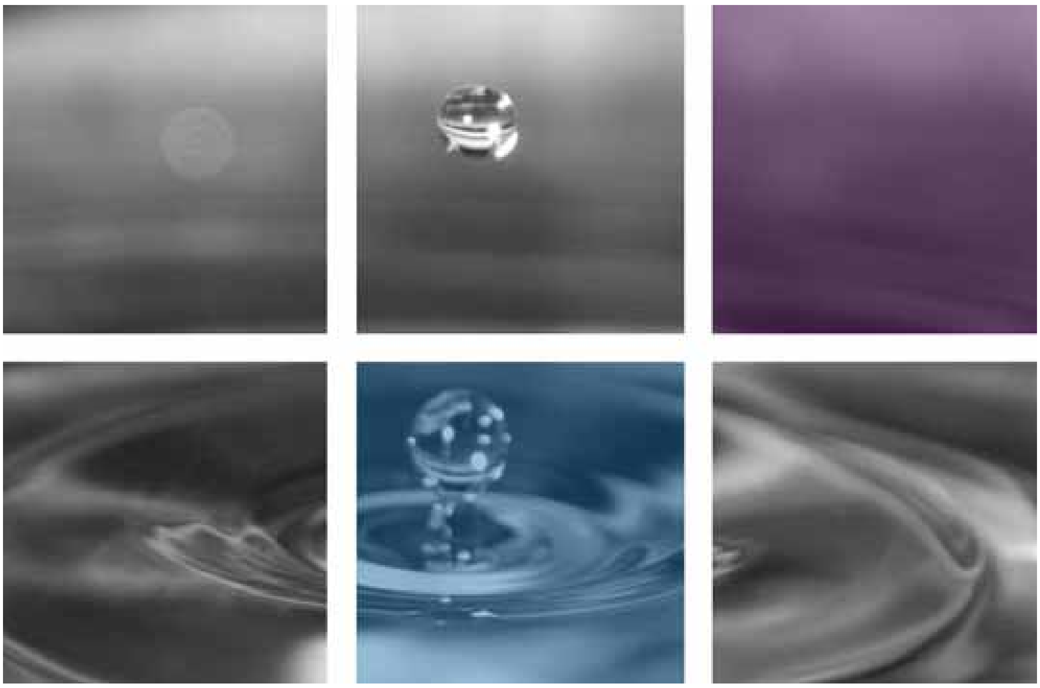
SUGARLOAF PIPELINE PROJECT

DESKTOP HYDROGEOLOGICAL ASSESSMENT

FEBRAURY 2008



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Contents

Abbreviations

DSE – Department of Sustainability and Environment

GDE – Groundwater dependent ecosystem

GIS – geographic information systems

GL – Gigalitres

GMA – Groundwater Management Area

GMS – Groundwater Management System (database)

DTM – Digital terrain model

l/sec – litres per second

Km – kilometres

m/d – metres per day

mg/L – milligrams per litre

SEPP – State Environmental Protection Policy

SGOBN – State Government observation bore network

WSPA – Water Supply Protection Area

Limitations

This Report:

- has been prepared by Melbourne Water, GHD Pty Ltd, Sinclair Knight Merz Pty Ltd, and John Holland, the participants in the Sugarloaf Pipeline Alliance (the ‘Alliance’);
- has been based on information provided up to 8 February 2008;
- has been produced as part of the Sugarloaf Pipeline Project Impact Assessment report and is for the purpose of identifying preferred pipeline corridors and associated management and mitigation measures for the Sugarloaf Pipeline Project.

This Report should not be altered, amended or abbreviated, issued in part or issued incomplete in any matter whatsoever without prior checking and approval by the Sugarloaf Pipeline Alliance. The Alliance expressly disclaims responsibility for any liability which may arise from the issue of this Report in part or incomplete or its modification in any way whatsoever.

Executive Summary

Methodology

This study was undertaken as a desktop review of available information and several site inspections along the length of the pipeline corridors. However no field investigations have been undertaken to date.

