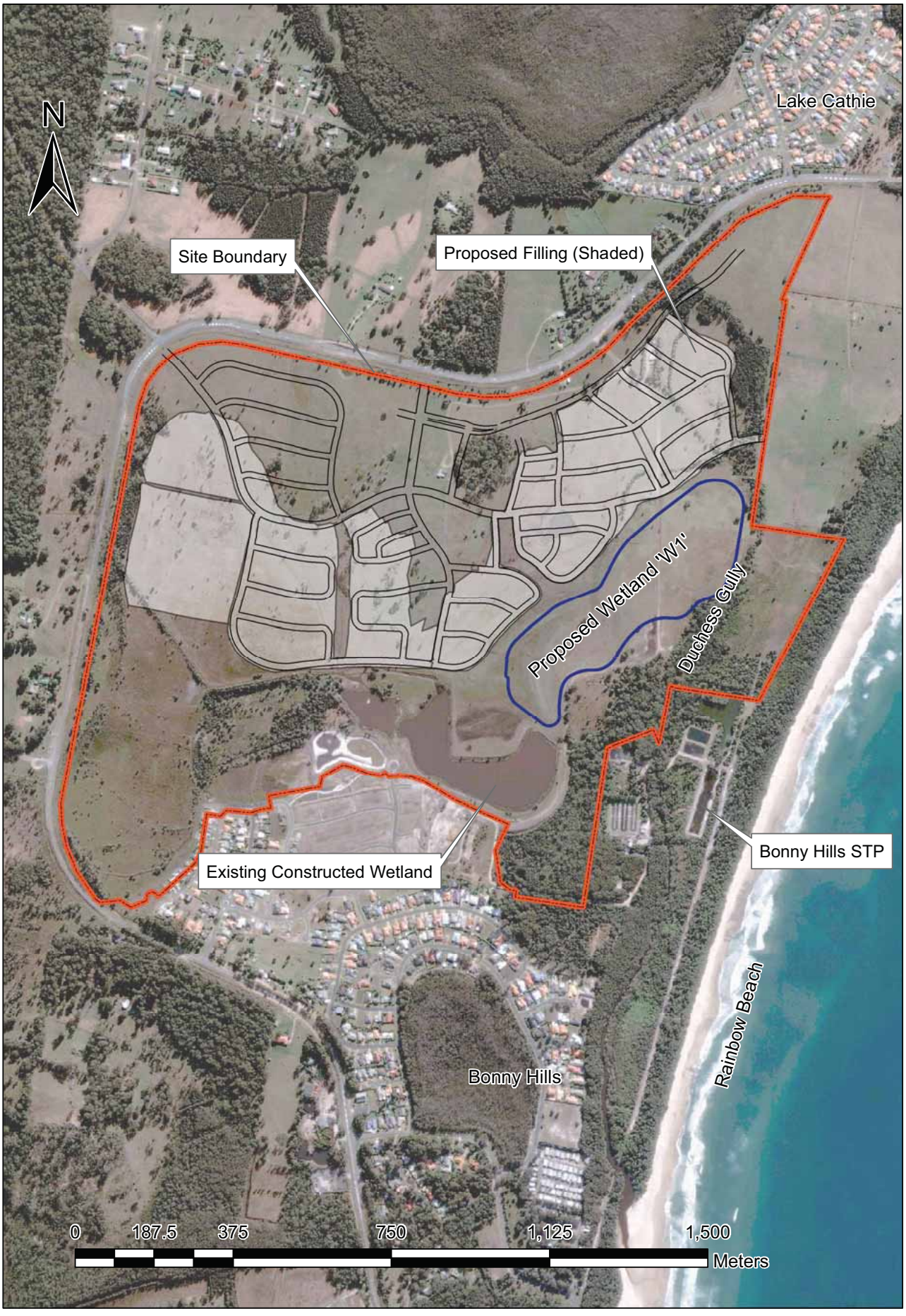
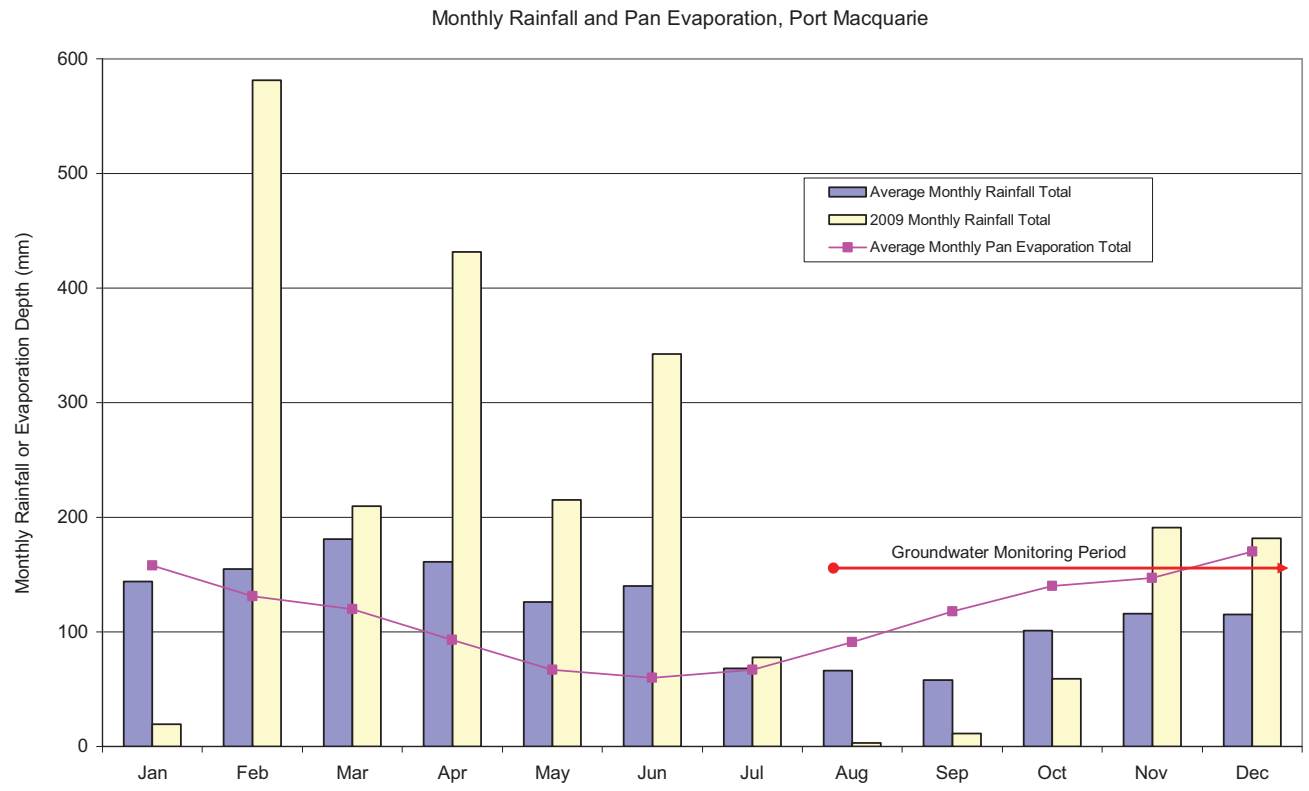
WRL Report No. 2009/32	SITE LOCATION	Figure 1 insert filename

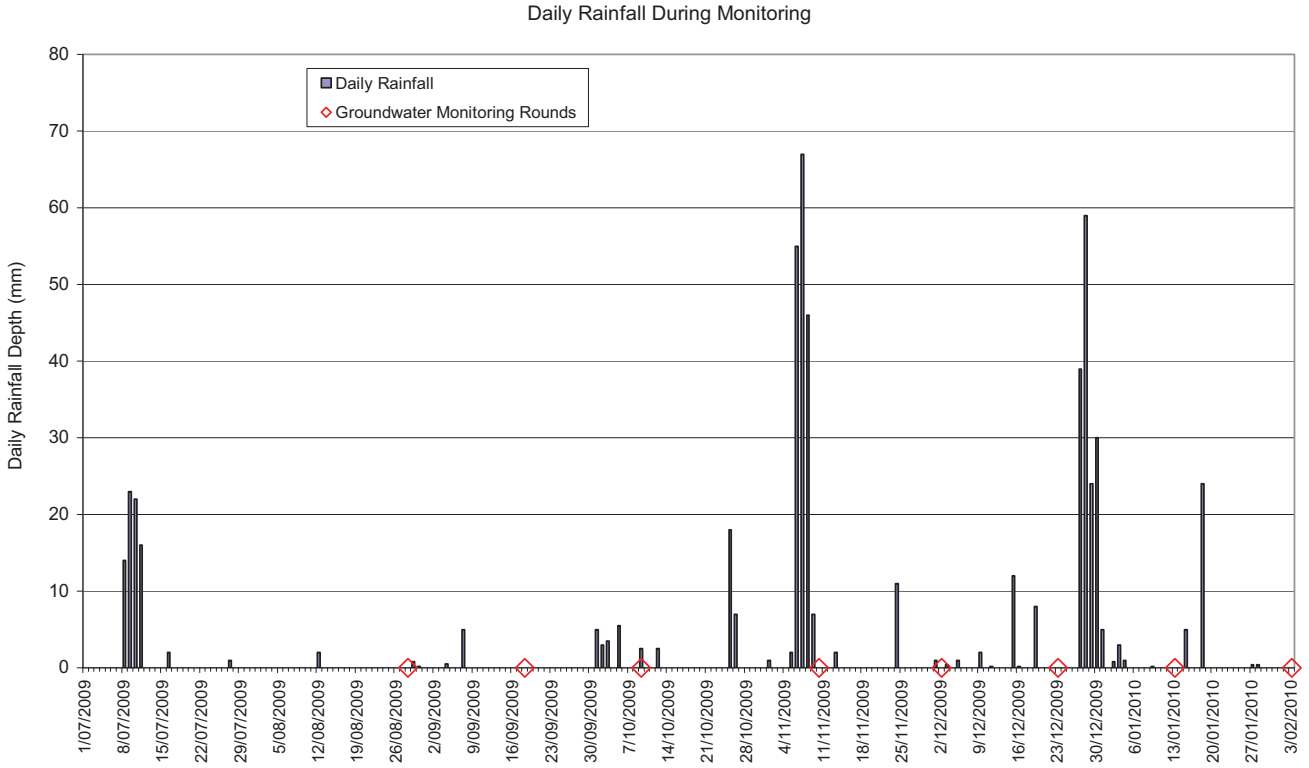
WRL Report No. 2009/32	OVERVIEW OF EXISTING SITE	Figure 2 insert filename



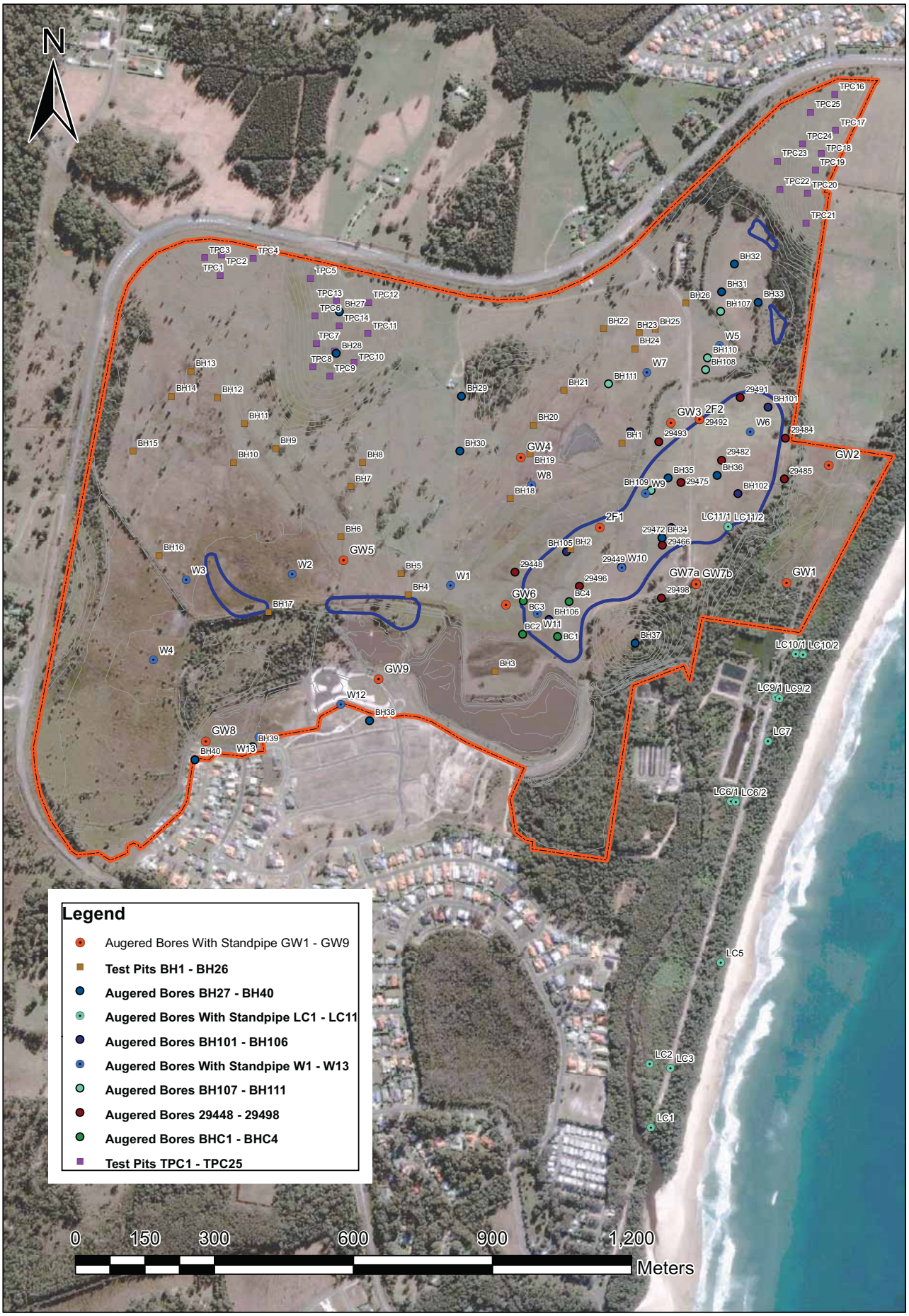
WRL Report No. 2009/32	OVERVIEW OF CONCEPT PLAN FOR THE SITE	Figure 3 insert filename

