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Gunns Bell Bay Pulp Mill – Groundwater Assessment

Prepared for

Gunns Limited

November 2006

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1. Introduction

Gunns Limited currently has a Project of State Significance development application before the Resource Planning and Development Commission (RPDC) for a new pulp mill near Bell Bay, Tasmania.

As part of the approvals process an assessment of site groundwater conditions in the area of the proposed pulp mill and landfill is required for submission to the RPDC.

Pitt & Sherry was commissioned in August 2006 to prepare an assessment of groundwater conditions in the area in accordance with the RPDC guidelines and expectations.

The regional and local settings for the groundwater investigation bores are shown in Figure 1 and Figure 2 respectively.

1.1 Scope

The scope of this report is to provide an overall description of groundwater behaviour in the vicinity of the proposed mill and landfill sites, review preliminary groundwater monitoring data and assess the likelihood of the passage of pollutants to groundwater.

1.2 Objectives

The objective of this report is to develop an understanding of the groundwater conditions on the site, including levels and flow directions, to facilitate assessment of potential contaminant movements in the area.

The specific objectives are to:

- Describe the regional geology and the inferred gross groundwater behaviour and characteristics.
- Provide details of the boreholes installed to date, including logs and construction details.
- Present and interpret groundwater measurements and water quality analysis results completed to date.
- Assess the implications of groundwater findings on risk profiles for major infrastructure components.
- Determine the need for additional bores, including the number, locations and depths of any additional bores required.

1.3 Site inspections

In addition to site inspections undertaken at various times during the installation of bores, inspections of both the mill site and landfill site groundwater borehole locations and terrain were undertaken on 22 and 23 August and 18 and 19 September 2006.

2. Environment

2.1 Topography

The topography of the area is dominated by the Tippogoree Hills, a series of hills that trend northwest – southeast. Locally these hills reach 360 m on northern end, and range down to 250 m at southern end, east of the mill site.

The landfill site is located within the southeast trending Williams Creek valley, near the headwaters of the creek, on the western side of the Tippogoree Hills. The side slopes of the creek in this area range from approximately 15 to 20 degrees.

On the mill site the land reaches a maximum height of approximately 80 m above sea level, and has a general slope of six to ten degrees towards the Tamar River (BFP Consultants Pty Ltd 2005[1]). The mill site is deeply dissected in places by local ephemeral watercourses with steep sloping gullies ranging from 10 to 20 degrees. The side slopes of Williams Creek where it joins the Tamar River on the southern edge of the site are particularly steep.

2.2 Regional geology

The general geology of the area is summarised on the Bell Bay 1:25000[2] and Beaconsfield 1:63360[3] geological maps (Figure 3).

A northwest trending graben structure, the Tamar Graben, formed by large-scale normal faulting in the Tertiary dominates the area. The eastern edge of this structure is defined by a major normal fault along the eastern edge of the Tamar River. The structure separates Jurassic dolerite on the eastern side from Tertiary sediments and basalt on the western side.

Jurassic dolerite outcrops extensively throughout the area, forming the locally prominent Tippogoree Hills. Variable thicknesses of Quaternary colluvium consisting of clays, some sands, gravels and angular cobbles occur on the

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[1] BFP Consultants Pty Ltd, 2005. *Pulp Mill, Longreach, Geotechnical Investigation for Gunns Limited.*
[2] McClenaghan, MP. 1988. *Bell Bay*, Tasmania. Digital Geological Atlas 1:25000 Series, Sheet 4844. Department of Mines, Tasmania.
[3] Gee, RD and Legge, PJ. 1971. Geological Atlas 1:63360 series, Sheet 30 (8215N). *Beaconsfield*. Department of Mines, Tasmania.

lower slopes of these dolerite hills. The thickness of the colluvium diminishes rapidly away from gully floors, resulting in extensive areas of outcrop on gully walls. A thin layer of Quaternary alluvium is associated with some of the drainage lines.

The Tippogoree Hills are marked by a large number of lineations, some of which parallel the major normal fault along the Tamar River. Many of the other lineations are orthogonal to the main lineaments. Any reactivation of these structures at the site is considered to be unlikely as there are no known active faults in Tasmania, although there are some that are suspected of having been active within the last thousand years or so, such as the Lake Edgar fault in southwest Tasmania.

Thin stony gradational soils have developed on the dolerite and stony clay uniform soils along the drainage lines.

2.3 Drainage

All drainage in the landfill and mill site areas is via ephemeral creeks to the Tamar River to the west. The paths of these drainage lines appear to be largely determined by the orientations of a number of major lineations within the dolerite.

The landfill site is drained by (ephemeral) Williams Creek, which initially flows southeast along a major lineation and then west along another lineation to the Tamar River at the southern end of the mill site.

Drainage across the mill site area is generally west across the site to the Tamar River, via Big Bay, Dirty Bay and Williams Creek in the northern, central and southern sections of the site respectively.

The orientations of the drainage lines across the centre of the mill site to Dirty Bay also appear to be largely controlled by lineations within the dolerite.

3. Groundwater

3.1 Groundwater prospectivity

Regional groundwater prospectivity of the area is shown in Figure 4. There are no known extraction bores in the vicinity of the site.

3.2 Regional aquifer characteristics

The aquifer types, generalised aquifer prospectivity and general aquifer characteristics associated with the various rock types that occur within the immediate region are summarised in Table 1.

Table 1: Aquifer types, generalised prospectivity and general aquifer characteristics associated with rock types of the immediate region.

Rock Type	Aquifer Type	Prospectivity	General Aquifer Characteristics
Quaternary sand and gravel	Porous (intergranular)	High	Often high yielding where sand, gravel deposits 5+ m thick. Yields may be limited where thick clay deposits exist. Quality usually suitable for most purposes. Vulnerability to pollution – very high unless layer of low permeability material, eg clay, overlies the aquifer.
Quaternary talus	Porous (intergranular)	Low - Moderate	Yields and groundwater storage are generally low, but in areas with low clay percentage some useful yields are possible. The main drilling targets in all areas are deep underlying aquifers. Water quality is variable. Usually better in high rainfall areas and in the vicinity of streams. Vulnerability to pollution – low (where clay layer overlies the aquifer) to high (where clay layer does not overlie the aquifer).
Permo–Triassic sediments	Fractured	Moderate - High	Yields suitable for most domestic and livestock purposes. Potential for limited crop irrigation in some areas. Quality variable – dependent on location. Vulnerability to pollution – high unless low permeability material occurs at the surface.
Dolerite	Fractured	Low - Moderate	Yields generally suitable for domestic and / or livestock purposes. Occasional crop irrigation yields. Quality variable – dependent on location. Vulnerability to pollution – moderate unless highly fractured zones occur without a low permeability cover.

3.3 Groundwater

The proposed mill site and landfill areas are entirely on dolerite. Groundwater within these areas is therefore likely to occur as deep unconfined aquifers within fracture zones in the dolerite, particularly the faults and major joint planes.

Groundwater is also likely to occur as seasonally perched water within the sandy and gravelly layers in the colluvium (weathered slope material) and as unconfined aquifers in hydrologic connection with associated drainage lines in the Quaternary alluvium and colluvium.

3.4 Existing groundwater boreholes

Dolerite

According to the groundwater prospectivity map (MRT 1:500 000 Ground Water Prospectivity Map), which contains borehole data as at July 2002, there are no existing groundwater boreholes in other ownership within the dolerite of the Tippogoree Hills area.

As both the mill and landfill sites are located on dolerite, or on relatively thin deposits of sands and gravels along drainage lines, there are no existing groundwater boreholes within or near these proposed sites.

Other Rocks

The closest existing groundwater boreholes in other ownership are in Quaternary sediments on the eastern side of the Tippogoree Hills, 3.5 and 4.5 km northeast of the landfill and pulp mill sites respectively.

3.5 Inferred gross behaviour and characteristics

General aquifer characteristics are summarised in Table 1.

As there were no pre-existing boreholes within the dolerite of the area, no specific information regarding groundwater movement in this area was available. However, as the size and location of aquifers within dolerite is a function of the nature and distribution of fractures within the rock, likely major directions of movement can be inferred from regional structural features.

Major structural features in the area trend generally northwest-southeast, parallel to the Tamar River, with shorter orthogonal features with a general westerly trend. Discharge from the deeper rock aquifers is therefore likely to be into the Tamar River via these major fracture systems, the faults and major joints within the dolerite.

Discharge from the seasonally perched water tables and unconfined aquifers is likely to be via the existing ephemeral drainage lines in these areas to the Tamar River.

Yield from the deeper aquifers in the dolerite is likely to be extremely variable. Groundwater flow in the dolerite is likely to be more related to the nature and orientation of fractures within the dolerite rather than to hydraulic head.

Yield from the shallower aquifers will be dependent on the clay content of the sediments, sediments with a low clay percentage having a higher yield.

Quality is likely to be quite good in general, but may show some variability locally.

4. Site groundwater investigations

4.1 Existing boreholes

Thirteen groundwater bores have been established to date for the pulp mill project, four on the proposed landfill site and nine on the proposed mill site.

The bores have been installed to deal with specific issues such as the potential for leachate contamination from the proposed landfill site or for future monitoring of potential contamination from the mill.

The installed groundwater monitoring borehole sites are shown in Figure 5. This figure also shows the location of proposed additional bores. The establishment of additional boreholes is discussed in Section 7.

Landfill Site

The landfill site currently has four boreholes positioned to give a good initial appreciation and delineation of the background groundwater levels and quality and to detect any potential impacts from the future landfill operations.

Three of the monitoring bores, GW2, GW3 and GW4, were installed within the site over the period from the 9th to the 23rd March 2005. The fourth bore (GW7) was installed in February 2006.

Borehole GW2 is located upslope of the proposed landfill site. Boreholes GW3 and GW4, which are located in the middle of the final landfill footprint, are expected to be operational for at least 5 years, and possibly up to 20 years, depending on beneficial reuse and hence landfill filling rates. GW3 and GW4 were installed to different depths to delineate between upper and deeper aquifers.

Borehole GW7 is located downslope and well outside the final footprint of the proposed landfill. This borehole is expected to be operational for the life of the landfill.

The number and location of the landfill boreholes have been determined in accordance with the Environment Division's *Landfill Sustainability Guide 2004*.

Mill Site

There are currently nine groundwater boreholes in the mill site area.

Borehole GW8 is located on the eastern side of the mill site, between the highway and railway line. Boreholes GW10 and GW11 are located on the northern edge of the mill site and GW15 and GW16 on the southern edge. Boreholes GW12, GW13 and GW14 are located along the western edge, between the mill site and the Tamar River. Borehole GW17 is located within the southern end of the mill site.

