Before Independent Hearing Commissioners appointed by Environment Southland

In the matter of	Application APP-20181129 by Southland District Council for resource consent to discharge treated wastewater to land and water, and to use land for construction of an effluent storage facility, for the Tokanui township sewage treatment system at 118 McEwan Street, Tokanui

Evidence of Brydon Nicholas Hughes

30 April 2019

Applicant's solicitor:

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Qualifications and experience

1 My name is Brydon Hughes. I am currently a director of LWP Ltd, an environmental and natural resources management consultancy based in Christchurch.

2 I am a Hydrogeologist with 24 years professional experience working in local government and private consultancy in New Zealand. I hold qualifications of Bachelor of Science (Geology) and a Master of Science in Engineering Geology (1st Class) from the University of Canterbury.

3 My areas of expertise include hydrogeological and groundwater quality investigations including aquifer testing, water supply evaluation, groundwater resource definition and assessment of land use impacts on water quality. I have significant experience in the technical assessment of resource consent applications to abstract groundwater and discharge wastewater to land.

4 I am familiar with the hydrogeological setting of the Southland Region having been involved with groundwater investigations, monitoring and management for Environment Southland since 1999. This involvement establishing regional groundwater investigation and monitoring programmes as well as input into the drafting of groundwater management provisions in the Regional Water Plan for Southland (RWPS) and Proposed Southland Water and Land Plan (pSWLP).

5 I was commissioned by Stantec on behalf of the Southland District Council to provide evidence related to the hydrogeological setting and potential effects on groundwater quality associated with the proposed discharge of wastewater from the Tokanui Waste Water Treatment Plant (WWTP).

6 I have read the Code of Conduct for Expert Witnesses in the Environment Court Practice Note 2014. This evidence has been prepared in accordance with it and I agree to comply with it. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

Scope of evidence

7 My evidence includes:

(a) A brief description of the proposed activity;

(b) A summary of the general geological and hydrogeological setting of the Tokanui WWTP;

(c) Description and analysis of hydrogeological investigations undertaken on the WWTP site in early 2019;

(d) Analysis of results from water quality investigations undertaken on the wider WWTP site; and

(e) Assessment of the potential effects of the proposed discharge on the quality of receiving waters.

Executive summary

8 Physical investigations on the Tokonui WWTP site show the subsurface geology comprises a thin layer of clayey/silty alluvium overlying greywacke basement. The alluvium hosts a low permeability unconfined aquifer that is hydraulically connected to the Tokanui River. Piezometric survey results indicate groundwater flow in a north to south direction across the wider WWTP site.

9 Seepage from the ponds results in a slight mounding of the water table in the underlying unconfined aquifer. This mounding is sufficient to result in local variation in groundwater flow meaning groundwater underlying the ponds will flow in a south-easterly direction reaching the Tokanui River a short distance downstream of the oxidation ponds.

10 Sampling of groundwater quality indicates significant attenuation of nutrients and microbial contaminants within a short distance of the oxidation ponds. Observed groundwater quality down-gradient of the ponds contains lower concentrations of contaminants than both groundwater up-gradient of the ponds and the Tokanui River upstream of the WWTP site. These results indicate seepage from the ponds is likely to result in minor effects on down-gradient groundwater quality and less than minor effects on water quality in the Tokonui River.

Proposed Activity

11 Southland District Council have applied for resource consents to enable continued operation of the Tokanui WWTP. The wastewater treatment system currently comprises two oxidation ponds, a larger facultative pond and a smaller maturation pond connected in series. Discharge of treated wastewater currently occurs via seepage through the base of the ponds and, at times, a direct discharge from the maturation pond to the Tokanui River.

12 It is proposed to construct an infiltration trench between the pond outlet and Tokanui River to provide further treatment of the effluent and reduce the volume of direct discharge to the river. It is expected that during the summer months, a large proportion of the effluent will evaporate or discharge to land (via pond seepage or the infiltration trench) so that there will be limited discharge to the Tokanui River. During winter, when inflows are higher and infiltration rates reduce, it is expected that a greater proportion of the total wastewater flow of up to 55 m^3/day will be discharged directly to the river after passage through the infiltration trench.

Geological and Hydrogeological Setting

13 The WWTP site is located approximately 300 metres west of Tokanui township.

14 Subsurface geology in the Tokanui area generally comprises a thin layer of locally-derived colluvial materials (clay, silt and gravel) overlain by loess deposits up to 2 to 3 metres thick in places. The thickness of the colluvial materials varies with position in the landscape from 1 to 2 metres on higher elevation and sloping areas, to over 10 metres within river valleys. The colluvial materials overlie greywacke bedrock of the Murihiku Terrane which typically comprises moderately well to well indurated sandstone and mudstone. The greywacke deposits are often moderately to extensively fractured and may be highly weathered along their upper surface.

15 Figure 1 illustrates the typical subsurface geology in the vicinity of the WWTP. The photograph shows a test pit excavated on the east site of the Tokanui River adjacent to the WWTP with a sequence of silt and clay approximately 2.5 metres thick overlying water-bearing silty gravel.

16 Available hydrogeological information indicates the presence of a thin, low permeability unconfined aquifer hosted in the colluvial materials that mantle the underlying greywacke bedrock throughout the Catlins area. This aquifer system is recharged by local rainfall and is assumed to be hydraulically connected to rivers and streams at lower elevations in the landscape. Due to its limited saturated thickness and generally low permeability, little use is made of this groundwater resource for stock or domestic water supply.

17 The primary groundwater resource of the Catlins area consists of a spatially extensive, low permeability fractured rock aquifer system hosted in the greywacke basement rocks. This groundwater resource is utilised for stock, dairy and household water supply.

18 Pearson and Rissmann (2019) undertook an assessment of the physiographic setting of the Tokanui WWTP. This assessment evaluated the potential influence of hydrological pathways and redox potential on water quality risks in the vicinity of the WWTP. Results of the assessment identified deep drainage as the main drainage pathway on areas of well drained Tokanui soils in the vicinity of the oxidation ponds, with slightly elevated artificial drainage and surface runoff potential on imperfectly drained Niagara soils along the margins of the Tokanui River.

19 Overall, the physiographic assessment identified areas overlain by Tokanui soils as having an elevated potential for Nitrogen loss, with low to moderate potential for removal of Nitrogen via denitrification in the underlying unconfined aquifer. The potential for losses of particulate Phosphorus were assessed as low due to

limited surface runoff potential and losses of dissolved reactive phosphorus via groundwater was also assessed as low due to the generally oxidising state of the unconfined aquifer.

Hydrogeological Investigations at the Tokanui WWTP site

20 Six piezometers were constructed in March 2019 to enable monitoring of groundwater levels and groundwater quality across the wider WWTP site, at the locations shown on Figure 2. The piezometers were generally installed to a target depth of 10 metres and screened across the entire thickness of saturated alluvium encountered.

21 Geological logs provided in **Appendix A** show subsurface geology across the site is characterised by poorly sorted sand and gravel deposits in an extensive silt or clay-rich matrix. The dominant lithologies recorded include clayey fine to medium gravel, gravelly clay with some sand and gravelly silt with some clay and sand. Greywacke basement was intercepted at a depth of 7.9 metres below ground in BH6, located on higher ground approximately 90 metres north-west of the oxidation ponds.

22 Falling head tests were undertaken in several of the piezometers to provide an estimate of the permeability of the unconfined aquifer. Due to limitations of the test method and instrumentation, data suitable for analysis of aquifer hydraulic properties was only able to be collected from BH1 and BH2. As outlined in **Appendix B**, analysis of test results from these piezometers indicates an aquifer hydraulic conductivity of the order of 15 m/day. A hydraulic conductivity of this order is consistent with literature values for silty sand and gravel (e.g., Freeze and Cherry (1979), Fetter (1994)).

