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Goulburn Mulwaree Council

Report for Highlands Source Project Environmental Assessment

Waterway Crossing Geomorphology Assessment

April 2010

INFRASTRUCTURE | MINING & INDUSTRY | DEFENCE | PROPERTY & BUILDINGS | ENVIRONMENT

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Glossary of Terms

Alluvial	Deposition from running waters. In this context, it refers to ‘alluvium’ — soils such as the fertile floodplain soils that consist of fine-grained sediments including clays, silts and sands.
Back-swamp	A depression in a floodplain, generally found in the valley margin.
Bank	Refers to the streambank of a stream channel; they appear as the steeply sloped outer walls of the channel.
Bankfull (Stage)	Water surface elevation at which a stream first overflows its natural banks, spilling water onto the floodplain
Bed	Refers to the streambed of a stream channel; the lowest part of the channel between streambanks. It is usually composed of mobile sediments such as gravels, sand or silts carried in the bedload, or by bedrock, and includes common stream features such as pools, riffles, runs, glides and cascades.
Bedrock-controlled	Refers to stream channels where their shape and behaviour is largely controlled by bedrock steps and outcrops of the underlying geological strata. Usually occur in upland streams of ‘hard rock’ catchments at the middle to top of catchments.
Bund	An impervious embankment of earth or a brick wall, which may form part or all of the perimeter of a compound that is provided to retain liquid.
Catchment	Total land area draining to any point in a stream.
Chain-of-ponds	A type of stream which appears as a series of ponds/pools which may be regularly spaced, or appear randomly. Between these ponds, the channel may be discontinuous, or appear as a slight depression or swale on the wide floodplain linking the ponds.
Channelisation	Straightening and (or) deepening a pre-existing channel, or constructing a new channel, for the purpose of runoff control or navigation.
Clay	A weathered form of aluminosilicate mineral particles, less than 0.004 mm in diameter.
Cohesive sediments	Composed primarily of clay-sized material, which have strong interparticle forces which acts to hold them together.
Colluvial Soil Landscapes	Are affected by mass movement. Soil parent material consists mostly of colluvial mass movement debris including scree and talus along with other landslide, mudflow and creep deposits. Colluvial soil landscapes usually include cliffs, cliff-footslopes, scarps and landslides.
Culvert	A totally enclosed drain under a road or railway.
Degradation	Removal of materials from one place to another via erosion, causing lowering of the elevation of streambeds and floodplains over time.
Degraded	A reach that has moved away from its intact condition and is not recovering; it is still adjusting to disturbance and is out of balance with its controls.
Deposition	The dropping of material which has been picked up and transported by wind, water, or other processes.
Dispersivity	Potential for soil to break down into fine particles in water.

Ephemeral	Periodically contains water only after unpredictable rain. Usually dry, but may contain water for rare and irregular periods.
Ephemeral Stream	A stream, whose channel is always above the water table, which flows briefly in direct response to precipitation, receiving no continued supply of water from snowmelt or springs
Erosion	A natural process where wind or water detaches a soil particle and provides energy to move the particle.
Erosional Soil Landscapes	Have been sculpted primarily by erosive action of running water. Soil depth is usually shallow (with occasional deep patches) and landscapes usually consist of steep to undulating hillslopes.
Floodplain	A level, low-lying area adjacent to streams that is periodically flooded by stream water. Floodplains are composed of sediments carried by rivers (alluvium) and deposited on land during flooding.
Fluvial	Refers to the processes associated with running water such as a river or other freshwater source
Geology	Science of the earth's history, composition, and structure, and the associated processes.
Geomorphology/Geomorphic	The study of the nature and history of landforms and the processes which create them.
Geomorphology	The interdisciplinary and systematic study of landforms and their landscapes, as well as the earth's surface processes that create and change them.
Geotechnical	A discipline of engineering associated with studying the ground and its geology.
Gradient	The degree of ascent or descent with a uniform slope.
Gravel	Sediment with diameters between 2 and 64 mm
Gully erosion	The removal of soil by an excessive concentration of running water, resulting in the formation of deep channels.
Headcut/Headward Erosion	A steep, actively eroding point in the streambed, which migrates in an upstream direction to lower the streambed and cause streambanks to collapse. Also known as a 'nickpoint'.
Headwaters	The upstream extents of a stream, generally located in upper catchment areas. They are generally ephemeral first-, second- and third-order streams.
Hydraulics	The physics of channel flow that create its depth, velocity and turbulence.
Hydraulic diversity	Variation in the physical effects of channel flow mechanics, such as depth, velocity and turbulence.
Hydrological regime	Rainfall and run-off processes and movement through the environment.
Hydrology	The study of rainfall and surface water run-off processes.
Morphology	In the context of this publication, it refers to the form and structure of waterways.
Mud	Fine sedimentary material, typically comprising both inorganic (mineral) and organic material.

Planform	The lateral, two-dimensional shape of a waterway through a valley, as viewed from above.
Reach	A section of stream with the same character and behaviour.
Residual Soil Landscapes	Are dominated by sites where deep soils have formed from in situ weathering of parent materials. Residual soil landscapes typically have level to undulating elevated landforms.
Riffles	Deposits of coarse-grained sediment across straight sections of stream, located between pools. Riffles are generally shallow-water areas where there is an increase in bed slope allowing for faster water flow. Gravels often become armoured along riffles, and low flow over them has a ripple effect on the surface.
Rill	Small channel that forms on bare earth after intense rain.
Riparian	Ecosystems particularly associated with all types of waterbodies.
Riparian zone	Land adjoining, directly influencing or which is directly influenced by waterbodies.
River Styles framework	River Styles® is a geomorphic approach for examining river character, behaviour, condition and recovery potential. This provides a physical template for river management.
Sand	Sediment with diameters between 0.06 mm to 2 mm
Scour	Streambank, bed or floodplain erosion where particles of sediment are removed individually by plucking or are sheared off. It is caused by the force of running water being greater than the sediment's ability to resist that force.
Sediment	Material of varying sizes that has been or is being moved from its site of origin by the action of wind, water or gravity.
Sediment transport capacity (of stream)	The maximum load of solid particles that a stream is capable of carrying. It is largely a function of the discharge, but influenced by particle size.
Sheet Erosion	The removal of thin layers of surface material more or less evenly from an extensive area of gently sloping land, by broad continuous sheets of running water rather than by streams flowing in well-defined channels.
Sheet runoff (or Surface Runoff)	The flow across the land surface of water that accumulates on the surface when the rainfall rate exceeds the infiltration capacity of the soil.
Silt	Sediment with diameters between 0.002 mm to 0.06 mm
Sinuosity	The extent of curvature or meandering of a stream in comparison to down-valley distance. Highly sinuous streams meander over a low gradient and short distance; streams with low sinuosity are straighter and have a steeper gradient.
Strahler Stream Order	A scale-dependent property of drainage networks that describes the position and approximate size of a stream segment in the network. First order streams are headwater streams that have no tributaries. A second order stream is formed where two first order streams join, a third order stream is formed where two second order streams join, etc. Note that the confluence of a second order stream with a first order stream remains a second order stream
Stream power	The rate at which a stream can do work, especially the transport of its load, and measured over a specific length. It is largely a function of channel slope and discharge.

Substrate	The basic surface on which material adheres, typically mineral and (or) organic material that forms the bed of a stream.
Topography	The description or representation of the features and configuration of land surfaces
Transferral Soil Landscapes	Are deep deposits of mostly eroded parent materials washed from areas up-slope. Transferral landscapes include footslopes, valley flats and fans.
Undercut	Erosion at the base or toe of the streambank which removes support to the streambank above.

Acronyms and Abbreviations

EP&A Act	*Environment Planning and Assessment Act 1979*
DoP	Department of Planning
DGR(s)	Director-General's Requirement(s)
GMC	Goulburn Mulwaree Council
HSP	Highlands Source Project
LGA	Local Government Area
NSW	New South Wales
WSC	Wingecarribee Shire Council
WTP	Water Treatment Plant

Units

km	Kilometres
ha	Hectares
m	Metres

1. Introduction

This waterway geomorphology assessment has been undertaken by GHD on behalf of the Goulburn Mulwaree Council (GMC) for the Highlands Source Project (referred to as 'the Project'). This report has been prepared to assess the potential impact of the construction and operation of the Project on the stability and geomorphic values of waterways intersected along the pipeline route.

1.1 Background

Goulburn has faced severe drought and water restrictions since 2002. By mid 2007 Goulburn had less then 12 month's water supply available. GMC, in conjunction with a State Government Task Force, identified an Emergency Pipeline from Wingecarribee Reservoir as the best means of overcoming the emergency and drought proofing Goulburn for the future (GMC & DoC, 2007). Subsequent rains in June 2007 removed the emergency aspect of the project; however the need for improved water security remains.

Since 2007, a range of options for securing Goulburn's water supply have been investigated. GMC has prepared a draft Integrated Water Cycle Management (IWCM) Strategy that will outline actions for improving long term water sustainability. The IWCM Strategy is expected to be finalised towards the end of 2009, and it is anticipated that the Highlands Source Project will be an integral part of this Strategy. Additionally, GMC has undertaken a Goulburn Water Supply Strategy Review, in which the Highlands Source Project was identified as the best solution for improving the city's water security.

1.2 Project Overview

The Project comprises a trunk water main and ancillary infrastructure, extending from Wingecarribee Reservoir within the Wingecarribee Local Government Area (LGA), to the Goulburn Water Treatment Plant (WTP) within the Goulburn Mulwaree LGA. The Wingecarribee LGA is located in the Southern Highlands and centred approximately 150 km south of Sydney. The scheme comprises approximately 81 km of DN 300 mm and DN 375 mm diameter pipeline, a pump station at the Wingecarribee Reservoir, power and controls and a telemetry system.

If the Project is approved, it is proposed to have the transfer scheme operational by June 2011. The Project's timeframe is set by the conditions governing the provision of government funding under the Australian Government Water Smart Australia Program.

Based on the preliminary assessment of the hydraulics and the method of operating this pipeline, it is expected that it would be operated as essentially a closed pumping system between booster pumps when the increased capacity is required.

