7.6 Groundwater

7.6.1 Introduction

A groundwater assessment study was conducted for the gas transmission pipeline component of the GLNG Project (refer Appendix P1). The following section provides a summary of the study findings, including a description of the existing environmental values, assessment of potential groundwater impacts and recommended mitigation measures. For discussion of the surface water environment, assessment of potential impacts and recommended mitigation measures, see Section 7.5.

As the gas transmission pipeline will carry CSG, the main impacts identified with regards to shallow groundwater are related to alterations to aquifer hydraulic parameters.

7.6.2 Methodology

Based on the proposed gas transmission pipeline details, a desktop review was conducted to assess groundwater resources and potential impacts along the pipeline corridor. Sufficient desktop data was available for a high level assessment of large scale groundwater resources along the 435 km route. No intrusive hydrogeological work was conducted; however proposed studies have been compiled to assist in addressing potential impacts and implementing mitigation measures.

7.6.3 Regulatory Framework

An outline of the groundwater regulatory framework is provided in Section 6.6.1.3.

7.6.4 Existing Environmental Values

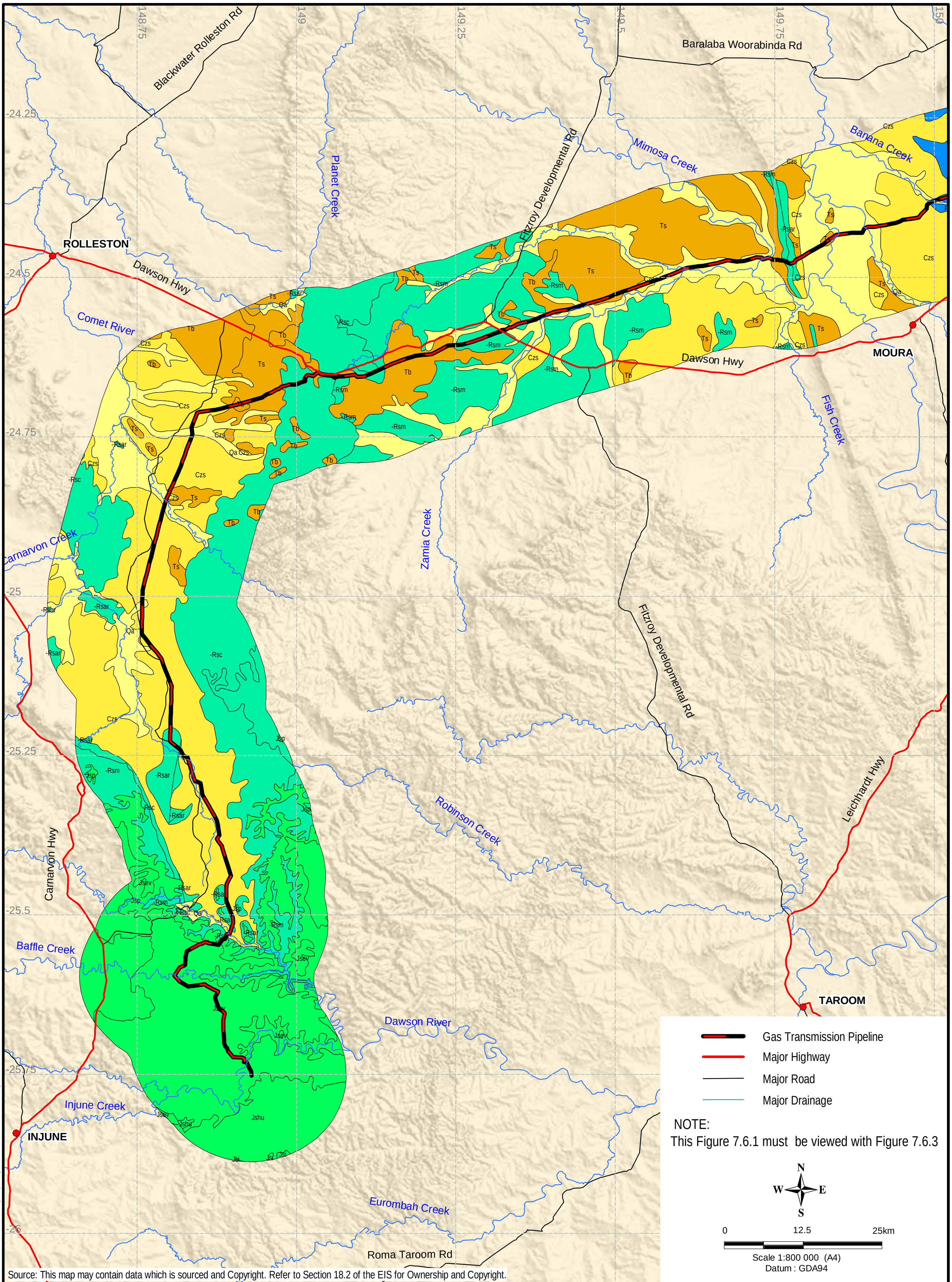
A desktop review of the surface outcrop geology along the gas transmission pipeline corridor, as shown in Figures 7.6.1 to 7.6.3, was conducted to identify potentially vulnerable groundwater resources.

