Tonkin+Taylor

Job No: 1011469
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Otago Regional Council
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Attention: Hilary Lenox

Dear Hilary

Technical Review: Smooth Hill Landfill - Appendix 8 - Groundwater Report

Introduction

1 Dunedin City Council (DCC) proposes to establish a new Class 1 landfill, to be located at Smooth Hill to the southeast of Dunedin Airport. DCC has applied to Otago Regional Council (ORC) for a range of resource consents required for the establishment and operation of the proposed landfill.

2 Tonkin & Taylor Ltd (T+T) has been engaged by ORC to undertake a technical review of the groundwater assessment lodged by DCC in support of its resource consent applications.

3 The purpose of this report is to set out the findings of our technical review of DCC's groundwater assessment to support a Section 42a report and inform a decision by ORC on the resource consent applications.

4 The following documents have been considered as part of this technical review:

- **Dunedin City Council - proposed Smooth Hill Landfill: Section 92 review - requests for further information:** *Report prepared for ORC by T+T, September 2020.* (herein referred to as the s92 request').
- **Revised Appendix 8 - Groundwater Report:** *GHD August 2020 (Updated May 2021). Waste Futures Phase 2 – Work Stream 3. Smooth Hill Landfill. Assessment of Effects to Groundwater. Report prepared by GHD Limited for Dunedin City Council.* (herein referred to as the 'Groundwater Report').
- **Smooth Hill Landfill further information.** *Provided by ORC as part of its s92 response of 4 August 2021.* (herein referred to as the 'further s92 response') .
- **Smooth Hill Landfill – Additional s92 Question responses – Groundwater**. *GHD provided a pdf of Figure 6 (Conceptual Groundwater Model), a jpeg of 'Conceptual proposed landfill toe cross section' and a jpeg of 'potential for groundwater during excavation' on 10 August 2021, previously not included in the Groundwater Report. Provided by ORC as part of its further s92 response of 4 August 2021. (herein referred to as the 'conceptual groundwater model figures').*
- **Smooth Hill Landfill Draft Conditions.** *Provided by ORC as part of its further s92 response of 4 August 2021.* (herein referred to as the 'draft conditions').

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- **Smooth Hill Proposed Landfill – Phase 3 Ground Investigation:** *GHD (24 August 2021) Technical Memorandum including borehole log BH301 and core photos – provided to T+T in February 2022.*
- **Smooth Hill Landfill –** *additional information provided by the applicant on 18 March 2022 comprising "Cross Section C", DCC responses to ORC questions and amended draft conditions.*

5 An on-line meeting was held between Sally Lochhead (T+T Senior Hydrogeologist) and Zoe Pattinson (GHD Hydrogeologist), Antony Kirk (GHD Principal and Technical Director) and Nick Eldred (GHD Technical Director) on 28 July 2021 to discuss aspects of the Groundwater Report and s92 response relating to the conceptual groundwater model. The meeting satisfactorily clarified a number of matters including confirmation that an addition bore drilled within the landfill footprint would include obtaining information on groundwater conditions at this part of the site.

6 A second on-line meeting was held between Sally Lochhead (T+T) and Zoe Pattinson (GHD) and Antony Kirk (GHD) on 29 March 2022 to clarify queries raised by T+T during the review of supporting information provided to ORC by GHD on 18 March 2022. The points of the meeting are included in our responses below.

7 This technical review has been undertaken by Sally Lochhead, Senior Hydrogeologist at T+T. It has been prepared in accordance with T+T's letter of engagement with the ORC dated 12 November 2019.

Description of the Proposal

8 The proposed Smooth Hill municipal landfill is intended to replace the existing Green Island landfill located in Dunedin. The Smooth Hill Landfill is reduced in scale from the original application as follows:

- A footprint of 18.6 ha instead of the original 44.5 ha.
- A gross capacity reduced form 7.9 million m^3 to 3.3 million m^3.
- Net waste capacity of 6.2 million m^3 to 2.9 million m^3.
- The predicted landfill life reduced from 55 years to 40 years.

