



Remarkables Ski Area Upgrade and Doolans Expansion - Wastewater Discharge Impact Assessment

NZSki Remarkables

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**Remarkables Ski Area Upgrade And Doolans Expansion -
Wastewater Discharge Impact Assessment**

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Executive Summary

NZSki is seeking consent to increase wastewater volumes discharged to land at The Remarkables Ski Area to support the proposed expansion into the Doolans Basin. This report assesses the performance of the existing onsite wastewater management system (OWMS), characterises the receiving environment, and evaluates the likely effects of accommodating additional wastewater through an upgraded treatment system.

The current OWMS includes the discharge of effluent to land via infiltration basins located on a terrace above the Rastus Burn. Historical monitoring (2015–2026) shows that while the discharge contributes detectable nutrient and microbial signals in groundwater and surface water during the ski season, the impacts are acceptable with biological monitoring reporting good-excellent ecological health.

Monitoring wells updated and installed in 2026 have improved the understanding of groundwater gradients, flow paths, and the depth of the unsaturated zone beneath the infiltration basins. The preliminary results confirm a shallow groundwater system within alluvial/colluvial deposits over bedrock, with a steep groundwater gradient to the north and west toward the Rastus Burn.

Establishing the relationship between nutrient loads and ecological condition allows for the identification of environmental thresholds and the development of performance criteria to maintain good-excellent conditions instream. These findings underpin the performance criteria of an upgraded treatment system required to support the additional wastewater volumes from the Doolans extension. This likely includes upgrading the OWMS to a secondary treatment system with nutrient removal, capable of meeting these performance criteria while accommodating increased wastewater volumes.

Some uncertainties remain around seasonal groundwater behaviour, flow metering accuracy, and variability of the discharge quality. These will be addressed through further investigations and with monitoring and operational refinements. Overall, the assessment finds that the proposed increase in wastewater discharge, when paired with an upgraded treatment system and adherence to the recommended performance criteria, will result in an acceptable level of adverse effects on soils, groundwater, surface water, wetlands, or aquatic ecology and will maintain the good-excellent ecological health of the Rastus Burn.



1 Introduction

NZSki is seeking consent to extend its skifield operations to the backcountry terrain of Doolans Creek headwaters, which increases the number of skiers and associated service infrastructure. In particular, the additional wastewater that will be generated is proposed to be managed by pumping it back to the Remarkables Skifield and the onsite wastewater management system therein (OWMS) (Stantec, 2026).

This report provides an assessment of the existing discharge to land and the effects on the receiving environment to inform the assessment of the potential effects of discharging an increased volume of effluent to land. To complete this assessment, we have reviewed the compliance monitoring dataset (section 4), conducted supplementary site investigations (section 3 and 4), reviewed available desktop and previous site investigations by others (section 3 and 4), and reviewed the available information about the proposed activity (section 2).

1.1 Scope of Work

In December 2025, e3s completed a desktop review of the Remarkables wastewater discharge site (e.g. compliance monitoring data) to understand the effects of the current OWMS. The desktop assessment recommended additional work to enable consenting of an increased wastewater discharge from the Doolans expansion at the Rastus Burn dispersal field. This report summarises the previous reporting in addition to completing the following scope of work to support the consent application:

- Drilling of additional monitoring wells;
- Groundwater sampling of wells to determine current groundwater conditions and flow paths;
- Development of a flow rating curve for the Rastus Burn by completing flow gauging events to assess the potential change in contaminant concentration as the Rastus Burn flow changes (to be completed end of Ski-season 2026);
- Analysis of the discharge and receiving water flows and quality data to develop a conceptual model of contaminant flow paths and likely attenuation and dilution rates;
- Identification of any uncertainty and risks associated with the conceptual site model and providing a list of actions required to mitigate those risks; and
- Preparation of Assessment of Effects for wastewater discharge to land to support consenting.



1.2 Limitations

The findings of this report are based on the Scope of Work outlined above. e3Scientific Limited (e3s) performed the services in a manner consistent with the normal level of care and expertise exercised by members of the environmental science profession. No warranties, express or implied, are made. The confidence in the findings is limited by the Scope of Work.

The results of this assessment are based upon compliance monitoring data provided by NZSki, preliminary site investigations conducted by e3s personnel, and reviews of available desktop information and information provided in other consultant's reports. All conclusions and recommendations regarding the properties are the professional opinions of e3s personnel involved with the project, subject to the qualifications made above. While normal assessments of data reliability have been made, e3s assumes no responsibility or liability for errors in any data obtained from regulatory agencies, statements from sources outside e3s, or developments resulting from situations outside the scope of this project.

1.3 Code of Conduct

The authors of this report are Simon Bloomberg and Jamie Lynds with reviews from Mark Hamer and Alexandra Badenhop.

Simon Bloomberg (MSc Hons) is an Earth system scientist focussing on geochemistry with 10+ years' experience in the environmental and natural resource sectors. Simon has led technical projects for high-level contaminated site classification, Preliminary and Detailed Site Investigations for contaminated land projects, surface water and groundwater risk assessments to support discharge consents, soil and landfill gas assessments, and site and soil assessments to support land developments which require onsite wastewater services. Simon provides technical science advice and peer review of contaminated land and discharge to land resource consents. At e3s, Simon contributes to both the Water and Environmental Management and Contaminated land teams and collaborates on multidisciplinary projects with the ecological teams.

Jamie Lynds is a Hydrologist with a background in Regulatory Compliance and field-based environmental and ecological monitoring. She holds a BSc (Geography and Environmental Management), PGDipSc (Geography) and a MSc (Geography) where her research focussed on the human impact on drought on the Ōmakō/Lindis River.



Archie Ellis-Stanley is an environmental scientist with a background in marine ecology. He studied at the University of Bristol, completing a masters in predator prey interactions. Archie has a strong background in statistics, coding and GIS. Over his career he has become fluent in using machine learning for ecological and geological applications.

Mark Hamer is a professional freshwater ecologist with over 17 years' experience working in the freshwater ecology and monitoring industry. Freshwater biomonitoring proficiency and experience includes wetland delineation, water and sediment quality assessments, eDNA, river periphyton, aquatic plant identification, riparian habitat assessment, macroinvertebrate collection and analysis. Freshwater fish monitoring using electric fishing, netting or spotlighting methods along with associated fish handling, analysis and fish passage assessments. At e3s for the past 3 years Mark's focus has been on ecological value assessments and reviewing and producing ecological impact assessments in the consenting process. He has been an expert witness at consent hearings and is a current member of the New Zealand Freshwater Sciences Society.

Alexandra Badenhop – Technical Director (Water and Environmental Management)
Alexandra is an environmental engineer with over 20 years' experience working in the water industry. She has a B.Eng (Environmental)(Hons 1) and M.Eng.Sci (Groundwater Studies) which also fulfilled the criteria for M.Eng.Sci (Water Quality) and enjoys collaborating on multidisciplinary projects with the ecology team. Her experience encompasses a range of engineering studies, including hydrogeochemistry and water quality assessments, literature and program reviews, wetland characterisation, groundwater testing and feasibility studies and numerical modelling. As the Technical Director -Water & Environmental Management team at e3s, Alexandra is responsible for groundwater and surface water supply and water quality assessments, technical reviews for regional councils, assessing and reviewing discharges to land, assessment of environmental effects, project management and environmental risk assessments.

We confirm that we have read the Code of Conduct for expert witnesses contained in the Environment Court Practice Note 2023. This report has been prepared in compliance with that Code, as if it was expert evidence presented in proceedings before the Environment Court. Unless we state otherwise, this report is within our area of expertise, and we have not omitted to consider material facts known to either of us that might alter or detract from the opinions expressed in this report.



2 Proposed Activity

2.1 Current Consent

The current consent RM14.336.01 is to “discharge treated wastewater to land for the purpose of disposal of treated wastewater and water supply by wash from the Remarkables Ski Field buildings” which expires on the 10 April 2030.

Condition 3 states that the maximum daily discharge volume is 127.44 m³/day including by wash water and the rate of application shall not exceed 20 mm/day in any part of the disposal area.

Condition 4 and 7 require the reporting of wastewater flow volumes and water quality sampling. Condition 8 sets out the required analytical suites for the water quality samples.

In terms of performance monitoring, there are no other numerical limits or even qualitative limits however Condition 10 states that if any downstream water quality sample results are greater than the upstream results, and are indicative of a decline in water quality downstream of the dispersal field then “the consent holder shall provide to the Consent Authority within 7 working days of receiving the sampling results a written explanation outlining the potential causes of the increase and any solutions to stop the decline in water quality”.

Condition 11 requires biological monitoring to be undertaken at no more than two yearly intervals to survey the Rastus Burn from the Upstream monitoring location to the downstream monitoring locations. The survey is to determine the effects on the aquatic ecosystem of the Rastus Burn. The survey must occur no later than 30th November each year, and must include the four monitoring locations (Upstream, Downstream 50m, Downstream 200m, Downstream 1.5km).

The discharge is proposed to continue to operate under a similar set of conditions (except for Condition 10) until 31 May 2029, when visitor numbers will increase to a maximum of 6,000 per day (e.g. Table 1).



2.2 Proposed Discharge

NZSki propose to discharge an increased volume of wastewater to the dispersal fields to cater for the planned increase in skifield capacity. To minimise adverse environmental effects, the OWMS is to be upgraded. This section summarises the design flows (Table 1) and potential treated effluent quality (Figure 1) required to meet the preliminary performance criteria including maintaining nutrient loads to the Rastus Burn.

Analysis of the performance criteria goals and their derivation is described further in Section 4.6.

2.2.1 Wastewater Flow Limits

Stantec (2026) report the current and forecasted wastewater flows as:

Table 1. Forecasted Wastewater Flows (Stantec, 2026)

Site Wide Occupancy	Peak Skiers/day	L/Person/Day	m ³ /day
Current Occupancy	3,500	32.5	127,440
Anticipated Occupancy - Doolans Expansion	6,000	34	204

The currently consented discharge is 127.44 m³/day, with planned increase to 204 m³/day to cover the peak day discharge for ski field expansion.

2.2.2 Potential Upgraded Wastewater Treatment System Design Discharge Criteria

To ensure the increase in wastewater volumes does not result in an increased contaminant load to the environment, the upgraded OWMS is required to meet design discharge criteria which are to be similar to that of Jack's Point e.g. Figure 1.

Estimated discharge limit	Value	Unit
cBOD ₅ <	20	mg/L
TSS <	30	mg/L
TN <	30	mg/L
TP <	15	mg/L
E. coli <	1,000	MPN/100 mL
Among these, total nitrogen (TN) is expected to be the limiting parameter influencing system design complexity and energy demand, particularly under cold conditions. These values have been provided by Innoflow and are based on comparable local developments and recent consent limits from Jack's Point, Mt. Cardrona Station, Coronet Peak, and Gibbston Valley Winery.		

Figure 1. Proposed Design Discharge Criteria (Reported by Innoflow; Stantec, 2026)



It's likely that a lower TP limit than 15 g/m³ would be required to ensure compliance with the proposed baseline performance criteria for TP e.g. 85 kg TP/5-year maximum. However, these criteria are subject to revision following further investigations during the 2026 ski season.

2.2.3 Wastewater Treatment Design

Table 2 summarises the alternative treatment options that were assessed by Stantec (2026) for the planned treatment upgrade; the likely OMWS upgrade option (option 5a) is a secondary treatment system with nutrient control (similar to the Coronet Peak system). While it is to be confirmed through further analysis and design work, Stantec (2026) state that with the conceptual designs 5a and 5b, it will be possible for NZSki to increase skier patronage and wastewater influent volumes and strength while maintaining the current water quality and ecological ecosystem health rating of good-excellent in the Rastus Burn.

Table 2: MCA tool output for alternative options assessment (NZSki, 2026)

Option	Description	Nutrient Control	Relative Capital	Assessment Position
1	Do Nothing	None	Very Low	Discounted
2	Operational Improvements	None (stability only)	Low	Stage 1 – Required
3	Upsize Primary Capacity	None	Moderate	Discounted
4	Secondary Treatment	Incidental reduction	Moderate	Stage 2 – Foundational Upgrade
5a	Secondary + Nutrient Control	Active control of nutrient loading	Moderate–High	Stage 3 – Preferred Configuration
5b	Enhanced Nutrient Reduction	High (active reduction)	High	Stage 4 – Contingency Only
6	Downhill Discharge	Dependent on plant	Extreme	Discounted



3 Site Environmental Context

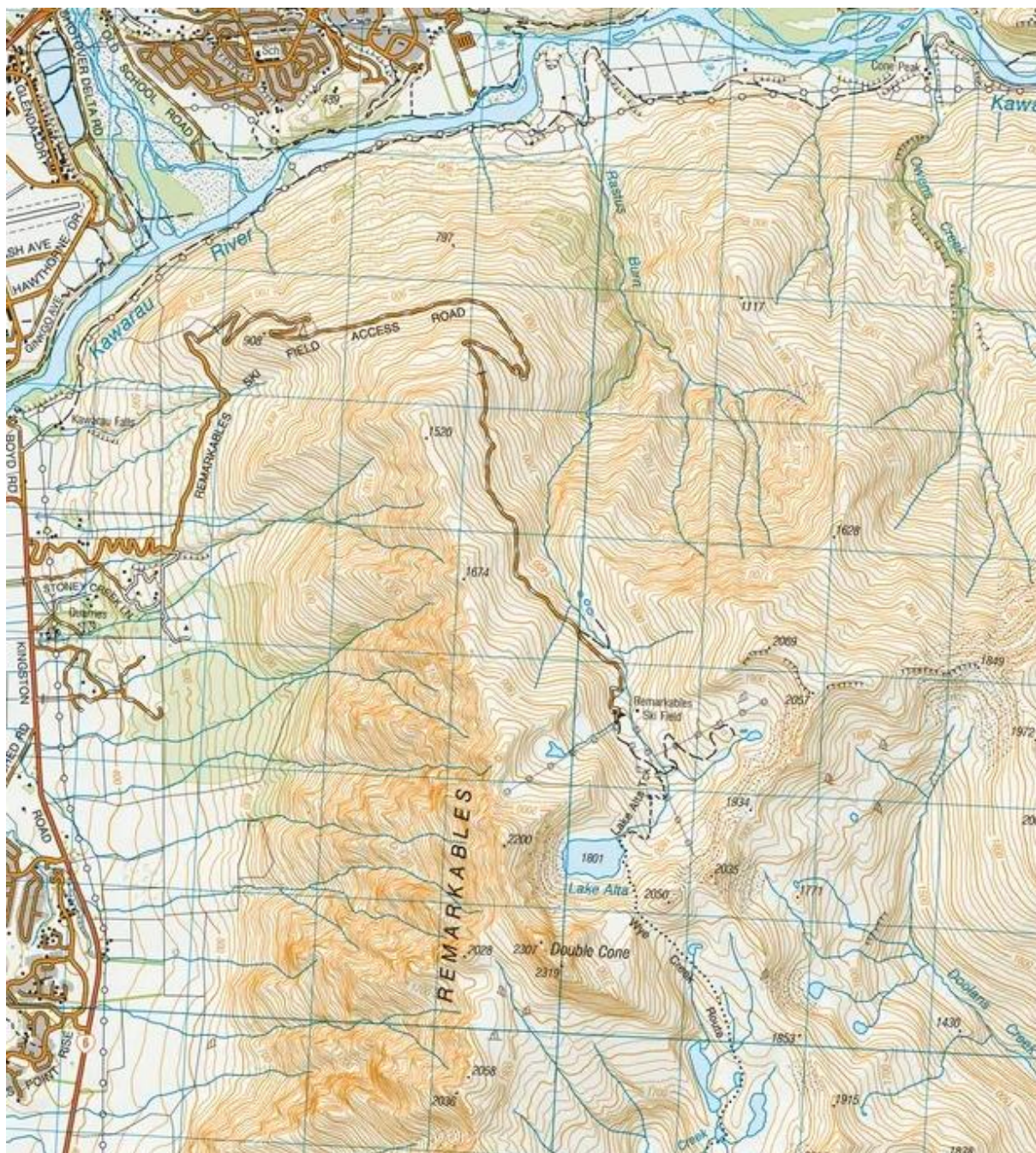


Figure 2. Site Topography © 2026 CC BY 4.0 Land Information New Zealand (LINZ).

The dispersal field lies within the Remarkables Conservation Area within the Rastus Burn Catchment (Figure 2). The Rastus Burn catchment has been developed to support The Remarkables ski field with ski lifts, roading, car parks and ski field buildings; however, there are still areas of undisturbed wetlands, lakes, and alpine terrain. The upper catchment is used for recreational alpine activities all year round however the Rastus Burn is not known for any swimming or fishing values. Further discussion of the aquatic ecology and values therein is included in section 3.7 below.



The catchment ranges from 2,300 mASL at its highest to 315 mASL at the confluence with the Kawarau River (See Photo's 1-6). The onsite wastewater treatment plant is located near the base building at 1600 mASL with the dispersal field lower down at 1440 mASL (Figure 1). The site is well described by Ryder (2014) and MWH (2014), and the site and its operation has not significantly changed since the 2014 upgrades.

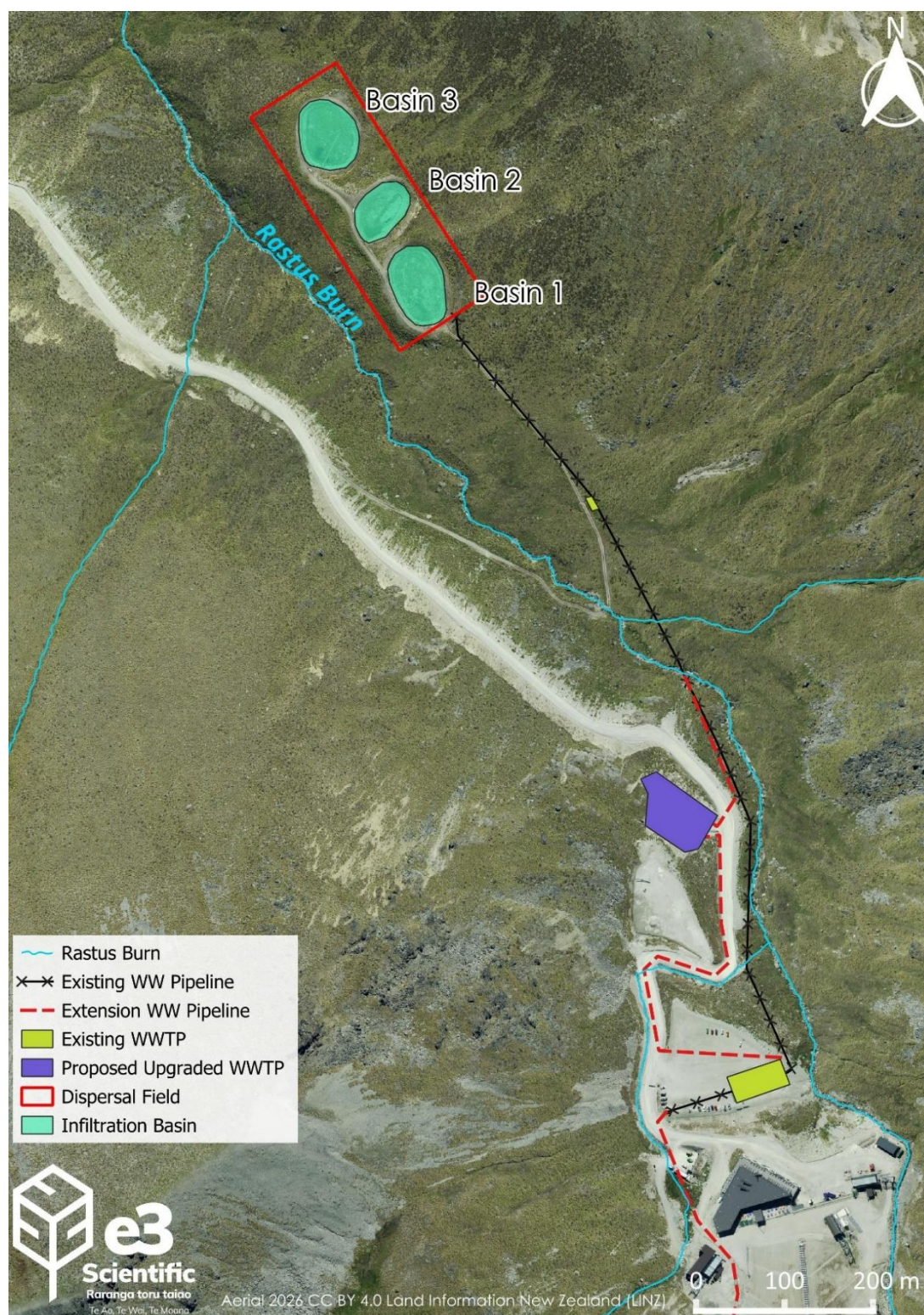


Figure 3: Site overview.



Photo 1. Rastus Burn 'Upstream' Monitoring Site, View Upstream (South)



Photo 2. Rastus Burn 'Upstream' Monitoring Site, View Downstream (North).



Photo 3. Dispersal Field, View South from Basin 3, Towards the Base Building



Photo 4. Dispersal Field, View North from Basin 3 Towards the Kawarau



Photo 5. Rastus Burn 'Downstream 200m' Monitoring Site, View North from Basin 3



Photo 6. Rastus Burn 'Downstream 200m' Monitoring Site, View North



3.1 Climate

The Regional Climate of Otago in which the site lies is strongly influenced by the main divide of the Southern Alps/Ka Tiritiri-o-te-Moana. They act as a barrier, separating the wettest region in the country (West Coast) from the driest region (Central Otago). This overall gives the region a semi-arid 'continental' climate (Macara, 2015). There are no permanent rainfall gauges in the Remarkables Ski Area although one is slated to be installed in 2026. Annual median rainfalls at the site, as mapped on the Grow Otago website ranged from 1000 -1250 mm in the valley and up to 1500 mm on the ridgeⁱ.

The Rastus Burn wastewater treatment system interacts with the climate in the following ways:

- Temperature:
 - There are microbial-mediated processes which are temperature dependent, e.g. colder temperatures reduce microbial activity, reducing treatment effectiveness.
 - Temperature controls whether precipitation falls as snow or rain.
 - Temperature partially controls evaporation rates
- Wind:
 - affects distribution of snow
 - evaporation is partially controlled by wind
 - effects ski operation, lifts cannot operate in high wind so the skifield will close.
- Water balance:
 - The Rastus Burn provides the potable supply to the base building and is the ultimate receiving water body of the wastewater discharge.

3.2 Anticipated Climate Change

Climate change risk is assessed at a high level with information gathered from the Climate Projections Map produced by the Ministry for the Environmentⁱⁱ. This has been generated to a 5 km resolution across the country. The proposed development site fell under the Central Otago District and had a comparison base period of 1986-2005 under a climate change scenario of SSP1 – 2.6 and a future period of 2021-2040 looking at annual variables.

ⁱ <https://maps.orc.govt.nz/OtagoViewer232/?map=a3d75c9e135142e68f4e02b6fb64eaf7>, accessed 4/03/2026

ⁱⁱ <https://map.climatedata.environment.govt.nz/>, accessed 11/03/26



The map indicated that under the above climate change scenario, the site would be expected to have change to average daily air temperature of +0.6°, average daily minimum temperature increases of +0.5°, total rainfall to increase by +2.2%, the number of rainy days <1mm to decrease -0.8 days, while number of rainy days >25mm set to change +0.5 days. Wind is expected to increase on average by +1.6%, and the number of windy days >10m/s increase by 5.7 days. Potential Evapotranspiration Deficit (PED) was used to estimate drought exposure, with this set to increase by approximately 17.9 mm.

3.3 Geology

GNS Science's QMAP compiles regional geological maps at a scale of 1:250,000. The map units for the Remarkables are predominantly basement schist described as "Well foliated psammitic and pelitic schist with incipient segregation; minor greenschist and metachert; quartz veins common; TZIII.". There are smaller deposits of glacial till, and alluvial/colluvial material typically in the bottom of gullies or downslope of large scarps described as "Undifferentiated till consisting of variably weathered, generally bouldery angular gravel with minor sand in cirque moraines" and "Loose, commonly angular, boulders, gravel, sand, and silt forming alluvial fans; grades into scree (upslope) and valley alluvium." (GNS Science, 2025).

Geological descriptions from the recent groundwater monitoring borehole installation confirms that the dispersal field is comprised of sandy gravels overlying schist bedrock. There appears to be a bedrock high on the northwestern edge of the terrace which is at a consistent elevation with the top of a schist outcrop on the opposite side of the Rastus Burn. The terrace that the dispersal field is located on is thus likely to be a ledge in the bedrock formed during previous glaciations.

3.4 Hydrogeology

The site does not overlie any mapped aquifers. Unconfined groundwater is present beneath the dispersal field within the thin deposit of alluvial/colluvial material that overlies the basement schist. Fractured rock aquifers are present in Otago schists where large fracture zones have enough permeability to connect the fractures ORC (2014, 2023). Fracture flow may be the sources of springs on the side of steeper terrain in the Rastus Burn, in the absence of alluvial deposits or elevated cirque basins. It is expected that any groundwater present would be low yielding, and there are no groundwater users in the catchment.



Three monitoring bores were installed around the dispersal fields in 2014, however there are no borehole logs or construction details available, only the depth of boreholes. All bores were dry after drilling with groundwater first appearing in BH1 and BH2 in late Autumn between mid-April and early May. Throughout the monitoring record BH1 was seasonally dry, and BH3 never intercepted groundwater. At BH2, groundwater levels peaked in late May, (which could coincide with autumn rain which is not falling as snow) and then again in October (likely due to snow melt).

To improve the monitoring network efficacy, NSZki installed two new monitoring bores (BH4 and BH5 (nested)) and extended the depths of BH1 and BH3 beyond the water table in 2026. The locations of the monitoring wells are presented in Figure 4.

Groundwater levels were measured in the wells using a dip meter. Using the LiDAR data collected in 2016, groundwater levels were converted into groundwater elevations in mASL (NZVD2016) to determine groundwater flow directions.

Table 3. Groundwater Monitoring Borehole Details

Site	Borehole	Purpose	Borehole Depth (m)	SWL (mbRL)	Reference Elevation	Groundwater Elevation (mASL)
Infiltration Basin 1	BH1	Upgradient	13.35	10.21	1460.71	1450.50
	BH4	Downgradient	26.10	22.10	1460.66	1438.56
Infiltration Basin 3	BH2	Upgradient	11.83	10.80	1441.41	1430.61
	BH3	Downgradient	21.2	16.17	1441.64	1425.47
	BH5	Downgradient	17.05	-	1442.24	<1,425.19*

*Groundwater not intercepted. Final depth of well is at 1,425.19 mASL

Note that BH5 intersected bedrock at 15.2 m below ground level and it was not clear if groundwater was intercepted at the time of drilling; during sampling a week later, no water was present in the well. This indicates the presence of a local bedrock high which channels groundwater flow to the north rather than west. It is possible that BH5 may seasonally intercept groundwater during winter/spring when higher volumes of wastewater are discharged, and snow melt increases groundwater levels.

Cross-sections and long section through the dispersal field were generated to assess groundwater-surface water interaction, and the depth of the unsaturated zone between the base of the infiltration basins and the groundwater (which may range from 5 to 10 mbgl).



Locations of sections are presented in Figure 4, with long section in Figure 5 and cross sections in Figure 6

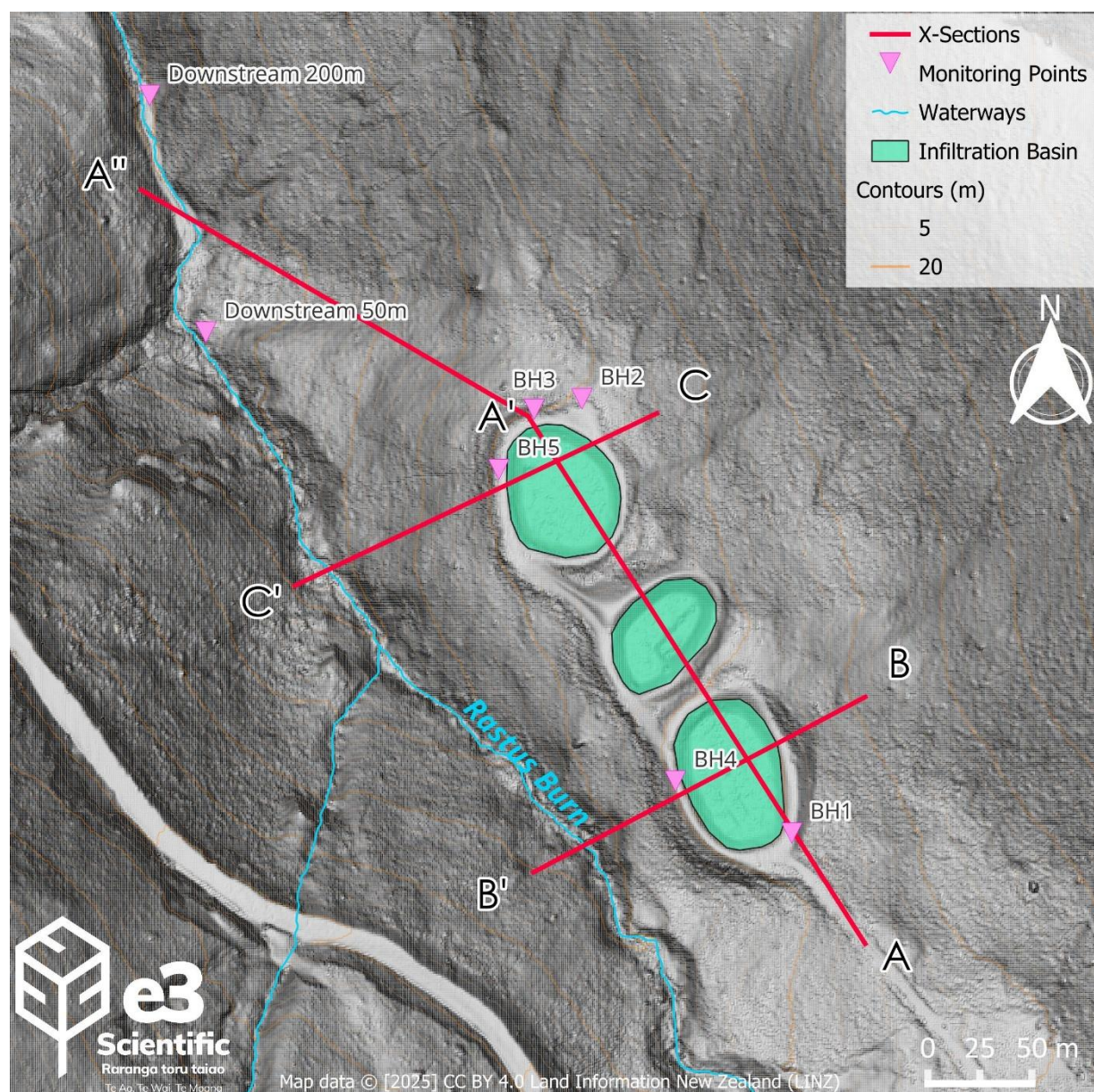


Figure 4. Monitoring Well Network and Section Locations



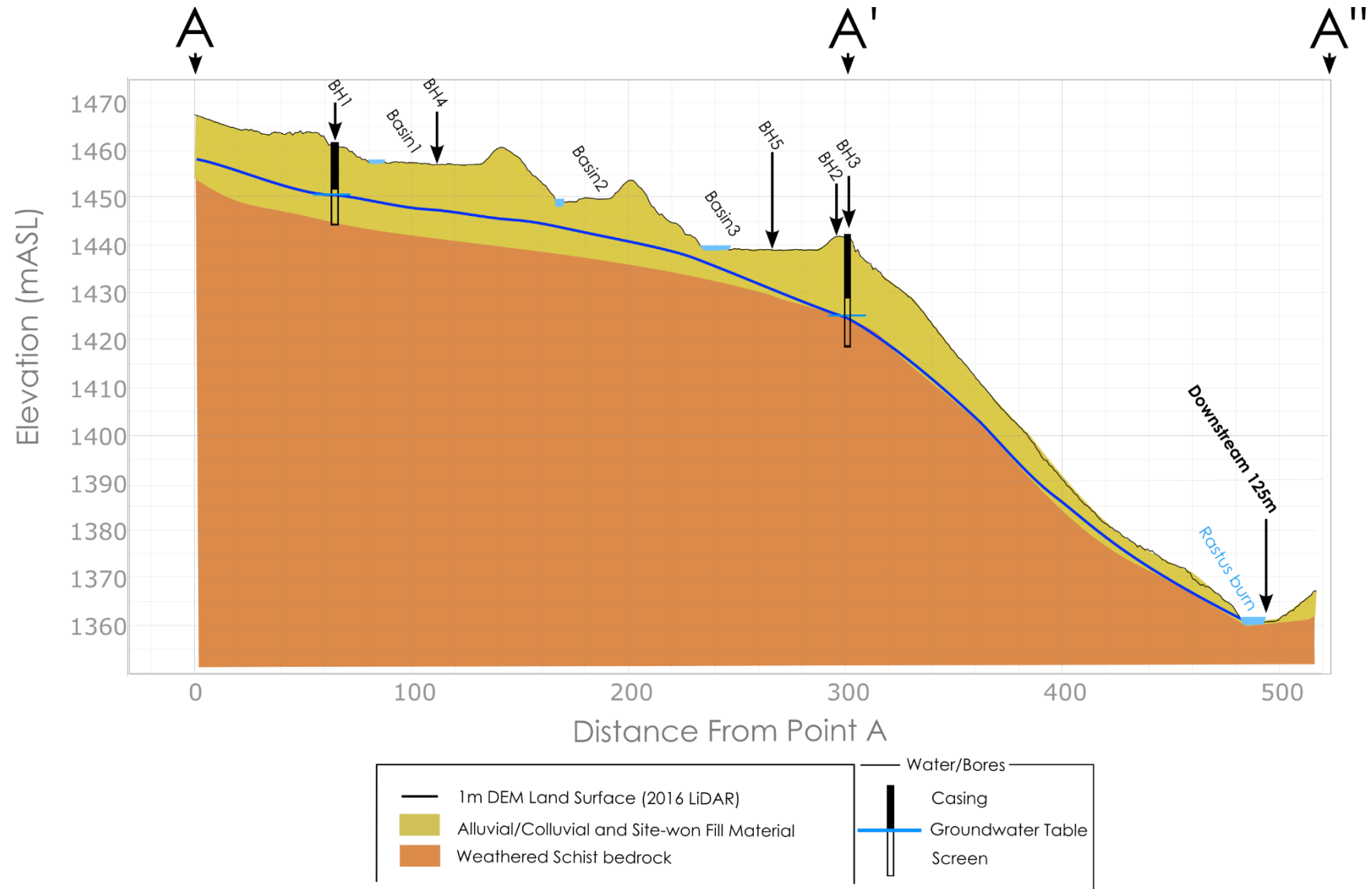


Figure 5. Long Section through the dispersal field



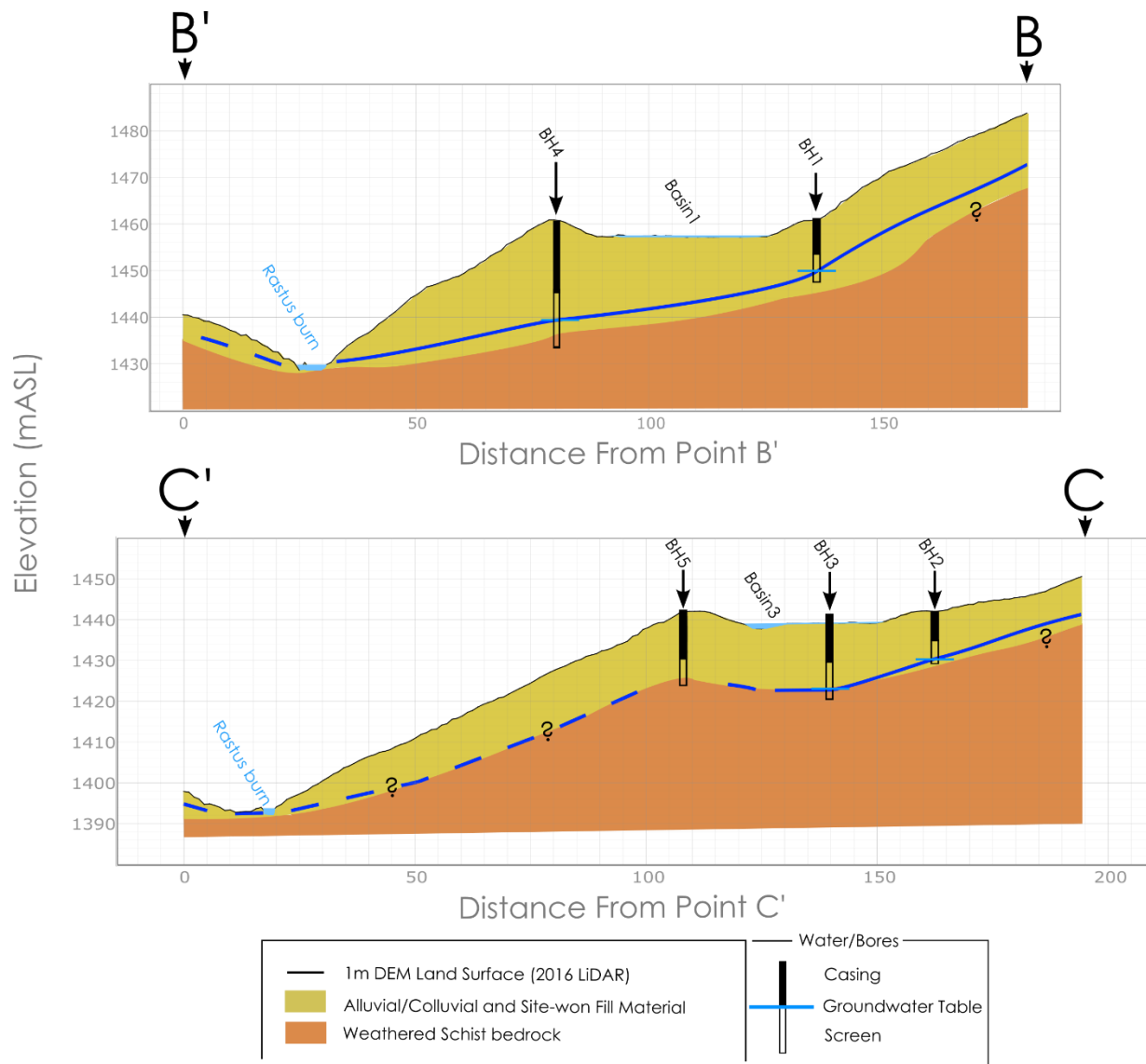


Figure 6. Cross sections through Basin 1 and Basin 3

3.5 Hydrology

The wastewater dispersal field is elevated about 50 – 100 m above the true right bank of the Rastus Burn, with a horizontal buffer of 50-100 m (see Figure 3 - Figure 6).

The entire Rastus Burn catchment is 1,450 ha however the catchment above the dispersal field is 581 ha. Assuming a rainfall recharge of 20% (less than the 23% assessed for Wakatipu Basin due to increased runoff from steep slopes in the upper catchment (ORC, 2014)), and an annual rainfall range of 1,000 to 1,500 mm/year ($L/m^2/year$), then a total volume of recharge could be on the order of 3,000-5,000 m^3/day . Due to rain falling as snow during winter and spring, precipitation is locked to the land surface which results in a marked seasonality for the groundwater-surface water system flows.



a one off gauging of the Rastus Burn was undertaken in May 2025 by e3s as part of a separate (and unrelated) assessment of Lake Alta. The flow in the Rastus Burn near the base building was 25 L/s on the 5th May 2025, (equivalent to 2,160 m³/day). The current consented surface water allocation requires a residual flow of 15 L/s to be maintained at all times which would be equivalent to 1,296 m³/day.

NIWA's river flow model (Whitehead, 2020) considers 25 L/s as 7th percentile flows (segment 14224707) (i.e. 93% of flows are higher), and lower than the modelled 1 in 5-year low flow of 29 L/s for July. The median and mean flow for the reach of the Rastus Burn adjacent to the dispersal fields is modelled as 70 L/s and 113 L/s or 6,048 m³/day and 9,763m³/day respectively. It is likely that the model overestimates the lower flows in the Rastus Burn, however it is useful to understand the range of possible flows based on the catchment size. Further flow gauging is planned during the 2026 ski season and snow melt period to confirm the NIWA models as flows are used in assessing the discharge effects on the stream including dilution rates.

Flow accumulation mapping was completed using WhiteBox and Serval Tools in QGIS to identify likely pre-development overland flow paths and areas of surface water concentration (Figure 7). This indicates pre-development there were some overland flow paths that passed through the dispersal field. In particular, it was noted that BH5 is situated in an area where flow accumulation was expected. Further BH2 is likely receiving water from upgradient flow paths, confirming its utility as a crossgradient/upgradient location.

At present there are small bunds and cut off drains which direct runoff around the dispersal field. It is possible that runoff from large events could enter the dispersal field and be intercepted by the infiltration basins, however this is most likely during the spring snow melt rather than during winter, and therefore overland flow is most likely to have a negligible effect on the operation of the discharge to land during the ski season.

These parts of the dispersal field may also be preferential pathways for groundwater where gullies have formed nick points in the underlying bedrock.