The environmental values of the shallow groundwater have been assessed according to the values identified in the EPP Water, as discussed in Section 6.6.1.4. The review of available data allowed for an initial assessment of the shallow groundwater resources along the proposed pipeline corridor. Groundwater is utilised for domestic and stock watering purposes from shallow groundwater resources. Small scale irrigation using groundwater also occurs from the various shallow aquifers within the vicinity of the gas transmission pipeline corridor.

The route originates in the plateau country of the Great Dividing Range northeast of Injune. Soils associated with the plateau are predominantly sandy in texture, often very shallow or stony, with areas of sandstone rock outcrop. This plateau is a major recharge area for the sandstone aquifers within the Great Artesian Basin (GAB) sequence. Seasonal seepage and discharge from the confined aquifers can occur within the Great Dividing Range, depending on topography and hydrostatic pressures. This seepage may sustain groundwater dependent environments through discharge to creeks and water holes. An assessment of the geology, elevation, and groundwater levels along the route through these competent formations will allow for an assessment of potential groundwater seepage, and thus vulnerable shallow groundwater resources.

At the base of the escarpment, the proposed gas transmission pipeline route intersects alluvium-rich soils of the Upper Dawson River. This alluvium material contains shallow groundwater resources, used for agriculture, which are vulnerable to surface contamination due to increased porosity and permeability in the sand and gravel material. These resources also have enhanced storage and recharge, which allows for moderate sustainable abstraction where the alluvium has large extent (spatial and depth) and interconnectivity.

The gas transmission pipeline route proceeds northward through the Arcadia Valley, which consists of gently sloping fans containing sandy soils and areas of medium to heavy clay.



