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SUPPLEMENTARY HYDROLOGY AND GEOMORPHOLOGY TECHNICAL REPORT

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Report

Bowen Gas Project SREIS

AUSTRALIA

Hydrology and Geomorphology Technical Report

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ABBREVIATIONS

Abbreviation	Description
%	percent
AEP	annual exceedance probability
ARI	annual recurrence interval
AR&R	Australian rainfall and runoff
Arrow	Arrow Energy Pty Ltd
BOM	Bureau of Meteorology
CBM	Coal Bed Methane
CL	continuing losses (millimetres per hour)
cm	centimetre
CSG	coal seam gas
DEM	Digital elevation model
EFO	Environmental Flow Objective
EIS	Environmental Impact Statement
GIS	geographic information systems
GL	gigalitres
GL/yr	gigalitres per year
ha	hectare
IFD	intensity-frequency-duration
IL	initial losses (mm)
InSAR	Interferometric Synthetic Aperture Radar
K_c	empirical coefficient applicable to the catchment
km	kilometre
km^2	square kilometre
LIDAR	Light detection and ranging
$m^{0.5}/s$	weir coefficient of spillway
m^3/s	cubic metres per second
mAHD	metres above Australian Height Datum
ML/d	megalitres per day
mm	millimetres
mm/hr	millimetres per hour
NRM	Department of Natural Resources and Mines
ROP	Resource Operations Plan
RORB	Runoff-Routing model
SREIS	Supplementary Report to the EIS
SRTM	Shuttle radar topography mission
TUFLOW	Two-dimensional flow model
URS	URS Australia Pty Ltd
Water Act	Water Act 2000
WRP	Water Resource Plan
WTF	Water Treatment Facility

EXECUTIVE SUMMARY

Arrow Energy Pty Ltd (Arrow) is required to prepare a Supplementary Report to the Environmental Impact Statement (SREIS) to present information on updates to the project description, address issues identified in the Environmental Impact Statement (EIS) as requiring further consideration and/or information, and to respond to comments raised in submissions on the EIS. The project description has been updated since the EIS and identifies areas of interest for location of two co-located water treatment facilities (WTFs) and central gas processing facilities (CGPFs).

This report describes the hydrologic, hydraulic and geomorphologic studies undertaken in regard to the surface water environment related to the possible discharge of coal seam gas (CSG) water into the Isaac River from the WTFs. This study also includes flood modelling for the two indicative WTF localities to ascertain the extent of areas which are flood free. The assessment of potential impacts to hydrological and geomorphic aspects of surface water resources as a result of the proposed Project activities utilises the information presented in this report as well as those related to water quality and aquatic ecology presented in the Surface Water Quality Technical Report (Appendix F) and Aquatic Ecology Technical Report (Appendix H) of the SREIS respectively.

Section 9 of this report includes a qualitative assessment of the potential impacts associated with disposal of CSG water generated as part of Project operations. It comprises an assessment of preferred beneficial use options and indicative controlled or uncontrolled discharge of CSG water into the Isaac River in the event that those beneficial use options become unavailable. Further site-specific assessments of potential impacts to surface water resources will be incorporated into future Environmental Authority (EA) application or amendment processes.

Environmental Flow (Spells) Analysis

Environmental Flow (Spells) Analysis of the existing flow regime in the Isaac River at theoretical discharge locations was undertaken based on methodology utilised by Alluvium (2013) for the Surat Gas Project SREIS assessment, to preserve a consistent approach across Arrow development projects.

The Environmental Flow Analysis involves consideration of the hydrological regime within the Isaac River (prior to any discharge of CSG water from the Project) under a range of climatic conditions, in order to gain perspective on the seasonality, and spatial and temporal extent of various flow conditions. Hydrological data was collected from Department of Natural Resources and Mines (NRM) gauges on the Isaac River at Goonyella (130414A; closest gauge to indicative WTF1 locality) and Deverill (1301410A; closest to indicative WTF2 locality). Seasonality of low and high flow conditions at each locality was characterised by analysing the frequency at which certain flow conditions occurred, including the following:

- Low band – cease to flow conditions;
- Mid band – baseflow conditions (the flow volume that is exceeded on 80% of days); and
- High band – high flow conditions (the flow volume that is exceeded on 20% of days).

This frequency analysis was also completed for drought, dry, average, and wet years.

It was found that in the reaches of Isaac River proximate to the indicative localities of each WTF, the highly ephemeral flow regime was limited to short duration flows occurring between December and April. For the remainder of the year the river is dry or is limited to a series of isolated pools. The results indicate that for both reaches of the Isaac River, high flow conditions (which are most favourable for releases) only occur three to four times per season and only last for a relatively short duration (average of 11 to 16 days). Bankfull flows occur on average once every two years and also persist for up to four days depending on location.

In order to preserve identified aquatic, water quality, stream flow and geomorphic objectives, the high seasonal variability of flows means that opportunities for the release of CSG water will need to take the findings of the Environmental Flow Analysis into consideration.

Hydrology and Flood Assessment

Hydrologic modelling of the catchments associated with the indicative localities identified for the two WTFs was conducted using a runoff-routing model (RORB) to obtain estimates of peak flows for the 1% annual exceedance probability (AEP) design storm event. The resulting peak flows were used as inputs into the two-dimensional hydraulic model of the study areas to estimate flood inundation extents and key channel hydraulic characteristics.

Flood modelling for 1% AEP flood event indicates that the two indicative WTF localities have substantial areas which are flood free; these areas are orders of magnitude larger than the minimum area required at the two localities assessed for potential gas compression and water treatment facility locations. This is typical for the catchment, even under scenarios of increased rainfall intensity and duration as a result of climate change. As such, it can be concluded that these two infrastructure hubs assessed can be located outside of the modelled 1% AEP flood inundation level. The flood models will be reviewed and/or revised on a site-specific basis where necessary, as further information becomes available, to ensure facilities are not located in potential areas of flood.

Geomorphology

A geomorphic assessment of the Isaac River and local watercourses proximate to the indicative WTF localities was conducted to inform the potential impacts associated with Project activities. The assessment was based on data obtained during field assessments conducted as part of the EIS and information sourced from the Queensland Wetland mapping program.

The Isaac River in the vicinity of WTF1 was characterised as an ephemeral river with sand bed stream that is largely alluvial downstream of the Burton Gorge dam and is terrace confined. The bankfull width of the Isaac River at sites downstream of the Burton Gorge dam assessed as part of the Red Hill Coal Mine Project EIS varies from 20 m to 40 m. The floodplain varies from 150 m to 500 m in width, with an upper terrace approximately 2 m to 4 m higher than the floodplain. The condition of the Isaac River shows excess sediment inputs from changes in land use. The riparian vegetation along these reaches remains reasonably continuous at the overstorey level but minimal at the understorey level. Groundcover is variable but often dense with exotic grasses dominant.

The Isaac River in the vicinity of WTF2 was characterised as a low sinuosity, single channel (30 m to 40 m bankfull width), with floodplain up to 800 m in width. Similar to the upper reaches of the Isaac River, the river is ephemeral in nature and has a coarse sand bed. The riparian vegetation was described as semi-continuous along both banks with on average 50% of the trees greater than 10 m in height.

This study indicated that upon implementation of appropriate mitigation and management measures, the impacts on the geomorphic character of the Isaac River would be insignificant.

Hydraulic Assessment and Impact Assessment of CSG Water Discharges

The Isaac River channel has a bankfull capacity of 270 m^3/s (23.3 GL/d) in the reaches near the WTF1 possible locality, and a bankfull capacity of 2,350 m^3/s (203 GL/d) in the reaches near the WTF2 possible locality. These relatively large volumes indicate that the Isaac River in flood has a high capacity to receive CSG water discharges without any significant impacts on its environment values (water quality, flows and geomorphic condition). The actual discharge conditions will be determined as part of the EA application process once the WTF localities have been finalised, and discharge rates adjusted accordingly to mitigate potential impacts, based on the final selected location of WTF's and subsequently location of discharge points.

Impacts to geomorphology as a result of localised disturbances of watercourses during construction activities or from subsidence, should any occur, could include localised erosion and sediment deposition. Works within watercourses should be conducted in the dry season as much as possible and in accordance with regulatory requirements for works conducted in watercourse channels. Monitoring and site specific erosion control measures should be developed at the design stage, including vegetation establishment or engineered erosion protection such as rock structures or energy dissipation structures.

Any potential wetland areas identified near the WTF1 and WTF2 localities will be better defined through field assessments in order to avoid inappropriate siting of infrastructure in relation to wetland areas where possible. At the construction phase of the Project, crossing of watercourses and floodplains near wetlands will be avoided as much as possible.

1 INTRODUCTION

1.1 Study Objectives

Arrow Energy Pty Ltd (Arrow) is required to prepare a Supplementary Report to the Environmental Impact Statement (SREIS) to present information on updates to the project description, address issues identified in the Environmental Impact Statement (EIS) as requiring further consideration and/or information, and to respond to comments raised in submissions on the EIS.

This report describes the hydrologic, hydraulic and geomorphologic studies undertaken to address the potential impacts caused by the construction and operation of two proposed water treatment facilities (WTFs), as well as assess potential impacts to the associated receiving environment during any possible discharges of treated or untreated coal seam gas (CSG) water. Studies conducted include:

- A 'Spells' or Environmental Flow Analysis to describe the current flow regime of the Isaac River main channel in the vicinity of the two WTF areas of interest to inform a management strategy for future CSG water discharges;
- A flood investigation to assess risks at two indicative central gas processing facility (CGPF) and WTF localities and associated infrastructure, including climate change consideration:
  a) Hydrologic modelling of 1% Annual Exceedance Probability (AEP) catchment runoff using runoff-routing software RORB, and
  b) Two-dimensional hydraulic modelling of the two potential CGPF and WTF localities, using the hydraulic flow model TUFLOW;
- Hydraulic assessment for possible surface water discharges; and
- Geomorphologic desktop assessment of the potential receiving stretches of the Isaac River main channel associated with the indicative WTF localities. Field assessments for stream geomorphology were not able to be undertaken as part of the SREIS due to insufficient rainfall during the 2013/2014 wet season. Geomorphology was assessed using field data obtained during the preparation of the EIS (URS, 2012), the Red Hill Mining Lease EIS (URS, 2013) and the EHP WetlandInfo database (EHP, 2012).

This technical report specifically addresses the hydrological and geomorphological aspects of any potential impacts related to activities described in the updated project description. These studies should be considered together with project impacts related to water quality in the Surface Water Technical Report (Appendix F) and the Aquatic Ecology Technical Report (Appendix H) of the SREIS. The different and inter-relating aspects that determine river health such as water quality, river hydrology, geomorphology and aquatic ecology, were considered simultaneously to protect all environmental values associated with the Isaac River. This approach was utilised in the assessment of impacts associated with potential discharges of CSG water. This interrelationship is depicted in Figure 1-1.

Details of the Environmental Flow (Spells) Analysis are provided in Section 4 while the hydrologic and hydraulic components of the flood modelling are described in Section 5 and Section 6 respectively. Hydraulic assessment of potential surface water discharges is described in Section 7 followed by geomorphology in Section 8. The impact assessment presented in this study also uses the information relating to water quality of the receiving environment reported in the Surface Water Quality Technical Report (Appendix F) of the SREIS.

1.2 Background

The initial project description was developed to inform the EIS. The project description formed the basis upon which all impact assessment studies were conducted and as of March 2012 was fixed, to allow EIS studies to progress.

The SREIS has been prepared to:

- Present any material changes to the project description (including any further impact assessment deemed necessary as a result of these changes); and
- Respond to the public submissions made on the EIS.

A summary of the changes to the project description in relation to water management since publication of the EIS is presented in Table 1-1.

Table 1-1 Summary of Key Project Description Water Components and Changes

Component	EIS Chapter 5 Project Description	SREIS Project Description Refinements
Production wells	• 6,625 production wells drilled over approximately 40 years • Single well pads only • Estimated total water produced 276 GL	• Approximately 4,000 production wells drilled over approximately 36 years • All multi-well pads of up to 6 production wells each • Estimated total water produced 153 GL
Field gathering and compression systems	• Ten field compressor facilities (FCF), and 17 drainage areas of approximately 12 km radius	• One FCF within each of 33 drainage areas of approximately 6 km radius
WTFs	• Four integrated processing facilities (IPFs; including both gas and water processing facilities) with dams up to 1 km^2 • Peak flows of 15-30 ML/day CSG water from each WTF	• Two CGPFs, each with a co-located WTF • Peak flow capacity of 12.9 ML/day CSG water produced at WTF1 • Peak flow capacity of 20 ML/day CSG water produced at WTF2 • Potential future third WTF in Blackwater area being considered

The SREIS project description identifies two WTFs to operate on site co-located with CGPFs. These WTFs will include a raw CSG water storage dam, a treated water dam, brine dams and treatment plants including large pumps and pipework. The SREIS assessment is based upon two preferred localities for the two WTFs. Once the final location is determined a site-specific environmental impact assessment will be completed to support specific approvals in an environmental authority. It is anticipated that the following items would be included in a site-specific assessment:

- Location of infrastructure in accordance with information contained in this report and the EIS; including consideration of areas with high constraint in relation to potential impacts and level of risk;
- Assessment of hydrological flow regime at the proposed new location(s), using similar methodology to that undertaken for this assessment;
- Detailed assessment of localised and regional impacts to surface water resources (including hydrological regime and geomorphology) potentially resulting from the proposed activity; and
- Justification of the location choice, compared with alternative scenarios.

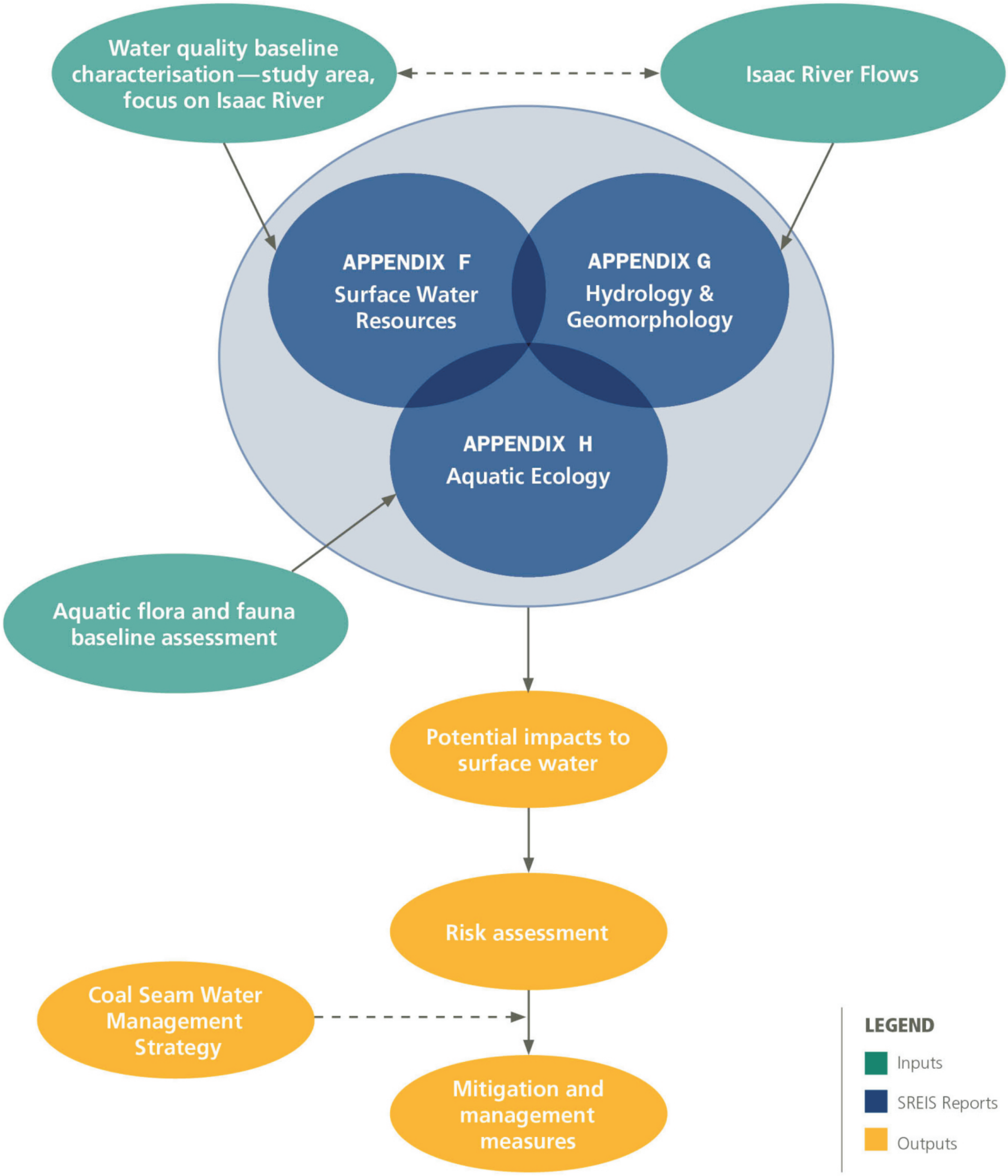
The layout and infrastructure associated with water treatment facilities were described in the EIS.

1.3 Current Preferred Area of Interest Locality for Water Treatment Facility 1

The current preferred area of interest of WTF1 is in the vicinity of Skull Creek; one of the tributaries of the upper Isaac River and downstream of the Burton Gorge Dam. This proposed locality is more than 4 km away from the nearest reaches of the Isaac River. Figure 1-2 demonstrates the current preferred locality for WTF1, and indicates the associated downstream receiving environment within the Isaac River.

1.4 Current preferred Locality for Water Treatment Facility 2

Scrubby Creek has been identified as the nearest watercourse flowing to the northeast of the WTF2 potential area of interest. The nearest reach of the lower Isaac River to the WTF2 area of interest is located approximately 10 km to the west. Figure 1-3 shows the current preferred locality for WTF2, and indicates the associated downstream receiving environment within the Isaac River.



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BOWEN GAS PROJECT SREIS

OVERVIEW OF IMPACT ASSESSMENT PROCESS FOR THE SURFACE WATER ENVIRONMENT

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HYDROLOGY - SURFACE WATER ASSESSMENT

Figure: 1-1

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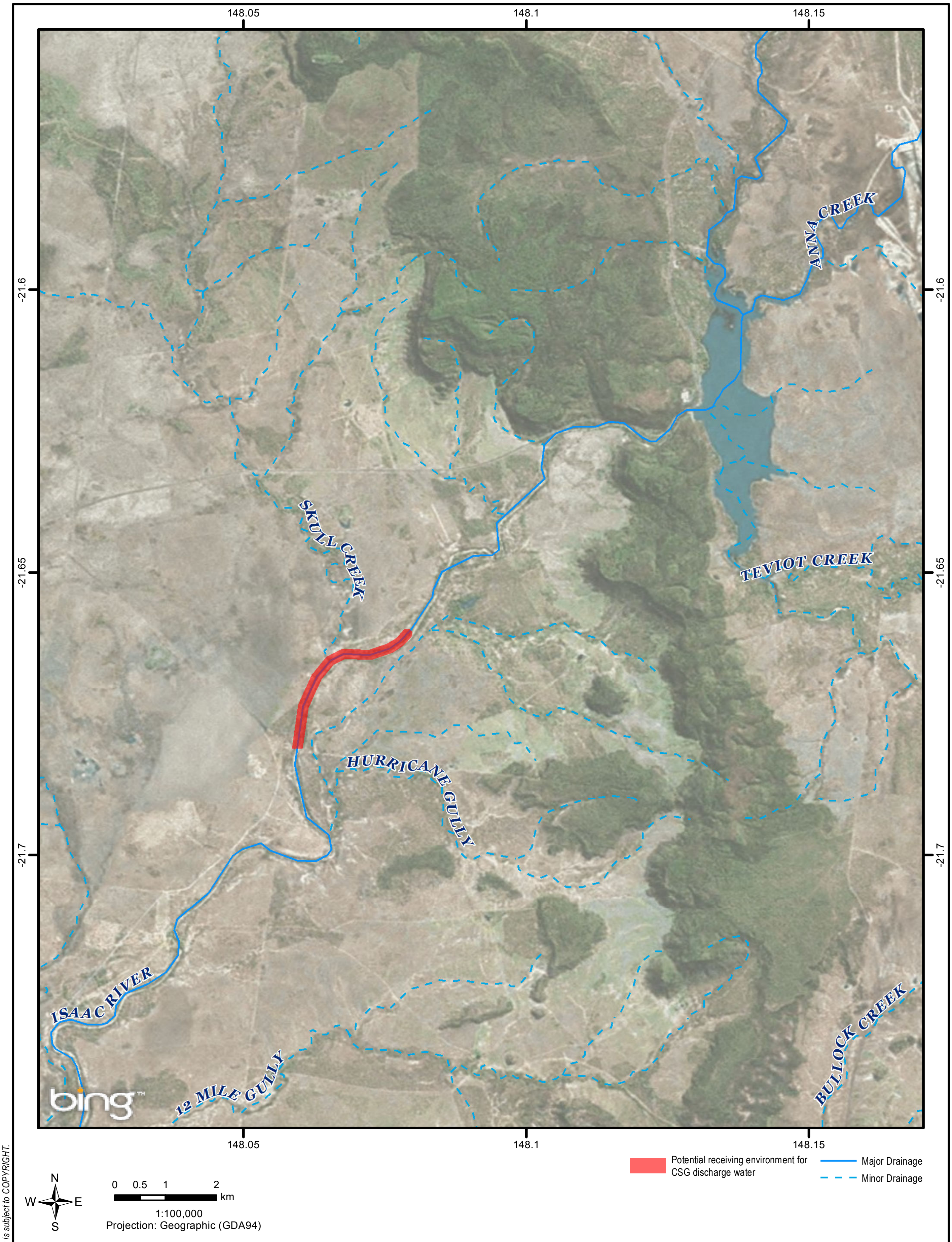

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BOWEN GAS PROJECT SREIS

POTENTIAL RECEIVING ENVIRONMENT FOR CSG WATER DISCHARGE FOR WATER TREATMENT FACILITY 1

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HYDROLOGY - SURFACE WATER ASSESSMENT

Figure: **1-2**

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BOWEN GAS PROJECT SREIS

POTENTIAL RECEIVING ENVIRONMENT FOR CSG WATER DISCHARGE FOR WATER TREATMENT FACILITY 2

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HYDROLOGY - SURFACE WATER ASSESSMENT

Figure: **1-3**

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2 LEGISLATIVE AND POLICY FRAMEWORK

This section describes the legislative context, relevant policies and standards at Commonwealth and State level that apply to the Project.

2.1 Environment Protection and Biodiversity Conservation Act 1999 (Cwlth)

The Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) outlines requirements relating to the management and protection of national and international flora and fauna of environmental significance, referred to as matters of national environmental significance (MNES) (Volume 1, Chapter 2, Part 3, Division 1). Subdivision FB relates to protection of water resources from CSG development and large coal mining development. Gas project developments can potentially disrupt aquatic ecosystems and therefore have adverse impacts on aquatic species, water resources and Ramsar wetland sites. An action with the potential for a significant impact on MNES must be referred to the Minister for the Commonwealth Department of the Environment (formerly Department of Sustainability, Environment, Water, Population and Communities) and may require approval under the EPBC Act.

