Preliminary Hydrogeological Investigations - Four Northland Aquifers

GLENBERVIE GROUNDWATER RESOURCE

- Report prepared for Northland Regional Council
- Final
- February 2005

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1. Introduction

Sinclair Knight Merz were commissioned by Northland Regional Council to provide preliminary hydrogeological assessments for four Northland aquifers – Mangawhai, Coopers Beach, Three Mile Bush and Glenbervi.e., These aquifers are recognised in the Northland Regional Water and Soil Plan as being “at-risk” aquifers with respect to groundwater demand and water quality issues (NRC, 2004).

The information obtained from this preliminary hydrogeological study will assist the Northland Regional Council (NRC) to effectively manage allocation of the groundwater resource.

The specific objectives of the study include the following:

- Develop an understanding of the aquifer hydrogeology (groundwater recharge, hydraulic characteristics and discharge dynamics)
- Provide a preliminary estimation of the sustainable yield
- Identify information gaps and recommend future actions to enable the sustainable management of the groundwater resource.

This report provides an assessment of the Glenbervie groundwater resource. The Regional Water and Soil Plan has classified the Glenbervie basalt aquifer as being “at-risk” based on the high actual or potential demand for groundwater.

2. Background Information

2.1 Site Location and Description

The Glenbervie basalt aquifer is located approximately 3 km west of Kamo township. The aquifer is approximately 1 km wide and 6 km long, and was emplaced and constrained within an old valley system extending towards the coastline. Most of the study area is relatively flat, with steep slopes along the edge of the basalt down to the bordering streams and surrounding geology. There are two scoria cones, Pukepoto and Puketotara, forming hills of up to 220 m elevation within the study area. The total study area is 8.7 km^2.

Groundwater is used for horticultural irrigation and as a supplementary domestic supply. The aquifer is classified as "at-risk" based on the high actual or potential demand for groundwater for horticultural irrigation. The abstraction of groundwater from the basalt has the potential to reduce spring and stream flow from the basalt.

- **Figure 1. Locality plan.**

(see A3 attachment at rear).

2.2 Regional Geology

The geology of the Glenbervie area is described on the 1:25,000 Geological Map Sheet 26 for the Whangarei Urban Area, and is reproduced in Figure 2. Part of the study area that is beyond the limits of the 1:25,000 map is described on the 1:250,000 Geological Map Sheet 2A for Whangarei (Thompson, 1961; White and Perrin, 2003).

The Glenbervie basalt is part of the Puhipuhi-Whangarei Volcanic Field and formed as a result of volcanic activity along the east-west oriented Ngunguru Fault. The lava flowed from two eruptive vents, marked by the Pukepoto and Puketotara scoria cones within the study area, and was emplaced and constrained within a pre-existing valley. The Pukepoto scoria and lava has been radiometrically dated at approximately 0.3 million years. The basalt is intermediate in composition (quartz tholeiite), alternating vesicular and non-vesicular (indicating a number of basalt flows), and sparsely to moderately porphyritic (Rollin, 1991; White and Perrin, 2003).

The Glenbervie basalt overlies and is flanked along the northern edge by hard Waipapa Terrane basement rock of Permian to Late Jurassic age (295 to 145 million years before present). The Waipapa Terrane consists of sheared and veined massive grey sandstone (greywacke) and interbedded sandstone and argillite, with scattered areas of hard reddish chert (White and Perrin, 2003). The greywacke has been uplifted beneath the study area along the Ngunguru Fault, which is concealed beneath the Glenbervie basalt.

Late Eocene to Early Oligocene age (37 to 28.5 million years before present) sedimentary rocks of the Te Kuiti Group unconformably overlie the greywacke basement rocks on the downthrown (southern) side of the Ngunguru Fault. These rocks consist of conglomerate, sandstone, mudstone and coal (Kamo Coal Measures) and blue to green-grey glauconitic, calcareous muddy sandstone (Ruatangata Sandstone). Shell fragments and foraminifera are common in the Ruatangata Sandstone, which may also include a basal conglomerate or limestone layer (White and Perrin, 2003).

Alluvial and swamp deposits overlie the basement and sedimentary rocks within the valleys surrounding the study area. These deposits consist of carbonaceous mud, peat, sand and minor gravel of Pleistocene to Recent age (1.8 Ma to present). Alluvial silts and ash also occur in places beneath the basalt within the old valley (Rollin, 1991).

- **Figure 2. Regional geology.**

(see A3 attachment at rear).

2.3 Drillers Borelogs

There are fifty-one boreholes registered on the NRC bore database for the Glenbervie study area. It is likely there are additional bores located within the study area that are not registered with the NRC, however no bore survey has been undertaken to confirm the total number of bores in the area. A summary of the relevant bore construction and hydraulic test details are included in Appendix A and Figure 1 shows their approximate locations.

The bores range between 11 and 196 m depth, with the base of the basalt intercepted in thirteen of the bores at between 31 and 107 m depth. The bores are 75 to 100 mm in diameter and are generally open (unscreened) through the basalt. Yields range from 10 to 264 m^3/day. In a few cases the bores have been abandoned or blasted to enhance yields (i.e., bore 205315 and 205325). The greatest yields are encountered where fractures are present, which are generally near the base of the basalt. The extent of fracturing does not appear to be widespread, however only a few bores extend to the base of the basalt or have enough detail on the borelog to confirm this.