The only surface expression of groundwater observed during site inspections was on the hillside immediately north of GW12, where seepage supports a groundcover of mosses and similar plants.

The nine boreholes around the mill site should give a good initial appreciation and delineation of the background groundwater levels and quality and be capable of detecting any potential impacts from future mill operations.

4.1.1 Locations

The locations of the existing groundwater monitoring boreholes are shown in Figure 5 and the map coordinates and nomenclature in Table 2.

The borehole nomenclature has been standardised for reporting convenience because the initial nomenclature used was variable, as the bores were sited, designed and installed by different parties. Accordingly, Table 2 contains both the installed and the revised borehole nomenclature but only the revised nomenclature is shown on Figure 5.

The GPS coordinates of the groundwater borehole sites have been reported in the UTM/UPS format in the GDA 94 map datum. The coordinates have been incorporated into Pitt & Sherry's ArcView GIS project database.

4.1.2 Borehole logs

Details of the boreholes are summarised in Table 3. The individual borehole logs are included in Appendix A.

Table 2: Borehole nomenclature changes and GDA 94 coordinates

Installed nomenclature	Monitoring nomenclature	Installation supervision	Installation date	Easting	Northing
Landfill site					
DH1	GW2	Pitt & Sherry	March 2005	494253	5445642
DH2	GW3	Pitt & Sherry	March 2005	494601	5445242
DH3	GW4	Pitt & Sherry	March 2005	494605	5445212
Mill site					
BH_ML/01	GW7	Pitt & Sherry	February 2006	494966	5444796
BFP W7	GW8	BFP	February 2005	494042	5444207
MB_M/01	GW10	Pitt & Sherry	May 2006	492947	5444864
MB_M/02	GW11	Pitt & Sherry	June 2006	492760	5444631
BFP W2	GW12	Pitt & Sherry	February 2005	493171	5444341
MB_M/04	GW13	Pitt & Sherry	May 2006	493264	5444141
MB_M/05	GW14	Pitt & Sherry	May 2006	493424	5443701
BFP W6	GW15	BFP	February 2005	494008	5443555
BFP W5	GW16	BFP	February 2005	493720	5443610
BFP W4	GW17	BFP	February 2005	493610	5443912

Table 3: Borehole details

Monitoring nomenclature	Installed nomenclature	Borehole depth (m)	Water depth (m)	Geology
Landfill site				
GW2	DH1	30	Dry	0.0 – 0.2 m: gravel 0.2 – 2.0 m: weathered dolerite 2.0 – 30 m: fresh dolerite
GW3	DH2	29.8	8.0	0.0 – 7.5 m: clay 7.5 – 29 m: weathered dolerite 29 – 29.8 m: fresh dolerite
GW4	DH3	8.0	5.0	0.0 – 6 m: clay 6 – 8 m: dolerite
GW7	BH_ML/01	14.45	Dry	0.0 – 2.5 m: clay 2.5 – 14.45 m: massive dolerite
Mill site				
GW8	BFP W7	14.5	7.0	0.0 – 1.2 m: sand 1.2 – 10.4 m: silty clay 10.4 – 14.5 m: dolerite
GW10	MB_M/01	15.6	Dry	0.7 – 15 m: massive dolerite
GW11	MB_M/02	15.16	Dry	0.0 – 1.5 m: clay, boulder 1.5 – 15.16 m: massive dolerite
GW12	BFP W2	13.3	8.8	0.0 – 0.4 m: sand 0.4 – 4.8 m: silty clay 4.8 – 13.3 m: dolerite
GW13	MB_M/04	15.5	Dry	0.0 – 1.1 m: clay 1.1 – 15.5 m: massive dolerite
GW14	MB_M/05	19.0	Dry	0.3 – 19 m: massive dolerite
GW15	BFP W6	9.0	2.6	0.0 – 2.8 m: silty clay 2.8 – 9.0 m: dolerite
GW16	BFP W5	27.0	Damp 14.3	0.0 – 27.0 m: silty clay
GW17	BFP W4	19.0	13.3	0.0 – 1.2 m: silty clay 1.2 – 19.0 m: dolerite

Landfill site

Borehole depths ranged from 8 to 30 m, all boreholes intersecting variable thicknesses of gravel and/or clay overlying dolerite ranging from extremely weathered to fresh.

Water conditions experienced in the boreholes varied. The water table was intersected at 5 and 8 m in boreholes GW3 and GW4 respectively. The other two boreholes were dry.

Mill site

Borehole depths ranged from 9 to 27 m with all boreholes, with the exception of GW16, intersecting variable thicknesses of sands and/or clays overlying dolerite. Borehole GW16 intersected 27 m of silty clay.

Water conditions experienced in the boreholes varied. The water table was intersected at varying depths, ranging from 2.6 to 13.3 m, in four of the boreholes. Of the remaining five boreholes, four were dry and one (GW3) experienced damp conditions at 14.3 m.

4.1.3 Installation details

As indicated, different contractors were involved in the installation of the groundwater monitoring bores. However, the bores were all constructed to the following general design criteria:

- Casing consisted of 50 mm diameter Class 18 screw-type uPVC conduit in prefabricated 3 m lengths with standard screw joints.
- Slotted casing (0.5 mm wide slots, 4 mm spacing) was used over the depth intersecting the groundwater table to allow groundwater ingress. In the dry boreholes, slotted casing was installed over the depth assumed to be likely to intersect the water table when groundwater levels are higher.
- The top of the casing protruded approximately 0.5 m above ground level.
- The annulus space between the casing and the drill or augur hole was backfilled with coarse sand (gravel pack 8/16 grade) preferably to approximately 0.5 m above the water table.
- A bentonite plug approximately 1.0 m in length was installed on top of the gravel pack.
- The annulus was further filled from the bentonite plug to the surface with gravel pack and drill cuttings to the surface.
- At the surface, the top of the borehole was sealed with more bentonite and a concrete cap.
- A steel monument was installed over the casing and set into the concrete cap.

Following construction, the boreholes were typically developed using a hand bailer to remove drilling fines and to ensure initial hydraulic connection with the aquifer in readiness for future monitoring.

A schematic diagram of the borehole design is shown in Figure 6.

4.1.4 Borehole installation observations

Details of the screen size and the nature of the material over the length of the screen for all boreholes is summarised in Table 4.

Table 4: Monitoring bore parameters

Borehole		Screen size (m)*	Comments
Monitoring	Installed		
Landfill Site			
GW2	DH1	15.0	Screen in dolerite; no defect details available.
GW3	DH2	21.3	Screen in dolerite; highly jointed (joints 45^0); highly fractured zone 24.5 – 25 m.
GW4	DH3	3.0	Upper 1 m of screen in clay, lower 2 m in dolerite.
GW7	BH_ML/01	13.65	7 sections of core loss, ranging from 0.1 m to 0.8 m; likely to represent significant fractures (joints) in the dolerite; as such, would provide significant channels for water movement.
Mill Site			
GW8	BFP W7	8.5	Upper 4 m of screen in silty clay, lower 4.5 m in dolerite.
GW10	MB_M/01	3.5	Screen in fresh dolerite; defect spacing 100 – 300 mm; ~ 7 joints, 1 – 4 mm thick, generally highly weathered.
GW11	MB_M/02	3.66	Screen in fresh dolerite; defect spacing 250 – 1000 mm; 5 joints, 1 – 5 mm thick; some calcite infill.
GW12	BFP W2	5.6	Screen in dolerite.
GW13	MB_M/04	6.0	Screen in fresh dolerite; defect spacing 100 – 1000+ mm; very small section < 30 mm; ~ 10 joints, 1 – 5 mm thick; 1 joint 20 – 35 mm thick, extremely weathered dolerite.
GW14	MB_M/05	3.5	Screen in fresh dolerite; defect spacing 100 – 1000+ mm; 0.25 m of ~30 mm defect spacing; very small section < 30 mm; ~ 7 joints 1 – 4 mm .
GW15	BFP W6	5.3	Screen in dolerite.
GW16	BFP W5	12.0	Screen in silty clay.
GW17	BFP W4	9.7	Screen in dolerite.

* Measured from the bottom of the bore hole

Landfill site

The four boreholes have screen sizes ranging from 3 to 21.3 m and a 0.5 m thick bentonite seal.

The screens in boreholes GW2 and GW3 are wholly in dolerite. Borehole GW4 has a 3 m slotted screen of which the upper 1 m is in clay and the lower 2 m in dolerite.

Borehole GW4 has a 13.65 m slotted screen of which the upper 1.7 m is in clay and the remaining 11.95 m is in dolerite.

Mill site

Screen sizes in the mill site monitoring boreholes ranged from 3.5 to 12 m and the bentonite seals from 0.6 to 1 m in thickness.

Screens in seven of the boreholes are wholly in dolerite and one (GW16) is wholly in silty clay. The upper 4 m of the screen in borehole GW8 is in silty clay whilst the lower 4.5 m is in dolerite.

4.2 Monitoring

Initial monitoring of the bores was undertaken following their installation to assist with the concept design of the landfill. A further round of sampling and analysis was undertaken in September 2006.

Gunns has also implemented an ongoing groundwater monitoring program. Details of the monitoring program, including results obtained to date, are discussed below.

4.2.1 Monitoring regime

The monitoring program is currently being undertaken on a three-monthly basis, the first monitoring run occurring in the period the 18 to 20 September 2006.

4.2.2 Monitoring methodology

The aim of the monitoring methodology is to comply with the Australian/New Zealand Standard® *Water quality – Sampling, Part 11: Guidance on sampling groundwaters, AS/NZS 5667.11:1998*.

The groundwater levels in the boreholes were measured, boreholes purged and sampled for analysis following recharge after purging.

Groundwater was pumped from the shallower boreholes into measuring containers, the times, volumes and water quality field measurements being taken and recorded during each purge operation.

A 12 Volt, Proactive Environmental ‘Cyclone’ groundwater pump constructed from PVC and stainless steel was used for purging of the shallower boreholes. Given the nature of the landfill and mill site area borehole design, the pumping to waste of approximately 3 times the internal groundwater volume of the borehole was deemed appropriate for representative sampling.

Purging of the deeper boreholes was undertaken using Enviroequip plastic disposable bailers.

Groundwater samples were taken for analysis, preserved in 'Eskis' with cooling blocks, and air transported to the NMI laboratory by overnight express.

4.2.3 Groundwater levels

The groundwater levels in the landfill and mill site boreholes at the time of installation (depth of water in the hole), together with levels prior to the first purging on 18 September 2006 and the recovered levels prior to sampling on 20 September 2006 (Standing Water Levels) are shown in Tables 5 and 6.