The nine MNES under the EPBC Act are as follows:

- World heritage properties;
- National heritage places;
- Wetlands of international importance (often called 'Ramsar' wetlands after the international treaty these wetlands are listed);
- Nationally threatened species and ecological communities;
- Migratory species;
- Commonwealth marine areas;
- The Great Barrier Reef Marine Park;
- Nuclear actions (including uranium mining); and
- A water resource, in relation to CSG development and large coal mining development.

2.1.1 Environment Protection and Biodiversity Conservation Amendment Act 2013

Changes made to the EPBC Act on 22 June 2013, resulted in water resources in relation to CSG and large coal mining developments now being considered as a MNES. In accordance with this legislative change, on 17 October 2013, the Commonwealth Minister for Environment determined that water resources were a controlling provision under Sections 24D and 24E of the EPBC Act for the Project. This was due to the information available to the Minister at that time, indicating that the Project may potentially directly or indirectly result in a substantial change to the hydrology and quality of water resources impacted by project activities. In making the decision, the Minister recognised that previously submitted documents, as well as subsequent documentation will be considered in the decision regarding the water resources controlling provision.

2.2 Water Act 2000 (Qld)

In Queensland, the Water Act establishes a system for the planning, allocating and use of non-tidal water. The Water Act is administered primarily by the Department of Natural Resources and Mines (NRM), except that the Department of Environment and Heritage Protection (EHP) administers Chapter 3, and the Department of Energy and Water Supply administers Chapter 2A and the part of Chapter 4 that relates to Category 1 Water Authorities.

2.2.1 Water Planning Provisions

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 and are applied on a catchment scale. The WRP establishes environmental flow objectives (EFO) that are of importance for waterway health, and sets water allocation security objectives which are important to maintain water availability for 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 study area is located within the Fitzroy Basin and water resources are therefore managed under the Water Resource (Fitzroy Basin) Plan 2011. The study area is in a supplemented area of the Fitzroy Basin which means that flows in the Isaac River are regulated by releases from upstream dams (Burton Gorge Dam and Teviot Dam) and weirs.

The Fitzroy Basin ROP came into force in January 2004, and was recently amended in October 2011 (Revision 3). It details how the objectives of the Fitzroy WRP will be met on an operational level, and defines strategies to support the overall goals of the WRP for water entitlement security and ecological health.

In general the ROP provides the basis and rules for trading of water allocations, allows for unallocated water to be identified and allocated and also details operating rules for the use of water management infrastructure such as weirs and dams.

Under the Water Act, WRP, and ROP, water storages required for the Project will not require approval for taking overland flow as these are required to meet the requirements of an environmental authority, and also have catchment areas less than 250 ha.

2.3 Environmental Protection Act 1994

The EP Act aims to protect Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends (ecologically sustainable development).

The EP Act governs the management of surface water with regards to gas fields, including the management and disposal of CSG water. The EP Act was amended in March 2013 to include requirements for site-specific applications related to CSG activities (Section 126). The primary instrument by which surface water management is achieved is the Environmental Protection (Water) Policy 2009. The EP Act is administered by the EHP.

The following regulations and policies are also relevant under the EP Act:

- Environmental Protection (Water) Policy 2009;
- Environmental Protection (Waste Management) Policy 2000;
- Environmental Protection (Waste Management) Regulation 2000; and
- Environmental Protection Regulation 2008.

These instruments are supported by the CSG Water Management Policy 2012.

3 ENVIRONMENTAL VALUES

The study area is located completely within the Isaac-Connors sub-catchment, of the greater Fitzroy Basin. In the greater regional catchment context, the study area is in the far upstream headwaters of the Fitzroy Basin. The proposed Project activities are expected to span across the Isaac River and tributary catchments of Skull Creek and Scrubby Creek.

The desktop assessment and subsequent targeted field investigations undertaken for the EIS identified environmental values associated with wetlands, rivers and other water bodies in the study area to inform the assessment of impacts and the development of mitigation measures.

Surface water related impacts are potentially varied due to different aspects of the Project, and how the Project operations interact with waterways (creeks, rivers, streams). The following generalised impacts may potentially arise from CSG related development and operations activity:

- There may be changes in the quantity (flow) and quality of waters downstream of the Project area, which could in turn affect water users, aquatic ecosystems, and other identified environmental values of waters. This may include changes that occur as a result of day to day activities as well as changes arising from unforeseen events. This report aims to identify potential impacts to the hydrological regime within the study area, as a result of proposed Project activities. This includes changes in the availability of water in Isaac River (an ephemeral watercourse) and any changes to discharge volume and stream level during flow periods. Further assessment of potential impacts to water quality and aquatic ecology within the study area is included in the Surface Water Quality Technical Report (Appendix F) and Aquatic Ecology Technical Report (Appendix H) of the SREIS respectively.
- Construction of major infrastructure such as CGPFs and WTFs may cause changes in flood characteristics, and this then has potential to influence geomorphological response of the waterways through and downstream of the study area. For this reason, this report also presents the geomorphological context, potential impacts and mitigation.

While site-specific impacts from Project infrastructure on surface water values could not be determined at the time, the EIS described the regional surface water system and determined that through the implementation of standard mitigation measures, the potential impacts could be managed. The impacts to hydrology and geomorphology that could potentially arise from Project activities are described in Section 9 of this report.

4 ENVIRONMENTAL FLOW (SPELLS) ANALYSIS

Streamflow is an essential supporting component of river ecosystems; it provides habitat for many aquatic flora and fauna and supports a variety of critical ecological processes (NRE, 2002). At a national level Kennard et al (2010) developed a methodology for the classification of natural hydrological regimes that provide an initial basis for predicting the ecological impacts of stream flow alteration. Flow regime classes were characterised based on streams across Australia which had minimal anthropogenic disturbance. The twelve flow regimes that were identified were differentiated on the basis of their seasonal flow patterns, flow permanence and frequency and magnitude of flood events. The premise of this classification was that all streams with similar hydrological properties have similar assemblage composition and species characteristics and therefore the ecological and geomorphic response to flow regime change should be similar.

The Environmental Flow Analysis has considered both the relevant literature and the previous work completed for the Arrow Surat Gas Project SREIS (Alluvium, 2013) in order to derive an appropriate methodology for describing the existing flow regime at both of the potential WTF areas of interest. The results of the Environmental Flow Analysis have been used as input to the Surface Water Quality Technical Report (Appendix F) of the SREIS to establish the potential impact of CSG water discharges.

4.1 Methodology and Assessment Parameters

The methodology used in this Environmental Flow Analysis was based on that adopted by Alluvium (2013) for the assessment of the Surat Basin conducted previously for Arrow. This methodology takes into account:

- Stream flows and climatic conditions throughout the study catchment (require stream flow / discharge data from local or regional stream gauges);
- On-line storages (for example, existing dams utilised for potable water supply to the surrounding region, situated upstream within the same catchment as the study area); and
- Assessment period; a defined period for which data is collected, which provides sufficient representation of as wide a variety of climatic and hydrological conditions as possible. Generally a longer record is optimal.

The assumptions made, and extent of information available, for each of the listed variables are detailed (along with analysis results) for each potential WTF area of interest below (Sections 4.2 and 4.3). The context in which data was collected, and relevant assumptions for each variable, are outlined in Sections 4.1.1 to 4.1.5 below.

4.1.1 Selection of Stream Gauge Data

The nearest Queensland NRM stream gauge to the WTF1 area of interest is Isaac River at Goonyella (130414A) located approximately 25 km downstream and with a reporting catchment area of 1,214 km^2.

The nearest NRM stream gauge to the WTF2 area of interest is the Isaac River at Deverill (130410A) which is located within the Coxendean East tenement and has a reporting catchment area of 4,092 km^2.

Both of the stream gauges are considered to be adequately representative of flow conditions likely to be present at potential discharge points from each WTF and an assessment of the quality and consistency of data available for each gauge was also conducted as part of the analysis.

4.1.2 Climatic Condition

Analysis of the existing flow regime in the Isaac River adjacent to both of the potential WTF areas of interest was considered under a range of climatic conditions which represent the four quartiles of the total annual discharge at each flow gauge:

- **Drought years** – all years where the total annual flow is in the lowest quartile (bottom 25% of years);
- **Dry years** – all years where the total annual flow is exceeded in 50-75% of years;
- **Average years** – all years where the total annual flow is exceeded in 25-50% of years; and
- **Wet years** – all years where the total annual flow is exceeded in 25% of years.

Annual flow was based on the calendar year rather than the normal water year of July through June. This has ensured that the low flow season does not become truncated during subsequent analysis. The low flow season is considered to be of greater interest as ecological risks are likely to be greater during this period as the assimilative capacity of the receiving water is likely to be lower due to reduced frequency and volume of natural discharges.

4.1.3 Flow Duration

Cumulative exceedance plots were produced for each gauge and show the probability of a particular flow being exceeded. While the results do not directly feed into the Environmental Flow Analysis they do provide additional insight into the flow regime of the Isaac River at each gauge by giving an important understanding of the typical duration of flows in the Isaac River. This is important for the management of potential CSG water discharges into the receiving environment.

4.1.4 Seasonality

The annual flow regime has been divided into two distinct seasons based on identified changes in the flow regime as follows:

- **Low flow season** – extended periods of low flow characterised by periods of base flow or cease to flow conditions with infrequent shorter periods of high flow caused by localised rainfall events; and
- **High flow season** – a period of higher base flow with frequent and extended periods of higher flows from larger and more widespread storms and seasonal rainfall.

Identification of each season has been conducted by completing a frequency analysis on daily flow data in each month. The percentage of daily flows that fall within a number of flow bands were used to identify the characteristics of each flow season:

- **Low band** – cease to flow conditions;
- **Mid band** – baseflow conditions (flow that is exceeded on 80% of days); and
- **High band** – high flow conditions (flow that is exceeded on 20% of days).

4.1.5 *Spells Analysis*

The Spells Analysis was conducted for each climatic condition (drought, dry, average and wet) and for each flow season (high and low flow). Five different flow conditions were defined and a range of criteria were assessed. Table 4-1 describes the various flow conditions and criteria that were used to conduct the analysis.

Table 4-1 Spells Analysis Flow Conditions and Criteria

Criteria / Flow Condition	Description
Flow (ML)	Minimum daily streamflow required to meet the flow condition
Number per season	Average number of spells (a spell being defined as a period of continuous days that the flow condition is met or exceeded)
Average duration	The average length of each spell (days)
Median duration	The median length of each spell (days)
Total duration	The average total number of days that each flow condition is met
Cease to flow	No recordable flow
Flow exceeded 80% of the time	Low fresh
Flow exceeded 20% of the time	High fresh (exceeded 20% of the time)
Flow exceeded 5% of the time	High fresh (exceeded 5% of the time)
1 in 2 ARI	Selected bankfull flow

4.2 Environmental Flow Assessment Results for WTF1

The following information provides context for the analysis conducted to determine environmental flows within the receiving environment associated with WTF1, including key assumptions and findings.

The nearest NRM stream gauge to the area of interest for WTF1 was on the Isaac River at Goonyella (130414A).

4.2.1 Selection of Assessment Period

Two dams are located upstream of the gauge as follows:

- Burton Gorge Dam (19,264 ML capacity) which was commissioned in 1992 and is located approximately 12 km upstream of the proposed WTF1 area of interest at the confluence of Teviot Creek and the Isaac River; and
- Teviot Creek Dam (24,000 ML capacity) which was commissioned in 2001 and is located approximately 12 km upstream of Burton Gorge Dam.

Flow data is available for the Goonyella gauge (130414A) from May 1983 to present day and due to the construction of Burton Gorge Dam only data from 1992 onwards has been used to conduct the Spells Analysis. To ensure consistency with the analysis of the Goonyella gauge for WTF1, analysis of the Deverill gauge for WTF2 was also conducted on data for the period 1992 to 2012 only. In addition, conducting the Environmental Flow Analysis on data recorded after the construction of Teviot Creek Dam (i.e. from 2002 to 2013) would result in an insufficient length of data for analysis.

It is important to note that construction of the Burton Gorge Dam and Teviot Dam will have significantly altered the downstream hydrologic regime particularly for low flow freshes which might be expected to be significantly reduced. This is of specific relevance given that potential discharges of either treated or untreated CSG water is dependent on the hydrological regime of the receiving environment and the construction of these dams is likely to have significantly reduced potential discharge opportunities during drought/dry conditions. During wet years or the high flow season the impact of the dam would be less relevant as the dam would typically spill as part of its normal operations.

Stream discharges measured at the Goonyella gauge will be slightly higher than at the area of interest for WTF1; however the gauge is considered to be close enough to be representative of actual conditions at any potential discharge point and no adjustments have been made to the data.

Data Quality Assessment

Analysis of the Goonyella gauge flow data for the period 01/01/1992 to 31/12/2012 indicated that there were no missing records or unusable data. The accuracy of the stream gauge and gauge rating curves has not been assessed as part of this study.

4.2.2 Climatic Condition

Table 4-2 shows the annual discharge quartiles for annual discharge at the Goonyella gauge for the period 1992 through 2013, while Figure 4-1 shows the annual discharge variability between years based on the quartile analysis.

- Annual discharge at the Goonyella gauge is extremely variable, ranging from zero in 2003 to 360 GL in 2008 and 2010; and
- Annual discharges are subjected to extended periods of extremely low flow, e.g. 1992 to 1996 and 2001 to 2006.

Table 4-2 Annual Discharge Quartiles (1992 – 2012) at Goonyella Gauge (130414A)

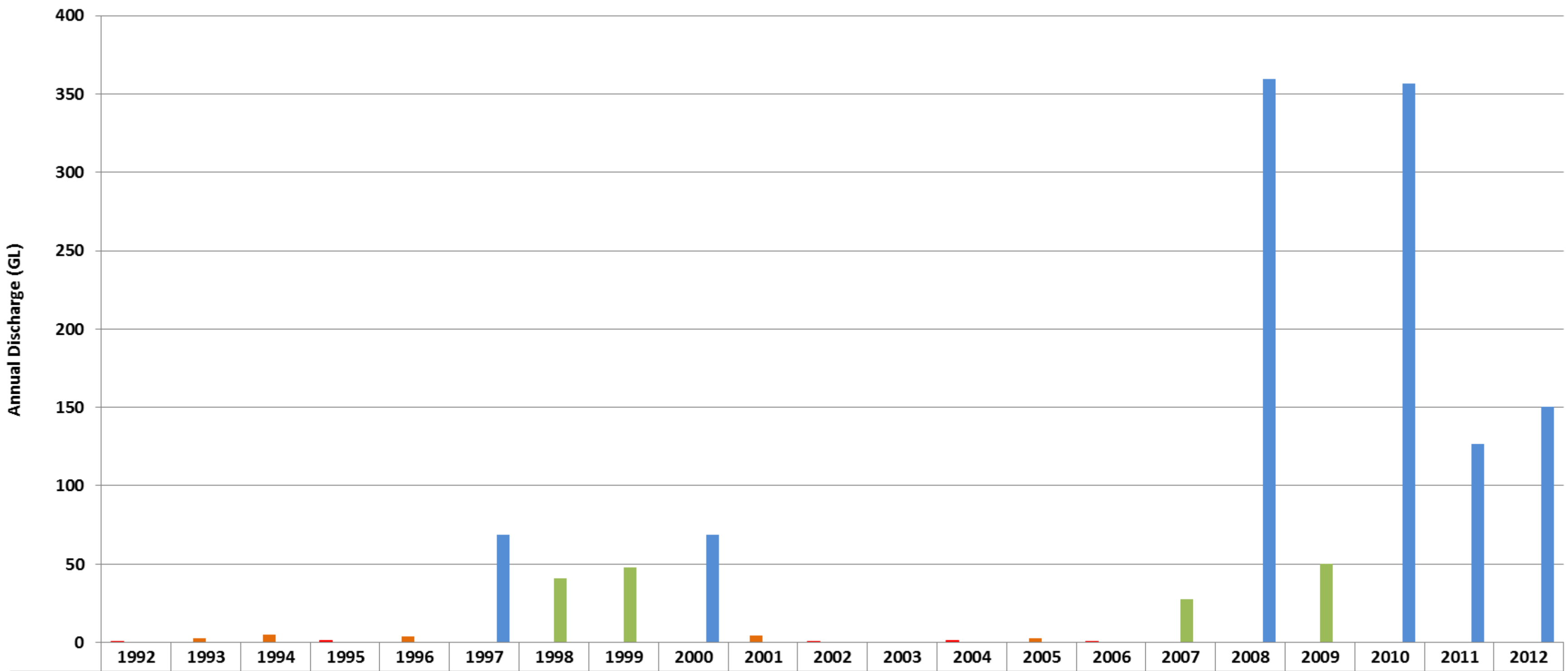
Climatic Condition	Definition	Annual Discharge (GL/y)
Drought	Less than or equal to the 25th percentile	≤ 1.45
Dry	Greater than the 25th percentile but less than or equal to the 50th percentile	> 1.45 and ≤ 4.92
Average	Greater than the 50th percentile but less than or equal to the 75th percentile	> 4.92 and ≤ 68.61
Wet	Greater than the 75th percentile	> 68.61

4.2.3 Flow Duration

Daily flow data for the Goonyella gauge has been plotted as a cumulative exceedance probability plot (refer to Figure 4-2) which gives the probability of a particular discharge being exceeded. From this it can be seen that:

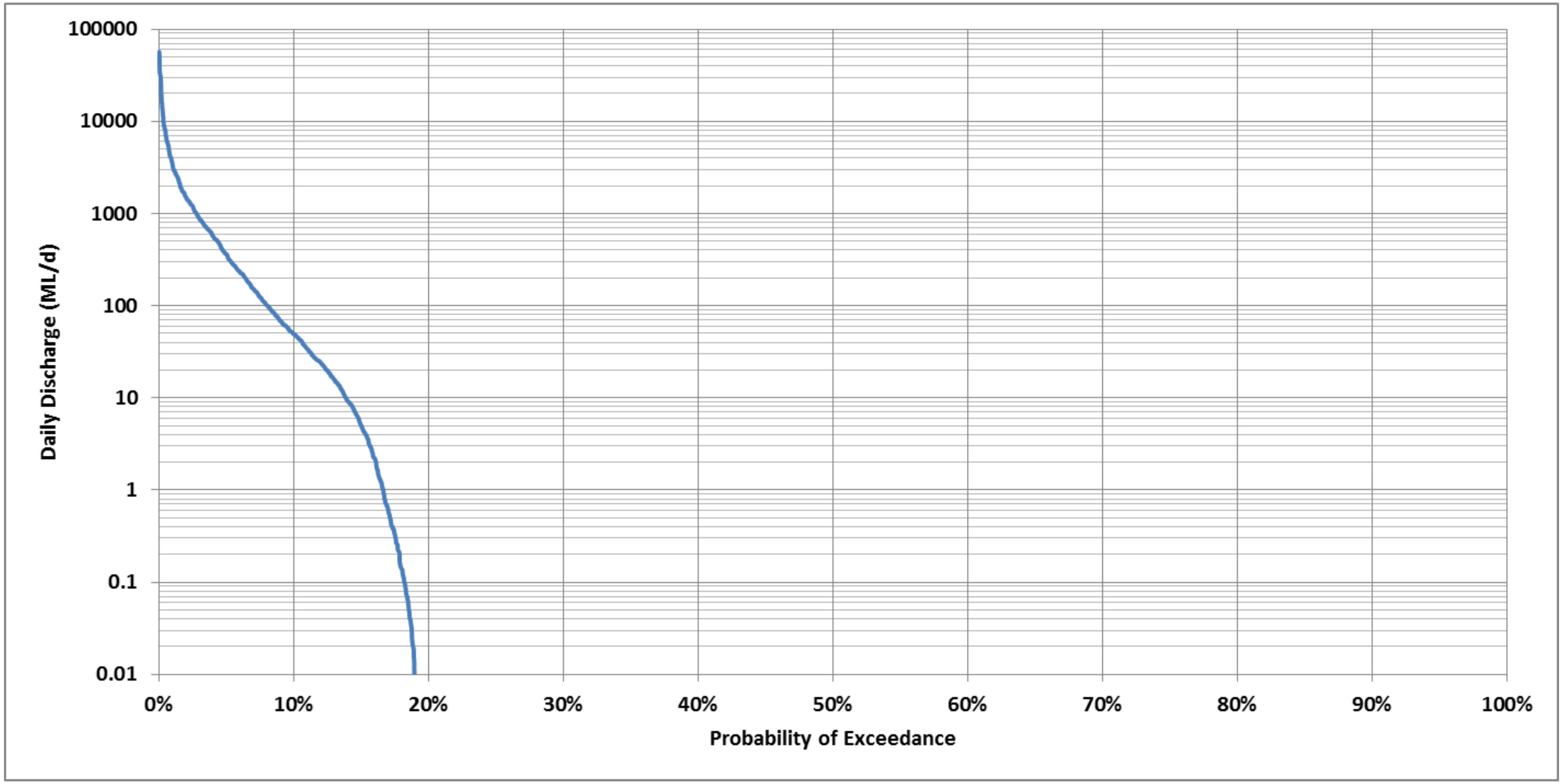
- Cease to flow conditions are present for approximately 82% of all days;
- Flow recession is likely to be rapid with flows only occurring during and immediately after significant rainfall events; and
- No clearly defined baseflow condition exists.

Figure 4-1 Annual Discharge at Goonyella Gauge (130414A)



	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Drought	0.55			1.06							0.03	0.00	1.45		0.25						
Dry		2.79	4.92		3.53					4.49				2.35							
Average							40.88	47.90								27.43		50.37			
Wet						68.61			68.90								359.39		356.85	126.54	150.24

Figure 4-2 Daily Discharge Cumulative Exceedance Probability (1992 - 2012) at Goonyella Gauge (130414A)



4.2.4 Seasonality

Due to the highly ephemeral nature of natural flows at the Goonyella gauge (cease to flow conditions are present for almost 95% of days in some months) and the absence of a defined baseflow condition, division of flow into three bands (low, mid and high) was not warranted. Therefore seasonality has been assessed on the basis of whether flow is typically present for more than 20% of days per month. Figure 4-3 shows the distribution of flows for each month.