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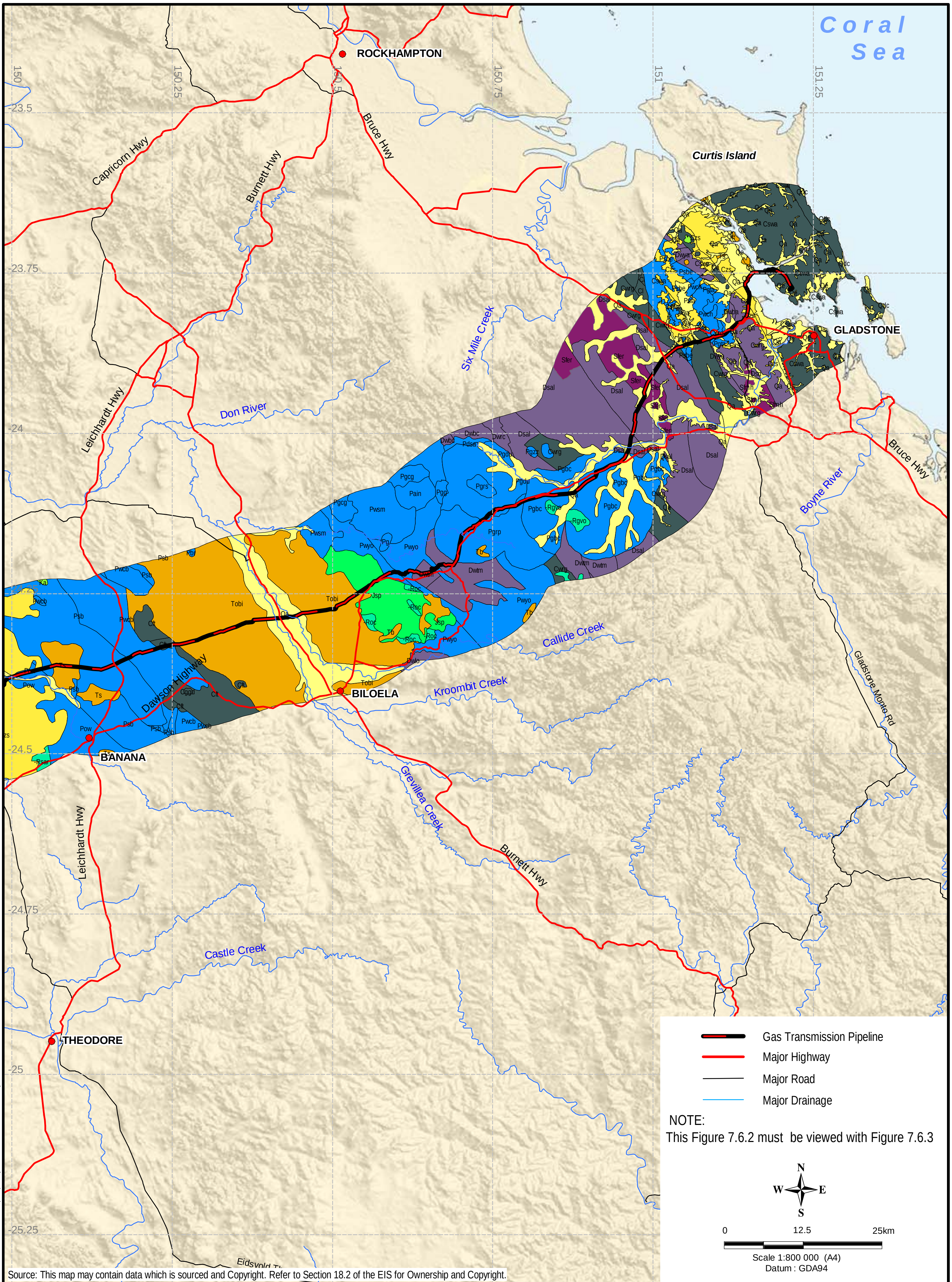
Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	**GAS TRANSMISSION PIPELINE CORRIDOR AND REGIONAL GEOLOGY WESTERN SECTION**
	Drawn: RG/CA · Approved: JB · Date: 29-01-2009	Figure: **7.6.1** · Rev:A
	Job No: **4262 6220** · File No: 42626220-g-870.wor	A4



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Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	**GAS TRANSMISSION PIPELINE CORRIDOR AND REGIONAL GEOLOGY EASTERN SECTION**

Drawn: RG/CA	Approved: JB	Date: 29-01-2009	Figure: **7.6.2**	Rev:A
Job No: **4262 6220**	File No: 42626220-g-870.wor			A4