The depth to groundwater is shown in Table 5 and the groundwater surface relative to the natural surface level is shown in Table 6.

Table 5: Groundwater levels in landfill and mill site boreholes

Borehole nomenclature		Bore depth (m)	Depth to groundwater (m)*		
Monitoring	**Installed**		**Installation**	**18/9/2006**	**20/9/2006**
Landfill site					
GW2	DH1	30	Dry	6.23	14.53
GW3	DH2	29.8	8.0	1.84	1.84
GW4	DH3	8.0	5.0	1.85	1.93
GW7	BH_ML/01	14.5	Dry	3.12	3.13
Mill Site					
GW8	BFP W7	14.5	7.0	7.44	7.44
GW10	MB_M/01	15.0	Dry	8.42	8.57
GW11	MB_M/02	15.6	Dry	11.77	12.27
GW12	BFP W2	13.3	9.0	8.20	8.23
GW13	MB_M/04	15.5	Dry	0.96	0.96
GW14	MB_M/05	19.0	Dry	6.37	6.42
GW15	BFP W6	9.0	2.6	1.27	1.07
GW16	BFP W5	27.0	15.0	18.84	18.79
GW17	BFP W4	19.0	13.0	13.56	13.56

* Depth from ground surface. Depth at installation is the depth to the water in the hole at the time of drilling; subsequent levels are Standing Water Levels (when water has risen in the hole)

On the landfill site:

- Two of the four boreholes (GW2 and GW7) were dry at the time of installation.
- Following purging, groundwater levels in the boreholes returned to the pre-purging levels within 24 hours, with the exception of the deep borehole (GW2) on the upstream end of the site.
- Groundwater recharge in GW2 was much slower. Prior to purging, the groundwater surface was 6.23 m from the ground surface; within 24 hours the groundwater surface had only returned to 14.53 m from the ground surface. That is, recharge in GW2 was much slower than in the other boreholes in the landfill site.

On the mill site:

- Four of the nine boreholes (GW10, GW11, GW13, GW14) were dry at the time of installation.
- Recharge in all of the boreholes was relatively rapid, with six boreholes showing very similar levels within 24 hours and three boreholes (GW8, GW13, GW17) showing identical levels.

The groundwater levels (relative to surface levels) in the landfill and mill site boreholes at the time of installation, together with levels prior to the first purging on 18 September 2006 and the recovered levels prior to sampling on 20 September 2006, are shown in Table 6.

Table 6: Relative levels (RL) of groundwater surface in landfill and mill site boreholes

Nomenclature		Borehole depth (m)	RL of natural surface (m)	RL of groundwater surface (m)*		
Monitoring	Installed			Installation	18/9/2006	20/9/2006
Landfill site						
GW2	DH1	30	133.62	< 103.62	127.39	119.09
GW3	DH2	29.8	115.68	107.68	113.84	113.84
GW4	DH3	8.0	115.70	110.70	113.85	113.77
GW7	BH_ML/01	14.5	99.97	< 85.47	96.85	96.84
Mill site						
GW8	BFP W7	14.5	66.49	59.49	59.05	59.05
GW10	MB_M/01	15.0	11.72	< -3.28	3.30	3.15
GW11	MB_M/02	15.6	22.08	< 6.48	10.31	9.81
GW12	BFP W2	13.3	20.90	11.90	12.70	12.67
GW13	MB_M/04	15.5	22.76	< 7.26	21.80	21.80
GW14	MB_M/05	19.0	41.47	< 22.47	35.10	35.05
GW15	BFP W6	9.0	45.42	42.82	44.15	44.35
GW16	BFP W5	27.0	48.35	33.35	29.51	29.56
GW17	BFP W4	19.0	63.67	50.67	50.11	50.11

* Depth from ground surface. RL at installation is the RL of the water surface in the hole at the time of drilling; subsequent RLs are Standing Water Levels (when water has risen in the hole)

On the landfill site:

- The groundwater surface, as indicated by the boreholes, reflects the topography in the landfill site.
- The depth to the groundwater surface decreases downslope.
- Groundwater flow is, therefore, assumed to be southeast down the Williams Creek valley.

On the mill site:

- The groundwater surface is not as easy to delineate as it is on the landfill site.
- There is a general decrease in depth to the groundwater surface towards the Tamar River.
- At the southern end of the site (GW15, GW16) there is a decrease southeast to Williams Creek and bay and at the northern end of the site (GW10 and GW11) there is a decrease northwest to Dirty Bay.
- Groundwater flow is therefore assumed to be generally towards the Tamar River, with localised flows towards creek lines.
- Groundwater flow in the area of GW8 is less clear, however, as it could be southeast along the southern side of the railway line or west along the major structural feature from this area to Dirty Bay.

4.2.4 Purging volumes

Details of purging for the sampling period 18 to 20 September 2006 are summarised in Table 7.

Table 7: Summary of borehole purging details

Borehole		Purged volume (L)			Nominal bore volume (L)	Number of borehole volumes purged
Monitoring	Installed	18/09/2006	19/09/2006	20/09/2006		
Landfill site						
GW2	DH1	48	37	10	47	2.0*
GW3	DH2	56	55	10	56	2.9
GW4	DH3	25	24	10	12	4.0
GW7	BH_ML/01	25	25	8	23	2.6*
Mill site						
GW8	BFP W7	15	20	5	13	3.0
GW10	MB_M/01	15	25	5	13	3.5
GW11	MB_M/02	6	9	5	6	3.4
GW12	BFP W2	11	25	4	11	3.8
GW13	MB_M/04	30	45	20	29	3.3
GW14	MB_M/05	25	30	20	25	3.0
GW15	BFP W6	16	21	10	16	2.9
GW16	BFP W5	20	37	10	15	4.5
GW17	BFP W4	11	17	15	11	4.0

* Purging of approximately three times the bore volume was not achieved for these boreholes

As indicated in Table 7, purging of approximately three times the borehole volume was not achieved for boreholes GW2 and GW7 because of the low recovery rates within the timeframe of the monitoring program.

As most of the boreholes and the associated slotted sections are located within dolerite, recovery rates are likely to be restricted.

Field logging data indicated that chemical equilibrium for the groundwater was being approached by the time that the GW2 sample was taken. However, this was not the case for GW7.

4.2.5 Yields

No systematic assessment of yields for the boreholes has been undertaken at this stage but estimated yields for the landfill site boreholes are shown in Table 8. No yield estimates have been made for the mill site area.

Table 8: Estimated yields for landfill site groundwater bores

Borehole		Water level at drilling (m)	Screen depth (m)	Water level below ground surface (m)		Yield (L/min)	
Monitoring	Installed			23/3/05	14/4/05	12/4/05	14/4/05
GW2	DH1	12.45	15 – 30	12.45	16.18	0.2	0.01
GW3	DH2	~8	8.5 – 29.8	–	2.78	1.3	0.6
GW4	DH3	5.0	5.0 – 8.0	–	2.97	0.3	0.2

The drilling contractors, Stacpoole Enterprises, measured the rate of groundwater inflow into the landfill site piezometers (known as yield testing) on 12 April 2005. The method used involved blasting air into the bores to remove the water until a constant flow was achieved. Pitt & Sherry also undertook yield testing of these bores prior to water quality sampling on 14 April 2005. The method used involved pumping the water out and measuring the rate of recovery of the groundwater inflow.

The differences in yield values obtained for boreholes GW2 and GW3 may reflect differences in the methods used or it may reflect differences in the geological structure, particularly the nature and distribution of fractured zones within the dolerite.

These yield investigations were undertaken during a period of dry weather. Total rainfall at the Low Head meteorological station during the January to March quarter of 2005 preceding the investigations was 60 mm, compared with a long term mean of 116 mm. In wetter conditions, groundwater flow, and hence yields in the bores, could be expected to be greater than that observed during the site investigations.

The yield from GW3 was considerably higher than from GW2, indicating that groundwater flows much more freely through the more fractured rock underneath the lower end of the site than it does through the less fractured rock at the upper end.

4.2.6 Flow directions

A general assessment of groundwater flow directions can be made, based on the observations to date.

In the proposed landfill area groundwater yields were an order of magnitude higher at the lower end than they were at the upper end. This indicates the presence of a strong gradient in the water table between the upper end of the proposed landfill footprint and the lower end. Groundwater flow direction in this area is therefore assumed to be southeast down the Williams Creek valley.

On the mill site, assessment of flow direction is more difficult because there are a relatively small number of boreholes spread over an area with considerable variations in topography. As a result of the variations in topography and also because of the presence of significant structural features in the area, groundwater flow across the mill site area is likely to be more complex. The general trend of groundwater flow is, however, likely to be towards the Tamar River.

A conceptual model of groundwater movements is shown in Figure 7.

4.2.7 Groundwater quality analyses – groundwater characterisation

Preliminary Landfill Site Analyses

Groundwater analyses were undertaken following two preliminary sampling runs: Pitt & Sherry 14/04/2005 and GHD 29/09/2005. These analytical results are provided in Appendix B. They are also provided in Appendix D of the *Solid Waste Landfill Conceptual Design* report, which appears as Appendix 55 to the *Draft Integrated Impact Statement*.

Comparison of the analytical results with ecosystem[4] guidelines and drinking water guidelines[5] indicated elevated aluminium, chromium, copper, lead, nickel and manganese and conductivity[6].

Manganese is at or above the recommended limit for drinking water in both the shallow and the deep bores. However, as noted in the guidelines, this is a common natural occurrence in Australian soils, the limit being set for aesthetics (taste) not toxicity.

[4] ANZECC (2000) *Australian and New Zealand Guidelines for Fresh and marine Water Quality*.
[5] NHMRC/ARMCANZ (2004) *Australian Drinking Water Guidelines*.
[6] GHD undertook a further round of analysis of PDH2 and PDH3 groundwater sampled on 29 September 2005. The results are available on request but not presented here because they simply confirm the findings of the Pitt & Sherry sampling and analysis.

The bore water had high conductivity levels (field 1296 – 3400 µS/cm, laboratory 1270 – 3380 µS/cm) and TDS (laboratory 810 – 3140 mg/L), with the 14/04/2005 sampling analysis showing a stoichiometric imbalance between the cation and anion analytes, which accounted for less than 50% of the total dissolved solids (TDS). However, the 29/09/2005 sampling analysis showed a reasonable balance between the cations and anions.

Other bores[7] in the George Town area to the north of the site have recorded TDS levels of 582 and 320 mg/L but bores in the Mount Direction area to the south have recorded TDS levels of 1330 and 830 mg/L. The latter results suggest that high TDS levels may be a feature of the groundwater in the hills on the eastern side of the Tamar. However, a much more comprehensive dataset would be needed before this could be confirmed.