Figure 4-3 Proportion of Daily Flows in Low and High Flow Bands at Goonyella Gauge (130414A)

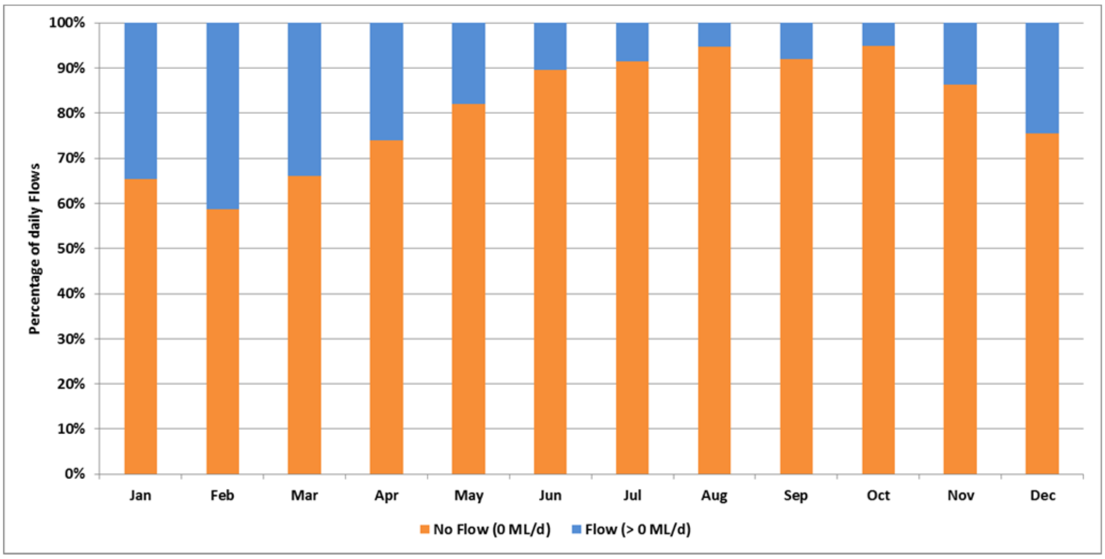


Figure 4-3 shows a defined high flow season, when discharge occurs for more than 20% of days, which generally occurs from December through April. A low flow season, where discharge occurs less than 20% of days, is present from May through November. Table 4-3 summarises the temporal extent of both flow seasons for the Goonyella stream gauge.

Table 4-3 Flow Seasons at Goonyella Gauge (130414A)

Flow Season	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Low Flow Season												
High Flow Season												

4.2.5 Summary of Environmental Flow Analysis in the Vicinity of WTF1

Table 4-4 details the results of the Spells Analysis for the Goonyella gauge. The analysis has been completed for each season (high and low flow) and for each climatic condition as well as all years of data. The results show that for all years analysed (1992 – 2012):

- Cease to flow conditions are present for approximately 90% (193 days) of the low flow season (May through November) and approximately 70% (103 days) of the high flow season (December through April);
- High flows (flow exceeded 20% of the time) of 43 ML/d occur three to four times per high flow season and last, on average for 11 days;
- High flows (flow exceeded 5% of the time) of 1,262 ML/d occur three to four times per high flow season and last, on average for eight days; and
- Bankfull flow (1 in 2 ARI) of 1,930 ML/d occurring, on average every two years and lasting, on average for three to four days during the high flow season.

It is important to note that the bankfull flows depicted here represent flows for the Isaac River at the Goonyella gauge, and not those calculated for Isaac River reaches tentatively identified as possible discharge locations for WTF1 (see Section 7.1.4). The bankfull flow is a standard flow component (Alluvium, 2013) that depicts a flow that fills the channel, but does not spill onto the floodplain.

4.3 Spells Analysis for Water Treatment Facility 2

The following information provides context for the analysis conducted to determine environmental flows within the receiving environment associated with WTF2, including key assumptions and findings.

The nearest NRM stream gauge to the area of interest for WTF2 was on the Isaac River at Deverill (130410A).

4.3.1 Selection of Assessment Period

As described in Section 4.2.1, the presence of both Burton Gorge and Teviot Creek Dams will influence downstream stream flow. While the influence of the dams could be expected to be less significant with increasing distance downstream some impact will occur. Therefore, in order to ensure the assessment is representative of the current stream flow conditions and for consistency with the analysis of the Goonyella gauge for WTF1, analysis of the Deverill gauge was conducted on data for the period 1992 to 2012 only.

Data Quality Assessment

Analysis of the Deverill gauge flow data for the period 01/01/1992 to 31/12/2012 indicated that there were no missing records or unusable data. The accuracy of the stream gauge and gauge rating curves was not assessed as part of this study.

Table 4-4 Environmental Flow Analysis Summary at Goonyella Gauge (130414A)

		Low Flow Season (May - Nov)					High Flow Season (Dec - Apr)				
		Flow Condition (ML/d)	Events per Season	Average Event Duration (Days)	Median Event Duration (Days)	Average Total Days per Season	Flow Condition (ML/d)	Events per Season	Average Event Duration (Days)	Median Event Duration (Days)	Average Total Days per Season
DROUGHT	Cease to flow	0.0	2.0	105.5	93.5	211.0	0.0	4.8	29.0	9.0	140.3
	Flow exceeded 80% of the Time	0.0					0.0				
	Flow exceeded 20% of the Time	0.0					0.0				
	Flow exceeded 5% of the Time	0.0					0.2	2.8	2.6	2.0	7.7
	1 in 2 ARI	1,930					1,930				
DRY	Cease to flow	0.0	1.8	117.9	173.0	212.2	0.0	4.8	26.9	12.0	129.0
	Flow exceeded 80% of the Time	0.0					0.0				
	Flow exceeded 20% of the Time	0.0					0.0				
	Flow exceeded 5% of the Time	0.0					57.6	2.6	2.9	2.0	7.6
	1 in 2 ARI	1,930					1,930				
AVERAGE	Cease to flow	0.0	1.8	110.9	121.0	194.0	0.0	4.6	13.8	6.5	89.8
	Flow exceeded 80% of the Time	0.0					0.0				
	Flow exceeded 20% of the Time	0.0					52.0	3.5	6.1	3.0	30.3
	Flow exceeded 5% of the Time	47.5	1.5	7.2	6.0	10.8	1349.6	2.3	2.4	2.0	7.8
	1 in 2 Year ARI	1,930	0.8	1.3	1.0	1.0	1,930	1.8	1.8	1.5	4.5
WET	Cease to flow	0.0	2.5	63.2	33.0	158.0	0.0	3.7	14.4	12.0	52.8
	Flow exceeded 80% of the Time	0.0					0.0				
	Flow exceeded 20% of the Time	3.3	3.2	13.5	11.0	42.8	722.5	5.2	5.9	3.0	30.3
	Flow exceeded 5% of the Time	84.0	2.3	4.6	2.5	10.8	5279.5	3.2	2.4	2.0	7.7

		Low Flow Season (May - Nov)					High Flow Season (Dec - Apr)				
		Flow Condition (ML/d)	Events per Season	Average Event Duration (Days)	Median Event Duration (Days)	Average Total Days per Season	Flow Condition (ML/d)	Events per Season	Average Event Duration (Days)	Median Event Duration (Days)	Average Total Days per Season
	1 in 2 Year ARI	1,930	0.7	1.0	1.0	0.7	1,930	3.5	4.5	2.0	15.7
ALL YEARS	Cease to flow	0.0	2.0	94.2	55.0	192.9	0.0	4.3	23.8	4.0	103.0
ALL YEARS	Flow exceeded 80% of the Time	0.0					0.0				
ALL YEARS	Flow exceeded 20% of the Time	0.0					43.1	3.7	10.8	3.5	40.2
ALL YEARS	Flow exceeded 5% of the Time	21.8	1.6	6.8	3.0	10.7	1261.6	3.3	7.8	2.0	25.9
ALL YEARS	1 in 2 Year ARI	1,930	0.3	1.1	1.0	0.4	1,930	1.5	3.6	2.0	5.3

Shaded cells indicate that the flow exceedance condition is equal to zero e.g. where the “Flow exceeded 20% of the time” is equal to zero, cease to flow conditions are present on more than 80% of days

4.3.2 Climatic Condition

Table 4-5 shows the annual discharge quartiles for annual discharge at the Deverill gauge for the period 1992 through 2013, while Figure 4-4 shows the climatic condition for each year of annual discharge based on the quartile analysis.

- Annual discharge at the Deverill gauge is extremely variable ranging from 0.84 GL in 1992 to 920 GL in 2012; and
- Annual discharges are subjected to extended periods of below average flow such as 2001 to 2006.

Table 4-5 Annual Discharge Quartiles at Deverill Gauge (130410A)

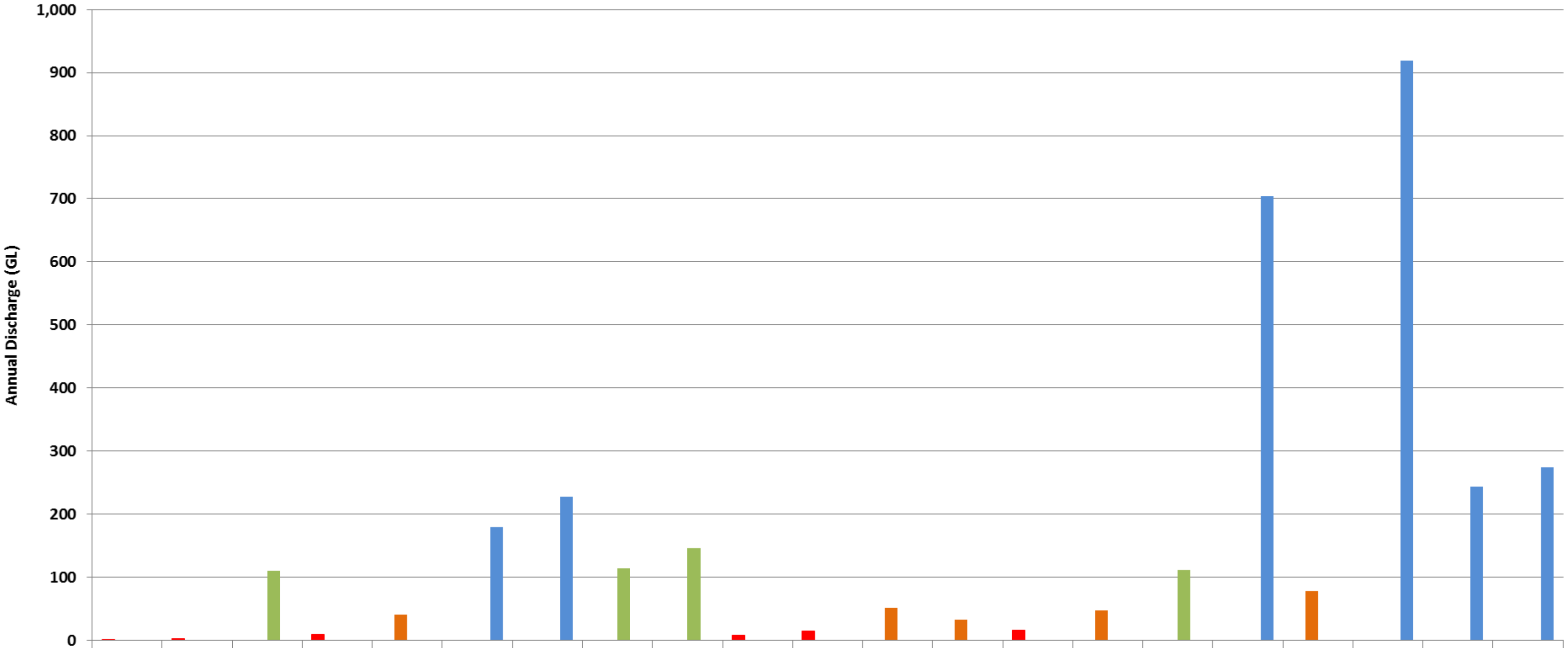
Climatic Condition	Definition	Annual Discharge (GL/y)
Drought	Less than or equal to the 25th percentile	≤ 16.40
Dry	Greater than the 25th percentile but less than or equal to the 50th percentile	> 16.40 and ≤ 77.90
Average	Greater than the 50th percentile but less than or equal to the 75th percentile	> 77.90 and ≤ 179.21
Wet	Greater than the 75th percentile	> 179.21

4.3.3 Flow Duration

Daily flow data for the Deverill gauge has been plotted as a cumulative exceedance probability plot (refer to Figure 4-5) which gives the probability of a particular discharge being exceeded. This plot shows that:

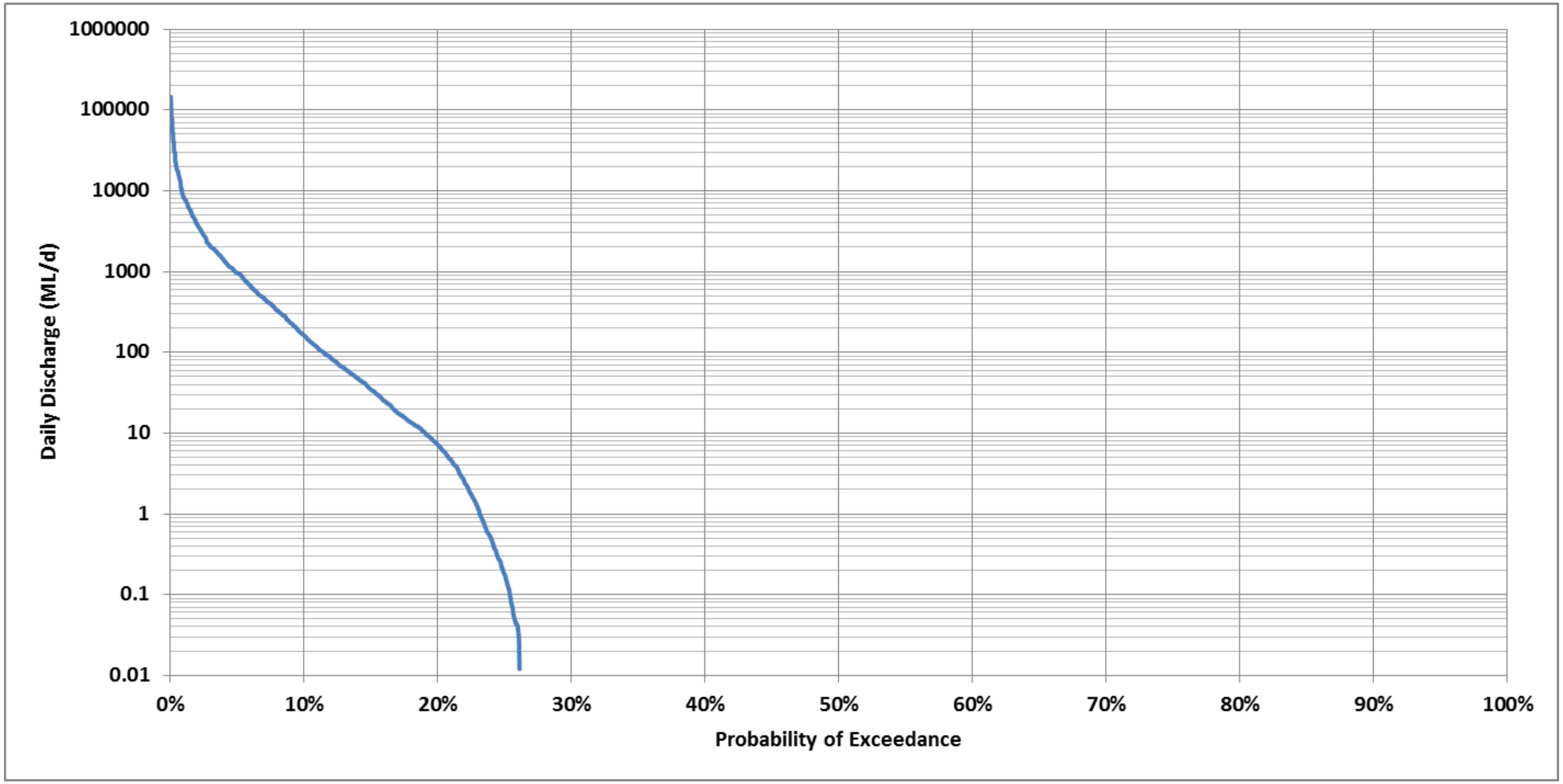
- Cease to flow conditions are present for approximately 74% of all days;
- Flow recession is likely to be rapid (but less than the Goonyella gauge as exhibited by the reduced gradient of the flow duration curve) with flows only occurring during and immediately after significant rainfall events; and
- Baseflow is likely to occur during prolonged flow recession in periods of extended rainfall.

Figure 4-4 Annual Discharge at Deverill Gauge (130410A)



	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Drought	0.84	2.80		9.45						8.79	14.14			16.40							
Dry					41.32							51.43	32.42		48.14			77.89			
Average			110.23					114.46	145.70							111.79					
Wet						179.21	227.09										704.52		918.28	243.55	274.58

Figure 4-5 Daily Discharge Cumulative Exceedance Probability (1992 - 2012) at Deverill Gauge (130410A)



4.3.4 *Seasonality*

Seasonality at the Deverill gauge was assessed as shown in Figure 4-6. The mid flow band, indicating baseflow conditions, as previously described in Section 4.2.2, represents flow exceeded on 80% of all days. It can be seen that baseflow conditions represent a small proportion of flows. Seasonality at the Deverill gauge has been defined as:

- A clearly defined high flow season where more than 20% of days exceed the 80th percentile (7.14 ML/d) exists from December through April; and
- A low flow season from May through November.

Table 4-6 shows the temporal distribution of both the high and low flow seasons.

Figure 4-6 Proportion of Daily Flows in Low, Medium and High Flow Bands at Deverill Gauge (130410A)

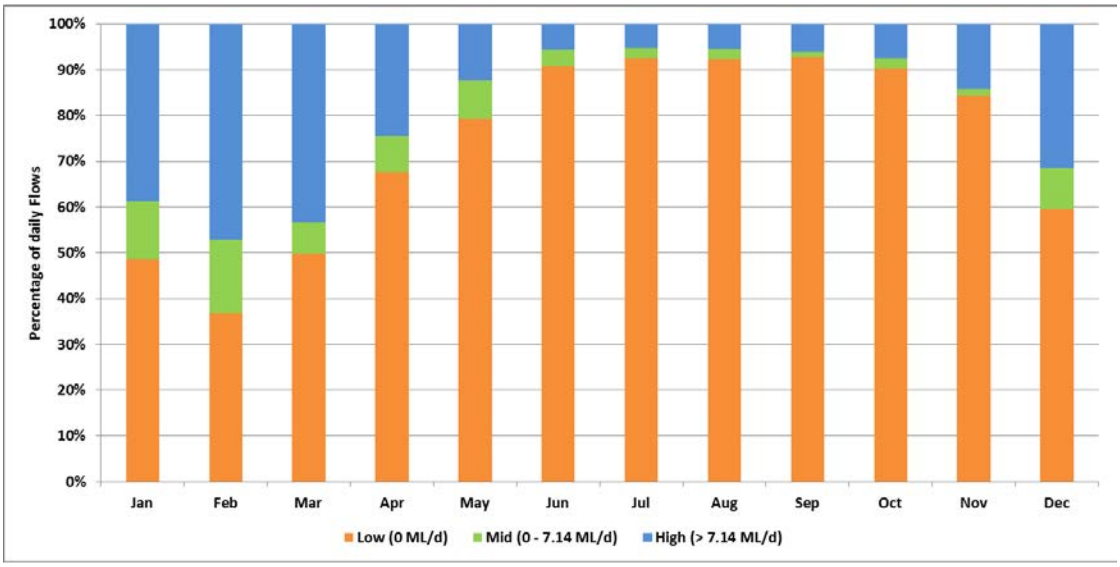


Table 4-6 Dominant Flow Seasons at Deverill Gauge (130410A)

Flow Season	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Low Flow Season												
High Flow Season												

4.3.5 Summary of Environmental Flow Analysis in the Vicinity of WTF2

Table 4-7 details the results of the Environmental Flow Analysis for the Deverill gauge. The analysis has been completed for each season (high and low flow) and for each climatic condition as well as for all years of data. The results show that for all years analysed (1992-2012):

- Cease to flow conditions are present for approximately 89% (190 days) of the low flow season (May through November) and approximately 53% (80 days) of the high flow season (December through April);
- High flows (flow exceeded 20% of the time) of 151 ML/d occur three to four times per high flow season and last, on average for 16 days;
- High flows (flow exceeded 5% of the time) of 2,866 ML/d occur three to four times per high flow season and last, on average for 7 days; and
- Bankfull flow (1 in 2 ARI) of 17,984 ML/d occurring, on average once every two years and lasting, on average for two days during the high flow season.

It is important to note that the bankfull flows depicted here represent flows for the Isaac River at the Deverill gauge, and not those calculated for Isaac River reaches tentatively identified as possible discharge locations for WTF2 (see Section 7.1.4). The bankfull flow is a standard flow component (Alluvium, 2013) that depicts a flow that fills the channel, but does not spill onto the floodplain.

Table 4-7 Isaac River at Deverill Gauge (130410A) - Environmental Flow Analysis

		Low Flow Season (May - Nov)					High Flow Season (Dec - Apr)				
		Flow Condition (ML/d)	Events per Season	Average Event Duration (Days)	Median Event Duration (Days)	Average Total Days per Season	Flow Condition (ML/d)	Events per Season	Average Event Duration (Days)	Median Event Duration (Days)	Average Total Days per Season
DROUGHT	Cease to flow	0.0	1.3	155.5	190.5	207.3	0.0	4.5	22.8	8.0	102.5
	Flow exceeded 80% of the Time	0.0					0.0				
	Flow exceeded 20% of the Time	0.0					5.9	4.3	7.2	5.0	30.3
	Flow exceeded 5% of the Time	0.0					207.6	3.2	2.4	2.0	7.7
	1 in 2 Year ARI	17,984					17,980				
DRY	Cease to flow	0.0	1.8	114.1	153.0	205.4	0.0	4.4	22.4	13.0	98.4
	Flow exceeded 80% of the Time	0.0					0.0				
	Flow exceeded 20% of the Time	0.0					23.5	3.4	8.9	7.0	30.4
	Flow exceeded 5% of the Time	0.0					1360.8	2.4	3.2	2.5	7.6
	1 in 2 Year ARI	17,984					17,980	0.2	1.0	1.0	0.2
AVERAGE	Cease to flow	0.0	2.0	96.9	76.5	193.8	0.0	2.7	18.7	19.0	70.3
	Flow exceeded 80% of the Time	0.0					0.0				
	Flow exceeded 20% of the Time	0.0					175.9	3.2	6.7	4.0	30.3
	Flow exceeded 5% of the Time	88.1	1.3	8.6	5.0	10.8	2818.3	2.3	2.4	2.0	7.8
	1 in 2 Year ARI	17,984					17,980	0.5	1.0	1.0	0.8
WET	Cease to flow	0.0	2.3	67.7	55.0	158.0	0.0	2.0	23.7	23.5	47.3
	Flow exceeded 80% of the Time	0.0					0.0				
	Flow exceeded 20% of the Time	5.5	2.2	19.8	12.0	42.8	1133.2	4.2	7.3	4.0	30.3
	Flow exceeded 5% of the Time	342.2	2.2	5.0	5.0	10.8	10147.1	2.8	2.7	2.0	7.7

		Low Flow Season (May - Nov)					High Flow Season (Dec - Apr)				
		Flow Condition (ML/d)	Events per Season	Average Event Duration (Days)	Median Event Duration (Days)	Average Total Days per Season	Flow Condition (ML/d)	Events per Season	Average Event Duration (Days)	Median Event Duration (Days)	Average Total Days per Season
	1 in 2 Year ARI	17,984	0.2	2.0	2.0	0.3	17,980	2.0	2.6	2.0	5.2
ALL YEARS	Cease to flow	0.0	1.9	102.4	86.0	190.2	0.0	3.2	25.0	13.5	79.6
	Flow exceeded 80% of the Time	0.0					0.0				
	Flow exceeded 20% of the Time	0.0					151.1	3.6	16.1	6.0	57.5
	Flow exceeded 5% of the Time	45.2	1.3	8.0	4.5	10.7	2865.5	3.5	6.8	3.0	23.6
	1 in 2 Year ARI	17,984	0.0	2.0	2.0	0.1	17,980	0.8	2.2	2.0	1.7

Shaded cells indicate that the flow exceedance condition is equal to zero e.g. where the “Flow exceeded 20% of the time” is equal to zero, cease to flow conditions are present on more than 80% of days

5 HYDROLOGY

An assessment of the hydrological regime within the surface water receiving environment adjacent to the currently preferred WTF localities was required to further characterise spatial and temporal trends in stream flow and hydraulics. The assessment includes estimation of peak discharges and flow velocities that could be expected within the study area during an event of 1% Annual Exceedance Probability (AEP). The 1% AEP was adopted to predict flows in the receiving environment during flood events in accordance with current guidelines (NRM, 2013). The assessment of peak discharges and flow velocities allows for an assessment of the assimilative capacity of the receiving environment to potential CSG water discharges. This information contributes to the flood assessment contained in Section 6.

