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The Project Manager
Murlan Consulting Pty Ltd
Jones Bay Wharf
Sydney
18 February 2009
Attn: Mr. Ben MacGibbon

Dear Sir,

RE: 35 WATER ST – WAHROONGA, FURTHER SUPPLEMENTARY HYDROGEOLOGY AND INFILTRATION REPORT.

Further to your request we have reviewed the Hospital design, provided by Tanner Architects on drawings AR.DA 002 to 012, and council's preliminary assessment of 3 April 2008 and the recommendations by Ian Grey Groundwater Consulting Pty Ltd (IGGC) dated 30 May 2008. We have installed continuous monitoring equipment on borehole piesometers on site and collected over 11,000 data points for groundwater. We have undertaken our investigation and assessment of the factors likely to affect the residual Blue Gum High Forest as mapped on the site, bearing in mind the 5 basic principles of the NSW DLWC (2002b) management groundwater dependent ecosystems and the NSW government's policy on Groundwater Quality Management.

The attached report sets out the information obtained, and the recommendations required to make a balanced and informed decision. Technically, there is no impediment to management methods which would allow proposed basement design and construction. There are several construction options which would provide a surety to the protection of the ecosystem and groundwater quality. We are of the opinion that should the recommendations proposed herein be implemented during the planning, design and construction phases of the proposed hospital project, the effect or potential change to the water regimes within Blue Gum High Forrest, mapped on the site, would be undetectable.

For & on Behalf of
D.F.Dickson & Associates Pty Limited

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SUPPLEMENTARY REPORT – HYDROGEOLOGY 35 WATER ST WAHROONGA

For Murlan Consulting

Reference: 27119-H03

Date: February 16 2009

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SUPPLEMENTARY REPORT – HYDROGEOLOGY 35 WATER ST WAHROONGA

Reference: 27119-H03
Date: February 16 2009

Introduction

- Further to a request from Murlan Consulting, D.F.Dickson and Associates Pty Ltd has been undertaking continuing hydrological monitoring of the piesometers installed in three bores on the site. We have prepared this hydrogeology report as it relates to the Hospital scheme as defined by Tanner Architects the drawings detailed below and the supporting reports and documentation provided to us by Murlan.

TITLE:	DWG NO:		
Tanner Architect Drawings		Rev	
050832-AR-DA 002	002	B	
050832-AR-DA 004	004	B	
050832-AR-DA 005	005	B	
050832-AR-DA 006	006	B	
050832-AR-DA 007	007	B	
050832-AR-DA 008	008	B	
050832-AR-DA 009	009	B	
050832-AR-DA 010	010	B	
050832-AR-DA 011	011	B	
050832-AR-DA 012	012	B	
LHO group drawings			
Civil Drainage Cover Sheet	C00	B	
Stormwater Concept Plan Basement B3	C01	B	
Stormwater Concept Plan Basement B2	C02	B	
Stormwater Concept Plan North	C03	B	
Stormwater Concept Plan South	C04	B	
OSD Tank & Details	C05	B	
Sediment & Erosion Control Plan – North	C06	B	
Sediment & Erosion Control Plan – South	C07	B	
Hydraulic Services Report		B	
Drainage Concept Plan (Report)		B	
Taylor Bramer Landscape Architects			
Site Strategy Plan LSDA05	05	B	
Douglas Partners			
Geotechnical report 43905 June 2006			

- This report provides the monitoring data collected and analysis of that data since our investigations commenced on site in early 2008. In accordance with Principals 1 and 4 of (DLWC 2002b)
- The report so investigates the potential effects of the proposed design on the hydrology of the site and, with respect to the management of the Blue Gum High Forrest (BGHF) in accordance with Principals 2 and 3 of (DLWC 2002b)
- The investigation including the basic design, the construction and management methods likely to be employed, the proposed drainage, hydraulics and, the possible edge effects associated with these construction methods in accordance with Principal 5 of (DLWC 2002b).

Summary

- The proposed development incorporates a basement car park which will be excavated into rock and residual clays, between RL188 and RL 185.75 (estimated bulk excavation level at its lowest eastern extremity).

- There has been a misconception that significant lateral groundwater flows may occur within the residual clay soil horizon on site and, that this could be measured and quantified using the existing and proposed new stand pipe piesometers. This has now been shown from the data collected not to be the case. The clays in fact act as an aquiclude (an impermeable layer below a water source, preventing water movement).

- A water table has not been found in BH1 and water levels slowly settled down in BH2 and BH3 to levels of 8m and 6.3m below the top of casing respectively in these bores, BH1 RL 199.3 (top of casing) located within the car park at the entrance to the site. This borehole was sunk into shale, with a 1.5m sump, 0.8m screen and 7m of casing. As previously noted the hole was dry and, after three days of continuous rain some 300mm of water collected in the sump, which was measured. After 6 months of measurement, the hole remains dry and small fluctuations, barely allowing recording, occur in the sump immediately following rain periods. BH2 TOC RL192.5 WL RL184.5 BH3 TOC RL

- The Douglas Partners Geotechnical report 43905 – June 2006, details a consistent geological model of clayey topsoil being not deeper than 100mm with a possible maximum depth of 300mm over a stiff to very stiff clay which as described appears to have been derived as a residual from the underlying shale, siltstone and laminite. All with low to very low permeabilities and all acting as an aquiclude.

- The soil materials, physical and chemical properties being of great importance in understanding and managing the hydrological component of the proposal and protection of the ecosystem.

- A misconception that significant lateral groundwater flows occur within the underlying shale has been dispelled by the data collected. The nature of the soil-water transfer mechanisms have been covered in our previous report 27119-H02 of June 2008.

