Report

30 January 2026

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From	GHD	**Project No.**	12645246
Project Name	Shotover WWTP Disposal Field Alternative Discharge		
Subject	Shotover Dose and Drain (DAD) assessment		

1. Executive summary

Queenstown Lakes District Council (QLDC) engaged GHD to assess the performance, failures, and future feasibility of using the Shotover Dose and Drain (DAD) disposal field, which operated between 2019 and April 2025, for the discharge of treated wastewater to ground. The DAD was intended to provide an alternative to a direct river discharge but experienced significant operational issues, leading to overflows, ongoing environmental effects, and enforcement action by the Environment Court.

This assessment aims to:

– Understand the causes of DAD failure.

– Characterise the likely capacity for discharge to ground and groundwater on the Shotover delta.

– Evaluate whether the DAD system could be remediated and reused in the future.

This was informed by extensive monitoring, recent field investigations (2025), and a review of historical data.

Key Findings

1. DAD remediation and infiltration

The DADs gravel media became clogged by biological growth and suspended solids. This reduced infiltration capacity and caused wastewater mounding within the disposal field. Remediation of the DAD is possible with removal of all impacted materials and aquifer material. Similarly, re-siting of the DAD is possible and not dissimilar to rapid infiltration options on the delta, considered for long term wastewater disposal. Improved and design is expected to mitigate the potential for future clogging.

2. Geological Variability

The delta contains interbedded layers of fine sands and silts that restrict vertical flow and limit the effectiveness of infiltration-based disposal. Historical investigations for the DAD design lacked the seasonal and spatial detail needed to identify these constraints.

3. Aquifer and Groundwater Constraints

Investigations confirmed that groundwater beneath the delta is shallow and highly responsive to river flows, with levels frequently reaching or exceeding ground surface during spring and high-flow periods. These conditions limit the aquifers capacity to receive applied wastewater and has resulted in persistent ponding and wastewater breakout downgradient of the DAD. The available capacity significantly decreases with higher groundwater / river levels, to point where wastewater discharge to ground via the DAD is unlikely to be feasible for extended periods during spring and/or other high flow periods.

4. Environmental Impacts

Monitoring showed elevated ammoniacal nitrogen in groundwater downgradient of the DAD, with levels comparable to treated wastewater. These contaminants are discharged to both the Shotover and Kawarau Rivers, causing relatively high nutrient concentrations in water at the riverbank. Minimal in-ground treatment of wastewater is being achieved and discharge of impacted groundwater from the DAD operation will continue to have effects to river water quality for an extended period of time.

Conclusions

The assessment concludes that the Shotover delta environment is unsuitable for continuous sub-surface wastewater disposal using the DAD approach. While there is potential to remediate the DAD and achieve partial discharge of wastewater to ground via the DAD, potentially in the order of 3,000 to 5,000 m^3/day, this capacity is expected to be seasonally limited by groundwater levels. The combination of shallow groundwater, limited aquifer capacity, clogging risks, and poor attenuation means the DAD cannot operate reliably as a full-time solution without causing surface breakout.

Given the scale of the constraints, an alternate long-term wastewater management solution is considered to be required to provide a sustainable wastewater disposal solution in the long term.

Where an alternate method includes discharge to surface water, remediation and use of the DAD or similar ground disposal infrastructure during periods of low river flow may assist to manage risks to surface water quality. Such dual discharge schemes can also assist in achieving a higher level of dilution under the Wastewater Environmental Performance Standards (WEPS), and potentially reduce the need for improved wastewater treatment.

Recommendations

Should QLDC want to further consider remediation and/or re-use of the DAD, the following is recommended to support cost estimation and decision making:

- Detailed investigation of ground conditions beneath and in the immediate vicinity of the DAD, to understand the extent and nature of any remedial activities.
- Comprehensive aquifer testing, including pumping tests to confirm aquifer conditions.
- Comprehensive 3D groundwater modelling to refine the understanding of appropriate discharge regime and appropriate configuration/orientation of the disposal structure.
- Undertake column testing of wastewater application to determine treatment level requirements to reduce clogging potential and long term operability needs, such as field rest periods.
- Undertake land class characterisation for the DAD operation to confirm requirements under the Water Services act, 2025.

2. Introduction

Queenstown Lakes District Council (QLDC) engaged GHD limited (GHD) to undertake a review of the Dose and Drain (DAD) field used to discharge treated wastewater to ground from 2019 until 1 April 2025. The DAD experienced significant issues within the first two years of operation, with overflows, ponding and uncontrolled discharges. A number of reports have been written looking at the causes (QLDC 2021, Beca, 2023), however these reports relied only on observations of overflows and limited site investigations undertaken as part of the DAD consenting process.

GHD completed site investigations on the delta in around the DAD in March and April 2025. These investigations were completed to:

- Provide supporting information for the short-term river discharge consent application.
- Characterise the groundwater and surface water environment on the delta and the effect of the DAD discharges on these in response to the Environment Court enforcement order.
- Characterise the delta conditions and inform the design of potential long term discharge options on the delta.

Groundwater and surface water monitoring has been undertaken since April 2025. This report provides a review of the monitoring data, GHD site investigations and historical investigations, to understand the reasons for the DAD failure and whether it can be remediated for future use.

2.1 Background

The Shotover Wastewater Treatment Plant (WWTP) was originally constructed in 1974, to treat wastewater for the wider Queenstown area with a basic inlet works channel and three oxidation ponds. The plant has been upgraded significantly over time to both improve plant infrastructure, treatment and allow for the plant to cater for population growth in the Wakatipu Basin.

Discharge of treated wastewater from the WWTP up until 2019 was via open channels to the Shotover River. Discharge of wastewater to ground, rather than direct discharge to river, commenced in 2019 with the commissioning of the Dose and Drain (DAD) field as part of the Stage 2 upgrades. The DAD field was constructed as a series of buried, gravel filled linear basket structures containing perforated pipes. The DAD field was excavated into the natural alluvial gravels and built up (1-2 m) above the river delta.

Operation of the DAD constituted flooding (dosing) of the gravels and allowing the treated wastewater to soak (drain) into the underlying gravels and into the shallow groundwater system. Groundwater flow from the area influenced by the DAD predominantly flows towards the Kawarau River.

2.2 Purpose of this report

This assessment aims to:

- Understand the causes of DAD failure.
- Characterise the likely capacity for discharge to ground and groundwater on the Shotover delta.
- Evaluate whether the DAD system could be remediated and reused in the future.

The purpose of the report is to present the findings of this assessment for consideration of the future use of the DAD as part of Shotover WWTP wastewater management infrastructure.

2.3 Limitations

This report: has been prepared by GHD for Queenstown Lakes District Council and may only be used and relied on by Queenstown Lakes District Council for the purpose agreed between GHD and Queenstown Lakes District Council as set out in section 2.2 of this report.

GHD otherwise disclaims responsibility to any person other than Queenstown Lakes District Council arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer section(s) 2.4 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

Accessibility of documents

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

GHD has prepared this report on the basis of information provided by Queenstown Lakes District Council and others who provided information to GHD (including Government authorities)], which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

2.4 Assumptions

We have assumed that the information obtained from GHD site investigations and monitoring, historical investigations and consent applications are representative of the site conditions.

2.5 Assessments completed

Numerous studies preceded the design and construction of the DAD, including consideration of alternate approaches for disposal to the Shotover delta. The performance of the DAD has also been previously reviewed. These reports and investigations are summarised below:

- Initial investigations and design of DAD:
  - Duffill Watts Consulting Group 2008 – test pits and infiltration tests
  - Lowe 2016a: Review of existing information and consent scoping
  - Lowe. 2016b. Shotover Wastewater treatment plant - Variation to discharge of treated sewage to land and landuse consent conditions and assessment of environmental effects.
- Review of WWTP and DAD field:
  - Beca. 2023(a). Shotover WWTP Disposal 'Full' Sizing, and Long List for Medium-Term Options.
  - Beca. 2023(b). Shotover WWTP disposal field report - assistance with remedial works.
  - QLDC/Veolia 2024: Shotover WWTP 2023 Annual Report
- Documentation and conferencing associated with ORC enforcement order
- GHD (2025) Project inception and gap analysis report
- Current investigations to support understanding of effects of disposal to the delta and to define the current environmental conditions on and around the Shotover delta (April 2025), includes:
  - Test pit investigation and collection of bulk samples for Particle Size Distribution analysis
  - Bore hole investigation and installation of groundwater piezometers
  - Hydraulic conductivity testing (April 2025)
  - Groundwater level monitoring (April 2025 -ongoing)
  - Groundwater quality (April 2025 – ongoing)
  - Surface water quality in the Kawarau and Shotover Rivers (March 2025 – ongoing)
- The ongoing monitoring programme is documented in Receiving Environment Monitoring Plan (REMP) prepared in response to the enforcement order.

2.5.1 Initial investigations (2016 and earlier)

Site investigations undertaken prior to the 2016 consent application included the following:

- Short duration aquifer test of shallow river gravels and groundwater monitoring (2 wells) for 3 months (Duffill Watts, 2008) – test data and full monitoring data set not sighted by GHD.
- Test pitting and infiltration tests around the lower delta (Duffill Watts, 2008) as shown in Figure 1.
- Soil sampling and analysis (particle size and hydraulic conductivity) (CPG, 2010, data not sighted by GHD).
- Test pitting and soil sampling within and around the DAD (LEI, 2016b).

Figure 1 Shotover Delta Test Pit and Infiltration Test Location Plan (From Duffill Watts, 2008)

A number of the reports were viewed without appendices, therefore key data, location plans and other information was not always sighted by GHD.

The previous investigations focussed primarily on the shallow soil profile, with test pitting and collection of soil samples for particle size distribution (PSD) or surface infiltration tests. LEI used a correlation developed by CPG data, which compared PSD results, against laboratory derived hydraulic conductivity, to estimate the hydraulic conductivity of the delta gravels. Unfortunately, the appendices to the CPG (2008) were missing from the report provided to GHD and the laboratory reports were not sighted. However, in our experience laboratory derived hydraulic conductivity data is often not representative of the in-situ conditions.