The study area for this assessment comprised the pipeline corridors, as well as a 5km area surrounding the corridor (similar to the project study area). This area was studied for the following reasons:

- The pipeline has the potential to be affected by more regional scale hydrogeological processes than operate within the vicinity of the pipeline corridor options (constructability in terms of dewatering requirements);
- The pipeline has the potential to affect more regional hydrogeological processes than occur within the pipeline corridor options (groundwater dependent ecosystems (GDE), flow and quality); and
- The paucity of hydrogeological information within the pipeline corridors as a whole necessitated the correlation and extrapolation of information from adjacent, similar hydrogeological terrains.

Hydrogeological models were developed based primarily on geology, groundwater salinity and depth to water table. Critical data gaps were identified during this process. Based on the hydrogeological models, groundwater risks were evaluated and possible mitigation measures identified. A preliminary scope of works to resolve the identified critical data gaps was developed.

Existing Conditions

The study area is characterised by Ordovician to Middle Devonian quartz sandstones and mudstones that were simply folded and faulted during the Early to Middle Devonian. The sediments were intruded by granites during the Devonian and then subject to prolonged erosion. Younger, Quaternary age alluvial sediments and colluviums derived from erosion of the older rocks have been deposited in valleys and low-lying areas.

Three hydrogeological models have been identified within the study area:

- Alluvial and colluvial aquifers in low lying areas confined to river / stream valleys where the flow direction is generally down-valley and the flow mechanism is as porous media flow;
- Bedrock aquifers where fracture systems exist and are saturated. Flow directions are anisotropic, generally paralleling north-west oriented regional structures, and dependant on the extent of and degree to which fracture systems are interconnected; and

- Regolith aquifers, which occur extensively throughout the area where bedrock is deeply weathered and saturated, and where the principle flow mechanism is as porous media flow.

The three aquifer systems may occur separately or in combination with each other. All are recharged predominantly by rainfall, although the alluvial/colluvial aquifers may also receive recharge from the regolith and fractured rock aquifers.

Groundwater salinity is variable across the study area. Broadly, salinities are highest in the fractured rock aquifers and lowest in the alluvial aquifers. The salinity of the regolith aquifers is unknown but expected to be similar to that of the alluvial aquifers.

Depth to water table mapping indicates that water levels are shallowest (less than 5m below ground surface) in the alluvial aquifers. Groundwater recharge provides base flow to streams during the summer months.

Key Issues

Based on the conceptual hydrogeological models and the depth to water table and groundwater salinity mapping, groundwater in the following areas is potentially vulnerable in terms of construction (dewatering volumes), GDE, water flows and water quality:

- Adjacent to the Goulburn River trench (i.e. at the off-take)
- Within the Yea River Valley north-east of Yea, southwards to Tea Tree Creek
- Within the Rellimeiggam Creek valley
- Caraman Creek crossing
- Yea River crossing at Devlins Bridge
- Kalatha Creek crossing
- Katy Creek crossing
- Eagle Nest Creek crossing
- Wee Creek crossing
- Yea River just north of Castella
- Dixons Creek river valley from Hunts Lane to Yarra Glen
- Steels Creek valley from the Old Kinglake Road – Steels Creek Road junction to Gulf Road.

DSE recognises areas of intensive groundwater use throughout Victoria. These areas have been defined as Groundwater Management Areas (GMAs) for the purposes of groundwater resource management. The pipeline corridors cross the Kinglake GMA in the vicinity of Mountain Creek (along Gordons Bridge Road), where the GMA boundary is within the pipeline options corridors.

The key potential groundwater impact relates to the possible interception by and diversion of shallow groundwater along the comparatively high hydraulic conductivity material of the pipeline trench backfill material, and the consequent decline in groundwater levels down gradient of the trench.

A key unknown is the impact caused by altered groundwater regimes (specifically water level and chemistry), both during and post construction, on base-flow from groundwater into surface water systems and related GDE. There is little understanding of these features, the governing hydrogeological processes and the likelihood of impact. They constitute a significant data gap.