23 Drilling records from piezometers installed on the WWTP site indicate the saturated thickness of the unconfined aquifer varies from less than 2 metres on higher elevation land to the west of the oxidation ponds (BH6) to over 8.5 metres adjacent to the Tokanui River (BH4, BH5). It is anticipated that the saturated thickness of the unconfined aquifer may be of the order of 15 metres in the vicinity of the WWTP.

24 Static groundwater levels were recorded in the six monitoring bores on the 28th March 2019. Stream stage was also measured at 4 locations in the Tokanui Stream and levels recorded in both oxidation ponds at the same time. Relative groundwater levels estimated at the various monitoring points are listed in Table 1.

25 Groundwater level and stream stage measurements recorded on 28th March 2019 were interpolated by kriging to generate the piezometric contour map shown in Figure 3. The figure shows groundwater flow across the Tokanui WWTP site in a

southerly direction from higher ground to the north toward the Tokanui River in the south. Results of the survey also indicate:

- At the time of the survey, water levels in the oxidation ponds were at approximately 35.78 m asl, while static water levels in adjacent piezometers (MB2 and MB3) were recorded as 33.45 and 33.34 m asl respectively. This indicates a head difference of approximately 2.3 m between the ponds and underlying unconfined aquifer. This difference is likely to reflect the low permeability of the pond lining materials and low rates of seepage into groundwater. As groundwater levels were likely near their seasonal low at the time of the survey, the head difference and rate of seepage are likely to have been near maximum;
- Stream stage appears to be coincident with adjacent groundwater levels, suggesting a moderate to high degree of hydraulic connection between the stream and unconfined aquifer. While some localised reversal of the hydraulic gradient may occur during high stage events, the overall piezometric gradient indicates that groundwater is likely to discharge to the Tokonui River across a majority of the reach adjacent to the Tokanui WWTP;
- The hydraulic gradient in the unconfined aquifer is greatest beneath higher ground north of the oxidations ponds (approximately 0.007 m/m), reducing to around 0.003 m/m on the lower-lying Tokanui River floodplain south of the ponds;
- Mounding of the water table in the order of 0.1 to 0.2 metres is indicated adjacent to the oxidation ponds. This mounding likely reflects dispersal of seepage from the ponds (of the order of 0.1 L/s) in the underlying silty gravel sediments and unconfined aquifer. This mounding results in a localised variation in groundwater flow from the oxidation ponds, largely towards the Tokanui River, with a steeper hydraulic gradient of up to 0.015 m/m;
- Assuming the aquifer permeability of 15 m/day indicated by falling head tests, application of Darcy's Law (assuming an effective porosity of 20 percent) indicates the following groundwater flow velocities in the vicinity of the Tokanui WWTP:
  - North of oxidation ponds - 0.52 m/day
  - South of oxidation ponds - 0.23 m/day
  - Between the oxidation ponds and Tokanui Stream - 1.13 m/day
- The hydraulic gradient resulting from mounding in the vicinity of the oxidation ponds shows groundwater flow in a south-easterly direction

down-gradient of the ponds toward the Tokanui River. This flow direction means a majority of wastewater infiltrating through the base of the ponds or from the proposed infiltration trench will reach the Tokanui River upstream of the surface water quality monitoring site located 150 metres downstream from of the ponds.

26 As previously noted, piezometric contours indicate groundwater flow in a general north to south direction across the Tokanui WWTP site. The oxidation ponds occupy a profile of approximately 60 metres perpendicular to the interpolated groundwater flow direction. Based on the estimated hydraulic gradient north of the ponds (0.007 m/m) and estimated aquifer hydraulic conductivity (15 m/day), application of Darcy's Law indicates throughflow of 63 m^3/day in the unconfined aquifer under the full width of the ponds (assuming a conservative saturated aquifer thickness of 10 metres).

27 As described in evidence by Mr Hoffman, a drop test conducted in September 2017 indicated seepage losses of approximately 10 m^3/day through the base of the ponds into the underlying unconfined aquifer. Assuming full mixing, the estimated aquifer throughflow volume indicates that pond seepage may potentially undergo a 6-fold dilution in the unconfined aquifer between the ponds and the Tokanui River. Assuming no other attenuation within the aquifer, this dilution would be sufficient to reduce concentration of contaminants in wastewater to less than 20% of those in the oxidation ponds (depending on background concentrations of individual parameters in groundwater up-gradient of the ponds).

Water quality investigations at the Tokanui WWTP site

28 Water quality samples were collected from the Tokanui WWTP site on 28 March 2019. Samples were collected from:

- The facultative pond (sample site near the north corner);
- The outlet from the maturation pond;
- The six recently installed monitoring bores (BH1 to BH6); and
- Three sampling sites in the Tokanui River (upstream of the discharge, 50 m downstream and 150 m downstream).

29 Figure 4 shows a plot of rainfall and river flow at the Environment Southland Waikawa River at Biggar Road monitoring site over the week preceding sample collection. This monitoring site is the closest automatic recorder to the Tokanui WWTP site and data is considered to be broadly representative of those in the Tokanui area. The data show flows were in stable low flow recession prior to the 26 March. Rainfall of 9.5 mm on 26th March and 6mm on 27th March resulted in a minor increase in flows. At the time of sampling, flows had returned to stable

recession, approximately 10% higher than those prior to the 26th March rainfall event.

30 The March sample date also coincides with the late summer period when groundwater levels are generally close to seasonal lows across much of Southland. Given the seasonality of discharge from the ponds to the Tokanui River (pond seepage is likely to be greatest in summer when groundwater levels are low and lowest in winter when groundwater levels are high), sample collection in late March is inferred to coincide with the period of greatest effect of pond seepage on groundwater.

31 Sample results from the 28 March 2019 investigation are summarised in Table 2. For context, Table 3 summarises historical surface water quality sample results from the Tokanui River (Stantec, 2019). The following section provides an assessment of the observed spatial distribution of individual water quality parameters along with interpretation of sample results in the context of potential effects on surface water and groundwater quality.

Chloride

32 Chloride has broad utility in groundwater quality investigations as it is a conservative ion that is not greatly impacted by geochemical processes in the subsurface environment (at least in the context of the relatively inert geological media in the Southland Region). The main natural Chloride inputs to groundwater are associated with rainout of marine aerosols in local rainfall and river recharge. However, many wastewater discharges contain elevated Chloride concentrations which have the potential to result in a corresponding increase in concentrations in down-gradient receiving environments, making Chloride a useful tracer of contaminant inputs to groundwater.

33 As illustrated in Figure 5, sample results indicate background Chloride concentrations in the Tokanui River, BH1 and BH5 of between 25 to 30 mg/L. Concentrations of this order are typical for groundwater in southern Southland, reflecting rainout of marine aerosols in a coastal environment (Rissmann *et al*., 2016).

34 Chloride concentrations in the oxidation ponds of 42 mg/L are assumed to reflect those in influent wastewater (potentially modified by rainfall/evaporation in the ponds). Similar concentrations of between 41 and 43 mg/L were observed in BH2 and BH3 reflecting the influence of pond seepage on groundwater immediately adjacent to the ponds. Elevated Choride concentrations (36 mg/L) in BH4 and the Tokanui River sampling point 50 m downstream are interpreted to reflect the passage of wastewater in a south-easterly direction from the oxidation ponds to the Tokanui River (i.e., consistent with the groundwater flow direction indicated by the piezometric contours shown on Figure 3).

35 Upstream and downstream Chloride concentrations in the Tokanui River were equivalent indicating any localised effect of wastewater discharge is not detectable below a localised zone of mixing. Historical surface water quality sampling results outlined in Table 2 similarly show upstream and downstream Chloride concentrations are equivalent in samples collected by SDC between August 2017 and January 2018.

