Environmental Effects of On-Site Sewage Management in Glenorchy Township

Stage 1 – Desktop Assessment

e3 Scientific

For Queenstown Lakes District Council

June 2017

Arrow Lane Arrowtown 9302

Environmental Effects of On-Site Sewage Management in Glenorchy Township

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Document Status

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1 Introduction

1.1 Background

Queenstown Lakes District Council (QLDC) commenced investigations into the provision of a reticulated sewerage scheme for Glenorchy in 2005. Otago Regional Council (ORC) has been advocating for the scheme to improve water quality and reduce natural hazards, particularly in response to the Regional Water Plan Change 6A (ORC, 2014) (QLDC, 2015). Both QLDC and ORC propose to implement the sewerage scheme in order to:

- "Improve levels of service to the community", and
- "Improve environmental conditions in terms of water quality and risks to water supplies (QLDC, 2015)"

In considering the range of options for managing sewage in the Glenorchy township, QLDC have asserted that the option of 'doing nothing' i.e. continuing the current use of on-site sewage management systems is unacceptable. The disadvantages of this option are stated to "include the risk of continued degradation of groundwater quality; the lack of resiliency during lake flood events and associated health risks; and the inability of some current property owners to meet current and future regional (ORC) standards for on-site wastewater disposal. There is also an ongoing compliance risk and cost for QLDC as they endeavour to respond and rebut regional policy requirements of the ORC" (QLDC, 2015).

As the adoption of a reticulated sewerage scheme for the community will impact the ratepayers of the Glenorchy township and surrounds, RCP has commissioned e3Scientific Limited (e3S) on behalf of QLDC to provide further assessment of the impacts of the 'Do Nothing' option i.e. the impact of on-site sewage management systems on soil and water quality within the township of Glenorchy.

1.2 Scope of Work

To assess the impact of on-site sewerage management systems on soil and water in Glenorchy, a two-stage project has been developed:

Stage 1: Desktop Assessment

Stage 2: Environmental Investigations

The purpose of this Stage 1 - Desktop assessment is to review all of the available information and determine what further investigations are required to assess the environmental effects associated with the current management of sewage in Glenorchy township. This assessment will then provide scope to the Stage 2 – Environmental investigation; and will inform the proposed Queenstown Lakes District Council's (QLDC) Glenorchy Wastewater Scheme.

The desktop assessment is structured as follows:

- Section 2: Brief description of the site, its environmental context and land use;
- Section 3: A review of all available reports and data;
- Section 4: Description of the ecological environment and regionally significant values present within the subject areas;
- Section 5: Analysis of Available Information; and
- Section 6: Conclusions and recommendations.

1.3 Limitations

The findings of this report are based on the Scope of Work outlined above. This scope excludes:

- Assessment of sewage management options for Glenorchy
- Additional investigations

e3 Scientific Limited (e3s) performed these services in a manner consistent with the normal level of care and expertise exercised by members of the environmental science profession. No warranties, express or implied, are made.

The results of this assessment are based upon information provided in previous reports and data sources. All conclusions and recommendations regarding the assessment are the professional opinions of e3s personnel involved with the project, subject to the qualifications made above. While normal assessments of data reliability have been made, e3s assumes no responsibility or liability for errors in any data obtained from regulatory agencies, statements from sources outside e3s, or developments resulting from situations outside the scope of this project.

2 Site Location and Description

2.1 Site Location

Glenorchy Township is located on a river delta at the head of Lake Wakatipu. The township is bordered by the lake to the west and old river terraces at the foot of the Richardson Mountains to the east. The Glenorchy Lagoon and Rees River lie to the north and to the south the Buckler Burn River define the township's natural boundaries (see Figure 1).

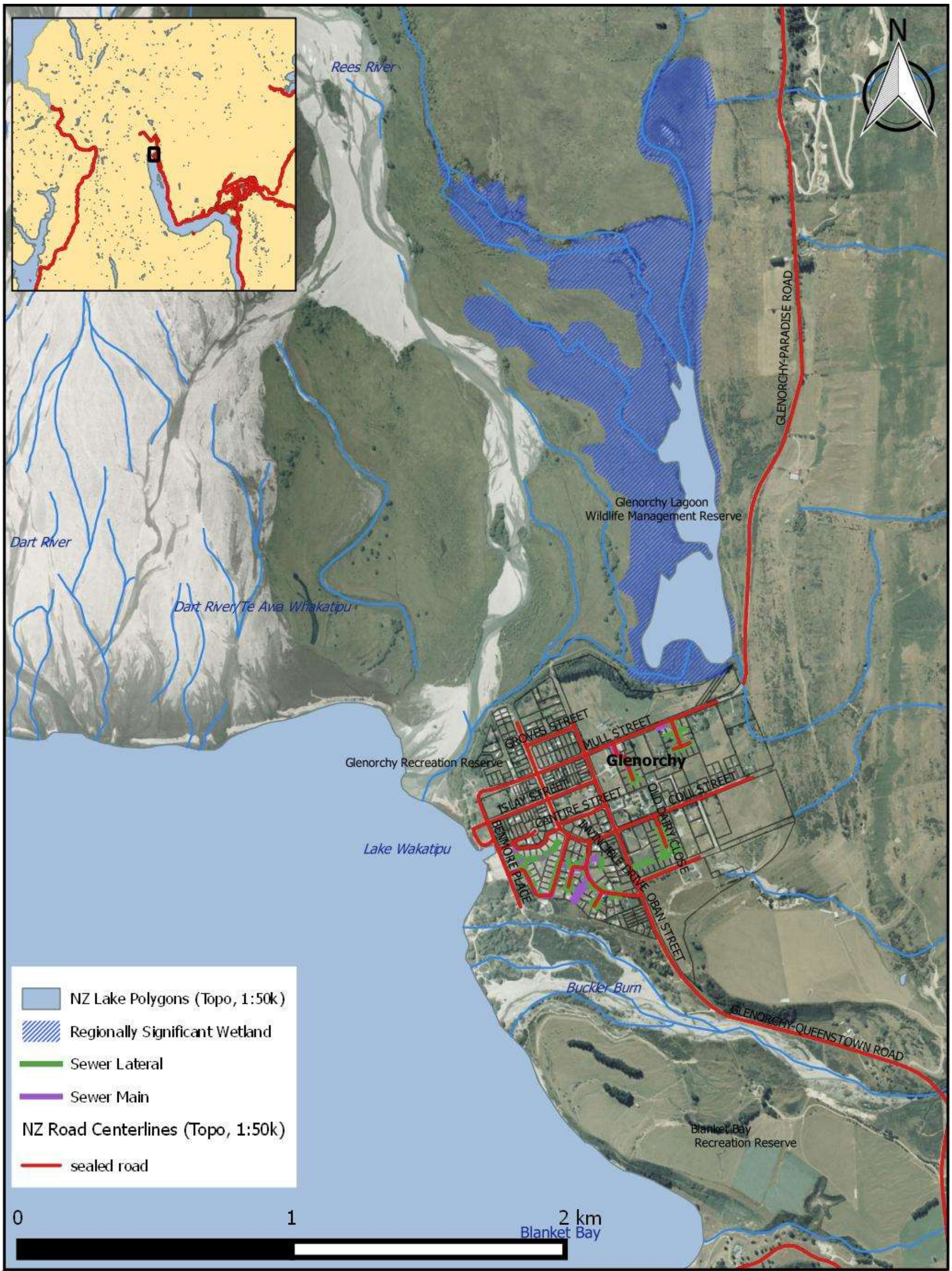
2.2 Site Description and Land use

The Glenorchy township encompasses an area of ~1 km^2 and has a mixture of full-time and part-time (holiday home) residents. The town is sustained by an eco-tourism industry, and has basic facilities including a camping ground, two small hotels, several guest houses, a school, a Department of Conservation visitor information centre and maintenance centre, and a service station (ORC, 2006).

Population projections were calculated by Glasson Potts Fowler Limited (2007) to determine design flows for the proposed sewerage scheme (Table 1). Glenorchy experienced a growth rate of 35 % between 2001 – 2013, with the resident population measured at 360 at the last census in 2013 (Selvarajah, 2015). Based on previous modelling, Glasson Potts Fowler Limited estimated an average household size of 2.3 people.

TABLE 1: CURRENT AND PROJECTED AVERAGE PERMANENT AND VISITOR DAY POPULATION FOR GLENORCHY USING THE RATIONALE MODEL (2006). SOURCE: GLASSON POTTS FOWLER LIMITED (2007).

	Year				
	2006	**2011**	**2016**	**2021**	**2026**
Usually Resident:	284	330	381	426	477
Visitors staying in:	216	250	289	324	363
TOTAL POPULATION	**500**	**580**	**670**	**750**	**840**
Number of Lots	**217**	**252**	**291**	**326**	**365**



NZ Property Titles, NZ Road Centre line (Electoral), NZ River Polygons (Topo, 1:50k), NZ Lake Polygons (Topo, 1:50k), NZ River Centrelines (Topo, 1:50k) sourced from the LINZ Data Service http://data.linz.govt.nz/ and licensed by LINZ for re-use under the Creative Commons Attribution 3.0 New Zealand licence.
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FIGURE 1: GLENORCHY TOWNSHIP

2.3 On-site Sewage Management in Glenorchy

2.3.1 Systems in Glenorchy

The township uses on-site sewage management in the form of individual septic tanks and advanced wastewater treatment plants. Sustainable Glenorchy completed a recent survey of wastewater systems in town and found the following "There are 157 residential dwellings and 131 empty sections in the town. 35 dwellings are at Humboldt Park, 96 have septic tanks and 22 have advanced wastewater treatment plants." (Fowler, 2017). There is a small privately-owned treatment plant with associated disposal fields servicing Lancaster Place (GHD, 2008), also known as Humboldt Park. The extent of the sewer mains can be seen on Figure 1.