A short duration (2 hour) pumping test was undertaken by Duffill Watts (2008) with a test well in the shallow gravels (to 4.5 m) tested at 2.5 and 3.3 L/s. Groundwater monitoring is also included in this report with water level data for three wells covering the period 4 December 2007 to 11 January 2008 (Dufill Watts, 2008) (Figure 2).

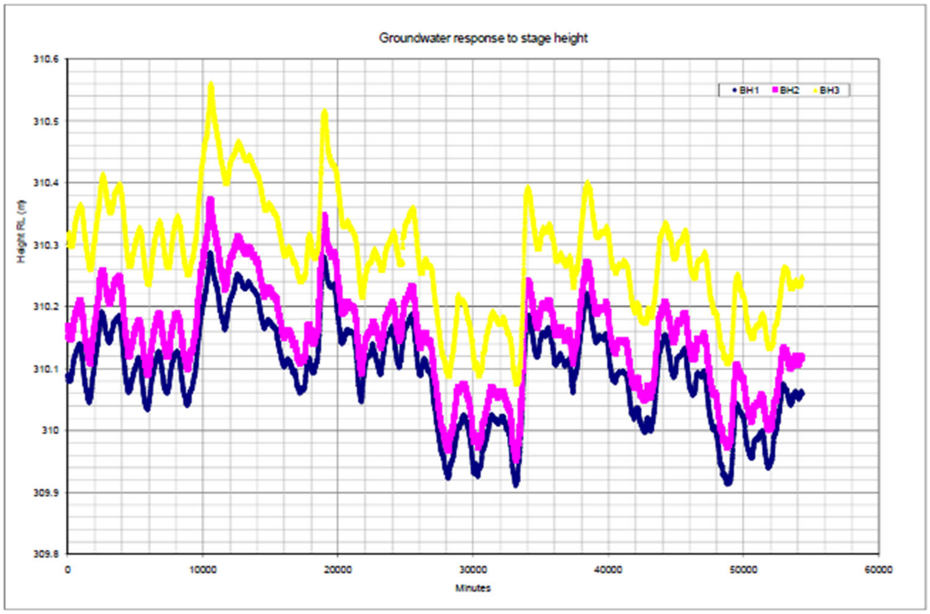

Figure 2 Groundwater monitoring Dec 2007 to Jan 2008 (Touch Water, 2008, included Appendix D of Duffill Watts 2008)

Groundwater monitoring was also undertaken from November 2013 to February 2014 at monitoring wells on the upstream end of the oxidation ponds (Groundwater Services, 2014). This report describes a visual correlation to river flows (at the time of writing the river data was not available), with prediction that groundwater levels may rise by 1.2 m should a flood event the similar to size of 1978 flood occur (approximately 1% AEP).

Based on the information reviewed, it appears that no long-term groundwater monitoring (covering the full seasonal range) was undertaken prior to the DAD construction and operation. Seasonal groundwater fluctuation is discussed further in later sections.

3. Disposal field operational issues

3.1 Overview

The DAD was commissioned in early 2019 as part of the Stage 2 upgrades. The field received treated wastewater from both the MLE/Clarifier process train (~80%) and oxidation ponds process (~20%) via UV treatment. The original design comprised a series of buried, linear basket structures within a raised gravel bed into which the treated wastewater was discharged. It is understood that underlying river delta gravels were excavated to a depth of 1-1.5 m below ground level to construct the disposal field.

Due to the ongoing disposal issues, the DAD was modified to a series of open infiltration ponds (approximately 2.5 m depth). Further modifications were undertaken in 2024, with a perimeter bund constructed to increase storage capacity, increase the hydraulic gradient for discharge to ground and prevent seepage through the perimeter (May 2024). An overflow pipe was also installed from the final cell to an adjacent pit, which then discharged to the delta, in order to reduce the risk of perimeter bund scouring and failure.

3.2 WWTP discharge quality

Discharge from the treatment plant (especially the pond stream) contains suspended solids that can, over time, block the pores in the gravel disposal field, reducing the capacity to receive discharge. In addition, biological growth occurred inside the DAD cells, reducing the ability of treated wastewater to discharge from the cells into the surrounding gravels.

In November 2023 and August 2024, there were issues with the operation of the WWTP resulting in effluent quality from the plant not achieving the quality parameters required under the resource consent for the discharge of treated wastewater to land. The followings Figure 3 and Figure 4 present the $cBOD_5$ and TSS data from 2023 to 2025, during which the operability of the DAD field declined. The ongoing accumulation of fine materials within the DAD and within the surrounding aquifer is likely to have been exacerbated by the periods of high TSS.

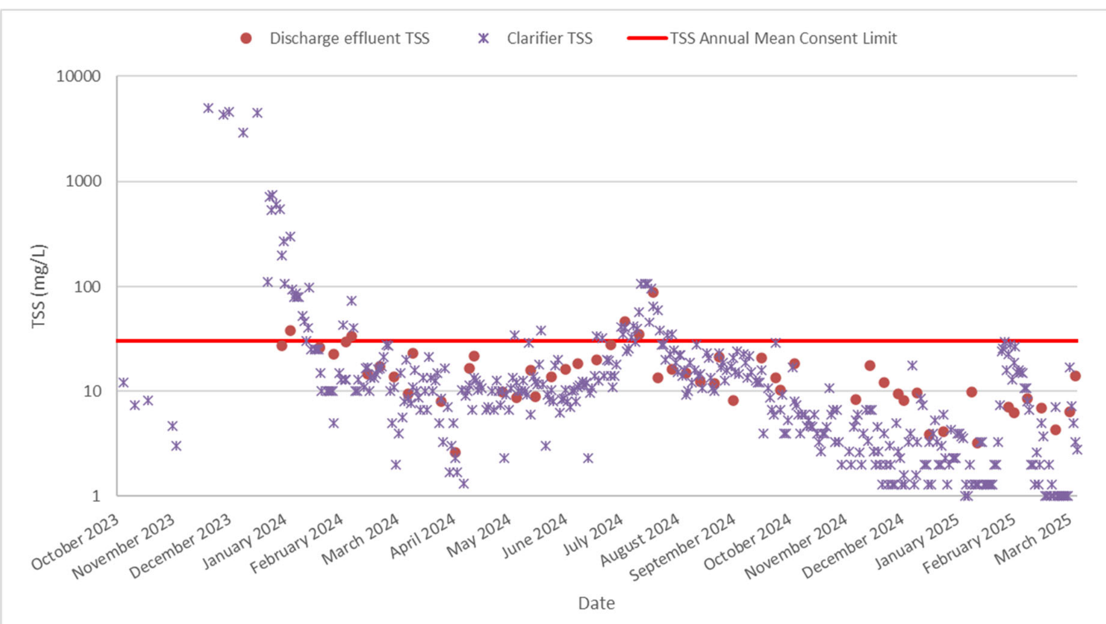

Figure 3 ***Treated wastewater quality – TSS (all sampling done by Eurofins)***

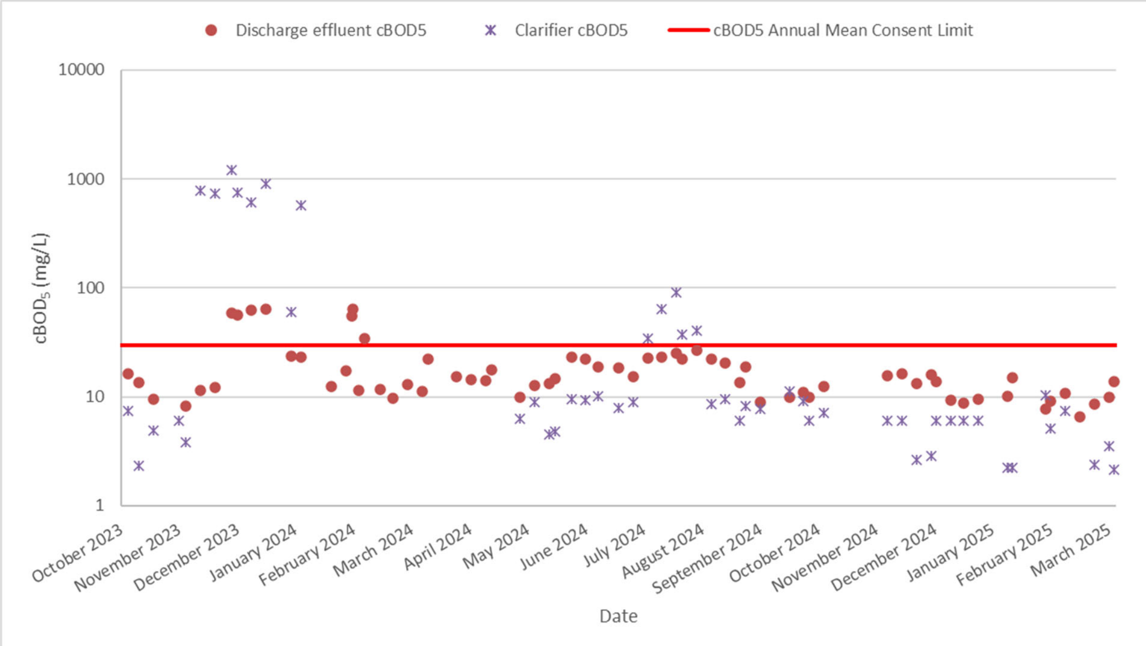

Figure 4 ***Treated wastewater quality – cBOD$_5$ (effluent sampling done by Eurofins, clarifier sampling done in-house)***

3.3 Compliance monitoring during DAD operation

The DAD discharge consent required water level and water quality monitoring of piezometers. The piezometers were installed around the perimeter of the disposal field, with two piezometers (ORC3 and ORC6) located in the middle of the DAD. Water levels were monitored via telemetry every 30 mins, with the collected data shown in Figure 5 and Figure 6. Anomalous value such as the sharp increase in February 2023 or values of 310 m RL (default system level) are considered to be erroneous.

Figure 5 shows water levels recorded over the first year of operation. Initially water levels fluctuated around a level of 310-311 mRL. It is assumed that water level peaks and recessions in the monitoring data follow river level fluctuations. Water levels increase from October 2019, likely related to seasonal high flows in the Shotover River. However, the elevated water levels are maintained throughout 2020-2021 (Figure 6) in some of the monitoring wells (in particular ORC3, in the centre of the DAD) possibly due to progressive clogging within the disposal field gravels and surrounding aquifer. In contrast monitoring wells at either end of the DAD (ORC1 and ORC8) continued to show seasonal fluctuations with water levels mirroring seasonal patterns in river levels.