Qe		estuarine and delta deposits	Estuarine, tidal delta deposits; coastal mud flats
Qdc		coastal dunes	Coastal dunes, beach ridge, barrier beach, foredune & shoreface sands
Qa		alluvium	Channel and flood plain alluvium; gravel, sand, silt, clay
Tb		volcanic rocks	Volcanic rocks, predominantly mafic; basalt, trachyte, rhyolite
Tobi		Biloela Formation	Mudstone, siltstone, oil shale, sandstone, minor lignite, coal and limestone
Ts		sediments	Tertiary sediments, undivided
Czs		sand plain	Sand plain, may include some residual alluvium; sand dominant, gravel, clay
Ka		trachyte	Trachyte, volcaniclastics, quartz porphyry, rhyolite aplite, granodiorite, diorite, gabbro
Kf		volcaniclastics	Intermediate and acid volcaniclastics and flows, rhyolite flow
Jshu	**Bundamba Group**	Hutton Sandstone	Sublabile to quartzose sandstone, siltstone, mudstone, minor conglomerate and coal
Jsev	**Bundamba Group**	Evergreen Formation	Labile and sublabile, sandstone, carbonaceous mudstone, siltstone and minor coal; local oolitic ironstone
Jsp	**Bundamba Group**	Precipice Sandstone	Thick-bedded, cross-bedded, pebbly quartzose sandstone, minor lithic sublabile sandstone, siltstone, mudstone
-Rsc	**Clematis Group**		Quartz rich sandstone, conglomerate, siltstone, mudstone
-Rgvo		Voewood Granite	Pale pink to grey medium-grained biotite granite, locally with pyrite along joint planes
-Rsm	**Mimosa Group**	Moolayember Formation	Micaceous lithic sandstone, micaceous siltstone
-Rsar	**Rewan Group**	Arcadia Formation	Lithic sandstone and green to reddish brown mudstone and minor conglomerate
-Rfw		Winterbourne Volcanics	Rhyolite, trachyte, ignimbrite, rhyolitic breccia, tuff, minor basalt
-Roc		Callide Coal Measures	Poorly sorted polymictic pebble to boulder conglomerate, sandstone, siltstone, coal seams, felsic tuff
Pgg	**Galloway Plains Igneous Complex**		Grey to dark grey medium-grained biotite-hornblende quartz diorite and augite-hypersthene-hornblende quartz gabbro
Pg		granodiorite	Granodiorite, granite, monzogranite, diorite, amphibolite, rhyolite
Pgd		hornblende diorite	Hornblende diorite, biotite-hornblend quartz diorite, monzodiorite, monzonite
Pgcg	**Littlemore Suite**	Craiglands Quartz Monzodiorite	Grey to pink medium-grained hornblende quartz monzodiorite, hornblende-augite quartz diorite, biotite-hornblende quartz diorite
Pdy		gabbro 39,477	Gabbro, diorite
Pdsa		Sawnee Gabbro	Grey medium-grained hornblende gabbro
Pgdu	**Dumgree Suite**	Dumgree Tonalite	Pale grey medium-grained leucocratic biotite-hornblende tonalite; grey medium-grained hornblende quartz diorite
Pgbc	**Galloway Plains Igneous Complex**	Bocoolima Granodiorite	Deeply weathered grey medium-grained biotite-hornblende granodiorite
Pgzz		Zig Zag Granodiorite	Pale grey medium-grained hornblende-biotite tonalite, locally with patches of epidote alteration
Pgma		Mannersley Granodiorite	Porphyritic biotite-hornblende quartz microdiorite with abundant secondary biotite along joints
Pgrs	**Littlemore Suite**	Redshirt Granite	Pink medium to coarse-grained hornblende-biotite granite with minor tourmaline pegmatite
Pgrp	**Rocky Point Granodiorite**		Grey to pinkish grey medium-grained biotite-hornblende granodiorite, locally with poikilitic K feldspar
Pgta	**Targinie Quartz Monzonite**		Hornblende-biotite quartz monzonite, quartz-alunite alteration
