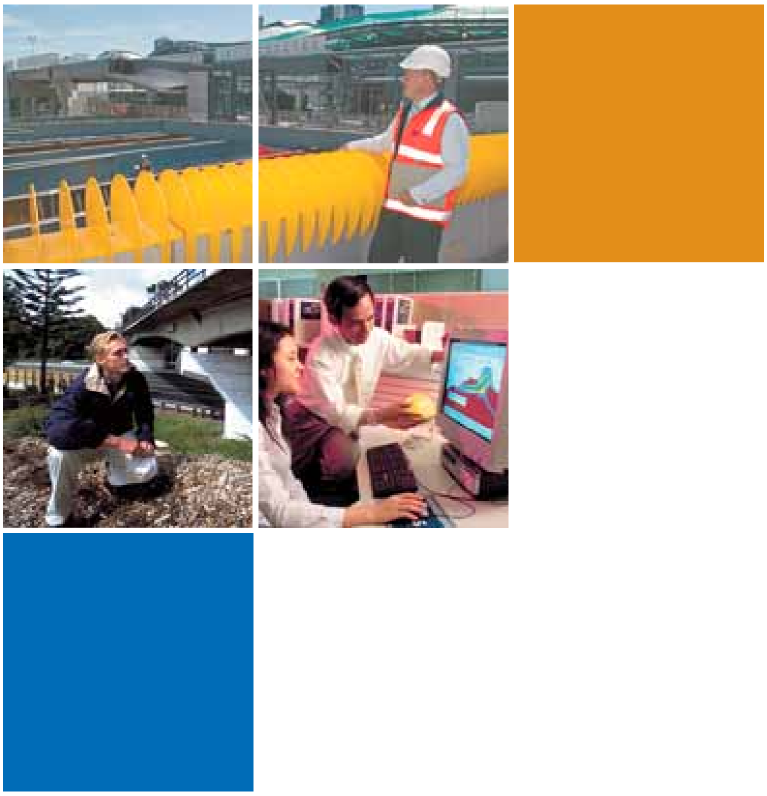
FINAL REPORT

Gladstone LNG Gas Transmission Pipeline – Surface water EIS



Prepared for

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9 February 2009

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Executive Summary

This Section of the EIS identifies the potential risks to the surface water environmental values as a result of the proposed Gladstone LNG gas transmission pipeline development.

The major rivers within the gas transmission pipeline corridor include Calliope River, Dawson River, and Brown River. Other tributaries within the pipeline corridor include Larcom, Bell, Kroombit, Banana, Kianga, Callide, Mimosa, Conciliation, Zamia, Clematis, Arcadia, Sardine, Spring, Hutton and Baffle Creeks. The wet season for the area is from October to April with the highest stream flows between November and April.

A hydrological assessment considering the catchment characteristic and local stream gauge records, for a range of events were undertaken for each watercourse. The assessment determined two regional flood frequency regression equations for each return period, to predict peak flow rates. To approximate the flood extents at each watercourse crossings, a basic hydraulic assessment of the 24 key watercourse crossing locations was been undertaken. Flood estimation predicts flooding of wide expanding floodplains in even minor flood events. Flood depths can vary from 1.5 m in a 2yr ARI flood on small ephemeral watercourses, to 16m to 20 m in a 100yr ARI flood on major watercourses such as the Dawson River. The seasonal timing of construction works should be scheduled with consideration to the flood risk, and alternate methods, such as HDD, should be considered for major watercourses such as the Dawson and Calliope Rivers.

The project has the potential to impact on the fresh water quality of the immediate and receiving environment. Results gathered from URS water quality monitoring activities and NRW data showed that nitrogen and phosphorous readings in the potentially affected watercourses generally exceeds water quality guidelines due to high annual sediment loads and potentially high loads of organic matter; and catchment land use which comprises industrial and agricultural.

A qualitative risk assessment approach was used to determine the potential impacts and mitigation measures through the different stages of construction, operation and decommissioning. Potential impacts from the pipeline are expected to be of higher risk during the construction phase. These include earth moving activities, works adjacent to/within drainage lines, contaminant mobilisation, pollution and flooding risks. These impacts are to be minimised using erosion and sediment control techniques such as contour drains and the implementation of Erosion and Sediment Control Plan and a Stormwater Management Strategy. During the operational phase of the project a routine operation and maintenance program will be implemented, including aerial and/or ground inspections.

It is expected that the proposed management and mitigation measures in this report will reduce risks to levels that will have minimal impact on the environmental values of the surface water environment in the study area.

Introduction Section 1

This report provides an assessment of the water resources of the Gladstone Liquefied Natural Gas (GLNG) project's gas transmission pipeline component. This assessment has been undertaken in the context of environmental values as defined by the *Environmental Protection (Water) Policy 1997*. The value of these resources to the community and the environment is discussed in terms of current legislation, water quality, regional hydrology, existing conditions of onsite drainage and flow regimes in the study area watercourses, including flooding aspects. Potential impacts from development activities on the environmental values are discussed and mitigation measures detailed to demonstrate appropriate management. Table 1-1 lists the sections of this report that address the Gladstone LNG Terms of Reference.

Table 1-1 Terms of Reference

Terms of Reference Section	Description	EIS Surface Water Section
2.5.2 Water Supply	Water usage by the Project for raw and treated water for the various processes and the sources of water for construction and operation.	3.3
	The capability of the water network to provide the demand including.	3.3
2.5.6 Stormwater	Proposals for drainage structures and dams and an overall site water balance	6.1 6.3 6.4 Appendix G
3.4 Surface Water Resources – Existing Environment	Existing surface in terms of physical, chemical and biological characteristics.	4.2 4.3
	Existing surface drainage patterns, ephemeral water systems, permanent and episodic wetlands, overland flows, history of flooding including extent, levels and frequency.	4.4
	Environmental values of the surface waterways of the affected area in terms of: Values identified in the EPP (Water); Physical integrity, fluvial processes and morphology of watercourses; Hydrology of waterways, in particular the interconnectiveness of surface water and aquifers to adjoining features; Any Water Resource Plans relevant to the affected catchments.	2 3.1 4.1 4.2 4.3
3.4 Surface Water Resources – Potential Impacts and Mitigation Measures	The potential impacts the proposed Project may have on the flow and the quality of surface waters from all	6.1 6.2

Terms of Reference Section	Description	EIS Surface Water Section
	phases of the Project, with particular reference to their suitability for the current and potential downstream users and discharge licenses.	6.3 6.4
	Chemical and physical properties of any waste water including stormwater at the point of discharge into natural surface waters, including the potential effects of effluent to flora and fauna.	7.1.1 7.4.1

1.1 Hydrological Overview

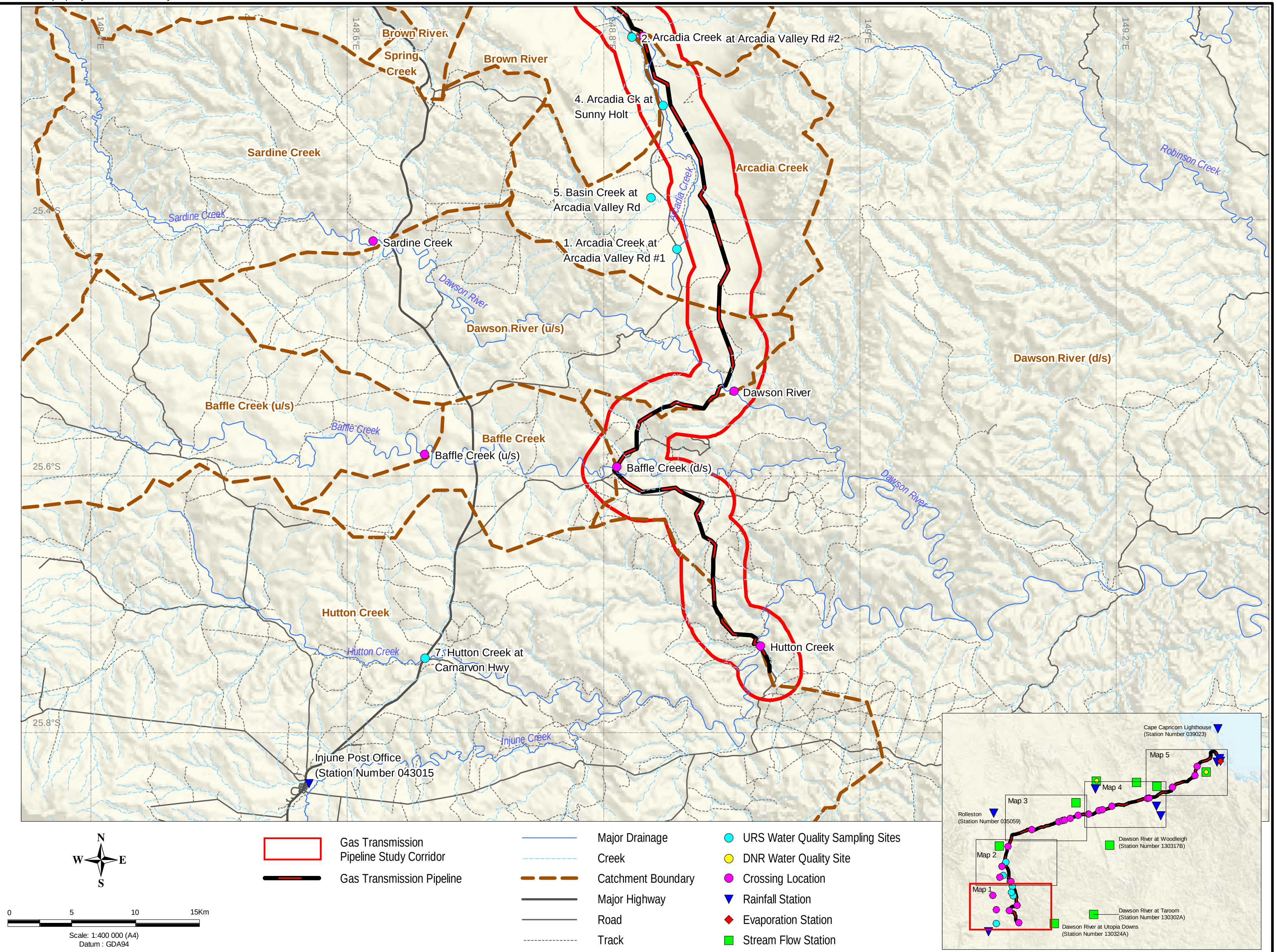
The proposed gas transmission pipeline will extend through two River Basins, Calliope and Fitzroy, commencing at the Fairview field, travelling north east for 435km to the LNG facility on Curtis Island. The major rivers within the study area include Calliope River, Dawson River, and Brown River. Other tributaries within the study area are Larcom, Bell, Kroombit, Banana, Kianga, Callide, Mimosa, Conciliation, Zamia, Clematis, Arcadia, Sardine, Spring, Hutton and Baffle Creeks. The local and regional drainage patterns are presented in Figures 1 to 5.

The majority of the study area is within the Fitzroy Basin, the largest river basin on the east coast of Australia. The study area is within the Boyne-Calliope and Dawson Sub-regions. Water resources in the Fitzroy basin have a number of important usages including farming, grazing, mining, recreational and urban activities. The gas transmission pipeline initially passes through the Calliope River Basin, which is located in the central coast region of the North East Coast Drainage division. Cattle grazing is the main land-use in the area. This is confined to the coastal plains. The upper ranges of the basin are still densely vegetated.

The majority of watercourses and tributaries within the study area are ephemeral. Periods of flow are generally short and limited to periods during and after rainfall. The Dawson River, however, is not ephemeral from Fairview downstream but has been noted to dry up downstream due to irrigation use.

Designated wetlands within the broad study area have been identified as the Palm Tree and Robinson Creeks, the Boggomoss Springs and Lake Nuga Nuga (refer Figure 6). The corridor of the gas transmission pipeline crosses none of these designated wetlands directly; however some tributaries feed into the wetlands. A description of the wetlands in relation to the proposed gas transmission pipeline corridor follows:

- Within the upstream catchment of the Dawson River, lies the Palm Tree and Robinson Creeks designated wetland, with a total area of 500km2, it is the largest designated wetland in the area. Tributary flows feeding the wetland are not crossed by the proposed gas transmission pipeline and therefore the pipeline is not anticipated to impact the wetland.
- Within the upstream catchment of the Dawson River, lies the EPA designated wetland Boggomoss Springs. Flows from the upper Dawson River, including the two crossing on Baffle Creek, Sardine Creek, Dawson River (downstream) and Hutton Creek appear to feed the lake feature. A site assessment of the lake was not undertaken, however it is anticipated that the crossing locations will not impact upon the wetland with appropriate sediment and pollution controls.



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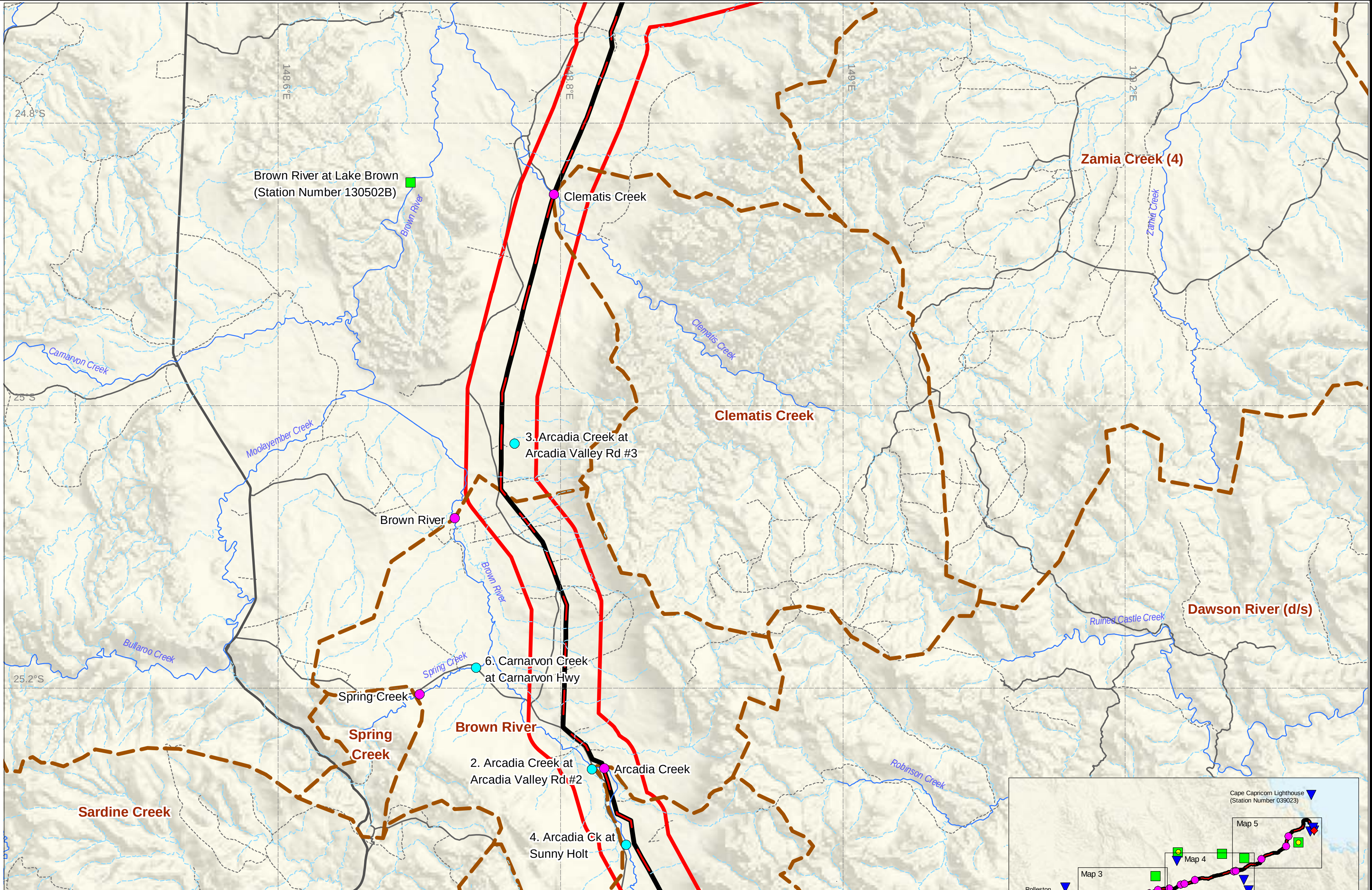
Project: GLADSTONE LNG PROJECT
GAS TRANSMISSION PIPELINE
SURFACE WATER REPORT

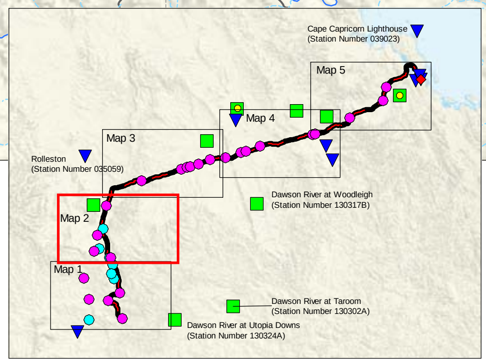
Drawn: RG | Approved: JB | Date: 23-01-2009

Job No: **4262 6220** | File No: 42626220-g-522b.wor

Title: **MAJOR WATERCOURSES
MAP 1 OF 5**

Figure: **1** | Rev: B | A4





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Gas Transmission Pipeline Study Corridor	Major Drainage	URS Water Quality Sampling Sites
Gas Transmission Pipeline	Creek	DNR Water Quality Site
	Catchment Boundary	Crossing Location
	Major Highway	Rainfall Station
	Road	Evaporation Station
	Track	Stream Flow Station

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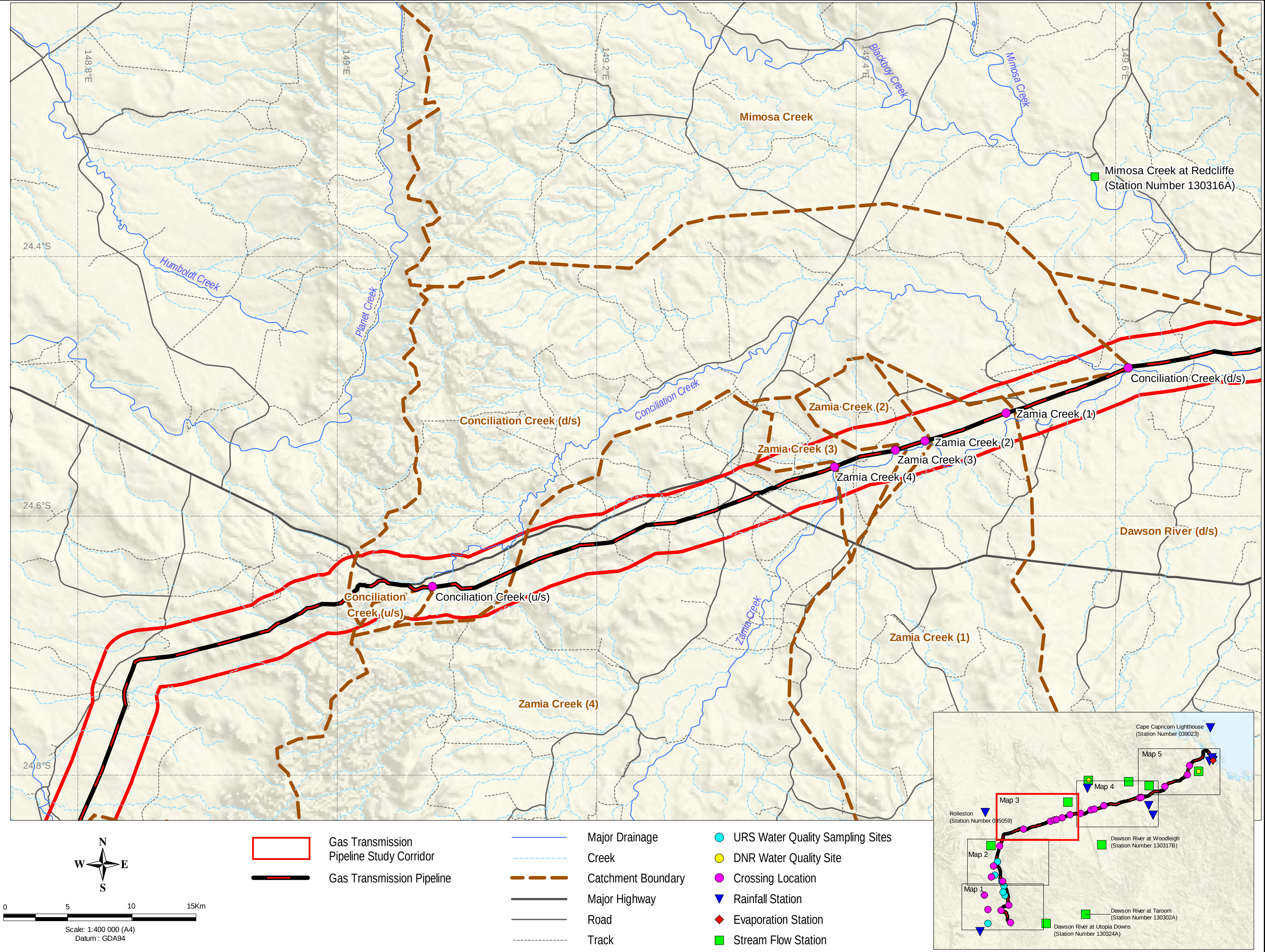

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Gas Transmission Pipeline Study Corridor
Gas Transmission Pipeline
Major Drainage
Creek
Catchment Boundary
Major Highway
Road
Track
URS Water Quality Sampling Sites
DNR Water Quality Site
Crossing Location
Rainfall Station
Evaporation Station
Stream Flow Station

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GAS TRANSMISSION PIPELINE
SURFACE WATER REPORT

Title
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MAP 3 OF 5

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File No: 42626220-g-524b.wor
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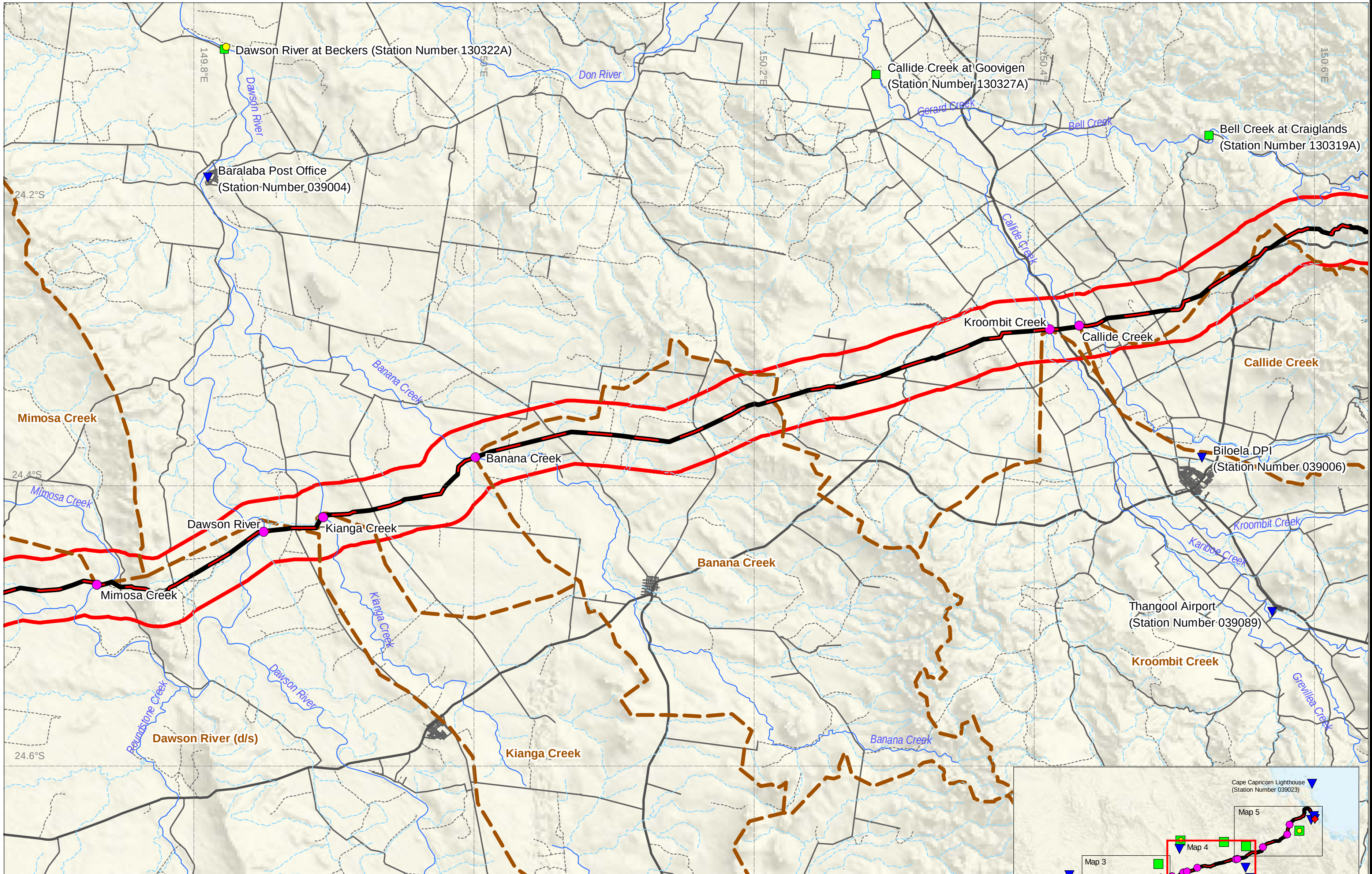

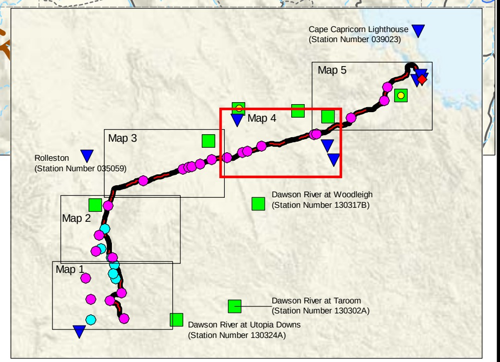

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Gas Transmission Pipeline Study Corridor	Major Drainage	URS Water Quality Sampling Sites
Gas Transmission Pipeline	Creek	DNR Water Quality Site
	Catchment Boundary	Crossing Location
	Major Highway	Rainfall Station
	Road	Evaporation Station
	Track	Stream Flow Station

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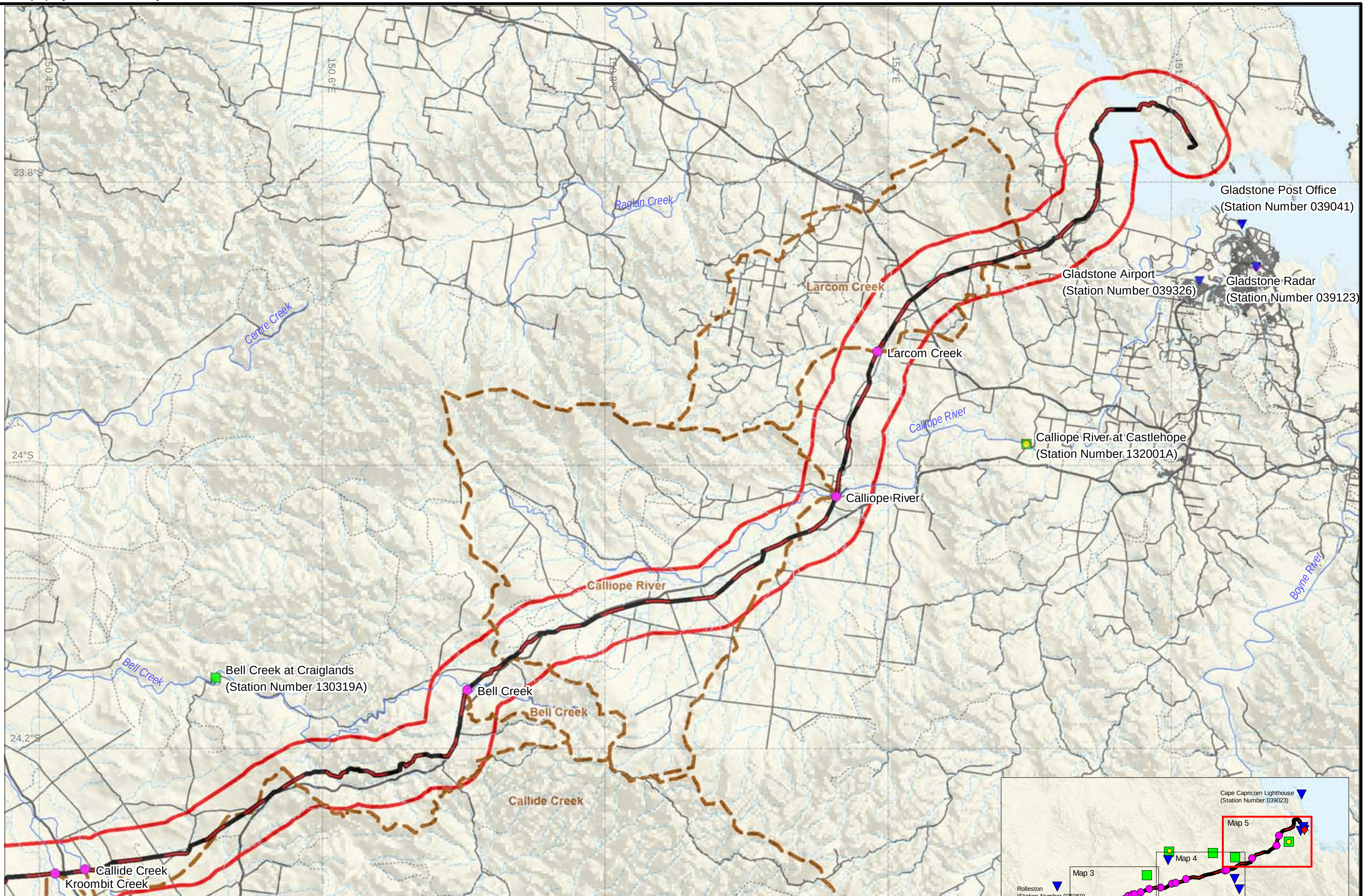

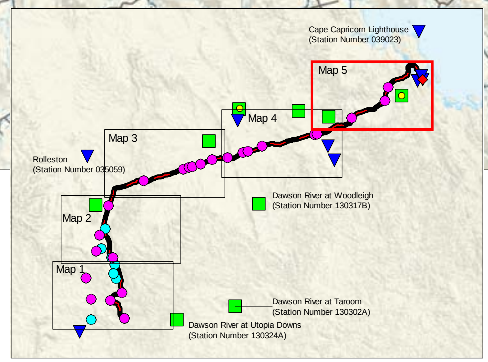

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Datum : GDA94

Gas Transmission Pipeline Study Corridor
Gas Transmission Pipeline
Major Drainage
Creek
Catchment Boundary
Major Highway
Road
Track
URS Water Quality Sampling Sites
DNR Water Quality Site
Crossing Location
Rainfall Station
Evaporation Station
Stream Flow Station

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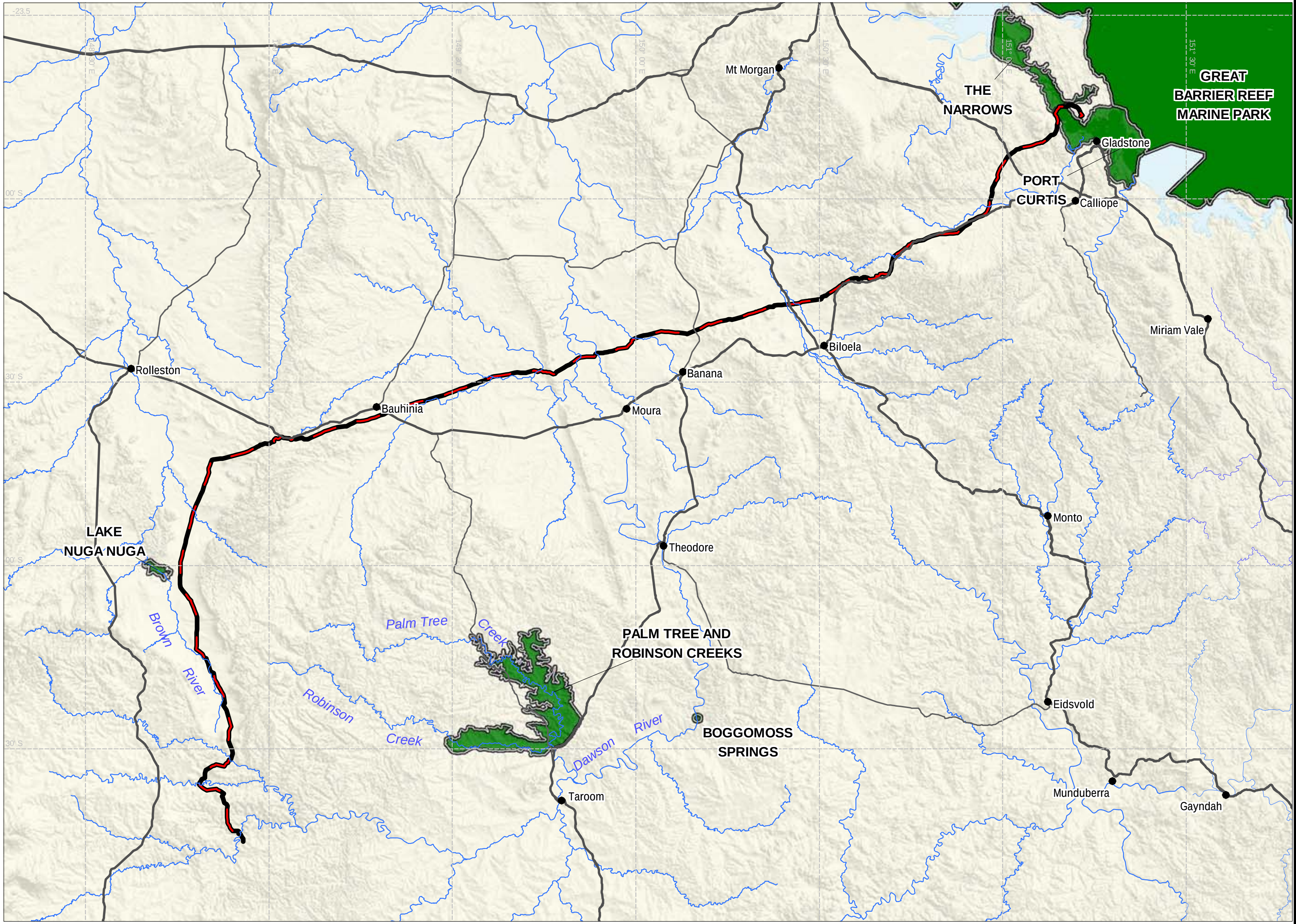

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Legend	
Designated Wetland Area	Major Drainage
Gas Transmission Pipeline	Major Highway
	Road

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Title: DESIGNATED WETLANDS OF THE LNG PIPELINE ALIGNMENT STUDY AREA

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- The downstream reaches of the Brown River enter the EPA designated wetland Lake Nuga Nuga. Upstream of the wetland, crossings are located at the Brown River, Spring Creek and Arcadia Creek. It is anticipated that the crossing locations will not impact upon the wetland with appropriate sediment and pollution controls.
- The map layer also identifies the Great Barrier Reef as a designated wetland. All crossing locations are upstream of this water body, however, due it's magnitude, insignificant risk is posed by the gas transmission pipeline crossing locations, with appropriate sediment and pollution controls.