9 The construction of the proposed landfill will include the placement of a landfill liner, designed to minimise leakage of the leachate into the underlying ground and groundwater, and a leachate drainage system to control the leachate head within the landfill, proposed by the Applicant to be controlled with a maximum head of 300 mm.

10 The construction of the proposed landfill will control and intercept shallow groundwater beneath the landfill. A network of subsoil drains will be constructed beneath the landfill lining system with drainage taken to an access manhole before discharge to the Ōtokia Creek catchment. A groundwater discharge rate of 87 m^3/d is predicted from the sub-surface drains.

11 The Groundwater Report provides a technical assessment of the potential effects on groundwater which includes consideration of the hydraulic connectivity with the surface water, and the effects of leachate leakage on groundwater quality.

12 The key discharge from the proposed landfill has been identified in the Groundwater Report as being leachate, which may result in contaminants entering groundwater.

13 The proposed landfill requires a resource consent for the taking of groundwater from the landfill groundwater drainage system and use for non-potable water supply.

Receiving Environment

14 The site is located within a range of hills between the Taieri Basin and the coast. This rural site setting is bounded by forestry land to the north and west, and farmland to the northeast.

15 Section 2 of the Groundwater Report describes the existing environmental setting for the proposed landfill, noting that until recently, the majority of the site was covered by forestry. Following the on-line meeting between T+T and GHD, the applicant confirmed that the forestry had been cleared up to 5 years prior and scrub/gorse covers most of the area.

16 Figures in the Groundwater Report of the site location show the application site and the Smooth Hill Designation (2GP) being a wider area which extends over multiple valleys. The landfill footprint is located in one valley in the eastern part of the wider designated area.

17 The proposed landfill footprint is shown to extend up a valley with side gullies between approximately 95 m above mean sea level (amsl) and 150 m amsl based on the contours included in figures of the Groundwater Report. Most of the site and upper reaches of the gullies are reported to be dry with ephemeral stream flows.

18 The proposed landfill footprint and associated infrastructure is located within the upper reaches of the Ōtokia Creek catchment which sits within the McColl Creek surface catchment. The downstream reaches of the Ōtokia Creek between the designation site and McLaren Gully Road appear to be perennial, or likely having surface water present all (or most) of the year.

19 The proposed landfill footprint is identified by the applicant to be in an area of limited groundwater resource. The McColl Creek surface water allocation is identified as the groundwater allocation catchment for the proposed landfill footprint. There are no bores or consents shown on the provided Figure 5, within the McColl Creek catchment.

20 Site investigations with the drilling of boreholes have been undertaken by the Applicant to identify the geological and hydrogeological conditions at the site. This includes the drilling of another borehole in August 2021, located mid-way between two existing bores to further inform the geotechnical investigation within the proposed landfill footprint.

21 Two groundwater systems (shallow and deep) are reported to exist at the site. The applicant has identified that the shallow groundwater system is limited to the valley setting and does not fully overlie the deeper groundwater system. The receiving groundwater system from the potential landfill discharges (leachate) has been identified predominantly as the shallow groundwater system.

22 Rainfall data provided in the Groundwater Report uses data within 25 km of the site and this is reported to vary significantly in rainfall amounts. During the on-line meeting between T+T and GHD (28 July 2021), the applicant emphasized that the catchment is relatively dry, and this is confirmed by the rainfall recorded at the on-site meteorological station which has been established at the site since mid-2020.

23 Overall, we agree with the Groundwater Report description of the receiving environment.

Assessment of Hydrogeological Setting

24 The site-specific investigations have shown the proposed landfill site is underlain by the Upper Cretaceous Henley Breccia (sandstone, siltstone and breccia units). The weathering of the Henley Breccia has been identified by the applicant in two groups; completely weathered to highly weathered, and unweathered to slightly weathered, although reference to moderately weathered bedrock is also made. The Henley Breccia is overlain by loess deposits which cover much of the existing slopes, with alluvial deposits and colluvium in the valley and gullies. The proposed landfill construction will remove the loess deposits, alluvial deposits and colluvium from the landfill footprint.