Figure 7 shows the ammoniacal nitrogen concentration in the upgradient (ORC1), downgradient (ORC 8) and mid field (ORC3) piezometers. Ammoniacal Nitrogen is generally lowest in the upgradient piezometer (ORC1). Very high concentrations up to 156 g/m^3 were recorded in ORC8 in 2024. During this period the ammoniacal nitrogen concentration in the effluent averaged 19.8 g/m^3, double the long term average (2018-2024) of ~7.5 g/m^3.

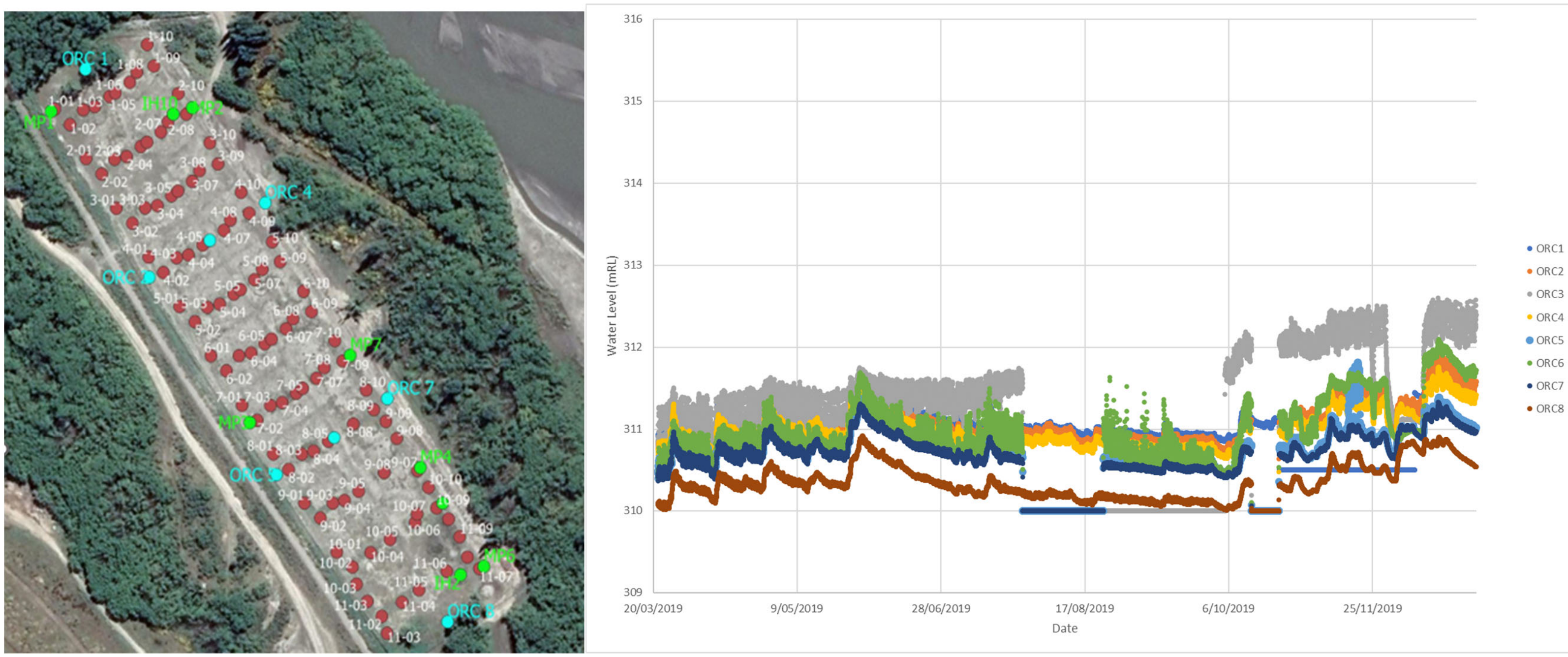

Figure 5 ***Water level monitoring in DAD piezometers - 2019***

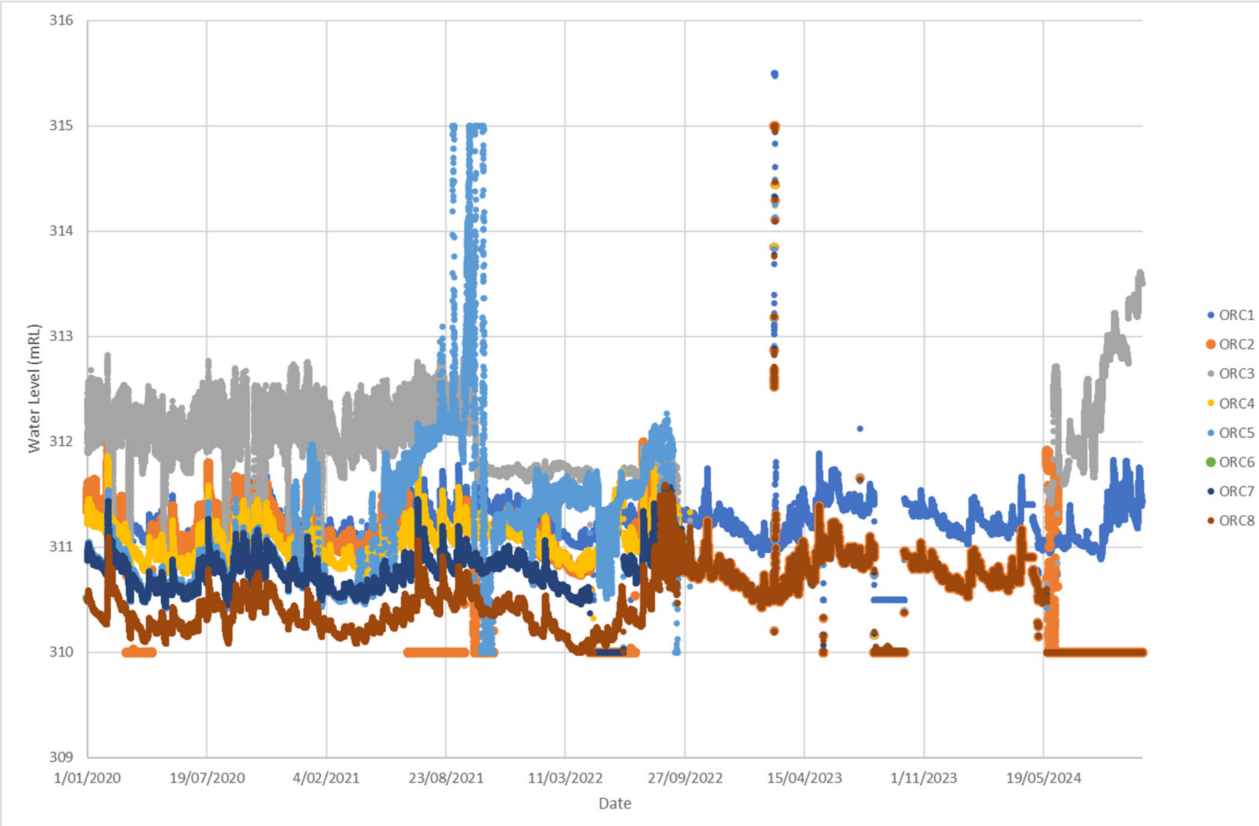

Figure 6 ***Water level monitoring in DAD piezometers – 2020-2024***

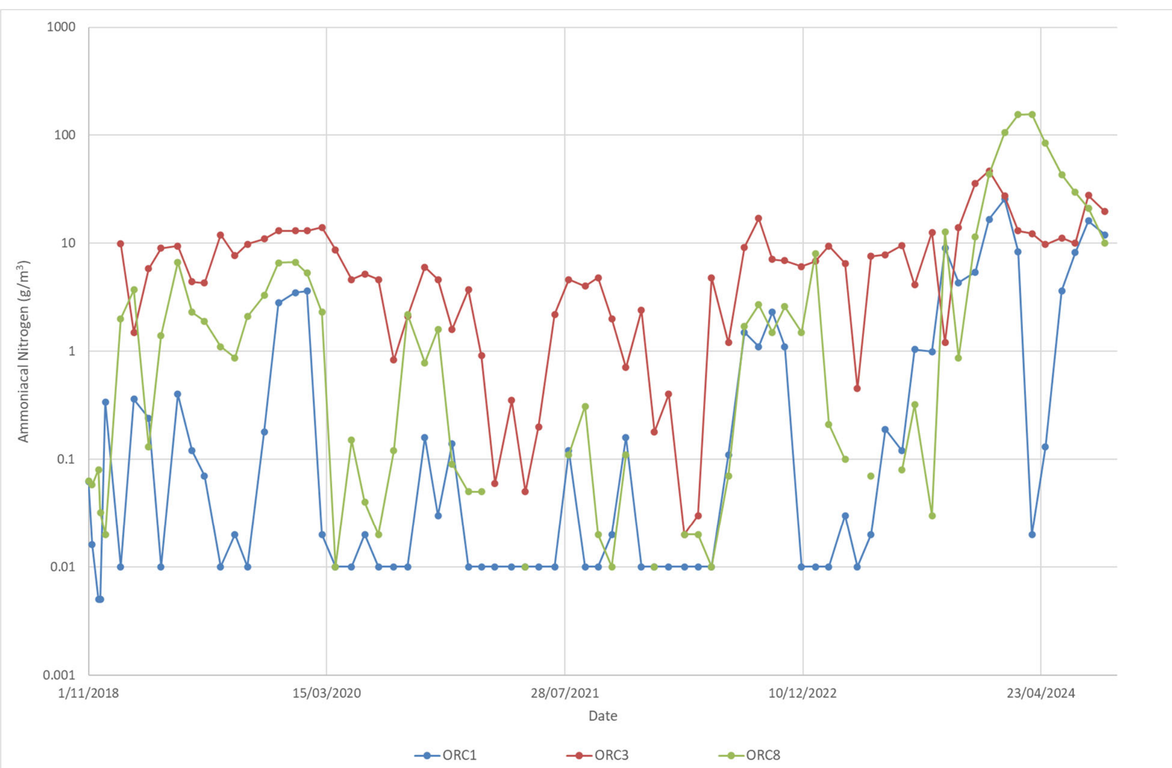

Figure 7 ***Ammoniacal Nitrogen concentration in DAD piezometers***

3.4 Summary and reasons for failure

Based on data reviewed, the primary reasons for the DAD failure are considered to relate to a combination of:

– Clogging of the disposal field media and underlying aquifer due to particulate material in the treated wastewater discharge and algal growth.