A sub-tropical humid climate is characteristic of the Fitzroy and Calliope regions, with wet summer periods generally between December and March, and dry winters generally between June and September. Climatic data is discussed in Section 4.1.

Environmental Values

The *Environmental Protection (Water) Policy 1997* (EPP Water, 1997) seeks to protect and/or enhance the suitability of Queensland's waters for various beneficial uses. The policy identifies environmental values for waters within Queensland and guides the setting of water quality objectives to protect the environmental values of any water resource. The environmental values include the biological integrity of the aquatic ecosystem and recreational, drinking water supply, agricultural and/or industrial uses.

Within the gas transmission pipeline corridor there are a significant number of major watercourses and various minor tributaries that will be subject to protection under the EPP Water (1997).

Specific environmental values for the watercourses within the study area are not defined within the EPP Water and there are no detailed local plans relating to environmental values for the catchments.

Using data gathered from a URS site visit (refer Appendix A) and desk top studies, environmental values have been identified for watercourses within the study area (refer Table 2-1).

Table 2-1 Environmental Values for the Watercourses and Receiving Environment of the Gas Transmission Pipeline

Environmental Values	Calliope Basin	Fitzroy Basin
Protection of high ecological value aquatic habitat	X	X
Protection of slightly to moderately disturbed aquatic habitat	✓	✓
Protection of highly disturbed aquatic habitat	X	X
Suitability for human consumers of aquatic food	✓	✓
Suitability for primary contact recreation (e.g. swimming)	✓	✓
Suitability for secondary recreation (e.g. boating)	✓	✓
Suitability for visual (no contact) recreation	✓	✓
Protection of cultural and spiritual values	✓	✓
Suitability for industrial use (including manufacturing plants, power generation)	✓	✓
Suitability for aquaculture (e.g. red claw, barramundi)	X	x
Suitability for drinking water supplies	X	x
Suitability for crop irrigation	✓	✓
Suitability for stock watering	✓	✓
Suitability for farm use	✓	✓

Table Notes:

✓: River basin is suitable for the environmental value.

X: River basin is not suitable for the environmental value.

The Water Act 2000 and the *Integrated Planning Act 1997* are the principal legislation governing approvals and licensing of water supply schemes and associated structures.

The Resource Operation Plan for the Fitzroy Basin makes provision under Section 6.7 for additional water entitlements to take water for a Significant Project. A Significant Project is defined as a project of economic or social importance to the state and the Gladstone LNG Project is defined as a Significant Project.

The Draft Resource Operation Plan for the Calliope Basin proposes that 5,000Ml of unallocated water will be made available for all purposes in the Calliope River Basin and an additional 500Ml of unallocated water for town water supplies.

3.1 Water Act 2000

The Water Act 2000 (the Act) provides a basis for the planning and allocation of Queensland water resources. Under the Act the provision of water for human uses such as irrigation, stock watering, drinking and industry must make allowances for the environmental requirements that support the ecological health of the river system.

The watercourses affected by the gas transmission pipeline will be subject to protection under the *Water Act 2000*, which will regulate the extraction of water from these watercourses and the diversion of these watercourses.

The Fitzroy Basin and Calliope Basin Water Resource Plan's cover the management of all surface water in the basin including overland flow. The Final Fitzroy Water Resource Plan was approved in December 1999 and the Final Calliope Water Resource Plan was approved in December 2006.

Due to the ephemeral nature of the watercourses along the gas transmission pipeline corridor, it is unlikely that water for construction and operation will be sourced from any of these watercourses. Water supply for pipeline construction and operational phases will potentially be sourced from existing municipal sources and transported in by truck.

3.2 Regulatory Framework

The Queensland *Environmental Protection (Water) Policy 1997* (EPP Water) seeks to protect and/or enhance the suitability of Queensland's waters for various beneficial uses. The policy identifies environmental values for waters within Queensland and guides the setting of water quality objectives to protect the environmental values of any water resource. The environmental values include the biological integrity of the aquatic ecosystem and recreational, drinking water supply, agricultural and/or industrial uses.

Brought into effect on the 1st January 2008, the Environmental Protection (Water) Amendment Policy (No. 1) 2008 amends the EPP Water. These changes do not however affect work prepared in 2008 on the EIS.

3.3 Water Demand and Usage

The following section attempts to identify impacts and risks, and regarding water supply, to the environment and project. It is anticipated that the key water uses during the construction phase will be:

- for a range of construction activities such as, dust suppression and soil compaction;
- for vehicle and plant wash down to prevent the spread of parthenium;
- to assist with horizontal directional drilling; as a component of drilling fluid and the production of concrete; and
- for domestic use at workers accommodations facilities.

During the commissioning phase, it is anticipated that large volumes of water will be required to undertake the pressure and leak tests. Minimal water demands are anticipated during the operational phase, with limited construction work and personal along the pipeline corridor.

It has been proposed that due to the limited local water supplies and the ephemeral nature of many watercourses in the region, water demands for construction and operation will be imported to the site. Detailed data regarding water demand volumes and sources is yet to be confirmed, and will need assessment prior to construction.

Surface Water Resources Section 4

Watercourses within the study area are within the Fitzroy Basin and Calliope Basin. The Fitzroy Basin is the largest coastal catchment in eastern Australia, covering an area of approximately 142,500km^2 (Waterwatch, 2002). It encompasses the river systems of the Nogoa, Isaac-Connors, Comet, Mackenzie, Dawson and Fitzroy, and drains to the southern end of the Great Barrier Reef, just east of Rockhampton. The Calliope Basin which covers an area of 2,236km^2 has two estuaries: The Narrows and Calliope River. The Calliope River rises in the Callide Range west of Gladstone and flows east and then north through Beecher to the estuary in Port Curtis, south of Curtis Island.

4.1 Climatic Data

Due to the location and in the case of the Fitzroy Basin its broad extent, both the Fitzroy and Calliope basins are subject to a range of climatic regimes. The region as a whole is described as subtropical to semi-arid, with a summer-dominant but variable rainfall pattern.

Rainfall and pan evaporation data was obtained from the Bureau of Meteorology (BoM). When available climatic data was sourced from a number of meteorological stations for a true representation of long term average rainfall along the entire pipeline corridor. The location of each gauging station in relation to the study area can be seen in Figures 1 to 5. The tabulated data is included in Appendix B.

4.1.1 Rainfall

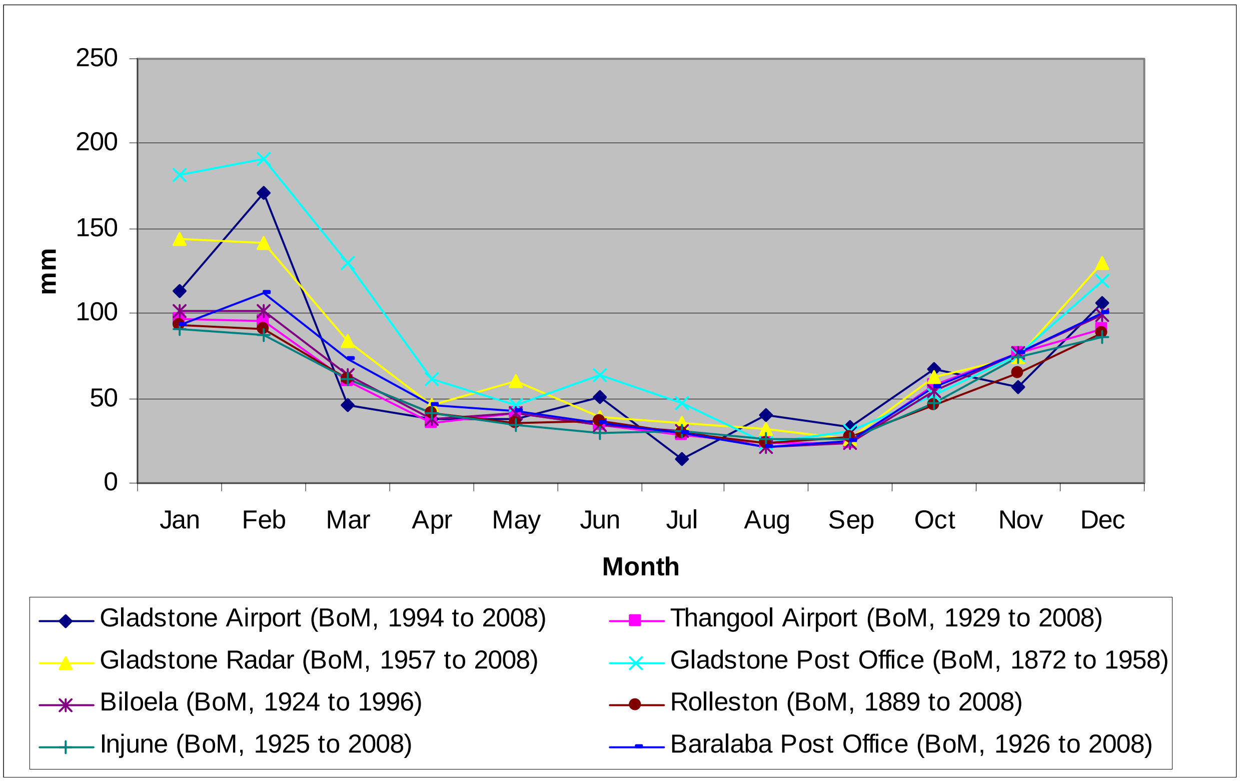
Mean monthly rainfall data was sourced from a number of meteorological stations to demonstrate the expected rainfall variation along the entire pipeline corridor.

Stations include Gladstone Airport (Station Number 039326), Thangool Airport (Station Number 039089), Gladstone Radar (Station Number 039123), Gladstone Post Office (Station Number 039041), Biloela DPI (Station Number 039006), Rolleston (Station Number 035059), Injune Post Office (Station Number 043015) and Baralaba (Station Number 039004).

Mean monthly rainfall (refer Figure 7) is greatest in January and February, with highest rainfall occurring at Gladstone Post Office station, and lowest in July at Gladstone Airport. The mean annual rainfall ranges from 630.5mm (Injune) to 1020.8mm (Gladstone Post Office). The mean annual rainfall for this area is 786.4mm. Rainfall averages suggest a distinct wet and dry season, with the wet generally October to April and the dry May to September (Table B1, Appendix B).

The average number of rain days in each month and each year for each meteorological station is shown in Table B2, Appendix B.

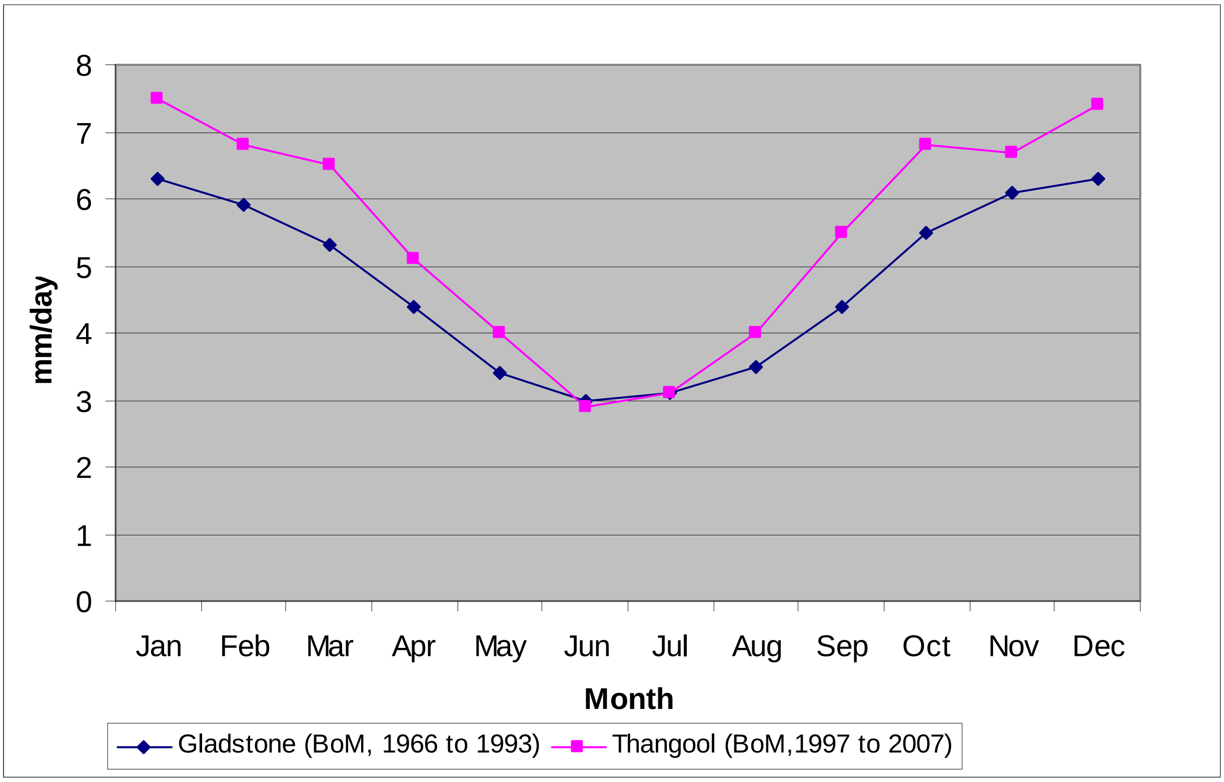
Figure 7 Mean Monthly Rainfall Data



4.1.2 Evaporation

Mean daily pan evaporation for each month was sourced from Gladstone Radar (Station Number 039123) (1966 to 1993) and Thangool Airport (Station Number 039089) (1997 to 2007) (refer Figure 8 and Table B3, Appendix B). Both these stations are located on the eastern reach of the gas transmission pipeline corridor; data for the central and western reaches was unavailable. The mean evaporation at Gladstone is greatest in December and January (6.3 mm/day) and lowest in June and July (3.0 and 3.1mm/day respectively). The annual mean evaporation is 4.8mm/day. The Thangool Airport station mean evaporation is greatest in December and January (7.4 and 7.5mm/day respectively) and lowest in June and July (2.9 and 3.1mm/day respectively). The annual mean evaporation is 5.5mm/day.

Figure 8 Mean Monthly Pan Evaporation



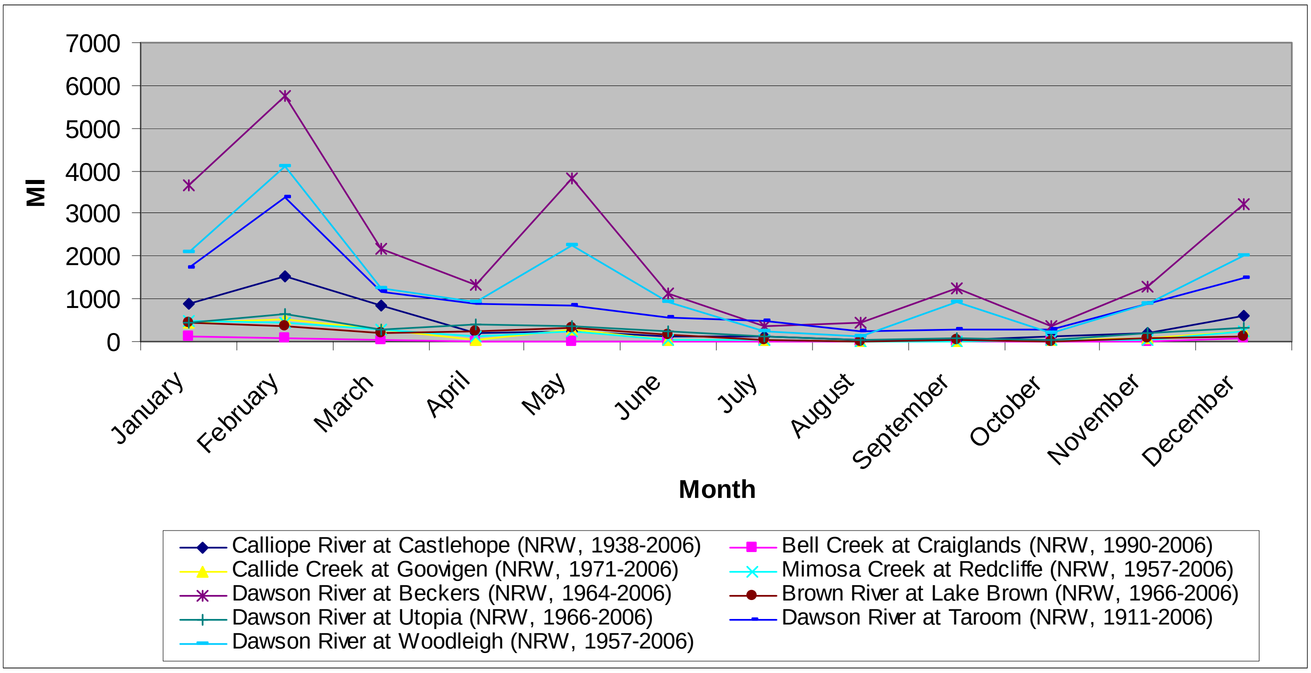
4.2 Stream Flows

The Fitzroy Basin is characterised by large variations in river flows. Most of the region's rainfall occurs during October to April (refer Section 4.1.1), causing most stream flows to occur in summer. Prolonged dry periods in the winter result in ephemeral characteristic in many of the key watercourses.

The Department of Natural Resources and Water (NRW) records stream flow, level and some water quality characteristics (refer Section 5.3.2) in a number of rivers and creeks within the study area. Figure 9 presents mean monthly flows for various watercourses within the study area. The locations of each stream flow gauging station can be seen in Figures 1 to 5. Monthly mean flow values and extent of record for each reviewed gauge is provided in Table B4, Appendix B.

Analysis of the data indicates large seasonal variations in flow with notable high flows between October and April. The watercourses with the highest flows were Dawson River (at Beckers, Station No 130322A) and Calliope River (at Castlehope, Station No 132001A) with little flow occurring in Bell Creek.

Figure 9 Mean Monthly Flow Volume



4.3 Geology and Soils

The pipeline corridor commences in the plateau country of the Great Dividing Range northeast of Injune. Soils here consist mostly of sandy-surfaced earthy and texture-contrast soils, often very shallow or stony, and areas of sandstone rock outcrop.

At the foot of the escarpment, the pipeline corridor crosses the narrow sandy floodplain of the upper Dawson River and proceeds northward through the Arcadia Valley, consisting of gently sloping fans containing some sandy-surfaced soils and areas of medium to heavy clay. Broad alluvial plains of the Brown River and other streams within the Arcadia Valley are dominated by cracking and non-cracking uniform clay soils.

East of the Expedition Range the pipeline 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 clay soils and non-cracking clays, with sandy-surfaced texture-contrast soils also occurring.

East of the Leichhardt Highway the pipeline corridor traverses undulating and gently inclined plains underlain by Tertiary sediments and the floodplains of Kroombit Creek and Callide Creek. The dominant soils within this sector comprise mainly cracking and non-cracking clays on the lowlands, with sandy surface duplex soils on the lower slopes of low rises.

The floodplains of the Calliope River and its major tributaries have occurrences of cracking clay soils and thin loamy surface duplex soils.

The pipeline corridor crosses undulating plains and gently inclined slopes with sandy and loamy surface duplex soils to the proposed bridge site, then descends onto the coastal estuarine tidal marine flats that have mainly deep soft saline clay, silt and muddy sand soils.

The alternative Gladstone State Development Area (GDSA) West Line, GDSA East Line and the GDSA Yarwun corridors near Gladstone, traverse the foot-slopes, undulating lowlands and low hilly lands to the west and north of Mt. Alma, before descending down to the coastal plains in the Friend Point area. The soils on the eastern side of the range comprise mainly sandy and loamy surface duplex soils and some uniform non-cracking clays on the alluvial and slope-wash deposits and deep soft saline clay, silt and muddy sand soils on the estuarine coastal flats.

Further information on the physical integrity of the soils in the local area is provided in the Land, Terrain and Soil study (refer Appendix L of the EIS) and summarised in Chapter 7.3 of the EIS.

4.4 Existing Flood Characteristics

4.4.1 Study Area Description

Due to the significant length of the LNG pipeline (435 km), the assessment of existing flood characteristics has been focused on major watercourses where significant environmental risk could occur from inappropriate design, or construction. A desk top analysis identified twenty four (24) key watercourse crossing locations (refer Figures 1 to 5)

4.4.2 Flood Hydrology

For each of the 24 key watercourse crossings hydrological estimates were undertaken using either regional flood frequency regression equations (IEAust, 1987) or the Rational Method based on Weeks (1991). Design peak flows were then derived for a range of probabilities average recurrence intervals (ARI), using the appropriate method (Table 4.1). Details of the hydrological assessment undertaken are provided in Appendix C.

Table 4-1 Predicted peak flows at key watercourse crossing locations

No	Watercourse	Catchment Area (km^2)	2yr ARI Peak Flow (m^3/s)	10yr ARI Peak Flow (m^3/s)	100yr ARI Peak Flow (m^3/s)
1	Larcom Creek	278	43	404	1,657
2	Calliope River	489	51	427	1,686
3	Bell Creek	46	61	142	339
4	Callide Creek	763	59	447	1,708
5	Kroombit Creek	2,340	82	500	1,767
6	Banana Creek	700	57	443	1,704
7	Kianga Creek	551	53	432	1,692
8	Dawson River (d/s)	32,735	448	1,200	2,354
9	Mimosa Creek	3,230	90	516	1,784
10	Conciliation Creek (d/s)	946	62	456	1,720
11	Zamia Creek (d/s 1)	2,590	85	505	1,772
12	Zamia Creek (d/s 2)	2,075	79	494	1,761
13	Zamia Creek (u/s 2)	2,025	79	492	1,759

No	Watercourse	Catchment Area (km^2)	2yr ARI Peak Flow (m^3/s)	10yr ARI Peak Flow (m^3/s)	100yr ARI Peak Flow (m^3/s)
14	Zamia Creek (u/s 1)	1,966	78	491	1,758
15	Conciliation Creek (u/s)	11	22	51	121
16	Clematis Creek	781	59	448	1,710
17	Brown River	1,041	64	461	1,724
16	Spring Creek	60	27	346	1583
19	Arcadia Creek	377	47	416	1,673
20	Dawson River (u/s)	1,134	117	612	1,990
21	Sardine Creek	667	56	441	1,702
22	Baffle Creek (u/s)	462	81	512	1,903
23	Baffle Creek (d/s)	654	94	549	1,936
24	Hutton Creek	2,791	86	509	1,776

4.4.3 Flood Assessment

To approximate the flood depths at each watercourse crossing, a basic hydraulic assessment of the 24 key watercourse crossing locations has been undertaken using industry accepted software (HEC-RAS v3). The water level results are summarized below in Table 4.2 (details of the assessment are provided in Appendix C).

Table 4-2 Predicted flood depths at key watercourse crossing locations

No.	Name	2yr ARI Depth (m)	10yr ARI Depth (m)	100yr ARI Depth (m)
1	Larcom Creek	1.5	4.2	6.7
2	Calliope River	1.6	3.3	6.0
3	Bell Creek	1.6	2.7	4.4
4	Callide Creek	1.9	5.4	6.5
5	Kroombit Creek	1.7	3.5	5.2
6	Banana Creek	2.4	3.8	5.2
7	Kianga Creek	2.4	2.9	3.6
8	Dawson River (d/s)	8.1	12.6	16.5
9	Mimosa Creek	1.7	4.3	6.4
10	Conciliation Creek (d/s)	2.4	3.7	5.1
11	Zamia Creek (d/s 1)	2.4	3.5	4.8
12	Zamia Creek (d/s 2)	2.4	4.5	5.1
13	Zamia Creek (u/s 2)	1.6	2.3	3.3
14	Zamia Creek (u/s 1)	2.2	4.1	5.0
15	Conciliation Creek (u/s)	1.3	1.5	1.8
16	Clematis Creek	3.9	11.1	20.5
17	Brown River	2.8	3.4	4.1

No.	Name	2yr ARI Depth (m)	10yr ARI Depth (m)	100yr ARI Depth (m)
18	Spring Creek	2.0	5.5	6.3
19	Arcadia Creek	2.9	4.5	6.9
20	Dawson River (u/s)	8.2	14.9	18.5
21	Sardine Creek	3.4	7.4	12.6
22	Baffle Creek (u/s)	3.6	6.9	9.2
23	Baffle Creek (d/s)	3.5	6.5	8.9
24	Hutton Creek	1.8	5.6	11.5

Existing Water Quality — Section 5

5.1 Guidelines

The Australian and New Zealand Environment and Conservation Council Guidelines (2000) (ANZECC) provides guideline values or descriptive statements for environmental values to protect aquatic ecosystems and human uses of waters (e.g. primary recreation, human drinking water, agriculture, stock watering). The ANZECC Guidelines (2000) are a broad scale assessment and it is recommended that, where applicable, locally relevant guidelines are adopted.

The Queensland EPAs Queensland Water Quality Guidelines 2006 (QWQG) are intended to address the need identified in the ANZECC Guidelines (2000) by:

- Providing guideline values that are specific to Queensland regions and water types; and
- Provide a process/framework for deriving and applying local guidelines for waters in Queensland (i.e. more specific guidelines than those in the ANZECC (2000).

Relevant water quality objectives for the study area were identified from QWQG (2006) to support and protect different environmental values for waters in the Fitzroy Central River Catchment (refer to Table 5-1). The physico-chemical indicators were obtained from the Central Coast Region upland stream values. Salinity guidelines were obtained from Appendix G of the QWQG (2006).

5.2 Existing Conditions

The existing water quality of the watercourses and downstream receiving environment of the gas transmission pipeline corridor was assessed to characterise the baseline water quality conditions. The assessment includes a review of existing water quality data.

Central Queensland's water quality assets are under pressure from poor ground cover, land clearing, water contaminants, invasive plants and animals, modification of riparian zones, floodplains and wetlands, stream bank erosion, waterway development, barriers to species movement and cost of changing management practices (FBA, 2000).

Baseline water quality in the vicinity of and in, receiving waters within the pipeline corridor was assessed to characterise the existing water quality conditions. The assessment included a review of relevant water quality data from NRW gauging stations located on four major watercourses in the area. A full ecological assessment of the pipeline crossings is included in the relevant nature conservation study (refer Appendix N), and summarised in Chapter 7.4 of the EIS).

5.3 Water Quality Analysis

5.3.1 Methodology

Physico-chemical parameters for major watercourses along the pipeline corridor were assessed using results gathered from two sources (refer to Appendix D):

- Water quality monitoring activities were undertaken by URS on 3 February, 14 March and 6 May 2008 at seven locations in close proximity to the pipeline corridor. The watercourses assessed included Arcadia Creek, Basin Creek, Carnarvon Creek and Hutton Creek; and

- Water quality data was obtained from NRW for three major watercourses within the study area. These include Dawson River (Station No 130322A), Calliope River (Station No 132001A) and Mimosa Creek (Station No 130316A).

Figures 1 to 5 identifies the water quality monitoring locations, in relation to the pipeline corridor.

5.3.2 Results

This section outlines the results obtained from the water quality monitoring undertaken by URS during March and May of 2008 and existing data obtained from NRW from 1994 to 2005 (only limited data available). Some limited monitoring has been undertaken along the potentially affected watercourses; however, the parameters measured are limited. Table 5-1 provides the median values for each of the monitoring locations. Refer to Appendix D for the raw data set.

Table 5-1 Median Water Quality Samples

Watercourse	EC (µg/L)	n*	DO (%sat)	n	pH	n	Turbidity (NTU)	N*	Total P (µg/L)	n	Total N (µg/L)	N*	Organic N (µg/L)	N*	NH4 (µg/L)	N*	TSS (mg/L)	n
NRW																		
1. Calliope River[2]	1082	9	82	9	8.1	9	2	9	30	9	465	6	425	2	10	1	10	9
2. Dawson River[3]	198	6	75	5	7.8	6	124	6	140	6	795	2	690	4	20	3	29.5	6
3. Mimosa Creek[4]	285	1	86	1	6.9	1	1.1	1	30	1			590	1	20	1	10	1
URS Sites																		
1. Arcadia Creek @ Arcadia Valley Rd #1	198	1	65	1	7.4	1	91	1	180	1	1100	1					64	1
2. Arcadia Creek @ Arcadia Valley Rd #2	203	2	76	2	6.4	2	51	2	950	2	1000	1					39.5	2
3. Arcadia Creek @ Arcadia Valley Rd #3	199	2	91	1	5.6	1	23	1	550	1	2400	1					133	2
4. Arcadia Ck @ Sunny Holt	185	1	118	1	7.2	1	8	1	130	1	1200	1					10.5	1
5. Basin Creek @ Arcadia Valley Rd	169	2	59	2	6.8	2	423	2	700	2	2050	2					188	2
6. Carnarvon Creek @ Carnarvon Hwy	443	2	103	2	8.2	2	24	2	80	1	600	1					25	1
7. Hutton Creek @ Carnarvon Hwy	373	2	69	2	7.1	2	14	2	70	1	900	1					13	1
QWQG (2006)	**340**		**85 - 110**		**6.5 – 8.5**		**50**		**50**		**500**		**420**		**20**		**na**	

* Number of samples

Table Notes:

NH4 = Ammonia Nitrate; TP = Total Phosphorus; DO = Dissolved Oxygen; Organic N = Organic Nitrogen

TN = Total Nitrogen; TSS = Total suspended solids; EC = Electrical Conductivity

Years of data: 1 1995-2005; 2. 1997-2003; 3. 1994-2001; 4. 1996

Information in Table 5.1 indicates that Total Nitrogen (TN) and Total Phosphorous (TP) exceed the water quality objectives in the majority of watercourses sampled. Unfortunately there is insufficient data for organic or inorganic nitrogen to determine if it is a result of loads of organic matter being swept downstream, or if in fact there are large inputs of Inorganic Nitrogen from industry or fertiliser runoff. These watercourses have been characterised as having a large annual sediment load which was evident through on-site investigation, so it is reasonable to assume that a large proportion of the (TN) is attributed to organic matter such as leaf litter.

Additionally dissolved oxygen is (DO) low for a number of the watercourses. This may have been affected by the sediment loads or could be a case of sampling occurring in incorrect conditions. Ideally, DO should only be recorded in watercourses that have a reasonable flow. All water sampled by URS was ponded with no flow. Of the NRW sites, very little (average of 0.1 m^3/s) was recorded. pH readings, in most cases comply with the water quality objectives.

Salinity has traditionally been a varied issue within the Fitzroy basin and has been associated with land degradation, soil erosion, tree clearing and the overuse of groundwater supplies (FBA, 1996). EC levels were however within the water quality objectives at the majority of sites with only elevated levels noted within the Calliope River.

Seasonality

Rainfall averages suggest a distinct wet and dry season (refer Section 4.1.1), with the majority of rain falling between October and April. To account for this wet/dry seasonal variability, three rounds of water quality monitoring were undertaken by URS; two in the wet season and one in the dry season (refer Section 5.3.1). NRW data has also been split into wet/dry season (refer Appendix D):

- Wet: October – April; and
- Dry: May – September.

Without a larger data set it is difficult to make conclusions regarding seasonal variation. The following comments are general observation of the data in Appendix D.

- Generally electrical/conductivity (EC) is higher in the dry season due to lower flows available to dilute the salts present;
- DO would be expected to be lower in the dry season, which is the case for some sites; although others show DO to be lower in the wet season; and
- The Arcadia Creek sites generally have a lower median pH in the wet season compared to the dry whilst all other sites analysed (refer Appendix D) do not show seasonal variation and remain constant at around pH 7.0 to 8.0.

Potential Impacts and Mitigation Measures — Section 6

The following information details the major planned activities for the LNG pipeline through the different stages of construction, commissioning, operation and decommissioning. The potential impacts are discussed and management measures to minimise those impacts are outlined. This was undertaken using a qualitative risk assessment approach (refer to Appendix E). Risk is the chance of something happening that will have an impact and it is measured in terms of the potential 'consequences' of an event and the 'likelihood' that the event will occur (AS/NZ4360). The detailed risk matrix for the LNG pipeline surface water activities is provided in Appendix F and the impacts and mitigation measures identified are outlined as follows.

6.1 Construction Phase

The proposed 435 km pipeline will be buried for its entire length, except for above ground infrastructure located at pipeline stations. The construction will be undertaken by 3 teams of approximately 100 workers and is intended to be undertaken over a 24 month period. The pipeline will be laid with a minimum 750mm cover. This will be increased to 1200mm for sections of pipeline adjacent to watercourses and road crossings.

A new road and bridge crossing is being considered to create a land transport link to the processing facility site, crossing Port Curtis between Friend Point (on the mainland) and Laird Point (on Curtis Island). The road (if constructed) will be dual lane, two directional, and constructed of asphalt concrete. The road is proposed to be constructed in accordance with Main Roads Department, Queensland (MRD) guidance. This includes; culverts conveying small magnitude flows underneath the road embankment and road runoff being directed into grass lined road swales, before entering the natural environment. Further investigation of the road drainage requirement will be required prior to construction when the road alignment is confirmed. The perimeter road has been assessed in the facility section of the EIS.