2.3.2 Nutrient loadings

Otago Regional Council (ORC) investigated groundwater contamination risk using nitrogen loading and septic tank density across Otago. Water Plan Change 6A (ORC, 2016) established nitrogen loading limits for diffuse discharges from agricultural discharges, however as the risk from septic tanks can be just as high, these limits were used to categorise the risk of septic tank densities. They recommended that areas where nitrogen loading exceeds 30 kg/ha/year should be considered high priority for change. Nitrogen loading rates were calculated based on a starting point of 4.5 kg N/person/year with 30% nitrogen removal in the septic tank resulting in 3.15 kg N/person/year. Full year occupation was assumed for the households and peak loading of 180 L/person/day from AS/NZS 1547:2000 guidelines. All lots (274) were assumed to have septic tanks. Using this methodology, Glenorchy was identified as a septic tank contamination hotspot, with total nitrogen loading for the area calculated as 2200 kg/year, and 183 septic tanks situated in locations where nitrogen loading would exceed 183 kg/ha/year (ORC, 2015). The report acknowledged that this approach was likely to overestimate the number of septic tanks, and that areas with advanced wastewater treatment were not a concern.

Using the same methodology, the nitrogen loading rates for Glenorchy can be updated with more realistic occupancy rates and the actual number of dwellings i.e. occupancy rate of 2.3 people per household, with 96 septic tanks (see Section 2.3.1). The lower occupancy rate would result in a loading of 7.2 kg/year for every household with a septic tank. In the township of Glenorchy, this would result in 691 kg N from septic tanks every year. While this is much less than the loading calculated by ORC (2015), in areas of the township with house lots sizes of approximately 500 m^2, nitrogen loading will equate to 144 kg N/ha/year.

No assessment has been made of the incidence of septic tank failure within the Glenorchy township.

2.3.3 Regulatory Environment

Otago Regional Council currently has no minimum lot size for on-site sewage management systems to be considered a permitted activity. However, it should be noted that some other regional councils do have specified minimum lot sizes, or specified performance conditions that must be met under a certain lot size. The current permitted activity rules for septic tanks within Otago are considered "outdated and lenient" (Selvarajah, 2015). Modelling of nitrogen loads into groundwater from septic tanks suggests that the minimum lot size should be 5,500 m^2 if the concentration of nitrogen in groundwater is not to be increased above the existing baseline (Hill & Lowe, 2008).

Water Plan Change 6A (ORC, 2016) established nitrogen loading limits for diffuse discharges from agricultural discharges. It identified Lake Wakatipu as a nitrogen sensitive zone; nitrogen loading in the catchment should not exceed 15 kg N/ha/year (ORC, 2014).

3 Review of available reports and data

Available historical reports and data pertaining to the Glenorchy township environments were sourced from Otago Regional Council (ORC), Queenstown Lakes District Council (QLDC), Department of Conservation (DOC), National Institute of Water and Atmosphere (NIWA), Veolia Water, Lowe Environmental Impact (LEI), Ryder Consulting Ltd, and several other consulting companies; individual reports and theses relevant to the site are listed in Table 2 below. Note that this is not the comprehensive list of documents reviewed as part of this process as many of the documents provided did not contain any additional information. The information extracted from the cited reports is then summarised further in Sections 3.1 – 3.6.

TABLE 2: SUMMARY OF REFERENCES

Category	*Reference*	*Content*	*Information extracted*
Contaminated land	*DCG. (2013). Glenorchy Trustee Limited Proposed Subdivision Preliminary Site Investigation. Arrowtown: Davis Consulting Group.*	*Preliminary site investigation of site adjacent to landfill for subdivision purposes. Includes test pits and soil sampling to delineate landfill extents and associated soil contamination.*	*Information regarding contaminated land and soil profiles*
	Imtech. (2000). Queenstown Lakes District Council Glenorchy Landfill Closure Plan.	*Landfill closure plan including required groundwater monitoring and waste composition. Locations of bores not documented within plan.*	*Groundwater sampling plan*
	PDP. (2005). Glenorchy Motors, 26-34 Mull street, Glenorchy Tank Removal TR 03/206. Christchurch: Pattle Delamore Partners Ltd.	*Soil testing to assess contamination after removal of underground petroleum storage system. TPH results of soil left in tank pit are below commercial/industrial and protection of groundwater quality guidelines.*	*Contaminated land information*
	QLDC. (2013). Glenorchy Landfill Closure Plan -updated September 2013. Queenstown: Queenstown Lakes District Council.	*Plan for managing the closed landfill including site description, monitoring and recommendations for managing hazards at the site.*	*Landfill description and groundwater monitoring programme*
	QLDC. (2013). Resource Consent Application and Supporting Information - Glenorchy Closed Landfill. Queenstown: Queenstown Lakes District Council.	*Management plan for closed landfill and summary of monitoring results to support consent application*	*Landfill groundwater monitoring*
Ecology	*Goldsmith, R., Stewart, B., & Ryder, G. (2006). Glenorchy Lagoon: Ecological Assessment. Dunedin: Ryder Consulting.*	*Water quality data in Glenorchy Lagoon, invertebrate data*	*yes*

Category	Reference	Content	Information extracted
Environment	*Lowe Environmental Impact. (2017). Resource Consent Application Assessment of Environmental Effects: Discharge of Treated Domestic Effluent into Land Glenorchy Township. Christchurch: LEI.*	*Resource consent application for the discharge of treated community (domestic) effluent into land. Including assessment of environmental effects of discharging treated effluent from Glenorchy township onto Glenorchy Airport land to the south of Stone Creek. While assessment is focused on the Glenorchy Airport site, descriptions of climate, surface waters and the statutory environment and objectives and policies are relevant also to the Glenorchy township.*	*Descriptions of climate, surface waters and the statutory environment and objectives and policies are relevant also to the Glenorchy township.*
	ORC. (2016). Regional Water Plan: Water for Otago. . Otago Regional Council.	*Regional water plan sets the framework for managing water in Otago.*	*Schedule of Regionally Significant Wetlands, Water Plan Change 6A amendments regarding nitrogen loading and Rules regarding discharge of human sewage*
	QLDC. (2015). Report for Agenda Item: 7 - Glenorchy Community Sewerage Scheme Report 30 June 2015.	*Discussion of the background of the scheme, considerations of options, disposal site considerations, scheme options, map of considered disposal locations*	*Background*
Geology	*Kober, F. (1999). Late Quaternary Geology of Glenorchy District, Upper Lake Wakatipu. Dunedin: Thesis. University of Otago.*	*Detailed geology report*	*Yes*
Groundwater	*Lindqvist, J. K. (1997). Otago Regional Council Groundwater Investigations 1996/97: Glenorchy. Dunedin: JK Lindvqist Research.*	*Groundwater quality survey to collect baseline data in Glenorchy. Included survey of bore locations, final depths and standing water levels for the 10 bores that could be located.*	*Standing water levels, bore locations, water quality*
	ORC. (2006). Groundwater Quality in Kingston and Glenorchy. Otago Regional Council.	*An assessment of available groundwater quality data from 1997-2003 using limited data (10 samples). Includes a map of the piezometric surface from Lindqvist (1997)*	*Groundwater quality and level data*

Category	Reference	Content	Information extracted
On-Site Sewage Management	*GHD. (2008). Glenorchy Wastewater Scoping Report.*	*Scoping Report to establish the preferred option and costs of an upgraded community wastewater collection and conveyance, treatment and disposal system.*	*Sewage projections*
	Glasson Potts Fowler Limited. (2007). Glenochy Community Sewage Scheme Conceptual Design.	*Provides estimates of population and wastewater flows, wastewater quality. Summarises a range of treatment options, advantages and disadvantages and includes cost estimates. Appendix D contains investigations of potential land treatment areas including near saturated conductivity test results near town.*	*Background loading information, some soil data*
	ORC. (2015). Groundwater Contamination Risk, Septic Tank Density and Distribution within Otago. Dunedin: Otago Regional Council.	*Modelling of septic tank density, nitrogen loading and groundwater contamination risk across Otago.*	*Nitrogen loading & calculation methodology*
	Selvarajah, S. (2015). Effective human wastewater management in rapidly growing towns in sensitive receiving environment - A perspective on Queenstown-Lakes District area. New Zealand Land Treatment Collective Conference, (p. KEY NOTE PAPER). Wanaka.	*Population dynamics wastewater management issues and proposed solutions within the Queenstown-Lakes District*	*Population information*
Soils	*Lavery, J. (2008, November 17). Glenorchy Soil Temperature Monitoring Summary Letter.*	*Results of soil temperature monitoring in Glenorchy*	*Soil temperatures*

3.1 Climate

Rainfall data has been collected sporadically in Glenorchy with no rainfall stations currently maintained within the Glenorchy township either by NIWA or ORC. Rainfall summaries for two sites were obtained from NIWA and are presented in Table 3. These data sets demonstrate low seasonal rainfall variability with only small peaks in Autumn and Spring rains with the lowest mean rainfall occurring in February (Summer).

TABLE 3: MEAN RAINFALL DATA (SOURCED FROM THE NATIONAL CLIMATE DATABASE HTTPS://CLIFLO.NIWA.CO.NZ, 2017).

Station	From - To	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Glenorchy School	1953-1978	91	76	105	102	112	96	82	91	116	114	102	98	1185
Glenorchy	1929 - 1944	103	72	112	111	138	104	91	103	128	122	104	94	1282

Grey shading denotes 3 highest rainfall months per year.

