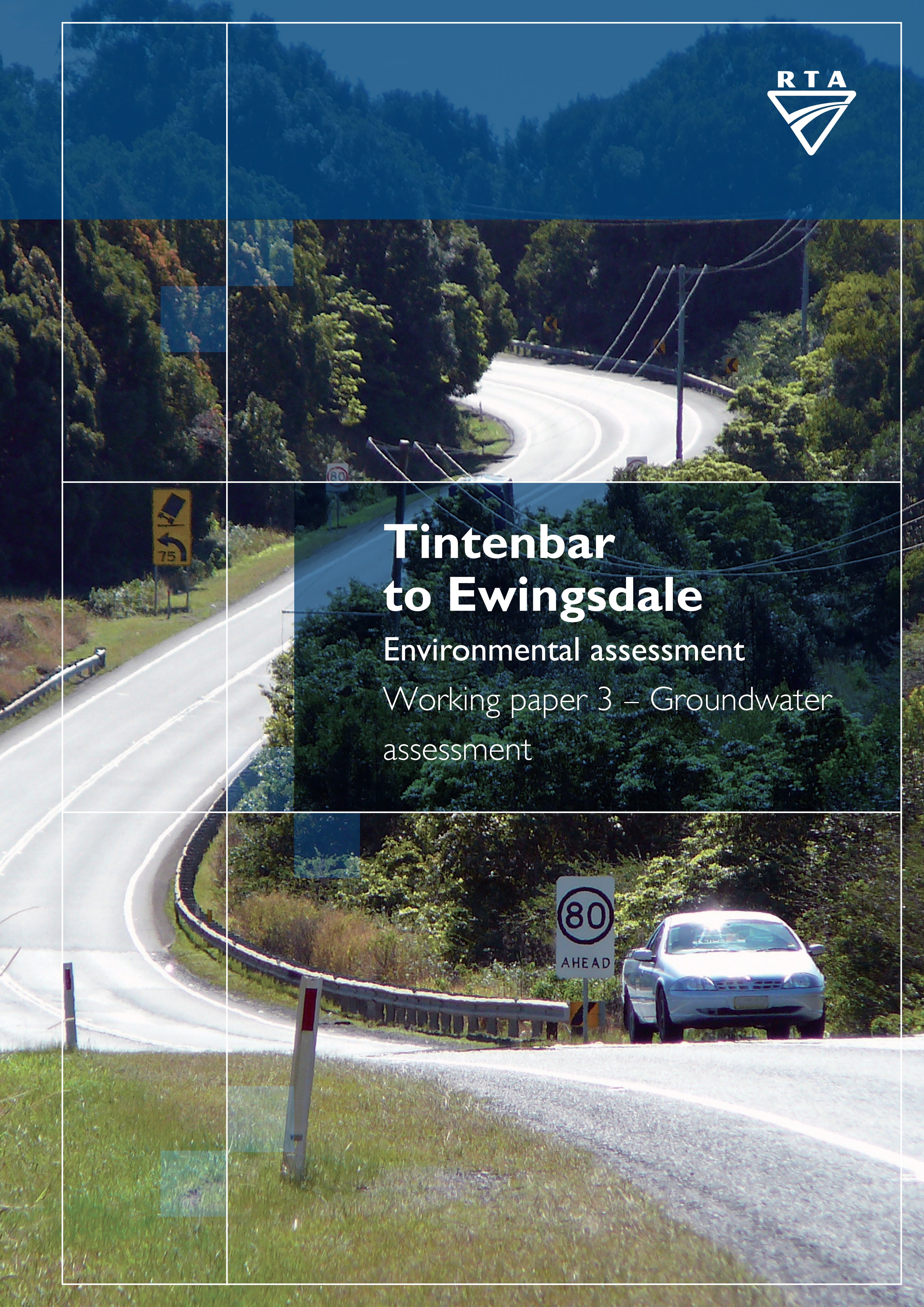

RTA

Tintenbar to Ewingsdale

Environmental assessment

Working paper 3 – Groundwater assessment

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**REPORT
ON**

PACIFIC HIGHWAY UPGRADE PROGRAM

TINTENBAR TO EWINGSDALE ENVIRONMENTAL ASSESSMENT

GROUNDWATER ASSESSMENT

Submitted to:

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EXECUTIVE SUMMARY

This report presents the results of a hydrogeological and groundwater impacts study carried out by Golder Associates Pty Ltd along and adjacent to the proposed upgrade of the Pacific Highway between Tintenbar and Ewingsdale (T2E), referred to as the “Pacific Highway Upgrade Program” (PHUP, or more simply, the proposed upgrade).

The objective of this study of groundwater impacts arising from the proposed upgrade works (road cuttings and the proposed tunnel under St. Helena Hill) is to address *key issues* raised in the Director-General’s requirements for the *Environmental Assessment* of the project (NSW Roads and Traffic Authority, 22 May 2007).

The Director-General’s requirements addressed by this study concern groundwater impacts, including the local impacts at each proposed deep road cuttings and the tunnel (Figures 2 to 8), and their cumulative impacts on the hydrogeology of the eastern Alstonville Plateau, and has considered:

- The extent of drawdown;
- Impacts to groundwater quality;
- Discharge requirements;
- Implications for groundwater-dependent surface flows (including springs, drainages, creeks and drinking water catchments);
- Implications for groundwater-dependent ecological (GDE) communities; and
- Implications for groundwater users, including the Alstonville Basalt Groundwater Source Water Sharing Plan.

The report has provides a description of the pertinent geological and hydrogeological environments studied, and which can be broadly represented as two groundwater systems, a shallow and deeper aquifer systems, having a likelihood of impact. These are underlain by a regional groundwater systems which extends across the entire Alstonville Plateau. The assessment has categorised the different road cuts (and tunnel), with respect to defined criteria, into three cut categories, namely *Type A*, *Type B*, and *Type C*.

Two typical examples of the first two categories (Cut 19 and Cut 6, representing *Type A*, and *Type B* cuts – Figures 9 and 10), assessed most likely to impact groundwater conditions were selected for field testing and modelling.

A third category, *Type C*, are not expected to impact groundwater conditions at all because they do not penetrate the groundwater table nor have a significant footprint.

As an outcome of the study it has been estimated that *Type A* cuts *may* impact the groundwater systems and GDEs by depriving the local shallow aquifer (perched systems mainly) of up to approximately 25% of recharge water (rainfall and diversion groundwater infiltration); the impact on local groundwater systems in the vicinity of *Type B* cuts is expected to be *low to negligible* or potentially not measurable (here regarded as a ‘minor’ impact); and local groundwater systems in the vicinity of *Type C* cuts are not expected to be impacted at all (impacts not measurable).

The proposed upgrade traverses Bangalow Zone 3 *Groundwater Source Zone*, Alstonville Zone 1 *Groundwater Source Zone* and is slightly overlying Lennox Zone 6 *Groundwater Source Zone* as defined by the DWE in the local Water Sharing Plan. The WSP prescribes protection of the high priority GDEs from “water supply work (bore)” and provides buffer zones around such GDEs and streams. These are covered by this study and will be impacted as detailed in Table ES-1 and will be managed as described in Table ES-2.

Whilst local groundwater and surface water impacts are predictable, the impact of the upgrade upon the regional groundwater resource is regarded as negligible to not measurable. This is primarily due to the insignificant footprint area of the alignment when compared with the total area of the aquifer system recharge for the Alstonville Plateau (limitation of recharge infiltration and diversion of run-off are insignificant on the scale of the aquifer system.

The following table summarises the estimated impact outcomes:

Table ES-1: Summary Table of Potential Impacts (refer to Figure 2 and Figures 4 to 8,)

Cut No.	Chainage	Type	Potential Impact before Mitigation
0	134750 - 135050	**B**	Minor reduction of groundwater to creek and potential spring C1-2 and local water resource within approximately 100m of cutting. Water course related GDE’s present in the vicinity of cut (no groundwater-reliant rainforest or wetlands are present in the area of potential impact.
1	135090 - 135430	**B**	Minor reduction of groundwater to creek and potential springs C1-2 and C1-1, and local water resource within approximately 100m of cutting. Potential impact to water course related GDE’s present in the vicinity of cut (no groundwater-reliant rainforest or wetlands are present in the area of potential impact).
2	135920 - 136150	**C**	No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.
3	136530 - 136750	**C**	No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.
4a+b	137365 - 138280	**A**	Reduction of groundwater to local creeks and streams, and local water resource in the southern portion of the cut, i.e. within approximately 100m of cutting. Potential impact to water course related GDE’s present in the vicinity of cut (no springs or groundwater-reliant rainforest or wetlands are present in the area of potential impact, i.e. within 200m of cutting).

Cut No.	Chainage	Type	Potential Impact before Mitigation
5	138990 - 139270	**A**	Reduction of groundwater to local creeks and streams, and local water resource in the southern portion of the cut, i.e. within approximately 100m of cutting. Potential impact to water course related GDE's present in the vicinity of cut (no springs or groundwater-reliant rainforest or wetlands are present in the area of potential impact, i.e. within 200m of cutting).
6	140090 – 140520 (investigated and modelled)	**B**	Minor reduction of groundwater to creek and 4 potential springs, C6-1 to C6-4, and SP-13, and local water resources within approximately 100m of cutting. Potential impact to water course related GDE's and groundwater-reliant rainforest (north of cutting) present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).
7	140760 - 140925	**C**	No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.
8	141140 - 141340	**B**	Minor reduction of groundwater to creek and potential spring C8-2 and water resource within approximately 100m of cutting. Potential impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant rainforest or wetlands are present in the area of potential impact).
9	141715 - 142020	**B**	Minor reduction of groundwater to creek and potential spring C8-1 and water resource within approximately 100m of cutting. Potential impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant rainforest or wetlands are present in the area of potential impact).
10	142265 - 142325	**C**	No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.
11	142680 - 142975	**B**	Minor reduction of groundwater to creek and water resource within approximately 100m of cutting. Potential impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant rainforest or wetlands are present in the area of potential impact).
12	143130 - 143340	**C**	No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.
14	143960 - 144215	**C**	No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.

Cut No.	Chainage	Type	Potential Impact before Mitigation
15	144530 - 144950	**B**	Minor reduction of groundwater to creek and potentially to springs C15-1 to C15-4, and SP 22 (C15-5 and C15-6, and SP17 to SP-21 negligible risk of impact), and local water resources within approximately 100m of cutting. Potential impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant rainforest or wetlands are present in the area of potential impact).
16	146230 - 146310	**C**	No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.
18a	147050 - 147250	**C**	No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.
18b	147345 - 147580	**C**	No measurable impact on local or regional groundwater systems or resources anticipated, there groundwater-reliant rainforest cluster (south) unlikely to be impacted. No wetlands are present in the vicinity of the cut.
19	147950 – 148335 (investigated and modelled)	**A**	Reduction of groundwater to local creeks, streams, springs (C19-2 and C19-3) and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant rainforest or wetlands are present in the area of potential impact).
20	148600 - 148815	**B**	Minor reduction of groundwater to creek and potential spring C20-1 to C20-3 and local water resources within approximately 100m of road cutting. Potential impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant rainforest or wetlands are present in the area of potential impact).
St Helena Hill Tunnel Area			
21	Cut on southbound carriageway only	**C**	No measurable impact on local or regional groundwater systems or resources anticipated. A cluster of groundwater-reliant rainforest may exist of the west and east of the Cut 21 but these are not likely to be impacted. No springs or groundwater-reliant wetlands are present in the vicinity of the cut.
22	149525 - 149705	**B**	Minor reduction of groundwater to creek and potential spring C22-1 and C22-2 and local water resource within approximately 100m of cutting. Potential impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant rainforest or wetlands are present in the area of potential impact).

Cut No.	Chainage	Type	Potential Impact before Mitigation
23	149970 – 150086 [tunnel south portal]	**B**	Minor reduction of groundwater to spring, creek and local water resource (groundwater well/s and dams) within approximately 100m of excavation. Potential impact to water course related GDE's present in the vicinity of cut (no springs, groundwater-reliant wetlands are present in the area of potential impact). Groundwater-reliant rainforest present around potentially likely to be impacted by portal cut.
Tunnel	150086 - 150426	**C**	Tunnel tanked, therefore no impact anticipated (leakage to tunnel essentially not measurable) within approximately 100m of excavation. No measurable impact on local or regional groundwater systems or resources anticipated. Groundwater-reliant rainforest clusters may be are present in the vicinity of the tunnel (over and east/west) but are unlikely to be impacted. No groundwater-reliant wetlands are present in the vicinity of the tunnel.
24	150426 – 150560 [tunnel north portal]	**B**	Minor reduction of groundwater to spring and associated creek leading to local water resource dam (and possible groundwater well/s). Minor local potential impact to water course related GDE's present in the vicinity of cut anticipated (no groundwater-reliant wetlands are present in the area of potential impact). Potential groundwater-reliant rainforest present around portal - potential minor impact anticipated.
25	150970 - 151260	**C**	No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.
26	151410 - 151810	**C**	No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.

The management strategy for these predicted impacts has been to pursue the following three-pronged approach:

(a) ***Assessment*** – this study, involving the investigations carried out and predictions made;

(b) ***Monitoring*** – to assess that the investigation and its predictions are accurate and to permit earlier intervention in the unlikely case/s that the actual outcomes deviate from predictions; and

(c) ***Mitigation*** – implement mitigation measures where predictions and/or monitoring measures suggest that these are required.

Management solutions have been proposed to mitigate and/or limit groundwater impacts through implementation of engineering measures that would require monitoring to assess any predicted (and unpredicted) impacts and the effectiveness of the mitigation measures. *Type A* cuts will require mitigation measures, likely to involve artificial recharge of captured surface water to the shallow groundwater system. *Type B* cuts are unlikely to require engineering mitigation, and this will need to be verified through further monitoring before, during and following construction.

Two categories of engineering management/mitigation measures could be considered at *Type A* cuts, and at *Type B* cuts, if monitoring indicates that engineering mitigation is required:

Option a) Engineering mitigation measures that transfer the seepage water downstream. Standard practice would be to collect the seepage from the cut face in the drainage system for the highway, which would be diverted into water quality ponds before being released back into the creek or natural drainage system at some point downstream.

Option b) Engineering mitigation measures that transfer the seepage water (where present) into the groundwater ecosystem immediately down-slope of the cut. These may involve collecting the seepage water from the cut face just above the level of the road, and piping it under the cut/fill platform to the down-slope side of the highway. This collection and piping system would also likely include seepage collected from the drainage blanket under the highway pavement. The collected water could then be returned to the ground through absorption trenches or discharged directly to the surface water system.

From the perspective of risk to GDEs and the local groundwater flow patterns, *Option b),* above, would provide the better solution for both *Type A* and *Type B* cuts, although a system combining both may need to be applied in some circumstances (depending on monitoring outcomes). The preferred method and exact form of the mitigation measures would be the subject of ongoing development of the concept design and environmental assessment process.

In summary, Golder Associates propose the following approach:

- ***Type A Cuts***: There is a higher likelihood that Type A cuts would impact on groundwater regimes. The implementation of engineering measures are likely to be required as part of construction to mitigate groundwater impacts. Long-term monitoring of the groundwater regime in the vicinity of Type A cuts should be commenced well in advance of the road construction. Depending on the results of the monitoring, before and during road construction, it may be that engineering mitigation would not be required at some (or all) of the Type A cuts. After road construction, the monitoring should continue to verify the effectiveness of the engineering mitigation, so that modifications can be made, if required.
- ***Type B Cuts***: It is less likely that Type B cuts would adversely impact on groundwater regimes. Engineering mitigation measures will probably not be required at Type B cuts. However, we propose long-term monitoring, commencing prior to construction, and observation of groundwater behaviour and impact during construction to verify impacts. As an outcome of the monitoring and observations, it may be necessary to implement engineering mitigation at some of the Type B cuts.
- ***Type C Cuts***: These cuts are expected to have no or negligible groundwater impacts. Monitoring and engineering mitigation measures are not required.

These recommendations are summarised in Table 3, which indicates the type of management and mitigation at each cut.

Table ES-2 Recommended Monitoring and Risk Management Strategies

	Location	**Water Table penetration***	**Monitoring Required**	**Impact Mitigation Measures Required**
	***TYPE A* CUTS AND TUNNEL**			
a	**Cut 4a**, Ch137365 - 138280	yes	yes	likely
b	**Cut 5**, Ch. 138990 - 139270	yes	yes	likely
c	**Cut 19**, Ch. 147950 - 148335	yes	yes	likely
	***TYPE B* CUTS**			
d	**Cut 0**, Ch. 134750 - 135050	probable	yes	unlikely
e	**Cut 1,** Ch. 135090 - 135430	yes	yes	unlikely
f	**Cut 6,** Ch. 140090 - 140520	yes	yes	unlikely
g	**Cut 8**, Ch. 141140 - 141340	yes	yes	unlikely
h	**Cut 9**, Ch. 141715 - 142020	possible	yes	unlikely
i	**Cut 11**, Ch. 142680 - 142975	possible	yes	unlikely
j	**Cut 15,** Ch. 144530 - 144950	no	yes	unlikely
k	**Cut 20**, Ch. 148600 - 148815	yes	yes	unlikely
l	**Cut 22**, Ch. 149525 - 149705	yes	yes	unlikely
m	**Cut 23**, Ch. 149970 - 150086	yes	yes	unlikely
n	**Cut 24**, Ch. 150426 - 150560	yes	yes	unlikely
	***TYPE C* CUTS**			
	All other cuts (13)	no	no	Not required

Notes: [*] based on groundwater table measured during the investigations in 2006 and 2007, and current cut design dated 3 August 2007; and

** tunnel is to be ‘tanked’ (fully lined with a low leakage concrete liner).

This strategy would be further detailed in a *Water Management Plan* to be prepared for both the project construction *and* operation phases.

GLOSSARY - DEFINITIONS

Item	Definition
adsorption	The attraction and adhesion of ions from an aqueous solution to the surface of solids.
AHD	Australian Height Datum
analytical model	A mathematical model that provides an exact or approximate solution of a differential equation (and the associated initial and boundary conditions) for subsurface water movement or transport.
anisotropy	The conditions under which one or more of the hydraulic properties of an aquifer vary with direction. (See also isotropy).
aquiclude	A geologic formation which may contain water (sometimes in appreciable quantities), but is incapable of transmitting significant quantities under ordinary field conditions.
aquifer	A consolidated or unconsolidated geologic unit (material, stratum, or formation) or set of connected units that yields a significant quantity of water of suitable quality to wells or springs in economically usable amounts. • confined (or artesian) - an aquifer that that is immediately overlain by a low-permeability unit (confining layer). A confined aquifer does not have a water table. • leaky / semi-confined - an aquifer that receives recharge via cross-formational flow through confining layers. The aquifer displays characteristics of both confined and unconfined aquifers. • perched - a local, unconfined aquifer at a higher elevation than the regional unconfined aquifer. An unsaturated zone is present between the two unconfined aquifers. • unconfined (or water-table) - the upper surface of the aquifer is the water table under atmospheric pressure. Water-table aquifers are directly overlain by an unsaturated zone of a surface water body.
aquitard	A semi-pervious geologic formation which can store water but transmits water at a low rate compared to the aquifer.
base flow	Part of the discharge which enters a stream channel mainly from groundwater (but also from lakes and glaciers) during long periods when no precipitation (or snowmelt) occurs.
bgl	Below Ground Level.
flow model	A digital computer model that calculates a hydraulic head field for the modelling domain using numerical methods to arrive at an approximate solution to the differential equation of groundwater flow.
GDE	Groundwater Dependent Ecosystem.
groundwater flow	The movement of water through openings in sediment and rock that occurs in the zone of saturation.

Item	Definition
groundwater model	A simplified conceptual or mathematical image of a groundwater system, describing the features essential to the purpose for which the model was developed and including various assumptions pertinent to the system. Mathematical groundwater models can include numerical and analytical models.
hydraulic conductivity (K)	The volume of fluid that flows through a unit area of porous medium for a unit hydraulic gradient normal to that area.
infiltration rate	Rate at which soil or rock under specified conditions absorbs falling rain, melting snow, or surface water; expressed in depth of water per unit time. Also, the maximum rate at which water can enter soil or rock under specific conditions, including the presence of an excess of water; expressed in units of velocity.
NMLC	Diamond Coring – drilling method.
piezometer	A tube or pipe, open to the atmosphere at the top and to water at the bottom, and sealed along its length, used to measure the hydraulic head in a geologic unit.
Piper diagram	A graphical means of displaying the ratios of the principal ionic constituents in water.
sorption	The general process by which solutes, ions, and colloids become attached (sorbed) to solid matter in a porous medium. Sorption includes absorption and adsorption.
well screen	A filtering device used to permit the flow of liquid or air but prevents the passage of sediments or backfill particles.

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1.0 INTRODUCTION

1.1 Objectives

This report presents the results of a groundwater impacts study carried out by Golder Associates Pty Ltd (Golder Associates) along the proposed upgrade of the Pacific Highway between Tintenbar and Ewingsdale (T2E), referred to as the "Pacific Highway Upgrade Program[1]" (PHUP).

The objective of this study of groundwater impacts arising from the proposed upgrade works was to address key issues raised in the Director-General's requirements (DGRs) for the Environmental Assessment (EA) of the project. The DGRs were set out in a letter from the NSW Government Department of Planning to the NSW Roads and Traffic Authority dated 22 May 2007, together with the formal project description, copies of which are provided in Appendix A. The DGRs addressed by this study are groundwater impacts, including the local impacts at each proposed deep cut and cumulative impacts on the hydrogeology, considering:

- The extent of drawdown;
- Impacts to groundwater quality;
- Discharge requirements;
- Implications for groundwater-dependent surface flows (including springs, drainages, creeks and drinking water catchments);
- Implications for groundwater-dependent ecological (GDE) communities; and
- Implications for groundwater users, including the Alstonville Basalt Groundwater Source Water Sharing Plan.

This report *also* considers the potential groundwater impacts of the proposed tunnel under St. Helena Hill.

The potential environmental impacts on the existing groundwater regime, springs and GDE's needs to be understood (through appropriate investigation) so that, if required, appropriate monitoring and mitigation measures can be implemented. The proposed road cuts and the tunnel *could* impact local surface water features by modifying groundwater recharge to the local groundwater system(s). This is because road cuts locally divert incident rainfall to a constructed drainage system reducing the potential for infiltration to the subsurface (reducing recharge) downgradient of the cut.

Further, some of the cuts and the tunnel penetrate below the existing groundwater table that are likely to capture local groundwater flow. This groundwater flow may be diverted to the surface water drainage system associated with each cut and out of the local groundwater system which may otherwise feed local springs and creeks.

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[1] The alignment of the proposed upgrade is simply referred to in this report as the "proposed upgrade".

Specifically, the proposed upgrade has the potential to impact on the groundwater regime and springs, including groundwater dependent ecosystems (GDEs) and drinking water resources, as follows:

- The construction of cuts/tunnel below the groundwater table may locally draw the groundwater table down, particularly where the base of the structure is deeper than the local groundwater table. Therefore, there is the potential for the drawdown to impact on the rate of flow and flow duration/frequency of local springs and/or creek flow outside of the cut footprint. Spring flow rates could decline and, possibly, periodically or permanently dry up if there is strong hydraulic connection between the spring and cut.
- The cut and tunnel portals may capture and divert potential recharge water (by restricting rainwater infiltration to the groundwater systems) to local surface water drainages. This has the potential to detrimentally impact the prevailing natural water balance in the immediate vicinity of the structures. Typically this captured water is redirected by the roadside drains to nearby creeks or other natural drainages and is therefore less likely to recharge the groundwater systems immediately beneath the cut footprint.
- Cuts (including for the tunnel portals) may encroach over known (and some currently unknown) springs and/or cause spring flows to decline and/or intermittently or permanently cease flowing.
- Unless the rate of groundwater recharge by surface infiltration is greater than the rate of recharge to upgradient spring recharge areas or seepage into the tunnel, the groundwater table will be locally drawn down.
- An unlined tunnel excavation will behave like a drain and cause the groundwater above the tunnel invert to seep into the open excavation. Unless the rate of surface infiltration is greater than the rate of seepage into the tunnel, the groundwater table will be locally drawn down. Where the tunnel is lined (“tanked”), as proposed, this effect is negligible or non-existent.
- Local GDEs have the potential to be impacted if rainfall water destined for recharge to groundwater and GDEs is diverted to nearby surface water flow systems.
- Similarly, Local GDEs have the potential to be impacted if groundwater seepage occurs from a cut embankment and is diverted away from local downgradient GDEs to neighbouring surface water flow systems; and
- Potential groundwater resource aquifers discussed in the Water Sharing Plan for the Alstonville Plateau Groundwater Sources (DIPNR 2004) that may be deprived of some recharge waters in the immediate vicinity of the cuts and tunnel.

1.2 The Proposed Upgrade

The proposed upgrade extends from a starting at Ross Lane in Tintenbar in the south to the existing Ewingsdale interchange, near the settlement of Ewingsdale, in the north (refer to “The Project Description” in Appendix A, and Figure 1). At Ross Lane, the proposed upgrade would connect to the north end of the Ballina bypass. Generally the alignment of the proposed upgrade lies in close proximity to existing Pacific Highway corridor from Ross Lane to the Bangalow bypass. The existing highway would be maintained for local and regional traffic. The length of the proposed upgrade would be approximately 17 km.

From Bangalow, the proposed upgrade would diverge away from the Bangalow bypass to the northeast through Tinderbox valley. From there, the proposed upgrade would avoid the steep grades of St Helena Hill by way of a tunnel approximately 340 m long and 45 m below the ridge line. North of the tunnel, the proposed upgrade alignment is located immediately to the east of the existing highway before tying into the Ewingsdale interchange.

1.3 Previous Investigations

This groundwater impacts study supplements earlier geotechnical investigations along the preferred route carried out by Golder Associates between 1997 and 2007. Reports for these previous investigations provide important background information about the proposed upgrade, site conditions (topographic characteristics, land use, drainage and climate), geology and hydrogeology along the alignment and a preliminary conceptual groundwater model.

The groundwater impacts investigation program carried out for the proposed upgrade included a preliminary assessment of the hydrogeological conditions and groundwater levels at each cut. The hydrogeology along the proposed upgrade alignment is complex because of the interlayered nature of the underlying basalt geology. Golder Associates' interpretative geotechnical reports included preliminary assessments of the likely groundwater impacts from the cuts and the tunnel (Golder Associates 2007a and 2007b). The preliminary groundwater assessments were based on broad-based data that had the primary aim of establishing, as a first pass, the geological and hydrogeological conditions and level of groundwater within the cuts. Addressing the DGRs was not part of the scope of work for the earlier reports.

1.4 Physical and Environmental Setting

The proposed upgrade alignment traverses an elevated rural region of low rolling hills and deeply incised valleys known as the Alstonville Plateau (typically at 70 to 190 m Australian Height Datum). The dominant land use along the proposed upgrade is agricultural, which includes grazing, poultry, banana, coffee, stone fruit and macadamia plantations. Rural residential development is present at localities along the route.

The predominant creek systems (and their tributaries) that lie within the proposed upgrade corridor (from south to north) are as follows:

- *Emigrant Creek* (part of the catchment for Emigrant Creek dam, which is a potable water supply for the area);
- *Skinners Creek*;
- *Byron Creek*; and
- *Tinderbox Creek*.

Rainfall during the four months preceding the groundwater impact study (April to July 2007) was lower than average, with two months about 50% lower than average. However, heavy rainfall occurred during the late August 2007 field activities, with 102 millimetres (mm) of rainfall recorded at Byron Bay weather station (and, for reference, 160 mm and 170 mm was recorded at Murwillumbah and Ballina weather stations, respectively).

1.5 Regional Geology and Hydrogeology

The regional geology in the area traversed by the proposed upgrade is illustrated on the 1:100,000 Lismore-Ballina Sheet 9640. The Alstonville Plateau is underlain by the *Lismore Basalt* of the Lamington Volcanics (Morand, 1994, Brodie and Green, 2002; and the Geological Survey of NSW) and have the following features pertinent to this groundwater impacts study:

- The Lismore Basalt typically consists of sub-aerially extruded basalt (lava flows) and is thought to be up to 150 m thick at the top of St Helena Hill;
- Time lapses between lava flows created the formation of interlayered soils and weathering zones. Clay layers or fossil soils are typically about 1 m to 5 m thick, and interbeds of high and low strength basalt vary from about 5 m to 25 m thick;
- The lava flows are commonly vesicular (containing air voids, typically less than about 10 mm in diameter) and, more rarely, amygdaloidal (almond-shaped minerals);
- The basalts are highly variable, laterally and vertically; and
- The regional dip of the individual lava flows is generally 0 to 5 degrees to the *north west*.

The generalised basalt geology and stratigraphy encountered during previous investigations by Golder Associates along the proposed upgrade can be described as residual soils (basalt derived) of mainly high plasticity to variable depths, typically between 3 m and 5 m depth, overlying extremely weathered basalt (exhibiting soil-like properties) to depths to at least 15 m with discrete layers of basalt bedrock ranging in strength from very low to extremely high and highly weathered to fresh bedrock (Golder Associates 2007a and 2007b).

In addition to the residual soil and basalt rock units described above, the steep slopes and escarpment are frequently draped with landslide debris and colluvium derived from the basalt. These features are noteworthy because they have a strong influence on the local shallow groundwater behaviour.

Before presenting a more simplified groundwater setting it is necessary to consider the following geological and groundwater characteristics that are pertinent to this groundwater impacts study:

- The local residual weathering profiles and regional layered geological sequences within the Lismore Basalt govern the nature of the 'shallower' and 'deeper' (respectively) groundwater systems in the studied profiles within/along the proposed upgrade alignment.
- Intermittent and perennial perched groundwater tables can be present within the shallow soil and residual profile studied. Groundwater tables may also be present locally, within the underlying weathered or fractured basalt sequences. These are either continuous or discontinuous extent forming a complex, largely layered, cascading[2] groundwater flow system.

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[2] 'Cascading' here is intended to convey the notion of groundwater flow which moves horizontally until a vertical flow zone (say at a thinning of a perched aquifer system, a discontinuity arising from a weathering, a fault or fracture conduit zone, or a combination of the above) is reached, whence vertical flow continues down to an impermeable zone and horizontal flow resumes and is visualised by considering a waterfall or cascading rapid system.

- Deeper groundwater systems exist within the more permeable fractured or weathered layers of basalt studied (immediately beneath the shallow groundwater system/s referred to above) that can be confined or semi-confined between the relatively massive and competent high strength, and less permeable, basalt layers, as shown in the diagram below (from Brodie and Green, 2002). With depth this transitions into the Regional Aquifer System (on a scale of 10s to 100s kilometres)
- Superimposed on this bedrock sequence is a surficial profile arising from the weathering of the bedrock sequence, that generally mimics (follows) the topography.
- Each of the above systems has its own unique influence on the way recharge water (rainfall) runs off or infiltrates into the subsurface, thus creating two dominant individual but hydrogeologically connected groundwater systems. There is likely to be a zone where the two systems overlap and where groundwater flow will be affected in part by each layering system. This zone produces a complex groundwater flow pattern, and one which is extremely difficult to interpret, predict and model.
- Regional groundwater flow in the Lismore Basalt generally follows the regional dip of the lava beds, that is, to the north west. Local flow directions will be largely governed by the local topography, geology, hydrogeology and the highly variable weathering profile.
- Each groundwater system has the potential to give rise to spring flow occurrences at the surface, largely where zones/layers of lower permeability ‘daylight’ (outcrop) at the ground surface.

For the purpose of this groundwater impacts study, and based on our understanding gained from the previous geotechnical investigations (Golder Associates 2007a and 2007b) and this study, the groundwater regimes in the area of the proposed upgrade can be represented as three types of aquifers:

- ***Shallow Aquifer/s***: A local shallow (or upper) aquifer that is present within the weathered or residual soil horizon generally at a depth of between 10 to 15 m bgl. This aquifer is unconfined and is likely to be discontinuous over the length of the proposed upgrade;
- ***Deeper Aquifer/s***: A local semi-confined deep (or intermediate depth) aquifer present within the layered basalt bedrock. Similarly to the shallow aquifer, the deep aquifer is likely to be discontinuous over the length of the proposed upgrade;
- ***Regional Aquifer***: The regional deep ‘aquifer’ that is present at depths greater than the extent of our investigations (including previous geotechnical investigations and this groundwater impacts study), deeper than the proposed cuts and tunnel, and has a lateral extent covering tens to hundreds of square kilometres, and is the subject of the Water Sharing Plan (DIPNR 2004). The cuts and tunnel were assessed to have zero or negligible impact on the regional aquifer (due to the immense scale difference between the two[3]) and consequently further assessment of the regional aquifer is not warranted.

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[3] the Regional Aquifer was not further due to its scale (>100km) relative to the local scale of each of the cutting (<100m); any groundwater diverted from the local aquifer systems is typically largely reintroduced at locations (streams, creeks) immediately adjacent to the cutting/s considered with respect to their impacts.

2.0 SCOPE OF STUDY AND METHODOLOGY

2.1 Study Approach

The approach to addressing the DGRs was to assess the sensitivity of groundwater systems and the associated springs to the proposed highway construction. This approach has required field testing, data collection, review of published information, and numerical groundwater modelling to be undertaken.

As a basis of this assessment, the proposed road cuttings (and tunnel) were separated into one of three categories. This initial categorisation was primarily based on the depth of penetration into the local water table and the length and area of the cutting or tunnel, since these are the dominant physical features which are most likely to generate impacts to the local and regional groundwater systems. These categories are:

- ***Type A Cuts*** – where the proposed cut has a significant depth of excavation into the topography, a large length and area of extent, a deep penetration into the groundwater table. This is the case for Cut 4a (southern portion of Cut 4), 5 and 19 (refer Table 1 and Figures 2 to 8).
- ***Type B Cuts*** – where the proposed cut has a relatively moderate depth of excavation into the topography, a small to moderate length and area of extent, limited penetration below the groundwater table (nominally, less than about 4 m). This is the case for Cuts 0, 1, 6, 8, 9, 11, 15, 20, 22, 23 and 24 (refer Table 1 and Figures 2 to 8).
- ***Type C Cuts* –** where the proposed cut is expected to be above the groundwater table or penetrate less than 1 m below the groundwater table. This is the case for Cuts 2, 3, 4b (northern portion of Cut 4), 7, 10, 12, 14, 16, 18a, 18b, 21, 24, 25 and 26 (refer Table 1 and Figures 2 to 8). Type C cuts are not expected to impact on the groundwater regime due the fact that they do not penetrate to the groundwater table, and, therefore, no further discussion is provided in this report. The St Helena Tunnel is considered to reside in this category since it is proposed to be fully tanked (negligible leakage inferred) and would not give rise to measurable impacts to the local and regional groundwater systems even though it penetrates up to 19m below the measured water table.

Information about the groundwater conditions at the twenty seven road cuts and the tunnel is shown in Table 1 and includes current knowledge about the expected depth of excavation and the depth of the groundwater table in relation to the proposed base of the excavation. This information is based on groundwater levels in piezometers installed as part of the proposed upgrade geotechnical investigations (Golder Associates 2007a and 2007b) supplemented with additional piezometers installed at two of the cuts specifically as a part of this study, as discussed later in this report.

Table 1: Groundwater Conditions and GDEs at Cuts and Tunnel
(refer to Figure 2 and Figures 4 to 8)

Cut No.	Chainage	Cut Depth (m)	Approx. Area Covered (m^2)	Approx. Penetration into groundwater table (m, max)	Type
0	134750 - 135050	8	23,010	1 - 2	**B**
1	135090 - 135430	12	42,000	2 - 3	**B**
2	135920 - 136150	1	16,740	-	**C**
3	136530 - 136750	13	19,200	-	**C**
4a+b	137365 - 138280	9	32,200	3	**A**
5	138990 - 139270	13	19,800	4 - 5	**A**
6	140090 - 140520	17	36,000	<1	**B**
7	140760 - 140925	14	14,410	-	**C**
8	141140 - 141340	9	25,740	<2	**B**
9	141715 - 142020	5	24,500	9 - 12	**B**
10	142265 - 142325	2	5,320	-	**C**
11	142680 - 142975	13	27,950	<3	**B**
12	143130 - 143340	7	16,830	-	**C**
14	143960 - 144215	10	17,480	-	**C**
15	144530 - 144950	28	57,550	<3	**B**
16	146230 - 146310	1	15,738	-	**C**
18a	147050 - 147250	13	14,900	-	**C**
18b	147345 - 147580	4	23,838	-	**C**
19	147950 - 148335	19	54,890	9	**A**
20	148600 - 148815	13	14,000	4	**B**
St Helena Hill Tunnel Area					
21	cut on southbound carriageway only		1100	-	**C**
22	149525 - 149705	7	11,250	<3	**B**
23	149970 - 150086	11	5795	Yes (portal)	**B**
Tunnel	150086 - 150426	?	7500	12 – 19 (tanked)	**C**
24	150426 - 150560	15	7500	Yes (portal)	**B**
25	150970 - 151260	13	13800	-	**C**
26	151410 - 151810	4	16000	-	**C**

Notes: Cut depth refers to the maximum excavation of the road cut below natural ground surface at the deepest point of penetration;

Area refers to the total area of the cut excavation;

Penetration into the groundwater table refers to the deepest vertical depth the cut excavation penetrates into the prevailing groundwater system/s present at the location in 2007;

Groundwater levels were collected for this study and those data from previous Golder Associates' investigation (Golder Associates 1997 through 2007);

A dash ("-") means not present or not affected; and

Chainage Information is based on the vertical and horizontal alignment for the proposed upgrade provided by ARUP in March 2008.

"tanked: refers to the fact that the tunnel will have a sealed concrete liner (impermeable liner will not permit measurable groundwater flows into the tunnel void).

The previous geotechnical investigations (Golder Associates 2007a and 2007b) for the preferred route report included developing a preliminary understanding of groundwater conditions and possible impacts. As an outcome of this initial work, it was established that further work was required to provide a more rigorous response to the DGRs. For that reason, additional investigations and analyses have been undertaken. The study approach was to select a typical Type A and Type B cut where penetration of the cut excavation into the groundwater table was proposed, make a rigorous assessment of the potential groundwater impacts at those two cuts, and extrapolate the results to the other Type A and B cuts. This work included carrying out supplementary field investigations at the selected Type A and B cuts, including additional boreholes, installation of monitoring wells, groundwater infiltration tests, and groundwater monitoring, as discussed in Section 3.0 of this report. This work was required to develop a more rigorous geological and hydrogeological model for use in the predictive modelling and groundwater impacts assessment.

The third cut category, Cut Type C, was assigned to cuts where the depth of cut is expected to be shallower than the level of the groundwater table and is likely to remain above the groundwater table even if groundwater levels rise above present level during wetter seasonal conditions. Type C cuts are therefore not expected to impact on the groundwater regime nor are there any vulnerable creeks, springs, wells or GDE’s within 100m of the cuts, and, therefore, no further discussion is provided in this report.

The two cuts selected for the study were:

- ***Type A*:** *Cut 19*, located at approximately Ch 147,950 to Ch. 148,335, was selected as this was the deepest proposed cut when this groundwater impact study commenced. The proposed cut base was up to about 12 m below the highest measured groundwater level. Even though the cut depth was revised to limit potential groundwater impacts (see below) the groundwater level has been measured about 9 m above the new proposed base level and is still the deepest proposed penetration into the groundwater table on the alignment, within the Tinderbox Creek catchment.
- ***Type B*:** *Cut 6*, located from about Ch. 140,090 to Ch. 140,520, is within the Emigrant Creek catchment and was initially selected because when this groundwater impact study commenced the proposed base of this cut would have been about 4 to 5 m below the highest measured groundwater level. During the data acquisition phase the cut depth was revised by Arup. The expected groundwater level is now at or just below the proposed cut base which is considered typical of several cuts.

Cut 19 is on the side of a steeply sloping hill used as grazing land. The slopes at Cut 6 are not as steep as at Cut 19, and the land is used for a variety of purposes including grazing, the existing Pacific Highway road corridor, orchards and residential.

It is important to highlight that subsequent to the commencement of this groundwater impact study, the vertical alignment of the proposed upgrade was altered at these cuts to reduce the potential impacts on groundwater. As a result, the base of Cut 19 is now about 9 m below the highest measured groundwater table, and Cut 6 no longer penetrates below the measured level of the groundwater table. The alignment of the proposed upgrade used for this groundwater impact study is based on Arup data dated 3 August 2007. The results presented in this report for Types A and B cuts are based on site-specific geological conditions at Cuts 6 and 19.

2.2 Scope of Work

The scope of work for the groundwater studies involved the following activities:

- Spring identification;
- Drilling boreholes;
- Installation of monitoring wells;
- Groundwater quality testing;
- Hydraulic conductivity testing including borehole and surface water infiltration testing;
- Review of existing data, including the applicable Water Sharing Plan (DIPNR 2004) and GDE assessments (Brodie and Green, 2002, *and* Biosis Research report, 2008);
- Development of geological and hydrogeological models;
- Numerical groundwater modelling; and
- Assessment of potential groundwater impacts and engineering mitigation measures.

The methodology for each of the field investigation tasks is presented in Appendix B. The fieldwork for this study was carried out in July and August 2007. The study been based on groundwater levels monitored at the cuts from late 2006 to January 2008.

3.0 RESULTS OF SUPPLEMENTARY FIELD INVESTIGATIONS AND DATA ASSESSMENT

3.1 Spring Identification

Brodie and Green, from the Bureau of Rural Sciences (BRS) in 2002 identified the location of Groundwater Dependant Ecosystems (GDE) and the location of springs on the Alstonville Plateau using aerial photography extending from the 1940s to recent. These springs locations, together with an assessment of current aerial photographs (circa 2005) for this study, established the location of potential[4] springs along the proposed upgrade especially in the vicinity of Cut 6 and Cut 19. These springs were subsequently verified by a visual inspection at each identified location.

Figure 4 to Figure 8 illustrate the location of identified springs and GDEs along the proposed upgrade, whilst Figures 9 and 10 show the presence of springs and GDEs proximal to Cut 6, and Cut 19, respectively.

It was not possible to verify the location of all identified springs due to the lack of access on some private properties.

Only one of the seven potential springs proximal to Cut 6 or Cut 19 identified by our assessment was verified as a location where groundwater emerges from the shallow aquifer to the ground surface such as a spring, seep, or creek. No other springs were observed during our walkover inspections of Cut 6 and Cut 19.

A summary of the spring verification task is provided as Table 2 with further information provided in Appendix B.

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[4] Referred to as “potential” here since they pinpointed using observations made from available aerial photographs, and as such, may not be actual springs until verified on the ground.

Table 2: Results of Spring Verification

Verification of Springs at Cut 6		Verification of Springs at Cut 19	
C6-1 (high priority)	No spring present at this location. The lusher vegetation is due to the very close proximity of the creek (alluvial flood plain), note the creek is misplaced on the map.	**C19-1** (not of interest)	Not checked (outside likely area of influence)
SP13	Spring exists at this location and is flowing.	**C19-2** (not of interest)	No spring present at this location
C6-2 (high priority)	Access to property not permitted	**C19-3** (high priority)	No spring present at this location. Subsurface water flow discharge observed during heavy rain.
C6-3 (low priority)	No spring present at this location. Drainage feature.		
C6-4 (high priority)	Access to property not permitted. Assessment from nearby property. No springs present in the vicinity of location C6-4. The cluster of vegetation seems to be due to a water hole feature. No water flowing after heavy rains.		

3.2 Boreholes and Well Installation

The geotechnical investigations for *preferred route* report included drilling boreholes at each cut and the installation of standpipe piezometers to monitor water levels. For the specific purpose of the groundwater impacts study, additional boreholes were drilled at Cuts 6 and 19. This work was carried out in July and August 2007 (Golder 2007a, 2007b). The additional boreholes were drilled along “transects,” near perpendicular to the proposed road alignment, and extending from the nearest groundwater divide (up gradient of the cut) to the creek below, and part-way up the adjacent slope. These additional boreholes that were installed for this groundwater impacts study are shown on Figures 9 and 10.

The investigation of the groundwater system along each transect was intended to develop a hydrogeological model on which to base the predictive numerical modelling and assess the groundwater and surface water systems and their interactions. Drilling data obtained from each transect included:

- The geological conditions along the transect;

- Water levels in the various water systems along the profile; and
- Possible hydrogeological conduits (preferential flow pathways) based on inferred rates of drilling water loss to the surrounding rock mass.

Five pairs of groundwater monitoring wells were drilled and constructed at approximately equal spacing along each transect. At each of the five locations a ‘deep’ groundwater piezometer was installed within the bedrock (up to about 25 m depth), together with a shallow piezometer within the weathered rock (about 10 m depth). The standpipe piezometers were completed as groundwater monitoring wells, to permit ongoing measurement of local groundwater levels (piezometric head) in each of the shallow and deep aquifers. Samples were obtained from the monitoring wells for water quality testing.

The borehole reports and well installation reports are presented in Appendix C.

3.3 Hydraulic Tests

To improve the rigour of the predictive numerical groundwater models, hydraulic testing was carried out, as follows:

- *Falling head test* (or slug test) methods were used in each of the newly installed groundwater monitoring wells, to estimate the hydraulic conductivity (permeability) of the basalt layers.
- *Talsma infiltration tests* (also called ring infiltrometer tests) were carried out to assess the permeability of the surficial soil. The test was carried out at each of the piezometer locations along each transect. The test provides an estimate of the rate of rainfall infiltration which is used to estimate the rate of groundwater recharge. The rate of infiltration at the surface is typically influenced by the presence of worm holes, roots and other soil features and defects.

The falling head test data was analysed using AQTESOLV v3.5 software to calculate hydraulic conductivity, storativity and other aquifer properties. Analysis reports for each test are provided in Appendix D.

Estimated hydraulic conductivities for the shallow and deep aquifers at Cuts 6 and 19, measured using the falling head test methods, are within the following ranges:

Shallow aquifer:	Cut 6	3.1E-07 to 3.6E-05 m/s
	Cut 19	2.5E-07 to 9.9E-07 m/s
Deep aquifer:	Cut 6	4.5E-08 to 3.2E-06 m/s
	Cut 19	1.8E-09 to 1.1E-07 m/s

Soil permeability testing to assess the vertical saturated hydraulic conductivity for the surface soils (infiltration tests) provided the following results:

Top of Transect	Cut 6	5.0E-06 to 1.7E-05 m/s
	Cut 19	1.0E-04 m/s
Middle of Transect	Cut 6	1.0E-04 m/s
	Cut 19	3.7E-05 m/s
Base of Transect	Cut 6	4.1E-05 to 1.3E-04 m/s
	Cut 19	5.2E-05 m/s

The values given above may vary by as much as a full order of magnitude from the true value.

The data presented above was used in the numerical seepage analysis presented in Section 4.3 (and Appendix G).

3.4 Water Quality Testing Results

The laboratory analysis for the water samples collected from groundwater monitoring wells and the creeks and springs (i.e. BH2003 to BH2007, and BH1021, Cut 19 creek and spring SP-13) are summarised in Appendix B. The laboratory certificates are presented in Appendix E.

The chemistry results were plotted on a Piper diagram (Appendix B, Figure B-2) to categorise the ‘water types’ according to the relative major ion composition of the water, namely, chloride, sulphate, bicarbonates, potassium, calcium, magnesium and sodium concentrations. Water samples from different origins often have different water types.

The Piper diagrams reveal the following:

- Groundwater samples from the deep aquifer plot separately from groundwater samples from the shallow aquifer and the creeks and springs;
- The shallow aquifer groundwaters and surface water creek samples are Na-Cl-SO_4 type and are similar in general water type, and are ‘young’ and more typical of rainfall recharge waters. This is generally typical of shallow groundwater systems which are readily recharged and drain rapidly to the surface drainage system (creeks and springs); and
- The deep aquifer groundwater samples are Na-Cl-HCO_3-SO_4 type waters, again reflecting rainfall recharge (normally Na-Cl dominant), however, influenced by longer residence time within the aquifer (mineral leaching is more pronounced). These deeper groundwaters are distinct from the more dynamic shallow water flows. They are also dissimilar to the creek and spring water quality, suggesting they do not contribute significantly to the local creek and spring flows.

On this basis it can be inferred that the baseflow to the creeks is provided largely by the shallow aquifer or local and intermediate groundwater flow systems. It is also inferred that the deep aquifer does not contribute significantly to creek baseflow. These points imply that any cut that significantly diverts potential rainfall recharge away from the local shallow groundwater system (even though they are largely intermittent) is likely to locally diminish water discharges to the creeks and springs. This hypothesis was tested by the predictive numerical modelling described in Section 4.0 (and Appendix G). The exception to this is in the specific case of the tunnel which penetrates deeper into the various aquifer systems (by 12 m to 19 m), namely the top portion of the deep aquifer system, and is less likely to directly impact local springs and creeks.

3.5 Water Level Measurements

The results of depth to groundwater measurements are provided in Appendix B. Copies of the borehole reports showing monitoring well construction information are provided in Appendix C.

The following inferences are considered pertinent to the study objectives:

- The groundwater systems, both shallower and deeper, on the Cut 6 transect are generally in full hydraulic connectivity. Cut 19 water levels patterns are not clear cut as for Cut 6, confirming the heterogeneity[5] of the aquifer systems;
- Groundwater in the shallow aquifer system at the crest of the hills (groundwater divides) is intermittent or absent;
- At mid-slope, the deep and shallow aquifer systems are largely independent (lack significant vertical hydraulic connectivity);
- groundwater piezometric levels in the deeper groundwater systems (semi-confined and confined) were generally deeper than the groundwater level in the shallow aquifer confirming the presence of at least two fully or partially independent groundwater systems and inferring a general downward groundwater flow pattern over most of the transect length (exception being at the creek alignment where flow directions reverse).

3.6 Groundwater Dependant Ecosystem Assessment (GDE)

Two studies have been referenced in assessing the likely impact of the proposed upgrade on local ecosystems in the vicinity of the alignment, these include:

(1) Bureau of Rural Sciences (BRS) - Brodie and Green, 2002 identified the location of Groundwater Dependant Ecosystems (GDE); and

(2) Biosis Research, 2008 - “Tintenbar to Ewingsdale Pacific Highway Upgrade: Environmental Assessment - Terrestrial Flora and Fauna Report”, referred to as “Working Paper 4” in the EA.

Brodie and Green, BRS, 2002, conducted an aerial photograph mapping study of the hydrogeology and groundwater dependent ecosystems (GDEs) of the Alstonville Plateau fractured basalt aquifers. Their GDE assessment included mapping potential wetlands, river base-flow systems and terrestrial vegetation communities. This mapping used aerial

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[5] Heterogeneous, meaning, highly variable vertically and horizontally, and comprising different rock-types, with variable fracture density and hydraulic properties.

photographs available from the 1940s onwards and was refined using information collected from flora and fauna studies to define significant remnants of freshwater wetlands, riparian, and rainforest vegetation communities. Brodie and Green identified three types of GDEs on the Alstonville Plateau. The GDE they identified and mapped are described as:

- *Wetlands* – aquatic communities and fringing vegetation dependent on groundwater fed lakes and wetlands. These are lands permanently or temporarily under water or water logged, and include groundwater springs and seepage areas;
- *River base flow systems* – aquatic and riparian ecosystems that exist in or adjacent to streams that are fed by groundwater base flow. Groundwater may be a significant contributor to flows in coastal streams supporting riparian forests, “sedgelands” and grasslands, as well as in stream flora and fauna; and
- *Terrestrial vegetation* – vegetation communities and dependant fauna that have seasonal or episodic dependence on groundwater. These include trees and shrubs that require the water table to be at least episodically or periodically within their root zone.

Biosis Research, 2008, has completed detailed vegetation on-the-ground mapping *along* the proposed upgrade and *within 50 m* on each of the proposed upgrade alignments (Figure 3 to 8). Greater emphasis has been placed on this work in the assessment of impacts of GDE’s. Of note is the fact that groundwater dependant wetlands were not identified along or adjacent to the proposed upgrade during the vegetation mapping. Rainforests which rely mostly on rainfall water and groundwater from the *shallow aquifer* were identified along and within 50m of the proposed upgrade (refer to Figures 2 to 8). A detailed description of the vegetation species encountered during the vegetation mapping can be found in the Biosis Research report (2008).

Note: the Brodie and Green (BRS, 2002) study used aerial photography study methods and was *not* verified on the ground using direct observations, and are therefore highly conservative. As such, this study has put greater emphasis on the results of the Biosis Research study and lesser emphasis on the Brodie and Green outcomes (but acknowledges that the information, whilst conservative, does extend of the entire area (more than the 50m wide corridors on each side of the alignment). It is worthy of note that the Biosis Research observations showed that there are some inaccuracies in the locations and extents of the Brodie and Green GDE boundaries, with many not being present at all.

Golder Associates has assessed which of those GDEs may be affected by the proposed cuts and tunnel. This assessment has considered:

- The geometry of the proposed cut such as proposed depth and horizontal planar area. Some cuts do not intersect the water table and have been classified as having no impact on GDEs. Cuts which intersect (or could potentially intersect) the water table are assessed on the importance of the cut being under the water table and the geographical extent of the cut;
- The distance from each GDE to the nearest proposed cut. GDEs located directly adjacent to a proposed cut are more likely to be impacted than a GDE located >200 m away from the cut;

- The groundwater flow direction and hydraulic gradient. Cuts intersecting the water table but for which the inferred groundwater flow direction is not directed towards a GDE are not considered to impact the GDE; and
- The outcome of the predictive groundwater modelling (numerical simulations). The groundwater modelling has identified the impact of the cuts on local seepage to creeks and springs. The results of the modelling are used in the assessment of impact to any GDE.

Figures 4 to 8 illustrate the location of the springs, creeks, vegetation and pertinent GDEs in relation to the road cuts and tunnel.

3.7 Review of the Local Water Sharing Plan and the Region Resource Issue

A *Water Sharing Plan for the Alstonville Plateau Groundwater Sources* (DIPNR, 2004) was prepared in February 2003 by NSW Department of Water and Energy (DWE) in accordance with the *Water Management Act (2000)*. The purpose of the water sharing plan was to sustainably allocate groundwater from the Alstonville Plateau source to environmental flows and other uses (including groundwater extraction from water bores and storages). The Alstonville Plateau groundwater source covers an area of about 391 square kilometres (km^2), some of which is located in the study area, and comprises a Tertiary Basalt plateau overlying Clarence Moreton basin sediments.

The annual average recharge of the aquifer was reported to be 44,472 megalitres per year (ML/yr), of which 80% or 35,578 ML/yr is allocated to environmental flows. Water allocated to *environmental flows* is to support river and stream base flows, as well as, groundwater dependent ecosystems. The WSP provides conditions for the protection of GDEs in Section 39 of the Water Sharing Plan.

The proposed upgrade traverses Bangalow Zone 3 *Groundwater Source Zone*, Alstonville Zone 1 *Groundwater Source Zone* and is slightly overlying Lennox Zone 6 *Groundwater Source Zone* as defined by the DWE. Those high priority GDEs requiring protection listed in the WSP that are present along the proposed upgrade include: terrestrial vegetation such as remnant rainforest, wetlands, and river baseflow (Section 3.6). The conditions of the Water Sharing Plan to protect these high priority GDEs specifically relate to “water supply work (bore)” and provides buffer zones around such GDEs and streams. The buffer zones to protect high priority GDEs do not apply to the proposed upgrade.

The impact on local and regional water users is discussed further in Section 4.

3.8 Numerical Groundwater Model

Two-dimensional *Conceptual Groundwater Models* (CGMs) illustrating the geological and groundwater conditions were developed to conceptualise the potential impacts of road construction on the groundwater systems and were based on Cut 6 and Cut 19. The models were used as the basis for subsequent numerical groundwater modelling to predict the impact of the cuts on local and regional groundwater seepage, spring and creek flows in the areas of the proposed road cuts. The details of these modelling assessments are presented in summary in Section 4 and in detail in Appendices F and G.

4.0 GROUNDWATER IMPACT ASSESSMENT

4.1 Conceptual Groundwater Model

Golder Associates (2007a) developed a preliminary *conceptual groundwater model* (CGM) as a means visualising the groundwater system and how the springs and creeks might be linked with the groundwater system (refer to Appendix F for a detailed description) to provide a simplified representation of the key physical features and their expected behaviour. The CGM forms the precursor to a numerical groundwater model which is a predictive tool used to estimate the likely future effects that may arise after the road cuts are excavated and constructed.

The preliminary CGM identified data required to provide a more robust and credible predictive groundwater model of the groundwater systems. This data included water table and deep confined aquifer water level profile, geological and hydrogeological boundaries, rainfall recharge rate information and hydraulic gradients. The data collected from the field investigation allowed a more complete CGM to be prepared (for typical road cuts, Cut 6 and Cut 19, i.e., representative of Type B and Type A cuts, respectively) and hence allowed more reliable predictive numerical model outcomes to be achieved. The St Helena Hill tunnel is here considered to fall into a Type A ‘cut’ category because of its deep penetration into one or more local groundwater systems, in a way similar to Cut 19.

4.2 Conceptual Hydrogeological Setting and Model Components

Separate CGMs were developed for Cut 6 and Cut 19 using Figures 9 and 10 that show spring and GDE locations along the proposed upgrade. These CGMs represent the two local groundwater systems, shallow and deeper, as follows (refer to Section 1.5 and Appendix F for details):

- *Shallow Groundwater Flow System:* A local shallow (or upper) groundwater aquifer within the weathered soil and rock (the regolith). The investigation borehole cores show that this shallow system comprises a sequence of variably weathered bedrock material within which remnant layers of less weathered rock are interspersed. By virtue of the geological variability (extremely to moderately weathered and laterally variable zones) of this sequence, it is likely to host numerous localised perched subsystems (largely unconfined). Groundwater flow within this complex geological system will be equally complex, with flow being dominantly horizontal in one areal location and dominantly vertical in an adjacent location. An analogy would be that the groundwater ‘cascades’ from one perched system to another, eventually reaching the deeper bedrock system below. Superimposed of this groundwater flow system is a moderately to densely spaced fracture pattern which is also likely to influence groundwater flow; and
- *Deeper Groundwater Flow System/s:* A local deeper groundwater system investigated, largely within the fractured porosity, is pervasively developed within moderately weathered to fresher basaltic lava flow sequences present at depth. Present within this stacked lava flow sequence are rare interbedded zones of moderately to highly weathered basalts, and some amygdaloidal, scoriaceous and fossil soil horizons. These interbeds are laterally variable, thickening and thinning out with lateral extent. Groundwater flow is dominated by the fracture plane porosity/permeability, and to a lesser extent the interbed

layers. On a macroscopic scale the groundwater flow is likely to behave in a porous media fashion (anisotropic, and controlled by the more dominant horizontal fracture and bedding planar features). On a mesoscopic (1m – 10m width) and microscopic scale flow is likely to be tortuous and highly variable. The deep aquifer behaves as a confined or semi-confined aquifer system.

Note: the *Regional Aquifer* was not considered in the numerical modelling due to its scale (>100km) relative to the local scale of each of the cutting (<250m). Any groundwater diverted from the local aquifer systems is typically largely reintroduced at locations (streams, creeks) immediately adjacent to the cutting/s considered with respect to their impacts.

Each system is characterised by different but variable hydraulic properties. The rainfall recharge (infiltration) to the two systems is complex and dependant on the topographic situation, thickness and density of the interbedded layers, vertical and horizontal hydraulic conductivity (permeability) contrasts and the overprint of a moderate to dense, tight fracture pattern of preferential flow pathways. As a consequence of these features, groundwater flow, both horizontal and vertical, is similarly controlled by low or moderate locally contrasting permeability and, hence, similarly characterised tortuous pathways. The mechanism and magnitude of the contribution that these groundwater systems (particularly the shallow flow system) make to the local springs or creeks is consequentially inferred to be highly variable, locally specific and largely seasonally controlled.

This dual groundwater system has a number of important characteristics which greatly affect the estimation of the nature and magnitude of the impact of the cuts on spring and creek flow, as follows:

- Groundwater flow within the shallow flow system (‘aquifer’) is largely responsible for the creek baseflow and springs, and it is likely that this is a local effect (not regional).
- The shallow aquifer system/s are intermittently to fully saturated (flow may be perennial, intermittent or may cease periodically), particularly in the upper sections of the topography (the hill top areas).
- A consistently downward groundwater flow gradient between the shallow and the deep flow systems is generally present along the transects. The exception to this general rule is noted adjacent to and beneath the creek lines.
- Moderate to strong hydraulic connectivity between the shallow and deep aquifer systems is evident along the creek alignments. This is particularly evident across the valley flat areas of Cut 6 suggesting that the creek down-gradient of Cut 6 is a ‘making’ creek environment (where the groundwater system discharges and supplements the creek flow).
- Spring occurrences, away from the creek alignments, whilst rare, are largely due to hydrogeologically differing rock layers (having contrasting hydraulic conductivities) daylighting at the ground surface.

Note: Groundwater level measurements collected during this stage of investigations occurred immediately after a period of above average rainfall. As a consequence, the CGM interpretation may be skewed towards an abnormally wet case-study condition. A further round of sampling would be required during dry weather conditions to confirm the relationship between the creek and springs, and the shallow aquifer.

4.3 Assessment of Potential Impact on Seepage using Numerical Groundwater Modelling

A cross-sectional seepage analysis model (two dimensional) was developed for each of the two type examples of the proposed cut configurations using Seep/W software. The models were constructed based on the CGM presented in Section 4.2 for Type A and B cuts.

The details for the models and the results of the predictive numerical modelling are presented in Appendix G and Figures G-1 to G-8.

Once the models had been calibrated to simulate the observed natural condition (pre-roadworks), they were then modified to represent the proposed cut geometry at both Cut 6 and Cut 19. Model prediction simulations were then undertaken to assess the likely impacts of the cut excavations. Figure G-7 present the results of prediction model simulations for proposed Cut 6 and Cut 19, being representative of Type B and Type A cuts, respectively.

In summary, the predictive model simulations suggest that:

- In the case of Cut 6 (Figure 5) a groundwater seepage face[6] on the up-gradient cut face of the cut is not expected to develop or be sustained (if present) because the dry season water table level is at or just below the invert of the cut (see Figure 9). Under normal or wetter rainfall conditions the cut may intersect the water table. Type B cuts are predicted to follow this behaviour;
- In the case of Cut 19 (Figure 7), predictive model simulations suggest that a seepage face on the up-gradient cut face of the cut may initially develop. Dewatering of the local up-gradient aquifer will reduce (and possibly eliminate) the seepage into the cut (see Figure 10). The degree of seepage into the road cut is likely to be heavily influenced by the local seasonal conditions. This is largely due to the dynamic behaviour of the shallow water flow system which is rapidly influenced by rainfall events. Such events will recharge the shallow aquifer more rapidly and consequentially raise the water table in that aquifer. Type A cut are predicted to follow this behaviour;
- The predicted extent of change in the water table profile in the proposed Type B cuts is limited to the near vicinity of the proposed cut (<100m), and does not cause extensive impacts on the flow conditions or magnitude of flow rate or flow volumes in the shallow flow system (regarded as minor). The deeper flow system is largely unaffected by the construction of the Type B road cuts;
- The predicted extent of change in the local water table profile surface in the vicinity of the more conservative-case Type A road cuts is potentially significant;
- The impact of the Type A (Cut 19) cut configuration is greatest at the mid-slope on the profile (beneath the cut footprint) where the impact on the local groundwater flow system is to lower the water table by up to 2 to 3 m;
- Further, the impact of the Type A (Cut 19) cut configuration on the groundwater flow volumes (or flux) which may locally contribute to spring and/or creek flow is predicted to

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[6] groundwater seepage face – is that portion to the cut excavation slope (normally on the upgradient side) which is fully saturated with groundwater, and which water seeps out of and trickles down the slope to a collection drain.

be up to approximately 25% less than it would otherwise be (measured over the linear length of creek down-slope of the same linear length of the cut).

- By comparison, the predicted relative change to groundwater flow volumes to creeks and springs down-gradient of Type B cuts is *low to negligible* or not measurable (regarded as ‘minor’);
- In the case of Type C cuts which are above the local water table, relative change to predicted groundwater flow volumes to creeks, springs and GDEs down-gradient of these cuts is negligible or non-existent (not measurable); and
- The predictive modelling on Cut 19 suggests that the extent of drawdown of the shallow groundwater in the vicinity of Type A cuts will be to the invert level of the cut. This effect will potentially cause a reduction in recharge to the local groundwater systems of up to approximately 25% of their normal groundwater recharge. The lateral extent of the drawdown impacts for Type A cuts could be up to 100m. With Cut 6, and by extrapolation, Type B cuts, the impact is low to negligible, with impact being largely un-measurable. The Type C road cuts, those which do not penetrate into any identified local groundwater system are estimated to have negligible to no impact on the supply of water to surface water and groundwater systems.

4.4 Risk of Impact to Spring Flow and Groundwater Flow

In summary, from the predictive modelling undertaken (described above), there is little evidence to suggest that there are groundwater springs at the representative transects (Cut 6 and Cut 19). The only verified spring is at Cut 6 (SP13 on Figure 9), which is on the opposing side of the groundwater divide and is therefore not likely to be influenced by the proposed cut. The water table profile presented in Figure G1 for Cut 6 and Figure F5 for Cut 19 indicates that the water table does not intersect the current ground surface at or in the vicinity of Cut 6 or Cut 19 and therefore springs are unlikely to form. This conclusion is supported by site inspection works presented in Section 3.1.

The southern portal cut along the tunnel alignment encroaches over the mapped location of a spring (not verified in the field) that is located in the side of the gully. After excavation of the portal cut, seepage due to the perched groundwater flow to the original position of the potential spring will occur from the excavated cut face. There is also a spring to the east of the northern portal feeding a small dam in that vicinity. The groundwater supply to this spring will potentially diminished as a consequence of tunnel construction. For these reasons, the tunnel portals areas are regarded as a Type B “cut”. The tunnel itself is planned to be fully tanked and as a consequence leakage of water from the local groundwater systems will be negligible. The tunnel itself is regarded as a Type C “cut”.

Predictive numerical modelling, however, suggests that there is likely to be an impact to the contribution which groundwater makes to the creeks and spring (if present) where the cut penetrates into the water table zone (in excess of 3-4m), such as in Cut 19 (Type A cuts). By contrast, where the cut does not penetrate into the water table zone impacts to the contribution which groundwater makes to the creeks and spring are likely to be negligible (Type A cuts). *As such, at locations other than those studied where cuts extend below the water table, there remains a potential to affect nearby groundwater springs and creek flows.*

Due to the prevailing below average rainfall conditions experienced during this groundwater impacts study, it was found that groundwater was *not* discharging directly to surface waterways at neither Cut 6 (representative of 'Type B cuts') nor Cut 19 (representative of 'Type A cut's) since the water table levels were below the creek bed level. However, the groundwater system is contributing to the hyporheic zone associated with the spring wetlands and creek waterways (and the GDE's) down-gradient of the proposed road cuts (Type A cuts, and to a much lesser extent Type B cuts). This condition has arisen out of a relatively dry weather period and therefore may vary under different short and long term seasonal circumstances.

The outcome of the predictive modelling carried out for this groundwater impacts study, suggests that impacts are likely in the case of cuts which penetrate into the water table zone upgradient of springs and creeks. As a consequence, consideration of methods to minimise or mitigate these impacts may be required. Possible mitigation measures are discussed in the sections which follow.

4.5 Risk of Impact on Groundwater Dependent Ecosystems

River based flow systems and terrestrial vegetation systems (namely rainforest along and within 50m of the proposed upgrade) are the only groundwater dependent ecosystems identified along the proposed upgrade.

Type A cuts *may* be affected by a reduction in groundwater contribution to any local ecosystem/s (flora and fauna) which inhabit the hyporheic[7] zone in the creek or spring immediately down-gradient of this type of road cut. The GDE's may have a strong reliance on sustained perennial or periodic groundwater flow from the shallow groundwater systems (particularly where these are 'making' creeks).

As a consequence, the GDEs in the vicinity of Type A, and potentially Type B (but not Type C), cuts may have the potential to be impacted if rainfall water destined for recharge of GDEs is diverted from the local surface and groundwater systems to more distant surface water flow systems.

4.6 Impacts on the Regional Groundwater Resource and WSP Issues

As discussed in Section 3.7, the proposed upgrade traverses Bangalow Zone 3 *Groundwater Source Zone*, Alstonville Zone 1 *Groundwater Source Zone* and is slightly overlying Lennox Zone 6 *Groundwater Source Zone* as defined by the DWE. Those high priority GDEs present along the proposed upgrade alignment and which require protection include remnant rainforest, wetlands, and river baseflow. The WSP describes protection of these high priority

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[7] The hyporheic zone is a region beneath and lateral to a stream bed, where there is mixing of shallow groundwater and surface water. The flow dynamics and behaviour in this zone (termed hyporheic flow) is recognized to be important for surface water/groundwater interactions, as well as fish spawning, among other processes.

GDEs from “water supply work (bore)” and provides buffer zones around such GDEs and streams. The buffer zones to protect high priority GDEs do not apply to the proposed upgrade. The GDE’s prescribed are, where they apply, those covered by this study and will be impacted as detailed in Section 4.7 and will be managed as described in Section 5 (Table 4).

Whilst local groundwater and surface water impacts are predictable, the impact of the upgrade upon the regional groundwater resource is regarded as negligible to not measurable. This is primarily due to the insignificant footprint area of the alignment when compared with the total area of the aquifer system recharge for the Alstonville Plateau (limitation of recharge infiltration and diversion of run-off are insignificant on the scale of the aquifer system.

4.7 Summary of Potential Impacts

The following table summarises the assessment outcomes:

Table 3: Summary Table of Potential Impacts (refer to Figure 2 and Figures 4 to 8,)

Cut No.	Chainage	Type	Potential Impact before Mitigation
0	134750 - 135050	**B**	Minor reduction of groundwater to creek and potential spring C1-2 and local water resource within approximately 100m of cutting. Water course related GDE’s present in the vicinity of cut (no groundwater-reliant rainforest or wetlands are present in the area of potential impact.
1	135090 - 135430	**B**	Minor reduction of groundwater to creek and potential springs C1-2 and C1-1, and local water resource within approximately 100m of cutting. Potential impact to water course related GDE’s present in the vicinity of cut (no groundwater-reliant rainforest or wetlands are present in the area of potential impact).
2	135920 - 136150	**C**	No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.
3	136530 - 136750	**C**	No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.
4a+b	137365 - 138280	**A**	Reduction of groundwater to local creeks and streams, and local water resource in the southern portion of the cut, i.e. within approximately 100m of cutting. Potential impact to water course related GDE’s present in the vicinity of cut (no springs or groundwater-reliant rainforest or wetlands are present in the area of potential impact, i.e. within 200m of cutting).

Cut No.	Chainage	Type	Potential Impact before Mitigation
5	138990 - 139270	**A**	Reduction of groundwater to local creeks and streams, and local water resource in the southern portion of the cut, i.e. within approximately 100m of cutting. Potential impact to water course related GDE's present in the vicinity of cut (no springs or groundwater-reliant rainforest or wetlands are present in the area of potential impact, i.e. within 200m of cutting).
6	140090 - 140520	**B**	Minor reduction of groundwater to creek and 4 potential springs, C6-1 to C6-4, and SP-13, and local water resources within approximately 100m of cutting. Potential impact to water course related GDE's and groundwater-reliant rainforest (north of cutting) present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).
7	140760 - 140925	**C**	No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.
8	141140 - 141340	**B**	Minor reduction of groundwater to creek and potential spring C8-2 and water resource within approximately 100m of cutting. Potential impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant rainforest or wetlands are present in the area of potential impact).
9	141715 - 142020	**B**	Minor reduction of groundwater to creek and potential spring C8-1 and water resource within approximately 100m of cutting. Potential impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant rainforest or wetlands are present in the area of potential impact).
10	142265 - 142325	**C**	No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.
11	142680 - 142975	**B**	Minor reduction of groundwater to creek and water resource within approximately 100m of cutting. Potential impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant rainforest or wetlands are present in the area of potential impact).
12	143130 - 143340	**C**	No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.
14	143960 - 144215	**C**	No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.

Cut No.	Chainage	Type	Potential Impact before Mitigation
15	144530 - 144950	**B**	Minor reduction of groundwater to creek and potentially to springs C15-1 to C15-4, and SP 22 (C15-5 and C15-6, and SP17 to SP-21 negligible risk of impact), and local water resources within approximately 100m of cutting. Potential impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant rainforest or wetlands are present in the area of potential impact).
16	146230 - 146310	**C**	No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.
18a	147050 - 147250	**C**	No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.
18b	147345 - 147580	**C**	No measurable impact on local or regional groundwater systems or resources anticipated, there groundwater-reliant rainforest cluster (south) unlikely to be impacted. No wetlands are present in the vicinity of the cut.
19	147950 - 148335	**A**	Reduction of groundwater to local creeks, streams, springs (C19-2 and C19-3) and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant rainforest or wetlands are present in the area of potential impact).
20	148600 - 148815	**B**	Minor reduction of groundwater to creek and potential spring C20-1 to C20-3 and local water resources within approximately 100m of road cutting. Potential impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant rainforest or wetlands are present in the area of potential impact).
St Helena Hill Tunnel Area			
21	Cut on southbound carriageway only	**C**	No measurable impact on local or regional groundwater systems or resources anticipated. A cluster of groundwater-reliant rainforest may exist of the west and east of the Cut 21 but these are not likely to be impacted. No springs or groundwater-reliant wetlands are present in the vicinity of the cut.
22	149525 - 149705	**B**	Minor reduction of groundwater to creek and potential spring C22-1 and C22-2 and local water resource within approximately 100m of cutting. Potential impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant rainforest or wetlands are present in the area of potential impact).

Cut No.	Chainage	Type	Potential Impact before Mitigation
23	149970 – 150086 [tunnel south portal]	**B**	Minor reduction of groundwater to spring, creek and local water resource (groundwater well/s and dams) expected within approximately 100m of portal excavation. Consequentially, mininal impact to water course related GDE's present in the vicinity of cut (no springs, groundwater-reliant wetlands are present in the area of potential impact). Groundwater-reliant rainforest present around potentially likely to be impacted by portal cut.
Tunnel	150086 - 150426	**C**	The tunnel is planned to be fully tanked (negligible leakage to tunnel), and therefore no impact anticipated (leakage to tunnel essentially not measurable) within approximately 100m of excavation. No measurable impact on local or regional groundwater systems or resources anticipated. Groundwater-reliant rainforest clusters may be are present in the vicinity of the tunnel (over and east/west) but are unlikely to be impacted. No groundwater-reliant wetlands are present in the vicinity of the tunnel.
24	150426 – 150560 [tunnel north portal]	**B**	Minor reduction of groundwater to spring and associated creek leading to local water resource dam (and possible groundwater well/s) expected within approximately 100m of excavation. Minimal local potential impact to water course related GDE's present in the vicinity of cut anticipated (no groundwater-reliant wetlands are present in the area of potential impact). Potential groundwater-reliant rainforest present around portal - potential minor impact anticipated.
25	150970 - 151260	**C**	No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.
26	151410 - 151810	**C**	No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.

5.0 POTENTIAL MANAGEMENT MEASURES

5.1 Management Timing : Construction Phase and Operational Phase

Impact to groundwater and management strategies needs to address the timing of the road upgrade. The impact to groundwater and surface water systems will vary during the two phases of the project: the construction phase and the operational phase.

Management strategies, described below, need to apply to be in place for the construction phase of the upgrade, especially monitoring and management strategies addressing the tunnel portals areas and deeper cuts as identified on Table 3.

5.2 Management Strategy

Cut Types A and B are expected to penetrate to and below the water table (Type A and B), and hence have the potential to impact on downstream groundwater patterns, spring, creeks and their associated GDEs.

The management strategy has been to follow the following three-pronged approach:

(d) ***Assessment*** – this study, involving the investigation carried out and predictions made;

(e) ***Monitoring*** – to assess that the investigation and its predictions are accurate and to permit earlier intervention in the unlikely case/s that the actual outcomes deviate from predictions; and

(f) ***Mitigation*** – implement mitigation measures where predictions and/or monitoring measures suggest that these are required.

This is on the basis that the approach to assessing groundwater impacts and requirements for management and mitigation has been to investigate a single cut from each of the two types of cut and assume that there would be similar impacts at the other Type A and B cuts. However, the actual groundwater impacts may differ from our predictions. This is because geological conditions are highly variable and can change away from the locations at which our investigations were performed. In addition, groundwater conditions change over time, depending on climatic conditions.

To effectively manage and mitigate groundwater impacts, and potential uncertainties about the actual impacts, we propose the following approach:

- ***Type A cuts***: There is a higher likelihood that Type A cuts would impact on groundwater regimes and GDEs. The implementation of engineering measures are likely to be required as part of construction to mitigate groundwater impacts. Long-term monitoring of the groundwater regime in the vicinity of Type A cuts should be commenced well in advance of the road construction. Depending on the results of the monitoring, before and during road construction, it may be that engineering mitigation would not be required at some (or all) of the Type A cuts. After road construction, the monitoring should continue to verify the effectiveness of the engineering mitigation, so that modifications can be made, if required.

- ***Type B cuts***: It is lesser likely that Type B cuts would adversely impact on groundwater regimes and GDEs. Engineering mitigation measures will probably not be required at Type B cuts. However, we propose long-term monitoring, commencing prior to construction, and observation of groundwater behaviour and impact during construction to verify impacts. As an outcome of the monitoring and observations, it may be necessary to implement engineering mitigation at some of the Type B cuts.
- ***Type C cuts***: These cuts are expected to have no or negligible groundwater impacts. Monitoring and engineering mitigation measures are not required.

These recommendations are summarised in Table 3, which indicates the type of management and mitigation at each cut.