6.1.1 Earth Moving Activities

Earthmoving activities are expected to include:

- Construction of the gas transmission pipeline, either by trenching or horizontal directional drilling (see below);
- Removal of vegetation;
- Top soil removal and stockpiling;
- Cut and fill;
- Construction of workers accommodation facilities;
- Construction of the lay down area for equipment storage; and
- Construction of a potential road following the pipeline corridor from Laird Point area on Curtis Island to the LNG facility at China Bay.

Sediment mobilised during construction activities may enter surface water runoff during rainfall events and discharge to drainage lines leading to deleterious effects on water quality and aquatic habitats. Sediment exposed or generated during construction may also be blown by wind into surface water bodies.

Areas of disturbed or exposed soil may be managed to reduce sediment mobilisation and erosion by:

- Concentrating work to as small an area as possible and progressively expanded to reduce the area potentially at risk;
- Minimizing the number of passes by heavy earth moving equipment;
- Stripping and stockpiled usable topsoil away from drainage lines to protect it from erosion;
- Implementing sediment limitation devices (e.g. settlement/evaporation ponds, drainage ditches);
- Constructing bunds to restrict flow velocities across the project site;
- Limiting vegetation clearing work during heavy rainfall;
- Requesting the earthworks contractor to prepare a Sediment and Erosion Control Plan prior to the commencement of construction;
- Adopting stormwater controls and upstream treatment, such as infiltration devices and vegetation filters;
- Locating vehicle wash bays away from watercourses;
- Revegetating and/or using of other stabilisation techniques, considering seasonal influences, upon completion of works;
- Minimising vegetation disturbance, especially riparian vegetation;
- Implementing dust suppression measures including irrigation and/or covering of stockpiles;
- Adopting erosion control, energy dissipation and scour protection, such as matting, riprap and gabions; and
- Preparing a Stormwater Management Plan (SWMP) for the construction of the LNG facility.

The application of the above proposed management measures will reduce both the likelihood and the consequences of the above impacts.

6.1.2 Works Adjacent to/within Drainage Lines

Works adjacent to or within drainage lines are expected to include:

- Pipeline construction; and
- Vehicle crossing of watercourses and drainage lines.

Construction activities at drainage lines, watercourse crossings and vehicle access crossings can mobilise sediment and alter flow and quality characteristics. The potential impacts from pipeline construction activities can be significant if not managed properly.

These potential impacts may be mitigated by:

- Installing suitable stormwater management infrastructure prior to commencing construction activities;
- Designing vehicle crossings (MRD), including under road drainage, for extreme flow conditions,;
- Using low flow diversions or coffer dams with pumping, to divert flows;

- Minimising disturbance by heavy earth moving equipment, especially in riparian areas; and
- Considering the time of construction when determining the standard of flood protection adopted.

Waterway Crossings

Waterway crossings are to be undertaken by either of two methods:

- Trenching; or
- Horizontal Directional Drilling.

Trenching

The majority of the pipeline has been proposed to be constructed using the standard open cut construction also known as trenching. Santos proposes using this technique to undertake watercourse crossing for all but two locations, the Dawson River (downstream) and the Calliope River. Below the trenching method is described, including suggested operations:

1) Fencing: Any existing fences transecting the right of way are to be severed and replaced with temporary gates for the duration of construction activities.
2) Clearing and grading of surfaces: Graders and bulldozers are used to clear the right of way of vegetation and topsoil. Topsoil should be typically graded to a depth of 100 to 150mm and stockpiled separately to vegetation within the right of way.
3) Trenching: Following the clearing of the pipeline right-of-way, the trench is to be dug for the pipeline by a trenching machine or excavator, in accordance with pre-defined design. The trench spoil should also be stockpiled separately to the topsoil.
4) Stringing: Steel pipe is trucked to the construction site and sections are laid end to end next to the trench. Selected methods propose that the sections are placed on sandbags and raised on blocks of wood to protect the pipe from corrosion and coating damage. Where required, pipe sections should be bent to match changes either in elevation or direction of the route.
5) Welding, Radiography and Joint Coating: Pipe sections are welded together in lengths up to one kilometre. Welds are inspected using x-ray or ultrasonic equipment. The area around the weld is cleaned and then coated with a protective coating to prevent corrosion.
6) Lowering-in and Backfill: Side booms, bulldozers with cranes, or excavators are used to lower the welded pipe into the trench and interconnecting sections of pipe. Where required, padding machines are used to sift the excavated subsoil to remove coarse materials to protect the pipe coating. The remaining fine material is used to pad beneath and on top of the buried pipe. Where only rocky soils exist, imported sand or foam pillows are used for padding instead. Trench spoil is returned to the trench and material compacted to minimise the likelihood of subsidence of material over the pipe.
7) Restoration and Rehabilitation: All waste materials should be removed from the work area and disposed of appropriately. As soon as practical after pipe laying and backfill, the easement is re-contoured to match surrounding landform and erosion controls constructed where necessary. Stockpiled topsoil is then respread evenly across the easement and any cleared vegetation placed across the easement, to assist in soil retention and provision of seed stock.

The potential impacts associated with trenching (as described under general earthmoving impacts in Section 6.1.1) may be mitigated by:

- In the event of heavy rain, it is suggested work is ceased until conditions improve. In the event that floods are predicted; the site may secured and equipment and materials removed away from the watercourse area.
- Watercourse bed and bank material and trench spoil will be stockpiled separately, away from banks to reduce the likelihood of sedimentation from surface run-off.
- Pipe string welding and concrete coating to occur prior to placement in the trench.
- The trench completion may be restricted through the banks until immediately prior to pipe installation.
- Tie-in points are located on high ground well away from the banks.
- All watercourses will be reinstated and profiled to original contours. Debris and spoil will be removed from watercourses to ensure no interruption to normal stream flow.
- The crossings are located at right angles to the direction of water flow, to minimise scour.
- Trenching of crossing is restricted to no or low flow conditions, and rehabilitation completed promptly.
- Watercourses to be stabilised with rock gabion, jute matting as required.
- Large and root stock retained for stabilisation of the banks.
- Riparian vegetation is retained, to buffer until pipe stringing is imminent.
- Minimise riparian vegetation clearing to the minimum practical for safe construction of the Pipeline and taking into consideration other environmental constraints (e.g. soil and brush stockpiling for rehabilitation).
- The Construction Manager is vigilant of weather and flood warnings and appropriate action will be undertaken to minimise damage and environmental impact.
- Trenching to be completed promptly.

Horizontal Directional Drilling

Horizontal directional drilling (HDD) is generally used to cross major watercourses where standard open cut methods are not feasible. Directionally controlled horizontal drilling is a process by which a drilling tool is steered along a pre-determined path while drilling is in process.

- The first stage consists of drilling a small diameter pilot hole along the designed directional path.
- The second stage involves enlarging this pilot hole to a diameter, which will accommodate the product pipe.
- The third stage involved pulling the product pipe through the enlarged hole.

Although HDD may reduce above ground impacts, the technique introduces additional environmental considerations, in particular the drilling fluid. It is proposed that the drilling fluid's key lubricating solvent will be bentonite slurry. Although a naturally occurring clay, Bentonite becomes toxic to the environment when released in large amounts. The fine mud slurry easily enters rock fractures and can potentially contaminate ground water aquifers. It is normal to expect some drill fluid loss, however a fluid tracking procedure and loss reporting system are proposed to limit spillage, ground water levels should also be considered prior to drilling.

Additionally general sediment and stormwater management controls will be employed around the pilot drilling hole (refer Section 6.1.1).

Riverine Protection Permit

Under Section 266 of the *Water Act 2000*, a Riverine Protection Permit is required from NRW where development will:

- Destroy vegetation in a watercourse;
- Excavate in a watercourse; or
- Place fill in a watercourse.

Specific management measures and conditions relating to each watercourse will be established by NRW. NRW as a minimum will require the following mitigation measures as conditions of a Riverine Protection Permit. The area of disturbance must be no greater than the minimum area necessary for the purpose.

- The area of bed and banks disturbed by the activities must be stabilised regardless of previous stability.
- The extent and duration of bare surface exposure must be minimised, and protected from weathering, rain drop impact, and water runoff.
- Clean water run-off must be diverted around areas of disturbance where practicable.
- Bed and bank stability must be managed to minimise erosion and reduce sedimentation.
- Where practicable, sediment must be captured and retained on-site.
- Machinery to be used in carrying out the activities must be selected on the basis of a type and size necessary and capable of safe operation to achieve minimal disturbance of the site.
- Constructed drainage and discharge structures must not alter the natural bed and bank profile.

6.1.3 Contaminant Mobilisation

The use of fuels and chemicals onsite will involve refuelling of vehicles and maintenance and construction of the pipeline.

Potential aqueous waste streams may include oily waste water (from equipment wash water), contaminated runoff from chemical storage areas, and potentially contaminated drainage from fuel oil storage areas, oil-filled transformer yard areas and general washdown water.

These potential impacts may be mitigated by:

- The construction of bunded storage areas for contaminants are recommended with spill cleanup kits in accordance with Australian Standards (AS1940 and AS3780) to prevent the contamination of surrounding surface runoff;
- The transfers of fuels and chemicals controlled and managed to prevent spillage outside bunded areas;

- Implement control so significant leakage/spillage is immediately reported and appropriate emergency clean-up operations implemented to prevent possible mobilisation of contaminants;
- Bunds and sumps are frequently drained, and effluent is treated appropriately;
- Contaminants or major spillages of stored material in the bunded areas are collected by licensed waste collection and transport contractors for disposal off site at a licensed facility.

The application of the above proposed management measure may reduce the likelihood and consequence of the above impacts.

The application of the above proposed management measure may reduce the likelihood of the above impacts.

6.1.4 Pollution

Potential sources of onsite pollution during the construction phase predominantly comprise diesel and other petroleum-based fuels and lubricants used by excavation and construction machinery. Pollution effects are not only on the environmental but are also a public health and safety issue.

Mitigation measures for pollution will be similar to contaminant mobilisation and are typical conditions set by environmental authority conditions. These are likely to include:

- Bunded storage areas for fuels and dangerous goods;
- Spill cleanup kits in accordance with Australian Standards (AS1940 and AS3780);
- Control and manage transfers of fuels and chemicals to prevent spillage outside the bunded areas
- Pollution from sewage can be managed with a Waste Management/Disposal Plan (refer to Chapter 5). Techniques of treatment of worksite sewage may include septic systems, mobile chemical treatment system or a sewage treatment plant.
- Pipeline construction generated waste also includes pipe off cuts, rope spacers and timber skids, which are generally recycled. Litter and other construction waste can be washed into watercourses during rain events and impact receiving waters. Waste should be removed and disposed of as per the Waste Management Strategy (refer to Chapter 5).

This is also detailed in the waste management chapter of the EIS (refer to Chapter 5).

The application of the above proposed management measure will reduce the likelihood of the above impacts.

6.1.5 Flooding

The possibility of out-of-bank/flash flood rainfall events during construction, present a risk to workers' health and safety, and may cause erosion and damage to erosion and sediment control infrastructure.

If possible, major construction activities should be avoided during the wet season (i.e. from October to April). Additionally to mitigate impacts, stormwater management measures such as drainage diversions and flood defence bunds (designed to provide an appropriate level of protection – recommended at AEP 0.01 or ARI 100 yr ARI) may be implemented before construction commences. Furthermore these should be inspected on a regular basis throughout the construction period, especially following significant storm events, and maintained as necessary.

Emergency response procedures (including evacuation procedures) and a flood warning system should be established and incorporated into the site's Health, Safety and Environment Plan to protect on-site personnel. . However, their effectiveness will be dependent on catchment size. The majority of watercourse crossings assessed have adequate upstream catchment areas to provide sufficient lag time to take evasive action prior to flooding, however small crossing, such as; Conciliation Creek upstream, Bell Creek, and Spring Creek, warnings should be dependent on rainfall predictions.

The application of the above proposed management measure may reduce the likelihood of the above impacts.

6.1.6 Water Supply

Due to the ephemeral nature of the majority of the watercourses along the pipeline corridor, it is assumed that local sources such as rivers will not be used. Water may potentially be trucked in from local municipal supplies located along the length of the pipeline. The volume and location of water supply has yet to be confirmed and will need to be assessed prior to construction.

A lack of water supply could result in inadequate dust suppression, soil compaction and washdown, allowing sediment movement into nearby watercourses, leading to deterioration in water quality.

The development, implementation and maintenance of a Water Supply Strategy and Emergency Plan is recommended. Sediment and erosion control measures may also be developed (as detailed in Section 6.2.1).

The application of the above proposed management measure may reduce the likelihood of the above impacts.

6.1.7 Weed Control

Refer to the EMP for mitigation measures of the above impacts.

6.2 Commissioning Phase

6.2.1 Hydrostatic Testing

The pipeline's integrity is verified by undertaking a hydrostatic test. This testing forms the key component of the commissioning phase for the project. The LNG pipelines will be tested for strength and leak tightness using water as a test medium. The pipeline will be divided into a number of sections for the testing to be conducted; the limits of each section will be determined by; water source constraints, elevation changes and weather.

The water testing medium source location and volume has yet to be determined, although it is possible that a local watercourse could be used as a potential supply. The ephemeral nature of the local watercourses in the study area may restrict their use as a reliable supply and if undertaken may have negative impacts on low flows and flora/fauna. It would be preferable to use another source of water, either from nearby municipal supplies or local groundwater boreholes (or possibly treated associated water which is pumped from the coal seam in order to extract the gas).

Testing water may potentially be treated with chemicals such a biocide, oxygen scavengers and corrosion inhibitors, depending on such factors as the water quality of test water and the length of pipe tested. Use of any chemical on site should be avoided and carefully controlled to avoid contamination of local water sources (refer to Chapter 5). If associated water is to be used for testing, then it is suggested that an appropriate water treatment technology is used to reduce the inherently high Total Dissolved Solids (TDS) concentrations (typically at around 3000ppm) to acceptable background levels (i.e. TDS of proposed streams to which water may be discharged).

The disposal of the waste testing water may cause localised erosion and scour or minor flooding. The disposal should be undertaken using an approved environmental procedure, potentially discharging into evaporation ponds or disposal to a regulated waste collector. The volume and quality of water and location of disposal was unknown. A detailed assessment of its impacts and recommended mitigation measures should be undertaken prior to construction.

Refer to the EMP for mitigation measures of the above impacts.

6.3 Operation Phase

Following the reinstatement and revegetation of the construction right of way, minimal above-ground infrastructure should be visible. Above ground infrastructure may be limited to marker posts to identify the location of the pipeline and the pumping/receiver stations including maintenance access tracks.

A routine operation and maintenance program may be implemented, which could potentially include leak detection surveys, ground and/or aerial patrols, repair or replacement of faulty pipe or other equipment, pigging and cleaning of the pipeline, corrosion monitoring and remediation and easement and lease area maintenance.

Aerial and/or ground inspections may include checking vegetation for discolouration which can be indicator of a leak, detection of erosion, monitoring of rehabilitation success and detection of weed species. Low level maintenance for erosion, subsidence and weeds is likely to be necessary particularly during the first 12 months following construction. These actions should be in accordance with the EMP and inline with the APPEA Code (2008).

The proposed pipe is to be thick walled pipe at watercourse crossings and areas of significant inundation to protect the external coating and to prevent the pipe ‘floating’ once in place.

Refer to the EMP for mitigation measures of the above impacts.

6.4 Decommissioning Phase

Currently decommissioning procedures require the removal of all above ground infrastructure and the restoration of associated disturbed areas. Although not yet fully determined it is possible that the below ground pipeline will be filled with inert material, such as sand, or protected with catalytic devices to prevent/limit corrosion. 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 APPEA Code (2008) and the *Petroleum and Gas Act* 2004. General conditions are covered in the following sections:

6.4.1 Sediment Mobilisation

Details of managing sediment mobilisation are contained in Section 6.1.1.

6.4.2 Works Adjacent to/within Drainage Lines

Details of managing works within drainage lines are contained in Section 6.1.2.

6.4.3 Contaminant Mobilisation

Details of managing contaminant mobilisation are contained in Section 6.1.3.

6.4.4 Pollution

Details of managing pollution are contained in Section 6.1.4.

Refer to the EMP for mitigation measures of the above impacts.

The potential risks associated with the construction, commissioning, operation and decommissioning phases of the gas transmission pipeline development have been considered. These risks have been allocated mitigation and management strategies to reduce them to a level that does not significantly impact upon the surrounding environmental values (refer to Appendix E and F for full details of the risk screening exercise).

Potential impacts from the pipeline are expected to be of higher risk during the construction phase. These include:

- Earth Moving Activities and Works Adjacent to/within Drainage Lines
  - The movement of sediment and potential erosion may be exacerbated from the trenching or drilling of the pipeline through the watercourses and from works adjacent to/within drainage lines, including pipeline construction and vehicle crossing of watercourses and drainage lines. These impacts may to be minimised using erosion and sediment control techniques such as contour drains (Appendix G) and the implementation of an Erosion and Sediment Control Plan and a Stormwater Management Strategy. Other measures such as Acid Soils Management Plan, Water Supply Strategy, Flood Forecasting System, Flood Emergency Management Plan, Diversion drains/ Coffer dams, water treatment technologies, dry season construction, water quality release guidelines, etc have also been proposed.
- Contaminant Mobilisation and Pollution
  - Contaminant mobilisation through the use of fuels and chemicals onsite including pollution such as diesel and other petroleum-based fuels and lubricants could enter into drainage lines and receiving waters, altering the physical and chemical quality of the water and waterway. These potential impacts may be mitigated by establishing spill and refuelling standards and practice. A Waste Management strategy may manage litter and other construction waste and the removal of sewage from worksites.
- Flooding
  - A risk to both workers' health and safety and to waterways is the possibility of out-of-bank/flash flood rainfall events, during construction. It is recommended that works occur outside the wet season, where practicable, and emergency response procedure and flood forecasting is incorporated into operating (and Health and Safety) procedures.

The commissioning of the pipeline will involve hydrostatic testing. The disposal of the test waste testing water could cause localised erosion and scour or minor flooding, and may contain pollutants such a biocide, oxygen scavengers and corrosion inhibitors. The disposal of test waste water should be carefully controlled to avoid contamination of local watercourses.

The operational phase of the project will require a routine operation and maintenance program. This may involve periodic aerial and/or ground inspections.

Glossary and Abbreviations

Section 8

Glossary, Acronyms and Abbreviations	
AEP	Annual Exceedence Period
ANRA	Australian Natural Resources Atlas
APPEA	Australian Petroleum Production and Exploration Association
ARI	Annual Reoccurrence Interval
AR&R	Australian Rainfall and Runoff
AS	Australian Standard
BOM	Bureau of Meteorology
EC	Electrical Conductivity
EIS	Environmental Impact Statement
EMP	Environmental Management Plan
EPA	Environmental Protection Agency (Queensland)
EPP Water	The *Environmental Protection (Water) Policy 1997*
FBA	Fitzroy Basin Association
GDSA	Gladstone State Development Area
HDD	Horizontal Directional Drilling
HEC RAS	Hydrologic Engineering Center River Analysis System
IEAust	Institute of Engineers Australia
LNG	Liquid Natural Gas
MRD	Main Roads Department (Queensland)
NH4	Ammonium Nitrate
NRW	Natural Resources and Water (Department of)
EPP Water	The *Environmental Protection (Water) Policy 1997*
BOM	Bureau of Meteorology
TDS	Total Dissolved Solids
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
DO	Dissolved Oxygen
QWQG	Queensland Water Quality Guidelines 2006
SWMP	Stormwater Management Plan

References

Section 9

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Limitations Section 10

URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of Santos Limited and only those third parties who have been authorised in writing by URS to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 12 September 2007.

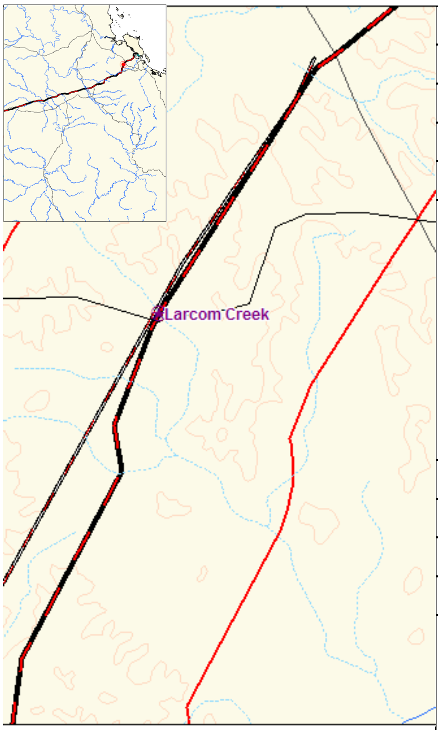
The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between 11 August 2008 and 23 January 2009, and is based on the information made available by Santos at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

Site Visit Assessment

Appendix A



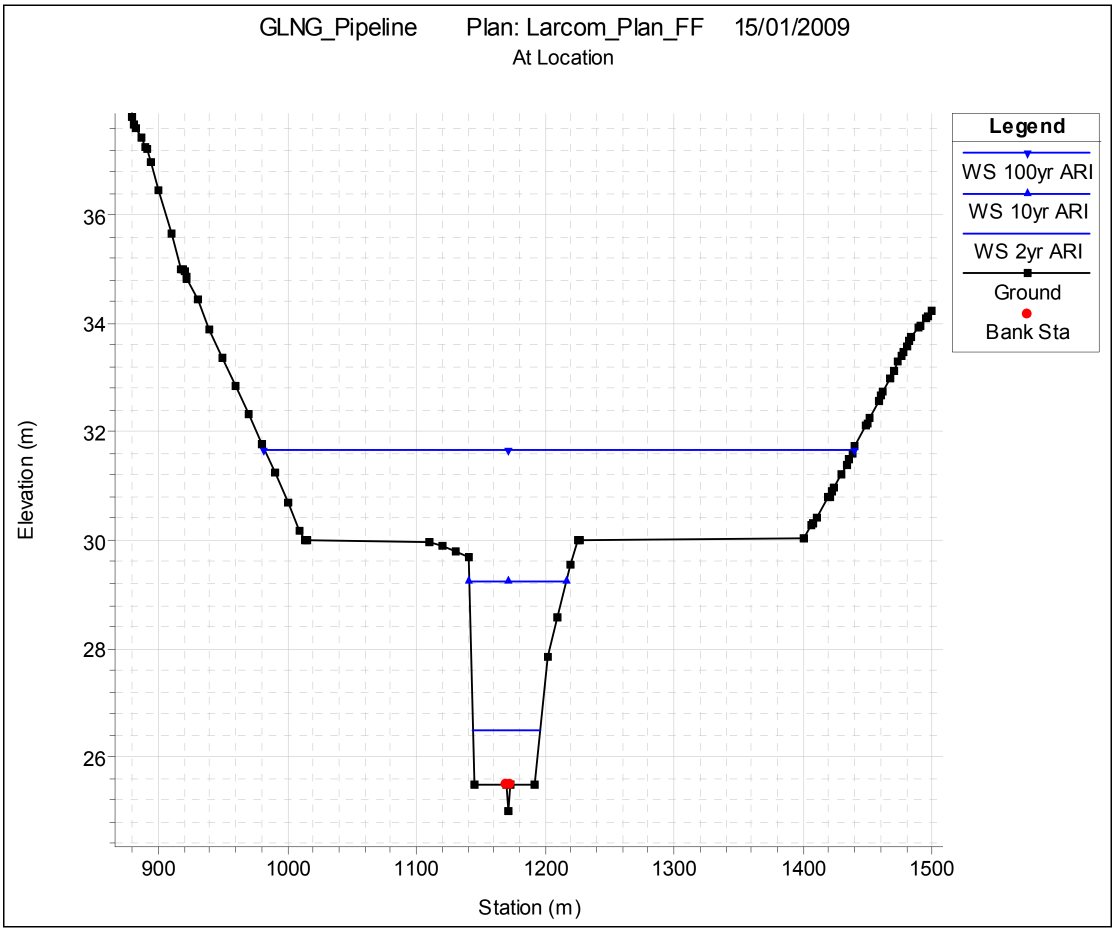
Plan: Larcom Creek

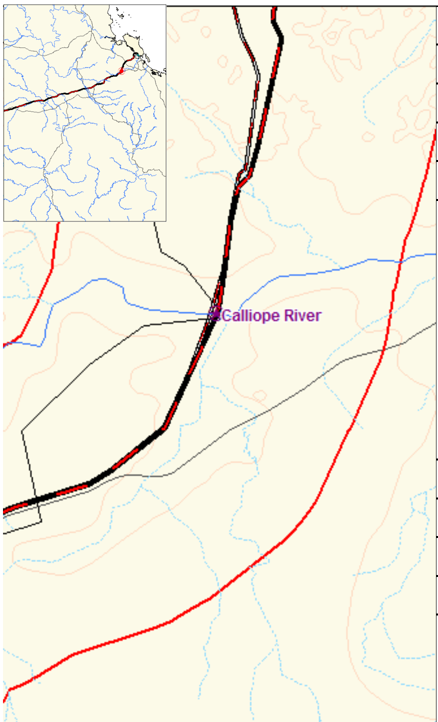
Photo: Looking Upstream

LNG Transmission Pipeline– Surface Water Assessment	
Location No.	**1**
Location Name	**Larcom Creek**
Easting:	295,899
Northing:	7,353,023
Site Description: *The small trickling stream is located to the south of Gladstone near Mount Larcom. The lower banks are covered by short grass whilst the upper banks are vegetated with longer grass. Algae growth is present in the low flow channel. The assessment was undertaken at the nearby road crossing of the watercourse as the proposed pipeline crossing location was inaccessible.*	
Channel Depth:	*5m*
Channel Width:	*50m*
Floodplain Slope:	*L 1:15, R 1:24*
Bank Slope:	*LB 1:1, RB 1:6*
Channel Banks: Both left and right banks appear stable, with no evidence of erosion or bank failure at the assessment location. The low grade slopes are concave in shape and vegetated with grass and a scatter of small trees.	
Substrate Type: The bed substrate is of moderate compaction with a dilated framework and low availability of interstitial spaces. The predominate particle size is a fine clay with a small a distribution of gravels.	
Channel Bed: The two staged channel has a low flow channel approximately 1.5m wide and an upper channel that then extends approximately 20-30m wide on each side. The low flow channel has a flat clay silt bed surface, whilst the upper bed is covered in grasses and small trees. Both lower and upper beds appear stable with no signs or erosion or deposition.	
Water Quality: No apparent odour or oils were present. The trickling water was reasonably clear; light brown in colour with algae growth.	
Floodplain: Grazed woodland.	

Catchment Size:	*278km²*		
Channel Slope:	*2.6 m/km*		
Catchment Storage: Well defined system of small watercourses.			
Catchment Relief: Flat, with slopes of 0 – 1.5%			
	Q2	Q10	Q100
Flow	$43m^3/s$	$404m^3/s$	$1,657m^3/s$
Depth	1.5m	4.2m	6.7m

Cross Section Larcom Creek





Plan: Calliope River

Photo: Looking Upstream

LNG transmission pipeline – Surface Water Assessment	
Location No.	**2**
Location Name	**Calliope River**
Easting:	293,174
Northing:	7,341,808

Site Description: *The Calliope River is located to the south west of Gladstone. The undulating stream bed results in both flowing and ponded water surfaces. The low flow channel bed has dense algal growth whilst the main channel bed has dense grass and shrub cover. The assessment was undertaken at a nearby road crossing of the watercourse as the pipeline crossing was inaccessible.*

Channel Depth:	*1.5m/10m*
Channel Width:	*1.5m/5m/100m*
Floodplain Slope:	*L 1:11, R 1:4*
Bank Slope:	*LB 1:13, RB 1:45*

Channel Banks: Both left and right banks appear stable, with little evidence of erosion or bank failure at the site location. The low grade slopes are concave in shape and are grassed with a scatter of small trees.

Substrate Type: The bed substrate is of low compaction with a moderate availability of interstitial spaces. The predominate particle size is a fine silt.

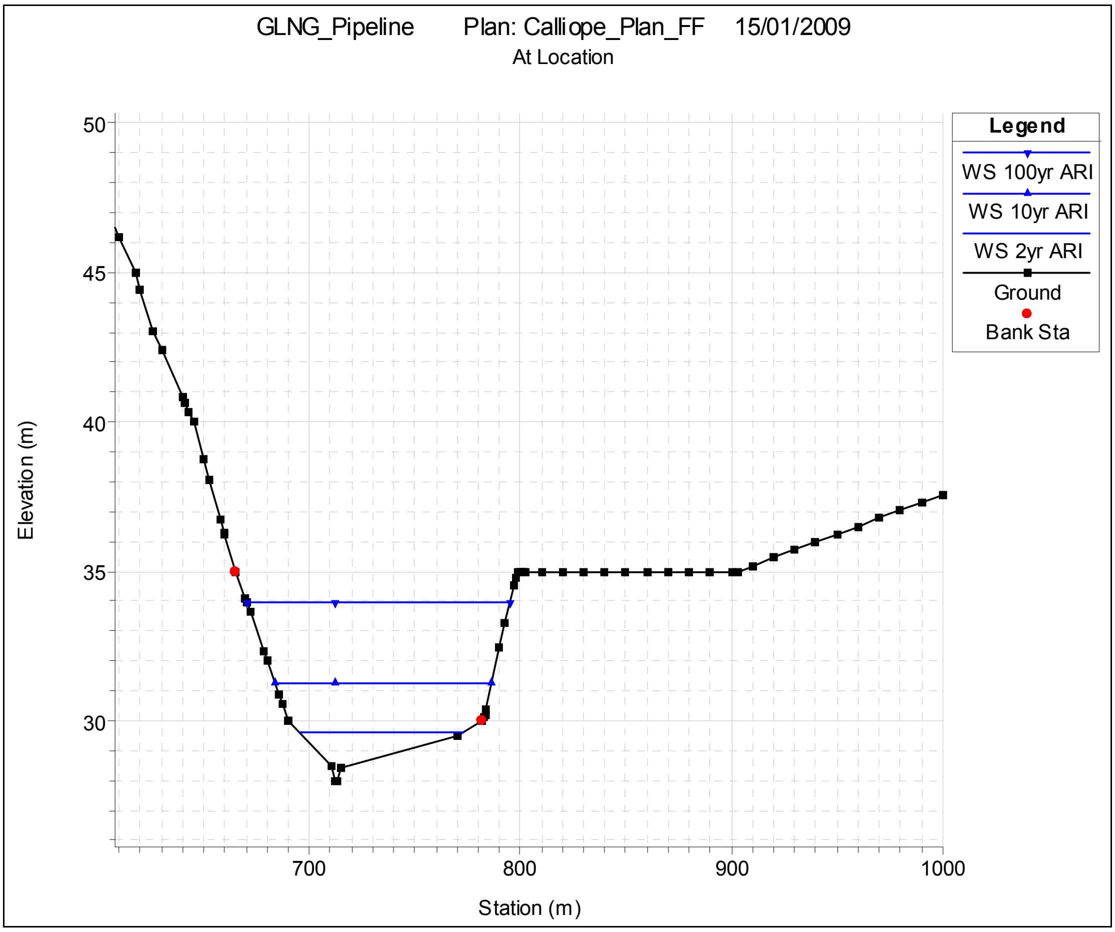
Channel Bed: The multistage channel has a low flow channel approximately 1.5m wide and a medium flow channel of approximately 5m and an upper channel that then extends approximately 100m. The low flow channel has an undulating silt bed surface, whilst the two upper beds are covered in grasses and small trees. Both lower and upper beds appear stable with no signs or erosion or deposition.

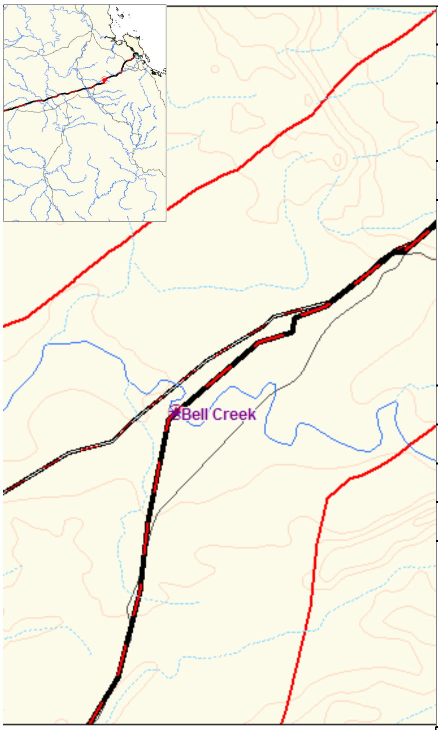
Water Quality: No apparent odour or oils were present. The trickling water was reasonably clear; light brown in colour with algae growth.

Floodplain: Grazed woodland.

<u>Catchment Size:</u>	*489km²*		
<u>Channel Slope</u>:	*3 m/km*		
<u>Catchment Storage:</u> Well defined system of small watercourses.			
<u>Catchment Relief</u>: Flat, with slopes of 0 – 1.5%			
	Q2	Q10	Q100
Flow	$51m^3/s$	$427m^3/s$	$1,686m^3/s$
Depth	1.6m	3.3m	6.0m

Cross Section Calliope Creek





Plan: Bell Creek

LNG transmission pipeline – Surface Water Assessment	
Location No.	**3**
Location Name	**Bell Creek**
Easting:	266,550
Northing:	7,326,278

Site Description: *Bell Creek is located to the south west of Gladstone. The flat bottom ephemeral stream is heavily vegetated with mature larger trees, dense scrubs on the banks and juvenile trees on the flat sandy bed.*

Channel Depth:	*2m*
Channel Width:	*10m*
Floodplain Slope:	*L 1:1, R 1:1*
Bank Slope:	*LB 1:1, RB 1:2.5*

Channel Banks: Both left and right banks appear stable, with no evidence of erosion or bank failure. Although hard to determine under the dense vegetation, the bank slopes appear steep yet concave in shape.