25 The proposed landfill footprint is located in the McColl Creek catchment, from which the Ōtokia Creek drains to the north from the proposed landfill. The application site boundary identified on Figure 1 of the Groundwater Report includes other surface water catchments. These are not discussed in the Groundwater Report because the landfill footprint is not sited

in the other surface water catchments. Although the southeast boundary of the landfill extends to the top of the McColl Creek catchment and borders the Fern Stream catchment.

26 A shallow groundwater system within the alluvial deposits, colluvium and shallow Henley Breccia has been identified at the proposed landfill site in the valley. (Comments and further details are provided below).

27 A deeper groundwater system has also been identified within the deeper moderately weathered to unweathered Henley Breccia at the proposed landfill site. (Comments and further details are provided below).

Shallow groundwater system

28 The extent of the shallow groundwater system is identified by the applicant to be limited to within the alluvium, colluvial deposits and the shallow Henley Breccia. The shallow groundwater system sits in the valley and has not been identified to extend toward the ridgelines. There is a gap in the data and the understanding on the extent of the shallow groundwater system across the south-eastern part of the landfill footprint.

29 A fine grained low permeability layer has been identified at some bore hole locations (recovered in the core) and by inference at another location (from observations in the drilling arisings) by the Applicant. This low permeability layer has been reported by the Applicant to separate the shallow groundwater system from the underlying groundwater system by acting as an aquitard (limiting groundwater movement). The lateral extent of this stratum is not well defined and has mostly been identified at the lower elevations at the site, in and close to the valley, although it is also encountered at the middle of the site (BH301) but not at the ridgelines.

30 The direction of groundwater flow in the shallow groundwater system has been assessed to be controlled by the topography with discharge in the valley. Within the proposed landfill footprint, shallow groundwater flows above the low permeability layer are inferred to be approximately toward the northwest.

31 The shallow groundwater system is described to locally provide flows to the Ōtokia Creek. Horizontal hydraulic gradients (flows inwards toward the valley) have been interpreted with minor artesian conditions at valley boreholes.

Deeper groundwater system

32 The deeper groundwater system has been assessed as not being topographically constrained and not defined by the surface water catchments, although the applicant infers that the groundwater divide in the deeper groundwater system is along the north-south trending ridgeline of the western portion of the application site. As shown in Figure 6 'Conceptual Groundwater Model' the deeper groundwater, assessed by the Applicant, flows southeast toward the Pacific Ocean.

33 Downward vertical gradients dominate the deeper groundwater flow because the site investigations undertaken by the Applicant have identified horizontal flow paths in the deeper Henley Breccia are restricted by the lack of defects, such as fractures in the recovered cores. This has also been assessed based on a comparison of the groundwater levels recorded in the deeper monitoring bores.

34 The Applicant installed an additional borehole (BH301) during August 2021, drilled within the proposed landfill footprint which contained nested groundwater monitoring piezometers screened at depths of 16 m to 18 m, and 30.80 m to 32.80 m. It is understood that the main objective of the bore was to obtain further geotechnical information within the landfill footprint (not previously investigated). During the online meeting on 28 July 2021 with T+T hydrogeologist, GHD (on behalf of the Applicant) advised that information gained by the drilling of the additional bore would be used to demonstrate the groundwater flow direction

within the landfill footprint. Details on bore BH301 were provided by the Applicant in a technical memo (24 August 2021) which confirms the geological sequence.

35 More recent information (18 March 2022) provided groundwater level records obtained from the nested piezometers. These show consistent groundwater levels recorded on the two monitoring occasions (February 2022 and March 2022) with groundwater levels at 110.7 m RL and 110.3 m RL in the shallower piezometer and at 100 m RL and 100.2 m RL in the deeper piezometer. The groundwater levels recorded in BH301 at both piezometers are for the deeper groundwater system. This is because the piezometers are installed below the fine grained low permeability layer, as identified on "Cross Section C".

36 The elevation (in m RL) of BH301 provided on the bore log of 144 m RL does not correspond with the elevation of BH301 shown on "Cross Section C". During the most recent on-line meeting of 29 March 2022, GHD confirmed the correct elevation of BH301 is that represented on "Cross Section C" and the most recent depths to groundwater are 10.5 m below top of casing (btoc) and 21.03 m btoc for the shallow and deep piezometers (respectively). The top of casing is 0.22 m above ground level (agl) for the shallow piezometer and 0.7 m agl for the deeper piezometer.