Some logs have brief comments relating to water quality. The water quality in the basalt is generally good, except where the bores are screened through the overlying soils or penetrate into the underlying sediments. In these cases the borelogs have comments relating to iron discolouration, soda water or bacteria.

2.4 Hydrology

The basalt aquifer is bordered by the Ngunguru River and Putunui Stream on the northern side, Waitangi River on the southern side, and Mangakino Stream on the western side. These streams are partly spring fed from the basalt. Spring and stream low-flow has been monitored by the NRC on a number of occasions since 1971. Table 1 summarises the low flow monitoring sites and the locations are shown on Figure 3.

Spring flow from the basalt ranges between 0.07 L/s and 5.9 L/s during low flow conditions, while stream low flow ranges between 0.01 L/s and 311 L/s.

- **Table 1. Stream and spring low-flow monitoring.**

River	Type	Site name	Period of monitoring	Flow (L/s)
Taheke River tributary	Spring	Harris Spring	Feb – May 93	0.07 – 3.0
Mangakino spring	Spring	Van der Hayden spring	Oct 83	3.4
Ngunguru River tributary	Spring	Andrews/Knight spring	Jan 82	4.4 – 5.9
Ngunguru River tributary	Spring	Batts spring	Nov 82	0.8
Ngunguru River tributary	Spring	Capsticks spring	Dec 91 – Jan 92	3.6 – 4.4
Ngunguru River	Stream	Howel d/s	Mar 78 – Feb 79	3.6 – 7.8
Ngunguru River tributary	Stream	Grassy meander	Jan 82	8.1 – 9.8
Ngunguru River tributary	Stream	Scotts gum trees	Sep 77	18.6
Ngunguru River tributary	Stream	Scotts mossy glade	Oct 77	15.3
Ngunguru River tributary	Stream	Capstick's	Dec 91 – Jan 92	6.4 – 9.1
Taheke River tributary	Stream	Kimber drain	Jan 82	0.7
Waitangi Stream	Stream	Ngunguru Rd	Jan 77 – Feb 94	16.8 – 208
Waitangi Stream	Stream	Waitangi Stream	Mar 73	0.7
Waitangi River	Stream	Waitangi River 1	Dec 71 – Apr 72	2.4 – 25.8
Waitangi River	Stream	Waitangi River 2	Mar 74	0.1
Waitangi River	Stream	Old weir	Dec 80 – Jan 87	87.4 - 243
Waitangi River	Stream	Pennington	Feb 74	32.4
Waitangi River	Stream	Gates	Dec 85 – Jan 92	44.1 - 272
Waitangi River	Stream	Waitangi Rd	Feb 86 – Feb 94	42.3 - 311
Waitangi River tributary	Stream	Bell	Feb 83	0.3
Waitangi River tributary	Stream	Kimber water supply	Jan 82	0.4
Waitangi River tributary	Stream	Kimber waterfall	Jan 82	0.4
Waitangi River tributary	Stream	Edginton Rd	Dec 71 – Jan 77	1.1 – 14.7
Waitangi River tributary	Stream	u/s Huanui dam	Dec 93 – Feb 94	1.6 – 2.3
Whitingaramara	Stream	Harris	Jan 91 – Jan 92	0.01 – 0.18

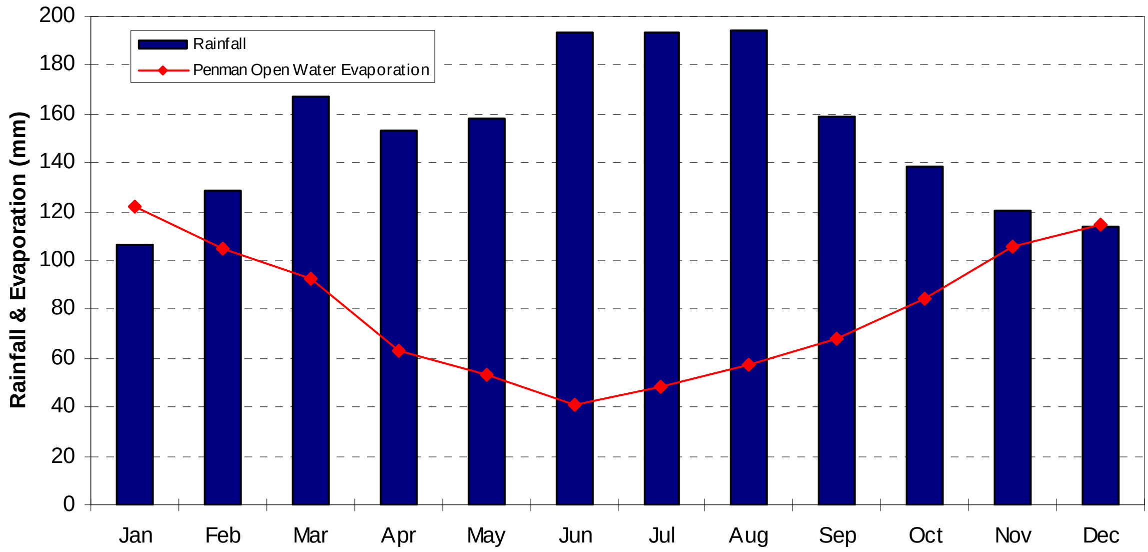
- **Figure 3. Existing consents & monitoring locations.**

(see A3 attachment at rear).