1.3 Objectives of this Report and the Director General's Requirements

The objectives of this waterway geomorphology assessment are to:

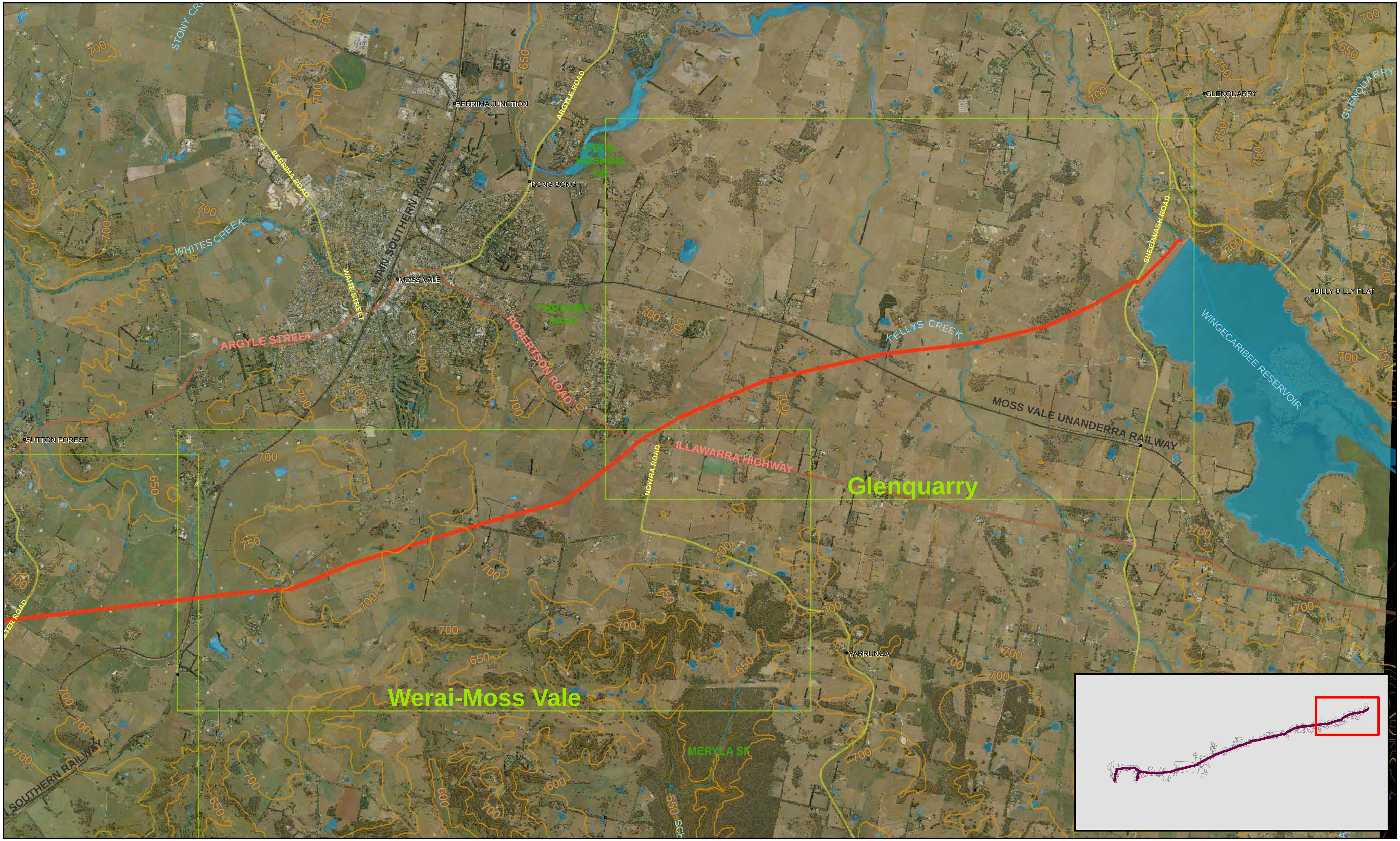
- Assess the potential impact of construction and operation of the Project on waterway stability; and
- Address the Director General's Requirements (DGRs) for the Environmental Assessment of the Project.

The latter requires the Environmental Assessment (EA) to address the impact of the proposal on waterway geomorphology as follows:

- *The EA must assess the potential for impacts to watercourses which are to be crossed by the pipeline, including a risk assessment justifying the proposed crossing method depending on stream classification and environmental significance and a strategy for rehabilitation of any watercourses disturbed by the project to an existing or better standard.*

These requirements are further embodied by the NSW Office of Water (NOW) who advises that the EA must demonstrate that the pipeline route will not adversely affect the stability of watercourses and request assessments among others of:

- Current watercourse stability;
- Impact of the proposal on watercourse stability; and
- Mitigation and rehabilitation measures to minimise/avoid impacts.



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Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Legend

Proposed Pipeline Alignment
(Raw Water)
(Treated Water)
Sector boundary
PrimaryRoad
ArterialRoad
Railway
Lakes, Dams
Rivers, Creeks
Local Government Area
50m Contour (Labelled)
Potential Offset Sites
10m Contour
Potential Offset Sites

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Goulburn Mulwaree Council
Highlands Source Project

Job Number	23-13312-15
Revision	0
Date	05 FEB 2010

Locality Map - Proposed
Pipeline Alignment
Sector: Werai - Glenquarry

Figure 1(a)

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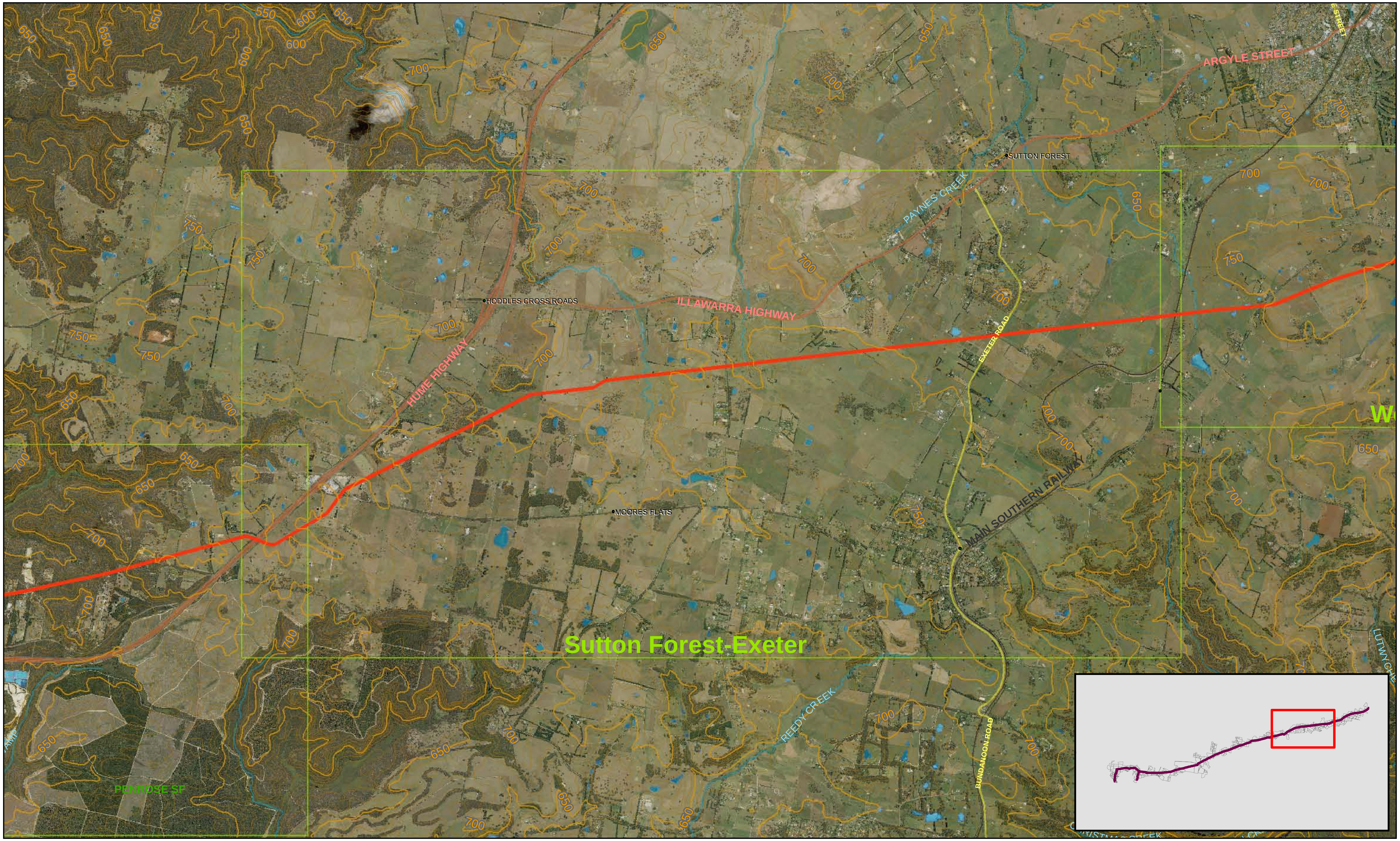
Level 7, 16 Marcus Clarke Street Canberra ACT 2601 T 61 2 6113 3200 F 61 2 6113 3299 E cbrmail@ghd.com.au W www.ghd.com.au

Data Source: NSW Lands Dept: crownlands,roadsegments,railways,hydroarea,hydroline,localgovernmentarea,npwreserve,stateforest - 2007. Created by: ccharalambou, trbellwood, bahambly



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Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Legend

- Proposed Pipeline Alignment
- (Raw Water)
- (Treated Water)
- Sector boundary
- PrimaryRoad
- ArterialRoad
- Railway
- Lakes, Dams
- Rivers, Creeks
- Local Government Area
- 50m Contour (Labelled)
- Potential Offset Sites
- 10m Contour
- Potential Offset Sites

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Locality Map - Proposed
Pipeline Alignment
Sector: Sutton Forest-Exeter

Figure 1(b)

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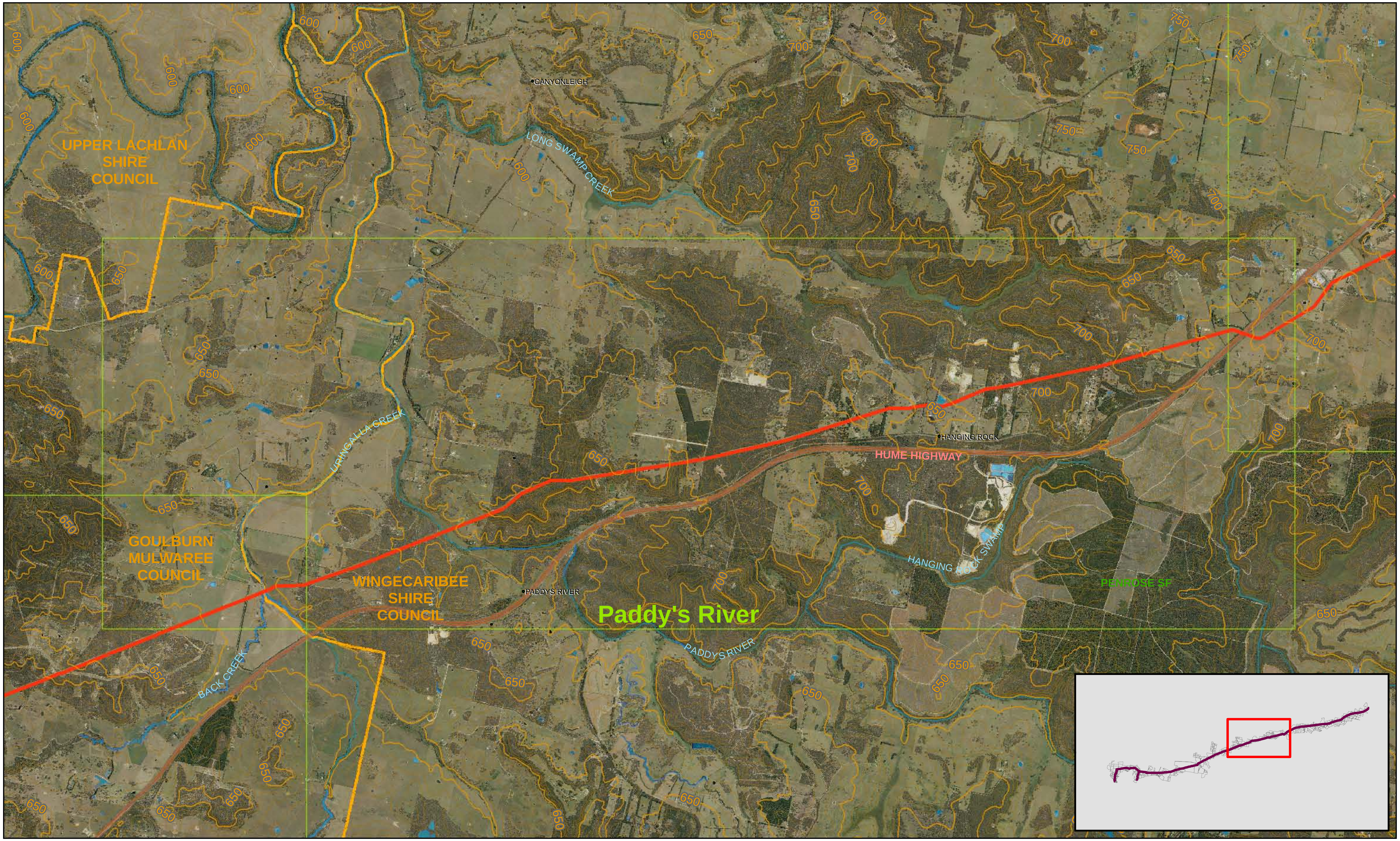
Level 7, 16 Marcus Clarke Street Canberra ACT 2601 **T** 61 2 6113 3200 **F** 61 2 6113 3299 **E** cbrmail@ghd.com.au **W** www.ghd.com.au