Control Measures

The identified groundwater impacts have been classified into those occurring during the construction phase, and those post construction. In most cases the impacts can be mitigated by engineering controls:

- Dewatering:
  - Avoiding areas requiring dewatering (specifically, alluvial areas)
  - Minimising dewatering effort (construction methods, durations)
  - Down-gradient re-injection of water during dewatering operations.
- Quality:
  - Implementation of an environmental management plan
  - Considered selection of pipe materials and backfill materials.
- Alteration of groundwater flow patterns:
  - Avoidance of areas where this may occur
  - Installation of vertical low permeability barriers within the trench backfill
  - Reinstatement / maintenance of confining / perching beds.

Knowledge Gaps

The following knowledge gaps were identified:

- Water levels adjacent to streams and the degree of groundwater / surface water interaction
- Groundwater salinities adjacent to streams
- Extent and significance of regolith aquifers and their salinities
- Hydraulic properties of the alluvium in the vicinity of the pipeline crossovers
- The importance of GDEs in the Yea River, Steels Creek and Dixons Creek
- The extent of fracturing of the basement and the significance of fractured rock aquifers.

Proposed Scope of Works

It is expected that the field investigations will be staged. The hydrogeological field program will link with other technical investigations, in particular geotechnical engineering. A suggested Stage 1 program is provided below:

- Installation of monitoring bores to determine depths to water table and groundwater salinities at critical locations. This would comprise 48 bores, of which 24 will be drilled as part of the geotechnical engineering program;
- Seismic geophysics traverses at 6 locations across the Yea River, Dixons Creek and Steels Creek at select locations to define the geometry of the bedrock, the thickness of the alluvial sediments and their physical characteristics (sand, clay, gravel), and correlation between geophysics and geological logs;
- Pumping/slug tests at 6 locations to determine aquifer hydraulics for dewatering purposes; and
- Water level and quality monitoring, including monthly monitoring all sites and automated monitoring at selected creek crossings to characterise pre-pipeline (background) conditions against which impacts, if present could be identified and later e compared.

Conclusion

Whilst it is considered that there will be little impact on groundwater resource volumes or qualities as a consequence of the pipeline, key potential impacts include the following:

1. Dewatering volumes during construction
2. Impacts on GDE during and following construction.

Whilst dependent upon the findings of the field investigations, a preliminary conclusion is that most impacts relating to point 1 above can be mitigated by engineering control measures. Point 2 is contingent on the value placed upon the ecosystems and in this respect the findings from this report should be considered in light of the Flora and Fauna Assessment.

It should also be noted that this hydrogeological assessment does not have a major bearing on the selection of the preferred pipeline corridors and subsequently the final pipeline alignment. This is because the hydrogeological considerations are fairly uniform on the relative small scale of the study area and corridors. Since the potential impacts on hydrogeological values will be similar for all preferred pipeline corridor options, hydrogeological considerations are primarily directed at mitigation and management measures.

1. Introduction

1.1 The Sugarloaf Pipeline Project

The Sugarloaf Pipeline Project aims to deliver additional water supply to Melbourne. The Project is a key component of the Victorian Government's *Our Water, Our Future The Next Stage of the Government's Water Plan* (DSE, 2007), which aims to secure Victoria's water supplies in the face of drought, climate change and a growing population.

The pipeline will transfer up to 75 gigalitres (GL) of water per year from the Goulburn River into Melbourne's water distribution network via Sugarloaf Reservoir in the Yarra Ranges. Water for the Sugarloaf Pipeline will be sourced from savings achieved through the Food Bowl Modernisation Project, which involves modernisation of irrigation infrastructure in the Goulburn-Murray Irrigation District.

The project will involve the construction and operation of a water pipeline, approximately 70 km in length, pump stations, a balancing storage and associated electrical infrastructure to deliver water to Sugarloaf Reservoir. The planning, design and construction phases of the Sugarloaf Pipeline Project will be undertaken by the Sugarloaf Alliance, an alliance formed by SKM Pty Ltd, GHD Pty Ltd, Melbourne Water Corporation and John Holland.

1.2 Purpose and Scope of the Study

The objectives of this study were to:

- Present factual information on hydrogeological conditions within the pipeline option corridors
- Identify critical knowledge gaps
- Develop a scope of works to resolve the critical knowledge gaps
- Identify groundwater related risks during construction and ongoing operation of the pipeline
- Present measures to mitigate such impacts.