Total Nitrogen

36 Figure 6 shows the spatial distribution of Total Nitrogen (TN) concentrations from the 28 March 2019 samples. Background groundwater concentrations of 1.3 mg/L in BH5 and 1.7 mg/L in BH6 are similar to those observed at the upstream Tokanui River site. The elevated TN concentration recorded in BH1 (8.9 mg/L) up-gradient of the WWTP site is inferred to reflect localised effects of agricultural land use.

37 As expected, samples from the oxidation ponds contain elevated TN concentrations of between 20 and 34 mg/L. Concentrations reduce markedly in monitoring bores adjacent to the oxidation ponds (0.7 mg/L BH2, 0.39 mg/L BH3 and 0.23 mg/L in BH4) indicating significant attenuation of N in wastewater seepage in close proximity to the ponds. Observed groundwater concentrations down-gradient of the oxidation ponds are also appreciably lower than those observed in the Tokanui River.

38 TN concentrations in the Tokanui River increase from 1.2 mg/L upstream of the discharge to 1.9 mg/L 50 m downstream and 1.7 mg/L 150 m downstream. Given the low TN concentrations in influent groundwater, the observed variations are inferred as unlikely to reflect the WWTP discharge to groundwater.

Nitrate-Nitrogen

39 Background Nitrate-Nitrogen concentrations in groundwater (BH5 and BH6) are relatively low (0.8 and 1.1 mg/L respectively), compared to the elevated concentration observed in BH1 (8.9 mg/l). As with TN, the elevated nitrate concentration in BH1 is interpreted to reflect localised effects of agricultural land use up-gradient of the WWTP discharge.

40 Nitrate-Nitrogen concentrations in the oxidation ponds (between 0.1 and 0.19 mg/L) and adjacent monitoring bores (0.007 to 0.13 mg/L) are appreciably lower than those observed in the Tokanui River (0.74 to 0.78 mg/L) indicating that groundwater discharge from the oxidation ponds is unlikely to add to cumulative Dissolved Inorganic Nitrogen (DIN) concentrations in the Tokanui River.

Ammoniacal Nitrogen

41 Concentrations of Ammoniacal Nitrogen are significantly elevated in the oxidation ponds (21 and 8.5 mg/L respectively). With the exception of BH2, Ammoniacal Nitrogen concentrations in groundwater range between <0.01 and 0.04 mg/L indicating oxic conditions and/or appreciable nitrification in the unconfined aquifer. Slightly elevated concentrations observed in BH2 (0.54 mg/L) may reflect incomplete nitrification of pond seepage at this location.

42 Concentrations of ammoniacal nitrogen in the Tokanui River varied from 0.04 mg/L at the upstream and 50 m downstream monitoring sites, to 0.06 mg/L at the 150 m downstream site. Historical surface water quality data listed in Table 2 indicate that ammoniacal nitrogen concentrations generally exhibit either no change, or decrease slightly, downstream of the WWTP discharge.

Dissolved Reactive Phosphorus

43 Dissolved Reactive Phosphorus (DRP) concentrations in the oxidation ponds were 3.0 mg/L at both sample points.

44 As illustrated on Figure ***7***7, DRP concentrations in groundwater ranged from 0.006 mg/L in BH3 to a maximum of 0.05 mg/L in BH1 and BH5. Lowest DRP were observed in BH2 and BH3 indicating significant attenuation of DRP immediately adjacent to the oxidation ponds.

45 DRP concentrations in the Tokanui River on 28 March 2019 ranged from 0.021 mg/L upstream to 0.029 mg/L 150 m downstream of the discharge point. As outlined Table 2, historical monitoring of surface water quality in the Tokanui River indicates DRP concentrations are either consistent or exhibit a slight decrease downstream of the WWTP site. This is consistent with the limited mobility of DRP in oxidized groundwaters.

E.coli

46 Sample results show elevated *E.coli* concentrations in the facultative pond (30,000 MPN/100 mL), with lower concentrations at the outlet from the maturation pond (3,900 MPN/100 mL), possibly reflecting natural die-off and disinfection within the oxidation ponds.

47 *E.coli* concentrations in groundwater were generally less than the method detection limit (<10 MPN/100 mL) except for BH4 and BH6. Both these bores exhibit concentrations between 40 to 50 MPN/100 mL (it is noted that positive detection of indicator bacteria in BH6 may reflect sample contamination associated with the nearby application of farm dairy effluent (Bevan McKenzie, SDC, *pers comm*.))

48 Elevated *E.coli* concentrations ranging between 2,200 and 3,100 MPN/100 mL were observed in the Tokanui River in the March 2019 samples. These results are consistent with historical surface water sampling data outlined in Table 2 that indicate median *E.coli* concentrations in the Tokanui River of around 1,300 cfu/100 mL) over the period 2005 to 2017, and between 3,100 and 3,900 cfu/100 mL in the August 2017 to January 2018 SDC samples (Stantec, 2019).

49 Overall, *E.coli* results indicate significant attenuation of microbial contaminants in the unconfined aquifer, with concentrations below detection in monitoring bores immediately adjacent to the oxidation ponds (BH2 and BH3), and significantly reduced concentrations in BH4 located between the oxidation ponds and Tokanui River. This attenuation is inferred to reflect natural die-off and physical attenuation (filtration and adsorption) in the fine-grained aquifer matrix. Observed concentrations of indicator bacteria in groundwater down-gradient of the ponds were in excess of two orders of magnitude lower than upstream concentrations in the Tokanui River.

Effects of Wastewater Discharge on Water Quality

50 Piezometric contours indicate a slight mounding of the water table around the oxidation ponds in response to ongoing seepage from the ponds to the underlying unconfined aquifer. Interpolation of relative groundwater levels measured on 28 March 2019 indicate groundwater flow from the ponds in a south-easterly direction toward the Tokanui River. Chloride concentrations observed in the unconfined aquifer are consistent with the interpreted groundwater flow direction, and indicate that a majority of seepage from the ponds is likely to reach the Tokanui River a short distance downstream from the oxidation ponds.

51 While wastewater contained in the oxidation ponds exhibits elevated concentrations of nutrients and microbial contaminants, groundwater quality adjacent to the oxidations ponds is relatively high and overall better than that observed in up-gradient of the ponds at BH1. Concentrations of both nutrients and indicator bacteria exhibit a significant reduction, even in monitoring bores located immediately adjacent to the oxidation ponds. Concentrations of both nutrients (N and P) and indicator bacteria in groundwater down-gradient of the ponds are also appreciably lower than those recorded in the Tokanui River upstream of the discharge. These observations indicate significant contaminant attenuation in the underlying unconfined aquifer.

52 Nitrification and denitrification are bacterially mediated processes that convert nitrogen from the ammonia form (predominant in wastewater) to nitrate (in oxidized groundwaters) and ultimately nitrogen gas (in reduced groundwaters). Groundwater quality sample results indicate a reduction in TN from between 23 to 34 mg/L in the oxidation ponds to less than 0.7 mg/L in down-gradient

groundwater. This concentration is significantly lower than those recorded in piezometers removed from the oxidation ponds (BH1, BH5 and BH6) and the Tokanui River upstream of the discharge. Similarly, ammoniacal nitrogen and nitrate-nitrogen concentrations in groundwater down-gradient of the oxidation ponds are appreciably lower than background groundwater concentrations and in the Tokanui River upstream of the discharge.