Groundwater flows

37 Horizontal hydraulic gradients are identified to be "*more influential*" in the shallow groundwater system, although only vertical hydraulic gradients have been calculated in the Groundwater Report which show a range of vertical hydraulic gradients for the groundwater systems.

38 An estimate of shallow groundwater velocities at the toe of the proposed landfill have been provided. Indicative groundwater velocities for the deeper groundwater system are provided based on estimates of hydraulic conductivities of the Henley Breccia at the periphery of the site based on field testing data. It is considered that these values would be representative of the underlying Henley Breccia beneath the landfill footprint due to intact nature of the Henley Breccia and the absence of fractures and defects within the cored boreholes.

Assessment of Conceptual Groundwater Model

39 The site-specific investigations were undertaken to provide information for both geotechnical and hydrogeological purposes which have formed the basis of the conceptual site hydrogeological model. The borehole locations targeted the ridgelines within the application site boundary and the valley locations. The proposed landfill footprint has been reduced in size since the original investigations and one additional borehole has been drilled through the landfill footprint.

40 The Applicant has used the factual information gained from the drilling of bore BH301 to provide more detail on the groundwater setting within the landfill footprint and has confirmed their previous conclusions that the groundwater flow direction in the deeper groundwater system (monitored in both shallow and deep piezometers at BH301) to be toward the southeast. The depth to the groundwater surface is shown to vary significantly across the proposed landfill footprint. Some shallow depth bores in the valley are shown to record artesian conditions, where the groundwater level is above the ground surface. Other bores on the lower valley slopes record groundwater depths at approximately 4 m to 5 m btoc. These shallower groundwater depths represent the shallow groundwater system. There is an absence of shallow groundwater data across a large part of the site which presents some uncertainty on the extent (and presence) of the shallow groundwater system.

41 Groundwater levels for the deeper groundwater system, in the ridgeline bores are at depths greater than 40 m btoc and at approximately 10 m and 21 m btoc within the middle part of

the landfill footprint at BH301. These overall groundwater levels show a progressive deepening of the deeper groundwater system from the northwest to the southeast.

42 Following the on-line meeting (28 July 2021) between T+T and GHD, the Applicant provided clarification and further description on the intact nature of the Henley Breccia and the absence of fractures and defects within the cored boreholes at depth. Further satisfactory explanation was provided on how the groundwater flows will be low and slow groundwater travel times would occur within the deeper groundwater system in the Henley Breccia.

43 Four cross sections showing the hydrogeological conceptual model were provided by the Applicant. These extend along the ridgeline at the western landfill footprint extent, two sections across part of the east valley side in the vicinity of the toe of the landfill and through the middle part (central) of the proposed landfill footprint.

44 These conceptual groundwater model figures show a low permeability layer to extend across a large part of the landfill footprint and separate the shallow and deeper groundwater systems. This stratum has been recorded in the core at four bore locations and inferred by observations from the drilling arisings at another location within the landfill footprint. Whilst the additional investigation at BH301 identifies this low permeability stratum at the middle of the site, based on the conceptual groundwater model figures it is not clear how far up the valley, in particular on the valley sides, the low permeability stratum and shallow groundwater system extend.

45 The lateral extent and effectiveness of the fine grained low permeability layer to act as an aquitard i.e. which limits the movement of groundwater between the two groundwater systems, is not fully understood. Groundwater quality data from monitoring wells above and below this stratum are reported to have differences in groundwater chemistry and this has been used to support the model showing the separate groundwater systems. No specific permeability testing on this stratum has been completed to show that it provides a barrier to groundwater movements between the two groundwater systems. However, we acknowledge that the potential for contaminant movement to occur into the deeper groundwater system from the landfill is low, due to the intact nature of the Henley Breccia and the preferential horizontal flow paths.