"*The makeup of the residual clays from the Ashfield shale has been documented by Won.G.W. Dept Main Roads Sydney (now the RTA) using the then Main Roads Test manual both in-site and in the laboratory. The average clay mineral mix derived from the Ashfield shale is 58 to 60% Kaolinite and 7 to 10% Illite, Silt predominantly quartz, mica and feldspar both of which have clay weathering products, Iron oxides 0 to 20% and Carbonaceous materials 0 to 10%. The permeability of the residual Ashfield clay soils is such that in most cases, they will form an aquiclude. It is likely that the water levels recorded in the piesometers to date represent rainfall or inflows from the topsoil horizon around the standpipes and not a true water table within the clay soils.*

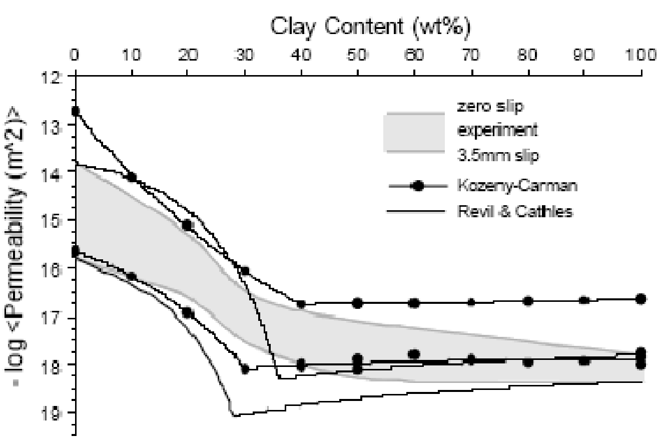


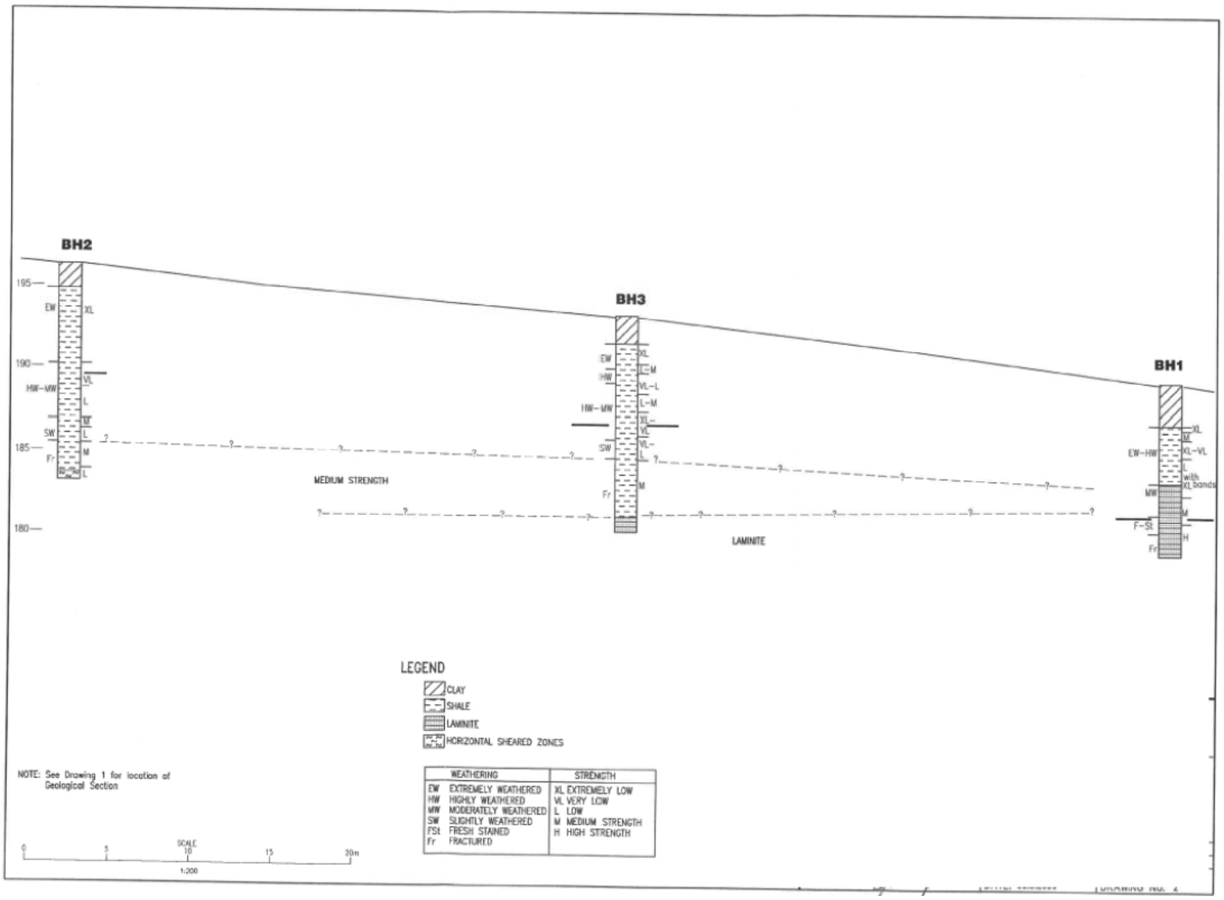
Figure 17 Comparison of model fits with experimental data

The above figure taken from reference 13, depicts the ranges of permeability to be expected in the materials based on the clay content. The permeability for the residual clays with the makeup described above, would be in the order of 10^{-16} m/sec/m^2, which equates to a transmission rate over a section equivalent to a basement wall abutting the clay, of say 20m long and 1m to 2m deep (the size of the proposed building C basement as the example) of *just 53 l/annum for the lower-bound rate. Similarly for the upper bound rate, using a theoretical soil landscape clay loam soil permeability of 0.0362m/day, (3 x 10^{-7} m/sec or several orders of magnitude greater), is equivalent to only 25 l/day (a garden hose flow for less than one minute per day)."*

- Infiltration into the clay soil, from rainfall directly onto the soil and its rate of ingress into bore standpipes has been observed and recorded during the past six months. These flows are faster and the primary mechanism is through tension cracks in the clay soils.