Groundwater may be forced to the surface nearer to the Rastus Burn where the ground surface oversteepens and/or bedrock shallows. Groundwater recharge to the Rastus Burn may be via springs at the surface in the form of seepage wetlands and then flows overland down to the Rastus Burn; or directly to the Rastus Burn via a conductive stream bed.



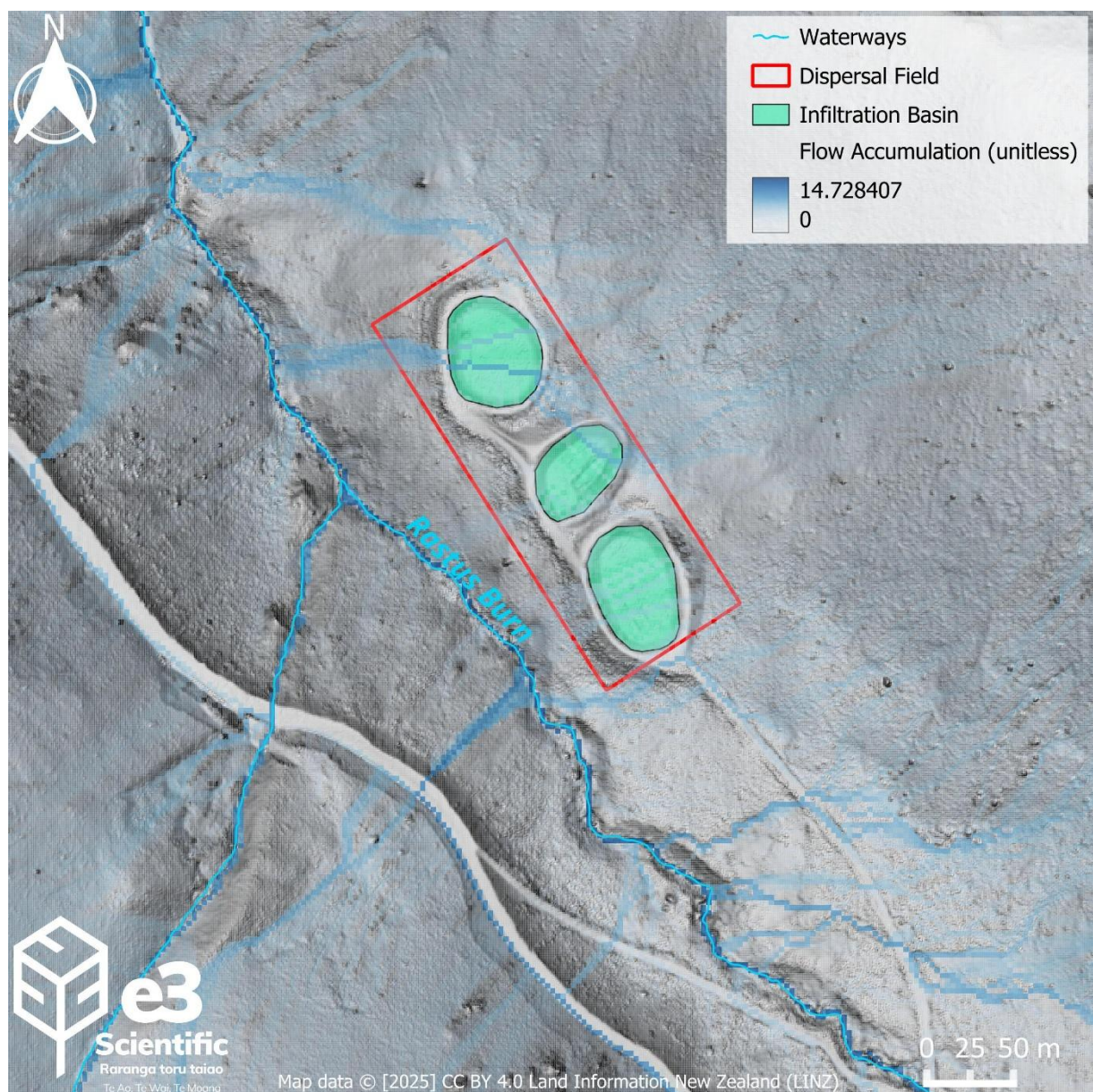


Figure 7. Modelled Flow Accumulation (filled sinks) for the Dispersal Field Area

3.6 Water Quality

3.6.1 Adopted Environmental Guidelines

The following guidelines were adopted for assessment of water quality.

- ANZG (2018) supersedes the ANZECC (2000) guidelines.
 - For toxicity-based default guideline values (DGV) for ammonia and nitrate, the guidelines for the protection of 99% of freshwater species were adopted, as these are relevant to the high alpine source, and limited modification of the catchment.



- For physico-chemical parameters (e.g. pH) ANZG (2018) provide regional DGVs which are derived using national and regional climate and topography class data. The site is described as 'cool wet mountain' as determined by NIWA's publicly available REC2 dataset. Where appropriate, these regional DGVs were superseded by the derivation of site-specific guidelines following the ANZG (2018) methodology. That is the 80%ile (or 20%ile) values from a minimum of two years of monthly samples at a suitable reference condition site. Based on the statistical analysis (Appendix A) it was determined that the upstream site was suitable for this purpose.
- Schedule 15 of the Regional Plan: Water for Otago sets out the numerical limits and targets for achieving acceptable water quality for all catchments in the Otago region. As the Rastus Burn is a tributary of the Kawarau River below the Shotover River the limits for Receiving Water Group 2 are applicable. These limits were adopted in 2012 except for nitrate which was adopted in 2025. The limits apply to 80% of sample collected at median flow or less over a five-year period.
- Other limits:
 - Didymo limit was adopted from recent guidance by NIWA as 2 ppbⁱⁱⁱ (0.002 mg/L).

3.6.2 Water Quality Review

Groundwater and surface water quality is excellent based on the high alpine source (cool temperatures), modest human modification of the catchment, limited nutrient inputs or other contaminants, and the relatively high velocity/throughput of the Rastus Burn due to the steep catchment which aerates the water.

Ryder (2014) summarise the Rastus Burn water quality upstream of the dispersal field as follows:

- Water temperatures in the Rastus Burn are very low, between 1.7°C and 5.1°C
- Conductivity, which provides an indicator of nutrient enrichment is low between 13 and 40 µS/cm.
- Dissolved oxygen levels are high, constantly above 11 mg O₂/L.
- pH ranges from 6.5 – 9 which is in the acceptable range for New Zealand streams.

ⁱⁱⁱ<https://niwa.co.nz/lakes/freshwater-update/freshwater-update-62-september-2014/didymo-new-zealand-ten-years>



- Turbidity and total suspended solids are occasionally high in the Rastus Burn, which may be associated with snow melt and suspension of fine material from the rocky upper basins.
- Nutrients are generally low but are more likely to be in dissolved inorganic forms than total organic forms.
- Faecal contamination in the upstream sample is generally always below the detection limit.

Surface water sampling in February 2026 recorded temperatures of 12°C, DO of >9 mg O₂/L, conductivity of 40 µS/cm, pH of 7.1, Turbidity of 1 NTU.

A groundwater quality sample was collected from the upgradient monitoring bore BH1 at the dispersal field in February 2026, which is representative of background conditions. The groundwater quality is excellent and summarised as follows:

- Temperature was 5°C
- Conductivity was 26.3 µS/cm.
- Dissolved oxygen was 93.2% or 10.1 mg/L.
- pH was 6.75.
- Total Nitrogen was 0.06 mg/L with nitrate-nitrogen 0.058 mg/L.
- Total Phosphorus was 0.038 mg/L with DRP 0.006 mg/L.

3.6.3 Hydrogeochemistry

The water source or hydrogeochemical facies assessment was undertaken on samples collected from all compliance monitoring locations including the extended groundwater monitoring network in February 2026, in off-season discharge conditions (approximating benchmark conditions) and June 2026 (immediately prior to commencement of 2026 ski season). The results are presented in a piper plot (Figure 8 and Figure 9), which shows the common cation and anion concentrations.

The piper plot is a useful reference for showing any mixing trends or water sources in a study area. Based on the below ratios of cations and anions, it appears that most waters are calcium bicarbonate (Ca-HCO₃) type, however the discharge point and BH4 appear to be on the boundary with mixed type between Ca-HCO₃/Na-HCO₃.

Based on the cation-anion diamond, BH1, BH2, the upgradient boreholes are firmly in the bicarbonate corner while the down gradient groundwater samples (BH3 and BH4) and wastewater sample (discharge point) are elevated in chloride. The Rastus Burn waters are more sulphate rich which could be due to weathering of pyrite in the schist bedrock in the headwaters. There appears to be a slight mixing trend with a groundwater source for the downstream 50, 200, and 1.5km samples, perhaps



indicating that groundwater is more connected to the stream at lower elevations and surface water interactions with schist weathering products decreases with distance from headwaters (e.g. less exposed schist, more tussock coverage).

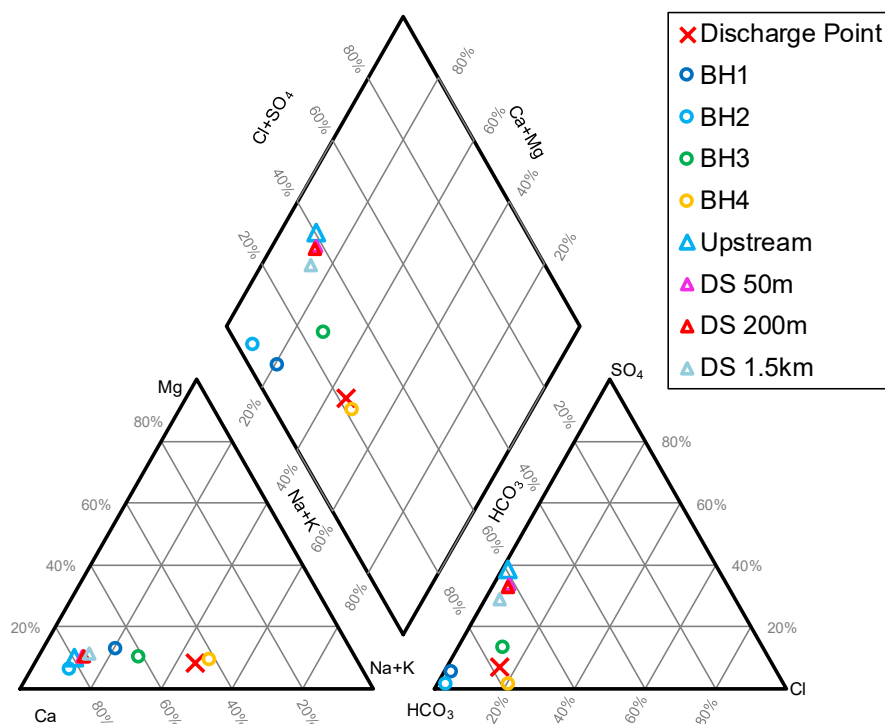


Figure 8. Piper Plot (February 2026 sampling event)

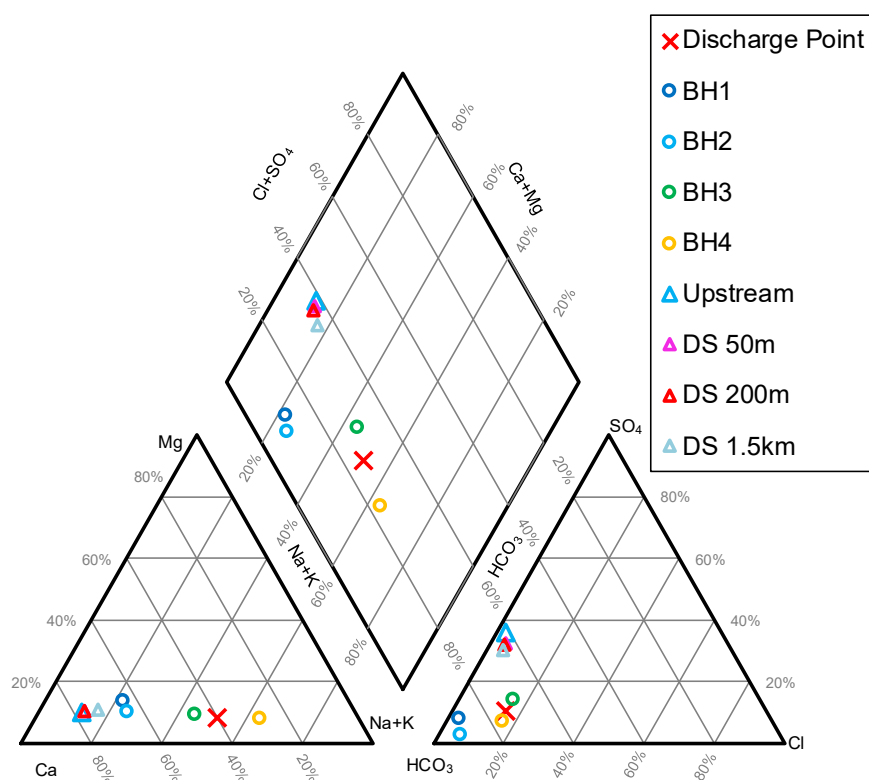


Figure 9. Piper Plot (June 2026 sampling event)



The redox condition of the sampled waters was classified according to the framework devised by McMahon & Chapelle (2008) using the concentrations of dissolved oxygen, nitrate, manganese, iron, and sulphate. In terms of redox status, all waters reported oxic redox categories ($O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$) except for BH3 and BH4 which reported a redox category mixed (Oxic-Anoxic) with the general process O_2 -Mn(IV) ($MnO_{2(s)} + 4H^+ + 2e^- \rightarrow Mn^{2+} + 2H_2O$). The mixed category is likely due to the presence of organic matter in the wastewater discharge which upon discharge to land consumes oxygen during bacterial decomposition. As oxygen is rapidly depleted, organic decomposition progresses at slower rates using the subsequent terminal electron acceptors.

3.7 Aquatic Ecosystem

A desktop review of the freshwater ecological monitoring data reported to date was completed in 2025 (e3Scientific (2025)) The summary of the report is reproduced in full below:

"In summary the cold, clear, well oxygenated water of the Rastus Burn and stable rock substrates free of fine sediment provide for an algal community typical of alpine environments with low cover of a few species including diatoms and filamentous red algae. The low algal biomass and allochthonous tussock leaves in turn provide a constrained food resource for the limited macroinvertebrate community present that comprises of taxa sensitive to organic pollution and that prefer cool well oxygenated water. The macroinvertebrate community is consistently representative of a "good-excellent" macroinvertebrate community although there was a temporary decline in 2023 to "fair to good".

The decline observed in 2023 was considered to either be due to the accidental discharge of wastewater to the Rastus Burn due to the blockage in the rodding eye, or due to the increase in nutrient load. It is considered that the leak might have resulted in significant adverse effects as toxicological limits were assumed to be exceeded over a 9-day period in July 2023. However, at the same time the decline in the instream community quality may be due to the increased nutrient load which can result in more productive periphyton or macroalgae which changes the habitat and the instream macroinvertebrate community. The changes observed in 2023 and subsequent return in 2025 indicate that whatever the cause of the decline it was reversed either by fixing the leak or returning to lower nutrient loads.

The recent introduction of didymo to the Rastus Burn catchment headwaters (Lake Alta outlet) could mean that blooms may occur in the future throughout the Rastus Burn and this could alter the macroinvertebrate community composition during didymo



bloom events. Didymo was observed in the lower reaches during the 2025 monitoring event near the downstream 200 m sample location.

Extensive fish surveys were carried out in 2008 and 2014 demonstrated the reach near the NZSki facilities and wastewater discharge (1500 m downstream and 1300 m upstream to Lake Alta) to be fishless. It is considered likely that the reach is naturally fishless due to the steep gorges downstream and associated waterfalls precluding access to fish. The lower 1.7 km of the Rastus Burn below the 1st waterfall at approximately 450 mASL may hold fish such as rainbow and brown trout, common bully, kōaro or longfin eels that are known to be present in the wider area. However, the majority of small tributaries surveyed have been fishless and it is considered more likely that only brown or rainbow trout may be present in the lower reaches of the Rastus Burn."

Readers are referred to the Freshwater Ecological Impact Assessment (e3Scientific, 2026) for a more detailed description of the freshwater ecology and values therein.

3.8 Soils

Specific soil data for the site does not exist. Using Manaaki Whenua 'Soil Map Viewer' soil in the area is generally 'Brown Soil'. This is classified as being a mature soil with distinct dark grey-brown topsoil, and a brown or yellow-brown subsoil (Button, 2024). Brown soils make up 50% of soil types in Otago. Mostly occurring on hilly to steep landscapes these soils generally have good drainage and structure with low fertility. Soils in the dispersal field area have been modified by the construction of the infiltration basins, surrounding bunds and access roads.

3.9 Natural Hazards and Flooding

Natural Hazards have been mapped extensively surrounding the Remarkables Ski Field areas. The existing wastewater site sits in an Avalanche Area (QLDC, 2026). Some field observations by NZSki and Stantec indicate that some of the wastewater infrastructure was impacted by avalanches.

Cardrona Fault forks down approximately 7 km west of the Doolans; this is an active fault (QLDC, 2026). The site is also possibly crossed by one inactive fault.



Flood Hazard has not been mapped at the site according to recently publicised map 'Flood Hazard across Aotearoa New Zealand' produced by Earth Sciences New Zealand^{iv}.

Noting that a specific Flood Risk Assessment has not been conducted, due to the terrain at the site, it may be assumed that flood risk to the dispersal field is low. This is due to the site being at a high elevation with surface water ponding risk minimal and high drainage capabilities due to its sloping terrain. The dispersal fields were designed with significant amounts of freeboard to account for large rainfall events.

As discussed further in Section 3.2, the site under a climate change scenario is expected to experience higher total rainfall, and for the number of events >25mm to increase for a future period of 2021-2040.

^{iv} <https://www.arcgis.com/apps/dashboards/8c1db2b8e37841f29a57a38675388897>, accessed 4/03/26



4 Historic Wastewater Discharge Review

This section reviews the existing wastewater discharge system (Section 4.1) and its efficacy based on the available monitoring data. This includes review of the discharge flows and quality (Section 4.1.1) and observed impacts on the Rastus Burn in terms of contaminant concentrations (Section 4.3). By comparing the historical contaminant load (Section 4.3.5) with the Rastus Burn water quality, preliminary performance criteria for the upgraded wastewater treatment plan have been derived which are needed to maintain good-excellent aquatic ecosystem health (Section 4.6).

4.1 Existing Onsite Wastewater Management System

Figure 3 presents the location of the OWMS.

The current onsite wastewater management system (OWMS) comprises the following:

- The toilet and grey water systems for the Remarkables staff and base building and a public toilet drain to a 35 m³ pre-settlement tank in Car Park 1.
- Flows are then split between twin 75 m³ septic tanks with outlet filters.
- The “treated” wastewater then flows via a buried 100 mm diameter PVC pipe. There are insulated steel pipe bridges where the pipeline crosses over the Rastus Burn prior to entering a below ground concrete sedimentation tank which has a volume of 31 m³. No sludge is observed in this tank.
- The flow from the sedimentation tank is split three ways in a flow splitting manhole and discharged to land through infiltration basins (or dispersal fields). The discharge piping has provision to operate either in series or in parallel, but records show that that these have always operated in parallel as required by the consent.
- In terms of maintenance, the sludge in the pre-settlement and storage tanks in car park 1 is removed twice a year in May and October.

MWH (2014) determined that the infiltration basins were comprised of Category 2 soils (AS/NZS 1547:2012) which for primary treated effluent discharge to a trench or bed had a recommended design irrigation rate of 20 mm/day. The discharge was then sized to the dispersal field at 6,372 m² at 20 mm (20 l/m²/day) which was equivalent to the consented maximum daily discharge volume of 127.44 m³/day. This is considered a conservative rate for gravels and sandy soils for primary treated effluent. The infiltration



basins are 2-3 m deep which provides storage enough for the estimated annual flows (MWH, 2014) and any inflows from precipitation and avalanches without overtopping.

In 2014, the basins were renovated by excavation and replacement of the basal material as uncompacted fill (Photo 7). This process was undertaken to break up any impermeable or pan layers in the base of the basins which may have limited infiltration.

Photo 7. Renovations and Installation of Groundwater Monitoring Bores (MWH, 2014).



4.1.1 Compliance Monitoring

The discharge consent requires monthly monitoring of the effluent (discharge pipe) and groundwater at the dispersal field, and surface water quality of the Rastus Burn (See Table 4).

There are separate analytical suites required for effluent and surface water, however the groundwater quality at BH2 is also tested under the effluent quality regime in Condition 8 (a).



Table 4. Compliance Monitoring Laboratory Analysis Suites

(a) Effluent	(b) Water
(i) BOD ₅	(i) Dissolved Reactive Phosphorus
(ii) Faecal Coliforms	(ii) <i>Escherichia coli</i> /faecal coliforms
(iii) Total Phosphorus	(iii) Nitrate-nitrite
(iv) Ammoniacal nitrogen	(iv) Ammoniacal Nitrogen
(v) pH	(vii) Conductivity
(vi) Total Suspended Solids	(viii) pH
(vii) <i>Escherichia coli</i>	(ix) Total Nitrogen
	(x) Turbidity

4.2 Wastewater Discharge Review

Compliance monitoring of the wastewater flows and discharge were reviewed to gain an understanding of the historical wastewater loading to the dispersal fields.

Flow data was provided to e3s from Stantec and via retrieval from NZSki's Watercheck service in February 2026. NZSki collected monthly wastewater and water quality samples from 2015 to 2025 (other than 2019 to 2021) which reported the concentration of nutrients (and other monitoring parameter's). The data included five blank data points for TN and TP which were substituted with an average of the results from the prior and following month. Not all years had complete datasets; the available data is summarised in Table 5. Load calculations could be completed for the six years that had complete datasets of both flow and discharge quality.



Table 5: Wastewater Discharge Data Available

Year	Flow	Quality	Load Calculations
2015		✓	
2016	✓	✓	✓
2017		✓	
2018	✓	✓	✓
2019	✓		
2020			
2021			
2022	✓	✓	✓
2023	✓	✓	✓
2024	✓	✓	✓
2025	✓	✓	✓
2026		✓	

4.2.1 Wastewater Flows

Flows are measured after the final sedimentation tank and before the flow splitter using a mag flow meter, with data reporting by Water Metrics. The meter has a known issue where it does not record low flows of approximately less than 20m³/day, and therefore may not report flows lower than this (Stantec, 2026). NZSki have replaced the magflow meter for the 2026 ski season.

Figure 10 shows the flows and an average flow value for all years with full datasets.



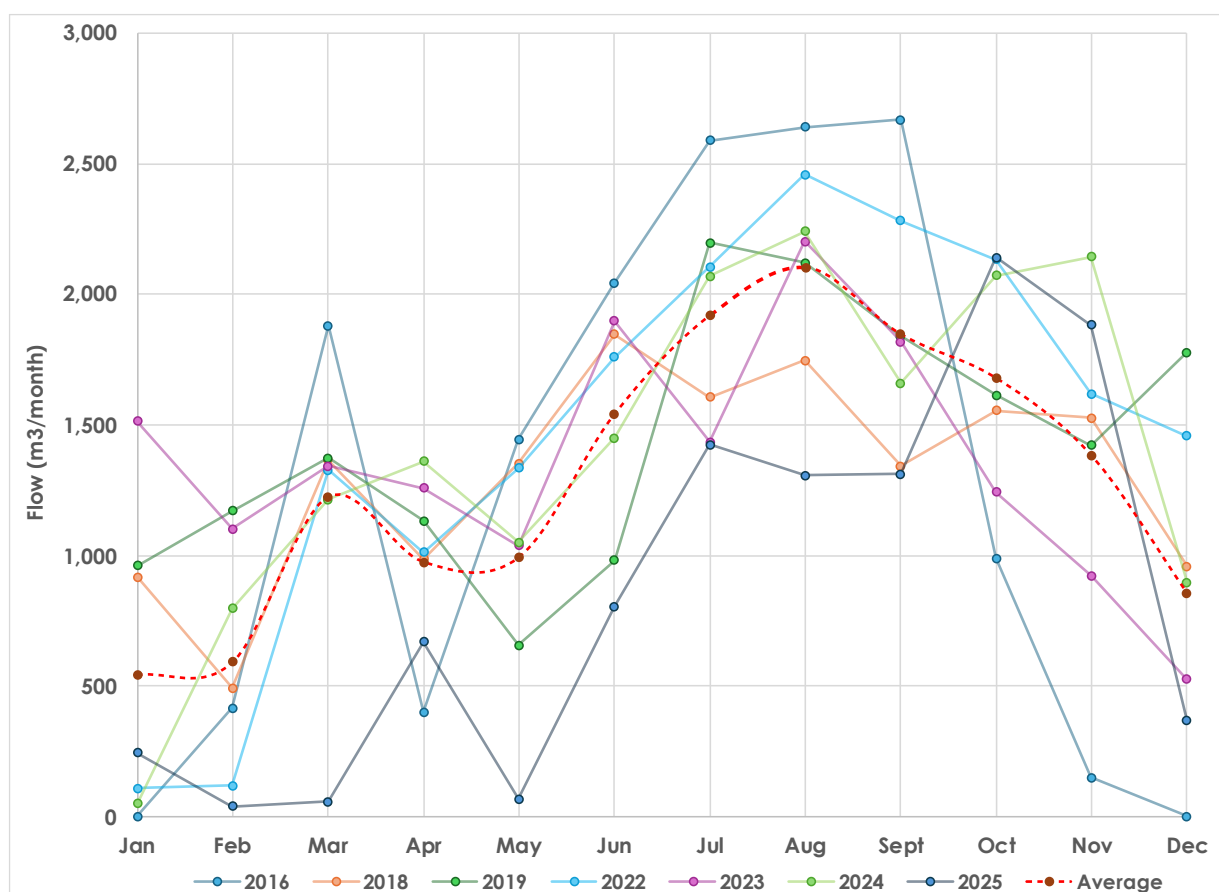


Figure 10. Monthly Wastewater Discharge Flows (m³/month)

For the above dataset, the average flows peak in August at 2,103 m³/month or 68 m³/day (Table 6). The comparatively high flows in the off-season are an artifact of the bywash system, which is discussed further in the following section.

Table 6. Average (2016-2025) Wastewater flows (m³)

Average Flow	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Monthly	542	591	1223	974	992	1540	1919	2103	1846	1678	1381	855
Daily	17	21	39	32	32	51	62	68	62	54	46	28

Total annual and ski season flows are reported in Table 14.

The 2025 year reported the lowest total ski season and annual flow, however the total number of skiers was similar to average. The difference may be due to a reduction in bywash discharge into the wastewater system, or the flow value may be underreported as 2025 recorded the highest number of zero flows.

This may be due to the flow meter not reporting a flow when a flow was occurring due to an insensitivity to low flows. Stantec (2026) identified this issue with the magflow meter and NZSki installed an upgraded system before the 2026 Ski-season.



4.2.2 Bywash

The daily wastewater discharge flow volume is not 100% attributable to the number of skiers on the field as in some cases the same daily flows are reported on off-season days with no skiers present on the field as for days when 1,000 or more skiers are on the field. This additional source of flow is from the potable system bywash.

In Table 6, the offseason (November to May) wastewater flows are approximately half to a third of the ski season: flows range from 17 to 46 m³/day. During this period the occupancy is considerably lower representing visitors using the public toilet facility and a few NZSki staff in the base building; a daily flow of 2-5 m³/day could be expected. Thus, the excess flow (15-25m³/day) is attributable to the potable system bywash which is continuously flushing through the plumbing system preventing issues with freezing in winter.

Thus, if a bywash of 15 to 25 m³/day is assumed, the bywash component may account for up to a third or more of winter flows. The diluting effect of the bywash can be observed in the concentration of nutrients in the wastewater effluent measured at the discharge point which has an average total nitrogen concentration of 51.1 mg/L; whereas Coronet Peak (which does not have bywash) has a higher average concentration of 134 mg/L. However, the total nutrient load is not affected by the bywash component as the bywash water has such low concentrations of nutrients that there is a negligible increase to the total nutrient load from the bywash component.

4.2.3 Wastewater Quality

4.2.3.1 Nitrogen

As noted above, the average total nitrogen concentration for the ski season discharge appears to be lower than Coronet at around 51 mg/L vs 134 mg/L respectively (Table 7). However, in 2025 flows were around 2/3 of previous annual flows (Figure 10) resulting in less dilution and the highest reported TN concentration of 153 mg/L in September 2025, and a 2025 ski season average of 81 mg TN/L.

Table 7. Average Monthly Total Nitrogen Concentration (mg/L) for all years.

Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct
3	5	3	2	2	2	3	31	60	86	62	16
Off Season: 3							Ski Season: 51				



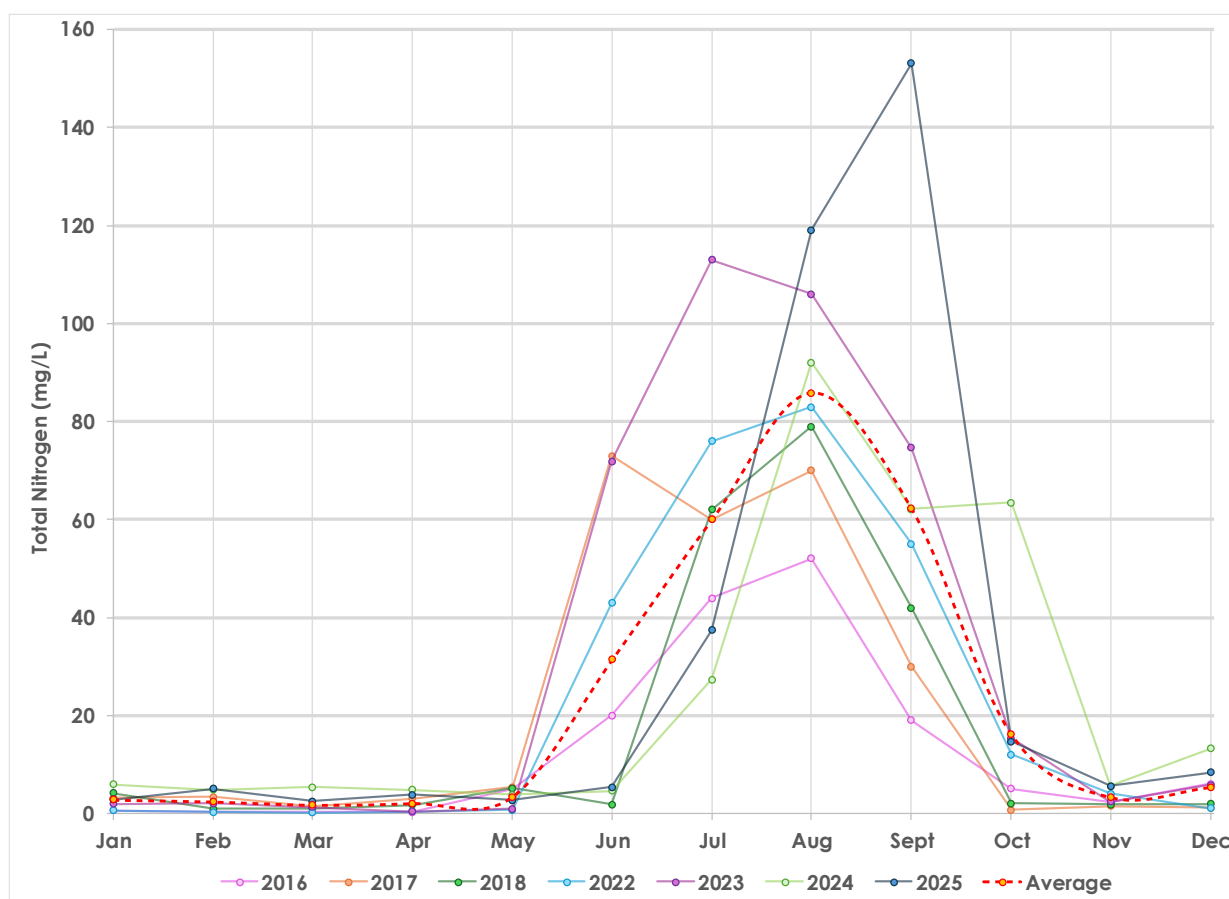


Figure 11. Monthly Total Nitrogen Concentrations (mg/L)

Table 8 presents monthly nitrogen analysis from 2023 to 2025, covering ammoniacal nitrogen, total oxidised nitrogen, and total nitrogen. During the ski season nitrogen is primarily present as ammoniacal nitrogen due to the high nutrient load to the OWMS and low temperatures; there is generally only oxidation of organic nitrogen as ammonification and no nitrification. However, during the summer months when temperatures are warmer, microbial communities can nitrify and thus nitrate concentrations increase.

Organic nitrogen is the fraction of Total Nitrogen remaining when ammoniacal nitrogen and total oxidised nitrogen are subtracted. Results show that negligible organic nitrogen is discharged to land during the ski season as ammoniacal nitrogen is 100% of the nitrogen discharge.



Table 8. Composition of Nitrogen Species (mg/L) in Discharged Wastewater

Date	TON	TAmN	TN	TAmN% of TN	Season
26/06/2023	0.04	71.9	71.94	100%	Ski-Season
12/07/2023	0.05	113	113.05	100%	
10/08/2023	0.05	106	106.05	100%	
14/09/2023	0.06	74.6	74.66	100%	
12/10/2023	0.02	15.4	15.42	100%	
7/11/2023	0.1	2.35	2.45	96%	Off-Season
11/12/2023	0.1	5.83	5.93	98%	
9/01/2024	0.57	4.21	4.78	88%	
8/02/2024	1.2	4.17	5.37	78%	
11/03/2024	2	2.86	4.86	59%	
15/04/2024	2.1	1.77	3.87	46%	
6/05/2024	0.65	3.94	4.59	86%	Ski-Season
17/06/2024	0.01	27.3	27.31	100%	
9/07/2024	0.04	92	92.04	100%	
7/08/2024	0.06	62.1	62.16	100%	
23/09/2024	0.04	63.4	63.44	100%	
16/10/2024	0.01	13.2	13.21	100%	Off-Season
16/12/2024	0.2	2.66	2.86	93%	
16/01/2025	0.83	4.25	5.08	84%	
11/02/2025	1.9	0.56	2.46	23%	
26/03/2025	3.2	0.61	3.81	16%	
15/04/2025	2.4	0.36	2.76	13%	
22/05/2025	3	2.39	5.39	44%	Ski-Season
18/06/2025	0.05	37.4	37.45	100%	
14/07/2025	0.06	119	119.06	100%	
5/08/2025	0.11	153	153.11	100%	
22/09/2025	0.02	14.7	14.72	100%	
15/10/2025	0.1	5.52	5.62	98%	Off-Season
24/11/2025	0.07	1.39	1.46	95%	
16/12/2025	0.12	8.23	8.35	99%	
27/01/2026	1.07	4.53	5.6	81%	
25/02/2026	1.29	8.01	9.49	84%	

4.2.3.2 Phosphorus

Prior to 2023, only total phosphorus was tested at the discharge point, while DRP was tested at other monitoring locations. Based on the available Total and DRP dataset (Table 9), DRP represents on average 70% of total phosphorus in the off-season, while during ski season DRP makes up 50% of total phosphorus.



Table 9. Composition of Phosphorus Species (mg/L) in Discharged Wastewater

Date	TP	DRP	DRP% of TP	Season
27/04/2023	0.23	0.205	89%	Off-Season
26/06/2023	6.14	2.97	48%	Ski-Season
12/07/2023	9.86	5.01	51%	
10/08/2023	11.6	5.05	44%	
14/09/2023	8.02	5.08	63%	
12/10/2023	2.94	1.89	64%	
7/11/2023	0.3	0.206	69%	Off-Season
11/12/2023	0.59	0.471	80%	
9/01/2024	0.52	0.466	90%	
8/02/2024	0.55	0.48	87%	
11/03/2024	0.49	0.315	64%	
15/04/2024	0.44	0.284	65%	
6/05/2024	0.44	0.327	74%	Ski-Season
17/06/2024	2.37	1.05	44%	
9/07/2024	9.35	3.53	38%	
7/08/2024	8.28	4.86	59%	
23/09/2024	6.67	3.15	47%	
16/10/2024	2.88	1.87	65%	Off-Season
16/12/2024	0.39	0.348	89%	
16/01/2025	0.63	0.367	58%	
11/02/2025	0.36	0.336	93%	
26/03/2025	0.46	0.333	72%	
15/04/2025	0.3	0.225	75%	
22/05/2025	0.57	0.462	81%	Ski-Season
18/06/2025	3.63	1.69	47%	
14/07/2025	9.31	6.32	68%	
5/08/2025	14	7.77	56%	
22/09/2025	3.41	1.39	41%	
15/10/2025	1.31	0.654	50%	Off-Season
24/11/2025	0.2	0.152	76%	
16/12/2025	0.79	0.579	73%	
27/01/2026	(≥0.482)	0.482	≤100%	
25/02/2026	0.858	0.876	~100%*	

(≥X) TP was not tested on this date, it is likely to be equal to or greater than DRP
 * DRP and TP were tested using different methods which has resulted in similar but inconsistent results. It is assumed that all P is present as DRP in this sample.

During the ski season, the influent increases in strength significantly, more solid material enters the OWMS. Thus there is an order of magnitude increase in the overall concentration of phosphorus and the proportion of total phosphorus increases.

Dissolved reactive phosphorus is highly mobile especially in poorly buffered soils such as the sandy gravels at the dispersal field. However, the discharge component that is



in other forms (particulate forms) may be assimilated into the subsoil at the dispersal field.

4.2.3.3 Other Monitored Parameters

Typical wastewater performance criteria include biological or chemical oxygen demand, total suspended solids, and microbial pathogens (e.g. *E. coli*). While these parameters are monitored at this site, monitoring of the Rastus Burn indicates that they are not impacting on water quality in the receiving environment and therefore are not discussed in detail.

4.3 Rastus Burn (Receiving Environment) Water Quality

The compliance monitoring results have shown that there are measurable but slight effects on the quality of water in the Rastus Burn from the discharge of wastewater to land. The dominant effects are noted as elevated nutrients and pathogens (faecal indicators) during the months of the ski season. Concentrations are, however, orders of magnitude lower than the concentrations in the effluent discharged to land indicating high attenuation and dilution. Instream ecological data was extracted from the NZSki bi-annual biological compliance monitoring reports (Ryder Consulting 2014, 2017; SLR 2023, 2025 (see Appendix B for all reports)). In general, NZSki appears to be managing the overall nutrient load so that the instream values remain in 'good-excellent' condition.

However, a leak reported in July 2023 resulted in elevated concentrations of wastewater contaminants in the Rastus Burn (including the upstream sample) measured on the 12th July 2023. The leak was noted on the 14th of July due to no or low recorded flows passing through the flow meter from the 5th July 2023. An inspection of the wastewater management system identified a blockage in one of the rodding eyes with effluent being expelled from it and flowing overland into the Rastus Burn just upstream of the upstream sample location. The leak was fixed, and processes updated to check flows daily for any indication of loss of flow. As noted in the annual report, the concentration of contaminants in the Rastus Burn returned to typical concentrations in the August sample.

NB. Access to the 'Downstream 1.5 km' surface water monitoring site during winter is often impeded by high snow levels, so the data for that site is more representative of off-season conditions.



4.3.1 Nitrogen

The effects of nitrogen on aquatic ecosystems can be partitioned into:

- a) direct ecotoxic effects from ammoniacal nitrogen (NH_3 and NH_4^+) and nitrates (NO_3^-); and
- b) chemical stress from excess nutrients in an alpine, nutrient-limited ecosystem (e.g. eutrophication) resulting in algal blooms/excess periphyton growth.

4.3.1.1 Ammoniacal Nitrogen

In terms of ecotoxicity, total ammoniacal nitrogen (that is the sum of un-ionised and ionised ammonia) becomes a contaminant at concentrations higher than the instream aquatic fauna can process (e.g. exhale or excrete). ANZG (2018, 2026) guidance indicates that the Rastus Burn falls outside of the generic DGV parameter conditions as the temperature and conductivity are lower than the generic parameters ($<10^\circ\text{C}$ and $<50\ \mu\text{S}/\text{Cm}$ respectively) and therefore site-specific guideline values may be necessary. In this case, the 99% DGV for total ammoniacal nitrogen for a pH of 7.2 and temperature of 10°C were applied conservatively. In such cold water, it is unlikely that significant un-ionised ammonia is present, and therefore higher amounts of total ammoniacal nitrogen than what currently occurs are required for toxicity to be a concern. The reported instream water quality meets the 99% species protection chronic toxicity DGV and the good water quality Schedule 15 limits (Figure 12 and Figure 13).