– Limited aquifer capacity to receive the treated wastewater, particular during periods of high river and groundwater levels.

Despite the ongoing issues, the DAD continued to operate until 2025, resulting uncontrolled ponding downgradient of the DAD. The limitations on aquifer capacity are discussed further in Section 4.

4. Shotover delta capacity for wastewater

4.1 Ponding observations

Occurrence of spring discharges immediately downgradient of the DAD, noted during site visits undertaken by GHD, indicate that the aquifer permeability was not sufficient to allow complete sub-surface flow of wastewater at the rates applied. The high wastewater level (elevation) within the DAD created steep hydraulic gradients, with the piezometric surface being greater than ground level. This was particularly evident during periods of high river and groundwater levels (spring and early summer).

A large area of ponded wastewater was present immediately downgradient of the DAD during GHD site visits in November 2024, December 2024 and March 2025. The approximate location is shown on Figure 8. The extent of ponding was greater during high river flows in spring. This is largely driven by river flood conditions raising groundwater levels in the delta gravels, with depressions and former river channels filling with river connected groundwater as shown in Figure 8. This aerial photo was captured in November 2025 several months after discharge to the DAD had been discontinued, however similar areas of ponding were observed in December 2024.

During low flow (river) conditions in March 2025, ponding was limited to the area immediately downgradient of DAD (Figure 9).

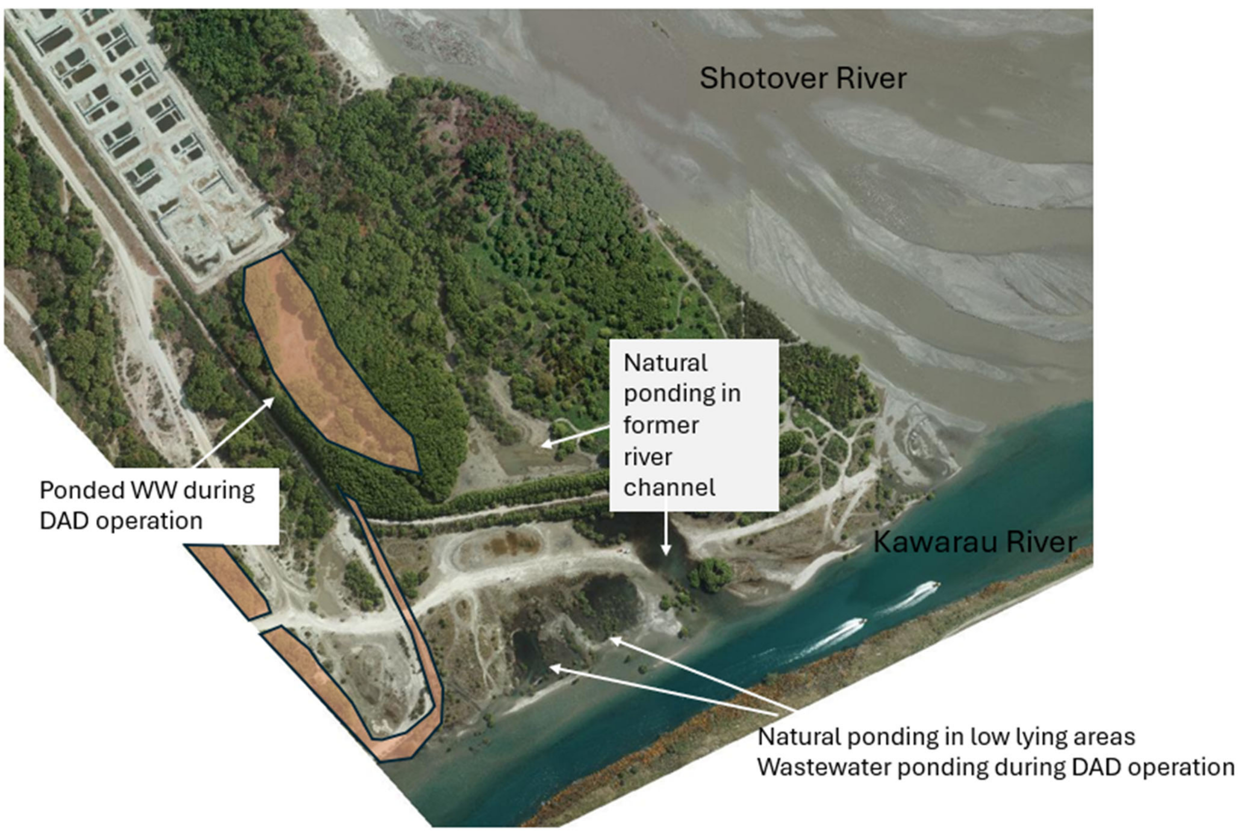

Figure 8 Aerial photograph of lower delta during high flow conditions (November 2025)

Figure 9 Residual ponding down gradient of DAD during low flow conditions (March 2025)

4.2 Aquifer setting

4.2.1 Geology

The Queenstown area is underlain by schist and semi-schist of the Torlesse and Caples supergroup. The schist forms the mountain ranges and high points (e.g. Morven Hill) in and around the Wakatipu Basin. The basin geology is influenced by multiple glacial advances, carving out the basin and leaving behind glacial sediments (till and outwash gravels) as the glaciers retreated.

Frankton flats and the Shotover Delta are underlain by recent (Holocene) alluvial and fan deposits, comprising unconsolidated gravel, sand and silt. The depth of the alluvium is unknown, with a 90 m deep bore hole drilled on the terrace (near 5 Mile development) not encountering basement schist (ORC, 2014).

Several investigations have been undertaken to understand the geology of the Shotover delta. These investigations were primarily undertaken to inform the design of the former disposal field. Recent investigations (2025) have been undertaken by GHD to provide a wider understanding of the geological variability across the delta. Investigation locations are included in Appendix A.

The geology underlying the delta is predominantly a gravelly fine to coarse sand or sandy gravel with some cobbles. The gravel is made up of subrounded to subangular schist fragments. However, there are lenses or layers with fine sand and silt. A geological cross section was created from borehole data extending from the top end (northwest) of the DAD to the Kawarau River (Figure 10). This section shows the following geological profile:

- Gravelly fine to coarse sand at surface extending for 1-2 m
- A layer of sandy gravel, ~1 to 2.5 m thick

- Gravelling fine to coarse sand extending to at least 20 m depth below ground level (based on the logs of IH2 and IH3)
- A fine silty sand is present near the Kawarau River (BH17 and 18) extending to at least 9 m depth. It is not known whether this sand continues deeper or is underlain by more permeable coarse sand or gravel.

The wider test pit and monitoring well investigation generally focussed on the shallow aquifer (to 3 m depth). In general most test pits were excavated into sandy gravel materials with the following exceptions:

- Gravelly fine to coarse sand to approximately to 2 m depth in TP12.
- A layer of fine to coarse sand (to 1.5-2.5 m depth) in TP18 and TP19
- A layer of fill material placed at the base of the terrace around TP01, TP02 and BH14

Bulk samples collected for particle size distribution (PSD) confirm the variability of the alluvium as shown in Figure 11.

