Lake Rotorua groundwater study: results of the 2004-2005 field programme

R Reeves, P A White, S G Cameron, G Kilgour, U Morgenstern,
C Daughney, W Esler and S Grant

Confidential
Client Report
2005/66

July
2005

Lake Rotorua groundwater study: results of the 2004-2005 field programme

Prepared for

ENVIRONMENT BAY OF PLENTY

R Reeves
P A White
S G Cameron
G Kilgour
U Morgenstern
C Daughney
W Esler
S Grant
Institute of Geological & Nuclear Sciences Limited

CONFIDENTIAL

Client Report 2005/66
Job Numbers 520W2054 to 520W2060 inclusive

July 2005

COMMERCIAL IN CONFIDENCE: This report has been prepared by the Institute of Geological & Nuclear Sciences Limited exclusively for and under contract to Environment Bay of Plenty. Unless otherwise agreed in writing, all liability of the Institute to any party other than Environment Bay of Plenty in respect of the report is expressly excluded.

LIST OF CONTENTS

LIST OF APPENDICES

LIST OF TABLES

LIST OF FIGURES

Page

Page

EXECUTIVE SUMMARY

The groundwater system of the Lake Rotorua catchment plays a crucial role in nutrient transport to Lake Rotorua. Nutrients associated with land use enter the groundwater systems through soil drainage and rainfall recharge. The nutrients reside in the groundwater system, probably for decades, but return to the surface through spring flows and direct recharge to the lake. An understanding of both the groundwater and surface water systems is required to plan remedial work to maintain and improve the lake's water quality.

The Institute of Geological and Nuclear Sciences (GNS) was commissioned by Environment Bay of Plenty (EBOP) to collect new geological, hydrological, water quality and water dating data to enable GNS to develop groundwater models of the Lake Rotorua catchment. This report only deals with new data collected as part of the field programme. The report only reports the new data, and does not attempt to interpret or analyse the data. Interpretation of new data will be done in a later report.

EBOP indicated that the priority area for fieldwork was an arc from approximately Mt Ngongotaha to the west of Lake Rotorua, around to Hamurana to the north of Lake Rotorua, and then to approximately Lynmore to the south west of Lake Rotorua. This has been the focus for new work.

Work completed as part of the field programme includes:

- Drilling and construction of a 150 m deep piezometer drilled into the Mamaku Ignimbrite formation on the western side of Lake Rotorua.
- Drilling and piezometer construction of two other piezometers drilled into the Huka sediment formation near Ngongotaha (20 m deep and 80.5 m deep).
- Two constant rate pump tests to determine groundwater aquifer transmissivity and storativity in the:
  - Mamaku formation – performed on the above bore at 113.2 m
  - Huka sediment formation – performed on the deep bore above at 36 m
- Collection and analyses of 41 water samples for either nutrients, major cations/anions and or water dating (tritium only, or, tritium, CFC's and SF_6).

- Locating 104 existing bores/springs not on the EBOP database.
- 43 bores/springs were surveyed using a high resolution global positioning system (GPS).
- Install a rainfall recharge site at Kaharoa to measure the amount of water infiltrating through the soil profile.
- Perform a lake edge survey identifying actual and potential water flows into Lake Rotorua.

Potential areas of groundwater/stream interaction in the Lake Rotorua catchment was done by EBOP staff, but not reported in this report.

1.0 INTRODUCTION

The groundwater system of the Lake Rotorua catchment plays a crucial role in nutrient transport inflows to Lake Rotorua. Nutrients associated with land use enter the groundwater systems through soil drainage and rainfall recharge. The nutrients reside in the groundwater system, probably for decades, but return to the surface through spring flows and direct recharge to the lake. Because of a lack of available information for the groundwater systems of the Lake Rotorua catchment, further hydrological data is needed to enable the effects of nutrients in groundwater systems to be characterised and to predict the effects on water quality of Lake Rotorua.

Environment Bay of Plenty (EBOP) has commissioned the Institute of Geological and Nuclear Sciences (GNS) and the National Institute of Water and Atmospheric Research (NIWA) to ultimately develop a series of models simulating nutrient transport through the groundwater and surface water systems in the Lake Rotorua catchment. GNS is expected to provide NIWA with a groundwater model of the catchment to feed into a model that will encompass both groundwater and surface water.

GNS is developing the groundwater model of the Rotorua catchment in several phases.

1. White, et al. (2004a) reviewed available data relevant to developing a groundwater model for the Lake Rotorua catchment. Gaps in hydrological data were identified. This is referred to as the phase 1 work.
2. White, et al. (2004b) recommended a programme of new data that needed to be collected to fill data gaps as identified in White, et al. (2004a).
3. Collection of new field data. This is referred to as the Field programme.
4. Develop initial groundwater models using the available data. This is known as the phase 2 work.
5. Link the groundwater models with the NIWA model and make adjustments as required. This is the phase 3 work.

This report is step 3 (above) – reporting the results of new data collected.

White, et al. (2004b) recommended a detailed list of work required to develop groundwater models of the Lake Rotorua catchment. This included drilling new bores, pump tests, water quality measurements, water dating measurements, geophysics, geothermal fluxes, water levels and physical hydrological measurements.

GNS was commissioned by EBOP to collect a subset of the data (Appendix 1.1) as suggested by White, et al. (2004b) in order to conform to budgetary and time constraints. EBOP indicated that the priority area for work was an arc from approximately Mt Ngongotaha to the west of Lake Rotorua, around to Hamurana to the north of Lake Rotorua, and then to approximately Lynmore to the south west of Lake Rotorua.

Work was prioritised based on EBOP's priority area.

This report presents the data collected as part of the field programme. The data reported reflects a combination of both the GNS and EBOP contributions (Appendix 1.1). No attempt is made to analyse or interpret the data, as this will occur in the next phase of the project. The report is split into five sections.

- **New boreholes** – detailing the geology, hydrological conditions and piezometer constructions of the new groundwater exploratory boreholes drilled as part of the programme.
- **Pump tests** – detailing methods and results of pump tests performed as part of the programme.
- **Water levels –** detailing bores located, water levels and survey results for bores.
- **Groundwater quality/water dating –** detailing water quality and water dating results for water samples collected as part of the field programme.
- **Groundwater catchment** – detailing installation of the rainfall recharge site, areas of stream/ groundwater interaction and a seep/spring survey.

Each section has been written as a 'stand alone' section.

1.1 References

White, P.A., Cameron, S.G., Kilgour, G., Mroczek, E., Bignall, G., Daughney, C. and Reeves, R.R., 2004(a). Review of groundwater in the Lake Rotorua catchment. GNS Client Report 2004/130.

White, P.A., Reeves, R.R., Cameron, S.G. and Daughney, C., 2004(b). Proposed field programme to define groundwater and nutrient flow into Lake Rotorua. Geological and Nuclear Sciences client report 2004/130a.

2.0 GEOLOGY AND PIEZOMETER CONSTRUCTION OF THE NEW DRILL HOLES

2.1 Introduction

Environment Bay of Plenty (EBOP) wants to collect more hydrological data on the groundwater systems in the Lake Rotorua catchment as part of a project identifying, characterising and predicting the effects of nutrients in groundwater on Lake Rotorua.

White et. al. (2004a) made recommendations for further work investigating the groundwater resources of the Lake Rotorua catchment based on a review of existing groundwater data relevant to the nutrient study (White et. al., 2004b). Thirty-two new boreholes were proposed to address a range of data gaps identified in these reports. Time and cost constraints meant 32 new boreholes could not be drilled as part of this field programme. Instead, boreholes were prioritised and constrained to five new groundwater investigation holes.

The Institute of Geological and Nuclear Sciences (GNS) was contracted by EBOP to provide geological and piezometer construction advice for up to five new groundwater exploratory holes in the Lake Rotorua catchment. Subsequently only three of these holes were drilled due to unexpected geologies and difficult drilling conditions. This chapter reports the results of the geological logging, piezometer constructions and issues surrounding each new groundwater investigation bore.

2.2 Dibley piezometer

2.2.1 Drilling

On 29 November, 2004 Bayliss Brothers Drilling started drilling a 150 mm groundwater monitoring piezometer (DP-1, EBOP bore number 10965) using the air rotary drilling technique. Air rotary drilling was considered to be the preferred technique because the method minimises additives which other drilling methods employ. Additives were not desired because they have the potential to chemically contaminate the groundwater and/or may affect aquifer permeability. This is an important issue because key groundwater quality and aquifer property information will be assessed from these boreholes for the project.

Caution should be used when interpreting cuttings using air-rotary drilling technique. This is because:

- Large grain sediments are reduced to sand – small gravel size sediments to enable the sediments to be blown up the casing. This can make identification of larger grained sediments difficult.

- High pressure air used to blow cuttings up the hole can cause;
  - Sediments to be blown into the formation instead, thus not coming up the hole for examination.
  - Sediments to stick to the casing walls, thus either delaying the 'depth' at which the sediments are seen, and, causing the potential to mix with other sediments at a deeper depth.

The purpose for drilling this hole was to:

1. Obtain an accurate geological log.
2. Obtain groundwater quality samples.
3. Perform a pump test to ascertain aquifer transmissivity and aquifer storativity.
4. Obtain the thickness of the Mamaku Ignimbrite.

Results of the pump test are discussed in Chapter 3.0 (pump test results).

The location of the piezometer is in a farm paddock on the Dibley property at NZMG grid co-ordinates 2788703.8, 6346607.6 (Figure 2.1).

Figure 2.1 Piezometer DP1. Piezometer under GPS tripod.

The location for drilling was dictated by the following factors:

- Exploration of a high priority area of interest to EBOP.
- Penetrate the Mamaku Ignimbrite.
- Proximity to an existing bore suitable for monitoring groundwater levels during the pump test.
- Be in an area where little was known about the geology.
- Being about mid way up the Mamaku Plateau.
- An area where access was available and permission to drill could be obtained.
- An area where future access to the bore by EBOP was possible.

The final piezometer construction is summarized in Table 2.1.

Table 2.1 Piezometer construction summary of piezometer DP1.

Item	**Distance from ground level (m)**	**Diameter (mm)**
Piezometer		
Casing (Steel)	-0.83 - 50.7	150
Casing (PVC)	-0.39 - 127	80
Casing (PVC)	127 - 138	50
Screened interval (PVC)	138 - 150	50
Total drilled depth	150	150/100
Casing – annulus backfill		
Concrete pad	0 - 0.2	
Bentonite	0.2 - 5	
Landscaping sand	5 - 30	
Bentonite	30 - 55.4	
Walton Park pea gravel backfill	55.4 - 150	

PVC casing was joined using 316 stainless steel sleeves riveted to the casing

Key issues which affected the piezometer construction included:

- The 150 mm steel casing used to 'drive' the hole got stuck at 50.7 m. This meant that 'open hole' drilling was used from 50.7 m – 119.2 m and the steel casing remained in the hole forming part of the piezometer construction.
- Drill cuttings were discontinuous between approximately 90 m to 119.2 m. This is probably due to cuttings having been 'blown' into the formations using the methods employed. A small amount of drilling foam was added to the hole at about 119 m in an attempt to retrieve cuttings. Because this did not work, drilling was suspended.
- Drilling was then re-started on 25 January, 2005 using a different drill rig. The drill rig continued drilling a cased (steel), 100 mm hole from 119.2 to 150 m using the air – rotary technique. The 100 mm steel casing was removed.
- Smaller diameter (50 mm) PVC casing was used from 127 m to 150 m which fitted down the 100 mm hole. A 316 stainless steel reducer was constructed to join the 50 mm diameter PVC to the 100 mm diameter PVC. Larger diameter PVC casing from 127 m to the surface was used to allow EBOP greater options when selecting a pump to sample the bore and to give the piezometer more strength down to 127 m.

- Water was encountered at 67.7 m and the water level rose to 59.2 m below ground level. Drilling continued to approximately 113.2 m depth before doing a 24 hr pump test (results of this are reported in the pump test section). Little return of cuttings was observed between 71 and 79 m suggesting that drilling encountered a series of cooling joints within the partially welded ignimbrite. These joints provide pathways for waterflow. From 90 m to 122 m, drilling encountered an unwelded unit of the Mamaku Ignimbrite that is water-bearing and permeable. A small (approx 0.8 m) water level difference compared to the initial water level at 67.7 m is observed from 90 m until the end of the hole.
- The piezometer was developed by pumping the bore for approximately five hours at approximately 24 l/minute once the piezometer had been constructed.
- The piezometer is finished with a concrete pad, lockable above-ground steel casing, and, a wooden fence.
- A large amount of Walton Park pea gravel was required to backfill between the PVC casing and the hole between 119 and 70 m. This suggests a large cavity formed somewhere in this area. This is consistent with the loss of cuttings from this depth range.
- Budgetary constraints prevented this hole from been drilled any further than 150 m.

2.2.2 Geology of Dibley Bore

One of the reasons for drilling this bore was to determine the thickness of the primary hydrolgeological unit in the Rotorua Catchment – Mamaku Ignimbrite. Mamaku Ignimbrite has been studied in detail by Milner et al. (2003) who used available exposures to subdivide the ignimbrite into three units; the lower (*l*), middle (*m*) and upper (*u*) Mamaku Ignimbrite. The middle (*m*) and upper (*u*) ignimbrite units in the cuttings analysed from this bore (Figure 2.2) are not clearly delineated and for the purposes of this report are considered a single, gradational entity. The *m/u* Mamaku is widely exposed in and around the Rotorua basin. The uppermost soft vapour-phase altered, grey-pink-purple ignimbrite becomes greyer, harder and less vapour-phase altered with depth. The progressive weak to moderate welding encountered from about 35 m to nearly 90 m is typical of the middle and lower part of the *m/u* Mamaku, although few deep exposures are known close to the caldera, as well as very few detailed borelogs.

Cuttings of the *m/u* Mamaku Ignimbrite contain abundant rock fragments mainly of rhyolite lava, but also of minor andesite lava, and in the uppermost level, fragments of recycled *m*

Mamaku Ignimbrite. These lithics are mostly mid grey, but many in the lower part of this unit are stained black by haematite that was most likely deposited by later cold groundwater inflows.

Welded ignimbrites routinely contain variably spaced cooling cracks that enable groundwater penetration. Groundwater was first encountered in this borehole at 67.7 m, rising on standing to 59.2 m (probably due to a series of thin cooling cracks). This moderate rise in water level, along with subsequent dry cuttings obtained suggested only slight permeability and the presence of a very minor aquifer. Injected air and most cuttings were lost into voids in the formation between 71 and 79 m (below casing). *M/u* Mamaku ignimbrite cuttings of increasing freshness and hardness were obtained from depths of 79 m to 89.2 m. The deepest cuttings of this unit are only moderately welded. The lower base unit of the ignimbrite was not encountered during drilling of this borehole.

The geological log of Dibley bore indicates the Mamaku Ignimbrite aquifer has variation in permeability over the thickness of penetrated aquifer. A water bearing fracture occurs between 67.7 m to 68 m depth. The ignimbrite was non-water bearing from 68 m to 73.5 m depth. Water bearing fractures occurred from 73.5 to 90 m depth and water bearing non-welded ignimbrite sediment from 90 m to 122 m depth. A change in permeability is indicated at 122 m to 123 m due to a fine sand and silt layer and again from 125 to 151 m due to a fine to medium sand layer. The lateral continuation of layers with different permeability away from the Dibley bore are unknown.

2.2.2.1 90-122 m Aquifer

Discontinuous cuttings from 90 to 122 m are pumiceous pebbly coarse sands. The pumice is up to 30 mm and is rounded, white to pale grey, mostly fresh (unaltered), and devoid of any signs of welding. Rounding may have occurred during the drilling process, but probably not to the same degree as seen in the cuttings. The pebbles are predominantly subangular rhyolite lava and rounded ignimbrite clasts. Sands are quartz-rich with hypersthene minerals dominant over hornblende.

No cuttings and minimal air return were obtained from 104.2 to 119.2 m coinciding with a minor hole collapse to 117 m. Cuttings bailed from this 117 m collapse are of similar lithology to those obtained from 104 m.

The fabric and origin of the 90-122 m unit is difficult to determine, however cuttings are consistent with the sandy unwelded "*l* Mamaku Ignimbrite" described by Milner et al. (2003). Horizontal permeability is much higher than the overlying ignimbrite, but this unit must be compacted, given the stability of the hole while significant compressed air was injected during drilling and later pumping. A substantial section of overgauged hole (larger diameter of hole than the size of the drill bit) developed somewhere below 90 m, as became apparent during backfilling around the piezometer (2120 kg of 2 mm Walton Park pea gravel was required to backfill to 70 m). It is assumed that this cavity coincided with the major non-return zone from 104-119 m, but due to the slow settling rate of the backfill this remains uncertain.

2.2.2.2 122-123 m

At 122 m a yellow/brown mud was returned. This possibly represents a buried soil, and therefore a significant time interval, or a thin sedimentary infill.

2.2.2.3 123-125 m

Alternating soft and very hard layers were reported by the driller; possibly lava boulders. Cuttings of red/brown rhyolite were returned. This could represent the apron of a nearby rhyolite lava dome or the basal, lag breccia of the main ignimbrite sequence. Further chemical analysis would help this interpretation.

2.2.2.4 125-151.5 m

Dark grey, very glassy, clean medium-coarse sand. The sand is composed almost entirely of clear-colourless to near-black volcanic glass with very minor feldspar and quartz crystals. Ferromagnesian content of this unit is very low, and appears to consist of hypersthene only. This unit appears to be massive and is interpreted as a compacted but unwelded pyroclastic fall deposit. The unit is unknown and is not described in published reports of the Mamaku Ignimbrite by Milner et al. (2003). There is a possibility that this deposit is another phase of the *l* Mamaku Ignimbrite, based on a section described by Fransen (1982). The major element chemistry (Figure 2.3) obtained through microprobe analysis, shows that the cuttings returned from 101-150 m are chemically indistinguishable from 'typical' Mamaku Ignimbrite. Therefore, if the fine unit between 122-123 m is not a paleosol (XRD results are ambiguous), then this glassy unit (from 125-151.5 m) is probably a chemically similar, but unassociated ash deposit sourced from near Rotorua and possibly Rotorua Caldera. Further trace element chemistry will help determine the source of this ash deposit. Abundant clean water was obtained from this unit during drilling and hydrological continuity between the sub-90 m units is possible. Therefore the Dibley bore did not drill through the bottom of the Mamaku Ignimbrite.

Summary of the geology:

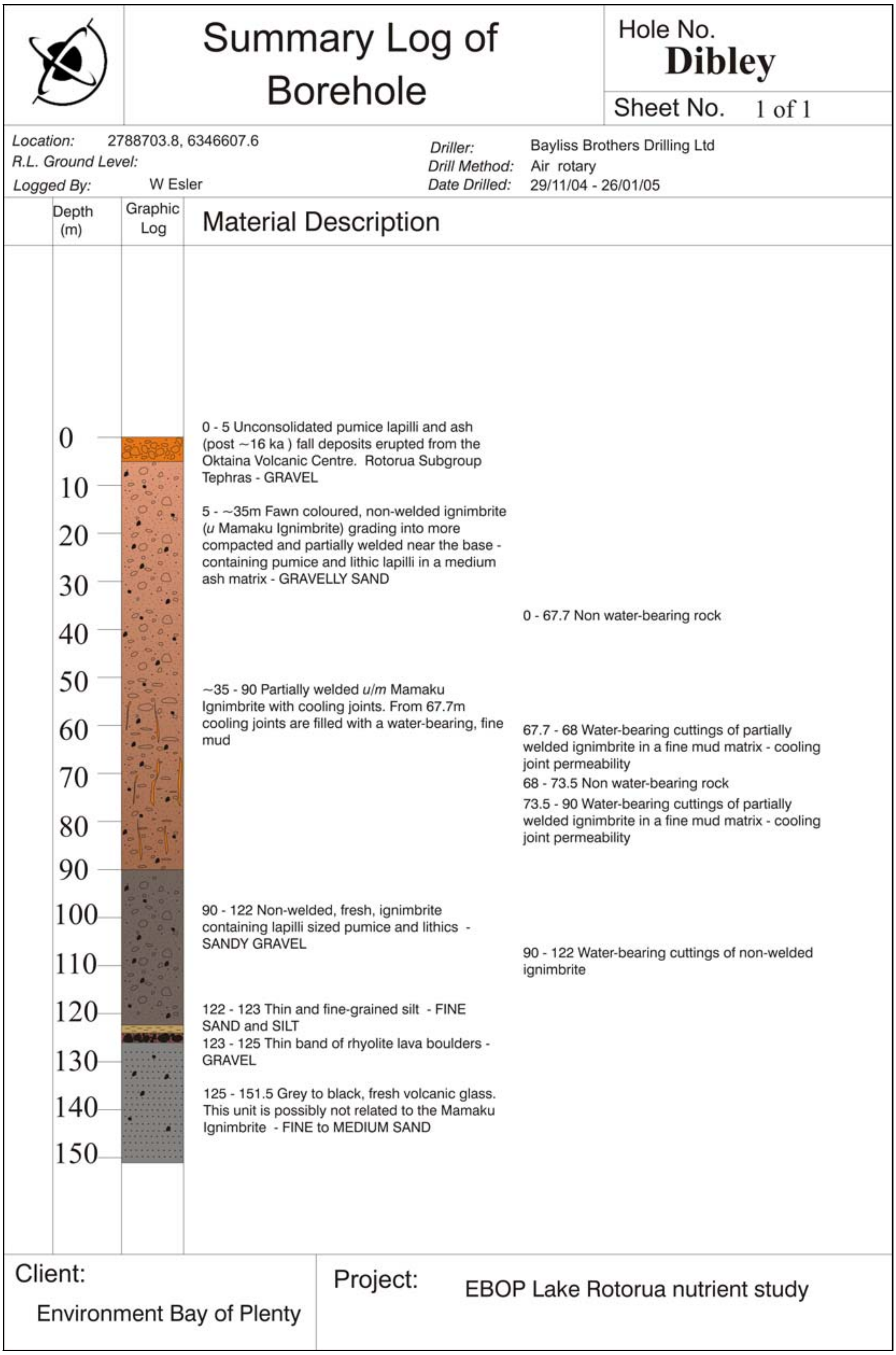
0-5 m	unconsolidated Rotorua Subgroup tephras
5-90 m	*u/m* Mamaku Ignimbrite. Compaction and degree of welding increase with depth. Joints or voids from 71 to ~79 m with no return of cuttings.
90-122 m	mid grey fresh compacted pumiceous pebbly coarse sands. Probably unwelded *l* Mamaku
122-123 m	yellow-brown fine-grained clay-rich deposit – possibly paleosol
123-125 m	thin hard bands of rhyolite boulders
125-151.5 m	dark grey and glassy, unidentified pyroclastic fall deposit with similar major element chemistry to the Mamaku Ignimbrite.

2.3 Jessie Martin Memorial Park Piezometers

2.3.1 Introduction

Two holes were drilled and piezometers constructed by Bayliss Brothers Drilling between 12 January 2005 and 8 February, 2005. The purpose of these holes was to:

1. Obtain an accurate geological log for the area.
2. Obtain groundwater quality samples.
3. Perform a pump test to ascertain aquifer transmissivity and aquifer storativity of the first sediment aquifer.
4. Obtain the thickness of the sediments overlying the Mamaku Ignimbrite.



Summary Log of Borehole

Hole No. **Dibley**

Sheet No. 1 of 1

Location: 2788703.8, 6346607.6
R.L. Ground Level:
Logged By: W Esler

Driller: Bayliss Brothers Drilling Ltd
Drill Method: Air rotary
Date Drilled: 29/11/04 - 26/01/05

Depth (m) | Graphic Log | Material Description

0 - 5 Unconsolidated pumice lapilli and ash (post ~16 ka) fall deposits erupted from the Oktaina Volcanic Centre. Rotorua Subgroup Tephras - GRAVEL

5 - ~35m Fawn coloured, non-welded ignimbrite (*u* Mamaku Ignimbrite) grading into more compacted and partially welded near the base - containing pumice and lithic lapilli in a medium ash matrix - GRAVELLY SAND

~35 - 90 Partially welded *u/m* Mamaku Ignimbrite with cooling joints. From 67.7m cooling joints are filled with a water-bearing, fine mud

90 - 122 Non-welded, fresh, ignimbrite containing lapilli sized pumice and lithics - SANDY GRAVEL

122 - 123 Thin and fine-grained silt - FINE SAND and SILT
123 - 125 Thin band of rhyolite lava boulders - GRAVEL

125 - 151.5 Grey to black, fresh volcanic glass. This unit is possibly not related to the Mamaku Ignimbrite - FINE to MEDIUM SAND

0 - 67.7 Non water-bearing rock

67.7 - 68 Water-bearing cuttings of partially welded ignimbrite in a fine mud matrix - cooling joint permeability
68 - 73.5 Non water-bearing rock
73.5 - 90 Water-bearing cuttings of partially welded ignimbrite in a fine mud matrix - cooling joint permeability

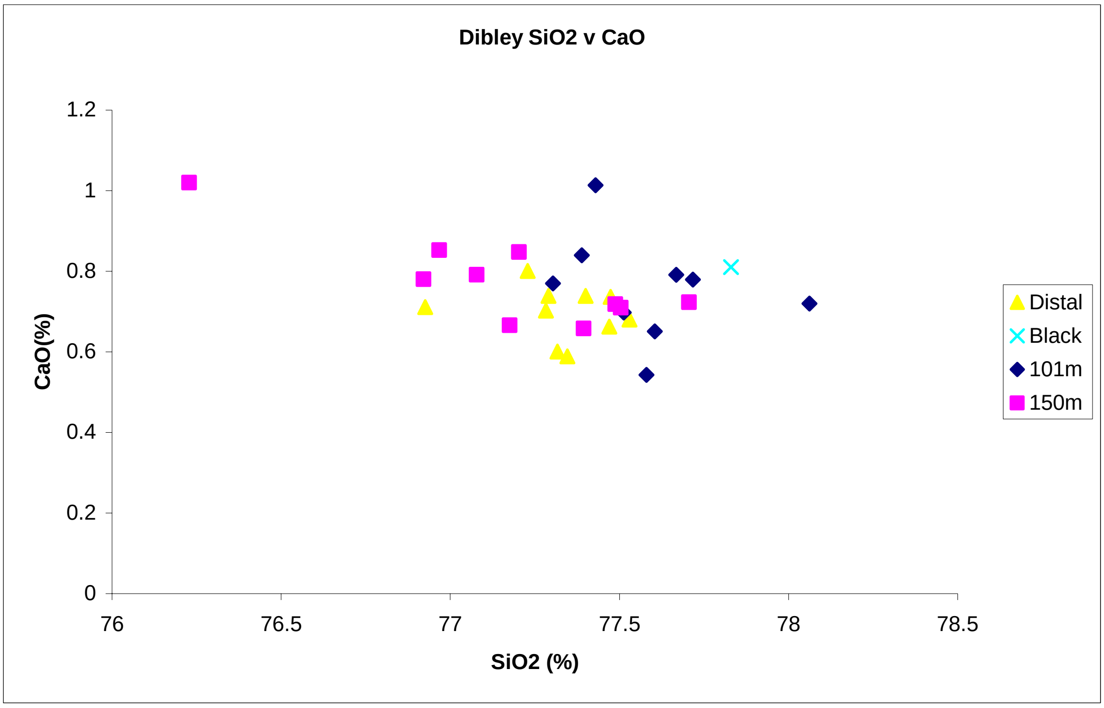
90 - 122 Water-bearing cuttings of non-welded ignimbrite

Client: Environment Bay of Plenty

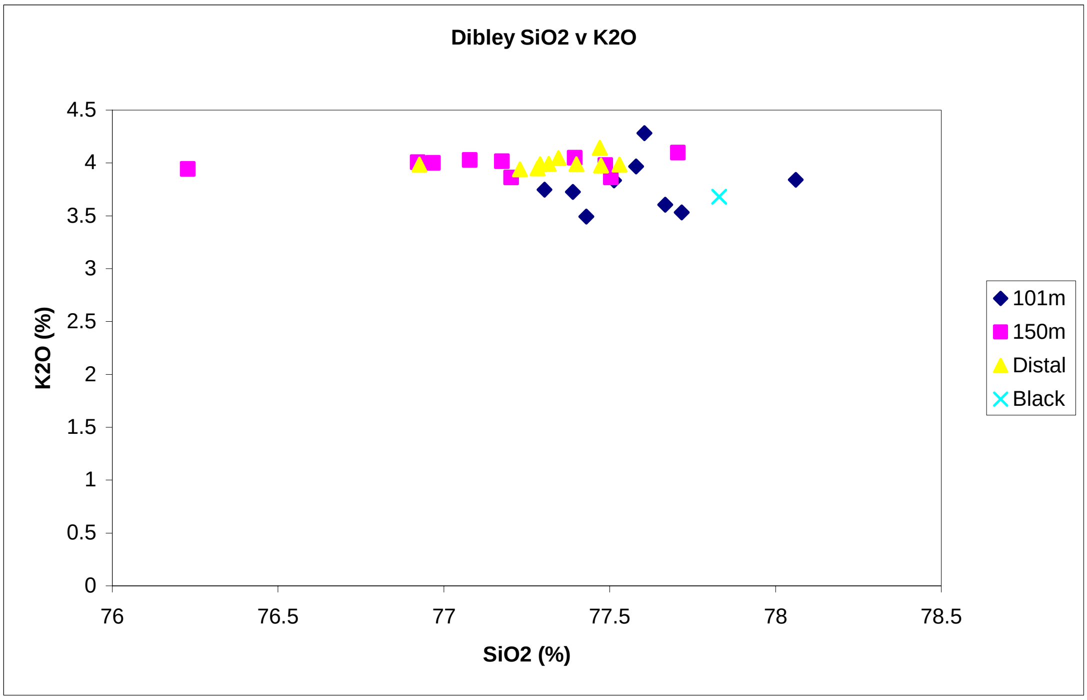
Project: EBOP Lake Rotorua nutrient study

Figure 2.2 Geological summary of DP-1.

(A)



(B)



-

Figure 2.3 Microprobe plots of samples from the DP-1 cuttings. A) SiO_2 vs CaO and B) SiO_2 vs K_2O. 101 – cuttings from 101 m; 150 – cuttings from 150 m; Distal – a sample of distal Mamaku Ignimbrite from coastal Bay of Plenty (Will Esler, pers. comm., 2005); Black – an average (from 12 samples) chemical composition of Mamaku Ignimbrite published in Black *et al.* (1996). Major elements are expressed as wt %.

The location of the piezometers is at the northern end of Jessie Martin Memorial Park (JMM Park), owned by Rotorua District Council. The deep piezometer (DP-2, EBOP bore number 10967) is at NGMG grid co-ordinates 2791569.6, 6342323.5 (Figures 2.4 and 2.5) and the shallow piezometer (D3, EBOP bore number 10966) is at NGMG grid co-ordinates 2791541.2, 6342329.3 (Figures 2.5 and 2.6).

The location for drilling was dictated by several factors:

- The location needs to be in a high priority area of interest to EBOP.
- The piezometer needed to tap the sediments above the Mamaku Ignimbrite.
- A bore suitable for monitoring groundwater levels was required nearby to pump test the aquifer.
- Close to Lake Rotorua.
- Drilling access and landowner permission were needed.
- Future access to the bores by EBOP was required.

Two bores were required to be drilled at the JMM park site as GNS could not locate a suitable observation or pumping bore that had enough information about the bore (e.g. bore depth, geology, screened interval) and that complied with the factors above. Two bores are required for pump testing a groundwater aquifer. One bore acts as a pumping bore, and the other acts as a monitor bore.

Permission was obtained for drilling the 2 bores at JMM Park from Rotorua District Council (RDC) prior to drilling (Street opening permit 10883). The permit states that holes should be " … finished flush with the ground so a mower can run over it". Permission was obtained from RDC (Bob Brake, e-mail 15/12/2004) to finish piezometer DP-2 with an above ground finish. This was recommended to preserve the piezometer given:

- The piezometer is currently located in a grazing area and maybe subject to animal interference, and,
- RDC had suggested earthworks around the site may occur in the future. The possibility of the piezometer been buried is minimised with an 'above ground' finish.

Figure 2.4 Piezometer DP-2.

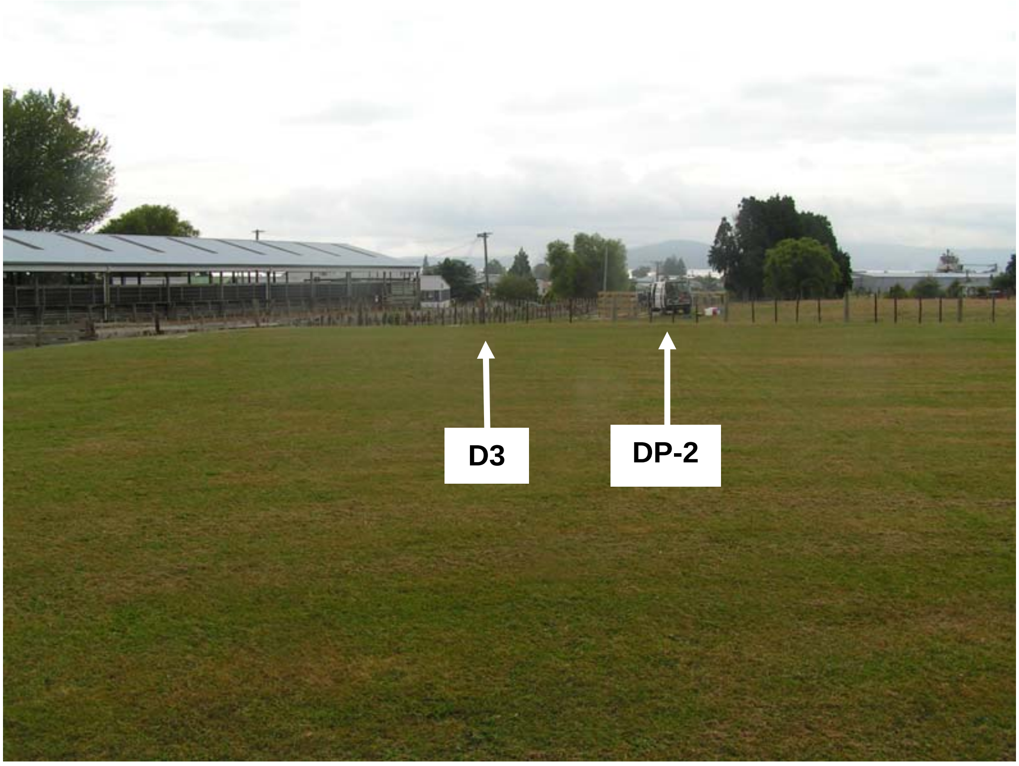


Figure 2.5 Piezometers DP-2 and D3.

Figure 2.6 Piezometer D3.

2.3.2 Summary of D3

2.3.2.1 Drilling

The Jessie Martin Memorial Park shallow piezometer was drilled and constructed first. This was done first to establish the location of the first groundwater aquifer and obtain an accurate static water level prior to the pump test. Bayliss Brothers Drilling commenced drilling a 150 mm hole on 12/01/2005 using the air – rotary and bailing drilling techniques. Bailing needed to be used as the sediments would ‘rush’ back into the drill casing each time the air was turned off to weld more casing on.

The final piezometer construction is summarized in Table 2.2. The bore construction was completed before drilling DP2.

Table 2.2 Piezometer construction summary of piezometer D3.

Item	**Distance from ground level (m)**	**Diameter (mm)**
Piezometer		
Casing (PVC)	0.12 - 20	50
Screened interval (PVC)	20 - 26	50
Total drilled depth	28	150
Casing – annulus backfill		
Concrete pad	0 - 0.2	
Bentonite	0.2 - 17.2	
Sand	17.2 - 17.8	
Walton Park pea gravel backfill	17.8 - 28.0	

Threaded PVC casing was used.

Key issues which effected the piezometer construction included:

- Sediment flowed back into the casing each time the compressed air was turned off. This then required bailing the bore to remove sediment after the usual drilling stoppages to add drilling rods and to ensure that cuttings were retrieved from the hole. Bailing bores is a slow process which meant the piezometer took longer to drill than anticipated.
- Water was encountered at 24 m below ground. The static water level quickly came up to 14.05 m, suggesting the aquifer is confined. Static water level measured 23/2/05 was 10.09 m to top of PVC casing.

2.3.3 Summary of DP-2

2.3.3.1 Drilling

Bayliss Brothers Drilling commenced drilling a 150 mm hole on 18/01/2005 using the air – rotary and bailing drilling techniques.

The final piezometer construction is summarized in Table 2.3.

Table 2.3 Piezometer construction summary of piezometer DP-2

Item	**Distance from ground level (m)**	**Diameter (mm)**
Piezometer		
Casing (PVC)	-0.513 - 62.5	50
Screened interval (PVC)	62.5 - 68.5	50
Total drilled depth	80.5	150
Casing – annulus backfill		
Concrete pad	0 - 0.2	
Backfill	0.2 - 5.5	
Bentonite	5.5 - 9.5	
Sand	9.5 - 54.5	
Walton Park pea gravel backfill	54.5 - 80.5	

Threaded PVC casing was used.

Key issues which effected the piezometer construction included:

- Sediment was coming back into the casing each time the compressed air was turned off. This meant bailing the bore was required to remove the sediment after any stoppages. This was particularly bad from about 30 m. Bailing bores is a slow process which meant the piezometer took much longer to drill than anticipated.
- A 12 hr pump test was conducted when the bore was at 36 m depth.
- As for D3, water was not encountered until 25 m. The water level rapidly rose to 9.1 m once the aquifer had been penetrated. The static water level on 23/2/05 was 9.77 m to top of the PVC casing.
- Due to budgetary constraints, the drilling was terminated when the hole was at 80.5 m without reaching the Mamaku Ignimbrite target.

2.3.4 Geology of the Jessie Martin Memorial Park bores

The main objective of drilling at this location was to determine the thickness of alluvium and lake sediments overlying the Mamaku Ignimbrite. The thickness of alluvium and fine-grained lake sediment within the Rotorua Caldera has been difficult to determine from outcrops. Therefore drilling in this area was aimed at quantifying the sediment thickness. These fine-grained lake sediments are probably acting as a significant aquitard to groundwater flow.

Both bores drilled in this area encountered similar geology and have been combined in the following descriptions (Figures 2.7, 2.8).

Primary and reworked pumiceous volcanic material erupted from the nearby and active Okataina Volcanic Centre (from the last 18 ka of eruptions) was drilled in the first 11 m of this bore. Below this, a 5 m thick, fine sand/silt diatomite deposit was encountered, indicating a calm and relatively sediment free depositional environment immediately after the Rotoiti Eruption. The early phase of the Rotoiti eruption was drilled between 16 and 25 m. These pyroclastic deposits consist of a sandy, unwelded ignimbrite overlying an impervious, fine ash, fall deposit. This package of sediment and primary pyroclastic material above 25 m is dry and is generally acting as a confining layer to groundwater flow.

From 25 to 69 m, the lithology is that of a silty, medium sand. This correlates to “Huka 2” alluvium and is water-bearing. It is the primary aquifer in this borehole and is described in detail below:

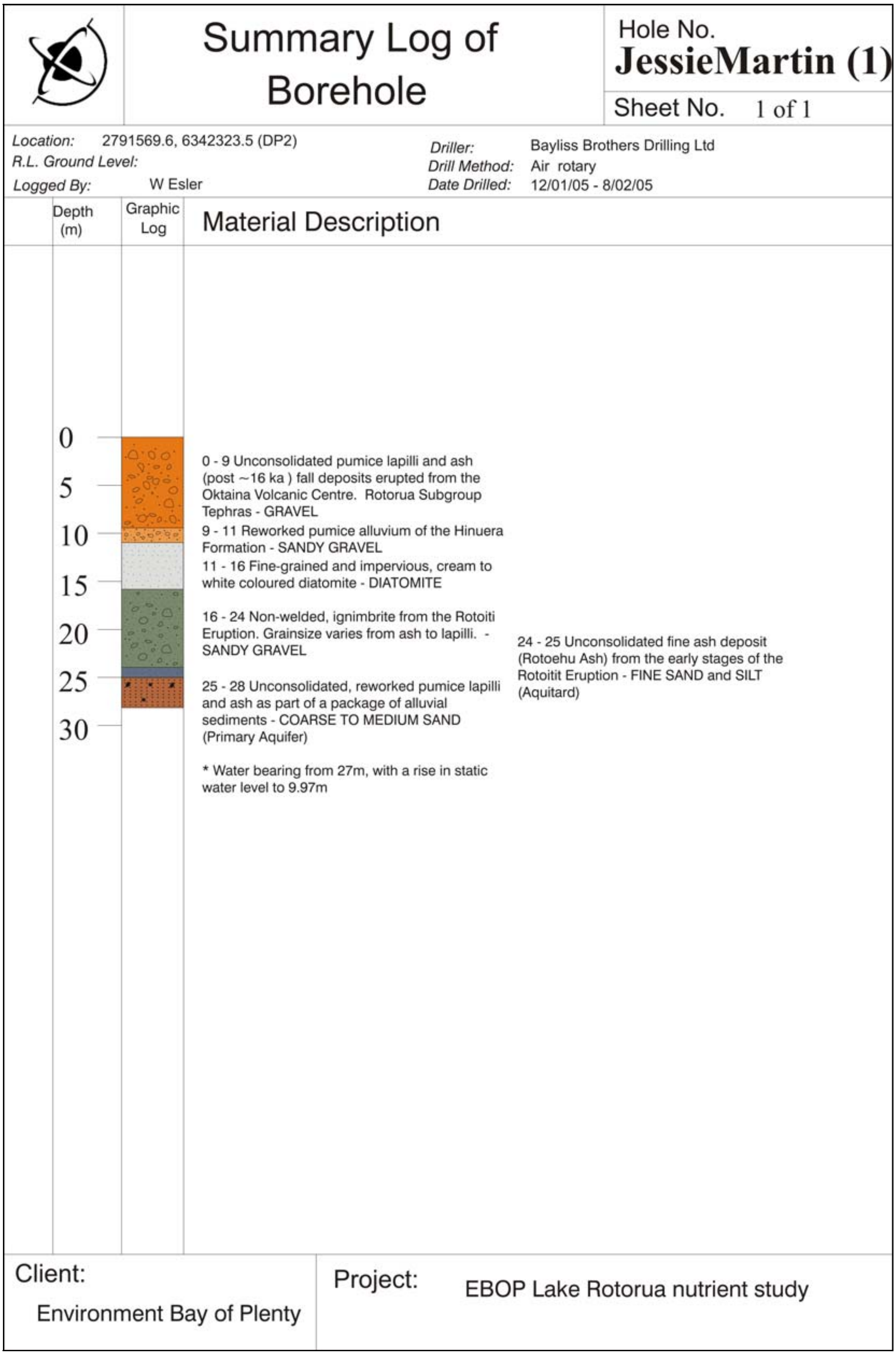
The aquifer is dominated by oxidised compositionally very mature sands, which are mostly >90% quartz, with minor feldspar, glass, and ironsand. Most ferromagnesian minerals have been dissolved and re-precipitated as rusty coatings on other grains. The sands were derived in late “Huka 2” time (~80-55 kyr) almost entirely from the erosion of weakly to moderately welded Mamaku Ignimbrite which makes up much of the catchment. The contribution of Ngongotaha rhyolites and associated Barugh Pyroclastics to these sediments is negligible at the bore site. The sands are a moderate-energy alluvial sequence and were graded to a former lake level at about 50 metres below the present. This lake would initially have been about the present size, but was progressively infilled. Contemporary peats are recorded at this depth in many Rotorua City boreholes. The previously much higher lake level had fallen due to the formation of the Tikitere Graben outfall. Few sediments of this age are exposed in the Rotorua Basin although older analogues outcrop in Paradise Valley.

The base of the aquifer is confined by impervious blue/grey, Huka 2 lake sediments. Likely correlatives outcrop in the mid/upper Paradise Valley. The thickness and attitude of these sediments is not known. The down-gradient extension of the aquifer is not well understood, but the numerous shallow circular depressions a few metres in diameter on the western bed of the lake are very likely to mark spring discharges from this unit. The aquifer probably extends semi-continuously below ca. 320 masl around much of the lake although its character will vary according to the pre-Rotoehu Ash paleogeography at each locality. The directly correlated Gee Rd bore aquifer (GNS Gee Road Letter Report prepared for EBOP, 31 March 2005) is of about the same age, but of an entirely different composition from the Jessie Martin Memorial Park site. Huka 3 diatomite is possibly absent from much of the eastern side of the basin, especially above about 310 m. The extension of the aquifer towards Hamurana was defined by the numerous Huka 3 diatomite prospecting bores drilled in the 1970s.

Recharge is presumably mainly from the Ngongotaha stream from about the Trout Hatchery upward. Porous Barugh Pyroclastics probably communicate with the streambed for about 1 km above the Hatchery.

Summary of Geology:

- 0-10 m fill; Rotorua Subgroup Tephras/tephric loess.
- 10-11 m Hinuera Formation sandy gravels.
- 11-16 m “Huka 3” diatomite.
- 16-26 m pumiceous sandy Rotoiti Ignimbrite (early phase only) over silty Rotoehu Ash.
- 26-69 m “Huka 2” alluvium. Yellow to brown slightly silty medium to coarse highly quartzose sand: iron oxide cemented in places, and minor gravel. Finer horizons at:
  - 40-41 m possibly a primary tephra.
  - 49-51 m probably deposits indicative of a swamp.
  - 69-80.5 m impermeable blue/grey slightly gravelly silty fine/medium sands (?delta) grading down to tightly laminated pure lakebed silts. Mostly diatomaceous and with fine plant fragments, including beech leaves.



Summary Log of Borehole

Hole No. **JessieMartin (1)**

Sheet No. 1 of 1

Location: 2791569.6, 6342323.5 (DP2)
R.L. Ground Level:
Logged By: W Esler

Driller: Bayliss Brothers Drilling Ltd
Drill Method: Air rotary
Date Drilled: 12/01/05 - 8/02/05

Depth (m) | Graphic Log | Material Description

0 - 9 Unconsolidated pumice lapilli and ash (post ~16 ka) fall deposits erupted from the Oktaina Volcanic Centre. Rotorua Subgroup Tephras - GRAVEL

9 - 11 Reworked pumice alluvium of the Hinuera Formation - SANDY GRAVEL

11 - 16 Fine-grained and impervious, cream to white coloured diatomite - DIATOMITE

16 - 24 Non-welded, ignimbrite from the Rotoiti Eruption. Grainsize varies from ash to lapilli. - SANDY GRAVEL

24 - 25 Unconsolidated fine ash deposit (Rotoehu Ash) from the early stages of the Rotoitit Eruption - FINE SAND and SILT (Aquitard)

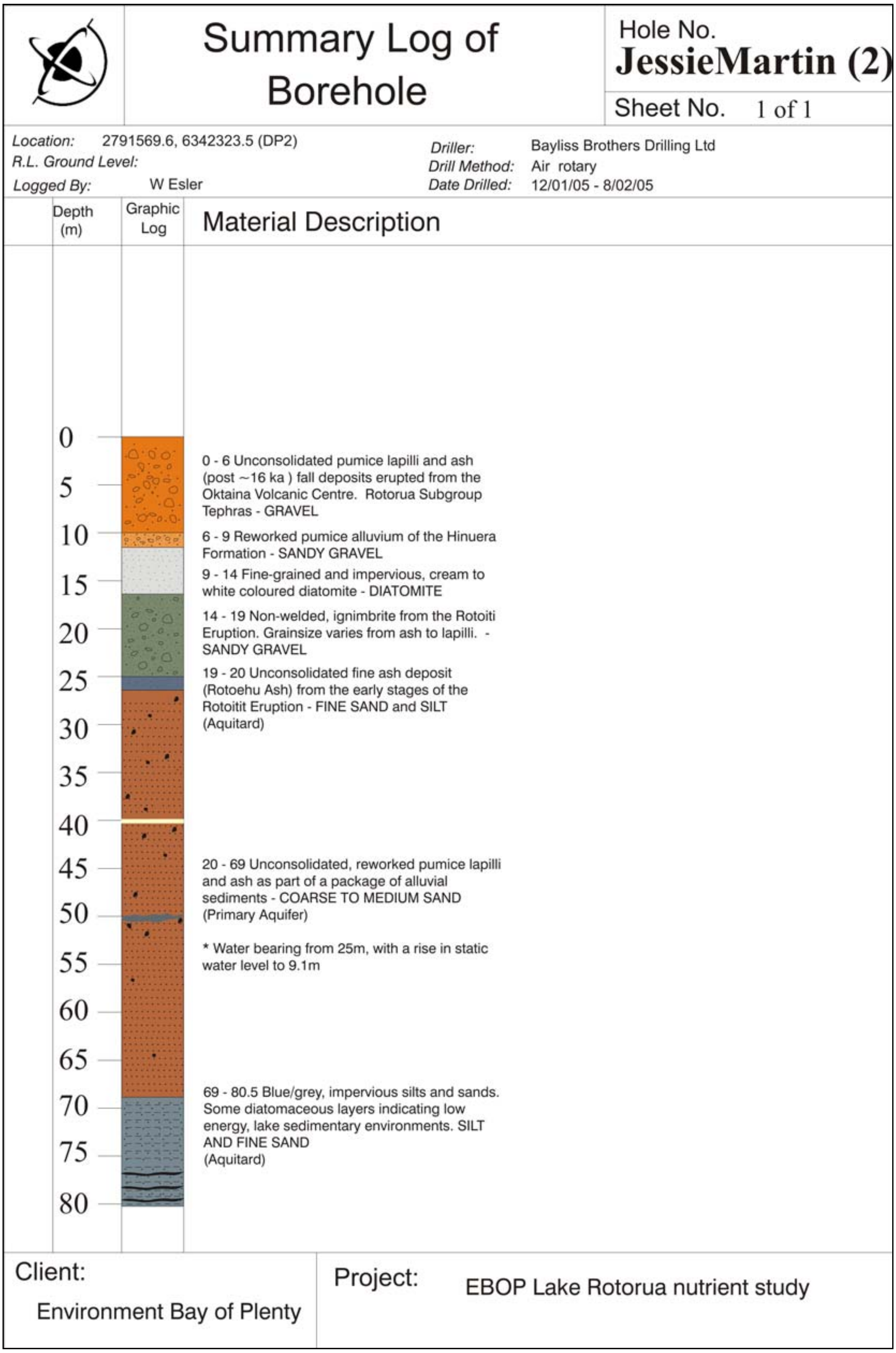
25 - 28 Unconsolidated, reworked pumice lapilli and ash as part of a package of alluvial sediments - COARSE TO MEDIUM SAND (Primary Aquifer)

* Water bearing from 27m, with a rise in static water level to 9.97m

Client: Environment Bay of Plenty

Project: EBOP Lake Rotorua nutrient study

Figure 2.7 Geological summary of piezometer D3.



Summary Log of Borehole

Hole No. **JessieMartin (2)**

Sheet No. 1 of 1

Location: 2791569.6, 6342323.5 (DP2)
R.L. Ground Level:
Logged By: W Esler

Driller: Bayliss Brothers Drilling Ltd
Drill Method: Air rotary
Date Drilled: 12/01/05 - 8/02/05

Depth (m)	Graphic Log	Material Description

0 - 6 Unconsolidated pumice lapilli and ash (post ~16 ka) fall deposits erupted from the Oktaina Volcanic Centre. Rotorua Subgroup Tephras - GRAVEL

6 - 9 Reworked pumice alluvium of the Hinuera Formation - SANDY GRAVEL

9 - 14 Fine-grained and impervious, cream to white coloured diatomite - DIATOMITE

14 - 19 Non-welded, ignimbrite from the Rotoiti Eruption. Grainsize varies from ash to lapilli. - SANDY GRAVEL

19 - 20 Unconsolidated fine ash deposit (Rotoehu Ash) from the early stages of the Rotoitit Eruption - FINE SAND and SILT (Aquitard)

20 - 69 Unconsolidated, reworked pumice lapilli and ash as part of a package of alluvial sediments - COARSE TO MEDIUM SAND (Primary Aquifer)

* Water bearing from 25m, with a rise in static water level to 9.1m

69 - 80.5 Blue/grey, impervious silts and sands. Some diatomaceous layers indicating low energy, lake sedimentary environments. SILT AND FINE SAND (Aquitard)

Client: Environment Bay of Plenty

Project: EBOP Lake Rotorua nutrient study

Figure 2.8 Geological summary of piezometer DP-2.

2.4 References

Black, T.M., Shane, P.A.R., Westgate, J.A., Froggatt, P.C., 1996. Chronological and palaeomagnetic constraints on widespread welded ignimbrites of the Taupo volcanic zone, New Zealand, Bulletin of Volcanology, 58 (2-3), p. 226-238, 1996.

Fransen, P.J.B. 1982. Geology of the western Mamaku Plateau and variations in the Mamaku Ignimbrite. Unpublished MSc thesis, University of Waikato, Hamilton.

Milner, D.M., Cole, J.W., Wood, C.P. 2003. Mamaku Ignimbrite; a caldera-forming ignimbrite erupted from a compositionally zoned magma chamber in Taupo volcanic zone, New Zealand, *Journal of Volcanology and Geothermal Research 122(3-4)*: 243-264.

White, P.A., Reeves, R.R., Cameron, S.G. and Daughney, C., 2004(a). Proposed field programme to define groundwater and nutrient flow into Lake Rotorua. Geological and Nuclear Sciences client report 2004/130a.

White, P.A., Cameron, S.G., Kilgour, G., Mroczek, E., Bignall, G., Daughney, C. and Reeves, R.R., 2004(b). Review of groundwater in the Lake Rotorua catchment. GNS Client Report 2004/130.

3.0 PUMP TEST RESULTS

3.1 Results of pump test on Dibley bore (DP-1)

3.1.1 Introduction

A 24 hour pump test was undertaken on the Dibley bore on 13 and 14 December 2004. The purpose of the pump test was to provide aquifer transmissivity and storativity values of the Mamaku Ignimbrite aquifer for input into a groundwater flow model that is to be developed to assist with resource management of the Lake Rotorua groundwater catchment. The pump test was commissioned by Environment Bay of Plenty as part of a larger Lake Rotorua groundwater catchment study undertaken by GNS. The pump test was undertaken by Bayliss Bros. drilling from Hawke's Bay. The bore was pumped at a constant rate of 3 l/s. Groundwater levels were measured in three bores (Figure 3.1) by automatic recorder at minute interval during the pumping and recovery phase of the test.

The pumping and observation bore details are summarised in Table 3.1 and 3.2. The pumping bore draws water from the Mamaku Ignimbrite aquifer. At the time of the pump test the bore was 113.2 m deep and the bottom of the aquifer had not been penetrated by the bore. The casing was set at 50.7 m depth and the bore was open hole to 113.2 m depth. After completion of the pump test the Dibley bore was deepened to 151.5 m which still did not penetrate the base of the Mamaku Ignimbrite. The top of the Mamaku Ignimbrite at the Dibley bore is approximately 5 m below ground surface. The total thickness of the Mamaku Ignimbrite at the test area is not known as no local bores have penetrated the base of the formation.

Groundwater level measurements recorded during the drilling of Dibley bore and results of pump test analysis indicate the Mamaku Ignimbrite aquifer is confined or semi-confined at the test site. Water-bearing sediment was encountered at 67.7 m depth (Chapter 2.0), giving 45.5 m of saturated thickness penetrated by the Dibley bore at the time of the pump test. During drilling of the bore, groundwater level rose 8.5 m above the top of the water-bearing sediment to 59.2 m depth, indicating the occurrence of lower permeability or unfractured sediment overlying the aquifer. The saturated thickness is greater than 83.8 m, based on the top of the groundwater bearing sediment at 67.7 m depth and completed bore depth of

151.5 m. An assumed aquifer thickness of 100 m has been used in the pump test analysis for adjustment for partial penetration effects. The geological log of Dibley bore (Figure 2.2) describes the water-bearing sediment at 67.7 m depth as partially welded ignimbrite with common cooling joints.

The geological log of Dibley bore indicates the Mamaku Ignimbrite aquifer has variation in permeability over the thickness of penetrated aquifer. A water bearing fracture occurs between 67.7 m to 68 m depth. The ignimbrite was non-water bearing from 68 m to 73.5 m depth. Water bearing fractures occurred from 73.5 to 90 m depth and water bearing non-welded ignimbrite sediment from 90 m to 122 m depth. A change in permeability is indicated at 122 m to 123 m due to a fine sand and silt layer and again from 125 to 151 m due to a fine to medium sand layer. The lateral continuation of layers with different permeability away from the Dibley bore are unknown.

The two observation bores (Obs 1 and 2, Table 3.1) appear to only partially penetrate the Mamaku Ignimbrite aquifer, based on observation bore depth and thickness of Mamaku Ignimbrite at Dibley bore. Observation bores 1 and 2 are 89.9 m and 89.5 m deep, respectively. The Mamaku Ignimbrite at the Dibley bore is greater than 146.5 m thick.

Table 3.1 Summary of pumping and observation bore details.

Bore	**Local ID**	**Purpose**	**Depth**	**Static**	**Distance from pumping bore**	**Screen or open hole interval**	**Maximum drawdown**
Unit			**m**	**mbmp**	**m**	**mbgl**	**m**
Dibley	Dibley pumped	Pumping	113.2	52.22	-	50.7 – 113.2	2.566
Obs 1	Dibley Obs	Observation	89.9	62.415	94.9	5 – 89.9	0.107
Obs 2	Price	Observation	89.5	74.562	1850	?	Nil

Table 3.2 Bore location.

Bore	**Easting**	**Northing**	**GPS method**
Dibley	2788703.8	6346607.6	RTK
Obs 1	2788613	6346572	Handheld
Obs 2	2790107	6347815	Handheld

3.1.2 Pump test results

All groundwater level data used in the pump test analyses were corrected for changes in barometric pressure that occurred during the test.

Table 3.3 Summary of aquifer transmissivity and storativity.

Bore	**Analyses**	**Transmissivity**		**Storativity**
		Drawdown	**Recovery**	
Pumping bore	Theis recovery		600 m^2/day	
Obs 1	Hantush (1961) (partial penetration of a confined aquifer)	600 m^2/day	815 m^2/day	4 x 10^{-3}

Maximum drawdown in the pumping bore after 24 hours pumping was 2.566 m (Table 3.1, Figure 3.2). Groundwater level recovered to within 98.5% of pre-pump test static approximately 17 hours after pumping ceased. Transmissivity calculated from the pumping bore recover data is 600 m^2/day (Table 3.3, Figure 3.3).

Maximum drawdown in Obs 1 was 0.107 m (Table 3.1, Figure 3.4). Transmissivity calculated from drawdown data was about 600 m^2/day using the Hantush (1961) solution for partial penetration of a confined aquifer and 815 m^2/day (Table 3.3, Figures 3.5 and 3.6). The value of 600 m^2/day calculated from Obs 1 drawdown data is considered to be the most reliable indication of aquifer transmissivity as this was the only observation bore that was affected by pumping. Aquifer storativity is calculated to be 4 x 10^{-3} from Obs 1 drawdown data (Table 3.3, Figure 3.5).

The Hantush (1961) analyses for partial penetration of a confined aquifer with r/B = 0.2 and Kz/Kr = 1, provided the best fit to Obs 1 drawdown data (Figure 3.6). The data deviates from the Hantush curve at about 450 minutes after the start of pumping (Figure 3.5), indicating the aquifer is either leaky-confined or the cone of depression intersected a recharge boundary after approximately 450 minute pumping. The reduced drawdown is not considered to be caused by a regional rise in groundwater level during the test, as the groundwater level rise was not observed in Obs 2 (Figure 3.7), which is located outside of the area of influence of pump test. The reduction in drawdown can not be attributed to rainfall as no rain was recorded at the EBOP Kaharoa rainfall site (Figure 3.8), located approximately 9 km to the northeast of Dibley bore, during the pump test period or during the preceding seven days.

About 800 minutes into the drawdown phase of the pump test there is another upward deflection in the data indicating a reduction in recharge or a lower permeability boundary. These changes may be a function of aquifer lithology or the partial penetration circumstances of both the test and observation bores. Despite these effects, the indicated transmissivity and storativity values appear to be reasonably valid.

An accurate estimate of aquifer hydraulic conductivity can not be made as aquifer thickness is unknown. An assumed aquifer thickness of 100 m provides a hydraulic conductivity value of 6 m/day.

This hydraulic conductivity volume is near the top of the range of literature values for hydraulic conductivity of a fractured igneous or metamorphic rock (~0.01 ⇒ 10 m/d) and at the lower end of the range for fractured basalt rock (0.01 ⇒ 1000 md/) (Freeze and Cherry, 1979).