46 Whilst the additional site investigations have identified two low permeability layers at BH301, both piezometers are installed below the low permeability layer which is identified by the Applicant to represent the deeper groundwater system in the centre of the landfill footprint. It is not known if the shallow groundwater system is present at this part of the site because there is no monitoring well at the shallow depth. Given that groundwater levels in the deeper groundwater system at this location have been recorded at approximately 10 m bgl during summer 2022, it is possible that shallower groundwater levels in the shallow groundwater system could be present, particularly in different seasons when groundwater recharge occurs. Therefore, there remains some uncertainty on the extent of the shallow groundwater system and the depth to shallow groundwater across the site which means the potential effect on shallow groundwater quality from leakage from the landfill is not well known.

47 Detailed quantification of recharge to the deep groundwater system has not been provided by the Applicant because they have identified the risks associated with this flow path are minimal relative to those of shallow groundwater. We are in disagreement with this statement. Information gained from the drilling of bore BH301 shows relatively shallow groundwater levels of approximately 10 m bgl in the deeper groundwater system which could mean a relatively short groundwater recharge flow path. Clarification on the recharge can be addressed through the proposed consent condition to monitor groundwater levels in the deeper groundwater at the head, middle and toe of the landfill (at the designated monitoring bores) and to compare with the onsite rainfall data.

48 Overall, clarification was sought on a number of matters through the s92 request for further information, the on-line meeting and subsequent questions. The provision of further information at the middle of the landfill footprint improves the understanding of the conceptual model and reduces the uncertainty in assessing the effects of the landfill on groundwater beneath the landfill. However, whilst we are generally satisfied with the updated conceptual model, we do not fully understand the lateral extent of and depth to the shallow groundwater system across parts of the landfill footprint. This means the potential effect on shallow groundwater quality from leakage from the landfill is not well known.

Assessment of Effects

Groundwater quantity

49 Groundwater seepages have been noted at a number of locations around the site. A plan has been provided showing the potential for groundwater to be encountered during excavation (construction of the landfill), predominantly at the valley floor and northeast side slopes in an area of proposed cut.

50 Recharge to the shallow groundwater system will be reduced as a result of the placement of the landfill which will prevent direct recharge to the shallow groundwater system from rainfall. Recharge to the shallow groundwater system is identified (in the Groundwater Report) to continue to occur from runoff and shallow groundwater recharge (upward flows) from within the shallow Henley Breccia. The extent of this recharge is not clearly known, given the uncertainty with the lateral extent of the shallow groundwater system. Section 4.4 of the Groundwater Report states that: "*there will be no further recharge to the shallow groundwater system….*" Therefore, there is some discrepancy with groundwater flow contributions. However, given the site context we consider the differences in groundwater flow contribution will be minor.

51 Groundwater levels in the shallow groundwater system are predicted to lower by 1 m due to the reduced groundwater recharge. This has been assessed to have a knock-on effect on the baseflows to the Ōtokia Creek resulting in the change in the location (further downstream) of where permanent stream flows will occur. The Applicant is proposing to allow stormwater in the attenuation pond to soak to ground and provide additional baseflow to the surface water.

52 It has also been assessed that the lowering of the groundwater levels through the reduction of recharge would result in a reduction in groundwater collection through the sub-surface drains to be negligible in the long term.

53 The volumes of shallow groundwater calculated are small based on the site setting and the information contained within the Groundwater Report, but there is some residual uncertainty on the changes to groundwater volumes as a result of reduced recharge from rainfall to the site due to the proposed landfill. To some extent, understanding these changes in groundwater volumes can be addressed through a proposed consent condition to monitor groundwater levels in the monitoring bores and at BH301 with comparison to the onsite rainfall data to support quantification of these volumes. Overall, given the site context, we consider the differences in groundwater volumes (associated with the shallow groundwater flows) could be small, however, based on the information in the paragraph below, further quantification would reduce the uncertainty.

54 The information provided from BH301, shows the depth to groundwater in the deeper groundwater system is approximately 10 m bgl below the fine grained low permeability layer beneath the landfill footprint. No groundwater levels can be provided for the shallow groundwater system at this location because no monitoring well was installed, therefore, it is not known if shallow groundwater exists at this location above the low permeability layer.