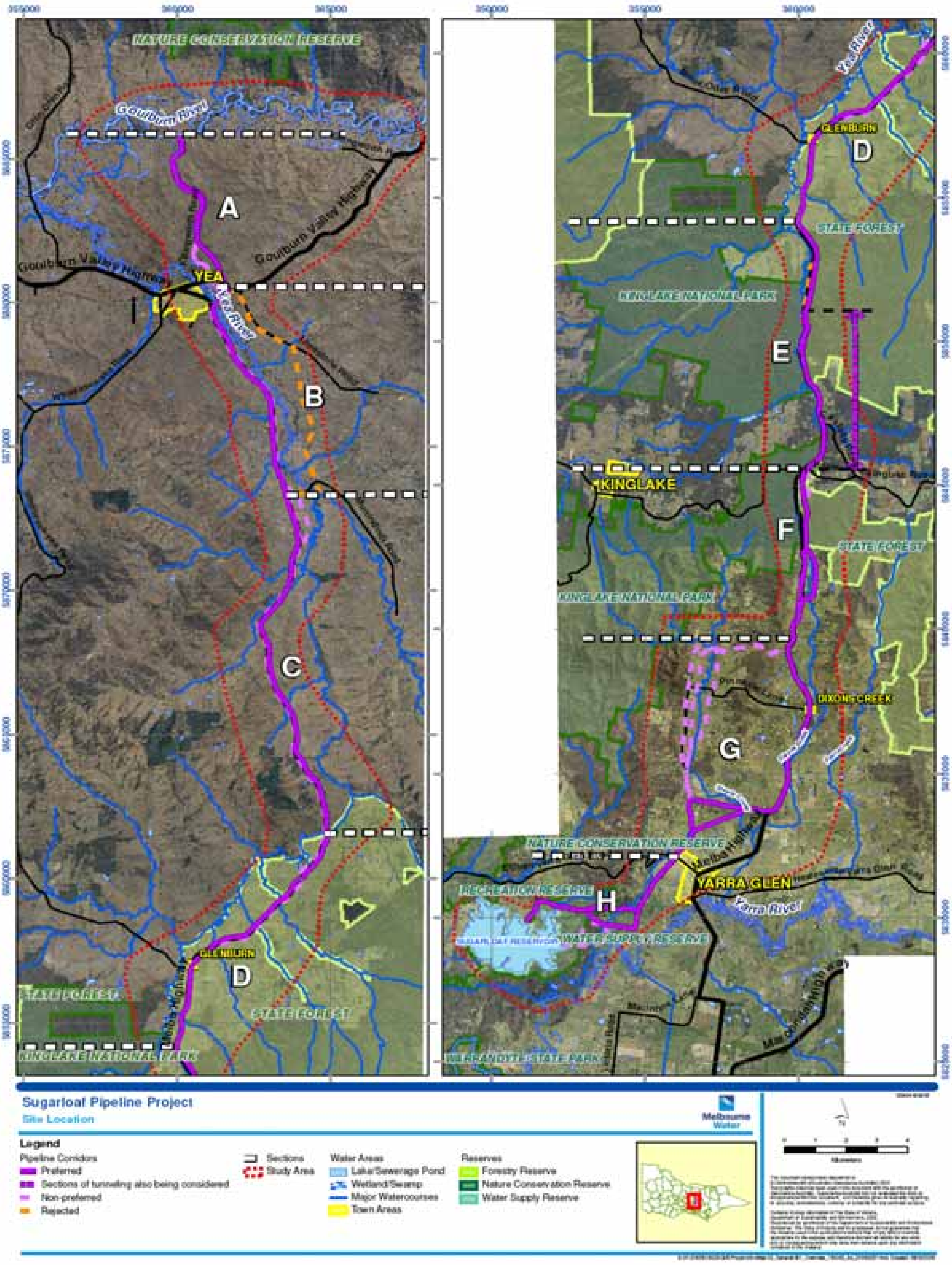
1.3 Study Area

The Sugarloaf Pipeline Project will begin at an off-take point at the Goulburn River north of Yea, approximately 100 kilometres northeast of central Melbourne, and end at the Sugarloaf Reservoir in the Yarra Ranges. The preferred pipeline corridors are shown on Figure 1.