5.1 Overview

Estimates of sub-catchment peak runoff for the 1% AEP event were obtained using RORB software (v6.15), developed by Laurenson *et al*. (2010). RORB simulates the runoff response of a catchment area, including the effects of stream and reservoir routing, by subtracting infiltration losses from rainfall inputs to calculate runoff hydrographs from rainfall excess.

Three separate hydrology models were constructed to estimate peak flows as follows:

1. Regional flows along the Isaac River from the top of the catchment down to a location approximately 30 km north-east of Dysart;
2. Local flows along streams in the vicinity of the proposed WTF1 locality; and
3. Local flows along streams in the vicinity of the proposed WTF2 locality.

Peak flows from this assessment are a primary input to the hydraulic modelling (refer to Section 6).

A flood assessment of the Isaac River down to Deverill was conducted by Alluvium Consulting, as part of a cumulative impact assessment of mine developments on the Isaac River catchment (Alluvium, 2008). A RORB model was developed for that study and was calibrated to observed stream flow gauges at Burton Gorge, Goonyella and Deverill. The results of this model were used to guide the selection of model parameters in lieu of model calibration.

5.2 Catchment Mapping

The delineation of catchment areas and stream reaches was achieved using the following information:

- Digitised stream and water body data from the Australian Hydrological Geospatial Fabric (available from Geoscience Australia), which can be relied upon down to the lowest spatial scale of 1:250,000.
- Digital elevation model (DEM) data from the shuttle radar topography mission (SRTM); data originally produced by NASA has been post-processed by Geoscience Australia (re-sampled from approximately 90 metre resolution to a 30 metre resolution). The post-processing allowed for a reduction in data ‘noise’ associated with water and vegetation, which makes the dataset much more appropriate for routine application than if it was used in its original form.

Detailed topographic light detecting and ranging (LIDAR) survey of the two study areas, supplied by Arrow. Data was provided as 1,004 tiles of 3 km x 3 km in area.

Figure 5-1, Figure 5-2 and Figure 5-3 illustrate the modelled sub-catchments and stream network for the three RORB models.

5.2.1 Sub-catchments

All model catchments, sub-areas and streams were delineated within geographic information system (GIS) software MapInfo, utilising surface information derived from SRTM data for the regional catchment model and LIDAR data within the vicinity of the two water treatment facilities proposed localities. Due to the land use of the study areas, all catchments were assumed to have no impervious surfaces.

5.2.2 Stream Network

Nodes representing the approximate inflow locations of rainfall excess from sub-catchments were manually relocated from the default points at the catchment centroids to nearby points on the stream network.

All channels were assumed to be of a “natural” reach type, apart from those reaches residing within the reservoir area upstream of Burton Gorge Dam (in the regional model) which were assigned a reach type of “drowned”.

5.2.3 Special Storages

For use in the regional model, reservoir parameters for Burton Gorge Dam and Teviot Creek Dam were obtained from the Alluvium (2008) and are reproduced below in Table 5-1.

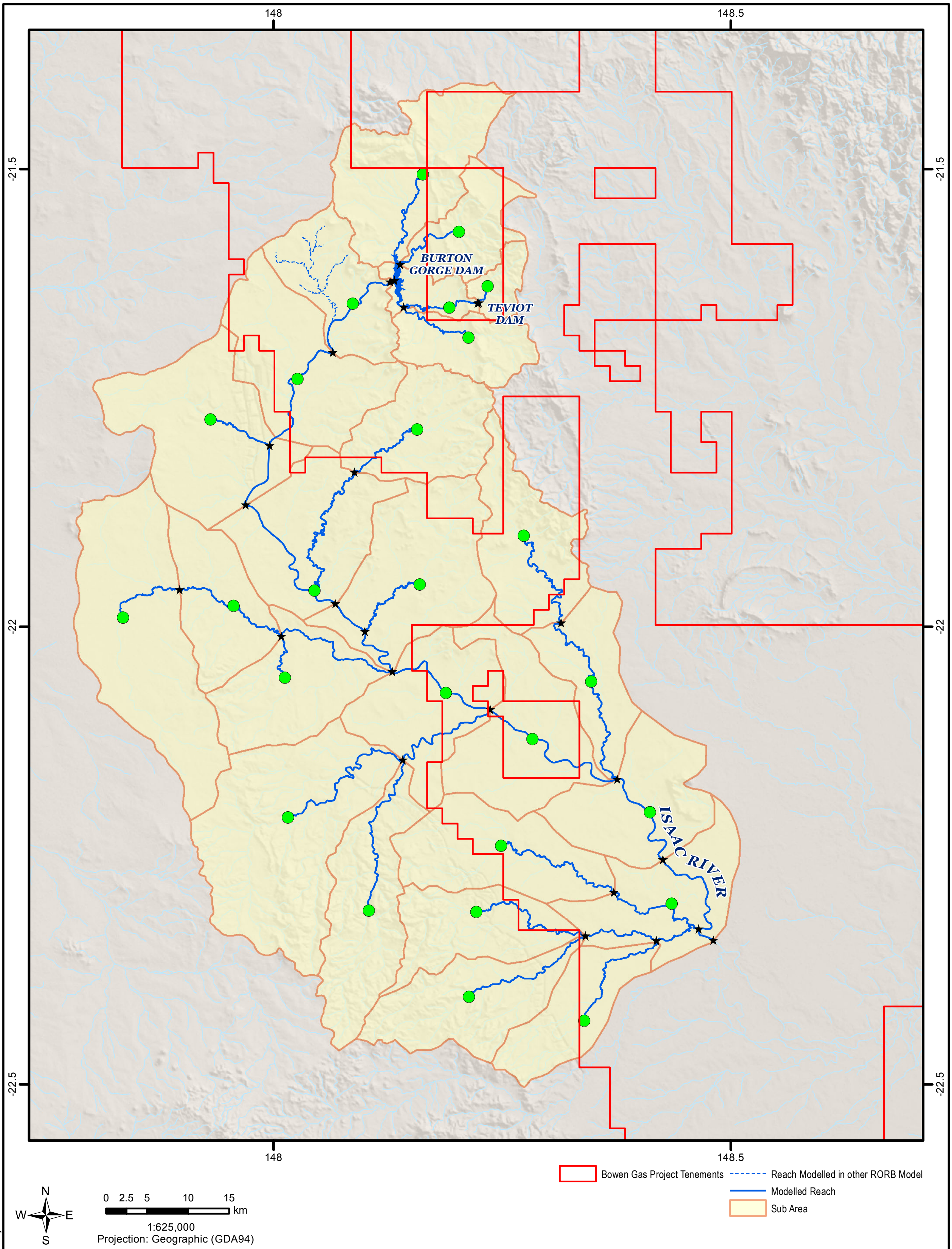
Table 5-1 Spillway Details for Modelled Dams (Alluvium, 2008)

Parameter	Units	Burton Gorge Dam	Teviot Creek Dam
Initial water level	mAHD	297.55	356.00
Spillway crest elevation	mAHD	297.55	356.00
Spillway effective length	m	160	30
Weir coefficient of spillway	N/A	2.15	1.45

Note: *’Initial water level’ is the technical term which refers to the water level at the beginning of the model simulation.

The reservoirs were assumed by Alluvium (2008) to be full at the start of each modelled storm event and outflows from the spillways for both dams were modelled using the weir equation. This is a conservative approach which assumes the dams start spilling at the start of the storm. Additionally, Alluvium (2008) conservatively assumed that the dams have vertical walls above full capacity, as the storage-elevation information provided only reached to the dams’ crests. This assumption is also conservative, because it is limiting the storage capacity of the dam.

As the regional model extent for this study is similar to that of the calibrated Alluvium (2008) model, all assumptions by Alluvium Consulting have been replicated herein, so that the Alluvium (2008) model can be utilised to validate current model parameters.



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BOWEN GAS PROJECT SREIS

SCHEMATIC OF RORB REGIONAL MODEL

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HYDROLOGY - SURFACE WATER ASSESSMENT

Figure: **5-1**

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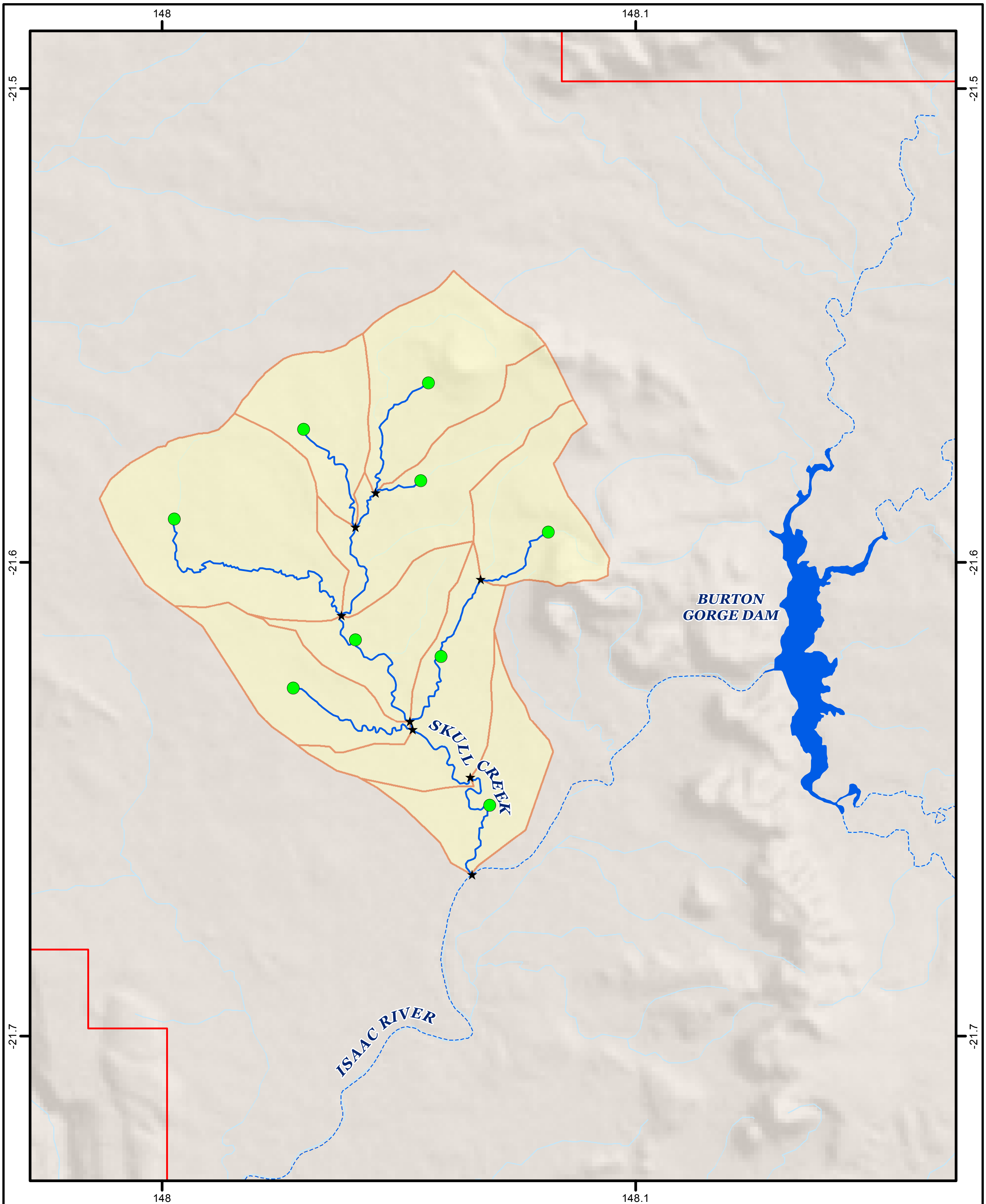

Bowen Gas Project Tenements
Modelled Reach
Reach Modelled in Other RORB Model
Sub Area
Sub-Area Node
Junction Node

N W E S

0 0.5 1 2 3 km

1:125,000

Projection: Geographic (GDA94)

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SCHEMATIC OF LOCAL RORB MODEL FOR WATER TREATMENT FACILITY 1

URS

HYDROLOGY - SURFACE WATER ASSESSMENT

Figure: **5-2**

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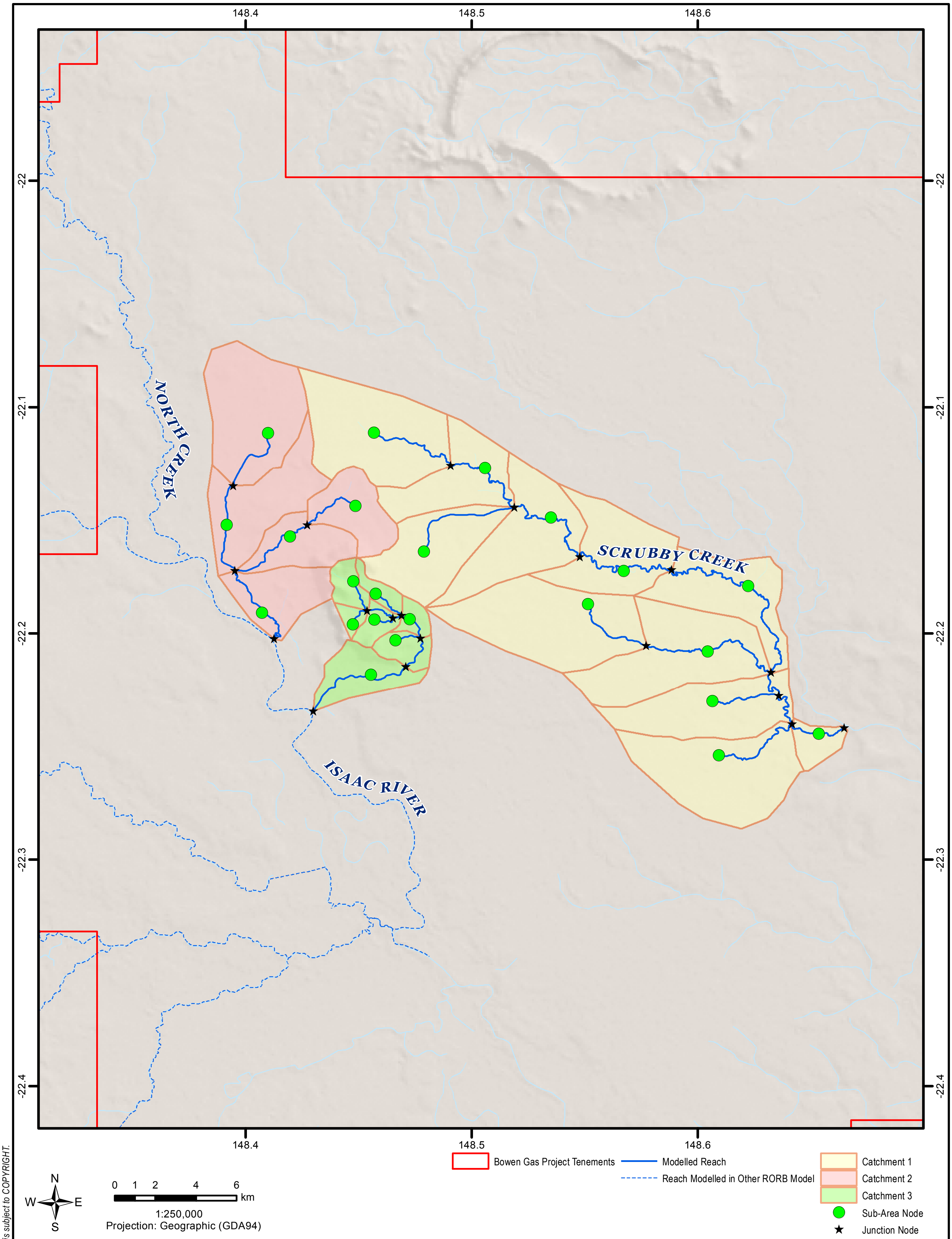

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SCHEMATIC OF LOCAL RORB MODEL FOR WATER TREATMENT FACILITY 2

URS

HYDROLOGY - SURFACE WATER ASSESSMENT

Figure: 5-3

File No: 42627140-g-2096c.mxd | Drawn: RG | Approved: DS | Date: 22-04-2014 | Rev.C | A4

5.3 Rainfall Estimates

5.3.1 Rainfall Depth

Rainfall estimates relating rainfall intensity to event duration and probability of occurrence were obtained from the Bureau of Meteorology's (BOM) *Rainfall Intensity-Frequency-Duration (IFD) Data System* (2013). Outputs provided from the online tool are point rainfall estimates for a single input location for AEPs up to 1% and durations up to 72 hours.

Eight separate outputs were generated based on randomly selected locations throughout the WTF areas of interest and regional catchment extent. Results were collated and compared to determine the variability in rainfall across the catchment, however it was found that there is not sufficient difference in the IFD data across the catchment to justify different rainfall inputs to the hydrology modelling. The 1% AEP input depths were subsequently derived for the centroid of the Isaac River Catchment to a location approximately 20 km downstream of a potential WTF2 discharge point. An overview of the IFD rainfall data used can be found in Appendix A.

5.3.2 Temporal Pattern

Temporal patterns for the 1% AEP rainfall events were obtained from Table 3.2 (Zone 3) within the second volume of *Australian Rainfall and Runoff* (AR&R) (Pilgrim, 1987).

Storm events ranging from one hour in duration up to 72 hours in duration were modelled in RORB in order to estimate the critical duration for each of the WTF areas. The critical duration peak runoff from all of the local sub-catchments resulted from the high intensity 1-hour rainfall events, whereas the critical duration at Burton Gorge Station and Deverill Station on the Isaac River was the 18-hour event.

5.4 Model Parameters

RORB models have two main routing parameters, K_c and *m*, and two rainfall loss parameters, initial loss (*IL*) and continuing losses (*CL*).

5.4.1 Routing Parameters

The applied K_c routing parameter for RORB is critical to the estimation of flood hydrograph routing through the catchment. Large K_c values result in greater attenuation effects, producing lower peak flow estimates, whereas a low K_c value results in less attenuation and higher peak flows. The K_c parameters for the regional model down to Deverill Station were adopted from the Alluvium (2008) based on the synonymous model extents. Downstream of Deverill Station, and for the local models, K_c was estimated using the empirical regional relationship, depicted in Equation 1 below:

Equation 1 $K_c = 0.88*A^{0.53}$,

Where K_c= Empirical coefficient applicable to the catchment

A= Catchment area (km²)

This relationship was developed by Weeks (1986) based on analysis of 94 calibrated RORB models of gauged catchments in Queensland. For this study, the *m* value used for all model catchments was set to 0.8 as recommended in AR&R (Pilgrim 1987) for ungauged streams in Queensland. This is also the value used in the Alluvium (2008) model for the Surat Basin.

5.4.2 Catchment Losses

Keeping with the calibrated Alluvium (2008) Surat Basin model, catchment losses were assumed to be uniform across the region, with a constant *CL* of 2.5 mm/hr applied to all models in all events, This is also the median value for Queensland recommended in AR&R (Pilgrim, 1987). Initial losses in Australian catchments usually range from 0 mm to around 50 mm (Laurenson *et al*., 2010), with zero often recommended for the lowest probability [i.e. the probable maximum flood]), events.

The calibrated Alluvium (2008) model utilised an *IL* of 95 mm above the Burton Gorge Station, and 25 mm for the remainder of the model. While 95 mm is considered high for design rainfall events, it is believed that this is a result of the conservative reservoir assumptions, which underestimates storage above the spillway and consequently overestimates outflows from the dam. Given that the Alluvium (2008) model has been calibrated however, and the regional model for this study is based on that model, the same values have been adopted throughout.

5.4.3 Summary of RORB Model Parameters

A summary of model input parameters is provided in Table 5-2.

Table 5-2 Summary of RORB Model Parameters

Model	Region	k_c	*m*	*IL*	*CL*
Local 1[A] (WTF1)	Entire modelled area	9.28	0.8	25	2.5
Local 2[B] (WTF2)	Entire modelled area	18.77	0.8	25	2.5
Regional	Upstream of Burton Gorge Station	20.0	0.8	95	2.5
Regional	Burton Gorge Station to Goonyella Station	27.5	0.8	25	2.5
Regional	Goonyella Station to Deverill Station	78.0	0.8	25	2.5
Regional	Deverill Station to model outlet	36.13	0.8	25	2.5

[A]As depicted in Figure 5-2

[B]As depicted in Figure 5-3.

5.5 Hydrology Modelling Results

Peak discharges from each of the local model sub-areas resulted from a 1-hour event, whereas the critical duration of the Burton Gorge Dam outflow was from the 18-hour event. Similarly, the estimated peak flow at the Deverill gauge, near the WTF2 area of interest, occurred for an 18-hour duration event. Table 5-3 and Table 5-4 show the estimated peak flow results, which were used as input into the hydraulic model for WTF1 and WTF2 respectively.

Table 5-3 RORB Results for WTF1 Hydraulic Model Input

Sub-Area or Station Name	Area (km^2)	Peak Runoff or Peak Routed Inflow (m^3/s)
A	10.9	630
C	7.1	410
B	17.9	1,040
D	11.1	640
E	7.9	460
F	6.9	400
G	7. 6	440
H	9.0	520
I	7.0	400
Burton Gorge Dam outflow	547.0	1,200

Table 5-4 RORB Results for WTF2 Hydraulic Model Input

Location	Sub-Area / Station Name	Area (km^2)	Peak Runoff or Peak Routed Inflow (m^3/s)
Catchment 1	A	27.1	1,570
	C	17.6	890
	B	15.4	1,020
	D	21.3	1,230
	E	18.3	1,060
	F	28.8	1,670
	G	18.0	1,040
	H	26.9	1,550
	I	19.7	1,140
	J	26.7	1,540
	K	4.0	230
Catchment 2	A	24.4	1,410
	B	17.9	1,030
	C	10.4	600
	D	9.8	570
	E	11.4	660

Location	Sub-Area / Station Name	Area (km^2)	Peak Runoff or Peak Routed Inflow (m^3/s)
Catchment 3	A	3.1	180
	B	1.3	80
	C	2.3	130
	D	2.7	160
	E	2.1	120
	F	3.7	220
	G	8.9	520
Isaac River	Deverill	5,210	4440
North Creek	NC2	139.7	730

6 FLOOD ASSESSMENT

Two separate, two-dimensional, steady-state, flood models of the potential WTF1 and WTF2 localities were created using hydraulic flow software TUFLOW (build 2013-12-AA). TUFLOW is a computer program used to simulate depth-averaged, two and one-dimensional free-surface flows, which commonly occur during flood events with significant floodplain interaction.

