MEMORANDUM **Job 10639**

To: Sarah Davidson

From: Terry Hughes, Brittany Paton, Brian Ellwood

Date: 15 March 2021

Subject: RFI Queenstown Lakes District Council – Kingston Township Wastewater Discharge Application RM20.164.01

Introduction

Queenstown Lakes District Council has submitted an application to Otago Regional Council for the discharge of treated domestic effluent to land for the purpose of disposal of wastewater from Kingston Township (Consent Application Number – RM20.164.01)

As part of the consenting process, Otago Regional Council has asked requested further information under section 92 of the Resource Management Act. The following memo sets the response from Queenstown Lakes District Council on the questions asked by Otago Regional Council. The following attachments have been added and are referred to throughout this response:

Attachment 1: Borelogs
Attachment 2: Ryder Ecology Report
Attachment 3: NIWA Stream Gauging Report
Attachment 4: Water Care Certificates of Analysis
Attachment 5: LEI Soil Reporting for LTA 1

Surface Water Ecological Assessment

The first question the Otago Regional Council had was regarding the surface water ecological assessment and is as follows:

E3 Scientific have provided an assessment of the application on the surface water and ecological aspects of the proposal. The application has been amended since E3 Scientific undertook a review of the pre- application on behalf of Otago Regional Council.
The application does not include a complete assessment on the aquatic values of identified water bodies that may be affected by the application and the potential ecological or surface water effects. An ecological and surface water assessment of the surrounding water bodies is therefore required to provide an understanding of the receiving freshwater environment and to identify further mitigation if required. The ecological assessment must include the following, but not limited to:
- *The wetland area adjacent to LTA 2;*
- *The unnamed tributary and any flow path from the wetland identified;*
- *The lake margins at Kingston Township (including Kingston Creek and the unnamed tributary confluences);*

• The pond within LTA 1 and any flow path with Kingston Creek identified; and
• Methods to avoid, remedy or mitigate any adverse effects on the aquatic values identified in the assessment, including any updated water quality monitoring requirements.

QLDC has completed an ecological assessment of the specified surface water features using Ryder Environmental (REL). Water quality at the Lake shore was also sampled. The assessment is attached to this memo as an Attachment 2.

The assessment confirmed there are no existing surface water connections between the proposed land treatment area and the identified surface water bodies within the vicinity. It concludes that the most likely way that surface water bodies could be impacted by the effluent is via groundwater connections to the proposed treatment area. The combination of a proposed secondary treatment plant, the low application rate, and the large depth of unsaturated soil and subsoil is said to reduce the potential for nutrient and faecal bacteria contaminants leaching to groundwater from the effluent application.

The survey also concludes that the existing aquatic communities in the vicinity of the application area are expected to be tolerant of any potential contaminant input should additional leaching occur.

The risk of contaminants entering Lake Wakatipu under the proposed land treatment system is also likely reduced when compared to the existing effluent management situation in Kingston, that is, uncontrolled individual treatment via septic tank systems.

Overall, Ryders conclude that any adverse effects on aquatic communities within surface water bodies will be less than minor. Monitoring has been proposed to ensure compliance with the proposed volume and nutrient loading limits within the application area, and to monitor the impact of the proposed activities on the environment (reference location in AEE).

This assessment supports the current proposal, reflects the pre application advice received, and no further mitigation is required other than monitoring conditions already proposed.

E3 mentioned the possibility that surface water could potentially enter a tributary of Kingston Creek if water flowed down a steep gully directly to the east of the pond adjacent to LTA1 and potentially into a culvert under State Highway 6 (SH6) at the base of the gully. This could potentially direct surface water runoff into a tributary of Kingston Creek located on the east side of SH6. A site visit by LEI in June 2020 confirms that there is no legitimate flow path due to the topographical constraints in the easterly direction. Although surface water could potentially flow in the direction proposed by E3, it is considered that the likelihood of surface flow reaching the Kingston Creek is very low. This is because no culvert laying beneath the highway where the catchment is likely to exit was observed and no overland flow erosion or any vegetation indicative of surface flow was also observed. Any overland flows will likely recharge to groundwater along at least 1km of farmland paddock and will essentially act as a swale.

The pond near LTA 1 has recently been drained by the landowner in this southerly direction. Figure 1 from June 2020 show the drainage of this pond in the southerly direction (Figure 1). Ryder Environmental did not assess this pond due to its drainage path.

Figure 1: Drainage of Nearby Surface Water Pond (near LTA 1)

Groundwater Assessment

Pattle Delamore Partners Ltd (PDP) have provided an assessment of the application on the surface water, groundwater and OVERSEER® aspects of this application.

No information has been provided to confirm the nature of the existing groundwater environment beneath the LTAs and Kingston, including groundwater flow paths and flow directions. A hydrogeological assessment of the groundwater system beneath the LTA and Kingston is required to understand the sensitivity of the environment (as required by Schedule 4, Part 6(1)(d) of the Resource Management Act 1991). The assessment must at least include the following (but not limited to):
• Groundwater levels and an assessment of flow direction;
• Groundwater quality, including the groundwater quality at the LTAs and within Kingston;
• Effects of the discharge on the groundwater environment and receiving water bodies, including effects of pathogens and nitrogen; and
• Methods to avoid, remedy or mitigate any adverse effects on the groundwater quality identified in the assessment, including any updated monitoring requirements.

LEI Kingston Groundwater Study

A meeting was held on the 26/08/2020 between the applicant, technical reviewers and ORC to discuss and confirm the RFI requirements. It was agreed that groundwater monitoring bores would be installed across and surrounding the site to assess groundwater levels and behaviour beneath the proposed land treatment areas. As part of the groundwater study, it was also decided to sample these bores for water quality and to survey in the Kingston Township Tributaries to determine gains and losses and subsequently areas of groundwater discharge. The results and implications for the assessment from these investigations are presented here.

Monitoring Bores

Subsequent discussions were held between Hilary Lough (PDP) and Terry Hughes (LEI) to confirm the bore locations. These discussions were conducted on the phone and via email and locations were confirmed with some acknowledgement that the locations could shift slightly due to site conditions and landowner considerations. The final locations for the 7 monitoring bores are presented in Figure 2. Washington's Drilling were employed to drill the holes and install the piezometers and screens. Screening depths were decided onsite in response to geological conditions encountered and in agreement between driller, LEI, PDP reviewer and the client (QLDC) project manager. Borelogs are contained within Attachment 1, and a summary of geology and construction details are presented in Tables' 1 and 2. Borehole descriptions are presented in drilling order.

Figure 2: Kingston LTA Monitoring Bore Locations

Table 1: Monitoring Well Details

Monitoring Bore	LiDAR GL (AMSL)	Drill depth (m)	Top of Screen (m AMSL)	Height to top of casing (m)	Depth to GWL (m)	GWL (AMSL)
GW1	350.4	21.0	331.9	0.75	16.7	334.4
GW 2	339.8	10.7	332.1	0.9	6.8	333.87
GW 3a	346.3	28.8	322.0	0.7	13.8	333.18
GW 3b	346.3	24.8	329.3.0	0.7	14.2	333.89
GW 4	383.0	60.0	-	-	-	-
GW 5	374.2	59.3	321.4	0.75	41.4	333.28
GW 6	374.8	59.0	322.3	0.65	42.3	333.32
GW 7	388.0	60.0	-	-	-	-

Table 2: Borehole Drilling Summary

Borehole ID	Drill date	General description
GW7	14/9/2020	This hole was drilled to a total depth of 60 m bgl with no groundwater or soil moisture encountered at depth. A large boulder was drilled through between 46 and 48 m and the driller communicated that the hole became drier with depth particularly below the boulder. As a result of the lack of soil moisture encountered, no piezometer was installed. Silty GRAVEL was the predominant geology encountered within this borehole and is inferred to be glacial till.
GW4	17/9/2020	This hole was drilled to a depth of 60 m bgl, also with no groundwater or soil moisture encountered and so no piezometer was installed. The driller also conferred that the hole became drier with depth and that cuttings were becoming dusty/dustier with depth. Silty GRAVEL was the predominant geology encountered within this borehole and is inferred to be glacial till.
GW3A and 3B	18/9/2020	Groundwater was encountered at different depths in this borehole indicating a separation of water bearing layers. Subsequent water quality analysis also indicates a separation of aquifers with samples from the different levels containing different water quality signatures. Prior to encountering a thick dry clay at 20.5 m depth, Gravelly SILT was encountered. Towards the base of this gravelly SILT, the soil became saturated and contained free water. Dry clay was present between 20.5 and 23 m bgl and appears to be capping a sandy GRAVEL. Beneath this dry clay layer, water was struck and rose up the hole indicating some sub-artesian pressure and confinement. A decision was made to screen both water bearing horizons. The geology encountered within this borehole was different to that encountered on top of the terminal moraine in Boreholes' GW4 and GW7 and is interpreted to be colluvium and or possibly beach deposits at depth.

Borehole ID	Drill date	General description
GW2	22/9/2020	With GW3 geology in mind, it was decided not to drill through any extensive dry clay layers and screen off the uppermost encountered water bearing layers. A water bearing silt was encountered at 3.8 m bgl and a decision was made to screen from 7.7 to 10.7 m bgl. Geology is inferred to be colluvial in origin.
GW1	23/9/2020	This hole was screened within the SILT encountered between 15 and 22 m bgl. A dry clay was encountered below this layer and it was decided to end the drilling before encountering any artesian pressure and screen off the layer that was likely to be recharged from the surface. Geology in this hole is inferred to be a mixture of till derived slope wash (containing high amounts of gravel) and colluvium
GW5	24/9/2020	Silty GRAVEL was encountered from 1.5 m down to a depth of 48.5 m bgl and moisture levels were dry. Beneath 48.5 m bgl the geology contained sands and was saturated, with water being struck. Water levels rose back to 44.5 m indicating sub-artesian pressures. The geology from 1.5 m to 59 m bgl is inferred to be glacial till.
GW6	30/9/2020	Silty GRAVEL was encountered from 5.0 m down to a depth of 47.5 bgl and moisture levels were dry. Beneath 47.5 m, the geology contained sands and was saturated, with water being struck. Water levels rose back to 43.2 m bgl indicating sub-artesian pressures. The geology from 5.0 m to 58.5 m bgl is inferred to be glacial till.

Water Levels and Interpretative Flow Direction

Water level data loggers were placed within the monitoring bores' GW1, GW2, GW3a, GW3b, GW5 and GW6. GW4 and GW7 were dry and therefore not considered for water level monitoring. Atmospheric pressure readings were also taken to compensate for total pressure readings. Approximately 3 months of recorded data has been processed and is presented in a hydrograph in Figure 3 below. A desktop assessment of water levels outside of the study area (both north and south) was also undertaken, albeit with sparse data.

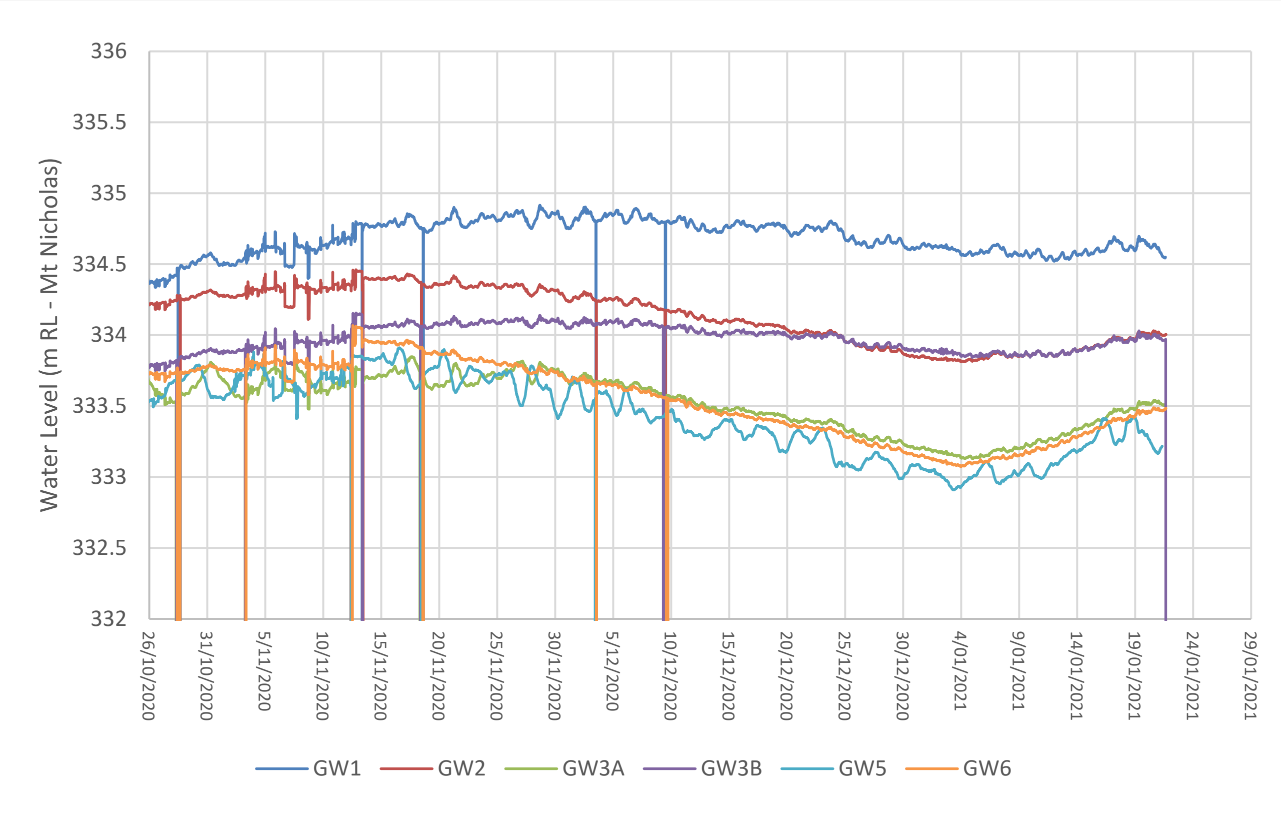

Figure 3: Kingston LTA Monitoring Bore Hydrographs

The water level study indicates that water level arrangement beneath the proposed LTA's is complicated. Plan and sections showing borehole locations and interpretative sections are presented in Figures 5, 6a and 6b. Conclusions that can be drawn from these water levels include:

- The dry bores (GW4 and GW7) are likely the result of highly compact glacial till, which are not able to contain wet to saturated amounts of groundwater or wet to saturated soils down to at least 323 m RL (LIDAR). This is at least 10 m below the water levels recorded in all other bores and signifies that the moraine is typical of a geologically complex depositional environment, such as the toe mounding of sediments in front of an ancient glacier.
- GW1 was uncharacteristically higher than all other water levels, indicating a localised groundwater perching that could be sourced from the nearby boggy area. It is understood from the Ryder Ecological Report (Attachment 2) that GW1 exists near to a stretch of stream that is dry and displays water loss. This perching of groundwater above a highly compact dense layering of silt was also observed in GW2 and GW3a when being drilled.
- GW3b displays somewhat different water level fluctuation behaviour than GW3a, indicating that it is likely to be in a separate water bearing layer, and supports the perched groundwater interpretation.
- GW5 and GW6 display fairly similar water levels with a slight drop to the north but otherwise indicating a fairly flat piezometric surface between these two wells. In addition, they also have similar water level behaviour over time and are likely connected. GW3a can be grouped with GW5 and GW6, given its similar water level behaviour over time.
- Further to the south in the Mataura catchment and towards Trotters Flat (Figure 4), some bores are present with details recorded on the Environment Southland GIS (Beacon). Of particular note is Bore F43/0049 that is calculated to have a water level (RL) of 334 m indicating that water levels do not necessarily drop off significantly to the south, however, this could also be indicative of local highs due to localised terrace highs. In comparison, Allen Creek sits within a localised

depression some 20 to 30 m lower than the outwash terraces and will likely draw groundwater from the terrace with a commensurate groundwater gradient. Bore F43/0048 sits within a gully structure dissecting the outwash surface approximately 5 km south of the site. Water level RL calculated for F43/0044 is significantly lower than F43/0049, but is likely controlled by topography and the drainage gully structure that the bore sits within, indicating that groundwater has a significant localised behaviour, adhering to topography.

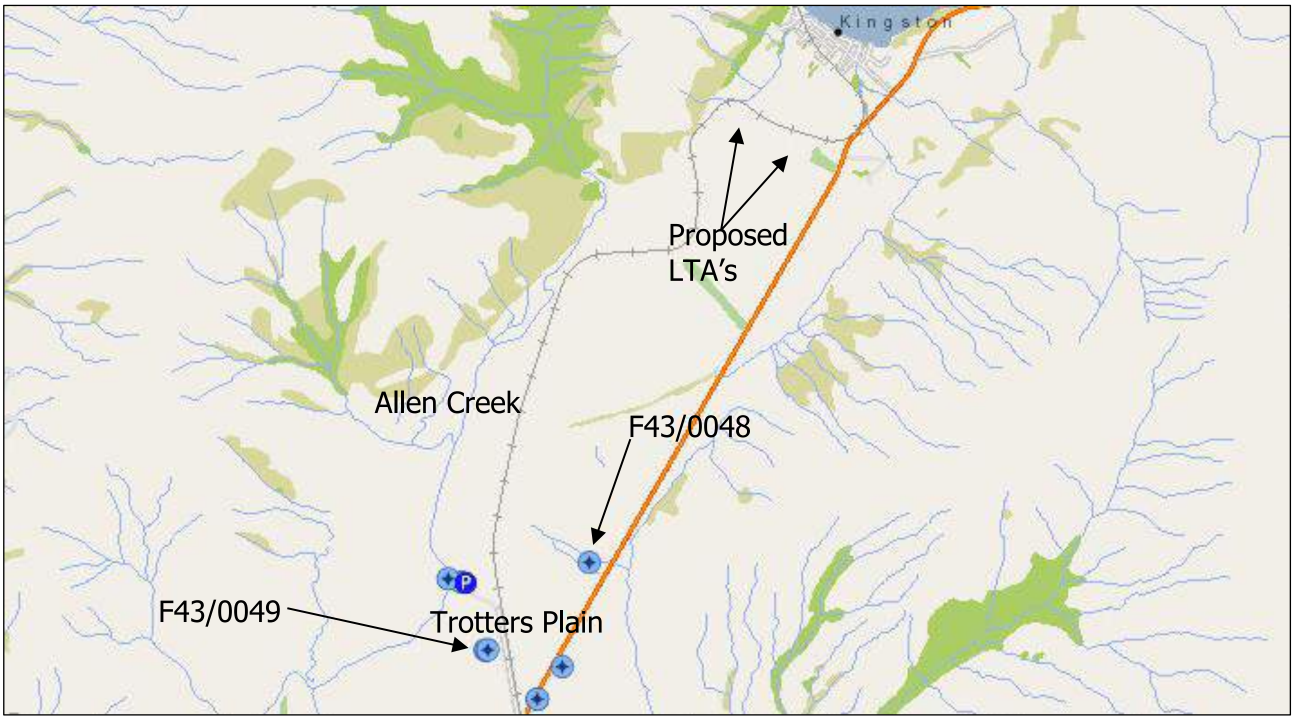

Figure 4: Mataura Catchment Bore Locations

- To the north of the proposed LTAs and within the Kingston township, several bores are present with relatively shallow groundwater depths (generally 2 to 3 m bgl) that are recorded on the ORC online GIS. These bores sit within a narrow range of topography between 325 m RL and 310 m RL (lake margin) and display a relatively steep groundwater gradient over a distance of approximately 400 m. Groundwater is most likely held within ancient beach deposits as the glacier regressed in a warming climate. No bores are present on the farmed area (Kingston Special Township Zone) between the existing township and the toe of the terminal moraine except for the KVL deep artesian monitoring bore (F42/0143), that appears to be unconnected to surface recharge influence. Water levels drop by approximately 12 to 14 m over a distance of approximately 700 m.