The drinking water guidelines note that water with TDS levels below 500 mg/L is good quality. Water with 500-1000 mg/L TDS is acceptable based on taste but above 1000 mg/L TDS the taste may be unacceptable.

Analysis of the groundwater in the landfill area indicates that it has a moderate salinity consisting mainly of sodium chloride, and is relatively clean with negligible levels of inorganic and organic contamination.

The deeper groundwater in GW3 has a higher EC than the shallower groundwater from GW4. GW3 is 30 m deep, with a bentonite seal at 8 m and slotting from 8 to 30 m in solid dolerite. GW4 has a bentonite seal at 5 m with slotting from 5 to 8 m, the upper 1 m of which is in clay and the lower 2 m in dolerite.

This suggests that the upper section of the aquifer is more free flowing and may be influenced more by incident rainfall and runoff than is likely to be occurring with the deeper zones of the aquifer.

September 2006 analyses

A further round of sampling and analysis was undertaken in September 2006.

The landfill and pulp mill area water quality field measurements for the individual borehole sampling undertaken on 18 to 20 September 2006 are summarised in the Table 9, together with the results for landfill sampling undertaken on 14 April 2005.

[7] George Town area: Bore 1550, 19.8 m, 582 mg/L; Bore 1608, 19.8 m, 320 mg/L. Mount Direction area: Bore 4807, 16.8 m, 1330 mg/L; Bore 15534, 82.3, 830 mg/L. Source: Mineral Resources of Tasmania online groundwater database.

Table 9: Groundwater field EC and pH results

Borehole		Groundwater quality			
Monitoring	Installed	EC µS/cm		pH	
		14/04/2005	20/09/2006	14/04/2005	20/09/2006
Landfill site					
GW2	DH1	1296	7.9*	7.5	6.87
GW3	DH2	3400	3500	7.1	6.99
GW4	DH3	2470	1255	7.4	7.13
GW7	BH_ML/01		1727		6.88
Mill site					
GW8	BFP W7		274		6.77
GW10	MB_M/01		3950		6.64
GW11	MB_M/02		2740		6.86
GW12	BFP W2		1861		6.71
GW13	MB_M/04		3900		6.88
GW14	MB_M/05		3420		7.02
GW15	BFP W6		4160		6.83
GW16	BFP W5		5510		7.01
GW17	BFP W4		12510		6.88

*This EC value appears spurious. The TDS results from the laboratory analysis would suggest an EC of the order of 780(TDS) x 1.6 = 1250µS/cm.

The EC of the September 2006 samples ranged from a minimum of 274 µS/cm at GW8 to a maximum of 12510 µS/cm at GW17 on the mill site, with an average value of 3734 µS/cm (excluding the probably spurious result of 7.9 µS/cm at GW2).

The pH ranged from a minimum of 6.64 (GW10) to a maximum of 7.13 (GW4), with an average value of 6.9.

No definitive explanation can be offered for the high EC readings that were recorded from some of the boreholes, particularly the 12500 µS/cm reading recorded from GW17. They may reflect remnant soluble silicates generated by the heat of drilling into solid dolerite or concrete and bentonite used in the borehole developments. If this is the case, ongoing monthly purging should lead to the removal of this material and result in significantly reduced EC values over time.

The analytical results for major cations and anions are shown in Table 10 and comments are provided in Table 11.

Table 10: Analytical results for major anions and cations in September 2006 samples

Site	Depth+ (m)	EC uS/cm	pH	TDS	EC*	TDS**	Na		Ca		K		Mg		SO_4		Cl		Total Alk	
							mg/L	mEq/L	mg/L	mEq/L	mg/L	mEq/L	mg/L	mEq/L	mg/L	mEq/L	mg/L	mEq/L	mg/L	mEq/L
GW2	-6.2	7.9[E]	6.9	780	1248	730	110	4.8	30	1.5	55	1.4	43	3.6	17	0.4	170	4.8	300	3.0
GW3	-1.8	3500	7.0	2500	4000	1900	380	16.5	100	5.0	2.7	0.1	130	10.8	43	0.9	880	24.8	360	5.9
GW4	-1.9	1255	7.1	870	1392	630	120	5.2	38	1.9	0.32	0.01	44	3.7	15	0.3	280	7.9	130	2.1
GW7	-3.1	1727	6.9	1300	2080	970	170	7.4	54	2.7	0.62	0.02	65	5.4	26	0.5	430	12.1	220	3.6
GW8	-7.4	274	6.8	210	336	160	32	1.4	6	0.3	0.7	0	7.5	0.6	3.9	0.1	44	1.2	62	1.0
GW10	-8.4	3950	6.6	2900	4640	2040	450	19.6	92	4.6	8.5	0.2	160	13.3	75	1.6	1100	31.0	150	2.5
GW11	-11.8	2740	6.9	2000	3200	1420	430	18.7	49	2.5	3.2	0.1	46	3.8	65	1.4	730	20.6	93	1.5
GW12	-8.2	1861	6.7	1400	2240	1010	300	13	18	0.9	0.3	0	30	2.5	63	1.3	490	13.8	110	1.8
GW13	-1.0	3900	6.9	2800	4480	2010	410	17.8	160	8.0	6.9	0.2	110	9.2	73	1.5	1000	28.2	250	4.1
GW14	-6.4	3420	7.0	1300	2080	1180	480	20.9	45	2.3	4.3	0.1	70	5.8	54	1.1	410	11.5	120	2.0
GW15	-18.8	4160	6.8	3000	4800	2650	420	18.3	90	4.5	4.3	0.1	150	12.5	440	9.2	1500	42.3	42	0.7
GW16	-1.3	5510	7.0	4900	7840	2870	720	31.3	210	10.5	6.3	0.2	140	11.7	75	1.6	1500	42.3	220	3.6
GW17	-13.6	12510	6.9	9900	15840	6590	1850	80.4	180	9.0	14	0.4	370	30.8	510	10.6	3600	101.4	62	1.0

+Depth below ground surface

* Calculated from TDS x 1.6

** Check calculation - calculated from adding major cations & anions & total alkalinity and rounding

E: This EC value appears spurious. The TDS results from the laboratory analysis would suggest an EC of the order of 780(TDS) x 1.6 = 1250μS/cm

Table 11: Comments on anion and cation balance in September 2006 samples

GW2	The cation and anion mEq/L balance correlates poorly. Cations mEq/L total = 11.3. Anions mEq/L total = 8.2 (assuming alkalinity as bicarbonate). Correlation = (Cation mEq/L – anion mEq/L) / (cation mEq/L + anion mEq/L) * 100 = 16%. 5% or less is considered an acceptable correlation. This borehole requires more purging to be more representative of the groundwater quality and for good connectivity with the groundwater.
GW3	The cation and anion mEq/L balance correlates well. Cations mEq/L total = 32.4. Anions mEq/L total = 31.6 (assuming alkalinity as bicarbonate). Correlation = (Cation mEq/L – anion mEq/L) / (cation mEq/L + anion mEq/L) * 100 = 1%. 5% or less is considered an acceptable correlation.
GW4	The cation and anion mEq/L balance correlates well. Cations mEq/L total = 10.8. Anions mEq/L total = 10.3 (assuming alkalinity as bicarbonate). Correlation = (Cation mEq/L – anion mEq/L) / (cation mEq/L + anion mEq/L) * 100 = 2%. 5% or less is considered an acceptable correlation.
GW7	The cation and anion mEq/L balance correlates well. Cations mEq/L total = 15.5. Anions mEq/L total = 16.2 (assuming alkalinity as bicarbonate). Correlation = (Cation mEq/L – anion mEq/L) / (cation mEq/L + anion mEq/L) * 100 = 2%. 5% or less is considered an acceptable correlation.
GW8	The cation and anion mEq/L balance correlates well. Cations mEq/L total = 2.3. Anions mEq/L total = 2.3 (assuming alkalinity as bicarbonate). Correlation = (Cation mEq/L – anion mEq/L) / (cation mEq/L + anion mEq/L) * 100 = 0%. 5% or less is considered an acceptable correlation.
GW10	The cation and anion mEq/L balance correlates reasonably well. Cations mEq/L total = 37.7. Anions mEq/L total = 35.1 (assuming alkalinity as bicarbonate). Correlation = (Cation mEq/L – anion mEq/L) / (cation mEq/L + anion mEq/L) * 100 = 4%. 5% or less is considered an acceptable correlation.
GW11	The cation and anion mEq/L balance correlates reasonably well. Cations mEq/L total = 25.1. Anions mEq/L total = 23.5 (assuming alkalinity as bicarbonate). Correlation = (Cation mEq/L – anion mEq/L) / (cation mEq/L + anion mEq/L) * 100 = 3%. 5% or less is considered an acceptable correlation.
GW12	The cation and anion mEq/L balance correlates well. Cations mEq/L total = 16.4. Anions mEq/L total = 16.9 (assuming alkalinity as bicarbonate). Correlation = (Cation mEq/L – anion mEq/L) / (cation mEq/L + anion mEq/L) * 100 = 2%. 5% or less is considered an acceptable correlation.
GW13	The cation and anion mEq/L balance correlates well. Cations mEq/L total = 16.4. Anions mEq/L total = 16.9 (assuming alkalinity as bicarbonate). Correlation = (Cation mEq/L – anion mEq/L) / (cation mEq/L + anion mEq/L) * 100 = 2%. 5% or less is considered an acceptable correlation.
GW14	The cation and anion mEq/L balance correlates poorly. Cations mEq/L total = 16.4. Anions mEq/L total = 16.9 (assuming alkalinity as bicarbonate). Correlation = (Cation mEq/L – anion mEq/L) / (cation mEq/L + anion mEq/L) * 100 = 33%. 5% or less is considered an acceptable correlation. This borehole requires more purging to be more representative of the groundwater quality and for good connectivity with the groundwater.
GW15	The cation and anion mEq/L balance correlates poorly. Cations mEq/L total = 35.4. Anions mEq/L total = 52.2 (assuming alkalinity as bicarbonate). Correlation = (Cation mEq/L – anion mEq/L) / (cation mEq/L + anion mEq/L) * 100 = 19%. 5% or less is considered an acceptable correlation. This borehole requires more purging to be more representative of the groundwater quality and for good connectivity with the groundwater.
GW16	The cation and anion mEq/L balance correlates poorly. Cations mEq/L total = 53.7. Anions mEq/L total = 47.5 (assuming alkalinity as bicarbonate). Correlation = (Cation mEq/L – anion mEq/L) / (cation mEq/L + anion mEq/L) * 100 = 6%. 5% or less is considered an acceptable correlation.
GW17	The cation and anion mEq/L balance correlates reasonably well. Cations mEq/L total = 120.6. Anions mEq/L total = 113 (assuming alkalinity as bicarbonate). Correlation = (Cation mEq/L – anion mEq/L) / (cation mEq/L + anion mEq/L) * 100 = 3%. 5% or less is considered an acceptable correlation.