Data Source: NSW Lands Dept: crownlands,roadsegments,railways,hydroarea,hydroline,logalgovernmentarea,npwreserve,stateforest - 2007. Created by: ccharalambou, trbellwood, bahambly



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Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

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Legend

Proposed Pipeline Alignment
(Raw Water)
(Treated Water)
Sector boundary
PrimaryRoad
ArterialRoad
Railway
Lakes, Dams
Rivers, Creeks
Local Government Area
50m Contour (Labelled)
Potential Offset Sites
10m Contour
Potential Offset Sites

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Job Number	23-13312-15
Revision	0
Date	05 FEB 2010

Locality Map - Proposed
Pipeline Alignment
Sector: Paddys River

Figure 1(c)

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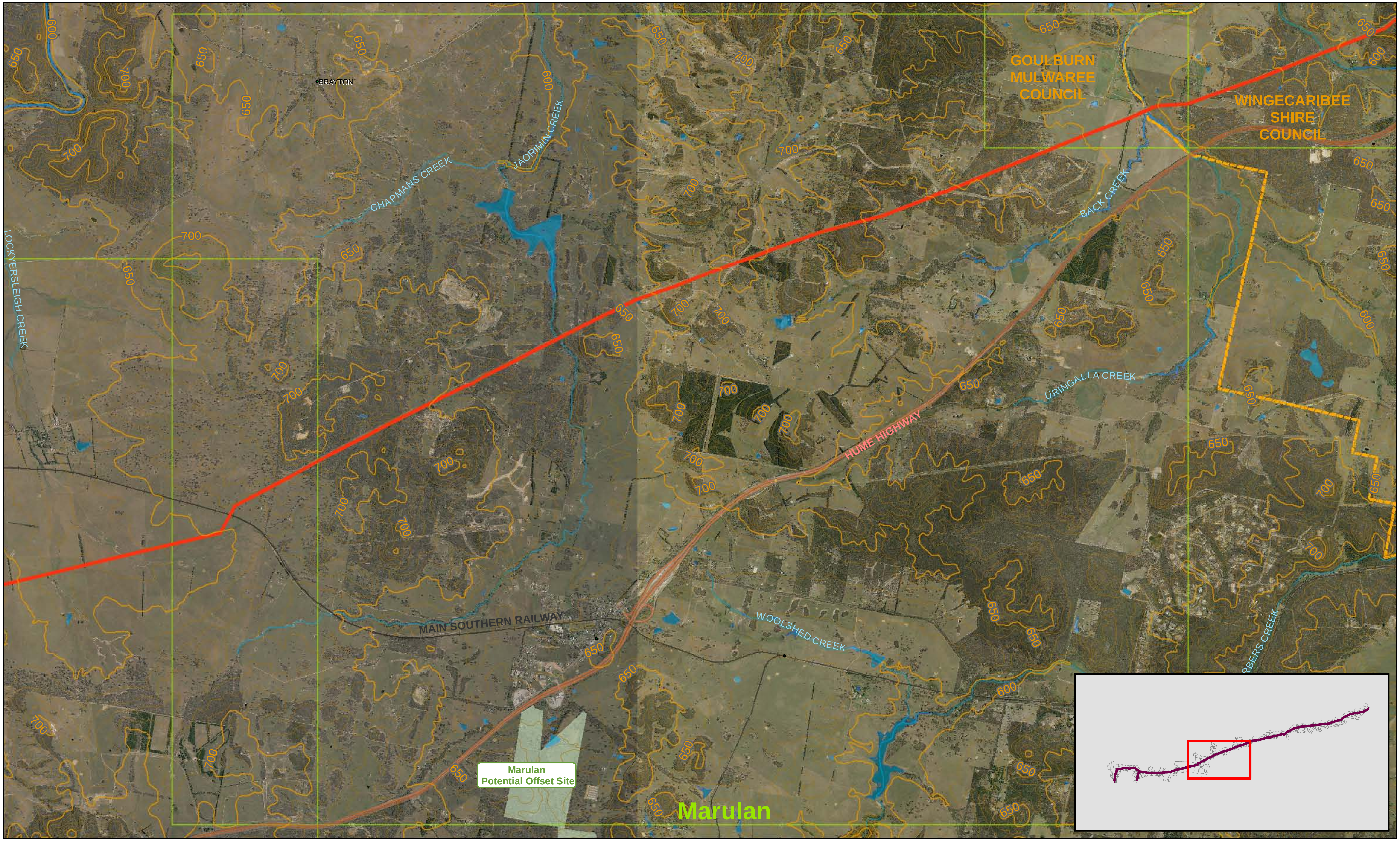
Level 7, 16 Marcus Clarke Street Canberra ACT 2601 **T** 61 2 6113 3200 **F** 61 2 6113 3299 **E** cbrmail@ghd.com.au **W** www.ghd.com.au

Data Source: NSW Lands Dept: crownlands,roadsegments,railways,hydroarea,hydroline,logalgovernmentarea,npwreserve,stateforest - 2007. Created by: ccharalambou, trbellwood, bahambly



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Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Legend

Proposed Pipeline Alignment
(Raw Water)
(Treated Water)
Sector boundary
PrimaryRoad
ArterialRoad
Railway
Lakes, Dams
Rivers, Creeks
Local Government Area
50m Contour (Labelled)
Potential Offset Sites
10m Contour
Potential Offset Sites

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Goulburn Mulwaree Council
Highlands Source Project

Job Number 23-13312-15
Revision 0
Date 05 FEB 2010

Locality Map - Proposed Pipeline Alignment
Sector: Marulan

Figure 1(d)

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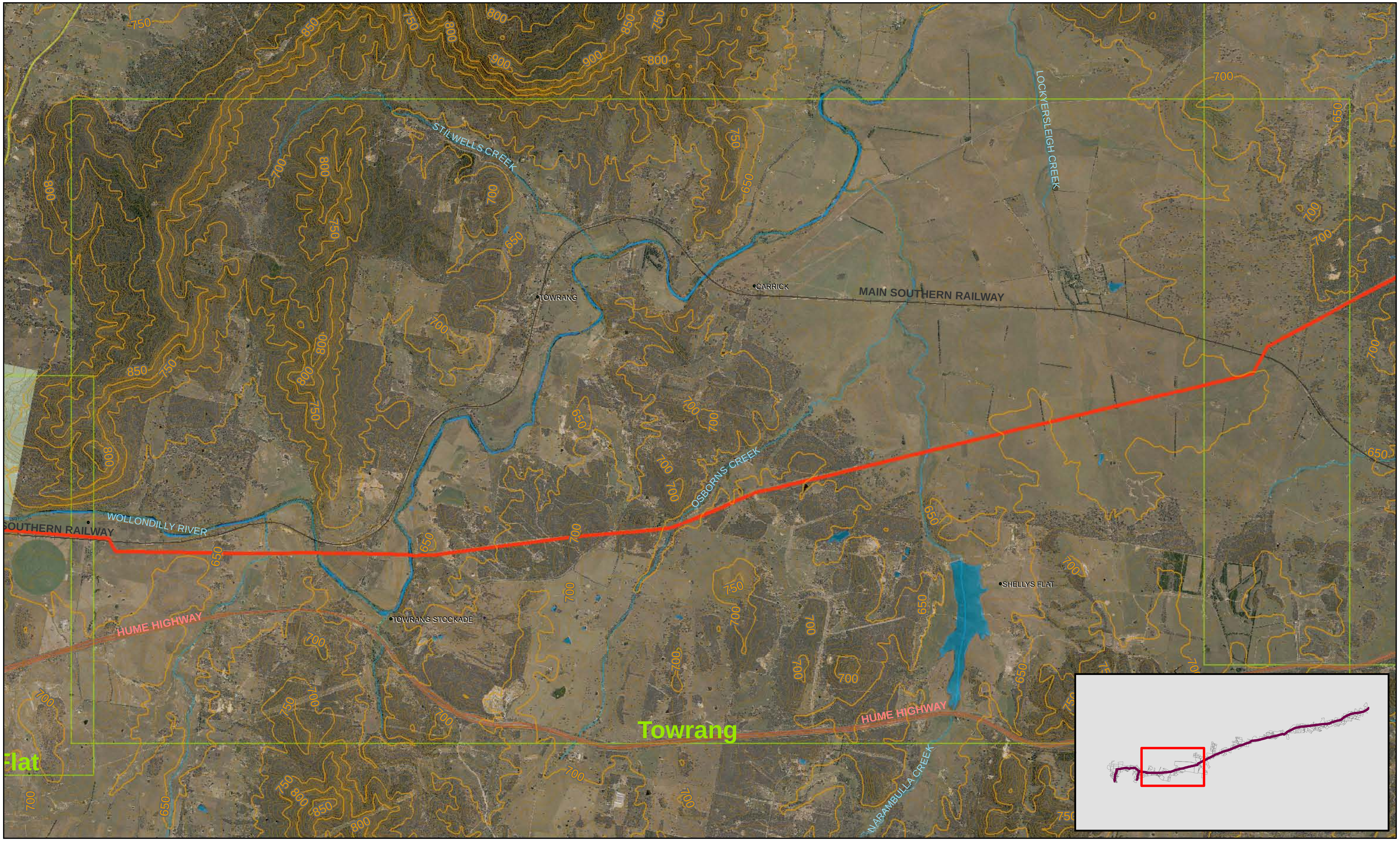
Level 7, 16 Marcus Clarke Street Canberra ACT 2601 T 61 2 6113 3200 F 61 2 6113 3299 E cbrmail@ghd.com.au W www.ghd.com.au