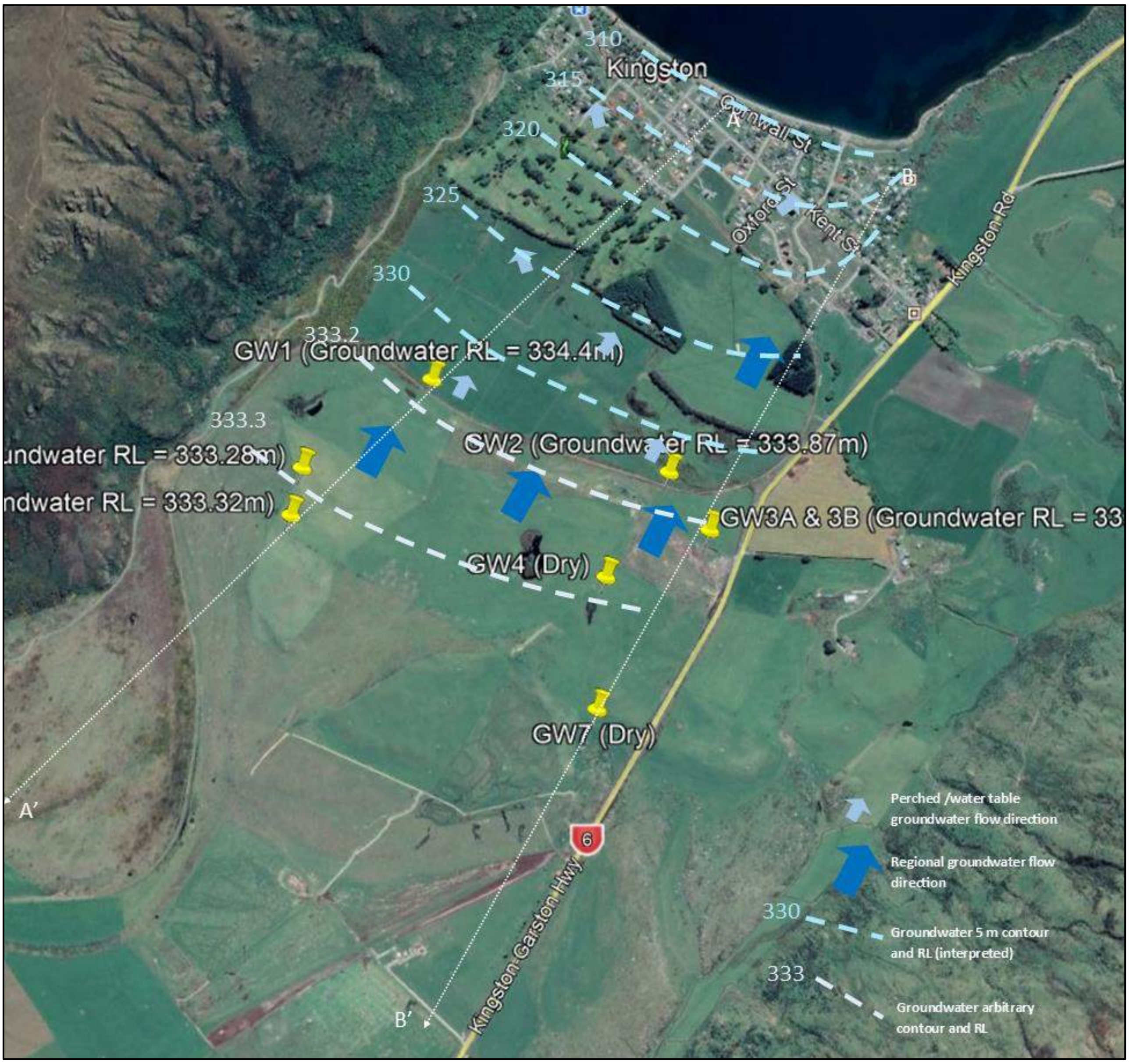

Figure 5: Interpretative Conceptual Hydrogeological Flow Model

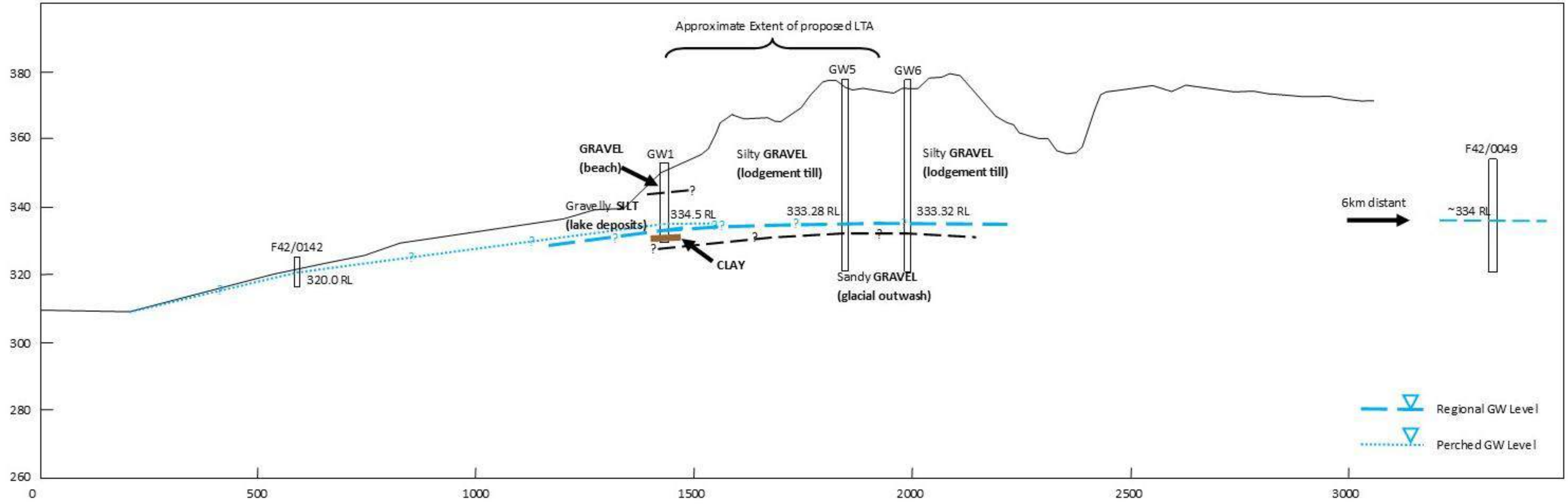

Figure 6a: Interpretative Conceptual Hydrogeological Sections A-A'(refer to Figure 5 for locations). Vertical exaggeration = 10:1 (approximate). Scale in metres.

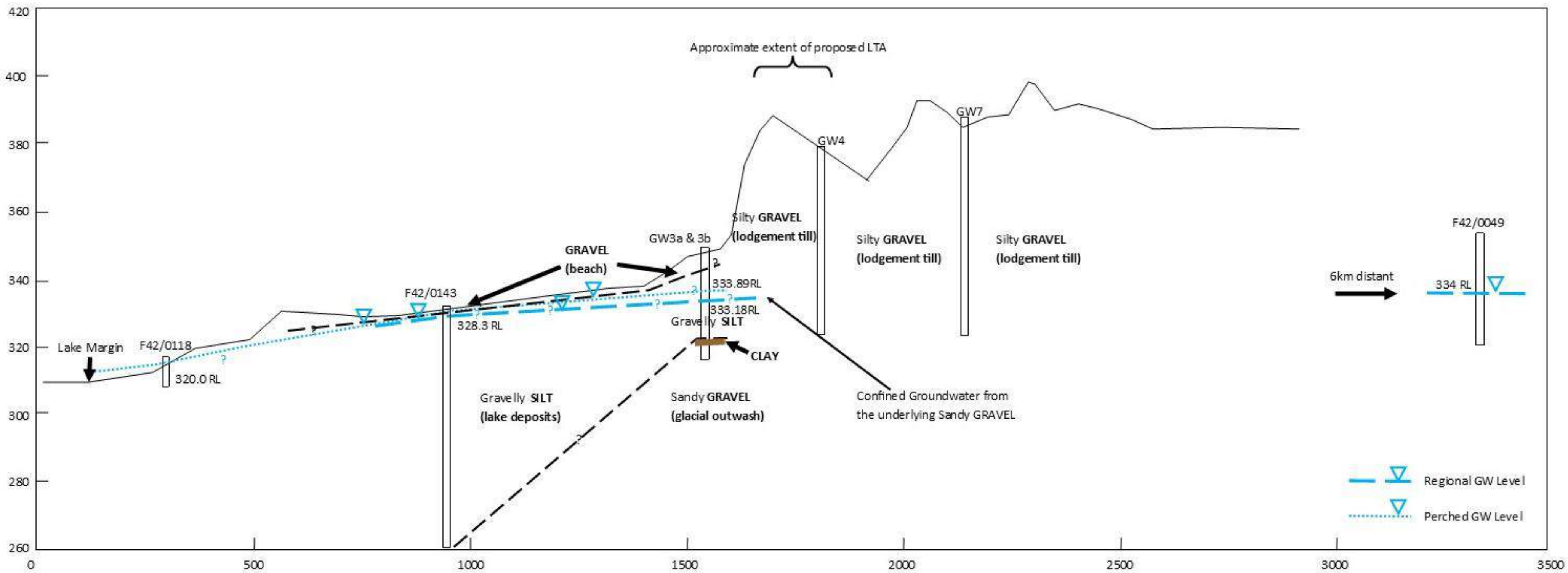

Figure 6b: Interpretative Conceptual Hydrogeological Sections B-B'(refer to Figure 5 for locations). Vertical exaggeration = 10:1 (approximate). Scale in metres.

In summary, the groundwater surface beneath the LTA is relatively flat with no definite indication of general groundwater flow direction. However, a steep hydraulic gradient exists to the north as water flows from a general RL of approximately 333m to 310m over a distance of approximately 1km (gradient of 0.023 m/m). In some areas, specifically GW4 and GW7, no groundwater is present down to a RL (LIDAR) of 323 m, at least 10 m below all other monitoring bore groundwater levels and it is likely these bores did not encounter outwash gravels that could bear free water. However, groundwater falls off relatively steeply to the north where a substantial drop in level is observed between the toe of the terminal moraine and township water bores and Lake Wakatipu. This steep groundwater gradient to the north will likely drive groundwater flow and flow direction. Some examples of groundwater following topography within the outwash terrace and gully features are also given and it is considered that groundwater within the Kingston Valley is likely to be somewhat topographically driven. The proposed LTA is situated on the northern slopes of the terminal moraine and therefore any recharge is likely to flow downwards in the unsaturated zone to the groundwater table and then north to the lake edge or terrace tributaries. Water quality readings provided below tend to support this assumption with greater concentrations of nitrate-nitrogen in monitoring bores present to the north of the proposed site particularly in GW1 and GW3A in the more perched groundwater zone.

The interpretative explanation (based on data available) for the site is that regional occurrence of groundwater is relatively flat within the topographical highs of the terminal moraine and outwash terraces. This groundwater then falls away to the north, flowing to Lake Wakatipu, which is acting as both a constant head boundary and large scale drainage structure, drawing water down with steep gradient from the valley infill deposits (moraine, outwash and lacustrine deposits). Water within the valley fill deposits could also be sourced from the high relief valley sides (Hector and Eyre Mountain Ranges) and evidence for this is in the sub-artesian nature of water struck within GW5 and GW6 as well as the KVL bore (F42/0143) further to the north within the proposed Kingston subdivision with chemical signatures (contains arsenic) unlike the overlying perched water. Evidence for water perching above low permeability sediments is present within all bores along the toe of the terminal moraine.

Flow Gauging

Flow gauging was undertaken by NIWA to generate an understanding of losses and gains along the unnamed tributary and Kingston Creek with a subsequent understanding of possible connections to groundwater within the Kingston lacustrine terrace. Flow losses or gains along these streams could estimate, albeit with low resolution, potential discharges from groundwater to these environments that could contain ecological value. For detailed reading on these flow gaugings, please refer to the NIWA report contained within Attachment 3. The NIWA report suggests that flows along the unnamed tributary are gaining from approximately the location of golf course to the lake margin by roughly 10 L/s. The situation within the Kingston Creek appears to be more complicated, with gains of approximately 15 L/s occurring from station KC3 to KC4, however the reverse occurs from KC4 to KC5. The drain that exists along the railway, near the railway station appears to discharge roughly 1 L/s, all source from groundwater with no clear upland source apparent. It is therefore considered that groundwater does discharge to these streams within their lower reaches and the amount is similar to what would be recharged from rainfall in the general area.

Water Quality

Water quality samples were taken from all bores to measure determinants as outlined in the proposed condition set (Condition 15), these were:

i. BOD_5;
ii. Total phosphorous;
iii. Total nitrogen;
iv. Nitrate-N;
v. NH_4-N; and
vi. Field measurements of pH, EC and dissolved oxygen;

Three sample rounds have been undertaken at the time of this response. Samples were collected in October, November and December 2020 and results are presented below in Table 3. The Certificates of Analysis for the samples are shown in Attachment 4. These and future samples collected prior to the scheme commissioning will form the baseline information that future monitoring comparisons can be made.

Table 3: Summary of Water Quality Parameters for Onsite Monitoring Bores (Oct, Nov, Dec). All samples presented as mg/L

Parameter	GW1	GW2	GW3a	GW3b	GW5	GW6
Conductivity	140, 140, 140	69, 66, 66	170, 140, 150	520, 280, 440	-, 190, -	100, 110
DO	11, 10.9, 10.4	9.4, 9.4, 8.8	2.5, 3.5, 9.8	0.6, 0.8, 1.0	-, 10, -	9.4, 8.9, -
pH	5.8, 5.9, 5.7	5.8, 6.0, 5.7	6.3, 6.5, 6.5	7.5, 7.4, 6.9	-, 6.8, -	6.6, 6.6
Ammon. N	<0.01, <0.01, <0.01	<0.01, <0.01, <0.01	<0.01, <0.01, <0.01	<0.01, <0.01, <0.01	<0.01, <0.01, -	<0.01, 0.05, -
$CBOD_5$	<2.0, <2.0, <2.0	<2.0, <2.0, <2.0	<2.0, <2.0, <2.0	4.9, <7.2, <6.0	<2.0, <2.0	<2.0, <2.0
Nitrate-Nitrogen	7.1, 7.1, 7.4	1.3, 1.7, 1.7	4.1, 4.3, 4.7	<0.01, <0.01, 1.2	2.2, 3.4, -	0.29, 0.25, -
T.N.	7.3, 7.5, 6.9	1.9, 1.9, 1.9	4.7, 4.3, 4.8	0.4, 0.63, 1.7	3.7, 3.1, -	0.44, 0.61, -
T.P.	0.07, 0.13, 0.06	0.1, 0.12, 0.05	0.15, 0.47, 0.34	0.39, 0.35, 3.3	<0.01, <0.01, -	<0.01, 0.01, -

Observations and subsequent considerations from sampling results in Table 3 include:

- GW1 has substantially higher concentrations of Nitrate-Nitrogen to all other bores, indicating near surface recharge source and a concentration indicative of surrounding landuse practices. It is in contrast with bores' GW5 and GW6 which both have substantial reductions in nitrate-N indicating either a different recharge source and/or a reflection of the depth of overlying unsaturated soil.

- GW3a and 3b have significantly different chemical signatures, indicating that water is sourced from a different water bearing layer separated by a low permeability soil.
- GW2 should have a similar value of Nitrate-Nitrogen to GW3a and GW1, but given that it is in a location unlikely to receive overland flow from the above moraine in the form of an existing overland flow path, it is reasonable to assume that it would receive no surface recharge from the moraine and hence a low Nitrate-Nitrogen concentration results. All other parameters appear to be reasonably consistent.
- No phosphorus readings were recorded in GW5 and GW6 and this could be explained by the upgradient location and relatively thicker depth of unsaturated soil compared with all other bores sampled

The Otago Regional Council prepared a report on Kingston groundwater quality in 2006. This report concluded that levels of nitrate-nitrogen average 0.44 mg/L, a median of 0.15 and a maximum of 2.42 mg/L recorded in one of the bores indicating proximity to a septic tank or application of fertiliser. In addition, high levels of ammonia were found in one of the township bores, indicating septic tank source. Although this report is 14 years old, development and farming practices have changed little over that time and it is presumed that these values will still be reported if further study was undertaken. The low levels of nitrate-nitrogen in comparison to the values recorded in boreholes GW1, GW2 and GW3a are intriguing and suggest that some attenuation or dilution is occurring with flow down the Kingston flat. Given the bounds of the aquifer, and therefore limited recharge across the general area, it is considered that groundwater that flows from the Moraine slopes and upper terraces will constitute the majority of groundwater flow, therefore some attenuation could be occurring for a reduction of nitrate-nitrogen to be occurring from existing farm inputs or there could be some recharge coming in from the valley sides and mountain ranges. The 2006 report highlights high iron content within the Kingston bore water and it is understood that high levels of iron can denitrify nitrate-nitrogen within groundwater and is a possible explanation for this attenuation. Rivett et al (2008) provides a good summary of the iron denitrification processes, both biotic and abiotic. The report also makes mention that the groundwater is likely sourced from recent recharge.

<u>Groundwater Travel Time and Pathogen Risk Assessment</u>

Groundwater flow travel time from the LTA to the Kingston township needs to be assessed for the transport of potential pathogens contained within the leached discharge. Water discharged to the land treatment areas will likely travel at least 15 to 40 m through unsaturated till prior to reaching any perched or regional groundwater flowing system. Once entrained in flowing groundwater, contaminants will move approximately at similar speeds to the groundwater flow velocity before exiting to valley side tributaries or lake margin.

For contaminants flowing unsaturated down through the glacial till, the following assumptions have been made:

- Flow speeds will be approximately equivalent to the permeability of the underlying soils, given that flow is in the vertical direction. This is conservative as these permeability measurements are calculated under saturated conditions and so flow speeds are likely to be much less due to soil suctions, however, continuous discharge will allow the unsaturated flow to increase over time;
- Book values for typical glacial till sediments are in the order of 0.1 to 0.01 m/day (Fetter, 2000);
- Unsaturated thickness of soil at the northern margin of the LTA is estimated to be approximately 15 m.

Given these assumptions, the travel time can be estimated to be between **150 and 1500 days**. These travel times will increase for effluent discharged further upslope, therefore these times represent the most conservative case accompanying a fraction of the total volume discharged.

For contaminants flowing in groundwater from the moraine toe to Kingston Township, the following list of assumptions are considered for the inputs to the travel time assessment:

- The distance between the northern edge of the LTA's and the first shallow bores within the Kingston township is approximately 1,000 m;
- Groundwater gradient is based on upgradient water levels observed within GW1, GW2 and GW3a, which are estimated to be approximately 333.5 m RL, whilst downgradient levels at 1,100 m are calculated based on the lake level, which is approximately 310 m RL (hydraulic gradient of 0.023);
- Hydraulic conductivities for the lake sediments that groundwater is travelling through have been estimated to be 0.1 to 1 m/day (Fetter, 2000). Supporting evidence for this geological interpretation is also based on a geotechnical assessment undertaken by Jacobs Engineering within the Stage 1 development area. Sixteen cone penetration tests were undertaken to estimate bearing capacities. These investigations found mainly alternating silt and sandy silt layers with groundwater only present in 5 of these investigations.
- Flow speeds are calculated using the Dupuit groundwater flow equation for unconfined aquifers:

$$Q' = \frac{1}{2}K\left(\frac{(h_1{}^2 - h_2{}^2)}{L}\right)$$

- And then dividing the flow by porosity to get the velocity

  = 0.5*1 m/d ((34^2-10^2)/1100)
  = 0.48 m^2d
  Velocity:
  = (1*i)/0.2 where i = -K*Δh
  = 0.109 m/d
  Travel Time:
  = 850 m/0.109 m/d
  = 7798 days or 21.8 years (this is based on a conservative hydraulic conductivity of 1 m/d, however, conductivity is likely to be much slower than this in places where silts persist)

  For a travel time to get to the first bores within the township, which are 850 m distant, it is estimated that groundwater will take 7,798 days plus the initial unsaturated flow time through the glacial till to arrive, or 21.8 years, based on a conservative value of hydraulic conductivity set at 1 m/day. This is somewhat more than the time it takes for pathogens such as Norovirus to remain detectable in groundwater, which is estimated to be 3 years (Seitz et al, 2011). It is therefore considered that downgradient groundwater users or lakeside recreators are not at risk of infections from pathogens being discharged at the proposed land treatment locations.

<u>Summary and Conclusions</u>

The Kingston land treatment area (LTA) is proposed to be sited on the terminal moraine south of the existing township and proposed subdivision. This moraine is comprised of typical deposits of glacial till and some 40 m plus of this glacial till is present in the unsaturated zone before the permanent groundwater table is encountered. Seven monitoring wells were drilled in and around the proposed LTA and were logged/characterised using a dominant/subdominant lithology by the driller, whilst this is fairly low resolution, enough information was gained to provide a reasonable geological and subsequent hydrogeological interpretation. Within 5 of the 7 holes drilled, water level records for 3 months of data was obtained using non-vented pressure transducers. Water quality samples were also obtained from these bores and flow gauging was undertaken in the Kingston tributaries to ascertain likely connection to groundwater. Conclusions based on LEI's hydrogeological interpretation include:

- The proposed LTA is underlain by typical glacial till deposits, underlain by water bearing glacial outwash deposits that display some sub-artesian pressure due to the overlying silty gravel. For this reason, any groundwater mounding within this geology due to the LTA operation is expected to be minimal, given the chaotic nature of glacial till and presence of silty lenses, which will likely direct flow horizontally in places.
- Water levels beneath the terminal moraine appear to be flat beneath the LTA site relative to the observably steep groundwater gradient to the north. Additionally, shallow groundwater levels are observed further south in Trotters flat similar to water levels beneath the terminal moraine, supporting this interpretation.
- Overall, groundwater flow beneath the site will be driven by the groundwater gradient to the north of the site, which is flowing north at a gradient of approximately 0.023;
- To the north of the LTA and at the toe of the terminal moraine, borehole records indicate lake sediments (massive silts and silty clayey gravels) and are typically distinct from composition within the terminal moraine;
- Perched groundwater is present above a hard pan layer, below which a water bearing gravel is present that also displays some sub-artesian pressure and is chemically distinct from the perched water (refer to boreholes GW3a and GW3b);
- Wastewater discharged within the proposed LTA's will travel downwards through the unsaturated zone and then travel north through the lake sediments of the Kingston Flat where it will discharge to either the tributaries and or lake margin. Flow gaugings undertaken by NIWA strongly suggest that groundwater is discharging to the Kingston tributaries.
- Water quality within the recently drilled monitoring bores show relatively high levels of nitrate-nitrogen, indicative of farming practices undertaken in and around the site. These high levels of nitrate-nitrogen are not present within groundwater sampled in Kingston Township bores, indicating that some attenuation is possible. Of note is the lower level of nitrate-nitrogen contained with GW6 with an increasing level of concentration present in the monitoring bores further to the north, which is supporting groundwater flow interpreted to the north.
- Groundwater flow travel times indicate that flow will take longer than three years to travel from the proposed LTA sites to the Kingston township.