Geotechnical background.

Reference is made to the Douglas Partners geotechnical report and the Sydney 1:100,000 Geological Map Series sheet 9130 (1983) and notes. The underlying bedrock is a part of the Wianamatta grout, being the Ashfield shale. The soils are residual clays derived from the shale and representative of the clay minerals derived from weathering of the shale in situ. The soils are iron rich as a result of the weathering and ironstone nodules and fragments are common. The Wianamatta inlier is relatively thin (from as little as a few meters to a few tens of meters thick) and is underlain by the Hawkesbury sandstone which is both porous and permeable and may be described as the true aquifer. There have been 6 boreholes drilled on site and three have been fitted with standpipe piesometers. The section shown on the following page, through the site taken from the Douglas partners report, indicates the depths of clay soils to the underlying shale. Additional sections showing the piesometers, basement excavation overlay and the recorded water levels is provided in the Appendix to the report.



The main element of the Wianamatta present is the Ashfield shale which has been described in detail in previous reports. The average clay mineral mix derived from the Ashfield shale is 58 to 60% Kaolinite and 7 to 10% Illite, Silt predominantly quartz, mica and feldspar both of which have clay weathering products, Iron oxides 0 to 20% and carbonaceous materials 0 to 10%. The permeability of the residual Ashfield clay soils is such that in most cases, they will form an aquiclude.

It is noted from observations during drilling the piesometers, that the residual clay soils were stiff to very stiff, becoming hard after 300mm below the surface. The shale was dry when initially drilled in all bores and, water inflows to the bores were from the surface layer beneath the bitumen road in BH202 and from the drainage layer beneath the bitumen car park in BH203.

The permeability for the residual clay soils has been estimated in numerous references as being in the range of 10^{-10} m/sec/m^2 (very low) but may be several orders of magnitude lower. (refer to figure 17, above).

Soil Moisture and water Infiltration Model.

- Rainfall in general infiltrates very slowly into saturated clay and in particular where the vertical permeability may be as low as 10^{-16} m/sec/m^2 (during prolonged rainfall events or over winter and when there is sufficient residual soil moisture to prevent tension cracking occurring within the clay soils). Where the clays can dry out, during the summer months, drought or prolonged exposure to the atmosphere without sufficient wetting, they crack deeply and surface water may infiltrate vertically very quickly through these tension cracks. This will continue until the clays around the tension cracks become sufficiently saturated to swell, closing or healing the cracks. The depth of the tension cracks is related to the clay properties, shear strength (Cu), unit weight (γ) and the internal angle of friction (ϕ). There are several relationships used to calculate the depth of a tension crack depending on the nature of the soil and any surface loading, as follows:

- $Hc = \frac{2Cu}{\gamma}$ for undrained conditions
- $Hc = \frac{2C'}{(\gamma\sqrt{ka})}$ for drained conditions where ka (coefficient of active earth pressure) = $\tan^2(45 - \frac{\emptyset}{2})$

From the above relationships it can be shown that the depth of tension cracks in undrained conditions can be as much as 2 to 3m with crack depths significantly greater (2 to 3 times). These depths are great enough to reach the underlying weathered shale surface. Water is not transmitted horizontally at any significant rate and, the effects are generally very localised as has been noticed in the data collection from standpipes HB1 BH2 and BH3.

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The significance of tension crack formation, during construction and after completion, is in managing the soil moistures present within the clay soil horizons to depths between 600mm and 1000mm where the bulk of the root system for the Blue Gum High Forrest will be located. (Tree Wise Men advice 800mm and, RG Skolmen 1974 "***Rooting Habit***- *Saligna eucalyptus develops roots throughout the soil profile so that it is quite wind-firm on deep soils, but easily wind-thrown on shallow soils**. It does not produce a taproot.** Roots are primarily from the stem below the lignotuber, although layering sometimes occurs a short distance from the lignotuber on buried stems. In plantations in Hawaii that are not subject to periodic short drought, about two-thirds of the root system is confined to the upper 61 cm (24 in) of soil where most of the available nutrients are found. In plantations subject to occasional drying of the surface soil, the shallow roots are killed and a deeper root system develops*.")

The data from Bore Holes appears to be a direct correlation of the rainfall events for the area and, it is noted that the speed with which the water level changed in the bores was more indication of a direct reading of the rainfall and not a reading of a true water table.

- We have proposed a more appropriate method of assessing the soil moisture available for maintaining the health of the Blue Gum High Forest. This method being the direct measurement of soil moisture available over the depth of the profile in which the root zone may be found, using agricultural moisture probes such as the Sentek (Diviner 2000) soil moisture probe.

Taking this into account and looking at the primary objective of the sustained management and preservation of the Blue Gum High Forrest assemblage, a direct assessment of the rate of change of moisture levels within the top 1m of the soil horizon is proposed and will be detailed in the recommendations.   It is noted that all of the water levels measured within the standpipes were greater than 6m from the surface, far out of reach of the BGHF species.