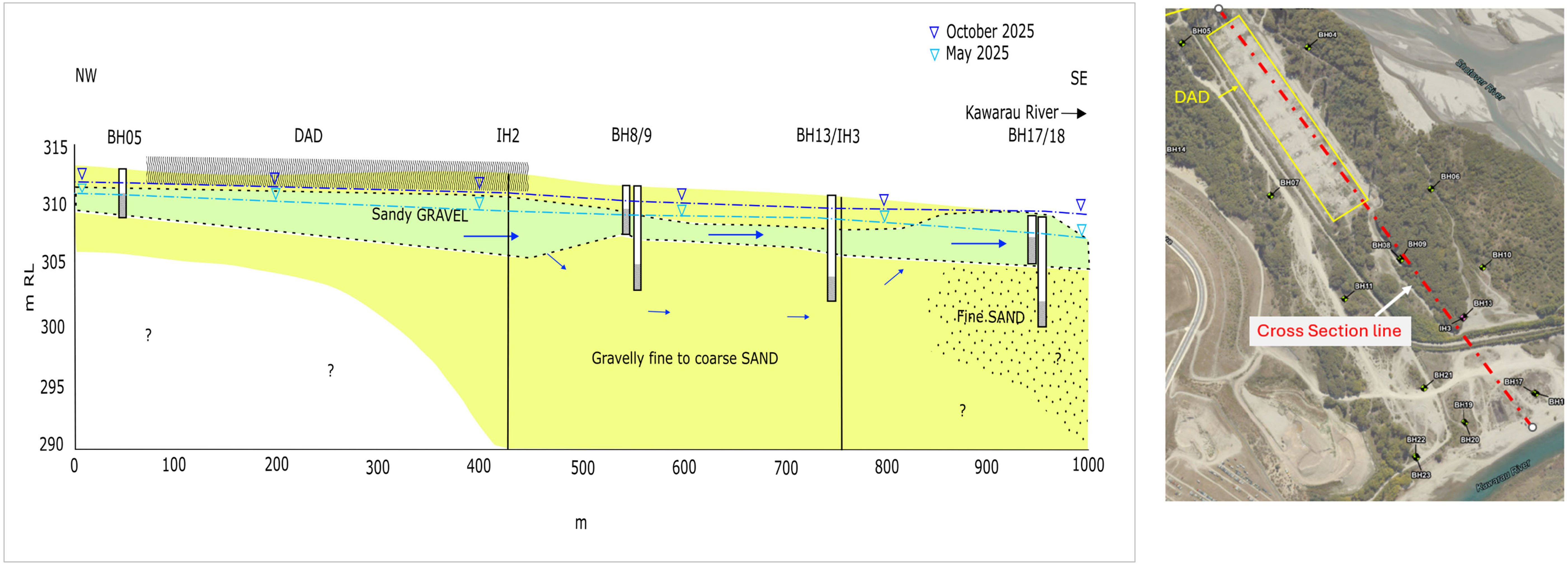

Figure 10	***Conceptual cross section***

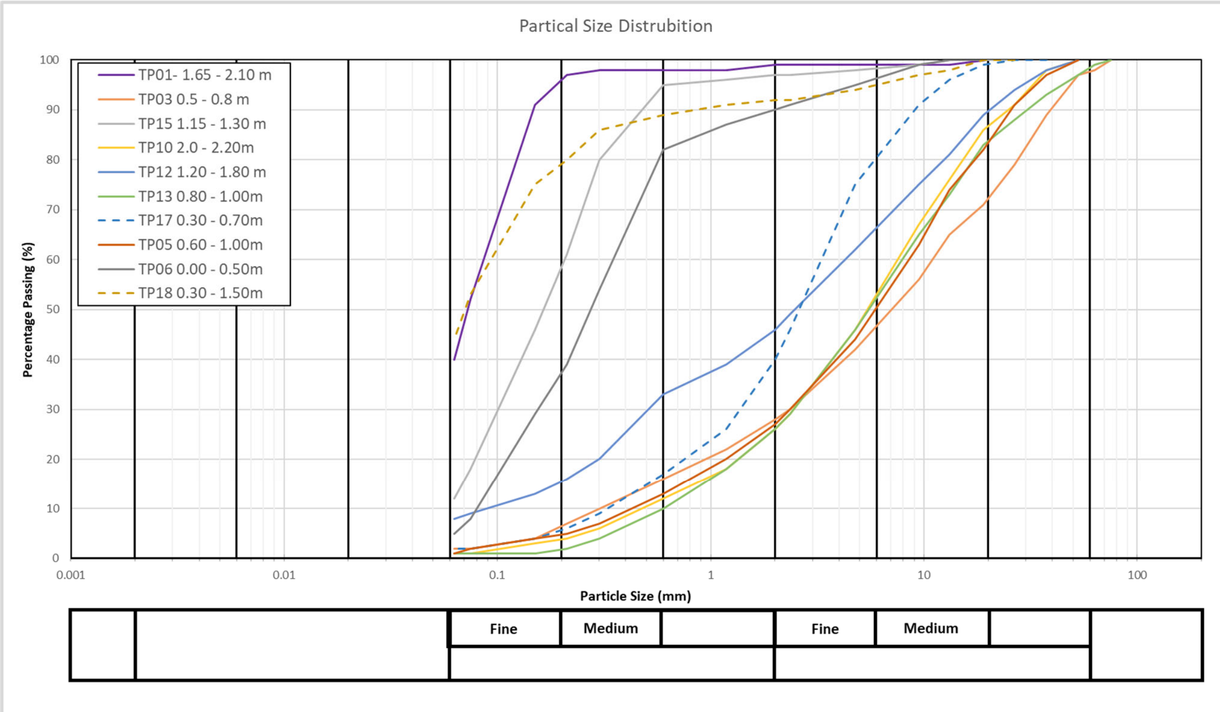

Figure 11 ***Particle size distribution of test pit samples collected during 2025 investigation***

4.2.2 Hydraulic properties

Hydraulic testing, comprising rising and falling head tests, of groundwater monitoring wells were carried out to provide an estimate of aquifer saturated hydraulic conductivity. This method is best suited to low to moderate permeability aquifers. In highly permeable aquifers the calculated hydraulic conductivity is often underestimated due to the rapid (near instantaneous) water level response. Testing of the sandy gravel indicates a hydraulic conductivity generally in excess of 1×10^{-3} m/s. There is an overlap between the hydraulic conductivity values for the sandy gravel and gravelly sand, reflecting the variability in the depositional setting and proportion of fine grained materials (sand/silt) within each layer. Summary hydraulic properties are included in Table 1.

Table 1 ***Summary hydraulic properties***

Material	Hydraulic conductivity (K)(m/s)	Comments
Sandy GRAVEL	$>1 \times 10^{-3}$	Most test results greater than 1×10^{-3} m/s with the exception of BH23 (3×10^{-4})
Gravelly SAND	2×10^{-4}	Average value from BH09 and BH13, BH01 higher K at 2×10^{-3}
Fine SAND	4.7×10^{-7}	Silty fine sand in BH18

The very high hydraulic conductivity in the sandy gravel is considered to reflect the potential horizontal hydraulic conductivity, rather than the potential infiltration rate. In contrast, testing of the fine sand deposits indicates a significantly lower permeability more consistent with a silty sand. The difference in permeability between materials is significant and layers or infilled zones of such fine grained materials may influence groundwater flow direction.

Previous investigations undertaken by LEI (2016) inferred a hydraulic conductivity of soils around the disposal field based on a grain size analysis of bulk samples from test pits. An average hydraulic conductivity of 30 m/day was estimated by LEI, equivalent to 3×10^{-4} m/s.

4.2.3 Groundwater levels

Groundwater levels have been measured since April 2025. Data loggers were installed in 15 wells and recorded water levels at 15 minute intervals. Groundwater levels are measured periodically in the remaining 7 wells.

Groundwater levels for shallow wells down gradient of the DAD are shown in Figure 12, however due to a blockage in the casing of IH3, the deep well (BH13) record is shown instead. The groundwater level data shows a strong correlation to river flow, with higher groundwater during high flow periods from mid September 2025 onwards. The highest mean daily flow of 338 m^3/s was on 23 October 2025, this flood event resulted in peak flows up to ~580 m^3/s (source ORC website[1]).

Table 2 Summary flow statistics Shotover River @ Bowens peak – 1 January to 12 December 2025 (source NIWA)

	Value (m^3/s)	Date
Maximum daily mean flow	338.19	23 October 2025
Minimum daily mean flow	9.65	16 March 2025
Median daily mean flow	22.30	-

Groundwater levels for May and October 2025 are shown on the cross section (Figure 10), with May representing average flow conditions and October representing high flow conditions. It is likely that the lower groundwater levels occurred in March 2025 (when Shotover River flow averaged at approximately 10 m^3/s) however the wells were not installed until April 2025. The groundwater data indicates:

– Groundwater levels between the DAD and Kawarau River are within 0.5 m or above ground surface for extended periods during spring. In addition, the groundwater level in BH17 was close to ground surface during relatively small flood events in May and June 2025.
– Groundwater level generally sits within the shallow sand layer, meaning that the (highly permeable) sandy gravel layer is fully saturated except during very low groundwater level periods.

The depositional environment is likely to have resulted in preferential groundwater flow paths with lenses and/or channels of higher permeability gravels and sands. In addition, the high groundwater levels and uneven topography, results in groundwater daylighting at surface in channels or depressions as shown in Figure 8 for extended periods.

[1] **Data - ORC Environmental Data Portal**

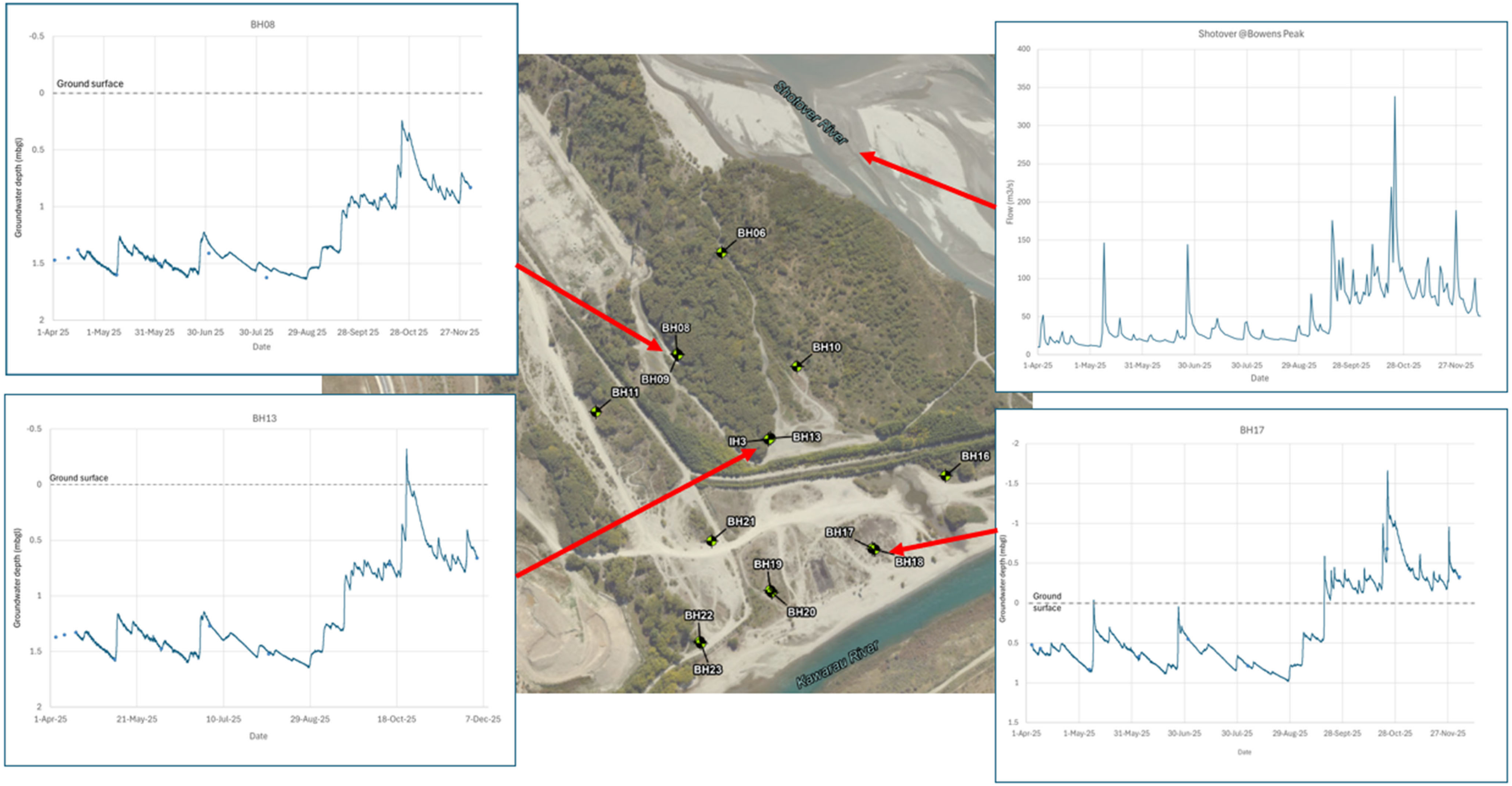

Figure 12 *Groundwater levels and river flow April to December 2025*

4.2.4 Groundwater flow direction

Wastewater discharged through the DAD is expected to flow generally towards the south to east, away from the DAD, discharging to the Kawarau and Shotover Rivers. Groundwater contours based on April 2025 water levels are shown in Figure 13. Seasonal variation in groundwater and river levels may locally influence groundwater flow direction, however the general flow direction is expected to be as shown in Figure 13.

