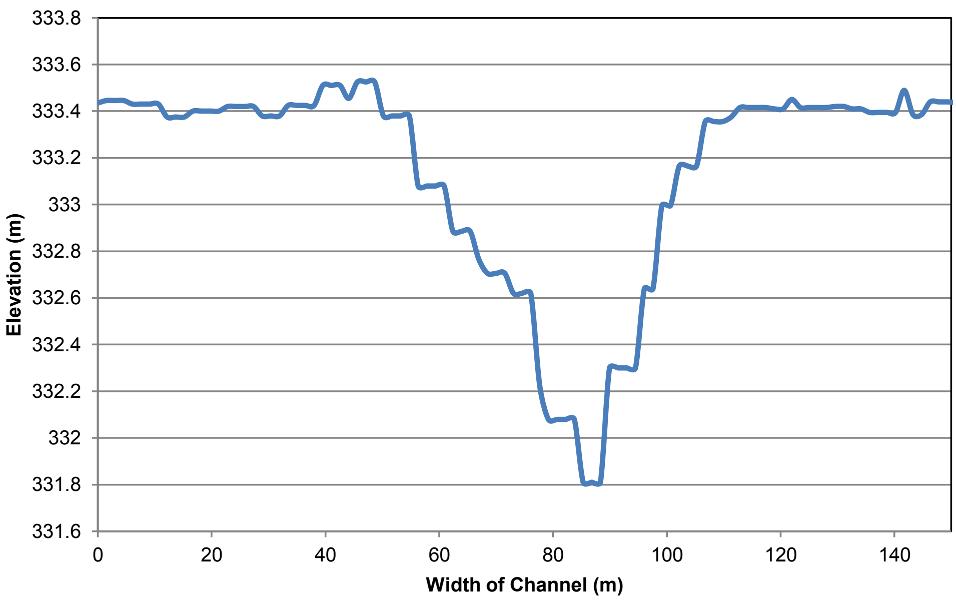


Figure 3.4 Typical Malcolm Creek Cross Section (Looking Downstream)

3.3 Saltbush Creek

Saltbush Creek is located adjacent to Lagoon Creek and runs parallel in a south to north direction before converging with Lagoon Creek north of the MLA boundary. Saltbush Creek has a catchment area of approximately 140 km². The headwaters are relatively steep resulting in a deeply incised channel with limited meandering. Within the MLA the creek converges with the Lagoon Creek floodplain where the geomorphic characteristics alter significantly. The active channel becomes highly discontinuous and transient with numerous remnant channels. Meandering also increases with some minor in stream benching typically limited to one side of the channel. These characteristics are evident in Figure 3.5 and Figure 3.6.

Figure 3.5 Typical Channel Form – Saltbush Creek

The significant discontinuity of the Saltbush Creek can be attributed to a number of on-stream storages that have been constructed for grazing activities. These storages act as permanent sediment stores therefore resulting in less in stream sediment deposition and benching when compared to Lagoon Creek. Significant clearing associated with the construction of these storages has resulted in areas with little to no riparian vegetation.

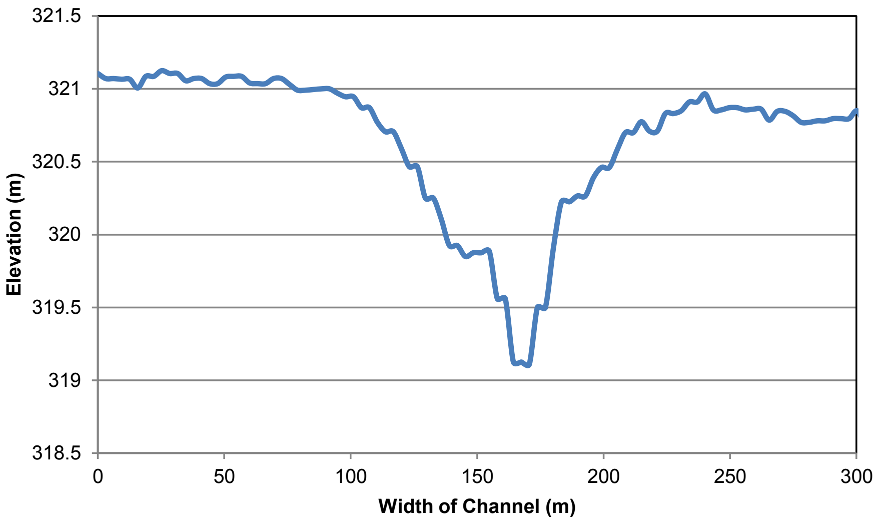


Figure 3.6 **Typical Saltbush Creek Cross Section (Looking Downstream)**

4. CATCHMENT HYDROLOGY

There are a number of waterway systems intersecting the subject site, all of which lie in the Burdekin River Basin. A catchment plan detailing watercourses and contributing catchment areas is provided in Appendix B.

The minimum elevation at the catchment outlet from the MLA is approximately 315 mAHD with an average slope through the majority of the mid to lower catchment of approximately 0.2%. Steeper catchments located in the upper headwaters are shown to have average catchment slopes of approximately 0.9%.

4.1 Hydrological Modelling

Hydrologic modelling was undertaken for the contributing catchments using the XP-RAFTS software package. Flood hydrographs have been determined for a range of design flood events including the 2, 50, 100 and 1000 year ARI design flood events.

The model estimates design hydrographs from an individual sub-catchment based on rainfall intensities, losses and temporal patterns, and the definition of a series of parameters that describe the sub-catchment characteristics. These parameters include the sub-catchment area, slope, roughness and fraction of impervious area.

Sub-catchment outflow hydrographs are routed downstream through the model via links. Routing links perform Muskingum-type channel routing calculations and require cross section dimensions, slope and the length of the channel. These cross section dimensions and slope have been taken from a 25 DEM for the Burdekin River basin provided by DERM.

Sub-catchment boundaries and slopes were determined using the same 25 m DEM provided by DERM. Refer to Appendix B for a map detailing the sub-catchment delineation for the model. Sub-catchment Manning's roughness values have been adopted based on interrogation of aerial photographs.

4.1.1 Design Rainfall

Design rainfall estimates for the 2, 50 and 100 year ARI design storm events were derived based upon the procedures outlined in Australian Rainfall and Runoff (IEAust, 2001). The 1,000 year ARI design rainfall estimates have been developed using the CRC-FORGE rainfall database for Queensland using the Rainfall Application software (Hargraves, 2004). Areal reduction factors have been applied to these design rainfall estimates in accordance with Australian Rainfall and Runoff due to the large contributing catchment area. Temporal patterns for all ARIs were sourced from Australian Rainfall and Runoff (IEAust, 1999). Table 4.1 summaries the design rainfall estimates for the catchment.

Table 4.1: Design Rainfall Estimates (mm/hr)[3]

Average Recurrence Interval (years)	Storm Duration (hours)						
	6	12	18	24	36	48	72
2	7.3	4.6	3.6	3.0	2.3	1.9	1.4
50	15.2	9.5	7.4	6.4	5.0	4.2	3.2
100	17.1	10.7	8.3	7.2	5.7	4.7	3.6
1000	28.8	17.0	13.1	10.8	8.3	7.1	5.3

4.1.2 XP-RAFTS Model Parameters

Design loss parameters for the XP-RAFTS model were based on values described in Australian Rainfall and Runoff (IE Aust, 2001). These losses have then been adjusted accordingly to match the validation results described in the following Sections. The model storage coefficient (β_x) has been used to adjust the model to achieve a suitable fit for validation. These adopted parameters for the modelling are summarised in Table 4.2.

Table 4.2: XP-RAFTS Adopted Model Parameters

Average Recurrence Interval (years)	Storage Coefficient (β_x)	Initial Loss (mm)	Continuing Loss (mm/hr)
2	0.7	65.0	2.5
50	0.7	55.0	2.5
100	0.7	25.0	2.5
1,000	0.7	0.0	2.5

4.2 Flood Frequency Analysis

There are currently no stream flow gauging stations on Lagoon Creek. DNRM operates a stream flow gauging station on the nearby Native Companion Creek. Although there are a number of additional flow gauging stations located further downstream of the site, Native Companion Creek has been adopted as the most suitable for use. This is due the length of data record available and similarities in catchment characteristics.

A flood frequency analysis was undertaken on the Native Companion Creek gauge (120305A) with the results summarised in Figure 4.1. The annual peak flows were provided by DNRM and the Log Pearson Type 3 (LPIII) distribution was fitted to the data

[3] Areal reduction factors applied.

as per Book 4 of Australian Rainfall and Runoff. The 100 year ARI peak discharge for Native Companion Creek gauging station is estimated at 2325 m³/s.

It should be noted that this peak 100 year ARI estimate is considerably larger than previous work undertaken as part of the preliminary flood study of the project (Engeny, 2011). This is due to the fact the flood frequency analysis was undertaken on peak annual discharges to 2010. Significantly larger events have occurred in the 2011 and 2012 wet seasons which have skewed the flood frequency analysis for large flood events.

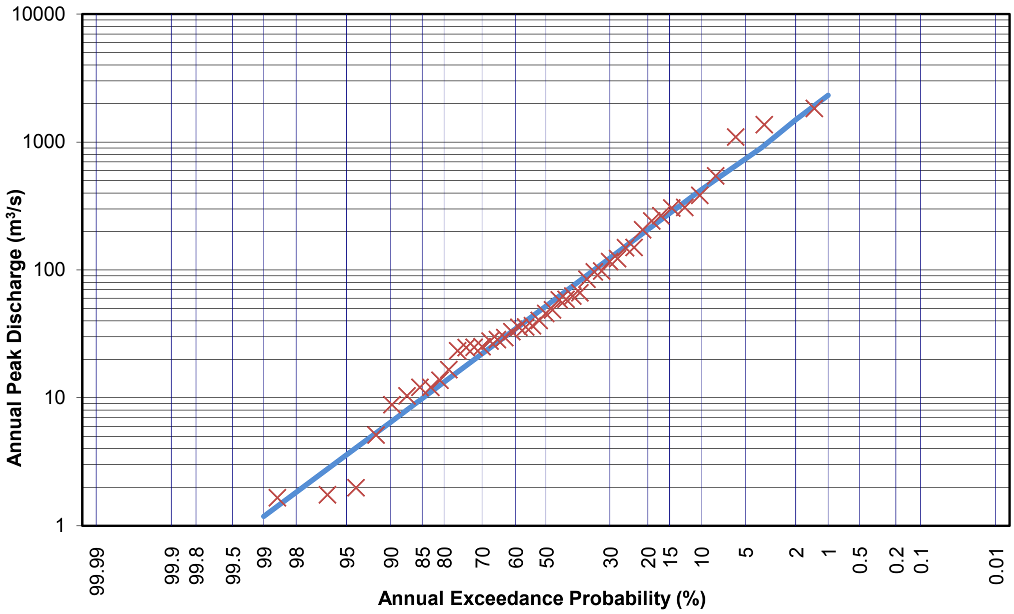


Figure 4.1 Native Companion Creek LPIII Annual Series Flood Frequency Plot

The Native Companion Creek Flood Frequency Analysis has been utilised to estimate peak flow rates for Lagoon Creek and provide validation for the hydrology model. This has been done by scaling of the flood frequency peak flow rates based on catchment area using the following equation:

$$Q_u = \left(\frac{A_u}{A_g}\right)^b Q_g$$

Where Q_u is the estimated peak flow for the ungauged catchment, A_u is the area for the ungauged catchment (1,316 km²), A_g is the catchment area for the stream gauging station (4,065 km²) and Q_g is the peak flow for the gauging station determined from the flood frequency analysis. The exponent b has been determined from the regional flood frequency regression analysis undertaken by the Queensland Department of Transport and Main Roads (Palmen & Weeks, 2008). This results in exponent values ranging between 0.644 and 0.757 for the 100 year and 2 year ARI events respectively. The results of these scaled peak flow results at the downstream MLA boundary are summarised in Table 4.3.

Table 4.3: Estimated Lagoon Creek Peak Flow Rates – Scaled FFA

Average Recurrence Interval (years)	Native Companion Creek LPIII Estimate (m³s)	Lagoon Creek Scaled FFA Discharge (m³s)
2	206	21
50	1,491	690
100	2,325	1,092
1000	8,194	2,534

4.3 ACARP Method

The ACARP method for estimation of peak flow rates was developed as part of the Bowen Basin River Diversions Design and Rehabilitation Criteria (ACARP, 2002). It was derived to estimate the flow for any number of flood events for any stream in the Bowen Basin area based on catchment area and rainfall intensity. It was based on regional flood frequency analysis for 66 stream flow gauging stations with catchment areas less than 5000 km² and record greater than 10 years. This flood frequency analysis was conducted for both annual maximum and partial series data.

The relationship between Mean Annual Flood and Average Partial Flood was estimated using regression analysis to produce a dimensionless frequency curve. The ACARP Method suggests partial series data is used for estimation of peak flows less than 10 year ARI events and annual series data for peak flows greater than 10 year ARI events. The ACARP method has been used as further validation of the hydrologic model. Table 4.4 summarises the results of the ACARP method for the Lagoon Creek catchment at the downstream MLA boundary.

Table 4.4: Estimated Lagoon Creek Peak Flow Rates - ACARP Method

Average Recurrence Interval (years)	Mean Annual Flood (m³/s)	Average Partial Series Flood (m³/s)	Ratio (Q_t/Q_{FFA})	ACARP Method Peak Discharge (m³/s)
2	N/A	527	0.5[4]	263
50	209	N/A	5.1[5]	1,066
100	209	N/A	6.3[5]	1,318

4 From Partial Series data
5 From Annual Series data

4.4 Model Validation and Results

Validation of the hydrologic modelling results has been undertaken using flood frequency analysis and the ACARP Method. Results of this analysis suggest a reasonable level of agreement between the hydrologic modelling and the validation methods. The hydrologic model results lie between the flood frequency analysis and ACARP method values with much better correlation for the larger ARI events. There is some disparity between the frequent events, most notably the 2 year ARI, the adopted values are considered suitable for use in hydraulic modelling as they have only been used to assess creek diversion performance and design and not set critical flood levels for levees or infrastructure. A summary of the validation results is provided in Table 4.5.

Table 4.5: XP-RAFTS Model Validation

Average Recurrence Interval (years)	XP-RAFTS Peak Discharge (m^3/s)	Scaled FFA Discharge (m^3/s)	ACARP Method Discharge (m^3/s)
2	40	21	263
50	760	690	1,066
100	1,097	1,092	1,318
1,000	3,050	3,390	N/A

The ACARP method does not make provision for flood events larger the 100 year ARI event and therefore has not been used in validation of the 1000 year ARI event. Results of the hydrologic model for critical locations through the MLA have been included in Table 4.6. The critical storm durations are also summarised in this table. The results indicate variations for the critical storm durations for the different branches within the catchment. This has been considered further within the hydraulic modelling with multiple storm durations run to determine which durations translate to the highest flood levels.

Table 4.6: XP-RAFTS Model Results

Location	Peak Discharge and Critical Storm Duration			
	2 Year ARI	50 Year ARI	100 Year ARI	1000 Year ARI
Lagoon Creek – D/S MLA	40 m³s (36 hr)	760 m³s (36 hr)	1097 m³s (18 hr)	3050 m³s (12 hr)
Malcolm Creek – U/S of Diversion	4 m³s (36 hr)	68 m³s (36 hr)	90 m³s (12 hr)	271 m³s (6 hr)
Saltbush Creek – U/S of Diversion	5 m³s (36 hr)	87 m³s (36 hr)	123 m³s (18 hr)	317 m³s (6 hr)
Confluence – Malcolm and Lagoon Creeks	35 m³s (36 hr)	659 m³s (36 hr)	905 m³s (18 hr)	2560 m³s (12 hr)
Confluence – Beta and Tallarenha Creeks	34 m³s (36 hr)	631 m³s (36 hr)	858 m³s (18 hr)	2376 m³s (12 hr)

4.4.1 Mine Impacts on Hydrology

As a result of the proposed creek diversions and open cut pits the catchment mapping for the project and hydrological modelling was amended to account for open cut pits and subsequent loss of catchment area. A catchment map has been provided in Appendix B. The key assumptions for the revised catchment mapping and hydrological modelling include:

- Catchment mapping was based on the Year 25 layout plan which represents the largest reduction in catchment area from open cut pits at approximately 1,500 ha.
- Catchments reporting to the high wall side of open cut pits have been assumed to be diverted around the pit to limit in pit flooding.
- All dams proposed as part of the onsite water management system have been not been included in the hydrologic modelling.
- The increase in impervious area from proposed mine infrastructure has been omitted from the revised hydrological modelling as the increase is considered insignificant.

These results have been used to assess the performance of the creek diversions and assess impacts to the flooding regime as a result of mine development.

5. CREEK DIVERSION CONCEPT DESIGN

The following Sections outline key design information that has been considered as part of the concept creek diversion and levee design. The level of detail is not considered sufficient for diversion licensing purposes but provides a functional design to demonstrate proof of concept. Further detailed design will be undertaken through the diversion licensing process and mine design.

5.1 Design Objectives

The concept design of the proposed creek diversions has been undertaken to maintain a state of dynamic equilibrium and mimic the natural condition as much as practical. The following key aspects have been considered as part of the design process to achieve this goal:

- A meandering alignment chosen (where possible) to maintain original stream length and gradient to prevent bed aggradation and increases to sediment supply downstream.
- No use of hydraulic control structures (e.g. drop structures) within the diversion or any other structure that would require maintenance after relinquishment of the mine lease.
- Inclusion of in channel features such as benching and low flow channels based on the outcome of the geomorphic review.
- Compliance with DERM hydraulic design criteria for stream power, shear stress and velocity to maintain sediment transport equilibrium.
- Inclusion of in channel features to provide habitat and promote ecological connectivity.

5.2 Alignment

A number of creek diversion alignment options have been considered as a part of the design process. The three shortlisted options are summarised in Table 5.1 with the indicative diversion centrelines provided in Appendix G. The options have been assessed in terms of practicality, anticipated stability and hydraulic effectiveness.

Table 5.1: Creek Diversion Design Options

Option1	Opportunities	Constraints
Option 1	• Lagoon Creek can be maintained close to original alignment • Saltbush Creek does not need to be diverted	• Straight diversion of Malcolm Creek required be MLA boundary and open cut pits • Malcolm Creek heavily impacted by subsidence • Significant volumes of cut required to diver Malcolm Creek • Significant flood levees required to protect CHPP and open cut mines • Bank rilling likely due to inflows from the west in level significant level difference between diversion and natural surface level
Option 2	• Meander can be achieved on Lagoon and Malcolm Creek diversions •	• Significant volumes of cut required to diver Malcolm Creek with impacts to heavily vegetated areas • Malcolm Creek heavily impacted by subsidence • Bank rilling likely due to inflows from the west in level significant level difference between diversion and natural surface level
Option 3	• Natural direction and flow regime of existing creeks can be maintained • Minimal impacts from subsidence	• Straight section of Malcolm Creek diversion required to pass open cut pits • Lagoon Creek and Saltbush Creek diversions need to be combined

The off take point for the selected diversion (option 3) will occur west of the open cut pits within the infrastructure corridor outside of any influences from subsidence. The section of diversion through the infrastructure corridor (approximately 6.8 km) is unable to contain any meandering due to constraints from open cut pits, conveyor system and administration buildings. Once the diversion passes through the infrastructure corridor the diversion has a meandering alignment with a tie-in to Lagoon Creek prior to the downstream lease boundary.

The CHPP, rail loop and train load out facilities are proposed to be located between the active channels of Lagoon Creek and Saltbush creek which both flow from the south before converging directly downstream of the MLA boundary. In order to protect this infrastructure from flood impacts it is proposed to divert Lagoon Creek around the CHPP and into the current alignment of Saltbush Creek. As a result the Saltbush Creek profile will be altered to increase capacity to cater for Lagoon Creek flows. The Lagoon Creek diversion off take will occur directly downstream of the confluence with Beta Creek and Tallarenha Creek. From the off take point the diversion follows the original alignment where possible with some minor deviations around proposed haul roads and open cut pits. From the point of intersection with Saltbush Creek the original alignment will remain to maintain stream length and meander radius. A flow split will occur where the diversion discharges back into Saltbush Creek with the balance of flow discharging back into Lagoon Creek. This split of flow will be self-regulated by the existing capacities of the natural creeks. This flow split will typically only occur during small events (<2 year ARI) due to the limited capacity of the existing creeks. Refer to Appendix C for concept design plans which detail the alignment of the diversions.

5.3 Design Summary

The qualitative assessment of the existing geomorphic features has been used to replicate natural conditions as much as practical. Both the Lagoon Creek and Malcolm Creek diversions have been designed as a composite channel with a dedicated low flow channel typically less than 2 year ARI capacity and high flow channel less than 50 year ARI capacity. This channel design also creates in stream benching which was identified as being present within all existing creeks proposed to be diverted. A summary of the design parameters for the diversions is provided in Table 5.2 with typical cross sections of the diversions provided with concept design drawings in Appendix C.

Table 5.2: Creek Diversion Design Features

Design Parameter	Lagoon Creek Diversion	Malcolm Creek Diversion
Existing Length (m)	18,700	21,100
Diversion Length (m)	19,100	17,100
Low Flow Channel Top Width (m)	59	22
High Flow Channel Top Width (m)	200	60
Bench Height (m)	1.5	1.0
Diversion Depth (m)	2.0	4.5
Batter Slope	1V:3H	1V:3H

The stream length of Malcolm Creek was unable to be maintained due to the straight section required to traverse the infrastructure corridor. Despite this the straight section has been kept at an absolute minimum grade in order to meet the specified hydraulic design criteria. Saltbush Creek will remain on its existing alignment with stream length, meander radius and sinuosity maintained.