WRL Report No. 2009/32	SURFACE WATER FEATURES	Figure 4 insert filename



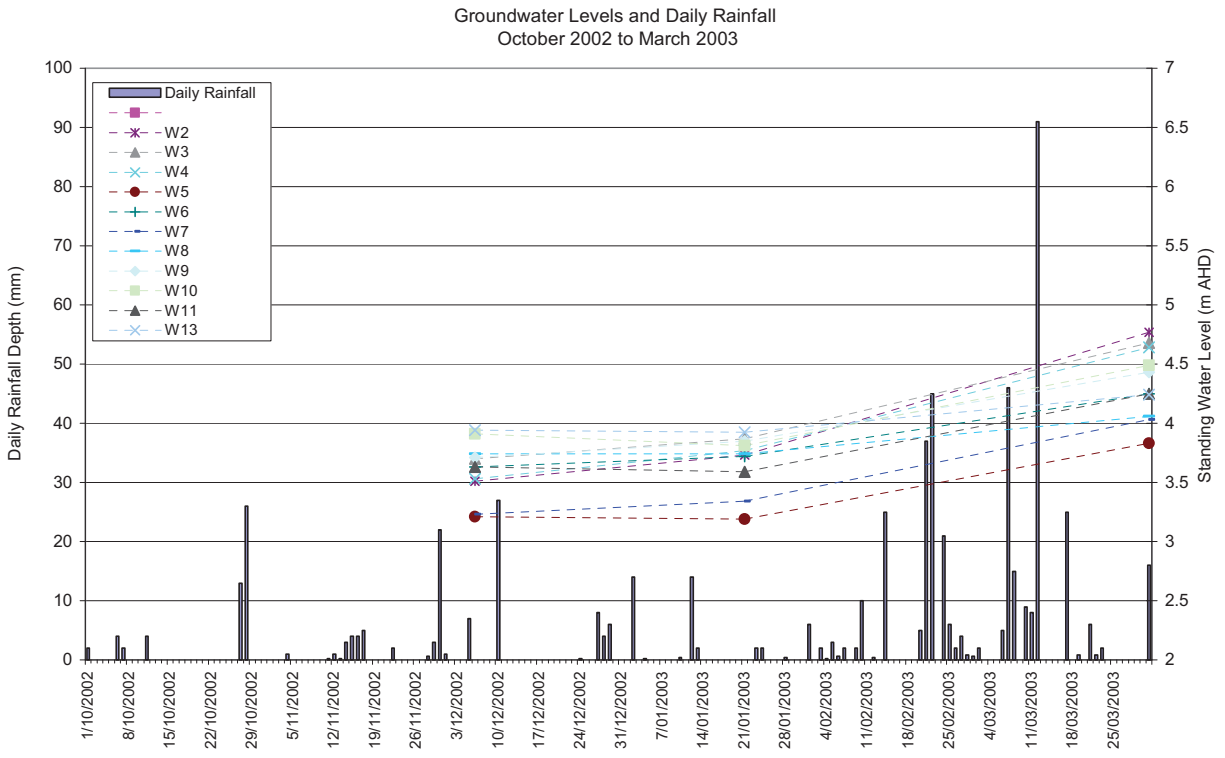


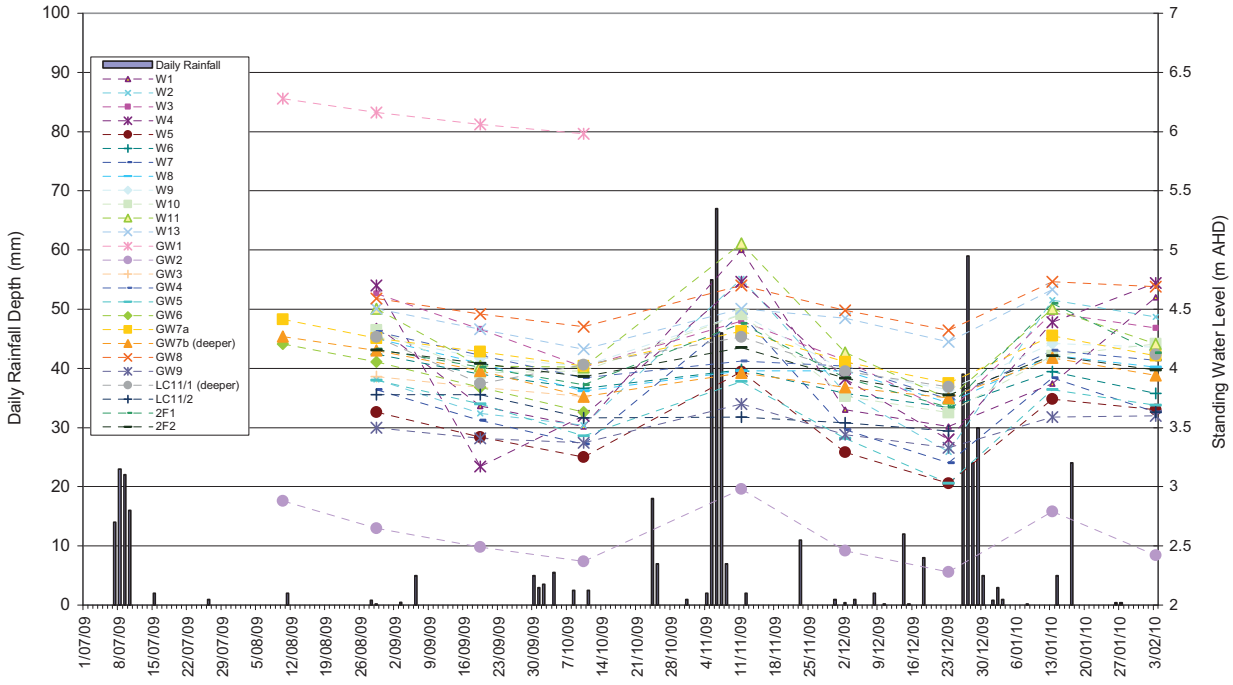
WRL Report No. 2009/32	RAINFALL AND EVAPORATION	Figure 5



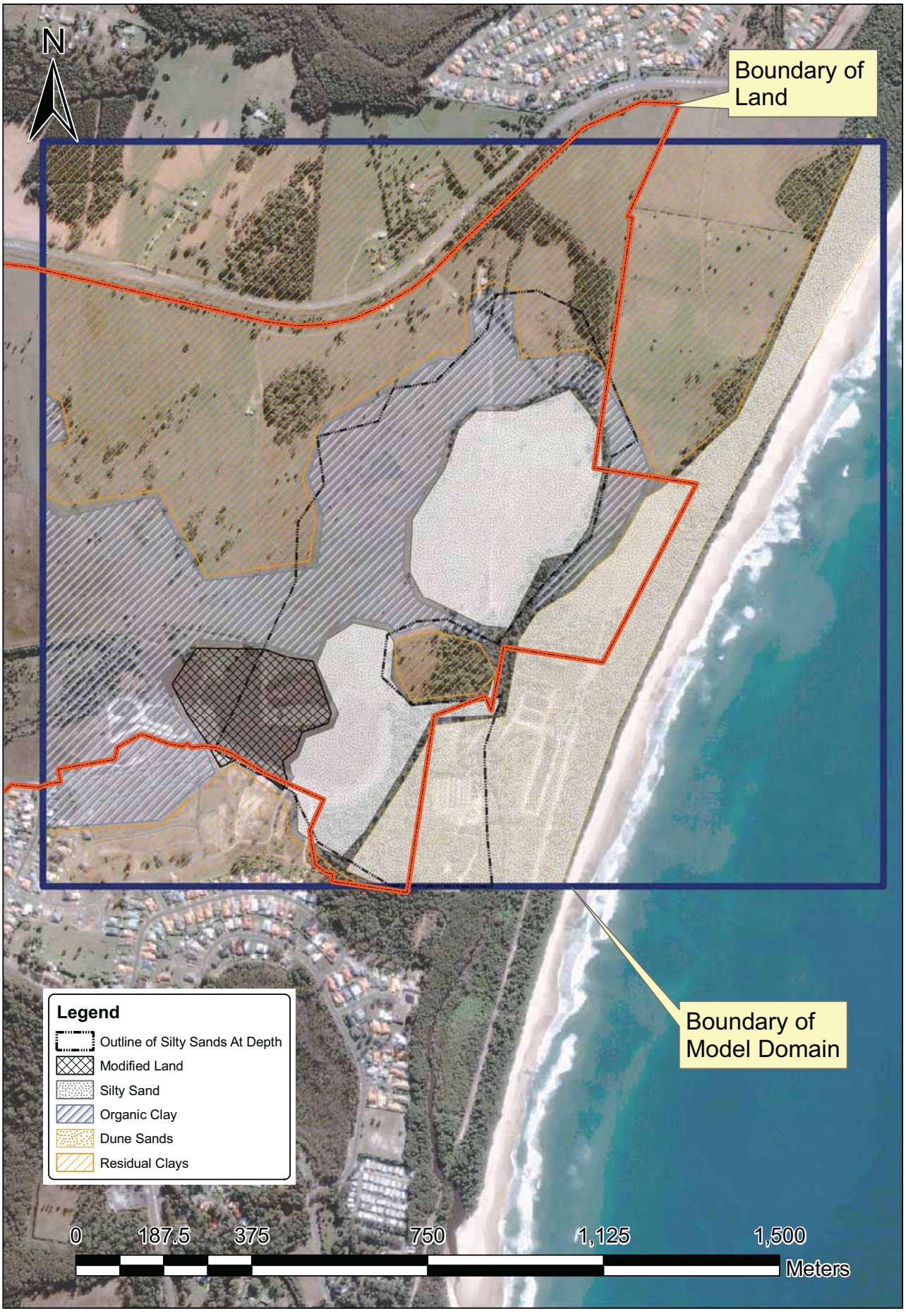
WRL Report No. 2009/32	LOCATIONS OF SITE GROUND INVESTIGATIONS	Figure 6 insert filename

WRL Report No. 2009/32	GROUNDWATER AND SURFACE WATER MONITORING LOCATIONS	Figure 7 insert filename

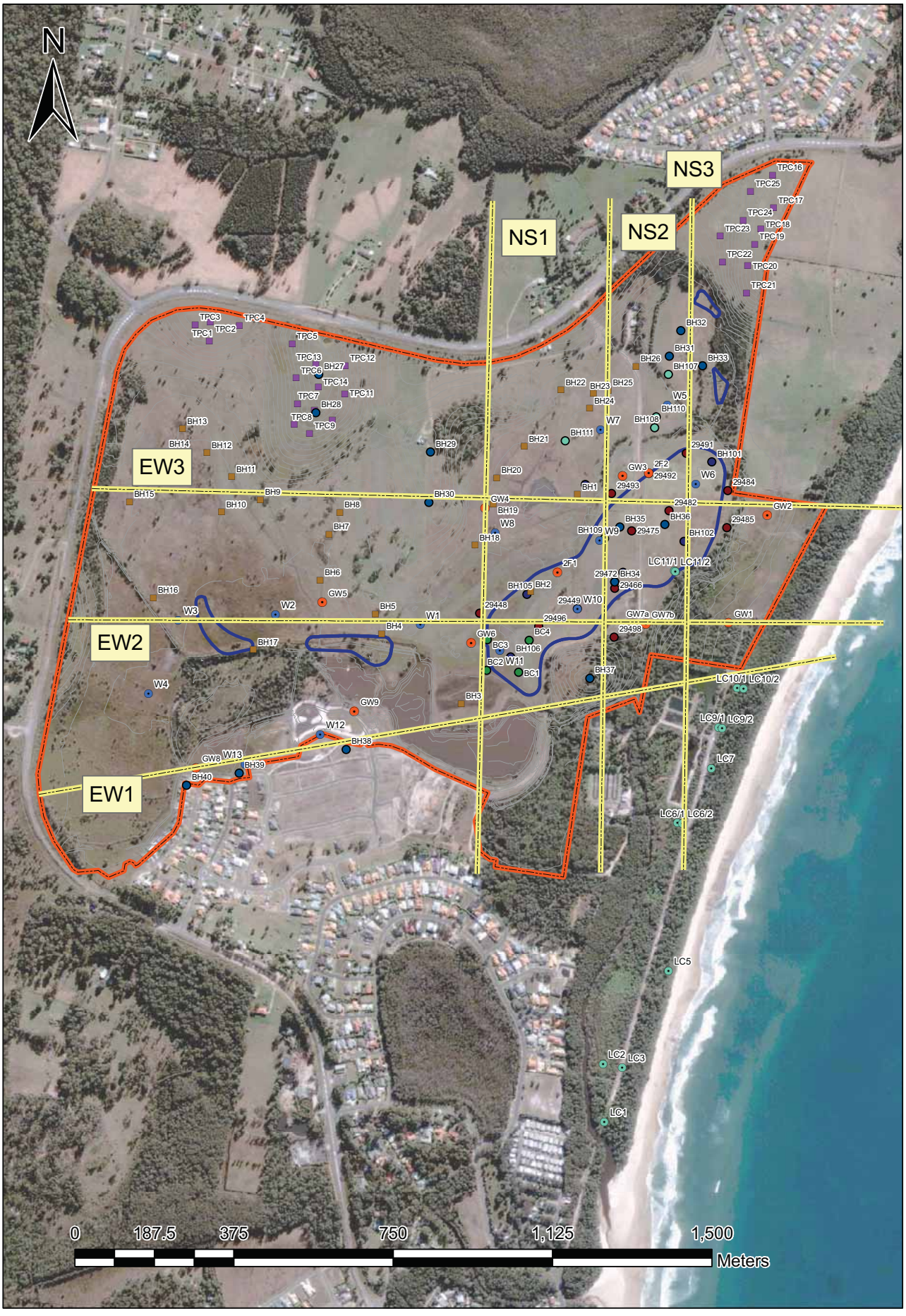




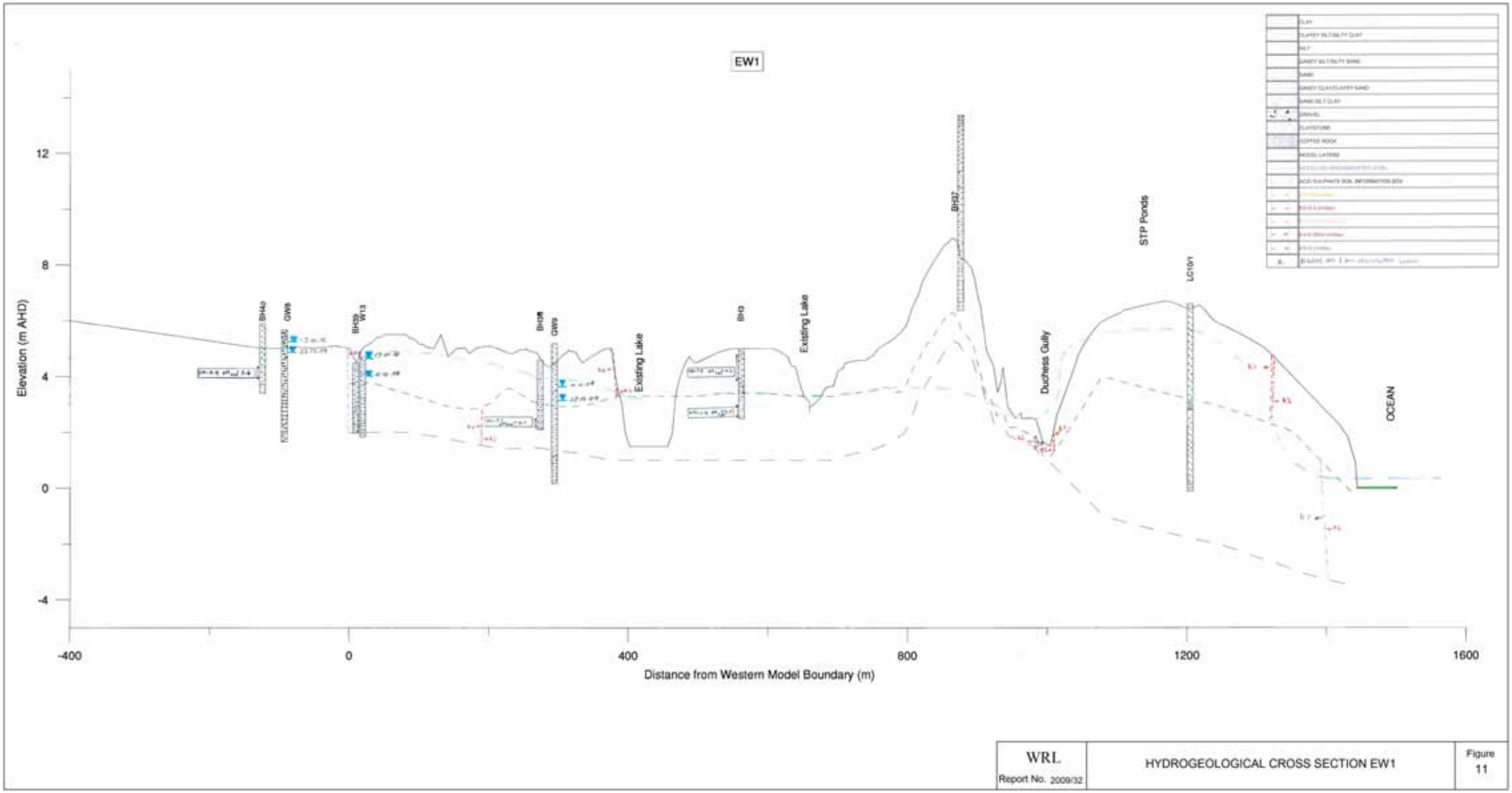
WRL Report No. 2009/32	RECORDED GROUNDWATER LEVELS	Figure 8