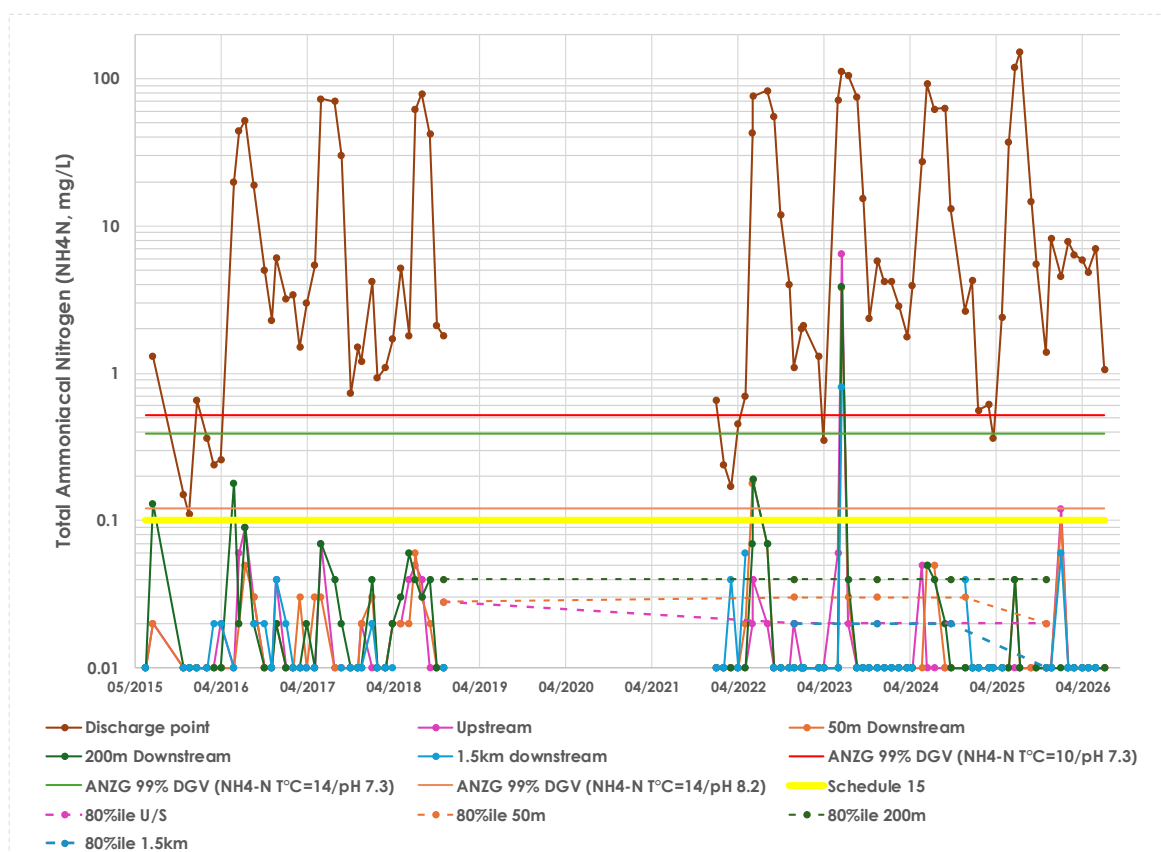


Figure 12. Total Ammoniacal Nitrogen Log Scale/All Data

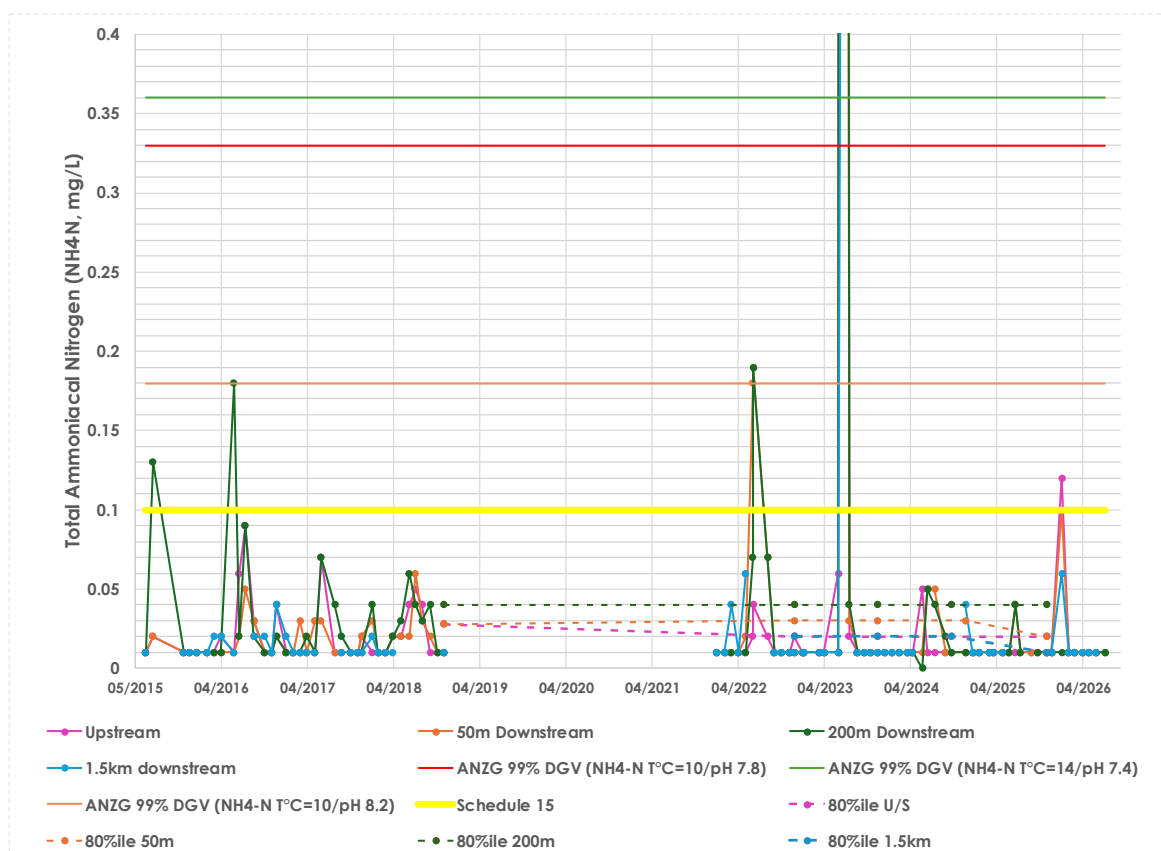


Figure 13. Total Ammoniacal Nitrogen Linear Scale/No Discharge Point



Ammonia concentrations in the Rastus Burn spike every ski season, as a result of the lower flows and increased nitrogen load into the groundwater which recharges the Rastus Burn along the monitored reach. Effects are measurable in the Rastus Burn within a month of the ski season commencing. These concentrations tend to peak at an order of magnitude less than the 99% species protection chronic toxicity DGV. Whilst the discharge has a measurable effect on the Rastus Burn, it appears to be at an acceptable level.

It is noted that on one occasion concentrations did exceed the ANZG Chronic toxicity DGV. This was the result of a documented leak in July 2023 (NZSki, 2023). With respect to performance criteria, spills or leaks are typically short-term duration events (<1 week) and should be excluded as an anomaly rather than incorporated in the long-term rolling means.

As the toxicity of ammoniacal nitrogen is dependent on temperature and pH, the following Table 10 presents seasonal concentration data with a modified (pH/Temperature) ammonia toxicity guideline value to be consistent with reported pH and estimated seasonal changes to water temperature.

Table 10. Maximum Seasonal Total Ammoniacal Nitrogen and pH, for all monthly samples (2015-2026); and Estimated Seasonal Maximum Water Temperature.

Maximum Value	Summer	Autumn	Winter	Spring
<i>Upstream</i>	0.12	0.02	0.09	0.03
<i>50m Downstream</i>	0.1	0.03	0.19	0.03
<i>200m Downstream</i>	0.04	0.03	0.19	0.04
<i>1.5km downstream</i>	0.06	0.06	0.01	0.02
<i>Maximum pH of Downstream 50m and 200m</i>	7.4	7.5	7.8	8.2
<i>Estimated Maximum Seasonal Water Temp ¹</i>	14	7	3	9
<i>Freshwater 99% species-protection guideline values for total ammonia (mg/L N) at different pH and temperature (ANZG, 2026)</i>	0.36	0.45 ²	0.33 ²	0.18 ²
¹ Estimated temperature based on field measurements from February, March, June, July 2026				
² Guideline values minimum temperature of 10 degrees.				

Based on the observations the maximum monthly concentrations of total ammoniacal nitrogen have not exceeded the seasonal modified ANZG (2026) 99% species protection guideline values.



4.3.1.2 Total Oxidised (Nitrate) Nitrogen

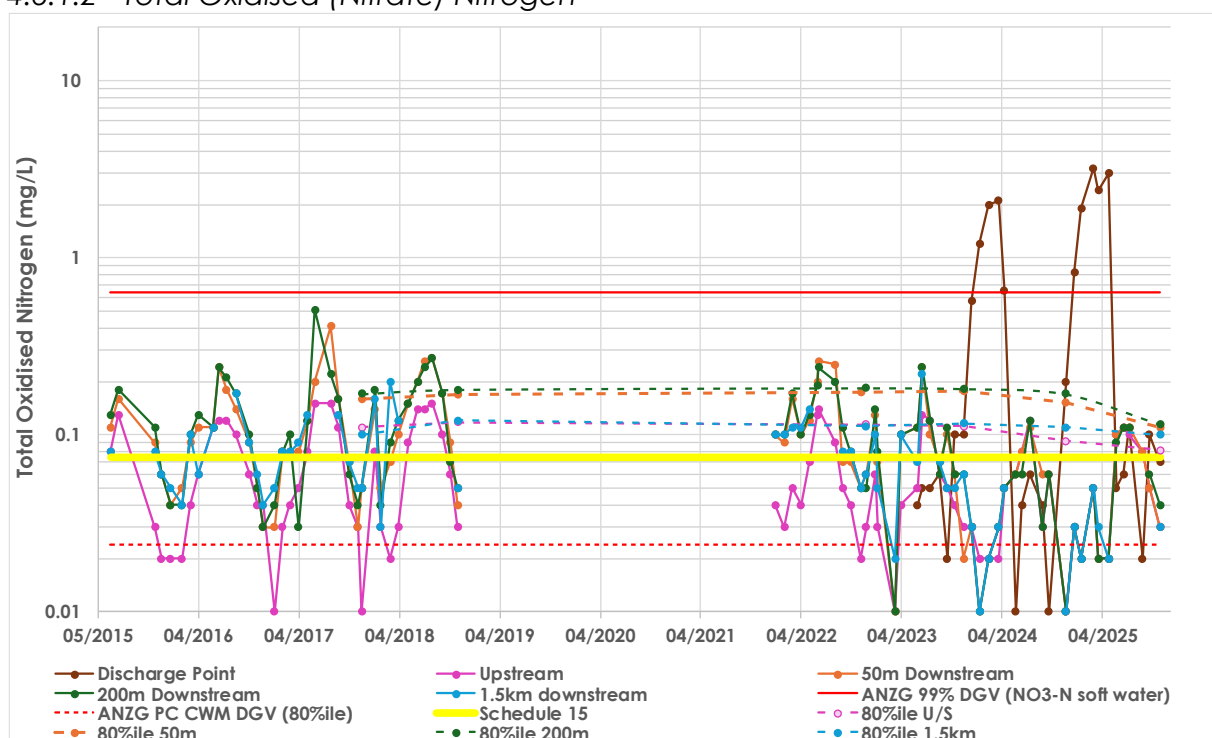


Figure 14. Total Oxidised Nitrogen (Nitrate) Compliance Monitoring Results

The concentrations of TON (nitrate^v) in the Rastus Burn do not exceed the ANZG (2018) DGV for nitrate toxicity effects; instream concentrations are generally around an order of magnitude below the guideline value (Figure 14).

The monthly upstream concentrations frequently exceed the Schedule 15 limit during winter, and 80% of upstream samples over a five-year period also exceed the schedule 15 limit (however it is not known if these samples are collected at median flows or not). Despite the presence of elevated nitrate above the Schedule 15 limit during the winter months and almost always exceeding the ANZG (2018) physico-chemical DGV, there does not appear to be any cumulative ongoing adverse ecological effects in the Rastus Burn e.g. eutrophication. This may be due to the cooler temperatures and overall low nutrients which limit microbial activity even in summer.

In the Rastus Burn, the highest concentrations are observed in winter and lower concentrations in summer which is opposite to the wastewater discharge. The source of elevated concentrations in winter is likely from a minor amount of nitrification occurring as the discharge infiltrates through the vadose zone and mixes with groundwaters. During the summer less nitrate is reported in the Rastus Burn despite a higher nitrate concentration in the discharge; this is likely due to the overall total

^v representing nitrate in this case as nitrite is almost always absent except in the discharge



nitrogen load being reduced by an order of magnitude (which is driven by lower wastewater flows) (see also Table 8 for comparison with the discharge water quality).

Sources of low nitrogen concentrations in the upstream sample are from biogeochemical cycling as a function of temperature and rainfall mediated break down of rock and organic matter, and from biological activity. As for the wastewater system, temperatures increases in the off-season also result in more nitrification in the Rastus Burn.

4.3.2 Phosphorus

Dissolved reactive phosphorus (DRP) has been measured consistently in the Rastus Burn and more recently at the discharge point, allowing an assessment of the mobile phosphorus fraction which may enter the Rastus Burn (Figure 15). ORC's Schedule 15 recommends a DRP limit of 0.01 mg/L, ANZG (2018) has a physico-chemical default guideline value for cool wet mountain (CWM) streams of 0.004 mg/L DRP, and Kilroy and Bothwell (2012) report a didymo growth limit of 0.002 mg/L. The method detection limit for DRP however has ranged from 0.002 to 0.005 depending on the laboratory QA/QC. This makes comparisons difficult, however currently DRP concentrations are meeting the Schedule 15 limits, and concentrations are at times above the didymo limit of 0.002 mg/L (below which didymo blooms are more likely; also the current laboratory limit of reporting).

Increased concentrations over winter are associated with lower flows and increased inputs from the wastewater discharge. As with TON, there is a significant source of DRP upgradient of the dispersal field which may be initially from weathering/erosion of schist bedrock and then subsequent nutrient cycling in the lakes and wetland areas in the upper catchment. Wetlands can have poorer soluble P retention as they become saturated with P over time and plant P cycling largely prefers particulate P sources rather than soluble sources (except for didymo) which are taken up from the water column). As the Rastus Burn flows downstream smaller tributaries add flow from steeper sided catchments with lower P concentrations resulting in further dilution e.g. tributary adjacent to the dispersal field located 100m upstream of the Downstream 50m sample location.



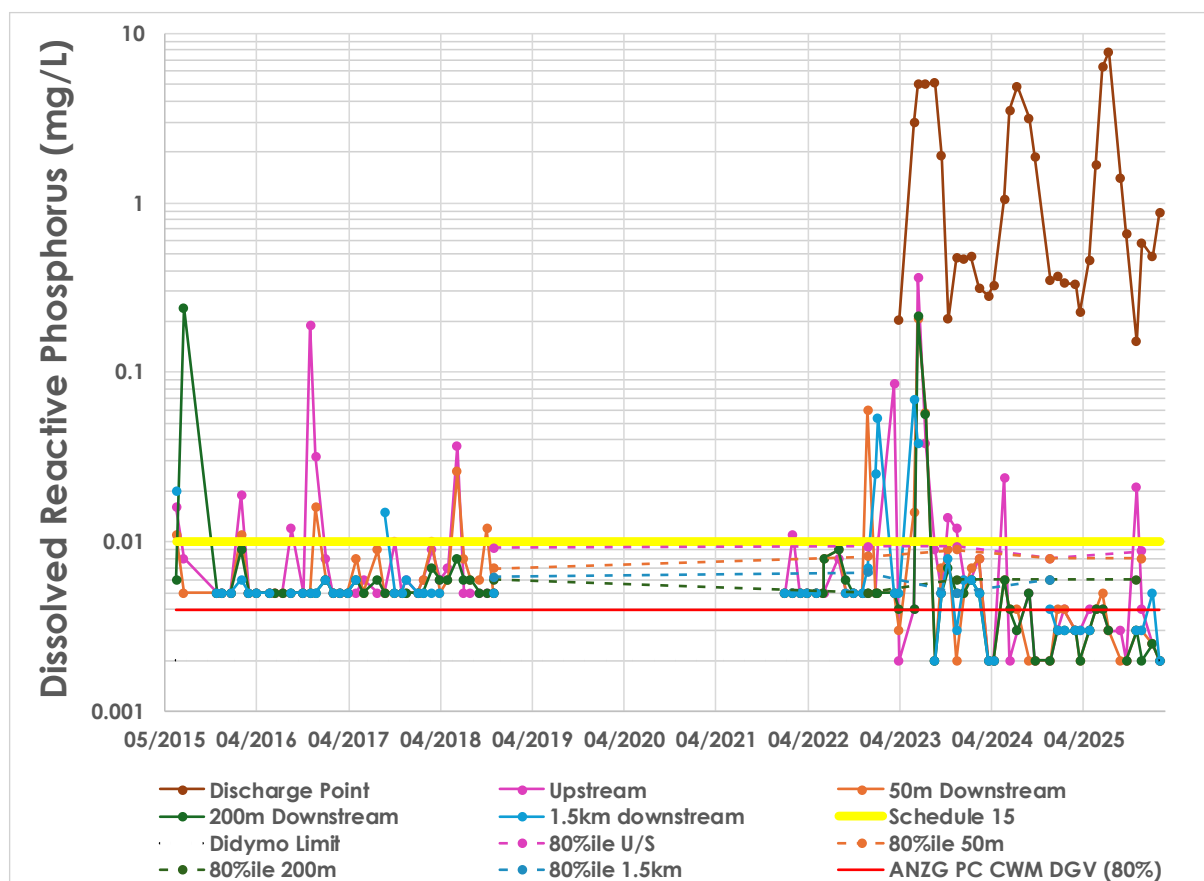


Figure 15. Dissolved Reactive Phosphorus Compliance Monitoring Results



4.3.3 *E. coli*

The same trends for nitrogen are present for *E. coli* (Figure 16) which show occasional measurable impacts to the Rastus Burn during the ski-season when higher flows are discharged to the infiltration basins. All Rastus Burn concentrations meet the schedule 15 limit of 260 cfu/100mL. However, this is generally understood as a limit that is protective of recreational contact. As there are not expected to be any recreational users of the Rastus Burn, the Schedule 15 limit is conservatively applied.

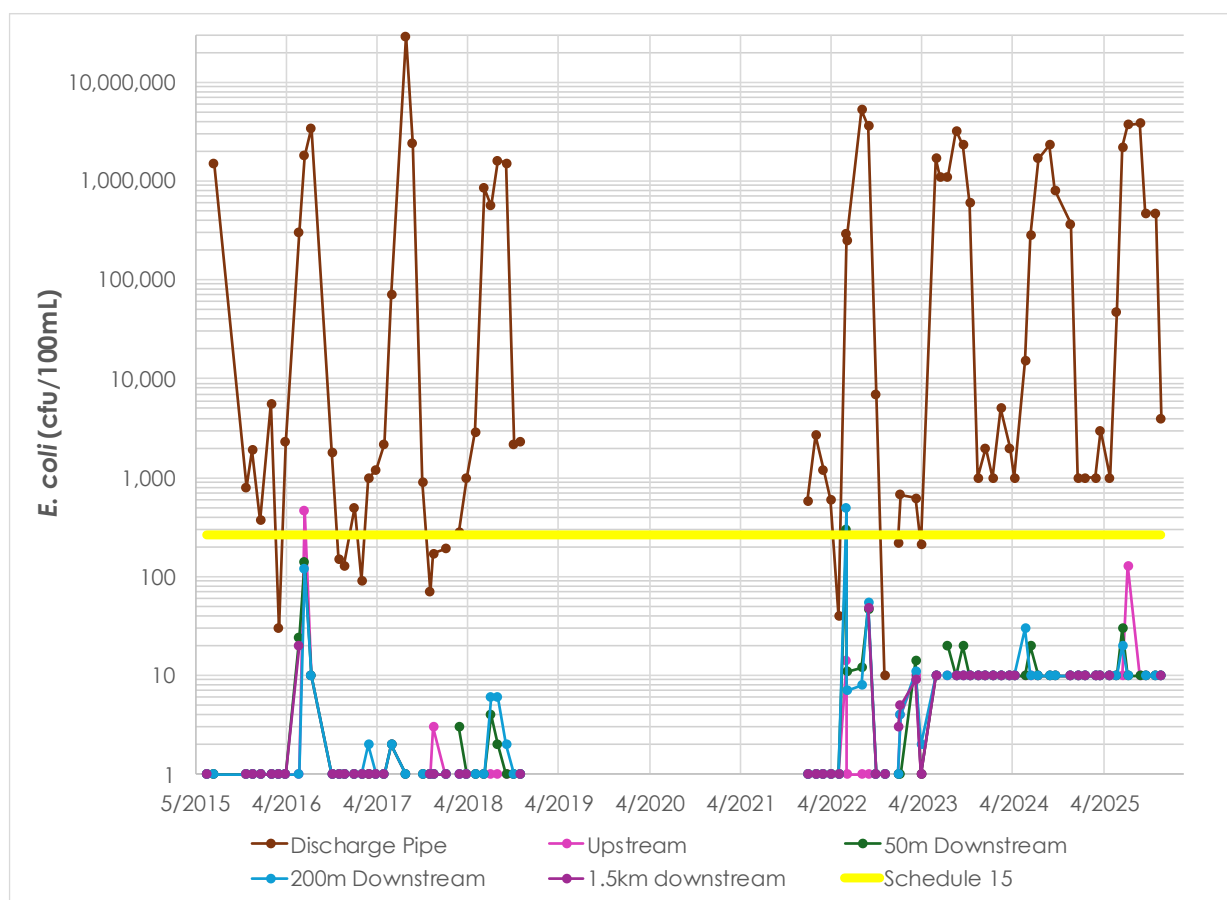


Figure 16. *Escherichia coli* Compliance Monitoring Results



4.3.4 Physico-Chemical Parameters

The following summary of physico-chemical parameters is useful for comparing the upstream quality to the downstream, to determine how the discharge is impacting upon the Rastus Burn.

4.3.4.1 Turbidity/TSS

Total suspended solids (TSS) and turbidity are tested at the discharge point (TSS) and turbidity is tested in the Rastus Burn. The schedule 15 limit applies to 80% of data over a five-year period for samples collected at median flows or lower. Figure 17 indicates an increasing trend at the upstream site, such that the Schedule 15 limit has been exceeded. Whilst concentrations at the downstream 50 m and downstream 200 m sites have also more recently exceeded the limit, it is by a lesser amount than the upstream value; this potentially indicates dilution with distance from the source of the sediment/turbidity.

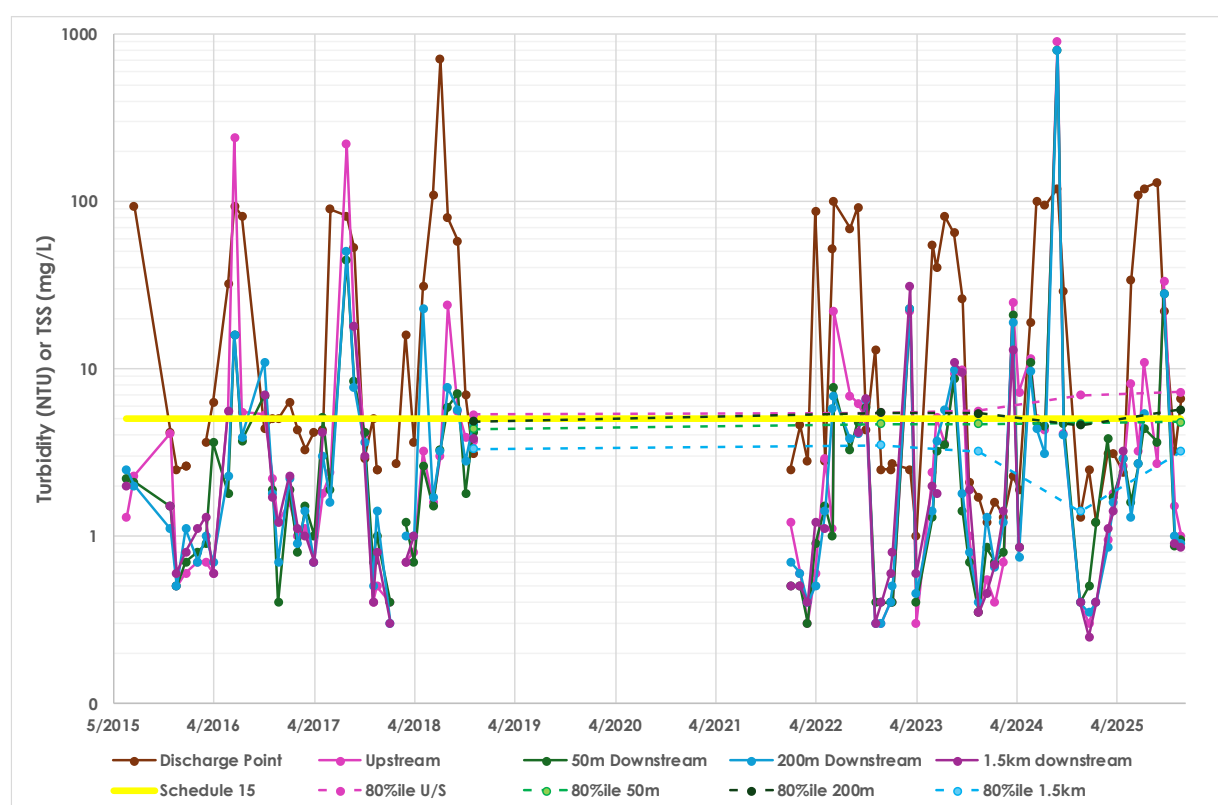


Figure 17. TSS (Discharge Point) and Turbidity (Rastus Burn) Compliance Monitoring Results

It is likely that there is a source of sediment higher up in the catchment as a result of the skifield activities (e.g. car parking/roading). Overall, there appears to be no significant correlation between the discharge and the concentration of sediment in the Rastus Burn (Table 11). This is to be expected as the dispersal fields and receiving soil provide significant filtering of suspended particles.



Table 11. Sample Pearson's correlation coefficient (r).

Sample Location	Discharge Point	Upstream	50m Downstream	200m Downstream
Upstream	0.14			
50m Downstream	0.11	0.96		
200m Downstream	0.11	0.96	1.00	
1.5km downstream	0.22	0.89	0.88	0.89

Instream turbidity concentrations were highly correlated (e.g. $r^2 > 0.88$). None of the instream samples showed any strong correlation with the discharge turbidity concentration. This is consistent with a discharge to land where all suspended sediments are adequately diluted and attenuated during infiltration and transport in groundwater.

4.3.4.2 Conductivity

Conductivity within the Rastus Burn is low to moderate (Upstream reference 80%ile of 45.8 $\mu\text{S}/\text{cm}$; ANZG (2018) suggest a range from low=20 $\mu\text{S}/\text{cm}$ to moderate=50 $\mu\text{S}/\text{cm}$), as expected for waters in the alpine headwaters with brief water-rock interactions (e.g. recharged with recent rainfall) or residence times in water bodies resulting in low dissolved solids. Given the conductivity concentration of the discharge can be as high as 1,000 $\mu\text{S}/\text{cm}$ in winter, low conductivity in the Rastus Burn during winter provides evidence of seasonally variable dilution. The largest dilution and decrease in concentration occur in spring during higher flows; after snowmelt concentrations increase again as flows taper off, until a minor decrease in autumn with increased rainfall. Conductivity concentrations increase in winter as precipitation is stored as snow and July is the month of lowest flows.



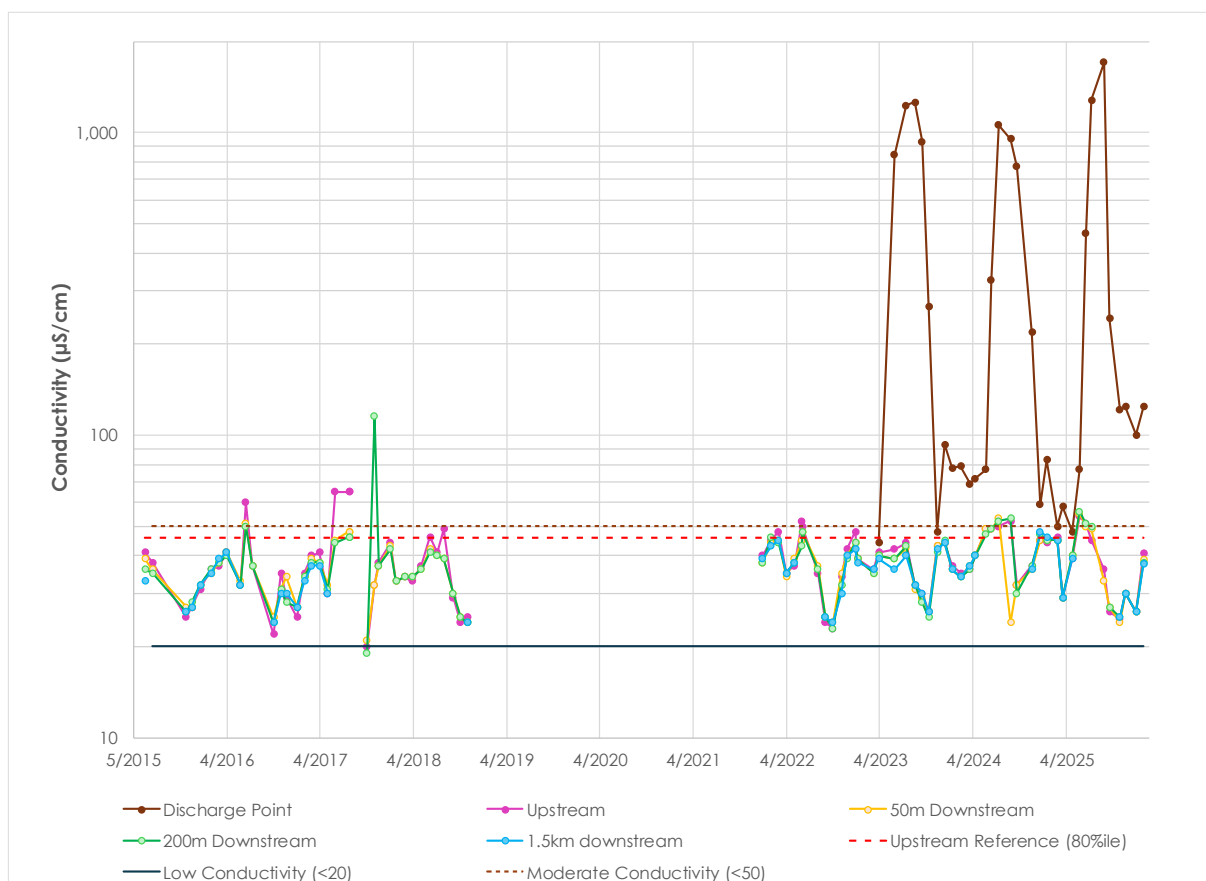


Figure 18. Conductivity Compliance Monitoring Results

4.3.4.3 pH

The discharge pH ranges from over 8 during winter, to less than 7 during summer (Figure 19). The Rastus Burn is effectively neutral (upstream has an average of pH 7.2), while there is significant variability along the monitored reach. During September 2024 the downstream 200 m pH was elevated above pH 8 but the next month's sample had returned to typical values.

With respect to adverse effects from acidity or alkalinity, ANZG (2018) PC DGVs for cold wet mountain (CWM) climate indicate a band of pH for 20% and 80% samples outside of which harm is possible, however ORC did not set a schedule 15 Limit for pH (Figure 20). The 20 and 80%ile values presented in Figure 19 were calculated using all samples from the upstream reference site. The compliance monitoring results are slightly more acidic than the regional DGVs and so it is consistent with the ANZG guidelines to rely on the site reference conditions instead. This acidity is not considered an issue as downstream and upstream concentrations are within 10% of each other and not indicative of any impacts from the discharge.



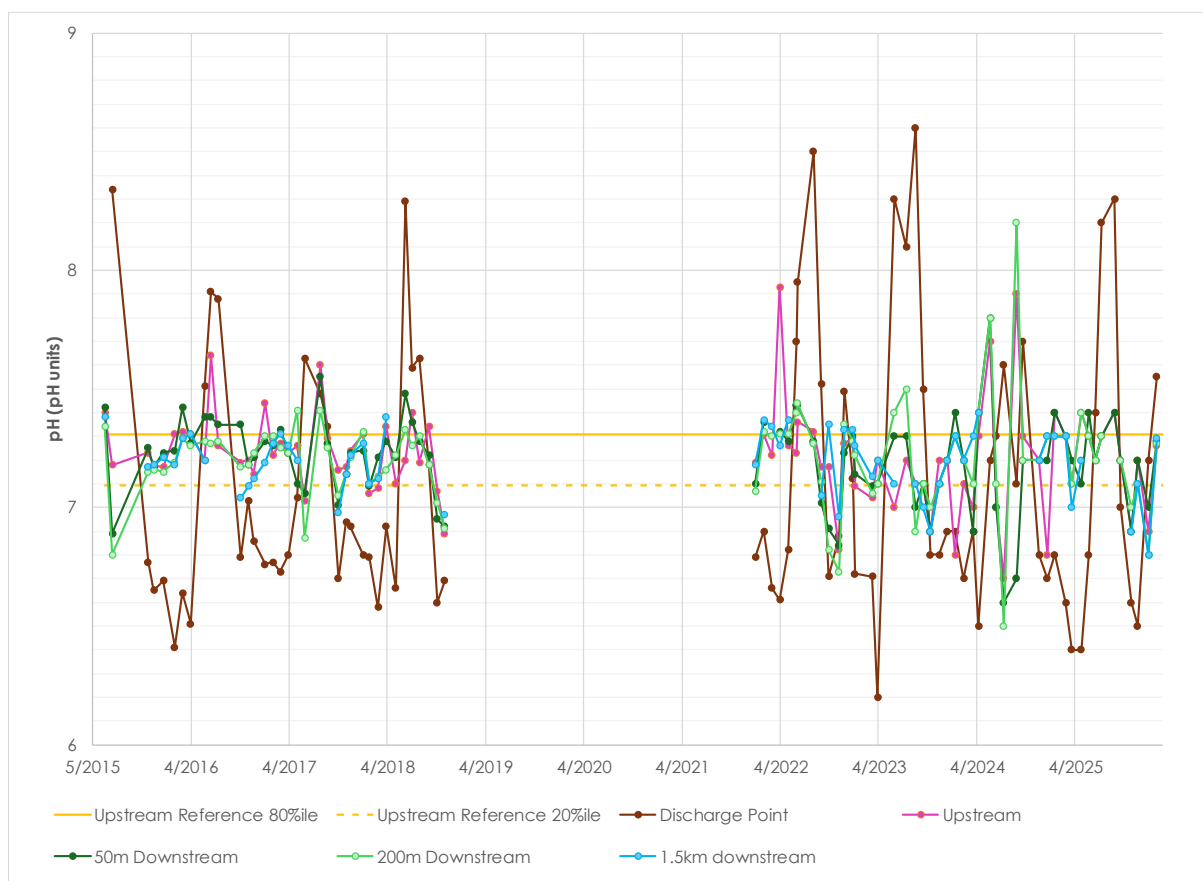


Figure 19. pH compliance monitoring results

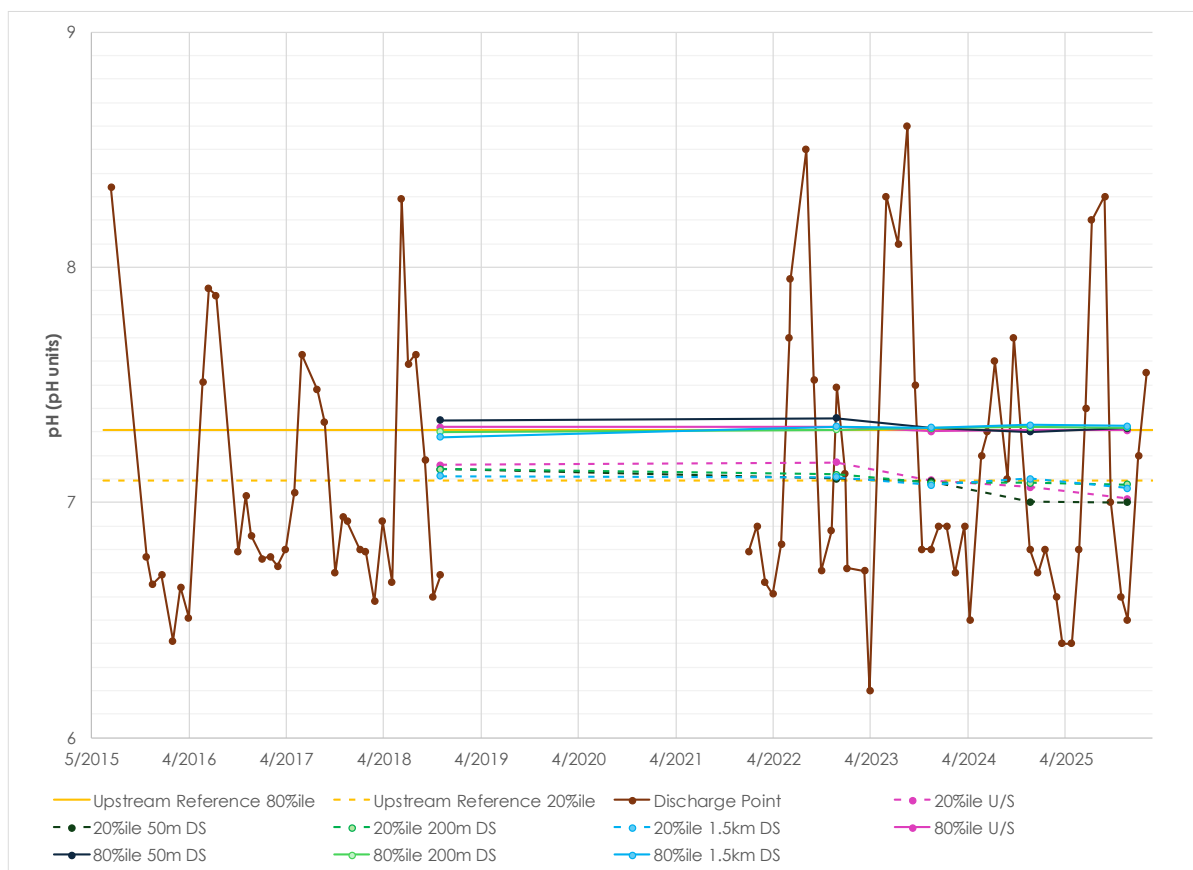


Figure 20. 20%ile and 80%ile pH Compliance Monitoring Results



4.3.5 Further Statistical Analysis

Trend and rank analysis was undertaken to assess if there were any statistically significant relationships in the monitoring data. The statistical analysis confirms previous assumptions that there is a slight but measurable effect during the ski season as measured downstream of the discharge. The effect was statistically significant for nitrogen species but not for dissolved reactive phosphorus. When sites were compared (and adjusted for seasonality) only TN and TON were significantly different between the monitoring sites; NH₄-N and DRP showed no difference. In terms of temporal trends, concentrations appeared to be decreasing or had no trend.

The off-season (highest risk period for toxicity effects due to warmer water temperatures) concentrations for ammoniacal nitrogen and nitrate have a lower average and 80%ile concentration than that of the ski-season; all of which meet the adopted guideline values. This supports the finding that there is a slight but measurable effect from the discharge during the ski-season, and generally no observable effect during the off-season. The inputs to the disposal field increase during the winter in terms of load (Increased flow and concentration) which is also the period of lower flows in the Rastus Burn which in turn result in the peak background concentration of solutes (e.g. as measured at the upstream site).

A memo has been prepared detailing the assessment and is provided in Appendix A.

4.4 Dilution and Attenuation

The concentrations of contaminants from the discharge to land are slight but measurable in the Rastus Burn. As the dispersal field was not designed to provide any land treatment from soil and plant uptake, dilution and attenuation are the dominant processes which mitigate the potential effects to the Rastus Burn. As the discharge infiltrates through the vadose zone, the discharge will be attenuated (e.g. adsorption, destruction). Dilution occurs as the infiltrating plume of wastewater mixes with the excellent quality groundwater beneath the dispersal field. Finally, further dilution occurs as groundwater recharges to the excellent quality Rastus Burn water.

Figure 21 compares the total daily flow as modelled for the Rastus Burn and wastewater discharge flows as measured by NZSki. Flows are compared to assess the potential for dilution in the surface water, as the potential for dilution by groundwater is not readily measurable.