The TUFLOW models were used to estimate the inundation extents of a 1% AEP event in the vicinity of the WTF areas of interest. In addition, estimates of the water level within the Isaac River at the locality of proposed discharge sites were obtained.

6.1 Methodology

6.1.1 Topographic Data

The TUFLOW model topographies and extents were developed based on LIDAR datasets with a 1 m resolution. DEMs of the ground surface were interpolated in the GIS software MapInfo from the LIDAR data and exported for use in the TUFLOW model.

6.1.2 Model Domain and Extent

The 2-Dimensional component of the models utilised a 10 m square grid within the model domain, with grid elements (z-points) sampling elevations from the GIS DEM at 5 m intervals. The model grid cells were based on an interpolation of surrounding elevation points and represent the ground topography proximate to the grid cell.

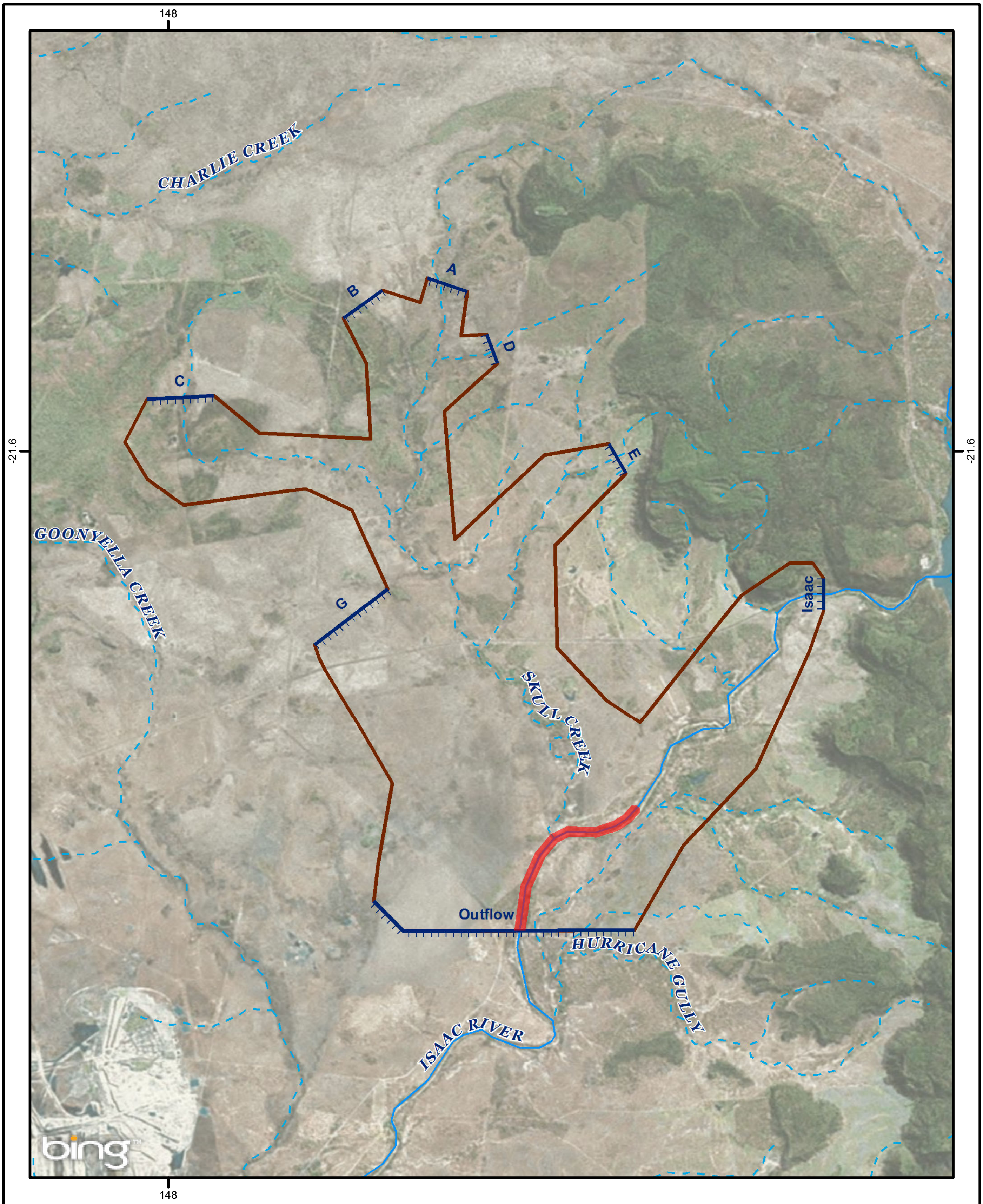
The WTF1 TUFLOW model extent includes an area that is approximately 13 km by 13 km, illustrated in Figure 6-1. The WTF2 TUFLOW model extent includes an area that is approximately 35 km by 22 km, as illustrated in Figure 6-2.

6.1.3 Boundary Conditions

6.1.3.1 Inflow Boundaries

Inflow boundaries, representing the local catchments upstream of the WTF areas of interest, peak runoff results from the sub-areas in the WTF1 and WTF2 RORB models provide the majority of inflow for the two corresponding TUFLOW models. Peak discharges in the Isaac River and, in the case of WTF2, North Creek proximate to the two sites were obtained from the regional RORB model to estimate potential influence on flooding from these nearby watercourses.

Flow inputs at these boundaries are presented in Section 5.5.



Potential receiving environment for CSG discharge water
Inflow Location
Model Boundary
Major Drainage
Minor Drainage

N S E W

0 0.5 1 2 km

1:100,000

Projection: Geographic (GDA94)

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WATER TREATMENT FACILITY 1 MODEL EXTENTS AND BOUNDARY CONDITION LOCATIONS

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HYDROLOGY - SURFACE WATER ASSESSMENT

Figure: **6-1**

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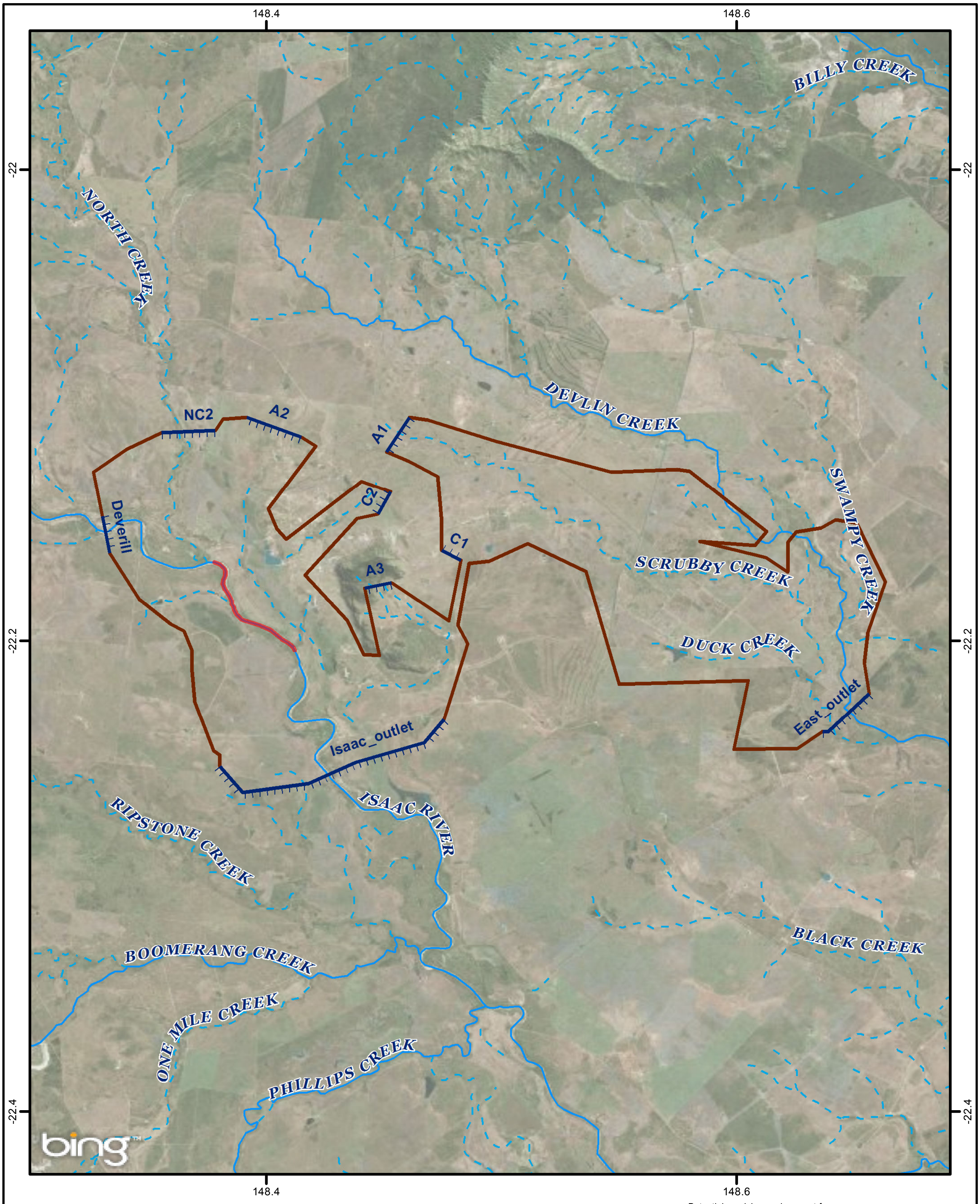

N
W E
S

0 0.5 1 2 3 4 5 6 km

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Projection: Geographic (GDA94)

Potential receiving environment for CSG discharge water

Inflow Location

Model Boundary

Major Drainage

Minor Drainage

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WATER TREATMENT FACILITY 2 MODEL EXTENTS AND BOUNDARY CONDITION LOCATIONS

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HYDROLOGY - SURFACE WATER ASSESSMENT

Figure: **6-2**

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6.1.3.2 *Downstream Boundaries*

Downstream boundary conditions representing model outflows consisted of sections across the Isaac River at a location sufficiently distant downstream of each of the potential WTF localities so that boundaries conditions allow an accurate representation of the flood regime. The WTF2 model also included an outflow on Scrubby Creek just prior to its confluence with Devlin Creek. TUFLOW automatically generates water level versus flow relationships at these boundaries as water exits the model, based on the flow depths and velocities along the delineated profiles.

6.1.4 Roughness Coefficient

The model hydraulic roughness of the streams and floodplains in the vicinity of the potential WTF areas of interest was represented by the Manning's roughness coefficient, *n*. Roughness coefficients were estimated by separating the study sites into land types of 'floodplain', 'medium density brush' and 'high density brush' based on proprietary Bing site aerial imagery. Estimates of the Manning's *n* values were undertaken based on general material or land-use type and commonly accepted hydraulic recommendations presented in Chow (1959). As a result, Manning's '*n*' values of 0.05, 0.07 and 0.10 were adopted for these categories, respectively.

6.2 Flood Assessment Results

Flood modelling results for the 1% AEP event for the potential WTF1 and WTF2 areas of interest are presented in this section. The purpose of the hydraulic modelling was to identify flood prone areas within the proposed property which might be inundated during a 1% AEP flood event and should be considered during the design phase to locate infrastructure outside of these areas as much as possible. Extents for the 1% AEP flood event for the potential WTF1 and WTF2 areas of interest are presented in Appendix B. A summary of the maximum estimated water surface elevation within the parcel boundaries is presented in Table 6-1.

Table 6-1 Maximum Estimated Water Surface Elevation at the Parcel Boundaries

Location		Water Surface Elevation (mAHD)
WTF1 locality	Northern Boundary	298.3
	South western Boundary	278.1
	Eastern Boundary	288.0
WTF2 locality	North western Boundary	190.4
	South western Boundary	190.4
	Northern Boundary	200.2
	North western Boundary	186.3
	Eastern Boundary	176.2

6.3 Climate Change Impact Assessment

During this investigation, sensitivity analyses have been undertaken to estimate the potential impact of climate change on flooding in this area. The Queensland Government document, *Increasing Queensland's resilience to inland flooding in a changing climate: Final Report on* *the Inland Flood Study (2010)* provides practical guidance for modelling the impact of climate change.

The document recommends adopting a two degree celsius temperature increase for 2050 and applying a 5% storm intensity increase for each degree celsius of temperature increase. In effect, this required that 1% AEP flood modelling be undertaken with storm intensities increased by 10% to account for climate change in the year 2050.

Although the increased rainfall intensity expands flood extents through the site, the areas specific to this Project showed minor sensitivity to the increases and in all cases the flood extents increased by an amount too small to affect the siting of infrastructure. This is demonstrated in Appendix B, Figure B-3, Figure B-4, Figure B-5 and Figure B-6. The minor increases in extent of flooding predicted under a climate change scenario for the two WTF potential localities are demonstrated by the green shading in Figure B-5 and Figure B-6.

7 HYDRAULIC ASSESSMENT FOR PROPOSED CSG WATER RELEASES

CSG water will be produced throughout the Project lifecycle. It will be transferred through FCFs and subsequently processed via the WTFs; at times being stored in feed water dams (storage facility for water collected throughout the gas fields). Treated or untreated CSG water (depending on user water quality requirements) will firstly be directed to beneficial uses (detailed in Section 9.1.1 of the Surface Water Quality Technical Report (Appendix F) of the SREIS, but may need to be released to surface watercourses periodically if any of the following conditions occur:

- Beneficial uses unable to take sufficient water due to, for example, significant rainfall events meeting the beneficial users requirements temporarily;
- Unforeseen events occur, such as significant natural events (earthquakes, weather) or unauthorised site activity (excavation in vicinity of dam), equipment failure which cannot be repaired in normal timeframes, safety incidents; and
- The structural and operational integrity of dams is at risk.

This section provides an assessment of the various flow conditions under which CSG water may be released, to inform the impact assessment presented in the Surface Water Quality Technical Report (Appendix F, Section 9) of the SREIS. By assessing the estimated hydraulic conditions near the indicative WTF localities (where releases of CSG water to local watercourses may occur), an understanding of the assimilative capacity and sensitivity of the surface water system to additional flows can be gained.

7.1 Bankfull Discharge

When a watercourse such as the Isaac River is at 'bankfull discharge stage', the channel is filled with water up to the crest of the bank, leaving no surface of the bank exposed (Whittow, 2000). This condition is reached immediately prior to a flood event, when the floodplain adjacent to the channel becomes inundated. The bankfull discharge stage could be viewed as a 'tipping point' at which, if extra flow volume is added to the system, inundation of the floodplain is triggered. The increased incidence of flooding can then have adverse effects on riparian ecosystems and infrastructure within the inundation zone; it can also cause erosion of banks and floodplains and result in the transport of large volumes of sediment downstream (Poff *et al.*, 2007). The significance of bankfull flows in relation to impacts from potential CSG water discharges is discussed further in Section 9.3.1.

Bankfull discharge was estimated for the Isaac River in the vicinity of indicatively located WTF1 and WTF2 to estimate potential impacts to the geomorphic conditions and flow conditions of the river from CSG releases.

The following steps were implemented to estimate bankfull discharge, which are discussed in this section:

1. Accessed flood frequency data for the Isaac River from *Isaac River Cumulative Impact Assessment of Mine Developments* (Alluvium, 2008).
2. Generated typical channel cross-sections and estimated average bed slope of the Isaac River at representative cross-sections near the WTF1 and WTF2 potential receiving environment areas.

3. Generated a discharge rating curve for the typical cross-sections using estimates of bed slope, channel geometry, and open channel flow (Manning's) bed and banks roughness coefficient.

4. Estimated bankfull elevations for the typical cross-section for the WTF1 and WTF2 potential receiving environment areas using channel geometry, site photographs, and aerial photographs as a reference.

5. Using the estimated bankfull elevations and discharge rating curves, bankfull discharge was estimated for the representative cross-sections.

7.1.1 Flood-Frequency Data for the Isaac River

Flood-frequency data for the Isaac River was obtained from *Isaac River Cumulative Impact Assessment of Mine Developments* (Alluvium, 2008). For the potential WTF1 area of interest, the flood frequency data at Burton Gorge Dam was assumed to be applicable, as the Burton Gorge Dam would regulate the flow rates down the Isaac River in that area. For the WTF2 area, the flood frequency data at the Deverill Gauge (located directly east of the WTF2 area) was adopted. The data obtained from Alluvium (2008) is presented in Table 7-1.

Table 7-1 Flood Frequency Data on the Isaac River (Alluvium, 2008)

AEP (1:X)	Burton Gorge (m^3/s)	Deverill Gauge (m^3/s)
2.5	22.3[A]	208[B]
5	310	1,120
10	520	1,690
20	860	2,340
50	1,340	3,280
100	1,830	4,170
200	2,330	4,980
500	3,030	6,420
1000	3,550	7,670
2000	4,170	8,980

[A]*Stream discharge obtained using data from Goonyella Gauge (130414A) (see Table 4-4 for details)*

[B]*Stream discharge obtained using data from Deverill Gauge (130410A) (see Table 4-7 for details)*

7.1.2 Typical Channel Cross-Sections and Average Bed Slope

To estimate bankfull discharge for the Isaac River, typical cross section geometry and average bed slope were estimated.

Using 1-metre resolution DEM data, typical channel cross-sections (XS) were developed at locations where the potential WTF localities are assumed to make possible releases into the Isaac River. These locations are shown in Figure 7-1 and Figure 7-2 for the WTF1 and WTF2 areas of interest, respectively. Typical channel cross-sections for the potential receiving environment near WTF1 and WTF2 are shown in Figure 7-3 and Figure 7-4, respectively.

Minimum bankfull width of the river at these locations is approximately 60 m wide and therefore, 1-metre resolution DEM considered as adequate.

Average bed slope of the Isaac River for the potential receiving environment near WTF1 and WTF2 were estimated to be 0.15% and 0.05% respectively.

7.1.3 Discharge Rating Curves in Isaac River at Representative Release Locations

Discharge rating curves were developed for the Isaac River using the Manning's Equation. The aforementioned average bed slope and channel geometry were used as inputs, along with an assumed Manning's "*n*" of 0.030 for both cross-section locations. From the analysis, the discharge rating curves for the assumed cross-section release locations near the potential receiving environment for WTF1 and WTF2 are presented as Figure 7-5 and Figure 7-6, respectively.

7.1.4 Bankfull Elevations

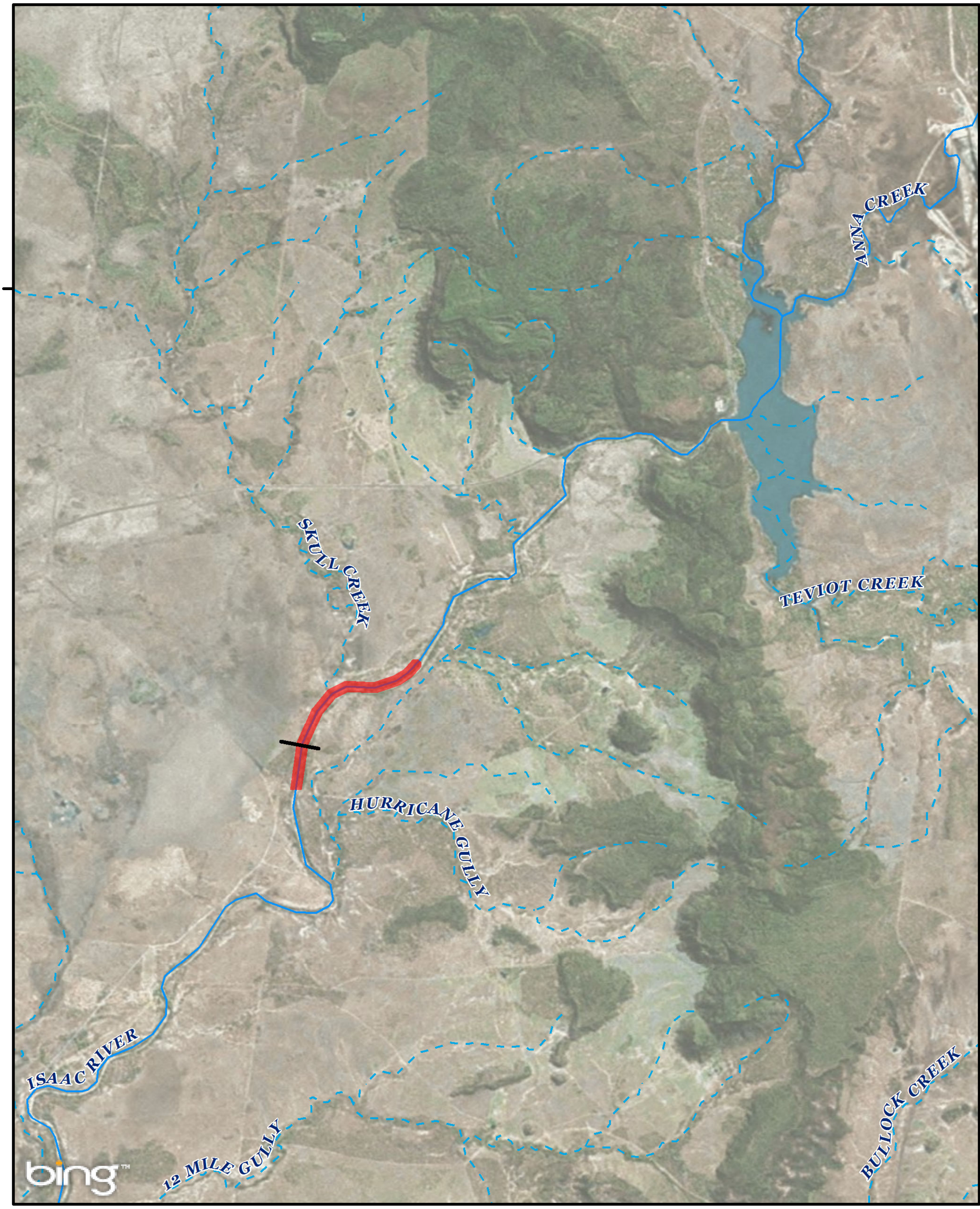
The bankfull elevation at the assumed representative cross section location for the WTF1 potential receiving environment was estimated to be 269.0 mAHD. This estimate was developed using aerial photography, geometry data, and site photographs. From the site photographs, a bench could be seen below the major floodplain which generally indicates the bankfull location for the channel. The geometry data and aerial photography both indicated bankfull width of around 60 m, which corresponds to the bench seen in the site photograph. As described at the beginning of Section 7.1, the elevation at which bankfull discharge occurs provides an indication of the stream level beyond which floodplain inundation will be 'triggered'.

For the assumed representative release location for the WTF2 potential receiving environment, the bankfull elevation was estimated to be 179.2 mAHD. This was estimated using channel geometry data at multiple cross sections upstream and downstream of the Deverill Gauge, which all showed a single bench leading from the main channel into the major floodplain, suggesting that the bankfull location was at the top of the main channel. The representative cross-section data indicated a bankfull width of approximately 110 m, which corresponds to estimates based upon the channel outline in aerial photographs.