Data Source: NSW Lands Dept: crownlands,roadsegments,railways,hydroarea,hydroline,logalgovernmentarea,npwreserve,stateforest - 2007. Created by: ccharalambou, trbellwood, bahambly



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Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Legend

Proposed Pipeline Alignment
(Raw Water)
(Treated Water)
Sector boundary
PrimaryRoad
ArterialRoad
Railway
Lakes, Dams
Rivers, Creeks
Local Government Area
50m Contour (Labelled)
Potential Offset Sites
10m Contour
Potential Offset Sites

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Highlands Source Project

Job Number	23-13312-15
Revision	0
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Locality Map - Proposed Pipeline Alignment
Sector: Towrang

Figure 1(e)

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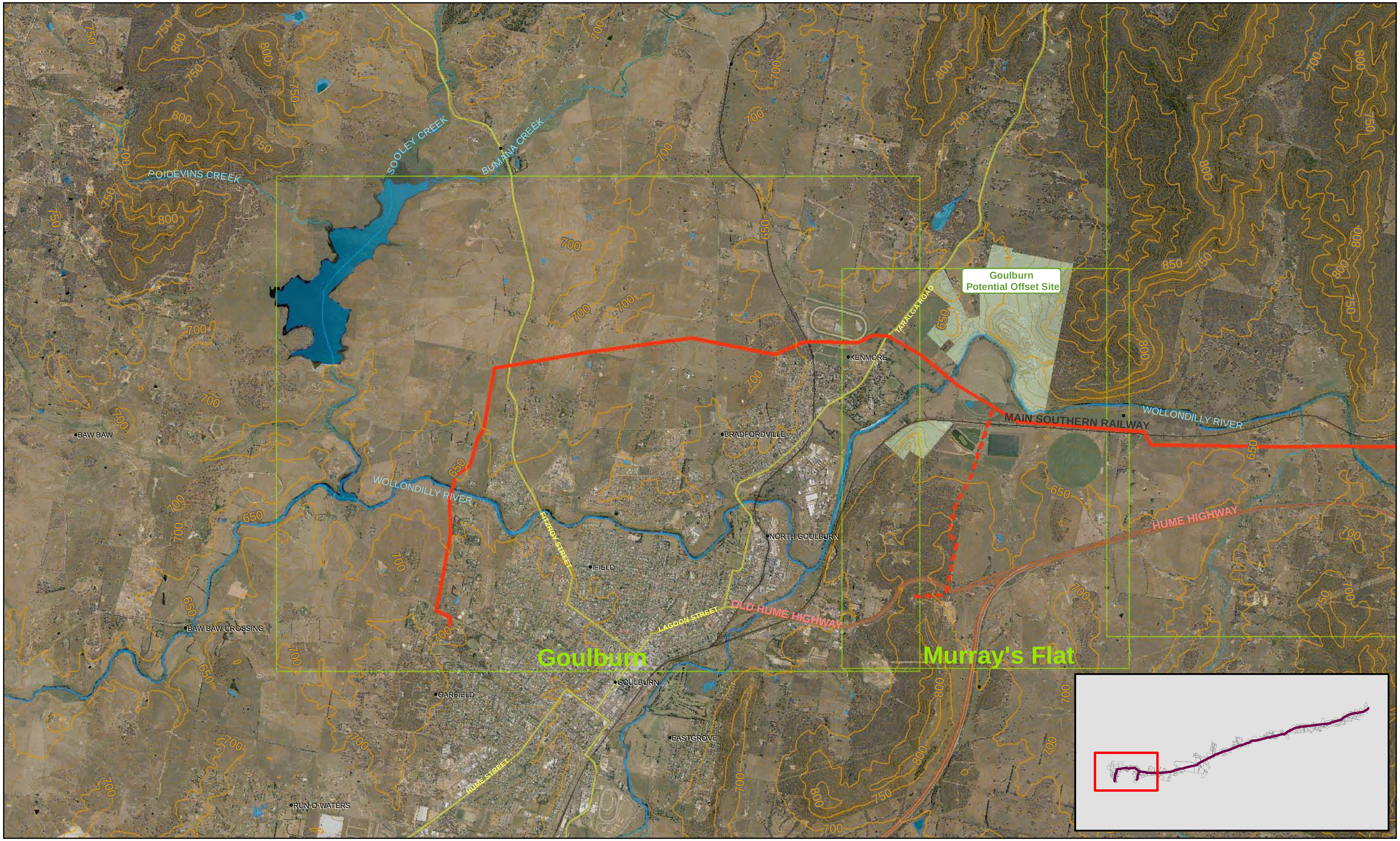
Level 7, 16 Marcus Clarke Street Canberra ACT 2601 **T** 61 2 6113 3200 **F** 61 2 6113 3299 **E** cbrmail@ghd.com.au **W** www.ghd.com.au

Data Source: NSW Lands Dept: crownlands,roadsegments,railways,hydroarea,hydroline,logalgovernmentarea,npwreserve,stateforest - 2007. Created by: ccharalambou, trbellwood, bahambly



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Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Legend

- Proposed Pipeline Alignment (Raw Water)
- (Treated Water)
- Sector boundary
- PrimaryRoad
- ArterialRoad
- Railway
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- Rivers, Creeks
- Local Government Area
- 50m Contour (Labelled)
- Potential Offset Sites
- 10m Contour
- Potential Offset Sites

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Highlands Source Project

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Locality Map - Proposed Pipeline Alignment
Sector: Goulburn-Murrays Flat

Figure 1(f)

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Level 7, 16 Marcus Clarke Street Canberra ACT 2601 **T** 61 2 6113 3200 **F** 61 2 6113 3299 **E** cbrmail@ghd.com.au **W** www.ghd.com.au

Data Source: NSW Lands Dept: crownlands,roadsegments,railways,hydroarea,hydroline,logalgovernmentarea,npwreserve,stateforest - 2007. Created by: ccharalambou, trbellwood, bahambly

2. Legislation

This section provides a discussion of the relevant Acts, environmental planning instruments and approvals applicable to the Proposal in respect to disturbance of waterways.

2.1 Relevant NSW Legislation

The following NSW legislation has relevance to the project in relation to waterway disturbance:

- *Protection of the Environment Operations Act 1997;* and
- *Water Management Act 2000.*

Additionally the following NSW policies have relevance to waterway stability and disturbance:

- NSW Sand and Gravel Extraction Policy for Non Tidal Rivers; and
- NSW State Rivers and Estuaries Policy.

The relevance of theses acts and policies in respect to impacts on waterway geomorphology and stability is further discussed in the following sections.

2.1.1 Protection of the Environment Operations Act 1997

The *Protection of the Environment Operations Act 1997* (POEO Act) is the key pollution control legislation in force in NSW. Amongst other things, it regulates pollution offences, including offences relating to:

- The wilful or negligent disposal of waste in a manner that harms or is likely to harm the environment;
- The wilful or negligent causing of a substance to leak, spill or otherwise escape in a manner that harms or is likely to harm the environment; and
- The pollution of waters through deliberate actions or actions that cause or permit pollution of waters. Under the Act, 'water pollution' includes introducing litter, wash water, soil, debris, detergent, paint, cement slurry, building materials etc. into waters or placing such material where it is likely to be washed or blown into waters or the stormwater system or percolate into groundwater.

The Project involves activities that could potentially destabilise waterways and cause an increase in sediment input and pollution of waters. The Project includes specific measures to minimise the risks of destabilising waterways.

2.1.2 Water Management Act 2000

The *Water Management Act 2000* (WMA) provides for the control of certain types of developments and activities that are carried out, in or near a river, lake or estuary. Such developments require a Controlled Activity Approval (CAA).

Under the WMA, a controlled activity means carrying any of the following works within 40 metres from a river, lake or estuary:

- The erection of a building or the carrying out of a work (within the meaning of the *Environmental Planning and Assessment Act 1979*);
- The removal of material (whether or not extractive material) or vegetation from land, whether by way of excavation or otherwise;
- The deposition of materials (whether or not extractive material) on land, whether by way of landfill operations or otherwise; and
- The carrying out of any other activity that affects the quantity or flow of water in a water source.

The Project would involve the excavation of soil materials, and the removal of vegetation from various waterways along the pipeline. However, public authorities, such as the Goulburn Mulwaree Council, are exempted under this Act for controlled activities they carry out in, on or under waterfront land.

2.1.3 NSW State Rivers and Estuaries Policy

The *NSW State Rivers and Estuaries Policy* was prepared in 1993 as the overarching policy for the sustainable management of NSW's rivers, estuaries and wetlands. The objectives of the policy are to manage rivers and estuaries in a ways which:

- Slow, halt or reverse the overall rate of degradation in the systems;
- Ensure the long term sustainability of their essential biophysical functions; and
- Maintain the beneficial use of the natural resources provided by the rivers and estuaries.

These objectives are to be achieved by adopting the six principles for sustainable management listed below.

- Encourage non-degrading uses of rivers and estuaries;
- Non-sustainable resource uses which are not essential should be progressively phased out;
- Environmentally degrading processes and practices should be replaced with more efficient and less degrading alternatives;
- Environmentally degraded areas should be rehabilitated and their biophysical functions restored;
- Remnant areas of significant environmental values should be accorded special protection; and
- An ethos for the sustainable management of river and estuarine resources should be encouraged in all agencies and individuals, who own, manage or use these resources.

The Project proposes to construct pipeline crossings through or under various watercourses including the Wollondilly River, Paddys River and various other creeks. The proposed construction and operational procedures include measures to minimise and prevent any degradation to the existing values of those systems and it is therefore considered that the Project is consistent with the above principles in relation to the potential impacts on waterway stability (Section 6.2 - Mitigation Measures).

2.1.4 NSW Sand and Gravel Extraction Policy for Non Tidal Rivers

The *NSW Sand and Gravel Extraction Policy for Non Tidal Rivers* is a component of the *NSW State Rivers and Estuaries Policy* (see above). Although the Proposal would not involve extensive extraction of sand and gravel from rivers in NSW, it would involve excavation of materials from river and creek banks, and as such the general intent of this policy has been considered. The three major objectives of this policy are as follows:

- To ensure that extraction of sand and gravel from a State's non tidal rivers is undertaken on a sustainable use basis;
- To manage such extraction in a way which minimizes and detrimental effects on the riverine environment thereby protecting other river uses and values; and
- To ensure that the extraction policy is consistent with the aims of the other Government policies and initiatives.

The Proposal, which involves construction controls and rehabilitation measures to protect and restore the environmental values of the watercourses that would be crossed, is considered to be generally consistent with the policy in relation to the potential impacts to waterway stability (Section 6.2 - Mitigation Measures).