4.2.8 Groundwater quality analyses – contaminants

Comprehensive laboratory analysis of groundwater has been undertaken on two occasions to date — September 2005 and September 2006 — and will be progressively supplemented through the ongoing quarterly monitoring program initiated by Gunns in September 2006.

Analytical reports and tabulated results are provided in Appendix B.

Findings for key parameters are presented and discussed below.

Metals, inorganics and common organics

Analytical results for metals, inorganics and common organics are provided in Table 11, together with guideline values.

The results show that the groundwater has no significant extraneous contamination. Exceedances probably reflect natural background values. The very high levels of some parameters in GW4 in September 2005 compared with September 2006 probably reflect initial contamination caused during bore installation. Natural background levels of some parameters exceed drinking water guidelines, indicating that the groundwater has little potential as a source of potable water.

Organics

Concentrations of organics other than dioxins, furans and PCBs are below the level of detection, apart from PAH, TPH and phthalate in GW11. The contamination at GW11 may reflect its proximity to the Bell Bay power station.

Dioxins and furans are above the level of detection in all bores for which analysis was undertaken.

Polychlorinated biphenyls (PCBs) are present above the level of detection in GW4, GW13, GW14 and GW16.

Dioxins and furans are a group of chemicals comprising 75 chlorinated dibenzo-*p*-dioxins and 135 chlorinated dibenzofurans. The World Health Organisation (WHO) has identified 17 that have a toxic effect on humans and animals. The WHO has also identified 12 dioxin-like PCBs that have dioxin-like behaviour.

Each of these chemicals is assigned a toxic equivalency factor relative to the most toxic form (2,3,7,8-TCDD) and these are then used to calculate total toxic equivalents (TEQ). These are shown for the individual chemicals in the laboratory reports in Appendix B.

Table 13 presents the TEQ summary results from the September 2006 sampling.

Table 12: Comparison of borehole groundwater metals, inorganics and common organics against guidelines (September 2005 and September 2006 samples)

Analyte	Units	Guideline*			Sept 2005		Sept 2006												
		DWH	DWA	FWE	GW3	GW4	GW2	GW3	GW4	GW7	GW8	GW10	GW11	GW12	GW13	GW14	GW15	GW16	GW17
Aluminium-Filtered	ug/L		200	55	20	75300	580	9	320	40	580	110	310	31	14	<5	10	140	31
Antimony-Filtered	ug/L				<1	<10	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Arsenic-Filtered	ug/L	7		13/24	<1	<10	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Barium-Filtered	ug/L	700			39	197	4.4	19	8.5	31	10	21	58	30	3	11	250	49	28
Boron-Filtered	ug/L	4000		370	<50	<100	<5	<5	<5	<5	6.5	14	5.5	<5	12	11	12	14	<5
Cadmium-Filtered	ug/L	2		0.2	<0.1	<1	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.3	<0.2	0.38
Chromium-Filtered	ug/L	50		1	<1	441	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cobalt-Filtered	ug/L				25	215	3.2	13	9	8.1	2.8	11	8.2	2	1.8	4.3	54	3	16
Calcium filtered	ug/L				116	8	30	100	38	54	5.6	92	49	18	160	45	90	210	180
Copper-Filtered	ug/L	2000	1000	1.4	1.4	124	4	1.5	<1	3.1	2.1	2.3	11	4	<1	<1	14	5.8	8.5
Iron-Filtered	ug/L		300		530	84100	360	25	170	100	170	110	330	36	300	1500	100	190	86
Lead-Filtered	ug/L	10		3.4	<1	52	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Manganese-Filtered	ug/L	500	100	1900	713	969	130	470	120	190	110	1600	940	29	1100	760	1400	2300	620
Mercury-Filtered	ug/L	1		0.6			<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Molybdenum-Filtered	ug/L	50			2	<10	10	<1	<1	<1	<1	26	8.9	<1	<1	6	<1	<1	<1
Nickel-Filtered	ug/L	20		11	14	245	26	13	2.8	3.5	3.5	24	22	6.4	<1	2.3	11	<1	28
Selenium-Filtered	ug/L	10		11	<10	<50	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Magnesium filtered	mg/L				153	9	43	130	44	65	7.5	160	46	30	110	70	150	140	370
Tin-Filtered	ug/L				<1	<10	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Vanadium-Filtered	ug/L				<10	440	3.5	8.9	6.3	4.2	<1	<1	<1	3.4	<1	<1	<1	<1	<1
Zinc-Filtered	ug/L		300	8	7	164	8.5	8.5	4.3	120	9.4	12	43	22	4.8	2.8	50	3.5	78
Phosphorus total	mg/L						0.63	0.023	<0.02	0.055	0.02	0.29	0.19	0.34	0.027	0.15	0.081	0.37	0.079
Potassium filtered	mg/L				2	<1	55	2.7	0.32	0.62	0.66	8.5	3.2	0.32	6.9	4.3	4.3	6.3	14
Sodium filtered	mg/L		180		350	41	110	380	120	170	32	450	430	300	410	480	420	720	1850
Chloride	mg/L		250		852	62	170	880	280	430	44	1100	730	490	1000	410	1500	1500	3600
Alkalinity-Total as CaCO3	mg/L		200		266	43	300	360	130	220	62	150	93	110	250	120	42	220	62

Analyte	Units	Guideline*			Sept 2005		Sept 2006												
		DWH	DWA	FWE	GW3	GW4	GW2	GW3	GW4	GW7	GW8	GW10	GW11	GW12	GW13	GW14	GW15	GW16	GW17
Ammonia-N	mg/L		0.5	0.9	0.07	0.02	0.011	<0.005	<0.005	<0.005	0.008	0.059	0.03	<0.005	0.062	0.049	0.007	0.059	0.019
Chromium - Hexavalent	mg/L						<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
COD	mg/L						30	15	11	52	19	22	49	52	10	30	22	22	30
Cyanide-Total as CN	mg/L			0.007			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Dissolved Org. Carbon	mg/L						<1	<1	2	<1	<1	2	2	4	<1	<1	<1	<1	5
Fluoride as F	mg/L	1.5			<0.1	<0.1	0.2	0.1	0.1	0.1	0.1	0.2	0.3	0.1	0.2	0.7	0.1	0.2	0.2
Nitrogen-Total as N	mg/L						0.35	0.1	0.12	0.26	0.21	0.36	0.98	0.51	0.07	0.65	0.17	0.28	0.66
Oil and Grease	mg/L						6	<5	<5	<5	<5	<5	<5	6	<5	<5	<5	<5	6
Orthophosphate as P	mg/L						<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Solids Total Dissolved	mg/L		500				780	2500	870	1300	210	2900	2000	1400	2800	1300	3000	4900	9900
Sulphate	mg/L	500	250		56	9	17	43	15	26	3.9	75	65	63	73	54	440	75	510
Nitrate-N	mg/L	50		0.7	<0.01	<0.01	<0.005	0.009	0.045	0.06	0.01	0.013	0.36	0.04	<0.005	0.009	0.009	0.01	0.16
Nitrite-N	mg/L	3			<0.01	0.042	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.012	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005

DWH: NHMRC/NRMMC Australian Drinking Water Guidelines – health related values
DWA: ARMCANZ/HNMRC Australian Drinking Water Guidelines – aesthetic guideline values
FWE: ANZECC Guidelines for Fresh and marine Water Quality trigger values (protection of 95% of ecosystems)
Shaded cells shown values that exceed one or more of the guideline/trigger values

Table 13: WHO total toxic equivalents for dioxins, furans and PCBs combined (TEQ_{DFP})

WHO_{05}-TEQ_{DFP}	Units	GW3	GW4	GW11	GW13	GW14	GW16
Lower bound (excluding below-detection-level values)*	pg/L	0.013	0.027	3.0	1.5	0.027	1.8
Middle bound (including half below-detection-level values)**	pg/L	0.67	0.80	11	3.9	1.6	4.6

*Values below level of detection are taken to be zero
**Values below level of detection are taken to be half the level of detection

The ANZECC Guidelines for Fresh and Marine Water Quality do not specify trigger values for dioxins because there are insufficient data to derive a reliable trigger value. However, the guidelines (section 8.3.7) note that "concentrations of dioxins and related furans have been found at cleaner sites at between 1 and 5 pg/L and at up to 100 pg/L at more contaminated sites".

Based on these ANZECC figures, the observed dioxin concentration in groundwater is therefore similar to background dioxin concentrations in clean aquatic environments.

The ANZECC guidelines (section 8.3.7) also note that "available information indicates that acute effects for some freshwater animal species exposed to TCDD occur at concentrations greater than 1.0 µg/L. Chronic concentrations are less than 0.01 µg/L, with a chronic concentration for rainbow trout of less than 0.001 µg/L". In picograms, these concentrations are 1000000, 10000 and 1000 pg/L respectively.

Based on these ANZECC figures, the groundwater dioxin concentration is therefore 300 times less than the lowest of these concentrations.

The ANZECC guidelines (section 8.3.7) also note that the USEPA "considered that water concentrations >0.00001 µg/L TCDD could lead to excessive levels of dioxin in fish and shellfish for human consumption". In picograms, this concentration is 10 pg/L.

Based on these ANZECC figures, the groundwater dioxin concentration is therefore less than the concentration of concern for growing fish and shellfish for human consumption.

Ongoing sampling

Gunns has implemented an ongoing regular groundwater sampling program, which will progressively add to the analytical database.

5. Groundwater implications for infrastructure

Landfill site:

At times of high groundwater levels the water table at the lower end of the landfill may be closer than the 5 m below the floor of the landfill desired by the landfill guidelines. It may therefore be necessary to lower the water table locally to avoid the water table encroaching on the landfill cell liner. The surface cutoff drains for the landfill are likely to reduce infiltration to groundwater and lower the water table accordingly. The ongoing monitoring program will determine the extent of this expected lowering, and hence the need for any additional engineering works. Options for further lowering the water table (in addition to the cutoff drains) include the installation of a drainage layer and/or the pumping down of the water table.

Mill site:

Excavations, either for individual buildings or to provide flat areas for plant location, may intersect the existing groundwater table. In any such areas, appropriate drainage measures will be required to divert water away from excavated areas.

Although the intersection of the groundwater table in some areas will result in a lowered groundwater table in other areas, this is unlikely to have any implications for infrastructure.

6. Infrastructure and operational implications for groundwater

Groundwater behaviour and quality may be modified locally by pulp mill infrastructure and operations.