To refresh the S92 requested:

> *Pattle Delamore Partners Ltd (PDP) have provided an assessment of the application on the surface water, groundwater and OVERSEER® aspects of this application.*
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> *No information has been provided to confirm the nature of the existing groundwater environment beneath the LTAs and Kingston, including groundwater flow paths and flow directions. A hydrogeological assessment of the groundwater system beneath the LTA and Kingston is required to understand the sensitivity of the environment (as required by Schedule 4, Part 6(1)(d) of the Resource Management Act 1991). The assessment must at least include the following (but not limited to):*
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> *• Groundwater levels and an assessment of flow direction;*
>
> *• Groundwater quality, including the groundwater quality at the LTAs and within Kingston;*
>
> *• Effects of the discharge on the groundwater environment and receiving water bodies, including effects of pathogens and nitrogen; and*
>
> *• Methods to avoid, remedy or mitigate any adverse effects on the groundwater quality identified in the assessment, including any updated monitoring requirements.*

The investigations and monitoring work carried out provides the assessment requested. Our conclusions from the investigations is that no additional adverse effects, over what is already observed within Kingston Township, are likely to occur. The thick sequence of terminal moraine till appears to be ideal to further treat the WWTP effluent and is likely to improve the groundwater environment and discharges to surface water within the Kingston township, considering the replacement of effluent discharge from current septic tanks.

This assessment supports the original applications mitigation of system design limits and monitoring conditions.

System Design, Nitrogen Loading and Plant Uptake

ORC asked 5 questions in relation to system design, nitrogen loading and plant uptake. These questions and Lowe Environmental Impact's response to each is as follows:

1. *The application has only presented nitrogen application, uptake and leaching values as a yearly average. It is expected that there will be seasonal fluctuations that will need to be addressed.*

An assessment on nitrogen application, uptake and leaching values on a monthly basis is required to address the effects of nitrogen applied to the LTAs during periods where there is low or no crop growth. The assessment must include (but not limited to):
• Potential dry matter production in each month;
• Potential nitrogen uptake in each month;
• Nitrogen applied in each month, including seasonal variations in effluent quality;
• Nitrogen surplus or deficit relative to potential plant uptake;
• Nitrogen uptake based on available nitrogen and potential plant uptake;
• Nitrogen leaching based on available nitrogen and potential plant uptake; and
• Methods to manage nitrogen leaching during low growth periods or wet periods.

The use of Overseer is an appropriate model to evaluate the likely long-term nutrient losses from the proposed LTA. Overseer has been used along with the mass balance approach to determine changes in catchment and ultimately the lake's nutrient load. Specifically, these are changes from the current farming and village septic tanks to a reduction in farming and an increase in the village nutrient load. The location of the discharge being some distance from the lake and the long travel times via the thick unsaturated zone beneath the LTA means that the variation in nutrient loss across the season will become obscured when the discharge reaches the lake shore and mixed with the surrounding loss. The majority of nutrient loss will be in the winter when there is drainage and low plant uptake. The basis of the analysis from the AEE is further explained with details of the monthly inputs and Overseer monthly outputs along with a higher nitrogen loaded winter leaching scenario.

In the Overseer model presented in the AEE, an annual average discharge of 900 cubic metres per day was modelled, with a monthly average nitrogen concentration of 20 mg/L over 15 ha. The wastewater treatment plant is designed for an ultimate average dry weather flow of 900 cubic metres per day and this is based on an occupancy of 3 people per household. A three person per household capacity sizing is in line with the 2015 and 2020 QLDC Housing Development Code of Practice.

In contrast, the long term expected occupancy is 2.6 people per household, with QLDC July 2020 projections for Kingston Township in 2051 at 2.38 person per household (combining permanent residents and visitor averages https://www.qldc.govt.nz/media/jg3bkh5a/qldc-demand-projections-summary_july2020.pdf). This means that modelling the wastewater treatment plant with 3 persons per household is conservative and provides some redundancy.

The Overseer model loading is assuming that the treatment plant is at full capacity with all dwellings occupied at 3 persons per household for 365 days of the year. It does not take into account the seasonal nature of Kingston occupancy that currently exists; this will mean there is likely to be lower N loading to the LTA area at times and the ability to reduce the nitrogen at the treatment plant at times of lower flow.

The nitrogen load onto the LTA is proposed to be restricted and controlled to 450 kg N/ha/per year. This load will be calculated based on daily WWTP flows and monthly treatment nitrogen sampling and the area of the LTA the water is applied to. This system of accounting for LTA nitrogen load means that if the wastewater flows or strength increases at certain times of the year due to population changes or seasonal impacts on the WWTP, the treatment plant and LTA effectiveness would need to improve to ensure that the overall loading per ha remains within consented nitrogen limits.

For example, if the population at Kingston is seasonal, the population increases would be seen in summer holidays, and perhaps at a lesser extent in winter ski season. Lucerne's water and nutrient requirements are highest during summer (See Figure 7 below), so any additional N load that is being applied over summer is being applied when there is a high plant uptake. Also, if nitrogen applied increased over summer, the nitrogen loading per ha over winter would have to decrease to remain within the 450 kg N/ha/yr limit. Given the staged development of the subdivisions, the WWTP systems and the LTA area, accurate monitoring and response action by QLDC will be possible. Please see Table 3.2 of the AEE for combinations of WWTP effluent quality and LTA area and nitrogen loadings.

The critical time for N loss is over winter, so a higher summer application under a fixed annual nitrogen load would result in a reduced winter N loading to remain below 450 kg N/ha/yr. Under this scenario the N loss overall from the LTA would decrease.

The risk from seasonal variation in population is during winter. Additional Overseer models have been developed which shows the impact of high winter N loading. Both the annual average and worst case high winter N load models are discussed further below.

As discussed, the original model prepared modelled an annual average discharge of 900 cubic metres per day, with a monthly average nitrogen concentration of 20 mg/L over 15 ha. This model had a relatively even distribution of the nutrient loading on each month, as shown n below, applying a total of 437.8 kg N/ha.

Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
37.2	33.6	37.2	36	37.2	36	37.2	37.2	36	37.2	36	37.2

The N loss from this scenario was 142 kg N/ha/yr from the 15 ha. OverseerFM presents overall nitrogen loss on an annual basis, as reported in the AEE, however, this presentation is based on additions and losses at a monthly scale. Figures' 7 and 8 present the nitrogen additions and losses from the LTA areas across the year.

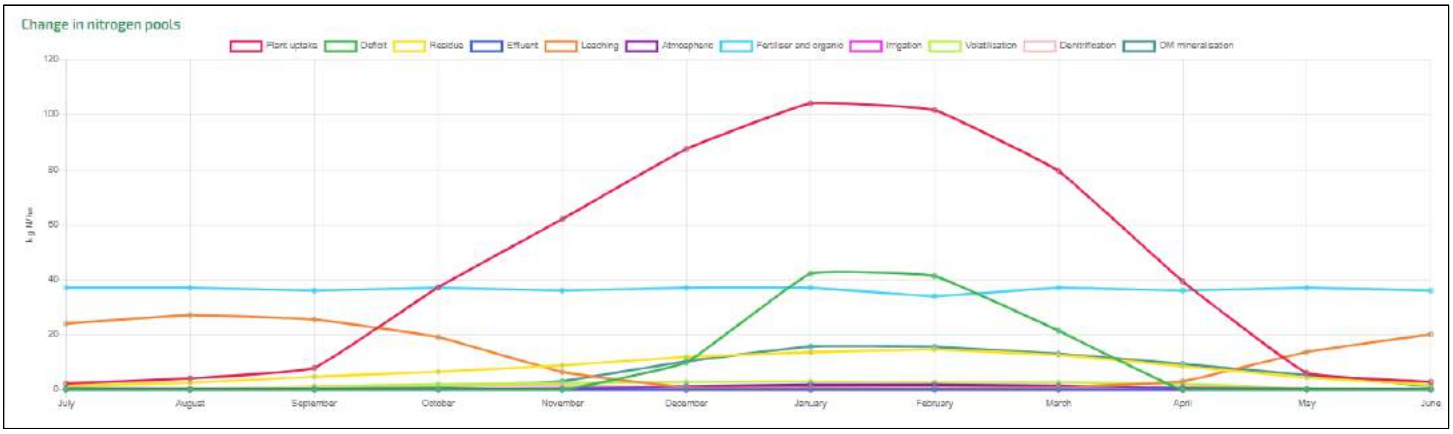

Figure 7: Full capacity 900 cubic metres over 365 days

In Figure 7, the pasture uptake per month is reported and it shows that lucerne growth is low over winter and is greatest in late summer. This matches the typical lucerne growth profile shown below in Figure 8, which shows typical lucerne monthly dry matter production in comparison to pasture. It shows that there is very low growth in June, July and August, with peak dry matter production in January and February.

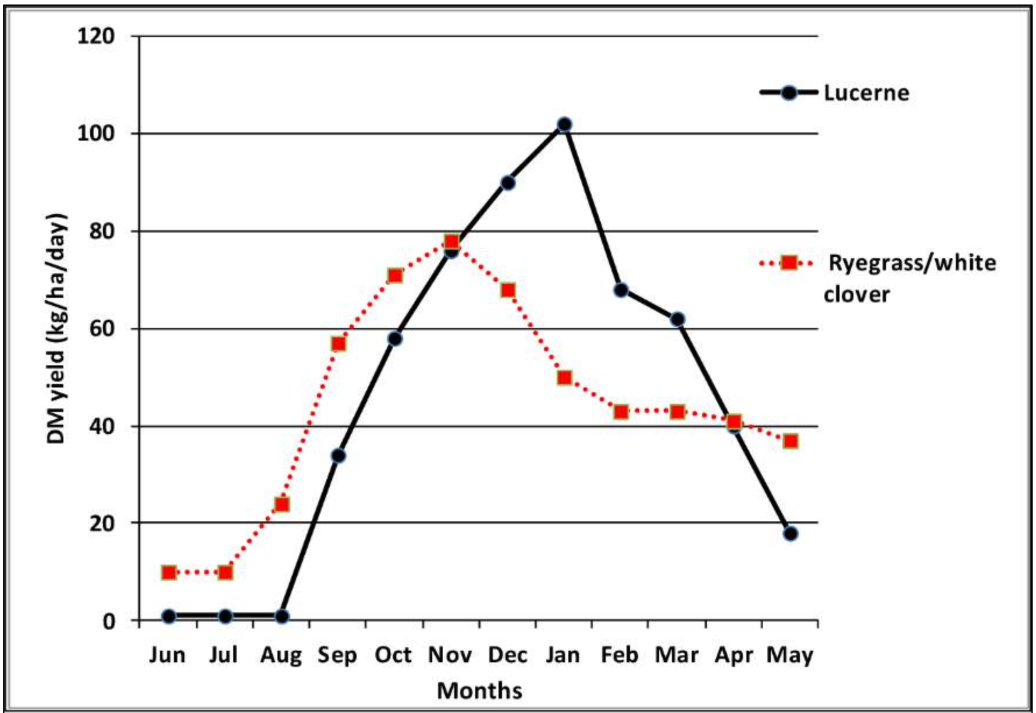

Fig. 2.4 The general production and productivity trends of lucerne and RG-WC pastures in response to the

Figure 8: Typical Lucerne Growth Pattern

Figure 7 shows that plant uptake (shown in red) of nitrogen increases between October to April and is low from May to September. The amount of nitrogen that plants are removing from the system ranges from 2.2 kg N/ha in winter to 104.1 kg N/ha/month in summer.

In the Overseer model, lucerne with a total annual growth of 12 t DM/ha was modelled. The lucerne is modelled as being harvested three times a year in January, April and November, with 4 t/ha being removed at each harvest event.

The total yield of 12 t is conservative and with the wastewater application, the yields of lucerne are expected to be higher. The soils and climate in the area are suitable for lucerne growth. Other crops have been successfully grown in the area without irrigation. Under irrigation, pure swards of lucerne can grow up to 21 t DM/ha/year (DairyNZ). This means that if bigger yields are achieved, more N will be removed from the system in plant uptake and the N leaching loss would be lower.

The N pool graph (Figure 7) shows that the leaching is occurring mainly over the winter months and that there is a nitrogen deficit in summer. The nitrogen loss estimates vary each month and as expected are showing higher N loss in winter than in summer when pasture uptake is low and there is profile drainage. The monthly N loss ranges from 0.6 kg/N/ha/month in February to 27.1 kg N/ha/month at the highest point in August.

In terms of seasonality of flow, if the summer N load increased overall, N loss would unlikely be impacted. This is because N loading consent constraints would likely require the reduction of winter loading.

The N-loading risk from seasonal variation in population is during winter. Therefore an additional Overseer model has been prepared which models the system when there is a worse case seasonal variation, with high winter nitrogen loading. This model has the winter N applications at 50% higher than the original scenario. The total loading in both the original and this scenario is 437 kg N/ha/yr.

The nitrogen loading per month for this worst-case scenario is shown below:

Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
18.5	18.5	27	36	37.2	54.7	55.7	55.7	45	37.2	36	18.5

Figure 9 below shows the monthly plant uptake and N losses within the system.

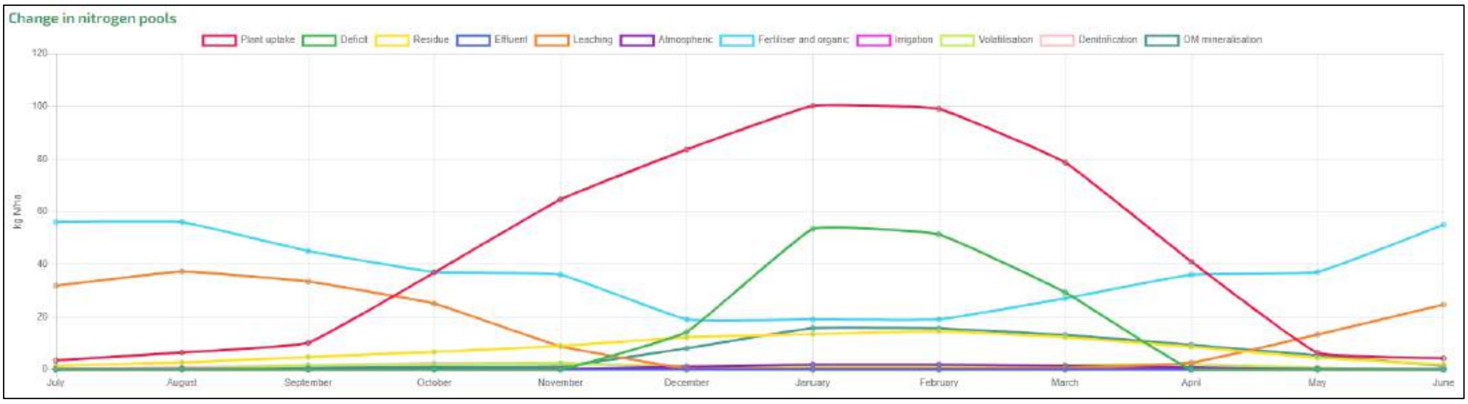

Figure 9: Seasonal Variation of N loading – High Winter

The N loss from this scenario was 178 kg/ha/yr from the 15 ha. This scenario applied 166 kg N/ha over the winter and overall the system is losing an additional 36 kg N/ha (i.e. 178 vs 142) over the winter. See Table 4 below for comparative scenarios and mass balance impact of greater winter leaching. However, given this scenario, the impact on the environment is still considered less than minor.

As mentioned, the original Overseer model was conservative to start with as it was assuming the system was already at full capacity over 365 days of the year. There is also additional LTA area available if the treatment plant is reaching capacity which will reduce the N loading per ha across the whole LTA area as shown in the AEE Table 3.2.

Comment from PDP: The proposed design irrigation rates have considered hydraulic conductivity but do not consider other relevant parameters including, but not limited to, crop evapotranspiration, precipitation and nitrogen loading. A complete assessment of all factors affecting DIR should be completed. We consider that the use of a soil moisture model is necessary for irrigation of this scale, especially considering the design loading rates are relatively high for a LTA. PDP would suggest that the current hydraulic loading rate will limit nitrogen fixation as the soluble nitrate will be through the soil limiting the availability for plant uptake.

The AEE has used infield and lab measurements of the unsaturated soil hydraulic conductivity to determine the maximum sustainable daily irrigation rates. The proposed maximum of 12 mm/day and an average of 6 mm/day are only 17% and 9% of the k-40 daily infiltration rates. Design guides state that 30% of the k-40 rates are sustainable to allow for other factors, such as organic and nutrient loading. Wastewater application at these low rates will allow micro and meso pore flow to be the primary transport pathway for the wastewater into the subsoil providing time for the soil to further treat the water. As rainfall increases and exceeds ET, there will be increased drainage, Overseer uses a monthly water balance to account the soil drainage and relates the drainage volume to soil pore water volumes in the prediction of leaching below the root zone. The plant nutrient uptake model accounts for the uptake by the plants based on seasonal growth rates with the surplus nitrogen available to be leached. Overseer modelling has been accepted by ORC for predicting leaching loss from farming systems in its regional plan framework Plans, and in previous resource consent applications and in the Environment Court Case Horowhenua District Council v Manawatu-Wanganui Regional Council and Horowhenua District Council [2018] NZEnvC 163 as an example. In Environment Court direct referral case, the Court considered a resource consent for the discharge of wastewater to land at the Foxton Wastewater Treatment plant operated by Horowhenua District Council. The key issue for this case was to determine the effects of nitrogen on aquatic receiving environments, both during construction and operation. OVERSEER® was an important tool in that assessment. We consider that a soil moisture model will not add anything to the assessment.

2. *A leaching rate of 140 kg N/ha/year is proposed. This rate is high when compared to the 15 kg N/ha/year limit under Rule 12.C.1.3. Please provide further information to support the high leaching rate and any methods or alternatives to avoid, mitigate or minimise the high leaching rate.*

It is inappropriate to compare the LTA leaching rate to the average property limit of 15 kg N/ha under the rule on a single Ha by Ha basis. The leaching is increasing under the LTA from a baseline of 16 kg to 142 kg N/ha/yr, while the regional nitrogen mass is decreased with the implementation of the community scale WWTP and LTA. The full mass balance for a number of development scenario's is presented in the AEE and expanded in LEI memo.

Essentially, the proposal is moving the concentration of nutrients from the township (septic tanks), near the lake, to the farmland south of the proposed subdivision. Coupled with the effluent from 950 new houses from the development, the resultant nutrient loading on the environment is less than the current loading from the farming of the subdivision and only ~225 houses due to the high level of treatment via the WWTP, LTA and change of land use for the 55 ha area.

In terms of the 15 kg N/ha for the current system, this has been assessed as an appropriate N loss amount to use. LEI has modelled the current system in OverseerFM. The area from the farm associated with this proposal (15 ha of LTA and 55 ha of proposal subdivision area) is part of a much larger property, which has a large area of extensive farming. The total Kingston station leaching would be well below 15 kg N/ha/yr and is a permitted farming activity under the current plan rules. However, the paddocks associated with the land treatment area is the farm's more productive and intensively farmed areas and would have higher leaching than other the more extensively farmed areas on the station.

Currently the LTA area is part of a cropping rotation, and is in a winter forage crop twice every 10 years, rotating between Kale or Swedes. At this time, a higher number of cows are grazed in June, July and August. The rest of the time the LTA area and the 55 ha subdivision area that isn't cropped are grazed by sheep and cattle at a stocking rate of 10 - 12 stock units per ha. All areas received 250 kg/ha super phosphate annually and when the crop blocks are planted, they receive 120 kg/ha DAP and 70 kg N/ha in November. The overall annual N loss modelled from the combined 70 ha area associated with the proposal is 16 kg N/ha/yr. The use of the 15 kg N/ha limit in the application was therefore deemed appropriate for the current activities.

The leaching from the 15 ha LTA is higher than grazed pasture when looking at the average of this part of the station, but a leaching rate of 140 kg N/ha is equivalent to what could be leached during the winter from intensive winter forage crop gazing regime. Overall, as stated in the application's cumulative effects mass balances, the proposed activity results in a net reduction of nitrogen to the catchment. There is 112 ha of land use associated with the application (15 ha of LTA, 42 ha of existing township, and 55 ha of new subdivision).

Additional mass balance scenarios have been prepared to demonstrate nitrogen loss pre and post-development. These are displayed and discussed further below in Table 4. These analyses have all been conservatively based on 15 ha of LTA receiving the full wastewater load within a 21 ha command area. This provided management flexibility and conservative assessment of the change in catchment nitrogen loads.

Water quality testing results from the area showed current nitrate-N concentrations in the groundwater of up to 7 mg/L. This level is not unreasonable from the current activities present in the area. Oversee FM is modelling predicts nitrate-N concentrations from drainage for existing landuse beneath the proposed LTA area as being between 5 mg/L from the grazed area, 13 mg/L when kale is present and up to 26 mg/L when swedes are used for winter forage for cattle.

The OverseerFM model of the proposed LTA activity is reporting a concentration of nitrogen in drainage of 6 mg/L. This is lower than what is seen in the groundwater near the proposed LTA, indicating a possible improvement in groundwater quality under the LTA area. The concentration is well below the WHO community drinking water limit of 11.3 mg/L.

The following tables demonstrate pre and post development scenarios.

Three leaching scenarios comparing pre and post development have been modelled. These are set at different leaching % rates (as a check on Overseer modelling), with the third model set at a higher leaching rate and increased area. Pre and post development are also further subdivided into 1.1 persons per existing Kingston Township property (based on 2018 census data) and 3 persons per existing Kingston Township base on QLDC design guidelines. The use of 3 persons may be a relevant future scenario as the population becomes more suburban centred instead of holiday centred.