Table 4 Recommended Monitoring and Risk Management Strategies

	Location	**Water Table penetration***	**Monitoring Required**	**Impact Mitigation Measures Required**
	***TYPE A* CUTS AND TUNNEL**			
a	**Cut 4a**, Ch137365 - 138280	yes	yes	likely
b	**Cut 5**, Ch. 138990 - 139270	yes	yes	likely
c	**Cut 19**, Ch. 147950 - 148335	yes	yes	likely
	***TYPE B* CUTS**			
d	**Cut 0**, Ch. 134750 - 135050	probable	yes	unlikely
e	**Cut 1,** Ch. 135090 - 135430	yes	yes	unlikely
f	**Cut 6,** Ch. 140090 - 140520	yes	yes	unlikely
g	**Cut 8**, Ch. 141140 - 141340	yes	yes	unlikely
h	**Cut 9**, Ch. 141715 - 142020	possible	yes	unlikely
i	**Cut 11**, Ch. 142680 - 142975	possible	yes	unlikely
j	**Cut 15,** Ch. 144530 - 144950	no	yes	unlikely
k	**Cut 20**, Ch. 148600 - 148815	yes	yes	unlikely
l	**Cut 22**, Ch. 149525 - 149705	yes	yes	unlikely
m	**Cut 23**, Ch. 149970 - 150086	yes	yes	unlikely
n	**Cut 24**, Ch. 150426 - 150560	yes	yes	unlikely
	***TYPE C* CUTS**			
	All other cuts (13)	no	no	Not required

Notes: * based on groundwater table measured during the investigations in 2006 and 2007, and current cut design dated 3 August 2007; and

** tunnel is to be ‘tanked’ (fully lined with a low leakage concrete liner).

This strategy would be further detailed in a *Water Management Plan* to be prepared for both the project construction *and* operation phases.

Surface water captured by the constructed road is likely to have a degraded chemical quality compared to rain fall. Typically elevated suspended solids and increased concentrations of metals can be expected. The water captured by a drainage system at each cut could need to be managed before being reintroduced into the natural groundwater system. Groundwater quality monitoring would be required.

5.3 Monitoring

Monitoring of both groundwater level and chemical quality is proposed as an essential measure to mitigate uncertainty in predictions of groundwater behaviour, which have been based largely on groundwater observations over a relatively short period of time. The monitoring would comprise:

- Installation and monitoring of wells.
- Groundwater sampling and analyses for suspended solids and metals.
- Visual observations of surface water flows at springs and creeks.
- An assessment of GDE healthiness.

Long-term monitoring of the existing monitoring wells should be continued up to, during and following construction of the cuts. The monitoring would be initiated prior to construction (background data collection), during construction and during the early years of operation, at a frequency to be determined (potentially quarterly for the first 5 years of operation, with a review of data to determine whether further monitoring is required).

New monitoring wells will need to be installed at Type A and B cuts where there are currently no monitoring wells installed. Additional monitoring wells may also be required at Cuts 6 and 19 where wells were previously installed for the purpose of this study.

The objective of long-term monitoring will be to:

- Obtain baseline groundwater data over a longer period than for this groundwater study and verify the validity of groundwater levels at the two cuts investigated during the study and at the other Type A and B cuts, verify long-term and adverse trends.
- For cuts at which engineering mitigation measures are implemented, permit an early assessment of groundwater behaviour in response to engineering mitigation measures and verify the effective functioning of the mitigation measures.
- At cuts where mitigation measures are not planned (Type B) verify that there are no adverse impacts as a result of the construction.

5.4 Potential Engineering Mitigation Measures

Two categories of engineering mitigation measures could be considered at Type A cuts, and at Type B cuts, if monitoring indicates that engineering mitigation is required:

Option a) Engineering mitigation measures that transfer the seepage water downstream. Standard practice would be to collect the seepage from the cut face in the drainage system for the highway, which would be diverted into water quality ponds before being released back into the creek or natural drainage system at some point downstream.

Option b) Engineering mitigation measures that transfer the seepage water (where present) into the groundwater ecosystem immediately down-slope of the cut. These may involve collecting the seepage water from the cut face just above the level of the road, and piping it under the cut/fill platform to the down-slope side of the highway. This collection and piping system would also likely include seepage collected from the drainage blanket under the highway pavement. The collected water could then be returned to the ground through absorption trenches or discharged directly to the surface water system.

From the perspective of risk to GDEs and the local groundwater flow patterns, *Option b),* above, would provide the better solution for both Type A and Type B cuts, although a system combining both may need to be applied in some circumstances (depending on monitoring outcomes). The preferred method and exact form of the mitigation measures would be the subject of ongoing development of the concept design and environmental assessment process.

6.0 CONCLUSIONS

Golder Associates has performed an assessment of the potential groundwater impacts relating to the different cut types and propose to manage and monitor the expected impacts, as discussed in this groundwater impacts study, to address the objectives of the study and, hence, the general requirements of the key groundwater issues identified by the DGR.

This report has provides a description of the geological and hydrogeological environment studied, and which can be broadly represented as two groundwater systems, a shallow and deeper aquifer, having a likelihood of impact. The assessment has categorised the different road cuts with respect to defined criteria into three cut categories, namely *Type A*, *Type B*, and *Type C*. As an outcome of the study it has been estimated that *Type A* cuts *may* impact the groundwater systems and GDEs by depriving the local shallow aquifer (perched systems mainly) of up to approximately 25% of recharge water (rainfall and diversion groundwater infiltration); the impact on local groundwater systems in the vicinity of *Type B* cuts is expected to be *low to negligible* or potentially not measurable (here regarded as a 'minor' impact); and local groundwater systems in the vicinity of *Type C* cuts are not expected to be impacted at all (impacts not measurable).

Management solutions have been proposed (see Section 5) to mitigate and/or limit groundwater impacts through implementation of engineering measures that would require monitoring to assess any predicted (and unpredicted) impacts and the effectiveness of the mitigation measures. Type A cuts will require mitigation measures, likely to involve artificial recharge of captured surface water to the shallow groundwater system. Type B cuts are unlikely to require engineering mitigation, and this will need to be verified through further monitoring before, during and following construction.

The key issues, identified in the DGRs, are addressed by this groundwater impact study through targeted investigations of local hydrogeological conditions and subsequent numerical modelling. These key issues to be addressed were extent of drawdown, impacts to groundwater quality, discharge requirements and implications for groundwater dependent surface flows and GDEs, and groundwater users, including the key requirements enunciated in the *Water Sharing Plan*.

The specific components of the groundwater key issues in the DGRs have been addressed by this groundwater impacts study. In summary, the geometry and groundwater setting of each proposed cut (see Sections 2 and 3) have been considered and numerical groundwater modelling predictions performed (see Sections 2 and 4) to estimate the potential for and magnitude of groundwater impacts. This assessment and modelling identified that the extent of drawdown would be a reduction in recharge to the localised shallow aquifers of up to about 25% due to some of the cuts (Type A, possibly Type B). There is also the potential for groundwater chemistry changes, namely an increase in suspended sediments (see Sections 3 and 4). A consequence of the deprivation of the shallow aquifers of surface water recharge potentially impacts on groundwater dependent surface flows and GDEs.

Management solutions are proposed to mitigate and/or limit these potential impacts (see Section 5). The impact on groundwater users (separate from the environmental flows and identified GDEs) identified in Water Sharing Plan (see Section 3) is expected to be negligible because the Water Sharing Plan refers largely to the regional aquifer that will have negligible impact from the cuts.

7.0 IMPORTANT INFORMATION

Your attention is drawn to the document - “Important Information About Your Geotechnical Engineering Report”, which is included in Appendix H of this report. This document has been prepared by the ASFE *(Professional Firms Practicing in the Geosciences)*, of which Golder Associates is a member. The statements presented in this document are intended to advise you of what your realistic expectations of this report should be, and to present you with recommendations on how to minimise the risks associated with the ground-works for this project. The document is not intended to reduce the level of responsibility accepted by Golder Associates, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in so doing.

We would be pleased to answer any questions about this important information from the reader of this report.

GOLDER ASSOCIATES PTY LTD

Ray Hatley
Principal Hydrogeologist

FH,JRB,RH/RH,CSC/fh,jrb,rh,csc
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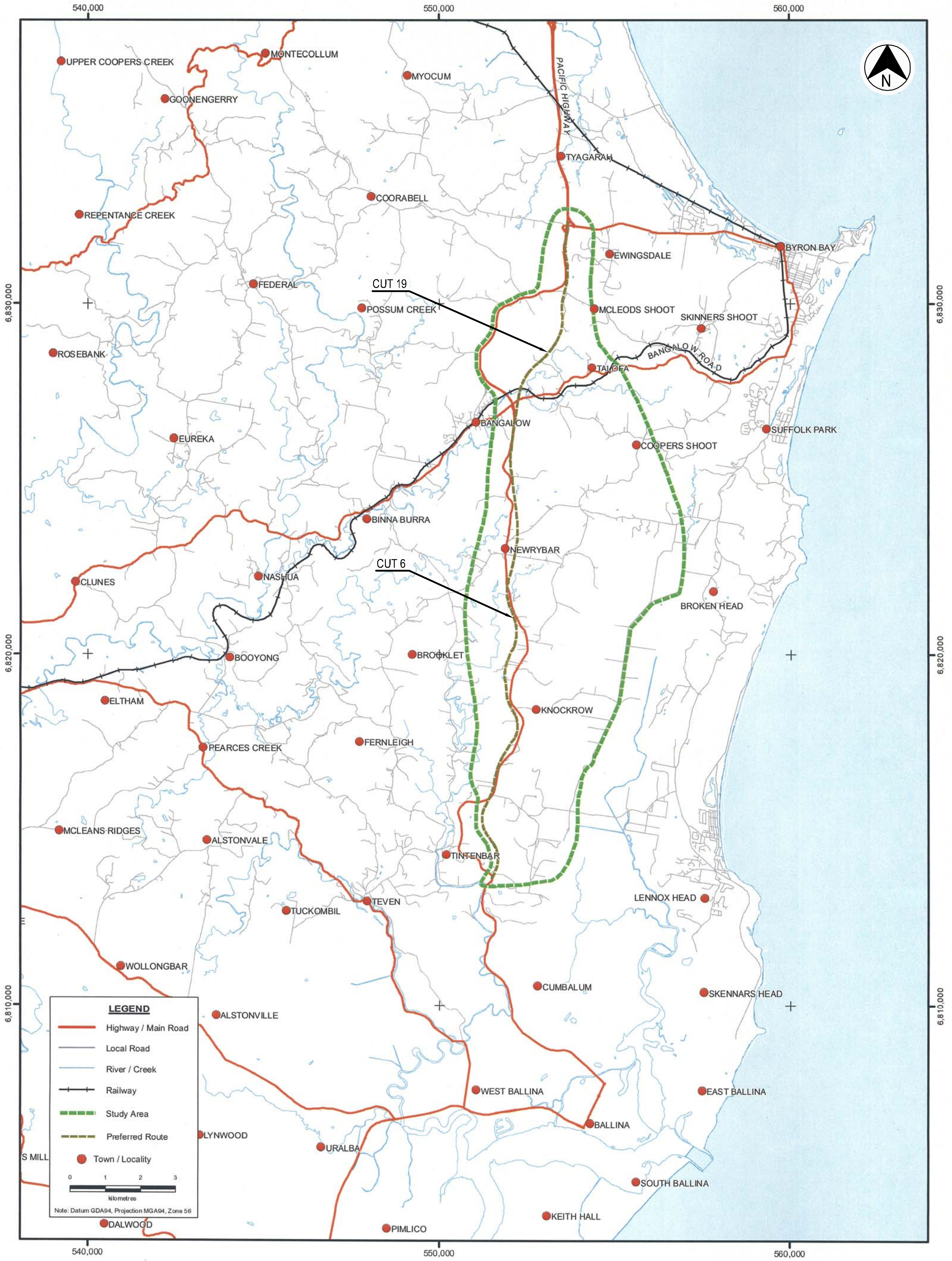
Figures



DRAWING TAKEN FROM MAPINFO AUSTRALIA PTY LTD DRG. No. BASE MAP

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SCALE
AS SHOWN
A3

PROJECT
PACIFIC HIGHWAY UPGRADE - TINTENBAR TO EWINGSDALE

TITLE
SITE LOCATION PLAN

PROJECT No
06622140-D0002

FIGURE No
FIGURE 1

REVISION
6

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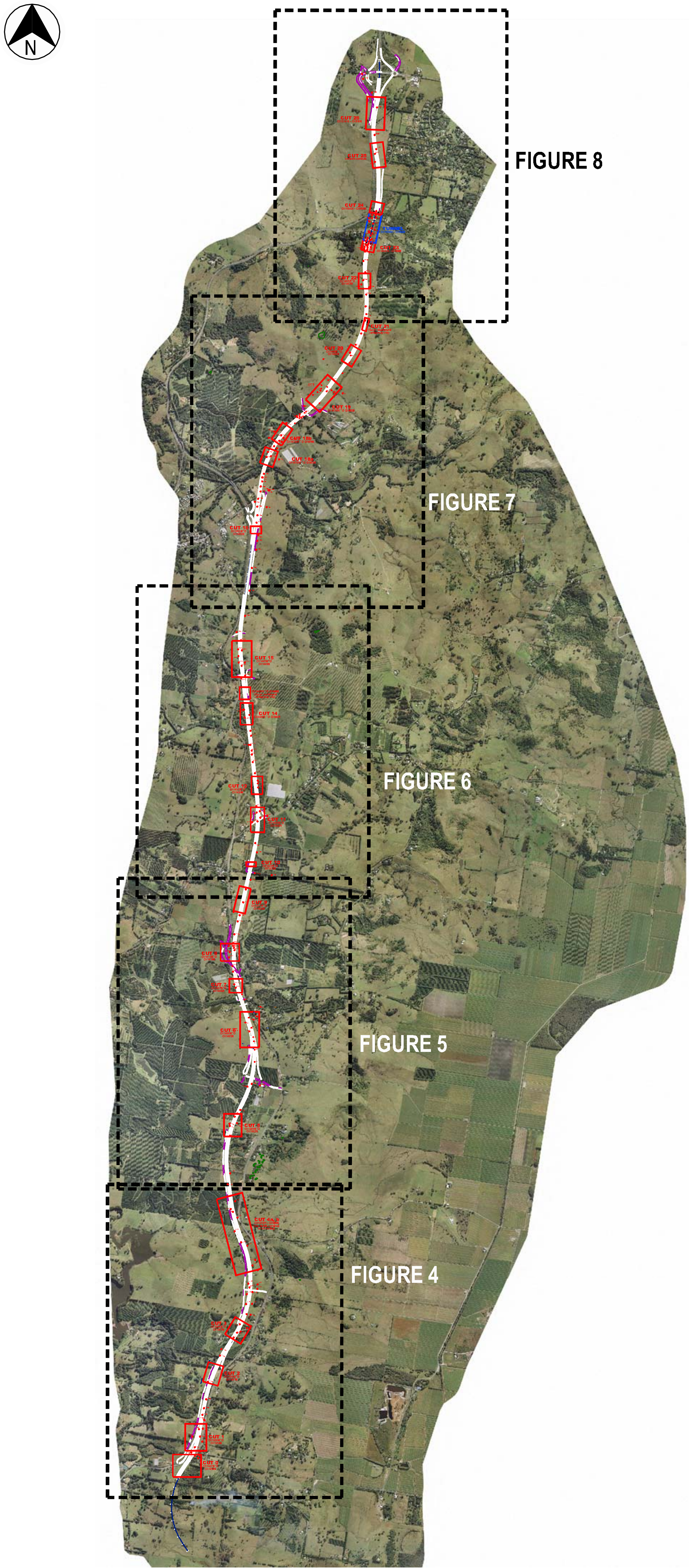


NOTES:

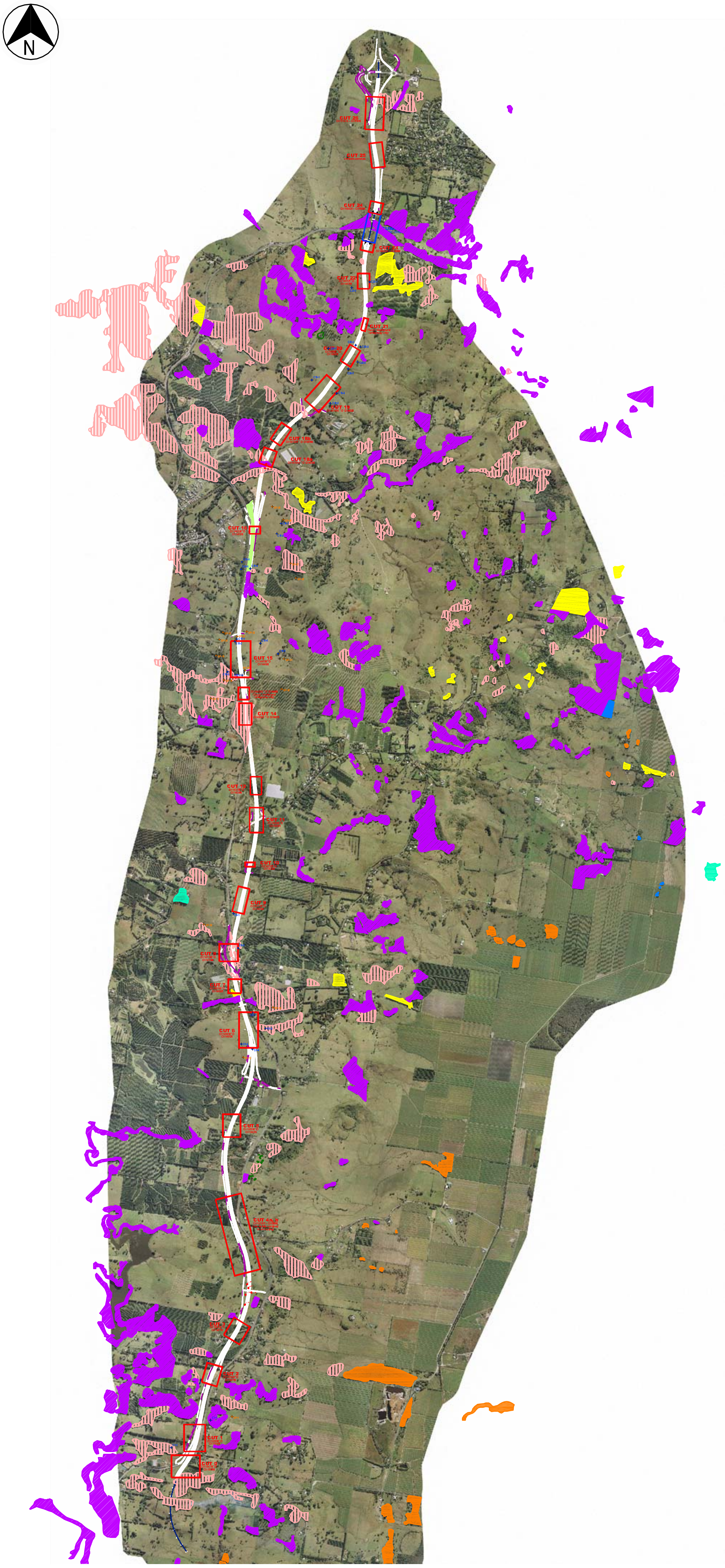
1. Alignment of road supplied by Arup , Preferred Route V7
2. mga grid, Zone 56
3. Extracted from "Tintenbar to Ewingsdale Pacific Highway Upgrade Environmental Assessment: Terrestrial Flora and Fauna Report".

1:50000 0 0.5 1 1.5 2 2.5km

Golder Associates
124 PACIFIC HIGHWAY ST. LEONARDS, N.S.W. 2065
Telephone (02) 9478 3900
Facsimile (02) 9478 3901

CLIENT ARUP		PROJECT PACIFIC HIGHWAY UPGRADE - TINTENBAR TO EWINGSDALE	
DRAWN H.C.	13.06.2008	TITLE CUTS LOCATION	
CHECKED F.H.	13.06.2008		
SCALE 1:50000	A3	PROJECT No 06622140-D0001	FIGURE No FIGURE 2 — REVISION 6

xref:-
cadfile:- J:\06Proj\101-150\06622140_Arup_T2E Preferred Route\8000 Technical\GW Dependent Eco-Systems\Drawings\06622140-D0001.dwg



LEGEND

VEGETATION MAPPING

▨	*Camphor Laurel**
▨	*Lowland Rainforest**
🟦	*Lowland Rainforest on Floodplain**
🟩	*Moist Sclerophyll Forest**
🟨	*Plantation**
🟩	*Revegetation* (refer note 3)
🟧	*Swamp Sclerophyll Forest**

* **Biosis Research Pty Ltd** , "Constraints Mapping, showing plant communities and locations of threatened species", File No. S4071, 21.12.2007

NOTES:

1. Alignment of road supplied by Arup , Preferred Route V7
2. mga grid, Zone 56
3. Extracted from "Tintenbar to Ewingsdale Pacific Highway Upgrade Environmental Assessment: Terrestrial Flora and Fauna Report".

1:50000 0 0.5 1 1.5 2 2.5km

Golder Associates

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CLIENT ARUP		PROJECT PACIFIC HIGHWAY UPGRADE - TINTENBAR TO EWINGSDALE	
DRAWN H.C.	13.06.2008	TITLE VEGETATION MAPPING ALONG PROPOSED UPGRADE	
CHECKED F.H.	13.06.2008		
SCALE 1:50000	A3	PROJECT No 06622140-D0001	FIGURE No FIGURE 3 — REVISION 6

xref:-
cadfile:- J:\06Proj\101-150\06622140_Arup_T2E Preferred Route\8000 Technical\GW Dependent Eco-Systems\Drawings\06622140-D0001.dwg

LEGEND

VEGETATION MAPPING

▥ *Camphor Laurel**

▨ *Lowland Rainforest**

* **Biosis Research Pty Ltd** , "Constraints Mapping, showing plant communities and locations of threatened species", File No. S4071, 21.12.2007

● **SP-1** SPRING IDENTIFIED BY NSW DWE (2002)

● **C1-2** OBSERVED SPRING (GOLDER 2008)

NOTES:

1. Alignment of road supplied by Arup , Preferred Route V7
2. mga grid, Zone 56
3. Extracted from "Tintenbar to Ewingsdale Pacific Highway Upgrade Environmental Assessment: Terrestrial Flora and Fauna Report".

1:10000 0 100 200 300 400 500m

Golder Associates

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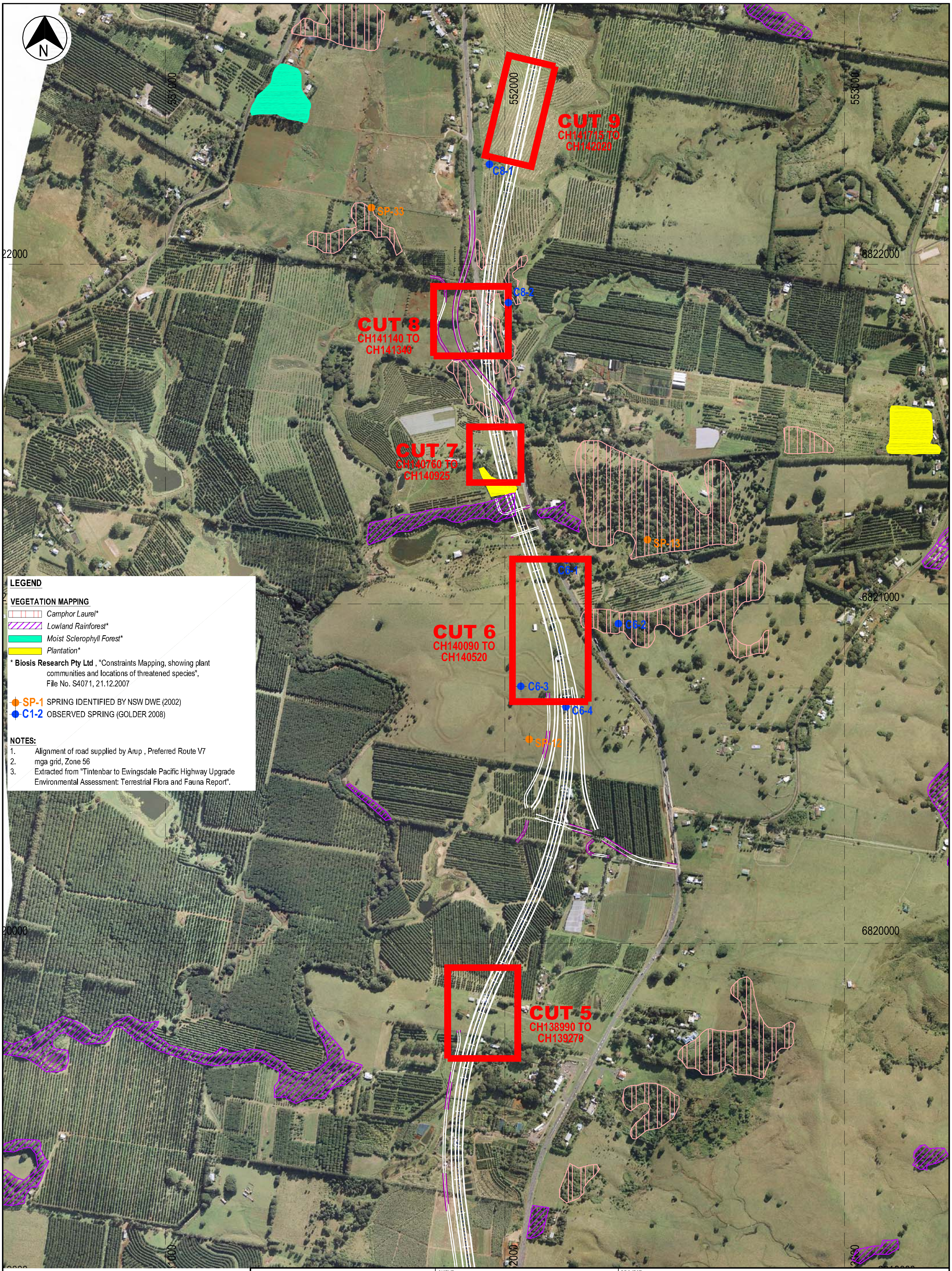
Facsimile (02) 9478 3901

CLIENT	ARUP	PROJECT	PACIFIC HIGHWAY UPGRADE - TINTENBAR TO EWINGSDALE
DRAWN	H.C. 13.06.2008	TITLE	LOCATION OF GDE, SPRINGS AND CUTS CUT 0 TO CUT 4a,b
CHECKED	F.H. 13.06.2008		
SCALE	1:1000 A3	PROJECT No	06622140-D0001
FIGURE No	FIGURE 4	REVISION	6

xref:-
cadfile:- J:\06Proj\101-150\06622140_Arup_T2E Preferred Route\8000 Technical\GW Dependent Eco-Systems\Drawings\06622140-D0001.dwg



LEGEND

VEGETATION MAPPING

▥	*Camphor Laurel**
▨	*Lowland Rainforest**
🟩	*Moist Sclerophyll Forest**
🟨	*Plantation**

* **Biosis Research Pty Ltd** , "Constraints Mapping, showing plant communities and locations of threatened species", File No. S4071, 21.12.2007

● SP-1	SPRING IDENTIFIED BY NSW DWE (2002)
● C1-2	OBSERVED SPRING (GOLDER 2008)

NOTES:

1. Alignment of road supplied by Arup , Preferred Route V7
2. mga grid, Zone 56
3. Extracted from "Tintenbar to Ewingsdale Pacific Highway Upgrade Environmental Assessment: Terrestrial Flora and Fauna Report".

1:10000 0 100 200 300 400 500m

Golder Associates

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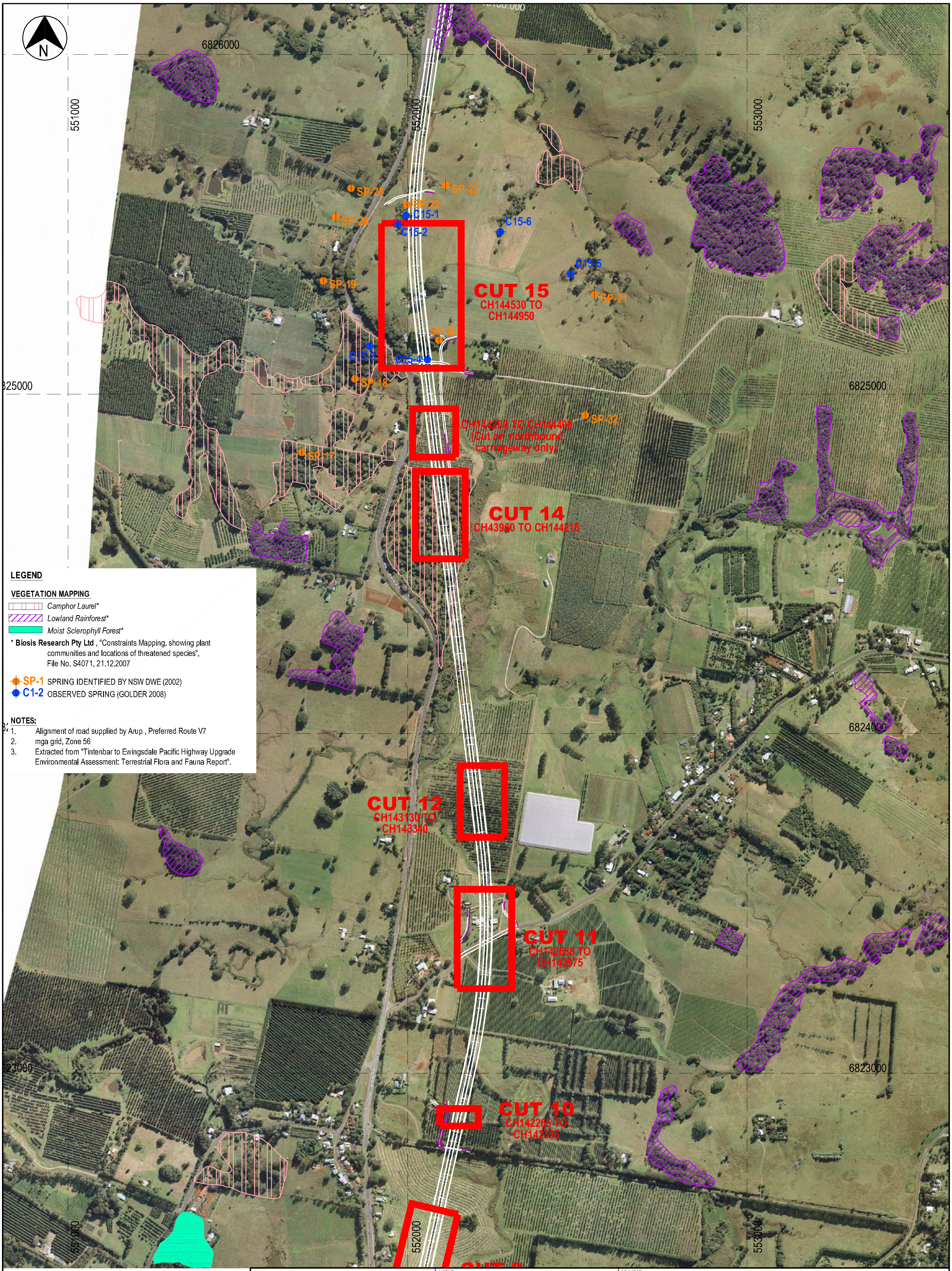
CLIENT ARUP		PROJECT PACIFIC HIGHWAY UPGRADE - TINTENBAR TO EWINGSDALE	
DRAWN H.C.	13.06.2008	TITLE LOCATION OF GDE, SPRINGS AND CUTS CUT 5 TO CUT 9	
CHECKED F.H.	13.06.2008		
SCALE 1:1000	A3	PROJECT No 06622140-D0001	FIGURE No FIGURE 5 — REVISION 6

xref:-
cadfile:- J:\06Proj\101-150\06622140_Arup_T2E Preferred Route\8000 Technical\GW Dependent Eco-Systems\Drawings\06622140-D0001.dwg



LEGEND

VEGETATION MAPPING

- ▥ *Camphor Laurel**
- ▨ *Lowland Rainforest**
- 🟩 *Moist Sclerophyll Forest**

* **Biosis Research Pty Ltd** , "Constraints Mapping, showing plant communities and locations of threatened species", File No. S4071, 21.12.2007

● SP-1 SPRING IDENTIFIED BY NSW DWE (2002)
● C1-2 OBSERVED SPRING (GOLDER 2008)

NOTES:

1. Alignment of road supplied by Arup , Preferred Route V7
2. mga grid, Zone 56
3. Extracted from "Tintenbar to Ewingsdale Pacific Highway Upgrade Environmental Assessment: Terrestrial Flora and Fauna Report".

1:10000 0 100 200 300 400 500m

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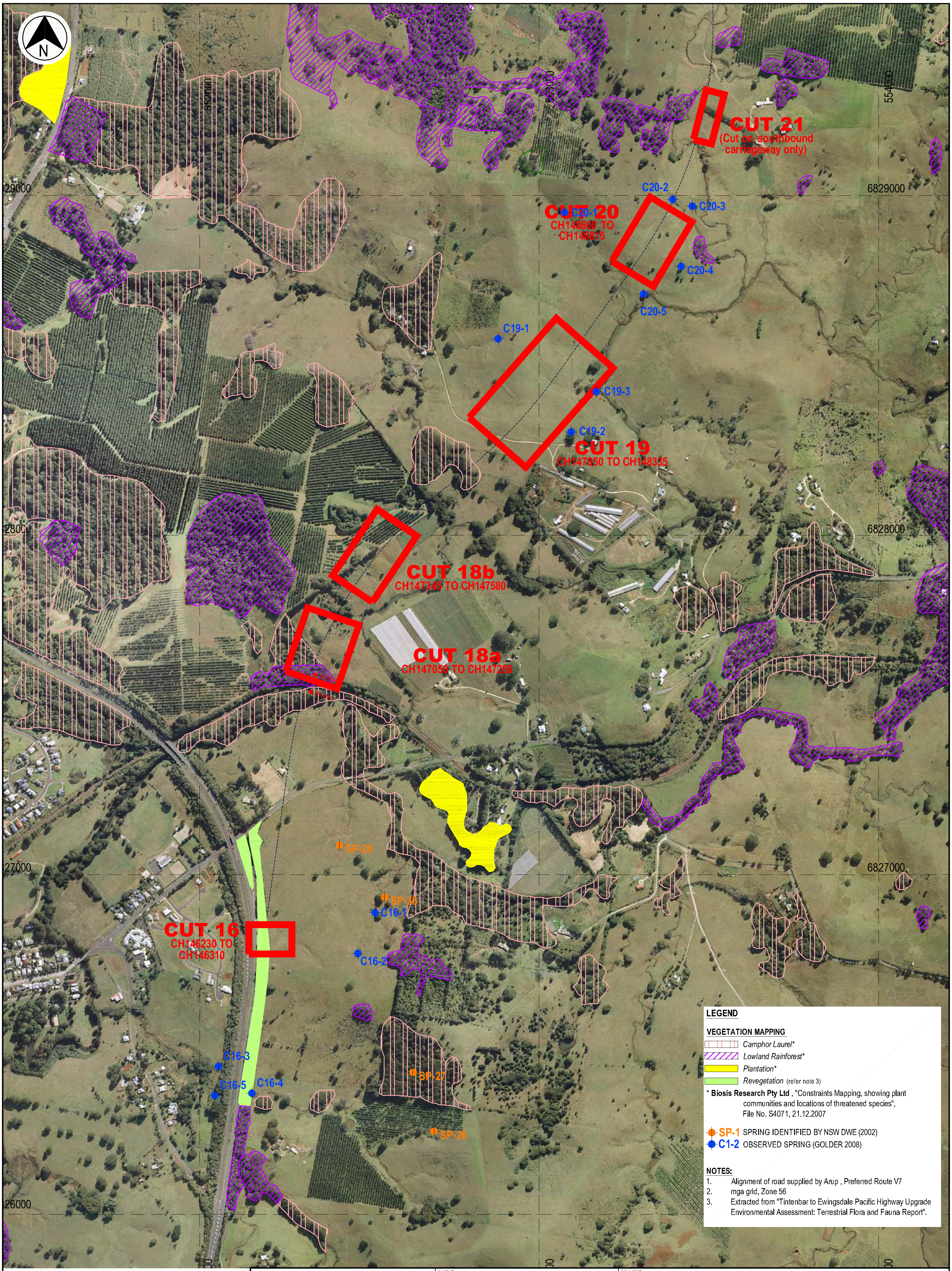
CLIENT ARUP
PROJECT PACIFIC HIGHWAY UPGRADE - TINTENBAR TO EWINGSDALE
DRAWN H.C. 13.06.2008
CHECKED F.H. 13.06.2008
TITLE LOCATION OF GDE, SPRINGS AND CUTS
CUT 10 TO CUT 15
SCALE 1:1000 A3
PROJECT No 06622140-D0001
FIGURE No FIGURE 6
REVISION 6

xref:-
cadfile:- J:\06Proj\101-150\06622140_Arup_T2E Preferred Route\8000 Technical\GW Dependent Eco-Systems\Drawings\06622140-D0001.dwg



* **Biosis Research Pty Ltd** , "Constraints Mapping, showing plant communities and locations of threatened species", File No. S4071, 21.12.2007

NOTES:

1. Alignment of road supplied by Arup , Preferred Route V7
2. mga grid, Zone 56
3. Extracted from "Tintenbar to Ewingsdale Pacific Highway Upgrade Environmental Assessment: Terrestrial Flora and Fauna Report".

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CLIENT ARUP

PROJECT PACIFIC HIGHWAY UPGRADE - TINTENBAR TO EWINGSDALE

DRAWN H.C. 13.06.2008

CHECKED F.H. 13.06.2008

TITLE LOCATION OFGDE, SPRINGS AND CUTS
CUT 16 TO CUT 21

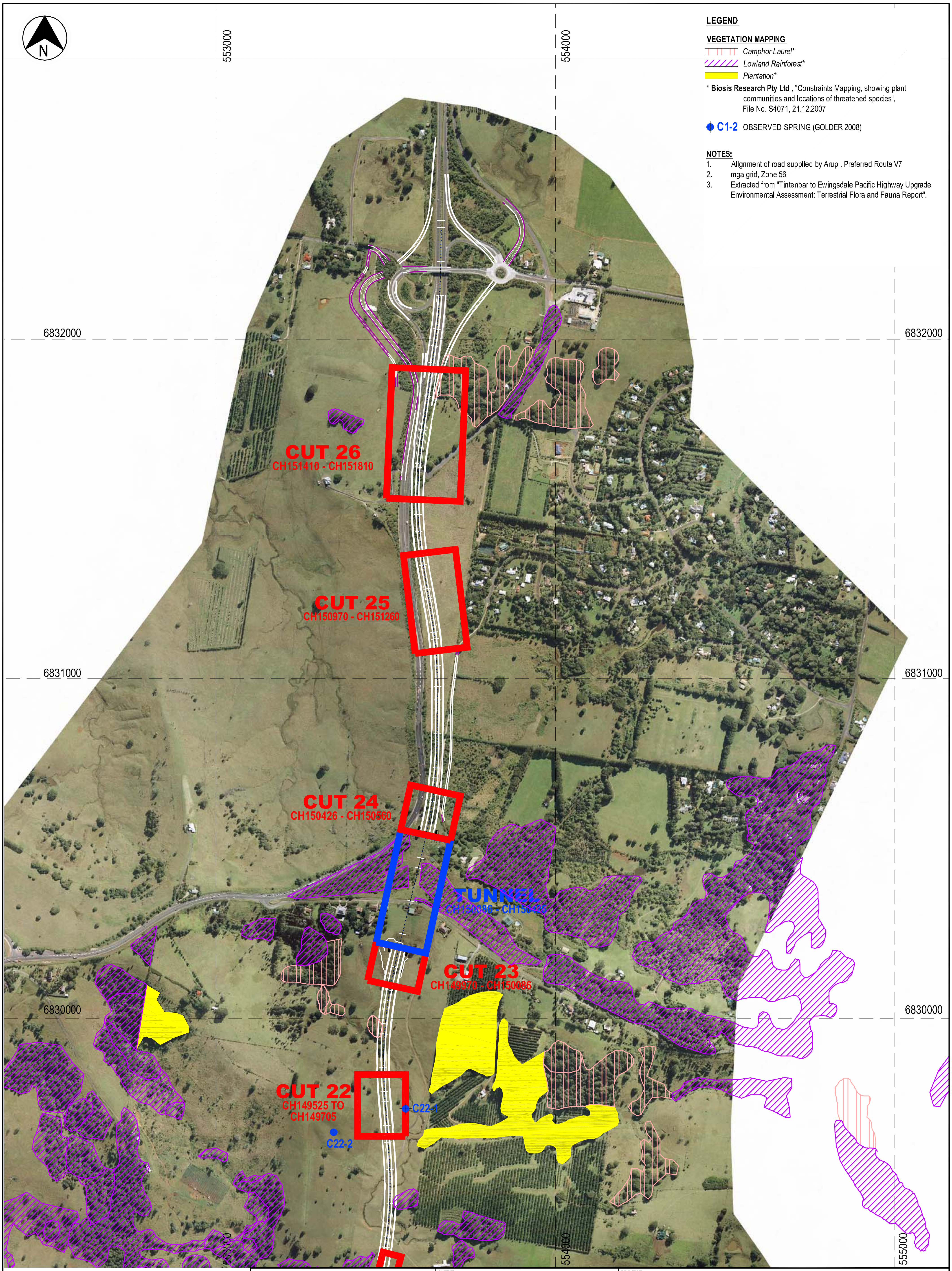
SCALE 1:1000 A3

PROJECT No 06622140-D0001

FIGURE No FIGURE 7

REVISION 6

xref:-
cadfile:- J:\06Proj\101-150\06622140_Arup_T2E Preferred Route\8000 Technical\GW Dependent Eco-Systems\Drawings\06622140-D0001.dwg



LEGEND

VEGETATION MAPPING

▥ *Camphor Laurel**

▨ *Lowland Rainforest**

🟨 *Plantation**

* **Biosis Research Pty Ltd** , "Constraints Mapping, showing plant communities and locations of threatened species", File No. S4071, 21.12.2007

● **C1-2** OBSERVED SPRING (GOLDER 2008)

NOTES:

1. Alignment of road supplied by Arup , Preferred Route V7
2. mga grid, Zone 56
3. Extracted from "Tintenbar to Ewingsdale Pacific Highway Upgrade Environmental Assessment: Terrestrial Flora and Fauna Report".

1:10000 0 100 200 300 400 500m

Golder Associates

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Telephone (02) 9478 3900
Facsimile (02) 9478 3901

CLIENT ARUP

DRAWN H.C. 13.06.2008

CHECKED F.H. 13.06.2008

SCALE 1:1000 A3

PROJECT PACIFIC HIGHWAY UPGRADE - TINTENBAR TO EWINGSDALE

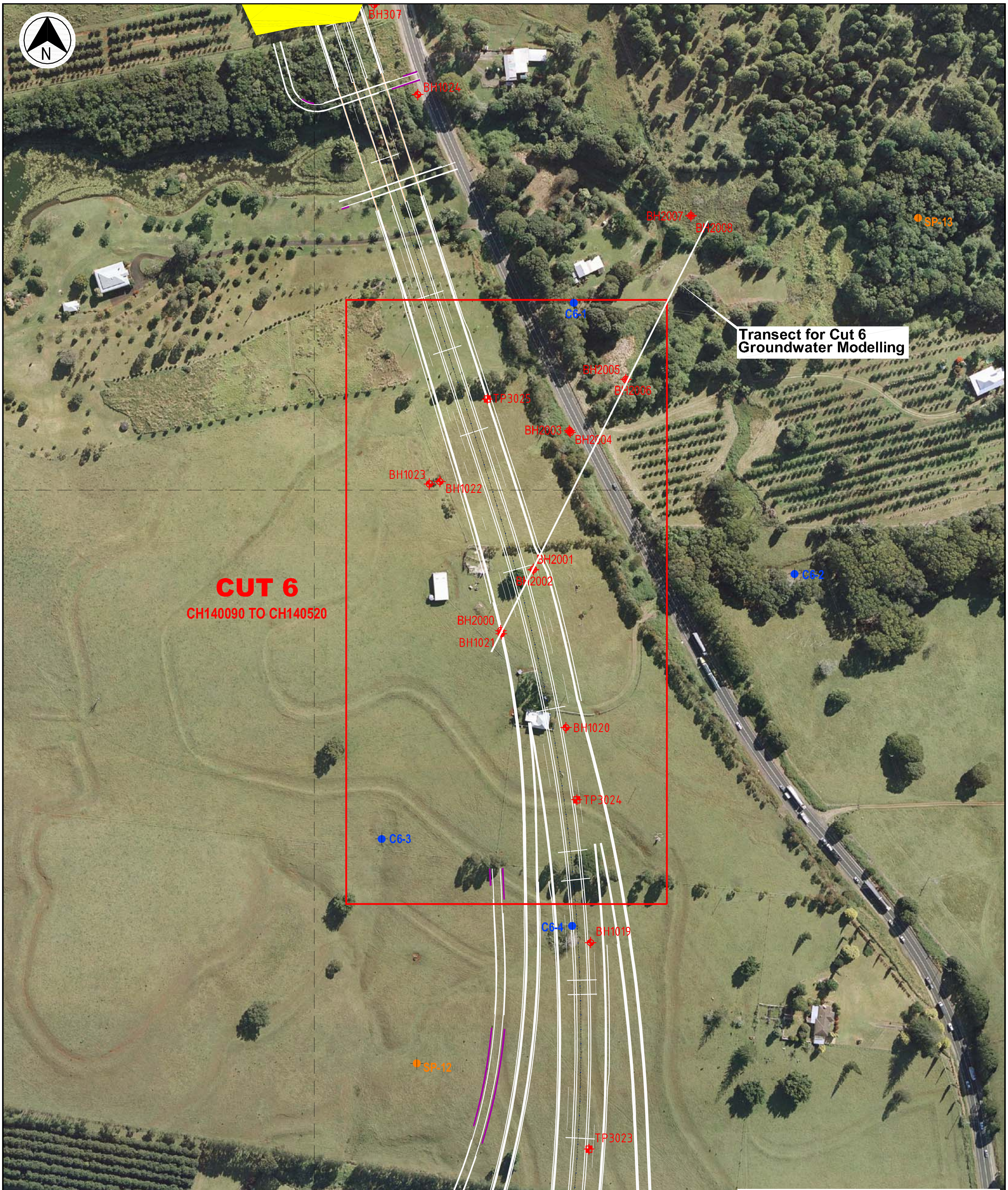
TITLE LOCATION OF GDE, SPRINGS AND CUTS
CUT 22 TO CUT 26, (INCLUDING ST HELENA TUNNEL)

PROJECT No 06622140-D0001

FIGURE No FIGURE 8

REVISION 6

xref:-
cadfile:- J:\06Proj\101-150\06622140_Arup_T2E Preferred Route\8000 Technical\GW Dependent Eco-Systems\Drawings\06622140-D0001.dwg



LEGEND

- SP-1 SPRING IDENTIFIED BY NSW DWE
- C1-2 POTENTIAL SPRING
- BH1035 EXISTING BOREHOLE LOCATION (2006, 2007)
- TP3007 EXISTING TEST PIT LOCATION (2006,2007)
- TP401 EXISTING TEST PIT LOCATION (2005)
- BH2006 BOREHOLE/WELL FOR GROUNDWATER IMPACT STUDY

NOTES:

1. Alignment of road supplied by Arup , Preferred Route V7
2. mga grid, Zone 56
3. Extracted from "Tintenbar to Ewingsdale Pacific Highway Upgrade Environmental Assessment: Terrestrial Flora and Fauna Report".

1:2500 0 25 50 75 100 125m

Golder Associates
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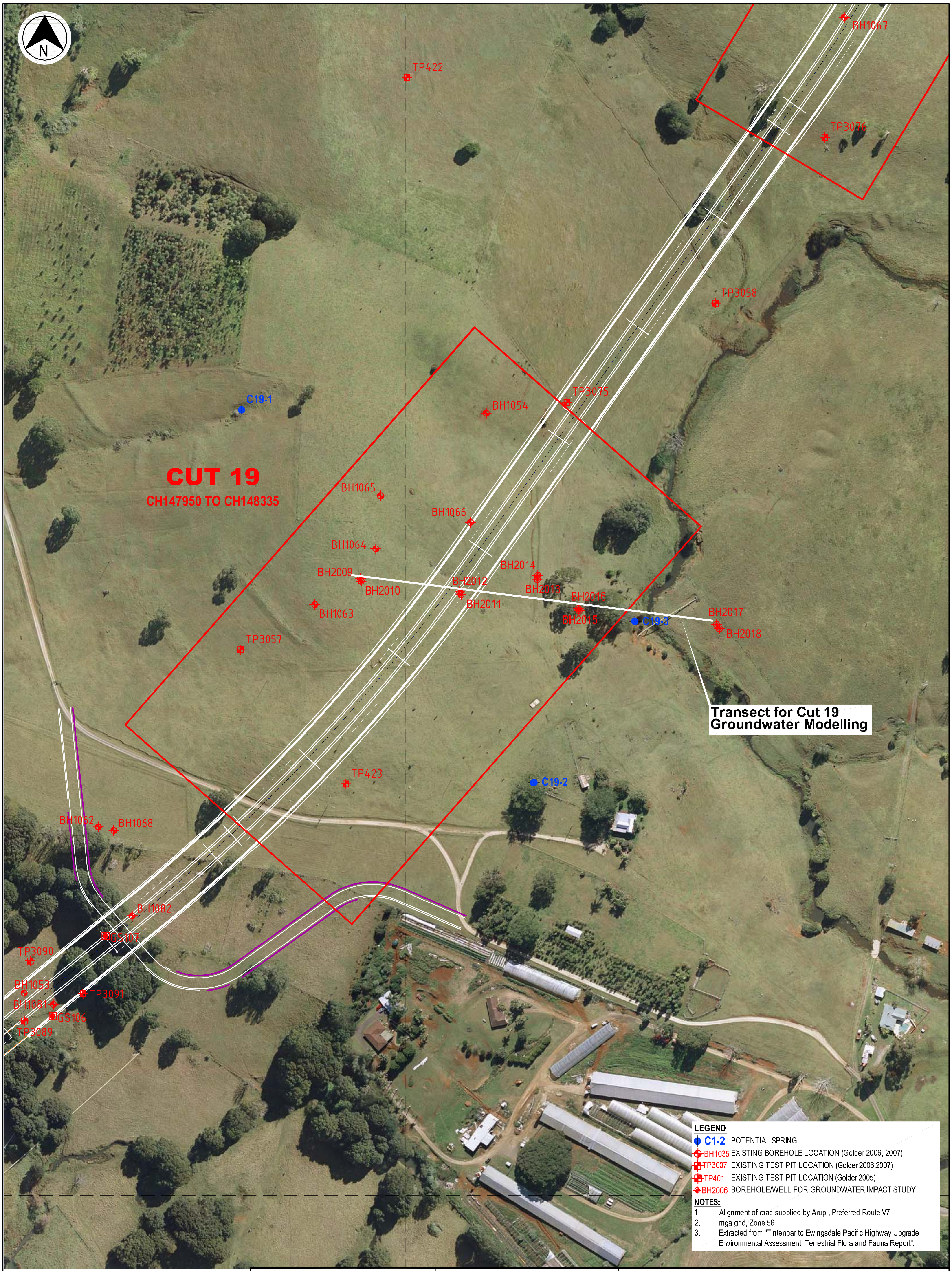
Telephone (02) 9478 3900
Facsimile (02) 9478 3901

CLIENT ARUP
DRAWN H.C. 13.06.2008
CHECKED F.H. 13.06.2008
SCALE 1:1000 A3
PROJECT PACIFIC HIGHWAY UPGRADE - TINTENBAR TO EWINGSDALE
TITLE SITE LAYOUT AND BOREHOLE LOCATION PLAN FOR PROPOSED CUT 6
PROJECT No 06622140-D0001
FIGURE No FIGURE 9
REVISION 6

xref:-
cadfile:- J:\06Proj\101-150\06622140_Arup_T2E Preferred Route\8000 Technical\GW Dependent Eco-Systems\Drawings\06622140-D0001.dwg



LEGEND

● C1-2	POTENTIAL SPRING
BH1035	EXISTING BOREHOLE LOCATION (Golder 2006, 2007)
TP3007	EXISTING TEST PIT LOCATION (Golder 2006,2007)
TP401	EXISTING TEST PIT LOCATION (Golder 2005)
BH2006	BOREHOLE/WELL FOR GROUNDWATER IMPACT STUDY

NOTES:

1. Alignment of road supplied by Arup , Preferred Route V7
2. mga grid, Zone 56
3. Extracted from "Tintenbar to Ewingsdale Pacific Highway Upgrade Environmental Assessment: Terrestrial Flora and Fauna Report".

1:2500 0 25 50 75 100 125m

Golder Associates
124 PACIFIC HIGHWAY ST. LEONARDS, N.S.W. 2065
Telephone (02) 9478 3900
Facsimile (02) 9478 3901

CLIENT	ARUP	PROJECT	PACIFIC HIGHWAY UPGRADE - TINTENBAR TO EWINGSDALE
DRAWN	H.C. 13.06.2008	TITLE	SITE LAYOUT & BOREHOLE LOCATION PLAN FOR PROPOSED CUT 19
CHECKED	F.H. 13.06.2008		
SCALE	1:1000 A3	PROJECT No	06622140-D0001
FIGURE No	FIGURE 10	REVISION	6

xref:-
cadfile:- J:\06Proj\101-150\06622140_Arup_T2E Preferred Route\8000 Technical\GW Dependent Eco-Systems\Drawings\06622140-D0001.dwg

Appendix A
Director-General's Requirements
And
Project Description

NSW GOVERNMENT
Department of Planning

Contact: Dinuka McKenzie
Phone: (02) 9228 6348
Fax: (02) 9228 6355
Email: Dinuka.McKenzie@planning.nsw.gov.au

Our ref: 9037893

Mr Bob Higgins
General Manager, Pacific Highway
NSW Roads and Traffic Authority
PO Box 576
GRAFTON NSW 2460

Dear Mr Higgins

Director General's Requirements for the Environmental Assessment of Proposed Pacific Highway Upgrade between Tintenbar and Ewingsdale

The Department has received your application for the proposed Pacific Highway Upgrade between Tintenbar and Ewingsdale Project (Application Number: 07_0051).

I have attached a copy of the Director-General's requirements (DGRs) for the environmental assessment of the Project. These requirements have been prepared following the Planning Focus Meeting held on Monday, 16 April 2007 and in consultation with the relevant government agencies.

It should be noted that the Director-General's requirements have been prepared based on the information provided to date. Under section 75F(3) of the Act, the Director-General may alter or supplement these requirements if necessary and in light of any additional information that may be provided prior to the proponent seeking approval for the Project.

I would appreciate it if you could contact the Department at least two weeks before you propose to submit the Environmental Assessment for the Project to determine:

- the fees applicable to the application;
- relevant land owner notification requirements;
- consultation and public exhibition arrangements that will apply;
- options available in publishing the Environmental Assessment via the Internet; and
- number and format (hard-copy or CD-ROM) of the Environmental Assessment that will be required.

Prior to exhibiting the Environmental Assessment, the Department will review the document to determine if it adequately addresses the DGRs. The Department may consult with other relevant government agencies in making this decision. If the Director-General considers that the Environmental Assessment does not adequately address the DGRs, the Director-General may require the proponent to revise the Environmental Assessment to address the matters notified to the proponent. Following this review period the Environmental Assessment will be made publicly available for a minimum period of 30 days.

If your proposal includes any actions that could have a significant impact on matters of National Environmental Significance, it will require an additional approval under the Commonwealth *Environment Protection Biodiversity Conservation Act 1999* (EPBC Act). This approval would be in addition to any approvals required under NSW legislation and it is your responsibility to contact the Department of Environment and Water Resources to determine if an approval under the EPBC Act is required for your proposal (6274 1111 or http://www.environment.gov.au).

Please note that the Commonwealth Government has accredited the NSW environmental assessment process for assessing impacts on matters of National Environmental Significance. As a result, if it is determined that an approval is required under the EPBC Act, please contact the Department immediately as supplementary Director-General's requirements will need to be issued.

If you have any enquiries about these requirements, please contact Dinuka McKenzie, A/Senior Environmental Planning Officer, Major Infrastructure Assessments on 02 9228 6348 or via email (dinuka.mckenzie@planning.nsw.gov.au).

Yours sincerely

Chris Wilson
Executive Director
As delegate for the Director-General

Director-General’s Requirements

Section 75F of the *Environmental Planning and Assessment Act 1979*

Application number	07_0051
Project	Pacific Highway Upgrade – Tintenbar to Ewingsdale
Location	Between the Ross Lane and the Ewingsdale Road interchanges of the Pacific Highway within the Byron Shire and Ballina Shire Local Government Areas.
Proponent	NSW Roads and Traffic Authority
Date issued	22 May 2007
Expiry date	22 May 2009
General requirements	The Environmental Assessment (EA) must include the following: 1. an **executive summary**. 2. a **detailed description** of the Project including: ▪ route alignment and corridor width; ▪ design elements (e.g. requirements for LOS, pedestrian and cyclists, rest areas and service centres etc); ▪ differentiate the limits of the Project with respect to the existing Pacific Highway including operational/ maintenance responsibilities; ▪ potential staging; ▪ ancillary facilities (e.g. compound site, batching plants etc); and ▪ resourceing (e.g. construction material needs, spoil disposal, natural resource consumption including water). 3. an **assessment of the key issues**, with the following aspects addressed for each key issue (where relevant): ▪ describe the existing environment; ▪ assess the potential impacts of the proposal at both construction and operation stages, in accordance with relevant policies and guidelines. Both direct and indirect impacts must be considered including potential interactions with the existing Pacific Highway (as relevant); ▪ identify how relevant planning, land use and development matters, (including relevant strategic and statutory matters), have been considered in the impact assessment and/ or in developing management/ mitigation measures; and ▪ describe measures to be implemented to avoid, minimise, manage, mitigate, offset and/or monitor the impacts of the Project and the residual impacts. 4. a **draft Statement of Commitments (SoC)**. The SoC must incorporate or otherwise capture all measures to avoid, minimise, manage, mitigate, offset and/or monitor impacts identified in the impact assessment sections of the EA and ensure that the wording of the SoC clearly articulates the desired environmental outcome of the commitment. The SoC must be achievable, measurable (with respect to compliance), and time specific, where relevant. 5. **certification** by the author of the Environment Assessment that the information contained in the Assessment is neither false nor misleading.
Key issues	▪ **Strategic Justification and Project –** outline the strategic outcomes for the Pacific Highway Upgrade Program (PHUP), including with respect to strategic need and justification, the aims and objectives of relevant State planning policies, the principles of Ecologically Sustainable Development, and cumulative and synergistic impacts associated with the Program as a whole. Identify how the project fits within these strategic outcomes and how impacts associated with the project will be considered and managed to achieve acceptable environmental planning outcomes across the PHUP. ▪ **Project Justification –** describe the need for and objectives of the project; alternatives considered (including an assessment of the environmental costs and benefits of the project relative to alternatives), and provide justification for the preferred project taking into consideration the objects of the *Environmental*

	Planning and Assessment Act 1979. ▪ **Land Use and Property -** including but not limited to: ▪ impacts to directly-affected properties and landuses adjacent to the project, including: impacts to landuse viability and future development potential, including property title impacts; land sterilisation and severance impacts; and impacts to the connectivity and contiguity of small settlements including Newrybar and Knockrow; ▪ consideration of project impacts on the attainment of the objectives of *Far North Coast Strategy*; and ▪ development of a mitigation strategy aimed at promoting appropriate final land uses on lands subject to partial or full acquisition as a result of the project, in consultation with Ballina and Byron Shire Councils. ▪ **Social and Economic -** including but not limited to: ▪ local community socio-economic impacts associated with landuse, property and amenity related changes; ▪ business (including agricultural producers) impacts on a case by case basis including impacts to the overall viability, profitability, productivity and sustainability of businesses; ▪ regional economic impacts to the agricultural sector taking into account the total loss of regional and State Significant farmland as identified in the *Northern Rivers Farmland Protection Project* (Department of Planning, February 2005); and ▪ regional economic impacts to the tourism sector taking into account agri-tourism impacts and impacts to local amenity, character and scenery. ▪ **Surface and Ground Water -** including but not limited to: ▪ water quality impacts to the catchments of Emigrant Creek and Wilson River, in consultation with Rous Water, taking into account impacts from both accidents and runoff (i.e. acute and chronic impacts) and considering relevant public health and environmental water quality criteria specified in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000*; ▪ groundwater impacts, considering local impacts at each deep cutting and cumulative impacts on regional hydrology. The assessment must consider: extent of drawdown; impacts to groundwater quality; discharge requirements; and implications for groundwater-dependent surface flows (including springs and drinking water catchments), groundwater-dependent ecological communities, and groundwater users including the *Alstonville Basalt Groundwater Source Water Sharing Plan*; ▪ flooding impacts, identifying changes to existing flood regimes, in accordance with the *Floodplain Development Manual* (former Department of Natural Resources, 2005) including impacts to existing receivers and infrastructure and the future development potential of affected land; and ▪ impacts to waterways to be modified as a result of the project, including ecological, hydrological and geomorphic impacts (as relevant) and measures to rehabilitate the waterways to pre-construction conditions or better. ▪ **Flora and Fauna -** including but not limited to: ▪ consideration of threatened terrestrial and aquatic species, populations, ecological communities and/or critical habitat; and ▪ assessment of the following issues: native vegetation loss; weed infestation; habitat fragmentation; impacts to wildlife corridors including riparian corridors; impacts to groundwater-dependent communities, riparian and aquatic habitat; and ▪ consideration of regional scale cumulative impacts and identify the significance of the impacts of the project in the context of the PHUP. ▪ **Noise and Vibration -** including but not limited to: ▪ an assessment of operational road traffic noise impacts including consideration of local meteorological conditions (as relevant) and any additional reflective noise impacts from proposed noise mitigation barriers; ▪ an assessment of construction noise and vibration including construction traffic noise and blasting impacts; and ▪ the assessment(s) must take into account the following guidelines as

	relevant: *Environmental Criteria for Road Traffic Noise* (EPA 1999), *Environmental Noise Management Manual* (RTA, 2001), *Environmental Noise Control Manual* (EPA, 1994), *Assessing Vibration: A Technical Guideline* (DEC, 2006); and *Technical Basis for Guidelines to Minimise Annoyance Due to Blasting Overpressure and Ground Vibration* (ANZECC, 1990). ▪ **Visual Amenity and Urban Design -** including but not limited to: ▪ consideration of project and urban design (including noise barriers, retaining walls and landscaping) consistent with overall design of the PHUP and the existing (and desired) character of affected localities; and ▪ consideration of the *Noise Wall Design Guideline* (RTA, 2006). ▪ **Traffic** - including but not limited to: ▪ demonstration of how the project design meets the traffic and transport objectives of the PHUP; ▪ assessment of operational traffic and transport impacts to the local and regional road network, including direct impacts from traffic rerouting and modified access to the upgraded highway, and indirect impacts from the increased accessibility of the Ballina and Byron Shires; and ▪ assessment of construction traffic impacts (including spoil haulage). ▪ **Air Quality** - including but not limited to: ▪ impacts to sensitive receivers (e.g. Newrybar School); consideration of local meteorological conditions; impacts to road users and other receivers at the tunnel section; and consideration of airborne pollutant impacts on drinking water catchments. ▪ **Indigenous Heritage** – including but not limited to: ▪ the consideration of both artefact and landscape scale mitigation measures, where relevant; and ▪ consideration of regional scale cumulative impacts and identify the significance of the impacts of the project in the context of the PHUP. ▪ **Environmental Risk Analysis –** notwithstanding the above key assessment requirements, the EA must include an environmental risk analysis to identify potential environmental impacts associated with the project (construction and operation), proposed mitigation measures and potentially significant residual environmental impacts after the application of proposed mitigation measures. Where additional key environmental impacts are identified through this environmental risk analysis, an appropriately detailed impact assessment of this additional key environmental impact must be included in the EA.
Consultation	You should undertake an appropriate and justified level of consultation with relevant parties during the preparation of the EA, including: ▪ local, State or Commonwealth government authorities and service providers such as Rous Water, the Department of Environment and Climate Change, the Department of Primary Industries, the Department of Water and Energy, the Department of State and Regional Development, Byron Shire Council and Ballina Shire Council; ▪ Specialist Interest Groups including Local Aboriginal Councils; and ▪ the public, including affected landowners. The EA must describe the consultation process, document all community consultation undertaken to date and identify the issues raised (including where these have been addressed in the EA).

Project description

The length of the proposed upgrade would be approximately 17 km starting at Ross Lane in Tintenbar and extending to the north to the existing Ewingsdale interchange, near the settlement of Ewingsdale. At Ross Lane, the proposed upgrade would connect to the north end of the Ballina bypass. Generally the proposed upgrade would be in close proximity to existing highway corridor from Ross Lane to the Bangalow bypass. The existing highway would be maintained for local and regional traffic.

From Bangalow, the proposed upgrade would diverge away from the Bangalow bypass to the northeast through Tinderbox valley. From there, the proposed upgrade would avoid the steep grades of St Helena Hill by way of a tunnel approximately 340 m long and 45 m below the ridge line. North of the tunnel, the proposed upgrade alignment is located immediately to the east of the existing highway before tying into the Ewingsdale interchange.

The general features of the proposed upgrade would be:

- Four-lane divided carriageways (two lanes in each direction), with a wide median allowing for the future addition of a third lane in each direction.
- Class M standard over the full length of the proposed upgrade. In accordance with the RTA’s Pacific Highway Design Guidelines, ’Class M’ projects are designed to 110 km/h freeway standard. This means a controlled access road with divided carriageways, no access for traffic between interchanges, grade separation at all intersections and alternative routes available for local traffic through the provision of service roads or local arterial road networks.
- Conversion of the Ross Lane interchange into a full interchange by construction of north-facing ramps providing access between the local road network and the proposed upgraded highway to the north. A partial interchange at Ross Lane will be constructed as part of the Ballina bypass project.
- Modifications to the existing Ewingsdale interchange to provide full access between the modified local and regional road network and the highway.
- A half interchange at Ivy Lane. North-facing ramps would provide access between the local road network and the proposed upgraded highway to the north.
- A half interchange at Bangalow. South-facing ramps would provide access between the local road network, including to Bangalow and Lismore, and the proposed upgrade to the south. This arrangement would replicate the arrangement with the existing Bangalow bypass which also has south-facing ramps only.
- Six twin bridges and four underpasses allowing roads and creeks to pass underneath the proposed upgrade. These would include twin bridges above Byron Creek and the existing Casino-Murwillumbah railway on the north side of Byron Creek.
- Two bridges carrying local roads over the proposed upgrade, one for Broken Head Road and one about 500 m north of Lawlers Lane providing access to several properties east of the upgrade. Protection screens would be provided on both bridges.

- Emergency u-turn and median crossovers at about 2.5 km intervals. These facilities incorporate lay-bys where vehicles could safely pull off the upgraded highway.
- Sedimentation basins to intercept run-off for treatment before discharging into the natural watercourses.
- Medians and outer verges, including safety barriers where required.
- Signage providing clear directions for traffic at the Ross Lane, Ivy Lane, Bangalow and Ewingsdale interchanges.
- Relatively flat gradients compared to the existing highway, with the maximum grade just south of Bangalow being approximately 5.4% over 1300 metres. There would also be a 4.4% grade over almost 2 km on the north side of the tunnel. An additional southbound climbing lane would be provided in both sections so that slow moving trucks would not be a significant safety hazard to other vehicles.
- The existing highway would be retained as a continuous road for local and regional traffic. It is further anticipated that between Ross Lane and Bangalow the existing highway would be handed over to the councils. Between Bangalow and Ewingsdale the existing highway would continue to function as a regional link between Lismore/Bangalow and the north and would be retained by RTA.
- Two significant diversions of the existing highway are proposed to retain it as a continuous local road. The first is just north of Emigrant Creek where the existing highway would be diverted underneath the bridge taking the proposed upgrade over Emigrant Creek. The other diversion is where the existing highway south of the Ewingsdale interchange is being diverted to a roundabout on the western side of the interchange.
- Additional local roads and property access would be provided including:

  safe access to all properties affected by the proposed upgrade, either directly to the existing highway or indirectly via a new local access road.

  new local roads as required to link the proposed interchanges with the existing highway and other local access roads.
- The proposed upgrade would incorporate twin parallel tunnels under St Helena ridge. The tunnels would each be about 340 m long and about 45 m below St Helena Road. One tunnel would be provided for each carriageway, separated by a rock pillar. The northbound tunnel would be 11.5 m wide between barriers, providing sufficient width for linemarking as 3 lanes in each direction if required in the future. The southbound tunnel would be 12.5 m wide to incorporate the southbound climbing lane while still allowing 1 m wide shoulders on each side. In view of the additional southbound lane proposed initially, there is no provision for adding an additional lane to the southbound carriageway through the tunnel. The precise dimensions of the tunnel may be modified slightly during detailed design.
- Intersections and interchanges designed to achieve at least a level of service C, 20 years after opening for the 100th highest hourly volume (refer to section 13.?? for a description of level of service).

Appendix B
Field Methodology and Results

TABLE OF CONTENTS

SECTION **PAGE**

APPENDIX A – TABLES & FIGURES

B-1 INTRODUCTION

This section provides with the methodology and results used by Golder on Site during the hydrogeological investigation.

Field work was carried out from 9 July to 31 July 2007 and on the 20 and 21 August 2007 and 31 August 2007. The 20 and 21 August activities were carried out during heavy rainfall. At that time, the locations at the toe of Cut 19 (BH2017 and BH2018) could not be accessed due to creek flooding, however, water level measurements were obtained on a subsequent site visit, 31 August 2007.

The hydrogeological field data were analysed and brought together to consolidate the conceptual hydrogeological models (CSM) at each of the selected sections. It is noted that these sections were selected to investigate the general case (Cut 6) and a more extreme case (Cut 19), of 26 cuts (and tunnel) proposed associated with the proposed works.

Golder has developed standard technical procedures for field activities. The field methodology for the hydrogeological groundwater investigation is based on Golder technical procedures and Site conditions.

B-2 DRILLING

A pair of boreholes was drilled at five locations along each transect in order to investigate both deep and shallow groundwater flow systems, which may be affected by the proposed excavations at Cut 6 and 19.

The deep boreholes were drilled to around 20 m depth within the basalt bedrock in order to target highly permeable zones where preferential groundwater flow was likely to occur. The shallow boreholes were drilled adjacent to the deeper boreholes in order to assess the presence and nature of groundwater flow within the regolith layer during (particularly after periods of high rainfall).

B-2.1 Drilling Methodology

Boreholes were advanced using both core and non-core drilling techniques. The boreholes were generally commenced using solid flight augers and wash boring techniques in residual soils and extremely weathered basalt (the regolith). NMLC (diamond core drilling – 52 mm) diamond coring techniques were then used to continue the boreholes to their target depth in the basalt to allow detailed observation of the bedrock encountered. The target depth was selected based on the nature of the basalt, including, the weathering (weathered to fresh basalt), fracturing, vesicularity and bedding.

Sampling was carried out in soils and rocks using Standard Penetration Tests (SPTs). SPT samples were examined in order to assess material type, plasticity and moisture and were kept to allow for further laboratory testing. A record of blow-counts taken to advance the SPT was recorded in order to assess the consistency of the material encountered.

Core recovered from the boreholes was logged by an experienced geotechnical engineer and was kept to allow for further examination and testing, as required. Point load tests were carried out on rock from within the proposed cuts in order to assess geotechnical parameters for the design of cut batters and excavation schedules. The logs recorded on site and core photography are presented in Appendix C.

B-2.2 Groundwater Monitoring Well Construction and Development

The groundwater wells were constructed and developed according to Golder Technical Procedure TP19: *Procedure for Installation of groundwater monitoring wells and standpipes*.

Standpipe piezometers were installed in all boreholes drilled as part of the hydrogeological investigation of Cuts 6 and 19. The wells were generally constructed with a 3 m screened interval in permeable weathered or highly fractured basalt which showed evidence of ongoing groundwater flow.

Gravel packs consisting of 2 mm graded sand were installed between the PVC standpipe and the bedrock and a bentonite plug was constructed above the screen to prevent the connection of the aquifers through the borehole. Boreholes were back filled above the bentonite plug using a cement-bentonite grout mix and were capped with steel Gattic covers finished flush with the existing ground surface.

Following construction, the monitoring wells were developed using the three bore volumes method. A minimum of three times the volume of water in the well in equilibrium state was removed from the well using a Waterra foot valve and PVC tubing, alternatively, the well was developed until the water became clear. The groundwater monitoring wells were surveyed at completion of the wells.

B-2.3 Geological Transects Assessment

Nine groundwater wells were completed along Cut 6 transect using an existing deep groundwater well (BH1021) to complete the pair of groundwater wells at the top of the hill on Cut 6. Ten groundwater wells were completed along Cut 19 transect.

Borehole names and depths for each of the cuts investigated are shown in Table B-1 (next page).

Table B-1: List of Groundwater Monitoring Wells

Borehole name	Deep/Shallow	Hole Depth (mBGS)[1]	Easting (mMGA)[2]	Northing (mMGA)	Surveyed Elevation (m AHD)[3]
Cut 6 Borehole Details					
BH1021	Deep	32.00	552130	6820900	120.20
BH2000	Shallow	11.00	552131	6820902	120.18
BH2001	Deep	20.10	552152	6820945	117.82
BH2002	Shallow	10.50	552153	6820942	118.03
BH2003	Deep	19.80	552178	6821040	94.94
BH2004	Shallow	12.00	552177	6821041	96.86
BH2005	Deep	15.40	552217	6821077	88.99
BH2006	Shallow	3.50	552217	6821077	88.93
BH2007	Deep	11.60	552261	6821192	88.62
BH2008	Shallow	5.00	552262	6821191	88.58
Cut 19 Borehole Details					
BH2009	Deep	30.30	552967	6828454	94.30
BH2010	Shallow	12.10	552967	6828452	94.01
BH2011	Deep	20.30	553041	6828442	84.58
BH2012	Shallow	11.00	553040	6828444	84.69
BH2013	Deep	18.00	553097	6828454	75.93
BH2014	Shallow	14.30	553097	6828457	76.03
BH2015	Deep	16.60	553128	6828431	69.35
BH2016	Shallow	8.10	553127	6828432	69.38
BH2017	Deep	21.00	553229	6828420	54.77
BH2018	Shallow	8.00	553231	6828417	54.75

[1] mBGS is metres Below Ground Surface; [2] mMGA is metres Map Grid of Australia 1994, Zone 56; [3] mAHD is metres Australian Height Datum.

The information collected during this task was analysed and used to develop hydrogeological cross sections (transects) for each road cutting. These transects were drawn using the geological information from the borehole logs (core information), the groundwater monitoring well completion details and the water level measurements. The boundary between the bedrock aquifer system and the weathered upper aquifer system was assessed from the borehole logs and plotted on the transect cross sections. The boundary was estimated to correspond with the beginning of the moderately weathered rock, slightly weathered rock and fresh rock. At each drilling location the groundwater monitoring wells were drawn and their respective water level indicated.

The interpreted hydrogeological transect for Cuts 6 and 19 are presented in Figures 4 and 5, respectively. It is noted that the water table level was interpreted, where appropriate.

B-2.4 Water Level Measurements

Water level measurement data from the boreholes is presented in Table B-2.

At each location groundwater level in the deep groundwater monitoring well was generally deeper than the groundwater level in the shallow monitoring wells, indicating the presence of two independent water systems (with a downward vertical hydraulic head and flow differential).

At the crest of the hills in both Cut 6 and Cut 19 the monitoring wells, screen in the weathering profile (inferred perched aquifer layer) were found dry (for water level measurements on two separate occasions) suggesting that the shallow groundwater system operates intermittently or is not present at all at these elevated locations.

At Cut 6, the water levels at each of the two locations at the base of the hillslope are similar within the shallow and deep groundwater monitoring wells, however, each groundwater monitoring well is observed to behave differently during development recovery and hydraulic testing.

The observations of the water levels suggest that:

- The groundwater systems in the valley of Cut 6 are in full hydraulic connectivity;
- There is no water in the shallow aquifer system at the top of the hills; and,
- At mid-slope, the deep and shallow aquifer systems are independent.

Note that BH2017 and BH2018 at Cut 19 were not accessible during the second survey due to floods preventing the crossing of the creek.

Table B-2: Groundwater Level Measurements:

Bore Name	Completion depth (mBGS)[1]	Screened from (mBGS)	Screened to (mBGS)	Water Level 27-30 July 2007 (mBGS)	Water Level 21-22 August 2007 (mBGS)	Water Level 31 August 2007 (mBTOC)[2]
BH1021	32.0	26.0	32.0	18.35	16.89	16.88
BH2000	11.0	8.0	11.0	dry	dry	dry
BH2001	20.1	17.1	20.1	19.80	19.06	19.61
BH2002	10.5	7.5	10.5	dry	dry	dry
BH2003	19.8	13.8	19.8	9.30	8.00 / 16.10 *	9.84
BH2004	12.0	9.0	12.0	9.75	8.00 / 9.40 *	9.22
BH2005	15.4	12.4	15.4	3.10	2.33	2.65
BH2006	3.5	1.6	3.5	3.10	1.99	2.60
BH2007	11.1	8.1	11.1	2.40	2.53	2.05
BH2008	5.0	2.0	5.0	2.40	1.32	1.99
BH2009	30.3	27.3	30.3	17.90	16.96	19.16
BH2010	12.1	9.1	12.1	dry	10.78	dry
BH2011	20.3	17.3	20.3	10.20	9.8	10.23
BH2012	11.0	8.0	11.0	dry	not accessible	10.12
BH2013	18.0	15.0	18.0	14.70	12.83	12.97
BH2014	14.3	11.0	14.3	12.10	12.07	12.15
BH2015	16.1	13.1	16.1	14.70	14.66	14.32
BH2016	7.9	4.9	7.9	dry	dry	dry
BH2017	21.0	18.0	21.0	4.50	not accessible	4.19
BH2018	8.0	5.0	8.0	4.40	not accessible	4.13

*: first value is WL estimated before purging (equipment failure), second value taken the next day before sampling, the well had possibly not fully recovered; [1] mBGS is metres Below Ground Surface; [2] mBTOC is metres Below Top of Casing.