5.4 Hydraulic Design Criteria

The following sections describe the key hydraulic parameters that have been used to assess the hydraulic performance of the diversion designs in accordance with the guideline, *Watercourse Diversions – Central Queensland Mining Industry* (DERM, 2011). A summary of the hydraulic design criteria is provided in Table 5.3.

Table 5.3: DERM Hydraulic Design Criteria

Scenario	Stream Power (W/m²)	Velocity (m/s)	Shear Stress (N/m²)
2 Year ARI (no vegetation)	<35	<1.0	<40
2 Year ARI (vegetated)	<60	<1.5	<40
50 Year ARI	<220	<2.5	<80

5.4.1 Shear Stress

Shear stress is described as the force exerted on the channel bed and banks to overcome friction forces by the action of water parallel to the direction of flow. It is a function of channel slope and discharge, and is described by the following equation:

$$\tau = \rho g d S$$

Where: τ = Shear stress (N/m²)

ρ = Water density (kg/m³)

g = Gravitational acceleration constant (m/s²)

d = Water depth (m)

S = Hydraulic grade (m/m)

5.4.2 Stream Power

Stream power is a product of channel slope and discharge that represents the excess energy available to do work on the bed and banks of the channel. A correct balance of stream power is required to maintain equilibrium within the channel. High stream powers will result in erosion and low stream power will result in sediment deposition. Stream power is described by the following equation:

$$\omega = \frac{\rho g Q S}{W}$$

Where: ω = Stream power (W/m²)

ρ = Water density (kg/m³)

g = Gravitational acceleration constant (m/s²)

Q = Flow rate (m³/s)

S = Hydraulic grade (m/m)

W = Water surface top width (m)

5.4.3 Flow Velocity

Flow velocity is the speed at which water passes through the channel. It is a function of flow rate and cross sectional area, and is defined by the following equation:

$$V = \frac{Q}{A}$$

Where: V = Velocity (m/s)

Q = Flow rate (m³/s)

A = Cross sectional flow area (m²)

5.5 Flood Protection Levees

Three flood protection levees with a combined length of 38 km are required to protect open cut pits and critical mine infrastructure. The Malcolm Creek diversion will require the construction of two levees on both sides of the diversion to prevent flood water ingress into pits. The Lagoon/Saltbush Creek diversion will require the construction of a levee along the western side of the diversion and around the CHPP to protect infrastructure and people working in these areas.

These levees will be deemed regulated structures under the *Manual for Assessing Hazard Categories and Hydraulic Performance of Dams* (DERM, 2012) under both 'failure to contain' and 'dam break' scenarios. Therefore levees have been designed in accordance with this Manual and will include the following key design criteria:

- Levee crest level based on the 1000 year ARI flood level with additional 500 mm freeboard;
- 3m top width to facilitate vehicle access for maintenance purposes;
- 1V in 3H topsoiled batters to facilitate the establishment of vegetation for a stable landform;
- Suitably sized scour protection to be provided at the toe of the levee to prevent erosion (where applicable);
- Full length cut-off trench to allow the levee to be keyed into the natural surface and prevent lateral movement;
- Where possible haul roads and the rail formation will be constructed to act as levees.

Concept design plans of the flood protection levees are provided in Appendix C. The final levee alignment and specific design requirements will be determined during detailed design.

5.6 Permanent Creek Diversion

Upon the end of mine life and the relinquishment of the mining lease the diversions will also be required to be relinquished to the regulatory authority. In order to return the creeks back to their original form as much as possible the Lagoon Creek diversion will be able to be returned back to its natural course. This can be done through the removal of the flood protection levees and the excavation of a small section of fill adjacent to the CHPP. The Malcolm Creek diversion will have to be permanently diverted along its proposed alignment due to the locations of final open cut voids.

6. HYDRAULIC MODELLING

6.1 Modelling Software

Estimation of flood behaviour for the project has been carried out using the TUFLOW software package. TUFLOW is an industry accepted software package that is highly suited to the investigation of flood behaviour in complex flow scenarios. The software can simulate unsteady hydrodynamic flow in two directions on a rectilinear grid as well as 1D unsteady hydrodynamic flow through waterway structures such as culverts. The model is based on a robust finite difference solution scheme able to compute both subcritical and supercritical flow regimes.

6.2 Model Parameters and Construction

A single TUFLOW model was constructed to predict flooding behaviour for the project area. The following sections summarise the various model components and parameters that have been used to estimate flooding behaviour.

6.2.1 2D Topographic Grid

The 2D model topography has been based on the 2 m ALS survey DEM for the project area. The size of the modelling area and model run times has been undertaken to determine the appropriate 2D grid size. It was determined that a 10 m grid size was appropriate as this allows for the required level of detail to be achieved whilst maintaining realistic model run times. Real world co-ordinate systems have been used for all modelling. The 2D hydraulic model is based on MGA94 Zone 55 horizontal datum and AHD vertically.

6.2.2 Model Extent

The modelling area was limited to the watercourses within the vicinity of proposed mine infrastructure including Saltbush, Tallarenha, Beta, Lagoon and Malcolm Creeks. This was due to the lack of ALS survey south of the MIA. As there is currently no infrastructure proposed in the southern half of the MLA this approach was considered suitable. The modelling area was extended a sufficient distance downstream of the MLA to adequately quantify any impacts on downstream properties and EPC 1210.

6.2.3 Tailwater Boundaries

Given the location of the study area and perennial nature of the waterway systems, it was considered appropriate to adopt a normal depth downstream boundary condition at the model outlet. This normal depth has been developed with consideration for expected flooding behaviour associated with the proposed Alpha Mine directly downstream. This has been done by developing a cross section of the downstream floodplain which is reduced as a result of a proposed flood protection levee on the Alpha Mine site.

6.2.4 Inflow Boundaries

The hydrographs developed as part of the XP-RAFTS hydrological analyses were extracted for the 2, 50, 100 and 1000 year ARI events. Hydrographs have then been applied to the TUFLOW model by way of direct application of either the representative local or total catchment hydrograph to the associated sub catchment area or inflow boundary.

6.2.5 Model Roughness Parameters

Delineation of areas of different hydraulic roughness was undertaken to accurately simulate spatially varying roughness across the floodplain areas. The roughness map was developed using aerial photography and therefore represents the waterway roughness at the time that the imagery was captured. A summary of the roughness parameters adopted for the modelling is provided in Table 6.1.

Table 6.1: Adopted Model Roughness Parameters

Land Use	Manning's 'n' Value
Light Vegetation	0.05
Medium Vegetation	0.06
Dense Vegetation	0.08
Open Water	0.02
Bare Earth (Diversions)	0.03

6.3 Existing Case Modelling

To understand the existing flood behaviour of the major watercourses to be impacted by the project, existing case modelling has been undertaken. The development of base case flood modelling results also allows impacts such as increases in flood level, inundation area and changes to velocity to be quantified. Four separate existing case models were developed for the following scenarios:

- 2 year ARI event to understand existing active channel capacities as well as shear stress, stream power and velocity values for comparison against DERM and ACARP guidelines;
- 50 year ARI event to understand existing active channel capacities as well as shear stress, stream power and velocity values for comparison against DERM and ACARP guidelines;
- 100 year ARI event to understand existing flood behaviour including flood extent and inundation. Results were considered for the placement of infrastructure including

access roads and construction camps. Also used as baseline results for comparison with developed results to quantify downstream impacts;

- 1000 year ARI event to quantify extreme flooding and define requirements for levees to protect critical infrastructure and open cut pits.

6.3.1 Existing Case Results

The existing case results have also been presented visually in the form of maps provided in Appendix D. These maps detail the peak flood depth and clearly depict the existing flood extent and active channel characteristics of the existing creeks.

The results of the existing case modelling indicate the existing creeks have very limited capacity with break out of the active channels occurring in events typically above the 2 year ARI event. This results in floodplain interaction between Saltbush Creek and Lagoon Creek which can be clearly seen in the 50 year ARI event flood map. Due to the significant amount of the storage within the Lagoon and Saltbush Creek floodplain the extent of inundation does not increase significantly between 50 year ARI and 100 year ARI event and there is only approximately difference of 1 m in peak flood levels.

An assessment of the values for shear stress, stream power and velocity in the 2 year ARI event indicates general compliance with the DERM watercourse diversion guidelines for shear stress and stream power. Flow velocities are generally elevated within Lagoon Creek and Saltbush Creek with average velocities of 2.5 m/s and 2 m/s respectively. This is due to the creeks flowing bank full during this event with little breakout into the flood plain.

For the 50 year ARI event all creeks are typically compliant with the DERM limits for shear stress, stream power and velocity. There are some minor localised deviations in the upper reach of the Malcolm Creek diversion. This is due to the steeper channel slope in this area and is evidenced by the erosion and channel incisement in the upper reach.

The 100 year and 1000 year ARI results display very similar characteristics with similar floodplain width and inundation area. This results in peak flood levels at the downstream lease boundary of 319.8 mAHD and 320.5 mAHD for the 100 year ARI and 1000 year ARI events respectively. Peak velocities for the 100 year and 1000 year ARI events typically do not exceed 1.5 m/s due to effect of the Lagoon Creek floodplain.

6.4 Developed Case Modelling

Developed case flood modelling has been undertaken to assess the performance of the proposed creek diversions and flood protection levees. A total of five separated models were constructed for a range of ARIs. Developed models have been based on revised topographical data to include the creek diversions and flood protection levees. A summary of these models is provided below:

- 2 year ARI event assuming no vegetation within the diversion channel to assess the hydraulic performance against ACARP and DERM guidelines;

- 2 year ARI event assuming light vegetation within the diversion channel to assess the hydraulic performance against ACARP and DERM guidelines;
- 50 year ARI event assuming light vegetation within the diversion channel to assess the hydraulic performance against ACARP and DERM guidelines;
- 100 year ARI event to confirm the placement of non-critical infrastructure and quantify the impacts to flood levels as a results of the creek diversions and flood protection levees;
- 1000 year ARI to confirm the final flood protection level requirements and quantify flood level impacts.

6.4.1 Developed Case Results

The developed case results indicate significant changes to the inundation characteristics within the MLA. This is due to changes in the alignments of active channels and the representation of flood protection levees within the model. The existing case results have been presented as flood inundation maps in Appendix E.

Analysis of the results indicates the proposed composite cross sections of the creek diversions align with the design intent. The 2 year ARI flood is contained wholly within the low flow channel while the 50 year ARI event is contained within the active channel with some areas of breakout across the wider floodplain downstream of the MIA.

Significant breakout from the active channel typically occurs in events greater than the 50 year ARI event which is consistent with the flood behaviour under natural conditions. Similarly to the existing case results, velocities typically do not exceed 1.5 m/s in the 100 and 1000 year ARI events. Peak flood levels at the downstream lease boundary are estimated at 319.1 mAHD and 319.4 mAHD for the 100 year ARI and 1000 year ARI events respectively.

An assessment of flood depths for the 1000 year ARI event indicates Malcolm Creek will require a levee with an average height one metre above natural ground level with the inclusion of freeboard. Flood protection levees along the Lagoon Creek diversion will range between one and four metres above natural ground with the inclusion of freeboard.

6.4.2 Creek Diversion Hydraulic Performance

Hydraulic results for the 2 year and 50 year ARI events for each the proposed creek diversions are provided in Table 6.2 with graphical representation along the diversion centreline provided in Appendix F. The results have been provided for shear stress, stream power and velocity as discussed in Section 5.4. The tabulated results have been summarised with median and maximum values along the diversions. Red values denote exceedances of the DERM design criteria while green denotes compliance.

Table 6.2: DERM Hydraulic Design Criteria

Scenario	DERM Limit	Lagoon Creek Diversion		Malcolm Creek Diversion	
		Median	Maximum	Median	Maximum
2 Year ARI Stream Power - No Vegetation (W/m²)	35	5.9	20.8	6.3	43.2
2 Year ARI Stream Power (W/m²)	60	5.4	19.5	5.9	39.6
50 Year ARI Stream Power (W/m²)	220	38.4	86.8	33.2	119.6
2 Year ARI Velocity-No Vegetation (m/s)	1.0	0.9	1.2	0.8	2.7
2 Year ARI Velocity (m/s)	1.5	0.6	1.4	0.6	2.4
50 Year ARI Velocity (m/s)	2.5	1.3	2.5	1.2	2.1
2 Year ARI Shear Stress-No Vegetation (N/m²)	40	6.7	16.3	7.8	28.4
2 Year ARI Shear Stress (N/m²)	40	8.9	21.4	11.3	36.3
50 Year ARI Shear Stress (N/m²)	80	28.6	49.5	40.8	145.2

Review of these results indicates the Lagoon Creek diversion is generally compliant with the DERM hydraulic design thresholds. There are a number of minor localised exceedances for the velocity threshold in the un-vegetated 2 year ARI event. These exceedances occur at approximately three locations along the diversion with the greatest exceedance being 0.2 m/s. This suggests the current design of the Lagoon Creek diversion is suitable and will behave as close as possible to the natural system.

The Malcolm Creek diversion experiences a number of exceedances of the DERM hydraulic design thresholds. The 2 year ARI un-vegetated scenario represents the worst case with peak velocities exceeding the threshold by up to 1.5 m/s. The exceedances of the hydraulic design thresholds are generally isolated to the straight section of the diversion within the infrastructure corridor which runs between the open cut pits.

Given that it will take a minimum of one year for groundcover vegetation to establish, it would be ideal for the chosen design to be below the velocity threshold with no vegetation. Therefore it is imperative that every effort be made to assist in the establishment of vegetation to ensure the stability of the creek for a 2 year ARI flow in the first year of operation. This will be achieved through the effective construction and establishment of the diversions which is discussed further in Section 7.

6.5 Flood Impact Assessment

A summary of the impacts to the flood levels for the 100 year and 1000 year ARI events is provided in Table 6.3. Positive values denote an increase in flood level between the existing and developed case results.

Table 6.3: Peak Flood Level Afflux

Location	100 Year ARI Afflux (m)	1000 Year ARI Afflux (m)
Beta Creek US Model Boundary	-0.604	-0.615
Tallarenha Creek US Model Boundary	-0.267	-0.407
Lagoon, Beta and Tallarenha Creek Confluence	-0.479	-0.422
Saltbush Creek US Model Boundary	0.001	0.012
Lagoon Creek Diversion and Saltbush Creek Confluence	-0.166	1.004
Lagoon Creek Floodplain 2km US of MLA	0.072	0.035
Downstream of MLA Boundary	-0.104	-0.364

There is a relatively minor impact to the peak flood levels as a result of the proposed creek diversions and flood protection levees. These impacts are mainly result in a reduction in flood level due to due to reduction in flow as a result of open cut mining and increased floodplain storage as a result of excavated diversions. There are also no increases to flood levels external to the MLA or on EPC 1210.

7. CREEK DIVERSION CONSTRUCTION AND ESTABLISHMENT

The following Sections describe the recommended management options and monitoring to be adopted to maintain the long term performance of the creek diversions and meet the design objectives outlined in Section 5.1.

Since the results of the hydraulic modelling indicate the creek diversions may be susceptible to elevated erosion rates with no vegetation, it is critical that efforts be undertaken to maximise vegetation establishment in the creek diversions. This should occur with overall min planning and detailed design.

7.1 Coffer Dams

It is recommended that the diversions undergo a minimum of 12 months establishment prior to being commissioned. This will be achieved through the use of coffer dams (where possible) to prevent the diversions flowing during the establishment period. During this period it is proposed to utilise the existing watercourses to convey flows through the site. Upon completion of the establishment phase and start of open cut mining these coffer dams will be removed to allow flow within the diversions. It is recommended coffer dams are provided at the following locations along the creek diversions:

- At the upstream end of the Malcolm Creek diversion (CH 0) to prevent inflow into the diversion until open cut mining commences;
- At the point where the existing Malcolm Creek alignment crosses the Malcolm Creek diversion (CH 8200) to enable Malcolm Creek to maintain its course and prevent inflow in the diversion until open cut mining commences;
- On the Lagoon Creek diversion (CH 6000) to prevent inflow into the diversion between CH 6500 and the confluence with Saltbush Creek;
- On the Lagoon Creek diversion directly downstream of the confluence with Saltbush Creek (CH 9000) to limit flow within the Lagoon Creek diversion.

These coffer dams will prevent or limit flow within the majority of the creek diversions and at locations that have been identified as non-compliant against the DERM hydraulic design thresholds. There will be locations where the diversion will have to be constructed online as the diversion is located on the existing creek alignment.

7.2 Construction Timing

As identified in the geomorphic assessment the creeks traversing the site are highly ephemeral with a clearly defined wet and dry season. Therefore it is recommended that construction of the creek diversions be undertaken during the dry season, typically April to September. This will provide the best opportunity for juvenile vegetation to be established prior to being subjected to high flow conditions or prolonged periods of inundation.

7.3 Earthworks Requirements

The concept design of the proposed creek diversions has been undertaken to limit cut and fill requirement and achieve a balance where possible. Excavated material from the diversion will be utilised within the flood protection levees, subject to a detailed geotechnical investigation. If material is required to be imported from elsewhere onsite additional geotechnical assessment will be undertaken to ensure it is not dispersive and is structurally suitable for the use within a levee. Additional geotechnical investigation will also be undertaken in areas of significant cut as the characteristics of the underlying material are unknown.

7.4 Revegetation

The establishment of riparian vegetation will be critical in creating and maintaining the stability of proposed diversions as well as providing habitat. Assessment of existing riparian vegetation will be undertaken as part of the detailed design phase to provide a basis for developing the detailed revegetation plan. Revegetation species should consist of predominantly ground cover and small shrubs endemic to the area. The need for importation of topsoil for the purposes of establishing vegetation will be assessed during the detailed design phase.

7.5 Pools and Riffles

Riffles are created by the presence of rocks or debris in the stream bed. They are important for aerating the water and providing habitats for aquatic plants and organisms. Pools are relatively deeper, stationary or very slow stretches and provide a deeper habitat for fish. The geomorphic assessment identified existing pools along Lagoon Creek (Figure 7.1). A detailed assessment considering the ecological requirement for pools and riffles will be undertaken during detailed design.

Figure 7.1 Example of Existing Pond on Lagoon Creek

7.6 Bank and Channel Stability

If the detailed design phase reveals the diversions may be prone to excessive erosion or significant lateral movement the need for timber piling to act as groynes to maintain diversion stability will be assessed. Timber piling is now considered best practice as a means of controlling bank and channel stability. An example of timber piling is shown in Figure 7.2.

Figure 7.2 Example of Timber Piling

7.7 Scour Protection

Scour protection in the form of rock armouring may be required at critical locations within the diversion such as outside bends, off take and tie in locations. As identified by the hydraulic modelling these locations are prone to higher erosion potential of the bed and banks. The purpose of scour protection will be to assist in the establishment of the diversion rather than a for long term management. The need for scour protection will be assessed further during the detailed design phase.

7.8 Erosion and Sediment Control

During and upon immediate completion of earthworks the exposed surfaces of the diversions and levees may be highly susceptible to erosion which could result in sediment mobilisation or even structural failure. During the detailed design phase of the project erosion and sediment control plans for construction will be developed. To limit the effects of erosion, construction should occur in stages with suitable erosion protection measures and sediment capture devices.

8. CREEK DIVERSION MONITORING

A monitoring program for the creek diversions has been developed to maintain the long term performance of the proposed diversions. The monitoring program has been developed in accordance with the ACARP program *Monitoring and Evaluation Program for Bowen Basin River Diversions* (ID&A, 2001). Although this program has been developed for diversions within the Bowen Basin the fundamental requirements are considered relevant to any watercourse diversion. There are four key stages to the monitoring program which are summarised in Table 8.1.

Table 8.1: Diversion Monitoring Program Stages

Monitoring Stage	Objective
Baseline Monitoring	To establish a baseline dataset that can be used for comparison at the time of licence renewal or diversion relinquishment.
Construction and Establishment Monitoring	To ensure diversion is constructed to the correct specification through technical oversight of construction and documentation of as constructed works including any amendments from design.
Operations Monitoring	To monitor and evaluate the diversion's performance is consistent with the original design intent.
Relinquishment Monitoring	To demonstrate that the diversion is operating as a watercourse and has reached equilibrium with adjoining reaches.

8.1 Baseline Monitoring

Baseline monitoring will be conducted for a minimum of 12 months prior to construction. Monitoring at this stage will ensure a baseline data set is developed to assess the performance requirements for operations and relinquishment monitoring.

Baseline monitoring will be utilized to establish control reaches for the diversions to determine if changes in the diversion are a result of isolated processes or an event affecting the whole stream system. The control reach locations will be located on Tallarenha Creek, upstream of the confluence with Lagoon Creek and on Malcolm Creek directly downstream of the MLA. The exact locations will be determined onsite and adequately marked to ensure consistency in monitoring.

The IDC method of recording and monitoring creek diversions will be used for the baseline monitoring in accordance with the ACARP program Monitoring and Evaluation Program for Bowen Basin River Diversions (ID&A, 2001). The IDC method is used to identify potential management issues rather than provide a scientific assessment of a diversion or stream. The IDC method utilises transects within the reaches with indicators for the geomorphic and riparian index assessed in each transect. The indicators for geomorphic index and riparian index are summarised below:

- Geomorphic Index Indictors;
  - Width of low flow and active channel;
  - Bank condition;
  - Bank piping;
  - Bed condition;
  - Recovery;
  - Proximity of spoil piles from bank.
- Riparian Index Indicators;
  - Structural stability of vegetation;
  - Vegetation health and growth rate;
  - Longitudinal connectivity of vegetation.

The baseline monitoring requirements are outlined in Table 8.2.