3.2 Geology

The underlying geology of the Glenorchy township is the adjoining of two gravel fan deltas built by the Buckler Burn and the Dart and Rees Rivers at the head of the glacial Lake Wakatipu. This land form has been created predominantly by debris and flood flows and includes a complex of alluvial sand and mud flats, mires and small ponds at the lower delta which includes the Glenorchy Lagoon (Lindqvist, 1997). The highest part of the alluvial fan is the section of the township located beside the Main Queenstown Glenorchy Road, then the land slopes away on either side of this higher section; towards the lake to the west, and towards the Richardson Mountains to the east (ORC, 2006).

The braided floodplains of the Dart and Rees Rivers deposit large quantities of highly erodible schist into the head of Lake Wakatipu creating a southward prograding delta (Lowe Environmental Impact, 2017).

Major faults in the immediate area of interest are the Buckler Burn Fault Zone and Stone Creek Fault. While the Bucker Burn Fault Zone is mainly north/northeast in trend, the Stone Creek Fault tends nearly east-west (Kober, 1999).

3.3 Soils

3.3.1 Soil Type

Soil descriptions for the Glenorchy township were obtained from Landcare Research S-Map Online (https://smap.landcareresearch.co.nz, accessed 25/04/2017). Soils under the township are Glenorchyf typic fluvial recent soils, typical for alluvial floodplains with distinct topsoils, but B horizons are either absent or only weakly expressed, variable texture and high special variability. Glenorchyf soils are shallow to very shallow, well drained with rapid permeability. Topsoils have low phosphorous retention, and high to very high nitrogen leaching vulnerability. GlenT_2a.1 (40%) is classified as having high bypass flow, which would allow nutrients and bacteria to leach quickly to groundwater. GlenT_5a.1 (60%) is classified as having low bypass flow as the soil is deeper and moderately stony, rather than very stony (Landcare Research, 2015).

Four test pits excavated within the cemetery reserve between Coll Street and Shiel Street contained shallow silt and clay loams to a depth of 0.3-0.4 m underlain by gravels and sands with varying amounts of clay to 1.3 m. Near saturated conductivity (K_{40}) tests were completed in four locations within the reserve, returning values ranging from 7-30 mm/hour (average 21 mm/hour) (Glasson Potts Fowler Limited, 2007). These findings support the S-Map descriptions of well drained, shallow soils.

3.3.2 Soil Temperatures

Duffill Watts Consulting was commissioned by GHD (on behalf of QLDC) in 2008 to carry out soil monitoring in order to establish whether the ground was frozen for prolonged periods of time. They monitored the soil temperatures for 4 months from 3/07/2008 – 1/11/2008. Within this time frame they found only 1 occasion where soil temperature dropped below zero, the 10th July where the surface probe recorded a -0.1° Celsius between 7.30am-10.30am. No subsurface probes returned temperatures below 0° Celsius (Lavery, 2008). Consequently, water infiltration into soils is unlikely to be inhibited by soil temperatures at any time of the year in the Glenorchy township.

3.4 Surface Water

As described in Section 2.1, Glenorchy is surrounded by surface water features on three sides – Lake Wakatipu to the west, the Rees River and Glenorchy Lagoon to the north, and the Buckler Burn to the south.

Lake Wakatipu is the second largest of the southern glacial lakes being 75.2 km long and up to 5 km wide and covers an area of 289 km^2. The lake is 310 m above mean sea level (a msl), is up to 389 m deep and occupies a single elongated glacial trench which has a gently sloping flat floor (ORC, 2009). The Dart and Rees Rivers flow into the northern end of Lake Wakatipu which then runs south for 30 km before turning abruptly to the east. Twenty kilometres further along, it turns sharply to the south, reaching its southern end 30 km further south, near Kingston. The lake is drained by the Kawarau River, which flows out from the lake's Frankton Arm, 8 km east of Queenstown. At the foot of the lake is a natural dam of moraine (ORC, 2009).

3.4.1 Water Quality Monitoring

The ORC carries out long-term water quality monitoring as part of its State of the Environment programme. In Lake Wakatipu, the water quality monitoring site is located within the Frankton Arm near the outfall to the Kawarau River. It is considered the water quality data from this site will provide an indication of the overall water quality of the lake. Table 4 provides the average monitoring values for Lake Wakatipu.

TABLE 4: AVERAGE MONITORING VALUES FOR LAKE WAKATIPU 2013 – 2015 (ORC, 2015)

Parameter	*E. Coli (cfu/100 ml)*	*TN (g/m^3)*	*NNN (g/m^3)*	*NH_4 (g/m^3)*	*DRP (g/m^3)*	*Turbidity (g/m^3)*
Average	*4.1*	*0.085*	*0.022*	*0.008*	*0.003*	*0.64*
Standard Deviation	*7.7*	*0.033*	*0.008*	*0.003*	*0.001*	*0.39*

The median bacterial content in samples of fresh or marine waters taken over the bathing season should not exceed:

- 150 faecal coliform organisms/100 mL (minimum of five samples taken at regular intervals not exceeding one month, with four out of five samples containing less than 600 organisms/100 mL); and
- 35 enterococci organisms/100 mL (maximum number in any one sample: 60–100 organisms/100 mL) (ANZECC, 2000).

QLDC conducted water quality monitoring at the Rees River Bridge, Rees River Argyle Street, Glenorchy Jetty and Glenorchy Harbour in 2012 - 2013. All surface water quality monitoring locations are presented in Figure 2. The monitoring took place on two occasions over this period; November 2012 and February 2013, and tested for Faecal coliforms (FC) and Total Nitrogen (TN); the full results are provided in Table 5. *E. coli (Escherichia coli*) is a type of faecal coliform bacteria commonly found in the intestines of animals and humans and the presence of faecal coliform bacteria in aquatic environments indicates that the water has been contaminated with the faecal material of humans or animals.

TABLE 5: QLDC SURFACE WATER MONITORING DATA (2012 – 2013), (TABLE SOURCED FROM LOWE ENVIRONMENTAL IMPACT, 2017).

Date	*Glenorchy Jetty*		*Glenorchy Harbour*		*Rees River (Argyle Street)*		*Rees River (Bridge)*	
	FC	*TN*	*FC*	*TN*	*FC*	*TN*	*FC*	*TN*
20/02/2013	*<1.6*	*<0.02*	*<1.6*	*0.23*	*66*	*<0.02*		
01/11/2012	*23*	*0.039*	*<1.6*	*0.2*	*54*	*0.11*	*1500*	*0.039*

FC = cfu/100 ml, TN = g/m3

While Total Nitrogen concentrations measured at Glenorchy Jetty and the Rees River were similar to the average values for Lake Wakatipu (0.085 g/m^3), concentrations in Glenorchy Harbour appear to be elevated. The Rees River was found to be subjected to higher levels of Faecal Coliforms than the lake sites. Given the highest concentration was found at the Rees River bridge upstream of the township, it may be concluded that upstream landuse or wildlife is also impacting on water quality in the Rees River. However, it is also possible that septic tanks are contributing to the Argyle St site concentrations via groundwater discharge (see Figure 2 below). Faecal Coliforms were also elevated in the November sampling at Glenorchy Jetty.

Only one water quality sample was available for the Buckler Burn, sampled below the bridge in 1997 (Lindqvist, 1997). This returned low concentrations of faecal coliforms, enterococci and nitrates.

While the locations of historical surface water quality samples may be useful for monitoring the impacts of on-site sewage management in Glenorchy, analysis of only two recent (2012 / 2013) sampling events for faecal coliforms and total nitrogen is insufficient to determine any impacts. A current Glenorchy water quality sampling regime would add weight and greater certainty to an impact assessment for this site. Figure 2 below shows the historical and proposed sampling sites that may be sampled or re-sampled during the Stage 2 phase of work. The actual sites to be sampled will depend on the outcomes of the water level survey proposed in Section 6.