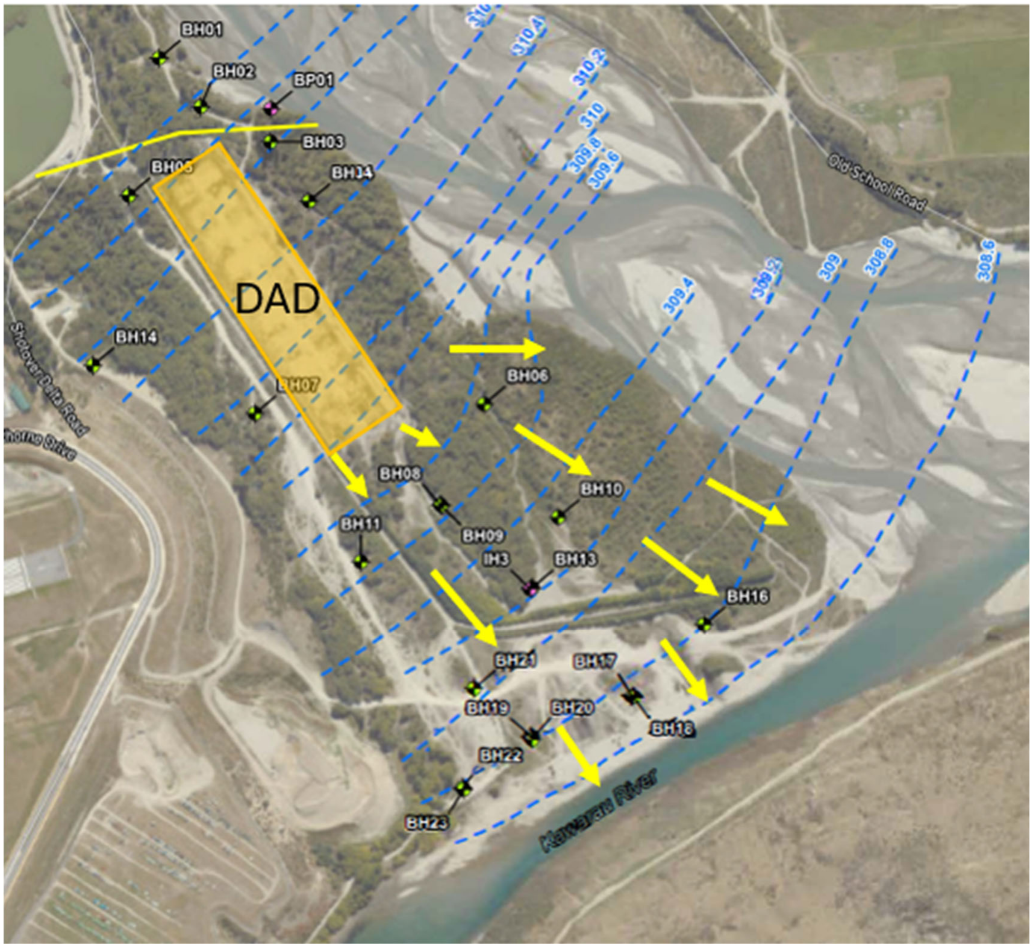

Figure 13 April 2025 groundwater contours, general groundwater flow direction downgradient of the DAD is shown by yellow arrows

4.3 Water quality

The routine compliance sampling (see section 3.3) focussed on piezometers within the DAD field only. Sampling of downgradient groundwater and surface water was not undertaken on a regular basis until 2025. GHD completed one surface water sampling round in March 2025 round prior to the discontinuation of the DAD discharge, these results and the ongoing monitoring are summarised in the following sections.

4.4 March 2025 sampling

The March 2025 sampling round was completed during low river flow conditions. Wastewater ponding was limited to the area immediately down gradient of the DAD (Figure 8). Sampling of the Kawarau and Shotover Rivers were completed to provide a baseline and understanding of the effects of the wastewater discharge. Shallow groundwater samples were also collected by digging a hole within the gravels on the Kawarau River frontage and collecting the seepage. The results are shown spatially in Figure 14, in summary:

– An increase in nutrient concentrations as the Kawarau River flowed past the Shotover Delta, with the highest concentrations in RS12 directly down gradient of the DAD.

– Nutrient concentrations were higher in the beach seepage samples.

The data suggests that wastewater impacted groundwater discharges to the river are having a measurable effect on nutrient concentrations of the Kawarau River at the riverbank, with this influence along the approximately 800 m length of the riverbank.

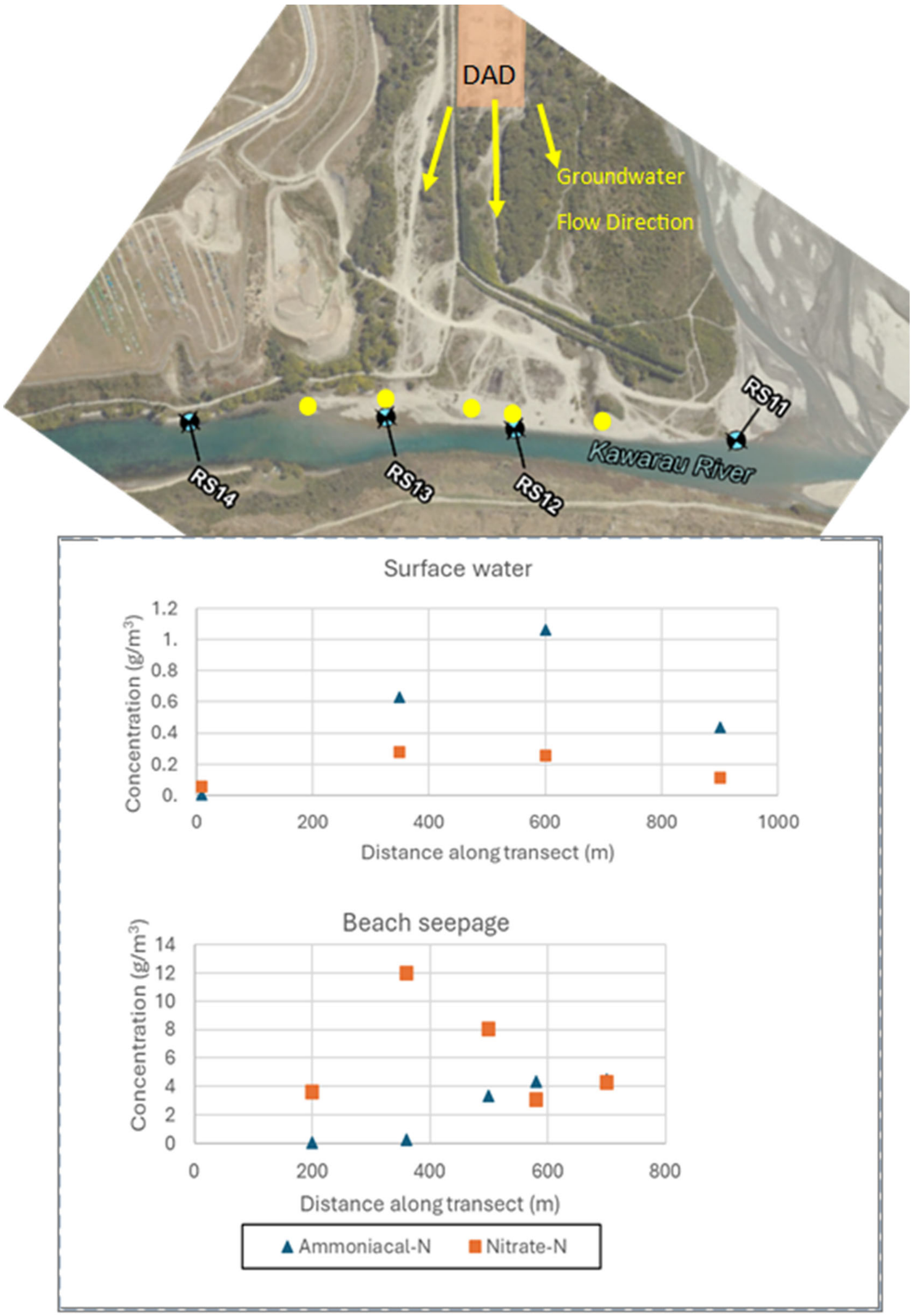

Figure 14 March 2025 sampling. Relative position of surface water samples (labelled on aerial) and seepage (yellow circles) line up to position on graphs

4.5 Ongoing monitoring of groundwater and surface water

Installation of groundwater monitoring wells in April 2025 allowed for characterisation of the groundwater environment in and around the Shotover delta. Groundwater wells were installed both up gradient and downgradient of the DAD, however the first monitoring round was only completed after the DAD discharge was discontinued. Water quality plots and a location plan are included in Appendix A with a selection shown below:

Figure 15 shows the groundwater quality directly downgradient from the DAD to the Kawarau River for wells shown on the cross section in Figure 10. The data shows

– Elevated ammoniacal-N downgradient of the DAD, with concentrations similar to the treated wastewater.