Table 4: Pre and Post Development Scenarios for Nitrate-N Leaching

<table>
<tr><th>Scenario</th><th>Persons per household (at existing Kingston properties)</th><th>Pre-development leaching – Existing Township plus LTA and Subdivision Grazing (kg/yr)</th><th>Post-development leaching (kg/yr)</th><th>Flux (-decrease, +increase over current state)

(kg/yr)</th></tr>
<tr><td rowspan="3">1</td><td colspan="4">LTA Leaching modelled at 142 kg N/ha (32% of total load leached) and 15 hectares of LTA</td></tr>
<tr><td>1.1</td><td>1,900</td><td>1,853</td><td>-47</td></tr>
<tr><td>3</td><td>3,246</td><td>2,120</td><td>-1,144</td></tr>
<tr><td rowspan="3">2</td><td colspan="4">LTA Leaching modelled at 178 kg N/ha (40% of total load leached) and 15 hectares of LTA</td></tr>
<tr><td>1.1</td><td>1,900</td><td>2,316</td><td>416</td></tr>
<tr><td>3</td><td>3,246</td><td>2,628</td><td>-618</td></tr>
<tr><td rowspan="3">3</td><td colspan="4">LTA Leaching set at 135 kg N/ha (43% of total load leached) and 21 hectares of LTA</td></tr>
<tr><td>1.1</td><td>1,996</td><td>1,654</td><td>-341</td></tr>
<tr><td>3</td><td>3,342</td><td>1,877</td><td>-1,465</td></tr>
<tr><td rowspan="2">4</td><td colspan="4">No community connection, 370 Lots, 27.5 ha subdivision and 15 ha LTA Leaching 43 kg N/ha/yr (32% of applied N leached)</td></tr>
<tr><td>3 per new development</td><td>680</td><td>648</td><td>-32</td></tr>
<tr><td rowspan="2">5</td><td colspan="4">No village connection, 975 Lots, 55 ha subdivision and 21 ha LTA Leaching 88 kg N/ha/y (32% of applied N leached)</td></tr>
<tr><td>3 per new development</td><td>1,216</td><td>1,708</td><td>492</td></tr>
<tr><td rowspan="2">6</td><td colspan="4">Status quo: Mass balance for just the Kingston Village and 200 additional new community advanced septic tanks on existing consented sections, no subdivision Lots</td></tr>
<tr><td>3 per new development</td><td>2,126</td><td>3,206</td><td>1,080</td></tr>
</table>

Most scenarios result in an improvement of nitrate-nitrogen leached. One conservative scenario of 1.1 persons per household and increased winter leaching rate of 40% of total load applied over a 15 ha area results in an increase of total nitrogen of 416 kg per year over the calculated baseline. As the base village population increases the nitrogen balance becomes a net improvement for the environment. The assessment is also based on a full new population per lot of 3 persons per household, providing wastewater to the treatment plant 365 days per year. The treatment plant nitrogen load in kg N/ha provides an upper limit to the mass of nitrogen applied that is very easily measurable on a monthly basis.

To close off all the scenario analyses, two development scenarios with no conversion of the township from septic tank to the community WWTP are included and full occupancy at 3 persons per new lot and 32% of the applied nitrogen leaching have been presented. In these theoretical scenario's, the mass balance of pre and post development show that the leaching loss of nitrogen is equivalent to the current nitrogen loss from the land under a grazed pastoral system.

Scenario 6 details the permitted development potential within the existing Kingston township authorised titles and onsite (individual) treatment. These sections can proceed as a permitted activity with the installation of an AS/NZS 1547 standard compliant onsite secondary treatment plant and disposal field. While these plants will produce a better effluent quality than a septic tank there may not be land treatment and further nutrient reductions are therefore not possible before entering the groundwater system and ultimately the lake. These sections add 1080 kg N to the existing catchment. No consent from ORC is required for these sections to develop.

To put the nitrogen leaching mass into context in this rural farmed environment, one ha of winter forage crop would leach between 80 and 150 kg N/ha/yr. The differences presented in the scenario's mass balances is small in the scale of the total catchment load. The proposed wastewater leaching is equivalent to adding or subtracting 10 ha of winter cattle grazed forage crops in the existing catchment. A change of 10 ha of winter grazed forage crop area in the catchment is a plausible scenario for this catchment.

In conclusion, the modelled current farming nitrogen loss is realistic and not only would the proposed treatment system likely result in less N being leached from that currently permitted, it also provides the opportunity to remove the leaching from a number of on-site systems located close to Lake Wakatipu, overall significantly reducing the total nitrogen load and microbiological contamination of groundwater and the lake. This is particularly true if current occupation in the existing township increases to the 425 lots permitted for development that will not have a higher standard of wastewater treatment through plant scale and land treatment. It combines an estimated 225 private on-site systems in one treatment plant that will be managed and operated by QLDC.

***3.** Please confirm that 200mm depth of dripper lines is suitable when considering plant uptake of nutrients and freezing levels.*

Lucerne has the potential to have a deep rooting system, with root depths that can be well over 1 m (Hanson and Barnes, 1978). A dripper line depth of 200 mm is within the lucerne root zone and the plants will be able to access the nitrogen that is applied to the LTA as it moves through the soil profile. In addition, capillary rise can occur bringing nutrients nearer to the surface.

As presented in the AEE Table 2.4, winter soil temperatures at 10 cm soil depth temperature will be within the range of 2 oC and 4 oC. Temperatures at the 10 cm depth are not expected to be below 0 degrees, so a dripper depth of 20 cm is sufficient to prevent the lines from freezing in winter at this location and also prevent mechanical damage during harvesting and other activities.

***4.** Please provide information on how the flow rates have been determined and information on local conditions that may affect flow rates, such as seasonal changes in occupancy that may affect the treatment ability of the wastewater treatment and disposal system and how the effects of this can be avoided, mitigated or remedied.*

The wastewater flows and influent characteristics from the Kingston community are based on knowledge and data of similar townships and with direction for QLDC engineering. Jacobs wastewater treatment plant design and staging have been based on the expected influent strength. Flows equal 3 people x 250 L/p/d x 1,175 = ~900 m^3/d and x 2 for peak wet weather. The village zone maps limit the area of the subdivision for non-residential purposes.

***5.** Further analysis of wastewater inputs (including industrial/trade premise sources) is required. As such please provide a detailed analysis of this and confirm that the proposed system is designed to treat such inputs.*

The zoning limitations that constrain the subdivision support the assumption that the inflows will be normal domestic strength influent. The more important factor relevant to this application are the wastewater strengths of the applied water to land. Limits for the key parameters are proposed in Conditions' 8, 14 and 14 b of consent. These must be complied with regardless of the influent strength.

Water Reticulation

The following question from Otago Regional was around the water reticulation system:

The existing water supply for Kingston residences is from bores downgradient of the discharge. The location and timing of this reticulation in relation to the commencement of the discharge is relevant in terms of understanding the existing environment for the assessment of effects. Please confirm the location and timing of the reticulated community supply.

Only a small number of existing houses rely on bore water supply. The majority of the existing Kingston township collects and stores rain-water for potable use (pers comm QLDC). Furthermore, there is small recent development area (Lakefield Estate) that is serviced from a shallow bore adjacent to Kingston Creek. This reticulated supply only serves as a supplementary supply to onsite rainwater collection and tank storage as every site is required to have 30m3 of storage. This bore is detailed in Section 2.8 and the effects assessed in Section 6.3.8 of the AEE.

The bore associated with the proposed reticulated community supply (Kingston HIF) was installed in June 2020. The location of the bore is in the same location as was proposed in the AEE (See image below). The bore number is F42/0147 and location coordinates are NZTM: 1265516E, 4970488N. This bore is not located in aquifers downgradient of the LTA, as shown in Figure 10.

The reticulated system is expected to be commissioned in conjunction with the development of the subdivision. The connection of properties other than the new subdivision will be determined between QLDC and each property.

Figure 10: Location of Proposed Bore

Cumulative Effects

Otago Regional Council asked for further cumulative effects assessment:

The definition of effect under Section 3 of the RMA includes any cumulative effect which arises over time or in combination with other effects. Schedule 4 Part 6(1)(b) requires an assessment of the actual or potential effects on the environment of the activity. This includes cumulative effects. Section 6.7 of the application has not specified or assessed any cumulative effects of the proposal. An assessment of cumulative effects is required including identification of any cumulative effects on water quality of surface and groundwater. This must include an assessment on the effects arising over time and the effects arising in combination with other effects.

A cumulative effects assessment was presented in the AEE in Section 6.3 and summarised in Section 6.7. The effects of the Kingston proposed land application of treated effluent within the boundary of Kingston Station to the South of Lake Wakatipu has been assessed as having a less than minor impact on the receiving environment. The mass balance assessment showed there are a large number of scenario's where the total catchment nitrogen loss is reduced. In all scenario's, the reduction in septic tank discharges will reduce nitrogen and pathogen contamination of the lake.

It is assessed that the proposed application of treated effluent to land is a significant improvement over that of the existing individual dwelling treatment and discharge systems. The permitted infilling of vacant sections within the Kingston township has the potential to add a further 200 dwellings. The discharge from these dwellings under QLDC and ORC rules need to meet the AS/NZS 1547 standard using a secondary treatment system and then discharge to a trench or subsurface dripper irrigation. With these systems, there are no nutrients exported by cut and carry of harvested materials, and most of the nutrients leaving the treatment plant field are likely to enter the lake. These systems are permitted under ORC Rule 12.A.1.4.

In terms of ecology, the proposed WWTP and LTA are considered to improve the water quality of Lake Wakatipu due to the discontinuation of the current septic tank system and enabling the development of an additional 950 house in Kingston. Ryders have concluded that local surface water tributaries that may gain and lose water to the groundwater system are not sensitive to additional nutrient loads.

Additional nitrogen mass balance assessments, which model nitrogen loss for different % leaching rates for Kingston normally resident population presented in the sections above, support this conclusion. With the development of the new WWTP and land treatment area, there will be an estimated reduction of N entering the environment every year as a result of the proposed activity (Table 4).

During the initial period of the development, as stages of the new subdivision are developed, the net reduction is expected to be greater. The proposal also takes into consideration and provides for the wellbeing of the community, amenity and cultural concerns.

Additional Soils Information – LTA 1

Recent additional field work completed by LEI for the additional LTA 1 area confirms that infiltration rates are similar and that the proposed application rate is appropriate for the new additional LTA site as well. There is no increased chance of throughflow or runoff as a result. A memo outlining the results is attached as Attachment 5 to this response.

Lowe Environmental Impact and Hadley Consulting had previously carried out investigations at Kingston LTA, in areas nearby the new proposed additional LTA area. It was found that the new LTA area had similar soils overall to those in the areas previously tested by LEI and Hadley Consultants.

Saturated and unsaturated hydraulic conductivity previously tested at the site by LEI in 2018 were slightly lower than the results found during the most recent testing. The results of the previous testing are shown below in Table 5.

Table 5: Field and Laboratory Measurement Hydraulic Conductivity Results (LEI AEE 2020)

Location	Saturated (K_{sat}) (mm/hr)	Unsaturated (K_{-40mm}) Field test (mm/hr)	Unsaturated (K_{-40mm}) LandCare (mm/hr)
Site 1	60	3.82	12
Site 2	156	2.96	50
Site 3	90		19
Site 4	45	4.52	27
Site 5	25.5	1.10	10
Site 6	122.5	1.78	7
Average	**83.17**	**2.83**	**20.13**

The test results for the new LTA area are generally higher than this at 112.1 mm/hr (field) and 243.25 mm/hr (lab - subsoil) for saturated hydraulic conductivity and 3.34 mm/hr (field) and 18.75 mm/hr (lab- subsoil) for unsaturated hydraulic conductivity.

This means that the design irrigation rates identified for the original LTA area are also applicable for this new additional LTA area and will be conservative for this area.

Determination of the DIR for the original LTA area is presented in Table 6 below. The proposed average irrigation rate is 6 mm/day and peak wet weather rate of 12 mm/day are less the measured and adjusted for organic and nutrients loading hydraulic capacity of the soils.

Table 6: AEE Design Irrigation Rate

Location	Saturated (K_{sat})	Field Unsaturated (K_{-40mm})
Field Measurement (mm/day)	1,996	68
Adjustment (%)	10	30
DIR (mm/day)	199	20.4
Recommended DIR (mm/day)	Maximum of 20	

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Attachment 1: Borelogs

PIEZO COMPLETION REPORT

Client	Lowe Environmental Impact	**GPS** NZMG	**East**	2173499
			North	5532123
Consent No.		**Well Name**	GW1	
Piezo Location	Kingston			
Client Contact				
Driller	Paul Washington	**Drill Method**	Rotary	
Machine/Rig	Rig 4 - Foremost DR24	**Bore Diameter**	150mm	

Drilling Engineer	
Geologist	

Start Date	23/09/2020	**Date Completed**	23/09/2020
Water Level	16.6 m	**Measured Depth**	22 m

Has the bore been capped or covered?	Yes
Does the bore have a concrete pad?	Yes
Is the bore sealed with concrete or Bentonite around the annulus?	Yes

All measurements taken from Ground Level

OPEN HOLE SECTION

Size	
From metres	
To metres	

CASING

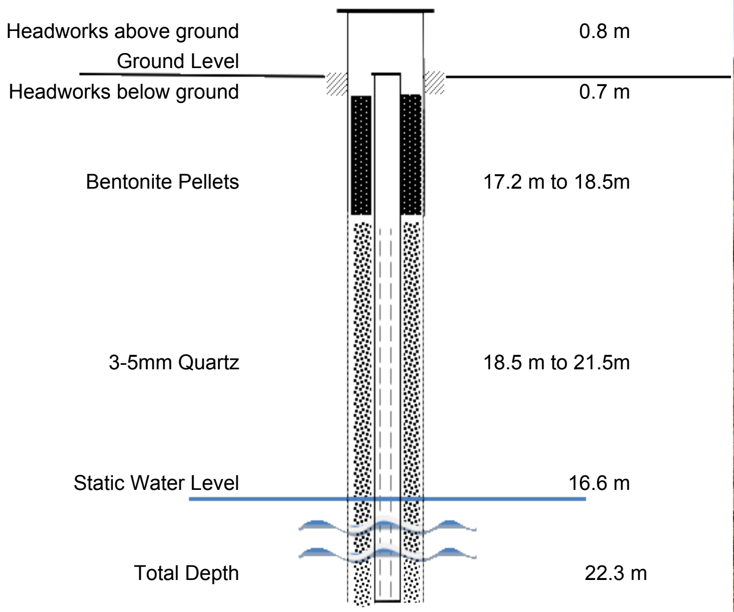
Casing	OD	ID	Weight	Grade	Thread	Range	Slotted	Length	Set at
Conductor									
Production (PVC)	60 mm	50 mm			No			-0.55 m	18.5 m
Screens (PVC)	60 mm	50 mm			No		0.5 mm	3 m	21.5 m
Sump									

WASHINGTONS EXPLORATION LIMITED NZ

PIEZO COMPLETION REPORT **CLIENT:** Lowe Environmental Impact

GEOLOGICAL LOG

Top Depth (m)	Bottom Depth (m)	Formation Type (Major, Secondary, Minor)	Colour	Grain Size	Water Content
0	0.3	Gravel Silt	Brown		Dry
0.3	2.3	Topsoil	Brown	Fine to coarse	Dry
2.3	7.8	Gravel	Grey	Fine to coarse	Dry
7.8	12.7	Silt	Grey		Dry
12.7	15	Gravel Silt	Grey, Brown	Fine to coarse	Dry
15	22	Silt	Brown		Water bearing
22	22.3	Gravel Silt Clay	White, Grey	Fine to medium	Dry



Addtional Information:

PIEZO COMPLETION REPORT

Client	Lowe Environmental Impact	**GPS** NZMG		**East**	2174171
				North	5531857
Consent No.		**Well Name**	GW 2		
Piezo Location	Kingston				
Client Contact					
Driller	Paul Washington	**Drill Method**	Dual Rotary		
Machine/Rig	Rig 4 - Foremost DR24	**Bore Diameter**	150mm		

Drilling Engineer	
Geologist	

Start Date	22/09/2020	**Date Completed**	22/09/2020
Water Level	6.3 m	**Measured Depth**	10.7 m

Has the bore been capped or covered?	Yes
Does the bore have a concrete pad?	Yes
Is the bore sealed with concrete or Bentonite around the annulus?	Yes

All measurements taken from Ground Level

OPEN HOLE SECTION

Size	
From metres	
To metres	

CASING

Casing	OD	ID	Weight	Grade	Thread	Range	Slotted	Length	Set at
Conductor									
Production (PVC)	60 mm	50 mm			No			-0.5 m	7.7 m
Screens (PVC)	60 mm	50 mm			No		0.5 mm	3 m	10.7 m
Sump									

WASHINGTONS EXPLORATION LIMITED NZ

PIEZO COMPLETION REPORT **CLIENT:** Lowe Environmental Impact

GEOLOGICAL LOG

Top Depth (m)	Bottom Depth (m)	Formation Type (Major, Secondary, Minor)	Colour	Grain Size	Water Content
0	0.3	Sand Silt	Brown		Dry
0.3	0.7	Topsoil	Brown	Medium	Dry
0.7	2.2	Sand	Grey		Dry
2.2	3.2	Gravel Sand Silt	Brown	Fine to medium	Dry
3.2	3.8	Sand Silt	Grey		Dry
3.8	10.9	Silt	Brown		Water bearing

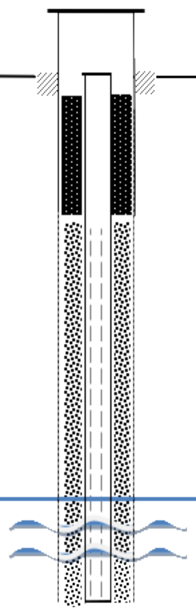
Headworks above ground 0.8 m
Ground Level
Headworks below ground 0.7 m

Bentonite Pellets 6.5 m to 7.7m

3-5mm Quartz 7.7 m to 10.7m

Static Water Level 6.3 m

Total Depth 10.7 m



Addtional Information:

PIEZO COMPLETION REPORT

Client	Lowe Environmental Impact	GPS NZMG		East North	2174294 5531699
Consent No.		Well Name	GW3		
Piezo Location	Kingston				
Client Contact					
Driller	Paul Washington	Drill Method		Dual Rotary	
Machine/Rig	Rig 4 - Foremost DR24	Bore Diameter		150mm	

Drilling Engineer	
Geologist	

Start Date	18/09/2020	Date Completed	22/09/2020
Water Level	14.35 m	Measured Depth	28.8 m

Has the bore been capped or covered?	Yes
Does the bore have a concrete pad?	Yes
Is the bore sealed with concrete or Bentonite around the annulus?	Yes

All measurements taken from Ground Level

OPEN HOLE SECTION

Size	
From metres	
To metres	

CASING

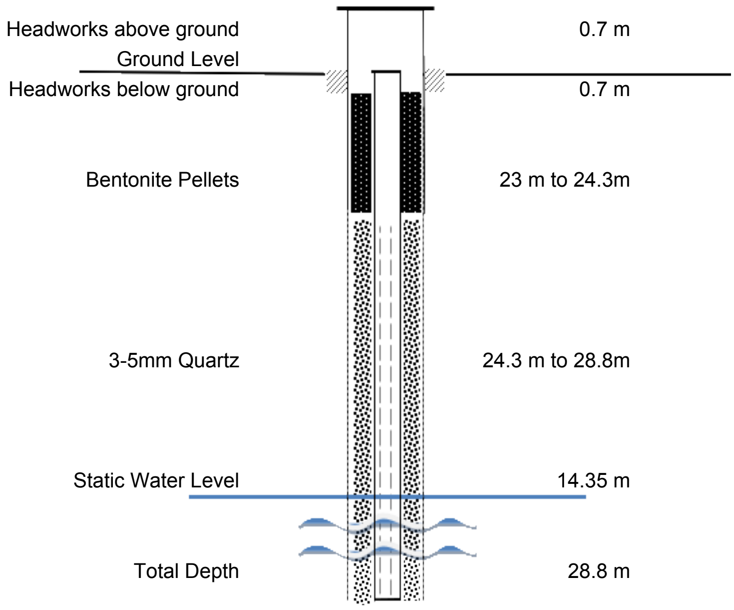
Casing	OD	ID	Weight	Grade	Thread	Range	Slotted	Length	Set at
Conductor									
Production (PVC)	60 mm	50 mm			No			-0.5 m	24.3 m
Screens (PVC)	60 mm	50 mm			No		0.5 mm	4.5 m	28.8 m
Sump									

WASHINGTONS EXPLORATION LIMITED NZ

PIEZO COMPLETION REPORT **CLIENT:** Lowe Environmental Impact

GEOLOGICAL LOG

Top Depth (m)	Bottom Depth (m)	**Formation Type** (Major, Secondary, Minor)	Colour	Grain Size	Water Content
0	0.2	Sand Silt	Brown		Dry
0.2	0.5	Topsoil	Brown		Dry
0.5	1.2	Gravel	Grey	Fine to coarse	Dry
1.2	20.5	Silt Sand Gravel	Brown	Fine to medium	Water bearing
20.5	23	Clay	Brown		Dry
23	25.5	Gravel Sand Silt	White, Grey, Brown	Fine to coarse	Water bearing
25.5	29	Gravel Sand Silt	White, Grey, Brown	Fine to coarse	Water bearing