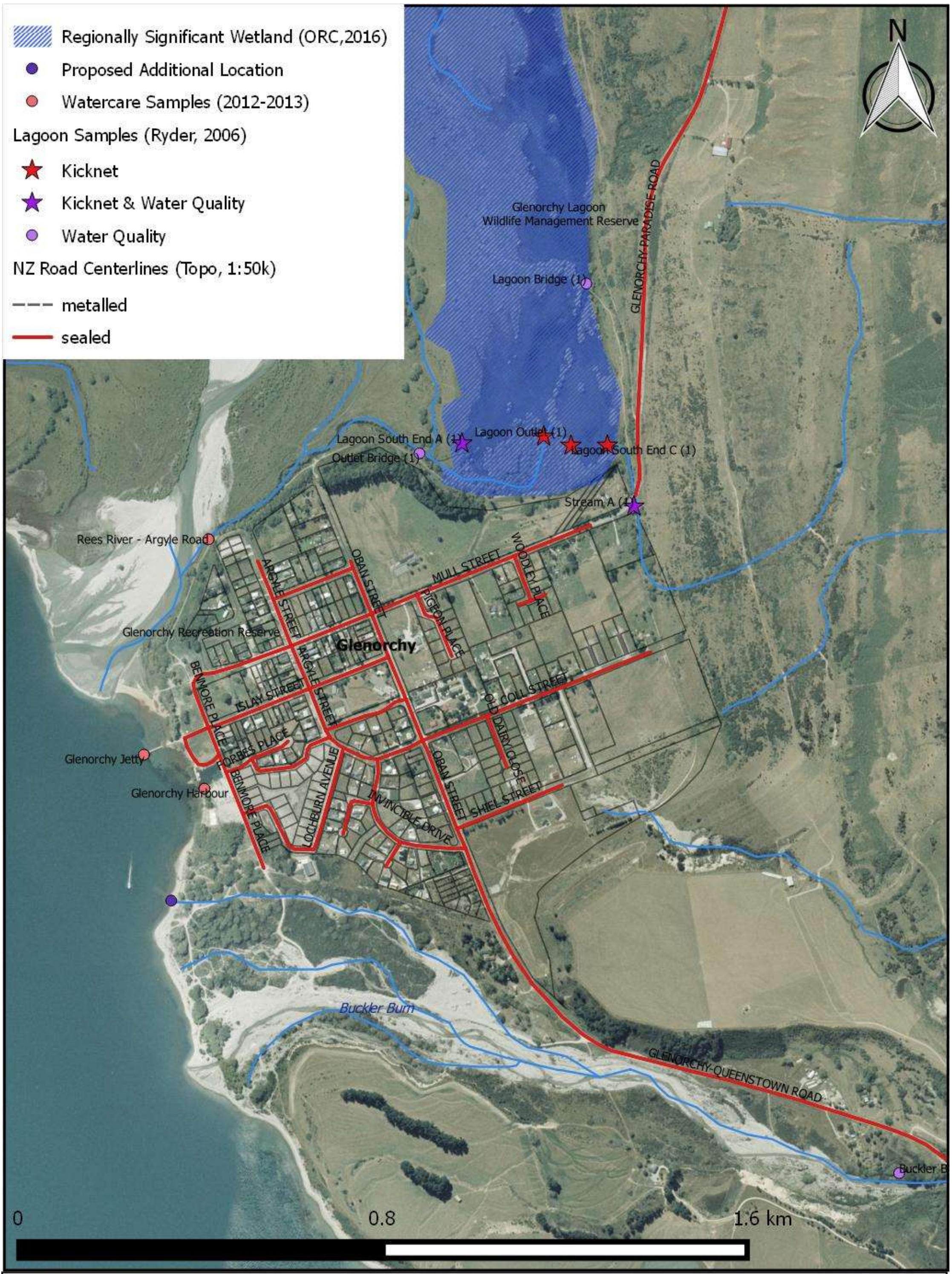

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FIGURE 2: SURFACE WATER QUALITY MONITORING LOCATIONS

3.4.2 Trophic Status

A water body's trophic state is largely regulated by nutrient inputs from the adjacent catchment. The major inputs into Lake Wakatipu are the Dart and Rees Rivers, which largely are believed to have good water quality (ORC, 2009). In ORC's assessment of the trophic state of Otago lakes, no mention is made of the Glenorchy catchment area and possible nutrient contribution to Lake Wakatipu.

The ORC monitoring to classify trophic status of Otago's lakes between 2006 and 2009 used sites located with Frankton Arm, Queenstown Bay, and an open water location triangulated between the other two. The results from these sites showed that Lake Wakatipu appears to be in a stable state, with little change in water quality occurring over the last three years. All three sites are classified as being in an oligotrophic state, although algal biomass falls into the microtrophic category, meaning the water quality is very good and has low nutrient and algae levels (NIWA, 2017). Any rates of change were found to be extremely slow and are unlikely to have any biological significance. The following Table 6 shows the four key parameters to determine trophic status (ORC, 2009).

TABLE 6: AVERAGE ANNUAL VALUES FOR THE FOUR KEY PARAMETERS; ALGAL BIOMASS (CHLA), CLARITY (SD), AND NUTRIENT CONCENTRATIONS (TP & TN) (ORC, 2009).

	Chla (mg/m^3)	SD (m)	TP (mg/m^3)	TN (mg/m^3)
Frankton Arm				
May 2006 - Apr 2007	0.3	11.47	4.38	116.88
May 2007 - Apr 2008	0.42	12.44	4.8	118.5
May 2008 - Apr 2009	0.47	14.5	4.13	92.83
Averages	0.40	12.80	4.44	109.40
Queenstown Bay				
May 2006 - Apr 2007	0.33	9.99	6.44	116.88
May 2007 - Apr 2008	0.42	10.31	5.38	156.25
May 2008 - Apr 2009	0.56	11.55	5.69	118.81
Averages	0.44	10.62	5.83	130.64
Open water				
Apr 2006 - Apr 2006	0.49	13.6	7	160
May 2006 - Apr 2007	0.3	12.98	6	106.54
May 2007 - Apr 2008	0.44	11.49	4.67	141.67
May 2008 - Apr 2009	0.34	15.08	5.04	124.17
Averages	0.39	13.29	5.68	133.09

This data provides us with a good indication of the water quality within Lake Wakatipu, specifically near the Queenstown township. However, due to the large surface area, depth and sampling locations the dilution effect means this data is not pertinent to characterising the water quality of Lake Wakatipu immediately adjacent to Glenorchy township.

3.4.3 Aquatic Ecosystem Health

NIWA's Lake Submerged Plant Indicators Index (Lake SPI) is a method of characterising the ecological health of lakes based on the amount of native and invasive plants growing in them. Data is collected by NIWA and the Department of Conservation (DOC). Presented as a percentage, higher Lake SPI scores are associated with the better water quality. The last recorded data for Lake Wakatipu was January 1992 and the status was 'Excellent' with a Lake SPI score of 90%. However, the historical nature of this data coupled with the uncertainty of sampling locations denotes that this data does not provide an accurate assessment of the current lake ecosystem health near the Glenorchy Township.

An ecological assessment of the Glenorchy Lagoon was conducted by Ryder Consulting Ltd in June 2006 (Goldsmith, Stewart, & Ryder, 2006). This assessment was conducted on a winter's day in June and no fishery assessments could be completed. Little plant or algae growth could be identified due to the temperature of the water (sampled water temperature was between 2.9 – 4.7 ° Celsius). The findings of this report states "*Despite it (the Glenorchy Lagoon) having the plan status as a wetland of regional significance and apparently having good water quality, the Glenorchy Lagoon is a modified pond environment and its associated ecosystem reflects this state… The benthic flora and fauna present in the lagoon are typical of those found in most pond-like environments and are not unique in any way. They are all tolerant of organic enrichment and soft sediment environments - characteristics typically associated with eutrophic environments. The type and distribution of macrophytes present in the lagoon suggest that some nutrient enrichment is already tolerated by the existing aquatic community… The lagoon fishery is likely to be dominated by trout and bullies, possibly eels also, and movement of koaro through the system to tributary streams. All these species are tolerant of modified, semi-enriched environments… predictions regarding nutrient enrichment remain valid (despite temperature limitations). Concentrations of bioavailable nutrients will theoretically increase in the lower section of the lagoon and in the outlet stream, however the increases are modest and still be within guidelines for preventing eutrophic conditions. The lower lagoon appears to be reasonably well flushed*" (Goldsmith, Stewart, & Ryder, 2006).

Based on the above observations and conclusions made by Goldsmith, Stewart and Ryder (2006), which are now over 10 years old, the Glenorchy Lagoon is not a pristine wetland environment. With the limited information available, it is difficult to ascertain whether there may be impacts from septic tanks within the Glenorchy township, or whether impacts are from upstream land uses. An ecological assessment of this area would be best completed during the summer months and include analysis for faecal indicators. To our knowledge, no other aquatic health monitoring or assessments have been carried out within the area surrounding the site.

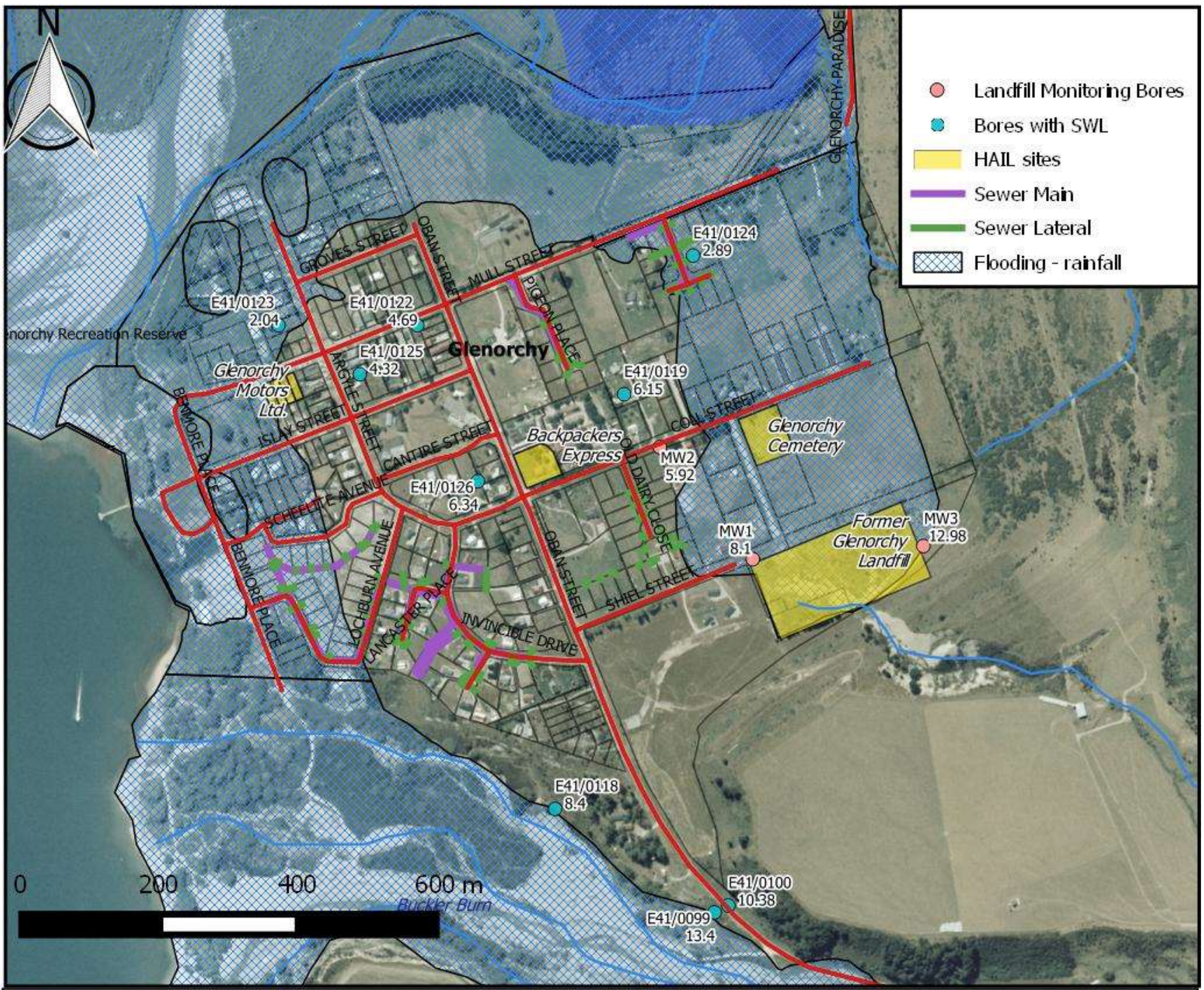
Due to the limited data available on aquatic ecosystem health within the Glenorchy environs, no conclusive findings can be made with regard to ecological impacts from current on-site sewage management.