B-3 HYDRAULIC CONDUCTIVITY ESTIMATION – FALLING HEAD TEST

B-3.1 Field Methodology

Hydraulic conductivity of the rock mass and the regolith was assessed using falling head test methods - carried out in each of the boreholes. The falling head tests were done after the bores were developed.

InSitu Level Troll 700 pressure transducers (water level dataloggers) were used to record the pressure head differential during the test (measuring the relaxation to the artificial pressure head created though the introduction of a slug of water at the beginning of the test).

The standing water level of the borehole was measured manually immediately prior to the test. The datalogger was lowered into the well and was initialised using a field laptop computer. Twenty litres (20 L) of potable water was injected into the well to create a pressure differential from the equilibrium state (i.e. the natural standing water level, or SWL). The boreholes were then left for between 3 and 12 hrs to allow water levels to recover to equilibrium conditions.

B-3.2 Data Analysis

Water level data downloaded from the automatic datalogger loggers was recovered as displacement data (expressed in metres), with corresponding time intervals (expressed in seconds). The time scale was reset to zero to correspond to the start of the falling head test (no more water added to borehole). Normalised displacement versus time since test initiated was then plotted using logarithmic axis scales.

The falling head tests were analysed using AQTESOLV v3.5, software which is designed to calculate hydraulic conductivity, storativity and other aquifer properties from data sets collected during slug and aquifer (pumping) tests. The normalized plots were matched using Bouwer-Rice (1976) method in most cases. The best-fit lines were manually adjusted to fit that portion of the falling head curve which was considered to optimally represent the hydraulic characteristics of the aquifer. The hydraulic conductivity was then obtained from the slope of the best-fit straight line. Analysis reports for each test are reported in Appendix E.

The following assumptions were used in the analysis of the falling head tests:

1. If the static water level (SWL) measured in the well prior to the start of the test was above the top of the gravel pack of the well, the aquifer was assumed to be confined. If the SWL was measured below the top of the gravel pack, the aquifer was assumed to be unconfined;
2. As the true thickness of the aquifer is unknown, the saturated thickness of the aquifer during analysis was assumed to be equal to the saturated thickness of the gravel pack;
3. An effective porosity of the gravel pack of 0.3 was assumed;
4. As many of the monitoring wells did not recover after inserting the slug to a water level measured prior to testing, the initial displacements were in most cases, calculated based on the water column at the end of the test; and

5. Conductivities were estimated assuming an anisotropic ratio of k_v/k_h = 1. Sensitivity analysis indicated that a ratio of 0.1 or 0.01 did not affect the resulting hydraulic conductivity estimates significantly (by more than one order of magnitude).

B-3.3 Estimated Hydraulic Conductivities

The following table (Table B-3) provides the estimated hydraulic conductivities from the falling head tests. It should be noted that the values produced by the analysis of the tests represents an estimate that may vary by as much as a full order of magnitude from the true value.

Table B-3: Estimated Hydraulic Conductivity - Falling Head Test

Hydraulic Conductivity (m/s) - Cut 6			Hydraulic Conductivity (m/s) - Cut 19		
BH1021	Deep	4.5E-08	BH2009	Deep	1.1E-7
BH2000	Shallow	Dry	BH2010	Shallow	Dry
BH2001	Deep	3.2E-06	BH2011	Deep	1.8E-09
BH2002	Shallow	Dry	BH2012	Shallow	Dry
BH2003	Deep	NA[1]	BH2013	Deep	1.2E-07
BH2004	Shallow	3.1E-07	BH2014	Shallow	2.5E-07
BH2005	Deep	NA	BH2015	Deep	9.9E-07
BH2006	Shallow	1.3E-07	BH2016	Shallow	Dry
BH2007	Deep	7.9E-07	BH2017	Deep	NA
BH2008	Shallow	3.6E-05	BH2018	Shallow	6.1E-07

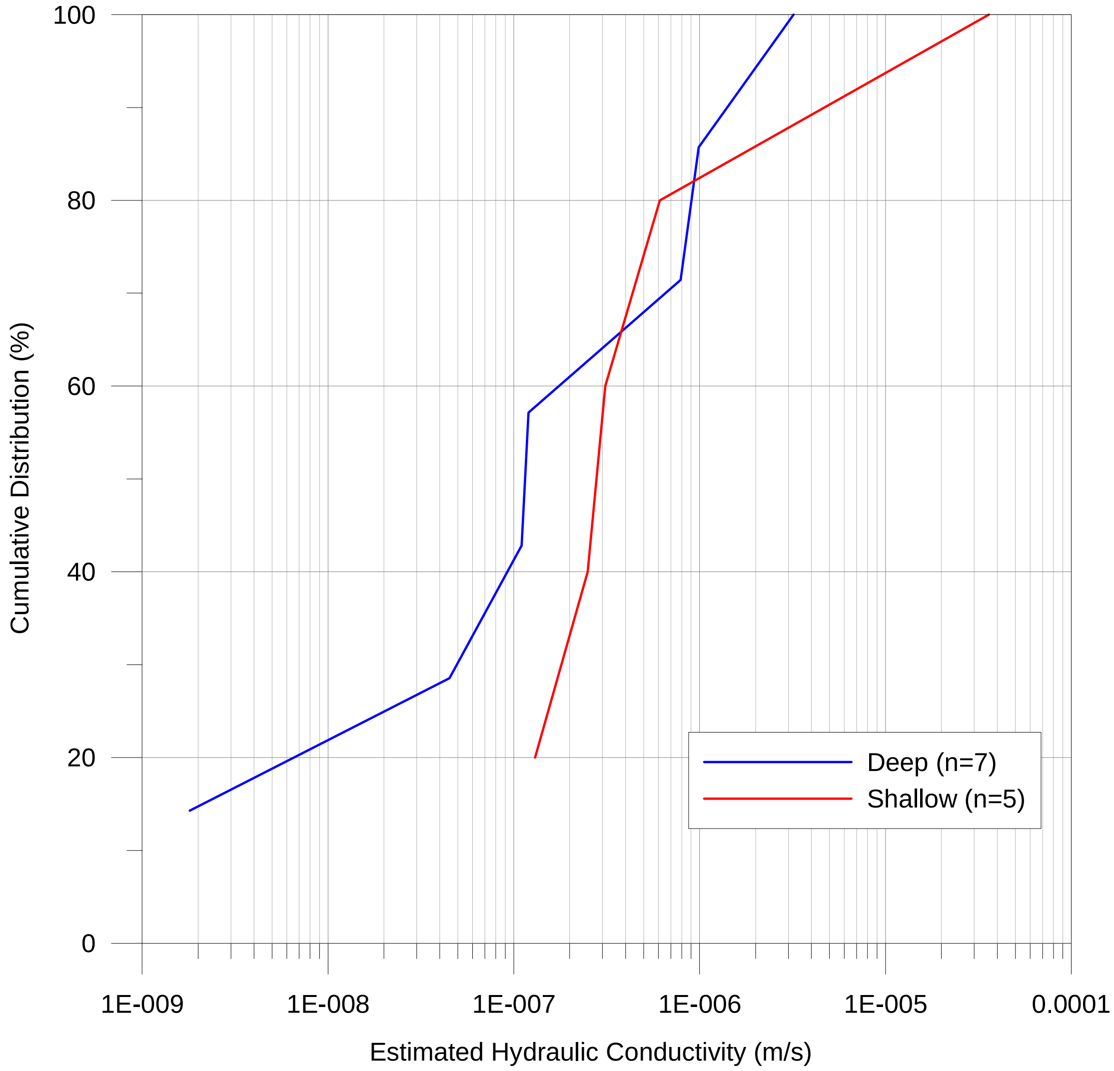
[1] NA - see text for explanation.

The results of hydraulic conductivity assessment were not available for three of the boreholes. Those boreholes are noted in Table b-3. with “NA”. The tests were conducted at those bore holes but the responses to the imposed hydraulic head were very low and not considered representative of the aquifer system (but rather the intervening aquitard/ aquiclude layers frequently encountered in the lava sequences).

The hydraulic conductivity for the deep aquifer, measured in metres per second, range from 1.8x10-9 m/s to 3.21x10-6 m/s. Most of the hydraulic conductivity values are of the 10 -7 m/sec order of magnitude. In the shallow aquifer, marginally higher conductivities were calculated, but most within a 10-7 m/s order of magnitude or higher, the maximum being observed in the valley at Cut 6, with 3.6x10-5 m/s at BH2008.

Figure B-1 presents the cumulative distribution of estimated hydraulic conductivity with respect to both the deep aquifer and shallow aquifer. The data presented in Figure B-1 was used in the predictive numerical seepage analysis (Seep/W modelling) presented in Appendix G.

Figure B-1: Cumulative Distribution of Estimated Hydraulic Conductivity (m/s)



B-4 SOIL PERMEABILITY ESTIMATION – TALSMA INFILTROMETER TEST

B-4.1 Field Test Method

Soil permeability was assessed in order to provide input to the estimate of rainfall recharge rate used in seepage analysis modelling. This testing used the ring infiltrometer test methods (Talsma test).

A steel ring of 500 mm diameter is hammered into the ground surface at three locations along each of the transects. For each location, a flat soil section was selected. The ring is hammered a few centimetres in the soil while avoiding rocking it. A rag is placed at the bottom of the ring to allow homogeneous water distribution. A 1:10 water level reading scale is placed across the ring (the scale is fitted with a bubble levels to ensure the right position angle. The ring is filled with water and the drop in water level was monitored continually for the duration of the test. When a quick infiltration rate is observed, the water level in the ring is topped up and further data are monitored.

The initial responses observed in a ring test correspond to soil sorptivity, when the infiltration observations have reached steady state, the permeability can be estimated. Long term flow rates are determined from the steady rate of flow seen as the ground became saturated. The July 2007 test did not all reach steady state by the time the ring was empty. The tests were repeated in August 2007, where the ring was refilled with water until the infiltration had reached a steady state. To increase reliability, the test was repeated 2 to 3 times at each location.

B-4.2 Results Analysis Method

To calculate soil permeability (saturated vertical hydraulic conductivity), accumulated infiltration was plotted against time in seconds. The mathematical solution of the plot corresponds to a square root function curve in the initial displacement, then a straight line, as follows:

$I = S\sqrt{t} + Kt$ with I being cumulative infiltration, m;
t, being time, s;
S, constant, corresponding to the sorption in the soil;
K, being the hydraulic conductivity, m/s.

When the soil is dry, the sorption factor will be observed and the first data points will not be used for the calculation of the saturated vertical hydraulic conductivity of the soil. When the soil is moist to wet, the sorption factor may not be observed. The soil permeability is deduced from the straight portion of the plot. Graphic representations and field data are provided at the end of this appendix.

B-4.3 Soil Permeability Testing Results

The following table presents the soil permeability results:

Table B-4: Estimated Vertical Hydraulic Conductivity – Talsma Infiltrometer Test

Hydraulic Conductivity (m/s) - Cut 6			**Hydraulic Conductivity (m/s) - Cut 19**		
Location in transect	**Range of result**	**Average**	**Location in transect**	**Range of result**	**Average**
Top	5.0E-06 1.7E-05	1.1E-05	Top	1.0E-04[1]	1.0E-04
Middle	1.0E-04	1.0E-04	Middle	3.8E-06 5.3E-05 3.1E-05 5.9E-05[1]	3.7E-05
Bottom	4.1E-05 1.3E-04 1.3E-04	1.0E-04	Bottom	5.2E-05[1]	5.2E-05

[1] Calculated from July 2007 field data, remainder from August 2007 data.

The tests done at mid-section of Cut 6 were located in the road corridor, and do not represent the natural conditions, as imported road construction materials underlies most of the area leading to an increased estimate of soil permeability.

The relative infiltration rate can be compared between locations. The infiltration rate at the bottom of Cut 6 (flat valley area) is 10 times higher than the infiltration rate in the upper grazed pasture area of Cut 6. At Cut 19, the infiltration rate on the top of the hill is higher than lower down the slope.

B-5 SPRING VERIFICATION

In addition to the groundwater springs identified previously by the *Bureau of Rural Sciences* (BRS, Brodie and Green, 2002), potential spring locations were assessed through the analysis of aerial photography and landscape features. A walkover at potential spring locations at Cut 6 and Cut 19 during the field works (refer Figures 2 and 3).

These potential spring locations were visited and the site features examined in order to verify the actual presence of a spring at each location. Notes were made on the geology of the locations including soil makeup and rock outcrops which were present. Observations of vegetation and any obvious seepage or moist ground was recorded and an assessment of the presence or otherwise of a spring at the site was made. Discussions with landowners were held, where possible.

Some of the potential spring locations could not be checked due to lack of access permission on private properties.

No further springs or seepage points other than those identified by the BRS were encountered, as described in the table below. However, a site walkover during heavy rainfall identified local points of subsurface water flow discharge. These points were not discharging the day following the heavy rainfall events, and, as such, are not considered springs.

We noted that rainfall events typically result in water ponding in flat-lying areas or depressions on the hill slopes. These areas are inferred to be from farming activities, such as erosion control structures, access paths or cattle tracks. They influence surface drainage by controlling the surface water runoff, however, are not considered springs.

Table B-5: Springs Verification Results

Verification of Springs at Cut 6		**Verification of Springs at Cut 19**	
C6-1 (high priority)	No spring present at this location. The lusher vegetation is due to the very close proximity of the creek (alluvial flood plane), note the creek is misplaced on the map.	C19-1 (not of interest)	Not checked (outside likely area of influence)
SP13	Spring exists at this location and is flowing.	C19-2 (not of interest)	No spring present at this location
C6-2 (high priority)	Access to property not permitted	C19-3 (high priority)	No spring present at this location. Subsurface water flow discharge observed during heavy rain.
C6-3 (low priority)	No spring present at this location. Drainage feature.		
C6-4 (high priority)	Access to property not permitted. Assessment from nearby property. No springs present in the vicinity of location C6-4. The cluster of		

Verification of Springs at Cut 6	Verification of Springs at Cut 19
vegetation seems to be due to a water hole feature. No water flowing after heavy rains.	

B-6 GROUNDWATER QUALITY ASSESSMENT

B-6.1 Groundwater Sampling Method

Water samples were collected from the creeks, springs and selected groundwater monitoring wells (ie. wells BH2003 to BH2007, and BH1021, Cut 19 creek and Spring SP-13). The groundwater monitoring wells were purged using the three bore volume method (Golder Technical Procedure TP20, *Groundwater sampling*) prior to sampling to make sure that the groundwater sampled best represented the groundwater within the aquifer.

Samples were collected in dedicated laboratory bottles which were identified with the sample location and date of sample collection. The samples were sent for analysis to EnviroLab Pty Ltd (EnviroLab), a NATA accredited laboratory in Sydney NSW. Quality Assurance – Quality Control (QA-QC) duplicates were taken based on a frequency of 10% (1 duplicate every 10 samples) and submitted with the other samples to the laboratory.

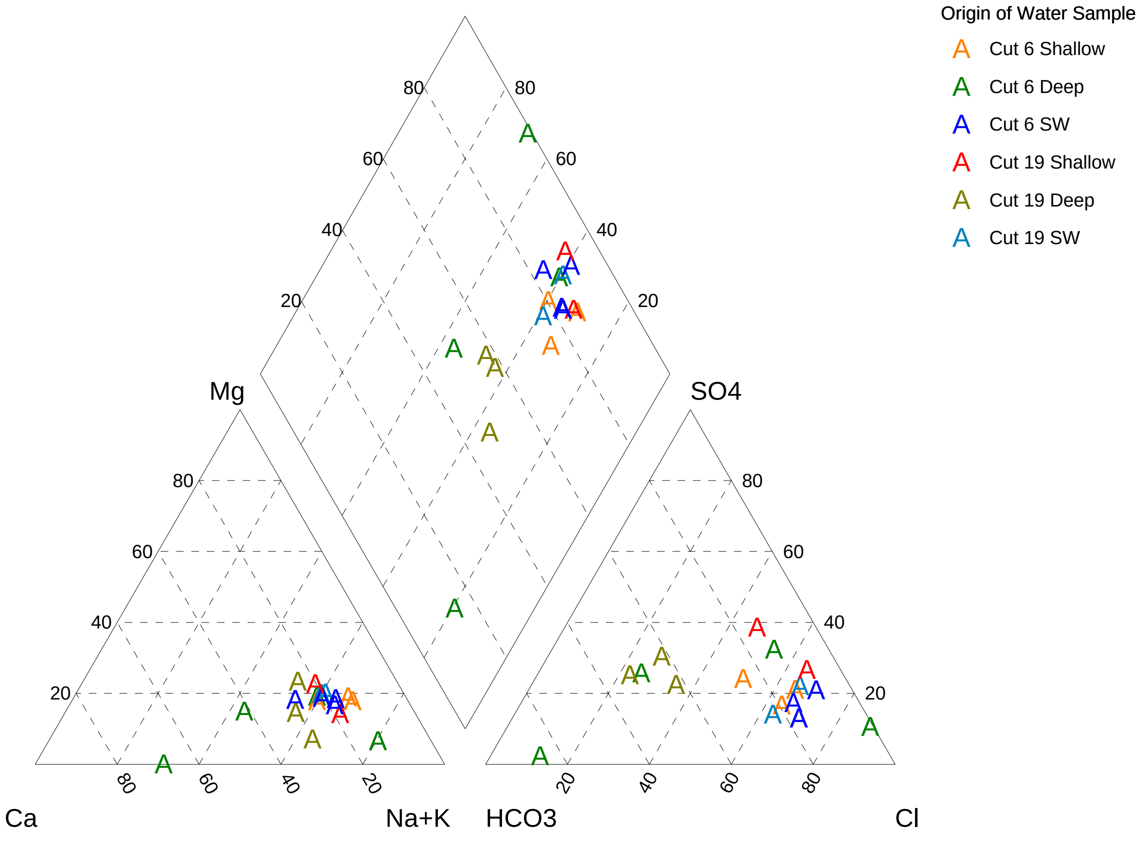
Field parameters (including pH, electrical conductivity and temperature) are unavailable for the samples and bore development due to weather conditions (high winds and heavy rainfall).

B-6.2 Water Quality Results

The laboratory analysis for the water samples collected from the groundwater monitoring wells and the creeks and springs are summarised in Table 1 at the end of this report. The laboratory certificates are presented in Appendix F.

The chemistry results are plotted below in a Piper diagram (Figure B-2). Piper diagrams allow classification of water according to their relative composition in major ions: chloride, sulphate, hydrocarbonates (i.e. bicarbonate), potassium, calcium, magnesium and sodium. On a Piper diagram, a water sample will plot in a specific location according to its composition. This location is also called a water type. Water samples from different origins often have different water types.

Figure B-2: Piper Plot - Groundwater and Surface Water (August 2007)



The Piper plots reveal the following:

- Groundwater samples from the deep aquifer plot separately from groundwater samples from the shallow aquifer and the creeks and springs suggesting they are of a different water type and origin, are ‘older’ (longer residence time in the aquifer);
- The shallow aquifer groundwaters and surface water creek samples are Na-Cl-SO_4 type and are similar in general water type, and being ‘young’ and more typical of rainfall recharge waters. This is general typical of shallow groundwater which are readily recharged and drain rapidly to the surface drainage system (creeks and springs); and
- Deeper aquifer groundwater samples are Na-Cl-HCO_3-SO_4 type waters, again reflecting rainfall recharge (normally Na-Cl dominant), however, influenced by longer residence time within the aquifer (mineral leaching is more pronounced). These waters characteristic suggest the deeper groundwaters are distinct from the more dynamic shallow water flows. They are also dissimilar to the creek and spring water quality, suggesting they do not contribute significantly to the local creek and spring flows.

On this basis it can be inferred that the baseflow to the creeks is provided largely by the shallow aquifer, local and intermediate groundwater flow systems, and that the deeper aquifer is not a significant contributor to creek baseflow. This implies that any cutting that significantly diverts potential rainfall recharge waters away from the local shallow groundwater systems (even though they are largely intermittent) is likely to locally diminish water discharges to the creeks and springs. This is hypothesis is tested by the predictive numerical modelling described in Appendix G.

Attachment
Permeability Test Data and Graphs

Report of Report Permeameter

Client : RTA
Job No. : 06622140
Project : Pacific Highway Upgrade - Tintenbar to Ewingsdale
Date : 31-Jul-07

Location		Location		Location		Location		Location		Location	
Cut 6 Top Section		Cut 6 Mid Section		Cut 6 Bottom Section		Cut 19 Top Section		Cut 19 Mid Section		Cut 19 Bottom Section	
Depth (mm)	Time (sec)	Depth (mm)	Time	Depth (mm)	Time	Depth (mm)	Time	Depth (mm)	Time	Depth (mm)	Time
0	0	0	0	0	0	0	0	0	0	0	0
1		1		1		1		1		1	
2	5	2	4	2		2	10	2	19	2	11
3		3		3		3		3		3	
4	11	4	6	4		4	20	4	38	4	22
5		5		5		5		5		5	
6	17	6	10	6	4	6	28	6	61	6	38
7		7		7		7		7		7	
8	22	8	13	8	7	8		8	85	8	56
9		9		9		9		9		9	
10	28	10		10		10	46	10	110	10	75
11		11		11		11		11		11	
12	34	12		12	12	12	70	12	135	12	99
13		13		13		13		13		13	
14	39	14		14	14	14	84	14	161	14	123
15		15		15		15		15		15	
16	44	16	26	16		16	103	16	188	16	153
17		17		17		17		17		17	
18	49	18		18		18	119	18	214	18	187
19		19		19		19		19		19	
20	55	20		20	22	20	137	20	242	20	220
21		21		21		21		21		21	
22	59	22		22		22	155	22	274	22	254
23		23		23		23		23		23	
24	64	24	37	24		24	174	24	311	24	294
25		25		25		25		25		25	
26	68	26	41	26	30	26	191	26	345	26	334
27		27		27		27		27		27	
28	73	28	44	28		28	210	28	379	28	380
29		29		29		29		29		29	
30	78	30	49	30	36	30	225	30	422	30	429

Report of Report Permeameter

Client :	RTA	Job No. :	06622140
Project :	Pacific Highway Upgrade - Tintenbar to Ewingsdale	Date :	31-Jul-07

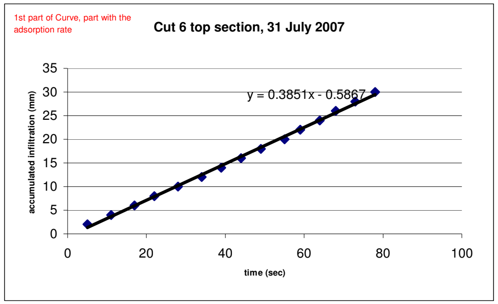
Location: Cut 19 Mid Section

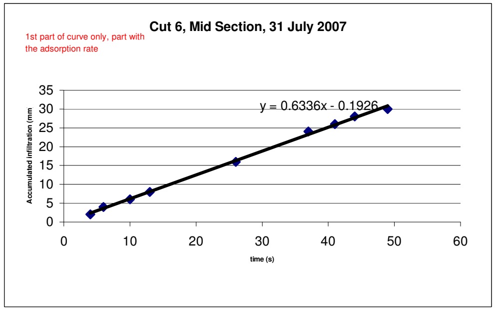
TEST 1		TEST 2		TEST 3	
Depth (mm)	Time (sec)	Depth (mm)	Time (sec)	Depth (mm)	Time (sec)
0	0	0	0	0	0
1	252	1	14	1	19
2	511	2	25	2	44
3	755	3	33	3	67
4	1066	4	49	4	87
5	1309	5	62	5	109
6	1591	6	75	6	138
7	1861	7	90	7	170
8	2135	8	100	8	200
9	2388	9	114	9	229
10	2672	10	127	11	279
		11	140	13	353
		13	169	15	414
		15	199	17	480
		17	230	19	542
		20	286	21	602
		21	294		
		24	348		
		25	369		
		27	408		
		29	441		
		31	482		
		33	522		
		35	556		
		37	585		
		39	615		
		41	649		
		43	689		
		45	728		
		47	758		
		49	790		
		51	834		
		53	874		
		55	913		
		57	951		
		59	995		

Report of Report Permeameter

Client : RTA
Job No. : 06622140
Project Pacific Highway Upgrade - Tintenbar to Ewingsdale
Date : 22-Aug-07

Cut 6 Top Section				Cut 6 Mid Section		Cut 6 Bottom Section					
TEST 1		TEST 2		TEST 1		TEST 1		TEST 2		TEST 3	
Depth	Time (sec)	Depth	Time (sec)	Depth	Time (sec)	Depth	Time (sec)	Depth	Time (sec)	Depth	Time (sec)
0	0	0	0	0	0	0	0	0	0	0	0
1	33	1	134	2	5	2	4	2	2	2	12
2	67	2	252	4	12	4	8	4	6	4	25
3	103	3	316	6	22	6	14	6	11	6	37
4	143	4	422	8	31	8	20	8	15	8	48
5	184	6	775	10	40	10	27	10	20	10	62
6	220	8	1084	12	54	12	34	12	24	12	75
7	260	10	1473	14	62	14	40	14	29	14	87
8	298	12	1816	16	76	16	48	16	34	16	102
9	338	14	2126	18	87	18	57	18	40	18	118
10	380	16	2548	20	98	20	67	20	46	20	132
11	421	18	2967	22	110	22	77	22	52	22	149
12	464	20	3320	24	121	24	87	24	59	24	164
15	603	22	3743	26	131	26	104	26	66	26	179
18	759	24	4201	28	148	30	122	28	76	28	198
20	850			30	160	32	170	35	127	30	214
22	926			32	200	34	181	39	144	32	232
24	1107			34	209	36	194	43	164	34	246
26	1220			38	233	38	208	46	174	36	257
28	1340			40	245	40	224	49	186	38	271
30	1480			42	256	42	230	51	197	40	283
				44	272	44	246	53	204	42	294
				46	286	46	263	55	215	44	320
				48	300	48	280	57	224	46	337
				50	314	50	298	60	242	48	350
				52	331	52	319	65	284	50	360
				54	347	54	340	68	296	52	374
				56	363	56	361	72	319	54	389
				58	379	58	385	74	327	56	404
				60	396	60	412	76	340	58	415
				62	411	62	439	78	352	60	437
				64	463	64	505	80	369	62	451
				66	484	66	532	82	385	64	500
				68	500	68	559	84	402	68	518
				70	520	70	596	86	416	70	528
				72	538	72	623	88	432	72	539
				74	560	74	662	90	446	74	557
				76	574	76	702	92	462	76	571
				78	592	78	745			78	586
				80	620	80	791			80	598
				82	645	82	837			82	617
				84	663	84	895			84	633
				86	678	86	941			86	652
				88	702	88	996			88	668
				90	725	90	1061			90	684
				92	743	92	1108			92	698
				94	759	94	1172			94	714


Cut 6 top section, 31 July 2007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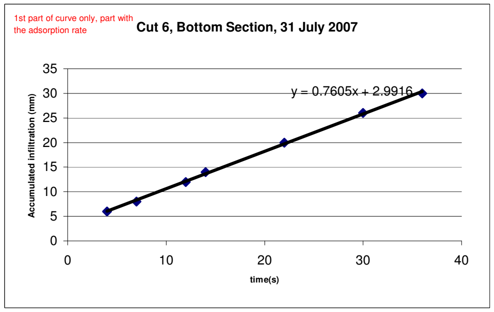
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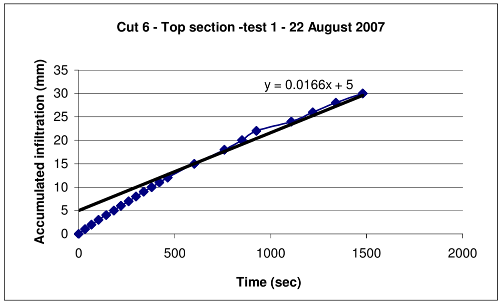
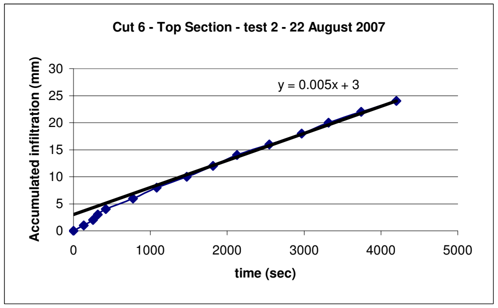

Cut 6 - Top section -test 1 - 22 August 2007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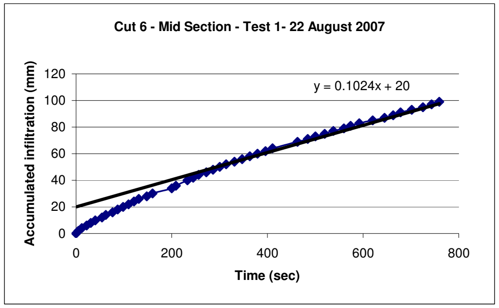
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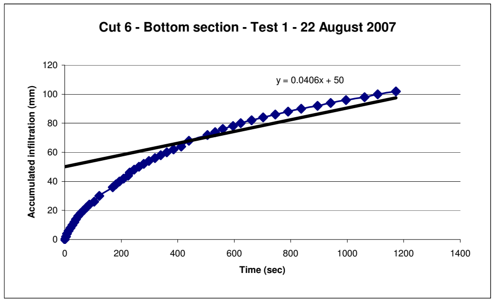
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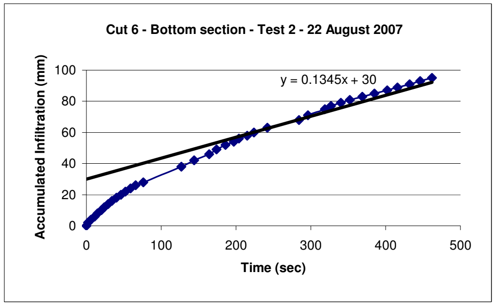
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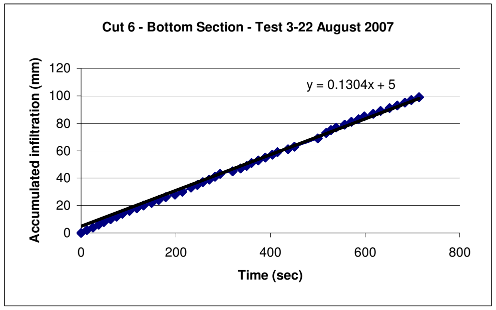
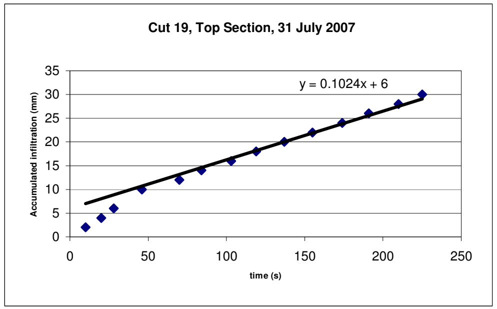
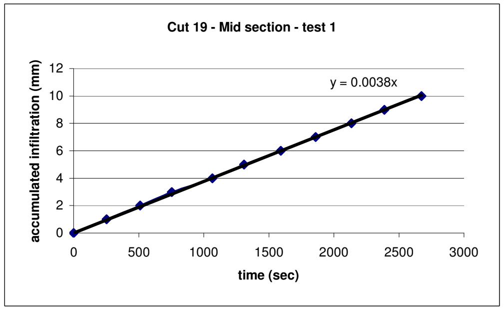
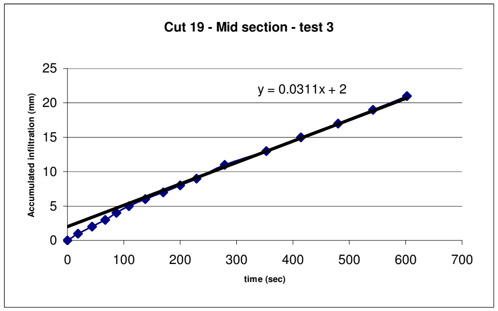

Cut 6 - Bottom Section - Test 3-22 August 2007


Cut 19, Top Section, 31 July 2007


Cut 19 - Mid section - test 1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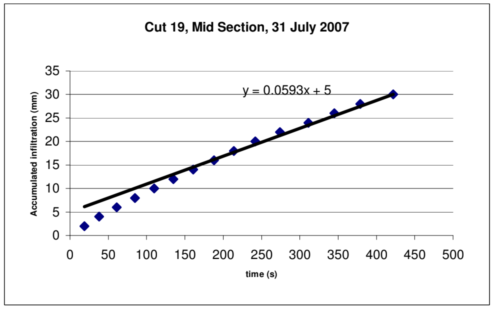
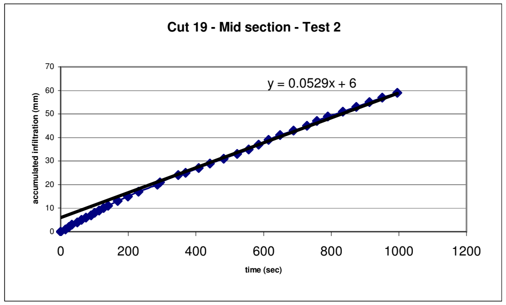
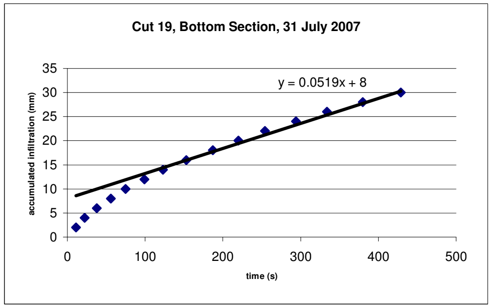

Cut 19, Mid Section, 31 July 2007


Cut 19 - Mid section - Test 2


Cut 19, Bottom Section, 31 July 2007

Appendix C
Borehole Reports, Core Photography and Explanatory Notes

REPORT OF BOREHOLE: BH1021

SHEET: 1 OF 6

CLIENT: ARUP	COORDS: 552130.1 m E 6820900 m N 56 MGA94	DRILL RIG: Pioneer 120	
PROJECT: Pacific Highway Upgrade	SURFACE RL: 120.20 m DATUM: AHD	DRILLER: North Coast Drilling	
LOCATION: Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: BC	DATE: 7/11/06
JOB NO: 06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 32.00 m	CHECKED: CSC	DATE: 6/2/07

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USC Symbol	SOIL / ROCK MATERIAL DESCRIPTION	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
ADT	M		0.0	120.20				MH	Clayey SILT, with trace fine gravel, high plasticity, red brown	D-M	St-VSt	RESIDUAL SOIL
			0.80	0.80 119.40				MH	Clayey Gravelly SILT, high plasticity, red with grey zones, fine to medium subangular gravel. Inferred residual weathered basalt (rock flour)	M		RESIDUAL to Extremely Weathered ROCK
			1.0		SPT 1.00-1.45 m 7,9,13 N = 22							
			1.8								F-St	
WB			2.5		SPT 2.50-2.95 m 1,2,4 N = 6							
			2.65	2.65 117.55					Iron staining appearing in sample in microfractures			
			2.90	2.90 117.30				MH	Clayey SILT, with trace of fine gravel, high plasticity, dark brown with lighter brown and red zones, some <2mm amygdules present. Inferred residual amygdaloidal basalt (rock flour)			
			4.0		SPT 4.00-4.45 m 3,8,9 N = 17							
			5.5		SPT 5.50-5.95 m 2,3,4 N = 7							
			6.5								St	
			7.0		SPT 7.00-7.45 m 4,6,10 N = 16							
			8.0									

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GAP gINT FN. F01a
RL2

REPORT OF BOREHOLE: BH1021

SHEET: 2 OF 6

CLIENT:	ARUP	COORDS: 552130.1 m E 6820900 m N 56 MGA94	DRILL RIG: Pioneer 120
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 120.20 m DATUM: AHD	DRILLER: North Coast Drilling
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: BC DATE: 7/11/06
JOB NO:	06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 32.00 m	CHECKED: CSC DATE: 6/2/07

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USC Symbol	SOIL / ROCK MATERIAL DESCRIPTION	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
WB	M		8.0					MH	Clayey SILT, with trace of fine gravel, high plasticity, dark brown with lighter brown and red zones, some <2mm amygdules present. Inferred residual amygdaloidal basalt (rock flour)	M	St	RESIDUAL to Extremely Weathered ROCK
			8.5		SPT 8.50-8.95 m 3,4,6 N = 10	■						
			10.0	*10.00* 110.20	SPT 10.00-10.45 m 4,5,5 N = 10	■			Brown with red ironstaining, seams of black sandy CLAY			
			11.5	*11.55* 108.65	SPT 11.50-11.64 m 25 for 150mm	■			BASALT, grey with red iron staining, highly weathered, low strength			Weathered ROCK
				11.80 108.40					For Continuation Refer to Sheet 3			
			12.0									
			12.5									
			13.0									
			13.5									
			14.0									
			14.5									
			15.0									
			15.5									
			16.0									

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Golder Associates

REPORT OF BOREHOLE: BH1021

SHEET: 3 OF 6

CLIENT: ARUP	COORDS: 552130.1 m E 6820900 m N 56 MGA94	DRILL RIG: Pioneer 120	
PROJECT: Pacific Highway Upgrade	SURFACE RL: 120.20 m DATUM: AHD	DRILLER: North Coast Drilling	
LOCATION: Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: BC	DATE: 7/11/06
JOB NO: 06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 32.00 m	CHECKED: CSC	DATE: 6/2/07

METHOD	WATER	TCR	RQD (SCR)	DEPTH (meters)	DEPTH RL	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING	DEFECT DESCRIPTION & Additional Observations
				8.0–11.80	11.80	Continuation of Sheet 2		
NMLC						Clayey SILT, brown with red iron staining, zones of intact rock, high plasticity	EW	11.80-11.96m: fine to coarse subangular gravel with clayey silt
		100	66 (100)		11.90 108.30	BASALT, grey with some red and brown iron staining in joints	SW	12.02m: J, 15°, Un, Sm, Ct, 2mm, black silt 12.12m: J, 55°, Un, Sm, Vr, calcite, 1mm 12.13-12.30m: J, 80-90°, Un, Sm, Vr, calcite, 1mm 12.30-12.33m: J, 25°, sp=25mm, Pl, Sm, Sn, 3mm
							FR	12.54m: J, 20°, Pl, Sm, Vr, calcite, 2mm 12.59m: J, 15°, Un, Sm, Vr, calcite, 2mm 12.95m: J, 35°, Un, Sm, Sn, 3mm
		100	83 (100)					13.47m: J, 5°, Un, Sm, Vr, calcite, 1mm 14.05m: J, 30°, Pl, Sm, Vr, calcite, 1mm 14.06-14.14m: J, 85°, Un, Sm, Vr, calcite, <1mm 14.15m: J, 5°, Un, Sm, Sn, 2mm 14.35-14.65m: J, 75°, Un, Sm, Ct, silty clay, 3mm 14.42-15.80m: J, 0°, sp=100-300mm, Un, Sm, Vr, limonite, 1mm
		100	90 (100)					14.85m: J, 35°, Un, Sm, Vr, calcite, 1mm 14.95m: J, 30°, Un, Sm, Vr, calcite, 1mm
							SW	15.20-15.30m: J, 70°, Un, Sm, Ct, limonite, 10mm 15.80-16.05m: J, 80°, sp=80mm, Pl, Sm, Vr, calcite, 2mm
				16.0				

INFERRED STRENGTH Is(50) MPa: EL 0.03 VL 0.1 L 0.3 M 1 H 3 VH 10 EH

AVERAGE DEFECT SPACING (mm): 10 30 100 300 1000 3000

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REPORT OF BOREHOLE: BH1021

SHEET: 4 OF 6

CLIENT: ARUP	COORDS: 552130.1 m E 6820900 m N 56 MGA94	DRILL RIG: Pioneer 120	
PROJECT: Pacific Highway Upgrade	SURFACE RL: 120.20 m DATUM: AHD	DRILLER: North Coast Drilling	
LOCATION: Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: BC	DATE: 7/11/06
JOB NO: 06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 32.00 m	CHECKED: CSC	DATE: 6/2/07

Drilling / Field Material Description

METHOD: NMLC

WATER: 22/08/2007 (approx. 16.7 m); 30/07/2007 (approx. 18.3 m)

TCR	RQD (SCR)
100	80 (100)
100	100 (100)
100	100 (100)
100	100 (100)

DEPTH RL	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING
	BASALT, grey with some red and brown iron staining in joints	SW
17.20 103.00	Amygdaloidal BASALT, mottled brown and red with calcite amygdules (1-3mm)	MW
19.80 100.40	Vesicular BASALT, grey with some green staining, 2-10mm vesicles	MW
21.10 99.10	BASALT, dark grey and pale grey	FR

Defect Information

DEFECT DESCRIPTION & Additional Observations

16.18m: J, 0-20°, Un, Sm, Vr, calcite, 1mm
16.28-16.45m: J, 75°, Un, Sm, Sn, 4mm, iron staining
16.80m: J, 40°, Un, Sm, Vr, calcite, 1mm
17.01m: J, 55°, Un, Sm, Sn, 3mm
17.05m: J, 0°, Un, Sm, Ct, 2mm, clayey silt
17.17m: J, 5°, Un, Sm, Cn, 1mm
17.50-17.56m: J, 40°, sp=60mm, Pl, Sm, Cn, 1mm
17.60m: J, 30°, Un, Sm, Ct, silty clay, 1mm
17.68m: J, 40°, Un, Sm, Ct, silty clay, 5mm
17.83-18.40m: J, 0-15°, sp=30-200mm, Un, Sm, Cn, 2mm
18.73m: J, 0°, Un, Sm, Cn, 1mm
18.81m: J, 0°, Pl, Sm, Cn, 2mm
19.01m: J, 65°, Un, Sm, Cn, 2mm
20.50m: J, 65°, Un, Sm, Cn, 1mm
20.58m: J, 55°, Un, Sm, Cn, 1mm
21.13m: J, 0-20°, St, Sm, Vr, calcite, 2mm
21.47m: J, 0-5°, Un, Sm, Ct, silty clay, 4mm
21.68m: J, 20°, Un, Sm, Ct, silty clay, 6mm
22.07m: J, 5°, Un, Sm, Vr, calcite, 3mm
22.36m: J, 10°, Pl, Sm, Vr, calcite, 1mm
22.75-23.43m: J, 90°, Un, Sm, Vr, calcite, <1mm
23.15-24.60m: J, 0-5°, sp=100-300mm, Un, Sm, Vr, calcite, 1-3mm

Golder Associates

REPORT OF BOREHOLE: BH1021

CLIENT: ARUP	COORDS: 552130.1 m E 6820900 m N 56 MGA94	SHEET: 5 OF 6	
PROJECT: Pacific Highway Upgrade	SURFACE RL: 120.20 m DATUM: AHD	DRILL RIG: Pioneer 120	
LOCATION: Tintenbar to Ewingsdale	INCLINATION: -90°	DRILLER: North Coast Drilling	
JOB NO: 06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 32.00 m	LOGGED: BC	DATE: 7/11/06
		CHECKED: CSC	DATE: 6/2/07

Drilling

METHOD	WATER	TCR	RQD (SCR)	DEPTH (meters)
NMLC				24.0–24.9
NMLC		100	100 (100)	24.9–27.9
NMLC		100	100 (100)	27.9–31.0
NMLC		100		31.0–32.0

Field Material Description

DEPTH RL	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING
	BASALT, dark grey and pale grey	FR
92.60	Vertical microfractures at 27.60-27.90m	
27.90		
30.50 89.70	Vesicular BASALT, grey 2-10mm vesicules, some green calcite deposits in vesicles	MW
32.00	END OF BOREHOLE @ 32.00 m Reached target depth Piezometer installed	

INFERRED STRENGTH $Is_{(50)}$ MPa: EL 0.03 VL 0.1 L 0.3 M 1 H 3 VH 10 EH

Defect Information

DEFECT DESCRIPTION & Additional Observations

- 24.50m: J, 20°, Un, Sm, Vr, calcite, 1mm
- 24.75m: IS, 55°, Pl, Sm, 2mm, calcite filling
- 24.90m: J, 20°, Un, Sm, Vr, calcite, 2mm
- 25.03-27.90m: J, 0-5°, sp=100-400mm, Un, Sm, Vr, calcite, 1mm
- 25.30-25.44m: J, 75°, Pl, Sm, Sn, fused, iron staining
- 25.50m: J, 30°, Un, Sm, Vr, calcite, 2mm
- 25.51-25.58m: J, 80°, Sm, Vr, calcite, 1mm
- 26.25m: J, 20°, Pl, Sm, Vr, calcite, 1mm
- 26.60-26.90m: J, 80°, Un, Sm, Vr, calcite, <1mm
- 26.90m: J, 55°, Un, Sm, Vr, calcite, <1mm
- 27.70m: J, 30°, Un, Sm, Vr, calcite, 1mm
- 27.80m: J, 20°, Un, Sm, Vr, calcite, 1mm
- 27.90-28.25m: J, 80°, Un, Sm, Vr, calcite, 1mm
- 28.30-30.40m: J, 0-5°, sp=200-300mm, Un, Sm, Vr, calcite, 1mm
- 29.50m: J, 20°, Pl, Sm, Vr, calcite, 1mm
- 30.50m: J, 65°, Un, <1mm
- 31.20m: J, 60°, Pl, Sm, Vr, calcite, 1mm
- 31.30-31.80m: J, 35°, sp=200mm, Un, Sm, Vr, calcite, 1mm

AVERAGE DEFECT SPACING (mm): 10 30 100 300 1000 3000

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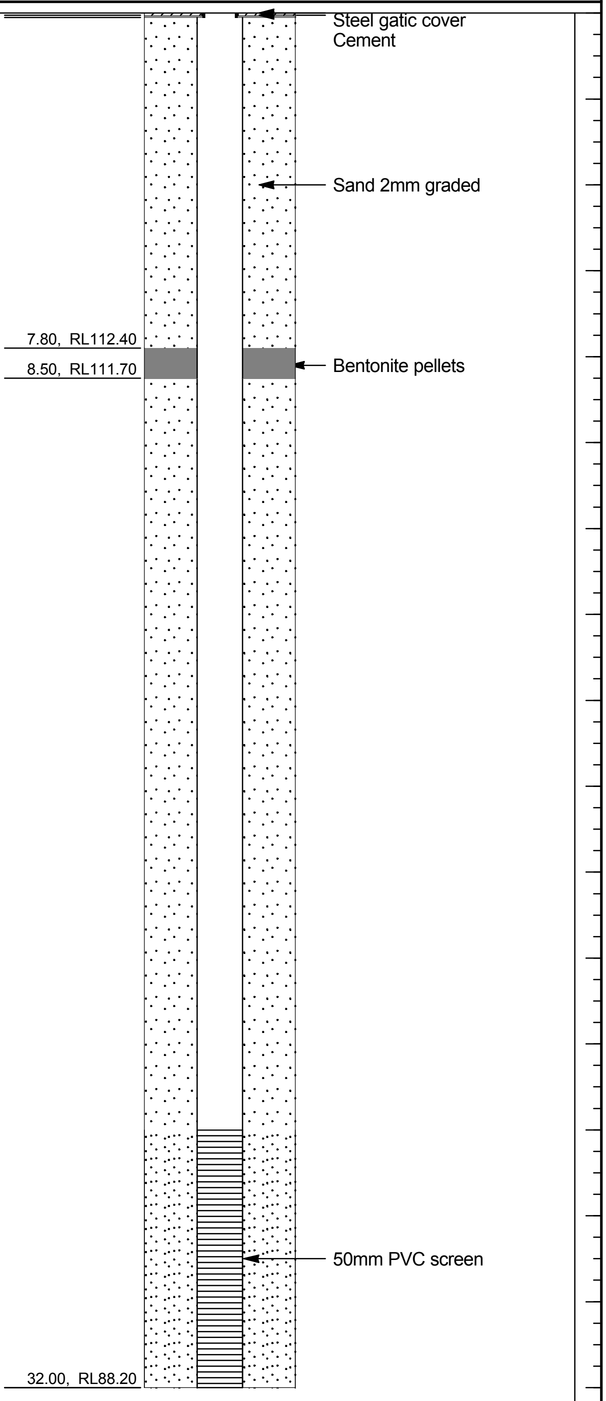
Golder Associates

REPORT OF STANDPIPE INSTALLATION: BH1021

CLIENT: ARUP	COORDS: 552130.1 m E 6820900 m N 56 MGA94	SHEET: 1 OF 1	
PROJECT: Pacific Highway Upgrade	SURFACE RL: 120.20 m DATUM: AHD	DRILL RIG: Pioneer 120	
LOCATION: Tintenbar to Ewingsdale	INCLINATION: -90°	DRILLER: North Coast Drilling	
JOB NO: 06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 32.00 m	LOGGED: BC	DATE: 7/11/06
		CHECKED: CSC	DATE: 6/2/07

Drilling | **Field Material Description** | **Instrumentation Details**

METHOD	WATER	DEPTH RL	ABBREVIATED SOIL / ROCK MATERIAL DESCRIPTION (Refer to Report of Borehole For Details)
ADT		120.20	Clayey SILT
		0.80 119.40	Clayey SILT
WB		2.90 117.30	Clayey SILT
NMLC		11.55	BASALT
		108.30	Clayey SILT
			BASALT
	22/08/2007	17.20 103.00	BASALT
	30/07/2007	19.80 100.40	BASALT
		21.10 99.10	BASALT
		27.60 92.30	
		30.50 89.70	BASALT
		32.00 88.20	



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REPORT OF CORE PHOTOGRAPHS: BH1021

SHEET: 1 OF 3

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 552130.1 m E 6820900 m N 56 MGA94
SURFACE RL: 120.20 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 32.00 m

DRILL RIG: Pioneer 120
DRILLER: North Coast Drilling
LOGGED: BC DATE: 7/11/06
CHECKED: CSC DATE: 6/2/07

This report of core photographs must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

Golder Associates

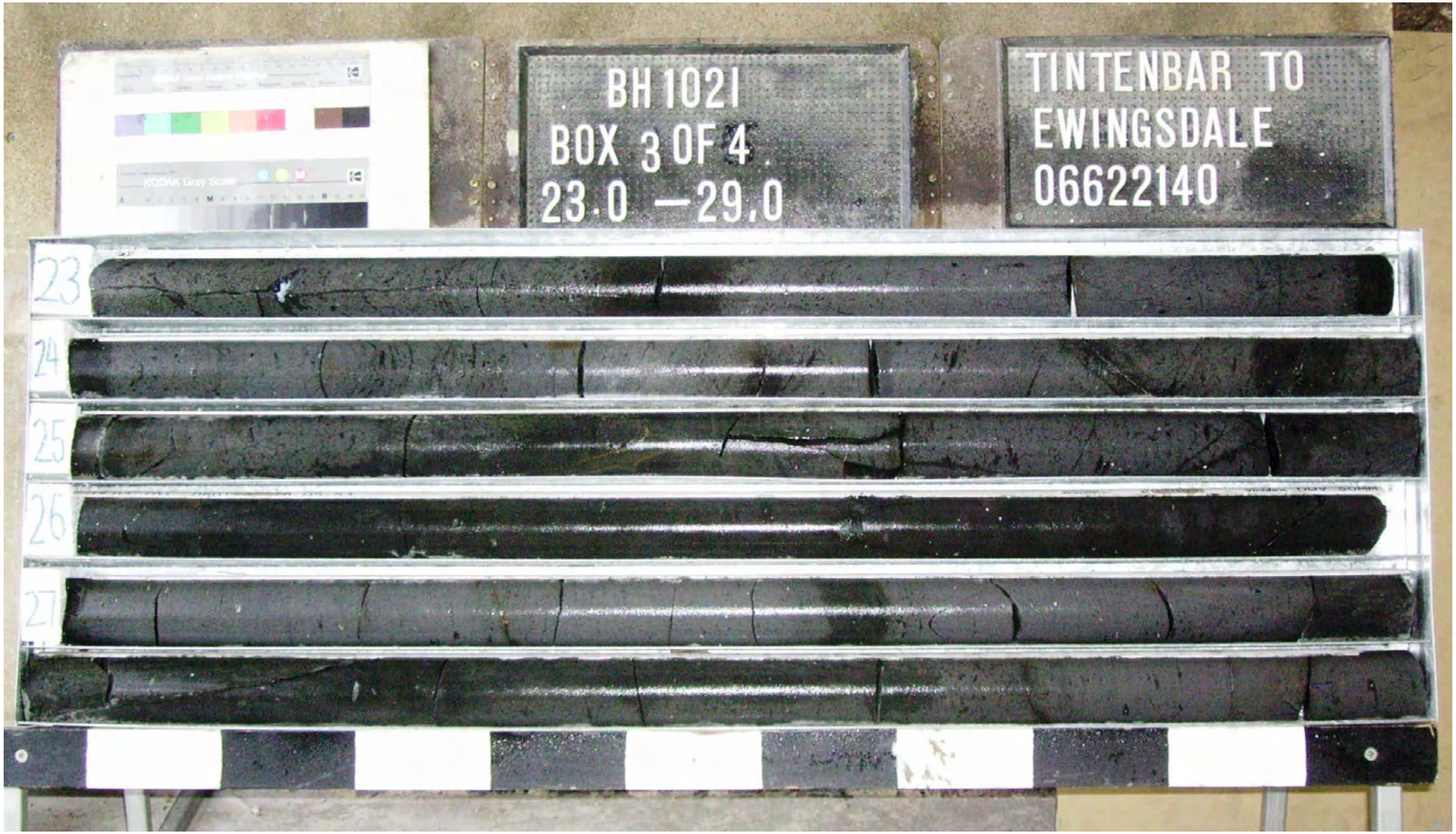
REPORT OF CORE PHOTOGRAPHS: BH1021

SHEET: 2 OF 3

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 552130.1 m E 6820900 m N 56 MGA94
SURFACE RL: 120.20 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 32.00 m

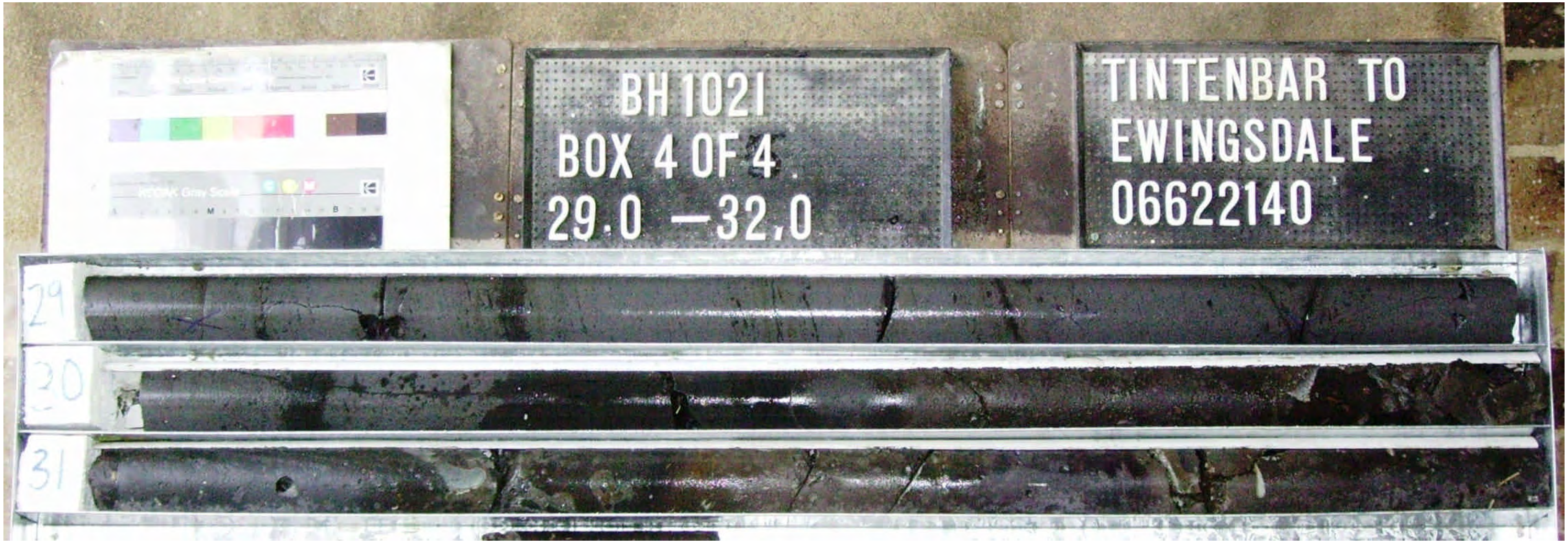
DRILL RIG: Pioneer 120
DRILLER: North Coast Drilling
LOGGED: BC DATE: 7/11/06
CHECKED: CSC DATE: 6/2/07



Golder Associates

REPORT OF CORE PHOTOGRAPHS: BH1021

CLIENT: ARUP	COORDS: 552130.1 m E 6820900 m N 56 MGA94	SHEET: 3 OF 3	
PROJECT: Pacific Highway Upgrade	SURFACE RL: 120.20 m DATUM: AHD	DRILL RIG: Pioneer 120	
LOCATION: Tintenbar to Ewingsdale	INCLINATION: -90°	DRILLER: North Coast Drilling	
JOB NO: 06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 32.00 m	LOGGED: BC	DATE: 7/11/06
		CHECKED: CSC	DATE: 6/2/07



Golder Associates

REPORT OF BOREHOLE: BH2000

SHEET: 1 OF 2

CLIENT:	ARUP	COORDS: 552131.3 m E 6820901.9 m N 56 MGA94	DRILL RIG: Pioneer 120		
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 120.18 m DATUM: AHD	DRILLER: North Coast Drilling		
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: AM	DATE: 8/7/07	
JOB NO:	06622140	HOLE DIA: 100 mm HOLE DEPTH: 11.00 m	CHECKED: CSC	DATE: 10/8/07	

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USC Symbol	SOIL / ROCK MATERIAL DESCRIPTION	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
ADT	L	Groundwater Not Observed	0.0	120.18				CI	Sandy CLAY, medium plasticity, red brown, medium grained sand, with fine subangular gravel, trace root fibres upper 200mm	M (<PL)		RESIDUAL SOIL
			2.0	2.00 118.18				CH	Sandy CLAY, high plasticity, brown	M (~PL)		
			5.0	5.00 115.18					BASALT, extremely weathered, extremely low strength, reworks to CLAY, high plasticity, red brown, with fine to medium grained sand.			EXTREMELY WEATHERED ROCK
	M		7.5									
			8.0									

This report of borehole must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

GAP gINT FN. F01a
RL2

GAP6_0-BETA_NEW ONE_25.06.07 SRAS ALTERED BY DATGEL 2007-07-02.GLB FULL PAGE J:\06PROJ\101-150\06622140_ARUP_T2E PREFERRED ROUTE\7000 FIELD AND LABORATORY DATA\7870 GINT\06622140 PH.GPJ GAP6_0-BETA-PH.GDT 05/09/2007 2:36:24 PM

Golder Associates

REPORT OF BOREHOLE: BH2000

SHEET: 2 OF 2

CLIENT:	ARUP	COORDS: 552131.3 m E 6820901.9 m N 56 MGA94	DRILL RIG: Pioneer 120		
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 120.18 m DATUM: AHD	DRILLER: North Coast Drilling		
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: AM	DATE: 8/7/07	
JOB NO:	06622140	HOLE DIA: 100 mm HOLE DEPTH: 11.00 m	CHECKED: CSC	DATE: 10/8/07	

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USC Symbol	SOIL / ROCK MATERIAL DESCRIPTION	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
ADT	M		8.0 8.5 9.0 9.5 10.0 10.5						BASALT, extremely weathered, extremely low strength, reworks to CLAY, high plasticity, red brown, with fine to medium grained sand.			EXTREMELY WEATHERED ROCK
			11.0 11.5 12.0 12.5 13.0 13.5 14.0 14.5 15.0 15.5 16.0	*11.00* 109.18					END OF BOREHOLE @ 11.00 m Piezometer installed Note: borehole drilled for piezometer installation only			

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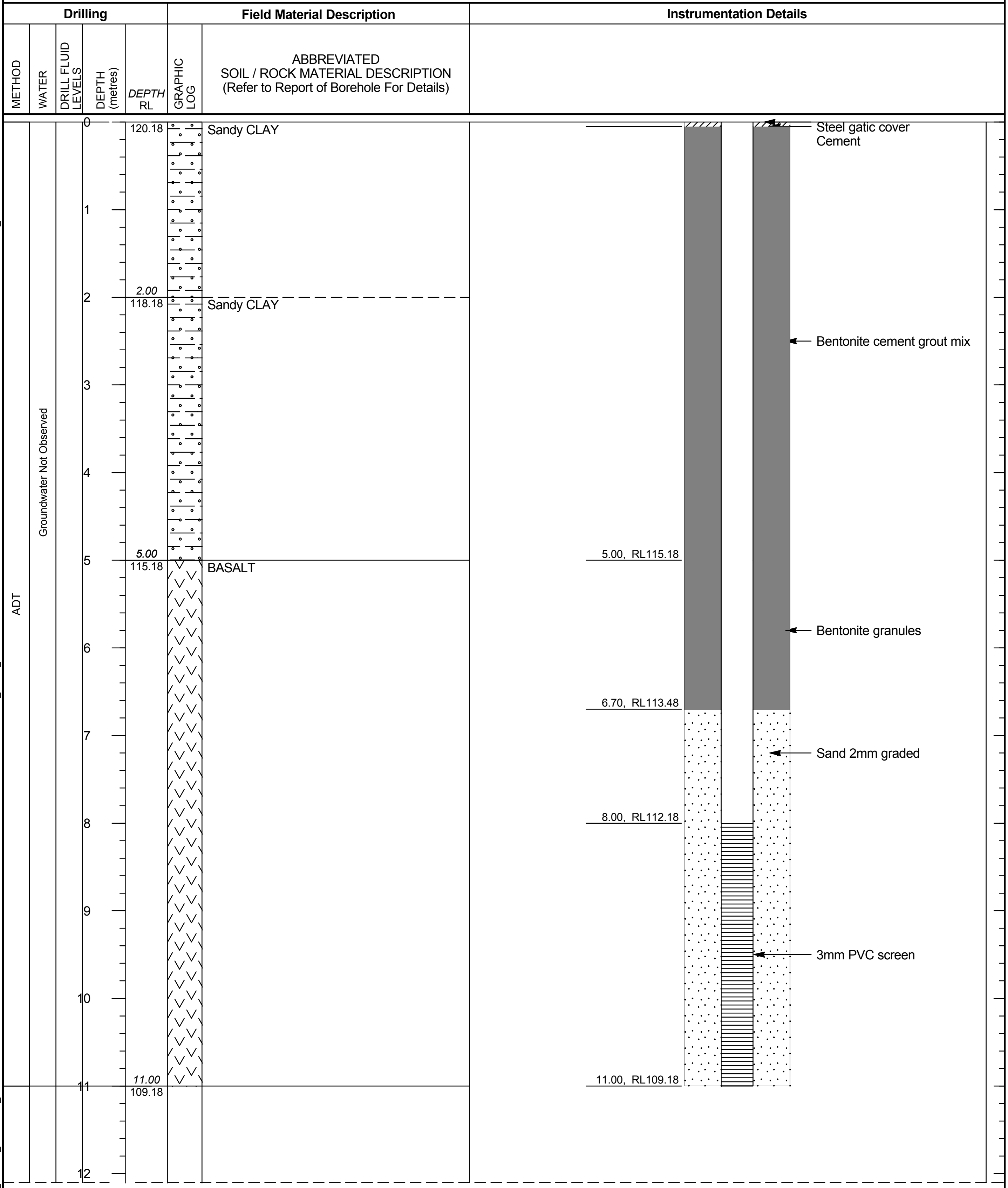
REPORT OF STANDPIPE INSTALLATION: BH2000

SHEET: 1 OF 1

CLIENT:	ARUP	COORDS: 552131.3 m E 6820901.9 m N 56 MGA94	DRILL RIG: Pioneer 120
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 120.18 m DATUM: AHD	DRILLER: North Coast Drilling
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: AM DATE: 8/7/07
JOB NO:	06622140	HOLE DIA: 100 mm HOLE DEPTH: 11.00 m	CHECKED: CSC DATE: 10/8/07



DEPTH / RL	ABBREVIATED SOIL / ROCK MATERIAL DESCRIPTION
120.18	Sandy CLAY
2.00 118.18	Sandy CLAY
5.00 115.18	BASALT
11.00 109.18	

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GAP gINT FN. F17
RL0

Golder Associates

REPORT OF BOREHOLE: BH2001

SHEET: 1 OF 4

CLIENT:	ARUP	COORDS: 552152.5 m E 6820944.8 m N 56 MGA94		DRILL RIG: Pioneer 120	
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 117.82 m	DATUM: AHD	DRILLER: North Coast Drilling	
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°		LOGGED: AM	DATE: 10/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm	HOLE DEPTH: 20.10 m	CHECKED: CSC	DATE: 10/8/07

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USC Symbol	SOIL / ROCK MATERIAL DESCRIPTION	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
ADT	L		0.0	117.82				CH	Sandy CLAY, high plasticity, red brown, medium grained sand, with root fibres upper 100mm	M (<PL)	St	RESIDUAL SOIL
			0.5									
			1.0		SPT 1.00-1.37 m 8,11,9/70mm HB	■						
				1.30 116.52					Grading to extremely weathered basalt			
			1.5	*1.50* 116.32					For Continuation Refer to Sheet 2			
			2.0									
			2.5									
			3.0									
			3.5									
			4.0									
			4.5									
			5.0									
			5.5									
			6.0									
			6.5									
			7.0									
			7.5									
			8.0									

Golder Associates

REPORT OF BOREHOLE: BH2001

SHEET: 2 OF 4

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 552152.5 m E 6820944.8 m N 56 MGA94
SURFACE RL: 117.82 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 20.10 m

DRILL RIG: Pioneer 120
DRILLER: North Coast Drilling
LOGGED: AM DATE: 10/7/07
CHECKED: CSC DATE: 10/8/07

METHOD	WATER	TCR	RQD (SCR)	DEPTH / RL	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING	DEFECT DESCRIPTION & Additional Observations
				1.50	Continuation of Sheet 1		
NMLC		100	30 (70)	1.65	BASALT, dark grey	FR	
				116.17	red and pale grey, with heavy iron staining	HW	1.63-1.96m: Set 1, J, 15°, sp=80mm, Un, Ro, Sn, Iron staining
		75	38 (72)	2.30			2.15m: J, 0°, Un, Sm, Cn 2.22m: J
				2.40	NO CORE 2.30-2.40m		
	10%	100	25 (65)	115.42 / 2.65	BASALT, red and pale grey, with heavy iron staining	HW	2.40-2.52m: Core recovered as fragmented rock
				2.75	dark grey	SW	2.61-3.00m: Set 1, J, 5°, sp=80mm, Pl, Sm, Sn, Iron staining
				115.07 / 3.40	red and pale grey, with heavy iron staining	HW	3.00-3.30m: Network of iron cemented microfractures 3.08m: J, 5°, Un, Sm, Sn, Iron staining
	50%	53	30 (60)	114.42 / 4.20	red and pale grey, with 1-2mm diameter iron stained amygdules		3.30-3.55m: Core recovered as fragmented rock 3.65m: J, 20°, Pl, Ro, Cn 4.14m: J, 5°, Un, Ro, Cn
				113.62 / 4.90	NO CORE 4.20-4.90m		
		88	13 (44)	112.92 / 5.60	BASALT, brown and pale grey, with iron staining	HW	5.10-5.60m: Set 1, J, 10°, sp=60mm, Un, Ro, Cn
				5.70	NO CORE 5.60-5.70m		
		40	20 (25)	112.12 / 6.10	BASALT, brown and pale grey, with iron staining	HW	5.70-5.80m: Core recovered as fragmented rock 5.88m: J, 0°, Un, Ro, Cn 6.03m: J, 5°, Un, Sm, Cn
				111.72 / 6.70	NO CORE 6.10-6.70m		
		66	11 (28)	111.12 / 7.30	BASALT, brown and pale grey, with iron staining	HW	6.73-6.83m: Core recovered as fragmented rock 6.91m: J, 10°, Un, Ro, Cn 7.06m: J, 50°, Un, Ro, Cn 7.11m: J, 45°, Pl, Ro, Cn 7.18m: J, 10°, Un, Sm, Cn
				110.52 / 7.65	NO CORE 7.30-7.65m		
		36	0	110.17 / 7.90	BASALT, brown and pale grey, with iron staining	HW	7.69m: J, 10°, Pl, Ro, Cn 7.73m: J, 0°, Pl, Sm, Cn 7.78-7.90m: 7.9°, Core recovered as fragmented rock
				109.92	NO CORE 7.90-8.30m		

Golder Associates

REPORT OF BOREHOLE: BH2001

SHEET: 3 OF 4

CLIENT:	ARUP	COORDS: 552152.5 m E 6820944.8 m N 56 MGA94		DRILL RIG: Pioneer 120	
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 117.82 m	DATUM: AHD	DRILLER: North Coast Drilling	
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°		LOGGED: AM	DATE: 10/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm	HOLE DEPTH: 20.10 m	CHECKED: CSC	DATE: 10/8/07

Drilling						Field Material Description		Defect Information
METHOD	WATER	TCR	RQD (SCR)	DEPTH (meters)	DEPTH RL	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING	DEFECT DESCRIPTION & Additional Observations
NMLC			(0)	8.0	8.30	NO CORE 7.90-8.30m		
		100	50 (86)	8.5	109.52	BASALT, brown and pale grey, with iron staining	HW	8.35-8.70m: Set 1, J, 15°, sp=70mm, Pl, Ro, Cn 8.85m: J, 0°, Pl, Sm, Cn 8.91m: J, 0°, Un, Sm, Cn
		88	35 (50)	9.0 9.5	9.70			9.11-9.70m: Set 1, J, 20°, sp=90mm, Un, Sm, Sn, Slight iron staining
					108.12 10.00	NO CORE 9.70-10.00m		
	70%	83	66 (80)	10.0 10.5	107.82	BASALT, grey and brown, with 2-10mm diameter calcium amygdules, with iron staining	HW	10.06m: J, 5°, Un, Ro, Cn 10.19m: J, 0°, Pl, Ro, Cn 10.33m: J, 25°, Un, Ro, Cn 10.50m: J, 60°, Pl, Sm, Ct, 2mm, Clay 10.54m: J, 50°, Pl, Sm, Cn 10.88-10.95m: Core recovered as fragmented rock
		100	33 (89)	11.0 11.5				11.17m: J, 10°, Pl, Sm, Cn 11.26m: J, 45°, Un, Ro, Cn 11.39-11.65m: Set 1, J, 20°, sp=70mm, Pl, Ro, Sn, Iron staining 11.72-11.88m: Set 1, J, 40°, sp=60mm, Pl, Sm, Sn, Slight iron stain 11.85m: J, 0°, Un, Ro, Cn
		100	25 (44)	12.0 12.5				11.90m: J, 0°, Un, Sm, Cn 12.12m: J, 35°, Un, Sm, Cn 12.28m: J, 35°, Pl, Sm, Cn 12.37m: J, 30°, Un, Sm, Cn 12.37-12.47m: DS 12.47-12.70m: Set 1, J, Un, Ro, Cn
		100	56 (64)	13.0 13.5 14.0				13.13-13.23m: Core recovered as fragmented rock 13.29m: J, 60°, Pl, Sm, Sn, Slight iron staining 13.34m: J, 0°, Pl, Sm, Sn, Slight iron staining 13.43-13.53m: Set 1, J, 0-10°, sp=40mm, Un, Sm, Cn 13.70m: J, 10°, Pl, Sm, Vr, calcite, 3mm thick 13.81m: J, 30°, Un, Ro, Cn 14.12-14.24m: Core recovered as fragmented rock
		83	25 (50)	14.5 15.0	15.20			14.29m: J, 25°, Un, Ro, Cn 14.36-14.74m: Set 1, J, 40°, sp=110mm, Pl, Ro, Cn 14.82m: J, 15°, Un, Ro, Cn 15.00-15.13m: J, Core recovered as fragmented rock
					102.62 15.40	NO CORE 15.20-15.40m		
		86	14 (50)	15.5 16.0	102.42 16.00	BASALT, pale grey and brown, with 2-10mm diameter calcium amygdules, with iron staining	HW	15.55-15.87m: Set 1, J, 5°, sp=110mm, Un, Ro, Cn

GRAPHIC LOG | INFERRED STRENGTH Is(50) MPa: 0.03 0.1 0.3 1 3 10 — EL VL L M H VH EH | AVERAGE DEFECT SPACING (mm): 10 30 100 300 1000 3000

GAP6_0-BETA_NEW ONE_25.06.07 SRAS ALTERED BY DATGEL 2007-07-02.GLB CORED BOREHOLE J:\06PROJ\101-150\06622140_ARUP_T2E PREFERRED ROUTE\7000 FIELD AND LABORATORY DATA\7870 GINT\06622140 PH.GPJ GAP6_0-BETA-PH.GDT 05/09/2007 2:37:17 PM

REPORT OF BOREHOLE: BH2001

SHEET: 4 OF 4

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 552152.5 m E 6820944.8 m N 56 MGA94
SURFACE RL: 117.82 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 20.10 m

DRILL RIG: Pioneer 120
DRILLER: North Coast Drilling
LOGGED: AM DATE: 10/7/07
CHECKED: CSC DATE: 10/8/07

Drilling						Field Material Description		Defect Information
METHOD	WATER	TCR	RQD (SCR)	DEPTH (meters)	DEPTH RL	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING	DEFECT DESCRIPTION & Additional Observations
NMLC				16.0	16.15 101.67	NO CORE 16.00-16.15m		15.95-16.00m: Core recovered as fragmented rock
		95	22 (72)	16.5		BASALT, red brown and pale grey, with 2-10mm diameter calcium amygdules, with iron staining	HW	16.23-17.27m: Set 1, J, 0-10°, sp=50-100mm, Pl, Ro, Cn
		100	38 (75)	17.0 17.5	17.00 100.82	As Above, pale grey and brown		17.37m: J, 30°, Un, Sm, Sn, Slight iron staining 17.41m: J, 30°, Un, Sm, Sn, Slight iron staining 17.55m: J, 15°, Pl, Ro, Sn, Iron staining 17.60m: J, 30°, Pl, Ro, Sn, Iron staining
		100	42 (54)	18.0				17.82m: J, 35°, Un, Sm, Cn 17.95-18.40m: Core recovered as fragmented rock
	22/08/2007			18.5	18.40 99.42	BASALT, dark grey, with trace iron staining	MW-SW	18.43m: J, 10°, Un, Sm, Cn 18.62m: J, sp=70-90mm, Un, Sm, Sn, Heavy iron staining 18.64-19.15m: Set 1, J, 0-5°, sp=30-60mm, Pl, Sm, Sn, Iron staining 18.76m: 75°, Un, Sm, Sn, Iron staining
	30/07/2007	100	0 (74)	19.0 19.5 20.0	20.10			19.20-20.05m: Set 1, J, 0-10°, sp=70mm, Un, Sm, Sn, Slight iron staining 19.35-19.90m: Set 2, J, 35°, sp=100mm, Pl, Sm, Sn, Slight iron staining
				20.5 21.0 21.5 22.0 22.5 23.0 23.5 24.0		END OF BOREHOLE @ 20.10 m		

INFERRED STRENGTH Is(50) MPa: EL 0.03 VL 0.1 L 0.3 M 1 H 3 VH 10 EH

AVERAGE DEFECT SPACING (mm): 10 30 100 300 1000 3000

GRAPHIC LOG

This report of borehole must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

GAP gINT FN. F02a
RL2

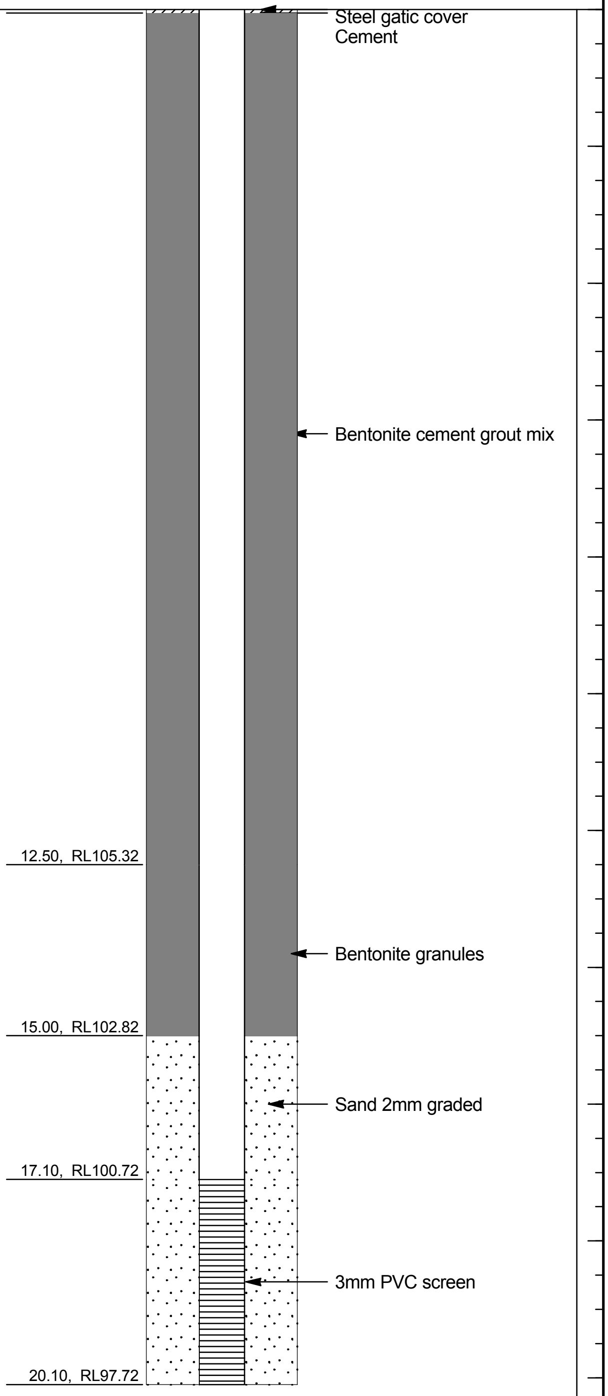
REPORT OF STANDPIPE INSTALLATION: BH2001