– Higher concentrations in shallow groundwater (BH08) compared to the deeper groundwater (BH09) immediately downgradient of the DAD (BH08 and BH09 are location adjacent to wastewater ponding area)

– Ammoniacal nitrogen at low concentrations (<0.2 g/m^3) in deeper down gradient wells (BH13 and BH18)

– Low nitrate nitrogen concentration in all wells (Figure 16)

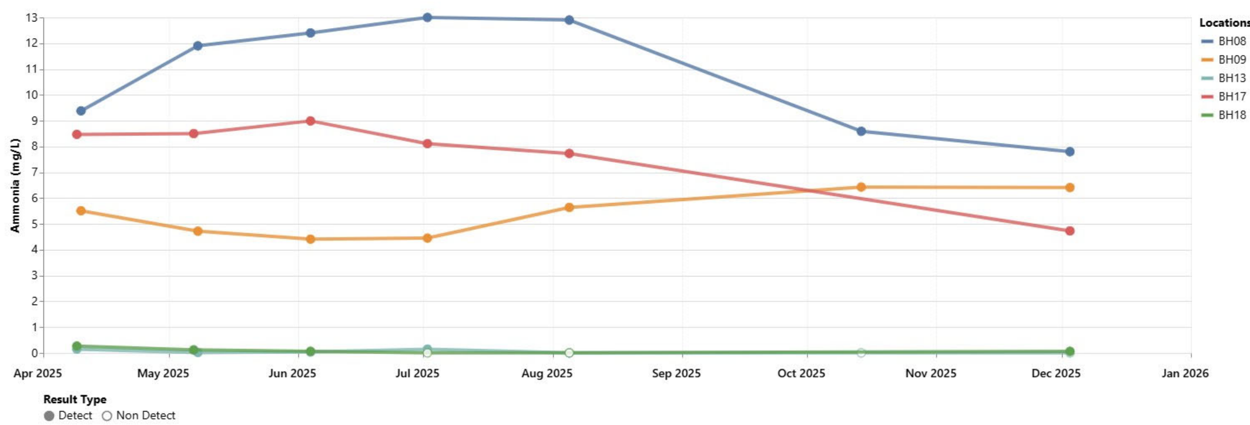

Figure 15 Ammoniacal-N concentration – transect from DAD to Kawarau River

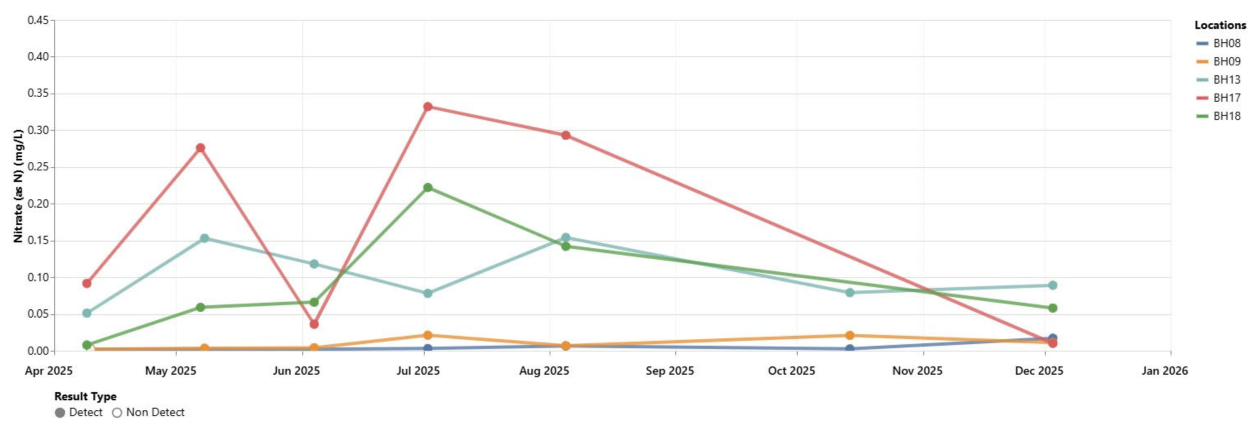

Figure 16 Nitrate-N concentration – transect from DAD to Kawarau River

Figure 17 shows the ammoniacal-N concentration in wells along the Kawarau River margin. Groundwater in these wells reflect the groundwater discharging to the Kawarau River. In summary:

– Ammoniacal- N concentration is highest in shallow monitoring wells directly downgradient of the DAD.

– Decreasing concentrations since June 2025, although this may be partially related to additional dilution during high flows in spring.

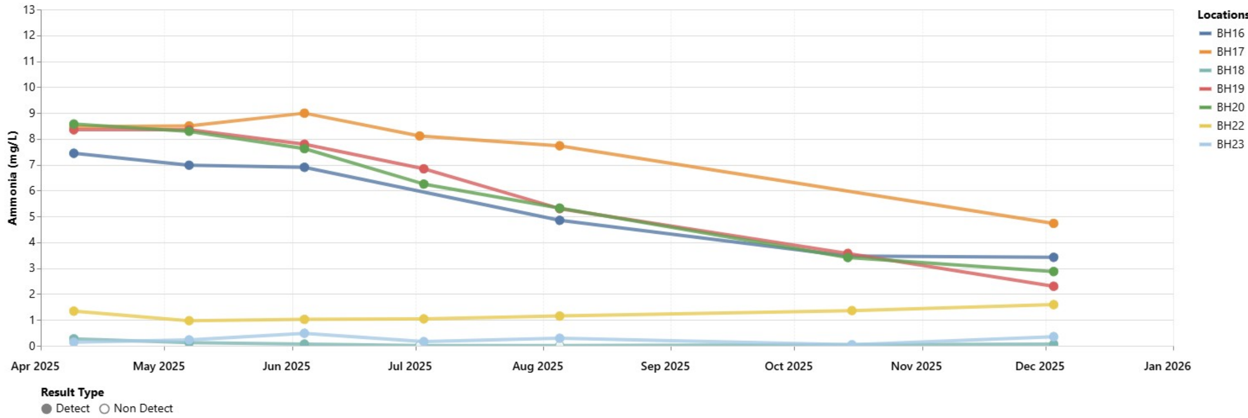

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Figure 17 Ammoniacal-N concentration – transect along Kawarau River frontage

The monitoring data indicates that there is a minimal in ground treatment of wastewater with elevated ammoniacal-N concentrations extensively present in downgradient groundwater and discharging to both the Shotover and Kawarau Rivers.

Similarly, while lower than treated wastewater applied to the DAD, phosphorous concentrations are elevated in groundwater discharging to the rivers. The lower concentrations (compared to the wastewater) indicate some degree of in-ground attenuation (Table 3).

Table 3 Average DRP – transect from DAD to Kawarau River compared to wastewater

Well	Depth (shallow or deep well)	Dissolved Reactive Phosphorous (DRP) g/m^3 Average April – December 2025
BH08	Shallow	0.672
BH09	Deep	0.004
BH13	Deep	0.009
BH17	Shallow	0.266
BH18	Deep	0.031
Wastewater	-	1.581

With the key nutrient parameters (in particular ammoniacal-N) in groundwater downgradient of the DAD generally consistent with treated wastewater, it is considered unlikely that the typical in-ground treatment benefits of disposal of wastewater to ground can be realised on the Shotover Delta.

5. Assessment

5.1 Introduction

The potential for sustainable discharge of wastewater to ground is typically constrained by the following:

1. The rate of infiltration to ground at the point of disposal, and potential for wastewater to mound on low permeability soil horizons.
2. The influence of disposal on groundwater levels and the capacity of the underlying aquifer to transmit and dissipate applied wastewater downgradient of the point of disposal.

3. The inground treatment of wastewater contaminants, and sensitivity of downgradient receptors to these contaminants (both environment and human receptors).

The design of the disposal scheme needs to respond to each of these, to ensure that effects can be adequately managed. In estimating the capacity of the DAD, each of these have been considered and are discussed below.

5.2 DAD wastewater infiltration constraints

The successful operation of the DAD for a period of time indicates that under optimal conditions, treated wastewater infiltration rates can be sufficiently high as to accommodate the rate applied. Infiltration testing carried out in previous assessments (LEI, 2016) indicated an average clean water infiltration rate within the footprint of the DAD in the order of 10 m/day. To allow for BOD and TSS in the discharge, the design flow rate was reduced by a factor of safety of 50% (LEI, 2016) to 5 m/day.

The accumulation of sediment from wastewater together with biological growth is considered to be the likely cause of reduced infiltration over time.

With remediation (such as with removal of affected media), it is assumed that the extent of existing clogging can be effectively removed, such that infiltration is unlikely to represent the primary constraint at the current disposal rates. The extent to which the sediment has impacted the aquifer beyond the DAD footprint is not known, with this a key uncertainty regarding the extent and ongoing cost of any remedial works. It is assumed that some degree of over-excavation of the DAD area would be required to remove the constraint on infiltration. With increasing population growth, it is expected that the disposal field would need to be upgraded and expanded to meet the capacity requirements, unless it is operated in combination with an alternate discharge (a dual discharge), such as a discharge to the Kawarau River.

5.3 Groundwater level and aquifer constraints

Groundwater level monitoring historically focussed on the influence of wastewater disposal in the immediate vicinity of the DAD and measured the local mounding of treated wastewater within the footprint of the DAD (Section 3.3). Observations made and monitoring of groundwater levels as part of the current investigations of the Shotover delta (Section 4.2.3), and subsequent to ceasing use of the DAD, have identified the following:

- Shallow groundwater levels across the extent of the delta.
- Seasonal fluctuation in groundwater levels, which frequently result in the occurrence of groundwater discharge to open drains and the ponding of water in lower lying areas. i.e. groundwater levels commonly exceed surface elevation in areas downgradient of the DAD.
- The limited potential for ponded wastewater to soak to ground in areas downgradient of the DAD.

These observations suggest that the capacity of the aquifer to accommodate soakage of treated wastewater to ground, without causing daylighting of treated wastewater on parts of the delta, is seasonally influenced, with greater capacity during periods of low groundwater levels (summer) and limited capacity during periods of high groundwater levels (typically spring).

To provide estimate of the available capacity in the aquifer downgradient of the DAD, a comparative analysis of impacts to groundwater levels was carried out using the following simplistic methods:

1. Analytical calculations (Darcy Law) analysis of groundwater flow.
2. 2D Numerical analysis of impacts to groundwater levels.

Given the spatial and subsurface context of the disposal and Shotover delta, each of these methods has notable limitations relating to approximation of groundwater flow, over a broad area. A comparison of predictions has been used to provide additional confidence in the aquifer capacity estimations. However, more refined analysis, such as using a 3D groundwater modelling methodology, and likely more extensive investigation of the delta, such as through pumping tests, are expected to be required to provide a more realistic representation of the aquifer and dissipation of wastewater.