Addtional Information:

2nd piezo installed from 23 to 17m for screen.
PVC has .450 stick-up
W-L 13.9

PIEZO COMPLETION REPORT

Client	Lowe Environmental Impact	**GPS** NZMG		**East**	2174003
				North	5531554
Consent No.		**Well Name**	GW4		
Piezo Location	Kingston				
Client Contact					
Driller	Paul Washington	**Drill Method**		Dual Rotary	
Machine/Rig	Rig 4 - Foremost DR24	**Bore Diameter**		150mm	

Drilling Engineer	
Geologist	

Start Date	16/09/2020	**Date Completed**	17/09/2020
Water Level	Dry Bore	**Measured Depth**	60 m

Has the bore been capped or covered?	No
Does the bore have a concrete pad?	No
Is the bore sealed with concrete or Bentonite around the annulus?	No

All measurements taken from Ground Level

OPEN HOLE SECTION

Size	
From metres	
To metres	

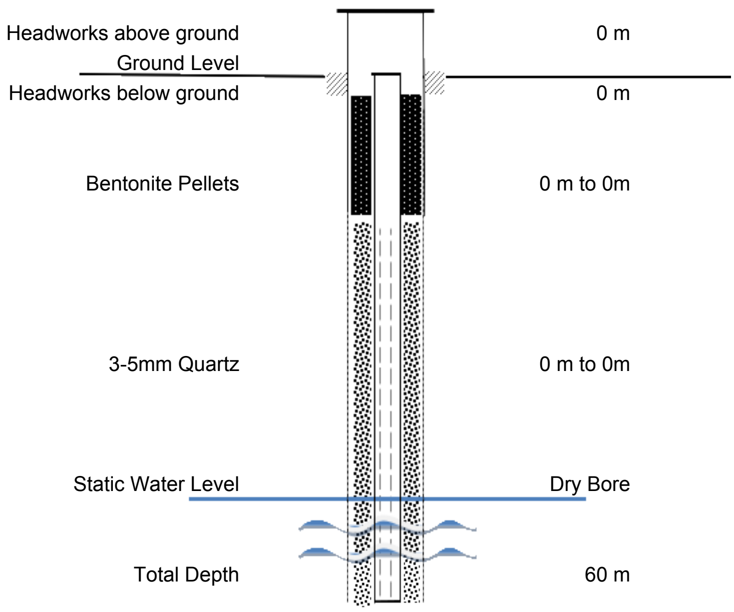
CASING

Casing	OD	ID	Weight	Grade	Thread	Range	Slotted	Length	Set at
Conductor									
Production (PVC)									
Screens (PVC)									
Sump									

PIEZO COMPLETION REPORT **CLIENT:** Lowe Environmental Impact

GEOLOGICAL LOG

Top Depth (m)	Bottom Depth (m)	**Formation Type** (Major, Secondary, Minor)	Colour	Grain Size	Water Content
0	0.3	Silt	Brown		Dry
0.3	9.8	Topsoil	Brown		Dry
9.8	22.4	Gravel Silt Clay	Grey	Fine to coarse	Dry
22.4	23	Gravel Silt	White, Grey, Brown	Fine to medium	Dry
23	60	Gravel Silt	Grey, Brown	Fine to coarse	Dry



Addtional Information:

PIEZO COMPLETION REPORT

Client	Lowe Environmental Impact	**GPS** NZMG		**East**	2173144
				North	5531874
Consent No.		**Well Name**	GW5		
Piezo Location	Kingston				
Client Contact					
Driller	Paul Washington	**Drill Method**	Rotary		
Machine/Rig	Rig 4 - Foremost DR24	**Bore Diameter**	150mm		

Drilling Engineer	
Geologist	

Start Date	24/09/2020	**Date Completed**	29/09/2020
Water Level	44.2 m	**Measured Depth**	59.3 m

Has the bore been capped or covered?	Yes
Does the bore have a concrete pad?	Yes
Is the bore sealed with concrete or Bentonite around the annulus?	Yes

All measurements taken from Ground Level

OPEN HOLE SECTION

Size	
From metres	
To metres	

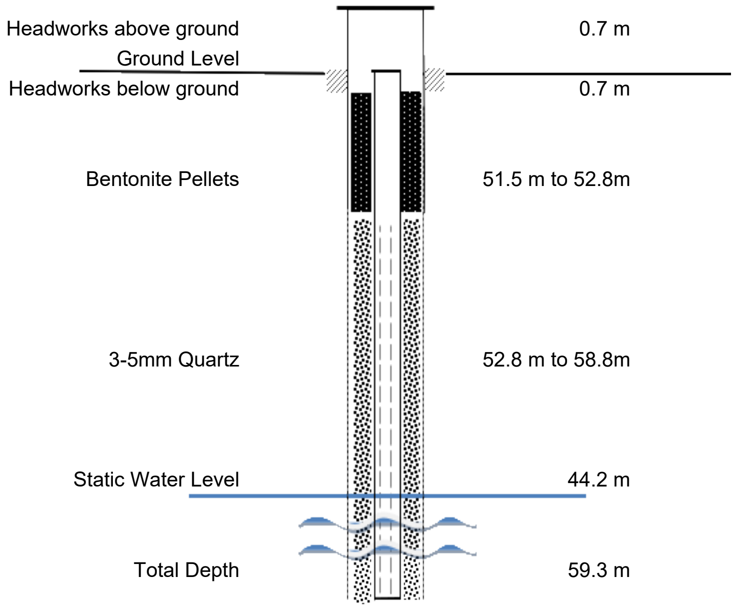
CASING

Casing	OD	ID	Weight	Grade	Thread	Range	Slotted	Length	Set at
Conductor									
Production (PVC)	60 mm	50 mm			No			52.8 m	-0.5 m
Screens (PVC)	60 mm	50 mm			No		0.5 mm	6 m	58.8 m
Sump									

PIEZO COMPLETION REPORT **CLIENT:** Lowe Environmental Impact

GEOLOGICAL LOG

Top Depth (m)	Bottom Depth (m)	Formation Type (Major, Secondary, Minor)	Colour	Grain Size	Water Content
0	0.3	Gravel Silt	Brown		Dry
0.3	1.5	Topsoil	Grey	Fine to coarse	Dry
1.5	48.5	Gravel Silt	White, Grey, Brown	Fine to coarse	Dry
48.5	59	Gravel Sand Silt	White, Grey, Brown, Green	Fine to coarse	Water bearing



Addtional Information:

PIEZO COMPLETION REPORT

Client	Lowe Environmental Impact	**GPS**		**East**	2173136
		NZMG		**North**	5531724
Consent No.		**Well Name**	GW6		
Piezo Location	Kingston				
Client Contact					
Driller	Paul Washington	**Drill Method**	Rotary		
Machine/Rig	Rig 4 - Foremost DR24	**Bore Diameter**	150mm		

Drilling Engineer	
Geologist	

Start Date	30/09/2020	**Date Completed**	02/10/2020
Water Level	43.2 m	**Measured Depth**	59 m

Has the bore been capped or covered?	Yes
Does the bore have a concrete pad?	Yes
Is the bore sealed with concrete or Bentonite around the annulus?	Yes

All measurements taken from Ground Level

OPEN HOLE SECTION

Size	
From metres	
To metres	

CASING

Casing	OD	ID	Weight	Grade	Thread	Range	Slotted	Length	Set at
Conductor									
Production (PVC)	60 mm	50 mm			No	0	0.5 mm	52.5 m	-0.5 m
Screens (PVC)	60 mm	50 mm			No		0.5 mm	6 m	58.5 m
Sump									

WASHINGTONS EXPLORATION LIMITED NZ

PIEZO COMPLETION REPORT　　**CLIENT:** Lowe Environmental Impact

GEOLOGICAL LOG

Top Depth (m)	Bottom Depth (m)	**Formation Type** (Major, Secondary, Minor)	Colour	Grain Size	Water Content
0	0.3	Silt Gravel	Brown		Dry
0.3	5	Topsoil	Grey, Brown	Fine to coarse	Dry
5	15	Gravel Silt	Brown	Fine to coarse	Dry
15	15.7	Rock	Grey		Dry
15.7	47.5	Gravel Silt	Grey, Brown	Fine to coarse	Dry
47.5	58.5	Gravel Sand Silt	White, Grey, Brown, Green	Fine to coarse	Water bearing

Headworks above ground　0.7 m

Ground Level

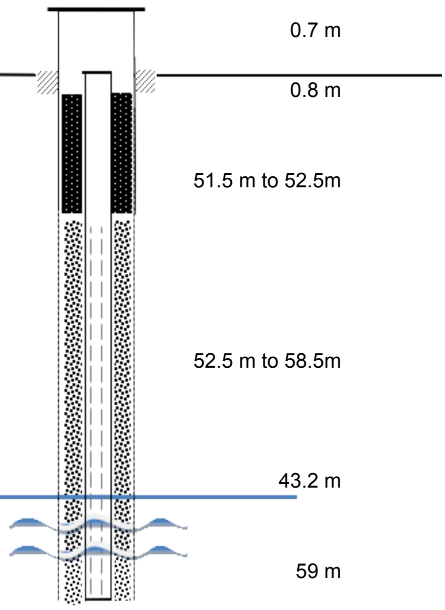
Headworks below ground　0.8 m

Bentonite Pellets　51.5 m to 52.5m

3-5mm Quartz　52.5 m to 58.5m

Static Water Level　43.2 m

Total Depth　59 m



Addtional Information:

PIEZO COMPLETION REPORT

Client	Lowe Environmental Impact	**GPS**		**East**	0
		NZMG		**North**	0
Consent No.		**Well Name**	GW 7		
Piezo Location	SH 6 Kingston				
Client Contact	Tim Court-Patience - QLDC				
Driller	Paul Washington	**Drill Method**	Rotary		
Machine/Rig	Rig 4 - Foremost DR24	**Bore Diameter**	160mm		

Drilling Engineer	
Geologist	

Start Date	14/09/2020	**Date Completed**	15/09/2020
Water Level	Dry Hole	**Measured Depth**	60 m

Has the bore been capped or covered?	No
Does the bore have a concrete pad?	No
Is the bore sealed with concrete or Bentonite around the annulus?	No

All measurements taken from Ground Level

OPEN HOLE SECTION

Size	125mm
From metres	48
To metres	60

CASING

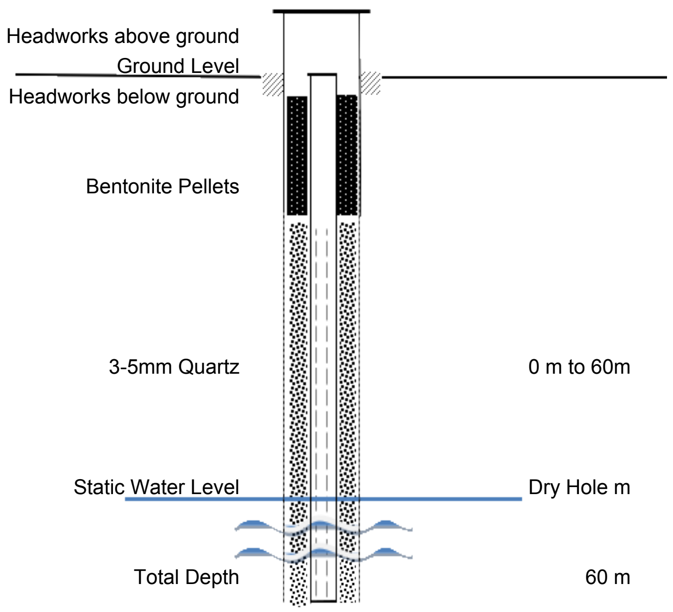
Casing	OD	ID	Weight	Grade	Thread	Range	Slotted	Length	Set at
Conductor	0 mm	0 mm			No	0			
Production (PVC)	0 mm	0 mm			No	0			
Screens (PVC)									
Sump									

WASHINGTONS EXPLORATION LIMITED NZ

PIEZO COMPLETION REPORT **CLIENT:** Lowe Environmental Impact

GEOLOGICAL LOG

Top Depth (m)	Bottom Depth (m)	Formation	Colour	Grain Size	Water Content
0	0.3	Clay	Brown		Dry
0.3	0.6	Topsoil	Brown		Dry
0.6	1	Gravel Silt	Grey		Dry
1	1.4	Gravel Silt Cobbles	Grey	Fine to coarse	Dry
1.4	46	Gravel Silt Clay	Grey	Fine to coarse	Dry
46	47.9	Rock	Grey, Green		Dry
47.9	48.5	Gravel Silt	Grey	Fine to coarse	Dry
48.5	60	Gravel Silt	Grey	Fine to coarse	Dry



Addtional Information: Dry
hole
48.3m - 54.0m - Dusty disharge

Terry Hughes

From: Hilary Lough <Hilary.Lough@pdp.co.nz>
Sent: Monday, 21 September 2020 4:17 pm
To: Terry Hughes
Cc: Tim Court-Patience; Brian Ellwood; Sarah Davidson
Subject: RE: Screen depths at GW3

Hi Terry,

Thanks for this and the phone conversations. Interesting findings. I agree with the idea of having both levels screened, if possible, and those screen locations sound reasonable to me.

NB: I have copied in Sarah to keep her in the loop.

Kind regards,
Hilary

Hilary Lough - ME(Civil), CPEng | Technical Director - Water Resources
PATTLE DELAMORE PARTNERS LTD
DDI - +64 3 345 7110 | Mob - +64 21 77 68 44 | Office - +64 3 345 7100

From: Terry Hughes <terry@lei.co.nz>
Sent: Monday, 21 September 2020 3:54 PM
To: Hilary Lough <Hilary.Lough@pdp.co.nz>
Cc: Tim Court-Patience <tim.court@qldc.govt.nz>; Brian Ellwood <brian@lei.co.nz>
Subject: Screen depths at GW3

Hi Hilary, as discussed the plan will be to double screen at GW3, screening both the gravel between 25.5 and 29 m (this has now shown a water level of 14 mbgl – so quite a bit of sub-artesian pressure, the screen length should account for all seasonal water levels, given the pressure head). The driller will also attempt to screen above the hard clay at 23 mbgl (very hard going between 23 and 25), we will screen 6 m to capture any seepage out of the sandy silt.

Geology – 0 to 20.5 Sandy SILT dry, 20.5 to 23m damp CLAY, 23 to 25.5 Hard/Compact dry CLAY, 25.5 – 26.5 claybound GRAVEL water bearing, 26 to 29 mbgl GRAVEL, water bearing.

The hard compact layer is definitely confining groundwater and is likely not to transmit water downwards, the soil layer is dry to moist.

Please feel free to comment.

Regards

Terry Hughes
Lowe Environmental Impact

| T | [+64] 3 359 3059 **| M |** [+64] 27 2179800 **| E |** terry@lei.co.nz **| W |** www.lei.co.nz

Attachment 2: Ryder Ecology Report

Queenstown Lakes
District Council

Kingston Township Community Wastewater Aquatic Ecology Assessment

November 2020

ryder

Queenstown Lakes District Council

Kingston Township Community Wastewater Aquatic Ecology Assessment

November 2020

Prepared for Queenstown Lakes District Council

by

Ruth Goldsmith, PhD.

Reviewed by

Ben Ludgate, MSc.

Ryder Environmental Limited
195 Rattray Street
PO Box 1023
DUNEDIN, 9054
New Zealand
Phone: 03 477 2119

Document version: 26 November 2020

Cover page: Aerial image of Kingston Township and the proposed land treatment area. Imagery from Google Earth 11/11/2019.

Table of Contents

1. Executive Summary

Queenstown Lakes District Council (QLDC) propose to develop a community wastewater treatment scheme for Kingston Township (Kingston). QLDC have applied to the Otago Regional Council (ORC) for resource consent to discharge treated wastewater effluent onto an approximately 25 ha area of land to the south of Kingston. Treated effluent will be discharged into land via drip irrigation at a depth of approximately 200 mm.

Ryder Environmental (REL) was engaged by Lowe Environmental Impact (LEI) to undertake an ecological and surface water impact assessment of all surface water bodies that could be affected by the discharge. A total of 10 surface water sites were sampled by REL in October 2020. The sites were located within a pond that is surrounded by the proposed land treatment area, two small tributaries of Lake Wakatipu located to the north of the area, and in Lake Wakatipu itself. Depending on the habitat present, water quality, benthic macroinvertebrate and/or fish community sampling was undertaken at each site. Visual investigation of upstream and downstream surface flow paths in order to describe connections between surface water bodies was also completed.

The assessment found that there are no existing surface water connections between the proposed land treatment area and the identified surface water bodies within the vicinity of the area, therefore the mostly likely way that surface water bodies could be impacted by the effluent is via groundwater connections to the proposed treatment area. The combination of a proposed secondary treatment plant, the low application rate and the large depth of soil and subsoil, will reduce the potential for nutrient and faecal bacteria contaminants leaching to groundwater as a result of effluent application. Based on the REL survey in October 2020, the existing aquatic communities in the vicinity of the application area are also expected to be tolerant of any potential contaminant input should leaching occur. The risk of contaminants entering Lake Wakatipu under the proposed land treatment system is also likely reduced from the existing effluent management situation in Kingston, which involves a large number of properties using uncontrolled individual treatment via septic tank systems (LEI 2020).

Overall, any adverse effects on aquatic communities within surface water bodies will therefore be less than minor. Monitoring has been proposed to ensure compliance with the proposed volume and nutrient loading limits within the application area, and to monitor the impact of the proposed activities on the environment (LEI 2020).

2. Background

Queenstown Lakes District Council (QLDC) propose to develop a community wastewater treatment scheme for Kingston Township (Kingston) and have applied to the Otago Regional Council (ORC) for resource consent to discharge treated wastewater effluent onto land. The proposed location of the land treatment area (approximately 25 ha) on Kingston Station to the south of Kingston is shown in Figure 1. Lowe Environmental Impact (LEI) was engaged by QLDC to undertake an assessment of environment effects (AEE) for the application (LEI 2020), and E3 Scientific have subsequently completed an aquatic ecological review of this assessment for the ORC (Appendix B, LEI 2020). Following on from the E3 Scientific review it has been identified that further assessment of the existing ecological values of the site is required.

Ryder Environmental (REL) was engaged by LEI to undertake an ecological and surface water impact assessment of all surface water bodies that could be affected by the discharge. The assessment included the following components:

- The Existing Environment - provides a description of the existing habitat and communities.
- Assessment of Effects – provides a discussion of the potential effects of the proposal on the existing environment.

Figure 1. Kingston Township Community Wastewater proposed land treatment command area (from LEI 2020).

3. Methodology

Sampling was undertaken at the 11 sites shown in Figure 2 on the 12 - 14 of October 2020. A summary of the sampling methods used at each of the sites is shown in Table 1. Sampling methods varied among the sites depending on the type of habitat present, which dictated the most appropriate method to use to describe the existing aquatic environment. Sampling methods were as follows:

- Aquatic habitat: At all sites a general description of available aquatic habitat (e.g., substrate, vegetation), including photographs.
- Surface flow paths: Visual investigation of upstream and downstream surface flow paths in order to describe connections between surface water bodies. Also, at SW3 (Unnamed tributary - upstream) the flow at the time of water quality sampling was estimated by flow gauging (using a FlowTracker).
- Water quality: Measurements were made at all sites on the same day (13 October). Water temperature, conductivity, dissolved oxygen, pH, and turbidity levels were measured using calibrated field meters. Water samples were collected and later processed at Watercare Laboratory Services (Queenstown and Invercargill) to determine concentrations of total biochemical oxygen demand ($TBOD_5$), total nitrogen, nitrate nitrogen, total ammoniacal nitrogen, nitrite nitrogen, dissolved reactive phosphorus, *Escherichia coli* (*E. coli*), and total coliforms.
- Benthic macroinvertebrates: Collection of one kicknet sample from the range of habitats at each site. Samples were preserved in ethanol and later processed at the REL laboratory to identify the taxa present and calculate key community metrics (e.g., MCI and SQMCI).
- Fish: Over-night sets of baited Gee-minnow traps (up to three per site) and fyke nets, if suitable habitat was present (i.e., deep water). Spotlighting at night to identify fish presence was also considered but the habitat was not suitable.

Table 1. Sampling methods at surface water sites, October 2020.

Site number	Site name/description	Water quality – field meter and water sample	Benthic macroinvertebrates – kicknet sample	Fish – minnow traps and/or fyke nets
SW5	Pond 1	No	No	No
SW6	Pond 2	Yes	Yes	3 traps, 1 fyke net
SW3	Unnamed tributary - upstream	Yes	Yes	3 traps
SW2	Unnamed tributary – downstream 1	Yes	Yes	3 traps
SW1	Unnamed tributary – downstream 2	Yes	Yes	3 traps
SW7	Unnamed tributary – at Lake	Yes	Yes	3 traps
SW4	Kingston Creek – upstream State Highway 6 (SH6)	Yes	Yes	3 traps
SW8	Kingston Creek – at Lake	Yes	Yes	No
SW9	Lake Wakatipu - East	Yes	Yes	3 traps, 1 fyke net
SW10	Lake Wakatipu - Mid	Yes	No	No
SW11	Lake Wakatipu - West	Yes	Yes	No

Figure 2. Kingston Township Community Wastewater proposed land treatment command area surface water quality sampling sites, October 2020.

4. The Existing Environment

Aquatic habitat and surface flow paths

Ponds

Two ponds (SW5 and SW6) are located within or adjacent to the proposed land treatment area (Figures 1 and 2). Pond 1 (SW5) had been drained prior to the October 2020 survey and therefore did not provide any existing aquatic habitat (Figure 3). Pond 1 was therefore not sampled (Table 1) and is not discussed any further in this assessment.