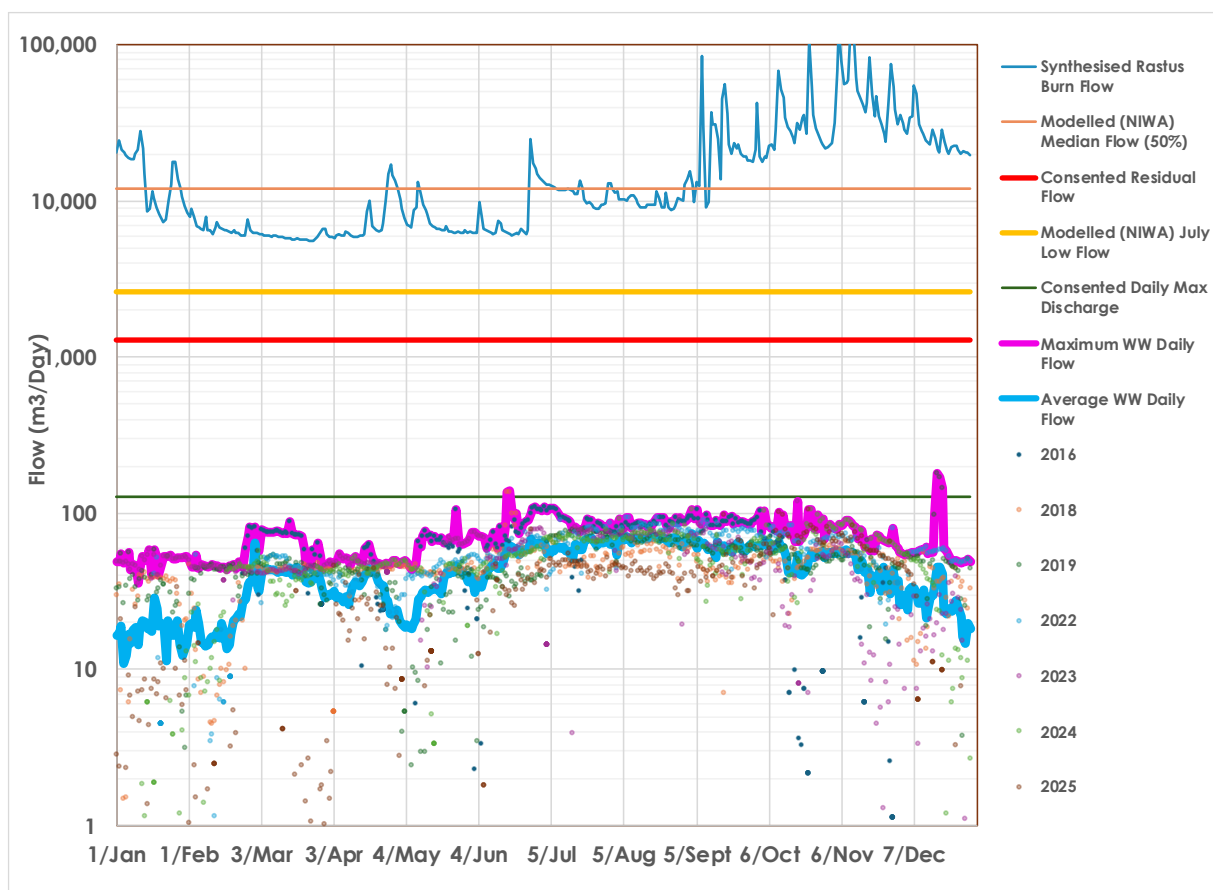


Figure 21. Comparison of Modelled Rastus Burn Flows to Remarkables Wastewater Discharge.

The modelled flows in the Rastus Burn are taken from the flow duration curves generated by Booker and Woods (2014) for the adjacent reach. Flows in the Rastus Burn for 2025/2026 were also synthesised from flow monitoring in Doolans Creek using a relationship between modelled flow duration curves for the two catchments by Booker and Woods (2014).

The residual flow of 15 L/s is required to be maintained in the Rastus Burn below the NZSki water take as a condition of consent. The Rastus Burn residual flow is likely to represent <1% of all flows and be the worst-case scenario, noting that there are additional flows into the Rastus Burn below the water take, and that groundwater provides significant dilution prior to the discharge entering the Rastus Burn. With a flow of 15 L/s in the Rastus Burn, the consented maximum daily discharge would be diluted 10:1, and the average effluent peak flow of 66 m³/day would be diluted 19:1. With average low flow of 25 L/s these dilution ratios increase to 17:1 and 32:1 respectively.



Table 12. Potential Worst-Case Volumetric Dilution Rates

Rastus Burn Flow Rate	Rastus Burn total Daily flow (m ³ /day)	Wastewater Discharge (m ³ /day)	Volumetric Rastus Burn Dilution Ratio
Residual Flow 15 L/s	1,296	127.44 (Consented Peak)	10
		77.5 (Leak Average)	17
		75.31 (June 2023)	17
		72.03 (August 2023)	18
		66 (Ski Season Average)	19
Average low flow 25 L/s	2,160	127.44 (Consented Peak)	17
		77.5 (July 2023 Average)	28
		75.31 (June 2023)	29
		72.03 (August 2023)	30
		66 (Ski Seasonal Average)	32

To assess whether the above Rastus Burn flow values are a reasonable approximation it was determined that the dilution ratio of total nitrogen from the July 2023 leak could provide a secondary line of evidence, as the unknown dilution and attenuation from groundwater was not confounding the dilution calculation. The leak data provides a useful metric for a worst-case scenario for how much dilution would occur should the ski season discharge be direct to surface water (e.g. peak ski season wastewater concentrations and flow rates, and potentially lowest Rastus Burn Flows).

The concentration dilution rate for the leak event was 17:1. The wastewater flow volumes for the leak period were not reported as the leak occurred above the flow meter, however the average daily flow before and after the leak is around 77.5 m³/day which gives an estimated volumetric dilution ratio of 17 as well.

The potential volumetric and concentration dilutions for the period June – August 2023 are presented in Table 12 and Table 13 respectively. The lowest of the June-August concentration dilution ratios (when the discharge is occurring to the infiltration field) is 505, compared to the ratio of 17 which occurred when the wastewater leaked directly to the stream.

Table 13. Total Nitrogen Concentration (mg/L) and Concentration Dilution Ratio Assessment for June – August 2023.

Date	Discharge point	Upstream	50m Downstream	200m Downstream	1.5km downstream
26/06/2023	71.9	0.11	0.12	0.12	0.08
	Dilution Ratio	654	600	600	899
12/07/2023	113	6.6	4.05	4.11	1.03
	Dilution Ratio	17	28	28	110
10/08/2023	106	0.19	0.21	0.18	-
	Dilution Ratio	558	505	589	



NB. The upstream value was used for the leak assessment as it was the samples closest to the location of the leak and thus the most representative of the dilution occurring at the point of discharge to the Rastus Burn. For June and August, the highest concentration in the downstream measuring points is regarded as providing a more conservative assessment of the scale of discharge from groundwater to surface water.

In Figure 22 the total nitrogen concentrations are presented for the June-August leak period. The red arrow identifies the July 2023 leak, while the blue arrows refer to compliant ski season discharges during June and August 2023 when all wastewater was discharged to the dispersal field.

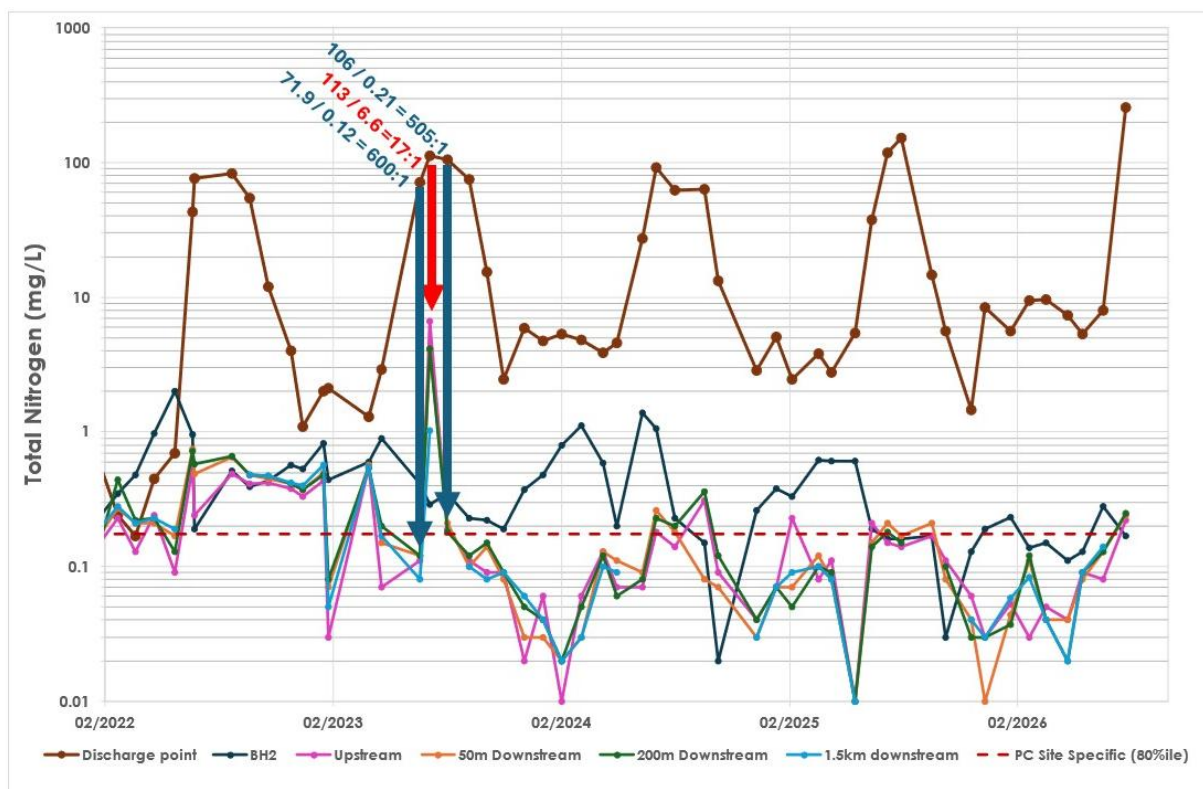


Figure 22. Total Nitrogen (mg/L) 2022 to 2026.

The data presented in Table 13 and Figure 22 indicates the capacity for dilution and attenuation between the discharge point, groundwater, and the Rastus Burn is quite large. The upstream samples were included in Table 13 to help identify the potential increase or decrease in concentration that occurs as the Rastus Burn passes by the dispersal field. It was expected that there would be an increase during the winter months as this is when the peak wastewater contaminant load is occurring. In both June and August 2023, the difference between the upstream site and the downstream site are a slight increase (0.01-0.02 respectively). In the June sample the 1.5km downstream site reports an overall decrease, suggesting that if the discharge was not occurring at all then the background concentrations at downstream 50 and 200m may also naturally decrease with distance from the upper catchment / source of nutrients



(see section 4.3.2). Further investigation of the Rastus Burn Flow including an assessment of losses and gains of flow is planned for ski season 2026.

During the off-season, concentration dilution ratios may be lower e.g. 20:1. Volumetric dilution is not currently well constrained, however in the off-season the wastewater load is measurably lower compared to the ski season, and likely more similar to the background load in the groundwater and/or in the Rastus Burn. Therefore, less dilution is required to attenuate the load to the same degree. i.e. regardless of the season, the concentrations of nutrients as measured in the Rastus Burn are slight but measurable and meet all adopted guideline values (as assessed in detail in section 4.3 and Appendix A).

Overall, the assessment of dilution before, during, and after the leak event in 2023 has helped to provide to constrain the critical factors in the site conceptual model which require characterisation in order to adequately assess the effects. These are:

- The upstream/background nutrient load in the Rastus Burn
- Background nutrient load in groundwater systems, and
- The wastewater discharge nutrient load.

More detailed assessment of the background and wastewater discharge nutrient loads is proposed for ski-season 2026 to validate the current conceptual model for wastewater impacted groundwaters to recharge the Rastus Burn. This is discussed further in Section 5 and section 6.

4.5 Existing Contaminant Load to the Receiving Environment

Monthly and annual total nutrient loads were estimated to determine the benchmarked performance of the dispersal field, as nutrients are the key contaminants that have the greatest potential to result in adverse effects to the receiving aquatic ecosystem. The current nutrient contaminant loads to the downgradient receiving environment are deemed suitable for use as performance criteria for maintenance of water quality conditions. While there are slight but measurable impacts to the water quality of the Rastus Burn, the adopted guidelines are generally being met (section 3.6.1). Further, the biennial biological monitoring has (excepting 2023) reported good-excellent aquatic ecosystem health in the Rastus Burn.

To develop estimations of load, monthly effluent flow data were paired with the relevant effluent quality sample data (e.g. flow and effluent quality concentration



data for May 2023) and multiplied to calculate an estimated monthly load that was discharged to land.

- Monthly load (kg/month) = Monthly concentrations (g/m³) x Monthly Total Flow (m³/month)

Table 14 collates the annual nutrient loads, patronage, wastewater discharge, and ecological monitoring data to provide for a general overview of the current discharge loads for nitrogen and phosphorus.

The key overall observation from Table 14 is that there appears to be a threshold that was crossed prior to the monitoring in 2023, resulting in a change from good-excellent instream values in the Rastus Burn (as measured in 2017) to 'Fair to Good' in 2023. This is attributed to both the leak that occurred in July 2023, and the two years of higher nutrients loads in 2022 and 2023. In 2025 the monitoring of instream quality indicators reported a return to good-excellent condition at all sites and the nutrient loads were less for 2024/2025 than 2022/2023.

During the leak concentrations of nitrogen (ammoniacal nitrogen) exceeded the 80% species protection toxicological effects DGV for presumably the entire time the leak was occurring e.g. 5th to 14th July 2023, 9 days. Although the exposure period was less than an invertebrate lifecycle, it is possible that the nine day direct discharge to surface water was sufficient to cause acute toxicological effects to sensitive freshwater species present. This may have affected species that were entering a sensitive period in their lifecycle. It is noted that the reported toxicological effect for mayfly (*Deleatidium sp.*) is 3.2 mg/L total ammoniacal nitrogen (ANZG, 2026), which was presumably exceeded at the upstream and downstream 50m and 200m monitoring sites for the entire 9-day period.

The *Deleatidium sp.* abundance declined in 2023 compared to 2014/2017 and still has not recovered as of the 2025 monitoring event. Therefore, it's possible that the community was significantly affected by the leak. When biological monitoring occurred more than three months later, evidence of the effects of the leak on the ecosystem health may still have been present. That may be the dominant factor in the decline from good-excellent in 2014/2017 to fair-good in 2023.

At the same time, higher nutrient loads were also discharged during 2022 and 2023 than were observed in the preceding and following years. High nutrient loads can result in a subtle increase in productivity which changes the instream community as it adjusts to more growth of periphyton and macroalgae. As these two factors (leak and nutrient loads) are both potential causes of the degraded instream values in 2023, it is assumed



that in addition to a leak exceeding toxicological thresholds, that a threshold for the cumulative ongoing nutrient load to the environment was also exceeded in 2022/2023. As the nutrient loads reduced in 2024 and 2025 and the biological monitoring in 2025 reported a return to good-excellent quality, it was conservatively assessed that an overall nutrient load threshold could be determined based on the calculated annual nutrient loads.

NB. The below EPT Taxa% quality bands were developed for the visual assessment of the reported data on sensitive and tolerant species and are not supported by national or international guidance.



Table 14. Review of nutrient load, patronage, wastewater flows, and ecological monitoring.

Table 11a: Nutrient load assessment	2016	2018	2022	2023	2024	2025	Average
Annual WW Discharge (m3/year)	15,227	15,693	17,724	16,299	17,009	10,311	15,659
Ski Season WW Discharge (m3/year)	10,933	8,095	10,744	8,597	9,494	6,989	9,087
Ski Season Patronage (person/year)	219,179	241,609	281,652	299,626	270,826	294,735	267,938
Ski Season WW L/person (bywash inclusive)	50	34	38	29	35	24	34
Discharged Annual N Load (kg/year)	356	320	601	701	549	463	498
Discharged Annual P Load (kg/year)	82	66	57	72	61	43	64

Table 11b: Ecological Monitoring		2013-2014	2016-2017	2022-2023	2024-2025	Average
Periphyton	All sites	Absent or rare across all sites	Absent or rare across all sites	Absent or rare across all sites	Absent or rare across all sites, didymo detected at 200 DS	-
EPT Taxa%	Upstream	51	44	49	63	52
	50m DS	47	52	39	48	46
	200m DS	49	43	36	60	47
	1500m DS	-	49	54	54	52
MCI Score	Upstream	114	119	99	123	114
	50m DS	125	130	105	130	123
	200m DS	129	117	96	132	119
	1500m DS	-	116	118	134	123
SQMCI Score	Upstream	7.3	7.4	5.6	7.4	7
	50m DS	6.9	7.3	4.9	7.6	7
	200m DS	7.1	6.3	5.2	7.3	6.5
	1500m DS	-	7.1	7.2	7.9	7

Interpretation guide for Table 11a.

Highest value
Mean value
Lowest value

Interpretation guide for Table 11b

Quality Class A	Quality Class B	MCI	SQMCI	EPT Taxa%
Clean water	Excellent	≥ 120	≥ 6.00	>50
Doubtful quality	Good	100 – 119	5.00 – 5.99	40-49
Probable moderate pollution	Fair	80 – 99	4.00 – 4.99	<40
Probable severe pollution	Poor	< 80	< 4.00	



4.5.1 Nitrogen Load

Based on the assessment (Table 15), the estimated nutrient loads from 2016-2018 appear to have doubled by 2022-2023 and then reduced back to lower values in 2024-2025 (see monthly loads in Figure 23). The increase in load in 2022/2023 appears to be directly related to the increases in wastewater flows and slight increases in nitrogen concentrations (Figure 24). It appears that although there is an increasing trend in total nitrogen concentration over time (NB. more pronounced in the maximum values) lower flows in 2025 resulted in lower loads.

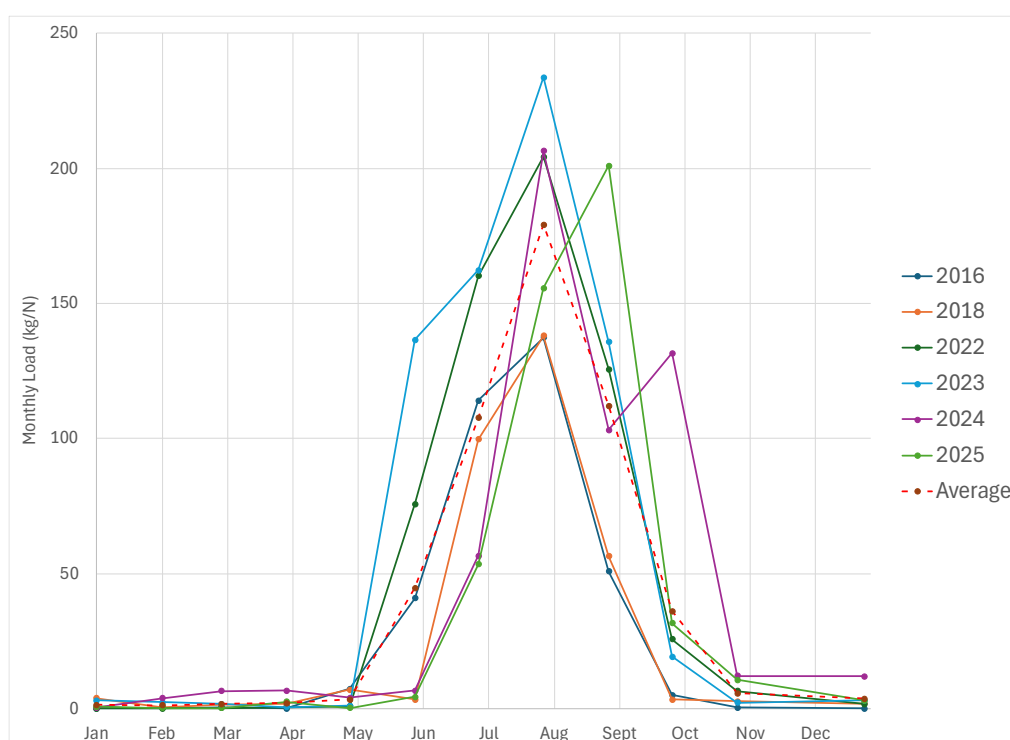


Figure 23. Estimated Monthly Total Nitrogen Load.

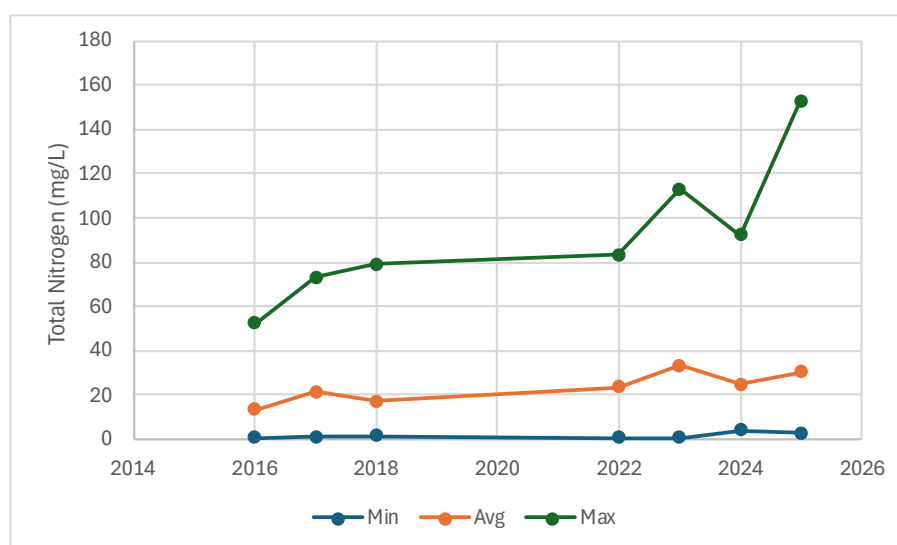


Figure 24. Annual Aggregated Total Nitrogen Concentrations



A critical factor for the discharge is that it is seasonal with highest loads during the winter-spring ski season, coinciding with the lowest flows in the Rastus Burn. Although no monitoring of aquatic ecology occurs during winter, due to low temperature in the Rastus Burn it is expected that the slight but measurable increase in nutrient load is unlikely to result in periphyton productivity increases (e.g. algal blooms) or chronic adverse effects on grazing invertebrates. Aquatic ecology is monitored following the ski season once snow melt has occurred to allow access to the creeks and provide a summary snapshot of the community following discharge of the bulk of the contaminant load. Based on the assessment in Table 8, the biological components in the treatment system are active from October to May, converting ammonia to nitrite/nitrate. At this time, increases in Rastus Burn flow, water temperature and daylight length allow instream flora and fauna to process any accumulated nutrients.

Based on the observation of adverse effects due to higher nutrient loads in 2022/2023, it is recommended that nutrient loads be maintained at the those measured in 2024-2025 when ecological indicators were good-excellent. Table 17 provides the proposed performance criteria for nitrogen.



Table 15. Estimated Total Nitrogen* Load (monthly (kg/month) and Annual (kg/year)

Month	2016	2018	2022	2023	2024	2025	Min Load	Mean Load	Max Load
Jan	0.1	3.9	0.1	3.0	0.3	0.7	0.1	1.3	3.9
Feb	0.1	0.5	0.0	2.3	3.8	0.2	0.0	1.2	3.8
Mar	0.5	1.5	0.2	1.7	6.5	0.1	0.1	1.8	6.5
Apr	0.1	1.7	0.5	0.5	6.6	2.5	0.1	2.0	6.6
May	7.2	7.0	0.9	1.0	4.1	1.9	0.9	3.7	7.2
Jun	40.9	3.3	75.7	136.5	6.7	4.3	3.3	44.6	136.5
Jul	114.0	99.6	160.1	161.9	56.5	53.3	53.3	107.6	161.9
Aug	137.3	137.9	204.2	233.6	206.4	155.7	137.3	179.2	233.6
Sept	50.7	56.3	125.6	135.7	103.2	200.9	50.7	112.1	200.9
Oct	4.9	3.3	25.6	19.1	131.4	31.5	3.3	36.0	131.4
Nov	0.3	2.7	6.5	2.2	12.0	10.6	0.3	5.7	12.0
Dec	0.0	1.9	1.6	3.1	12.0	3.1	0.0	3.6	12.0
Annual Load (% change)	356	320 ↓10%	601 ↑88%	701 ↑17%	549 ↓22%	465 ↓15%	250	499	916

*In some cases, total nitrogen was not assessed at the discharge point, however total ammoniacal nitrogen was analysed and was found to be generally representative of the total nitrogen load as there is a negligible amount of organic nitrogen (TKN) and inorganic oxidised nitrogen (nitrate/nitrite) in the primary treated wastewater. See Table 4 for a breakdown of nitrogen species.



4.5.2 Phosphorus Load

Based on Table 16, phosphorus inputs to the Rastus Burn catchment are modest. On average, 50% of the total P load during the ski-season is reported as DRP. Concentrations in the Rastus Burn from 2024 and 2025 were below the Schedule 15 limit.

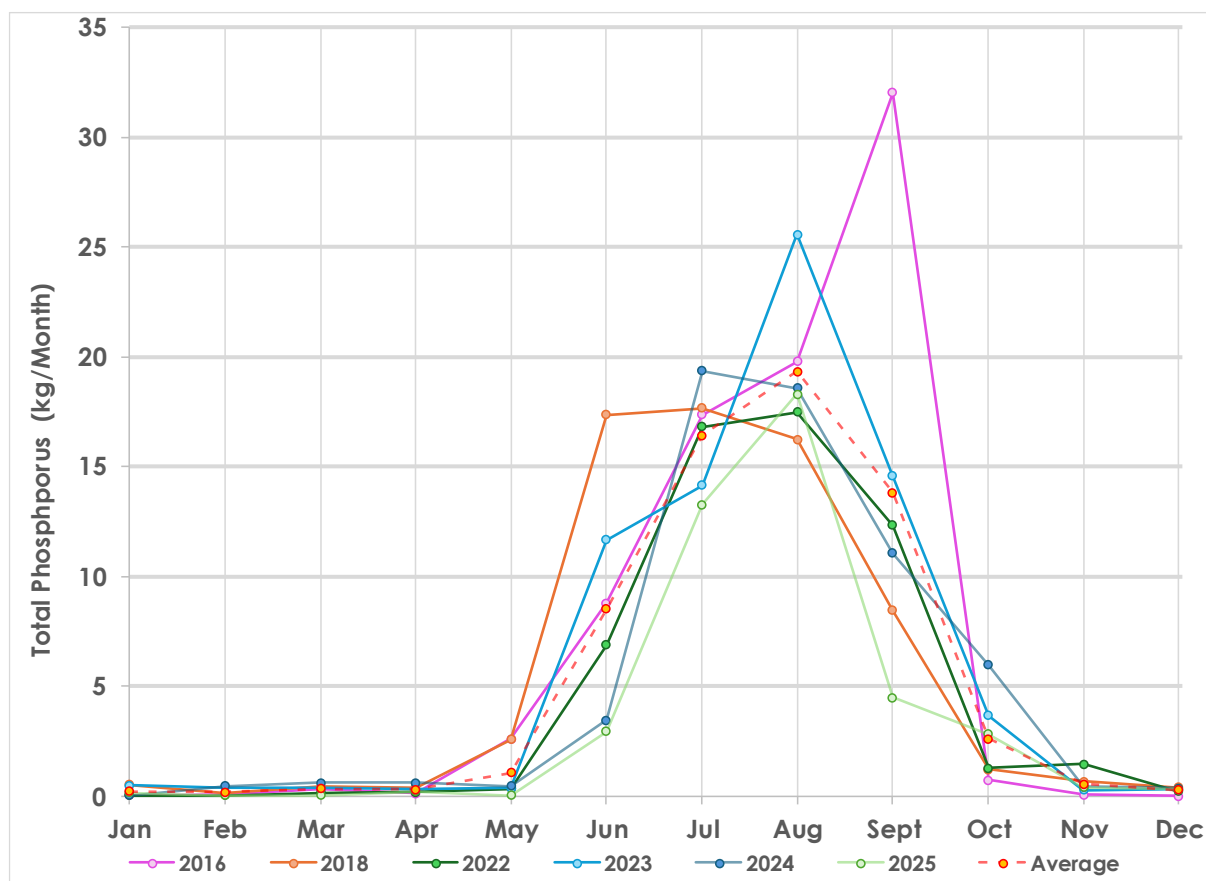


Figure 25. Estimated Monthly Total Phosphorus Load.

In general, waters in New Zealand are phosphorus limited, therefore while nitrogen is considered a more pressing concern, the total phosphorus load should also be managed such that excess nutrients are not available in the receiving environment. Performance criteria were therefore derived from the historic month to month load (Figure 25) and overall annual phosphorus loads (Table 16). Table 14 provides the performance criteria for phosphorus.



Table 16. Estimated Total Phosphorus Load (monthly (kg/month) and annual (kg/year))

Month	2016	2018	2022	2023	2024	2025	Min Load	Mean Load	Max Load
Jan	0.02	0.50	0.02	0.47	0.03	0.15	0.02	0.20	0.50
Feb	0.08	0.10	0.02	0.39	0.44	0.01	0.01	0.17	0.44
Mar	0.34	0.42	0.16	0.36	0.59	0.03	0.03	0.32	0.59
Apr	0.10	0.38	0.17	0.29	0.60	0.20	0.10	0.29	0.60
May	2.60	2.57	0.32	0.31	0.46	0.40	0.31	1.11	2.60
Jun	8.79	17.35	6.87	11.66	3.44	2.92	2.92	8.50	17.35
Jul	17.35	17.68	16.81	14.13	19.35	13.26	13.26	16.43	19.35
Aug	19.80	16.24	17.47	25.57	18.57	18.31	16.24	19.32	25.57
Sept	32.04	8.45	12.33	14.59	11.07	4.47	4.47	13.83	32.04
Oct	0.71	1.21	1.28	3.65	5.97	2.81	0.71	2.60	5.97
Nov	0.05	0.66	1.46	0.28	0.43	0.38	0.05	0.54	1.46
Dec	0	0.38	0.20	0.31	0.35	0.29	0.00	0.26	0.38
Annual Load (% change)	82	66 ↓20%	57 ↓14%	72 ↑26%	61 ↓15%	43 ↓30%	38	64	107



4.5.3 Other Contaminants

4.5.3.1 TSS

With respect to TSS, the discharge is to highly permeable gravel bedded infiltration basins. The TSS is expected to be largely filtered by the gravels so is not a concern for the Rastus Burn, however clogging of the pore spaces is a long-term concern for acceptance of the wastewater at the dispersal field. A maintenance schedule will be provided to ensure particulates do not clog pore spaces and lower infiltration rates. Observations are that the basins are currently performing as expected, therefore by maintaining the same TSS load the dispersal field should remain fit for purpose. Table 14 provides performance criteria for TSS

4.5.3.2 Biological Oxygen Demand (BOD)

The BOD is a measure of the organic matter in the sample. A key concern for land dispersal of wastewater is the land's continuing capacity to assimilate organic matter. However, the organic loading rate is not critical at this site as the dispersal field is not designed for any land treatment. Further, significant algal mats or other organic growths are unlikely to clog up the pore spaces of the dispersal field as the temperatures are far too cold to support high growth rates. In the offseason when temperatures are warm enough for such growth there is very little organic matter discharged at the site. Ongoing monitoring of the base of each infiltration basin is recommended as a key action for managing the risk of clogging from excess organic matter.

4.5.4 *E. coli*

The existing dispersal field is likely to provide excellent pathogen removal (as indicated by *E. coli*) due to the thickness of sandy gravel above the groundwater table, and distance that any pathogens must travel before entering a surface water body. As the site is not located near any recreational sites for water use, and there is no drinking water supply within 1 km of the discharge, no performance criterion for *E. coli* is recommended.

While not a performance criterion for the OWMS, monitoring of *E. coli* is still required, especially in the case of monitoring risks from any leaks or spills.



4.6 Preliminary Performance Criteria for Water Quality

Based on the review of historical discharge loads and ecological health of the Rastus Burn in Section 4.3.5, preliminary performance criteria for discharge quality are proposed in Table 17.

Table 17. Preliminary[#] Performance Criteria for discharge quality at the discharge point for maintaining the existing Water Quality Conditions in the Rastus Burn.

Parameter	Criteria	Rationale
Nitrogen Load	Five-year rolling mean is ≤ 500 kg nitrogen/year	The average value (rounded) of reported loads, particularly 2024 and 2025
	Must not exceed 600 kg nitrogen/year in any calendar year	Potential threshold as the lower of the two years 2022 and 2023
Phosphorus Load	Five-year rolling mean is ≤ 65 kg phosphorus/year	The average value (rounded) of reported loads
	Must not exceed 85 kg phosphorus/year in any calendar year	Halfway between the average value and the maximum possible load as per Table 16..
TSS Concentration	Five year rolling mean is ≤ 40 mg/L TSS	Average concentration (rounded) of the compliance monitoring dataset at the discharge
	Five year rolling 95%ile is ≤ 110 mg/L TSS	95%ile value (rounded) of the compliance monitoring dataset at the discharge pipe
BOD Concentration	Five year rolling mean is ≤ 80 mg O ₂ /L (BOD ₅)	Average concentration (rounded) of the compliance monitoring dataset at the discharge
	Five year rolling 95%ile is ≤ 320 mg O ₂ /L (BOD ₅)	95%ile value (rounded) of the compliance monitoring dataset at the discharge pipe
E. coli	No criterion	A performance criterion for human faecal pathogens is not required as the natural die-off rates are high, and there are no sensitive receptors in the affected downstream reach.

[#]Further investigation is required to validate the preliminary performance criteria for water quality as there are some risks associated with the way in which the concentration and flow data are considered representative of the actual discharge

NZSki have confirmed that the current nutrient loads will be maintained to preserve the good-excellent aquatic ecology in the Rastus Burn despite an increase in patronage and associated wastewater flows. The monitoring of ecosystem health indicators in the Rastus Burn indicates that overall, a good-excellent quality has been maintained since the discharge monitoring commenced in 2014. To improve the ecosystem health indicators for the Rastus Burn, a reduction in nutrients compared to current load is needed. However, while water quality may improve (e.g. no detection of the discharge in the Rastus Burn), it should be noted that this may not necessarily be reflected in an improvement in the ecosystem health indicators in the immediate



downstream reach as the level of productivity in the ecosystem may be partially supported by the discharge.

5 Conceptual Site Model and Risk Assessment

To summarise the current understanding of the discharge, the transport and fate of the contaminants, and their effects on the environment, a conceptual site model has been developed. The conceptual site model is summarised in Table 18.

Table 18. Summary Conceptual Site Model

Source	Discharge of skifield wastewater to land via infiltration basins
Pathway	<p>The discharge to land infiltrates through base of the dispersal field which is largely comprised of sandy gravel with silt overlying shallow bedrock. The discharge infiltrates and intersects groundwater at depths of 5-10m below ground level (refer to cross sections in section 3.4). During infiltration pathogens die off at high rates.</p> <p>The process of organic matter decomposition begins in the vadose zone where oxygen is available. At the water table an oxidation/reduction front is present where excess organic matter is decomposed through reduction of other oxidising agents (e.g. manganese oxide).</p> <p>The two waters mix, and a plume of dissolved contaminants follows the steep groundwater gradient and travels 50 – 100m in a northerly and westerly direction towards the Rastus Burn. It is conservatively expected that groundwater does not penetrate the bedrock in any significant volume due to the relatively low permeability of the schist compared to the overlying unconsolidated materials.</p>



Receptor	<p>The Rastus Burn receives groundwater recharge indirectly via seeps at breaks in slope which flow overland; or directly via more diffuse groundwater gains through the channel bed along a reach of over 500 m. The impacted groundwater may also follow preferential flow paths. The discharge is diluted on average 170 times by the time it mixes with the Rastus Burn. As discussed in section 4.4.1, there is a seasonality associated with the current discharge. The risk to the sensitive receptor is greatest during early winter when the combination of peak wastewater contaminant load is paired with low flow in the Rastus Burn. Outside of the ski season, the increased flow in the Rastus Burn during summer and risk posed from warmer water temperatures is mitigated by negligible wastewater contaminant load, and during autumn when Rastus Burn flows decrease, temperatures begin to decrease as well.</p>
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6 Ongoing Investigations

While the anticipated environmental effects are well understood, further investigations are recommended to reduce uncertainty regarding the conceptual site model (Table 18) and preliminary performance criteria. These uncertainties can be grouped by their respective part of the CSM framework (source, pathway, receptor).

6.1 Limitations, Risks, and Mitigation

6.1.1 Flow Meter

The flow meter has been shown to only report flows above a certain threshold and has reported negative flows at times. This introduces uncertainty into the calculation of wastewater nutrient loads which utilised recorded total daily flow values. Therefore, the monthly flow totals used in load calculations potentially underestimating the flows, and thus lower loads were calculated and suggested as preliminary performance criteria.

A new flow meter was installed in April 2026 by NZSki to improve the accuracy at low flows.



6.1.2 Treated Wastewater Quality

Historically the monthly grab sample from the discharge point to the infiltration basins is collected in the morning between 7am and 12pm. This introduces some uncertainty over and above the use of a single monthly discharge sample in estimating a monthly nutrient load. The time of day at which the sample is collected, and the day of the month are important as they should seek to sample representative conditions.

The issue of timing is due to the lag time between the skier's activity and the processing and discharge of treated wastewater. Due to the lag time, bywash is likely to dominate flows early in the morning, with treated effluent becoming a dominant stream from afternoon into the evening, before reverting to baseflow once the days load has been processed.

Hourly sampling of the flow and the discharge quality should be undertaken during future investigations to understand whether the available historic monitoring datasets are representative of the variation in daily and monthly concentrations to confirm the performance criteria.

6.2 De-risking Investigations

While sufficient information is available to understand the scale of the risk to the environment posed by the proposed activity, further information is required to confirm the preliminary performance criteria and thus the design of the upgraded wastewater treatment system. Table 19 sets out the requirements for de-risking investigations to be completed by the consented timeframes. This will primarily allow for the investigations to occur over the 2026 ski season and providing time for any follow up investigations and reporting.



Table 19. De-risking Investigations

CSM	Issue	Mitigation	Comment
Source	Low flows are not counted by the flow meter	<ul style="list-style-type: none"> Investigate options for improving accuracy at low flows 	<ul style="list-style-type: none"> New Magflow installed April 2026
	Bywash and operations management	<ul style="list-style-type: none"> Contextual information gathering (snow making, potable water supply flow meter) No harsh cleaning agents) Reducing or managing the bywash is part of the operational changes required to maintain water quality in the Rastus Burn. 	<ul style="list-style-type: none"> Stantec to lead bywash and operations management assessments
	Monthly water quality sampling not representative of variability in discharge quality	<ul style="list-style-type: none"> Hourly autosampler targeted to identify whether composite sampling is effective by identifying the range of concentrations over a day. To determine ideal sampling timeframe for the treated discharge. Fortnightly sampling during the ski season to refine accuracy of load estimates Collection of contextual information (maintenance schedule/flow buffering, assess type of water quality sampling (performance monitoring or hydrogeochemical)) 	<ul style="list-style-type: none"> TBC, benchmark sample collected in February 2026 Stantec to lead on assessing contextual information, e3s to lead on assessing water quality sampling
Pathway	Groundwater Conceptual Model, groundwater flow rates uncertain	<ul style="list-style-type: none"> Install water level loggers to accurately map groundwater level over the ski season and hence flow directions 	<ul style="list-style-type: none"> TBC
		<ul style="list-style-type: none"> Undertake slug testing of the groundwater monitoring network to determine hydraulic properties of the subsurface and aquifer 	<ul style="list-style-type: none"> TBC
	Dispersal field long term acceptance rate	<ul style="list-style-type: none"> Undertake renovation of the infiltration basins and complete infiltration testing to confirm design irrigation rate 	<ul style="list-style-type: none"> Completed April 2026
	Dry groundwater monitoring bores	<ul style="list-style-type: none"> Install new groundwater monitoring bores and deepen dry bores, 	<ul style="list-style-type: none"> Completed February 2026
		<ul style="list-style-type: none"> Survey borehole elevations and locations 	<ul style="list-style-type: none"> TBC
Receptor	Rastus Burn flow variability	<ul style="list-style-type: none"> Gauging events during winter 	<ul style="list-style-type: none"> First event completed March 2026, Three events planned during ski season (June, August, October).
		<ul style="list-style-type: none"> Install surface water level logging site to correlate flows to levels on the long term, reduces the requirement for more gauging 	<ul style="list-style-type: none"> SWL site installed March 2026
		<ul style="list-style-type: none"> Complete an elevation survey of the level logging site 	<ul style="list-style-type: none"> TBC



7 Assessment of Environmental Effects

7.1 Overview

A discharge of this size has the potential to cause adverse effects on the receiving environment should it not be managed appropriately. The following assessment of effects considers the history of compliance achieved by the current OWMS, and how the same level of effects will be possible under the forecasted increase in visitor numbers.

The current OWMS only provides primary treatment to the wastewater discharge; solids are removed but the wastewater largely passes through the OWMS unmodified. Therefore, from basically a zero-treatment baseline there is significant room for improvement when upgrading the OWMS to include nutrient management. NZSki is familiar with the requirements of an advanced secondary treatment OWMS at their Coronet Peak skifield and so it can be considered that an upgraded system designed to meet the performance criteria can be adopted and the resulting system operated and maintained with the same diligence and care that is applied to the Remarkables skifield operation.

The following assessment of effects is based on the upgraded OWMS operating to the proposed preliminary performance criteria to ensure that the existing water quality and ecosystem health conditions are maintained under future development scenarios. That is, that the measurable water quality effects remain at an acceptable level, and the reported good-excellent ecosystem health is maintained.

7.2 Effects on Soils and Plants

The discharge primarily occurs over winter when snow covers soil and plants and biological activity is reduced or in hibernation. The soil and plants most likely to interact with the impacted groundwaters are in the riparian margin of the Rastus Burn for the reach adjacent to the dispersal field. This is primarily where seeps occur as groundwater is forced to the surface by bedrock or hydraulic head.

The current model for the groundwater discharge to the Rastus Burn is that it occurs as diffuse recharge through the stream bed across the whole adjacent reach. However, recharge also has been observed to occur from overland flow from seepage wetlands



on the banks above the Rastus Burn. These seeps have yet to be sampled but may discharge diluted impacted groundwaters over short distances (<10 m) into the Rastus Burn.

Soils and the flora and fauna that cohabitate in the riparian margin may have a slight benefit from the increase in nutrients. It is unlikely that adverse effects such as clogging of pore spaces would occur as the riparian margin is in places up to 100 m from the discharge, and therefore all particulate organic matter is expected to have been assimilated prior to any discharge to seeps.

Overall, there is most likely to be negligible effects on soil and flora/fauna therein.