Substrate Type: The bed substrate is of low compaction with a high availability of interstitial spaces. The predominate particle size is a sand with some finer silts and coarser small gravels.

Photo: Looking Upstream

Channel Bed: The two stage channel has a low flow channel approximately 10m wide and a medium flow channel is approximately a further 10m wide. Both the low and medium flow channels have a reasonably flat surface dense with juvenile tree vegetation. Both lower and upper beds appear stable with no signs or erosion or deposition.

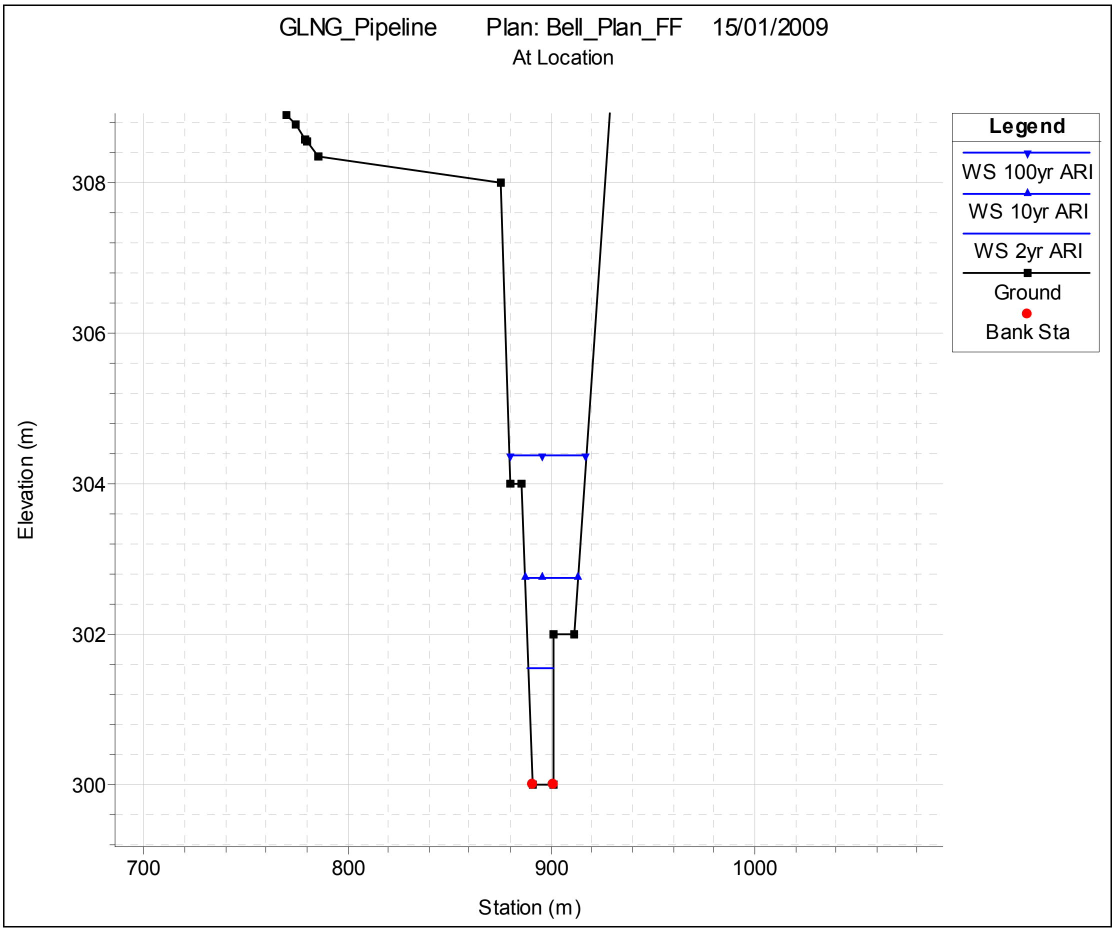
Water Quality: No water present, no assessment undertaken

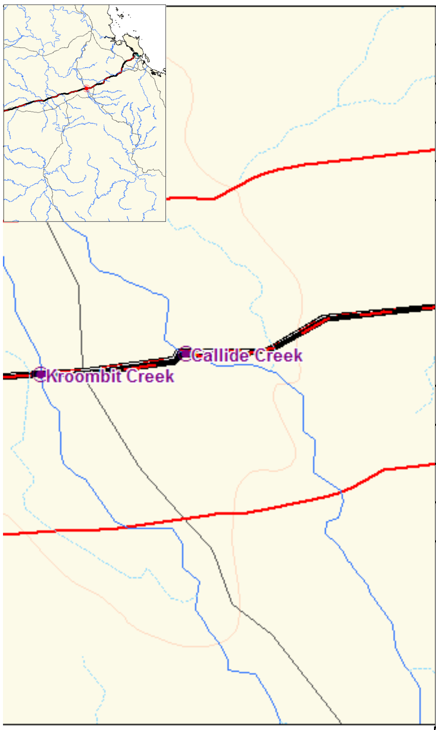
Floodplain: Grazed pasture.

Photo: Looking Downstream

Catchment Size:	*46km²*		
Channel Slope:	*16 m/km*		
Catchment Storage: Well defined system of small watercourses.			
Catchment Relief: Rolling, with slopes of 1.5 - 4%			
	Q2	Q10	Q100
Duration	195min		
Intensity	16mm/hr	24mm/hr	37mm/hr
Flow	$61m^3/s$	$142m^3/s$	$339m^3/s$
Depth	1.5m	2.7m	4.4m

Cross Section Bell Creek





Plan: Callide Creek


Photo: Looking Upstream

LNG transmission pipeline – Surface Water Assessment	
Location No.	**4**
Location Name	**Callide Creek**
Easting:	239,170
Northing:	7,311,743

Site Description: *Callide Creek is located to the north of Biloela. The flat bottom ephemeral stream has a shallow yet wide sandy low flow channel with mature larger trees on the upper bed of the multilevel waterway.*

Channel Depth:	*1.5m*
Channel Width:	*14m*
Floodplain Slope:	*L 1:5, R 1:5*
Bank Slope:	*LB 1:1, RB 1:1*

Channel Banks: Both left and right banks appear stable, with little evidence of erosion or bank failure. The banks are stepped in shape with moderately steep lower banks and low slope on the upper levels.

Substrate Type: The bed substrate is of low compaction with a high availability of interstitial spaces. The predominate particle size is a sand with some finer silts and courser small gravels.

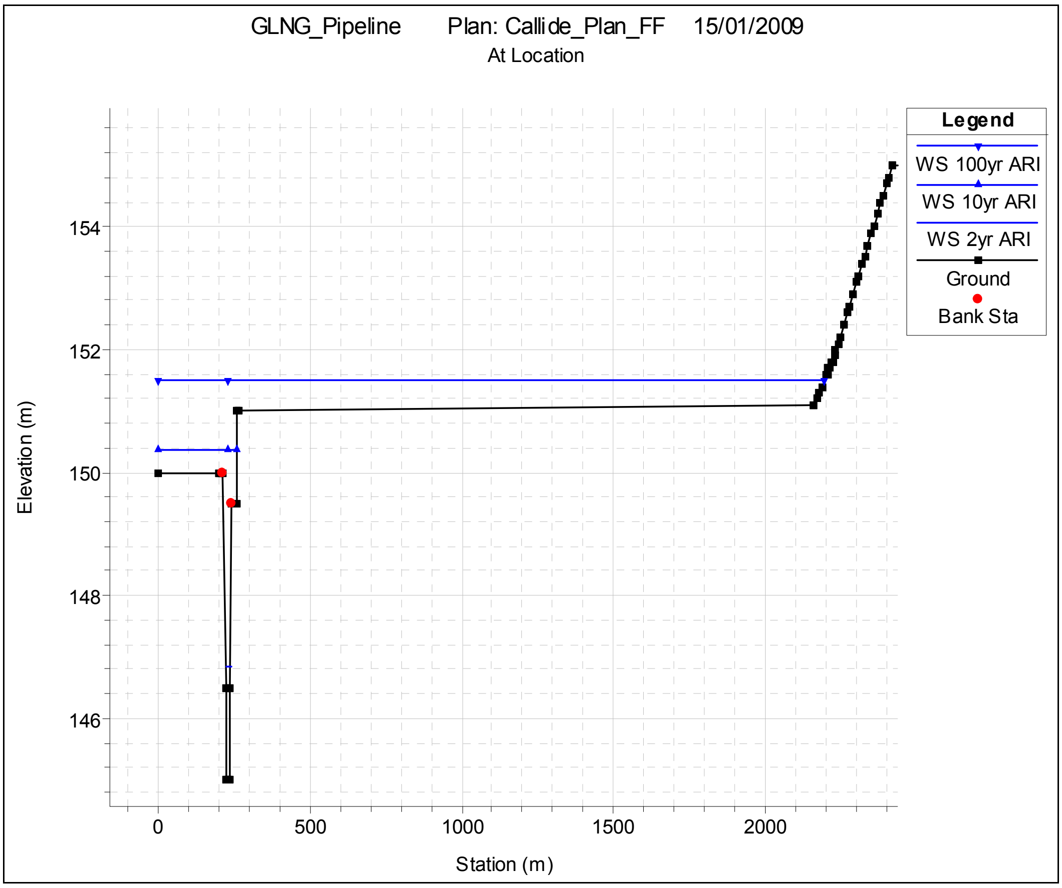
Channel Bed: The multistage channel has a low flow channel approximately 14m wide with a wide flat sandy bed which is sparsely grassed. The banks are then stepped with a scattering of mature trees. The bed appears stable with no signs or erosion or deposition.

Water Quality: No water present, no assessment undertaken

Floodplain: Grazed pasture.

Catchment Size:	*763km²*		
Channel Slope:	*3 m/km*		
Catchment Storage: Well defined system of small watercourses.			
Catchment Relief: Flat, with slopes of 0 - 1.5%			
	Q2	Q10	Q100
Flow	$59m^3/s$	$447m^3/s$	$1,708m^3/s$
Depth	1.9m	5.4m	6.5m

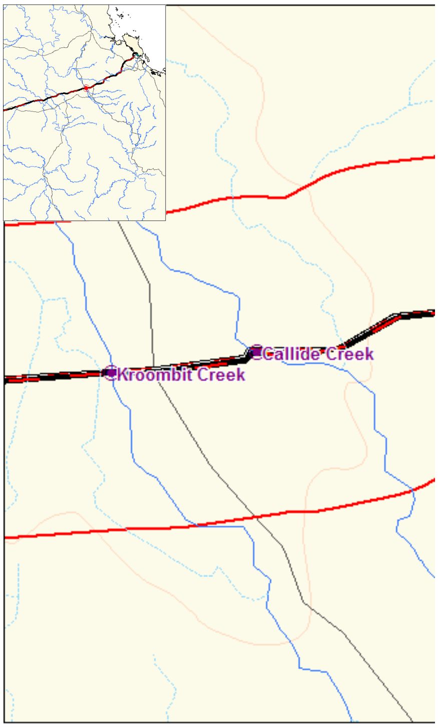
Cross Section Callide Creek



At the watercourse crossing location the left floodplain of Callide Creek and the right floodplain of the Kroombit Creek join in minor flood events. The Callide Creek cross-section left floodplain has been truncated at the predicted highpoint between the two creek floodplains. The joining of the floodplain will effect the downstream conditions and hence the flood levels at this location, as this is a simple assessment these factors have not be further assessed and hence must be considered when assessing the accuracy of the results.

Photo: Left Bank

Photo: Right Bank



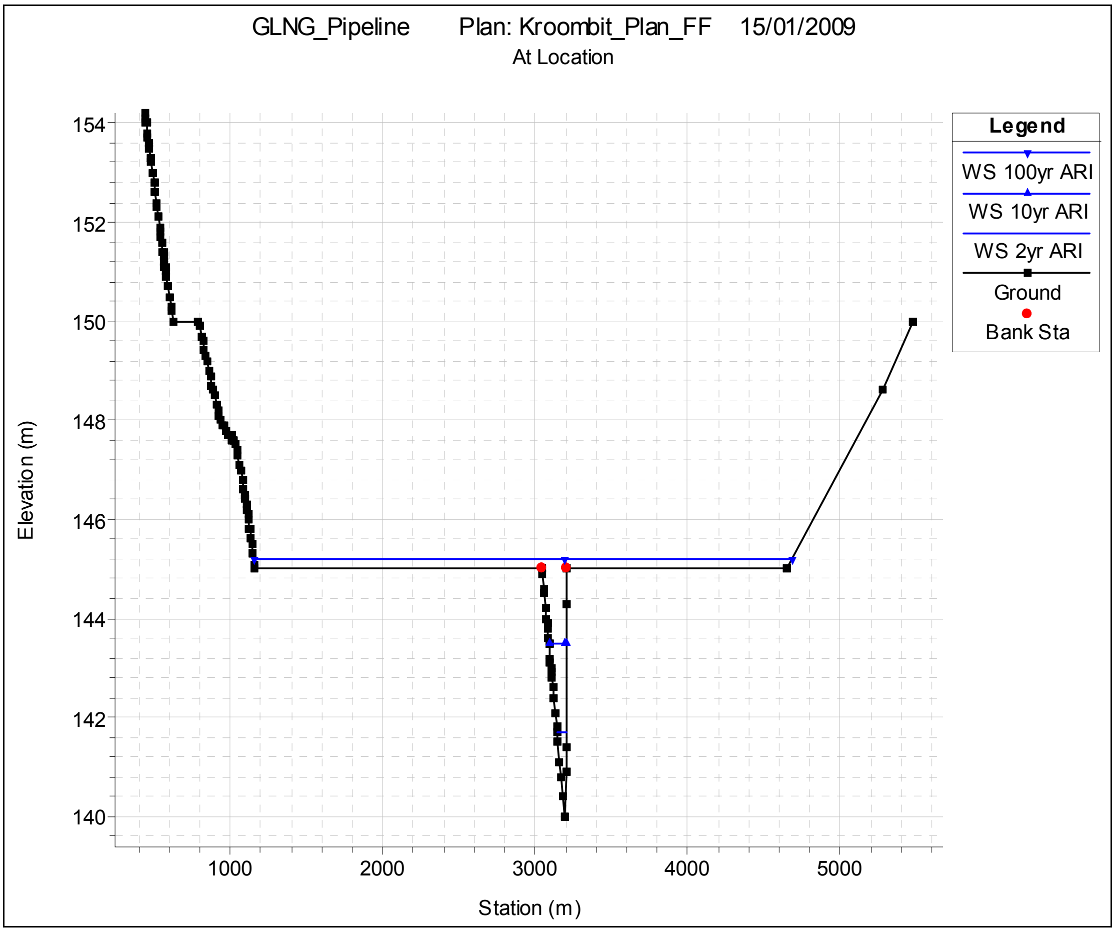
Plan: Kroombit Creek

Photo: Looking Downstream

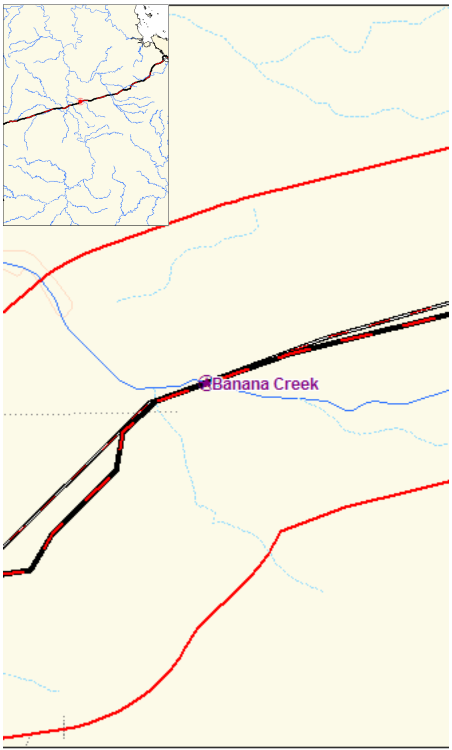
LNG transmission pipeline – Surface Water Assessment	
Location No.	**5**
Location Name	**Kroombit Creek**
Easting:	237,171
Northing:	7,311,399
Site Description: *Kroombit Creek is located to the north of Biloela. The ephemeral stream is an irregular U shaped channel with an undulating bed and large wooden debris deposits. There are signs of both bed and bank erosion from flow and erosion from livestock.*	
Channel Depth:	*3m*
Channel Width:	*7m*
Floodplain Slope:	*L 1:90, R 1:45*
Bank Slope:	*LB 1:3.7, RB 1:3.7*
Channel Banks: Both left and right banks are moderately eroded, with short sparse grass on lower areas and trees on upper banks. The banks are convex in shape with a low slope.	
Substrate Type: The bed substrate is of low compaction with a low availability of interstitial spaces. The pre-dominate particle size is a silt with some fine sands.	
Channel Bed: The irregular U shaped channel has an eroded, undulating and silty sandy, bed which is sparsely grassed.	
Water Quality: No water present, no assessment undertaken	
Floodplain: Grazed pasture.	

Catchment Size:	*2340km^2*		
Channel Slope:	*4 m/km*		
Catchment Storage: Well defined system of small watercourses.			
Catchment Relief: Flat, with slopes of 0 - 1.5%			
	Q2	Q10	Q100
Flow	82m^3/s	500m^3/s	1,767m^3/s
Depth	1.7m	3.5m	5.2m

Cross Section Kroombit Creek



At the watercourse crossing location the right floodplain of Kroombit Creek and the left floodplain of the Callide Creek join in minor flood events. The Kroombit Creek cross-section right floodplain has been truncated at the predicted highpoint between the two creek floodplains. The joining of the floodplain will effect the downstream conditions and hence the flood levels at this location, as this is a simple assessment these factors have not be further assessed and hence must be considered when assessing the accuracy of the results.



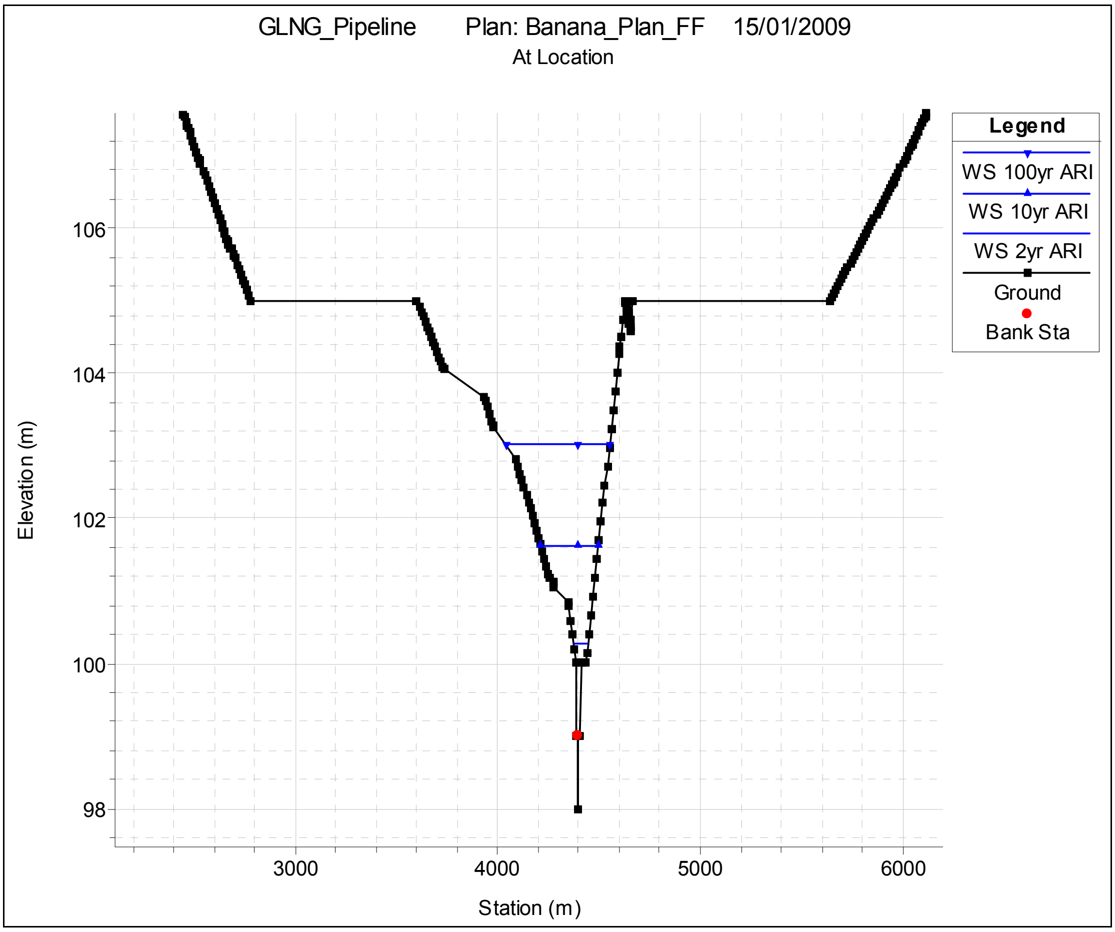
Plan: Banana Creek

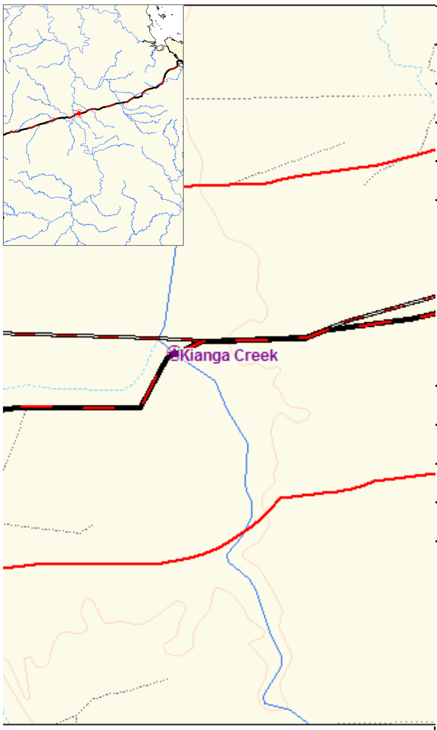
Photo: Looking Upstream

LNG transmission pipeline – Surface Water Assessment	
Location No.	**6**
Location Name	**Banana Creek**
Easting:	201,414
Northing:	7,300,296
Site Description: *Banana Creek is located to the north of the small town of Banana. The dry irregular stream has a sandy bed, low flow channel and grassy upper channel.*	
Channel Depth:	*2m*
Channel Width:	*2m*
Floodplain Slope:	*L 1:50, R 1:40*
Bank Slope:	*LB 1:2.5, RB 1:7.5*
Channel Banks: Both left and right banks appear moderately unstable, with 30 – 60% of bank reaches with evidence of erosion. The banks are stepped, convex is shape and steep in nature. The flat steps of the bank are vegetated with long grass and a scatter of smaller trees.	
Substrate Type: The bed substrate is of low compaction with a high percentage of fines making it predominately matrix dominated. The predominate particle size is a sand with some finer silts and coarser small gravels.	
Channel Bed: The multistage channel has a low flow channel approximately 2m wide with a shallow flat sandy bed. The banks are then stepped with long grass and a scattering of small tree vegetation. There is a moderate build up of fine sediments at obstructions and bars.	
Water Quality: No water present, no assessment undertaken	
Floodplain: Grazed pasture.	

Catchment Size:	*700km²*		
Channel Slope:	*5.5 m/km*		
Catchment Storage: Well defined system of small watercourses.			
Catchment Relief: Flat, with slopes of 0 - 1.5%			
	Q2	Q10	Q100
Flow	$57m^3/s$	$443m^3/s$	$1,704m^3/s$
Depth	2.4m	3.8m	5.2m

Cross Section Banana Creek





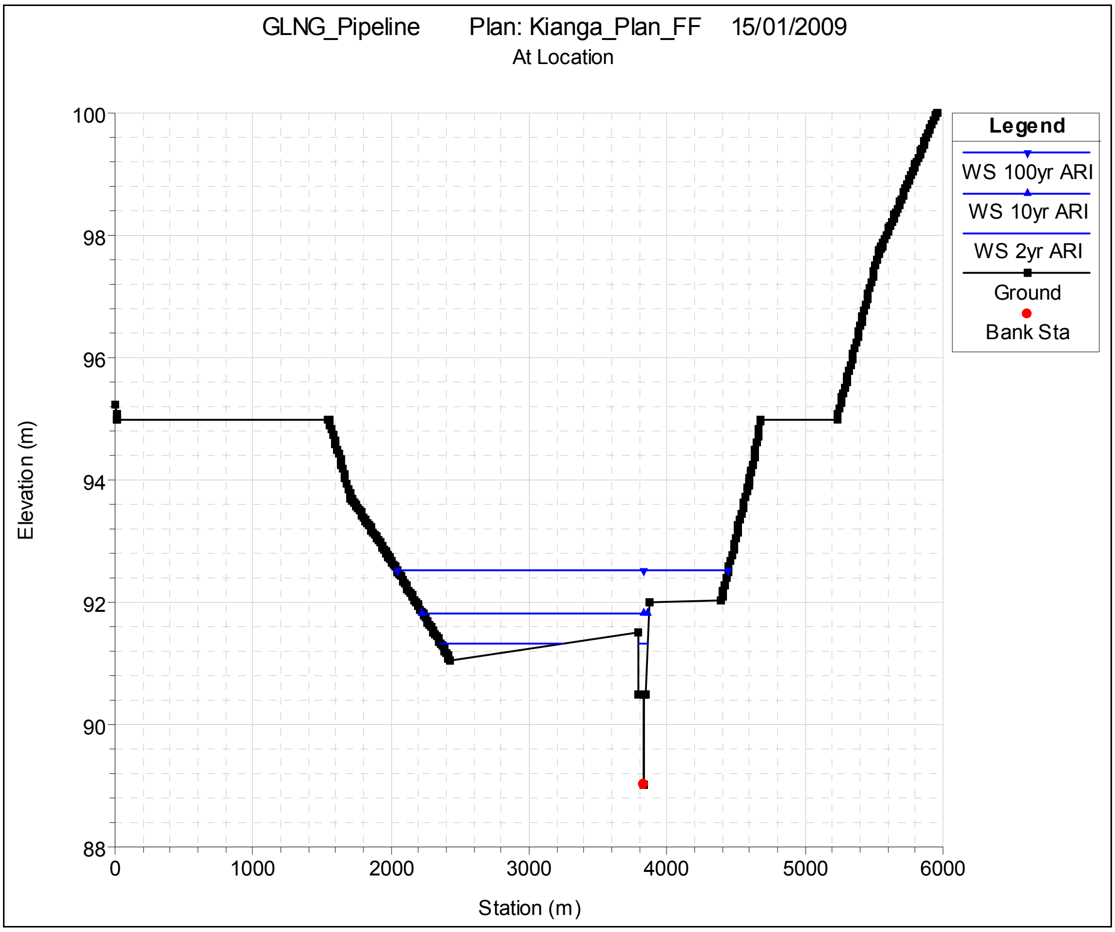
Plan: Kianga Creek

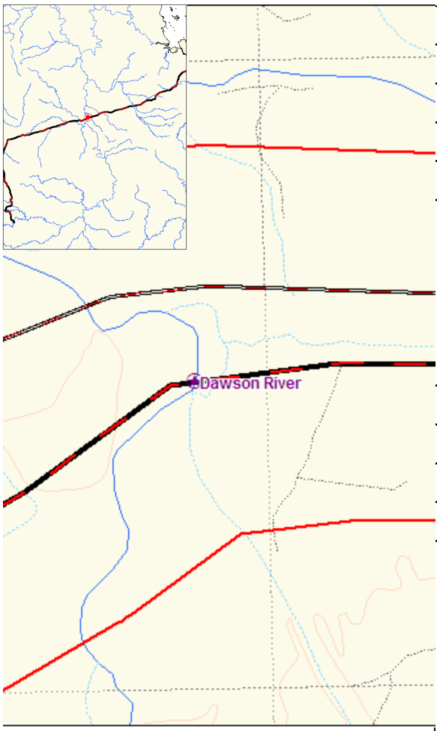
Photo: Looking Upstream

LNG transmission pipeline – Surface Water Assessment	
Location No.	**7**
Location Name	**Kianga Creek**
Easting:	793,338
Northing:	7,295,964
Site Description: *Kianga Creek is located to the north of the small town of Moura. The dry stream has several undulating low flow channels. The channels have a silty bottom whilst the higher flow areas have short grass and trees.*	
Channel Depth:	*1.5m*
Channel Width:	*2m*
Floodplain Slope:	*L 1:220, R 1:94*
Bank Slope:	*LB 1:17, RB 1:13*
Channel Banks: Both left and right banks appear moderately unstable, with 30 – 60% of reaches with evidence of bank erosion. The banks are stepped, convex is shape and steep in nature. The flat steps of the bank are sparsely vegetated with grass and a scatter of small trees.	
Substrate Type: The bed substrate is moderately compacted with a high percentage of fines making it predominately framework diluted. The predominate particle size is a well rounded silt.	
Channel Bed: The multistage channel has a low flow channel approximately 2m wide with a shallow undulating silty bed. There is moderate erosion with signs of channel deepening. The channel sinuosity is good with bends increasing the stream length by 2 to 3 times.	
Water Quality: No water present, no assessment undertaken	
Floodplain: Grazed pasture.	

Catchment Size:	*551km²*		
Channel Slope:	*1 m/km*		
Catchment Storage: Well defined system of small watercourses.			
Catchment Relief: Flat, with slopes of 0 - 1.5%			
	Q2	Q10	Q100
Flow	$53m^3/s$	$432m^3/s$	$1,692m^3/s$
Depth	2.4m	2.9m	3.6m

Cross Section Kianga Creek





Plan: Dawson River

Photo: Looking Upstream

LNG transmission pipeline – Surface Water Assessment

Location No.	**8**
Location Name	**Dawson Creek (DS)**
Easting:	789,172
Northing:	7,294,985

Site Description: *The downstream crossing of the Dawson River is located to the north west of the small town of Moura. The major watercourse has pooling stagnant water, large log jams and sand bars. The left bank is steep and has signs of erosion.*

Channel Depth:	*13m*
Channel Width:	*20m*
Floodplain Slope:	*L 1:5, R 1:20*
Bank Slope:	*LB 12:1, RB 1:4*

Channel Banks: Both left and right banks have poor stability, many eroded areas, even along straight reaches. The banks are concave in shape and have almost vertical banks along some sections. The steep banks are vegetated with long grassy clumps, whilst the more moderately sloped banks have more consistent grass vegetation and mature trees.

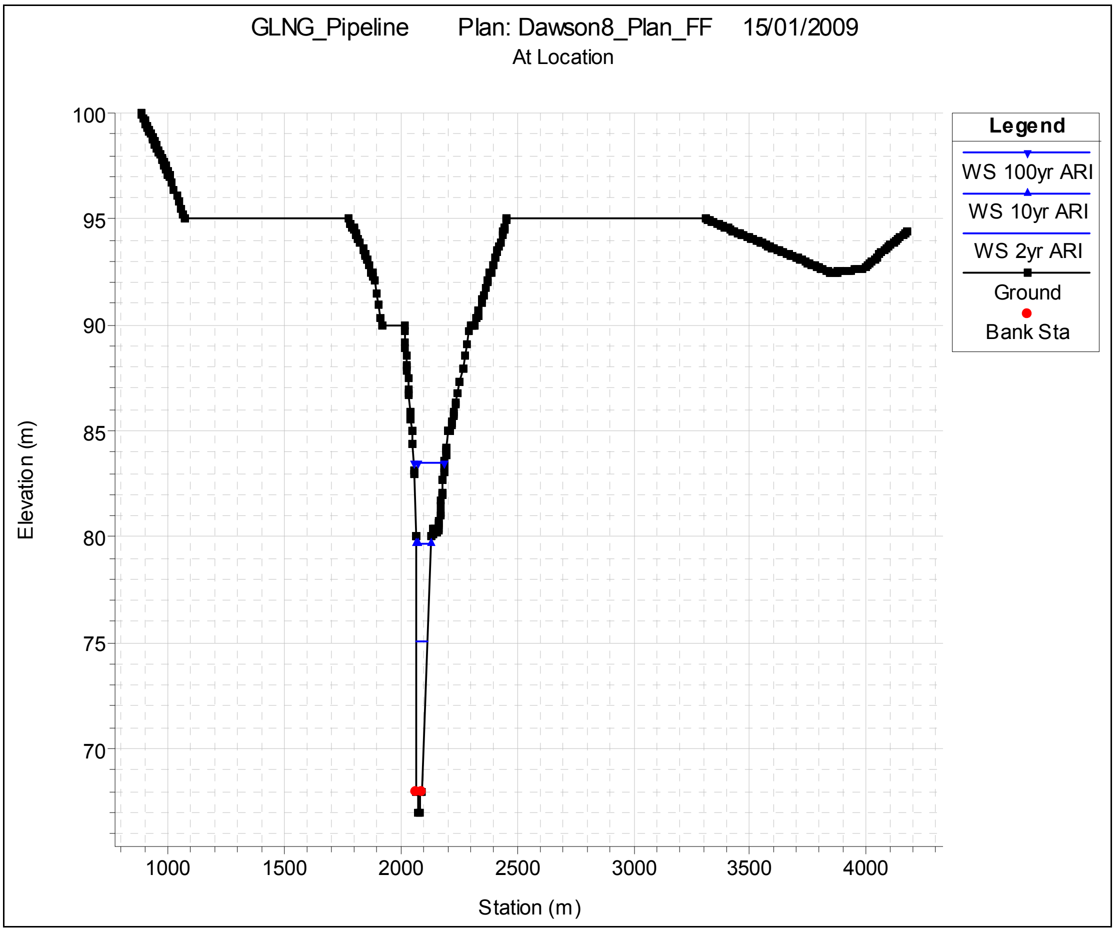
Substrate Type: The bed substrate is of low compaction with a high percentage of fines making it predominately framework diluted. The pre-dominate particle size is a clay like silt.