2.5 Rainfall and Evaporation

Figure 4 shows mean monthly rainfall for Glenbervie Forest Headquarters at Hatea (Station 546301) for the period 1947 to 2000, and mean monthly Penman Open Water evaporation for

Whangarei Aero AWS (Station A54737) for the period 1992 to 2004 (missing data 1993 to 1994). The annual average rainfall is 1,870 mm. Rainfall exceeds evaporation for all months except January and December, indicating the availability of water for groundwater and surface water recharge for most of the year.



- **Figure 4. Mean monthly rainfall and evaporation.**

2.6 Groundwater Abstraction

Table 2 summarises the consented groundwater take details. There are 17 consented groundwater takes ranging from 7 to 120 m^3/day. The total consented groundwater allocation is 704 m^3/day. Figure 3 shows the location of the consented groundwater takes.

Groundwater takes of less than 1 m^3/day within an "at risk" aquifer do not require a resource consent (NRC, 2004). Assuming that the remaining 35 bores on the NRC bore database[1] that do not have consented allocations are using their permitted water right, the total groundwater allocation for the Glenbervie aquifer would be 739 m^3/day.

The total groundwater allocation for the aquifer is unlikely to reflect actual groundwater use. A survey to identify all existing bores in the study area, as well as a review of water use records is required before this can be determined.

▪ **Table 2. Existing groundwater consents.**

NRC No.	Name	Allocation (m^3/day)	Bore depth (m)	Expiry date	Purpose
20000195201	LA Sowry	48	27.4	31/05/2012	Horticultural Irrigation
20000728001	D Agassis	7		31/05/2012	Horticultural Irrigation
20000890901	CG Davidson	12	60.5	31/05/2012	Horticultural Irrigation
20010159801	TD Strachan	120	53.0	31/05/2012	Horticultural Irrigation
20010213501	DM McNaughton	76	59.0	31/05/2011	Horticultural Irrigation
20010270901	CS & MA Wrack Family Trust	60	50.0	31/05/2011	Horticultural Irrigation
20010286801	HJ Nyhuis	15	30.5	31/05/2012	Horticultural Irrigation
20010289601	Huanui Orchards	100	46.1	31/05/2012	Horticultural Irrigation
20010417601	RD MacLean	35	103.0	30/11/2010	Horticultural Irrigation
20010458801	TG Dunsbee	15	92.0	31/05/2012	Horticultural Irrigation
20010492501	CS Robertson	10	87.0	31/05/2011	Private Water supply
20010724201	HF Stunzner	28	63.0	31/05/2011	Horticultural Irrigation
20020209401	ZE Charlton	30	67.0	31/05/2012	Horticultural Irrigation
20020485301	CW Green	30	67.0	31/05/2012	Horticultural Irrigation
20020718001	Bee & Gee Investments Ltd	30	16.5	31/05/2011	Horticultural Irrigation
20020796101	Huanui Orchards	38	50.0	31/05/2012	Horticultural Irrigation
20030230601	JPM Moolenschot	50	21.6	31/05/2012	Horticultural Irrigation
	Total consented allocation	**704**			
	35 permitted takes of 1 m^3/day	35			
	Total GW allocation	**739**			

2.7 Surface Water Abstraction

There are 7 consented surface water takes located within the Glenbervie study area (Figure 3). The individual consent allocations range between 5 and 340 m^3/day, with a total consented allocation of 753 m^3/day.

The total permitted surface water take for reasonable domestic needs is 2 m^3/day (NRC, 2004). There are 18 consents on the NRC consent database that have been either cancelled, withdrawn or not renewed. Assuming that these consents are using their permitted water right, the total surface water allocation for the study area would be 789 m^3/day.

[1] Includes 2 bores that are not on the NRC bore database (ie. have drillers borelogs) but for which the NRC have aquifer test information.

Similar to the groundwater allocation, the surface water allocation may not represent the actual surface water abstraction for the area, as a review of all users and water use has not been carried out. It is likely that during extended dry periods the surface water allocation estimate may be underestimated.

The potential for surface water recharge of the groundwater system is expected to be minimal, due to the general confinement of the streams around the boundary of the basalt and the low conductance nature of the underlying stream geology (i.e., alluvium, greywacke). However, a reduction in spring flow from the basalt due to declining groundwater levels has the potential to affect downgradient surface water users.

- **Table 3. Existing surface water consents.**

NRC No.	Name	Allocation (m^3/day)	Expiry date	Purpose
19940715101	GP Hansen	40	31/05/2005	Horticultural Irrigation
19960194601	Putanui Water Association Limited	340	31/05/2004	Horticultural Irrigation
19990718601	DE & ER Hosking Family Trust	68	31/05/2008	Horticultural Irrigation
20000169701	Kiripaka Orchards Limited	110	31/05/2015	Horticultural Irrigation
20000717101	DE & ER Hosking Family Trust	90	31/05/2008	Horticultural Irrigation
20020255201	Stanton Community Water Supply	50	31/05/2022	Private Water supply
20030875401	DV Robertson	50	31/05/2005	Horticultural Irrigation
19900279001	Westwood Farms	5	Permitted	Horticultural Irrigation
	Total consented allocation	**753**		
	18 permitted takes of 2 m^3/day	36		
	Total SW allocation	**789**		

3. Aquifer Conceptualisation

3.1 Aquifer Lithology

Borelogs from the NRC bore database show the site geology to generally consist of the following:

- Dark brown clay up to 12 m thick with occasional basalt and scoria boulders and thin grey ash layers (volcanic soil).
- Soft brown and hard grey basalt up to 45 m thick (weathered basalt). Occasional red scoria layers up to 6 m thick are present in some bores above and/or below the weathered basalt. The presence of scoria layers within the basalt is indicative of a series of basalt flows over the eruptive period.
- Hard, grey vesicular and non-vesicular basalt up to 60 m thick with occasional fracturing. The extent and location of fracturing is variable, and fractures are infilled with clay in some places. There are also occasional thin lenses (>0.5 m thick) of grey volcanic ash.
- Ash or sand and silt up to 10 m thick (alluvium) underlying the basalt.
- Brown or grey greywacke basement rock (weathered Waipapa Terrane).