3.5 Groundwater

Bore logs and construction details for all available bores in the Glenorchy township area and nearby surrounds were obtained from ORC. Additional bore information was obtained from groundwater reports and the landfill closure plan (QLDC, 2013) and is described in more detail in the following sections. A summary of the bores is provided in Appendix A.

3.5.1 Groundwater use

Prior to the 1980's, Glenorchy residents maintained their own water supply using private bores. Town water is now supplied by two shallow bores (E41/0099, E41/0100) to the south of the town which is stored in four concrete tanks. Landowners were surveyed in 1997 which recorded the presence of ten groundwater bores, only one of which (the town water supply) was in use (Lindqvist, 1997).



NZ Property Titles, NZ Road Centre line (Electoral), NZ River Polygons (Topo, 1:50k), NZ Lake Polygons (Topo, 1:50k), NZ River Centrelines (Topo, 1:50k) sourced from the LINZ Data Service http://data.linz.govt.nz/ and licensed by LINZ for re-use under the Creative Commons Attribution 3.0 New Zealand licence.
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FIGURE 3: DEPTH OF GROUNDWATER BELOW GROUND SURFACE

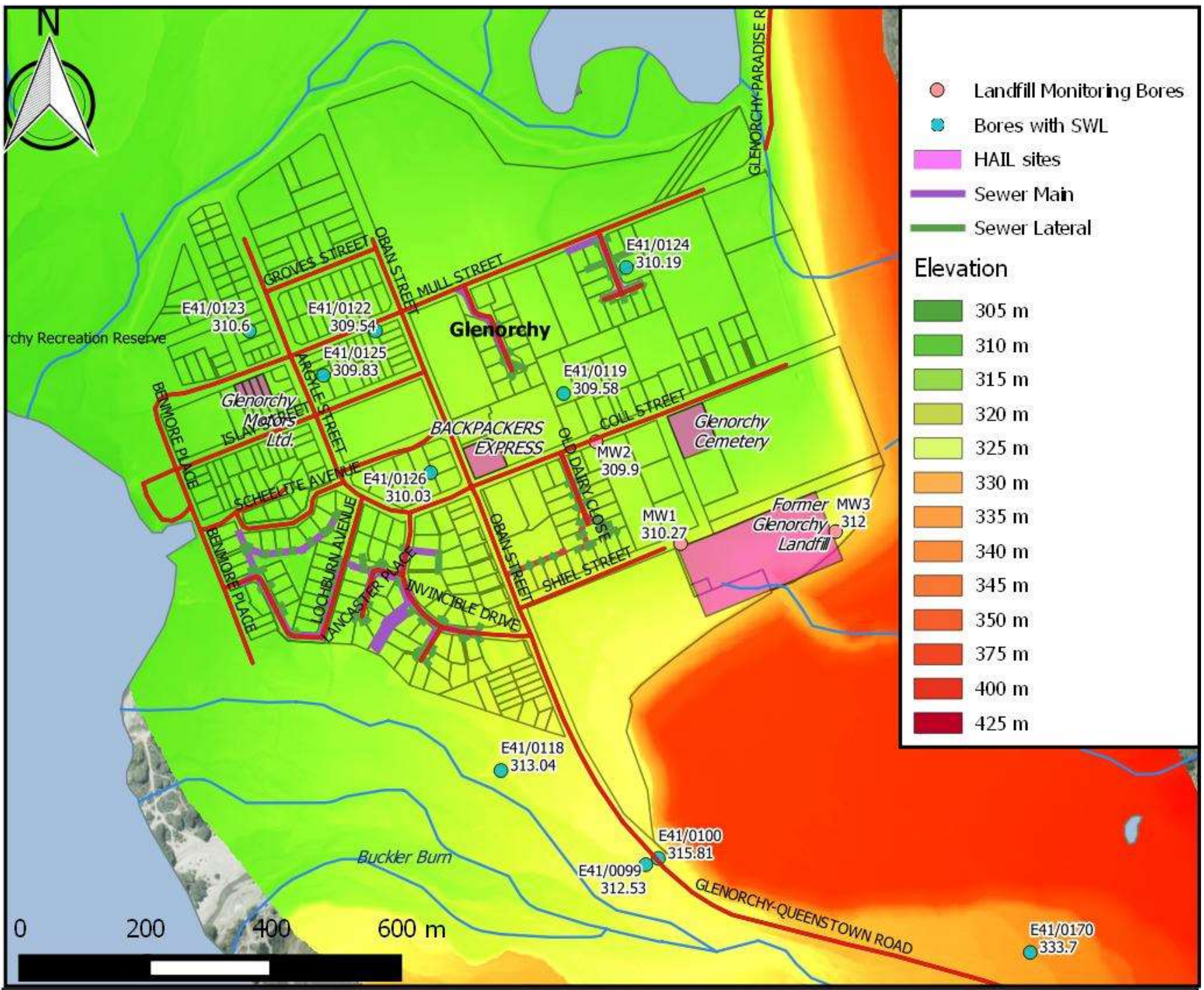
3.5.2 Aquifer characteristics

Alluvial deposits around the Buckler Burn have been described as generally clay and silt-free gravels with good aquifer characteristics (Lindqvist, 1997). Only five bore logs were obtained from ORC, only two of which were close to the Glenorchy township: E41/0099, E41/0100 (town water supply bores). Both of these bores are situated to the south of the Glenorchy township, approximately 10-15 m above the elevation of the town, and intersected sandy and silty gravels to a maximum depth of 23 m below ground surface. Consequently, the extent of the aquifer below the Glenorchy township is unknown.

Groundwater levels were provided from ORC, Lindqvist (1997) and from landfill monitoring (QLDC, 2013), however much of this data was incomplete. The locations of some bores were altered based on the survey completed by Lindqvist (1997). The coordinates of landfill monitoring bores were obtained by georeferencing maps provided in the landfill closure plan (QLDC, 2013). Groundwater surveys in Lindqvist (1997) provided depths below ground surface of groundwater level reference points for three bores. Where this information was available, groundwater levels were adjusted to depth below ground surface. Groundwater depths below ground surface are presented in Figure 3. The median groundwater level in the monitoring record was used for the landfill monitoring bores.

Groundwater levels are shallow across the township and are a subdued reflection of topography. In areas of lower elevation to the northwest of the township, groundwater depths are as little as 2 m below ground surface. Quarterly water level measurements were made at the landfill monitoring bores MW1 and MW2 between 1999-2013. Groundwater levels fluctuated within a range of 4 m at MW1 and 4.7 m at MW2.

To assess groundwater flow directions, ground surface elevations at the corrected bore locations were then extracted from the 0.5 m DEM provided by QLDC. Groundwater levels were then translated into groundwater elevations. These are presented with the ground surface DEM in Figure 4. This figure demonstrates that groundwater flow is likely to be towards Lake Wakatipu and possibly the Rees River. As each water level measurement presents only a snapshot in time, conceptualisation of flow would be improved by concurrent water level monitoring across the township.



NZ Property Titles, NZ Road Centre line (Electoral), NZ River Polygons (Topo, 1:50k), NZ Lake Polygons (Topo, 1:50k), NZ River Centrelines (Topo, 1:50k) sourced from the LINZ Data Service http://data.linz.govt.nz/ and licensed by LINZ for re-use under the Creative Commons Attribution 3.0 New Zealand licence.
DEM supplied by QLDC.

FIGURE 4: GROUNDWATER ELEVATIONS AND GROUND SURFACE ELEVATIONS

3.5.3 Groundwater Quality

There is no groundwater monitoring program currently in place in the Glenorchy township. Limited groundwater quality monitoring has been completed in the past. Lindqvist aimed to complete a baseline groundwater survey in 1997, however only three samples were taken – one bailed from a disused bore in the camping ground, one from the QLDC bore near the Buckler Burn and a surface water sample from the Buckler Burn below the bridge on the Queenstown-Glenorchy Road. Groundwater samples returned low values of faecal coliforms, but 4 enterococci/100 mL from the town water supply bore. Nitrate and nitrogen concentrations were low in the QLDC bore and the Buckler Burn sample but higher in the camping ground bore (0.81 mg/L), which Lindqvist (1997) concluded may be due to septic tank contamination. Analysis of the major ions within the QLDC and Buckler Burn sample provided evidence of the connection between the QLDC bore and surface waters in the Buckler Burn. Consequently, protection of the Buckler Burn catchment is required to protect drinking water in Glenorchy (Lindqvist, 1997).