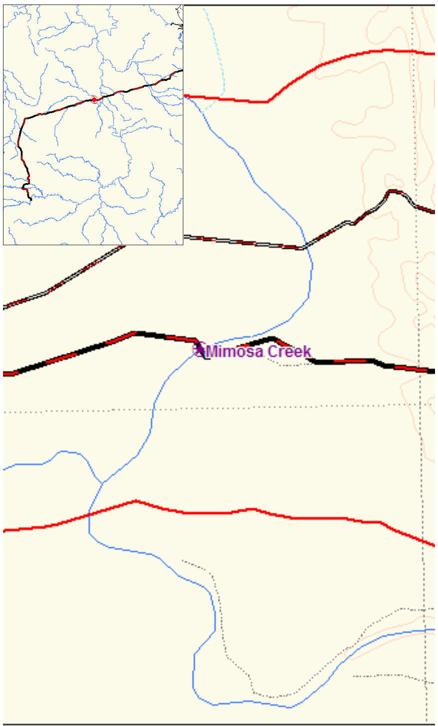
Channel Bed: The multistage channel has a low flow channel approximately 4m wide with a shallow reasonably flat silty clay bed. There is several log jams and rotting debris. The channel sinuosity is fair with bends increasing the stream length by 1 to 2 times.

Water Quality: The stagnant water appeared to have no sediment, water oils or odour. It is slightly turbid in nature and light brown in colour. A slight algae growth near the bed of the watercourse was noted.

Floodplain: Grazed pasture.			
Catchment Size:	*32,735km²*		
Channel Slope:	*0.5 m/km*		
Catchment Storage: Well defined system of small watercourses.			
Catchment Relief: Flat, with slopes of 0 - 1.5%			
	Q2	Q10	Q100
Flow	$448m^3/s$	$1,200m^3/s$	$2,354m^3/s$
Depth	8.1m	12.6m	16.5m

Cross Section Dawson Creek





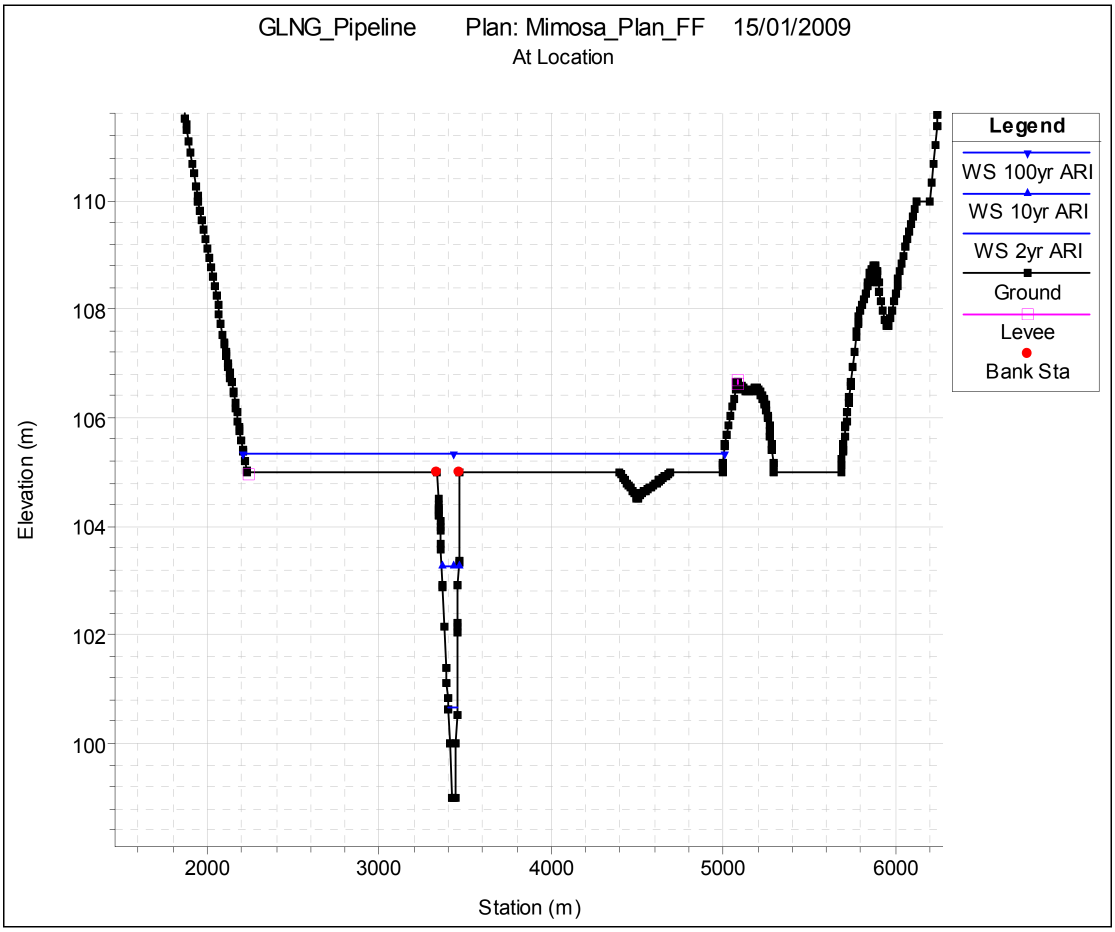
Plan: Mimosa Creek

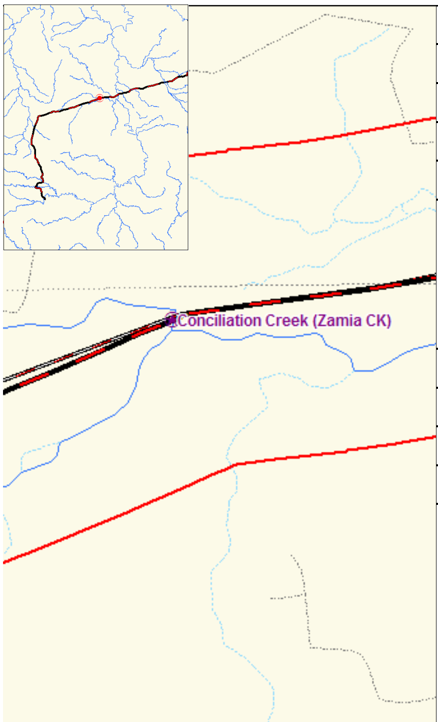
Photo: Looking Upstream

LNG transmission pipeline – Surface Water Assessment	
Location No.	**9**
Location Name	**Mimosa Creek**
Easting:	778,391
Northing:	7,291,707
Site Description: *Mimosa Creek is located to the north west of the small town of Banana. The flat 'U' shaped channel has a flat sandy bed with grassed and tree lined banks.*	
Channel Depth:	*6m*
Channel Width:	*20m*
Floodplain Slope:	*LB 1:55, RB 1:76*
Bank Slope:	*LB 1:5, RB 1:2*
Channel Banks: Both left and right banks appear stable, with only localised erosion. The right bank is convex in shape and moderately steep, whilst the left bank is stepped and has only a low slope angle. The flat sloped banks are vegetated with long grass and a scatter of tall mature trees.	
Substrate Type: The bed substrate is of low compaction with a high percentage of fines making it predominately matrix dominated. The predominate particle size is a sand with some finer silts.	
Channel Bed: The flat 'U' shaped channel has a wide flat sandy bed with a scattering of short grass. Areas of bed erosion have filled with stagnant water. There is a moderate build up of fine sediments at obstructions and bars.	
Water Quality: The stagnant water appeared to have no sediment or water oils or odour. It is slightly turbid in nature and light brown in colour.	
Floodplain: Grazed bushland.	

Catchment Size:	*3,230km²*		
Channel Slope:	*3 m/km*		
Catchment Storage: Well defined system of small watercourses.			
Catchment Relief: Flat, with slopes of 0 - 1.5%			
	Q2	Q10	Q100
Flow	$90m^3/s$	$516m^3/s$	$1{,}784m^3/s$
Depth	1.7m	4.3m	6.4m

Cross Section Mimosa Creek



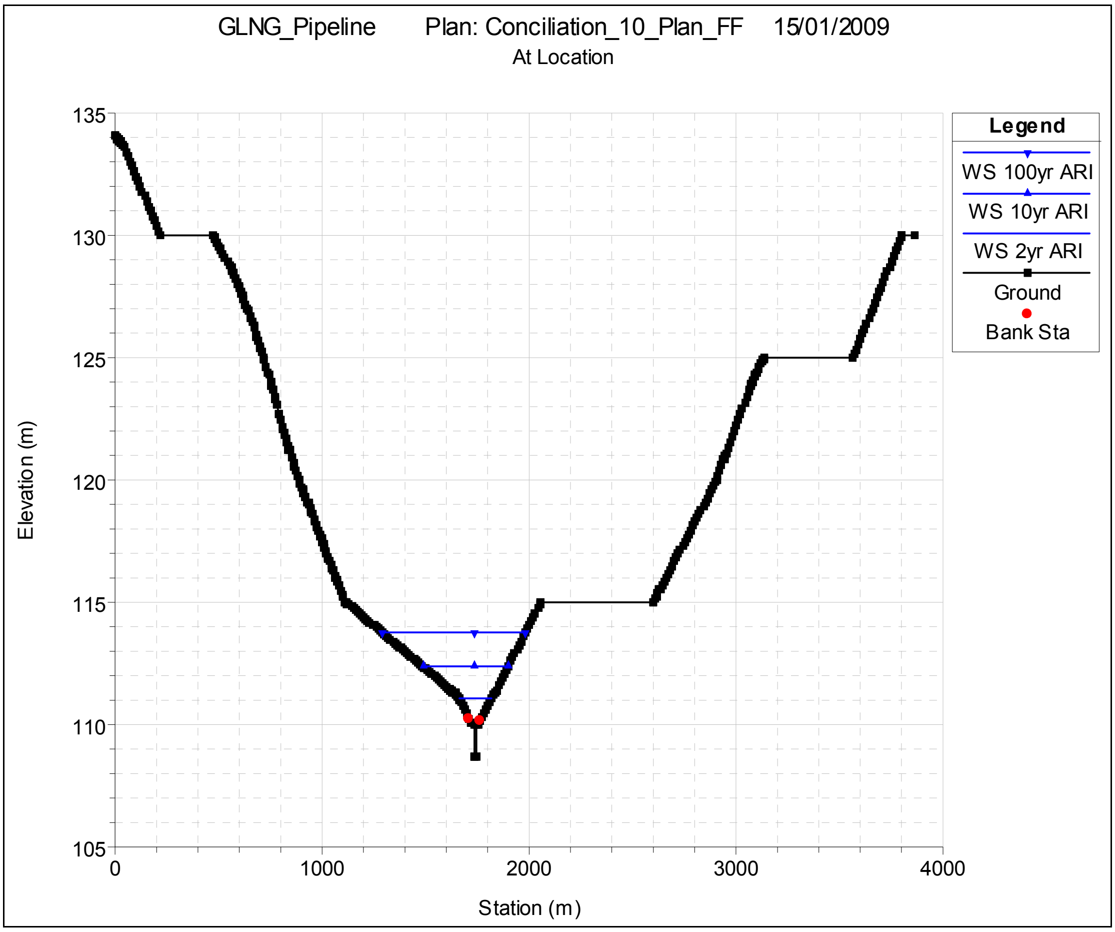


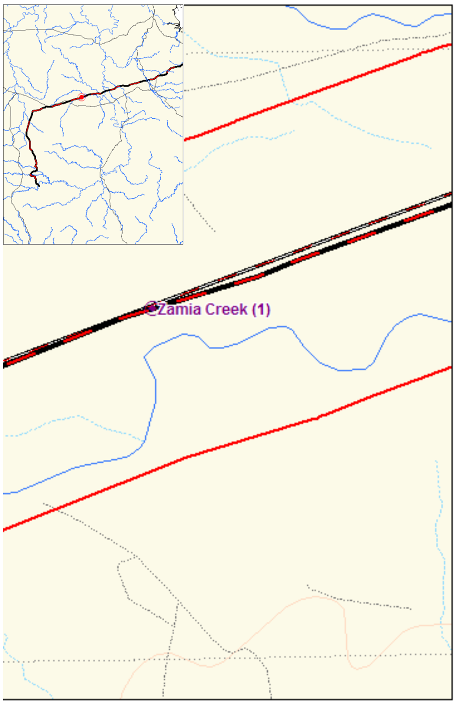
Plan: Conciliation Creek

LNG transmission pipeline – Surface Water Assessment	
Location No.	**10**
Location Name	**Conciliation Creek**
Easting:	755,517
Northing:	7,291,593
Site Description: *Access to Conciliation Creek was not possible during the organised field visit. Due to the close location of Zamia Creek the assessment was based on observations at this site.*	
Channel Depth:	*1.3m*
Channel Width:	*5m*
Floodplain Slope:	*L 1:15, R 1:15*
Bank Slope:	*LB 1.3:1, RB 1.3:1*
Channel Banks: Both left and right banks appear stable, with only localised erosion. Additionally both banks are concave in shape and moderately steep. The bank faces are bare of vegetation, whilst the top of bank have a combination of long grass and small yet mature trees.	
Substrate Type: The bed substrate is of moderate compaction with a high percentage of fines. The predominate particle size is a clay.	
Channel Bed: The flat 'U' shaped channel has a wide flat silty clay bed. The dry bed surface is cracking from the dry weather. The bed is moderately eroded which is predominately from livestock. The channel sinuosity increases the stream length by 1 to 2 times.	
Water Quality: No water present, no assessment undertaken.	
Floodplain: Grazed pasture.	

Catchment Size:	*946km²*		
Channel Slope:	*1.5 m/km*		
Catchment Storage: Well defined system of small watercourses.			
Catchment Relief: Flat, with slopes of 0 - 1.5%			
	Q2	Q10	Q100
Flow	$62m^3/s$	$456m^3/s$	$1,720m^3/s$
Depth	2.4m	3.7m	5.1m

Cross Section Conciliation Creek





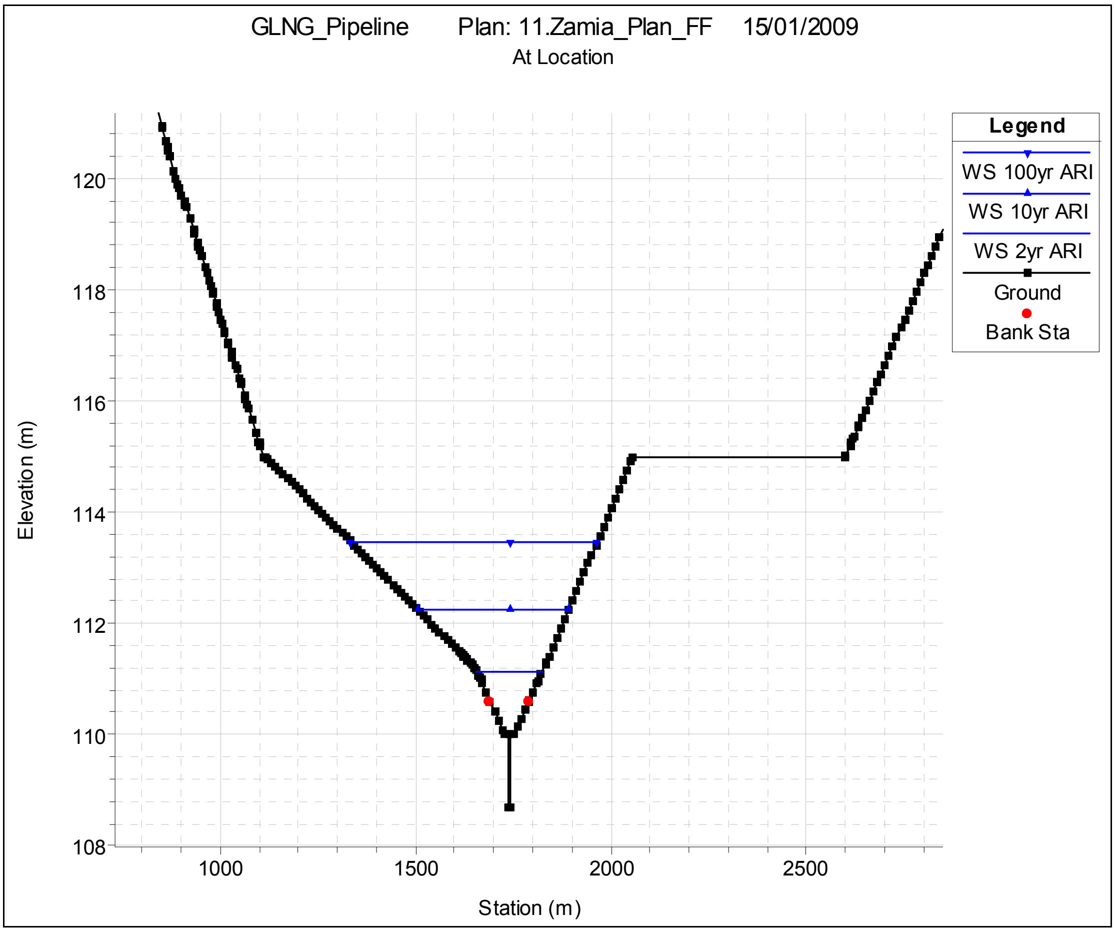
Plan: Zamia Creek

Photo: Looking Upstream

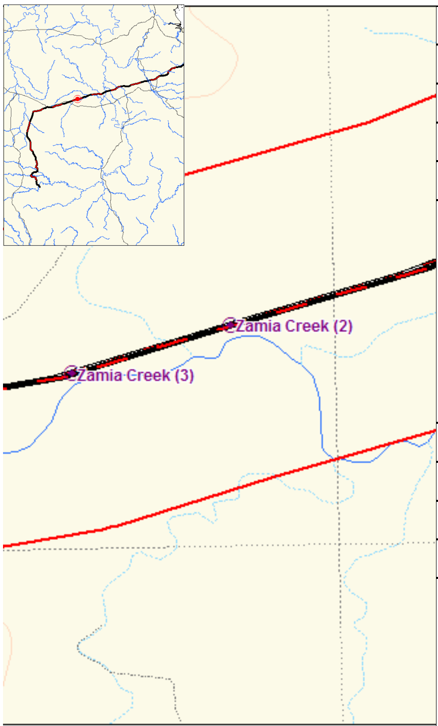
LNG transmission pipeline – Surface Water Assessment	
Location No.	**11**
Location Name	**Zamia Creek**
Easting:	755,085
Northing:	7,285,320
Site Description: *The ephemeral Zamia Creek has a flat 'U' shaped channel blocked with tree debris and leaf litter. The survey was undertaken close to the roadway, with the crossing location being inaccessible. Therefore the same field information has been used for all 4 Zamia Creek crossing locations.*	
Channel Depth:	*1.3m*
Channel Width:	*5m*
Floodplain Slope:	*L 1:124, R 1:64*
Bank Slope:	*LB 1.3:1, RB 1.3:1*
Channel Banks: Both left and right banks appear stable, with only localised erosion. Additionally both banks are concave in shape and moderately steep. The bank slopes are bare of vegetation, whilst the top of bank have a combination of long grass and small yet mature trees.	
Substrate Type: The bed substrate is of moderate compaction with a high percentage of fines. The predominate particle size is a clay.	
Channel Bed: The flat 'U' shaped channel has a wide flat silty clay bed. The dry bed surface is cracking from the dry weather. The bed is moderately eroded from livestock. The channel sinuosity increases the stream length by 1 to 2 times.	
Water Quality: No water present, no assessment undertaken.	
Floodplain: Grazed pasture.	

Catchment Size:	*2,590km^2*		
Channel Slope:	*3 m/km*		
Catchment Storage: Well defined system of small watercourses.			
Catchment Relief: Flat, with slopes of 0 - 1.5%			
	Q2	Q10	Q100
Flow	85m^3/s	505m^3/s	1,772m^3/s
Depth	2.4m	3.5m	4.8m

Cross Section Zamia Creek (1)



LNG transmission pipeline – Surface Water Assessment	
Location No.	**12**
Location Name	**Zamia Creek**
Easting:	748,498
Northing:	7,283,069
Site Description: *The ephemeral Zamia Creek has a flat 'U' shaped channel blocked with tree debris and leaf litter. The survey was undertaken close to the roadway, with the crossing location being inaccessible. Therefore the same field information has been used for all 4 Zamia Creek crossing locations.*	
Channel Depth:	*1.3m*
Channel Width:	*5m*
Floodplain Slope:	*L 1:40, R 1:185*
Bank Slope:	*LB 1.3:1, RB 1.3:1*
Channel Banks: Both left and right banks appear stable, with only localised erosion. Additionally both banks are concave in shape moderately steep. The bank slopes are bare of vegetation, whilst the top of bank have a combination of long grass and small yet mature trees.	
Substrate Type: The bed substrate is of moderate compaction with a high percentage of fines. The predominate particle size is a clay.	
Channel Bed: The flat 'U' shaped channel has a wide flat silty clay bed. The dry bed surface is cracking from the dry weather. The bed is moderately eroded which is predominately from livestock. The channel sinuosity increases the stream length by 1 to 2 times.	
Water Quality: No water present, no assessment undertaken.	
Floodplain: Grazed pasture.	

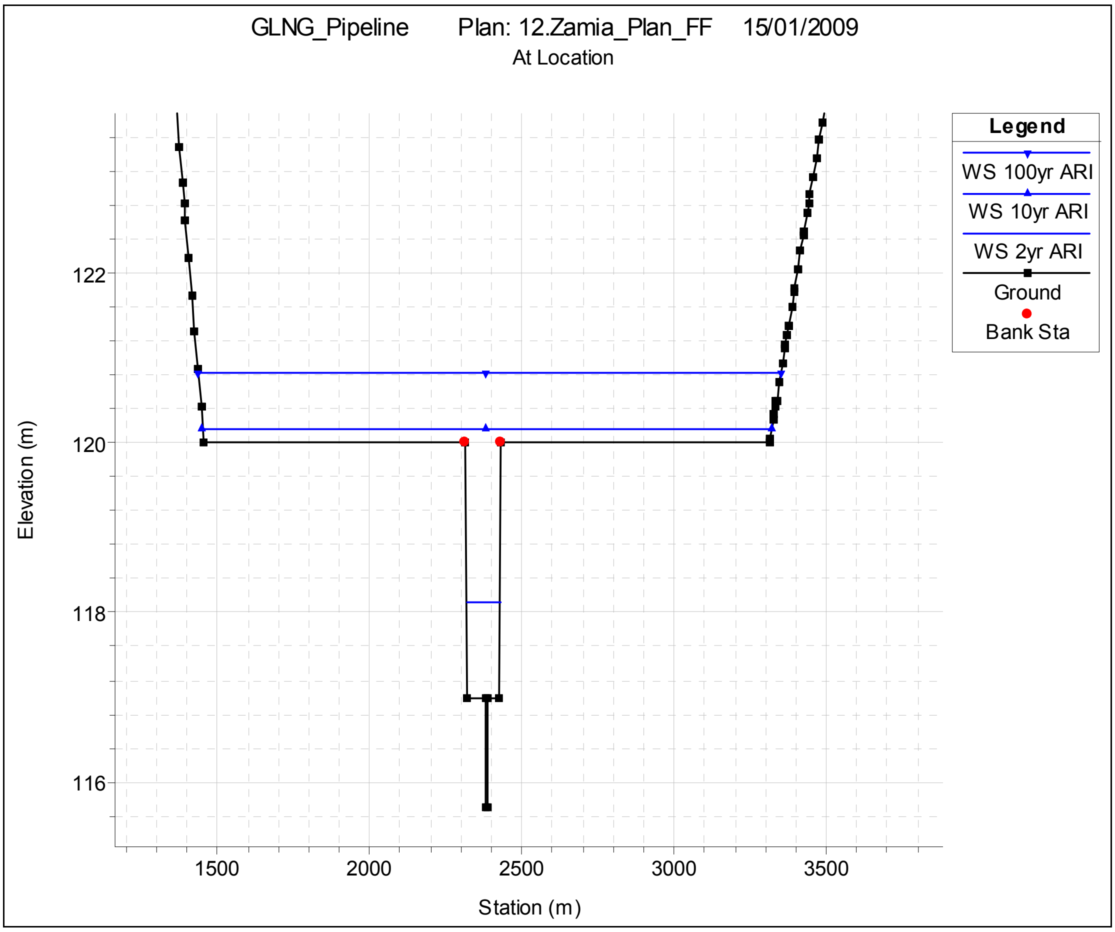


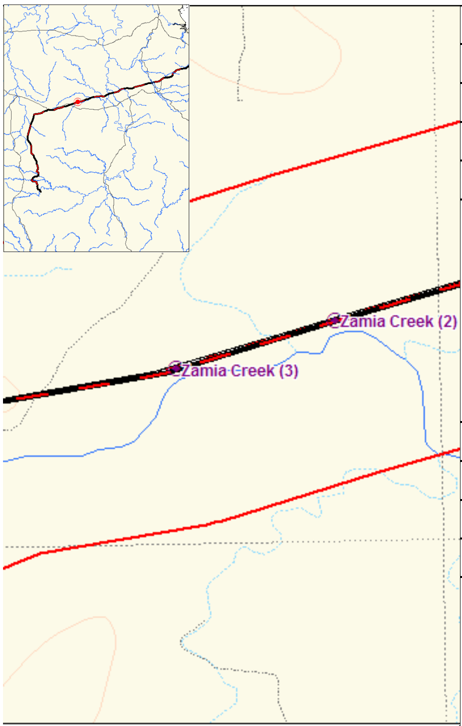
Plan: Zamia Creek

Photo: Looking Upstream

Catchment Size:	*2,075km²*		
Channel Slope:	*3 m/km*		
Catchment Storage: Well defined system of small watercourses.			
Catchment Relief: Flat, with slopes of 0 - 1.5%			
	Q2	Q10	Q100
Flow	$79m^3/s$	$494m^3/s$	$1,761m^3/s$
Depth	2.4m	4.5m	5.1m

Cross Section Zamia Creek (2)





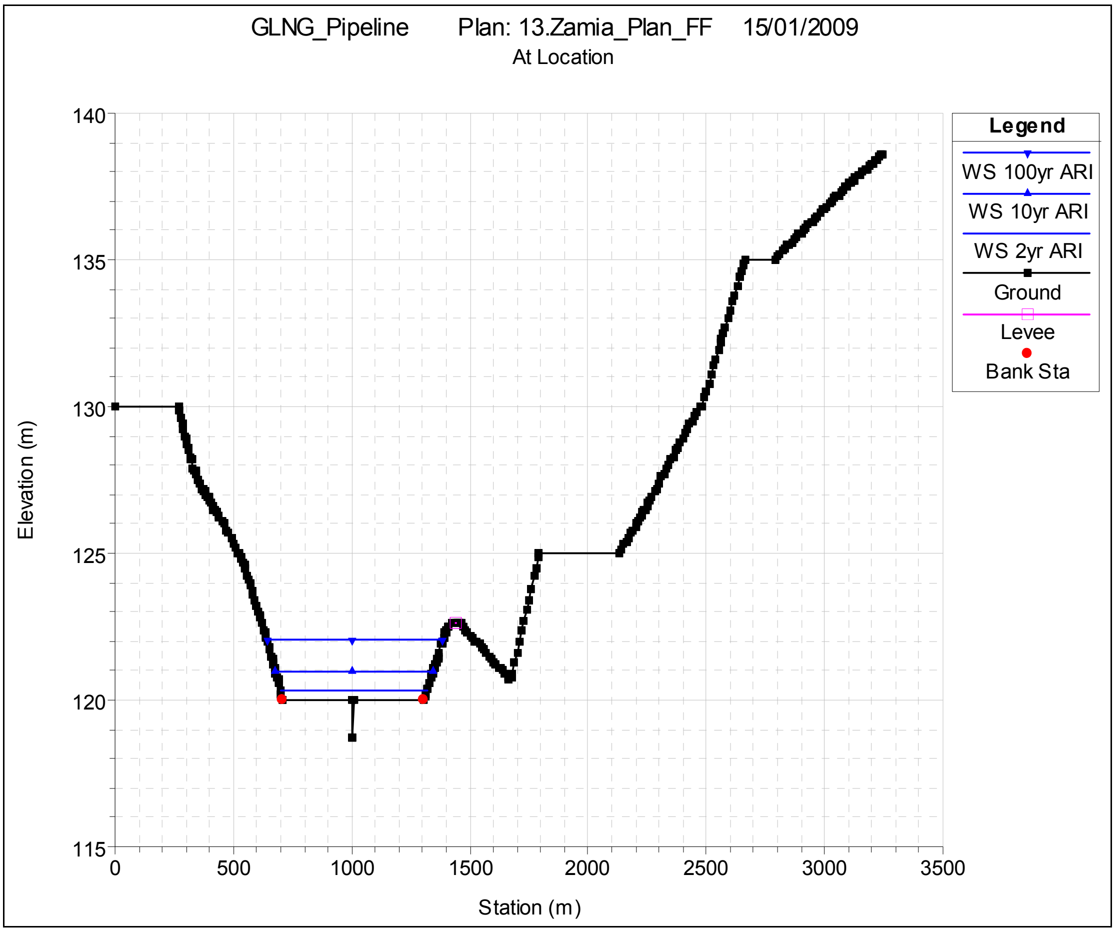
Plan: Zamia Creek

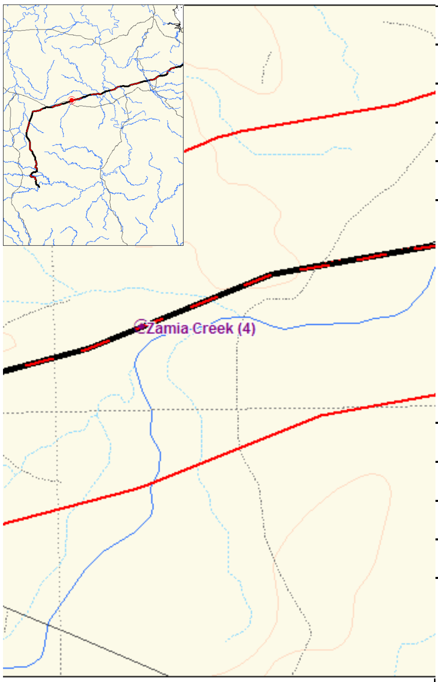
Photo: Looking Upstream

LNG transmission pipeline – Surface Water Assessment	
Location No.	**13**
Location Name	**Zamia Creek**
Easting:	755,085
Northing:	7,285,320
Site Description: *The ephemeral Zamia Creek has a flat 'U' shaped channel with tree debris and leaf litter. The survey was undertaken close to the roadway, with the crossing location being inaccessible. Therefore the same field information has been used for all 4 Zamia Creek crossing locations..*	
Channel Depth:	*1.3m*
Channel Width:	*5m*
Floodplain Slope:	*L 1:45, R 1:50*
Bank Slope:	*LB 1.3:1, RB 1.3:1*
Channel Banks: Both left and right banks appear stable, with only localised erosion. Additionally both banks are concave in shape moderately steep. The bank slopes are bare of vegetation, whilst the top of bank have a combination of long grass and small yet mature trees.	
Substrate Type: The bed substrate is of moderate compaction with a high percentage of fines. The predominate particle size is a clay.	
Channel Bed: The flat 'U' shaped channel has a wide flat silty clay bed. The dry bed surface is cracking from the dry weather. The bed is moderately eroded from livestock. The channel sinuosity increases the stream length by 1 to 2 times.	
Water Quality: No water present, no assessment undertaken.	
Floodplain: Grazed pasture.	

Catchment Size:	*2,025km²*		
Channel Slope:	*3 m/km*		
Catchment Storage: Well defined system of small watercourses.			
Catchment Relief: Flat, with slopes of 0 - 1.5%			
	Q2	Q10	Q100
Flow	$79m^3/s$	$492m^3/s$	$1,756m^3/s$
Depth	1.6m	2.3m	3.3m

Cross Section Zamia Creek (3)





Plan: Zamia Creek

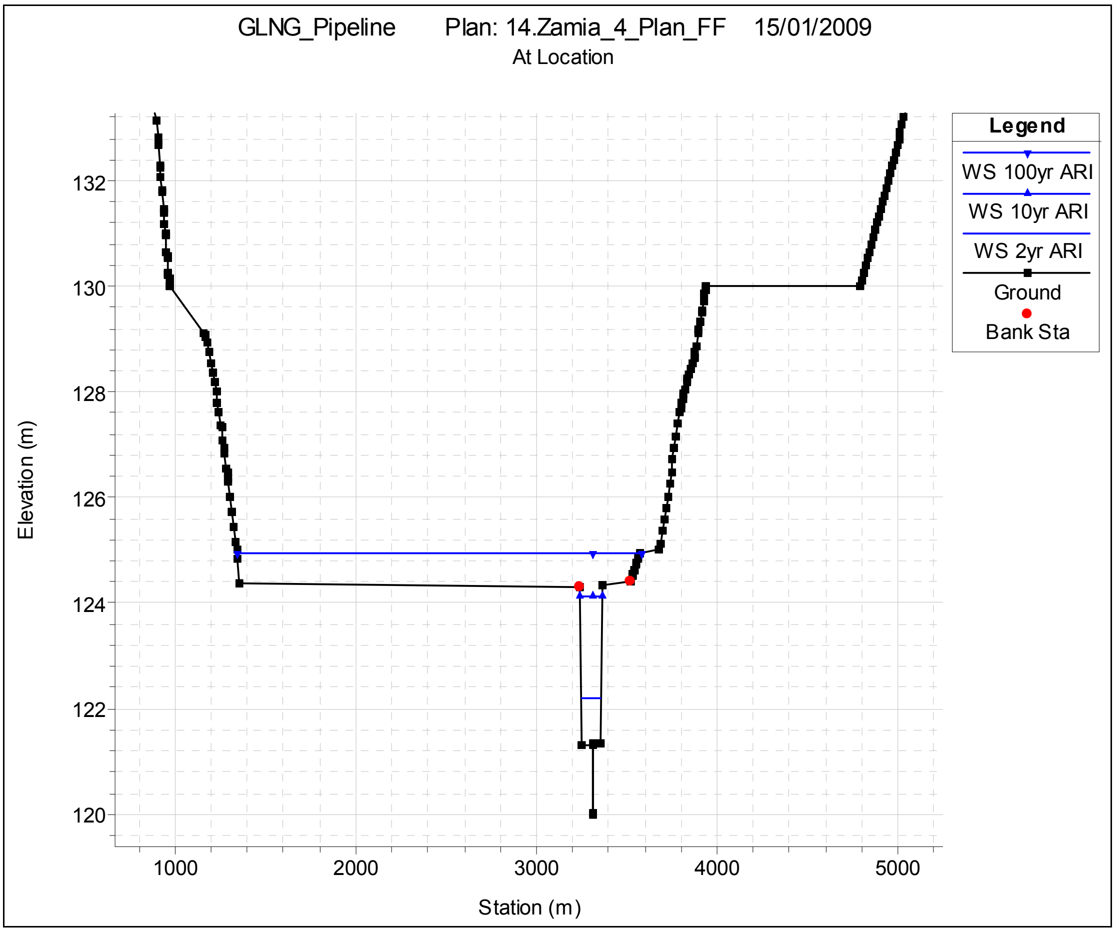
Photo: Looking Upstream

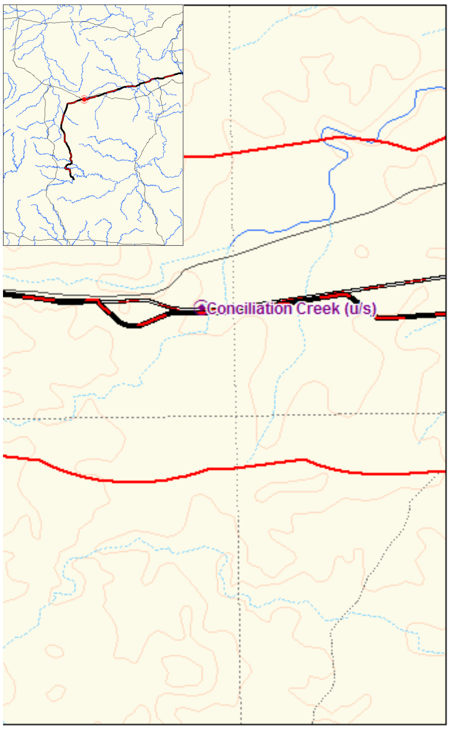
LNG transmission pipeline – Surface Water Assessment	
Location No.	**14**
Location Name	**Zamia Creek**
Easting:	741,373
Northing:	7,281,409
Site Description: *The ephemeral Zamia Creek has a flat 'U' shaped channel with tree debris and leaf litter. The survey was undertaken close to the roadway, with the crossing location being inaccessible. Therefore the same field information has been used for all 4 Zamia Creek crossing locations.*	
Channel Depth:	*1.3m*
Channel Width:	*5m*
Floodplain Slope:	*L 1:45, R 1:50*
Bank Slope:	*LB 1.3:1, RB 1.3:1*
Channel Banks: Both left and right banks appear stable, with only localised erosion. Additionally both banks are concave in shape moderately steep. The bank slopes are bare of vegetation, whilst the top of bank have a combination of long grass and small yet mature trees.	
Substrate Type: The bed substrate is of moderate compaction with a high percentage of fines. The predominate particle size is a clay.	
Channel Bed: The flat 'U' shaped channel has a wide flat silty clay bed. The dry bed surface is cracking from the dry weather. The bed is moderately eroded from livestock. The channel sinuosity increases the stream length by 1 to 2 times.	
Water Quality: No water present, no assessment undertaken.	
Floodplain: Grazed pasture.	