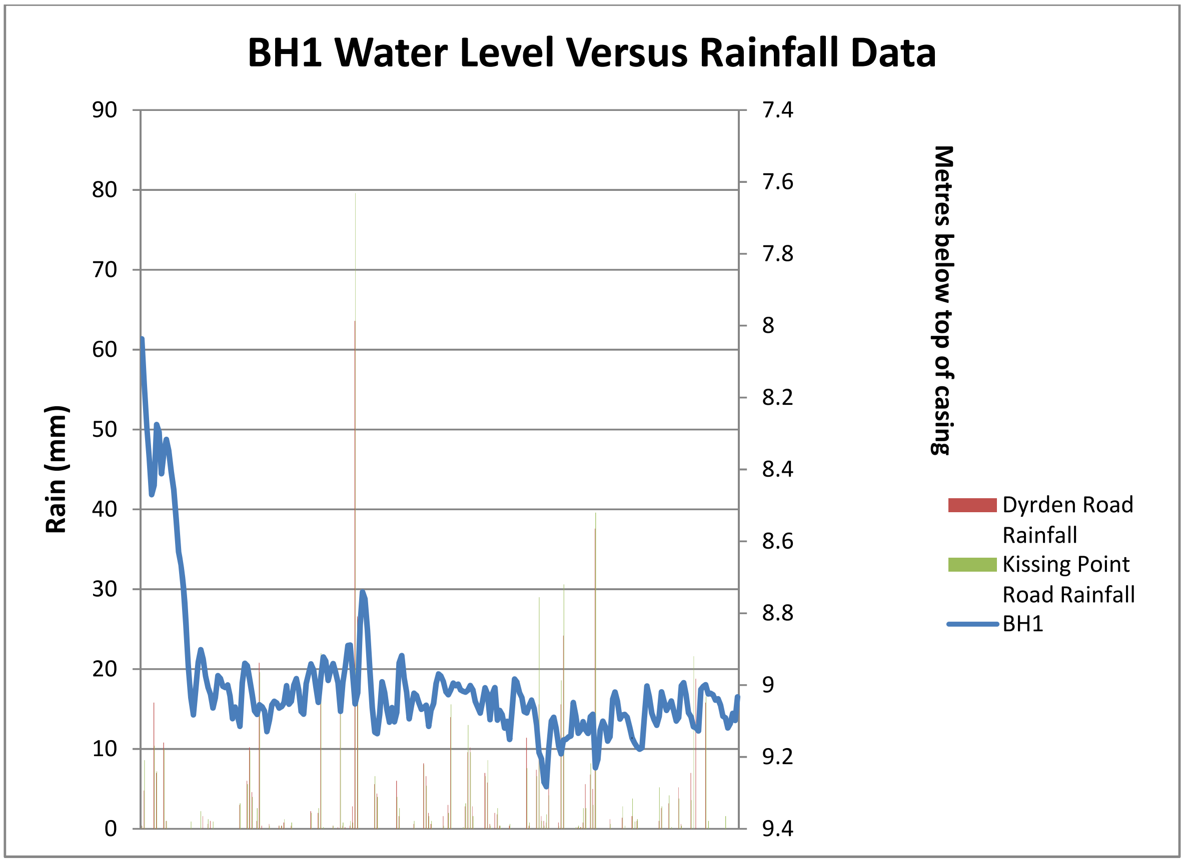
Data Collected.

Data was collected from the standpipes using the In-Situ Inc - Minitrol automated recorders model A 30 PSIA (pressure) with barometric correction from a Barrotrol sensor. The data was recovered and analysed using the Winsitu recording and logging software. Data for daily rainfall was provided by the Bureau of meteorology for two measuring stations one at Dryden Rd (Station no:66114) and one at Kissing Point Road (Station No 66158). The period of rainfall data was from 13 May 2008 until 13 February 2009. The data was overlain on information collected from the boreholes to provide a graphical representation of the information and the correlation between the data sets. This data shows a direct correlation between the recorded rainfall and the water depths measured below top of casing in the bores. BH1 and BH2 were remarkable in the accuracy with which the rainfall could be noted.

Large scale infiltration tests were not carried out on site due to the restrictions on surface from paved areas, restrictions within the BGHF mapped zones and the time required for results to be obtained, however, work was performed using a methyl blue infiltration test in 50mm diameter undisturbed samples from several depths. A 50mm undisturbed sample was obtained using a thin walled clear polycarbonate sample tube, driven to refusal in clay soil from a depth of 300mm adjacent to BH2. The sample was provided with a constant head of 50mm of water coloured using methyl blue dye. The sample was timed for a period of 4320 seconds (72 hrs) and the rate of infiltration measured. Penetration into the clay was marginal at best and measured 14.32mm at its greatest depth an infiltration rate of 3.3×10^{-6} m/sec for the sample, at a driving head of 50mm. Given the nature of the sample and the test, the in situ rate may be one or two orders of magnitude less than this (3.3×10^{-8} m/sec).

The speed with which the rise and subsequent fall of water levels does not correlate with the known permeability of the soils and is therefore of little use for prediction of a relationship between available water for the BGHF. What is apparent is the long term depth of available water in the stand pipes, being greater than 8m, 7m and 6m respectively from the surface.

It has been proposed to use agricultural direct soil moisture measuring techniques to monitor the available soil moisture available to the root zones and to measure the lateral extent of drying of the soil from excavation and desiccation. The details of this plan will be discussed in the conclusions of this report.



The results from BH2 and 3 mirror BH. BH1 has been chosen to show the data without clutter. It must be noted that for the 10 days prior to installation of the bores 177mm of rainfall was recorded and, on the day the bores were installed, rainfall occurred for most of the day accounting for 4.8mm.