The hydrogeological study area extended a further 5km beyond the boundaries of the pipeline corridors to account for the following:

- The pipeline could be affected by more regional scale hydrogeological processes than would operate within the pipeline option corridors. Consequently, we have not identified specific pipeline options corridors within this report

- **Figure 1 - Study Area showing Pipeline Option Corridors**



- The pipeline could affect more regional hydrogeological processes than would occur within the pipeline option corridors

The paucity of hydrogeological information within the pipeline option corridors required the correlation and extrapolation of existing information from adjacent, similar hydrogeological environments. Given the above, have not identified specific pipeline options corridors within this report.

1.4 Report Structure

The report has been structured in three parts. Factual information regarding the pipeline options has been presented in the first part. This includes the following specific technical information:

- Geological setting
- Hydrogeology, including:
  - Groundwater occurrence
  - Aquifer types
  - Water quality and use
  - Depth to groundwater and long term trends.

The second part of the document synthesises and interprets the information presented in the first part with respect to groundwater vulnerability and risk. The third part develops a work plan based on data gap analysis and presents a preliminary scope of works for field investigations. Information in parts 2 and 3 may change (or will be supported) by on-going site investigation works. Figures and other appendices are attached at the rear of the document.

2. Project Objectives and Assessment Criteria

This report has been prepared to provide background information on groundwater conditions along the pipeline option corridor. The information is used to evaluate groundwater impacts along the pipeline option corridor within the broad study area, support various approval applications required for the pipeline route selection, and provide inputs into the construction process.

Assessment criteria relevant to this study have been defined with consideration to the following legislative requirements and policy objectives:

- *Environment Protection Act 1970*
- State Environment Protection Policy - Groundwaters of Victoria (1997)
- State Environment Protection Policy - Waters of Victoria (1988).

Specific assessment criteria include:

- Depth to water table
- Groundwater chemistry
- Aquifer hydraulics.

This report evaluates and presents information within the framework of the above legislation and assessment criteria.

3. Methodology

The study was undertaken primarily as a desktop review of available information, although brief site inspections along the length of the pipeline option corridors were conducted. No specific fieldwork has yet been undertaken but will be undertaken ?????

The specific scope of works included the following activities:

- Data compilation:
  - Geological and hydrogeological data was compiled from readily available published studies, maps, plans and air photos, and state and local government records
  - The existing data sets were reviewed
  - An inspection of the pipeline options corridor was conducted to identify and record surface features, topography and soil and rock outcrops related to hydrogeology
  - Relevant information describing the hydrogeology within the pipeline option corridors was documented and appropriate data layers for a Geographic Information System (GIS) developed, including a depth to water table map
  - Potential hydrogeological "hot spots" that might be impacted by, or represent a potential risk to, the project, were identified
  - Critical data gaps were identified and a preliminary scope of works developed to resolve the deficiencies and allow for timely and effective site investigations in potential high impact areas
  - Proactive interaction occurred with other teams to communicate issues and impacts so that overall knowledge was enhanced and collective evaluation of risks and mitigations measures could be undertaken. This has enabled other field studies within the pipeline option corridors to inform this effort where appropriate.
- Development of conceptual hydrogeological models. Hydrogeological models were developed based on geology, groundwater salinity and depth to water table mapping
- A qualitative risk assessment. Based on the hydrogeological models, risks to groundwater from the proposed development, and risks to the pipeline from groundwater, were qualitatively evaluated and possible mitigation options identified
- Reporting: This report has been compiled to describe hydrogeological conditions within the pipeline option corridors, identify data gaps, outline potential hydrogeological impacts during the construction and operation of the project, including possible mitigation measures, and to present a field investigation program.

4. Existing Conditions

4.1 Rainfall

Rainfall conditions including detailed information on rainfall has been considered and described in detail in other documents associated with this investigation. Consequently, only a summary is provided in this report.

There is a steep rainfall gradient along the study area associated with the increase in elevation at the Great Dividing Range. Median, 50 percentile of annual rainfall increases from 700mm at Yea to 1,300mm at the Great Dividing Range and declines quickly to less than 600mm south of the Great Dividing Range.

There is a strong correlation between rainfall and the salinity of the upper-most unconfined (water table) aquifer, with lower salinities occurring in higher rainfall areas (Nahm, 1985; Leonard, 1992).

4.2 Surface Water Features

Meandering streams occur within broad Yea River and Dixons Creek river valleys north and south of the Great Dividing Range respectively. Beyond these, creeks and rivers are generally located within well defined, incised gullies. All streams and rivers are likely to rely on a component of base-flow from groundwater during dry months (Leonard, 1992), although the exact significance of base-flow is unknown at this time.

Waterways located within the study area were identified within the Hydrology, Water Resource and Water Crossings Impact Assessment (January 2008) conducted for this project. This study identified the following main waterways (however but not limited to) as follows:

- Goulburn River
- Break Oday Creek
- Steels Creek
- Ross Creek
- Dixons Creek
- Eagle Nest Creek
- Yea River
- Wee Creek
- Caraman Creek
- Mountain Creek
- Kalatha Creek

- Dry Creek
- Katy Creek
- Island Creek
- Limestone Creek
- Sugarloaf Creek
- Tea Tree Creek
- Triangle Creek (also Sawpit Gully Creek)
- Ewing Creek
- Rellimeiggam Creek.

4.3 Geology

4.3.1 Regional Setting

4.3.1.1 Stratigraphy

The pipeline option corridors have been identified on the Geological Survey of Victoria Melbourne 1:250,000 scale geological map sheet (VandenBerg 1997). In simple terms the Yea area is characterised by a continuous sequence of Ordovician to Middle Devonian quartz sandstones and mudstones that were simply folded and faulted during the early to Middle Devonian. The sediments were intruded by granites during the Devonian and then subject to prolonged erosion (Thomas, 1967). Younger, Quaternary age sediments are principally alluvial and colluvial in origin and are derived from erosion of the older sediments and igneous intrusive rocks.

A simplified stratigraphy has been summarised in Table 1.

- **Table 1 - Stratigraphic Summary**

Period	Sub-period	Formation	Lithological Description	Outcrop Areas[1]
Quaternary	Recent to Pleistocene	Undifferentiated alluvial sediments	River alluvium: variable mixtures of sands, silt clay and minor gravel.	Restricted to floodplains of the major surface water systems.
		Undifferentiated colluvial sediments	Colluvial fan deposits, gravel, sand, minor silt, granitic sand.	Mapped north and west of Yarra Glen, generally along foothills.
Devonian	Upper	Undifferentiated	Granodiorite, adamellite, quartz diorite. With associated metamorphic aureoles.	Isolated outcrops north and north east of Yarra Glen.
	Lower	Broadford	Siltstone with interbedded sandstone, turbiditic sequences.	West and east of Yea.
		Humevale	Siltstone with interbedded sandstone, turbiditic sequences. Locally bedded limestone lenses.	Bulk of the pipeline option corridors.

Period	Sub-period	Formation	Lithological Description	Outcrop Areas[1]
Silurian	Upper	Dargile	Laminated and current bedded sandstone, minor interbedded mudstone and shale.	East and west of region between Dixon Creek and Castella.

Note: Refer to Figure 2 for geology plan.

The older (Silurian) sediments constitute the geological basement of the area and as such are several kilometres in thickness. For this report, the indurated Silurian and Devonian sediments have been grouped together and referred to as the geological basement as they generally have similar hydrogeological properties.

4.3.1.2 Geological Structure

The Silurian and Devonian sediments were deformed during the east-west directed compression of the Middle Devonian. These sediments were faulted and folded into broad north-south trending regional synclines and anticlines. The faults coincide with the axial traces of regional folding (McDonald, 1997).

The Yarra Fault has been mapped at the southern end of the pipeline option corridors. The easterly dipping structure has been mapped from Wonga Park (south of Sugarloaf Reservoir) to Skenes Creek, north of Yarra Glen (VandenBerg 1997).

The influence of geological structure on the hydrogeology in the vicinity of the pipeline option corridor is unknown, although elsewhere in Victoria fractures are often saturated and can store and transmit groundwater. This is discussed in more detail in Section 4.4.1.