Catchment Size:	*1,966km²*		
Channel Slope:	*3 m/km*		
Catchment Storage: Well defined system of small watercourses.			
Catchment Relief: Flat, with slopes of 0 - 1.5%			
	Q2	Q10	Q100
Flow	$78m^3/s$	$491m^3/s$	$1,758m^3/s$
Depth	2.2m	4.1m	5.0m

Photo: Looking Downstream

Cross Section Zamia Creek (4)



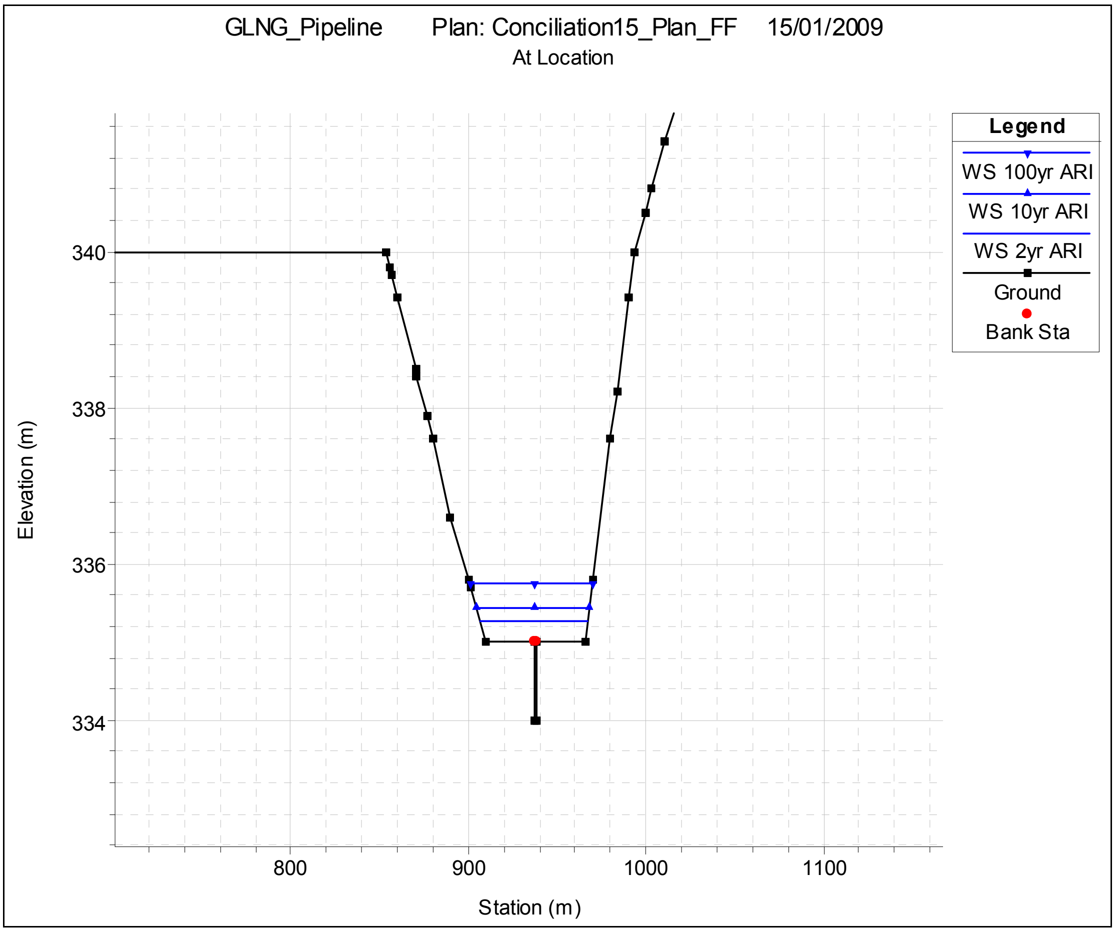


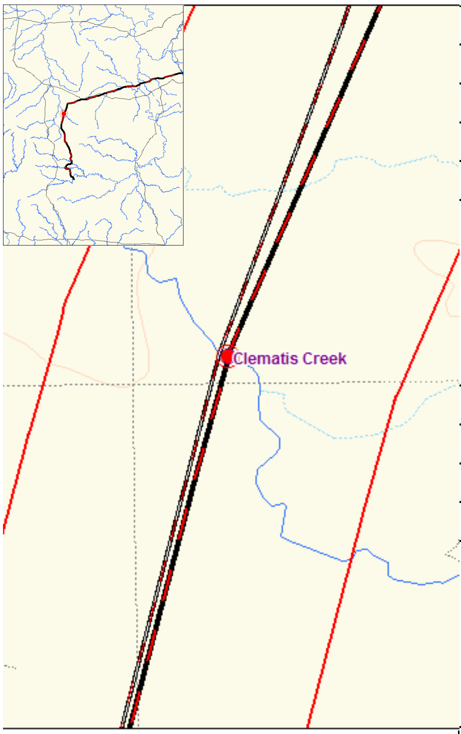
Plan: Conciliation Creek

LNG transmission pipeline – Surface Water Assessment	
Location No.	**15**
Location Name	**Conciliation Creek**
Easting:	764,493
Northing:	7,289,593
Site Description: *Access to Conciliation Creek was not possible during the organised field visit. Due to the close location of Zamia Creek the assessment was based on observations at this site.*	
Channel Depth:	*1m*
Channel Width:	*1m*
Floodplain Slope:	*LB 1:15, RB 1:15*
Bank Slope:	*LB 1:1, RB 1:1*
Channel Banks: Both left and right banks appear stable, with only localised erosion. Additionally both banks are concave in shape and moderately steep. The bank slopes are bare of vegetation, whilst the top of bank have a combination of long grass and small yet mature trees.	
Substrate Type: The bed substrate is of moderate compaction with a high percentage of fines making. The predominate particle size is a clay.	
Channel Bed: The flat 'U' shaped channel has a wide flat silty clay bed. The dry bed surface is cracking from the dry weather. The bed is moderately eroded from livestock. The channel sinuosity increases the stream length by 1 to 2 times.	
Water Quality: No water present, no assessment undertaken.	
Floodplain: Grazed pasture.	

Catchment Size:	*11.5km^2*		
Channel Slope:	*25 m/km*		
Catchment Storage: Well defined system of small watercourses.			
Catchment Relief: Flat, with slopes of 0 - 1.5%			
	Q2	Q10	Q100
Duration	120min		
Intensity	23.5mm/hr	34mm/hr	52mm/hr
Flow	22m^3/s	51m^3/s	121m^3/s
Depth	1.3m	1.5m	1.8m

Cross Section Conciliation Creek



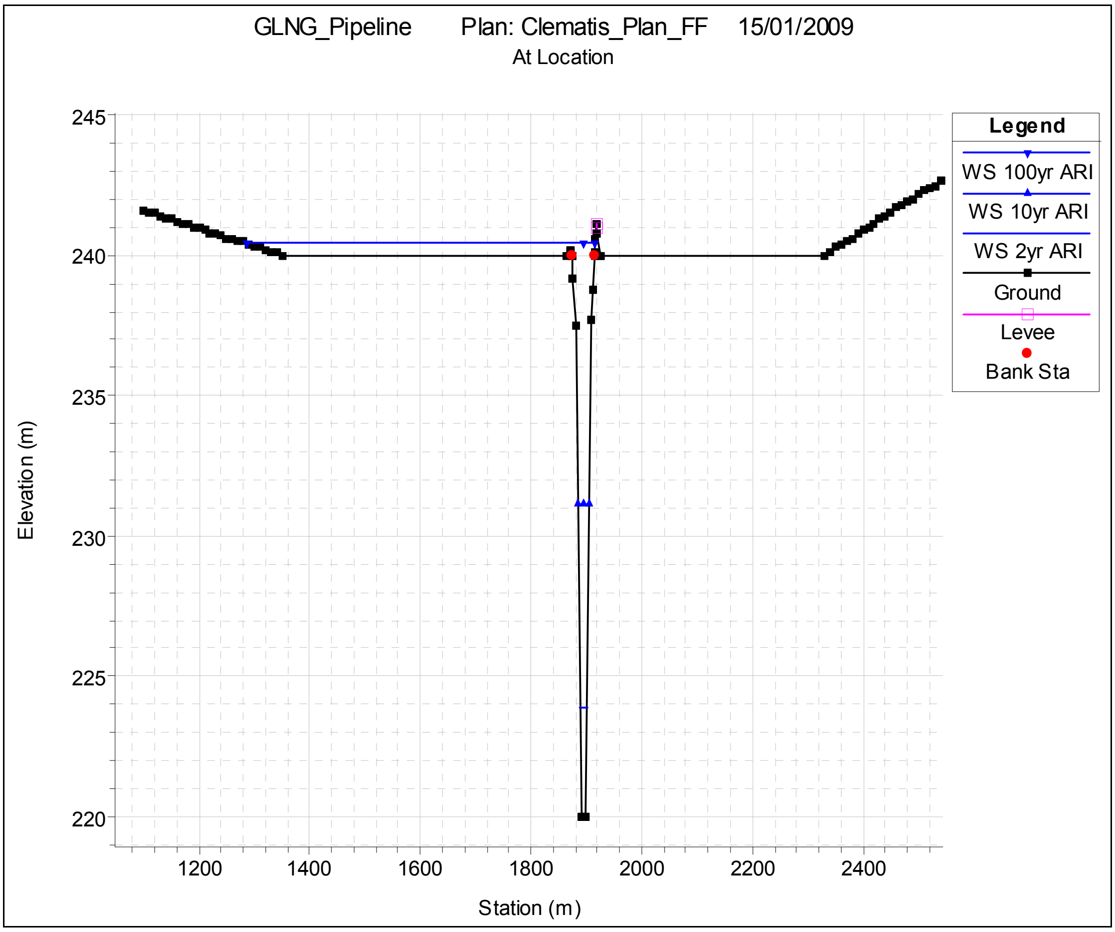


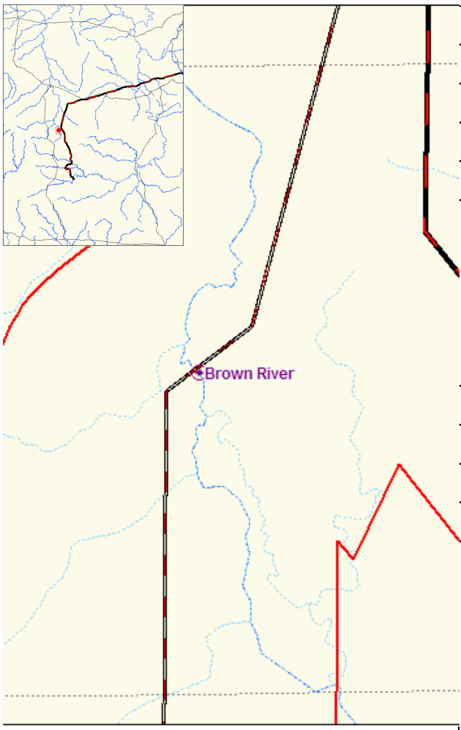
Plan: Clematis Creek

LNG transmission pipeline – Surface Water Assessment	
Location No.	**16**
Location Name	**Clematis Creek**
Easting:	681,223
Northing:	7,250,716
Site Description: *The ephemeral Clematis Creek has a deep 'V' shaped channel. Both banks are vegetated with long grass and large mature trees. The dry bed appears to have a sandy bottom. There was limited access to this crossing location.*	
Channel Depth:	*6m*
Channel Width:	*20m*
Floodplain Slope:	*L 1:480, R 1:90*
Bank Slope:	*LB 4:1, RB 4:1*
Channel Banks: Despite the steepness, both left and right banks appear stable, with only localised erosion. The bank shape is convex and the banks are well vegetated with long grass and mature trees.	
Substrate Type: The bed substrate is of low compaction with a high percentage of fines. The predominate particle size is a sand.	
Channel Bed: The flat 'V' shaped channel has a narrow flat sandy bed with a scattering of short grass. The bed appears stable from the survey location.	
Water Quality: There was no water present. No assessment was undertaken.	
Floodplain: Grazed pasture.	

Catchment Size:	*781km²*		
Channel Slope:	*3 m/km*		
Catchment Storage: Well defined system of small watercourses.			
Catchment Relief: Flat, with slopes of 0 - 1.5%			
	Q2	Q10	Q100
Flow	$59m^3/s$	$448m^3/s$	$1,710m^3/s$
Depth	3.9m	11.1m	20.5m

Cross Section Clematis Creek





Plan: Brown River

LNG transmission pipeline – Surface Water Assessment	
Location No.	**17**
Location Name	**Brown River**
Easting:	673,988
Northing:	7,225,119

Site Description: *The Brown River at the location of the proposed pipeline crossing could not be accessed. The survey location used for Arcadia Creek, approximately 30km upstream, has been adopted as the channel description.*

Channel Depth:	*2.5m*
Channel Width:	*3m*
Floodplain Slope:	*L 1:300, R 1:300*
Bank Slope:	*LB 2.5:2, RB 2.5:2*

Channel Banks: Both left and right banks appear unstable, with severe erosion located along both straight reaches and bends. The left bank was concave in shape whilst the right bank is convex. Small trees vegetate the lower banks, whilst long grass is located on the upper banks.

Substrate Type: The bed substrate is of moderate compaction with a high percentage of fines. The pre-dominate particle size is a silt.

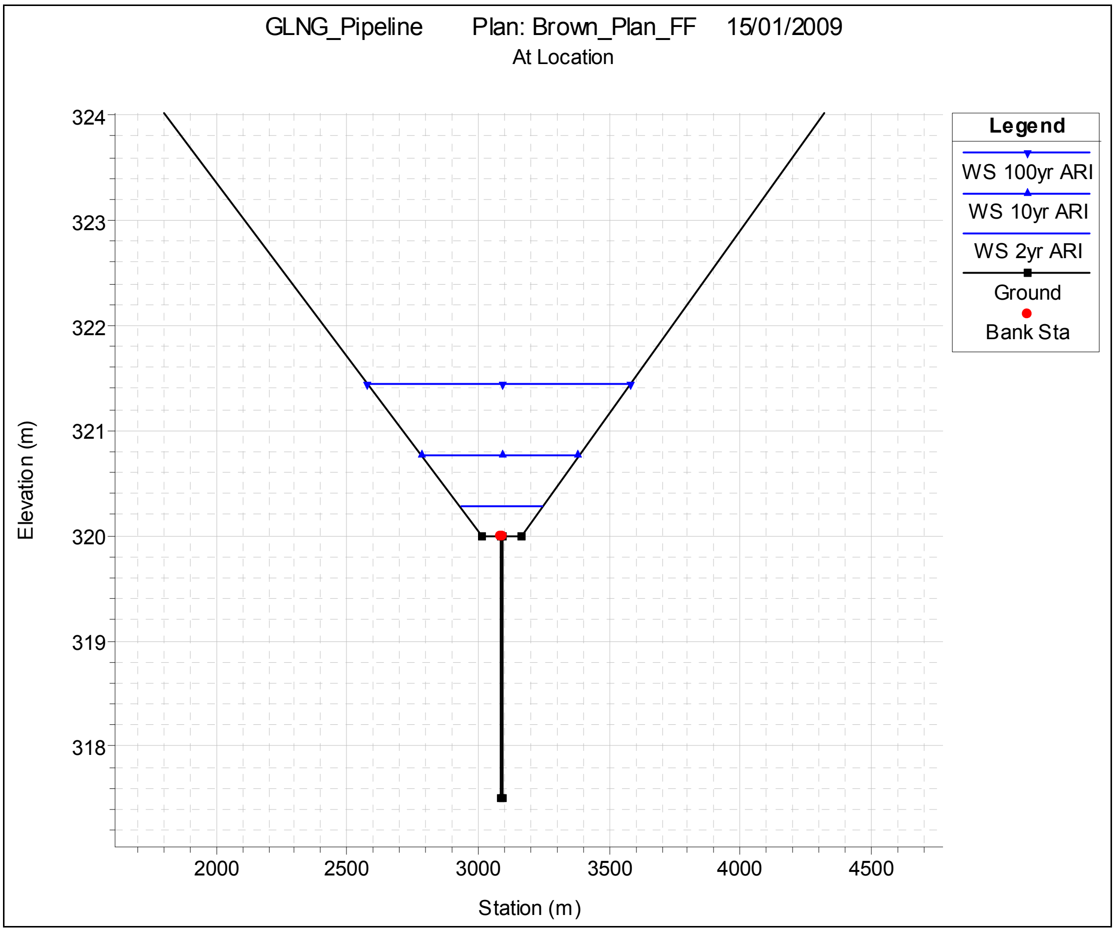
Channel Bed: The 'U' shaped channel has a narrow muddy bed. The bed appears stable, with no erosion, at the survey location. The channel sinuosity is moderate, and adds 2 to 3 times in length.

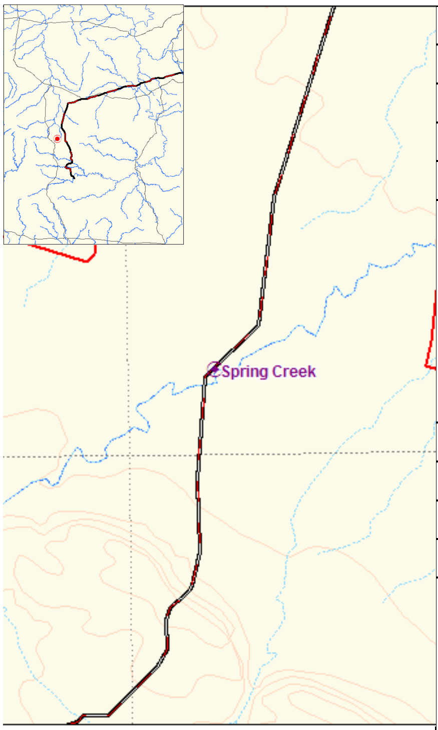
Water Quality: There was a slight oily sheen to the water however no sediment of water odours were detected. The water was slightly turbid and light brown in colour.

Floodplain: Grazed pasture.

Catchment Size:	*1,041km²*		
Channel Slope:	*5 m/km*		
Catchment Storage: Well defined system of small watercourses.			
Catchment Relief: Flat, with slopes of 0 - 1.5%			
	Q2	Q10	Q100
Flow	$64m^3/s$	$461m^3/s$	$1,724m^3/s$
Depth	2.8m	3.4m	4.1m

Cross Section Brown Creek





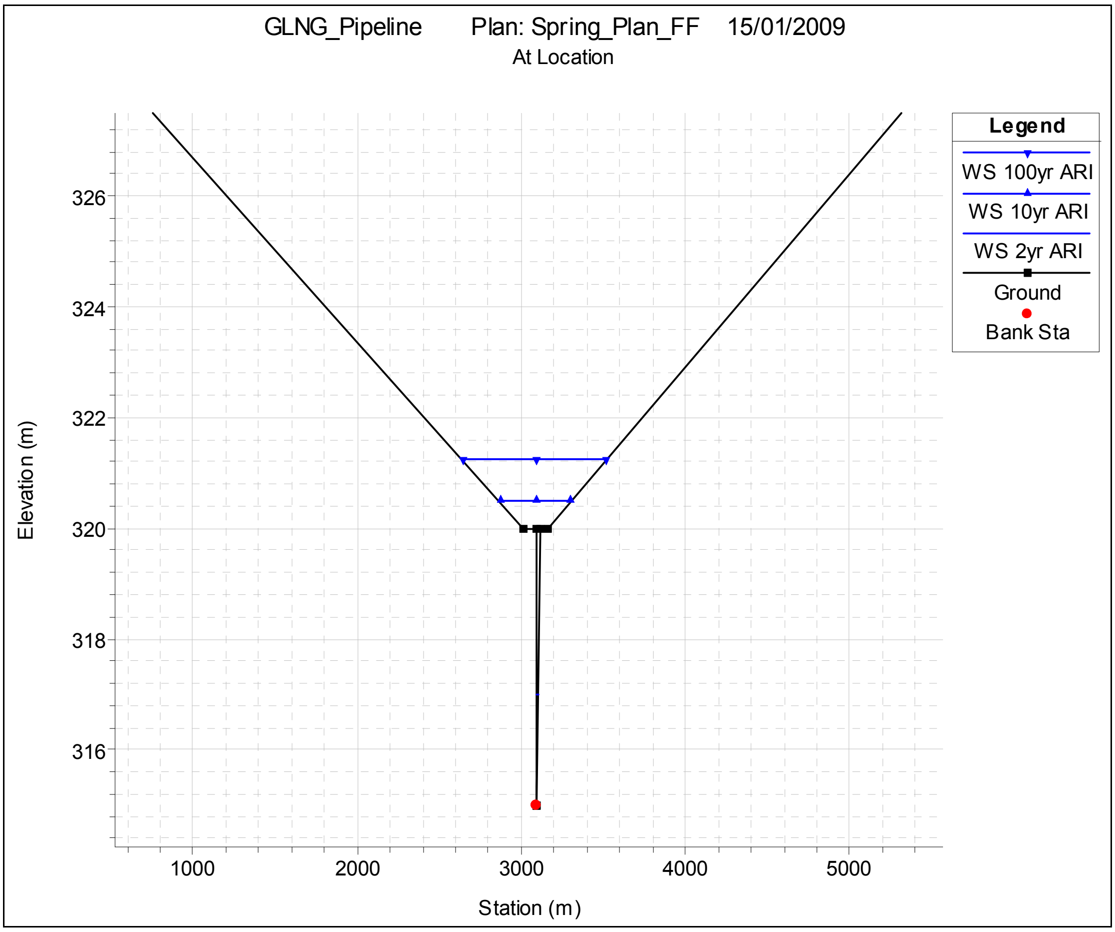
Plan: Spring Creek

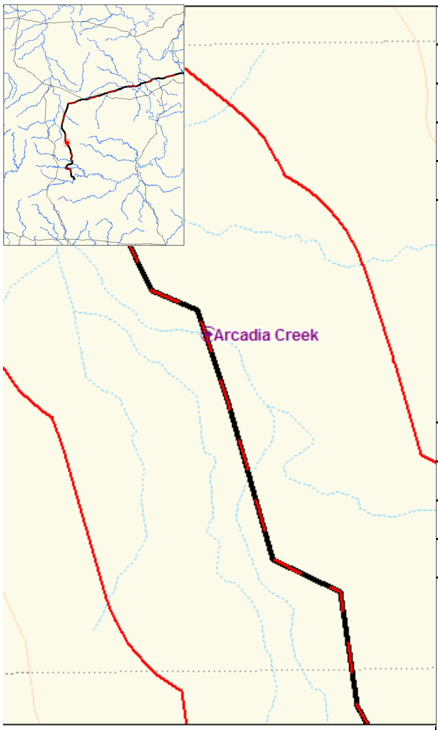
Photo: Looking Upstream

LNG transmission pipeline – Surface Water Assessment	
Location No.	**18**
Location Name	**Spring Creek**
Easting:	675,391
Northing:	7,213,322
Site Description: *The ephemeral Spring Creek has a deepened 'U' shaped channel. The narrow channel has a sandy cobbled bed with areas of both deposition and erosion. There was limited access to the crossing location, hence the site was assessed between two roadways.*	
Channel Depth:	*5m*
Channel Width:	*1m*
Floodplain Slope:	*L 1:300, R 1:300*
Bank Slope:	*LB 5:2, RB 1:5*
Channel Banks: Both left and right banks are concave in shape. The left bank has a steep slope whilst the right has a low slope. The steep left bank is heavily eroded and of poor stability. Mature trees flank both banks, with a sparse vegetation of grass.	
Substrate Type: The bed substrate is of low compaction with a mixture of fine and course sediment. The pre-dominate particle size is a sand, with cobbles along the downstream bed.	
Channel Bed: The deepened 'U' shaped channel has a narrow flat sandy bed with leaf debris upstream of the assessment location and cobbles downstream. The bed appears to be moderately eroded potentially from the nearby roadway runoff.	
Water Quality: There was no water present. No assessment was undertaken.	
Floodplain: Grazed pasture.	

Catchment Size:	*61km²*		
Channel Slope:	*8 m/km*		
Catchment Storage: Well defined system of small watercourses.			
Catchment Relief: Flat, with slopes of 0 - 1.5%			
	Q2	Q10	Q100
Flow	$27m^3/s$	$346m^3/s$	$1,583m^3/s$
Depth	2.0m	5.5m	6.3m

Cross Section Spring Creek





Plan: ArcadiaCreek

Photo: Looking Upstream

LNG transmission pipeline – Surface Water Assessment	
Location No.	**19**
Location Name	**Arcadia Creek**
Easting:	673,988
Northing:	7,225,119

Site Description: *Arcadia Creek is located within the Arcadia Valley, the location of the proposed pipeline crossing could not be accessed, and a roadside location was alternatively adopted. The small watercourse on the day of survey had approximately 0.25m deep, pooling water.*

Channel Depth:	*2.5m*
Channel Width:	*3m*
Floodplain Slope:	*L 1:25, R 1:65*
Bank Slope:	*LB 2.5:2, RB 2.5:2*

Channel Banks: Both left and right banks appear unstable, with severe erosion frequently located along both straight reaches and bends. The left bank was concave in shape whilst the right bank is convex. Small trees vegetate the lower banks, whilst long grass is located on the upper banks.

Substrate Type: The bed substrate is of moderate compaction with a high percentage of fines. The pre-dominate particle size is a silt.

Channel Bed: The ‘U’ shaped channel has a muddy bed. The bed appears stable at the survey location. The channel sinuosity is moderate and adds 2 to 3 times in length.

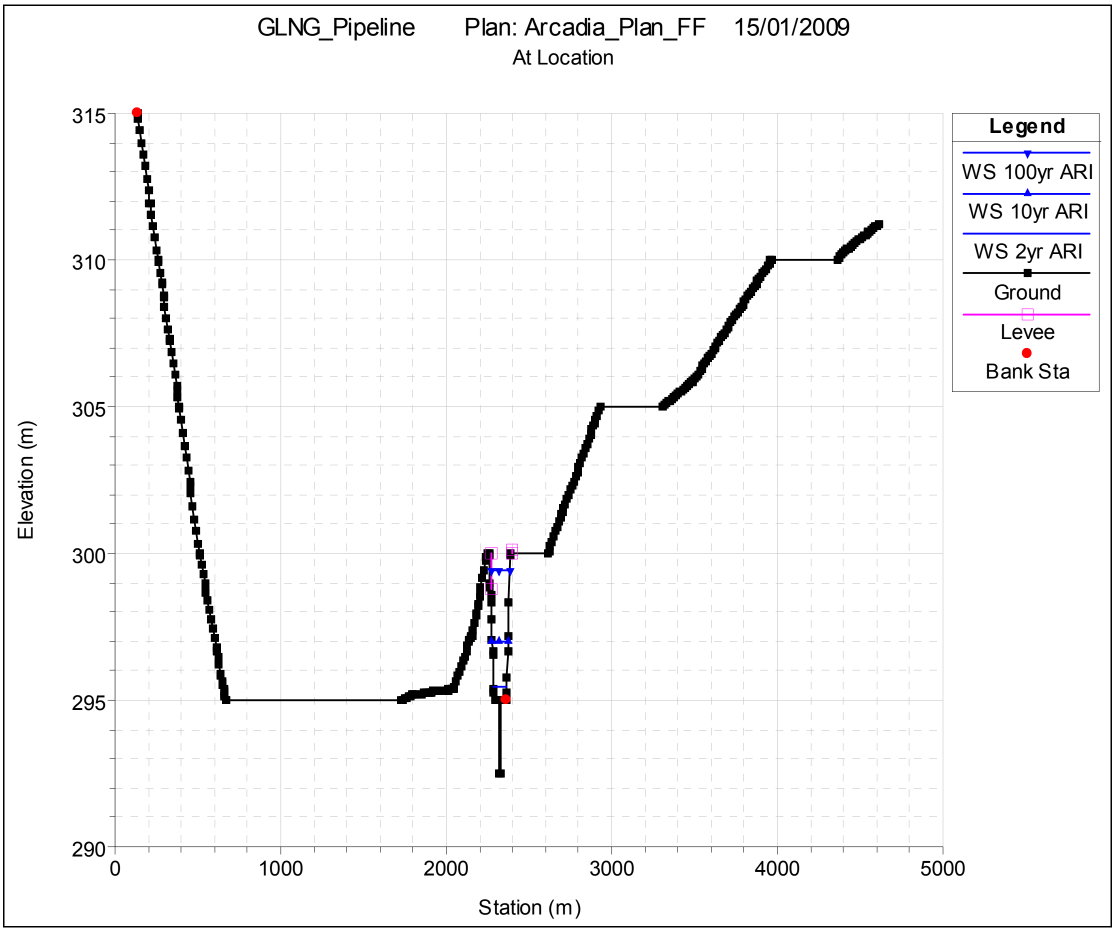
Water Quality: There was a slight oily sheen to the water however no sediment of water odours were detected. The water was slightly turbid and light brown in colour.

Floodplain: Grazed pasture.

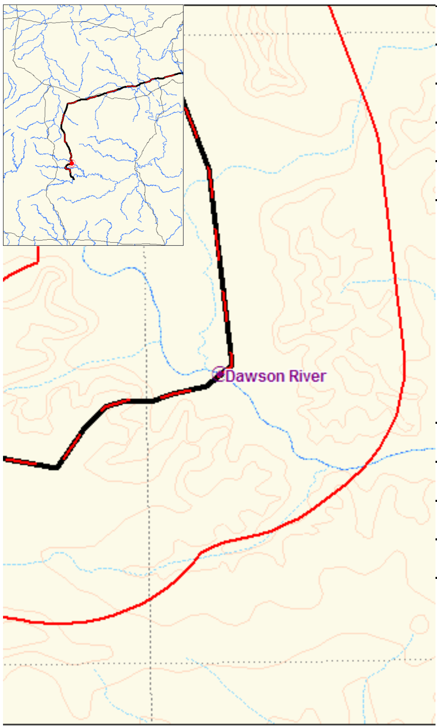
Catchment Size:	*369km²*		
Channel Slope:	*5 m/km*		
Catchment Storage: Well defined system of small watercourses.			
Catchment Relief: Flat, with slopes of 0 - 1.5%			
	Q2	Q10	Q100
Flow	47m^3/s	416m^3/s	1,673m^3/s
Depth	2.9m	4.5m	6.9m

Photo: Looking Downstream

Cross Section Arcadia Creek



LNG transmission pipeline – Surface Water Assessment	
Location No.	**20**
Location Name	**Dawson River**
Easting:	683,826
Northing:	7,179,197
Site Description: *This site of the Dawson River is located within the Lonesome National Park. The location of the proposed pipeline crossing was inaccessible; an assessment at the park's campground was alternatively adopted. The watercourse was dry, with a multilevel channel and heavily vegetated banks.*	
Channel Depth:	*226m*
Channel Width:	*42m*
Floodplain Slope:	*L 1:2, R 1:8*
Bank Slope:	*LB 1:1, RB 1:8*
Channel Banks: Both left and right banks appear stable, heavily vegetated with long grass and a scatter of small trees. Both left and right banks are convex in shape and have steep and moderately slopes respectively.	
Substrate Type: The bed substrate is of moderate compaction with a moderate percentage of fines. The pre-dominate particle size is a silty sands, with a scatter of cobbles.	
Channel Bed: The multi staged channel with a sandy bed. The bed appears stable from the survey location. The channel sinuosity is fair and adds 1 to 2 times in length.	
Water Quality: No water present, no assessment undertaken.	
Floodplain: Woodland.	