The Development proposed, construction options and consequence for Hydrology

The planned development involves a excavation in the area of the main hospital North wing to a floor level of RL188.25 and, as noted by the Geotechnical engineers and our own investigations it is likely that some groundwater will be intersected within the shale at a depth of 8 to 9m below natural ground. The basement will only intersect this depth at the north west corner and will for the most part be within a weathered to extremely weathered shale. The shale will not be self supporting over the entire excavation depth and a shoring system will be required. The type of system envisaged and most commonly used for this type of excavation will be a bored soldier pile and infill panel system, however, other similar systems are available to the builder with similar characteristics. The system favoured by the writer would be soldier piles as concrete piles between 750mm diameter and 900mm diameter bored to depths of 1.5 to 3m below the base of excavation and filled prior to excavation. These piles are supported by rock anchors bored through the pile and anchored at depth to form a tie back. The first row of anchors is generally located between 1.5 and 2m below the top of the pile and angled at 35 to 45 degrees down so that for each meter away from the wall they generally fall by between 800mm and 1m. The excavation proceeds to the base where a floor slab is poured and precast concrete panels are erected as the infill, however, other methods such as shotcrete or cast in situ panels are also used. Each system will have a drainage cell added behind the permanent wall and this connected to a passive drain regulating any pressure head developed in the system, this may include a fully hydrostatic system or be relieved passively at the low point of the excavation. The flow can be calculated from the permeability and head for the clay soils and for the shale horizons which in both cases produces a small volume (25 l/day). This can be used passively to infiltrate into garden areas or collected and directed to the stormwater harvesting and re-use system.

These methods all have their own merits, the salient points for each and every system are to control the rate of drying of the first 1.0m of soil depth during the construction. This is easily controlled using the soldier pile method by excavating to the anchor level and shotcreting a blinding layer 50 to 100mm thick over the excavated soils as soon as the excavation is complete. The shotcrete layer can be drained using spitters (50mm diameter PVC tubes at 1.2m centres) or as an open toe to prevent failure from excess hydrostatic pressure during rainfall events. The soil is then effectively sealed on the excavated face and irrigation used to control soil moisture will not be unnecessarily lost due to lateral evaporation. The basements closer to the BGHF mapped areas such as the east wing has similar basement design characteristics, albeit at a depth of between 5.7m and 300mm. The same design principals apply, with pile spacing adjusted to take account of the lower lateral loads imposed by the excavation.

From considerable experience working with piling companies and in basement shoring design we can be confident in the fact that the equipment required to undertake such a system can be operated entirely within the basement footprint and not disturb the areas outside the footprint and construction zone. The types of equipment used for the operation include hydraulic excavators, Pile Boring rig as shown in a very small site in Manly (above), concrete pumping equipment and crawler crane. All are tracked and do not require the construction of road access, however, for the removal of spoil, trucks will be required and suitable access using the existing paved surfaces can be arranged with DGB aggregate topping to prevent damage and spreading from the footprint of these accesses.

Infiltration and drainage

The landscape concept plan and the stormwater management plans listed above from LHO Group have been studied in light of the hydrological aspects of drainage and water use on site and in particular with respect to applying a similar surface water load to the landscape from the finished works as could be expected from the current situation. The landscape plan and stormwater management plans envisage the re-use of collected rainwater for irrigation of the landscaped areas and other uses on site. The current plans utilise storage and a large on site detention tank at the bottom of the site (south east corner), prior to discharge to the stormwater network. LHO Group Drawing 0608-008 C03 and C04 Rev D which show the proximity of the existing paved areas, the new buildings and the areas remaining as extensively un-touched. The paved area footprint has in the past been mostly undrained and has provided a catchment which supplies a passive irrigation system along its lower edge, to the landscaping and existing gardens as infiltration zones for soil moisture.

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The design essentially maintains these hard surfaces and catchments which, can be managed to supply the same areas both during construction and on completion with a similar volume in a better managed way using the storage and re-use systems planned. The amount of re-use through irrigation can be managed from the data provided by the soil moisture measurement network and automated and managed by the horticulturalists managing the gardens and the BGHF. This system would still have little or no impact on the true water table which is well below the vadose zone being managed.

Conclusions and recommendations:

- Based on the data obtained to date, the reliability of information provided by borehole piesometers in the clay soils on this site has been shown to at best be a rainfall indicator. It is not recommended that additional stand pipes be installed.
- The collection and management of soil moisture data is better conducted using a grid of soil moisture probes at 20m to 30m spacing on two lines in critical areas and with those lines at 10m and 30m away from the construction zone. The soil moisture probes should measure the soil moistures within the zone of root development of the BGHF and at intervals of 10cm 30cm and 60cm in that zone.
- It is recommended that an automated system of data collection such as the Sentek enviroscan plus remote data logging and management system using multi level

measurement soil moisture probes, such as the diviner or other Sentek probes in an array. The system should be established prior to completion of the planning stages to collect background soil moisture conditions and maintained during the construction period for control of soil moisture by irrigation. The system should be maintained for a minimum period of 6 months following completion of construction or for such a period of time longer than 6 months, required to ensure that soil moistures are maintained in accordance with the background levels measured.

- Given the extremely slow rate of horizontal transmission through the clays and the underlying Ashfield Shale it is our opinion that the edge effects can be managed by sealing of the soils during excavation using a soldier pile and infill panel design and shotcrete blinding of the soil horizon.