53 The significant attenuation of nitrogen in pond seepage is consistent with observed variations in Total Alkalinity down-gradient of the oxidation ponds. Nitrification reactions consume alkalinity, while alkalinity increases in response to denitrification. While background concentrations in groundwater and the Tokanui River range between 30 and 40 mg/L, concentrations recorded in down-gradient piezometers range from 22 mg/L in BH3 to 130 mg/L in BH2. The wide variance in Total Alkalinity down-gradient of the ponds is interpreted to reflect nitrification and denitrification processes (which can occur simultaneously) in the unconfined aquifer between the ponds and the Tokanui River.

54 The greater extent of denitrification occurring down-gradient of the oxidation ponds compared to that occurring more generally in the unconfined aquifer is interpreted to reflect the elevated organic carbon concentration contained in the wastewater which promotes microbial activity in the subsurface environment.

55 Lowest observed DRP concentrations were recorded in the two monitoring bores closest to the oxidation ponds (BH2 and BH3), with the observed concentration in BH4 lower than background groundwater (BH1, BH5 and BH6) and the Tokanui River.

56 Similarly, concentrations of indicator bacteria (E.coli) in groundwater indicate appreciable attenuation of microbial contaminants in the unconfined aquifer in close proximity to the oxidation ponds. Samples from both BH2 and BH3 exhibited concentrations below the method detection limit (<10 MPN/100 mL), while the sample from BH4 exhibited a concentration almost 3 log-scales lower than observed in the oxidation pond and two log-scales lower than that observed in the Tokanui River.

57 Overall, water quality results from historical surface water sampling and the March 2019 water quality survey indicate that:

- Seepage from the oxidation ponds results in minor effects on groundwater quality down-gradient of the ponds. Concentrations of nutrients and microbial indicators are generally lower than background concentrations in the unconfined aquifer, and in the Tokanui River upstream of the discharge; and

- Infiltration of seepage from the oxidation ponds into the Tokanui River over the reach immediately downstream of the ponds does not appear to result in more than minor changes in downstream water quality.

58 The proposed discharge of wastewater to the Tokanui River via an infiltration trench has the potential to mitigate potential effects on surface water associated with the existing discharge. The trench will facilitate increased infiltration of wastewater to the unconfined aquifer (aside from mid to late-winter period when groundwater levels are near their seasonal peak) resulting in the additional attenuation of nutrients and microbial contaminants in the underlying unconfined aquifer (as identified in the March 2019 water quality sample results). The proposed design of the infiltration trench will also provide an overall increase in wastewater storage capacity and, depending on final design, potentially provide additional attenuation of contaminants associated with nutrient uptake and filtration by vegetation grown in the trench.

Though the trench will increase the total load of contaminants entering groundwater, the effects on groundwater quality are predicted to be minor given:

- The physical and geochemical characteristics of the vadose zone and unconfined aquifer underlying the ponds have been shown to result in significant attenuation of contaminants, and

- Groundwater flow toward the river is likely to remain, resulting in the majority of contaminants entering the river rather than migrating down-gradient within the aquifer.

59 It is noted that the Assessment of Environmental Effects utilised modelling to predict potential effects on groundwater quality. Sampling of groundwater quality down-gradient of the ponds demonstrates that the conservative assumptions adopted for the modelling significantly over-predict actual effects on groundwater due to:

  - The low seepage rates from the pond
  - The extent of nitrification and denitrification in the vadose zone and unconfined aquifer which significantly reduce Ammoniacal Nitrogen, Nitrate-Nitrogen and Total Nitrogen concentrations in the unconfined aquifer; and
  - Higher rates of pathogen removal due to natural die-off (due to the slow rate of infiltration) and higher rates of physical attenuation (adsorption and filtration) in the clayey silt materials underlying the ponds.

Conclusion

60 Hydrogeological investigations undertaken at the Tokanui WWTP site indicate seepage from the oxidation ponds flows in a south-easterly direction and infiltrates into the Tokanui River immediately downstream from the ponds. Water quality sampling indicates significant attenuation of nutrients (N and P) and microbial contaminants in the unconfined aquifer. Groundwater quality down-gradient of the ponds generally exhibits lower concentrations of nutrients and indicator bacteria that background concentrations in groundwater and in the Tokanui River upstream of the discharge.

61 Overall, based on available data, I consider it reasonable to conclude that seepage from the oxidation ponds and proposed infiltration trench is likely to result in minor effects on the quality of down-gradient groundwater and less than minor effects on the quality of downstream receiving waters in the Tokanui River.

Brydon Hughes

Brydon Hughes

30 April 2019

References

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Figure 1. *Subsurface geology exposed in a test pit adjacent to the Tokanui WWTP site.*

Figure 2. *Location of piezometers installed on the Tokanui WWTP site, March 2019.*

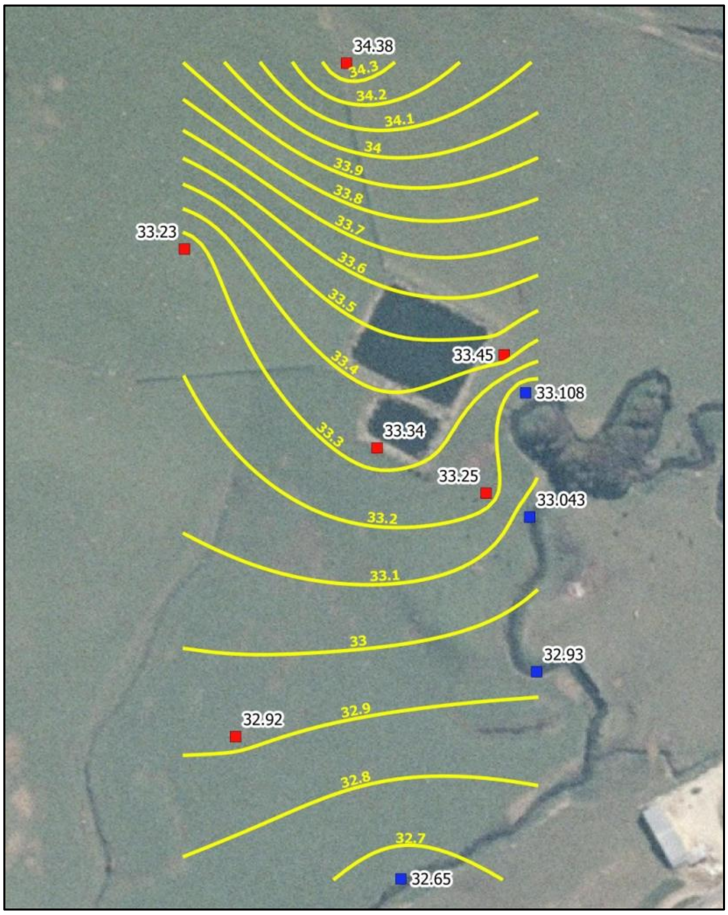

Figure 3. *Interpolated piezometric contours (m asl) for the Tokanui WWTP site. (Note: red squares represent static water levels measured in piezometers, blue squares represent stage height in the Tokanui Stream)*

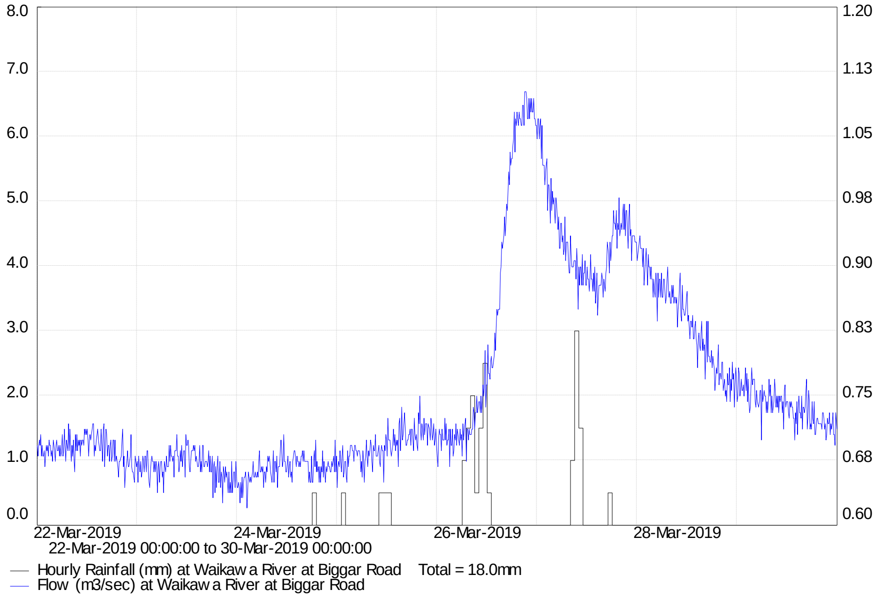

Figure 4. *Rainfall and river flow at the Environment Southland Waikawa River at Biggar Road monitoring site, 22-29 March 2019*.

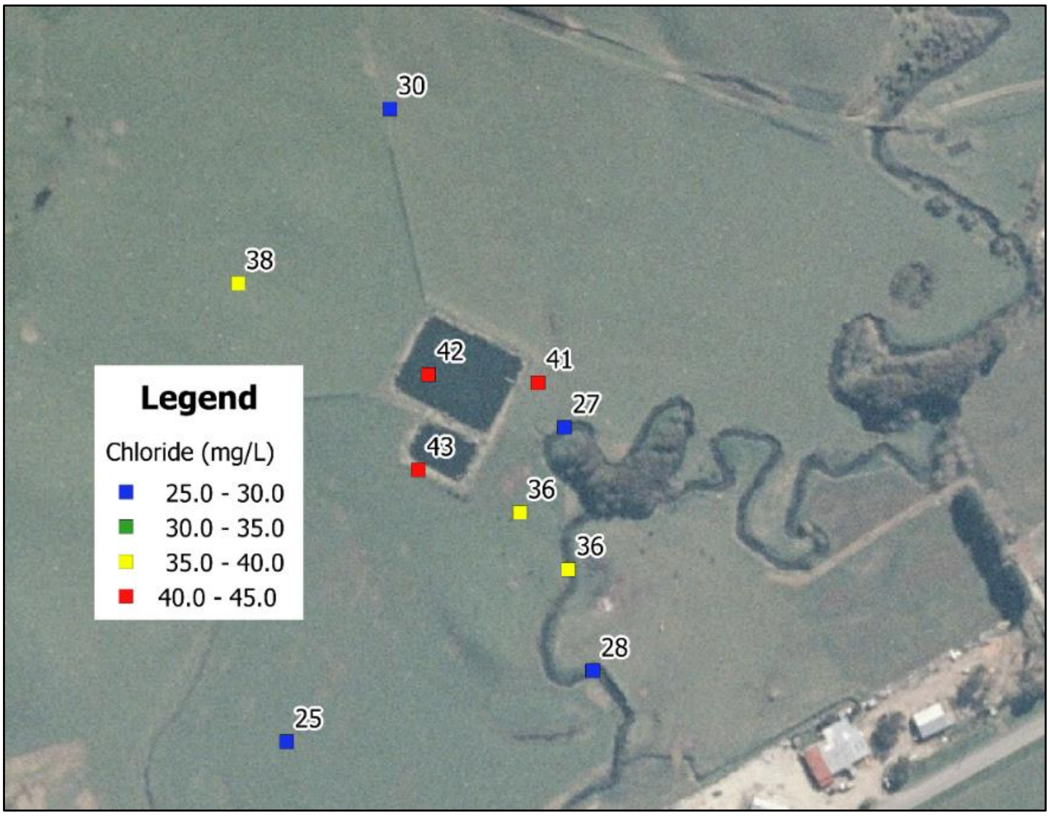

Figure 5. *Spatial distribution of Chloride concentrations in 28 March 2019 sample results.*

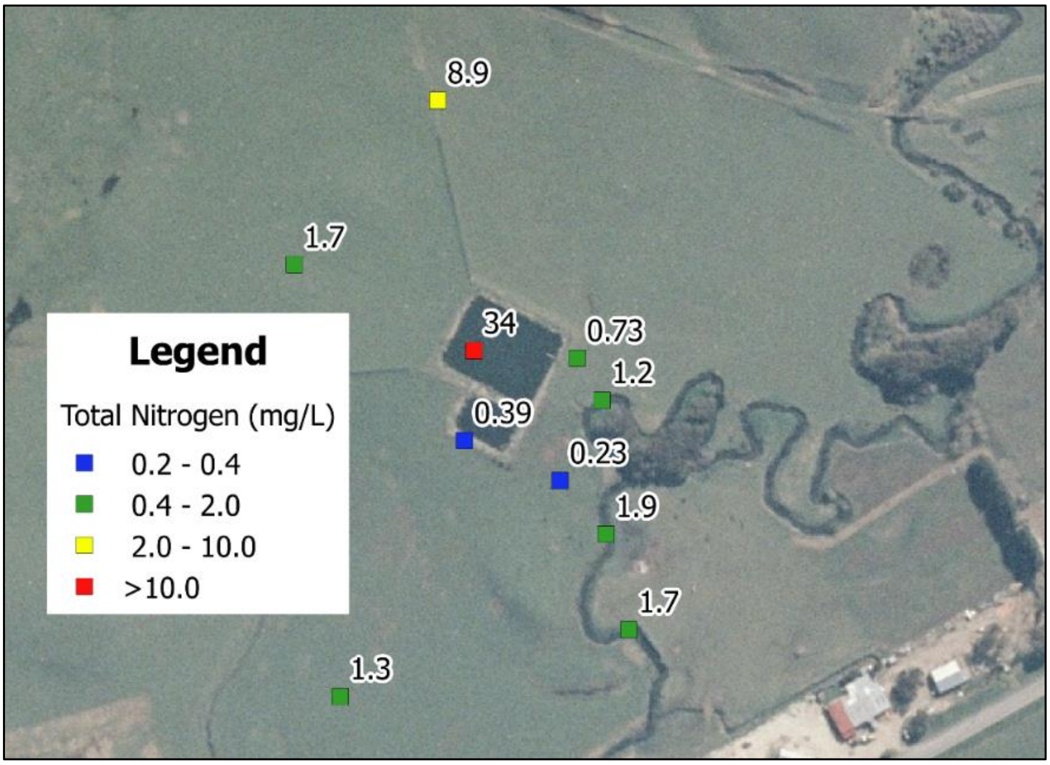

Figure 6. *Spatial distribution of Total Nitrogen (TN) concentrations in 28 March 2019 sample results.*