Table 8.2: Baseline Monitoring Requirements

Actions	Purpose
Index of Diversion Condition	The IDC method will be undertaken at four transects for each at each of the control reaches and within the reaches to be diverted. Photographs will be taken to record the condition of the stream or river before works are initiated. Photographs will be taken of the control reach, the reach to be diverted and the downstream reach. It is recommended that photographs be taken from fixed points along the control and diversion reaches to allow future comparisons.
Aerial Photographs	Aerial photos displaying the existing condition of the creeks and also the location of the new diversion will be taken before works begin. The scale of the aerial photo should be sufficient to allow accurate measurements of the diversion and adjoining river or stream.
Survey	A cross section survey and long section survey of the stream or river upstream (Control reach) and downstream (Downstream reach) of the proposed diversion will be conducted as part of diversion detailed design. This information will be useful during relinquishment monitoring to demonstrate the diversion has had no adverse impacts on upstream and downstream reaches.
Vegetation	The species, abundance and diversity of vegetation in the reach to be diverted will be recorded prior to diversion detailed design and construction. This information will also be used as part of the revegetation of the new diversion and used for comparison during relinquishment monitoring.
Flow Events	In the absence of flow data, information regarding the site and frequency of flow events will be approximated by validation of debris marks against hydraulic modelling undertaken in this report.

8.2 Construction and Establishment Monitoring

Construction and establishment monitoring will start with construction of the diversions and continue until the diversions become operational. A summary of the monitoring requirements to be undertaken during this phase are provided in Table 8.3.

Table 8.3: Construction Monitoring Requirements

Actions	Purpose
Execution Outputs	An execution output database will be developed to record descriptions of the design activities completed. The date of activity and completion will be noted along with details of any accompanying photographs. Design activities not completed to specification are to be recorded through as constructed drawings with an explanation and details of the modified design.
Photographs	Photographs will be taken during and immediately after the construction work is finished. Photographs will be taken from fixed photo points where possible and details such as date, time and weather conditions should accompany the photographs.
Aerial Photographs	Aerial photographs will be taken immediately after diversion construction and establishment has been completed. These photos will accurately display the extent of change and provide a baseline reference for changes that may occur in the future. Additionally, a particular feature of the rehabilitation program may be modified and details of the modification may not be recorded in the database. An aerial photograph may record the modification.

8.3 Operational Monitoring

Operational monitoring will commence after commissioning of the diversions to assess and maintain the long term performance of the systems. A summary of the operational monitoring requirements is provided in Table 8.4.

A combination of pre-determined frequency and event-based monitoring will be used throughout the life of the creek diversions. This combination represents the most effective strategy for assessing long term trends as well as the direct impacts associated with large defined flood events. The monitoring frequency for the diversions is summarised below:

- Event based monitoring for flood events greater than the 10 year ARI event;
- Pre-determined frequency at 1, 2, 5, 7, 10, 15, 20, 25 and 30 years with the monitoring event taking place directly after the wet season.

Table 8.4: Operational Monitoring Requirements

Actions	Purpose
Survival of Works	The survival of in stream works including scour protection, timber piling and vegetation should be assessed during this phase of monitoring. Early detection of failure is likely to increase the options for remedial action.
Photographs	Photographs will be taken from fixed photo points along the Control reach, Diversion reach and Downstream reach on an annual basis.
Aerial Photographs	Aerial photographs of the Control reach, Diversion reach and Downstream reach should be taken on an annual basis.
Index of Diversion Condition	The IDC method will be undertaken at four transects for each at each of the control reaches and within diversions. Photographs will be taken to record the condition of the stream within the control and diversion reaches. It is recommended that photographs be taken from fixed points along the control and downstream reaches to allow future comparisons.
Survey	Longitudinal section and cross section surveys should be conducted in the Control reach, Diversion reach and Downstream reach. These surveys should be repeated every 5 years or after a major flood event.
Flow Events	Flow events should be monitored to determine the size of events the diversion has carried.

8.4 Relinquishment Monitoring

Relinquishment monitoring will commence at the end of the mine life to demonstrate that the diversions are operating as waterways in dynamic equilibrium and not having an adverse impact on adjoining reaches. A summary of the operational monitoring requirements is provided in Table 8.5.

ENGENY WATER MANAGEMENT

Table 8.5: Relinquishment Monitoring Requirements

Actions	Purpose
Stage 1 Survey	Long section and cross section survey will be conducted during the first year of relinquishment monitoring. The survey should include the control reach, diversion reach and downstream reach. This survey should be compared to the 'as built' long section to assess the change in bed elevation.
Stage 1 Evaluation	Survey data from baseline and operational monitoring should be compared with data from relinquishment monitoring. Rates of change for channel top width, cross section area, horizontal displacement and vertical displacement for the control reach, diversion reach and downstream reach should be calculated.
Vegetation Assessment	Detailed vegetation assessment should be conducted during first year of relinquishment monitoring to determine key species absent from Diversion reach but present in Control reach.
Photographs	Photographs should be taken from fixed photo points in the Control, Diversion and Downstream reaches.
Aerial Photographs	Aerial photos of diversion and Control, Diversion and Downstream reaches should be taken on an annual basis.
Stage 2 Survey	A final long section and cross section survey should be conducted prior to application for licence relinquishment.
Stage 2 Evaluation	All data should be evaluated and photographs collated for presentation to regulators.

9. CONCLUSION

This study has been undertaken to provide a conceptual level assessment to support the submission of the SEIS and address stakeholder concerns raised during the public consultation process of the EIS submission for the Galilee Coal Project mine site. The following key points have been summarised below:

- The desktop geomorphic assessment of the existing watercourses found that active channels have very limited capacity with breakout into the floodplain occurring typically in events greater than the 2 year ARI. The assessment also found there is considerable sediment bed load due to infrequent rainfall and low energy conditions within the system. The geomorphic and riparian condition of all creeks was disturbed as part of farming activities.

- Hydrological modelling and validation was undertaken to determine the existing and developed flood behaviour through the project area. Hydrology estimates have been revised from the *Mine Development Flood Assessment* (Engeny, 2011) due to a number of large flood events that have recently occurred in the region.

- Results of the existing hydraulic modelling revealed the proposed open cut pits and MIA would be prone to flooding in frequent events. Therefore it is necessary to divert both Malcolm Creek and Lagoon Creek through the MLA. The alignment and design of these diversions was optimised to mimic the natural process and features of the existing watercourses as much as practical. Hydraulic modelling of the creek diversions demonstrates overall compliance with ACARP and DERM standards.

- Developed case hydraulic modelling demonstrates the development of the mine will not have adverse impacts on downstream properties or areas external to the MLA. The developed case modelling was also used to undertake conceptual design of flood protection levees to prevent pit inundation and protect critical infrastructure. These levees will be deemed regulated structures under a future environmental authority and are designed to provide 1000 year ARI flood immunity.

- Considerations for the construction and establishment of the creek diversions have been included to enhance the long term performance. These considerations will be explored further during the detailed design and licensing process of the creek diversions.

- A monitoring program for the creek diversions has been developed to maintain the long term performance of the proposed diversions. The monitoring program has been developed in accordance with the ACARP program *Monitoring and Evaluation Program for Bowen Basin River Diversions* (ID&A, 2001).

10. QUALIFICATIONS

a. In preparing this document, including all relevant calculation and modelling, Engeny Management Pty Ltd (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

b. Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

c. Engeny reserves the right to review and amend any aspect of the works performed including any opinions and recommendations from the works included or referred to in the works if:

   (i) additional sources of information not presently available (for whatever reason) are provided or become known to Engeny; or

   (ii) Engeny considers it prudent to revise any aspect of the works in light of any information which becomes known to it after the date of submission.

d. Engeny does not give any warranty nor accept any liability in relation to the completeness or accuracy of the works, which may be inherently reliant upon the completeness and accuracy of the input data and the agreed scope of works. All limitations of liability shall apply for the benefit of the employees, agents and representatives of Engeny to the same extent that they apply for the benefit of Engeny.

e. This document is for the use of the party to whom it is addressed and for no other persons. No responsibility is accepted to any third party for the whole or part of the contents of this report.

f. If any claim or demand is made by any person against Engeny on the basis of detriment sustained or alleged to have been sustained as a result of reliance upon the report or information therein, Engeny will rely upon this provision as a defence to any such claim or demand.

11. REFERENCES

ACARP (2000). *Maintenance of Geomorphic Processes in Bowen Basin River Diversions Stage 1*. Australian Coal Association Research Program. Program No. C8030. May 2000.

Bureau of Meteorology 2010. *Australian Climate Group - Köppen Classification System*. Viewed 16 July 2012. http://www.bom.gov.au/iwk/climate_zones/map_1.shtml

DERM (2012). *Manual for Assessing Hazard Categories and Hydraulic Performance of Dams*. Department of Environment and Resource Management. February 2012.

DERM (2011). *Watercourse Diversions – Central Queensland Mining Industry – Version 5*. Department of Environment and Resource Management. March 2011.

E3 Consult (2010). *China First Surface Water Assessment.* Report to Waratah Coal Inc. From E3 Consulting Pty Ltd. September 2010.

Engeny Water Management (2011). *Mine Development Flood Assessment – Revision 2.* Report to Waratah Coal Inc. from Engeny Management Pty Ltd. 1 February 2011.

Fisher Stewart (2002). Bowen Basin River Diversions – Design and Rehabilitation Criteria. Australian Coal Association Research Program. Program No. C9068. July 2002.

Hargraves, G (2004). *CRCFORGE and (CRC) ARF Techniques, Queensland and Border Locations, Development and Application*. Water Assessment Group - Natural Resources & Mines.

ID&A (2001). *Monitoring and Evaluation Program for Bowen Basin River Diversions*. Australian Coal Association Research Program. Program No. C9068. February 2001.

IEAUST (1999). *Australian Rainfall and Runoff – Volume 1: A Guide To Flood Estimation*. The Institution of Engineers Australia.

Leopold L B & Wolman M G (1960). *River Meanders*. Bulletin of the Geological Society of America Vol. 71. March 1960.

Palmen, L & Weeks, W (2008). *Regional Flood Frequency for Queensland using the Quantile Regression Technique.* Queensland Department of Main Roads.

Queensland Government (1994). *Environmental Protection Act 1994*. Reprint No. 10G. April 2011.

Queensland Government (2009). *Sustainable Planning Act 2009*. Reprint No. 2. March 2012.

Queensland Government (2000). *Water Act 2000*. Reprint No. 9. June 2012.

ENGENY
WATER MANAGEMENT

APPENDIX A

Mine Infrastructure Layout

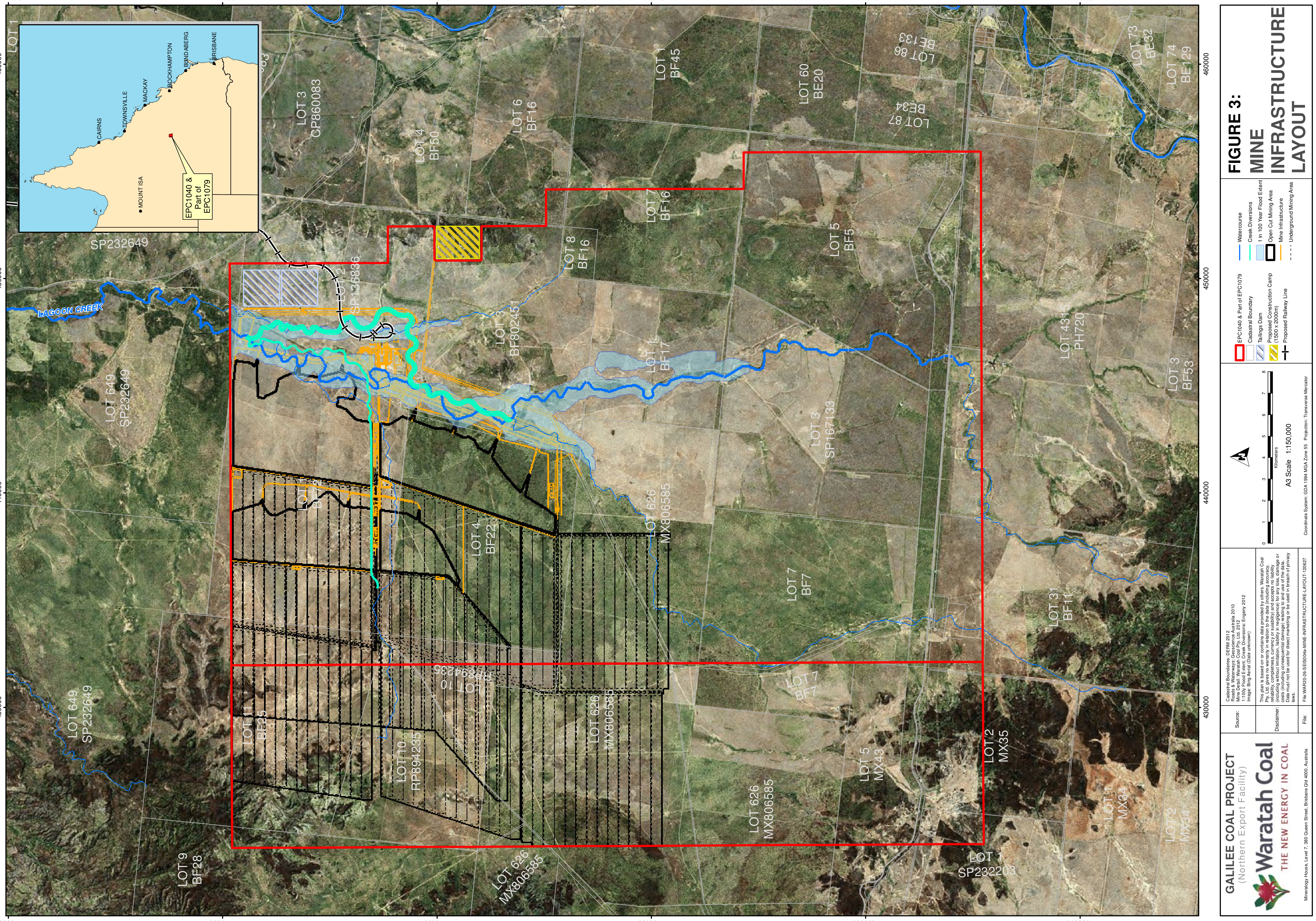


FIGURE 3:
MINE INFRASTRUCTURE LAYOUT
EPC1040 & Part of EPC1079
Cadastral Boundary
Tailings Dam
Proposed Construction Camp (1500 x 2000m)
Proposed Railway Line
Watercourse
Creek Diversions
1 in 100 Year Flood Extent
Open Cut Mining Area
Mine Infrastructure
Underground Mining Area
A3 Scale 1:150,000
LAGOON CREEK
EPC1040 & Part of EPC1079
CAIRNS
TOWNSVILLE
MACKAY
ROCKHAMPTON
BUNDABERG
BRISBANE
MOUNT ISA
GALILEE COAL PROJECT
(Northern Export Facility)
Waratah Coal
THE NEW ENERGY IN COAL

APPENDIX B

Catchment Plans

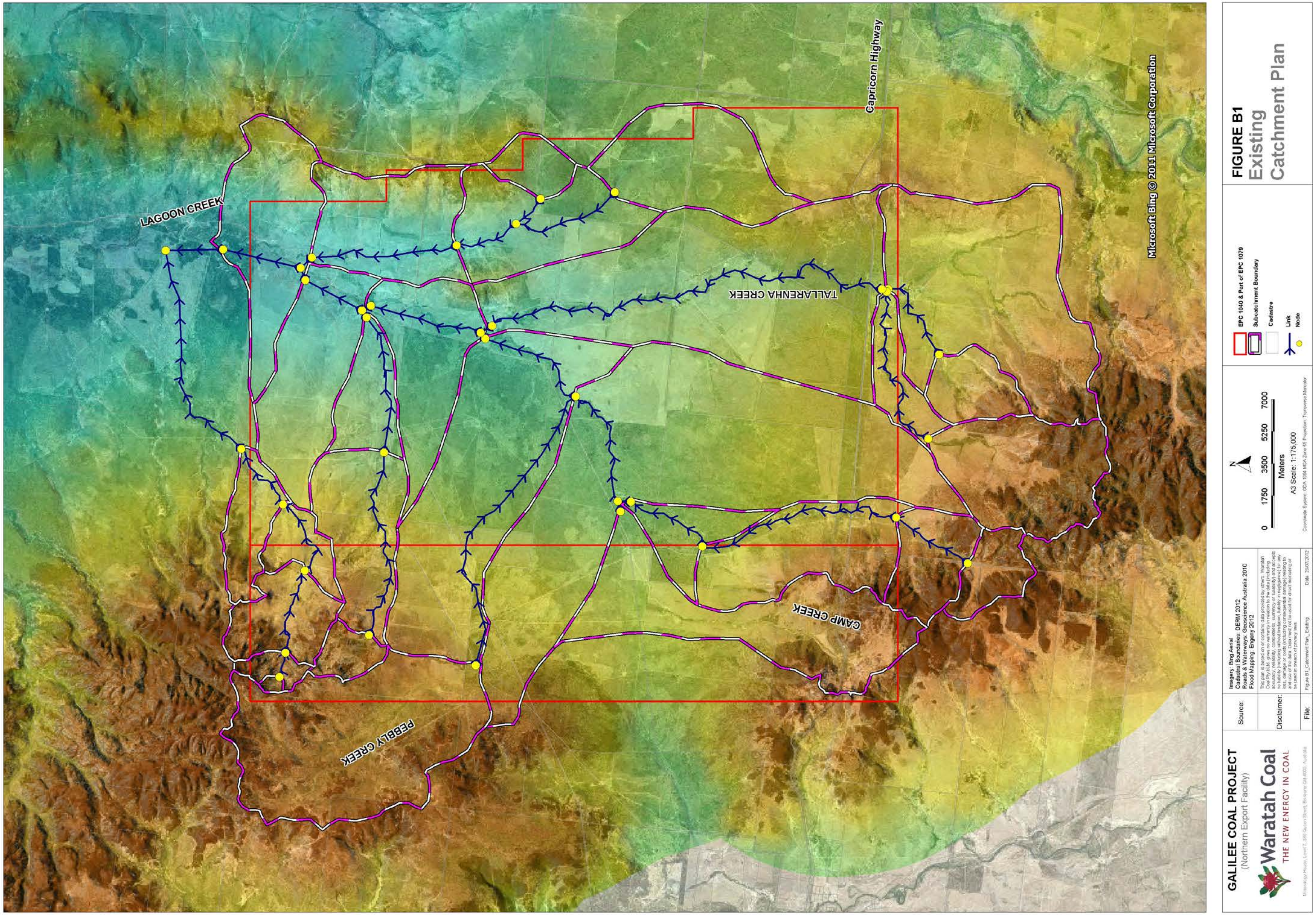
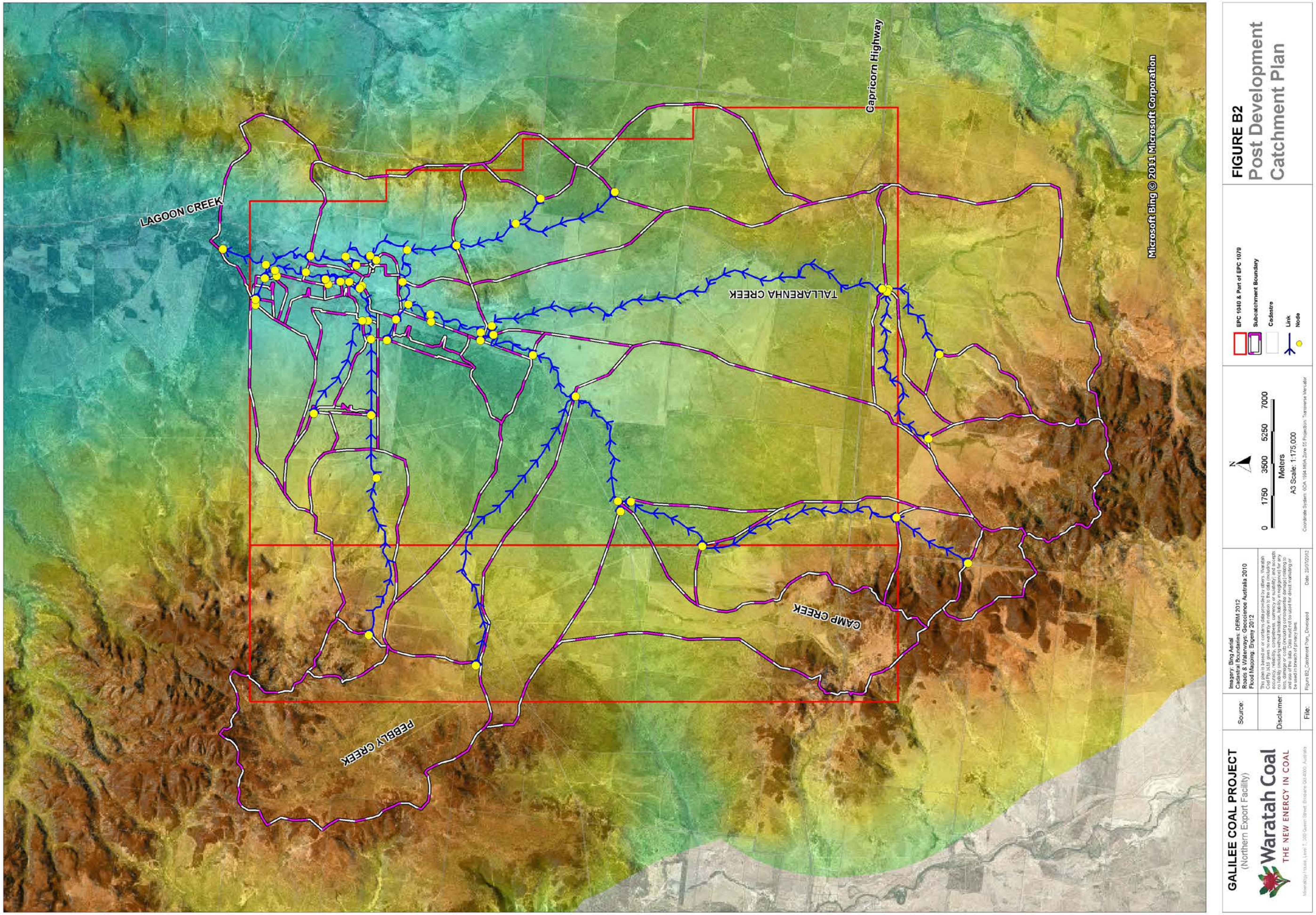