Using the estimates of bankfull elevation along with the discharge rating curves, a bankfull discharge was estimated. A summary of the results is presented in Table 7-2.

Table 7-2 Estimates of Bankfull Elevation and Discharge of Isaac River at Assumed Representative Locations

Representative Location	Bankfull Elevation for Representative Cross-section (m)	Bankfull Discharge (m^3/s)	Bankfull Width for Representative Cross-section (m)
WTF1	269.0	270	60
WTF2	179.2	2,350	110



N
W E
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0 0.4 0.8 1.6 2.4 km

1:100,000

Projection: Geographic (GDA94)

Potential receiving environment for CSG discharge water

Cross Section

Major Drainage

Minor Drainage

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REPRESENTATIVE LOCATION FOR WATER TREATMENT FACILITY 1 RELEASES INTO THE ISAAC RIVER

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HYDROLOGY - SURFACE WATER ASSESSMENT

Figure: **7-1**

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Projection: Geographic (GDA94)

Cross Section

Potential receiving environment for CSG discharge water

Major Drainage

Minor Drainage

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BOWEN GAS PROJECT SREIS

REPRESENTATIVE LOCATION FOR WATER TREATMENT FACILITY 2 RELEASES INTO THE ISAAC RIVER

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HYDROLOGY - SURFACE WATER ASSESSMENT

Figure: **7-2**

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Figure 7-3 Typical Channel Cross-Section in Isaac River at the Representative Release Location for WTF1

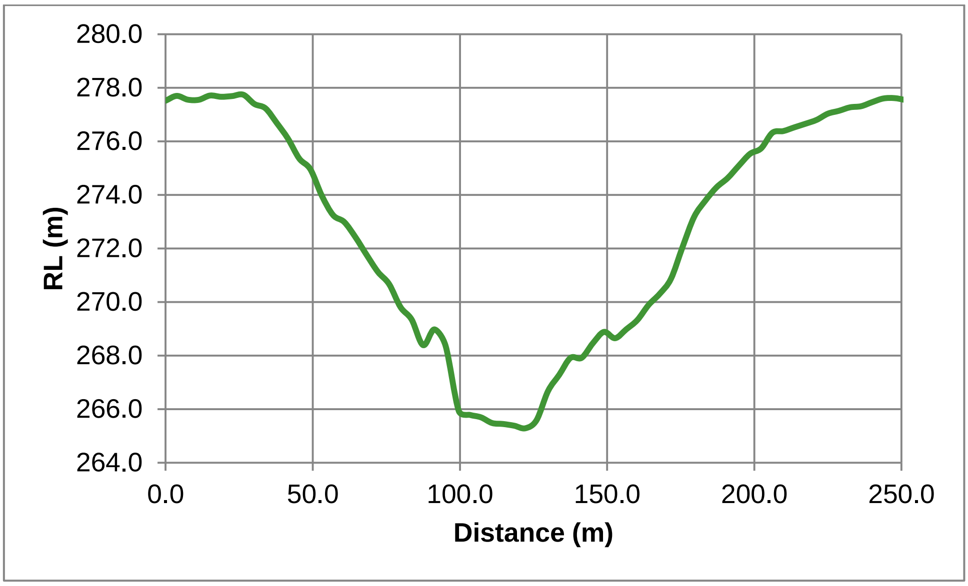


Figure 7-4 Typical Channel Cross-Section in Isaac River at the Representative Release Location for WTF2

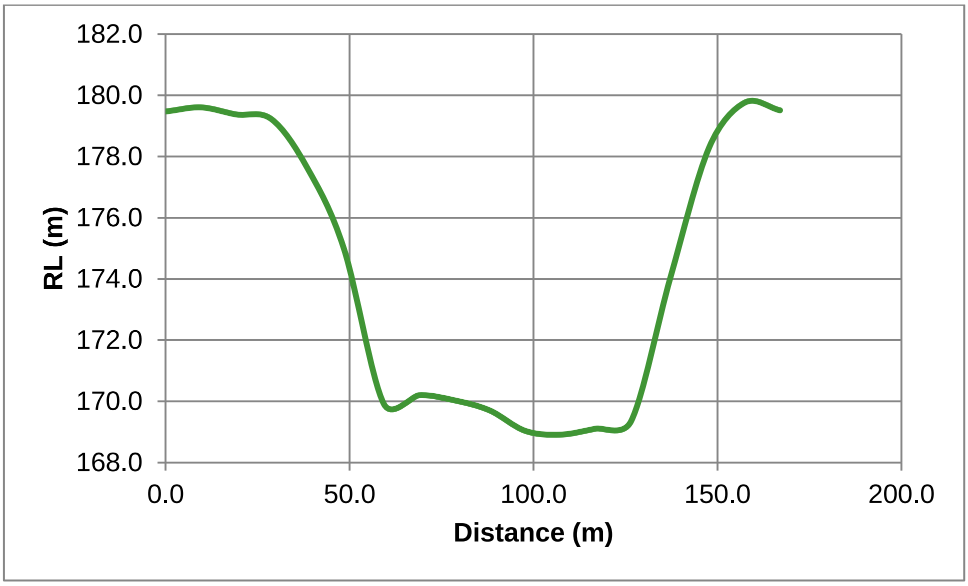


Figure 7-5 Discharge Rating Curve for Representative WTF1 Release Location

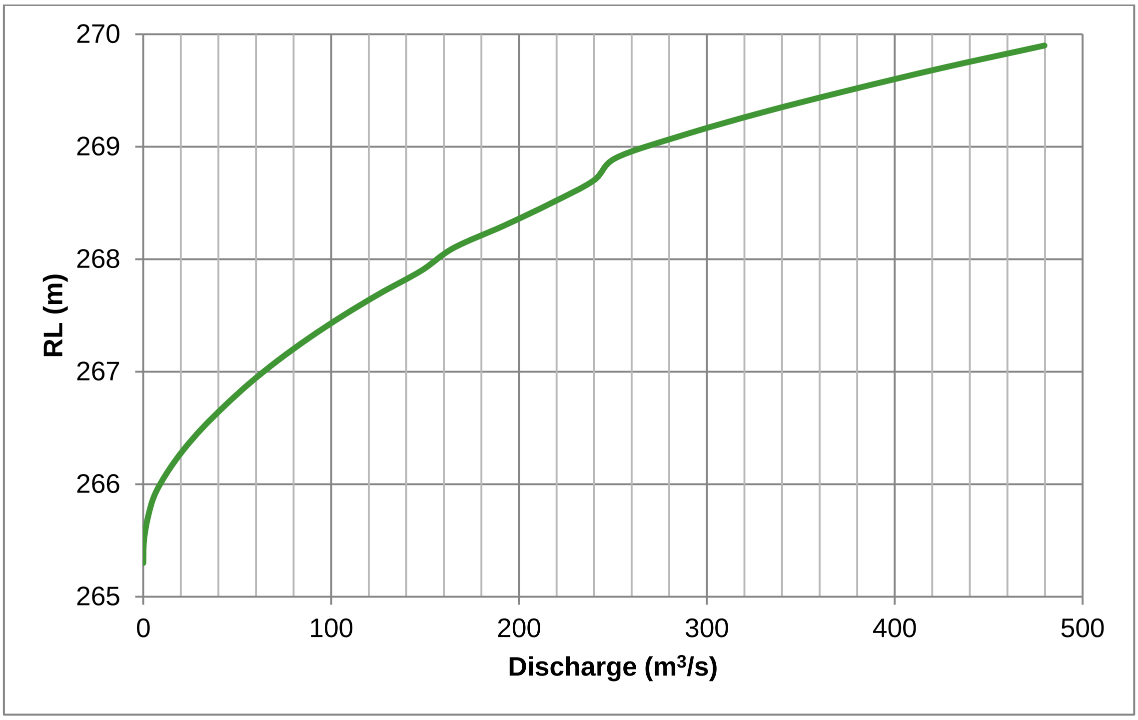
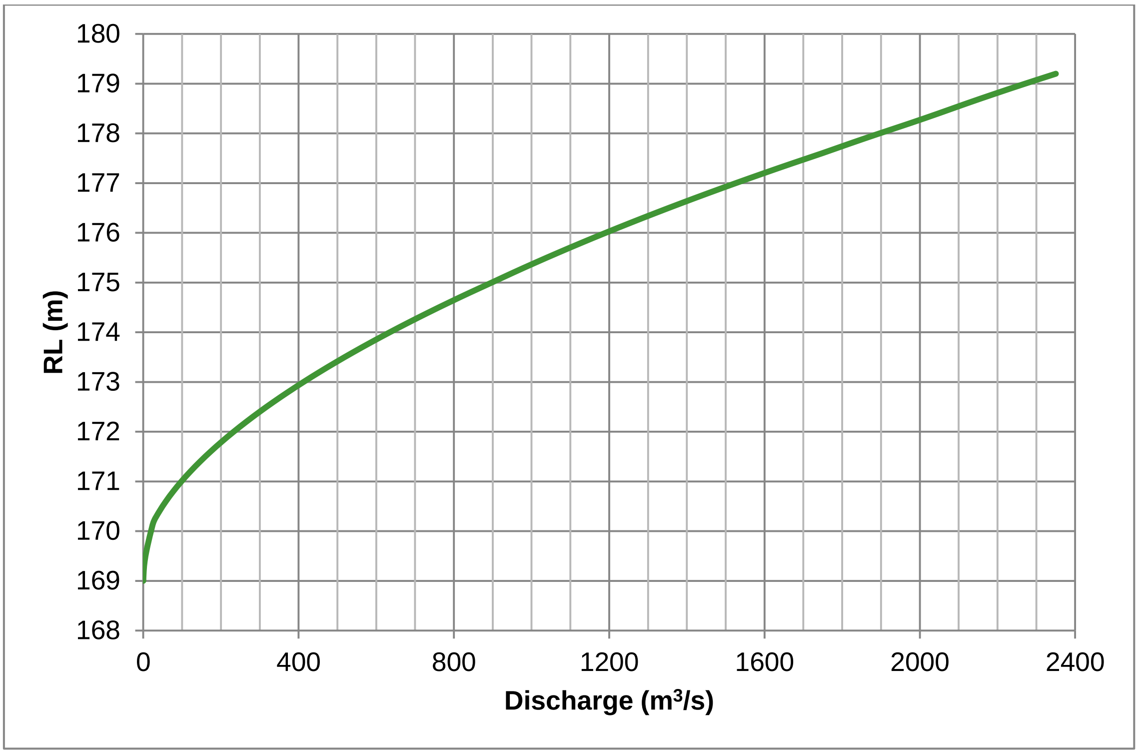


Figure 7-6 Discharge Rating Curve for Representative WTF2 Release Location



8 GEOMORPHOLOGY

Fluvial geomorphology describes the form of landscapes in relation to watercourses, and identifies key processes that have taken place historically, and in the present landscape, to develop that form. Key processes that contribute to the geomorphic character of a catchment, such as the Isaac River, may include movement of sediment through the system (via erosion, transport, and deposition processes); interaction between the hydraulic geometry of the river channel and changes in flow velocity and volume (such as scouring or incision of a deep channel at the bottom of slope), or the formation and/or influence of in-channel geomorphic features such as vegetated islands and lateral bars (sediment deposits on the inside bend of a channel).

The amount of energy and type of material (such as gravel, bedrock, sand, or fine sediments such as clay and silt) are the driving factors behind the physical form of a watercourse. If these factors fall out of balance, or are changed dramatically and intensively over a short time period (compared with the natural rate of change common to the study catchment), this can lead to the acceleration of processes that are detrimental to the long term condition of the watercourse’s natural geomorphic character. It is this imbalance, or potential for change that is outside of what appears to be the natural regime within the catchment, that would be considered an adverse impact on the system.

The following section provides a preliminary assessment of the geomorphic character of the Isaac River and local watercourses proximate to the currently preferred WTF localities, to inform the impact assessment contained in Section 9. Data from field investigations completed at sub-catchment level for the EIS assessment were combined with more site-specific data obtained from desktop sources, to provide a more local assessment of geomorphology for the SREIS. Secondary sources of information included the WetlandInfo database (EHP, 2013).

This desktop study describes the baseline geomorphic character of sections of the Isaac River that are in the general vicinity of, but not identical to, those reaches assessed as part of the hydraulic study discussed in Section 7 of this report.

8.1 Geomorphic Description of Watercourses Running Through the Sites

A geomorphologic field assessment of select reaches of the Isaac River was conducted in May 2012 (URS, 2013). The three reaches nearest to the WTF1 and WTF2 areas of interest were site ID SW 5 located upstream of Burton Gorge Dam, site ID SW37 (located downstream of the Peak Downs Highway), and site ID SW 9 (located downstream of the Fitzroy Development bridge), respectively. Although site ID SW5 is located nearest to the WTF1 area of interest, it was not used for this analysis as the morphology of the river upstream of the dam is different to that downstream of the dam. Instead, information from the Red Hill EIS (URS, 2013), a proposed underground mining operation, that would be located downstream of the potential WTF1 area, was used to characterise the morphology of the river.

It should be noted that no field assessments have been made to date of the local watercourses proximate to the WTF areas (Skull Creek and Scrubby Creek), however the impacts are expected to be minor as a result of any construction works for pipelines crossing the creeks to discharge CSG water into the Isaac River.

8.1.1 Isaac River Near WTF1 Area

The Red Hill Mining Lease EIS characterised the Isaac River as an ephemeral river with sand bed stream that is largely alluvial downstream of the Burton Gorge dam and is terrace confined. The bankfull width varies from 20 m to 40 m, as shown in Plate 8-1. The floodplain varies from 150 m to 500 m in width, with an upper terrace approximately 2 m to 4 m higher than the floodplain. The condition of the Isaac River shows excess sediment inputs from changes in land use. The riparian vegetation along the Red Hill Mine reaches remains reasonably continuous at the overstorey level but minimal at the understorey level. Groundcover is variable but often dense with exotic grasses dominant. These provide conditions for deposition of a mud drape which enhances bank stability. Additional geomorphic information regarding the Isaac River through this reach can be found in Appendix I6, Geomorphology Technical Report (Alluvium) of the Red Hill Mining Lease EIS (URS, 2013).

Plate 8-1 Isaac River near upstream limit of proposed Red Hill Mine (Alluvium 2011)

8.1.2 Isaac River Near WTF2 Area

The field assessment of the Isaac River at site ID SW 37 and SW 9, located upstream and downstream of the WTF2 area of interest, showed similar geomorphologic characteristics. The river was characterised as a low sinuosity, single channel (30 m to 40 m bankfull width), with floodplain up to 800 m in width. Similar to the upper reaches of the Isaac River, the river is ephemeral in nature and has a coarse sand bed, as shown in Plate 8-2. The riparian vegetation was described as semi-continuous along both banks with on average 50% of the trees greater than 10 m in height. Additional geomorphic information regarding the Isaac River through this reach can be found in the Surface Water Technical Report (Appendix N) of the EIS.

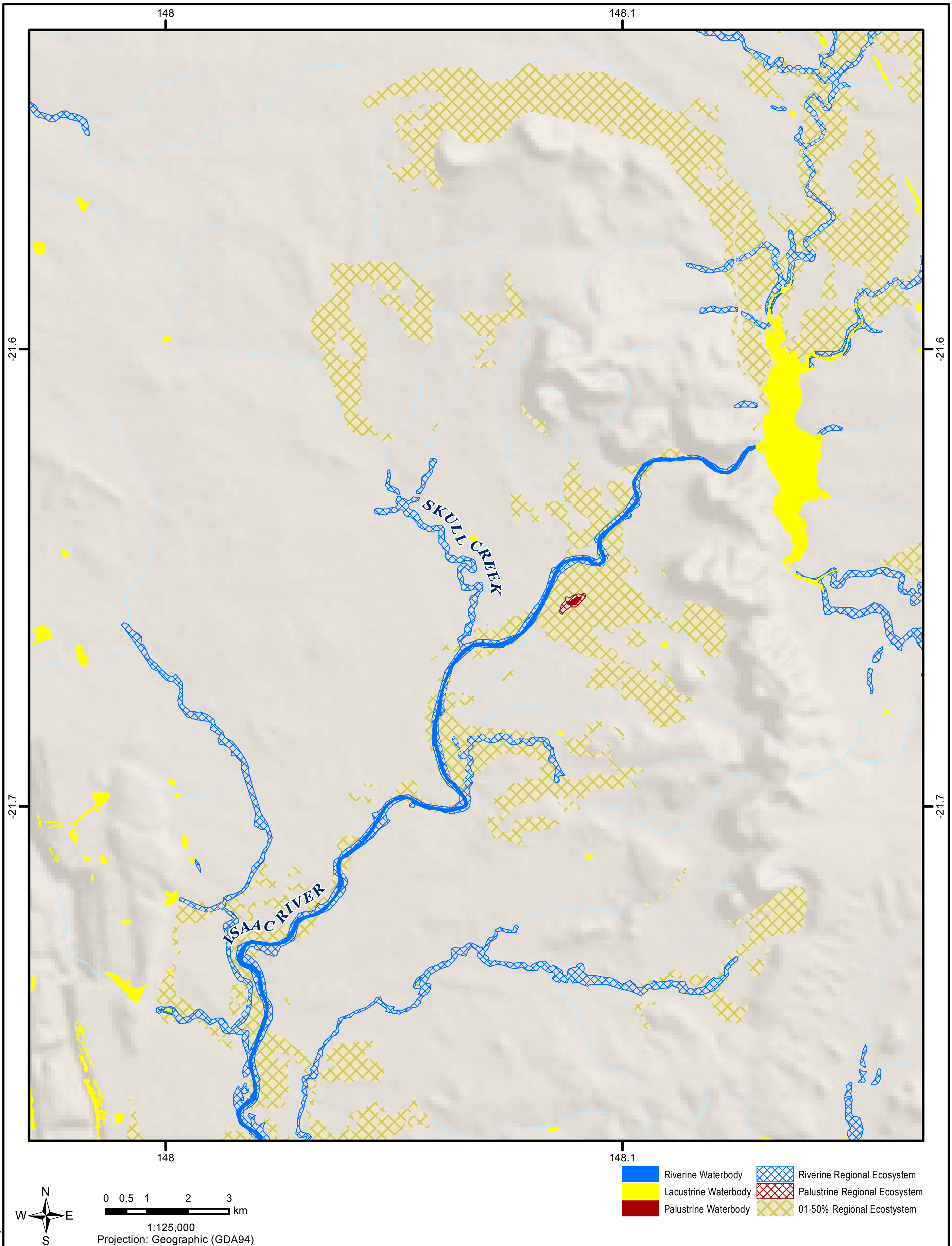
Plate 8-2 Isaac River at Deverill Gauge Looking Downstream from NRM Streamflow Database

8.2 Wetland Characterisation

A desktop assessment to identify potential wetlands locations proximate to the WTF localities was conducted using the Queensland Wetlands Program (Version 3.0). The wetlands characterisation identifies those potentially sensitive areas that need to be protected whenever possible; the wetland characterisation also informs the impact assessment. The following wetland classifications were identified for the two potential WTF discharge areas of interest:

- WTF1 area (Figure 8-1):
  - Riverine system – Wetlands and deepwater habitats contained within a channel:
    - This area was identified in the Isaac River channel and the Skull Creek channel, as shown in Figure 8-1 as the hatched blue area; and
  - Remnant regional ecosystem – these are areas that may (or may not) include wetlands:
    - Area identified in the Isaac River floodplain, as shown in Figure 8-1 as the hatched light yellow area;
- WTF2 area (Figure 8-2):
  - Riverine system – Wetlands and deepwater habitats contained within a channel:
    - This area was identified in the Isaac River channel and the Scrubby Creek channel, as shown in Figure 8-2 as the hatched blue area;

- Palustrine system – Wetlands dominated by persistent emergent vegetation or where water in deepest part of the basin is less than 2 m:
  - This area was identified several areas of the Isaac River floodplain, as shown in Figure 8-2 as the red hatched areas; and
- Remnant regional ecosystem – these are areas that may (or may not) include wetlands:
  - Areas identified in the Isaac River floodplain and an unnamed tributary, as shown in as the hatched light yellow area.



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POTENTIAL WETLAND AREAS NEAR WATER TREATMENT FACILITY 1

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HYDROLOGY - SURFACE WATER ASSESSMENT

Figure: **8-1**

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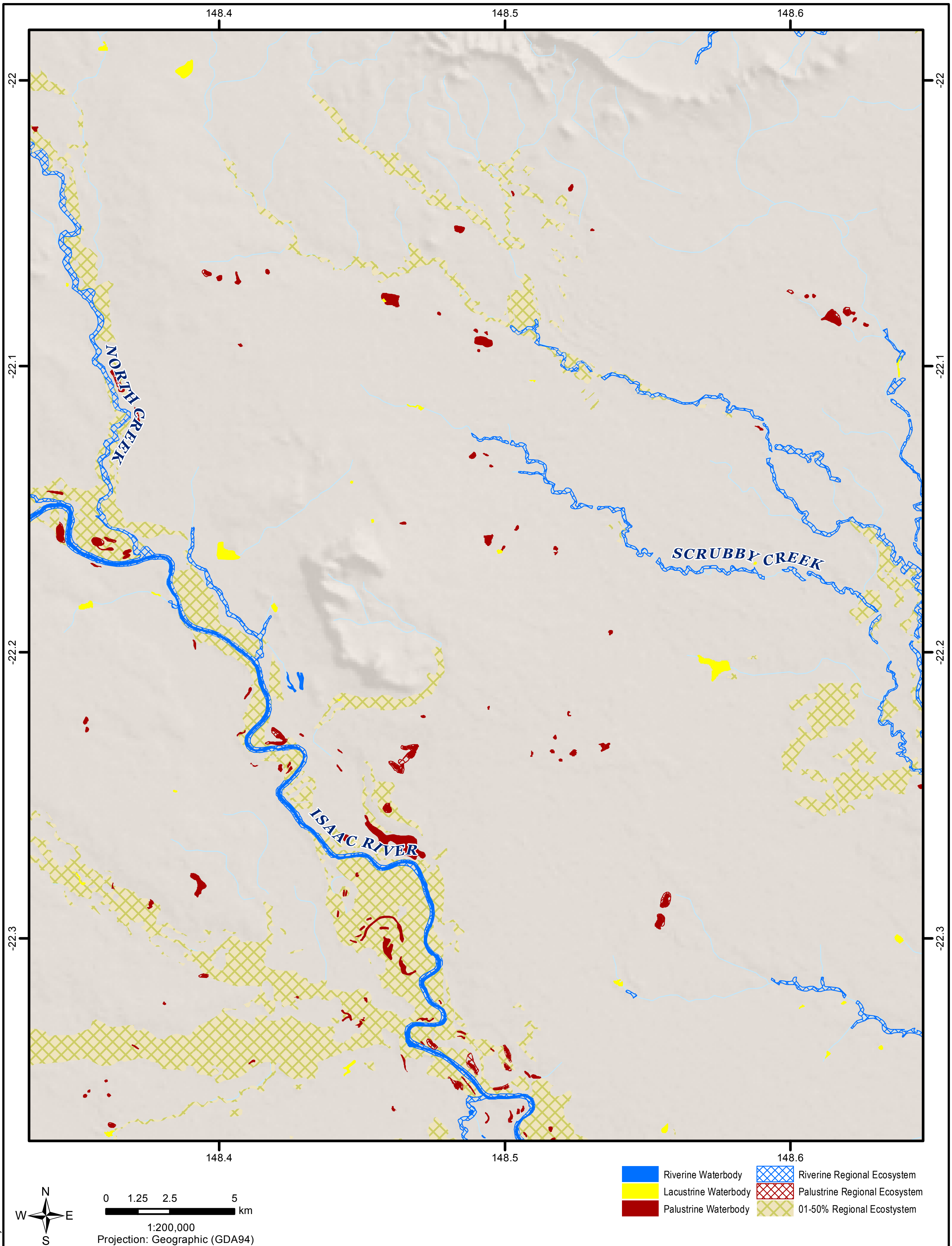

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POTENTIAL WETLAND AREAS NEAR WATER TREATMENT FACILITY 2

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HYDROLOGY - SURFACE WATER ASSESSMENT

Figure: 8-2

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9 IMPACT ASSESSMENT

A qualitative assessment of the potential impacts to the surface water hydrology and geomorphology arising from proposed activities associated with the Project was completed for the EIS in 2012, based on the information available at that time. The EIS assessment outlined standard operational measures that would be taken to minimise the potential impacts identified at the time. In the interim, the proposed activities associated with the Project have been refined, and greater detail is available in relation to the location and/or arrangement of Project infrastructure, expected peak flows for produced water, and designed water treatment capacity across the Project area.