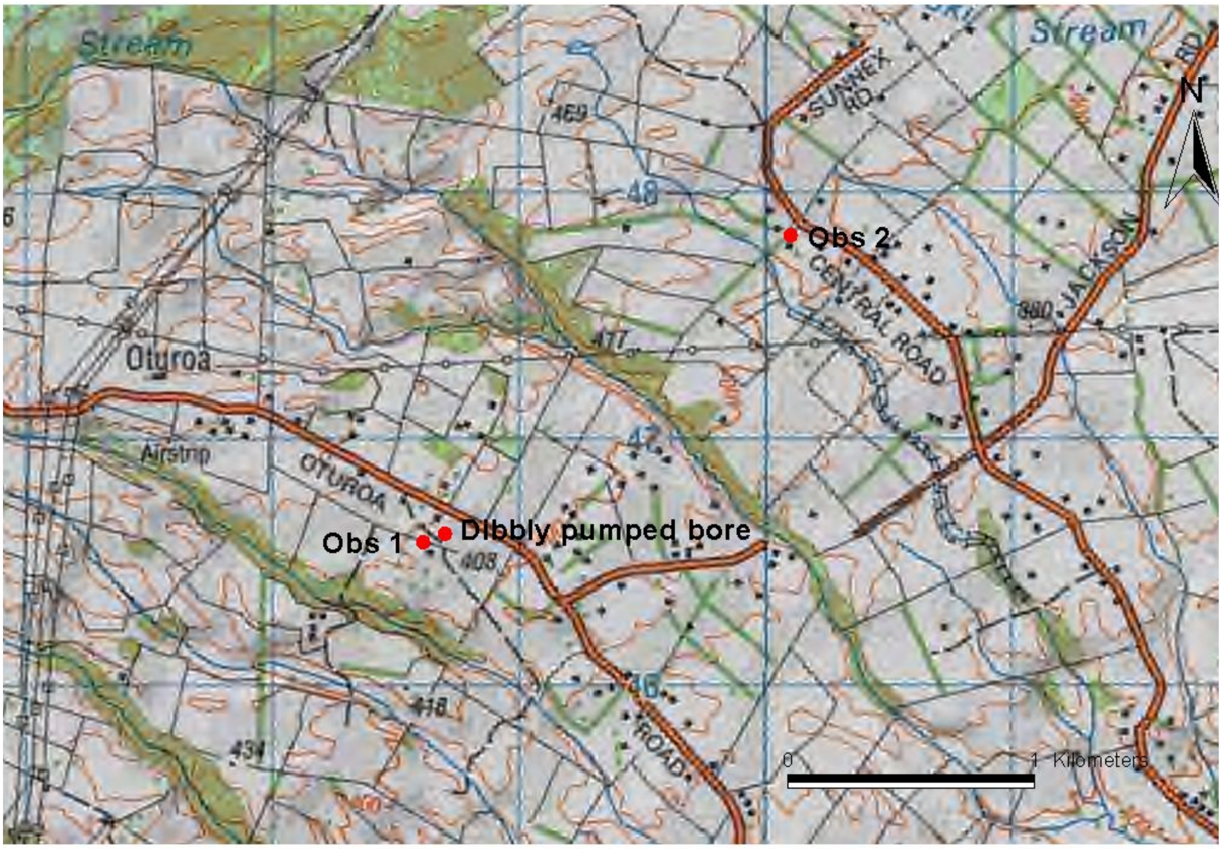


Figure 3.1 Location map of DP-1 pump test bores.

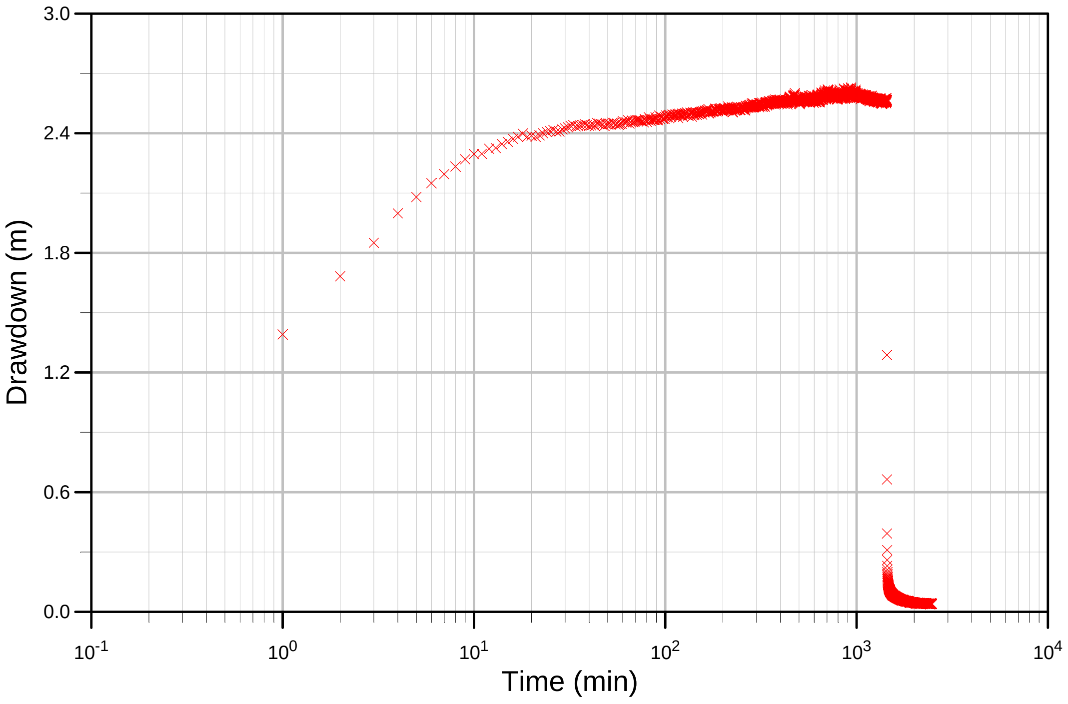


Figure 3.2 Pumping bore drawdown and recovery.

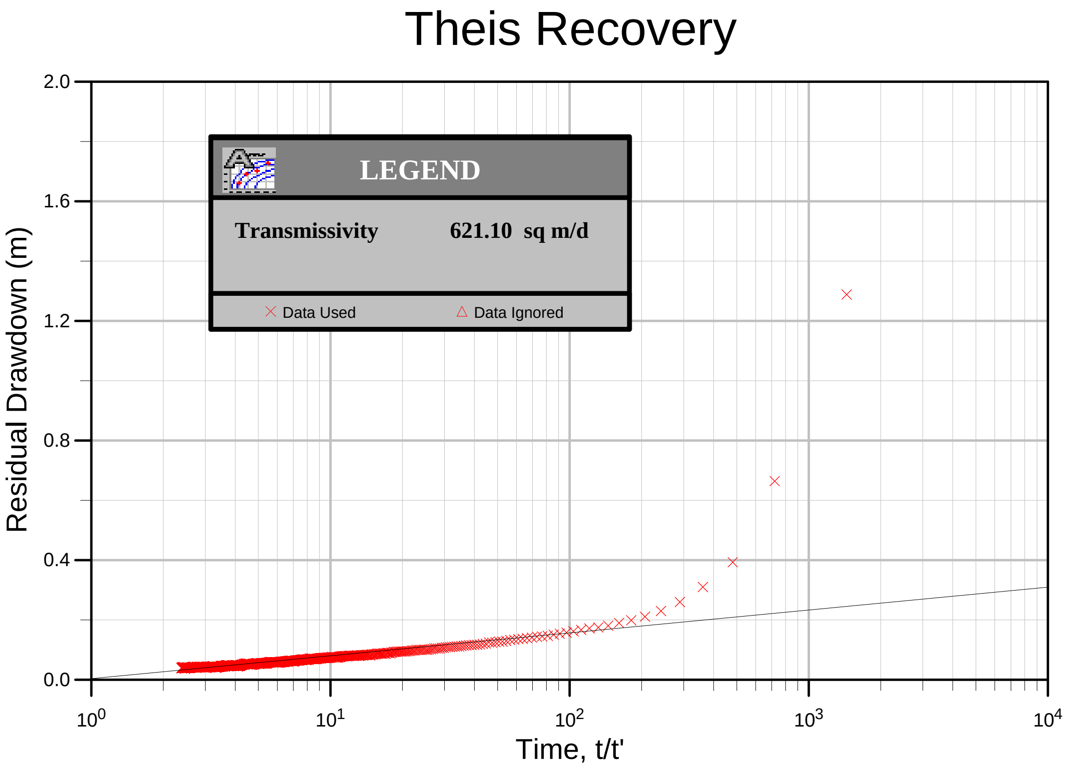


Figure 3.3 Pumping bore Theis recovery analyses.

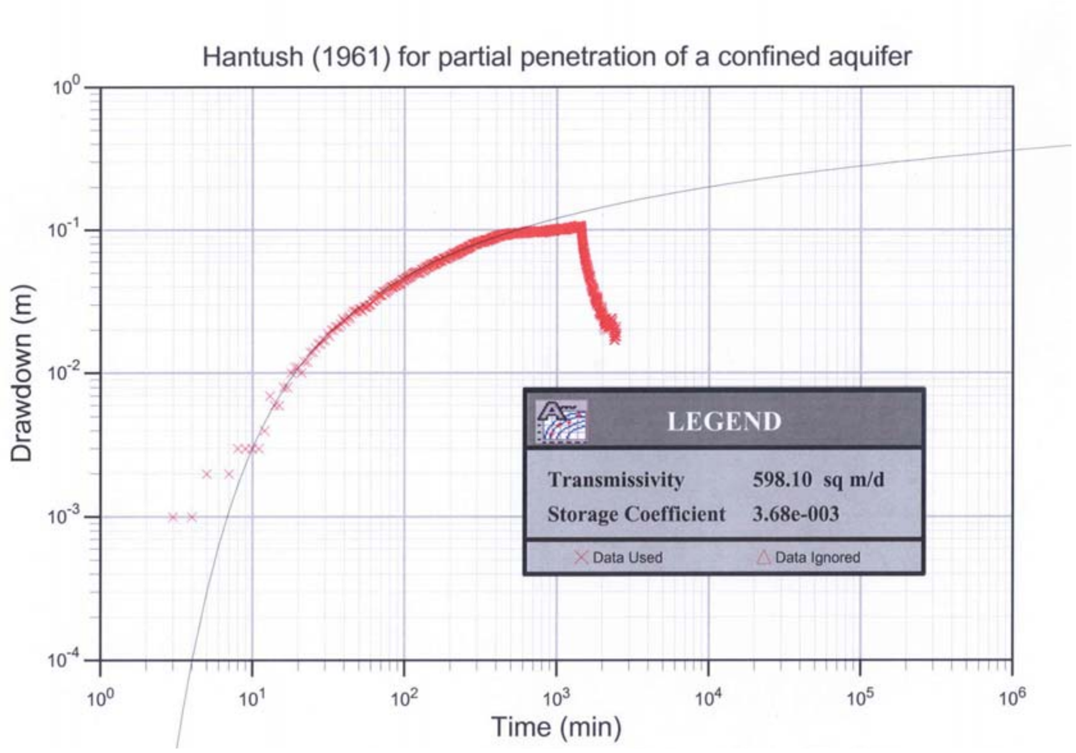


Figure 3.4 Obs 1 bore drawdown and recovery.

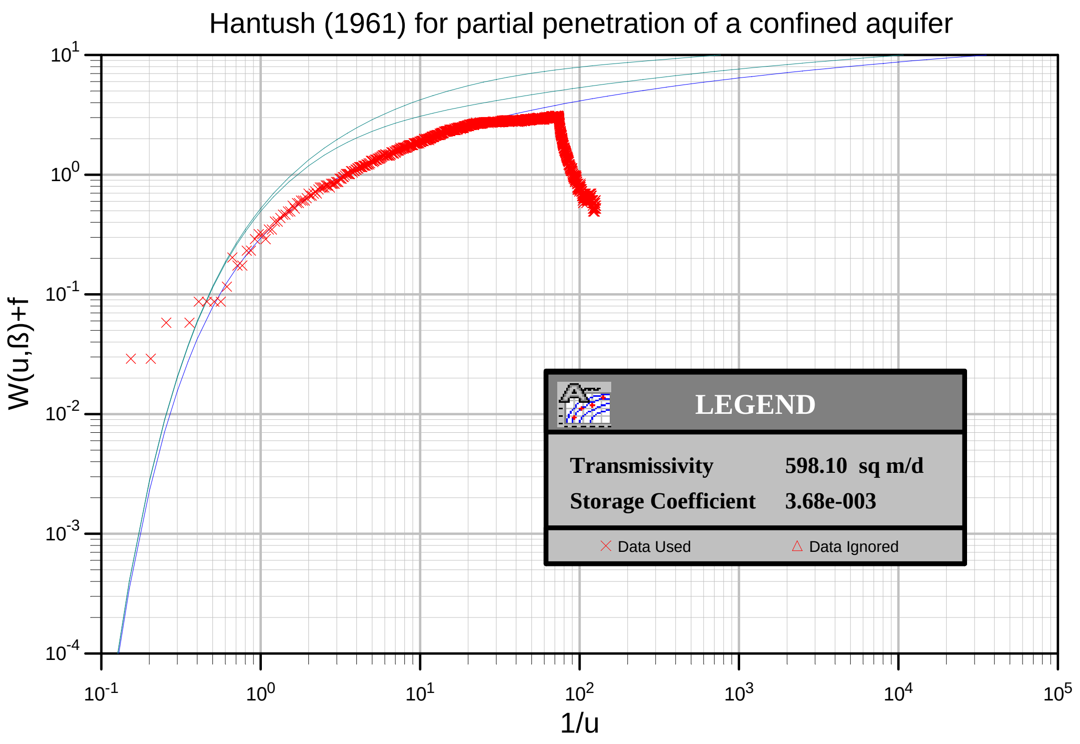


Figure 3.5 Obs 1 Hantush and Jacob (1955) leaky aquifer analysis.

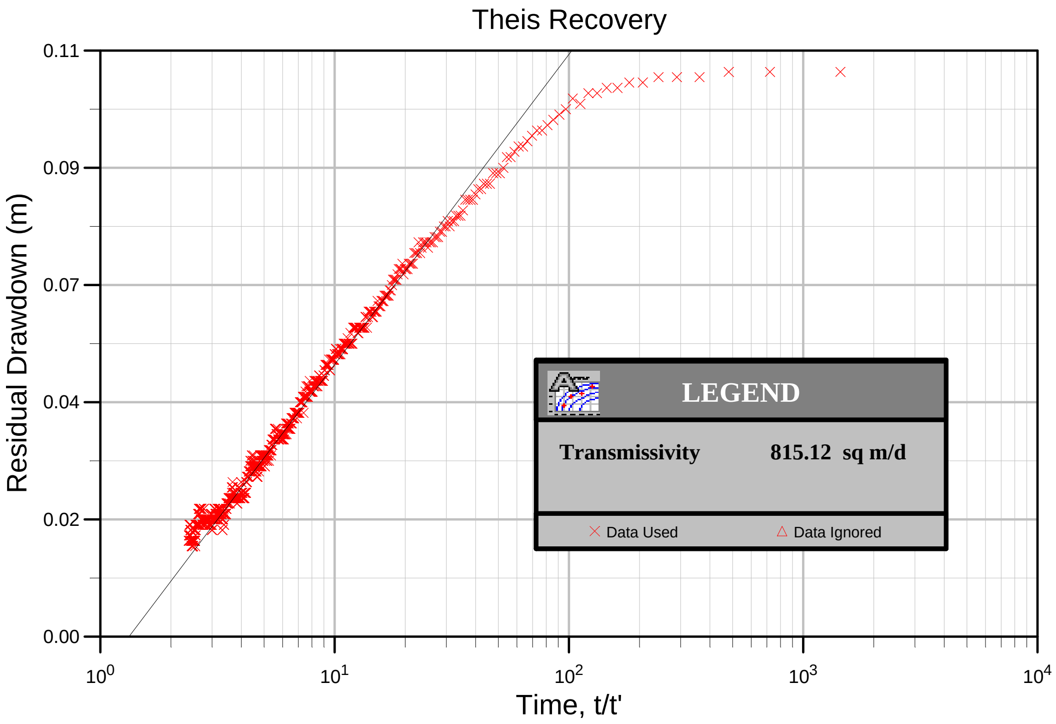


Figure 3.6 Obs 1 Theis recovery analysis.

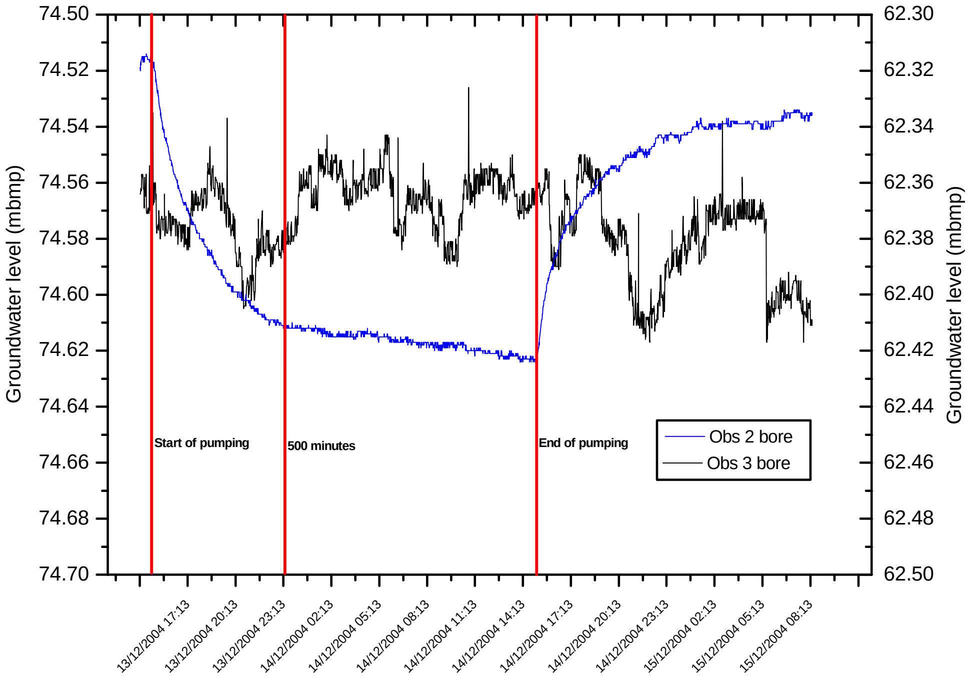


Figure 3.7 Groundwater level at observation bores 2 and 3.

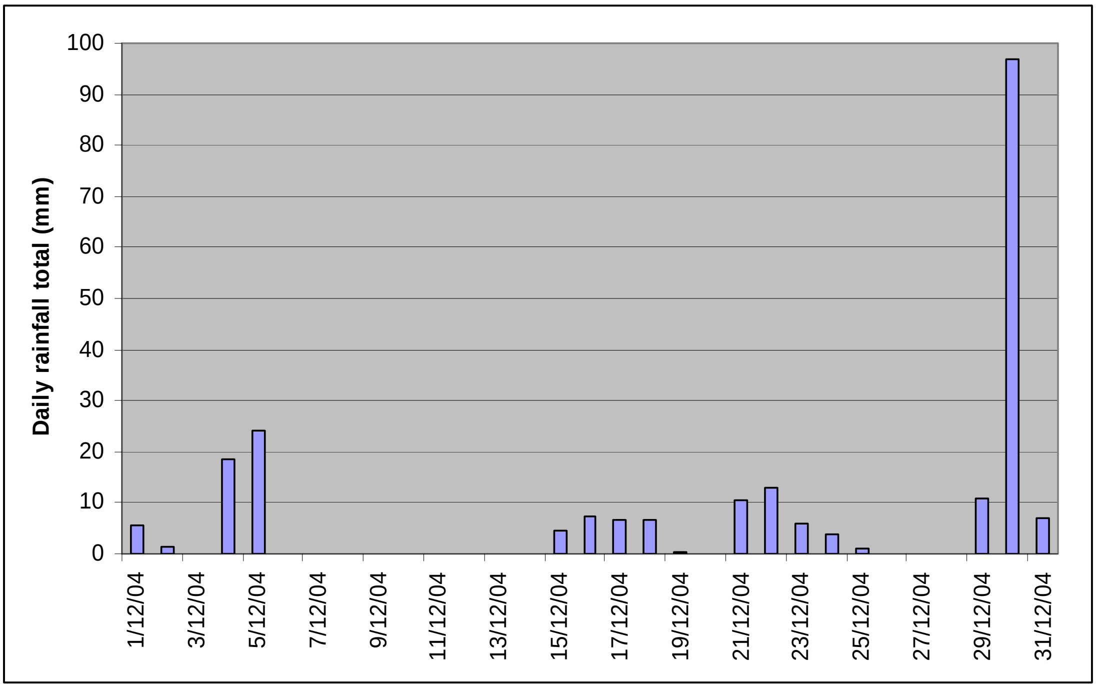


Figure 3.8 Daily rainfall at Kaharoa during December 2004.

3.2 Results of pump test on JMM Park bore (DP-2)

3.2.1 Introduction

A 12 hour pump test was undertaken on the JMM Park bore on 20 and 21 January 2005. The bore was pumped at a constant rate of 5 l/s. Groundwater levels were measured in two bores (Figure 3.9, Tables 3.4 and 3.5) by automatic recorder at minute intervals during the pumping and recovery phase of the test.

At the time of the pump test the JMM Park bore was at 36 m depth. After the pump test the bore was deepened to 80.5 m to investigate the thickness of the Huka Group sediment. Bore details described in this pump test section pertain to bore construction at the time of the test. The pumping bore draws water from a silty, sandy, gravely pumice aquifer within the Huka Group sediments. The aquifer material is described as unconsolidated, reworked pumice lapilli and ash (Figure 2.8). The pumping bore was screened over a 12 m length from 24 m to 36 m depth. At the time of the pump test the aquifer was only partially penetrated.

Subsequent deepening of the bore indicated the aquifer is 43 m thick and extends to 69 m depth. At 69 m depth the aquifer overlies a low permeability blue grey silt and fine sand sediment.

During drilling of the JMM Park bore water-bearing sediment was not encountered until 25 m depth. Water level rose to 9.77 m depth after the aquifer had been penetrated, indicating the aquifer is confined at the JMM Park bore site. The overlying confining sediment is indicated by the drilling report (Chapter 2.0, this report) to be the 17 m thickness of sediment from 11 m to 26 m depth, consisting of (Figure 2.7):

- 7 m thickness of fine grained diatomite between 7 and 14 m depth,
- 5 m thickness of reworked Rotoiti Ignimbrite pumice deposit between 14 and 19 m depth, and
- 5 m thickness of silty gravely sand from a 20 to 25 m depth.

The JMM Park Obs 1 bore is located 29 m to the northwest of the pumping bore (Figure 2.7). Obs 1 was drilled to 28 m depth. The screen was installed from 20 m to 26 m depth. The 2 m length of open hole from 26 m to 28 m was left open and is likely to have collapsed. The bore log indicates that groundwater was encountered between 24 m and 25 m depth within ash and lapilli sediment, but the higher permeability part of the aquifer was not penetrated until 27 m to 28 m depth. As the screen is set between 20 m and 26 m it suggests the bore is not screened in the main part of the aquifer. However, hydraulic connection with the aquifer is indicated as static groundwater level in Obs 1 is 10.09 m below top of casing. This is very similar to static groundwater level of 9.77 m below top of casing in the pumping bore.

Table 3.4 Summary of pumping and observation bore details.

Bore	**Local ID**	**Purpose**	**Depth**	**Static water level**	**Distance from pumping bore**	**Screen or open hole interval**	**Maximum drawdown**
Unit			**m**	**mtoc**	**m**	**mbgl**	**m**
JMM Park pumping	JMM Park	Pumping	36	9.77	-	24 – 36	3.398
JMM Park Obs 1	Piezometer D3	Observation	28	10.09	29	20 - 26	0.432

Table 3.5 Bore location.

Bore	Easting	Northing	GPS method of bore location
JMM Park pumping	2791569.6	6342323.5	RTK
JMM Park Obs 1	2791541.2	6342329.3	RTK

3.2.2 Pump test results

All groundwater level data used in the pump test analyses were corrected for changes in barometric pressure that occurred during the test.

Table 3.6 Summary of aquifer transmissivity and storativity.

Bore	Analyses	Transmissivity		Storativity
		Drawdown	Recovery	
JMM Park Pumping	Theis recovery		239 m^2/day	
JMM Park Obs 1	Hantush (1964) (partial penetration of a leaky confined aquifer)	200 m^2/day	290 m^2/day	2.0×10^{-3}

Maximum drawdown in the pumping bore after 12 hours pumping was 3.398 m (Table 3.4, Figure 3.10). Groundwater level recovered to within 99% of pre-pump test static approximately two hours after pumping ceased. Transmissivity calculated from the pumping bore recover data is 239 m^2/day (Table 3.6, Figure 3.11).

Maximum drawdown in Obs 1 was 0.432 m (Table 3.4, Figure 3.12). Transmissivity calculated from drawdown data was 200 m^2/day and 290 m^2/day from recovery data (Table 3.6, Figures 3.13 and 3.14). The value of 200 m^2/day calculated from Obs 1 drawdown data is considered to be the most reliable indication of aquifer transmissivity as observation bore drawdown data provides the best assessment of bulk aquifer hydraulic properties. Aquifer storativity is calculated to be 2.0×10^{-3} from Obs 1 drawdown data (Table 3.6, Figure 3.14).

The Hantush (1964) analyses for partial penetration of a leaky confined aquifer with r/B = 0.5 and Kz/Kr = 0.04 provided the best fit to Obs 1 drawdown data (Figure 3.14).

Figure 3.9 Location map of the DP-2 pump test bores.

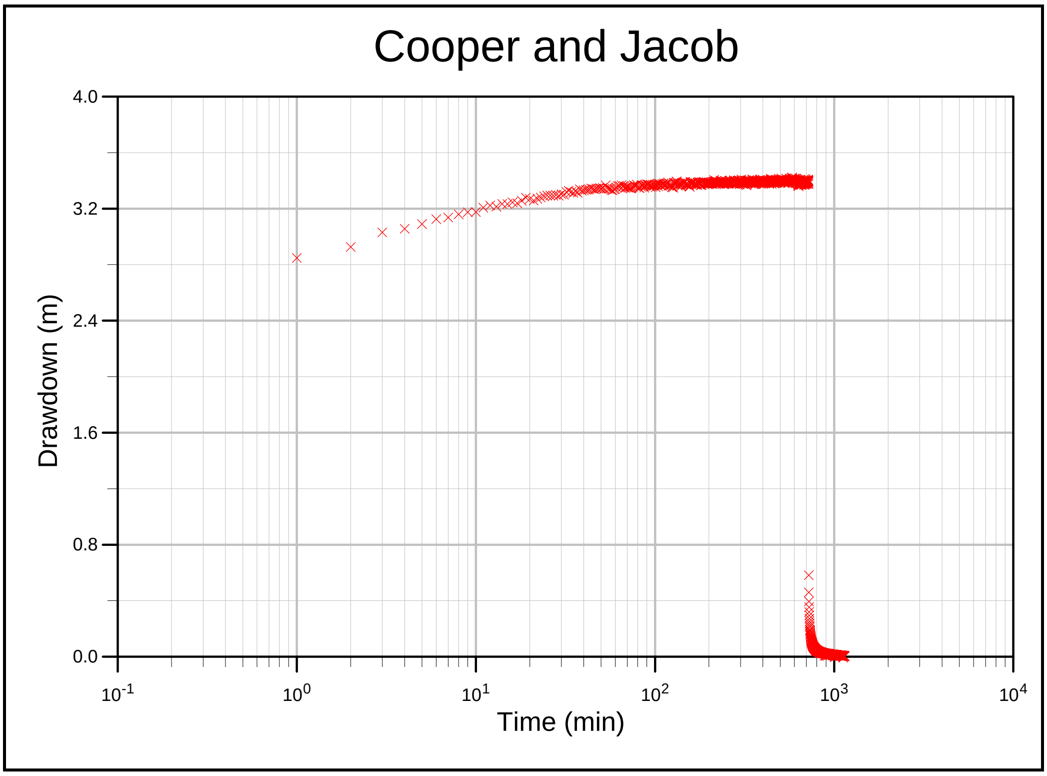


Figure 3.10 Pumping bore drawdown and recovery.

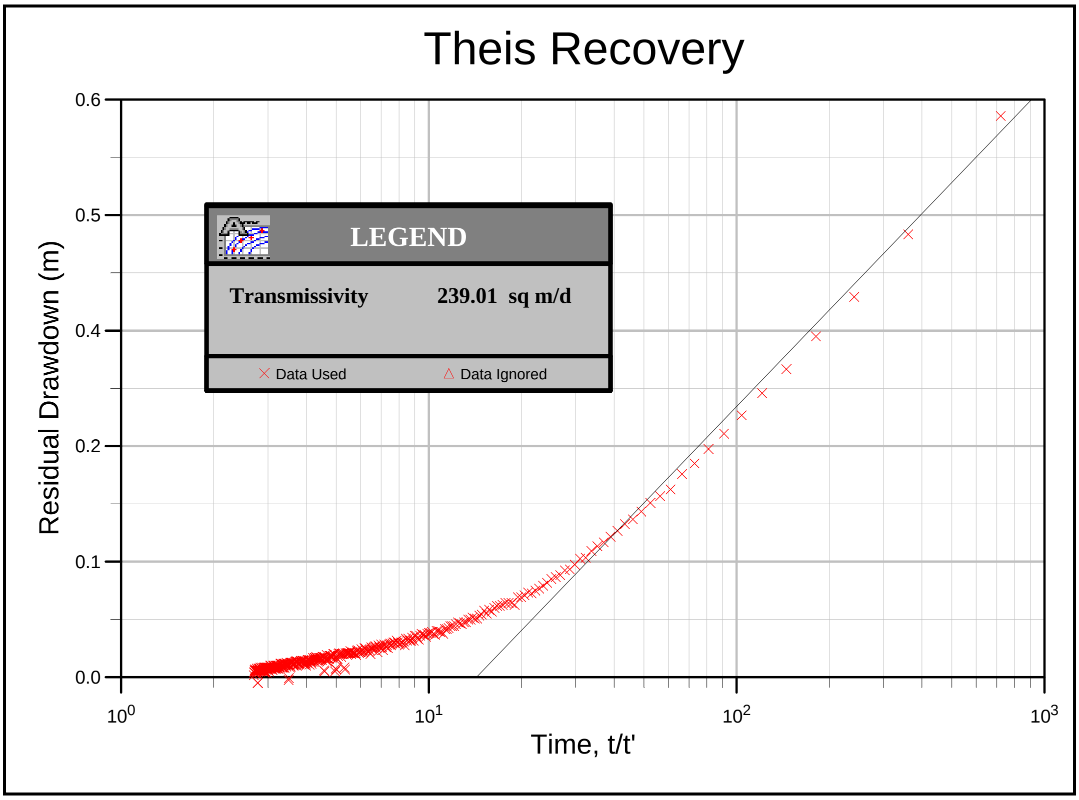


Figure 3.11 Pumping bore Theis recovery analyses.

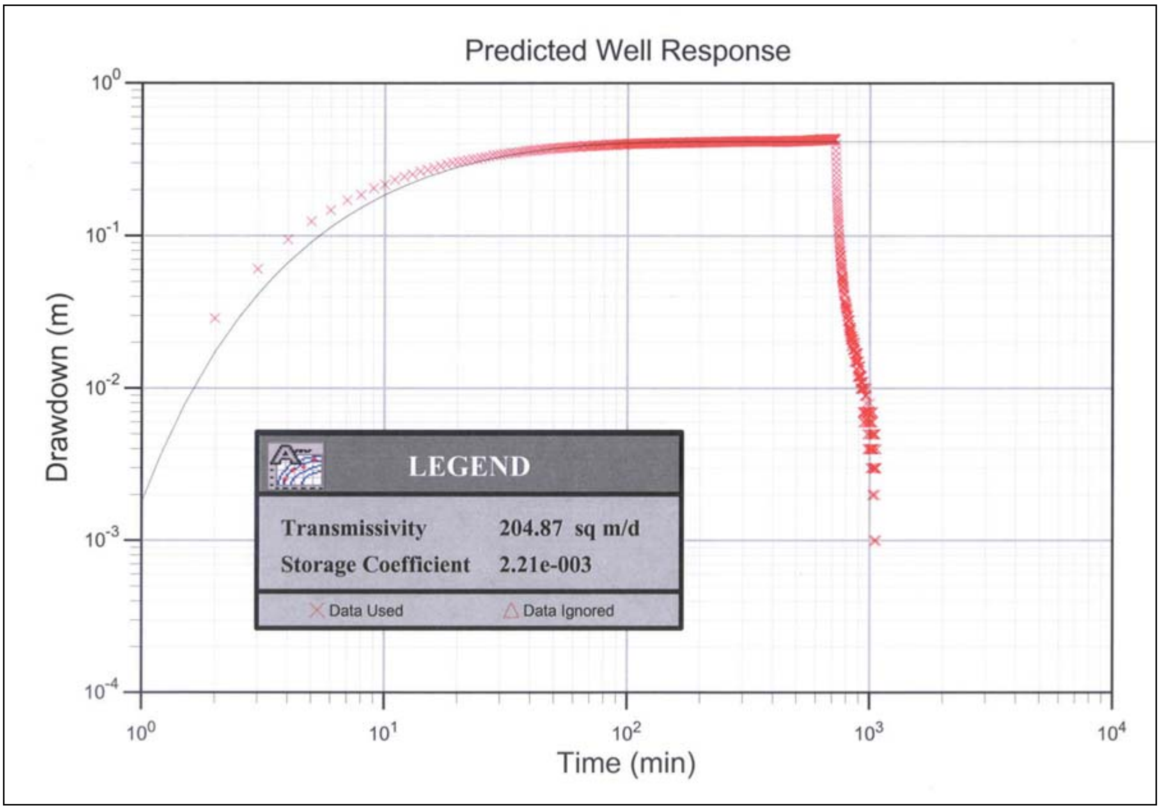


Figure 3.12 Obs 1 bore drawdown and recovery.

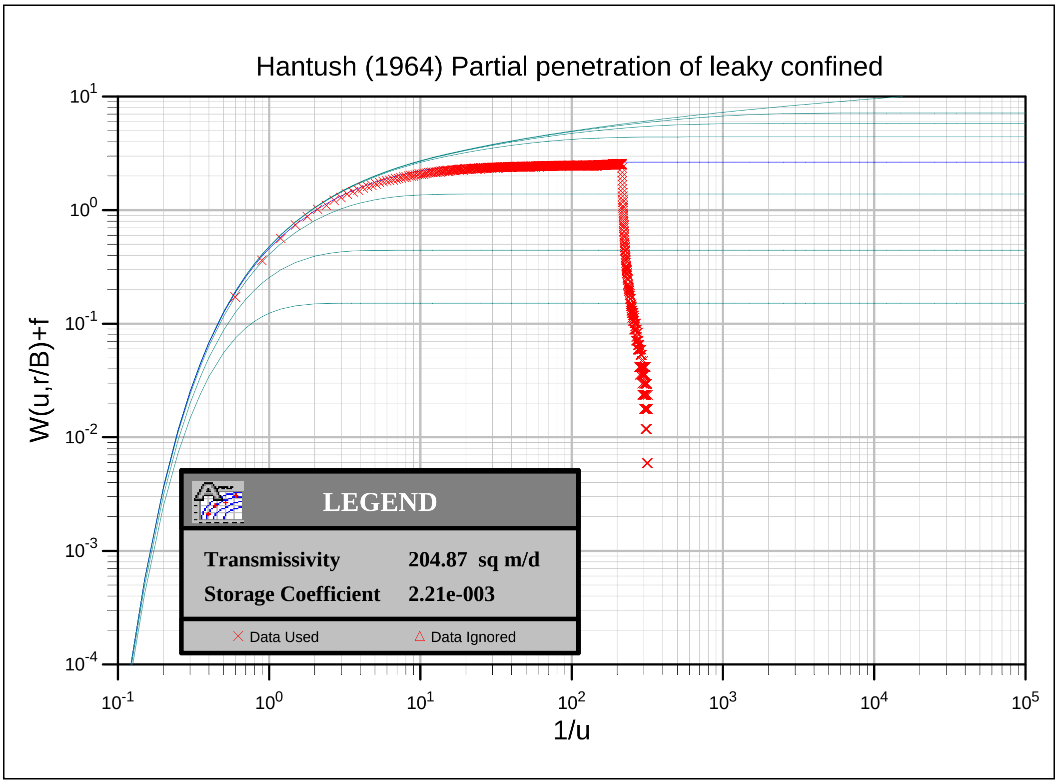


Figure 3.13 Obs 1 Hantush and Jacob (1955) leaky aquifer analysis.

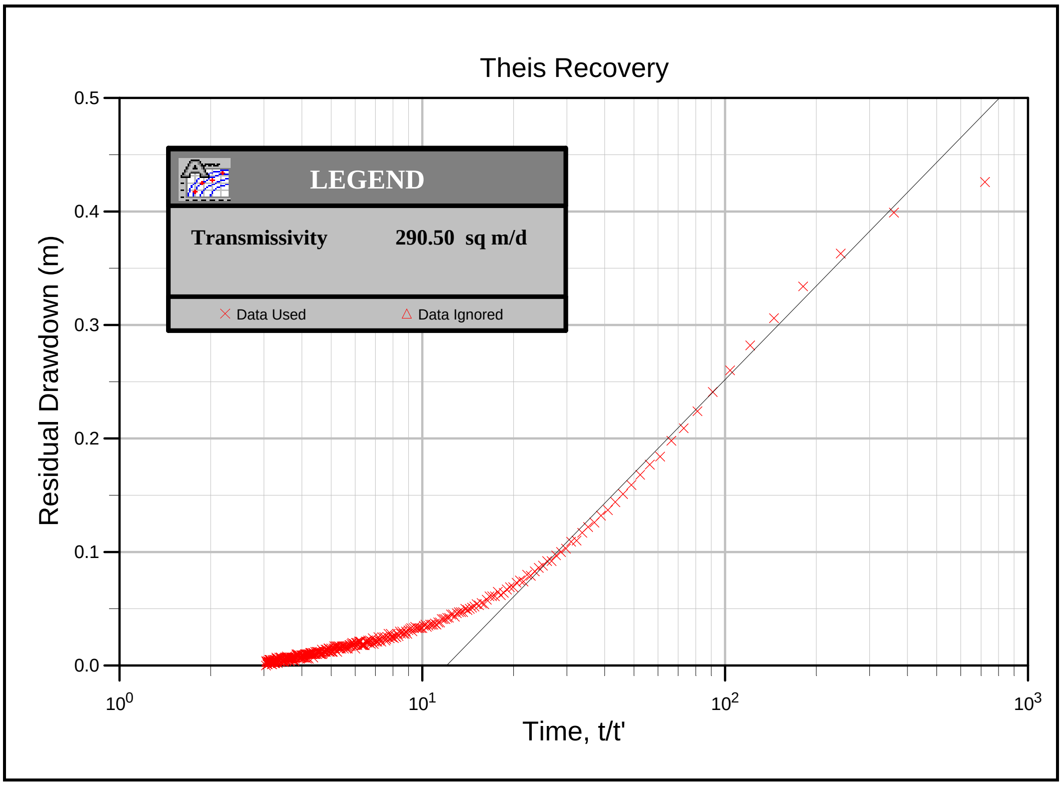


Figure 3.14 Obs 1 Theis recovery analysis.

3.2.3 Conclusions

At the pump test site, the Mamaku Ignimbrite aquifer is considered to be leaky-confined, or confined with intersection of a recharge boundary condition after approximately 450 minutes pumping.

Aquifer transmissivity and storativity for the Mamaku Ignimbrite is calculated to be 600 m^2/day and 4 x 10^{-3}, respectively. An assumed aquifer thickness of 100 m provides a hydraulic conductivity of 6 m/day.

At the pump test site, the Huka Group Sediment aquifer is considered to be leaky-confined.

Aquifer transmissivity and storativity for the Huka Group Sediment is calculated to be 200 m^2/day and 2.0 x 10^{-3}, respectively. Aquifer thickness of 43 m provides a hydraulic conductivity value of approximately 4.5 m/day.

3.2.4 Mamaku Township pump test

GNS was provided with results of a pump test undertaken at Mamaku township production bore (Bore ID: RDC bore 3 or 2102) on 21 and 22 September 2002. The pump was undertaken by Rotorua District Council. A copy of the pump test data are presented in Appendix 3. No analyses of the pump test data was provided to GNS. Review and analyses of the pump test data by Stewart Cameron (GNS Hydrogeologist) found the data inappropriate for obtaining reliable analysis results. Pumping rate during the test was not able to be held constant due to falling head in the pumping bore. Intermittent simultaneous pumping from RDC bore 4 during the pumping and recovery phases appear to have affected results. No drawdown interference was recorded in monitored observation bores. GNS recommend that the pump test be repeated if an indication of aquifer hydraulic properties are required in the Mamaku township area.

3.2.5 References

Freeze, A.R., Cherry, J.A., 1979. Groundwater. Prentice-Hall Inc. NJ.

Hantush, M.S., 1961. Aquifer tests on partially penetrating wells. J. Hydraul. Div., Proc. Amer. Soc. Civil Engrs., Vol, 87 (HYS), pp. 171-195.

Hantus, M.S., 1964. Hydraulics of wells. In V.T. Chow (editor) Advances in hydroscience Vol. I., pp. 281-432. Academic Press, NY & London.

Theis, C.V., 1935. The relation between the lowering of piezometric surface and the rate and duration of discharge of a bore using groundwater storage. Trans. Amer. Geophys. Union, 2, pp 519-524.

4.0 LAKE ROTORUA CATCHMENT BORE SURVEY

4.1 Introduction

White et al (2004) identified gaps in data required to develop groundwater models for the Lake Rotorua catchment. Fundamental to the development of any groundwater model is knowledge of groundwater levels in the area of interest, and their relationship to other water bodies such as lakes and rivers.

Hydraulic relationships of these bodies can provide key information such as:

- Groundwater flow directions.
- Groundwater divides.
- Areas of groundwater recharge and discharge.

These are all important in the context of this study where GNS wants to define groundwater catchments (and sub-catchments) and potential pathways for contaminants.

This section of the work has three components:

- Identifying existing bore holes not in the EBOP database, in areas of interest to EBOP.
- Measuring water levels in areas where data are scarce. This also includes field checking key water levels recorded in the EBOP database.
- Surveying bores to obtain accurate elevation data in key areas so accurate relative level (above mean sea level) water levels could be calculated.

4.2 Methods

The data and potentiometric surface map produced in White, et al. (2004) was used as a basis for further work. The data used to produce this is dominated by data stored in the EBOP database. The new work focused on EBOP’s high priority areas to the west of, north of and to the east of Lake Rotorua.

4.2.1 Bore locating

Locating bores not in the EBOP database, and, examining some existing bores was required for two main purposes:

1) **Pump tests** - bores needed to be identified that could be used as either a pumping bore or observation bore for the pump tests. If suitable bore(s) could be identified, this would either significantly decrease the cost of the drilling programme, or, enable other holes to be drilled.
2) **Water level/chemistry** - bores needed to be identified where water level and/or water chemistry coverage was scarce and/or in areas of high priority to EBOP.

Four key areas were identified to locate/check bores:

1) Near Ngongotaha township. This was particularly important to locate/check bores that could be used for the 2 pump tests (Huka formation and the Mamaku Ignimbrite) scheduled for this area.
2) North of Lake Rotorua. This was important as not only is there a lack of data, but is also in EBOP's high priority area.
3) East-south east of Lake Rotorua. This was important as there was a lack of data.
4) South of Rotorua. This was given low priority.

Door knocking and a leaflet drop were the two techniques used to locate/check bores. Door knocking involved asking people (mainly farmers) if they had a bore on their property. If a bore was located, as much information as possible was recorded about the bore. Where possible, GPS co-ordinates were also collected. The door knocking campaign was done by EBOP, sub contractors to EBOP and GNS staff. This was done in all 4 areas identified above, although most of the effort was directed to areas 1 to 3.

The leaflet drop was an EBOP initiative that was designed and run by EBOP. The leaflet asked property owners/occupiers if they knew of any groundwater bores/springs on their property or close by. Responses were sent directly to EBOP to collate. The leaflet drop focused on area 2 only.

4.2.2 Measuring water levels

New water level measurements were taken from:

- Some bores found in the bore search.
- Newly drilled bores.
- Selected existing bores in the EBOP database (with water level data), which were in areas of high importance (i.e. the Hamurana area) to check that the water level in the database is correct.
- Where possible, bore sites selected for water quality/water dating.

In many cases, access to the bore head was restricted by pumps (operating and abandoned), pipe work or casing finish. Rotorua Farm and Industrial Pump Services was contracted to gain access to bores (with the owners permission) where access to a borehole was considered by GNS to be critical. Water levels were measured with either a Heron or Solinst water level meter to a datum (usually top of steel casing). Some water levels were obtained from the property owners memory where bore access was not obtained.

4.2.3 Bore survey

New bores, selected springs and selected existing bores were surveyed to obtain an accurate NZMG easting, NZMG northing and elevation (relative to mean sea level) using Leica SR530 GPS receivers recording in differential mode. Elevations are required so that depth to water data (water levels) can be reduced to the same datum and easily be compared to other water level data and other hydrological features.

The survey is designed to produce data suitable for a regional water level map. Most elevations used to reduce depth to water data stored in the EBOP database in White et al (2004) were obtained from a 20 m grid digital terrain model. This means some elevations may be up to 20 m in error and eastings/northings may be up to 100 m in error. The GPS survey was designed to have maximum elevation errors of 0.5 m and errors in the eastings and northings of 5 m.

The GPS was set up as close to the site as possible (usually, right over the bore or spring) and left to record in differential mode for at least 10 minutes. Cases where the GPS could not be set over the feature are noted, and additional estimated errors to the site location are added.

Data from the GPS were reduced in Leica SKI-Pro v3.0 software using data from the RGMK (Makatiti), TRNG (Tauranga) or the TAUP (Taupo) GPS base stations. Five benchmarks from the greater Rotorua area were included in the GPS survey to relate the measured GPS geoid elevation to a relative level (RL) elevation. This was done by relating measured GPS elevations to a simple surface modelled from the GPS benchmark measurements. GNS estimates RL elevation errors to be +/- 0.3 m using this technique.

4.3 Results

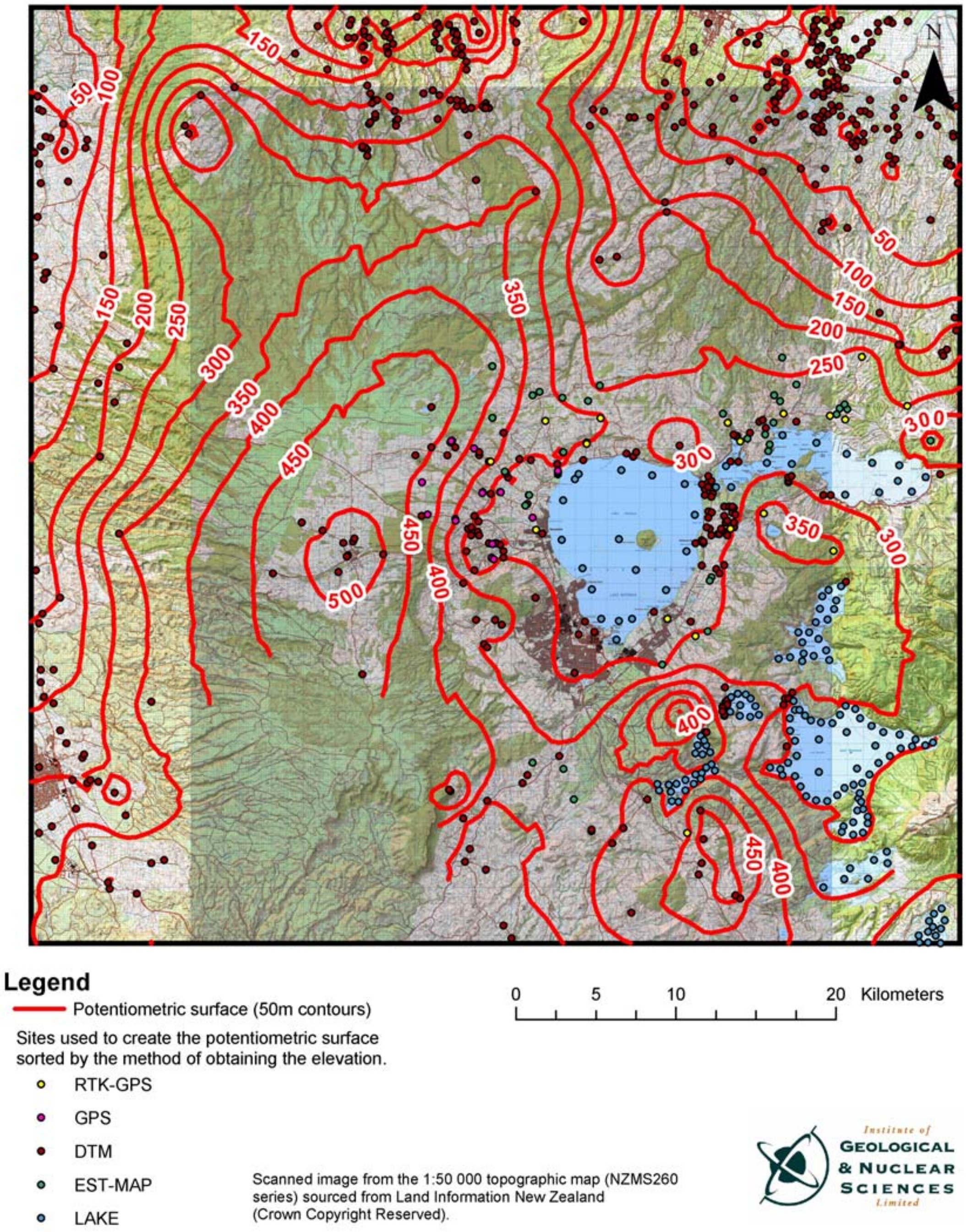
Appendix 4.1 summarises the new bores found and results of the surveying. 104 new bores and/or springs were located in the greater Rotorua area. This includes work for this project and a small amount of work for a GNS research project around Lake Rotoiti and excludes the work in Chapter 6 of this report. The Lake Rotoiti work is included here as it has the potential to influence the piezometric map around Lake Rotorua, particularly in the north east corner.

43 sites have been surveyed (Figure 4.1). Of these, 38 were bores newly located, one existing bore and four newly drilled bores. Note that one of these new bores (site 10110) was drilled by EBOP as part of another project immediately after the other three bores of this project had been drilled.

Water level data used by White et. al. (2004) is updated to include the new information above to produce another potentiometric surface map of the Lake Rotorua catchment (Figure 4.1). Appendix 4.2 summarises data used to make the piezometric map. Techniques used to constrain/develop the potentiometric surface map include:

- Adding spot heights representing the mean lake level around the lake edges as described by White, et al. (2004).
- Most bore elevations have had elevations estimated from a digital terrain model. Some bore elevations have been estimated from the 1:50,000 map.
- Bores that have a depth to water recorded in the EBOP database as 0 have been deleted.

- In general, the depth to water of the shallow bore is taken where multiple water levels exist at a location (this can happen for bores at approximately the same grid reference).



Scanned image from the 1:50 000 topographic map (NZMS260 series) sourced from Land Information New Zealand (Crown Copyright Reserved).

Figure 4.1 Potentiometric surface map of the Lake Rotorua region.

4.4 Limitations

The potentiometric surface map (Figure 4.1) is designed to be viewed at a regional scale and give an overview of the general groundwater flow directions. Use and interpretation of the data should consider:

1) The bulk of the data were obtained from the EBOP and Environment Waikato (EW) bore databases.
    - In most cases, the data has not been checked by GNS.
    - In most cases, the water levels have been obtained from drillers reports. Water levels may have been affected from the drilling process.
    - The water levels obtained from the drillers reports probably represent the water level in the aquifer the bore is completed in. This may not be the top aquifer.
    - Any long term trend in the water levels may affect the regional potentiometric surface map given that the water levels in the database have been measured over a period of approx 60 years.

2) Bore elevations estimated from the digital terrain model and from the 1:50,000 map have estimated errors of up to 20 m.

4.5 References

White, P.A., Cameron, S.G., Kilgour, G., Mroczek, E., Bignall, G., Daughney, C. and Reeves, R.R., 2004. Review of groundwater in the Lake Rotorua catchment. GNS client report 2004/130.

5.0 GROUNDWATER QUALITY AND WATER DATING

5.1 Introduction

EBOP are interested in defining current nutrient concentrations and time it takes groundwater to move nutrients through the aquifer systems to Lake Rotorua. The nutrients in the Lake Rotorua catchment are transported via groundwater flow or spring fed streams. To characterise nutrient concentrations in the groundwater and estimate the time lags between nutrient addition to the groundwater and nutrient arrival at Lake Rotorua, both a water quality and water dating programme was initiated in unison.

White et al (2004a) identified gaps in water quality data required to characterise groundwater in the Lake Rotorua catchment. White et al (2004b) recommended 30 new/existing sites that should be sampled as part as the field programme.

Tritium, Chlorofluorocarbons (CFCs) and Sulphur hexafluoride (SF_6) are isotopes (tritium) or contaminants (CFC's, SF_6) in the water used to obtain the mean residence time of groundwater. The mean residence time is taken to be an average "age" of the water since the water was recharged into the groundwater aquifer.

Morgenstern et al (2004) uses water dating with water quality (including nutrients) to estimate nutrient travel times in groundwater bores on the north-west catchments of Lake Rotorua and in major streams. Data collected in this report extends the water dating/water quality work in groundwater bores and streams to cover more of the high priority catchments defined by EBOP, and to resolve sampling and water age issues associated with the Morgenstern et al., (2004) sampling round.

5.2 Methods

5.2.1 Site selection

Site selection can be categorized into two categories.

- New sites, and,

- Sites that needed to be re-sampled as suggested by Morgenstern et al (2004).

New sites were selected based on:

- Water quality data gaps identified by White, et al. (2004a) in conjunction with data gaps from Morgenstern, et al. (2004)
- Sites selected were generally close to Lake Rotorua to establish the current nutrient flux
- Data gaps in EBOP's high priority areas were given high priority. The high priority area for EBOP is defined approximately as catchments from Mt Ngongotaha, around Lake Rotorua to the north, and then down to the south east corner of Lake Rotorua
- Budgetary constraints

New sites are a combination of existing bores, drive point piezometers, temporary piezometers or springs. Drive point piezometers are small diameter stainless tubing with a pointed end that is screened, used to sample shallow groundwater. Drive point piezometers enable small volumes of water to be sampled. Temporary piezometers are hand augured holes which went below the water table. PVC screen and casing was put down the hole to stop the hole from collapsing. Temporary piezometers enable a large pump to be put down the PVC casing enabling larger volumes of water to be sampled. In this project, the drive point and temporary piezometers were used to sample groundwater approximately 0.5 m below the water table. Near lake springs sampled are assumed to be representative of local groundwater entering Lake Rotorua.

Morgenstern, et al. (2004) identified several springs and streams that needed to be re-sampled to improve the nutrient load calculations into Lake Rotorua. Re-sampling was recommended because:

- Morgenstern, et al. (2004) sampled springs and streams in dry conditions. This will most likely affect the age (much older water discharges into the streams at this time) and therefore may not give an age which is representative for the average of the year.
- Morgenstern, et al. (2004) only sampled major springs where large spring complexes existed (e.g. Hamurana). Other sub springs should also be sampled to obtain an age range /nutrient range coming out of the spring complex.

These recommendations formed the basis of re-sampling some springs and streams.

5.2.2 Sampling/analyses

Nine springs, 12 existing bores (including bores drilled as part of the programme), three streams and five drive-point/temporary piezometers were sampled between 13 December 2004 and 14 May 2005 as part of the field programme. Sampling methodology and the bottles collected at each site varied depending on the analyses required (Table 5.1). In most cases, electric conductivity, pH, water temperature, dissolved oxygen (DO), turbidity and oxidation – reduction potential (ORP) of the groundwater were measured in the field prior to collecting the sample.

Table 5.1 Bottles collected for each analyses.

Analyses	**Bottles collected**
Nutrients	100 ml PE filtered, 100 ml PE raw, 250 ml PE raw with H_2SO_4 - all chilled
Anions/cations	100 ml PE filtered, 100 ml PE filtered + HNO_3, 250 ml PE raw, all chilled
Tritium	1.1 l Nalgene
CFC/SF_6	2 x 100 ml glass, 1 x 1l Schott (or 1 x 2l amber)

Notes:

- PE = polyethylene bottle
- Where samples were collected for a full chemistry analyses, both the nutrient and anion/cation bottles were collected.
- Tritium, anion/cation and nutrient bottles (without preservative) were rinsed 3 times with appropriate water before filling.

Spring samples were collected at the point they emerge from the aquifer using a grab technique. Samples collected for CFC/SF_6 were sampled by placing the bottle in the spring outlet and fresh uncontaminated water was sucked through the bottle until the water was displaced 3-5 times using nylon tubing attached to a vacuum pump. Bottles were then quickly screw-sealed below the water surface.

Water samples collected from bores were made after measuring the water level (where possible), and then purging the bore of at least three casing volumes prior to sampling. Sites Murphy, Kiriona and Patchell are domestic bores and already had pumps installed. The existing pumps were used to purge and sample these bores. A portable Grundfos MP1 submersible pump was used to sample at sites Britton, JMM shallow, RDC Pohutukawa Dr – deep and Wharenui-control. A whale pump was used to sample site JMM deep. The driller's pump/pump contractor's pump was used to sample sites Blimler, Dibley bore @ 80 m (immediately after the pump test) and Dibley bore @ 150 m. The Wallace bore was "grab sampled" with a Teflon bailer due to the large cost of installing a pump to obtain a groundwater sample. Given that the bore could not be purged, GNS still sampled this site due to its location immediately north of Hamurana springs – in one of EBOP's high priority areas. Water chemistry results from this site should be used only as an indicator of nutrient concentrations.

"Grab samples" were collected from the three stream sites.

Drive point piezometers and temporary piezometers were used to sample shallow groundwater near Lake Rotorua where a suitable existing site could not be found. Drive point piezometers are driven into the ground until the water table has been intersected. Site 3 was the only site sampled with a drive point piezometer. The drive point was driven down to 1.4 m and was sampled by applying a vacuum to disposable tubing inserted down the drive point. The drive point was purged three casing volumes before a sample was collected.

Temporary piezometers are hand augured holes drilled below the water table to enable temporary casing and screen to be inserted. After collecting the sample, the screen and casing are removed, and the hole is filled in. The intention of temporary piezometers was to allow a pump to be put down the casing and enable larger volumes of water to be pumped compared to a drive point piezometer. This allows water samples to be collected for CFC and SF_6 as air can be excluded during the sampling process. However, high sediment loads at three of the four sites (Site 8, Kaska-DP and Site 52) prevented a large pump from been used, and therefore these sites could not be sampled for CFC's and SF_6.

Water samples were sent to their respective laboratories as soon as possible after the sampling. Three laboratories were used to analyse the water depending on the analyses suite.

- **Nutrients** - total ammoniacal-N, total kjeldahl Nitrogen (TKN), nitrate-N + nitrite-N (TON), nitrate-N, nitrite-N, dissolved reactive phosphorus and total phosphorus were sent to R.J. Hill laboratories
- **Anions/cations** - Alkalinity (as HCO_3), pH, sodium, potassium, calcium, magnesium, iron (dissolved), manganese (dissolved), silica (as SiO_2), fluoride, chloride, bromide, sulphate, and conductivity at GNS, Wairakei.

- **Isotopes –** CFC, SF_6 and tritium at GNS, Gracefield.

Appendix 5.1 summarises results and the methods used for all analyses.

5.2.3 Re-sampling

The nutrient samples for 10 sites (Site 8, Kaska-DP, Wallace, Site 41, JMM shallow, JMM deep, Site 52, RDC Pohutukawa Dr – deep, Wharenui-control and Wallace-springs) collected between 23/2/2005 and 25/2/2005 went missing between the courier company (NZ Couriers) and R.J. Hill Laboratories. An internal investigation by both GNS and R.J. Hill laboratories could not clearly establish where the samples went missing once they were dispatched from GNS, Wairakei. The samples were not recovered.

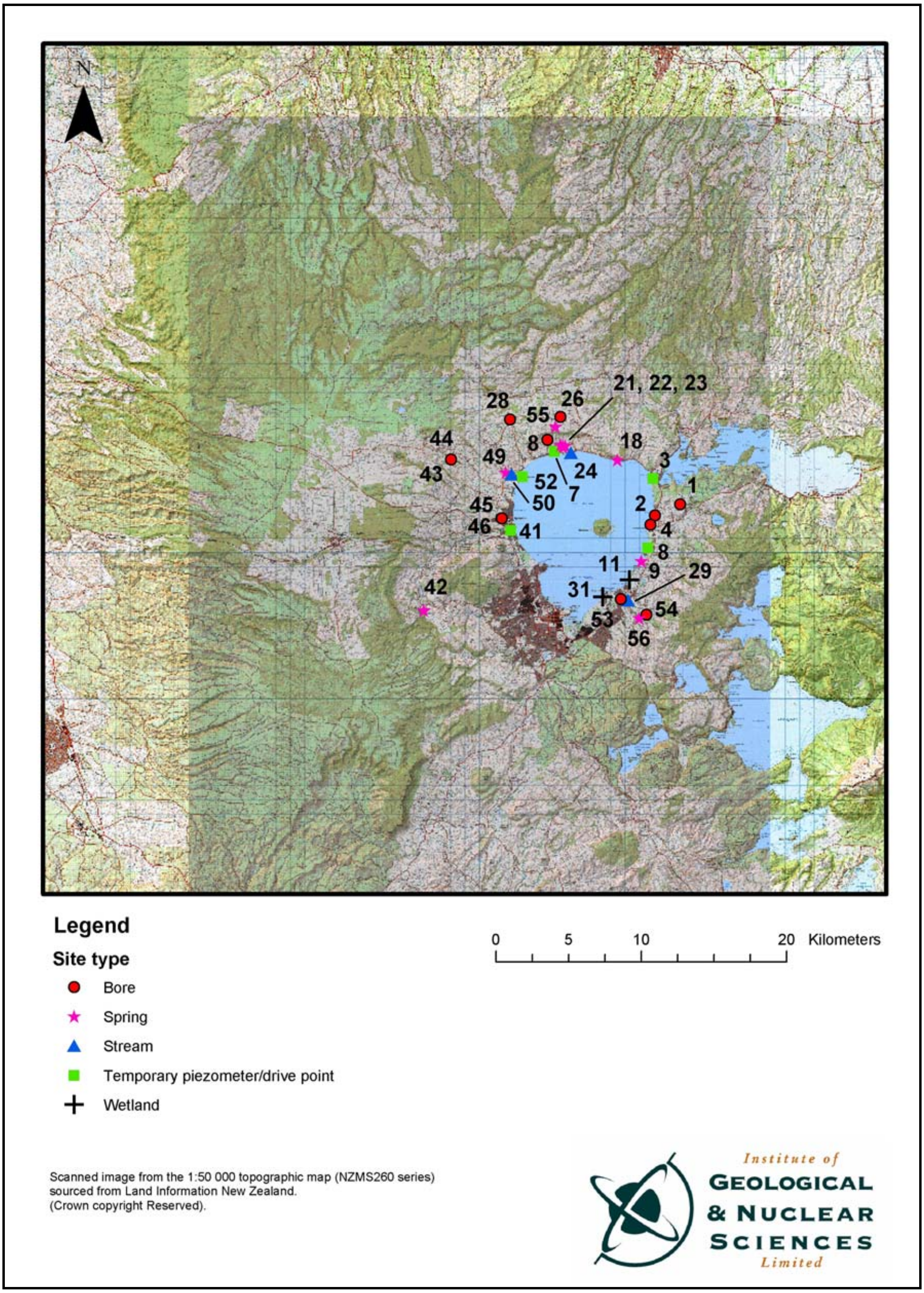
The 10 sites were re-sampled 26/4/2005 - 4/5/2005 for nutrients and anions/cations only. A temporary piezometer at Site 8 had to be re-augured as the exact location of the hole could not be found. The new site was probably within a 5 m of the site augured on the first sample run.