3. Methodology

This assessment was undertaken based on available project information which consisted of:

- Plans showing the proposed pipeline route;
- A description of the Project, information regarding the pipeline construction, with regard to above and below ground works, proposed creek crossings and location of scour valves;
- Operational maintenance requirements; and
- Likely construction methodologies.

GHD assessed the existing environment, by considering the catchments, topography and climate of the region. Information was obtained from the project team and the Bureau of Meteorology. Information on soils was obtained from the NSW Department of Environment, Climate Change and Water (DECCW) (2009).

3.1 Waterway Identification and Classification

A desktop assessment of existing information (GIS data and aerial imagery) was undertaken to classify and preliminarily define the geomorphic type and condition (see Section 3.2) of waterways at crossing locations as detailed below.

The method for waterway classification at each crossing location was undertaken in general accordance with the parameters set out in Table 3-1.

Table 3-1 Waterway Crossing Classification Descriptions

Waterway Classification	Catchment Area (ha)	Stream Order*	Valley/Channel Definition
Drainage Line	< 100	Unmapped to first order	No defined channel and valley floor fill < 10 metres wide.
Minor Creek	100 to 500	First to second order	Defined channel < 5 m wide or valley floor fill 10 to 20 metres wide.
Moderate Creek	500 to 2,000	Second to third order	Defined channel 5 to 10 m wide or valley floor fill 20 to 50 metres wide.
Major Creek/River	> 2,000	Third order and higher	Defined channel > 10 m wide or valley floor fill > 50 metres wide.

* Based on Department of Lands 1:25,000 drainage layer

3.2 Waterway Types and Geomorphic Condition

The type of waterways at each crossing location was defined based on the River Styles framework (Brierley and Fryirs, 2005).

Assessment of geomorphic condition was based on Outhet and Cook (2004) who describe a rapid method of condition assessment that frames geomorphic condition in the context of natural and human induced variability and divide stream condition into three broad categories: Good, Moderate and Poor.

The characteristics relating to each of the categories of geomorphic condition are outlined below (based on Outhet and Cook 2004).

Good Condition – must contain all of the following characteristics:

- River character and behaviour is similar to the pre-development state presenting a high potential for ecological diversity.
- Minimal alteration to catchment controls such as sediment supply and the hydrological regime allowing fast recovery from natural disturbance.
- Relatively intact and effective vegetation coverage dominated by native species, giving resistance to natural disturbance and accelerated erosion.

Moderate Condition – contains one or more of the following characteristics:

- Localised degradation of river character and behaviour, typically marked by modified patterns of geomorphic units.
- Patchy effective vegetation coverage allowing some localised accelerated erosion.

Poor Condition – contains one or more of the following characteristics:

- Abnormal or accelerated geomorphic instability (reaches are prone to accelerated and/or inappropriate patterns or rates of planform change and/or bank and bed erosion).
- Excessively high volumes of sediment inputs which blanket the bed, reducing flow diversity.
- Absent or geomorphologically ineffective coverage by vegetation (allowing most locations to have accelerated rates of erosion).

3.3 Field Assessment

The geomorphic field investigation was undertaken between 19th and 22nd of February 2010 and assessed and recorded key information concerning the morphology of each waterway crossed by the pipeline including:

- Channel form and instream morphology;
- Bed and bank stability;
- Nature of bed and bank sediments;
- Channel controls;
- Adjoining landuses;
- Features indicative of flow levels (e.g. debris); and
- Nature and location of any existing infrastructure.

For each waterway crossing investigated, these values were assessed for approximately 50 metres upstream and downstream of the pipeline crossing location. This will allow identification of any immediate off site geomorphic processes that may impact on the proposed pipeline.

The field assessment encompassed all identified Major and Moderate named and unnamed waterway crossings. Additionally, a selection of Minor Waterways and Drainage Lines were also investigated to verify the range of geomorphic types and condition of these waterways as determined through the desktop assessment.

3.4 Determination of crossing method and impact assessment

The crossing method for each waterways was determined based on the classifications above (see Section 3.1 and Section 3.2), the field assessment and the recommendations for crossings provided by NOW as follows:

- Crossings of waterways/riparian land should be underbored or attached to existing structures (such as bridges) to avoid direct impacts on the aquatic and riparian environment, where:
  - there is permanent flow in the waterway; or
  - there is existing native riparian vegetation; or
  - the creek is in good natural condition; or
  - there is a potential fish passage Class 1 or 2.
- The NOW recommends that underboring commence from the outer edge of the riparian land and that it is bored for the full width of the watercourse and riparian land;
- Trenching may be an option if:
  - the waterway is a dry intermittent creek;
  - the native riparian vegetation has previously been cleared; and
  - there are no watercourse instability issues.
- If there are areas of the existing creek instability below the pipeline route the creek crossing needs to be designed so as to ensure for the future stability of the waterways and reduce risk to the pipeline itself.

The potential impact to the waterways has been assessed against the worst-case-scenario, that being that the waterway would be crossed by trenching. This was applied to all 138 waterways and despite most “major” waterways being crossed by HDD as the proposed measure, during the impact assessment, some of these waterways have been identified as suitable for trenching or alternative crossing methods. Further support of trenching for some permanently flowing waterways is required n the form of aquatic ecology surveys and geotechnical surveys which would be undertaken prior to construction.

4. Existing Environment

4.1 Overview

The pipeline corridor runs north of, and roughly parallel to, the catchment boundary separating the Hawkesbury Nepean catchment from the Southern Rivers catchment, placing it entirely within the Sydney Catchment Authority's drinking water catchments that drain into Warragamba Dam.

The site falls within the area managed by the Hawkesbury Nepean Catchment Management Authority (CMA). The area through which the proposed pipeline would traverse generally drains north, with the eastern section of the pipeline route draining naturally into the Wingecarribee River, and the western section of the pipeline route draining into the Wollondilly River. The confluence of these two rivers is located within the Wollondilly Nature Reserve.

The pipeline follows an upward sloping gradient from an altitude of approximately 675 metres at Moss Vale to 702 metres above sea level at Goulburn. The pipeline route is mostly gently undulating in topography, crossing creeks, rivers and other infrastructure. Named waterways bisected by the pipeline route include:

- Wollondilly River;
- Paddys River;
- Uringalla Creek;
- Kellys Creek;
- Jaorimin Creek;
- Narambula Creek;
- Black Bobs Creek;
- Boxers Creek;
- Medway Rivulet;
- Kenmore Creek;
- Osborns Creek; and
- Paynes Creek.

4.2 Soils

The pipeline area is underlain by rocks of a Palaeozoic age and an overlying sequence of sediments and volcanics forming the Cookbundoon Syncline. The region is covered by landscapes such as tablelands and associated grassy woodlands, alluvial flats, dissected plateaus, escarpment country and porphyrys. The natural ecosystems within the region have been extensively modified since European settlement and the extent of the component vegetation communities within the proposed development area has been dramatically reduced.

Based on Soil Landscape publications for the Hawkesbury-Nepean Catchment, 34 soil landscapes can be identified along the pipeline route. These may be grouped broadly into erosional, alluvial, transferral, colluvial and residual soil landscapes.

In general, there appears to be a widespread hazard for sheet erosion along the route. There also appears to be a general hazard for localised gully erosion along the pipeline. For a more detailed assessment of the soil conditions, the geotechnical study should be referred to.

4.3 Waterway Identification and Classification

A series of maps showing the alignment of the Project and location of identified waterway crossings has been included in Appendix A. Waterway crossing identification codes have been numbered sequentially from east west along the pipeline alignment. Details of each individual waterway crossing are provided in Appendix B with further details on Major Creeks/Rivers and Moderate Creeks provided in Appendix C.

Of the 138 identified waterway crossings:

- 12 were classified as crossings of Major Creeks/Rivers which are all named as follows:
  - W3 - Kellys Creek.
  - W56 – Uringalla Creek.
  - W52 - Paddys River.
  - W57 - Back Creek.
  - W69 - Jaorimin Creek.
  - W84 - Narambulla Creek.
  - W108 - Boxers Creek.
  - W120 - Kenmore Creek.
  - W105, W106, W119 and W131 - Wollondilly River.
- 8 as Moderate Creeks crossings of which 6 are named as follows:
  - W14 – Medway Rivulet.
  - W22 – Black Bobs Creek.
  - W95 – Osborns Creek.
  - W122, W123 and W124 – Kenmore Creek.
- 25 as Minor Creek crossings including 3 named waterways as follows:
  - W19 – Wells Creek.
  - W27 – Long Swamp Creek.
  - W81 – Lockyersleigh Creek.
- 93 as Drainage Lines which are all unnamed.

4.4 Waterway Types

The waterways inspected for the purposes of this assessment were predominately set within a rural or semi-rural land use context and have been modified over time by land clearance, the construction of the gas pipelines and other agricultural practices. Most waterways are ephemeral in nature and flows were observed at only some of the Moderate and Major Creeks/Rivers at the time of the site inspections.

The following sections provide a summary description of the eight (8) broad waterway types observed during the field inspection.

Headwater Systems

Headwaters consist of steep gradient channels that are bedrock dominated and have limited deposits of sediments within the channel. Floodplains are non-existent. The channel may slowly erode the valley wall if it consists of weathered bedrock or colluvium.

Many of the headwater systems had relatively undefined flow paths such that flows at the crossing point are largely derived from hillslope sheet flow rather than concentrated within a defined channel or valley.

- Of the 138 crossings, 43 are Headwater systems which have all been classified as Drainage Lines.

Confined Systems

Confined systems are characterised by a single, symmetrical channel often in bedrock controlled, irregular V or U shaped valleys. Channel geometry and sinuosity is valley controlled and the bed is composed of bedrock, boulder, cobble and gravel. The system may also transport sand, depending on local geology. The banks are composed of bedrock and boulders and floodplains are absent. These are geomorphically stable reaches that are subject to very slow rates of change due to the high degree of bedrock confinement.

- Of the 138 crossings, one (1) is a Confined System which has been classified as a Moderate Creek (W95 – Osborns Creek).

Valley Fill Systems

Many of the Minor Waterways were generally typical of valley fill system. These systems are characterised by a relatively flat, unincised valley floor surface with substrates comprised of alluvial fine silts and muds. Such features are typically formed by flows that lose their velocity and competence as they spread over an intact valley floor and deposit their sediment load. Material eroded from the catchment is not transported through the reach, which is often on a relatively flat longitudinal grade.

- Of the 138 crossings, 57 are Valley Fill systems of which the bulk has been classified as Drainage Lines or Minor Creeks. One Valley Fill system has been classified as a Moderate Creek (W124 – Kenmore Creek).

Channelised Fill Systems

Some waterways displayed slightly different characteristics and have been described as ‘incised valley fill systems’. While these are similar to the valley fill systems described above, they have a more defined watercourse channel. In some cases, the waterways have been channelised or formed as a constructed drainage line. Generally it is likely that these were also once valley fill systems however have been modified to convey flows in order to drain land for agricultural use.

- Of the 138 crossings, 20 are Channelised Fill systems of which the bulk has been classified as Drainage Lines or Minor Creeks. One Channelised Fill system has been classified as a Moderate Creek (W121 – Unnamed Creek) and one as a Major Creek (W108 – Boxes Creek).