Thus, the purpose of the SREIS impact assessment is to provide further detail for impacts and mitigation measures that previously had a high degree of uncertainty, and highlight any gaps in knowledge or proposed activities that will be refined at a later stage of the Project. The discussions of mitigation measures within this section contain some references to earlier management options outlined in the EIS documentation; notably the Surface Water Technical Report (Appendix N) of the EIS.

The key changes to the proposed Project activities, applied since the EIS, may potentially contribute to the following impacts on the surface water hydrology and geomorphology within the Project area:

- Change in size / distribution of Project infrastructure footprints; and
- Drainage areas (which form the basis for field development staging) have been halved in area, and doubled in number; drainage areas are now spread out more evenly both temporally and spatially across the Project area.

These activities, their potential associated impacts to surface waters, and applicable mitigation measures, are discussed further in Table 9-4.

9.1 Impact Assessment Methodology

The assessment of the potential impacts of the development of the Project on surface water resources was undertaken in the context of environmental values, as defined by the EPP Water, using a significance assessment methodology. This type of assessment was adopted to provide an understanding of the vulnerability of the surface water environment. The methodology was previously developed and used in Arrow's Surat Gas Project EIS (Arrow, 2011). The significance and magnitude of impacts identified by this study are summarised in Table 9-6.

The significance of an impact was assessed by considering the vulnerability or sensitivity of the environmental value and the magnitude of the impact, before and after the application of mitigation and management measures. It assumes that the impact will occur and that its consequence will be identified and assessed. The significance of the residual impact was assessed assuming successful implementation of proposed mitigation and management measures.

Potential cumulative impacts on surface water resources are discussed in Section 9.3.4.

9.1.1.1 *Sensitivity of Environmental Values*

An environmental value's sensitivity was determined by its susceptibility or vulnerability to threatening processes and consequently, its intrinsic value. Criteria for sensitivity are presented in Table 9-1.

Table 9-1 Criteria for Sensitivity

Sensitivity	Description
High	The environmental value is listed on a recognised or statutory state, national or international register as being of conservation significance. The environmental value is intact and retains its intrinsic value. The environmental value is unique to the environment in which it occurs. It is isolated to the affected system/area which is poorly represented in the region, territory, country or the world. It has not been exposed to threatening processes, or they have not had a noticeable impact on the integrity of the environmental value. Project activities would have an adverse effect on the value.
Moderate	The environmental value is recorded as being important at a regional level, and may have been nominated for listing on recognised or statutory registers. The environmental value is in a moderate to good condition despite it being exposed to threatening processes. It retains many of its intrinsic characteristics and structural elements. It is relatively well represented in the systems/areas in which it occurs but its abundance and distribution are limited by threatening processes. Threatening processes have reduced its resilience to change. Consequently, changes resulting from Project activities may lead to degradation of the prescribed value. Replacement of unavoidable losses is possible due to its abundance and distribution.
Low	The environmental value is not listed on any recognised or statutory register. It might be recognised locally by relevant suitably qualified experts or organisations e.g., historical societies. It is in a poor to moderate condition as a result of threatening processes which have degraded its intrinsic value. It is not unique or rare and numerous representative examples exist throughout the system / area. It is abundant and widely distributed throughout the host systems / areas. There is no detectable response to change or change does not result in further degradation of the environmental value. The abundance and wide distribution of the environmental value ensures replacement of unavoidable losses is achievable.

9.1.1.2 *Magnitude of Impacts*

The magnitude of an impact on an environmental value included an assessment of the geographical extent, duration and severity of the impact. Criteria for magnitude are presented in Table 9-2.

Table 9-2 Criteria for Magnitude

Magnitude	Description
High	An impact that is widespread, long lasting and results in substantial and possibly irreversible change to the environmental value. Avoidance through appropriate design responses or the implementation of site-specific environmental management controls are required to address the impact.

Magnitude	Description
Moderate	An impact that extends beyond the area of disturbance to the surrounding area but is contained within the region where the project is being developed. The impacts are short term and result in changes that can be ameliorated with specific environmental management controls.
Low	A localised impact that is temporary or short term and either unlikely to be detectable or could be effectively mitigated through standard environmental management controls.

9.1.1.3 *Significance of Impacts*

The significance of an impact on an environmental value was determined by the sensitivity of the value itself and the magnitude of the impact it experiences. The significance assessment matrix presented in Table 9-3 shows how, using the criteria above, the significance of an impact was determined.

Table 9-3 Significance Assessment Matrix

Magnitude of Impact	Sensitivity of Environmental Value		
	High	Moderate	Low
High	Major	High	Moderate
Moderate	High	Moderate	Low
Low	Moderate	Low	Negligible

The classifications (major, high, moderate, low or negligible) for significance of an impact are as follows:

- **Major** significance of impact - arises when an impact will potentially cause irreversible or widespread harm to an environmental value that is irreplaceable because of its uniqueness or rarity. Avoidance through appropriate design responses is the only effective mitigation.
- **High** significance of impact - occurs when the proposed activities are likely to exacerbate threatening processes affecting the intrinsic characteristics and structural elements of the environmental value. While replacement of unavoidable losses is possible, avoidance through appropriate design responses is preferred to preserve its intactness or conservation status.
- **Moderate** significance of impact - although reasonably resilient to change, the environmental value would be further degraded due to the scale of the impact or its susceptibility to further change. The abundance of the environmental value ensures it is adequately represented in the region, and that replacement, if required, is achievable.
- **Low** significance of impact - occurs where an environmental value is of local importance and temporary and transient changes will not adversely affect its viability provided standard environmental management controls are implemented.
- **Negligible** significance of impact - impact on the environmental value will not result in any noticeable change in its intrinsic value and hence the proposed activities will have negligible effect on its viability. This typically occurs where the activities occur in industrial or highly disturbed areas.

9.1.2 Comparison of EIS and SREIS scenarios

The following table provides a summary of the key changes to the Project (arising since completion of the EIS), and offers an additional qualitative assessment of potential impacts that may be associated with those changes.

9.2 Subsidence Impact on Surface Water

Review of available information from CSG proponents (Origin Energy, QGC and Santos) by Geoscience Australia (2010) in relation to the likely groundwater impacts of proposed CSG activities in the Surat and Bowen Basins, identified potential for subsidence to occur. Whilst Williams (2012) also identified the potential for land subsidence as a result of CSG extraction, on the basis of an assessment of CSG activities in similar environments, Geoscience Australia and Habermehl (2010) concluded that the risk of impacts to shallow groundwater systems was low.

In recognition of the identified potential for subsidence, albeit low, Altamira Information Ltd (Altamira) was engaged to complete a ground motion baseline study on behalf of Arrow Energy for their existing Moranbah Gas project in the Bowen Basin (Altamira, 2013). The study involved analysing ground surface motion across the Moranbah Gas Project area to allow a comparison between known rates of CSG production and ground movement over the same time period. A review of the baseline assessment of subsidence undertaken by Altamira (2013) at the Moranbah Gas project site was undertaken by Coffey (2013). The results showed that the vast majority of the area monitored was subject to movement of less than 8 mm/year over the monitoring period. Whilst isolated locations with greater rates of movement were identified, further interpretation was conducted and found consistent with site surface features. Details of selected individual movement locations showing greater than average movement presented in the Altamira report (2013) include:

- Swelling of reactive clay soils in response to changes in soil moisture;
- Localised settlement areas associated with areas of bare earth possibly associated with erosion;
- Settlement at an isolated location at a production well site over the period January 2007 to December 2010;
- Localised upward movement interpreted at a site which appears to be a gas processing site over the period January 2007 to December 2010, possibly related to swelling of reactive clay soils in an area which has been cleared of vegetation;
- Settlement interpreted on a circular embankment apparently constructed for a rail loop; and
- Settlement interpreted at the embankment for a water storage pond associated with a racecourse.

Overall these findings indicate that the potential for subsidence resulting from CSGdevelopment in the Bowen Basin is low, and substantially less than that arising from longwall coal mining, where subsidence is typically greater than 1 m. Therefore on the basis of these reports the potential for any subsidence impacts on the surface water environment in the Bowen Basin as a result of CSG extraction activities is considered to be negligible. For further information please refer to Section 5.6 of the Supplementary Groundwater Assessment Report (Appendix E) of the SREIS.

9.3 CSG Water Discharge

Whilst Arrow will seek to beneficially reuse as much of its CSG water as possible, there may still be a requirement for the discharge of treated or untreated CSG water into the receiving environment. The revised project description for the SREIS has indicatively identified localities of two WTFs in the vicinity of the Isaac River (5 km to 20 km away) to undertake a qualitative impact assessment for the SREIS to demonstrate that the potential impacts of discharges can be assessed and mitigated if required. It is envisaged that this impact assessment methodology will then be applied on a site-specific and more quantitative basis at EA application/amendment stage, when it is necessary to consider the possibility of releasing CSG water under a full range of flow conditions. This report has examined the existing hydrological, hydraulic and geomorphic conditions of the receiving environment in order to ascertain the capacity of the Isaac River to receive possible CSG water discharges. The potential impacts identified with the possible discharges of CSG water into the Isaac River include:

- Increased bank erosion and changes in geomorphic character of banks due to increased flows;
- Changes in stream hydrological regime and perturbations to flow-dependent ecosystems; and
- Impacts on the receiving environment's water quality.

The Environmental Flow Analysis undertaken in this study indicates that the Isaac River in the vicinity of the potential WTF localities being considered is highly ephemeral with a distinct dry season with no flows, and a wet season between December and April characterised by periods of high flows. Any possible releases of CSG need to be considered in context of the hydrological nature of the Isaac River in order to mitigate potential impacts that CSG water discharges might have.

9.3.1 Controlled CSG Water Releases

The bankfull flood typically has the greatest erosion and assimilative potential and as such was assessed for the Isaac River for the potential release areas. The Isaac River channel has a bankfull capacity of 270 m^3/s (23.3 GL/d) in the reaches near the potential WTF1 area of interest, and a bankfull capacity of 2,350 m^3/s (203 GL/d) in the vicinity of the possible WTF2 locality. These relatively large volumes indicate that the Isaac River in flood has a high capacity to receive CSG water discharges without any significant impacts on its environment values (geomorphology, water quality, stream flow). Given that the WTF localities are indicative, the actual discharge conditions will need to be determined as part of the EA application process, and discharge rates adjusted accordingly to mitigate potential impacts.

Table 9-4 SREIS Impact Assessment Summary

Project Component	EIS Scenario (2012)	SREIS Scenario (2014)	Associated potential impacts	Key changes in degree of potential impact	Applicable Mitigation Measures
Drainage areas	• 17 'drainage areas'	• 33 'drainage areas'	• Localised alteration of flows and flow paths • Erosion and sediment mobilisation	• May result in increased *localised* impacts compared with EIS scenario	• Mitigation measures outlined in Sections 9.2.1, 9.2.2 and 9.2.3 of the Surface Water Technical Report (Appendix N) of the EIS still apply
Production wells	• 6,625 production wells • Single well pads only	• Approximately 4,000 production wells • Multi-Branch Lateral wells is base case. All multi-well pads, with up to 6 production wells located on a pad	• Ponding in subsided void areas • Localised alteration of flows and flow paths • Erosion and sediment mobilisation	• Reduced area of potential ponding of rainfall in subsided voids	• Mitigation measures outlined in Sections 9.2.2.1, 9.2.2.2 and 9.2.2.3 of the Surface Water Technical Report (Appendix N) of the EIS still apply
Project infrastructure	• Four integrated gas and water processing facilities (, with dams up to 1 km^2 in area • One FCF per drainage area	• Two co-located CGPFs and WTF located near Peak Downs and Red Hill (both relatively near to Isaac River) • One FCF per drainage area	• Flooding of Project infrastructure could cause contamination of floodwaters • Scour or sedimentation at watercourse crossings could impact geomorphology and potential wetlands	• Reduced footprint and number of gas processing facilities • Larger footprint area for FCFs • Reduced watercourse crossings • Reduced number of well pads and associated linear infrastructure	• Mitigation measures outlined in Sections 9.2.1.1 to 9.1.2.4, and 9.2.2 of the Surface Water Technical Report (Appendix N) of the EIS still apply

Impacts to geomorphology as a result of localised disturbances of watercourses during construction activities or from subsidence, should any occur, could include localised erosion and sediment deposition. Works within watercourses should be conducted in the dry season as much as possible and in accordance with regulatory requirements for works conducted in watercourse channels. Monitoring and site specific erosion control measures should be developed at the design stage, including vegetation establishment or engineered erosion protection such as rock structures or energy dissipation structures.

Any potential wetland areas identified near the WTF1 and WTF2 potential localities will be better defined through field assessments in order to avoid inappropriate siting of infrastructure in relation to wetland areas where possible. At the construction phase of the Project, crossing of watercourses and floodplains near wetlands will be avoided as much as possible.

9.3.2 Uncontrolled Releases of CSG Water

Uncontrolled releases of treated or untreated CSG water may have significant impacts on the receiving environment depending on the timing, volumes and discharge rates of the release. The impact assessment of such uncontrolled releases on the hydrological, hydraulic and geomorphic environmental values, as well as that for controlled releases discussed above, are summarised in Table 9-5. Impacts on surface water quality are discussed in the Surface Water Quality Technical Report (Appendix F) of the SREIS.

9.3.3 Residual Impacts

The summary of impacts that potentially remain in association with the proposed Project activities, after application of suitable management and mitigation measures described above, are summarised in Table 9-6.

9.3.4 Cumulative Impacts

The Isaac River is known to be the receiving environment for discharges for a significant number of coal mines operating in the area. Likewise, the proponent may also choose to release CSG water into the Isaac River if beneficial use options for this water are insufficient at a particular time. Releases of mine affected water or CSG water into the Isaac River are regulated by conditions that stipulate the quality, volumes, timing and duration of the water that can be released under controlled conditions. Under these conditions the river's environmental flow objectives are preserved and as such, under periods of high flows, the cumulative impacts on the natural flows and geomorphic integrity of the Isaac River are protected. Providing that all further planned developments are managed with sufficient mitigation measures and with discharge strategies having the same objectives as that of the Project, significant cumulative impacts on the river's flow regime and geomorphic character should not occur.

9.3.5 Inspection and Monitoring

A baseline monitoring program should be initiated prior to the commencement of Project activities at locations that would include works in and around watercourses and wetlands. Monitoring sites would be selected upstream and downstream of each potential impact location.

An ongoing monitoring program will be implemented to measure the impact of the Project at locations where significant impacts are identified as possible and to assess the effectiveness of mitigation measures. Given the indicative nature of the discharge and infrastructure locations, the ongoing monitoring program details cannot yet be established. During the rehabilitation of watercourse crossings an assessment of the impacts on geomorphology will be undertaken and rectification works undertaken where adverse geomorphological impacts have arisen in accordance with the recommendations in Table 9-4.

Table 9-5 Impact assessment for CSG water release on hydrology and geomorphology of the Isaac River

CSG Water Release Scenario	Contributing factor	Potential impacts	Magnitude of Impact	Significance of Impact
Uncontrolled release of *untreated* CSG water	Flooding (dams over capacity; inundation of infrastructure) , dam failure, WTF operational emergency- Dry Season	• During periods of low flow, sudden release of large volumes of moderately saline water could result in: – Potential inundation of riparian margins and floodplain areas not usually inundated during dry season. – Transport of large quantities of sediment and large woody debris downstream.	High	High
	Flooding (dams over capacity; inundation of infrastructure) and dam failure- Wet Season	• During periods of high flow, sudden release of large volumes of moderately saline water will have a minimal impact on the natural low flow regime and may cause limited erosion to stream banks. • Transport of large quantities of sediment and large woody debris downstream. • During periods of high flow, there may be a slight increase in stream water level and impacts on stream physical integrity.	Low	Low
Uncontrolled release of *treated* CSG water	Flooding (dams over capacity; inundation of infrastructure) , dam failure, WTF operational emergency- Dry Season	• During periods of low flow, sudden release of large volumes of water could result in: – Potential inundation of riparian margins and floodplain areas not usually inundated during dry season. – Transport of large quantities of sediment and large woody debris downstream.	Moderate	Moderate
	Flooding (dams over capacity; inundation of infrastructure) and dam failure- Wet Season	• During periods of high flow, sudden release of large volumes of water will have a minimal impact on the natural low flow regime and may cause limited erosion to stream banks. • Transport of large quantities of sediment and large woody debris downstream. • During periods of high flow, there may be a slight increase in stream water level and impacts on stream physical integrity.	Low	Low

CSG Water Release Scenario	Contributing factor	Potential impacts	Magnitude of Impact	Significance of Impact
Controlled release of treated and untreated CSG water	Release according to EA conditions (where beneficial use is not appropriate/available)	• Treated CSG water is released at volume and water quality that does not cause a significant impact on the receiving environment, based on findings of site-specific baseline assessment.	Low	Low to negligible

Table 9-6 Residual Impacts to the Isaac River's flow regime and geomorphic character arising from Project activities

Project Component	Associated potential impacts	Applicable Mitigation Measures	Residual Impact	Magnitude of Residual Impact	Significance of Residual Impact
Drainage areas	• Alteration of flows and flow paths • Erosion and sediment mobilisation • Improper disposal of wastes from construction and operations activities • Potential release of contaminants to watercourses (adverse effects on surface water quality)	Mitigation measures outlined in Sections 9.2.1, 9.2.2 and 9.2.3 of the Surface Water Technical Report (Appendix N) of the EIS still apply.	Potential release of sediment and contaminated water to overland flows paths if management controls fail (for example, sediment fence is washed away or vandalised).	Low	Low
Production wells	• Alteration of flows and flow paths • Erosion and sediment mobilisation	Mitigation measures outlined in Sections 9.2.2.1, 9.2.2.2 and 9.2.2.3 of the Surface Water Technical Report (Appendix N) of the EIS still apply.	Potential localised impact to river geomorphology if engineering/management control options fail (potential for larger volume of sediment to be mobilised from multi-well pads, on a local scale only).	Low	Low to negligible

Project Component	Associated potential impacts	Applicable Mitigation Measures	Residual Impact	Magnitude of Residual Impact	Significance of Residual Impact
Gas compression infrastructure	• Alteration of flows and flow paths • Erosion and sediment mobilisation	Mitigation measures outlined in Sections 9.2.1.1 to 9.1.2.4, and 9.2.2 of the Surface Water Technical Report (Appendix N) of the EIS still apply	Potential localised impact to stream geomorphology in surface water catchments containing FCFs, if engineering/management control options fail (potential for larger volume of sediment to be mobilised from FCFs with increased area).	Low	Low to negligible
Water Treatment facilities	• Release of treated and untreated CSG water to surface watercourses (potential adverse effects on stream flows and geomorphology) • Uncontrolled release of contaminated water to grade and/or watercourses due to spills (from water gathering lines; trucks transporting wastewater and treated water from water transfer stations) Reduced risk of adverse impacts to water quality, with fewer discharge points (a function of having fewer WTFs)	Mitigation measures outlined in Sections 9.2.1.1 to 9.1.2.4, and 9.2.2 of the Surface Water Technical Report (Appendix N) of the EIS still apply. Section 9.2.2.4 (Discharge of CSG Water to Waterways) of the Surface Water Technical Report (Appendix N) of the EIS specifically applies to any releases from WTFs to the receiving environment, along with information outlined in Sections 9.1 and 9.2 of the same report.	Potential impact to surface water hydrology and geomorphology in the event of uncontrolled releases (where it is not possible to control the volume released, such as in an emergency). Impact to surface water hydrology and geomorphology is dependent on the actual rate and water quality of release. Magnitude of impact depends on size of flow in the Isaac River main channel.	Moderate	Moderate
Linear infrastructure (e.g. roads and pipelines)	• Alteration of flows and flow paths • Erosion and sediment mobilisation	Mitigation measures outlined in Sections 9.2.2.1, 9.2.2.2 and 9.2.2.3 of the Surface Water Technical Report (Appendix N) of the EIS still apply.	Potential localised impact to stream hydrology and geomorphology if engineering/management control options fail.	Low	Low to negligible

10 CONCLUSIONS

The hydrology and geomorphology assessment undertaken for the SREIS has provided information on the likely impacts with activities included in the updated project description, and informs the CSG water management strategy for the Project.

A detailed Environmental Flow Assessment describes the Isaac River at the reaches proximate to the areas being considered for the proposed WTFs as highly ephemeral with flows occurring only for short duration between December and April. For the remainder of the year the river is dry or is limited to a series of isolated pools. The hydraulic assessment indicates that the Isaac River supports very significant flows during the wet season, flows that are considered to be large enough to more than cater for the release of CSG water without causing any environmental flows or geomorphic impacts. The hydrological and hydraulic nature of the Isaac River therefore links the release rates of CSG water to flow conditions. The findings of this report, as well as those presented in the Surface Water Quality Technical Report (Appendix F) of the SREIS, will enable the proponent to develop a CSG water discharge strategy according to the variable water quality and stream flow conditions within the BGP area as part of the EA application or amendment process. Further hydraulic assessments of the receiving environment may need to be undertaken at the EA application stage should the facilities be located outside of the areas assessed in this report.

A modelled estimate of flood inundation that would occur as a result of a 1% AEP flood event indicates that the two indicative WTF localities have substantial areas which are flood free; these areas are orders of magnitude larger than the minimum area required for the two localities assessed for potential gas compression and water treatment facility locations. This is typical for the catchment, even under scenarios of increased rainfall intensity and duration as a result of climate change. As such, it can be concluded that these two infrastructure hubs assessed can be located outside of the modelled 1% AEP flood inundation level.

This study has indicated that the Isaac River has a large assimilative capacity for potential CSG water discharges, and that carefully managed and using the principles outlined in this study and in the Surface Water Quality Technical Report (Appendix F) of the SREIS, controlled releases of both treated and untreated CSG water are not expected to have any significant impact on the EVs of the Isaac River main channel. Potential impacts on the river's hydrology and geomorphology associated with emergency releases of treated and untreated CSG water have also been considered in this study. The impacts arising from uncontrolled releases will vary depending on a number of variables including flows and water quality in the receiving environment, and volume, discharge rate and quality of the CSG water released. Adoption of the principles presented in this report together with further site-specific baseline assessments during the EA application or amendment process, together with a robust monitoring program, would effectively mitigate potential impacts to stream hydrology and geomorphology.