Landfill site:

Although landfill leachate will be piped to the pulp mill’s wastewater treatment plant, imperfections in liner materials could cause small quantities of leachate to leak through the liner. This leakage in turn should largely report to the underlying witness sump of the landfill, and hence would also be piped to the treatment plant but a small proportion could escape collection and migrate to the groundwater.

A detailed discussion of this is provided in a separate concept design report for the mill[8]. In summary:

- The concentration of substances in the leachate that are considered to be ecosystem toxicants require an order of magnitude dilution to be below the *ANZECC Guidelines for Fresh and Marine Water Quality 2000* trigger values for ecosystem protection (99% of species), which will be achieved within a few metres of any leakage point.
- Transport of any leaked leachate in groundwater will lead to further dilution and the concentration of ecosystem toxicants that may over time reach the Tamar River will be several orders of magnitude lower than the *ANZECC Guidelines for Fresh and Marine Water Quality 2000* trigger values for ecosystem protection (99% of species).
- Leachate leakage presents no credible significant risk to any ecosystem.

In addition to the leachate constituents discussed in the concept design report, there may be trace amounts of dioxins in the leachate.

A new publication has become available since the preparation of the concept design report. That paper[9] presents the results of measurements of dioxins in power boiler ash and landfill leachate at coastal pulp mills, and is therefore relevant to the Gunns pulp mill and its landfill.

Dioxins are tightly bound on the ash and hence not easily removed by water leaching.

The paper found TEQ loadings of between 1 and 10 parts per billion in power boiler ash and typically less than 5 pg/L (picograms per litre) in the associated landfill leachate. TEQ means toxic equivalent, and weights the toxicity of different forms of dioxins as a fraction of the toxicity of 2,3,7,8-TCDD, the most toxic dioxin.

The ANZECC *Guidelines for Fresh and Marine Water Quality* do not specify trigger values for dioxins because there are insufficient data to derive a reliable trigger value. However, the guidelines (section 8.3.7) note that "concentrations of dioxins and related furans have been found at cleaner sites at between 1 and 5 pg/L and at up to 100 pg/L at more contaminated sites".

Based on these ANZECC figures, the expected dioxin concentration in the leachate (before dilution) would therefore be similar to background dioxin concentrations in clean aquatic environments.

The ANZECC guidelines (section 8.3.7) also notes that "available information indicates that acute effects for some freshwater animal species exposed to TCDD occur at concentrations greater than 1.0 µg/L. Chronic concentrations are less than 0.01 µg/L, with a chronic concentration for rainbow trout of less

[8] Pitt & Sherry (June 2006) *Gunns Pulp Mill Solid Waste Landfill Conceptual Design*, appendix 55 the *Draft Integrated Impact Statement*

[9] Uloth, V., Wenli, D., Leclerc, D., Karidio, I., Kish, J and Singbeil, D. (2005) *Investigations into the variability and control of dioxins formation and emissions from coastal power boilers*. Technical Association of the Pulp and Paper Industry - Engineering, Pulping, and Environmental Conference 2005

than 0.001 µg/L”. In picograms, these concentrations are 1000000, 10000 and 1000 pg/L respectively.

Based on these ANZECC figures, the expected dioxin concentration in the leachate (before dilution) would therefore be 200 times less than the lowest of these concentrations.

The ANZECC guidelines (section 8.3.7) also note that the USEPA “considered that water concentrations >0.00001 µg/L TCDD could lead to excessive levels of dioxin in fish and shellfish for human consumption”. In picograms, this concentration is 10 pg/L.

Based on these ANZECC figures, the expected dioxin concentration in the leachate (before dilution) would therefore be less than the concentration of concern for growing fish and shellfish for human consumption.

The nearest potentially affected permanent aquatic ecosystem is the Tamar River. This is approximately 2 km from the landfill. The leachate dilution factor over this distance would be several orders of magnitude and dioxin concentrations at the Tamar River would correspondingly be several orders of magnitude below their undiluted concentrations, which are already below levels of concern.

Leachate leakage therefore presents no credible significant dioxin risk to any ecosystem or to human health.

Mill site:

Mill operations could lead to soil contamination (for example, through spills) and contaminants could therefore migrate through the soil to groundwater. Appropriate management procedures will be implemented to minimise this risk. Ongoing monitoring of groundwater will be conducted to detect any contamination.

7. IIS requirements

Because the various boreholes were installed for different purposes, borehole and screen depths in the thirteen holes vary considerably. Nine of the screens are wholly in dolerite, one is dominantly in dolerite, one is wholly in silty clay and two are in mixed lithologies (upper part in clay or silty clay, lower part in dolerite).

Borehole GW4 in the landfill area has a 3 m slotted screen, the upper 1 m of which is in clay whilst the lower 2 m is in dolerite. Borehole GW8, on the eastern side of the mill site, has an 8.5 m slotted screen, the upper 4 m of which is in silty clay whilst the lower 4.5 m is in dolerite.

Both these boreholes are therefore potentially drawing from two different aquifers, an upper (shallow) one in the silty clay and a lower (deeper) one in the dolerite. The relative contributions from the two different aquifers is, therefore, uncertain and is likely to change over time, particularly following major rainfall events.

The establishment of groundwater boreholes and a systematic groundwater monitoring program was a requisite of the IIS guidelines.

Specifically, the IIS guidelines require the following:

- Details of groundwater on the development site and in the surrounding areas.
- Water quality data for water resources, including groundwater.
- The project should be consistent with the objectives and requirements of the *Water Management Act 1999* and the *State Policy on Water Quality Management 1997* with respect to groundwater, including groundwater resources, maintenance of beneficial use of groundwater and its quality to ensure ecosystem maintenance.
- Identification of the potential for pollutants emitted from the mill to accumulate in groundwater.
- Identification of the potential for groundwater pollution as a result of the development of any new roads and / or rail link.

As indicated in Section 3.4, there was no pre-existing groundwater data for the wider area that contains the mill and landfill sites.

Establishment of the thirteen boreholes, as outlined in Section 4.1, together with the commencement of a systematic monitoring and analytical program, provides detail on groundwater levels, movement and quality in the area sufficient to satisfy the requirements of the IIS.

However, additional boreholes may be required once the mill commences operations for the following reasons:

- Two of the existing boreholes in the landfill site will be buried over the life of the landfill.
- Changes in mill layout may result in the destruction or burial of some of the existing boreholes.
- Additional boreholes in some areas may provide improved understanding of groundwater levels and flows in those areas.

8. Future additional boreholes

It is recommended that five additional boreholes be installed prior to the commencement of mill operations. Three of these additional sites (GW1, GW5 and GW6) are in the landfill area and two (GW9 and GW18) are in the mill area. The locations of these sites are shown in Table 14 and Figure 5 (both existing and proposed borehole locations are shown on the figure).

Table 14: Proposed locations for additional boreholes

Monitoring nomenclature	Proposed depth (m)	Easting	Northing
Landfill Site			
GW1	30	494281	5445781
GW5	30	494749	5445038
GW6	8	494652	5444970
Mill Site			
GW9	15	493640	5444594
GW18	15	493333	5443875

The reasons for establishing these additional boreholes in the landfill area are as follows:

- GW1: This proposed borehole, upstream of the proposed landfill site, would be used to determine groundwater quality before it reaches the landfill area, throughout the lifetime of the landfill. The existing borehole upstream of the site (GW2) may be buried under the landfill.

- GW5: This proposed borehole, downstream of the ultimate extent of the proposed landfill, would be used throughout the lifetime of the landfill to monitor the deep aquifer. It would be used as a replacement for GW3 when that site becomes incorporated within the landfill approximately 8 years from commencement of the landfill.

- GW6: This proposed borehole, downstream of the ultimate extent of the proposed landfill, would be used throughout the lifetime of the landfill to monitor the shallow aquifer. It would be used as a replacement for GW4 when that site becomes incorporated within the landfill approximately 8 years from commencement of the landfill.

Millsite:

- GW9: This proposed borehole would be used to identify groundwater flow and quality near the northeastern edge of the mill site and would be used throughout the lifetime of the mill.

- GW18: This proposed borehole at southeastern end of site, east of the transmission line, would be used to determine the quality of the groundwater on the eastern side of the mill site and the direction of groundwater flow in this area. It would be used throughout the life of the mill.

Although these additional bores could be installed now, this is not recommended because the mill infrastructure is still only at a conceptual design stage. The locations of the additional bores should not be finalised until the detailed design stage. Premature decisions could result in the bores being wrongly located relative to the final footprints of the infrastructure.

9. Conclusions

The following conclusions are drawn, based on available information:

- Groundwater in the area is contained predominantly in fractured aquifers within the dolerite.
- Some groundwater also occurs within porous (intergranular) aquifers within the colluvium (weathered slope material) and in the Quaternary sediments in the drainage lines. This groundwater is likely to be seasonal.
- Groundwater movement in the area is likely to be ultimately towards the Tamar River, with directions of movement controlled by the orientations of the major fracture systems in the dolerite.
- Thirteen monitoring boreholes have been established, four on the proposed landfill site and nine on the proposed mill site.
- A monitoring and analytical program has commenced.
- Groundwater samples from a number of the boreholes have elevated EC values.
- Groundwater quality indicates no extraneous contamination but some parameters naturally exceed guideline values.
- Operation of the pulp mill and associated infrastructure has the potential to cause contamination of groundwater but with the anticipated management practices and pollution controls, no significant impact on groundwater values is likely.
- Construction and operation of the pulp mill and associated infrastructure may cause or require lowering of the water table but these effects will be localised.
- A further five monitoring boreholes are recommended to be installed prior to mill operations commencing, three on the landfill site and two on the mill site.