- The construction management plan provides for a 3m construction zone which is adequate room for the construction equipment and, techniques required to be construct the basements without adversely impacting on the surrounding flora and environment. This zone will only be utilised for pedestrian and incidental use and serves as a buffer zone between the construction outline and the ecological outline.

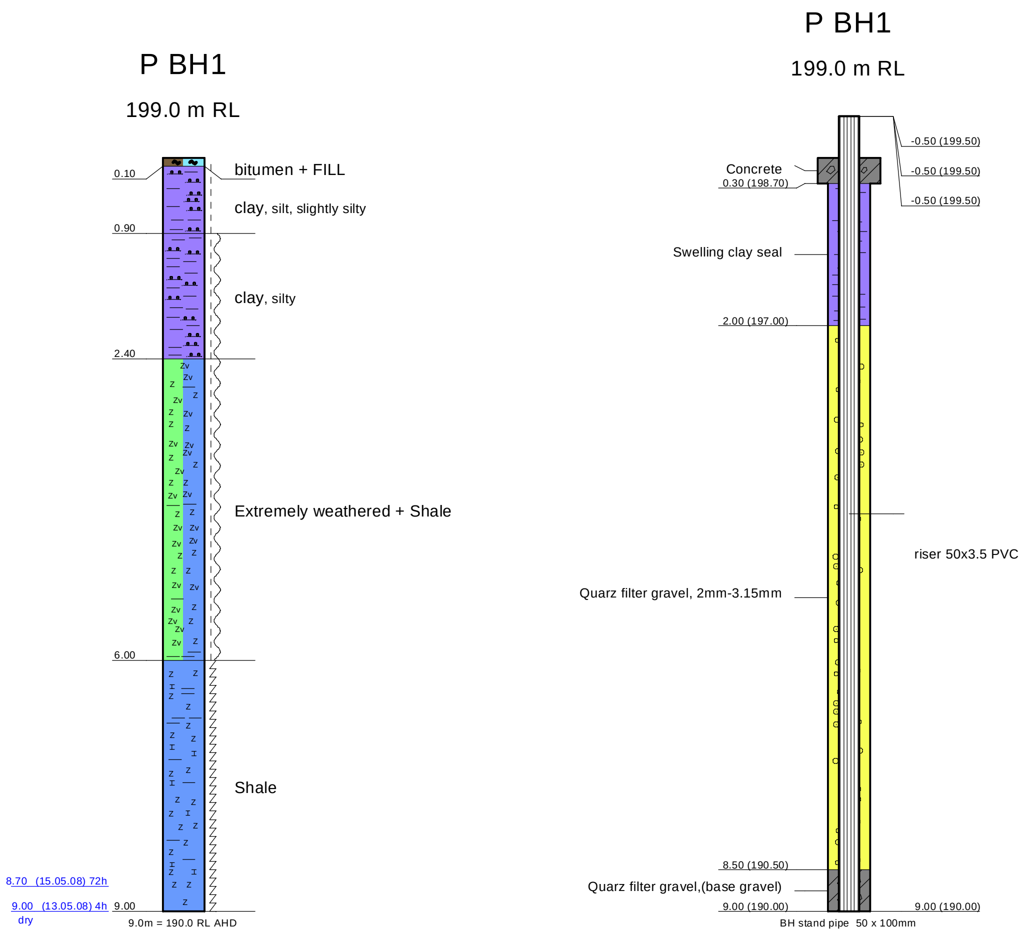
- The proposed water harvesting and management plan is best suited for controlled management of soil moisture after construction and the management of the gardens and BGHF soil moistures. The proposed system guarantees the soil moisture in a less hap hazard manner than at present and allows for the future management of the landscape.

For & on Behalf of
D.F.Dickson & Associates Pty Limited

D.F.Dickson BSc MS (q) MIEA CPEng (rtd) GSA NPER 2074820

Further documents and references used in preparation of this report are as follows:

1. Councils Preliminary Assessment DA1333/07 Letter dated 3 April 2008-06-09
2. IGGC letter Ref DJ00\LT163b 30 May 2008 - Review of interim hydro geological investigation 35 Water St Wahroonga (Ian Grey).
3. Tree Wise Men Australia Letter of 3 June 2008 and 11 June 2008 - Arboricultural Comments.
4. Vegetation Management Plan – UBM consulting
5. Hydraulic Services Report and Drainage Concept plan by LHO Group.
6. Geotechnical Report Douglas Partners Project 43905 June 2006
7. Eucalyptus Saligna Sm. Myrtaceae – Roger G. Skolmen 1974 USDA Forest Service research Note PSW288.
8. Leaf, tree and soil properties in a Eucalyptus saligna forest exhibiting canopy decline. Christine Stone and Jack Simpson. New South Wales Department of Primary Industries Science and Research, Beecroft, NSW 2119, AUSTRALIA.
9. Soil physical properties affecting root growth in rehabilitated gold mine tailings Selva Kumar Arunachalam, Christoph Hinz and Graham Aylmore School of Earth and Geographical Sciences, Faculty of Natural and Agricultural Sciences, The University of Western Australia.
10. Summary Report of the 1st IMAGE-TRAIN Advanced Study Course ”Innovative Groundwater Management Technologies” Held in Katowice (Poland) from June 24 – 28 2002
11. A Review of the Engineering Properties of the Wianamatta Group Shales William, E. and Airey, DW Proceedings of the 8th Australia New Zealand Conference
12. Engineering Geology of the Sydney Region Pells, PJN et al A.A. Balkema 1985
13. Porosity-permeability Relationships in Clay-bearing Fault Gouge B.R.Crawford, Exxon Mobil Upstream Research Company, R.D.Myers, Exxon Mobil Upstream Research Company, A.Woronow, Exxon Mobil Upstream Research Company, D.R.Faulkner, The University of Manchester and E.H.Rutter, The University of Manchester.
14. IGGC - Revised Modelling of Groundwater - Effect of Deep Soil and Trees in Final Landform. Lednez site Rhodes 12 September 2006 – Ian Grey Grundwater Consulting.
15. D.F.Dickson and Associates Interim Hydrogeology investigation report 13 May 2008.
16. D.F.Dickson and Associates Interim Hydrogeology investigation report 12 June 2008.
17. LWA Groundwater dependent ecosystems SKP2 1996-1997
18. SCCG Groundwater Management Handbook - 2006