5.3.1 Analytical calculations

A high level analytical assessment (Table 4) was undertaken based on Darcy flow equation,

$$Q = KiA$$

Where:

Q Groundwater flow

K Hydraulic conductivity of the aquifer

i Hydraulic gradient

A Area of the aquifer (width x thickness)

For this assessment, the following approach was undertaken:

– Estimate natural groundwater flow based on average groundwater level.
– Estimate total potential flow capacity in the aquifer.
– Subtract the natural groundwater flow from the total potential flow, with the remainder being available for wastewater discharge.

Table 4 Analytical calculations

	Existing groundwater	At potential capacity	Comments
Groundwater level at end of DAD (m RL)	309.65		~1.5 m bgl
Maximum groundwater level at end of DAD (m RL)		310.65	~0.5 m from ground surface
Kawarau River level (m RL)	308.5		Surveyed April 2025
Distance (m)	500		From end of DAD to Kawarau
Gradient	0.002	0.0048	
Cross sectional area (m^2)	6000		600 m width, 10 m aquifer thickness
Hydraulic conductivity (K) (m/day)	190		2.2 x 10^{-3} m/s (sandy gravel)
Flow (Q) – m^3/day	2600	5400	

The high level analytical assessment indicates that there is potential for a wastewater discharge of ~3000 m^3/day, however this assessment is based on average groundwater levels and average ground surface level. As such, capacity estimates would be significantly reduced during periods of high groundwater levels, and likely greater during low groundwater levels.

5.3.2 2D modelling

A two-dimensional finite element numerical model was developed using SEEP/W and utilised to simulate the groundwater conditions and estimate the volume of wastewater that could be discharged to the aquifer. For this assessment, an axisymmetric model rotated around a 90° angle was adopted to simulate the aquifer down gradient of the DAD. This approach allows for radial dissipation of wastewater away from the DAD.

The model geology was adopted from the cross section shown in Figure 10 and represents the geology encountered in the centre of the model “wedge”. While this simplification may not reflect the localised channels and geological variability within the alluvial sediments, it is considered representative of the typical geological profile in this area. The size of the DAD in the model has been adjusted to be representative the actual discharge area (due to the model geometry).

Model details are summarised in Table 5. Hydraulic properties are summarised in Table 6. The adopted properties are based on site investigation data (see section 4.2.2). The hydraulic conductivity of the DAD fill material reflects a degree of clogging inherent with wastewater discharge.

The modelling approach comprised

– Simulation of aquifer without DAD discharges (base case model). Calibration of model to approximate groundwater level recorded at BH8 by adjusting upgradient head boundary.
– Conversion of upgradient head boundary to flow boundary using the groundwater flow rate extracted from the base case model.
– Application of recharge flux (wastewater) to DAD, recharge rate was adjusted to maximise discharge without resulting in downgradient ponding.

Table 5 SEEP/W Model set up

Parameter	Adopted properties and values	Comments
Model type	Two dimensional, axisymmetric - 90° rotation	Model “wedge” reflects the downgradient dispersal of wastewater.
Upgradient boundary	Flux -90 L/s	Calibrated to achieve measured groundwater levels downgradient of the DAD.
Downgradient boundary	Total head representing approximate Kawarau River level	
Wastewater flux	1.7×10^{-6} $m^3/s/m$	Adjusted to maximise discharge without inducing ponding in downgradient areas.

Table 6 SEEP/W model hydraulic properties

	Material	Material model	Water content function	Hydraulic conductivity Kx (m/s)	Ky/Kx
	Coarse sand	Saturated/unsaturated	Sand	4.0×10^{-4}	1
	Fine sand	Saturated only	-	4.7×10^{-7}	1
	Sandy Gravel	Saturated/unsaturated	Sand	3.0×10^{-3}	1
	DAD fill	Saturated/unsaturated	Sand	5.0×10^{-3}	1

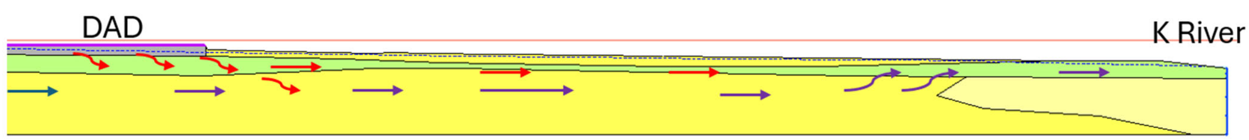

Figure 18 Model layout with indicative groundwater flow paths

The results of the modelling indicate a potential wastewater discharge rate in the order of approximately 5,000 m^3/day. This value represents the potential discharge rate at average to low groundwater levels, while avoiding downgradient surface breakout (ponding) of applied wastewater. A simulation was not undertaken to reflect high groundwater level periods (spring) as natural ponding already occurs due to high river levels, therefore it is considered that there is no capacity for wastewater during these periods.

5.3.3 Summary

The high level analytical and modelling assessments suggest that there is limited capacity in the aquifer for wastewater discharge. The estimated capacity is in the order of 3,000 to 5,000 m^3/day, this volume is consistent with minimum - very low daily wastewater loads. The available capacity significantly decreases with higher groundwater / river levels, to point where wastewater discharge to ground via the DAD is unlikely to be feasible for extended periods during spring and/or other high flow periods.

5.4 Water quality constraints

The DAD operation represents a high rate infiltration method under the Water Services Act 2025, with the site expected to be classified as Site Category 5, due to a shallow water table and periods of prolonged soil saturation. Discharge to such sites is an exception to the wastewater environmental performance standards under Clause 87 of the Act. It therefore likely that assessment of the effects of the DAD discharge to groundwater and into the Kawarau and Lower Shotover River, would likely need to consider:

– Effect on environmental receptors and ecological outcomes, including assessment of periphyton growth at the riverbank
– Effect on recreational users and human health risk

The groundwater quality monitoring data collected to date indicates that little to no in-ground nutrient treatment of wastewater contaminants is occurring as the wastewater moves through the DAD and through groundwater. This is resulting in downgradient groundwater having nutrients concentrations (in particular ammoniacal-N) at similar concentrations to treated wastewater being applied to the DAD. Some degree of bacterial die-off does appear to be occurring in-ground.

The discharge is having a measurable effect on shallow riverbank waters of the Kawarau and Shotover Rivers, quality across a wide extent of the delta. Such waters are particularly sensitive to groundwater discharges due to the initially limited extent of mixing groundwater receives. It is considered likely that the effects of the DAD discharge on river water quality are greater than was anticipated at the time of consenting of the discharge.

While water quality effects measured to over the period of river bank monitoring do not reflect the improvements in WWTP treatment that have been realised since cessation of DAD operation, the potential effects to river bank water quality remains as a potential constraint on the volume of treated wastewater that may be discharged via a remediated DAD or on the level of treatment this wastewater may require.

6. Conclusions

This review has highlighted the influence of seasonal variability in the river flow on groundwater levels of the Shotover delta and the impact of these on the potential for sustainable wastewater discharge to ground via the DAD. During high river flows in spring, groundwater levels rise close to or above ground surface in areas downgradient of the DAD, resulting in extensive ponding on the lower Shotover delta. During these high groundwater level periods, wastewater discharge via the DAD is unlikely to be possible without causing surface breakout of wastewater and further ponding.

During average flow/groundwater conditions, the high-level assessment indicates that there is potential for partial discharge of wastewater ground via the DAD in the order of 3,000 to 5,000 m^3/day. The actual volume that can be accommodated within the delta aquifer will vary as a function of conditions at the time. In comparison, the current daily average flows are approximately10,000 m^3/day, with this projected to increase with population growth.

In summary:

– Overflows and ponding of wastewater in the DAD is likely to have resulted from clogging of the soils and aquifer due to suspended sediment and nutrient loads. Remediation of the DAD would likely require removal of these clogged materials, following which it is likely that infiltration rates would be adequate to discharge volumes up to those rates previously discharged.
– Discharge to the DAD is considered to be feasible for only a portion of the wastewater discharge volume, due to downgradient aquifer capacity limitations.
– Discharge to the DAD is likely to be seasonally limited, with no aquifer capacity for an extended period in spring when groundwater levels are high.
– Operation of the DAD is likely to be an exception to the WEPS, with any consenting needed likely needing to be supported with a comprehensive assessment of effects. Water quality and ecology outcomes may then impact upon the acceptable discharge volume or level of treatment needed.

- Discharge to the DAD during periods of low river flow and low groundwater levels, as part of a dual discharge scheme together with discharge to the Kawarau River, may assist with reducing effects to surface water quality and potential treatment requirements for discharge to the river.

Should QLDC want to further consider remediation/re-use of the DAD, the following is recommended to support cost estimation and decision making:

- Detailed investigation of ground conditions beneath and in the immediate vicinity of the DAD, to understand the extent and nature of any remedial activities.
- Comprehensive aquifer testing, including pumping tests to confirm aquifer conditions.
- Comprehensive 3D groundwater modelling to refine the understanding of appropriate discharge regime and appropriate configuration/orientation of the disposal structure.
- Undertake column testing of wastewater application to determine treatment requirements to reduce clogging potential and long term operability needs, such as field rest periods.
- Undertake land class characterisation for the DAD operation to confirm requirements under the Water Services act, 2025.

7. References

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Appendices

Appendix A

Investigations site plan

Map Projection: Transverse Mercator
Horizontal Datum: NZGD 2000
Grid: NZGD 2000 New Zealand Transverse Mercator

GHD

Queenstown Lakes District Council
Short term discharge assessment

Investigation Plan - Groundwater and Test pits

Project No. **12645246**
Revision No. **0**
Date **28/04/2025**

FIGURE 3.7

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Print date: 28 Apr 2025 - 13:23

Data source: NZ - Imagery: Eagle Technology, Land Information New Zealand, GEBCO, Community maps contributors. Created by: nrama

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Document title	Report | Shotover Dose and Drain (DaD) assessment						
Project number	12645246						
File name	Shotover Dose and Drain (DaD) assessment						
Status Code	**Revision**	**Author**	**Reviewer**		**Approved for issue**		
			Name	**Signature**	**Name**	**Signature**	**Date**
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