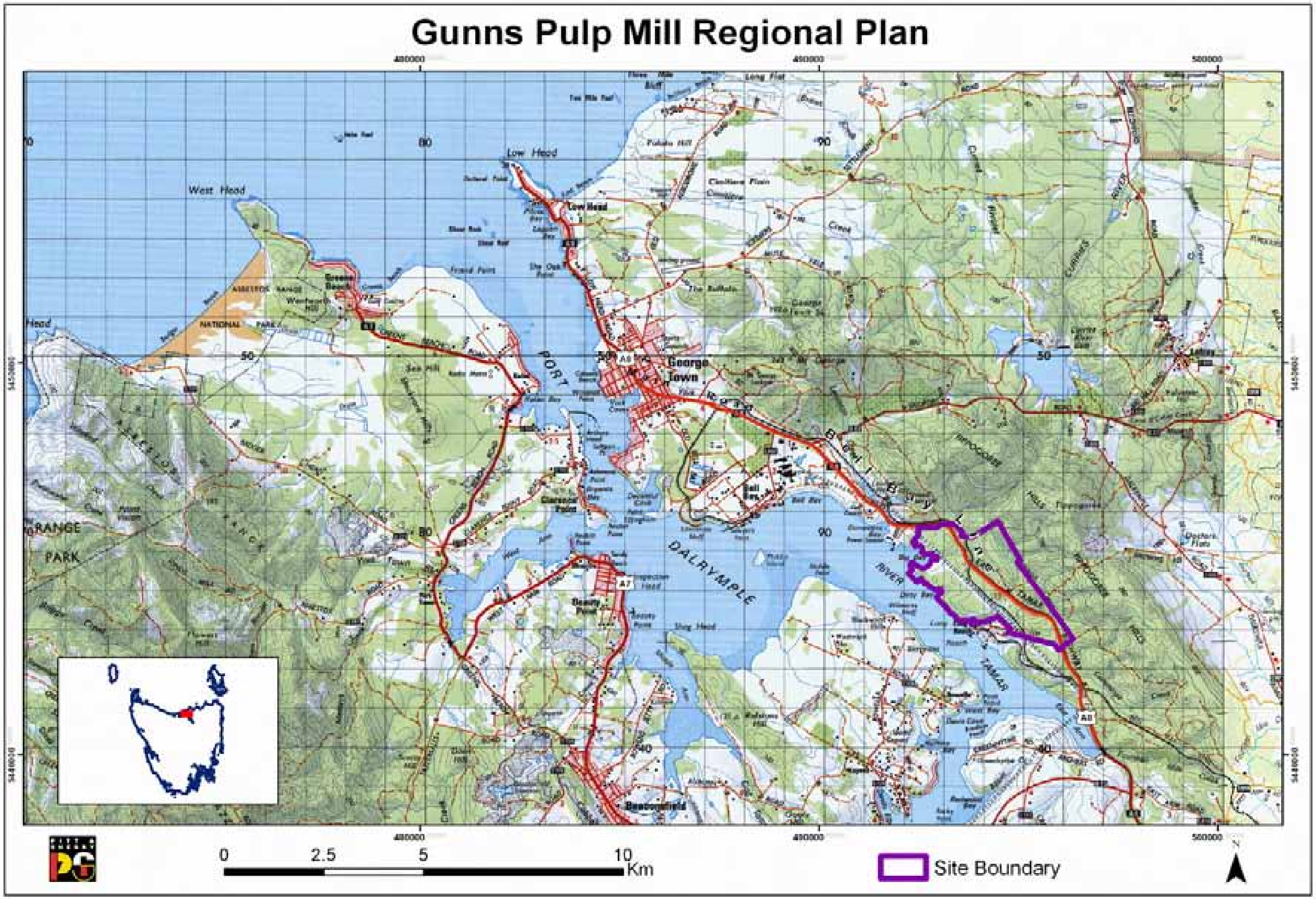

Figure 1: Regional setting

Figure 2: Local setting

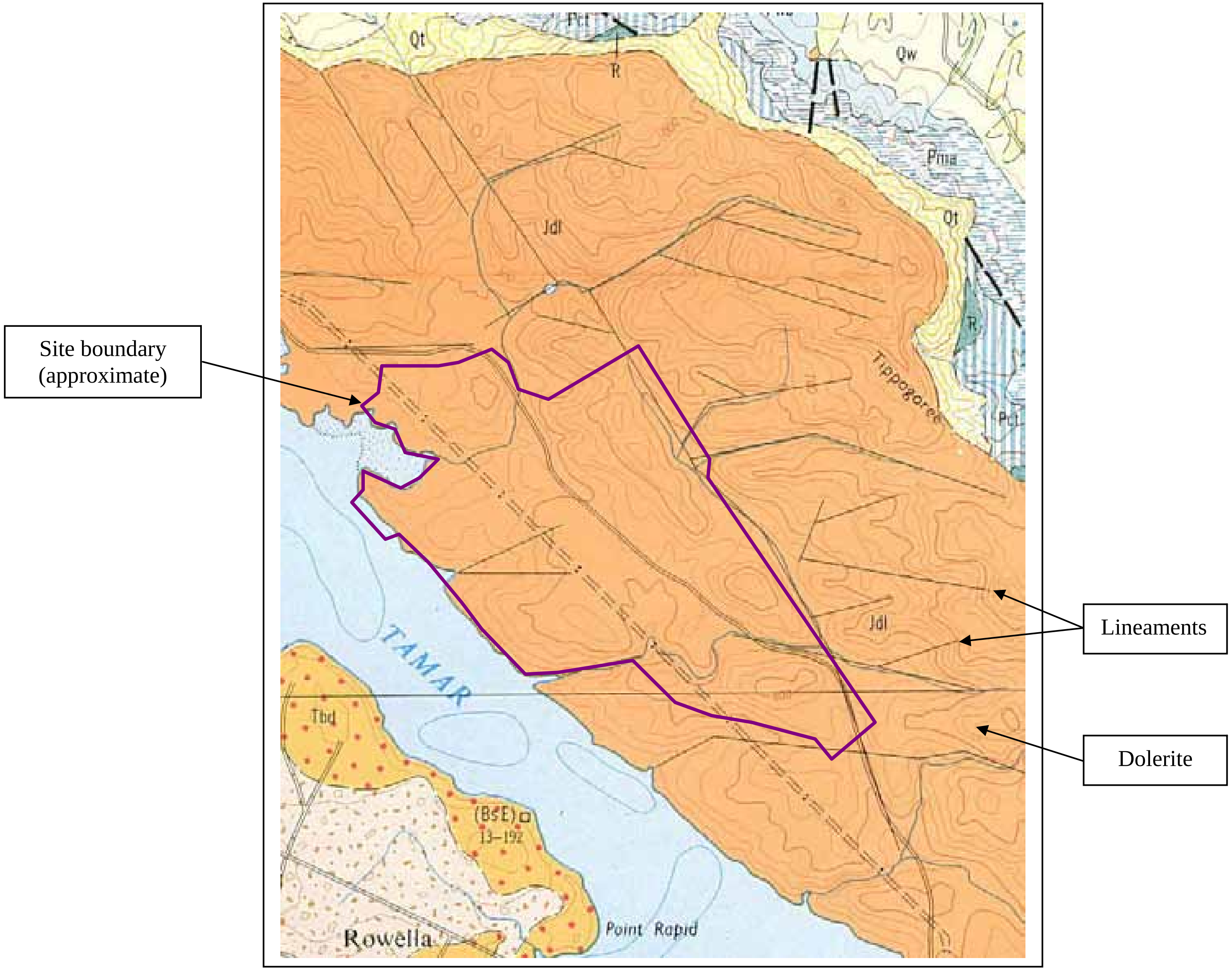

Figure 3: Regional geology (Geological Atlas 1 Mile Series: Beaconsfield)

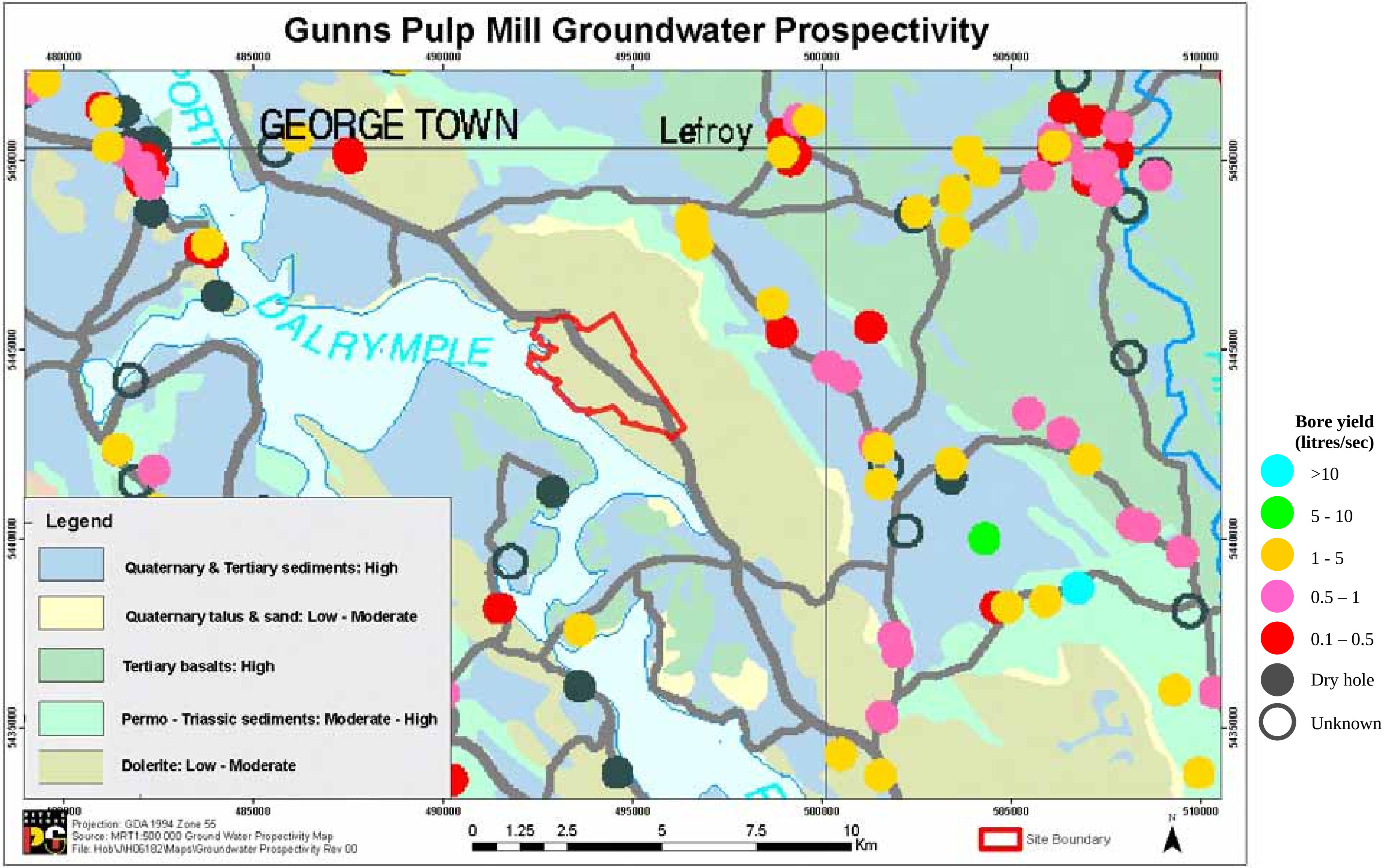

Figure 4: Regional groundwater prospectivity (MRT 1:500 000 Ground Water Prospectivity Map)