SHEET: 1 OF 1

CLIENT:	ARUP	COORDS: 552152.5 m E 6820944.8 m N 56 MGA94	DRILL RIG: Pioneer 120
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 117.82 m DATUM: AHD	DRILLER: North Coast Drilling
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: AM DATE: 10/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 20.10 m	CHECKED: CSC DATE: 10/8/07

Drilling					Field Material Description	
METHOD	WATER	DRILL FLUID LEVELS	DEPTH (metres)	*DEPTH* RL	GRAPHIC LOG	ABBREVIATED SOIL / ROCK MATERIAL DESCRIPTION (Refer to Report of Borehole For Details)
ADT			0	117.82		Sandy CLAY
NMLC				116.17		BASALT
			2	*2.30*		BASALT
	10%					BASALT
				115.17		BASALT
	50%		4	*4.20* 113.62		
				4.90 112.92		BASALT
				5.60		
			6	*6.10*		BASALT
				111.72 *6.70*		
				111.12		BASALT
				7.30		
				7.65		BASALT
			8	*8.30* 109.52		BASALT
				9.70		
	70%		10	*10.00* 107.82		BASALT
			12			
			14			
				15.20		NO CORE
				102.42		BASALT
			16	*16.00* 101.67		NO CORE BASALT
			18	*18.40* 99.42		BASALT
	22/08/2007					
	30/07/2007		20	*20.10* 97.72		
			22			

Instrumentation Details



This report of standpipe installation must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

GAP gINT FN. F17
RL0

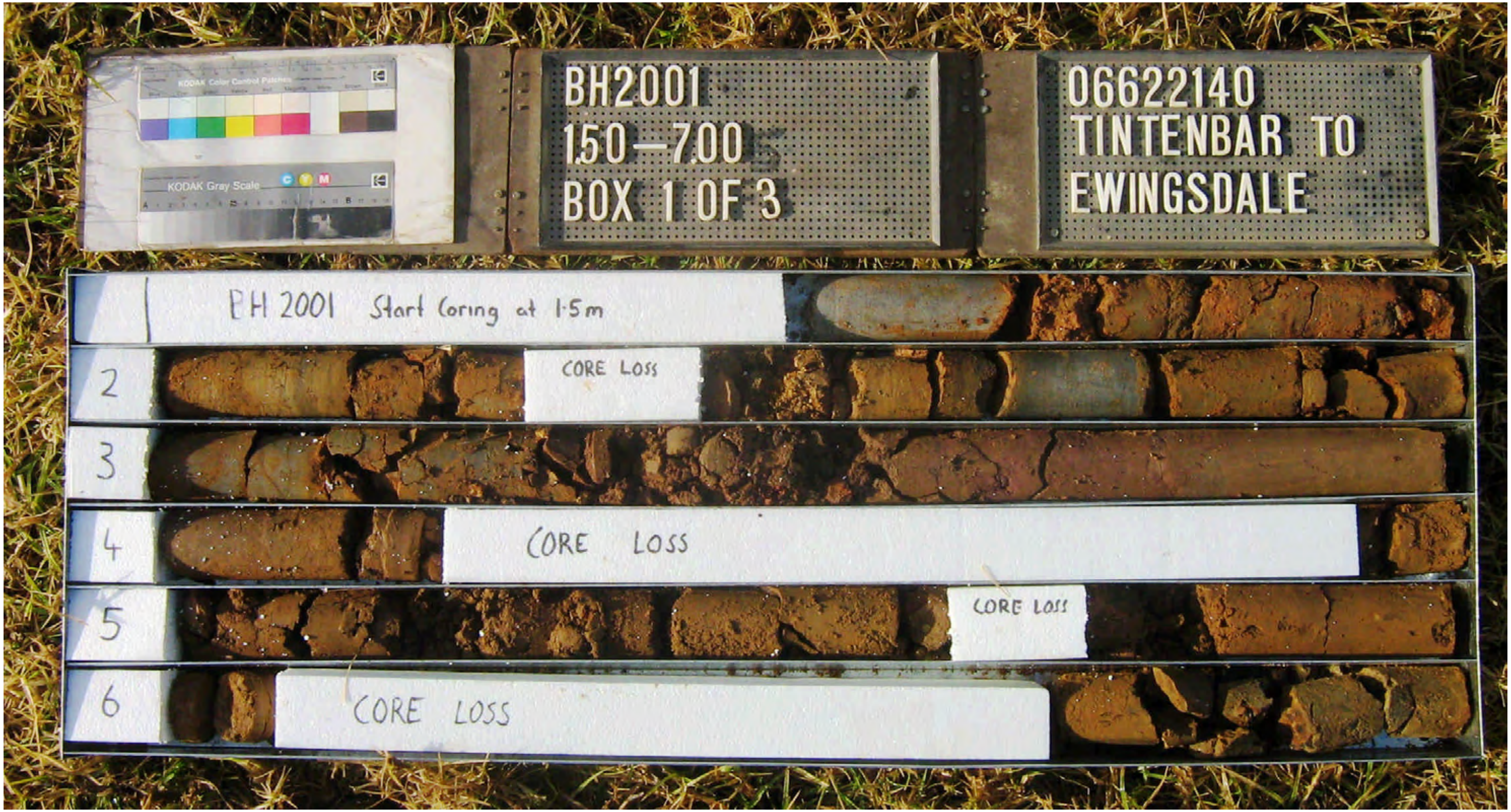
Golder Associates

REPORT OF CORE PHOTOGRAPHS: BH2001

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 552152.5 m E 6820944.8 m N 56 MGA94
SURFACE RL: 117.82 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 20.10 m

SHEET: 1 OF 3
DRILL RIG: Pioneer 120
DRILLER: North Coast Drilling
LOGGED: AM DATE: 10/7/07
CHECKED: CSC DATE: 10/8/07



REPORT OF CORE PHOTOGRAPHS: BH2001

SHEET: 2 OF 3

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 552152.5 m E 6820944.8 m N 56 MGA94
SURFACE RL: 117.82 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 20.10 m

DRILL RIG: Pioneer 120
DRILLER: North Coast Drilling
LOGGED: AM DATE: 10/7/07
CHECKED: CSC DATE: 10/8/07

This report of core photographs must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

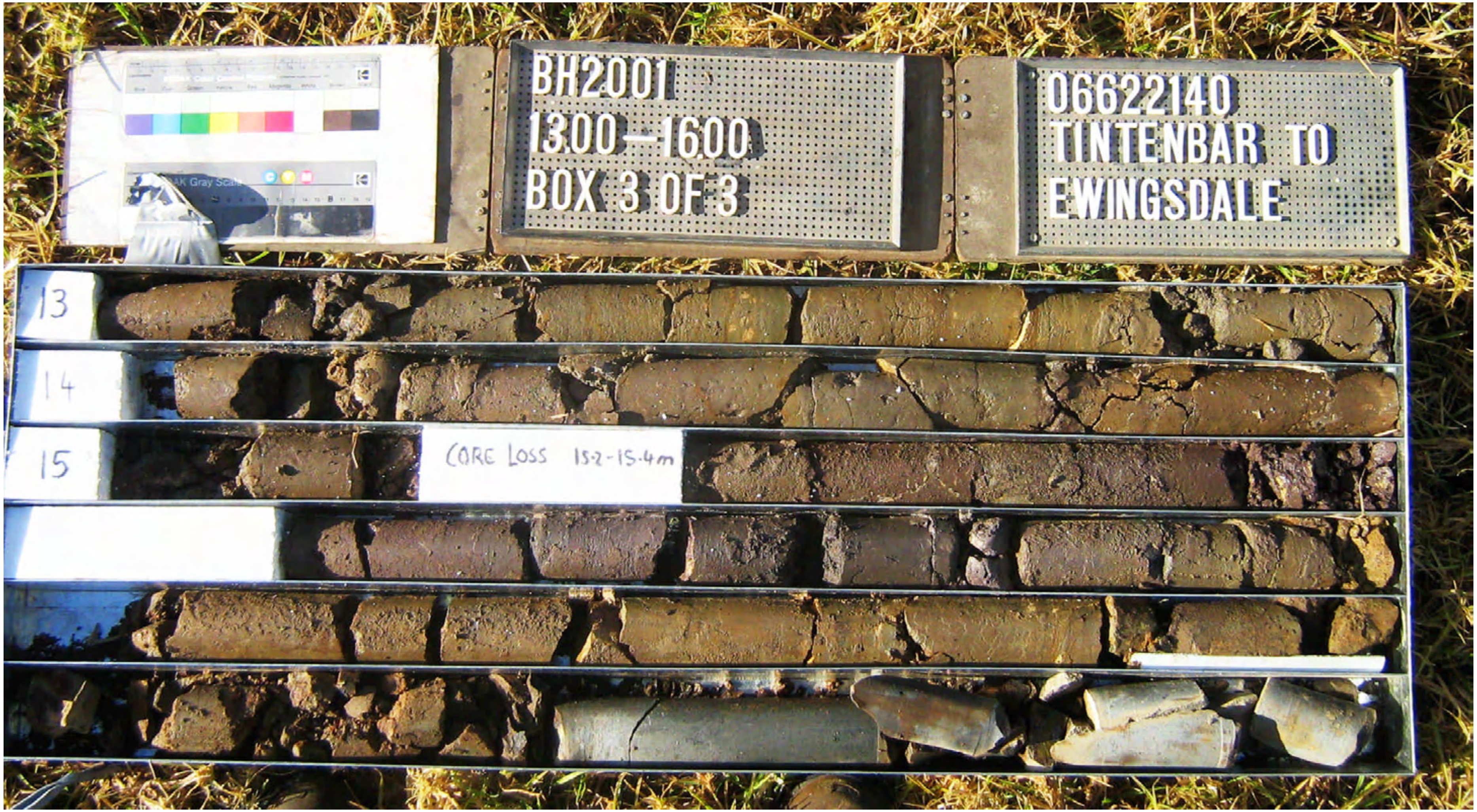
REPORT OF CORE PHOTOGRAPHS: BH2001

SHEET: 3 OF 3

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 552152.5 m E 6820944.8 m N 56 MGA94
SURFACE RL: 117.82 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 20.10 m

DRILL RIG: Pioneer 120
DRILLER: North Coast Drilling
LOGGED: AM DATE: 10/7/07
CHECKED: CSC DATE: 10/8/07



This report of core photographs must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

REPORT OF BOREHOLE: BH2002

SHEET: 1 OF 2

CLIENT:	ARUP	COORDS: 552152.6 m E 6820942.2 m N 56 MGA94	DRILL RIG: Pioneer 120		
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 118.03 m DATUM: AHD	DRILLER: North Coast Drilling		
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: AM	DATE: 11/7/07	
JOB NO:	06622140	HOLE DIA: 100 mm HOLE DEPTH: 10.50 m	CHECKED: CSC	DATE: 10/8/07	

Drilling: METHOD	Drilling: PENETRATION RESISTANCE	Drilling: WATER	DEPTH (metres)	DEPTH RL	Sampling: SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USC Symbol	SOIL / ROCK MATERIAL DESCRIPTION	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
ADT	L	Ground water not encountered	0.0	118.03				CH	Silty CLAY, high plasticity, red brown, with fine to medium grained sand	M (<PL)		RESIDUAL SOIL
			2.00	2.00 116.03					BASALT, highly weathered, inferred very low strength, reworks to Sandy CLAY, high plasticity orange brown and grey, medium grained sand			WEATHERED ROCK
	M (from approx. 4.3)		5.50	5.50 112.53					Inferred low strength			
	H (from 7.5)		8.0									

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Golder Associates

REPORT OF BOREHOLE: BH2002

SHEET: 2 OF 2

CLIENT:	ARUP	COORDS: 552152.6 m E 6820942.2 m N 56 MGA94	DRILL RIG: Pioneer 120		
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 118.03 m DATUM: AHD	DRILLER: North Coast Drilling		
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: AM	DATE: 11/7/07	
JOB NO:	06622140	HOLE DIA: 100 mm HOLE DEPTH: 10.50 m	CHECKED: CSC	DATE: 10/8/07	

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USC Symbol	SOIL / ROCK MATERIAL DESCRIPTION	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
ADT	H		8.0						Inferred low strength			WEATHERED ROCK
			8.5									
			9.0									
			9.5									
			10.0									
			10.5	*10.50* 107.53					END OF BOREHOLE @ 10.50 m Piezometer installed Note: borehole drilled for piezometer installation only			
			11.0									
			11.5									
			12.0									
			12.5									
			13.0									
			13.5									
			14.0									
			14.5									
			15.0									
			15.5									
			16.0									

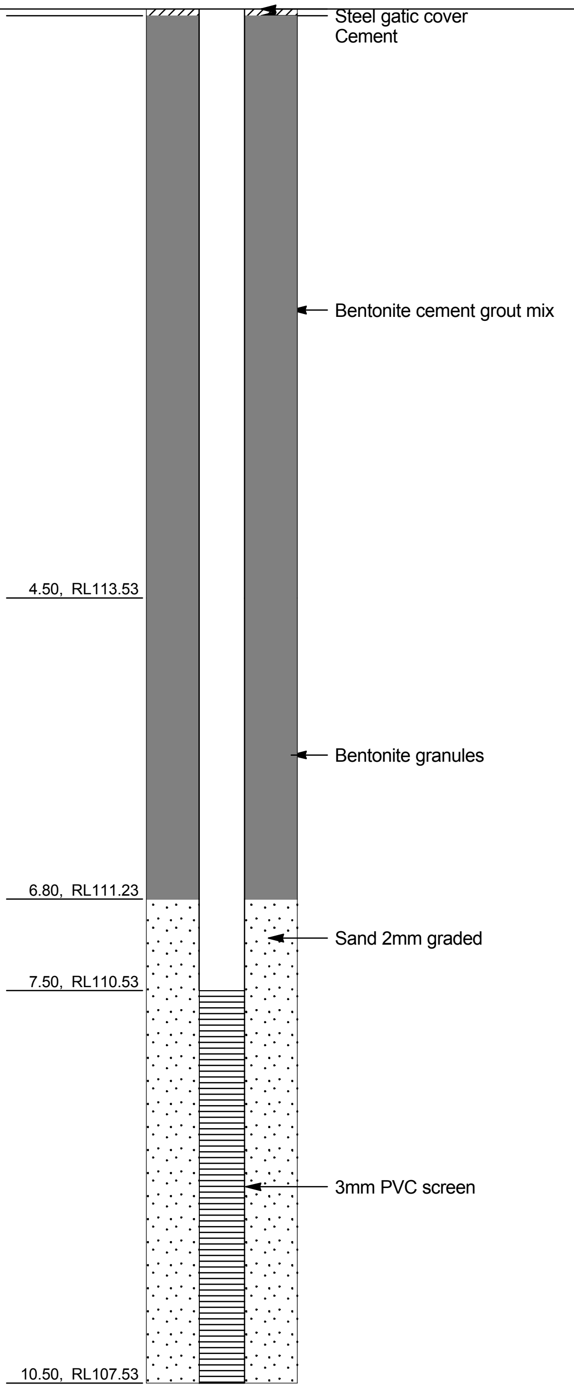
REPORT OF STANDPIPE INSTALLATION: BH2002

SHEET: 1 OF 1

CLIENT:	ARUP	COORDS: 552152.6 m E 6820942.2 m N 56 MGA94	DRILL RIG: Pioneer 120
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 118.03 m DATUM: AHD	DRILLER: North Coast Drilling
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: AM DATE: 11/7/07
JOB NO:	06622140	HOLE DIA: 100 mm HOLE DEPTH: 10.50 m	CHECKED: CSC DATE: 10/8/07

Drilling					Field Material Description	
METHOD	WATER	DRILL FLUID LEVELS	DEPTH (metres)	DEPTH RL	GRAPHIC LOG	ABBREVIATED SOIL / ROCK MATERIAL DESCRIPTION (Refer to Report of Borehole For Details)
ADT	Ground water not encountered		0	118.03	×—×	Silty CLAY
			2	2.00 116.03	V V	BASALT
			5.50	5.50 112.53	V V	BASALT
			10.50	10.50 107.53		

Instrumentation Details



GAP6_0-BETA_NEW ONE_25.06.07 SRAS ALTERED BY DATGEL 2007-07-02.GLB WELL3 J:\06PROJ\101-150\06622140_ARUP_T2E PREFERRED ROUTE\7000 FIELD AND LABORATORY DATA\7870 GINT\06622140 PH.GPJ GAP6_0-BETA-PH.GDT 05/09/2007 2:38:27 PM

This report of standpipe installation must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

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REPORT OF BOREHOLE: BH2003

SHEET: 1 OF 4

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 552178.1 m E 6821040.2 m N 56 MGA94
SURFACE RL: 96.94 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 19.80 m

DRILL RIG: Pioneer 120
DRILLER: North Coast Drilling
LOGGED: AM DATE: 16/7/07
CHECKED: CSC DATE: 10/8/07

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USC Symbol	SOIL / ROCK MATERIAL DESCRIPTION	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
ADT	L		0.0	96.94				MI	Sandy SILT, medium plasticity, brown, medium grained sand with fine to medium subangular gravel	M (~PL)	VSt	RESIDUAL SOIL
			1.0		SPT 1.00-1.45 m 4,7,13 N = 20							
WB			1.5									
			2.5	2.50 94.44	SPT 2.50-2.95 m 3,5,8 N = 13				Some rock structure evident		St	
			3.5	3.50 93.44					BASALT, grey and orange brown, extremely low to very low strength, highly weathered			WEATHERED ROCK
			4.0		SPT 4.00-4.45 m 5,11,12/100mm HB							
			4.5	4.50 92.44					For Continuation Refer to Sheet 2			

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REPORT OF BOREHOLE: BH2003

SHEET: 2 OF 4

CLIENT:	ARUP	COORDS: 552178.1 m E 6821040.2 m N 56 MGA94		DRILL RIG: Pioneer 120	
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 96.94 m	DATUM: AHD	DRILLER: North Coast Drilling	
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°		LOGGED: AM	DATE: 16/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm	HOLE DEPTH: 19.80 m	CHECKED: CSC	DATE: 10/8/07

Drilling						Field Material Description				Defect Information	
METHOD	WATER	TCR	RQD (SCR)	DEPTH (meters)	*DEPTH* RL	GRAPHIC LOG	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING	INFERRED STRENGTH $Is_{(50)}$ MPa (EL, VL 0.03, L 0.1, M 0.3, H 1, VH 3, EH 10)	DEFECT DESCRIPTION & Additional Observations	AVERAGE DEFECT SPACING (mm) (10, 30, 100, 300, 1000, 3000)
				0.0 – 4.5							
NMLC		100	93 (100)	4.5	*4.50* 92.44	V V	Continuation of Sheet 1 BASALT, pale grey and orange, with 1-5mm diameter calcium amygdules, with iron staining	HW	VL	4.65m: J, 45°, Un, Ro, Cn	3000
		93	90 (93)	6.0		V V		HW	L – M	5.95m: J, 25°, Un, Ro, Cn 6.05m: J, 0°, Un, Sm, Cn 6.14-7.05m: Set 1, J, 15-20°, sp=150mm, Pl, Sm, Sn, Iron staining, healed/cemented	3000
				7.3					EL		
	30%			7.40	*7.40* 89.54		NO CORE 7.40-7.60m				
		89	78	7.60	*7.60* 89.34	V V	BASALT, pale grey and orange, with 1-5mm diameter calcium amygdules, with iron staining	HW	EL – VL		300
				8.0							

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GAP gINT FN. F02a
RL2

GAP6_0-BETA_NEW ONE_25.06.07 SRAS ALTERED BY DATGEL 2007-07-02.GLB CORED BOREHOLE J:\06PROJ\101-150\06622140_ARUP_T2E PREFERRED ROUTE\7000 FIELD AND LABORATORY DATA\7870 GINT\06622140 PH.GPJ GAP6_0-BETA-PH.GDT 05/09/2007 2:39:08 PM

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REPORT OF BOREHOLE: BH2003

SHEET: 3 OF 4

CLIENT:	ARUP	COORDS: 552178.1 m E 6821040.2 m N 56 MGA94	DRILL RIG: Pioneer 120
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 96.94 m DATUM: AHD	DRILLER: North Coast Drilling
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: AM DATE: 16/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 19.80 m	CHECKED: CSC DATE: 10/8/07

Drilling

METHOD: NMLC

WATER: 30/07/2007; 10%

TCR	RQD (SCR)
	(89)
83	72 (83)
100	100 (100)
87	50 (75)
100	95 (100)
100	93 (100)
100	100 (100)
100	100 (100)

Field Material Description

DEPTH (meters)	DEPTH RL	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING
8.0		BASALT, pale grey and orange, with 1-5mm diameter calcium amygdules, with iron staining	HW
9.15	9.15	NO CORE 9.15-9.30m	
9.30	9.30 87.64	BASALT, pale grey and orange, with 1-5mm diameter calcium amygdules, with iron staining	HW
11.00	11.00	NO CORE 11.0-11.10m	
11.10	11.10 85.84	BASALT, pale grey and brown, with 1-5mm diameter calcium amygdules, with trace iron staining	HW
12.20	12.20 84.74	BASALT, dark grey, with trace blue green calcite amygdules up to 10mm diameter	SW-FR

INFERRED STRENGTH Is(50) MPa: EL 0.03 VL 0.1 L 0.3 M 1 H 3 VH 10 EH

Defect Information

DEFECT DESCRIPTION & Additional Observations

8.27m: J, 10°, Un, Sm, Cn
8.32m: J, 5°, Un, Sm, Cn
9.88m: J, 0°, Pl, Ro, Cn
11.27m: J, 35°, Pl, Sm, Cn
11.44m: J, 20°, Un, Ro, Cn
11.77m: J, 50°, Pl, Sm, Cn
11.83m: J, 30°, Pl, Sl, Cn
11.98m: J, 0°, Pl, Ro, Cn
12.04-12.17m: Set 1, J, 0°, sp=10-30mm, Pl, Ro, Cn
12.76m: J, 12°, Pl, Ro, Cn
13.21m: J, 15°, Pl, Ro, Cn
13.61m: J, 10°, Un, Ro, Cn
13.70m: J, 15°, Un, Sm, Cn
13.81m: J, 0°, Pl, Ro, Sn
14.25m: J, 25°, Pl, Sm, Cn
14.66m: J, 30°, Un, Sm, Cn
15.19m: J, 0°, Un, Ro, Cn
15.26m: J, 0°, Un, Sm, Cn
15.71m: J, 10°, Pl, Sm, Cn

AVERAGE DEFECT SPACING (mm): 10 30 100 300 1000 3000

Depth scale: 8.0 8.5 9.0 9.5 10.0 10.5 11.0 11.5 12.0 12.5 13.0 13.5 14.0 14.5 15.0 15.5 16.0

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REPORT OF BOREHOLE: BH2003

SHEET: 4 OF 4

CLIENT:	ARUP	COORDS: 552178.1 m E 6821040.2 m N 56 MGA94		DRILL RIG: Pioneer 120	
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 96.94 m	DATUM: AHD	DRILLER: North Coast Drilling	
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°		LOGGED: AM	DATE: 16/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm	HOLE DEPTH: 19.80 m	CHECKED: CSC	DATE: 10/8/07

Drilling						Field Material Description				Defect Information	
METHOD	WATER	TCR	RQD (SCR)	DEPTH (meters)	DEPTH RL	GRAPHIC LOG	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING	INFERRED STRENGTH Is(50) MPa EL VL L M H VH EH 0.03 0.1 0.3 1 3 10	DEFECT DESCRIPTION & Additional Observations	AVERAGE DEFECT SPACING (mm) 10 30 100 300 1000 3000
NMLC				16.0			BASALT, dark grey, with trace blue green calcite amygdules up to 10mm diameter	SW-FR		16.04m: J, 5°, Un, Sm, Cn	
										16.33m: J, 10°, Pl, Sm, Cn	
				16.5							
										16.79m: J, 5°, Pl, Sm, Cn 16.88m: J, 5°, Pl, Sm, Cn 16.94m: J, 10°, Un, Sm, Cn	
		100	97 (100)	17.0							
										17.18m: J, 5°, Un, Sm, Cn	
										17.34m: J, 10°, Pl, Sm, Cn	
				17.5							
										17.81m: J, 10°, Pl, Sm, Cn	
				18.0							
										18.17m: J, 0°, Un, Sm, Cn	
										18.40m: J, 0°, Un, Sm, Cn	
				18.5							
		100	97 (100)								
				19.0							
										19.15m: J, 10°, Un, Sm, Cn 19.21m: J, 5°, Un, Sm, Vr, 2mm, Calcite	
				19.5							
										19.60m: J, 45°, Un, Sm, Cn	
					19.80					19.75m: J, 45°, Un, Sm, Cn	
							END OF BOREHOLE @ 19.80 m Piezometer installed				
				20.0							
				20.5							
				21.0							
				21.5							
				22.0							
				22.5							
				23.0							
				23.5							
				24.0							

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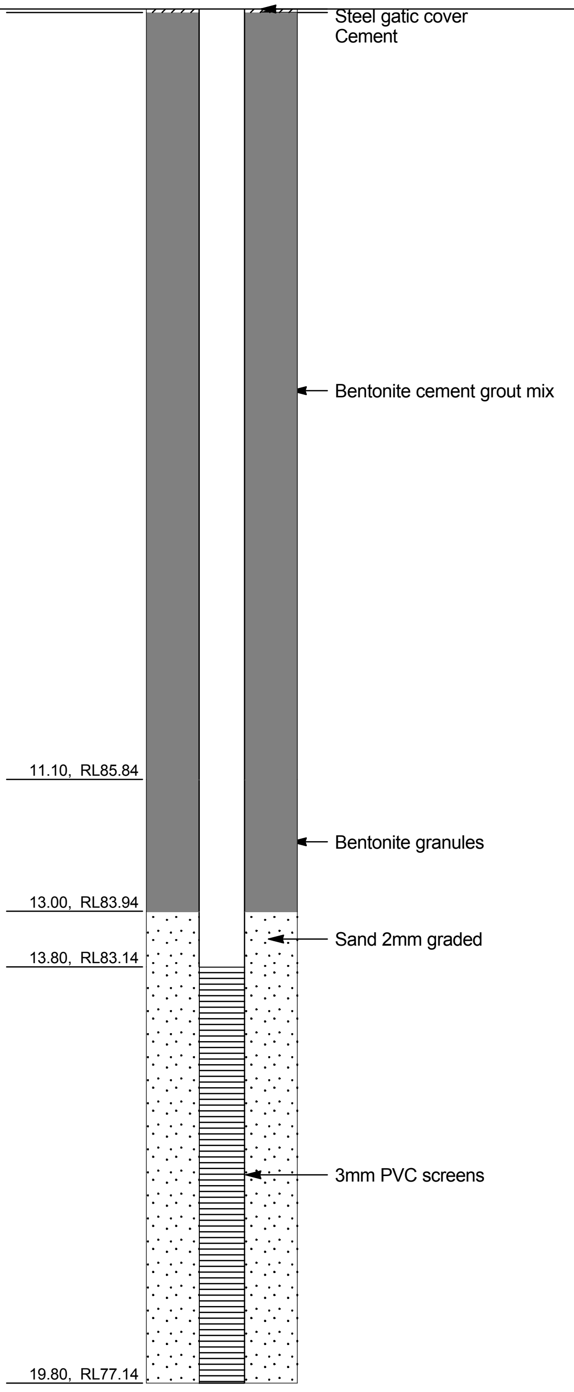
REPORT OF STANDPIPE INSTALLATION: BH2003

SHEET: 1 OF 1

CLIENT:	ARUP	COORDS: 552178.1 m E 6821040.2 m N 56 MGA94	DRILL RIG: Pioneer 120
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 96.94 m DATUM: AHD	DRILLER: North Coast Drilling
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: AM DATE: 16/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 19.80 m	CHECKED: CSC DATE: 10/8/07

Drilling | **Field Material Description** | **Instrumentation Details**

METHOD	WATER	DRILL FLUID LEVELS	DEPTH (metres)	DEPTH RL	ABBREVIATED SOIL / ROCK MATERIAL DESCRIPTION (Refer to Report of Borehole For Details)
ADT			0	96.94	Sandy SILT
WB			2		
				3.50 93.44	BASALT
			4	4.50 92.44	BASALT
NMLC			6		
	30%			7.40	NO CORE
	30/07/2007		8	89.34	BASALT
				9.15	NO CORE
			10	87.64	BASALT
				11.00	NO CORE
				85.84	BASALT
	10%		12	12.20 84.74	BASALT
			14		
			16		
			18		
				19.80 77.14	
			20		



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REPORT OF CORE PHOTOGRAPHS: BH2003

SHEET: 1 OF 3

CLIENT:	ARUP	COORDS: 552178.1 m E 6821040.2 m N 56 MGA94	DRILL RIG: Pioneer 120	
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 96.94 m DATUM: AHD	DRILLER: North Coast Drilling	
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: AM	DATE: 16/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 19.80 m	CHECKED: CSC	DATE: 10/8/07

GAP6_0-BETA_NEW ONE_25.06.07 SRAS ALTERED BY DATGEL 2007-07-02.GLB CORE PHOTO 1 PER PAGE J:\06PROJ\101-150\06622140_ARUP_T2E PREFERRED ROUTE\7000 FIELD AND LABORATORY DATA\7870 GINT\06622140 P

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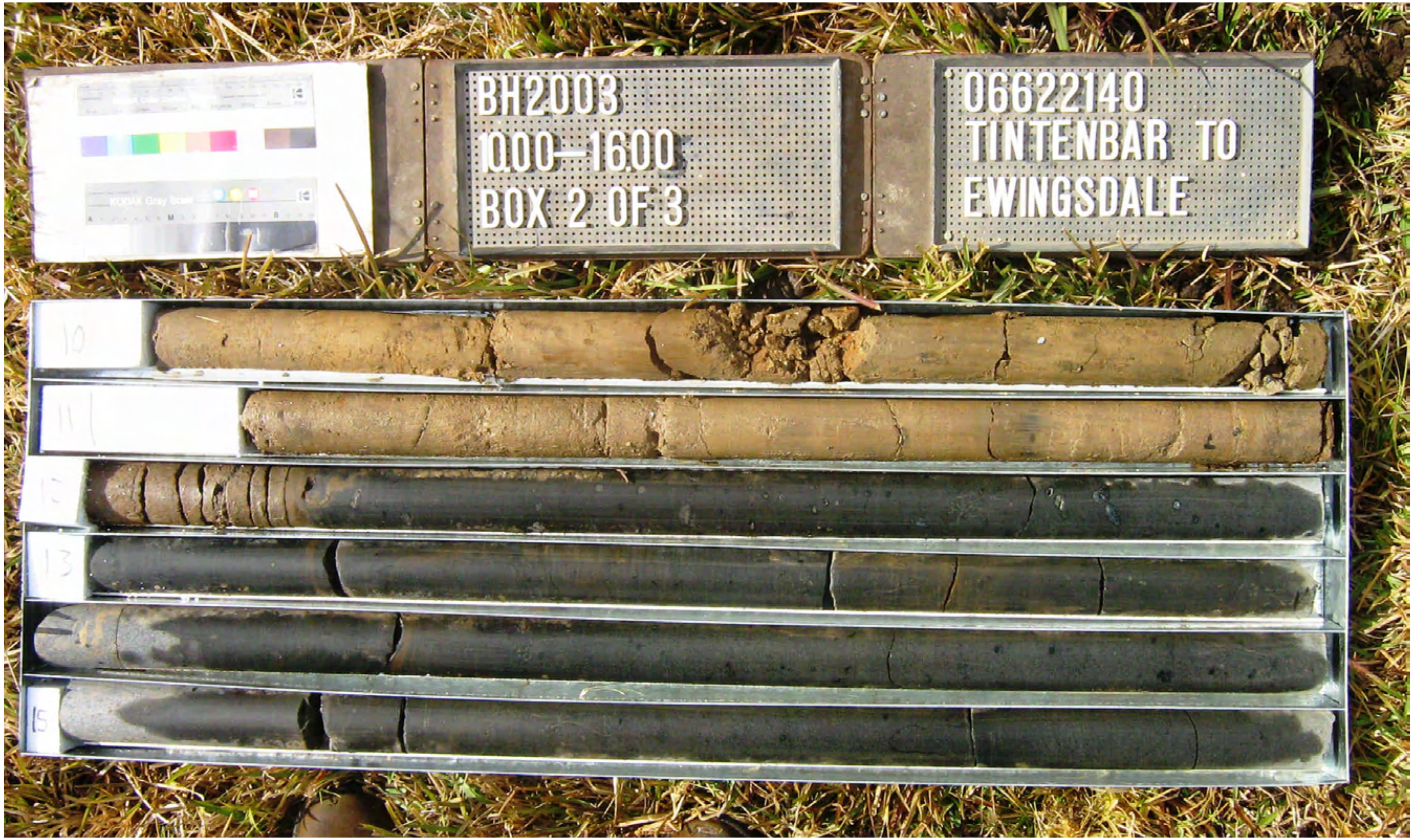
REPORT OF CORE PHOTOGRAPHS: BH2003

SHEET: 2 OF 3

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 552178.1 m E 6821040.2 m N 56 MGA94
SURFACE RL: 96.94 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 19.80 m

DRILL RIG: Pioneer 120
DRILLER: North Coast Drilling
LOGGED: AM DATE: 16/7/07
CHECKED: CSC DATE: 10/8/07



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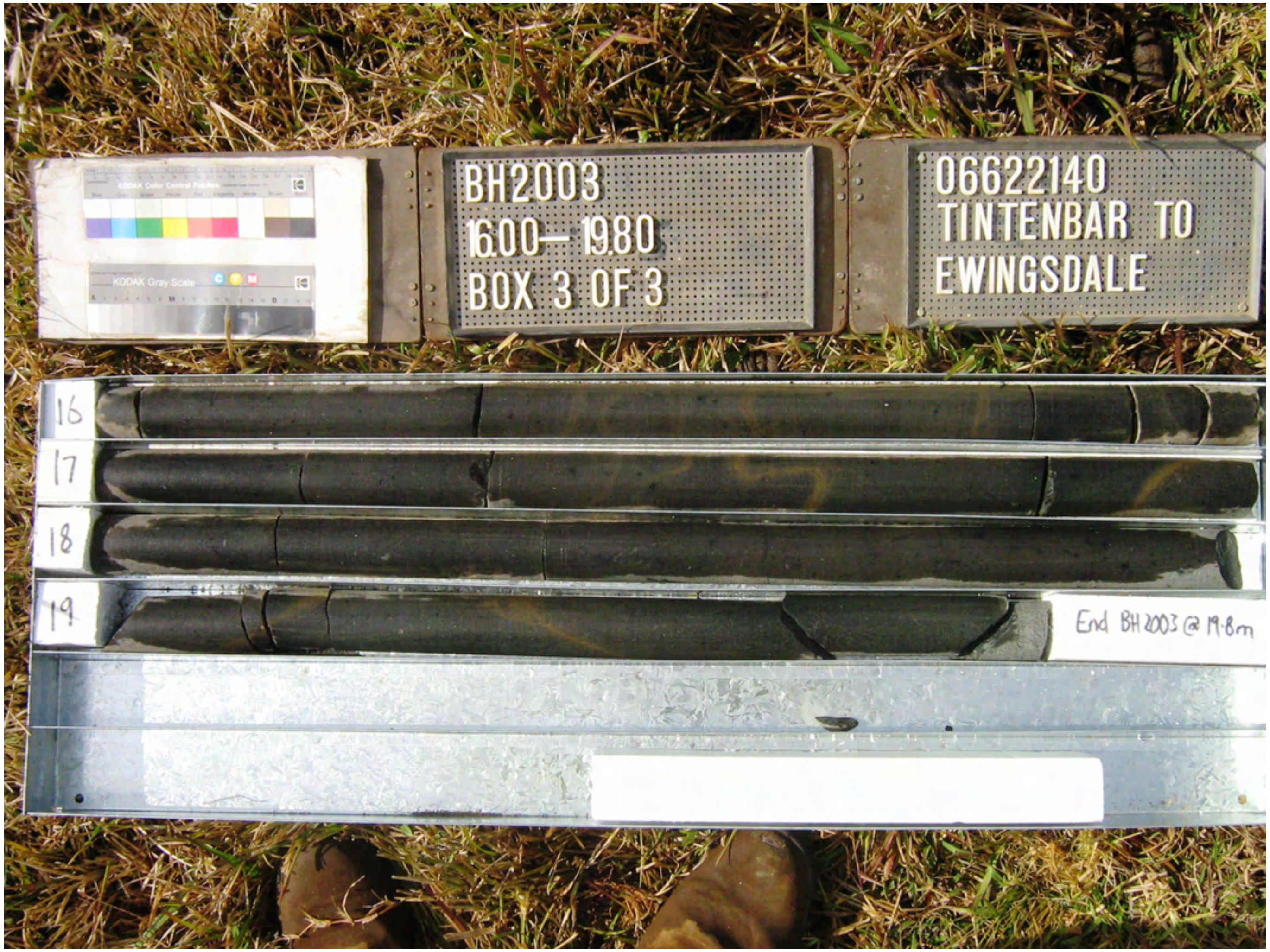
REPORT OF CORE PHOTOGRAPHS: BH2003

SHEET: 3 OF 3
DRILL RIG: Pioneer 120
DRILLER: North Coast Drilling
LOGGED: AM DATE: 16/7/07
CHECKED: CSC DATE: 10/8/07

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 552178.1 m E 6821040.2 m N 56 MGA94
SURFACE RL: 96.94 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 19.80 m



This report of core photographs must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

REPORT OF BOREHOLE: BH2004

CLIENT:	ARUP	COORDS: 552178.1 m E 6821040 m N 56 MGA94	SHEET: 1 OF 2
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 96.94 m DATUM: AHD	DRILL RIG: Pioneer 120
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°	DRILLER: North Coast Drilling
			LOGGED: AM DATE: 16/7/07
JOB NO:	06622140	HOLE DIA: 100 mm HOLE DEPTH: 12.00 m	CHECKED: CSC DATE: 10/8/07

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USC Symbol	SOIL / ROCK MATERIAL DESCRIPTION	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
ADT	L		0.0	96.94				MI	Clayey Sandy SILT, medium plasticity, brown, fine to medium grained sand	M		RESIDUAL SOIL
RD			1.5									
			2.0	*2.00* 94.94					BASALT, highly weathered, inferred very low strength, orange mottled pale grey			WEATHERED ROCK
	M		6.5	*6.50* 90.44					BASALT, highly weathered, inferred very low to low strength, pale grey			
			8.0									

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REPORT OF BOREHOLE: BH2004

				SHEET: 2 OF 2	
CLIENT:	ARUP	COORDS: 552178.1 m E 6821040 m N 56 MGA94		DRILL RIG: Pioneer 120	
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 96.94 m	DATUM: AHD	DRILLER: North Coast Drilling	
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°		LOGGED: AM	DATE: 16/7/07
JOB NO:	06622140	HOLE DIA: 100 mm	HOLE DEPTH: 12.00 m	CHECKED: CSC	DATE: 10/8/07

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USC Symbol	SOIL / ROCK MATERIAL DESCRIPTION	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
RD	M	22/08/2007 30/07/2007	8.0 8.5 9.0 9.5 10.0 10.5 11.0 11.5						BASALT, highly weathered, inferred very low to low strength, pale grey			WEATHERED ROCK
			12.0 12.5 13.0 13.5 14.0 14.5 15.0 15.5 16.0	*12.00* 84.94					END OF BOREHOLE @ 12.00 m Reached target depth Piezometer installed Note: borehole drilled for piezometer installation only			

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GAP gINT FN. F01a
RL2

GAP6_0-BETA_NEW ONE_25.06.07 SRAS ALTERED BY DATGEL 2007-07-02.GLB FULL PAGE J:\06PROJ\101-150\06622140_ARUP_T2E PREFERRED ROUTE\7000 FIELD AND LABORATORY DATA\7870 GINT\06622140 PH.GPJ GAP6_0-BETA-PH.GDT 05/09/2007 2:40:09 PM

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REPORT OF STANDPIPE INSTALLATION: BH2004

SHEET: 1 OF 1

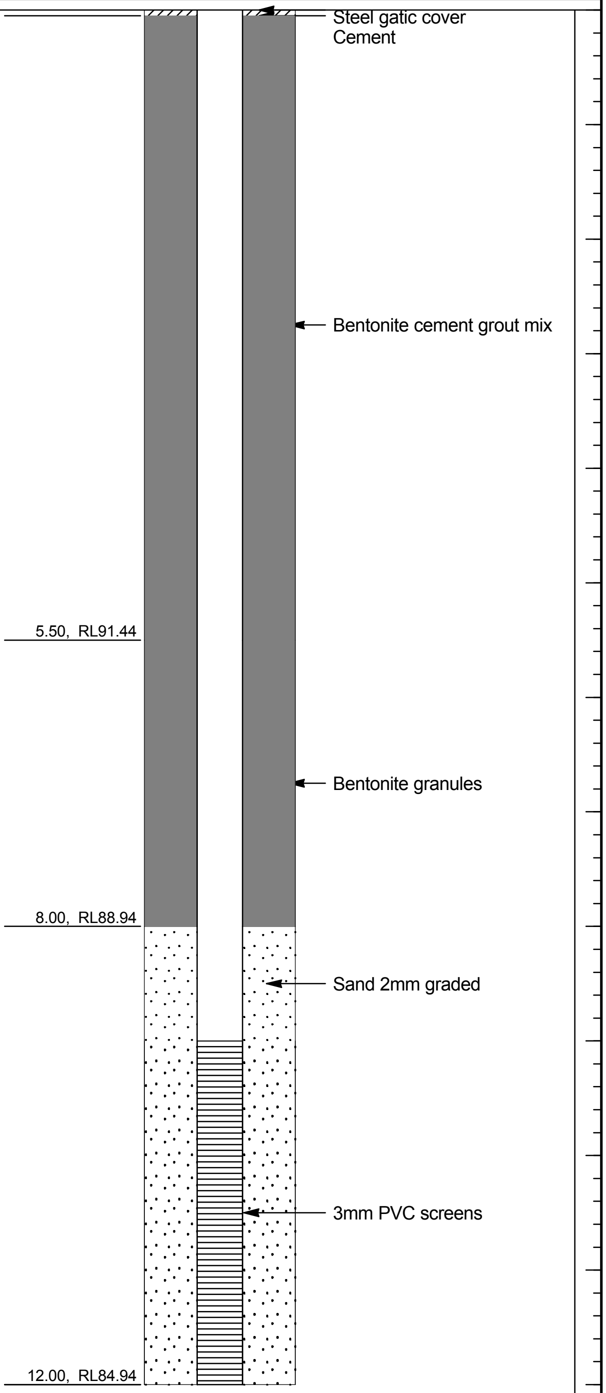
CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 552178.1 m E 6821040 m N 56 MGA94
SURFACE RL: 96.94 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100 mm HOLE DEPTH: 12.00 m

DRILL RIG: Pioneer 120
DRILLER: North Coast Drilling
LOGGED: AM DATE: 16/7/07
CHECKED: CSC DATE: 10/8/07

Drilling					Field Material Description	
METHOD	WATER	DRILL FLUID LEVELS	DEPTH (metres)	DEPTH RL	GRAPHIC LOG	ABBREVIATED SOIL / ROCK MATERIAL DESCRIPTION (Refer to Report of Borehole For Details)
ADT			0	96.94		Gravelly Clayey SILT
RD			2	2.00 94.94		BASALT
			6.5	6.50 90.44		BASALT
	22/08/2007 30/07/2007		12	12.00 84.94		

Instrumentation Details



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GAP gINT FN. F17
RL0

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REPORT OF BOREHOLE: BH2005

SHEET: 1 OF 3

CLIENT:	ARUP	COORDS: 552216.8 m E 6821076.9 m N 56 MGA94		DRILL RIG: Pioneer 120	
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 88.99 m	DATUM: AHD	DRILLER: North Coast Drilling	
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°		LOGGED: BC	DATE: 19/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm	HOLE DEPTH: 15.40 m	CHECKED: CSC	DATE: 10/8/07

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USC Symbol	SOIL / ROCK MATERIAL DESCRIPTION	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
ADT	M		0.0	88.99				CH	Silty CLAY, high plasticity, red brown, some root fibres	D-M	VSt	RESIDUAL SOIL
			1.0		SPT 1.00-1.45 m 5,8,12 N = 20							
	M-H	22/08/2007	2.0	*2.00* 86.99				CH	Silty CLAY, high plasticity, red brown and grey, zones of iron staining, some rock structure evident	D-M	St	RESIDUAL SOIL TO EXTREMELY WEATHERED ROCK
WB	M		2.5		SPT 2.50-2.95 m 4,4,6 N = 10							
		30/07/2007	3.0									
			4.0	*3.90* 85.09					For Continuation Refer to Sheet 2			

Depth scale: 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0

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Golder Associates

REPORT OF BOREHOLE: BH2005

SHEET: 2 OF 3

CLIENT:	ARUP	COORDS: 552216.8 m E 6821076.9 m N 56 MGA94		DRILL RIG: Pioneer 120	
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 88.99 m	DATUM: AHD	DRILLER: North Coast Drilling	
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°		LOGGED: BC	DATE: 19/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm	HOLE DEPTH: 15.40 m	CHECKED: CSC	DATE: 10/8/07

Drilling						Field Material Description				Defect Information	
METHOD	WATER	TCR	RQD (SCR)	DEPTH (meters)	*DEPTH* RL	GRAPHIC LOG	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING	INFERRED STRENGTH $Is_{(50)}$ MPa EL 0.03 VL 0.1 L 0.3 M 1 H 3 VH 10 EH	DEFECT DESCRIPTION & Additional Observations	AVERAGE DEFECT SPACING (mm) 10 30 100 300 1000 3000
				0.0 – 3.5							
					3.90 85.09		Continuation of Sheet 1				
NMLC		100	97 (100)	4.0			BASALT, grey, with trace green amygdules, trace brown iron staining	SW-FR	VH	4.00m: J, 20°, Pl, Ro, Sn 4.05-4.06m: J, 30°, Pl, Ro, Sn	
				4.5						4.41m: J, 0-20°, Un, Ro, Cn 4.52m: J, 0-10°, Un, Ro, Cn	
				5.0						4.92m: J, 5°, Un, Sm, Cn 5.12-5.20m: J, 55°, Un, Sm, Vr 5.21m: J, 20°, Pl, Sm, Vr, (blue oxide)	
		100	94 (100)	5.5							
				6.0						6.15m: V, ironstained	
				6.5						6.37m: J, 0°, Un, Ro, Cn 6.50-6.69m: J, 70°, Un, Sm, Cn 6.75m: J, 15 and 35°, St, Sm, Cn 6.90m: J, 0-40°, Un, Sm, Cn	
				7.0						7.15m: J, 0°, Un, Sm, Vr, calcite	
				7.5						7.48m: J, 0°, Un, Ro, Cn	
				8.0							

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GAP gINT FN. F02a
RL2

GAP6_0-BETA_NEW ONE_25.06.07 SRAS ALTERED BY DATGEL 2007-07-02.GLB CORED BOREHOLE J:\06PROJ\101-150\06622140_ARUP_T2E PREFERRED ROUTE\7000 FIELD AND LABORATORY DATA\7870 GINT\06622140 PH.GPJ GAP6_0-BETA-PH.GDT 05/09/2007 2:41:30 PM

Golder Associates

REPORT OF BOREHOLE: BH2005

SHEET: 3 OF 3

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 552216.8 m E 6821076.9 m N 56 MGA94
SURFACE RL: 88.99 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 15.40 m

DRILL RIG: Pioneer 120
DRILLER: North Coast Drilling
LOGGED: BC DATE: 19/7/07
CHECKED: CSC DATE: 10/8/07

Drilling						Field Material Description				Defect Information
METHOD	WATER	TCR	RQD (SCR)	DEPTH (meters)	DEPTH RL	GRAPHIC LOG	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING	INFERRED STRENGTH Is(50) MPa	DEFECT DESCRIPTION & Additional Observations
NMLC		100	100 (100)	8.0			BASALT, grey, with trace green amygdules, trace brown iron staining	SW-FR		
				8.5						
										8.64m: J, 0°, Un, Sm, Cn
				9.0						
										9.36m: J, 0°, Un, Sm, Vr, (blue oxide)
				9.5						
		100	100 (100)							9.64m: J, 0°, Un, Sm, Cn
										9.86m: J, 0°, Un, Ro, Cn
				10.0						
										10.08m: J, 5°, Pl, Sm, Vr, (blue oxide)
				10.5						
										10.80m: J, 0-5°, Un, Sm, Cn
		100	100 (100)	11.0						
				11.5						11.50m: J, 5°, Pl, Sm, Vr, (blue oxide) 11.61m: J, 5°, Pl, Sm, Vr, (blue oxide)
				12.0						
										12.19m: J, 0°, Un, Ro, Cn
				12.5						
										12.78m: J, 10°, Pl, Sm, Vr, (blue oxide)
				13.0						
										13.31m: J, 0°, Un, Sm, Cn
				13.5						
		100	89 (100)	14.0						
										14.12-14.14m: J, 30°, Pl, Sm, Cn 14.21-14.23m: J, 40°, Pl, Sm, Ct, (blue oxide 2mm) 14.31-14.38m: J, 60°, Pl, Sm, Vr, (blue oxide)
				14.5						
										14.57m: J, 20°, Un, Sl-Sm, Vr, (partially blue oxide)
				15.0						
										15.16m: J, 25°, Pl, Sm, Vr, (blue oxide)
					15.40		END OF BOREHOLE @ 15.40 m Piezometer installed			
				15.5						
				16.0						

INFERRED STRENGTH Is(50) MPa: EL VL L M H VH EH; 0.03 0.1 0.3 1 3 10

AVERAGE DEFECT SPACING (mm): 10 30 100 300 1000 3000

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Golder Associates

REPORT OF STANDPIPE INSTALLATION: BH2005

SHEET: 1 OF 1

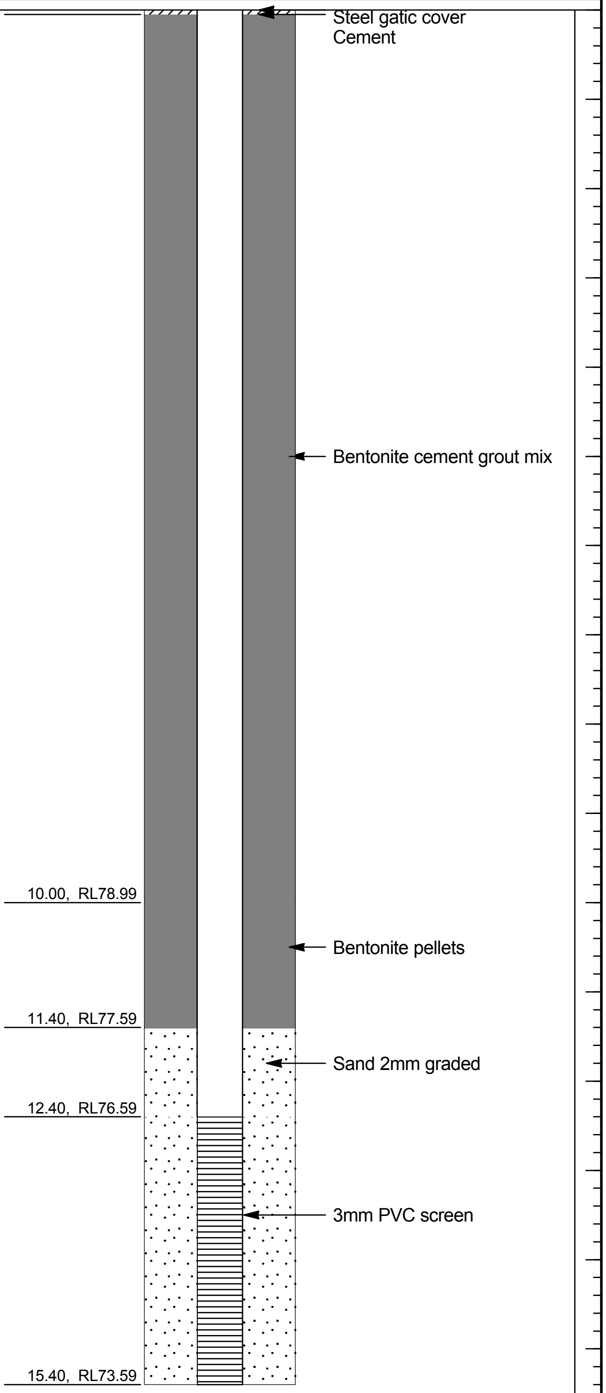
CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 552216.8 m E 6821076.9 m N 56 MGA94
SURFACE RL: 88.99 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 15.40 m

DRILL RIG: Pioneer 120
DRILLER: North Coast Drilling
LOGGED: BC DATE: 19/7/07
CHECKED: CSC DATE: 10/8/07

Drilling					Field Material Description	
METHOD	WATER	DRILL FLUID LEVELS	DEPTH (metres)	DEPTH RL	GRAPHIC LOG	ABBREVIATED SOIL / ROCK MATERIAL DESCRIPTION (Refer to Report of Borehole For Details)
ADT			0	88.99		Silty CLAY
	22/08/2007		2.00	86.99		Silty CLAY
WB	30/07/2007					
NMLC			3.90	85.09		BASALT
			15.40	73.59		

Instrumentation Details



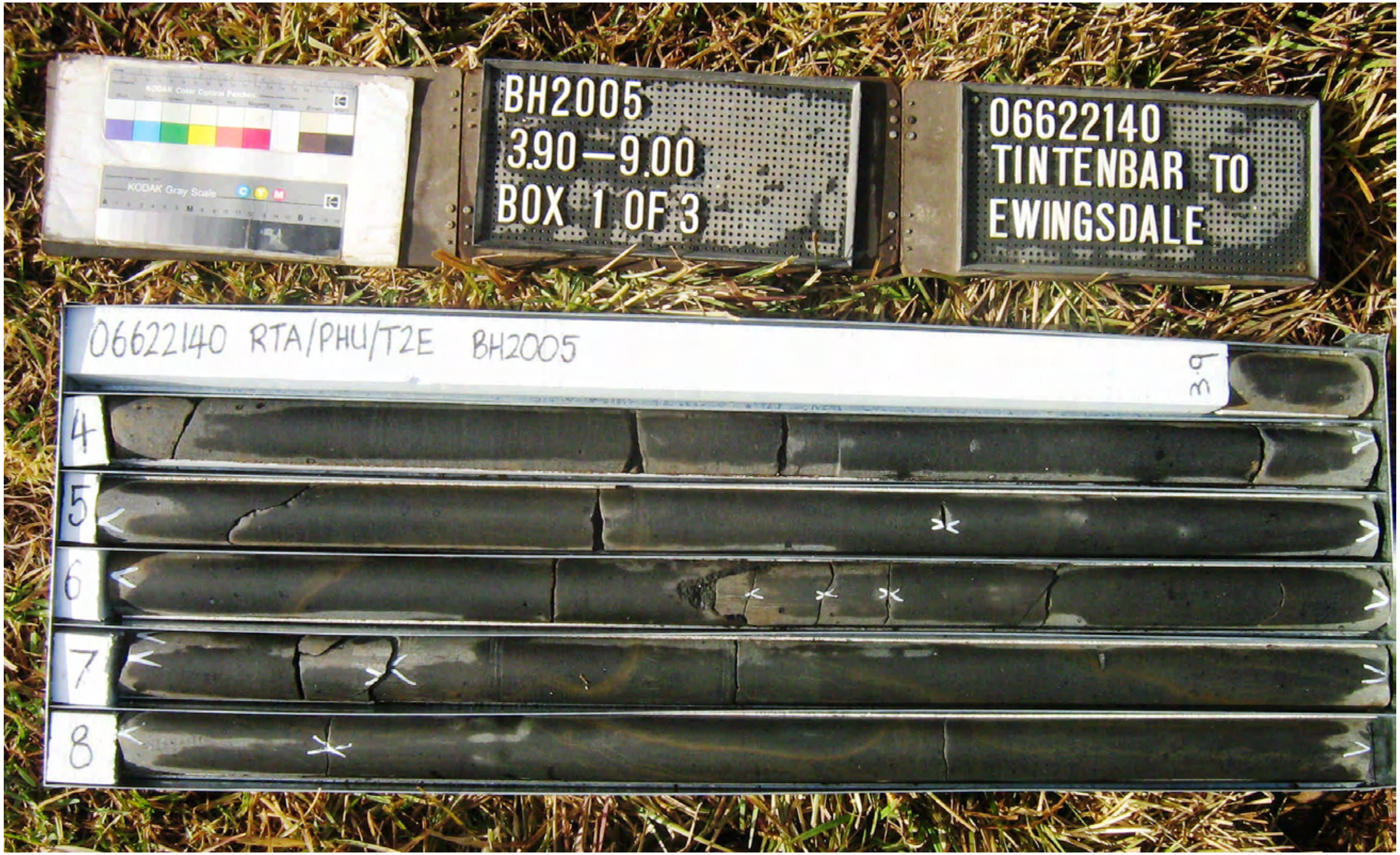
This report of standpipe installation must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

Golder Associates

REPORT OF CORE PHOTOGRAPHS: BH2005

SHEET: 1 OF 3

CLIENT: ARUP	COORDS: 552216.8 m E 6821076.9 m N 56 MGA94	DRILL RIG: Pioneer 120	
PROJECT: Pacific Highway Upgrade	SURFACE RL: 88.99 m DATUM: AHD	DRILLER: North Coast Drilling	
LOCATION: Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: BC	DATE: 19/7/07
JOB NO: 06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 15.40 m	CHECKED: CSC	DATE: 10/8/07



GAP6_0-BETA_NEW ONE_25.06.07 SRAS ALTERED BY DATGEL 2007-07-02.GLB CORE PHOTO 1 PER PAGE J:\06PROJ\101-150\06622140_ARUP_T2E PREFERRED ROUTE\7000 FIELD AND LABORATORY DATA\7870 GINT\06622140 PI

Golder Associates

REPORT OF CORE PHOTOGRAPHS: BH2005

SHEET: 2 OF 3

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 552216.8 m E 6821076.9 m N 56 MGA94
SURFACE RL: 88.99 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 15.40 m

DRILL RIG: Pioneer 120
DRILLER: North Coast Drilling
LOGGED: BC DATE: 19/7/07
CHECKED: CSC DATE: 10/8/07

This report of core photographs must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

GAP gINT FN. F31
RL0

Golder Associates

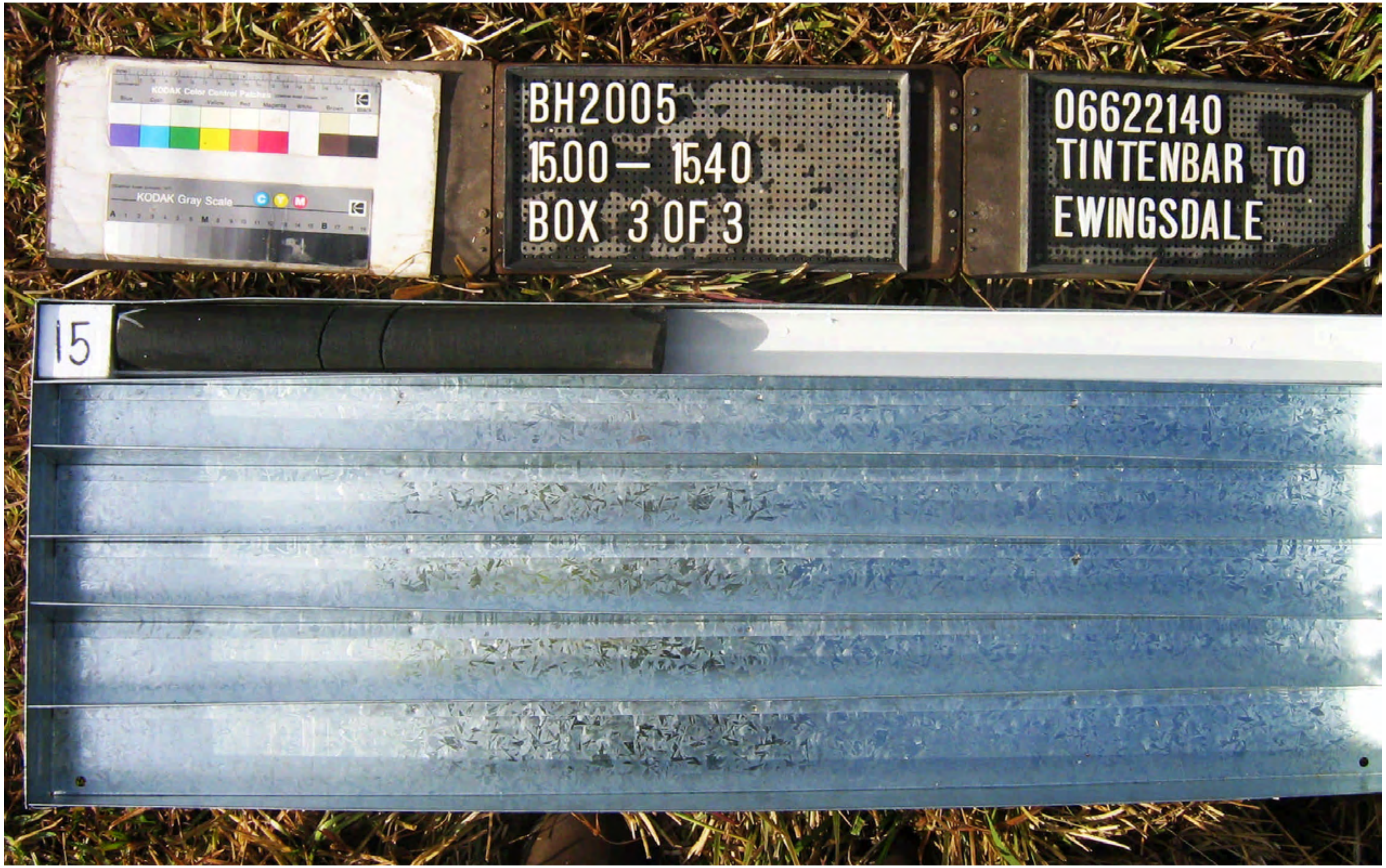
REPORT OF CORE PHOTOGRAPHS: BH2005

SHEET: 3 OF 3

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 552216.8 m E 6821076.9 m N 56 MGA94
SURFACE RL: 88.99 m   DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm   HOLE DEPTH: 15.40 m

DRILL RIG: Pioneer 120
DRILLER: North Coast Drilling
LOGGED: BC   DATE: 19/7/07
CHECKED: CSC   DATE: 10/8/07



This report of core photographs must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

Golder Associates

REPORT OF BOREHOLE: BH2006

SHEET: 1 OF 1

CLIENT:	ARUP	COORDS: 552217.5 m E 6821077.3 m N 56 MGA94	DRILL RIG: Pioneer 120		
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 88.93 m DATUM: AHD	DRILLER: North Coast Drilling		
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: BC	DATE:	20/7/07
JOB NO:	06622140	HOLE DIA: 100 mm HOLE DEPTH: 3.50 m	CHECKED: CSC	DATE:	13/8/07

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USC Symbol	SOIL / ROCK MATERIAL DESCRIPTION	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
ADT	M		0.0	88.93				CH	Silty CLAY, high plasticity, red brown	D-M		RESIDUAL SOIL
			0.5									
			1.0									
			1.5									
	M-H	22/08/2007	2.0									
			2.5									
		30/07/2007	3.0									
			3.5	*3.50* 85.43					END OF BOREHOLE @ 3.50 m Piezometer installed Note: borehole drilled for piezometer installation only			
			4.0									
			4.5									
			5.0									
			5.5									
			6.0									
			6.5									
			7.0									
			7.5									
			8.0									

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GAP gINT FN. F01a
RL2

GAP6_0-BETA_NEW ONE_25.06.07 SRAS ALTERED BY DATGEL 2007-07-02.GLB FULL PAGE J:\06PROJ\101-150\06622140_ARUP_T2E PREFERRED ROUTE\7000 FIELD AND LABORATORY DATA\7870 GINT\06622140 PH.GPJ GAP6_0-BETA-PH.GDT 05/09/2007 2:42:52 PM

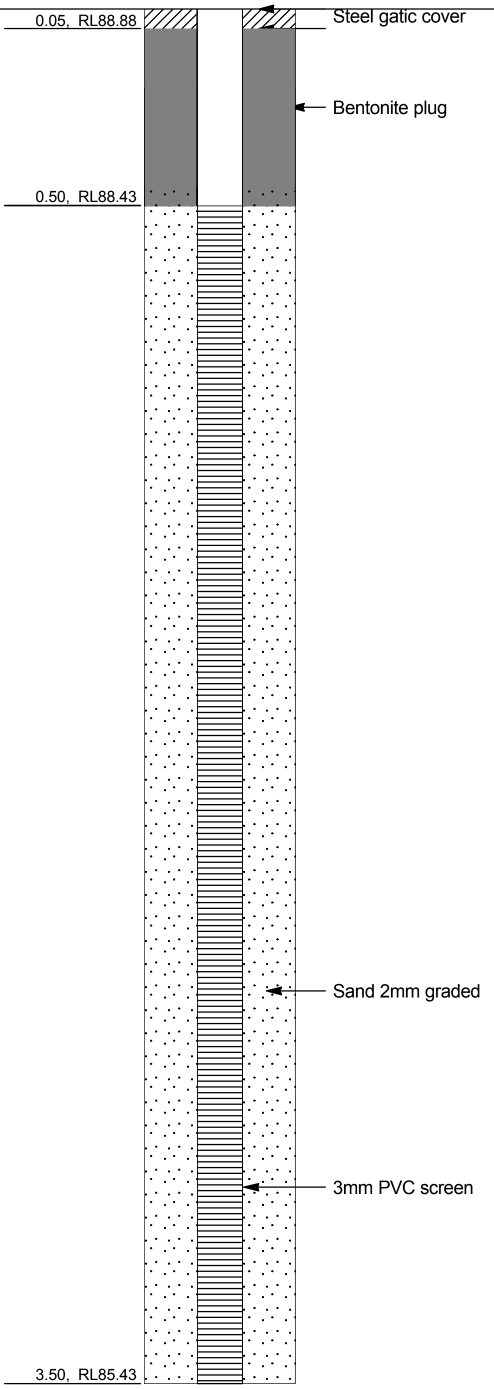
REPORT OF STANDPIPE INSTALLATION: BH2006

SHEET: 1 OF 1

CLIENT:	ARUP	COORDS: 552217.5 m E 6821077.3 m N 56 MGA94	DRILL RIG: Pioneer 120
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 88.93 m DATUM: AHD	DRILLER: North Coast Drilling
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: BC DATE: 20/7/07
JOB NO:	06622140	HOLE DIA: 100 mm HOLE DEPTH: 3.50 m	CHECKED: CSC DATE: 13/8/07

Drilling					Field Material Description	
METHOD	WATER	DRILL FLUID LEVELS	DEPTH (metres)	DEPTH RL	GRAPHIC LOG	ABBREVIATED SOIL / ROCK MATERIAL DESCRIPTION (Refer to Report of Borehole For Details)
ADT			0.0	88.93		Silty CLAY
			0.5			
			1.0			
			1.5			
	22/08/2007		2.0			
			2.5			
	30/07/2007		3.0			
			3.5	85.43		

Instrumentation Details



This report of standpipe installation must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

GAP gINT FN. F17
RL0

GAP6_0-BETA_NEW ONE_25.06.07 SRAS ALTERED BY DATGEL 2007-07-02.GLB WELL3 J:\06PROJ\101-150\06622140_ARUP_T2E PREFERRED ROUTE\7000 FIELD AND LABORATORY DATA\7870 GINT\06622140 PH.GPJ GAP6_0-BETA-PH.GDT 05/09/2007 2:43:23 PM

Golder Associates

REPORT OF BOREHOLE: BH2007

SHEET: 1 OF 3

CLIENT:	ARUP	COORDS: 552261.3 m E 6821191.7 m N 56 MGA94	DRILL RIG: Tracked Scout		
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 88.62 m DATUM: AHD	DRILLER: Drillsearch		
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: BC	DATE: 28/7/07	
JOB NO:	06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 11.60 m	CHECKED: CSC	DATE: 13/8/07	

Drilling					Sampling	Field Material Description						
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USC Symbol	SOIL / ROCK MATERIAL DESCRIPTION	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
ADT	M		0.0 – 0.80	88.62				CH	Silty CLAY, high plasticity, red brown	M	St	RESIDUAL SOIL
	M-H		0.80 – 1.5	0.80 87.82	SPT 1.00-1.40 m 6,20,20/100mm	■			BASALT, grey brown with red zones, very low strength, extremely to highly weathered, ironstaining along joints, 1-2mm diameter amygdules present.			WEATHERED ROCK
	H	30/07/2007	1.5 – 2.40									
		22/08/2007	2.40 – 8.0	2.40 86.22					For Continuation Refer to Sheet 2			

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Golder Associates

REPORT OF BOREHOLE: BH2007

SHEET: 2 OF 3

CLIENT:	ARUP	COORDS: 552261.3 m E 6821191.7 m N 56 MGA94	DRILL RIG: Tracked Scout
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 88.62 m DATUM: AHD	DRILLER: Drillsearch
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: BC DATE: 28/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 11.60 m	CHECKED: CSC DATE: 13/8/07

Drilling | **Field Material Description** | **Defect Information**

METHOD	WATER	TCR	RQD (SCR)	DEPTH (meters)	DEPTH RL	GRAPHIC LOG	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING	INFERRED STRENGTH Is(50) MPa
				2.40			Continuation of Sheet 1		
NMLC		100	84 (90)	2.40	86.22	V V	BASALT, grey with some red iron stained veins	HW	L
								HW-MW	M
				2.85	85.77	V V	As above, trace brown iron stained veins	SW	VH
		100	88 (100)						

DEFECT DESCRIPTION & Additional Observations

2.40-2.50m: recovered as fragmented rock
2.47-2.50m: J, 40°, Un, Ro, Sn
2.49-2.56m: J, 60°, Pl, Ro, Sn, iron
2.58m: J, 0°, Pl, Ro, Sn, iron
2.63m: J, 5°, Pl, Sm, Sn, iron
2.68-2.72m: DS, 15°, coarse subangular basalt gravel
2.75-2.77m: J, 20°, Pl, Ro, Sn
2.77m: J, 15°, Un, Ro, Sn, iron
2.81-2.83m: DS, 20°, fine to medium sized gravel
2.95m: J, 20°, Pl, Ro, Sn, iron
3.12-3.17m: J, 70°, Pl, Sm, Sn, blue oxide
3.17m: J, 15°, Pl, Sm, Sn, iron
3.72-3.75m: J, 30°, Un, Sm, Cn
3.94m: J, 30°, Un, Sm, Vr, calcite
4.10-4.12m: J, 30°, Pl, Sm, Sn, blue oxide
4.47-4.50m: J, 40°, Un, Ro, Sn, blue oxide
4.60-4.64m: J, 30-50°, Un, Sm, Vr, blue oxide
4.95m: J, 30°, Pl, Sm, Sn, blue oxide
5.37m: J, 10°, Pl, Sm, Sn, blue oxide
5.74-5.75m: J, 20°, Un, Sm, Sn, blue oxide
6.00m: J, 20°, Un, Ro, Cn
6.61m: J, 5°, Pl, Sm, Cn
6.91m: J, 15°, Pl, Sm, Sn, blue oxide
7.29-7.30m: J, 20°, Un, Sm, Sn, blue oxide
7.68m: J, 15°, Pl, Sm, Sn, blue oxide
7.86m: J, 15°, Pl, Sm, Sn, calcite

AVERAGE DEFECT SPACING (mm): 10 30 100 300 1000 3000

Depth scale: 0.0 – 8.0

Golder Associates

REPORT OF BOREHOLE: BH2007

SHEET: 3 OF 3

CLIENT:	ARUP	COORDS: 552261.3 m E 6821191.7 m N 56 MGA94		DRILL RIG: Tracked Scout	
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 88.62 m	DATUM: AHD	DRILLER: Drillsearch	
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°		LOGGED: BC	DATE: 28/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm	HOLE DEPTH: 11.60 m	CHECKED: CSC	DATE: 13/8/07

Drilling						Field Material Description				Defect Information	
METHOD	WATER	TCR	RQD (SCR)	DEPTH (meters)	*DEPTH* RL	GRAPHIC LOG	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING	INFERRED STRENGTH Is(50) MPa (EL 0.03 VL 0.1 L 0.3 M 1 H 3 VH 10 EH)	DEFECT DESCRIPTION & Additional Observations	AVERAGE DEFECT SPACING (mm) (10 30 100 300 1000 3000)
NMLC		100	83 (100)	8.0			BASALT, grey with some red iron stained veins	SW	VH	8.10-8.12m: J, 60°, Un, Ro, Vr, blue oxide 8.25-8.26m: J, 30°, Un, Ro, Sn, blue oxide 8.27-8.70m: J, 20-90°, Un, Ro, Sn, blue oxide 8.48m: J, 10°, Un, Ro, Cn 8.54m: J, 10°, Un, Ro, Cn 8.72-9.00m: J, 50-90°, Un, Ro, Sn 8.73m: J, 15°, Un, Ro, Cn 9.00m: J, 0°, Un, Ro, Cn 9.10m: J, 5°, Un, Ro, Cn 9.69m: J, 0°, Un, Sm, Cn	100-300 (8.0-8.25) 30-100 (8.25-9.1) 300-1000 (9.1-11.6)
				10.0	*10.00* 78.62		iron stained vein content increasing			10.28m: J, 20°, Un, Ro, Cn 10.74m: J, 5°, Un, Sm, Vr, blue oxide 11.09-11.11m: J, 45°, Un, Sm, Sn, iron	
				11.5	*11.60*		END OF BOREHOLE @ 11.60 m Reached target depth Piezometer installed				

Depth scale: 8.0, 8.5, 9.0, 9.5, 10.0, 10.5, 11.0, 11.5, 12.0, 12.5, 13.0, 13.5, 14.0, 14.5, 15.0, 15.5, 16.0

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GAP gINT FN. F02a
RL2

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Golder Associates

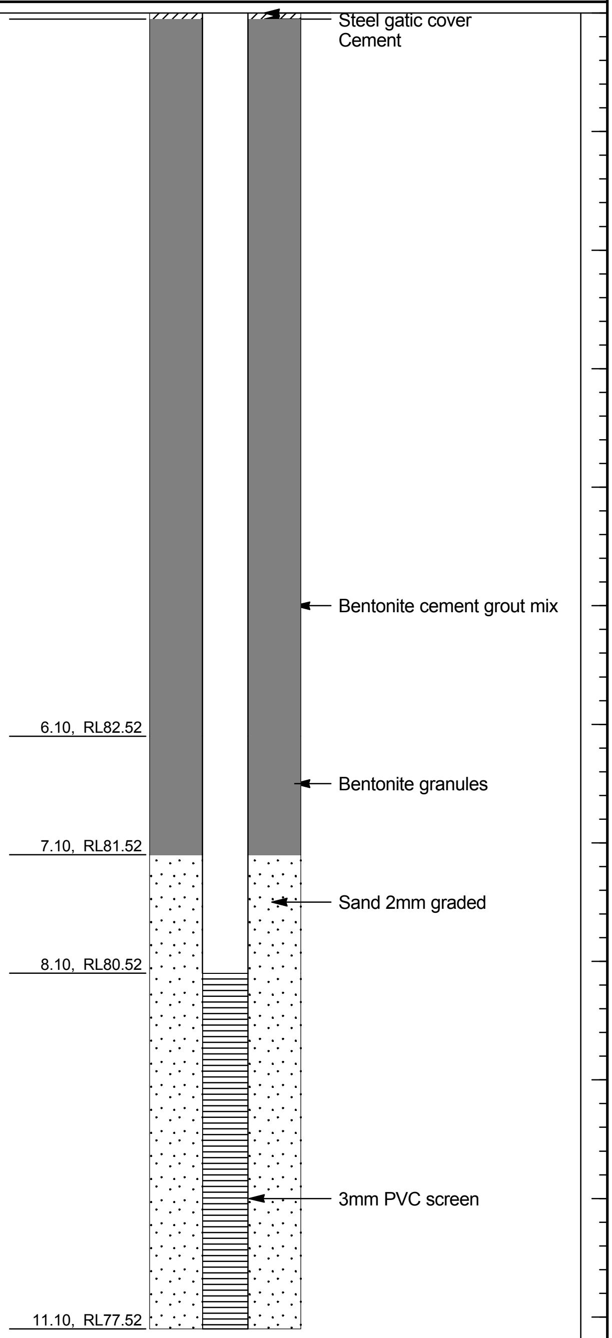
REPORT OF STANDPIPE INSTALLATION: BH2007