These geological descriptions are consistent with the regional geology described in Section 2.2.

The depth to the base of the aquifer varies from 31 to 107 m below ground. The thickest parts of the basalt are in the general proximity of the scoria cones and along the centre of the lava flow (Rollin, 1991). Table 4 summarises the details of those bores drilled through the base of the basalt.

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- **Table 4. Depth to base of basalt.**

Bore	Name	Depth of bore (m)	Depth to base of basalt (m)	Basalt thickness (m)
205321	Z Charlton	60	52.5	33.5
205329	B Sowry	63	54.0	46.5
205331	Plaisted	46	39.0	32.0
205334	Plaisted	46	31.3	23.1
205367	F Johnson	196	86.5	86.5
205368	DSIR	87	86.5	86.5
205375	A Mollard	107	107.0	105.0
205532	G Parker	76	75.5	66.1
205575	Plant World	64	43.6	40.6
205576	D Knight	61	56.0	56.0
205594	C Green	67	59.0	56.5
205597	F Johnson	87	83.0	72.5
205832	S Culham	44	43.0	41.0
	AVERAGE		62.8	57.4

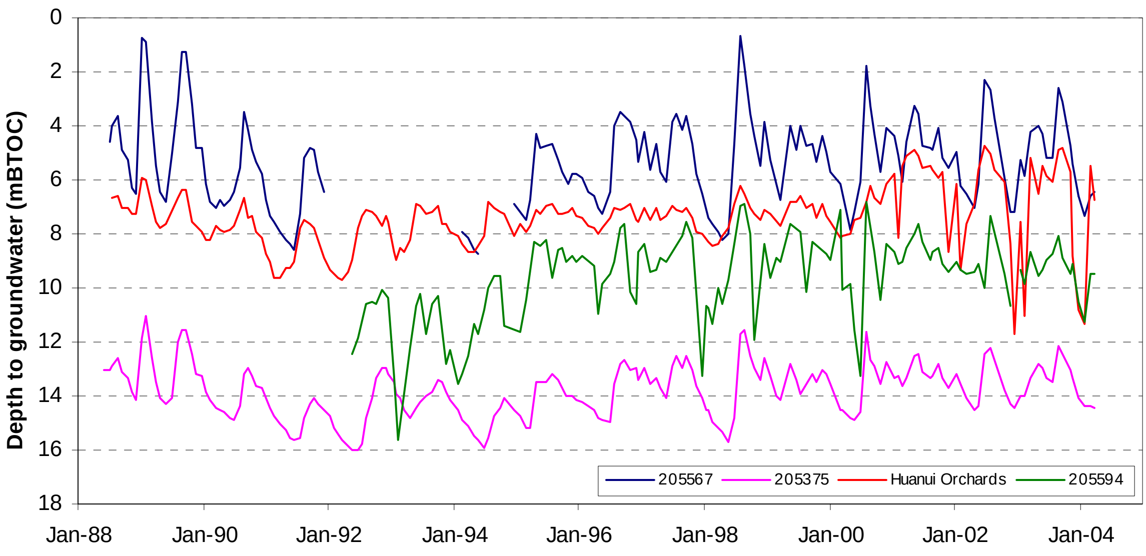
3.2 Groundwater Levels

Groundwater levels have been monitored in four bores since 1988. Table 5 summarises the bore details and monitoring frequency and Figure 5 shows the groundwater hydrographs for each bore. The locations of the groundwater monitoring bores are shown on Figure 3.

Groundwater levels for the four monitoring bores range between 0.5 m and 16 m below ground level (mBGL). The groundwater level in each monitoring bore fluctuates over a 4 to 8 m range. Depth to groundwater for other bores in the area, obtained from the drillers logs, varies between 0.6 and 34 mBGL.

- **Table 5. Groundwater level monitoring bore details.**

Bore	Name	Bore depth (m)	Period of record	Frequency of monitoring
205567	Wrack	50	1988 - 2004	Monthly
205375	Mollard	107	1988 - 2004	Monthly
-	Huanui Orchards	67	1988 - 2004	Monthly
205594	Green	46.1	1992 - 2004	Monthly



- **Figure 5. Groundwater hydrographs.**

3.3 Piezometric Surface

Figure 6 shows the piezometric surface distribution for the basalt aquifer, which was constructed from depth to groundwater information contained in drillers borelogs, NRC water level monitoring data and estimated ground level elevations. Groundwater elevations along the streams were assigned ground level elevation to represent the locations of springs.

Groundwater pressures range from 53 mAMSL along the eastern boundary of the site to 123 mAMSL beneath Pukepoto scoria cone. The groundwater flow direction is from the higher elevation ground in the proximity of the two scoria cones towards the edge of the basalt.

- **Figure 6. Piezometric surface.**

(see A3 attachment at rear).