Chain of Ponds Systems

These waterways display a series of symmetrical (occasionally irregular) ponds that occur at irregular intervals along a drainage line. The bank of the ponds and the bed in which they exist is composed of fine sand, mud and organic material. Ponds tend to retain water throughout the year and during high flows, sands and finer material are transported downstream. This waterway type is often associated with lower gradients and lower flow velocity. Chain of Ponds systems are regarded to be a relatively rare and fragile waterway type, such that they are prone to channelisation between the ponds forming a continuous channel. This reduces the water retention capacity of the ponds with associated loss of aquatic habitat.

- Of the 138 crossings, one (1) is a Chain of Ponds System which has been classified as a Major Creek (W84 – Narambulla Creek).

Bedrock Controlled Fine Grained Systems

The channel of these waterways is single, trench-like and symmetrical and has low sinuosity with moderate lateral and vertical stability. It is often bedrock floored. Valley width and alignment controls channel sinuosity and floodplain extents, creating discontinuous floodplains as the river migrates between valley margins. Cohesive fine-grained sediments dominate the bed and alluvial banks.

- Of the 138 crossings, five (5) are Bedrock Controlled Fine Grained Systems which all have been classified as Major Creeks/Rivers as follows:
  - W52 (Paddys River).
  - W105 (Wollondilly River).
  - W106 (Wollondilly River).
  - W119 (Wollondilly River).
  - W131 (Wollondilly River).

Bedrock Controlled Sand Systems

The Bedrock Controlled, Sand channel consists of a single, laterally stable, bedrock floored channel with a sandy bed. Some lateral movement can occur where discontinuous floodplains are formed as the channel crosses from valley margin to valley margin. The channel is usually prone to enlargement through erosion.

- Of the 138 crossings, one (1) is a Bedrock Controlled Sand System which has been classified as a Major Creek (W69 – Jaorimin Creek).

Low Sinuosity Fine Grained Systems

This waterway type exhibits a low sinuosity channel with wide, continuous floodplains and relatively stable, cohesive bank due to the fine-grained material. The bed consists of fine-grained sediments with some sand and gravel sections creating moderate hydraulic diversity within the channel. The channel itself is of low gradient and usually low energy allowing a build up of fine-grained sediment.

- Of the 138 crossings, ten (10) are Low Sinuosity Fine Grained Systems of which:

One (1) has been classified as a Minor Creek and is unnamed (W16).

Five (5) have been classified as Moderate Creek waterway crossings and are listed as follows:

- W14 (Medway Rivulet).
- W22 (Black Bobs Creek).
- W112 (unnamed).
- W122 (Kenmore Creek).
- W123 (Kenmore Creek).

Four (4) Low Sinuosity Fine Grained Systems have been classified as Major Creek waterway crossings and are listed as follows:

- W3 (Kellys Creek).
- W56 (Uringalla Creek).
- W57 (Back Creek).
- W120 (Kenmore Creek).

4.5 Waterway Existing Condition

European land clearance has resulted in altered hydrological regimes which have had an impact on the morphological character of many of the waterways within the vicinity of the proposed pipeline route.

Land clearance can have impacts on catchment and waterway character and behaviour. Catchment responses to land clearance include increased runoff, increased drainage density, increased erosion and sediment yields within the catchment. In response to altered hydrological regimes channel morphology changes can occur as the result of bank erosion, channel incision and floodplain scour which are generally associated with increasing stream power and sediment transport capacity.

Prior to European land clearance, many of the waterways along the proposed route would have been either Chain of Ponds or Valley Fill waterway systems while now they exhibit an incised, channel form. Many of the waterways have significantly altered their form and some continue to exhibit signs of channel instabilities.

Additionally, the alignment follows the existing gas pipelines from approximately the Hume Highway through to Goulburn encompassing waterway crossings W27 to W128 (with the exception of waterway crossings W113 to W118 that would eventuate if the treated water option is adopted). As a result, the waterways, although generally stable, have been disturbed previously and lack native riparian vegetation coverage in the vicinity of the crossing locations.

Due largely to the above impacts, many of the waterways at the crossing sites were considered to be in moderate to poor geomorphic condition.

Of the 138 waterway crossings:

- Waterways were assessed to be in good condition at 31 of the crossings. These are all Minor Creeks with Headwater and Valley Fill systems apart from the Major Creek/River crossing at W69 (Jaorimin Creek).
- Waterways were assessed to be in moderate condition at 92 of the crossings, ten (10) of which are classed as Major Creeks/Rivers and four (4) as Moderate Creeks.

- Waterways were assessed to be in poor condition at 15 of the crossings, one (1) of which is a Major Creek/River (W108, Boxers Creek) and four (4) are Moderate Creeks.

4.5.1 Waterway Stability

Most waterways along the pipeline route are considered to be relatively geomorphologically stable. This is a reflection of the landscapes and type of waterway systems the proposed pipeline traverses. In particular, 100 of the 138 waterway crossings are either:

- Valley Fill systems composed of fine-grained (silt and/or clay) cohesive sediments that dissipate flows over a broad, flat surface, limiting the potential for scour and erosion.
- Headwater systems that are entirely bounded by bedrock and are therefore not prone to bed or bank scour.

Nevertheless, some waterways displayed existing instabilities in the form of either headward erosion or bank erosion. These instabilities and their locations are discussed in the following:

4.5.2 Bed Instability – Headward Erosion

Headward erosion ('headcut') is erosion which occurs along a channel in the opposite direction to water flows. This causes down cutting or incision of the bed of a stream and can alter the longitudinal profile of the waterway. Erosion can result in increased rates of sediment to be transported downstream.

- Headward erosion was evident downstream of four (4) of the waterways assessed encompassing W8, W20, W42 and W80.

4.5.3 Bank Instability

Bank instabilities were evident in some waterways crossed by the proposed pipeline. Many banks are irregular in shape indicating that erosion has occurred in the past. Banks are generally stable under the current flow regimes, many of which are stabilised by pasture grasses.

- Existing bank instabilities were evident at nine (9) of the waterway crossings encompassing W1, W14, W19, W42, W67, W69, W79, W108 and W111.

5. Impact Assessment

5.1 Project Details

The preferred pipeline route corridor would be located mostly adjacent to existing infrastructure easements (gas, electricity and optical fibre) that have previously been cleared and either remain cleared or have regenerating vegetation present. From Wingecarribee Reservoir, the pipeline route largely runs adjacent to existing power line easements until it crosses the Hume Highway. After crossing the Hume Highway, the pipeline route would be located adjacent to and outside of an existing gas pipeline easement, which it follows almost the entire way to Goulburn.

Two options are still being considered for the point at which the pipeline would enter the Goulburn water supply system. The options considered are:

- Pumping raw water from the Wingecarribee Reservoir to a reservoir located at the Goulburn WTP. If this option were to proceed, waterway crossings W113 to W118 would not be required.
- Pumping treated water from the Wingecarribee WTP to connect to the Goulburn Mulwaree mains supply. If this option were to proceed, waterway crossings W114 to W138 would not be required.

Both of these options would be progressed until detailed design phase and both would be subject to further environmental assessment. The raw water pipeline route corridor is approximately 81 km long while the treated water pipeline route is approximately 75 km long.

Key infrastructure associated with the project is described below.

5.1.1 Trenched Pipeline

Raw water would be pumped to the Goulburn supply network through a new, dedicated long-distance buried water transmission pipeline approximately 81 km long from the Wingecarribee Reservoir. This would connect into the existing Goulburn supply network at the Goulburn Water Treatment Plant. Alternatively under the second option, treated water would be pumped to the Goulburn supply network through a new, dedicated long-distance water transmission pipeline approximately 76 km long from the Wingecarribee Reservoir. For the trenching operation:

- The pipeline construction corridor would be in the order of 20 m wide while the pipeline is being constructed;
- Where specific obstacles such as large trees, endangered ecological communities and large boulders or significant landscapes are identified along the route, the construction corridor would be narrowed to 6 m to 8 m wide;
- The pipeline trench would be approximately 1 m wide and excavated to a nominal depth of 1.5 m to 2.0 m below ground surface using either a tracked excavator or a tracked chain trencher;
- Stockpile areas of approximately 10 m by 10 m wide would be located intermittently along the pipeline easement; and
- Following construction, an easement (of approximately 10 m in width) would be maintained as a cleared landscape to allow access for ongoing maintenance activities.

5.1.2 Pump Station

A high lift pumping station would be located adjacent to the existing raw water pumping station between the dam and the Wingecarribee WTP. This pumping station would be initially equipped to achieve a flow rate of 5 ML/d and would involve approximately 100 KW of pumping capacity. Alternatively under the second option, a new treated water pump station would be located near the Wingecarribee Water Treatment Plant. The transfer pump station would pressurise the pipeline and initiate the flow of water through the pipeline.

5.1.3 Air Valves, Scour Valves and Other Valves

Air valves would be used to exhaust air from the pipeline at high points. Scour valves would be used to release scour water from the pipeline at low points, in a managed manner.

5.1.4 Crossings

The pipeline would cross railways (including the Moss Vale Unanderra Railway) and major roads (*e.g.* the Hume and Illawarra Highways), local roads, various water bodies (including the Wollondilly River) and a number of services. Alternative methods to trenching are likely to be used to traverse these features due to a number of factors, such as the need to limit disturbance to normal operation of roads and railways, limiting environmental disturbance to waterway crossings and avoiding important services (i.e. gas and optical fibre). The methods that may be employed include:

- Thrust boring.
- Horizontal directional drilling (HDD).
- Pipe bridges.

The crossing techniques have been determined following consideration of technical, environmental and geological constraints; however they may be further refined during the detailed design phase.

5.1.5 Connection/Outlet Points

The water would be pumped to an existing tank located behind the Goulburn WTP. Alternatively, it may be mixed into the existing 600 mm diameter rising main from the weir supply system in Goulburn and taken directly to the intake works.

5.1.6 Other Infrastructure

The pipe would require ancillary infrastructure such as, access points for testing, divide valves, cathodic protection. Site compounds, storage, stockpile and lay down areas would be required at various locations along the pipeline. The proposed locations of the facilities have generally been selected to occupy existing cleared areas or areas that would be cleared for the excavation of the pipeline trench.

5.2 Waterway Crossing Construction Methods and Impacts

There are a number of available methods for constructing waterway crossings, depending on environmental and engineering constraints. For the environmental impact assessment, it has been assumed that most waterways with permanent flowing water ("major waterways") would be crossed by HDD, with all other waterways crossed by open cut trenching, unless there are sensitive waterways or associated environments. Further aquatic ecology surveys and geotechnical investigations will determine the final method of crossing during detailed design.

This assessment therefore considers the potential impacts associated with the trenching method on waterway stability for all waterways as a base case scenario.

As a base case, all waterways have been assessed for the suitability for trenching as a crossing method. Where it is determined that trenching would not be a feasible crossing method, an alternative method has been identified (i.e. HDD or anchored pipeline).