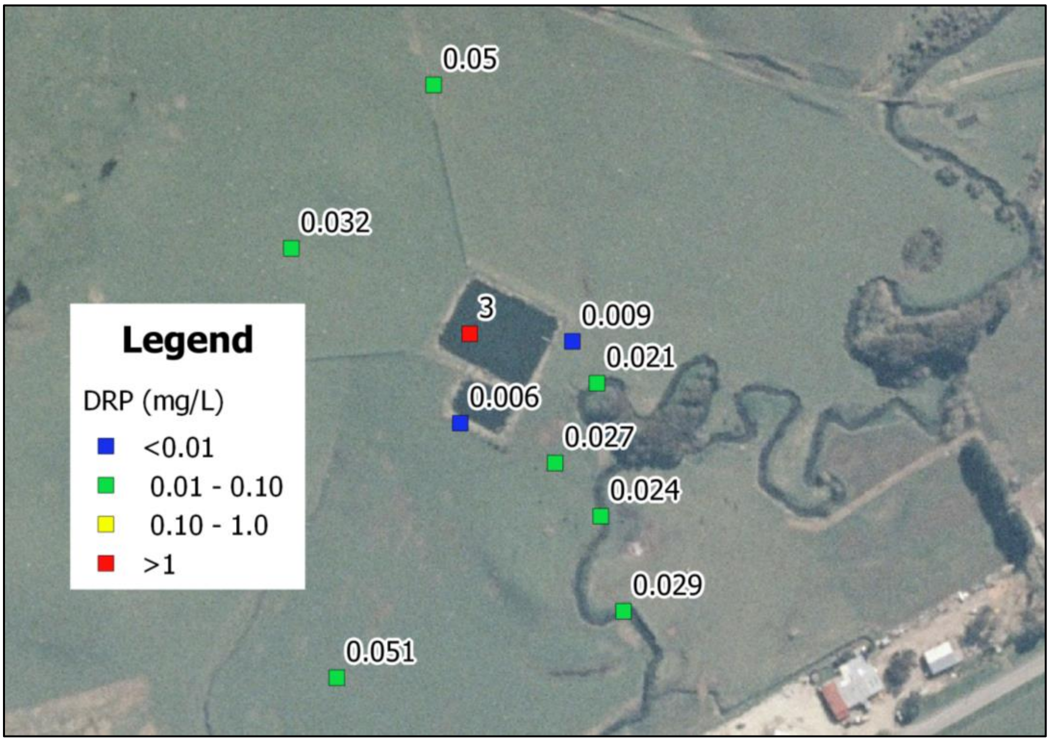

Figure 7. *Spatial distribution of Dissolved Reactive Phosphorus (DRP) concentrations in 28 March 2019 sample results.*

Table 1. *Reduced water levels (m asl) at the Tokanui WWTP site, 28 March 2018*

Site	Type	Easting	Northing	Reference point (m asl)	Depth to water (m)	Water Level (m asl)
BH1	Groundwater	1288696	4835375	38.446	4.07	34.38
BH2	Groundwater	1288769	4835240	35.784	3.57	33.45
BH3	Groundwater	1288710	4835196	36.911	2.33	33.34
BH4	Groundwater	1288760	4835176	35.122	1.865	33.25
BH5	Groundwater	1288645	4835063	34.989	2.07	32.92
BH6	Groundwater	1288621	4835229	39.739	6.51	33.23
Warratah A	Pond 1	1288721	4835275	36.37	0.60	35.77
	Pond 2	1288732	4835196			35.78
Warratah D	Tokanui Stream	1288779	4835222	33.80	0.69	33.11
Warratah E	Tokanui Stream	1288781	4835165	33.40	0.36	33.04
Warratah F	Tokanui Stream	1288784	4835093	33.31	0.38	32.93
Warratah G	Tokanui Stream	1288721	4834996	33.21	0.56	32.65

Table 2. *Results of water quality samples collected from the Tokanui WWTP site, 28 March 2019*

Parameter	Units	Pond	Discharge	BH1	BH2	BH3	BH4	BH5	BH6	Tokanui River upstream	Tokanui River 50 m downstream	Tokanui River 150 m downstream
Chloride	mg/L	42	42	30	41	43	36	25	38	27	36	28
Nitrate (as N)	mg/L as N	0.1	0.19	8.9	0.007	0.13	0.053	1.1	0.81	0.74	0.73	0.78
Sulphate	mg/L	13	8.2	7.3	3.9	11	3.1	9.5	10	5.8	5.7	6.1
Ammoniacal Nitrogen	mg/L as N	21	8.5	<0.01	0.54	0.04	0.02	0.02	<0.01	0.04	0.04	0.06
CBOD5	mg/L (as O_2)	28	30	<2.0	<2.0	<2	2.1	2.4	5.4	2.1	2.0	2.1
COD	mg/L as O_2	180	180	<30	<30	32	40	<30	130	30	<30	<30
Dissolved Reactive Phosphorus	mg/L as P	3.0	3.0	0.05	0.009	0.006	0.027	0.051	0.032	0.021	0.024	0.029
Total Alkalinity	mg/L as $CaCO_3$	140	92	31	130	22	120	78	81	38	38	38
Total Nitrogen	mg/L as N	34	20	8.9	0.73	0.39	0.23	1.3	1.7	1.2	1.9	1.7
Total Phosphorus	mg/L as P	5.0	4.5	0.05	0.17	0.05	0.21	0.42	0.55	0.07	0.08	0.08
Total Suspended Solids	mg/L	53	57	28	68	730	1,500	640	15,00	14	6.2	5.4
E.coli (MPN)	MPN/100mL	20,000	3,900	<10	<10	<10	41	<10	52	2,800	3,100	2,200

Table 3. *Mean surface water quality results from historical monitoring at the WWTP site (from Stantec, 2019)*

Parameter	**Units**	**Compliance Monitoring 2005-2017**		**August 2017 to January 2018**		
		Upstream	**150 m downstream**	**Upstream**	**50 m downstream**	**150 m downstream**
Ammoniacal Nitrogen	mg/L as N	0.06	0.05	0.04	0.04	0.04
Conductivity	mS/m	18.1	18.4	18.3	18.1	18.3
Temperature	^{o}C	11.2	11.7	11.2	11.1	11.1
E.coli	CFU/100 mL	1,315	1,275	3,910	3,439	3,147
Faecal Coliforms	CFU/100 mL	1,841	1,784	1,644	1,685	1,449
Dissolved Oxygen	% sat	95	89	9.4	9.4	9.3
pH		7.2	7.2	7.4	7.4	7.3
Dissolved Reactive Phosphorus	mg/L as P	0.033	0.027	0.041	0.021	0.020
Turbidity	NTU	10.3	10.5	9	11	10
Chloride	mg/L			26		26
Bromide	mg/L			0.13		0.13

Appendix A. Bore Logs

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BOREHOLE LOG

Job No: 80508133	
Hole No: MB01	
Sheet: 1 of 1	
Client: Southland District Council	Started: 20/03/19
Project: Tokanui Waste Water Pond Consents Location: Tokanui, Southland	Finished: 20/03/19
Description: North of pond	Logged: NWH
	Checked:
Easting: 1288695.955m Northing: 4835375.331m Inclination: Vertical	RL Surface: 38.446m
Diameter (Int/Ext): 36mm/60mm	Datum: Dunedin-Bluff 1960

Depth (m)	Elevation (m)	Samples Type	Shear Vane (kPa) Peak Strength/ Residual Strength	Standard Penetration Tests Blows (Seating // 75mm/150mm, 225mm/300mm)	Standard Penetration Tests N Value/ Refusal Data	Material Description (Logging carried out in accordance with Guidelines for the Field Classification of Soil and Rock for Engineering Purposes. New Zealand Geotechnical Society, 2005)	Graphic Log	Moisture Condition	Groundwater	Other Observations	Installation
						SAND with organics. Grey; moist; organics, rootlets. [TOPSOIL]. *(0.2)*		moist			
						Silty CLAY with minor gravel and sand. Light yellowish brown; moist; gravel, fine; sand; coarse. *(3.5)*			▼ 28/3 AD2		
						Becomes wet. *(7)*					
						Some gravel. *(8)*					
						Clay bound GRAVEL. Brown; saturated. *(10.17)*		saturated			
						Borehole terminated at 10.17m due to Target Depth					

Depth (m): 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0

Elevation (m): 38.0, 37.0, 36.0, 35.0, 34.0, 33.0, 32.0, 31.0, 30.0, 29.0, 28.0, 27.0

Drilling Method: **Rotary-percussion**	Casing: **n/a (casing removed)**	Remarks: Air Rotary Drill Method
Contractor: **South Drill**	Flush:	
Equipment Type: **Schramm T555**		