3.4 Aquifer Hydraulic Properties

Information on aquifer hydraulic properties is available from aquifer test pumping exercises conducted on 7 bores in the study area by the Northland Catchment Commission (now NRC). The hydraulic properties are summarised in Table 6.

Transmissivity of the basalt ranges between 0.2 and 39 m^2/day. Although the drillers borelog information is limited, the higher transmissivity values generally occur where the basalt is weathered (i.e., bore 205323) or highly fractured. The drawdown in bore 205368 increased dramatically after 23 hours pumping, most likely reflecting the presence of a no-flow boundary such as the edge of the basalt (located approximately 600 m from the bore) or a reduction in the fracture connectivity. The pumping test did not continue past 24 hours to better ascertain the cause of the drawdown increase.

Hydraulic conductivity was estimated from the saturated thickness of the aquifer and the transmissivity, and ranged between 0.005 and 0.6 m/day. These values are consistent with, although are at the less permeable end of literature values for basalt (Freeze and Cherry, 1979).

- **Table 6. Summary of aquifer hydraulic properties.**

Bore	Name	Bore depth (m)	Casing depth (m)	Saturated thickness (m)	Q (m^3/day)	T (m^2/day)	K (m/day)
205294	Van der Heyden	56.6	6.5	41.1	70 - 136	0.2 - 3.6	0.005 – 0.09
205322	Strachan	38.5	6.5	36.1	59 - 239	1.8 – 8.2	0.05 – 0.23
205323	Hutchinson	32.0	18.0	29.9	64	12.1 – 17.5	0.40 – 0.59
-	Hutchinson	34.5	18.0	29.9	139	2.2 – 9.6	0.07 – 0.32
205368	Mentieth Park	86.5	37.0	80.4	50 - 200	3.6 – 5.6	0.04 – 0.07
205375	Mollard	107.0	-	80.5	115 - 130	4 - 39	0.05 – 0.48
-	McNaughton	50	-	36.6	76	7.8 - 12	0.21 – 0.33
	AVERAGE			47.8		9.1	

3.5 Groundwater Recharge

The main mechanism for groundwater recharge to the basalt aquifer is most likely rainfall recharge directly onto the surface of the volcanic soils/rock. It is probable, due to the extensive clay layer above the fresh basalt that the bulk of the aquifer recharge occurs at the scoria cones.

Annual average rainfall recharge to the basalt and scoria cones has been estimated separately in this study based on different rainfall recharge coefficients. Annual average rainfall recharge to the basalt has been estimated as 2,000 m^3/day to 6,100 m^3/day, based on a basalt surface area of 7.92 km^2, average annual rainfall of 1,870 mm, and an average annual recharge coefficient of 5% to 15%. Annual average rainfall recharge to the scoria cones has been estimated as 2,100 m^3/day to 2,600 m^3/day, based on a volcanic cone area of 0.78 km^2 and an average annual recharge coefficient of 55% to 65%. Total combined annual average rainfall recharge to the basalt aquifer is estimated as 4,200 m^3/day to 8,700 m^3/day. Table 7 summarises the parameters used in the assessment of groundwater recharge.

The lower magnitude of recharge for the basalt (5% to 15%) accounts for the low permeability of the overlying soils (weathered basalt) and the proportion of rainfall recharge lost through soil evaporation and plant uptake before reaching the basalt. The wide range for both recharge coefficients indicates the uncertainty involved in estimation of the recharge coefficient, without more detailed modelling.

- **Table 7. Estimated daily groundwater recharge.**

Area	Recharge area (m^2)	Average annual rainfall (mm)	Rainfall recharge (m/yr)	Average daily recharge (m^3/day)
Scoria cones	7.8×10^5	1,870	1.0285 – 1.2155	2,198 – 2,598
Basalt	7.92×10^6	1,870	0.0935 – 0.2805	2,029 – 6,086
TOTAL	8.70×10^6			4,227 – 8,684

3.6 Groundwater Discharge

An assessment of groundwater discharge has been calculated from the hydraulic properties shown in Table 6, and the piezometric surface shown in Figure 6. Table 8 summarises the parameters used in the assessment of groundwater discharge.

The saturated thickness of the aquifer is assumed to be the average thickness of the basalt from the 7 bores shown in Table 6. The saturated thickness is 47.8 m. The average hydraulic conductivity of the aquifer has been estimated as 0.19 m/day based on the saturated thickness and transmissivity for the bores shown in Table 6. The hydraulic gradient for the aquifer is approximately 0.03 m/m.

Discharge for the aquifer has been estimated at 5,400 m^3/day. This is within the estimated recharge range of 4,200 to 8,700 m^3/day assessed in Section 3.5. The discharge calculation represents discharge from the entire perimeter of the aquifer.

It should be noted that the discharge estimate of 5,400 m^3/day may not represent the true value for the aquifer, due to the limited number of bores the aquifer properties and hydraulic gradient are based on. In particular, fractures within the basalt aquifer will impart a large anisotropy to the permeability of the aquifer that may not be encompassed in the limited number of aquifer test pumping exercises carried out.

- **Table 8. Estimated daily groundwater discharge.**

Average hydraulic gradient (m/m)	Average hydraulic conductivity (m/day)	Discharge area	Discharge volume (m^3/day)
0.03	0.19	19.9 km × 47.8 m	5,422

3.7 Groundwater Quality

The NRC has monitored groundwater quality in two bores since 1996. Table 9 summarises the groundwater quality results and the location of the bores is shown on Figure 3.

