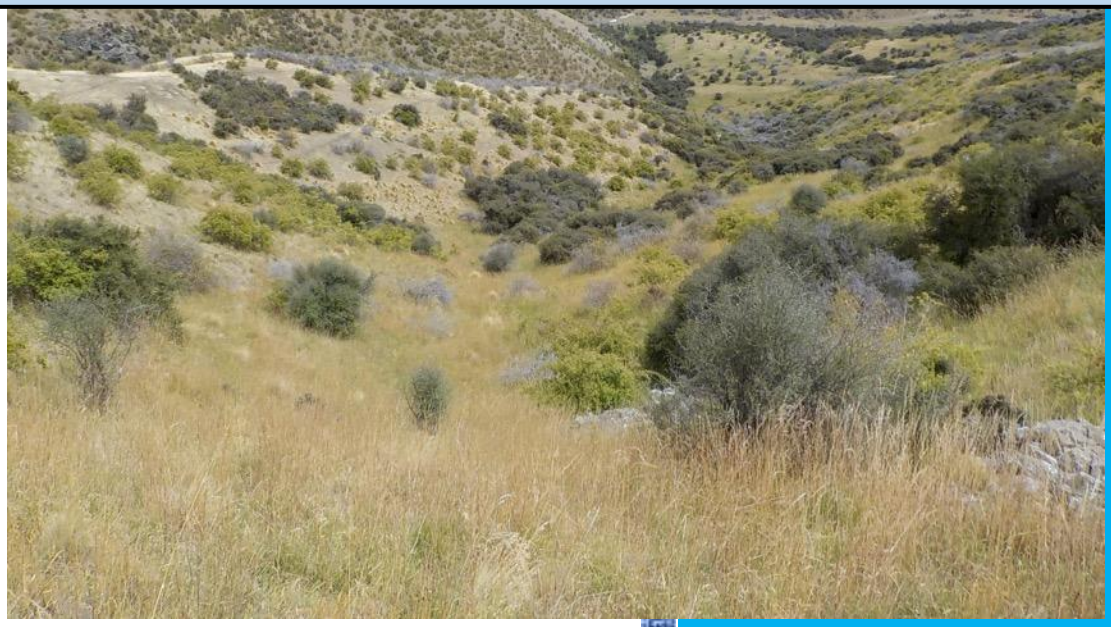
Water Ways Consulting

Bendigo Ophir Gold Project: Assessment of Effects on Aquatic Habitat



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Cover photo: A view into Shepherds Creek from one of the hillside spring locations.

Table of Contents

List of Tables

List of Figures

EXECUTIVE SUMMARY

The aim of this study was to characterise the streams, aquatic fauna and adjacent watercourses, to assess the effects of the proposed Bendigo-Ophir Gold Project (BOGP) and associated infrastructure on these streams, in particular Shepherds Creek and Rise and Shine Creek that have been modified by stock grazing, localised channel modifications and water abstraction for pastoral use over the past century. In general, the study found that the ecological value of the Shepherds and Rise and Shine Creeks and associated tributaries varied from moderate-to-high in the upper reaches to moderate-to-low in the lower reaches. No fish, kourā and kākahi are present in Shepherds Creek or Rise and Shine Creek. Shepherds Creek is considered representative of a fishless low gradient Dunstan Mountains small perennial stream. In Rise and Shine Creek the macroinvertebrate fauna was relatively sparse aside from in the perennial tributary draining Mt Moka. Outside of the project footprint to the south-west, Clearwater and Bendigo streams by comparison include diverse high-quality macroinvertebrate communities.

Shepherds Creek

The current extent of modification is limited to the effects of agricultural activity such as stock grazing, and water abstraction. The absence of introduced fish and the limited range of other introduced species suggests most of the stream is currently subject to low to moderate impacts. The presence of the Ardgour Conservation Area in the headwaters provides a clean water supply to the stream and there is a low level of nitrogen increase in the farmed perennial reach of Shepherds Creek indicating that stock impacts are more limited to physical damage than to declines in water quality.

Shepherds Creek has a number of tributaries that, aside from Jean Creek, can be divided into two groups: the perennial flowing spring fed streams and the ephemeral streams that have very short duration flow periods. The ephemeral streams do not retain any aquatic macroinvertebrates as the streams flow for very short periods (hours or days) and cannot be successfully colonised by macroinvertebrates. The macroinvertebrate faunas in the small spring fed streams were of low quality and low diversity. The effects of the small stream size, stock damage, mud dominated stream bed and low habitat diversity are expected to be limiting the macroinvertebrate fauna in these spring fed streams.

In the wider Dunstan Mountains stream setting Shepherds Creek supports moderately diverse macroinvertebrate fauna but is lacking some of the diversity of taxa that are present in streams with more boulder and cobble riffle habitat, such as Clearwater Creek and Bendigo Creek.

Therefore, Shepherds Creek is considered representative of a low gradient Dunstan Mountains perennial small stream. This assessment indicates that Shepherds Creek can be divided into reaches:

- The upper reaches of Shepherd Creek from the Ardgour Conservation Area boundary to at least the downstream gorge section in the middle of project area has moderate to high ecological value. The extent of modification is limited to stock impacts, and this reach has good water quality, low to moderate habitat diversity and no introduced species. eDNA sampling showed good habitat or water quality macroinvertebrate species including two stoneflies and the caddisfly *Oeconesus*.
- Downstream of the gorge section the aquatic values can be considered of moderate value. Habitat modification increases with various impacts including water abstraction, channel modifications (e.g., the dam), crack willow, and stock impacts are marginally more noticeable.

- The state of Shepherds Creek upstream of the main abstraction can be summarised as having a moderately diverse macroinvertebrate fauna, that is composed of a broad range of insects, molluscs and worms. The stream has no threatened macroinvertebrates, no kourā or kākahi and no freshwater fish. eDNA sampling showed common, poor water or habitat quality indicator taxa, such as the purse case caddisflies and *Corynoneura* present in the reach closest to the main water abstraction, a reach that is also limited in terms of diversity and provides relatively low-quality riffle habitat. The stream fauna does have a very high level of naturalness and problematic introduced species, such as brown trout are absent and crack willow is well controlled.

Rise and Shine Creek

The Rise and Shine catchment has a range of ephemeral, intermittent and perennial streams that support a fauna of high to low ecological value:

- The stream draining Mt Moka in the upper Rise and Shine catchment is considered a high-quality habitat area, aside from the lower 200 m where historic and present modifications occur.
- Rise and Shine Creek downstream of the Mt Moka Stream confluence is a perennial stream and is considered to have low to moderate ecological value.
- Rise and Shine Creek and its tributaries upstream of the Mt Moka Stream confluence are intermittent and ephemeral water courses.

In Rise and Shine Creek the macroinvertebrate fauna was relatively sparse with between six and ten taxa detected at four sites. All sites were characterised by a lack of stoneflies and the only mayfly detected was *Deleatidium.* The best stream fauna was detected in the Mt Moka tributary. The macroinvertebrate fauna in this stream (20-50 cm wide) is likely limiting the number of resident taxa due to a limited array of available habitat types.

The upper reaches of Rise and Shine Creek were mapped as intermittent or ephemeral. The intermittent reaches retain some macroinverterbrates that tolerate the no flow conditions. The ephemeral reaches are not expected to retain any freshwater macroinvertebrates.

By comparison, Bendigo Creek, downstream and beyond the project footprint had relatively diverse macroinvertebrate communities with between 20 and 25 taxa detected across the sampling points. Clearwater Creek, a Bendigo Creek tributary that Rise and Shine Creek flows into that is also outside of the project footprint, included diverse high-quality macroinvertebrate communities, with between 22 to 27 taxa found.

Assessment of Effects

There are four general categories of potential adverse effects on stream habitat from the BOGP:

- Complete loss of habitat;
- Permanent diversion of streams;
- Long term changes to stream flow; and
- Potential water quality changes.

These effects are not spread evenly across the water courses in the project area. The effects on perennial stream habitat has the largest effect. Whereas the impacts on intermittent water courses will have a lesser effect on aquatic communities as these streams have more limited aquatic flora and

fauna. The loss of ephemeral streams and watershed areas will affect water flow paths but will not lead to the direct loss of habitat used by aquatic species as these water course have no aquatic fauna and flora.. Therefore, the assessment of effects has assessed the impact on stream course habitat for each stream category separately.

These effects on the stream courses have been divided into two categories, stream loss when the stream is buried or excavated and impacted when the stream course is modified but retained in or near its existing location. Stream loss in the proposed Tailings Storage Facility (TSF), Engineered Landforms (ELF), and mine pits amount to 13,710 m of water course (ephemeral, intermittent and perennial) and of this 8,536 m is perennial water course (Table E.1). An additional 2,090 m of 2nd order + perennial stream will be realigned to accommodate the process plant and services corridor in Shepherds Creek. This gives rise to direct impacts on 10,626 m of perennial stream.

Table E.1: Summary of the length of stream modified in the BOGP footprint.

Stream type	Ephemeral	Intermittent	Minor perennial order	Perennial 2nd order +	Watershed
Stream length lost Shepherd Creek	4,474 m	1,631 m	1,236 m	5,903 m	1,438 m
Stream length realigned, Shepherds Creek	0 m	0 m	0 m	2,960 m	0 m
Stream length lost, Rise and Shine Creek	700 m	0 m	305 m	1,092 m	0 m
Non-permanent stream length loss at soil storage sites	672 m	97 m	19 m	0 m	312 m

1. INTRODUCTION

1.1. Background

Matakanui Gold Limited ("**MGL**") is proposing to establish within the Bendigo-Ophir Gold Project ("**BOGP**"), a new gold mine, ancillary facilities and environmental mitigation measures on Bendigo and Ardgour Stations in the Dunstan Mountains of Central Otago. The project site is located approximately 20 km north of Cromwell.

The BOGP is located within the footprint of Minerals Exploration Permit 60311, which overlays several pastoral stations that have grazed sheep and cattle in the area for over 100 years. MEP60311 is held by MGL under the Crown Minerals Act 1991. MGL has land access agreements with Bendigo and Ardgour Stations. The BOGP is located adjacent to land administered by the Department of Conservation ("**DOC**"), including the Bendigo Historic Reserve, the Bendigo Conservation Area and the Ardgour Conservation Area. The BOGP planned operations do not directly impact these areas.

The BOGP's exploration has discovered numerous soil geochemical anomalies and extensive drill evaluation has defined four (4) gold deposits worthy of economic extraction. The most significant is the Rise and Shine ("**RAS**") discovery which is the most significant gold discovery in New Zealand in the past 4 decades. The other discoveries at Come in Time ("**CIT**"), Srex ("**SRX**") and Srex East ("**SRE**") are smaller in size and tenor.

The defined orebodies are planned to be mined by open pit methods. Underground mining is planned for the deeper parts of the RAS orebody in the later years of development.

The majority of the mining activities, ancillary facilities and associated infrastructure will be located in the Shepherds Valley somewhat hidden from the view of the public. Access, and service and administration offices are planned to be located on the adjoining Ardgour Terrace.

Figure 1 above provides an overview of the footprint associated with the establishment, operation and rehabilitation within the BOGP. Direct disturbance in the pastoral area will be approximately 380 hectares. A disturbance contingency has been allowed around the mine and infrastructure for footprint adjustments during detailed design. A further 18 ha (approximately) of disturbance will be needed to establish the Thomson Gorge Road alternative alignment (Ardgour Rise). Maximum potential disturbance in the pastoral area, including contingency and Ardgour Rise, is 568ha.

Additional disturbance of approximately 52 ha will be required in the agricultural area on Ardgour Terrace. This area will be used for offices, security, medical, laboratory, laydown, storage, contractor areas, topsoil storage, emulsion manufacture and magazine facilities plus quarries and roading.

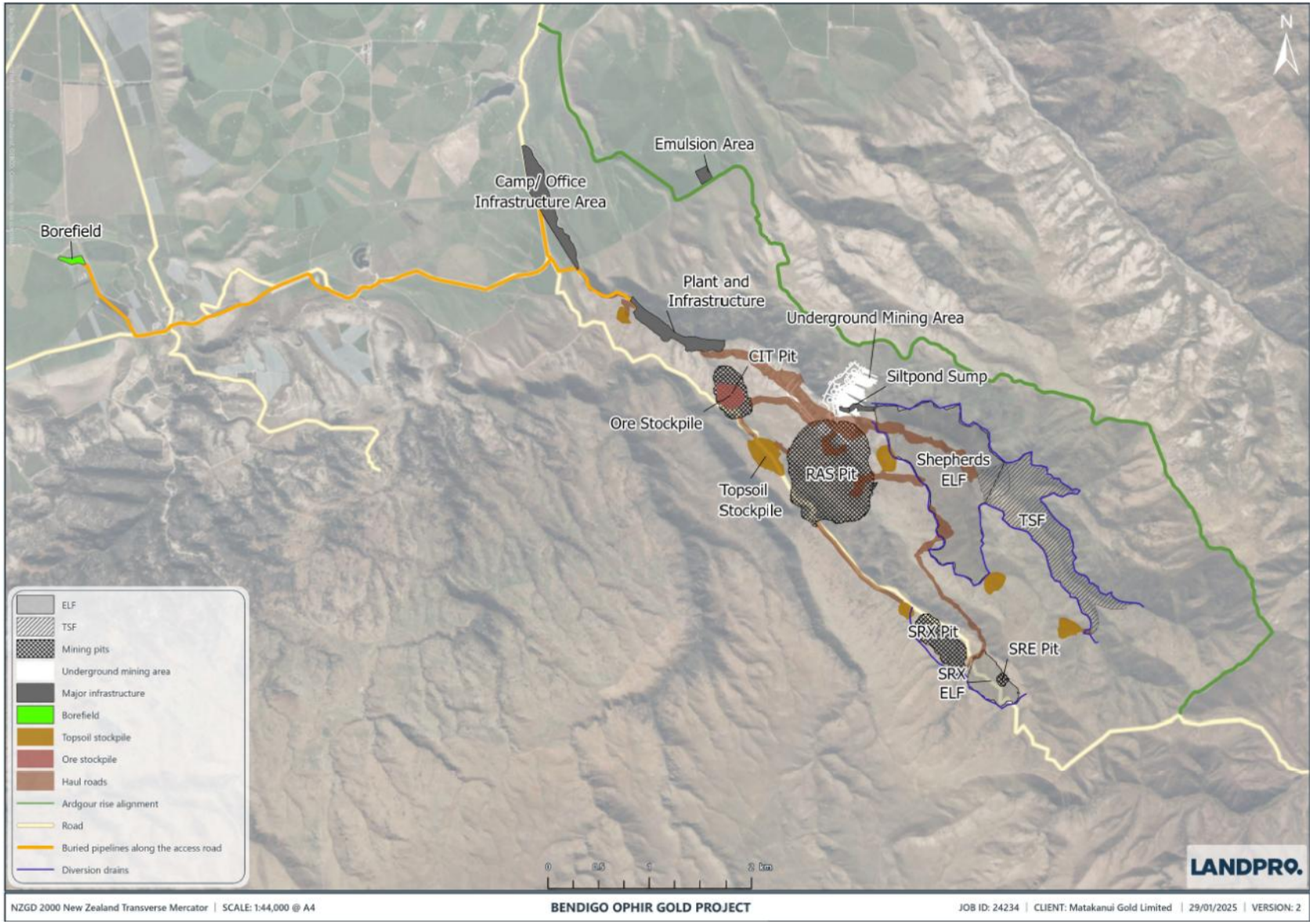

Figure 1: Overview layout of the Bendigo-Ophir Gold Project.

Ecological work will include rehabilitation on direct disturbed areas, ecological uplift activities and pest exclusion area(s) adjacent to the footprint on nearby areas such as Ardgour and Bendigo Stations. A full description of the various activities comprising the establishment, operation and rehabilitation within the BOGP is provided in the Assessment of Environmental Effects prepared by Mitchell Daysh Limited. However, by way of summary, the BOGP includes the following components:

- The establishment of the RAS Open Pit and SRX Open Pit, which are planned to form partial pit lakes at closure;
- The establishment of RAS Underground;
- The establishment of the CIT Open Pit, which is the smallest of footprints and is planned to be progressively backfilled with waste rock from the RAS Open Pit and profiled to integrate with the surrounding terrain. Rehabilitation will enable nearby native herb fields to be re-established at the completion of mining activities;
- The establishment of the small SRE Open Pit, which will be backfilled with waste rock before being covered with overburden to form the engineered landform for the adjoining SRX Open Pit ("**SRX ELF**").
- A conventional hard rock gold processing plant (1.2 million tonnes per annum expandable to 1.8Mtpa) applying modern Carbon-in-Leach ("CIL") technology constructed in the lower reach of Shepherds Valley. The plant will operate in a closed water circuit with the TSF. Residual chemicals in the tailings slurry will be detoxified and/or precipitated with specialist plant.
- The operation of the process plant will be supported by ancillary facilities such as maintenance workshops, raw material and process chemical storage, fuel depot, laboratory and warehousing. Mine offices, carparking and security services will also be established.
- The construction of the plant in the lower reaches of the Shepherds valley will include the realignment of Shepherds Creek;
- The establishment of water storage dams and tankage for use in the process plant, dust suppression and drinking water supply;
- The establishment of a Tailings Storage Facility ("**TSF**") in the upper reach of Shepherds Valley (including clean water diversion drains), which will utilise waste rock from mining activities within the project site;
- The establishment of permanent engineered landforms in the Shepherds Valley ("**Shepherds ELF**") and an unnamed creek west of RAS pit **("WELF")**;
- The establishment of temporary topsoil, vegetation and brown rock stockpiles around the project site;
- The extraction of groundwater from the Bendigo Aquifer for use in mining-related activities as well as supplying BOGP drinking water and replacing small irrigation water takes from Shepherds Creek. Bore water will be pumped to the processing plant via a pipeline over a distance of approximately 7 km.
- The establishment of supporting infrastructure / activities for the project, such as the upgrade of Ardgour Road and parts of Thomson Gorge Road to provide improved access to the BOGP, internal mine access and haul roads, water pipelines and underground utilities, and electricity supply to the project site from Lindis Crossing via a new 66kV overhead powerline that will follow the existing road reserve corridor;

- A realignment of part of Thomson Gorge Road, via Ardgour Station (Ardgour Rise) is planned to provide public access through to the Manuherikia Valley.
- Main explosives magazines and emulsion mixing facilities (located outside the project site on Ardgour Terrace);
- The establishment of non-operational infrastructure associated with the BOGP on the Ardgour Terrace, including security, first aid and administrative offices, geology facilities, high voltage substation and temporary construction workers accommodation; and
- The establishment of pest exclusion area(s) for ecological enhancement activities.

1.2. Scope of this study

The aim of this study was to characterise the streams and the aquatic fauna in the project area and adjacent watercourses (Figure 2) and to assess the effects of the proposed mine and associated infrastructure on these streams. The report does not assess potential mitigation, offset or compensation work for aquatic environments for the BOGP.

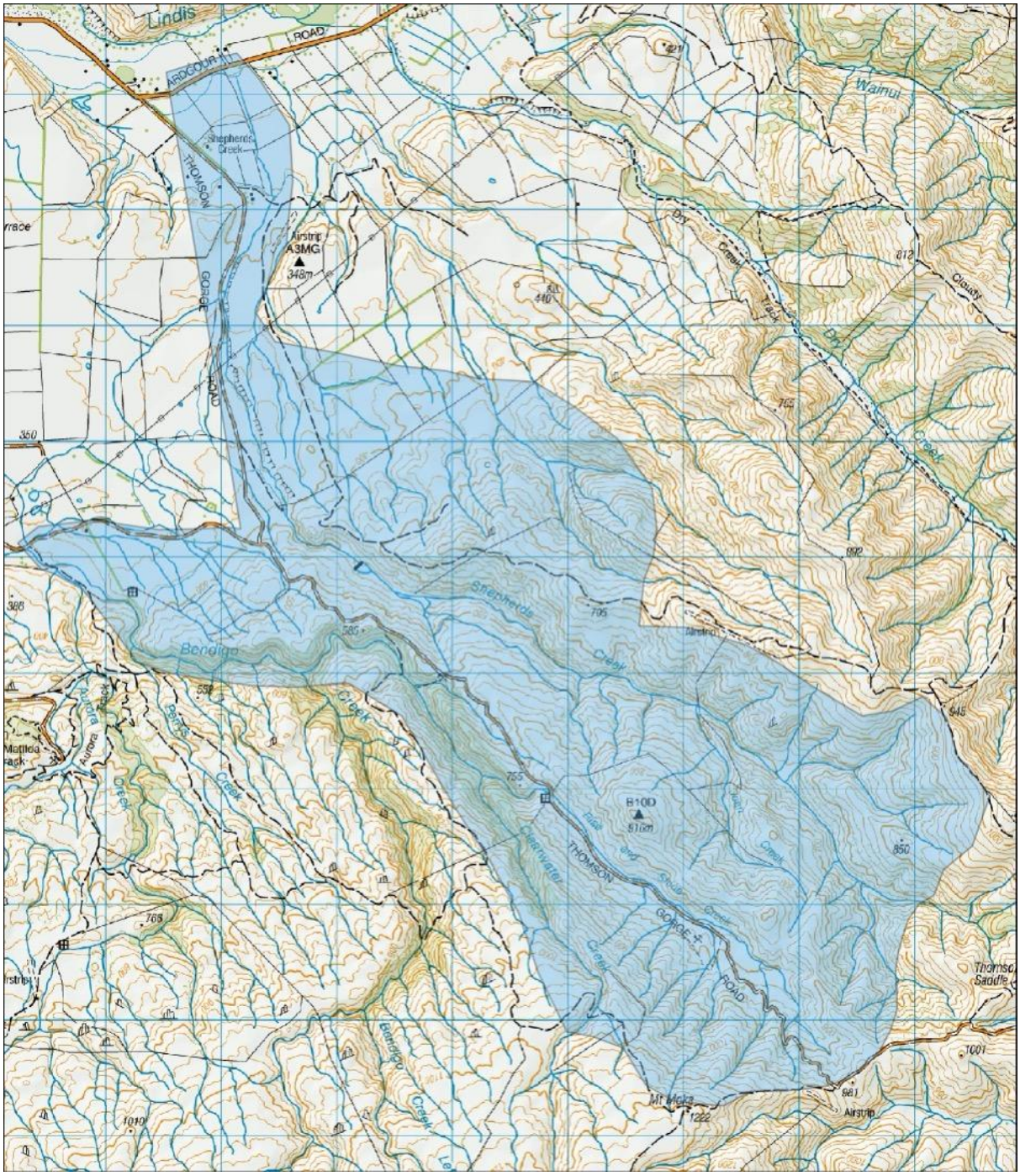

Figure 2: The aquatic survey area (shaded blue).

2. METHODS

2.1. Water Course Mapping

2.1.1 Stream walk mapping

Shepherds Creek, Rise and Shine Creek, and areas of Bendigo Creek, Clearwater Creek and an un-named stream in the project area were walked between January and April 2024 mapping the water course types and locations of springs (Figure 22). The permeance of flow and of water in the stream courses were assessed to classify and map the occurrence of four water course types:

- Perennial streams:
- Intermittent streams:
- Ephemeral streams; and
- Watersheds.

The mapping also recorded the location of spring heads that were the source points for first order streams.

During the stream classification walks notes were taken on the state of the stream habitat, features of the riparian vegetation and the impacts of stock on the water courses. Perennial water courses were then divided into sections with different instream habitat.

2.1.1 Freshwater Environments New Zealand mapping

The Freshwater Environments New Zealand (FENZ) was accessed to provide an additional stream mapping tool for assessing the areas affected by the BOGP. FENZ has been developed to map stream environments in New Zealand and was used to assess whether the freshwater environments in a project area include any environments considered rare on a national or local basis. The FENZ Environments are provided at four Levels with each level splitting into small more narrow environmental classes as follows;

- Level 1 Environments are broad general environments with only twenty across New Zealand, named Environment A to Environment T and all have a descriptive title e.g. Group D South Island, low-elevation streams and rivers in dry inland areas;
- Level 2 Environments split the Level 1 environments into 100 narrower environmental classes and are named using the higher Level 1 category and a number e.g. D3;
- Level 3 has 200 environments and represent a further narrowing of the environmental conditions in an Environment and have the naming convention D3.1; and
- Level 4 has 400 environments and is the final narrowing of the Environment in a category and using the naming convention D3.1a.

GIS mapping can show what Environment (at any of the four levels) a stream has been classified as and the stream length of that Environment or a subset of streams in that Environment can be determined. FENZ can also be used to locate streams from the same environmental category outside the project footprint for offset or compensation work. Storey (2012) was used to provide brief descriptions of the environments. However, it was noted that Storey (2012) when assessing fish communities in the FENZ Environments is out of date with respect to the present taxonomic status of New Zealand fish and so this aspect of Storey (2012) was not used.

FENZ was used to determine the Environments present in the survey area (Figure 2) and the total area of the Environment affected by the project both as an absolute area and as a percentage of total area in that Environment.

2.2. Present Day Stream State Assessment

The stream state assessment mapped impact effects and features that influence the distribution of aquatic species. The effects mapped were:

- stock access and damage;
- reaches subject to water abstraction;
- fish passage barriers;
- presence and density of crack willow; and
- occurrence of introduced species.

The stock access effect was assessed during the stream mapping with the extent of hoof damage to the stream and riparian margin noted and the presence of manure along the water courses.

The location of water abstractions and the provision of fish passage at the intakes was assessed when abstraction sites were encountered.

The occurrence of crack willow was assessed during the stream walks and from aerial imagery for stream reaches in the Bendigo Creek catchment where access was not readily available.

Introduced freshwater species were assessed from the fish survey results and the aquatic species detected in the eDNA surveys and Surber samples (discussed in following sections).

Mine Waste Management (2024) has provided flow data for Shepherds Creek at:

- Immediately upstream of the main irrigation take;
- Shepherds Creek upstream of the gorge section; and
- Jean Creek at the confluence with Shepherds Creek.

And two sites in Rise and Shine Creek:

- Downstream of the Rise and Shine farm pond; and
- Downstream of the confluence of Rise and Shine Creek and Mt Moka tributary.

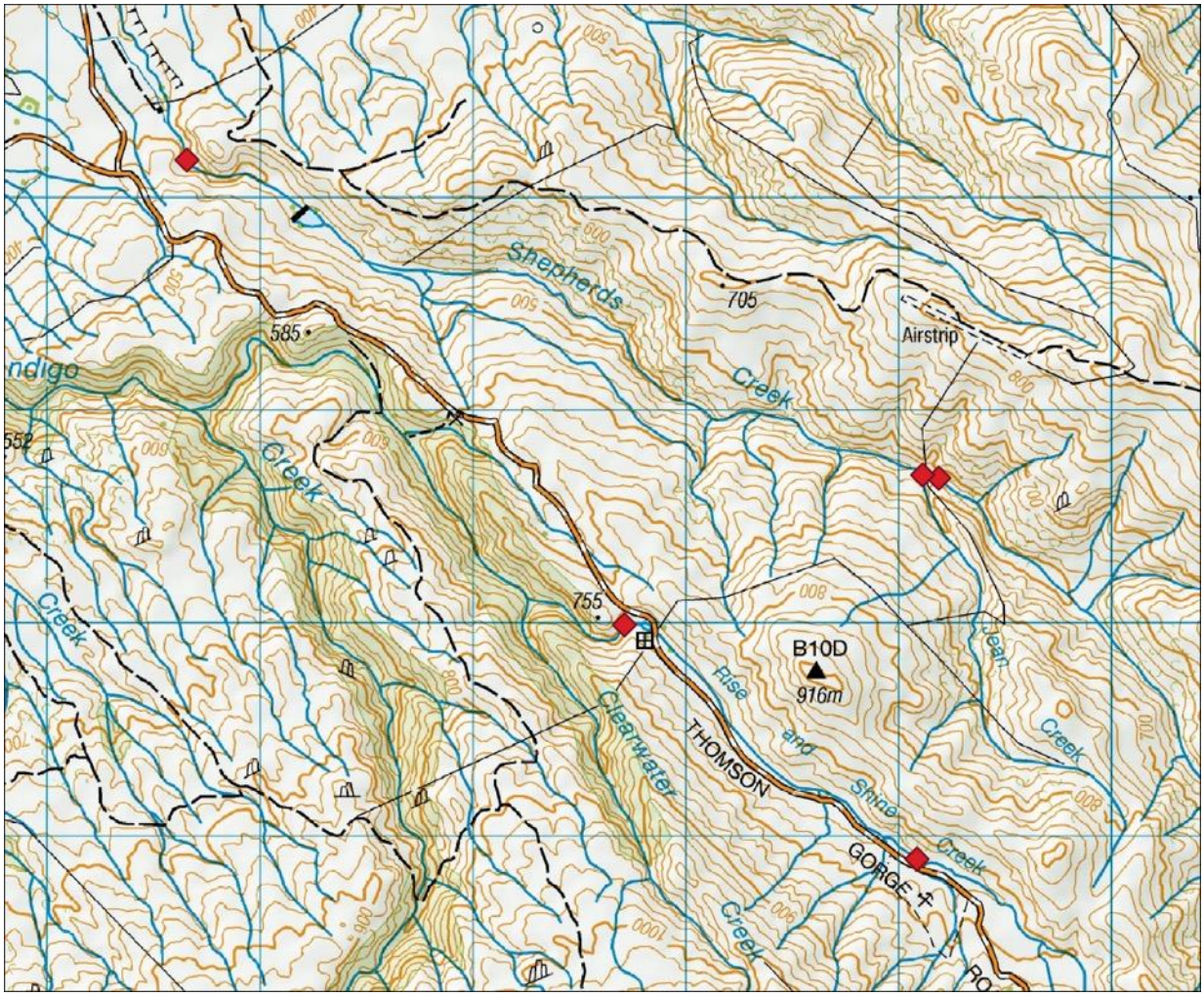

Figure 3: The location of flow monitoring sites established by Mine Waste Management.

2.3. Fish

The fish fauna of the area was assessed using three methods. Electric fishing was conducted in Shepherd Stream, Rise & Shine Creek, and Bendigo Creek by E^3 Scientific (2023), and at a further five sites in Bendigo Creek during this study. Additional historic data was provided by an earlier Bendigo Creek fish survey work by Water Ways Consulting (2020). Environmental DNA (eDNA) sampling was also undertaken at Shepherd Stream, Rise & Shine Creek, Clearwater Creek and Bendigo Creek by Santana Staff, E^3 Scientific staff and Water Ways staff and the New Zealand freshwater fish database (NZFFD) was accessed to check for further fisheries information.

The electric fishing surveys were conducted using Kainga 300 electric fishing machines and the survey area varied at each site depending on access, fishable water and limitation imposed by riparian vegetation and stream size.

Fish caught by electric fishing were identified to species level and measured to the nearest mm and then returned to the water. The location of fish survey sites was recorded using GPS.

Further detail on eDNA sampling undertaken is provided in section 2.5.

2.4. Macroinvertebrates

Previous macroinvertebrate data collected using Surber samplers by E^3 Scientific (2023) was one method used to identify macroinvertebrate communities. Samples were collected from perennial streams and some intermittent stream sites within the study area. The macroinvertebrates collected in Surber samples were generally identified to genus level and the results used to calculate a range of macroinvertebrate parameters, taxa richness, macroinvertebrate community index (MCI), quantitative macroinvertebrate community index (QMCI) and EPT taxa (mayflies, stoneflies and caddisflies) richness as indictors of stream health. As most of the Surber sample identifications are to genus level, these samples were not used to determine if any threatened macroinvertebrates were present in the study area.

The eDNA sampling provided macroinvertebrate detection data from the eDNA analysis. The eDNA data for insects, crustaceans, molluscs, oligochaetes and Platyhelminthes were sorted to exclude terrestrial taxa and freshwater taxa lists were compiled for each site. Full species lists of macroinvertebrates from the eDNA sample sites are provided in Appendix A.

The eDNA species and genera list for sites were used to calculate a range of macroinvertebrate parameters, taxa richness, macroinvertebrate community index (MCI), quantitative macroinvertebrate community index (QMCI) and EPT taxa (mayflies, stoneflies and caddisflies) richness as indictors of stream health.

2.5. Environmental DNA Sampling

An initial fifteen eDNA samples were collected by various parties from November 2022 to April 2024 in Bendigo Creek, Rise and Shine creek and Shepherds Creek catchments (Table 1, Figure 4). The sampling utilised a mix of syringe kit and drogue kit sampling depending on the site access and ability to return the following day to retrieve samples. Samples were either a single sample or two replicate samples at each site.

In September 2024 an additional suite of syringe eDNA samples were collected by Water Ways Consulting from Shepherds Creek, Rise and Shine Creek and Clearwater Creek (Table 1, Figure 4). The September 2024 sampling collected nine samples in Shepherds Creek catchment from the boundary of the Ardgour Conservation Area downstream to the main water intake site at the downstream end of the perennial flow reach of Shepherds Creek. Six of these samples were from the mainstem and three from tributaries. Four samples were collected from Rise and Shine Creek and one from Clearwater Creek downstream of the Rise and Shine confluence. These samples aimed to provide a longitudinal snapshot of the aquatic communities and ecosystem state in these two streams.

All samples were forwarded to Wilderlab in Wellington for analysis.

The list of species identified in the eDNA analysis was checked for the presence of threatened fish and macroinverterbrates according to the threat rankings of Dunn *et. al.* (2018) and Grainger *et. al.* (2018).

The eDNA data was used to provide commonly used macroinvertebrate metrics:

- Taxa richness;
- EPT taxa richness; and
- An eDNA result derived MCI score (Suren et al 2024).

The eDNA results provided taxa presence data at difference levels of taxonomic resolution ranging from species level up to order. Oligochaetes were included in the assessment when freshwater taxa,

e.g., *Ohaetogaster* were present. Standard sorting and identification of freshwater macroinvertebrates is usually conducted to family and genus level with few species identified to species level unless they are from a genus with a single species (e.g., the New Zealand dobsonfly *Archichauliodes diversus*). Therefore, when the taxa richness was calculated from the eDNA data the full species level and genus level data was used. If multiple species from within a genus were present (e.g. *Austroclima* mayflies) each species was counted separately. This differs from the taxa counts in physical macroinvertebrate samples where sorting occurs to genus level and multiple species within a genus would not be reported. However, for the calculation of the eDNA MCI the taxonomic resolution used was the taxonomic level used in the MCI score (Stark et al 1993) and is generally to genus level for insects and molluscs. Therefore, multiple species within a genus were only scored once in the eDNA MCI. For instance, if two species of *Austroclima* were present this taxon was only scored once in the eDNA MCI calculation.

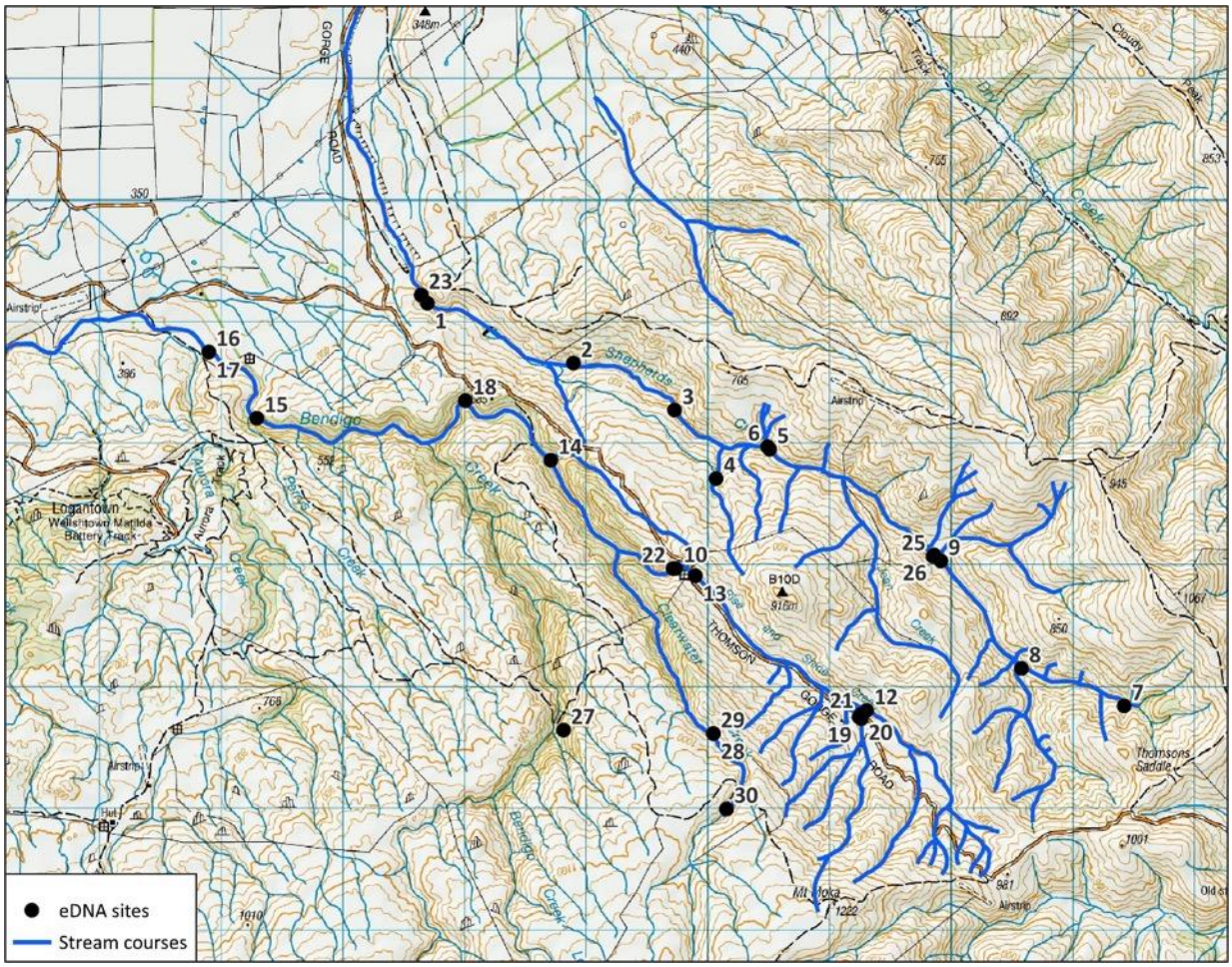

Figure 4: eDNA sampling sites.

Table 1: eDNA sample sites and sample methods

Site #	eDNA sample site names	Stream	Latitude	Longitude	Sample date	Sample type
1	B eDNA1	Shepherds	-44.9242	169.3975	10/9/2024	Syringe, 1000 ml
2	B eDNA2	Shepherds	-44.9291	169.4124	10/9/2024	Syringe, 1000 ml
3	B eDNA3	Shepherds	-44.9329	169.4227	10/9/2024	Syringe, 800 ml
4	B eDNA4	Shepherds trib	-44.9381	169.4267	10/9/2024	Syringe, 1000ml
5	B eDNA5	Shepherds	-44.9361	169.4324	10/9/2024	Syringe, 1000 ml
6	B eDNA6	Shepherds trib	-44.9359	169.4322	10/9/2024	Syringe, 1000 ml
7	B eDNA7	Shepherds	-44.9562	169.4681	10/9/2024	Syringe, 750 ml
8	B eDNA8	Shepherds trib	-44.9531	169.4576	10/9/2024	Syringe, 700 ml
9	B eDNA9	Shepherds	-44.9449	169.4497	10/9/2024	Syringe, 600 ml
10	B eDNA10	Rise & Shine	-44.9446	169.4221	10/9/2024	Syringe500, ml
11	B eDNA11	Mt Moka	-44.9563	169.4407	10/9/2024	Syringe, 1000 ml
12	B eDNA12	Rise & Shine	-44.9557	169.4413	10/9/2024	Syringe, 1000 ml
13	B eDNA13	Rise & Shine	-44.9452	169.4241	10/9/2024	Syringe, 1000 ml
14	B eDNA14	Clearwater	-44.9362	169.4096	10/9/2024	Syringe, 750 ml
15	Bendigo waterfall	Bendigo	-44.93213	169.37923	25/1/2024	Syringe, 1000 ml
16	Lower Bendigo CK	Bendigo	-44.92709	169.37454	19/12/2022	Syringe, 1000 ml
17	Lower Bendigo Ck	Bendigo	-44.927083	169.37455	9/11/2022	Syringe, 1000 ml
18	Mid Bendigo Creek	Bendigo	-44.93152	169.400986	19/12/2022	Syringe, 1000 ml
19	Rise and Shine u/s Mt Moka	Rise & Shine	-44.95616	169.44048	16/1/2024	Syringe, 1000 ml
20	Mt Moka Stream	Rise & Shine	-44.955973	169.440698	15/3/2024	Drogue, 24 hr
21	Mt Moka Stream	Rise & Shine	-44.955973	169.440698	15/3/2024	Drogue, 24 hr
22	Rise & Shine below dam	Rise & Shine	-44.9446	169.421824	19/12/2022	Syringe, 1000 ml
23	Shepherds @ intake	Shepherds	-44.92357	169.3969	19/12/2022	Syringe, 1000 ml
24	Shepherds @ intake	Shepherds	-44.923583	169.3969	9/11/2022	Syringe, 1000 ml
25	Shepherds main stem	Shepherds	-44.94454	169.44890	25/1/2024	Syringe, 400 ml
26	Shepherds main trib	Shepherds	-44.94444	169.44901	25/1/2024	Syringe, 400 ml
27	Lower Clearwater	Clearwater	-44.956166	169.409686	15/3/2024	Syringe, 1000 ml
28	Upper Clearwater (A)	Clearwater	-44.956913	169.425248	14/3/2024	Syringe, 1000 ml
29	Upper Clearwater (B)	Clearwater	-44.956913	169.425248	14/3/2024	Syringe, 1000 ml
30	Upper most Clearwater	Clearwater	-44.962529	169.426262	14/3/2024	Syringe, 1000 ml

For the interpretation of MCI scores the categories provided by Stark (1998) and Stark & Maxted (2007) were used (Table 2).

Table 2: Macroinvertebrate community index score interpretations.

Water quality description (Stark (1998)	Quality Class (Stark & Maxted 2007)	MCI	QMCI
Clean water	Excellent	≥ 120	≥ 6.00
Doubtful quality	Good	100 -119	5.00 - 5.99
Probably moderate pollution	Fair	80 - 99	4.00 - 4.99
Probable severe pollution	Poor	< 80	< 4.00

For further indicative interpretation the MCI in the National Policy Statement – Freshwater Management (NPS-FM) (2020) was used. The attributes states divide the indices scores into four bands A-D with A indicating high quality and D low quality with D band considered under the desired bottom line for ecosystem health (Table 3). However, it is important to note that to comply with the NPS-FM (2020) five years of sampling is required with samples collected between December and March (inclusive) before sites can be placed in an attribute band. Therefore, for this report, the MCI scores from eDNA data are compared to the attribute bands to provide an indicative state of the sites, but not for assessing compliance with the attribute bands.

Table 3: NPS-FM (2020) macroinvertebrate attribute Bands.

Band	Description	MCI range	QMCI range	ASPM range
A	Macroinvertebrate communities indicative of pristine conditions and high ecological integrity	≥ 130	≥ 6.5	≥ 6.00
B	Macroinvertebrate communities indicative of mild organic or nutrient pollution and mild to moderate loss of ecological integrity	≥110 and < 130	≥ 5.5 and <6.5	< 6.00 and ≥ 0.4
C	Macroinvertebrate communities indicative of moderate organic or nutrient pollution and moderate to severe loss of ecological integrity	≥ 90 and < 110	≥ 4.5 and < 5.5	< 0.4 and ≥ 0.3
D	Macroinvertebrate communities indicative of severe organic or nutrient pollution and loss of ecological integrity	< 90	< 4.5	< 0.3

Wilkinson et al (2024) have developed a stream health index called the Taxonomically Independent Community Index (TICI). This uses eDNA data to provide the index score of stream health and the values have been bench marked against TICI scores from pristine to heavily impacted streams to provide a range of descriptive terms for the stream health condition (Wilkinson et al 2024, Table 4). The eDNA samples from across the survey area were used to calculate the TICI for stream condition assessment.

Table 4: The stream condition categories for difference TICI scores from Wilkinson et al (2024).

TICI Range	Stream Condition
<80	Very poor
80-90	Poor
90-100	Average
100-110	Good
110-120	Excellent
>120	Pristine

3. RESULTS

3.1. Streams Descriptions

3.1.1 Shepherds Creek habitats

- The Shepherds Creek catchment includes a range of stream types. Most of the main stem of Shepherds Creek is a gentle gradient single channel stream 0.5-1.0 m wide flowing along a 10-100 m wide valley floor. The stream can be divided into five sections (Figure 5). Two main headwater tributaries rise along the Dunstan Mountains ridge line and are in the Department of Conservation Ardgour Conservation Area;
- Gentle gradient reaches in the two tributaries and the main-stem downstream from the confluence of these two tributaries (Figure 6);
- A short gorge section of higher gradient stream with bedrock bluffs and steep hillsides where the stream is confined to a narrow valley floor and has cobble and boulder in the streambed (Figure 7, Figure 8);
- A long low gradient reach flowing along a wide valley floor (Figure 9, Figure 10, Figure 11) to the main irrigation water take, which within this reach is a now breached reservoir;
- An ephemeral reach downstream of the main water abstraction site where the stream course flows across an alluvial terrace to the Lindis River (Figure 12).

The stream bed in the gentle reaches is composed predominately of a matrix of gravels, fine gravel, sand and mud with occasional small cobbles. These reaches are dominated by run habitat with small gentle riffles and short pool sections. The lack of large substrate particles means that even the riffle habitat has little if any broken water. The only variation to this is in the upper reaches where occasional small landslides have created valley floor bars. Upstream of the bars valley floor wide wetlands have formed and the stream flows over the landslide material short in cascades of 1-2 m long.

The riparian zone is a mosaic grey scrub, that includes matagouri, coprosmas and rosehip briar, pasture areas with pasture grasses (Figure 6) and grazed *Carex* and *Juncus,* and partially bare ground with weeds such as thistles. Water cress, often grazed to a short height is a common macrophyte along these reaches. The banks are well grassed unless shaded by riparian shrubs and then the banks are often bare, eroding soil.

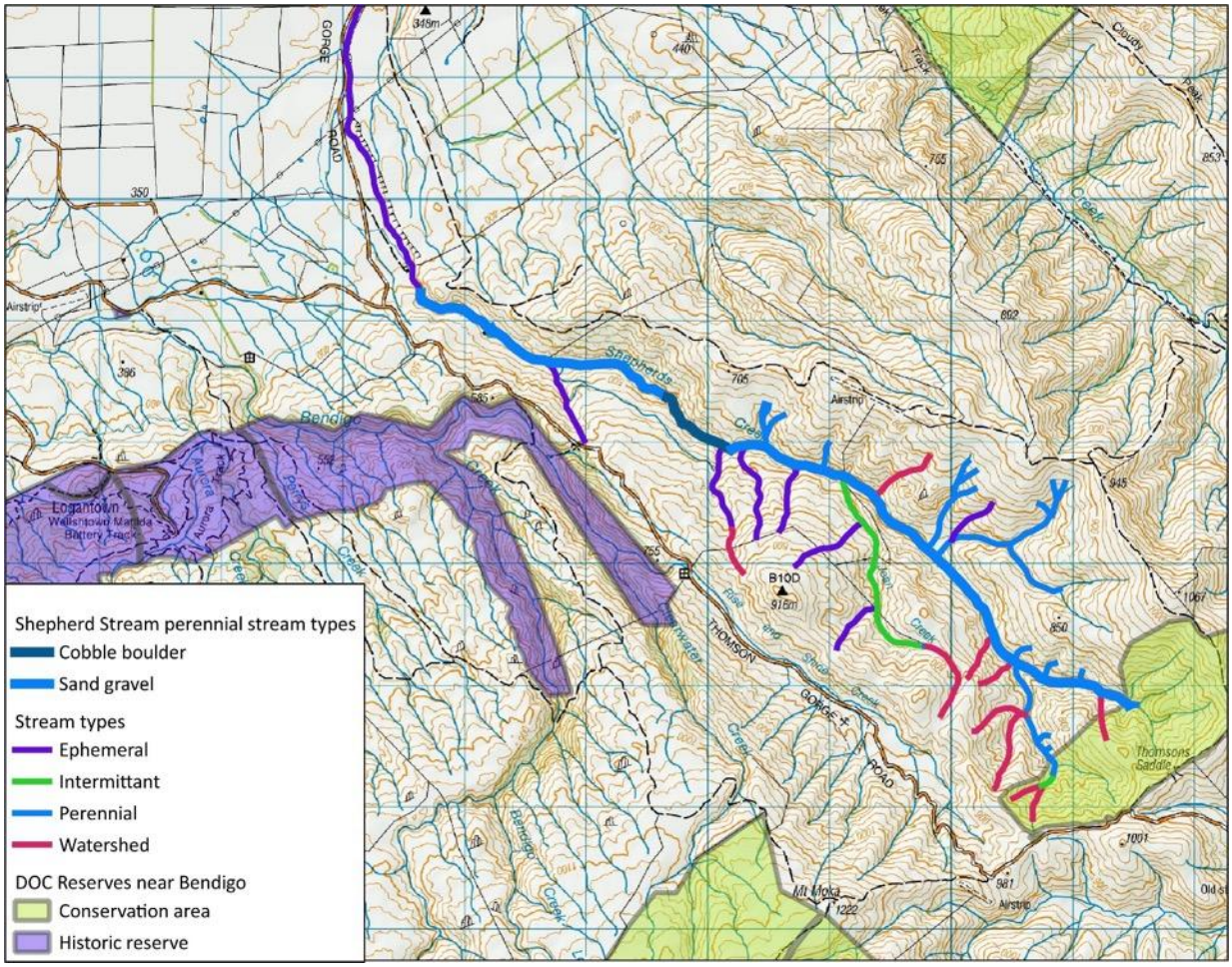

Figure 5: The Shepherds Creek catchment perennial stream types.

Figure 6: A grazed run reach of the main tributary of Shepherds Creek.

Figure 7: A small waterfall and pool amongst boulders in the gorge reach of Shepherds Creek.

In the gorge reach the stream has a rocky bed with boulders, and several small waterfalls and plunge pools (Figure 7). The riparian vegetation is dense shrubs and stock access is reduced by the combination of boulders, bedrock bluffs and shrubs (Figure 8). The stream bed has more cobble, but fine sediment deposits are still present in the pools.

Figure 8: Riffle habitat in Shepherds Creek in the gorge section.

The second gentle gradient reach is where the stream flows across an increasingly wide alluvial outwash deposit that has been deposited on the valley floor. Downstream of the small gorge section the valley is still narrow, but it widens in a downstream direction. As the valley floor becomes wider it is progressively developed for grazing and in the lower part of this reach there is a wide valley floor that is predominately vegetated with pasture grasses (Figure 10). In this low gradient reach water cress becomes a significant instream feature and can fill the whole stream channel (Figure 11). This reach terminates at the main Ardgour water take. The stream is modified in one short reach by the creation of a dam and upstream pond. The dam wall has been broken and only a small pond now remains upstream of the dam.

Figure 9: Shepherds Creek downstream of the gorge section with weedy bare riparian zone and downstream a matagouri rosehip shrub riparian zone.

Figure 10: Shepherds Creek in a wide gentle gradient valley.

Figure 11: Shepherds Creek downstream of the pond, with grazed riparian zone and the stream course filled with water cress and dead crack willows on the stream margin.

The ephemeral reach downstream of the water intake has been developed for pastoral grazing and the lower reaches are irrigated pasture. In this reach there is no evidence of stream course due to the pasture development activity. The upstream half is dry country grazing with dryland grasses and a small dry stream channel that can have flow during high flow periods and when the water abstractions are not operating. This reach was assessed in summer (January to March 2024) and in early spring

(September 2024) and was dry on both occasions. Downstream of Ardgour Road the agricultural development has completely removed evidence of any water course.

Figure 12: Lower Shepherds Creek (Feb 2024) showing the dryland grazing and irrigated pasture reaches of the ephemeral stream reach.

The perennial streams in the Shepherds Creek catchment include a series of spring fed tributaries. All but one of the springs are located on the northern side of Shepherds Creek and a single spring was found in Jean Creek. These springs were all flowing during the summer low flow period providing part of the base flow of Shepherds Creek.

3.1.2 Shepherds Creek flow

The Mine Waste Management (2024) stream flow gauging found flows at the two Shepherds Creek sites range from nearly zero flow to high flows just over 140 L/s (Figure 13). The summer low flows are less than 20 L/s second and often below 10 L/s upstream of the irrigation take. In summer the flow in the mid-reaches is higher than at the irrigation take and it is expected this is due to the stock water abstraction reducing the flow between the two flow monitoring sites.

The flow in Jean Creek ranges from 0 L/s to just under 30 L/s (Figure 14). Aside from floods and freshes, the flow in Jean Creek is less than 5 L/s. The flow record also found that the lower reaches were dry for almost six months from February to July 2024.

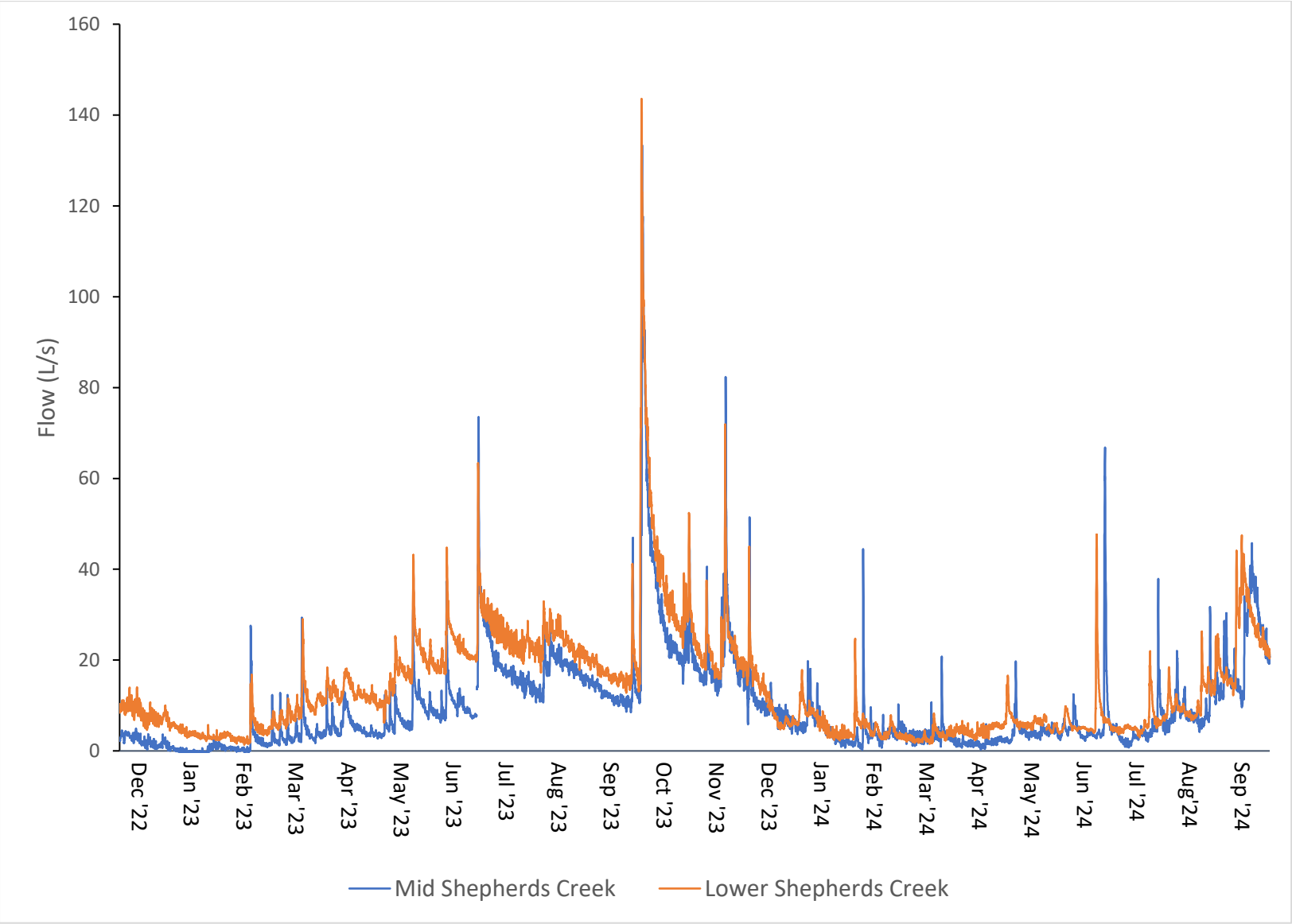

Figure 13: Flow (L/s) in Shepherds Creek.

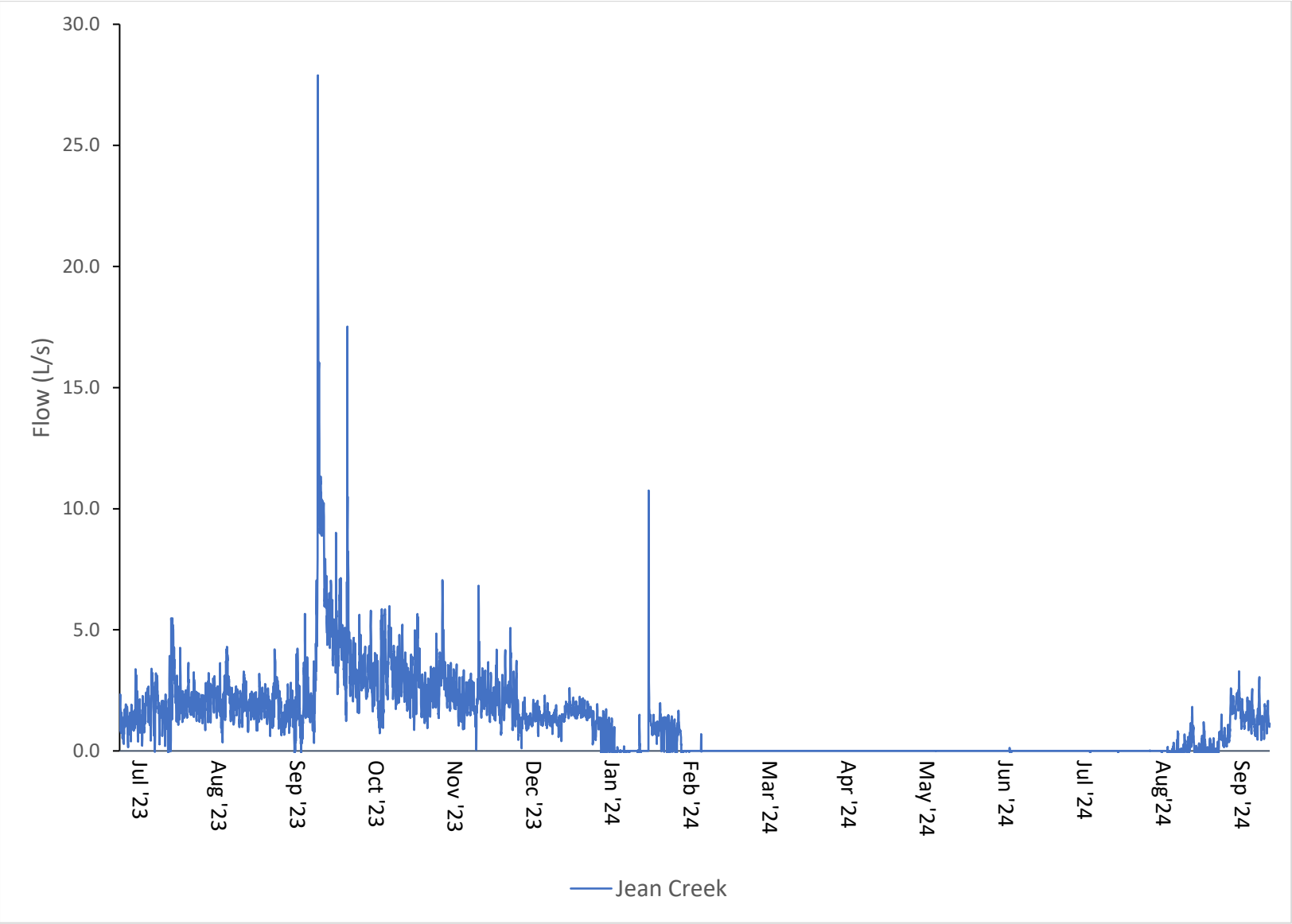

Figure 14: Flow (L/s) in the lower reaches of Jean Creek, 7 July 2023 to 4 April 2024.

3.1.3 Rise and Shine Creek habitat

Rise and Shine Creek can be divided into four sections:

- tributaries that rise on the southern side of the valley,
- an upper valley floor section,
- a lower valley floor section and
- downstream gorge reach.

The tributaries drain the steep hillside rising on the ridge on the southern side of the catchment and this includes streams draining Mt Moka (Figure 15). There are springs in the head of some tributaries and a series of these springs provide permanent flow for tributaries on the north side of Mt Moka. All these water courses have steep upper reaches, but the gradient reduces close to the valley floor. None of the stream channels are large with a maximum width of 0.5 m and most less than 0.3 m wide (Figure 16). The lower elevation areas of these tributaries have riparian zones with pasture grazing grasses and some historic alteration due to mining and farm track construction. Grazing occurs along all these stream courses, but this is limited in areas where the dense grey scrub restricts stock access to the streams. The valley floors are modified tussock grassland and scrubland with matagouri, coprosma and rosehip briar common in the riparian zone. The lower elevation areas and gentle gradient reaches have *Juncus* rush and *Carex* present in the wetter wider valley floors. Some valley floor areas show little evidence that water courses are present (Figure 17).

Figure 15: The steeper higher elevation tributary areas in the Rise and Shine catchment.

The tributaries and valley floor mainstem streams upstream of the Mt Moka tributary inflow are intermittent or ephemeral streams. The tributary inflows from the Mt Moka provide the permanent flow sources for the perennial valley floor stream reach of Rise and Shine Creek. The reach from the Mt Moka tributary confluence to the Thomson Gorge Road crossing where a small pond has been built

has been modified with historic dams and water races. While the stream channel is narrow, generally less than 1 m wide, it flows through some wider wetland areas (Figure 18, Figure 19). Stock access is available along the whole reach. The lower gradient nature of the reach means the habitat is predominately run with occasional pools, often at stock crossing points. The streambed is composed of fine grade materials, mud, sand and fine gravel and the channel has emergent macrophyte communities.

Downstream of the pond the stream flows into a gorge where the gradient increases and the riparian zone is characterised by very dense woody scrub vegetation. The habitat includes more stream like structures with pools and riffles being created by boulder material in the stream bed. This reach is heavily shaded and macrophyte and riparian grasses are absent from the stream and riparian zone due to this shading effect (Figure 20).

Figure 16: The small Mt Moka stream that provides perennial water flow to Rise and Shine Creek.

3.1.1 Rise and Shine Creek flow

There are no water abstractions in Rise and Shine Creek, so the flow is unmodified. Flow monitoring at two sites indicates that the peak flows can reach nearly 140 L/s, but the flow remains under 20 L/s for most of the monitoring period. During the summer low flow period flow is often as low as 1-2 L/s (Figure 21) and occasionally lower than 1 L/s at the Thomson Gorge Road crossing.

Figure 17: The lower gradient grazed ephemeral valley floor streams.

Figure 18: The Rise and Shine Creek wetland valley floor.

Figure 19: A straightened stream channel in Rise & Shine Creek.

Figure 20: Rise and Shine Creek in the matagouri shrub zone in the lower gorge reach.

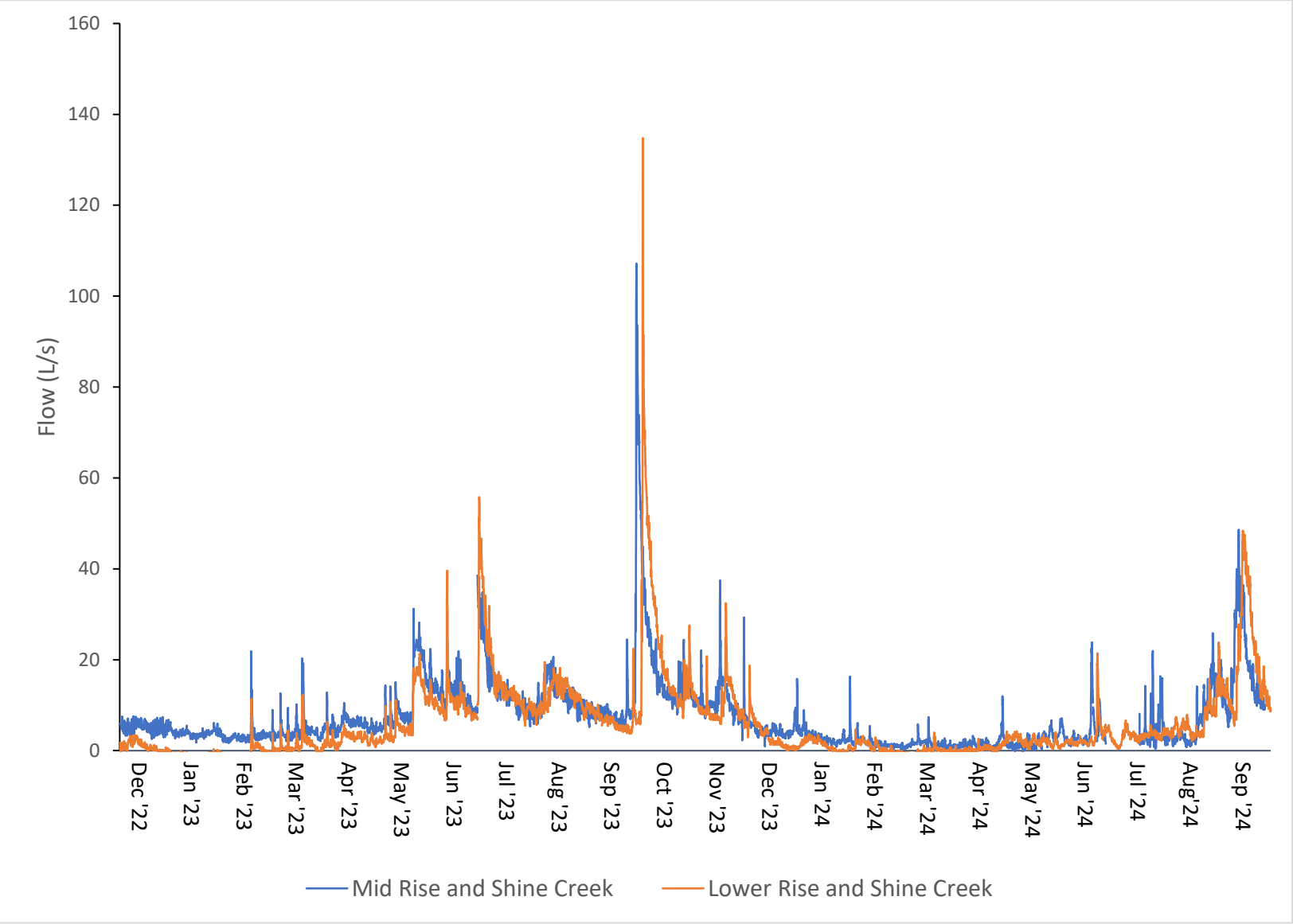

Figure 21: Flow (L/s) in Rise and Shine Creek, 15 December 2022 to 2 April 2024.

3.2. Stream Mapping

3.2.1 Stream types

Stream mapping was conducted from mid-January 2024 to mid-April 2024. This period was a low rainfall period and stream flows were low with drought or near drought conditions. The mapping located the sources of flow for Rise and Shine Creek and its tributaries, for Shepherd Creek and its tributaries (downstream of the Ardgour Conservation Area), and mapped areas outside the BOGP footprint in Bendigo Creek and Clearwater Creek, and two un-named tributaries of the Lindis River to provide some wider context for the stream assessments.

Five stream types were mapped (Figure 22):

- **Perennial streams**. The flowing water courses and springs were all categorised as perennial water courses as they either never dry or would only dry during extremely dry conditions (Figure 23). Perennial streams in the Rise and Shine and Shepherd creek catchments have been divided into two categories, small, generally first order hillside streams and the named mainstem second and third order streams;
- **Intermittent streams.** Water courses with standing or flowing water interspersed with dry sections that do support aquatic communities for periods of time;
- **Ephemeral streams**. Water courses with flow for short periods after rainfall and the gullies have obvious flow and channel features created by flowing water but no aquatic fauna and no terrestrial vegetation growing in the channels (Figure 25).
- **Watersheds**. The upper reaches of water courses with terrestrial vegetation across the valley floor and no obvious channel features (Figure 26).
- **Springs**. Localised outflows of water from the ground to the surface, generally, but not always to a downstream water course (Figure 27).

In total 57.45 km of water course was mapped (Table 5, Figure 22) in the project area and adjacent water courses. Mapping concentrated on the Rise and Shine Creek and Shepherds Creek catchments as these are the main project catchments. Then mapping extended out to partially map adjacent catchments. The mapping of watersheds was not comprehensive as this mapping was only conducted to check water courses that appear on topographic maps and when confirming whether a valley floor had a stream course. This was primarily aimed at eliminating what are essentially terrestrial environments from the aquatic assessment. Therefore, the mapping does present a complete map of perennial, intermittent and ephemeral streams not all the watersheds have been mapped.

Table 5: The water course distances mapped in catchment areas in the project area.

Catchment area	Total distance mapped (km)	First order Perennial (km)	Mainstem Perennial streams (km)	Intermittent (km)	Ephemeral (km)	Watershed (km)
Bendigo Creek	7.449	4.557		2.892	0.0	0.0
Clearwater Creek	4.591	3.108		1.483	0.0	0.0
Rise and Shine Creek	14.396	2.374	3.111	1.358	3.574	3.979
Shepherds Creek	27.883	4.02	9.147	1.869	8.819	4.028
Lindis River tributaries	3.136	0.925		0.0	2.211	0.0

The mapping found that ephemeral and intermittent reaches occurred in smaller tributaries and in the lower reaches of Bendigo Creek, Shepherds Creek and the un-named Lindis River tributaries when the flow paths left the Dunstan Mountains to flow across the Clutha and Lindis terraces. These downstream dry reaches were the result of water abstraction and/or the loss of surface water to ground water as the streams flowed across porous alluvial deposits.

3.2.2 Freshwater Ecosystems New Zealand

The FENZ stream classification predicted two Level 2 Freshwater Environments, Environments D3 and D4, in Rise and Shine Creek and Shepherds Creek. Group D streams are almost exclusively found in inland areas of Otago and Canterbury, in the Clutha, Taieri and Waitaki catchments with a total stream length in category D of 18,592 km. These streams have warm mid-summer temperatures (air temperature average 15.3°C) and are in dryland areas with a low frequency of heavy rainfall events. The differences between sub-groups D3 and D4 are that D3 streams are generally higher elevation small headwater streams and D4 are the larger, higher order, low altitude streams. The total area in the D3 environment covers 6,904 km of stream courses split between two Level 3 Freshwater Environments, D3.1 (3,290 km) and D3.2 (3,614 km). The D4 environment has only a single Level 3 Freshwater Environment D4.1 so has the same total length as Environment D4, 5,254 km.

Shepherds Creek, from the headwaters to the Ardgour main irrigation water take, includes all three Level 3 Freshwater Environments, D3.1, D3.2 and D4.1 (Figure 28). The Rise and Shine Creek has two Freshwater Environments from the headwaters to the dam at the Thomson Gorge Road, D3.1 and D3.2. The combined total length of the streams in the three level 3 Freshwater Environments is 0.3% or less of the total stream length in these three Freshwater Environments (Table 6).

Table 6: The FENZ Level 3 stream lengths and percentage of the total environment area for in Shepherds and Rise and Shine creeks.

Stream	**FENZ Level 3 Environments, stream lengths and percentage of total environment stream length**		
	D3.1	**D3.2**	**D4.1**
Shepherds Creek	2.43 km (0.07 %)	8.25 km (0.2 %)	4.68 km (0.09 %)
Rise and Shine Creek	1.88 km (0.06 %)	3.99 km (0.1 %)	0 km (0.0 %)

Comparisons between the on the ground stream course mapping and the FENZ stream environment mapping found that the FENZ environments do not distinguish the perennial, intermittent, ephemeral and watershed water courses and that some perennial water courses, particularly those draining Mt Moka are not even mapped as streams (Figure 22, Figure 28). Therefore, on the local scale the FENZ Freshwater Environment mapping did not accurately represent the basic stream environments. For this reason, the assessment of effects uses the mapped stream courses rather than the FENZ freshwater environments to assess habitats impacted.

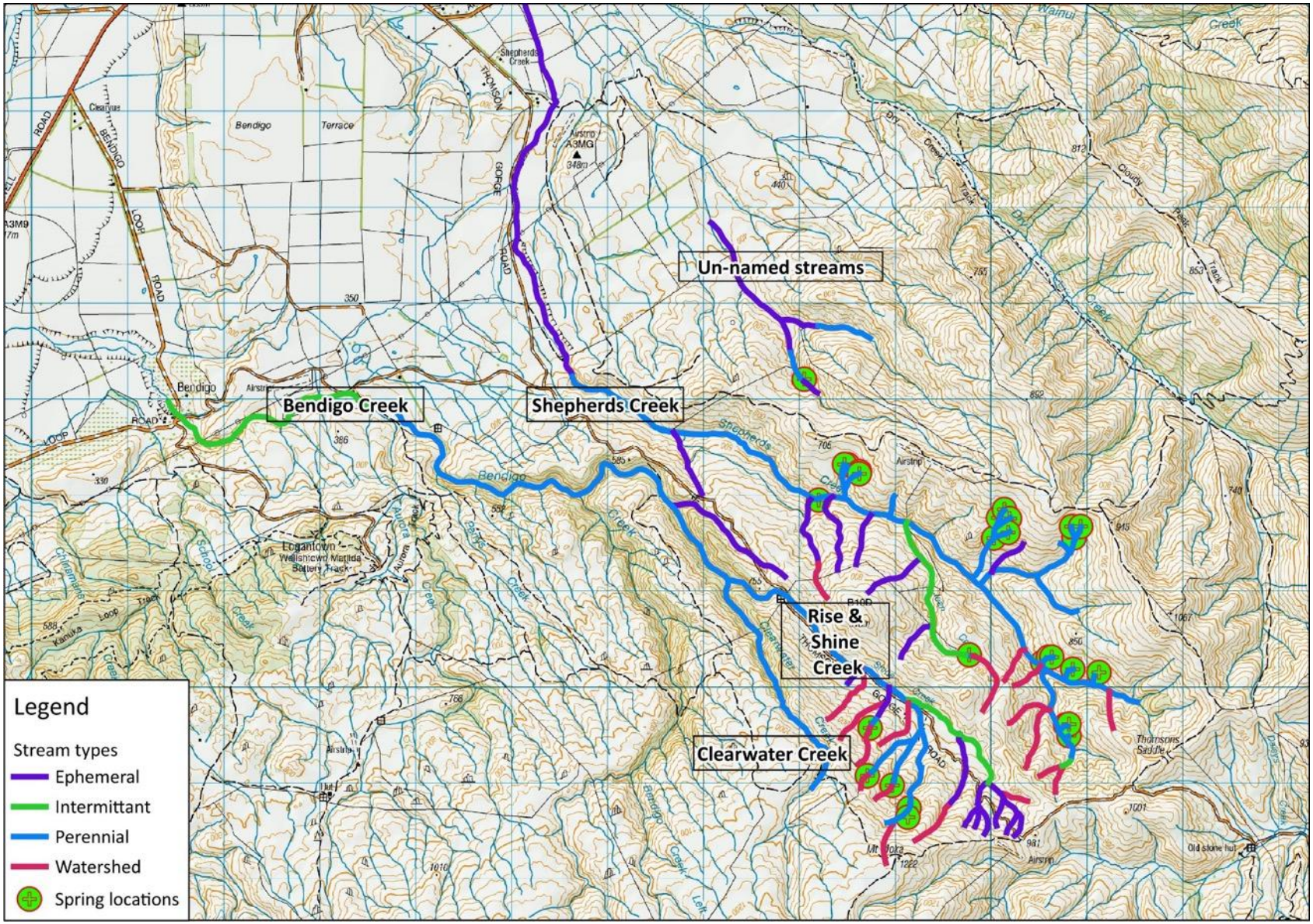

Figure 22: The mapped stream courses.

Figure 23: Perennial water courses, Bendigo Creek (left) and upper Shepherds Creek (right).

Figure 24: An intermittent water course with downstream drying reach (left) and an upstream wet reach (right) in Jean Creek.

Figure 25: Ephemeral Shepherds Creek tribs.

Figure 26: Watershed areas in the Rise and Shine catchment.

Figure 27: Springs in the Shepherds Creek catchment.

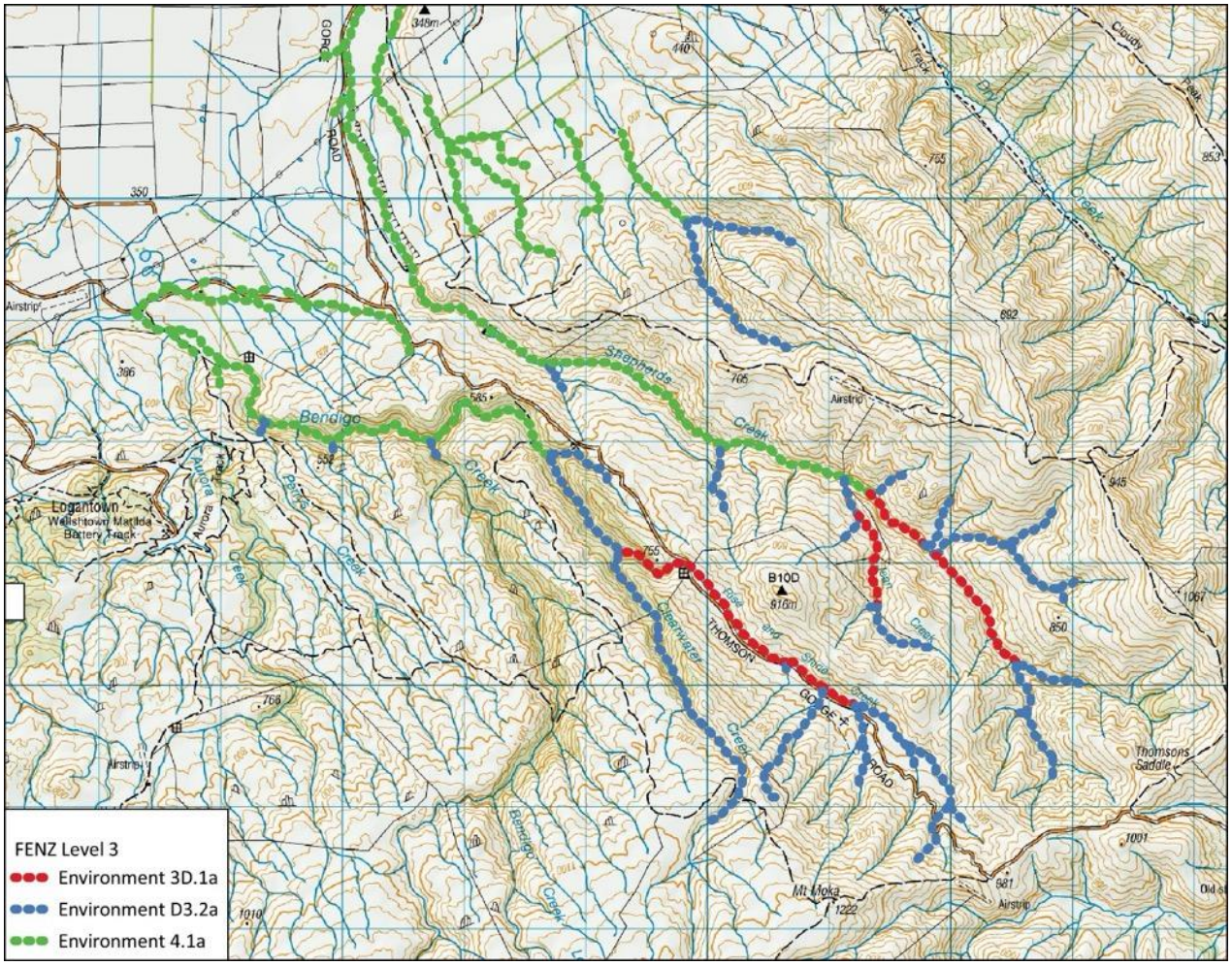

Figure 28: FENZ level 3 environments in the study area.

3.3. Stream fauna: Fish

3.3.1 Shepherds Creek

Electric fishing and eDNA sampling at seven sites by E3 Scientific (2023) and this study in Shepherds Creek did not detect any fish species present (Figure 29). There are two previous fish survey records from within the project area in the NZFFD for Shepherds Creek. These surveys were undertaken in 2001 and did not collect any fish.

3.3.2 Bendigo Creek

Two fish species have been detected in Bendigo Creek: koaro (*Galaxias brevipinnis,* Figure 30) and introduced brown trout (*Salmo trutta*, Figure 31). The electric fishing surveys only collected brown trout, and they were limited to a short perennial reach of Bendigo Creek, although they can occur in the downstream intermittent reach when this has flow. Koaro have only been detected using the eDNA sampling and the population appears to be centred in Bendigo Creek upstream of the brown trout population and possibly only for a short distance. Electric fishing upstream of the brown trout population (this study) and previous electric fishing (Allibone 2020) 100-200 metres further upstream failed to find any koaro. However, Bendigo Creek in this area is hard to access and much of the stream flows under boulders or is deep pools that provide fish with refuges from electric fishing.

The brown trout caught by electric fishing on the 18 January 2024 ranged in length from 50 mm to nearly 300 mm. The population was dominated by young of the year fish and then moderate numbers of brown trout 150-300 mm long. Large brown trout 200-300 mm were the most abundant in the pool at the upstream limit of brown trout population in Bendigo Creek.

The fish and eDNA surveys were used to map the distribution of the brown trout in Bendigo Creek. The population has an upstream boundary at a fish passage barrier waterfall (Figure 46) and the downstream limit varies with flow in the downstream intermittent reach of Bendigo Creek. During the low flow period the downstream end of the flowing water in Bendigo Creek was determined on the 18 January 2024 and recorded by GPS. Fishing at this location found brown trout and unless lower flows occur this represents the downstream limit of the permanent brown trout population. During higher flow periods the downstream limit varies with the extent of wetted habitat and at least occasionally Bendigo Creek has a connecting flow to the Clutha River / Mata Au. A previous fish survey by Allibone (2020) found brown trout in the intermittently flowing reach showing brown trout do migrate into the intermittently flowing reach.

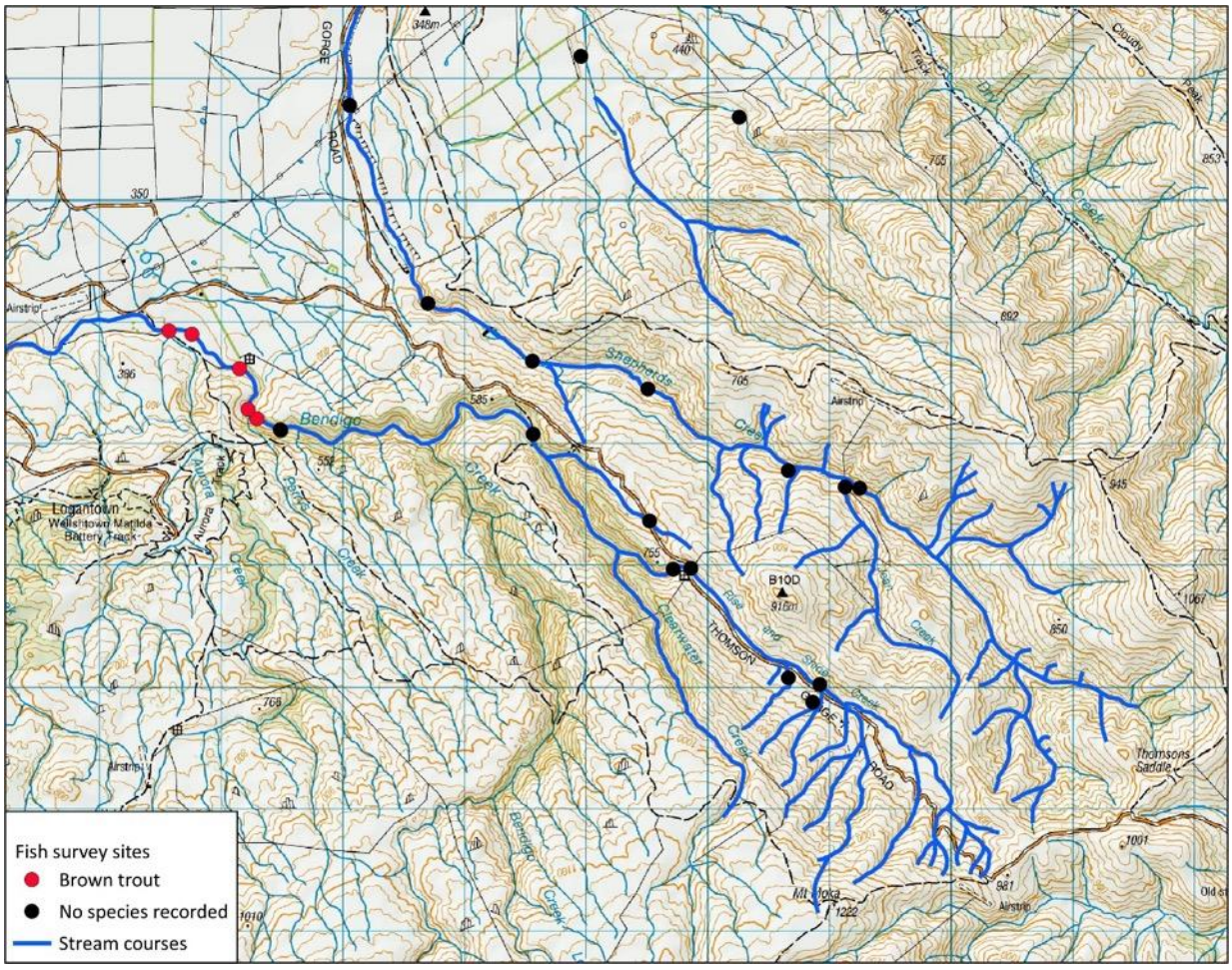

Figure 29: The no fish present and brown trout present fish survey locations.

The habitat in the trout occupied reach varied with the upper part of the reach being steep with cascades and riffles interspersed with pools. Bedrock and boulders were common in the riverbed and the riparian margin is densely vegetated with grey scrub, rosehip briar and crack willows. In the lower part of the reach the stream had transformed into a low gradient cobble gravel bed stream with numerous pools and small connecting riffles. The riparian zone vegetation was bare stones, heavily

grazed grass (possibly by rabbits rather than sheep and cattle) with rosehip briar and small crack willows.

Figure 30: Koaro individuals, small post whitebait to large adult (photo R Allibone).

Figure 31: A large brown trout caught in Bendigo Creek (photo R Allibone).

3.3.3 Bendigo Creek tributaries

Electric fishing (Allibone 2020) and eDNA sampling (this study) in Rise and Shine Creek and Clearwater Creek have not detected any fish present. These results provide additional confirmation that koaro do not penetrate far upstream in the Bendigo Creek catchment.

3.3.4 Threatened fish

No threatened fish were collected or detected in the Bendigo and Shepherds Creek catchments. Koaro is classified as a declining fish species with the qualifier of partial decline as landlocked population of koaro such as those present in Lake Whakatipu and Wanaka areas are considered stable (Dunn et al 2018). Koaro in Bendigo Creek have their rearing habitat in Lake Dunstan or are from the upstream natural lakes. Therefore, these koaro are part of a stable landlocked population or are part of a new population developing in the tributaries of Lake Dunstan since the lake was filled.

3.3.5 Migratory fish access

The presence of koaro in Bendigo Creek indicates there are periods when there has been sufficient flow in Bendigo Creek to provide a connecting flow downstream to the Clutha River / Mata Au. This must have occurred for a sufficient length of time and at a time of year that allowed koaro to migrate upstream from the Clutha River / Mata Au. Longevity studies on koaro (Allibone unpub. data.) indicate koaro can live over twenty years. Therefore, to maintain a koaro population in Bendigo Creek upstream migration may only be occurring sporadically over a 10-20 year period.

The presence of koaro also indicates that at times it is possible for brown trout to either out-migrate to the Clutha River / Mata Au and/or migrate upstream from the Clutha River / Mata Au to Bendigo Creek. However, if an upstream brown trout migration occurs there must be sufficient flow for large brown trout to swim upstream and this will require considerably more flow than needed for the outmigration of juvenile brown trout or upstream and/or downstream migration of larval and juvenile koaro.

It was noted that Bendigo Creek at State Highway 6 near the Clutha River / Mata Au has little in the way of a discernable stream channel, so a connecting flow is expected to be rare. Google Earth images of the lower reaches of Bendigo Creek also indicate it is generally dry and has been subject to some modification over the last ten years as the area has undergone irrigation development.

The approximately 3 km lower ephemeral reach of Shepherds Creek has flow very infrequently and represents a major fish passage barrier. The lack of a stream channel in the very lower reaches of Shepherds Creek downstream of Ardgour Road also represents an impediment to fish passage even when wetted. Therefore, passage for upstream migrating fish is extremely unlikely in Shepherds Creek. This is supported by the absence of any fish in Shepherds Creek despite the presence of a perennial flowing reach upstream of the main water abstraction.

3.4. Stream fauna: Macroinvertebrates

The eDNA sampling has provided lists of taxa present in the streams within the study area in the reaches upstream of the sampling site(s). The eDNA data below is taken from the two sampling programs: the first, the initial explorative sampling from November 2022 to April 2024; and the second, a single longitudinal eDNA sampling of Shepherds Creek and Rise and Shine Creek in September 2024.

3.4.1 Shepherds Creek Nov 2022 to April 2024

The initial eDNA samples in 2022 to April 2024 were collected at two sites in Shepherds Creek, twice just upstream of the irrigation water take and one from the two main tributaries just upstream of their confluence (Figure 32). The two upstream sites had fewer macroinvertebrate taxa (Table 7), but EPT taxa (mayflies, stoneflies and caddisflies) were more prevalent giving rise to high MCI scores. The TICI scores are in the 100-108 range but do show a very small downstream decline along the main stem of Shepherds Creek (Figure 32).

At the irrigation water intake, the taxa diversity was higher and included more caddisfly and mollusc taxa, but less stoneflies. The diversity of EPT taxa is slightly lower than at the upstream sites. The eDNA sequence data does indicate the *Potamopyrgus* snails and *Chaetogaster* (worms) are more abundant at the downstream sites, with sequence detection rates 2-3x and 15x greater respectively for the two taxa. The MCI scores at the intake are lower than the two upstream sites and indicate lower water and or habitat quality at the downstream reach of Shepherds Creek.

3.4.1 Shepherds Creek September2024

The suite of eDNA samples collected along Shepherds Creek in September show that macroinvertebrate taxa diversity and EPT taxa diversity was highest in the gorge section of the Shepherds Creek (Table 8). The EPT taxa detections were dominated by mayfly *Deleatidium* and the caddisfly *Hudsonema.* The taxa diversity in the mainstem Shepherds Creek taxa diversity was lowest at the most upstream site, the boundary with Ardgour Conservation Area. The EPT taxa diversity was also the lowest at the Conservation Area boundary and at the most downstream site, the Shepherds Creek main water intake. (Table 8). The eMCI indicates that while EPT tax diversity is low at the Ardgour Conservation Area boundary the other taxa present have high MCI scores and the eMCI for the Ardgour Conservation Area boundary was 102.5, the second highest score with only the next site downstream scoring higher for the eMCI (114). The other eMCI scores indicate a decline in macroinvertebrate quality in a downstream direction with a very low score of 64 at the downstream site, the main water intake. Therefore, macroinvertebrate community does appear to a decline in the community quality in a downstream direction, but that the boulder cobble bed reach in the gorge sections supports a good quality macroinvertebrate fauna within that generally downstream decline.

TICI scores indicate the macroinvertebrates and freshwater ecosystem are in good to excellent condition. However, the TICI assesses more than just the macroinvertebrate taxa present and includes eDNA from a suite of flora and fauna detected and the low range of scores indicates that the general ecosystem in Shepherds Creek was not showing a large variation in quality.

Table 7: Summary indices for macroinvertebrates in eDNA samples from Shepherds Creek (Nov 2022 to April 2024).

Macroinvertebrate indices	Shepherds main stem	Shepherds main trib	Shepherds @ intake (Dec)	Shepherds @ intake (Nov)
Number of taxa detected*	13	10	16	13
Number of EPT taxa detected	7	5	8	5
Number of EPT taxa detected minus Hydrophidiae	7	5	6	4
eMCI score[3]	106.15	112.00	86.25	76.92
Quality class (MCI)	Good	Good	Fair	Poor
NPS-FM (2020) MCI attribute band	C	B	D	D
TICI	104.3	107.4	103	102.4
Quality class (TICI)	Good	Good	Good	Good

*Counts species level identifications when species and genus level eDNA sequences are found in the eDNA sample.

This MCI score is derived from the taxa detected in the eDNA samples, using the standard taxon classification levels and tolerance scores used from standard MCI calculations.

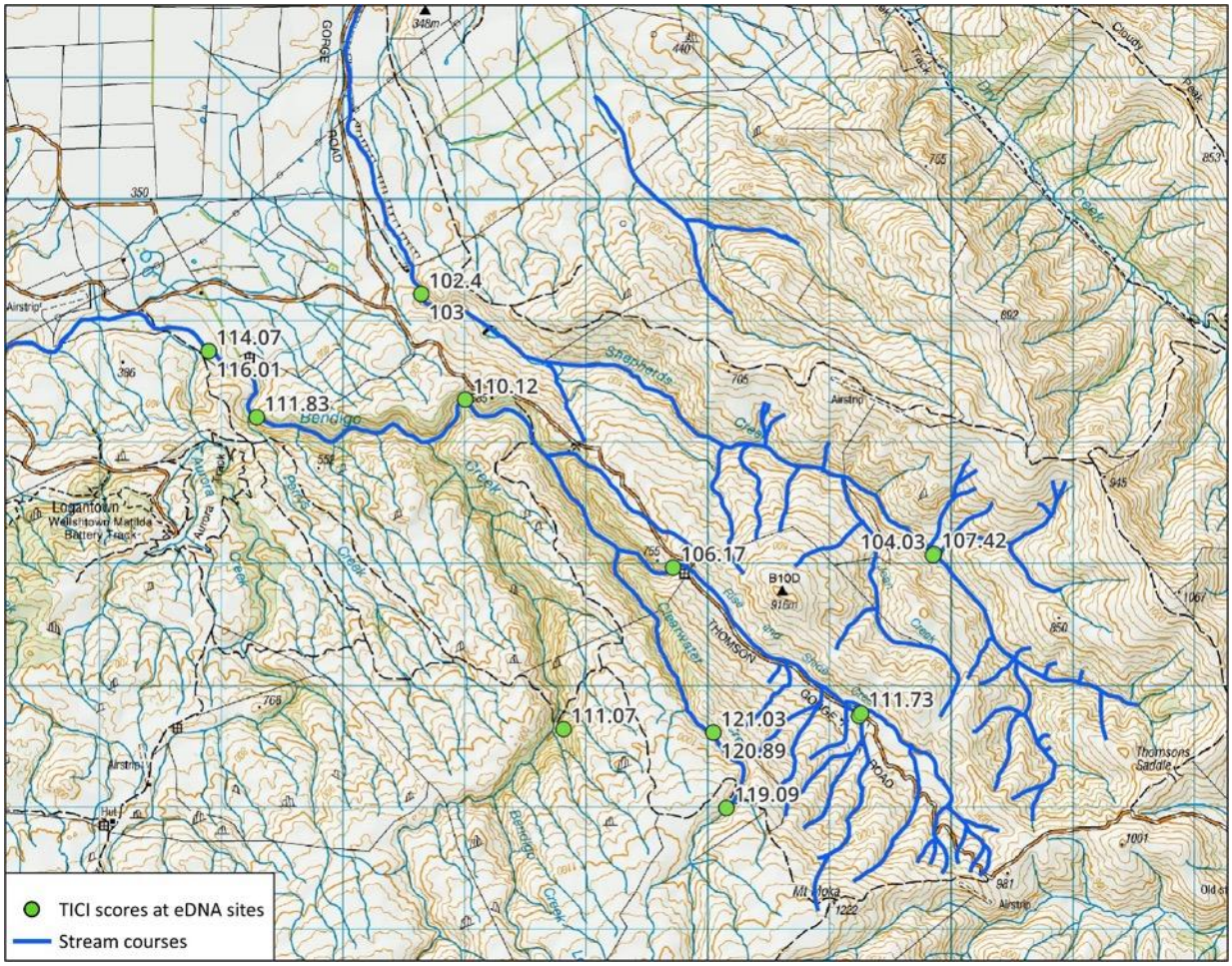

Figure 32: TICi score from eDNA sampling sites (mixed dates Nov 2022 to April 2024).

Table 8: Summary indices for macroinvertebrates in eDNA samples from Shepherds Creek (September 2024).

Macroinvertebrate indices	Shepherds intake	Shepherds u/s pond	Shepherds @ gorge	Shepherds u/s gorge 1	Shepherds Creek B eDNA8	Shepherds Creek B eDNA9	Shepherds Creek @ DOC boundary B eDNA7	Shepherds Creek RAS Pit trib B eDNA4	Shepherds Creek Spring fed trib B eDNA6
Number of taxa detected*	10	13	15	14	10	11	8	5	6
Number of EPT taxa detected	3	6	8	9	6	6	3	1	1
Number of EPT taxa detected minus Hydrophidiae	3	6	8	9	6	6	3	1	1
eMCI score	64.00	89.23	82.67	101.43	114.00	98.18	102.50	52.00	63.33
Quality class (MCI)	Poor	Fair	Fair	Good	Good	Fair	Good	Poor	Poor
NPS-FM (2020) MCI attribute band	D	D	D	C	B	C	C	D	D
TICI	105.88	110.77	111.03	101.09	114.67	110.96	114.74	107.28	108.35
Quality class (TICI)	Good	Excellent	Excellent	Good	Excellent	Excellent	Excellent	Good	Good

* