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Alpha Coal Project Environmental Impact Statement

11 Surface Water

Section 11 Surface Water

11.1 Introduction

11.1.1 Overview

This section of the Environmental Impact Statement (EIS) presents the surface water resource aspects of the Alpha Coal Project (Mine) (the Project). The information and assessments describe:

- Relevant legislation for surface water management;
- Assessment methodologies;
- Existing surface water environment and associated environmental values;
- Project elements that actively or passively manage surface water as relevant for impact assessment;
- Identification of potential impacts and impact assessment;
- Residual risk potential impacts; and
- Proposed mitigation measures.

11.1.2 Inter-relationship with other EIS Studies

Some of the surface water aspects of significance to meet the holistic requirements of the EIS Terms of Reference (TOR) are intrinsically linked with several other key study areas. The assessment of surface water has drawn upon the findings of a broad range of the EIS studies and also informed other studies to ensure that overall potential environmental impacts of the Project can be holistically managed. To obtain a complete understanding of the significance of surface water values and possible impacts of the Project the following EIS studies of relevance to surface water are referenced:

- Topography and soils (Volume 2, Section 5);
- Land use (Volume 2, Section 6);
- Aquatic ecology (Volume 2, Section 10);
- Groundwater (Volume 2, Section 12); and
- Mine waste (Volume 2, Section 16).

11.1.2.1 Surface Water context of the Project location

The Project is located adjacent to Lagoon Creek which is high in the headwaters of the Burdekin Basin. Lagoon Creek flows to Sandy Creek, Belyando River, Suttor River, and joins the main Burdekin River channel several hundred kilometres north of the Project site. Further detailed description of the catchment context of the Project area is presented in Section 11.4.1.

11.2 Legislative Framework

Key relevant legislative Acts for surface water management include the:

- *Water Act 2000;*
- *Water Supply (Safety and Reliability) Act 2008;*

- *Environmental Protection Act 1994;* and
- *Sustainable Planning Act 2009.*

This legislation and its relevance to surface water values and surface water management for the Project are described below.

11.2.1 Water Act 2000

In Queensland, the *Water Act 2000* (Water Act) is the primary statutory document that establishes a system for the planning, allocating and use of non-tidal water. The Act is administered by the Department of Environment and Resource Management (DERM).

11.2.1.1 Water Planning Provisions of Water Act

The Water Act prescribes the process for preparing Water Resource Plans (WRP) and Resource Operation Plans (ROP) which are specific for catchments within Queensland. Under this process, the WRP identifies a balance between waterway health and community needs. The WRP establishes Environmental Flow Objectives (EFO) which are of importance for waterway health, and sets Water Allocation Security Objectives which are important to maintain community needs. The ROP provides the operational details on how this balance can be achieved. The WRP and ROP determine conditions for granting water allocation licences, permits and other authorities, as well as rules for water trading and sharing. The Water Act makes the provision for the preparation of land and water management plans in specific areas. DERM has advised there are no such plans in place in the vicinity of the Project.

The Project is located within the Belyando-Suttor subcatchment area covered by the Burdekin Basin Water Resource Plan 2007 (refer WRP schedules 1 & 2). The Project site is outside (excluded) from declared Water Management Areas in Part 2 Section 6 of the Burdekin Basin WRP. Part 3 Section 12 (g) of the Burdekin WRP has provisions to make water available in the Belyando-Suttor subcatchment to support growth in irrigated agriculture.

All of the statutory EFO in the Burdekin WRP apply to locations (nodes) that are a long distance downstream of the Project site. The closest WRP node for which some EFO apply is at the junction of the Suttor River and Burdekin River. As the Project location is a long distance upstream of closest the EFO location and the site area is a very small portion of the total catchment to the closest EFO location, the Project will not materially impact on the State's ability to achieve statutory EFO prescribed in the Burdekin WRP.

For surface water aspects of the Project, the main significance of water planning provisions of the Water Act will be the potential impacts on nearby downstream existing water entitlements. The existing downstream entitlements are discussed further in section 11.4.4.

A second WRP (the Great Artesian Basin WRP 2006) also administered under the Water Act is applicable to the Project location. This Great Artesian Basin WRP is primarily focussed on groundwater and is not discussed further in this section. Further information on the Great Artesian Basin WRP 2006 and its significance to the Project is presented in Volume 2, Section 12 (Groundwater).

11.2.1.2 Protection of Watercourses provisions of Water Act

The Water Act specifies requirements for works requiring disturbance to the bed and banks of watercourses (e.g. stream diversions). Declared watercourses potentially impacted by the Project are listed in Section 11.4.3

11.2.2 Water Supply (Safety and Reliability) Act 2008

Relevant aspects of the *Water Supply Safety and Reliability Act 2008* include the regulations for licensing and safety management of Referable Dams in Queensland. It should be noted that the provisions of this Act for Referable Dams apply to dams that do not contain hazardous waste (i.e. clean water dams).

11.2.3 Environmental Protection Act 1994

The *Environmental Protection Act 1994* (EP Act) provides the key legislative framework for environmental management and protection in Queensland.

Chapter 5 of the EP Act establishes a process for obtaining an Environmental Authority (EA) for mining activities. A Level 1 EA (mining activities) is applicable to the Project. In addition, an Environmental Management Plan (EM Plan) is also required under section 201 of the EP Act.

Under the EP Act, DERM is the regulatory authority with responsibility for granting the EA, as well as compliance, auditing and monitoring of the environmental management of the Project activities.

11.2.3.1 EM Plan and Environmental Authority relevance to Surface Water Management

The EP Act regulation of mining activities and associated environmentally relevant activities (ERAs) with the EM Plan and EA conditions provides means to regulate surface water management for the Project.

Dams containing hazardous waste (including tailings storage facilities and mine water dams) which are not Referable Dams (under the *Water Supply Safety and Reliability Act 2008*) are regulated through EA conditions. Surface water discharges from the Project and associated needs for surface water monitoring are also regulated with EA conditions.

Conceptual details and design criteria of the water management systems for the Project are described in the following sections, with this information contributing to proposed conditions of the EM Plan and EA for the Project.

11.2.3.2 Environmental Protection (Water) Policy 2009

The Environmental Protection (Water) Policy 2009 (EPP Water) is subordinate legislation under the EP Act that functions to establish environmental values (EV) associated with water, and ensuring that broad environmental protection measures are defined for protecting these environmental values. The schedules of the EPP Water include prescribed EV for some parts of the Queensland. The Project site is not in area where EVs are currently defined by the EPP Water. Consequently the Project has identified preliminary EVs based on the findings of the EIS studies, and these are described further in Section 11.4.

11.2.4 Sustainable Planning Act 2009

The *Sustainable Planning Act 2009* (SP Act) does not directly prescribe requirements for surface water management that are directly relevant for the Project. The relevance of the SP Act for surface water aspects of the Project is that this Act facilitates the approvals process for works and or operations administered under other legislation. An example is that the approval for the Project stream diversions under the Water Act will be administered through the SP Act.

11.3 Assessment Methodologies

A number of impact assessment studies were undertaken to prepare the surface water section of the EIS. These include the following technical reports which can be found in Volume 5, Appendix F (Surface Water) and Appendix J (Waste):

- Flood Impact Assessment;
- Geomorphology Study and Concept Diversion Designs;
- Surface Water Quality;
- Mine Water Management System and Water Balance Assessment; and
- Alpha Coal Tailings Storage Facility – Concept Design Report.

The methodologies utilised in these assessment studies are summarised below.

11.3.1 Flood assessment

A flooding investigation of the catchment of Lagoon Creek, Spring Creek and Sandy Creek was undertaken to determine the flood risk of the area, the potential impact of the mine development and required mitigation works.

The key objectives of this investigation were to determine if the Alpha Coal Project (Mine) development would adversely impact on the flood risk to existing infrastructure, and to determine the likely flood risk to Alpha Coal Project (Mine) development and operations.

The methodology is discussed in detail in section 2.1 of the Flooding Technical Report (Volume 5, Appendix F2). In summary, the process undertaken was as follows:

- Review of relevant legislation and guidelines;
- Undertake hydrological assessment of the catchments at the Project site and surrounding areas to determine rainfall frequency and intensity and design peak flow rates at key locations;
- Develop hydraulic models of the existing case to determine flows, inundated areas, depths, velocity and stream power for a range of design flood events;
- Develop hydraulic models of the proposed development case to determine flows, inundated areas, depths, velocity and stream power for a range of design flood events;
- Compare existing case and proposed development case hydraulic model results to assess the potential altered flow conditions as a result of mine development, and the expected performance of the proposed creek diversions;
- Identify where the design of the proposed watercourse diversions should be improved to minimise impact on the natural creek systems; and

- Identify mitigation measures to ensure equilibrium and long term stability of the proposed watercourse diversion works.

Topographic surveys utilised for the flood study were derived from a digital terrain model using information sourced from AAM Global, ecological data from AARC report (2010) and hydrologic data from the DERM gauging stations network.

Further detailed description of the flood assessment is presented in the Flood Study Technical Report (Volume 5, Appendix F2).

11.3.2 Geomorphology assessment

A geomorphological assessment was undertaken to:

- Assess the existing geomorphic characteristics of streams in the Project area;
- Guide concept designs for the watercourse diversions which flow through the Project area;
- Evaluate hydraulic parameters that influence geomorphology; and
- Assess the performance of the proposed concept diversion alignments and channel features.

Data used in the assessment were derived from information collected in the field as well as from existing data sets. Spatially referenced data sets of land use, topography, and soils were obtained from several sources. Hydrology and hydraulic modelling to support the geomorphology assessment was referenced from the Flood Study Technical Report (Volume 5, Appendix F2).

Field inspection of selected stream reaches and flood plain areas was undertaken to assess stream characteristics. Some stream-channel characterisation was done at selected stream cross-sections. Detailed photographs of the stream conditions at selected locations were taken and are presented in the Geomorphology Technical Report (Volume 5, Appendix F1).

11.3.3 Surface water quality assessment

A preliminary surface water quality assessment (Volume 5, Appendix F4) was undertaken to characterise the existing surface water resources area. The assessment was undertaken in the context of identifying preliminary environmental values with categories as defined in the EPP Water, Australian New Zealand Environment and Conservation Council Guidelines (ANZECC 2000), and the Queensland Water Quality (QWQ) Guidelines 2009 (DERM 2009).

The methodology of the surface water quality impact assessment included:

- Identification of relevant Environmental Values applicable to water quality management using classifications outlined in the EPP Water;
- Assessment and preliminary description of the background surface water quality based on available historic water quality datasets from a nearby DERM monitoring station. In addition to the DERM monitoring station data, some Project specific water sampling quality data was available from earlier studies. After review, this data was deemed unsuitable as the sampling methods did not appear to adequately conform with accepted standard assessment methodologies (e.g. Queensland DERM Monitoring and Sampling Manual 2009). Therefore, the Project specific data was not used in the assessment;

- Description of the features and activities of the Project that will be relevant to the surface water quality impact assessment and description of potential impacts;
- Identification of mitigation strategies and measures required to manage the potential impacts on surface water quality;
- Planning of two comprehensive Project specific monitoring programs: the first is designed to determine baseline conditions (for determination of site specific trigger values) and the second is an ongoing program to monitor impacts on water quality during the life of the Project. The comprehensive Project baseline monitoring program is now being implemented; and
- Identification of the potential residual impacts, following implementation of mitigation strategies and measures.

The watercourses in and through the Project site are not covered in Schedule 1 of the EPP Water. The following documents were used to guide the preliminary identification of applicable Environmental Values for the watercourse at the Project site:

a) The QWQ guidelines; and
b) ANZECC 2000 guidelines.

11.3.4 Mine Water Management System and water balance assessment

The purpose of the Mine Water Management System technical report was to establish the concept level planning of the proposed Project mine water management system and undertake a preliminary water balance assessment to characterise the expected performance of the system. The mine water management system (WMS) is the control measure to manage surface water flows from all areas disturbed by the mining activities and associated infrastructure and processing operations.

A conceptual water management strategy has been developed in accordance with the following requirements:

- Development of surface water management system concepts at various phases through the Project life;
- Diversion of runoff from undisturbed catchments (clean water) around the Project area (i.e. bypass the WMS);
- Segregation of waters within the Project site based on expected quality;
- Reuse of contaminated water around site, with contaminated water preferentially reused in the mine operations for coal processing;
- Determine sufficient storage capacity within site dams for mine water containment; and
- Prepare a preliminary water balance of the Project site to estimate runoff volumes and simulate the balance of runoff (and other mine water generation) with mine water consumption to identify potential overflows and identify potential water deficits / surpluses for the Year 1, 5, 10, 20 and 30 landforms.

The relevant guidelines used to prepare the concept water management strategy are described in detail in sections 2.2 – 2.2.3 of the Site Water Management System and Water Balance Technical Report in Volume 5, Appendix F3. In summary, these are as follows:

- *Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland* (Department of Mines and Energy, 1995). These are commonly referred to as the DME Guidelines and require, among other things, that the design of a site water management system for any mining and processing operation should be based on the concept of risk management for the purpose of protection of the environment;
- *Code of Environmental Compliance for Environmental Authorities for High Hazard Dams Containing Hazardous Waste* (developed by DERM);
- Conditions for Coal Mines in the Fitzroy Basin Approach to Discharge Licensing (developed by DERM, 2009); and
- Model Water Conditions for Coal Mines in the Fitzroy Basin (developed by DERM, 2009).

Adopted design criteria for the mine water management system, and proposed end-of-pipe discharge criteria for releases from the mine water management system are described in section 11.5.5

11.4 Existing Surface Water Environment

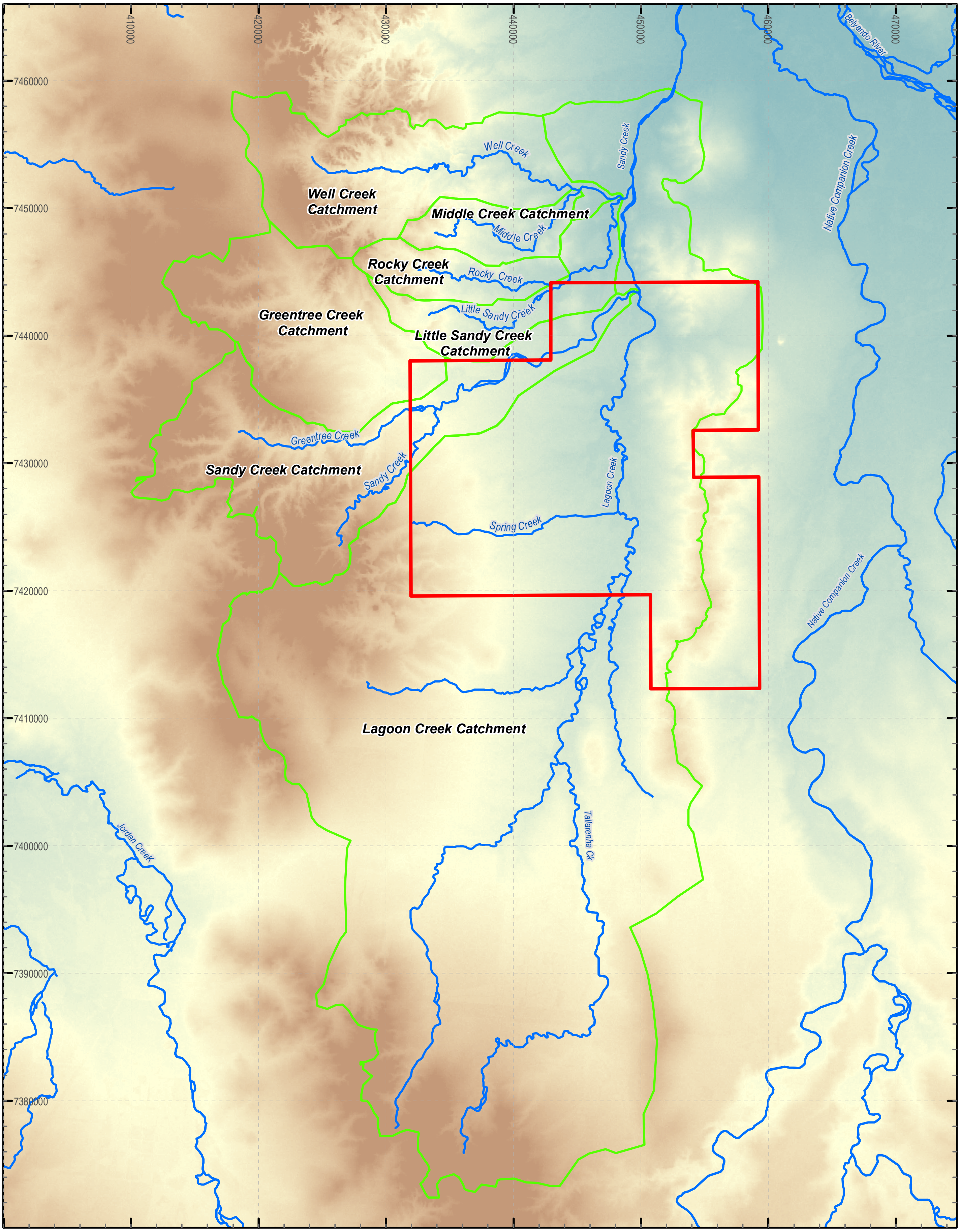
11.4.1 Catchment context

The Project area is located within the Lagoon and Sandy Creek catchments, forming the south-westerly portion of the Belyando River catchment, which is part of the Burdekin Basin. The Lagoon Creek catchment is bounded by the Great Dividing Range to the west and a north-south line of low hills to the east and extends to the south of the Capricorn Highway and northward to around Wendouree. The catchments of the local watercourses and an overlay of the Mining Lease Application (MLA) 70426 area are presented on Figure 11-1.

The Sandy Creek catchment covers an area of approximately 7,700 km^2 to the junction with Belyando River. The catchments analysed with modelling in the EIS studies (as shown on Figure 11-1 and used for the extent of flooding analyses and hydrological assessment for the mine water management system – Technical Reports in Volume 5, Appendix F) extended to approximately 10 km downstream (north) of the MLA 70426 boundary where the total Sandy Creek catchment is 2,734 km^2. For comparison, the MLA 70426 covers approximately 337 km^2 (approximately 12% of the catchment of Sandy Creek that was modelled for the EIS studies.

11.4.1.1 Catchment land use

The region is characterised by predominantly large rural properties with cattle grazing and limited cropping being the most common land use. The Surface Water Quality Technical Report in Volume 5, Appendix F4 identified that some land has been disturbed by low intensity cattle grazing. The degree of land disturbance was considered as part of identifying the preliminary Environmental Values for assessment of water quality conditions (described in Section 11.4.6).



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Source: See Copyright Details below and for full disclosure Please Refer to the EIS ***Volume 4 - References***. Satellite Imagery Sourced from Bingmaps, Copyright 2010

0 2.5 5 10 Km

Scale 1:400,000 (A4)

Datum: GDA94, MGA Zone55

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Alpha Coal Project
Environmental Impact Statement

CATCHMENTS AROUND PROJECT AREA

Job Number	4262 6580
Revision	A
Date	22-09-2010

Figure: 11-1

File No: 42626580-g-2114.mxd

11.4.2 Climate and Hydrology

11.4.2.1 Climate

A detailed description the climate at the Project site is presented in Volume 2, Section 3. The primary climate influences on hydrology and surface water flows are rainfall and evaporation which are summarised herein.

Historical daily rainfall and evaporation data for the region was obtained from the DERM Silo Data Drill facility. Data for the closest Bureau of Meteorology recording station at the Barcaldine Post Office was also obtained. The data obtained indicates that mean annual rainfall at the Project site is 535 mm (based on DERM Silo Data Drill) and 500 mm (based on the Bureau of Meteorology recording station at Barcaldine). These estimates and climate maps available on the Bureau of Meteorology web site show that there is not much spatial variation in mean annual rainfall across the region. Although mean annual rainfall totals are relatively uniform across the region, individual rainfall events (particularly thunderstorm events) can occur over localised areas with potential for distinct spatial variation in rainfall event totals across local to catchment scales.

The potential for localised rainfall events is an important factor for the Project water management and setting of conditions for licensing of discharges. The water management system will be designed to not discharge where high rainfall may occur over the Project site but do not occur over the broader catchment with sufficient extent and magnitude to produce stream flow in the main watercourses.

Key rainfall and evaporation statistics are summarised in Table 11-1. It is notable in the climate statistics that annual rainfall totals are considerably more variable than evaporation. This has important implications for Project mine water management including sufficient mine water resources to maintain supply to Project operations in dry years, and capacity of the mine water management system to contain high rainfall runoff in wet years. The rainfall records show highest rainfall in the wet season months between November and February and lowest during the dry months of winter.

Table 11-1 Summary climate statistics Alpha (1889 to 2009)

Statistic	Annual rainfall (mm)	Annual evaporation (mm)	Annual potential evapotranspiration (mm)
10th percentile	293	2,187	1,656
50th percentile (median)	477	2,293	1,772
90th percentile	779	2,385	1,869
99th percentile	1322	2523	1944
Mean	526	2,292	1,767
Minimum	190	1,810	1,518
Maximum	1,385	2,657	1,977
Standard deviation	220	103	86

Further more detailed analysis and estimates of rainfall including wet season rainfall statistics, and design rainfall intensities for flood estimation and drainage design are presented respectively in the Water Management System Technical Report, and Flood Study Report in Volume 5, Appendix F.

11.4.2.2 Hydrology

The trends evident in climate data for rainfall are reflected in the general characteristics of stream flow hydrology in the local water courses. The Project site is located relatively high in the headwaters of the broader catchment (in the context of the entire Belyando and Burdekin basin area). The catchment areas upstream of the Project site are not sufficient to maintain baseflow and the stream flow hydrology is highly ephemeral. Flow periods are sporadic and limited to direct response to rainfall events and a very short period of baseflow recession after rainfall ceases. The sandy bed conditions in the larger watercourses assist to sustain baseflow but only to a very limited degree.

There is no available stream gauge data for the specific watercourses across the Project area. Data collection and modelling for more regional stream gauge locations (adjacent sub-catchments and downstream river catchments) was utilised for the EIS hydrology studies and is presented in the Water Management System Technical Report, and Flood Study Report in Volume 5, Appendix F.

Runoff modelling was undertaken with calibration to the DERM Belyando River stream gauge at Gregory Development Road (GS120301B approximately 170 km downstream where the catchment area is approximately 35,411 km^2). Details of the runoff modelling methods and calibration are presented in the Water Management System Technical Report in Volume 5, Appendix F3.

The data and modelling indicates that catchment mean annual runoff was 17 mm/yr for the period 1976 to 2009. This corresponds to a mean annual runoff rate of approximately 3 to 4% of mean annual rainfall. Runoff rates increase with rainfall intensity and this has been considered in the development of the Project mine water management system.

The available data and modelling indicate that at least 40% of time there is no flow in the Belyando River at Gregory Development Road (stream gauge GS120301B). For the watercourses at the Project site, which are relatively in the headwaters of the catchment it is likely that due to limited catchment size and less baseflow storage influences on hydrology, the periods of no flow could be substantially greater (e.g. potentially up to 80% of time with no flow).

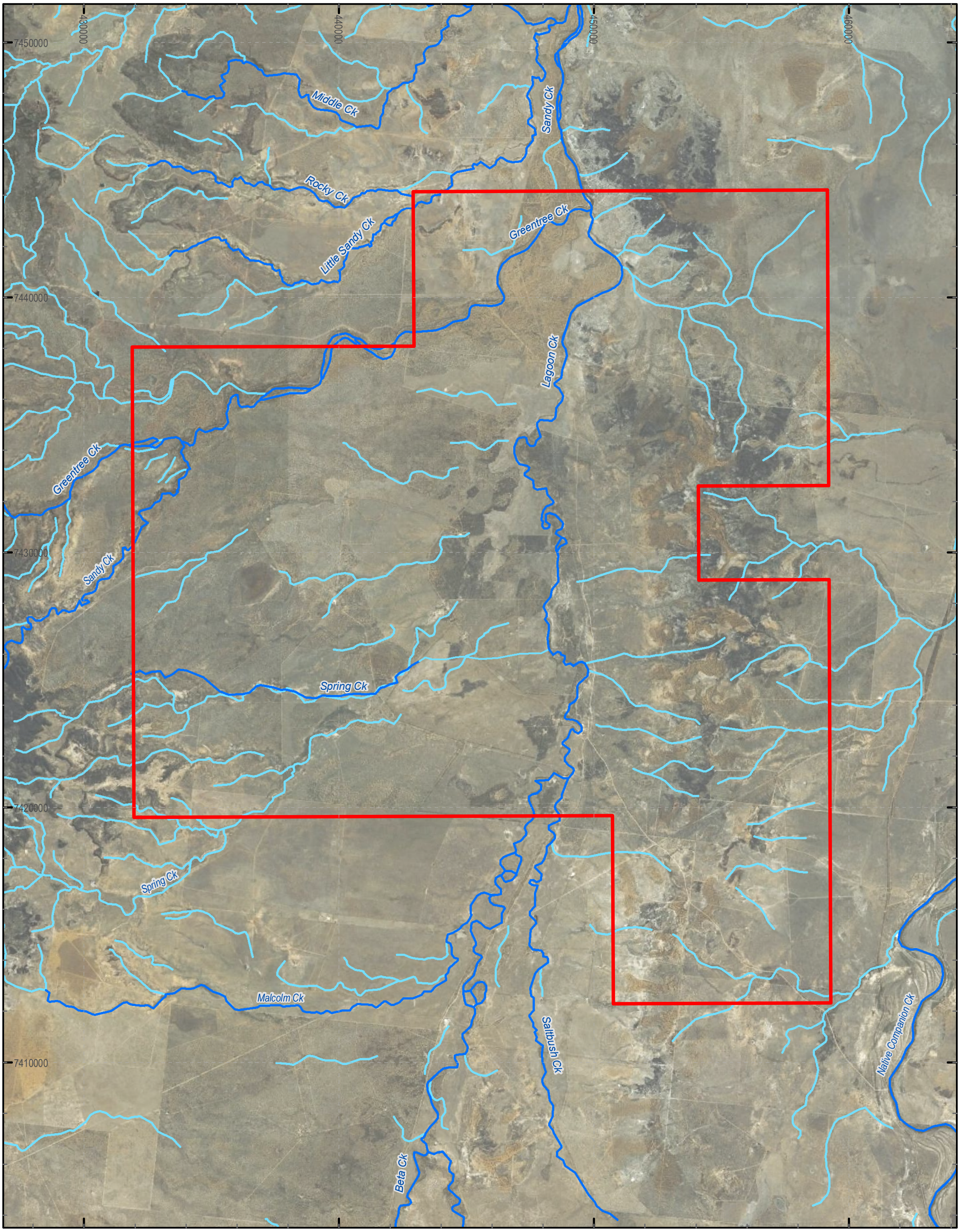
11.4.3 Watercourses

Five key streams within the Project area have been identified as defined watercourses (as defined under section 5 of the *Water Act 2000*). The defined watercourses are Rocky Creek, Little Sandy Creek, Sandy Creek (also known as Greentree Creek), Spring Creek and Lagoon Creek and these are presented on Figure 11-2. With respect to Spring Creek, DERM has determined that in accordance with the definition of 'watercourse' in section 5 of the Water Act, the downstream limit of Spring Creek occurs at a point approximately 5 km upstream of its intersection with Lagoon Creek, where Spring Creek spreads out onto a floodplain.

The significance of the creeks stated to be defined watercourses under Water Act, is that the Project development and operation will need to:

- Obtain approvals to divert the watercourses (licensed stream diversion);
- Manage operations and any temporary works in the watercourse areas in accordance with the DERM "Guideline – activities in a watercourse, lake or spring associated with mining operations" within the provisions allowed under that guideline; and
- Obtain Riverine Protection Permits for other works or activities in the watercourse areas that do not fall within the provisions under the DERM guideline.

Key characteristics of these streams are outlined in Tables 11-2, 11-3, and 11-4, and identified Environmental Values for these streams are presented in Section 11.4.6.



Source: Data supplied by Parsons Brinckerhoff

Mining Lease Application (MLA70426) Boundary

Defined Watercourses (per section 5 Water Act 2000)

Minor Streams

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0 1.25 2.5 5 Km

Scale 1:200,000 (A4)

Datum: GDA94, MGA Zone55

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Alpha Coal Project
Environmental Impact Statement

DECLARED WATERCOURSES

Job Number 4262 6580
Revision A
Date 22-09-2010

Figure: 11-2

File No: 42626580-g-2115.mxd

11.4.4 Existing Water uses

As the existing watercourses in the Project area are highly ephemeral and do not sustain persistent flow, the beneficial uses of surface water resources around the Project area are limited. A search of the State of Queensland Water Entitlements System was undertaken to identify regional surface water license holders. The search indicated that there are no license holders on Lagoon Creek downstream of the Project. The closest surface water license holder downstream of the Project is located on the Belyando River near the Gregory Development Road, approximately 175 km downstream of the MLA 70426 boundary. This is a license to take water for domestic supply (Licence Number 48434F).

Details of the search for the surface water licence holders are presented in Appendix A of the Water Management System Technical Report in Volume 5, Appendix F3 and include maps of the locations in Figure 3-5 in the same Technical Report.

11.4.5 Existing stream geomorphologic conditions

11.4.5.1 Landscape scale

The landscape drainage features (watercourses) in the Project area flow over Quaternary age alluvium dominated by valley fill sediments. The alluvium is characterised by interbedded sands and clays, and varies in thickness from 30 m to 125 m. The streams are also sediment stores, in which sediment only migrates downstream during infrequent flood events that have sufficient flow energy to mobilise bed sediments.

The valley fills in the confined and steeper upper catchments are often dissected by short bedrock controlled sections where the longitudinal profile steps down. Downstream of these sections, the waterways flood out into the broader valley floors of the higher order waterway. Beyond the current assessment, for subsequent detailed geotechnical and geomorphologic investigations to support detailed design of the proposed Project stream diversion channels, further baseline investigation will be undertaken to identify if there are bedrock outcrops in the watercourse reaches to be diverted, assess their significance for the stream controls, and to guide the diversion channel design.

Energy conditions are inferred to be generally low in the broad valley floors where the flows are generally shallow and widespread. The watercourses convey and transport stream flow slowly, particularly when vegetation is intact. Hydraulic modelling presented in the Flood Study and Geomorphology technical reports (Volume 5, Appendix F) confirm the low energy flow conditions particularly when floods exceed the bank-full flow capacity of the channel and spread out onto the floodplain.

Lagoon Creek is the primary valley drainage feature. Sandy Creek and Spring Creek are tributary drainage features with their floodplains coalescing with the main Lagoon Creek floodplain.

11.4.5.2 Watercourse Features

Characterisation of the individual water courses is presented in the Geomorphology Technical Report (Volume 5 Appendix F1).

Channel morphology in the Project area is generally a pool – riffle – run bed profile sequence and compound asymmetrical cross section with benches on one side of the channel. Isolated pools are present on Lagoon Creek. In low-lying areas, such as along Lagoon Creek, groundwater studies show the water table was encountered between 8m and 10m depth from ground surface and at up to

15m depth further west of Lagoon Creek, in slightly elevated ground. Based on current knowledge, the waterholes in Lagoon Creek do not appear to be sustained by groundwater.

The condition of individual streams in the Project area is described in detail in sections 4.2 – 4.5 of the Geomorphology Technical Report in Volume 5, Appendix F1, and is summarised below in Tables 11-2 to 11-4.

Table 11-2 Lagoon Creek Geomorphologic Feature Summary

Feature category	Lagoon Creek Description
Active channel geometry	Meandering channel of limited capacity. Channel width varies from 1 m to 20 m and depth from 0.5 m to 3.0 m. Channel is shallow relative to width and exhibits asymmetrical geometry on bend apex. Banks slope are 5° to 30° and moderately stable.
Channel Pattern	Occurrence of multiple low flow, secondary channels, except a few single channel sections, such as the Hobartville Road crossing. Extensive lateral and mid channel bars. High lateral migration potential within the areas exhibiting secondary channels. Symmetrical and trapezoidal where confined to single channel. Classified as having wandering meanders of the low flow (active) channel within a relatively linear flood channel and flood plain corridor. Channel banks are vegetated and mostly stable, with isolated occurrences of bank instability, such as slumping.
Geomorphic Units	The bed load is mainly sand and appears to have oversupply of sediment. Channel bed is mobile. Banks intersect sandy to silty clay materials and during high flows bank erosion and migration occurs. These features allow the low flow channel to meander within a relatively linear flood channel and floodplain corridor. The floodplain eastern (right bank) extents are confined to the line of low hills parallel and immediately adjacent to Lagoon Creek. The floodplain western (left bank) extents indistinctly defined and vary depending on magnitude of flooding.
Geomorphic Behaviour	Prior to European settlement, the stratigraphy of valley fills in Lagoon catchment reflects recurrent phases of cutting and filling over recent geologic time. Sediment movement is vegetation dependent. Where the channel bed is not grazed, the bed acts as sediment store. Where the channel bed is grazed, it acts as a sediment source.
Sediment Transfer Behaviour	Slow rate of accretion in long term.

Table 11-3 Sandy Creek Geomorphologic Feature Summary

Feature category	Sandy Creek Description
Active channel geometry	Varies between symmetrical and asymmetrical section with generally compound cross section. Variable width to depth ratio. Width varies from 10 m to 20 m and channel depth from 0.5 m to 2.5 m. Incised channel.
Channel Pattern	Low to moderate sinuosity single continuous channel with discontinuous secondary channels, classified as wandering meander system. Rare impingements on valley margin. Banks appear stable and mostly vegetated with dead trees and grass on the channel bed. Bed sediment mainly comprises coarse sand with occasional gravel.
Geomorphic Units	A third order stream with pools and riffles, waterholes, mid-channel islands and bars. In channel bench complexes occur. Occasional clay plugs exposed. Floodplain does not exhibit distinct natural levee, and has very gentle back slope to

Feature category	Sandy Creek Description
	floodplain margin. Narrow, up to 1 km wide floodplain sub-parallel to the channel. Floodplain coalescing with Lagoon Creek floodplain to form wide flat area.
Geomorphic Behaviour	Limited lateral adjustment, dominated by vertical and oblique accretion and potential for avulsion in long term. Trees along the banks provide stability by trapping sediment in place and capturing additional debris. Creek morphology can be considered as moderately intact. Channel migration through secondary channels and floodout splays.
Sediment Transfer Behaviour	Sandy Creek catchment has low relief with little hydraulic driver of sediment transport, which leads to a natural discontinuous channel form in the upper section. Acts as a sediment source in the western section of the Project area and a sediment deposition at downstream section. Slow rate of accretion in long term.

Table 11-4 Spring Creek Geomorphologic Feature Summary

Feature category	Spring Creek Description
Channel geometry	Discontinuous channel of limited capacity. Highly variable shape, ranging from asymmetrical compound to symmetrical in some straight sections. Channel is relatively narrow (1 m to 5 m width) and shallow (0.2 m to 1.5 m depth). Channel is often symmetrical and trapezoidal where confined to single channel.
Channel Pattern	High lateral migration potential due to shallow channel and alluvial fan floodplain surrounds. Classified as wandering meanders.
Geomorphic Units	Channel bedload comprises mainly medium grained, mobile sand. Spring Creek crosses an alluvial fan/outwash complex comprising mainly coarse grained sediments with surficial fine grained deposits. The flood plain is poorly defined within the outwash plain. The discontinuous channel pattern and poorly defined floodplain demonstrate evidence of historical migration of the channel with several former channel scars evident across the lower floodplain sections towards the junction with Lagoon Creek.
Geomorphic Behaviour	High rates of material reworking and sediment transport. Acts as a sediment source and transport of valley fill (i.e. older alluvial fan/outwash sediments). Depositional zone at the confluence with Lagoon Creek.
Sediment Transfer Behaviour	Source and transport zone, very little accumulation except for benches.

11.4.5.3 Significance of geomorphologic features to guide design of the Project stream diversions

The geomorphologic assessment has identified characteristics of the existing watercourses. For sustainable design of the proposed Project stream diversions the following conclusions have been drawn to replicate the key features and geomorphologic processes of the watercourses through and surrounding the Project Area.

1. The Lagoon Creek watercourse diversion will maintain this watercourse as the primary valley scale drainage feature.. The geomorphic behaviour of Lagoon Creek is a key influence on the floodplain evolution and channel conditions for the lower reaches of the Sandy Creek and Spring Creek tributaries.

2. Sandy Creek and Spring Creek have evidence of lateral channel migration across the floodplain areas due to the evolution of alluvial fan outwash associated with the interaction with Lagoon Creek. The evidence of channel scars across the floodplain areas indicates that locations of the channel confluences (Sandy Creek into Lagoon Creek, and Spring Creek into Lagoon Creek) have varied historically. The floodplains of Spring Creek and Sandy Creek are important features to dissipate excess flow energy for floods that exceed the bank-full flow capacity of the channel and this limits the frequency and severity of channel migration.

   The alignments of Spring Creek and Sandy Creek can be varied by the Project design, to join Lagoon Creek at different locations relative to current conditions, providing that the channels are designed to be relatively stable (dynamic equilibrium) and allow for dispersed dissipation of flow energy for flood events that exceed the bank-full flow capacity.

3. The apparent moderate and random, meandering of the Lagoon Creek watercourse is limited to meandering of the low flow channel within a relatively linear floodplain corridor. The diversion of Lagoon Creek will mimic the meandering of the low flow channel. Confinement of the floodplain corridor is possible providing that channel velocity and stream power is not excessively increased to ensure that designed low flow channel meandering can be sustained. The proposed Lagoon Creek low flow channel meandering will aim to mimic the variability of the existing low flow channel meanders (including wavelength, amplitude, and frequency) subject to constraints of the available floodplain corridor including an allowance for possible meander migration.

4. The generally low existing meandering of Sandy Creek and Spring Creek is likely to be due to the floodplain dissipation of excess flow energy where floodplain gradients slope away from the main channel towards Lagoon Creek. If the floodplain extent of these creeks is constrained by the Project design, increased meandering of the low flow channel relative to existing conditions will be provided to allow for possible meander migration.

5. The stream diversions will be designed to form sandy bed deposits on the bed of the low flow channel (mobile bed conditions). This will likely occur due to natural sediment transport from upstream reaches and catchments and deposit along the channel bed when floods recede. The natural process of mobilisation of the sandy bed deposits (typically in the rise and peak of floods) and transport downstream will be allowed for in the diversion design.

6. The presence of pools and lagoons in or adjacent to the Lagoon Creek low flow channel does not appear to be a necessary feature to maintain geomorphologic processes but rather appears to be a result of the geomorphologic evolution of Lagoon Creek. It will not be necessary to replicate channel lagoons solely to maintain geomorphic stability of the stream. However, the need for designed Lagoons or pools in the Lagoon Creek diversion channel may be required for other environmental dependencies (e.g. ecology).

In addition to the above Project specific geomorphologic context to guide the Project stream diversion design, the designs of the Project stream diversions will maintain hydraulic performance of the channels within acceptable limits (i.e. velocity, stream power, and shear stress parameters) based on existing stream conditions and the Australian Coal Association Research Program (ACARP) guidelines which are recognised as the leading guideline for design of stream diversions for mining projects.

11.4.6 Existing Water Quality

Characterisation of existing water quality was undertaken from review of suitable and available water quality data for the region. As part of assessing existing water quality conditions, a review and preliminary identification of Environmental Values for surface waters in the local watercourses was undertaken to guide selection of appropriate water quality trigger values for comparison with the available water quality data. The details of the assessment are presented in the Water Quality Study report in Volume 5, Appendix F4.

11.4.6.1 Environmental values

Environmental Values (EV) for Project area which is in the headwater sub-catchment of the broader Burdekin river basin are not specifically established in the Schedule 1 of the EPP Water. To guide the identification of EV for the local watercourses, the EV classifications in the EPP Water were considered and these include:

- Biological integrity (either as high ecological value waters, slight to moderately disturbed waters, disturbed water and for highly disturbed waters);
- Suitability for recreational or aesthetic use;
- Suitability for supply as drinking water;
- Suitability for primary industry;
- Suitability for industrial use; and
- Cultural and spiritual values of the water.

For biological integrity, the Lagoon Creek and tributary watercourses are deemed to be slight to moderately disturbed systems. Historical land clearing in the catchments and grazing impacts are factors that influence the designation of the slight to moderately disturbed category. Aquatic fauna surveys (refer Volume 2, Section 10) identified that fish species in the streams are limited to hardy species that tolerate the naturally variable water quality and habitat conditions. The aquatic surveys for macroinvertebrate assemblages found that no sites fell within the “pristine” category.

The ephemeral surface water flow characteristics of the local watercourses with substantial periods of no flow substantially limit the use of the local streams for recreational or aesthetic purposes related to water, and do not provide a permanent water supply for livestock drinking or sufficient supply reliability for industrial use. It is however recognised that available surface water during limited periods of stream flows can be valuable to opportunistically supplement livestock drinking water supplies. Surface water licences for livestock water supply exist for locations a long distance downstream of the Project area.

The EV consequently identified as potentially applicable to the watercourses of the Project area include:

- Biological integrity of a slight to moderately disturbed ecosystem;
- Cultural and spiritual values (refer to the Cultural Heritage Technical Report in Volume 5, Appendix L); and
- Suitability for primary industry uses, including irrigation and stock drinking water.

11.4.6.2 Existing water quality assessment

For assessing water quality relative to suitability to protect the identified EV, the water quality objectives (WQO) for protection of slight to moderately disturbed ecoystems are the most applicable because the trigger value criteria are more stringent than water quality objectives for primary industry (irrigation or livestock drinking). That is, it can be demonstrated that if water quality meets criteria required to protect aquatic ecosystems for specific parameters, the water quality will also be suitable to protect uses for irrigation and livestock drinking water for that parameter.

The relevant guideline indicators for protection of aquatic ecosystems are:

- Biological indicators;
- Physical and chemical stressors;
- Toxicants; and
- Sediments.

Due to the absence of suitable site-specific water quality data, the expected water quality characteristics for the Project area watercourses were determined from historical data available for Native Companion Creek (DERM stream gauge and water quality monitoring station GS120305A). The water quality of Native Companion Creek is expected to be comparable to the water quality of the watercourses within the Project area, as they have similar stream and catchment characteristics, being upland freshwater streams above 150 m in elevation, ephemeral, in relatively close proximity to each other, and relatively similar catchment size. Data for sediments was not available, and the water quality assessment therefore focussed primarily on water quality parameters for physical and chemical stressors and toxicant concentrations. Data for biological indicators is presented and discussed in Volume 2, Section 10 (Aquatic Ecology).

Field measurements of various water quality parameters were measured at Native Companion Creek monitoring station from 1968 to 2010. As not all the parameters were consistently analysed from 1968 to 2010, the number of samples for each parameter are listed in Table 11-5 which summarises the available water quality results with comparison against water quality objectives (trigger values) derived for the identified EV. Notes for the source derivation of the trigger values for each parameter are presented in Table 11-5.

Table 11-5 Native Companion Creek (DERM GS120305A) Water Quality Summary

Water Quality Parameters	Dates	No. (n)	Median	20th - 80th Percentile Range	WQO (trigger values)		Parameters that exceed WQO
					Value	Notes	
Electrical Conductivity (uS/cm)	1978–2010	65	135	105 – 213	168	(QWQ)[1]	
Turbidity (NTU)	1987–2010	39	200	57 – 452	25		X
pH	1970–2010	60	7.3	7.0 – 7.6	6.5 - 8.0	(range)	
Total Alkalinity (mg/L)	1970–2010	60	57	40 – 96	NE		
Hardness (mg/L)	1970–2010	60	49	34 – 74	NE		
Total Dissolved Solids (mg/L)	1970–2010	60	90	76 – 140	247	(QWQ)[2]	
Total Suspended Solids (mg/L)	1973–2010	54	110	34 – 387	NE		
Calcium soluble (mg/L)	1970–2010	60	11	8 – 19	1000	(ANZECC)[3]	
Chloride (mg/L)	1970–2010	60	10	6 – 20	NE		
Magnesium soluble (mg/L)	1970–2010	60	4.8	3 – 8	2000	(ANZECC)[3]	
Total Nitrogen (mg/L)	1998–2010	12	0.95	0.9 – 1.3	0.25	(QWQ)	X
Organic Nitrogen (mg/L)	1995–2010	15	1.14	0.6 – 1.4	0.225	(QWQ)	X
Nitrate + nitrite (mg/L)	1995–2010	28	0.04	0.01 – 0.11	0.15	(QWQ)	X
Ammonia as N (mg/L)	1995–2010	28	0.04	0.02 – 0.06	0.01	(QWQ)	X
Dissolved Oxygen saturation (%)	1995–2010	30	72	60 – 92	90 – 110	(QWQ)	X
Total Phosphorus (mg/L)	1994–2010	30	0.20	0.06 – 0.3	0.03	(QWQ)	X
Sulphate (mg/L)	1974–2010	43	1.8	1.2 – 2.5	1000	(ANZECC)[3]	
Aluminium soluble (mg/L)	1991–2010	32	0.05	<0.01 – 0.22	0.055	(ANZECC)[4]	X
Boron (mg/L)	1973–2010	38	0.05	<0.01 – 0.10	0.37	(ANZECC)	
Copper soluble (mg/L	1991–2010	32	0.03	<0.01 – 0.05	0.0017	(ANZECC)[5]	X
Fluoride (mg/L)	1970–2010	59	0.18	0.11 – 0.26	2	(ANZECC)[6]	
Iron soluble (mg/L)	1973–2010	42	0.08	<0.01 – 0.96	NE		
Manganese soluble (mg/L)	1983–2010	34	0.01	<0.01 – 0.02	1.9	(ANZECC)	
Zinc soluble (mg/L)	1991–2010	32	0.01	<0.01 – 0.05	0.012	(ANZECC)[5]	X

Notes:
NE – not established for this parameter
(QWQ) based on Queensland Water Quality Guidelines (2009) Version 3 for East Coast Central Queensland Upland Stream
(ANZECC) based on ANZECC (2000) Guidelines 95% level of protection for slight – moderately disturbed ecosystem

1. derived from QWQ Table G.1 – Belyando Suttor catchment – 75th percentile
2. electrical conductivity trigger value converted to TDS (as EC / 0.68)
3. NE for aquatic ecosystems protection, trigger value applied for livestock drinking water (sulphate for no adverse effects)
4. aluminium trigger value for pH > 6.5
5. Hardness modified trigger value for copper and zinc trigger – refer ANZECC Table 3.4.3 (hardness 50mg/L adopted)
6. fluoride trigger value for low risk to livestock drinking water (ANZECC Table 4.3.2)

The available water quality data compared against relevant trigger values for the EV identified the following existing water quality conditions:

- pH was consistently within the guideline range;
- Dissolved oxygen (DO) saturation can be frequently below the preferred guideline range;
- No clear relationship between flow and low DO concentrations was found. The low levels of DO appears to be a consistent other evidence of waterbodies in the region (refer Volume 2, Section 10, Aquatic Ecology);
- Turbidity is high;

  The high turbidity is typical of ephemeral streams which are characterised by short periods of flow (Smith et al, 2004) and for catchments exhibiting natural erosion and impacting land use that can increase erosion. This finding is consistent with geochemistry investigations undertaken for the EIS which show that clay subsurface materials are dispersive (Volume 5, Appendix J) and surface soils investigations (Volume 2, Section 5) that found localised areas, primarily within the Rhi and Dunrobin soil mapping units along minor drainage lines which originate from the upper slopes exhibit moderately to severe sheet and gully erosion;
- Nutrient concentrations (N, P) are elevated relative to guideline trigger values.

  The source of elevated nutrients is likely attributable to grazing land use and erosion in the catchment. All soils present on the Project site are considered largely deficient of major soil nutrients (Volume 2, Section 5), erosion alone may not be the dominant influence on nutrient levels in the local surface waters. In streams, decay of organic matter is also a potential source of elevated nutrients. The exceedence of the guideline values for nutrient concentrations does not necessarily indicate that the levels are unsustainable or unnatural. Rather it draws attention to the limited scientific data available to characterise natural concentrations, speciation, and variability of nutrients in ephemeral streams and emphasises the need for the Project to maintain reference site water quality monitoring; and
- Some metalloid toxicant concentrations in the surface water data exceed the identified trigger values for protection of aquatic ecosystems, including copper, zinc, and aluminium. Not all of the available water quality sample results exceeded the identified trigger value. The median concentrations for aluminium and zinc were below the trigger value. Copper was the only metal where concentrations consistently exceeded the identified trigger value.

  The elevated soluble concentrations of these metals in the local surface water are inferred to be directly attributable to erosion of natural sediments from the catchment and the high turbidity observations. Multi-element analyses in the geochemistry investigations undertaken for the EIS (Volume 5, Appendix J) show that clay subsurface materials have copper concentrations of 20-30 mg/kg, zinc concentrations of 40-110 mg/kg, and aluminium concentrations of 60,000 - 100,000 mg/kg. Distilled water extracts of geochemistry investigation samples reported copper concentrations up to 0.004 mg/L, zinc concentrations of 0.02 to 0.09 mg/L, and aluminium concentrations of 0.08 to 2 mg/L.

Based on these findings of the preliminary water quality assessment, the monitoring and sampling for metals concentrations will be maintained as part of the reference site water quality monitoring program.

The available water quality data did not identify any concerns with water quality required for livestock drinking water supply.

The identified potential exceedance of trigger values for some baseline water quality parameters above were limited to the EV for protection of aquatic ecosystems. This does not mean that water quality is unsuitable to protect aquatic ecosystems. The findings may indicate that the guideline trigger values may not be adequately representative of the local endemic aquatic systems capacity to variable water quality such as due to ephemeral flow conditions, elevated turbidity, and natural catchment mineralisation. Site specific baseline monitoring will be conducted to manage this potential uncertainty and will include reference site and impact site monitoring and biological indicator monitoring within an overall Receiving Environment Monitoring Program (REMP).

11.4.7 Flooding

11.4.7.1 Flood modelling

An assessment of existing flood conditions was undertaken with a flood hydrology study to determine the magnitude of flood flow events for a range of probable design floods, and subsequent flood hydraulic modelling to assess the extents, depths, and flow velocities of flood flows along the existing watercourses through the Project area and including reaches upstream and downstream of the lease. A detailed description of the studies undertaken is presented in Volume 5, Appendix F2.

11.4.7.2 Flood hydrology

The summary results of the flood hydrology estimates of peak design flood flows for the existing watercourses are presented in Table 11-6. Locations where flood flow estimates are reported are presented on Figure A-2 in the Flood Study technical report (Volume 5, Appendix F2). There is no recorded history of floods on the Project site.

Table 11-6 Existing watercourse peak flood flow estimates (m3/s)

Location	Model Node	Critical storm hours	Average Recurrence Interval (years)				
			2	10	50	100	1000
Sandy Creek downstream of junction with Lagoon Creek (near north boundary of lease)	K	18 to 36	26	210	532	795	2250
Lagoon Creek upstream of Sandy Creek confluence	J	18 to 36	20	168	416	609	1725
Lagoon Creek upstream of Spring Creek confluence (near south boundary of lease)	A	18 to 36	20	168	416	606	1633
Sandy Creek upstream of Lagoon Creek confluence	I	18 to 36	10	87	203	301	740
Spring Creek upstream of Lagoon Creek confluence	D	12 to 24	1.1	11	26	38	82

11.4.7.3 Flood Levels and Extents

A summary of the existing peak water levels at different reporting locations along Lagoon Creek for the 1,000 and 3,000 year Average Recurrence Interval (ARI) design flood events is presented in Table 11-7. A map showing the existing flooding extents for the 1,000 year and 3,000 year ARI flood event is presented on Figure 6-1 in the Flood Study technical report (Volume 5, Appendix F2). A longitudinal profile of the modelled flood levels along Lagoon Creek is presented in Figure B-1 in the Flood Study technical report (Volume 5, Appendix F2).

The flood inundation map for the 1,000 year ARI flood shows that the existing floodplain corridor for this magnitude of flooding is approximately 2 to 3 km wide. The flooding is widespread and shallow with the maximum flood depths typically less than 5m above the channel bed. The flood profiles show that there is approximately 20 m difference in flood levels between the southern and northern extents of the proposed mine lease area.

Table 11-7 Peak flood levels for existing Lagoon Creek Floods

Description	Easting	Northing	Modelled Flood level (mAHD)	
			1000 year ARI	3000 year ARI
8 km D/S of mine site	448712	7452178	288.9	289.1
North lease boundary	449303	7444873	299.2	299.4
Wendouree Homestead	449048	7436775	306.4	306.9
Hobartville Homestead	448984	7423198	316.3	316.5
South lease boundary	448340	7419974	319.1	319.2
6.4 km U/S of mine site	445561	7414129	325.3	325.4

11.4.7.4 Stream geomorphology hydraulic parameters

The flood hydraulic modelling of existing watercourse and floodplain conditions can provide a reference condition for identifying key hydraulic indicators of relevance to existing channel geomorphologic stability and to guide acceptable criteria for design of stream diversions and/or constriction of the floodplain corridor for establishing levee banks to protect the mine from flooding.

To characterise the key hydraulic conditions for stream channel stability the parameters commonly used are flow velocity (channel and floodplain), channel shear stress, and channel stream power. These parameters can vary markedly along watercourse reaches and are presented as longitudinal profiles in Appendix C of the Geomorphology Study technical report (Volume 5, Appendix F1). A hydraulic model layout plan is presented in Figures C-1 and C-2 in Appendix C of the Flood Study technical report (Volume 5, Appendix F2).

The existing Lagoon Creek characteristics of the channel velocity, streampower, and shear stress for the 50 year ARI flood event are summarised in Table 11-8. Design criteria based on ACARP design guidelines (ACARP Project C9068 Maintenance of Geomorphic Processes in Bowen Basin River Diversions 2000-2002) are presented in Table 11-8.

The hydraulic modelling results generally show that the existing velocity, streampower, and shear stress conditions in Lagoon Creek are relatively low. The modelled hydraulic results are consistently lower than the recommended guideline design criteria which indicates that the existing Lagoon Creek channel is stable from hydraulic perspective.

Table 11-8 Velocity, Streampower, and Shear Stress for Lagoon Creek 50 year ARI Flood

Reach and Result type	Velocity (m/s)	Streampower (W/m^2)	Shear Stress (N/m^2)
Downstream (north) of lease boundary (model chainage 0 km to 13km)			
Typical average	1.1 to 1.3	20	10
Maximum values and frequency along stream	2.4 at approx 5 km average intervals	50 up to 100 at approx 3 km average intervals	30 up to 60 at approx 3 km average intervals
Downstream end of proposed diversion to lease boundary (model chainage 13 km to 19 km)			
Typical average	0.7 to 0.9	10	5 to 10
Maximum values and frequency along stream	1.3 at approx 3 km average intervals	20 at approx 3 km average intervals	20 at approx 3 km average intervals
Lagoon Creek reach proposed to be diverted (model chainage 19 km to 31 km)			
Typical average	0.6 to 0.9	10	5 to 10
Maximum values and frequency along stream	1.3 at approx 3 km average intervals	25 at approx 3 km average intervals	20 at approx 4 km average intervals
Upstream of proposed diversion to upstream (south) lease boundary (model chainage 31 km to 45 km)			
Typical average	0.5 to 0.6	10	5 to 10
Maximum values and frequency along stream	0.9 at approx 3 km average intervals	20 at approx 2 km average intervals	15 at approx 5 km average intervals
ACARP Stream Diversion Design Guideline Criteria			
Maximum values (50 year ARI event)	1.5 to 2.5	100 to 150	< 80

11.5 Proposed Project Surface Water Management

11.5.1 Overview

Proposed project elements that will actively or passively manage surface water as relevant for impact assessment are described below to establish the context for the EIS surface water impact assessment which is later described in Section 11.6. This builds upon the high level project description in Volume 2, Section 2 and provides more detailed description of the project elements that could impact on surface water environmental values. Relevant aspects include:

- Construction and Operational phase project water supply and potable water requirements;
- Sewage treatment and stormwater management for areas outside the mine operations;
- Proposed stream diversion designs;
- Proposed flood protection for the mine; and
- Proposed mine water management system, including containment / reuse, and proposed discharge criteria.

11.5.2 Status of Design

The Project design for surface water management is at concept to preliminary design stage and built upon the pre-feasibility study mine plan prepared by the Proponent. Mine plan and infrastructure optimisation is underway as part of the bankable feasibility study for the Project. As the mine plan is refined, design for surface water management (including flood protection, stream diversions, and mine water infrastructure) will also be refined and developed to detailed design level. The process to refine surface water design elements of the Project will incorporate the findings and mitigation strategies identified in this EIS.

The current concept designs for surface water management will need to be further developed to detailed design to obtain the approvals required which occur after EIS approval, such as the separate approvals for stream diversions, flood protection levees (as regulated structures), and hazardous dams. As part of the process for developing the detailed design for surface water management infrastructure, further investigations will also be undertaken particularly to assess geotechnical conditions at the various infrastructure locations and suitability of materials for construction.

Although the Project design for surface water management is not finalised, it is considered sufficiently defined to facilitate impact assessment and identify mitigation measures required to protect surface water and associated environmental values. The philosophy adopted was to ensure that concept definition of the surface water management works and operations would be sufficient to demonstrate that environmental impacts can be managed and the required works can be integrated into the Project.

11.5.3 Water supply and storage requirements

11.5.3.1 Construction water supply

Water for the construction phase of the Project is proposed to be supplied or sourced from groundwater bores as part of the advanced mine dewatering and/or existing storages. The means of sourcing construction water supply from groundwater is discussed in Volume 2, Section 12. The proposed raw water dam will be constructed early in the construction schedule and used to store the construction water supply.

Construction phase water demands are currently estimated at approximately 290 kL/day on average through the construction period. Generally, construction water will be required for the following tasks:

- Dust suppression on cleared construction areas;
- Moisture adjustment for compaction of engineered fill;
- Concrete mixing; and
- Construction accommodation village potable water requirements.

11.5.3.2 Operational water supply

Mine water collected in the mine water management system including surface runoff from disturbed operational areas of the mine and groundwater dewatering will be used to supply a portion of the mines operational needs for non-potable uses. The proposed mine water management system is discussed further in Section 11.5.5. Preliminary water balance modelling has shown the mine water management system will not be able to supply all of the mine operational needs, particularly in dry years, and make-up water supply will be required to sustain the Project operations.

At the current planning phase of the Project, it is expected that make-up water supply for the operational phase will be sourced from a combination of groundwater pumped from local aquifers as part of the advance mine dewatering, and a new bulk water pipeline operated by SunWater from Moranbah. The external pipeline water supply will be relied upon to meet potable demands (after treatment) and as a secondary source for make-up water when there is insufficient mine water on the site. A commercial supplier will be responsible for providing the delivery pump station, pipeline, discharge infrastructure and all associated control and communications necessary for the operation of the system.

A 400 ML raw water dam will serve as terminal storage for the bulk water supply pipeline. The purpose of the raw water dam is to provide a storage reserve in the event of a bulk water supply interruption and to facilitate transfer of raw water to the mine infrastructure area (MIA) and coal handling and preparation plant (CHPP) for process, fire, dust suppression, and general wash use.

With the arrangements outlined above, the Project will not be seeking to extract natural flows from the local watercourses.

11.5.3.3 Potable water requirements

The bulk water supply is to be treated on-site with a package potable water treatment plant (WTP), such as a reverse osmosis system to supply the potable water needs for the Project. Water storage tanks for potable water will be required at the WTP and at the accommodation village as the water supply at the village must have sufficient reserve for fire fighting. Potable water is to be reticulated throughout the site in dedicated services corridors proposed to be created throughout the MIA/CHPP areas and in a dedicated corridor to the accommodation village.

For construction potable water, the permanent WTP will be supplemented with a temporary potable water package treatment plant, with a treatment capacity of 125 kL/day, giving a peak supply capacity of 575 kL/day during the construction phase.

11.5.4 Sewage and wastewater management

All sewage waste generated during the Project is to be collected and treated to Class A effluent quality on site. Sewage from the MIA, CHPP and accommodation village will be collected and conveyed to a package sewage treatment plant (STP) and the effluent disposed to the tailings decant dam. The tailings decant dam will be of suitable capacity to ensure no release of effluent to the environment. Solids by-products from STP will be removed by a contractor and transported to a licensed disposal facility. Sewage from the remote dragline construction site and the run of mine (ROM) dump stations will be collected in septic tank systems and trucked back to the STP for treatment.

The sewage reticulation and rising mains is planned to be constructed in the dedicated services corridors proposed to be created throughout the MIA/CHPP areas and in a dedicated corridor between the accommodation village and STP.

The following design criteria were applied for sizing of the sewage infrastructure:

- Average daily waste water generation based on 55 litres per person per day water use at the MIA, CHPP and dragline construction site, and 240 litres per person per day at the accommodation village with 90% of this water use generating waste water.
- Peak instantaneous sewage flows on the mine site calculated in accordance with AS.3500, which is based on probable simultaneous use of sewage generating devices such as toilets, showers, kitchens fixtures, etc. An additional loading factor of 20% of the volumetric peak flow is allowed for wet weather infiltration.
- All rising mains designed to have a minimum velocity of 1 m/s to facilitate self cleansing conditions.
- All pump stations and disposal sites located above the 1,000 year ARI flood event inundation levels and to be readily accessible from site roads and the reticulated power supply.
- All pump stations to be submersible below ground installations, with an elevated motor control centre in a weather proof kiosk with visible failure alarm system. All pumps will be controlled on a simple level transducer that will switch pumps off and on.
- Sewerage pump station sumps will either be provided with emergency storage in the event of a power failure or will be connected into an emergency power system.

Projected wastewater generation rates are summarised in Table 11-9.

Table 11-9 Projected wastewater generation rates

Period	Design flow (kL/day)
Early works	76
Construction works	433
Operations	358

11.5.4.1 Stormwater management outside the mine area (accommodation village)

The proposed accommodation village is the only Project facility outside the mine area that will require a stormwater management network and treatment devices. All other areas within the mine area (including mine, CHPP, MIA, tailings storage facility [TSF], and train load-out [TLO] facilities) will be serviced as part of the integrated mine water management system that is described in Section 11.5.7.

As the accommodation village will effectively be a small compact residential facility, the stormwater system will be designed in accordance with best practice urban drainage design and incorporate water sensitive urban design principles. Design will be undertaken in accordance with the Queensland Urban Drainage Manual (DERM 2007), Australian Runoff Quality – A guide to water sensitive urban design (2005), and requirements of the local Regional Council. Planning for the accommodation village stormwater design will consider features such as rainwater tanks, swales, gross-pollutant traps, and basins to mitigate increases in peak flow and filter sediment and nutrients.

11.5.5 Creek diversions

The diversion of defined watercourses for Lagoon Creek, Sandy Creek, and Spring creek will be required for the Project to gain unimpeded access to coal reserves that would otherwise be inaccessible due to the risk of flooding. To supplement the stream diversion channels, flood protection levee banks will be required to protect the mine from flooding and these are discussed in Section 11.5.6. The proposed concept designs for the stream diversions are described below.

11.5.5.1 Design process

There are two recognised design processes for the design of a creek diversion: the ‘reference reach’ approach and the ‘design criteria’ approach.

The ‘reference reach’ approach requires the diversion to replicate the existing natural channel reach as much as possible. This includes, but is not limited to, replicating the floodplain width, channel meanders, vegetation, velocities and geomorphic characteristics. This approach is suitable when the diversion is to be constructed in an area of similar topography to the existing reach.

The ‘design criteria’ approach requires the diversion to perform in accordance with the criteria set out in the design specification. For example, the design specification for the ACARP (2002) guideline includes, but is not limited to, limiting velocities, limiting shear stress, limiting stream power, providing vegetation and maintaining geomorphic processes. This approach is suitable when the diversion is to be constructed in an area of different topography to the existing reach, or when the original channel conditions are not easily replicated (e.g. due to topography or geology conditions).

The Lagoon Creek diversion concept was designed using the ‘reference reach’ approach. The concepts designs for the Spring Creek and Sandy Creek diversions were initially designed using the 'design criteria' approach as the topography, mine layout, and need for geotechnical investigations partly constrain the 'reference reach' approach. Further design refinement for the diversions will be undertaken as part of detailed design including consultation with DERM and geotechnical investigations to evaluate expected substrate conditions. Although further refinement diversion designs is anticipated, the assessments of the concept diversion designs presented in this EIS demonstrate that stable diversion channel designs should be achievable.

Australia does not have a formal recognised standard or set of design criteria for stream diversions. For the purpose of the Project, the commonly used ACARP guideline has been adopted and this is recognised to represent best practice. The key requirements for design and rehabilitation criteria of the ACARP guidelines for stream diversions have been adopted by the DERM in the *Central West Water Management and Use Regional Guideline for Watercourse Diversions*. This guideline has been adopted for the Project creek diversions as it is the best available guideline and is directly applicable to this Project.

11.5.5.2 Diversion design objectives and criteria

The key design objectives and criteria for creek diversions for this Project include:

- **Lengths and Longitudinal Gradient:**

  The creek diversion active channels (low flow channel) will be designed with lengths at least equal to the reach of the existing stream active low flow channel. The upstream and downstream bed levels will be designed to match the existing stream bed levels. This combination of criteria will ensure that the longitudinal gradient of the channel bed will not be increased and the diversion channels should not require the use of drop structures to control erosion.

- **Active Channel:**
  An active (low flow) channel will be provided within a high flow channel of each creek diversion. The active channel dimensions and geometry will provide similar flow capacity as "bank full" capacity of the active channel in each of the existing watercourses. The bank full flow capacity is assessed as equivalent to a 2 year ARI event. The active channel may, as required to achieve equilibrium, meander within the high flow channel.

- **High Flow:**
  A high flow (flood) channel will be provided to convey flows up to a 50 year ARI event for each creek diversion. If large flood flows exceed the capacity of the flood channel, the flood flows will spread onto the adjacent flood plain areas and be confined by a levee on the mine pit side and higher natural ground levels on the opposite side.

- **Vegetation:**
  Diversions will be vegetated prior to commissioning. The adopted roughness coefficient assumes the presence of vegetation.

- **Substrate:**
  The diversion active channels will allow for replication of substrate conditions similar to the existing stream substrates of significance for geomorphic processes, water quality, vegetation, and aquatic habitat features as required. As a minimum this is expected to include allowance for channel bed deposits (mobile bed conditions), and channel banks typically in sand to silty clay materials.

- **Hydraulic design:** Hydraulic performance including channel velocities, stream power and shear stress will limited to the guideline criteria in the DERM *Central West Water Management and Use Regional Guideline – Watercourse Diversions*, Table 1.

11.5.5.3 Diversion Layouts and Lengths

The proposed diversion concepts for Lagoon Creek, Spring Creek and Sandy Creek are presented on Figure 11-3. The current concepts designs will be refined to account for the findings of the EIS studies and in consultation with DERM (agency responsible for approvals and licensing of stream diversions) prior to final detail design and approval.

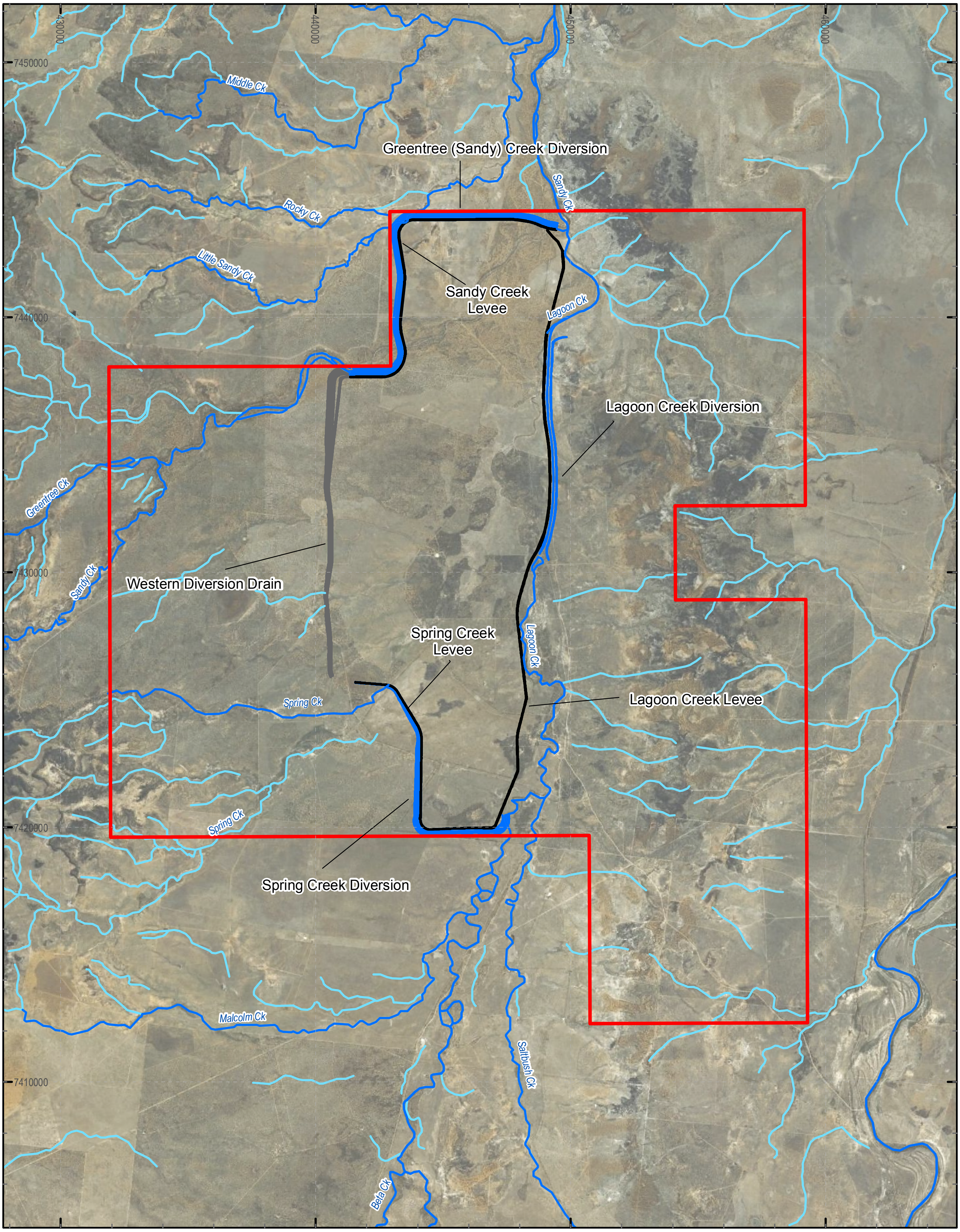
The Lagoon Creek diversion will be a 9 km diversion that will join the existing Lagoon Creek channel at both upstream and downstream ends.

The Sandy Creek diversion will start approximately 12 km upstream of the existing confluence with Lagoon Creek, flow north and then east around the proposed mine pits to re-join the existing Sandy Creek approximately 400 m upstream of the existing Sandy Creek confluence with Lagoon Creek. The Sandy Creek diversion flood channel length will be approximately 13.4 km (some 1.6 km longer than the existing Sandy Creek reach). Note that in the Geomorphology technical reports (Volume 5, Appendix F1), the proposed Sandy Creek diversion design is stated to be 26 km long, however this refers to the combined length of Sandy Creek diversion, and a proposed clean water catch diversion drain along the western side of the proposed pits. The diversion channel for the clean water catch drain is not a defined watercourse (under the Water Act), the actual defined watercourse diversion length of Sandy Creek is 13.4 km.

The Spring Creek diversion will start approximately 8 km upstream of the existing confluence with Lagoon Creek, and flow south and the east around the proposed mine pits to join Lagoon Creek at a new confluence location approximately 1 km inside the southern lease boundary. The length of the flood channel for Spring Creek diversion will be 10 km (approximately 2 km longer than the existing Spring Creek reach from the diversion off-take to Lagoon Creek). It is noted that the reach of Spring Creek defined to be a watercourse under the Water Act by DERM does not include the full length of Spring Creek to Lagoon Creek. This is merely a legal peculiarity of how DERM define watercourses under the Water Act, and does not reflect the fact that existing Spring Creek stream flow continues to Lagoon Creek.

A new confluence location for the junction of Spring Creek and Lagoon Creek is considered to be acceptable based on the existing stream geomorphologic history which has demonstrated previous migration of the channel confluence (refer Section 11.4.5). The confluence of Spring Creek diversion with the existing Lagoon Creek will be designed such that junction occurs with an outside bend of the Spring diversion joining with an outside bend of the existing (Lagoon Creek) meander, as occurs in natural evolution of stream junctions.

All of the physical works extents of the proposed stream diversions will be contained with the MLA 70426 boundary. The containment of the diversion works to within the proposed mine lease boundary is solely for legal aspects to allow licensing of the complete diversion works and is not specifically necessary for any other reason to replicate existing stream characteristics and geomorphic processes.



Source: Data supplied by Parsons Brinckerhoff

(red outline)	Mining Lease Application (MLA70426) Boundary
(blue line)	Defined Watercourses (per section 5 Water Act 2000)
(light blue line)	Minor Streams
(black line)	Levee

Source: See Copyright Details below and for full disclosure Please Refer to the EIS ***Volume 4 - References*** . Satellite Imagery Sourced from Bingmaps, Copyright 2010

0 1.25 2.5 5 Km

Scale 1:200,000 (A4)

Datum: GDA94, MGA Zone55

N W E S

HANCOCK PROSPECTING PTY LTD

Alpha Coal Project
Environmental Impact Statement

PROPOSED CONCEPT DIVERSIONS AND FLOOD MANAGEMENT LEVEES

Job Number	4262 6580
Revision	A
Date	22-09-2010

Figure: 11-3

File No: 42626580-g-2116.mxd

11.5.5.5 Active channel meandering concepts

The proposed diversions will have an active (low flow) channel that meanders within a broader relatively linear flood channel diversion corridor.

The need for meandering is cited by the ACARP guidelines as a means to provide adequate length to the diversion channel to maintain the longitudinal bed gradient of the diversion channel similar to the original stream (i.e. avoid steepening of bed grade and associated erosion risks). For the proposed Project diversion alignments the reach lengths will be maintained or extended more than the existing streams, and hence meandering is not essential for sole purpose of the preserving the longitudinal bed gradient. Meandering of the active channel also needs to account for the substrate conditions to be intercepted by the diversion channel excavation and local scale hydraulic conditions. Meandering is also considered by some as important to maintain the aesthetic natural look of the stream.

For the purpose of the concept diversion layouts presented on Figure 11-3, a minimum possible regular meandering pattern of the active channel is indicatively shown. This is shown to demonstrate that meandering of the active channel within the diversion corridor (flood channel) can conceptually be incorporated into the diversion design. The minimum meander size is conceptually shown and is based on parameters (wavelength, radius, amplitude) determined using equations and graphs developed by Langbein and Leopold (1966), and Julien (1985) for alluvial stream meandering. It is acknowledged that the conceptual meandering visually appears different to the existing watercourses, and that greater variability in the meandering may be desirable.

As part of the detailed design (prior to submission for stream diversion approvals), the optimal meandering patterns for the active channels will be designed. The information and processes to support the detailed active channel meandering design will include geotechnical investigations along the diversion route, assessment of risk of meander migration (particularly where this could impinge on flood protection levees), compatibility with mobile bed conditions, consideration of diversion rehabilitation methods, and consultation with DERM.

It is expected that design based on these principles will create a geomorphologic stable creek in dynamic equilibrium, requiring minimal management in the short and medium term, with no ongoing management in the extended term beyond mining operations.

11.5.5.6 Concept active channel section

The conceptual dimensions and geometry of the active channel for the stream diversions are summarised in Table 11-10 and were designed nominally to provide capacity for 2 year ARI flow events (to approximately replicate existing stream bank-full flow capacity of the active channels). The larger flood channel dimensions were designed to contain the 50 year ARI flood events.

Table 11-10 Overview of creek diversion concept design dimensions

Watercourse	Active (low flow) channel				Diversion flood corridor width (m) – 50 year ARI
	Depth (m)	Bed width (m)	Channel gradient (%)	Side slopes	
Lagoon Creek	1.5	20	0.075	1:3 (V:H)	240
Sandy Creek	1.0	8 to 10	0.15	1:3 (V:H)	240
Spring Creek	1.0	7 to 10	0.03	1:3 (V:H)	240

11.5.5.7 Surface treatments and habitat enhancement

It will be desirable to minimise the use of large extents of rock armouring in the diversion works to ensure appropriate substrate conditions can be provided to maximise success of rehabilitation of the channel banks and natural characteristics of the creek banks. The use of rock armouring will be minimised where possible through detailed design by optimising the diversion layout and geometry including combination of detailed design geometry of the active channel, meandering, and broader flood channel. The geotechnical investigations required for detailed design will be an important factor as part of this process. Localised areas of rock armouring may be required to provide bank protection at key locations where channel migration poses unacceptable risk to significant infrastructure or poses risk to destabilise the diversion channels. Should rock armouring be needed, it is proposed to use sandstone selected from mine overburden materials which is non-acid forming and has low potential to produce saline leachate. The rock armouring would be placed as a mixture of topsoil and rock and seeded to allow vegetation to establish and eventually take over as the primary means of erosion protection as the sandstone breaks down due to weathering.

The establishment of riparian vegetation will be a key component of all waterway diversions. Riparian vegetation plays an integral role in creating and maintaining the stability of newly constructed channels. Further assessment of riparian vegetation will be undertaken as part of the detailed design to provide a basis for developing a detailed revegetation plan. Revegetation will include the use of a mixt of indigenous groundcover, shrubs and tree over-storey species. The potential need or benefit of installing large woody debris for additional habitat will also be investigated as part of detailed design.

Further geotechnical investigation for detailed design of the diversions will also be important to finalise bank and excavation surface treatments. The majority of the diversion works will involve excavation and are likely in some areas to intercept clay subsurface materials which have been identified to be dispersive (refer Volume 2, Sections 5 and 16). Treatments will be required to ensure that dispersive soils are not left exposed on the diversion bed, bank, or floodplain surfaces. The two options treat the dispersive clays are in-situ gypsum treatment (to reduce dispersion potential) or to cap the dispersive soils with non-dispersive soils and or rock.

11.5.6 Flood protection for the mine

11.5.6.1 Layout and Extents

Flood protection levee banks are proposed to protect the mine open cut and overburden dump areas from floods in Lagoon, Sandy and Spring Creeks. The proposed extents of flood protection levee banks are presented on Figure 11-3. A flood levee bank will be required on the western side of Lagoon Creek for the majority length of the mine. For the Sandy Creek diversion a flood levee bank will be required along the eastern side of the diversion flood corridor for the section of diversion that flows north, and on both sides of the diversion flood corridor for the section that flows east to Lagoon Creek. For the Spring Creek diversion a flood levee bank will be required on the eastern side of the diversion flood corridor for the section of diversion that flows south, and on both sides of the diversion flood corridor for the section that flows east to Lagoon Creek.

11.5.6.2 Level of Flood Protection

The flood levee banks are nominally designed at concept stage to provide protection up to the 3000 year ARI flood level. The nominal level of flood protection equates to a 1% probability of an extreme flood overtopping the levee bank for the 30 year mine life and corresponds to the inferred expectation of DERM requirements for flood protection. It is noted that the DERM requirements for flood protection for mining projects are not formal and are not explicitly documented in any endorsed State government policy or guideline.

The inferred regulatory authority (DERM) expectation for the level of flood protection arises from acknowledged community concerns regarding the mine flooding incidents and subsequent management of pumping out flooded coal mine pits in the Bowen Basin in the 2008 floods. The potential community concerns regarding flooded mine pits do not necessarily directly relate to warrant that extreme conservative levels of flood protection for mine pits are necessary. The appropriate level of flood protection will be based on a risk based approach and consider the range of options that can be implemented to recover flooded mine pits in an environmentally responsible manner. For example a flooded mine pit could be recovered with minimal environmental impact if the flood water is appropriately treated to acceptable water quality standards prior to discharge to the waterways, or could be recovered by constructing regulated dams to allow dewatering of the mine pits.

The nominal 3,000 year ARI level of flood protection will be further reviewed as part of detailed design and subject to a detailed risk assessment including various consequences that may arise from different methods to recover the mine pit(s) in the event of an extreme flood. Discussions will be held with DERM during the detailed design phase to agree on an appropriate risk based level of flood protection. At this stage, from a business risk perspective, the Proponent considers that the minimum acceptable level of flood protection would be up to a 1,000 year ARI flood event.

11.5.6.3 Design construction and maintenance of flood protection levee banks

Subject to further geotechnical investigation regarding the suitability of materials, it is proposed that the flood protection levee banks will be constructed using benign mine overburden materials and excess spoil from the stream diversion excavations. Materials quality and compatibility with practical construction methods will be a key factor in levee bank design. Slope stability, flood velocities and the risks of piping failure (i.e. internal erosion either through the embankment or beneath the levee foundation) will be assessed and mitigated in the detail design. The levee embankment alignments may also need to vary slightly from the concept alignments depending on the conditions encountered during detailed design geotechnical investigations and for finalising the stream diversion designs.

The flood protection levee banks will be regulated structures with conditions administered through the Environmental Authority. This will require design to be undertaken by a suitably qualified and experience engineer (as defined by DERM) and certification of the design and construction of the levee bank. The Environmental Authority conditions will also require certified annual surveillance inspections by a suitably qualified and experience engineer and obligation for the EA holder to rectify deficiencies identified in the annual surveillance outcomes.

11.5.7 Mine Water Management System

11.5.7.1 Overview of the mine water management system

The proposed mine water management system comprises runoff containment systems from all disturbed areas, mine water dams with a range of functions (runoff capture, transfer dams, storage dams), and network of pumps pipes and drains to transfer mine water through the system. The overall system as a whole serves three important functions which include:

- Ability to capture and contain mine affected water and prevent uncontrolled runoff into the environment to minimise impact on surface water quality. This is the primary means of defence for protection of surface water quality in the local watercourse.
- Allow mine water to be collected and reused in the mine operations (including CHPP operations, industrial uses and for dust suppression). This function assists to reduce requirements for external mine water supply and also draws down the mine water inventory to free up storage capacity to maintain capacity to contain runoff.
- Allow dewatering of mine pits to sustain mining operations (including direct pumping from pits after runoff accumulates in pits and the mine water dams to store and redistribute groundwater dewatering).

The mine water management system will be limited to the disturbed areas of the mine site that produce mine affected water (including CHPP, MIA, and TSF) and exclude clean water catchments. The clean water catchments will passively bypass the mine water management system through the proposed stream diversions. A clean water diversion drain will also be constructed along the western edge of the mine pits to intercept and divert clean overland sheet flow from the western side of the mine.

11.5.7.2 Key influences for the required mine water management system

Key factors that determine the mine water system requirements include:

- **Catchments, local climate, and surface runoff volumes:**

  The mine plan and corresponding extent of mine disturbed catchments. This influences the quantity of surface water runoff from rainfall events. Local climate data is used to determine the amount of rainfall that could be expected to produce runoff ranging from individual events through to entire wet season rainfall conditions. The catchments extents will vary throughout the mine life as the open cut pits progress to the west.

- **Groundwater dewatering volumes:**

  Groundwater dewatering is an additional source into the mine water management system and combined with surface runoff volumes influences the total inflows into the system.

- **Discharge criteria:**

  The criteria for discharges from the mine water management system influences the ability to release excess mine water during exceptional or prolonged wet weather periods. The criteria for uncontrolled releases (overflows) from the mine water system influences the total storage capacity required for the mine water management system. The potential for uncontrolled release recognises that any containment system that is open to rainfall inputs has some potential that it could overflow. To establish acceptable criteria for uncontrolled releases, the philosophy adopted is to ensure that the probability of overflow is extremely low. Further discussion of the proposed discharge criteria is presented below.

- **Mine water demands and consumption:**

  The demands for mine water use (including CHPP, industrial use, and dust suppression) affect the consumption from the mine water management system and net water balance. Mine water demands generally remain relatively constant and are related to mine production. The system inflows particularly runoff volumes vary across seasons and years resulting in variable net water balance from year to year that is influenced extensively by rainfall. The mine water consumption can be considered as the “stabilising force” on the mine water system capacity to contain mine water and rainfall influences on runoff volumes can be considered as the variable “destabilising force”. In this context, the consumptive reuse of mine water from the mine water management system is a significant influence on the available storage capacity required to prevent overflows from the system in exceptionally wet or prolonged wet seasons.

- **Other losses:**

  In addition to the factors outlined above, other losses of water from the mine water management system influence the net mine water balance. These losses can include seepage loss from mine water dams (generally to be avoided through appropriate design) and evaporation losses from the surface of mine water dams. Evaporation losses tend to have greatest influence for the mine water system ability to maintain mine water reuse supply to the operations during extended drought periods.

The integration of the above influences on the mine water management system is analysed with a mine water balance model that can assess expected performance under a range of climatic conditions including droughts, extreme wet seasons, and potential for sequential years of above average rainfall. To perform water balance modelling to assess the expected mine water management system performance, a philosophy for segregating differing types (levels of contamination) of mine water is required, and operating assumptions for transfer of mine water through the system are also required.

11.5.7.3 Proposed segregation of mine waters

Adopting best practice for mine water management, it is proposed to segregate water within the mine site according to its quality to optimise the storage and preferential reuse of mine water and ensure that only the least contaminated sources of mine water are discharged in accordance with proposed discharge conditions.

The mine water management system will be limited to mine affected waters (i.e. disturbed catchments, contaminated water sources, and contaminating processes). Clean waters (runoff and stream flow) from undisturbed areas on the site and upstream catchments will be diverted to passively flow to downstream waterways. It is envisaged that during the course of the mine life, progressive rehabilitation of available (no longer needed) disturbed areas will be undertaken and after established and demonstrated to produce acceptable quality runoff, these areas will be diverted away from the mine water management system through clean water bypass drains.

The following four mine water classifications have been identified for the mine water management system:

- **Process water management system** – this includes process water that has been used in the CHPP. This system includes the TSF, decant dam and return water system. These waters are expected to contain elevated salinity, potentially elevated sulfate concentrations, and have relatively neutral pH.
- **Contaminated water management system** – this includes runoff from the open pit and other areas that could contribute contaminants, such as the MIA, CHPP, coal stockpiles and dump stations. These waters where rainfall or runoff contact with coal (either from in pit, or around processing areas) is the main influence on water quality are expected to contain elevated salinity, potentially low pH, possible elevated metals and sulfate concentrations.
- **Groundwater management system** – this includes groundwater will be extracted from the aquifer using a borefield to minimise seepage into the pit and for advance mine dewatering. Bore water is expected to be of reasonably high quality and will be kept separate from dirty and contaminated water.
- **Spoil (overburden dump) runoff catchments** – the mine spoil dump runoff is expected to be substantially less contaminated than the process water system and contaminated water systems and possibly suitable for discharge in accordance with proposed discharge criteria. From experience at other coal mines in Queensland it is likely that spoil runoff will produce low salinity, and have potentially elevated sediments which can be settled out prior to discharge. However there remains some uncertainty regarding the potential variability and extremes of spoil runoff water quality and it is possible that spoil runoff and associated surface seepage may also have elevated salinity, and slightly elevated pH. The potential variability of spoil runoff and associated surface seepage quality and implications for the proposed mine water management are discussed further below.

The groundwater management system is discussed in the Groundwater technical report (Volume 5, Appendix G).

11.5.7.4 Spoil runoff quality and implications for mine water management

The potential variability and range of water quality from the spoil dump runoff and surface seepage will be highly dependant on overburden geochemistry, management practices including segregation of different types of overburden materials from the mining operations, methods of placement in the spoil dumps, status of spoil dump completion towards final profiles throughout the mine life, and measures to control surface erosion from the spoil dumps.

An initial geochemical assessment of the overburden materials has been undertaken by SRK Consulting Australasia Pty Ltd (2010) (Volume 5, Appendix J). The geochemical assessment found that:

- Test results indicate that between 81% and 94% of the overburden is non acid forming (NAF) and less than 7% may be potentially acid forming (PAF). Indications are that the PAF material has low acid forming capacity (sulphide content of less than 0.2%). The acid forming potential of the remaining 6 to 13% of overburden is uncertain.

- Neutral waters contacting the overburden would be expected to remain relatively neutral. Salinity release (probably sourced from contained pore water) would be expected to occur over the short term (as a short term flush). Salinity release would not be expected to occur in the longer term. Metal and metalloid concentrations of waters contacting the overburden are not expected to increase significantly.
- Dispersivity testing conducted on samples selected from overburden indicates that the claystones, mudstones and clays are dispersive or potentially dispersive. The siltstones and sandstones are slightly dispersive (occasionally dispersive).

The above conclusions indicate low overall 'net' potential for water contamination from the overburden materials as a whole, however the potential the variability between overburden material types indicates that spoil management will be important and the overburden dump design will be important. A potential concern is that clay materials indicate some potential to produce runoff with slightly elevated salinity (acid base test extracts with EC in range of 1,000 to 4,000 µS/cm, and distilled water extracts with sulfate concentrations in the range of 20 to 200 mg/L, chloride concentrations in the range of 100 to 800 mg/L, and sodium concentrations in the range of 70 to 500 mg/L). These results indicate some potential for saline runoff from the clay overburden materials however it should be noted that geochemistry analyses and methods are typically focussed on characterising leachate (seepage) quality and may not necessarily provide good representation of likely runoff quality in actual field conditions.

The EIS studies and mine waste section (Volume 2, Section 16) have identified a preferred strategy for potentially saline materials to be placed at depth in the spoil dumps and be covered with benign materials. This strategy if deemed compatible with economic mining methods will assist to reduce the potential for saline runoff from the spoil dumps. The overburden placement strategy and design will also need to be supplemented with measures to control erosion from the spoil dumps.

Broader experience from coal mines in the Bowen Basin indicates that spoil runoff can often be of suitable quality to allow discharge following settling in sediment dams providing that spoil dump infiltration is limited, erosion is adequately controlled and also subject to the geochemistry of spoil materials. The Alpha Project will be the first in the Galilee Basin and recognises that overburden characteristics may be different to the experience and knowledge of Bowen Basin overburden materials. Hence, a precautionary approach for management of spoil dump runoff and surface seepage is proposed until sufficient operational monitoring and knowledge is obtained.

Overall, the expectations from available data is that if the spoil dumps are properly managed, the spoil dump runoff could be suitable for discharge under controlled conditions in accordance with the proposed criteria which are presented below.

To allow for potential uncertainty or variability, the planning of the mine water management system has also considered a conservative scenario where spoil dump runoff and surface seepage waters may not be suitable for controlled discharge and may need to be contained within the mine water management system.

11.5.7.5 Proposed controlled discharge criteria

From experience in managing mine affected waters at coal mines in Queensland where acid forming potential is low and adequately managed and sediments are adequately managed, the salinity of mine water is the dominant contaminant of concern. Experience shows that if salinity levels can be managed other contaminants such as sulphate, sodium, and chloride can also be adequately managed. The proposed criteria for controlled discharges have therefore focussed on determining appropriate salinity release limits.

The water quality objectives for the Project watercourses (identified in Section 11.4.6) apply to in-stream receiving water conditions to protect the in-stream environmental values are not directly translatable as enforceable discharge limits. This is recognised in ANZECC 2000 guidelines which caution against using receiving water quality objectives to define discharge criteria viz: "*They are not intended to be an instrument to assess 'compliance' and should not be used in this capacity*".

The proposed controlled discharge criteria (end-of-pipe release into the streams) for the Project have been developed based on recent changes introduced by DERM to standardise and improve licensing of discharges from coal mines based on the following studies and guidelines:

- Review of the Fitzroy River Water Quality Issues (Hart, 2008);
- A study of the cumulative impacts on water quality of mining activities in the Fitzroy River Basin (formerly EPA now DERM, April 2009);
- Conditions for Coal Mines in the Fitzroy Basin - Approach to Discharge Licensing (DERM, June 2009); and
- Final Model Water Conditions for Coal Mines in the Fitzroy Basin (DERM September 2009).

The following key factors and objectives are drawn from these studies and guidelines:

- Discharges will be managed such that the water quality (electrical conductivity) downstream of discharge point will not exceed 1,000 μS/cm EC. This is based on information in the review of Fitzroy Basin water quality (Hart 2008) that identifies that salinity effects on macro-invertebrates are unlikely at or below 1,000 μS/cm.
- Discharges will only be allowed when there is a minimum natural flow in the receiving stream (upstream of the discharge point, and not affected by other point sources). This ensures that discharge waters can adequately mix with the receiving stream waters with the aim to achieve the limits downstream of the discharge point.
- The discharge rate will be limited to 20% of the receiving stream upstream flow. Or, in other words the minimum volumetric dilution of the discharge will be 1:5. This is an essential element that will be used to control the loading of the discharge relative to the stream flow to remain below the recommended downstream maximum EC.

These objectives for managing controlled discharge are proposed to be incorporated into the controlled discharge criteria for the Project. The criteria will be regulated through the Water conditions in the Environmental Authority and be supplemented with conditions that require implementation of a Receiving Environment Monitoring Program (upstream and downstream) and reporting to the Regulatory Agency (DERM) with details of each controlled discharge event.

For establishing the discharge criteria it is important to understand the difference between the EC maximum limit of 1,000 μS/cm identified by Hart (2008) at which macro-invertebrates are unlikely to be affected, and the median EC water quality objective identified from QWQ guidelines. The EC water quality objective based on QWQ guidelines is an objective for the median water quality (assessed over a number of samples/instances) when there is stream flow. Individual instances of in stream EC exceeding the median water quality objective do not necessarily infer that physico-chemical stress on the aquatic ecosystem values will occur, and occasional instances of elevated EC values do occur naturally. Physico-chemical stress on the aquatic ecosystem is inferred as a potential concern when the median in stream EC exceeds the water quality objective. Controlled discharges from the mine water management system will not occur in every instance that there is stream flow and will not necessarily impact on median EC in the stream. The greater relevance for controlled discharges is the potential short term impact that may occur during the infrequent discharge events. To ensure that discharges are managed to protect the aquatic ecosystem values, a maximum limit of in stream EC (such as 1000µS/cm identified by Hart to protect macro-invertebrates) is more directly applicable to derive discharge limits to adequate control potential short term impacts.

The proposed controlled discharge criteria will only allow discharges to occur when the upstream flow in Lagoon Creek equals or exceeds 1 m^3/s. The proposed criteria will limit the discharge rate to 20% of the upstream Lagoon Creek flow. These criteria applied in combination will ensure that all controlled discharges achieve a 1:5 dilution of the discharge waters with the receiving stream flow.

For the purpose of undertaking dilution calculations to derive an appropriate end-of-pipe discharge limit for EC (as the measure for salinity), a conservatively high background upstream salinity of 500 µS/cm was assumed. This is conservative because a higher background upstream salinity infers less ability for the stream to assimilate salinity and remain below the downstream maximum EC limit. The 500 µS/cm assumption is a conservative assumption for background upstream salinity based on the observations of the Native Companion Creek data which shows that electrical conductivity is typically in the range of 100 to 200 µS/cm (i.e. actual data demonstrates greater capacity to assimilate salinity compared to the assumed value).

An end-of-pipe electrical conductivity limit of 2,000µS/cm is proposed for controlled discharges in combination with the criteria to ensure adequate dilution. With the assurance that 1:5 dilution is required for the controlled discharges, the net downstream electrical conductivity will not exceed 750 µS/cm if the upstream Lagoon Creek flow EC is assumed to be 500 µS/cm. If a more realistic estimate of upstream flow EC is applied at say 200 µS/cm, with the same criteria for end-of-pipe controlled discharge EC (2,000µS/cm), the net downstream electrical conductivity will not exceed 500 µS/cm.

The proposed End-of-Pipe discharge EC limit of 2,000 µS/cm in combination with the criteria to ensure 1:5 dilution, should ensure that the downstream salinity (EC) will not effect macro-invertebrates (i.e. downstream EC will be substantially less than 1,000µS/cm).

11.5.7.6 Expected frequency, source and location of controlled discharges

The proposed Project mine water management system assessed with water balance modelling has identified that in dry, average, and wet weather years the overall site water balance will operate in a net deficit and will need to import raw water from third party suppliers to maintain supply operations. With the expectation of a frequent deficit of mine water, the Project will not be seeking to make frequent controlled discharges as the water captured in the mine water management system will be valuable to maintain mine operations. Under most circumstances the ability to contain, store and reuse mine water will be preferred over releasing mine water and corresponding need to import more raw water. The reasons that the Project requires allowance for controlled discharge criteria are to:

- allow flexibility in the mine water management systems ability to free up available storage in short duration intense rainfall events (when there is substantial stream flow in Lagoon Creek and corresponding capacity to discharge);
- allow flexibility in the mine water management systems ability to manage exceptionally high wet season rainfall (rare events that exceed design storage allowance) as it is preferable to make a compliant controlled discharge rather than allow dams to passively overflow (uncontrolled discharges); and
- to provide a balance between containment of water in the mine water management system (increase potential impacts of reduced downstream watercourse flow volumes) against the benefits of allowing safe discharge to supplement downstream watercourse stream flows (i.e. reduced impacts on downstream flow volumes).

The proposed controlled discharges of compliant quality mine water are to be released from the Spoil Runoff water management system. The spoil runoff water system is expected to have the lowest salinity of the surface water runoff streams across the mine water management system.

At this concept stage, for simplicity in operations, the proposed location for controlled discharges is from one location at Spoil runoff dam (SRD)21 near the northern end of MLA 70426. The location for controlled discharges will be reviewed as part of detailed design of the water management system. The further review will consider the practicality of the likely pumping distances and transfer dams required to consolidate compliant quality water at the controlled discharge location at the northern end of the mine. If a single controlled discharge location is not deemed practical (for example, if the pumping time required to transfer mine water to the northern end may be unsuitable to ensure appropriate timing of discharge relative to stream flow) multiple controlled discharge points from the spoil runoff system may be applied for as part of final design. It is acknowledged that the operation of multiple controlled discharge points could substantially complicate the controlled discharge operations particularly to ensure the require dilution of the controlled discharges are achieved relative to stream flow. If it is deemed necessary to require multiple controlled discharge points due to practical constraints of water management system infrastructure, the controlled discharge criteria (EA conditions) will be structured such that the maximum combined instantaneous discharge rate of all discharge locations does not exceed 20% of the upstream Lagoon Creek flow (i.e. this will ensure that the dilution ratio criteria is enforced).

The proposed mine water management system and controlled discharge criteria will not allow controlled discharges from the pit water dams or environmental dams, including proposed mine water containment dams on the eastern side of Lagoon Creek (CHPP areas and TSF).

11.5.7.7 Design criteria to limit uncontrolled discharges

The objective to limit the potential for uncontrolled discharges (overflows) from the mine water management system is to ensure that adequate storage capacity is designed into the mine water management system to provide capacity to contain extreme wet season rainfall and corresponding runoff volumes. In simple terms the objective is to ensure the probability of an overflow is very low.

The criteria to limit the probability of an uncontrolled discharge are applied through conditions in the Environmental Authority for Regulated Dams (otherwise known as Hazardous Dams). The criteria are specified according the hazard category of each dam for the potential hazard of failure to contain the contents of the dams (i.e. hazard of overflow). The hazard category of the mine water dams (and tailings dams) is determined using the "Technical Guidelines for environmental management of mining and exploration activities (DME, 1995)", and in the future will be in accordance with the DERM "Manual for Assessing Hazard Categories and Hydraulic Performance of Dams" which is currently being prepared and will apply when endorsed by the State Government.

Hazard categories for the proposed dams for the mine water management system will be determined as part of detailed design when the geometry of the dams, their failure hazards, and overflow locations can be defined to the level required to assess the specific hazard for each dam. At this concept stage, it is envisaged that most of the Project mine water dams will be defined as a significant hazard category.

The criterion for storage capacity to limit the probability of overflow can be applied as either a Design Storage Allowance (DSA) to ensure adequate available storage capacity at the start of each wet season to contain runoff from the design probability wet season rainfall, or to limit the probability of an overflow demonstrated through water balance modelling taking account of operating procedures for the mine water management system. The storage criteria for significant hazard dams are expected to be:

- Sufficient capacity to contain 1 in 20 AEP wet season rainfall (conservatively assuming 100%) runoff when using the DSA deciles method (as defined in 1995 DME guidelines, and future DERM Manual for Dams); or
- Probability of overflow to be less than 1:100 AEP when assessed using the detailed water balance modelling method (future DERM 'Manual for Dams' when this guideline is endorsed).

The proposed EA conditions for Regulated Dams will also include requirement for annual update of the hazard assessment, and annual review of the mine water system capacity to ensure sufficient storage capacity to limit the potential for uncontrolled discharges. The proposed condition will also require a Mandatory Reporting Level (MRL) to be defined for each dam which controls the operation of the available storage volume below the spillway crest, equivalent to the lower of the 1:100 AEP 72-hour storm or the wave allowance 1:100 AEP wind speed. The conditions will require that DERM must be notified when the MRL level is exceeded.

11.5.7.8 Overall arrangement of the proposed mine water management system

The proposed water management system is described in detail in the Site Water Management System and Water Balance technical report (Volume 5, Appendix F3).

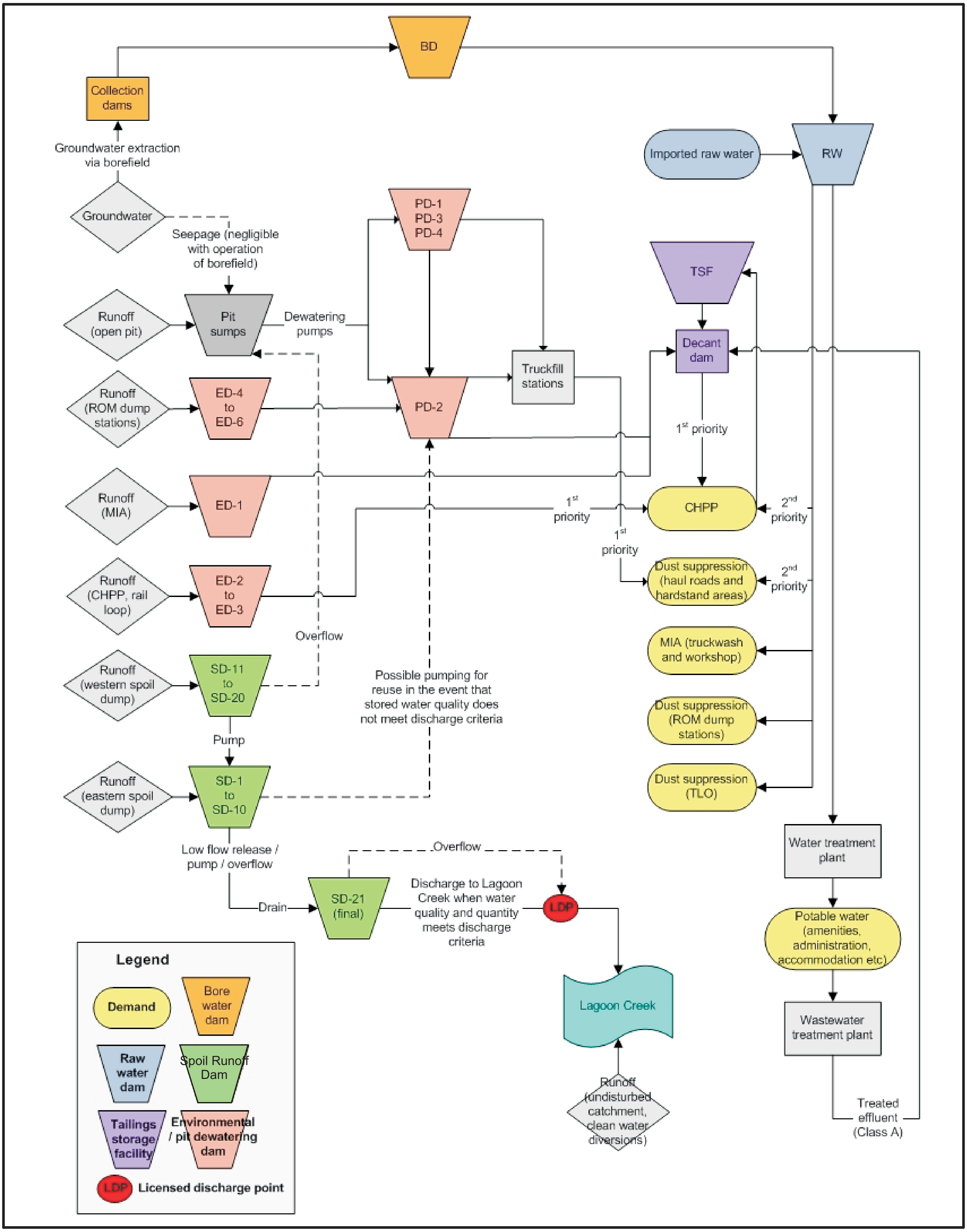
Figure 11-4 presents a schematic diagram of the mine water management system. Figures 11-5 to 11-9 present the concept staging of the implementation of mine water management infrastructure over the life of the mine.

The concept layout of the proposed mine water management system are presented to demonstrate that the required mine water management infrastructure can be accommodated in the mine layout plan. Geotechnical and hydro-geological investigations for the mine water dam sites are to be undertaken as part of detailed design to confirm the suitability of the dam locations and to develop the dam designs and mitigation (safety) measures to the standards required for Regulated Dams. The approval process for the Regulated Dams occurs after EIS approval, and the EA conditions will prohibit construction of Regulated (Hazardous) dams unless approved by DERM. Certified detailed design documentation, with geotechnical and hydrological information required to support the design to the required standards will be submitted when applying for approvals for each of the Regulated Dams.

11.5.7.9 TSF and Process Water System

The Alpha Coal Tailings Storage Facility Concept Design Report (Volume 5, Appendix J) provides details on the tailings management strategy for the Project and associated interaction with the process water system. The tailings will deposit in the TSF and the excess water will be decanted into a separate decant dam downstream of the main TSF embankment where pumps and pipelines will return the water to the CHPP for reuse. A seepage interception drainage system will be installed along the external perimeter toe of the TSF embankment. The TSF seepage interception system will drain into the decant water dam.

The TSF and decant dam will be classified as Regulated (Hazardous) Dams and designed, built and operated to the standards required for Regulated Dams including sufficient storage to limit the probability of overflow. Upslope clean water diversion drains will be constructed around the eastern perimeter of the TSF to minimise the catchment area of the TSF and ensure that the storage requirements to contain wet season rainfall are practical. All the clean water diversion drains will be sized to contain the peak flow from a 100 year ARI storm duration corresponding to the time of concentration from the upslope catchment. The clean water diversion drains will form part of the regulated extent of works for the TSF Regulated Dam, have monitoring and maintenance requirements defined in the mandatory operations plan for the TSF and be included in the annual surveillance of the TSF.



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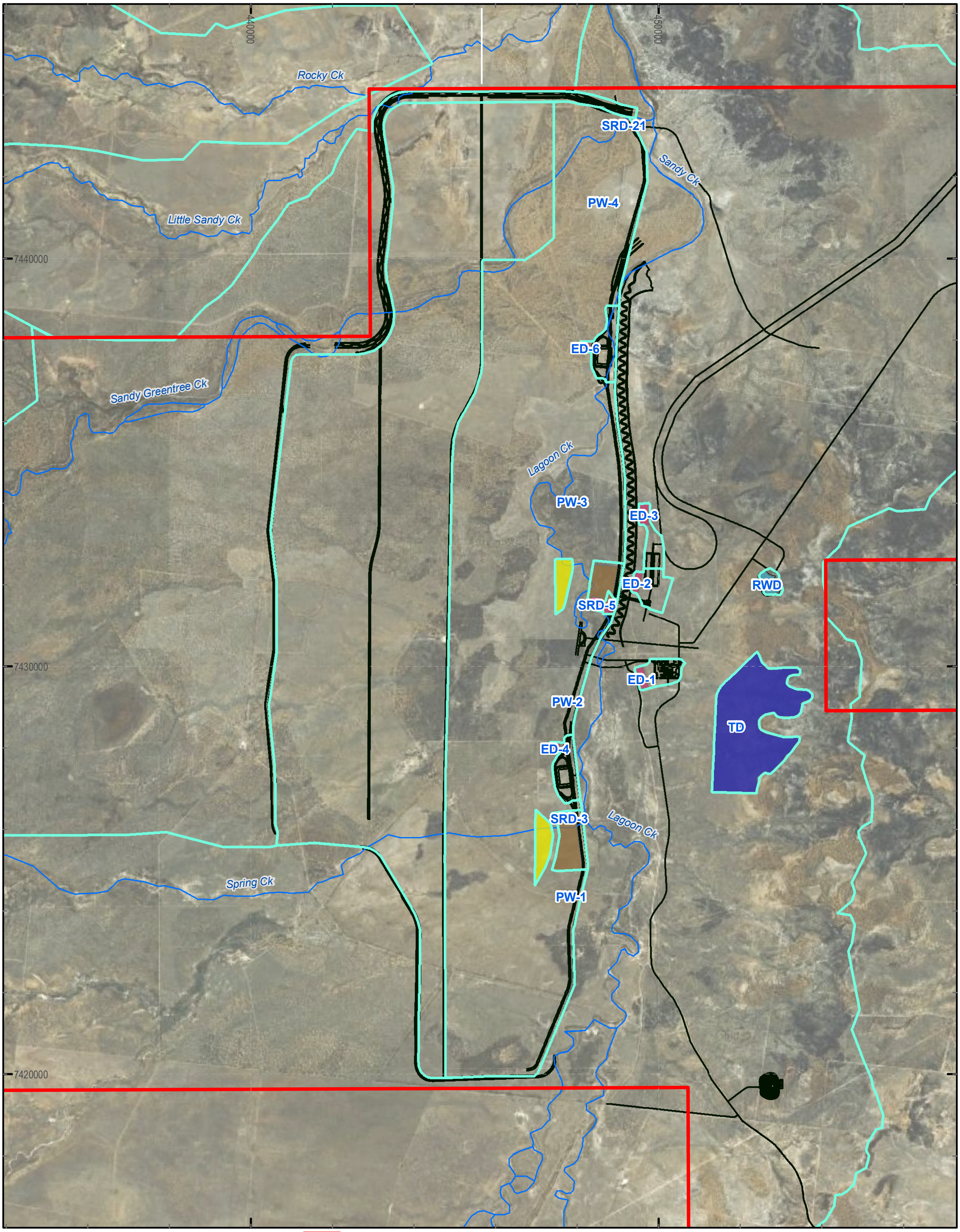
WATER MANAGEMENT SYSTEM SCHEMATIC

Job Number | 4262 6580
Revision | A
Date | 24-09-2010

Figures: 11-4

File No: 42626580-g-2117.cdr



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Mining Lease Application (MLA70426) Boundary
Year 1 Catchments
Watercourse
Infrastructure

Year 1 Dams
- Environmental Dam
- Pit Dewatering Dam
- Raw Water Dam
- Spoil Runoff Dam
- Tailings Storage Facility

Year 1 Landuse
- Pit
- Spoil

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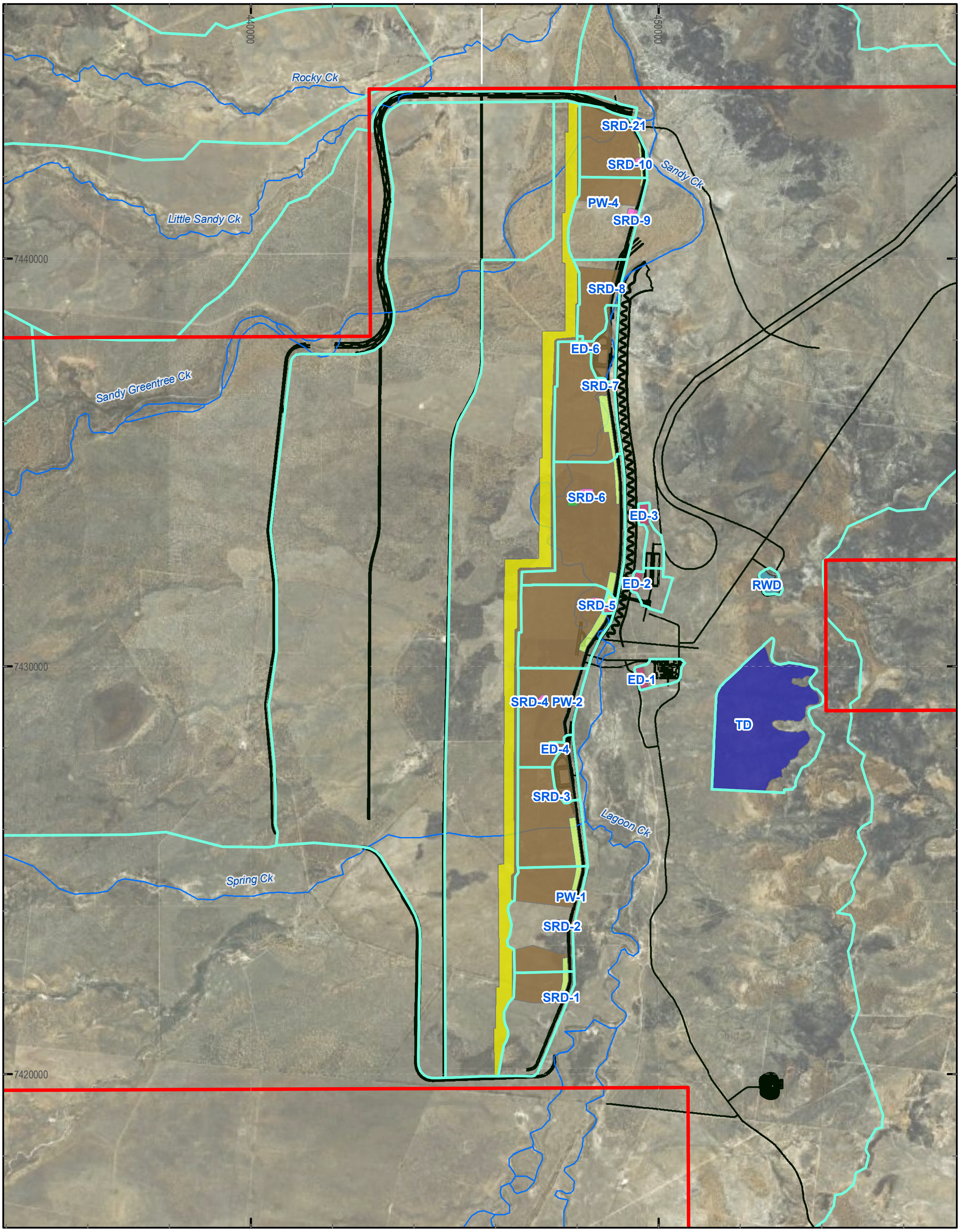
Environmental Impact Statement

CONCEPT WATER MANAGEMENT SYSTEM - YEAR 1

Job Number | 4262 6580
Revision | A
Date | 24-09-2010

Figure: 11-5

File No: 42626580-g-2118.mxd



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Mining Lease Application (MLA70426) Boundary
Year 5 Catchments
Watercourse
Infrastructure

Year 5 Dams
Environmental Dam
Pit Dewatering Dam
Raw Water Dam
Spoil Runoff Dam
Tailings Storage Facility

Year 5 Landuse
Pit
Rehabilitation
Spoil

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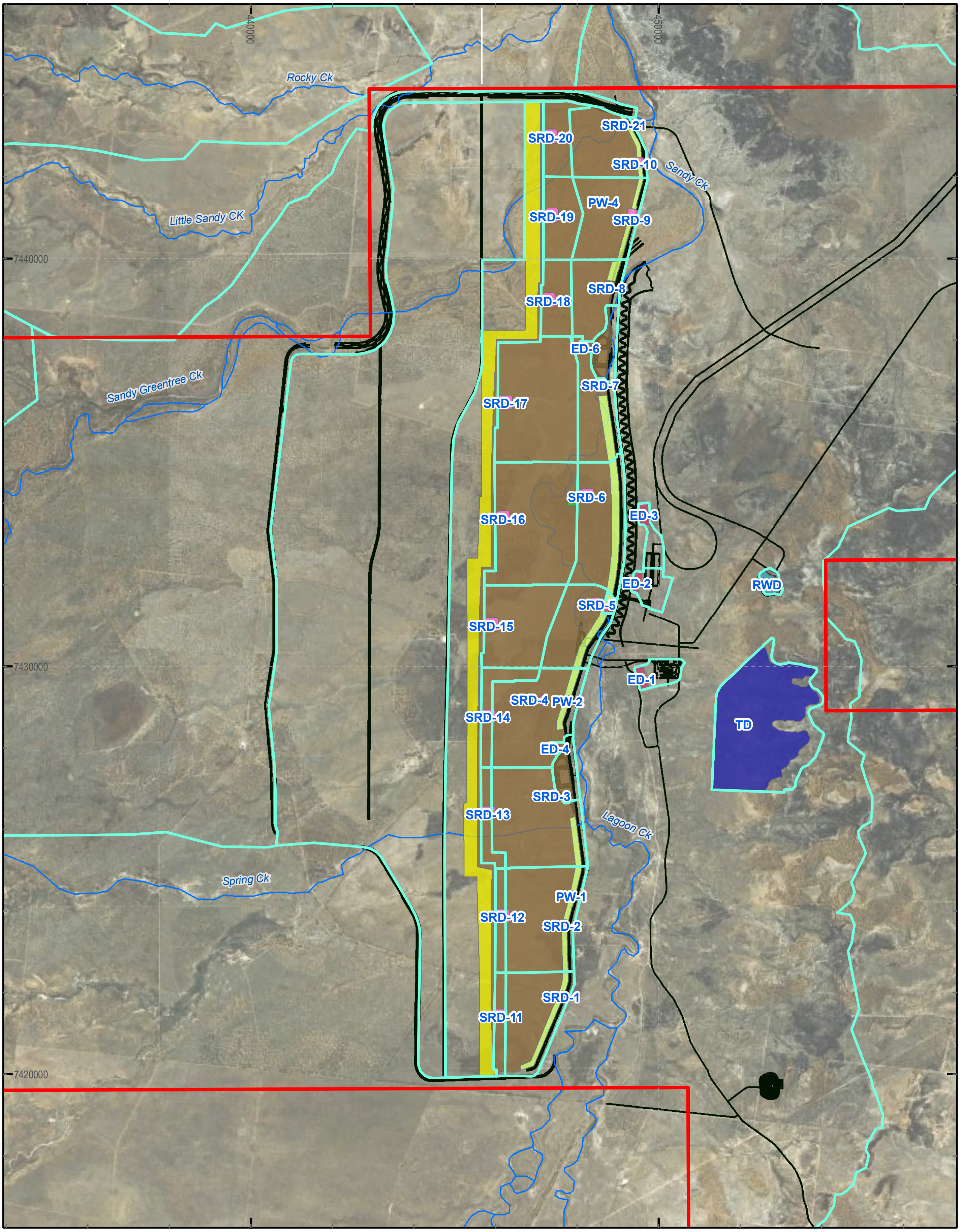
CONCEPT WATER MANAGEMENT SYSTEM - YEAR 5

Job Number	4262 6580
Revision	A
Date	24-09-2010

Figure: 11-6

File No: 42626580-g-2119.mxd



Source: Data supplied by Parsons Brinckerhoff

Legend	
Mining Lease Application (MLA70426) Boundary	
Year 10 Catchments	
Watercourse	
Infrastructure	

Year 10 Dams

- Environmental Dam
- Pit Dewatering Dam
- Raw Water Dam
- Spoil Runoff Dam
- Tailings Storage Facility

Year 10 Landuse

- Pit
- Rehabilitation
- Spoil

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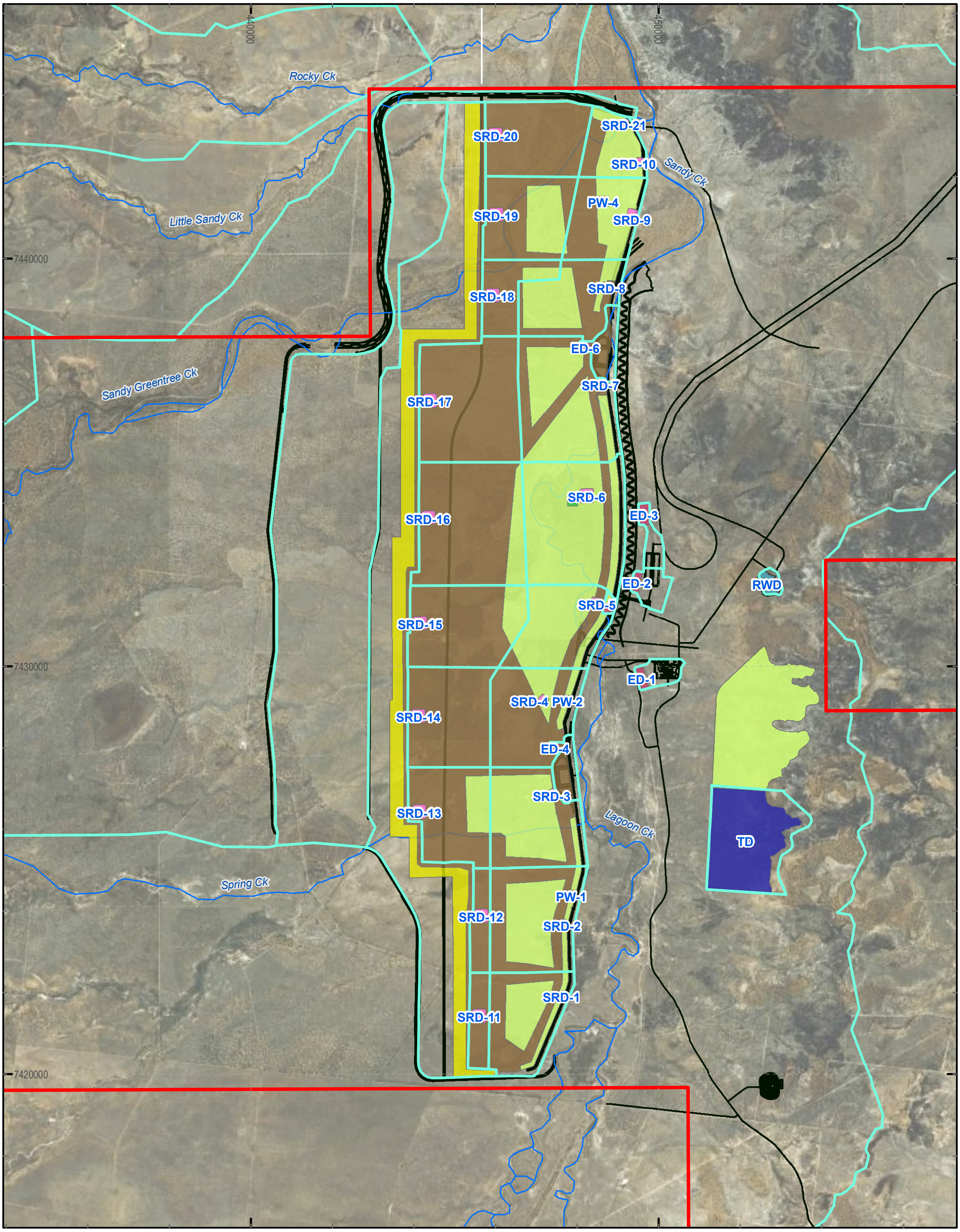
CONCEPT WATER MANAGEMENT SYSTEM - YEAR 10

Job Number 4262 6580
Revision A
Date 24-09-2010

Figure: 11-7

File No: 42626580-g-2120.mxd



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Mining Lease Application (MLA70426) Boundary
Year 20 Catchments
Watercourse
Infrastructure

Year 20 Dams

Environmental Dam
Pit Dewatering Dam
Raw Water Dam
Spoil Runoff Dam
Tailings Storage Facility

Year 20 Landuse

Pit
Rehabilitation
Spoil

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Alpha Coal Project
Environmental Impact Statement

CONCEPT WATER MANAGEMENT SYSTEM - YEAR 20

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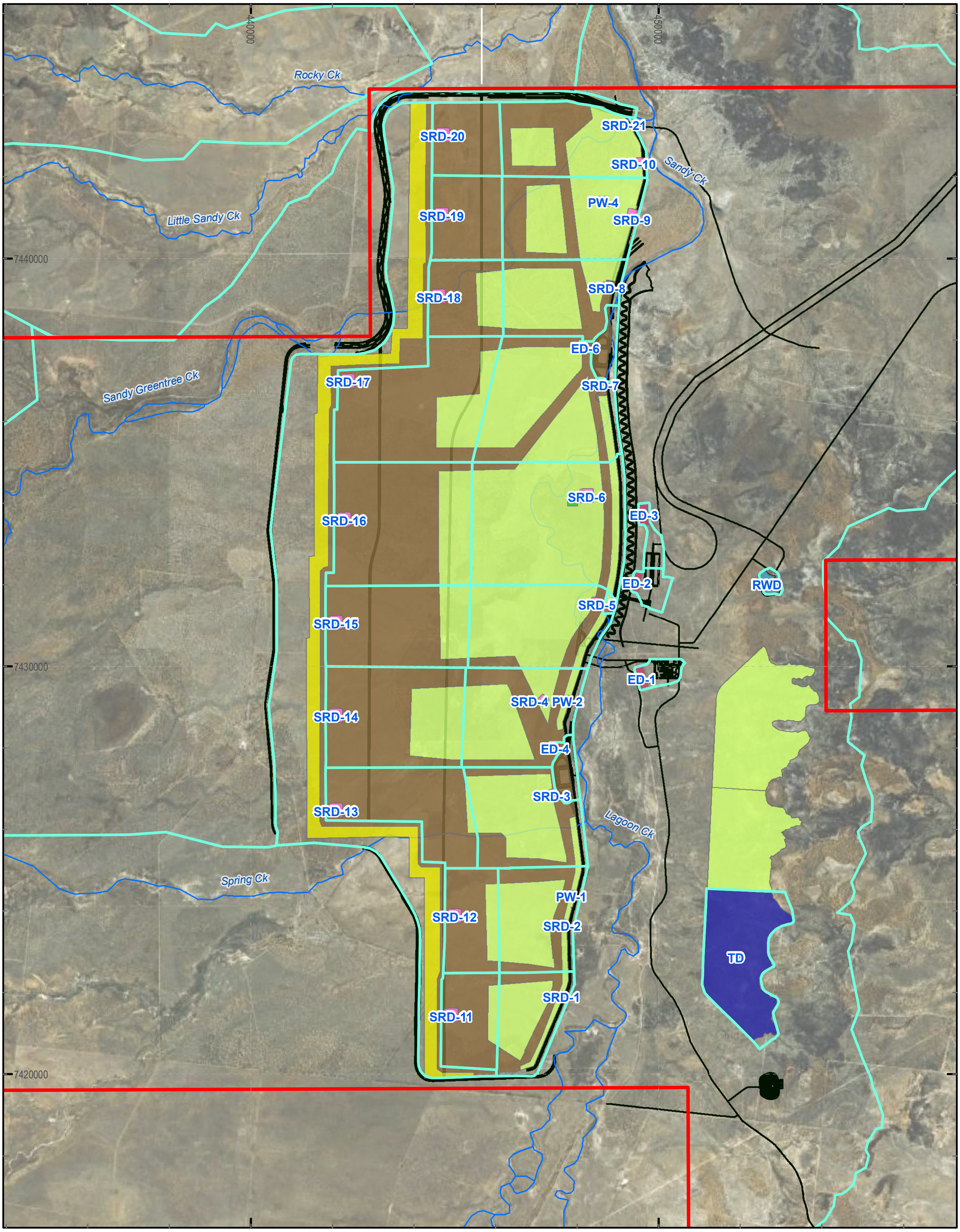
Revision A
Date 24-09-2010

Figure: 11-8

File No: 42626580-g-2121.mxd



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Mining Lease Application (MLA70426) Boundary
Year 30 Catchments
Watercourse
Infrastructure

Year 30 Dams

Environmental Dam
Pit Dewatering Dam
Raw Water Dam
Spoil Runoff Dam
Tailings Storage Facility

Year 30 Landuse

Pit
Rehabilitation
Spoil

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Environmental Impact Statement

CONCEPT WATER MANAGEMENT SYSTEM - YEAR 30

Job Number 4262 6580
Revision A
Date 24-09-2010

Figure: 11-9

File No: 42626580-g-2122.mxd

11.5.7.14 Contaminated water management system

The proposed contaminated water management system will comprise:

- Detailed mine planning and overburden dump design controls to minimise the catchment areas draining into the mine pits. This will include clean water diversion drains on the western (highwall) side of the mine pits to divert upslope overland sheet flow away from the pits.
- Small sumps in the pit floor to collect and contain local surface water runoff from the pit floor, high wall, low wall and end walls.
- Pit dewatering pumps and associated dewatering pipelines to transfer pit water to the nearest pit dewatering dam. Small staging dams may be required as part of the transfer system for pit water.
- A drainage system to convey runoff from disturbed areas to the nearest environmental dam.
- Environmental and pit dewatering dams to store and contain contaminated water from the above sources. The location of storages and the layout of the drainage system will minimise the areas draining to these dams, so as to optimise the storage requirements and reduce the probability of overflows.
- A return water pump and pipeline system from each environmental and pit dewatering dam to transfer stored water to either:
  - a nearby truck fill station (for haul road dust suppression)
  - the CHPP
  - the tailings decant dam.
- A borefield to minimise groundwater seepage into the pit.

Environmental dams on the eastern side of Lagoon Creek (that capture runoff from the CHPP, MIA, coal stockpile areas) will be sized to provide sufficient storage for the criteria corresponding to a significant hazard Regulated Dam to limit the potential for overflow.

Pit dewatering dams (receiving water from the pits) are proposed to be 'turkey nest' type dams with minimal external catchment beyond the immediate dam surface area. For the purposes of conceptual design and impact assessment, pit dewatering dams were sized to achieve no discharge when operated as part of the overall site WMS determined through water balance modelling assessed with 100 years of climatic data.

Water captured in the contaminated water management system will be used as a priority to meet water demands for mining operations in order to minimise the volume of stored water and therefore limit the probability of overflow. Imported water will only be used to meet demands when there is a water deficit in the mine water management system or high quality water is required. During exceptionally high prolonged wet weather periods, surplus contaminated water will be stored in-pit until storage capacity becomes available in the ex-pit dams. This contingency will be governed by operating rules for the mine water management system.

Mine water from the contaminated mine water system will not be used for dust suppression of the section of the heavy vehicle access road that traverses across Lagoon Creek.

11.5.7.15 Spoil runoff water management system

The spoil runoff water management system will comprise dams and drains to intercept runoff from the overburden dump. The eastern portion of the overburden dump drains east, and dams will be sited to intercept runoff to prevent uncontrolled discharge to Lagoon Creek. The eastern spoil runoff system dams (SRD1 to SRD10) will overflow to a drain running along the western side of the main haul road inside the flood protection levee. The main drain will flow to the final SRD (SRD21), where controlled discharges can be made into Lagoon Creek.

The western portion of the overburden dump drains towards the open cut mine pits and dams will be located to intercept spoil runoff before it reaches the pit. Water captured in the western spoil runoff dams (SRD11 to SRD20) will be pumped back to the eastern spoil runoff dams. The western spoil runoff dams will overflow to the mine pit during large storm events.

Key specific design elements of the spoil runoff system to enable and ensure appropriate control of compliant discharges to Lagoon Creek will include:

- An engineered outlet gate or variable pumping system that can control the discharge with ability to stop the discharge at any time;
- Hydraulic design of the gate or pumping system such that the discharge rate can be precisely controlled;
- Hydraulic design such that gate or pump flow can be rated to allow the discharge rate to be precisely measured;
- Provide access to enable sampling / measurement of the discharge water (end-of-pipe monitoring); and
- Discharge location and control systems are accessible in wet weather (as discharges will only be permitted when the Lagoon Creek is flowing).

Active discharges from spoil runoff system will be limited to the proposed controlled discharge criteria. In the event that water stored in spoil runoff system dams cannot be discharged, this water will be reused onsite to minimise the probability of overflow.

11.5.7.16 Referrable dams

The difference between Referrable Dams (clean water dams) administered under the Water Act and Regulated (hazardous dams) administered under the EP Act is described in Sections 11.2.2 and 11.2.3.

All of the mine water dams deemed to contain Hazardous substances will be Regulated Dam and be licensed through the EA administered under the EP Act.

The only dam which could potentially be classified as a Referrable (clean water dam) under the Water Act is possibly the Raw Water dam where bulk water supply from third party suppliers will be stored prior to use in the mine operations. At the current concept stage of the Project Design, the raw water dam is anticipated to be approximately 400 ML capacity and would not be classified as a Referrable Dam.

11.5.7.17 Site water balance model

A water balance model of the Project was developed in GoldSim, which widely used software for mine site water balance and water resource simulation studies. The water balance model was developed and refined to a level of detail suitable for concept design of water management infrastructure and to assess expected performance for purpose of the EIS studies. A detailed description of the water balance model development is presented in Volume 5, Appendix F3.

Runoff parameters for the water balance model were based on calibration of natural catchment runoff characteristics to available DERM stream gauging data, and runoff parameters for the mine water system catchments were adjusted to represent expected runoff rates from the mine water management system (disturbed land) catchments.

The water balance model included representation of the both the mine water management system catchments and clean stream flow watercourse catchments (including clean water bypass system) to enable assessment of the downstream hydrological impacts (i.e. the impact of the mine water system containment removing a small portion of the natural catchment system).

For simplicity the TSF and decant dam were not explicitly modelled. Water sent to the TSF, drained, to the decant dam, and returned to the CHPP can be effectively considered as a closed system and this assumption does not materially affect the mine water balance conclusions.

11.5.7.18 Model catchment data

Catchment boundaries for the water management system were delineated using the conceptual mine plans. The area draining into the mine water management system increases steadily over the life of the Project, as the pits progress to the west and spoil dump areas expand. The change in land use breakdown within the water management system catchment is summarised in Table 11-11.

Table 11-11 Change in land use for the surface water management catchment

Land Use	Year 1 (ha)	Year 5 (ha)	Year 10 (ha)	Year 20 (ha)	Year 30 (ha)
Undisturbed	47	4,153	1,544	1,905	1,779
Rehabilitated Spoil	0	114	297	3,222	5,618
Industrial / hardstand	318	318	318	318	318
Open Pit	92	696	789	909	980
Unrehabilitated Spoil	135	2,616	5,207	5,823	6,913
Raw Water Dam	27	27	27	27	27
Tailings dam	1,816	1,816	1,816	1,816	1,816
Total	**2,435**	**9,740**	**9,998**	**14,022**	**17,452**

The contributing catchment inflow was modelled for each storage in the water balance model by summing the products of unit runoff depth time-series (derived using the rainfall-runoff models) and the corresponding partial catchment areas.

11.5.7.19 Model storage capacities

Environmental dam capacities adopted in the water balance model were sized for the 2% AEP 3-month critical wet season rainfall criteria for significant hazard dams.

Pit dewatering dams with an assumed 'turkeys nest' configuration (i.e. minimal external catchment area) were assumed to receive mainly pumped inflows from the open cut mine pit sumps. Pit dewatering dams were sized based on the results of historical water balance modelling, to achieve no overflow for the 110-year climate sequence in the water balance model simulation.

No limit was applied in the water balance model for the volume of in-pit sump storages.

Conceptual stage-storage relationships for dams were included in the water balance model and were based on an assumed depth of 5.5 m and side slopes of 1:3 (V:H). This assumption will be refined at as part of the detailed design.

11.5.7.20 Mine water management system operating rules

The following operating rules are proposed for the concept mine water management system. These will be refined as part of final design of the mine water management system.

- Pumping from pit sumps to pit dewatering dam PW1, PW3 and PW4 stops if the dam capacity exceeds 75%.
- Pumping from pit sumps to PW2 stops if the dam capacity exceeds 50% (trigger level set lower for PW2 to ensure adequate capacity is available to receive pumped inflows from environmental dams).
- During extended wet periods, water will be remain in the mine pits until sufficient storage capacity becomes available in the pit dewatering dams.
- Pumping from environmental dam (ED4, ED5, ED6, PW1, PW3 and PW4 to PW2) occurs when the capacity of these dams exceeds 25.9 ML (maximum daily pump rate). Pumping stops if the volume of PW2 exceeds 75%.
- Demands for the mine area dust suppression (water truck fill stations) are sourced from PW1, PW2, PW3 and PW4. The demand was apportioned evenly between these four dams. If adequate water is not available from a pit dewatering dam, the spoil runoff system dams or raw water dam can be used to satisfy the dust suppression demand.
- The CHPP demand is sourced from the following dams (in order of priority):

1. Tailing decant dam and Environmental dams around the CPP area (eastern side of Lagoon Creek). Water will be sourced from the dam with the highest water level which will ensure that the available storage capacity for wet season rainfall will be equally maintained across the dams.
2. The main pit dewatering dam PW2. When PW2 is empty (e.g. prolonged dry weather conditions, mine water in PW2 can be supplemented from the spoil runoff dams).
3. Raw water dam.

- The MIA, sprayer and potable water demands are always sourced from the raw water dam (as high quality water is required).
- When the raw water dam falls below 50% storage, imported water (pipeline water supply) is supplied into the raw water dam.

The following pump rates were adopted in the water balance model:

- pit sump to pit dewatering dam – 25.9 ML/day each (300 L/s)
- environmental dam / pit dewatering dam to PW2 – 25.9 ML/day each (300 L/s)
- western spoil runoff system dams to eastern spoil runoff system dams – 25.9 ML/day each (300 L/s)

For water balance modelling purposes, it has been assumed that bore water will be pumped to the raw water dam at a rate equal to the daily extraction rate from the aquifer. The expected groundwater extraction rates are described in Volume 2, Section 12.

11.5.7.21 Model water sources

Water inputs for the Project comprise:

- surface water runoff;
- groundwater (either extracted from the dewatering borefield or from seepage into the mining void); and
- imported raw water (pipeline water supply).

Groundwater will be extracted using a borefield in order to minimise seepage into the mine pits. Extracted groundwater would be pumped to the raw water dam via several bore water collection dams.

Preliminary borefield extraction rates were estimated, and are further discussed in the Groundwater technical report (Volume 5, Appendix G). Estimates for the 'low to average aquifer transmissivity case' are provided in Table 11-12.

Table 11-12 Estimated borefield extraction rates

Year	Extraction rate (ML/yr)
Year 1	1,577
Year 5	1,261
Year 10	946
Year 20	631
Year 30	631

11.5.7.22 Estimated water demands for mine operations

Mine water demands for the Project comprise:

- CHPP make-up water;

- Haul road and hardstand watering (dust suppression);
- Workshop and vehicle wash (MIA);
- Potable water; and
- Miscellaneous uses, such as construction water.

CHPP make-up water requirements, net of tailings return water, are provided in Table 11-13. The CHPP water make-up demand estimates equate to approximately 190 L per tonne of ROM coal which is comparable to estimates for other coal mines with efficient operations.

Table 11-13 CPP make-up water demand estimates

Year	ROM coal (Mt/yr)	CHPP make-up water (ML/yr)
Year 1	26.5	4,981
Year 5	43.2	8,111
Year 10	43.2	8,111
Year 20	43.2	8,111
Year 30	43.2	8,111

Mine water demands for dust suppression on haul roads, hardstand areas and the ROM stockpiles are summarised in Table 11-14.

Table 11-14 Dust suppression demand estimates

Year	Haul road and hardstand (ML/yr)	ROM dump and transfer station sprayers (ML/yr)	Total dust suppression demand (ML/yr)
Year 1	1,747	205	1,952
Year 5	1,996	205	2,201
Year 10	2,307	205	2,512
Year 20	2,929	205	3,134
Year 30	3,552	205	3,757

Water will be required in the MIA for use in the vehicle wash and workshop. It will be sourced from the raw water dam, as contaminated water is not suitable for this use. A summary of the MIA demands is presented in Table 11-15.

Table 11-15 Mining Infrastructure Area (MIA) demand estimates

Year	MIA demand (ML/yr)
Year 1	240
Year 5	391
Year 10	391
Year 20	391
Year 30	391

Potable water will be required in the administration building, amenities and accommodation village. A summary of the potable water demands is presented in Table 11-16. Potable water will be obtained from treatment of water supplied from the raw water dam.

Table 11-16 Potable water demand estimates

Year	Potable water demand (ML/yr)
Year 1	210
Year 5	167
Year 10	140
Year 20	144
Year 30	154

A summary of total mine operations water demand is presented in Table 11-17.

Table 11-17 Water demand summary

Year	CHPP make-up water (ML/yr)	Dust suppression (ML/yr)	MIA demand (ML/yr)	Potable water demand (ML/yr)	Total site demand (ML/yr)
Year 1	4,981	1,952	240	210	7,383
Year 5	8,111	2,201	391	167	10,870
Year 10	8,111	2,512	391	140	11,154
Year 20	8,111	3,134	391	144	11,780
Year 30	8,111	3,757	391	154	12,413

11.5.7.23 Results of water balance modelling

The water balance results indicate there will be a frequent mine water deficit throughout the life of the Project, and that imported water will be required to make-up the deficit. The requirement for imported water is greatest in Year 30, when mine operation water demands are highest. It should noted that irrespective of the mine water available from the mine water management system a moderate volume of imported water is required for demands that require high quality water such as potable applications, workshop, vehicle wash, and sprayers. Treated bore water is of suitable quality for these applications, however it is not of sufficient quantity to meet demands during the later years of the Project when borefield extraction rates are lowest and demands are higher.

The requirement for imported water during a representative 10th percentile (dry) year is summarised in Table 11-18.