Values in Table 9 that exceed the Drinking Water Standards for New Zealand (DWSNZ) published by the Ministry of Health (2000) are highlighted in red. Exceedances occur for the following list of parameters (guideline values in brackets):

- Colour (10 TCU)
- Iron (0.2 mg/L)
- Manganese (0.05 mg/L)
- pH (7.0 – 8.5)
- *Escherischia coli* (<1 cfu/100mL)

Colour, iron, manganese and pH in the Strachan bore (bore 205322) exceed the aesthetic Guideline Value (GV) under the DWSNZ. Exceedance of the GVs for aesthetic determinands indicates that the groundwater has an unpleasant taste and appearance. Elevated iron and manganese has the potential to cause “rusting” of bore and plumbing fixtures, while the low pH is potentially corrosive. *Escherischia coli* (E.coli) in the Strachan bore exceeds the Maximum Acceptable Value (MAV) for micro-organisms of health significance under the DWSNZ.

The elevated parameters in the Strachan bore is most likely due to contamination from the overlying soil extending into the basalt. The casing in this bore extends approximately 0.7 m below the base of the topsoil and weathered rock.

The water quality in the Green bore (bore 205594) is generally good, apart from slightly low pH on occasions. The casing in this bore extends through the basalt into the underlying ash, clay and sandstone.

Figure 7 is a Piper Diagram of the major cations and anions (presented in milli-equivalents) for the latest monitoring round with a complete data set for each of the bores. The tri-linear diagram enables the water to be characterised in terms of its major constituents, which are governed by geologic and chemical processes.

Groundwater that has no dominant cations and is proportionally higher in bicarbonate is classified as Ca-HCO_3 type water. This type of water is relatively young recharging water that has not had time to dissolve rock minerals or mix with other water types. Both bores have this type of groundwater.

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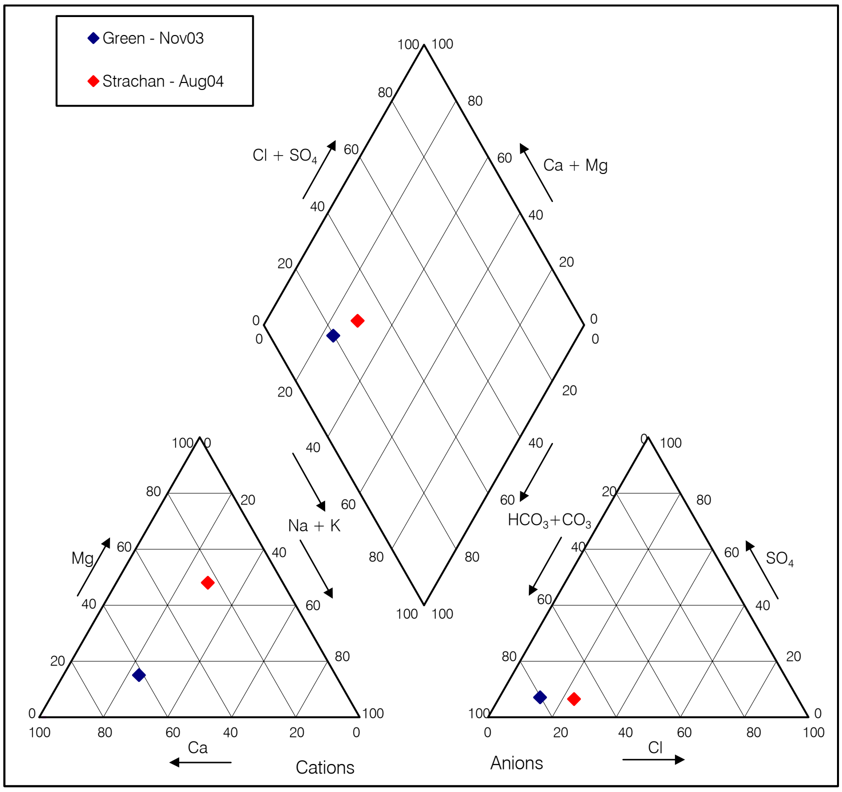
Table 9. Summary of groundwater quality results.

Parameter (mg/L)	Green (205594)				Strachan (205322)			
	Min	Max	Avg	Sampling rounds	Min	Max	Avg	Sampling rounds
Bicarbonate	35	163	131	5	93	124	112	7
Carbonate	146	146	146	1	91	120	102	5
Total alkalinity	38	186	155	24	99	99	99	1
Arsenic	<0.001	<0.001	<0.001	1				
Bromide	<0.01	0.1	0.07	27	<0.05	22.6	3.3	7
Calcium	<0.1	48	38	30	6.9	13.5	11.8	7
Chloride	13.3	43.0	15.7	30	<0.04	24.3	18.5	7
Colour (n/100mL)					10	1467	706	6
Conductivity (mS/m)	<19	46	32	30	26.4	28.1	27.1	6
Chromium	<0.0005	<0.0005	<0.0005	1				
Copper	0.0006	0.0006	0.0006	1				
Dissolved oxygen	1.3	6.5	3.4	13	1.3	2.2	1.8	2
DRP	<0.05	0.12	0.08	6	0.081	0.113	0.096	6
E.coli (MPN/100mL)					<1	96	17	7
Fluoride	<0.03	0.09	0.07	24	<0.05	0.07	0.06	7
Dissolved iron	<0.02	0.11	0.05	27	<0.02	14.2	2.18	7
Total hardness					94	99	97	3
Potassium	0.6	2.2	1.5	30	0.93	15.8	3.10	7
Magnesium	4.7	6.6	6.0	30	0.083	16.8	13.6	7
Dissolved manganese	<0.005	0.02	0.009	29	0.0018	0.1	0.07	7
Sodium	13.2	20.0	17.6	29	16.5	37.2	20.4	7
Ammoniacal-N	<0.01	1.1	0.05	29	<0.01	<0.04	<0.01	7
Nitrate-N	0.23	6.10	1.49	29	<0.002	0.008	0.005	2
Nitrite-N					0.106	1.72	0.808	7
Lead	0.0003	0.0003	0.0003	1				
pH (pH units)	6.5	8.5	7.3	30	6.9	7.5	7.3	7
Silica	23	29	25	28	14.6	36.7	32.0	7
Sulphate	6.1	13.9	10.9	30	0.13	9.8	7.2	7
Temperature (°C)	15.2	19.5	18.1	26	14.8	16.8	16.3	6
Total organic carbon					1.3	2.5	1.9	2
Total phosphorus					0.129	0.129	0.129	1