SHEET: 1 OF 1

CLIENT: ARUP	COORDS: 552261.3 m E 6821191.7 m N 56 MGA94	DRILL RIG: Tracked Scout	
PROJECT: Pacific Highway Upgrade	SURFACE RL: 88.62 m DATUM: AHD	DRILLER: Drillsearch	
LOCATION: Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: BC	DATE: 28/7/07
JOB NO: 06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 11.60 m	CHECKED: CSC	DATE: 13/8/07

Drilling					Field Material Description	
METHOD	WATER	DRILL FLUID LEVELS	DEPTH (metres)	*DEPTH* RL	GRAPHIC LOG	ABBREVIATED SOIL / ROCK MATERIAL DESCRIPTION (Refer to Report of Borehole For Details)
ADT	22/08/2007 30/07/2007		0	88.62	×	Silty CLAY
				0.80 87.82	V	BASALT
NMLC				*2.40* 86.22	V	BASALT
				11.60 77.02		

Instrumentation Details



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GAP gINT FN. F17
RL0

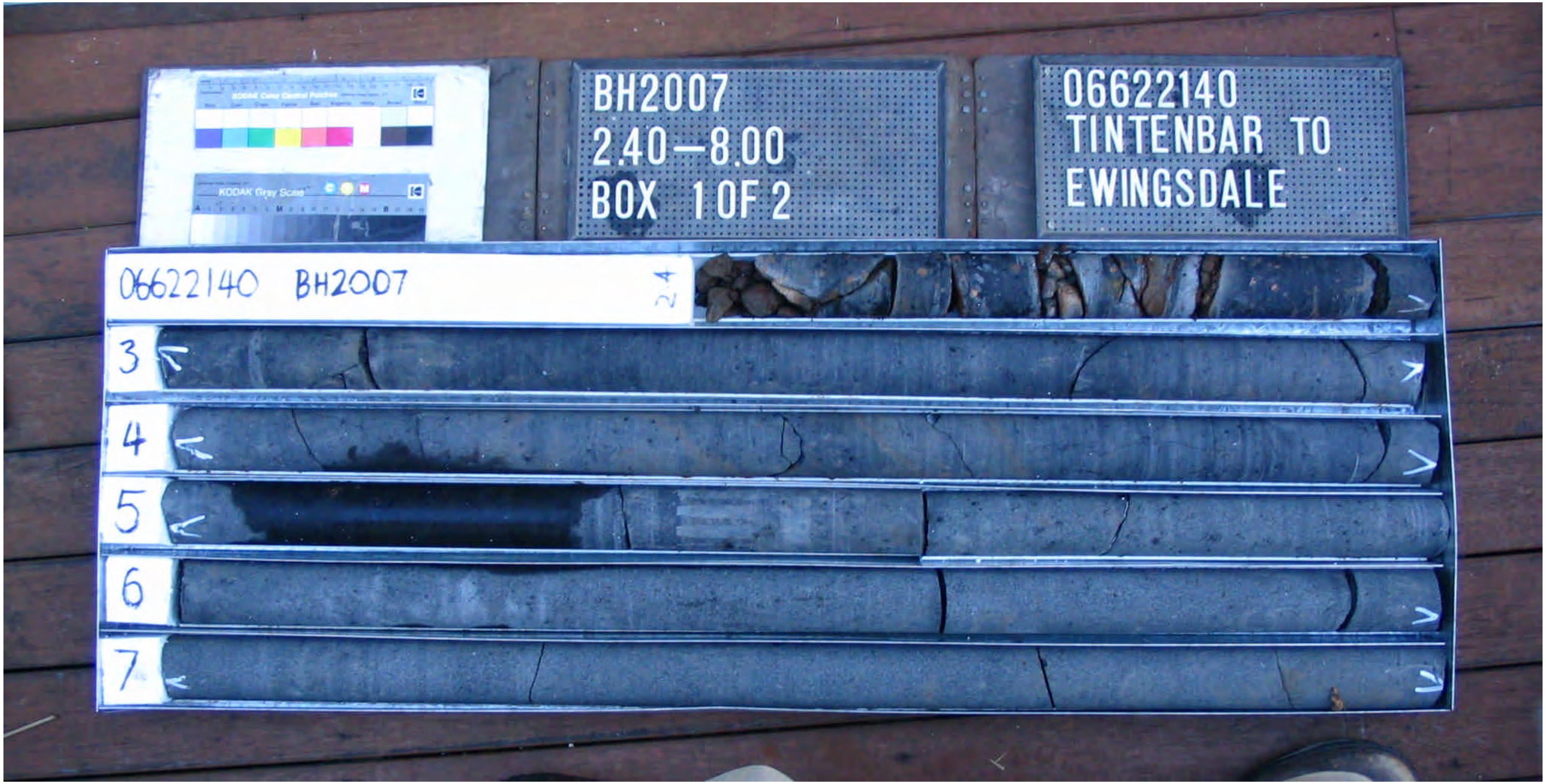
GAP6_0-BETA_NEW ONE_25.06.07 SRAS ALTERED BY DATGEL 2007-07-02.GLB WELL3 J:\06PROJ\101-150\06622140_ARUP_T2E PREFERRED ROUTE\7000 FIELD AND LABORATORY DATA\7870 GINT\06622140 PH.GPJ GAP6_0-BETA-PH.GDT 05/09/2007 2:44:57 PM

REPORT OF CORE PHOTOGRAPHS: BH2007

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 552261.3 m E 6821191.7 m N 56 MGA94
SURFACE RL: 88.62 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 11.60 m

SHEET: 1 OF 2
DRILL RIG: Tracked Scout
DRILLER: Drillsearch
LOGGED: BC DATE: 28/7/07
CHECKED: CSC DATE: 13/8/07



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Golder Associates

REPORT OF CORE PHOTOGRAPHS: BH2007

SHEET: 2 OF 2

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 552261.3 m E 6821191.7 m N 56 MGA94
SURFACE RL: 88.62 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 11.60 m

DRILL RIG: Tracked Scout
DRILLER: Drillsearch
LOGGED: BC DATE: 28/7/07
CHECKED: CSC DATE: 13/8/07

Golder Associates

REPORT OF BOREHOLE: BH2008

SHEET: 1 OF 2

CLIENT: ARUP	COORDS: 552262.1 m E 6821190.6 m N 56 MGA94	DRILL RIG: Tracked Scout	
PROJECT: Pacific Highway Upgrade	SURFACE RL: 88.58 m DATUM: AHD	DRILLER: Drillsearch	
LOCATION: Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: BC	DATE: 27/7/07
JOB NO: 06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 5.00 m	CHECKED: CSC	DATE: 13/8/07

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USC Symbol	SOIL / ROCK MATERIAL DESCRIPTION	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
ADT	M		0.0	88.58				CH	Silty CLAY, high plasticity, red brown	M		RESIDUAL SOIL
	H	22/08/2007	1.0	1.00 87.58					BASALT, grey brown and red, very low to low strength, extremely to highly weathered			WEATHERED ROCK
		30/07/2007	2.5	2.50 86.08					For Continuation Refer to Sheet 2			
			3.0									
			3.5									
			4.0									
			4.5									
			5.0									
			5.5									
			6.0									
			6.5									
			7.0									
			7.5									
			8.0									

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GAP gINT FN. F01a
RL2

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REPORT OF BOREHOLE: BH2008

SHEET: 2 OF 2

CLIENT:	ARUP	COORDS: 552262.1 m E 6821190.6 m N 56 MGA94		DRILL RIG: Tracked Scout	
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 88.58 m	DATUM: AHD	DRILLER: Drillsearch	
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°		LOGGED: BC	DATE: 27/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm	HOLE DEPTH: 5.00 m	CHECKED: CSC	DATE: 13/8/07

Drilling						Field Material Description				Defect Information	
METHOD	WATER	TCR	RQD (SCR)	DEPTH (meters)	DEPTH RL	GRAPHIC LOG	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING	INFERRED STRENGTH $Is_{(50)}$ MPa EL VL L M H VH EH 0.03 0.1 0.3 1 3 10	DEFECT DESCRIPTION & Additional Observations	AVERAGE DEFECT SPACING (mm) 10 30 100 300 1000 3000
				0.0 – 2.5	2.50		Continuation of Sheet 1				
NMLC		100	84 (95)	2.5	86.08		BASALT, grey with red iron stained veins	MW		2.60m: J, 20°, Pl, Ro, Sn, iron stained 2.62m: J, 25°, Pl, Ro, Sn, iron stained 2.68m: J, 10°, Pl, Sm, Sn, iron stained	
				3.0				SW		2.83m: J, 15°, Pl, Ro, Sn, iron stained 2.86m: J, 10°, Un, Sm, Sn, iron stained 2.91m: J, 15°, Un, Ro, Sn, iron stained	
				3.5						3.54m: J, 30°, Un, Sm, Sn, blue oxide 3.80m: J, 20°, Pl, Sm, Cn	
				4.5						4.52m: 40°, Un, Sm, Vr, blue oxide 4.83m: J, 15°, Un, Sm, Cn	
				5.0	5.00		END OF BOREHOLE @ 5.00 m Reached target depth Piezometer installed Note: borehole drilled for piezometer installation only				
				5.5 – 8.0							

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GAP gINT FN. F02a
RL2

REPORT OF STANDPIPE INSTALLATION: BH2008

SHEET: 1 OF 1

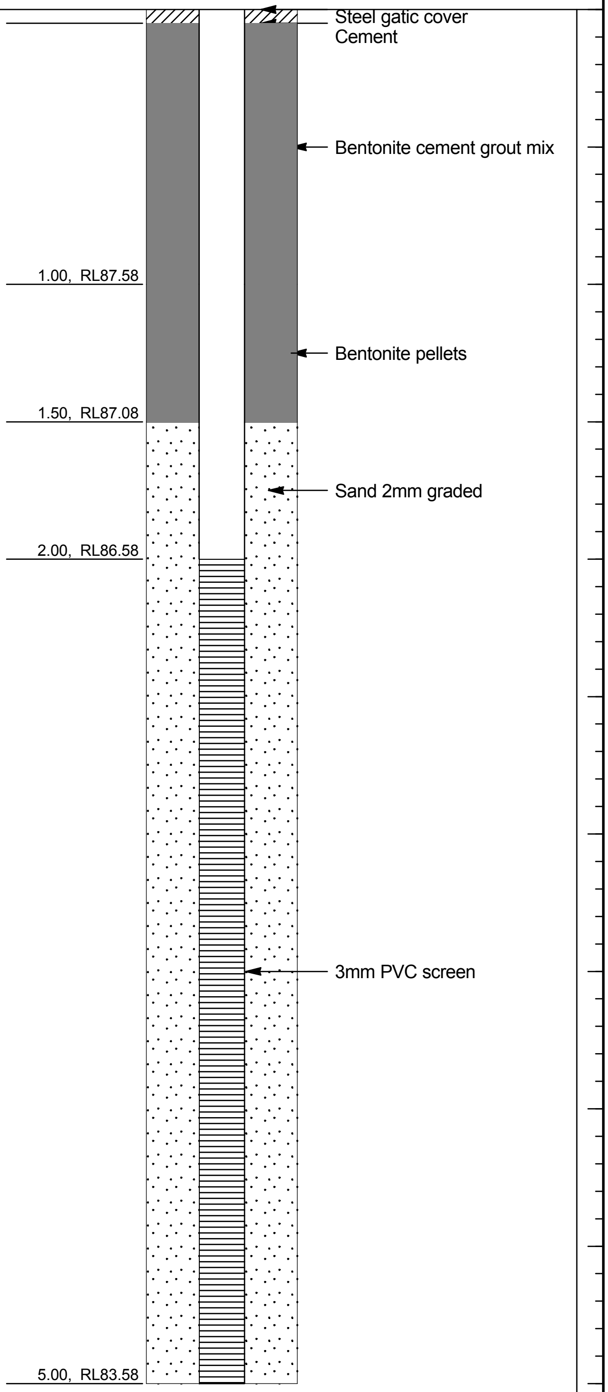
CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 552262.1 m E 6821190.6 m N 56 MGA94
SURFACE RL: 88.58 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 5.00 m

DRILL RIG: Tracked Scout
DRILLER: Drillsearch
LOGGED: BC DATE: 27/7/07
CHECKED: CSC DATE: 13/8/07

Drilling | **Field Material Description** | **Instrumentation Details**

METHOD	WATER	DRILL FLUID LEVELS	DEPTH (metres)	DEPTH RL	GRAPHIC LOG	ABBREVIATED SOIL / ROCK MATERIAL DESCRIPTION (Refer to Report of Borehole For Details)
ADT			0.0	88.58		Silty CLAY
	22/08/2007 30/07/2007		1.0	1.00 87.58		BASALT
NMLC			2.5	2.50 86.08		BASALT
			5.0	5.00 83.58		
			5.5			



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REPORT OF CORE PHOTOGRAPHS: BH2008

SHEET: 1 OF 1

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 552262.1 m E 6821190.6 m N 56 MGA94
SURFACE RL: 88.58 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 5.00 m

DRILL RIG: Tracked Scout
DRILLER: Drillsearch
LOGGED: BC DATE: 27/7/07
CHECKED: CSC DATE: 13/8/07

REPORT OF BOREHOLE: BH2009

SHEET: 1 OF 5

CLIENT:	ARUP	COORDS: 552966.8 m E 6828454.4 m N 56 MGA94		DRILL RIG: Pioneer 120	
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 94.30 m	DATUM: AHD	DRILLER: North Coast Drilling	
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°		LOGGED: AM	DATE: 13/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm	HOLE DEPTH: 30.30 m	CHECKED: CSC	DATE: 13/8/07

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USC Symbol	SOIL / ROCK MATERIAL DESCRIPTION	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
ADT	L		0.0	94.30				MI	Sandy Clayey SILT, medium plasticity, red, medium grained sand, with trace of root fibres upper 200mm	M (~PL)	VSt	RESIDUAL SOIL
			1.0	1.00 93.30	SPT 1.00-1.45 m 3,7,10 N = 17	■		MH	As above, high plasticity			
WB			1.5									
			2.0	2.00 92.30					BASALT, grey and orange, extremely low strength, extremely to highly weathered			EXTREMELY WEATHERED ROCK
			2.5		SPT 2.50-2.95 m 6,5,9 N = 14	■						
			4.0		SPT 4.00-4.45 m 7,7,7 N = 14	■						
			5.5	5.50 88.80	SPT 5.50-5.95 m 2,3,5 N = 8	■			red, with trace calcite amygdules			
			7.0		SPT 7.00-7.30 m 12,20/140 N = HB	■						
			7.30	7.30 87.00					For Continuation Refer to Sheet 2			
			7.5									
			8.0									

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GAP gINT FN. F01a
RL2

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REPORT OF BOREHOLE: BH2009

SHEET: 2 OF 5

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 552966.8 m E 6828454.4 m N 56 MGA94
SURFACE RL: 94.30 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 30.30 m

DRILL RIG: Pioneer 120
DRILLER: North Coast Drilling
LOGGED: AM DATE: 13/7/07
CHECKED: CSC DATE: 13/8/07

Drilling						Field Material Description				Defect Information	
METHOD	WATER	TCR	RQD (SCR)	DEPTH (meters)	DEPTH RL	GRAPHIC LOG	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING	INFERRED STRENGTH Is(50) MPa (EL, VL, L, M, H, VH, EH; 0.03, 0.1, 0.3, 1, 3, 10)	DEFECT DESCRIPTION & Additional Observations	AVERAGE DEFECT SPACING (mm) (10, 30, 100, 300, 1000, 3000)
	40%				7.30		Continuation of Sheet 1				
NMLC					87.00		BASALT, dark grey, with trace 1-2mm diameter calcite amygdules	FR			
	80% 50%				7.70 86.60		BASALT, orange and brown with 2mm diameter calcite amygdules, with iron staining	HW		7.68m: J, 15°, Un, Ro, Sn, iron staining 7.75-7.94m: core recovered as fragmented rock	
				8.0	8.00						

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REPORT OF BOREHOLE: BH2009

SHEET: 3 OF 5

CLIENT:	ARUP	COORDS: 552966.8 m E 6828454.4 m N 56 MGA94		DRILL RIG: Pioneer 120	
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 94.30 m	DATUM: AHD	DRILLER: North Coast Drilling	
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°		LOGGED: AM	DATE: 13/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm	HOLE DEPTH: 30.30 m	CHECKED: CSC	DATE: 13/8/07

Drilling | **Field Material Description**

METHOD	WATER	TCR	RQD (SCR)	DEPTH (meters)	DEPTH RL	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING
NMLC		83	24 (24)	8.0	86.30	BASALT, dark brown to grey, with trace 1-2mm calcite amygdules	EW
				8.5	8.70 85.60	NO CORE 8.70-9.00m	
		57	47 (47)	9.0	9.00 85.30	BASALT, orange and grey brown with 2mm diameter calcite amygdules, with iron staining	EW
				9.5	9.85 84.45	NO CORE 9.85-10.60m	
				10.0			
		86	81 (81)	10.5	10.60 83.70	BASALT, orange and grey brown with some 2mm diameter calcite amygdules, with iron staining	EW
					10.80 83.50	Amygdaloidal BASALT, brown and orange, 2-5mm diameter calcite amygdules, with iron staining	
	90% ◀	100	88 (88)	11.0	11.10 83.20	BASALT, orange and grey brown with trace 2mm diameter calcite amygdules, with iron staining	
		100	89 (100)	11.5			
	50%	100	52 (89)	12.0	12.30	NO CORE 12.30-12.45m	
	◀	86	36 (41)	12.5	12.45 81.85	BASALT, orange and grey brown with some 2mm diameter calcite amygdules, with iron staining	HW
		100	64 (82)	13.0	13.10 81.20	BASALT, dark grey with zones of orange brown, heavily iron stained basalt	MW
		94	44 (63)	13.5 14.0 14.5 15.0 15.5 16.0	16.00		

INFERRED STRENGTH $Is_{(50)}$ MPa: EL 0.03 VL 0.1 L 0.3 M 1 H 3 VH 10 EH

Defect Information

DEFECT DESCRIPTION & Additional Observations

AVERAGE DEFECT SPACING (mm): 10 30 100 300 1000 3000

8.04-8.70m: Set 1, J, 20°, sp=50mm, Un, Ro, Cn
8.22-8.39m: J, 80-90°, Un, Ro, Cn
9.00-9.85m: cemented sub-vertical joint
9.80-9.84m: core damaged in barrel grippers
10.70m: J, 5°, Pl, Ro, Cn
10.70-11.20m: core recovered as fragmented rock
10.75m: J, 35°, Un, Ro, Cn
10.90m: J, 50°, Un, Ro, Cn
11.12m: J, 20°, Pl, Ro, Cn
11.19m: J, 5°, Un, Ro, Cn
11.41m: J, 10°, Un, Ro, Cn
11.49m: J, 5°, Pl, Ro, Cn
11.68-12.07m: Set 1, J, 5-10°, sp=100mm, Pl, Ro, Cn
12.05-12.30m: core recovered as fragmented rock
12.20m: J, 0°, Pl, Ro, Cn
12.57m: J, 0°, Un, Ro, Cn
12.71m: J, 40°, Pl, Ro, Cn
12.81m: J, 0°, Un, Sm, Cn
12.85-13.13m: Set 1, J, 20°, sp=30mm, Un, Sm, Cn
13.13-13.40m: J, 80°, Pl, Ro, Cn
13.45m: J, 10°, Un, Sm, Sn, iron staining
13.52m: J, 20°, Un, Sm, Sn, iron staining
13.58m: J, 25°, Un, Sm, Sn, iron staining
13.69m: J, 19°, Un, Sm, Cn, iron staining
13.75m: J, 0°, Un, Sm, Cn, iron staining
13.86-13.93m: core recovered as fragmented rock
14.08m: J, 55°, Un, Ro, Cn
14.13m: J, 10°, Un, Ro, Cn
14.36m: J, 10°, Pl, Ro, Cn
14.40m: J, 45°, Pl, Ro, Cn
14.40-14.50m: core recovered as fragmented rock
14.59m: J, 40°, Un, Ro, Cn
14.68m: J, 60°, Un, Ro, Cn
14.82m: J, 5°, Pl, Ro, Cn
14.92m: J, 20°, Pl, Sm, Sn, slight iron staining
15.06m: J, 45°, Pl, Ro, Cn
15.06-15.36m: J, 70-90°, Un, Ro, Sn, iron staining
15.36m: J, 30°, Pl, Sm, Cn
15.42m: J, 15°, Pl, Sm, Cn
15.71m: J, 5°, Pl, Ro, Cn

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REPORT OF BOREHOLE: BH2009

CLIENT:	ARUP	COORDS: 552966.8 m E 6828454.4 m N 56 MGA94		DRILL RIG: Pioneer 120	
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 94.30 m	DATUM: AHD	DRILLER: North Coast Drilling	
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°		LOGGED: AM	DATE: 13/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm	HOLE DEPTH: 30.30 m	CHECKED: CSC	DATE: 13/8/07

Drilling						Field Material Description		Defect Information
METHOD	WATER	TCR	RQD (SCR)	DEPTH (meters)	DEPTH RL	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING	DEFECT DESCRIPTION & Additional Observations
NMLC				16.0–16.10	16.10 78.20	NO CORE 16.00-16.10m		
		100 70	0 (50) 50 (65)	16.10–16.50	16.50 77.80	BASALT, dark grey and orange brown, heavily iron stained zones	HW SW	16.21m: J, 0°, St, Ro, Cn 16.25m: J, 15°, Un, Ro, Sn, slight iron staining 16.39m: J, 10°, Pl, Sm, Cn
	22/08/2007			16.50–17.00	17.00 77.30	As above, grey brown and orange	HW	16.51m: J, 5°, Pl, Ro, Cn 16.56m: J, 5°, Un, Ro, Cn 16.94m: J, 20°, Un, Sm, Cn
				17.00–17.60	17.60 76.70	NO CORE 17.00-17.60m		
	30/07/2007	80	37 (43)	17.60–18.80	18.80 75.50	BASALT, orange and pale grey, heavily iron stained zones	HW	17.96-18.08m: core recovered as fragmented rock 18.12-18.55m: Set 1, J, 15°, sp=100mm, Un-St, Ro, Cn 18.30m: J, 65°, Un, Ro, Sn, iron staining 18.40-18.53m: J, 80°, Un, Ro, Sn, iron staining 18.43m: J, 50°, Un, Sm, Sn, iron staining 18.72-18.80m: core recovered as fragmented rock
	50%	100	42 (58)	18.80–20.00	20.00 74.30	BASALT, red, with 2-10mm calcite amygdules	MW	18.94m: J, 20°, Un, Sm, Cn 19.03-19.33m: Set 1, J, 0°, sp=90mm, Un, Ro, Cn 19.44-19.74m: Set 1, J, 0°, sp=30mm, Un, Ro, Cn 19.84m: J, 65°, Pl, Ro, Cn 19.93m: J, 40°, Un, Ro, Cn
				20.00–20.20	20.20 74.10	NO CORE 20.00-20.20m		
		86 100 100	18 (36) 30 (70) 73 (90)	20.20–22.70	22.70 71.60	BASALT, grey, with trace iron staining, with some vesicles and 2-5mm calcite amygdules	MW SW	20.20-20.71m: Set 1, J, 0-10°, sp=20mm, Un, Ro, Cn, possible drilling breaks 20.85-21.03m: Set 1, J, 35°, sp=40mm, Un, Sm, Cn 21.10-21.23m: Set 1, J, 0°, sp=50mm, Un, Sm, Cn 21.35-21.38m: J, 0°, Pl, Sm, Ct, clay, 3mm 21.38m: Jx2, 30°, Pl, Sm, Ct, clay, 2mm 21.44m: J, 0°, Pl, Sm, Cn 21.50m: J, 0°, Un, Ro, Cn 21.65m: J, 15°, Un, Sm, Sn, slight iron staining 21.72-22.72m: Set 1, J, 15-20°, sp=80mm, Un, Sm, Cn 22.03m: J, 45°, Pl, Sm, Sn, iron staining 22.15m: Jx2, 30°, Pl, Ro, Sn, iron staining 22.48m: J, 5°, Un, Sm, Sn, slight iron staining 22.52m: J, 50°, Pl, Sm, Sn, iron staining
	10%			22.70–24.0		BASALT, dark grey	FR	22.52-22.57m: core recovered as fragmented rock 23.11m: J, 10°, Pl, Sm, Cn 23.22m: J, 0°, Un, Sm, Cn 23.85m: J, 20°, Pl, Sm, Vr, calcite veneer <1mm thick

INFERRED STRENGTH $Is_{(50)}$ MPa: EL, VL 0.03, L 0.1, M 0.3, H 1, VH 3, EH 10

AVERAGE DEFECT SPACING (mm): 10, 30, 100, 300, 1000, 3000

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REPORT OF BOREHOLE: BH2009

SHEET: 5 OF 5

CLIENT:	ARUP	COORDS: 552966.8 m E 6828454.4 m N 56 MGA94		DRILL RIG: Pioneer 120	
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 94.30 m	DATUM: AHD	DRILLER: North Coast Drilling	
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°		LOGGED: AM	DATE: 13/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm	HOLE DEPTH: 30.30 m	CHECKED: CSC	DATE: 13/8/07

Drilling

METHOD	WATER	TCR	RQD (SCR)	DEPTH (meters)
NMLC		100	100 (100)	24.0–24.9
NMLC		100	100 (100)	24.9–26.3
NMLC		100	100 (100)	26.3–28.8
NMLC		100	100 (100)	28.8–30.3

Field Material Description

DEPTH RL	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING	INFERRED STRENGTH $Is_{(50)}$ MPa
	BASALT, dark grey	FR	H
28.10 66.20	Vescular BASALT, dark grey, 1-15mm diameter vesicles	SW	M
28.30 66.00	red and grey, with green calcite amygdules	MW	M
28.90 65.40	BASALT, dark grey, with 1-10mm vesicles, and 2-5mm calcite amygdules (concentrated in lenses/layers)	SW	H
30.30	END OF BOREHOLE @ 30.30 m Piezometer installed		

Defect Information

DEFECT DESCRIPTION & Additional Observations

24.72m: J, 5°, Pl, Sm, Cn
24.88m: J, 5°, Pl, Sm, Cn
24.90m: J, 0°, Un, Sm, Cn
25.74m: J, 5°, St, Sm, Cn
26.24m: J, 5°, Pl, Sm, Cn
26.44m: J, 0°, Pl, Sm, Cn
26.69m: J, 5°, Pl, Sm, Cn
26.95m: J, 0°, Pl, Sm, Cn
27.10m: J, 5°, St, Sm, Cn
27.36m: J, 70°, Pl, Sm, Cn
27.66m: J, 25°, Pl, Sm, Cn
27.90m: J, 10°, Pl, Ro, Cn
28.12m: J, 0°, Pl, Ro, Cn
28.24m: J, 40°, Un, Ro, Cn
28.30m: J, 40°, Un, Ro, Cn
28.30-28.60m: core recovered as fragmented rock
28.42m: J, 10°, Un, Ro, Cn
28.60m: J, 25°, Un, Ro, Cn
28.84m: J, 15°, Pl, Ro, Cn
29.18m: J, 5°, St, Ro, Cn
29.28m: J, 15°, Pl, Ro, Cn
29.52m: J, 35°, Pl, Sm, Cn
29.63m: J, 45°, St, Sm, Cn
30.08m: J, 10°, Pl, Sm, Cn

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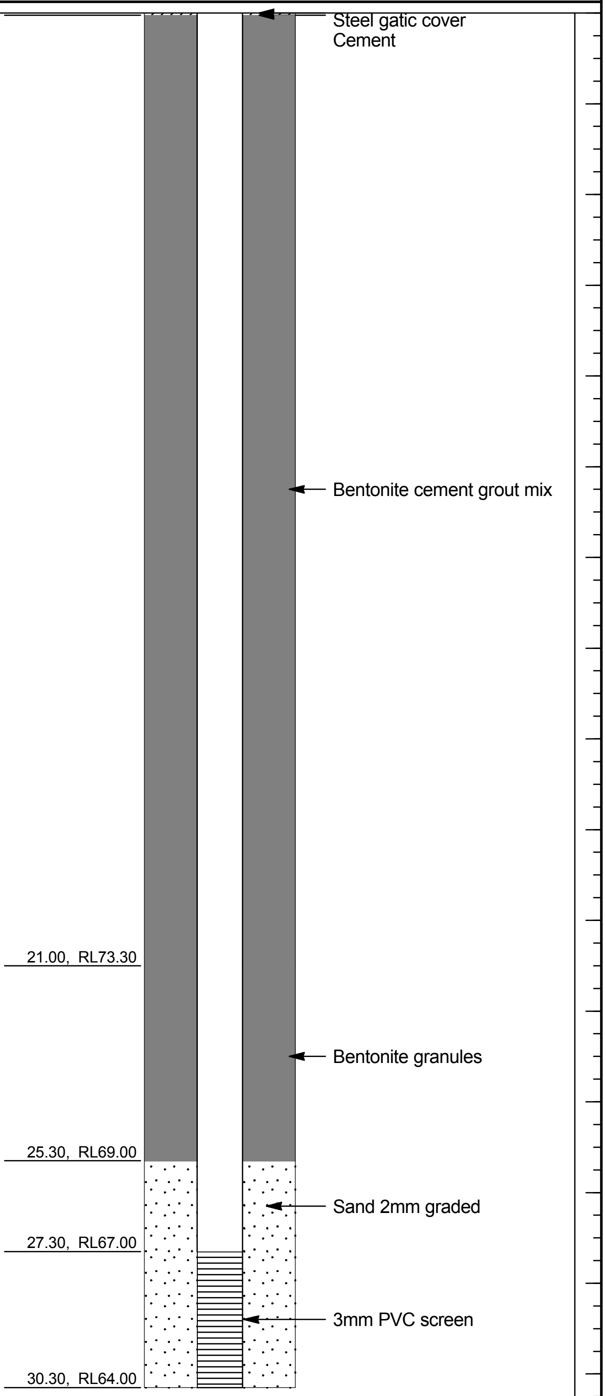
REPORT OF STANDPIPE INSTALLATION: BH2009

SHEET: 1 OF 1

CLIENT:	ARUP	COORDS: 552966.8 m E 6828454.4 m N 56 MGA94		DRILL RIG: Pioneer 120	
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 94.30 m	DATUM: AHD	DRILLER: North Coast Drilling	
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°		LOGGED: AM	DATE: 13/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm	HOLE DEPTH: 30.30 m	CHECKED: CSC	DATE: 13/8/07

Drilling					Field Material Description	
METHOD	WATER	DRILL FLUID LEVELS	DEPTH (metres)	*DEPTH* RL	GRAPHIC LOG	ABBREVIATED SOIL / ROCK MATERIAL DESCRIPTION (Refer to Report of Borehole For Details)
ADT			0	94.30		Clayey SILT
				1.00 93.30		Clayey SILT
WB			2	*2.00* 92.30		BASALT
			4			
			6			
NMLC	50%			*7.30*		BASALT
			8			BASALT
				8.70		NO CORE
				85.30		BASALT
			10	*9.85* 84.45		NO CORE
				10.60		BASALT
	30%			83.20		BASALT
						BASALT
	50%		12	*12.30*		NO CORE
				13.10 81.20		BASALT
						BASALT
			14			
	17/08/2007		16	*16.00* 78.20		NO CORE
						BASALT
				17.00		NO CORE
	30%		18	*17.60* 76.70		BASALT
	30/07/2007			*18.80* 75.50		BASALT
	50%		20	*20.00* 74.10		BASALT
						BASALT
			22	*22.70* 71.60		BASALT
	10%		24			
			26			
			28	*28.10* 66.20		BASALT
				28.90 65.40		BASALT
			30	*30.30* 64.00		
			32			

Instrumentation Details



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GAP gINT FN. F17
RL0

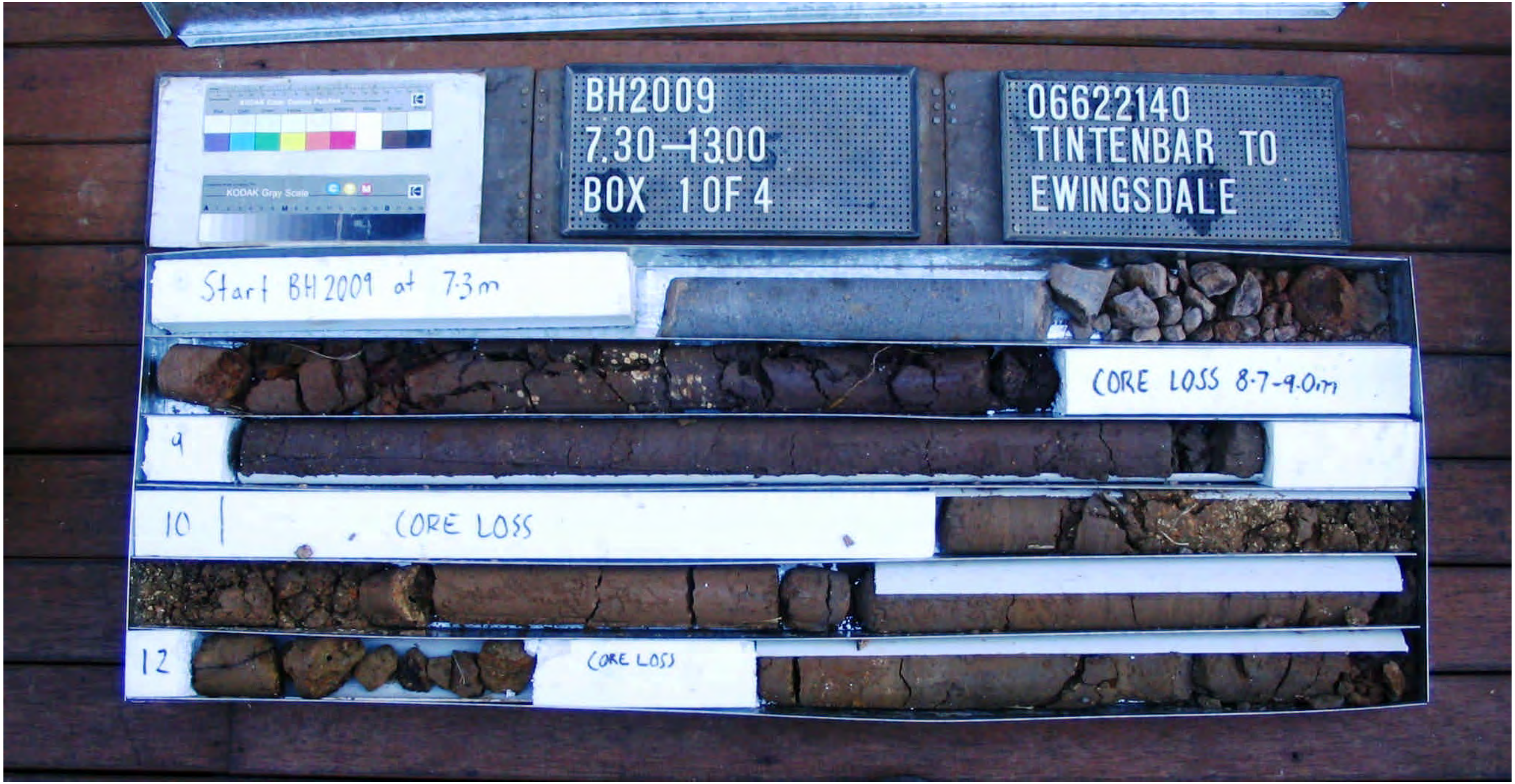
REPORT OF CORE PHOTOGRAPHS: BH2009

SHEET: 1 OF 4

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 552966.8 m E 6828454.4 m N 56 MGA94
SURFACE RL: 94.30 m   DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm   HOLE DEPTH: 30.30 m

DRILL RIG: Pioneer 120
DRILLER: North Coast Drilling
LOGGED: AM   DATE: 13/7/07
CHECKED: CSC   DATE: 13/8/07



GAP6_0-BETA_NEW ONE_25.06.07 SRAS ALTERED BY DATGEL 2007-07-02.GLB CORE PHOTO 1 PER PAGE J:\06PROJ\101-150\06622140_ARUP_T2E PREFERRED ROUTE\7000 FIELD AND LABORATORY DATA\7870 GINT\06622140 P

Golder Associates

REPORT OF CORE PHOTOGRAPHS: BH2009

SHEET: 2 OF 4
DRILL RIG: Pioneer 120
DRILLER: North Coast Drilling
LOGGED: AM DATE: 13/7/07
CHECKED: CSC DATE: 13/8/07

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 552966.8 m E 6828454.4 m N 56 MGA94
SURFACE RL: 94.30 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 30.30 m

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Golder Associates

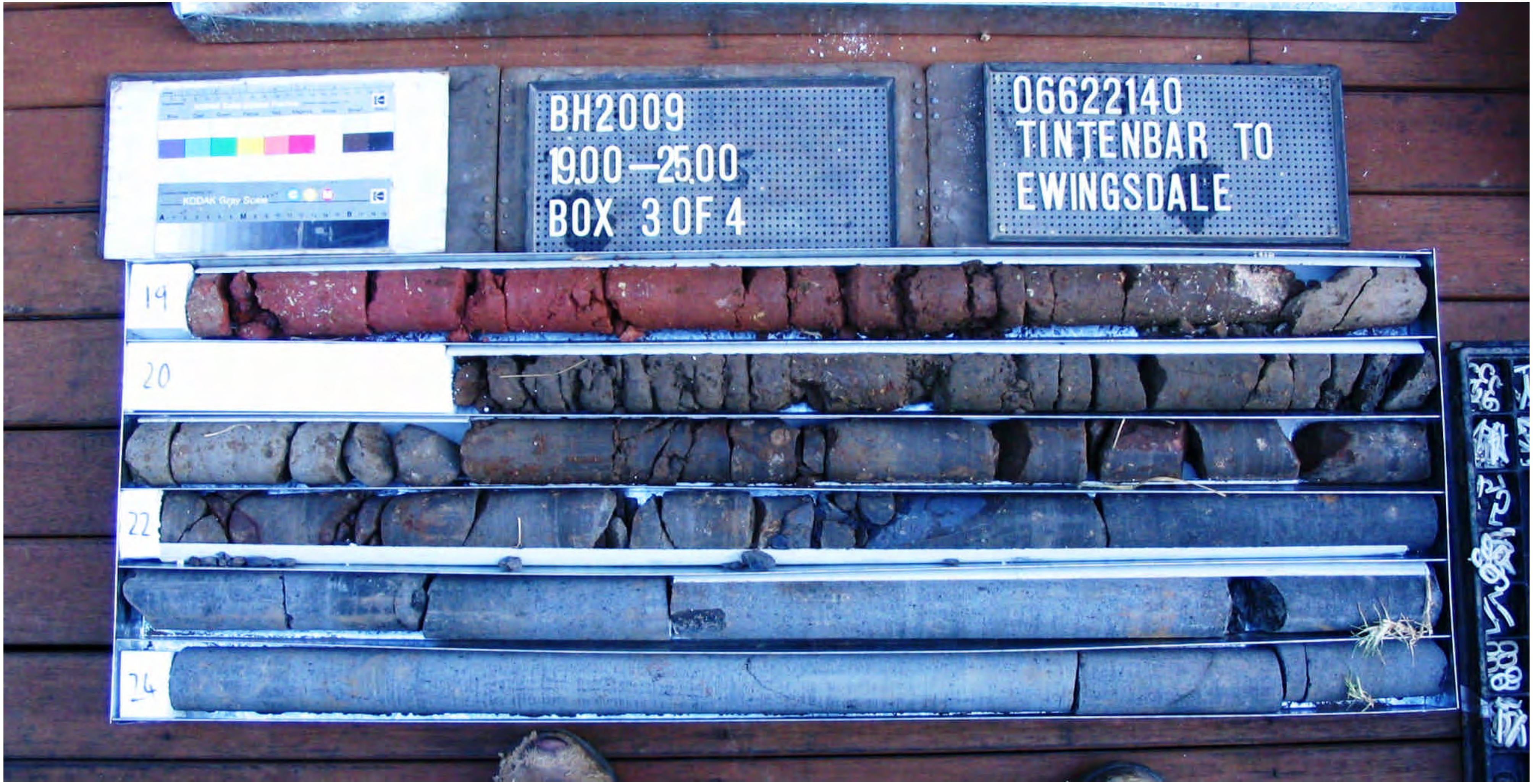
REPORT OF CORE PHOTOGRAPHS: BH2009

SHEET: 3 OF 4

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 552966.8 m E 6828454.4 m N 56 MGA94
SURFACE RL: 94.30 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 30.30 m

DRILL RIG: Pioneer 120
DRILLER: North Coast Drilling
LOGGED: AM DATE: 13/7/07
CHECKED: CSC DATE: 13/8/07



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Golder Associates

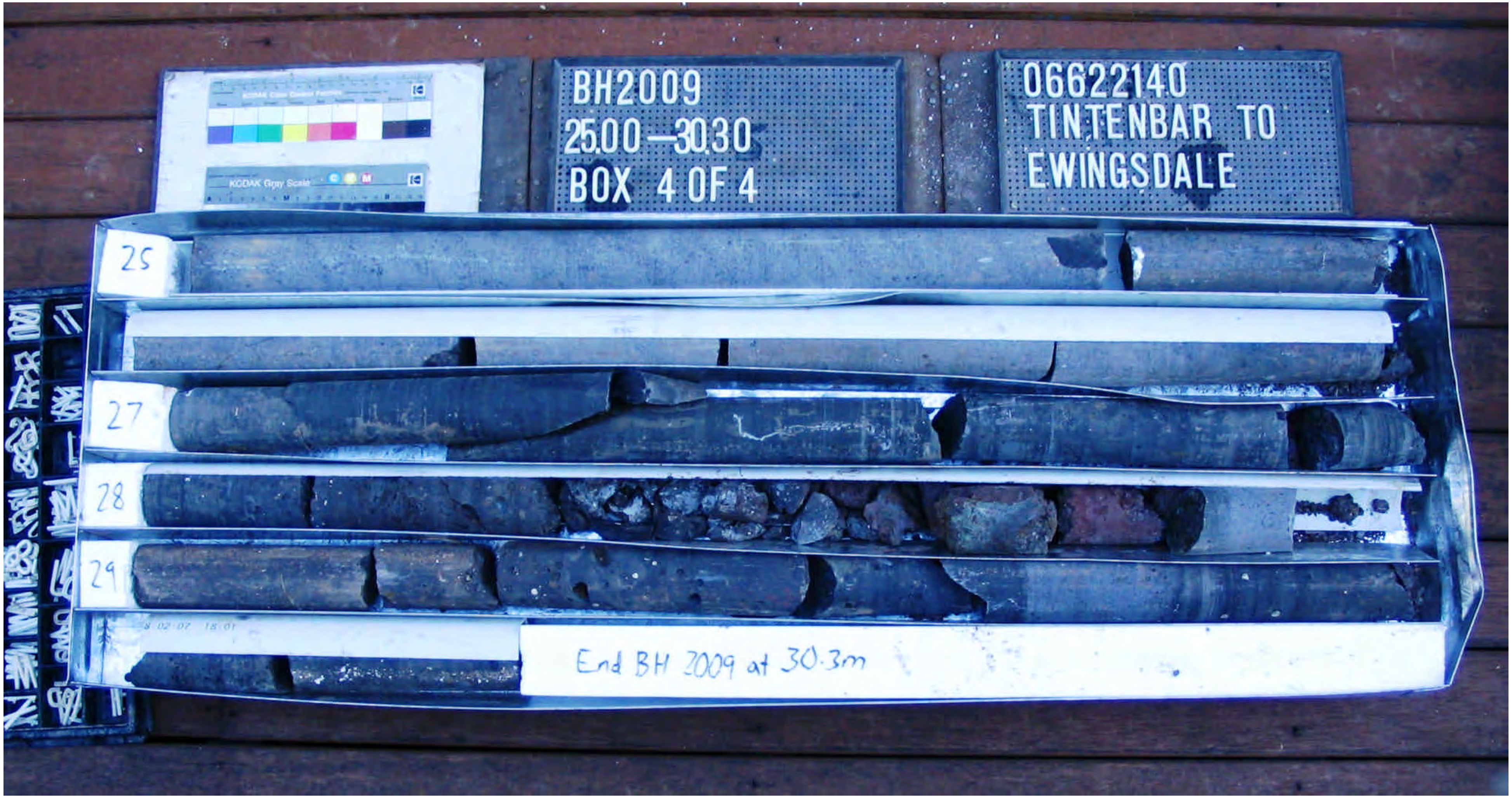
REPORT OF CORE PHOTOGRAPHS: BH2009

SHEET: 4 OF 4

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 552966.8 m E 6828454.4 m N 56 MGA94
SURFACE RL: 94.30 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 30.30 m

DRILL RIG: Pioneer 120
DRILLER: North Coast Drilling
LOGGED: AM DATE: 13/7/07
CHECKED: CSC DATE: 13/8/07



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Golder Associates

REPORT OF BOREHOLE: BH2010

SHEET: 1 OF 2

CLIENT:	ARUP	COORDS: 552967.2 m E 6828452.3 m N 56 MGA94		DRILL RIG: Pioneer 120	
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 94.01 m	DATUM: AHD	DRILLER: North Coast Drilling	
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°		LOGGED: BC	DATE: 18/7/07
JOB NO:	06622140	HOLE DIA: 100 mm	HOLE DEPTH: 12.10 m	CHECKED: CSC	DATE: 13/8/07

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USC Symbol	SOIL / ROCK MATERIAL DESCRIPTION	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
WB	L-M		0.0	94.01				CH	Silty CLAY, high plasticity, red brown			RESIDUAL SOIL
	M		1.0	*1.00* 93.01				MH	Clayey SILT, high plasticity, red brown			RESIDUAL SOIL TO EXTREMELY WEATHERED ROCK
	H		7.5									
	M-H											
			8.0									

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GAP gINT FN. F01a
RL2

Golder Associates

REPORT OF BOREHOLE: BH2010

CLIENT: ARUP	COORDS: 552967.2 m E 6828452.3 m N 56 MGA94	SHEET: 2 OF 2	
PROJECT: Pacific Highway Upgrade	SURFACE RL: 94.01 m DATUM: AHD	DRILL RIG: Pioneer 120	
LOCATION: Tintenbar to Ewingsdale	INCLINATION: -90°	DRILLER: North Coast Drilling	
JOB NO: 06622140	HOLE DIA: 100 mm HOLE DEPTH: 12.10 m	LOGGED: BC	DATE: 18/7/07
		CHECKED: CSC	DATE: 13/8/07

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USC Symbol	SOIL / ROCK MATERIAL DESCRIPTION	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
WB	M-H	22/08/2007 (at 10.7) ◄ (at 11.1)	8.0					MH	Clayey SILT, high plasticity, red brown			RESIDUAL SOIL TO EXTREMELY WEATHERED ROCK
			12.10	81.91					END OF BOREHOLE @ 12.10 m Piezometer installed Note: borehole drilled for piezometer installation only			

Depth scale: 8.0, 8.5, 9.0, 9.5, 10.0, 10.5, 11.0, 11.5, 12.0, 12.5, 13.0, 13.5, 14.0, 14.5, 15.0, 15.5, 16.0

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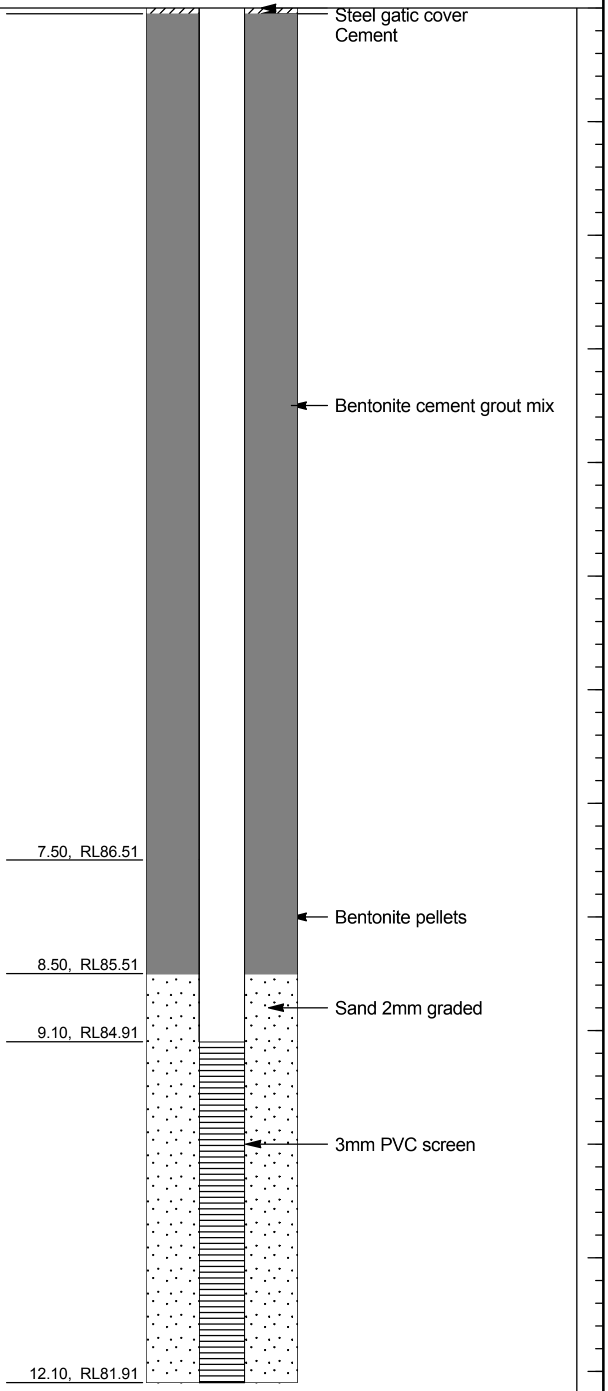
REPORT OF STANDPIPE INSTALLATION: BH2010

SHEET: 1 OF 1

CLIENT: ARUP	COORDS: 552967.2 m E 6828452.3 m N 56 MGA94	DRILL RIG: Pioneer 120	
PROJECT: Pacific Highway Upgrade	SURFACE RL: 94.01 m DATUM: AHD	DRILLER: North Coast Drilling	
LOCATION: Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: BC	DATE: 18/7/07
JOB NO: 06622140	HOLE DIA: 100 mm HOLE DEPTH: 12.10 m	CHECKED: CSC	DATE: 13/8/07

Drilling					Field Material Description		Instrumentation Details
METHOD	WATER	DRILL FLUID LEVELS	DEPTH (metres)	DEPTH RL	GRAPHIC LOG	ABBREVIATED SOIL / ROCK MATERIAL DESCRIPTION (Refer to Report of Borehole For Details)	
WB			0	94.01		Silty CLAY	
			1	1.00 93.01		Clayey SILT	
	22/08/2007		11				
			12	12.10 81.91			
			13				



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GAP gINT FN. F17
RL0

GAP6_0-BETA_NEW ONE_25.06.07 SRAS ALTERED BY DATGEL 2007-07-02.GLB WELL3 J:\06PROJ\101-150\06622140_ARUP_T2E PREFERRED ROUTE\7000 FIELD AND LABORATORY DATA\7870 GINT\06622140 PH.GPJ GAP6_0-BETA-PH.GDT 05/09/2007 2:50:29 PM

REPORT OF BOREHOLE: BH2011

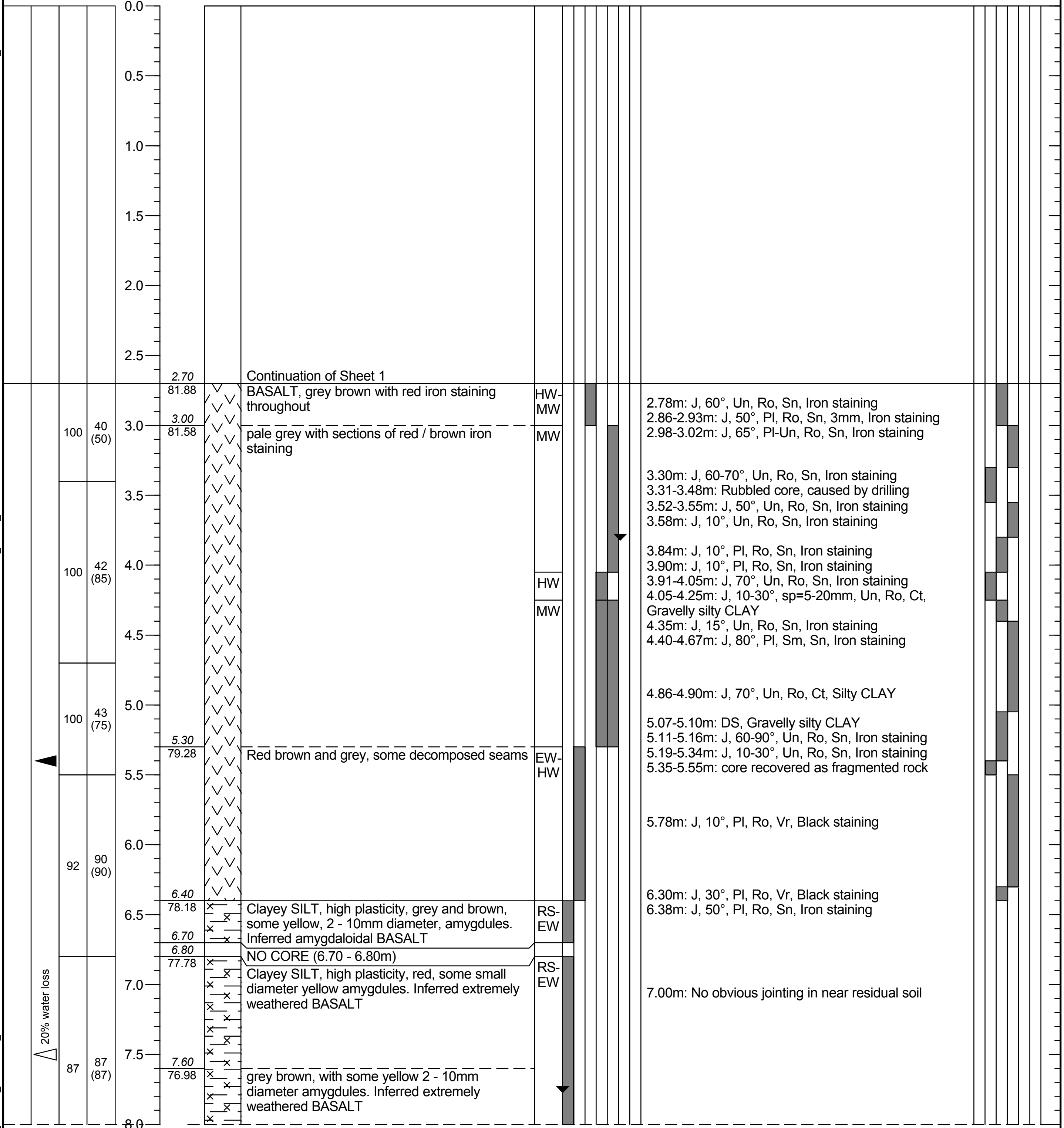
CLIENT: ARUP	COORDS: 553040.9 m E 6828442.5 m N 56 MGA94	SHEET: 1 OF 4	
PROJECT: Pacific Highway Upgrade	SURFACE RL: 84.58 m DATUM: AHD	DRILL RIG: Pioneer 120	
LOCATION: Tintenbar to Ewingsdale	INCLINATION: -90°	DRILLER: North Coast Drilling	
JOB NO: 06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 20.30 m	LOGGED: BC	DATE: 17/7/07
		CHECKED: CSC	DATE: 13/8/07

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USC Symbol	SOIL / ROCK MATERIAL DESCRIPTION	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
ADT			0.0	84.58				MH	Clayey SILT, high plasticity, brown with trace fine grained sand, with root fibres upper 200mm	M	St	RESIDUAL SOIL
			1.0	*1.00* 83.58	SPT 1.00-1.45 m 4,7,10 N = 17			MH	Clayey SILT, high plasticity, brown mottled grey, rock structure evident		VSt	RESIDUAL SOIL TO EXTREMELY WEATHERED ROCK
WB			1.5									
			2.5		SPT 2.50-2.60 m 15/100 N = HB							
				2.70 81.88					For Continuation Refer to Sheet 2			
			3.0									
			3.5									
			4.0									
			4.5									
			5.0									
			5.5									
			6.0									
			6.5									
			7.0									
			7.5									
			8.0									

REPORT OF BOREHOLE: BH2011

SHEET: 2 OF 4

CLIENT:	ARUP	COORDS: 553040.9 m E 6828442.5 m N 56 MGA94		DRILL RIG: Pioneer 120	
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 84.58 m	DATUM: AHD	DRILLER: North Coast Drilling	
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°		LOGGED: BC	DATE: 17/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm	HOLE DEPTH: 20.30 m	CHECKED: CSC	DATE: 13/8/07



METHOD	WATER	TCR	RQD (SCR)	DEPTH (meters)	DEPTH RL	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING	DEFECT DESCRIPTION & Additional Observations
				2.70		Continuation of Sheet 1		
		100	40 (50)		81.88	BASALT, grey brown with red iron staining throughout	HW-MW	2.78m: J, 60°, Un, Ro, Sn, Iron staining 2.86-2.93m: J, 50°, Pl, Ro, Sn, 3mm, Iron staining
				3.00	81.58	pale grey with sections of red / brown iron staining	MW	2.98-3.02m: J, 65°, Pl-Un, Ro, Sn, Iron staining 3.30m: J, 60-70°, Un, Ro, Sn, Iron staining 3.31-3.48m: Rubbled core, caused by drilling
		100	42 (85)					3.52-3.55m: J, 50°, Un, Ro, Sn, Iron staining 3.58m: J, 10°, Un, Ro, Sn, Iron staining 3.84m: J, 10°, Pl, Ro, Sn, Iron staining 3.90m: J, 10°, Pl, Ro, Sn, Iron staining 3.91-4.05m: J, 70°, Un, Ro, Sn, Iron staining
							HW	4.05-4.25m: J, 10-30°, sp=5-20mm, Un, Ro, Ct, Gravelly silty CLAY
							MW	4.35m: J, 15°, Un, Ro, Sn, Iron staining 4.40-4.67m: J, 80°, Pl, Sm, Sn, Iron staining
		100	43 (75)					4.86-4.90m: J, 70°, Un, Ro, Ct, Silty CLAY 5.07-5.10m: DS, Gravelly silty CLAY 5.11-5.16m: J, 60-90°, Un, Ro, Sn, Iron staining 5.19-5.34m: J, 10-30°, Un, Ro, Sn, Iron staining
	◄			5.30	79.28	Red brown and grey, some decomposed seams	EW-HW	5.35-5.55m: core recovered as fragmented rock
		92	90 (90)					5.78m: J, 10°, Pl, Ro, Vr, Black staining 6.30m: J, 30°, Pl, Ro, Vr, Black staining 6.38m: J, 50°, Pl, Ro, Sn, Iron staining
				6.40	78.18	Clayey SILT, high plasticity, grey and brown, some yellow, 2 - 10mm diameter, amygdules. Inferred amygdaloidal BASALT	RS-EW	
				6.70		NO CORE (6.70 - 6.80m)		
	20% water loss	87	87 (87)	6.80	77.78	Clayey SILT, high plasticity, red, some small diameter yellow amygdules. Inferred extremely weathered BASALT	RS-EW	7.00m: No obvious jointing in near residual soil
				7.60	76.98	grey brown, with some yellow 2 - 10mm diameter amygdules. Inferred extremely weathered BASALT		

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REPORT OF BOREHOLE: BH2011

SHEET: 3 OF 4

CLIENT:	ARUP	COORDS: 553040.9 m E 6828442.5 m N 56 MGA94		DRILL RIG: Pioneer 120	
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 84.58 m	DATUM: AHD	DRILLER: North Coast Drilling	
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°		LOGGED: BC	DATE: 17/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm	HOLE DEPTH: 20.30 m	CHECKED: CSC	DATE: 13/8/07

Drilling

METHOD | WATER | TCR | RQD (SCR) | DEPTH (meters)

WATER: 30/07/2007; 22/08/2007

TCR	RQD (SCR)
13	0 (8)
100	85 (90)
100	89 (100)
100	70 (90)
100	90 (95)
100	100 (100)

Field Material Description

DEPTH RL	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING
8.17 76.41	NO CORE (8.17 - 8.40m)	
8.40 8.50 76.08	Clayey SILT, high plasticity, red, some small diameter yellow amygdules. Inferred extremely weathered BASALT NO CORE (8.50 - 9.20m)	RS-EW
9.20 75.38	Clayey SILT, high plasticity, red, some small diameter yellow amygdules and black veins. Inferred extremely weathered BASALT.	RS-EW EW
11.05 73.53	BASALT, grey with some green amygdules, microfractures throughout	HW-MW MW SW
12.50 72.08	Vesicular BASALT, grey / dark grey with 2 - 10mm diameter vesicles. Some vesicles infilled with green white amygdules	MW-SW
13.10 71.48	BASALT, red, vesicular	HW-MW
14.55 70.03	Vesicles infilled with calcite	
15.30 69.28	Frequency of vesicles decreasing	MW-SW

INFERRED STRENGTH $Is_{(50)}$ MPa: 0.03 0.1 0.3 1 3 10 — EL VL L M H VH EH

Defect Information

DEFECT DESCRIPTION & Additional Observations

AVERAGE DEFECT SPACING (mm): 10 30 100 300 1000 3000

- 8.06m: J, 20°, Un, Ro, Cn
- 8.45m: J, 30-80°, Un, Ro, Sn
- 9.39m: J, 10°, Un, Ro, Cn
- 10.06m: J, 10°, Un, Ro, Cn
- 10.11-10.20m: core recovered as fragmented rock
- 10.35m: J, 0°, Pl, Ro, Cn
- 10.42-10.44m: J, 10°, Un, Sm, Ct, 20mm
- 10.73m: J, 15°, Pl, Ro, Sn
- 11.11-11.21m: J, 20-40°, sp=10-30mm, Pl, Ro, Sn
- 11.41m: J, 10-30°, Un, Sm, Sn
- 11.42-11.54m: J, 70°, Pl, Sm, Sn
- 11.53-11.65m: J, 0°, sp=10-30mm, Un, Ro, Sn
- 11.73m: J, 5°, Pl, Sm, Sn
- 12.25m: J, 15-50°, Un, Ro, Cn
- 13.03m: J, 30°, Un, Ro, Cn
- 13.08-13.11m: J, 0-70°, Un, Ro, Sn
- 13.25-13.30m: J, 0-15°, sp=20mm, Un, Ro, Cn
- 13.68m: J, 20°, Un, Ro, Cn
- 14.36m: J, 30°, Un, Sm, Cn
- 15.07m: J, 20°, Un, Sm, Cn
- 15.23-15.28m: J, 50°, Un, Ro, Cn
- 15.83m: J, 15°, Un, Sm, Cn

DEPTH (meters): 8.0, 8.5, 9.0, 9.5, 10.0, 10.5, 11.0, 11.5, 12.0, 12.5, 13.0, 13.5, 14.0, 14.5, 15.0, 15.5, 16.0

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REPORT OF BOREHOLE: BH2011

SHEET: 4 OF 4

CLIENT:	ARUP	COORDS: 553040.9 m E 6828442.5 m N 56 MGA94		DRILL RIG: Pioneer 120	
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 84.58 m	DATUM: AHD	DRILLER: North Coast Drilling	
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°		LOGGED: BC	DATE: 17/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm	HOLE DEPTH: 20.30 m	CHECKED: CSC	DATE: 13/8/07

Drilling					Field Material Description		Defect Information
METHOD	WATER	TCR	RQD (SCR)	DEPTH (meters) / *DEPTH* RL	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING	DEFECT DESCRIPTION & Additional Observations
				16.0		MW-SW	16.18m: J, 25-35°, Un, Sm, Cn
		100	100 (100)	*16.30* 68.28	BASALT, grey with trace amygdules	SW-FR	16.36m: J, 45°, Un, Sm, Cn
							16.95m: J, 10°, Un, Ro, Cn
		100	97 (97)				17.40-17.42m: J, 40°, Un, Sl, Cn
							17.65m: Drill break
							18.16-18.57m: J, 75-85°, Un, Sl, Vr, green mineral
							18.51-18.54m: J, 0-5°, sp=5-20mm, Un, Ro, Cn
		100	93 (100)				19.29m: J, 15°, Un, Ro, Vr, Some green mineral deposits
							19.88-19.97m: J, 70°, sp=30mm, Un, Sm, Cn
				20.30	END OF BOREHOLE @ 20.30 m Piezometer installed		

Depth scale: 16.0, 16.5, 17.0, 17.5, 18.0, 18.5, 19.0, 19.5, 20.0, 20.5, 21.0, 21.5, 22.0, 22.5, 23.0, 23.5, 24.0

GRAPHIC LOG

INFERRED STRENGTH $Is_{(50)}$ MPa: EL, VL 0.03, L 0.1, M 0.3, H 1, VH 3, EH 10

AVERAGE DEFECT SPACING (mm): 10, 30, 100, 300, 1000, 3000

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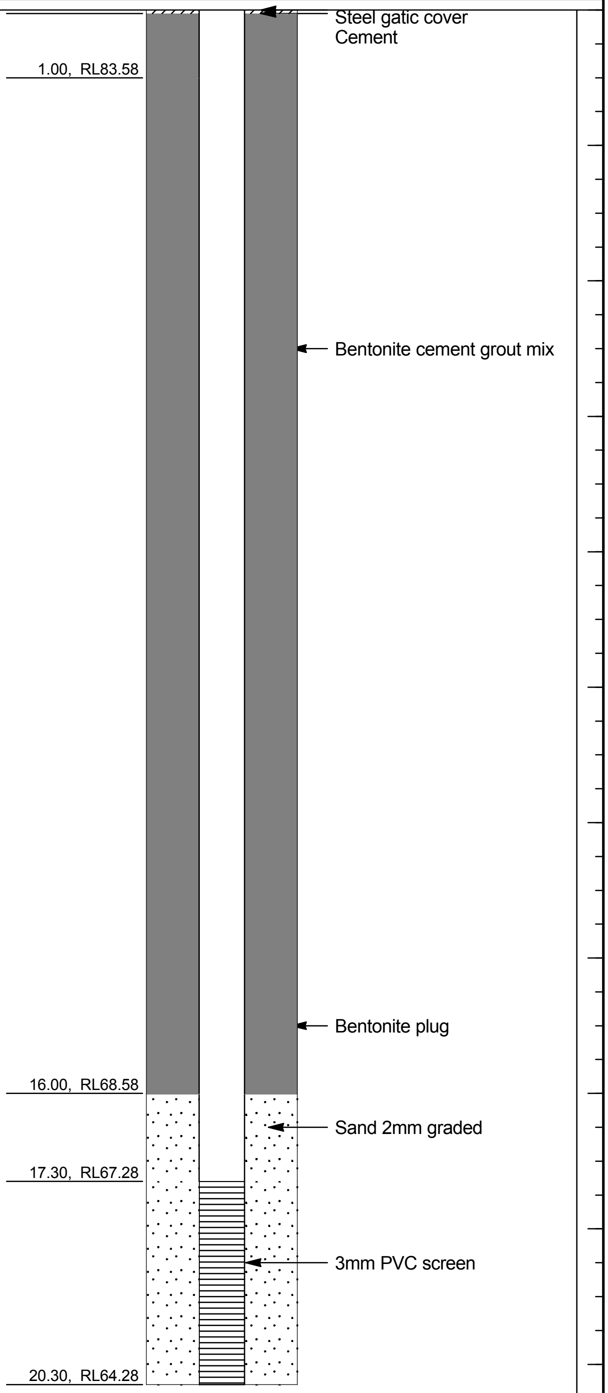
REPORT OF STANDPIPE INSTALLATION: BH2011

SHEET: 1 OF 1

CLIENT:	ARUP	COORDS: 553040.9 m E 6828442.5 m N 56 MGA94		DRILL RIG: Pioneer 120	
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 84.58 m	DATUM: AHD	DRILLER: North Coast Drilling	
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°		LOGGED: BC	DATE: 17/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm	HOLE DEPTH: 20.30 m	CHECKED: CSC	DATE: 13/8/07

Drilling					Field Material Description		Instrumentation Details
METHOD	WATER	DRILL FLUID LEVELS	DEPTH (metres)	DEPTH RL	GRAPHIC LOG	ABBREVIATED SOIL / ROCK MATERIAL DESCRIPTION (Refer to Report of Borehole For Details)	
ADT			0	84.58		Clayey SILT	
				1.00 83.58		Clayey SILT	1.00, RL83.58
WB			2	2.70 81.88		BASALT	
	20% water loss		4 6	6.40		Clayey SILT	
				6.70 77.78		CORE LOSS	
						Clayey SILT	
	30/07/2007 22/08/2007		8	8.17		CORE LOSS	
				76.08		Clayey SILT	
				9.20		CORE LOSS	
			10	75.38		Clayey SILT	
				11.05 73.53		BASALT	
			12	12.50 72.08		BASALT	
			14 16	16.30 68.28		BASALT	16.00, RL68.58 17.30, RL67.28
			18 20	20.30 64.28			20.30, RL64.28
			22				



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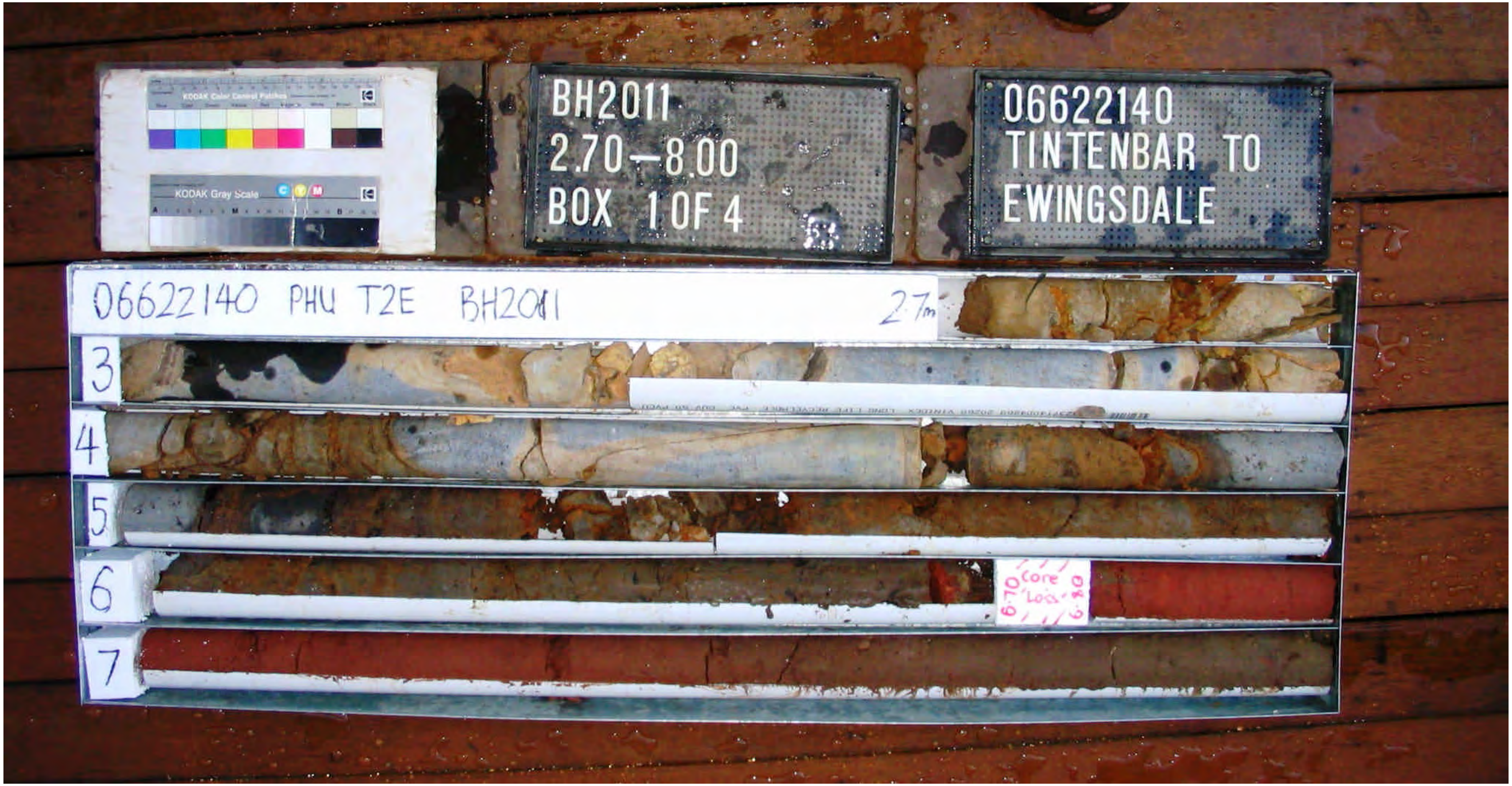
GAP gINT FN. F17
RL0

GAP6_0-BETA_NEW ONE_25.06.07 SRAS ALTERED BY DATGEL 2007-07-02.GLB WELL3 J:\06PROJ\101-150\06622140_ARUP_T2E PREFERRED ROUTE\7000 FIELD AND LABORATORY DATA\7870 GINT\06622140 PH.GPJ GAP6_0-BETA-PH.GDT 05/09/2007 2:52:31 PM

GAP6_0-BETA_NEW ONE_25.06.07 SRAS ALTERED BY DATGEL 2007-07-02.GLB CORE PHOTO 1 PER PAGE J:\06PROJ\101-150\06622140_ARUP_T2E PREFERRED ROUTE\7000 FIELD AND LABORATORY DATA\7870 GINT\06622140 P

REPORT OF CORE PHOTOGRAPHS: BH2011

			SHEET: 1 OF 4
CLIENT: ARUP	COORDS: 553040.9 m E 6828442.5 m N 56 MGA94		DRILL RIG: Pioneer 120
PROJECT: Pacific Highway Upgrade	SURFACE RL: 84.58 m DATUM: AHD		DRILLER: North Coast Drilling
LOCATION: Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: BC	DATE: 17/7/07
JOB NO: 06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 20.30 m	CHECKED: CSC	DATE: 13/8/07



REPORT OF CORE PHOTOGRAPHS: BH2011

SHEET: 2 OF 4

CLIENT:	ARUP	COORDS: 553040.9 m E 6828442.5 m N 56 MGA94		DRILL RIG: Pioneer 120	
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 84.58 m DATUM: AHD		DRILLER: North Coast Drilling	
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°		LOGGED: BC	DATE: 17/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 20.30 m		CHECKED: CSC	DATE: 13/8/07

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Golder Associates

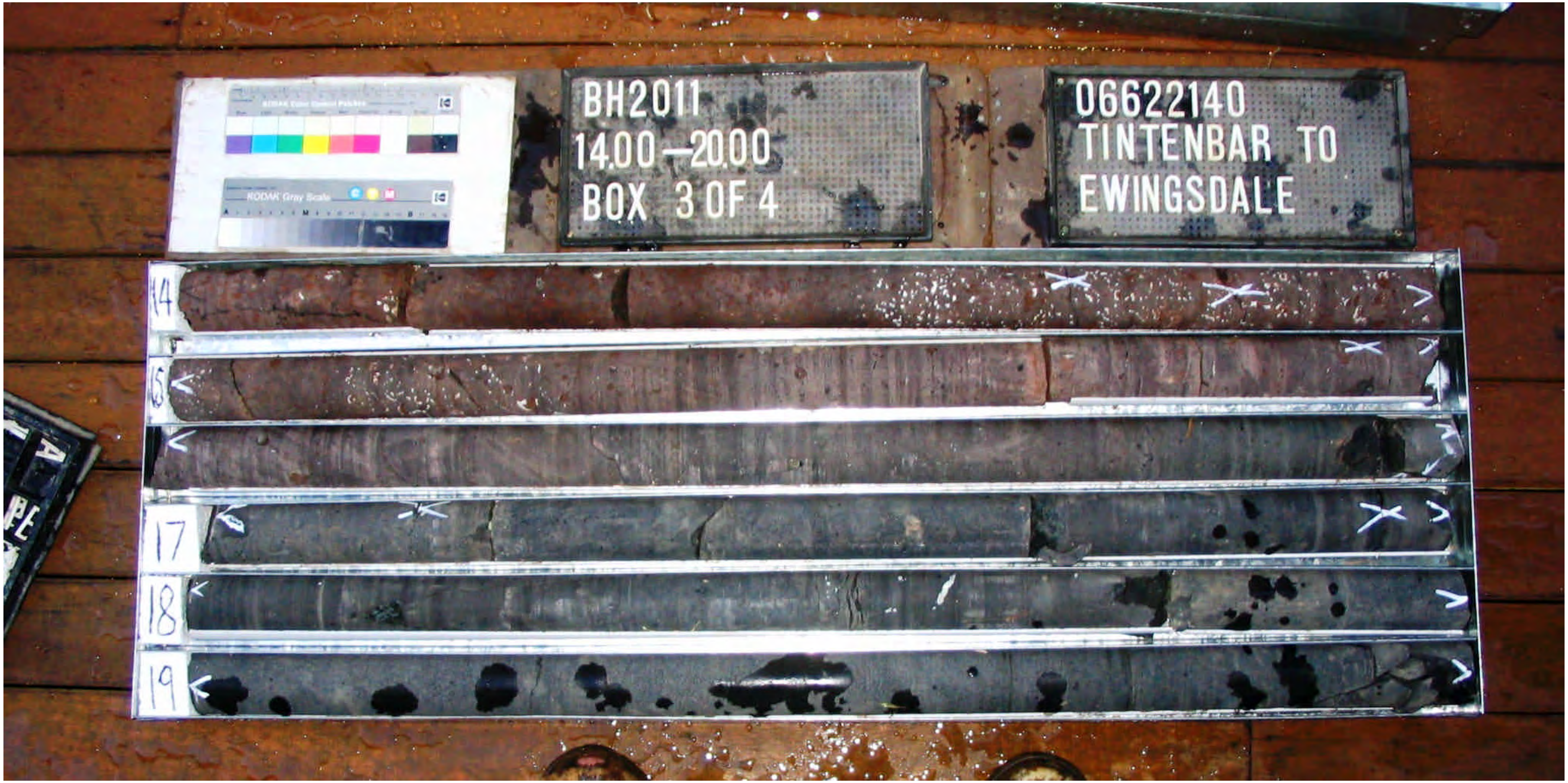
REPORT OF CORE PHOTOGRAPHS: BH2011

SHEET: 3 OF 4

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 553040.9 m E 6828442.5 m N 56 MGA94
SURFACE RL: 84.58 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 20.30 m