5.2.1 Trenching

Standard open cut trenching is most often utilised in low flow, shallow or dry conditions. This technique involves setting up a stable work platform on each side of the watercourse and then excavating a trench. The trench is not completed until immediately prior to placement of the pipeline. Tie in points are located on high ground away from the banks. Pipes are then placed into the trench using slings from the excavators at either side of the waterway. The spoil from the watercourse bed and bank and trench spoil material are stored separately.

This crossing method may also be applied in sensitive streams where rapid construction is considered the best means of minimising environmental impacts. The primary risk of impact associated with trenching is the potential for release of high sediment loads during excavation and backfilling. If managed inappropriately, it could increase turbidity, impacting upon downstream water quality. Mitigation measures to reduce the environmental impact of trenching include, flow diversion, sediment capture devices and strict environmental management controls.

Where higher water volumes and flows are present, open trenching using streamflow diversion can be used. This technique typically involves creating a dry construction area within which to work by pumping around the area. Other diversion techniques include diverting the water flow through a flume pipe installed between the dams. Diverted flow is maintained at a flow rate and water quality, which would allow the downstream reaches of the waterway to continue to function.

5.2.2 Construction Impacts

Key *construction activities* include:

- Installation of sediment controls and flow diversions.
- Trench excavations and placement of the pipeline.
- Reinstatement / revegetation.

5.2.3 Trenching Impacts

Impacts associated with trenching may include:

- Disturbance to bed and banks of waterway channels.

- Disturbance to floodplains.
- Stream bed degradation.
- Stream bank erosion.
- Scour potential from poor pipeline orientation:
  - The impact of erosion from bed and bank disturbance can include water quality impacts on the downstream environment. General construction activities (e.g. stockpiling of material, etc.) may lead to sedimentation issues.
  - Impacts to riparian and aquatic flora and fauna.
  - Disturbances or loss of native vegetation (including seedbank, instream and riparian vegetation).

5.2.4 Waterway access track crossings

To allow trenching to occur across waterways temporary access tracks would need to be created to allow machinery to cross the waterway. Most waterways would not require significant additional works to allow this to occur due to their geomorphology; however some larger waterways may require some bed level crossings or bridges to be installed during the works. This may also include bank cutting to allow machinery to access the bed or bridge. These waterway crossings would be identified during the detailed design phase and specific access methods and associated erosion and sediment controls, as well as waterway rehabilitation would be fully documented in the project CEMP.

Specific impacts that may occur as a result of access track crossing include the following:

- Disturbance to bed and banks of waterway channels.
- Disturbance to floodplains.
- Stream bed degradation.
- Stream bank erosion.
- The impact of erosion from bed and bank disturbance can include water quality impacts on the downstream environment.
- Impacts to riparian and aquatic flora and fauna.
- Disturbances or loss of native vegetation (including seedbank, instream and riparian vegetation). and
- Weir- or dam-like effects and other changes to the flow regime.

Waterways that are being underbored (HDD) would be accessed from either side of the crossing and only where existing bridges or accessways are present, would access be gained across the waterway.

No permanent waterway crossings have been proposed in this project. Where access is required post-construction, existing accesses across waterways would be used.

5.3 Specific Transfer Pipeline Route Impacts on Waterway Geomorphology

5.3.1 Alteration of Channel Morphology

Trenching to lay the pipe would disrupt the bed and banks of waterways along the proposed pipeline alignment resulting in altered channel and floodplain morphology if appropriate mitigation is not implemented.

5.3.2 Stability

Site based assessment indicates that headward erosion and bank erosion is occurring in the vicinity of some waterway crossing locations along the alignment. These bed and bank instabilities may be further exacerbated by construction associated with laying of the transfer pipeline. This may:

- Increase the risk of headward erosion. Where headcuts are evident downstream there is a risk that the pipeline would create bed instabilities leading to further channel incision in an upstream direction. An additional consequence of this may be the risk of exposing the pipeline asset in the future.
- Bank disturbance would occur during trenching activities. If appropriate reinstatement is not implemented this may lead to bank erosion.

Works on waterways during construction of the Project also have the potential to increase bed and bank instabilities due to removal of existing instream and riparian vegetation and disturbance of the channel profile.

5.3.3 Waterway Types and Impacts

The following sections provide an assessment of the general impact of pipeline construction on waterway stability by waterway types.

Headwater and Confined Systems are completely bounded by bedrock and are not prone to bed scour or bank erosion. As a result, the channel is extremely stable and with appropriate treatment and rehabilitation the construction of the pipeline will have an extremely low risk of increased channel instabilities on these systems.

Valley Fill Systems do not have a defined channel and therefore cannot be subject to bed scour or bank erosion. These systems dissipate flows over a flat, broad area and are generally composed of cohesive fine grained sediments. Hence, they are considered stable landforms when in intact. However, disturbance can result in the incision of a channel within the fill surface that can lead to significant erosion and release of sediments to downstream environments. In the case of pipeline construction:

- Exposure and disturbance of valley fill sediments from trenching and other construction activities can destabilise the valley fill surface allowing a point where channelisation could be initiated. With appropriate treatment and rehabilitation the risk of channel initiation is low, however, the risk is considered moderate at locations where the pipeline alignment traverses along (rather than across) the valley surface. In such cases, the trench is aligned parallel to flows, increasing the propensity for scour of sediments during runoff events. This occurs at one location along the proposed pipeline route for the waterway encompassed by waterway crossings W132 to W136.
- Flow diversion structures for construction may concentrate flows resulting in an increased potential for scour during run-off events and initiating channel development. The risk of this is considered low

due to the relatively rapid construction requirements of the pipeline (up to 300 metres per day), limiting the need for flow diversions structures if construction is undertaken during dry periods.

Additionally, headward erosion was evident downstream of a number of waterway crossings within Valley Fill systems. This poses a risk of potential future exposure of the pipeline in the event further upstream retreat of the headward erosion occurs. Waterway crossings where headward erosion is evident downstream are W8, W20, W42 and W80.

Channelised Fill Systems are created through the development of a continuous, defined channel within a valley fill surface usually through the headward retreat of a gully system. In most cases, the depth of incision is limited by underlying bedrock or by some downstream base level control. Hence, the propensity for further vertical incision of the channel is limited. However, the banks of such systems can exhibit prolonged instability following the initial development of the channel. Channelised Fill waterway crossing locations where ongoing bank instability was identified are W1, W19 (Wells Creek), W79, W108 (Boxers Creek) and W111. Construction of the pipeline has a low to moderate risk of exacerbating bank instabilities in the immediate locality of these crossings.

Chain of Ponds Systems exhibit a series of elongated ponds separated by connections that do not have a defined channel. Similar to Valley Fills, disturbance of pond connections can result in the incision of a channel within the connections that can lead to significant erosion, the release of sediments to downstream environments and the loss of the permanent/near permanent pond environments. Only one Chain of Ponds system was identified along the pipeline route, W84 (Narambulla Creek). The crossing point is located towards the downstream extent of a pond and, hence, trenching activities and pipeline placement will not directly disturb a pond connection. However, the immediate upstream extent of the downstream connection is likely to be used as a crossing point for vehicles and machinery. While, vehicular movements may disturb the soils at this location, it is at a point in the connection where the likelihood of initiating channel development is extremely low. Nevertheless, soil disturbance will need to be minimised to reduce the potential for turbidity impacts through construction of an appropriate temporary crossing.

Bedrock Controlled Fine Grained and Bedrock Controlled Sand Systems have some capacity to adjust in response to disturbances, usually through localised bank erosion and/or bed degradation. These responses are generally limited in extent due to the presence of regular bedrock controls along these waterway types. In the case of the construction of the pipeline, the potential degree and extent of these impacts will be site specific. Hence, the potential impacts of the pipeline on each of the waterway crossings of these waterway types are discussed below.

- **W52 (Paddys River)** – At the proposed crossing site, Paddys River exhibits a riffle zone composed of angular cobbles indicative of limited transport capacity of bed materials. The channel is less than 5 m wide and abuts the steep, bedrock valley margin on the left bank. The right bank is less than 1 m high and is composed of alluvial silts. A relatively flat floodplain grades gently up from the right bank to the right bank valley margin and is approximately 130 m wide. The channel is stable and well vegetated with a mixture of willows and native vegetation (ti-tree). Channel scour potential during high flows is limited due to the dense channel vegetation and low channel depth which allows flood flows to readily dissipate across the floodplain.
  - The high degree of bedrock control and limited bed mobility/scour potential at the proposed crossing site means that the risk of a trenched pipeline construction to cause channel instabilities

is low if standard mitigation measures are implemented. The narrow width of the channel means that the duration of construction impacts will be limited.

- **W69 (Jaorimin Creek)** – At the crossing site, Jaorimin Creek exhibits a shallow (0.5 m deep) pool. The bed of the pool is composed of sand and is considered mobile under moderate to high flow. The channel is less than 5 m wide and banks are low, stable and well-vegetated with grasses. A rock ford crossing downstream controls upstream channel bed and water levels in the pool. A steep drop exists downstream of the ford crossing and banks are eroding, posing a risk the ford may fail in the future. This would lead to a drop in the bed level and water level of the pool, with a risk of exposing the pipeline in the future.
  - The risk of pipeline construction to cause channel instabilities is considered low if appropriate bank re-instatements are implemented and the pipeline is set at a depth below the influence of bed scour. However, the potential future failure of the ford downstream poses a risk to the pipeline and the stability of the channel at the crossing location. The narrow width of the channel means that the duration of construction impacts will be limited.
- **W105 (Wollondilly River)** – At this crossing site, the Wollondilly River exhibits a large, deep pool (> 5m water depth) inset within a broader macro-channel approximately 80 m wide. Stable, alluvial banks grade gently up to floodplains elevated approximately 5 m above the pool water surface level.
  - Given the depth of the pool, a trenched pipeline at this crossing location is unlikely to be feasible. The current alternatives, subject to geotechnical and hydraulic investigations, are to either lay the concrete encased pipeline across the channel bed or to use a Horizontal Directional Drill (HDD) method. Both these methods will result in minimal disturbance to the channel bed during the construction phase, although banks will be excavated to transition the pipe into and out of the channel if the anchored option is selected. However, with appropriate re-instatement and rehabilitation the risk of ongoing bank erosion is considered low.
- **W106 (Wollondilly River)** – This crossing site is located on a riffle zone of the Wollondilly River. The riffle is inset within a stable macro-channel (30 m wide and 3 m deep) and is composed of large angular cobbles and gravels within a sand/silt matrix. This indicates bed materials are mobilised infrequently under high magnitude flow events. The riffle largely has a pasture grass cover apart from a narrow (3 m wide) low flow channel that runs through the centre of the riffle zone. Bedrock is exposed in the base of the low flow channel indicating the low flow channel is vertically stable. However, the low flow channel has the potential to move laterally across the entire width (approximately 20 m) of the macro-channel invert over time and in response to high magnitude flow events.
  - The exposure of bedrock in the low flow channel means that the pipe will be able to be inset within a bedrock trench and concrete encased. This construction method will need to be implemented across the entire width of the macro-channel to limit the exposure of the pipe through potential lateral adjustments of the low flow channel in the future. This, in conjunction with appropriate flow diversions and bed and bank re-instatements, provides a low risk of pipeline construction to cause channel instabilities at this site.
- **W119 (Wollondilly River)** – This crossing is located at the downstream extent of a pool on the Wollondilly River inset within a broader macro-channel (approximately 60 m wide and 5 metres deep). The depth of water at the crossing site at the time of inspection was less than 0.5 m, following a recent rainfall event. The pool is controlled by a downstream riffle zone composed of cobbles and

gravels. A rock causeway crosses the river at the riffle zone. Banks are alluvial and are stable being well graded and grassed.