55 The Applicant has identified this low permeability stratum to impede the percolation of recharge to the deeper groundwater system. Whilst the Applicant has not made further interpretation on the assessment of the effects of the landfill on the deeper groundwater beneath the for the central part of the landfill footprint, they have inferred that the deeper groundwater system is a separate groundwater 'unit' and by implication, the effects of the proposed landfill would be less than the effect on the shallow groundwater system which we agree with.

Groundwater Quality

56 Limited groundwater (and surface water) sampling has been completed. The water quality results show that the groundwater quality is different to the surface water quality. Further groundwater (and surface water) monitoring needs to be completed to establish the baseline data prior to commencement of the construction works and conditions of consent are proposed to provide such baseline data.

57 The existing groundwater quality has been analysed and reducing (anaerobic) groundwater conditions have been identified in monitoring wells BH02, BH201 and BH04B based on low dissolved oxygen concentrations (BH02) and low concentrations of sulphate and the presence ammoniacal-N. Differences in the groundwater chemistry (analysed parameter concentrations) have been used to support conclusions on groundwater movement such as in the inferred locations of the low permeable silt layer and the separate units of the shallow and groundwater systems.

58 High levels of nitrate have been identified in the existing groundwater quality obtained from some of the monitoring bores. The source of this has not been confirmed. Whilst a number of reasons have been postulated by the Applicant for high nitrate sources, no evidence has been substantiated. However, any seepage of from the landfill is unlikely to contain nitrate and it is not expected that the presence of the landfill would impact on nitrate levels in the groundwater.

59 Assessment of potential effects to surface water and groundwater have been modelled using the HELP software, which includes assessment of leachate generation and leakage of leachate through the landfill liner during different phase of the landfill operation. The greatest leachate generation volumes have been assessed at Stage 4 of the landfill operations.

60 Greatest volumes of leachate are predicted to be generated during Stage 4 of the operations and after landfill closure. The predicted leachate leakage rate through the landfill liner during this period is 0.26 m^3/yr.

61 Leachate contaminant flux has been assessed using concentrations from Class 1 Landfills (published data) and the groundwater data obtained from monitoring at the site. Contaminant flux has been modelled during Stage 4 of the operations, expected to be the worst case, and after landfill closure to show long term effects on surface water and groundwater quality. The assessment includes mixing of the shallow groundwater and migration of leachate with groundwater flow as a result of the leachate leakage.

62 Levels of lead dissolved reactive phosphorous (DRP), ammoniacal-N and iron are assessed to increase in concentrations as a result of the potential leachate leakage but not to exceed the adopted water quality criteria presented in Table 9.

63 We acknowledge that potential leachate ingress to the deeper groundwater system could occur, but is less likely given the location of the deeper groundwater underlying the low permeability layer and the depth to the deeper groundwater at the site. However, the unknown extent and the efficacy of the low permeability layer means that there is some residual uncertainty on the impact on the deeper groundwater quality from the landfill. This can be addressed through consent conditions, which need to be further developed, as outlined in the following sections

64 Recharge to the shallow groundwater system will be restricted by the placement of the landfill which will prevent direct groundwater recharge from rainfall and the potential leachate volumes are expected to be low. However, there are some limitations from the investigation data which have resulted in gaps in the understanding, particularly relating to the extent of the shallow groundwater system and the potential overlap with the deeper groundwater system.

65 Based on the current level of information, we are unable to conclude if the potential effects on the groundwater quality of the shallow groundwater system (either by itself or following the implementation of the proposed mitigation measures) would be minor or less than minor because the presence and depth to shallow groundwater across the wider landfill footprint is not well known. The monitoring bore piezometers at BH301 do not include monitoring of the shallow groundwater system which means all data for the shallow groundwater is limited to predominantly the north-western periphery of the landfill footprint.

Mitigation

66 A key focus of the T+T review of groundwater effects has been related to the potential for leachate via leakage to reach the receiving groundwater and result in the contamination of the receiving environment. A hydrogeological conceptual model of the wider landfill site is pertinent to understanding the potential impact on groundwater from the proposed activity.