DRILL RIG: Pioneer 120
DRILLER: North Coast Drilling
LOGGED: BC DATE: 17/7/07
CHECKED: CSC DATE: 13/8/07



Golder Associates

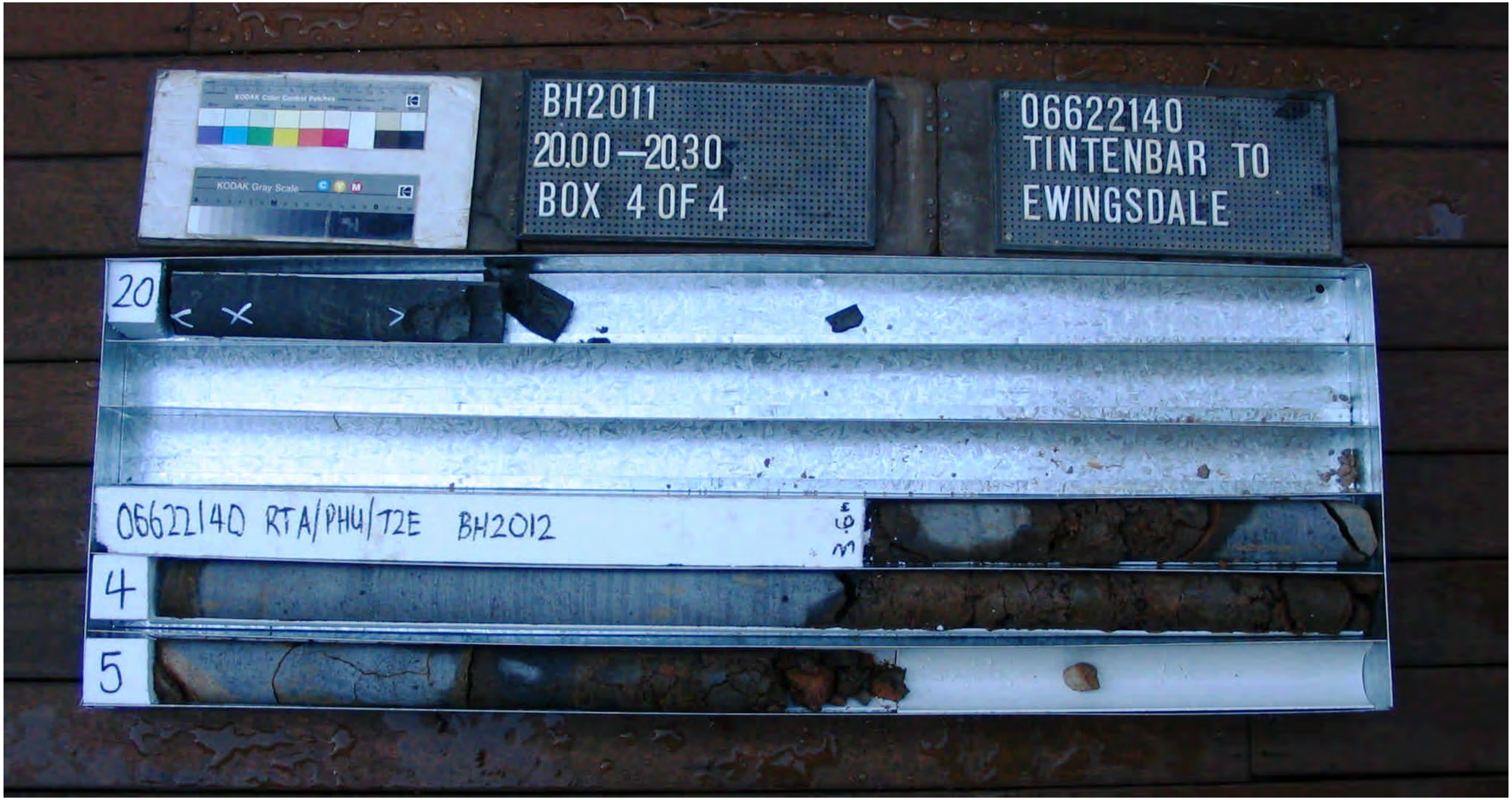
REPORT OF CORE PHOTOGRAPHS: BH2011

SHEET: 4 OF 4

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 553040.9 m E 6828442.5 m N 56 MGA94
SURFACE RL: 84.58 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 20.30 m

DRILL RIG: Pioneer 120
DRILLER: North Coast Drilling
LOGGED: BC DATE: 17/7/07
CHECKED: CSC DATE: 13/8/07



GAP gINT FN. F31
RL0

GAP6_0-BETA_NEW ONE_25.06.07 SRAS ALTERED BY DATGEL 2007-07-02.GLB CORE PHOTO 1 PER PAGE J:\06PROJ\101-150\06622140_ARUP_T2E PREFERRED ROUTE\7000 FIELD AND LABORATORY DATA\7870 GINT\06622140 P

Golder Associates

REPORT OF BOREHOLE: BH2012

SHEET: 1 OF 3

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 553039.9 m E 6828444.5 m N 56 MGA94
SURFACE RL: 84.69 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 11.00 m

DRILL RIG: Pioneer 120
DRILLER: North Coast Drilling
LOGGED: BC DATE: 18/7/07
CHECKED: CSC DATE: 13/8/07

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USC Symbol	SOIL / ROCK MATERIAL DESCRIPTION	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
WB	M	Groundwater not encountered	0.0	84.69				MH	Clayey SILT, high plasticity, brown with some grey sections	M		RESIDUAL SOIL
			0.5									
			1.0									
			1.5									
			2.0									
			2.5									
			3.0									
			3.5									
				3.60 81.09					For Continuation Refer to Sheet 2			
			4.0									
			4.5									
			5.0									
			5.5									
			6.0									
			6.5									
			7.0									
			7.5									
			8.0									

Golder Associates

REPORT OF BOREHOLE: BH2012

SHEET: 2 OF 3

CLIENT: ARUP	COORDS: 553039.9 m E 6828444.5 m N 56 MGA94	DRILL RIG: Pioneer 120	
PROJECT: Pacific Highway Upgrade	SURFACE RL: 84.69 m DATUM: AHD	DRILLER: North Coast Drilling	
LOCATION: Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: BC	DATE: 18/7/07
JOB NO: 06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 11.00 m	CHECKED: CSC	DATE: 13/8/07

Drilling						Field Material Description											Defect Information						
									INFERRED STRENGTH Is(50) MPa									AVERAGE DEFECT SPACING (mm)					
METHOD	WATER	TCR	RQD (SCR)	DEPTH (meters)	*DEPTH* RL	GRAPHIC LOG	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING	EL	VL 0.03	L 0.1	M 0.3	H 1	VH 3	EH 10	DEFECT DESCRIPTION & Additional Observations	10	30	100	300	1000	3000
				0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5	*3.60*		Continuation of Sheet 1															
NMLC		100	63 (100)		*3.75*	⋁	BASALT, grey with some red iron staining	MW					▨			3.60-3.75m: J, 60-90°, Un, Ro, Sn			▨			
	◄				*3.85*	⋁	Grey brown with red iron staining	EW		▨										▨		
				4.0 4.5	80.84 *4.60*	⋁	Brown and red, some iron staining	MW-SW					▨			3.86m: J, 50°, Pl, Ro, Sn 3.98m: J, 25°, Un, Ro, Sn				▨	▨	
		100	59 (70)		80.09 *5.00*	⋁	Brown and red	EW		▨						4.58m: J, 0-10°, Un, Ro, Sn 4.65-5.00m: sp=5-20mm, Weathered zone, highly fractured		▨				
				5.0	79.69 *5.35*	⋁	Grey with red iron staining	MW				▨	▨			5.00-5.60m: numerous closed / tight microfractures throughout 5.10m: J, 15°, Un, Ro, Sn 5.26m: J, 0°, Un, Ro, Sn				▨		
				5.5	79.34 *5.60*	⋁	Brown and red	EW		▨						5.35-5.60m: sp=5-20mm, Weathered zone, highly fractured		▨				
WB	◁ 40%			6.0 6.5 7.0 7.5 8.0	79.09	×	Clayey SILT, high plasticity, brown	RS								5.60-11.00m: RESIDUAL SOIL to Extremely Weathered ROCK (rotary drilled from 5.6m)						

This report of borehole must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

GAP gINT FN. F02a
RL2

Golder Associates

REPORT OF BOREHOLE: BH2012

SHEET: 3 OF 3

CLIENT:	ARUP	COORDS: 553039.9 m E 6828444.5 m N 56 MGA94		DRILL RIG: Pioneer 120	
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 84.69 m	DATUM: AHD	DRILLER: North Coast Drilling	
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°		LOGGED: BC	DATE: 18/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm	HOLE DEPTH: 11.00 m	CHECKED: CSC	DATE: 13/8/07

Drilling						Field Material Description				Defect Information	
METHOD	WATER	TCR	RQD (SCR)	DEPTH (meters)	*DEPTH* RL	GRAPHIC LOG	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING	INFERRED STRENGTH $Is_{(50)}$ MPa EL VL 0.03 L 0.1 M 0.3 H 1 VH 3 EH 10	DEFECT DESCRIPTION & Additional Observations	AVERAGE DEFECT SPACING (mm) 10 30 100 300 1000 3000
WB				8.0			Clayey SILT, high plasticity, brown	RS		8.00m: RESIDUAL SOIL to Extremely Weathered ROCK (rotary drilled from 5.6m)	
				8.5							
				9.0							
				9.5							
				10.0							
				10.5							
				11.0	*11.00*		END OF BOREHOLE @ 11.00 m Piezometer installed Note: borehole drilled for piezometer installation only				
				11.5							
				12.0							
				12.5							
				13.0							
				13.5							
				14.0							
				14.5							
				15.0							
				15.5							
				16.0							

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Golder Associates

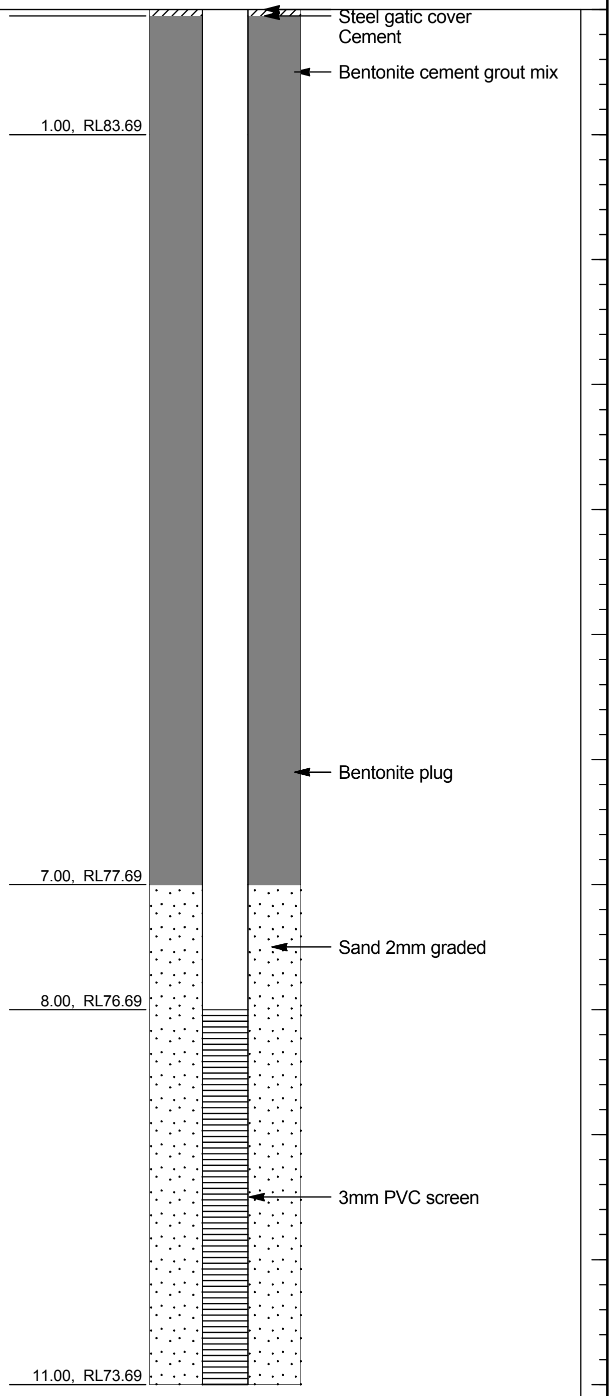
REPORT OF STANDPIPE INSTALLATION: BH2012

SHEET: 1 OF 1

CLIENT: ARUP	COORDS: 553039.9 m E 6828444.5 m N 56 MGA94	DRILL RIG: Pioneer 120	
PROJECT: Pacific Highway Upgrade	SURFACE RL: 84.69 m DATUM: AHD	DRILLER: North Coast Drilling	
LOCATION: Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: BC	DATE: 18/7/07
JOB NO: 06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 11.00 m	CHECKED: CSC	DATE: 13/8/07

Drilling					Field Material Description	
METHOD	WATER	DRILL FLUID LEVELS	DEPTH (metres)	DEPTH RL	GRAPHIC LOG	ABBREVIATED SOIL / ROCK MATERIAL DESCRIPTION (Refer to Report of Borehole For Details)
WB	Groundwater not encountered		0	84.69		Clayey SILT
NMLC				3.60 81.09		BASALT
WB	40%			5.60 79.09		Clayey SILT
				11.00 73.69		

Instrumentation Details



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GAP gINT FN. F17
RL0

GAP6_0-BETA_NEW ONE_25.06.07 SRAS ALTERED BY DATGEL 2007-07-02.GLB WELL3 J:\06PROJ\101-150\06622140_ARUP_T2E PREFERRED ROUTE\7000 FIELD AND LABORATORY DATA\7870 GINT\06622140 PH.GPJ GAP6_0-BETA-PH.GDT 05/09/2007 2:55:05 PM

REPORT OF BOREHOLE: BH2013

CLIENT:	ARUP	COORDS: 553097 m E 6828453.7 m N 56 MGA94	SHEET: 1 OF 4		
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 75.93 m DATUM: AHD	DRILL RIG: Gemco		
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°	DRILLER: Drillsearch		
JOB NO:	06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 18.00 m	LOGGED: NPP	DATE: 21/7/07	
			CHECKED: CSC	DATE: 13/8/07	

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USC Symbol	SOIL / ROCK MATERIAL DESCRIPTION	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
ADT	L		0.0	75.93				MH	Clayey SILT, high plasticity, red brown, with some medium angular (basaltic) gravel	D-M	St	RESIDUAL SOIL
			0.5								VSt	
			1.0		SPT 1.00-1.45 m 4,6,9 N = 15					M (<PL)		
	M		1.5									
			2.0								St	
			2.5									2.4m - Possible cobble / corestone. Driller indicates "crunching" on V-bit
					SPT 2.80-3.25 m 3,4,6 N = 10							
			3.0	*3.00* 72.93				MI	Sandy SILT, medium plasticity, red grey and brown, with fine rounded gravel inclusions, remnant rock structure evident, (inferred extremely weathered amygdaloidal basalt, extremely low strength)	D-M	VSt	RESIDUAL SOIL TO EXTREMELY WEATHERED ROCK Rock structure evident, some layers of completely weathered rock with no remnant rock structure
			3.5									
			4.0									
			4.5		SPT 4.40-4.85 m 4,7,14 N = 21							
			5.0									
			5.5	*5.50* 70.43				MI	Clayey SILT, medium plasticity, grey brown and dark grey	M (<PL)	St	Increased moisture from 5.5m depth, possible water table?
			6.0		SPT 5.90-6.35 m 2,4,5 N = 9							
			6.5									
			7.0									
				7.20 68.73					BASALT, grey brown, very low to low strength, moderately to highly weathered, some medium strength pieces			Weathered ROCK
			7.5		SPT 7.40-7.70 m 5,15,HB							
WB												
			8.0	*8.00*								

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GAP gINT FN. F01a
RL2

GAP6_0-BETA_NEW ONE_25.06.07 SRAS ALTERED BY DATGEL 2007-07-02.GLB FULL PAGE J:\06PROJ\101-150\06622140_ARUP_T2E PREFERRED ROUTE\7000 FIELD AND LABORATORY DATA\7870 GINT\06622140 PH.GPJ GAP6_0-BETA-PH.GDT 05/09/2007 2:55:53 PM

REPORT OF BOREHOLE: BH2013

SHEET: 2 OF 4

CLIENT:	ARUP	COORDS: 553097 m E 6828453.7 m N 56 MGA94	DRILL RIG: Gemco		
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 75.93 m DATUM: AHD	DRILLER: Drillsearch		
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: NPP	DATE: 21/7/07	
JOB NO:	06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 18.00 m	CHECKED: CSC	DATE: 13/8/07	

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USC Symbol	SOIL / ROCK MATERIAL DESCRIPTION	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
			8.0	67.93					For Continuation Refer to Sheet 2			
			8.5									
			9.0									
			9.5									
			10.0									
			10.5									
			11.0									
			11.5									
			12.0									
			12.5									
			13.0									
			13.5									
			14.0									
			14.5									
			15.0									
			15.5									
			16.0									

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GAP6_0-BETA_NEW ONE_25.06.07 SRAS ALTERED BY DATGEL 2007-07-02.GLB FULL PAGE J:\06PROJ\101-150\06622140_ARUP_T2E PREFERRED ROUTE\7000 FIELD AND LABORATORY DATA\7870 GINT\06622140 PH.GPJ GAP6_0-BETA-PH.GDT 05/09/2007 2:55:54 PM

REPORT OF BOREHOLE: BH2013

SHEET: 3 OF 4

CLIENT:	ARUP	COORDS: 553097 m E 6828453.7 m N 56 MGA94		DRILL RIG: Gemco	
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 75.93 m	DATUM: AHD	DRILLER: Drillsearch	
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°		LOGGED: NPP	DATE: 21/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm	HOLE DEPTH: 18.00 m	CHECKED: CSC	DATE: 13/8/07

GAP6_0-BETA_NEW ONE_25.06.07 SRAS ALTERED BY DATGEL 2007-07-02.GLB CORED BOREHOLE J:\06PROJ\101-150\06622140_ARUP_T2E PREFERRED ROUTE\7000 FIELD AND LABORATORY DATA\7870 GINT\06622140 PH.GPJ GAP6_0-BETA-PH.GDT 05/09/2007 2:56:44 PM

Drilling

METHOD	WATER	TCR	RQD (SCR)	DEPTH (meters)
NMLC		100	20 (35)	8.0–9.0
	◀	100	74 (74)	9.0–10.5
	◀ 22/08/2007	94	15 (65)	10.5–13.0
	◀ 30/07/2007	100	82 (87)	13.0–14.9
	◀	100	35 (45)	14.9–16.0

Field Material Description

DEPTH RL	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING
8.00 67.93	BASALT, dark grey and brown, with some amygdules	HW-MW
9.00 66.93	BASALT, dark grey, iron stained on joints	SW
		MW
11.60 64.33	with some vesicles	
12.00 63.93	Amygdaloidal BASALT, red brown, amygdules to 5mm diameter, with some vesicles	HW
12.85	NO CORE (12.85 - 13.00m)	
13.00 62.93	Amygdaloidal BASALT, red brown, amygdules to 5mm diameter	HW
13.40 62.53	brown grey	
13.75 62.18	BASALT, dark grey	FR
		SW
15.25 60.68	Amygdaloidal and Vesicular BASALT, dark grey brown and red brown, vesicles to 4mm diameter, infilled with calcite and chloride amygdules	HW-MW
16.00		

INFERRED STRENGTH $Is_{(50)}$ MPa: EL 0.03 VL 0.1 L 0.3 M 1 H 3 VH 10 EH

Defect Information

DEFECT DESCRIPTION & Additional Observations

8.00-8.45m: Recovered as coarse gravel size pieces, with fractures generally 10-20° and 60-70°, Un, Ro, Ct, clay
8.30-8.40m: With fine grained material throughout
8.45-9.00m: J, 0-10°, sp=30-100mm, Pl, Sm-Ro, Sn
8.80m: DS, 0°, Pl, clay, 20mm
9.05m: J, 30°, St, Ro, Sn
9.17m: J, 45°, Pl, Ro, Sn
9.37m: J, 15°, Pl, Ro, Sn, 10mm
9.83m: J, 70-75°, Un, Ro, Sn
10.15m: J, 0°, Pl, Ro, Sn
10.34m: J, Pl, Ro, Sn
10.38m: J, 15°, Un, Ro, Sn
10.42m: J, 20°, Pl, Ro, Sn
10.50m: J, 65-70°, Pl, Ro, Sn
10.60m: J, 10°, St, Ro, Sn
10.65m: J, 50°, Un, Ro, Sn
10.73m: J, 50°, Pl, Ro, Sn
10.78m: J, 45°, Pl, Ro, Sn
10.92m: J, 55°, Pl, Ro, Sn
11.00-11.30m: J, 60-70°, Pl, Sm-Ro, Sn, Joint swarm, possible onset of corestone weathering?
11.33m: J, 10°, St, Ro, Sn
11.50-12.00m: J, 5-10°, sp=30-50mm, Pl, Sm-Ro, Sn
11.60m: J, 45°, Pl, Sm-Ro, Sn
11.64m: J, 40°, Pl, Sm, Sn
11.86m: J, 20°, Pl, Sm, Sn
12.13m: J, 0-10°, Pl, Ro, Sn, subrounded fine gravel
12.20m: J, 0-10°, Pl, Ro, Sn
12.30m: J, 0-10°, Pl, Ro, Sn
12.43m: J, 60°, Pl, Sm, Sn
12.45m: J, 0°, Pl, Ro, Sn, fine gravel chips
12.59m: J, 65°, Un, Sm, Sn
12.60-12.80m: core recovered as fragmented rock
13.05-13.23m: J, 5-10°, Pl, Ro, Cn-Sn
13.35m: J, 5°, Pl, Ro, Sn
13.43m: J, 5°, Pl, Ro, Sn
13.52m: J, 20°, Pl, Ro, Sn
13.61m: J, 15°, Pl, Ro, Sn
13.72m: J, 30°, St, Ro, Sn
13.75m: possible contact?
14.28m: J, 10°, Pl, Sm, Cn
14.71m: J, Pl-Un, Sm, Cn
15.25m: J, 10°, Pl, Ro, Cn
15.34m: J/DS, Pl, Sm, Cn, fine gravel , possible drilling break, 30mm
15.40-15.55m: core recovered as fragmented rock
15.55-16.00m: J, 0-10°, sp=10-30mm, Pl-Un, Sm, Cn
15.74m: J, 70°, Pl, Sm, Cn-Sn

AVERAGE DEFECT SPACING (mm): 10 30 100 300 1000 3000

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Golder Associates

REPORT OF BOREHOLE: BH2013

CLIENT:	ARUP	COORDS: 553097 m E 6828453.7 m N 56 MGA94	SHEET: 4 OF 4	
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 75.93 m DATUM: AHD	DRILL RIG: Gemco	
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°	DRILLER: Drillsearch	
JOB NO:	06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 18.00 m	LOGGED: NPP	DATE: 21/7/07
			CHECKED: CSC	DATE: 13/8/07

Drilling						Field Material Description				Defect Information	
METHOD	WATER	TCR	RQD (SCR)	DEPTH (meters)	*DEPTH* RL	GRAPHIC LOG	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING	INFERRED STRENGTH Is$_{(50)}$ MPa EL VL L M H VH EH 0.03 0.1 0.3 1 3 10	DEFECT DESCRIPTION & Additional Observations	AVERAGE DEFECT SPACING (mm) 10 30 100 300 1000 3000
NMLC	◀	100	67 (71)	16.0	59.93		Amygdaloidal and Vesicular BASALT, dark grey brown and red brown, vesicles to 4mm diameter, infilled with calcite and chloride amygdules	MW		16.13m: J, 25°, Un, Sm, Sn 16.20m: J, Un, Ro, Sn 16.21m: Pl, 15mm, crushed / gravelly 16.33m: J, 50°, Un, Ro, Sn 16.42-16.45m: drilling breaks 16.48m: J, 65°, Pl, Sm, Sn 16.58-16.73m: J, 0-10°, Pl, Ro, Sn, 20-40mm, possible drilling break 16.96-17.03m: J, 0-10°, Pl, Ro, possible drilling break	
				16.5			some amygdules to 15mm diameter	SW			
				17.0	*17.00* 58.93		without amygdules or vesicles			17.24m: J, 60-70°, Pl, closed / tight 17.33m: J, 50°, Pl, Sl, Vr	
				17.5	*17.50* 58.43		with amygdules and vesicles, grey	SW-FR		17.74-17.85m: J, 0-5°, Pl, Ro, Cn, possible drilling break	
				18.0	*18.00*		END OF BOREHOLE @ 18.00 m Piezometer installed				
				18.5							
				19.0							
				19.5							
				20.0							
				20.5							
				21.0							
				21.5							
				22.0							
				22.5							
				23.0							
				23.5							
				24.0							

Golder Associates

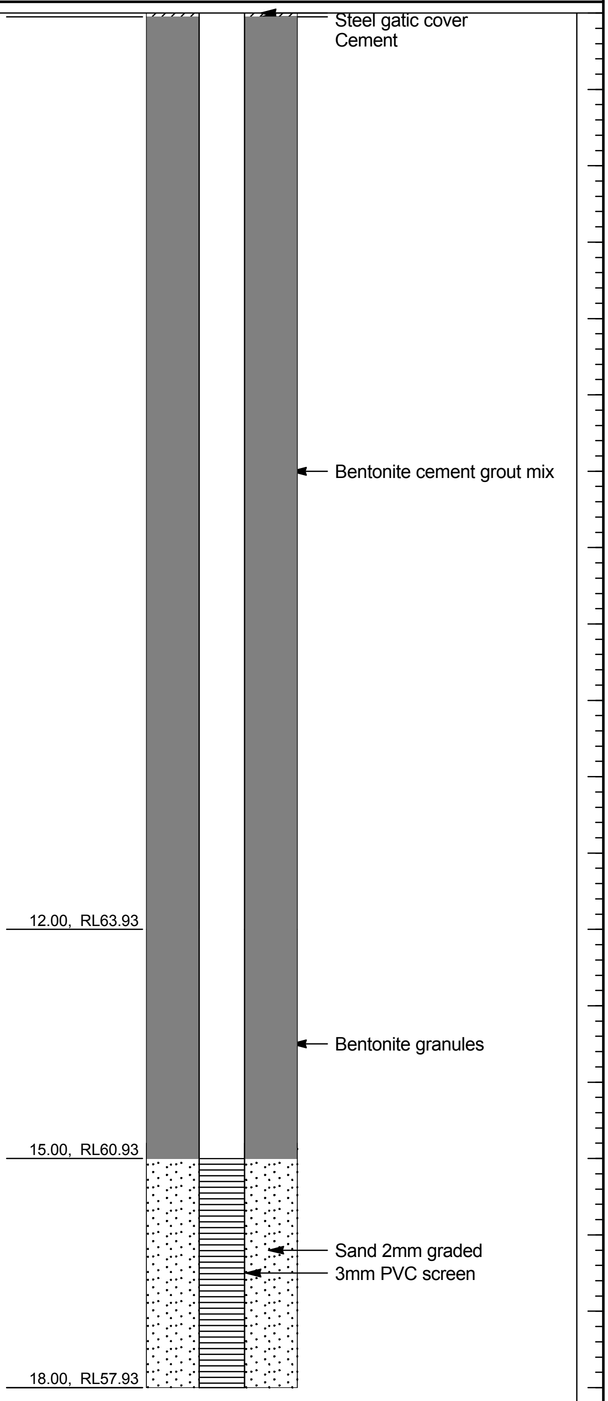
REPORT OF STANDPIPE INSTALLATION: BH2013

CLIENT:	ARUP	COORDS: 553097 m E 6828453.7 m N 56 MGA94	SHEET: 1 OF 1	
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 75.93 m DATUM: AHD	DRILL RIG: Gemco	
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°	DRILLER: Drillsearch	
JOB NO:	06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 18.00 m	LOGGED: NPP	DATE: 21/7/07
			CHECKED: CSC	DATE: 13/8/07

Drilling				Field Material Description	
METHOD	WATER	DRILL FLUID LEVELS	DEPTH RL	GRAPHIC LOG	ABBREVIATED SOIL / ROCK MATERIAL DESCRIPTION (Refer to Report of Borehole For Details)
ADT			75.93		Clayey SILT
			3.00 72.93		Sandy SILT
			5.50 70.43		Clayey SILT
			7.20 68.73		BASALT
WB			*8.00* 67.93		BASALT
NMLC			*9.00* 66.93		BASALT
			12.00 63.93		BASALT
	|◁ 30/07/2007 |◁		*12.85* 62.93		NO CORE BASALT
			13.75 62.18		BASALT
			15.25 60.68		BASALT
			18.00 57.93		

DEPTH (metres): 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

Instrumentation Details



GAP6_0-BETA_NEW ONE_25.06.07 SRAS ALTERED BY DATGEL 2007-07-02.GLB WELL3 J:\06PROJ\101-150\06622140_ARUP_T2E PREFERRED ROUTE\7000 FIELD AND LABORATORY DATA\7870 GINT\06622140 PH.GPJ GAP6_0-BETA-PH.GDT 05/09/2007 2:57:31 PM

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REPORT OF CORE PHOTOGRAPHS: BH2013

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

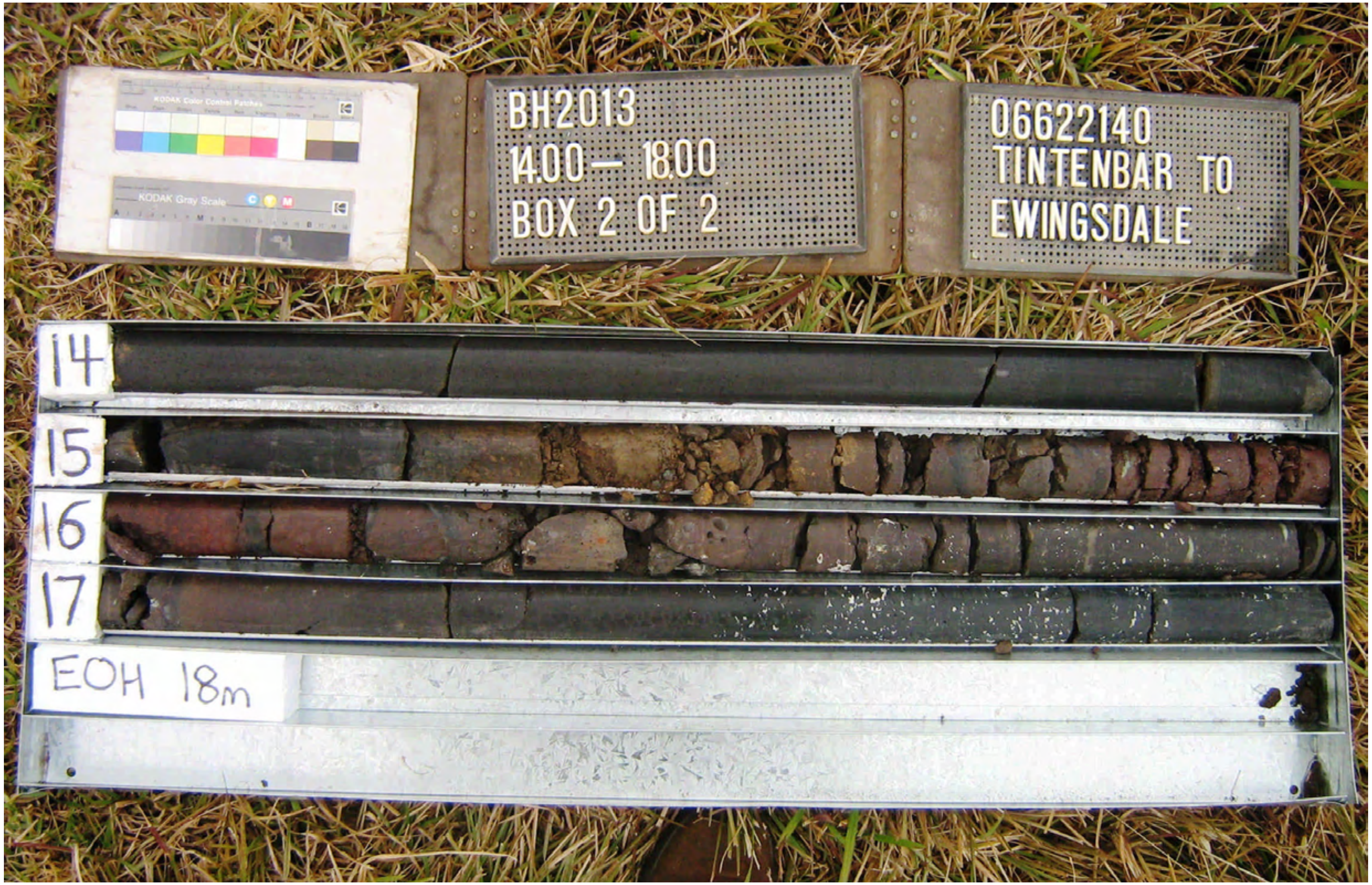
COORDS: 553097 m E 6828453.7 m N 56 MGA94
SURFACE RL: 75.93 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 18.00 m

SHEET: 1 OF 2
DRILL RIG: Gemco
DRILLER: Drillsearch
LOGGED: NPP DATE: 21/7/07
CHECKED: CSC DATE: 13/8/07

REPORT OF CORE PHOTOGRAPHS: BH2013

SHEET: 2 OF 2

CLIENT:	ARUP	COORDS: 553097 m E 6828453.7 m N 56 MGA94	DRILL RIG: Gemco	
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 75.93 m DATUM: AHD	DRILLER: Drillsearch	
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: NPP	DATE: 21/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 18.00 m	CHECKED: CSC	DATE: 13/8/07



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Golder Associates

REPORT OF BOREHOLE: BH2014

SHEET: 1 OF 3

CLIENT:	ARUP	COORDS: 553094.4 m E 6828456.5 m N 56 MGA94		DRILL RIG: Gemco	
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 76.03 m	DATUM: AHD	DRILLER: Drillsearch	
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°		LOGGED: NPP	DATE: 21/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm	HOLE DEPTH: 14.30 m	CHECKED: CSC	DATE: 13/8/07

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USC Symbol	SOIL / ROCK MATERIAL DESCRIPTION	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
ADT	L		0.0	76.03				MH	Clayey SILT, high plasticity, red and brown, with some medium to coarse subangular gravel	D-M		RESIDUAL SOIL
	L-M		6.5	*6.50* 69.53				ML	Sandy (fine) SILT, medium plasticity, dark grey and brown, inferred completely weathered basalt, some pieces (coarse gravel size) of medium to high strength rock in cuttings	M		RESIDUAL SOIL to Extremely Weathered ROCK
			8.0									

Depth scale: 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0

REPORT OF BOREHOLE: BH2014

SHEET: 2 OF 3

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 553094.4 m E 6828456.5 m N 56 MGA94
SURFACE RL: 76.03 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 14.30 m

DRILL RIG: Gemco
DRILLER: Drillsearch
LOGGED: NPP DATE: 21/7/07
CHECKED: CSC DATE: 13/8/07

Drilling					Sampling	Field Material Description						
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USC Symbol	SOIL / ROCK MATERIAL DESCRIPTION	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
ADT	L-M		8.0					ML	Sandy (fine) SILT, medium plasticity, dark grey and brown, inferred completely weathered basalt, some pieces (coarse gravel size) of medium to high strength rock in cuttings	M		RESIDUAL SOIL to Extremely Weathered ROCK
	M			*9.60* 66.43					BASALT, grey brown, inferred very low to low strength, inferred highly weathered to moderately weathered			Weathered ROCK
	H											
				12.80 63.23					For Continuation Refer to Sheet 3			

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Golder Associates

REPORT OF BOREHOLE: BH2014

SHEET: 3 OF 3

CLIENT: ARUP	COORDS: 553094.4 m E 6828456.5 m N 56 MGA94	DRILL RIG: Gemco	
PROJECT: Pacific Highway Upgrade	SURFACE RL: 76.03 m DATUM: AHD	DRILLER: Drillsearch	
LOCATION: Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: NPP	DATE: 21/7/07
JOB NO: 06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 14.30 m	CHECKED: CSC	DATE: 13/8/07

METHOD	WATER	TCR	RQD (SCR)	DEPTH (meters)	DEPTH RL	GRAPHIC LOG	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING	INFERRED STRENGTH Is(50) MPa	DEFECT DESCRIPTION & Additional Observations	AVERAGE DEFECT SPACING (mm)
	30/07/2007 ▽ 22/08/2007			8.0 – 12.80	12.80		Continuation of Sheet 2				
NMLC		100	30 (33)	12.80 – 14.30	63.23	⩗⩗	Amygdaloidal and Vesicular BASALT, red brown and dark grey, amygdules to 15mm, vesicles to 10mm, some with clay infilling	HW MW		12.80-13.50m: Core recovered as fragmented rock 13.68m: J, 20°, Pl-Un, Ro, Sn 14.15m: J, 0-5°, Pl, Sm-Ro, Sn 14.26m: J, 0-5°, Pl, Sm-Ro, Sn 14.28m: J, 0-5°, Pl, Sm-Ro, Sn	
				14.30	14.30		END OF BOREHOLE @ 14.30 m Reached target depth Piezometer installed Note: borehole drilled for piezometer installation only				

Strength scale: EL VL L M H VH EH; 0.03 0.1 0.3 1 3 10

Defect spacing scale: 10 30 100 300 1000 3000

Depth scale: 8.0 8.5 9.0 9.5 10.0 10.5 11.0 11.5 12.0 12.5 13.0 13.5 14.0 14.5 15.0 15.5 16.0

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REPORT OF STANDPIPE INSTALLATION: BH2014

Golder Associates

SHEET: 1 OF 1

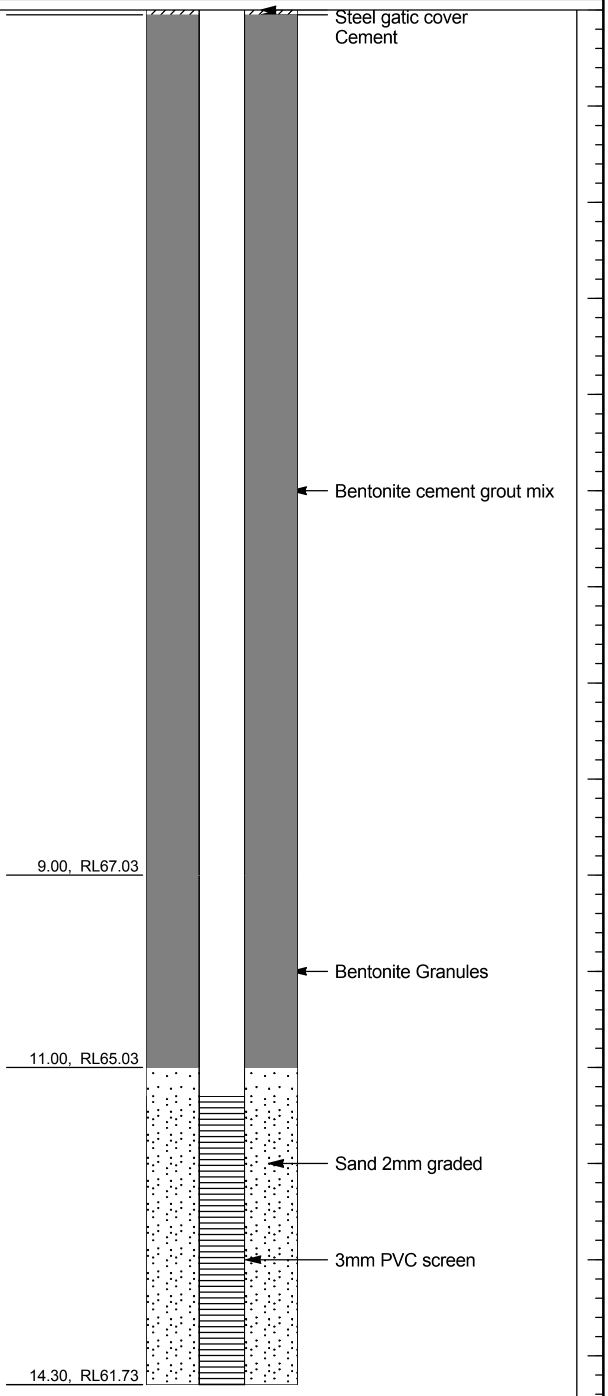
CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 553094.4 m E 6828456.5 m N 56 MGA94
SURFACE RL: 76.03 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 14.30 m

DRILL RIG: Gemco
DRILLER: Drillsearch
LOGGED: NPP DATE: 21/7/07
CHECKED: CSC DATE: 13/8/07

Drilling					Field Material Description	
METHOD	WATER	DRILL FLUID LEVELS	DEPTH (metres)	DEPTH RL	GRAPHIC LOG	ABBREVIATED SOIL / ROCK MATERIAL DESCRIPTION (Refer to Report of Borehole For Details)
ADT			0	76.03		Clayey SILT
				6.50 69.53		Sandy SILT
	30/07/2007 ▽ 22/08/2007			9.60 66.43		BASALT
NMLC				12.80 63.23		BASALT
				14.30 61.73		

Instrumentation Details



This report of standpipe installation must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

GAP gINT FN. F17
RL0

GAP6_0-BETA_NEW ONE_25.06.07 SRAS ALTERED BY DATGEL 2007-07-02.GLB WELL3 J:\06PROJ\101-150\06622140_ARUP_T2E PREFERRED ROUTE\7000 FIELD AND LABORATORY DATA\7870 GINT\06622140 PH.GPJ GAP6_0-BETA-PH.GDT 05/09/2007 3:00:23 PM

Golder Associates

REPORT OF CORE PHOTOGRAPHS: BH2014

SHEET: 1 OF 1

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 553094.4 m E 6828456.5 m N 56 MGA94
SURFACE RL: 76.03 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 14.30 m

DRILL RIG: Gemco
DRILLER: Drillsearch
LOGGED: NPP DATE: 21/7/07
CHECKED: CSC DATE: 13/8/07

This report of core photographs must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

GAP gINT FN. F31
RL0

GAP6_0-BETA_NEW ONE_25.06.07 SRAS ALTERED BY DATGEL 2007-07-02.GLB CORE PHOTO 1 PER PAGE J:\06PROJ\101-150\06622140_ARUP_T2E PREFERRED ROUTE\7000 FIELD AND LABORATORY DATA\7870 GINT\06622140 P

Golder Associates

REPORT OF BOREHOLE: BH2015

SHEET: 1 OF 4

CLIENT:	ARUP	COORDS: 553127.7 m E 6828430.5 m N 56 MGA94	DRILL RIG: Tracked Scout		
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 69.35 m DATUM: AHD	DRILLER: Drillsearch		
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: BC	DATE: 25/7/07	
JOB NO:	06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 16.60 m	CHECKED: CSC	DATE: 13/8/07	

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USC Symbol	SOIL / ROCK MATERIAL DESCRIPTION	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
ADT	M		0.0	69.35				CH	Silty CLAY, high plasticity, red brown	D-M	St	RESIDUAL SOIL
			0.60	*0.60* 68.75	SPT 0.90-1.35 m 5,18,20 N = 38 SPT 2.40-2.70 m 17,10,18/100mm			MH	Clayey SILT, high plasticity, grey brown, red ironstaining throughout, some medium subangular angular basalt gravel	D-M	H	RESIDUAL SOIL TO EXTREMELY WEATHERED ROCK
WB	M		3.0									
			3.40	*3.40* 65.95					For Continuation Refer to Sheet 2			

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REPORT OF BOREHOLE: BH2015

SHEET: 2 OF 4

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 553127.7 m E 6828430.5 m N 56 MGA94
SURFACE RL: 69.35 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 16.60 m

DRILL RIG: Tracked Scout
DRILLER: Drillsearch
LOGGED: BC DATE: 25/7/07
CHECKED: CSC DATE: 13/8/07

Drilling						Field Material Description		Defect Information
METHOD	WATER	TCR	RQD (SCR)	DEPTH (meters)	*DEPTH* RL	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING	DEFECT DESCRIPTION & Additional Observations
				0.0	*3.40*	Continuation of Sheet 1		
NMLC		90	70 (80)	3.5	65.95	BASALT, grey (possible boulder?)	SW	
	◄			4.0	*3.75* 65.60	BASALT, grey brown with iron staining	HW	3.77m: J, 0°, Un, Ro, Cn 3.80-4.20m: J, 0-10°, sp=0-10mm, Un, Ro, Sn, iron, some gravel
				4.5 5.0	*4.20* 65.15	Clayey SILT, red brown, with some 1-3mm diameter amygdules, inferred extremely weathered amygdaloidal basalt	EW	4.20-5.20m: defects generally weathered into soil matrix 4.65m: J, 15°, Un, Ro, Sn
					5.20 64.15	NO CORE 5.20-5.40m		
		73	46 (60)	5.5 6.0	*5.40* 63.95	BASALT, red brown, zones of residual soil	EW-HW	5.40-5.90m: core recovered as fragmented rock 5.95-6.28m: J, 0-10°, sp=10-20mm, Un, Ro, Sn
				6.5	*6.28* 63.07	NO CORE 6.28-6.60m		
		83	52 (75)	7.0 7.5	*6.60* 62.75	BASALT, grey	SW	6.60m: J, 30°, Pl, Ro, Sn, iron 7.00m: J, 40°, Un, Ro, Sn, iron 7.44m: J, 40°, Pl, Ro, Sn, iron 7.56-7.70m: DZ, gravelly silt
				8.0	*7.60* 61.75	BASALT, brown	HW	7.72m: J, 35°, Pl, Ro, Sn, iron 7.80m: J, 20°, Pl, Ro, Sn, iron

INFERRED STRENGTH $Is_{(50)}$ MPa: EL 0.03 VL 0.1 L 0.3 M 1 H 3 VH 10 EH

AVERAGE DEFECT SPACING (mm): 10 30 100 300 1000 3000

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REPORT OF BOREHOLE: BH2015

SHEET: 3 OF 4

CLIENT:	ARUP	COORDS: 553127.7 m E 6828430.5 m N 56 MGA94	DRILL RIG: Tracked Scout
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 69.35 m DATUM: AHD	DRILLER: Drillsearch
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: BC DATE: 25/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 16.60 m	CHECKED: CSC DATE: 13/8/07

Drilling

METHOD	WATER	TCR	RQD (SCR)	DEPTH (meters)
NMLC				8.0–8.4
NMLC		76	25 (55)	8.4–11.4
NMLC		80	22 (70)	11.4–14.4
NMLC	30/07/2007 ◁ 22/08/2007	84	34 (55)	14.4–16.0

Field Material Description

DEPTH	RL	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING
8.10	61.25	NO CORE 8.10-9.10m	
9.10	60.25	Amygdaloidal BASALT, purple brown with red zones, 1-3mm diameter calcite amygdules, zones of clayey silt (high plasticity)	EW-HW
11.40	57.95	NO CORE 11.40-12.00m	
12.00	57.35	BASALT, grey brown with some amygdules and red ironstaining, zones of clayey silt	EW-HW
14.40	54.95	NO CORE 14.40-14.75m	
14.75	54.60	BASALT, grey with red iron staining	HW HW-MW

INFERRED STRENGTH $Is_{(50)}$ MPa: EL VL L M H VH EH (0.03 0.1 0.3 1 3 10)

Defect Information

DEFECT DESCRIPTION & Additional Observations

AVERAGE DEFECT SPACING (mm): 10 30 100 300 1000 3000

7.81-8.10m: J, 0-10°, sp=40-80mm, Un, Ro, Sn
9.10-9.60m: core recovered as fragmented rock
9.69m: J, 20°, Pl, Ro, Sn
9.72m: J, 10°, Pl, Ro, Cn
9.79m: J, 0°, Un, Ro, Cn
9.81m: J, 0-10°, Un, Ro, Cn
9.94-9.98m: J, 60°, Pl, Sm, Sn
10.05m: J, 0°, Un, Ro, Cn
10.21-10.23m: J, 50°, Pl, Ro, Cn
10.35m: J, 20°, Pl, Sm, Cn
10.36-10.44m: J, 70°, Pl, Sm, Cn
10.52m: J, 10°, Pl, Sm, Cn
10.58-10.62m: J, 60°, Pl, Sm, Sn
10.72m: J, 0°, Un, Ro, Cn
10.95-11.25m: J, 0-10°, sp=30-50mm, Un, Ro, Cn
11.28-11.31m: J, 40°, Un, Ro, Cn
11.33-11.38m: J, 20-90°, St, Sm, Cn
12.05m: J, 0°, Un, Ro, Cn
12.10m: J, 45°, Pl, Ro, Sn
12.21-12.50m: J, 10°, sp=50-80mm, Un, Ro, Sn
12.45m: J, 40°, Pl, Sm, Sn, iron staining
12.55-12.58m: J, 10°, sp=10mm, Pl, Ro, Sn
12.75-12.76m: J, 80°, Pl, Sm, Sn
12.82m: J, 40°, Un, Ro, Cn
13.05m: J, 5°, Pl, Sm, Cn
13.17m: J, 30°, Pl, Sm, Sn
13.23m: J, 40°, Pl, Sm, Sn
13.32m: J, 10°, Un, Ro, Cn
13.45m: J, 5°, Un, Ro, Cn
13.49-13.58m: J, 35°, sp=80mm, Pl, Sm, Sn
13.53m: J, 0°, Un, Ro, Cn
13.71m: J, 20°, Pl, Ro, Cn
13.75-13.95m: J, 20-40°, sp=30-50mm, Pl, Sm, Sn
14.01-14.06m: J, 45°, Pl, Sm, Cn
14.08-14.18m: J, 50-90°, Un, Sm, Cn
14.34-14.40m: core recovered as fragmented rock
14.75-14.82m: core recovered as fragmented rock
14.85m: J, 20°, Pl, Sm, Cn
14.86-14.93m: J, 30-90°, St, Sm, Cn
14.87m: J, 15°, Pl, Sm, Cn
14.93m: J, 30°, Pl, Sm, Sn
15.01-15.05m: J, 80°, Un, Ro, Cn
15.17m: J, 0°, Un, Sm, Cn
15.28-15.56m: J, 30-60°, sp=10-90mm, Pl, Sm, Sn
15.47m: J, 50°, Pl, Sm, Cn
15.72m: J, 10°, Un, Ro, Cn
15.89-15.95m: J, 45°, Pl, Ro, Cn

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REPORT OF BOREHOLE: BH2015

SHEET: 4 OF 4

CLIENT:	ARUP	COORDS: 553127.7 m E 6828430.5 m N 56 MGA94	DRILL RIG: Tracked Scout		
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 69.35 m DATUM: AHD	DRILLER: Drillsearch		
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: BC	DATE:	25/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 16.60 m	CHECKED: CSC	DATE:	13/8/07

Drilling						Field Material Description				Defect Information
METHOD	WATER	TCR	RQD (SCR)	DEPTH (meters)	*DEPTH* RL	GRAPHIC LOG	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING	INFERRED STRENGTH $Is_{(50)}$ MPa (EL 0.03 VL 0.1 L 0.3 M 1 H 3 VH 10 EH)	DEFECT DESCRIPTION & Additional Observations
NMLC				16.0	*16.30* 53.05		BASALT, grey with red iron staining		H	16.05m: J, 10°, Un, Ro, Sn 16.16m: J, 5°, Un, Sm, Cn 16.25-16.60m: core recovered as fragmented rock
				16.5	*16.60*		BASALT, red brown	HW	L	
							END OF BOREHOLE @ 16.60 m Reached target depth Piezometer installed			

AVERAGE DEFECT SPACING (mm): 10 30 100 300 1000 3000

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Golder Associates

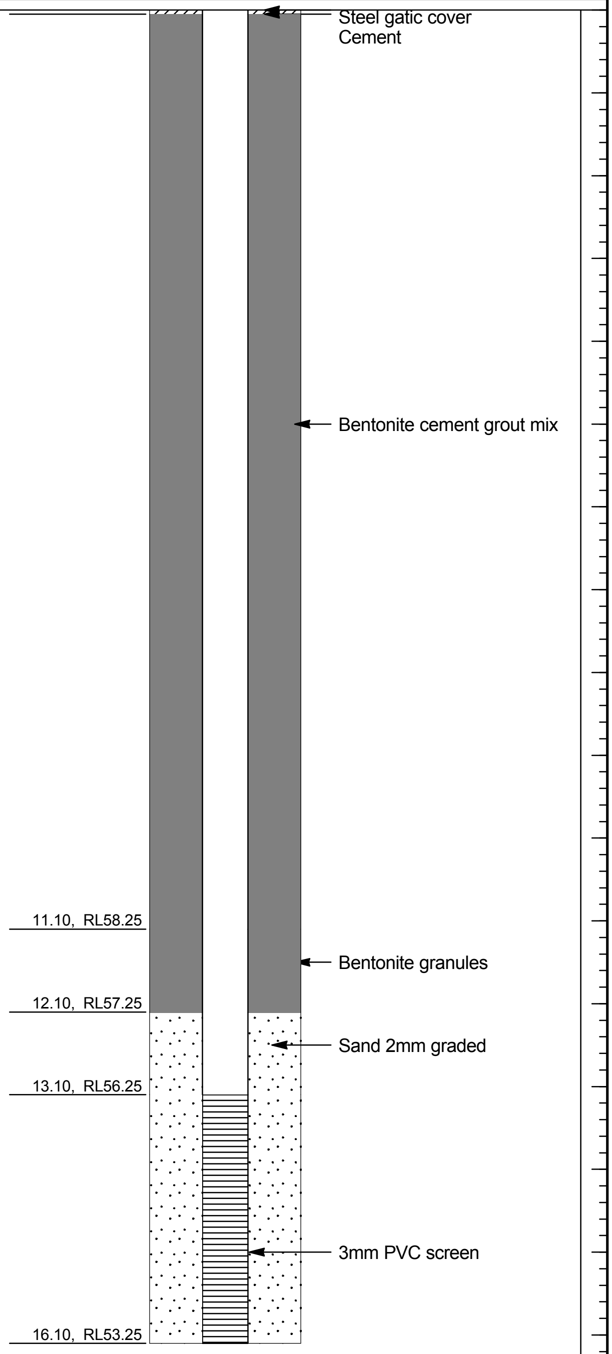
REPORT OF STANDPIPE INSTALLATION: BH2015

SHEET: 1 OF 1

CLIENT: ARUP	COORDS: 553127.7 m E 6828430.5 m N 56 MGA94	DRILL RIG: Tracked Scout	
PROJECT: Pacific Highway Upgrade	SURFACE RL: 69.35 m DATUM: AHD	DRILLER: Drillsearch	
LOCATION: Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: BC	DATE: 25/7/07
JOB NO: 06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 16.60 m	CHECKED: CSC	DATE: 13/8/07

Drilling | **Field Material Description** | **Instrumentation Details**

METHOD	WATER	DEPTH RL	ABBREVIATED SOIL / ROCK MATERIAL DESCRIPTION (Refer to Report of Borehole For Details)
ADT		0.00 69.35	Silty CLAY
		0.60 68.75	Clayey SILT
WB		3.40	BASALT
NMLC	◄	3.75 65.60	BASALT
		4.20 65.15	Clayey SILT
		5.20	NO CORE
		63.95	BASALT
		6.28	NO CORE
		6.60 62.75	BASALT
		7.60 61.75	BASALT
		8.10 61.25	NO CORE
		9.10 60.25	BASALT
		11.40 57.95	NO CORE
		12.00 57.35	BASALT
	30/07/2007 22/08/2007	14.40	NO CORE
		14.75 54.60	BASALT
		16.30	BASALT
		16.60 52.75	



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REPORT OF CORE PHOTOGRAPHS: BH2015

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 553127.7 m E 6828430.5 m N 56 MGA94
SURFACE RL: 69.35 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 16.60 m

SHEET: 1 OF 3
DRILL RIG: Tracked Scout
DRILLER: Drillsearch
LOGGED: BC DATE: 25/7/07
CHECKED: CSC DATE: 13/8/07

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REPORT OF CORE PHOTOGRAPHS: BH2015

SHEET: 2 OF 3

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 553127.7 m E 6828430.5 m N 56 MGA94
SURFACE RL: 69.35 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 16.60 m

DRILL RIG: Tracked Scout
DRILLER: Drillsearch
LOGGED: BC DATE: 25/7/07
CHECKED: CSC DATE: 13/8/07

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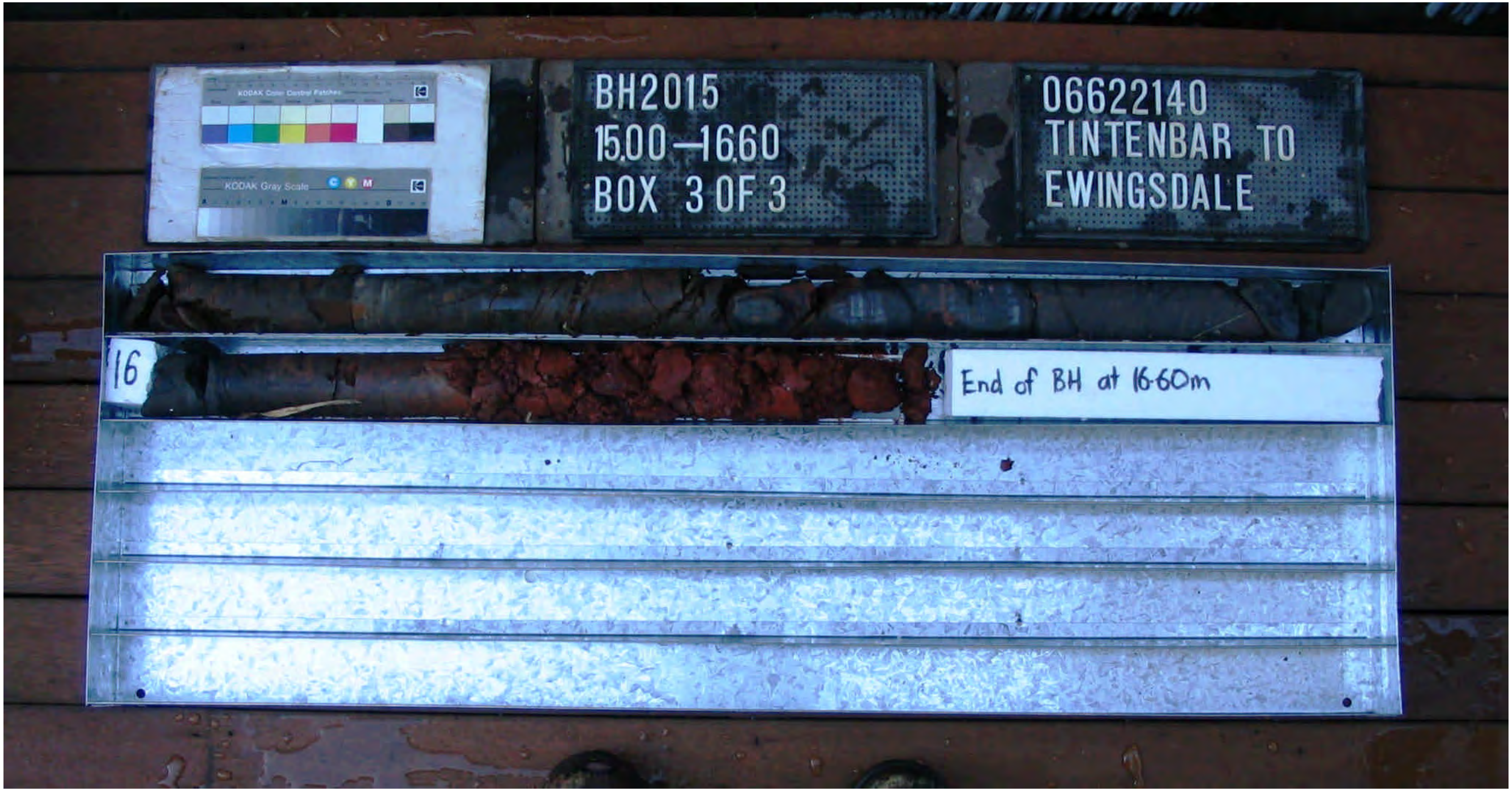
Golder Associates

REPORT OF CORE PHOTOGRAPHS: BH2015

SHEET: 3 OF 3

CLIENT:	ARUP	COORDS: 553127.7 m E 6828430.5 m N 56 MGA94	DRILL RIG: Tracked Scout	
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 69.35 m DATUM: AHD	DRILLER: Drillsearch	
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: BC	DATE: 25/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 16.60 m	CHECKED: CSC	DATE: 13/8/07



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Golder Associates

REPORT OF BOREHOLE: BH2016

SHEET: 1 OF 3

CLIENT: ARUP	COORDS: 553127.2 m E 6828432 m N 56 MGA94	DRILL RIG: Tracked Scout	
PROJECT: Pacific Highway Upgrade	SURFACE RL: 69.38 m DATUM: AHD	DRILLER: Drillsearch	
LOCATION: Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: BC	DATE: 26/7/07
JOB NO: 06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 8.10 m	CHECKED: CSC	DATE: 13/8/07

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USC Symbol	SOIL / ROCK MATERIAL DESCRIPTION	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
ADT	M	Groundwater not observed	0.0 0.5 1.0 1.5 2.0 2.5 3.0	69.38				CH	Silty CLAY, high plasticity, red brown, some fine to medium basalt gravel	D-M		RESIDUAL SOIL
			3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0	*3.30* 66.08					For Continuation Refer to Sheet 2			

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REPORT OF BOREHOLE: BH2016

SHEET: 2 OF 3

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 553127.2 m E 6828432 m N 56 MGA94
SURFACE RL: 69.38 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 8.10 m

DRILL RIG: Tracked Scout
DRILLER: Drillsearch
LOGGED: BC DATE: 26/7/07
CHECKED: CSC DATE: 13/8/07

Drilling						Field Material Description			Defect Information	
METHOD	WATER	TCR	RQD (SCR)	DEPTH (meters)	*DEPTH* RL	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING	INFERRED STRENGTH $Is_{(50)}$ MPa (EL VL L M H VH EH)	DEFECT DESCRIPTION & Additional Observations	AVERAGE DEFECT SPACING (mm)
				0.0 – 3.30						
NMLC					*3.30* 66.08	Continuation of Sheet 1 BASALT, grey	SW	H	3.30-3.75m: Possible boulder?	1000
	◁ 80%				*3.75* 65.63	BASALT, red brown, with clayey silt zones	EW	EL – VL	3.75-5.00m: J, 0-10°, sp=50-300mm, Un 4.40-4.70m: Core recovered as fragmented rock. 4.90-5.00m: Core recovered as fragmented rock.	30 – 100
					5.00 64.38	NO CORE 5.00-6.40m				
					6.40 62.98	BASALT, red brown and grey, varying zones of strength	EW	EL – VL	6.40-6.60m: Core recovered as fragmented rock. 6.65-7.30m: J, 0-10°, sp=50-200mm, Un 7.35-7.85m: Core recovered as fragmented rock.	30 – 100
					7.70 61.68	7.7-7.85m: Gravel zone			7.90m: J, 0°, Un	
				8.0						

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GAP gINT FN. F02a
RL2

GAP6_0-BETA_NEW ONE_25.06.07 SRAS ALTERED BY DATGEL 2007-07-02.GLB CORED BOREHOLE J:\06PROJ\101-150\06622140_ARUP_T2E PREFERRED ROUTE\7000 FIELD AND LABORATORY DATA\7870 GINT\06622140 PH.GPJ GAP6_0-BETA-PH.GDT 05/09/2007 3:05:19 PM

REPORT OF BOREHOLE: BH2016

SHEET: 3 OF 3

CLIENT:	ARUP	COORDS: 553127.2 m E 6828432 m N 56 MGA94		DRILL RIG: Tracked Scout	
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 69.38 m	DATUM: AHD	DRILLER: Drillsearch	
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°		LOGGED: BC	DATE: 26/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm	HOLE DEPTH: 8.10 m	CHECKED: CSC	DATE: 13/8/07

Drilling						Field Material Description				Defect Information	
METHOD	WATER	TCR	RQD (SCR)	DEPTH (meters)	*DEPTH* RL	GRAPHIC LOG	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING	INFERRED STRENGTH Is$_{(50)}$ MPa EL VL L M H VH EH 0.03 0.1 0.3 1 3 10	DEFECT DESCRIPTION & Additional Observations	AVERAGE DEFECT SPACING (mm) 10 30 100 300 1000 3000
				8.0	*8.10*				▨	8.00-8.10m: Core recovered as fragmented rock.	▨
							END OF BOREHOLE @ 8.10 m Reached target depth Piezometer installed Note: borehole drilled for piezometer installation only				

Depth scale: 8.5, 9.0, 9.5, 10.0, 10.5, 11.0, 11.5, 12.0, 12.5, 13.0, 13.5, 14.0, 14.5, 15.0, 15.5, 16.0

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GAP gINT FN. F02a
RL2

GAP6_0-BETA_NEW ONE_25.06.07 SRAS ALTERED BY DATGEL 2007-07-02.GLB CORED BOREHOLE J:\06PROJ\101-150\06622140_ARUP_T2E PREFERRED ROUTE\7000 FIELD AND LABORATORY DATA\7870 GINT\06622140 PH.GPJ GAP6_0-BETA-PH.GDT 05/09/2007 3:05:20 PM

Golder Associates

REPORT OF STANDPIPE INSTALLATION: BH2016

SHEET: 1 OF 1

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

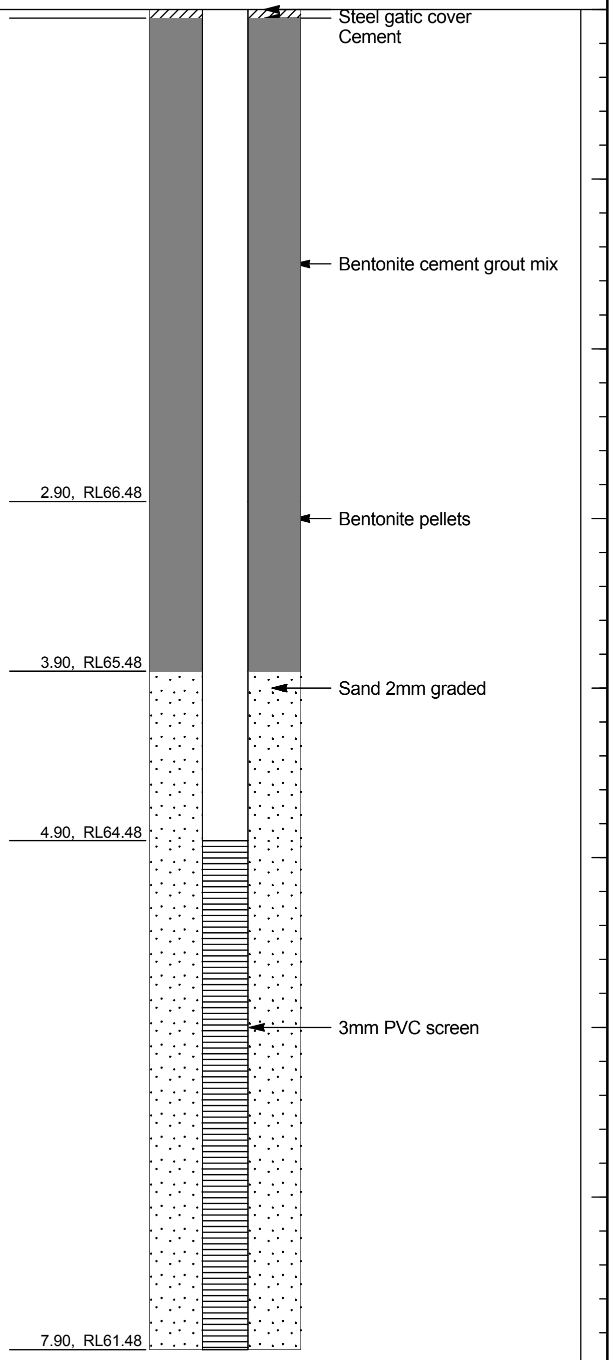
COORDS: 553127.2 m E 6828432 m N 56 MGA94
SURFACE RL: 69.38 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 8.10 m

DRILL RIG: Tracked Scout
DRILLER: Drillsearch
LOGGED: BC DATE: 26/7/07
CHECKED: CSC DATE: 13/8/07

GAP6_0-BETA_NEW ONE_25.06.07 SRAS ALTERED BY DATGEL 2007-07-02.GLB WELL3 J:\06PROJ\101-150\06622140_ARUP_T2E PREFERRED ROUTE\7000 FIELD AND LABORATORY DATA\7870 GINT\06622140 PH.GPJ GAP6_0-BETA-PH.GDT 05/09/2007 3:06:13 PM

Drilling					Field Material Description	
METHOD	WATER	DRILL FLUID LEVELS	DEPTH (metres)	DEPTH RL	GRAPHIC LOG	ABBREVIATED SOIL / ROCK MATERIAL DESCRIPTION (Refer to Report of Borehole For Details)
ADT	Groundwater not observed		0	69.38		Silty CLAY
NMLC	80%		3.30	66.08		BASALT
			3.75	65.63		BASALT
			5.00	64.38		NO CORE
			6.40	62.98		BASALT
			8.10	61.28		

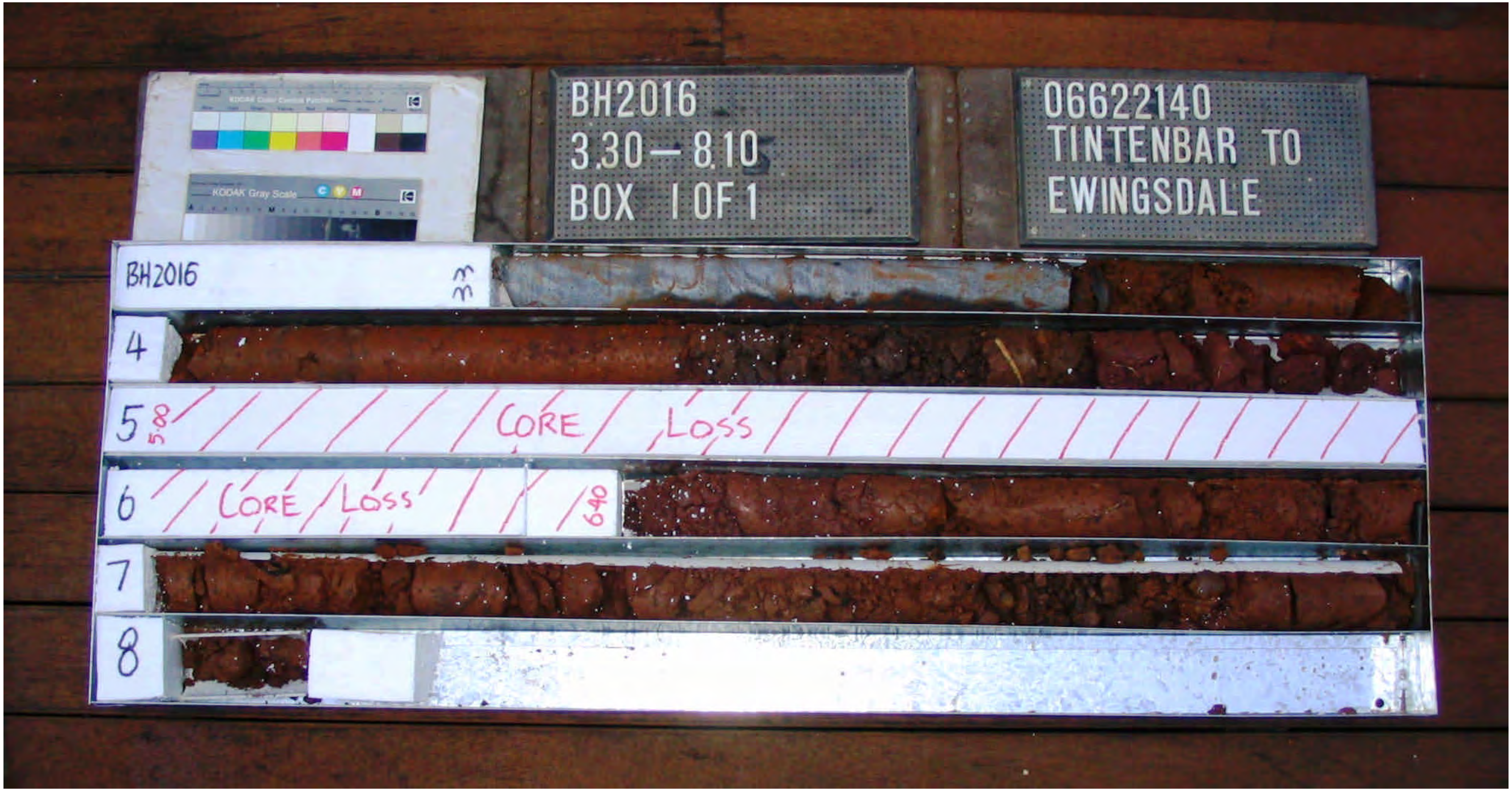
Instrumentation Details



REPORT OF CORE PHOTOGRAPHS: BH2016

SHEET: 1 OF 1

CLIENT:	ARUP	COORDS: 553127.2 m E 6828432 m N 56 MGA94	DRILL RIG: Tracked Scout
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 69.38 m DATUM: AHD	DRILLER: Drillsearch
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: BC DATE: 26/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 8.10 m	CHECKED: CSC DATE: 13/8/07



This report of core photographs must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

Golder Associates

REPORT OF BOREHOLE: BH2017

SHEET: 1 OF 4

CLIENT:	ARUP	COORDS: 553228.9 m E 6828420.4 m N 56 MGA94		DRILL RIG: Gemco	
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 54.77 m	DATUM: AHD	DRILLER: Drillsearch	
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°		LOGGED: BC	DATE: 23/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm	HOLE DEPTH: 21.00 m	CHECKED: CSC	DATE: 13/8/07

Drilling					Sampling		Field Material Description				
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	USC Symbol	SOIL / ROCK MATERIAL DESCRIPTION	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
ADT	M		0.0	54.77			CH	Silty CLAY, high plasticity, red brown with some fine gravel	D-M	St	RESIDUAL SOIL
			1.20		SPT 1.20-1.65 m 3,6,7 N = 13	■					
			2.70		SPT 2.70-3.15 m 3,4,6 N = 10	■					
	M-H		4.00	4.00 50.77			MH	Clayey SILT, high plasticity, red brown with grey zones, red ironstaining, rock structure evident, some jointing. Inferred weathered Basalt	M	F-St	RESIDUAL SOIL TO WEATHERED ROCK
		◁ 30/07/2007	4.40		SPT 4.40-4.85 m 3,2,5 N = 7	■					
			5.90		SPT 5.90-6.35 m 4,3,4 N = 7	■					
			7.00							St	
			7.30		SPT 7.30-7.75 m 3,4,9 N = 13	■					
			7.80	7.80 46.97				For Continuation Refer to Sheet 2			
			8.0								

REPORT OF BOREHOLE: BH2017

CLIENT:	ARUP	COORDS: 553228.9 m E 6828420.4 m N 56 MGA94	SHEET: 2 OF 4
			DRILL RIG: Gemco
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 54.77 m DATUM: AHD	DRILLER: Drillsearch
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: BC DATE: 23/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 21.00 m	CHECKED: CSC DATE: 13/8/07

Drilling						Field Material Description				Defect Information	
METHOD	WATER	TCR	RQD (SCR)	DEPTH (meters)	*DEPTH* RL	GRAPHIC LOG	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING	INFERRED STRENGTH Is(50) MPa EL VL L M H VH EH 0.03 0.1 0.3 1 3 10	DEFECT DESCRIPTION & Additional Observations	AVERAGE DEFECT SPACING (mm) 10 30 100 300 1000 3000
				0.0							
				0.5							
				1.0							
				1.5							
				2.0							
				2.5							
				3.0							
				3.5							
				4.0							
				4.5							
				5.0							
				5.5							
				6.0							
				6.5							
				7.0							
				7.5							
					7.80 46.97		Continuation of Sheet 1 BASALT, red brown and grey brown	HW			
				8.0							

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Golder Associates

REPORT OF BOREHOLE: BH2017

SHEET: 3 OF 4

CLIENT: ARUP	COORDS: 553228.9 m E 6828420.4 m N 56 MGA94	DRILL RIG: Gemco	
PROJECT: Pacific Highway Upgrade	SURFACE RL: 54.77 m DATUM: AHD	DRILLER: Drillsearch	
LOCATION: Tintenbar to Ewingsdale	INCLINATION: -90°	LOGGED: BC	DATE: 23/7/07
JOB NO: 06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 21.00 m	CHECKED: CSC	DATE: 13/8/07