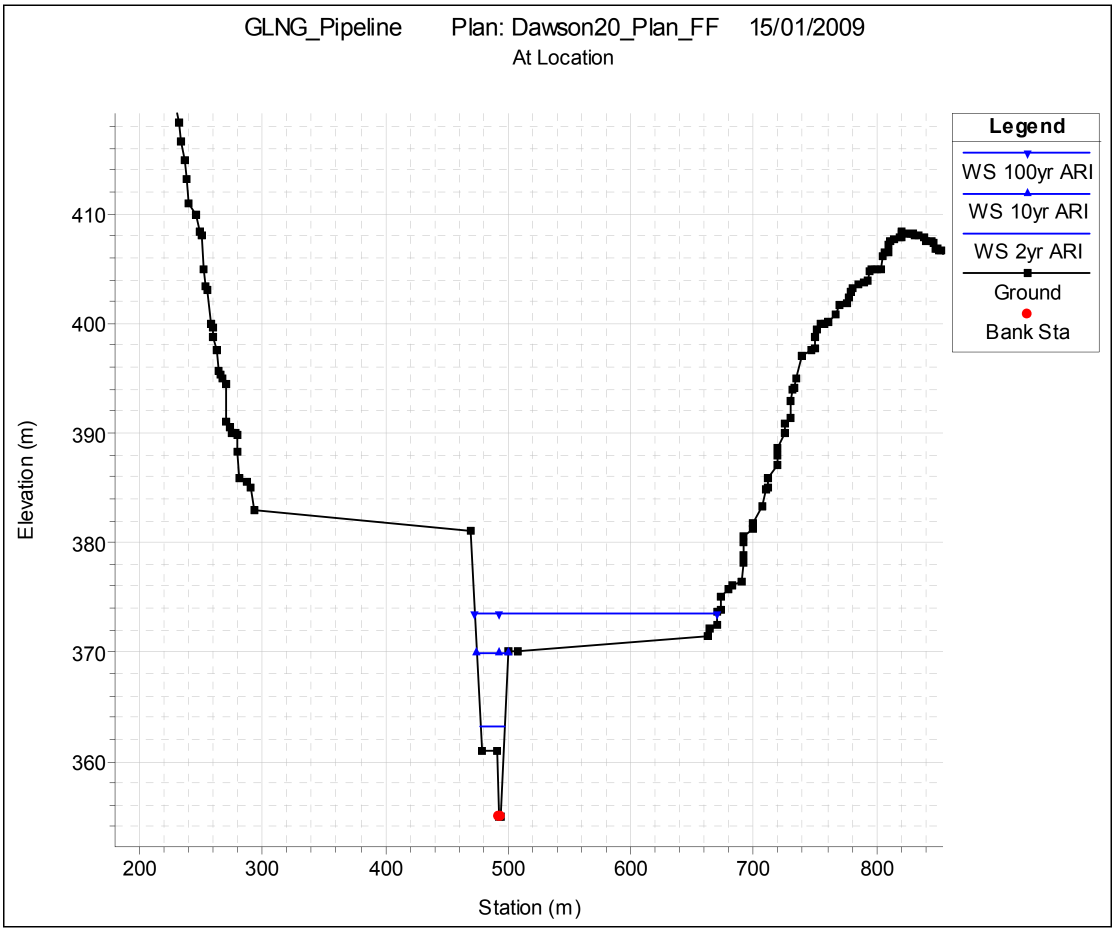


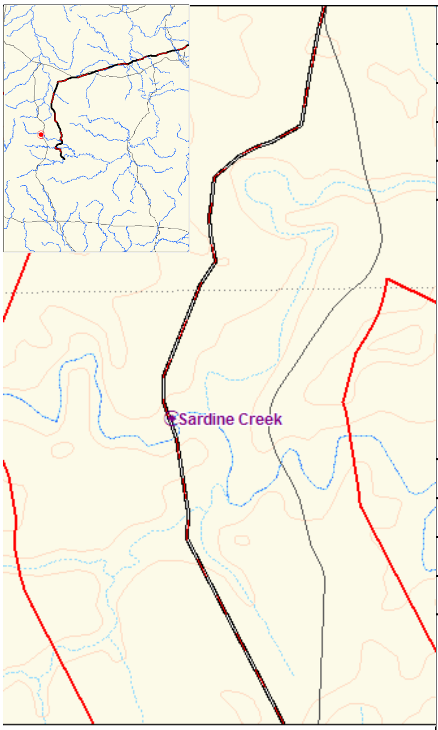
Plan: Dawson River (u/s)

Photo: Looking Downstream

Catchment Size:	*1,134km^2*		
Channel Slope:	*2 m/km*		
Catchment Storage: Well defined system of small watercourses.			
Catchment Relief: Flat, with slopes of 0 - 1.5%			
	Q2	Q10	Q100
Flow	117m^3/s	612m^3/s	1,990m^3/s
Depth	8.2m	14.9m	18.5m

Cross Section Dawson River





Plan: Sardine Creek

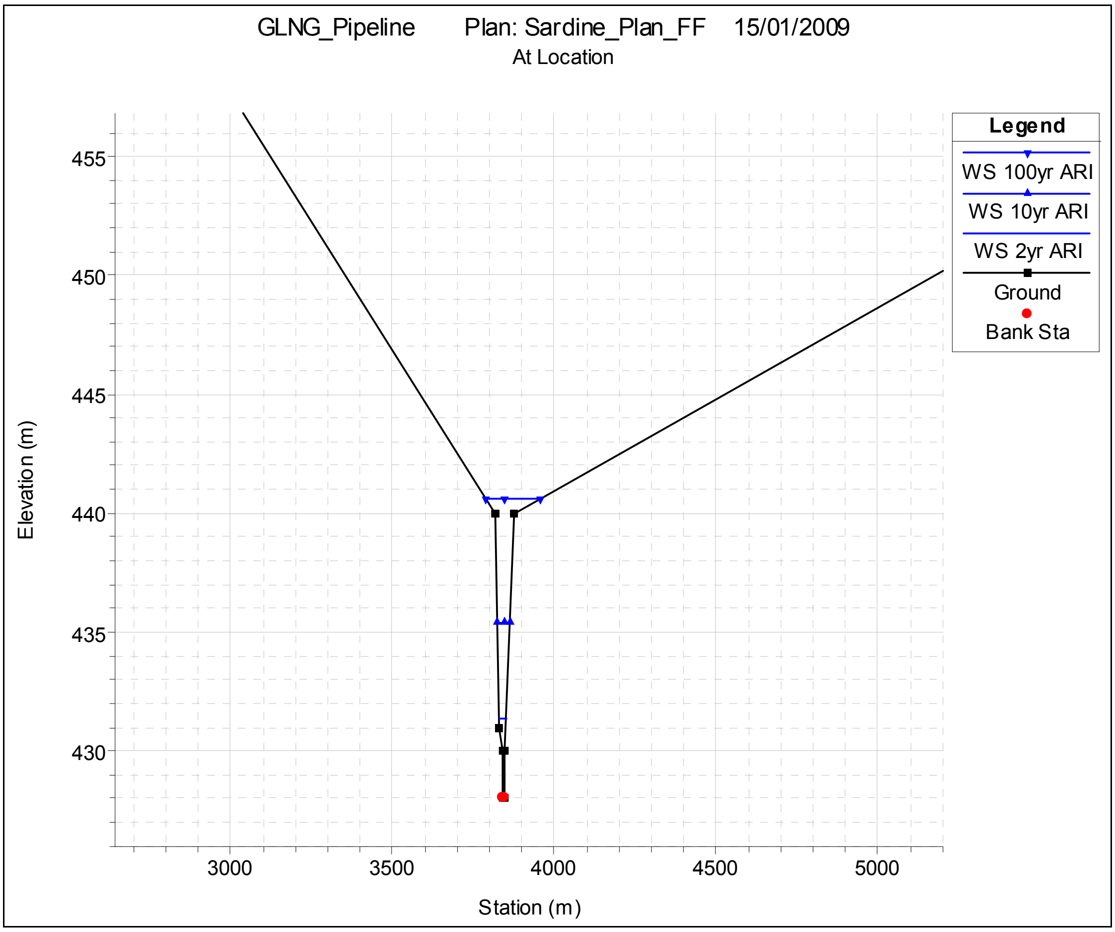
Photo: Looking Downstream

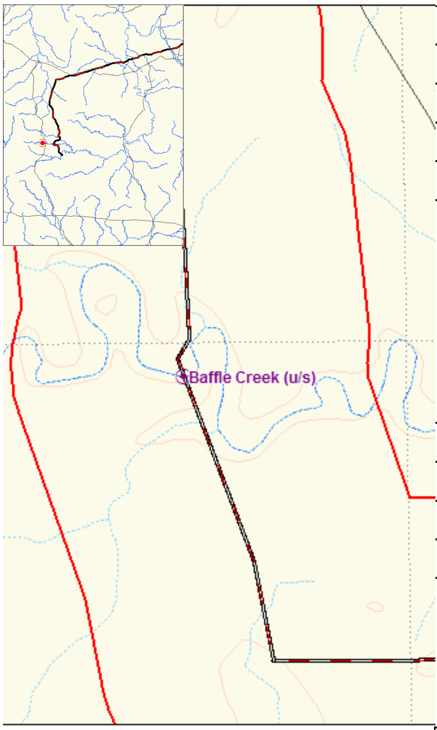
LNG transmission pipeline – Surface Water Assessment	
Location No.	**21**
Location Name	**Sardine Creek**
Easting:	662,934
Northing:	7,187,955
Site Description: *This site of Sardine Creek was inaccessible; the assessment was alternatively undertaken at the road crossing further downstream. At the assessment location water was ponded within the low flow channel; the downstream upper bed was grassed, whilst upstream the channel showed signs of severe deposition.*	
Channel Depth:	*50m*
Channel Width:	*12m*
Floodplain Slope:	*L 1:2, R 1:8*
Bank Slope:	*LB 1:2, RB 1:2*
Channel Banks: Both left and right banks appear stable, heavily vegetated with long grass and a scatter of small to medium sized trees. Both left and right banks are concave in shape and are of moderately to low steepness.	
Substrate Type: The bed substrate is of moderate compaction with a moderate percentage of fines. The pre-dominate particle size is a silty sands, gravels are also common downstream.	
Channel Bed: The multi staged channel has a sandy low flow bed and short grassy surface on the upper channel bed. Particularly upstream, there is extensive build up of fine sediments. The channel sinuosity is fair and adds 1 to 2 times in length.	
Water Quality: Water was slightly turbid and light brown in colour.	
Floodplain: Grazed woodland.	

Photo: Looking Upstream

Catchment Size:	*430km²*		
Channel Slope:	*2 m/km*		
Catchment Storage: Well defined system of small watercourses.			
Catchment Relief: Flat, with slopes of 0 – 1.5%			
	Q2	Q10	Q100
Flow	$56 m^3/s$	$441 m^3/s$	$1,702 m^3/s$
Depth	3.4m	7.4m	12.6m

Cross Section Sardine Creek



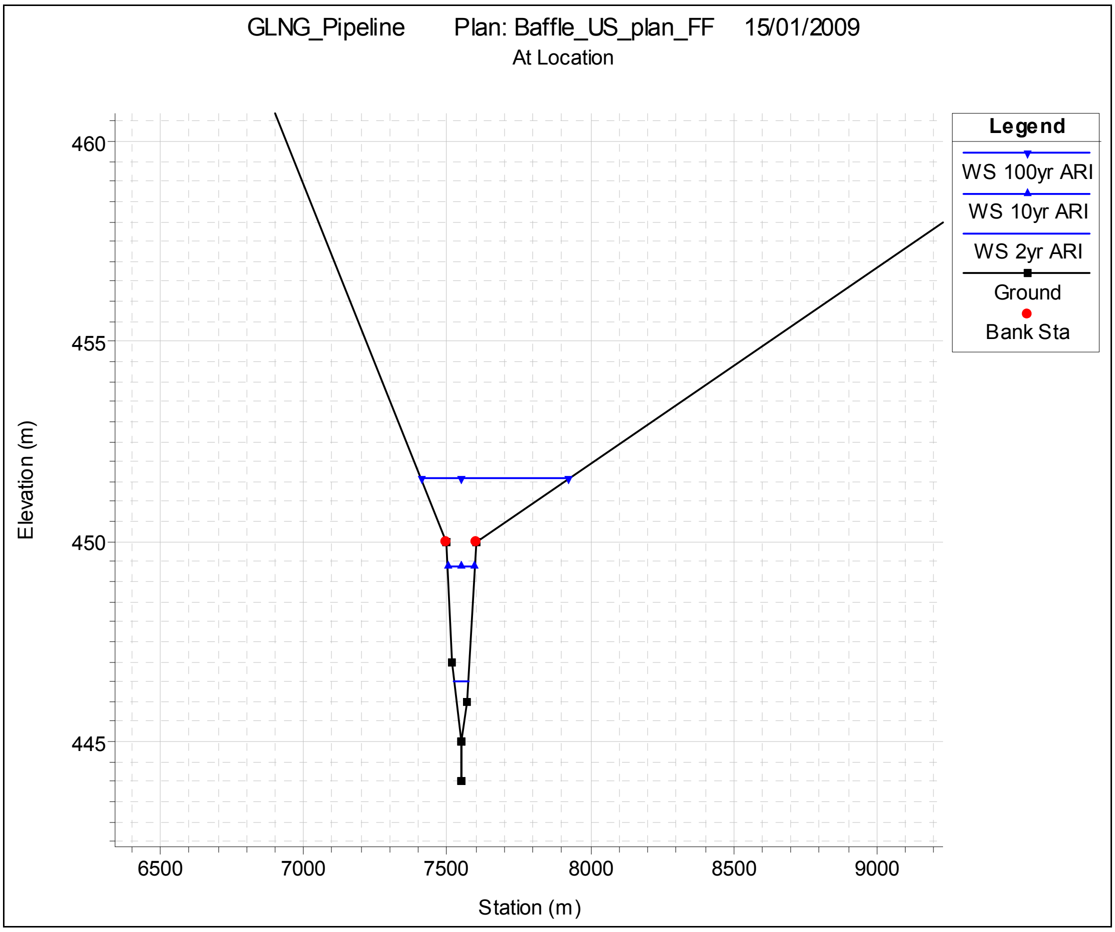


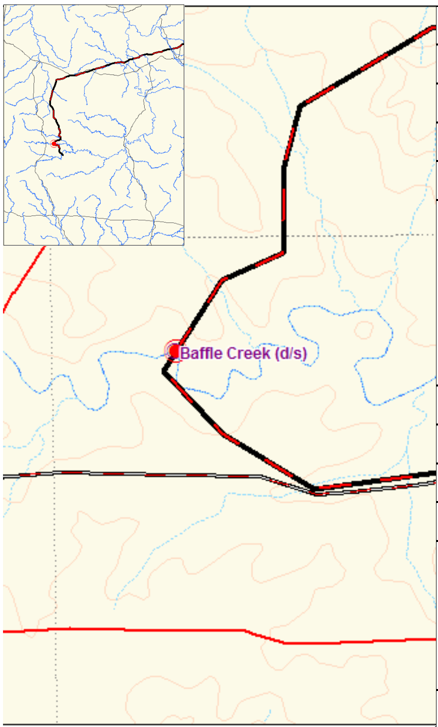
Plan: Baffle Creek

LNG transmission pipeline – Surface Water Assessment	
Location No.	**22**
Location Name	**Baffle Creek**
Easting:	666,922
Northing:	7,169,983
Site Description: *This site of the Baffle Creek proposed pipeline crossing was inaccessible, the assessment of Baffle Creek near Beilba Road was alternatively adopted. Here the watercourse had a two-staged channel, with ponded water over bedrock in the low flow channel and long grass on the upper bed.*	
Channel Depth:	*6m*
Channel Width:	*100m*
Floodplain Slope:	*L 1:100, R 1:200*
Bank Slope:	*LB 1:10, RB 1:10*
Channel Banks: Both left and right banks appear stable, heavily vegetated with long grass and a scatter of small trees. The right bank is concave in shape whilst the left banks in convex.	
Substrate Type: The channel substrate is of moderate compaction with a moderate percentage of fines. The surface of the channel is predominately bedrock. Fine silts are distributed within the cracks of rock and are moderately compacted.	
Channel Bed: The multi staged channel, has a low channel surface of bedrock and dense long grass vegetating the upper channel. There are no signs of erosion.	
Water Quality: Water present is pooled and stagnant, turbid and light brown in colour. There is also algae growth on the bedrock surface.	
Floodplain: Grazed woodland.	

Catchment Size:	*463km²*		
Channel Slope:	*0.6 m/km*		
Catchment Storage: Well defined system of small watercourses.			
Catchment Relief: Flat, with slopes of 0 - 1.5%			
	Q2	Q10	Q100
Flow	$81m^3/s$	$512\ m^3/s$	$1,903m^3/s$
Depth	3.6m	6.5m	8.9m

Cross Section Baffle Creek (us)





Plan: Baffle Creek

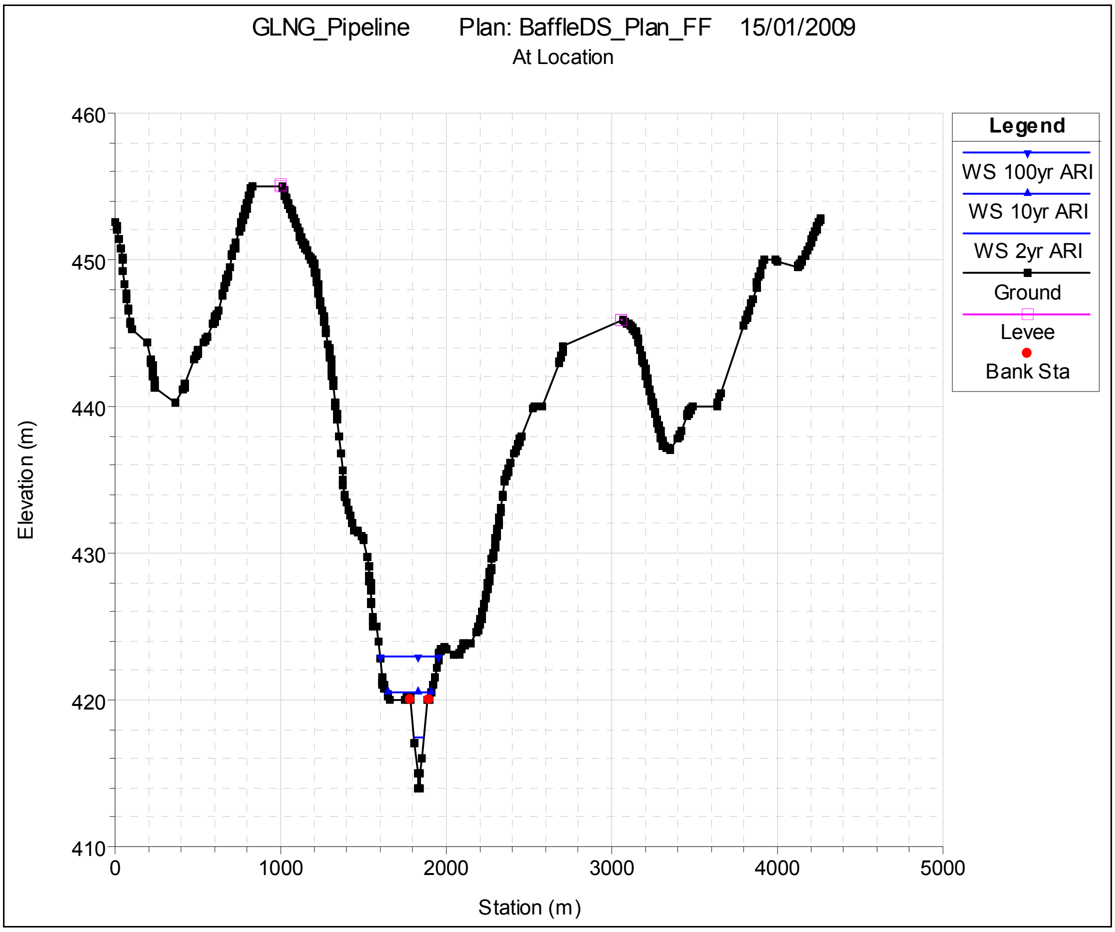
Photo: Looking Upstream

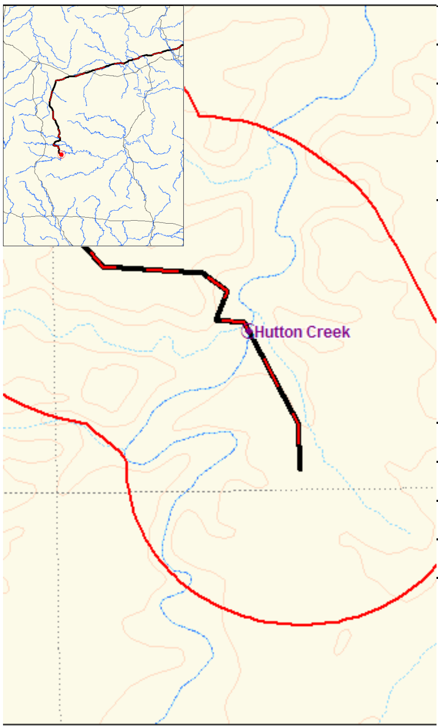
LNG transmission pipeline – Surface Water Assessment	
Location No.	**23**
Location Name	**Baffle Creek**
Easting:	681,796
Northing:	7,168,177
Site Description: *The assessment for this site was undertaken near Bilba Road. Here the watercourse had a two-staged channel, with ponded water over bedrock in the low flow channel and long grass on the upper bed.*	
Channel Depth:	*6m*
Channel Width:	*100m*
Floodplain Slope:	*L 1:2, R 1:8*
Bank Slope:	*LB 1:10, RB 1:10*
Channel Banks: Both left and right banks appear stable, heavily vegetated with long grass and a scatter of small trees. The right bank is concave in shape whilst the left bank is convex.	
Substrate Type: The channel substrate is of moderate compaction with a moderate percentage of fines. The surface of the channel is predominately bedrock. Fine silts are distributed within the cracks of rock and are moderately compacted.	
Channel Bed: The multi staged channel, has a low flow channel surface of bedrock and dense long grass vegetating the upper channel bed. There are no signs of erosion.	
Water Quality: Water present is pooled and stagnant, turbid and light brown in colour. There is also algae growth on the bedrock surface.	
Floodplain: Woodland	

Catchment Size:	*654km²*		
Channel Slope:	*0.8 m/km*		
Catchment Storage: Well defined system of small watercourses.			
Catchment Relief: Flat, with slopes of 0 - 1.5%			
	Q2	Q10	Q100
Flow	$94m^3/s$	$549m^3/s$	$1,936m^3/s$
Depth	3.5m	6.5m	8.9m

Photo: Looking Downstream

Cross Section Baffle Creek (ds)





Plan: Hutton Creek

Photo: Looking Downstream

LNG transmission pipeline – Surface Water Assessment	
Location No.	**24**
Location Name	**Hutton Creek**
Easting:	692,823
Northing:	7,152,538
Site Description: *The Hutton River is located at the southern extent of the pipeline in the Fariview gas field. The watercourse had a depth of approximately 1m of slow moving water at the time of survey. The channel is constricted with large wooden debris and vegetated bars.*	
Channel Depth:	*14m*
Channel Width:	*34m*
Floodplain Slope:	*L 1:7.5, R 6.5*
Bank Slope:	*LB 3:2, RB 3:2*
Channel Banks: Both left and right banks appear stable, heavily vegetated with long grass and a scatter of small to medium sized trees. The left bank is stepped, whilst the right bank is concave in shape and the banks have low and moderately steepness respectively.	
Substrate Type: The bed substrate is of low compaction with a well rounded sediment. The pre-dominate particle size is a silty clay, with occasional gravels.	
Channel Bed: The flatten U shaped channel shows signs of severe deposition with extensive build up of fine sediment forming bars along the channel bed. The channel sinuosity is good and adds 2 to 3 times in length.	
Water Quality: Water is slightly turbid and green in colour with high algal growth present. Neither oils nor odours were visual detected.	
Floodplain: Woodland.	

Photo: Bank

Catchment Size:	*2,791km²*		
Channel Slope:	*2 m/km*		
Catchment Storage: Well defined system of small watercourses.			
Catchment Relief: Flat, with slopes of 0 - 1.5%			
	Q2	Q10	Q100
Flow	$86m^3/s$	$509m^3/s$	$5,112m^3/s$
Depth	1.8m	5.6m	11.5m

Cross Section Hutton Creek

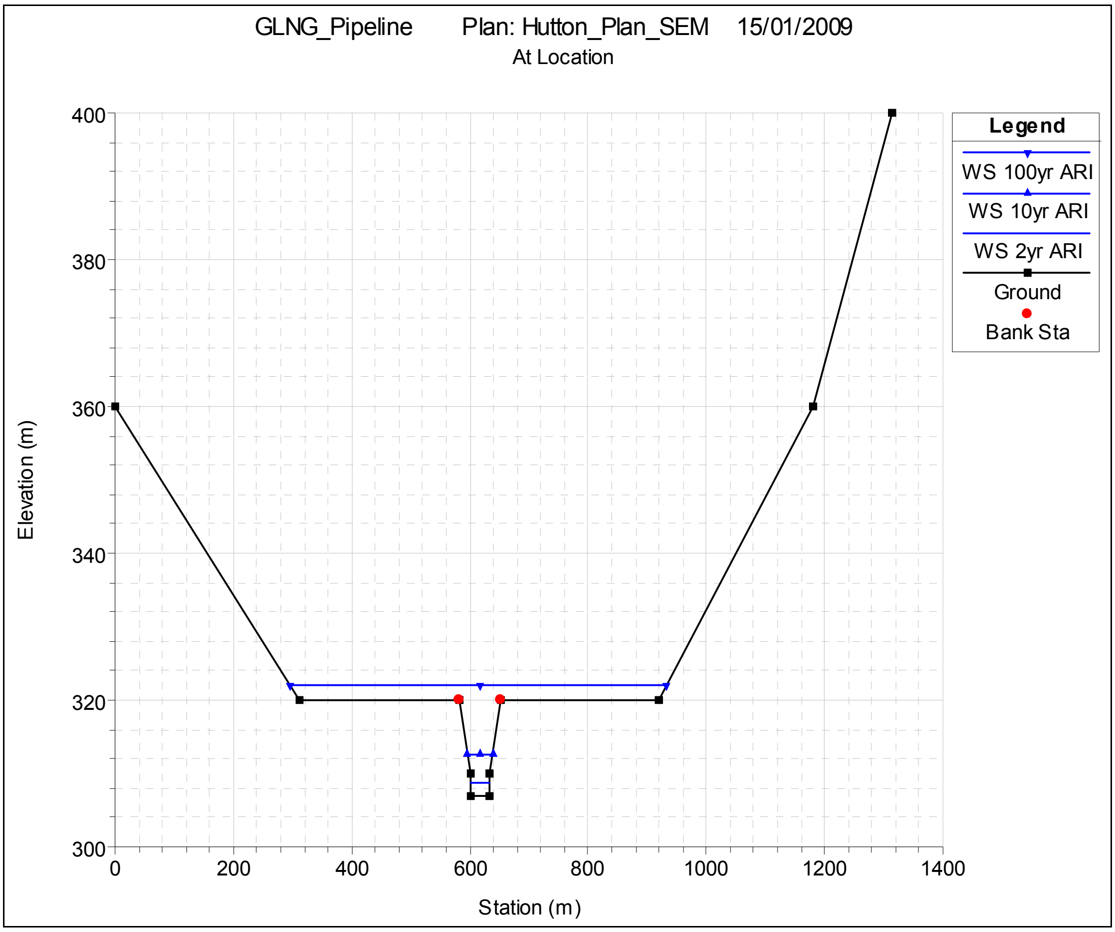


Photo: In-channel –debris

Photo: In-channel - bars

Climate Data | Appendix B

Table B 1: Mean Monthly Rainfall Data (mm)

	Mean Monthly Rainfall (mm)												
Gauge	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Gladstone Airport (1994 to 2008)	113.7	170.8	46.2	37.9	37.5	50.6	13.7	39.8	32.6	66.7	56.3	106.4	786.4
Thangool Airport (1929 to 2008)	96.5	95.4	60.4	35.6	40.8	33.7	28.5	23.2	23.7	57.8	77	90.4	663.4
Gladstone Radar (1957 to 2008)	144.2	141.5	83.5	45.5	60.5	39.4	35.2	32.4	26.5	62.3	74.2	129.8	876.7
Gladstone Post Office (1872 to 1958)	181.6	191.1	129.6	61	46.1	63.1	47.3	23.7	30.9	51.9	75.1	118.7	1020.8
Biloela DPI (1924 to 1996)	101.3	101.4	63.1	38	41.4	34.4	30.1	21.4	23.3	54	76.5	98.6	683.9
Rolleston (1889 to 2008)	93.6	91	60.9	41.3	35.8	36.3	29.2	23.4	26.8	46.2	64.3	88.2	636.4
Injune Post Office (1925 to 2008)	90.9	86.8	61	40.9	33.7	29.9	30.3	25.4	25.4	47.1	74.2	86.6	630.5
Baralaba Post Office (1926 to 2008)	93.1	112.3	73.2	45.5	42.1	35.6	29.7	21.4	24.6	56.2	77.1	99.7	709.6

Source: Bureau of Meteorology (2008)

Climate Data

Appendix B

Table B 2 Average Rain Days

Gauge	Average Rain Days (Days)												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Gladstone Airport (1994 to 2008)	11.8	11.2	7.4	6.8	6.4	7.0	5.7	4.7	4.4	7.9	8.6	9.8	86.7
Thangool Airport (1929 to 2008)	7.3	7.0	5.4	3.8	3.7	3.4	3.5	3.0	3.0	5.5	6.3	6.9	58.3
Gladstone Radar (1957 to 2008)	12.2	11.8	10.0	7.2	7.5	5.9	5.7	5.2	4.7	7.6	8.9	10.5	95.4
Gladstone Post Office (1872 to 1958)	31.0	28.2	31.0	30.0	31.0	30.0	31.0	31.0	30.0	31.0	30.0	31.0	362.8
Biloela DPI (1924 to 1996)	9.2	8.3	6.6	4.7	4.4	4.1	4.2	3.5	3.4	6.1	6.9	8.1	68.8
Rolleston (1889 to 2008)	7.0	6.1	5.1	3.2	3.2	3.1	2.9	2.6	2.9	4.7	5.6	6.5	52.8
Injune Post Office (1925 to 2008)	7.5	6.9	5.1	3.8	3.7	3.7	3.5	3.3	3.5	5.7	6.8	7.8	61.0
Baralaba Post Office (1926 to 2008)	7.3	7.5	5.8	3.6	3.7	3.3	3.2	2.7	2.8	5.1	6.1	7.1	57.7

Table B 3 Mean Monthly Evaporation Data (mm/day)

	Mean Monthly Evaporation (mm/day)												
Gauge	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Gladstone (1966 to 1993)	6.3	5.9	5.3	4.4	3.4	3	3.1	3.5	4.4	5.5	6.1	6.3	4.8
Thangool (1997 to 2007)	7.5	6.8	6.5	5.1	4	2.9	3.1	4	5.5	6.8	6.7	7.4	5.5

Source: Bureau of Meteorology (2008)

Table B 4 Mean Monthly Flows (Ml)

Mean Monthly Flow Volume (Ml)									
	Calliope River at Castlehope (Station No 132001A)	Bell Creek at Craiglands (Station No 130319A)	Callide Creek at Goovigen (Station No 130327A)	Mimosa Creek at Redcliffe (Station No 130316A)	Dawson River at Beckers (Station No 130322A)	Brown River at Lake Brown (Station No 130502B)	Dawson River at Utopia Downs (Station No 130324A)	Dawson River at Taroon (Station No 130302A)	Dawson River at Woodleigh (Station No 130317B)
January	883	108	460	476	3666	445	430	1746	2088
February	1546	82	526	447	5759	357	643	3360	4095
March	856	37	301	277	2154	184	262	1154	1259
April	201	9	56	127	1317	250	398	889	944
May	249	12	264	237	3838	317	345	861	2263
June	103	7	41	39	1142	162	259	545	935
July	120	9	54	23	358	40	135	490	250
August	54	3	0.6	16	430	10	48	240	136
September	52	6	11	11	1252	29	61	285	927
October	108	9	60	21	382	14	55	301	202
November	186	13	67	31	1271	71	186	886	869
December	618	69	257	223	3236	133	334	1477	1997

Source: Department of Natural Resources and Water (2008)

Table B 5 Gauging Station Details

Watercourse	Gauging Station	Date	Duration of Data	Basin	Catchment Size (km^2)
Calliope River	Castlehope: 132001A	October 1938 – September 2006	68 years	Calliope	1,288
Bell Creek	Craiglands: 130319A	December 1990 - July 2006	16 years	Fitzroy	300
Callide Creek	Goovigen:130327A	August 1971 – November 2006	55 years	Fitzroy	4,457
Mimosa Creek	Redcliffe: 130316A	January 1957 - September 2006	49 years	Fitzroy	2,473
Brown River	lake Brown: 130502B	June 1966 – October 2006	40 years	Fitzroy	3,027
Dawson River	Beckers: 130322A	July 1964 – November 2006	42 years	Fitzroy	40,500
Dawson River	Utopia Downs: 130324A	June 1966 – November 2006	40 years	Fitzroy	6,039
Dawson River	Taroom: 130302A	January 1911 – November 2006	95 years	Fitzroy	15,846
Dawson River	Woodleigh: 130317B	March 1957 – August 2006	49 years	Fitzroy	28,503

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Flood Assessment   Appendix C

C.1 Study Area Description

The 435 km gas transmission pipeline will extend from the CSG fields in Fairview, north through the Expedition National Park, along the Arcadia Valley, to just south of Rolleston. The pipeline then turns east and crosses rural grazing land to the north of the townships of Moura, Banana and Biloela, over the Calliope Range and north east to Gladstone. It then crosses Port Curtis between Friend Point (on the mainland) and Laird Point (on Curtis Island) and traverses south to the LNG facility at China Bay.