ORC completed a groundwater sampling program in 2002-2003 which was compared with monitoring completed in 1996-1997 (Lindqvist, 1997). The program aimed to identify spatial and temporal trends and make recommendations for further monitoring (ORC, 2006). Ten groundwater bores in Glenorchy were identified, however only the QLDC town water supply bore was found to be in use (Lindqvist, 1997).

Only ten water quality samples were collected from Glenorchy bores from 1996-1997, with six of the samples collected from the concrete holding tanks for the town water supply. These samples collected from the reservoirs are unlikely to be representative of in-situ groundwater conditions due to physical and chemical changes that will occur as a result of storage (ORC, 2006). However, nitrite-nitrate nitrogen (NNN) is relatively conservative in water under oxidising conditions. An assessment of the NNN concentrations in the reservoir provided some indication of an increasing trend. This change was considered to be the impact of land use in the Buckler Burn Catchment (upgradient from the Glenorchy township). ORC assessed the water in Glenorchy to be Calcium-Bicarbonate water that is recently recharged. While susceptible to landuse impacts in the catchment, due to the location of the town water supply bore, ORC stated that the supply was not vulnerable to septic tank impacts (ORC, 2006). The report did not recommend any ongoing monitoring for Glenorchy.

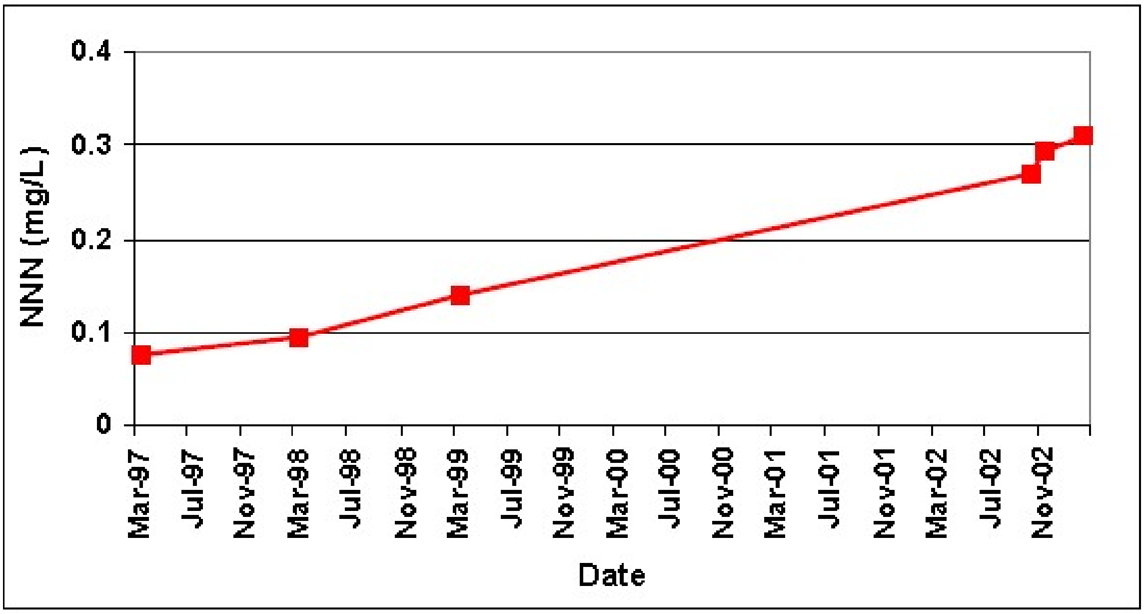


FIGURE 5: NNN CONCENTRATIONS IN GLENORCHY TOWN WATER SUPPLY STORAGE. SOURCE: ORC (2006)

Groundwater monitoring of two bores was required as part of the resource consent 95279 for the closed Glenorchy landfill since 1999. Samples were taken every three months and analysed for pH, conductivity, ammoniacal-N, chloride, faecal coliforms, zinc, cadmium, arsenic, chromium, Total Kjehldal Nitrogen (TKN), nitrate, orthophosphate (PO_4) (Imtech, 2000). This was extended to a third monitoring bore in 2006. QLDC ceased groundwater quality monitoring in 2013, as it was considered that the programme was no longer required for resource consent given the size and age of the landfill. QLDC asserts that at the time monitoring ceased that groundwater chemistry in the downstream landfill monitoring bores had stabilised and is not being adversely affected by landfill leachate (QLDC, 2013). We note that it was outside the scope of this assessment to determine whether the landfill is continuing to impact on groundwater quality.

No detailed analysis has been completed on this data at this time, however Nitrate-N concentrations from bores MW1 (down gradient and adjacent to landfill site) and MW2 (downgradient of MW1) are presented in Figure 6. This figure demonstrates that nitrate-N concentrations in the down-gradient bore MW2 (median 3.77 mg/L) are greater than concentrations in MW1 (median 2.8 mg/L), and therefore that groundwater is being impacted by nitrogen sources other than the landfill, which may be septic tanks. Note that there were no corresponding fluxes in faecal coliforms in the data.

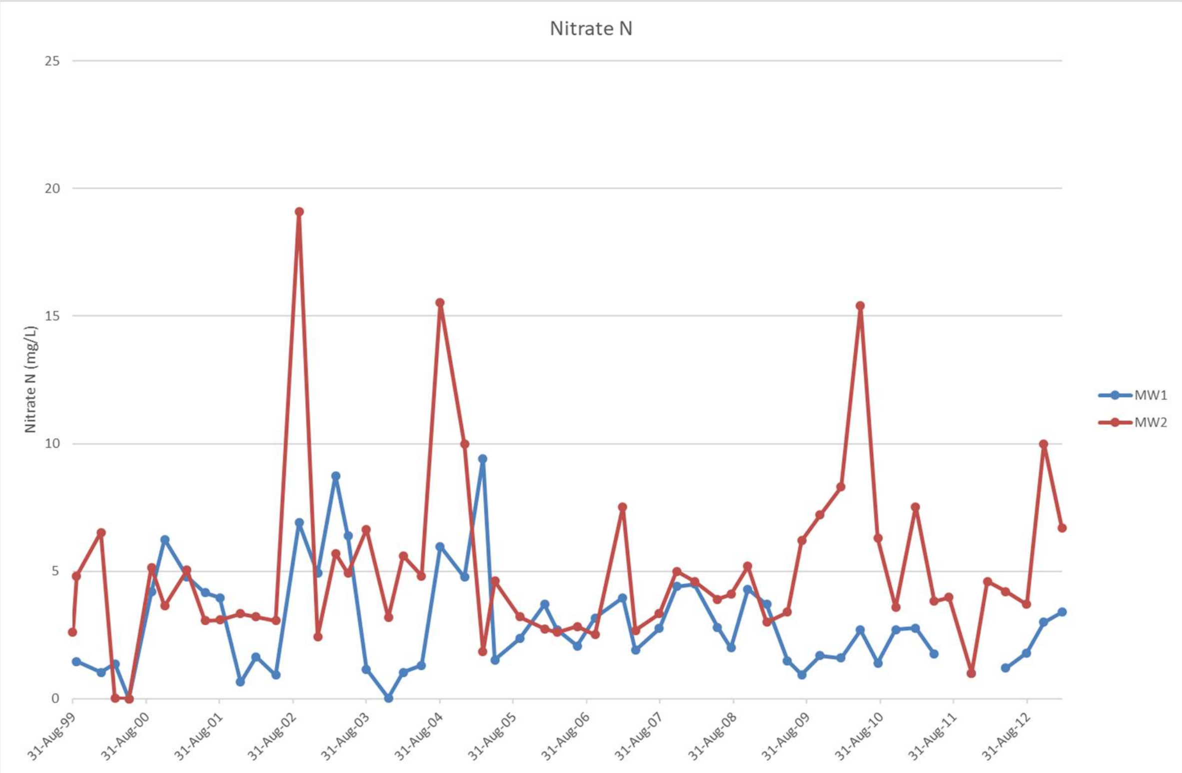


FIGURE 6: NITRATE N CONCENTRATIONS IN GROUNDWATER FROM LANDFILL MONITORING BORES

3.6 Contaminated Land

Contaminated land has been reviewed as part of this assessment to identify activities other than septic tanks that may be impacting on soil and groundwater. While DRASTIC modelling was used to assess groundwater contamination risk for known aquifers in Otago, it was not completed for Glenorchy (ORC, 2015). Three sites were identified by QLDC on their register of contaminated land as having had activities on the HAIL (Hazardous Activities and Industries List (MfE, 2012). The HAIL is a compilation of activities and industries intended to identify most situations in New Zealand where hazardous substances could cause land contamination. The three sites are Glenorchy Motors, Backpackers Express and the closed Glenorchy Landfill. A fourth site has been identified as part of this study as the Glenorchy cemetery. The locations of these sites are presented in Figure 4.

3.6.1 Glenorchy Motors

Glenorchy Motors (26-34 Mull Street) has been identified due to current HAIL activities on the site including a service station and a motor vehicle workshop. An underground petroleum storage system comprising of four fuel storage tanks was removed from the site in 2005. Bedding materials impacted by petroleum hydrocarbon contamination were removed and remaining soils complied with Tier 1 soil acceptance criteria for protection of groundwater quality (PDP, 2005).

3.6.2 Backpackers Express

Backpackers Express is listed as potentially contaminated on QLDC's register due to a QLDC Dangerous Goods licence for a 1,350 litres A/G tank at the site, however the current use is retail. No further investigations regarding the site are available.