Figure 3. Pond 1 (SW5).

Pond 2 (SW6) is surrounded on three sides by the proposed land treatment area (Figures 1 and 4). The pond has a surface area of approximately 0.09 ha and is artificial, having been created by excavation of a naturally wet area, some of which remains (Figure 4, bottom). It is also isolated, having no direct connection to any other surface water bodies. Pond 2 is surrounded by grazed pasture and there is no restriction to stock access. Water quality was measured, and a benthic macroinvertebrate sample taken (by sweeping a kicknet along the pond margins). Three Gee-minnow traps and one fyke net were set overnight in the pond (Table 1).

Figure 4. Pond 2 (SW6). Top: Pond 2. Bottom: Wet area of pasture connected to the pond.

Unnamed tributary

A small unnamed tributary of Lake Wakatipu is located to the north of the proposed land treatment area (Figures 1 and 2). The unnamed tributary has no surface flow connection with the proposed land treatment area but skirts the northern side of the area and may potentially receive groundwater inflows. The tributary has a total length of approximately 2 km, flowing from steep hillside to the west of the site and then turning to flow north, entering the lake at Kingston Township. Four sites were sampled on the tributary: SW3, SW2, SW1 and SW7 (from upstream to downstream, Figure 2). At each of the sites water quality was measured, a benthic macroinvertebrate sample collected, and three Gee-minnow traps were set overnight (Table 1).

The unnamed tributary – upstream site (SW3) was located upstream of any potential influence of the proposed land treatment area. The tributary channel here was initially poorly defined, flowing off the steep hillside through a wide, heavily vegetated (dominated by monkey musk) area with a soft fine sediment substrate (Figure 5, top). Immediately upstream of the cycleway culvert the tributary channel then became more defined and downstream of the culvert continued to flow through a narrow, incised channel with a firm, gravel and cobble substrate (Figure 5, bottom). Flow at this point was gauged to be 3 L/s. Approximately 3 m downstream of the cycleway culvert the tributary entered a second culvert, flowing in a defined channel for a short distance after it exited the culvert before widening again into an undefined wet area. The channel in this section of the tributary downstream to the unnamed tributary – downstream site 1 (SW2) was fenced from stock grazing and overhung with tall broom and other exotic shrubs. Due to the dense vegetation cover it was not possible to follow the channel the entire 150 m to downstream site 1 (SW2), however from what was observed there was a surface flow connection throughout.

Figure 5. Unnamed tributary - upstream (SW3). Top: Wide undefined channel upstream of cycleway culvert. Bottom: Confined channel downstream of cycleway culvert, with Gee-minnow trap.

Unnamed tributary – downstream site 1 (SW2) was similar to that of the upstream site. Within this site the channel varied from being an undefined wide, heavily vegetated (again dominated by monkey musk) area with a soft fine sediment substrate (Figure 6, top), to being narrow and incised with gravel and cobble dominated substrate (Figure 6, bottom). Immediately downstream of the site there was an approximately 10 m long section with no visible surface flow at the time of sampling. It appeared though that during higher flows this section of channel would have surface flow.

Unnamed tributary – downstream site 2 (SW1) was located approximately 300 m downstream of downstream site 1 (Figure 2). Here the channel varied again from being wide and heavily vegetated (Figure 7, top) to narrow and incised (Figure 7, bottom). The channel was uniformly straight and it appeared that it had been excavated in the past. It was open to stock access and the banks were dominated by grazed pasture grasses.

Figure 6. Unnamed tributary – downstream 1 (SW2). Top: Wide undefined channel. Bottom: Confined channel.

Figure 7. Unnamed tributary – downstream 2 (SW1). Top: Wide undefined channel. Bottom: Confined channel.

The fourth site (SW7) on the unnamed tributary was located approximately 50 m upstream of Lake Wakatipu and approximately 1 km downstream of the proposed land treatment area (Figure 2). The habitat at this site differed from that at the other unnamed tributary sites upstream, in that the channel was uniformly open with minimal vegetation and had a mobile, gravel dominated substrate (Figure 8). The site was located within a recreational reserve, and there was mown grass and occasional shrubs and trees on the banks.

Figure 8. Unnamed tributary – at Lake (SW7).

Kingston Creek

This small unnamed tributary of Lake Wakatipu is known locally as Kingston Creek. Kingston Creek has no surface flow connection with the proposed land treatment area and is located approximately 500 m to the north (Figures 1 and 2). The creek has a total length of approximately 4.5 km, flowing from steep hillside to the east of the site. Two sites were sampled in Kingston Creek: SW4 and SW8 (Figure 2). At both sites water quality was measured, and a benthic macroinvertebrate sample collected. Three Gee-minnow traps were also set overnight at the Kingston Creek – upstream SH6 site (SW4). Habitat at the Kingston Creek – at Lake site (SW8) was not suitable for minnow trap setting (due to the fast flowing and shallow water) (Table 1).

The Kingston Creek – upstream SH6 site (SW4) was located within a grazed paddock, immediately upstream of the SH6 road culvert (Figure 2). The channel was open to stock and some slumping of the creek banks was visible (Figure 9). Willow trees were present on the banks in places. The substrate included soft, fine sediments amongst gravel and cobbles, and patches of vegetation were also present (dominated by monkey musk) (Figure 9).

Figure 9. Kingston Creek – upstream SH6 (SW4).

The Kingston Creek – at Lake site (SH8) was located approximately 50 m upstream of Lake Wakatipu (Figure 2). The habitat at this site differed from that at the site upstream, in that the channel was wide and open with minimal vegetation and had a mobile, gravel and cobble dominated substrate (Figure 10). The site was located within a recreational reserve, and there was mown grass and occasional shrubs and trees on the banks.

Figure 10. Kingston Creek – at Lake (SW8).

Lake Wakatipu

Three sites were sampled on the shore of Lake Wakatipu: SW9, SW10 and SW11 (Figure 2, from east to west). Water quality was measured at all three sites (Table 1). At the Lake Wakatipu – East site (SW9) a benthic macroinvertebrate sample was also collected, and three Gee-minnow traps and one fyke net were set overnight (Table 1). Due to strong on-shore waves it was not possible to collect a benthic macroinvertebrate sample or set nets at the Lake Wakatipu – Mid site (SW10). Nets were also not set at the Lake Wakatipu – West site (SW11), however a benthic macroinvertebrate sample was collected.

Aquatic habitat at all three Lake Wakatipu sites was similar, with a gravel and cobble dominated substrate and occasional large boulders (Figures 11 and 12). A small unnamed tributary entered the lake near the Lake Wakatipu – West site (SW11) and there was some woody debris and leaf matter on the lake bed at this site in association with this.

Figure 11. Lake Wakatipu – West (SW11).

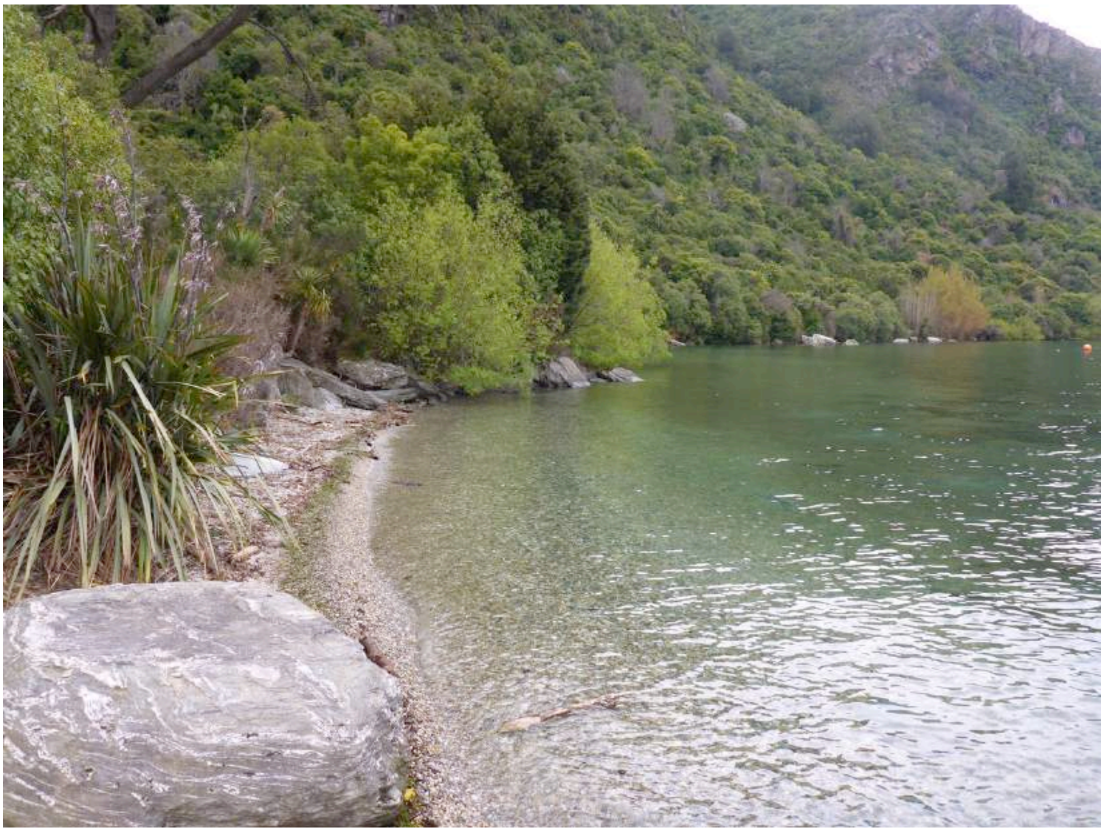


Figure 12. Lake Wakatipu – East (SW9).

Water quality

There was no existing surface water quality data for the surface water bodies in the vicinity of the proposed land treatment area. To inform this assessment water quality was therefore measured at each of the 10 sites in October 2020 (Table 2).

Overall, water quality was poorest in Pond 2 which had, for example, the lowest dissolved oxygen concentration, and highest turbidity, total nitrogen, *E.* coli, total coliforms and total biochemical oxygen demand ($TBOD_5$) concentrations (Table 2). This was expected given that it is a small, artificial pond draining agricultural land with no defined surface inflows or outflows.

Of the four unnamed tributary sites, the most downstream site (at Lake, SW7) had the highest nutrient concentrations (dissolved reactive phosphorus and nitrate nitrogen) (Table 2). This is typical, as contaminant inputs tend to increase downstream. Faecal bacteria (*E. coli*) concentrations were, however, lowest at the downstream site (SW7) and highest at the most upstream site (upstream, SW3). Feral pigs were observed upstream of SW3 during sampling and their presence in the area may have contributed to the relatively high *E. coli* concentration observed at this site. Sheep were grazing in the paddocks adjacent to tributary site downstream 2 (SW1), however *E. coli* concentrations here were lower than further upstream (Table 2). The opposite was true of total coliforms, which were highest at downstream 1 (SW2) and lowest upstream (SW3). Aside from nutrients and faecal bacteria, other water quality parameters (i.e., dissolved oxygen, pH, conductivity, turbidity, $TBOD_5$) were similar among all four unnamed tributary sites (Table 2).

Nutrient concentrations (nitrate nitrogen and total nitrogen) and turbidity levels were higher at the Kingston Creek downstream site (at Lake, SW8) than the upstream site (upstream SH6, SW4) (Table 2). As in the unnamed tributary, faecal bacteria concentrations were higher at the upstream site (SW4) than downstream (SW8). Other water quality parameters (i.e., dissolved oxygen, pH, conductivity, $TBOD_5$) were similar between the two Kingston Creek sites (Table 2).

The three Lake Wakatipu sites had similar, and the overall lowest, faecal bacteria concentrations (Table 2). Nutrient concentrations varied between the lake sites, with dissolved reactive phosphorus highest at the Lake Wakatipu – East site (SW9) and total nitrogen highest at the Lake Wakatipu – Mid site (SW10). Other water quality parameters (i.e., dissolved oxygen, pH, conductivity, turbidity, $TBOD_5$) were similar among the three lake sites (Table 2).

Schedule 15 of the Regional Plan: Water for Otago (2018) sets water quality limits that are to be achieved in Lake Wakatipu (receiving water group 5) and its tributaries (receiving water group 3). These limits are achieved when 80% of samples collected at a site, when flows are at or below median flow, over a rolling

5-year period, meet or are better than the limits in Schedule 15. There is not sufficient data to assess water quality in Lake Wakatipu, the unnamed tributary and Kingston Creek against these limits, however to provide some context the limits are presented along with the relevant existing values in Table 3. Turbidity limits were met in Lake Wakatipu but at some sites total nitrogen and *E. coli* limits were not met. All limits were met in the unnamed tributary, with the exception of *E. coli* at the upstream site (SW3) and dissolved reactive phosphorus at the lake site (SW7). In Kingston Creek all limits were not met.

Table 2. Water quality at surface water sites, 13 October 2020.

Water quality parameters	Units	SW6	SW3	SW2	SW1	SW7	SW4	SW8	SW9	SW10	SW11
		Pond 2	Unnamed tributary - upstream	Unnamed tributary – downstream 1	Unnamed tributary – downstream 2	Unnamed tributary – at Lake	Kingston Creek – upstream SH6	Kingston Creek – at Lake	Lake Wakatipu - East	Lake Wakatipu - Mid	Lake Wakatipu - West
Time of day	h	1005	0930	1030	1055	1205	1115	1140	1215	1150	1125
Temperature	°C	11.2	8.6	8.6	9.9	9.0	10.6	10.3	10.8	10.8	11.3
Dissolved oxygen	%	64.6	88.7	84.0	81.2	95.2	101.0	98.6	97.9	94.7	97.6
Dissolved oxygen	mg/L	7.04	10.37	9.84	9.16	11.00	11.26	11.04	10.90	10.48	10.80
pH	-	8.6	6.8	7.0	7.1	6.6	7.1	6.6	7.0	6.9	7.1
Conductivity	µS/cm	46.1	40.6	35.9	34.9	38.5	55.9	45.7	49.2	50.6	53.8
Turbidity	NTU	79.7	1.4	2.1	0.6	2.0	16.0	3.9	1.0	1.3	2.0
Dissolved reactive phosphorus	mg/L	<0.005	<0.005	0.005	0.005	0.009	0.008	0.008	0.022	<0.005	<0.005
Nitrate nitrogen	mg/L	<0.01	<0.01	<0.01	<0.01	0.06	0.09	0.39	0.03	0.17	0.07
Nitrite nitrogen	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total nitrogen	mg/L	8.90	0.30	0.35	0.35	0.36	0.37	0.55	0.08	0.22	0.12
E. coli	MPN/100 mL	130	58	18	6	3	190	55	12	3	11
Total coliforms	MPN/100 mL	>2,400	520	1,400	690	1,300	1,600	580	120	140	120
$TBOD_5$	mg/L	41	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0

Table 3. Regional Plan: Water for Otago (2018) Schedule 15 water quality limits and water quality values at surface water sites, 13 October 2020. Values that exceed limits are highlighted in yellow. Note that as the limits only apply to 80% of samples collected at a site, when flows are at or below median flow, over a rolling 5-year period, there is not sufficient data for the surface water sites to provide a true limit assessment.

Water quality parameters	**Units**	**SW3**	**SW2**	**SW1**	**SW7**	**SW4**	**SW8**	**SW9**	**SW10**	**SW11**
		Unnamed tributary - upstream	**Unnamed tributary – downstream 1**	**Unnamed tributary – downstream 2**	**Unnamed tributary – at Lake**	**Kingston Creek – upstream SH6**	**Kingston Creek – at Lake**	**Lake Wakatipu - East**	**Lake Wakatipu - Mid**	**Lake Wakatipu - West**
Turbidity limit	NTU	3	3	3	3	3	3	3	3	3
Turbidity value	NTU	1.4	2.1	0.6	2.0	16.0	3.9	1.0	1.3	2.0
Dissolved reactive phosphorus limit	mg/L	0.005	0.005	0.005	0.005	0.005	0.005	-	-	-
Dissolved reactive phosphorus value	mg/L	<0.005	0.005	0.005	0.009	0.008	0.008	-	-	-
Nitrate nitrogen limit	mg/L	0.075	0.075	0.075	0.075	0.075	0.075	-	-	-
Nitrate nitrogen value	mg/L	<0.01	<0.01	<0.01	0.06	0.09	0.39	-	-	-
Total nitrogen limit	mg/L	-	-	-	-	-	-	0.10	0.10	0.10
Total nitrogen value	mg/L	-	-	-	-	-	-	0.08	0.22	0.12
Escherichia coli limit	cfu/100 mL	50	50	50	50	50	50	10	10	10
Escherichia coli value	MPN/100 mL	58	18	6	3	190	55	12	3	11

Benthic macroinvertebrates

Benthic macroinvertebrate communities were sampled at nine sites in October 2020 (Tables 4a and 4b). A combined total of 58 taxa were identified across all sites. The number of taxa varied among sites from 7 to 30 taxa, which was expected, given the variety of habitats sampled. The lowest number of taxa (7) was recorded at the Lake Wakatipu – East site (SW11). Sampling was difficult at this site due to the large on-shore waves and it is likely that more taxa were present at the site than collected in the sample. The next lowest number of taxa (14) was collected at the Lake Wakatipu – West site (SW9).

The number and percent of Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) (EPT) taxa[1] also varied among sites. There were no EPT taxa recorded in Pond 2 (SW6) and the maximum of seven EPT taxa was recorded at the unnamed tributary – upstream (SW3, Table 4a) and Kingston Creek – upstream SH6 sites (SW4, Table 4b).

The low number of EPT taxa at all sites was reflected in macroinvertebrate community index (MCI) scores[2], which ranged from being indicative of 'poor' to 'fair' water quality and/or habitat condition (Tables 4a and 4b). Semi-quantitative MCI (SQMCI) scores ranged from being indicative of 'poor' to 'good' water quality and/or habitat condition. At all of the four unnamed tributary sites and the two Kingston Creek sites SQMCI scores ranged from being indicative of 'poor' to 'good' conditions, with macroinvertebrate taxa that are tolerant of a range of conditions abundant (e.g., Dipterans, Molluscs, Oligochaeta).

Although they were not collected in the sample from the Lake Wakatipu – East site (SW11), freshwater mussels (*Echydridella menziesii*) are known to be present in Lake Wakatipu (Goldsmith *et al.* 2007) and are listed by the Department of Conservation as 'at risk – declining' (Grainger *et al.* 2018).

[1] These insect groups are generally dominated by invertebrates that are indicative of higher quality conditions. In stony bed rivers, the number of EPT taxa usually increases with improved water quality and increased habitat diversity.
[2] Note that the soft-bottomed MCI was used for Pond 2, reflecting the soft-bottomed habitat present.

Table 4a. Benthic macroinvertebrate communities in Pond 2 and the Unnamed tributary, October 2020.

TAXON	MCI-sb score	SW6	MCI score	SW3	SW2	SW1	SW7
		Pond 2		Unnamed tributary - upstream	Unnamed tributary - downstream 1	Unnamed tributary - downstream 2	Unnamed tributary - at Lake
ACARINA	5.2		5	R	A		R
COLEOPTERA							
Elmidae	7.2		6				
Enochrus species	2.6	R	5				
Hydraenidae	6.7	R	8	R			
Hydrophilidae	8	R	5				
Liodessus species	4.9	C	5				
Rhantus species	1	A	5				
COLLEMBOLA	5.3	R	6	C	VA	R	C
CRUSTACEA							
Cladocera	0.7	A	5				
Copepoda	2.4	A	5	R			
Ostracoda	1.9	VVA	3	A	C		C
Talitridae	5.5		5	R			
DIPTERA							
Austrosimulium species	3.9	R	3	A	C	VA	R
Ceratopogonidae	6.2	R	3	R			
Chironomus species	3.4	C	1				
Empididae	5.4		3			R	
Eriopterini	7.5		9	R			
Harrisius species	4.7		6	R			
Hexatomini	6.7		5				
Maoridiamesa species	4.9		3				
Molophilus species	6.3		5				
Muscidae	1.6		3	R			
Orthocladiinae	3.2	R	2	VVA	VA	A	A
Paradixa species	8.5		4	A	C	R	
Paralimnophila skusei	7.4		6		R		
Podonominae	6.4		8	A	VVA	A	A
Polypedilum species	8		3	A			
Stratiomyidae	4.2	R	5	R	R	C	
Tanyderidae	5.9		4				
Tanypodinae	6.5		5	VA	A	R	R
Tanytarsini	4.5		3				
Tipulidae	3.4		5		R		
Zelandotipula species	3.6		6		R	R	
EPHEMEROPTERA							
Deleatidium species	5.6		8	A	A		C
HEMIPTERA							
Anisops species	2.2	A	5				
Microvelia macgregori	4.6		5		C		R
Sigara species	2.4	A	5				
MOLLUSCA							
Gyraulus species	1.7	R	3			C	
Physa / Physella species	0.1	R	3		C	R	R
Potamopyrgus antipodarum	2.1	R	4	VVA	VA	VA	A
Sphaeriidae	2.9		3	VA	VA	R	R
NEMATODA	3.1	VA	3	A		R	R
ODONATA							
Aeshna species	1.4	R	5				
Xanthocnemis zealandica	1.2	C	5		R	VA	
OLIGOCHAETA	3.8	VA	1	A	VA	C	A
PLATYHELMINTHES	0.9		3	R	R		
PLECOPTERA							
Acroperla species	5.1		5				
Spaniocerca species	8.8		8	R			R
Zelandobius species	7.4		5	C	VA	R	A
TRICHOPTERA							
Hudsonema alienum	6.5		6	R	R		
Hudsonema amabile	6.5		6	C			R
Hydrobiosis umbripennis group	6.7		5				R
Oeconesidae	6.4		9	C	R		
Oxyethira albiceps	1.2	R	2	A	C	VA	C
Paroxyethira species	3.7		2			R	
Polyplectropus species	8.1		8		C		
Psilochorema species	7.8		8	A	C		
Pycnocentrodes species	3.8		5				
Number of taxa		24		30	26	19	19
Number of EPT taxa (excluding Hydroptilidae)		0		7	6	1	5
% EPT taxa (excluding Hydroptilidae)		0		23	23	5	26
MCI score		61		99	98	77	89
MCI score interpretation		Poor		Fair	Fair	Poor	Fair
SQMCI score		2.3		3.4	5.5	3.6	4.2
SQMCI score interpretation		Poor		Poor	Good	Poor	Fair

Table 4b. Benthic macroinvertebrate communities in Kingston Creek and Lake Wakatipu, October 2020.