7.3 Effects on Groundwater Quality

Groundwater quality is impacted significantly in the immediate vicinity of the dispersal basins as monitored in the downgradient bores. However as the nearest sensitive receptor is between 50 and 100m downgradient, there is scope for large amounts of dilution and attenuation (e.g. 100xDAF).

The groundwater migrates to the north and west and most likely recharges to the adjacent reach of the Rastus Burn due to hydraulic head and/or shallow bedrock forcing groundwater to the surface at nick points (waterfalls). Due to the slope of the land, the hydraulic gradient is steep. The dominant permeability in the dispersal field is most likely in the horizontal plane due to various degrees of imbrication in the unconsolidated alluvial and colluvial material. Lower permeability in the vertical direction allows for infiltration to continue until it is eventually arrested by the presence of a slowly permeable layer, i.e. the shallow schist bedrock identified during the recent drilling. Any groundwater infiltrating down to the bedrock layer will then also flow horizontally along the upper surface of the bedrock.

It is possible some flow partitioning occurs with groundwater entering fracture networks in the schist bedrock, but it is unlikely that this is a significant proportion of the impacted groundwater, due to the relative contrast in permeability between the bedrock and overlying unconsolidated alluvial/colluvial materials.

For fracture networks to be an issue for this site they would need to be connected over vast distances and as there are no human groundwater users in the vicinity in which



impacted groundwater is likely to be present (a nominal 1 km radius), effects on human groundwater users are unlikely.

7.4 Effects on Surface Water Quality

In the steep Rastus Burn catchment, the impacted groundwater is forced to the surface by the concave morphology of the shallow bedrock which concentrates flow downslope. Groundwater may gain or lose flow from surface water and therefore the potential for adverse effects from the degraded groundwater quality are considered for surface water quality, the receptors living in the surface water, and other users of surface water.

As reported in Section 3, 4, and 5, during the ski season there are slight but measurable impacts in the Rastus Burn reach adjacent to the dispersal field. To date, compliance monitoring results indicate that most adopted guideline values are being met for the contaminants of concern. Further, biennial biological monitoring indicates that the Rastus Burn has good-excellent ecosystem health when considering the instream values (periphyton, invertebrates).

The downgradient monitoring site at 1.5 km from the dispersal field reports generally no effects or very minor effects, indicating that water quality returns to its upstream values over this distance. Surface water is likely to be used by grazing pests (deer, chamois) but the key risk to these species is from pathogen or ingestion of toxic algae, and neither of these risk factors are consistently present in the Rastus Burn at concentrations that would be cause for concern.

Overall, there is a slight but measurable effect on surface water quality under the existing discharge conditions, however, to date the effects are considered acceptable. If the proposed increase in wastewater volumes is managed to maintain the current standard of water quality, then there will be no increase in the scale or intensity of adverse effects on water quality. Therefore, the proposed activity will also have a slight but measurable effect on surface water quality which generally meets the adopted environmental guidelines.

7.5 Effects on Freshwater Ecology

A freshwater ecological impact assessment is being prepared by e3s in support of the fast-track application. Readers are referred to that report for detailed description of



the aquatic ecosystem and an assessment of the potential effects from the discharge of treated wastewater to land. In summary, the Rastus Burn has been assessed as having Moderate ecological value and the key potential effect of increased wastewater discharge volume is nutrient enrichment, which could alter algal and macroinvertebrate communities if nutrient levels rise. A 'Low' level of ecological effect is assigned, and management actions recommended to maintain the existing good-excellent aquatic health (e3Scientific, 2026).

7.6 Climate Change Effects

Climate change has the potential to influence the discharge over the next 15 - 30 years however the scale and intensity of this effect is forecast to be modest.

Climate change may result in both positive and negative effects. For example slightly warmer temperatures may reduce power costs associated with temperature sensitive wastewater treatment systems. Slight increases to total rainfall may result in high winter flows in the Rastus Burn, slightly increasing dilution and attenuation, however increased wind and the PED may mean that less water is in the Rastus Burn at other times. Currently the OWMS is sized to allow for large rainfall events during winter while also discharging the required volume of wastewater. Any changes to the dispersal field will need to be designed to account for increased rainfall e.g. modified design irrigation rates. The dominant storm system cycle that provides the precipitation and snow may change as ocean currents adjust to warmer temperatures.

Overall, it is expected that the current dynamic equilibrium that the system is designed for may slowly change over the next two decades as the effects of climate change set in. This may mean that the design and operation of any upgraded treatment system needs to consider any impacts to the operation from a changing climate.

7.7 Cumulative Effects

Skifield operations in the Rastus Burn have resulted in modification of the natural topography such as roading which has increased human access, led to the displacement of wetlands, the concentration of stormwater flows, the destabilisation of slopes, and the discharge of wastewater to land. The net effect of the skifield operation on the Rastus Burn water quality appears to be overall acceptable as the adopted environmental guidelines are generally met and recent reporting indicates good-excellent ecosystem health indicators prevail. However, there are some issues to



be contended with, such as the presence of didymo algae in Lake Alta and recently identified in Rastus Burn which may change the diversity and abundance of freshwater species over time however these are unrelated to the wastewater discharge.

The proposed development is largely in the adjacent Doolans catchment so the effects from additional earthworks in the Rastus Burn are less intensive and limited to new access roading, underground services, gondola infrastructure, and the wastewater and base building upgrades. The Rastus Burn faces an increase in discharged wastewater volumes but any potential increase in nutrient load is to be mitigated by upgrading the OWMS so that the water quality is maintained to the current standard. Overall, the cumulative effects are acceptable in terms of water quality. Notwithstanding the challenges of a changing climate the proposed activity is to be well planned and serviced by an operator such as NZSki.



8 Summary

This assessment has evaluated the performance of the existing Remarkables onsite wastewater management system (OWMS), characterised the effects on the receiving environment, and the potential effects of increasing wastewater volumes associated with NZSki's proposed Doolans expansion. The investigation incorporated reviews of desktop and previous site investigations, analysis of the compliance monitoring datasets, and supplementary site investigations.

The dispersal field is situated on a terrace above the Rastus Burn, with groundwater present at 5-10 m below the base of the infiltration basins in thin alluvial/colluvial deposits overlying bedrock. Groundwater flows north and west toward the Rastus Burn over the adjacent downgradient reach. Monitoring confirms slight but measurable seasonal nutrient and microbial signals attributable to the discharge. However, the receiving environment maintains good-excellent water quality and ecological health. These effects are expected to be maintained with the expansion of the skifield and associated upgrade of the treatment plant and are strongly moderated by the high-quality alpine catchment and substantial stream dilution.

Nutrient load analysis indicates that the ecological community may be sensitive to the annual nutrient load if it is too high. Environmental thresholds were identified that are suggested as preliminary performance criteria be used to maintain existing instream conditions and form the basis of the upgraded treatment system. The proposed upgrade to the wastewater treatment plant is expected to achieve these criteria and therefore maintain current environmental outcomes despite increased skier numbers and associated increase in wastewater volumes.

Remaining uncertainties and issues have been identified particularly around seasonal groundwater behaviour, flow metering accuracy, and discharge quality variability. These are to be addressed through further investigations and with ongoing monitoring and operational refinements. An output of the investigations is a report which shall include recommendations for any updates to the operation and management conditions of the discharge. Overall, the assessment concludes that, with the proposed treatment upgrade and adherence to the recommended performance criteria, the increased discharge to land results in an acceptable level of adverse effects on soils, groundwater, surface water, wetlands, or aquatic ecology.



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**Appendix A:
Further Statistical Analysis**

To: Simon Bloomberg
Cc:
From: Archie Ellis-Stanley
Date: 15/7/2026
Subject: Re: request for further statistical analysis – Rastus Burn Water Quality

1 Introduction

Water quality is measured at four sites within the Rastus Burn. This memo reports a statistical re-analysis of that record for the period 2015 to 2026. It addresses two questions:

1. Do concentrations differ among the four sites; and
2. Are they changing over time?

2 Methodology

2.1 Data and sampling design

Receiving-water quality is monitored at four sites. These are Upstream, 50 m downstream, 200 m downstream and 1.5 km downstream. The discharge point and the BH2 bore are excluded from this analysis.

All results from 12 July 2023 are excluded as these were compromised by the leak which occurred and do not represent typical discharge conditions.

The sites are not sampled on a common calendar. The 1.5 km site is rarely accessible in midwinter and holds no August record and only one record for July. The remaining three sites are sampled in every month of the year. Figure 1 sets out the sampling frequency by month and site.

Concentrations vary strongly with season. Values recorded between June and October are two to three times those recorded between November and May. The June to October window corresponds to the operating season. Season is therefore correlated with site coverage. The 1.5 km site is represented disproportionately by its lower-concentration months, so its unadjusted mean is biased downward. The bias is a property of the monitoring programme rather than of the receiving water. Therefore, season is included in the model to remove the bias.

Samples collected per calendar month, by site

The 1.5 km site is under-represented in July and August, the highest-concentration months.

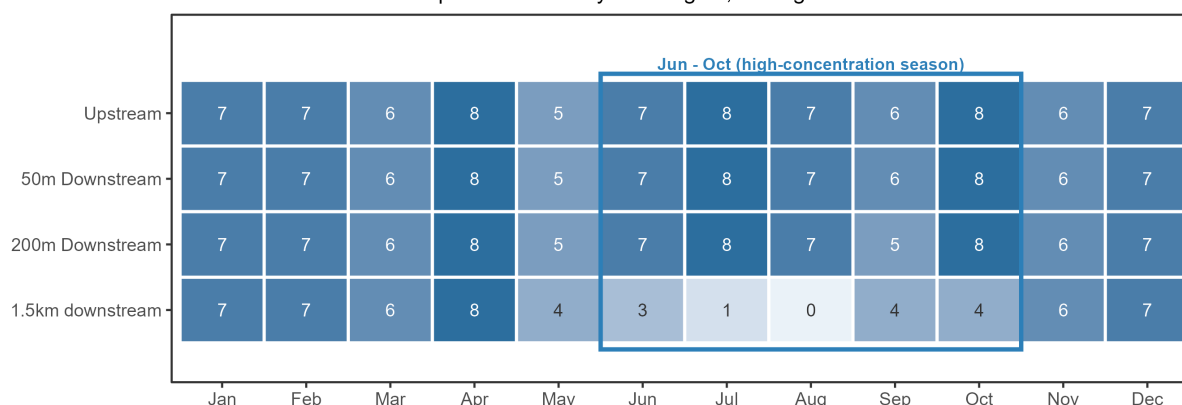


Figure 1: Samples collected per calendar month at each receiving site.

2.2 Treatment of censored data

Concentrations below the analytical detection limit were retained as left-censored observations. They were not replaced by a substituted constant such as one-half the detection limit. Substitution can introduce bias and artefactual trends, and is not recommended for environmental data (Helsel, 2012).

Detection limits changed over the monitoring period. Each observation was therefore censored at its own sample-specific limit rather than at a series-wide constant.

2.3 Among site statistical model

Among-site differences were tested with a left-censored regression, also known as a Tobit model (Tobin, 1958). The response was the base-10 logarithm of concentration. Concentrations are right-skewed and approximately lognormal. The log scale stabilises the variance and makes the estimated effects multiplicative.

The model was fitted by maximum likelihood using 'survreg' from the survival package (Therneau, 2024). The error distribution was set explicitly to Gaussian, because the package default is Weibull. Each non-detect is entered as left-censored at its sample-specific detection limit.

All four sites are sampled on the same occasion. Observations collected on the same day are therefore correlated, because antecedent flow and weather act on all sites simultaneously. Treating them as independent would understate the standard errors.

Standard errors were made robust using a sandwich estimator clustered on sampling date (White, 1980). There are 84 clusters, which is ample for cluster-robust inference.

Season entered as a two-level fixed factor. The levels were June to October and November to May. The split was chosen a priori to reflect the operating season. It is consistent with the observed concentration cycle. Season entered as a main effect only. No site by season interaction is included in the fitted model. Model code is presented below.

```
survreg(Surv(log10(C), event, type = "left") ~ Site + Season + Year +
        cluster(DateF), data = d, dist = "gaussian", robust = TRUE)
```

Site marginal means were estimated with 'emmeans' (Lenth, 2024). The robust covariance matrix from the clustered model was supplied explicitly, so that all intervals and tests respect the same-day correlation.

The marginal mean for a site is the model prediction averaged over the two seasons with equal weight, and over years. It is the concentration expected at that site under a balanced sampling design. This is what is meant by a season-adjusted mean. It is an estimate under a common sampling composition and not an observed average.

Back-transformed means, obtained as 10 raised to the fitted value, are geometric means. Equivalently they are lognormal medians. They are not arithmetic means and are not described as such.

The overall among-site test is a joint Wald test evaluated on the robust covariance. Pairwise contrasts between all site pairs were adjusted using the Sidak correction. Results are summarised as a compact-letter display at a significance level of 0.05.

Sites sharing a letter are not significantly different. A shared letter denotes an absence of detected difference. It is not evidence of equivalence.

The overall test and the pairwise tests can disagree. Where the overall test is significant but no pair survives adjustment, no site difference is reported.

2.4 Temporal statistical model

Trends over time were assessed independently for every site and analyte combination. The model described above estimates no trend, because year enters it as a factor. Trends are a separate analysis and use a separate method.

Each series was analysed with the non-parametric Seasonal Kendall test and the Sen slope estimator (Sen, 1968; Hirsch et al., 1982). These were implemented in the 'LWP-Trends toolkit, version 2502' (Snelder and Fraser, 2025). The toolkit extends the Mann-Kendall framework to censored data, following Helsel (2012).

Season is handled by blocking rather than by modelling. The Kendall S statistic is computed within each season and the seasonal values are then summed, as are their variances. Observations are only ever compared with other observations from the same season. Seasonality therefore cannot contaminate the estimated trend.

Non-detects entered as tied comparisons. No concentration was imputed below the detection limit. The test is rank-based and is invariant to monotone transformation, so no logarithm is applied to the data.

Trend direction was taken from the sign of S. The strength of evidence for that direction was expressed as a directional confidence, Cd, calculated as 1 minus p divided by 2. Cd is the confidence that the trend is decreasing. Values were classified using the IPCC calibrated-likelihood terminology (Mastrandrea et al., 2010).

Trends are reported using three quantities together. A trend is reported as decreasing or increasing where the two-sided Mann-Kendall p-value is below 0.05. A trend is reported as likely decreasing or likely increasing where it is not significant but the directional confidence is at least 0.90. All other series are reported as no trend.

The Sen slope was reported as a percentage change per year relative to the series median. Where the median coincides with the detection limit, the percentage is undefined and is reported as not applicable. In those cases, only the direction and its confidence are interpreted. This affects ammoniacal nitrogen and dissolved reactive phosphorus, which are heavily censored.

The fitted lines on the temporal figures are left-censored regressions of log₁₀ concentration on date. They are shown for visualisation only and are solid where the Kendall trend is significant and dashed where the trend is not significant. The Kendall test, and not the fitted line, is the basis of every reported trend.

The trend analysis uses the same dataset as the among-site analysis. All results from 12 July 2023 are excluded.

2.5 Assumptions and limitations

The seasonal adjustment to the mean assumes that the seasonal effect is common to all four sites. This is encoded by having the assumption of season as a main-effect. It cannot be verified at the 1.5 km site, because the July and August records required to test it do not exist. If that site responds to season differently from the others, the seasonally-adjusted mean is biased.

The adjusted mean is a model-based estimate under a balanced sampling design. It is not an observed mean. No sample was collected at the 1.5 km site in the months for which the adjustment compensates.

Left-censored modelling assumes lognormality below the detection limit. Ammoniacal nitrogen is 45 to 71 percent censored depending on season. Its estimates depend on that assumption more heavily than the other analytes.

Guideline reference lines are drawn on the figures where applicable. These comprise ANZG default guideline values for toxicity and physico-chemical stressors, Schedule 15 values and the Didymo limit for dissolved reactive phosphorus. They are shown for context and do not constitute a compliance assessment.

Flow is not specified in the model as this data is not currently available, however it likely has a large effect on concentration in the Rastus Burn. Flow data is being collected for the 2026 ski season and will be assessed and reported in the further investigations review report.

2.6 Software

All analyses were undertaken in R 4.5.1 (R Core Team, 2025). Model fitting used the 'survival' package. Marginal means and contrasts used 'emmeans'. Letter displays used multcomp. The separate trend analysis used the 'LWP-Trends toolkit, version 2502'.

3 Results

3.1 Seasonal variation in concentration

Concentrations between June and October are 2.1 to 3.1 times those between November and May. The seasonal effect is significant for all three nitrogen species. Dissolved reactive phosphorus shows no seasonal cycle (Table 1, Figure 2).

Table 1: Seasonal effect on concentration, estimated from the season-adjusted model.

Analyte	Jun-Oct : Nov-May ratio	P value	Significant
Total Ammoniacal Nitrogen	3.06	<0.0001	Yes
Total Nitrogen	2.09	<0.0001	Yes
Total Oxidised Nitrogen	2.36	<0.0001	Yes
Dissolved Reactive Phosphorus	1.21	0.255	No

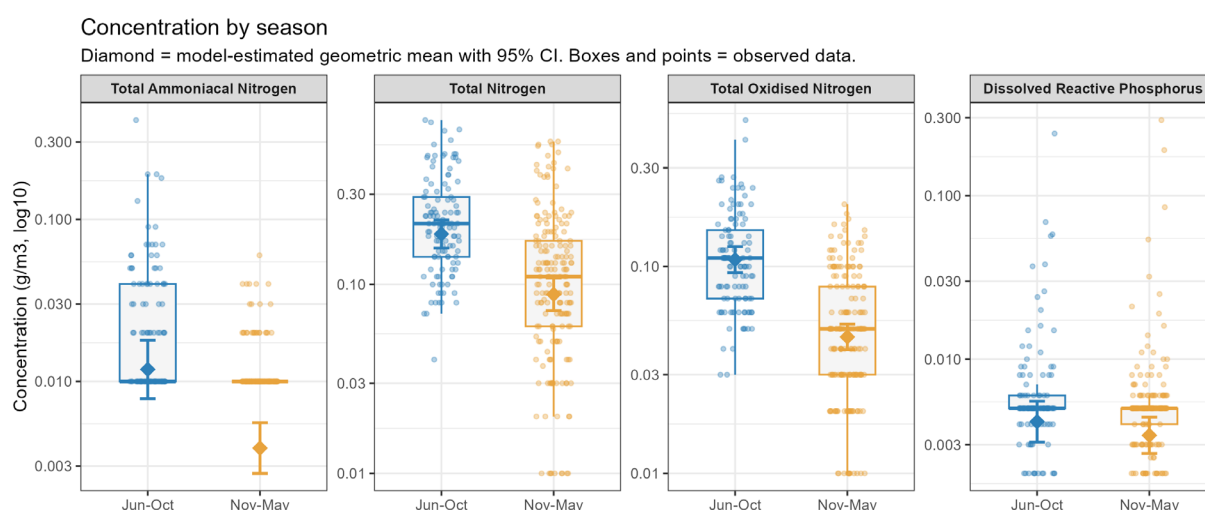


Figure 2: Observed concentrations by season. Diamonds are model-estimated geometric means with 95 percent confidence intervals.

3.2 Site comparison (season-adjusted)

Adjusting for season raises the estimated mean at the 1.5 km site by 28 to 50 percent for the three nitrogen species, against 2 to 9 percent for Dissolved reactive phosphorus (Table 2).

Total oxidised nitrogen differs strongly among sites ($p < 0.0001$). All three downstream sites are elevated relative to upstream. Upstream mean is estimated at 0.051 g/m^3 and the downstream sites at 0.075 to 0.081 g/m^3 (Figure 3).

Total nitrogen also differs among sites ($p = 0.0007$). All three downstream sites are elevated relative to upstream. Upstream mean is estimated at 0.110 g/m^3 and the downstream sites at 0.133 to 0.137 g/m^3 (Figure 5).

Total ammoniacal nitrogen shows no difference among sites ($p = 0.384$) (Figure 7). Dissolved reactive phosphorus is marginal ($p = 0.053$) and no pair of sites is separable. Neither is interpreted as a site difference (Figure 9).

Table 2: Geometric mean concentration (g/m³) at each site, unadjusted and adjusted for season.

Analyte	Site	n	Unadjusted mean	Season-adjusted mean	Change	Group
Total Ammoniacal Nitrogen	Upstream	81	0.0056	0.0061	+9%	a
	50m Downstream	81	0.0061	0.0067	+9%	a
	200m Downstream	80	0.0074	0.0080	+9%	a
	1.5km downstream	56	0.0043	0.0065	+50%	a
Total Nitrogen	Upstream	84	0.1017	0.1102	+8%	a
	50m Downstream	84	0.1227	0.1330	+8%	b
	200m Downstream	83	0.1254	0.1367	+9%	b
	1.5km downstream	52	0.1048	0.1337	+28%	b
Total Oxidised Nitrogen	Upstream	81	0.0481	0.0507	+5%	a
	50m Downstream	81	0.0746	0.0787	+6%	b
	200m Downstream	80	0.0765	0.0812	+6%	b
	1.5km downstream	56	0.0580	0.0751	+29%	b
Dissolved Reactive Phosphorus	Upstream	84	0.0047	0.0048	+2%	a
	50m Downstream	84	0.0034	0.0035	+2%	a
	200m Downstream	83	0.0033	0.0033	+2%	a
	1.5km downstream	59	0.0034	0.0036	+7%	a

3.3 Temporal trends

Every trend in the record is downward. No increasing trend is detected at any site for any analyte (Table 3).

Total oxidised nitrogen declines significantly at all four sites, at 2.9 to 11.4 percent per year (Figure 4). Total nitrogen declines significantly at the three downstream sites, at 6.3 to 8.4 percent per year, and is likely decreasing upstream (Figure 6).

Total ammoniacal nitrogen declines significantly at three sites and is likely decreasing at 1.5 km (Figure 8). Dissolved reactive phosphorus is likely decreasing at three sites and shows no trend at 1.5 km (Figure 10). Neither rate can be quantified, because both series have medians at the detection limit.

Table 3: Censored Seasonal Kendall trends, 2015 to 2026.

Analyte	Site	Trend	Significant	% / y	S	Cd	P value
Total Ammoniacal Nitrogen	Upstream	Decreasing	Yes	n/a	-754	1.000	<0.05
	50m Downstream	Decreasing	Yes	n/a	-81	0.996	<0.05
	200m Downstream	Decreasing	Yes	n/a	-92	0.998	<0.05
	1.5km downstream	Likely decreasing	No	n/a	-89	0.942	0.116
Total Nitrogen	Upstream	Likely decreasing	No	-1.72	-32	0.915	0.17
	50m Downstream	Decreasing	Yes	-7.05	-89	1.000	<0.05
	200m Downstream	Decreasing	Yes	-6.27	-53	0.989	<0.05
	1.5km downstream	Decreasing	Yes	-8.39	-113	0.996	<0.05
Total Oxidised Nitrogen	Upstream	Decreasing	Yes	-2.88	-56	0.996	<0.05
	50m Downstream	Decreasing	Yes	-6.94	-92	1.000	<0.05
	200m Downstream	Decreasing	Yes	-6.98	-94	1.000	<0.05
	1.5km downstream	Decreasing	Yes	-11.4	-220	1.000	<0.05
Dissolved Reactive Phosphorus	Upstream	Likely decreasing	No	n/a	-364	0.927	0.145
	50m Downstream	Likely decreasing	No	n/a	-331	0.909	0.183
	200m Downstream	Likely decreasing	No	n/a	-432	0.962	0.0753
	1.5km downstream	No trend	No	n/a	-56	0.876	0.247
S is the Kendall statistic Cd is the confidence that the trend is decreasing. A percentage per year is not reported where the series median lies at the detection limit.							