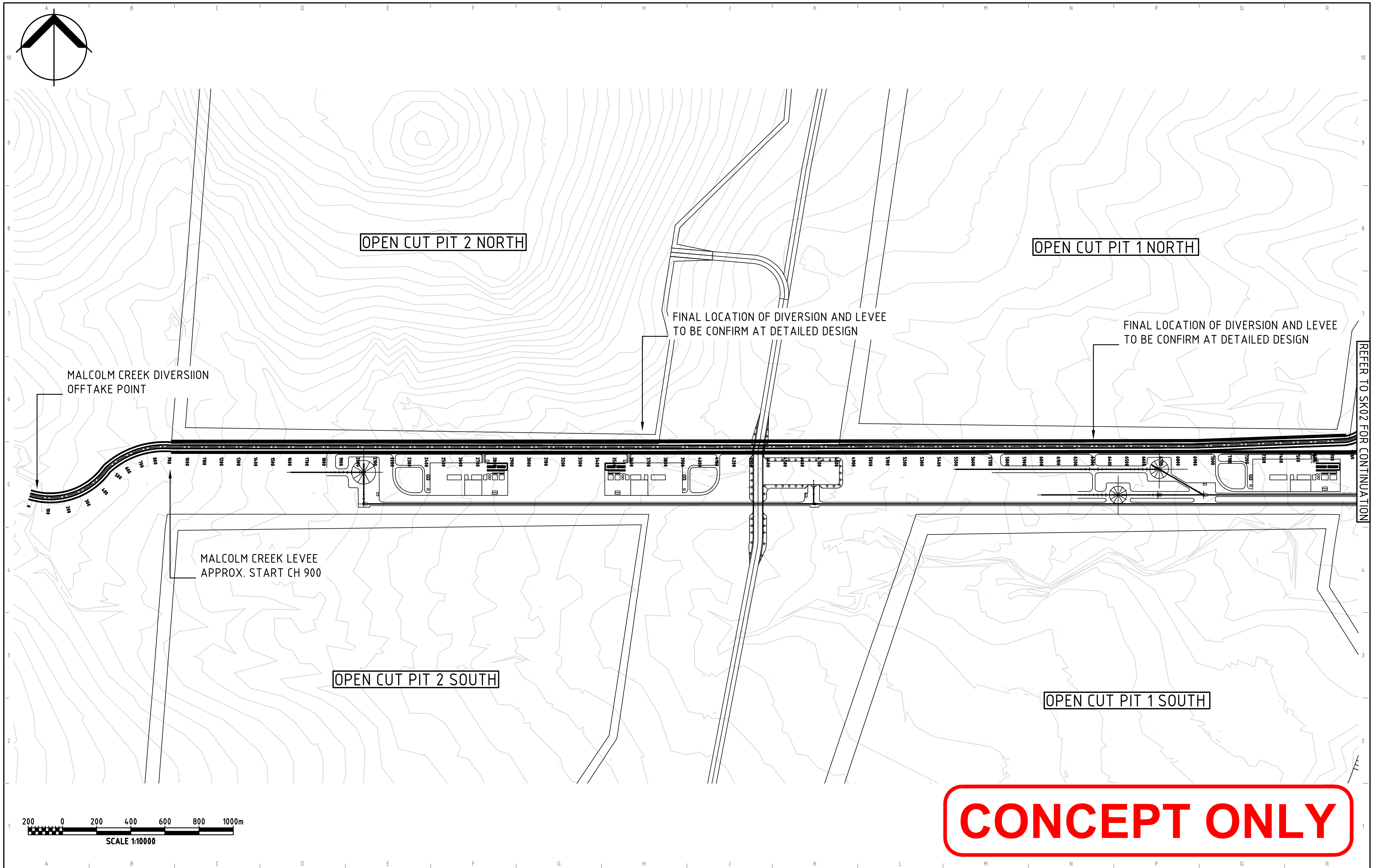
FIGURE B1
Existing
Catchment Plan
Microsoft Bing © 2011 Microsoft Corporation
Capricorn Highway
LAGOON CREEK
TALLARENHA CREEK
CAMP CREEK
PEBBLY CREEK
EPC 1040 & Part of EPC 1079
Subcatchment Boundary
Cadastre
Link
Node
N
0 1750 3500 5250 7000
Meters
A3 Scale: 1:175,000
Coordinate System: GDA 1994 MGA Zone 55 Projection: Transverse Mercator
Source:
Imagery: Bing Aerial
Cadastral Boundaries: DERM 2012
Roads & Waterways: Geoscience Australia 2010
Flood Mapping: Engeny 2012
Disclaimer:
This plan is based on or contains data provided by others. Waratah Coal Pty Ltd. gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to and use of the data. Data must not be used for direct marketing or be used in breach of privacy laws.
File:
Figure B1_Catchment Plan_Existing
Date: 23/07/2012
GALILEE COAL PROJECT
(Northern Export Facility)
Waratah Coal
THE NEW ENERGY IN COAL

This page is intentionally left blank.


LAGOON CREEK
TALLARENHA CREEK
CAMP CREEK
PEBBLY CREEK
Capricorn Highway
Microsoft Bing © 2011 Microsoft Corporation
FIGURE B2
Post Development Catchment Plan
EPC 1040 & Part of EPC 1079
Subcatchment Boundary
Cadastre
Link
Node
0 1750 3500 5250 7000
Meters
A3 Scale: 1:175,000
Source:
Imagery: Bing Aerial
Cadastral Boundaries: DERM 2012
Roads & Waterways: Geoscience Australia 2010
Flood Mapping: Engeny 2012
Disclaimer:
File:
GALILEE COAL PROJECT
(Northern Export Facility)
Waratah Coal
THE NEW ENERGY IN COAL

APPENDIX C

Creek Diversion and Levee Concept Design Plans



DESIGNED:	BJ	DATE:	19/7/12	USE FIGURED DIMENSIONS ONLY. DO NOT DIMENSION OFF THIS PLAN. NOT FOR CONSTRUCTION.			
DESIGN CHECK:	BK	DATE:	19/7/12				
DRAWN:	BK	DATE:	19/7/12				
DRAWING CHECK:	AV	DATE:	19/7/12				
SCALE:	1:10000 @ A1		A1 ORIGINAL				

REV	DATE	REVISION DESCRIPTION	ORIG	CKD	ENG

ENGENY WATER MANAGEMENT

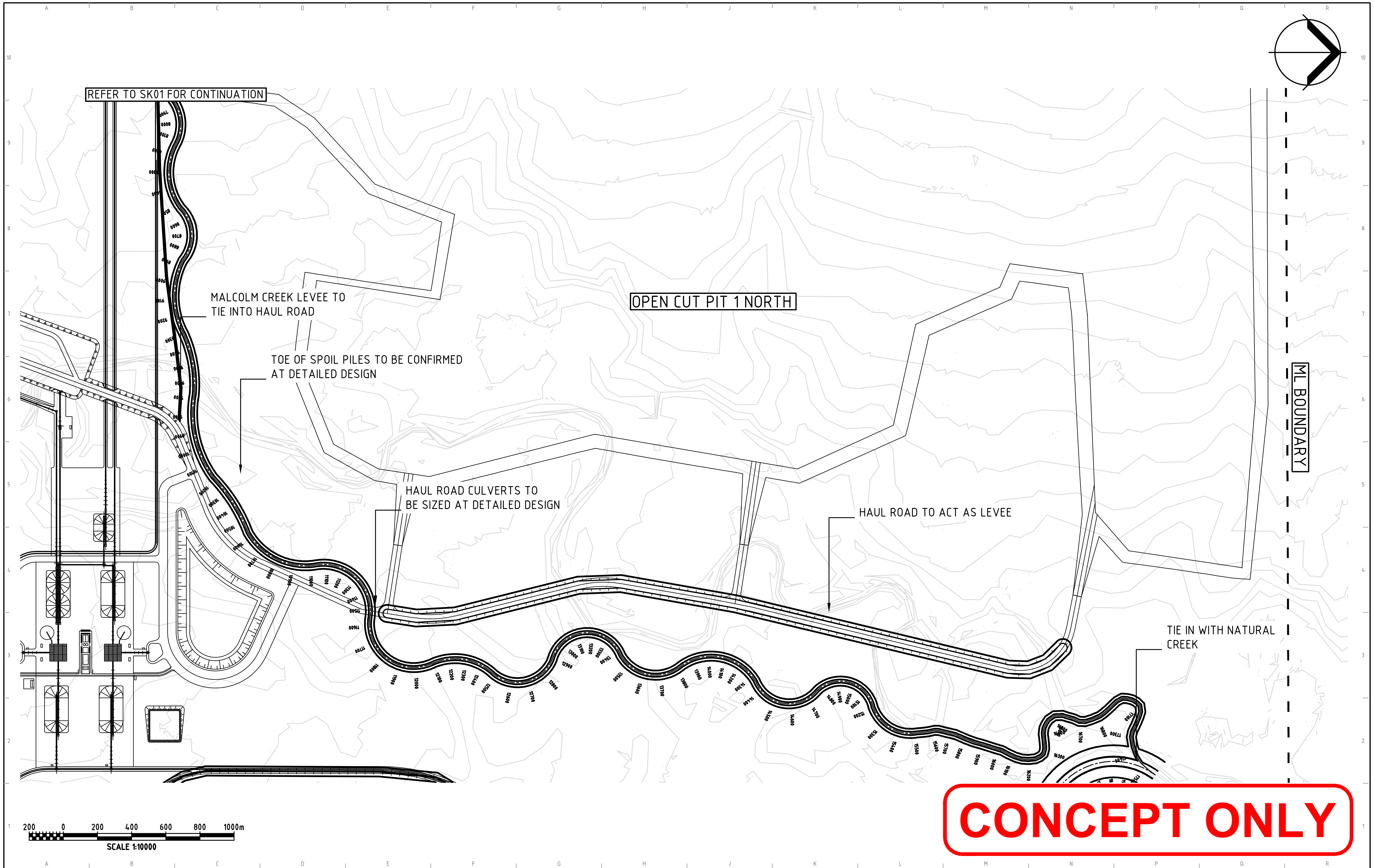
Ph. 07 3221 7174
Fax. 07 3236 2399
Level 11, 344 Queen St Brisbane QLD
PO Box 10183 Brisbane QLD 4000
www.engeny.com.au

PREPARED FOR:
Waratah Coal
THE NEW ENERGY IN COAL

GALILEE COAL PROJECT SEIS
MINE SITE CREEK DIVERSION CONCEPT DESIGN
MALCOLM CREEK DIVERSION PLAN
CH 0.0 TO 7800.0

DRAWING NO: M1700-005-SK01 REV: -

M:\Projects\M1700_Waratah Coal\M1700_005 SEIS Water Management\Design\AutoCAD\Report Drawings\M1700-005-SK01.dwg, 19/07/2012 12:26:08 PM, ISO full bleed A3 (297.00 x 420.00 MM)



DESIGNED: BJ	DATE: 19/7/12
DESIGN CHECK: BK	DATE: 19/7/12
DRAWN: BK	DATE: 19/7/12
DRAWING CHECK: AV	DATE: 19/7/12
SCALE: 1:10000 @ A1	A1 ORIGINAL

REV | DATE | REVISION DESCRIPTION | ORIG | CKD | ENG

USE FIGURED DIMENSIONS ONLY.
DO NOT DIMENSION OFF THIS PLAN.
NOT FOR CONSTRUCTION.

ENGENY WATER MANAGEMENT

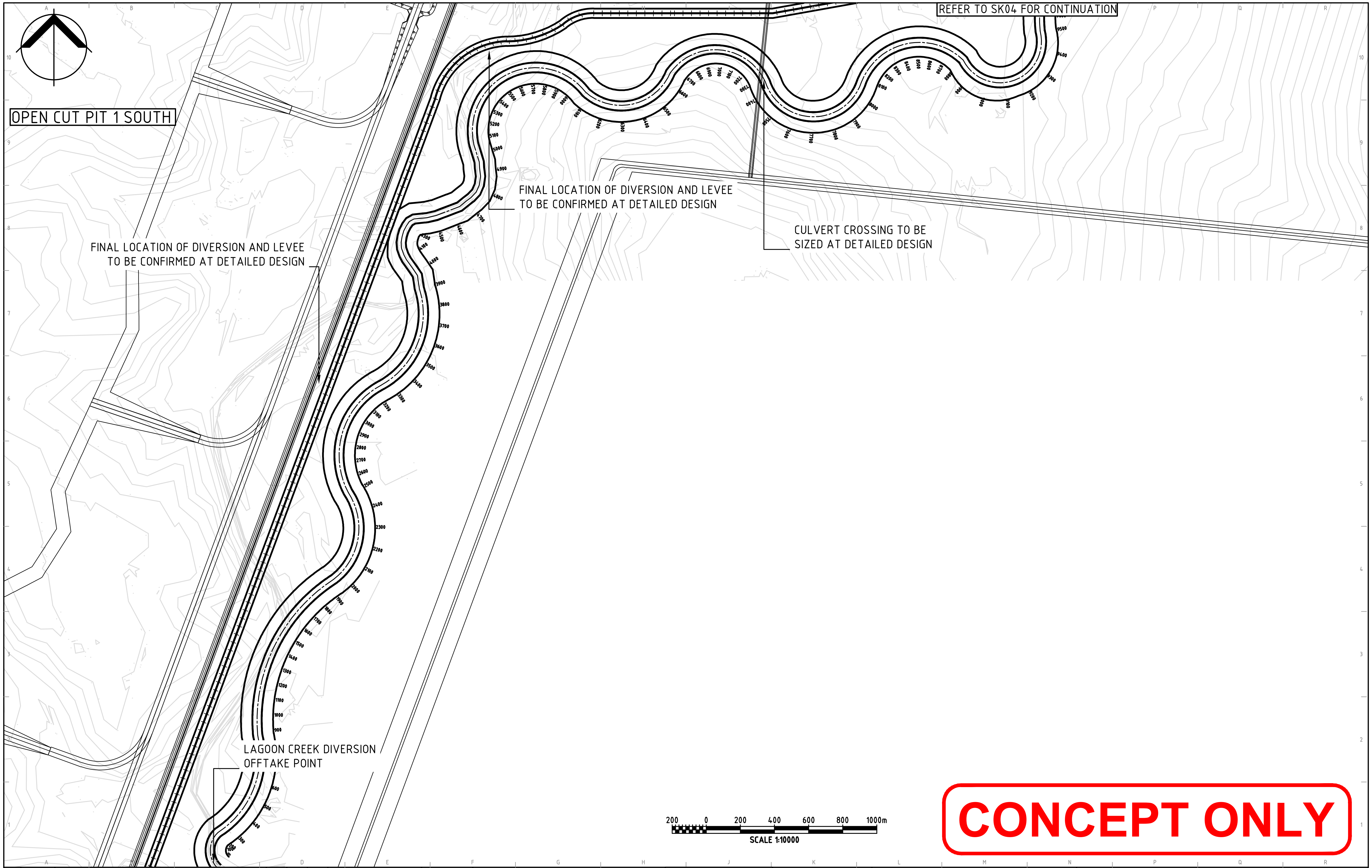
Ph. 07 3221 7174
Fax. 07 3236 2399
Level 11, 344 Queen St Brisbane QLD
PO Box 10183 Brisbane QLD 4000
www.engeny.com.au

PREPARED FOR: Waratah Coal THE NEW ENERGY IN COAL

GALILEE COAL PROJECT SEIS
MINE SITE CREEK DIVERSION CONCEPT DESIGN
MALCOLM CREEK DIVERSION PLAN
CH 7800.0 TO 17100.0

DRAWING NO: M1700-005-SK02 REV: -

M:\Projects\M1700_Waratah Coal\M1700_005 SEIS Water Management\Design\AutoCAD\Report Drawings\M1700-005-SK02.dwg, 19/07/2012 12:48:22 PM, ISO full bleed A3 (297.00 x 420.00 MM)



DESIGNED:	BJ	DATE: 19/7/12
DESIGN CHECK:	BK	DATE: 19/7/12
DRAWN:	BK	DATE: 19/7/12
DRAWING CHECK:	AV	DATE: 19/7/12
SCALE:	1:10000 @ A1	A1 ORIGINAL

REV | DATE | REVISION DESCRIPTION | ORIG | CKD | ENG

USE FIGURED DIMENSIONS ONLY.
DO NOT DIMENSION OFF THIS PLAN.
NOT FOR CONSTRUCTION.

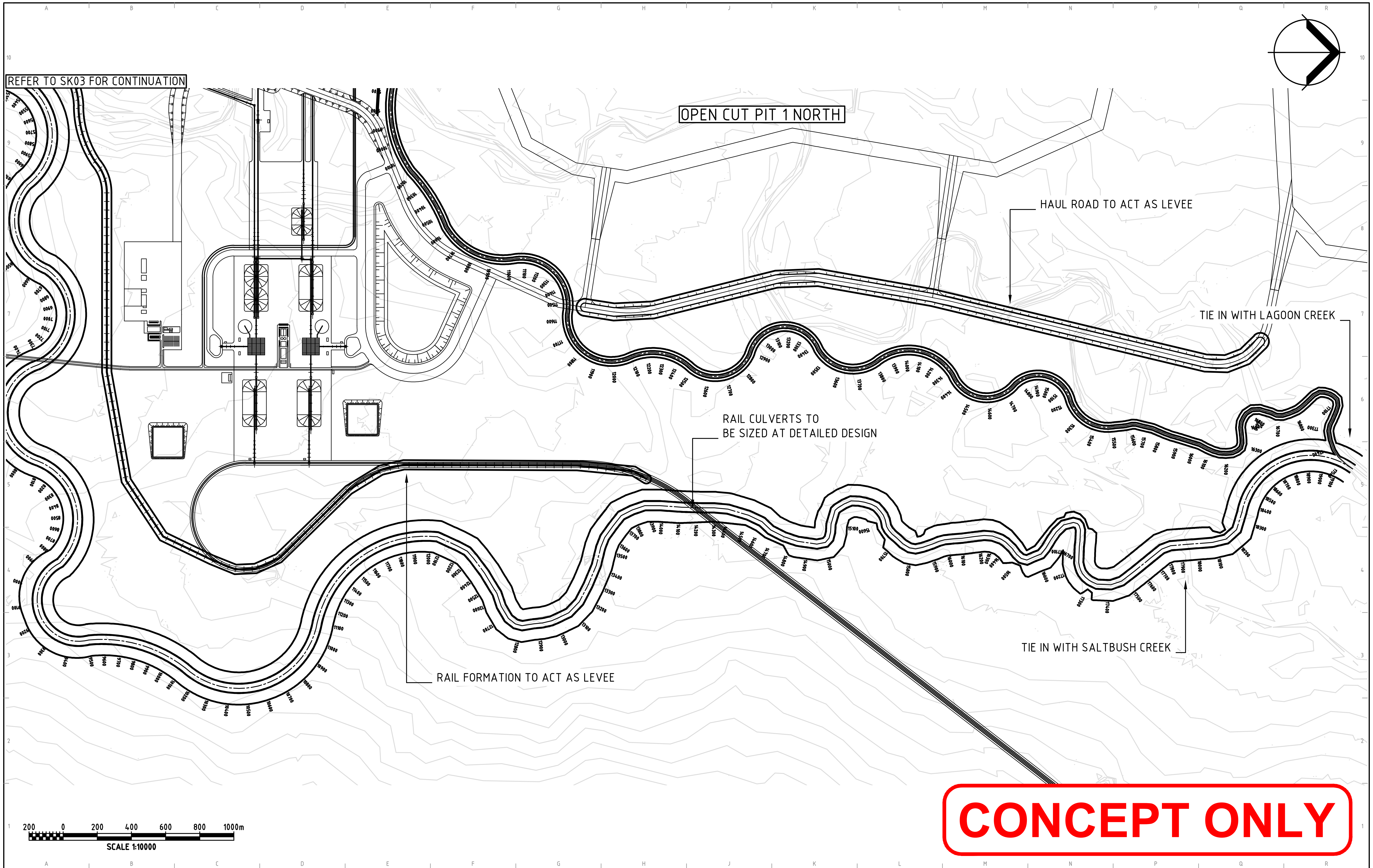
ENGENY WATER MANAGEMENT
Ph. 07 3221 7174
Fax. 07 3236 2399
Level 11, 344 Queen St Brisbane QLD
PO Box 10183 Brisbane QLD 4000
www.engeny.com.au

PREPARED FOR:
Waratah Coal
THE NEW ENERGY IN COAL

GALILEE COAL PROJECT SEIS
MINE SITE CREEK DIVERSION CONCEPT DESIGN
LAGOON CREEK DIVERSION PLAN
CH 0.0 TO 9600.0

DRAWING NO: M1700-005-SK03 REV: -

M:\Projects\M1700_Waratah Coal\M1700_005 SEIS Water Management\Design\AutoCAD\Report Drawings\M1700-005-SK03.dwg, 3/08/2012 3:55:51 PM, ISO full bleed A3 (297.00 x 420.00 MM)



REV	DATE	REVISION DESCRIPTION	ORIG	CKD	ENG

DESIGNED: BJ DATE: 19/7/12
DESIGN CHECK: BK DATE: 19/7/12
DRAWN: BK DATE: 19/7/12
DRAWING CHECK: AV DATE: 19/7/12
SCALE: 1:10000 @ A1 A1 ORIGINAL

USE FIGURED DIMENSIONS ONLY.
DO NOT DIMENSION OFF THIS PLAN.
NOT FOR CONSTRUCTION.

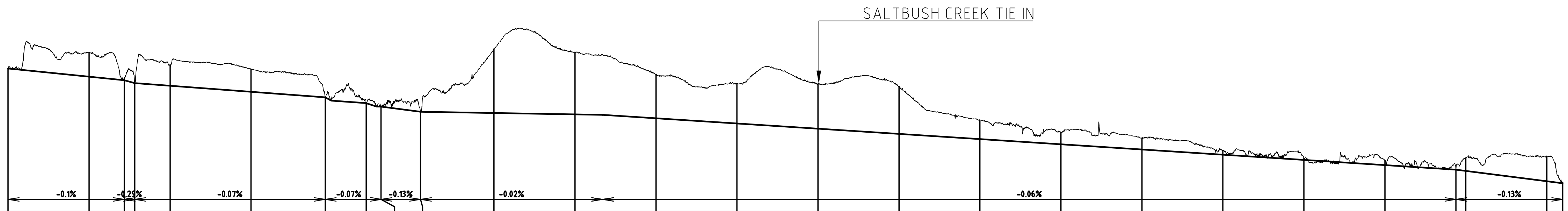
ENGENY WATER MANAGEMENT
Ph. 07 3221 7174
Fax. 07 3236 2399
Level 11, 344 Queen St Brisbane QLD
PO Box 10183 Brisbane QLD 4000
www.engeny.com.au

PREPARED FOR: Waratah Coal THE NEW ENERGY IN COAL

GALILEE COAL PROJECT SEIS
MINE SITE CREEK DIVERSION CONCEPT DESIGN
LAGOON CREEK DIVERSION PLAN
CH 9600.0 TO 19100.0

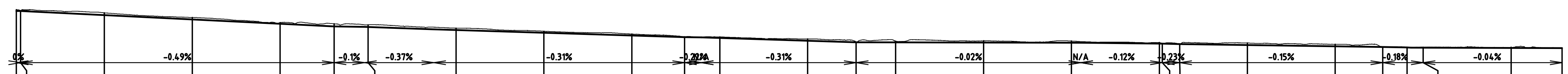
DRAWING NO: M1700-005-SK04 REV: -

M:\Projects\M1700_Waratah Coal\M1700_005 SEIS Water Management\Design\AutoCAD\Report Drawings\M1700-005-SK04.dwg, 19/07/2012 1:09:14 PM, ISO full bleed A3 (297.00 x 420.00 MM)



DIVERSION CL	EXISTING SURFACE	DEPTH OF CUT	CHAINAGE
330.637	330.442	-0.195	0.000
329.636	332.609	2.973	1000.000
329.201	329.201	-0.000	1434.170
328.825	328.843	0.017	1562.585
328.500	331.110	2.610	2000.000
327.756	330.549	2.793	3000.000
327.075	327.075	0.000	3915.347
326.371	326.371	0.000	4421.693
325.931	325.931	-0.000	4604.611
325.299	325.300	0.001	5092.269
325.150	333.063	7.913	6000.000
324.986	332.639	7.653	7000.000
324.507	329.935	5.428	8000.000
323.865	328.759	4.893	9000.000
323.223	328.715	5.492	10000.000
322.581	328.442	5.861	11000.000
321.939	324.283	2.345	12000.000
321.297	322.748	1.451	13000.000
320.654	322.037	1.382	14000.000
320.012	320.562	0.550	15000.000
319.370	319.599	0.229	16000.000
318.728	319.316	0.588	17000.000
318.164	318.164	0.000	17877.379
318.009	319.621	1.611	18000.000
316.746	319.817	3.072	19000.000
316.500	316.620	0.120	19194.401

LONGITUDINAL SECTION - LAGOON CREEK DIVERSION
SCALE 1:30000 HORIZONTAL
SCALE 1:3000 VERTICAL



DIVERSION CL	EXISTING SURFACE	DEPTH OF CUT	CHAINAGE
358.777	360.338	1.561	0.000
358.777	358.777	-0.000	47.593
354.072	356.680	2.608	1000.000
349.131	351.386	2.255	2000.000
344.190	345.613	1.422	3000.000
341.159	344.230	3.071	3613.560
340.830	343.056	2.225	3958.876
340.679	343.122	2.443	4000.000
337.943	340.398	2.455	4746.250
337.163	339.347	2.183	5000.000
334.091	335.785	1.694	6000.000
331.018	332.585	1.567	7000.000
329.174	329.235	0.061	7599.897
328.099	329.264	1.165	8000.000
325.003	326.995	1.992	9000.000
323.295	323.293	-0.003	9551.568
323.209	324.539	1.330	10000.000
323.017	324.911	1.894	11000.000
322.825	324.640	1.815	12000.000
321.750	322.904	1.154	13000.000
321.710	321.710	0.000	13034.350
321.258	321.258	0.000	13230.157
320.106	322.459	2.353	14000.000
318.610	321.015	2.405	15000.000
317.800	317.828	0.028	15541.198
317.299	317.299	-0.000	15817.112
317.093	317.588	0.496	16000.000
316.717	317.583	0.866	17000.000
316.500	316.620	0.120	17579.530

LONGITUDINAL SECTION - MALCOLM CREEK DIVERSION
SCALE 1:30000 HORIZONTAL
SCALE 1:3000 VERTICAL

REV	DATE	REVISION DESCRIPTION	ORIG	CKD	ENG

DESIGNED:	BJ	DATE:	18/07/12
DESIGN CHECK:	BK	DATE:	18/07/12
DRAWN:	BK	DATE:	18/07/12
DRAWING CHECK:	AV	DATE:	18/07/12
SCALE:	AS SHOWN		A1 ORIGINAL

USE FIGURED DIMENSIONS ONLY.
DO NOT DIMENSION OFF THIS PLAN.
NOT FOR CONSTRUCTION.

ENGENY WATER MANAGEMENT
Ph. 07 3221 7174
Fax. 07 3236 2399
Level 11, 344 Queen St Brisbane QLD
PO Box 10183 Brisbane QLD 4000
www.engeny.com.au

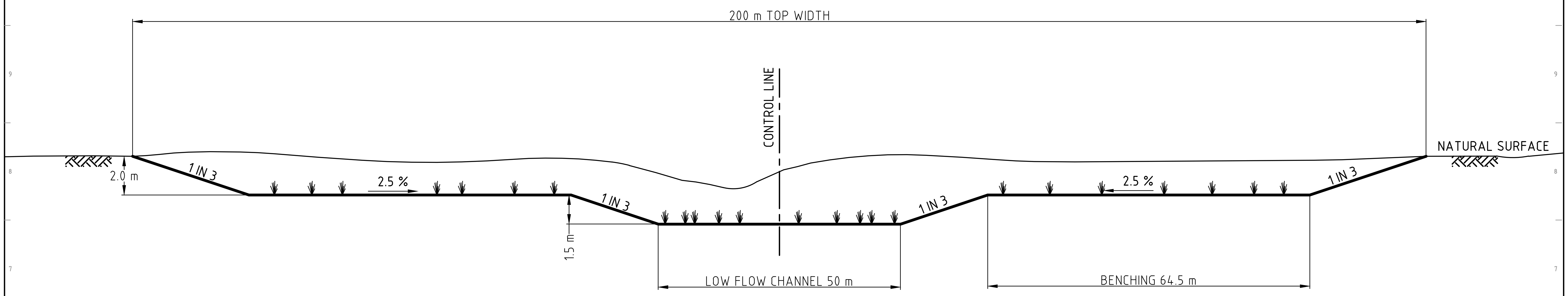
PREPARED FOR:
Waratah Coal
THE NEW ENERGY IN COAL

GALILEE COAL PROJECT SEIS
MINE SITE CREEK DIVERSION CONCEPT DESIGN
CREEK DIVERSION LONGITUDINAL SECTIONS

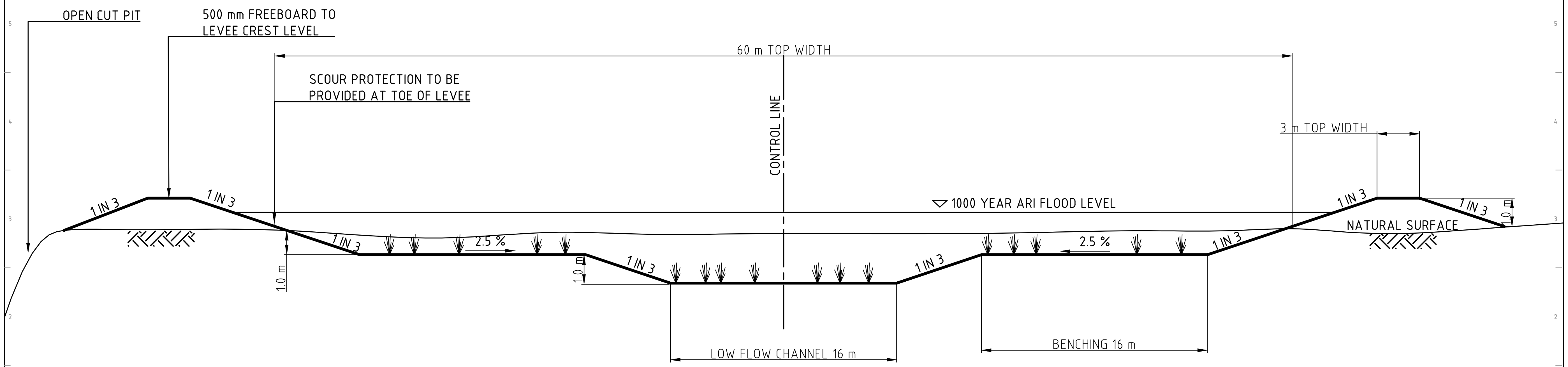
DRAWING NO: M1700-005-SK05
REV: -

M:\Projects\M1700_Waratah Coal\M1700_005 SEIS Water Management\Design\AutoCAD\Report Drawings\M1700-005-SK05.dwg, 3/08/2012 4:04:47 PM, ISO full bleed A3 (297.00 x 420.00 MM)

This page is intentionally left blank.



LAGOON CREEK DIVERSION TYPICAL SECTION
NTS



MALCOLM CREEK DIVERSION TYPICAL SECTION
NTS

REV	DATE	REVISION DESCRIPTION	ORIG	CKD	ENG

DESIGNED: BJ DATE: 19/07/12
DESIGN CHECK: BK DATE: 19/07/12
DRAWN: BK DATE: 19/07/12
DRAWING CHECK: AV DATE: 19/07/12
SCALE: AS SHOWN A1 ORIGINAL

USE FIGURED DIMENSIONS ONLY.
DO NOT DIMENSION OFF THIS PLAN.
NOT FOR CONSTRUCTION.

ENGENY WATER MANAGEMENT
Ph. 07 3221 7174
Fax. 07 3236 2399
Level 11, 344 Queen St Brisbane QLD
PO Box 10183 Brisbane QLD 4000
www.engeny.com.au

PREPARED FOR:
Waratah Coal
THE NEW ENERGY IN COAL

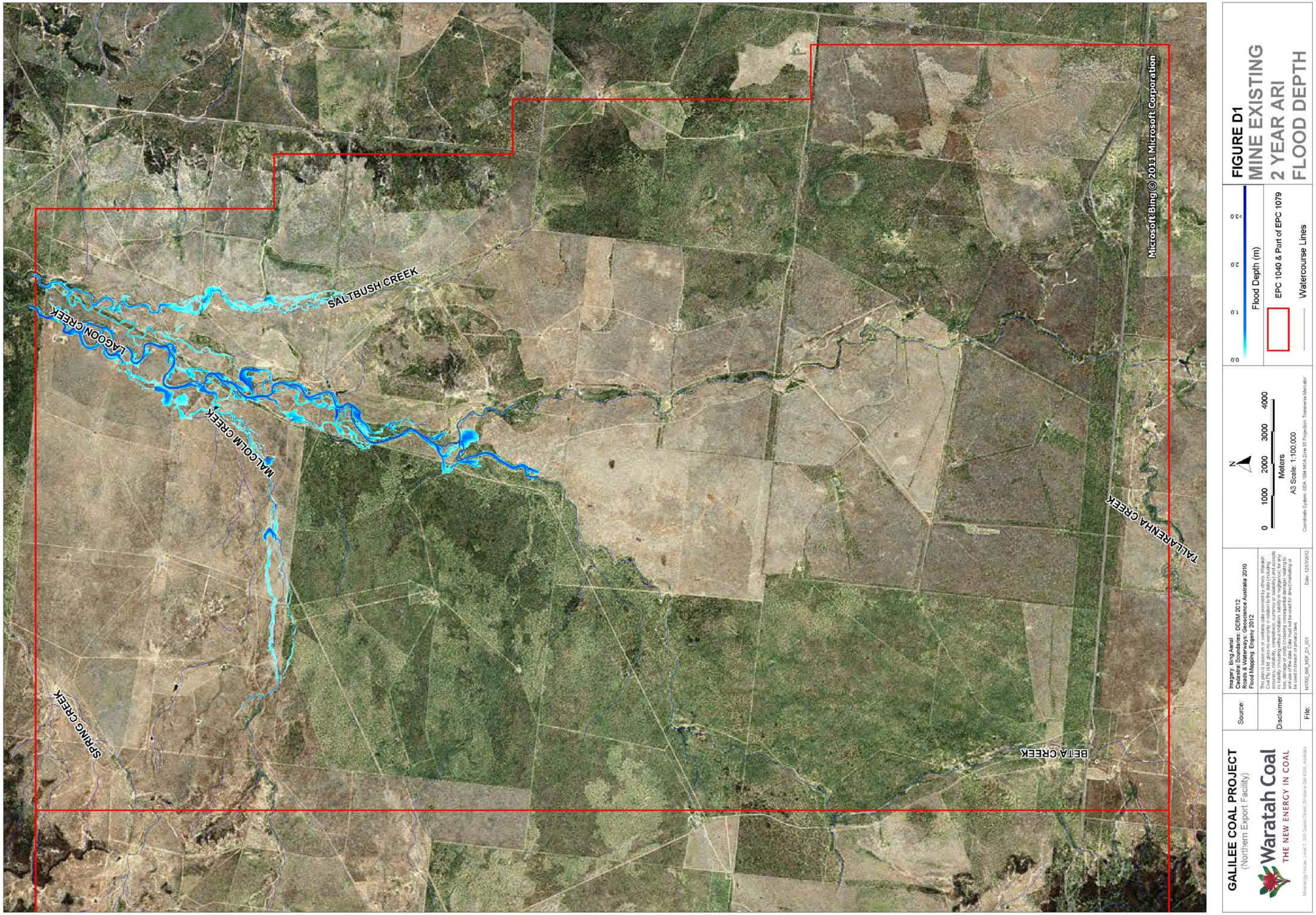
GALILEE COAL PROJECT SEIS
MINE SITE CREEK DIVERSION CONCEPT DESIGN
CREEK DIVERSION TYPICAL CROSS SECTIONS

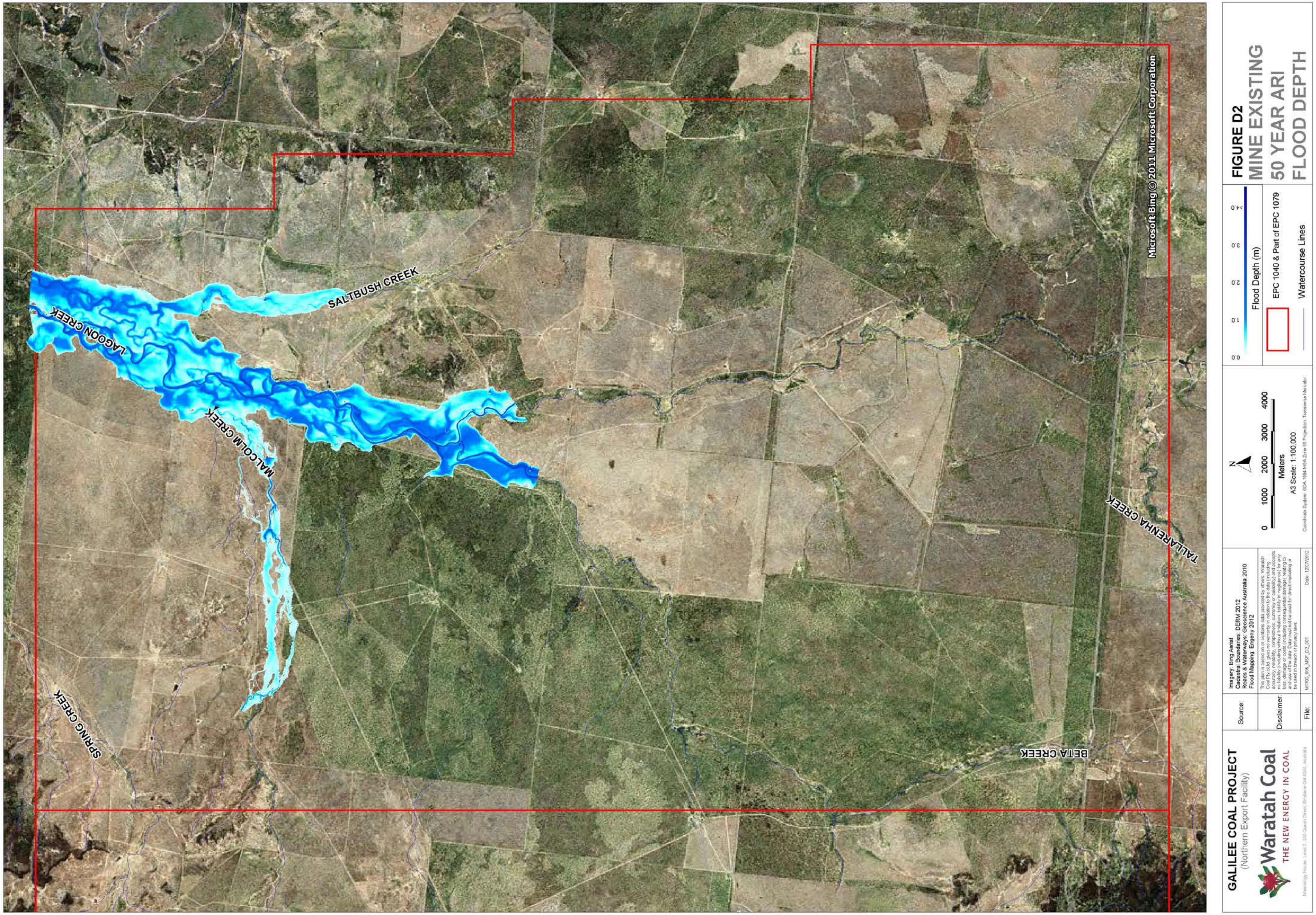
DRAWING NO: M1700-005-SK06
REV: -

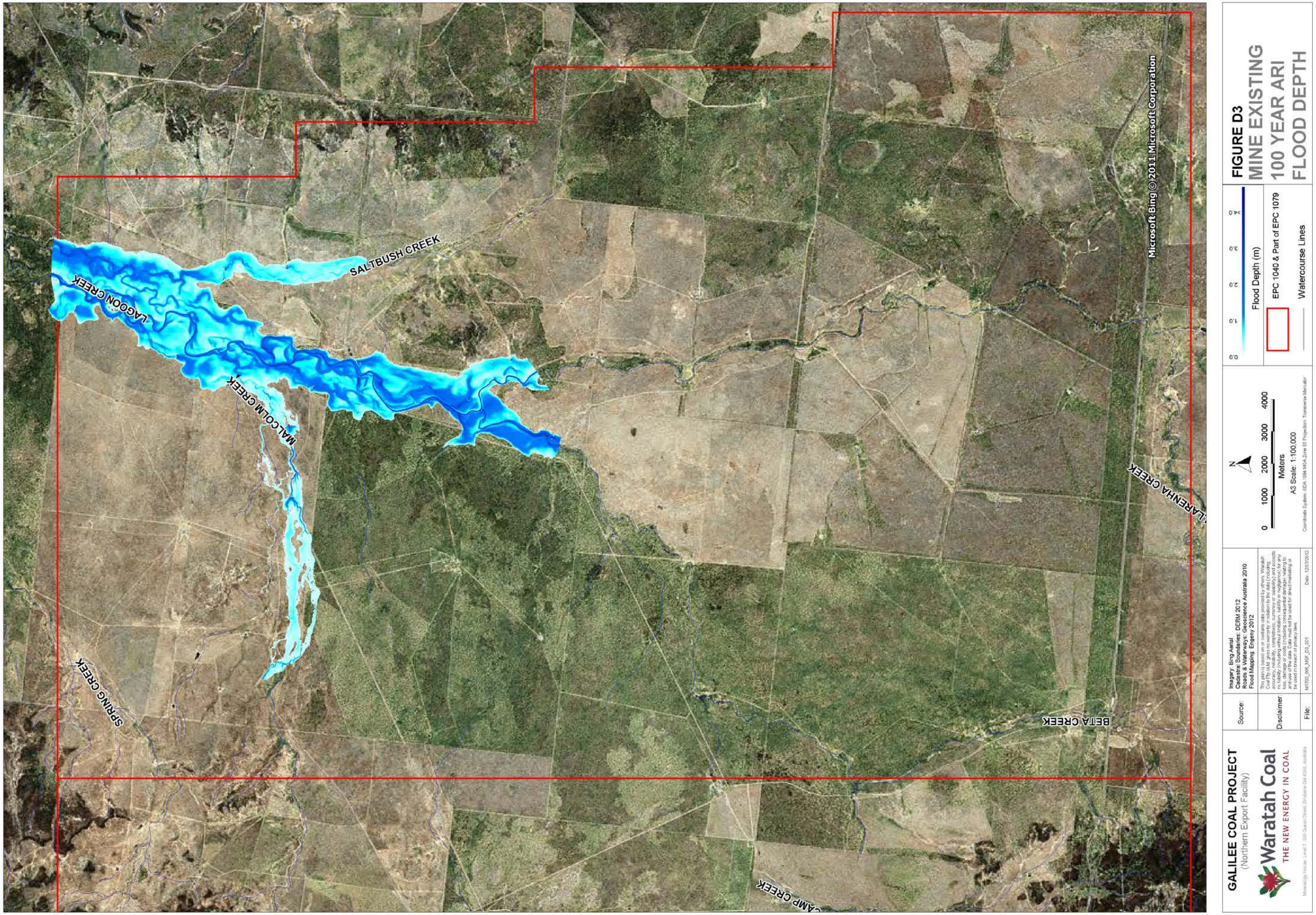
M:\Projects\M1700_Waratah Coal\M1700_005 SEIS Water Management\Design\AutoCAD\Report Drawings\M1700-005-SK06.dwg, 20/07/2012 12:14:23 PM, ISO full bleed A3 (297.00 x 420.00 MM)

APPENDIX D

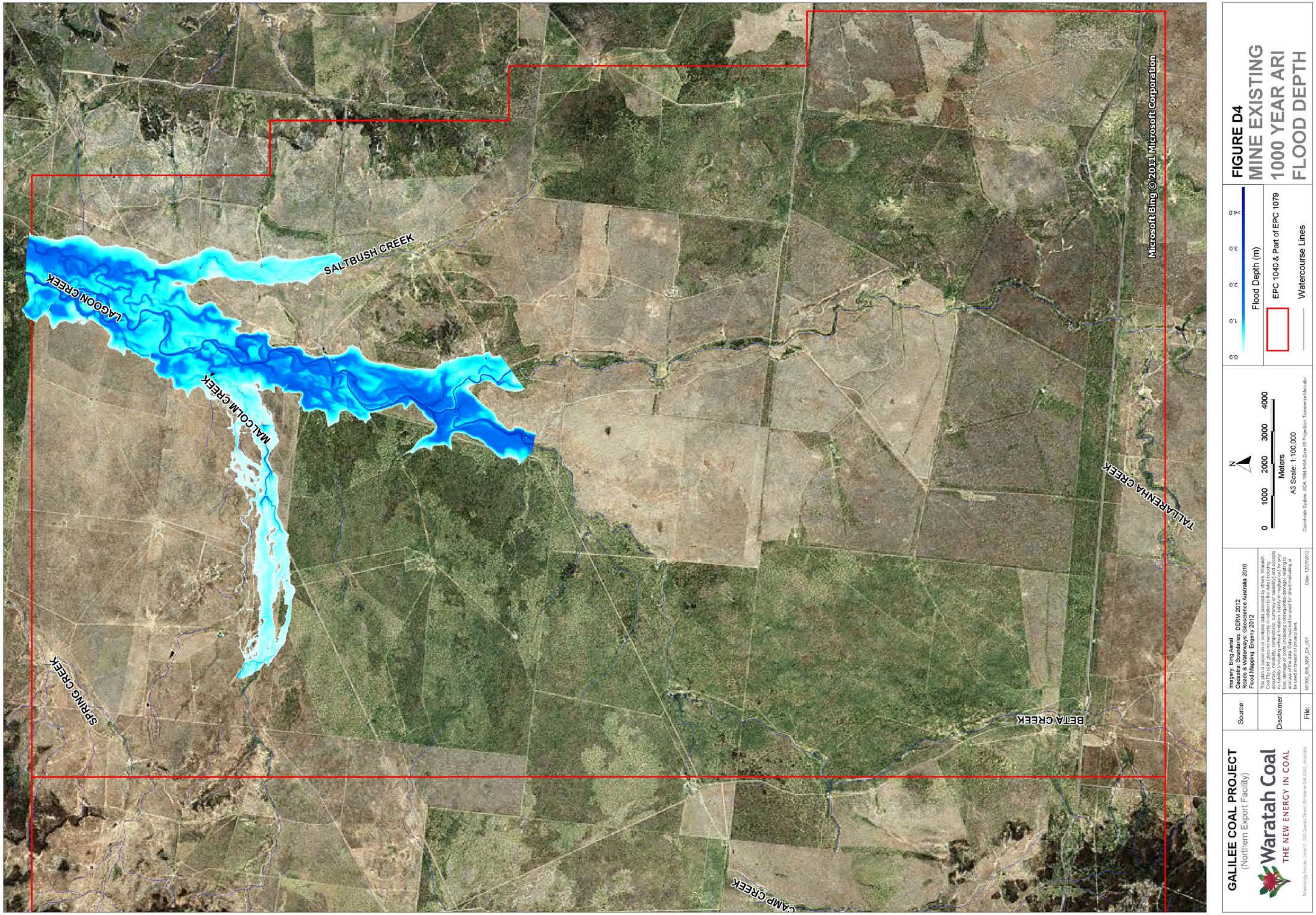
Existing Case Flood Mapping


SALTBUSH CREEK
LAGOON CREEK
MALCOLM CREEK
SPRING CREEK
TALLARENHA CREEK
BETA CREEK
Microsoft Bing © 2011 Microsoft Corporation
FIGURE D1
MINE EXISTING
2 YEAR ARI
FLOOD DEPTH
0.0
1.0
2.0
>3.0
Flood Depth (m)
EPC 1040 & Part of EPC 1079
Watercourse Lines
N
0 1000 2000 3000 4000
Meters
A3 Scale: 1:100,000
Coordinate System: GDA 1994 MGA Zone 55 Projection: Transverse Mercator
Source:
Imagery: Bing Aerial
Cadastral Boundaries: DERM 2012
Roads & Waterways: Geoscience Australia 2010
Flood Mapping: Engeny 2012
Disclaimer:
This plan is based on or contains data provided by others. Waratah Coal Pty Ltd. gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to and use of the data. Data must not be used for direct marketing or be used in breach of privacy laws.
File: M1700_005_MSF_D1_001
Date: 12/07/2012
GALILEE COAL PROJECT
(Northern Export Facility)
Waratah Coal
THE NEW ENERGY IN COAL


SALTBUSH CREEK
LAGOON CREEK
MALCOLM CREEK
SPRING CREEK
TALLARENHA CREEK
BETA CREEK
Microsoft Bing © 2011 Microsoft Corporation
FIGURE D2
MINE EXISTING
50 YEAR ARI
FLOOD DEPTH
0.0 1.0 2.0 3.0 4.0
Flood Depth (m)
EPC 1040 & Part of EPC 1079
Watercourse Lines
N
0 1000 2000 3000 4000
Meters
A3 Scale: 1:100,000
Source: Imagery: Bing Aerial
Cadastral Boundaries: DERM 2012
Roads & Waterways: Geoscience Australia 2010
Flood Mapping: Engeny 2012
Disclaimer:
File:
GALILEE COAL PROJECT
(Northern Export Facility)
Waratah Coal
THE NEW ENERGY IN COAL


SALTBUSH CREEK
LAGOON CREEK
MALCOLM CREEK
SPRING CREEK
ALARENHA CREEK
BETA CREEK
CAMP CREEK
Microsoft Bing © 2011 Microsoft Corporation
FIGURE D3
MINE EXISTING
100 YEAR ARI
FLOOD DEPTH
0.0
1.0
2.0
3.0
>4.0
Flood Depth (m)
EPC 1040 & Part of EPC 1079
Watercourse Lines
N
0
1000
2000
3000
4000
Meters
A3 Scale: 1:100,000
Coordinate System: GDA 1994 MGA Zone 55 Projection: Transverse Mercator
Source:
Imagery: Bing Aerial
Cadastral Boundaries: DERM 2012
Roads & Waterways: Geoscience Australia 2010
Flood Mapping: Engeny 2012
Disclaimer:
File:
M1700_005_MSF_D3_001
Date: 12/07/2012
GALILEE COAL PROJECT
(Northern Export Facility)
Waratah Coal
THE NEW ENERGY IN COAL

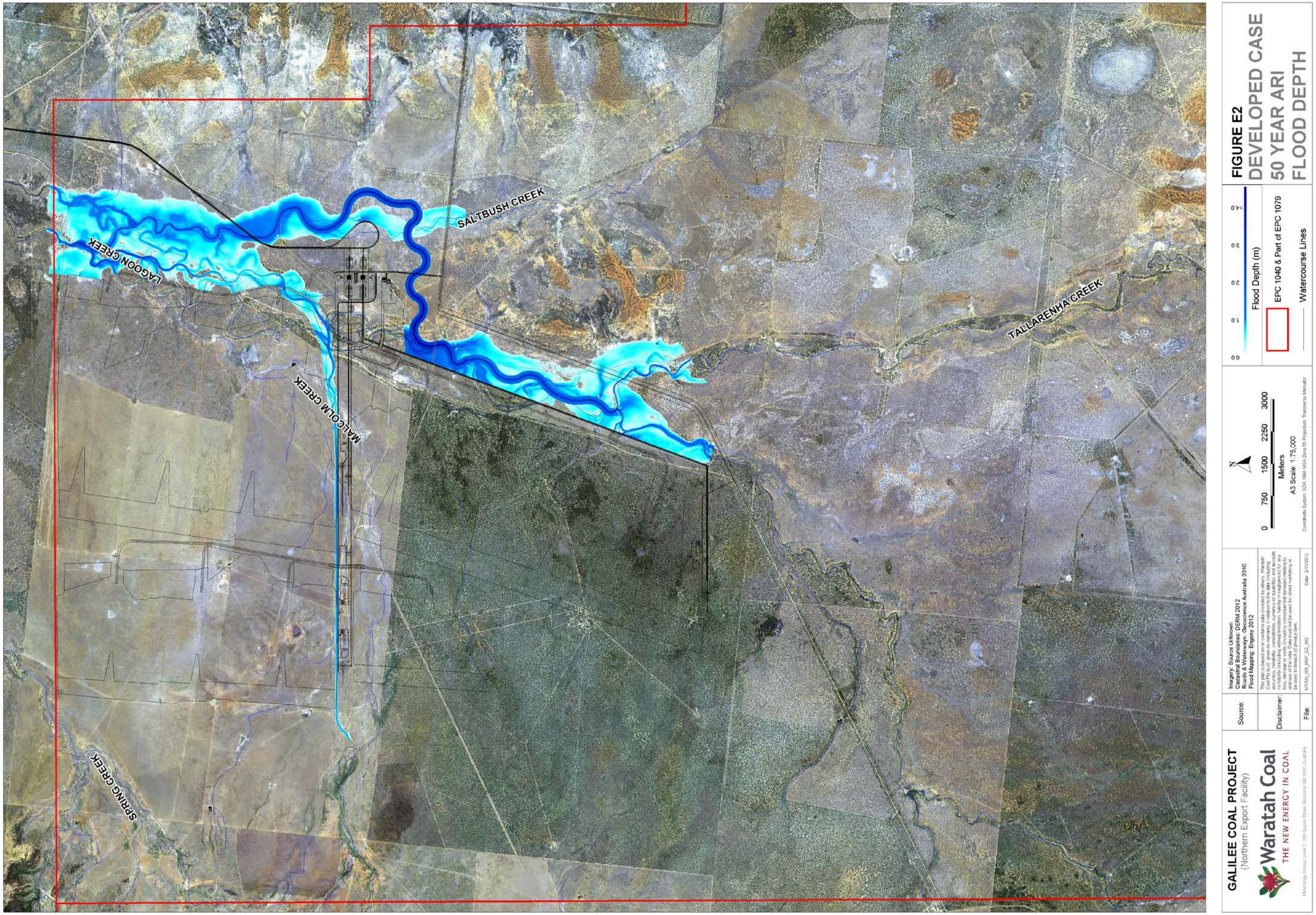
This page is intentionally left blank.


SPRING CREEK
LAGOON CREEK
MALCOLM CREEK
SALTBUSH CREEK
CAMP CREEK
BETA CREEK
TALLARENHA CREEK
Microsoft Bing © 2011 Microsoft Corporation
GALILEE COAL PROJECT
(Northern Export Facility)
Waratah Coal
THE NEW ENERGY IN COAL
Source:
Imagery: Bing Aerial
Cadastral Boundaries: DERM 2012
Roads & Waterways: Geoscience Australia 2010
Flood Mapping: Engeny 2012
Disclaimer:
This plan is based on or contains data provided by others. Waratah Coal Pty oLtd. gives no warranty in relation to the data (including accuracy, reliability, completness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to and use of the data. Data must not be used for direct marketing or be used in breach of privacy laws.
File:
M1700_005_MSF_D4_001
Date: 12/07/2012
N
0 1000 2000 3000 4000
Meters
A3 Scale: 1:100,000
Coordinate System: GDA 1994 MGA Zone 55 Projection: Transverse Mercator
0.0 1.0 2.0 3.0 >4.0
Flood Depth (m)
EPC 1040 & Part of EPC 1079
Watercourse Lines
FIGURE D4
MINE EXISTING
1000 YEAR ARI
FLOOD DEPTH

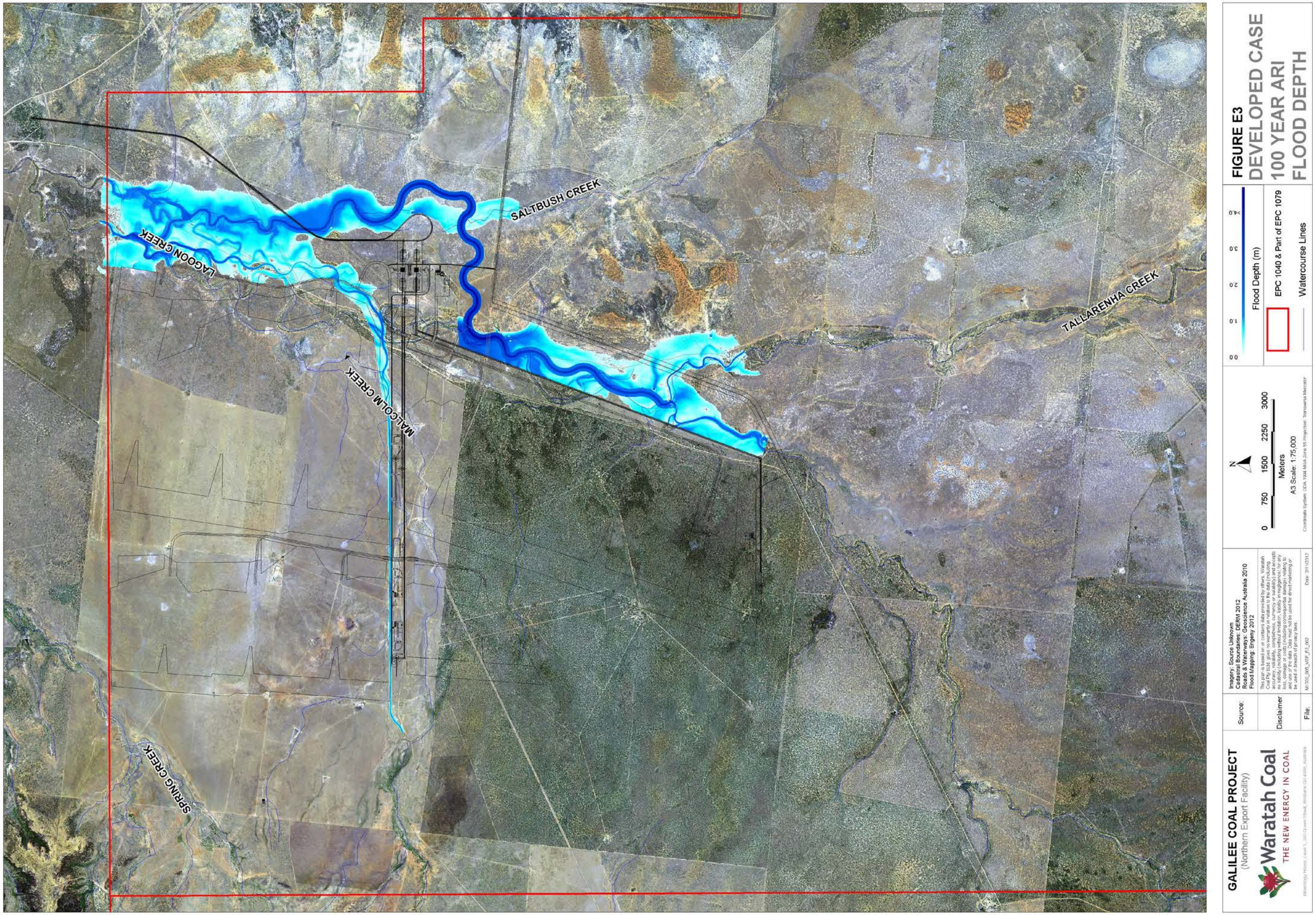
APPENDIX E

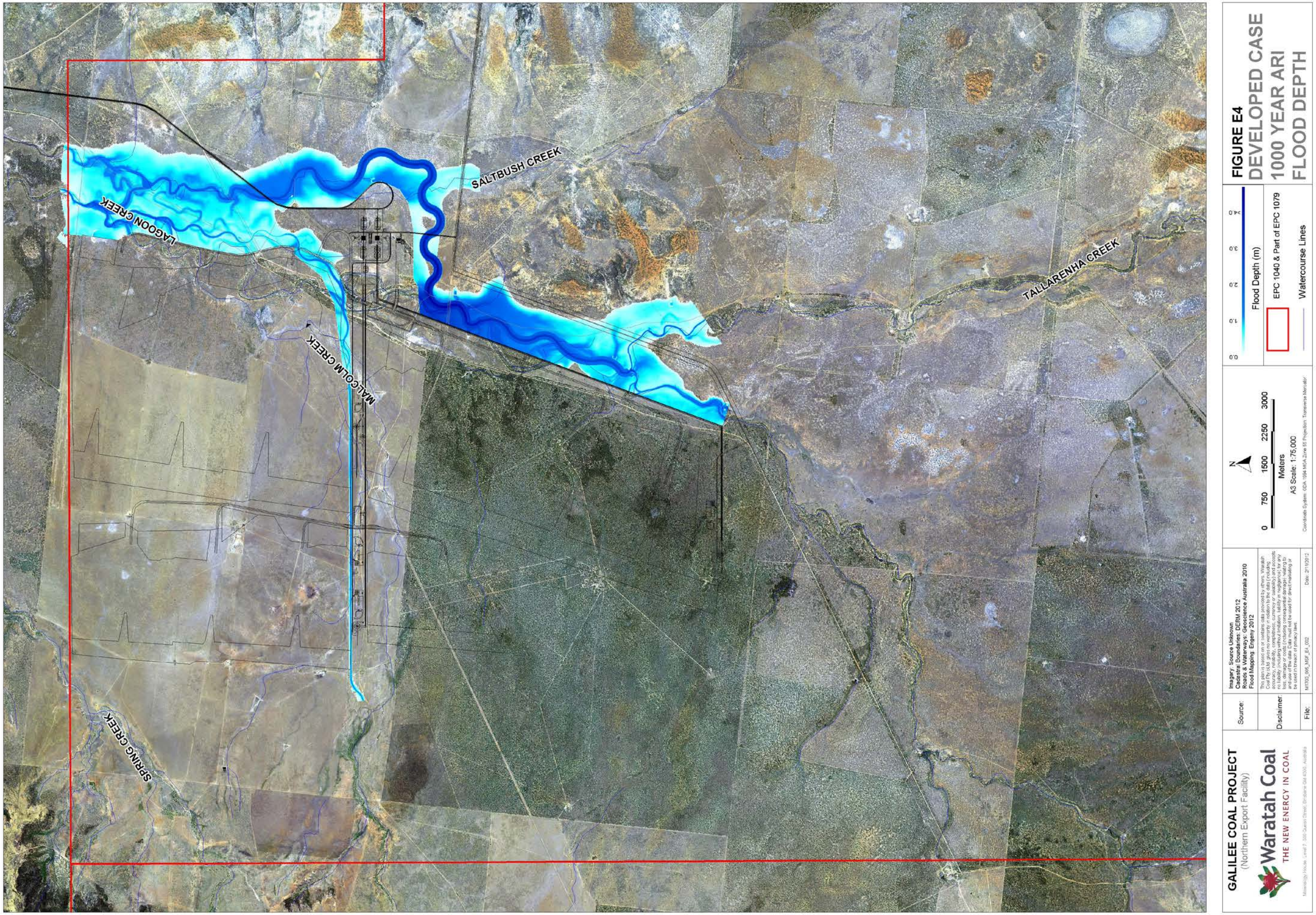
Developed Case Flood Mapping

SALTBUSH CREEK
LAGOON CREEK
MALCOLM CREEK
TALLARENHA CREEK
SPRING CREEK
FIGURE E1
DEVELOPED CASE
2 YEAR ARI
FLOOD DEPTH
0.0
1.0
2.0
>3.0
Flood Depth (m)
EPC 1040 & Part of EPC 1079
Watercourse Lines
N
0 750 1500 2250 3000
Meters
A3 Scale: 1:75,000
Source: Imagery: Source Unknown
Cadastral Boundaries: DERM 2012
Roads & Waterways: Geoscience Australia 2010
Flood Mapping: Engeny 2012
File: M1700_005_MSF_E1_001
Date: 25/07/2012
GALILEE COAL PROJECT
(Northern Export Facility)
Waratah Coal
THE NEW ENERGY IN COAL