GAP6_0-BETA_NEW ONE_25.06.07 SRAS ALTERED BY DATGEL 2007-07-02.GLB CORED BOREHOLE J:\06PROJ\101-150\06622140_ARUP_T2E PREFERRED ROUTE\7000 FIELD AND LABORATORY DATA\7870 GINT\06622140 PH.GPJ GAP6_0-BETA-PH.GDT 05/09/2007 3:08:21 PM

Drilling

METHOD	WATER	TCR	RQD (SCR)	DEPTH (meters)
NMLC		100	96 (96)	8.0–9.0
NMLC		62	12 (20)	9.0–11.6
NMLC		100	0 (15)	11.6–13.7
NMLC		33	0 (10)	13.7–13.9
NMLC		69	0 (40)	13.9–16.0

Field Material Description / **Defect Information**

DEPTH RL	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING	DEFECT DESCRIPTION & Additional Observations
8.0	BASALT, red brown and grey brown	HW	8.17m: J, Un, Ro, Sn, iron 8.32m: J, 20°, Un, Ro, Sn, iron 8.48m: J, 25°, Pl, Ro, Sn 8.60m: J, 10°, Un, Ro, Sn
8.85 45.92	BASALT, grey	SW	8.80-8.85m: core recovered as fragmented rock
9.15 45.62	BASALT, red brown with some zones of grey, red ironstaining in microfractures	HW-MW	
10.00 44.77	NO CORE 10.00-11.00m		
11.00 43.77	BASALT, red brown, with some zones of grey, red ironstaining on microfractures	HW	11.00-11.09m: fragmented core 11.10m: J, 10-20°, Un, Ro, Sn 11.16m: J, 40°, Pl, Ro, Sn 11.17-11.90m: J, 0-30°, sp=10-30mm, Pl-Un, Ro, Sn 11.91-12.50m: J, 0-30°, sp=5-20mm, Pl-Un, Ro, Sn 12.15m: J, 65°, Pl, Ro, Sn, iron staining 12.53-12.85m: J, 0-10°, sp=40mm, Un, Ro, Cn 12.86-13.70m: J, 0-20°, sp=2-20mm, Pl, Ro, Sn 12.90m: J, 70°, Pl, Ro, Sn, iron staining 13.40m: J, 45-90°, Un, Ro, Sn, iron staining
13.70 41.07	NO CORE 13.70-14.75m		
14.75 40.02	Amygdaloidal BASALT, red brown and grey brown, with 2-8mm diameter amygdules	HW	14.76-14.80m: J, 50°, Pl, Sm, Sn 14.85-15.36m: DZ, fine subangular basalt gravel 15.45-16.75m: J, 0-10°, sp=40-80mm, Un, Ro, Cn
16.0			

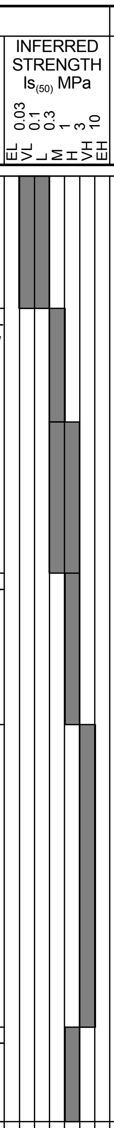
INFERRED STRENGTH $Is_{(50)}$ MPa: EL 0.03 VL 0.1 L 0.3 M 1 H 3 VH 10 EH

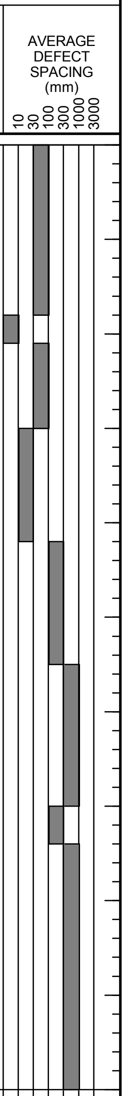
AVERAGE DEFECT SPACING (mm): 10 30 100 300 1000 3000

REPORT OF BOREHOLE: BH2017

CLIENT: ARUP	COORDS: 553228.9 m E 6828420.4 m N 56 MGA94	SHEET: 4 OF 4	
PROJECT: Pacific Highway Upgrade	SURFACE RL: 54.77 m DATUM: AHD	DRILL RIG: Gemco	
LOCATION: Tintenbar to Ewingsdale	INCLINATION: -90°	DRILLER: Drillsearch	
JOB NO: 06622140	HOLE DIA: 100/76 mm HOLE DEPTH: 21.00 m	LOGGED: BC	DATE: 23/7/07
		CHECKED: CSC	DATE: 13/8/07

Drilling						Field Material Description				Defect Information	
METHOD	WATER	TCR	RQD (SCR)	DEPTH (meters)	*DEPTH* RL	GRAPHIC LOG	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING	INFERRED STRENGTH $Is_{(50)}$ MPa	DEFECT DESCRIPTION & Additional Observations	AVERAGE DEFECT SPACING (mm)
NMLC				16.0			Amygdaloidal BASALT, red brown and grey brown, with 2-8mm diameter amygdules	HW		16.07-16.17m: J, 80-90°, Un, Ro, Cn	
		100	0 (85)		*16.70* 38.07		BASALT, grey brown	HW-MW		16.87-17.05m: core recovered as fragmented rock 17.07-17.25m: J, 0-5°, sp=30-50mm, Un, Ro, Cn 17.35-17.38m: J, 30°, Pl, Ro, Cn 17.41m: J, 5-10°, St, Ro, Vr, black veneer 17.45-17.48m: J, 50°, Un, Ro, Vr, black veneer 17.51-17.54m: J, 45°, Pl, Ro, Vr, black veneer 17.58-18.10m: J, 0-20°, sp=10-30mm, Pl, Ro, Sn 17.80m: J, 45°, Pl, Ro, Sn, iron staining 18.00m: J, 30°, Pl, Ro, Sn, iron staining	
		100	100 (100)		*18.10* 36.67		BASALT, grey with 2-5mm diameter calcite amygdules	MW-SW		18.13m: J, 0°, Un, Ro, Cn 18.39-18.65m: undulating microfractures with blue mineral veneer 18.45-18.49m: J, 40°, Un, Ro, Cn 18.70-18.78m: J, 30°, Un, Ro, Vr	
					18.90 35.87		decreasing amygdule content	SW		19.18m: J, 0°, Un, Ro, Cn 19.49m: J, 10°, Pl, Ro, Sn, blue oxide 19.61-19.70m: J, 50°, Un, Ro, Sn, blue oxide 20.21m: J, 20°, Pl, Ro, Cn	
					20.50 34.27		Vesicular BASALT, grey with 2-10mm diameter vesicles, some 3-10mm diameter calcite amygdules, becoming red brown with depth	MW-SW		20.69m: DS, 0°, fine subangular gravel	
				21.0	*21.00*		END OF BOREHOLE @ 21.00 m Reached target depth Piezometer installed				





Depth scale: 16.0, 16.5, 17.0, 17.5, 18.0, 18.5, 19.0, 19.5, 20.0, 20.5, 21.0, 21.5, 22.0, 22.5, 23.0, 23.5, 24.0

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Golder Associates

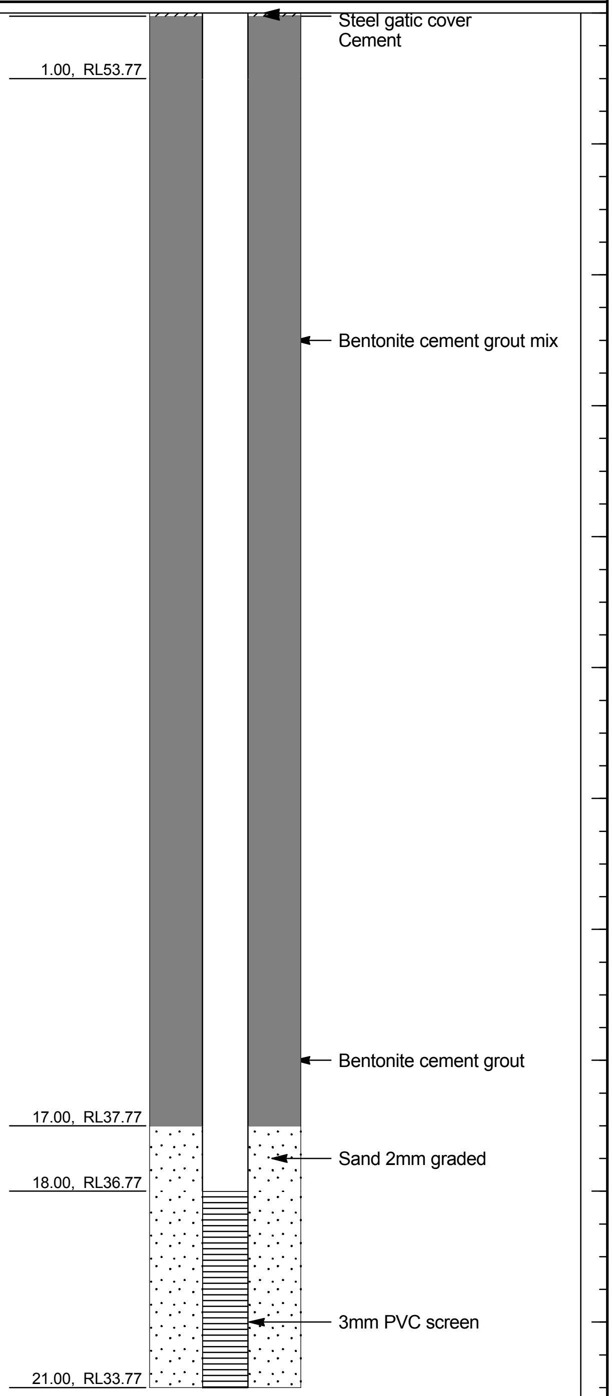
REPORT OF STANDPIPE INSTALLATION: BH2017

SHEET: 1 OF 1

CLIENT:	ARUP	COORDS: 553228.9 m E 6828420.4 m N 56 MGA94		DRILL RIG: Gemco	
PROJECT:	Pacific Highway Upgrade	SURFACE RL: 54.77 m	DATUM: AHD	DRILLER: Drillsearch	
LOCATION:	Tintenbar to Ewingsdale	INCLINATION: -90°		LOGGED: BC	DATE: 23/7/07
JOB NO:	06622140	HOLE DIA: 100/76 mm	HOLE DEPTH: 21.00 m	CHECKED: CSC	DATE: 13/8/07

Drilling					Field Material Description	
METHOD	WATER	DRILL FLUID LEVELS	DEPTH (metres)	DEPTH RL	GRAPHIC LOG	ABBREVIATED SOIL / ROCK MATERIAL DESCRIPTION (Refer to Report of Borehole For Details)
ADT	30/07/2007		0	54.77		Silty CLAY
			4	4.00 50.77		Clayey SILT
NMLC			8	7.80 46.97		BASALT
				8.85		BASALT
				9.15 45.62		BASALT
			10	10.00 44.77		NO CORE
				11.00 43.77		BASALT
			14	13.70 41.07		NO CORE
				14.75 40.02		BASALT
				16.70 38.07		BASALT
			18	18.10 36.67		BASALT
				20.50		BASALT
				21.00 33.77		

Instrumentation Details



This report of standpipe installation must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

Golder Associates

REPORT OF CORE PHOTOGRAPHS: BH2017

SHEET: 1 OF 3
DRILL RIG: Gemco
DRILLER: Drillsearch
LOGGED: BC DATE: 23/7/07
CHECKED: CSC DATE: 13/8/07

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 553228.9 m E 6828420.4 m N 56 MGA94
SURFACE RL: 54.77 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 21.00 m

Golder Associates

REPORT OF CORE PHOTOGRAPHS: BH2017

SHEET: 2 OF 3

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 553228.9 m E 6828420.4 m N 56 MGA94
SURFACE RL: 54.77 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 21.00 m

DRILL RIG: Gemco
DRILLER: Drillsearch
LOGGED: BC DATE: 23/7/07
CHECKED: CSC DATE: 13/8/07

Golder Associates

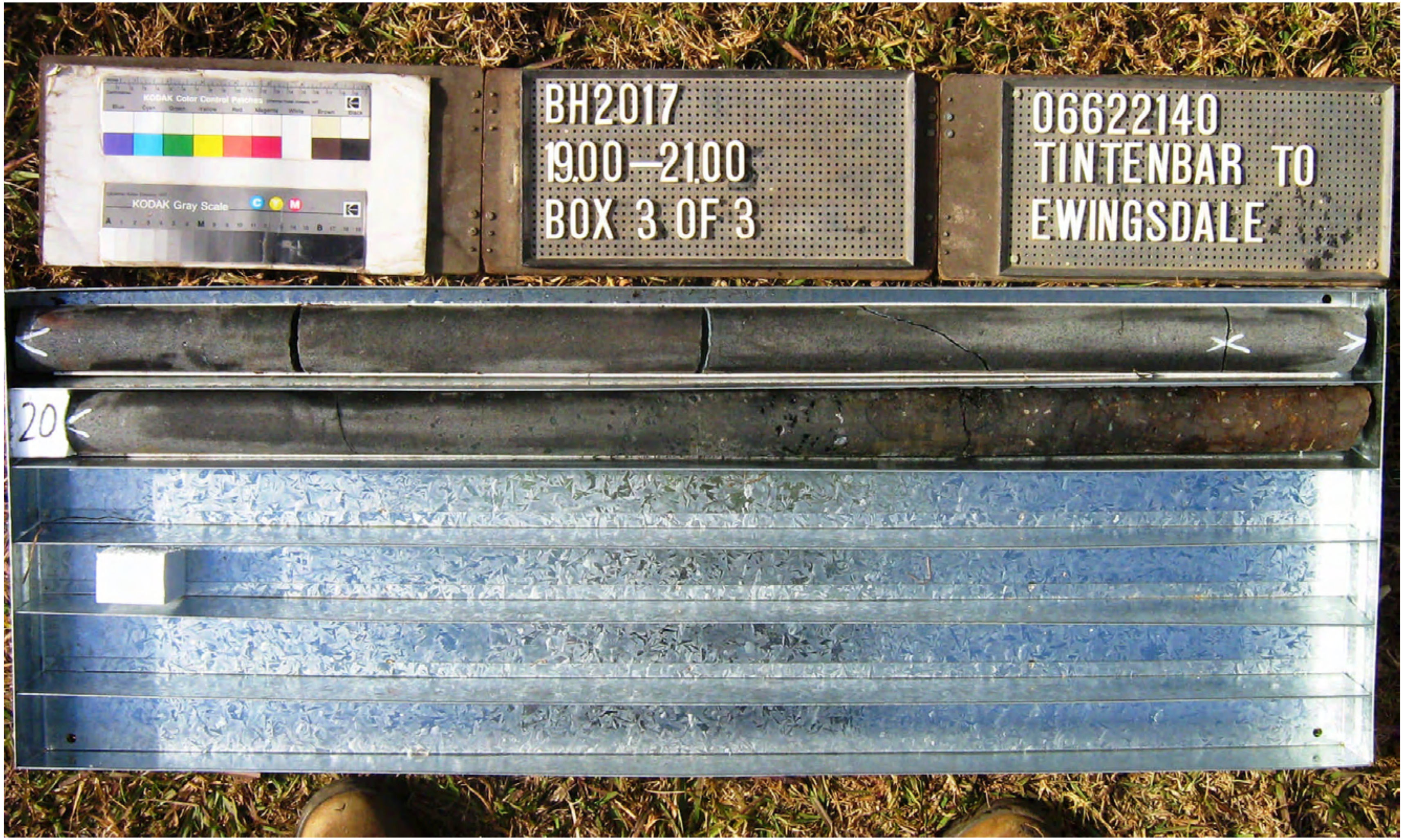
REPORT OF CORE PHOTOGRAPHS: BH2017

SHEET: 3 OF 3

CLIENT: ARUP
PROJECT: Pacific Highway Upgrade
LOCATION: Tintenbar to Ewingsdale
JOB NO: 06622140

COORDS: 553228.9 m E 6828420.4 m N 56 MGA94
SURFACE RL: 54.77 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 21.00 m

DRILL RIG: Gemco
DRILLER: Drillsearch
LOGGED: BC DATE: 23/7/07
CHECKED: CSC DATE: 13/8/07



Golder Associates

REPORT OF BOREHOLE: BH2018

CLIENT: ARUP	COORDS: 553231 m E 6828417.3 m N 56 MGA94	SHEET: 1 OF 1	
PROJECT: Pacific Highway Upgrade	SURFACE RL: 54.75 m DATUM: AHD	DRILL RIG: Tracked Scout	
LOCATION: Tintenbar to Ewingsdale	INCLINATION: -90°	DRILLER: Drillsearch	
JOB NO: 06622140	HOLE DIA: 100 mm HOLE DEPTH: 8.00 m	LOGGED: BC	DATE: 24/7/07
		CHECKED: CSC	DATE: 13/8/07

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USC Symbol	SOIL / ROCK MATERIAL DESCRIPTION	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
ADT	M		0.0	54.75				CH	Silty CLAY, high plasticity, red brown			RESIDUAL SOIL
			0.5									
	L-M		1.0									
			1.5									
			2.0									
			2.5									
			3.0	3.00 51.75				MH	Clayey SILT, high plasticity, grey brown			
			3.5									
			4.0									
		30/07/2007	4.5									
			5.0									
			5.5									
			6.0									
			6.5									
			7.0									
			7.5						END OF BOREHOLE @ 8.00m Reached target depth Piezometer installed Note: borehole drilled for piezometer installation only			
			8.0	8.00								

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GAP gINT FN. F01a
RL2

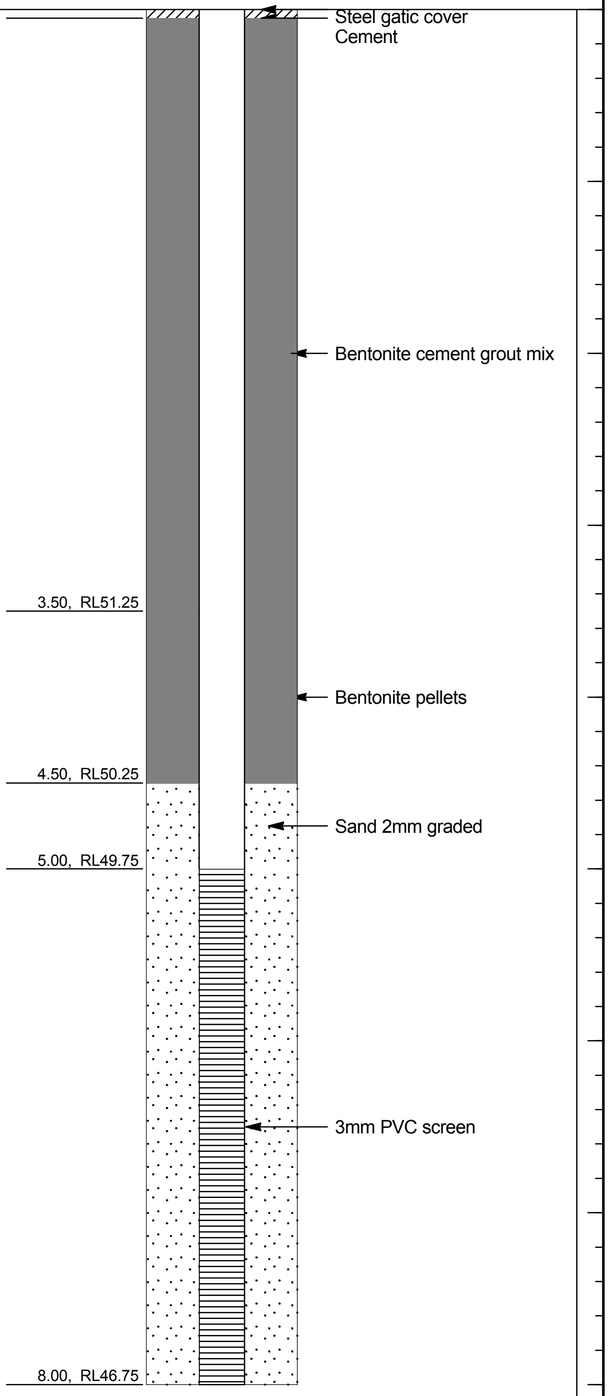
GAP6_0-BETA_NEW ONE_25.06.07 SRAS ALTERED BY DATGEL 2007-07-02.GLB FULL PAGE J:\06PROJ\101-150\06622140_ARUP_T2E PREFERRED ROUTE\7000 FIELD AND LABORATORY DATA\7870 GINT\06622140 PH.GPJ GAP6_0-BETA-PH.GDT 05/09/2007 3:10:45 PM

Golder Associates

REPORT OF STANDPIPE INSTALLATION: BH2018

CLIENT: ARUP	COORDS: 553231 m E 6828417.3 m N 56 MGA94	SHEET: 1 OF 1	
PROJECT: Pacific Highway Upgrade	SURFACE RL: 54.75 m DATUM: AHD	DRILL RIG: Tracked Scout	
LOCATION: Tintenbar to Ewingsdale	INCLINATION: -90°	DRILLER: Drillsearch	
JOB NO: 06622140	HOLE DIA: 100 mm HOLE DEPTH: 8.00 m	LOGGED: BC	DATE: 24/7/07
		CHECKED: CSC	DATE: 13/8/07

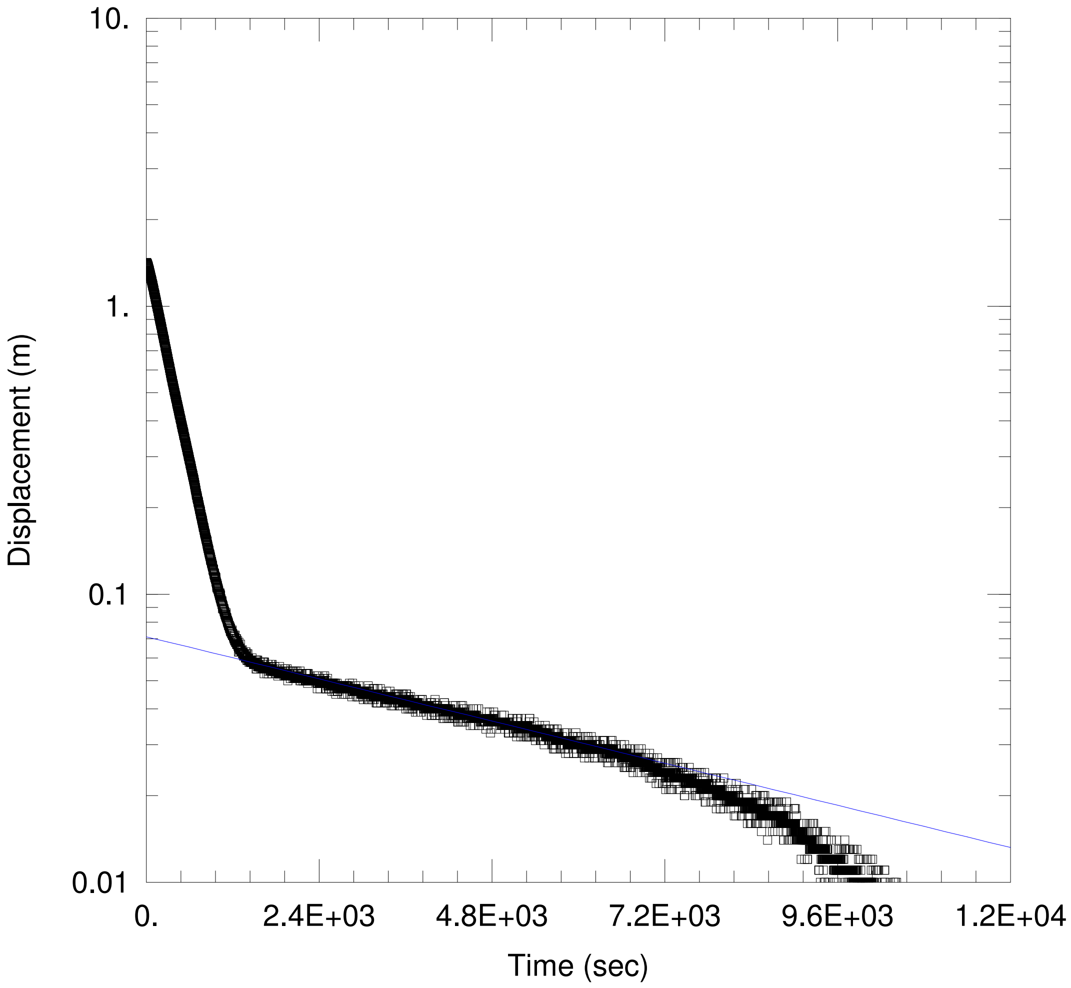
Drilling					Field Material Description		Instrumentation Details
METHOD	WATER	DRILL FLUID LEVELS	DEPTH (metres)	DEPTH RL	GRAPHIC LOG	ABBREVIATED SOIL / ROCK MATERIAL DESCRIPTION (Refer to Report of Borehole For Details)	
ADT	30/07/2007		0	54.75		Silty CLAY	
			3	3.00 51.75		Clayey SILT	
			8	8.00 46.75			



This report of standpipe installation must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

GAP6_0-BETA_NEW ONE_25.06.07 SRAS ALTERED BY DATGEL 2007-07-02.GLB WELL3 J:\06PROJ\101-150\06622140_ARUP_T2E PREFERRED ROUTE\7000 FIELD AND LABORATORY DATA\7870 GINT\06622140 PH.GPJ GAP6_0-BETA-PH.GDT 05/09/2007 3:11:45 PM

Appendix D
Slug Test Analysis Reports



WELL TEST ANALYSIS

Data Set: J:\...\BH1021_final.aqt
Date: 08/27/07
Time: 16:32:32

PROJECT INFORMATION

Company: Golder Associates
Client: ARUP
Project: 06622140
Test Location: Tintenbar to Ewingsdale
Test Well: BH1021
Test Date: 1/08/2007

AQUIFER DATA

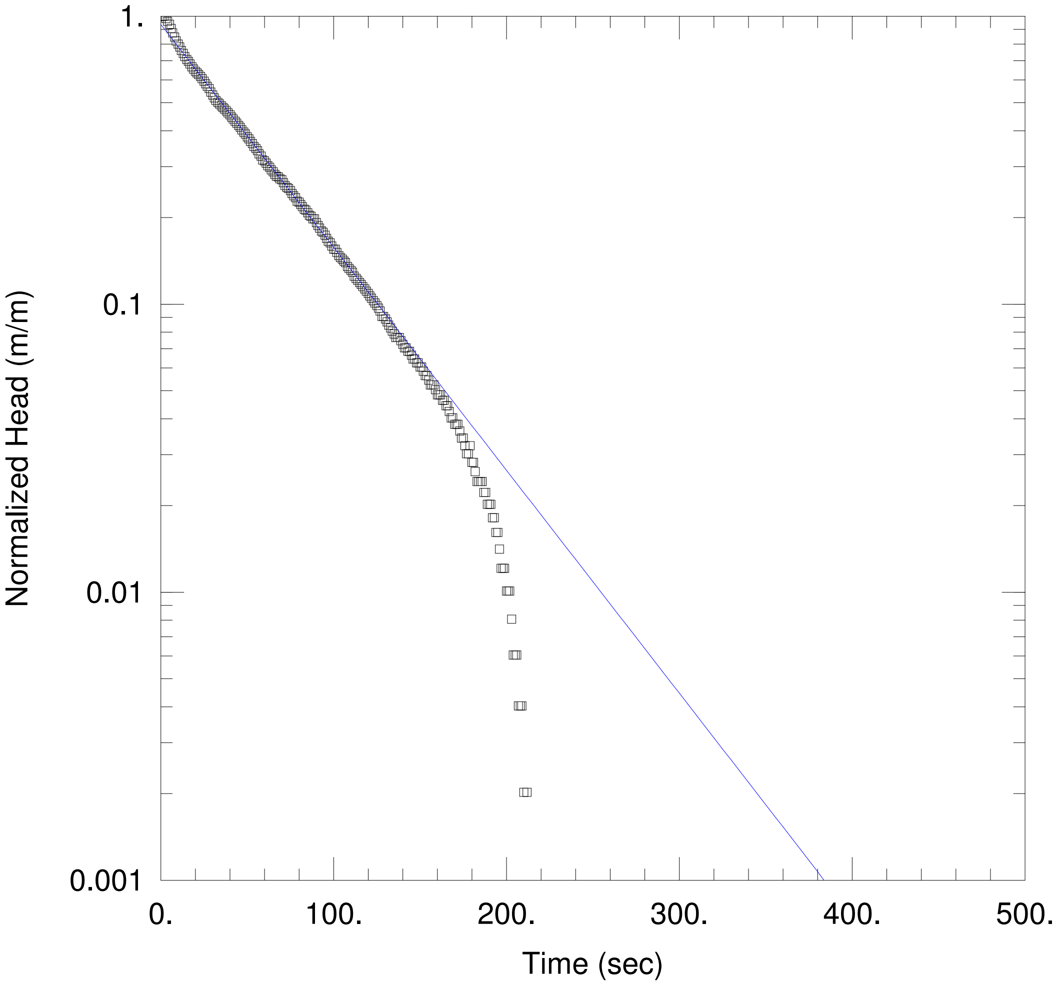
Saturated Thickness: 13.65 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BH1021)

Initial Displacement: 1.415 m
Water Column Height: 13.65 m
Casing Radius: 0.025 m
Wellbore Radius: 0.038 m
Screen Length: 6. m
Gravel Pack Porosity: 0.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 4.535E-08 m/sec
y0 = 0.07115 m



BH2001 SLUG TEST

Data Set: J:\...\2001_BR.aqt
Date: 08/09/07
Time: 11:38:11

PROJECT INFORMATION

Company: Golder Associates
Client: ARUP
Project: 06622140
Location: Tintenbar to Ewingsdale
Test Well: BH2001
Test Date: 1/8/2007

AQUIFER DATA

Saturated Thickness: 0.3 m
Anisotropy Ratio (Kz/Kr): 1.

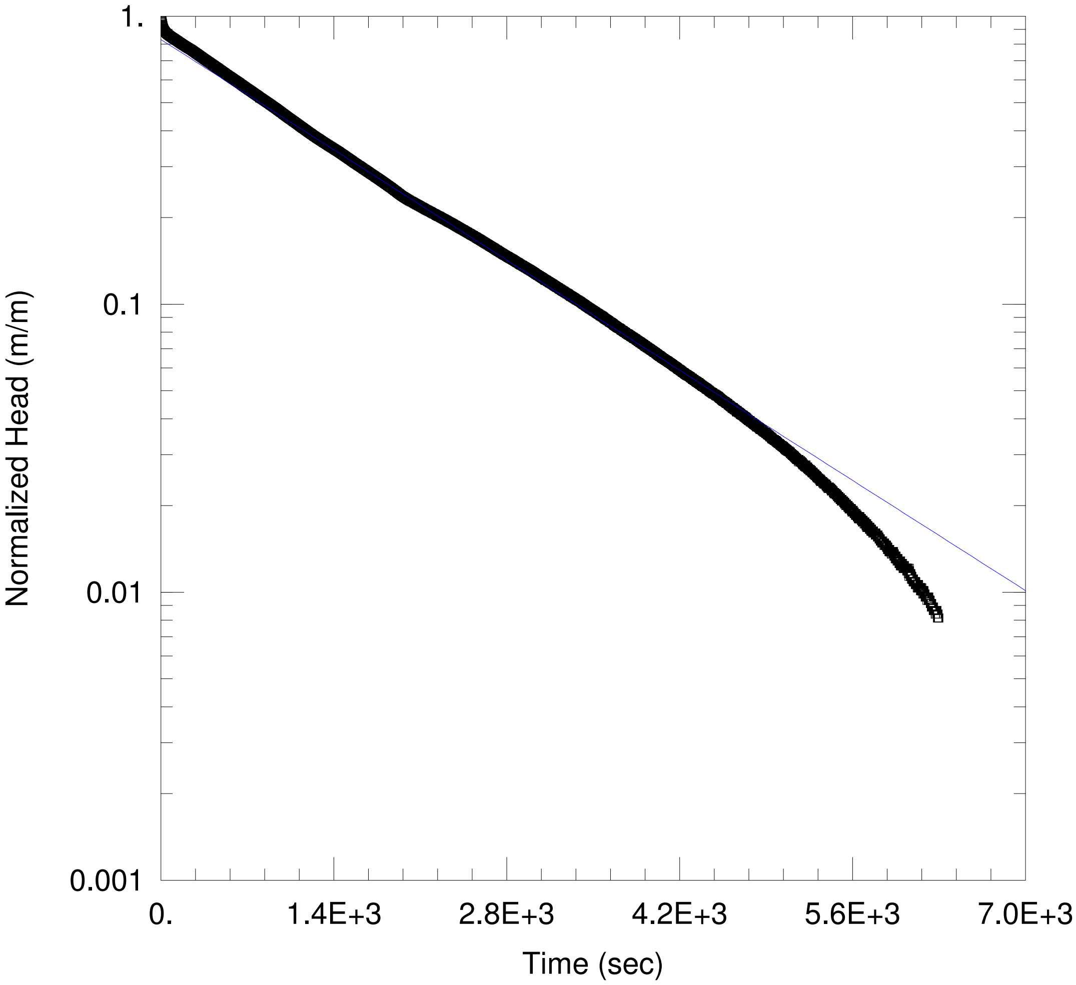
WELL DATA (BH2001)

Initial Displacement: 0.496 m
Static Water Column Height: 0.3 m
Total Well Penetration Depth: 0.3 m
Screen Length: 3. m
Casing Radius: 0.025 m
Wellbore Radius: 0.038 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 3.209E-6 m/sec
y0 = 0.4639 m



BH2004 SLUG TEST

Data Set: J:\...\2004_BR_Late.aqt
Date: 08/21/07
Time: 09:12:55

PROJECT INFORMATION

Company: Golder Associates
Client: ARUP
Project: 06622140
Location: Tintenbar to Ewingsdale
Test Well: BH2014
Test Date: 2/8/2007

AQUIFER DATA

Saturated Thickness: 2.25 m
Anisotropy Ratio (Kz/Kr): 0.1

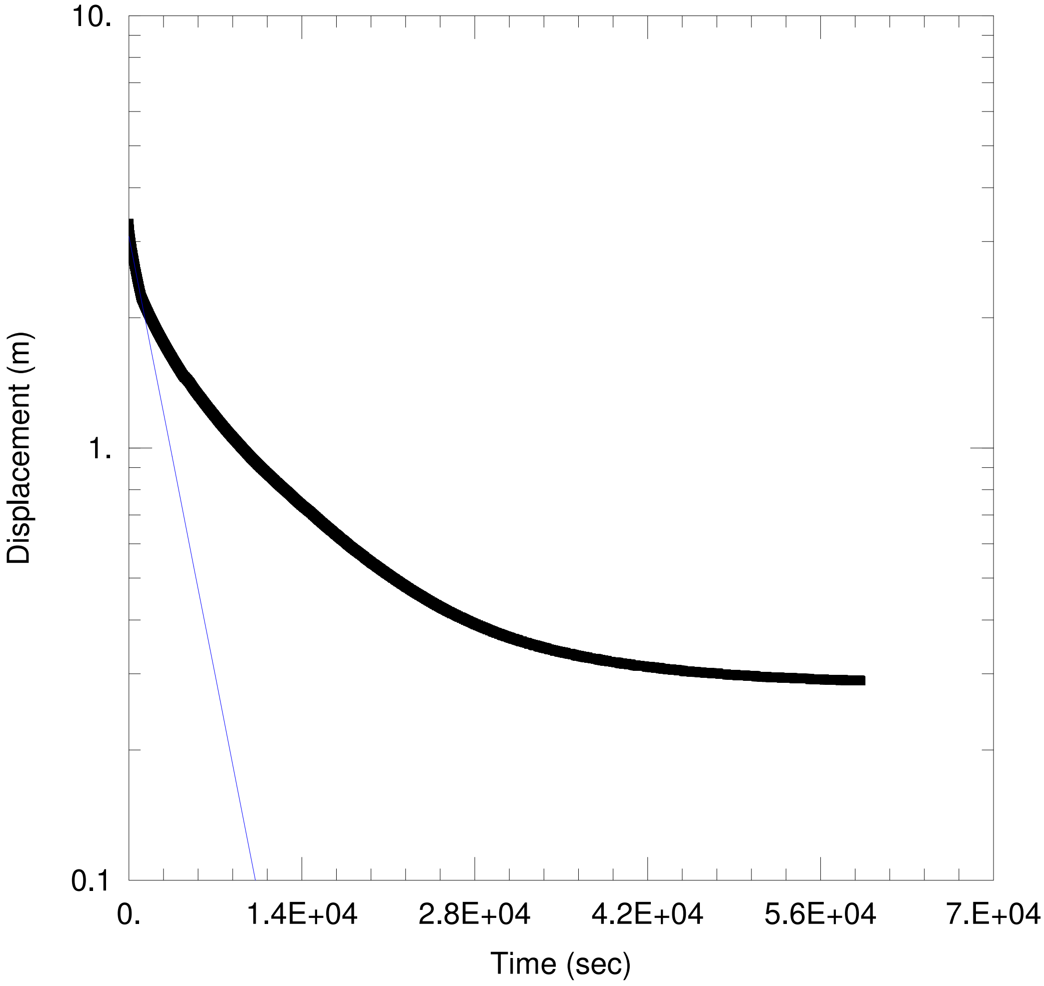
WELL DATA (BH2004)

Initial Displacement: 4.053 m
Static Water Column Height: 2.25 m
Total Well Penetration Depth: 2.25 m
Screen Length: 3. m
Casing Radius: 0.025 m
Wellbore Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 3.139E-7 m/sec
y0 = 3.36 m



WELL TEST ANALYSIS

Data Set: J:\...\BH2006.aqt
Date: 08/24/07 Time: 13:32:52

PROJECT INFORMATION

Company: Golder Associates
Client: ARUP
Project: 06622140
Test Location: Tintenbar to Ewingsdale
Test Well: BH2006
Test Date: 31/07/2007

AQUIFER DATA

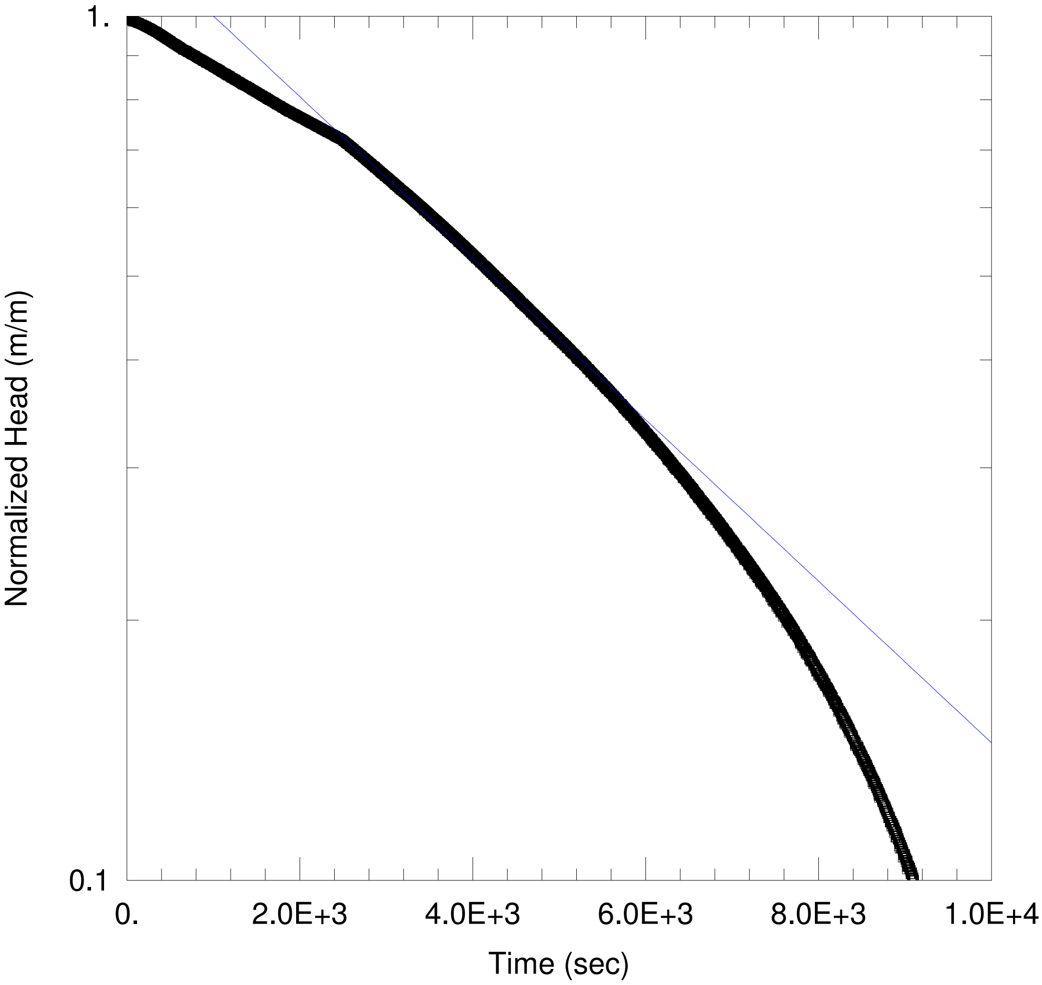
Saturated Thickness: 3.5 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BH2006)

Initial Displacement: 3.309 m
Water Column Height: 0.4 m
Casing Radius: 0.025 m
Wellbore Radius: 0.038 m
Screen Length: 2. m
Gravel Pack Porosity: 0.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 1.278E-07 m/sec
y0 = 3.084 m



BH2007 SLUG TEST

Data Set: J:\...\2007_BR.aqt
Date: 08/09/07
Time: 12:20:06

PROJECT INFORMATION

Company: Golder Associates
Client: ARUP
Project: 06622140
Location: Tintenbar to Ewingsdale
Test Well: BH2007
Test Date: 31/7/2007

AQUIFER DATA

Saturated Thickness: 4. m
Anisotropy Ratio (Kz/Kr): 1.

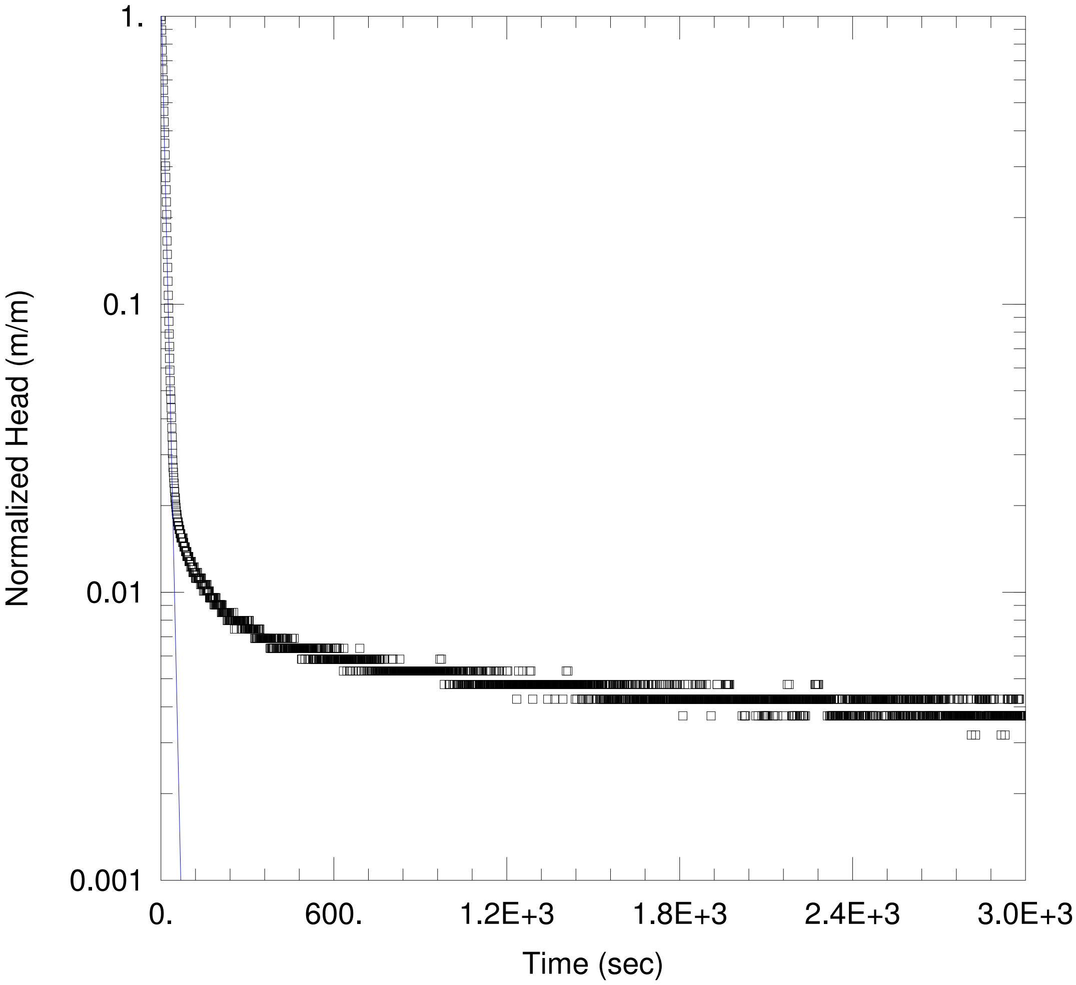
WELL DATA (BH2007)

Initial Displacement: 1.527 m
Static Water Column Height: 8.7 m
Total Well Penetration Depth: 4. m
Screen Length: 3. m
Casing Radius: 0.025 m
Wellbore Radius: 0.038 m

SOLUTION

Aquifer Model: Confined
Solution Method: Bouwer-Rice

K = 7.939E-8 m/sec
y0 = 1.895 m



BH2008 SLUG TEST

Data Set: J:\...\2008_BR.aqt
Date: 08/21/07 Time: 09:14:58

PROJECT INFORMATION

Company: Golder Associates
Client: ARUP
Project: 06622140
Location: Tintenbar to Ewingsdale
Test Well: BH2008
Test Date: 31/7/2007

AQUIFER DATA

Saturated Thickness: 2.6 m
Anisotropy Ratio (Kz/Kr): 1.

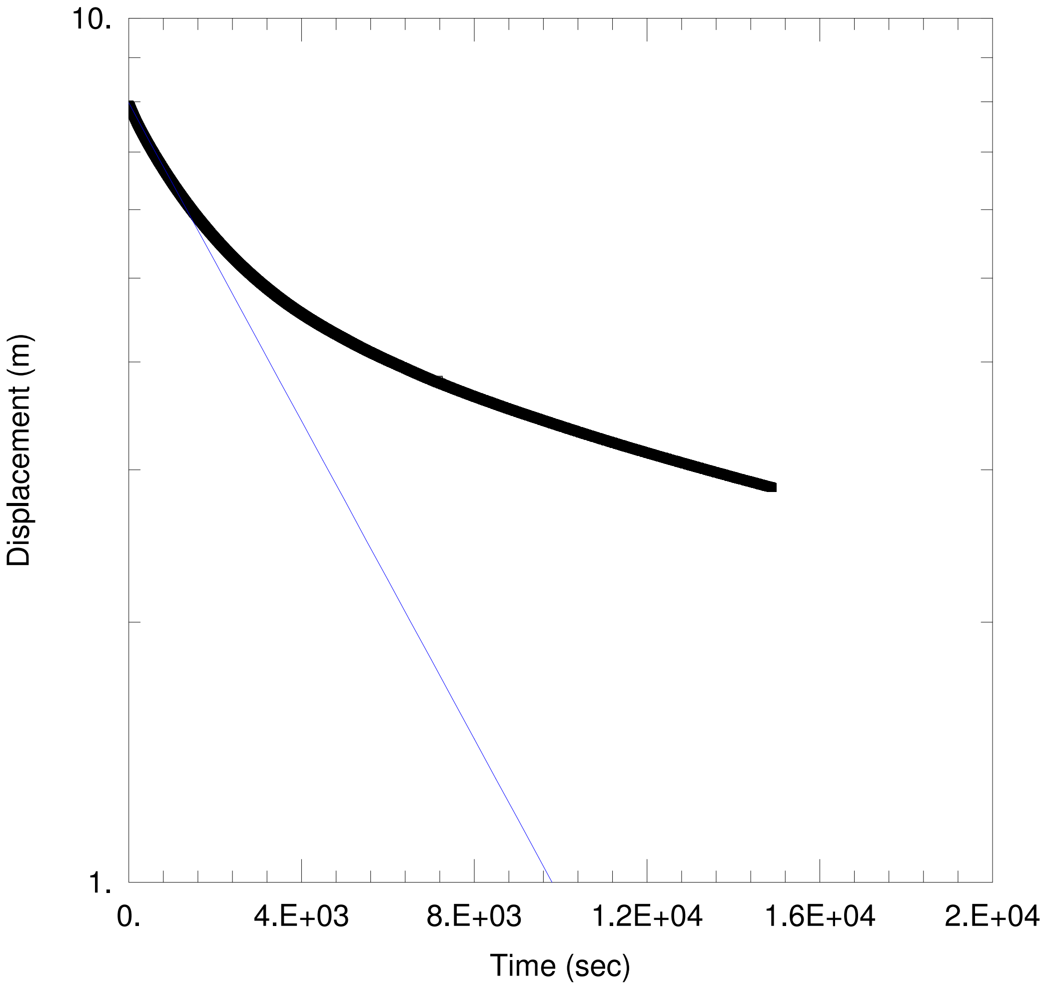
WELL DATA (BH2008)

Initial Displacement: 1.881 m
Static Water Column Height: 2.6 m
Total Well Penetration Depth: 2.6 m
Screen Length: 3. m
Casing Radius: 0.025 m
Wellbore Radius: 0.038 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 3.57E-5 m/sec
y0 = 2.624 m



BH2009

Data Set: J:\...\BH2009.aqt
Date: 08/27/07 Time: 16:37:19

PROJECT INFORMATION

Company: Golder Associates
Client: ARUP
Project: 06622140
Test Location: Tintenbar to Ewingsdale
Test Well: BH2009
Test Date: 31/07/2007

AQUIFER DATA

Saturated Thickness: 30.3 m Anisotropy Ratio (Kz/Kr): 1.

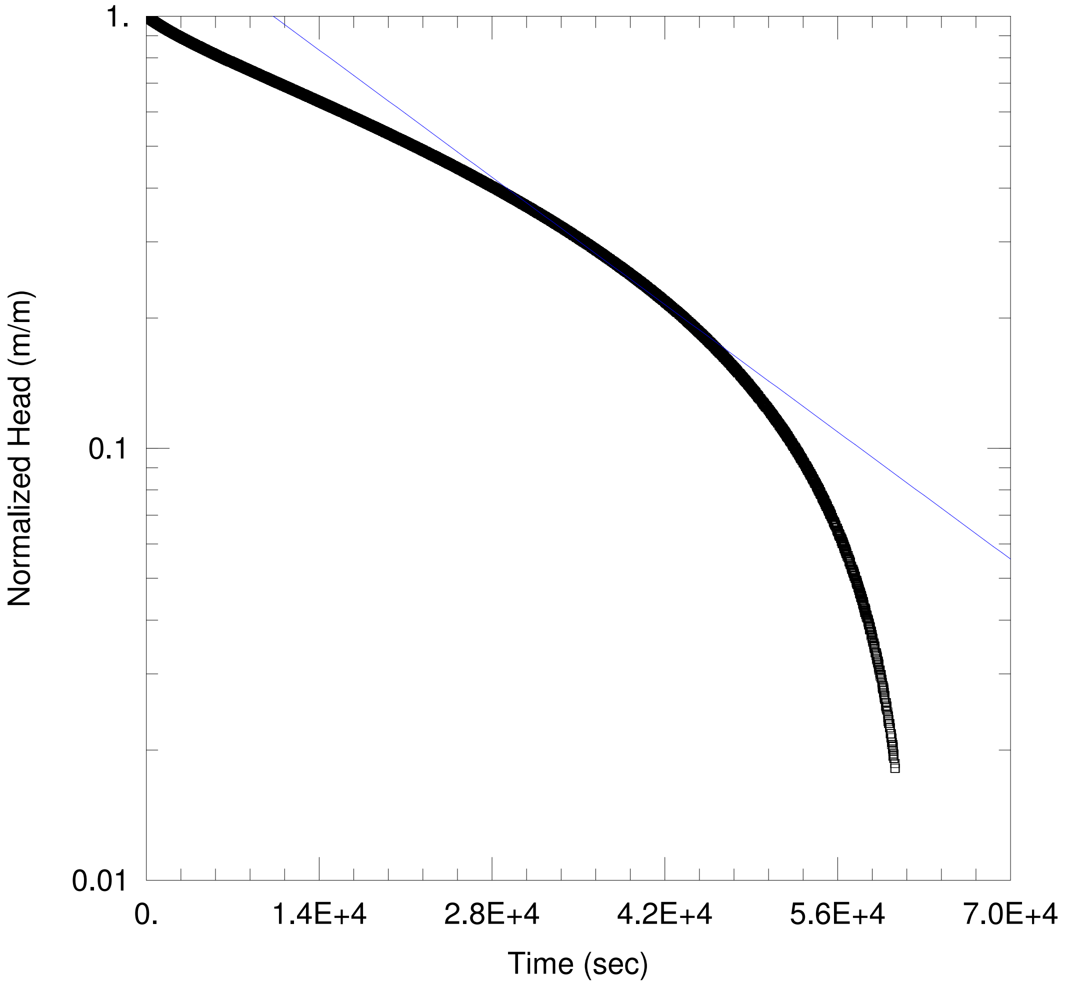
WELL DATA (BH2009)

Initial Displacement: 7.93 m Water Column Height: 12.4 m
Casing Radius: 0.025 m Wellbore Radius: 0.038 m
Screen Length: 3. m Gravel Pack Porosity: 0.3

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice

K = 1.071E-07 m/sec y0 = 7.978 m



BH2011 SLUG TEST

Data Set: J:\...\2011_BR.aqt
Date: 08/21/07 Time: 09:17:59

PROJECT INFORMATION

Company: Golder Associates
Client: ARUP
Project: 06622140
Location: Tintenbar to Ewingsdale
Test Well: BH2011
Test Date: 30/7/2007

AQUIFER DATA

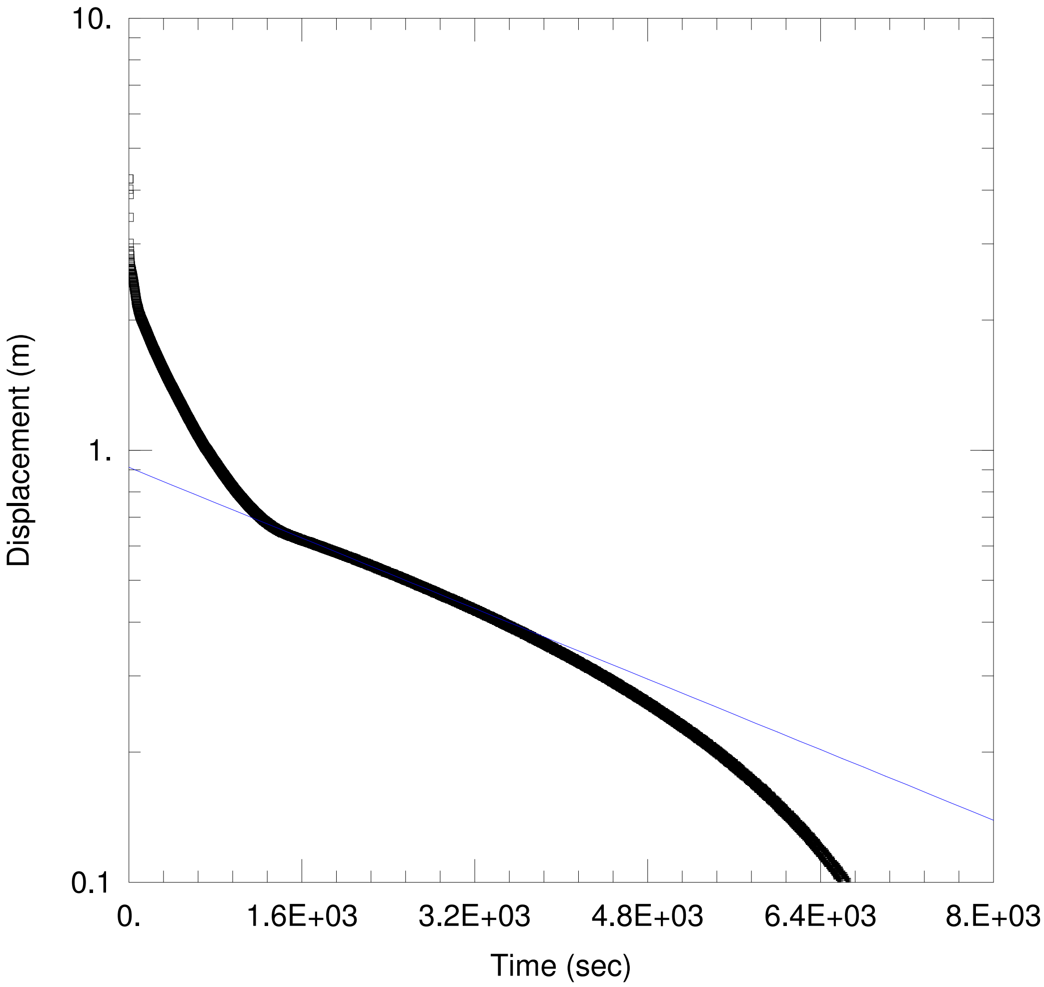
Saturated Thickness: 4.3 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BH2011)

Initial Displacement: 4.079 m
Static Water Column Height: 10.1 m
Total Well Penetration Depth: 4.3 m
Screen Length: 3. m
Casing Radius: 0.025 m
Wellbore Radius: 0.038 m

SOLUTION

Aquifer Model: Confined
Solution Method: Bouwer-Rice
K = 1.811E-8 m/sec
y0 = 6.709 m



WELL TEST ANALYSIS

Data Set: J:\...\BH2013_final.aqt
Date: 08/27/07 Time: 16:33:06

PROJECT INFORMATION

Company: Golder Associates
Client: ARUP
Project: 06622140
Test Location: Tintenbar to Ewingsdale
Test Well: BH1021
Test Date: 1/08/2007

AQUIFER DATA

Saturated Thickness: 3. m
Anisotropy Ratio (Kz/Kr): 1.

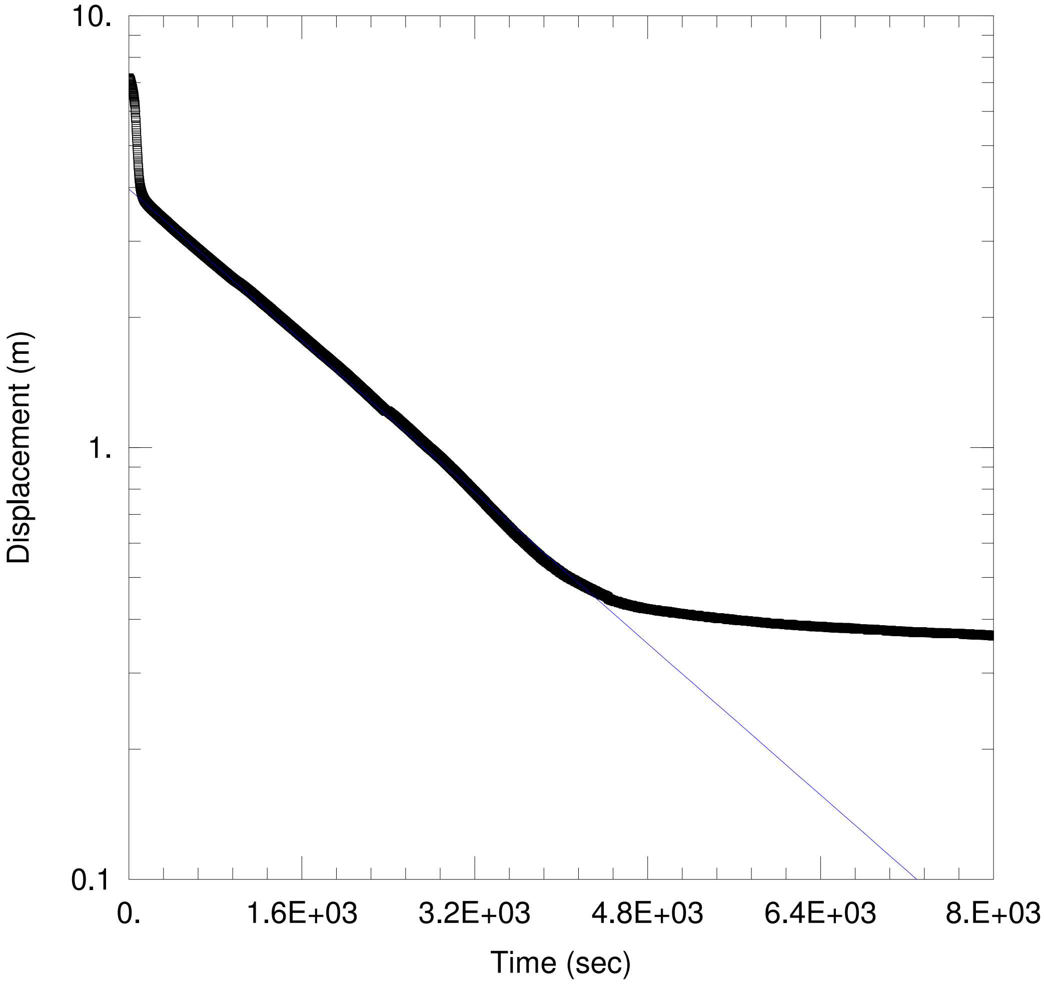
WELL DATA (BH2013)

Initial Displacement: 4.241 m
Water Column Height: 3.3 m
Casing Radius: 0.025 m
Wellbore Radius: 0.038 m
Screen Length: 3. m
Gravel Pack Porosity: 0.3

SOLUTION

Aquifer Model: Confined
Solution Method: Bouwer-Rice

K = 1.166E-07 m/sec
y0 = 0.9121 m



WELL TEST ANALYSIS

Data Set: J:\...\BH2014.aqt
Date: 08/27/07 Time: 16:40:38

PROJECT INFORMATION

Company: Golder Associates
Client: ARUP
Project: 06622140
Test Location: Tintenbar to Ewingsdale
Test Well: BH2014
Test Date: 22/08/2007

AQUIFER DATA

Saturated Thickness: 14.3 m Anisotropy Ratio (Kz/Kr): 1.

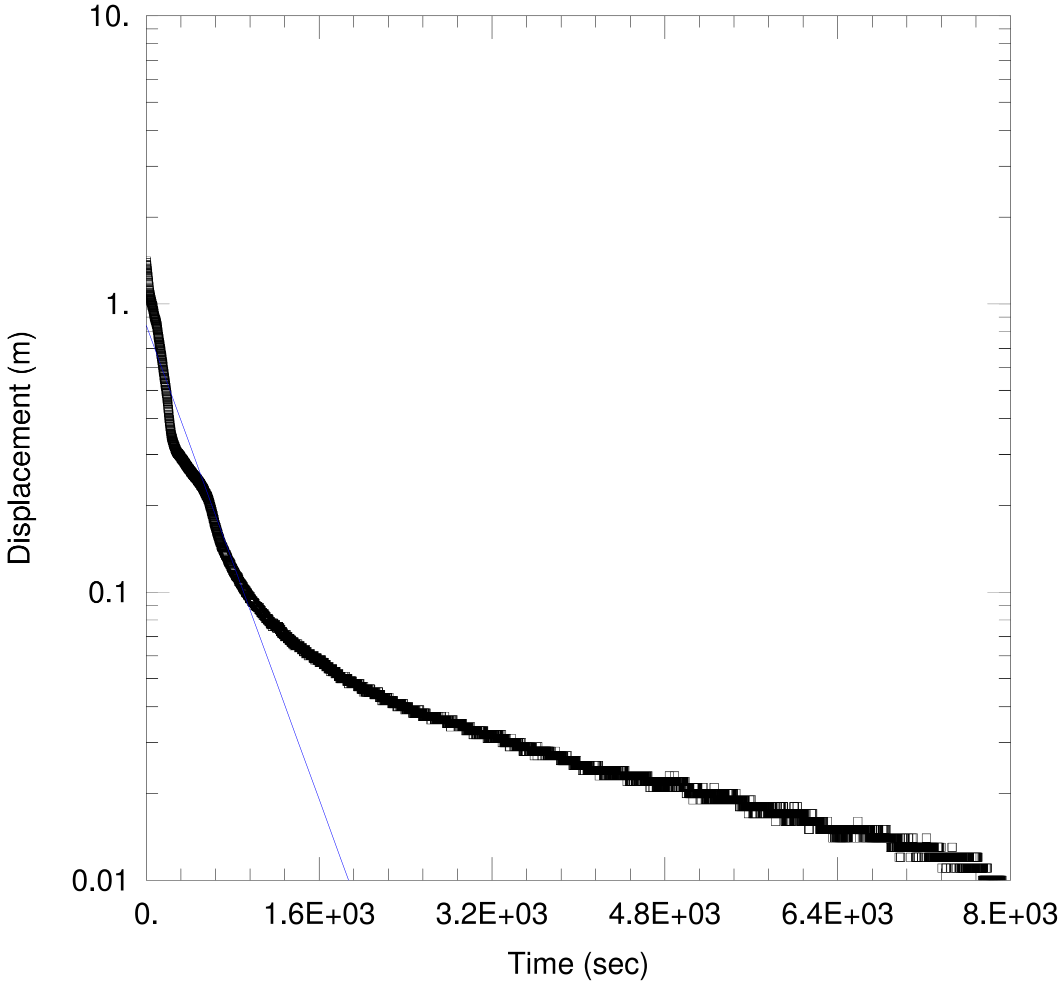
WELL DATA (BH2014)

Initial Displacement: 7.173 m Water Column Height: 2.2 m
Casing Radius: 0.025 m Wellbore Radius: 0.038 m
Screen Length: 2.3 m Gravel Pack Porosity: 0.3

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 2.523E-07 m/sec y0 = 3.965 m



WELL TEST ANALYSIS

Data Set: J:\...\BH2015.aqt
Date: 08/27/07
Time: 16:15:36

PROJECT INFORMATION

Company: Golder Associates
Client: ARUP
Project: 06622140
Test Location: Tintenbar to Ewingsdale
Test Well: BH2015
Test Date: 31/07/2007

AQUIFER DATA

Saturated Thickness: 1.4 m
Anisotropy Ratio (Kz/Kr): 1.

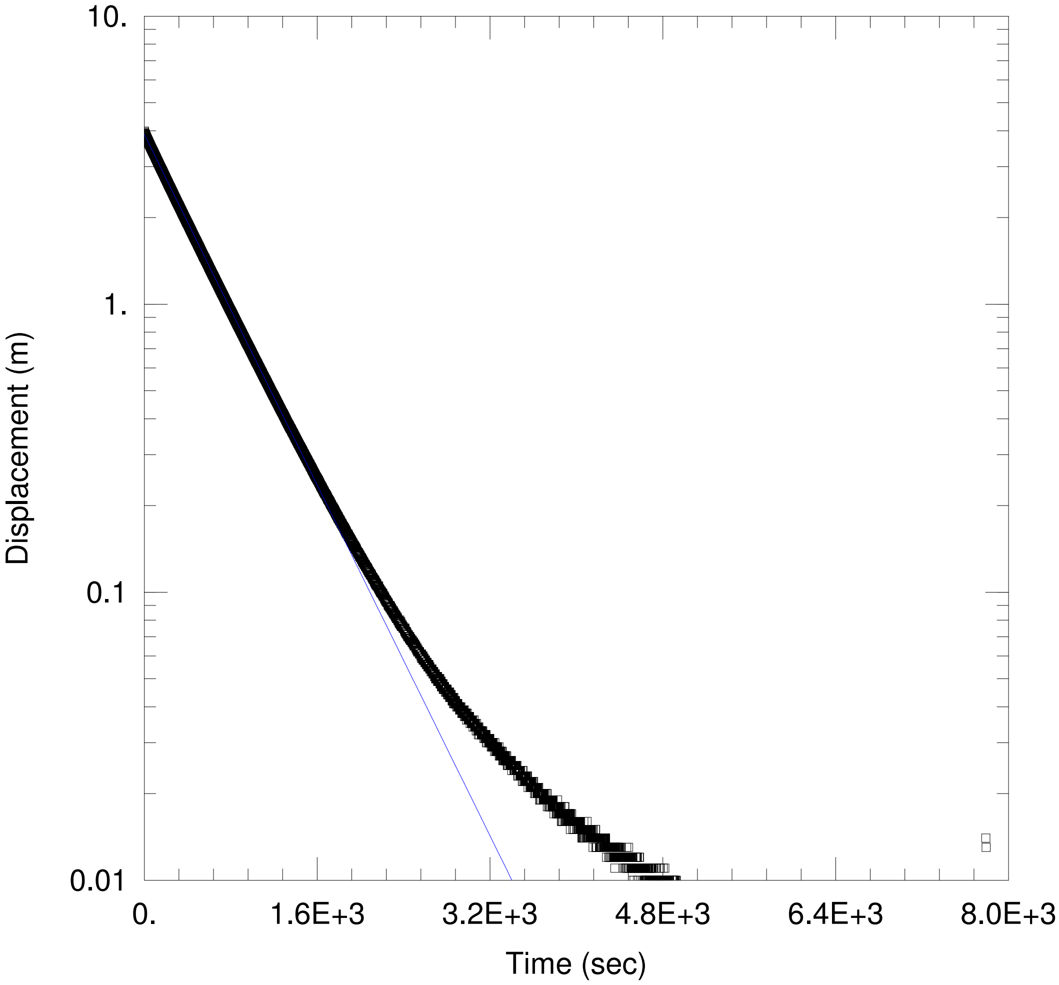
WELL DATA (BH2015)

Initial Displacement: 1.406 m
Water Column Height: 1.5 m
Casing Radius: 0.025 m
Wellbore Radius: 0.038 m
Screen Length: 3. m
Gravel Pack Porosity: 0.3

SOLUTION

Aquifer Model: Confined
Solution Method: Bouwer-Rice

K = 9.941E-07 m/sec
y0 = 0.8404 m



SLUG TEST

Data Set: J:\...\2018_BR.aqt
Date: 08/09/07
Time: 12:00:18

PROJECT INFORMATION

Company: Golder Associates
Client: ARUP
Project: 06622140
Location: Pacific Highway Upgrade
Test Well: BH2018
Test Date: 31/07/2007

AQUIFER DATA

Saturated Thickness: 3.5 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BH2018)

Initial Displacement: 10.19 m
Total Well Penetration Depth: 3.5 m
Casing Radius: 0.0254 m
Static Water Column Height: 3.6 m
Screen Length: 3. m
Wellbore Radius: 0.05 m
Gravel Pack Porosity: 0.3

SOLUTION

Aquifer Model: Confined
Solution Method: Bouwer-Rice

K = 6.103E-7 m/sec
y0 = 3.884 m

Appendix E
Water Sample Laboratory Certificates

Envirolab Services Pty Ltd
ABN 37 112 535 645
54 Frenchs Rd Willoughby NSW 2068
ph 02 9958 5801 fax 02 9958 5803
email: tnotaras@envirolabservices.com.au

CERTIFICATE OF ANALYSIS 13294

Client:
Golder Associates
88 Chandos St
St Leonards
NSW 2065

Attention: Fabienne d'Hautefeuille

Sample log in details:

Your Reference:	**6622140, T2E**
No. of samples:	20 Waters
Date samples received:	23/08/07
Date completed instructions received:	23/08/07

Analysis Details:

Please refer to the following pages for results, methodology summary and quality control data.
Samples were analysed as received from the client. Results relate specifically to the samples as received.
Results are reported on a dry weight basis for solids and on an as received basis for other matrices.
Please refer to the last page of this report for any comments relating to the results.

Report Details:

Date results requested by:	24/08/07
Date of Preliminary Report:	Not Issued
Issue Date:	24/08/07

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This document is issued in accordance with NATA's accreditation requirements.
Accredited for compliance with ISO/IEC 17025.
Tests not covered by NATA are denoted with *.

Results Approved By:

David Springer
Business Development & Quality Manager

Ion Balance						
Our Reference:	UNITS	13294-1	13294-2	13294-3	13294-4	13294-5
Your Reference	-------------	BH2003-20070822	BH2004-20070822	BH2005-20070822	BH2006-20070821	BH2007-20070821
Date Sampled	------------	22/08/07	22/08/07	22/08/07	21/08/07	21/08/07
Type of sample		Water	Water	Water	Water	Water
Calcium	mg/L	180	4.0	32	2.5	3.8
Potassium	mg/L	6.8	1.5	2.9	0.64	0.72
Sodium	mg/L	93	22	38	15	12
Magnesium	mg/L	0.11	3.4	7.1	2.1	2.1
Carbonate Alkalinity as $CaCO_3$	mg/L	160	<0.1	<0.1	<0.1	<0.1
Bicarbonate Alkalinity as $CaCO_3$	mg/L	<0.1	18	120	8	8
Sulphate, SO4	mg/L	<5.0	14	50	10	16
Chloride (titration) - water	mg/L	31	22	37	23	<20

Ion Balance						
Our Reference:	UNITS	13294-6	13294-7	13294-8	13294-9	13294-10
Your Reference	-------------	BH2008-20070821	BH2009-20070821	BH2013-20070821	BH2014-20070821	BH2015-20070821
Date Sampled	------------	21/08/07	21/08/07	21/08/07	21/08/07	21/08/07
Type of sample		Water	Water	Water	Water	Water
Calcium	mg/L	3.2	11	24	3.3	6.0
Potassium	mg/L	0.94	2.0	2.5	0.76	0.76
Sodium	mg/L	9.7	24	62	14	15
Magnesium	mg/L	1.6	3.4	3.7	1.6	3.6
Carbonate Alkalinity as $CaCO_3$	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1
Bicarbonate Alkalinity as $CaCO_3$	mg/L	10	50	130	10	40
Sulphate, SO4	mg/L	7.0	29	50	22	17
Chloride (titration) - water	mg/L	<20	<20	34	<20	<20

Ion Balance						
Our Reference:	UNITS	13294-11	13294-12	13294-13	13294-14	13294-15
Your Reference	-------------	Creek Cut6-20070821	Creek Cut19-20070821	SP13-20070821	SC19-3-20070821	Dup1-20070821
Date Sampled	------------	21/08/07	21/08/07	21/08/07	21/08/07	21/08/07
Type of sample		Water	Water	Water	Water	Water
Calcium	mg/L	2.1	2.6	3.4	2.0	2.0
Potassium	mg/L	2.5	2.9	2.2	6.0	2.6
Sodium	mg/L	5.9	7.5	6.7	3.2	6.1
Magnesium	mg/L	1.2	1.6	1.4	1.4	1.2
Carbonate Alkalinity as $CaCO_3$	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1
Bicarbonate Alkalinity as $CaCO_3$	mg/L	4	6	8	4	4
Sulphate, SO4	mg/L	8.0	9.0	7.0	11	9.0
Chloride (titration) - water	mg/L	<20	<20	<20	<20	<20

Ion Balance **Our Reference:** **Your Reference** **Date Sampled** **Type of sample**	**UNITS** ------------- ------------	**13294-16** **Dup2-20070821** **21/08/07** **Water**	**13294-17** **Creek Cut6-20070822** **22/08/07** **Water**	**13294-18** **Creek Cut19-20070822** **22/08/07** **Water**	**13294-19** **SP13-20070822** **22/08/07** **Water**	**13294-20** **BH1021-20070822** **22/08/07** **Water**
Calcium	mg/L	32	2.7	3.2	3.0	12
Potassium	mg/L	2.8	1.6	2.0	0.95	2.0
Sodium	mg/L	36	11	11	12	89
Magnesium	mg/L	7.0	1.8	2.1	1.7	3.9
Carbonate Alkalinity as $CaCO_3$	mg/L	<0.1	<0.1	<0.1	<0.1	60
Bicarbonate Alkalinity as $CaCO_3$	mg/L	120	8	12	8	230
Sulphate, SO4	mg/L	56	5.0	6.0	5.0	<5.0
Chloride (titration) - water	mg/L	36	<20	<20	<20	<20

Method ID	Methodology Summary
Metals.20 ICP-AES	Determination of various metals by ICP-AES.
LAB.6	Alkalinity - determined titrimetrically in accordance with APHA 20th ED, 2320-B.
LAB.9	Sulphate determined turbidimetrically.
LAB.11	Chloride determined by argentometric titration.