3.6.3 Glenorchy Landfill

Closed in 2000, the Glenorchy landfill occupies a quarried hollow and was used primarily for household wastes with farming, commercial and industrial waste accepted by approval of the Council (QLDC, 2000). DCG completed soil sampling to delineate the extent of the closed landfill (DCG, 2013); the mapped extent has been modified based on these findings. Surface soil samples taken from around the landfill, and one within the landfill were analysed for TPH, BTEX, Metals, pH and multiresidue pesticides. Concentrations of TPH and BTEX in all samples were below laboratory detection limits. Cadmium, Chromium, Copper, Lead Nickel and Zinc levels in all samples analysed returned concentrations either below detection limits or the adopted guideline value. Three of the seven soil samples returned arsenic concentrations that exceeded the soil guideline values, however it is likely that this is sourced from the local geology, rather than from anthropogenic sources. These samples were further analysed for Gastric Extractable Arsenic, to determine the bioavailable fraction found in site soils. As the percentage of bioavailable arsenic ranged from <6% to 27%, DCG confirmed that arsenic is highly unlikely to affect the human health of site occupants (DCG, 2013). Test pits within the landfill were excavated to a depth of 2.2 m. The extent of landfill wastes below this depth is unknown.

Groundwater monitoring of two bores was required as part of the resource consent 95279 for the closed Glenorchy landfill since 1999. Samples were taken every three months and analysed for pH, conductivity, ammoniacal-N, chloride, faecal coliforms, zinc, cadmium, arsenic, chromium, Total Kjehldal Nitrogen (TKN), nitrate, orthophosphate (PO_4) (Imtech, 2000). This was extended to a third monitoring bore in 2007. QLDC ceased groundwater quality monitoring in 2013, as it was considered that the programme was no longer required for resource consent given the size and age of the landfill. QLDC asserts that at the time monitoring ceased that groundwater chemistry in the downstream landfill monitoring bores had stabilised and was not being adversely affected by landfill leachate (QLDC, 2013).

3.6.4 Agricultural land

Note that landuse changes, agricultural land is often tested for the presence of pesticides in the soils. Samples within the agricultural land adjacent to the landfill were analysed for TPH, BTEX, Metals, pH, Multiresidue pesticides. All multiresidue pesticide results were below laboratory detection limits (DCG, 2013).

4 Ecological Environment and Regionally Significant Values

Lake Wakatipu has several natural values, including significant presence of trout and salmon. It is an outstanding natural feature for numerous reasons, including the protection of nursery and breeding areas for native fish and birds (kohanga) and the recognition of the lake as a treasured resource (waahi taoka) (see Regional Water Plan: Schedule 1A, ORC, 2012). Lake Wakatipu is a popular holiday and visitor destination. Recreational boating is popular on the lake and the shores of the lake are regularly utilised for picnicking, swimming, and fishing. Water quality has a major impact on these values (Lowe Environmental Impact, 2017).

Schedule 1A of the ORC Regional Water Plan sets out: (a) ecosystem values; (b) outstanding features or landscape; and, (c) significant indigenous vegetation and habitat of indigenous fauna for Lake Wakatipu. It states that the lake is:

- A large water body that provides diverse life cycle requirements for a particular species or range of species, has important macrophyte bed composition for resident biota, is weed free, has juvenile rearing areas, riparian vegetation of significance to aquatic habitats, has significant presence of eel, salmon and trout, significant range of indigenous fish diversity including rare fish and indigenous aquatic vegetation.
- Outstanding as a fishery, for its scenic characteristics, scientific value (in particular water clarity and bryophyte community), recreational and historical purposes, significance in accordance with tikanga Maori. Scenic values including clear blue colour of the water, river deltas and beaches.
- Significant habitat for koaro and rare association of aquatic plants.

There are no large consented discharges into Lake Wakatipu, but residential and commercial development is changing the nature of the catchment, which may have an impact on future water quality (ORC, 2009). Table 7 shows the discharge thresholds for Lake Wakatipu in order to ensure water quality is maintained. These values are currently unknown for the Glenorchy township catchment area.

TABLE 7: PERMITTED ACTIVITY DISCHARGE THRESHOLDS FOR WATER QUALITY BY DISCHARGE THRESHOLD AREA (REGIONAL WATER PLAN: SCHEDULE 16, ORC, 2012)

Discharge Threshold Catchments	Nitrate-nitrite nitrogen	Dissolved reactive phosphorus	Ammoniacal nitrogen	Escherichia coli
Lake Wakatipu	1.0 mg/l	0.035 mg/l	0.2 mg/l	550 cfu/100 ml

Other regionally significant environs bordering on the Glenorchy township include uncommon ecosystems including braided riverbeds, a wetland / lagoon and the lake margin. These ecosystems have been classified as endangered and vulnerable respectively (Holdaway, Wiser, & Williams, 2012). Specific vulnerable or threatened flora and fauna would require a site assessment to establish presence within the site location.

4.1 Braided Riverbeds

Braided Rivers flow in multiple, mobile channels across a gravel floodplain and carry a high sediment load. They show evidence of recent channel migration within the active riverbed and of historical movement of the active bed across the floodplain (Gray & Harding, 2007). The Rees River (see Figure 1), which lies on the north boundary of Glenorchy township, is a notable example of a braided river and is included in the Regional Water Plan: Schedule 1A for a number of natural values and outstanding natural and physical characteristics. These include (ORC, 2016):

- A high level of naturalness (free from significant interference by human practices);
- Significant trout, eel and salmon populations;
- Free from aquatic pest plants; and
- It is included as an area of importance to internationally uncommon species, such as the black fronted tern, wrybill and banded dotterel.

There are several threats to this ecosystem which contribute to its current classification as Endangered (Holdaway, Wiser, & Williams, 2012). Human impacts (i.e. deforestation, stopbanks, willow plantings) have changed the magnitude of flooding, sediment loads, and fire frequency. Braided riverbeds are very susceptible to a wide range of weeds, particularly hard-seeded legumes. Browsing impacts from both domestic stock and wild mammals have been reported (deer, goats, rabbits, hares). Predatory mammals (stoats, cats, hedgehogs) have an impact on breeding of riverbed birds, such as wrybills, and by disturbing bird colonies. Gravel extraction and some recreational use (i.e. trail biking/quad driving) damage plant communities and disturb nesting birds. Abstraction of water for agriculture is a looming threat to the dynamics of braided rivers, for example by reducing the number of islands for breeding birds (Landcare Research, 2017).

The Buckler Burn River is also noted for a high degree of naturalness above 900 metres asl (ORC, 2016).

4.2 Wetland / Lagoon

A lagoon can be defined as a shallow lake that is intermittently connected with a river, a deeper lake, or the sea (Landcare Research, 2017). In this instance, the Glenorchy Lagoon is a freshwater wetland / lagoon that is connected to the head of Lake Wakatipu (see Figure 1) and considered a Regionally Significant Wetland under the Regional Water Plan (ORC, 2016).

Lagoons are extremely important habitat for bird conservation and are important refuges for birds during the shooting season. The Glenorchy Lagoon is recognised as a regionally significant habitat for waterfowl and swamp birds, including paradise shelduck (*Tadorna variegata*), mallard (*Anas platyrhynchos*), grey duck (*Anas superciliosa*), black swan (*Cygnus atratus*), grey teal (*Anas gracilis*), swamp hen/pukeko (*Porphyrio porphyrio melanotus*) and oystercatchers (*Haematopodidae*) (ORC, 2016). The grey duck is listed as Nationally Critical and is easily mistaken for a mallard which is a Not Threatened species (Robertson, et al., 2016).

Lagoons are also important breeding grounds for native fish. Goldsmith, Stewart and Ryder (2006) identified the presence of 7 species within the Glenorchy Lagoon via published and unpublished reports. These were longfin eel (*Anguilla dieffenbachii*), goldfish (*Carassius auratus*), koaro (*Galaxias brevipinnis*), common bully (*Gobiomorphus cotidianus*), rainbow trout (*Oncorhynchus mykiss*), chinook salmon (*Oncorhynchus tshawytscha*) and brown trout (*Salmo trutta*). Both the longfin eel and koaro are listed as At Risk – Declining (Goodman, et al., 2013).

Several threats to the lagoon environment contribute to its Endangered threat status (Holdaway, Wiser, & Williams, 2012). Lagoon margins are a fragile system and the greatest threat to unfenced lagoon margins is grazing and trampling by domestic and feral animals. There are potential problems of nutrient enrichment from fertiliser and stock and from urban runoff into lagoons close to human settlements. Lagoon systems are therefore under greatest development threat near centres of population (Landcare Research, 2017).

The ORC Regional Water Plan: Section 10 intends for Otago's wetlands and their individual and collective values and uses to be maintained or enhanced for present and future generations; and that Otago's Regionally Significant Wetlands and their values and uses are recognised and sustained (ORC, 2016). It is therefore important to ascertain the levels and sources of possible contaminants entering the Glenorchy Lagoon to ensure flora, fauna and habitat can be maintained and enhanced by mitigating any current or potential issues arising.

4.3 Lake Margins

The beds and margins of Otago's lakes and rivers are complex and dynamic natural systems. These systems provide diverse habitats for plants and animals, valued mahika kai, and opportunities for recreational use. Their outstanding natural features and landscapes are an integral part of the natural character of the region (ORC, 2016).

Often because of their outstanding natural features these areas are becoming increasingly inhabited by people wishing to enjoy the beautiful scenery and pristine environment. This in turn removes some of the natural beauty of an area and places pressure on the receiving environment. This is largely why lake margins are now classified as a vulnerable ecosystem (Holdaway, Wiser, & Williams, 2012). Nitrification from urban or agricultural run-off can aid the establishment of exotic aquatic weeds such as Lagarosiphon (*Lagarosiphon major*) by inhibiting native species growth rates and allowing aquatic weed species to dominate. This can also impact breeding locations and fauna health. Leachate from septic tanks or other urban contaminants reduces water quality and will impact the high recreational value of Lake Wakatipu within the Glenorchy surrounds (boating, fishing and bathing).