TAXON	MCI score	SW4	SW8	SW9	SW11
		Kingston Creek - upstream SH6	Kingston Creek - at Lake	Lake Wakatipu - West	Lake Wakatipu - East
ACARINA	5			C	C
COLEOPTERA					
Elmidae	6	R	R		
Enochrus species	5				
Hydraenidae	8				
Hydrophilidae	5				
Liodessus species	5				
Rhantus species	5				
COLLEMBOLA	6				R
CRUSTACEA					
Cladocera	5				
Copepoda	5				
Ostracoda	3	C	R	R	
Talitridae	5				
DIPTERA					
Austrosimulium species	3	A	C		
Ceratopogonidae	3				
Chironomus species	1			R	
Empididae	3				
Eriopterini	9		R		
Harrisius species	6				
Hexatomini	5	R			
Maoridiamesa species	3	A	C		
Molophilus species	5		R		
Muscidae	3				
Orthocladiinae	2	VVA	A	C	
Paradixa species	4				
Paralimnophila skusei	6				
Podonominae	8				
Polypedilum species	3				
Stratiomyidae	5				
Tanyderidae	4				R
Tanypodinae	5		C	C	
Tanytarsini	3		R		
Tipulidae	5				
Zelandotipula species	6				
EPHEMEROPTERA					
Deleatidium species	8	A	VA	C	A
HEMIPTERA					
Anisops species	5				
Microvelia macgregori	5				
Sigara species	5				
MOLLUSCA					
Gyraulus species	3				
Physa / Physella species	3		R		
Potamopyrgus antipodarum	4	A		R	
Sphaeriidae	3			R	
NEMATODA	3	C		R	
ODONATA					
Aeshna species	5				
Xanthocnemis zealandica	5				
OLIGOCHAETA	1	A	A	VA	R
PLATYHELMINTHES	3				
PLECOPTERA					
Acroperla species	5			A	R
Spaniocerca species	8			R	
Zelandobius species	5	R	R	A	C
TRICHOPTERA					
Hudsonema alienum	6				
Hudsonema amabile	6	R	R		
Hydrobiosis umbripennis group	5	C	A		
Oeconesidae	9				
Oxyethira albiceps	2	C			
Paroxyethira species	2				
Polyplectropus species	8	R			
Psilochorema species	8	C	R	R	
Pycnocentrodes species	5	R	R		
Number of taxa		17	17	14	7
Number of EPT taxa (excluding Hydroptilidae)		7	6	5	3
% EPT taxa (excluding Hydroptilidae)		41	35	36	43
MCI score		91	94		
MCI score interpretation		Fair	Fair		
SQMCI score		2.4	5.8		
SQMCI score interpretation		Poor	Good		

Fish

The New Zealand Freshwater Fish Database (NZFFD) includes records for kōaro and brown trout in Lake Wakatipu. There are also existing NZFFD records for brown trout in Kingston Creek. There are no NZFFD records for the unnamed tributary.

Four fish species were found during the October 2020 survey: brown trout, common bully, koaro, and longfin eel (Table 5). The later three species are native, and of these kōaro and longfin eels are classified by the Department of Conservation as 'at risk - declining' (Dunn *et al.* 2018). Common bully are not considered to be threatened.

No fish were caught in Pond 2 or at the three upper sites in the unnamed tributary (SW3, SW2, and SW1) closest to the proposed land treatment area. In addition to no fish being caught at the upper three unnamed tributary sites, the substrate present is not suitable for kōaro or brown trout spawning (dominated by aquatic plants and soft fine sediments). In contrast, kōaro, brown trout and common bully were all caught in the unnamed tributary at the lake (SW7), where the gravel dominated substrate is suitable for spawning.

Kōaro were also caught at the Kingston Creek site at the lake (SW8)[3]. The only other fish caught in Kingston Creek was a single small brown trout at the upstream site (SW4).

One common bully and a large longfin eel were caught at the Lake Wakatipu – East site.

[3] Minnow traps could not be set at this site due to the high water velocities but koaro were accidentally caught with a kicknet during benthic macroinvertebrate sampling.

Table 5. Fish caught at surface water sites, October 2020. Number of fish with length range (mm) in brackets.

Site number	Site name/description	Fish species			
		Brown trout (*Salmo trutta*)	**Common bully (*Gobiomorphus cotidianus*)**	**Koaro (*Galaxias brevipinnis*)**	**Longfin eel (*Anguilla dieffenbachii*)**
SW6	Pond 2				
SW3	Unnamed tributary - upstream				
SW2	Unnamed tributary – downstream 1				
SW1	Unnamed tributary – downstream 2				
SW7	Unnamed tributary – at Lake	4 (69 – 71)	2 (89 – 102)	1 (56)	
SW4	Kingston Creek – upstream SH6	1 (31)			
SW8	Kingston Creek – at Lake			4 (~50)	
SW9	Lake Wakatipu - East		1 (80)		1 (~850)

5. Assessment of Effects

Treated effluent will be discharged into land via subsurface pressure compensating drip irrigation, buried at a depth of approximately 200 mm. No surface runoff is expected from the site as a result of the drip irrigation. Land treatment of wastewater will assimilate BOD_5, sediment, nitrogen, phosphorus and pathogens contained in the wastewater. The land within the treatment area will also be managed as a 'cut and carry'[4] system to allow for enhanced nutrient uptake (LEI 2020).

There are no existing surface water connections between the proposed land treatment area and the identified surface water bodies within the vicinity of the area. As treated effluent will be discharged subsurface, the mostly likely way that surface water bodies could be impacted by the effluent is via groundwater connections to the proposed treatment area. LEI (2020) concluded that as a result of the combination of a proposed secondary treatment plant, the low application

[4] "Cut" refers to mowing grass or grass type crops, tree felling (replanting with juvenile plants) or pruning vegetation back to stimulate regrowth. "Carry" refers to removing produced dry-matter off-site.

rate and the large depth of soil and subsoil, the potential for nutrient and faecal bacteria contaminants leaching to groundwater as a result of effluent application is reduced. There is a small risk that surface run-off of effluent could occur from the treatment area, resulting from either a system failure or excessive rainfall beyond normal expectations. However, LEI (2020) consider that this is unlikely and in any event the resulting run-off would be significantly diluted, have filtered up through the soil and then percolating across a vegetated surface that has the ability to remove any remaining suspended contaminants prior to entering surface water.

The closest surface water body to the area is Pond 2 (SW6), which is surrounded on three sides by the proposed land treatment area. This pond is isolated, having no direct connection to any other surface water bodies upstream or downstream. Pond 2 had the overall poorest water quality of all sites sampled, with relatively high nitrogen and faecal bacteria concentrations, which was expected given that it is a small, artificial pond draining agricultural land. No fish were captured in the pond and the existing macroinvertebrate community was indicative of 'poor' water quality and/or habitat condition. The existing aquatic community of Pond 2 is therefore expected to be tolerant of any potential contaminant input should leaching occur.

The protection of groundwater quality within and outside of the application area is ensured by treatment of the (already treated) effluent within the soil profile (through the mechanisms of filtration, absorption and natural attrition), the effectiveness of which will increase with increasing distance from the application area. Kingston Creek is located approximately 500 m north of the application area, and therefore is considered at negligible risk of receiving contaminant inputs via groundwater inflows from the application area.

The unnamed tributary is located on the northern side of the area, approximately 40 m away from the boundary at its closest point, and therefore is at lower risk than Pond 2 but at a higher risk than Kingston Creek of receiving groundwater inflows. As already noted, there are no existing surface water connections between the proposed land treatment area and the unnamed tributary. The existing aquatic community in the unnamed tributary in the vicinity of the land treatment area did not include fish, and was indicative of 'poor' to 'good' water quality and/or habitat condition. In particular, faecal bacteria concentrations were relatively high at the most upstream site in the unnamed tributary. As for Pond 2, the existing aquatic community of the unnamed tributary is therefore expected to be tolerant of any potential contaminant input should leaching occur. The dominance of aquatic plants within the channel will also assist with nutrient uptake. At the time of sampling in October 2020 there was no surface flow connection in the unnamed tributary for a distance of approximately 10 m. The lack of surface flow connection within the unnamed tributary, at times, will also minimise the risk of any contaminant transfer downstream via the tributary into Lake Wakatipu.

The risk of contaminants entering Lake Wakatipu under the proposed land treatment system is also likely reduced from the existing effluent management situation in Kingston, which involves a large number of properties using uncontrolled individual treatment via septic tank systems (LEI 2020).

6. Conclusion

QLDC propose to develop a community wastewater treatment scheme for Kingston Township to discharge treated wastewater effluent onto a land area of approximately 25 ha within Kingston Station. Treated effluent will be discharged into land via drip irrigation at a depth of approximately 200 mm. There are no existing surface water connections between the proposed land treatment area and the identified surface water bodies within the vicinity of the area, therefore the mostly likely way that surface water bodies could be impacted by the effluent is via groundwater connections to the proposed treatment area. The combination of a proposed secondary treatment plant, the low application rate and the large depth of soil and subsoil, will reduce the potential for nutrient and faecal bacteria contaminants leaching to groundwater as a result of effluent application. Based on the REL survey in October 2020, the existing aquatic communities in the vicinity of the application area are also expected to be tolerant of any potential contaminant input should leaching occur. The risk of contaminants entering Lake Wakatipu under the proposed land treatment system is also likely reduced by the existing effluent management situation in Kingston, which involves a large number of properties using uncontrolled individual treatment via septic tank systems (LEI 2020). Overall, any adverse effects on aquatic communities within surface water bodies will therefore be less than minor. Monitoring has been proposed to ensure compliance with the proposed volume and nutrient loading limits within the application area, and to monitor the impact of the proposed activities on the environment (LEI 2020).

7. References

Dunn, N.R., Allibone, R.M., Closs, G.P., Crow, S.K., David, B.O., Goodman, J.M., Griffiths, M., Jack, D.C., Ling, N., Waters, J.M. and Rolfe, J.R. 2018. Conservation status of New Zealand freshwater fishes, 2017. *New Zealand Threat Classification Series 24*. Department of Conservation, Wellington. 11 p.

Goldsmith, R., Ludgate, B., Stewart, B. and Ryder, G.I. 2007. Frankton Marina development – Lake ecological assessment. Prepared for John Edmonds and Associates on behalf of Queenstown Marina Developments Limited. Ryder Consulting, Dunedin.

Grainger, N., Harding, J., Drinan, T., Collier, K., Smith, B., Death, R., Makan, T. and Rolfe, J. 2018. Conservation status of New Zealand freshwater invertebrates, 2018. *New Zealand threat classification series 28.* Department of Conservation, Wellington. 25 p.

LEI. 2020. Resource Consent Application Assessment of Environmental Effects: Discharge of Treated Domestic Effluent into Land Kingston Township. Prepared for Queenstown Lakes District Council by Lowe Environmental Impact, May 2020.

Attachment 3: NIWA Stream Gauging Report

20 November 2020

Lowe Environmental Impact Ltd.

Attn : Terry Hughes

RE : Kingston Gaugings 16 November 2020

As requested, NIWA was engaged to complete a series of flow gaugings to observe potential flow loss or gains in the Kingston area. The work was carried out by two technicians on 16 November 2020.

A total of 15 requested locations were visited and gauged by the NIWA technician team. The difficult weedy and boggy locations required raking and minor channel modification to obtain the best possible flow measurement.

Two locations (railway drain sites) could not be measured due to the nature of the weedy channel and no significant flow. An estimated flow was recorded by the NIWA technicians. A pipe draining water into the RD channel was observed roughly 5 metres below the RD 1 location. This pipe was draining at roughly 0.5 to 1.0 L/s.

One site (UT 3) was unable to be measured due to the channel being too weedy and boggy to obtain a suitable measurement. The tributary channel directly above this site was measured instead.

An additional site (TRKC) was added to the Kingston creek tributary arm 70 meters above its intersection with the KC channel.

The upper sections of the UT channel were very boggy and weedy making measurements very difficult with flows being very low in the first 5 measurement sites.

UT 6 was measured in a large boggy (7-8 m wide) area, where the flow channel was most restricted [see figure 6]. There is potently flow being missed here as it may be passing through the boggy areas above and below the main channel.

The entire length of the channels from the first gauging location to the lake were observed by the technicians. No other obvious tributaries or diversions of flow were noticed.

If there are any questions about this summary, please let me know.
Yours sincerely

Adrian Aarsen
NIWA Environmental Monitoring Technician
Phone: +64-3-440-0244
adrian.aarsen@niwa.co.nz

National Institute of Water & Atmospheric Research Ltd
PO Box 9340
9 Ellis Street
Alexandra 9340
NIWA Project: SCJ219PRO / LEI MF KINGSTON

1. Gauging Results

Site	Mean Time (NZST)	Flow result L/s	Observations	Notes
KC 1	*15:35*	17.0	Gravel channel, some weeds around edges	
KC 2	*15:08*	18.6	Gravel channel, some weeds around edges	
KC 3	*14:35*	108.6	Linear flow- Gravel channel	
TRKC	*15:30*	80.1	Linear flow- Gravel channel, between culverts	Kingston creek 70m above intersection with KC channel
KC 4	*14:53*	124.8	Linear flow- Gravel channel	
KC 5	*14:25*	110.1	Linear flow- Gravel channel	
UT 1	*11:11*	3.0	Very weedy and boggy.	
UT 2	*11:15*	2.6	Very weedy and boggy.	
UT 3	*10:56*	1.3	Very weedy and boggy.	Tribute channel above UT3. Requested site was unmeasurable
UT 4	*12:02*	3.1	Very weedy and boggy.	Large boggy area below with deep pools.
UT 5	*13:14*	3.2	Very weedy and boggy.	10 m above pipe, 40 m above original location
UT 6	*12:40*	9.6	Good linear flow	Channel is in a large weedy and boggy area. Measured 10m below channels intersection
UT 7	*13:41*	14.3	Slow linear flow.	Channel is much more restricted than UT 6
UT 8	*13:58*	16.4	Linear flow – Gravel channel	
RD 1		>1	Still water very boggy drain	Between RD1 and RD2 a small pipe drained into the RD channel 5 m below RD1.
RD 2		1-1.5		
RD = Rail Drain **KC = Kingston Creek** **UT = Un-named Tributary**				

2. Site photos appendix

Figure 1: Still image showing true measured locations and additional measured sites.

Figures 2 and 3 : From left downstream views of gaugings locations UT 1 and UT 2.

Figure 4 and 5 : From left downstream view of shifted gauging location for UT 3 (figure 4) and downstream view of gauging location for UT 4.

Figure 6 : Gauging section for UT 6 is in lower left corner of shot. Intersection of tribute channel and UT channel (under bridge) can be seen in centre of shot.

Figure 7: Gauging location for UT 8.

Figure 8: RD channel at RD 1.

Figure 9: Pipe 5m below RD 1

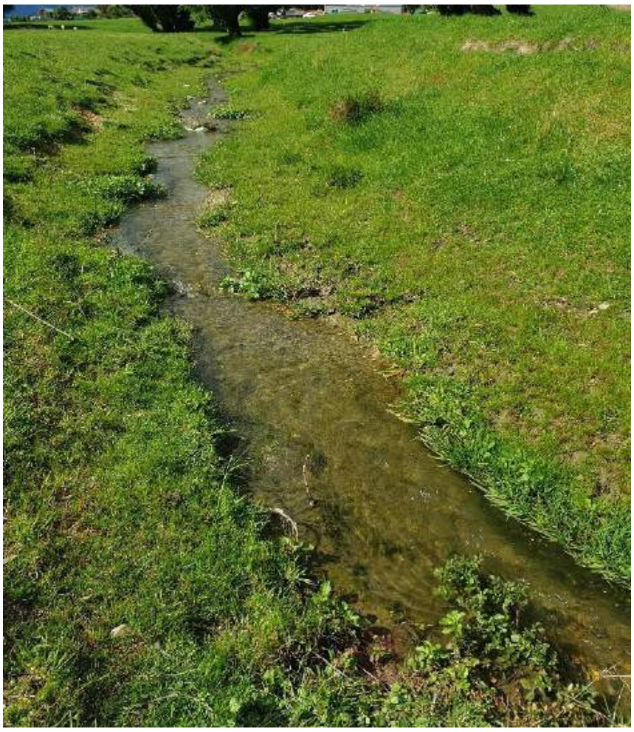


Figure 10 & 11: From left downstream views of gauging sections for KC 1 and KC 2.

Figure 12: Downstream view of gauging section for KC 3.

Attachment 4: Water Care Certificates of Analysis

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Certificate of Analysis
Laboratory Reference:201020-145

Attention:	Terry Hughes	*Final Report:*	**387383-0** *Replaces Report* **387151-0**
Client:	**QUEENSTOWN LAKE DISTRICT COUNC**	*Report Issue Date:*	**13-Nov-2020**
Address:	**PO Box 50072, Queenstown, 9348**	*Received Date:*	**28-Oct-2020**
		Sampled By:	**CB & ES**
Client Reference:	**Kingston Bores**		
Purchase Order:	**P0037604**	*Quote Reference :*	**12485**

Please note Bore 5 yielded very little water. Field tests were not able to be measured.

Sample Details		WATERS	WATERS	WATERS	WATERS
Lab Sample ID:		**201020-145-1**	**201020-145-2**	**201020-145-3**	**201020-145-4**
Client Sample ID:					
Sample Date/Time		28/10/2020 13:07	28/10/2020 16:23	28/10/2020 09:17	28/10/2020 10:12
Description:		GW 1	GW 2	GW 3a	GW3b
Sample Parameters and Field Testing					
Conductivity	µS/cm	140 *	69 *	170 *	520 *
Dissolved Oxygen	mg/L	11.0 *	9.4 *	2.5 *	0.6 *
pH	pH unit	5.8 *	5.8 *	6.3 *	7.5 *
General Testing					
Ammoniacal Nitrogen (as N)	mg/L	<0.01	<0.01	<0.01	<0.01
CBOD5 (as O2)	mg/L	<2.0	<2.0	<2.0	4.9
Nitrate Nitrogen (as N)	mg/L	7.1	1.3	4.1	<0.01
Total Nitrogen (as N)	mg/L	7.3	1.9	4.7	0.4
Total Phosphorus (as P)	mg/L	0.07	0.1	0.15	0.39

Sample Details		WATERS	WATERS
Lab Sample ID:		**201020-145-5**	**201020-145-6**
Client Sample ID:			
Sample Date/Time		28/10/2020 17:00	28/10/2020 14:36
Description:		GW 5	GW 6
Sample Parameters and Field Testing			
Conductivity	µS/cm	-	100 *
Dissolved Oxygen	mg/L	-	9.4 *
pH	pH unit	-	6.6 *
General Testing			
Ammoniacal Nitrogen (as N)	mg/L	<0.01	<0.01
CBOD5 (as O2)	mg/L	<2.0	<2.0
Nitrate Nitrogen (as N)	mg/L	2.2	0.29
Total Nitrogen (as N)	mg/L	3.7	0.44
Total Phosphorus (as P)	mg/L	<0.01	<0.01

*Results marked with * are not accredited to International Accreditation New Zealand*

Where samples have been supplied by the client, they are tested as received.
The results of analysis contained in this report relate only to the sample(s) tested. A dash indicates no test performed.

Reference Methods

The sample(s) referred to in this report were analysed by the following method(s)

Analyte	Method Reference	MDL	Samples	Location
Sample Parameters and Field Testing				
Conductivity	APHA (online edition) 2510 B	5 µS/cm	1, 2, 3, 4, 6	Queenstown
Dissolved Oxygen	APHA (online edition) 4500-O G	0.1 mg/L	1, 2, 3, 4, 6	Queenstown
pH	APHA (online edition) 4500-H B	0.1 pH unit	1, 2, 3, 4, 6	Queenstown

General Testing				
Ammoniacal Nitrogen (as N) by Colorimetry/Discrete Analyser	ISBN 0117516139 (modified)	0.010 mg/L	All	Invercargill
Carbonaceous Biochemical Oxygen Demand, CBOD5 (as O 2) by Electrode	APHA (online edition) 5210 B	2 mg/L	All	Invercargill
Nitrate Nitrogen (as N) by Colorimetry/Discrete Analyser	Nitrate-N Calculation: (Nitrate-N + Nitrite-N) - Nitrite-N	0.010 mg/L	All	Invercargill
Total Nitrogen (as N) by Persulphate Digestion and Colorimetry/Discrete Analyser	APHA (online edition) 4500-P J, 4500-NO3 H	0.010 mg/L	All	Invercargill
Total Phosphorus (as P) by Persulphate Digestion and Colorimetry/Discrete Analyser	APHA (online edition) 4500-P B, J (modified)	0.010 mg/L	All	Invercargill

The method detection limit (MDL) listed is the limit attainable in a relatively clean matrix. If dilutions are required for analysis the detection limit may be higher. For more information please contact the Operations Manager.