All samples for nutrients were immediately submitted to R.J. Hill laboratories while samples for anions/cations were put on hold at the GNS laboratory. Nitrate-N data for five of the sites from the 1st round of samples submitted to GNS could be obtained from the anion run, even though these analyses were not requested. The four temporary piezometer sites that were repeated (Site 8, Kaska-DP, Site 41 and Site 52) have a second full anion/cation analyses (except alkalinity) given the variability of the field parameters between sampling rounds and differences in nitrate concentrations between the GNS first round samples and the R.J. Hill second round samples. Anion/cation samples for the other sites were not analysed.

5.3 Results

Figure 5.1 shows the locations and types of the sites that were sampled. Table 5.2 summarises the field parameters measured in the field and the chemistry results. The original laboratory reports with methods are in Appendix 5.1.

Interpretation of the data is expected to be done in later phases of the project.



Scanned image from the 1:50 000 topographic map (NZMS260 series) sourced from Land Information New Zealand. (Crown copyright Reserved).

Figure 5.1 Location of sites sampled in the EBOP Lake Rotorua Groundwater study – field programme.

Table 5.2 Summary of chemistry results sampled in the EBOP Lake Rotorua Groundwater study – field programme.

								Field results								**RJ Hill laboratory results**						
Site ID to use	Easting	Northing	Site type	site name	Sampling notes	Date sampled	sample#	Depth to water	Depth to water datum	pH	Conductivity	Water temperature	ORP	Turbidity	DO	NH_4-N	TKN	TON	NO_3-N	NO_2-N	DRP	TP
								(m)		pH units	uS/cm	°C	mV	NTU	mg/l	g m^{-3}	g m^{-3}	g m^{-3}	g m^{-3}	g m^{-3}	g m^{-3}	g m^{-3}
1	2803818	6343298	Bore	Murphy	Some bubbles in water	08/03/2005	14			6.16	79	15.3	347	49	9.1	<0.01	<0.1	1.12	1.12	<0.002	0.207	0.221
2	2802082	6342521	Bore	Britton		21/03/2005	20	2.61	concrete	6.22	139	14	350	4.1	4.4	<0.01	<0.1	2.36	2.36	<0.002	0.083	0.08
3	2801951	6345080	TP	Site 3		08/03/2005	17	1.05	ground	5.82	108	15	357	80	7.2	<0.01	0.2	4.51	4.5	0.004	0.076	0.157
4	2801787	6341894	Bore	Kiriona	Water started off orange, but goes clear.	08/03/2005	15	2.36	steel casing	6.35	94	12.7	314	108	6.7	<0.01	<0.1	1.16	1.16	<0.002	0.083	0.085
8	2801599	6340298	TP	Site 8	No CFC/SF_6 due to sediment load interfering with pumping	25/02/2005	12	1.06	ground	6.62	153	19.2	327		9.3							
8	2801599	6340298	TP	Site 8	Repeat sample	26/4/2005	23			6.74	197	14.6	202	460	5	< 0.01	0.3	0.512	0.505	0.007	0.013	0.177
9	2801176	6339385	Spring	Airport spring		10/05/2005				6.3	116	12.2	338		6.4	< 0.01	< 0.1	3.62	3.62	< 0.002	0.093	0.099
11	2800323	6338091	Wetland	Site 11	Algae in sample	08/03/2005	18			6.04	159	14.9	214	11	3	<0.01	0.8	0.003	<0.002	<0.002	0.021	0.237
14	2795189	6346929	TP	Kaska-DP	Couldn't do water dating or full chemistry due to sediment load	24/02/2005	8	1.4	ground	6.37	49	17.1	285	>600	6.7							
14	2795189	6346929	TP	Kaska-DP	Repeat sample	26/4/2005	22			6.72	78	14.6	226	186		0.23	2.7	0.36	0.358	< 0.002	0.006	0.736
16	2794701	6347717	Bore	Patchell	Sampled water from reservoir	08/03/2005	16	55.88	steel casing	6.48	71	14.4	334	5	9.4	<0.01	<0.1	2.16	2.16	<0.002	0.039	0.04
18	2799510	6346340	Spring	S73 (Morea spring)	Site approx 200m up stream gully from lake	10/05/2005				5.8	106	10.5	309	1.9	4.4	< 0.01	< 0.1	1.79	1.79	< 0.002	0.053	0.057
21	2795914	6347325	Spring	Hamurana Head Spring		10/05/2005				6.6	61	9.6	299	1.1	7.1	< 0.01	< 0.1	0.699	0.697	< 0.002	0.079	0.085
22	2795621	6347367	Spring	Hamurana Spring @ water intake		09/05/2005	34			6.67	71	10.1	307	0.5	7.8	< 0.01	< 0.1	0.667	0.666	< 0.002	0.093	0.096
23	2795763	6347294	Spring	Hamurana Spring @#1		09/05/2005	33			6.13	66	9.8	325	1	8.7	< 0.01	< 0.1	0.669	0.667	< 0.002	0.085	0.087
24	2796292	6346867	Stream	Hamurana stream		09/05/2005	32			6.1	66	10	344	0.8	10.3	< 0.01	< 0.1	0.658	0.656	0.002	0.082	0.085
26	2795580	6349309	Bore	Wallace	Bailed well - no purging	25/02/2005	11	172.37	steel casing	6.85	65	11.6	303									
26	2795580	6349309	Bore	Wallace	Repeat sample	28/4/2005	27			7.23	62	12.8	322	135		< 0.01	0.2	1.33	1.33	< 0.002	0.024	0.076
28	2792134	6349123	Bore	Blimler	Water level measured by Russell West	02/03/2005	13	81.5	steel casing	6.4	104	12.5	337	51	8.7	<0.01	<0.1	4.57	4.56	0.009	0.033	0.044
29	2800219.314	6336704.774	Stream	Waingaehe Stream @ Te Ngae Rd (WST-2)		14/05/2005				6.83	113	13.1	87	9	7.1	< 0.01	0.1	1.45	1.45	< 0.002	0.099	0.109
29	2800219.314	6336704.774	Stream	Waingaehe Stream @ Te Ngae Rd (WST-2)	Collected after rainfall	19/05/2005	U6									0.11	0.2	1.34	1.34	0.002	0.091	0.097
31	2798493	6336914	Wetland	Site 31	Water is clear, yellow, H_2S smell	08/03/2005	19			6.21	587	16.8	93	45	3.8	22	24.4	0.006	0.004	<0.002	3.18	3.42
41	2792178	6341517	TP	Site 41		23/02/2005	5	0.91	ground	5.76	112	18.6	397	13.4	0.9							
41	2792178	6341517	TP	Site 41	Repeat sample	28/4/2005	25			6.23	118	15.1	321	9.9	5.5	< 0.01	0.2	2.23	2.23	< 0.002	0.006	0.004
42	2786200	6336000	Spring	Te Waireka (Paradise Spring)		13/05/2005				7.1	65	10.7	247	0.6		< 0.01	< 0.1	1.8	1.79	< 0.002	0.028	0.025
43	2788058.292	6346364.997	Bore	Dibbly bore@80m	Sampled straight after pump test	13/12/2004	1			6.08	73	11	357	12.6	8.6	0.01	0.2	2.22		<0.002	0.05	0.04
44	2788058.292	6346364.997	Bore	Dibbly bore@150m		15/02/2005	2			6.86	70	9.7	331	17	7.5	<0.01	0.2	0.405	0.404	<0.002	0.06	0.064
45	2791545	6342328	Bore	JMM shallow		23/02/2005	4	10.09	PVC casing	6.05	108	14.7	399	30.2	7.4							
45	2791545	6342328	Bore	JMM shallow	Repeat sample, pH meter not working	04/05/2005	30	10.3	PVC casing		105	12.6	363	7.3	7.4	< 0.01	< 0.1	6.33	6.33	< 0.002	0.052	0.051
46	2791570	6342319	Bore	JMM deep		23/02/2005	3	9.77	PVC casing	6.5	75	11.8	239	78	4							
46	2791570	6342319	Bore	JMM deep	Repeat sample, pH meter not working	04/05/2005	29	9.94	PVC casing		83	11.7	232	6.7	4.6	0.23	0.4	1.68	1.68	< 0.002	0.013	0.015
49	2791832	6345487	Spring	Taniwha Spring		09/05/2005	35			6.6	74	10.9	328	6.1	8.2	< 0.01	< 0.1	1.45	1.45	< 0.002	0.066	0.068
50	2792233	6345372	Stream	Awahou stream		09/05/2005	31			6.27	71	10.3	363	2	9.1	< 0.01	< 0.1	1.26	1.25	< 0.002	0.066	0.069
50	2792233	6345372	Stream	Awahou stream	Collected after rainfall	19/05/2005	U1									0.02	< 0.1	1.28	1.28	0.002	0.06	0.062
52	2792985	6345196	TP	Site 52	No CFC/SF_6 due to sediment load interfering with pumping	24/02/2005	9	1.34	ground	7.01	172	15.5	170	>600	2.1							
52	2792985	6345196	TP	Site 52	Repeat sample	28/4/2005	28			6.93	133	14.6	187	>600		0.25	17.6	0.095	0.081	0.014	0.017	4.73
53	2799747	6336763	Bore	RDC Pohutukawa Dr - deep		24/02/2005	10	-0.66	ground	6.23	154	13.9	375	0	8							
53	2799747	6336763	Bore	RDC Pohutukawa Dr - deep	Repeat sample	26/4/2005	24			6.28	148	12.7	357	4.1	7.5	< 0.01	< 0.1	6.67	6.67	< 0.002	0.098	0.098
54	2801502	6335693	Bore	Wharenui-control		24/02/2005	6	28.99	PVC casing	6.73	87	13.7	289	9	8.8							
54	2801502	6335693	Bore	Wharenui-control	Repeat sample	26/4/2005	21	29.24	steel casing	6.99	103	13.6	255	19	8.4	< 0.01	< 0.1	0.68	0.68	< 0.002	0.09	0.105
55	2795258	6348636	Spring	Wallace-springs		24/02/2005	7			6.34	34	12.7	324	n/m	9.3							
55	2795258	6348636	Spring	Wallace-springs	Repeat sample	28/4/2005	26			6.42	45	10.7	319	10	9.1	< 0.01	0.2	1.65	1.65	< 0.002	0.006	0.021
56	2801026	6335455	Spring	WSP4		12/05/2005				6.22	116	13.9	134	1.8	4.5	< 0.01	< 0.1	0.569	0.569	< 0.002	0.127	0.122

					GNS water/gas laboratory results																	GNS Water dating laboratory results							
Site ID to use	Easting	Northing	Site type	site name	Alkalinity (as HCO3)	pH	Analysis Temperature	Sodium	Potassium	Calcium	Magnesium	Iron	Manganese	Silica (as SiO2)	Fluoride	Chloride	Bromide	Sulphate	Conductivity	Nitrate (as N)	Phosphate (as P)	Tritium lab ID	Tritium ratio	Tritium ratio error	SF6	CFC 11	CFC 11 error	CFC 12	CFC 12 error
					g m^{-3}	pH units	°C	g m^{-3}	g m^{-3}	g m^{-3}	g m^{-3}	g m^{-3}	g m^{-3}	g m^{-3}	g m^{-3}	g m^{-3}	g m^{-3}	g m^{-3}	uS/cm	g m^{-3}	g m^{-3}		TU		pptv	pptv		pptv	
1	2803818	6343298	Bore	Murphy	22	6.24	16	9.3	1.8	4.3	1.7	<0.02	<0.005	85	0.062	5.9	<0.04	11.3	70	1.2	0.2	403	1.08	0.04	2.75	247.9	1.1	484.1	6.3
2	2802082	6342521	Bore	Britton	43	6.2	24	13.1	4.5	9.1	2.6	<0.02	<0.005	73	0.1	6.8	<0.04	15.8	109	2.3	0.08	405	0.931	0.038	3.73	210.6	7.2	471.8	13.0
3	2801951	6345080	TP	Site 3	27	6	18	9.3	3.5	6.3	2.6	0.26	0.006	70	0.043	7.1	<0.04	4.4	83	4.7	0.08								
4	2801787	6341894	Bore	Kiriona	41	6.35	17	9.9	2.4	6.4	1.8	0.02	<0.005	75	0.066	4.8	<0.04	5.9	69	1.2	0.09	404	1.04	0.04					
8	2801599	6340298	TP	Site 8	62	6.16	18	7	4.3	10.7	8.5	0.022	0.077	64	0.07	5.1	<0.10	29	128	0.09	<0.05	401	1.43	0.06					
8	2801599	6340298	TP	Site 8				9.9	4.7	11.4	10.2	1.8	0.22	74	0.098	5.6	<0.04	36		0.5	<0.004								
9	2801176	6339385	Spring	Airport spring	29	6.44	14	10.4	4.5	6.5	2.3	<0.02	<0.005	74	0.071	4.7	<0.04	11.4				412	1.13	0.03	4.11	527.9	14.8	490.7	11.1
11	2800323	6338091	Wetland	Site 11																									
14	2795189	6346929	TP	Kaska-DP																									
14	2795189	6346929	TP	Kaska-DP				4.9	3.4	3.6	0.94	1.3	0.27	31	0.06	5.1	<0.04	9		0.38	<0.004								
16	2794701	6347717	Bore	Patchell	26	6.41	18	6.7	2.8	5.4	1.3	<0.02	<0.005	49	0.046	6.1	<0.04	1.1	63	2.3	0.1								
18	2799510	6346340	Spring	S73 (Morea spring)	43	5.17	14	10	6.3	5.6	2.2	<0.02	<0.005	74	0.023	5.9	0.056	2.4				413	1.43	0.06	3.74	1053.1	35.0	3194.0	90.0
21	2795914	6347325	Spring	Hamurana Head Spring																		414	0.631	0.027					
22	2795621	6347367	Spring	Hamurana Spring @ water intake																		409	0.379	0.022					
23	2795763	6347294	Spring	Hamurana Spring @#1																		408	0.529	0.027					
24	2796292	6346867	Stream	Hamurana stream																		407	0.569	0.027					
26	2795580	6349309	Bore	Wallace	19.3	5.99	18	7.2	3.6	2.1	1	<0.02	<0.005	65	0.09	4.5	<0.10	3.3	47	1.3	<0.05	400	1.41	0.04					
26	2795580	6349309	Bore	Wallace																									
28	2792134	6349123	Bore	Blimler	22	5.86	13	9.6	2.2	5.3	2.5	0.036	<0.005	39	0.032	7.9	<0.04	4.1	117	4.7	0.04	402	1.22	0.04					
29	2800219.314	6336704.774	Stream	Waingaehe Stream @ Te Ngae Rd (WST-2)																									
29	2800219.314	6336704.774	Stream	Waingaehe Stream @ Te Ngae Rd (WST-2)																		443	0.526	0.030					
31	2798493	6336914	Wetland	Site 31																									
41	2792178	6341517	TP	Site 41	38	5.06	14	4.9	5.1	12.5	1.2	<0.02	<0.005	24	0.03	4	<0.10	8.5	80	1.3	<0.05	396	1.72	0.04	4.74	161.0	15.1	571.2	5.4
41	2792178	6341517	TP	Site 41				4.7	5.4	11.9	1.5	<0.02	<0.005	26	0.023	3.8	<0.04	8.8		2.2	<0.004								
42	2786200	6336000	Spring	Te Waireka (Paradise Spring)																		416	1.37	0.04					
43	2788058.292	6346364.997	Bore	Dibbly bore@80m	24	5.98	14	8.5	2.2	4.2	2	<0.02	<0.005	40	<0.05	6.6	<0.10	4.7	98	2.22		392	1.19	0.04	2.08	233.4	0.8	633.6	81.9
44	2788058.292	6346364.997	Bore	Dibbly bore@150m	43	6.82	15	12.2	0.53	2.8	1.9	<0.02	0.008	68	0.1	5.5	<0.10	1.3	63	0.39	0.08	393	0.110	0.018	0.21	162.5	49.1	478.4	151.0
45	2791545	6342328	Bore	JMM shallow	19	5.17	13	11.5	5.2	4.2	1.9	0.034	0.014	76	0.09	6.7	<0.10	0.84	80	>5	<0.05	395	1.16	0.04	2.89	248.5	18.6	513.4	65.9
45	2791545	6342328	Bore	JMM shallow																									
46	2791570	6342319	Bore	JMM deep	23	4.99	14	8.2	3.3	2.8	2.1	1.3	0.34	56	0.16	6.4	<0.10	3.2	60	2	<0.05	394	1.32	0.04					
46	2791570	6342319	Bore	JMM deep																									
49	2791832	6345487	Spring	Taniwha Spring																		410	0.751	0.032					
50	2792233	6345372	Stream	Awahou stream																									
50	2792233	6345372	Stream	Awahou stream																		438	0.843	0.033					
52	2792985	6345196	TP	Site 52	90	6.41	17	14.1	3	13.5	3.6	1.2	0.31	52	0.13	6.5	<0.10	3.1	113	<0.03	<0.05	398	0.930	0.028					
52	2792985	6345196	TP	Site 52				15	2.4	14.2	3.1	2	0.66	49	0.027	5.1	<0.04	19.3		0.002	0.21								
53	2799747	6336763	Bore	RDC Pohutukawa Dr - deep	26	6.02	18	14.7	5.2	6.5	3.1	<0.02	<0.005	73	0.1	9.1	<0.10	13.5	109		<0.05	399	1.21	0.04	2.06	353.9	22.7	680.1	40.3
53	2799747	6336763	Bore	RDC Pohutukawa Dr - deep																									
54	2801502	6335693	Bore	Wharenui-control	29	6.2	18	9.8	3.3	3.8	2.2	0.056	0.014	69	0.14	5.5	<0.10	10.5	65	0.69	0.07	397	0.150	0.020	1.14	220.2	22.0	600.4	34.8
54	2801502	6335693	Bore	Wharenui-control																									
55	2795258	6348636	Spring	Wallace-springs																									
55	2795258	6348636	Spring	Wallace-springs	45	6.45	20	13.5	2.6	4	3.8	<0.02	<0.005	83	0.2	7.8	<0.04	10.2											
56	2801026	6335455	Spring	WSP4																		421	0.116	0.021	0.13	8.5	0.9	18.7	2.1

5.4 References

White, P.A., Cameron, S.G., Kilgour, G., Mroczek, E., Bignall, G., Daughney, C. and Reeves, R.R., 2004a. Review of groundwater in the Lake Rotorua catchment. GNS client report 2004/130.

White, P.A., Reeves, R.R., Cameron, S.G., Daughney, C., Bignall, G. and Morgenstern, U., 2004b. Proposed field programme to define groundwater and nutrient inflow to Lake Rotorua - discussion document. GNS confidential client report 2004/130a.

Morgenstern, U., Reeves, R., Daughney, C., Cameron, S., and Gordon, D., In press. Groundwater Age and Chemistry, and Future Nutrient Load in the Lake Rotorua Area. GNS Science Report 2004/31.

6.0 GROUNDWATER CATCHMENT

6.1 Introduction

Environment Bay of Plenty commissioned the Institute of Geological and Nuclear Sciences to identify locations of groundwater discharge to surface water, areas where streams were gaining/losing water to groundwater, and measure rainfall recharge in the vicinity of Lake Rotorua. This work aims to contribute to the identification of all surface water discharges into Lake Rotorua.

Surface water flow and quality are regularly measured in the catchment (e.g. Rutherford, 2003) on major streams. However, these measurements do not capture the full effects of land use on nutrient loading to Lake Rotorua: about 69 km^2 of the catchment in the vicinity of the lake is ungauged and surface water does not flow regularly in about 48 km^2 of catchment. Streams are not the only pathway by which water may enter Lake Rotorua; (White et al., 2004) groundwater may discharge directly to the lake through the lake bed or to the lake via wetlands.

Published flow and nutrient measurements in the Lake Rotorua catchment, reviewed here, focus on the major streams. The work described in this chapter aims to:

- identify the locations of springs, small streams and seeps around the lake,
- measure or estimate flow in the lakeside spring and streams,
- identify areas of stream loss or gain due to groundwater, and
- report on the installation of a rainfall recharge site.

6.2 Review

Fish (1975) completed a nutrient inflow to Lake Rotorua based on inputs of nitrogen (in the ammonium and nitrate forms) and phosphorous in rainfall, eight streams and city sewage effluent:

- NH_3-N (called ammonium) inflow 254 kg/day,
- NO_3-N inflow 443 kg/day, and
- PO_4-P inflow 186 kg/day.

Hoare (1987) monitored water quality in the nine major streams (and 16 tributaries) in the period 1975-1980 including flood flows and estimated nutrient loadings to Lake Rotorua of:

ammonium-N	28.9 tonnes yr^{-1},
NO_3-N	193.2 tonnes yr^{-1}, and
phosphate-P	27.9 tonnes yr^{-1}.

A water balance for Lake Rotorua (Hoare, 1980) for 1976 has:

streams ('major' sites plus 'minor' sites)	13.7 $m^3 s^{-1}$,
rainfall direct to lake	4.5 $m^3 s^{-1}$, and
ungauged flow	2.1 $m^3 s^{-1}$.

The ungauged flow is that required to balance inputs and outputs. The ungauged catchment consists of about 69 km^2 of land around Lake Rotorua with no gauged surface water flow.

The Ministry of Works (Gordon pers. comm. 2004) collected information on miscellaneous Lake Rotorua catchment flows in 1973 (Kaituna River Catchment Water Resources Survey) and 1982 (Hamilton District Low-flow Water Resources Study). Both of these studies focused on the larger streams and rivers of the region.

Five Lake Rotorua wetlands were identified by Gibbs and Lusby (1996): (1) near the 3D maze; (2) Hannahs Bay; (3) Holdens Bay; (4) Hinemoa Point; and (5) Owhata Road. Measurements of water chemistry on the wetland and in groundwater aimed, over a two-year period, to determine the efficiency of wetlands for removing nitrogen. Surface drainage features are associated with the Hannah's Bay and Holden's Bay wetlands. Groundwater discharges off shore from the Owhata Road wetland (remnant) and enters the lake 'as a series of submerged springs quite close to shore' (Gibbs and Lusby, 1996). Other wetlands probably discharge groundwater through the beach into the lake.

During March 2004 lake margin wetlands at thirteen lakes in the Rotorua Lakes Ecological District were mapped via boat survey at a scale of 1:5000 on the 2003 Regional Digital Aerial

Mosaic (RDAM2003). Johanna Taylor, a scientist from Environment Bay of Plenty, developed the method with advice from Sarah Beadel, botanist/ecologist at Wildland Consultants. Field work was conducted by Craig Bishop, a botanist from Wildland Consultants, and Sarah Higham, a science assistant from Environment Bay of Plenty.

The survey assessed the extent and condition of lake margin wetlands within 500 metres of the lake edge. The thirteen lakes surveyed were: Rotorua, Rotoiti, Rotoma, Rotoehu, Okataina, Okareka, Okaro, Rerewhakaaitu, Rotomahana, Tarawera, Tikitapu, Rotokakahi and Rotokawau (Williams, pers. comm. 2005).

6.3 The field programme

Four elements to the field programme are:

- identification of the nature and location of water discharges into Lake Rotorua, including springs, seeps and drains,
- measurement of surface water flows into Lake Rotorua as a ‘snapshot’ of surface water discharge from the catchment in summer 2004,
- identification of where streams lose/gain water from/to groundwater, and
- measure the amount of water that seeps through the soil profile to groundwater.

6.3.1 Nature and location of water discharge

Lakeside springs, seeps and drains were identified in November and December 2004, primarily in consultation with:

- Vance Fulton, Environment Bay of Plenty
- Richard Mallinson, Environment Bay of Plenty
- Max Gibbs, National Institute of Water and Atmospheric Research (NIWA)

The work brief included:

- review of existing information on springs, seeps and wetlands. This survey did not repeat the wetland survey of Environment Bay of Plenty. The wetland features identified in this work would probably not be classed as wetlands, in the Environment Bay of Plenty work, because the features are small and commonly support a small area of vegetation usually including willows, blackberry, etc;

- identification of surface water features from walking surveys of the lake edge where access is possible and collect the following information: locate features using GPS, photograph, and a note of any distinctive characteristics (e.g. geothermal springs);
- identification of surface water features from a boat survey where lake access is not possible;
- identification of any lake-bottom springs from discussions with lake users

6.3.1.1 Results

The survey identified 75 water features around the lake including springs, seeps and wetlands. A description of the sites (Appendix 6.1) includes location, text description and photographs for most of the sites. Included in these sites are:

- a spring (Site 73) not visited in the survey that was identified by Will Esler
- lakebed springs (Site 74) identified by boaties and by Gibbs (pers. comm. 2005)
- lakebed springs (Site 75) identified by Gibbs and Lusby (1996) offshore from Owhata Road

The survey records some features (e.g. Sites 1, 2, 3, 4, 5 and 6, Figure 6.1) that are not directly on the lake shore.

6.3.2 Measurement of water discharge

Environment Bay of Plenty hydrologists measured flows into Lake Rotorua on 7, 8 and 9 December 2004 and 2 February 2005 (Appendix 6.2). Sites in this survey include:

- major streams that are part of Environment Bay of Plenty's regular monthly lake-inflow monitoring (these are coded with 'RLNBR' in Appendix 6.2).
- features identified in the lake edge survey (Appendix 6.1)

- features not identified in the lake edge survey (Appendix 6.1) capable of channelling water into the lake (e.g. culverts). Culverts are numbered with the Rotorua District Council asset number. Features in this class are identified with site numbers from 76 to 192 (Appendix 6.2). Most of the culverts record zero water discharge.

Flow measurements are made with one of three methods:

1) visual estimation (for low flows);
2) volumetric measurement and
3) flow meter (Ellery pers. comm., 2005)

6.3.3 Combined list of lake-side sites

The list of sites combined from Appendix 6.1 and Appendix 6.2 are plotted, in Figure 6.1, by type:

- spring (including lake bed springs)
- seeps
- stream
- pond
- culvert
- drain
- wetland

6.3.4 Surface water flow rates

Water flow is measured at a total of 185 sites (Figure 6.2). Flows were measured or estimated at 167 sites in December 2004 and at 17 sites in February 2005.

These sites included:

- 11 regular EBOP monitoring sites
- 173 lake side (i.e. lake edge and near lake edge) sites

Zero flow is observed at 86 of these sites. Flows between 0 and 5 L s^{-1} are measured or estimated at 65 sites. Flows between 5.5 L s^{-1} and 100 L s^{-1} are measured or estimated at 15 sites and flows between 100 L s^{-1} and 2543 L s^{-1} are measured at 19 sites (Figure 6.3). The largest flow rate is measured at Hamurana Springs.

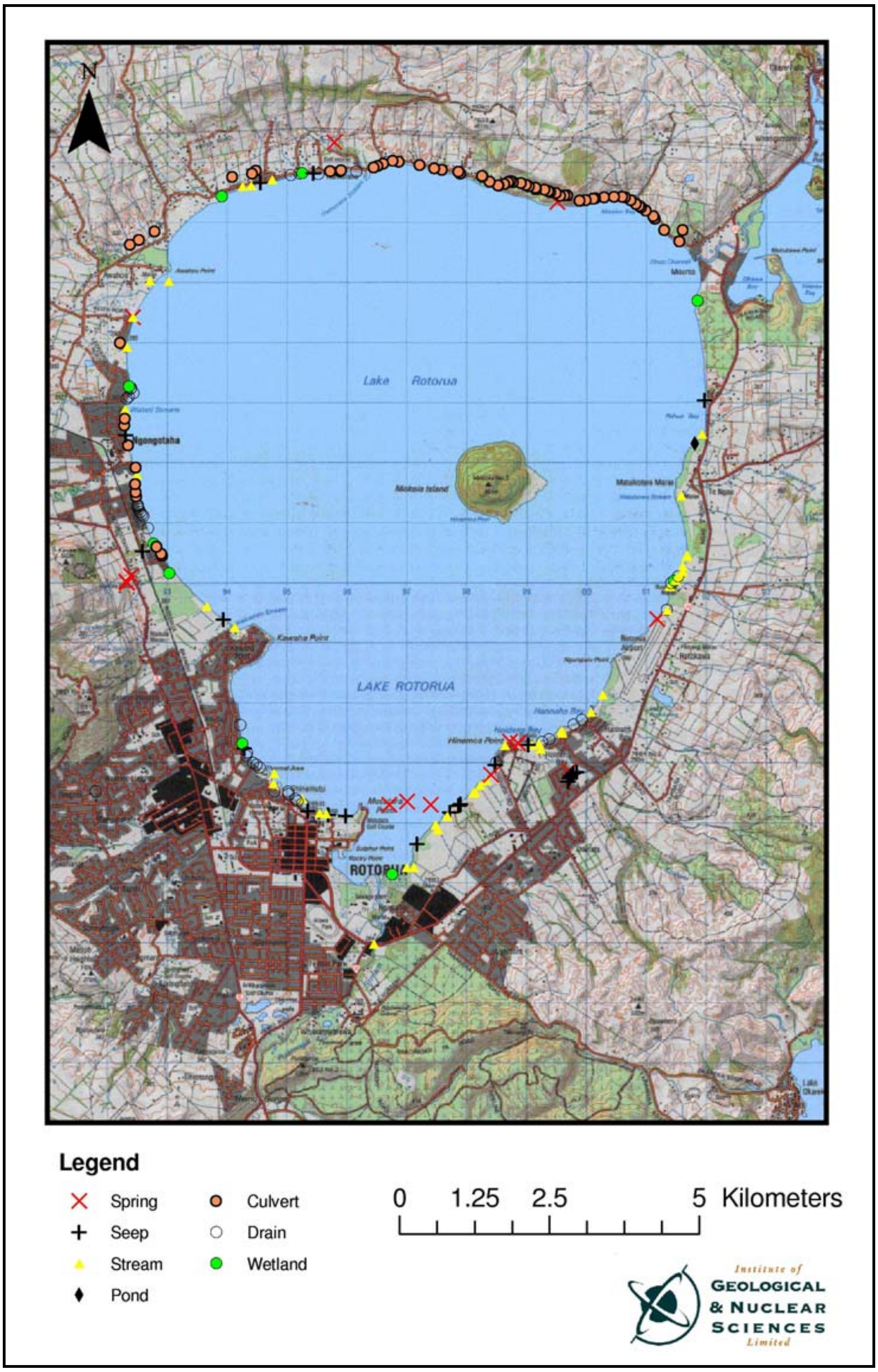


Figure 6.1 Location of near-shore and lake-shore features, Lake Rotorua.

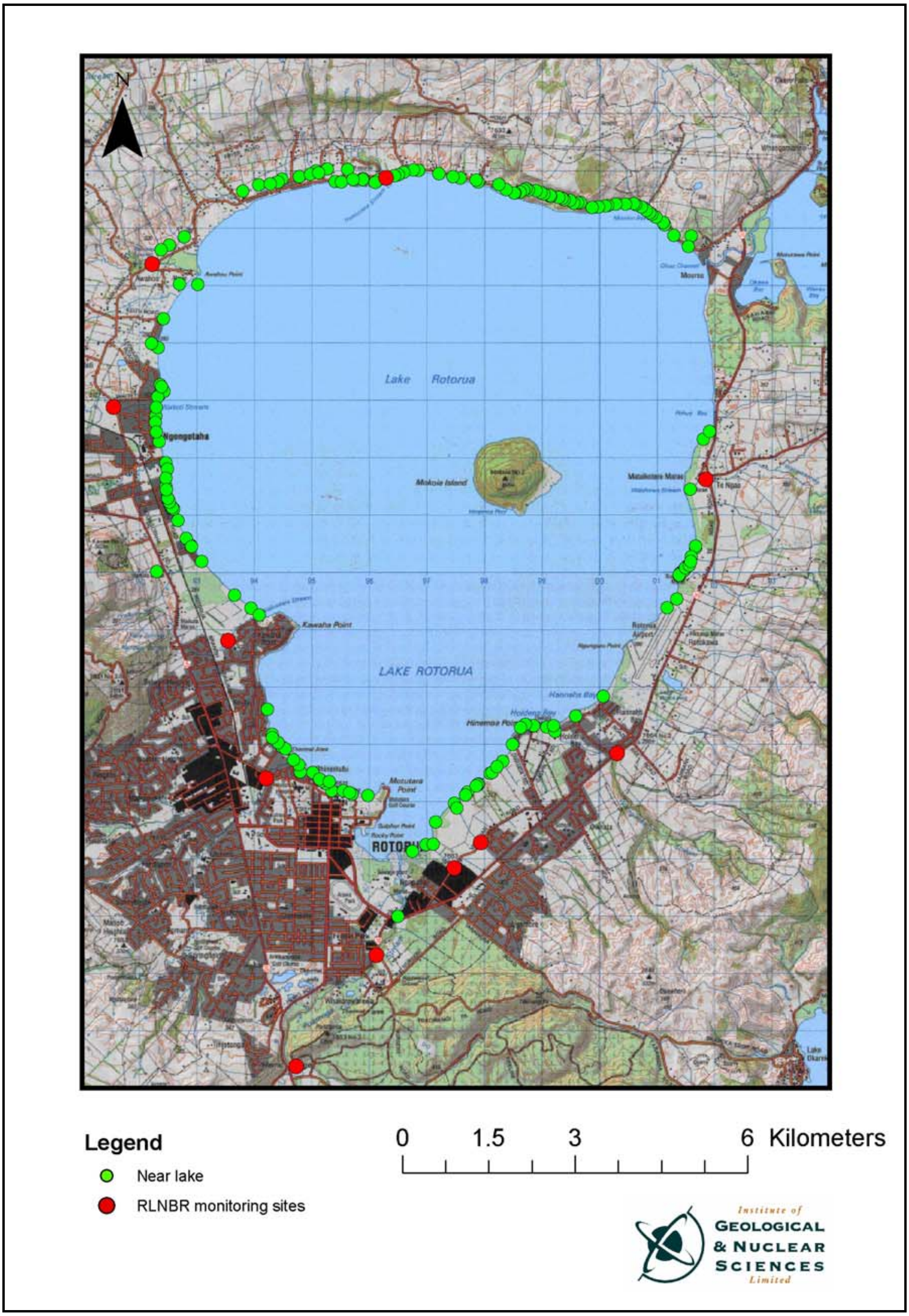


Figure 6.2 Sites at which flows were measured (December 2004 and February 2005).

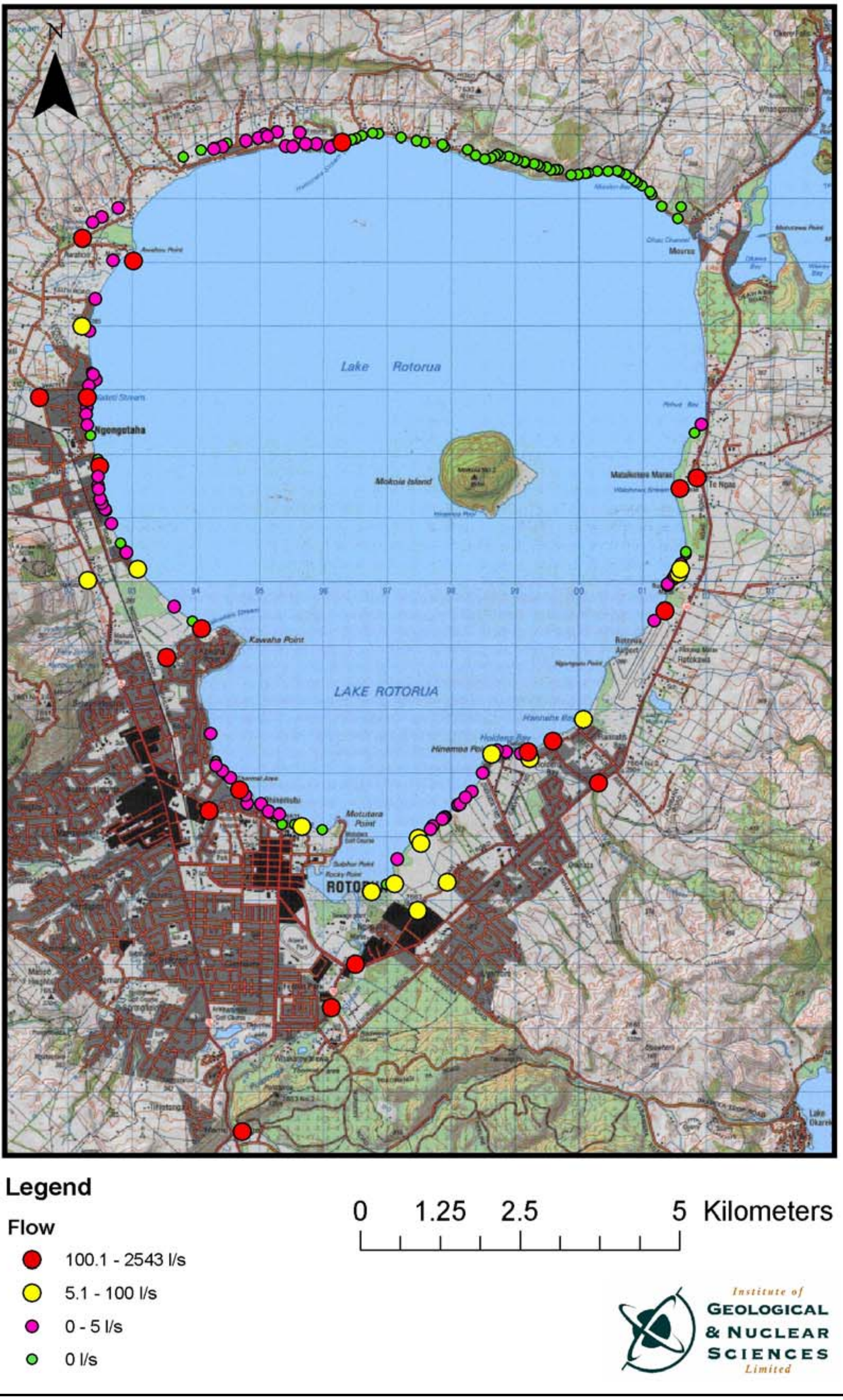


Figure 6.3 Measured flow December 2004 and February 2005.

6.3.5 Stream losses/gains to/from groundwater

EBOP conducted a number of stream gauging measurements on streams that flow into Lake Rotorua in the summer of 2004/05 to identify areas in streams that either gain water from groundwater, or areas that lose water to groundwater. These data were unavailable at the time of compiling this report.

6.3.6 Rotorua rainfall recharge lysimeter installation

6.3.6.1 Introduction

A soil lysimeter site was installed on farmland off Penny Road, Rotorua, for the purpose of estimating rainfall recharge to the underlying groundwater system. Installation of the site was commissioned by EBOP to provide groundwater recharge information for input into the groundwater flow model. The lysimeter site was installed at about map reference NZMG 2796900, 6349200 between 28 February and 4 March 2005. This site was selected for installation of the lysymeters as EBOP already have a telemetered rainfall measuring site (Mangorewa at Kaharoa Link) at this location (Figure 6.4). Installation of the site was overseen by Stewart Cameron (GNS) with assistance from Rob Reeves (GNS) and Greg Brosley (Landscape New Zealand, Rotorua).

The materials and method of installation were based on installation procedures for similar lysimeters developed by Lincoln Ventures (Cameron, 1992), and information provided by Hugh Thorpe (Canterbury University) and Brian Todd (Environment Canterbury).

6.3.6.2 Materials and methods

Two lysimeter casings were made by Lincoln Ventures. The casings were manufactured from 5 mm thick steel plate, rolled and welded to produce a cylinder 700 mm high by 500 mm in diameter. An internal cutting ring (5 mm thick by 50 mm high) was fitted to one end of the lysimeter cylinder. The edge of the lysimeter casing was bevelled at 45^{o} angle.

The casings were driven into the ground with combination of weight from hydraulic digger and sledge hammer (Figures 6.5 and 6.6). The area around the casings was excavated as the casing was lowered to facilitate driving and decrease the risk of damaging the soil column (Figures 6.6 and 6.7). After the casing had been driven to a level approximately 5 cm below the original ground surface, a cutting plate was inserted beneath the soil monolith (Figure 6.8). Long bolts with eyelets were fitted to lugs on the top of the casing to hold the cutting plate in place as the soil monolith was lifted out of the excavated pit (Figure 6.9). The cutting plate was then removed and the base of the monolith shaped with a spatula (Figure 6.10). A double layer of shade cloth was then laid on the base of the monolith and held in place by galvanised nails. A base plate with drainage hole was then bolted in place (Figure 6.11).

A 20 l pail of Shell Petrolite (food grade petroleum jelly) was heated on a barbeque until free flowing and injected down the cavity between the soil monolith and the casing using a hand pump.

The pit was then excavated for installation of a box section to house rain-gauges (Figure 6.12). When the box section was in place, the pit was backfilled to the level of the bottom of the soil monolith (Figure 6.13). An alkathene pipe was fitted to the base of the monolith with Hansen fittings. The alkathene pipe will conduit water that has infiltrated through the soil column, from the base of the monolith to a tipping bucket raingauge located in the box section area. A PVC pipe and concrete blocks were placed beneath the monolith to house the alkathene pipe and provide a stable platform for the monolith to rest (Figure 6.14). A hole was drilled in the box section wall to pass the alkathene pipe from the base of the monolith to the rain-gauge. Backfilling of the excavated pit was then completed (Figure 6.15) and the grass sod reinstated (Figure 6.16). An electric fence was installed around the site to protect the grass from stock while the grass re-established, and to protect the stock from falling into the open box section hole while cover grating was constructed and rainfall gauges installed.

The tipping bucket raingauges are connected to EBOP’s datalogger at the neighbouring climate station recording total 15 minute readings. This data can be extracted by EBOP via their telemetered radio system.

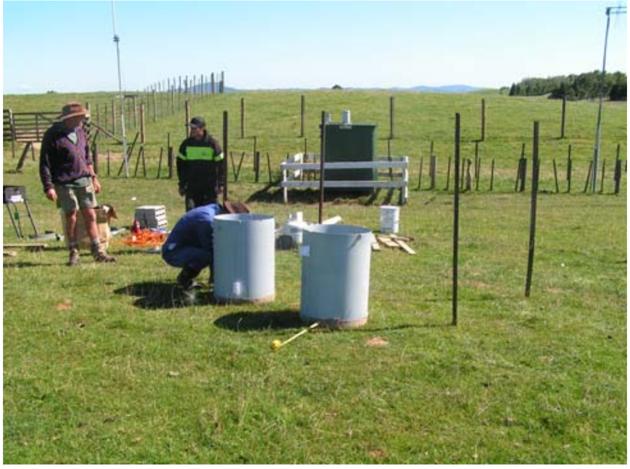


Figure 6.4 Kaharoa rainfall recharge site.

Figure 6.5 Recharge site prior to driving casings.

Figure 6.6 Initial placing of casing.

Figure 6.7 Casing excavation.

Figure 6.8 Cutting plate.

Figure 6.9 Lifting the soil column.

Figure 6.10 Cutting plate removed.

Figure 6.11 Base preparation of the soil column.

Figure 6.12 Digging the box section.

Figure 6.13 Lysimeter installation.

Figure 6.14 Lysimeter outlet.

Figure 6.15 Backfilling the pit.

Figure 6.16 Completed lysimeter installation.

6.4 Summary

A total of 192 lake-edge, and near-lake-edge, surface hydrological are identified around Lake Rotorua. These features include: streams, springs, seeps, wetlands, drains, culverts and lakebed springs.

Surface flow rates are measured in 174 of these features (and 11 regular EBOP monitoring sites) during December 2004 and February 2005. Zero flow is observed at 85 of these sites; the maximum measured flow is 2543 L s^{-1} at Hamurana Springs.

EBOP have completed a stream flow survey of streams flowing into Lake Rotorua, but the results were not ready for inclusion in this report.

A rainfall recharge site measuring rainfall infiltrating through the soil profile has been installed at Kaharoa. This is recording total 15 minute recharge, and is connected to an EBOP telemetered rainfall station.

6.5 References

Cameron, K.D., Smith, N.P., McLay, C.D.A., Fraser, P.M., McPherson, R.J., Harrison, D.F. and Harbottle, P., 1992. Lysimeters without edge flow: an improved design and sampling procedure. Published in Soil Sci. Soc. Am. J. 56: 1625-1628.

Fish, G.R., 1975. A nutrient budget for Lake Rotorua. *In* Jolly, V.H. and Brown, J.M.A., eds. New Zealand Lakes. p150-157.

Gibbs, M.M., and Lusby, F.E., 1996. Lake edge wetlands: their environmental significant to the Rotorua lakes NIWA consultancy report BPR005/2 to Environment Bay of Plenty. 45p.

Hoare, R.A., 1980. Inflows to Lake Rotorua Journal of Hydrology (New Zealand) 19(1). 49-59.

Hoare, R.A., 1987. Nitrogen and Phosphorus in the catchment of Lake Rotorua. Ministry of Works and Development Water Quality Centre Publication No. 11. 110p.

Rutherford, K., 2003. Lake Rotorua nutrient load targets. NIWA Client Report Ham 2003-155. 59p.

White, P.A., Cameron, S.G., Kilgour, G., Mroczek, E., Bignall, G., Daughney, C. and Reeves, R.R., 2004. Review of groundwater in the Lake Rotorua catchment. GNS Client Report 2004/130.

Appendix 1.1 Scope of work for the field programme (Note that the contract is not reproduced in full).

Introduction

The groundwater system of the Lake Rotorua catchment plays a crucial role in nutrient inflows to the lake. Nutrients associated with land use enter the groundwater systems through soil drainage and rainfall recharge. The nutrients reside in the groundwater system, probably for decades, but return to the surface through spring flows and direct recharge to the lake. An understanding of both the groundwater and surface water systems is required to plan remedial work to maintain and improve the lake's water quality.

This proposal is submitted in response to a request from Paul Dell and Dougall Gordon of Environment Bay of Plenty (EBOP), to collect groundwater/hydrological data in the Lake Rotorua catchment.

This proposal presents field work that will lead to improvements in our knowledge of groundwater quality, groundwater age, groundwater levels and groundwater catchments.

This proposal has been prepared with consideration of details supplied by Paul Dell and Dougall Gordon.

Background to project

This proposal is submitted in response to a request from Paul Dell and Dougall Gordon of EBOP. The work plan presented has been developed following discussions between EBOP, the Institute of Geological & Nuclear Sciences (GNS), and Rotorua District Council (RDC). The work programme is complementary to work by NIWA on the surface waters. It has been designed to fill the gaps in EBOP's current knowledge of the groundwater and nutrient loads in the Lake Rotorua catchment (White et al., 2004a)[1], and to provide adequate knowledge from which to formulate water quality protection measures. This project focuses on the collection of additional data only.

---

[1] White, P.A., Reeves, R.R., Cameron, S.G., Daughney, C., Bignall, G., Morgenstern, U., 2004a. Proposed field programme to define groundwater and nutrient flow to Lake Rotorua. GNS client report 2004/130a.

The major aim of the project is to collect new data which will be used to better define groundwater sub catchments and provide data required for groundwater modelling. EBOP has indicated to GNS that groundwater catchments S1, E1, E2, E3, N1, N2, N3, W3 and W4 in White et al.(2004b)[2] are of priority.

Project design

We propose that the project be structured into eight categories.

1. Groundwater drilling – GNS will provide geological advice and piezometer construction advice for approximately five groundwater exploration bores in the Lake Rotorua catchment. The number of holes may vary depending on the drilling conditions and objectives for each hole.
2. Pump tests – GNS will organise drillers and analyse data for up to four pump tests in bores in the Lake Rotorua catchment. The number of tests may vary depending on budget constraints. It is expected some of the new drill holes (above) will be pump tested.
3. Groundwater quality – Groundwater will be sampled at up to 30 spring/well sites and analysed for major anions, cations and nutrients.
4. Groundwater age dating – Groundwater will be sampled for tritium, CFCs and SF_6 for up to 20 sites. Age interpretations for each sample will be calculated. Sites will be a combination of springs, bores and possibly streams. Full isotope analyses may not be required for all samples.
5. Groundwater levels + surveying – Groundwater levels will be measured (where possible) in the study area. Sites where groundwater levels are measured will be surveyed with GPS to define location and elevation for the regional piezometric map.
6. Groundwater catchments – GNS will install a rainfall recharge site; identify locations of groundwater discharge to streams and stream discharge to groundwater from historical records, perform walking surveys and gauging measurements; map small streams, wetlands, lake seeps, using available information and walking surveys; and assess lake-bottom springs from available information.

---

[2] White, P.A., Cameron, S.G., Kilgour, G., Mroczek, E., Bignall, G., Daughney, C. and Reeves, R.R., 2004b. Review of groundwater in the Lake Rotorua catchment. GNS client report 2004/130.

7. Project management and report – GNS will manage the project, collate data and report basic data (without interpretations) in a GNS client report.

Drilling costs are difficult to precisely estimate given the many ‘unknowns’ that can affect the amount of time taken to drill and depths required to achieve the target depth. GNS will communicate drilling progress to EBOP on a regular basis to ensure issues are dealt with rapidly. Drilling issues will be resolved with EBOP’s collaboration.

This programme assumes that a satisfactory number of suitable groundwater monitor bores for the pump test can be found. It is essential that the survey of existing bores be completed prior to a decision being taken to site new bores.

The project will run from October 2004 to June 2005.

Timetable

We propose a start date of 1 October 2004. Deliverable dates will shift accordingly should there be any delays.

Field programme component	**Proposed timetable**
Bore Locations	**Immediate**, Oct 2004
Drilling	Oct 2004 - Feb 2005
Pump tests	Oct 2004 - Feb 2005
Groundwater quality	Sampling: Nov 2004 to March 2005
Water dating	Sampling: Nov 2004 to Feb 2005
Water levels + surveying	Oct 2004 to Dec 2004
Groundwater catchment	
	Groundwater recharge monitoring site: Dec 2004 to Feb 2005
	Groundwater-stream interaction: Oct 2004 to Dec 2004
	Locations of groundwater discharge in, and near, the lake: Oct 2004 to Dec 2004
Project management	Ongoing
Data management	Data entry: to June 2005
Report	Draft report in June 2005

Contributions by Environment Bay of Plenty

- EBOP will initiate a ‘bore locating’ programme to identify bores not in the EBOP database that are in the study area. Data collected from this programme will be supplied to GNS no later than October 28, 2004.

- EBOP will locate bores suitable for monitoring the groundwater during pump tests.
- EBOP will assist GNS with site selection for new drill holes
- EBOP will assist GNS with resource consents required for the new drill holes
- EBOP will obtain written landowners permission for new drill holes
- EBOP will supply (where possible) groundwater bore details as requested.
- EBOP will assist GNS with groundwater quality site selection and sampling. EBOP will arrange access to private properties/bores that need to be sampled.
- EBOP will assist GNS with groundwater age dating site selection and sampling. EBOP will arrange access to private property/bores that need to be sampled.
- EBOP will collect data and maintain the rainfall recharge site once GNS has commissioned the site.
- EBOP will supply GNS with historic stream flow information (e.g.: DSIR 1980s work) by December 17, 2004.
- EBOP will perform walking surveys of the main streams flowing into Lake Rotorua and assess where they think streams are losing or gaining water to groundwater. EBOP will supply GNS a GIS map showing locations of stream gain/loss by December 17, 2004.
- EBOP will stream gauge (at least once) all major streams flowing into Lake Rotorua. Stream gauging sites will be selected by GNS and EBOP and be based on the EBOP walking survey of the main streams. EBOP will supply GNS the stream gauge data by December 17, 2004.
- EBOP may be requested to gauge streams flowing into Lake Rotorua identified by the lake walking survey.
- EBOP will supply GNS with a GIS land use map of the Lake Rotorua catchment.
- GNS will assist EBOP prepare the bid documents for the drilling/pump test tenders. The drilling /pump test contract will be between the drillers and EBOP. EBOP will be responsible for paying the drillers directly.

Deliverables

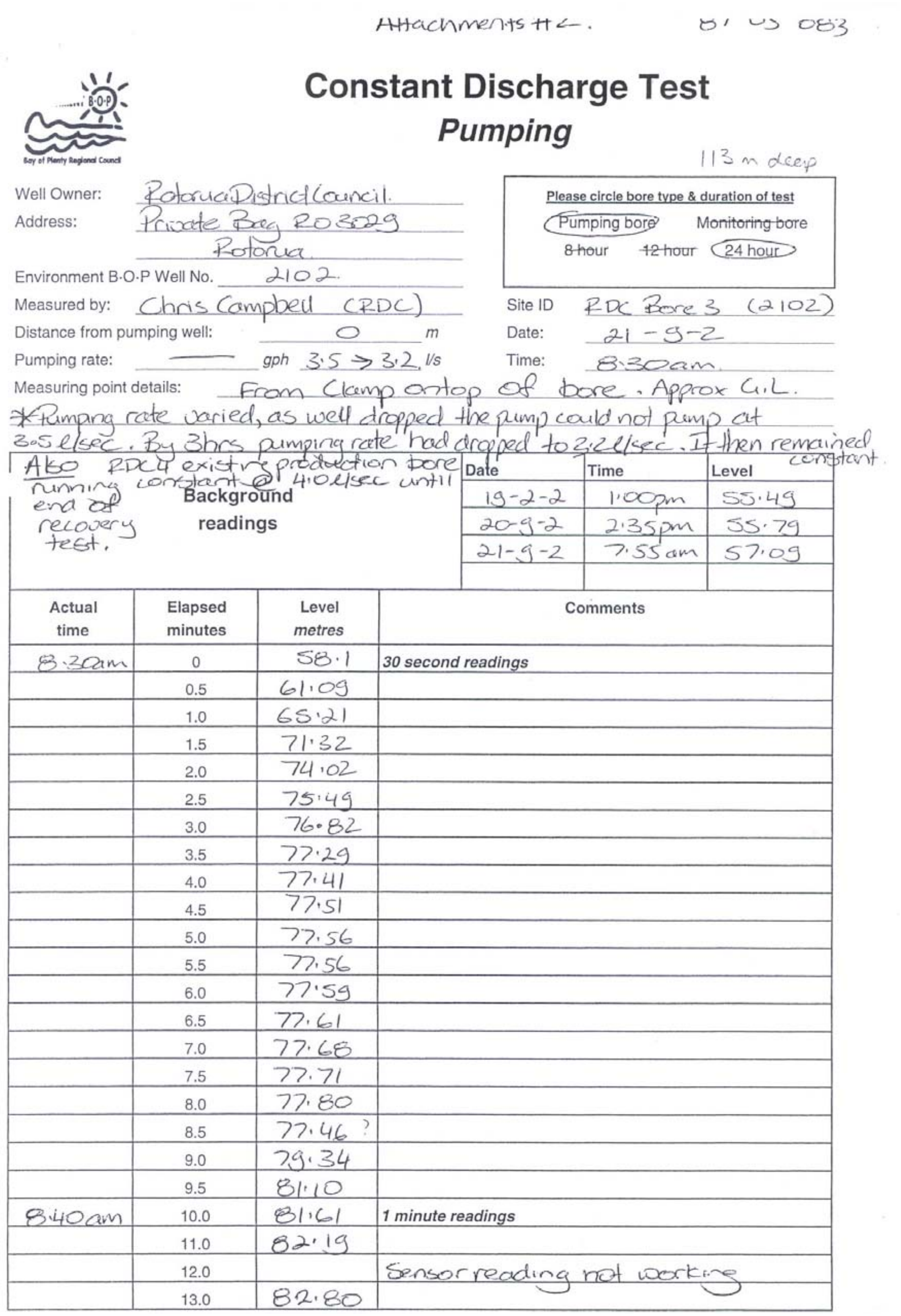
GNS will provide EBOP with two letters updating the progress of the project by 1 December, 2004 and 1 March, 2005.

GNS will provide to EBOP a draft report summarizing drilling conditions, water levels, pump test data, interpretations of the pump test data, summary of all chemical results, age dating results, survey data, maps of stream gain/loss to groundwater and a map of lake gain/loss to groundwater in June 2005. No interpretation of the data will be made. Interpretation of the data is expected to take place in later phases of the project.

EBOP will supply GNS with any comments on the draft report within two weeks of its receipt. The final report will be completed by GNS within two weeks of receiving the EBOP comments.

Appendix 3. Pump test data supplied to GNS for the Mamaku township bores.

Pump test carried out by Rotorua District Council:



Attachments #2. 8/ 05 083

Constant Discharge Test
Pumping

Bay of Plenty Regional Council

113 m deep

Well Owner: Rotorua District Council.
Address: Private Bag RO3029
Rotorua.
Environment B·O·P Well No. 2102.
Measured by: Chris Campbell (RDC)
Distance from pumping well: 0 m
Pumping rate: —— gph 3.5 → 3.2 l/s
Measuring point details: From Clamp ontop of bore. Approx G.L.

Please circle bore type & duration of test

[✓ Pumping bore] ~~Monitoring bore~~

~~8 hour~~ ~~12 hour~~ [✓ 24 hour]

Site ID RDC Bore 3 (2102)
Date: 21-9-2
Time: 8.30am.

*Pumping rate varied, as well dropped the pump could not pump at 3.5 l/sec. By 3hrs pumping rate had dropped to 3.2 l/sec. It then remained constant.

Also RDC4 existing production bore running constant @ 4.0 l/sec until end of recovery test.

Background readings

Date	Time	Level
19-2-2	1:00pm	55.49
20-9-2	2:35pm	55.79
21-9-2	7.55 am	57.09

Actual time	Elapsed minutes	Level *metres*	Comments
8.30am	0	58.1	***30 second readings***
	0.5	61.09	
	1.0	65.21	
	1.5	71.32	
	2.0	74.02	
	2.5	75.49	
	3.0	76.82	
	3.5	77.29	
	4.0	77.41	
	4.5	77.51	
	5.0	77.56	
	5.5	77.56	
	6.0	77.59	
	6.5	77.61	
	7.0	77.68	
	7.5	77.71	
	8.0	77.80	
	8.5	77.46 ?	
	9.0	79.34	
	9.5	81.10	
8.40am	10.0	81.61	***1 minute readings***
	11.0	82.19	
	12.0		Sensor reading not working
	13.0	82.80	

ENVIRONMENT B·O·P
Bay of Plenty Regional Council

Pumping

page 2

EBOP Driller's Log Form No. ____________ Well No.: RDC3 (2102)

Date: 21-9-2 Time: 8·30am Start.

Actual time	Elapsed minutes	Reading *metres*	Comments
	14.0	83·01	
	15.0	83·40	
	16.0	83·59	
	17.0	83·81	
	18.0	83·95	
	19.0	84·10	
8·50	20.0	84·22	***2 minute readings***
	22.0	84·49	
	24.0	84·64	
	26.0	84·75	3·5 l/sec pumping rate.
	28.0	84·88	
9·00	30.0	85·04	***5 minute readings***
	35.0	85·48	
	40.0	85·68	
	45.0	85·86	
	50.0	86·18	
	55.0	86·50	
9·30	60.0	86·53	***10minute readings***
	70.0	86·60	Stop watch restart 0·00sec
	80.0	87·01	Sensor playing up
	90.0	87·05	[Bore 4 (RDC) @ 4·0 l/sec]
10·00 am	100.0	87·08	***20 minute readings***
	120.0	87·91	
	140.0	88·22	3·3 l/sec Pumping Rate
	160.0	88·31	" " "
11·30	180.0	88·76	***30 minuté readings*** 3·2 l/sec PumpingRate
12·00	210.0	88·90	
12·30 pm	240.0	89·41	" " " "
13·00	270.0	90·08	
13·30	300.0	90·27	***60 minute readings***
14·30	360.0	90·85	3·2 " " "
15·30	420.0	91·08	3·2 " " "
16·30	480.0	91·28	3·2 " " "
17·30	540.0	91·75	3·2 " " "
6·30	600.0	92·00	***5 hour readings*** 3·2 " " "
11·30pm	900.0	93·45	3·2 " " "
4·30am	1200.0	93·58	3·2 " " "
9·30am	1500.0	93·48	3·2 " " "

ENVIRONMENT B·O·P
Bay of Plenty Regional Council

Constant Discharge Test
Recovery

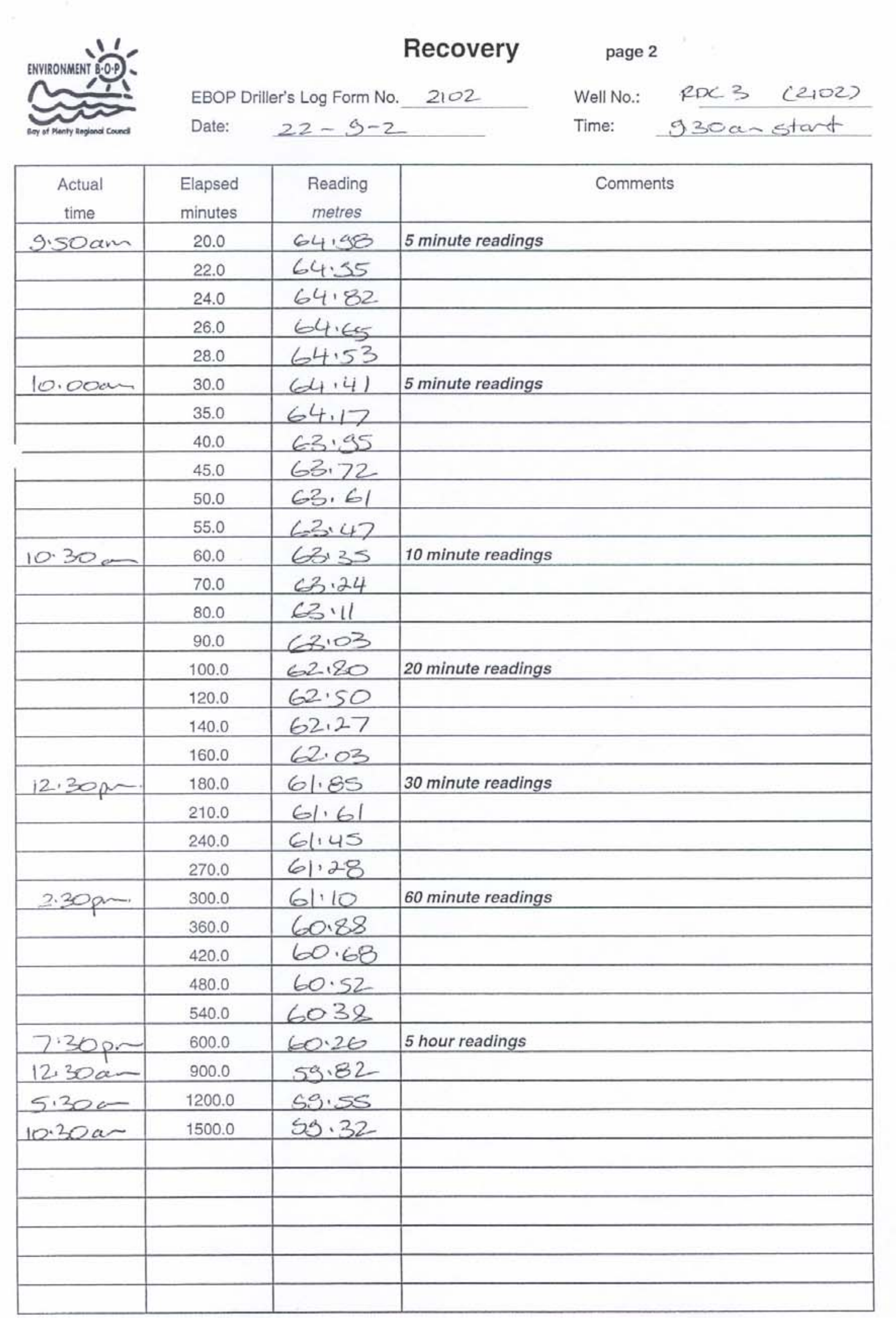
Well Owner: Rotorua District Council.
Address: Private Bag RO3029
Rotorua
EBOP Driller's Log Form No. 2102
Measured by: Chris Campbell (RDC)
Distance from pumping well: 0 *m*
Measuring point details: from top of clamp ~GL.

Please circle bore type & duration of test
[✓ Pumping bore] ~~Monitoring~~ bore
~~8 hour~~ ~~12 hour~~ [✓ 24 hour]

Well No.: RDC Bore3 (2102)
Date: 22-9-2
Time: 930am.

*Note RDC #4 production bore running @ 4.0 l/sec from start of pumping test to end of recovery test.

Actual time	Elapsed minutes	Reading *metres*	Comments
930am	0	92.46	***30 second readings***
	0.5	89.01	
	1.0	85.50	
	1.5	81.46	
	2.0	79.18	
	2.5	77.78	
	3.0	77.68	
	3.5	77.52	
	4.0	77.49	
	4.5	77.40	
	5.0	76.23	
	5.5	74.36	
	6.0	73.18	
	6.5	71.90	
	7.0	70.91	
	7.5	70.23	
	8.0	69.59	
	8.5	68.82	
	9.0	68.41	
	9.5	68.02	
9.40 am	10.0	67.68	***1 minute readings***
	11.0	67.05	
	12.0	66.71	
	13.0	66.43	
	14.0	66.10	
	15.0	65.89	
	16.0	65.68	
	17.0	65.47	
	18.0	65.30	
	19.0	65.15	



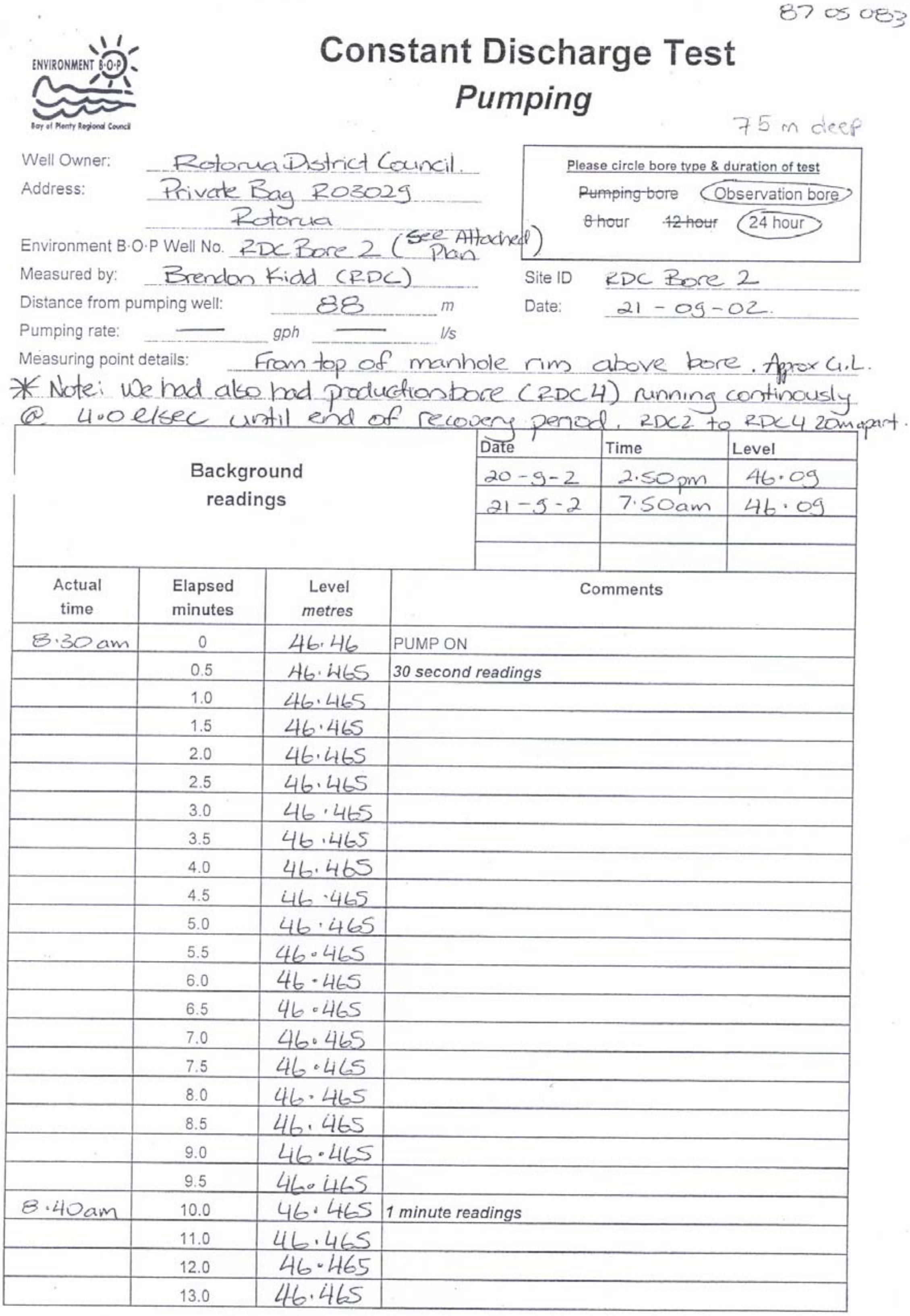
ENVIRONMENT B·O·P
Bay of Plenty Regional Council

Recovery

page 2

EBOP Driller's Log Form No. 2102
Well No.: RDC 3 (2102)
Date: 22-9-2
Time: 930am start

Actual time	Elapsed minutes	Reading *metres*	Comments
9·50am	20.0	64·98	***5 minute readings***
	22.0	64·95	
	24.0	64·82	
	26.0	64·65	
	28.0	64·53	
10·00am	30.0	64·41	***5 minute readings***
	35.0	64·17	
	40.0	63·95	
	45.0	63·72	
	50.0	63·61	
	55.0	63·47	
10·30am	60.0	63·35	***10 minute readings***
	70.0	63·24	
	80.0	63·11	
	90.0	63·03	
	100.0	62·80	***20 minute readings***
	120.0	62·50	
	140.0	62·27	
	160.0	62·03	
12·30pm	180.0	61·85	***30 minute readings***
	210.0	61·61	
	240.0	61·45	
	270.0	61·28	
2·30pm	300.0	61·10	***60 minute readings***
	360.0	60·88	
	420.0	60·68	
	480.0	60·52	
	540.0	60·38	
7·30pm	600.0	60·26	***5 hour readings***
12·30am	900.0	59·82	
5·30am	1200.0	59·55	
10·30am	1500.0	59·32	



87 05 083

ENVIRONMENT B·O·P
Bay of Plenty Regional Council

Constant Discharge Test
Pumping

75 m deep

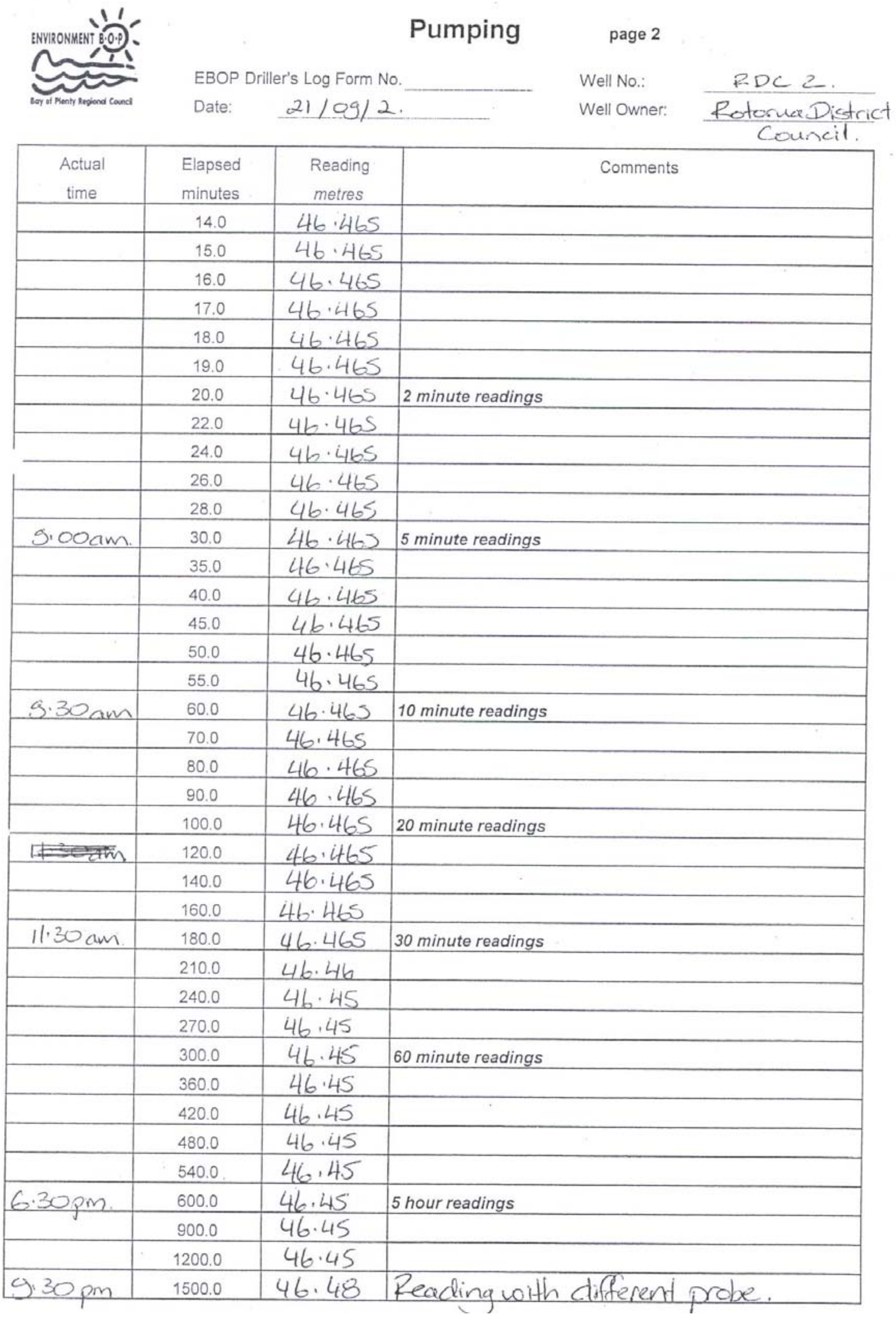
Well Owner: Rotorua District Council.
Address: Private Bag R03029
Rotorua
Environment B·O·P Well No. RDC Bore 2 (See Attached Plan)
Measured by: Brendon Kidd (RDC)
Distance from pumping well: 88 m
Pumping rate: —— gph —— l/s
Measuring point details: From top of manhole rim above bore. Approx G.L.
✱ Note: We had also had production bore (RDC 4) running continously @ 4.0 l/sec until end of recovery period. RDC2 to RDC4 20m apart.

Please circle bore type & duration of test
~~Pumping bore~~ [✓ Observation bore]
~~8 hour~~ ~~12 hour~~ [✓ 24 hour]

Site ID RDC Bore 2
Date: 21 - 09 - 02.

Background readings	Date	Time	Level
	20 - 9 - 2	2.50pm	46.09
	21 - 9 - 2	7.50am	46.09

Actual time	Elapsed minutes	Level *metres*	Comments
8.30 am	0	46.46	PUMP ON
	0.5	46.465	*30 second readings*
	1.0	46.465	
	1.5	46.465	
	2.0	46.465	
	2.5	46.465	
	3.0	46.465	
	3.5	46.465	
	4.0	46.465	
	4.5	46.465	
	5.0	46.465	
	5.5	46.465	
	6.0	46.465	
	6.5	46.465	
	7.0	46.465	
	7.5	46.465	
	8.0	46.465	
	8.5	46.465	
	9.0	46.465	
	9.5	46.465	
8.40am	10.0	46.465	*1 minute readings*
	11.0	46.465	
	12.0	46.465	
	13.0	46.465	

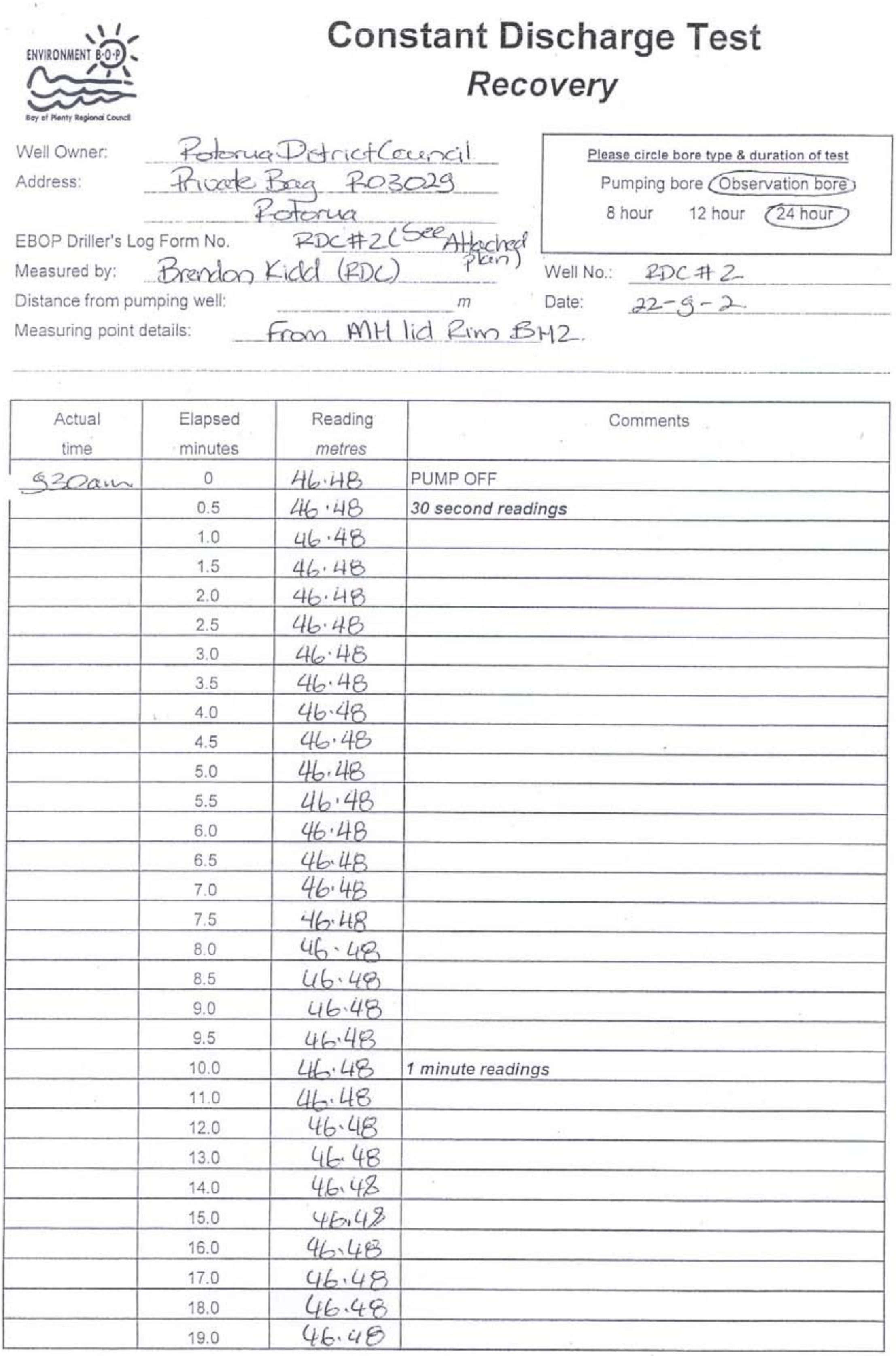


ENVIRONMENT B·O·P
Bay of Plenty Regional Council

Pumping page 2

EBOP Driller's Log Form No. ______
Date: 21/09/2.
Well No.: RDC 2.
Well Owner: Rotorua District Council.

Actual time	Elapsed minutes	Reading metres	Comments
	14.0	46.465	
	15.0	46.465	
	16.0	46.465	
	17.0	46.465	
	18.0	46.465	
	19.0	46.465	
	20.0	46.465	*2 minute readings*
	22.0	46.465	
	24.0	46.465	
	26.0	46.465	
	28.0	46.465	
9.00am.	30.0	46.465	*5 minute readings*
	35.0	46.465	
	40.0	46.465	
	45.0	46.465	
	50.0	46.465	
	55.0	46.465	
9.30am	60.0	46.465	*10 minute readings*
	70.0	46.465	
	80.0	46.465	
	90.0	46.465	
	100.0	46.465	*20 minute readings*
~~11:30am~~	120.0	46.465	
	140.0	46.465	
	160.0	46.465	
11·30am.	180.0	46.465	*30 minute readings*
	210.0	46.46	
	240.0	46.45	
	270.0	46.45	
	300.0	46.45	*60 minute readings*
	360.0	46.45	
	420.0	46.45	
	480.0	46.45	
	540.0	46.45	
6.30pm.	600.0	46.45	*5 hour readings*
	900.0	46.45	
	1200.0	46.45	
9.30pm	1500.0	46.48	Reading with different probe.



ENVIRONMENT B·O·P
Bay of Plenty Regional Council

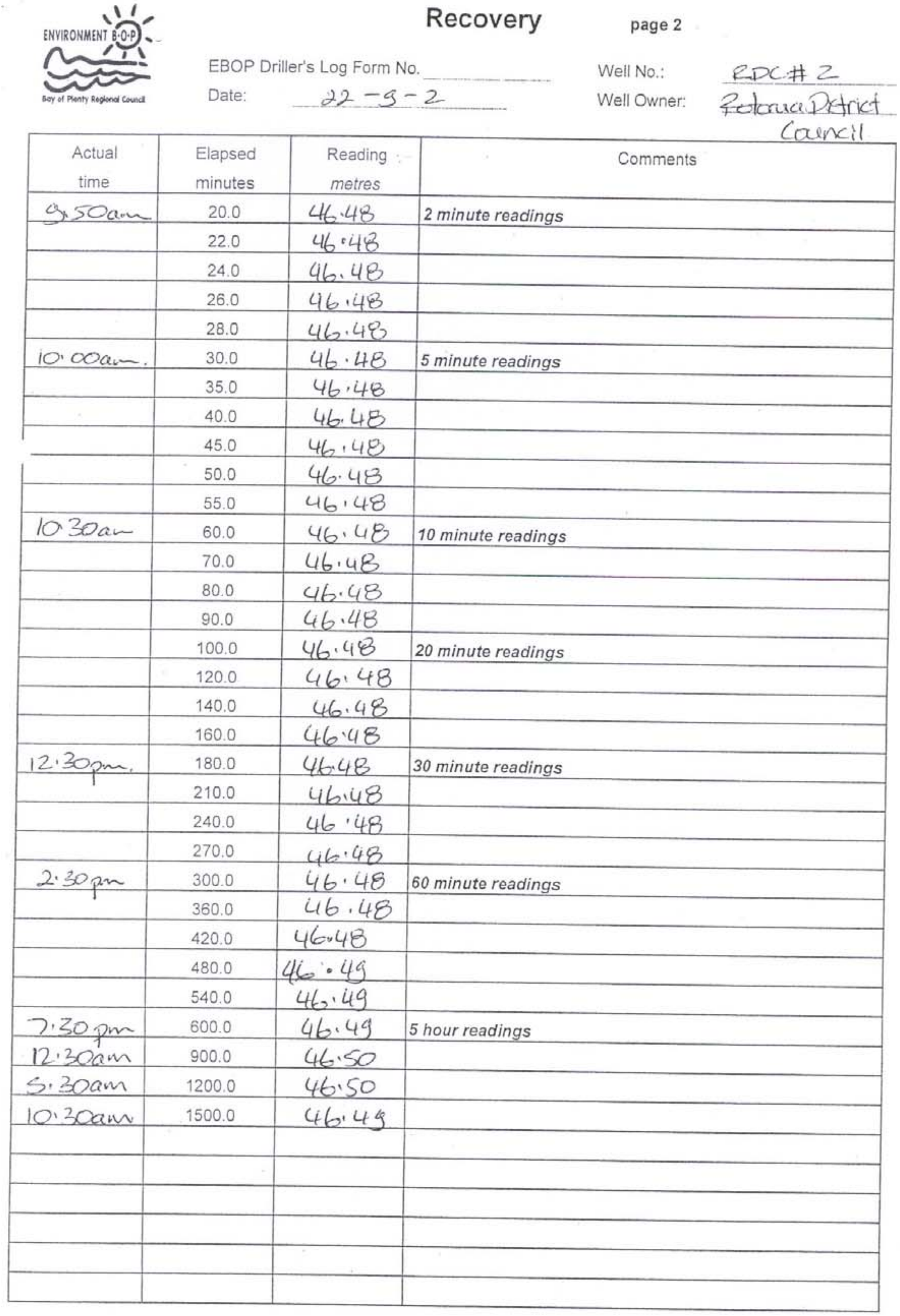
Constant Discharge Test
Recovery

Well Owner: Rotorua District Council
Address: Private Bag R03029
Rotorua
EBOP Driller's Log Form No. RDC#2 (See Attached plan)
Measured by: Brendon Kidd (RDC)
Distance from pumping well: m
Measuring point details: From MH lid Rim BH2.

Please circle bore type & duration of test
Pumping bore [✓ Observation bore]
8 hour 12 hour [✓ 24 hour]

Well No.: RDC # 2
Date: 22-9-2

Actual time	Elapsed minutes	Reading *metres*	Comments
930am	0	46.48	PUMP OFF
	0.5	46.48	*30 second readings*
	1.0	46.48	
	1.5	46.48	
	2.0	46.48	
	2.5	46.48	
	3.0	46.48	
	3.5	46.48	
	4.0	46.48	
	4.5	46.48	
	5.0	46.48	
	5.5	46.48	
	6.0	46.48	
	6.5	46.48	
	7.0	46.48	
	7.5	46.48	
	8.0	46.48	
	8.5	46.48	
	9.0	46.48	
	9.5	46.48	
	10.0	46.48	*1 minute readings*
	11.0	46.48	
	12.0	46.48	
	13.0	46.48	
	14.0	46.48	
	15.0	46.48	
	16.0	46.48	
	17.0	46.48	
	18.0	46.48	
	19.0	46.48	

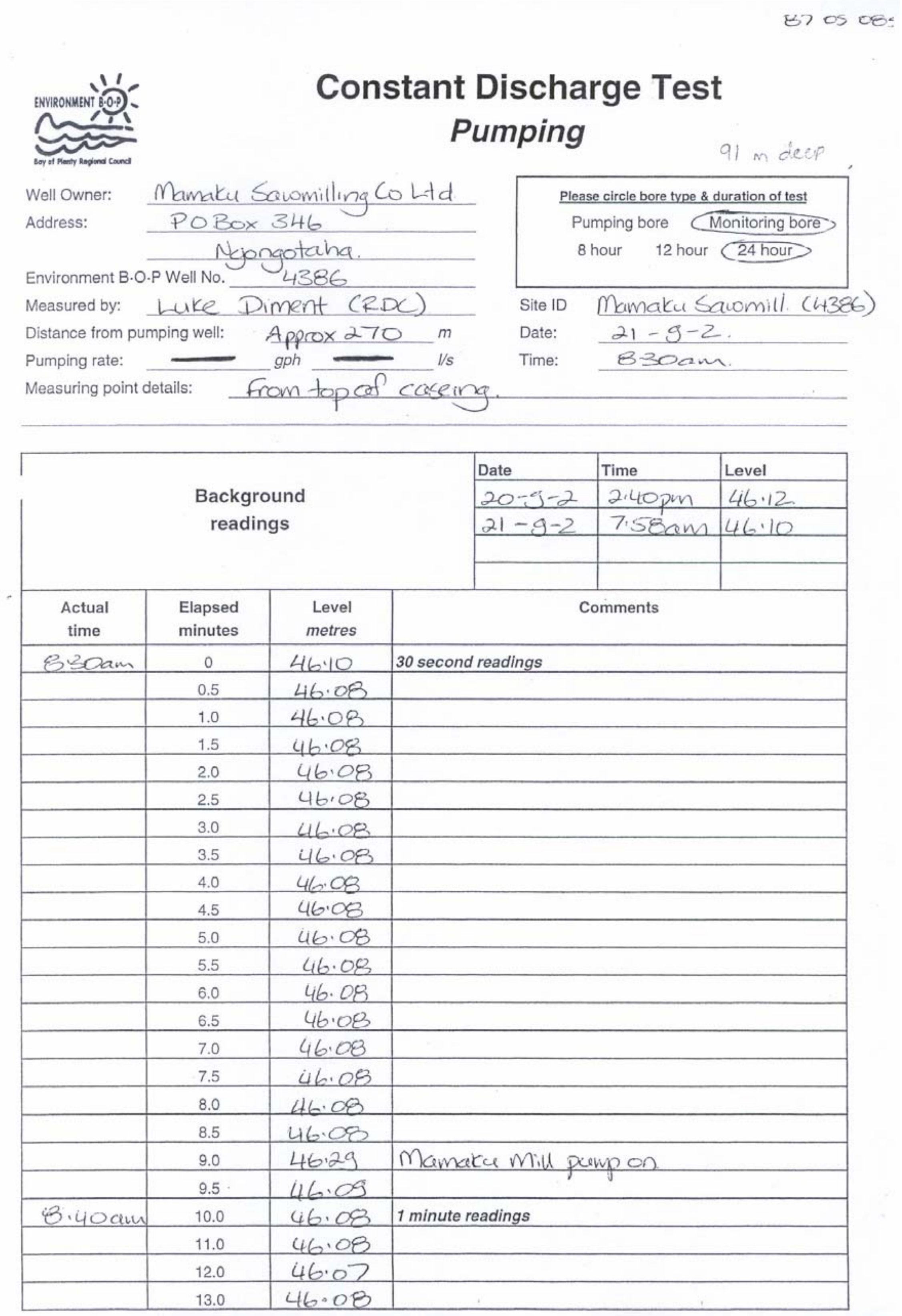


ENVIRONMENT B·O·P
Bay of Plenty Regional Council

Recovery page 2

EBOP Driller's Log Form No. ____________
Date: 22-9-2
Well No.: RDC # 2
Well Owner: Rotorua District Council

Actual time	Elapsed minutes	Reading *metres*	Comments
9·50am	20.0	46·48	*2 minute readings*
	22.0	46·48	
	24.0	46·48	
	26.0	46·48	
	28.0	46·48	
10·00am.	30.0	46·48	*5 minute readings*
	35.0	46·48	
	40.0	46·48	
	45.0	46·48	
	50.0	46·48	
	55.0	46·48	
10·30am	60.0	46·48	*10 minute readings*
	70.0	46·48	
	80.0	46·48	
	90.0	46·48	
	100.0	46·48	*20 minute readings*
	120.0	46·48	
	140.0	46·48	
	160.0	46·48	
12·30pm.	180.0	46·48	*30 minute readings*
	210.0	46·48	
	240.0	46·48	
	270.0	46·48	
2·30pm	300.0	46·48	*60 minute readings*
	360.0	46·48	
	420.0	46·48	
	480.0	46·49	
	540.0	46·49	
7·30pm	600.0	46·49	*5 hour readings*
12·30am	900.0	46·50	
5·30am	1200.0	46·50	
10·30am	1500.0	46·49	



87 05 08

ENVIRONMENT B·O·P
Bay of Plenty Regional Council

Constant Discharge Test

Pumping

91 m deep

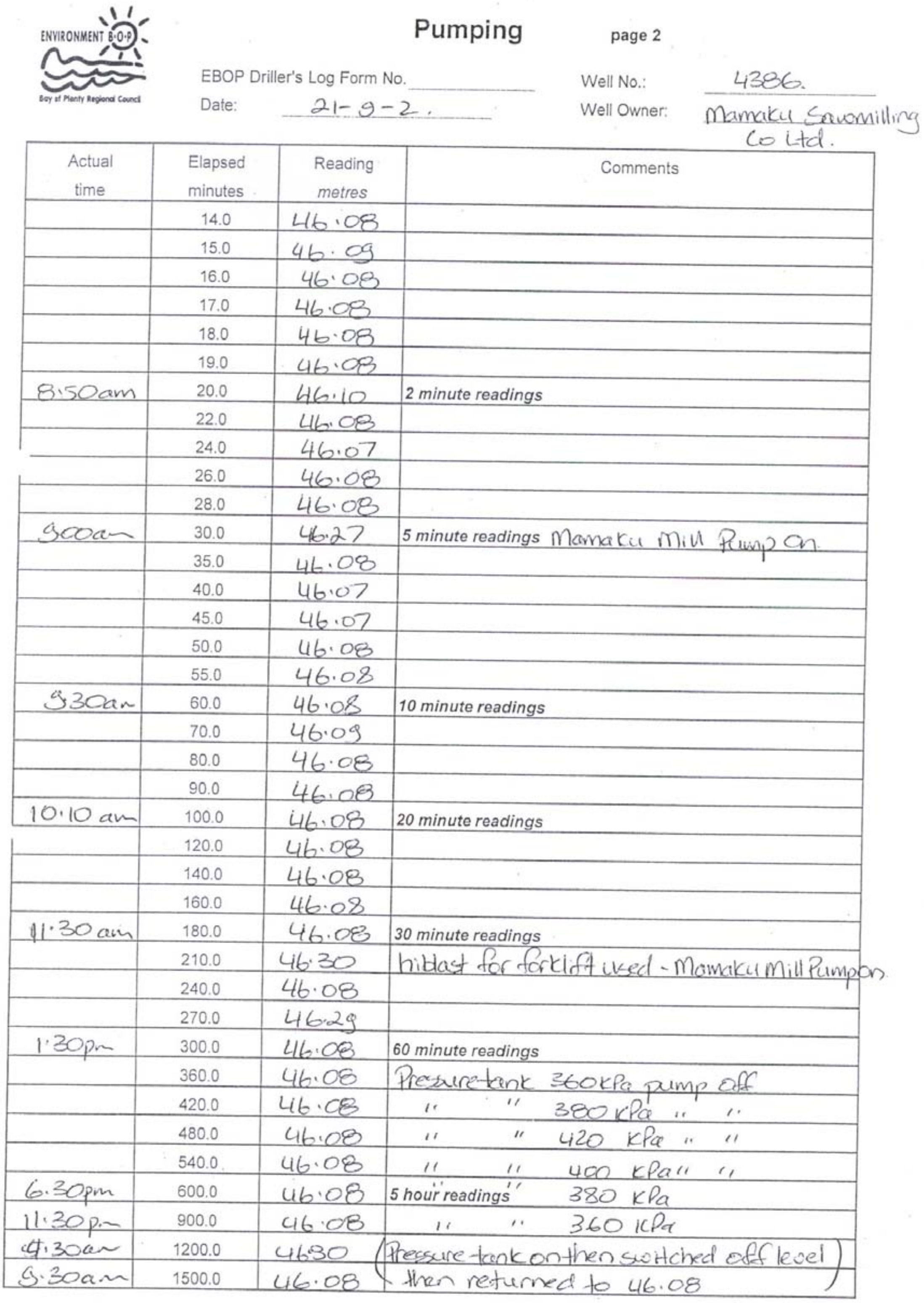
Well Owner: Mamaku Sawmilling Co Ltd
Address: PO Box 346
Ngongotaha.
Environment B·O·P Well No. 4386
Measured by: Luke Diment (RDC)
Distance from pumping well: Approx 270 m
Pumping rate: — gph — l/s
Measuring point details: From top of caseing.

Please circle bore type & duration of test
Pumping bore [✓ Monitoring bore]
8 hour 12 hour [✓ 24 hour]

Site ID Mamaku Sawmill (4386)
Date: 21-9-2.
Time: 830am.

Background readings	Date	Time	Level
	20-9-2	2:40pm	46.12
	21-9-2	7:58am	46.10

Actual time	Elapsed minutes	Level *metres*	Comments
8:30am	0	46.10	***30 second readings***
	0.5	46.08	
	1.0	46.08	
	1.5	46.08	
	2.0	46.08	
	2.5	46.08	
	3.0	46.08	
	3.5	46.08	
	4.0	46.08	
	4.5	46.08	
	5.0	46.08	
	5.5	46.08	
	6.0	46.08	
	6.5	46.08	
	7.0	46.08	
	7.5	46.08	
	8.0	46.08	
	8.5	46.08	
	9.0	46.29	Mamaku Mill pump on
	9.5	46.08	
8.40am	10.0	46.08	***1 minute readings***
	11.0	46.08	
	12.0	46.07	
	13.0	46.08	



ENVIRONMENT B·O·P
Bay of Plenty Regional Council

Pumping

page 2

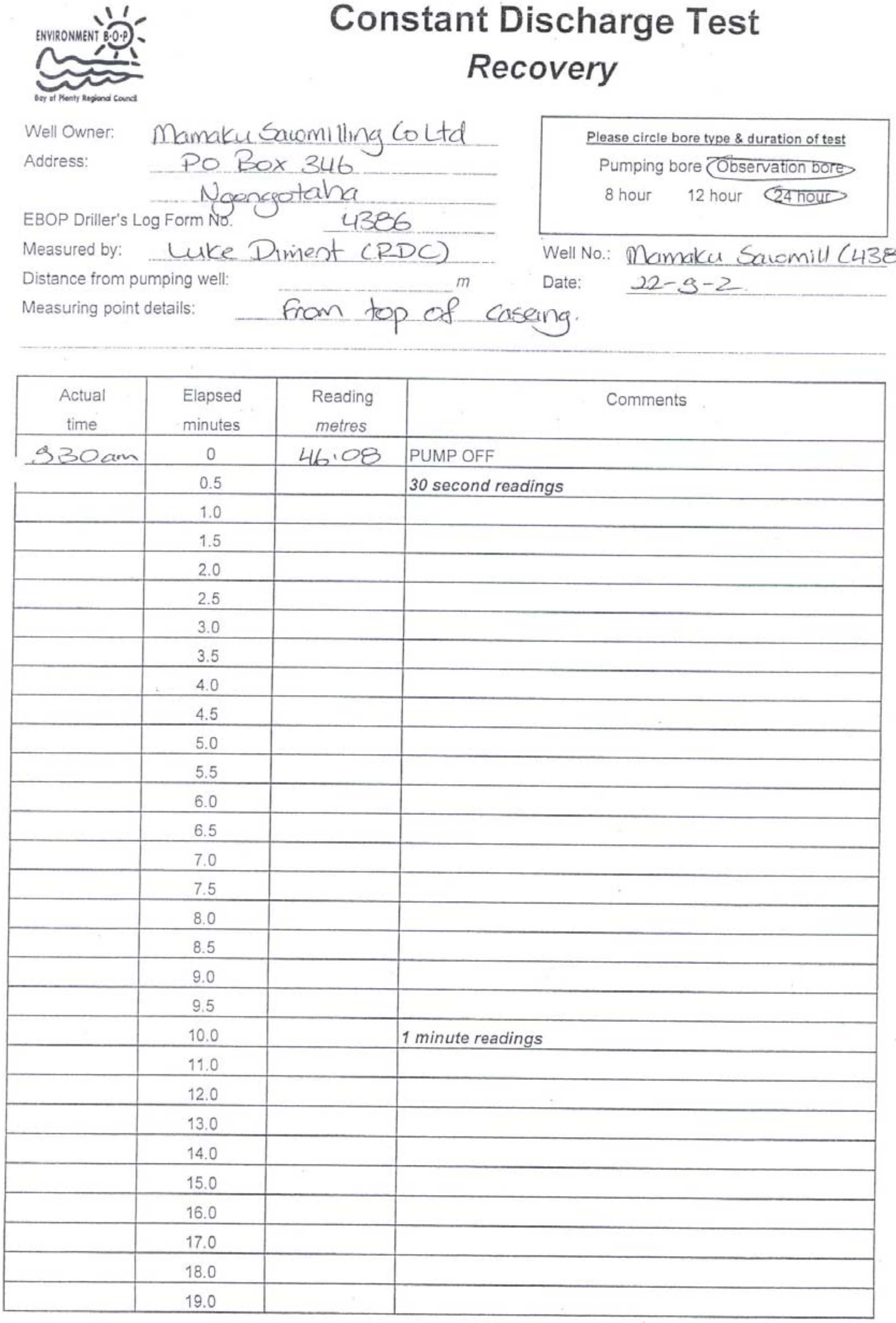
EBOP Driller's Log Form No. ______

Date: 21-9-2.

Well No.: 4386.

Well Owner: Mamaku Sawmilling Co Ltd.

Actual time	Elapsed minutes	Reading *metres*	Comments
	14.0	46·08	
	15.0	46·09	
	16.0	46·08	
	17.0	46·08	
	18.0	46·08	
	19.0	46·08	
8·50am	20.0	46·10	**2 minute readings**
	22.0	46·08	
	24.0	46·07	
	26.0	46·08	
	28.0	46·08	
900am	30.0	46·27	**5 minute readings** Mamaku Mill Pump On.
	35.0	46·08	
	40.0	46·07	
	45.0	46·07	
	50.0	46·08	
	55.0	46·08	
930am	60.0	46·08	**10 minute readings**
	70.0	46·09	
	80.0	46·08	
	90.0	46·08	
10·10 am	100.0	46·08	**20 minute readings**
	120.0	46·08	
	140.0	46·08	
	160.0	46·08	
11·30 am	180.0	46·08	**30 minute readings**
	210.0	46·30	hiblast for forklift used - Mamaku Mill Pump on.
	240.0	46·08	
	270.0	46·29	
1·30pm	300.0	46·08	**60 minute readings**
	360.0	46·08	Pressure tank 360kPa pump off
	420.0	46·08	" " 380 kPa " "
	480.0	46·08	" " 420 kPa " "
	540.0	46·08	" " 400 kPa " "
6·30pm	600.0	46·08	**5 hour readings** " " 380 kPa
11·30pm	900.0	46·08	" " 360 kPa
4·30am	1200.0	46·30	(Pressure tank on then switched off level
9·30am	1500.0	46·08	then returned to 46·08)



ENVIRONMENT B·O·P
Bay of Plenty Regional Council

Constant Discharge Test

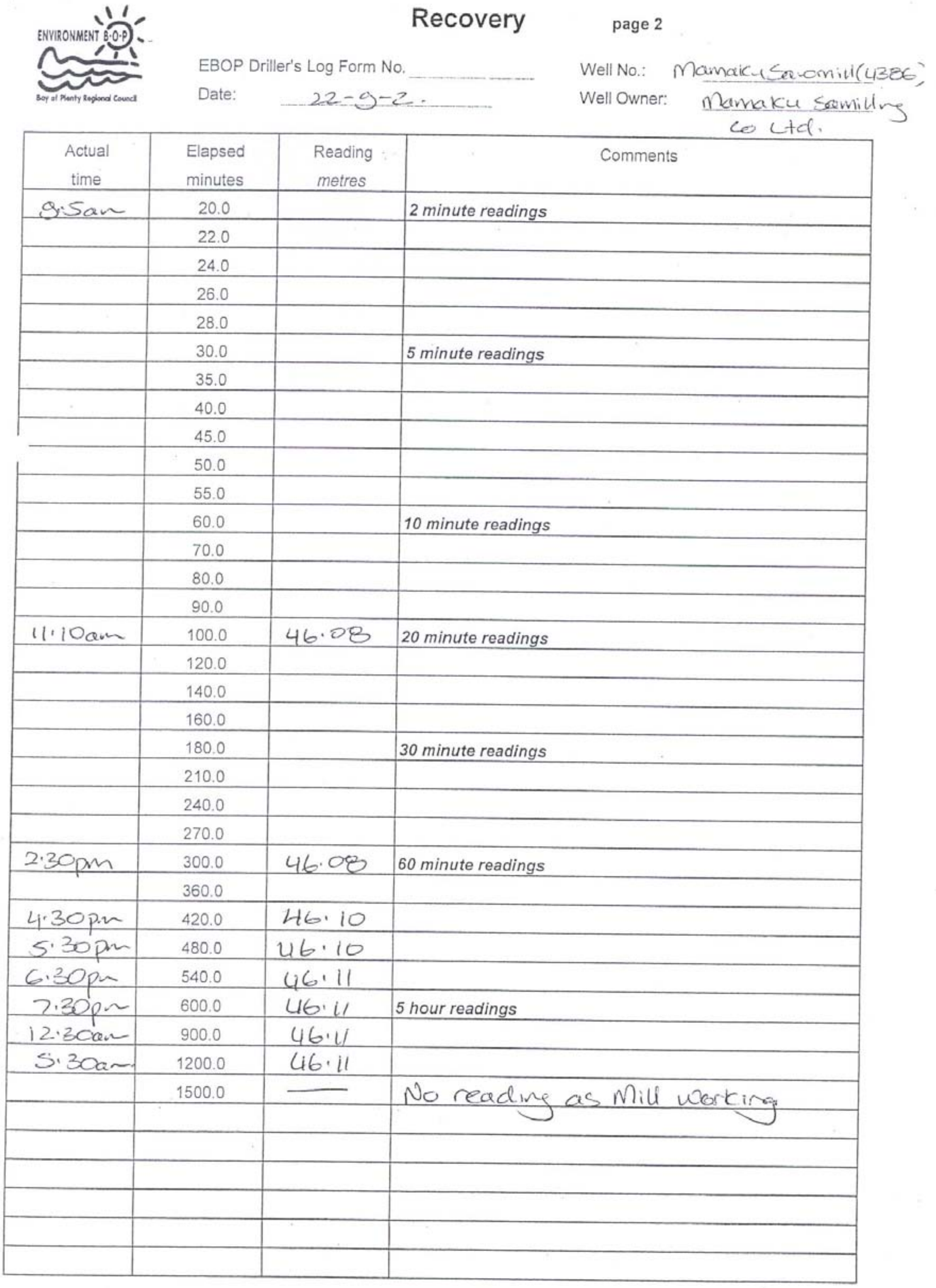
Recovery

Well Owner: Mamaku Sawmilling Co Ltd
Address: PO Box 346
Ngongotaha
EBOP Driller's Log Form No. 4386
Measured by: Luke Diment (RDC)
Distance from pumping well: ______ *m*
Measuring point details: from top of caseing.

Please circle bore type & duration of test
Pumping bore [✓ Observation bore]
8 hour 12 hour [✓ 24 hour]

Well No.: Mamaku Sawmill (4386)
Date: 22-9-2

Actual time	Elapsed minutes	Reading *metres*	Comments
930am	0	46·08	PUMP OFF
	0.5		*30 second readings*
	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		
	8.5		
	9.0		
	9.5		
	10.0		*1 minute readings*
	11.0		
	12.0		
	13.0		
	14.0		
	15.0		
	16.0		
	17.0		
	18.0		
	19.0		



ENVIRONMENT B·O·P
Bay of Plenty Regional Council

Recovery

page 2

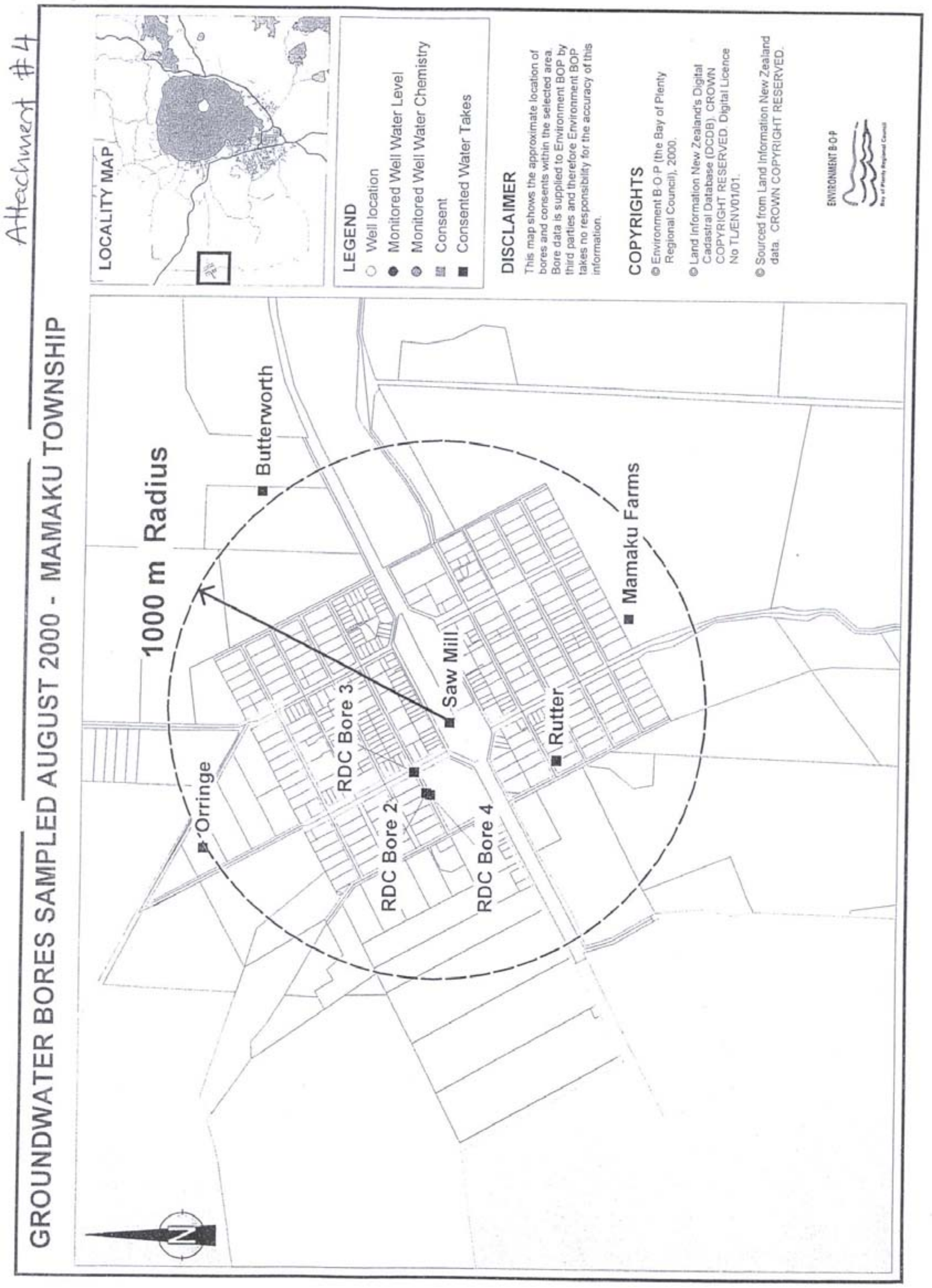
EBOP Driller's Log Form No.
Date: 22-9-2.
Well No.: Mamaku Sawmill (4386)
Well Owner: Mamaku Sawmilling Co Ltd.

Actual time	Elapsed minutes	Reading *metres*	Comments
9:5am	20.0		*2 minute readings*
	22.0		
	24.0		
	26.0		
	28.0		
	30.0		*5 minute readings*
	35.0		
	40.0		
	45.0		
	50.0		
	55.0		
	60.0		*10 minute readings*
	70.0		
	80.0		
	90.0		
11:10am	100.0	46.08	*20 minute readings*
	120.0		
	140.0		
	160.0		
	180.0		*30 minute readings*
	210.0		
	240.0		
	270.0		
2:30pm	300.0	46.08	*60 minute readings*
	360.0		
4.30pm	420.0	46.10	
5.30pm	480.0	46.10	
6.30pm	540.0	46.11	
7.30pm	600.0	46.11	*5 hour readings*
12.30am	900.0	46.11	
5.30am	1200.0	46.11	
	1500.0	—	No reading as Mill working

Attachment #3

Existing (Production Bore 1) RDC Bore 4.
Mamaku. Township.

Attechment #4



DISCLAIMER

This map shows the approximate location of bores and consents within the selected area. Bore data is supplied to Environment BOP by third parties and therefore Environment BOP takes no responsibility for the accuracy of this information.

COPYRIGHTS

© Environment B·O·P (the Bay of Plenty Regional Council), 2000.

© Land Information New Zealand's Digital Cadastral Database (DCDB). CROWN COPYRIGHT RESERVED. Digital Licence No TL/ENV01/01.

© Sourced from Land Information New Zealand data. CROWN COPYRIGHT RESERVED.

Appendix 4.1 New bores found and the survey results.

Status	Source	GNS Site ref	Feature type	Location	Date of observation	Easting	Northing	Method of obtaining Location	Est XY Error	Elevation (m)	Method of elevation	Est elevation error (m)	Bore Depth (m)	Depth to water (m)	Measure from:	Bore diameter (mm)	Casing type	Screened from	Screened to
Found	GNS	10001	bore	Rotoiti	19/11/2004	2810136.1	6341009.7	RTK-GPS	0.3	415.9	RTK-GPS	0.5	53.3	47.925	top of steel casing	100	steel		
Found	GNS	10002	spring	Rotoiti	19/11/2004	2805780.3	6343355.1	RTK-GPS	5	369.4	RTK-GPS	5		0					
Found	GNS	10003	bore	Rotoiti	24/11/2004	2803368.9	6343170.0	RTK-GPS	0.3	326.9	RTK-GPS	0.5				100			
Found	GNS	10004	bore	Rotoiti	24/11/2004	2803692.6	6342407.6	RTK-GPS	0.3	307.2	RTK-GPS	0.5	approx. 30m - not measured.	approx. 13m - not measured.	Not measured	100	steel		
Found	GNS	10005	bore	Rotoiti	24/11/2004	2804295.2	6347870.5	RTK-GPS	0.3	279.7	RTK-GPS	0.5	9.233	2.21	top of steel casing	100	steel		
Found	GNS	10006	bore	Rotorua (south)	25/11/2004	2797522.6	6315089.0	RTK-GPS	0.3	373.7	RTK-GPS	0.5	80 ft - not measured. Converted = 24.4m	30 ft - not measured. Converted = 9.14m	not measured	75			
Found	GNS	10007	bore	Rotorua (south)	25/11/2004	2786978.9	6315977.1	RTK-GPS	0.3	395.0	RTK-GPS	0.5				110	steel		
Found	GNS	10008	bore	Rotorua (south)	25/11/2004	2789747.7	6320739.8	RTK-GPS	0.3	389.1	RTK-GPS	0.5	Apparently very deep.				steel		
Found	GNS	10009	bore	Rotorua (south)	25/11/2004	2793061.1	6318028.1	RTK-GPS	0.3	303.8	RTK-GPS	0.5				170	steel		
Found	GNS	10010	bore	Rotorua (south)	29/11/2004	2795069.4	6322524.7	RTK-GPS	0.3	425.8	RTK-GPS	0.5				120	steel		
Found	GNS	10011	bore	Rotorua (south)	29/11/2004	2796402.0	6322888.1	RTK-GPS	0.3	439.5	RTK-GPS	0.5				~120	silver and thin?		
Found	GNS	10012	bore	Rotorua (south)	29/11/2004	2798832.6	6321600.2	RTK-GPS	0.3	420.8	RTK-GPS	0.5				~180	steel		
Found	GNS	10013	bore	Rotoiti	1/12/2004	2805906.9	6353313.8	RTK-GPS	0.6	239.4	RTK-GPS	0.6				~150	silver and thin?		
Found	GNS	10014	bore	Rotoiti	1/12/2004	2807642.0	6349963.3	RTK-GPS	0.3	335.9	RTK-GPS	0.5	Owner said 8 - 13 rods. Not measured		Not measured	~100	too grimy to see		
Found	GNS	10015	bore	Rotorua (south)	13/12/2004	2800988.3	6323383.2	RTK-GPS	0.3	433.3	RTK-GPS	0.5	11.59	1.97	top of steel casing	240	steel		
Found	GNS	10016	bore	Rotoiti	14/12/2004	2809111.5	6349703.8	RTK-GPS	0.3	337.7	RTK-GPS	0.3				~100	too grimy to see		
Found	GNS	10017	bore	Rotoiti	14/12/2004	2811081.8	6349767.6	RTK-GPS	0.3	274.1	RTK-GPS	0.3	10 x 22ft rods according to owner		Not measured	~100	too grimy to see		
Found	GNS	10018	bore	Rotoiti	14/12/2004	2812924.3	6355575.8	RTK-GPS	0.3	196.4	RTK-GPS	0.3				~140	steel		
Found	GNS	10019	bore	Rotoiti	14/12/2004	2813323.2	6355211.6	RTK-GPS	0.3	233.5	RTK-GPS	0.3				~130	steel		
Found	GNS	10020	bore	Rotoiti	14/12/2004	2813319.5	6354835.9	RTK-GPS	0.3	184.6	RTK-GPS	0.3				130-140	steel		
Found	GNS	10021	bore	Rotoiti	14/12/2004	2814162.6	6354604.1	RTK-GPS	0.3	195.1	RTK-GPS	0.3				100 - 130	steel		
Found	GNS	10022	bore	Rotoiti	15/12/2004	2812068.8	6349873.9	RTK-GPS	1	326.4	RTK-GPS	0.3	apparently 15 rods?			~100	too grimy to see		
Found	GNS	10023	bore	Rotoiti	15/12/2004	2813881.1	6348045.5	RTK-GPS	0.3	374.8	RTK-GPS	0.3					steel		
Found	GNS	10024	bore	Rotoiti	17/12/2004	2811430.4	6352033.8	RTK-GPS	0.3	226.2	RTK-GPS	0.3				~120	steel		
Found	GNS	10025	spring	Rotoiti	17/12/2004	2811904.3	6353153.2	RTK-GPS	5	273.1	RTK-GPS	3		0					
Found	GNS	10026	bore	Rotoiti	20/12/2004	2809913.9	6349463.2	RTK-GPS	1	331.7	RTK-GPS	1	100m owner stated		Not measured				
Found	GNS	10027	spring	Rotoiti	5/01/2005	2807014.2	6349590.7	RTK-GPS	10	293.1	RTK-GPS	2		0					
Found	GNS	10028	spring	Rotoiti	5/01/2005	2803524.1	6349025.1	RTK-GPS	0.3	274.4	RTK-GPS	0.3		0					
Found	GNS	10029	bore	Rotoiti	10/01/2005	2812361.6	6350671.2	RTK-GPS	1	305.7	RTK-GPS	0.3				~80	steel		
Found	GNS	10030	bore	Rotoiti	12/01/2005	2810856.7	6349217.7	RTK-GPS	0.3	294.0	RTK-GPS	0.3				100	steel		
Found	GNS	10031	spring	Rotoiti	12/01/2005	2814730.6	6350066.4	RTK-GPS	20	246.9	RTK-GPS	5		0					
Found	GNS	10032	bore	Rotorua (south)	14/01/2005	2794673.7	6330721.6	RTK-GPS	0.3	323.0	RTK-GPS	0.3							
Found	GNS	10033	bore	Rotorua (south)	14/01/2005	2791333.7	6327818.4	RTK-GPS	0.3	418.0	RTK-GPS	0.3				~100			
Found	GNS	10034	bore	Rotorua (north)	18/01/2005	2794645.4	6351413.0	RTK-GPS	0.3	390.2	RTK-GPS	0.3	75.21	no water found	top of steel casing	80	steel		
Found	EBOP	10084	bore	Rotorua	26/10/2004	2788649.4	6352785.1	RTK-GPS	0.3	497.0	RTK-GPS	0.3	31.77	no water found		75	steel		
Found	EBOP	10092	bore	Rotorua	27/10/2004	2795576.4	6349310.4	RTK-GPS	0.3	479.3	RTK-GPS	0.3	approx 225	172.37	top of steel casing	150	steel		
Found	GNS	10037	spring	Rotorua (south)	5/01/2005	2805849	6348299	GPS	20	306	EST-MAP	20		0					
Found	GNS	10038	spring	Rotorua (south)	5/01/2005	2806139	6347660	GPS	20	295	EST-MAP	20		0					
Found	GNS	10039	bore	Rotorua (south)	5/01/2005	2806375	6347414	GPS	20			20	apparently 50 ft, not measured		Not measured	~ 70	steel		
Found	GNS	10040	spring	Rotorua (south)	5/01/2005	2806045	6347265	GPS	20	290	EST-MAP	20		0					
Found	GNS	10041	spring	Rotorua (south)	14/01/2005	2793263	6327389	GPS	20	365	EST-MAP	20		0					
Found	GNS	10042	spring	Rotorua (south)	14/01/2005	2793900	6325500	EST-MAP	200	365	EST-MAP	20		0					
Found	EBOP	10086	bore	Rotorua	26/10/2004	2792136.1	6349133.5	RTK-GPS	0.3	404.6	RTK-GPS	0.3		79		75	steel		
Found	GNS	10044	bore	Rotoiti	19/11/2004	2816831	6345739	GPS	20	295	EST-MAP	20	>200	Could be 60m, not measured.		100	steel		
Found	GNS	10045	bore	Rotoiti	19/11/2004	2803938	6343841	GPS	20										
Found	GNS	10046	spring	Rotoiti	15/12/2004	2806383	6349040	GPS	20	310	EST-MAP	20		0					
Found	GNS	10047	spring	Rotoiti	20/12/2004	2806416	6350746	GPS	20	280	EST-MAP	20		0					
Found	GNS	10048	spring	Rotoiti	20/12/2004	2807806	6351410	GPS	30	260	EST-MAP	20		0					
Found	GNS	10049	spring	Rotoiti	17/12/2004	2810524	6349918	GPS	20	300	EST-MAP	20		0					
Found	GNS	10050	spring	Rotoiti	17/12/2004	2811002	6349869	GPS	20	280	EST-MAP	20		0					
Found	GNS	10051	spring	Rotoiti	17/12/2004	2810317	6349545	GPS	20	300	EST-MAP	20		0					
Found	GNS	10052	spring	Rotoiti	17/12/2004	2810813	6350178	GPS	20	274	EST-MAP	20		0					
Found	GNS	10053	spring	Rotoiti	24/11/2004	2804752	6348026	GPS	20	295	EST-MAP	20		0					
Found	GNS	10058	spring	Rotoiti	5/01/2005	2803221	6349590	GPS	20	290	EST-MAP	20		0					
Found	GNS	10059	spring	Rotoiti	7/01/2005	2806792	6350371	GPS	20	275	EST-MAP	20		0					
Found	GNS	10060	spring	Rotoiti	7/01/2005	2806910	6353107	GPS	30	222	EST-MAP	20		0					
Found	GNS	10061	spring	Rotoiti	10/01/2005	2816180	6347909	GPS	300	380	EST-MAP	20		0					
Found	EBOP	10062	bore	Rotorua	08/10/2004	2788824	6349343	GPS	20	470	EST-MAP	20	76	88m		150	steel to 104m		
Found	EBOP	10063	bore	Rotorua	11/10/2004	2787340	6347868	GPS	20				85						
Found	EBOP	10064	bore	Rotorua	11/10/2004	2790095	6347817	GPS	20				85			100			
Found	EBOP	10065	bore	Rotorua	11/10/2004	2790154	6347828	GPS	20				75						
Found	EBOP	10066	bore	Rotorua	11/10/2004	2790431	6347537	GPS	20										
Found	EBOP	10067	bore	Rotorua	11/10/2004	2790519	6347798	GPS	20										
Found	EBOP	10068	bore	Rotorua	11/10/2004	2790491	6347410	GPS	20										
Found	EBOP	10069	bore	Rotorua	12/10/2004	2790991	6340809	GPS	20										
Found	EBOP	10070	bore	Rotorua	12/10/2004	2791248	6340922	GPS	20										
Found	EBOP	10071	pump from stream	Rotorua	12/10/2004	2788018	6340324	GPS	20										
Found	EBOP	10072	bore	Rotorua	12/10/2004	2787643	6343121	GPS	20										
Found	EBOP	10073	bore	Rotorua	12/10/2004	2792384	6339359	GPS	20										
Found	EBOP	10074	pump from stream	Rotorua	12/10/2004	2791300	6330300	GPS	20										
Found	EBOP	10075	bore	Rotorua	12/10/2004	2802260	6335990	GPS	20	350	EST-MAP	20		SWL ~50m					
Found	EBOP	10076	bore	Rotorua	12/10/2004	2802244	6336266	GPS	20										
Found	EBOP	10077	bore	Rotorua	12/10/2004	2800951	6336200	GPS	20										
Found	EBOP	10078	bore	Rotorua	12/10/2004	2799826	6335424	GPS	20										
Found	EBOP	10079	bore	Rotorua	12/10/2004	2799425	6333922	GPS	20	335	EST-MAP	20		SWL 40-45m					
Found	EBOP	10080	bore	Rotorua	12/10/2004	2801337	6332808	GPS	20										
Found	EBOP	10081	bore	Rotorua	12/10/2004	2800196	6334825	GPS	20										
Found	EBOP	10082	bore	Rotorua	12/10/2004	2791324	6327793	GPS	20	410	EST-MAP	20	72	SWL 31m		65	Steel		
Found	EBOP	10083	bore	Rotorua	27/10/2004	2788812	6352560	GPS	20	490	EST-MAP	20	over 85m	65		100	steel		
Found	EBOP	10085	bore	Rotorua	26/10/2004	2791320	6350735	GPS	20	415	EST-MAP	20		91.4		75	steel		
Found	EBOP	10087	bore	Rotorua	26/10/2004				20					67 and 79					
Found	EBOP	10088	bore	Rotorua	26/10/2004	2791754	6350951	GPS	20	395	EST-MAP	20		82.2		75	steel		
Found	EBOP	10089	bore	Rotorua	26/10/2004	2794800	6350400	GPS	20	435	EST-MAP	20	220	152		75	steel		
Found	EBOP	10090	bore	Rotorua	26/10/2004	2795528	6351357	GPS	20	355	EST-MAP	20		116		75	steel		
Found	EBOP	10091	bore	Rotorua	26/10/2004	2793200	6350600	GPS	20	385	EST-MAP	20	153.6	89		100 + 75	steel		
Found	EBOP	10093	bore	Rotorua		2789052	6341739	GPS	20										
Found	EBOP	10094	bore	Rotorua	04/11/2004	2789782	6344265	GPS	20				55			100	steel		
Found	EBOP	10095	bore	Rotorua	04/11/2004	2788321	6343893	GPS	20	350	EST-MAP	20	80	about halfway up					
Found	EBOP	10096	bore	Rotorua	04/11/2004	2789602	6344551	GPS	20				60 (?)						
Found	EBOP	10097	bore	Rotorua	04/11/2004	2790867	6343845	GPS	20	305	EST-MAP	20	90	18		100		open hole	open hole
Found	EBOP	10098	bore	Rotorua	04/11/2004	2791134	6344513	GPS	20	305	EST-MAP	20	61	14		100		0	52
Found	EBOP	10099	bore	Rotorua	04/11/2004	2791106	6344507	GPS	20	305	EST-MAP	20	122	15		150		0	52
Found	EBOP	10100	bore	Rotorua	05/11/2004	2793206	6347183	GPS	20	330	EST-MAP	20	70	around 45		100		0	12
Found	EBOP	10101	bore	Rotorua	05/11/2004	2793864	6347509	GPS	20										
Found	EBOP	10102	bore	Rotorua	05/11/2004	2793251	6347197	GPS	20	330	EST-MAP	20		18?					
Found	EBOP	10103	bore	Rotorua	05/11/2004	2794211	6347630	GPS	20										
Found	EBOP	10104	bore	Rotorua	25/11/2004	2788782	6340572	GPS	20										
Found	EBOP	10105	bore	Rotorua	25/11/2004	2789606	6345975	GPS	20	365	EST-MAP	20	65	44		100			
Found	EBOP	10106		Rotorua	25/11/2004	2794679	6347277	GPS	20										
Found	EBOP	10107	bore	Rotorua	25/11/2004	2789487	6346914	GPS	20										surface
Found	EBOP	10108	bore	Rotorua	25/11/2004	2789850	6346088	GPS	20										deepwell
Found	GNS	10109	bore	Rotoiti		2822400	6362400	EST-MAP	100	105	EST-MAP	20	160	42		150	steel	110	160
New	GNS	10110	bore	Rotorua	17/03/2005	2801502.1	6335698.2	RTK-GPS	0.3	335.6	RTK-GPS	0.3	43.5	28.97	PVC casing	100	PVC	37.5	43.5
New	GNS	10111	bore	Rotorua	17/03/2005	2788703.8	6346607.6	RTK-GPS	0.3	416.5	RTK-GPS	0.3	150	59.2	Ground level	80/50	PVC	138	150
Found	GNS	10112	bore	Rotorua	21/03/2005	2799747.3	6336770.0	RTK-GPS	0.3	286.8	RTK-GPS	0.3	12	-0.66	Ground level	150	Steel		
New	GNS	10113	bore	Rotorua	21/03/2005	2791569.6	6342323.5	RTK-GPS	0.3	293.9	RTK-GPS	0.3	68.5	9.77	PVC casing	50	PVC	62.5	68.5
New	GNS	10114	bore	Rotorua	21/03/2005	2791541.2	6342329.3	RTK-GPS	0.3	294.4	RTK-GPS	0.3	26	10.09	PVC casing	50	PVC	20	26
Existing	GNS	10115	bore	Rotorua	17/03/2005	2794701.7	6347715.9	RTK-GPS	0.3	338.4	RTK-GPS	0.3		55.88					
Found	EBOP	10116	bore	Rotorua	31/03/2005	2802506.0	6339362.0	GPS	20	310	EST-MAP	20	29.27	16.18	Steel casing	100			
Found	EBOP	10117	bore	Rotorua	31/03/2005	2802391.0	6339146.0	GPS	20	320	EST-MAP	20	40.88	31.13	Steel casing	100			

Appendix 4.2 Data used for the piezometric map.

GNS Site Ref	Feature type	Easting	Northing	Bore depth (m)	Elevation (m)	Static water level (m)	RLwaterlevel	Elevation method
1	bore	2803500	6331600	29	357	3.66	353.34	DTM
2	bore	2780000	6374200	222.5	120	80.77	39.23	DTM
3	bore	2802300	6374000	542.5	31	13.72	17.28	DTM
4	bore	2788000	6373400	155.4	138	100.6	37.4	DTM
5	bore	2776500	6372100	157	180	62.5	117.5	DTM
6	bore	2786500	6373500	121.9	176	31.1	144.9	DTM
7	bore	2785300	6373300	242.6	160	39	121	DTM
8	bore	2788300	6335200	159	481	135	346	DTM
9	bore	2812700	6367400	192	40	9.2	30.8	DTM
11	bore	2803300	6330700	18.3	358	3.05	354.95	DTM
12	bore	2802400	6370300	110	96	72.2	23.8	DTM
17	bore	2801900	6341600	44.2	296	2	294	DTM
18	bore	2803500	6331500	42.7	366	7.62	358.38	DTM
25	bore	2802500	6345200	20	279	2.7	276.3	DTM
26	bore	2789100	6341500	123.5	328	40	288	DTM
27	bore	2803400	6331500	67.1	396	16	380	DTM
29	bore	2803300	6343800	140	337	76.2	260.8	DTM
32	bore	2801900	6340100	32	293	3.4	289.6	DTM
35	bore	2801700	6320800	74.7	510	41	469	DTM
37	bore	2787900	6342200	73	340	45.7	294.3	DTM
42	bore	2817750	6366990	121.9	40	24	16	DTM
43	bore	2803400	6331600	15.3	365	10.7	354.3	DTM
44	bore	2803500	6331700	17.1	349	3	346	DTM
48	bore	2802600	6344600	51	293	2	291	DTM
50	bore	2801900	6321500	70.1	520	39	481	DTM
52	bore	2802300	6345300	22.6	283	1	282	DTM
53	bore	2802100	6344500	19	301	1.52	299.48	DTM
54	bore	2804100	6348200		289	13	276	DTM
56	bore	2801900	6341700	19.5	296	1	295	DTM
57	bore	2807000	6331400	26	365	7.9	357.1	DTM
58	bore	2794700	6347800	60	341	33.1	307.9	DTM
59	bore	2794500	6346700	70	277	4	273	DTM
61	bore	2803200	6331300	92	417	66	351	DTM
64	bore	2803300	6330800	19.5	352	7.3	344.7	DTM
65	bore	2798900	6337200	19.5	288	-0.1	288.1	DTM
66	bore	2802100	6344900	25	300	1	299	DTM
68	bore	2787400	6322400	67.1	355	12	343	DTM
69	bore	2797200	6347100	64	297	27	270	DTM
70	bore	2788500	6325400	97.6	359	12	347	DTM
71	bore	2776900	6342800	85.5	560	61	499	DTM
72	bore	2807100	6331800	32	389	12	377	DTM
73	bore	2789800	6345600	122	353	122	231	DTM
74	bore	2789300	6341400	18.9	318	3	315	DTM
78	bore	2810000	6371000	335	20	9.1	10.9	DTM
79	bore	2781000	6370100	91.4	214	18.3	195.7	DTM
80	bore	2811100	6367000	196.6	41	67.1	-26.1	DTM
81	bore	2782400	6369400	176.8	247	89.92	157.08	DTM
82	bore	2809200	6367200	100.6	60	41.15	18.85	DTM
83	bore	2803650	6365400	112.8	152	32	120	DTM
84	bore	2812000	6366600	187.5	59	42.1	16.9	DTM
85	bore	2785400	6368000	115.2	301	65.53	235.47	DTM
86	bore	2809800	6369800	135.9	20	22.58	-2.58	DTM
88	bore	2778500	6371100	195.1	188	49.68	138.32	DTM
89	bore	2788300	6368700	178.3	314	53.34	260.66	DTM
90	bore	2788200	6368800	298.7	313	61.87	251.13	DTM
92	bore	2786800	6372400	70.1	207	17.68	189.32	DTM
93	bore	2809500	6368500	48	40	18	22	DTM
94	bore	2819000	6356100	15	160	11	149	DTM
95	bore	2806750	6371550	48	31	21	10	DTM
96	bore	2809000	6367400	98	55	27	28	DTM
97	bore	2806500	6368600	130	65	63	2	DTM
98	bore	2818800	6366700		38	31	7	DTM
99	bore	2810000	6368900	164	33	24	9	DTM
100	bore	2810300	6370600	114	20	14	6	DTM
101	bore	2819490	6371720	9	5	1	4	DTM
102	bore	2810600	6368200	180	42	30	12	DTM
103	bore	2795100	6368600	72	169	24	145	DTM
106	bore	2804040	6348180	40	287	7.3	279.7	DTM
107	bore	2782200	6372500	212	180	125	55	DTM
110	bore	2806700	6369400	124	59	56	3	DTM
111	bore	2810900	6371200	114.3	19	10.4	8.6	DTM
113	bore	2811800	6372000	18.3	14	4.6	9.4	DTM
114	bore	2810800	6371880	12	17	4	13	DTM
115	bore	2782300	6372200	237.7	184	112	72	DTM
117	bore	2813800	6365200	137	60	77.7	-17.7	DTM
118	bore	2810070	6373730	85	9	9	0	DTM
119	bore	2769600	6367600	120	418	23	395	DTM
120	bore	2817300	6365500	128	59	24	35	DTM
122	bore	2802600	6367500	201.2	140	116.4	23.6	DTM
123	bore	2801400	6372200	249.9	83	56.4	26.6	DTM
124	bore	2786500	6347500	134.1	500	73.6	426.4	DTM
125	bore	2788000	6347000	134.1	447	77.1	369.9	DTM

GNS Site Ref	Feature type	Easting	Northing	Bore depth (m)	Elevation (m)	Static water level (m)	RLwaterlevel	Elevation method
126	bore	2780200	6373100	268.2	143	115.8	27.2	DTM
127	bore	2789300	6344700	103.6	341	51.8	289.2	DTM
128	bore	2806400	6369200	117.3	62	22.9	39.1	DTM
129	bore	2802300	6345000	37.5	284	3.6	280.4	DTM
131	bore	2817600	6367100	158.5	39	18	21	DTM
132	bore	2811600	6366700	195.1	57	44.8	12.2	DTM
133	bore	2780100	6341600	79.2	581	39.6	541.4	DTM
134	bore	2782400	6373100	115.8	160	66.1	93.9	DTM
136	bore	2806500	6371600	109.7	39	27.13	11.87	DTM
137	bore	2779510	6341510	91.44	581	46.3	534.7	DTM
138	bore	2782300	6372100	283.5	185	24.97	160.03	DTM
140	bore	2812100	6368500	73.15	30	16.76	13.24	DTM
142	bore	2781400	6369200	121.9	246	59.74	186.26	DTM
143	bore	2772700	6370000	149.4	282	32.61	249.39	DTM
144	bore	2780200	6341800	99.06	587	57.61	529.39	DTM
145	bore	2801200	6336600	61	315	28.04	286.96	DTM
146	bore	2815500	6367000	78	50	26.9	23.1	DTM
147	bore	2806500	6367800	196	80	67.1	12.9	DTM
149	bore	2810200	6370000	124	20	19.2	0.8	DTM
150	bore	2805300	6372700	95	23	60.2	-37.2	DTM
155	bore	2780800	6372600	109	172	60.96	111.04	DTM
159	bore	2803800	6343400	127	337	61.3	275.7	DTM
160	bore	2814100	6367500	82	45	10	35	DTM
161	bore	2813000	6355900	110	196	78.6	117.4	DTM
162	bore	2803300	6343200	100	338	46	292	DTM
164	bore	2784000	6347000	124	533	63	470	DTM
165	bore	2785000	6347500	137	529	78	451	DTM
166	bore	2802800	6339900	74.5	318	48	270	DTM
167	bore	2807200	6328800	32.5	363	8	355	DTM
168	bore	2789400	6336400	39	380	15	365	DTM
169	bore	2802500	6344400	69.8	319	20.4	298.6	DTM
170	bore	2787800	6336700	67	409	47	362	DTM
171	bore	2780700	6333300	242	658	190	468	DTM
172	bore	2787700	6339800	45	309	24	285	DTM
173	bore	2801920	6345170	43.5	285	3	282	DTM
174	bore	2801800	6324800	87	540	32.5	507.5	DTM
175	bore	2795000	6323500	73	418	35.8	382.2	DTM
176	bore	2800500	6347600	130.5	406	81.9	324.1	DTM
177	bore	2803500	6342000	40	298	12	286	DTM
178	bore	2791000	6327000	87	399	31.5	367.5	DTM
179	bore	2788000	6342000	82.5	319	56.5	262.5	DTM
180	bore	2789000	6336700	81.5	440	53.7	386.3	DTM
181	bore	2786200	6326000	51.5	584	12.4	571.6	DTM
182	bore	2786100	6326100	110.5	529	80	449	DTM
183	bore	2795000	6323600	79	406	36.8	369.2	DTM
184	bore	2789000	6341500	149	333	46	287	DTM
185	bore	2803880	6348270	52.45	284	33	251	DTM
186	bore	2787200	6341000	149	377	88	289	DTM
187	bore	2803500	6331400	31	365	6	359	DTM
189	bore	2789500	6340600	19	309	3	306	DTM
190	bore	2807300	6331800	37	302	6	296	DTM
191	bore	2792900	6345800	45	292	16	276	DTM
192	bore	2802500	6345400	19.56	280	1	279	DTM
193	bore	2803300	6331100	32	362	10	352	DTM
194	bore	2804900	6348400	28	302	20.1	281.9	DTM
198	bore	2797600	6346900	47	297	6.7	290.3	DTM
201	bore	2789500	6341000	45	294	20.1	273.9	DTM
202	bore	2797800	6347200	48	315	22.3	292.7	DTM
204	bore	2811800	6368500	46.3	27	24.4	2.6	DTM
205	bore	2795500	6359200	225.5	343	159.1	183.9	DTM
206	bore	2782700	6368500	182.9	278	74.7	203.3	DTM
207	bore	2782800	6367900	134.1	287	73.4	213.6	DTM
208	bore	2788700	6344600	87	353	52	301	DTM
209	bore	2791500	6338100	371.9	567	251.5	315.5	DTM
210	bore	2794500	6374100	76.2	341	17.7	323.3	DTM
211	bore	2790300	6372800	116	305	46	259	DTM
212	bore	2809830	6373380	112.78	12	9.75	2.25	DTM
214	bore	2809360	6367590	143.2	56	44.8	11.2	DTM
216	bore	2805500	6367500	195.1	97	105	-8	DTM
217	bore	2797400	6368100	185.9	200	60	140	DTM
218	bore	2810400	6370500	103.6	19	18.9	1.00E-01	DTM
221	bore	2814780	6374110	74	21	21.2	-0.2	DTM
222	bore	2817200	6365200	122	60	48.8	11.2	DTM
223	bore	2800400	6371500	85.35	99	35.36	63.64	DTM
225	bore	2814600	6370800	144.5	14	2.11	11.89	DTM
226	bore	2808900	6373600	103.6	15	7.9	7.1	DTM
229	bore	2813640	6374200	90	13	2	11	DTM
231	bore	2799800	6369400	61	161	29.3	131.7	DTM
232	bore	2819400	6361400	12	49	3.5	45.5	DTM
233	bore	2804000	6343300	170.1	338	46	292	DTM
234	bore	2792910	6345900	73.1	294	15.3	278.7	DTM
235	bore	2809700	6370100	138.7	19	23	-4	DTM
237	bore	2801400	6368900	225.5	140	110	30	DTM
238	bore	2817200	6353600	111.2	220	35	185	DTM
239	bore	2786700	6372400	160	203	16	187	DTM

GNS Site Ref	Feature type	Easting	Northing	Bore depth (m)	Elevation (m)	Static water level (m)	RLwaterlevel	Elevation method
240	bore	2803900	6343700		336	57	279	DTM
241	bore	2782300	6373500	143.2	152	102	50	DTM
242	bore	2804280	6373420	30.5	19	6	13	DTM
243	bore	2787300	6342400	131.1	380	72	308	DTM
245	bore	2811000	6361200	12.2	73	2	71	DTM
247	bore	2797700	6368100	170.7	197	73.2	123.8	DTM
248	bore	2812200	6372400	97.5	12	2.3	9.7	DTM
249	bore	2809500	6369400	79.2	19	3	16	DTM
250	bore	2809500	6369600	97.5	19	6.1	12.9	DTM
251	bore	2786900	6369100	79.2	293	70.7	222.3	DTM
252	bore	2807200	6371000	115.8	29	20.7	8.3	DTM
253	bore	2806300	6370300	158.5	45	51.8	-6.8	DTM
254	bore	2800200	6367500	213.4	200	132.9	67.1	DTM
255	bore	2800900	6369700	219.5	146	104.9	41.1	DTM
256	bore	2809600	6374200	85.3	9	9.1	-1.00E-01	DTM
257	bore	2810200	6372950	109.7	13	1.1	11.9	DTM
258	bore	2807100	6369900	97.5	45	41.8	3.2	DTM
260	bore	2806480	6369160	117	45	22.9	22.1	DTM
261	bore	2786900	6372500	262.1	206	73.2	132.8	DTM
262	bore	2781100	6367700	121.9	279	59.4	219.6	DTM
263	bore	2781000	6366100	128	323	59.4	263.6	DTM
265	bore	2811000	6371200	152	17	5.4	11.6	DTM
266	bore	2809820	6373380	100.6	12	9.7	2.3	DTM
267	bore	2809800	6361600	254.5	140	20.4	119.6	DTM
268	bore	2814000	6368700	135	32	26.5	5.5	DTM
269	bore	2781200	6369600	120	239	53.34	185.66	DTM
270	bore	2781200	6367800	135	279	64	215	DTM
271	bore	2781100	6373100	400	142	6.57	135.43	DTM
272	bore	2807230	6371250	118.5	21	17.3	3.7	DTM
273	bore	2806000	6370800	148	43	44.2	-1.2	DTM
274	bore	2803600	6343800	159	340	64	276	DTM
275	bore	2790100	6374200	92	279	30	249	DTM
276	bore	2787100	6368600	43	302	35	267	DTM
277	bore	2781500	6368100	130	280	60.96	219.04	DTM
278	bore	2779790	6340730	113	579	55	524	DTM
279	bore	2779710	6340670	96.4	579	47	532	DTM
280	bore	2803800	6343800	137	338	61	277	DTM
281	bore	2802100	6329700	15.08	431	10	421	DTM
282	bore	2847040	6344900	80	13	42	-29	DTM
283	bore	2802200	6329700	14.9	469	10	459	DTM
284	bore	2788000	6347200	124	459	72	387	DTM
285	bore	2805500	6349100	27.5	311	3	308	DTM
286	bore	2802000	6341500	24	295	4.5	290.5	DTM
287	bore	2802000	6341600	30	295	10.6	284.4	DTM
288	bore	2794600	6336600	44	285	1	284	DTM
290	bore	2786500	6343000	124	414	66	348	DTM
291	bore	2787500	6342500	124	372	66	306	DTM
292	bore	2796300	6322750	67	445	40.5	404.5	DTM
293	bore	2809950	6344500	19	296	1	295	DTM
294	bore	2810900	6339100	44	320	16.77	303.23	DTM
295	bore	2802910	6342090	45.5	293	7.2	285.8	DTM
296	bore	2787000	6339000	86	375	10	365	DTM
297	bore	2802500	6342000	80	299	52	247	DTM
298	bore	2803900	6342500	36	327	8	319	DTM
299	bore	2775060	6384640	178	163	6	157	DTM
300	bore	2802000	6323000	19	543	8	535	DTM
301	bore	2786000	6347000	147.5	499	74	425	DTM
302	bore	2798500	6325500	76.25	440	9	431	DTM
303	bore	2801500	6341500	30	299	2	297	DTM
304	bore	2786400	6373500	68.58	176	18.9	157.1	DTM
305	bore	2786380	6373390	123.4	178	15.83	162.17	DTM
306	bore	2781400	6369100	123.4	248	52.43	195.57	DTM
307	bore	2781500	6368300	164.6	272	64.01	207.99	DTM
308	bore	2812000	6367100	204.2	51	17.09	33.91	DTM
309	bore	2787700	6374100	77.72	124	31.39	92.61	DTM
310	bore	2799700	6362200	283.5	264	41.73	222.27	DTM
311	bore	2782100	6373200	335.3	149	97.54	51.46	DTM
312	bore	2784400	6343200	128	483	60	423	DTM
313	bore	2786600	6368800	53	285	27.58	257.42	DTM
314	bore	2787000	6368800	86	300	49	251	DTM
315	bore	2805900	6348700	38	287	23.5	263.5	DTM
316	bore	2805700	6349200	61	301	52	249	DTM
318	bore	2780700	6366200	146	320	63.5	256.5	DTM
319	bore	2770600	6369500	68	380	25	355	DTM
320	bore	2784500	6369600	176	263	82	181	DTM
321	bore	2780900	6366200	148	321	65	256	DTM
322	bore	2786200	6369200	93	283	48	235	DTM
323	bore	2803400	6342800	93	340	49	291	DTM
324	bore	2807100	6370300	102.5	40	47	-7	DTM
325	bore	2781000	6365700	137	340	67	273	DTM
326	bore	2778200	6342300	110	559	65	494	DTM
327	bore	2810860	6369900	23	20	12	8	DTM
328	bore	2811600	6366600	51.5	58	14.3	43.7	DTM
329	bore	2812400	6368300	75	38	19.5	18.5	DTM
330	bore	2809400	6372600	17.37	15	10.5	4.5	DTM

GNS Site Ref	Feature type	Easting	Northing	Bore depth (m)	Elevation (m)	Static water level (m)	RLwaterlevel	Elevation method
331	bore	2811300	6366500	68.5	59	26	33	DTM
332	bore	2803700	6346600	79	289	2.7	286.3	DTM
333	bore	2788600	6341500	110	322	49	273	DTM
334	bore	2788400	6369000	60	300	21	279	DTM
335	bore	2794200	6335800	79	284	2.25	281.75	DTM
336	bore	2787800	6364200	185	399	73	326	DTM
338	bore	2808900	6367500	78	54	39	15	DTM
339	bore	2817900	6364000	18	36	0.5	35.5	DTM
340	bore	2809500	6368100	93	42	33	9	DTM
341	bore	2780800	6373300	65	138	14	124	DTM
342	bore	2809200	6371400	18	19	11	8	DTM
343	bore	2817800	6354800	24	178	9	169	DTM
344	bore	2809100	6371700	17	18	11	7	DTM
345	bore	2782600	6372700	170	162	102	60	DTM
346	bore	2814300	6353900	132	233	102	131	DTM
347	bore	2806000	6370000	115.8	63	20.7	42.3	DTM
349	bore	2816220	6368110	121.9	20	7.62	12.38	DTM
351	bore	2805400	6372700	95	25	60	-35	DTM
352	bore	2804700	6372800	95.7	32	56	-24	DTM
354	bore	2799600	6368800	219.5	178	91.44	86.56	DTM
355	bore	2786600	6373100	51	188	16	172	DTM
356	bore	2809800	6368300	46.5	37	19	18	DTM
357	bore	2818900	6356300	72	141	30	111	DTM
358	bore	2809200	6372500	18	16	10	6	DTM
359	bore	2814200	6353900	45	235	18	217	DTM
360	bore	2782800	6367600	160	299	77	222	DTM
369	bore	2810590	6374180	5.48	7	4.5	2.5	DTM
370	bore	2799600	6362800	262	280	152	128	DTM
371	bore	2820000	6362600	120	31	40	-9	DTM
373	bore	2818200	6373300	48	2	-4	6	DTM
374	bore	2782900	6368000	147	285	75	210	DTM
375	bore	2814200	6367000	69	45	25.5	19.5	DTM
376	bore	2788600	6368700	75	313	21	292	DTM
377	bore	2813500	6367400	69	24	21	3	DTM
378	bore	2818100	6355100	36	162	8	154	DTM
379	bore	2809300	6372500	18	15	10.5	4.5	DTM
380	bore	2787200	6371600	54	236	21	215	DTM
381	bore	2785400	6374000	242	143	78	65	DTM
382	bore	2809290	6372370	18	16	8	8	DTM
383	bore	2805500	6373200	44	19	25	-6	DTM
384	bore	2817700	6355600	90	159	30	129	DTM
385	bore	2812500	6372800	60	11	2	9	DTM
386	bore	2814500	6369300	132	20	0.5	19.5	DTM
387	bore	2813900	6368200	36	41	18.5	22.5	DTM
388	bore	2818800	6356200	81	145	15	130	DTM
389	bore	2809100	6367400	87	56	27	29	DTM
390	bore	2811500	6366300	78	66	27	39	DTM
391	bore	2796600	6359400	258	341	155	186	DTM
392	bore	2808600	6371500	18	19	14	5	DTM
393	bore	2809000	6368100	60	39	33	6	DTM
394	bore	2809500	6367200	96	60	27	33	DTM
395	bore	2802400	6342400	21	300	3.5	296.5	DTM
396	bore	2814120	6370400	25	16	9	7	DTM
397	bore	2816200	6361700	153	119	110	9	DTM
398	bore	2777900	6373800	153	166	102	64	DTM
399	bore	2804300	6319300	120	519	60	459	DTM
400	bore	2809110	6374210	16	11	7	4	DTM
401	bore	2811700	6365500	96	79	37	42	DTM
402	bore	2803500	6342900	90	339	48	291	DTM
403	bore	2809100	6369700	39	20	12	8	DTM
404	bore	2810100	6368500	84	38	20	18	DTM
405	bore	2809500	6371600	22	17	10	7	DTM
406	bore	2790300	6374000	13.5	291	7	284	DTM
407	bore	2809000	6374200	14	11	9.5	1.5	DTM
408	bore	2791220	6346700	124.66	347	54	293	DTM
410	bore	2816800	6345800	60	289	12	277	DTM
411	bore	2778740	6388640	225	0	160	-160	DTM
412	bore	2799700	6371800	138	118	80	38	DTM
415	bore	2817500	6365100	120	59	25	34	DTM
416	bore	2795800	6368500	85	179	45	134	DTM
417	bore	2809100	6374200	16	11	7	4	DTM
418	bore	2817400	6365100	122	51	28	23	DTM
419	bore	2809100	6372300	19	17	9	8	DTM
420	bore	2810856.7	6349217.7	95	294	40	254	RTK-GPS
421	bore	2808900	6369500	35	17	15	2	DTM
422	bore	2817800	6368800	130	19	1.9	17.1	DTM
423	bore	2813600	6365700	74	40	20	20	DTM
424	bore	2807300	6345300	13	319	1	318	DTM
425	bore	2787000	6324300	30	361	6	355	DTM
426	bore	2807300	6345400	16	301	0.5	300.5	DTM
427	bore	2782000	6340800	87.5	555	52	503	DTM
428	bore	2787500	6342000	118	340	58.5	281.5	DTM
429	bore	2789500	6348400	250	441	88	353	DTM
430	bore	2803010	6342070	38	296	2	294	DTM
431	bore	2800700	6331000	32	580	13	567	DTM

GNS Site Ref	Feature type	Easting	Northing	Bore depth (m)	Elevation (m)	Static water level (m)	RLwaterlevel	Elevation method
432	bore	2804200	6346580	56	300	22	278	DTM
433	bore	2807400	6345600	19	294	5.4	288.6	DTM
434	bore	2807300	6345600	38	313	3.6	309.4	DTM
435	bore	2807500	6345700	45	290	3.6	286.4	DTM
436	bore	2802300	6343490	56	303	19	284	DTM
437	bore	2788500	6335000	164	482	140	342	DTM
440	bore	2802530	6343420	26	301	21.52	279.48	DTM
442	bore	2803300	6340140	180	338	21	317	DTM
443	bore	2791010	6343970	85.3	300	18.3	281.7	DTM
445	bore	2788600	6346600	95	418	63.93	354.07	DTM
456	bore	2786200	6347800	180	504	85	419	DTM
458	bore	2786300	6347900	180	503	85	418	DTM
459	bore	2818000	6364500	8.7	79	8.15	70.85	DTM
460	bore	2818000	6368800	133	20	1.9	18.1	DTM
464	bore	2780800	6371700	251.46	185	124.66	60.34	DTM
465	bore	2818600	6368400	130	20	1	19	DTM
468	bore	2810360	6372330	6	16	2.7	13.3	DTM
469	bore	2816400	6369600	10	17	8	9	DTM
470	bore	2817400	6369200	3.66	18	2.44	15.56	DTM
471	bore	2808800	6373000	54.86	17	27.43	-10.43	DTM
473	bore	2779800	6373100	274.3	140	137.2	2.8	DTM
474	bore	2814000	6365500	152.4	58	5.49	52.51	DTM
475	bore	2809700	6370300	144	19	23	-4	DTM
476	bore	2812920	6373490	91	11	3.6	7.4	DTM
481	bore	2810500	6368800	146.3	37	17.7	19.3	DTM
491	bore	2788400	6368800	106.68	312	21.34	290.66	DTM
492	bore	2788400	6368700	106.68	315	21.34	293.66	DTM
498	bore	2779900	6373900	173.7	126	99.1	26.9	DTM
501	bore	2816900	6353400	117.35	220	57	163	DTM
502	bore	2808900	6373800	7	14	4.8	9.2	DTM
509	bore	2786900	6372000	178.31	221	53.34	167.66	DTM
517	bore	2817000	6353200	110.64	220	51.82	168.18	DTM
520	bore	2787200	6371100	55	241	27	214	DTM
521	bore	2780800	6373500	131.06	127	91.44	35.56	DTM
523	bore	2808700	6371400	99.36	20	12.19	7.81	DTM
524	bore	2781600	6369200	152	239	9.14	229.86	DTM
529	bore	2813900	6366700	86.87	60	21.34	38.66	DTM
531	bore	2808100	6368200	70.1	38	21.34	16.66	DTM
532	bore	2791100	6344500	60	300	13	287	DTM
537	bore	2812400	6369200	153.92	19	-1.84	20.84	DTM
538	bore	2811300	6368000	121.92	22	7.01	14.99	DTM
539	bore	2786600	6373300	122	182	25	157	DTM
544	bore	2803900	6369300	91.44	102	54.86	47.14	DTM
546	bore	2809000	6363900	131.06	58	21.34	36.66	DTM
547	bore	2786500	6372100	290	200	68	132	DTM
548	bore	2813800	6374000	60	14	2	12	DTM
549	bore	2785200	6372800	121.9	181	27.4	153.6	DTM
552	bore	2780700	6372500	60.96	174	36.58	137.42	DTM
555	bore	2791100	6389900	96	0	1	-1	DTM
556	bore	2810136.1	6341009.7	53.3	415.9	47.925	367.975	RTK-GPS
559	bore	2785500	6372400	182.9	196	57.9	138.1	DTM
563	bore	2785100	6369800	67.06	237	48.77	188.23	DTM
566	bore	2786500	6372900	85	191	17	174	DTM
569	bore	2787700	6343200	79	360	65	295	DTM
572	bore	2806800	6369600	106.68	59	53.52	5.48	DTM
573	bore	2810700	6371300	18	19	9	10	DTM
574	bore	2811200	6371800	9.1	16	3.7	12.3	DTM
576	bore	2802600	6367100	204.22	156	116.43	39.57	DTM
580	bore	2810500	6371880	6.1	18	4.57	13.43	DTM
583	bore	2808900	6373200	30.5	17	6.1	10.9	DTM
585	bore	2782100	6374000	167.6	131	117.3	13.7	DTM
586	bore	2807100	6372100	45.72	17	30.48	-13.48	DTM
588	bore	2780900	6374100	100.6	121	60	61	DTM
592	bore	2812000	6372300	6.1	13	3	10	DTM
596	bore	2786100	6373900	68.58	160	30.78	129.22	DTM
599	bore	2780700	6366300	137.5	319	57.9	261.1	DTM
600	bore	2817600	6366900	91.4	40	45.7	-5.7	DTM
601	bore	2781300	6369000	131.06	256	54.86	201.14	DTM
602	bore	2798700	6368100	149	227	115.9	111.1	DTM
604	bore	2809900	6372200		17	2.44	14.56	DTM
607	bore	2800700	6367800	201.17	180	123.44	56.56	DTM
608	bore	2782200	6373400	335	155	146	9	DTM
609	bore	2810400	6369900	33.54	20	14.33	5.67	DTM
610	bore	2805100	6366700	106.68	99	89.92	9.08	DTM
613	bore	2818700	6369400	116	20	7	13	DTM
617	bore	2803000	6339600	244	319	27.5	291.5	DTM
623	bore	2809300	6368200	78	42	36	6	DTM
631	bore	2803200	6331200	34.65	396	7.23	388.77	DTM
633	bore	2803200	6331000	25.23	378	10.87	367.13	DTM
635	bore	2802300	6345700	26.89	280	0.73	279.27	DTM
636	bore	2794900	6367600	217	223	45	178	DTM
637	bore	2787300	6367000	102	344	60	284	DTM
638	bore	2793940	6333400	140.5	301	12	289	DTM
640	bore	2787950	6342860	89	347	56	291	DTM
641	bore	2804000	6319500	221	557	24	533	DTM

GNS Site Ref	Feature type	Easting	Northing	Bore depth (m)	Elevation (m)	Static water level (m)	RLwaterlevel	Elevation method
643	bore	2803200	6342300	42	298	0.4	297.6	DTM
644	bore	2786600	6369200	72	269	39	230	DTM
645	bore	2811200	6371700	26	17	4	13	DTM
646	bore	2810300	6373900	30	8	10.5	-2.5	DTM
647	bore	2803900	6342800	144	345	62	283	DTM
648	bore	2803100	6342400	120	299	38	261	DTM
649	bore	2811500	6373000	96	13	1	12	DTM
651	bore	2785300	6373900	41	141	22	119	DTM
652	bore	2812900	6374000	64	11	0.9	10.1	DTM
653	bore	2816600	6367600	58	31	24	7	DTM
654	bore	2809600	6364900	140	38	8	30	DTM
655	bore	2812300	6373400	93	11	2	9	DTM
656	bore	2810600	6371600	125	18	24	-6	DTM
657	bore	2808300	6368300	72	26	21	5	DTM
658	bore	2809100	6373500	27	15	9.5	5.5	DTM
659	bore	2802300	6343100	22	299	11	288	DTM
661	bore	2816100	6368600	21	20	11	9	DTM
662	bore	2787500	6368700	80	299	58	241	DTM
663	bore	2809200	6368000	196	42	32	10	DTM
664	bore	2808100	6364900	67	97	46	51	DTM
665	bore	2790510	6346760	118.5	365	60	305	DTM
666	bore	2809913.9	6349463.2	119	331.7	78	253.7	RTK-GPS
667	bore	2809500	6361500	78	151	52.5	98.5	DTM
668	bore	2803100	6370630	195.18	94	78.1	15.9	DTM
671	bore	2799590	6370270	197.8	139	79.4	59.6	DTM
674	bore	2806050	6367950	219	80	73	7	DTM
681	bore	2811560	6367660	152.4	39	51.8	-12.8	DTM
682	bore	2801400	6372500	128	64	52	12	DTM
684	bore	2806460	6369070	152	39	124	-85	DTM
685	bore	2809800	6370230	144	19	28	-9	DTM
687	bore	2791530	6363470	122	401	44	357	DTM
689	bore	2788200	6344700	102	377	66	311	DTM
690	bore	2859600	6342700	85	15	70	-55	DTM
691	bore	2869700	6326800	16	56	9	47	DTM
692	bore	2810400	6373900	17	8	9.5	-1.5	DTM
693	bore	2816000	6369800	108	17	7.5	9.5	DTM
695	bore	2809400	6361000	180	162	75	87	DTM
696	bore	2871300	6349600	112	20	72	-52	DTM
697	bore	2809600	6371800	18	17	6	11	DTM
698	bore	2820400	6362700	96	86	2	84	DTM
699	bore	2808810	6372820	88	17	11.5	5.5	DTM
702	bore	2802200	6342500	4	298	1.5	296.5	DTM
704	bore	2840700	6350500	84	0	52	-52	DTM
705	bore	2769850	6367100	95	429	20.9	408.1	DTM
706	bore	2810430	6373840	108	8	7.5	0.5	DTM
707	bore	2795190	6335940	74	286	3	283	DTM
708	bore	2807550	6332150	70	318	17	301	DTM
709	bore	2846400	6323700	117	90	55	35	DTM
710	bore	2848500	6346500	15	30	15	15	DTM
715	bore	2785600	6376100	108	84	27	57	DTM
716	bore	2846700	6345900	86	5	18	-13	DTM
718	bore	2820400	6364800	150	87	10	77	DTM
719	bore	2807800	6349100	64	296	38	258	DTM
720	bore	2886100	6339800	83	4	54	-50	DTM
721	bore	2805700	6364700	60	111	13	98	DTM
723	bore	2872500	6341000	30	0	6	-6	DTM
725	bore	2785500	6369500	72	209	30	179	DTM
727	bore	2809400	6370900	28	20	10	10	DTM
728	bore	2785500	6373700	232	160	72	88	DTM
729	bore	2837200	6303300	105.8	170	9.05	160.95	DTM
740	bore	2810400	6370100	141	20	17.1	2.9	DTM
741	bore	2784100	6374400	130	118	70	48	DTM
744	bore	2767500	6397400	42	19	8	11	DTM
745	bore	2857100	6354000	126	0	69	-69	DTM
746	bore	2809500	6344500	43	289	2.5	286.5	DTM
747	bore	2778000	6390800	33	17	2.6	14.4	DTM
748	bore	2813500	6374100	63	12	0.95	11.05	DTM
750	bore	2784777.9	6343300.91		472.934	47.57	425.364	GPS
751	bore	2788826.84	6341450.97		336.606	45.82	290.786	GPS
752	bore	2789325.19	6344682.75		346.812	51.75	295.062	GPS
753	bore	2791338.04	6343089.65		288.38	2.32	286.06	GPS
754	bore	2788781.2	6340580.05		297.394	2.61	294.784	GPS
755	bore	2788902.28	6340489.35		296.065	2.63	293.435	GPS
756	bore	2789659.05	6345860.03		367.617	47.03	320.587	GPS
757	bore	2787677.58	6347433.21		461.652	72.71	388.942	GPS
758	bore	2786236.89	6347882.17		541.981	89.97	452.011	GPS
759	bore	2784409.81	6345314.66		508.711	76.32	432.391	GPS
760	bore	2786527.92	6342901.89		419.256	68.11	351.146	GPS
761	bore	2788183.7	6344643.39		385.751	52.48	333.271	GPS
762	bore	2792912.42	6346014.83		300.801	15.1	285.701	GPS
763	bore	2794701.7	6347715.9		338.4	55.88	282.52	RTK-GPS
778	bore	2762700	6369100	73.2	60	10.9	49.1	DTM
779	bore	2761200	6366800	13.7	70	5.4	64.6	DTM
783	bore	2760600	6364000	93.8	80	24.6	55.4	DTM
786	bore	2762800	6370000	125	100	111	-11	DTM

GNS Site Ref	Feature type	Easting	Northing	Bore depth (m)	Elevation (m)	Static water level (m)	RLwaterlevel	Elevation method
787	bore	2763500	6366700	28.5	69	7	62	DTM
788	bore	2760400	6369400	30	60	6.9	53.1	DTM
789	bore	2760500	6368600	14	63	4.3	58.7	DTM
791	bore	2760500	6365200	8.23	70	5	65	DTM
792	bore	2763400	6366200	9.5	71	4.5	66.5	DTM
794	bore	2762000	6367700	70	63	14.3	48.7	DTM
795	bore	2760700	6368500	10.3	63	3.6	59.4	DTM
796	bore	2760900	6366900	13.4	69	6.4	62.6	DTM
797	bore	2760600	6366300	34.5	70	7.73	62.27	DTM
799	bore	2790000	6316800	55	343	36.6	306.4	DTM
800	bore	2788400	6321100	43	347	9	338	DTM
804	bore	2790700	6326500	60	400	11.5	388.5	DTM
806	bore	2797500	6318400	195	479	30.5	448.5	DTM
807	bore	2793000	6328200	46	369	17	352	DTM
808	bore	2787100	6321600	73	340	1	339	DTM
810	bore	2789500	6317600	55	359	19.2	339.8	DTM
811	bore	2775100	6339600	122	547	85	462	DTM
812	bore	2797000	6323700	65.3	440	39	401	DTM
813	bore	2779200	6339700	75	579	55	524	DTM
814	bore	2785000	6350000	89	539	57	482	DTM
820	bore	2760600	6332800	70	279	43	236	DTM
825	bore	2761000	6358400	85	91	18.75	72.25	DTM
828	bore	2760500	6323400	100	358	47	311	DTM
839	bore	2761800	6338100	128	307	107	200	DTM
847	bore	2760300	6339800	140.2	253	80.4	172.6	DTM
849	bore	2760800	6358000	88	101	16.5	84.5	DTM
851	bore	2764200	6326600	65	352	41	311	DTM
923	bore	2764900	6319900	73.76	399	35.7	363.3	DTM
932	bore	2761300	6323800	90	359	28	331	DTM
937	bore	2763500	6326500	142	362	72	290	DTM
938	bore	2765200	6325900	166	358	73	285	DTM
943	bore	2760900	6358400	54	90	13	77	DTM
950	bore	2760700	6337100	177	260	59.7	200.3	DTM
954	bore	2765500	6342100	98	360	10	350	DTM
956	bore	2767500	6331600	96	424	50	374	DTM
960	bore	2766000	6354000	186	257	72.5	184.5	DTM
961	bore	2764500	6359500	60.9	161	23.7	137.3	DTM
962	bore	2763200	6328100	195	362	97	265	DTM
966	bore	2761400	6352400	112	191	90	101	DTM
972	bore	2762200	6329000	64.3	335	52.8	282.2	DTM
991	bore	2760200	6359400	53	90	22	68	DTM
993	bore	2764800	6320300	102	400	57	343	DTM
999	bore	2762600	6326700	59.5	341	36	305	DTM
1002	bore	2763700	6326700	77	357	39	318	DTM
1003	bore	2765500	6352500	135	301	84	217	DTM
1010	bore	2759900	6321300	100	368	20.71	347.29	DTM
1015	bore	2764200	6351500	111.3	276	89	187	DTM
1017	bore	2762800	6324900	70	354	30	324	DTM
1018	bore	2764300	6346900	180	323	121	202	DTM
1020	bore	2760500	6336500	80	249	42	207	DTM
1042	bore	2760200	6356100	79	90	3	87	DTM
1043	bore	2765200	6350300	60	228	14	214	DTM
1046	bore	2760400	6361900	95	82	13	69	DTM
1047	bore	2762300	6364100	107	89	17	72	DTM
1048	bore	2761800	6329800	80	321	67	254	DTM
1049	bore	2760800	6331900	132	292	60	232	DTM
1050	bore	2760600	6333600	240	277	70.2	206.8	DTM
1052	bore	2761400	6333600	217	279	76	203	DTM
1053	bore	2765900	6324500	201	398	85.7	312.3	DTM
1055	bore	2761700	6355100	36	100	5	95	DTM
1056	bore	2763800	6322600	32	399	1.8	397.2	DTM
1057	bore	2760800	6369900	82.5	61	18	43	DTM
1058	bore	2761500	6321700	53	373	32	341	DTM
1059	bore	2762100	6366000	70	64	29	35	DTM
1060	bore	2761400	6331500	168	343	69	274	DTM
1061	bore	2763300	6328300	156	381	110	271	DTM
1062	bore	2768300	6321700	103	410	30.2	379.8	DTM
1063	bore	2767500	6321500	85	410	31.4	378.6	DTM
1064	bore	2760200	6365900	13.5	69	6.4	62.6	DTM
1065	bore	2760500	6327500	106.5	334	40	294	DTM
1067	bore	2766600	6319600	117	420	57	363	DTM
1074	bore	2792871	6346460		331	16	315	DTM
1075	bore	2791945	6342100		286	2.74	283.26	DTM
1076	bore	2803342	6332487		358	1.15	356.85	DTM
1078	lake	2794206	6345831		281	0	281	LAKE
1079	lake	2793237	6344185		281	0	281	LAKE
1080	lake	2793141	6341716		281	0	281	LAKE
1081	lake	2794448	6339925		281	0	281	LAKE
1082	lake	2795029	6338618		281	0	281	LAKE
1083	lake	2795610	6336778		281	0	281	LAKE
1084	lake	2796723	6336633		281	0	281	LAKE
1085	lake	2796578	6335471		281	0	281	LAKE
1086	lake	2797546	6336778		281	0	281	LAKE
1087	lake	2799676	6338569		281	0	281	LAKE
1088	lake	2800935	6340990		281	0	281	LAKE

GNS Site Ref	Feature type	Easting	Northing	Bore depth (m)	Elevation (m)	Static water level (m)	RLwaterlevel	Elevation method
1089	lake	2801467	6343265		281	0	281	LAKE
1090	lake	2800838	6345202		281	0	281	LAKE
1091	lake	2798805	6345734		281	0	281	LAKE
1092	lake	2796868	6346073		281	0	281	LAKE
1093	lake	2793964	6345492		281	0	281	LAKE
1094	lake	2796723	6341765		281	0	281	LAKE
1095	lake	2797788	6339828		281	0	281	LAKE
1096	lake	2803404	6346315		280	0	280	LAKE
1097	lake	2803743	6345008		280	0	280	LAKE
1098	lake	2802774	6345008		280	0	280	LAKE
1099	lake	2805970	6346509		280	0	280	LAKE
1100	lake	2806938	6348252		280	0	280	LAKE
1101	lake	2807519	6346460		280	0	280	LAKE
1102	lake	2809068	6347768		280	0	280	LAKE
1103	lake	2810956	6347090		280	0	280	LAKE
1104	lake	2810859	6344524		280	0	280	LAKE
1105	lake	2812989	6344669		280	0	280	LAKE
1106	lake	2815023	6344718		280	0	280	LAKE
1107	lake	2815894	6345637		280	0	280	LAKE
1108	lake	2812554	6346509		280	0	280	LAKE
1109	lake	2814151	6345395		280	0	280	LAKE
1110	lake	2814248	6346364		280	0	280	LAKE
1111	lake	2821214	6346286		298	0	298	LAKE
1112	lake	2821146	6347065		298	0	298	LAKE
1113	lake	2820807	6347472		298	0	298	LAKE
1114	lake	2820333	6347811		298	0	298	LAKE
1115	lake	2820502	6348556		298	0	298	LAKE
1116	lake	2820502	6349335		298	0	298	LAKE
1117	lake	2819893	6348691		298	0	298	LAKE
1118	lake	2819351	6348149		298	0	298	LAKE
1119	lake	2819317	6346997		298	0	298	LAKE
1120	lake	2818876	6346252		298	0	298	LAKE
1121	lake	2819960	6346388		298	0	298	LAKE
1122	lake	2820231	6346964		298	0	298	LAKE
1123	lake	2825381	6347133		319	0	319	LAKE
1124	lake	2824534	6347065		319	0	319	LAKE
1125	lake	2824398	6346523		319	0	319	LAKE
1126	lake	2824331	6345812		319	0	319	LAKE
1127	lake	2823822	6345913		319	0	319	LAKE
1128	lake	2823484	6346184		319	0	319	LAKE
1129	lake	2822840	6346388		319	0	319	LAKE
1130	lake	2822874	6346049		319	0	319	LAKE
1131	lake	2823484	6345879		319	0	319	LAKE
1132	lake	2824229	6345473		319	0	319	LAKE
1133	lake	2824737	6344829		319	0	319	LAKE
1134	lake	2824365	6344253		319	0	319	LAKE
1135	lake	2823653	6344016		319	0	319	LAKE
1136	lake	2824060	6343135		319	0	319	LAKE
1137	lake	2824669	6342424		319	0	319	LAKE
1138	lake	2825483	6342424		319	0	319	LAKE
1139	lake	2826194	6342830		319	0	319	LAKE
1140	lake	2825787	6343339		319	0	319	LAKE
1141	lake	2825415	6343779		319	0	319	LAKE
1142	lake	2825483	6344694		319	0	319	LAKE
1143	lake	2825415	6345304		319	0	319	LAKE
1144	lake	2825076	6345947		319	0	319	LAKE
1145	lake	2825754	6345879		319	0	319	LAKE
1146	lake	2825516	6346557		319	0	319	LAKE
1147	lake	2810610	6338799		315	0	315	LAKE
1148	lake	2809831	6338562		315	0	315	LAKE
1149	lake	2809424	6338189		315	0	315	LAKE
1150	lake	2809289	6337410		315	0	315	LAKE
1151	lake	2809018	6336563		315	0	315	LAKE
1152	lake	2808611	6335919		315	0	315	LAKE
1153	lake	2807933	6335919		315	0	315	LAKE
1154	lake	2808171	6335309		315	0	315	LAKE
1155	lake	2808272	6334598		315	0	315	LAKE
1156	lake	2807425	6334361		315	0	315	LAKE
1157	lake	2806714	6334293		315	0	315	LAKE
1158	lake	2808171	6334124		315	0	315	LAKE
1159	lake	2808882	6334462		315	0	315	LAKE
1160	lake	2809864	6334191		315	0	315	LAKE
1161	lake	2809661	6334801		315	0	315	LAKE
1162	lake	2809187	6335513		315	0	315	LAKE
1163	lake	2809763	6336732		315	0	315	LAKE
1164	lake	2810169	6337376		315	0	315	LAKE
1165	lake	2810305	6337918		315	0	315	LAKE
1166	lake	2804647	6332057		355	0	355	LAKE
1167	lake	2804139	6332091		355	0	355	LAKE
1168	lake	2803732	6331888		355	0	355	LAKE
1169	lake	2803665	6330973		355	0	355	LAKE
1170	lake	2804308	6331379		355	0	355	LAKE
1171	lake	2804275	6330702		355	0	355	LAKE
1172	lake	2804918	6330634		355	0	355	LAKE
1173	lake	2805460	6330770		355	0	355	LAKE

GNS Site Ref	Feature type	Easting	Northing	Bore depth (m)	Elevation (m)	Static water level (m)	RLwaterlevel	Elevation method
1174	lake	2805257	6331312		355	0	355	LAKE
1175	lake	2804952	6331786		355	0	355	LAKE
1176	lake	2801835	6329448		420	0	420	LAKE
1177	lake	2801632	6328872		420	0	420	LAKE
1178	lake	2801496	6328364		420	0	420	LAKE
1179	lake	2801937	6328296		420	0	420	LAKE
1180	lake	2802411	6328432		420	0	420	LAKE
1181	lake	2802174	6328872		420	0	420	LAKE
1182	lake	2802039	6329177		420	0	420	LAKE
1183	lake	2802513	6327687		396	0	396	LAKE
1184	lake	2802174	6327483		396	0	396	LAKE
1185	lake	2801903	6327145		396	0	396	LAKE
1186	lake	2801496	6327043		396	0	396	LAKE
1187	lake	2800887	6326704		396	0	396	LAKE
1188	lake	2800311	6326467		396	0	396	LAKE
1189	lake	2799836	6326399		396	0	396	LAKE
1190	lake	2799125	6326433		396	0	396	LAKE
1191	lake	2799227	6326060		396	0	396	LAKE
1192	lake	2799972	6325959		396	0	396	LAKE
1193	lake	2800040	6325383		396	0	396	LAKE
1194	lake	2800446	6325349		396	0	396	LAKE
1195	lake	2800887	6326060		396	0	396	LAKE
1196	lake	2801395	6326467		396	0	396	LAKE
1197	lake	2801835	6326772		396	0	396	LAKE
1198	lake	2802716	6327280		396	0	396	LAKE
1199	lake	2807629	6331650		299	0	299	LAKE
1200	lake	2807730	6331075		299	0	299	LAKE
1201	lake	2807391	6330566		299	0	299	LAKE
1202	lake	2807425	6329787		299	0	299	LAKE
1203	lake	2807730	6329143		299	0	299	LAKE
1204	lake	2807832	6328229		299	0	299	LAKE
1205	lake	2807290	6327788		299	0	299	LAKE
1206	lake	2806815	6327382		299	0	299	LAKE
1207	lake	2806172	6327483		299	0	299	LAKE
1208	lake	2806951	6327009		299	0	299	LAKE
1209	lake	2807730	6326941		299	0	299	LAKE
1210	lake	2808069	6326298		299	0	299	LAKE
1211	lake	2808408	6325688		299	0	299	LAKE
1212	lake	2809051	6325417		299	0	299	LAKE
1213	lake	2809729	6325383		299	0	299	LAKE
1214	lake	2810373	6325756		299	0	299	LAKE
1215	lake	2810813	6326196		299	0	299	LAKE
1216	lake	2811389	6326399		299	0	299	LAKE
1217	lake	2811694	6325552		299	0	299	LAKE
1218	lake	2811626	6324807		299	0	299	LAKE
1219	lake	2811355	6324062		299	0	299	LAKE
1220	lake	2810745	6323791		299	0	299	LAKE
1221	lake	2810644	6323452		299	0	299	LAKE
1222	lake	2811355	6323282		299	0	299	LAKE
1223	lake	2811965	6323418		299	0	299	LAKE
1224	lake	2812270	6323994		299	0	299	LAKE
1225	lake	2812270	6324400		299	0	299	LAKE
1226	lake	2811999	6324875		299	0	299	LAKE
1227	lake	2811863	6325349		299	0	299	LAKE
1228	lake	2811762	6325891		299	0	299	LAKE
1229	lake	2811931	6326501		299	0	299	LAKE
1230	lake	2812372	6327043		299	0	299	LAKE
1231	lake	2812947	6327754		299	0	299	LAKE
1232	lake	2813659	6328195		299	0	299	LAKE
1233	lake	2814336	6328669		299	0	299	LAKE
1234	lake	2815048	6328805		299	0	299	LAKE
1235	lake	2815861	6328872		299	0	299	LAKE
1236	lake	2816335	6329042		299	0	299	LAKE
1237	lake	2815251	6329245		299	0	299	LAKE
1238	lake	2814269	6329550		299	0	299	LAKE
1239	lake	2813252	6329685		299	0	299	LAKE
1240	lake	2812507	6330092		299	0	299	LAKE
1241	lake	2811796	6330566		299	0	299	LAKE
1242	lake	2811491	6331142		299	0	299	LAKE
1243	lake	2810881	6331346		299	0	299	LAKE
1244	lake	2810542	6330770		299	0	299	LAKE
1245	lake	2810068	6330261		299	0	299	LAKE
1246	lake	2809356	6330295		299	0	299	LAKE
1247	lake	2808713	6330431		299	0	299	LAKE
1248	lake	2808340	6330736		299	0	299	LAKE
1249	lake	2808001	6331075		299	0	299	LAKE
1250	lake	2809221	6329245		299	0	299	LAKE
1251	lake	2809221	6327212		299	0	299	LAKE
1252	lake	2810949	6329685		299	0	299	LAKE
1253	lake	2811592	6327416		299	0	299	LAKE
1254	lake	2812744	6328839		299	0	299	LAKE
1255	lake	2816877	6318675		437	0	437	LAKE
1256	lake	2816403	6318336		437	0	437	LAKE
1257	lake	2816098	6317896		437	0	437	LAKE
1258	lake	2816030	6317218		437	0	437	LAKE

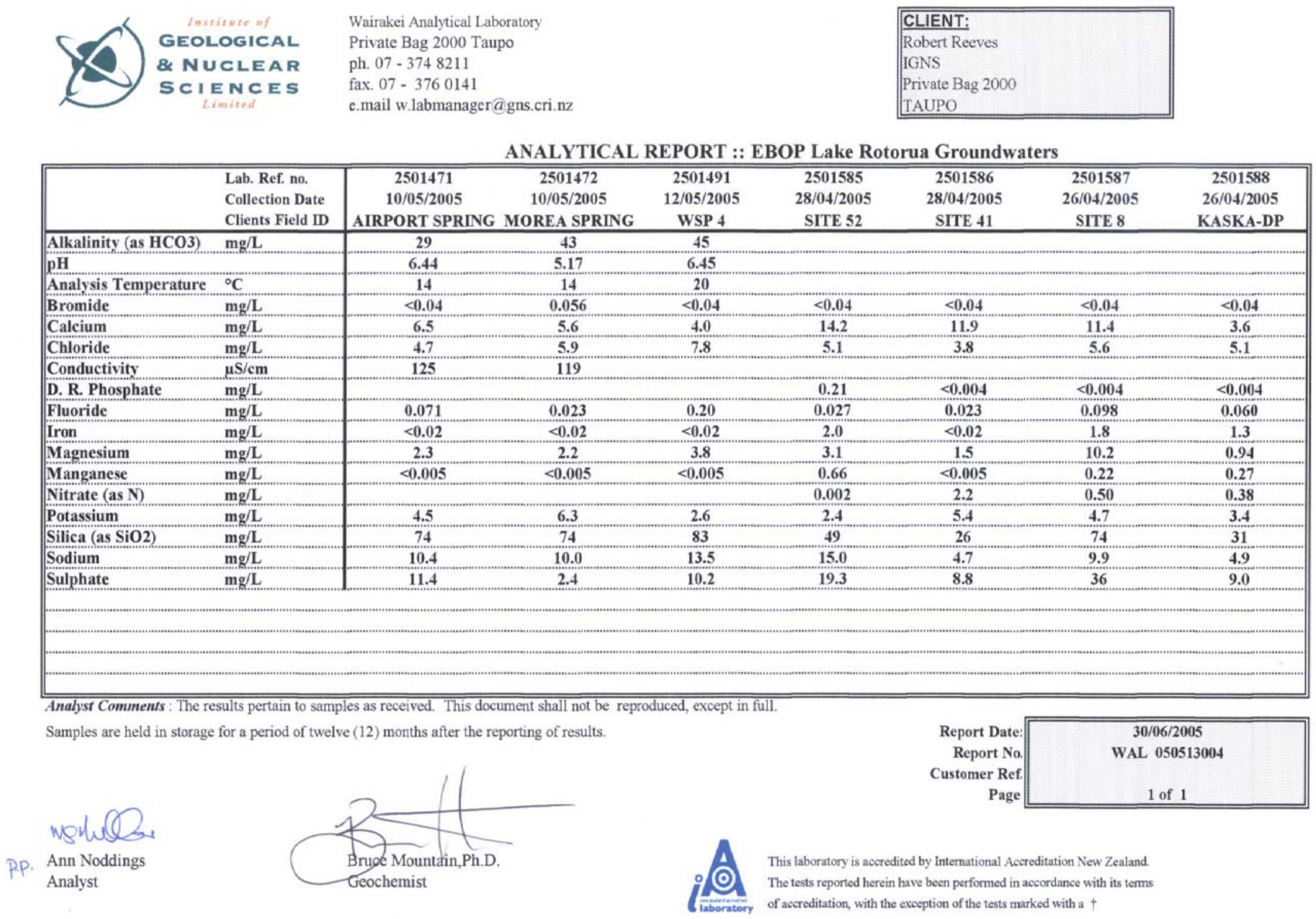
GNS Site Ref	Feature type	Easting	Northing	Bore depth (m)	Elevation (m)	Static water level (m)	RLwaterlevel	Elevation method
1259	lake	2815454	6316981		437	0	437	LAKE
1260	lake	2815488	6316202		437	0	437	LAKE
1261	lake	2816030	6316541		437	0	437	LAKE
1262	lake	2816505	6316981		437	0	437	LAKE
1263	lake	2816810	6316507		437	0	437	LAKE
1264	lake	2816640	6315999		437	0	437	LAKE
1265	lake	2817148	6315931		437	0	437	LAKE
1266	lake	2817623	6316134		437	0	437	LAKE
1267	lake	2816843	6317421		437	0	437	LAKE
1268	lake	2817081	6317930		437	0	437	LAKE
1269	lake	2816335	6317523		437	0	437	LAKE
1270	lake	2815488	6316541		437	0	437	LAKE
1363	lake	2813450	6322220		338	0	338	LAKE
1364	lake	2812650	6321700		338	0	338	LAKE
1365	lake	2811176	6321190		338	0	338	LAKE
1366	lake	2809500	6319990		338	0	338	LAKE
1367	lake	2890150	6319940		338	0	338	LAKE
1368	lake	2812300	6320530		338	0	338	LAKE
1369	lake	2813500	6321500		338	0	338	LAKE
1370	lake	2810800	6320500		338	0	338	LAKE
10002	spring	2805780.3	6343355.1		369.4	0	369.4	RTK-GPS
10004	bore	2803692.6	6342407.6	30	307.2	13	294.2	RTK-GPS
10005	bore	2804295.2	6347870.5	9.233	279.7	2.21	277.49	RTK-GPS
10006	bore	2797522.6	6315089	24.4	373.7	9.14	364.56	RTK-GPS
10015	bore	2800988.3	6323383.2	11.59	433.3	1.97	431.33	RTK-GPS
10025	spring	2811904.3	6353153.2		273.1	0	273.1	RTK-GPS
10027	spring	2807014.2	6349590.7		293.1	0	293.1	RTK-GPS
10028	spring	2803524.1	6349025.1		274.4	0	274.4	RTK-GPS
10031	spring	2814730.6	6350066.4		246.9	0	246.9	RTK-GPS
10037	spring	2805849	6348299		306	0	306	EST-MAP
10038	spring	2806139	6347660		295	0	295	EST-MAP
10040	spring	2806045	6347265		290	0	290	EST-MAP
10041	spring	2793263	6327389		365	0	365	EST-MAP
10042	spring	2793900	6325500		365	0	365	EST-MAP
10046	spring	2806383	6349040		310	0	310	EST-MAP
10047	spring	2806416	6350746		280	0	280	EST-MAP
10048	spring	2807806	6351410		260	0	260	EST-MAP
10049	spring	2810524	6349918		300	0	300	EST-MAP
10050	spring	2811002	6349869		280	0	280	EST-MAP
10051	spring	2810317	6349545		300	0	300	EST-MAP
10052	spring	2810813	6350178		274	0	274	EST-MAP
10053	spring	2804752	6348026		295	0	295	EST-MAP
10058	spring	2803221	6349590		290	0	290	EST-MAP
10059	spring	2806792	6350371		275	0	275	EST-MAP
10060	spring	2806910	6353107		222	0	222	EST-MAP
10061	spring	2816180	6347909		380	0	380	EST-MAP
10062	bore	2788824	6349343	76	470	88	382	EST-MAP
10075	bore	2802260	6335990		350	50	300	EST-MAP
10079	bore	2799425	6333922		335	43	292	EST-MAP
10082	bore	2791324	6327793	72	410	31	379	EST-MAP
10083	bore	2788812	6352560		490	65	425	EST-MAP
10085	bore	2791320	6350735		415	91.4	323.6	EST-MAP
10086	bore	2792136.1	6349133.5		404.6	79	325.6	RTK-GPS
10088	bore	2791754	6350951		395	82.2	312.8	EST-MAP
10089	bore	2794800	6350400	220	435	152	283	EST-MAP
10090	bore	2795528	6351357		355	116	239	EST-MAP
10091	bore	2793200	6350600	153.6	385	89	296	EST-MAP
10092	bore	2795576.4	6349310.4	225	479.3	172.37	306.93	RTK-GPS
10097	bore	2790867	6343845	90	305	18		EST-MAP
10099	bore	2791106	6344507	122	305	15	290	EST-MAP
10100	bore	2793206	6347183	70	330	45	285	EST-MAP
10102	bore	2793251	6347197		330	18	312	EST-MAP
10105	bore	2789606	6345975	65	365	44	321	EST-MAP
10109	bore	2822400	6362400	160	105	42	63	EST-MAP
10110	bore	2801502.1	6335698.2	43.5	335.38	28.97	306.41	RTK-GPS
10111	bore	2788703.8	6346607.6	150	416.5	59.2	357.3	RTK-GPS
10112	bore	2799747.3	6336770	12	285.945	-0.66	286.605	RTK-GPS
10113	bore	2791569.6	6342323.5	68.5	293.792	9.77	284.022	RTK-GPS
10114	bore	2791541.2	6342329.3	26	294.524	10.09	284.434	RTK-GPS
10116	bore	2802506	6339362	29.27	310	16.18	293.82	EST-MAP
10117	bore	2802391	6339146	40.88	320	31.13	288.87	EST-MAP

Key for elevation method:

DTM	Elevation estimated from a digital terrain model.
EST-MAP	Elevation estimated from a 1:50,000 topographic map.
GPS	Elevation measured using a handheld GPS in differential mode.
LAKE	Mean lake level.
RTK-GPS:	Elevation measured using a RTK GPS in differential mode.

Appendix 5.1 Laboratory result reports and methods.

GNS reports:



Institute of GEOLOGICAL & NUCLEAR SCIENCES Limited

Wairakei Analytical Laboratory
Private Bag 2000 Taupo
ph. 07 - 374 8211
fax. 07 - 376 0141
e.mail w.labmanager@gns.cri.nz

CLIENT:
Robert Reeves
IGNS
Private Bag 2000
TAUPO

ANALYTICAL REPORT :: EBOP Lake Rotorua Groundwaters

	Lab. Ref. no.	2501471	2501472	2501491	2501585	2501586	2501587	2501588
	Collection Date	10/05/2005	10/05/2005	12/05/2005	28/04/2005	28/04/2005	26/04/2005	26/04/2005
	Clients Field ID	AIRPORT SPRING	MOREA SPRING	WSP 4	SITE 52	SITE 41	SITE 8	KASKA-DP
Alkalinity (as HCO3)	mg/L	29	43	45				
pH		6.44	5.17	6.45				
Analysis Temperature	°C	14	14	20				
Bromide	mg/L	<0.04	0.056	<0.04	<0.04	<0.04	<0.04	<0.04
Calcium	mg/L	6.5	5.6	4.0	14.2	11.9	11.4	3.6
Chloride	mg/L	4.7	5.9	7.8	5.1	3.8	5.6	5.1
Conductivity	µS/cm	125	119					
D. R. Phosphate	mg/L				0.21	<0.004	<0.004	<0.004
Fluoride	mg/L	0.071	0.023	0.20	0.027	0.023	0.098	0.060
Iron	mg/L	<0.02	<0.02	<0.02	2.0	<0.02	1.8	1.3
Magnesium	mg/L	2.3	2.2	3.8	3.1	1.5	10.2	0.94
Manganese	mg/L	<0.005	<0.005	<0.005	0.66	<0.005	0.22	0.27
Nitrate (as N)	mg/L				0.002	2.2	0.50	0.38
Potassium	mg/L	4.5	6.3	2.6	2.4	5.4	4.7	3.4
Silica (as SiO2)	mg/L	74	74	83	49	26	74	31
Sodium	mg/L	10.4	10.0	13.5	15.0	4.7	9.9	4.9
Sulphate	mg/L	11.4	2.4	10.2	19.3	8.8	36	9.0

Analyst Comments : The results pertain to samples as received. This document shall not be reproduced, except in full.

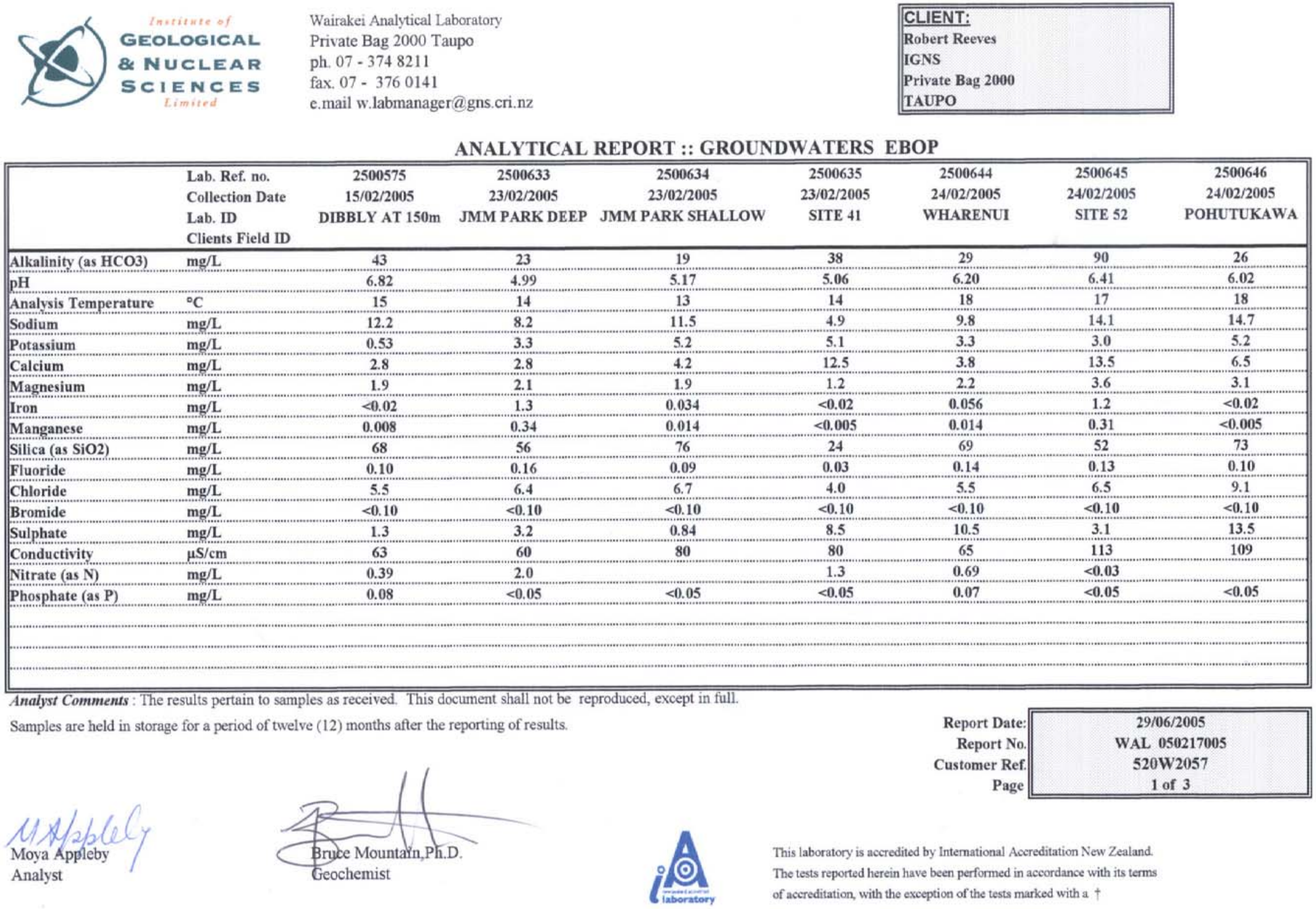
Samples are held in storage for a period of twelve (12) months after the reporting of results.

Report Date:	30/06/2005
Report No.	WAL 050513004
Customer Ref.	
Page	1 of 1

pp. Ann Noddings
Analyst

Bruce Mountain, Ph.D.
Geochemist

This laboratory is accredited by International Accreditation New Zealand.
The tests reported herein have been performed in accordance with its terms of accreditation, with the exception of the tests marked with a †



GEOLOGICAL & NUCLEAR SCIENCES Limited

Wairakei Analytical Laboratory
Private Bag 2000 Taupo
ph. 07 - 374 8211
fax. 07 - 376 0141
e.mail w.labmanager@gns.cri.nz

CLIENT:
Robert Reeves
IGNS
Private Bag 2000
TAUPO

ANALYTICAL REPORT :: GROUNDWATERS EBOP

	Lab. Ref. no.	2500575	2500633	2500634	2500635	2500644	2500645	2500646
	Collection Date	15/02/2005	23/02/2005	23/02/2005	23/02/2005	24/02/2005	24/02/2005	24/02/2005
	Lab. ID	DIBBLY AT 150m	JMM PARK DEEP	JMM PARK SHALLOW	SITE 41	WHARENUI	SITE 52	POHUTUKAWA
	Clients Field ID							
Alkalinity (as HCO3)	mg/L	43	23	19	38	29	90	26
pH		6.82	4.99	5.17	5.06	6.20	6.41	6.02
Analysis Temperature	°C	15	14	13	14	18	17	18
Sodium	mg/L	12.2	8.2	11.5	4.9	9.8	14.1	14.7
Potassium	mg/L	0.53	3.3	5.2	5.1	3.3	3.0	5.2
Calcium	mg/L	2.8	2.8	4.2	12.5	3.8	13.5	6.5
Magnesium	mg/L	1.9	2.1	1.9	1.2	2.2	3.6	3.1
Iron	mg/L	<0.02	1.3	0.034	<0.02	0.056	1.2	<0.02
Manganese	mg/L	0.008	0.34	0.014	<0.005	0.014	0.31	<0.005
Silica (as SiO2)	mg/L	68	56	76	24	69	52	73
Fluoride	mg/L	0.10	0.16	0.09	0.03	0.14	0.13	0.10
Chloride	mg/L	5.5	6.4	6.7	4.0	5.5	6.5	9.1
Bromide	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Sulphate	mg/L	1.3	3.2	0.84	8.5	10.5	3.1	13.5
Conductivity	µS/cm	63	60	80	80	65	113	109
Nitrate (as N)	mg/L	0.39	2.0		1.3	0.69	<0.03	
Phosphate (as P)	mg/L	0.08	<0.05	<0.05	<0.05	0.07	<0.05	<0.05

Analyst Comments : The results pertain to samples as received. This document shall not be reproduced, except in full.

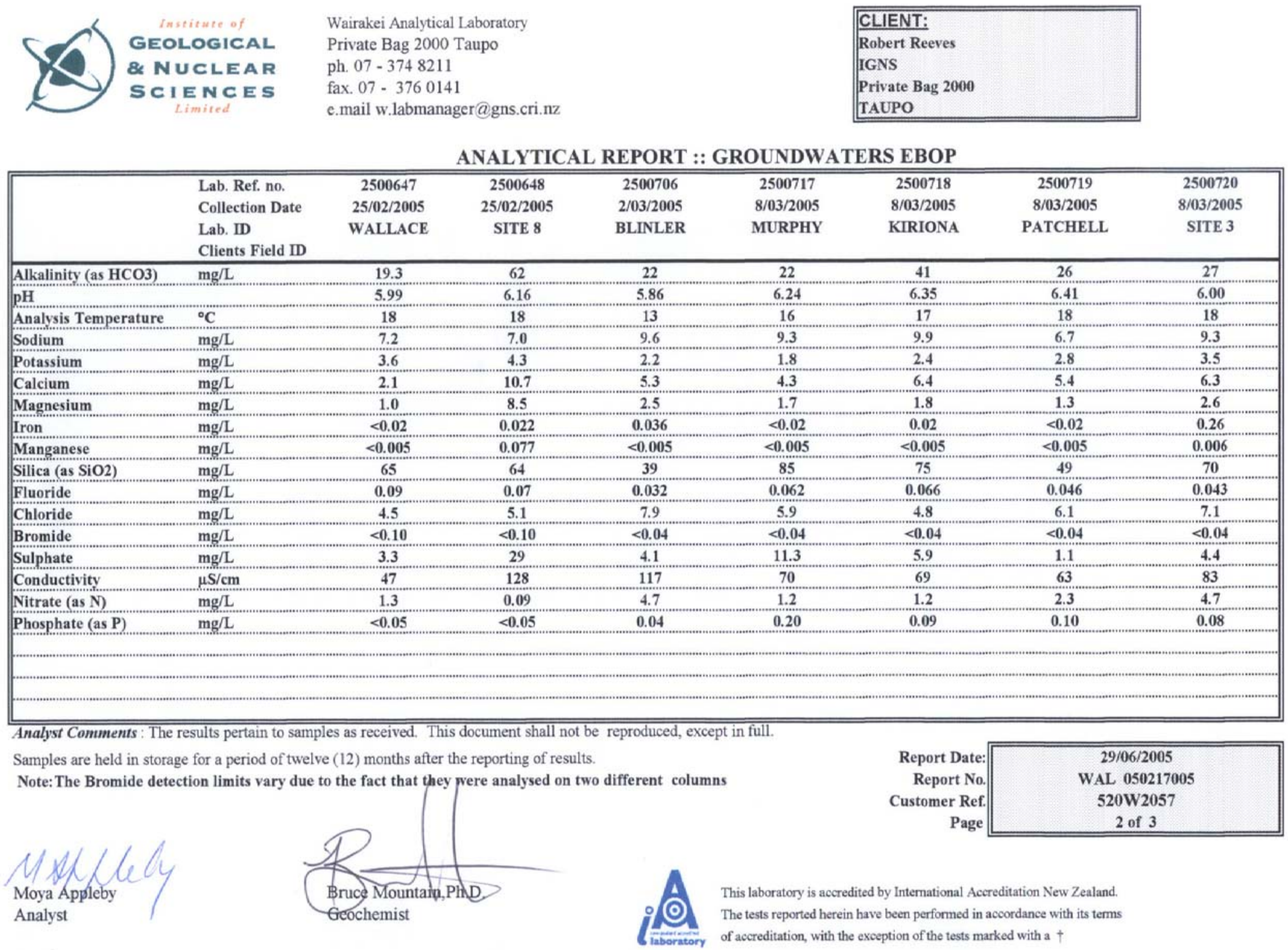
Samples are held in storage for a period of twelve (12) months after the reporting of results.

Report Date:	29/06/2005
Report No.	WAL 050217005
Customer Ref.	520W2057
Page	1 of 3

M Appleby
Moya Appleby
Analyst

Bruce Mountain, Ph.D.
Geochemist

This laboratory is accredited by International Accreditation New Zealand.
The tests reported herein have been performed in accordance with its terms of accreditation, with the exception of the tests marked with a †



Institute of GEOLOGICAL & NUCLEAR SCIENCES Limited

Wairakei Analytical Laboratory
Private Bag 2000 Taupo
ph. 07 - 374 8211
fax. 07 - 376 0141
e.mail w.labmanager@gns.cri.nz

CLIENT:
Robert Reeves
IGNS
Private Bag 2000
TAUPO

ANALYTICAL REPORT :: GROUNDWATERS EBOP

	Lab. Ref. no.	2500647	2500648	2500706	2500717	2500718	2500719	2500720
	Collection Date	25/02/2005	25/02/2005	2/03/2005	8/03/2005	8/03/2005	8/03/2005	8/03/2005
	Lab. ID Clients Field ID	WALLACE	SITE 8	BLINLER	MURPHY	KIRIONA	PATCHELL	SITE 3
Alkalinity (as HCO3)	mg/L	19.3	62	22	22	41	26	27
pH		5.99	6.16	5.86	6.24	6.35	6.41	6.00
Analysis Temperature	°C	18	18	13	16	17	18	18
Sodium	mg/L	7.2	7.0	9.6	9.3	9.9	6.7	9.3
Potassium	mg/L	3.6	4.3	2.2	1.8	2.4	2.8	3.5
Calcium	mg/L	2.1	10.7	5.3	4.3	6.4	5.4	6.3
Magnesium	mg/L	1.0	8.5	2.5	1.7	1.8	1.3	2.6
Iron	mg/L	<0.02	0.022	0.036	<0.02	0.02	<0.02	0.26
Manganese	mg/L	<0.005	0.077	<0.005	<0.005	<0.005	<0.005	0.006
Silica (as SiO2)	mg/L	65	64	39	85	75	49	70
Fluoride	mg/L	0.09	0.07	0.032	0.062	0.066	0.046	0.043
Chloride	mg/L	4.5	5.1	7.9	5.9	4.8	6.1	7.1
Bromide	mg/L	<0.10	<0.10	<0.04	<0.04	<0.04	<0.04	<0.04
Sulphate	mg/L	3.3	29	4.1	11.3	5.9	1.1	4.4
Conductivity	µS/cm	47	128	117	70	69	63	83
Nitrate (as N)	mg/L	1.3	0.09	4.7	1.2	1.2	2.3	4.7
Phosphate (as P)	mg/L	<0.05	<0.05	0.04	0.20	0.09	0.10	0.08

Analyst Comments : The results pertain to samples as received. This document shall not be reproduced, except in full.

Samples are held in storage for a period of twelve (12) months after the reporting of results.

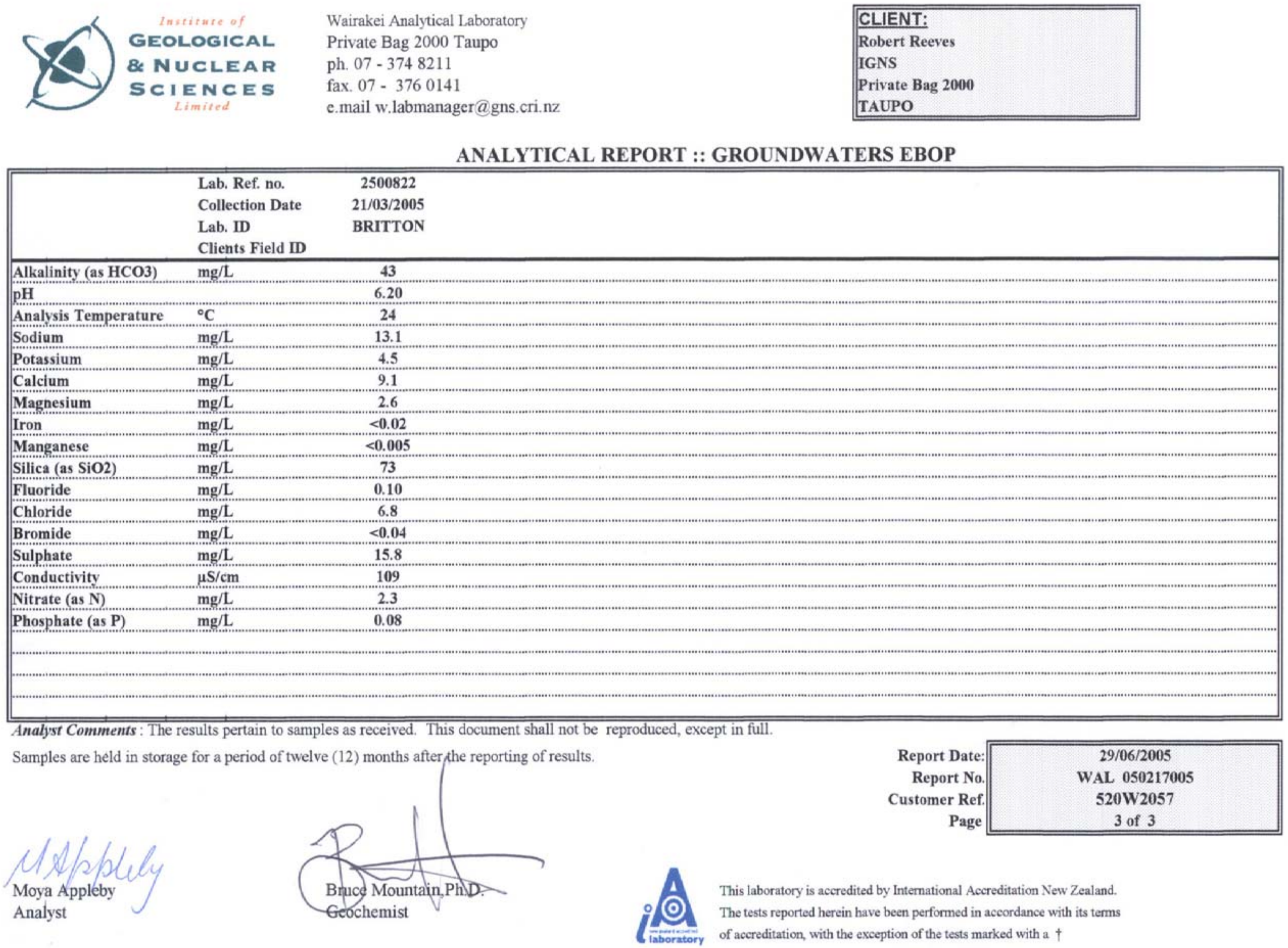
Note: The Bromide detection limits vary due to the fact that they were analysed on two different columns

Report Date:	29/06/2005
Report No.	WAL 050217005
Customer Ref.	520W2057
Page	2 of 3

Moya Appleby
Analyst

Bruce Mountain, PhD
Geochemist

This laboratory is accredited by International Accreditation New Zealand.
The tests reported herein have been performed in accordance with its terms of accreditation, with the exception of the tests marked with a †



GEOLOGICAL & NUCLEAR SCIENCES Limited

Wairakei Analytical Laboratory
Private Bag 2000 Taupo
ph. 07 - 374 8211
fax. 07 - 376 0141
e.mail w.labmanager@gns.cri.nz

CLIENT:
Robert Reeves
IGNS
Private Bag 2000
TAUPO

ANALYTICAL REPORT :: GROUNDWATERS EBOP

	Lab. Ref. no.	**2500822**
	Collection Date	**21/03/2005**
	Lab. ID	**BRITTON**
	Clients Field ID	
Alkalinity (as HCO3)	mg/L	43
pH		6.20
Analysis Temperature	°C	24
Sodium	mg/L	13.1
Potassium	mg/L	4.5
Calcium	mg/L	9.1
Magnesium	mg/L	2.6
Iron	mg/L	<0.02
Manganese	mg/L	<0.005
Silica (as SiO2)	mg/L	73
Fluoride	mg/L	0.10
Chloride	mg/L	6.8
Bromide	mg/L	<0.04
Sulphate	mg/L	15.8
Conductivity	µS/cm	109
Nitrate (as N)	mg/L	2.3
Phosphate (as P)	mg/L	0.08

Analyst Comments : The results pertain to samples as received. This document shall not be reproduced, except in full.

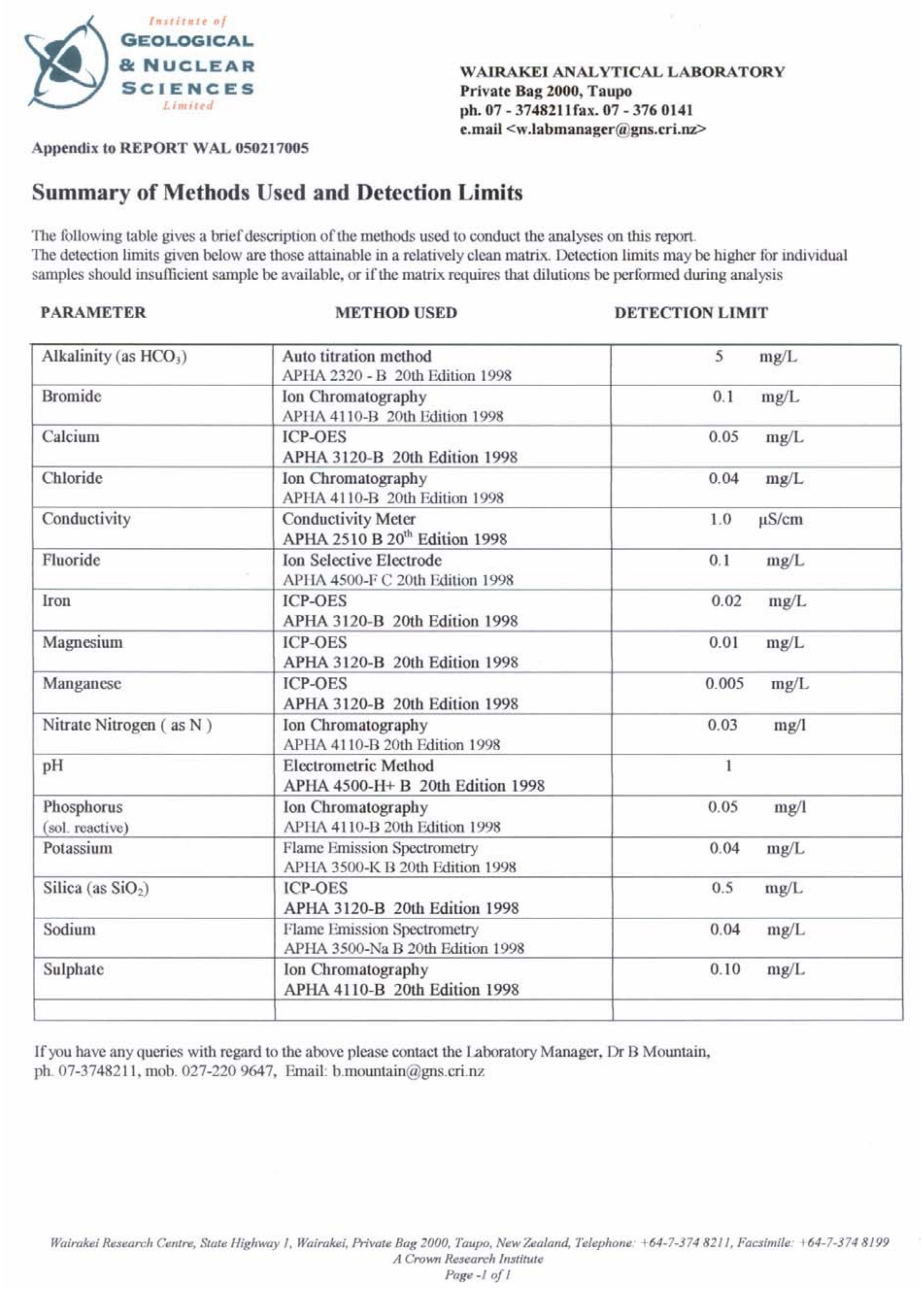
Samples are held in storage for a period of twelve (12) months after the reporting of results.

Report Date:	**29/06/2005**
Report No.	**WAL 050217005**
Customer Ref.	**520W2057**
Page	**3 of 3**

M Appleby
Moya Appleby
Analyst

Bruce Mountain, Ph.D.
Geochemist

This laboratory is accredited by International Accreditation New Zealand.
The tests reported herein have been performed in accordance with its terms of accreditation, with the exception of the tests marked with a †



Institute of
GEOLOGICAL
& NUCLEAR
SCIENCES
Limited

WAIRAKEI ANALYTICAL LABORATORY
Private Bag 2000, Taupo
ph. 07 - 3748211fax. 07 - 376 0141
e.mail <w.labmanager@gns.cri.nz>

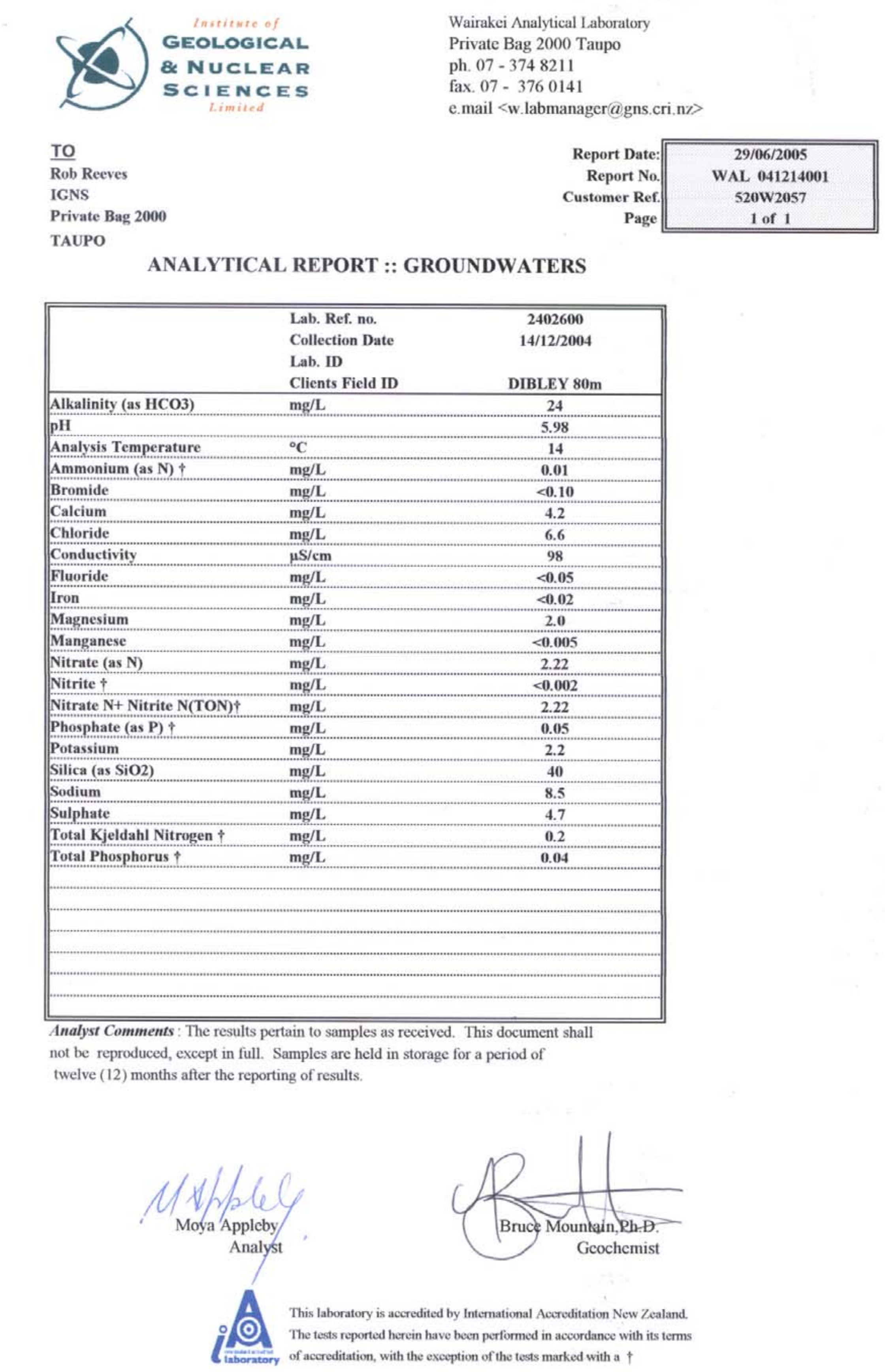
Appendix to REPORT WAL 050217005

Summary of Methods Used and Detection Limits

The following table gives a brief description of the methods used to conduct the analyses on this report.
The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis

PARAMETER	METHOD USED	DETECTION LIMIT
Alkalinity (as HCO_3)	Auto titration method APHA 2320 - B 20th Edition 1998	5 mg/L
Bromide	Ion Chromatography APHA 4110-B 20th Edition 1998	0.1 mg/L
Calcium	ICP-OES APHA 3120-B 20th Edition 1998	0.05 mg/L
Chloride	Ion Chromatography APHA 4110-B 20th Edition 1998	0.04 mg/L
Conductivity	Conductivity Meter APHA 2510 B 20th Edition 1998	1.0 µS/cm
Fluoride	Ion Selective Electrode APHA 4500-F C 20th Edition 1998	0.1 mg/L
Iron	ICP-OES APHA 3120-B 20th Edition 1998	0.02 mg/L
Magnesium	ICP-OES APHA 3120-B 20th Edition 1998	0.01 mg/L
Manganese	ICP-OES APHA 3120-B 20th Edition 1998	0.005 mg/L
Nitrate Nitrogen (as N)	Ion Chromatography APHA 4110-B 20th Edition 1998	0.03 mg/l
pH	Electrometric Method APHA 4500-H+ B 20th Edition 1998	1
Phosphorus (sol. reactive)	Ion Chromatography APHA 4110-B 20th Edition 1998	0.05 mg/l
Potassium	Flame Emission Spectrometry APHA 3500-K B 20th Edition 1998	0.04 mg/L
Silica (as SiO_2)	ICP-OES APHA 3120-B 20th Edition 1998	0.5 mg/L
Sodium	Flame Emission Spectrometry APHA 3500-Na B 20th Edition 1998	0.04 mg/L
Sulphate	Ion Chromatography APHA 4110-B 20th Edition 1998	0.10 mg/L

If you have any queries with regard to the above please contact the Laboratory Manager, Dr B Mountain, ph. 07-3748211, mob. 027-220 9647, Email: b.mountain@gns.cri.nz



Institute of
GEOLOGICAL
& NUCLEAR
SCIENCES
Limited

Wairakei Analytical Laboratory
Private Bag 2000 Taupo
ph. 07 - 374 8211
fax. 07 - 376 0141
e.mail <w.labmanager@gns.cri.nz>

TO
Rob Reeves
IGNS
Private Bag 2000
TAUPO

Report Date:	29/06/2005
Report No.	WAL 041214001
Customer Ref.	520W2057
Page	1 of 1

ANALYTICAL REPORT :: GROUNDWATERS

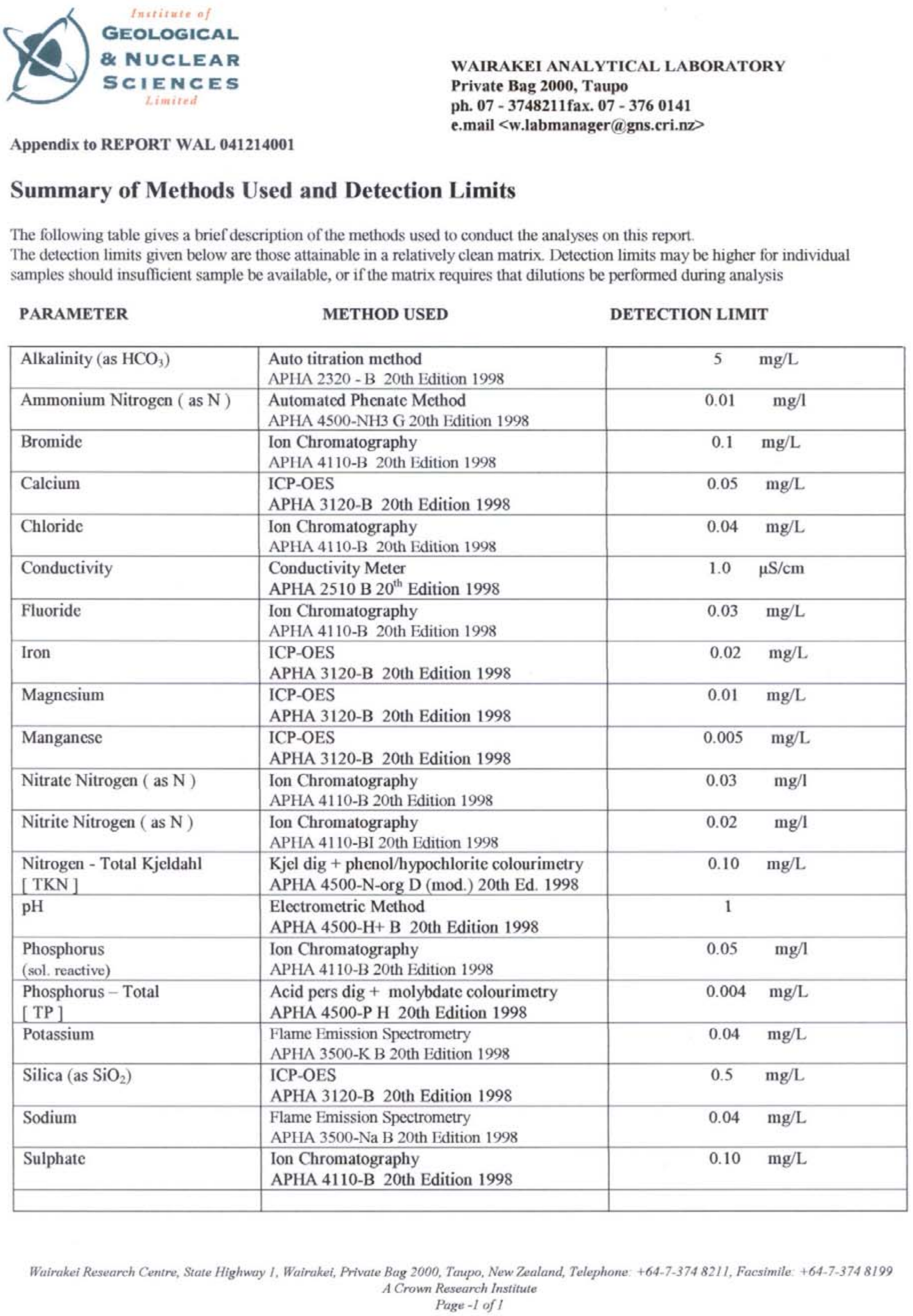
	Lab. Ref. no.	**2402600**
	Collection Date	**14/12/2004**
	Lab. ID	
	Clients Field ID	**DIBLEY 80m**
Alkalinity (as HCO3)	mg/L	24
pH		5.98
Analysis Temperature	°C	14
Ammonium (as N) †	mg/L	0.01
Bromide	mg/L	<0.10
Calcium	mg/L	4.2
Chloride	mg/L	6.6
Conductivity	µS/cm	98
Fluoride	mg/L	<0.05
Iron	mg/L	<0.02
Magnesium	mg/L	2.0
Manganese	mg/L	<0.005
Nitrate (as N)	mg/L	2.22
Nitrite †	mg/L	<0.002
Nitrate N+ Nitrite N(TON)†	mg/L	2.22
Phosphate (as P) †	mg/L	0.05
Potassium	mg/L	2.2
Silica (as SiO2)	mg/L	40
Sodium	mg/L	8.5
Sulphate	mg/L	4.7
Total Kjeldahl Nitrogen †	mg/L	0.2
Total Phosphorus †	mg/L	0.04

Analyst Comments : The results pertain to samples as received. This document shall not be reproduced, except in full. Samples are held in storage for a period of twelve (12) months after the reporting of results.

Moya Appleby
Analyst

Bruce Mountain, Ph.D.
Geochemist

This laboratory is accredited by International Accreditation New Zealand. The tests reported herein have been performed in accordance with its terms of accreditation, with the exception of the tests marked with a †



Institute of
GEOLOGICAL
& NUCLEAR
SCIENCES
Limited

WAIRAKEI ANALYTICAL LABORATORY
Private Bag 2000, Taupo
ph. 07 - 3748211fax. 07 - 376 0141
e.mail <w.labmanager@gns.cri.nz>

Appendix to REPORT WAL 041214001

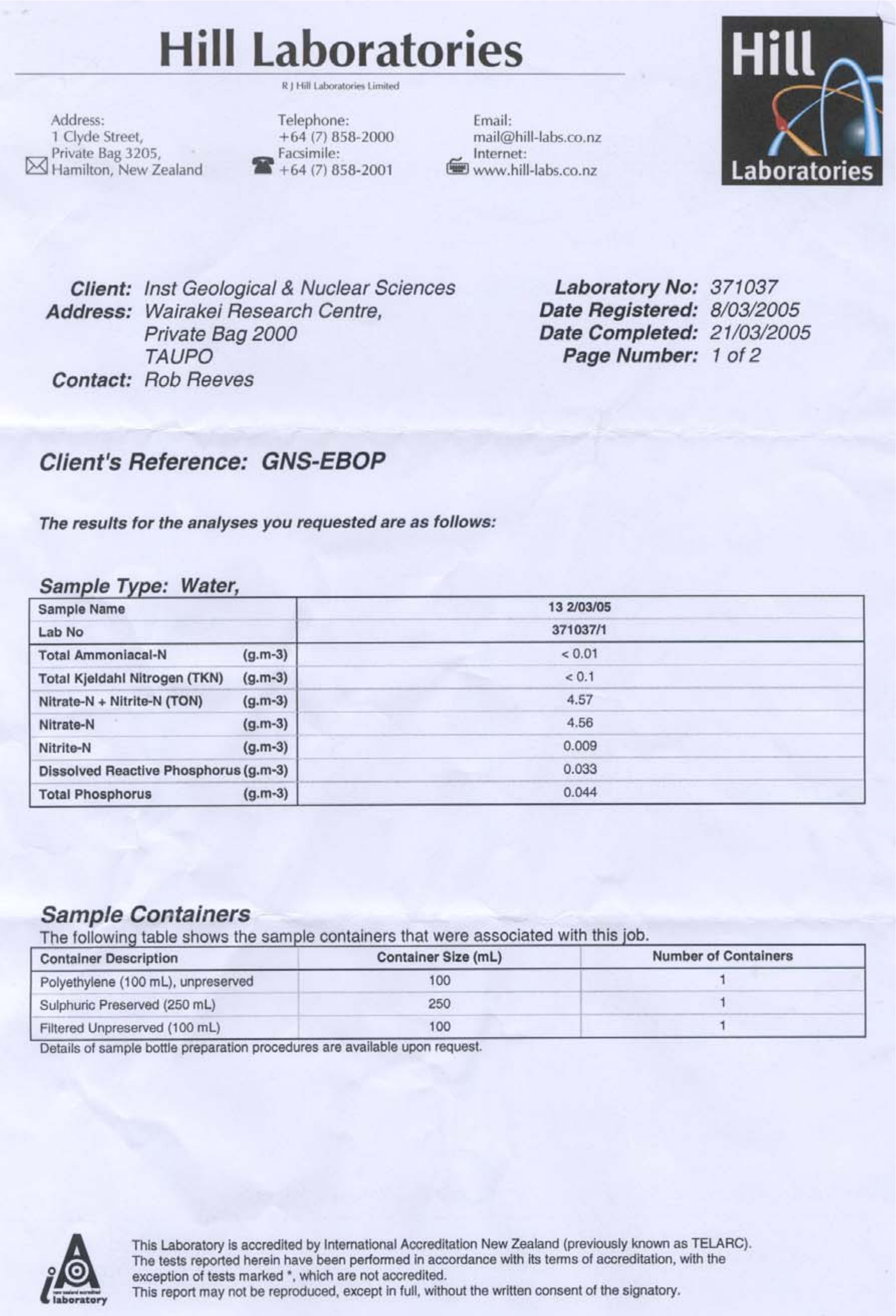
Summary of Methods Used and Detection Limits

The following table gives a brief description of the methods used to conduct the analyses on this report.
The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis

PARAMETER	METHOD USED	DETECTION LIMIT
Alkalinity (as HCO_3)	Auto titration method APHA 2320 - B 20th Edition 1998	5 mg/L
Ammonium Nitrogen (as N)	Automated Phenate Method APHA 4500-NH3 G 20th Edition 1998	0.01 mg/l
Bromide	Ion Chromatography APHA 4110-B 20th Edition 1998	0.1 mg/L
Calcium	ICP-OES APHA 3120-B 20th Edition 1998	0.05 mg/L
Chloride	Ion Chromatography APHA 4110-B 20th Edition 1998	0.04 mg/L
Conductivity	Conductivity Meter APHA 2510 B 20th Edition 1998	1.0 µS/cm
Fluoride	Ion Chromatography APHA 4110-B 20th Edition 1998	0.03 mg/L
Iron	ICP-OES APHA 3120-B 20th Edition 1998	0.02 mg/L
Magnesium	ICP-OES APHA 3120-B 20th Edition 1998	0.01 mg/L
Manganese	ICP-OES APHA 3120-B 20th Edition 1998	0.005 mg/L
Nitrate Nitrogen (as N)	Ion Chromatography APHA 4110-B 20th Edition 1998	0.03 mg/l
Nitrite Nitrogen (as N)	Ion Chromatography APHA 4110-BI 20th Edition 1998	0.02 mg/l
Nitrogen - Total Kjeldahl [TKN]	Kjel dig + phenol/hypochlorite colourimetry APHA 4500-N-org D (mod.) 20th Ed. 1998	0.10 mg/L
pH	Electrometric Method APHA 4500-H+ B 20th Edition 1998	1
Phosphorus (sol. reactive)	Ion Chromatography APHA 4110-B 20th Edition 1998	0.05 mg/l
Phosphorus – Total [TP]	Acid pers dig + molybdate colourimetry APHA 4500-P H 20th Edition 1998	0.004 mg/L
Potassium	Flame Emission Spectrometry APHA 3500-K B 20th Edition 1998	0.04 mg/L
Silica (as SiO_2)	ICP-OES APHA 3120-B 20th Edition 1998	0.5 mg/L
Sodium	Flame Emission Spectrometry APHA 3500-Na B 20th Edition 1998	0.04 mg/L
Sulphate	Ion Chromatography APHA 4110-B 20th Edition 1998	0.10 mg/L

Wairakei Research Centre, State Highway 1, Wairakei, Private Bag 2000, Taupo, New Zealand, Telephone: +64-7-374 8211, Facsimile: +64-7-374 8199
A Crown Research Institute
Page -1 of 1

Hill Laboratory reports:



Hill Laboratories

R J Hill Laboratories Limited

Address:
1 Clyde Street,
Private Bag 3205,
Hamilton, New Zealand

Telephone:
+64 (7) 858-2000
Facsimile:
+64 (7) 858-2001

Email:
mail@hill-labs.co.nz
Internet:
www.hill-labs.co.nz

Client: *Inst Geological & Nuclear Sciences*
Address: *Wairakei Research Centre,*
Private Bag 2000
TAUPO
Contact: *Rob Reeves*

Laboratory No: *371037*
Date Registered: *8/03/2005*
Date Completed: *21/03/2005*
Page Number: *1 of 2*

Client's Reference: GNS-EBOP

The results for the analyses you requested are as follows:

Sample Type: Water,

Sample Name		13 2/03/05
Lab No		371037/1
Total Ammoniacal-N	(g.m-3)	< 0.01
Total Kjeldahl Nitrogen (TKN)	(g.m-3)	< 0.1
Nitrate-N + Nitrite-N (TON)	(g.m-3)	4.57
Nitrate-N	(g.m-3)	4.56
Nitrite-N	(g.m-3)	0.009
Dissolved Reactive Phosphorus	(g.m-3)	0.033
Total Phosphorus	(g.m-3)	0.044

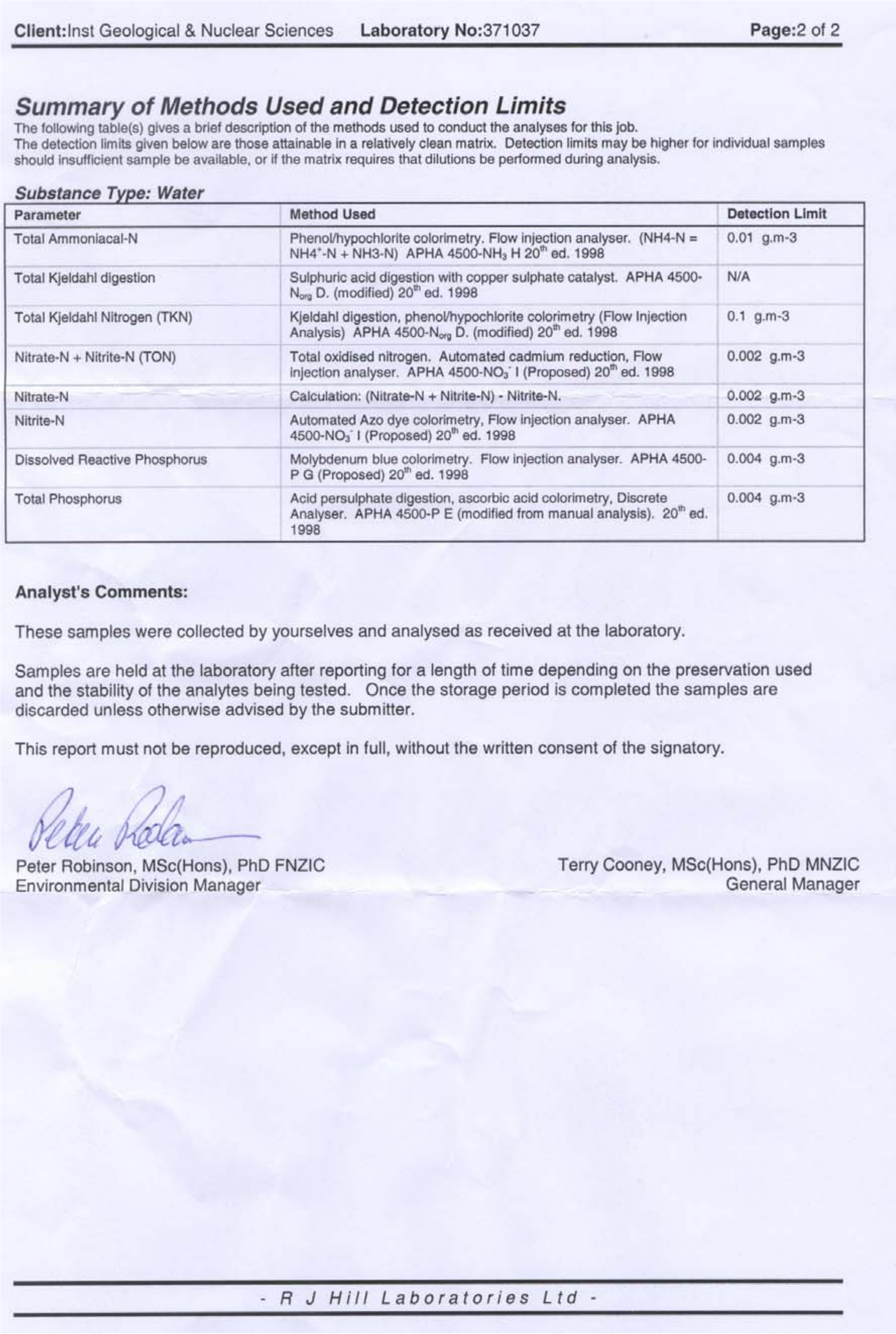
Sample Containers

The following table shows the sample containers that were associated with this job.

Container Description	Container Size (mL)	Number of Containers
Polyethylene (100 mL), unpreserved	100	1
Sulphuric Preserved (250 mL)	250	1
Filtered Unpreserved (100 mL)	100	1

Details of sample bottle preparation procedures are available upon request.

This Laboratory is accredited by International Accreditation New Zealand (previously known as TELARC). The tests reported herein have been performed in accordance with its terms of accreditation, with the exception of tests marked *, which are not accredited.
This report may not be reproduced, except in full, without the written consent of the signatory.



Client: Inst Geological & Nuclear Sciences **Laboratory No:**371037 **Page:**2 of 2

Summary of Methods Used and Detection Limits

The following table(s) gives a brief description of the methods used to conduct the analyses for this job.
The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Substance Type: Water

Parameter	Method Used	Detection Limit
Total Ammoniacal-N	Phenol/hypochlorite colorimetry. Flow injection analyser. (NH4-N = $NH4^+$-N + NH3-N) APHA 4500-NH_3 H 20th ed. 1998	0.01 g.m-3
Total Kjeldahl digestion	Sulphuric acid digestion with copper sulphate catalyst. APHA 4500-N_{org} D. (modified) 20th ed. 1998	N/A
Total Kjeldahl Nitrogen (TKN)	Kjeldahl digestion, phenol/hypochlorite colorimetry (Flow Injection Analysis) APHA 4500-N_{org} D. (modified) 20th ed. 1998	0.1 g.m-3
Nitrate-N + Nitrite-N (TON)	Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO_3^- I (Proposed) 20th ed. 1998	0.002 g.m-3
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - Nitrite-N.	0.002 g.m-3
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (Proposed) 20th ed. 1998	0.002 g.m-3
Dissolved Reactive Phosphorus	Molybdenum blue colorimetry. Flow injection analyser. APHA 4500-P G (Proposed) 20th ed. 1998	0.004 g.m-3
Total Phosphorus	Acid persulphate digestion, ascorbic acid colorimetry, Discrete Analyser. APHA 4500-P E (modified from manual analysis). 20th ed. 1998	0.004 g.m-3

Analyst's Comments:

These samples were collected by yourselves and analysed as received at the laboratory.

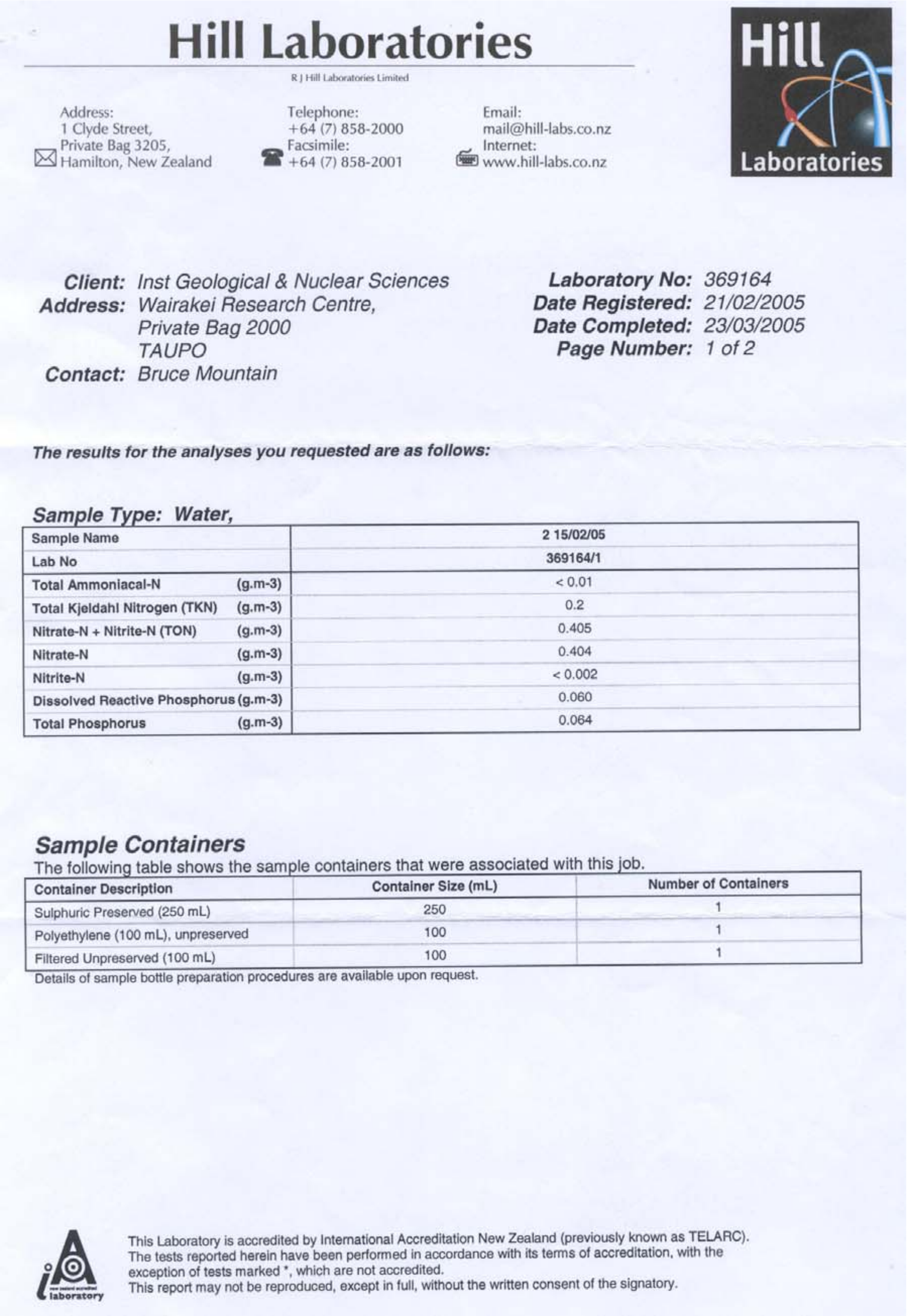
Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the submitter.

This report must not be reproduced, except in full, without the written consent of the signatory.

Peter Robinson, MSc(Hons), PhD FNZIC
Environmental Division Manager

Terry Cooney, MSc(Hons), PhD MNZIC
General Manager

- R J Hill Laboratories Ltd -



Hill Laboratories

R J Hill Laboratories Limited

Address:
1 Clyde Street,
Private Bag 3205,
✉ Hamilton, New Zealand

Telephone:
+64 (7) 858-2000
Facsimile:
☎ +64 (7) 858-2001

Email:
mail@hill-labs.co.nz
Internet:
www.hill-labs.co.nz

Client: *Inst Geological & Nuclear Sciences*
Address: *Wairakei Research Centre,*
Private Bag 2000
TAUPO
Contact: *Bruce Mountain*

Laboratory No: *369164*
Date Registered: *21/02/2005*
Date Completed: *23/03/2005*
Page Number: *1 of 2*

The results for the analyses you requested are as follows:

Sample Type: Water,

Sample Name		**2 15/02/05**
Lab No		**369164/1**
Total Ammoniacal-N	**(g.m-3)**	< 0.01
Total Kjeldahl Nitrogen (TKN)	**(g.m-3)**	0.2
Nitrate-N + Nitrite-N (TON)	**(g.m-3)**	0.405
Nitrate-N	**(g.m-3)**	0.404
Nitrite-N	**(g.m-3)**	< 0.002
Dissolved Reactive Phosphorus	**(g.m-3)**	0.060
Total Phosphorus	**(g.m-3)**	0.064

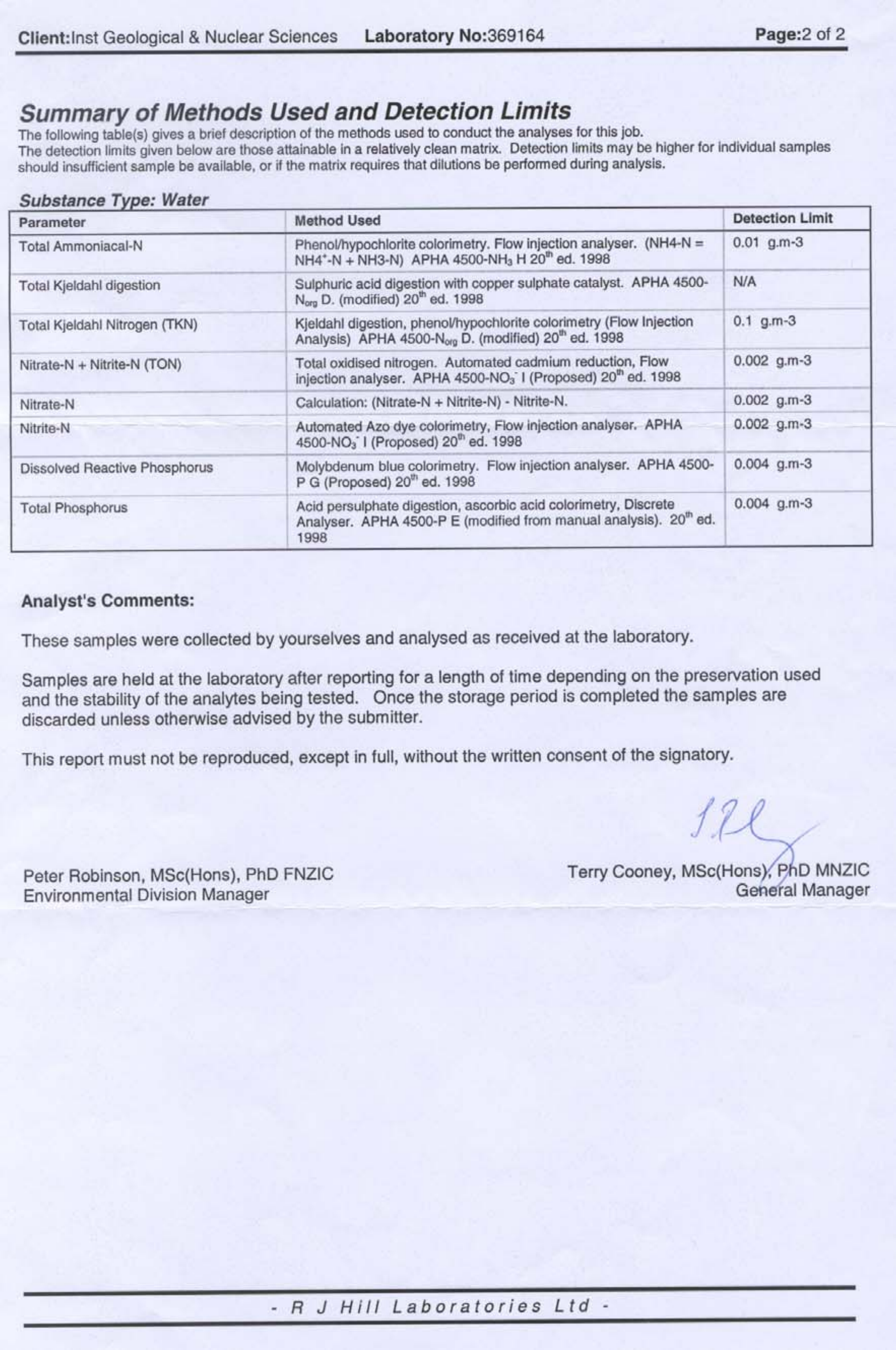
Sample Containers

The following table shows the sample containers that were associated with this job.

Container Description	**Container Size (mL)**	**Number of Containers**
Sulphuric Preserved (250 mL)	250	1
Polyethylene (100 mL), unpreserved	100	1
Filtered Unpreserved (100 mL)	100	1

Details of sample bottle preparation procedures are available upon request.

This Laboratory is accredited by International Accreditation New Zealand (previously known as TELARC). The tests reported herein have been performed in accordance with its terms of accreditation, with the exception of tests marked *, which are not accredited.
This report may not be reproduced, except in full, without the written consent of the signatory.



Client: Inst Geological & Nuclear Sciences **Laboratory No:**369164 **Page:**2 of 2

Summary of Methods Used and Detection Limits

The following table(s) gives a brief description of the methods used to conduct the analyses for this job.
The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Substance Type: Water

Parameter	Method Used	Detection Limit
Total Ammoniacal-N	Phenol/hypochlorite colorimetry. Flow injection analyser. (NH4-N = $NH4^+$-N + NH3-N) APHA 4500-NH_3 H 20th ed. 1998	0.01 g.m-3
Total Kjeldahl digestion	Sulphuric acid digestion with copper sulphate catalyst. APHA 4500-N_{org} D. (modified) 20th ed. 1998	N/A
Total Kjeldahl Nitrogen (TKN)	Kjeldahl digestion, phenol/hypochlorite colorimetry (Flow Injection Analysis) APHA 4500-N_{org} D. (modified) 20th ed. 1998	0.1 g.m-3
Nitrate-N + Nitrite-N (TON)	Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO_3^- I (Proposed) 20th ed. 1998	0.002 g.m-3
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - Nitrite-N.	0.002 g.m-3
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (Proposed) 20th ed. 1998	0.002 g.m-3
Dissolved Reactive Phosphorus	Molybdenum blue colorimetry. Flow injection analyser. APHA 4500-P G (Proposed) 20th ed. 1998	0.004 g.m-3
Total Phosphorus	Acid persulphate digestion, ascorbic acid colorimetry, Discrete Analyser. APHA 4500-P E (modified from manual analysis). 20th ed. 1998	0.004 g.m-3

Analyst's Comments:

These samples were collected by yourselves and analysed as received at the laboratory.

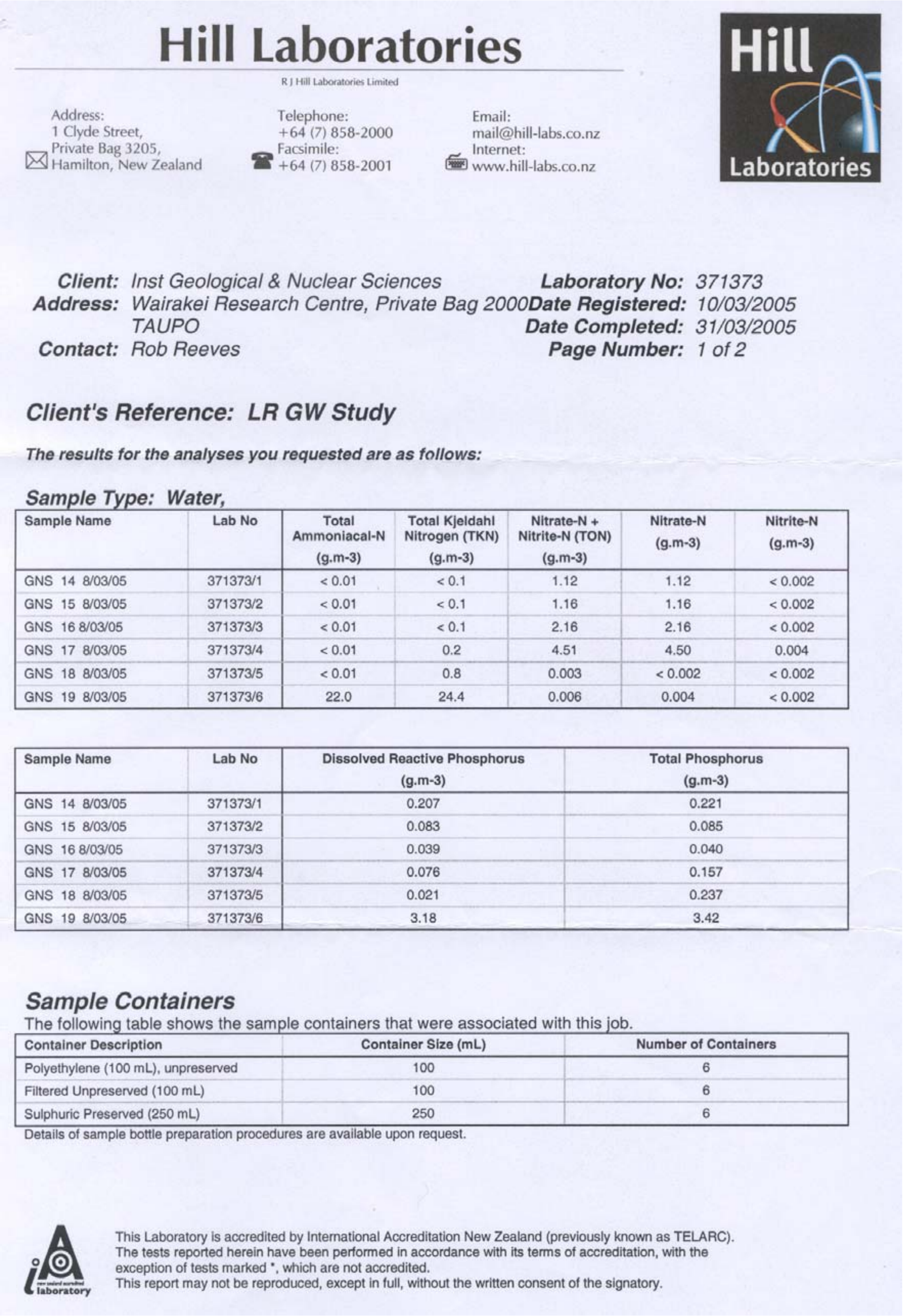
Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the submitter.

This report must not be reproduced, except in full, without the written consent of the signatory.

Peter Robinson, MSc(Hons), PhD FNZIC
Environmental Division Manager

Terry Cooney, MSc(Hons), PhD MNZIC
General Manager

- R J Hill Laboratories Ltd -



Hill Laboratories

R J Hill Laboratories Limited

Address:
1 Clyde Street,
Private Bag 3205,
Hamilton, New Zealand

Telephone:
+64 (7) 858-2000
Facsimile:
+64 (7) 858-2001

Email:
mail@hill-labs.co.nz
Internet:
www.hill-labs.co.nz

Client: *Inst Geological & Nuclear Sciences*
Address: *Wairakei Research Centre, Private Bag 2000*
TAUPO
Contact: *Rob Reeves*

Laboratory No: *371373*
Date Registered: *10/03/2005*
Date Completed: *31/03/2005*
Page Number: *1 of 2*

Client's Reference: LR GW Study

The results for the analyses you requested are as follows:

Sample Type: Water,

Sample Name	Lab No	Total Ammoniacal-N (g.m-3)	Total Kjeldahl Nitrogen (TKN) (g.m-3)	Nitrate-N + Nitrite-N (TON) (g.m-3)	Nitrate-N (g.m-3)	Nitrite-N (g.m-3)
GNS 14 8/03/05	371373/1	< 0.01	< 0.1	1.12	1.12	< 0.002
GNS 15 8/03/05	371373/2	< 0.01	< 0.1	1.16	1.16	< 0.002
GNS 16 8/03/05	371373/3	< 0.01	< 0.1	2.16	2.16	< 0.002
GNS 17 8/03/05	371373/4	< 0.01	0.2	4.51	4.50	0.004
GNS 18 8/03/05	371373/5	< 0.01	0.8	0.003	< 0.002	< 0.002
GNS 19 8/03/05	371373/6	22.0	24.4	0.006	0.004	< 0.002

Sample Name	Lab No	Dissolved Reactive Phosphorus (g.m-3)	Total Phosphorus (g.m-3)
GNS 14 8/03/05	371373/1	0.207	0.221
GNS 15 8/03/05	371373/2	0.083	0.085
GNS 16 8/03/05	371373/3	0.039	0.040
GNS 17 8/03/05	371373/4	0.076	0.157
GNS 18 8/03/05	371373/5	0.021	0.237
GNS 19 8/03/05	371373/6	3.18	3.42

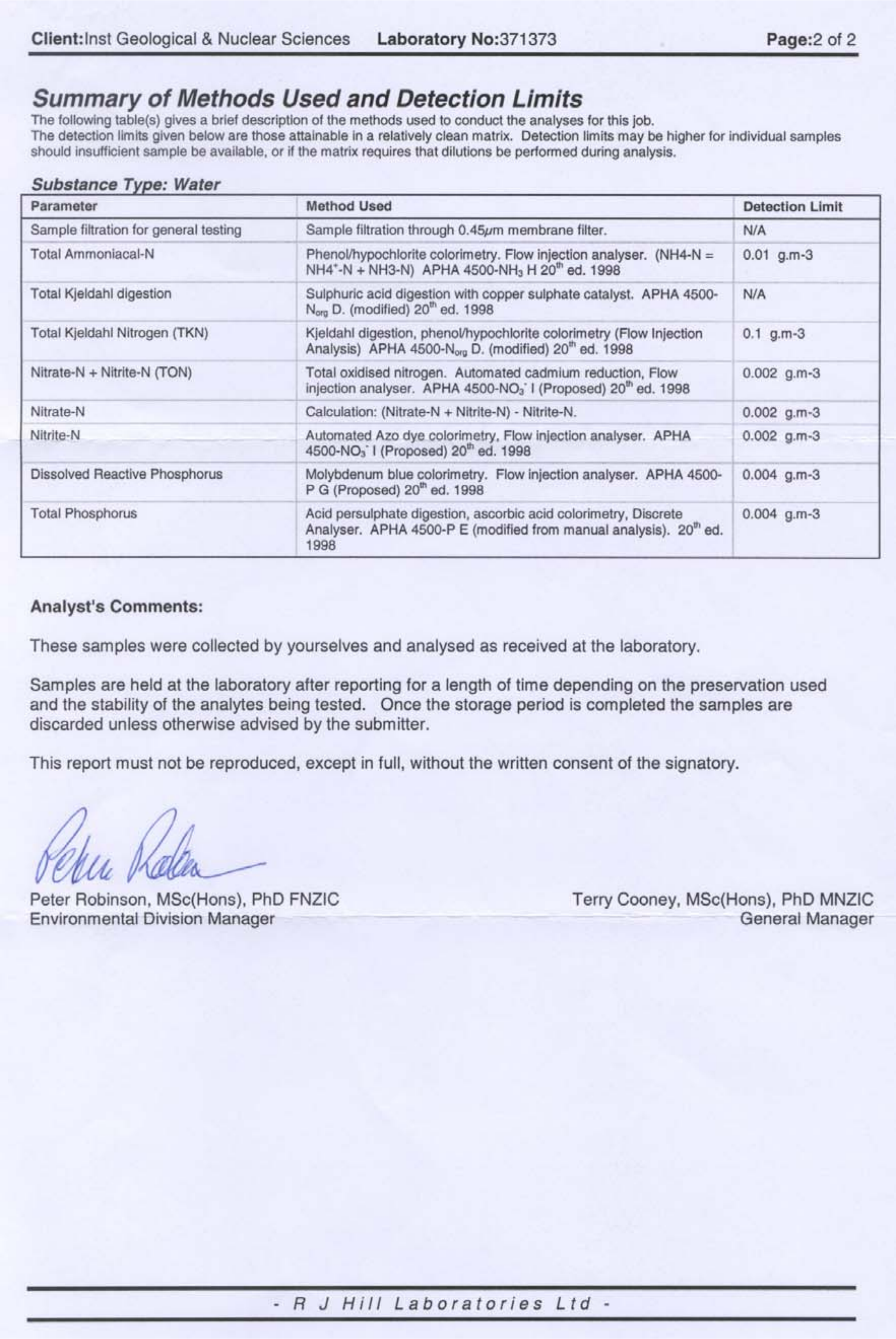
Sample Containers

The following table shows the sample containers that were associated with this job.

Container Description	Container Size (mL)	Number of Containers
Polyethylene (100 mL), unpreserved	100	6
Filtered Unpreserved (100 mL)	100	6
Sulphuric Preserved (250 mL)	250	6

Details of sample bottle preparation procedures are available upon request.

This Laboratory is accredited by International Accreditation New Zealand (previously known as TELARC). The tests reported herein have been performed in accordance with its terms of accreditation, with the exception of tests marked *, which are not accredited.
This report may not be reproduced, except in full, without the written consent of the signatory.



Client: Inst Geological & Nuclear Sciences **Laboratory No:**371373 **Page:**2 of 2

Summary of Methods Used and Detection Limits

The following table(s) gives a brief description of the methods used to conduct the analyses for this job.
The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Substance Type: Water

Parameter	Method Used	Detection Limit
Sample filtration for general testing	Sample filtration through $0.45\mu m$ membrane filter.	N/A
Total Ammoniacal-N	Phenol/hypochlorite colorimetry. Flow injection analyser. (NH4-N = NH4$^+$-N + NH3-N) APHA 4500-NH$_3$ H 20th ed. 1998	0.01 g.m-3
Total Kjeldahl digestion	Sulphuric acid digestion with copper sulphate catalyst. APHA 4500-N$_{org}$ D. (modified) 20th ed. 1998	N/A
Total Kjeldahl Nitrogen (TKN)	Kjeldahl digestion, phenol/hypochlorite colorimetry (Flow Injection Analysis) APHA 4500-N$_{org}$ D. (modified) 20th ed. 1998	0.1 g.m-3
Nitrate-N + Nitrite-N (TON)	Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO$_3^-$ I (Proposed) 20th ed. 1998	0.002 g.m-3
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - Nitrite-N.	0.002 g.m-3
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO$_3^-$ I (Proposed) 20th ed. 1998	0.002 g.m-3
Dissolved Reactive Phosphorus	Molybdenum blue colorimetry. Flow injection analyser. APHA 4500-P G (Proposed) 20th ed. 1998	0.004 g.m-3
Total Phosphorus	Acid persulphate digestion, ascorbic acid colorimetry, Discrete Analyser. APHA 4500-P E (modified from manual analysis). 20th ed. 1998	0.004 g.m-3

Analyst's Comments:

These samples were collected by yourselves and analysed as received at the laboratory.

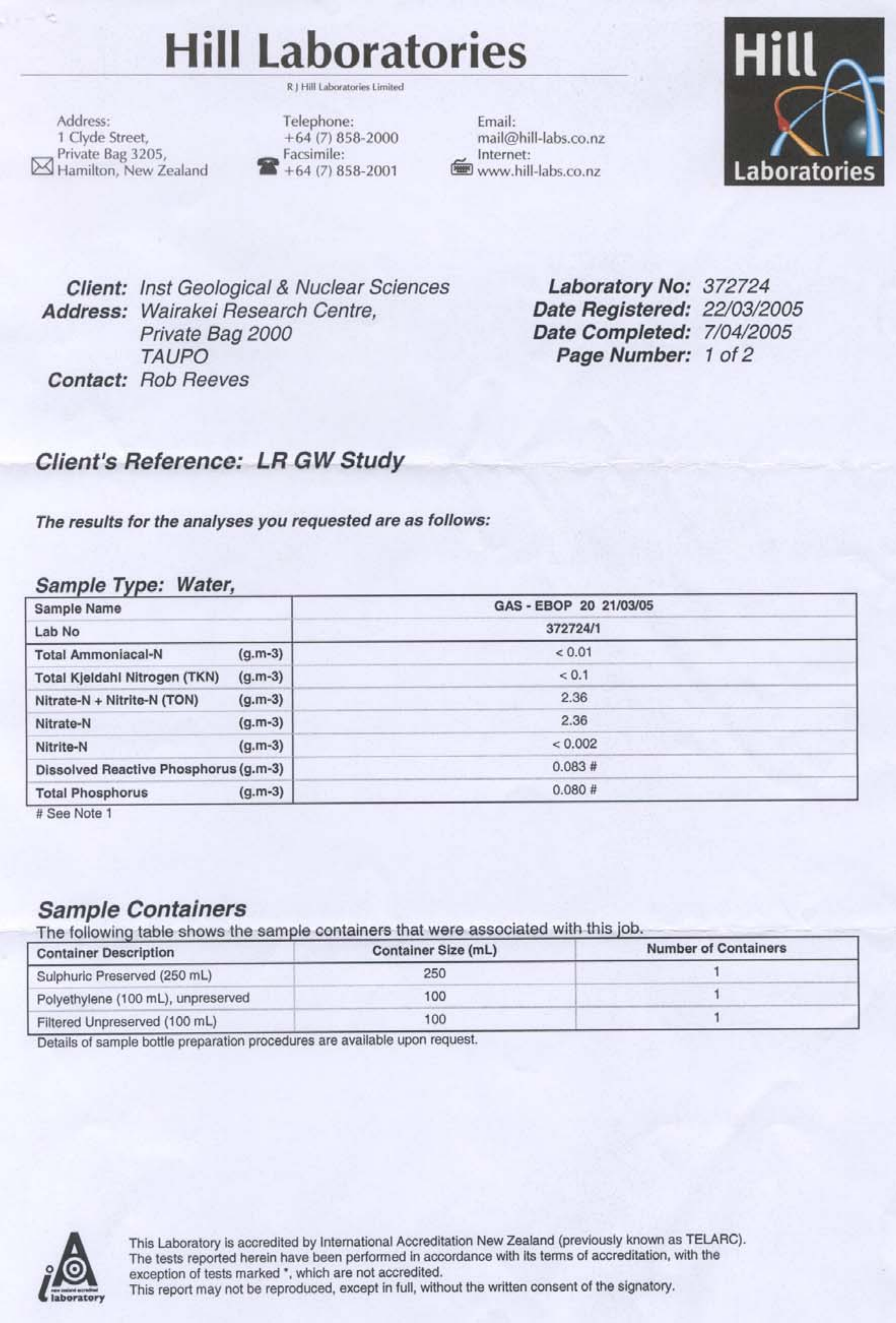
Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the submitter.

This report must not be reproduced, except in full, without the written consent of the signatory.

Peter Robinson, MSc(Hons), PhD FNZIC
Environmental Division Manager

Terry Cooney, MSc(Hons), PhD MNZIC
General Manager

- R J Hill Laboratories Ltd -



Hill Laboratories

R J Hill Laboratories Limited

Address:
1 Clyde Street,
Private Bag 3205,
Hamilton, New Zealand

Telephone:
+64 (7) 858-2000
Facsimile:
+64 (7) 858-2001

Email:
mail@hill-labs.co.nz
Internet:
www.hill-labs.co.nz

Client: *Inst Geological & Nuclear Sciences*
Address: *Wairakei Research Centre,*
Private Bag 2000
TAUPO
Contact: *Rob Reeves*

Laboratory No: *372724*
Date Registered: *22/03/2005*
Date Completed: *7/04/2005*
Page Number: *1 of 2*

Client's Reference: LR GW Study

The results for the analyses you requested are as follows:

Sample Type: Water,

Sample Name		GAS - EBOP 20 21/03/05
Lab No		372724/1
Total Ammoniacal-N	(g.m-3)	< 0.01
Total Kjeldahl Nitrogen (TKN)	(g.m-3)	< 0.1
Nitrate-N + Nitrite-N (TON)	(g.m-3)	2.36
Nitrate-N	(g.m-3)	2.36
Nitrite-N	(g.m-3)	< 0.002
Dissolved Reactive Phosphorus	(g.m-3)	0.083 #
Total Phosphorus	(g.m-3)	0.080 #

See Note 1

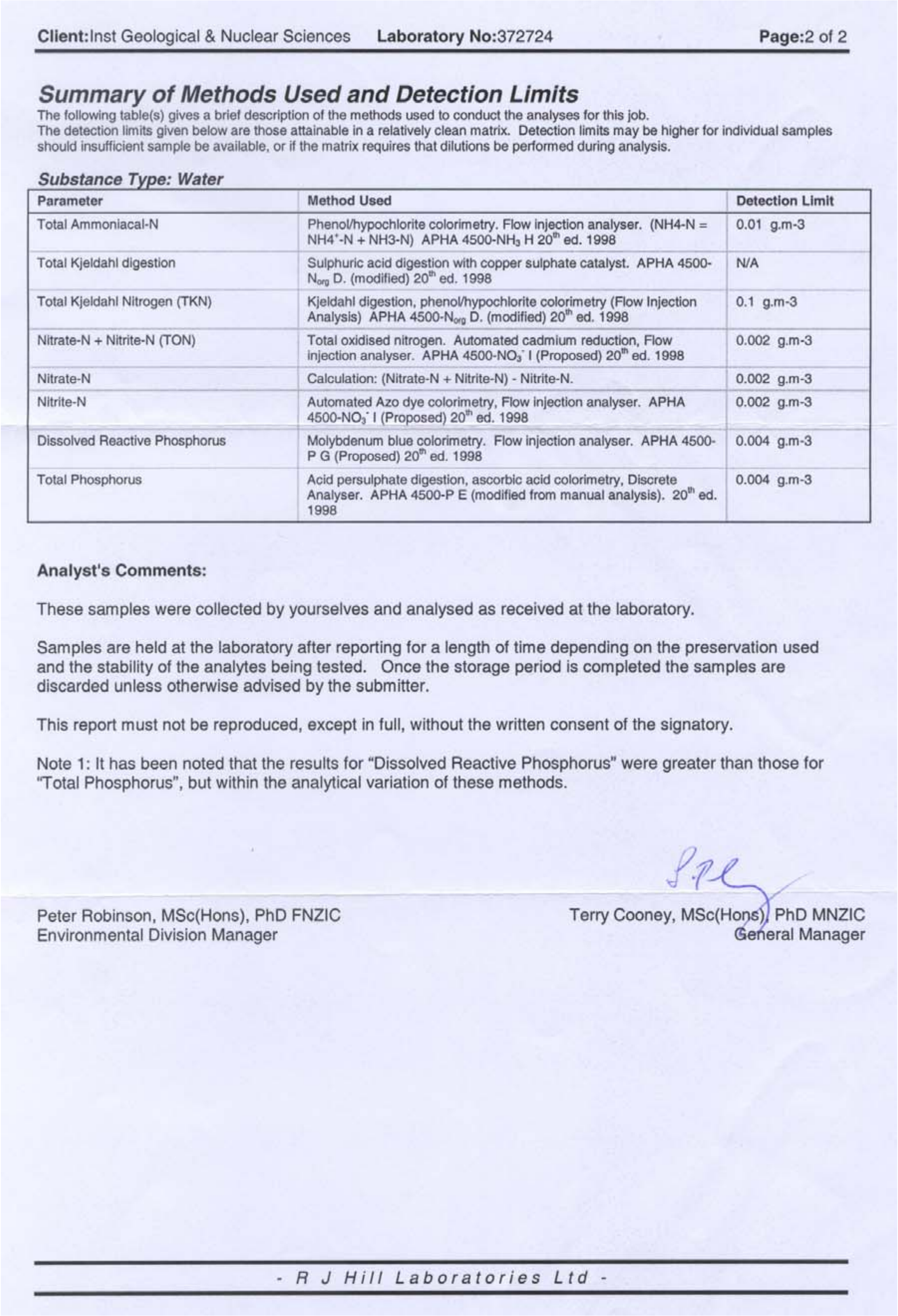
Sample Containers

The following table shows the sample containers that were associated with this job.

Container Description	Container Size (mL)	Number of Containers
Sulphuric Preserved (250 mL)	250	1
Polyethylene (100 mL), unpreserved	100	1
Filtered Unpreserved (100 mL)	100	1

Details of sample bottle preparation procedures are available upon request.

This Laboratory is accredited by International Accreditation New Zealand (previously known as TELARC). The tests reported herein have been performed in accordance with its terms of accreditation, with the exception of tests marked *, which are not accredited.
This report may not be reproduced, except in full, without the written consent of the signatory.



Client: Inst Geological & Nuclear Sciences **Laboratory No:**372724 **Page:**2 of 2

Summary of Methods Used and Detection Limits

The following table(s) gives a brief description of the methods used to conduct the analyses for this job.
The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Substance Type: Water

Parameter	Method Used	Detection Limit
Total Ammoniacal-N	Phenol/hypochlorite colorimetry. Flow injection analyser. (NH4-N = NH4$^+$-N + NH3-N) APHA 4500-NH_3 H 20th ed. 1998	0.01 g.m-3
Total Kjeldahl digestion	Sulphuric acid digestion with copper sulphate catalyst. APHA 4500-N_{org} D. (modified) 20th ed. 1998	N/A
Total Kjeldahl Nitrogen (TKN)	Kjeldahl digestion, phenol/hypochlorite colorimetry (Flow Injection Analysis) APHA 4500-N_{org} D. (modified) 20th ed. 1998	0.1 g.m-3
Nitrate-N + Nitrite-N (TON)	Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO_3^- I (Proposed) 20th ed. 1998	0.002 g.m-3
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - Nitrite-N.	0.002 g.m-3
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (Proposed) 20th ed. 1998	0.002 g.m-3
Dissolved Reactive Phosphorus	Molybdenum blue colorimetry. Flow injection analyser. APHA 4500-P G (Proposed) 20th ed. 1998	0.004 g.m-3
Total Phosphorus	Acid persulphate digestion, ascorbic acid colorimetry, Discrete Analyser. APHA 4500-P E (modified from manual analysis). 20th ed. 1998	0.004 g.m-3

Analyst's Comments:

These samples were collected by yourselves and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the submitter.

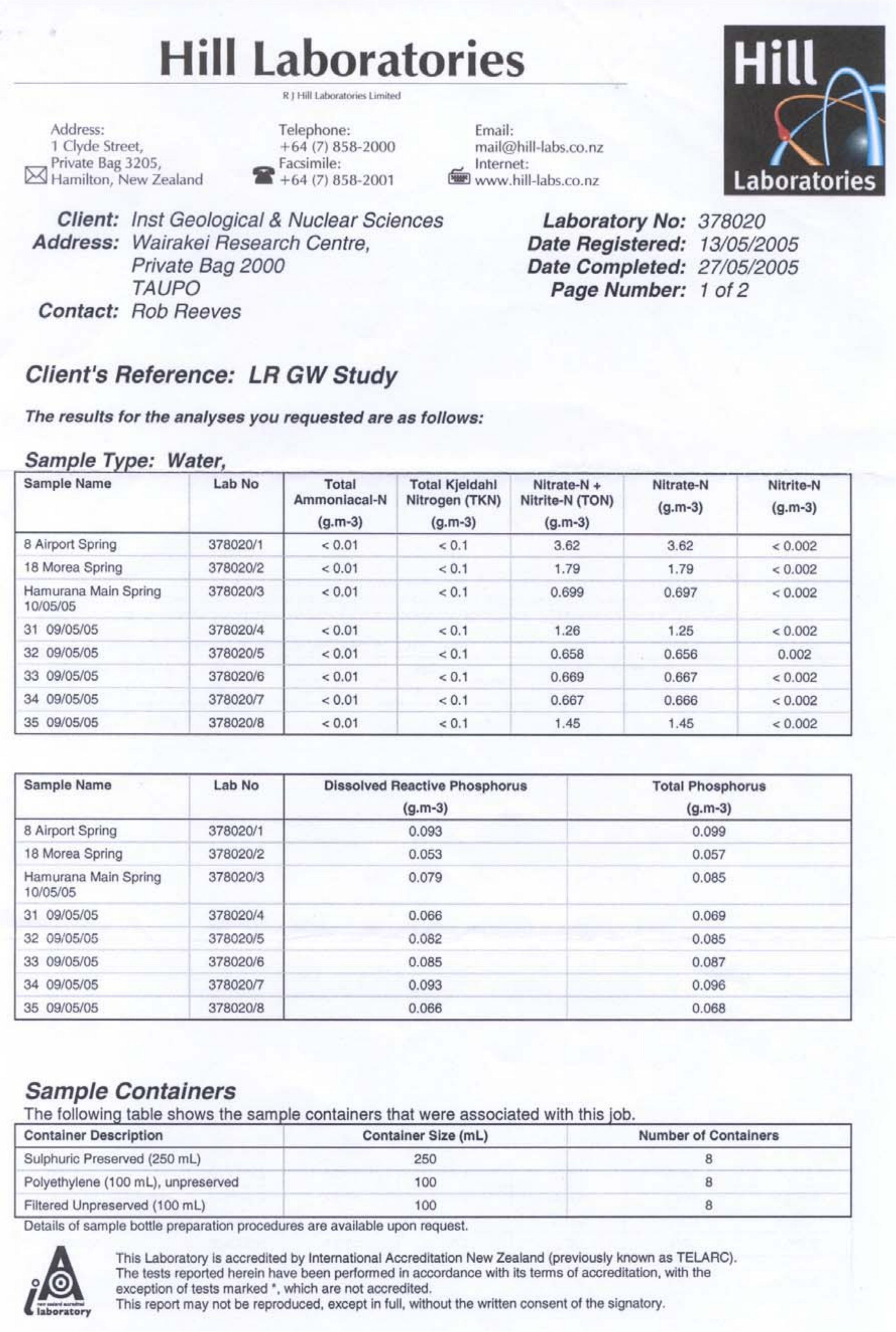
This report must not be reproduced, except in full, without the written consent of the signatory.

Note 1: It has been noted that the results for "Dissolved Reactive Phosphorus" were greater than those for "Total Phosphorus", but within the analytical variation of these methods.

Peter Robinson, MSc(Hons), PhD FNZIC
Environmental Division Manager

Terry Cooney, MSc(Hons), PhD MNZIC
General Manager

- R J Hill Laboratories Ltd -



Hill Laboratories

R J Hill Laboratories Limited

Address:
1 Clyde Street,
Private Bag 3205,
Hamilton, New Zealand

Telephone:
+64 (7) 858-2000
Facsimile:
+64 (7) 858-2001

Email:
mail@hill-labs.co.nz
Internet:
www.hill-labs.co.nz

Client: Inst Geological & Nuclear Sciences
Address: Wairakei Research Centre,
Private Bag 2000
TAUPO
Contact: Rob Reeves

Laboratory No: 378020
Date Registered: 13/05/2005
Date Completed: 27/05/2005
Page Number: 1 of 2

Client's Reference: LR GW Study

The results for the analyses you requested are as follows:

Sample Type: Water,

Sample Name	Lab No	Total Ammoniacal-N (g.m-3)	Total Kjeldahl Nitrogen (TKN) (g.m-3)	Nitrate-N + Nitrite-N (TON) (g.m-3)	Nitrate-N (g.m-3)	Nitrite-N (g.m-3)
8 Airport Spring	378020/1	< 0.01	< 0.1	3.62	3.62	< 0.002
18 Morea Spring	378020/2	< 0.01	< 0.1	1.79	1.79	< 0.002
Hamurana Main Spring 10/05/05	378020/3	< 0.01	< 0.1	0.699	0.697	< 0.002
31 09/05/05	378020/4	< 0.01	< 0.1	1.26	1.25	< 0.002
32 09/05/05	378020/5	< 0.01	< 0.1	0.658	0.656	0.002
33 09/05/05	378020/6	< 0.01	< 0.1	0.669	0.667	< 0.002
34 09/05/05	378020/7	< 0.01	< 0.1	0.667	0.666	< 0.002
35 09/05/05	378020/8	< 0.01	< 0.1	1.45	1.45	< 0.002

Sample Name	Lab No	Dissolved Reactive Phosphorus (g.m-3)	Total Phosphorus (g.m-3)
8 Airport Spring	378020/1	0.093	0.099
18 Morea Spring	378020/2	0.053	0.057
Hamurana Main Spring 10/05/05	378020/3	0.079	0.085
31 09/05/05	378020/4	0.066	0.069
32 09/05/05	378020/5	0.082	0.085
33 09/05/05	378020/6	0.085	0.087
34 09/05/05	378020/7	0.093	0.096
35 09/05/05	378020/8	0.066	0.068

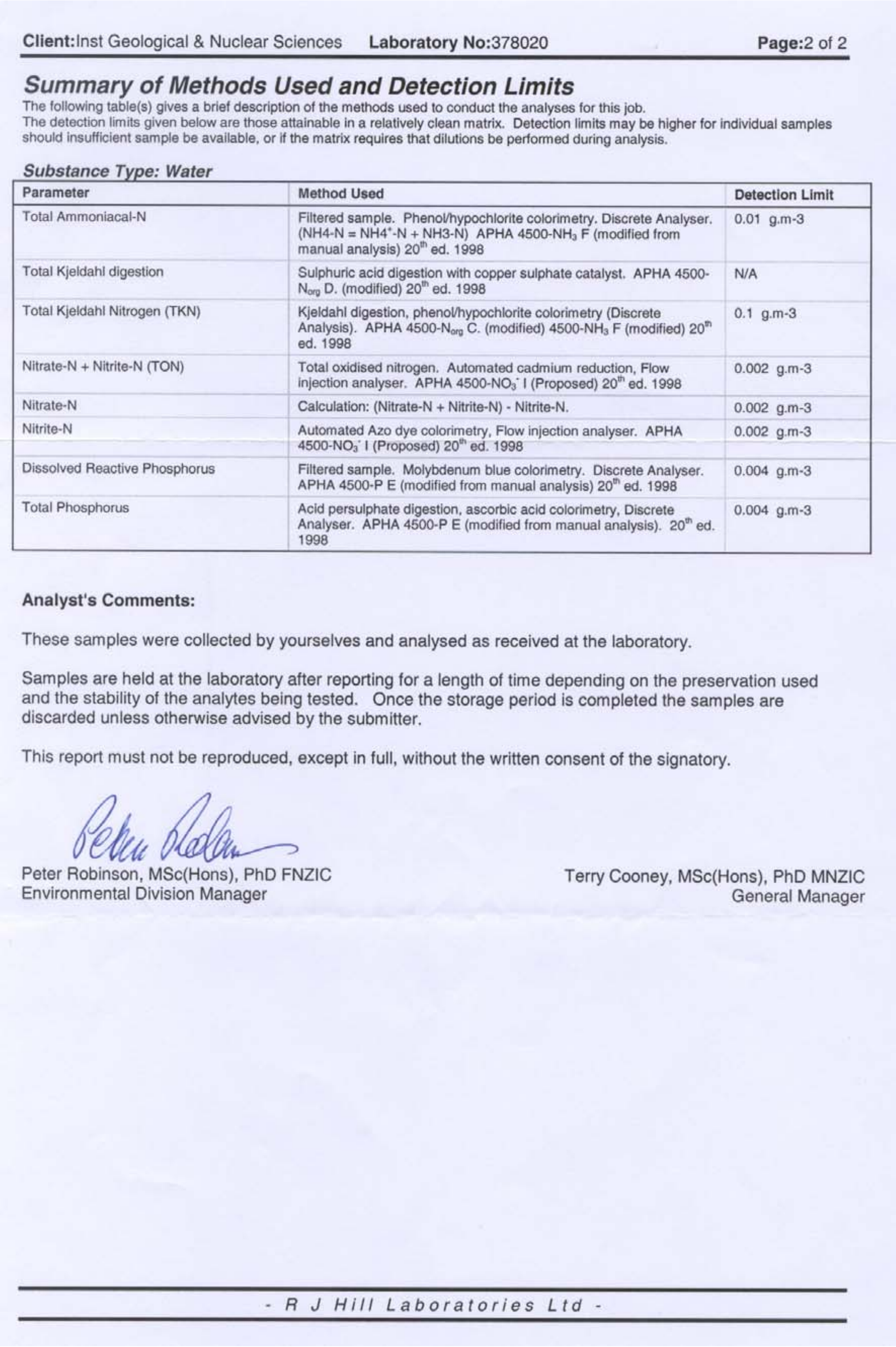
Sample Containers

The following table shows the sample containers that were associated with this job.

Container Description	Container Size (mL)	Number of Containers
Sulphuric Preserved (250 mL)	250	8
Polyethylene (100 mL), unpreserved	100	8
Filtered Unpreserved (100 mL)	100	8

Details of sample bottle preparation procedures are available upon request.

This Laboratory is accredited by International Accreditation New Zealand (previously known as TELARC). The tests reported herein have been performed in accordance with its terms of accreditation, with the exception of tests marked *, which are not accredited.
This report may not be reproduced, except in full, without the written consent of the signatory.



Client: Inst Geological & Nuclear Sciences **Laboratory No:** 378020 **Page:** 2 of 2

Summary of Methods Used and Detection Limits

The following table(s) gives a brief description of the methods used to conduct the analyses for this job.
The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Substance Type: Water

Parameter	Method Used	Detection Limit
Total Ammoniacal-N	Filtered sample. Phenol/hypochlorite colorimetry. Discrete Analyser. (NH4-N = $NH4^+$-N + NH3-N) APHA 4500-NH_3 F (modified from manual analysis) 20th ed. 1998	0.01 g.m-3
Total Kjeldahl digestion	Sulphuric acid digestion with copper sulphate catalyst. APHA 4500-N_{org} D. (modified) 20th ed. 1998	N/A
Total Kjeldahl Nitrogen (TKN)	Kjeldahl digestion, phenol/hypochlorite colorimetry (Discrete Analysis). APHA 4500-N_{org} C. (modified) 4500-NH_3 F (modified) 20th ed. 1998	0.1 g.m-3
Nitrate-N + Nitrite-N (TON)	Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO_3^- I (Proposed) 20th ed. 1998	0.002 g.m-3
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - Nitrite-N.	0.002 g.m-3
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (Proposed) 20th ed. 1998	0.002 g.m-3
Dissolved Reactive Phosphorus	Filtered sample. Molybdenum blue colorimetry. Discrete Analyser. APHA 4500-P E (modified from manual analysis) 20th ed. 1998	0.004 g.m-3
Total Phosphorus	Acid persulphate digestion, ascorbic acid colorimetry, Discrete Analyser. APHA 4500-P E (modified from manual analysis). 20th ed. 1998	0.004 g.m-3

Analyst's Comments:

These samples were collected by yourselves and analysed as received at the laboratory.

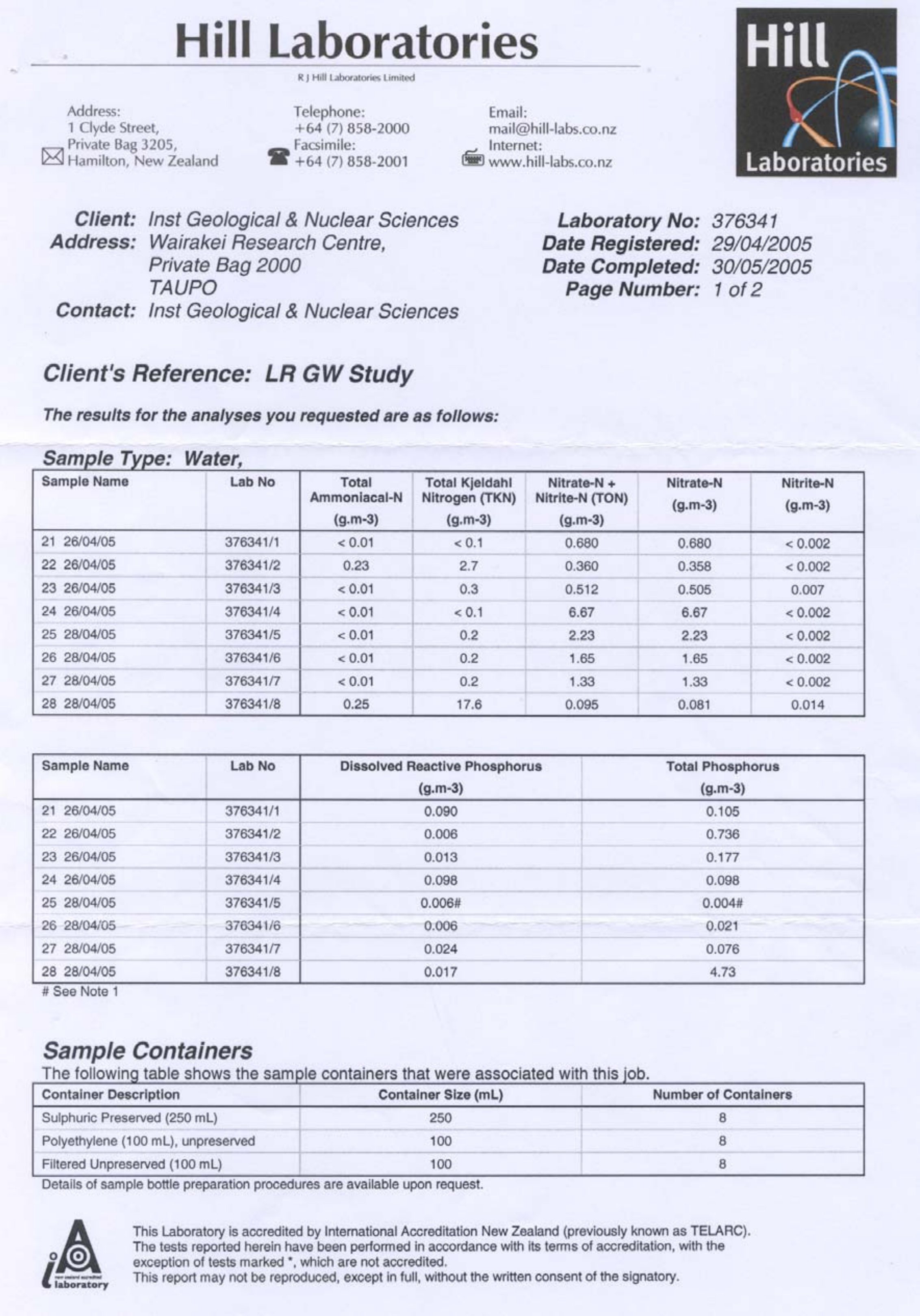
Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the submitter.

This report must not be reproduced, except in full, without the written consent of the signatory.

Peter Robinson, MSc(Hons), PhD FNZIC
Environmental Division Manager

Terry Cooney, MSc(Hons), PhD MNZIC
General Manager

- R J Hill Laboratories Ltd -



Hill Laboratories

R J Hill Laboratories Limited

Address:
1 Clyde Street,
Private Bag 3205,
Hamilton, New Zealand

Telephone:
+64 (7) 858-2000
Facsimile:
+64 (7) 858-2001

Email:
mail@hill-labs.co.nz
Internet:
www.hill-labs.co.nz

Client: *Inst Geological & Nuclear Sciences*
Address: *Wairakei Research Centre,*
Private Bag 2000
TAUPO
Contact: *Inst Geological & Nuclear Sciences*

Laboratory No: *376341*
Date Registered: *29/04/2005*
Date Completed: *30/05/2005*
Page Number: *1 of 2*

Client's Reference: LR GW Study

The results for the analyses you requested are as follows:

Sample Type: Water,

Sample Name	Lab No	Total Ammoniacal-N (g.m-3)	Total Kjeldahl Nitrogen (TKN) (g.m-3)	Nitrate-N + Nitrite-N (TON) (g.m-3)	Nitrate-N (g.m-3)	Nitrite-N (g.m-3)
21 26/04/05	376341/1	< 0.01	< 0.1	0.680	0.680	< 0.002
22 26/04/05	376341/2	0.23	2.7	0.360	0.358	< 0.002
23 26/04/05	376341/3	< 0.01	0.3	0.512	0.505	0.007
24 26/04/05	376341/4	< 0.01	< 0.1	6.67	6.67	< 0.002
25 28/04/05	376341/5	< 0.01	0.2	2.23	2.23	< 0.002
26 28/04/05	376341/6	< 0.01	0.2	1.65	1.65	< 0.002
27 28/04/05	376341/7	< 0.01	0.2	1.33	1.33	< 0.002
28 28/04/05	376341/8	0.25	17.6	0.095	0.081	0.014

Sample Name	Lab No	Dissolved Reactive Phosphorus (g.m-3)	Total Phosphorus (g.m-3)
21 26/04/05	376341/1	0.090	0.105
22 26/04/05	376341/2	0.006	0.736
23 26/04/05	376341/3	0.013	0.177
24 26/04/05	376341/4	0.098	0.098
25 28/04/05	376341/5	0.006#	0.004#
26 28/04/05	376341/6	0.006	0.021
27 28/04/05	376341/7	0.024	0.076
28 28/04/05	376341/8	0.017	4.73

See Note 1

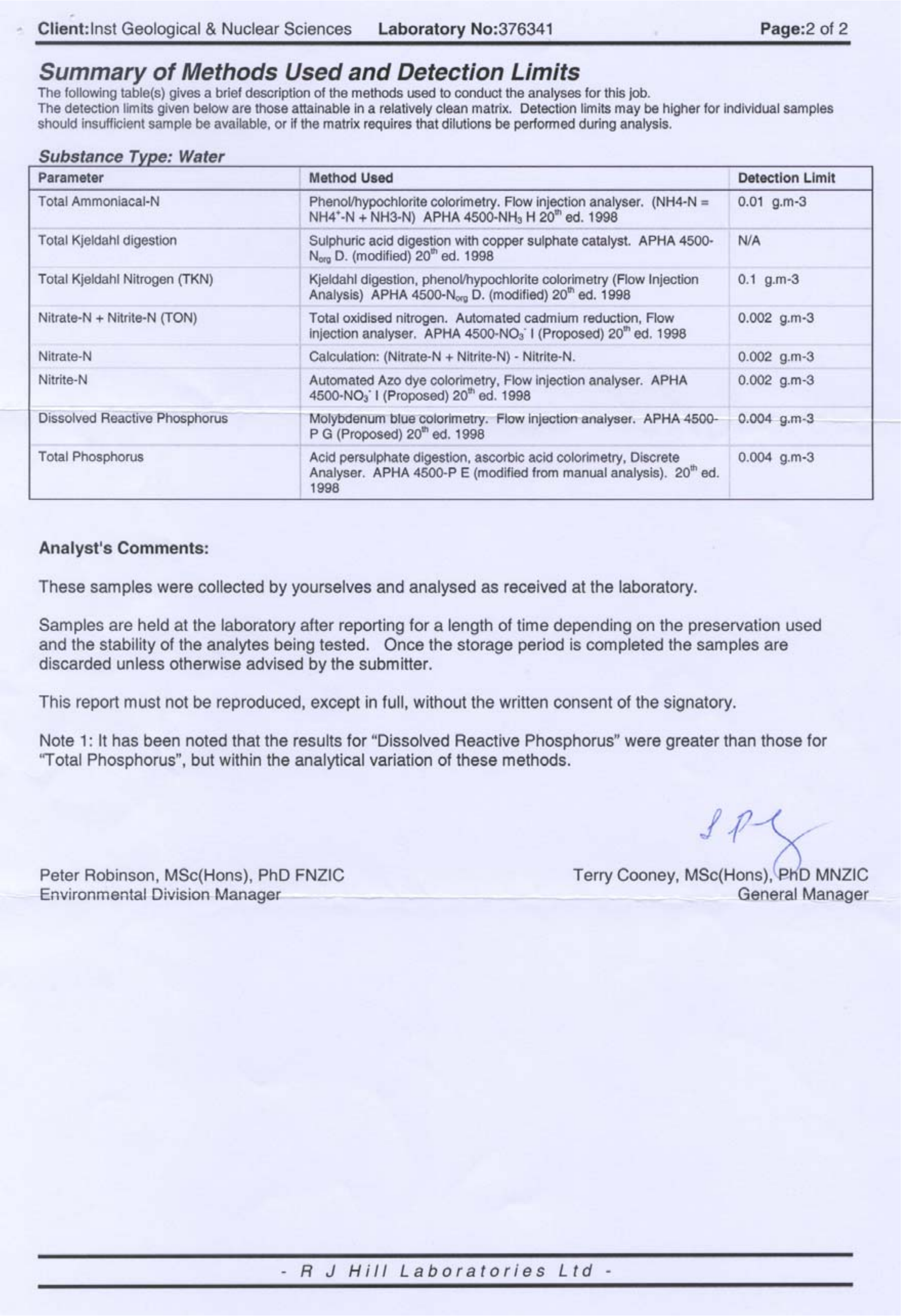
Sample Containers

The following table shows the sample containers that were associated with this job.

Container Description	Container Size (mL)	Number of Containers
Sulphuric Preserved (250 mL)	250	8
Polyethylene (100 mL), unpreserved	100	8
Filtered Unpreserved (100 mL)	100	8

Details of sample bottle preparation procedures are available upon request.

This Laboratory is accredited by International Accreditation New Zealand (previously known as TELARC). The tests reported herein have been performed in accordance with its terms of accreditation, with the exception of tests marked *, which are not accredited.
This report may not be reproduced, except in full, without the written consent of the signatory.



Client: Inst Geological & Nuclear Sciences **Laboratory No:**376341 **Page:**2 of 2

Summary of Methods Used and Detection Limits

The following table(s) gives a brief description of the methods used to conduct the analyses for this job.
The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Substance Type: Water

Parameter	Method Used	Detection Limit
Total Ammoniacal-N	Phenol/hypochlorite colorimetry. Flow injection analyser. (NH4-N = $NH4^+$-N + NH3-N) APHA 4500-NH_3 H 20th ed. 1998	0.01 g.m-3
Total Kjeldahl digestion	Sulphuric acid digestion with copper sulphate catalyst. APHA 4500-N_{org} D. (modified) 20th ed. 1998	N/A
Total Kjeldahl Nitrogen (TKN)	Kjeldahl digestion, phenol/hypochlorite colorimetry (Flow Injection Analysis) APHA 4500-N_{org} D. (modified) 20th ed. 1998	0.1 g.m-3
Nitrate-N + Nitrite-N (TON)	Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO_3^- I (Proposed) 20th ed. 1998	0.002 g.m-3
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - Nitrite-N.	0.002 g.m-3
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (Proposed) 20th ed. 1998	0.002 g.m-3
Dissolved Reactive Phosphorus	Molybdenum blue colorimetry. Flow injection analyser. APHA 4500-P G (Proposed) 20th ed. 1998	0.004 g.m-3
Total Phosphorus	Acid persulphate digestion, ascorbic acid colorimetry, Discrete Analyser. APHA 4500-P E (modified from manual analysis). 20th ed. 1998	0.004 g.m-3

Analyst's Comments:

These samples were collected by yourselves and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the submitter.

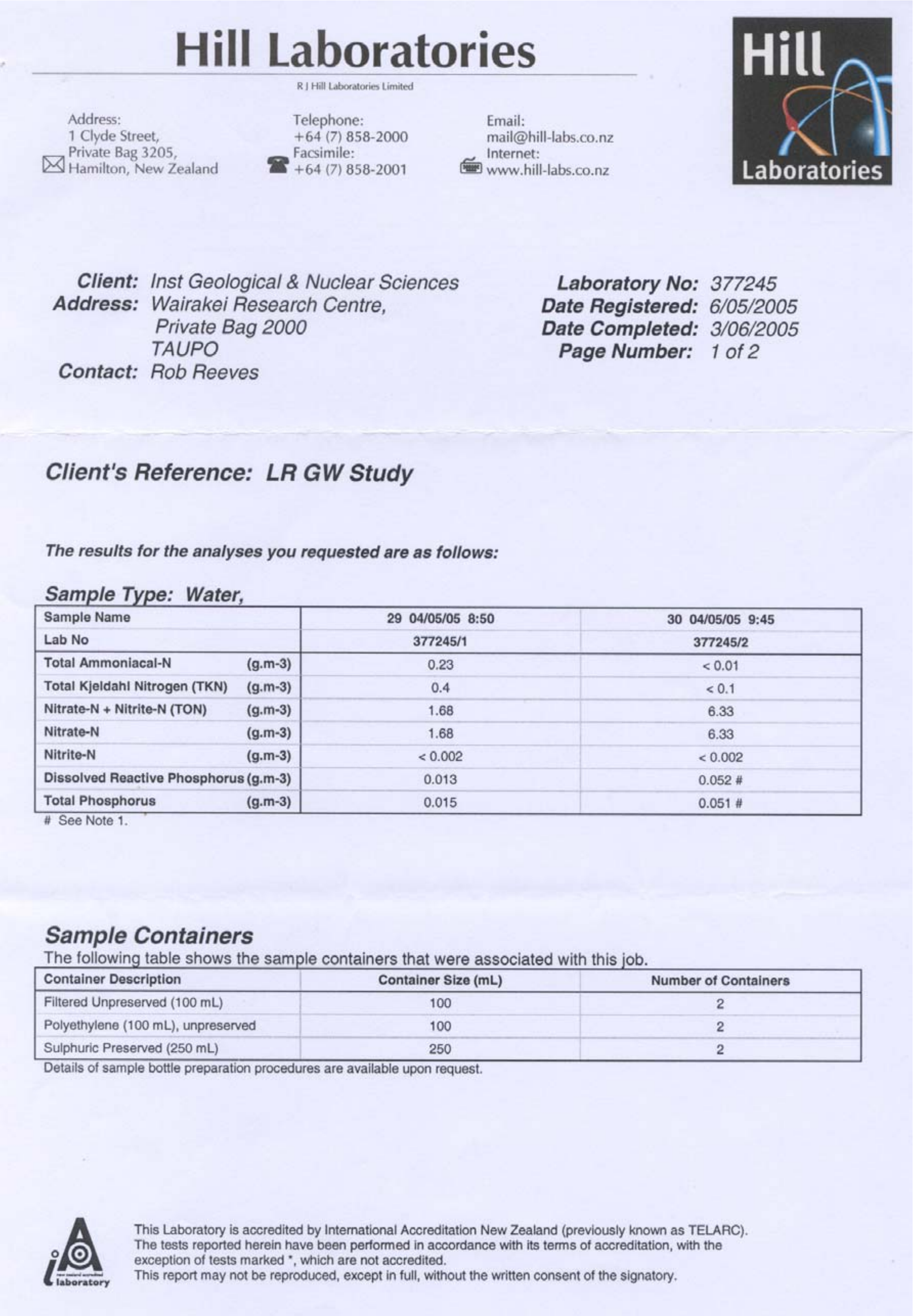
This report must not be reproduced, except in full, without the written consent of the signatory.

Note 1: It has been noted that the results for "Dissolved Reactive Phosphorus" were greater than those for "Total Phosphorus", but within the analytical variation of these methods.

Peter Robinson, MSc(Hons), PhD FNZIC
Environmental Division Manager

Terry Cooney, MSc(Hons), PhD MNZIC
General Manager

- R J Hill Laboratories Ltd -



Hill Laboratories

R J Hill Laboratories Limited

Address:
1 Clyde Street,
Private Bag 3205,
Hamilton, New Zealand

Telephone:
+64 (7) 858-2000
Facsimile:
+64 (7) 858-2001

Email:
mail@hill-labs.co.nz
Internet:
www.hill-labs.co.nz

Client: *Inst Geological & Nuclear Sciences*
Address: *Wairakei Research Centre,*
Private Bag 2000
TAUPO
Contact: *Rob Reeves*

Laboratory No: *377245*
Date Registered: *6/05/2005*
Date Completed: *3/06/2005*
Page Number: *1 of 2*

Client's Reference: LR GW Study

The results for the analyses you requested are as follows:

Sample Type: Water,

Sample Name		29 04/05/05 8:50	30 04/05/05 9:45
Lab No		377245/1	377245/2
Total Ammoniacal-N	(g.m-3)	0.23	< 0.01
Total Kjeldahl Nitrogen (TKN)	(g.m-3)	0.4	< 0.1
Nitrate-N + Nitrite-N (TON)	(g.m-3)	1.68	6.33
Nitrate-N	(g.m-3)	1.68	6.33
Nitrite-N	(g.m-3)	< 0.002	< 0.002
Dissolved Reactive Phosphorus	(g.m-3)	0.013	0.052 #
Total Phosphorus	(g.m-3)	0.015	0.051 #

\# See Note 1.

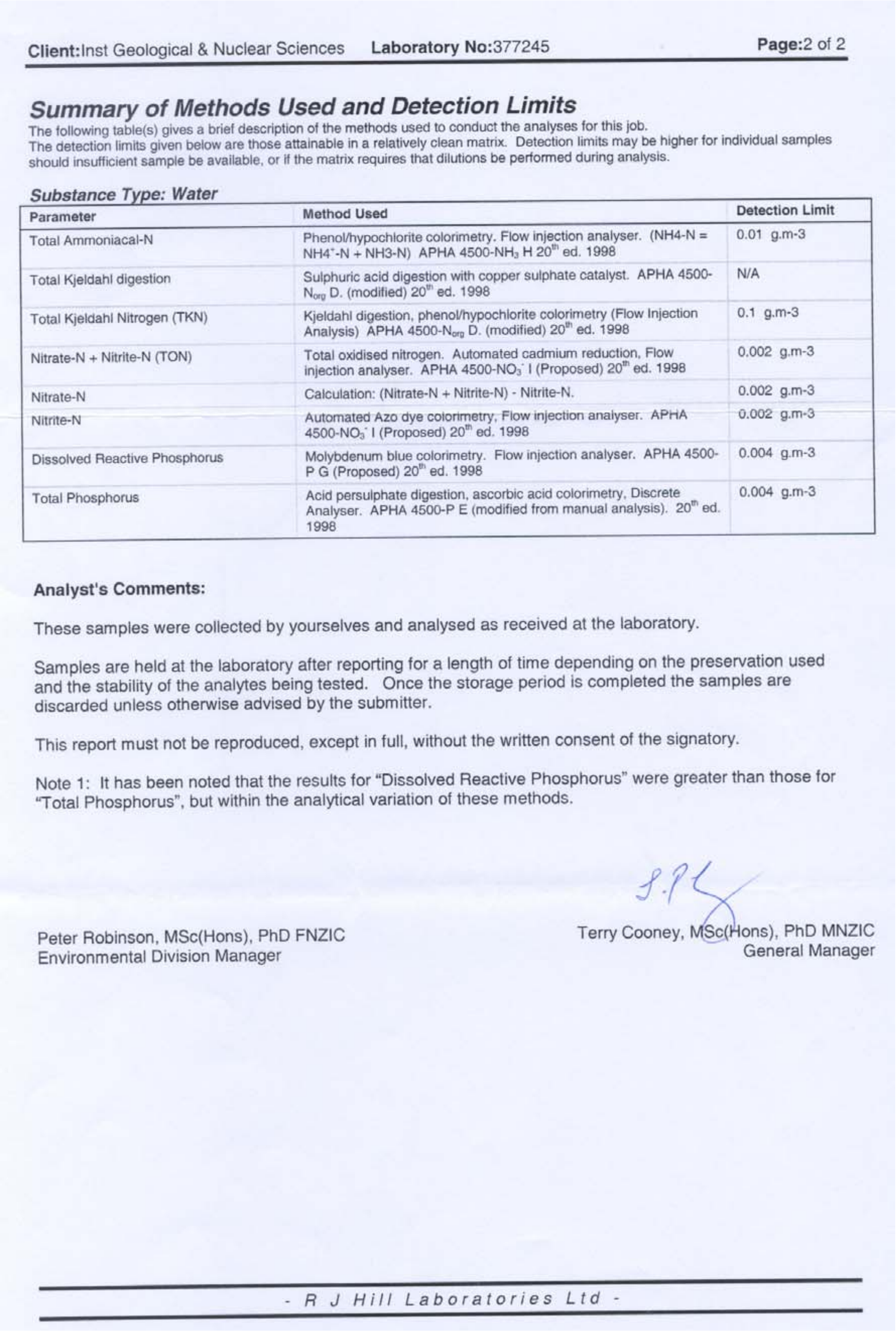
Sample Containers

The following table shows the sample containers that were associated with this job.

Container Description	Container Size (mL)	Number of Containers
Filtered Unpreserved (100 mL)	100	2
Polyethylene (100 mL), unpreserved	100	2
Sulphuric Preserved (250 mL)	250	2

Details of sample bottle preparation procedures are available upon request.

This Laboratory is accredited by International Accreditation New Zealand (previously known as TELARC). The tests reported herein have been performed in accordance with its terms of accreditation, with the exception of tests marked *, which are not accredited.
This report may not be reproduced, except in full, without the written consent of the signatory.



Client: Inst Geological & Nuclear Sciences **Laboratory No:**377245 **Page:**2 of 2

Summary of Methods Used and Detection Limits

The following table(s) gives a brief description of the methods used to conduct the analyses for this job.
The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Substance Type: Water

Parameter	Method Used	Detection Limit
Total Ammoniacal-N	Phenol/hypochlorite colorimetry. Flow injection analyser. (NH4-N = NH4$^+$-N + NH3-N) APHA 4500-NH$_3$ H 20th ed. 1998	0.01 g.m-3
Total Kjeldahl digestion	Sulphuric acid digestion with copper sulphate catalyst. APHA 4500-N$_{org}$ D. (modified) 20th ed. 1998	N/A
Total Kjeldahl Nitrogen (TKN)	Kjeldahl digestion, phenol/hypochlorite colorimetry (Flow Injection Analysis) APHA 4500-N$_{org}$ D. (modified) 20th ed. 1998	0.1 g.m-3
Nitrate-N + Nitrite-N (TON)	Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO$_3^-$ I (Proposed) 20th ed. 1998	0.002 g.m-3
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - Nitrite-N.	0.002 g.m-3
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO$_3^-$ I (Proposed) 20th ed. 1998	0.002 g.m-3
Dissolved Reactive Phosphorus	Molybdenum blue colorimetry. Flow injection analyser. APHA 4500-P G (Proposed) 20th ed. 1998	0.004 g.m-3
Total Phosphorus	Acid persulphate digestion, ascorbic acid colorimetry, Discrete Analyser. APHA 4500-P E (modified from manual analysis). 20th ed. 1998	0.004 g.m-3

Analyst's Comments:

These samples were collected by yourselves and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the submitter.

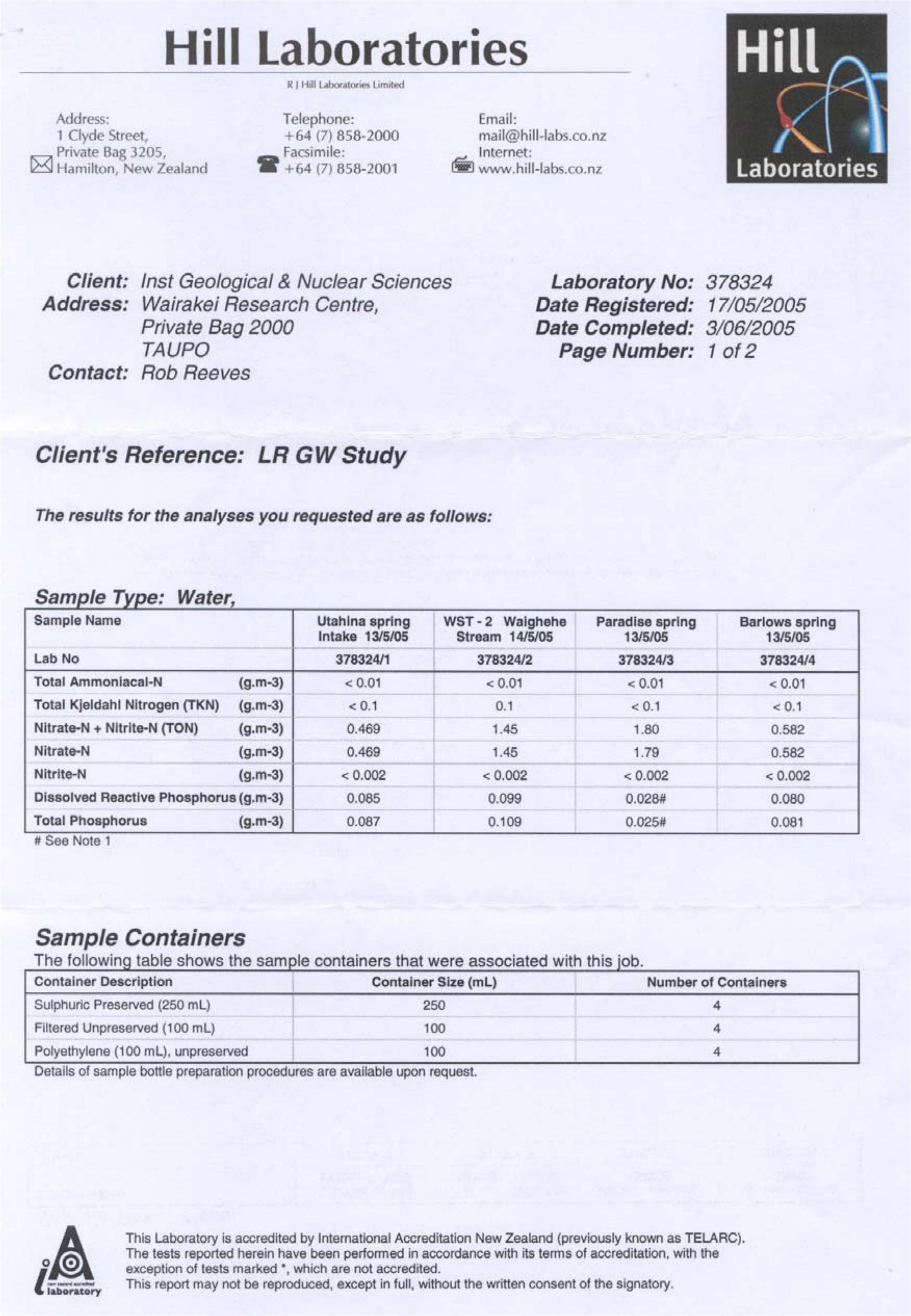
This report must not be reproduced, except in full, without the written consent of the signatory.

Note 1: It has been noted that the results for "Dissolved Reactive Phosphorus" were greater than those for "Total Phosphorus", but within the analytical variation of these methods.

Peter Robinson, MSc(Hons), PhD FNZIC
Environmental Division Manager

Terry Cooney, MSc(Hons), PhD MNZIC
General Manager

- R J Hill Laboratories Ltd -



Hill Laboratories

R J Hill Laboratories Limited

Address:
1 Clyde Street,
Private Bag 3205,
Hamilton, New Zealand

Telephone:
+64 (7) 858-2000
Facsimile:
+64 (7) 858-2001

Email:
mail@hill-labs.co.nz
Internet:
www.hill-labs.co.nz

Client: Inst Geological & Nuclear Sciences
Address: Wairakei Research Centre,
Private Bag 2000
TAUPO
Contact: Rob Reeves

Laboratory No: 378324
Date Registered: 17/05/2005
Date Completed: 3/06/2005
Page Number: 1 of 2

Client's Reference: LR GW Study

The results for the analyses you requested are as follows:

Sample Type: Water,

Sample Name		Utahina spring Intake 13/5/05	WST - 2 Waighehe Stream 14/5/05	Paradise spring 13/5/05	Barlows spring 13/5/05
Lab No		378324/1	378324/2	378324/3	378324/4
Total Ammoniacal-N	(g.m-3)	< 0.01	< 0.01	< 0.01	< 0.01
Total Kjeldahl Nitrogen (TKN)	(g.m-3)	< 0.1	0.1	< 0.1	< 0.1
Nitrate-N + Nitrite-N (TON)	(g.m-3)	0.469	1.45	1.80	0.582
Nitrate-N	(g.m-3)	0.469	1.45	1.79	0.582
Nitrite-N	(g.m-3)	< 0.002	< 0.002	< 0.002	< 0.002
Dissolved Reactive Phosphorus	(g.m-3)	0.085	0.099	0.028#	0.080
Total Phosphorus	(g.m-3)	0.087	0.109	0.025#	0.081

See Note 1

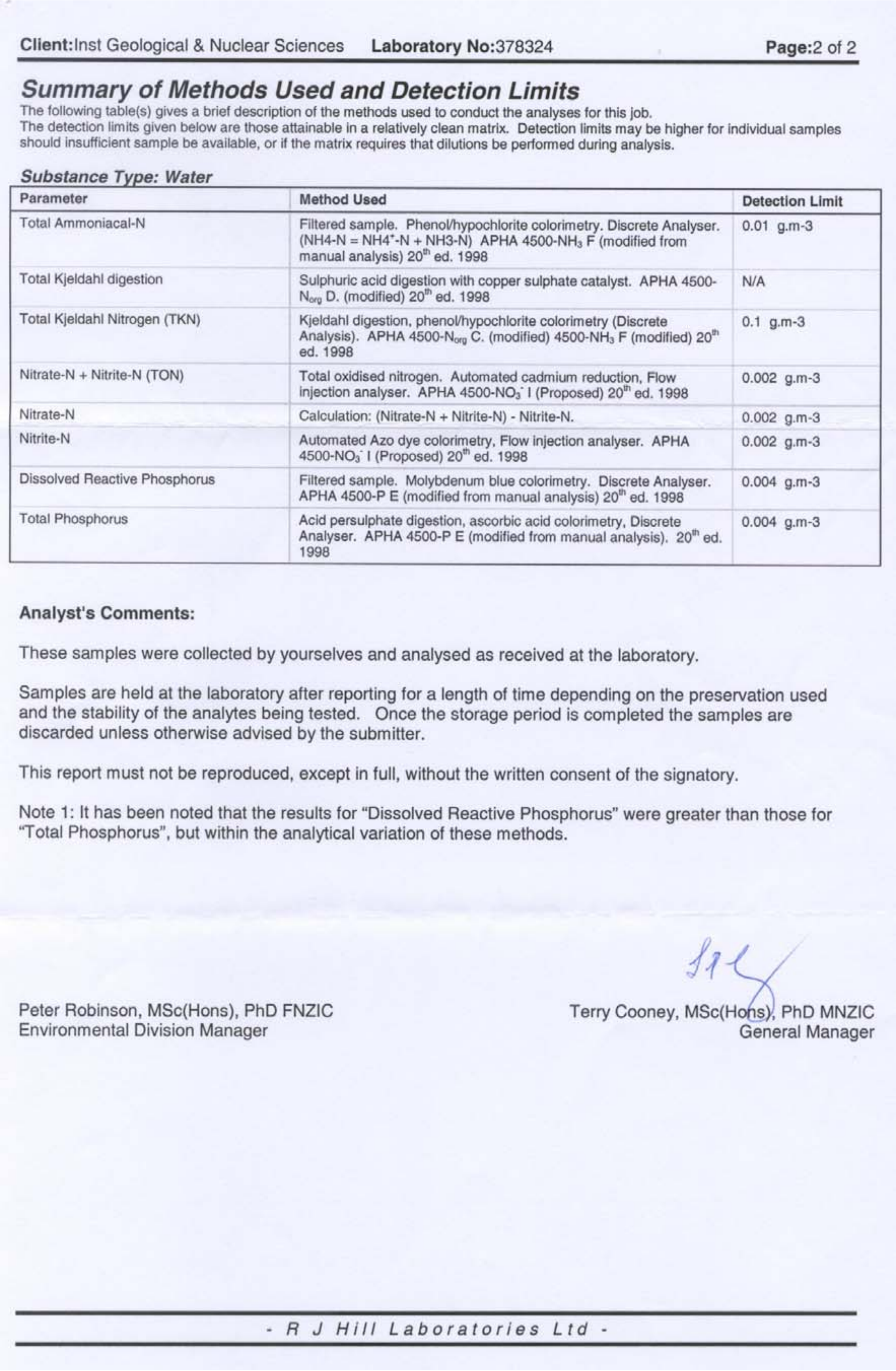
Sample Containers

The following table shows the sample containers that were associated with this job.

Container Description	Container Size (mL)	Number of Containers
Sulphuric Preserved (250 mL)	250	4
Filtered Unpreserved (100 mL)	100	4
Polyethylene (100 mL), unpreserved	100	4

Details of sample bottle preparation procedures are available upon request.

This Laboratory is accredited by International Accreditation New Zealand (previously known as TELARC). The tests reported herein have been performed in accordance with its terms of accreditation, with the exception of tests marked *, which are not accredited.
This report may not be reproduced, except in full, without the written consent of the signatory.



Client: Inst Geological & Nuclear Sciences **Laboratory No:**378324 **Page:**2 of 2

Summary of Methods Used and Detection Limits

The following table(s) gives a brief description of the methods used to conduct the analyses for this job.
The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Substance Type: Water

Parameter	Method Used	Detection Limit
Total Ammoniacal-N	Filtered sample. Phenol/hypochlorite colorimetry. Discrete Analyser. (NH4-N = $NH4^{+}$-N + NH3-N) APHA 4500-NH_3 F (modified from manual analysis) 20th ed. 1998	0.01 g.m-3
Total Kjeldahl digestion	Sulphuric acid digestion with copper sulphate catalyst. APHA 4500-N_{org} D. (modified) 20th ed. 1998	N/A
Total Kjeldahl Nitrogen (TKN)	Kjeldahl digestion, phenol/hypochlorite colorimetry (Discrete Analysis). APHA 4500-N_{org} C. (modified) 4500-NH_3 F (modified) 20th ed. 1998	0.1 g.m-3
Nitrate-N + Nitrite-N (TON)	Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO_3^- I (Proposed) 20th ed. 1998	0.002 g.m-3
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - Nitrite-N.	0.002 g.m-3
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (Proposed) 20th ed. 1998	0.002 g.m-3
Dissolved Reactive Phosphorus	Filtered sample. Molybdenum blue colorimetry. Discrete Analyser. APHA 4500-P E (modified from manual analysis) 20th ed. 1998	0.004 g.m-3
Total Phosphorus	Acid persulphate digestion, ascorbic acid colorimetry, Discrete Analyser. APHA 4500-P E (modified from manual analysis). 20th ed. 1998	0.004 g.m-3

Analyst's Comments:

These samples were collected by yourselves and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the submitter.

This report must not be reproduced, except in full, without the written consent of the signatory.

Note 1: It has been noted that the results for "Dissolved Reactive Phosphorus" were greater than those for "Total Phosphorus", but within the analytical variation of these methods.

Peter Robinson, MSc(Hons), PhD FNZIC
Environmental Division Manager

Terry Cooney, MSc(Hons), PhD MNZIC
General Manager

- R J Hill Laboratories Ltd -

Tritium/CFC/SF_6 Method

The tritium samples were analysed using the Institute of Geological & Nuclear Sciences Ltd. (GNS) state-of-the-art tritium measurement system with extremely high detection sensitivity for the low tritium concentrations prevailing in New Zealand’s waters. The detection limit is 0.03 TU, using ultra low-level liquid scintillation spectrometry and electrolytic enrichment prior to detection. One litre of water is required for analysis. Reproducibility of a standard enrichment is 2%, and an accuracy of 1% can be achieved via deuterium calibrated enrichment (Taylor 1994). Water gas (CFCs and SF6) concentrations were analyzed at GNS by gas chromatography.

Reference

Taylor, C.B., 1994. The relationship between electrolytic deuterium and tritium separation factors, and attainment of improved accuracy in radiometric low-level tritium measurement. Appl. Radiat. Isot. Vol. 45, No. 6, pp. 683-692.

Appendix 6.1 Description of Lake Rotorua springs, seeps and wetlands identified in the lake-edge survey.

Site 1

This seep is situated at the side of the road in front of 60 Pohutukawa Drive, on the south-eastern side of Lake Rotorua. The location of this site is 2799702, 6336862, using Garmin GPS, with an error of +/- 20m. The flow emerges from the grass by the footpath, and runs west for approximately 40 metres along the gutter to the drain. The driveway is also wet. The flow rate can possibly be measured in the trickle of water by the grass. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 22 November 2004.

Figure 1.1. Seep in gutter outside 60 Pohutukawa Drive, Rotorua.

Figure 1.2. Seep on driveway of 60 Pohutukawa Drive, Rotorua.

Site 2

Seeps situated next to the footpath outside 54A Pohutukawa Drive, on the south-eastern side of Lake Rotorua. The location of this site is 2799733, 6336781, using the handheld Garmin GPS, with an error of +/- 20 m. This property is opposite the Pohutukawa Drive reserve, and the seep is approximately 2 m west of the letterbox. It covers an area of 2 m x 2 m, and wets the gutter on the side of the road towards the west. Flow rate is unlikely to be measurable due to the small amount of flow, and abundance of mud. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 22 November 2004.

Figure 2.1. Seep outside 54A Pohutukawa Drive, Rotorua.

Site 3

The wetland is located at south side of Pohutukawa Drive Reserve, approximately 15 m from the road, at the south-eastern side of Lake Rotorua. One point on the area's western edge is 2799773, 6336819, using the handheld Garmin GPS, with an error of +/- 20 m. The wetland covers an area of approximately 40m x 20m and can be seen as a patch of long grass. It is a boggy area, so it is unlikely that surface water flow rate could be easily measured. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 22 November 2004.

Figure 3.1. Wetland area at south end of Pohutukawa Drive reserve.

Site 4

This wetland area is located at the north-eastern side of Pohutukawa Drive reserve, approximately 15 metres south of the stream, at the south-eastern part of Lake Rotorua. It is situated at 2799840, 6336842, using Garmin GPS, with an error of +/- 20 m. The area of wetland is roughly 30 m x 2 m, runs east, and is at right angles to another small boggy region or ditch. Due to the lack of flow and amount of mud, a surface water flow rate is unlikely to be able to be measured. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 22 November 2004.

Figure 4.1. Wetland area at north-eastern end of Pohutukawa Drive reserve.

Site 5

This seep is situated on and around the property of 48 Pohutukawa Drive, at the south-eastern part of Lake Rotorua. The location of this site is 2799711, 6336746, using the handheld Garmin GPS, with an error of +/- 20 m. The water has formed a muddy hole in the grass outside the house, and also boggy areas in front of the house next door (46 Pohutukawa Dr.), and house behind. The wet area covers approximately 30 m x 4 m on the front yard and road side of fence. The property owner stated that both the front yard and the back yard often flood, and the water is only about 5 cm below the ground surface. The front lawn drains into the road-side gutter, and the back lawn drains into the property behind. It would be difficult to obtain a surface flow measurement. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 22 November 2004.

Figure 5.1. Seep in front of 48 Pohutukawa Drive, Rotorua.

Site 6

This seep is beside the footpath outside 38 Pohutukawa Drive, at the south-eastern side of Lake Rotorua. The location is 2799686, 6336687, using the handheld Garmin GPS, with an error of +/- 20 m. Both sides of the footpath are wet, and the water drains down the gutter for about 15 m. It is only a very small amount of water, so it is unlikely a flow rate would be able to be measured. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 22 November 2004.

Figure 6.1. Seep outside 38 Pohutukawa Drive, Rotorua.

Site 7

This area of seepage is at the south-east side of the Karenga Street Reserve, at the south-western side of Lake Rotorua. It has a location of 2794284, 6337242, using the Garmin GPS, with an error of +/- 20 m. The area is roughly 10m x 10m, and is wet, spongy grass to the lake edge. Water can be seen when the grass is pressed. The flow rate is unlikely to be able to be measured, as there is no obvious flow or outlet. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 22 November 2004.

Figure 7.1. Area of seepage at South-east corner of Karenga Street Reserve.

Site 8

The area of seepage at site eight is located at the northern end of the Karenga Street Reserve, at the south-western side of Lake Rotorua. It is situated at 2794248, 6337322, using the Garmin GPS, with an error of +/- 20 m. This site is approximately 80 metres north of site seven, and has an area of 20 m x 15 m, and extends for another 20 metres along the lake edge to the south. It is wet, and nearby residents said the area used to be muddy, but has now been planted to stabilize the ground. Due to the lack of drainage channel, it is unlikely a flow rate could be measured. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 22 November 2004.

Figure 8.1. Area of seepage at northern end of Karenga Street Reserve.

Site 9

This small area of seepage is located approximately 30 metres north of 172 Parawai Rd, on the opposite side of the road to a wetland area, near Ngongotaha at the western side of Lake Rotorua. The location is 2792588, 6340520, using the Garmin GPS, with an error of +/- 20 m. The seep covers an area of 1 m x 1.5 m and drains into the ditch at the side of the road. As the small amount of water can be seen running into the drain, it may be possible to measure the flow rate. The stream in the ditch is not very close to the lake edge. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 22 November 2004.

Figure 9.1. Seep draining into ditch on Parawai Road, Rotorua

Site 10

This wetland is situated next door to 172 Parawai Road in a north direction, at the western side of Lake Rotorua. The location of the wetland extends from 10m south of 2792770, 6340646 at its northern extremity, to a few metres northwest of 2792665, 6340522 at its western end, measured using Garmin GPS, which has an error of +/- 20 m. It is an ‘L’ shape, approximately 170 m x 120 m. A brown stream runs parallel with one arm, but no other drainage channel was observed, particularly due to the blackberry bushes which barred lake access. Therefore, flow rate measurements would be difficult, unless the brown stream was measured, but its source is unknown. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 22 November 2004.

Figure 10.1. North end of wetland on Parawai Road, Rotorua, looking southwest.

Figure 10.2. Southwest end of wetland on Parawai Road, Rotorua, looking north.

Site 11

The wetland is at the end of Waikuta Road, beside number 48. The area is on the western side of Lake Rotorua. When visiting the site, the property owners were away, so access was limited. A stream flowed under the driveway at 2793032, 6340155, measured using Garmin GPS, which has an error of +/- 20 m, but the source of the stream remains unobserved. This area, including Parawai Road, is likely to feature on the wetlands map. Visited by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 22 November 2004.

Site 12

Access to the spring at site twelve is through the property at 89 Mokoia Road (RD2), owned by Douglas Black. The location is 2793032, 6340155 measured using Garmin GPS, which has an error of +/- 20 m. The spring can be seen on the bank by the path around the pongas. Water is piped down the hill and drains onto the grass at the base, where it is boggy. The spring is approximately 3 m west horizontally from the lake edge, and 10 m higher than lake level. Douglas Black reported that flow rate dramatically decreases during dry conditions, and increases during wet conditions. A flow rate measurement can be taken in the pipe to the left of the path when descending. Observed by Sally Grant and Rob Reeves from Wairakei Geological and Nuclear Sciences, on 29 November 2004.

Figure 12.1. Spring emerges at bank on the left, at 89 Mokoia Road, Rotorua.

Figure 12.2. Spring is behind the pongas at centre of photograph.

Site 12A

A wetland area appears to exist just north of 89 Mokoia Rd, with a pool and wetlands. No drainage channel was observed as the land was not accessed.

Site 13

Hamurana Springs, just north of Hamurana Road at the northern end of Lake Rotorua, drains into Lake Rotorua as Hamurana Stream. There are several sources which form the springs, a couple of which are shown in the photographs. The springs are located at 2795789, 6347331 using Garmin GPS, which has an error of +/- 20 m. The spring to the east has a sign stating a flow rate of 4,5000,000 litres per hour, a depth of 15 metres, and an elevation of 280 m above sea level. A flow rate can be obtained from the stream draining into the lake. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 1 December 2004.

Figure 13.1. North-western spring at Hamurana Springs.

Figure 13.2. Large eastern spring at Hamurana Springs.

Figure 13.3. Spring emerging on eastern arm of Hamurana Springs.

Site 14

A possible seep exists approximately 70 metres west along a walking track from a small reserve at Mission Bay, at the north-eastern end of Lake Rotorua. The bank is 2 m north of the track, and was dripping into a small pool at its base. No drainage channel was observed, and the seep may be runoff from rainfall. Flow rate measurements may be difficult here. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 1 December 2004.

Figure 14.1. Seep emerging from bank, Mission Bay, Rotorua.

Site 15

A spring emerges at a farm called the S6 block, on Ngongotaha Rd, on the western side of Lake Rotorua. The owners name is Alec Wilson, and he can be contacted on 027 4832974. All of the following GPS recordings used the handheld Garmin GPS which has an error of +/- 20 m. There are four springs that join to form Waikuta Stream, which crosses under Ngongotaha Road at 2792387, 6340111. This is the easiest place to measure the combined flow of the springs, at the western side of the road. The first spring is the main spring welling up in a pond at 2792324, 6340000, with an elevation of 283 m. The two banks to the west have a spring each, the southern most bank is at 2792308, 6340009, with the spring at the base of the bank, two metres below. The northern bank is 10 metres to the north, and has a larger flow. The older spring is 100 m south of the main pond, and used to be the main spring until an earthquake slowed flow (Wilson pers. comm.). The source was not observed due to vegetation. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 6 December 2004.

Figure 15.1. Main spring at S6 Ngongotaha Rd, Rotorua.

Figure 15.2. Springs at S6 Ngongotaha Rd, Rotorua, looking north.

Figure 15.3. Springs at S6 Ngongotaha Rd, Rotorua, looking south. The south-western bank is on the right of the photo, and the main spring in the centre. The older spring is in the direction of the top right of the photo.

Site 16

Taniwha Springs, north-western side of Lake Rotorua, off Hamurana Road, Awahau. The source of these large springs was not observed due to vegetation. A flow rate could be measured near the bridge. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 6 December 2004.

Figure 16.1. Taniwha Springs stream, Awahau, Rotorua,

Site 17

A small wetland area occurs at northern end of lake, west of Hamurana Springs. It runs approximately 100 m perpendicular to the lake edge, at 2793908, 6346435, at lake level elevation of 292 m. The only apparent drainage is two small streams at its eastern edge, and the flow rate could be measured from these, but the rest of the area is muddy and not flowing. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 6 December 2004.

Figure 17.1. Wetland area at northern edge of lake, west of Hamurana.

Figure 17.2. Wetland area at northern edge of lake, west of Hamurana, wide view.

Site 17A

Stream joins the lake at: 2794254, 6346595, at an elevation of 296 m.

Site 17B

Small stream joins the lake at 2794393, 6346615, at an elevation of 275 m. It is piped under the road, but could not find where it came out of the other side.

Site 18

This seep emerges at a boat ramp, west of Hamurana, on the northern side of Lake Rotorua. It is located at 2794554, 6346665, at a 278 m elevation. Water is seeping out of the cracks of the boat ramp, and on both sides on the banks. Also, a concrete trough has flowing water from no apparent source, 5 m to the east of the ramp. The flow rate of the water can be measured on both sides of the ramp. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 6 December 2004.

Figure 18.1. Seep emerging from boat ramp just west of Hamurana. Water is seeping out of cracks (centre) and both sides of ramp. Trough is to the east of the ramp.

Site 18A

This stream joins the lake near 2794753, 6346709, elevation of 269 m. It flows into the sand and a flow rate could be measured here.

Site 18B

There are about three boggy areas (up to 2 m wide) in the reserve along the lakefront west of Hamurana Springs.

Site 18C

A pipe with flowing water surfaces at 2795060, 6346788, at 276 m elevation.

Site 18D

Water flows out of concrete pipes at 2795203, 6346811, at 287 m elevation, and the flow rate can be measured.

Site 19

This wetland is an area approximately 20 m x 20 m on the northern side of Hamurana Road, and feeds into a small stream under the road which flows into the lake from a concrete trough at 2795249, 6346844, elevation of 289 m. Flow rate could be measured in trough. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 6 December 2004.

Site 19A

A small flow joins the lake at 2795406, 6346818, 277m elevation.

Site 20

This seep is in a bank immediately west of the Hamurana reserve and occurs along 20 to 30 m of bank at 2795442, 6346823. Banks are directly above the edge of the lake, and are eroding. Some flow rates could be measured from the small flows at the base of the bank. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 6 December 2004.

Figure 20.1. Wide view of seeping bank immediately west of Hamurana reserve.

Figure 20.2. Seeping bank immediately west of Hamurana reserve.

Site 20A

A pipe emerges from the ground opposite the western entrance to Hamurana reserve, and there are approximately three other concrete pipes surfacing along the lake front in this reserve.

Site 20B

A concrete drain is at 2795516, 6346806, elevation 271 m, with a wet patch beside it. This could be a spring, or just wet from the waves and currently high lake level.

Site 21

A spring on the eastern side of the lake, near the Rotorua airport, surfaces at 2801176, 6339385, at lake level. The spring flows into a pool 2 m x 1 m, which drains into the lake where a flow rate can be measured. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 7 December 2004. Access is by boat.

Figure 21.1. Spring emerges from vegetation close to the lake edge, eastern side of Lake Rotorua.

Figure 21.2. Outlet from the spring to Lake Rotorua.

Site 21A

A drain flows to 2801330, 6339541, elevation of 287m (lake level) out of long grass. Source is unobserved.

Site 22

A stream drains from a wetland area, and flows into the lake at 2801556, 6340119, elevation 286 m. Flow rate could be measured from the stream. A second stream draining from the same wetland is 50 m north of this stream, and a third stream is 100 m north of this second stream. Further streams probably flow into the lake just south of these, but willow trees block visibility and access. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 7 December 2004.

Figure 22.1. First drainage stream from wetland, eastern side of Lake Rotorua.

Figure 22.2. Second drainage stream from wetland, eastern side of Lake Rotorua.

Figure 22.3. Third drainage channel from wetland, eastern side of Lake Rotorua.

Site 23

This channel is the outlet to swampy area at 2801666, 6340428, elevation 284 m. Another similar stream is 20 m north of this stream. Flow rates could be measured in the streams. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 7 December 2004.

Figure 23.1. Swampy area, eastern side of Lake Rotorua.

Figure 23.2. Outlet channel 20 m north of swampy area.

Site 24

This wetland has a pond and a drainage outlet at 2801921, 6342478, at lake level elevation of 282 m. Flow rate could be measured from the outlet channel. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 7 December 2004.

Figure 24.1. Wetlands pond, eastern side of Lake Rotorua.

Figure 24.2. Drainage channel to wetlands area, eastern side of Lake Rotorua.

Site 25

This feature appears to be road run-off to a pool that stops 3 m from the lake, and is not flowing. Is situated at 2801972, 6343040, 277 m elevation. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 7 December 2004.

Figure 25.1. Pool of road run-off water, eastern side of Lake Rotorua.

Site 26

The wetland area is approximately 50 m x 10 m with no observed drainage channel at 2801840, 6344699, elevation 280 m. Water is not flowing. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 7 December 2004.

Figure 26.1. Wetland area, eastern side of Lake Rotorua.

Site 27

This wetland drainage channel stops 3m from lake edge and is not flowing. It is situated at 2800264, 6338133, by the Lee Rd boat ramp, eastern Lake Rotorua. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 27.1. Wetland drainage pool, near Lee Road boat ramp, Rotorua.

Site 28

This stream flows into lake at 2800068, 6337836, elevation 261 m and is next to the playground by Lee Road, eastern Lake Rotorua. Flow rate could be measured in the stream. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 28.1. Stream flows into lake near Lee Road playground.

Site 29

A concrete and steel drain has water flowing into the lake from the sides of the road at the Holden Bay reserve, eastern Lake Rotorua. The pipes end one metre offshore, at 2799917, 6337716, just below lake level. Flow rate could be measured in the holes in the pipe on the beach. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 29.1. Steel pipes emerge offshore from Holdens Bay reserve.

Site 30

This drain runs along lake bed for 10m offshore at 2799778, 6337633, approximately one metre below lake level. Measuring the flow rate in this drain would probably be difficult. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 30.1. Drain runs along lake bed for 10m offshore, eastern Lake Rotorua.

Site 31

This stream flows into the lake under willow trees at 2799575, 6337528, elevation 284 m. Flow rate could be measured in stream. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 31.1. Stream flows into lake under willow trees, eastern Lake Rotorua.

Site 32

A small flow of water comes out of steel pipes at 2799368, 6337393, elevation 281 m. Flow rate could be measured at the end of the pipe. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 32.1. Steel pipes emit flowing water, eastern side of Lake Rotorua.

Site 33

Flow from this steel pipe emerges at 2799251, 6337344, at lake level. Flow rate could be measured at the end of the pipe. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 33.1. Large steel pipes have flowing water, eastern side of Lake Rotorua.

Site 34

The Robinson Ave Floodway flows into the lake at 2799197, 6337322, elevation is lake level. The floodway is wide and the flow rate could be measured as it flows into the lake. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 34.1. Outlet channel of Robinson Ave floodway, eastern Lake Rotorua.

Figure 34.2. Robinson Ave floodway, eastern side of Lake Rotorua.

Site 35

This stream reaches the eastern side of Lake Rotorua at 2799080, 6337297, just above lake level. It flows between houses, and the flow rate could be measured as it reaches the lake. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 35.1. Stream flowing into Lake Rotorua.

Site 36

This drain stops 3 m from lake edge, and has no flow. Is situated at 2799023, 6337294, at 279 m elevation. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 36.1. Drain with no water flowing, eastern Lake Rotorua.

Site 37

The area includes four geothermal springs with warm water (Mallinson pers. comm.) at the lake edge. The first is 10 cm above lake level at 2798860, 6337321, and is the northern-most spring. It has a measurable flow.

The second spring is approximately 0.8 m above lake level, and is at 2798852, 6337323.

The third spring is 30 m south of the previous spring, under flax, and the fourth spring is 20 m south of the third spring. All flow rates could be measured.

Figure 37.1. Wide view of first and northern most spring, eastern side of Lake Rotorua.

Figure 37.2. The second geothermal spring, eastern side of Lake Rotorua.

Figure 37.3. The fourth and most southern geothermal spring, eastern Lake Rotorua.

Site 38

A drain flows into the lake, which has two sources, one behind the tree house, the other in the wooden drain. This drain possibly contains geothermal water (landowner pers. comm.). Located at 2798715, 6337353, 278 m elevation. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 38.1. Drain flowing into lake, eastern Lake Rotorua.

Site 39

Flow reaches lake at 2798629, 6337291, running over an orange rock. Is possibly geothermal, and the flow rate can be measured. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 39.1. Small flow runs into eastern side of Lake Rotorua.

Site 40

This drain possibly contains road run-off, at 2798484, 6337001, elevation 278 m. Flow rate could be measured. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 40.1. Drain, eastern side of Lake Rotorua.

Site 41

This drain has no apparent flow and stops 3 m from the lake edge. The drain is situated at 2798474, 6336961, 278 m elevation. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 40.1. Drain with no flow, eastern side of Lake Rotorua.

Site 42

This stream flows into the lake at 2798321, 6336703 at lake level. No source was observed due to vegetation. Flow rate can be measured in stream. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 42.1. Stream draining into lake from vegetation, eastern side of Lake Rotorua.

Site 43

This stream flows through vegetation and joins the lake at 2798218, 6336620, at lake level. Flow rate can be measured in stream. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 43.1. Stream emerges from vegetation, eastern Lake Rotorua.

Site 44

The stream drains through fields from unknown source and flows into lake at 2798129, 6336509, elevation 275 m. Flow rate could be measured in stream. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 44.1. Stream drains through fields and flows into eastern Lake Rotorua.

Site 45

A small stream drains from fields and flows into Lake Rotorua at 2798102, 6336490, elevation 276 m. Flow rate could be measured from stream. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 45.1. Stream drains through fields and flows into eastern Lake Rotorua.

Site 46

A small seepage from wetland emerges under gorse bush at 2797897, 6336310, 278 m elevation. The flow rate is quite low. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 46.1. Wetland seepage emerges under gorse bush, eastern Lake Rotorua.

Site 47

A small seepage issues from a wetland (site 46), located at 2797884, 6336291. The flow rate is quite low. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 47.1. Wetland seep, eastern Lake Rotorua

Site 48

Seepage along a 0.5m high bank occurs from the same wetland as site 46. The flow rate is quite low. Located at 2797876, 6336291. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 48.1. Seepage along bank from wetlands, eastern Lake Rotorua.

Site 49

Another seep from the wetland of site 46 is located at 2797860, 6336283. It would be difficult to measure flow rate as the flow rate is low. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Site 50

This seepage is from a wetland dripping off a small bank at 2797714, 6336171. The flow rate is low. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 50.1. Wetland seepage dripping off bank, eastern Lake Rotorua.

Site 51

This stream is from wetland at 2797671, 6336111 and flows into lake. It can be measured for a flow rate. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 51.1. Outlet stream from a wetland, eastern Lake Rotorua.

Site 52

This wide stream flows into the lake at 2797476, 6335966. Flow rate could be measured. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 52.1. Stream flowing into the eastern side of Lake Rotorua.

Site 53

This seepage from a wetland is located at 2797166, 6335645, at lake level. There is no surface flow. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 53.1. Wetland seepage with no flow, south-east side of Lake Rotorua.

Site 54

This stream flows into Lake Rotorua at 2796995, 6335256. Flow rate could be measured in the stream. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 54.1. Outlet to stream, South-east Lake Rotorua.

Figure 54.2. Stream, south-east Lake Rotorua.

Site 55

Swamp land (geothermal) southeast of Sulphur Point stops about 10m from lake edge, and has a stream which flows west, parallel to the lake. Flow rate could be measured in the stream. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 55.1. Outlet stream to geothermal swamp, Southeast of Sulphur Point

Figure 55.2. Geothermal swamp southeast of Sulphur Point.

Site 56

This drain stops one metre from the lake on Sulphur Point and is not flowing. The drain is located at 2795975, 6336112, at lake level. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 56.1. Drain on Sulphur Point, not flowing.

Site 57

This is a manmade channel containing water; the water does not flow into the lake. Located at 2795694, 6336134. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 57.1. Manmade channel on Sulphur Point, no water flowing.

Site 58

This stream flows into Lake Rotorua near the large childrens playground, Lake Rotorua waterfront. Flow rate measurements could be made here. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 58.1. Stream flows into Lake Rotorua near the waterfront and playground.

Site 59

A stream occurs at 2795538, 6336166, near Rotorua's waterfront. The stream flows into sand. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 59.1. Water does not reach lake edge due to sandbank, near Rotorua's waterfront.

Site 60A

This large pipe is under a walkway by the cruise offices at Rotorua's waterfront, at 2795247, 6336318. Flow rate could be measured. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 60.1. Large pipe at Rotorua's waterfront.

Site 60B

A pipe emerges under the walkway to Mokoia Island cruises on the lake front at 2795168, 6336355.

Figure 60.2. Drainage pipe at Rotorua Lakefront.

Site 60C

A drain is located 20 m west of Site 60B and there is a big pipe emerging at the lake front at 2795130, 6336385.

Figure 60.3. Big pipe at Rotorua Lakefront

Site 61

A drain with hot water emerges at 2795018, 6336473. Water flow could possibly be measured. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Site 62

A concrete pipe is situated at 2795016, 6336511, at the south end of Lake Rotorua. Flow rate could be measured in the drain. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 62.1. Drain at south end of Lake Rotorua.

Site 63

An inlet at the south of Lake Rotorua, at Ohinemutu, has four geothermal hot water drains flowing into it. The most western pipe is located at 2794792, 6336519. The second pipe is 20 m east of the previous pipe, and the third and fourth are at the eastern end of the inlet. Flow rate measurements should be possible. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 63.1. Western hot water pipe at Ohinemutu inlet, Lake Rotorua.

Another small pipe is dripping hot water in from a marae at the side of the inlet, at 2794825, 6336575.

Site 64

This drain (or stream) is located at 2794768, 6336649. Flow rate measurements could be made in the stream. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 64.1. Drain (or stream) near Ohinemutu, Lake Rotorua.

Site 65

Utuhina Stream flows into the south end of Lake Rotorua at 2794783, 6336822. Flow rate could be measured in the stream. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 65.1. Utahina Stream flowing into the south end of Lake Rotorua

Site 66

A small pipe one metre high has water flowing into the lake at 2794542, 6336918, and there is a similar pipe 50 m west of these coordinates. A flow rate measurement is possible. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 66.1. Small pipe with water flowing into lake, south side of Lake Rotorua.

Site 67

At the end of a road, two concrete pipes drain roadside water into the south end of Lake Rotorua. Flow rates could be measured from these pipes. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 67.1. Roadside runoff drains through pipes into lake.

Houses 30 m west of this location have drains that discharge into the lake.

Site 68

A drain in the camping ground carries flowing water into the south end of Lake Rotorua at 2794427, 6336998, at lake level, near the wharf. A flow rate measurement is possible. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 68.1. Camping ground drain

Site 69

Road runoff drains into the lake from both sides of the road at 2794315, 6337115, at lake level. Flow rate measurements can be made in the drains. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 69.1. Eastern side of the road, water drains into Lake Rotorua.

Figure 69.2. Western side of road, water drains into Lake Rotorua.

Site 70

A drain occurs at 2794322, 6337171 and flow rates could be measured. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 70.1. Drain by houses, southwest Lake Rotorua.

Site 71

A road drain occurs beside a reserve at 2794213, 6337623, southwest Lake Rotorua. Flow rate could be measured in the pipe. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 71.1. Drain by reserve, southwest Lake Rotorua.

<u>Site 72</u>

Waiowhiro stream at the end of Aquarius Drive, western Lake Rotorua, located at 2794211, 6339256. Flow rate can easily be measured in stream. Observed by Sally Grant, from Wairakei Geological and Nuclear Sciences, on 8 December 2004.

Figure 72.1. Waiowhiro Stream, western Lake Rotorua.

<u>Site 73</u>

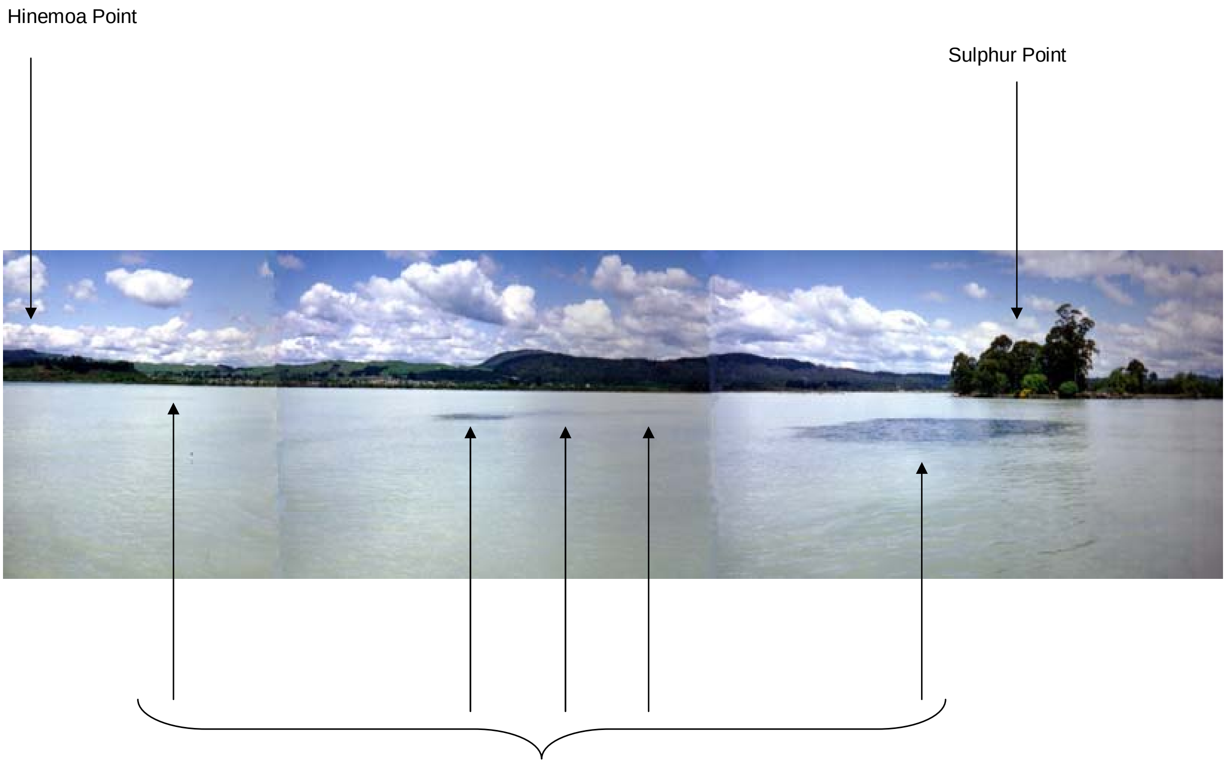
A spring between Mission Bay and Wilson Bay at the north end of Lake Rotorua is located at 2799510, 6346340 (located by reading co-ordinates off a topographic map). This location is estimated from the topographic map. It was last observed by Will Esler, of Waikato University on 24 July 2002, and he estimates that it has a constant approximate flow rate of 5 l/s. The site was not visited in 2004.

Glenn Ellery attempted to find the spring in February 2005. He spent half an hour bush bashing along the lake edge but could not find the spring (Ellery pers. comm., 2005).

Site 74

At least three lake-bed springs exist near Motutara Point. Spring locations are marked by dark areas in the lake surface (Gibbs, pers. comm., 2004). Dark areas are caused by plumes of cold water displacing the turbid surface film of sulphur and sediment. The springs appear to be aligned, possibly indicating the location of a lake-bed fault.

These springs were not observed by the authors of this report.



Dark areas are caused by vertical plumes of cold water from lake bed springs displacing the turbid surface film of sulphur and sediment

Photo credit: This composite photograph shows locations of five possible springs not far off the boat ramp at Sulphur Point (Gibbs pers. comm., 2004). Note that the correct name for the point in the photograph is probably Motutara Point.

Locations of springs, estimated by Max Gibbs, are approximately:

2796700	6336300
2797000	6336350
2797400	6336300

On some days, clouds of silt from the lake bed can be seen at the surface from upwelling water, according to the harbourmaster.

Site 75

These are ‘a series of submerged springs quite close to shore’ mentioned by Gibbs and Lusby (1996). A remnant wetland, pasture and a 10 m – wide band of blackberries and small trees make up the catchment immediately behind the beach.

These springs were not observed by the authors of this report.
Locations of the springs are approximately 2798400 6336800

Notes:

1) All GPS recordings were made using the handheld Garmin GPS, which has an error of +/- 20 m.

2) The area covered between Kawaha point and Hamurana Springs was only searched for seeps and springs, and therefore no streams or pipes were located. However they are described for all other searched areas.

3) The northern side of the lake has been carefully searched from the site 17 wetland to 2796637, 6346993. East of here, access to the lake is too difficult, and a boat must be used to observe features.

4) Elevation estimates of features listed in this appendix provided by GPS are relatively unreliable, for example lake elevation estimates show some inconsistency.

Reference

Gibbs, M.M. Lusby, F.E. 1996. Lake edge wetlands: their environmental significance to the Rotorua lakes. NIWA consultancy report to Environment Bay of Plenty BPR005/2. 45p.

Appendix 6.2 Flow measurements made by Environment Bay of Plenty in December 2004 and February 2005.

Date	Site	GPS Co-ordinates	Guage Type	Discharge L/sec	Lake-edge feature number
8-Dec-04		2793089 6340187	Meter	62	11
2-Feb-05		2792418 6344419	Visual	0	12
2-Feb-05		2792308 6340009	Visual	30	15
8-Dec-04	Culvert 5.22	2793798 6346648	Visual	0	17
8-Dec-04	Culvert 6.78	2795268 6347032	Estimation	0.07	19
2-Feb-05		2801176 6339385	Visual	3	21
8-Dec-04		2801558 6340119	Estimation	6	22
8-Dec-04		2801672 6340426	Visual	0	23
8-Dec-04		2801918 6342455	Estimation	4	24
2-Feb-05		2800068 6337836	Visual	15	28
8-Dec-04	Waingaehe Stm @ Lwr Right Branch	2799588 6337492	Meter	183	31
2-Feb-05		2799197 6337322	Meter	110	34
2-Feb-05		2799080 6337297	Visual	4	35
2-Feb-05		2798860 6337321	Visual	2	37
2-Feb-05		2798715 6337353	Visual	3	38
2-Feb-05		2798629 6337291	Visual	6	39
2-Feb-05		2798484 6337001	Visual	0.25	40
10-Dec-04	Stream2 @ Vaughan Rd	2798316 6336699	Estimation	2.5	42
10-Dec-04	Stream1 @ Vaughan Rd	2798219 6336609	Meter	3.671	43
8-Dec-04		2798137 6336509	Estimation	1.5	44
8-Dec-04		2798100 6336489	Estimation	1	45
8-Dec-04		2797901 6336309	Estimation	0.3	46
8-Dec-04		2797884 6336301	Estimation	0.75	47
8-Dec-04		2797871 6336281	Estimation	0.005	48
8-Dec-04		2797861 6336276	Estimation	1.5	49
8-Dec-04		2797710 6336164	Estimation	0.005	50
2-Feb-05		2797671 6336113	Visual	3	51
2-Feb-05		2797476 6335968	Meter	24	52
8-Dec-04		2797152 6335646	Estimation	0.05	53
10-Dec-04	Stream by Mill	2796987 6335247	Visual	0	54
2-Feb-05		2796752 6335136	Visual	10	55
8-Dec-04		2795972 6336106	Visual	0	56
8-Dec-04		2795694 6336133	Visual	0	57
8-Dec-04		2795660 6336157	Estimation	5.5	58
8-Dec-04		2795543 6336187	Visual	0	59
8-Dec-04		2795248 6336320	Visual	0	60
8-Dec-04		2795014 6336511	Visual	0.01	62
8-Dec-04		2794797 6336520	Estimation	0.75	63
8-Dec-04		2794777 6336645	Estimation	1.5	64
7-Nov-04	Utuhina @ Lake Front	2794685 6336726	Meter	1692	65
2-Feb-05		2794542 6336918	Visual	0.1	66
8-Dec-04		2794479 6336959	Visual	0	67
8-Dec-04		2794414 6337027	Estimation	0.3	68
8-Dec-04		2794313 6337115	Estimation	4	69
8-Dec-04		2794316 6337177		0	70

Date	Site	GPS Co-ordinates	Guage Type	Discharge L/sec	Lake-edge feature number
8-Dec-04		2794231 6337608		0.3	71
7-Dec-04	Waiowhiro @ Lake	2794085 6339258	Meter	298	72
7-Dec-04	Culvert 13.85	2801596 6345871	Visual	0	76
7-Dec-04	Culvert 13.81	2801547 6345679	Visual	0	77
7-Dec-04	Culvert 13.51	2801290 6345876	Visual	0	78
7-Dec-04	Culvert 13.28	2801135 6346065	Visual	0	79
7-Dec-04	Culvert 13.18	2801108 6346099	Visual	0	80
7-Dec-04	Culvert 13.04	2800980 6346199	Visual	0	81
7-Dec-04	Culvert 12.97	2800904 6346248	Visual	0	82
7-Dec-04	Culvert 12.91	2800873 6346274	Visual	0	83
7-Dec-04	Culvert 12.82	2800815 6346309	Visual	0	84
7-Dec-04	Culvert 12.72	2800734 6346369	Visual	0	85
7-Dec-04	Culvert 12.62	2800633 6346415	Visual	0	86
7-Dec-04	Culvert 12.58	2800592 6346428	Visual	0	87
7-Dec-04	Culvert 12.43	2800455 6346426	Visual	0	88
7-Dec-04	Culvert 12.38	2800286 6346419	Visual	0	89
7-Dec-04	Culvert 12.11	2800141 6346399	Visual	0	90
7-Dec-04	Culvert 12.08	2800103 6346392	Visual	0	91
7-Dec-04	Culvert 11.94	2799983 6346372	Visual	0	92
7-Dec-04	Culvert 11.83	2799876 6346360	Visual	0	93
7-Dec-04	Culvert 11.60	2799672 6346447	Visual	0	94
7-Dec-04	Culvert 11.55	2799625 6346450	Visual	0	95
7-Dec-04	Culvert 11.47	2799552 6346442	Visual	0	96
7-Dec-04	Culvert 11.39	2799483 6346490	Visual	0	97
7-Dec-04	Culvert 11.28	2799389 6346500	Visual	0	98
7-Dec-04	Culvert 11.24	2799354 6346520	Visual	0	99
7-Dec-04	Culvert 11.19	2799295 6346542	Visual	0	100
7-Dec-04	Culvert 11.07	2799153 6346555	Visual	0	101
7-Dec-04	Culvert 11.01	2799139 6346573	Visual	0	102
7-Dec-04	Culvert 10.90	2799033 6346600	Visual	0	103
7-Dec-04	Culvert 10.84	2798984 6346624	Visual	0	104
7-Dec-04	Culvert 10.74	2798899 6346654	Visual	0	105
7-Dec-04	Culvert 10.59	2798761 6346670	Visual	0	106
7-Dec-04	Culvert 10.55	2798723 6346689	Visual	0	107
7-Dec-04	Culvert 10.50	2798683 6346670	Visual	0	108
7-Dec-04	Culvert 10.42	2798625 6346636	Visual	0	109
7-Dec-04	Culvert 10.29	2798527 6346616	Visual	0	110
7-Dec-04	Culvert 10.22	2798521 6346615	Visual	0	111
7-Dec-04	Culvert 10.13	2798377 6346674	Visual	0	112
7-Dec-04	Culvert 10.02	2798376 6346676	Visual	0	113
7-Dec-04	Culvert 9.91	2798256 6346765	Visual	0	114
7-Dec-04	Culvert 9.84	2798254 6346770	Visual	0	115
7-Dec-04	Farm Culvert @ 961 Hamurana Rd	2797888 6346808	Visual	0	116
7-Dec-04	Stormwater Culverts @ Unsworth Rd	2797857 6346843	Visual	0	117
7-Dec-04	Culvert 9.18	2797577 6346874	Visual	0	118
7-Dec-04	Culvert 9.06	2797454 6346901	Visual	0	119
7-Dec-04	Culvert 8.80	2797207 6346955	Visual	0	120
7-Dec-04	Culvert 8.42	2796861 6347013	Visual	0	121
7-Dec-04	Culvert 8.32	2796761 6347022	Visual	0	122

Date	Site	GPS Co-ordinates	Guage Type	Discharge L/sec	Lake-edge feature number
7-Dec-04	Culvert 8.16	2796596 6346976	Visual	0	123
7-Dec-04	Culvert 8.04	2796504 6346936	Visual	0	124
7-Dec-04	Culvert 7.98	2796439 6346915	Visual	0	125
7-Nov-04	Waignaehe @ Lwr Left Branch	2799228 6337221	Meter	99.67	126
7-Dec-04	Waiohewa @ Lake Edge	2801578 6341448	Meter	364	127
7-Dec-04	Basley Rd @ Lake Front	2797518 6335884	Meter	33	128
7-Dec-04	Lynmore @ Lake front	2797113 6335257	Meter	40	129
7-Dec-04	Ohinemutu @ St Faiths		Meter	5	130
8-Dec-04	200m west of hamurana river	2796149 6346846	Visual	0	131
8-Dec-04	Culvert 250m west of toilet block	2795879 6346854	Estimation	0.016	132
8-Dec-04	Culvert 100m west of toilet block	2795895 6346868	Visual	0	133
8-Dec-04	Culvert 250m east of playground	2795715 6346851	Estimation	0.5	134
8-Dec-04		2801340 6339536	Meter	2.7	135
8-Dec-04		2801340 6339536	Meter	184.4	136
8-Dec-04		2793940 6339377	Visual	0	137
8-Dec-04		2801382 6339934	Estimation	1	138
8-Dec-04		2793655 6339602	Estimation	2.5	139
8-Dec-04		2801388 6339952	Estimation	3	140
8-Dec-04		2801403 6339989	Visual	0	141
8-Dec-04		2801459 6340031	Estimation	1	142
8-Dec-04	Culvert 5.81	2794479 6346857	Visual	0	143
8-Dec-04	Culvert 5.71	2794409 6346812	Estimation	3	144
8-Dec-04		2801474 6340037	Estimation	1	145
8-Dec-04		2801496 6340076	Estimation	4	146
8-Dec-04		2801517 6340101	Visual	0	147
8-Dec-04		2801588 6340188	Estimation	15	148
8-Dec-04	Culvert 5.61	2794077 6346759	Visual	0	149
8-Dec-04		2792911 6340446	Estimation	0.5	150
8-Dec-04		2792895 6340474	Visual	0	151
8-Dec-04		2801596 6340270	Estimation	5	152
8-Dec-04		2792813 6340593	Visual	0	153
8-Dec-04		2801671 6340462	Visual	0	154
8-Dec-04		2792677 6340901	Estimation	3	155
8-Dec-04		2792597 6341106	Visual	0	156
8-Dec-04		2792569 6341130	Estimation	0.25	157
8-Dec-04		2792543 6341170	Visual	0	158
8-Dec-04		2792522 6341223	Estimation	0.3	159
8-Dec-04		2792522 6341224	Visual	0	160
8-Dec-04		2792506 6341249	Visual	0	161
8-Dec-04		2792504 6341275	Visual	0	162
8-Dec-04		2792500 6341292	Estimation	<0.25	163
8-Dec-04		2792476 6341437	Estimation	<0.25	164
8-Dec-04		2792466 6341501	Estimation	0.5	165
8-Dec-04		2792460 6341642	Estimation	<0.1	166
8-Dec-04		2792468 6341914	Visual	0	167
8-Dec-04	Culvert 3.10	2792376 6345624	Estimation	0.25	168
8-Dec-04		2792343 6342284	Visual	0	169
8-Dec-04	Culvert 3.58	2792784 6345850	Estimation	1	170
8-Dec-04		2792300 6342450	Estimation	<0.25	171

Date	Site	GPS Co-ordinates	Guage Type	Discharge L/sec	Lake-edge feature number
8-Dec-04	Culvert 3.28	2792521 6345709	Estimation	0.06	172
8-Dec-04		2801807 6342320	Visual	0	173
8-Dec-04	Culvert	2792278 6342617	Estimation	2	174
8-Dec-04	Culvert	2792291 6342725	Estimation	0.5	175
8-Dec-04	Stream @ Maxwell Rd	2792703 6345024	Estimation	2	176
8-Dec-04		2795133 6336391	Estimation	0.3	177
8-Dec-04		2792322 6343059	Estimation	0.5	178
8-Dec-04		2792349 6343089	Estimation	0.25	179
8-Dec-04		2792430 6343157	Estimation	0.25	180
8-Dec-04		2792385 6343237	Estimation	0.5	181
8-Dec-04		2792388 6343242	Estimation	0.1	182
8-Dec-04		2792360 6343268	Estimation	0	183
8-Dec-04	Mokoia Rd Culvert	2792210 6343994	Meter	15	184
8-Dec-04		2792330 6343920	Estimation	0.1	185
8-Dec-04	Spring @ 89 Mokoia Rd	2792418 6344419	Estimation	0.01	186
8-Dec-04		2795343 6336187	Visual	0	187
8-Dec-04		2795168 6336359	Visual	0	188
10-Dec-04	Awahou Stm @ Mouth	2793019 6345019	Meter	1176	189
10-Dec-04	Waiteti Stm @ Mouth	2792299 6342879	Meter	1030	190
10-Dec-04	Ngongotaha @ Mouth	2792493 6341799	Meter	1372	191
10-Dec-04	Puarenga @ SH 30 Bridge		Meter	1767	192
2-Feb-05		2795406 6346818	Visual	0.005	19a
2-Feb-05			Visual	0.01	20a
2-Feb-05		2795516 6346806	Visual	0.005	20b
8-Dec-04	585 Hamurana Rd	2794275 6346776	Meter	3	17a
8-Dec-04	Ward Rd Culvert	2794780 6346905	Volumetric	0.281	18a
8-Dec-04	Culvert 6.47	2794978 6346940	Estimation	1	18c
8-Dec-04	Culvert 6.58	2795077 6347002	Volumetric	0.167	18c
8-Dec-04	Culvert 7.11	2795619 6347027	Volumetric	0.081	18d
8-Dec-04	Culvert 6.37	2795120 6346970	Meter	1	18d
2-Feb-05				0	21a
7-Dec-04	Waiteti @ TGA Direct Rd Bridge	2791550 6342880	Meter	1116	RLNBR
7-Dec-04	Awahou @ TGA Direct Rd Bridge	2792220 6345370	Meter	1530	RLNBR
7-Dec-04	Waiowhero @ Bonningtons Farm	2793540 6338800	Meter	303	RLNBR
7-Dec-04	Utuhina @ SH 5 Bridge	2794200 6336398	Meter	1749	RLNBR
7-Dec-04	Puarenga @ Hemo Gorge	2794720 6331380	Meter	1796	RLNBR
7-Dec-04	Puarenga @ F.R.I	2796120 6333320	Meter	2055	RLNBR
7-Dec-04	Hamurana St @ Hamurana Rd Bridge	2796290 6346880	Meter	2543	RLNBR
7-Dec-04	Lynmore St @ Vaughan Rd Culvert	2797470 6334840	Meter	43	RLNBR
7-Dec-04	Basley Rd @ Vaughan Rd Culvert	2797930 6335280	Meter	9	RLNBR
7-Dec-04	Waingaehe @ SH 30	2800300 6336840	Meter	216	RLNBR
7-Dec-04	Waiohewa @ SH 30	2801850 6341620	Meter	360	RLNBR