Pwch	**Berserker Group**	Chalmers Formation	Siltstone, lithic sandstone, rhyolitic to andesitic volcaniclastic breccia, rhyolitic and dacitic tuff, minor andesitic tuff
Psla	**Berserker Group**	Lakes Creek Formation	Siltstone and lithic sandstone
Pain		Inverness Volcanics	Trachyte to dacite, volcanic breccia; numerous small hornblende quartz monzodiorite intrusions
Psb	**Back Creek Group**		Sandstone, siltstone, carbonaceous shale, minor coal and sandy coquinite
Pow	**Blackwater Group**		Sandstone, siltstone, shale, mudstone, coal, tuff, conglomerate
Psbe		Berserker beds	Siltstone, lithofeldspathic sandstone, intermediate to felsic intrusive and extrusive domes, volcanic breccia, minor conglomerates
Pwyo		Youlambie Conglomerate	Polymictic conglomerate, felsic volcaniclastic sandstone, carbonaceous siltstone, dacitic to rhyolitic ignimbrite, breccia, mudstone, minor coal
Pbr		Rookwood Volcanics	Basalt and high-level mafic intrusives, minor rhyodacite lava, volcaniclastic breccias, sandstones, siltstones, mudstone
Pwsm		Smoky beds	Andesitic conglomerate and sandstone, mudstone, minor andesite lava
Pwcb	**Back Creek Group**	Camboon Volcanics	Andesite, basalt, dacite, rhyolitic tuff and flows, conglomerate, sandstone, siltstone, breccia
Cwrg	**Rockhampton Group**		Mudstone, siltstone, volcaniclastic sandstone, polymictic conglomerate, ooid-bearing sandstone, oolitic limestone
Cssh		Shoalwater Formation	Quartzose sandstone, mudstone; local quartz-muscovite-biotite schist
Cl		siltstone 39,453	Siltstone, sandstone, conglomerate, limestone, mudstone
Cft		Torsdale Volcanics	Dacitic to rhyolitic ignimbrite, volcaniclastic rocks and lava; subordinate andesitic rocks; volcanilithic conglomerate and sandstone
Cggd		Glandore Quartz Monzonite	Medium-grained, biotite-hornblende granite, granodiorite or monzonite, biotite granite, hornblende diorite
Cswa		Wandilla Formation	Mudstone, lithic sandstone, siltstone, jasper, chert, slate; local schist
Dwba	**Curtis Island Group**	Doonside Formation	Basaltic to andesitic lava and volcaniclastic rocks, felsic volcaniclastic rocks, chert, mudstone, limestone
Dsd	**Curtis Island Group**	Doonside Formation	Chert, jasper, mudstone, siltstone, lithic sandstone, tuff, limestone, and altered basalt
Dwya		Yarwun beds	Interbedded sandstone and siltstone, dacitic to rhyolitic volcaniclastic conglomerate with rip-up clasts, limestone
Dwtm		Three Moon Conglomerate	Andesitic to basaltic polymictic conglomerate, lithofeldspathic sandstone, siltstone, mudstone, andesite, minor acid tuff, limestone
Dwbc		Balaclava Formation	Rhyolitic volcaniclastic sandstone and conglomerate, minor ignimbrite, rare rhyolite, siltstone and oolitic limestone
Dsal		Mount Alma Formation	Sandstone, siltstone and thick beds of conglomerate with andesitic to dacitic clasts and siltstone rip-up-clasts, fossilifereous limestone
Dwrc	**Capella Creek Group**	Raspberry Creek Formation	Basaltic to rhyolitic volcaniclastic sandstone and conglomerate and minor lavas, siltstone, mudstone, chert, jasper, limestone
Dwlo		Lochenbar beds	Andesitic breccia and conglomerate, feldspatholithic sandstone, amygdaloidal locally porphyritic andesite, siltstone
Sfer		Erebus beds	Dacitic to rhyolitic volcaniclastic sandstone and conglomerate, minor siltstone, fossiliferous limestone and marble
Sfmh		Mount Holly beds	Basaltic to andesitic (rarely dacitic and rhyolitic) volcaniclastic sandstone and conglomerate, limestone, siltstone, andesite