Samples, with suitable preservation and stability of analytes, will be held by the laboratory for a period of two weeks after results have been reported, unless otherwise advised by the submitter.

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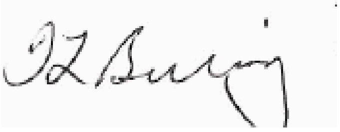

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Certificate of Analysis
Laboratory Reference:201118-078

Attention:	Terry Hughes	*Final Report:*	**390145-0**
Client:	**QUEENSTOWN LAKE DISTRICT COUNC**	*Report Issue Date:*	**04-Dec-2020**
Address:	**PO Box 50072, Queenstown, 9348**	*Received Date:*	**20-Nov-2020**
		Sampled By:	**CB & RML**
Client Reference:	**Kingston Bores**		
Purchase Order:	**P0037604**	*Quote Reference :*	**12485**

Sample Details		WATERS	WATERS	WATERS	WATERS
Lab Sample ID:		**201118-078-1**	**201118-078-2**	**201118-078-3**	**201118-078-4**
Client Sample ID:					
Sample Date/Time		18/11/2020	18/11/2020	18/11/2020	18/11/2020
Description:		GW 1	GW 2	GW 3a	GW3b
Sample Parameters and Field Testing					
Conductivity	µS/cm	140 *	66 *	150 *	440 *
Dissolved Oxygen	mg/L	10.9 *	9.4 *	3.5 *	0.8 *
pH	pH unit	5.9 *	6.0 *	6.5 *	7.4 *
General Testing					
Ammoniacal Nitrogen (as N)	mg/L	<0.01	<0.01	<0.01	<0.01
CBOD5 (as O2)	mg/L	<2.0	<2.0	<2.0	>7.2
Nitrate Nitrogen (as N)	mg/L	7.1	1.7	4.3	<0.01
Total Nitrogen (as N)	mg/L	6.9	1.9	4.3	0.63
Total Phosphorus (as P)	mg/L	0.13	0.12	0.47	0.35

Sample Details		WATERS	WATERS
Lab Sample ID:		**201118-078-5**	**201118-078-6**
Client Sample ID:			
Sample Date/Time		18/11/2020	18/11/2020
Description:		GW 5	GW 6
Sample Parameters and Field Testing			
Conductivity	µS/cm	190 *	110 *
Dissolved Oxygen	mg/L	10.0 *	8.9 *
pH	pH unit	6.8 *	6.6 *
General Testing			
Ammoniacal Nitrogen (as N)	mg/L	<0.01	0.05
CBOD5 (as O2)	mg/L	<2.0	<2.0
Nitrate Nitrogen (as N)	mg/L	3.4	0.25
Total Nitrogen (as N)	mg/L	3.1	0.61
Total Phosphorus (as P)	mg/L	<0.01	<0.01

*Results marked with * are not accredited to International Accreditation New Zealand*

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Reference Methods
The sample(s) referred to in this report were analysed by the following method(s)

Analyte	Method Reference	MDL	Samples	Location
Sample Parameters and Field Testing				
Conductivity	APHA (online edition) 2510 B	5 µS/cm	All	Queenstown
Dissolved Oxygen	APHA (online edition) 4500-O G	0.1 mg/L	All	Queenstown
pH	APHA (online edition) 4500-H B	0.1 pH unit	All	Queenstown
General Testing				
Ammoniacal Nitrogen (as N) by Colorimetry/Discrete Analyser	ISBN 0117516139 (modified)	0.010 mg/L	All	Invercargill

General Testing				
Carbonaceous Biochemical Oxygen Demand, CBOD5 (as O2) by Electrode	APHA (online edition) 5210 B	2 mg/L	All	Invercargill
Nitrate Nitrogen (as N) by Colorimetry/Discrete Analyser	Nitrate-N Calculation: (Nitrate-N + Nitrite-N) - Nitrite-N	0.010 mg/L	All	Invercargill
Total Nitrogen (as N) by Persulphate Digestion and Colorimetry/Discrete Analyser	APHA (online edition) 4500-P J, 4500-NO3 H	0.010 mg/L	All	Invercargill
Total Phosphorus (as P) by Persulphate Digestion and Colorimetry/Discrete Analyser	APHA (online edition) 4500-P B, J (modified)	0.010 mg/L	All	Invercargill

The method detection limit (MDL) listed is the limit attainable in a relatively clean matrix. If dilutions are required for analysis the detection limit may be higher. For more information please contact the Operations Manager.

Samples, with suitable preservation and stability of analytes, will be held by the laboratory for a period of two weeks after results have been reported, unless otherwise advised by the submitter.

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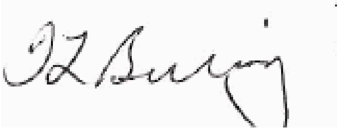

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Certificate of Analysis
Laboratory Reference:201209-001

Attention:	Terry Hughes	*Final Report:*	**393053-0**
Client:	**QUEENSTOWN LAKE DISTRICT COUNC**	*Report Issue Date:*	**29-Dec-2020**
Address:	**PO Box 50072, Queenstown, 9348**	*Received Date:*	**09-Dec-2020**
		Sampled By:	**RML & ES**
Client Reference:	**Kingston Bores**		
Purchase Order:	**P0037604**	*Quote Reference :*	**12485**

GW3b cBOD approx 3.7 mg/L

Sample Details		WATERS	WATERS	WATERS	WATERS
Lab Sample ID:		**201209-001-1**	**201209-001-2**	**201209-001-3**	**201209-001-4**
Client Sample ID:					
Sample Date/Time		09/12/2020	09/12/2020	09/12/2020	09/12/2020
Description:		GW 1	GW 2	GW 3a	GW3b
Micro Summary View					
Escherichia coli (Colilert-18)	MPN/100 mL	<1.0	1.0	<1.0	<1.0
Total Coliforms (Colilert-18)	MPN/100 mL	390	170	7.5	410
Sample Parameters and Field Testing					
Conductivity	µS/cm	140 *	66 *	140 *	280 *
Dissolved Oxygen	mg/L	10.4 *	8.8 *	9.8 *	1.0 *
pH	pH unit	5.7 *	5.7 *	6.5 *	6.9 *
General Testing					
Ammoniacal Nitrogen (as N)	mg/L	<0.01	<0.01	<0.01	<0.01
CBOD5 (as O2)	mg/L	<2.0	<2.0	<2.0	<6.0
Nitrate Nitrogen (as N)	mg/L	7.4	1.7	4.7	1.2
Total Nitrogen (as N)	mg/L	7.5	1.9	4.8	1.7
Total Phosphorus (as P)	mg/L	0.06	0.05	0.34	3.3

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Reference Methods
The sample(s) referred to in this report were analysed by the following method(s)

Analyte	**Method Reference**	**MDL**	**Samples**	**Location**
Micro Summary View				
Escherichia coli (Colilert-18)	APHA (online edition) 9223 B Colilert Quantitray	1 MPN/100 mL	All	Queenstown
Total Coliforms (Colilert-18)	APHA (online edition) 9223 B Colilert Quantitray	1 MPN/100 mL	All	Queenstown
Sample Parameters and Field Testing				
Conductivity	APHA (online edition) 2510 B	5 µS/cm	All	Queenstown
Dissolved Oxygen	APHA (online edition) 4500-O G	0.1 mg/L	All	Queenstown
pH	APHA (online edition) 4500-H B	0.1 pH unit	All	Queenstown
General Testing				
Ammoniacal Nitrogen (as N) by Colorimetry/Discrete Analyser	ISBN 0117516139 (modified)	0.010 mg/L	All	Invercargill
Carbonaceous Biochemical Oxygen Demand, CBOD5 (as O 2) by Electrode	APHA (online edition) 5210 B	2 mg/L	All	Invercargill
Nitrate Nitrogen (as N) by Colorimetry/Discrete Analyser	Nitrate-N Calculation: (Nitrate-N + Nitrite-N) - Nitrite-N	0.010 mg/L	All	Invercargill
Total Nitrogen (as N) by Persulphate Digestion and Colorimetry/Discrete Analyser	APHA (online edition) 4500-P J, 4500-NO3 H	0.010 mg/L	All	Invercargill

General Testing				
Total Phosphorus (as P) by Persulphate Digestion and Colorimetry/Discrete Analyser	APHA (online edition) 4500-P B, J (modified)	0.010 mg/L	All	Invercargill

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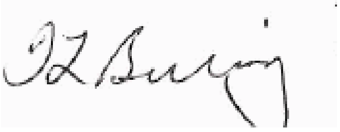

Tonia Bulling
KTP Signatory

Attachment 5: LEI Soil Reporting for LTA 1

LOWE Environmental Impact

MEMORANDUM **Job 10639**

To: Tim Court-Patience

From: Lowe Environmental Impact

Date: 6th August 2020

Subject: Further LTA Fieldwork Investigations

PURPOSE

The purpose of this memo is to provide a summary of recent fieldwork investigations carried out by Lowe Environment Impact at Kingston Station in June 2020, at the site of a proposed wastewater land treatment area.

BACKGROUND

QLDC has identified Kingston as an area that can be used to develop critical housing infrastructure for the growing Queenstown Lakes District. The majority of existing dwellings within Kingston source water individually via roof catchments and shallow bores, while wastewater is managed via individual septic tank and on-site disposal systems.

A development agreement has now been established between QLDC and a developer (Kingston Village Ltd, KVL) with the ultimate goal of providing 750 new residential dwellings in Kingston. QLDC is to deliver a communal wastewater and potable water scheme that supports housing within the new development (~750 dwellings); whilst also allowing for the future connection of new (~200) and existing (~225) houses within the Kingston Township (~1,175 dwellings in total).

Lowe Environment Impact has been asked to prepare the resource consent application for the disposal to land of any wastewater and sewage from the proposed WWTP. The wastewater is proposed to be discharged on nearby Kingston Station.

Recently, the proposed Land Treatment Areas (LTA) have changed and QLDC would like to confirm that the soils on new LTA areas are similar to soils in the investigation areas that have previously been carried out on Kingston Station.

THE INVESTIGATION

Four test sites on the new proposed additional land treatment area were investigated, as shown in Figure 1. At each of the four sites:

- A test pit was dug using an excavator to determine subsoil depths and physical properties. Soil logs similar to those previously produced in other areas on the farm were created.
- The GPS location of each test pit was taken, and the soil profile and surrounding landscape photographed.
- Saturated and Unsaturated hydraulic conductivity testing was carried out at each site at a 150-200mm depth. Soil hydraulic conductivity measurements were performed using double ring

infiltrometers (K_{sat}) and the plate permeameter (K_{-40mm}) method of Perroux and White (1998). Three or four replicate tests were carried out for each K measurement at each site (e.g. 4 x K_{sat} & 3 x K_{-40mm} tests).

- Soil cores were taken at each site for laboratory determination of:
    - Water holding capacity
    - Bulk density
    - Saturated and Unsaturated hydraulic conductivity.

Soil cores were taken from the topsoil at a depth of 0 – 100mm and from the subsoil at a depth of 150mm to 200mm at a similar depth to the hydraulic conductivity tests.

Figure 1: Location of Test Pits on Additional LTA Area.

RESULTS

Soil Properties

The soil across all four sites tested were similar, being pallic orthic brown, shallow silty loams. The soils across the site generally comprised of 100 mm - 300 mm depth of organic/silt loam topsoil, overlying a silt loam with varying amounts of sand and gravel. Please see Appendix for the soil log records and photos of the soil profiles.

Groundwater was not encountered in any of the test pits during the investigation.

Saturated Hydraulic Conductivity Results

In-field Results:

Site No.	Average (mm/h)
Site 1	94.3 ± 16.86
Site 2	117 ± 5.20
Site 3	133.3 ± 50.36
Site 4	103.6 ± 28.29
Average	**112.08** ± 16.94

The average saturated hydraulic conductivity across all four sites was **112.1** ± 16.94 mm/h or 2690.4 mm per day.

Laboratory Results:

Sample name	K_{sat} (mm/h)
Kingston Site 1 Topsoil	185
Kingston Site 1 Subsoil	127
Kingston Site 2 Topsoil	289
Kingston Site 2 Subsoil	624
Kingston Site 3 Topsoil	578
Kingston Site 3 Subsoil	150
Kingston Site 4 Topsoil	70
Kingston Site 4 Subsoil	72

The average saturated hydraulic conductivity from the laboratory results for the topsoil is **280.5** ± 217.56 mm/hr and for the subsoil it is **243.25 ±** 255.93 mm/hr.

Unsaturated Hydraulic Conductivity Results

In-field Results:

Site No.	Unsaturated (K-40mm) (mm/hr)
Site 1	3.99 ± 0
Site 2	3.43 ± 0.79
Site 3	2.54 ± 1.02
Site 4	3.41 ± 1.66
Average	**3.34** ± 0.6

The average unsaturated hydraulic conductivity across all four sites was 3.34 mm/hr or 80.16 mm/day.

Laboratory Results:

Sample name	K_{-40} (mm/h)
Kingston Site 1 Topsoil	8
Kingston Site 1 Subsoil	29
Kingston Site 2 Topsoil	9
Kingston Site 2 Subsoil	12
Kingston Site 3 Topsoil	10
Kingston Site 3 Subsoil	27
Kingston Site 4 Topsoil	12
Kingston Site 4 Subsoil	7

The average unsaturated hydraulic conductivity from the laboratory for the topsoil is **9.75** ± 1.7 mm/hr and for the subsoil it is **18.75** ± 10.9 mm/hr

Available Water Capacity and Bulk Density Results

Sample name	Particle density (g/cm^3)	Dry bulk density (g/cm^3)	Porosity (%)	Macro-porosity (-10 kPa) (%)	Field capacity (%)	AWC (%)
Kingston Site 1 Topsoil	2.65	1.23	54	16	37	23
Kingston Site 1 Subsoil	2.71	1.45	46	17	29	15
Kingston Site 2 Topsoil	2.62	1.15	56	13	43	27
Kingston Site 2 Subsoil	2.71	1.47	46	14	32	15
Kingston Site 3 Topsoil	2.59	1.09	58	19	39	20
Kingston Site 3 Subsoil	2.73	1.30	52	15	37	15
Kingston Site 4 Topsoil	2.64	1.21	54	13	41	25
Kingston Site 4 Subsoil	2.73	1.52	44	11	34	18

Gravimetric Water Content Results

Sample name	Grav. water content @ -10 kPa (%w/w)	Grav. water content @ -1500 kPa (%w/w)	Vol. water content @ -10 kPa (%w/w)	Vol. water content @ -1500 kPa (%w/w)
Kingston Site 1 Topsoil	30	12	37	14
Kingston Site 1 Subsoil	20	10	29	14
Kingston Site 2 Topsoil	37	14	43	16
Kingston Site 2 Subsoil	22	11	32	17
Kingston Site 3 Topsoil	36	17	39	19
Kingston Site 3 Subsoil	29	17	37	22
Kingston Site 4 Topsoil	34	14	41	16
Kingston Site 4 Subsoil	22	11	34	16

COMPARISON TO PREVIOUS RESULTS

Lowe Environmental Impact and Hadley Consulting had previously carried out sampling at Kingston LTA, in areas nearby the new proposed additional LTA area. It was found that the new LTA area had similar soils overall to those in the areas previously tested by LEI and Hadley Consultants.

Saturated and unsaturated hydraulic conductivity previously tested at the site by LEI in 2018 were slightly lower than the results found during the most recent testing. The results of the previous testing are shown below.

Table 2.5: Field and Laboratory Measurement Hydraulic Conductivity Results (LEI AEE 2020)

Location	Saturated (K_{sat}) (mm/hr)	Unsaturated (K_{-40mm}) Field test (mm/hr)	Unsaturated (K_{-40mm}) LandCare (mm/hr)
Site 1	60	3.82	12
Site 2	156	2.96	50
Site 3	90		19
Site 4	45	4.52	27
Site 5	25.5	1.10	10
Site 6	122.5	1.78	7
Average	**83.17**	**2.83**	**20.13**

The test results for the new LTA area are generally higher than this at 112.1 mm/hr (field) and 243.25 mm/hr (lab - subsoil) for saturated hydraulic conductivity and 3.34 mm/hr (field) and 18.75 mm/hr (lab- subsoil) for unsaturated hydraulic conductivity.

This means that the design discharge rates identified for the original LTA area are also applicable for this new additional LTA area and will be conservative for this area.

The Design Discharge Rates (DDR) that were previously identified for the site are based on the following methodologies.

Crites and Tchobanoglous (1998) recommend a value of 10% - 30% of the K_{sat} to provide a DDR; LEI has adopted the more conservative of 10% of K_{sat} or 30% of K_{-40mm} as a design standard.

Determination of the DDR for the original LTA area is presented in the table below:

Table.1

Table.1 Previous Design Discharge Rate

Location	**Saturated (K_{sat})**	**Unsaturated (K_{-40mm})**
Field Measurement (mm/day)	2690.4	80
Adjustment (%)	10	30
DDR (mm/day)	260	24.04
Recommended DDR (mm/day)	**Maximum of 24**	

The difference between K_{sat} and K_{-40mm} indicate that saturated flow is substantially higher than unsaturated flow. This is an important consideration when designing a discharge rate where macro pore drainage is to be minimised and full matrix flow through the soil is encouraged. The DDR should be based on K_{-40mm} rather than K_{sat} to avoid excessive drainage occurring and to maximise contact with the soil. Therefore, LEI recommends the conservative maximum discharge rate of an average of 24 mm/day; this is considered suitable for long term application on the original and addition LTA area with regard to absorbance, infiltration and adsorption.

LOWE Environmental Impact

Project Number: 10639
Site: Kingston Station
Date: 15th June 2020

Test Pit: **NO 1**
Location: See Site Plan
Weather Conditions: Windy, Cloudy, Overcast

Depth B.G.L	Soil Symbol	Soil Description	Notes
0 cm - 15 cm		Brown organic matter topsoil, damp, granular crumb structure, silty loam, minor presence of gravels, no mottling present. Indistinct boundary	
15cm - 35cm		Orange brown silty loam, with minor sand and some gravels, granular, crumb structure, minor presence of gravels, no mottling present, compact, slightly damp Indistinct boundary	
35cm - 1.5m		Silt with minor fine sand, gravels and rock fragments, compact, dry, grey	

LOWE Environmental Impact	Project Number: 10639 Site: Kingston Station Date: 15th June 2020

Test Pit: **NO 2**
Location: See Site Plan
Weather Conditions: Light Breeze

Depth B.G.L	Soil Symbol	Soil Description	Notes
0 cm – 35 cm		Brown topsoil, damp, granular crumb structure, silty loam, , minor presence of gravels, no mottling present. Indistinct boundary – 27-35cm	difficult to form ball
35 cm – 70 cm		Orange brown silty loam, damp, granular, crumb structure, minor presence of gravels, no mottling present Indistinct boundary between 65-75cm	can form a ball, however this is difficult
70cm – 85cm		damp, granular crumb structure, flakey, no mottling present, creamy brown/white colour, minor present of stones indistinct boundary 80- 85cm	will not form a ball kind of feels a bit like powder,
85cm – 1.5m		Silty clay loam, damp, crumb, granular no mottling, no gravels or stones	difficult to form a ball will smear when foot run down it does not feel like powder, unlike above layer

LOWE Environmental Impact	Project Number: 10639 Site: Kingston Station Date: 16th June 2020

Test Pit: **NO 3**
Location: See Site Plan
Weather Conditions: Windy, Cloudy, Overcast

Depth B.G.L	Soil Symbol	Soil Description	Notes
0- 20 cm		Brown topsoil silty loam, damp, granular, crumb, no mottles, strong presence of gravels, small to large 40-50% Indistrinct boundary between 20-25cm to next horizon	Cannot form into a ball
20-45cm		Orange brown silt loam, presence of stones (all sizes, small to large – 30-50%), damp, no mottling indistinct boundary between 38-45cm	has more clay feel compared to above layer difficult to form ball (easier than above layer however)
45-70cm		Grey clay silt layer, presence of stones, although less than above layers. Still presence of large sized stones – 10-20%, damp, no mottling Indistinct boundary from 70-80cm	can fairly easily form a ball smears
70cm – 1.5m		Creamy brown/white colour clay/sand, powdery texture, damp, very minor presence of stones <1%, no mottles	Difficult to form ball , More lighter coloured compared to the above layers Does have feel of sand as well as clay - Smears when rubbed with boot

LOWE Environmental Impact

Project Number: 10639
Site: Kingston Station
Date: 16th June 2020

Test Pit: **NO 4**
Location: See Site Plan
Weather Conditions: Windy, Cloudy, Overcast

Depth B.G.L	Soil Symbol	Soil Description	Notes
0-30cm		Brown topsoil silty loam with some sands, damp, granular, crumb, no mottles, presence of fine roots Indistinct boundary	
30cm - 85cm		Orange brown silt with minor sands, compact, presence of small gravels, damp Indistinct boundary	Perched lines where water sits
85cm – 1.5m		Grey silt clay with minor fine cand, compact, dry, gravel (assorted sizes), no roots	Flat oranges streaks through subsoil at 85cm -95cm depth

SOIL PROFILE IMAGES

Site 1

Site 2

Site 3

Site 4