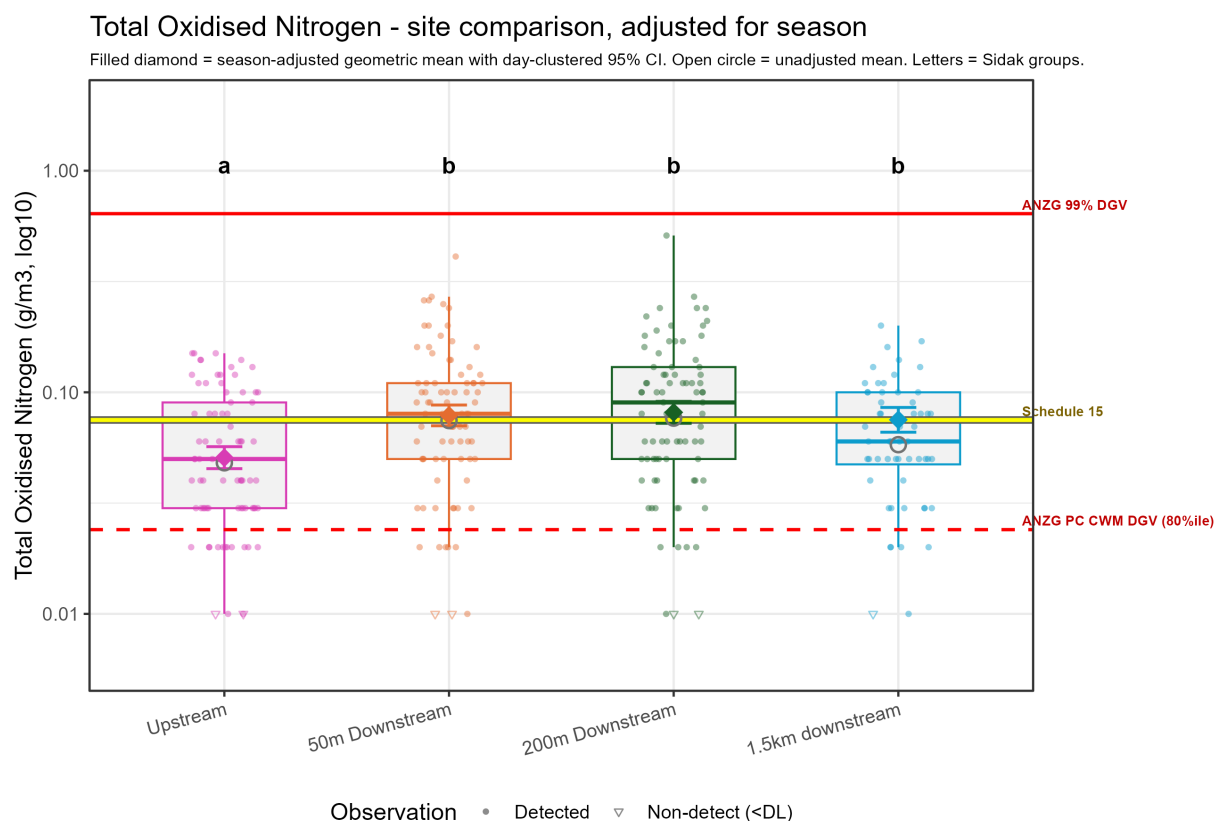


Figure 3: TON - site comparison

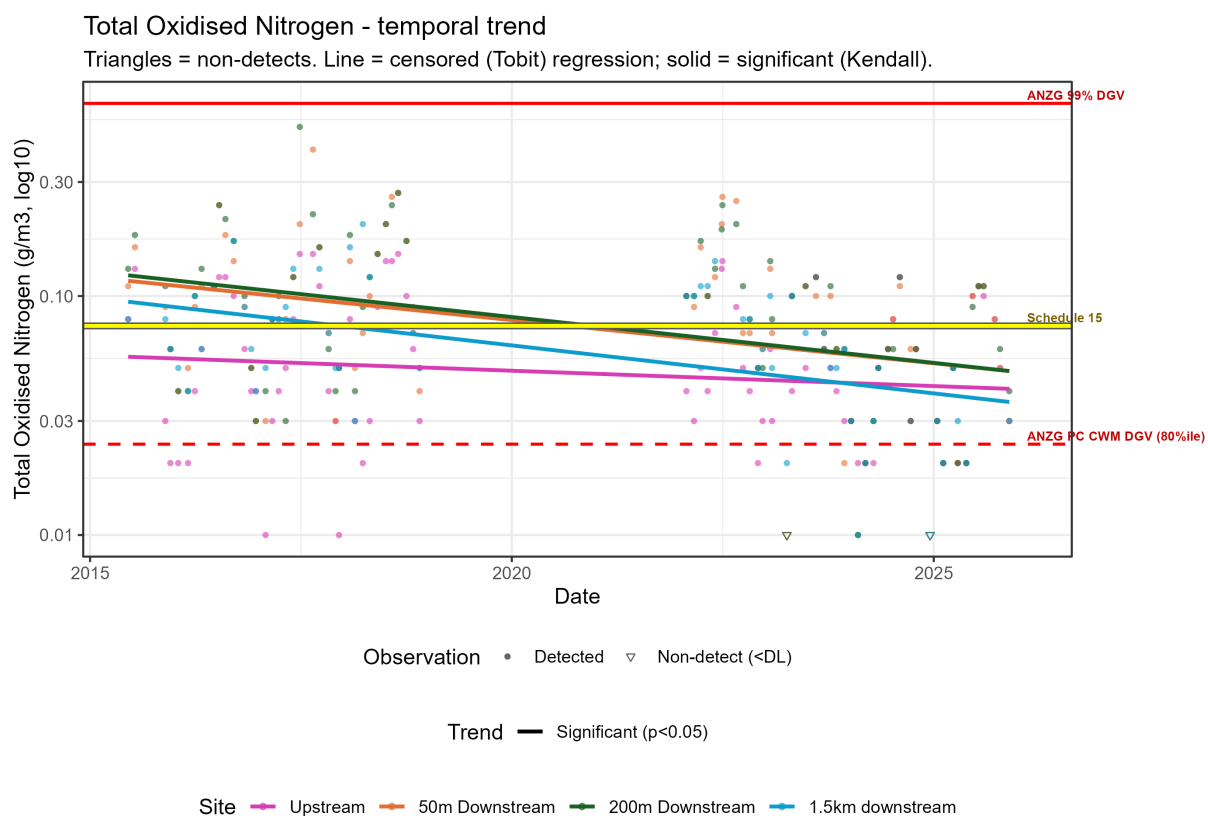


Figure 4: TON - temporal trend

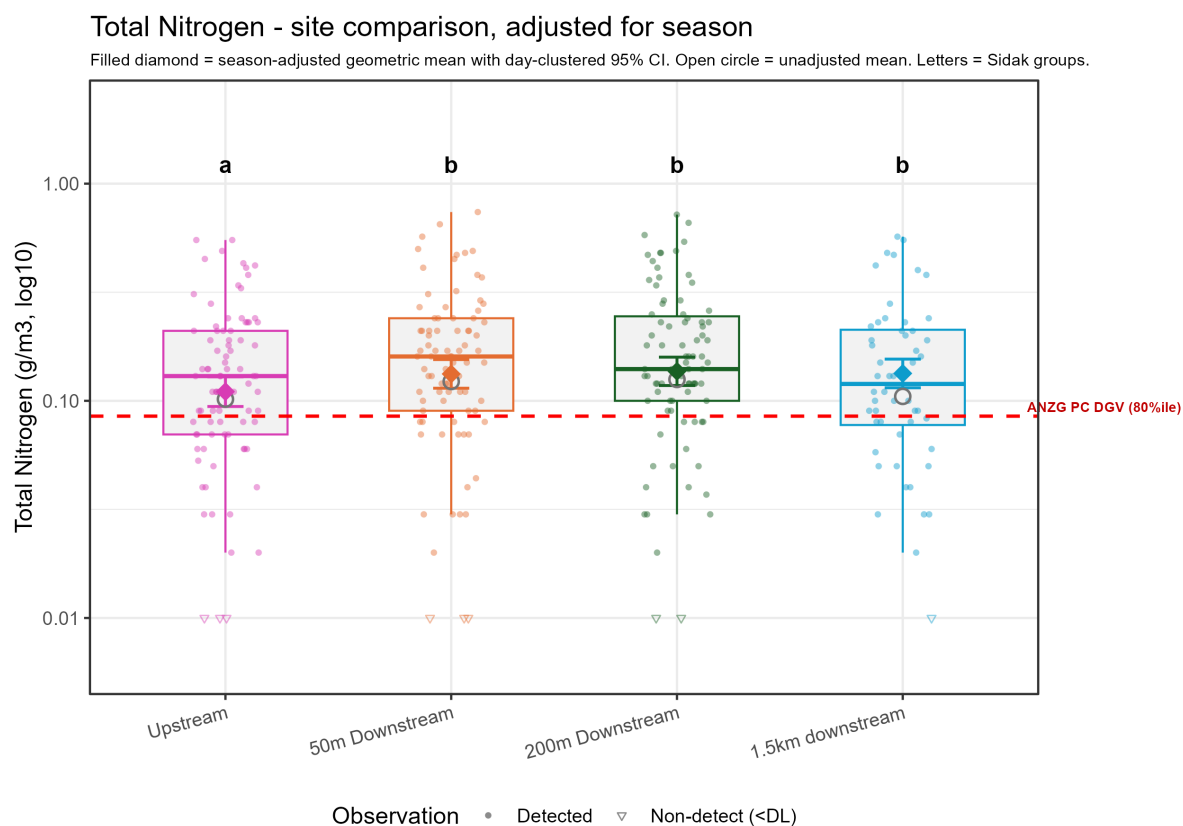


Figure 5: TN - site comparison

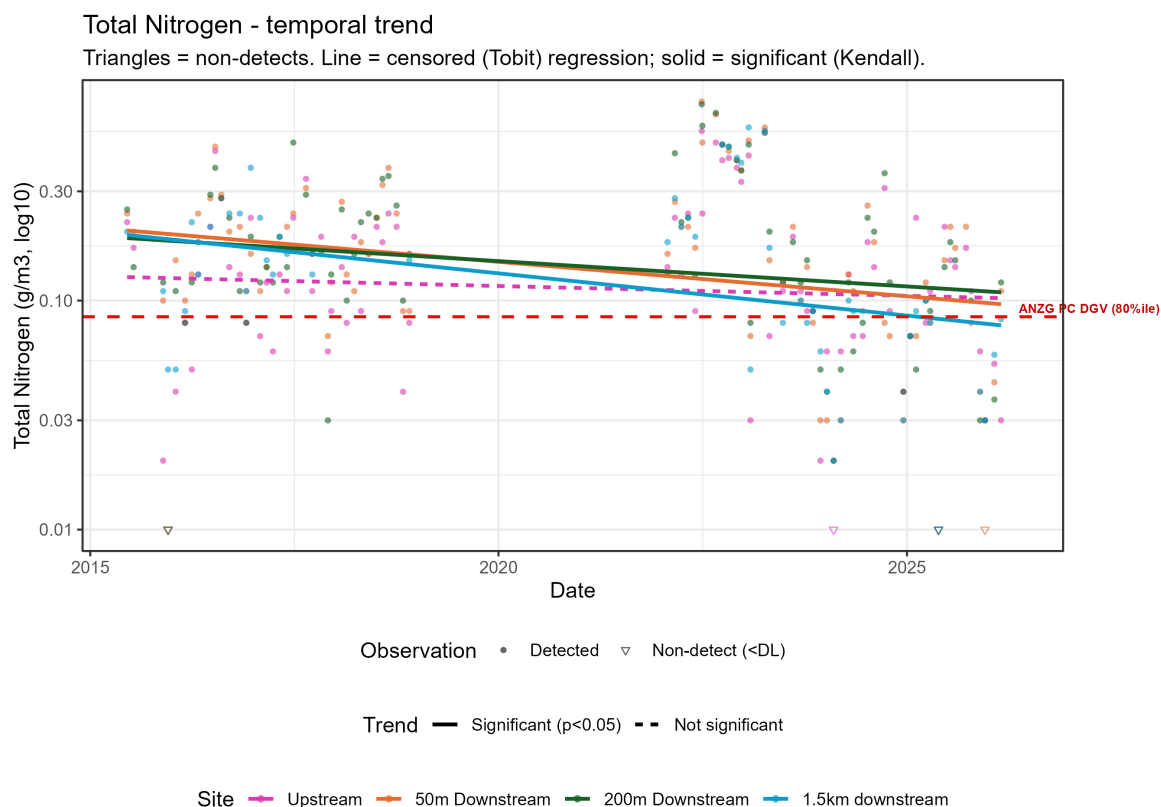


Figure 6: TN - temporal trend

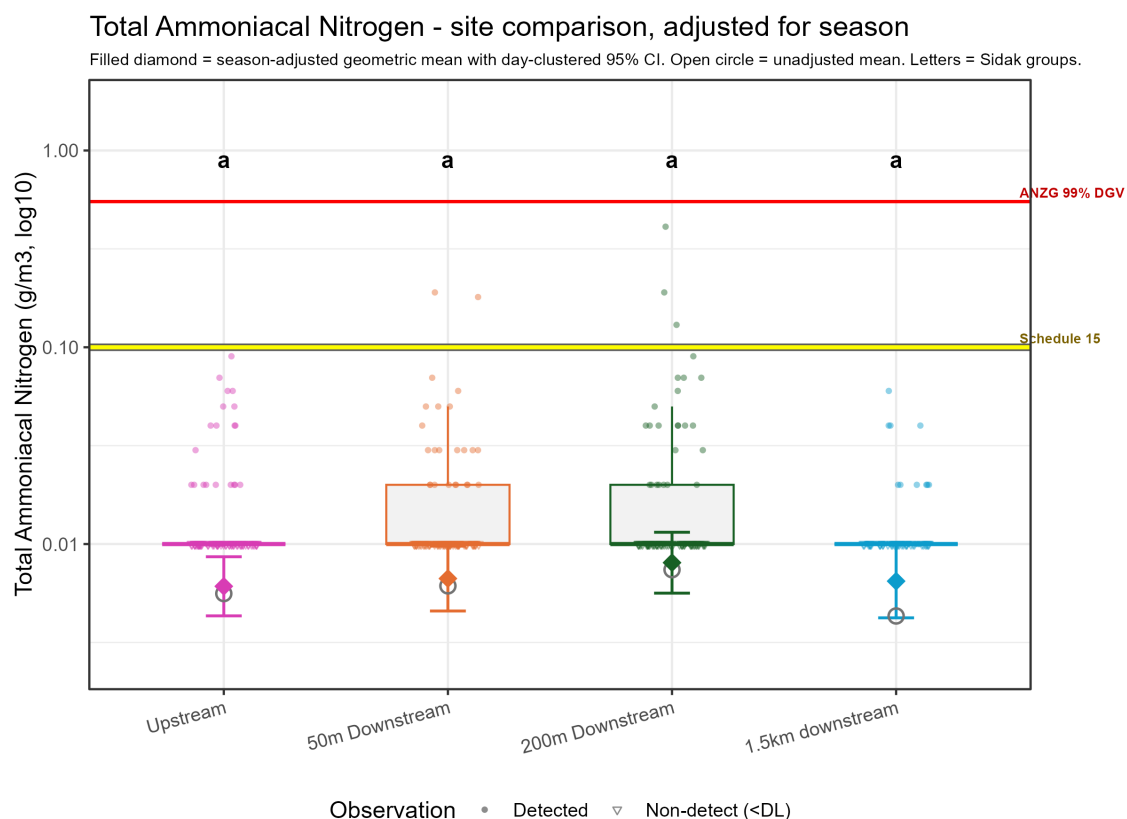


Figure 7: TAN - Site comparison

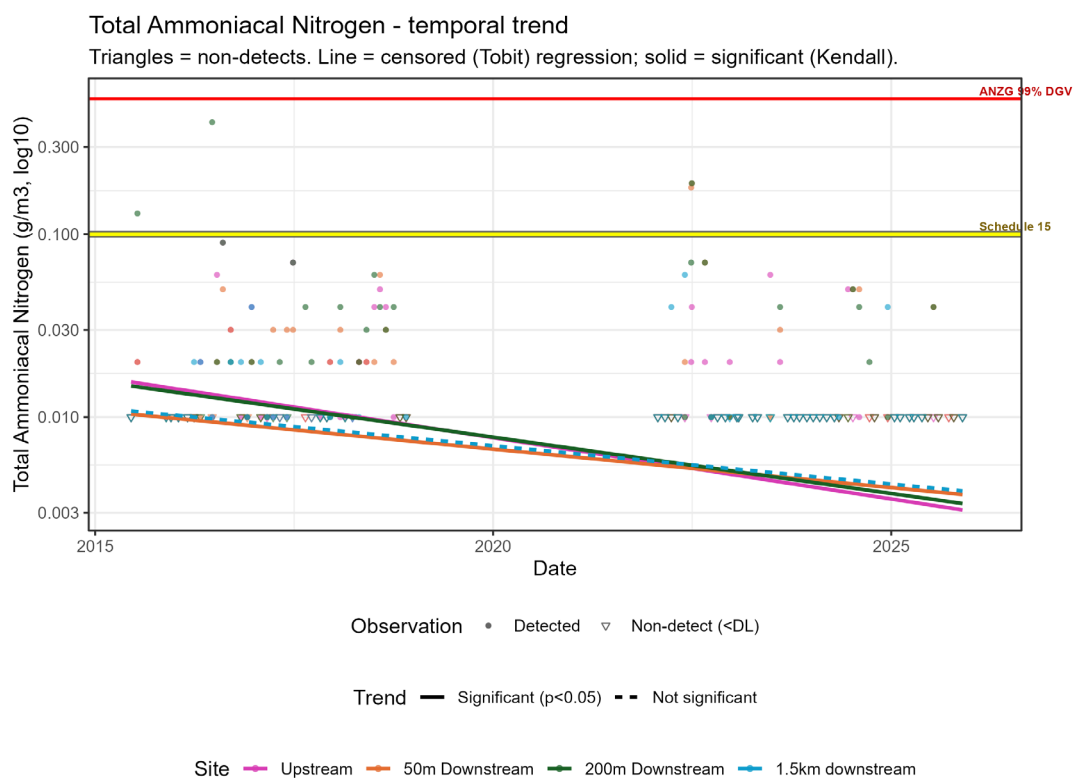


Figure 8: TAN - temporal trend

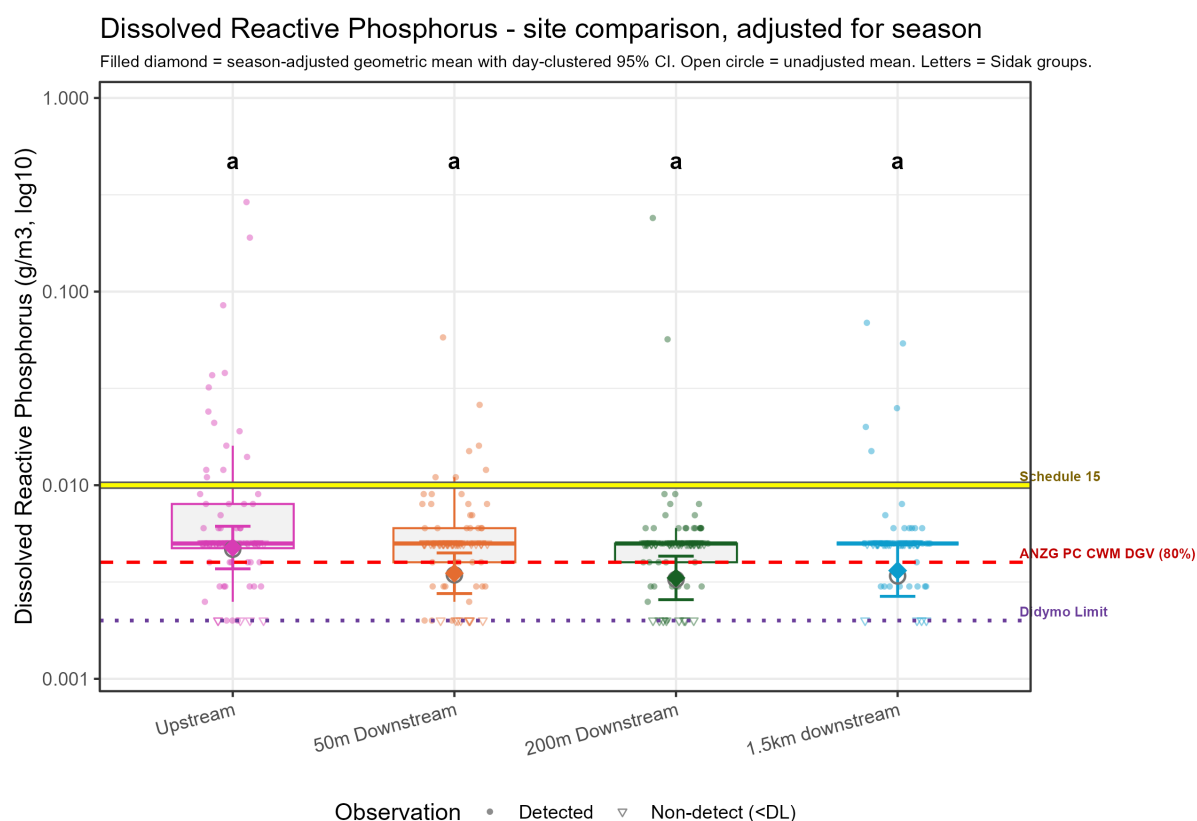


Figure 9: DRP - site comparison

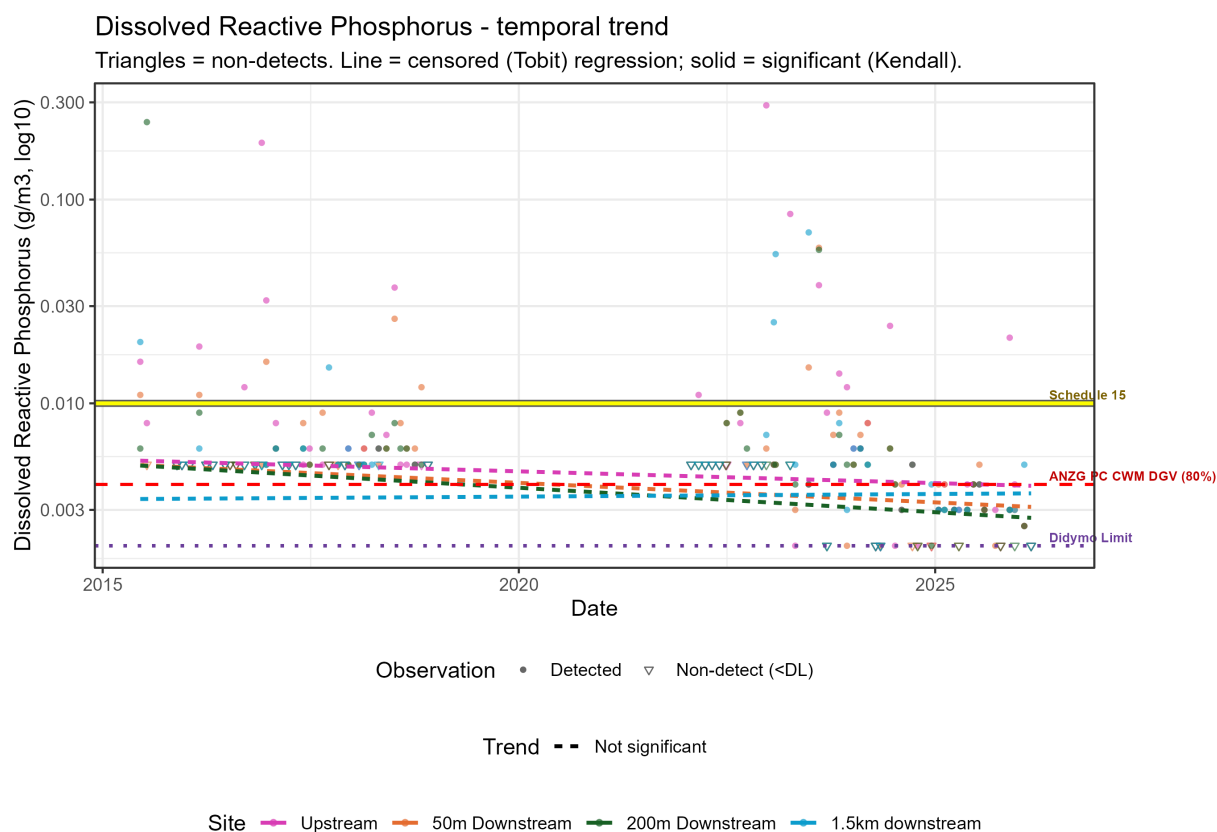


Figure 10: DRP - temporal trend

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Appendix B:
Rastus Burn Compliance Biological Monitoring Reports 2014 - 2026

Remarkables Ski Area

ORC Resource Consent No. 2000.044_V1,
Condition 5

Receiving Water Monitoring: March 2014



ryderconsulting
environment + planning + project management

Remarkables Ski Area

ORC Resource Consent No. 2000.044_V1, Condition 5

Receiving Water Monitoring: March 2014

prepared for NZSki Limited
by Ryder Consulting Limited

Author: Greg Ryder, PhD.

Document version: 6/06/2014

Cover photo: Looking up the Rastus Burn catchment with the Remarkables Ski Area oxidation ponds lying elevated on an adjacent terrace.

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1. INTRODUCTION

NZSki Limited have consent from the Otago Regional Council (Consent 2000.044_V1) to discharge to land up to 60.6 cubic metres per day of wastewater for the purpose of disposal of treated wastewater and water supply bywash from the Remarkables Ski Field. The discharge is leachate from three oxidation ponds that sit on a terrace above the Rastus Burn, which may potentially receive some leachate. For that reason, Condition 5 of Consent 2000.044_V1 requires biological monitoring of the Rastus Burn.

Condition 5 states:

“The consent holder shall at 3 yearly intervals, have an appropriately qualified freshwater ecologist carry out a biological survey of the Rastus Burn upstream and downstream of the oxidation ponds, for the purpose of determining the effect of the discharge(s) from the oxidation ponds on the aquatic ecosystem of the river. On each occasion surveys shall be carried out during or immediately prior to the end of the ski season (i.e. by the end of November at the latest) unless it is impractical to do so, in which case the survey shall be carried out as soon after the end of the ski season as stream conditions reasonably permit. The survey shall comprise as a minimum, three replicate samples from one upstream and two downstream sites.

The results of the surveys shall be reported in writing to the Consent Authority by 31 January following the year in which the survey was undertaken.”

Ryder Consulting Limited was engaged to undertake a survey of the Rastus Burn in March 2014. The survey date falls outside the time specified in Condition 5, but is not intended to fulfil the requirements of Condition 5. However, it does provide additional ‘baseline’ information on the water quality and aquatic ecology of the Rastus Burn outside of the ski season. This information will support a new resource consent application for the discharge of treated waste water to ground. The existing resource consent for the oxidation ponds expires in 2015.

2. SAMPLING LOCATIONS & GENERAL CHARACTER

The three oxidation ponds are situated above a steep face approximately 50 vertical metres above the Rastus Burn (see cover photo and Figure 1). The land surrounding the stream is dominated by large specimens of snow tussock (*Chionochloa* species) with an under-storey of native herbs and sedges. Low shrubs (mainly *Dracophyllum*) are present in drier areas and extensive turf and mound communities are present in boggy areas.

An upstream site (used as a control) is located just above a ford associated with the maintenance road to the oxidation ponds and is a relatively low gradient section (Figures 1 and 2). Discharge of leachate from the oxidation ponds is thought to occur in the vicinity of the Rastus Burn immediately below the third (most downstream) pond. As in previous years, the stream was sampled immediately below this area (Downstream site 1) and approximately 400m further downstream (Downstream site 2) (Figures 1 and 3). The gradient at the Downstream 1 site is steeper than at the two other sites, resulting in more turbulent water (Figure 3).

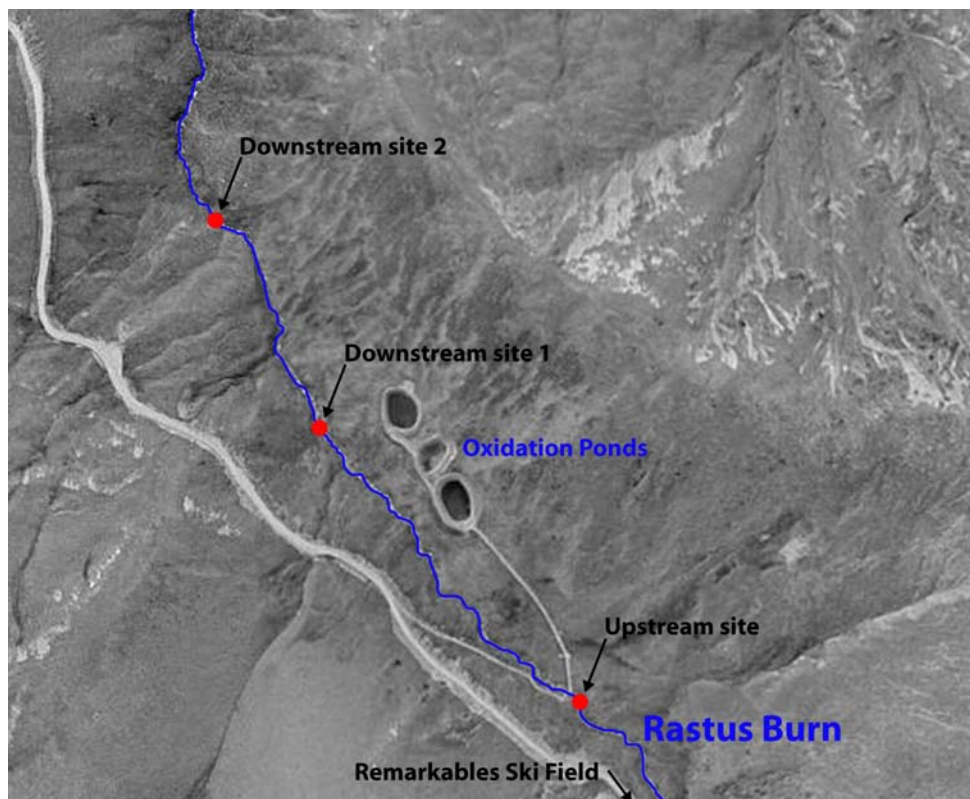


Figure 1 Map of the Rastus Burn showing the location of the oxidation ponds and monitoring sites.



Figure 2 Upstream site.



Figure 3 Left: Downstream site 1. Right: Downstream site 2.

3. SURVEY METHODOLOGY AND ANALYSIS TECHNIQUES

3.1 Water quality

Water quality measurements were taken at each stream site and in the third oxidation pond for pH, temperature (°C), dissolved oxygen (% and mg/L) and conductivity (µS/cm), using a handheld YSI Professional Plus multi-probe field meter.

3.2 Periphyton (benthic algae)

Periphyton cover was visually assessed in the field. Scrapings of rock surfaces using a toothbrush were collected and inspected under a microscope in the laboratory at 200-400x magnification to identify any algal species present using the keys of Biggs and Kilroy (2000), Entwisle *et al.* (1988) and Moore (2000). Relative abundance of each taxa was scored using the scheme of Biggs and Kilroy (2000), which scores taxa from 1 (rare) to 8 (absolutely dominant/monoculture).

3.3 Benthic macroinvertebrates

Benthic macroinvertebrates were sampled using a kick-net with 500µm diameter mesh. Samples were collected by disturbing the bed substrate in a representative area immediately upstream of the net. Three replicate samples were collected from each site. In the laboratory the samples were passed through a 500µm sieve to remove fine material. Contents of the sieve were then placed in a white tray and macroinvertebrates were identified under a dissecting microscope (10-40x) using criteria from Winterbourn *et al.* (2006).

For each site, benthic macroinvertebrate community health was assessed by determining the following characteristics:

Number of taxa: Reflects health of the community through a measurement of the variety of the taxa present. Taxonomic richness generally increases with increasing water quality, habitat diversity, and habitat stability.

Number of Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa, and percentage of the total abundance comprising EPT taxa (% EPT): These insect groups are generally dominated by invertebrates that are indicative of higher quality conditions. In stony

bed rivers, these indexes usually increase with improved water quality and increased habitat diversity.

Macroinvertebrate Community Index (MCI) (Stark 1993): The MCI uses the occurrence of specific macroinvertebrate taxa to determine the level of organic enrichment in a stream. Taxon scores are between 1 and 10, 1 representing invertebrates indicative of lower quality conditions (e.g., worms and some dipteran species) and 10 representing invertebrates indicative of higher quality conditions (e.g., most mayflies and stoneflies). A site score is obtained by summing the scores of individual taxa and dividing this total by the number of taxa present at the site. These scores can be interpreted in comparison with national standards (Table 1). For example, a low site score (e.g., 40) represents 'poor' quality conditions and a high score (e.g., 140) represents 'excellent' quality conditions.

$$MCI = \left(\frac{\text{Sum of taxa scores}}{\text{Number of scoring taxa}} \right) \times 20$$

Semi-quantitative MCI (SQMCI) (Stark 1998): The SQMCI uses the same approach as the MCI but weights each taxa score based on how abundant each taxa is within the community. The abundance of all taxa is recorded using a five-point scale (i.e., rare = 1-4 animals per sample, common = 5-19, abundant = 20-99, very abundant = 100-499, very very abundant = >500). As for MCI, SQMCI scores can be interpreted in the context of national standards (Table 1).

$$SQMCI = \frac{\text{Sum of (Taxa coded abundance x Taxa score)}}{\text{Sum of coded abundances for sample}}$$

Table 1 Interpretation of macroinvertebrate community index values from Boothroyd and Stark (2000) (Quality class A) and Stark and Maxted (2007) (Quality class B).

Quality Class A	Quality Class B	MCI	SQMCI
Clean water	Excellent	> 120	> 6.00
Doubtful quality	Good	100 – 119	5.00 – 5.99
Probable moderate pollution	Fair	80 – 99	4.00 – 4.99
Probable severe pollution	Poor	< 80	< 4.00

Values for invertebrate metrics (number of taxa, number of EPT taxa, % EPT, MCI and SQMCI) were compared between the three monitoring sites using a one-factor analysis of variance (ANOVA) using the statistical package Data Desk®. In these tests, a p-value of less than 0.05 indicates a statistically significant difference between sampling sites.

4. RESULTS AND DISCUSSION

4.1 General

The Rastus Burn was sampled on the 10th of March 2014. At the time of sampling the stream was full, fast flowing and slightly discoloured. Bed substrate at all three sites was dominated by medium to large boulders and cobbles, although patches of coarse gravels were present particularly at the Upstream site. The gradient at Downstream site 1 was steeper than that at the other two sites.

4.2 Water quality

Water quality data is presented in Table 2. Water in the third oxidation pond was very diluted and probably dominated by rainfall or infiltration rather than waste water from the ski field facilities. This is not surprising given the survey was undertaken well outside of the skiing and snow boarding season. While conductivity in the pond was elevated relative to that in the Rastus Burn, it was still quite low and indicative of low levels of dissolved ions. Nutrient and *E. coli* concentrations were also very low for waste water and more indicative of good quality stream water (Table 2).

All three Rastus Burn sampling sites had good quality characterised by low conductivity and nutrient levels, and high dissolved oxygen concentrations (Table 2). There were no downstream trends in water quality parameters and no indication that leachate from the oxidation ponds was affecting water quality.

4.3 Periphyton

There was no obvious visible signs of periphyton (benthic algae) at any of the three monitoring sites (Figure 4). The stone surfaces were clean with no tufts or strands of algae. Scrapings from the rock surface revealed the presence of small microscopic diatoms (*Diatoma*, *Navicula*, *Synedria*) at all three sites in equal abundance.

Table 2 Water quality parameters at three sites in the Rastus Burn and the third oxidation pond, 10th March 2014. Nutrient and E. coli testing undertaken by Watercare Laboratory Services.

Water quality parameter	Upstream	Downstream 1	Downstream 2	Oxidation Pond
pH	8.4	8.3	8.3	8.9
Temperature (°C)	8.0	9.3	8.7	12.4
Dissolved oxygen (%)	85.1	87.0	85.0	96.5
Dissolved oxygen (mg/L)	10.10	9.89	9.96	10.19
Conductivity (µS/cm)	16.2	17.2	17.1	36.3
Ammoniacal nitrogen (mg/L)	0.007	0.006	0.005	<0.4
Nitrate nitrogen (mg/L)	0.027	0.027	0.035	0.002
Dissolved reactive phosphorus (DRP)	0.006	0.006	0.006	0.050
<i>Escherichia coli</i> (cfu/100mL)	< 9	< 9	< 9	< 9



Figure 4 Rastus Burn bed character. Left: Downstream site 1. Right: Downstream site 2.

4.4 Macroinvertebrates

Twenty five distinct invertebrate taxa were identified from the samples collected from the three monitoring sites (Table 4). Taxonomic richness was lowest at the Upstream site, but differences between sites were not statistically significant ($p > 0.05$, Table 5).

As found in the December 2011 survey, taxonomic richness at all sites was lower than the national median of 18 taxa per site, as determined by Scarsbrook *et al.* (2000) from samples collected from 66 sites throughout New Zealand.

Table 5 Results of a one factor analysis of variance (ANOVA) testing for a difference between monitoring sites in the Rastus Burn, 10th March 2014. Statistically significant differences ($p < 0.05$) are shown in bold.

Metric	$F_{2,6}$	p -value
Number of taxa	4.98	0.053
Number of EPT taxa	3.70	0.089
% EPT	0.37	0.705
MCI score	8.43	0.018
SQMCI score	0.28	0.761

Invertebrate communities at all three sites were dominated by mayfly larvae (*Deleatidium* and *Nesameletus*) and *Zelandobius* stonefly larvae (Table 4). Elmids beetle larvae were abundant in at least one sample collected from each site. Blephariceridae (*Neocurupira* sp.), which are characteristic of alpine stream invertebrate communities, were abundant in two of the samples collected from the Downstream 1 site (Table 4). Blephariceridae have suction discs under their body and are adapted for rapids and waterfalls of alpine streams. These types of habitat are more common at the Downstream 1 site. A number of taxa belonging to the Diptera (true flies) and Trichoptera (caddis flies) insect families were found at all sites but were generally uncommon in number.

EPT taxa (% EPT, invertebrates typically indicative of higher quality conditions, e.g., caddisflies, mayflies and stoneflies) represented approximately half the population at each site (Table 4, Figure 5). EPT taxonomic richness at all three sites was lower than the national median of 8 EPT taxa per site, as determined by Scarsbrook *et al.* (2000). Invertebrate community health scores (MCI and SQMCI) were high at all three sites (Table 4, Figure 5). Average SQMCI scores were indicative of 'excellent' quality conditions at all sites, as were MCI scores at both downstream sites. The MCI score at the Upstream site indicated 'good' quality conditions using Stark's narrative terminology (Tables 1 and 4, Figure 5).

Table 4 Macroinvertebrate taxa found in Kick-net samples collected from the Rastus Burn in the vicinity of the Remarkables Ski Area oxidation ponds, 10th March 2014. Results are expressed as relative abundance (see Section 3 for details).

TAXON	MCI score	Upper			Mid			Lower		
		1	2	3	1	2	3	1	2	3
COLEOPTERA										
Elmidae	6	C	R	A	C	A	C	A	C	A
Scirtidae	8				R					
DIPTERA										
<i>Aphrophila</i> species	5					R				
Empididae	3				R					
Eriopterini	9	C		C	R	R	R	R	C	R
Hexatomini	5				R	R			R	
<i>Maoridiamesa</i> species	3			R			R			
Muscidae	3	R		R						
<i>Neocurupira</i> species	7				R	A	A	R	R	R
<i>Nothodixa</i> species	4							R		
Orthocladiinae	2	R		R	R	R	R	R	R	R
Tanypodinae	5				R		R			
EPHEMEROPTERA										
<i>Deleatidium</i> species	8	VA	A	VA	VA	VA	VA	VA	VA	VA
<i>Nesameletus</i> species	9	VA	A	C	A	A	VA	VA	A	VA
MECOPTERA										
<i>Nannochorista philpotti</i>	7				R			R		
OLIGOCHAETA	1	C	R	R	R	R	R	R	R	R
PLATYHELMINTHES	3	R	A					R		
PLECOPTERA										
<i>Austroperla cyrene</i>	9				R	R	R	R	R	R
<i>Zelandobius</i> species	5	A	C	A	VA	VA	VA	VA	VA	VA
<i>Zelandoperla</i> species	10		R	C	C	C	A	C	C	R
TRICHOPTERA										
<i>Costachorema</i> species	7	R		C	R	C	R	C	R	R
<i>Hudsonema alienum</i>	6	R					R			
Hydrobiosidae early instar	5				R		R			
<i>Hydrobiosis charadraea</i> group	5	R								
<i>Philarheithrus agilis</i>	8						R			
Number of taxa		12	7	11	17	13	17	14	12	11
Number of EPT taxa		6	4	5	7	6	9	6	6	6
% EPT taxa		50	57	45	41	46	53	43	50	55
MCI score		107	120	115	125	128	124	124	130	133
SQMCI score		7.9	6.5	7.3	6.7	6.7	7.4	7.2	6.8	7.2
Average MCI score		114			125			129		
Average SQMCI score		7.3			6.9			7.1		

This difference in MCI scores was statistically significant ($p > 0.05$, Table 5), but unlikely to be related to longitudinal changes in organic enrichment given the low and stable nutrient environment at all three sites (see Table 2). Subtle physical differences, such as a lower gradient at the Upstream site and smaller substrate size, may influence community relative abundance.

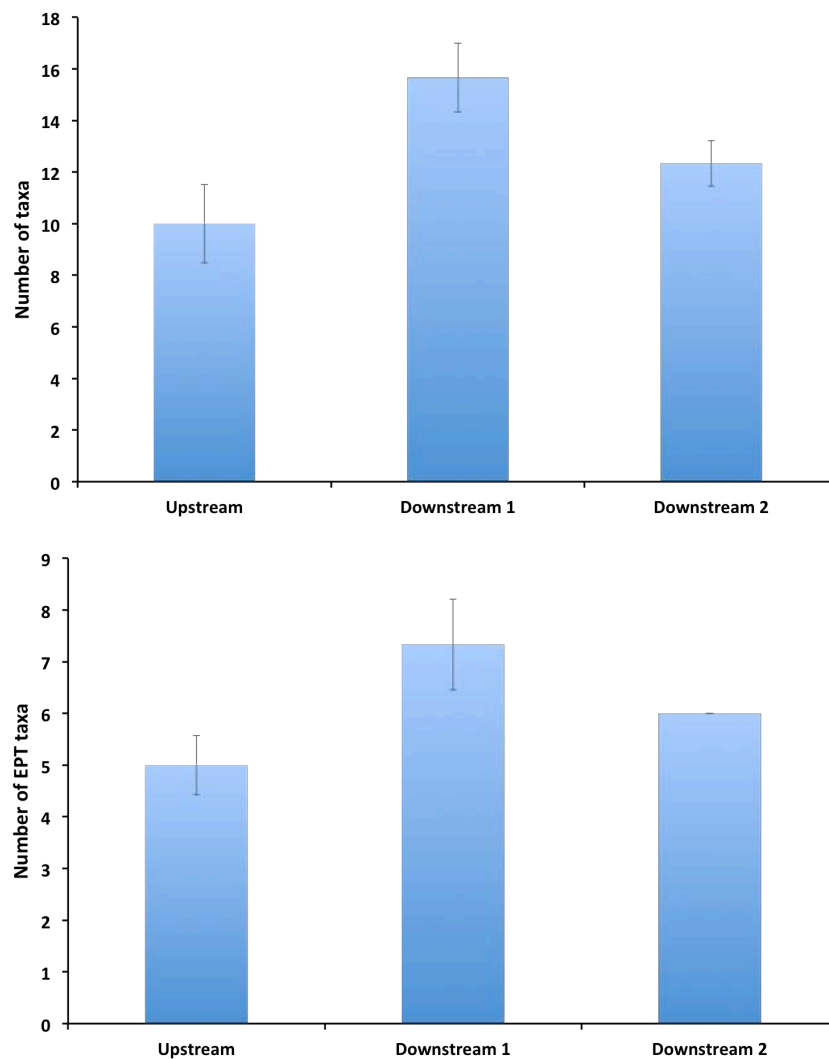


Figure 5 Values for invertebrate metrics for samples collected from the Rastus Burn in the vicinity of the Remarkables Ski Area oxidation ponds, 10th March 2014. EPT = Ephemeroptera, Trichoptera and Plecoptera aquatic insect families. Error bars are +/- one standard error. Continued on the following page.

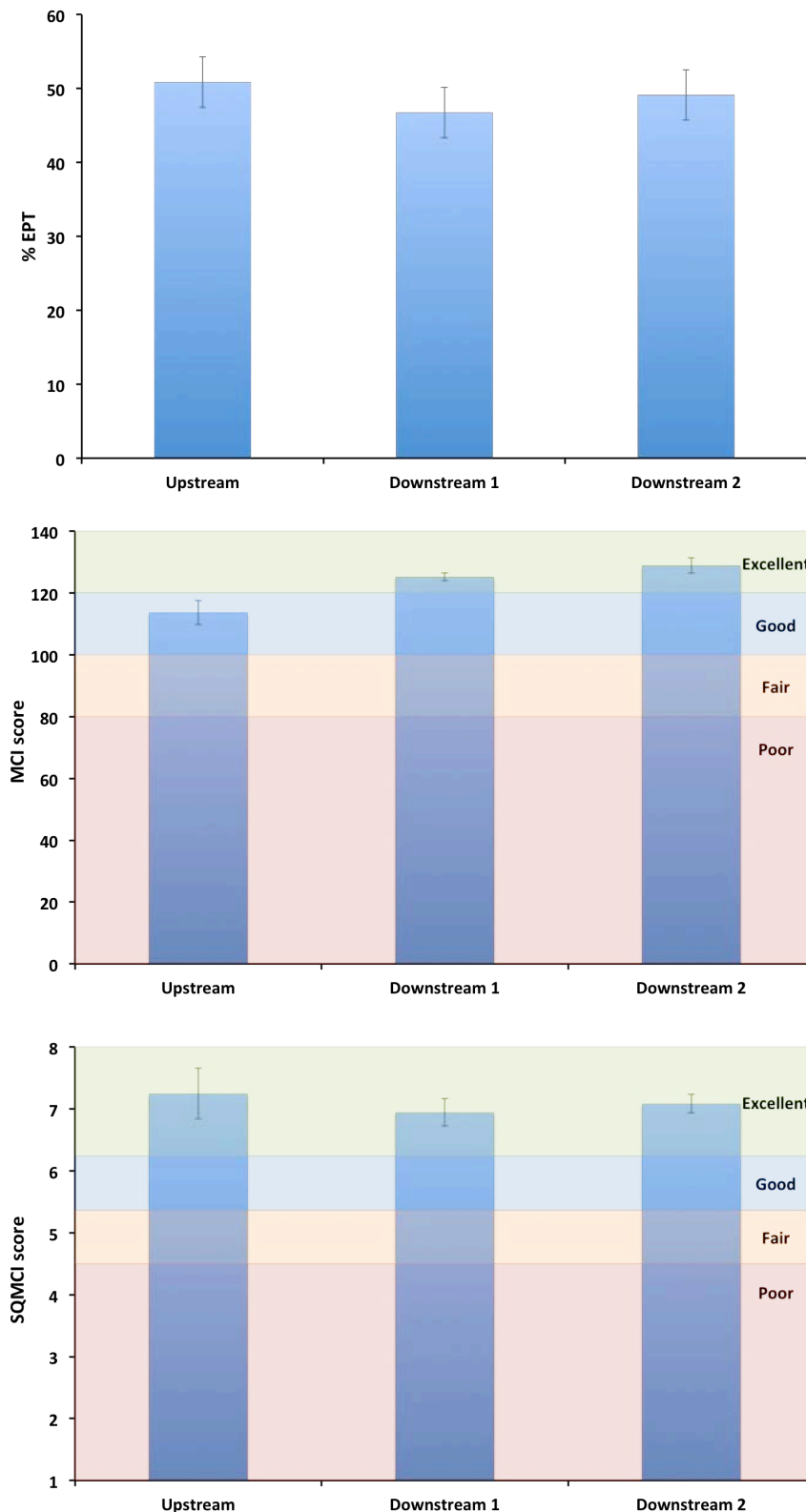


Figure 5 (cont'd) Values for invertebrate metrics for samples collected from the Rastus Burn in the vicinity of the Remarkables Ski Area oxidation ponds, 10th March 2014. EPT = Ephemeroptera, Trichoptera and Plecoptera aquatic insect families. Error bars are +/- one standard error.

5. Summary and conclusions

The survey of the Rastus Burn in the vicinity of the Remarkables Ski Area oxidation ponds found healthy benthic communities indicative of their alpine creek environment. The creek has a steep gradient and drains a high altitude catchment that has little in the way of activities that generate nutrients and oxygen demanding substances. Hence water quality is characterised by high oxygen saturation and low conductivity, nutrients and temperature. The water is fast flowing and well mixed, and the stream channel appears stable despite the steep gradient and frequent high rainfall events. Visible periphyton cover is almost non-existent which is likely to be a reflection of the high velocity and low nutrient status of the water.

Macroinvertebrates are dominated by mayflies and stoneflies. Invertebrate density is difficult to determine because the boulder nature of the bed makes quantitative sampling methods impractical. However, invertebrates are readily observable on stone surfaces and kick-net samples quickly fill with invertebrates. These visual observations suggest healthy abundance.

The March 2014 survey found no evidence of any influence on water quality or benthic communities that might be attributable to leachate sourced from the oxidation ponds. Given the time of year that the survey was undertaken (well outside the ski season), this was not surprising, but is consistent with surveys undertaken in previous years at the same sites, but more closely following the end of the ski season (e.g., Ryder Consulting 2008).

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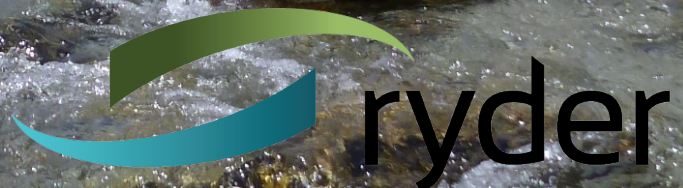
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NZSki Limited

Remarkables Ski Area

Biological survey of the Rastus Burn

December 2017



Remarkables Ski Area

Biological survey of the Rastus Burn

December 2017

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1. Introduction

NZSki Limited has consent from the Otago Regional Council (Consent No. RM14.336.01) to discharge treated wastewater to land from the Remarkables Ski Field buildings. Under the consent, up to 127.44 m³ of treated wastewater and water supply bywash may be discharged per day to a disposal area over three ponds in the vicinity of the Rastus Burn. Seepage from the three ponds, which sit on a terrace above the Rastus Burn, may potentially enter the receiving water of the Rastus Burn. For this reason, Condition 11 of the consent requires a biological survey of the Rastus Burn.

Condition 11 states:

- (a) The consent holder shall at two yearly intervals engage an appropriately qualified freshwater ecologist to carry out a biological survey of the Rastus Burn upstream and downstream of the disposal ponds for the purpose of determining the effects of the discharge on the aquatic ecosystem of the Rastus Burn.*
- (b) The biological survey shall be undertaken either during or immediately after the end of the ski season but in all cases shall be no later than 30th November. The survey shall be conducted at the four Rastus Burn monitoring locations shown on the plan in Appendix 1.*
- (c) The first survey shall be conducted by the end of the first ski season following the grant of this consent.*

Ryder Environmental was engaged by NZSki Limited to undertake the biological survey of the Rastus Burn in 2017.

2. Survey sites

Sampling was undertaken at one site upstream and three sites downstream of the disposal ponds (Figure 1). The upstream site was located immediately upstream of a ford on the maintenance road to the ponds. The downstream sites were 50 m, 200 m, and 1500 m downstream of the ponds (Figure 1). These sites have been previously surveyed (Arthur & Ludgate 2015).

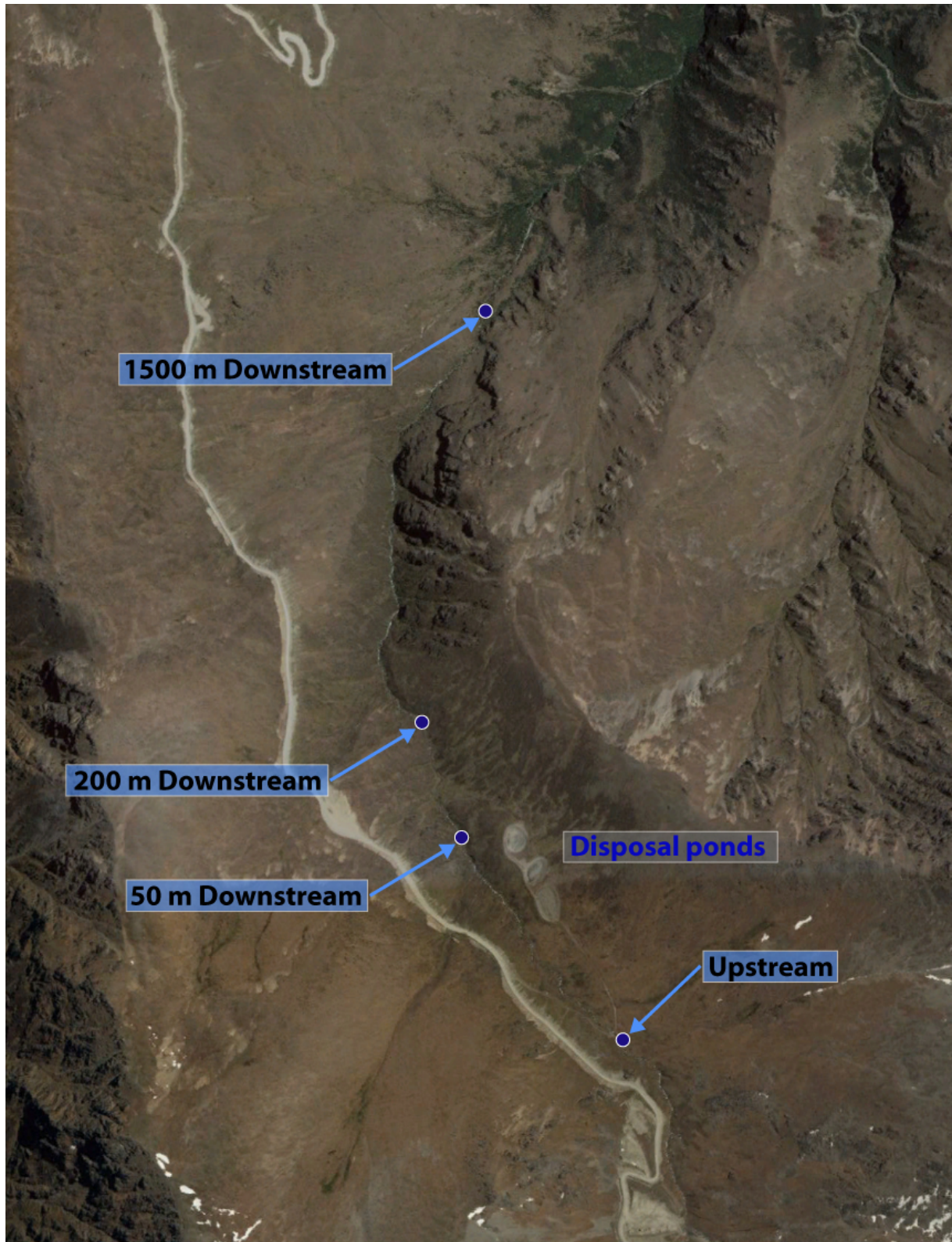


Figure 1 Map showing the location of the Rastus Burn survey sites, December 2017.

3. Survey and Analysis Techniques

3.1 Periphyton

Periphyton (algae, fungi and bacteria that form a growing biofilm) was visually assessed at each site. Different substrates available for periphyton growth (e.g., gravels, cobbles) were inspected and underwater photos taken. Samples of representative algal cover were collected from each site and returned to the laboratory for further identification.

In the laboratory, each sample was inspected under an inverted microscope according to the “relative abundance using an inverted microscope” method outlined in Biggs and Kilroy (2000). Samples were inspected under 200-400x magnification to identify algal species present using the keys of Biggs and Kilroy (2000), Entwistle *et al.* (1988) and Moore (2000). Algae were given an abundance score using the reduced ranks scheme, with 1 representing rare, 2 representing common and 3 representing abundant.

3.2 Macroinvertebrates

Field collection

Benthic macroinvertebrates were sampled using a kicknet (500 µm mesh) according to collection protocol ‘C1: hard-bottomed semi-quantitative’, as described in the Ministry for the Environment’s ‘Protocols for sampling macroinvertebrates in wadeable streams’ (Stark *et al.* 2001). Samples were collected by disturbing the substrate in a representative area immediately upstream of the net. Two samples were collected from each site. Samples were preserved in 70% ethanol for later identification.

Laboratory assessment

In the laboratory, samples were processed following “Protocol ‘P1: Coded abundance”, outlined in Stark *et al.* (2001). Samples were sieved through a 500 µm sieve to remove fine material and residual ethanol. Contents of the sieve were then placed in a white tray. Each taxon present in the sample was assigned to one of five coded abundance categories (Table 1). Up to 20 individuals representative of each taxon were removed from each sample to confirm identifications under a dissecting microscope (10-40x) using criteria from

Winterbourn *et al.* (2006).

Table 1 Coded abundance scores used to summarise macroinvertebrate data (after Stark 1998).

Abundance	Coded abundance	Weighting factor
1 – 4	Rare (R)	1
5 – 19	Common (C)	5
20 – 99	Abundant (A)	20
100 – 499	Very abundant (VA)	100
> 500	Very very abundant (VVA)	500

Data presentation and analyses

For each site, benthic macroinvertebrate community health was assessed by determining the following characteristics:

Number of taxa: A measurement of the number of taxa present.

Number of Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa, and percentage of the total number of taxa comprising EPT taxa (% EPT taxa): These insect groups are generally dominated by invertebrates that are indicative of higher quality conditions. In stony bed rivers, these indexes usually increase with improved water quality and increased habitat diversity.

Macroinvertebrate Community Index (MCI) (Stark 1993): The MCI uses the occurrence of specific macroinvertebrate taxa to determine the level of organic enrichment in a stream. Taxon scores are between 1 and 10, 1 representing species highly tolerant to organic pollution (e.g., worms and some dipteran species) and 10 representing species highly sensitive to organic pollution (e.g., most mayflies and stoneflies). A site score is obtained by summing the scores of individual taxa and dividing this total by the number of taxa present at the site. These scores can be interpreted in comparison with national standards (Table 2). For example, a low site score (e.g., 40) represents ‘poor’ conditions and a high score (e.g., 140) represents ‘excellent’ conditions.

$$MCI = \left(\frac{\text{Sum of taxa scores}}{\text{Number of scoring taxa}} \right) \times 20$$

Semi-quantitative MCI (SQMCI) (Stark 1998): The SQMCI uses the same approach as the MCI but weights each taxa score based on how abundant the taxa is within the community. Abundance of all taxa is recorded using a five-point scale (Table 2). As for MCI, SQMCI scores can be interpreted in the context of national standards (Table 2).

$$SQMCI = \frac{\text{Sum of (Taxa coded abundance} \times \text{Taxa score)}}{\text{Sum of coded abundances for sample}}$$

Table 2 *Interpretation of macroinvertebrate community index values from Boothroyd and Stark (2000) (Quality class A) and Stark and Maxted (2007) (Quality class B).*

Quality Class A	Quality Class B	MCI	SQMCI
Clean water	Excellent	≥ 120	≥ 6.00
Doubtful quality	Good	100 – 119	5.00 – 5.99
Probable moderate pollution	Fair	80 – 99	4.00 – 4.99
Probable severe pollution	Poor	< 80	< 4.00

Data has been presented graphically as means +/- one standard error. A one-way Analysis of Variance (ANOVA) was used to test for differences between sites using the statistical package Data Desk®. Analysis of variance tables can be interpreted by looking to see whether the 'p-values' for tests are less than 0.05. If they are, then an effect is said to be 'statistically significant'. Following ANOVA testing, Bonferroni post hoc testing was employed to determine which sites differed significantly from others.