NOTE: This Figure 7.6.3 must be viewed with Figure 7.6.1 and 7.6.2

Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	**GAS TRANSMISSION PIPELINE CORRIDOR AND REGIONAL GEOLOGY LEGEND**
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	Job No: **4262 6220** · File No: 42626220-g-870.wor	**A4**

Broad alluvial plains of the Brown River and other streams within the Arcadia Valley are dominated by expansive uniform clay soils. The low permeability of the clay allows for the protection of deeper weathered and fractured rock aquifers within the sediments below the clay.

East of the Expedition Range the corridor traverses mainly undulating plains and lowland as well as the floodplains of Zamia Creek, Mimosa Creek, the Dawson River, Banana Creek and other streams, all of which contain large areas of mainly cracking and non-cracking clay soils and sandy soils. Groundwater potential is enhanced within these floodplains due to the increased recharge (both rainfall and creek flow), storage, and transmissivity. The groundwater in these floodplains is used for agriculture, both stock watering and irrigation.

To the east of the Leichhardt Highway the proposed gas transmission pipeline route traverses undulating and gently inclined plains underlain by tertiary sediments, which comprise sandstone, siltstone, claystone and conglomerate, and the floodplains of Kroombit Creek and Callide Creek. The soils within this section of the gas transmission pipeline route comprise cracking and non-cracking clays (in the lowlands) and sandy surface soils on the lower slopes of low rises. The tertiary sediments, in their pristine state, have low groundwater potential and require secondary processes, such as faulting, weathering, etc., to enhance the groundwater potential, and are generally of limited use. Saturated sandy soils can provide storage and recharge to the underlying secondary aquifers.

The floodplains of the Calliope River and its major tributaries comprise cracking clay soils and thin loamy surface soils. The thin clay-rich soils are envisaged to have limited permeability and transmissivity. The alluvial sediments have the potential to be used for stock watering and irrigation.

The final portion of the gas transmission pipeline route crosses undulating plains and gently inclined slopes with sandy and loamy surface soils. The coastal areas comprise coastal estuarine tidal marine flats that have mainly deep soft saline clay, silt and muddy sand soils. The groundwater resources, as identified at the proposed LNG facility, are limited with poor groundwater quality.

A review of the available geological maps indicate limited geological structures along the proposed route, however, areas of potential instability and enhanced groundwater potential can occur. Large faults have been mapped within the surficial geology, especially in the sandstone units along the route. These faults, if active, can impact on the structural integrity of the gas transmission pipeline. The faulting can also increase the groundwater potential of the country rocks.

7.6.5 Potential Impacts and Mitigation Measures

7.6.5.1 Potential Impacts

As the gas transmission pipeline will carry CSG the main possible impacts identified with regard to shallow groundwater are related to alterations to aquifer hydraulic parameters associated with pipeline installation activities.

The proposed 435 km gas transmission pipeline will be buried at a minimum depth of 0.75 m. The depth will be increased to 1.2 m in high consequence areas, and up to 2 m under water courses. Should horizontal directional drilling (HDD) be used, depth would be more than 2 m. Due to the shallow nature of the pipeline installation, consideration of impacts is restricted to aquifers which are unconfined in the proposed pipeline route.

The gas transmission pipeline will be constructed by a combination of either trenching or HDD. Trenching involves the mechanical excavation of soil, regolith, and shallow bedrock in order to facilitate the laying of the gas transmission pipeline. Blasting or the addition of formation stabiliser may be utilised, depending on the competency of the underlying lithology.

The use of HDD techniques reduces above ground impacts; however, the technique can introduce drilling mud and fluids directly into shallow aquifers. Drilling fluids, such as bentonite, are utilised for lubrication and wall stability to facilitate the drilling and pipeline installation. This natural clay can alter (reduce) the permeability of the intersected units.

Based on the shallow nature of the trenches and the overall deep groundwater, it is envisaged that the impact on the shallow groundwater (reduction or increase in hydraulic characteristics) will be negligible except where the gas transmission pipeline directly intersects shallow groundwater.

The shallow groundwater environment could be temporarily affected if dewatering of the trench is required during pipeline installation activities.