Konsistenzen
- jointed
- plastic
- semiliq. - plastic

Well type : Stand pipe piesometer 800mm slotted screen

Drawn/Engnr : dfd

Project : Rippon Grange 35 Water st
Drawing Title : BH1 installation
Scales : Horz = 1 : 50 Vert = 1 : 100

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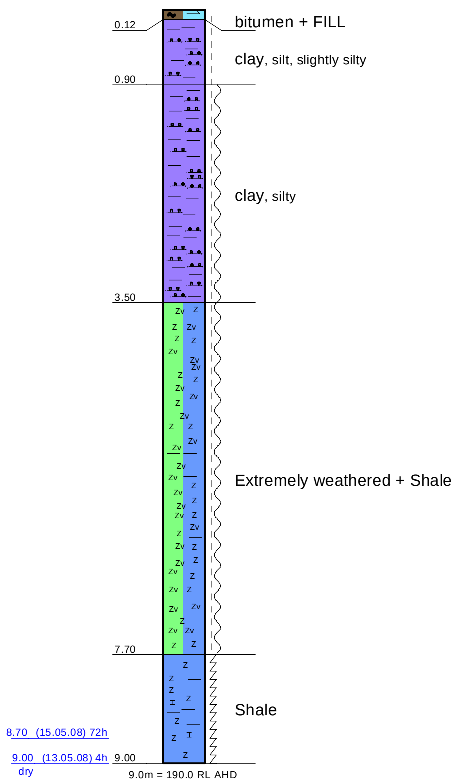
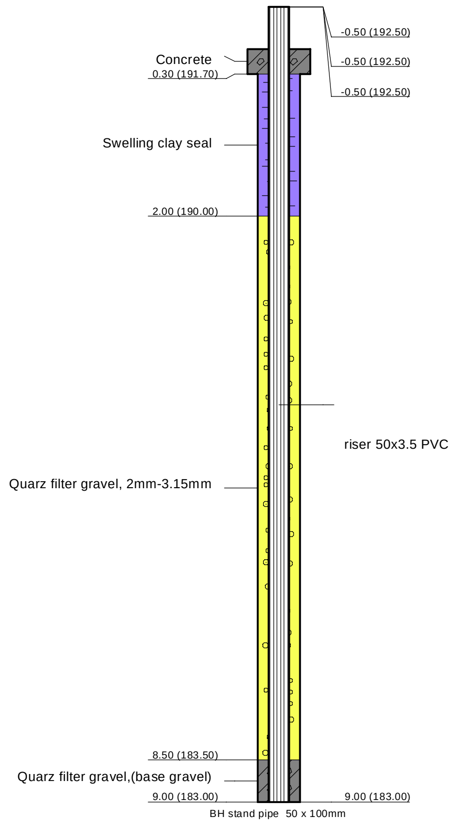
P BH2

192.0 m RL



P BH2

192.0 m RL



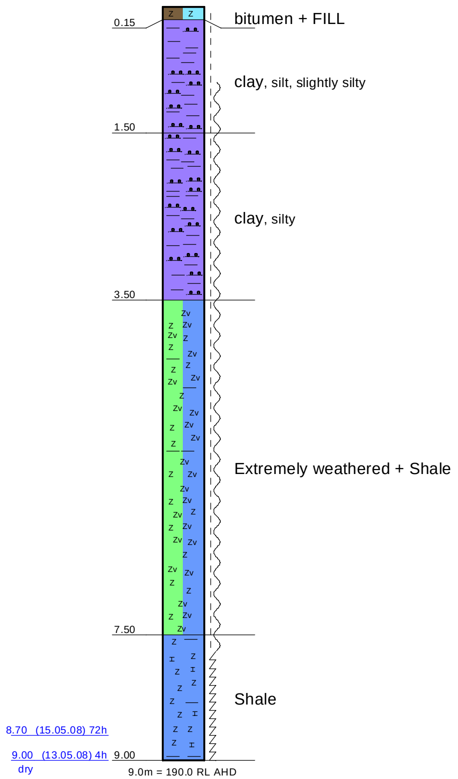
Konsistenzen
- jointed
- plastic
- semiliq. - plastic

Well type : Stand pipe piesometer 800mm slotted screen

Drawn/Engnr : dfd	Project : Rippon Grange 35 Water st Drawing Title : BH2 installation Scales : Horz = 1 : 50 Vert = 1 : 100	DFDickson and Associates Pty. Ltd. ABN 32 098 813 462 ph : 99978778 fax : 99972130 welltone@nbeaches.com.au