4.3.1.3 Route

The geology of the pipeline option corridors is shown in Figure 2. The corridors largely traverse Silurian – Devonian basement rocks. These rocks are visible in the bed and cuttings of a number of surface water systems (e.g. Yea River at Devlins Bridge) and road cuttings along the Melba Highway.

There are minor areas where these materials are overlain by Quaternary sediments, particularly along the northern section where the flatter topographies dominate the terrain.

4.4 Hydrogeology

4.4.1 Aquifer Types

4.4.1.1 Hydrostratigraphy

Each of the stratigraphic sequences identified in Table 1 is expected to constitute an aquifer to a varying degree. The aquifers have not been differentiated or named, but are described briefly in Table 2.

- **Table 2 - Identified Aquifers**

Hydrostratigraphy	Aquifer Type	Distrbution[1]
Quaternary alluvium and colluvium	Porous media	Colluvium - areas of extensive faulting (e.g. Yarra Fault), base of steep slopes, where broad scale weathering of bedrock has occurred. Alluvium - river valleys and flood plains of major surface water systems, confined to drainage lines within basement rocks.
Devonian Granite	Fractured rock	Isolated, small areas outcropping at the ground surface.
Silurian – Devonian sediments ('basement')	Fractured rock	Within all pipeline option corridors, outcropping at the ground surface.

Note: Refer to Figure 2 for geology plan.

4.4.2 Hydraulic Interaction

On a regional scale, the three geological units comprise the unconfined aquifer as follows:

- Where a low permeability barrier (e.g. a clay lens) within the Quaternary sediments inhibits the downward movement of groundwater resulting in a "perched aquifer" which is hydraulically separated from deeper aquifers
- Where the downward movement of groundwater is inhibited by a low permeability weathered zone (regolith) immediately overlying the Devonian granites or Silurian – Devonian basement rocks resulting in a perched aquifer within the regolith
- Where fracture systems in basement rocks are saturated and connected to the ground surface.

The interaction between the aquifer systems is unknown. It is likely that on a regional scale all three aquifer types are hydraulically connected.

4.4.3 Groundwater Levels

4.4.3.1 Depth to Water Table

A search of the Victorian DSE Groundwater Management System (GMS) database (DSE, 2007) was undertaken. Water level information was only available for 6 bores within the study area. Additionally the available information had been collected almost exclusively immediately following drilling. Given that the drilling process can significantly affects water levels, it is unclear whether the available data represented truly equilibrated groundwater levels; consequently there was some doubt about the veracity of the data.

A depth to water table map was therefore compiled using an analysis derived from the Digital Elevation Model (DTM). The DTM was compiled from the VicMap 25,000 topography data (DSE, 2006). The underlying basis for the analysis was that, in unconfined aquifers flowing under topographic gradients the water table is a smoothed and subdued reflection of topography (Salama *et al*, 1996; Haitjema & Mitchell, 2005). A secondary assumption was that, at a large scale, groundwater movement in fractured rock aquifers operates in a similar manner to that in porous medium aquifers.

Comparison of the derived map against observed water levels indicated an acceptable error margin of less than 0.5m in topographically low lying areas and less than 5m in the most elevated areas.

The derived depth to water table map is provided as Figure 3. The map categorises depth to the water table using the following categories:

- Shallower than 5 m (i.e. 0 - 5m)
- 5 - 10m depth
- 10 - 20m, depth
- 20 - 50m depth
- Greater than 50m depth.

In terms of potential groundwater impacts, critical areas are those with water tables shallower than 5m, as indicated by the red shading on the map.

Notwithstanding the accuracy of the depth to water table map as suggested by the comparison of derived and observed measurements, it is considered that the map is preliminary until fieldwork can be undertaken to provide data against which it can be more broadly calibrated.

4.4.3.2 Seasonal Water Level Responses

A search of the GMS was undertaken to identify the presence of active State Groundwater Observation Bore (SGOBN). The SGOBN bores are usually the only bores with time series water level monitoring data, and at some sites, water quality monitoring data.

A summary of the SGOBN bores identified is provided in Table 3. Bore locations are shown in Figure 4.The GMS search indicated only one bore with time series data, bore G8010294/01, which is located at Devlins Bridge. The hydrograph for this bore is presented in Figure 5. The