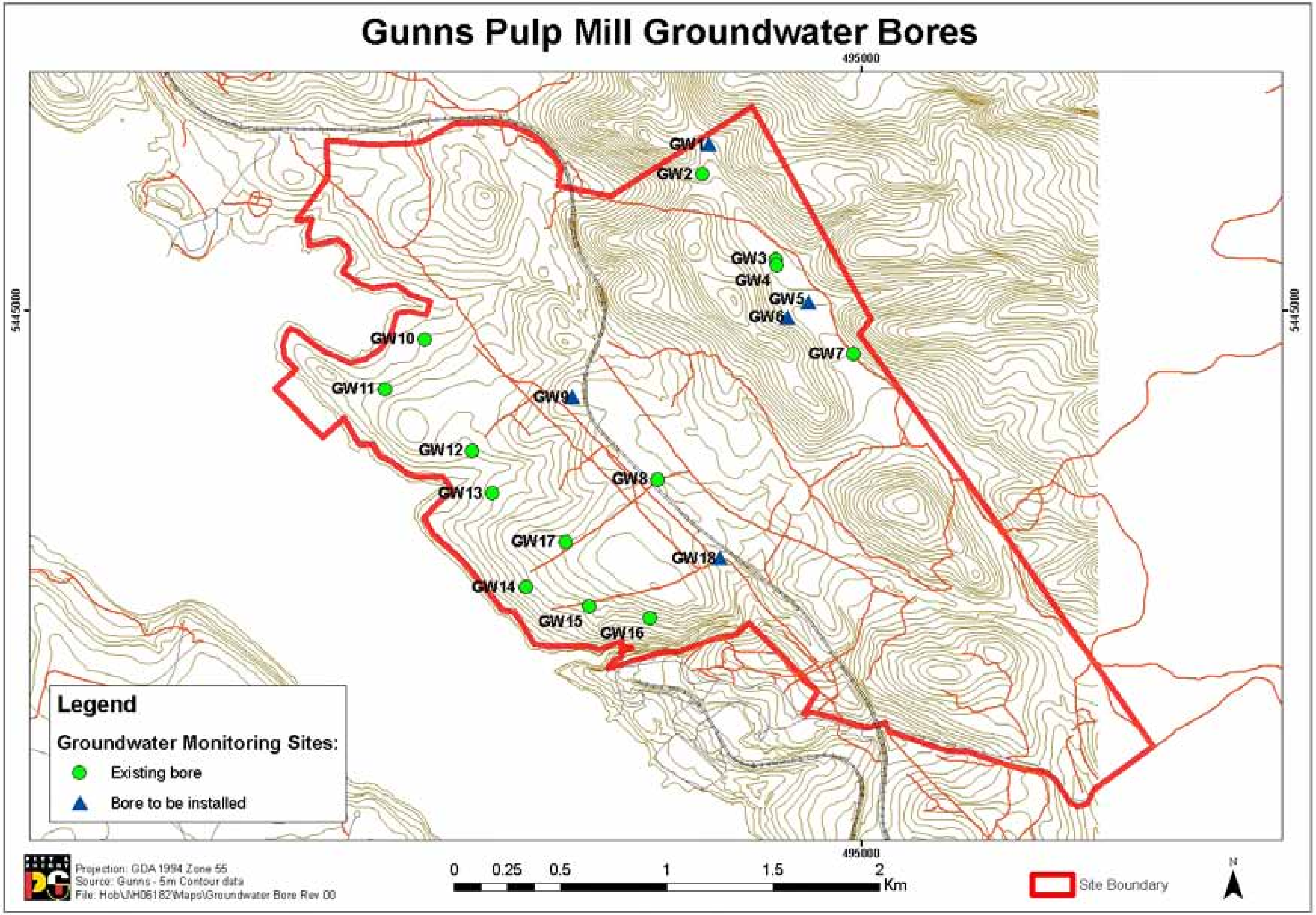

Figure 5: Installed and proposed bore locations

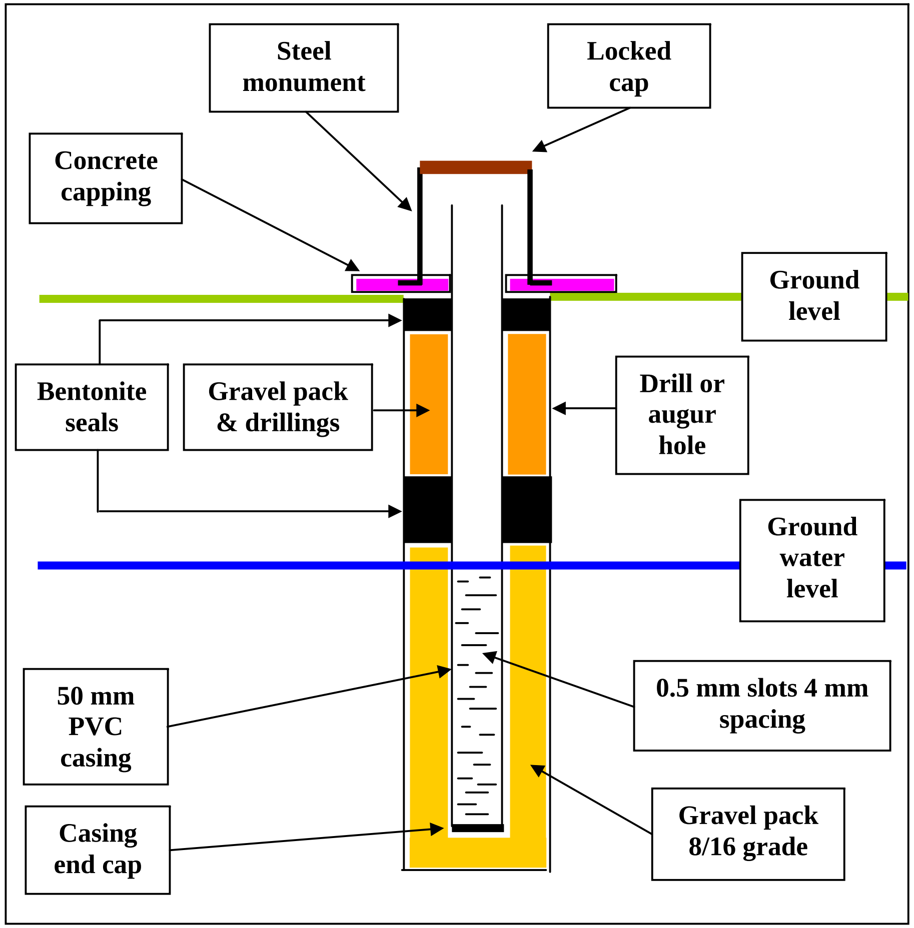

Figure 6: Schematic diagram showing typical design of installed groundwater monitoring bores

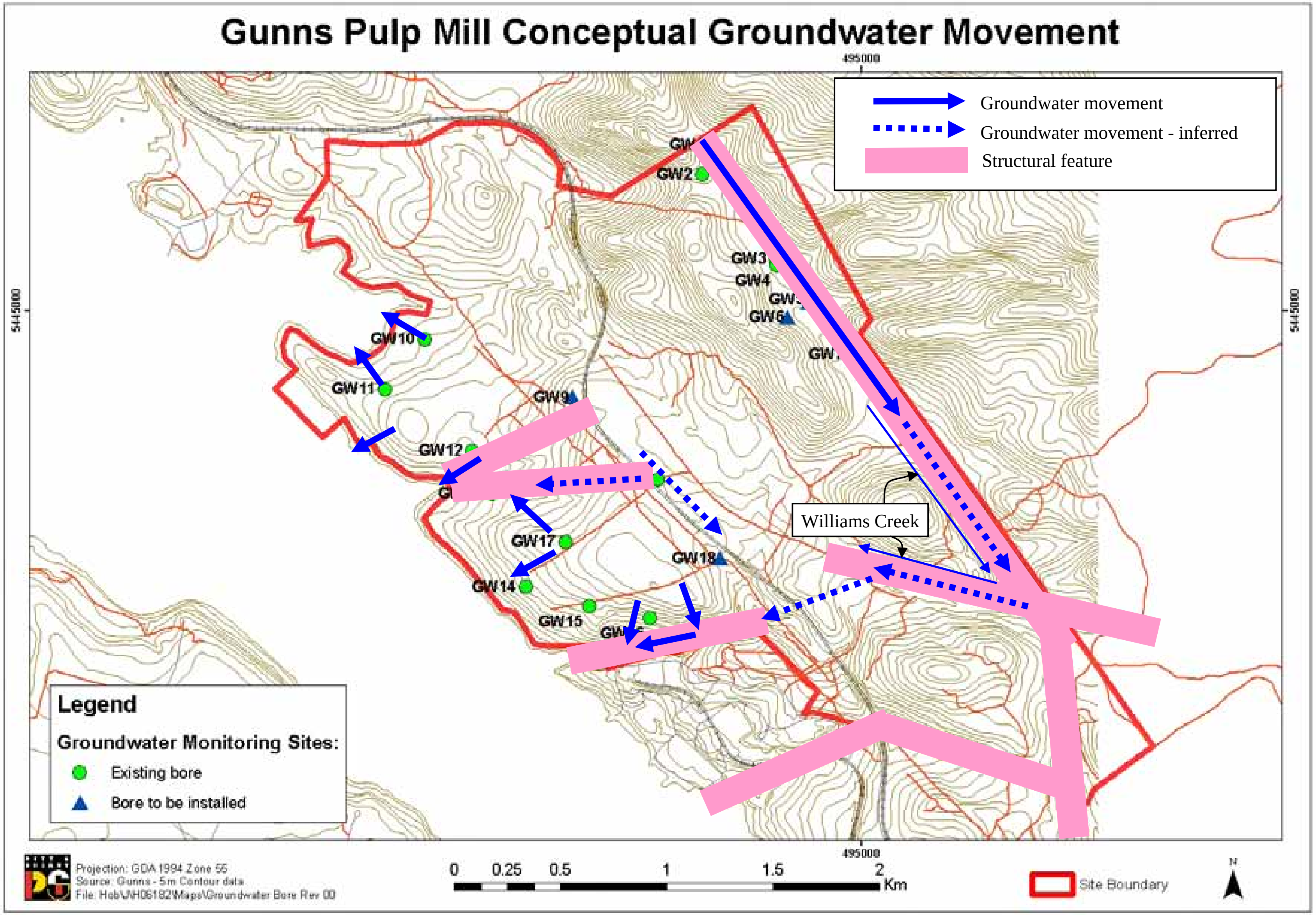

Figure 7: Conceptual model of groundwater movement