67 The landfill liner will be designed to minimise leakage of the leachate and will comprise either a Type 1 or a Type 2 liner, designed to meet the WasteMINZ landfill guideline specifications.

68 Quantification of recharge to the groundwater systems is limited, and this, to some extent can be addressed through a proposed consent condition to monitor groundwater levels in the monitoring bores and at BH301 with comparison to the onsite rainfall data.

69 The Applicant installed an additional borehole (BH301) during August 2021, drilled within the proposed landfill footprint which contained nested piezometers both targeting the deeper groundwater system which shows the shallowest groundwater levels at approximately 10 m bgl. There remains a lack of information and interpretation on the shallow groundwater system at this part of the site (within the landfill footprint) which impacts on the Applicant's assessment of effects. Improvements on the proposed monitoring bore locations (further described below) can go some way to address this uncertainty on the effects of the landfill on shallow groundwater. However, further investigative information at the site on the shallow groundwater system should be provided to support the existing conceptual model.

70 Reliance on the landfill management plan (LMP) to address some matters raised by the s92 questions has been made. The Applicant acknowledges that the LMP is incomplete, and information will be included following the groundwater level and quality monitoring as part of the baseline monitoring which is proposed in the consent conditions. However, the frequency of groundwater monitoring proposed (quarterly monitoring of groundwater for 18 months) is insufficient to understand groundwater quality and variability. It will result in a dataset containing six data points and would augment an already limited data set of a maximum of five sampling rounds.

71 Further supporting information provided to ORC by GHD on 18 March 2022 show the details of monitoring bores GW 1 to GW 6, and BH202 (shown on Drg C309) that will be used to establish the derivation of the groundwater trigger levels prior to landfill construction.

72 In our review, we have identified that not all of these locations achieve the desired outcomes, for the following reasons:

- The location of GW1 (which is bore BH201 and shown on Drg C309) is incorrect and the location of BH201 does not capture groundwater downgradient of the landfill footprint.

This means that there are no monitoring bores which target the down gradient deeper groundwater system.

- The location of GW2 for the monitoring of the shallow groundwater system is located in a different sub-catchment to the landfill footprint and may not capture and be representative of the immediate downgradient water quality from the landfill.
- GW5 will monitor both the shallow and deeper groundwater system. The location of GW5 is greater than 150 m down gradient of the landfill toe, and a greater distance from the landfill cells which means the down gradient shallow groundwater quality at this bore would not be representative of the immediate down gradient water quality effects on the shallow groundwater system. The deeper groundwater monitoring at this location is appropriate for an upgradient monitoring bore.
- The location of BH202 does not capture groundwater downgradient of the landfill footprint. This bore will be useful to provide baseline groundwater quality to support the derivation of the trigger levels, but will not be appropriate for the groundwater monitoring during the operation of the landfill.
- Monitoring location GW7 is shown on Drg C309, but no information is provided for this location.

73 During the on-line meeting between T+T and GHD (29 March 2022), we asked about the locations of the monitoring bores listed in the paragraph above, and were provided with the following responses:

- GHD have acknowledged bore GW1 is shown in the wrong place on Drg C309. They have confirmed that another bore will be drilled for monitoring purposes into the deeper groundwater system, and this will bore will be located to the northeast of the existing position of GW1 along Big Stone Road.
- The monitoring of the shallow groundwater system at GW3 would better represent the immediate groundwater quality downgradient of the landfill. There was discussion about the drilling of another shallow monitoring bore downslope of GW2 to better capture the shallow groundwater quality immediately below the landfill, although the outcome of this discussion was not entirely clear.
- The location of GW5 is selected to monitor the effects on the wetland which supports the Ōtokia stream.
- Monitoring location GW7 is to monitor the groundwater quality in the subsoil drainage beneath the landfill.

Based on these discussions, the installation of another shallow bore downslope of GW2 and in line with the landfill toe would address the concerns regarding the shallow groundwater monitoring at GW2 and GW5. The drilling of another deeper bore along Big Stone Road bore is essential for monitoring of the downgradient deeper groundwater system.

74 In general, there is some residual uncertainty with some groundwater aspects. The absence of information of the shallow groundwater conditions in the centre of the landfill footprint presents an uncertainty in being able to assess the effects of the landfill and the potential for contamination to reach the groundwater beneath the landfill.

Proposed Conditions

75 The proposed consent conditions and updates of 18 March 2022 have been reviewed and are broadly appropriate subject to some refinement to address specific matters relating to the monitoring wells.

76 Based on our comments in paragraphs 74 and 75, Condition 22 should be repeated to reflect the drilling of one additional monitoring bore on Big Stone Road and one additional

monitoring bore downgradient of GW2. The proposed conditions should be worded as such to reflect the shallow/deeper groundwater systems for each additional bore such as:

> *An additional groundwater monitoring well at location XXX as shown on drawing 12506381-C309 shall be installed at least 18 months prior to construction of the landfill to enable collection of baseline groundwater level and groundwater quality data and monitoring for leachate contamination of groundwater during operation. The additional well at XXXX shall be installed to monitor the shallow/deep groundwater system [select appropriate system] with a screen between XXX and XXX m RL and shall be constructed in accordance with NZ4411:2001 Environmental Standard for Drilling of Soil and Rock.*

77 In addition to the above paragraphs, a new condition is proposed to include the ongoing monitoring of groundwater levels and groundwater quality at BH301 during the pre-construction monitoring to obtain further groundwater information within the landfill footprint. The frequency of the groundwater monitoring shall be the same as the other monitoring bores and for the same water quality parameters as identified in Attachment 1 (including the proposed amendments).

78 In addition to the above paragraphs, a new condition is proposed to include the monitoring of rainfall data at the site over the same pre-construction period (18 months) as for the groundwater monitoring. On site rainfall data shall be compared with the groundwater level data at each monitoring bore to identify when recharge from rainfall occurs on the groundwater levels.

79 Condition 23 to be updated to include the additional monitoring bores described in paragraph 77.

80 Condition 24 is supported in principle but with the amendment to monthly monitoring of groundwater quality.

81 Attachment 1 (first referred to in Condition 24) is not well developed and this needs to include units of measurement and to specify whether it refers to the total fraction or dissolved fraction of specific parameters. Some key parameters such as Total Organic Carbon, Total Kjeldahl Nitrogen, Total Phosphorus should be included.

82 It is expected (in Condition 25) that specific trigger levels will be developed for each monitoring parameter and monitoring bore due to the variation in the groundwater quality between the shallow and deeper groundwater systems.

83 Condition 26 is supported in principle with the following addition:

> *26 c. Protection of the receiving environment downstream **and downgradient** of the landfill by ensuring that the landfill does not have an adverse effect on water quality when compared with the current regime.*

84 The trigger levels need to be developed in a manner that is protective of the values in the receiving environment, rather than the context of the current regime.

Conclusion

85 As the information currently stands, we consider that some uncertainty remains with the conceptual hydrogeology model and there is a gap in knowledge.

86 Whilst, we have doubts on the efficacy of the low permeability stratum acting as a barrier between the shallow and deeper groundwater systems, we acknowledge that the potential for contaminant movement to occur into the deeper groundwater system from the landfill is low due to the intact nature of the Henley Breccia and the preferential horizontal flow paths.

87 However, we are not clear on the shallow groundwater system, such as the depth to groundwater particularly over the south-eastern part of the landfill footprint and on the sides of the valley. Based on the existing data, this means that there is uncertainty on whether the

effects of contamination from the landfill would be minor or less than minor on the shallow groundwater system.

88 Further information on the presence or absence of shallow groundwater above the low permeability stratum within the landfill footprint in areas where no investigations have been undertaken would help to understand the potential effects of the landfill on the shallow groundwater system.

89 The implementation of the above paragraph, combined with further development of the proposed consent conditions would provide a greater confidence on the potential effects of the landfill on the groundwater systems as a minor effect is likely. This would be in addition to the residual potential effects of the landfill development being appropriately managed through the proposed conditions of consent.

Applicability

This Report been prepared for the exclusive use of our client Otago Regional Council , with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Tonkin & Taylor Ltd

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