Table 11-18 Imported water requirement for a 1 in 10 AEP dry year

Year	Imported water (ML/yr)
Year 1	6,022
Year 5	9,518
Year 10	10,412
Year 20	11,150
Year 30	11,772

11.6 Potential impacts and mitigation strategies

Potential impacts and corresponding mitigation strategies of the proposed Project on surface are described in this section. The potential impacts are described in the following sequence:

- Impacts on hydrology (stream flows in the local water courses);
- Impact on surface water quality;
- Impacts on flooding;
- Impacts on stream stability (geomorphology).

The impacts are assessed assuming that the proposed management of surface waters and associated control measures as descried in Section 11.5 will be implemented. Additional mitigation measures are also identified to minimise potential significant impacts

11.6.1 Impacts on watercourse hydrology

If no controls were implemented to manage surface water, the impacts on hydrology of the stream flows in the local water courses could be impacted by:

- Changes in the catchment extents;
- Changes in the catchment runoff characteristics;
- The timing of discharges from the mine; and
- Changes flood flows through the Project area and downstream.

The proposed Project plans and controls to manage surface water have been designed specifically to mitigate these impacts, and significant impacts on hydrology are not expected to occur.

11.6.1.1 Impacts on downstream flow volumes (water resources)

The proposed mine water management system is in accordance with best practice management of mine water and includes separation of clean and dirty / contaminated areas. The clean undisturbed catchment areas (including watercourse catchments upstream of the mine) and clean overland sheet flow draining toward the mine area will be diverted away from the mine water management system and allowed to passively drain into the local water courses. The clean water diversion strategy minimises unnecessary containment of clean water and assists to optimise the catchment arrangements to minimise impacts on downstream watercourse flows for environmental flows and beneficial uses.

For best practice protection of surface water quality it is necessary for the mine water management system to contain runoff from disturbed mine areas, and this inevitably results in a reduction in the total catchment area that sustains stream flow to the downstream watercourse.

For the worst case scenario, the greatest reduction in stream flow catchment of the downstream water course will occur in the later stages of the mine life when the catchment extents of the mine water management system are greatest. The mine water system catchment data (refer Table 11-11) show that in year 30 the concept mine water management system would contain runoff from a total area of 174 km^2 for a worst case assumption that rehabilitated areas are not yet sufficiently established to allow runoff from these areas to be diverted out of the mine water management system. If runoff from the rehabilitated areas is sufficiently clean in Year 30 to allow it to be diverted (flow passively to the watercourses), the total area contained in the mine water management system will be approximately 118 km^2. The impact of reduced total catchment is presented in Table 11-19 for an assessment location in Lagoon Creek approximately 12 km downstream of the mine (i.e. catchment extent as shown in Figure 11-1). At this location the total existing catchment of Lagoon – Sandy Creek is 2,734 km^2.

Table 11-19 Potential worst case mine water system impact on downstream flow volumes

Description	Existing conditions	With MWS Year 30 all spoil runoff and rehabilitation areas contained	With MWS Year 30 disturbed spoil runoff contained and rehabilitated spoil runoff diverted
Lagoon–Sandy Creek watercourse stream flow catchment area (km^2)	2,734	2,559	2,616
Impact on catchment area (%)	n/a	-6.4%	-4.3%
Mean Annual Flow ML/year (17mm/yr mean runoff x catchment area)	46,480	43,503	44,472
Impact on mean annual flow (%)	n/a	-6.4%	-4.3%
Reduction in mean annual flow (ML)		2,975	2,000

The estimates of downstream mean annual flow for the worst case scenario (no controlled discharges, and largest extent of the mine water management system) show a potential reduction in the order of 2,000 to 3,000 ML/year or approximately 6%. The potential minor reduction in downstream mean annual flow will not materially impact on downstream beneficial uses of water, because the closest existing surface water licence holder is approximately 175 km downstream at the crossing of Gregory Development Road over the Belyando River. At this location, the total catchment is approximately ten times larger, mean annual flow is approximately 600,000 ML/year, and the reduction in mean annual flow due to the mine water management system catchment containment will be less than 1%.

Mitigation of the relatively minor impacts on downstream flow volumes can be achieved by:

- Progressively rehabilitating overburden dump areas and other disturbed areas through the mine life when areas become available, and diverting the runoff from the rehabilitated areas (when runoff is demonstrated to be clean). The practicality of diverting rehabilitated areas to flow passively to the downstream environment will need to consider the constraints imposed by the layout of the mine water management system.
- Making compliant controlled release of water from the spoil runoff water management system (in accordance with the criteria proposed in Section 11.5.5 and to be incorporated in the EA conditions)

11.6.1.2 Impact on temporal flow characteristics

The water management strategy for the Project will allow clean undisturbed areas to passively drain to the local watercourse at similar flow velocities, and with similar flow recession characteristics as the existing catchment. This will result in no measurable change in the temporal characteristics of the watercourse stream flow hydrology and the existing ephemeral flow characteristics will be maintained.

11.6.1.3 Impacts on downstream flood hydrology

The proposed Project could produce a slight change to downstream flood hydrology due to a range of influences which to tend compensate each other and minimise the net impact on flood flows.

The potential influences on flood flow events in Lagoon Creek include:

- The disturbed mine areas and hardstand areas will tend to produce higher runoff rates during intense storm events. In actual operations this will not impact on the watercourse floods because these impacts will be contained within the mine water management system;
- The mine water management system will contain runoff from the mine areas, and this will result in a reduction in catchment areas contributing to flood hydrograph volumes and peak flows. This will tend to reduce the peak flows in the downstream watercourse;
- The proposed watercourse diversion of Spring Creek will result in Spring Creek flood flows entering Lagoon Creek at a new confluence location approximately 9km upstream of the existing confluence. This will tend to slightly increase peak flows in Lagoon Creek in a localised reach between the existing confluence and new upstream confluence; and
- The proposed (essential) flood protection levees will constrict the floodplain area and result in some loss of floodplain storage and consequent effect on flood routing along the watercourses. This will tend to slightly increase the peak flows in the downstream watercourse and this effect would be greater for larger flood events.

The potential influences outlined above were assessed with combined flood hydrology modelling (to derive watercourse flood inflow hydrographs) and dynamic hydraulic modelling (to assess the routing of the flood hydrographs through the watercourse and associated floodplain areas). A detailed description of the flood hydrology assessment methodology and assumptions is presented in the Flood Study technical report (Volume 5, Appendix F2). The assessment adopted a worst case scenario (pessimistic) assuming that the mine water management system would not be able to contain flood flows and mine area catchments would contribute to flood events in the downstream water course.

Hydrograph outputs from the dynamic hydraulic modelling were assessed to identify the change in peak design flood flows for the downstream hydrograph at a hydrological reference point located approximately 12 km downstream of the northern MLA 70426 boundary. The estimated changes in peak flood flows are presented in Table 11-20.

The peak flood flow results indicate a potential impact ranging from 10% increase for small floods reducing to 6% increase for the 100 year ARI flood and less for extreme floods. As described above these estimates are for a worst case scenario assuming that the mine water management system fails to contain flood runoff from the mine catchments.

Table 11-20 Impact on peak flood flows in Lagoon Creek downstream of the mine

Flood Event (Years ARI)	Peak Flows m^3/s		Worst Case Impact refer table note
	Existing case	Design case * refer table note	% Change
2	28	31	10.7%
5	131	144	9.9%
10	225	247	9.8%
20	311	340	9.3%
50	583	624	7.0%
100	880	931	5.8%
1000	2,512	2,533	0.8%
3000	3,495	3,502	0.2%

* Note Design case assumes worst case scenario of inability to contain flood waters from the mine area catchments.

Mitigation of the impacts on peak flood flows can be achieved by ensuring that the mine water management system can contain flood event runoff from the mine catchments for events at least up to the 100 year ARI flood. This will be expected to apply through the Environmental Authority conditions for criteria to limit the probability of overflow from the mine water management system dams. With flood runoff from the mine area catchments contained within the mine water management system, it is expected that the reduction in catchment area will compensate the other influences on flood hydrology (as outlined above) to the extent that slight reductions in peak flood flows are expected. The potential impact on changes in the flood flow hydrology will not adversely impact on stream stability or environmental values.

11.6.2 Surface Water Quality Impacts and Mitigation

If no controls were implemented for hazards to surface water runoff quality, the impacts on surface water could occur through all phases of development. The range of potential impacts is extensive and could include:

- Increased catchment surface erosion due to land disturbance during the construction phase, operational phase, and post closure phases (if rehabilitation is not successful);
- Stream channel erosion and destabilisation if stream diversions are not adequately designed, or rehabilitated, or if flood protection levee banks place too much constriction on the flood plain corridor;
- Uncontrolled or non-compliant release of contaminated mine water; and
- Water management incidents, including spills, poor storage of contaminating substances, or if the mine water management system is not adequately maintained and operated.

The consequent effects of potential uncontrolled impacts on surface water quality can include:

- Increased turbidity;
- Increased sediment bedload and consequent physical impact on aquatic ecosystems;
- Increased salinity; including sulphates, chloride, and sodium concentrations with consequent impacts causing physical-chemical stress on aquatic ecosystems, and impact on macro invertebrate communities. If salinity, or the concentrations of salt species is excessively increased, the surface water quality may impact on environmental values for primary industry and livestock drinking water supply;
- Increased dissolved metals concentrations and consequent toxic effects on aquatic biota;
- Elevated nutrient concentrations and consequent effects on eutrophication of downstream waterbodies; and
- Release of imported (unnatural) contaminants that do not occur naturally such as chemicals and pesticides and consequent toxicity effects on aquatic biota or long term effects for bio-accumulation in aquatic biota.

The Project planning has extensively considered the potential impacts on surface water quality, and the proposed project water management (as outlined in Section 11.5) was developed to mitigate these impacts. Further description on the assessment of potential surface water impacts is described below for the construction, and operation phases of the Project.

11.6.2.1 Construction phase water quality impacts and mitigation strategies

The potential water quality impacts during the construction phase will mainly be limited to potential for uncontrolled erosion and management of construction materials and supplies. The key strategies to manage the potential construction phase impacts will include:

- Preparation of an Erosion and Sediment Control Plan (ESCP) that is strategically tailored to suit the specific site conditions and construction sequence.
- Strategic sequencing and timing of construction activities.
- Management plans for storage and handling of contaminating substances including fuels, construction materials and supplies.

An ESCP will be prepared and implemented during the construction of mine infrastructure. The plan will be in accordance with appropriate statutory requirements, including conditions of the EA. Controls will be established to a standard consistent with Institution of Engineers Australia Erosion and Sediment control guidelines.

The ESCP preparation and implementation will include:

- Identification of soil and water management issues, including existing site conditions, soil and climatic data, erosion prone areas, location of the nearest and other relevant environmentally sensitive areas.
- Clear understanding and application of proposed control measures including the following actions - minimise disturbance and erosion sources, provide temporary and permanent drainage measures as early possible, identification of suitable erosion and sediment controls for the site, interception and capture of sediment-laden runoff, implement effective revegetation.

- Drawings to accompany the ESCP identifying the development and staging of works of temporary erosion and sediment control measures, including measures to manage heavy rainfall events to aid in limiting unforseen construction delays due to wet weather.
- Compliance with the recognised approval processes.
- Maintain and supervise implementation of the ESCP, and undertake scheduled inspections of the implementation of the ESCP.
- Undertake monitoring of the effectiveness of the ESCP including diary notes/logbook entries of control techniques used on-site, and water quality sampling both upstream and downstream of disturbed areas.

Erosion and sediment controls will include:

- Avoid unnecessary disturbance to natural watercourses and riparian areas, and reinstate any disturbed areas.
- Reduce or limit overland flow runoff volume and velocity by minimising catchment size, increasing flowpath length, and ensuring drains are adequately sized.
- During the construction phase, early planning and construction of temporary drainage systems will minimise erosion and avoid delays in initial earthworks.
- Diversion of upslope water to reduce on-site erosion by limiting catchment size, thereby reducing total volume of contaminated runoff requiring treatment and reduced downtime following prolonged rain events.
- Install permanent drainage structures as early as possible, including stabilised drainage outlets.

A strategic sequencing plan for construction of the Project will greatly assist to manage potential erosion hazard during the construction phase of the Project. At this concept stage, and subject to detailed design and construction planning, it is envisaged the following sequence will assist to minimise erosion impacts:

- Early construction of the Lagoon Creek flood protection levee and stream diversions. It is envisaged that the levee bank and stream diversion will be built simultaneously with the materials excavated from the diversion channel utilised to form the levee bank (subject to materials suitability).

  The early construction of the diversion channel will allow rehabilitation of the diversion channel to progress at the earliest possible opportunity. It will also allow any exposed dispersive soils to be identified and treated or covered.

  The early construction of the flood protection levee can then function to contain surface runoff from disturbed upslope areas west of the levee bank as subsequent top soil stripping and construction of the mine infrastructure takes place.
- Early construction of the proposed mine pit high wall clean water diversion drain. This will assist to minimise clean water run on to the working areas.
- Early construction of the proposed operational environmental dams associated with the CHPP, MIA, and ROM and coal stockpile areas. These dams can then function to capture sediment laden runoff as construction of the CHPP, MIA, and coal stockpile areas progress.

- Scheduling the construction of the conveyor and road crossings across Lagoon Creek to occur during the dry season.
- Construction of the Decant Dam prior to construction of the TSF. During construction of the TSF, the Decant Dam can be utilised to capture sediment laden runoff from the TSF construction area.

Temporary fuel storage and handling areas, and areas required to store potentially contaminated construction materials and supplies (e.g. cement, adhesives etc) will be bunded. Excess water collected in the bunded areas will be pumped to the constructed Environmental Dams.

With the implementation of the erosion and surface water quality control measures outlined above, the construction phase of the Project is not expected to produce adverse effects on surface water quality. Monitoring of surface water quality and the effectiveness of the control measures will also form an important part of construction phase surface water quality management.

11.6.2.2 Operational phase water quality impacts and mitigation strategies

With the implementation of the proposed mine water management system as described in Section 11.5.7, surface water quality impacts during the operational phase are not expected to occur. Implementation of the key mine water management system controls particularly discharge criteria, storage criteria for mine water dams, monitoring and reporting will be enforceable through the EA conditions.

In summary, the proposed mine water management system will provide holistic control of a wide range of potential surface water impacts through the following strategies:

- Ensuring that all disturbed surfaces that have potential to generate contaminated mine water are within the extents of the mine water management system. This will contain all potentially contaminated mine water.
- Reusing mine water from the mine water management system to supply the mine operations water demands. This will ensure that storage capacity can be continually maintained to ensure capacity to contain heavy rainfall events.
- Controls enforced through environmental authority conditions to ensure sufficient storage is provided to cater for extreme wet season rainfall events.
- Controlled discharges are compliant with controlled discharge criteria that have been developed to protect the downstream environment. The controlled discharge criteria include that controlled discharges are only allowed when Lagoon Creek has sufficient flow, a limit on the rate of discharge to ensure sufficient dilution, end-of-pipe water quality limits, and ensuring that downstream salinity (EC) will be less than 1000 µS/cm and consistent with other water quality objectives for the downstream environmental values.

Further more comprehensive description of the proposed mine water management system, design, and operations is outlined in Section 11.5.7.

The proposed EA conditions for water quality will comprise the following sets of criteria:

- Maximum values for end-of-pipe contaminant release criteria (outlined in Table 11-21) and associated criteria that only allow a maximum release rate of 20% of upstream Lagoon Creek flow when Lagoon Creek is flow above 1 m3/s. These will be mandatory compliance criteria.

- Monitoring of end-of-pipe quality of controlled discharges, upstream and downstream receiving water quality in Lagoon Creek to compare against trigger levels outlined in Table 11-22. If the trigger levels in Table 11-22 are exceeded during discharges mandatory investigations (enforced through EA conditions) will be required to assess the environmental impact or potential for environmental harm and identify changes required to the mine water management system or operations, or potential adjusted discharge criteria to mitigate the potential for environmental harm.
- Monitoring of the receiving water quality upstream and downstream of the controlled discharge locations to confirm that controlled discharges are appropriately managed. If the monitoring shows exceedance of the trigger levels in Table 11-23 during discharges, mandatory investigations (enforced through EA conditions) will be required to assess the environmental impact or potential for environmental harm and identify changes required to mitigate the potential for environmental harm.

Table 11-21 Proposed End-of-Pipe contaminant release limits for controlled discharges

Parameters	Release limits	Monitoring frequency
pH	6.0 (minimum) 9.0 (maximum)	Daily during release with the first sample taken within 2 hours of the commencement of release
Turbidity (NTU)	500 (maximum)	Daily during release with the first sample taken within 2 hours of the commencement of release
Electrical conductivity ($\mu S.cm^{-1}$)	2,000 (maximum)	Daily during release with the first sample taken within 2 hours of the commencement of release
Sulphate (mg/L)	1,000 (maximum)	Daily during release with the first sample taken within 2 hours of the commencement of release

Table 11-22 End-of-pipe release and receiving contaminant trigger investigation levels

Parameter	Release limits	Comments
Total Phosphorus (mg P/L)	0.3 (maximum)	80^{th} percentile of Native Companion Creek data
Total Nitrogen (mg N/L)	1.34 (maximum)	80^{th} percentile of Native Companion Creek data
Calcium (mg/L)	1,000 (maximum)	ANZECC value for livestock drinking water protection
Nitrate (mg N /L)	1.34 (maximum)	80^{th} percentile of Native Companion Creek data
Fluoride (mg/L)	2,000 (maximum)	ANZECC value for livestock drinking water protection
Aluminium (mg/L)	0.2 (maximum)	80^{th} percentile of Native Companion Creek data
Arsenic (mg/L)	0.024 (maximum)	ANZECC 95% SMD value for aquatic ecosystem protection
Boron (mg/L)	0.37 (maximum)	ANZECC 95% SMD value for aquatic ecosystem protection
Cadmium (µg/L)	0.2 (maximum)	ANZECC 95% SMD value for aquatic ecosystem protection
Chromium (mg/L)	0.001 (maximum)	ANZECC 95% SMD value for aquatic ecosystem protection
Copper (mg/L)	0.05 (maximum)	80^{th} percentile of Native Companion Creek data
Cobalt (mg/L)	0.09 (maximum)*	Fitzroy Basin trigger limits
Iron (mg/L)	0.3 (maximum)*	Fitzroy Basin trigger limits
Lead (µg/L)	3.4 (maximum)	ANZECC 95% SMD value for aquatic ecosystem protection
Manganese (mg/L)	1.9 (maximum)	ANZECC 95% SMD value for aquatic ecosystem protection

Parameter	Release limits	Comments
Mercury (µg/L)	0.06 (maximum)	ANZECC 99% SMD value for aquatic ecosystem protection
Molybdenum (mg/L)	0.034 (maximum)*	Fitzroy Basin trigger limits
Nickel (mg/L)	0.011 (maximum)	ANZECC 95% SMD value for aquatic ecosystem protection
Selenium (mg/L)	0.010 (maximum)	Fitzroy Basin trigger limits
Silver (mg/L)	0.001 (maximum)*	Fitzroy Basin trigger limits
Zinc (mg/L)	0.05 (maximum)	80th percentile of Native Companion Creek data
Vanadium (mg/L)	0.01 (maximum)*	Fitzroy Basin trigger limits
Uranium	0.001 (maximum)*	Fitzroy Basin trigger limits
TPH (C6-C9) (mg/L)	20 (maximum)*	Fitzroy Basin trigger limits
TPH (C6-C9) (mg/L)	100 (maximum)*	Fitzroy Basin trigger limits

*local trigger values to be developed prior to notification of the draft EA

Table 11-23 Receiving water contaminant trigger investigation levels

Parameters	Release limits	Monitoring frequency
pH	6.0 (minimum) 9.0 (maximum)	Daily during release with the first sample taken within 2 hours of the commencement of release
Turbidity (NTU)	500 (maximum)	Daily during release with the first sample taken within 2 hours of the commencement of release
Electrical conductivity ($\mu S.cm^{-1}$)	1,000 (maximum)	Daily during release with the first sample taken within 2 hours of the commencement of release
Sulphate (mg/L)	1,000 (maximum)	Daily during release with the first sample taken within 2 hours of the commencement of release

With proper implementation of the proposed mine water management system there should be no adverse impacts on surface water quality associated due to poor management of mine water during the operational phase of the Project. Risk management, updates of the mine water management system and adequate contingency planning will also need to be regularly undertaken. A summary of key residual surface water quality risks and mitigation measures is presented in Table 11-24.

Table 11-24 Surface water quality impact risk management and contingency measures

Hazard	Possible Consequence	Mitigation and contingency
Mine water management system catchments do not match disturbed areas or not updated. Mine plan changed without updating the mine water management plan.	Overloading of the mine water management with increased potential for overflow. Runoff from disturbed areas not adequately contained.	Annual survey, update of mine catchments, reassessment of mine water system storage capacity, and expected water management performance. Upgrade system capacity.
Failure of mine water management system infrastructure including diversion system, storages, transfer systems, or release systems.	Diminished capacity to contain wet weather runoff volumes. Increased probability of uncontrolled discharges (overflows). Non-compliant controlled discharges.	Undertake system failure risk assessment during project detailed design and regularly update the risk register. Prepare contingency plans for possible failure of system critical infrastructure.

Hazard	Possible Consequence	Mitigation and contingency
Inappropriate storage of hazardous materials outside the mine water management system footprint.	Spill or contaminated runoff incident.	Annual audits of storage of hazardous materials. Rectify incorrectly stored materials.

11.6.3 Impacts on flooding levels

The combination of the proposed stream diversions and flood protection levee bank works required for the Project can potentially impact on flood levels along Lagoon Creek. Changes in design flood event peak water levels may not be necessarily a concern in a remote area providing that risk to third party infrastructure and facilities are not impacted and the Project design accommodates the design flood levels.

The change in flood level due to a proposed development (test case) relative to existing flood levels (base case) is commonly referred to as afflux. A positive afflux indicates an increase in flood level, and a negative afflux indicates a decrease in flood level. The changes in flood levels could impact on existing or road diversions constructed as part of the Project. All of the new roads will maintain the same level of flood immunity and time of closure as those currently on the site.

11.6.3.1 Estimated flood level with Project diversion and flood levee works

The impact on flood levels was assessed with the flood model that were prepared to assess baseline conditions (refer Flood Study technical report, Volume 5, Appendix F2). The flood models were modified to include representation of the proposed concept stream diversion works and flood protection levee.

A summary of changes in flood levels after development are shown as the afflux values in Table 11-25. These results identify that some changes in flood levels are likely as a result of the mine development, but these changes are not considered to change the flood risk to existing infrastructure (roads, houses, etc) in the area.

Table 11-25 Changes in Peak flood level for 1000 and 3000 year ARI flood events

Description	Easting	Northing	Flood levels (developed case)			
			1000 yr ARI	*Afflux**	3000 yr ARI	*Afflux**
			(mAHD)	*(mm)*	(mAHD)	*(mm)*
8 km D/S of mine site	448712	7452178	289.1	*170*	289.3	*170*
North lease boundary	449303	7444873	299.3	*180*	299.6	*190*
Wendouree Homestead	449048	7436775	305.9	*-550*	306.5	*-490*
Hobartville Homestead	448984	7423198	316.5	*190*	316.7	*220*
South lease boundary	448340	7419974	319.2	*140*	319.4	*180*
6.4 km U/S of mine site	445561	7414129	325.3	*<10*	325.4	*<10*

**Afflux levels are 'with development'.*

The increase in the 1,000 year ARI peak flood level at Hobartville Homestead is estimated to be 190 mm. At Wendouree Homestead a reduction in the 1,000 year ARI peak flood level of 550 mm is estimated. The impacts on flood levels at these two existing homesteads are not a concern because there properties are within the mine lease area and will most likely be resumed by the Proponent when the Project proceeds or relocated.

At 8 km downstream (north) of the proposed mine lease boundary, an increase in the 1000 year ARI peak flood of 170 mm is estimated. There is no existing infrastructure or facilities within 8km downstream of the mine that would be adversely impacted by increased flood levels. The potential for increased flood levels downstream of the mine lease is not considered to be real and is more likely to be an influence of excessively conservative flood modelling assumptions. This will be further reviewed as part of detailed design.

Typically within the diversion channel, water levels vary by up to 800 mm above the existing case flood levels. This is due to the effect that the essential flood protection levee bank will have on constriction of the floodplain corridor. Further design optimisation will be required as part of the detail design and mine plan optimisation to ensure that adequate floodplain corridor is maintained through the mine lease. The increase in flood levels is not necessarily a concern but if the floodplain corridor is constricted too much the concentration of flood flow could be a concern for stream channel stability. The potential impacts on stream channel stability and mitigation measures are described in Section 11.6.4.

Results of the assessment show that there will be minor to some changes to flood water levels near the mine site. These changes are largely attributed to the constrictions of the floodplain due to the levee banks and to a lessor degree the redistribution of flows from the various watercourses.

The proposed development will have negligible impact further than 6 km upstream (south) of the MLA 70426 boundary.

11.6.4 Geomorphologic impacts of stream diversions

11.6.4.1 Overview of potential geomorphologic impacts

Stream diversions for mining projects are historically known to potentially produce adverse impacts on stream channel geomorphology. Best practice stream diversion design implemented over the last eight to ten years, since the research and publication of the ACARP guidelines for stream diversions is now widely recognised to improve sustainability of modern stream diversions.

The potential adverse impacts of poorly designed stream diversions can include instability of stream channel with potential for adverse impacts including:

- Excessive erosion leading to water quality impacts, unsustainable downstream sediment loads, and impacts on aquatic ecosystems; and
- Excessive lateral migration of the stream channel with risk to valuable infrastructure, riparian vegetation loss, and impacts on terrestrial ecosystems near the stream.

The most common causes of impacts due to inadequate stream diversion design can include:

- Diversion channels that are too short and / or steep relative to the original stream;
- Channel dimensions not matching the original channel resulting in change of the bank-full flood capacity of the channel which modifies the frequency and energy of bank-full flood events and floodplain interaction;

- Meander design not compatible with the expected channel flow energy and substrate conditions;
- Channel substrates that are markedly different to the original stream resulting in either poor ability to rehabilitate the stream, and / or greater vulnerability to erosion; and
- Excessive constriction of the floodplain corridor resulting in concentration of floodplain flow and higher energy in the stream channel.

11.6.4.2 Impacts of proposed diversion alignment and stream lengths

The proposed stream diversion of Lagoon Creek, Sandy Creek, and Spring Creek are described in Section 11.5.5. All of the proposed stream diversion will involve reach lengths at least equal to or greater than the existing streams. The proposed stream diversion bed levels will match the existing stream bed levels at the upstream and downstream end of each diversion. The diversion channels will be designed with a low and uniform longitudinal bed gradient and will not rely on drop structures. Consequently there will no impacts arising from shortening and / or steepening of the stream length.

11.6.4.3 Impacts of proposed diversion low flow channel geometry

The dimensions and geometry of the proposed diversion low flow channels were based on replicating the existing stream channel geometry to maintain similar bank-full flow capacity. The existing bank-full flow capacity is estimated to be approximately a 2 year ARI flood event. The proposed diversion works are not expected to produce adverse impacts arising from in appropriate size of the low flow channel.

11.6.4.4 Impacts of proposed diversion low flow meander design

The low flow channel for each diversion is proposed to meander within a high flow (flood) channel corridor. The proposed meandering has only been developed to concept level at this stage to demonstrate that it will be possible to provide a meandering low flow channel. The minimum meander dimensions based on meandering theory for erodible alluvial streams were determined and have been used to demonstrate the potential for meandering within the concept designs (refer to description in Section 11.5.3). It is acknowledged that the concept low flow channel meander design appears different to the existing stream meander characteristics. Theoretically the concept meander design will be stable however further assessment and design is required to confirm this.

To ensure appropriate meandering, further investigation and optimisation of the proposed diversion low flow channel meandering characteristics will be required including more detailed geomorphologic assessment and geotechnical investigations to assess the expected subsurface materials to confirm a suitable (sustainable) low flow channel meander characteristics. These assessments will be undertaken as part of detailed design and in consultation with DERM prior to submission of the detailed design plans for approval to construct the stream diversions.

11.6.4.5 Substrate conditions and water quality impacts

The proposed stream diversion mitigation strategies will ensure that any dispersive soils encountered in the diversion channel excavation will not be left exposed. Surface exposures of dispersive soils will be either treated to minimise dispersion potential, or covered with topsoil to ensure that the dispersive substrates are not left exposed. This will ensure that direct rainfall impact on the diversion surfaces will not adversely impact on water quality.

11.6.4.6 Hydraulic impacts on stability of the proposed diversion channels

The hydraulic impacts of the proposed diversion channel works and flood protection levees were assessed with the flood models developed for the EIS studies. A detailed description of the flood modelling is presented in the Flood Study technical report and Geomorphology technical report in Volume 5, Appendix F. Assessment of the results from the hydraulic modelling included impacts on channel flow velocity, stream power, and shear stress. A summary comparison between diverted case and existing channel hydraulic parameters is presented in Tables 11-26 to 11-28. Longitudinal profiles of the hydraulic parameter results are presented in Figures C-1 to C-6 in Appendix C of the Geomorphology study technical report (Volume 5, Appendix F).

From the comparison of existing and diverted case hydraulic parameters for Lagoon Creek the following conclusions are drawn:

- The proposed Lagoon Creek diversion design will not impact on velocity, stream power and shear stress for reaches upstream and downstream of the proposed diversion channel. The existing channel reaches upstream and downstream of the diversion are expected to be stable for floods up to at least 50 year ARI.
- The proposed Lagoon Creek diversion design will generally slightly increase the channel flow energy (i.e. velocity, streampower, and shear stress) within the diversion channel relative to the existing channel reach. The increases will generally not exceed ACARP guideline design criteria and the overall diversion channel as a whole should be stable. The increase in the diversion channel flow energy relative to existing stream conditions warrants that comprehensive monitoring of the condition of the diversion channel be undertaken.
- A marked localised increase in flow energy is estimated from the modelling based on the current design near the upstream end of the diversion channel. The localised peak shear stress and stream power will marginally exceed ACARP criteria. This indicates a potential for localised channel instability in this area. It is expected that this localised area of increased in flow energy can be mitigated through refinement of the design particularly for the transition from the upstream existing stream into the diversion channel. The potential mitigation options include better channel transition and increasing the capacity of the floodplain either through adjustment to the levee bank location, or excavation (and rehabilitation) of the floodplain.

With due recognition that the diversion design for Lagoon Creek is currently at concept design level and that further investigations and detailed design will be required prior to approvals, it is considered that the proposed diversion (with refinement of the design) can be undertaken with an outcome of sustainable conditions for geomorphologic stability of the stream.

Table 11-26: Comparison of Lagoon Creek Channel Velocity for 50 year ARI Flood

Reach and Result type	Existing channel Velocity (m/s)	Diverted case Velocity (m/s)
Downstream (north) of MLA boundary (model chainage 0 km to 13 km)		
Typical average	1.1 to 1.3	No measurable change
Maximum values and frequency along stream	2.4 at approx 5 km intervals	No measurable change
Downstream end of proposed diversion to MLA boundary (model chainage 13 km to 19 km)		
Typical average	0.7 to 0.9	No measurable change
Maximum values and frequency along stream	1.3 at approx 3 km intervals	No measurable change
Lagoon Creek reach proposed to be diverted (model chainage 19 km to 31 km)		
Typical average	0.6 to 0.9	1.0 to 1.1
Maximum values and frequency along stream	1.3 at approx 3 km intervals	2.5 at one location at upstream end of diversion
Upstream of proposed diversion to upstream (south) MLA boundary (model chainage 31 km to 45 km)		
Typical average	0.5 to 0.6	No measurable change
Maximum values and frequency along stream	0.9 at approx 3 km intervals	No measurable change
ACARP Stream Diversion Design Guideline Criteria		
Maximum values (50 year ARI event)	1.5 to 2.5	

Table 11-27: Comparison of Lagoon Creek Stream Channel Stream power for 50 year ARI Flood

Reach and Result type	Existing channel Streampower (W/m^2)	Diverted case Streampower (W/m^2)
Downstream (north) of MLA boundary (model chainage 0 km to 13 km)		
Typical average	20	No measurable change
Maximum values and frequency along stream	50 to 100 at 3km intervals	No measurable change
Downstream end of proposed diversion to MLA boundary (model chainage 13 km to 19 km)		
Typical average	10	No measurable change
Maximum values and frequency along stream	20 at approx 3 km intervals	No measurable change
Lagoon Creek reach proposed to be diverted (model chainage 19 km to 31 km)		
Typical average	10	20
Maximum values and frequency along stream	25 at approx 3 km intervals	150 to 250 two localised areas at upstream end
Upstream of proposed diversion to upstream (south) MLA boundary (model chainage 31 km to 45 km)		
Typical average	10	No measurable change
Maximum values and frequency along stream	20 at approx 2 km intervals	No measurable change
ACARP Stream Diversion Design Guideline Criteria		
Maximum values (50 year ARI event)	100 to 150	

Table 11-28: Comparison of Lagoon Creek Stream Channel Shear Stress for 50 year ARI Flood

Reach and Result type	Existing channel Shear Stress (N/m^2)	Diverted case Shear Stress (N/m^2)
Downstream (north) of MLA boundary (model chainage 0 km to 13 km)		
Typical average	10	No measurable change
Maximum values and frequency along stream	30 up to 60 at approx 3 km intervals	No measurable change
Downstream end of proposed diversion to MLA boundary (model chainage 13 km to 19 km)		
Typical average	5 to 10	No measurable change
Maximum values and frequency along stream	20 at approx 3 km intervals	No measurable change
Lagoon Creek reach proposed to be diverted (model chainage 19 km to 31 km)		
Typical average	5 to 10	12 to 15
Maximum values and frequency along stream	20 at approx 4 km intervals	70 to 95 at two localised areas at upstream end
Upstream of proposed diversion to upstream (south) MLA boundary (model chainage 31 km to 45 km)		
Typical average	5 to 10	No measurable change
Maximum values and frequency along stream	15 at approx 5 km intervals	No measurable change
ACARP Stream Diversion Design Guideline Criteria		
Maximum values (50 year ARI event)	< 80	

11.6.4.7 Adequacy of Lagoon Creek floodplain corridor for extreme floods

The ACARP stream diversion design guidelines only provide guidance for sustainable flow energy in designed stream diversions for small to large floods up to 100 year ARI events and do not provide criteria for acceptable constriction of the floodplain extents for extreme floods. The impacts of flood protection levee systems during extreme event floods can also pose a risk to stream channel stability if the floodplain corridor is excessively constricted and floodplain flow is concentrated.

The flood modelling results for the 1000 year ARI event were utilised to assess the potential impact of the proposed flood protection levee on floodplain corridor and stream stability for extreme events. The results of the modelling are presented in Figures B.8 and B.9, Appendix B of the Flood Study technical report (Volume 5, Appendix F2).

The results of the diverted case for the 1,000 year ARI flow event shows that average diversion floodplain corridor velocities will be typically in the range of 1.5 to 2.5 m/s. Localised areas of velocity up to and exceeding 3 m/s are also estimated from the modelling. The results indicate that the impact of the flood protection levee banks may excessively constrict the floodplain corridor for extreme floods.

Although the probability of an extreme flood occurring during the mine life is very low, a sustainable floodplain corridor will be essential for the proposed flood protection levee and stream diversion design because these works will constrain the permanent floodplain capacity beyond mine closure.

Further assessment to analyse extreme flood event stream power and shear stress will be carried out in combination with detailed design refinement of the levee bank location and width of floodplain corridor along the stream diversion. The assessment will also include comparison to stream power and shear stress estimates for extreme floods through the existing Lagoon Creek floodplain corridor to assess the significance and determine a sustainable floodplain corridor. The potential mitigation options if required to improve the design floodplain corridor hydraulics for extreme floods can include:

- Repositioning of the flood protection levee bank further to the west subject to compatibility and flexibility to adjust the mine plan to accommodate this.
- Excavation to shape the high ground on the eastern side of Lagoon Creek to provide increase floodplain capacity (and subsequent floodplain revegetation after the excavation).

With the implementation of these mitigation strategies, the combination of the flood protection levee bank and stream diversion works should ensure sustainable floodplain capacity to allow passage of extreme floods.

11.7 Surface Water Monitoring

The proposed surface water monitoring for the Project will include surface water quality, and monitoring of the stream diversion performance. The proposed monitoring programs are outlined in this section.

11.7.1 Surface water quality monitoring programs

Two monitoring programs are to be implemented:

1. A baseline monitoring program designed to collect additional background data and derive site specific trigger values. This program implementation is currently underway and will continue until mine construction commences.
2. An on-going monitoring program developed for the continuous monitoring of the water quality of stream flows in the watercourses while the mine is operating. This program will include the mandatory compliance monitoring required for controlled of discharges of water from the spoil runoff water management system.

For the baseline monitoring program, two (2) reference sites, and sites within and immediately adjacent to the Project area will be monitored to collect data and establish derived values for physio-chemical and biological parameters. Reference sites are sites that are subject to minimal / limited disturbance are required. According to ANZECC (2000) guidelines, a reference site is a site whose condition is considered to be a suitable baseline or benchmark for assessment and management of sites in similar water bodies and streams. The proposed reference sites include:

- Well Creek which is a tributary stream to the north with similar characteristics to Sandy Creek and Spring Creek. The land surrounding Well Creek is classified as National Park. No significant intensive activities have been identified upstream of this proposed reference site.

- Native Companion Creek to the east which has similar characteristics to Lagoon Creek. The land surrounding the Native Companion Creek is mainly used for low intensity cattle grazing. No significant intensive activities have been identified upstream of the proposed reference site.

The water quality at these selected reference sites is expected to be comparable to the water quality of stream flow in the watercourses within the Project area, as they are both ephemeral, upland freshwater streams above 150 m in elevation.

The baseline monitoring sites within and immediately adjacent to the Project area and the sites for the on-going monitoring program are the same. Monitoring of these sites will be implemented to allow effective water quality monitoring of the watercourses upstream and downstream of the mine site. It will facilitate performance review of the various mitigation measures and plans to be implemented to protect the surface water environmental values within the Project area. The program is designed to monitor the mine operations impacts on water quality, including stream ecological and physical processes. The proposed monitoring locations are outlined in Table 11-29.

Table 11-29: Water quality and sediment site monitoring locations

Site number	Site description	Code	Coordinates		Comment
			Easting	Northing	
Lagoon Creek					
1	Lagoon Ck upstream	LCU	447249.7	7418923	For conditions prior to entering the mine site
2	Lagoon Ck	LCL	448159	7426371	Murdering Lagoon monitoring
3	Lagoon Ck, Sandy Creek downstream	LCSCD	450868	7440441	For conditions after exiting the mine site
4	Lagoon Ck: final SRD discharge	LCD	449480.3	7444277	For conditions after point of discharge from the final SRD
Sandy Creek					
5	Sandy Ck upstream	SCU	440745.8	7438237	For conditions prior to entering the mine site
Rocky Creek					
6	Rocky Ck upstream	RCU	442215.1	7444155	For conditions prior to entering the mine site
Little Sandy Creek					
	Little Sandy Ck upstream	LSCU	442378.4	7443298	For conditions prior to entering the mine site
8	Little Sandy Ck downstream	LSCRCD	445276.3	7445135	For conditions of LSC and RC after exiting the mine site
Spring Creek					
9	Spring Ck upstream	SPU	438988.9	7424345	For conditions prior to entering the mine site

Section 9 in the Surface Water Quality Technical Report (Volume 5, Appendix F4) provides full details on the requirements, parameters and frequency of sampling for each program.

11.7.2 Stream diversions monitoring program

A comprehensive monitoring program for the proposed stream diversions is outlined in Section 7 of the Geomorphology technical report (Volume 5, Appendix F1).

The proposed monitoring program is to be applied to the Sandy, Spring and Lagoon Creek Diversions and is based on the "Monitoring and Evaluation Program for Bowen Basin Diversions" (ID&A, 2000) undertaken for the Australian Coal Association Research Program (i.e. the ACARP guidelines for stream diversions). The monitoring of the stream diversions will extend from pre-construction to licence relinquishment and comprises four components as shown in Table 11-30.

The aim of the monitoring program is for the diversions to be considered as a reach or stream operating in dynamic equilibrium in order to achieve diversion license relinquishment. Application for diversion license relinquishment will occur at mine closure and depend on outcomes of the monitoring program.

Table 11-30: Diversion monitoring requirements

Monitoring package components	Objective
1. Baseline monitoring	To establish a baseline data set that can be used for comparison when applying for licence renewal and relinquishment. This occurs one year before construction and is to establish data that be used for comparison to assess the performance of the diversion.
2. Construction monitoring	To demonstrate works have been undertaken to specification.
3. Operations monitoring	To monitor and evaluate the diversion's performance to ensure it is operating in dynamic equilibrium. Occurs for ten years after construction.
4. Relinquishment monitoring	To attain licence relinquishment by demonstrating the diversion is operating in dynamic equilibrium and not adversely impacting on adjoining reaches. Occurs for ten years after operations preceding application for relinquishment.

Baseline monitoring requirements are presented in Table 11-31. Construction monitoring requirements are presented in Table 11-32. Operation monitoring requirements are outlined in Table 11-33. Relinquishment (i.e. the decommissioning and rehabilitation period) monitoring requirements are shown in Table 11-34.

Following comprehensive comparison of monitoring data post construction with the baseline data, an evaluation of the results to distinguish if the diversion is stable (i.e. dynamic equilibrium) and sustainable will be undertaken. It is important that the data comparisons include at least three moderate to large flood events. If it is found the diversion works do not achieve dynamic equilibrium, mitigation measures will be identified and implemented towards a goal of achieving sustainable long term stability.

Table 11-31: Baseline monitoring requirements

Baseline monitoring undertaken	
Index of Diversion Condition	Photographs will be taken to record the condition of the stream before works are initiated. Photographs will be taken of the Control reach, the reach to be diverted and the downstream reach. Photographs are to be taken from fixed points along the control and downstream reaches, to allow future comparisons. Refer to Appendix C of ACARP (2001) for an aerial photograph showing recommended photo locations and directions. Further details of fixed photo monitoring points are provided in Appendix C of ACARP – "Monitoring and Evaluation Program for Bowen Basin River Diversions".
Vegetation	The species, abundance and diversity of vegetation in the reach to be diverted will be recorded before the diversion in conducted. This information will be used for revegetating the new diversion and used for comparison during relinquishment monitoring.
Aerial Photographs	Take aerial photos displaying the existing condition of Lagoon, Spring and Sandy Creeks and also the location of the new diversion before works begin. The scale of the aerial photo will be sufficient to allow accurate measurements of the diversion and adjoining river or creek. Further details of aerial photographs are provided in ACARP (2001).
Flow Events	Information regarding the size and frequency of flow events may be assessed by checking debris marks and hydrologic data compiled as part of the engineering design process should there not be a flow gauging station. This will be a key part of DERM's assessment process as to what range of flow the diversion has been subjected to.
Survey	Cross-section and long-section surveys are required for all monitoring reaches. The sections generated will be included as part of the monitoring database and will be used to monitor the performance of the diversions during their operation by comparison with future sections. This will also contribute to relinquishment monitoring.

Table 11-32: Construction monitoring requirements

Construction monitoring requirements	
Execution Outputs	An execution output database will be established to record descriptions of the construction activities completed. The date of activity completion should be noted along with details of any accompanying photographs. Construction activities not completed to specification will be recorded in the database along with an explanation and details of the modified design.
Photographs	Photographs will be taken during construction/rehabilitation and immediately after the work is finished. Photographs will be taken from fixed photo monitoring points (refer Appendix C of ACARP - "*Monitoring and Evaluation Program for Bowen Basin River Diversions*").
Aerial Photographs	If practical, an aerial photo will be taken immediately after diversion construction or rehabilitation has been completed. These photographs will accurately display the extent of change and provide a baseline reference for changes that may occur in the future.
"Issued for Construction" Drawings	Design drawings issued to the contractor for construction are to be supplied.
"As Constructed" Drawings	As Constructed Drawings to be supplied upon completion of works to DERM.

Table 11-33: Operations monitoring requirements

Operations monitoring requirements		
Survival of Works	The survival of creek structures and works such as riprap and vegetation will be assessed during this phase of monitoring. Early detection of any damage is likely to increase the options for remedial action.	
Photographs	Photographs will be taken from fixed photo monitoring points along all of the reaches on an annual basis. Refer to Appendix C of ACARP - "*Monitoring and Evaluation Program for Bowen Basin River Diversions*" for more details.	
Aerial Photographs	Aerial photographs of the control reaches, diversion reaches and downstream reaches will be taken on an annual basis.	
Visual Assessment	The control reaches, diversion reaches and downstream reaches will be visually assessed using the IDC, which will be repeated in the following years after construction: 1^{st}, 2^{nd}, 5^{th}, 10^{th}, 15^{th}, 20^{th} years and after significant flow events.	
Index of Diversion Condition	Inspection will include assessment of:	
	• bank condition • piping • bed condition • recovery • proximity of spoil piles from bank	• stability of creek structures • structural intactness of vegetation • regeneration of vegetation • longitudinal continuity of vegetation

Operations monitoring requirements	
Survey	Longitudinal section and cross section surveys will be conducted in the Control reaches, Diversion reaches and Downstream reaches. These surveys will be repeated every 5 years or after a major flood event (e.g. 20 year ARI event). Refer to Appendix C of ACARP - "*Monitoring and Evaluation Program for Bowen Basin River Diversions*" for more details.
Flow events	Flow events will be monitored to determine the size of events the diversions have carried. Refer to Appendix C of ACARP – "*Monitoring and Evaluation Program for Bowen Basin River Diversions*" for more details.

Table 11-34: Relinquishment monitoring requirements

Relinquishment monitoring requirements	
Survey	Long section and cross section surveys will be conducted during the first year of relinquishment monitoring. The surveys will include the Control reaches Diversion reaches and Downstream reaches. Final long section and cross section surveys will be conducted prior to application for licence relinquishment.
Vegetation Assessment	Detailed vegetation assessment will be conducted during the first year of relinquishment monitoring to determine key species absent from the diversion reaches but present in control reaches where this is appropriate. The diversion reaches may therefore have different geomorphic and ecological characteristics than the reaches being replaced.
Photographs	Photographs will be taken from the fixed photo monitoring points in the control, diversion and downstream reaches.
Aerial Photographs	Aerial photos of diversions and controls, diversion and downstream reaches will continue to be taken on an annual basis.
Flow Events	Flow events will be monitored to determine the size of events the diversions have been subjected to.

Relinquishment evaluation requirements are shown in Table 11-35.

Table 11-35: Relinquishment evaluation requirements

Relinquishment evaluation requirements	
Survey	Quantitative assessment of data. Assess against flow data and baseline data. This survey will be compared to the 'as constructed' long sections to assess the changes in bed elevation.
Vegetation Assessment	Qualitative assessment of all data. Assess against flow data and baseline data.
Photographs	Qualitative assessment of all data. Assess against flow data and baseline data. Compare visually with previous photographs.
Aerial Photographs	Qualitative assessment of all data. Assess against flow data and baseline data. Compare with previous years to detect changes in vegetation and topography.

Relinquishment evaluation requirements	
Stage 1 Evaluation	Survey data from baseline and operation monitoring will be compared with data from relinquishment monitoring.
Stage 2 Evaluation	All data will be evaluated and photographs collated for presentation to regulators. An example of relinquishment monitoring and evaluation is presented in Appendix F of ACARP – “*Monitoring and Evaluation Program for Bowen Basin River Diversions*”.