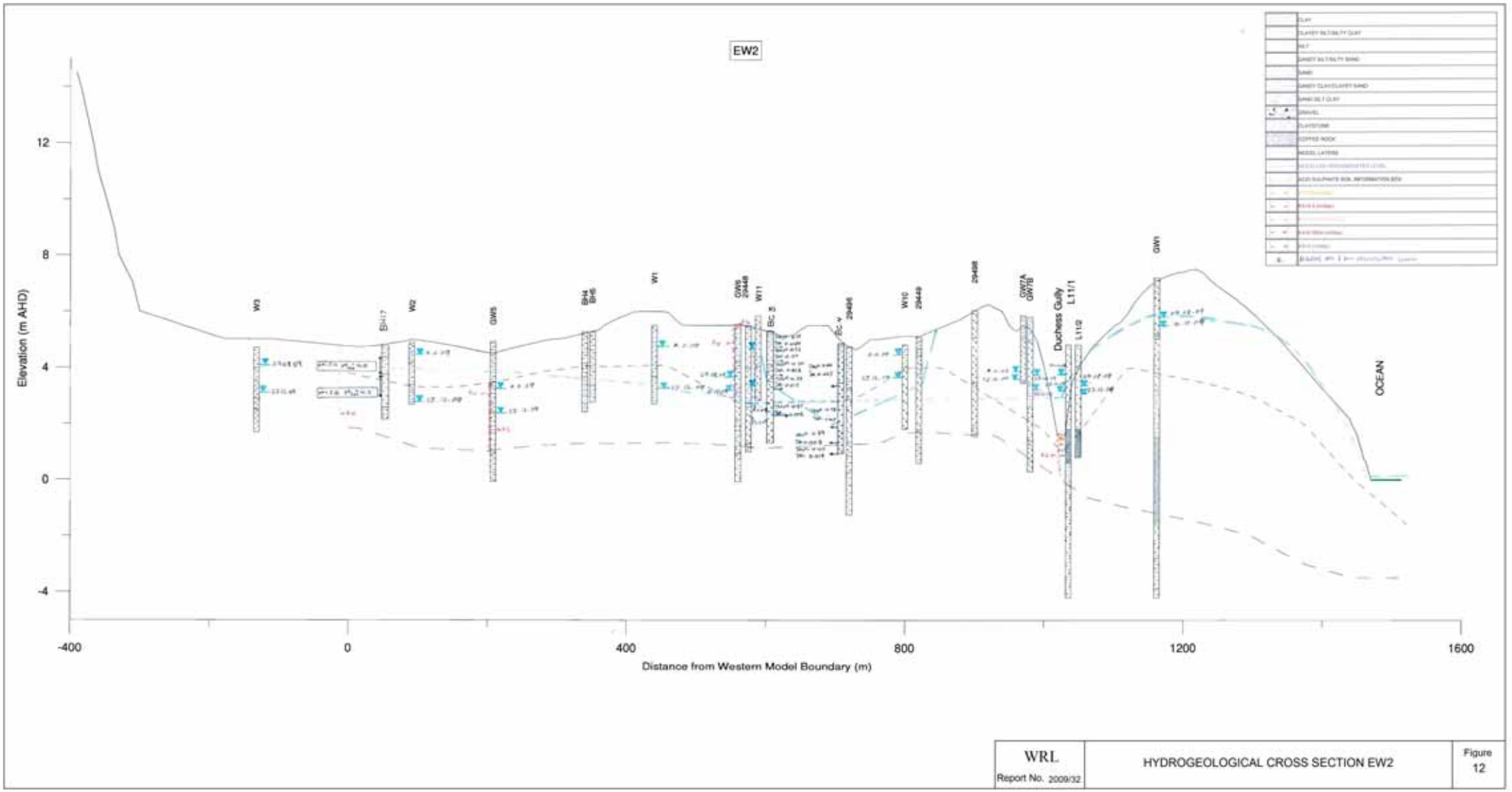
WRL Report No. 2009/32	GEOLOGICAL UNITS FOUND AT THE SURFACE	Figure 9 insert filename



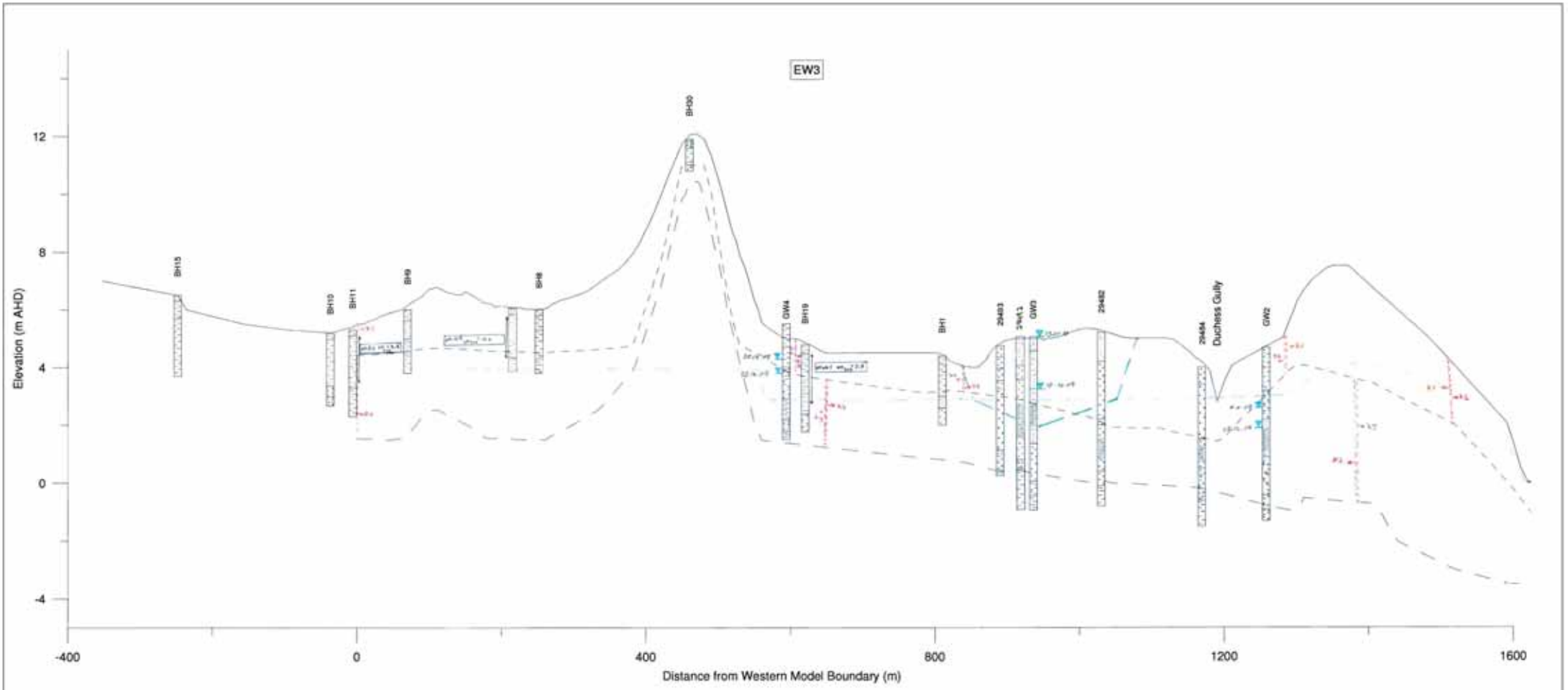
WRL Report No. 2009/32	ORIENTATION OF HYDROGEOLOGICAL CROSS SECTIONS	Figure 10 insert filename



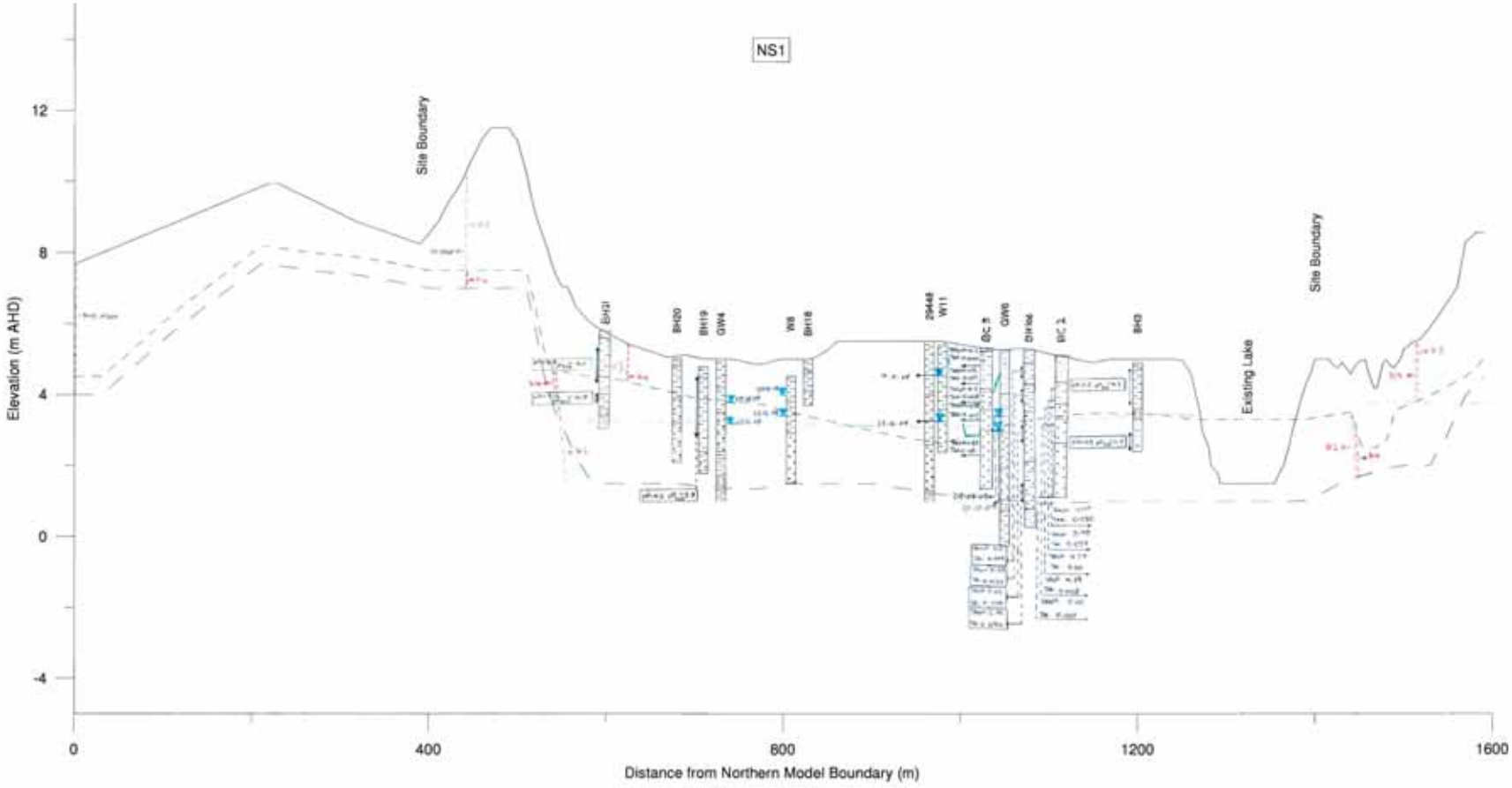
WRL Report No. 2009/32	HYDROGEOLOGICAL CROSS SECTION EW1	Figure 11



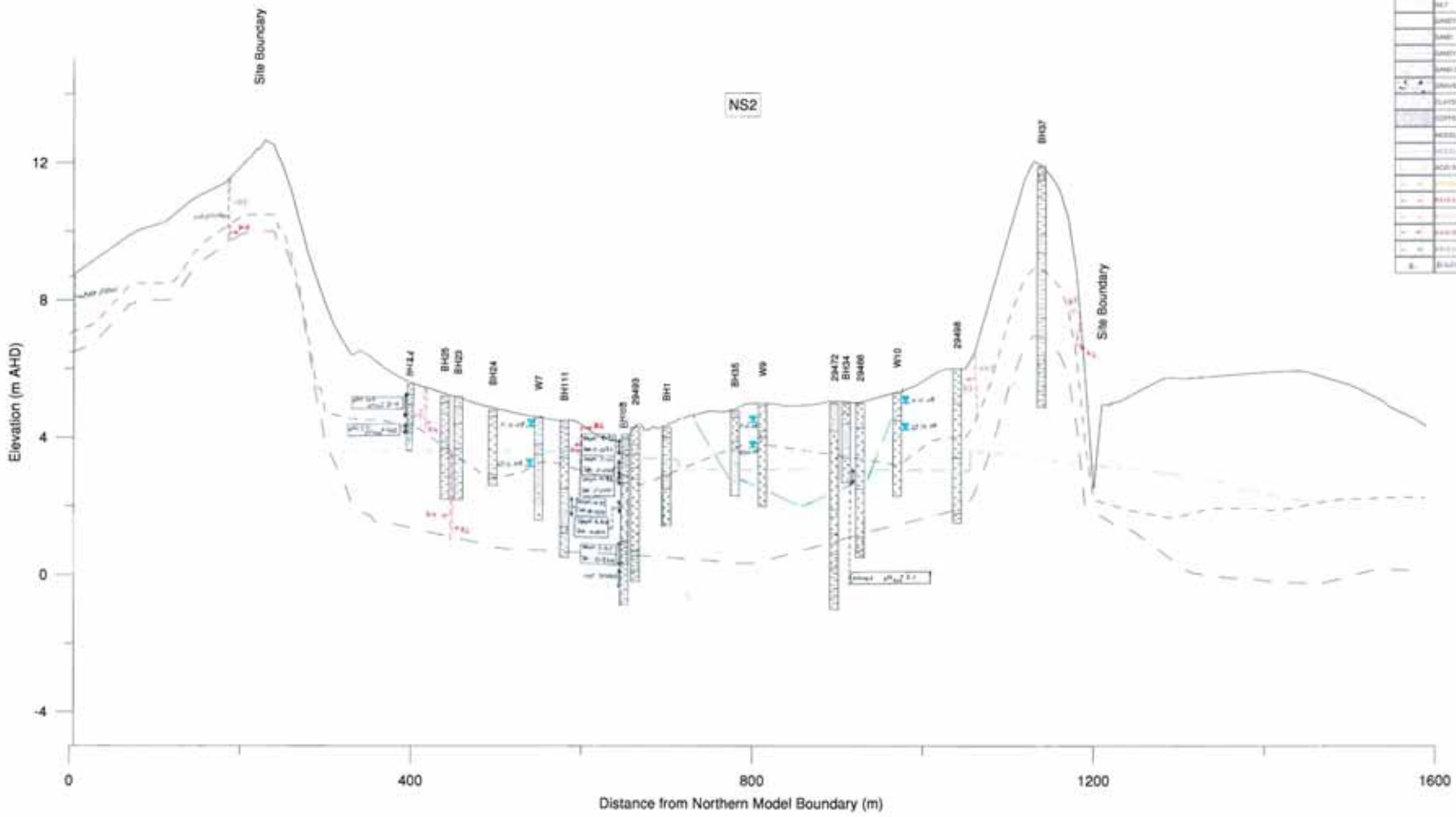
WRL	HYDROGEOLOGICAL CROSS SECTION EW2	Figure
Report No. 2009/32		12