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BOREHOLE LOG

Job No: 80508133
Hole No: MB02
Sheet: 1 of 1

Client: Southland District Council
Started: 20/03/19

Project: Tokanui Waste Water Pond Consents
Location: Tokanui, Southland
Finished: 20/03/19
Logged: NWH

Description: East edge of pond
Checked:

Easting: 1288768.832m
Northing: 4835239.804m
Inclination: Vertical
RL Surface: 35.784m

Diameter (Int/Ext): 36mm/60mm
Datum: Dunedin-Bluff 1960

Depth (m)	Elevation (m)	Samples Type	Shear Vane (kPa) Peak Strength/ Residual Strength	Standard Penetration Tests Blows (Seating // 75mm/150mm, 225mm/300mm)	N Value/ Refusal Data	Material Description (Logging carried out in accordance with Guidelines for the Field Classification of Soil and Rock for Engineering Purposes. New Zealand Geotechnical Society, 2005)	Moisture Condition	Groundwater	Other Observations
						Silty SAND with organics. Brownish grey; moist; organics, rootlets. [TOPSOIL]. *(0.4)*	moist		
1.0 2.0 3.0	35.0 34.0 33.0 32.0					CLAY with trace gravel. Orangeish brown; moist; no plasticity; gravel; fine to medium. *(4)*		▼ 28/3 AD2	
4.0 5.0 6.0	31.0 30.0 29.0					Becomes wet. *(7)*	wet		
7.0 8.0	28.0					Clayey GRAVEL with minor sand. Yellowish brown; saturated; sand, coarse. *(8.5)*	saturated		
9.0	27.0 26.0					CLAY with some gravel and sand. Yellowish brown; saturated; gravel, fine; sand, coarse. *(9.88)*			
10.0 11.0	25.0 24.0					Borehole terminated at 9.88m due to Target Depth			

Drilling Method:
Rotary-percussion

Casing:
n/a (casing removed)

Contractor:
South Drill

Flush:

Equipment Type:
Schramm T555

Remarks: Air Rotary Drill Method

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BOREHOLE LOG

Job No: 80508133
Hole No: MB03
Sheet: 1 of 1
Client: Southland District Council
Started: 21/03/19
Project: Tokanui Waste Water Pond Consents
Finished: 21/03/19
Location: Tokanui, Southland
Logged: NWH
Description: South east of pond
Checked:
Easting: 1288710.057m Northing: 4835195.582m Inclination: Vertical
RL Surface: 36.911m
Diameter (Int/Ext): 36mm/60mm
Datum: Dunedin-Bluff 1960

(Logging carried out in accordance with Guidelines for the Field Classification of Soil and Rock for Engineering Purposes. New Zealand Geotechnical Society, 2005)

Depth (m)	Elevation (m)	Samples Type	Shear Vane (kPa) Peak Strength/ Residual Strength	Standard Penetration Tests Blows (Seating // 75mm/150mm, 225mm/300mm)	N Value/ Refusal Data	Material Description	Moisture Condition	Groundwater	Other Observations
0.0–0.2						Silty SAND with organics. Brownish grey; moist; organics, rootlets. [TOPSOIL]. (0.2)	moist		
0.2–1.0	36.0					CLAY with trace gravel. Orangeish brown; moist; no plasticity; gravel; fine to medium. (1)	moist		
1.0–6.0	35.0–31.0					Silty CLAY; light yellowish brown; wet; low plasticity. (6)	wet	28/3 AD2	
6.0–8.0	30.0–29.0					Some gravel and trace sand; gravel. fine to medium, sub angular; sand, coarse. (8)	wet		
8.0–9.65	28.0					Becomes brown. (9.65)	wet		
9.65						Borehole terminated at 9.65m due to Target Depth			

Drilling Method: **Rotary-percussion**
Casing: **n/a (casing removed)**
Remarks: Air Rotary Drill Method
Contractor: **South Drill**
Flush:
Equipment Type: **Schramm T555**

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BOREHOLE LOG

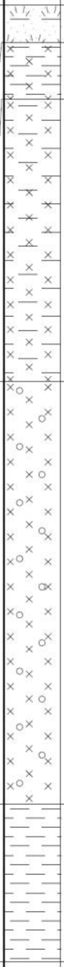
Job No: 80508133	Client: Southland District Council
Hole No: MB04	Project: Tokanui Waste Water Pond Consents
Sheet: 1 of 1	Location: Tokanui, Southland
Started: 21/03/19	Description: South edge of pond
Finished: 21/03/19	Easting: 1288760.408m Northing: 4835175.591m Inclination: Vertical
Logged: NWH	Diameter (Int/Ext): 36mm/60mm
Checked:	
RL Surface: 35.112m	
Datum: Dunedin-Bluff 1960	

Depth (m)	Elevation (m)
	35.0
1.0	34.0
2.0	33.0
3.0	32.0
4.0	31.0
5.0	30.0
6.0	29.0
7.0	28.0
8.0	27.0
9.0	26.0
10.0	25.0
11.0	24.0

Samples: Type — Shear Vane (kPa): Peak Strength/ Residual Strength — Standard Penetration Tests: Blows (Seating // 75mm/150mm, 225mm/300mm) — N Value/ Refusal Data

Material Description (Logging carried out in accordance with Guidelines for the Field Classification of Soil and Rock for Engineering Purposes. New Zealand Geotechnical Society, 2005)	Moisture Condition	Groundwater
SILT with minor organics. Greyish brown; moist; organics, rootlets. [TOPSOIL]. *(0.4)*	moist	
Silty CLAY with minor organics and trace gravel. Greyish brown with yellowish orange mottling; moist; organics, rootlets; gravel, fine. [TOPSOIL]. *(1)*		▼ 28/3 AD2
Clayey SILT with some sand and trace gravel. Brownish grey with some orange mottling; wet; sand, fine to coarse; gravel, fine. *(4)*	saturated	
Gravelly SILT with some clay and sand. Yellowish brown; saturated; gravel, fine to medium. *(8.5)*	saturated	
CLAY with trace gravel. Yellowish brown; saturated; gravel, fine. *(10.18)*		
Borehole terminated at 10.18m due to Target Depth		

Graphic Log — Other Observations — Installation



Drilling Method: **Rotary-percussion**	Casing: **n/a (casing removed)**	Remarks: Air Rotary Drill Method
Contractor: **South Drill**	Flush:	
Equipment Type: **Schramm T555**		

Stantec STANTEC NEW ZEALAND Hazeldean Business Park 6 Hazeldean Road Christchurch 8024 Tel: 03 366 7449 Fax: 03 366 7780	**BOREHOLE LOG**	Job No: 80508133 Hole No: MB05 Sheet: 1 of 1
	Client: Southland District Council	Started: 22/03/19
	Project: Tokanui Waste Water Pond Consents Location: Tokanui, Southland	Finished: 22/03/19 Logged: NWH
	Description: South of pond	Checked:
	Easting: 1288644.721m Northing: 4835062.506m Inclination: Vertical	RL Surface: 34.989m
	Diameter (Int/Ext): 36mm/60mm	Datum: Dunedin-Bluff 1960

Depth (m)	Elevation (m)	Samples Type	Shear Vane (kPa) Peak Strength/ Residual Strength	Standard Penetration Tests Blows (Seating // 75mm/150mm, 225mm/300mm)	N Value/ Refusal Data	Material Description (Logging carried out in accordance with Guidelines for the Field Classification of Soil and Rock for Engineering Purposes. New Zealand Geotechnical Society, 2005)	Graphic Log	Moisture Condition	Groundwater	Other Observations	Installation
						Silty SAND with organics. Brownish grey; moist; organics, rootlets. [TOPSOIL]. *(0.2)*					
1.0 2.0 3.0	34.0 33.0 32.0					Clayey fine to medium GRAVEL. Brown mottled orange; wet. *(4)*		moist to wet	▼ 28/3 AD2		
4.0 5.0 6.0	31.0 30.0 29.0					Gravelly CLAY with some sand. Brown; wet, gravel, fine. *(7)*		wet			
7.0	28.0					Observed as Silty SAND. Light brown; saturated. Assumed completely weathered mudstone. *(7.5)*		saturated			
8.0 9.0 10.0	27.0 26.0 25.0					Some clay. *(10.32)*					
11.0	24.0					Borehole terminated at 10.32m due to Target Depth					