Blasting of rock outcrop can potentially alter fracture patterns and cause collapse or damage to nearby (± 200 m) boreholes. A borehole census along sections of the selected route, where blasting is required, will be conducted to identify any boreholes that may be impacted on during blasting activities, and blasting methods can be engineered to reduce impacts.

To summarise, the possible impacts of the trenching, HDD, gas transmission pipeline installation and backfilling on the groundwater, include:

- The alteration of recharge (increased) along the trench;
- The alteration of permeability, porosity and storage within the trench (altered soil / regolith);
- The impact of blasting on aquifers (fractured rock) and existing boreholes;
- Alterations in shallow groundwater flow patterns, localised along the trench;
- Temporary dewatering during the installation of the gas transmission pipeline in areas of shallow groundwater near surface water bodies;
- Alterations in permeability due to HDD; and
- Introduction of possible contamination sources.

Potential sources of onsite contamination during the construction phase comprise diesel and other petroleum-based fuels and lubricants used by excavation and construction machinery. The use of fuels and chemicals on site will involve refuelling of vehicles and maintenance during the construction phase. Potential aqueous waste streams can include oily waste water (from equipment wash water), potentially "dirty" runoff from maintenance and chemical storage areas, potentially contaminated drainage from fuel oil storage areas, and general wash down water. The ponding or runoff water from these potential source areas during rainfall events can potentially act as artificial recharge to the shallow groundwater. Waste water from accommodation camps has the potential to contaminate aquifers locally. The management systems to be utilised at on site to contain, treat and then dispose of waste water, will reduce the potential impacts associated with these limited volumes of water.

7.6.5.2 Mitigation Measures

The preliminary assessment of the gas transmission pipeline route combined with the shallow nature of the gas transmission pipeline installation and the limited groundwater contamination potential of the feed gas indicate that the proposed gas transmission pipeline will have limited impact on the groundwater resources.

Sections of the pipeline route through competent (hard rock) formations may require blasting, which could impact on existing boreholes. Construction of the pipeline under watercourses will potentially require dewatering of the watercourse sediments, which will have a temporary impact on surrounding (alluvial) aquifers.

A bore census, conducted where blasting or creek crossings are envisaged, will allow for the identification of all groundwater use and users (including springs and seeps). The hydrocensus data to be collected should include groundwater levels, abstraction rates, pumping equipment (status and depth), borehole depth and casing details. Data collected before and after construction (including blasting and dewatering activities) can be compared to determine any impacts on the existing users.

The use of HDD in areas where shallow groundwater is being utilised, i.e. with alluvium aquifers adjacent to watercourse crossings, can potentially impact on the permeability, transmissivity, and storage of the aquifers. To minimise any alteration to groundwater resources, biodegradable drilling fluids and mud, will be utilised where possible. This will reduce the zone of influence and the duration of any potential impact the HDD may have on the shallow aquifers.

Secondary containment (bunded) storage areas for possible contaminants will be constructed on site to prevent poor water quality runoff, ponding of water, and possible poor quality artificial recharge. Any significant leaks or spills of hazardous materials will be cleaned up immediately according to appropriate emergency clean-up operations. This will be done to prevent possible mobilisation of contaminants into the groundwater. Any contaminants or major spillages of stored material in the bunded areas will be collected by licensed waste collection and transport contractors for disposal off site at a licensed facility.

The disposal of the hydrotest water may cause localised impacts on the groundwater regime, thus the disposal will be undertaken using approved environmental procedures.

Decommissioning procedures require the removal of all above ground infrastructure and the restoration of associated disturbed areas. The buried gas transmission pipeline will be filled with inert material and protected with catalytic devices to prevent/limit corrosion, or allowed to corrode away. The range of potential impacts and recommended mitigation measures for any on-site works undertaken during the decommissioning phase will be in accordance with Australian Standards, the APIA Code of Environmental Practice and the *Petroleum and Gas Act* 2004 or the standards relevant at the time.

7.6.5.3 Cumulative Impacts

Section 1 identifies other proposed gas transmission pipelines associated with other potential CSG Projects. There is limited information available as to the planned development or timing of these projects. However, a qualitative assessment can be made of the possible cumulative impacts.