  - Given the low water depths at this crossing site, a trenched crossing is feasible and will result in minimal long term disturbance to the channel bed and banks if constructed during low flow periods and appropriate flow diversions, sediment controls and bed and bank re-instatements are implemented. However, the bed of the channel is composed of fluvial gravels, sands and silts and excessive scour may expose the pipe during high magnitude flood events.

- **W131 (Wollondilly River)** – The Wollondilly River channel at this crossing location is 25 m wide and exhibits a pool (2 to 3 m deep) that is influenced by a weir further downstream. Banks are alluvial and, although near vertical, are stable and well vegetated with grasses.

  - Given the depth of the pool a trenched pipeline at this crossing location is unlikely to be feasible. The current alternative, subject to geotechnical and hydraulic investigations, is to anchor the pipeline to the channel bed via concrete blocks. This will result in minimal disturbance to the channel bed during the construction phase, although banks will be excavated to transition the pipe into and out of the channel. However, with appropriate re-instatement and rehabilitation the risk of ongoing bank erosion is considered low.

Low Sinuosity Fine Grained Systems are generally stable due to the bed and banks of the channel being composed of cohesive fine, grained sediments. As a result most of these systems along the alignment are stable at the proposed pipeline crossing locations. With appropriate treatment and rehabilitation the risk of bed and bank erosion posed by pipeline construction is generally low. The exception is waterway crossing W14 (Medway Rivulet) where ongoing bank instability was evident at the crossing location. Construction of the pipeline has a low to moderate risk of exacerbating bank instabilities in the immediate locality of this crossing.

6. Mitigation Measures

6.1 General Impact Mitigation

A range of measures are commonly used to mitigate potential impacts on the surface water environments and waterway stability. These measures are outlined below and should be incorporated into an Environmental Management Plan (EMP).

6.1.1 Erosion and Sediment Control Measures

- Erosion and sediment control measures should be established prior to construction.
- Erosion and sediment control measures should be regularly inspected, particularly following rainfall events, to ensure their ongoing functionality.
- Vegetation clearance should be avoided where possible to protect soils from erosion. If clearance cannot be avoided, the area of vegetation cleared at any one time should be minimised.
- Reinstatement of vegetation as quickly as practicable after construction.
- All stockpiled material should be stored in bunded areas and kept remote from waterways to avoid sediment entering the waterway.
- Diversion drains and bunds should be established during construction works to manage site runoff and minimise the transport of sediment from the construction site into the waterway.
- Preferably a waterway should be crossed on a straight portion of the waterway to avoid the risk of erosion. Where this is not possible bank stability works should be implemented.

6.1.2 Timing of Construction

- Waterway crossings should be avoided during periods of heavy rainfall and flooding.
- Contingency plans to address heavy rainfall and flood events during construction should be included in an EMP. The contingency plan should address:
  - Limiting stormwater entering excavation areas.
  - Enhancement of controls when heavy rain is forecast.
  - Siting of facilities.
  - Clean up procedures.
  - A flood warning system for crossings on Major waterways.
  - Procedures for limiting loss of spoil and other hazardous materials.

6.1.3 Minimise Site Disturbance

Actions to be taken to avoid site-based disturbance during the construction period should include:

- Minimise the width and effective footprint of works across waterways.
- Control the route used by machinery into and out of the works site.

- Avoid the need for access of heavy machinery to the bed of the waterways as works should be undertaken from the top of the banks where possible.
- Avoid disturbance of surrounding banks by machinery or other construction works.

6.1.4 Depth of Pipeline at Waterway Crossings

- Depending on depth to bedrock, provide a minimum of 1 metre from the top of the pipe to the bed of the channel for Moderate Creeks, Minor Creeks and Drainage Lines.
- Depending on depth to bedrock, provide a minimum of 2 metres from the top of the pipe to the bed of the channel for Major Creeks.
- For Valley Fill and Chain of Ponds systems, the minimum depth should be maintained across the entire width of the valley to reduce the risk of exposure of the pipe in the event a channel develops in the valley fill surfaces in the future.

6.1.5 Waterway crossings

Existing disturbed areas or accessways would be used, where possible, for vehicles that need to cross the waterways. This may include existing farm tracks and culverts or areas where vegetation has already been cleared. Waterways requiring new access tracks, or those that contain saturated ground at the time of construction may require bed level stabilisation in the form of coarse aggregate to allow vehicles to pass through the waterway. Any additional waterway crossings would be appropriately stabilised and rehabilitated and would not consist of culverts or be raised above bed level so as not to impede fish passage. The details of proposed rehabilitation for specific waterways would be determined by a project agronomist and detailed in both the CEMP and the project rehabilitation plan.

6.1.6 Stream Flow Diversion Measures

- Implement stream flow diversion measures during construction where high water volumes and flows are present and unavoidable.

6.1.7 Reinstate Profile

- Replace sediments in order they were removed.
- Reshape according to current profile.
- Design recommendations informed by the geotechnical investigation to address the potential for differential settlements in areas containing soft or compressible soil types.

6.1.8 Stability

- Reinstate bank soils over pipeline with a soil-rock mix (~100-300 mm), jute matting and regrassing to reduce risk of bank erosion.
- Reinstate bed and banks with rock in erosion sensitive areas to protect from bank erosion.

6.2 Specific Mitigation Measures

In addition to the standard management requirements that would be expected during construction, some waterways may require additional mitigation measures to ensure adequate protection. These measures are outlined within Table 6-1 for specific waterway types and/or waterway crossings.

Table 6-1 Recommendations for Specific Waterway Mitigation Measures

Waterway Type	Waterway Crossings	Potential Impact	Recommended Mitigation
Valley Fill	All	Concentration of drainage due to flow diversions and/or soil disturbance leading to channel development.	Avoid or limit the use of flow diversions during construction phase. Undertake construction during dry conditions to limit soil disturbance and need for flow diversions. Ensure final landform merges to pre-existing surface levels to avoid changes in flow distribution across valley fill surface. Implement rehabilitation measures immediately following construction.
	W132 to W136	Pipeline traverses longitudinally along valley fill surface increasing the risk of scour and channel development.	As per above and including: ◗ Limit the extent of open trench exposed at any time. ◗ Provide emergency bunding (eg sand bags) to divert flows from open trench in the event rainfall is forecasted during construction. ◗ Rehabilitate completed works and disturbed areas with a surface rock (50 to 100 mm) and soil mixture, jute matting and revegetation immediately following construction.
	W8, W20, W42 and W80	Retreat of existing downstream headward erosion leading to exposure of pipeline in the future.	Set pipeline at a depth below the invert of the developed channel downstream; and/or Monitor headward erosion and install stabilisation works in the event exposure of the pipeline is imminent.
Channelised Fill	W1, W19, W79, W108 and W111	Exacerbation of existing channel instabilities.	Provide rock protection to disturbed banks ensuring the protection merges to existing surfaces and the risk of outflanking by existing upstream or downstream erosion is minimised.
Chain of Ponds	W84	Disturbance of downstream pond connection through	Install a temporary causeway for construction composed of loose rock (100 to 200 mm). This shall be underlain by a geotextile to allow

Waterway Type	Waterway Crossings	Potential Impact	Recommended Mitigation
		vehicular movements	removal of rock following cessation of construction activities in the area. Undertake construction during dry conditions to limit soil disturbance.
Bedrock Controlled Fine Grained	W106	Exposure of pipe through lateral movement of low flow channel in the future.	Inset pipe within bedrock across entire width of the macro-channel.
	W119	Bed scour and pipe exposure during high flow events.	Undertake geotechnical and hydraulic investigations to determine potential scour depth at crossing site. Set pipe below this depth and provide appropriate protection.
Bedrock Controlled Sand	W69	Bed scour and pipe exposure during high flow events.	Undertake geotechnical and hydraulic investigations to determine potential scour depth at crossing site. Set pipe below this depth and provide appropriate protection.
		Failure of downstream ford leading to exposure of pipe and channel instability at crossing site.	Given the ford will be likely to be used as a crossing for vehicles during construction, it is recommended that the ford be upgraded through construction of a rock dissipation ramp and provision of rock bank protection immediately downstream of the ford.
Low Sinuosity Fine Grained	W14	Exacerbation of existing channel instabilities.	Provide rock protection to disturbed banks ensuring the protection merges to existing surfaces and the risk of outflanking by existing upstream or downstream erosion is minimised.

6.3 Operational Management Measures

Additional requirements may need to be addressed during the operational phase of the Proposal in order to minimise the impact on the surface water environment: These may include:

- Monitoring of the downstream bed stability of the waterway where erosion has been identified as a key concern to ensure that mitigation is appropriate to protect the asset and prevent waterway degradation.
- The restriction of inspection access in sensitive areas (e.g. waterways) to foot as much as possible.
- All inspections portals, valves, etc. are not installed in the vicinity of the waterway crossings as they may be inundated during periods of high flow.

7. Summary and Conclusions

Goulburn Mulwaree Council, in conjunction with a State Government Task Force, identified an Emergency Pipeline from Wingecarribee Reservoir as the best means of overcoming the emergency and drought proofing Goulburn for the future. The Project is to construct and operate the water supply scheme that would transfer water from the Wingecarribee reservoir to the Goulburn WTP. The scheme comprises approximately 83 km of DN 300 mm to DN 375 mm diameter pipeline, a pump station at the Wingecarribee Reservoir, power and controls, a balance tank, and a telemetry system. If approved it is proposed to have the transfer scheme operational by June 2011.

Key construction activities include trench excavations and placement of the pipeline and construction of railway, road and river crossings, pump station and controls at the Wingecarribee Reservoir site and a balance tank at an appropriate location along the pipeline (subject to design requirement).

Key operational activities would include regular maintenance of the pumping station, air valves and scour valves and less frequent maintenance of the pipeline (*e.g.* pigging to remove blockages, or repairing bursts as required).

A number of potential impacts have been identified concerning the construction and operational phases of the projects. For this report, these are concerned with the impact that construction of the pipeline has on the form and stability of the potential 138 waterways crossed by the pipeline. Waterway assessments indicated that the bulk of waterways are Drainage Lines or Minor Creeks and are relatively stable. Hence, with appropriate construction practices, re-instatements and rehabilitation, the impact of pipeline construction on waterway form and stability will be low. Nevertheless, some waterway crossing sites exhibit existing instabilities and/or sensitivities for which additional mitigation measures have been provided. With adoption of these additional measures, the overall impact of pipeline construction on waterway form and stability will be low.

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