4. Results and Discussion

4.1 General

Sampling was undertaken on the 12th of December 2017. Weather conditions were fine. A cold front the previous night resulted in a light dusting of snow on the mountain tops, but the Rastus Burn was flowing clearly and above summer base flow conditions.

4.2 Survey site descriptions

The land surrounding the stream is dominated by large specimens of snow tussock (*Chionochloa* species) with an under-storey of native herbs and sedges. Low shrubs (mainly *Dracophyllum* species) are present in drier areas, and extensive turf and mound communities are present in boggy areas. Moss is present along the wetted edge of the stream.

The Upstream site has tumbling water over large boulders, with some short sections of lower gradient water where the substrate is a mixture of flat cobbles and large gravels (Figure 2).



Figure 2 Left: Upstream site. Right: 50 m Downstream site. December 2017. Photos: G.Ryder.

The 50 m Downstream site has a steeper gradient than the Upstream and 200 m Downstream sites. The site contains large boulders forming short steep drops, with a large waterfall immediately upstream of the sampling area (Figure 2).

The 200 m Downstream site is contained within a confined channel, with a long cascading run of small boulders, medium and large cobbles and with coarse gravels in interstitial spaces (Figure 3).

The 1500 m Downstream site has a very steep gradient, and is a continuous cascade of waterfall type habitat with very high velocities (Figure 3). The substrate is large boulders with occasional small patches of smaller material.



Figure 3 Left: 200 m Downstream site. Right: 1500 m Downstream site. December 2017. Photos: G.Ryder.

4.3 Periphyton

Periphyton (benthic algae) was either absent or rare at each sampling site in the Rastus Burn. Most stones surfaces appeared very clean (Figure 4), with algal cover restricted to very thin films on a few surfaces. Scrapings from the rock surfaces revealed the community comprised the filamentous red algae *Audouinella* and several types of diatom (Table 3). *Audouinella* is commonly found in clean waterways. In general, the low algal biomass indicates a low nutrient/high disturbance (steep gradient, high velocities and frequent flash floods) environment.

Table 3 *Benthic algae found in the Rastus Burn, December 2017. Values from the reduced ranks scheme described in Biggs and Kilroy (2000) indicating relative abundance scores with 1 representing rare, 2 representing common and 3 representing abundant.*

	Upstream	50 m Downstream	200 m Downstream	1500 m Downstream
Filamentous red algae				
<i>Audouinella</i>	2		1	3
Filamentous diatoms				
<i>Melosira</i>	1			
Diatoms				
<i>Cymbella</i>		1		
<i>Pinnularia</i>	1			
<i>Synedra</i>	1		1	



Upstream site



50 m downstream



200 m downstream

Figure 4 Rastus Burn benthic environment, December 2017 (photos: G.Ryder).

4.4 Macroinvertebrates

A total of 33 different invertebrate taxa were identified from the four survey sites, with a total of 19 taxa identified Upstream, 21 taxa from 50 m downstream, 19 taxa from 200 m Downstream, and 22 taxa from 1500 m Downstream (Table 4). There were no statistically significant differences between sites in the number of taxa ($p>0.05$, Table 5, Figure 5).

A total of 13 different EPT taxa (insect larvae typically indicative of higher water quality; mayflies, stoneflies and caddisflies) were identified from the four sites (Table 4). A total of seven EPT taxa were identified Upstream and at 200 m Downstream, with eight EPT taxa from 50 m Downstream and ten EPT taxa from 1500 m Downstream. The average contribution of EPT taxa to overall diversity per site (% EPT taxa) was between 43% and 52% at each site (Table 4, Figure 5). There were no statistically significant differences between sites in the number of EPT taxa or % EPT taxa ($p>0.05$, Table 5, Figure 5).

Macroinvertebrate communities at each site were numerically dominated by EPT taxa: *Deleatidium* and *Nesameletus* mayflies, *Zelandobius* and *Zelandoperla* stoneflies (Table 4). Elmid riffle beetles were also abundant at each site.

Macroinvertebrate community health index (MCI) and semi-quantitative MCI (SQMCI) scores were all similarly high, with average MCI scores indicative of 'good-excellent' quality conditions Upstream, 'excellent' quality conditions at 50 m Downstream, and 'good' quality conditions at 200 and 1500 m Downstream, using the narrative terminology of Stark and Maxted (2007) (Tables 2 and 4, Figure 5). Average SQMCI scores were indicative of 'excellent' quality conditions at each site (Table 4, Figure 5). There were no statistically significant differences between sites in any of the community health index scores ($p>0.05$, Table 5, Figure 5).

Table 4 Macroinvertebrate taxa found in the Rastus Burn, December 2017.

TAXON	MCI score	Upstream			50 m Downstream			200 m Downstream			1500 m Downstream		
		1	2	3	1	2	3	1	2	3	1	2	3
ACARINA	5						R					R	
COLEOPTERA													
Elmidae	6	C	A	C	C	A	A	A	C	C	A	A	C
Scirtidae	8						R	R					
Staphylinidae	5		R										
DIPTERA													
<i>Austrosimulium</i> species	3	R					R			R		R	
Empididae	3		R										
Eriopterini	9	R	R	R		R	R		R				
<i>Limonia</i> species	6						R						
<i>Maoridiamesa</i> species	3								R		R	R	
<i>Molophilus</i> species	5											R	
Muscidae	3		R				R					R	
<i>Neocurupira</i> species	7		R	R	R	R		C	R	R	R	C	C
Orthocladinae	2	R	R				C	C	C		C	C	C
<i>Paralimnophila skusei</i>	6												R
Tanypodinae	5		R				R	R				R	
Tanytarsini	3						R						
EPHEMEROPTERA													
<i>Austroclima</i> species	9												R
<i>Deleatidium</i> species	8	A	VA	A	VA	VA	VA	VA	A	A	VA	VA	A
<i>Nesameletus</i> species	9	A	A	A	C	A	A	A	A	A	A	A	A
NEMATODA	3							R					
NEMATOMORPHA	3	R						R	R				
OLIGOCHAETA	1	C	A	R	C	C	A	C	A	C	C	A	R
PLATYHELMINTHES	3	R	C				A		VA	R	C	R	C
PLECOPTERA													
<i>Austroperla cyrene</i>	9					R	R	R	R		R	C	R
<i>Zelandobius</i> species	5	C	C	C	C	C	A	A	A	C	C	C	C
<i>Zelandoperla</i> species	10	C	A	C	C	C	A	C	C	C	R	C	C
TRICHOPTERA													
<i>Aoteapsyche</i> species	4											R	
<i>Beraeoptera roria</i>	8		R										
<i>Costachorema</i> species	7		R	R		R	R				R	R	
Hydrobiosidae early instar	5		R										
<i>Hydrobiosis charadraea</i> group	5										R		
<i>Philorheithrus agilis</i>	8						R		R			R	
<i>Tiphobiosis</i> species	6								R				
Number of taxa		11	17	9	7	10	20	13	15	9	13	19	12
Number of EPT taxa		4	7	5	4	6	8	5	7	4	7	8	6
% EPT taxa		36	41	56	57	60	40	38	47	44	54	42	50
MCI score		107	113	138	131	142	116	117	119	116	115	108	125
SQMCI score		7.2	7.1	7.9	7.6	7.6	6.6	7.2	4.4	7.3	7.2	6.8	7.2
Average MCI score		119			130			117			116		
Average SQMCI score		7.4			7.3			6.3			7.1		

Table 5 Results of one-way analysis of variance (ANOVA) testing for differences between sites for each of the main invertebrate metrics measured.

Variable	$F_{3,8}$	p-value	Interpretation
Number of taxa	0.19	0.90	No significant difference
Number of EPT taxa	0.77	0.54	No significant difference
% EPT taxa	0.78	0.54	No significant difference
MCI score	0.93	0.47	No significant difference
SQMCI score	0.87	0.50	No significant difference

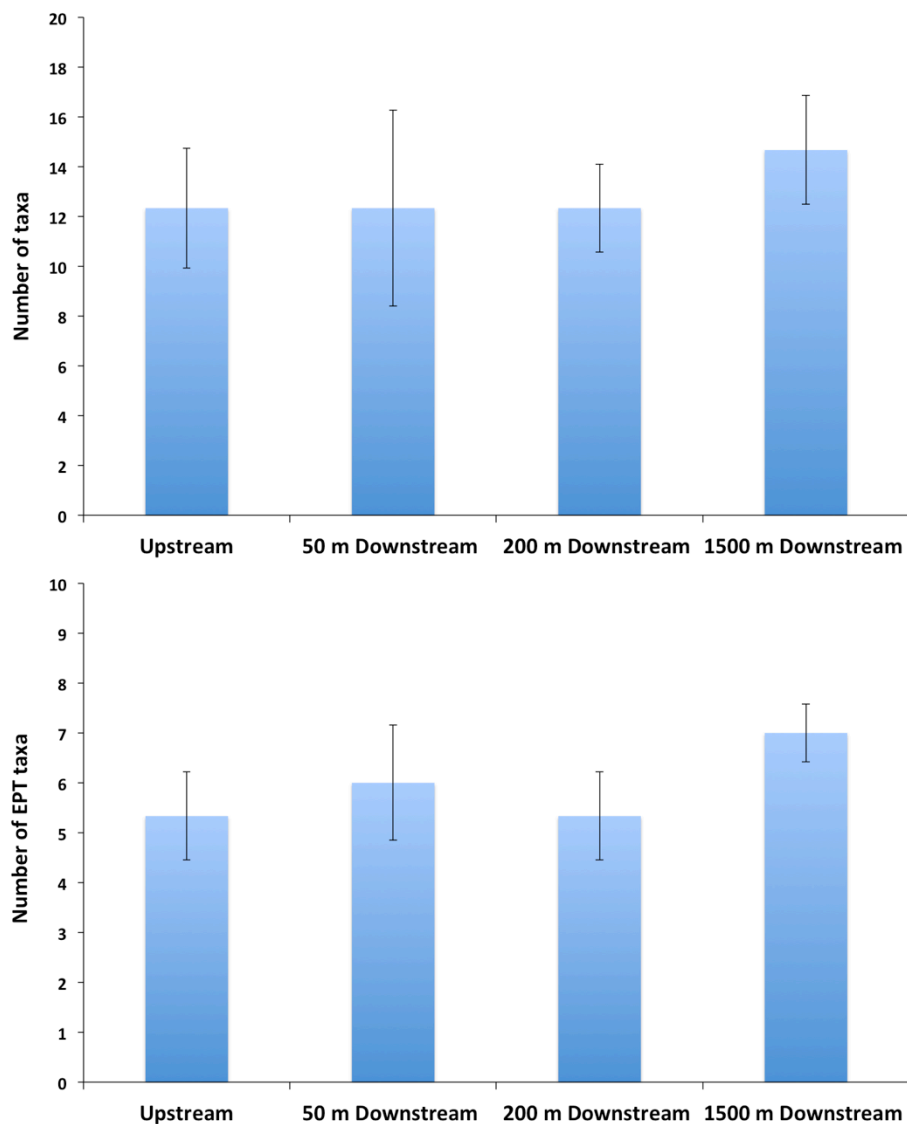


Figure 5 Values for invertebrate metrics for samples collected from the Rastus Burn, December 2017. Error bars are +/- one standard error.

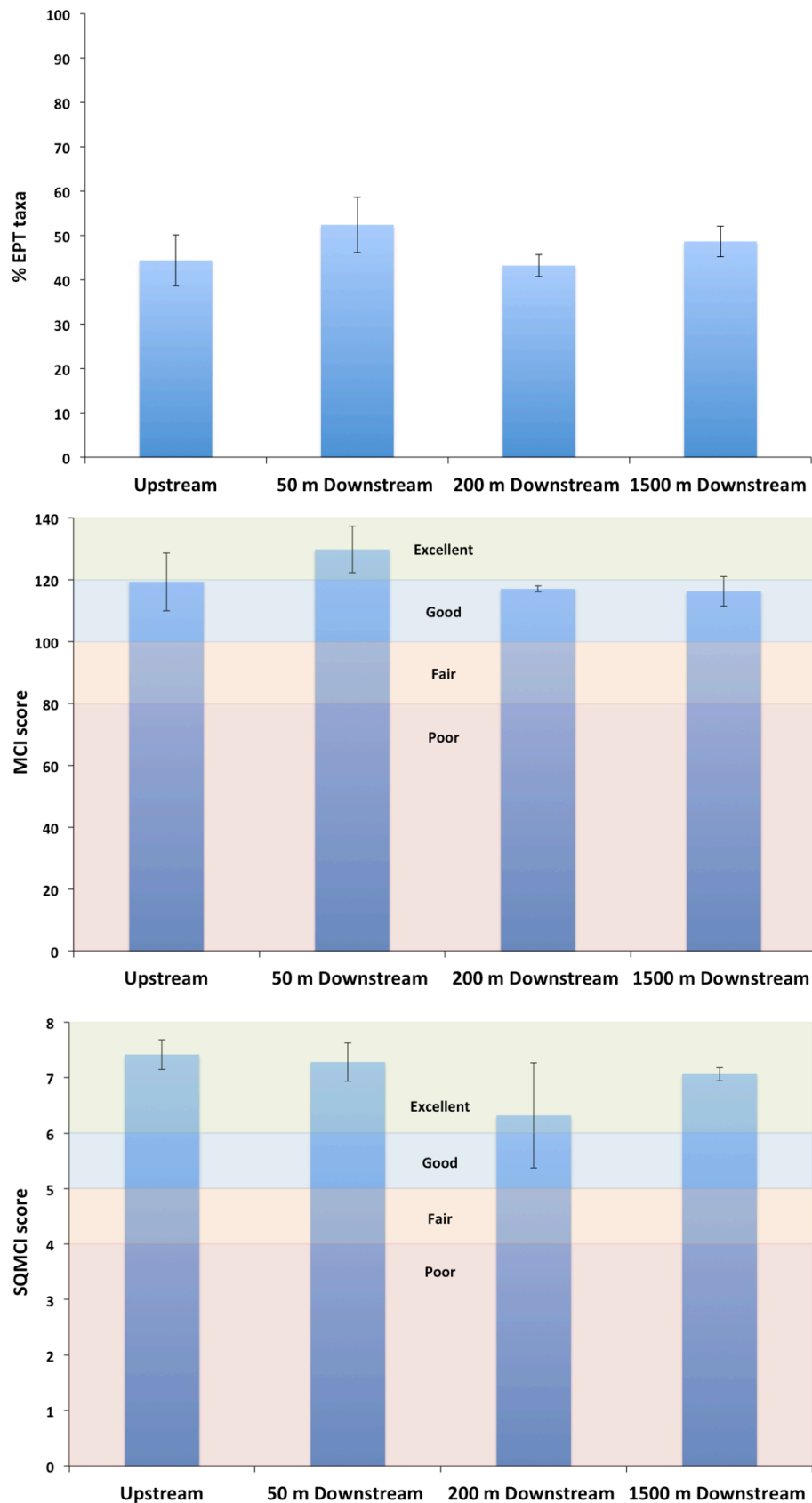


Figure 5 (cont.)

Values for invertebrate metrics for samples collected from the Rastus Burn, December 2017. Error bars are +/- one standard error.

5. Summary and Conclusion

The December 2017 biological survey of the Rastus Burn in the vicinity of the Remarkables Ski Field disposal ponds revealed healthy and diverse benthic macroinvertebrate communities typical of high gradient alpine streams. Benthic communities were characterised by little or no visual periphyton cover and high abundance of mayflies and stoneflies. Overall, there was no difference in community composition between survey sites upstream and downstream of the disposal ponds, indicating that the Remarkables Ski Field wastewater system was not adversely affecting stream communities.

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Remarkables Ski Area

Biological survey of the Rastus Burn

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19 December 2023

Revision: 1.0

Revision Record

Revision	Date	Prepared By	Checked By	Authorised By
1.0	19 December 2023	Zoe Psarouthakis	Ruth Goldsmith	Ben Ludgate

Basis of Report

This report has been prepared by SLR Consulting New Zealand (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with NZSki Limited. Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of NZSki Limited. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to NZSki Limited and others in respect of any matters outside the agreed scope of the work.



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1.0 Introduction

NZSki Limited has consent from the Otago Regional Council (Consent No. RM14.336.01) to discharge treated wastewater to land from the Remarkables Ski Field buildings. Under the consent, up to 127.44 m³ of treated wastewater and water supply bywash may be discharged per day to a disposal area over three ponds in the vicinity of the Rastus Burn. Seepage from the three ponds, which sit on a terrace above the Rastus Burn, may potentially enter the receiving water of the Rastus Burn. For this reason, Condition 11 of the consent requires a biological survey of the Rastus Burn.

Condition 11 states:

- a) The consent holder shall at two yearly intervals engage an appropriately qualified freshwater ecologist to carry out a biological survey of the Rastus Burn upstream and downstream of the disposal ponds for the purpose of determining the effects of the discharge on the aquatic ecosystem of the Rastus Burn.
- b) The biological survey shall be undertaken either during or immediately after the end of the ski season but in all cases shall be no later than 30th November. The survey shall be conducted at the four Rastus Burn monitoring locations shown on the plan in Appendix 1.
- c) The first survey shall be conducted by the end of the first ski season following the grant of this consent.

NZSki engaged SLR Consulting to undertake the biological survey of the Rastus Burn in 2023. This report summarises the monitoring undertaken on 6 November 2023.

2.0 Survey Sites

Sampling was undertaken at one site upstream and three sites downstream of the disposal ponds, as required by the consent (Figure 1). The upstream site was located upstream of a ford on the maintenance road to the ponds. The downstream sites were 50 m, 200 m, and 1500 m downstream of the ponds (Figure 1). These sites have been previously surveyed (e.g., Ludgate and Ryder 2017).





3.0 Sampling Requirements and Methods

3.1 Periphyton

Field collection

Periphyton (algae, fungi and bacteria that form a growing biofilm) was visually assessed at each site. Different substrates available for periphyton growth (e.g., gravels, cobbles) were inspected. Samples of representative algal cover were collected from each site and returned to the laboratory for further identification.

Laboratory assessment

In the laboratory, each sample was inspected under an inverted microscope according to the “relative abundance using an inverted microscope” method outlined in Biggs and Kilroy (2000). Samples were inspected under 200-400x magnification to identify algal species present using the keys of Biggs and Kilroy (2000), Entwisle *et al.* (1988) and Moore (2000). Algae were given an abundance score using the reduced ranks scheme, with 1 representing rare, 2 representing common and 3 representing abundant.

3.2 Macroinvertebrates

Field collection

Benthic macroinvertebrates were sampled using a kicknet (500 µm mesh) and according to collection protocol ‘C1: hard-bottomed semi-quantitative’, as described in the Ministry for the Environment’s ‘Protocols for sampling macroinvertebrates in wadeable streams’ (Stark *et al.* 2001). Samples were collected by disturbing the substrate in a representative area immediately upstream of the net. Three samples were collected from each site. Samples were preserved in ethanol for later identification.

Laboratory assessment

In the laboratory, samples were processed following “Protocol ‘P3: Full count with subsampling option”, outlined in Stark *et al.* (2001). Samples were sieved through a 500 µm sieve to remove fine material and residual ethanol. Contents of the sieve were then placed in a white tray and macroinvertebrates were counted by working systematically across the tray, removing individuals for identification under a dissecting microscope (10-40x) using criteria from Winterbourn *et al.* (2006)

Data presentation and analyses

For each site, benthic macroinvertebrate community health was assessed by determining the following characteristics:

Number of taxa: A measurement of the number of taxa present.

Number of Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa, percentage of the total number of taxa comprising EPT taxa (% EPT taxa), and percentage of the total abundance comprising EPT taxa (% EPT abundance): These insect groups are generally dominated by invertebrates that are indicative of higher quality conditions (i.e., mayflies, stoneflies, and caddisflies). In stony bed rivers, these indexes usually increase with improved water quality and increased habitat diversity.



Macroinvertebrate Community Index (MCI) (Stark 1993): The MCI uses the occurrence of specific macroinvertebrate taxa to determine the level of organic enrichment in a stream. Taxon scores are between 1 and 10, 1 representing species highly tolerant to organic pollution (e.g., worms and some dipteran species) and 10 representing species highly sensitive to organic pollution (e.g., most mayflies and stoneflies). A site score is obtained by summing the scores of individual taxa and dividing this total by the number of taxa present at the site. These scores can be interpreted in comparison with national quality classes (Table 1). For example, a low site score (e.g., 40) represents 'poor' conditions and a high score (e.g., 140) represents 'excellent' conditions.

$$MCI = \left(\frac{\text{Sum of taxa scores}}{\text{Number of scoring taxa}} \right) \times 20$$

Semi-quantitative MCI (SQMCI) (Stark 1998): The SQMCI uses the same approach as the MCI but weights each taxa score based on how abundant the taxa is within the community. Abundance of all taxa is recorded using a five-point scale (Table 1). As for MCI, SQMCI scores can be interpreted in the context of national quality classes (Table 1).

$$SQMCI = \frac{\text{Sum of (Taxa coded abundance x Taxa score)}}{\text{Sum of coded abundances for sample}}$$

Table 1: Interpretation of macroinvertebrate community index values from Boothroyd and Stark (2000) (Quality class A) and Stark and Maxted (2007) (Quality class B).

Quality Class A	Quality Class B	MCI	SQMCI
Clean water	Excellent	≥ 120	≥ 6.00
Doubtful quality	Good	100 – 119	5.00 – 5.99
Probable moderate pollution	Fair	80 – 99	4.00 – 4.99
Probable severe pollution	Poor	< 80	< 4.00

Data has been presented graphically as means +/- one standard error. A one-way Analysis of Variance (ANOVA) was used to test for differences between sites using the statistical package R version 4.1.1. Analysis of variance tables can be interpreted by looking to see whether the 'p-values' for tests are less than 0.05, which would indicate that there are significant differences in the values of the measured metrics between sites. A turkey's post hoc analysis can then be undertaken to identify between which specific sites these significant differences lie.



4.0 Results and Discussion

4.1 General

Sampling was undertaken on 6 November 2023. Weather conditions were fine. There were some banks of snow on the mountain tops, but the Rastus Burn was flowing clearly, with levels above summer base flow conditions.

4.2 Survey site descriptions

The land surrounding the survey sites was dominated by large specimens of *Chionochloa* species (snow tussock) and *Aciphylla* species (spaniard). Low shrubs (most notably *Dracophyllum* species) were present, and there was moss along the wetted edges of the stream.

The Upstream site had tumbling water over medium boulders and bedrock, with some small patches of lower velocity water where substrate was a mixture of flat cobbles and medium gravel (Figure 2, left).

The 50 m Downstream site had a steeper gradient than the Upstream and 200 m Downstream sites. The site contained large boulders forming steep drops with a large cascading waterfall immediately upstream of the sampling area (Figure 2, right).

The 200 m Downstream site was contained within a confined channel, with a long run of small boulders, medium and large cobbles and with coarse gravels in intermittent spaces (Figure 3, left).

The 1500 m Downstream site had a very steep gradient and was a continuous cascade of waterfall-type habitat with very high velocities (Figure 3, right). The substrate was large boulders with occasional small patches of smaller gravel. The surrounding vegetation overhung the channel in places.





Figure 2: Rastus Burn survey sites, 6 November 2023. Left: Upstream site. Right: 50 m Downstream site.



Figure 3: Rastus Burn survey sites, 6 November 2023. Left: 200 m Downstream site. Right: 1500 m Downstream site.



4.3 Periphyton

Periphyton (benthic algae) was either absent or rare at each sampling site in the Rastus Burn. Most stone surfaces appeared very clean, with algal cover restricted to very thin films on a few surfaces. Scrapings from the rock surfaces revealed the community comprised the filamentous red algae *Audouinella* and several types of diatom (Table 2). *Audouinella* is commonly found in clean waterways. In general, the low algal biomass indicates a low nutrient/high disturbance (steep gradient and high velocities) environment.

Table 2: Benthic algae found in the Rastus Burn, 6 November 2023. Values from the reduced ranks scheme described in Biggs and Kilroy (2000) indicating relative abundance scores with 1 representing rare, 2 representing common and 3 representing abundant.

	Upstream	50 m Downstream	200 m Downstream	1500 m Downstream
Filamentous green algae				
<i>Mougeotia</i>			1	
Filamentous red algae				
<i>Audouinella</i>	2	3	3	1
Filamentous diatoms				
<i>Melosira</i>	1	1		2
Diatoms				
<i>Achnantheidium</i>			2	
<i>Cymbella</i>	1			
<i>Epithemia</i>				1
<i>Pinnularia</i>	1			
<i>Synedra</i>				2

4.4 Macroinvertebrates

A total of 29 different macroinvertebrate taxa were identified from the four survey sites in the Rastus Burn, with a total of 12 taxa identified Upstream, 17 taxa from 50 m Downstream, 15 taxa from 200 m Downstream, and 15 taxa from 1500 m Downstream (Table 3). There were no statistically significant differences between sites in the number of taxa ($p>0.05$, Table 4, Figure 4).

A total of 11 different EPT taxa (insect larvae typically indicative of higher water quality; mayflies, stoneflies, and caddisflies) were identified from the four sites (Table 3). A total of four EPT taxa were identified Upstream, six EPT taxa from 50 m Downstream and 200 m Downstream, with eight EPT taxa from 1500 m Downstream. The average contribution of EPT taxa to overall diversity per site (% EPT taxa) was between 36% and 53% at each site (Table 3, Figure 6). There were no statistically significant differences between sites in the number of EPT taxa or % EPT taxa ($p>0.05$, Table 4, Figures 5 and 6).



Macroinvertebrate communities at each site were numerically dominated by EPT taxa, including *Deleatidium* and *Nesameletus* mayflies and *Zelandobius* stoneflies (Table 3). Elmid riffle beetles, Orthocladiinae dipterans and Oligochaeta worms were also present at each site.

Macroinvertebrate community health index (MCI) and semi-quantitative MCI (SQMCI) scores were all similar, with average MCI scores indicative of 'fair' to 'good' quality conditions at each site using the narrative terminology of Stark and Maxted (2007) (Tables 1 and 3, Figure 7). Average SQMCI scores were indicative of 'fair-good' to 'good' quality conditions at the Upstream, 50 m Downstream, and 200 m Downstream sites, and 'excellent' conditions at the 1500 m Downstream site (Table 3, Figure 8). There were no statistically significant differences between sites in any of the community health index scores ($p > 0.05$, Table 4, Figures 7 and 8).



Table 3: Macroinvertebrate taxa and metrics at the four survey sites in the Rastus Burn, 6 November 2023.

ORDER	TAXON	MCI tolerance value	Upstream			50 m Downstream			200 m Downstream			1500 m Downstream		
			A	B	C	A	B	C	A	B	C	A	B	C
ACARINA	ACARINA	5	3											
COLEOPTERA	Elmidae	6	1			5	1	3	8	2	7	1	7	18
	Scirtidae	8						1						
COLLEMBOLA	COLLEMBOLA	6			1									
CRUSTACEA	Copepoda	5	1											
DIPTERA	Empididae	3						1						
	Eriopterini	9				2							4	4
	<i>Limonia</i>	6				1		2						
	<i>Maoridiamesa</i>	3					2				3	2		
	<i>Molophilus</i>	5										1		
	Muscidae	3						1						
	Orthoclaadiinae	2	2		3	6	1	3	2				6	2
	<i>Paralimnophila</i>	6					1		1				1	
	Tanypodinae	5								1				
	Tanytarsini	3							1	1				
EPHEMEROPTERA	<i>Deleatidium</i>	8	13	7	45	63	4	32	7	6	12	9	16	26
	<i>Nesameletus</i>	9		5	3	10	4	1		1		7	23	15
NEMATODA	NEMATODA	3	1						1					
OLIGOCHAETA	OLIGOCHAETA	1	25	1	5	28	6	9	10	4	8		3	2
PLATYHELMINTHES	PLATYHELMINTHES	3	2		1	4		1	3		5			
PLECOPTERA	<i>Austroperla</i>	9												1
	<i>Zelandobius</i>	5	1	1	3	23	1	8	2		2	1	1	
	<i>Zelandoperla</i>	10				2								
TRICHOPTERA	<i>Costachorema</i>	7							1					
	<i>Hudsonema amabile</i>	6										1		
	Hydrobiosidae early instar	5						1	1					
	<i>Hydrobiosis charadraea</i> group	5	1					1				4		2
	<i>Hydropsyche</i> - <i>Aoteapsyche</i>	4										1		
	<i>Philorheithrus</i>	8							1					1
Number of invertebrates (per sample)			50	14	61	144	20	64	38	15	37	27	61	71
Number of taxa			10	4	7	10	8	13	12	6	6	9	8	9
Number of EPT taxa			3	3	3	4	3	5	5	2	2	6	3	5
% EPT taxa			30	75	43	40	38	38	42	33	33	67	38	56
MCI score			86	115	97	118	100	98	95	107	87	113	115	127
SQMCI score			2.8	7.6	6.3	5.0	3.7	6.0	4.9	6.4	4.5	7.0	7.2	7.5
Average MCI score			99			105			96			118		
Average SQMCI score			5.6			4.9			5.2			7.2		



Table 4: Results of the one-way analysis of variance (ANOVA) testing for differences between sites for each of the invertebrate metrics measured.

Metric	$F_{3,8}$	p-value	Interpretation
Number of taxa	0.85	0.50	No significant difference
Number of EPT taxa	1.26	0.35	No significant difference
% EPT taxa	1.05	0.42	No significant difference
MCI score	2.38	0.15	No significant difference
SQMCI score	1.52	0.28	No significant difference

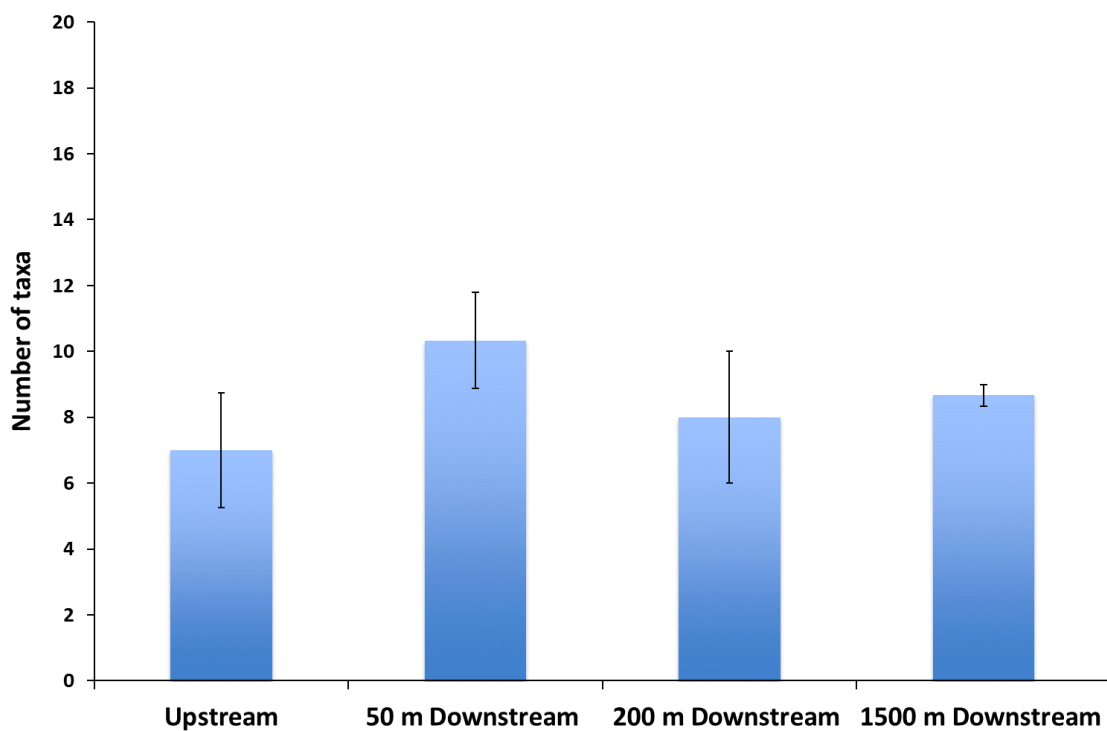


Figure 4: Average number of taxa at Rastus Burn sites, 6 November 2023. Error bars are +/- one standard error.



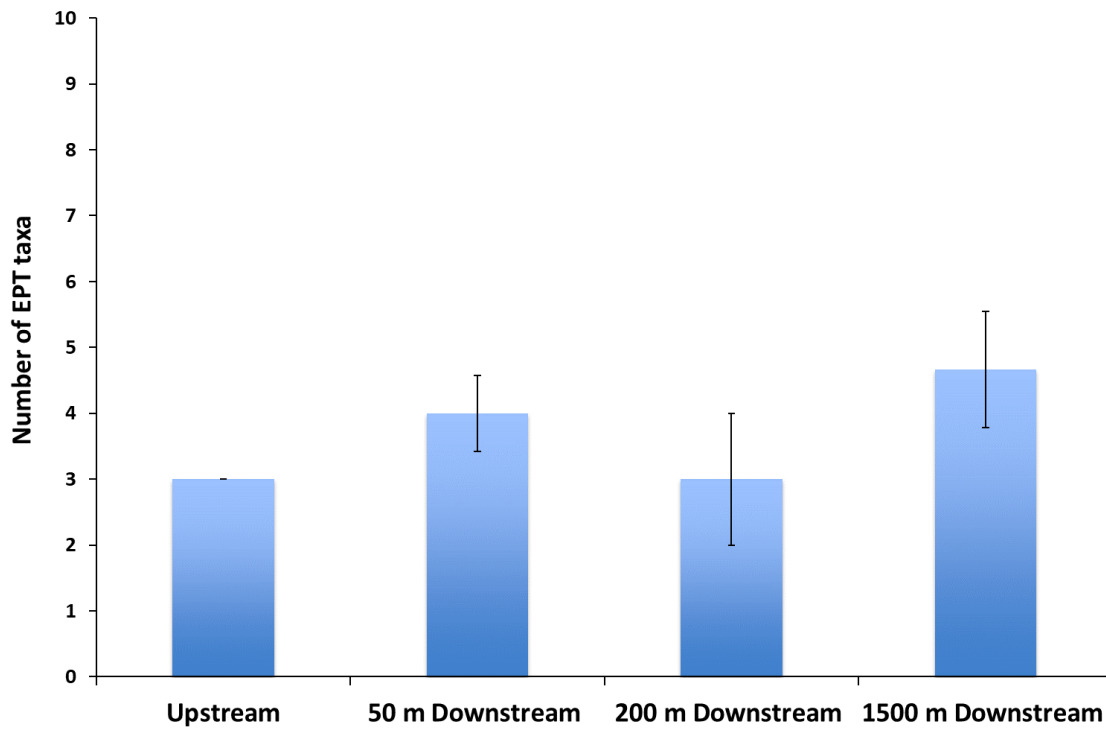


Figure 5: Average number of EPT taxa at Rastus Burn sites, 6 November 2023. Error bars are +/- one standard error.

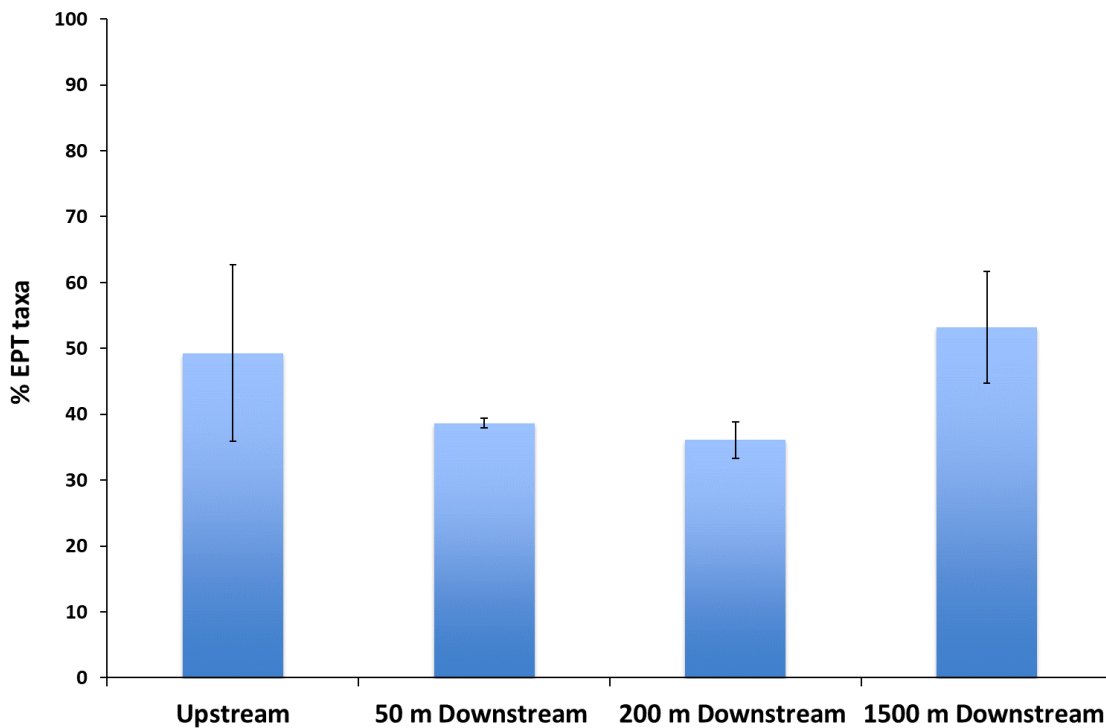


Figure 6: Average percent EPT taxa at Rastus Burn sites, 6 November 2023. Error bars are +/- one standard error.



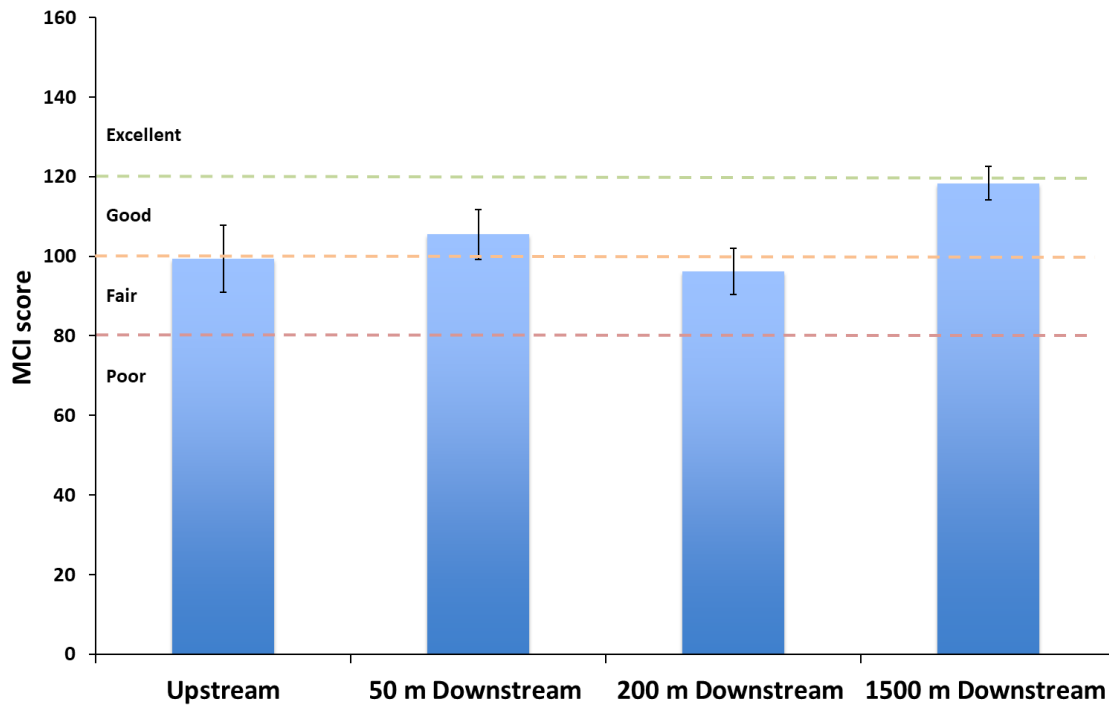


Figure 7: Average MCI scores at Rastus Burn sites, 6 November 2023. Error bars are +/- one standard error.