WRL Report No. 2009/32	HYDROGEOLOGICAL CROSS SECTION EW1	Figure 13

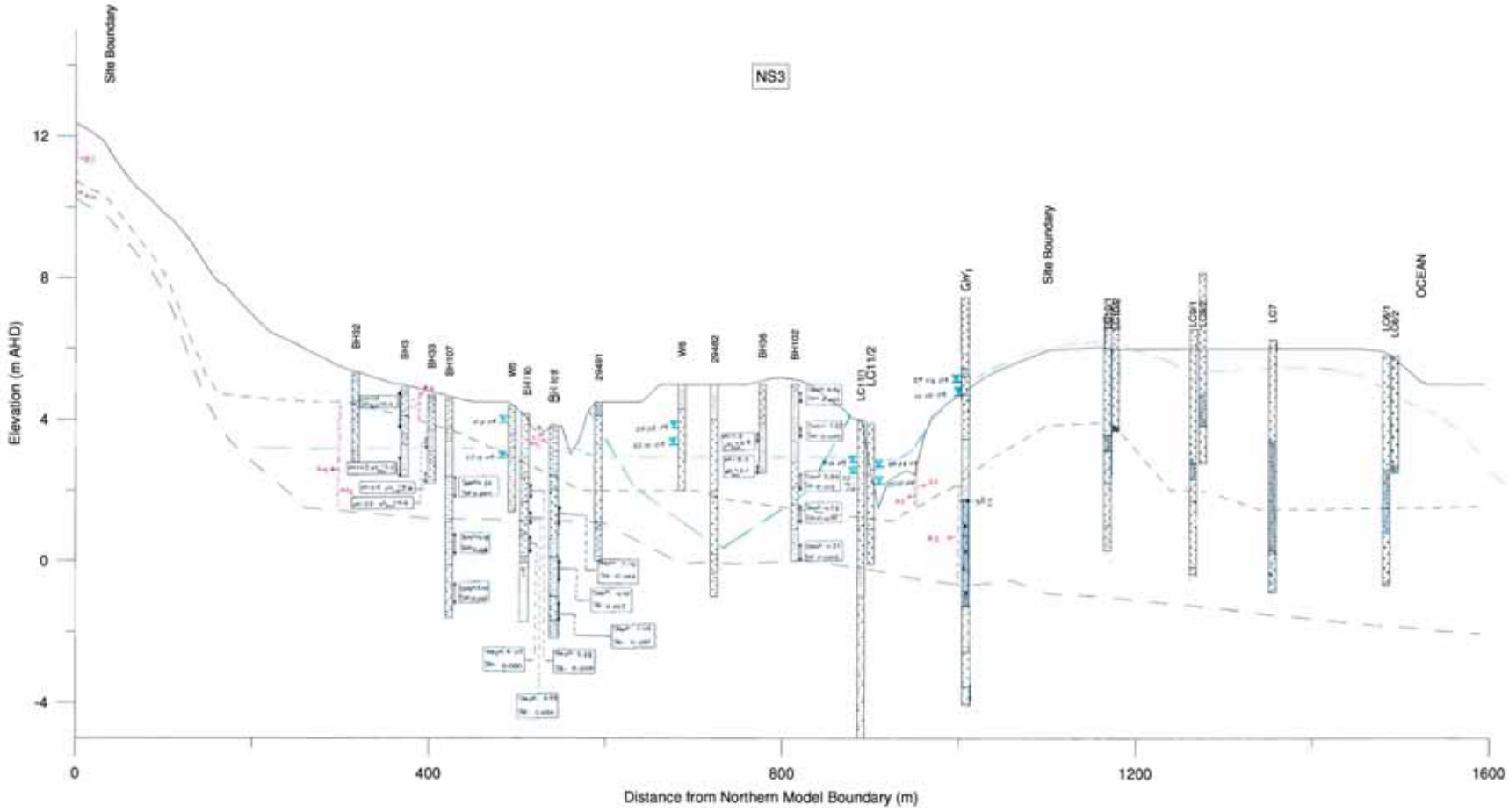


WRL Report No. 2009/32	HYDROGEOLOGICAL CROSS SECTION NS1	Figure 14



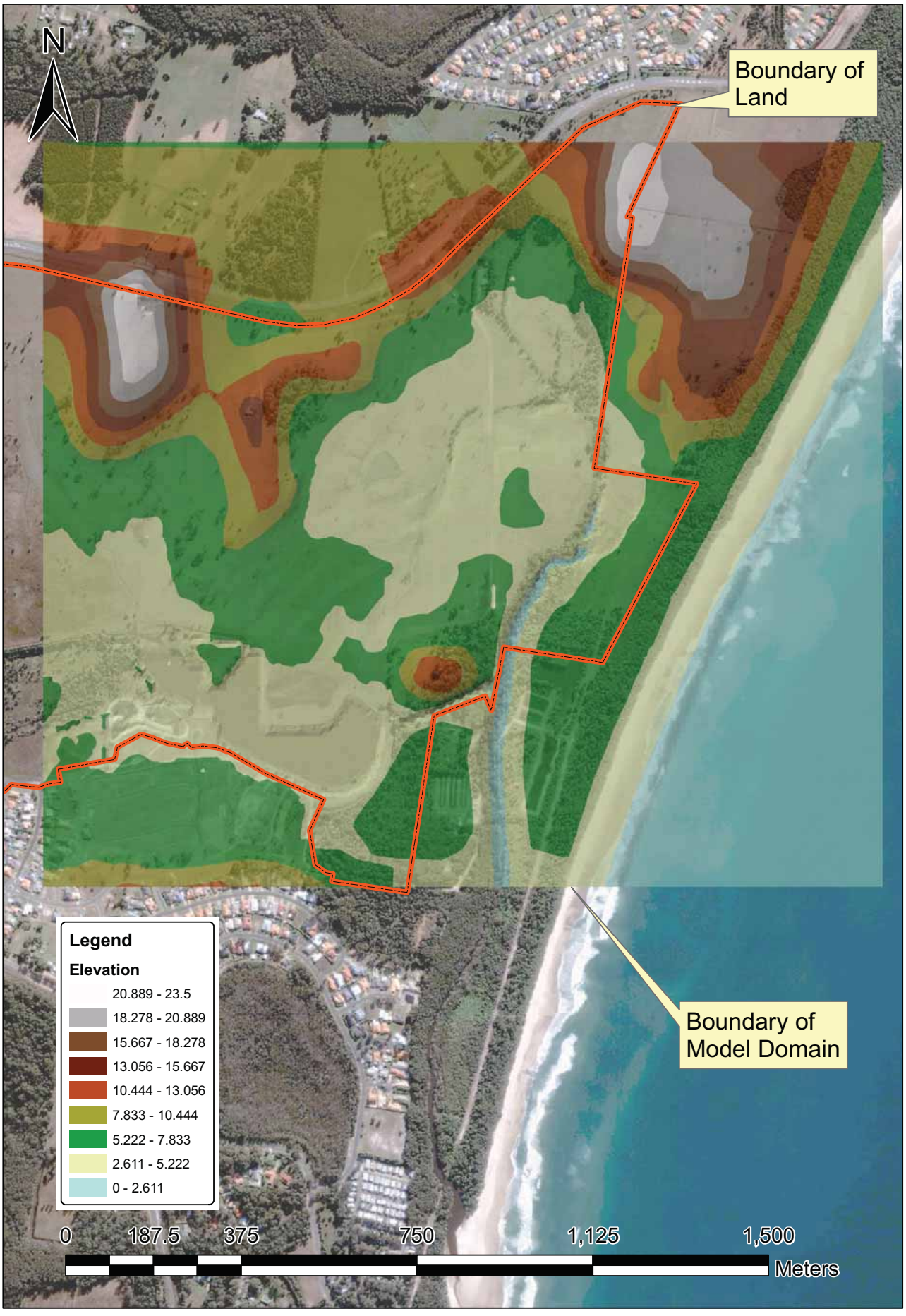
WRL Report No. 2009/32	HYDROGEOLOGICAL CROSS SECTION NS2

Figure 15

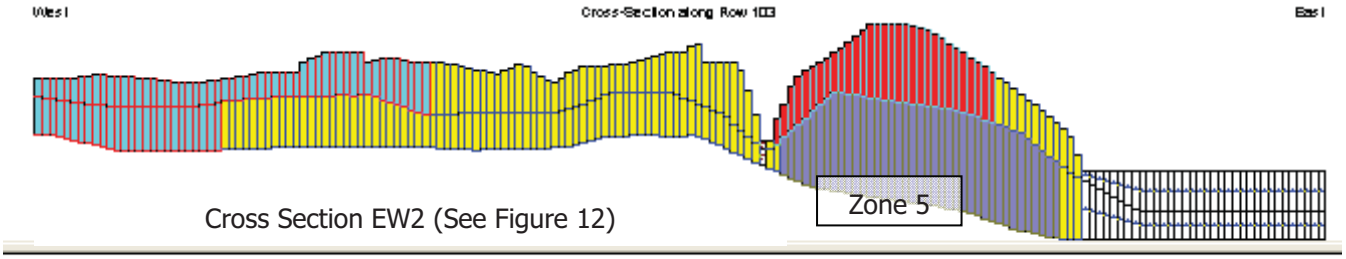


WRL Report No. 2009/32	HYDROGEOLOGICAL CROSS SECTION NS3	Figure 16

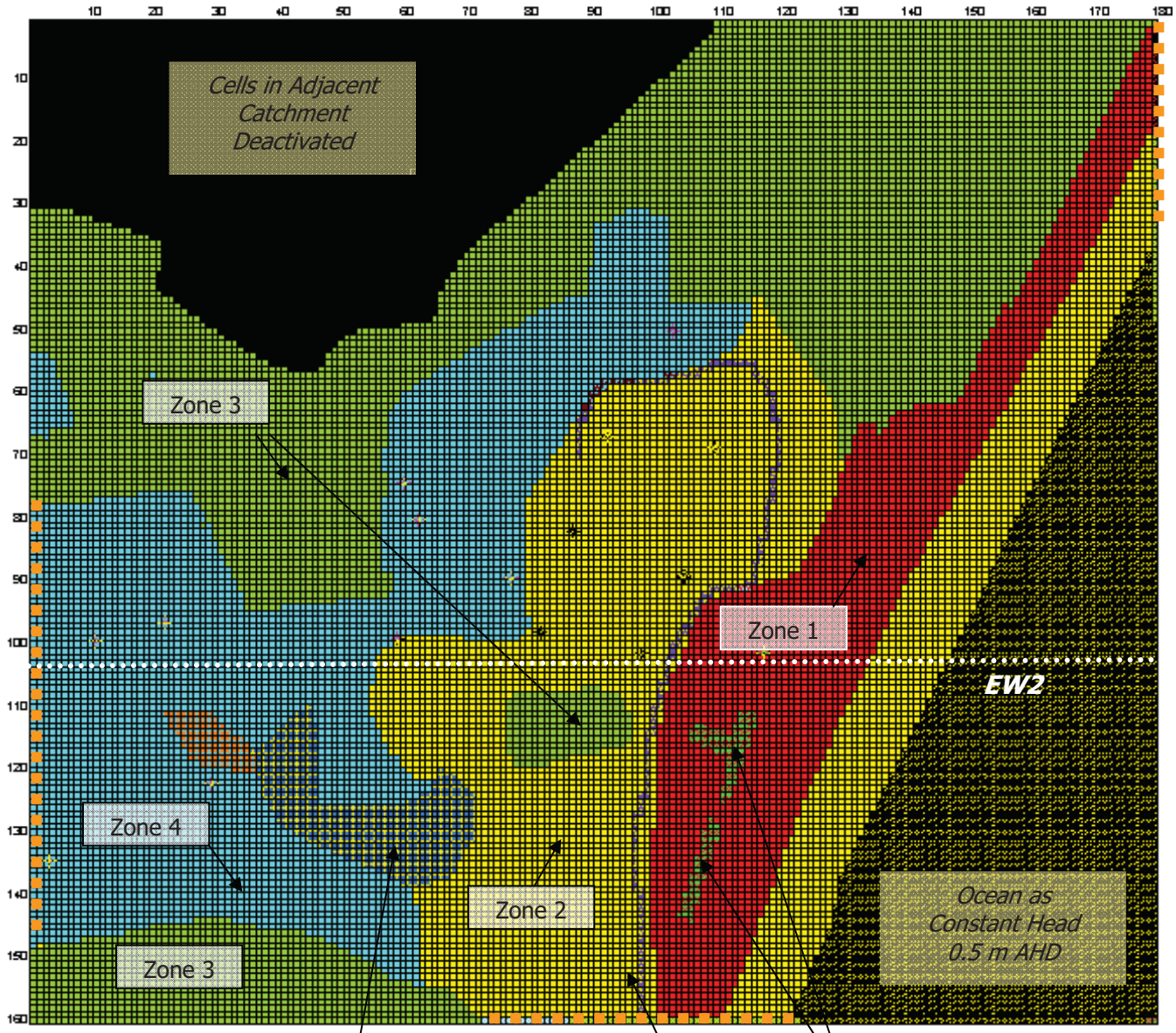
WRL Report No. 2009/32	RECORDED GROUNDWATER LEVELS AUGUST 2009	Figure 17 insert filename



WRL Report No. 2009/32	GROUNDWATER MODEL DOMAIN AND SURFACE TOPOGRAPHY	Figure 18 insert filename

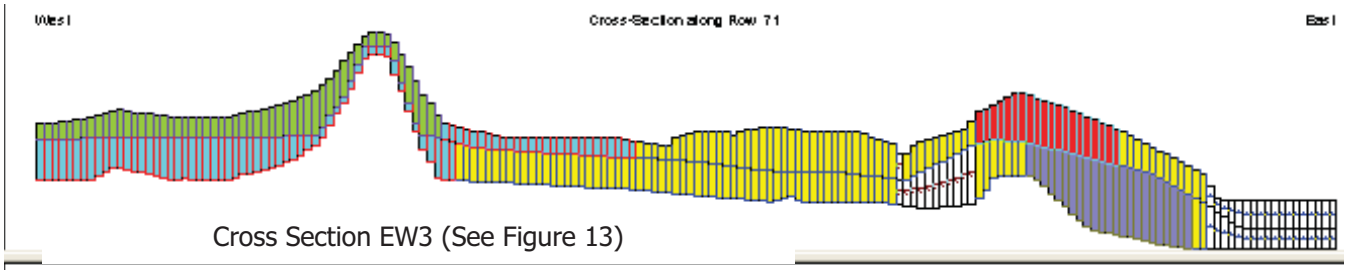


Cross Section EW2 (See Figure 12)

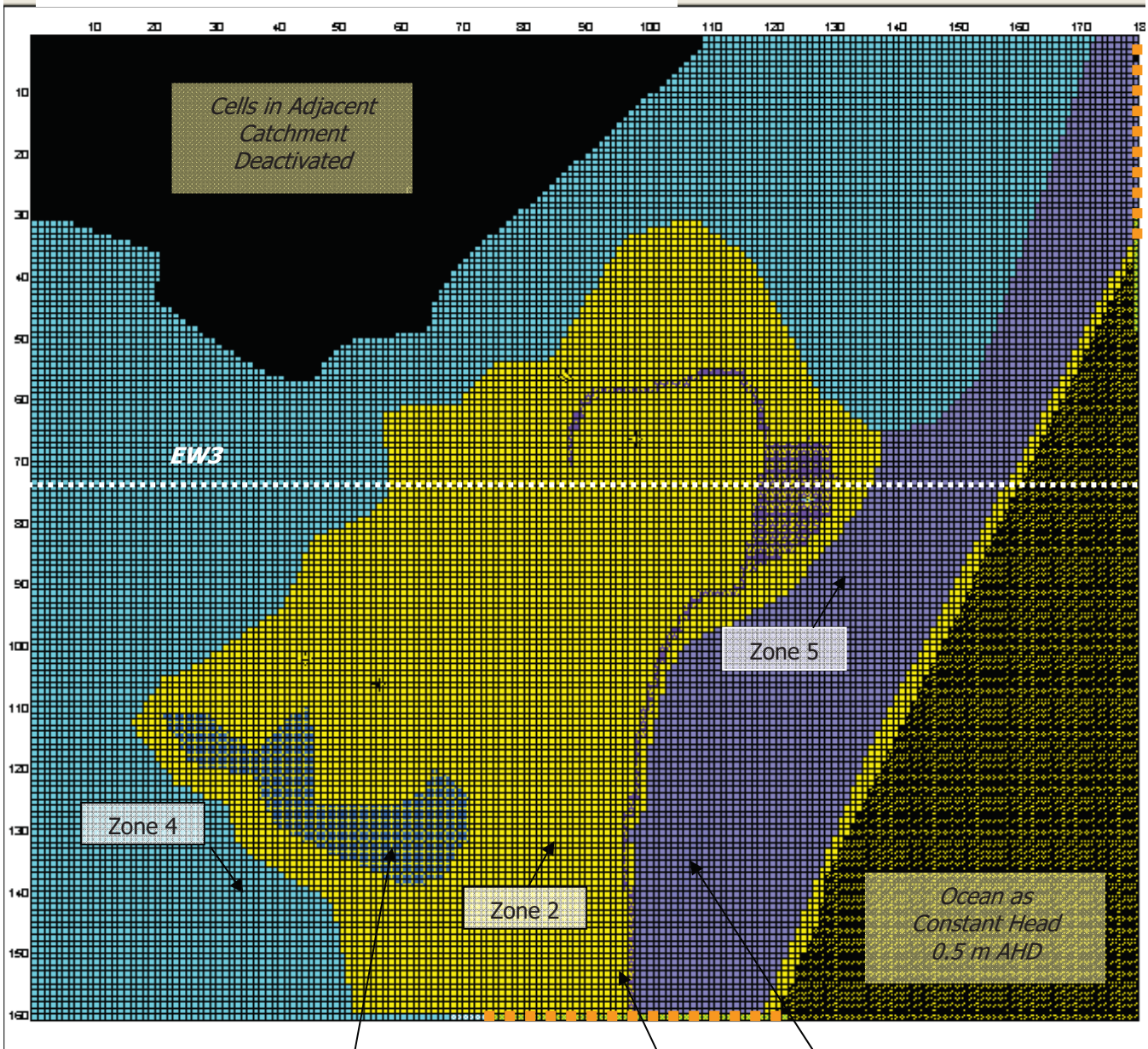


Dashed Orange Line Denotes General Head Boundary. (All other perimeters use no flow boundary)

WRL Report No. 2002/32	MODFLOW MODEL CONCEPTUALISATION LAYER 1	Figure 19



Cross Section EW3 (See Figure 13)



Dashed Orange Line Denotes General Head Boundary.
(All other perimeters use no flow boundary)

WRL Report No. 2002/32	MODFLOW MODEL CONCEPTUALISATION LAYER 2	Figure 20

WRL Report No. 2009/32	STEADY STATE SIMULATION OF EXISTING CONDITIONS REPRESENTING MEDIAN GROUNDWATER LEVELS	Figure 21 insert filename

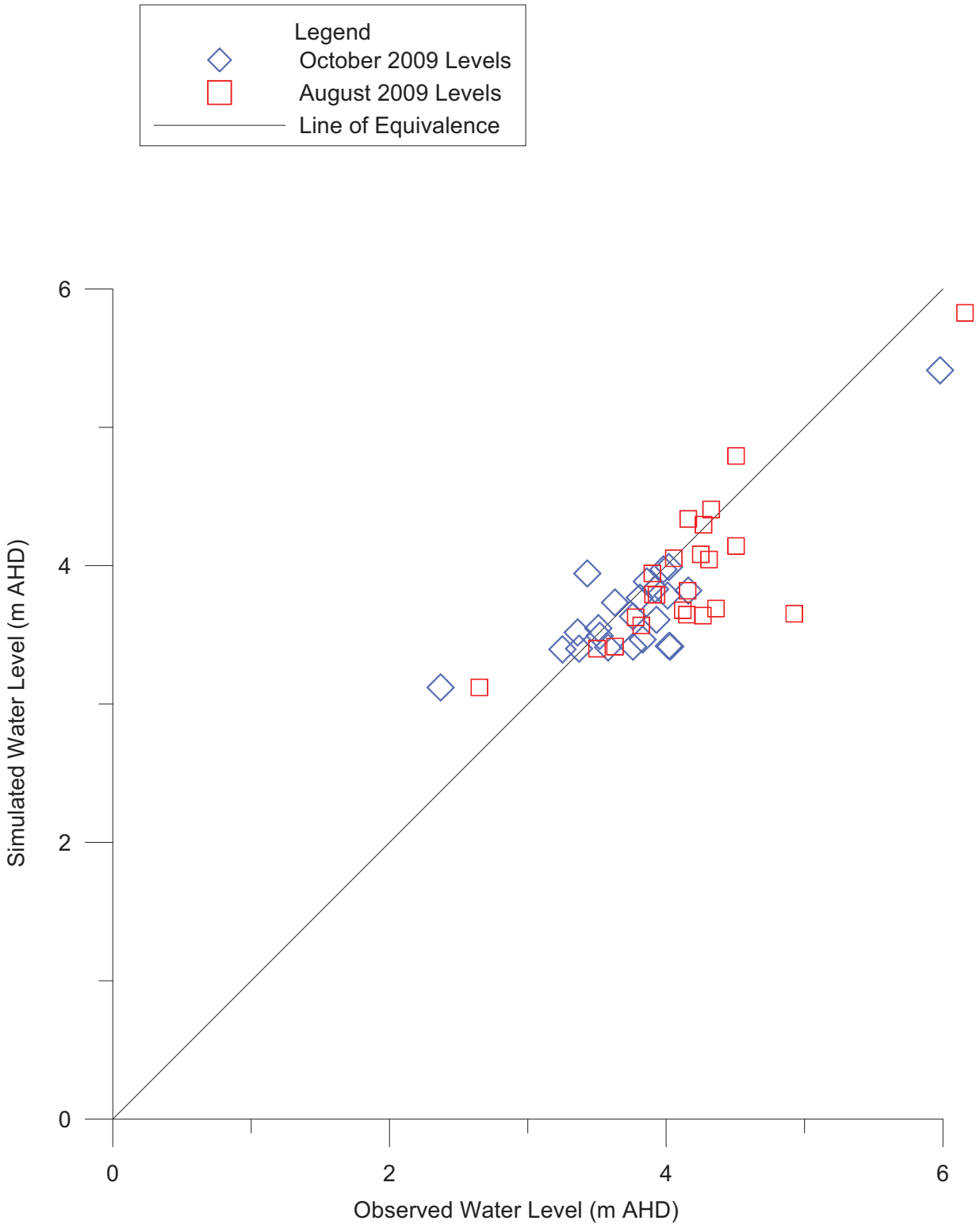
WRL
Report No. 2009/32

STEADY STATE SIMULATION OF EXISTING CONDITIONS REPRESENTING LOW GROUNDWATER LEVELS

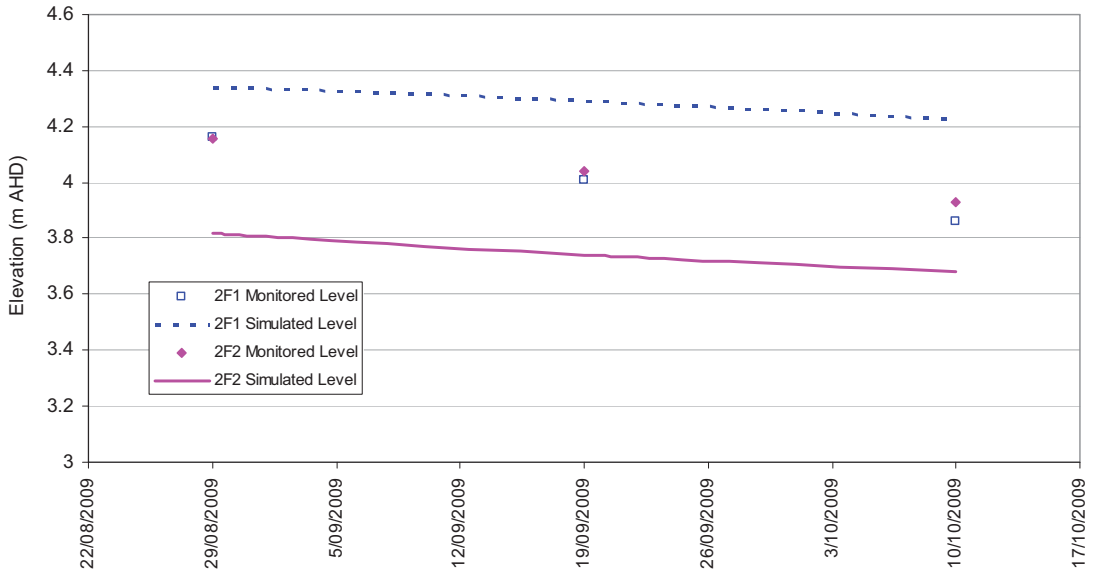
Figure 22

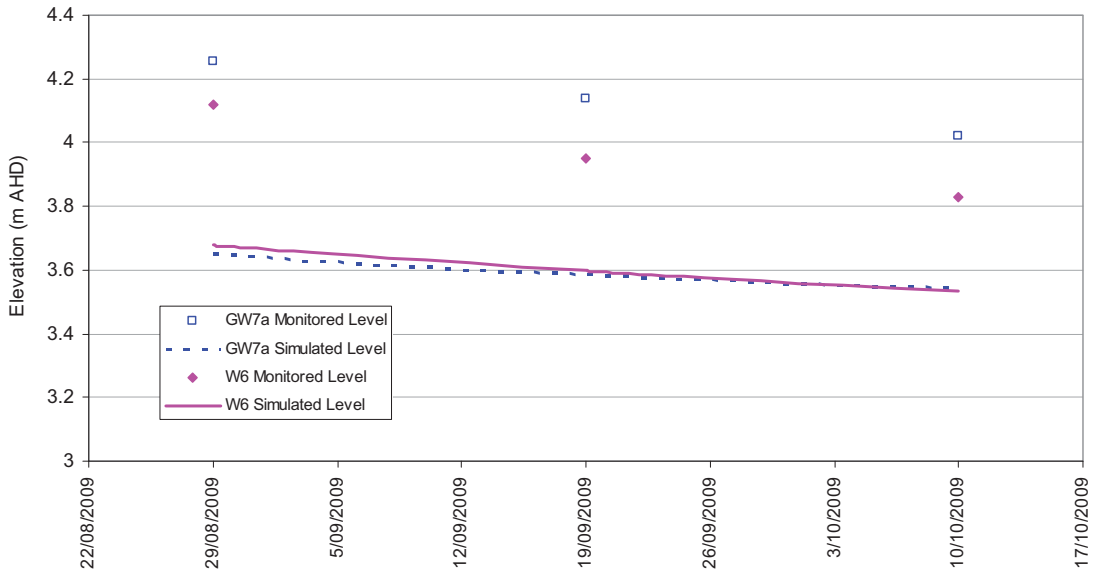
insert filename

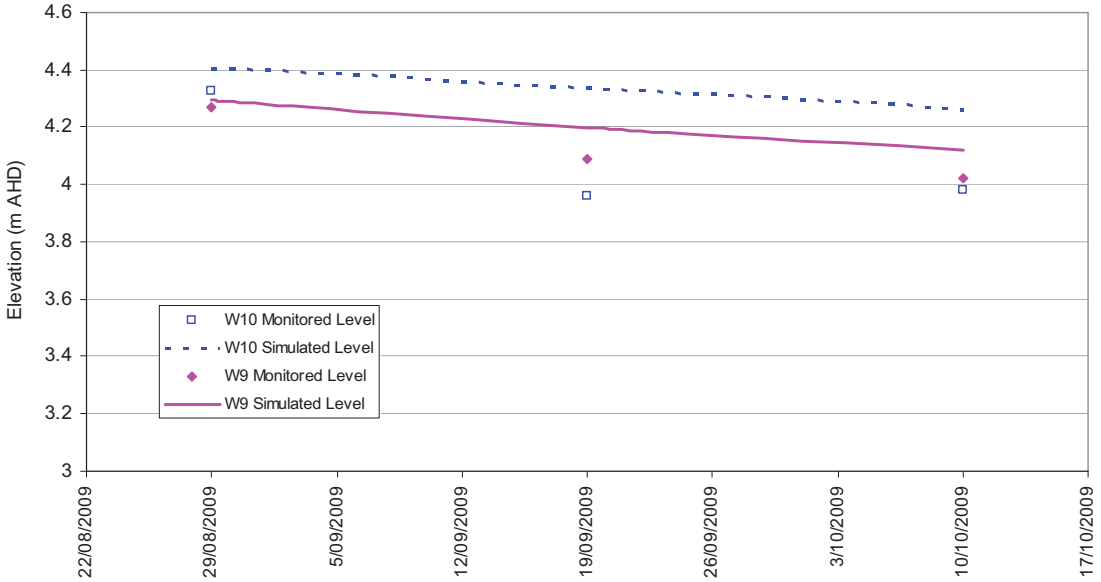
WRL Report No. 2009/32	STEADY STATE SIMULATION OF EXISTING CONDITIONS REPRESENTING HIGH GROUNDWATER LEVELS	Figure 23 insert filename



WRL Report No. 2009/32	STEADY STATE CALIBRATION	Figure 24





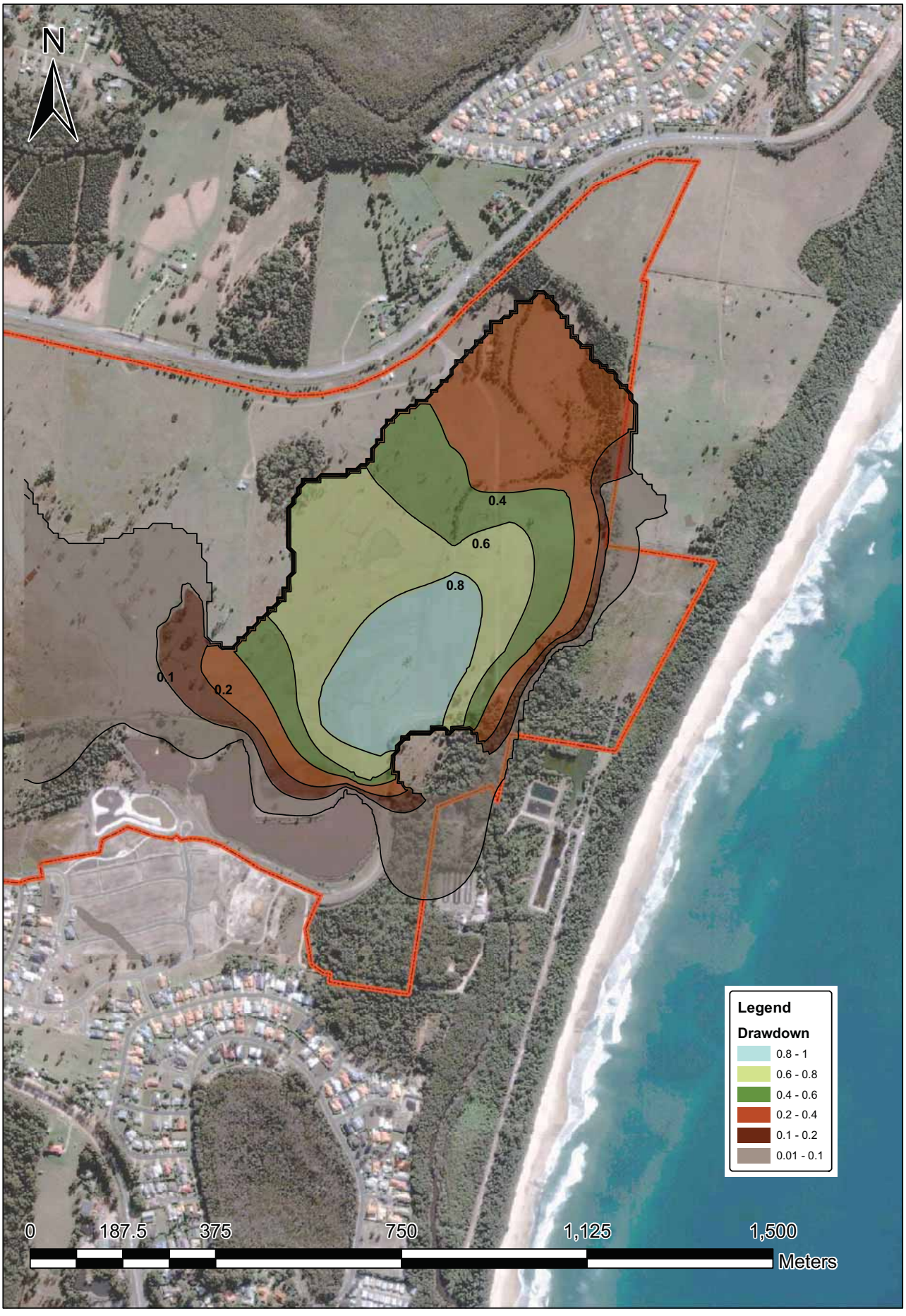


WRL Report No. 2009/32	TRANSIENT VALIDATION AGAINST MONITORING PERIOD SELECTED BORES	Figure 25

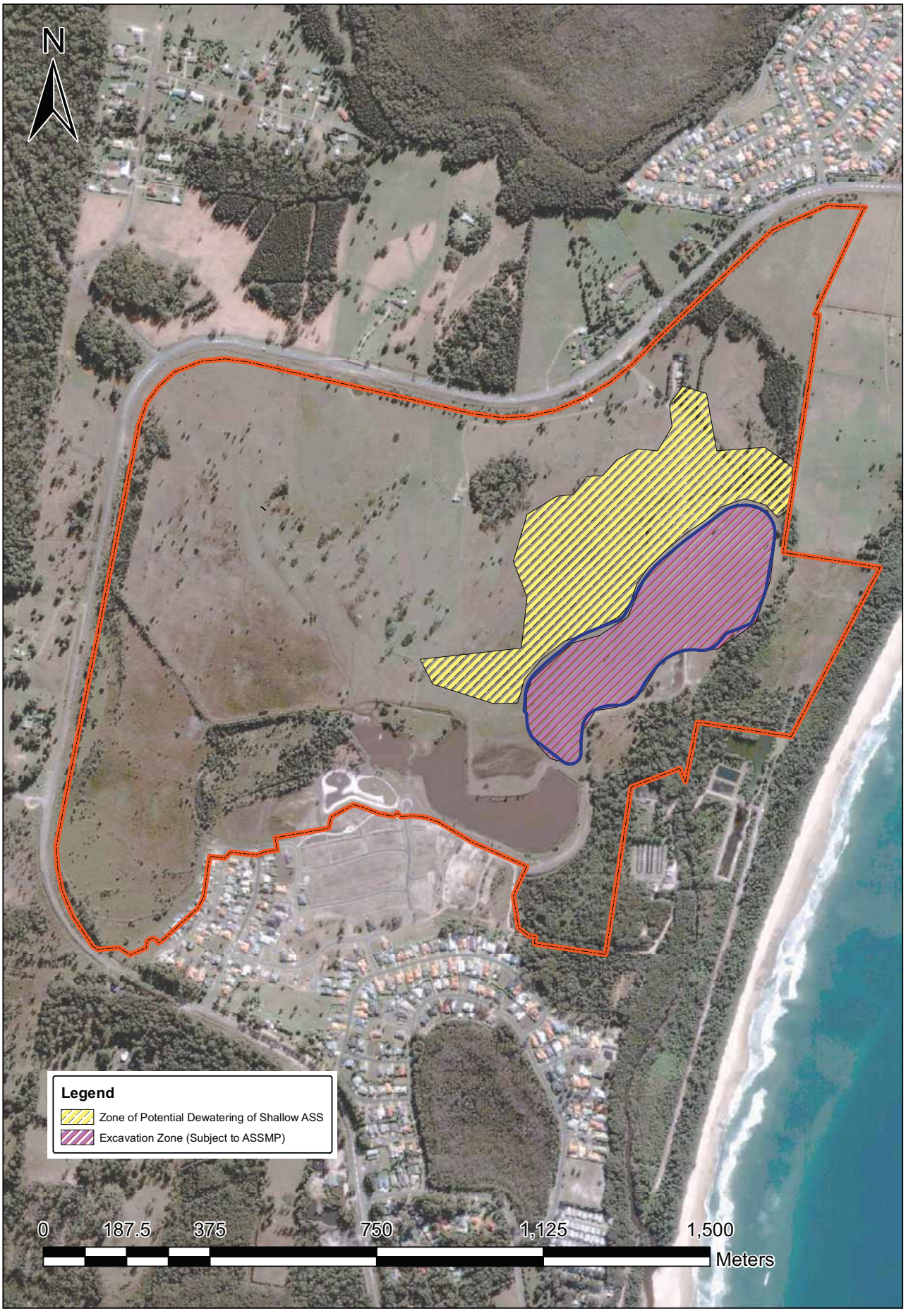
WRL Report No. 2009/32	STEADY STATE SIMULATION OF POST DEVELOPMENT REPRESENTING MEDIAN GROUNDWATER LEVELS	Figure 26 insert filename

WRL Report No. 2009/32	STEADY STATE SIMULATION OF POST DEVELOPMENT REPRESENTING LOW GROUNDWATER LEVELS	Figure 27 insert filename

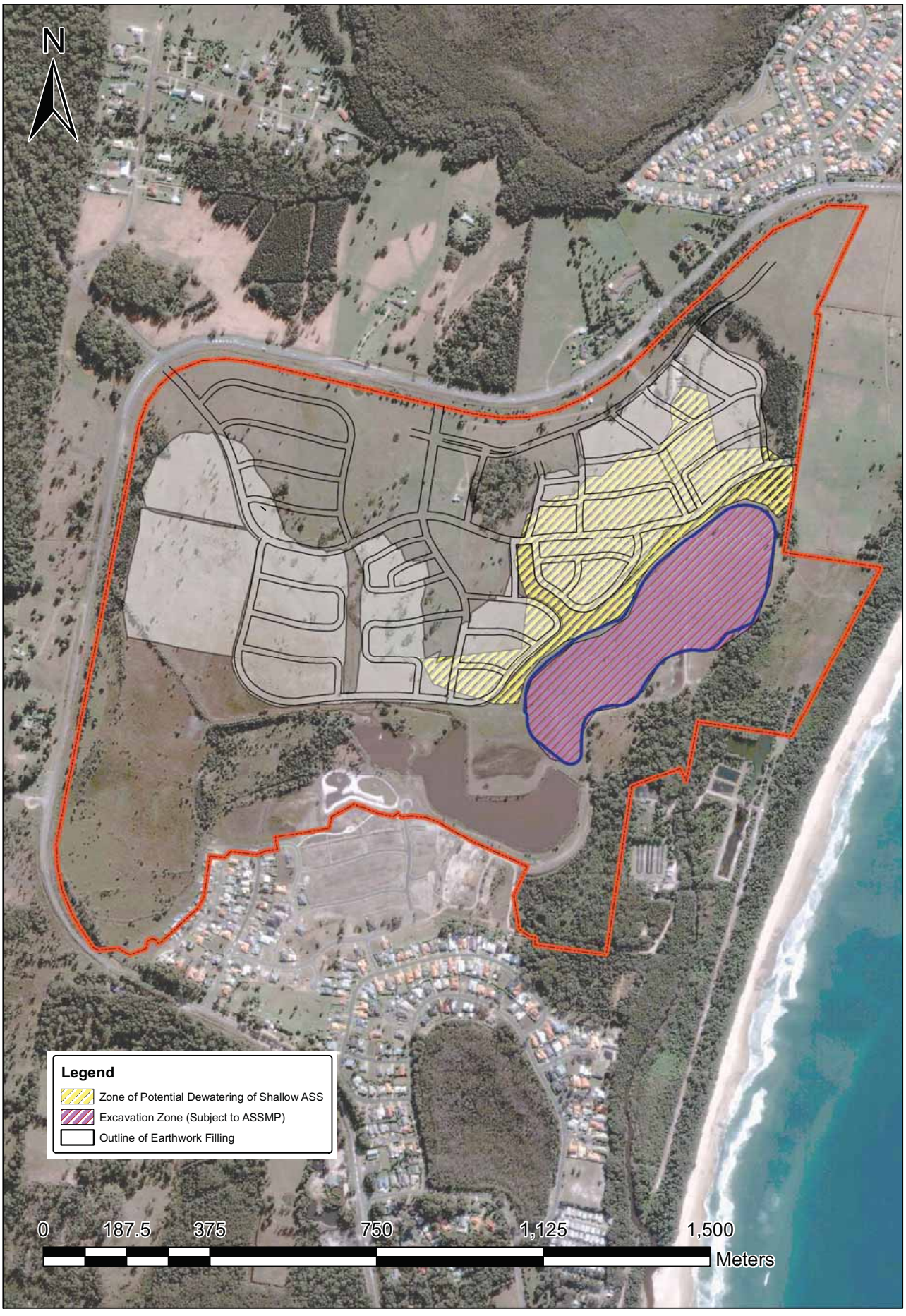
WRL Report No. 2009/32	STEADY STATE SIMULATION OF POST DEVELOPMENT REPRESENTING HIGH GROUNDWATER LEVELS	Figure 28 insert filename



WRL Report No. 2009/32	GROUNDWATER DRAWDOWN PRE MINUS POST DEVELOPMENT, AVERAGE ANNUAL LEVELS	Figure 29 insert filename



WRL Report No. 2009/32	ACID SULFATE SOIL POTENTIAL RISK ZONES DUE TO PROPOSED LAKE	Figure 30 insert filename



WRL Report No. 2009/32	ACID SULFATE SOIL POTENTIAL RISK ZONES SHOWING PROPOSED FILL AND DEVELOPMENT LOCATIONS	Figure 31 insert filename

APPENDIX A
WRL BORE LOGS

University of New South Wales
School of Civil & Environmental Engineering

Water Research Laboratory

Project: 09056 Rainbow Beach Estate
Hole No. GW6
Driller: Atkins
Method of Drilling: Hollow Flight Auger

Date: 11-Aug-09
Logged By: SEP
Drill Hole Diameter: 200 mm
Coordinates: 484401 mE, 6506799 mN

Depth Below Ground (m)	Lithology	Graphic Log	Features	Well Construction	Well construction comments
0.0 – 1.2	SILTY CLAY. Black. Soft to firm. Moist.		RL 5.835 - Top of PVC Casing RL 5.455 - Ground		Top Cap lockable steel monument Concrete Backfill 25 mm NB Class 18 PVC Casing
1.2 – 2.2	CLAY. Metallic grey. Soft. High plasticity.		RL 4.205 - SWL: 1.63 BTC (1.25 m BGL) 11/8/09		Bentonite Plug
2.2 – 3.4	SAND. Light grey. Med to fine. Some yellow mottling. Saturated.				Gravel Pack Machine Slotted Screen 2.5 to 4.0 m BGL
3.4 – 4.6	CLAYEY SAND. Light grey. Med to fine. Some yellow mottling. Saturated.		RL 1.835 - End of Piezometer		End Cap Backfill: Natural Collapse
4.6 – 5.4	CLAY. High plasticity. Soft. Saturated.		End of Borehole		

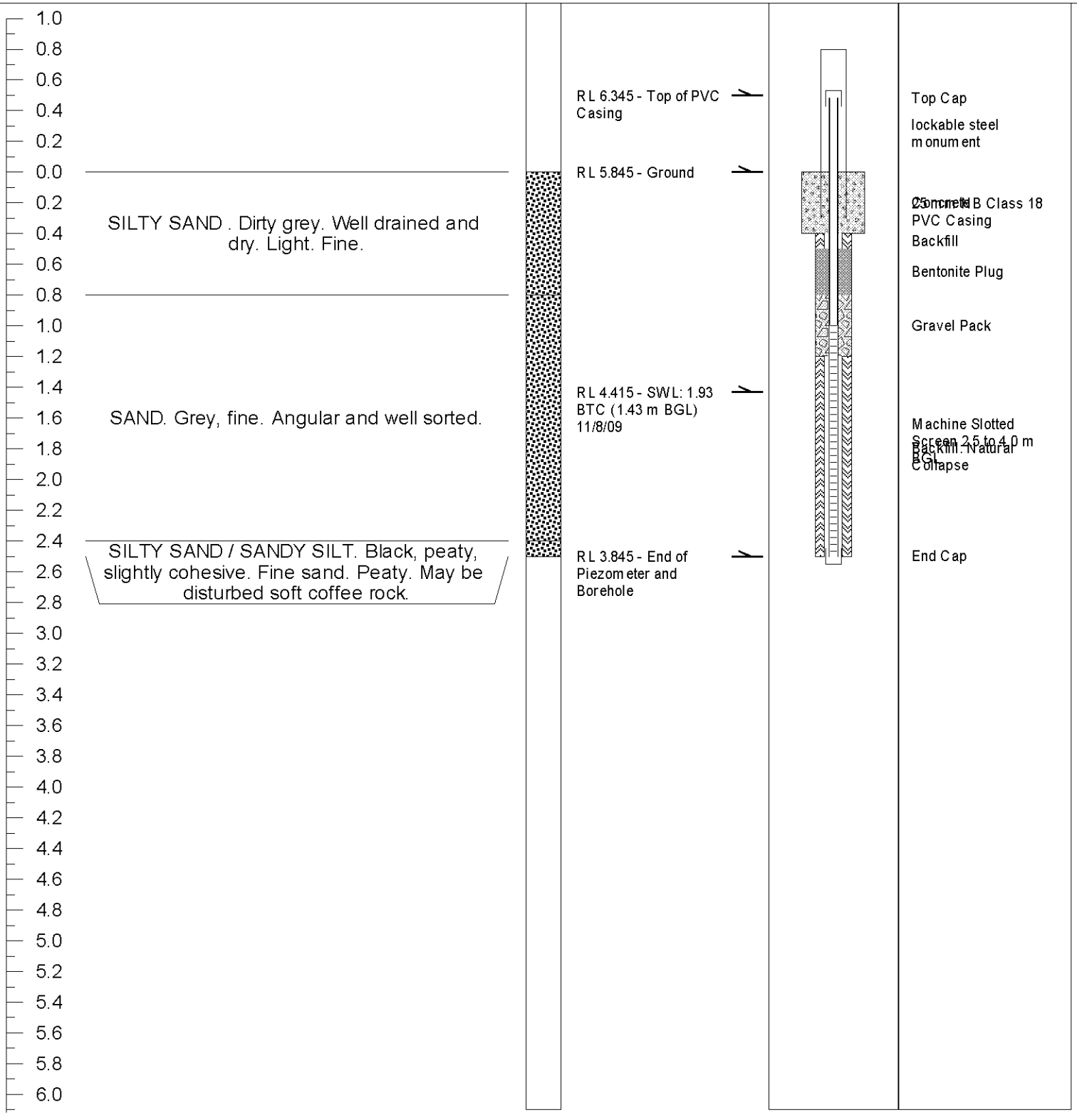
University of New South Wales
School of Civil & Environmental Engineering

Water Research Laboratory

Project: 09056 Rainbow Beach Estate
Hole No. GW7A
Driller: Atkins
Method of Drilling: Hollow Flight Auger

Date: 11-Aug-09
Logged By: SEP
Drill Hole Diameter: 200 mm
Coordinates: 484813 mE, 6506843 mN

Depth Below Ground (m)	Lithology	Graphic Log	Features	Well Construction	Well construction comments
0.0 – 0.8	SILTY SAND . Dirty grey. Well drained and dry. Light. Fine.		RL 6.345 - Top of PVC Casing RL 5.845 - Ground		Top Cap lockable steel monument 25mm dia Class 18 PVC Casing Backfill Bentonite Plug
0.8 – 2.4	SAND. Grey, fine. Angular and well sorted.		RL 4.415 - SWL: 1.93 BTC (1.43 m BGL) 11/8/09		Gravel Pack Machine Slotted Screen 2.5 to 4.0 m BGL Backfill. Natural Collapse
2.4 – 2.8	SILTY SAND / SANDY SILT. Black, peaty, slightly cohesive. Fine sand. Peaty. May be disturbed soft coffee rock.		RL 3.845 - End of Piezometer and Borehole		End Cap



University of New South Wales
School of Civil & Environmental Engineering

Water Research Laboratory

Project: 09056 Rainbow Beach Estate
Hole No. GW7B
Driller: Atkins
Method of Drilling: Hollow Flight Auger

Date: 11-Aug-09
Logged By: SEP
Drill Hole Diameter: 200 mm
Coordinates: 484813 mE, 6506845 mN

Depth Below Ground (m)	Lithology	Graphic Log	Features	Well Construction	Well construction comments
0.0 – 0.8	SILTY SAND . Dirty grey. Well drained and dry. Light. Fine.		RL 6.29 - Top of PVC Casing RL 5.84 - Ground		Top Cap lockable steel monument Concrete
0.8 – 2.4	SAND. Grey, fine. Angular and well sorted.		RL 4.27 - SWL: 2.02 BTC (1.57 m BGL) 11/8/09		Backfill 25 mm NB Class 18 PVC Casing
2.4 – 3.2	SILTY SAND / SANDY SILT. Black, peaty, slightly cohesive. Fine sand. Peaty. May be disturbed soft coffee rock.				Bentonite Plug
3.2 – 4.4	Recovered sample of dark grey sand and clay, difficult drilling indicate rock formation. Occassional large rounded gravel to 40 mm (5 to 10%).				Backfill: Natural Collapse
4.4 – 5.2	SAND. Med to fine. Grey. Saturated.				Machine Slotted Screen 4.5 to 5.5 m BGL
5.2 – 5.4	SANDY CLAY. Grey. Med sand with soft clay of high plasticity.		RL 0.79 - End of Piezometer and Borehole		End Cap

University of New South Wales
School of Civil & Environmental Engineering

Water Research Laboratory

Project: 09056 Rainbow Beach Estate
Hole No. GW8
Driller: Atkins
Method of Drilling: Hollow Flight Auger

Date: 11-Aug-09
Logged By: SEP
Drill Hole Diameter: 200 mm
Coordinates: 483753 mE, 6506504 mN

Depth Below Ground (m)	Lithology	Graphic Log	Features	Well Construction	Well construction comments
0.0 – 0.6	SANDY CLAY / Topsoil. Black. Med-high plast. Firm.		RL 6.16 - Top of PVC Casing RL 5.66 - Ground		Top Cap lockable steel monument Concrete
0.6 – 2.4	CLAY. Dark grey / black. V high plast. Firm. Damp.		RL 4.59 - SWL: 1.57 BTC (1.07 m BGL) 29/8/09		25 mm NB Class 18 PVC Casing Backfill Bentonite Plug
2.4 – 3.6	SANDY CLAY. Orange. Soft to very soft clay. Med sand. Fraction angular gravel (5% up to 20mm). Saturated.				Gravel Pack Machine Slotted Screen 2.5 to 4 m BGL Backfill: Natural Collapse
3.6 – 4.0	CLAY. Grey / light grey. Stiff. Some sand.		RL 2.16 - End of Piezometer and Borehole		End Cap

University of New South Wales
School of Civil & Environmental Engineering

Water Research Laboratory

Project: 09056 Rainbow Beach Estate
Hole No. GW9
Driller: Atkins
Method of Drilling: Hollow Flight Auger

Date: 11-Aug-09
Logged By: SEP
Drill Hole Diameter: 200 mm
Coordinates: 484126 mE, 6506637 mN

Depth Below Ground (m)	Lithology	Graphic Log	Features	Well Construction	Well construction comments
0.0 – 0.8	CLAY. Black. High plast. Firm. Damp.		RL 5.17 - Top of PVC Casing RL 4.72 - Ground		Top Cap lockable steel monument Concrete
0.8 – 1.6	CLAY. Dark grey / black. V high plast. Firm. Damp.		RL 3.5 - SWL: 1.67 BTC (1.22 m BGL) 29/8/09		25 mm NB Class 18 PVC Casing Backfill
1.6 – 4.0	CLAYEY SAND. Grey / light grey angular medium to fine. Damp.				Bentonite Plug Gravel Pack Machine Slotted Screen 2.5 to 4 m BGL
4.0 – 5.0	CLAY. Light grey. Very soft. Saturated		RL 1.17 - End of Piezometer and Borehole End of Borehole		Backfill: Natural Collapse End Cap

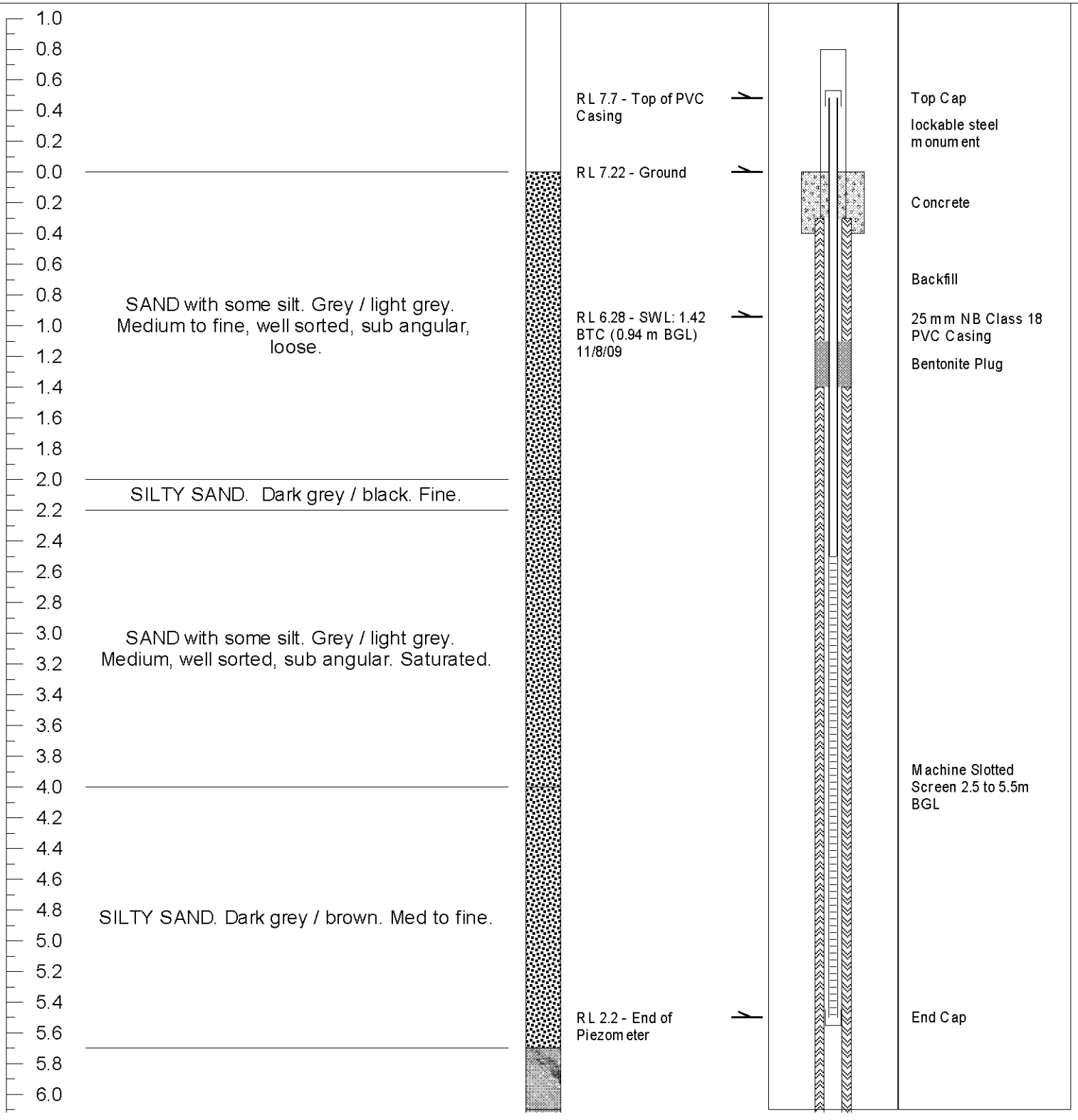
University of New South Wales
School of Civil & Environmental Engineering

Water Research Laboratory

Project: 09056 Rainbow Beach Estate
Hole No. GW1
Driller: Atkins
Method of Drilling: Hollow Flight Auger

Date: 10-Aug-09
Logged By: SEP
Drill Hole Diameter: 200 mm
Coordinates: 485008 mE, 6506846 mN

Depth Below Ground (m)	Lithology	Graphic Log	Features	Well Construction	Well construction comments
0.0	SAND with some silt. Grey / light grey. Medium to fine, well sorted, sub angular, loose.		RL 7.7 - Top of PVC Casing RL 7.22 - Ground RL 6.28 - SWL: 1.42 BTC (0.94 m BGL) 11/8/09		Top Cap lockable steel monument Concrete Backfill 25 mm NB Class 18 PVC Casing Bentonite Plug
2.0	SILTY SAND. Dark grey / black. Fine.				
2.2	SAND with some silt. Grey / light grey. Medium, well sorted, sub angular. Saturated.				Machine Slotted Screen 2.5 to 5.5m BGL
4.0	SILTY SAND. Dark grey / brown. Med to fine.		RL 2.2 - End of Piezometer		End Cap
5.6					



University of New South Wales
School of Civil & Environmental Engineering

Water Research Laboratory

Project: 09056 Rainbow Beach Estate
Hole No. GW2
Driller: Atkins
Method of Drilling: Hollow Flight Auger

Date: 10-Aug-09
Logged By: SEP
Drill Hole Diameter: 200 mm
Coordinates: 485099 mE, 6507100 mN

Depth Below Ground (m)	Lithology	Graphic Log	Features	Well Construction	Well construction comments
0.0			RL 5.08 - Top of PVC Casing		Top Cap
					lockable steel monument
0.0			RL 4.7 - Ground		
					Concrete
0.0 – 1.6	SILTY CLAY / CLAYEY SILT Black high plasticity. Firm.				25 mm NB Class 18 PVC Casing
					Backfill
1.6 – 2.4	CLAYEY SAND. Med-fine. Grey / brown mottled.		RL 2.88 - SWL: 2.2 BTC (1.82 m BGL) 11/8/09		Bentonite Plug
2.4 – 3.8	Recovered sample of SILTY SAND with clay fraction and 10% angular med gravel, dark brown. may be disturbed coffee rock.				Gravel Pack
3.8 – 5.6	Recovered sample of dark grey sand and clay, mixed with large rounded gravel to 40 mm (50%).				Machine Slotted Screen 2.5 to 5.5m BGL
					Backfill: Natural Collapse
5.6			RL -0.42 - End of Piezometer		End Cap
5.6 – 6.0	SANDY CLAY. Grey. Sand med, clay soft. Saturated.				
6.0			End of Borehole		

University of New South Wales
School of Civil & Environmental Engineering

Water Research Laboratory

Project: 09056 Rainbow Beach Estate
Hole No. GW3
Driller: Atkins
Method of Drilling: Hollow Flight Auger

Date: 10-Aug-09
Logged By: SEP
Drill Hole Diameter: 200 mm
Coordinates: 484758 mE, 6507191 mN

Depth Below Ground (m)	Lithology	Graphic Log	Features	Well Construction	Well construction comments
0.0 – 0.4	SILTY SAND. Med. Brown/black mottled. Organic.'Topsoil'		RL 5.56 - Top of PVC Casing RL 5.18 - Ground		Top Cap lockable steel monument Concrete
0.4 – 1.8	SILTY SAND. Orange. Med. Angular. Damp.		RL 3.93 - SWL: 1.63 BTC (1.25 m BGL) 29/8/09		25 mm NB Class 18 PVC Casing Backfill
1.8 – 3.6	SILTY SAND with 5% angular med gravel, dark brown. may be disturbed coffee rock. Saturated.				Bentonite Plug Gravel Pack
3.6 – 5.0	SAND with some silt. Light grey. Fine to med.				Machine Slotted Screen 2.5 to 5.5m BGL Backfill: Natural Collapse
5.0 – 5.4	SANDY CLAY. Grey. Sand med, clay soft. Saturated.				
5.4 – 6.0	CLAY. Metallic grey. Soft, wet. Very high plasticity.		RL 0.06 - End of Piezometer End of Borehole		End Cap

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School of Civil & Environmental Engineering

Water Research Laboratory

Project: 09056 Rainbow Beach Estate
Hole No. GW4
Driller: Atkins
Method of Drilling: Hollow Flight Auger

Date: 11-Aug-09
Logged By: SEP
Drill Hole Diameter: 200 mm
Coordinates: 484434 mE, 6507116 mN

Depth Below Ground (m)	Lithology	Graphic Log	Features	Well Construction	Well construction comments
0.0 – 0.8	CLAY. Brown. High plasticity. Firm.		RL 5.51 - Top of PVC Casing RL 5.13 - Ground RL 4.31 - SWL: 1.2 BTC (0.82 m BGL) 29/8/09		Top Cap lockable steel monument Concrete Backfill 25 mm NB Class 18 PVC Casing Bentonite Plug
0.8 – 1.0	CLAY. Grey. Very High Plasticity, firm.				
1.0 – 2.6	CLAYEY SAND / SANDY CLAY. Grey. Sand med, clay high plasticity, firm. Moist.				Gravel Pack
2.6 – 3.4	CLAY. Residual. Orange / grey mottled. Damp.				Machine Slotted Screen 2.0 to 4.0m BGL
3.4 – 3.6	SANDY CLAY. Residual. Orange / grey mottled. Med to coarse sand. Dry.				
3.6 – 4.0	Highly weathered rock. Orange / grey mottled sand and clay. Med to coarse sand. Clay very soft. Saturated		RL 1.51 - End of Piezometer and Borehole		End Cap

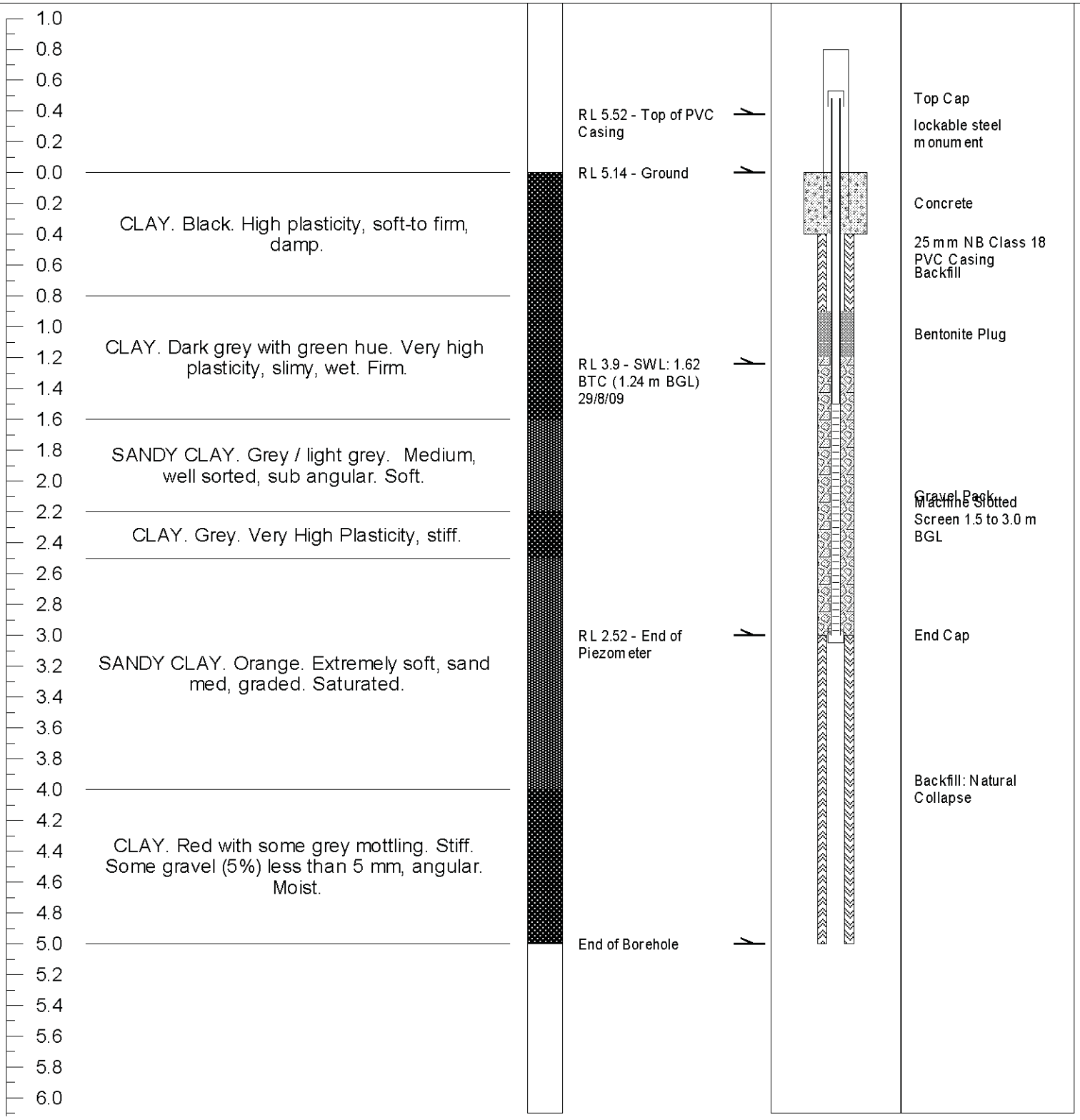
University of New South Wales
School of Civil & Environmental Engineering

Water Research Laboratory

Project: 09056 Rainbow Beach Estate
Hole No. GW5
Driller: Atkins
Method of Drilling: Hollow Flight Auger

Date: 11-Aug-09
Logged By: SEP
Drill Hole Diameter: 200 mm
Coordinates: 484051 mE, 6506894 mN

Depth Below Ground (m)	Lithology	Graphic Log	Features	Well Construction	Well construction comments
0.0 – 0.8	CLAY. Black. High plasticity, soft-to firm, damp.		RL 5.52 - Top of PVC Casing RL 5.14 - Ground		Top Cap lockable steel monument Concrete
0.8 – 1.6	CLAY. Dark grey with green hue. Very high plasticity, slimy, wet. Firm.		RL 3.9 - SWL: 1.62 BTC (1.24 m BGL) 29/8/09		25 mm NB Class 18 PVC Casing Backfill Bentonite Plug
1.6 – 2.2	SANDY CLAY. Grey / light grey. Medium, well sorted, sub angular. Soft.				Gravel Pack Machine Slotted Screen 1.5 to 3.0 m BGL
2.2 – 2.6	CLAY. Grey. Very High Plasticity, stiff.				
2.6 – 4.0	SANDY CLAY. Orange. Extremely soft, sand med, graded. Saturated.		RL 2.52 - End of Piezometer		End Cap Backfill: Natural Collapse
4.0 – 5.0	CLAY. Red with some grey mottling. Stiff. Some gravel (5%) less than 5 mm, angular. Moist.		End of Borehole		



APPENDIX B
GROUNDWATER MANAGEMENT PLAN

B1. INTRODUCTION

This Groundwater Management Plan (GMP) has been developed for the proposed Rainbow Beach Estate development, between the coastal towns of Lake Cathie and Bonny Hills on the NSW Mid-North Coast.