▪ **Figure 7. Groundwater chemical characterisation plot (Piper Diagram).**

3.8 Summary of Conceptual Aquifer Understanding

The conceptual understanding of the aquifer is as follows:

- The main mechanism for groundwater recharge to the basalt aquifer is rainfall recharge directly onto the surface of the volcanic soils/rock. Due to the thick clay layer over the basalt, recharge is most likely greatest through the scoria cones.
- Groundwater flow direction is from the higher elevation ground in the proximity of the Puketotara and Pukepoto scoria cones towards the basalt boundary.
- Estimates of hydraulic conductivity from aquifer test pumping exercises are at the lower end of the expected range of values for basalt, suggesting that the extent and connectivity of fractures and vesicles is relatively low. A number of bores drilled into the basalt were abandoned or blasted after drilling to increase the extent of fracturing and bore yield.
- Yields range from 10 m^3/day to 264 m^3/day (0.1 to 3.1 L/s). Some bores may experience a decline in yield after extended pumping periods due to a decline in fracture connectivity or proximity to the edge of the basalt.

- Groundwater quality within the basalt is good, with the exclusion of bores screened through the overlying soils or underlying sediments.

4. Assessment of Sustainable Yield

The sustainable yield of the aquifer is defined in this study as the volume of groundwater available for abstraction without compromising the performance of environmental ecosystems, such as spring flow.

Rainfall recharge represents the potential upper limit of water available for abstraction, without considering the ecosystem requirement. The groundwater recharge estimated in Section 3.5 ranged between 4,200 m^3/day and 8,700 m^3/day.

In the absence of detailed site-specific groundwater recharge investigations, 30% of groundwater recharge is generally set aside for maintaining environmental flows. An additional 30% is allowed for in this study for conservatism and to account for permitted surface water use (which is partly groundwater-fed). Therefore the sustainable yield of the aquifer is estimated at 40% of groundwater recharge. Using the groundwater recharge estimate of 4,200 m^3/day to 8,700 m^3/day, a sustainable yield of approximately 1,680 m^3/day to 3,480 m^3/day is provided for the Glenbervie aquifer.

Total water allocation for the aquifer is estimated as 1,528 m^3/day, which includes groundwater and surface water consents and permitted activities. This value is marginally below the most conservative estimate of sustainable yield within the range of sustainable yield and suggests that the aquifer is potentially nearing full allocation. However, there is currently no evidence of long-term decline in groundwater levels or water quality to confirm that the aquifer is potentially nearing full allocation.

5. Summary & Conclusions

This study provides a preliminary hydrogeological assessment of the Glenbervie basalt groundwater resource. The assessment is based on information contained in borelogs, aquifer test pumping exercises and NRC long-term monitoring data.

The basalt aquifer formed as a result of volcanic activity from two eruptive vents, marked by the Pukepoto and Puketotara scoria cones within the study area. The lava was emplaced and constrained within a pre-existing valley, of which the surrounding surface geology is comprised of greywacke basement rock (Waipapa Terrane) and sandstone, mudstone and conglomerate. The basalt ranges between 23 m and 105 m depth. Groundwater yields vary between 10 m^3/day and 260 m^3/day, depending on the extent of fracturing.

Groundwater levels vary between 0.5 and 34 mBGL, as assessed from drillers logs and NRC monitoring data. Groundwater pressures vary from 53 mAMSL along the eastern boundary to 123 mAMSL beneath Pukepoto scoria cone.

Groundwater quality within the basalt is generally good, however high bacteria, iron and manganese is common where the bores are screened close to or through the overlying soils or underlying sediments.

A preliminary assessment of sustainable yield based on estimated rainfall recharge suggests that the aquifer is near to or fully allocated. However, due to the uncertainties involved in the assessment of sustainable yield and the lack of evidence of declining groundwater levels and water quality, the amount of groundwater that is potentially allocated is uncertain.