SALTBUSH CREEK
LAGOON CREEK
MALCOLM CREEK
TALLARENHA CREEK
SPRING CREEK
FIGURE E2
DEVELOPED CASE
50 YEAR ARI
FLOOD DEPTH
Flood Depth (m)
0.0
1.0
2.0
3.0
>4.0
EPC 1040 & Part of EPC 1079
Watercourse Lines
N
0 750 1500 2250 3000
Meters
A3 Scale: 1:75,000
Source: Imagery: Source Unknown
Cadastral Boundaries: DERM 2012
Roads & Waterways: Geoscience Australia 2010
Flood Mapping: Engeny 2012
File: M1700_005_MSP_E2_002
Date: 2/11/2012
GALILEE COAL PROJECT
(Northern Export Facility)
Waratah Coal
THE NEW ENERGY IN COAL

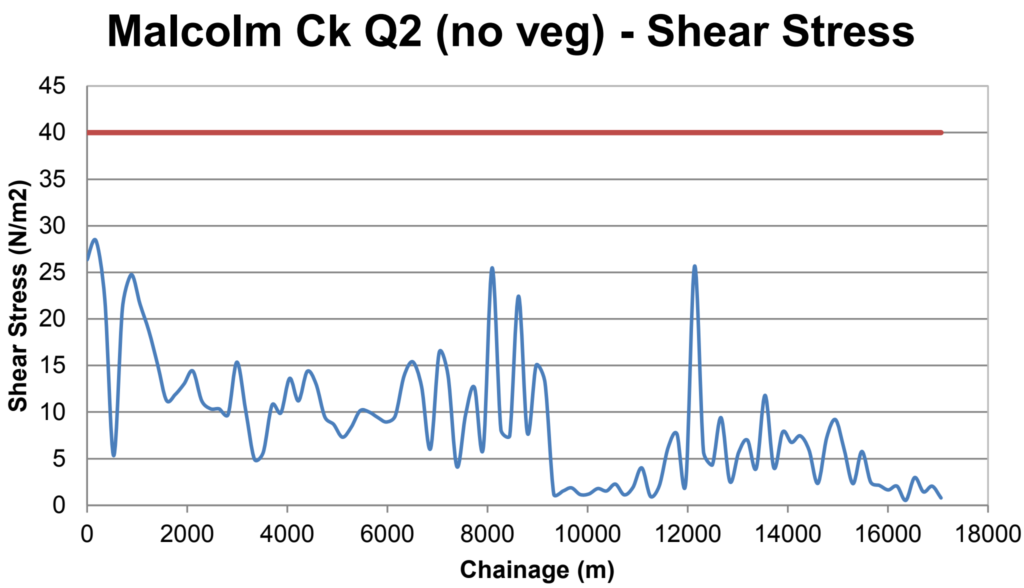

SALTBUSH CREEK
LAGOON CREEK
MALCOLM CREEK
TALLARENHA CREEK
SPRING CREEK
FIGURE E3
DEVELOPED CASE
100 YEAR ARI
FLOOD DEPTH
Flood Depth (m)
0.0
1.0
2.0
3.0
>4.0
EPC 1040 & Part of EPC 1079
Watercourse Lines
0 750 1500 2250 3000
Meters
A3 Scale: 1:75,000
Source:
Imagery: Source Unknown
Cadastral Boundaries: DERM 2012
Roads & Waterways: Geoscience Australia 2010
Flood Mapping: Engeny 2012
Disclaimer
File:
GALILEE COAL PROJECT
(Northern Export Facility)
Waratah Coal
THE NEW ENERGY IN COAL

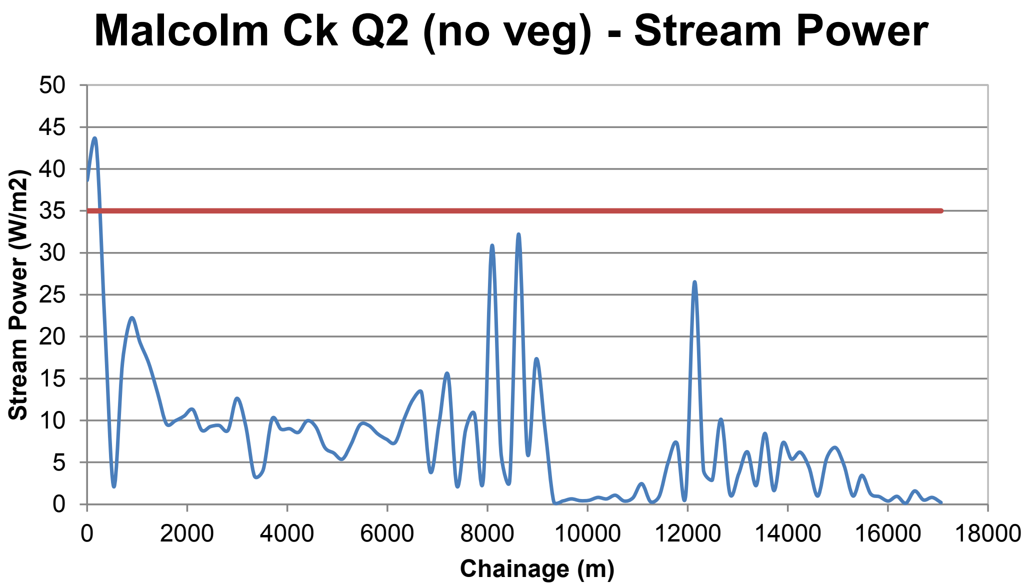

SALTBUSH CREEK
LAGOON CREEK
MALCOLM CREEK
TALLARENHA CREEK
SPRING CREEK
FIGURE E4
DEVELOPED CASE
1000 YEAR ARI
FLOOD DEPTH
Flood Depth (m)
0.0
1.0
2.0
3.0
4.0
EPC 1040 & Part of EPC 1079
Watercourse Lines
N
0 750 1500 2250 3000
Meters
A3 Scale: 1:75,000
GALILEE COAL PROJECT
(Northern Export Facility)
Waratah Coal
THE NEW ENERGY IN COAL
Source:
Imagery: Source Unknown
Cadastral Boundaries: DCDB 2012
Roads & Waterways: Geoscience Australia 2010
Flood Mapping: Engeny 2012
Disclaimer:
File:

APPENDIX F

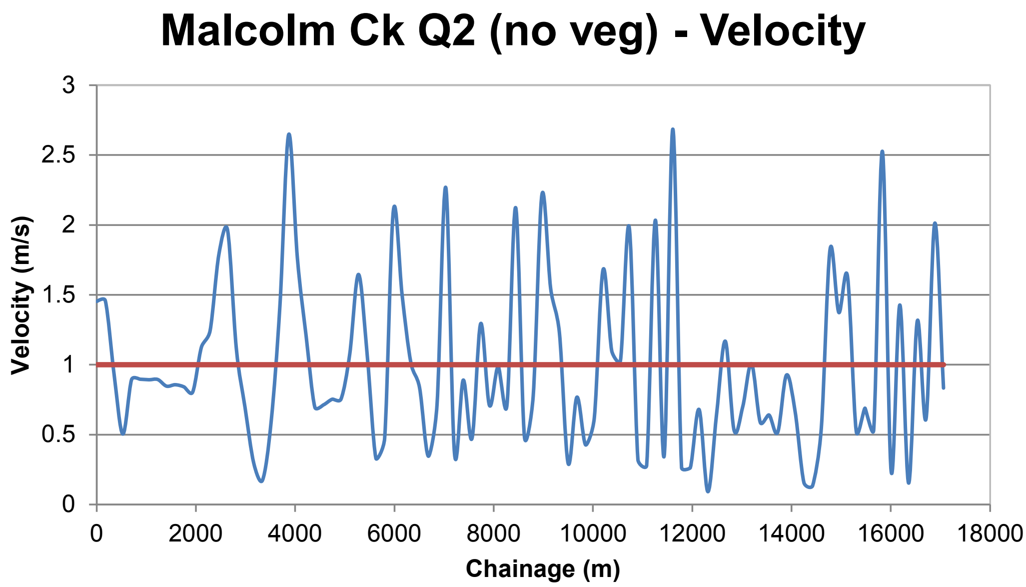
Creek Diversion Hydraulic Design Results

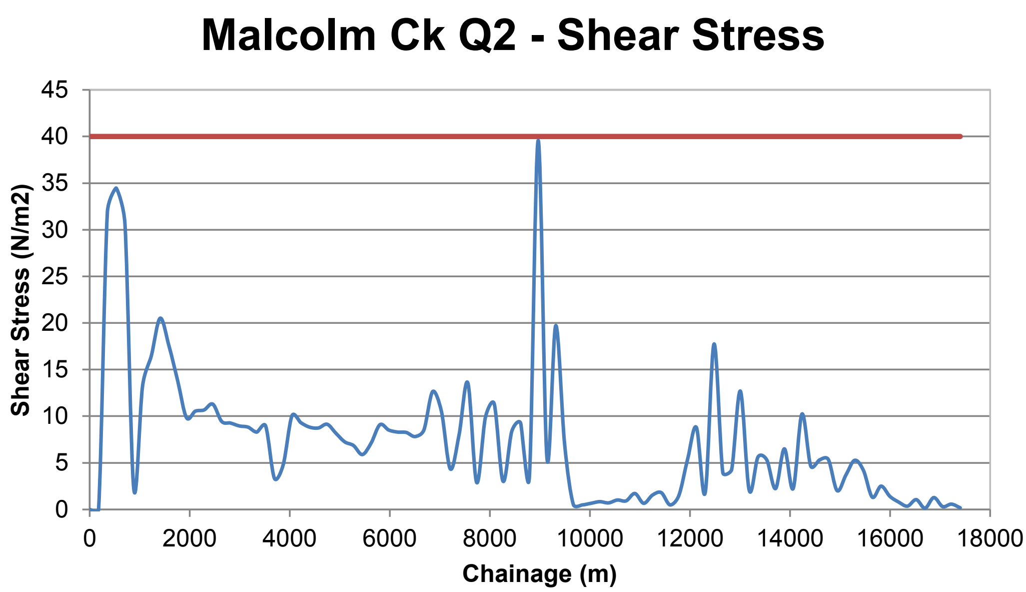
MALCOLM CREEK DIVERSION – HYDRAULIC DESIGN RESULTS

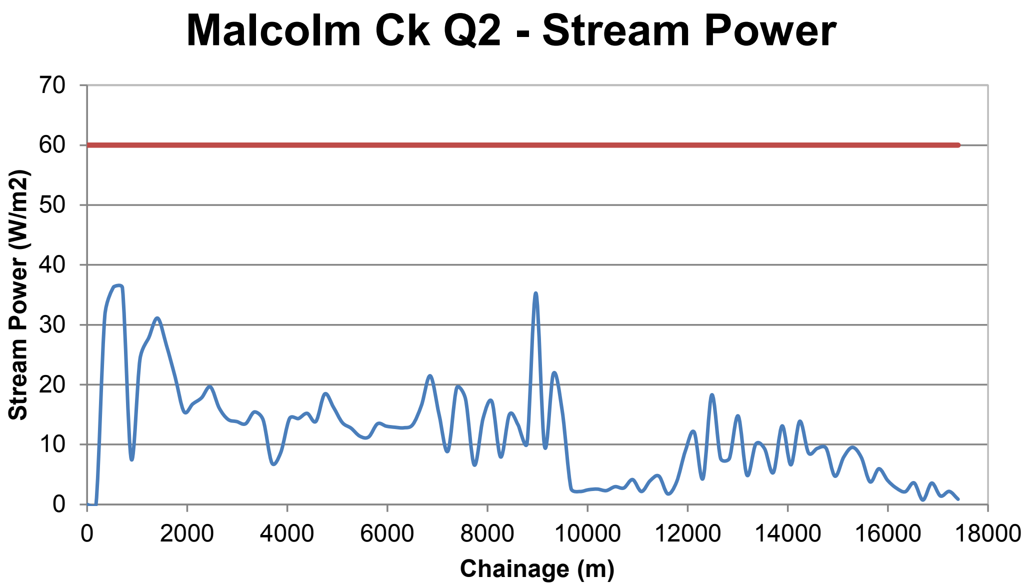


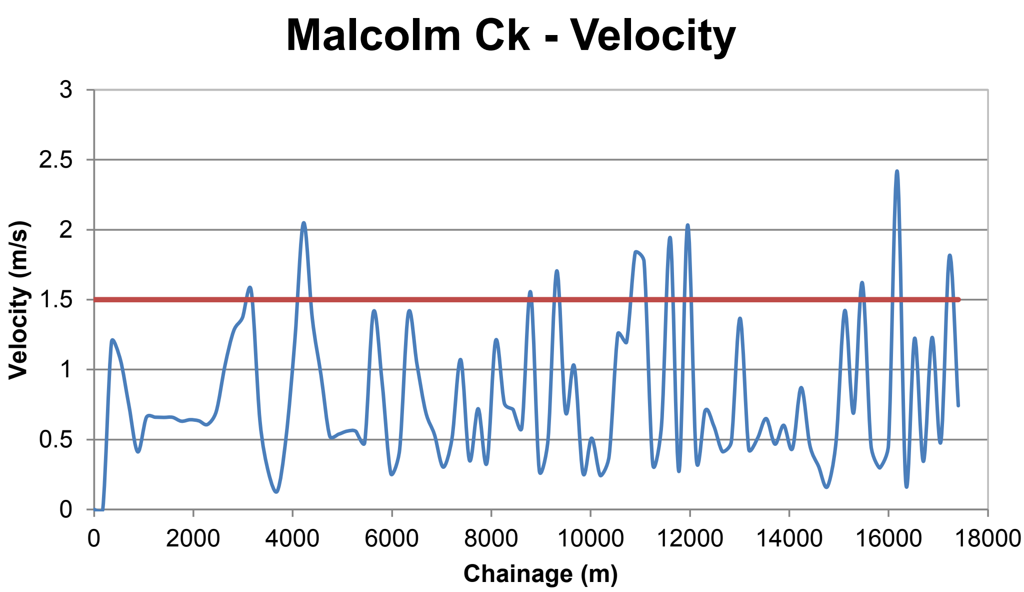


WARATAH COAL
MINE SITE CREEK DIVERSION AND FLOODING



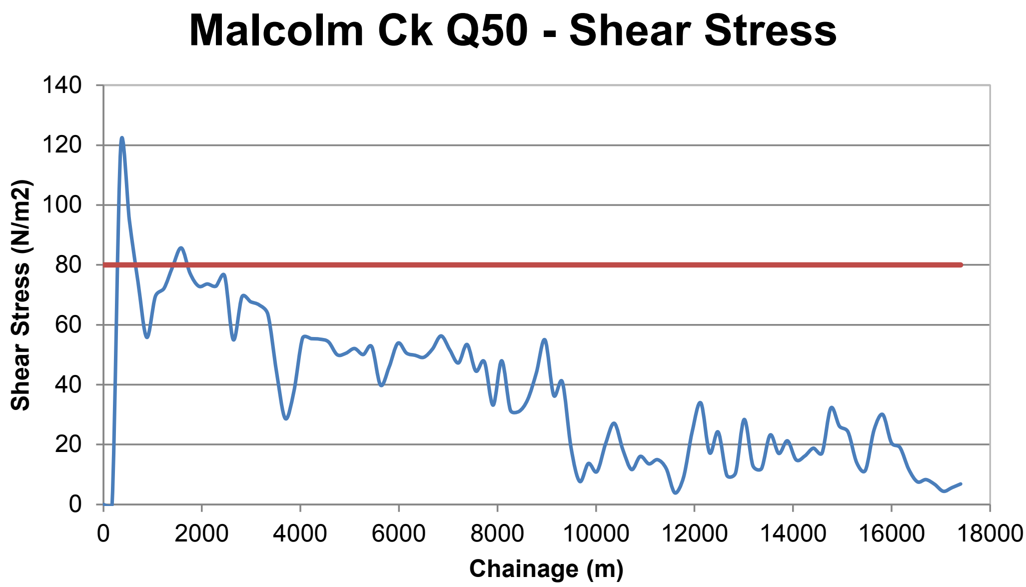


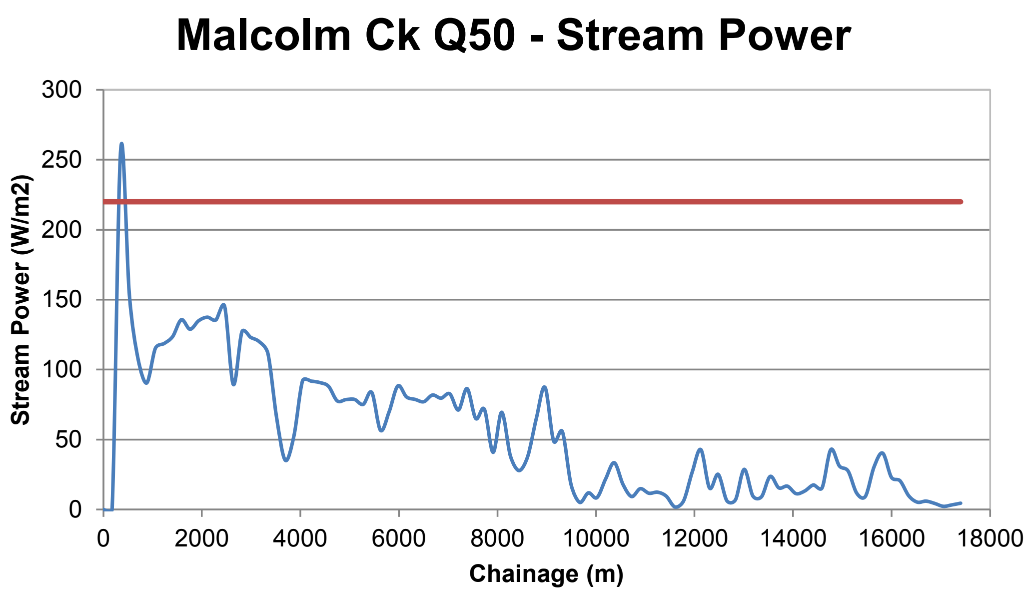

Malcolm Ck Q2 - Stream Power
Stream Power (W/m2)
70
60
50
40
30
20
10
0
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
Chainage (m)

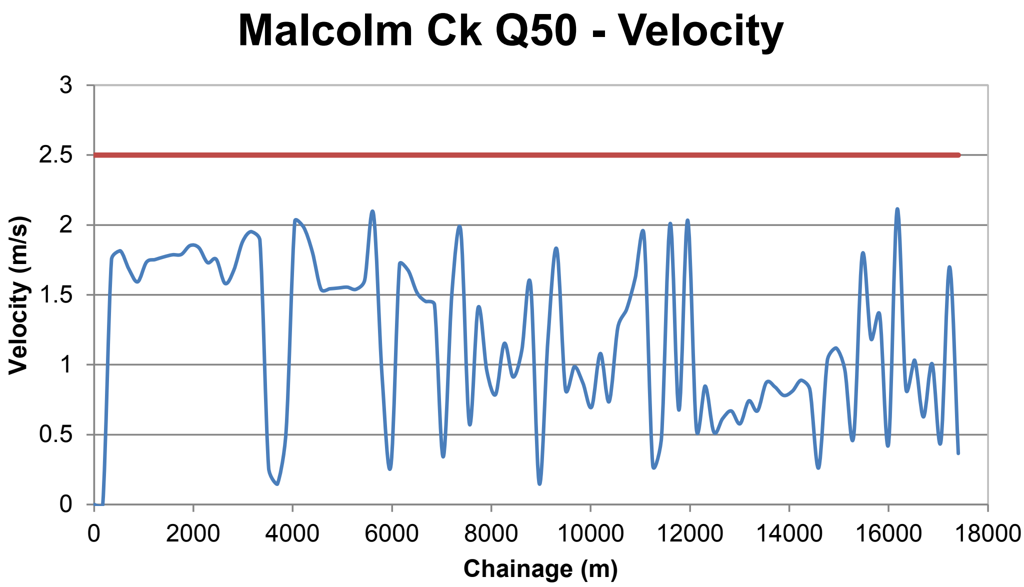

Malcolm Ck - Velocity
Velocity (m/s)
3
2.5
2
1.5
1
0.5
0
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
Chainage (m)