Lake margins encompass a range of dynamic processes including the nature of water flow, sediment transport and flooding, and the diverse range of human activities occurring in these areas. Therefore, there is a need for management and assessment of human activities, including building and contaminant run-off, on the beds and margins of lakes and rivers to avoid, remedy or mitigate any adverse effects, including cumulative effects.

5 Analysis of Available Information

5.1 Conceptual Model

Based on the review of available information, a basic conceptual model for the Glenorchy township has been developed. Movement of contaminants into the groundwater and surface water will be governed by flow paths, attenuation, transformation, dispersion. On the mostly flat land of the Glenorchy township, rainfall and septic tank effluent willl infiltrate quickly through the shallow soils overlying gravels to recharge shallow groundwater.

Due to the thin shallow soils overlying gravels there is unlikely to be much nutrient or bacterial attenuation prior to effluent reaching shallow groundwaters. Within oxidising groundwater, phosphorous migration may be attenuated by adsorption, however nitrates will be transported within the groundwater. Groundwater is likely to discharge into Lake Wakatipu and possibly the Rees River.

In times of heavy rainfall, flooding may occur around the town margins, compromising septic tank functioning and resulting in pulses of contaminants entering Lake Wakatipu.

5.2 Information Gaps

This desktop assessment has endeavoured to obtain all the historical and current ecological data that would further inform the QLDC's Glenorchy Wastewater Scheme by assessing current ecological impacts of the existing on-site sewage system in Glenorchy. Overall, the current surface water and groundwater quality monitoring data found within the Glenorchy environs does not adequately represent the current state of the environment; due to limited sites, infrequent monitoring, and the range of parameters analysed.

The key information gaps identified in this assessment are as follows:

- Concurrent groundwater level and surface water level data to confirm groundwater flow paths;
- Septic tank mapping and assessment of failure within Glenorchy township;

- Coordinated surface water and groundwater quality monitoring data at strategic locations for parameters that will isolate the impacts of septic tanks apart from other sources of contamination such as the landfill and upstream landuses; and
- An ecological assessment of the lake margins during the summer months.

6 Recommendations and Conclusions

Glenorchy Township is located on a river delta at the head of Lake Wakatipu. The township is bordered by the lake to the west and old river terraces at the foot of the Richardson Mountains to the east. The Glenorchy Lagoon and Rees River lie to the north and to the south the Buckler Burn River define the township's natural boundaries. Sewage in the township is managed using on-site systems; 96 dwellings have septic tanks, 22 have advanced wastewater treatment plants and there is a small privately-owned treatment plant with associated disposal fields servicing Lancaster Place.

Queenstown Lakes District Council (QLDC) commenced investigations into the provision of a reticulated sewerage scheme for Glenorchy in 2005 to improve water quality and reduce natural hazards. As the adoption of a reticulated sewerage scheme for the community will impact the ratepayers of the Glenorchy township and surrounds, RCP commissioned e3Scientific Limited (e3S) on behalf of QLDC to provide further assessment of the impacts of the 'Do Nothing' option i.e. the impact of on-site sewage management systems on soil and water quality within the township of Glenorchy.

e3Scientific has reviewed all of the available reports and data regarding the sites environmental attributes – soils, geology, climate, surface water and groundwater to determine a conceptual model of how septic tank effluent will be transported into the receiving environment. In addition, e3S has reviewed available information regarding potentially contaminated sites in the Glenorchy township which may also be influencing soil and water quality.

To be able to provide an accurate assessment of the impact of on-site sewage management systems on surface water quality within the township of Glenorchy, the information gaps identified in Section 5.2 need to be filled. In order to do this, the following tasks are required for the Stage 2 Scope of Works:

- Installation of groundwater monitoring piezometers- Three additional monitoring piezometers should be installed around the town margin – one towards the north end of Argyle Street, one in the reserve near the jetty, and one near the golf club. These piezometers will be sited to enable a clearer delineation of flow paths, and to enable groundwater down-gradient of the Glenorchy township to be sampled. It is proposed that these piezometers can be monitored in conjunction with the landfill monitoring bores, and possibly the town water supply bore (if the bore can be sampled directly, rather than from the storage tanks).

- Water level survey – survey of Lake, Lagoon, Rees River, Buckler Burn and groundwater levels i.e. survey piezometer reference points in the new monitoring network. Continuous water level loggers can be installed in the monitoring piezometers to capture water level fluctuations and any changes in flow paths due to flows and rainfall.
- Septic tank mapping and assessment of failure within Glenorchy township
- Coordinated surface water and groundwater quality sampling program using the newly established groundwater monitoring network and strategic surface water locations. The locations of surface water samples will be confirmed after the water level survey, and will utilise historical locations where possible. Samples will be analysed for parameters that will isolate the impacts of septic tanks apart from other sources of contamination such as the landfill and upstream landuses, such as major ions, Bromide, *E.coli*, enterococci, faecal sterols, dissolved organic carbon and nutrients.
- An ecological assessment of the lake margins during the summer months

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Appendix A: Bores in Glenorchy township

Well Number	*Drilled Depth (m.b.g.)*	*Standing Water Level (m.b.g.)*	*Easting (NZTM)*	*Northing (NZTM)*	*Elevation# (mASL)*	*Owner*	*Location*	*Screen Top*	*Use*	*Water Quality Sampling*
E41/0099	*22.15*	*13.4*	*1235902.87*	*5022569.4*	*325.93*	*QLDC*	*Glenorchy to west of main road near Buckler Burn*	*19.63*	*Town water supply*	*Ongoing*
*E41/0100**	*23.1*	*10.38*	*1235922.89*	*5022579.43*	*326.19*	*QLDC*	*0.95 Km North of Buckler Burn Bridge*	*20.83*	*Town water supply*	*Ongoing*
E41/0113	*30*		*1235371.53*	*5023420.12*		*GLENORCHY HOTEL*			*Disused*	
E41/0114	*30*		*1235271.7*	*5023019.51*		*A H I UNITS*			*Disused*	*1998*
E41/0116	*25*		*1236090.99*	*5021430.05*		*Charterhall Trustees*			*Domestic*	
*E41/0118**	*6.23*	***8.395***	*1235672.46*	*5022719.42*	*321.44*	*Department of Conservation*	*Glenorchy*		*Disused*	
*E41/0119**	*7.2*	***6.15***	*1235772.13*	*5023320.29*	*315.73*	*Kemp G, Glenorchy Holiday Park*	*2 Oban Street, Glenorchy Holiday Park*		*Disused*	*1997, 1998*
E41/0120	*0*		*1235471.81*	*5023219.93*		*Ministry of Education*	*Glenorchy Primary School, Oban Street, Glenorchy*		*Disused*	
E41/0121	*0*		*1235471.74*	*5023320.06*		*CROW R*	*Cnr (NW) Islay and Oban Streets*		*Disused*	
*E41/0122**	*5.6*	*4.685*	*1235471.66*	*5023420.19*	*314.23*	*Thompson H F*	*Cnr Mull and Oban Streets (SW)*		*Disused*	
*E41/0123**	*5.36*	***2.04***	*1235271.4*	*5023420.04*	*312.64*	*Gollop R*	*Glenorchy Cafe, Mull Street*		*Disused*	*2002, 2003*
*E41/0124**	*3.7*	*2.89*	*1235872.11*	*5023520.63*	*313.08*	*Millar D H*	*Mull Street, Glenorchy*		*Disused*	
*E41/0125**	*6.3*	*4.325*	*1235388.6*	*5023348.98*	*314.16*	*Campbell J & L*	*Cnr Mull and Argyle Streets (SE)*		*Disused*	
*E41/0126**	*6.8*	*6.335*	*1235560*	*5023194*	*316.37*	*Bakker I J*	*Second House West of Cnr Coll and Oban Street*		*Disused*	

Well Number	*Drilled Depth (m.b.g.)*	*Standing Water Level (m.b.g.)*	*Easting (NZTM)*	*Northing (NZTM)*	*Elevation# (mASL)*	*Owner*	*Location*	*Screen Top*	*Use*	*Water Quality Sampling*
E41/0129	*40.95*	*14.08*	*1235773.51*	*5021517.92*		*Charterhall Trustees*	*Blanket Bay, Glenorchy*	*39.6*	*Scheme*	
E41/0133 - MW1[1]	*0*	*310.27*	*1235958*	*5023081*	*318.37*	*Q L D C*	*Landfill Monitoring well*		*Monitoring*	*1999-2013*
E41/0144	*12*		*1236673.99*	*5022419.79*		*L Fox*	*Bucklerburn Valley adjacent to the Glenorchy Queen*		*Consented scheme*	
E41/0170	*14.64*	*2.07*	*1236516*	*5022429*	*335.77*	*Dave Greenberg*	*Campbelltown, Glenorchy*	*13.64*	*Domestic*	
E41/0165	*207*	*53*	*1237344*	*5020146*		*Cabo Limited*	*Blanket Bay*		*Domestic - Dry*	
MW2[1]		*309.9*	*1235822*	*5023244*	*315.82*	*QLDC*	*Coll St*		*Monitoring*	*1999-2013*
MW3[1]		*312*	*1236205*	*5023100*	*324.98*	*QLDC*	*East of Landfill*		*Monitoring*	*2006-2013*

** Bore located by Lindqvist (1997)*
 # Elevations extracted from 0.5 m DEM supplied by QLDC based on adjusted locations
***2.04** Water levels in bold adjusted according to reference levels described in field sheets in Lindqvist (1997)*
1235958 underlined locations altered based on Lindqvist (1997) descriptions of locations in field sheets.
[1] Locations obtained by georeferencing map from QLDC (2013).