QUALITY CONTROL Ion Balance	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base ll Duplicate ll %RPD	Spike Sm#	Spike % Recovery
Calcium	mg/L	0.03	Metals.20 ICP-AES	<0.030	13294-1	180 || 180 || RPD: 0	LCS-1	96%
Potassium	mg/L	0.03	Metals.20 ICP-AES	<0.030	13294-1	6.8 || 6.7 || RPD: 1	LCS-1	97%
Sodium	mg/L	0.03	Metals.20 ICP-AES	<0.030	13294-1	93 || 93 || RPD: 0	LCS-1	90%
Magnesium	mg/L	0.03	Metals.20 ICP-AES	<0.030	13294-1	0.11 || 0.10 || RPD: 10	LCS-1	91%
Carbonate Alkalinity as $CaCO_3$	mg/L	0.1	LAB.6	<0.1	13294-1	160 || 160 || RPD: 0	[NR]	[NR]
Bicarbonate Alkalinity as $CaCO_3$	mg/L	0.1	LAB.6	<0.1	13294-1	<0.1 || <0.1	LCS-1	100%
Sulphate, SO4	mg/L	5	LAB.9	<5.0	13294-1	<5.0 || <5.0	LCS-1	113%
Chloride (titration) - water	mg/L	20	LAB.11	<20	13294-1	31 || 26 || RPD: 18	LCS-1	105%

QUALITY CONTROL Ion Balance	UNITS	Dup. Sm#	Duplicate Base + Duplicate + %RPD	Spike Sm#	Spike % Recovery
Calcium	mg/L	13294-11	2.1 || 2.2 || RPD: 5	13294-2	90%
Potassium	mg/L	13294-11	2.5 || 2.6 || RPD: 4	13294-2	94%
Sodium	mg/L	13294-11	5.9 || 6.2 || RPD: 5	13294-2	93%
Magnesium	mg/L	13294-11	1.2 || 1.2 || RPD: 0	13294-2	90%
Carbonate Alkalinity as $CaCO_3$	mg/L	13294-11	<0.1 || <0.1	[NR]	[NR]
Bicarbonate Alkalinity as $CaCO_3$	mg/L	13294-11	4 || 4 || RPD: 0	[NR]	[NR]
Sulphate, SO4	mg/L	13294-11	8.0 || [N/T]	13294-2	105%
Chloride (titration) - water	mg/L	13294-11	<20 || <20	[NR]	[NR]

QUALITY CONTROL Ion Balance	UNITS	Dup. Sm#	Duplicate Base + Duplicate + %RPD	Spike Sm#	Spike % Recovery
Bicarbonate Alkalinity as $CaCO_3$	mg/L	13294-18	12 || [N/T]	LCS-1	100%
Sulphate, SO4	mg/L	13294-18	6.0 || 6.0 || RPD: 0	[NR]	[NR]

Report Comments:

Asbestos analysed by: Not applicable for this job

INS: Insufficient sample for this test
RPD: Relative Percent Difference
NR: Not requested
NT: Not tested
NA: Test not required
<: Less than
PQL: Practical Quanitation Limit
LCS: Laboratory Control Sample
>: Greater than

Quality Control Definitions

Blank: This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, can be determined by processing solvents and reagents in exactly the same manner as for samples.
Duplicate: This is the complete duplicate analysis of a sample from the process batch. If possible, the sample selected should be one where the analyte concentration is easily measurable.
Matrix Spike: A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.
LCS (Laboratory Control Sample): This comprises either a standard reference material or a control matrix (such as a blank sand or water) fortified with analytes representative of the analyte class. It is simply a check sample.
Surrogate Spike: Surrogates are known additions to each sample, blank, matrix spike and LCS in a batch, of compounds which are similar to the analyte of interest, however are not expected to be found in real samples.

Laboratory Acceptance Criteria:
Duplicates: <5xPQL - any RPD is acceptable; >5xPQL - 0-50% RPD is acceptable.
Matrix Spikes and LCS: Generally 70-130% for inorganics/metals; 60-140% for organics and 10-140% for SVOC and speciated phenols is acceptable. Surrogates: Generally 60-140% is acceptable.

Appendix F
Conceptual Groundwater Model

TABLE OF CONTENTS

APPENDIX G - TABLES

F-1 INTRODUCTION

To assist in undertaking predictive numerical modelling of the hydrogeological system and groundwater flow conditions likely to be operating along the proposed T2E road alignment, Golder has constructed a *conceptual groundwater model* (CGM). The CGM attempts to provide as robust a representation of the key features of the physical system and its behaviour, as is possible from the data collected to date.

This section provides detailed descriptions of the key components of the CGM, and how they are used to characterise the hydrogeology of the typical road cutting and the groundwater flow system/s which operate therein. From this assessment it is possible to estimate how the road cutting may impact on the likely groundwater and surface water flows to the creeks and springs

F-2 GEOLOGY AND SOILS

F-2.1 Regional Geology

The regional geology in the area traversed by the preferred route is illustrated on the 1:100,000 Lismore-Ballina Sheet 9640.

The Alstonville Plateau is underlain by Lismore Basalt of the Lamington Volcanics. The basalt was erupted as lava flows from Mt Warning about 20 million years ago (Tertiary). The lava flows solidified on the former land surface, comprising weathered rock of the Neranleigh-Fernvale Group of Devonian-Carboniferous age.

F-2.2 Neranleigh-Fernvale Group

The oldest rocks in the area are part of the Neranleigh-Fernvale Group. The Neranleigh-Fernvale Group includes sedimentary rocks such as shales, greenstone and conglomerate, and low grade metamorphic rocks such as greywacke and argillite. Extensive deformation and folding has resulted in steeply dipping strata.

The Neranleigh-Fernvale Group is present at depth beneath the Alstonville Plateau, but does not outcrop along the preferred route alignment. Strata inferred to be part of the Neranleigh-Fernvale Group were encountered at depth below the proposed floor of a cut in some of the recent investigation boreholes within the vicinity of the proposed Ross Lane Interchange.

F-2.3 Lismore Basalt

The Lismore Basalt typically consists of sub-aerially extruded basalt (lava flows). The basaltic lavas were extruded over the former land surface of irregularly eroded and weathered rock of the Neranleigh-Fernvale Group in individual lava flows, usually less than 25 m thick.

Time lapses between lava flows were often sufficient for significant weathering, soil formation and deposition of thin layers of usually poorly lithified sedimentary rocks to take place between eruptions.

Corestone weathering profiles and columnar joint patterns are common within the basalt. Weathering penetrates the rock along vertical and horizontal joints and along the top of flows. The weathering zone develops outward from the joints and fracture plains, and isolates blocks or boulders of fresh rock to form corestones. The corestones boulders may have a columnar profile. They may later become incorporated into colluvial deposits, as observed in some of the recent test pits. In some areas, corestones become remnants on the ground surface and may roll down slopes during periods of high rainfall.

The lava flows are commonly vesicular (containing air voids, typically less than about 10 mm in diameter) near the top, sometimes with red-brown and purple-brown “boles” (fossil soils) of variable thickness. Subsequent mineralisation sometimes leads to infilling of the vesicles with small crystals known as amygdules (amygdaloidal basalt). “Amygdule” is from the Latin for almond, which is the typical shape of the crystals that fill the vesicles.

The vertical variability in the basalt is apparent from investigations undertaken by Golder Associates, and water bore logs obtained from the *Department of Infrastructure, Planning and Natural Resources* (DIPNR, see Golder Associates, 2004), which indicate interbedded high and low strength layers and clay layers. Clay layers or fossil soils are typically about 1 m to 5 m thick, and interbeds of high and low strength basalt vary from about 5 m to 25 m thick. The regional dip of the individual lava flows is generally 0 to 5 degrees to the north west.

The fossil soils are likely to have developed on a previous erosional surface which is likely to have an irregular profile.

A report by Brodie and Green (2002) on the hydrogeology of the Alstonville Plateau indicates that the base of the Lismore Basalt varies between about RL 0 m and RL 50 m. The resulting total thickness of the Lismore Basalt is thought to be up to 150 m at the top of St Helena Hill. Near Ross Lane, Tintenbar, a borehole penetrated the base of the Lismore Basalt at RL 65m (15 m depth). The thickness of the Lismore Basalt is not known in other areas of Tintenbar, but the thickness is generally expected to increase in the northerly direction.

The generalised basalt stratigraphy encountered during previous investigations by Golder Associates within the area broadly comprises:

- Residual soils (basalt derived) of mainly high plasticity, to variable depth but often between about 3 m and 5 m depth;

- Extremely weathered basalt (with essentially soil properties), often to at least 15 m depth; over,
- Discrete layers of basalt ranging from very low to extremely high strength, highly weathered to fresh.

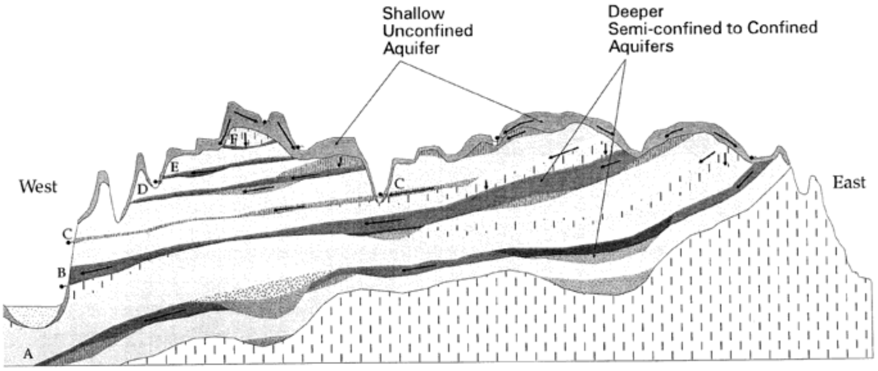
In addition to the residual soil and basalt rock units described above, the steep slopes and escarpment are frequently draped with landslide debris and colluvium derived from the basalt.

F-3 HYDROGEOLOGY

The local residual weathering profiles and regional layered bedrock geological sequences within the Lismore Basalt govern the nature of the shallow and deeper/regional (respectively) groundwater regimes in the area. Perched groundwater tables can be present within the shallow residual soil profile (regolith) and, locally, within the underlying weathered or fractured basalt sequences. Deeper groundwater systems (the ‘deeper’ systems studied and the regional system/s) exist within the more permeable fractured or weathered layers of basalt that are confined or semi-confined between the relatively massive and competent high strength, and less permeable, basalt layers, as shown in the diagram below (from Brodie and Green, 2002).

Superimposed on this bedrock sequence is a surficial profile (with a typical ‘rind’ layering) arising from the weathering of the bedrock sequence, and having a configuration that generally mimics (follows) the topography. The ‘rind’ layers are irregular in thickness and depth (determined largely by location on the topographic slope, location and underlying geology from which they are derived) and variably stratified with regard to their degree of weathering.

Each of the above systems has its own unique influence on the way recharge water (rainfall) runs off or infiltrates into the subsurface, thus creating two dominant individual but hydrogeologically connected groundwater systems. There is likely to be a zone where the two systems overlap and where groundwater flow will be affected in part by each layering system. This zone produces a complex groundwater flow pattern, and one which is extremely difficult to interpret, predict and model.



From Brodie and Green (2002)

Regional groundwater flow in the Lismore Basalt generally follows the regional dip of the lava beds, that is, to the north west. Brodie and Green (2002) indicate that this is the case in the north of the area. Cut 19 is located within that area. South of Newrybar, the regional groundwater flow in the area is reported to be both to the east and north west. The exact line of dissection is not clear from their report. Cut 6 is located within that area. Given that the proposed cuts are relatively shallow, however, it is expected that the local groundwater system will be more influenced by surficial topography than underlying geological structure.

Each groundwater flow regime has the potential to give rise to spring flow occurrences at the surface, largely where zones/layers of lower permeability 'daylight' (outcrop) at the ground surface. Anecdotal evidence suggests that some springs are perennial, while others appear to be permanent features. Springs are also often associated with zones of slope instability. The hydrogeological characteristics are significant to the development of landslides.

Spring locations identified by the *Bureau of Rural Sciences* (BRS, Brodie and Green, 2002) are shown on Figure 2 and 3 for Cut 6 and Cut 19. Verification of spring occurrences was included in this scope of works due to some uncertainty about the location and nature of inferred and identified springs, specifically the potential for there to be more springs than that shown by the BRS mapping.

The perched aquifer systems which arise from the near surface weathering profile stratification (the shallow 'rind' referred to earlier) are more likely to give rise to local spring occurrences (particularly where the transition to fresher bedrock outcrops). They contrast with the deeper layered bedrock 'aquifers' (within the lava flow sequence) which are more likely to give rise to regional spring occurrences (potentially at greater distance from the applicable recharge area/s). In particular, the regional springs are likely to occur on the western slopes of hill slopes (stratigraphically down-dip) and, most likely, on the western slopes of the Alstonville Plateau. For the two cuts selected for detailed study, it has been found that the local groundwater system is more influenced by surficial topography than underlying geological structure. i.e. groundwater flow within the top of the deeper groundwater flow system is in a locally eastward direction toward the perennial surface waterway. Flow within the regional groundwater system/s is largely to the west.

The level of the groundwater table along the preferred route is expected to be variable depending on groundwater flow system/s operating within the layered basalt. Monitoring of groundwater bores by various public authorities indicates that the groundwater levels in the ‘shallow’ aquifers respond to rainfall events exceeding about 100 mm per week, while the ‘deeper’ aquifers show little response to rainfall.

F-4 CONCEPTUAL GROUNDWATER MODEL

F-4.1 Introduction

A *conceptual groundwater model* (CGM) is a simplified representation of the key features of the physical system and its behaviours. A CGM attempts to identify the parameters and features that are characterising the system. The CGM is also the precursor to the numerical groundwater model, the predictive tool used to calculate likely future effects which may arise after the road cuttings are excavated and constructed, which is described in Appendix H.

Previous conceptualisation of the system had identified a lack of critical data[1] required for predictive groundwater modelling of the system. The data from the recent hydrogeological investigation has provided updated information necessary to refine the CGM for Cut 6 and Cut 19 and associated numerical simulations.

F-4.2 Conceptual Geological and Hydrogeological Setting

The conceptual geological setting has been described in Section F-2. The key component of the CGM is that the site groundwater system is organised in two key systems:

- *Shallow Groundwater Flow System:* A local shallow (or upper) groundwater aquifer within the weathered soil and rock (the regolith). The investigation borehole cores show that this shallow system comprises a sequence of variably weathered bedrock material within which remnant layers of less weathered rock are interspersed. By virtue of the geological variability (extremely to moderately weathered and laterally variable zones) of this sequence, it is likely to host numerous localised perched subsystems (largely unconfined). Groundwater flow within this complex geological system will be equally complex, with flow being dominantly horizontal in one areal location and dominantly vertical in an adjacent location. An analogy would be that the groundwater ‘cascades’ from one perched system to another, eventually reaching the deeper bedrock system below. Superimposed of this groundwater flow system is a moderately to densely spaced fracture pattern which is also likely to influence groundwater flow; and

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[1] Water table and deeper aquifer hydraulic head profile, geological and hydrogeological boundaries and composition, soil permeability, hydraulic gradients, potential for surface water-groundwater interaction at respective creeks.

- *Deeper Groundwater Flow System/s:* A local deeper groundwater system investigated, largely within the fractured porosity, is pervasively developed within moderately weathered to fresher basaltic lava flow sequences present at depth. Present within this stacked lava flow sequence are rare interbedded zones of moderately to highly weathered basalts, and some amygdaloidal, scoriaceous and fossil soil horizons. These interbeds are laterally variable, thickening and thinning out with lateral extent. Groundwater flow is dominated by the fracture plane porosity/permeability, and to a lesser extent the interbed layers. On a macroscopic scale the groundwater flow is likely to behave in a porous media fashion (anisotropic, and controlled by the more dominant horizontal fracture and bedding planar features). On a mesoscopic (1m – 10m width) and microscopic scale flow is likely to be tortuous and highly variable. The deeper aquifer/s behaves as a confined or semi-confined aquifer system.

Note: the *Regional Aquifer* was not considered in the numerical modelling due to its scale (>100km) relative to the local scale of each of the cutting (<100m). Any groundwater diverted from the local aquifer systems is typically largely reintroduced at locations (streams, creeks) immediately adjacent to the cutting/s considered with respect to their impacts.

Each system is characterised by different hydraulic properties. Their recharge from rainfall and their contribution to springs or creeks are also different. The interactions between the aquifers can also vary spatially. It is noted, though, that for the two cuts selected for detailed study groundwater flow within the top of the deeper groundwater flow system is in a locally eastward direction toward the perennial surface waterway.

Each system is characterised by different but variable hydraulic properties. The rainfall recharge (infiltration) to the two systems is complex and dependant on the topographic situation, thickness and density of the interbedded layers, vertical and horizontal hydraulic conductivity (permeability) contrasts and the overprint of a moderate to dense, tight fracture pattern of preferential flow pathways. As a consequence of these features, groundwater flow, both horizontal and vertical, is similarly controlled by low or moderate locally contrasting permeability and, hence, similarly characterised tortuous pathways. The mechanism and magnitude of the contribution that these groundwater systems make to the local springs or creeks is consequentially inferred to be highly variable and seasonally controlled.

This dual groundwater system has a number of important characteristics which greatly affect the estimation of the nature and magnitude of the impact on spring and creek flow.

- Groundwater flow within the shallow flow system (‘aquifer’) is largely responsible for the creek baseflow and springs, and it is likely that this is a local effect (not regional).
- The shallow aquifer system/s are intermittently to fully saturated (flow may be perennial, intermittent or may cease periodically), particularly in the upper sections of the topography (the hill top areas).
- A consistently downward groundwater flow gradient between the shallow and the deeper flow systems is generally present along the transects. The exception to this general rule is noted adjacent to and beneath the creek lines.

- Moderate to strong hydraulic connectivity between the shallow and deeper aquifer systems is evident along the creek alignments. This is particularly evident where the transect across the valley flat areas of Cut 6 suggesting that the creek down-gradient of Cut 6 is a ‘making’ creek environment (where the groundwater system discharges and supplements the creek flow).
- Spring occurrences, away from the creek alignments, whilst rare, are largely due to hydrogeologically differing rock layer (having contrasting hydraulic conductivities) daylight at the ground surface, that is, groundwater flow within the shallow aquifer is driven by favourable hydraulic gradients to emerge at the surface).

Note: Groundwater level measurements collected during this stage of investigations occurred immediately after a period of above average rainfall. As a consequence, the CGM interpretation may be skewed towards an abnormally wet case-study condition. A further round of sampling would be required during dry weather conditions to confirm the relationship between the creek and springs, and the shallow aquifer.

F-4.3 Conceptual Groundwater Model Characteristics

On the basis of the geological and hydrogeological evidence collected a CGM was built for each of the two cuts. Refer to Figure 4 and 5 for the CGM at Cut 6 and Cut 19, respectively. Common characteristics of the conceptual models for each cuts and individual characteristics are highlighted in Table F-1 below.

Table F-1 : Cut 6 and Cut 19 Conceptual Groundwater Models Characteristics

Cut 6	Cut 19
Two groundwater systems: a *shallow* system (potentially perched, however, likely to be a transient phenomenon since shallow monitoring wells on top of hillslopes were dry on each monitoring occasion) within the weathered rock and a *deeper* groundwater system within the less weathered, tightly fractured rock and/or fresh rock. It is noted that the monitoring wells installed in the deeper aquifer at each of the transects are only relatively shallow and appear more influenced by surficial topography than underlying structural geology i.e. the hydraulic gradient of the “deep” aquifer reflects local and intermediate flow systems rather than regional-scale groundwater flow system.	
The groundwater level profile from hilltop to base of creek levels suggests that groundwater in the shallow aquifer system in the *upper portion* of the profile (the hill-top zone) is largely absent or infrequently saturated (i.e., it is dry or perennial, responding substantially to recharge events). This is not the case in the *lower portion* of the profile where groundwater in the shallow aquifer is present and persistent (from a location at the midpoint of the hill slope).	
The land use is predominantly grazed pasture, the lower half of Cut 6 being occupied by the road and private garden land (grass, trees and shrubs). Typical of the land usage for the alignment, and as such, recharge to both of the groundwater systems is impacted by local land	

<table>
<tr><th>Cut 6</th><th>Cut 19</th></tr>
<tr><td colspan="2">development (enhanced by land-clearing, and cropping and grazing).</td></tr>
<tr><td colspan="2">On the hill slopes, seepage points develop in response to rainfall events. This localised occurrence of intermittent or temporary spring flows reflect the perennial behaviour of the shallow aquifer system (perched) and/or farming activities such as erosional control features.</td></tr>
<tr><td colspan="2">The surface water chemistry is similar in both Cut 6 and Cut 19 areas, namely, they are typically sodio-chloro-sulphate (Na-Cl-SO_4) water types.</td></tr>
<tr><td>No evidence of hydraulic connection between the two aquifer systems in the upper part of the hill apparent since the shallow system is unsaturated. The deeper aquifer system/s are considered to be effectively hydraulically confined or semi-confined in nature. Full connectivity of the two aquifer systems occurs only in the valley floor (creek) areas of the profile.</td><td>No proven hydraulic connection between the two aquifer systems again, since the shallow system is unsaturated. The deeper aquifer system is considered as a confined or semi-confined system. The valley floor area is narrow, and deeper aquifer and shallow aquifer water levels are similar suggesting good connectivity between the aquifers. The aquifer connection, however, has not been confirmed by groundwater sampling of the aquifers at the valley floor due to access restrictions at that time.</td></tr>
<tr><td>The hydraulic head of both the shallow and deeper groundwater system adjacent the creek is below the base of the creek. This implies that groundwater is not discharging directly to the creek bed, however, is contributing to the creeks' hyporheic[2] zone. The hyporheic zone is the region beneath and lateral to a stream bed, where there is mixing of shallow groundwater and surface water.</td><td>Creek supplied by shallow aquifer base flow via the hyporheic zone and surface catchment run-off. Across the creek, the groundwater levels in both the shallow and deeper aquifers are lower than the creek bed, suggesting possible supply of the creek to the groundwater system.</td></tr>
</table>

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[2] The hyporheic zone is the critical interface between groundwater and surface water environments and is shown to be a dynamic ecotone (a transitional zone between two communities containing the characteristic species of each) characterised by steep, hydraulic, chemical and biological gradients.

Cut 6	**Cut 19**
Hydraulic conductivity (permeability) of the shallow aquifer and soil permeability on the lower of the transect profile (the creek valley portion of the profile, much greater than at the hilltop portion of the profile: $K_{\text{deeper aquifer}}$ of the order of 10^{-6} to 10^{-8}m/s $K_{\text{shallow aquifer}}$ or the order 10^{-5} to 10^{-7}m/s	Hydraulic conductivity (permeability) of the shallow aquifer and overlying soil permeability consistent through the transect profile: $K_{\text{deeper aquifer}}$ of the order of 10^{-7} to 10^{-9}m/s $K_{\text{shallow aquifer}}$ of the order 10^{-7} m/s

The shallow groundwater aquifer system is considered to contribute to the hyporheic zone of the creek system. The creeks are also supplied by local catchment run-off during rainfall events.

The deeper groundwater aquifer studied appears to be in hydraulic connection with the hyporheic zone of the creek, especially where the shallow aquifer is very thin. The hydraulic data collected suggests there is a minor downward hydraulic gradient between the shallow (alluvium) and the deeper aquifer, suggesting that both creeks are losing creeks at the selected sections. Hydrogeochemical testing implies, however, that local shallow groundwater flow is dominant since shallow aquifer water type matches the water type of surface samples collected.

The regional aquifer is inferred to be in hydraulic connection with the overlying Deeper Aquifer.

Appendix G
Numerical Groundwater Model

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APPENDIX G - TABLES

G-1 INTRODUCTION

Golder has undertaken predictive numerical simulation of changes to the hydrogeological system operating along the proposed T2E road alignment.

This section provides the methodology used by Golder to simulate groundwater flow and seepage, and investigation of potential impact on groundwater spring flow along the alignment.

G-2 ASSESSMENT OF POTENTIAL IMPACT ON SEEPAGE USING NUMERICAL GROUNDWATER MODELLING

G-2.1 Model Construction

A cross-section seepage analysis model was developed for two examples of the proposed cuttings associated with this phase of the upgrade to the Pacific Highway. These models were constructed based on the CGM presented in Appendix F and represent a typical example of the type of cutting proposed (Cut 6), where the base of the cutting is above the water table, and a more extreme example of the type of cutting proposed (Cut 19), where the base of the cutting is expected to intersect the water table. It is noted that there are 26 cuts/tunnel proposedassociated with the upgrade, therefore these analyses are meant to provide indicative impacts that can be used to infer expected behaviour at these specific locations and elsewhere.

Figure G1 presents the implemented CGM for Cut 6, including the model mesh and model boundary conditions, discussed below. Figure G5 presents the implement CGM for Cut 19, including the model mesh and model boundary conditions.

Each model was divided into various regions according to the interpreted geological transects; detailed review of borehole logs; hydraulic head data and the results of hydraulic test analyses. Three idealised hydrogeologic units were adopted, as follows:

Shallow Aquifer:

- a silty clay unit, representing the completely weathered to extremely weathered basalt. This unit is of moderate to low permeability; and
- a clayey sandy silt unit, representing alluvium material adjacent the creek bed at each cutting. This unit is of moderate permeability.

Deeper Aquifer:

- a slightly weathered rock or unweathered rock unit. This unit is of low permeability.

An appropriate saturated/unsaturated hydraulic description of each of these units was obtained from the SEEP /W database and modified as required. Table G-1 presents a summary of the hydrogeological units identified from the CGM and the corresponding hydraulic conductivity (HC) functions adopted from the SEEP /W database.

Table G-1: Model Hydraulic Functions and Descriptions:

Model Unit Name	Description from Fieldwork	SEEP Database Function No.
Shallow (silty clay)	Clayey SILT; Silty CLAY; CLAY; Clayey Gravelly SILT	#16
Shallow (clayey sandy silt)	Silty CLAY; Clayey SILT;	#19
Deeper (slightly weathered rock)	BASALT	#20

It is noted that the hydraulic function selected for the slightly weathered rock unit was chosen to encapsulate the free draining nature of this unit. The adopted HC functions for each of the hydrogeologic units are presented at the end of this appendix.

G-2.2 Model Boundary Conditions and Model Calibration

Following model construction, various hydraulic parameters were adjusted and selected boundary conditions to fit the observed data, assuming that the conceptual model for each cut is reasonable. The adjustable parameters include the saturated hydraulic conductivity and the vertical to horizontal anisotropy of hydraulic conductivity. It is noted that simulations were conducted assuming steady state conditions, therefore the value of porosity was not adjusted during model calibration. An appropriate default value for porosity was adopted, however, not presented here.

For each modelled profile a fixed head boundary condition was applied at the right hand edge of the model domain. The value assigned to each fixed head boundary condition was guided by the groundwater level in the deeper aquifer and adjusted during model calibration, where appropriate. A recharge rate of 5% (equivalent to 85 mm/yr) was selected for all simulations, being typical for the terrain and its location and consistent with the estimated vertical saturated hydraulic conductivity (soil permeability) derived from Talsma Infiltrometer testing. The adopted model boundary conditions for Cut 6 are presented in Figure G-1. The adopted model boundary conditions for Cut 19 are presented in Figure G5.

The calibration dataset was based on water table and potentiometric levels obtained during the July 2007 sampling round. Table G-2 presents a summary of the calibrated model parameters. Table G-3 presents a comparison between modelled and observed hydraulic head (water table level or potentiometric level, depending on whether the water table is intersected by the screened interval of the piezometer). Figure G-2 illustrates the modelled water table profile of existing conditions at Cut 6. Figure G-6 presents the modelled water table profile of existing conditions at Cut 19.

Table G-2: Model Calibration – Calibrated Hydraulic Parameters

Unit No.	Unit	Parameter	Cut 6	Cut 19
1	*Shallow* (silt clay)	KSat[1]	2.0E-07 m/s	2.0E-07 m/s
		K z/h[2]	1:5	1:5
2	*Shallow* (clayey sandy silt)	KSat	2.0E-06 m/s	1.0E-06 m/s
		K z/h	1:2.5	1:2.5
3	*Deeper* (slightly weathered rock)	KSat	2.0E-08 m/s	2.0E-08 m/s
		K z/h	1:5	1:5
N/A	N/A	CHBC[3]	83.0 mAHD	50.5 mAHD

[1] Calibrated saturated hydraulic conductivity (m/s); [2] Calibrated vertical to horizontal anisotropy; [3] Calibrated constant head boundary condition.

Table G-3 : Model Calibration Results – Modelled vs Observed

Transect	**Borehole**	**Hydraulic Head (mAHD)**		**Difference (m)**
		Modelled	**Observed[1]**	
Cut 6	BH2000 (Shallow)	Dry	Dry	N/A
	BH1021 (Deeper)	100.7	101.8	- 1.1 m
	BH2002 (Shallow)	Dry	Dry	N/A
	BH2001 (Deeper)	99.1	98.0	+ 1.1 m
	BH2004 (Shallow)	87.8	87.1	+ 0.7 m
	BH2003 (Deeper)	88.0	85.6	+ 2.4 m
	BH2006 (Shallow)	85.9	85.8	+ 0.1 m
	BH2005 (Deeper)	86.2	85.9	+ 0.3 m
Cut 19	BH2010 (Shallow)	Dry	Dry	N/A
	BH2009 (Deeper)	77.5	76.4	+ 1.1 m
	BH2012 (Shallow)	Dry	Dry	N/A
	BH2011 (Deeper)	72.6	74.4	- 1.8 m
	BH2014 (Shallow)	64.6	63.9	+ 0.7 m
	BH2013 (Deeper)	62.8	61.2	+ 1.6 m
	BH2016 (Shallow)	Dry	Dry	N/A
	BH2015 (Deeper)	55.7	54.7	+ 1.0 m

[1] Observation data derived from July 2007 sampling round.

From Table G-3 and Figure G-2 and G-6, respectively, the observed hydraulic head along transect Cut 6 is satisfactorily matched by model simulation. Similarly, the observed hydraulic head along transect Cut 19 is also satisfactorily matched by model simulation. The hydraulic parameters used in calibration model simulations are presented in Appendix B and also match satisfactorily the field testing and measurement results, as presented in Appendix B. The calibration model simulations therefore appear to be a reasonable representation of the observed data and conceptual model.

G-2.3 Model Simulation

The calibrated models presented in Section G-2.2 were then modified to represent the proposed cut geometry at both Cut 6 (a typical example of the type of cutting proposed in this project) and Cut 19 (a more extreme example of the type of cutting proposed in this project). Figure G-3 presents the model mesh and implemented conceptual model for Cut 6. Figure G7 presents the equivalent model for Cut 19.

Model prediction simulations were undertaken assuming the calibrated hydraulic parameters would not change associated with the proposed works. In addition, the Constant Head Boundary Condition (CHBC) in Cut 6 and Cut 19 was assumed to not change with the proposed works. The unit flux boundary condition, representing a fraction of the long term average rainfall recharge (5%), was also retained, however, was adapted to apply to the surface of the updated geometry. The updated boundary conditions for each of the models are presented in Figure G3 and Figure G7, respectively.

Given the above assumptions, each of the models was executed in predictive mode. Figure G4 presents the results of prediction model simulations of Cut 6. Figure G8 presents the results of prediction model simulations of Cut 19. Table G-4 presents the predicted change at each of the monitoring well reference points presented in Table G-3.

From Figure G4, prediction model simulations suggest that a seepage face is not expected to develop at Cut 6, given this combination of recharge and hydraulic parameters. From Figure G8, prediction model simulations suggest that a seepage face may develop at Cut 19, given this combination of recharge and hydraulic parameters. Table G-5 presents a comparison of the modelled flux rate, before and after the proposed excavations. It is noted that a steady state recharge rate of 5% was fixed, it being typical of the terrain and location, and calibration undertaken with respect to level by adjusting appropriate hydraulic parameters. Accordingly, the relative impact of changes on cross-sectional flux should be only considered in Table G-5 rather than absolute values since flux is linearly dependent on recharge rate. It is noted that the model is 1 m deep with respect to the page.

Table G-4: Model Simulation Results – Predicted Change in Hydraulic Head (m)

Transect	Borehole	Hydraulic Head (mAHD)		Predicted Change (m)
		Modelled Existing	Modelled Proposed	
Cut 6	BH2000 (Shallow)	Dry	Dry	N/A
	BH1021 (Deeper)	100.7	101.0	+ 0.3 m
	BH2002 (Shallow)	Dry	Dry	N/A
	BH2001 (Deeper)	99.1	99.2	+ 0.1 m
	BH2004 (Shallow)	87.8	87.8	± 0.0 m
	BH2003 (Deeper)	88.0	88.0	± 0.0 m
	BH2006 (Shallow)	85.9	85.9	± 0.0 m
	BH2005 (Deeper)	86.2	86.2	± 0.0 m
Cut 19	BH2010 (Shallow)	Dry	Dry	N/A
	BH2009 (Deeper)	77.5	75.5	- 2.0 m
	BH2012 (Shallow)	Dry	Dry	N/A
	BH2011 (Deeper)	72.6	66.8	- 5.8 m[1]
	BH2014 (Shallow)	64.6	Dry	N/A
	BH2013 (Deeper)	62.8	60.4	- 2.4 m
	BH2016 (Shallow)	Dry	Dry	N/A
	BH2015 (Deeper)	55.7	54.2	- 1.5 m

[1] The proposed cut almost intersects the screened interval of this piezometer.

Table G-5: Model Simulation Results – Predicted Change in Relative Flux[1] (%))

Transect	Calibrated Model		Simulation Model		Predicted Change (%)
	Input Flux (m^3/s)	Output Flux (m^3/s)	Input Flux (m^3/s)	Output Flux (m^3/s)	
Cut 6	4.7E-07 m3/s	4.7E-07 m3/s	4.7E-07 m3/s	4.7E-07 m3/s	± 0%
Cut 19	4.9E-07 m3/s	5.2E-07 m3/s	3.8E-07 m3/s	3.8E-07 m3/s	- 25%

[1] model calibrated to steady state conditions, assuming a rainfall recharge rate of 5% of annual average rainfall.

From Table G-4, the predicted extent of change in the water table profile in the typical proposed cut, Cut 6, is limited to the near vicinity of the proposed cut. The predicted extent of change in the water profile and potentiometric surface of the more extreme proposed cut,

Cut 19, is significant. The impact is highest at mid-slope on the profile, where impact to potentiometric level is of the order of 2 to 3 m.

From Table G-5, the predicted relative change in simulated groundwater flux is an approximate 25% decline for Cut 19. The predicted relative change to simulated flux for Cut 6 is essentially negligible.

Model simulation results suggest that the more extreme type of excavation proposed, of which Cut 19 is an example, may lead to a reduction in groundwater contribution to the hyporheic zone of the down-gradient surface waterway.

G-3 SUMMARY OF OUTCOMES

G-3.1 Conceptual Spring Flow and Numerical Modelling Outcomes

There are many potential spring locations identified at each of the study sites. Site inspection suggests that many of these locations are associated with local surface drainage features and are unlikely to be ‘groundwater springs’, in the formal definition, and accordingly are less likely to be affected by changes in the up-gradient groundwater catchment geometry.

Numerical simulations suggest that there is a potential that a seepage face may develop at Cut 19, the example of the more extreme type of cutting proposed. However, the numerical simulations suggest that a seepage face is unlikely to develop at Cut 6, the example of the typical type of cutting proposed, where cutting does not intersect the water table.

G-3.2 Risk of Impact to Spring Flow and Groundwater Flow

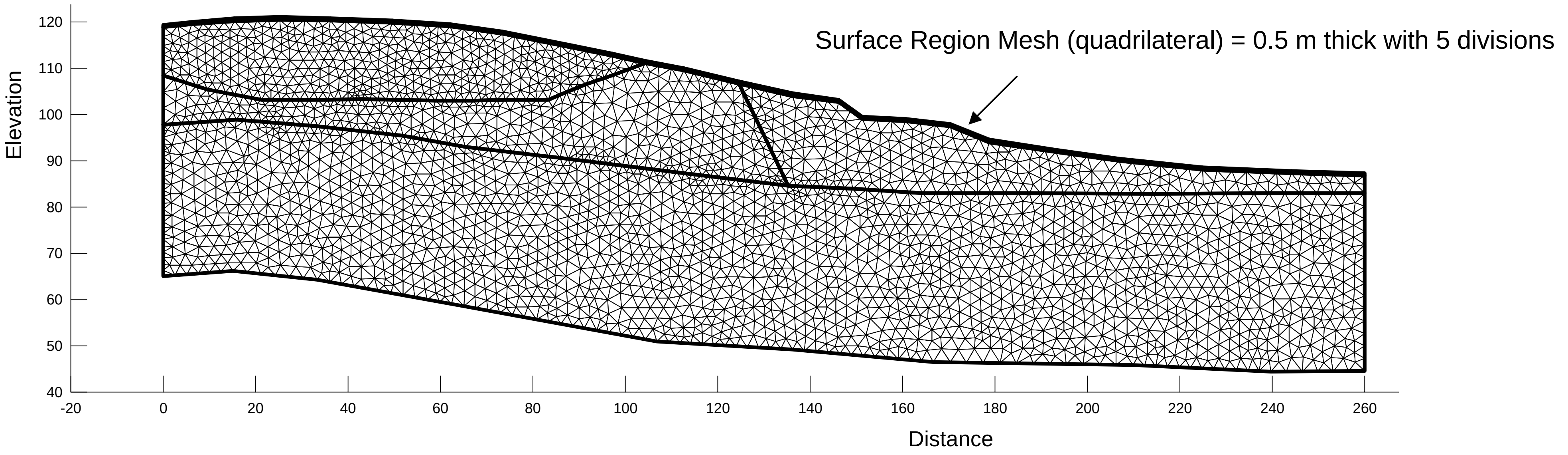
For the transects which are the subject of this detailed investigation, there is little evidence to suggest that there are groundwater springs at these sites. The only verified spring is at Cut 6 (SP13), which is on the opposing side of the groundwater divide and is therefore not influenced by the proposed cut. The water table profile presented in Figure G-4 for Cut 6 and Figure G-5 for Cut 19 indicates that the water table does not intersect the current ground surface at Cut 6 or Cut 19 and therefore springs cannot form. This conclusion is supported by site inspection works.

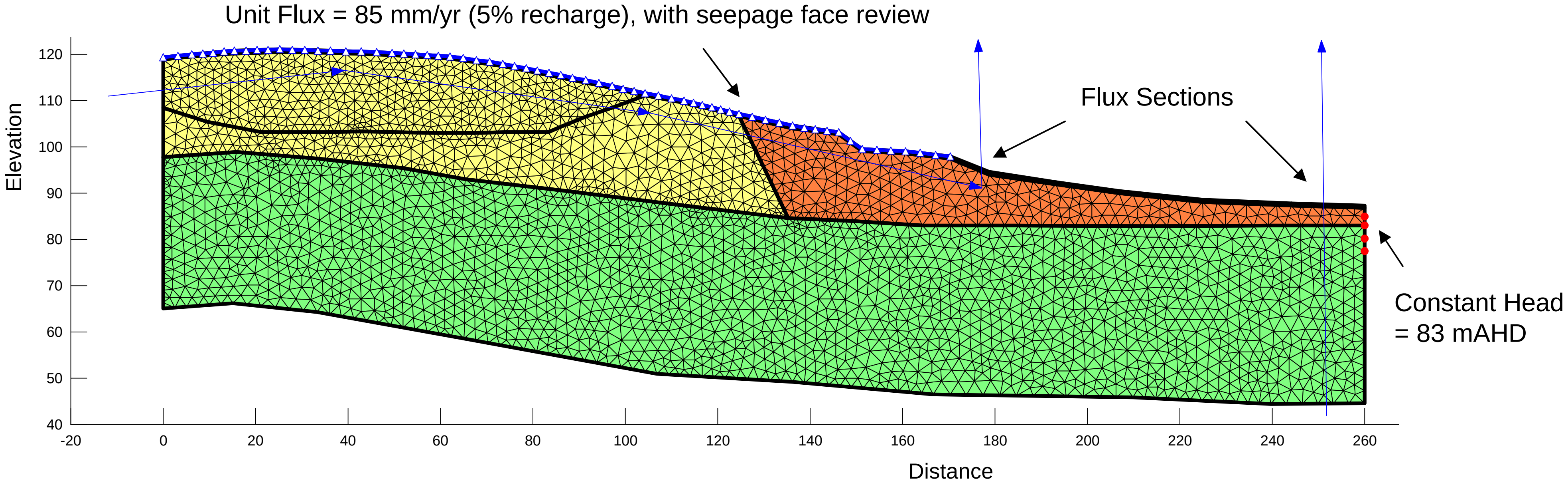
Numerical modelling, however, suggests that there is likely to be impact to the phreatic surface where a seepage face develops, such as in Cut 19. As such, at locations other than those studied where cuts extend below the water table, there remains a potential to affect nearby groundwater springs.

It was found that groundwater is not discharging directly to surface waterways at Cut 6 and Cut 19, however, the groundwater system is contributing to hyporheic zone of those waterways. That contribution is dominated by shallow aquifer contribution. Accordingly, consideration may need to be given to the water quality of road runoff from the highway that may recharge the groundwater system

From a quantitative perspective, an environmental objective for this project is to reduce the potential adverse impacts on groundwater contribution to the hyporheic zone of surface waterways, down-gradient. Accordingly, consideration could be given to methods to enhance recharge to groundwater adjacent the proposed highway, to offset potential impact associated with development of a seepage face. This is discussed further in Section 7.5 of the report.

Groundwater dependant ecosystems (GDEs) near the valleys may be affected whenever the water flow in the creek is lessened or the shallow groundwater table lowered. GDEs are least likely to be found on the hill slopes, as the hill slopes are mostly grazing land and GDEs are more likely to be found closer to creeks.





LEGEND

🟨 Silty Clay, Ksat = 2.0E-7 m/s;
Anisotropy Factor = 1:5

🟧 Clayey Sandy Silt, Ksat = 2.0E-6 m/s;
Anisotropy Factor = 1:2.5

🟩 Slightly Weathered Rock / Fresh Rock,
Ksat = 2.0E-8 m/s; Anisotropy Factor = 1:5

Golder Associates

CLIENT	ARUP Pty Ltd		
Drawn	JRB	Date	01/02/2008
Checked	RH	Date	06/09/2007
SCALE	1H:1V		

PROJECT
Pacific Highway Upgrade: T2E

TITLE
Existing Conditions (Cut 06) – Finite Element Mesh,
Boundary Conditions and Material Properties

Project No.	06622140	Figure No.	G-1	Rev No.	3	A4

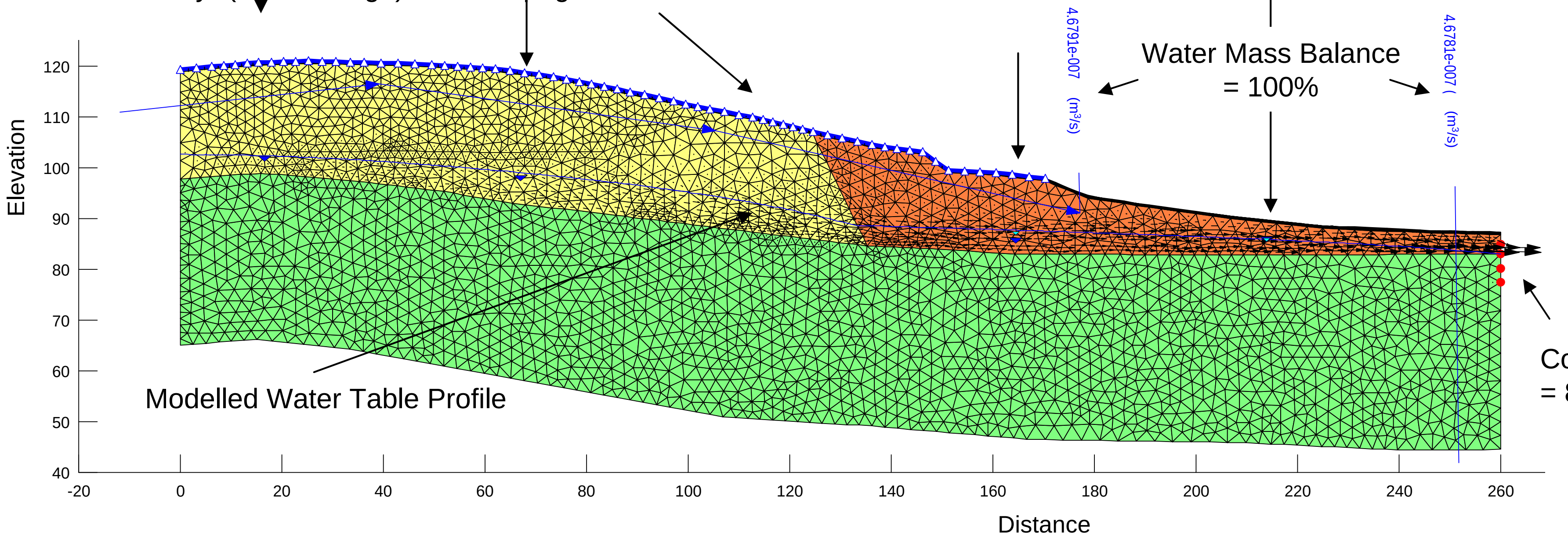
BH2000 (Shallow) = Dry
BH1021 (Deep) = 101.8 mAHD

BH2002 (Shallow) = Dry
BH2001 (Deep) = 98.0 mAHD

BH2004 (Shallow) = 87.1 mAHD
BH2003 (Deep) = 85.6 mAHD

BH2006 (Shallow) = 85.8 mAHD
BH2005 (Deep) = 85.9 mAHD

Unit Flux = 85 mm/yr (5% recharge), with seepage face review



Water Mass Balance
= 100%

Modelled Water Table Profile

Constant Head
= 83 mAHD

LEGEND

🟨 Silty Clay, Ksat = 2.0E-7 m/s;
Anisotropy Factor = 1:5

🟧 Clayey Sandy Silt, Ksat = 2.0E-6 m/s;
Anisotropy Factor = 1:2.5

🟩 Slightly Weathered Rock / Fresh Rock,
Ksat = 2.0E-8 m/s; Anisotropy Factor = 1:5

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PROJECT Pacific Highway Upgrade: T2E

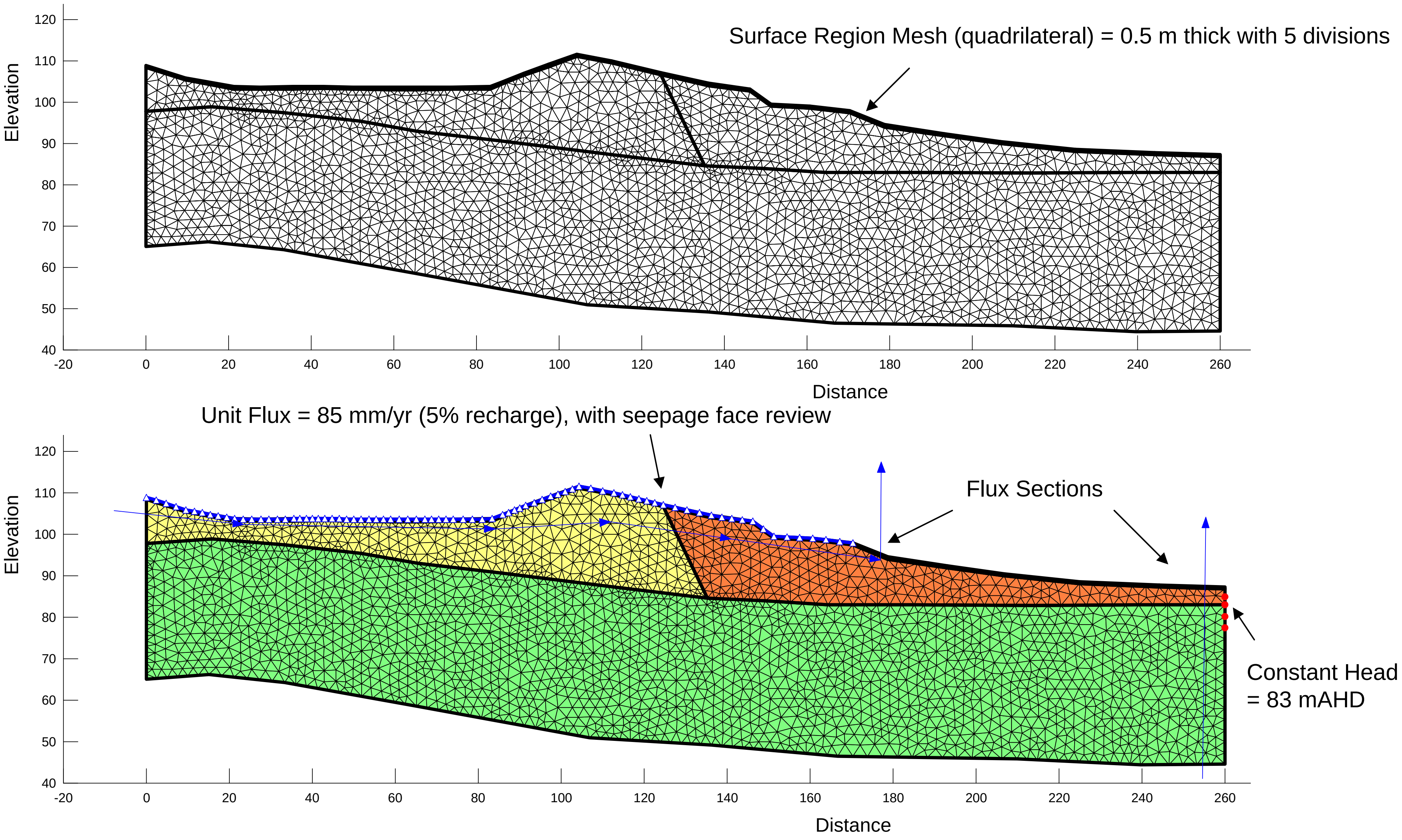
Drawn JRB
Date 01/02/2008

Checked RH
Date 06/09/2007

TITLE Existing Conditions (Cut 06) – Calibration Run

SCALE 1H:1V

Project No. 06622140
Figure No. G-2
Rev No 3
A4



LEGEND

🟨 Silty Clay, Ksat = 2.0E-7 m/s;
Anisotropy Factor = 1:5

🟧 Clayey Sandy Silt, Ksat = 2.0E-6 m/s;
Anisotropy Factor = 1:2.5

🟩 Slightly Weathered Rock / Fresh Rock,
Ksat = 2.0E-8 m/s; Anisotropy Factor = 1:5

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CLIENT
ARUP Pty Ltd

PROJECT
Pacific Highway Upgrade: T2E

Drawn
JRB
Date
01/02/2008

Checked
RH
Date
06/09/2007

TITLE
Proposed Conditions (Cut 06) – Finite Element Mesh,
Boundary Conditions and Material Properties

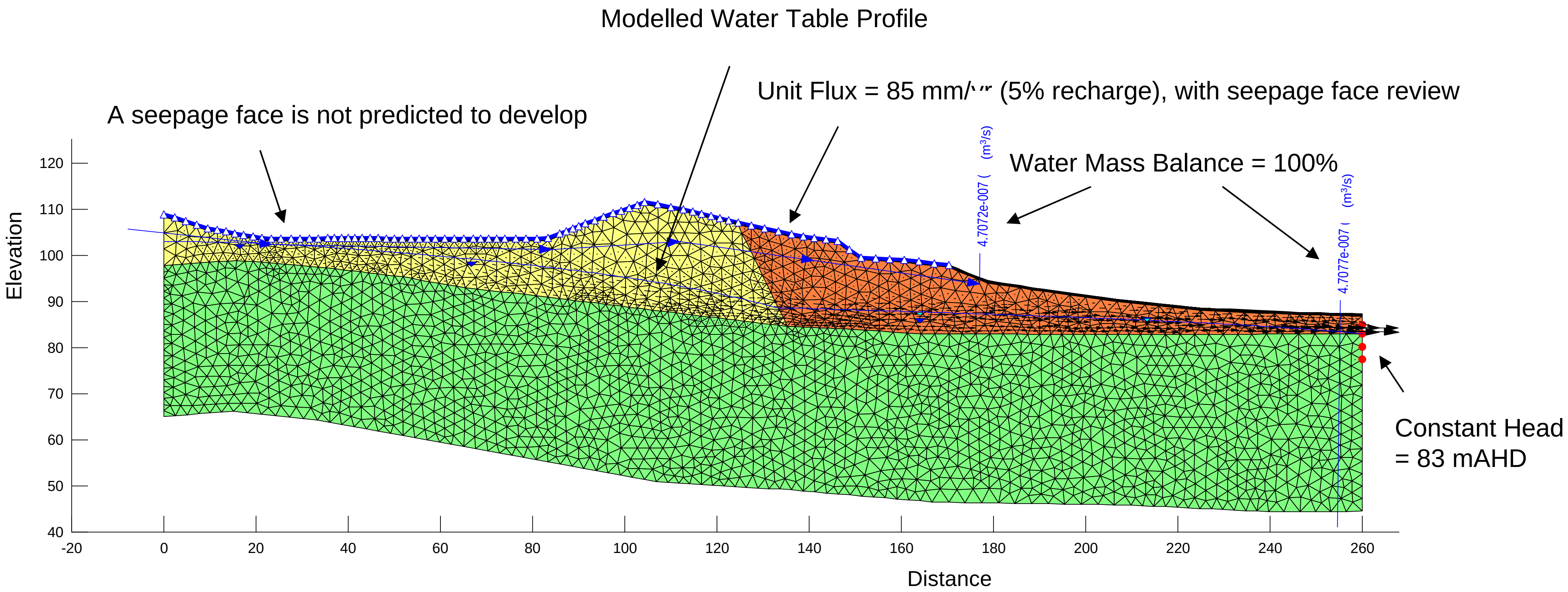
SCALE
1H:1V

Project No.
06622140

Figure No. G-3

Rev No
3

A4



LEGEND

🟨 Silty Clay, Ksat = 2.0E-7 m/s;
Anisotropy Factor = 1:5

🟧 Clayey Sandy Silt, Ksat = 2.0E-6 m/s;
Anisotropy Factor = 1:2.5

🟩 Slightly Weathered Rock / Fresh Rock,
Ksat = 2.0E-8 m/s; Anisotropy Factor = 1:5

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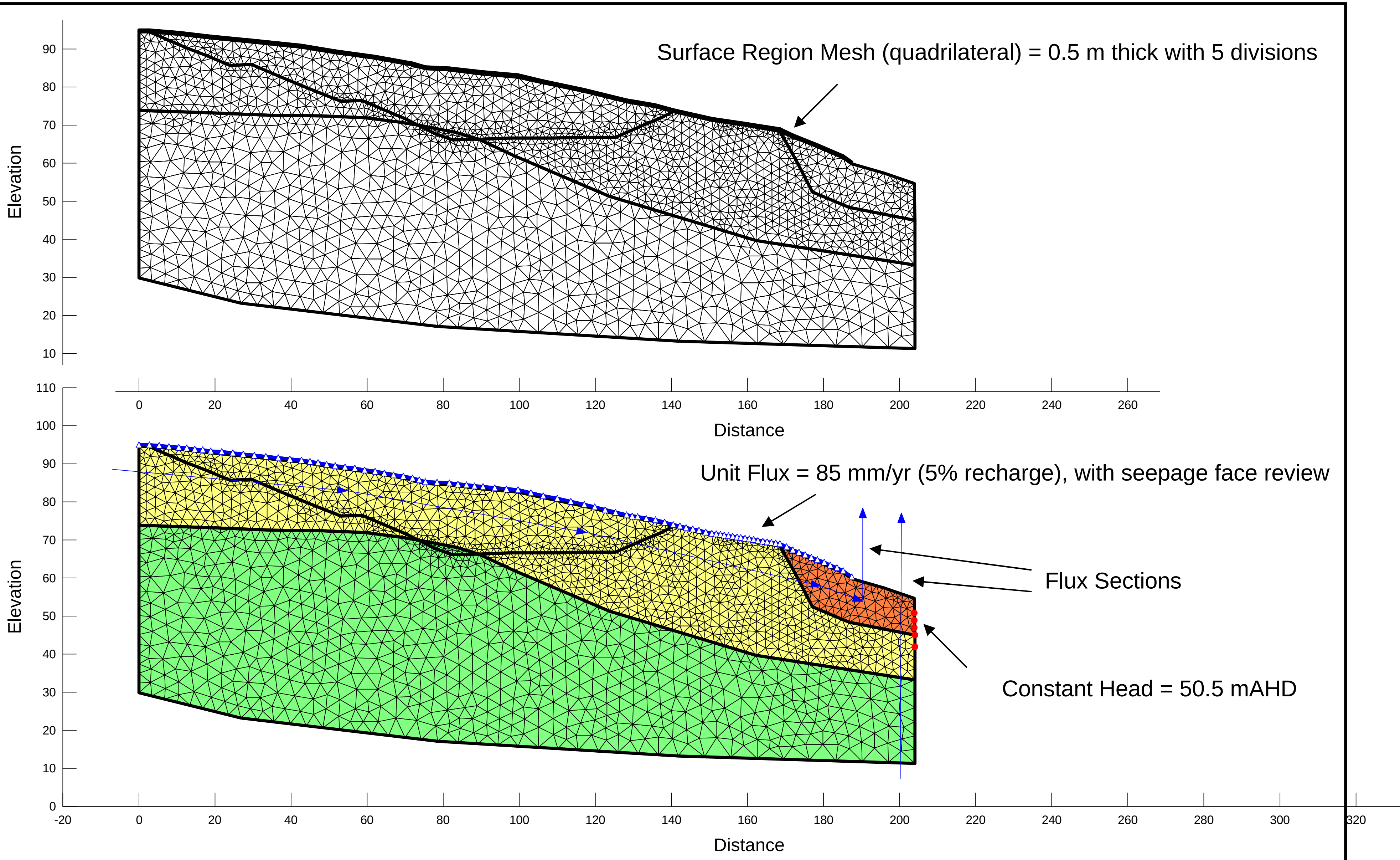
CLIENT ARUP Pty Ltd		PROJECT Pacific Highway Upgrade: T2E	
Drawn JRB	Date 01/02/2008	TITLE Proposed Conditions (Cut 06) – Simulation Run	
Checked RH	Date 06/09/2007		
SCALE 1H:1V		Project No. 06622140	Figure No. G-4
		Rev No. 3	A4



LEGEND

🟨 Silty Clay, Ksat = 1.0E-7 m/s; Anisotropy Factor = 1:5

🟧 Clayey Sandy Silt, Ksat = 1.0E-6 m/s; Anisotropy Factor = 1:2.5

🟩 Slightly Weathered Rock / Fresh Rock, Ksat = 2.0E-8 m/s; Anisotropy Factor = 1:5

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PROJECT Pacific Highway Upgrade: T2E

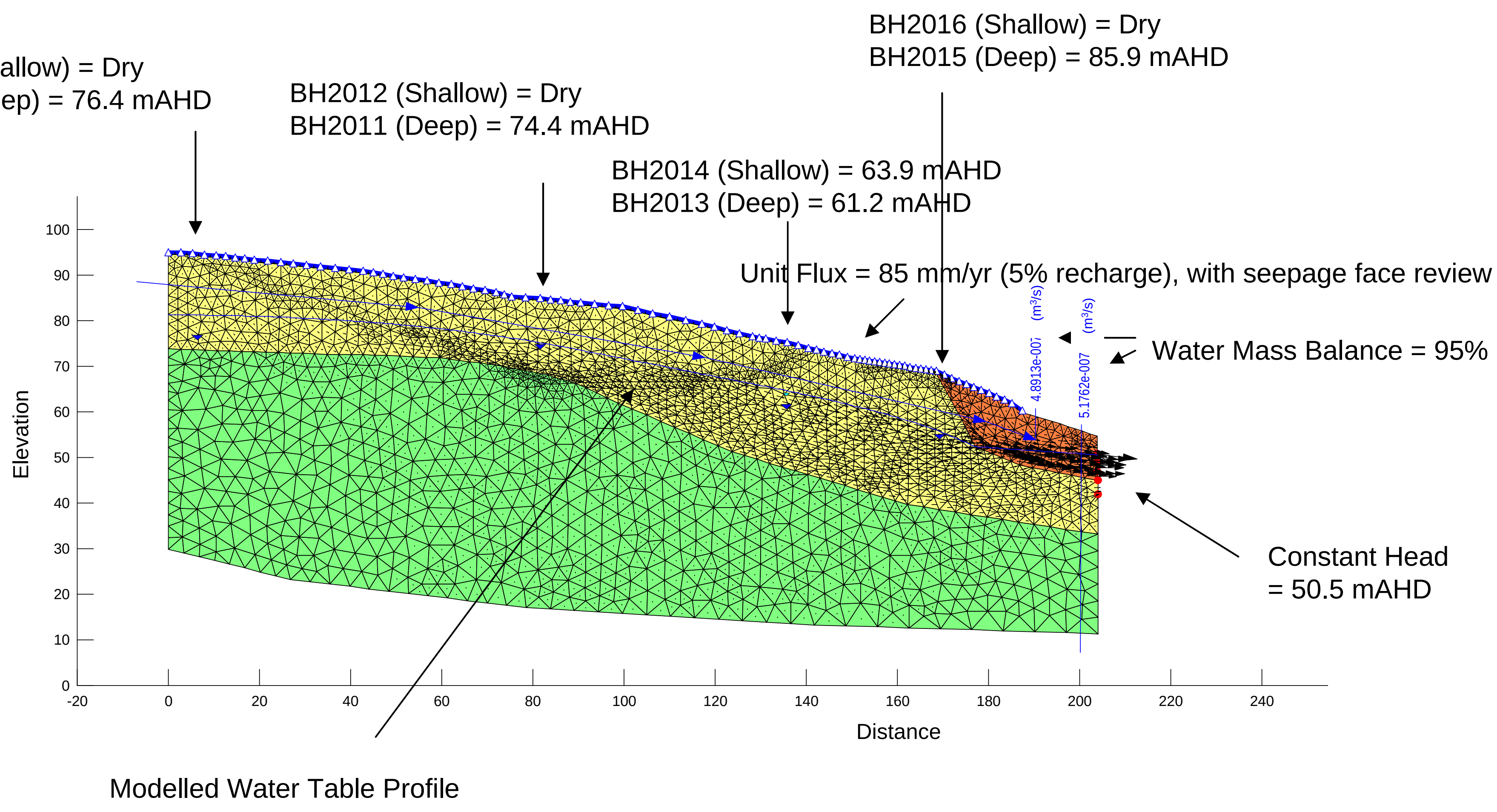
Drawn JRB
Date 01/02/2008

Checked RH
Date 06/09/2007

TITLE
Existing Conditions (Cut 19) – Finite Element Mesh, Boundary Conditions and Material Properties

SCALE 1H:1V

Project No. 06622140
Figure No. G-5
Rev No. 3
A4



LEGEND

🟨 Silty Clay, Ksat = 1.0E-7 m/s;
Anisotropy Factor = 1:5

🟧 Clayey Sandy Silt, Ksat = 1.0E-6 m/s;
Anisotropy Factor = 1:2.5

🟩 Slightly Weathered Rock / Fresh Rock,
Ksat = 2.0E-8 m/s; Anisotropy Factor = 1:5

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PROJECT Pacific Highway Upgrade: T2E

Drawn JRB

Date 01/02/2008

Checked RH

Date 06/09/2007

TITLE Existing Conditions (Cut 19) – Calibration Run

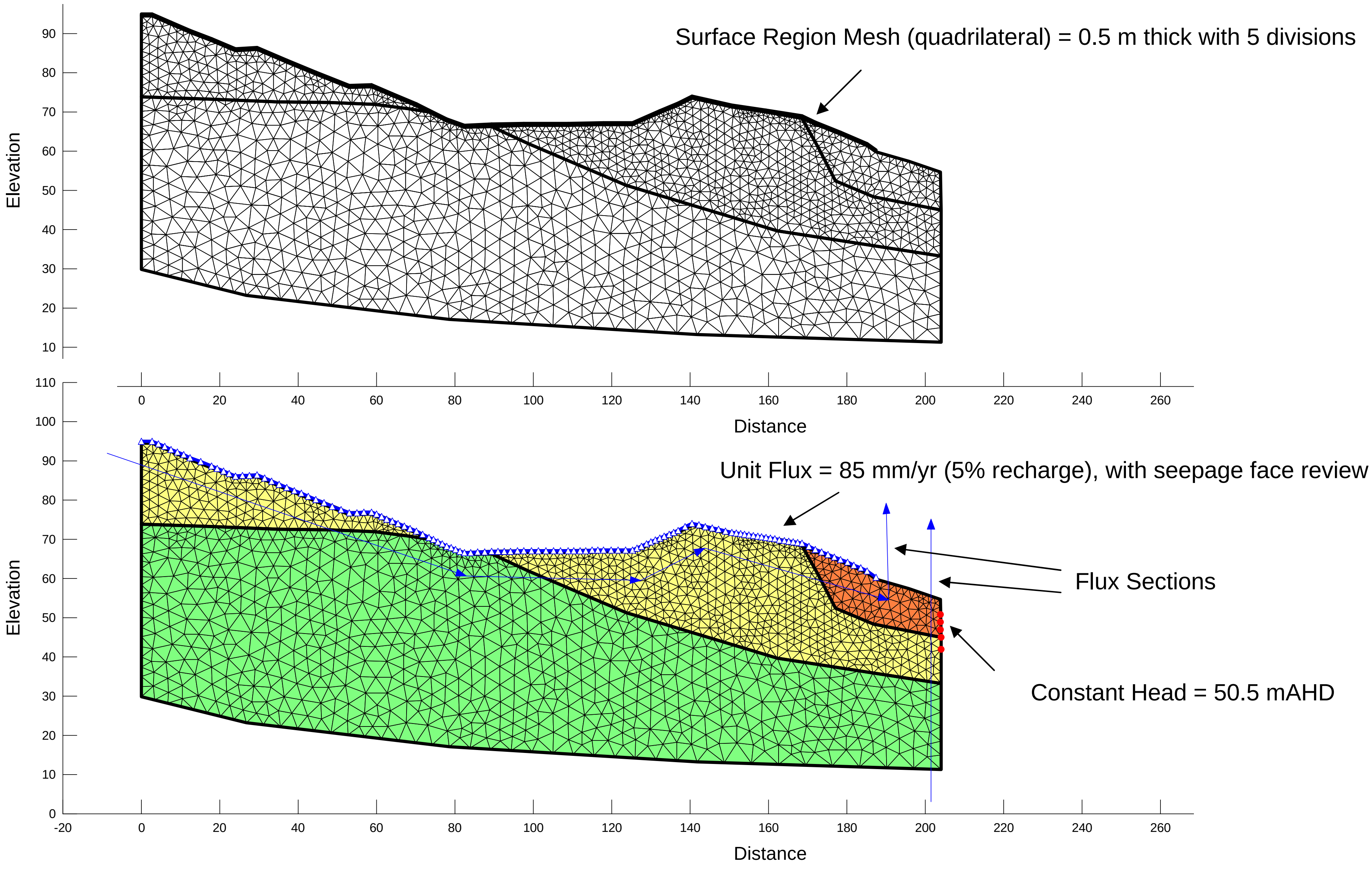
SCALE 1H:1V

Project No. 06622140

Figure No. G-6

Rev No. 3

A4



Surface Region Mesh (quadrilateral) = 0.5 m thick with 5 divisions

Unit Flux = 85 mm/yr (5% recharge), with seepage face review

Flux Sections

Constant Head = 50.5 mAHD

LEGEND

🟨 Silty Clay, Ksat = 1.0E-7 m/s; Anisotropy Factor = 1:5

🟧 Clayey Sandy Silt, Ksat = 1.0E-6 m/s; Anisotropy Factor = 1:2.5

🟩 Slightly Weathered Rock / Fresh Rock, Ksat = 2.0E-8 m/s; Anisotropy Factor = 1:5

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PROJECT Pacific Highway Upgrade: T2E

Drawn JRB

Date 01/02/2008

Checked RH

Date 06/09/2007

TITLE Proposed Conditions (Cut 19) – Finite Element Mesh, Boundary Conditions and Material Properties

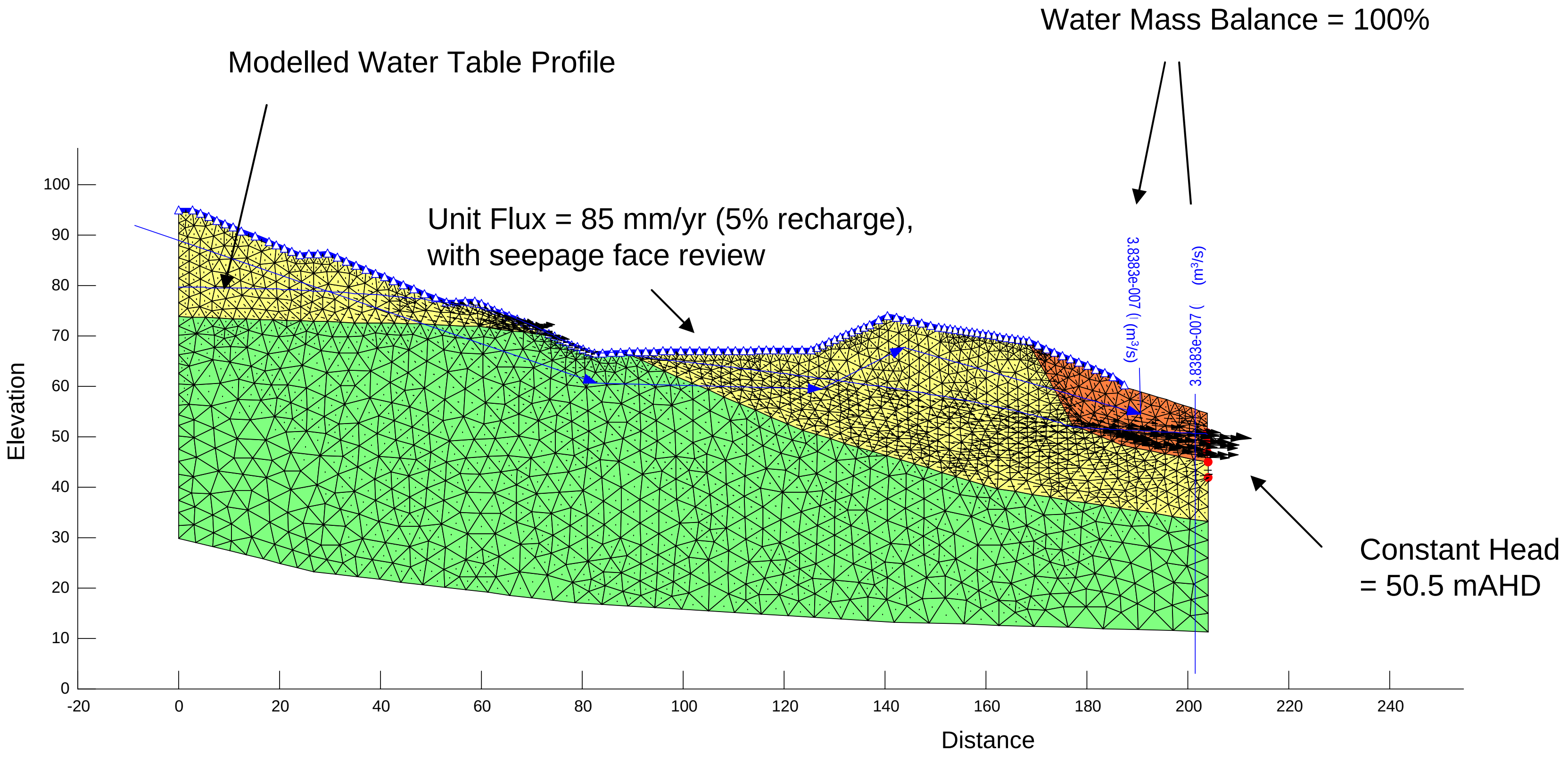
SCALE 1H:1V

Project No. 06622140

Figure No. G-7

Rev No. 3

A4



Water Mass Balance = 100%

Modelled Water Table Profile

Unit Flux = 85 mm/yr (5% recharge), with seepage face review

Constant Head = 50.5 mAHD

LEGEND

🟨 Silty Clay, Ksat = 1.0E-7 m/s; Anisotropy Factor = 1:5

🟧 Clayey Sandy Silt, Ksat = 1.0E-6 m/s; Anisotropy Factor = 1:2.5

🟩 Slightly Weathered Rock / Fresh Rock, Ksat = 2.0E-8 m/s; Anisotropy Factor = 1:5

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CLIENT ARUP Pty Ltd

PROJECT Pacific Highway Upgrade: T2E

Drawn JRB

Date 01/02/2008

Checked RH

Date 06/09/2007

TITLE Proposed Conditions (Cut 19) – Simulation Run

SCALE 1H:1V

Project No. 06622140

Figure No. G-8

Rev No. 3

A4

Appendix H
Important Information about your Geotechnical Engineering Report

Important Information About Your

Geotechnical Engineering Report

***Subsurface problems are a principal cause of construction delays,
cost overruns, claims and disputes.***

The following information is provided to help you manage your risks.

Geotechnical Services Are Performed for Specific Purposes, Persons, and Projects

Geotechnical engineers structure their services to meet the specific needs of their clients. A geotechnical engineering study conducted for a civil engineer may not fulfil the needs of a construction contractor or even another civil engineer. Because each geotechnical engineering study is unique, each geotechnical engineering report is unique, prepared *solely* for the client. *No one except you* should rely on your geotechnical engineering report without first conferring with the geotechnical engineer who prepared it. *And no one – not even you* – should apply the report for any purpose or project except the one originally contemplated.

A Geotechnical Engineering Report Is Based on A Unique Set of Project-Specific Factors

Geotechnical engineers consider a number of unique, project-specific factors when establishing the scope of a study. Typical factors include : the client's goals, objectives, and risk management preferences; the general nature of the structure involved, its size, and configuration; the location of the structure on the site; and other planned or existing site improvements, such as access roads, parking lots, and underground utilities. Unless the geotechnical engineer who conducted the study specifically indicates otherwise, *do not rely on a geotechnical engineering report* that was :

- not prepared for you,
- not prepared for your project,
- not prepared for the specific site explored, or
- completed before important project changes were made.

Typical change that can erode the reliability of an existing geotechnical engineering report include those that affect :

- the function of the proposed structure, as when it's changed from a parking garage to an office building, or from a light industrial plant to a refrigerated warehouse,
- elevation, configuration, location, orientation, or weight of the proposed structure,
- composition of the design team, or
- project ownership.

As a general rule, *always* inform your geotechnical engineer of project changes – even minor ones – and request an assessment of their impact. *Geotechnical Engineers cannot accept responsibility or liability for problems that occur because their reports do not consider developments of which they were not informed.*

Subsurface Conditions Can Change

A geotechnical engineering report is based on conditions that existed at the time the study was performed. *Do not rely on a geotechnical engineering report* whose adequacy may have been affected by : the passage of time; by man-made events, such as construction on or adjacent to the site; or by natural events, such as floods, earthquakes, or groundwater fluctuations. *Always* contact the geotechnical engineer before applying the report to determine if it is still reliable. A minor amount of additional testing or analysis could prevent major problems.

Most Geotechnical Findings Are Professional Opinions

Site exploration identifies subsurface conditions *only* at those points where subsurface tests are conducted or samples are taken. Geotechnical engineers review field and laboratory data and then apply their professional judgement to render an *opinion* about subsurface conditions throughout the site. Actual subsurface conditions may differ – sometimes significantly – from those indicated in your report. Retaining the geotechnical engineer who developed your report to provide construction observation is the most effective method of managing the risks associated with unanticipated conditions.

A Report's Recommendations Are *Not* Final

Do not overrely on the construction recommendations included in your report. *Those recommendations are not final*, because geotechnical engineers develop them principally from judgement and opinion. Geotechnical engineers can finalise their recommendations only by observing actual subsurface conditions revealed during construction. *The geotechnical engineer who developed your report cannot assume responsibility or liability for the report's recommendations if that engineer does not perform construction observation.*

A Geotechnical Engineering Report Is Subject to Misinterpretation

Other design team members' misinterpretation of geotechnical engineering reports has resulted in costly problems. Lower that risk by having your geotechnical engineer confer with appropriate members of the design team after submitting the report. Also retain your geotechnical engineer to review pertinent elements of the design team's plans and specifications. Contractors can also misinterpret a geotechnical engineering report. Reduce that risk by having your geotechnical engineer participate in prebid and preconstruction conferences, and by providing construction observation.

Do Not Redraw the Engineer's Logs

Geotechnical engineers prepare final boring and testing logs based upon their interpretation of field logs and laboratory data. To prevent errors or omissions, the logs included in a geotechnical engineering report should *never* be redrawn for inclusion in architectural or other design drawings. Only photographic or electronic reproduction is acceptable, *but recognise that separating logs from the report can elevate risk.*

Give Contractors a Complete Report and Guidance

Some owners and design professionals mistakenly believe they can make contractors liable for unanticipated subsurface conditions by limiting what they provide for bid preparation. To help prevent costly problems, give contractors the complete geotechnical engineering report, *but* preface it with a clearly written letter of transmittal. In that letter, advise contractors that the report was not prepared for purposes of bid development and that the report's accuracy is limited; encourage them to confer with the geotechnical engineer who prepared the report (a modest fee may be required) and/or to conduct additional study to obtain the specific types of information they need or prefer. A prebid conference can also be valuable. *Be sure contractors have sufficient time* to perform additional study. Only then might you be in a position to give contractors the best information available to you, while requiring them to at least share some of the financial responsibilities stemming from unanticipated conditions.

Read Responsibility Provisions Closely

Some clients, design professionals, and contractors do not recognise that geotechnical engineering is far less exact than other engineering disciplines. This lack of understanding has created unrealistic expectations that have led to disappointments, claims, and disputes. To help reduce such risks, geotechnical engineers commonly include a variety of explanatory provisions in their reports. Sometimes labelled "limitations", many of these provisions indicate where geotechnical engineers responsibilities begin and end, to help others recognise their own responsibilities and risks. *Read these provisions closely.* Ask questions. Your geotechnical engineer should respond fully and frankly.

Geoenvironmental Concerns Are Not Covered

The equipment, techniques, and personnel used to perform a *geoenvironmental* study differ significantly from those used to perform a *geotechnical* study. For that reason, a geotechnical engineering report does not usually relate any geoenvironmental findings, conclusions, or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. *Unanticipated environmental problems have led to numerous project failures.* If you have not yet obtained your own geoenvironmental information, ask your geotechnical consultant for risk management guidance. *Do not rely on an environmental report prepared for someone else.*

Rely on Your Geotechnical Engineer for Additional Assistance

Membership in ASFE exposes geotechnical engineers to a wide array of risk management techniques that can be of genuine benefit for everyone involved with a construction project. Confer with your ASFE member geotechnical engineer for more information.

ASFE
PROFESSIONAL
FIRMS PRACTICING
IN THE GEOSCIENCES

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