WARATAH COAL
MINE SITE CREEK DIVERSION AND FLOODING

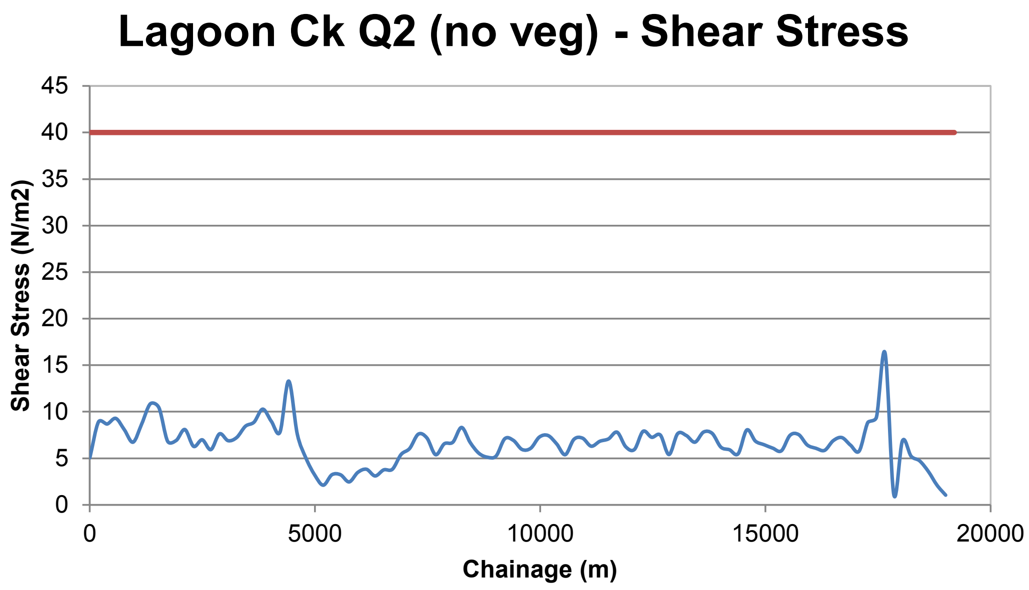
ENGENY WATER MANAGEMENT

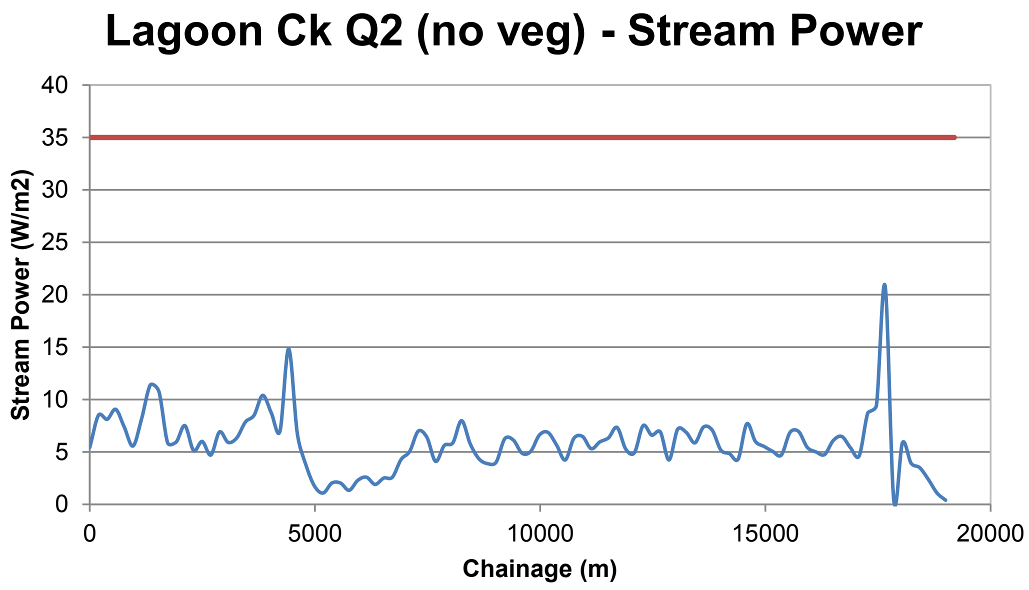




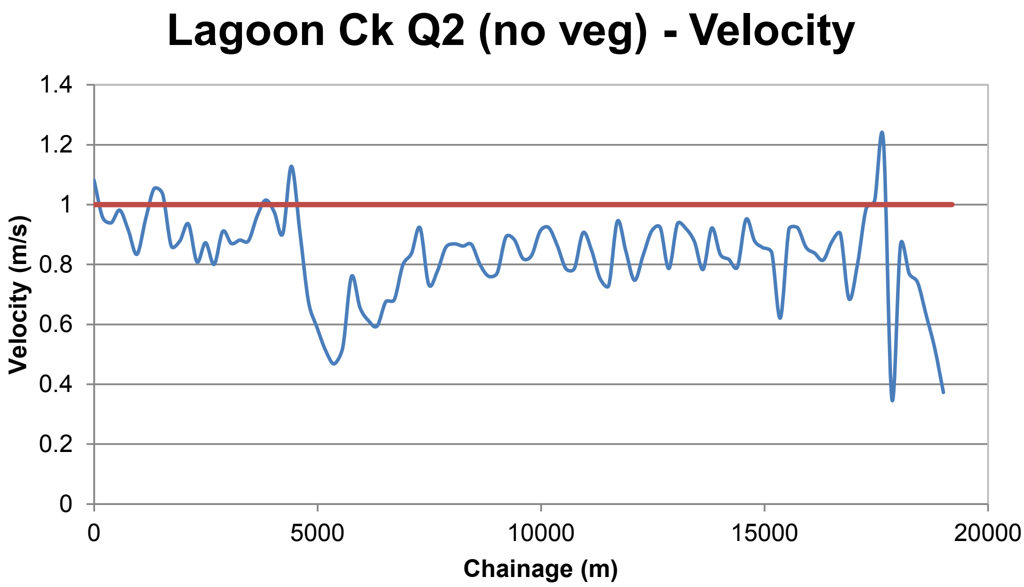

Malcolm Ck Q50 - Velocity
Velocity (m/s)
3
2.5
2
1.5
1
0.5
0
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
Chainage (m)

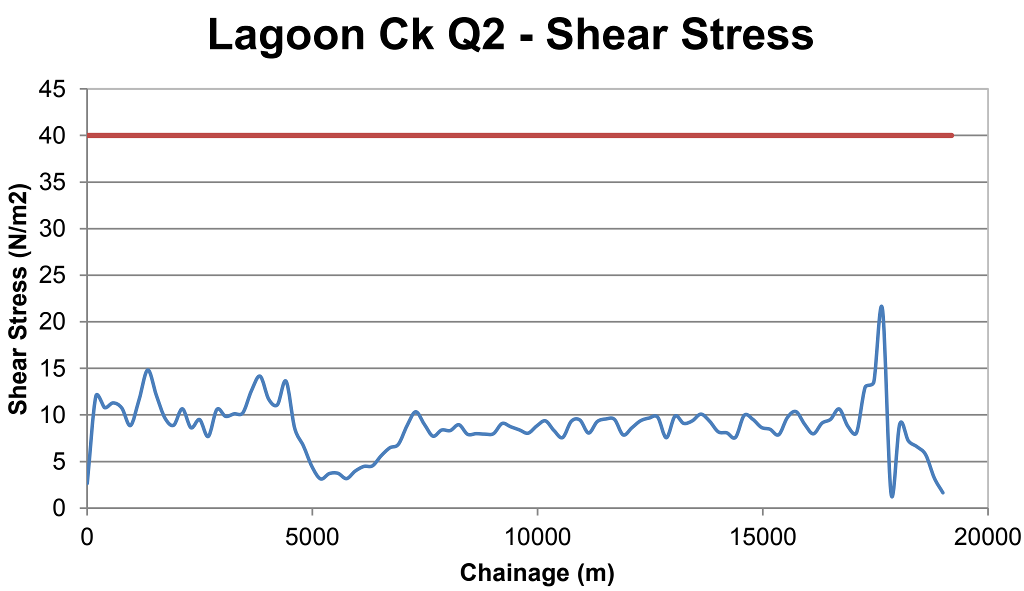
LAGOON CREEK DIVERSION – HYDRAULIC DESIGN RESULTS

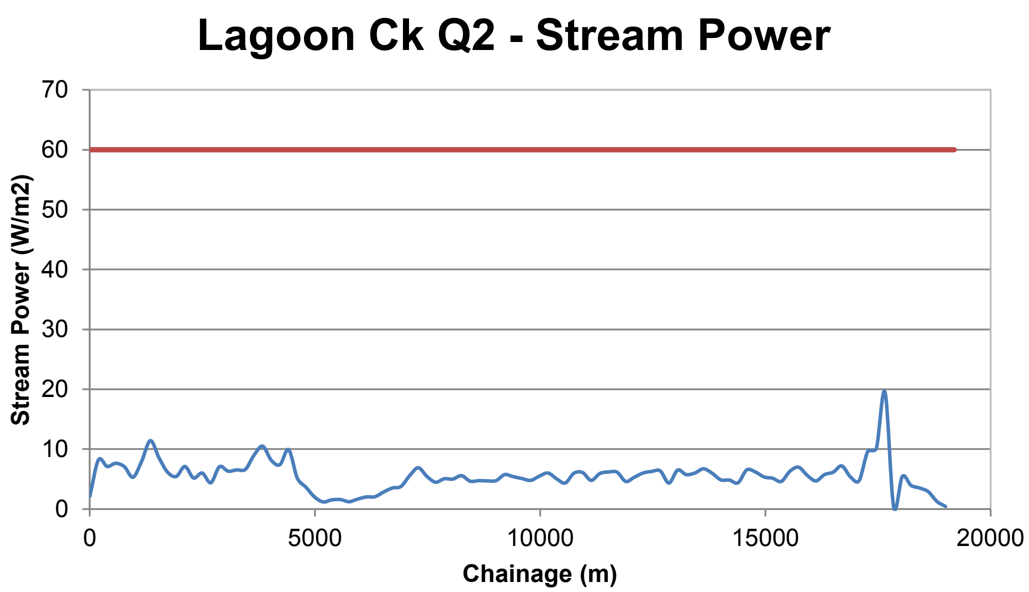


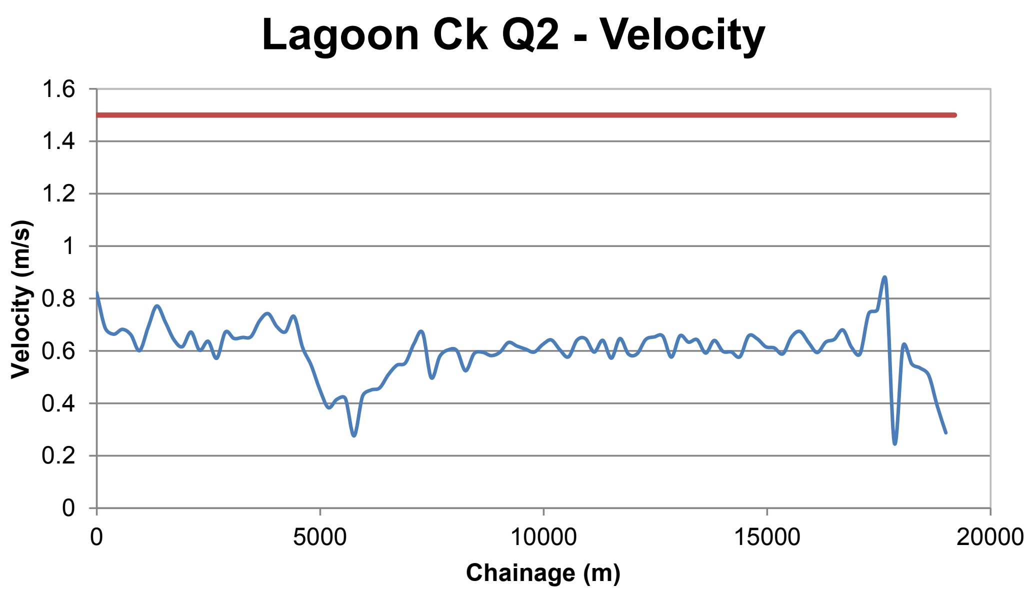


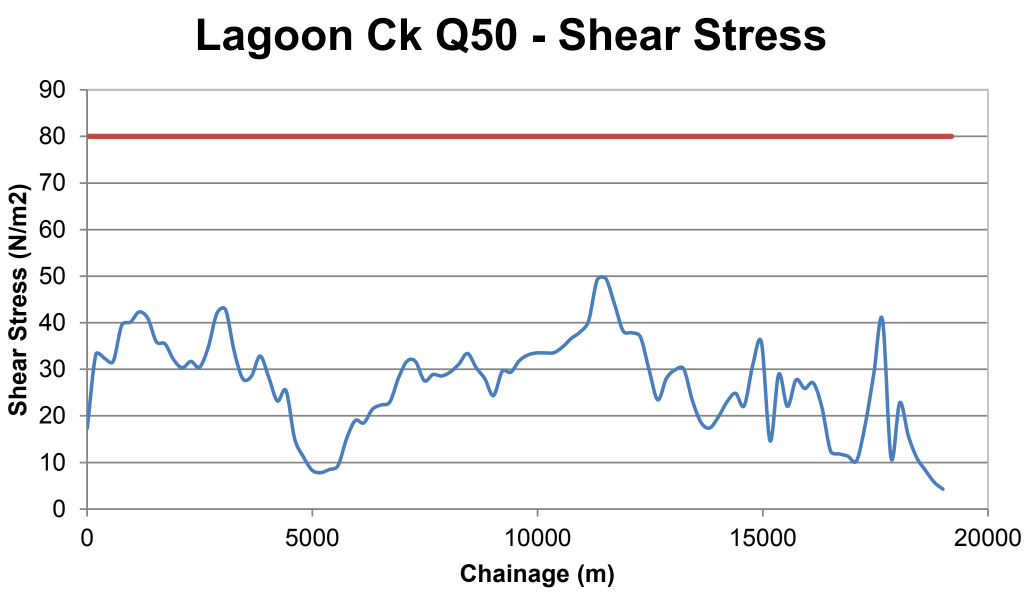
WARATAH COAL
MINE SITE CREEK DIVERSION AND FLOODING

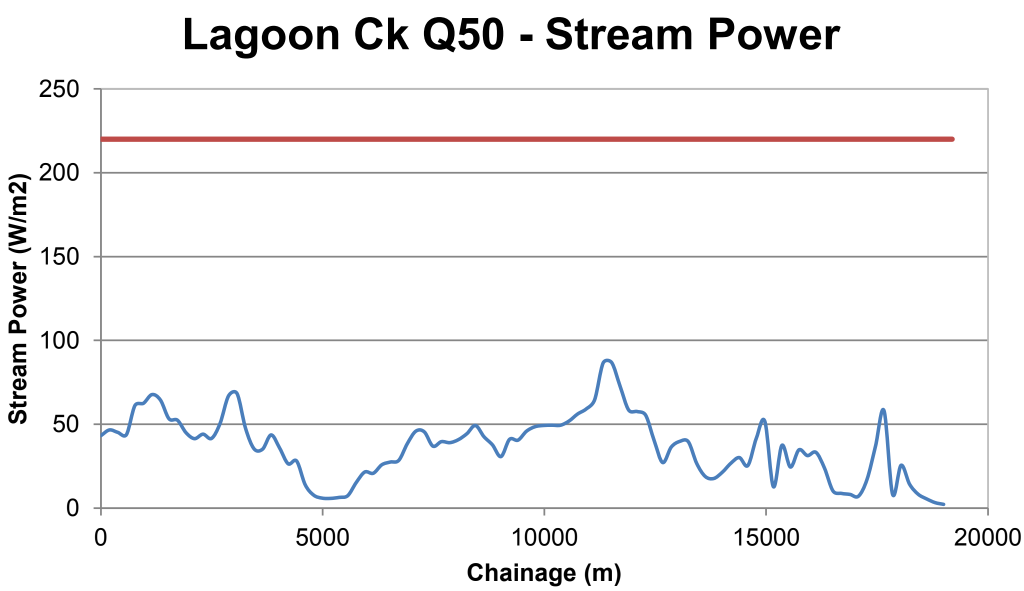




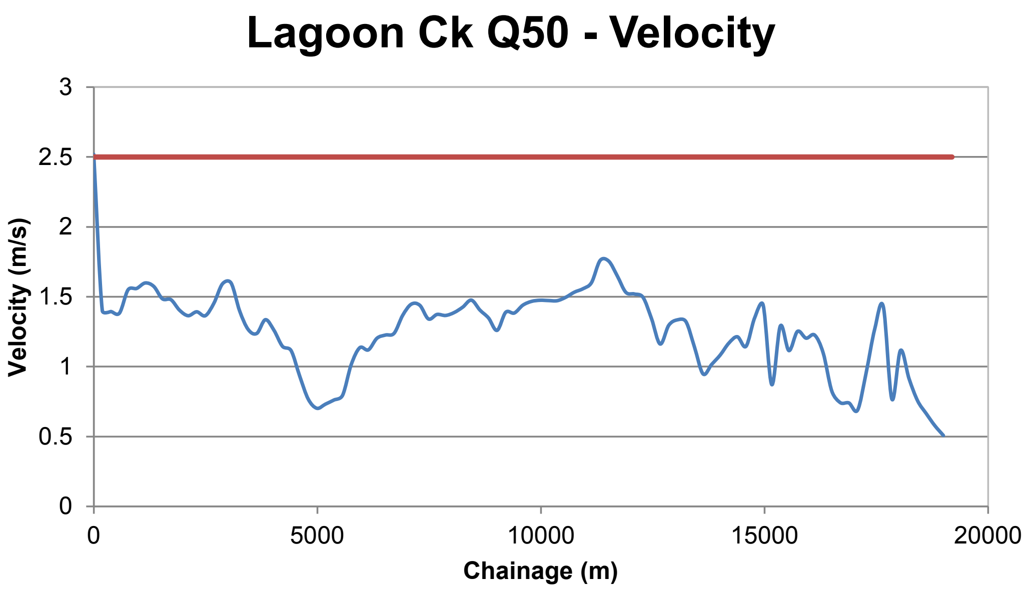

Lagoon Ck Q2 - Stream Power
Stream Power (W/m2)
70
60
50
40
30
20
10
0
0
5000
10000
15000
20000
Chainage (m)


Lagoon Ck Q2 - Velocity
Velocity (m/s)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
5000
10000
15000
20000
Chainage (m)


Lagoon Ck Q50 - Shear Stress
Shear Stress (N/m2)
0
10
20
30
40
50
60
70
80
90
0
5000
10000
15000
20000
Chainage (m)


Lagoon Ck Q50 - Stream Power
Stream Power (W/m2)
0
50
100
150
200
250
0
5000
10000
15000
20000
Chainage (m)

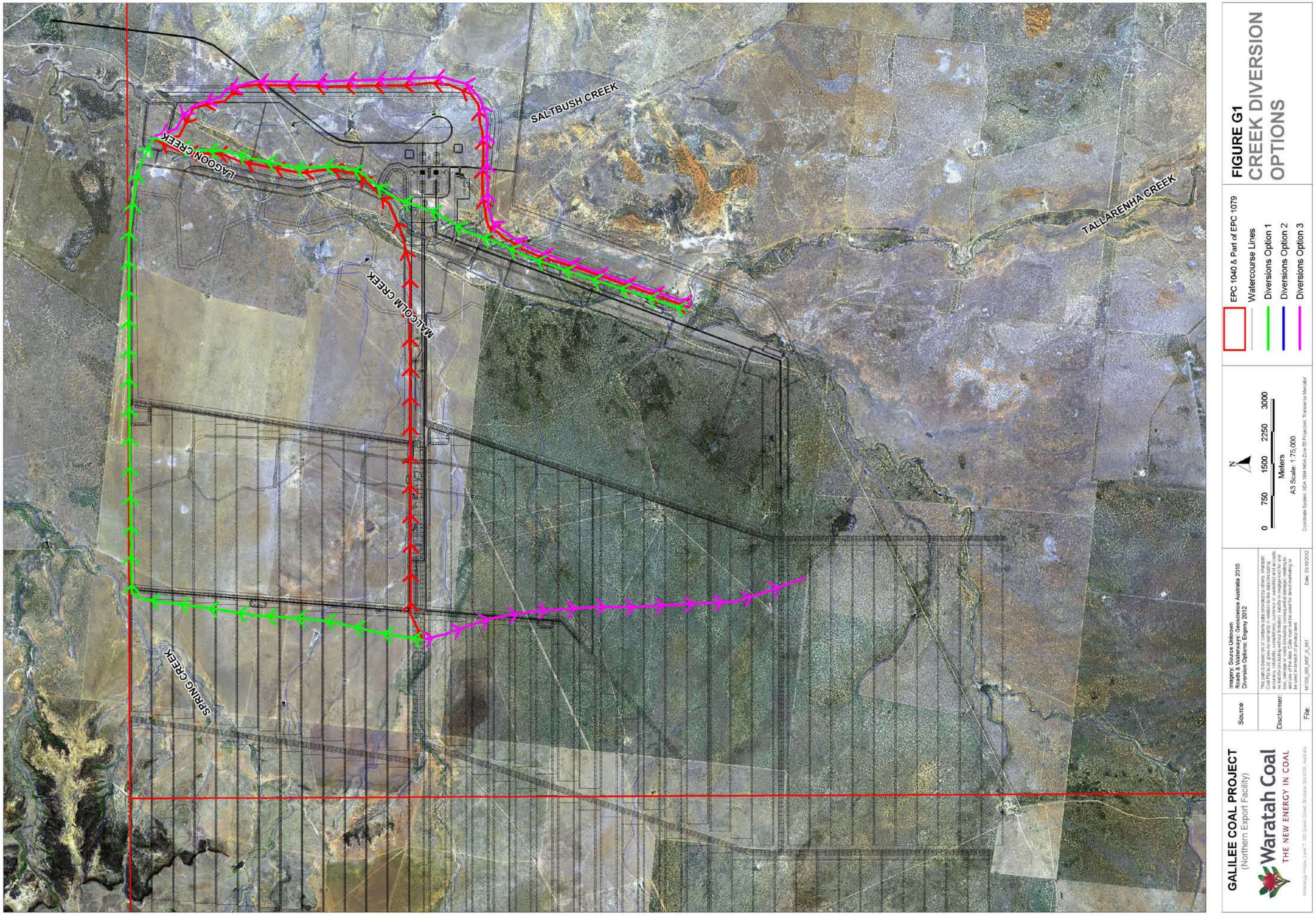
WARATAH COAL
MINE SITE CREEK DIVERSION AND FLOODING



ENGENY
WATER MANAGEMENT

APPENDIX G

Creek Diversion Options


SALTBUSH CREEK
LAGOON CREEK
MALCOLM CREEK
TALLARENHA CREEK
SPRING CREEK
FIGURE G1
CREEK DIVERSION OPTIONS
EPC 1040 & Part of EPC 1079
Watercourse Lines
Diversions Option 1
Diversions Option 2
Diversions Option 3
N
0 750 1500 2250 3000
Meters
A3 Scale: 1:75,000
Source:
Imagery: Source Unknown
Roads & Waterways: Geoscience Australia 2010
Diversion Options: Engeny 2012
Disclaimer:
File: M1700_005_MSF_G_001
Date: 30/10/2012
GALILEE COAL PROJECT
(Northern Export Facility)
Waratah Coal
THE NEW ENERGY IN COAL

This page is intentionally left blank.