Drilling Method: **Rotary-percussion**	Casing: **n/a (casing removed)**	Remarks: Air Rotary Drill Method
Contractor: **South Drill**	Flush:	
Equipment Type: **Schramm T555**		

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BOREHOLE LOG

Job No: 80508133	
Hole No: MB06	
Sheet: 1 of 1	
Client: Southland District Council	Started: 22/03/19
Project: Tokanui Waste Water Pond Consents Location: Tokanui, Southland	Finished: 22/03/19
Description: West of pond	Logged: NWH
	Checked:
Easting: 1288621.087m Northing: 4835228.994m Inclination: Vertical	RL Surface: 39.739m
Diameter (Int/Ext): 36mm/60mm	Datum: Dunedin-Bluff 1960

Material Description (Logging carried out in accordance with Guidelines for the Field Classification of Soil and Rock for Engineering Purposes. New Zealand Geotechnical Society, 2005)

Depth (m)	Material Description	Moisture Condition	Groundwater
0.0 – (0.2)	Silty SAND with organics. Brownish grey; moist; organics, rootlets. [TOPSOIL].	moist	
(0.2) – (4.5)	Silty CLAY with minor gravel and sand. Light yellowish brown; moist; gravel, fine; sand; coarse.		
(4.5) – (7.9)	Becomes wet. Some gravel, fine to medium, rounded.	wet	▼ 28/3 AD2
(7.9) – (8.24)	Grey siltstone type rock, asuumed bedrock. From GNS Geology Map "Fossiliferous mudstone with minor shellbeds"		
	Borehole terminated at 8.24m due to Target Depth		

Depth (m): 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0
Elevation (m): 39.0, 38.0, 37.0, 36.0, 35.0, 34.0, 33.0, 32.0, 31.0, 30.0, 29.0, 28.0

Samples: Type | Shear Vane (kPa): Peak Strength/ Residual Strength | Standard Penetration Tests: Blows (Seating // 75mm/150mm, 225mm/300mm) | N Value/ Refusal Data | Graphic Log | Other Observations | Installation

Drilling Method: **Rotary-percussion**	Casing: **n/a (casing removed)**
Contractor: **South Drill**	Flush:
Equipment Type: **Schramm T555**	

Remarks: Air Rotary Drill Method

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Appendix B. Falling Head Tests

Bouwer and Rice (1976) method to determine hydraulic conductivity in an unconfined aquifer

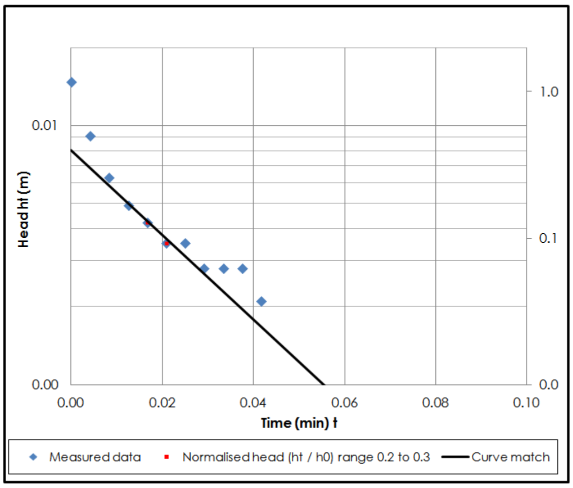
For **partially penetrating wells** where the length of the well casing below the water table (d) is less saturated aquifer thickness (D)

K= (rc^2 In(R_(e)/r_w))/2d
1/t In h_o/h_t

In R_e/R_w = [1.1/(In(b/r_w)) + (A+B
In[(D−b)/r_w])/(d/r_w)] (−1)¦

T=KD

BH1



Transmissivity	T	109 m^2/d
Hydraulic conductivity	K	14.2 m/d
		1.6E-04 m/s
Radius of the unscreened part of the well where the head is rising / falling	r_c	0.025 m
Horizontal distance from well centre to undisturbed aquifer	r_w	0.04 m
Radial distance over which difference in h_o is dissipated in the aquifer	R_e	1.51 m
Head in the well at time, t_o = 0 = y intercept	h_o	0.40 m
Head in the well at time, t > t_0	h_t	0.00 m
Time at h_t	t > t_0	0.09 min
Top of water table to bottom of aquifer equal to satuarted aquifer thickness	D	12 m
Distance from top of water table to bottom of the screen	b	6.76 m
Screen length or open section of well	d	7.67 m
Full penetration	d < b	
	In (R_e/ r_w	3.64
A and B are dimensionless	A	6.09
functions of d / r_w	B	1.13
	d / r_w	192

Reference

Bouwer, H & Rice, R.C. (1976). *A slug test for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells. Water Resources Research* , Vol. 12(3), pp 423 - 428.

Bouwer and Rice (1976) method to determine hydraulic conductivity in an unconfined aquifer

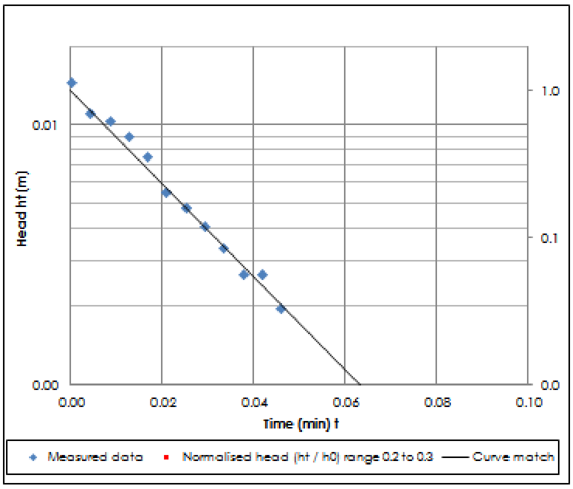
For **partially penetrating wells** where the length of the well casing below the water table (d) is less saturated aquifer thickness (D)

K= (rc^2 In(R_(e)/r_w))/2d
1/t In h_o/h_t

In R_e/R_w = [1.1/(In(b/r_w)) + (A+B
In[(D−b)/r_w])/(d/r_w)] (−1)¦

T=KD

BH2



Transmissivity	T	116	m^2/d
Hydraulic conductivity	K	15.4	m/d
		1.8E-04	m/s
Radius of the unscreened part of the well where the head is rising / falling	r_c	0.025	m
Horizontal distance from well centre to undisturbed aquifer	r_w	0.04	m
Radial distance over which difference in h_o is dissipated in the aquifer	R_e	2.04	m
Head in the well at time, t_o = 0 = y intercept	h_o	1.00	m
Head in the well at time, t > t_0	h_t	0.00	m
Time at h_t	t > t_0	0.035	min
Top of water table to bottom of aquifer equal to satuarted aquifer thickness	D	7	m
Distance from top of water table to bottom of the screen	b	5	m
Screen length or open section of well	d	7.5	m
Full penetration	d < b		
	In (R_e/ r_w)	3.53	
A and B are dimensionless	A	6.03	
functions of d / r_w	B	1.11	
	d / r_w	188	

Reference

Bouwer, H & Rice, R.C. (1976). *A slug test for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells. Water Resources Research* , Vol. 12(3), pp 423 - 428.