Some sections of the proposed gas transmission pipeline corridor may be located within an area where these other pipelines are proposed to be located in the future. Within these areas there will be an increased disturbed area and possible impacts on shallow groundwater. The envisaged impacts of the pipeline installation, due to blasting or dewatering, are considered to be the same for the other pipelines.

In the event that the “Yarwun Neck” in the Gladstone State Development Area (GSDA) contains multiple pipelines, cooperation between the relevant pipeline development proponents and regulatory agencies will be required to minimise impacts to groundwater.

The Queensland Government has advised that its preference is for the gas transmission pipelines for all LNG facilities proposed for Curtis Island to be located in a common pipeline corridor across the GSDA, including the Port Curtis Crossing and Curtis Island pipeline sections to minimise potential impacts in this area.

It is expected that the other gas transmission pipeline development projects will include some or all of the proposed mitigation measures in relation to groundwater described in this section. By utilising the mitigation methods the expectation is the minimisation of the cumulative impacts on the receiving environment.

Table 7.6.1 provides a summary of potential groundwater impacts and mitigation measures for the gas transmission pipeline.

Table 7.6.1 Potential Groundwater Impacts and Mitigation Measures

Aspect	Potential Impact	Mitigation Measures	Objective
Construction			
Local hydrogeology.	Alterations in permeability due to HDD.	Use biodegradable drilling muds / additives where practicable.	Reduce long term impacts of altered permeability and limit reduction in aquifers.
Local groundwater supplies.	The impact of blasting on aquifers (fractured rock) and existing boreholes.	Identify blast areas, conduct hydrocensus of groundwater resources within 200 m and mitigate as necessary in consultation with affected parties.	Identify groundwater resources which could be damaged during blasting.
	Oil, fuel and chemical contamination.	Store and handle fuel and chemicals in accordance with relevant industry standards.	Reduce potential for contamination due to oil and fuel spills, reduce potential for groundwater clean up.
Operations			
None			
Decommissioning and Rehabilitation			
Shallow groundwater resources.	Possible long term contamination source.	Fill gas transmission pipeline with inert material or protect with catalytic devices.	Ensure compliance to regulations regarding the decommissioning of the gas transmission pipeline.

7.6.6 Summary of Findings

Based on the proposed gas transmission pipeline details, a desktop review was conducted to assess groundwater resources and potential impacts along the gas transmission pipeline corridor. Sufficient desktop data was available for a high level assessment of large scale groundwater resources along the 435 km route.

The review of available data allowed for an initial assessment of the shallow groundwater resources along the proposed gas transmission pipeline route. Groundwater is utilised for domestic and stock watering purposes from shallow groundwater resources. Small scale irrigation using groundwater also occurs from the various shallow aquifers within the vicinity of the gas transmission pipeline corridor.

Although the 435 km pipeline corridor crosses a wide variety of topography, geology, watersheds and land uses the impact on the shallow groundwater (reduction or increase in hydraulic characteristics) will be negligible due to the nature of the trenches and the overall deep groundwater.

Where the gas transmission pipeline directly intersects shallow groundwater, the shallow groundwater environment could be temporarily affected if dewatering of the trench is required during pipeline installation activities.

HDD requires the use of drilling fluids and mud to facilitate the installation of the gas transmission pipeline casing, if required. These drilling additives can potentially have impacts on localised aquifers through the reduction of permeability.

To minimise any alteration to groundwater resources, biodegradable drilling fluids and mud, will be utilised where possible. This will reduce the zone of influence and the duration of any potential impact the HDD may have on the shallow aquifers.

A bore census, conducted where blasting or creek crossings are envisaged, will allow for the identification of all groundwater use and users (including springs and seeps). The hydrocensus data to be collected should include groundwater levels, abstraction rates, pumping equipment (status and depth), borehole depth and casing details. Data collected before and after construction (including blasting and dewatering activities) can be compared to determine any impacts on the existing users.