The main issues potentially affecting the quality and quantity of groundwater in the study area includes the following:

- ***Abstraction*** – the preliminary assessment of sustainable yield is similar to current water allocation, which indicates that the aquifer is possibly fully allocated. Further abstraction may reduce spring and stream flow.
- ***Bore construction*** – bores screened close to or through the overlying soil and weathered rock or the underlying rocks may experience poorer water quality, including elevated iron, manganese and bacteria.
- ***Bore location*** – bores located close to the edge of the basalt may experience reduced yields after extended periods of pumping.
- ***Basalt permeability*** – the permeability of the basalt is relatively low compared to literature values, which suggests low fracture and vesicle connectivity and spacing. Some fractures are

infilled with clay. The yields of some bores may reduce after extended periods of pumping. New bores may require blasting to improve yields.

6. Recommendations

Based on the preliminary findings contained within this report, SKM recommend the following:

- Due to the aquifer being potentially fully allocated, and further horticultural development likely in the study area, a refinement of the sustainable yield is recommended in order to provide a more accurate assessment of the volume of groundwater available for allocation. A numerical model based on dynamic estimates of groundwater recharge would provide a better assessment of sustainable yield and may in fact determine that more water is available, especially since the analytical approach taken in this report was necessarily conservative.
- It is recommended that Council undertake concurrent monitoring of spring and stream flow at various locations immediately, should Council wish to commission a groundwater modelling exercise.
- Continuous (daily) groundwater level monitoring is recommended within at least two of the monitoring bores available, so that this data can be used in calibration of the groundwater model. Monitoring should continue through an extended dry period to allow the effects of abstraction to be better assessed.
- Soil infiltration tests are also recommended as they will also assist in refinement of the understanding of groundwater recharge dynamics, in particular on the scoria cones where it is considered that rainfall recharge is higher.
- It is considered that the four existing NRC groundwater level monitoring sites are sited appropriately for monitoring in the basalt aquifer, being well distributed across the site and of varying depths. One of the groundwater quality monitoring bores has elevated concentrations of iron, manganese, pH and *E.coli*, which has been attributed to contamination from the overlying soil. The casing in this bore (205322) extends approximately 0.7 m below the base of the topsoil and weathered rock. It is recommended that a replacement bore that is cased deeper into the unweathered basalt (and preferably cement grouted) be sampled for groundwater quality. Bore 205324, located in the same general proximity of the Strachan bore may be appropriate. This bore is cased 1.9 m into the unweathered basalt and is 46 m deep.

7. References

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Appendix A Bore Details

Bore	Name	Drilled date	Depth (m)	Cased depth (m)	Yield (m^3/hr)	Drawdown (m)
204060	M Mathers	12/02/1992	63	9	5	18
205294	Van der Hayden	23/04/1983	57	6.5	5.7	19.3
205301	L Sowrey	19/09/1983	27	9	3.42	3.4
205306	A Pikmere		17	7.3	3.66	0
205315	T Strachan	3/08/1983	58			
205316	T Strachan	10/01/1968	15	13.1	0.4	
205318	T Strachan	25/11/1977	15	10.5	2.73	
205319	T Strachan	10/09/1978	11	9.5	2.97	
205321	Z Charlton	28/03/1984	60			
205322	T Strachan		39	6.8	10	23.2
205323	W Hutchinson	7/03/1983	32	7	2.7	4.0
205324	W Hutchinson	1/03/1983	46	16.9		
205325	W Hutchinson	19/02/1983	63	13		
205327	R Sanson	28/02/1974	13	8.2		
205329	B Sowry	4/11/1983	63	8.6		
205330	A McQueen	28/05/1982	49	12		
205331	Plaisted		46			
205333	AJ Kimber		32	10.5	2.27	
205334	Plaisted		46			
205340	N Hutchinson	26/03/1971	43			
205363	J Dryer	6/09/1983	44	10	3.18	6
205364	H Stewart	21/06/1967	35	11.3		
205365	R Dobson	17/07/1972	18	6.1	3.64	
205366	D Dobson	1/10/1968	59	8.2		
205367	F Johnson	1/01/1980	196			
205368	DSIR		87	37	8.34	35.1
205370	R Cochrane	15/04/1983	16	10	2.82	10.5
205371	B Powell	2/02/1981	41	19	2.73	25.9
205372	D Scott	30/04/1974	58	12.8	0.91	
205374	D Dobson	1/12/1981	27	41.5	2.76	18.5
205375	A Mollard	18/08/1981	107		5.41	24.6
205377	G Laing	8/08/1979	24	12	3.64	
205524	Singer		86		3.12	6
205532	G Parker	23/10/1984	76	11		
205533	M Ashby	4/04/1986	81	18.8		
205564	G Laing	3/04/1987	76	20.3	11	23
205565	T Vitali	1/07/1987	54	6.5	5.5	28
205567	C Wrack	29/07/1987	50	10.2	5.75	18

Bore	Name	Drilled date	Depth (m)	Cased depth (m)	Yield (m^3/hr)	Drawdown (m)
205575	Plant World	27/09/1989	64	5.5	1.8	34
205576	D Knight	30/11/1984	61	17		
205577	Plant World		100			
205578	R Bryant		60		1.33	
205594	C Green	17/12/1991	67	16.5		
205597	F Johnson	4/02/1992	87	14	4	37
205608	Cochran	15/12/1992	33	10.5	1.4	
205611		18/12/1992	31	6	8	18
205746	Les Herbert	25/08/1992	12	10.5	4.8	2
205832	S Culham	25/09/1996	44	19	1.6	11
205848	A Tazaterley	16/09/1990	103			
209201	Greg Barron	14/02/2004	35	6.2	1.8	9
-	McNaughton		50		3.17	23.8
-	W Hutchinson			18	5.8	24.9