Due to the large extent of the pipeline, the assessment of existing flood characteristics has been limited to major watercourses where significant environmental risk could occur from inappropriate design, or construction, a desk top analysis identified twenty four (24) key watercourses to be crossed by the proposed LNG pipeline.

C.2 Flood Hydrology

Flood hydrology uses statistical or deterministic methods to estimate the depth of rainfall to occur and the likely flow, for any point within a catchment, for a particular probabilistic flood event. Hydrological assessments consider the catchment characteristic and local hydrological patterns for a range of event durations to determine the most critical, it is this duration that depths and flows are predicted.

To estimate the flood depths at the key watercourse crossings, a hydrological assessment has been undertaken at each of the crossing location. Estimates of flood flows were derived using hydrological methods in Australian Rainfall and Runoff (AR&R) (IEAust, 1987). The assessment considers probable design floods, a theoretically derived flood which has a certain likelihood of occurrence, expressed as an average recurrence interval (ARI). Flood flow estimates for the watercourse were estimated for a range of flood events considered as mean, minor and major respectively: 2, 10, and 100 year ARI events.

A catchment area, upstream of the pipeline crossing, was attributed to each of the 24 key locations. Each watercourse's catchment was delineation based on 1:100 000 topographical maps which illustrate ground elevations in 20m contours.

Flood estimation was determined using two methods.

- Flood Frequency
- Rational Method

C.2.1 Flood Frequency Analysis

A flood frequency analysis enables the magnitude of floods of a selected probability of exceedence to be estimated by statistical analysis of recorded flow data. The statistical analysis adopted for this investigation was Log Pearson III (IEAust 1987) and was undertaken using an annual flood series. The series was comprised of the highest daily rate of discharge in each year of record, as taken from Department of Natural Resources and Water, Queensland (NRW) stream gauges records.

Although several watercourses had long term stream gauges, no gauge was located within 15km of the crossing locations, and as such was likely to over or under estimate the design flood peak flows.

Alternatively a regional flood frequency relationship was developed. In addition to their use for estimating design floods at ungauged sites, regional flood frequency procedures have the potential for improving estimates at gauged sites, especially where the record length is short. The regional relationship can stabilise site estimates, particularly for parameters such as skew, which are prone to small-sample errors.

There are a variety of approaches used to determine the regional relationship. For the Gladstone LNG assessment the multiple regression method was adopted. This approach considers floods of various ARIs by a frequency analysis (Log Pearson III) on each catchment with suitable records. For each ARI, flood discharges were then related to catchment area to develop a regression equation.

NRW stream gauges along the 435 km length of the proposed pipeline corridor were assessed for their suitability in the analysis. Primarily gauges within the central reach of the pipeline corridor, between Biloela and Moura were selected to represent pipeline catchments. This provides low certainty for sites away from this reach, such as the Brown and Calliope Rivers, however an initial analysis using all gauges along the corridor resulted in an undefinable relationship. As four, long term, stream gauges are located along the Dawson River, a separate regression equation was developed for the estimation of Dawson River and the upper Dawson tributaries (such as Baffle Creek).

Stream gauges used to evaluate the flood frequency regression are summaries in Table C-1 below:

Table C-1: - Gauges surrounding the proposed 435 km of pipeline

Watercourse	Gauge Name	River Catchment	Gauge Number	Upstream Catchment Size (km^2)	No. Years of Record
Dawson River	Dawson @ Taroom	Dawson	130302A	15,846	48
Dawson River	Dawson @ Woodleigh	Dawson	130317B	28,503	19
Dawson River	Dawson @ Beckers	Dawson	130322A	40,500	41
Dawson River	Dawson @ Utopia Downs	Dawson	130324A	6,039	39
Bell Creek	Bell Creek @ Craiglands	Dawson	130319A	300	44
Callide Creek	Callide Creek @ Goovigen	Dawson	130327A	4,457	34
Mimosa Creek	Mimosa Creek @ Redcliffe	Dawson	130316A	2,473	46

C.2.2 Rational Method

The selection of hydrological estimation method was based from guidance provided in the technical reference AR&R (IEAUST, 1987). AR&R Section 5.3 suggests, for small ungauged catchments where considerable data is available for a site, flood frequency, unit hydrograph or runoff routing methods are preferred.

As explained previously (C.2.1) a flood frequency analysis for the region was undertaken however an assessment of available data (Table C-1) determined the minimum upstream catchment size, of the NRW gauge located within the Dawson River basin, was 300km^2. As several key watercourses have catchment sizes substantially less, Bell Creek (46km^2), Conciliation Creek-upstream (11km^2) and Spring Creek (60km^2), a flood frequency analysis was considered to provide poor representation of these small catchments. Again, with the small catchment area sizes and the lack of available data for the site, the complex unit hydrograph and runoff routing methods were also considered unsuitable.

The reference (AR&R, Section 5.3) also notes; where no data is available for the site and little time is available to produce a design, a published regional method should be applied. Following this, the Rational Method was applied to estimate peak flows for design floods for crossing locations. The Rational Method is given by the equation:

$$Q_Y = 0.278 \cdot C_Y I_{t_c,Y} A$$ *Equation 1*

Where Q_Y = peak flow rate (m^3/s) of average recurrence interval (ARI) of Y years

C_Y = runoff coefficient (dimensionless) for ARI of Y years

A = area of catchment (km^2)

$I_{tc,Y}$ = average rainfall intensity (mm/hr) for design duration of t_c hours and ARI of Y years.

The Rational Method is a statistical relationship which relates rainfall of a particular probability to the flood discharge of the same probability. A paper titled "Design Floods for Small Rural Catchments in Queensland" (W.D. Weeks, 1991) discusses further analysis undertaken for rational methods application in Queensland. The paper was developed from an analysis of all gauged catchments in Queensland with a catchment area of less than $250km^2$ and more than 20 years of stream flow record.

Weeks (1991) suggested that time of concentration estimated by Bransby Williams formula (AR&R, 1987) gives extended durations and the flow estimation method provides a large number of unrealistically high runoff coefficients. The alternate Pilgrim and McDermott formula (1982) was recommended as a result of Weeks' (1991) analysis undertaken, as this provided consistently shorter durations. The hydrological estimations for Bell Creek, Conciliation Creek upstream and Spring Creek adopted the Pilgrim and McDermott formula, a slightly more conservative approach.

Design rainfall intensity, were obtained by using the AusIFD program and AR&R (IEAust, 1987).

Two methods of calculating the runoff coefficient were undertaken for the small watercourse hydrological estimation;

- Queensland Main Roads Department (MRD) Bridge – Branch Method (AR&R, 1987), and ;
- Weeks (1991).

The Weeks (1991) method was developed for catchments with limited land use and terrain information. The MRD method considered catchment characteristics and provided a higher flow estimate. In view of this, a conservative approach was adopted and the MRD method was used for determining the rational method runoff coefficients.

The 0.1 AEP runoff coefficient was adjusted for a range of flood probabilities using Equation 2, developed by Weeks (1991).

$$C_Y = (0.54 \cdot Log(Y) + 0.46) \cdot C_{10}$$ *Equation 2*

C.2.3 Peak Flows

Table C-2 below provides the predicted peak flow values for the 24 key locations. Bell Creek, Conciliation Creek upstream and Spring Creek all adopted the Rational Method for the hydrological estimation. The other 21 sites utilised one of the two regression equations developed from a regional flood frequency analysis.

Table C-2 – Predicted peak flows at key watercourse crossing locations

No	Watercourse*	Catchment Area (km^2)	2yr ARI Peak Flow (m^3/s)	10yr ARI Peak Flow (m^3/s)	100yr ARI Peak Flow (m^3/s)
1	Larcom Creek	278	43	404	1,657
2	Calliope River	489	51	427	1,686
3	Bell Creek	46	61	142	339
4	Callide Creek	763	59	447	1,708
5	Kroombit Creek	2,340	82	500	1,767
6	Banana Creek	700	57	443	1,704
7	Kianga Creek	551	53	432	1,692
8	Dawson River (d/s)	32,735	448	1,200	2,354
9	Mimosa Creek	3,230	90	516	1,784
10	Conciliation Creek (d/s)	946	62	456	1,720
11	Zamia Creek (d/s 1)	2,590	85	505	1,772
12	Zamia Creek (d/s 2)	2,075	79	494	1,761
13	Zamia Creek (u/s 2)	2,025	79	492	1,759
14	Zamia Creek (u/s 1)	1,966	78	491	1,758
15	Conciliation Creek (u/s)	11	22	51	121
16	Clematis Creek	781	59	448	1,710
17	Brown River	1,041	64	461	1,724
16	Spring Creek	60	27	346	1583
19	Arcadia Creek	377	47	416	1,673
20	Dawson River (u/s)	1,134	117	612	1,990
21	Sardine Creek	667	56	441	1,702
22	Baffle Creek (u/s)	462	81	512	1,903
23	Baffle Creek (d/s)	654	94	549	1,936
24	Hutton Creek	2,791	86	509	1,776

* (u/s) denotes upstream location, whilst (d/s) denotes downstream location.

Further details of each watercourse is provided in Appendix A.

C.3 Flood Hydraulics

To approximate the flood depths at watercourse crossings, a flood assessment of the 24 key watercourse crossing locations, as identified above in Section C2, has been undertaken.

The US Army Corps developed Hydrologic Engineering Centers River Analysis System, known commonly as HEC RAS, is a one-dimensional hydraulic estimation model. The hydraulic model was adopted for flood estimation of the 24 crossing locations along the proposed gas transmission pipeline corridor. The model inputs include geometric file, flow file, and simulation parameters.

Using a 12d digital terrain model, developed from available survey, predominately 5m contours, rudimentary cross section were extraction from each of the 24 locations. The cross sections were further detailed with information gathered during the site visit, primarily providing channel definition. The cross-sections were then replicated in an upstream direction, using the average watercourse gradient for a distance of 400m. Once the series of cross-sections were developed for each assessment location, they were then exported to the HEC RAS to form a simplistic 400m model extent.

Along with the cross-sectional data the geometric file requires a description of the bed, channel wall and floodplain roughness. Hydraulic roughness values (Mannings 'n') were adopted from hydraulic references based on field observations. The values relate to land use, reference values are provided in Table C-3 below:

Table C-3 – Adopted Mannings 'n' values

Surface Type	Roughness Value
Floodplains	
• Cultivated areas	0.04
• Light brush and trees, in winter	0.06
• Medium to dense brush, in winter	0.07
• Heavy stand of timber, a few down trees, little undergrowth	0.08 – 0.1
Main Channel	
• Clean, winding, some pools and shoals, some weeds and stones	0.04- 0.045
• Clean, winding, some pools and shoals, some weeds and stones, lower stages, ineffective slopes and sections	0.05
• Sluggish reaches, weedy, deep pools	0.07

Sources: Chow, 1959, Open Channel Hydraulics, McGraw-Hill Book Company, Inc.

Each model contains two boundary conditions, an upstream flow boundary and a downstream water level boundary. The inflow values were taken from the peak flows determine in the hydrological analysis (Table C-2) at each location. As the downstream environment was relatively flat, a normal depth downstream boundary was adopted; this was based on the watercourse gradient determined from 20m contour maps.

The HEC RAS model was simulated using steady state conditions, due to the flat topographic nature of all the watercourses identified; subcritical flow conditions were also adopted.

Table C4 below provides the flood depths for each key watercourse location.

Table C-4 – Predicted flood depths, at key watercourse crossing locations

No.	Name	2yr ARI Depth (m)	10yr ARI Depth (m)	100yr ARI Depth (m)
1	Larcom Creek	1.5	4.2	6.7
2	Calliope River	1.6	3.3	6.0
3	Bell Creek	1.6	2.7	4.4
4	Callide Creek	1.9	5.4	6.5
5	Kroombit Creek	1.7	3.5	5.2
6	Banana Creek	2.4	3.8	5.2
7	Kianga Creek	2.4	2.9	3.6
8	Dawson River (d/s)	8.1	12.6	16.5
9	Mimosa Creek	1.7	4.3	6.4
10	Conciliation Creek (d/s)	2.4	3.7	5.1
11	Zamia Creek (d/s 1)	2.4	3.5	4.8
12	Zamia Creek (d/s 2)	2.4	4.5	5.1
13	Zamia Creek (u/s 2)	1.6	2.3	3.3
14	Zamia Creek (u/s 1)	2.2	4.1	5.0
15	Conciliation Creek (u/s)	1.3	1.5	1.8
16	Clematis Creek	3.9	11.1	20.5
17	Brown River	2.8	3.4	4.1
18	Spring Creek	2.0	5.5	6.3
19	Arcadia Creek	2.9	4.5	6.9
20	Dawson River (u/s)	8.2	14.9	18.5
21	Sardine Creek	3.4	7.4	12.6
22	Baffle Creek (u/s)	3.6	6.9	9.2
23	Baffle Creek (d/s)	3.5	6.5	8.9
24	Hutton Creek	1.8	5.6	11.5

Further detail of each watercourse crossing is provided in Appendix A.

The above flow and water depth results have been calculated with limited data of the site and have not been calibrated to real data. Of particular concern is the topographic information which was limited to 35m strip of 5m to 20m contours. With access limitation to many of the sites, channel definition was often estimated from nearby roadside locations or other surrounding watercourses. The combined lack of topographic accuracy and using a method of uniform cross-sectional replication ignored the existence of upstream and downstream constraints. Due to the simplistic nature of this investigation and the lack of data, the level of accuracy is very low. Hence any results provided in this appendix should only be used to obtain an indicative understanding of the flooding behaviour they are not suitable for design purposes.

Raw Data

NRW Water Quality Data											
Watercourse	Date	EC (µS/cm)	DO (mg/L)	DO (%sat)	pH	Total N (µg/l)	TP (µg/l)	TSS (mg/l)	Turbidity (NTU)	NH4 (µg/l)	Organic N (µg/l)
Calliope River at Castelhope (Station No 132001A)	3-Jun-97	1082	10	108	8.1	-	30	5	0.9	-	-
	17-Nov-97	1250	9	117	8.5	-	10	10	1.0	-	-
	27-May-98	917	10	105	8.2	470	10	3	0.3	-	-
	22-Oct-98	760	6	66	7.8	-	30	10	1.0	-	-
	15-May-02	1200	7	75	7.9	460	20	10	2.0	-	-
	22-Oct-02	1530	4	49	7.6	720	30	9	2.3	-	-
	12-May-03	1150	5	54	8.1	390	40	13	5.1	-	-
	27-Oct-03	1050	7	84	7.8	540	70	20	13.0	-	-
	21-May-04	1050	10	107	8.2	260	20	10	2.0	-	-
Median		**1082**	**7**	**84**	**8.1**	**465**	**30**	**10**	**2.0**		
Dawson River at Beckers Station No 130322A)	24-Oct-94	257	-	-	7.8	-	30	10	7.0	6	500
	3-May-95	158	3	33	7.2	-	410	2	200.0	20	1080
	30-Aug-95	164	8	86	7.7	-	220	38	323.0	30	680
	30-Apr-96	201	7	78	7.9	-	150	29	57.0	-	700
	1-Jun-01	195	6	61	7.9	1040	130	300	190.0	-	-
	8-Oct-01	208	9	110	7.8	550	40	30	31.4	-	-
Median		**198**	**7**	**78**	**7.8**	**795**	**140**	**29.5**	**123.5**	**20**	**690**
Mimosa Creek at Redcliffe (Station No 130316A)	30-Apr-96	285	8	87	6.9		30	10	1.1	20	590
Median		**285**	**8**	**87**	**6.9**	**0**	**30**	**10**	**1.1**	**20**	**590**
QWQG (2006)		340		85-110	6.5-8.5	500	50		50	20	420

URS Water Quality Data										
Watercourse	**Date**	**EC (µS/cm)**	**DO (mg/l)**	**DO (%sat)**	**pH**	**Turbidity (NTU)**	**Total P (µg/l)**	**Total N (µg/l)**	**Organic N (µg/l)**	**NH4 (µg/l)**
Arcadia Creek @ Arcadia Valley Rd #1	3-Feb-08	198	5	65	7.4	91	-	-	-	-
Arcadia Creek @ Arcadia Valley Rd #1	6-Mar-08	-	-	-	-	-	180	1100	-	-
Arcadia Creek @ Arcadia Valley Rd #1	14-May-08	-	-	-	-	-	-	-	-	-
Median		**198**	**5**	**65**	**7.4**	**91**	**180**	**1100**	**-**	**-**
Basin Creek @ Arcadia Valley Rd	3-Feb-08	110	2	25	6.5	170	-	-	-	-
Basin Creek @ Arcadia Valley Rd	6-Mar-08	-	-	-	-	-	1020	2500	-	-
Basin Creek @ Arcadia Valley Rd	14-May-08	228	7	92	7.1	675	380	1600	-	-
Median		**169**	**5**	**59**	**6.8**	**423**	**700**	**2050**	**-**	**-**
Arcadia Creek @ Arcadia Valley Rd #2	3-Feb-08	199	7	89	5.9	58	-	-	-	-

URS Water Quality Data										
Watercourse	**Date**	**EC (µS/cm)**	**DO (mg/l)**	**DO (%sat)**	**pH**	**Turbidity (NTU)**	**Total P (µg/l)**	**Total N (µg/l)**	**Organic N (µg/l)**	**NH4 (µg/l)**
Arcadia Creek @ Arcadia Valley Rd #2	6-Mar-08	-	-	-	-	-	40	-	-	-
Arcadia Creek @ Arcadia Valley Rd #2	14-May-08	207	5	62	7.0	44	150	1000	-	-
Median		**203**	**6**	**76**	**6.4**	**51**	**95**	**1000**	**-**	**-**
Arcadia Creek @ Arcadia Valley Rd #3	3-Feb-08	199	7	91	5.6	23	-	-	-	-
Arcadia Creek @ Arcadia Valley Rd #3	6-Mar-08	-	-	-	-	-	550	2400	-	-
Arcadia Creek @ Arcadia Valley Rd #3	14-May-08	-	-	-	-	-			-	
Median		**199**	**7**	**91**	**5.6**	**23**	**550**	**2400**	-	-
Carnarvon Creek @ Carnarvon Hwy	3-Feb-08	395	7	86	8.1	46		-	-	-
Carnarvon Creek @ Carnarvon Hwy	6-Mar-08	-	-	-	-	-	80	600	-	-
Carnarvon Creek @ Carnarvon Hwy	14-May-08	490	10	120	8.2	2	-	-	-	-

URS Water Quality Data

Watercourse	Date	EC (µS/cm)	DO (mg/l)	DO (%sat)	pH	Turbidity (NTU)	Total P (µg/l)	Total N (µg/l)	Organic N (µg/l)	NH4 (µg/l)
Median		**443**	**8**	**103**	**8.2**	**24**	**80**	**600**	**-**	**-**
Arcadia Ck @ Sunny Holt	6-Mar-08	-	-	-	-	-	130	1200	-	-
Arcadia Ck @ Sunny Holt	14-May-08	185	9	118	7.2	8	-	-	-	-
Median		**185**	**9**	**118**	**7.2**	**8**	**130**	**1200**	**-**	**-**
Hutton Creek @ Carnarvon Hwy	5-Mar-08	-	-	-	-	-	-	-	-	-
Hutton Creek @ Carnarvon Hwy	3-Feb-08	485	5	56	7.2	5	-	-	-	-
Hutton Creek @ Carnarvon Hwy	13-May-08	260	7	82	7.0	22	70	900	-	-
Median	**-**	**373**	**6**	**69**	**7.1**	**14**	**70**	**900**	**-**	**-**
QWQG (2006)	**-**	**340**	**-**	**85-110**	**6.5-8.5**	**50**	**50**	**500**	**420**	**20**

Seasonal Medians

Watercourse	Season*	EC (µS/cm)	n**	DO (%sat)	n	pH	n	Turbidity (NTU)	n	TP (µg/l)	n	TN (µg/l)	n	Organic N (µg/l)	n	NH4 (µg/l)	n	TSS (mg/l)	n
Calliope River at Castlehope (Station No 132001A)	Wet	1150	4	72	4	7.8	4	2	4	30	4	720	2	400	1	10	1	10	4
	Dry	1082	5	103	5	8.1	5	2	5	20	5	425	4	450	1		0	10	5
Dawson River at Beckers	Wet	208	3	92	2	7.8	3	31	3	40	3	550	1	600	2	18	2	38	3

Water Quality Data

Appendix D

Watercourse	Season*	EC (µS/cm)	n**	DO (%sat)	n	pH	n	Turbidity (NTU)	n	TP (µg/l)	n	TN (µg/l)	n	Organic N (µg/l)	n	NH4 (µg/l)	n	TSS (mg/l)	n
(Station No 1303221A)	Dry	164	3	65	3	7.7	3	200	3	220	3	1040	1	880	2	20	1	10	3
Mimosa Creek at Redcliffe (Station No 130316A)	Wet	285	1	84	1	6.9	1	1	1	30	1			590	1	20	1	10	1
	Dry																		
Arcadia Creek @ Arcadia Valley Rd #1	Wet	198	1	65	1	7.4	1	91	1	180	1	110	1						
	Dry																		
Arcadia Creek @ Arcadia Valley Rd #2	Wet	199	1	89	1	5.9	1	58	1	40	1		1						
	Dry	207	1	62	1	7	1	44	1	150	1	100	1						
Arcadia Creek @ Arcadia Valley Rd #3	Wet	199	1	91	1	5.6	1	23	1	550	1	2400	1						
	Dry																		
Arcadia Ck @ Sunny Holt	Wet									130	1	1200	1						
	Dry	185	1	118	1	7.2	1	8	1										
Basin Creek @ Arcadia Valley Rd	Wet	110	1	25	1	6.5	1	170	1	1020	1	2500	1						
	Dry	228	1	92	1	7.2	1	675	1	380	1	1600	1						
Carnarvon Creek @ Carnarvon Hwy	Wet	395	1	86	1	8.1	1	46	1	80	1	600	1						
	Dry	490	1	120	1	8.2	1	2	1										
Hutton Creek @ Carnarvon Hwy	Wet	485	1	56	1	7.2	1	5	1										
	Dry	260	1	82	1	7	1	22	1	70	1	900	1						
QWQG (2006)		**340**	**-**	**85-110**	**-**	**6.5-8.5**	**-**	**50**		**50**		**500**		**420**		**20**			

* Wet season (October to April), Dry season (May to September).

** Sample size

Likelihood Scale

Likelihood is defined as a general description of probability and/or frequency (AS/NZ4360, 2004). Applied to this project it is the water quality impact within the pipeline corridor and using the following likelihood scale.

Level	Likelihood	Description
1	Rare	Will ONLY occur in exception circumstances
2	Unlikely	Could occur but not expected
3	Possible	Could occur at some time
4	Likely	Will probably occur in most circumstances
5	Almost Certain	Expected to occur in most circumstances

Consequence Scale

Consequence is defined as the outcome or impact of an event (AS/NZ4360, 2004).

Level	Consequence	Description
1	Insignificant	Trivial environmental impact
2	Minor	Unreasonable interference with the environment. (Results in minor illness or injury)
3	Moderate	Clearly visible impact to aquatic ecosystem. Requires localised remediation. (Results in illness or injury)
4	Major	Damage to the environment that requires significant remediation. (Results in serious illness or injury)
5	Catastrophic	Environmental damage is irreversible, of high impact or widespread. (Results in death)

Risk Rating Matrix

A combination of the consequences and likelihood assigned to each measure to calculate the overall risk rating.

Likelihood	Consequences				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost Certain	**High**	**High**	**Extreme**	**Extreme**	**Extreme**
Likely	**Medium**	**High**	**High**	**Extreme**	**Extreme**
Possible	**Low**	**Medium**	**High**	**High**	**Extreme**
Unlikely	**Low**	**Low**	**Medium**	**High**	**Extreme**
Rare	**Low**	**Low**	**Medium**	**High**	**Extreme**

Impacts Table

Appendix F

Aspect	Potential Impact	Inherent Risk rating	Mitigation Strategy	Residual Risk Rating
Construction				
Erosion and Sediment Mobilisation	Sediment from earth moving and stockpiling can enter surface water runoff during rainfall events or blown by wind and discharge to watercourses leading to deleterious effects on water quality and aquatic habitats.	High	Appropriate design (erosion and scour protection) for sections of pipeline crossing active floodplain and main channel; Stormwater management (development, implementation and maintenance of plan), to include: Erosion control and energy dissipation, watercourse stabilisation i.e. matting, riprap and gabions; Stormwater controls and upstream treatment, i.e. infiltration devices and vegetation filters; Stabilisation techniques, i.e. revegetation; Construction to occur in dry season; Crossings to be at right angles to direction of flow; Stockpiling of topsoil located away from watercourses; Vehicle wash bay to be located away from watercourses; Minimise vegetation disturbance; Routine inspection.	Low
Pollution	Oily waste water (from miscellaneous plant and equipment wash water); Contaminated runoff from chemical storage areas; Potentially contaminated drainage from fuel oil storage areas; Oil-filled transformer yard areas and general washdown water. Diesel and other petroleum-based fuels and lubricants used by excavation and construction machinery. Environmental and public health and safety issue.	High	Chemical and fuel storage areas to be appropriately bunded; Spill cleanup kits in accordance with Australian Standards (AS1940 and AS3780) to be located in convenient locations, i.e. work vehicles; Refuelling to occur in bunded areas; Should a spill occur, ensure it is contained and does not enter drainage lines or watercourses; Follow all other operational procedures.	Medium

Impacts Table

Appendix F

Aspect	Potential Impact	Inherent Risk rating	Mitigation Strategy	Residual Risk Rating
HDD drill mud spillage and seepage	Mud may enter watercourses and increase turbidity and sediment loads causing an adverse impact to receiving waters.	High	Develop, implement and maintain drilling procedure; Should a spill occur ensure as far as practicable that mud is contained and disposed of as per the Waste Management Strategy.	Medium
Improper disposal of all construction wastes	Litter and other construction waste can be washed into watercourses during rain events and impact receiving waters.	Medium	Develop, implement and maintain Waste Management/Disposal Plan	Low
Works adjacent to/within drainage lines and watercourses	Trenching at watercourse crossings and vehicle access crossings can alter flow characteristics.	High	Diversion of watercourse either by low flow diversion or coffer dam with pumping; Construction activities that will affect existing drainage channels and control measures must only be carried out after suitable stormwater management infrastructure has been implemented onsite; Minimal disturbance by heavy earth moving equipment; Vehicle crossings should be adequately designed for a range of flow conditions, including under road drainage.	Low
Flooding	Possibility of out-of-bank/flash flood rainfall event during construction causing erosion and damage to erosion and sediment control infrastructure.	High	It is recommended that major construction works are scheduled appropriately during the wet season However if not possible, make sure a flood assessment has been conducted; Stormwater management e.g. drainage diversions and bunding; Emergency response procedures and flood forecasting.	Medium
Lack of water supply	Inadequate dust suppression, soil compaction and washdown	High	Develop, implement and maintain Water Supply Strategy and Emergency Plan	Medium
Contaminant Mobilisation	Oxidation of acid sulfate soils producing runoff with high acidic levels detrimental to surrounding environment	High	Develop, implement and maintain Acid Sulfate Soil Management Plan	Medium

Impacts Table

Appendix F

Aspect	Potential Impact	Inherent Risk rating	Mitigation Strategy	Residual Risk Rating
Commissioning				
Lack of water supply	Insufficient water to undertake hydrostatic testing	High	Water Supply Strategy.	Low
Use of local water sources	Decreasing environmental flows	Medium	Water Supply Strategy, including license required to extract water	Low
Disposal of water	Improper disposal of water used in hydrostatic testing - impact surrounding environment and receiving waters (erosion)	Medium	Water management/disposal procedures.	Low
Pipeline failure	Discharge of water to environment	Low	Hydrostatic testing procedure	Low
Erosion and Sediment Mobilisation	Permanent structures and minor earth disturbance can result in localised erosion and sediment mobilisation leading to deleterious effects on water quality and aquatic habitats.	Medium	Stormwater management to include: Localised erosion control and energy dissipation measures; Stabilisation techniques, i.e. revegetation; Routine inspection and maintenance of existing erosion and sediment control measures.	Low
Incomplete rehabilitation	Erosion and movement of sediment. Turbid and sediment laden runoff into watercourses.	Medium	Develop, implement and maintain Rehabilitation Plan	Low
Pollution	Diesel and other petroleum-based fuels and lubricants used by operational vehicles and machinery entering watercourses.	Low	Chemical and fuel storage areas to be appropriately bunded; Spill cleanup kits in accordance with Australian Standards (AS1940 and AS3780) to be located in convenient locations, i.e. work vehicles; Refuelling to occur in bunded areas; Should a spill occur, ensure it is contained and does not enter drainage lines or watercourses; Follow all other operational procedures.	Low

Impacts Table

Appendix F

Aspect	Potential Impact	Inherent Risk rating	Mitigation Strategy	Residual Risk Rating
Improper disposal of all operational wastes	Litter and other operational waste can be washed into watercourses during rain events and impact receiving waters.	Low	Develop, implement and maintain Waste Management/Disposal Plan	Low
Flooding	Possibility of out-of-bank/flash flood rainfall event causing failure of erosion and sediment control infrastructure.	High	Monitoring and maintenance of erosion and sediment control features; Emergency Response Procedures and flood forecasting	Medium
Ground disturbance during above ground infrastructure removal	Erosion and movement of sediment, potential adverse impact to water quality	Medium	Implement and maintain a Decommissioning Environmental Plan. Apply sediment and erosion control measures prior to earth moving activities.	Low
Lack of water supply	Insufficient water to undertake hydrocarbon purging	High	Develop, implement and maintain Water Supply Strategy	Low
Use of local water sources	Decreasing environmental flows	Medium	Water Supply Strategy, including license required to extract water	Low
Disposal of water	Improper disposal of water used following purging (hydrocarbons) impacting surrounding environment and receiving waters.	High	Water management/disposal procedures	Medium
Pipeline failure	Discharge of water to environment	Medium	Develop, implement and maintain purging procedure	Medium
Incomplete rehabilitation	Erosion and movement of sediment, potential adverse impact to water quality	High	Decommissioning Rehabilitation Plan (including replanting of riparian and other erosion sensitive zones)	Low

Contour Drains

Appendix G

The overall design objective of surface water controls is to resist erosion of the cleared areas resulting from high intensity rainfall events. To achieve this it is essential that drainage works:

- Are designed for the function of conveying flows safely away from cleared right of way areas, particularly the trench, towards areas with established vegetation to limit the contributing catchment and velocities.
- Drainage layout and drain types are compatible with their respective capacity to resist erosion and slopes that the drains traverse.

The design of drainage works needs to cater for peak flow conditions particularly for bare earth or unrehabilitated sites. The erosion potential and sediment transport capacity of surface runoff increases exponentially with increasing flow, and hence peak flows from storm events represent the highest potential for erosion. Peak flows are related to the contributing catchment area and time of concentration of the catchment. This presents a particular challenge for drainage at the micro-scale (e.g. slope runoff) where very short duration storms cause critical flow conditions and have very high rainfall intensity (i.e. at Curtis Island 100yr ARI 274 mm/hr for a 5 minute duration storm). It is proposed that contour drains are used to control erosion from slope runoff.

The proposed contour drains have been designed to resist erosion for peak flows for small to moderate rainfall events with bare earth conditions during the revegetation phase. With an expectation of revegetation requiring 1 to 3 years for establishment, the design criteria for a 1 in 5 year ARI rainfall intensity has been considered appropriate for assessing drainage adequacy with bare earth conditions at this site. Design for more extreme storms during the establishment phase is not considered practical relative to the infrequent occurrence of larger events and impact on the cost of works. It must however be recognised that very high intensity storms can occur in any year during the storm season.

Contour Drains

Spacing of contour drains

As mentioned above, it is proposed that regularly spaced contour drains are implemented in the cleared right of ways as the primary form of defence against sheet flow causing rilling and gully erosion after the reinstatement of vegetation.

The spacing of the contour drains is critical in limiting the velocity of sheet flow and hence the slope of cleared area is critical. However as the natural slope results in variable slopes along the pipeline, the resultant spacing of contour drain varies along the right of way.

Under bare earth conditions the top soil cover is predicted to resist sheet flow velocities up to 0.6m/s (IEAust Australia, 1996). The spacing has been determine to limit catchment areas and slope reach such that theoretical estimates of sheet flow velocities are less than 0.6m/s in storms with up to 5 year ARI rainfall intensity. Table G1 provides spacing distance between each contour drain for a variety of slopes.

Contour Drains

Appendix G

Table G1 – Suggest spacing of contour drains

Slope	Slope Length
1: (m)	(m)
2	15
5	30
10	50
15	70
25	100
30	115
35	130
40	145
45	160
50	180
75	300
100	420
150	750
250	1550
500	7750

Longitudinal gradient and form of the contour drains

It is suggested that the steep slope contour drains are to be constructed with a slightly steeper longitudinal gradient to minimise excessive siltation and ensure compatibility with practical construction methods. The recommended longitudinal gradient is 1V in 50H e.g. 2m for 100m reach of contour drain.

Across the flatter slopes, longitudinal gradient of contour drains should be no flatter than 1V in 200H. These contour drains may be susceptible to siltation, however the general gradient 1V in 50H would be expected to generate only minor quantities of sediment and the risk of siltation should be minor providing the length of contour drain (and hence contributing catchment areas and flows) is limited to design specifications.

The cross-sectional shape of the contour drain has significant effect on the hydraulics of the flow within the drain and associated erosion potential in high flows and siltation potential in low flows. V-shaped drains, with relatively flat side sloped are considered suitable for this site. As the name suggests the slope of the embankment is mirrored by a raising embankment, forming a V shape.

Length of Contour Drain

The recommended maximum length of contour drain is based on limiting the catchment area and flow contributing to the drain and consequent peak flow velocity in the drain. The adopted velocity criteria for flow in the contour drains is based on maximum velocity of 1.0 m/s for bare earth conditions in storms with in to 5 year rainfall intensity.

It should be noted that most literature reports maximum permissible velocity in unlined drains with bare earth conditions up to 0.6 or 0.7 m/s. However this limit is considered too severe and would require very short contours drains (approximately 15m). At locations where this length is insufficient, if temporary small rock check dams are placed at regular intervals along the contour drains during, the length can be extended to approximately 100m.