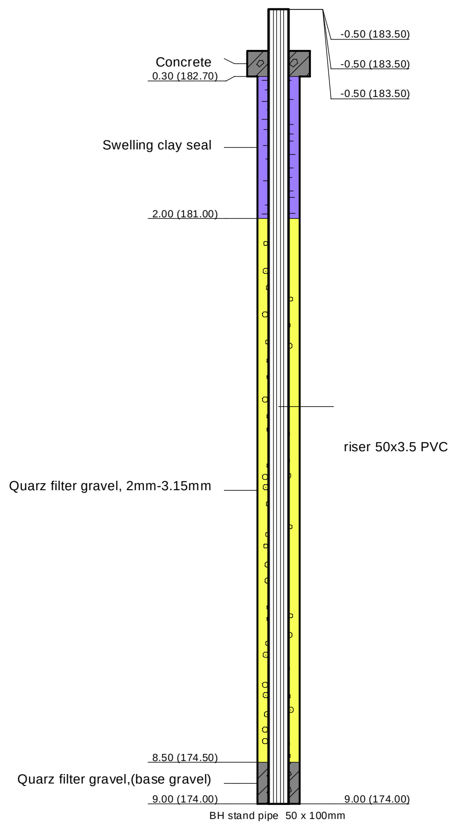
P BH3

183.0 m RL



P BH3

183.0 m RL

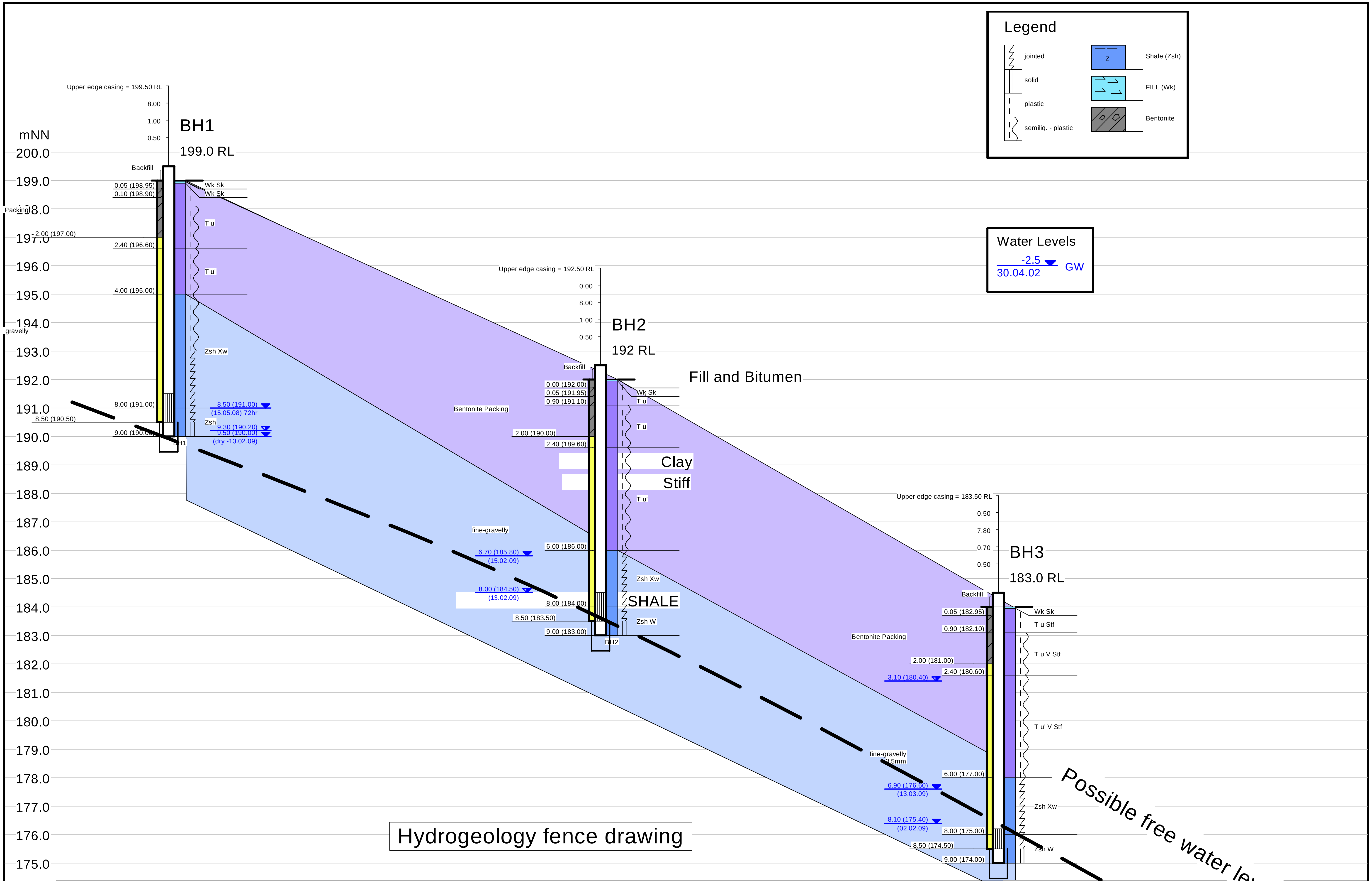


Konsistenzen

- jointed
- plastic
- semiliq. - plastic

Well type : Stand pipe piesometer 800mm slotted screen

Drawn/Engnr : dfd	Project : Rippon Grange 35 Water st Drawing Title : BH3 installation Scales : Horz = 1 : 50 Vert = 1 : 100	DFDickson and Associates Pty. Ltd. ABN 32 098 813 462 ph : 99978778 fax : 99972130 welltone@nbeaches.com.au



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Date: 20/02/2009
Time: 8:25:14 AM

Drawn/Engnr : DFD

Project : RIPPON GRANGE HOSPITAL
Drawing Title : HYDROLOGY INSTALLATION

Scales : Horz = 1 : 120 Vert = 1 : 600

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