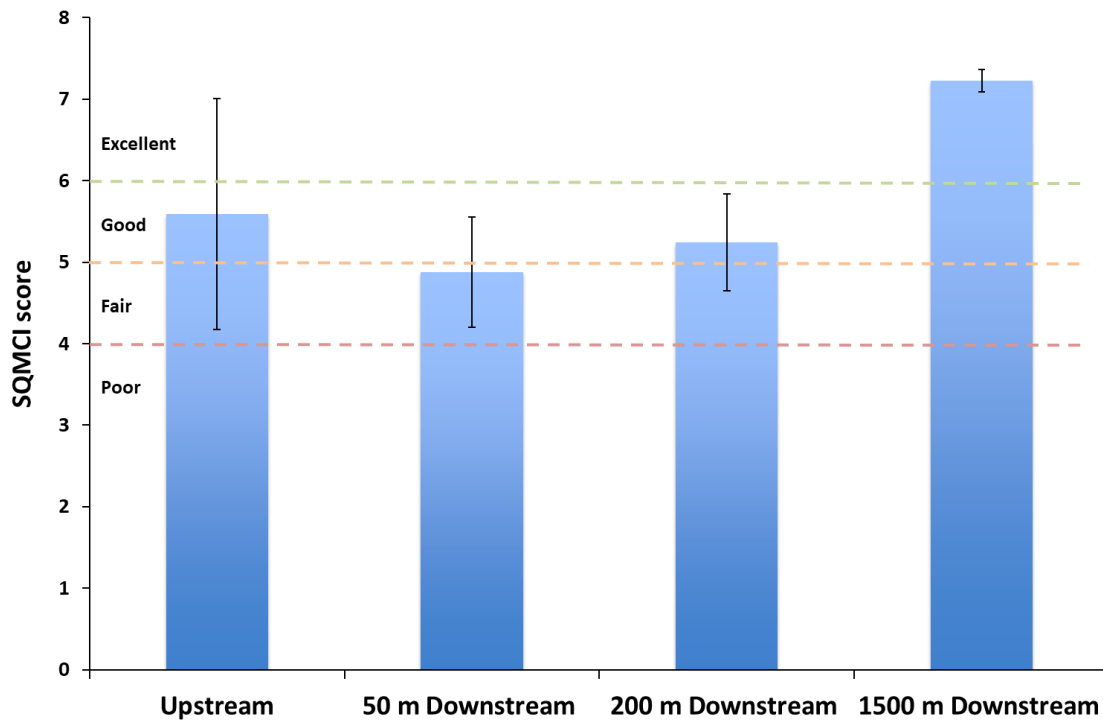


Figure 8: Average SQMCI scores at Rastus Burn sites, 6 November 2023. Error bars +/- one standard error.



5.0 Summary and Conclusion

The 6 November 2023 biological survey of the Rastus Burn in the vicinity of the Remarkables Ski Field disposal ponds revealed healthy and diverse benthic macroinvertebrate communities typical of high gradient alpine streams. Benthic communities were characterised by little or no visual periphyton cover and a macroinvertebrate community indicative of fair to excellent quality conditions. Overall, there was no difference in community composition between survey sites upstream and downstream of the disposal ponds, indicating that the Remarkables Ski Field wastewater system was not adversely affecting stream communities.

6.0 References

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Sincerely,

SLR Consulting New Zealand



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Ecology Technician



Ben Ludgate
Principal Ecologist

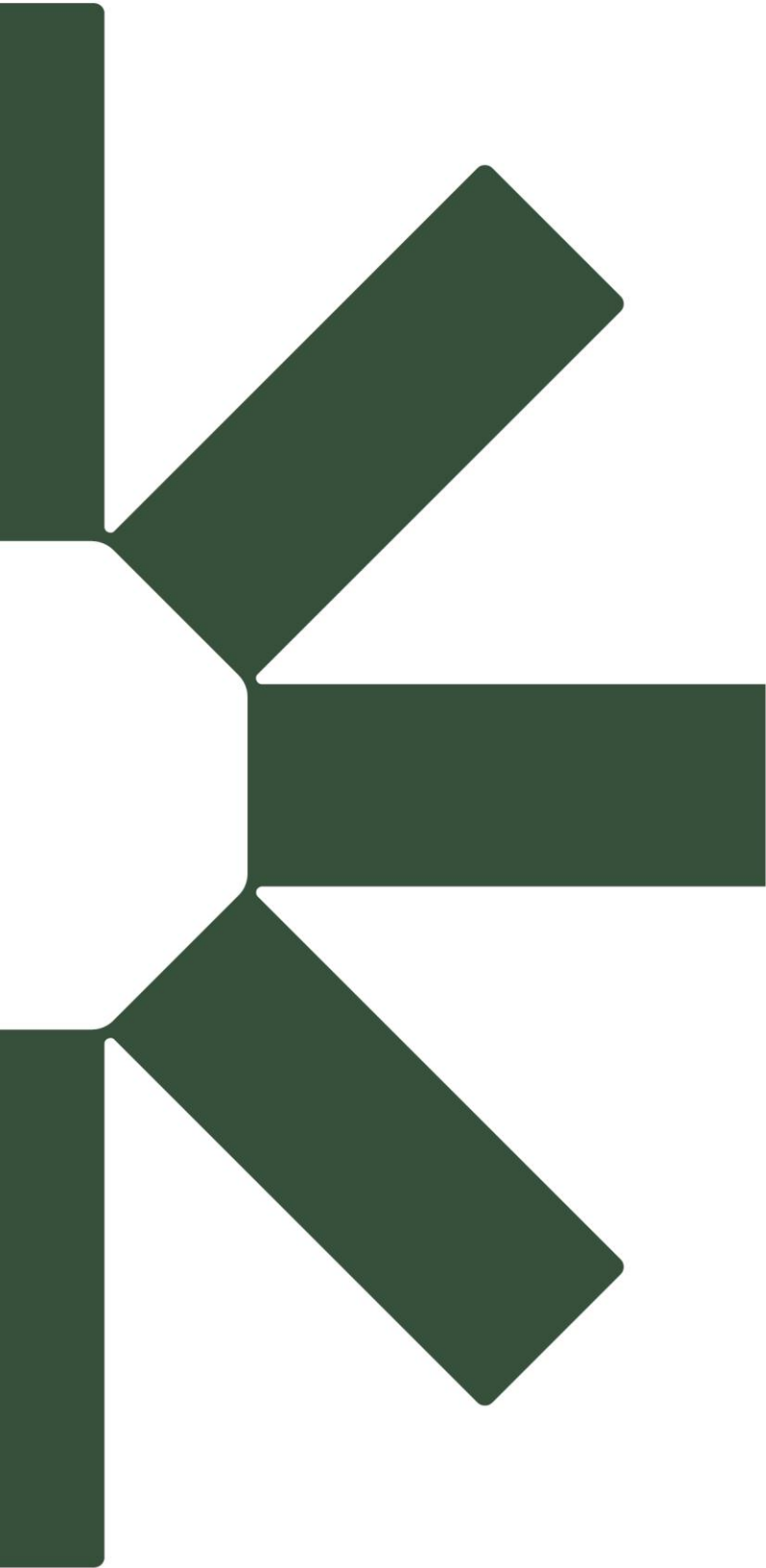


7.0 Feedback

At SLR, we are committed to delivering professional quality service to our clients. We are constantly looking for ways to improve the quality of our deliverables and our service to our clients. Client feedback is a valuable tool in helping us prioritise services and resources according to our client needs.

To achieve this, your feedback on the team's performance, deliverables and service are valuable and SLR welcome all feedback via <https://www.slrconsulting.com/en/feedback>. We recognise the value of your time and we will make a \$10 donation to our 2023 Charity Partner - Lifeline, for every completed form.







Remarkables Ski Area

Biological Survey of the Rastus Burn

NZSki Limited

PO Box 359, Queenstown

Prepared by:

SLR Consulting New Zealand

SLR Project No.: 875.016825.00001

17 February 2026

Revision: 1.0

Revision Record

Revision	Date	Prepared By	Checked By	Authorised By
1.0	17 February 2026	Ainsley Adams	Ben Ludgate	Ben Ludgate

Basis of Report

This report has been prepared by SLR Consulting New Zealand (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with NZSki Limited (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.



Executive Summary

NZSki Limited has consent from the Otago Regional Council (Consent No. RM14.336.01) to discharge treated wastewater to land from the Remarkables Ski Field buildings. Under the consent, up to 127.44 m³ of treated wastewater and water supply bywash may be discharged per day to a disposal area over three ponds in the vicinity of the Rastus Burn. As required by condition 11 of the consent a biological survey was carried out on 20 November 2025 to determine if there is any effect from the discharge on the aquatic ecosystem in the Rastus Burn.

Sampling was undertaken at one site upstream and three sites downstream of the ponds. The upstream site was located upstream of a ford on the maintenance road to the ponds. The downstream sites were 50 m, 200 m, and 1500 m downstream of the ponds. Periphyton cover was visually assessed and periphyton and macroinvertebrate samples were collected from the Rastus Burn at each site and returned to SLR's laboratory for processing and analysis.

The results of the survey revealed healthy benthic macroinvertebrate communities typical of high gradient alpine streams. Benthic communities were characterised by little or no visual periphyton cover and a macroinvertebrate community dominated by mayflies and indicative of excellent quality conditions.

Overall, there was no difference in community composition between survey sites upstream and downstream of the disposal ponds, indicating that the Remarkables Ski Field wastewater system was not adversely affecting stream communities.



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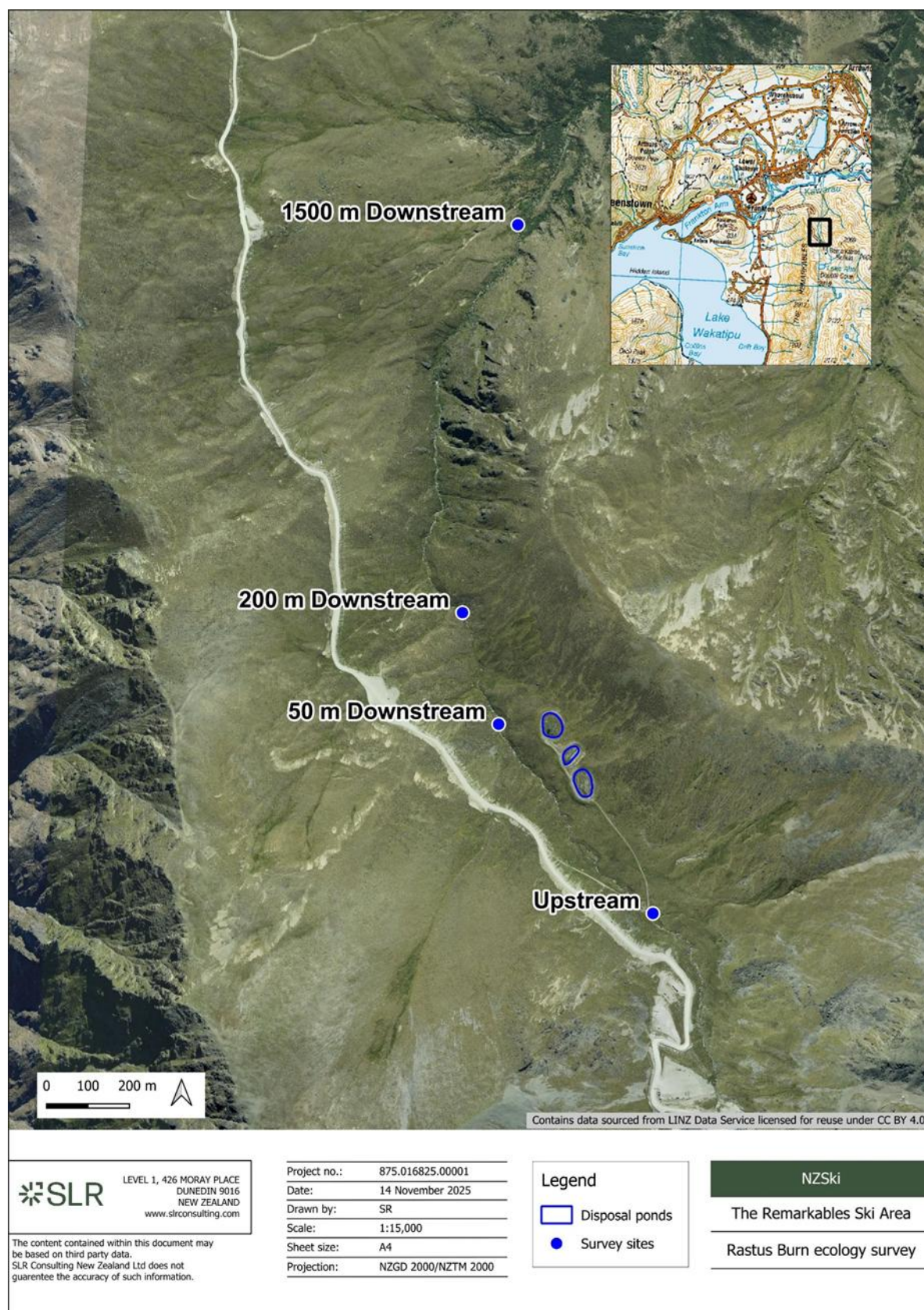


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Taxon scores are between 1 and 10, 1 representing species highly tolerant to organic pollution (e.g., worms and some dipteran species) and 10 representing species highly sensitive to organic pollution (e.g., most mayflies and stoneflies). A site score is obtained by summing the scores of individual taxa and dividing this total by the number of taxa present at the site. These scores can be interpreted in comparison with national quality classes (Table 1). For example, a low site score (e.g., 40) represents 'poor' conditions and a high score (e.g., 140) represents 'excellent' conditions.

$$MCI = \left(\frac{\text{Sum of taxa scores}}{\text{Number of scoring taxa}} \right) \times 20$$

Semi-quantitative MCI (SQMCI) (Stark 1998): The SQMCI uses the same approach as the MCI but weights each taxa score based on how abundant the taxa is within the community. Abundance of all taxa is recorded using a five-point scale (Table 1). As for MCI, SQMCI scores can be interpreted in the context of national quality classes (Table 1).

$$SQMCI = \frac{\text{Sum of (Taxa coded abundance x Taxa score)}}{\text{Sum of coded abundances for sample}}$$

Table 1: Interpretation of macroinvertebrate community index values from Boothroyd and Stark (2000) (Quality class A) and Stark and Maxted (2007) (Quality class B).

Quality Class A	Quality Class B	MCI	SQMCI
Clean water	Excellent	≥ 120	≥ 6.00
Doubtful quality	Good	100 – 119	5.00 – 5.99
Probable moderate pollution	Fair	80 – 99	4.00 – 4.99
Probable severe pollution	Poor	< 80	< 4.00

Data has been presented graphically as means +/- one standard error. A one-way Analysis of Variance (ANOVA) was used to test for differences between sites using the statistical package R version 4.1.1. ANOVA tables can be interpreted by looking to see whether the 'p-values' for tests are less than 0.05, which would indicate that there are significant differences in the values of the measured metrics between sites. A tukey's post hoc analysis can then be undertaken to identify between which specific sites these significant differences lie.

4.0 Results and Discussion

4.1 General

Sampling was undertaken on 20 November 2025. Weather conditions were overcast with light wind. There was some residual snow seen in patches and while the Rastus Burn was flowing clearly, river flows were above base flow conditions.



4.2 Survey Site Descriptions

The land surrounding the survey sites was dominated by large specimens of *Chionochloa* species (snow tussock) and *Aciphylla* species (spaniard). Low shrubs (most notably *Dracophyllum* and *Veronica* species) were present and small alpine herbs. Moss was noted on the edges of the stream and on rocks within the stream. The 1500 m Downstream site had a more diverse and taller vegetation assemblage than the other sites, with *Phormium cookianum* (mountain flax), taller *Coprosma* species and scattered *Discaria* (matagouri) and *Carmichaelia* (native broom) also noted.

The Upstream site included tumbling water over medium boulders, with some small patches of lower velocity water where substrate was a mixture of flat cobbles and medium gravel (Figure 2).

The 50 m Downstream site had a steeper gradient than the Upstream and 200 m Downstream sites. The site contained large boulders forming steep drops with a large cascading waterfall immediately upstream of the sampling area (Figure 2).

The 200 m Downstream site was contained within a confined channel, with a long run and bed substrates of small boulders, medium and large cobbles and with coarse gravels in intermittent spaces (Figure 3).

The 1500 m Downstream site had a very steep gradient and was a continuous cascade of waterfall-type habitat with very high velocities (Figure 3). The substrate was large boulders and bedrock with occasional small patches of smaller gravel. The surrounding vegetation overhung the channel in places.



Figure 2: Rastus Burn sites, November 2025. Left: Upstream site. Right: 50 m Downstream site.





Figure 3: Rastus Burn sites, November 2025. Left: 200 m Downstream site. Right: 1,500 m Downstream site.

4.3 Periphyton

Periphyton (benthic algae) was either absent or rare at each sampling site in the Rastus Burn. Most stone surfaces appeared very clean, with algal cover restricted to very thin films on a few surfaces, however, at the 200 m Downstream site there was a small area with higher algae cover noted on the stream edge at the base of a seep (Figure 4). The seep was located well away from, and therefore not associated with, the wastewater pond seepage.

Scrapings from the rock surfaces revealed the community throughout the Rastus Burn sites comprised of various diatoms and the filamentous red algae *Audouinella* (Table 2).

Didymosphenia cells were found in low numbers in the sample collected from the 200 m Downstream site; this invasive diatom has not previously been found in the Rastus Burn. *Audouinella* is commonly found in clean waterways.

In general, the low algal biomass indicates a low nutrient/high disturbance (steep gradient and high velocities) environment.





Figure 4: Periphyton cover observed in a small, defined area at the base of a seep 200 m downstream of the discharge, November 2025.



Table 2: Benthic algae found in the Rastus Burn, November 2025. Values from the reduced ranks scheme described in Biggs and Kilroy (2000) indicating relative abundance scores with 1 representing rare, 2 representing common and 3 representing abundant.

	Upstream	50 m Downstream	200 m Downstream	1500 m Downstream
Filamentous red algae				
<i>Audouinella</i>	2	1		1
Diatoms				
<i>Cocconeis</i>			1	
<i>Cymbella</i>			1	
<i>Didymosphenia</i>			1	
<i>Gomphonema</i>			3	
Naviculoid diatoms			2	1
<i>Pinnularia</i>				1
Other diatoms*	1		2	

* Very small, unidentified diatoms.

4.4 Macroinvertebrates

A total of 24 different macroinvertebrate taxa were identified from the four survey sites in the Rastus Burn, with a total of 12 taxa identified Upstream, 17 taxa from 50 m Downstream, 9 taxa from 200 m Downstream, and 12 taxa from 1500 m Downstream (Table 3). There were no statistically significant differences between sites in the number of taxa ($p > 0.05$; Table 4, Figure 5).

A total of nine different EPT taxa (insect larvae typically indicative of higher water quality; mayflies, stoneflies, and caddisflies) were identified from the four sites (Table 3). A total of six EPT taxa were identified Upstream, with five EPT taxa identified from each of the 50 m Downstream, 200 m Downstream and 1500 m Downstream sites. The average contribution of EPT taxa to overall diversity per site (% EPT taxa) was between 48% and 63% (Table 3, Figure 7). There were no statistically significant differences between sites in the number of EPT taxa or % EPT taxa ($p > 0.05$; Table 4, Figures 6 and 7).

While the relative abundance of macroinvertebrates was low at each site, communities at each site were numerically dominated by EPT taxa, including *Deleatidium* and *Nesameletus* mayflies and *Zelandobius* stoneflies (Table 3). *Oligochaeta* worms and *Maoridiamesa* (Chironomidae) midge larvae were also present at each site but abundance was low.

Macroinvertebrate community health index (MCI) and semi-quantitative MCI (SQMCI) scores were all similarly high, with average MCI and SQMCI scores at all sites indicative of 'Excellent' quality conditions, using the narrative terminology of Stark and Maxted (2007) (Tables 1 and 3, Figures 8 and 9). There were no statistically significant differences between sites in any of the community health index scores ($p > 0.05$; Table 4, Figures 8 and 9).



Table 3: Macroinvertebrate taxa and metrics at the four survey sites in the Rastus Burn, November 2025

ORDER	TAXON	MCI tolerance value	Upstream			50m Downstream			200m Downstream			1500m Downstream		
			A	B	C	A	B	C	A	B	C	A	B	C
ACARINA	ACARINA	5											1	
COLEOPTERA	<i>Elmidae</i>	6	1						4	9		1		2
	<i>Hydrophilidae</i>	5					1							
	<i>Scirtidae</i>	8					1							
COLLEMBOLA	COLLEMBOLA	6	1									1		
DIPTERA	<i>Austrosimulium</i>	3	1					2						
	<i>Eriopterini</i>	9				1	1	2	1					
	<i>Limonia</i>	6				1						1		
	<i>Maoridiamesa</i>	3	1					1		10	1	2	1	
	<i>Muscidae</i>	3						1						
	<i>Neocurupira</i>	7											1	
	<i>Orthoclaadiinae</i>	2	1	1				3						
	<i>Paralimnophila</i>	6				1								
	<i>Tanypodinae</i>	5				1								
EPHEMEROPTERA	<i>Deleatidium</i>	8	18	29	69	10	12	30	13	32	9	12	8	4
	<i>Nesameletus</i>	9	4	9	11	5	4	45	7	3	14	36	6	21
NEMATODA	NEMATODA	3						1						
OLIGOCHAETA	OLIGOCHAETA	1		2	1			4		1		5		
PLECOPTERA	<i>Zelandobius</i>	5		1		4	1	12			9	1		
	<i>Zelandoperla</i>	10	1	1	4			2						
TRICHOPTERA	<i>Costachorema</i>	7											1	
	<i>Hydrobiosis</i>	5		1							1			
	<i>Phylorheithrus</i>	8				1	1			1				
	<i>Tiphobiosis</i>	6			1									
	<i>Zelolessica</i>	10										1		
Number of invertebrates (per sample)			28	44	86	24	21	103	25	56	34	60	18	27
Number of taxa			8	7	5	8	7	11	4	6	5	9	6	3
Number of EPT taxa			3	5	4	4	4	4	2	3	4	4	3	2
% EPT taxa			38	71	80	50	57	36	50	50	80	44	50	67
MCI score			118	114	136	140	149	102	160	117	120	120	130	153
SQMCI score			6.6	7.6	7.9	7.8	7.6	7.5	8.3	6.8	6.9	7.3	7.6	8.8
Average MCI score			123			130			132			134		
Average SQMCI score			7.4			7.6			7.3			7.9		



Table 4: Results of the one-way ANOVA testing for differences between sites for each of the invertebrate metrics measured. There were no significant differences.

Metric	$F_{3,8}$	p-value	Interpretation
Number of taxa	1.72	0.23	No significant difference
Number of EPT taxa	1.33	0.32	No significant difference
% EPT taxa	0.53	0.67	No significant difference
MCI score	0.19	0.89	No significant difference
SQMCI score	0.46	0.71	No significant difference

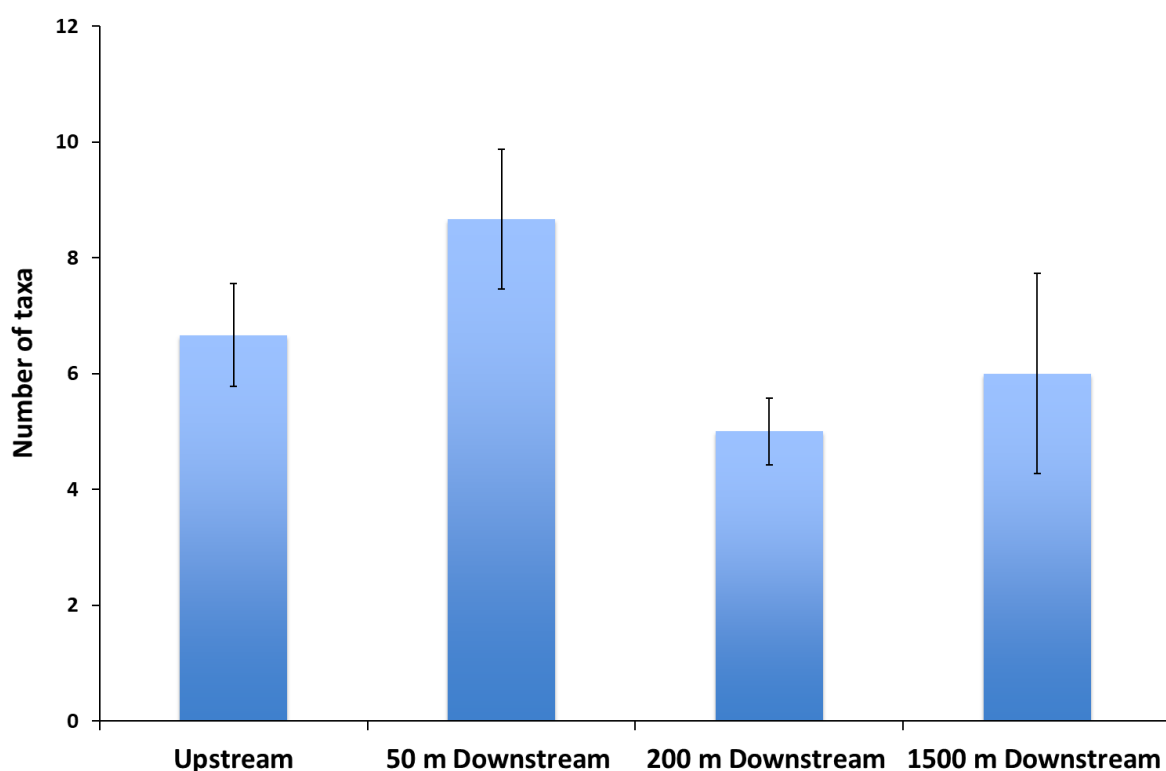


Figure 5: Average number of taxa at Rastus Burn sites, November 2025. Error bars are +/- one standard error.



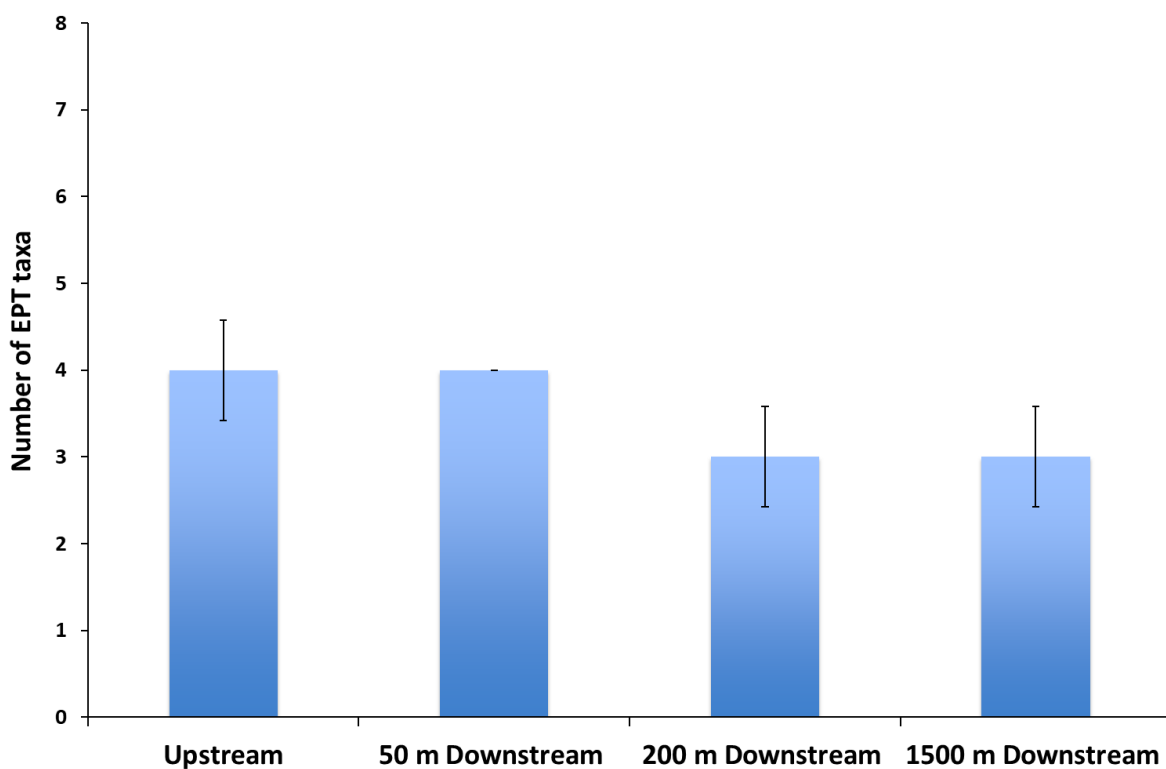


Figure 6: Average number of EPT taxa at Rastus Burn sites, November 2025. Error bars are +/- one standard error.

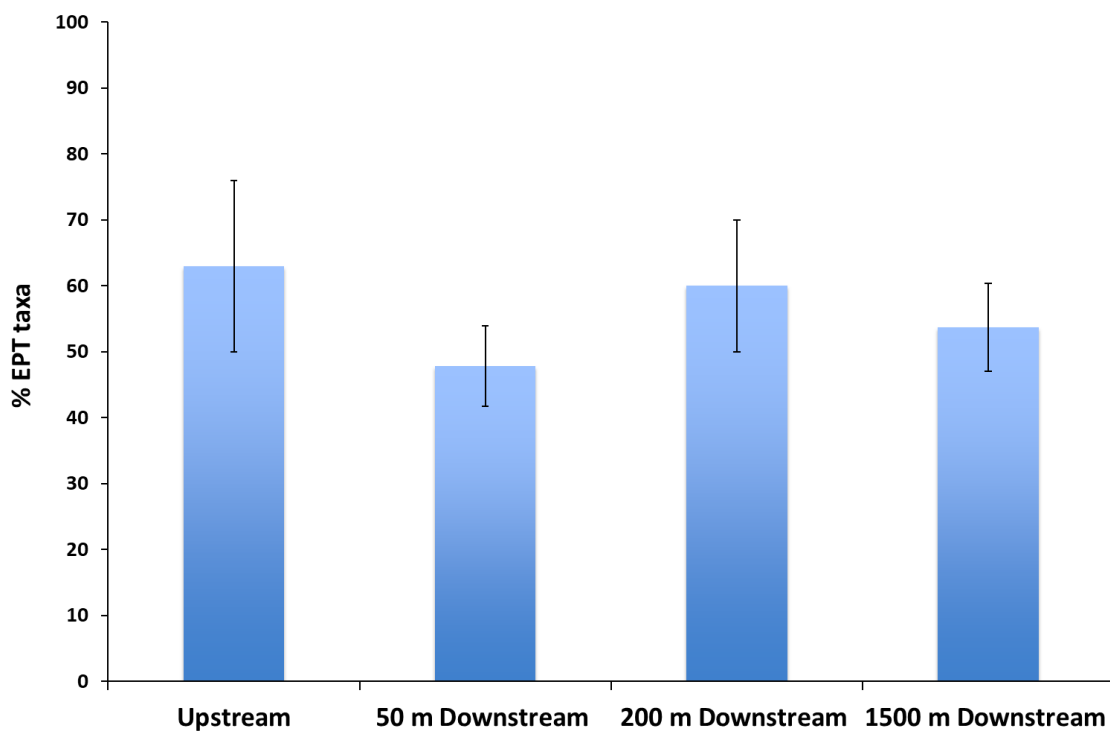


Figure 7: Average percent EPT taxa at Rastus Burn sites, November 2025. Error bars are +/- one standard error.



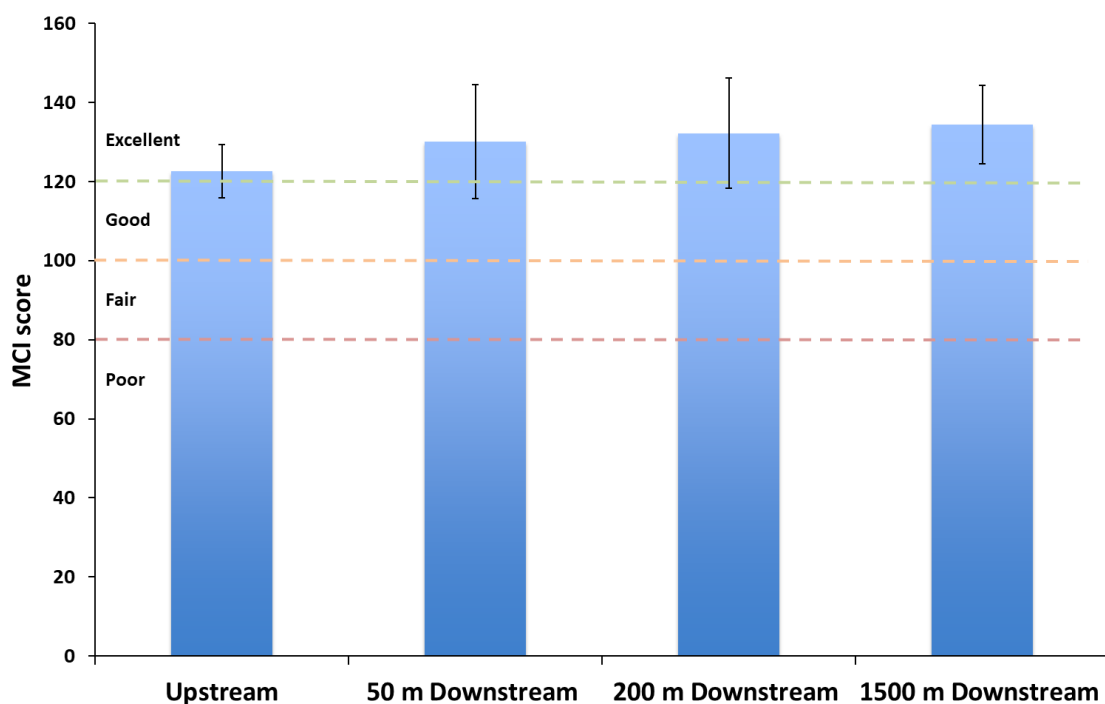


Figure 8: Average MCI scores at Rastus Burn sites, November 2025. Error bars are +/- one standard error.

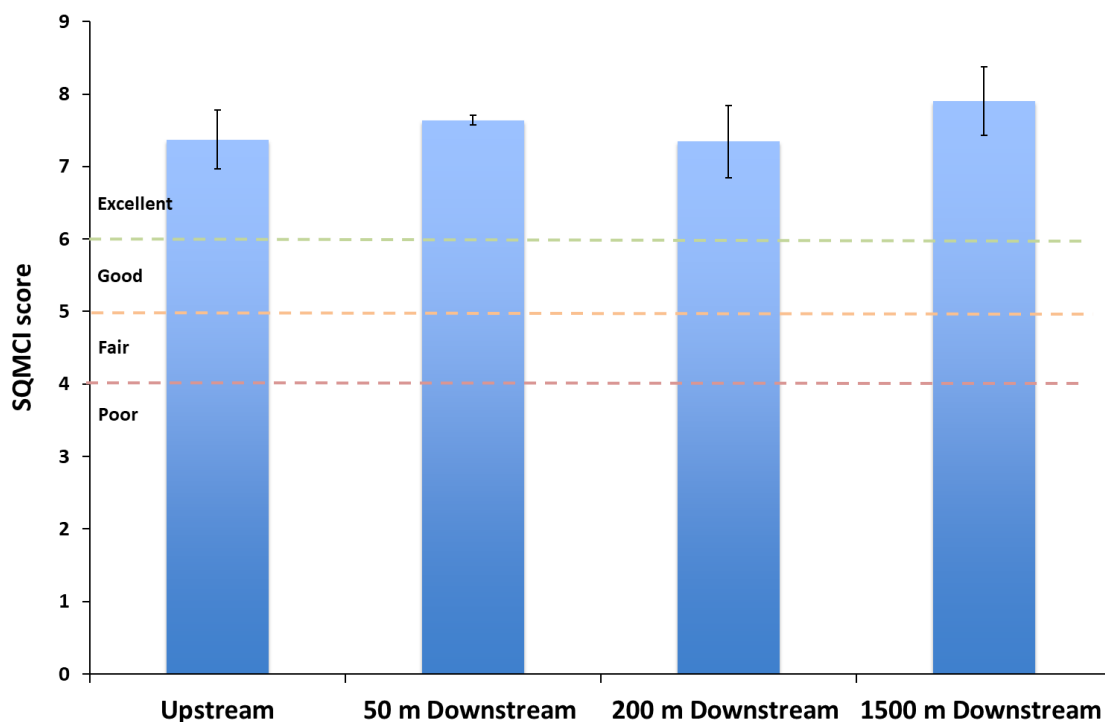


Figure 9: Average SQMCI scores at Rastus Burn sites, November 2025. Error bars +/- one standard error.

5.0 Summary and Conclusion



The November 2025 biological survey of the Rastus Burn in the vicinity of the Remarkables Ski Field disposal ponds revealed healthy benthic macroinvertebrate communities typical of high gradient alpine streams. Benthic communities were characterised by little or no visual periphyton cover and a macroinvertebrate community dominated by mayflies and indicative of excellent quality conditions.

Overall, there was no difference in community composition between survey sites upstream and downstream of the disposal ponds, indicating that the Remarkables Ski Field wastewater system was not adversely affecting stream communities.

6.0 References

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7.0 Closure

Sincerely,

SLR Consulting New Zealand



Ainsley Adams
Senior Project Consultant – Ecology and
Biodiversity



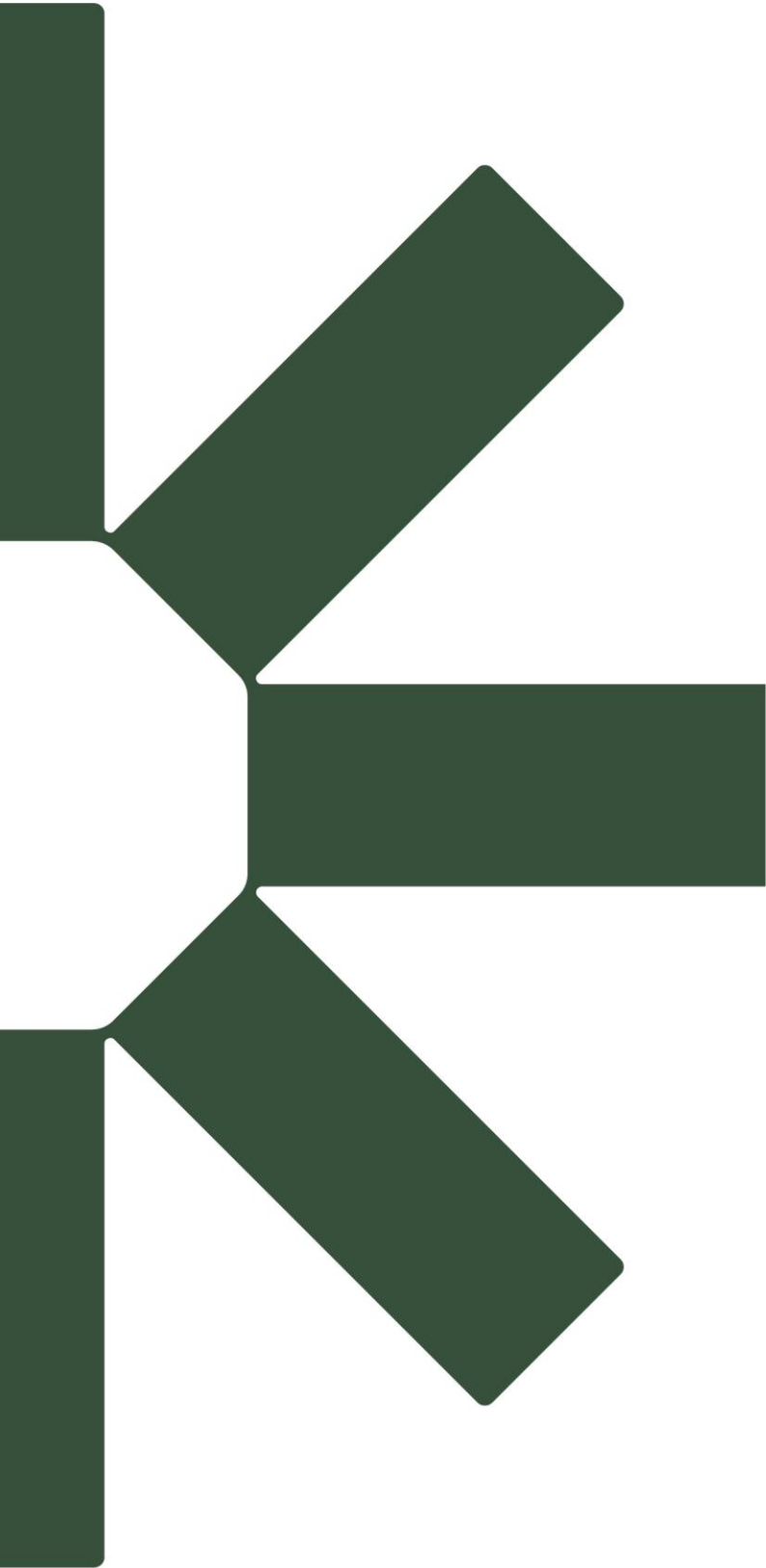
Ben Ludgate
Principal Ecologist

8.0 Feedback

At SLR, we are committed to delivering professional quality service to our clients. We are constantly looking for ways to improve the quality of our deliverables and our service to our clients. Client feedback is a valuable tool in helping us prioritise services and resources according to our client needs.

To achieve this, your feedback on the team's performance, deliverables and service are valuable and SLR welcome all feedback via <https://www.slrconsulting.com/en/feedback>. We recognise the value of your time and we will make a \$10 donation to our Charity Partner - Lifeline, for every completed form.





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