The GMP has been prepared to provide a specification for a groundwater monitoring program for the site, from the present through the development phase and for a 2 year period following development. The monitoring program may be extended at this time subject to qualified review.

Guidance has been provided on the locations (Section B2), frequency (Section B3) and specification of water level and water quality sampling (Section B4). The data collected should be subject to qualified review at two distinct times: shortly after completion of the construction phase, and; at the end of the (2 year) monitoring program. Guidance is also given in the GMP to assist in preliminary interpretation which to be undertaken immediately after every sampling event to allow for timely checking for any impacts.

This purpose of the GMP is to monitor the impacts to groundwater from the development, with consideration to:

- Protection of Groundwater resources as per the requirements of the NSW State Groundwater Policy Framework Document (DLWC, 1997);
- Protection of the littoral rainforest to the east of the site[1], and;
- Acid Sulfate Soil (ASS) risks.

For the latter case (ASS), monitoring specified here has the purpose of detecting, if possible, the unplanned oxidation of pyrites and any associated impacts to the proposed wetland.

This GMP is not to supersede or replace in anyway the role of the Acid Sulfate Soils Management Plan (ASSMP) that is required to guide management of ASS during the development phase. Similarly, this GMP provides some recommended surface water monitoring actions, but is not to supersede requirements for surface water monitoring at the site.

[1] The other identified protection area, the "Wallum Froglet habitat", is not considered by WRL to be a groundwater dependant issue and hence is not addressed in this GMP.

B2. MONITORING LOCATIONS

The monitoring program requires sampling and measurements to be undertaken from a consistent suite of locations referred to as the "monitoring network".

The monitoring network will comprise a selection of the existing standpipe piezometers shown in Table B1. Construction works should, to the extent possible, avoid disturbance of these standpipe piezometers. If disturbance cannot be avoided, replacement standpipe piezometers should be installed at the nearest practicable location. The new standpipe should: be installed prior to removal of the old one (to allow cross referencing); be installed in a manner conforming to the specification set out in Section B2.1, and; monitor from the same groundwater body (i.e. screen depth) as the piezometer being replaced.

Selected surface water monitoring locations are also stipulated in this GMP. These are stipulated solely for assisting with the detection of any impacts due to ASS. The locations and sampling requirements for these surface water monitoring may be incorporated into the greater surface water monitoring plans for the site.

Table B1
Monitoring Network

	ID	Location (MGA Zone 56 GDA 94)		Level of Top of Casing (m AHD)
		mE	mN	
Groundwater	GW1	485007.51	6506846.14	7.700
	GW2	485098.96	6507099.89	5.080
	GW3	484758.12	6507191.45	5.560
	GW4	484433.50	6507116.48	5.510
	GW5	484051.05	6506894.33	5.520
	GW6	484401.39	6506799.19	5.835
	GW7a	484812.83	6506844.88	6.345
	GW7b	484812.84	6506842.77	6.290
	W3	483710.82	6506852.09	5.200
	W5	484862.90	6507358.70	4.480
	W7	484705.53	6507300.68	4.75
Surface Water	SW2	Duchess Gully between GW1 and GW7		
	SW3	Outlet to Existing Wetland		
	SW7	Within Southern Quarter of Proposed Wetland		
	SW8	Within Northern Quarter of Proposed Wetland		

B3. MONITORING PROGRAM

B3.1 Pre-development

A baseline groundwater characterisation study has already been completed. The results of water quality testing and three instances of water level measurements are published in:

- Laxton, J. and Laxton, E. (2009) *Quality of Ground Water and Surface Water at Bonny Hills, NSW, November 2009*. Report for the St Vincents Foundation.

In addition, monthly water level readings have been undertaken since August 2009 as presented in Table 4 of WRL TR 2009/32.

Monthly water level monitoring (dips) should be continued up until development. An additional single round of water quality should be undertaken from the monitoring network prior to commencement of development.

B3.2 During Development

Monthly measurements of water levels from the monitoring network should continue throughout the development period.

Quarterly monitoring of water quality should be undertaken from the monitoring network during the construction phase.

In addition, more regular monitoring of selected water quality constituents may be undertaken during the construction (and associated dewatering activities) of the proposed wetland as stipulated in the ASSMP.

B3.3 Post Development

Following completion of development, the collected groundwater monitoring data should be reviewed by a person qualified in hydrogeology and ASS. Subject to their review and any special concerns, quarterly measurements of water levels and water quality from the monitoring network should be continued for a period of 2 years from completion of development. At the end of this 2 year period, the data should again be subject to a formal review by a person qualified in hydrogeology and ASS. Further monitoring may be recommended subject to the findings of the review.

B3.4 Summary

The proposed frequency of monitoring and formal review are summarised in Tables B2 and B3 respectively.

Table B2
Monitoring Frequency

Period	Water Level Monitoring	Water Quality Monitoring
Pre-development	Monthly	One additional round prior to commencement of construction
During Development*	Monthly	Quarterly
Post Development	Quarterly	Quarterly

* Additional construction-specific water level and water quality monitoring may be stipulated in the ASSMP.

Table B3
Monitoring Formal Review

Item	Comment
Review 1	A formal review of all water quality and water level data every 2 years, starting from the commencement of construction, or; at the completion of construction, whichever comes first.
Review 2	A formal review of all water quality and water level data at the completion of the 2 year post – construction monitoring program.

B4. MONITORING SPECIFICATIONS

B4.1 Water Level Monitoring

Manual measurement of water level in standpipes should be undertaken using a dip meter, measuring the distance from the highest point on the PVC casing to the standing water level in the standpipe. The 'dip reading' should then be reduced to an elevation in m AHD with reference to the surveyed elevation of the PVC casing and the time and date of the measurement should be recorded.

B4.2 Water Quality Monitoring

Routine water quality monitoring will tests for the same constituents from all locations in the monitoring network as set out in Table B4.

Table B4
Water Quality Parameters

Parameter Type	Parameters
Physical Properties*	pH, EC, Temperature, DO, Eh
Major Anions	Cl, SO_4, Ca, Mg, Na, K, Alkalinity
Trace Metals	Fe (total and soluble), Al (total and soluble), As, Cd, Co, Pb, Mn, Hg, Zn
Nutrients	TKN, Total N, Total Phosphorous

* parameters measured in the field

A recommended water quality sampling procedure is set out below.

1. Preparation

Parameters measuring physical properties should be measured in the field using appropriate probes. The remaining parameters will be testing in laboratory. Pre-treated containers for collection of samples appropriate to the parameters being measured are to be obtained from the laboratory that will analyse the samples.

2. Calibration of Meters

Water quality meters must be calibrated to standard solutions according to the manufacturers instructions at the beginning of each sampling day.

3. Measuring Standing Water Level

If manual measurements of water levels are conducted as part of the water quality sampling, then the standing water level is to be measured prior to sampling.

4. Purging

Groundwater sampling should be completed using an electric submersible pump. The well or borehole is to be sufficiently pumped prior to sampling to ensure that the water sampled is representative of the aquifer (AS/AZS 5667.1:1998). Either the volume of water pumped is to be measured, or a flow rate and amount of time pumping. This can be completed with a bucket of known volume and a stop watch. Changes within field parameters are to be ± 10% prior to sampling, or less than ±0.2 ºC and at least one borehole volume of water extracted (AS/AZS 5667.11:1998), but a volume of over 5 boreholes is recommended. For low yield bores, the bore may be simply pumped dry once and allowed to recover sufficient volume to complete sampling.

5. Recording Data

A log sheet should be kept for each sampling location, and the following information should be recorded for each locations on each sampling event:

- Standing water level
- Calibration of meters
- Set depth of pump
- Volume of water pumped
- Method of sampling
- Sample appearance at time of collection (colour, clarity and odour)
- Preservation techniques
- Field parameters (pH, EC, DO, Temperature and Eh)
- Any information which may affect the results of the analysis.

6. Sampling

Parameters measuring physical properties should be measured in the field using appropriate probes. Field measurement of Eh and DO should be done with the use of flow cells.

Samples to be measured in the laboratory should be stored in pre-treated containers appropriate to the parameters being measured, as obtained from the laboratory that will analyse the samples.

When taking microbiological samples, disposable latex gloves should be worn to prevent contamination of the sample. Care must be taken not to touch the top of the bottle during removal or replacement of the lid and the cap is never to be placed on any surface. The cap must be replaced tightly as soon as the container is filled, and the sample must be kept chilled until it reaches the laboratory.

It is best that all sample containers are filled to the top without any headspace, taking care not to overfill the bottles as preservative may be lost. Check all bottle caps are tightly

secured. Each sample must be clearly labelled at the time of sampling with the borehole ID and the date of sampling.

7. Preservation and Transport of Samples

Groundwater samples obtained for water quality analysis are to be collected, handled and preserved as per the Standards Association of Australia (1998) 'Water Quality -Sampling Part 1: Guidance on the Design of Sampling Programs, Sampling Techniques and the Preservation and Handling of Samples' Australian/New Zealand Standard AS/NZS 5667.1:1998. These guidelines contain specific protocols and procedures suitable for groundwater quality sampling and analysis.

Filled sample containers are to be kept cold in an esky with ice-packs. Bags of ice are not to be used as melt water can contaminate samples and leak from eskies. Samples for microbiological analysis are to arrive at the laboratory within 24 hours of sampling and must be kept chilled. Packing material is to be used to fill the esky prior to couriering to the laboratory. Samples are to arrive at the laboratory on Thursday afternoon at the latest to ensure that the microbiological analysis can be completed prior to the weekend.

Chain-of-custody documentation as required by the laboratory is to be included in the esky with the samples, and is to include the ID's of each sample and the analysis required.

8. Disinfection

Between each bore, pumping equipment must be disinfected. Chlorination is the most simple method available. A batch of water for disinfection may be made up on site by adding bleach (commercially available sodium hypochlorite solution) to water to obtain chlorine concentrations of 100 mg/L. The amount of bleach required to make 100 L of solution as shown in Table B5:

Table B5
Disinfection Recommendations

Bleach strength (% sodium hypochlorite)	Volume of Bleach Required (mL)
3	330
5	200
10	100
12.5	80

Equipment should be soaked in this solution during transport between sampling locations or for at least 15 minutes prior to rinsing and re-use. Care is also to be taken not place any

equipment on the ground. A plastic sheet or tarpaulin may be used on the ground. Rinse water from a clean town water supply may be used. Water quality meters may be triple rinsed using the water to be sampled.

8. Laboratory Analysis Requirements

Groundwater sample analysis is to be undertaken by a laboratory that is NATA-registered for the analysis conducted. Collectors are to ensure that samples are received by the laboratory within 24 hours. Holding times for bacteriological analysis are not to be exceeded.

9. Quality Control Requirements

Groundwater sampling is to be undertaken by suitably trained personnel, following the procedures laid out in this document. For quality control 5% of samples should be submitted as blind duplicates, and one blank (distilled water) and one spiked sample should be submitted with every 20 samples (Jiwan & Gates, 1992). The blind duplicate to the laboratory is to be labelled with a false bore number.

Standard laboratory practice is that a QA/QC compliance report be provided and that laboratories that are NATA certified for analysis of major ions supply a report of charge balance errors (CBE). Satisfactory CBE <5% should be verified prior to payment of the laboratory invoice. If the CBE is not satisfactory and the samples cannot be re-analysed, fresh groundwater samples will need to be obtained and analysed.

B5. DATA INTERPRETATION AND RESPONSE

The data collected as part of the monitoring program should be subject to formal review by a qualified specialist as per Table B3. This review will assess general impacts to groundwater levels and quality and should seek to determine if the highest existing beneficial usage category is being maintained. The review should make reference to the characterisation of existing groundwater resources presented Section 3 of WRL TR 2009/32. The monitoring review should also compare observed drawdown against predicted drawdown presented in Figures 26 to 28 of WRL TR 2009/32 and comment on the implications for identified sensitive areas and activation of ASS. The monitoring program may be subject to changes following the findings of the reviews.

If it is found that the developments are reducing the quality of the existing groundwater resources, the following actions may be considered by the reviewer:

- Identify and remove point sources of contamination
- Reinforce community education / awareness
- Review current landuse practices or operation and maintenance of stormwater treatment devices
- Initiate community based projects

A preliminary level of data interpretation should also be undertaken after each sampling event to allow for earlier identification of any impacts. This relates specifically to assessing impacts due to ASS, and requires that monitored values are compared against the trigger preliminary levels presented in Table B6. These are referred to as preliminary as they may be subject to change or reinterpretation following each of the formal review stages.

If any of these trigger levels are exceeded, the first response should be to retest from the sample location in question to confirm the validity of results. If the retesting confirms that the trigger level are exceeded immediate action will be required. The nature of action required will be specific to the observed issue, but may include the following:

- Engagement of a qualified specialist to identify the cause or mechanism of trigger level exceedence and propose appropriate actions.
- Increase monitoring frequency.
- In the case of exceedences during the construction or dewatering phase, comply with response measures as stipulated in the ASSMP.

- For the case of exceedence of trigger levels from samples within the proposed wetland, consider dilution and buffering of surface waters by control of weirs to the existing lake.
- Consider application of lime dosing to buffer water quality within the existing or proposed wetland.
- For the case of groundwater, consider techniques to block or treat the water *insitu*, such as cutoff walls or lime injection.

The application of lime should conform to the requirements of the NSW Acid Sulfate Soils Management Manual.

Table B6
Preliminary Trigger Levels for ASS Impacts

Observation	**Criteria**
Groundwater Levels	• Groundwater levels are below 3 m AHD in more that two standpipes (excluding GW2) for two consecutive monitoring periods, or; • Groundwater levels in GW2 are below 2 m AHD, and are below 3 m AHD in another standpipe for two consecutive monitoring periods.
Groundwater Quality	• pH is below 4.5 and the ratio of Cl to $S0_4$ ions is less than 1 in any bore. • Soluble Iron in excess of 40 mg / L is recorded in any location for two consecutive monitoring periods, or; • Soluble iron increases consecutively by more that 50% at any one location for two consecutive monitoring rounds.
Surface Water Quality	• pH is below 4.5 and the ratio of Cl to $S0_4$ ions is less than 1 in any surface water location. • Soluble Iron in excess of 40 mg / L is recorded in any location for two consecutive monitoring periods, or; • Soluble iron increases consecutively by more that 50% at any one location for two consecutive monitoring rounds.