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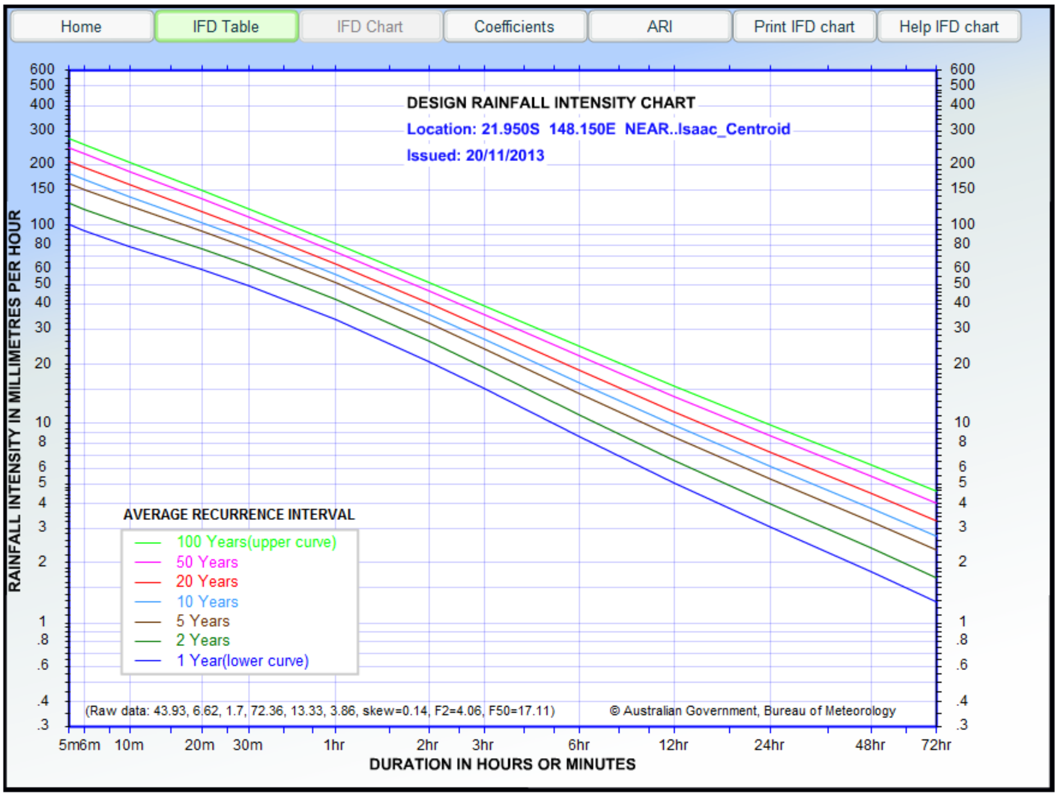
APPENDIX A BOM INTENSITY FREQUENCY DURATION RAINFALL DATA

Table-A-1 BoM IFD Output

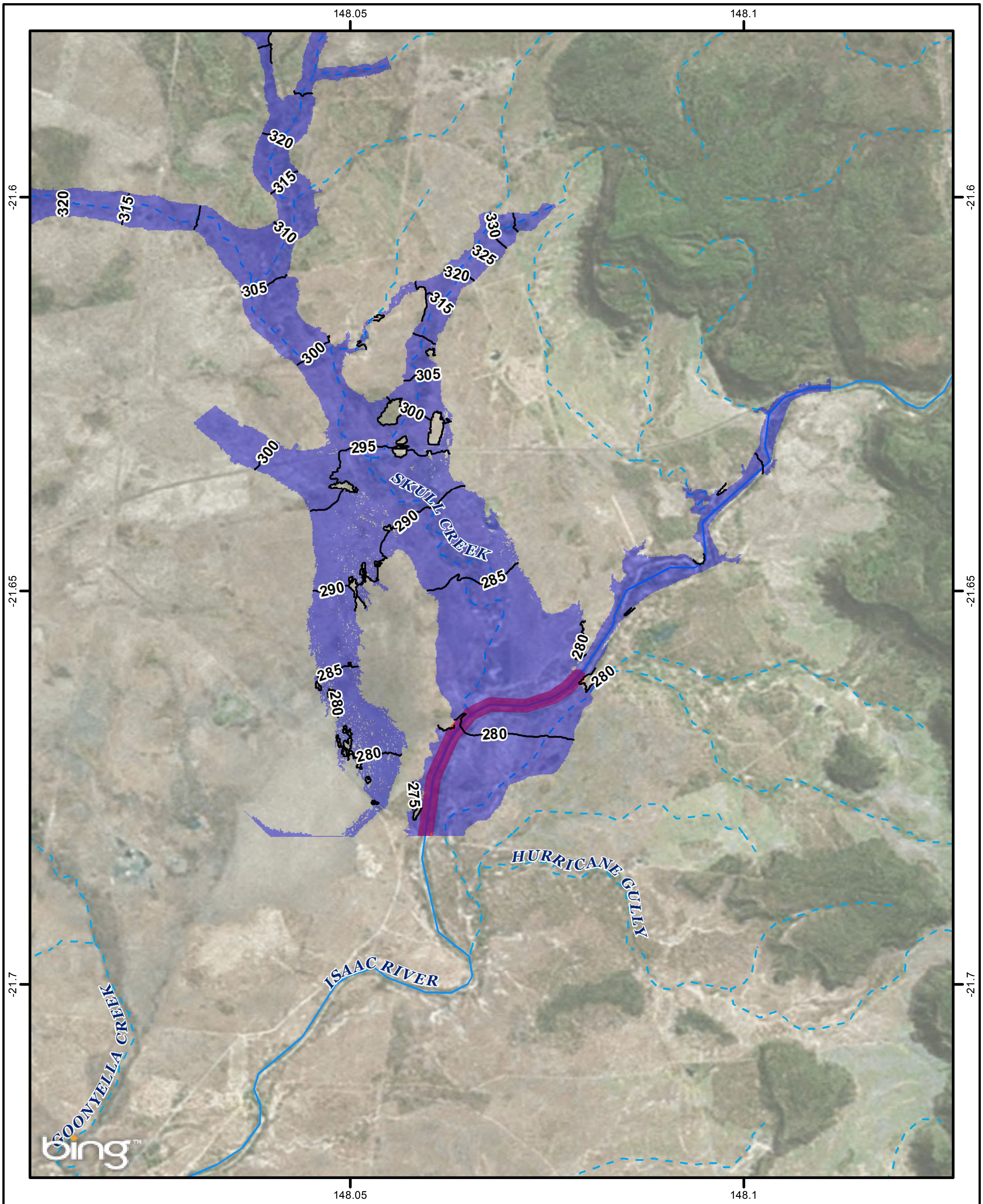
Duration	Rainfall Intensity (mm/hr)							100 yr Depth (mm)
	1 yr	2 yrs	5yrs	10 yrs	20 yrs	50 yrs	100 yrs	
5Mins	101	129	162	182	209	245	**273**	**22.8**
6Mins	93.6	120	151	170	195	229	**254**	**25.4**
10Mins	78	99.6	125	139	160	186	**207**	**34.5**
20Mins	59.9	76.1	93.4	103	117	136	**150**	**50.0**
30Mins	49.7	62.9	76.6	84.5	95.5	110	**121**	**60.5**
1Hr	33.5	42.3	51.4	56.5	63.8	73.3	**80.6**	**80.6**
2Hrs	20.6	26.2	32.2	35.6	40.5	46.8	**51.6**	**103.2**
3Hrs	15.1	19.2	23.9	26.7	30.5	35.5	**39.3**	**117.9**
6Hrs	8.64	11.1	14.2	16.1	18.6	22	**24.6**	**147.6**
12Hrs	5.03	6.55	8.58	9.84	11.5	13.7	**15.5**	**186.0**
18Hrs *	4.03	5.26	6.94	7.99	9.36	11.21	**12.7**	**211.8**
24Hrs	3.03	3.97	5.29	6.13	7.22	8.72	**9.9**	**237.6**
48Hrs	1.81	2.38	3.23	3.77	4.48	5.45	**6.22**	**298.6**
72Hrs	1.27	1.68	2.32	2.72	3.25	3.99	**4.59**	**330.5**

** Interpolated*

Figure-A-1 BoM IFD Chart



APPENDIX B FLOOD INUNDATION EXTENTS



Area of Innundation
Surface Water Contour (mAHD)
Potential receiving environment for CSG discharge area for CSG water
Major Drainage
Minor Drainage

N
W E
S

0 0.5 1 2 km

1:75,000

Projection: Geographic (GDA94)

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BOWEN GAS PROJECT SREIS

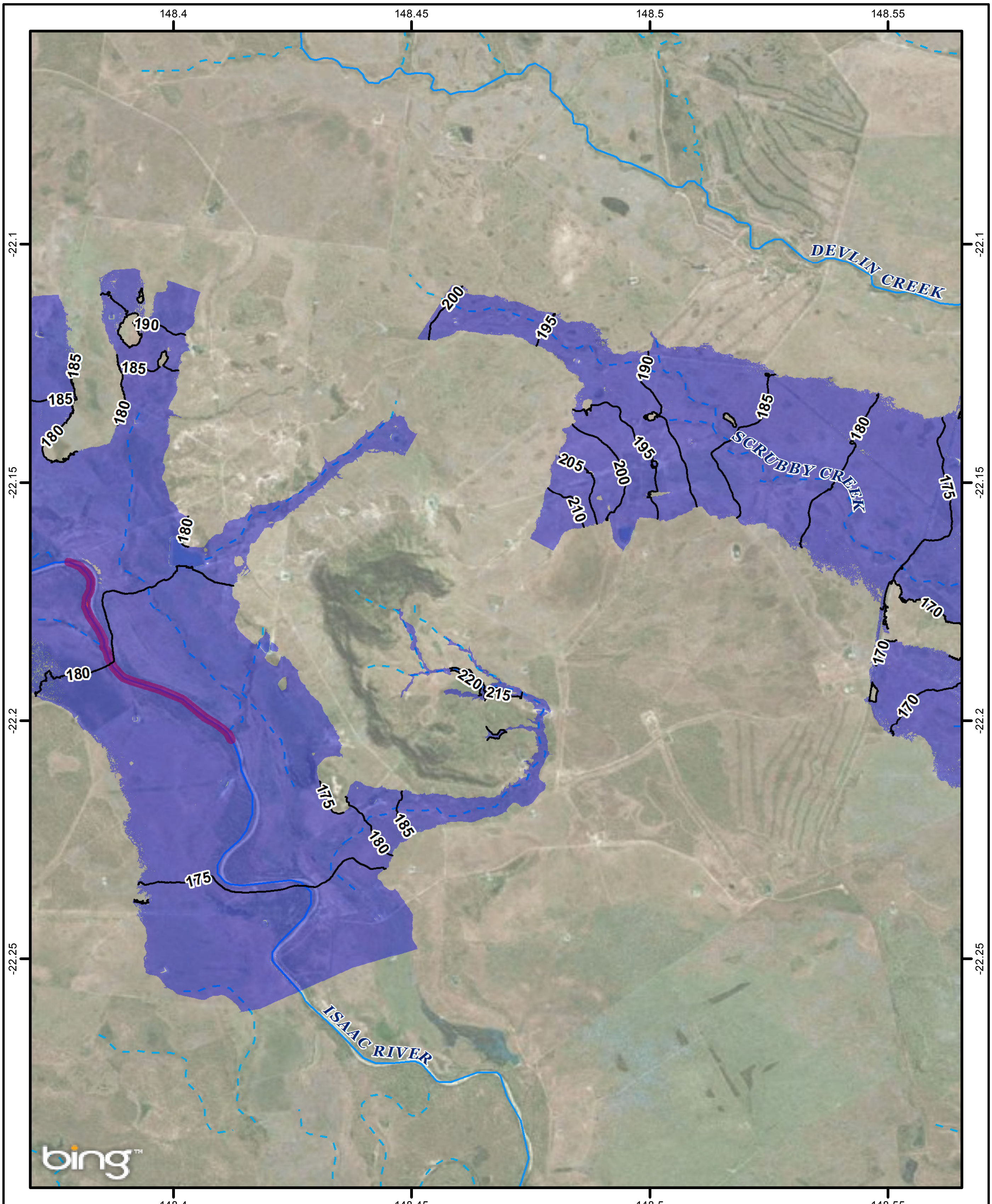
1% AEP MAXIMUM FLOOD INUNDATION EXTENTS FOR WTF1 POTENTIAL LOCALITY

URS

HYDROLOGY - SURFACE WATER ASSESSMENT

Figure: **B-1**

File No: **42627140-g-2070c.mxd** Drawn: **RG** Approved: **DS** Date: **22-04-2014** Rev. **C** A4



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0 0.5 1 2 3 km

1:125,000

Projection: Geographic (GDA94)

Area of Innundation

Surface Water Contour (mAHD)

Potential receiving environment for CSG discharge area for CSG water

Major Drainage

Minor Drainage

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1% AEP MAXIMUM FLOOD INUNDATION EXTENTS FOR WTF2 POTENTIAL LOCALITY

URS

HYDROLOGY - SURFACE WATER ASSESSMENT

Figure: **B-2**

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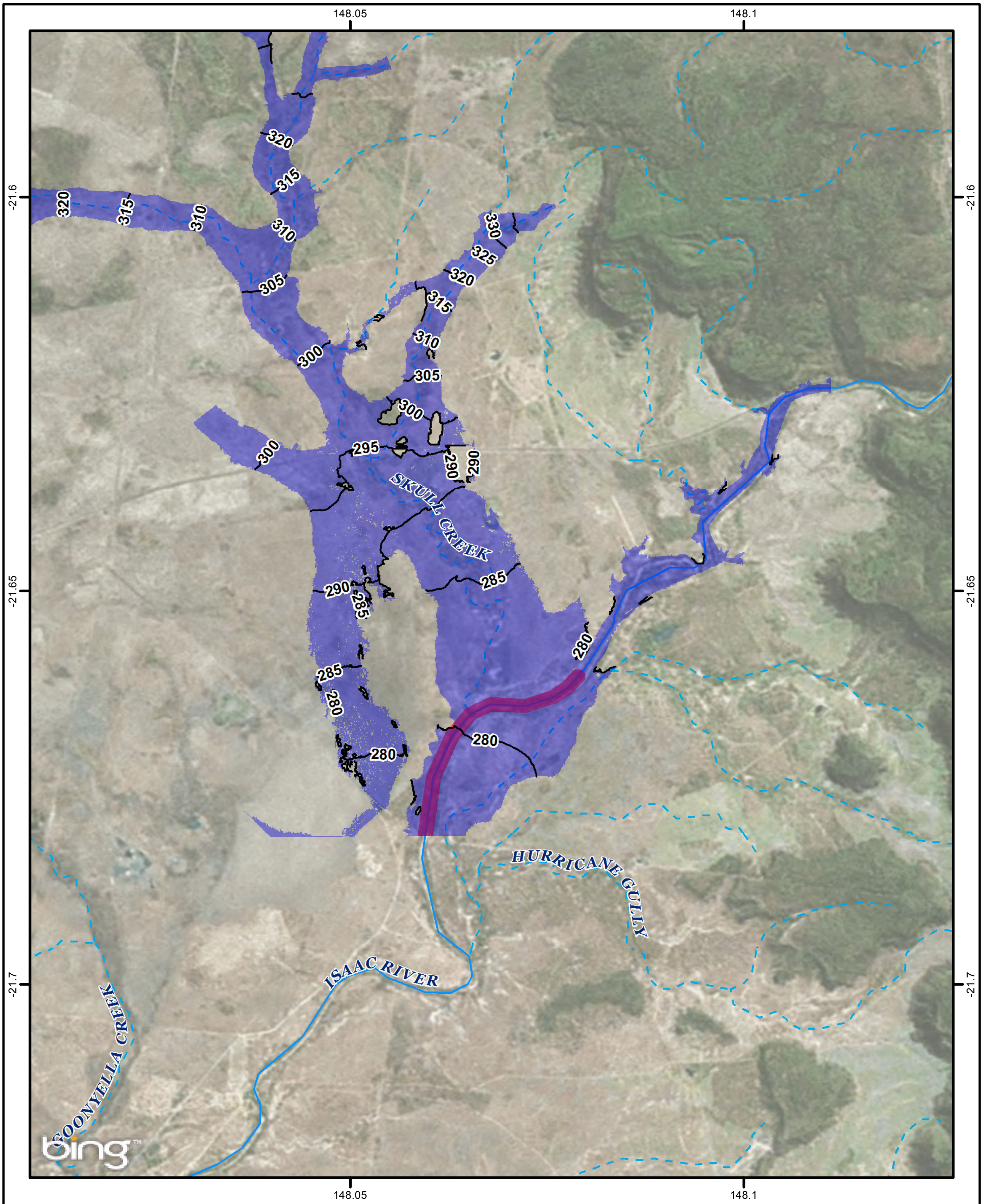

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Projection: Geographic (GDA94)

Area of Innundation

Surface Water Contour (mAHD)

Potential receiving environment for CSG discharge area for CSG water

Major Drainage

Minor Drainage

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1% AEP MAXIMUM FLOOD INUNDATION EXTENTS FOR WTF1 POTENTIAL LOCALITY (CLIMATE CHANGE IMPACT)

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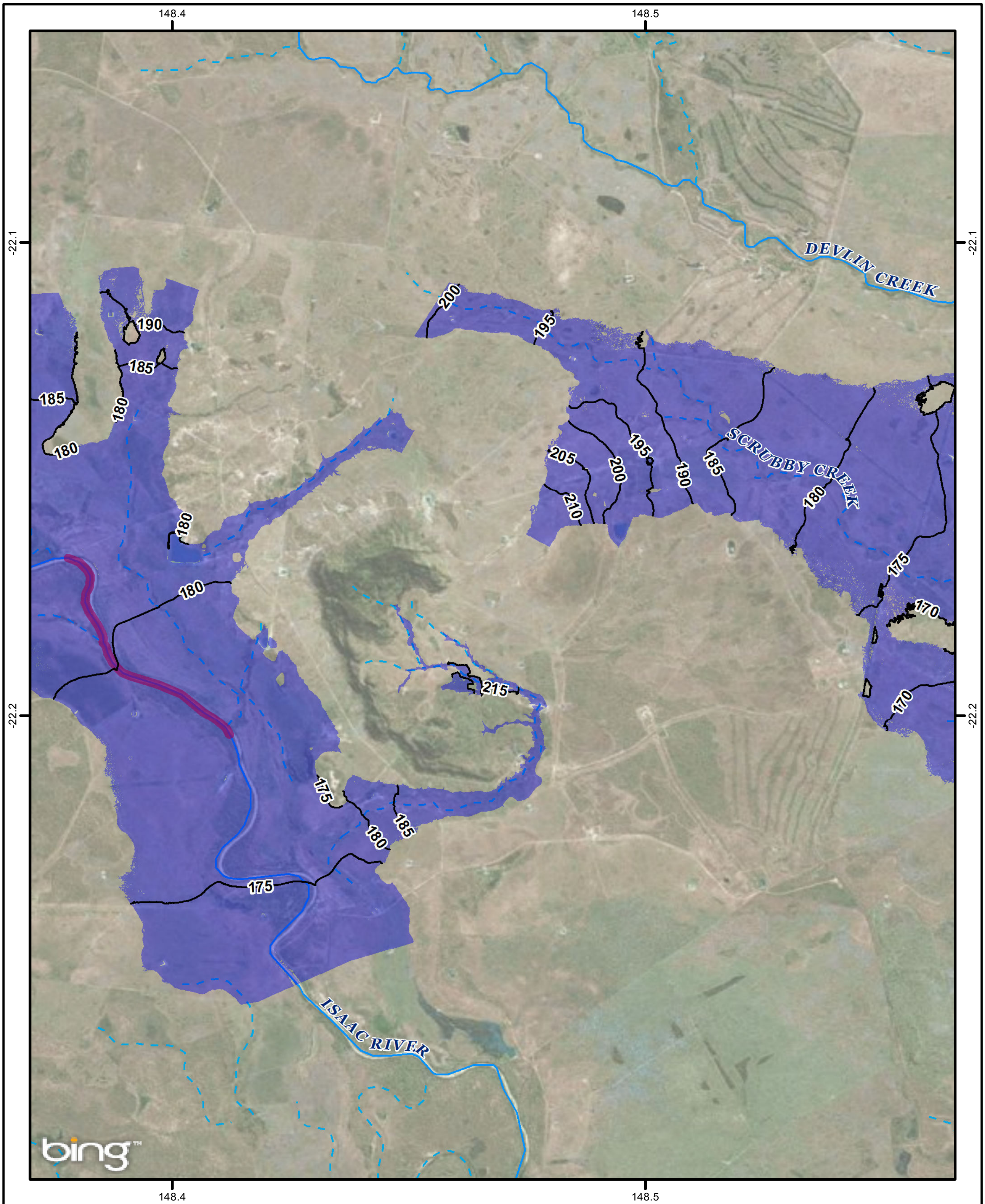
HYDROLOGY - SURFACE WATER ASSESSMENT

Figure: B-3

File No: 42627140-g-2072c.mxd | Drawn: RG | Approved: DS | Date: 22-04-2014 | Rev.C | A4



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0 0.5 1 2 3 km

1:125,000

Projection: Geographic (GDA94)

- Area of Innundation
- Surface Water Contour (mAHD)
- Potential receiving environment for CSG discharge area for CSG water
- Major Drainage
- Minor Drainage

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1% AEP MAXIMUM FLOOD INUNDATION EXTENTS FOR WTF2 POTENTIAL LOCALITY (CLIMATE CHANGE IMPACT)

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HYDROLOGY - SURFACE WATER ASSESSMENT

Figure: B-4

File No: 42627140-g-2073d.mxd | Drawn: RG | Approved: DS | Date: 22-04-2014 | Rev. D | A4

148.1

- Area of Innundation
- Area of Innundation (Climate Change Impact)
- Potential receiving environment for CSG discharge area for CSG water
- Major Drainage
- Minor Drainage

N E S W

0 0.5 1 2 km

1:75,000

Projection: Geographic (GDA94)

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BOWEN GAS PROJECT SREIS

COMPARISON OF 1% AEP MAXIMUM FLOOD INUNDATION EXTENTS FOR WTF1 POTENTIAL LOCALITY

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HYDROLOGY - SURFACE WATER ASSESSMENT

Figure: B-5

File No: 42627140-g-2074c.mxd Drawn: RG Approved: DS Date: 22-04-2014 Rev.C A4

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1:125,000

Projection: Geographic (GDA94)

Area of Innundation

Area of Innundation (Climate Change Impact)

Potential receiving environment for CSG discharge area for CSG water

Major Drainage

Minor Drainage

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COMPARISON OF 1% AEP MAXIMUM FLOOD INUNDATION EXTENTS FOR WTF2 POTENTIAL LOCALITY

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HYDROLOGY - SURFACE WATER ASSESSMENT

Figure: B-6

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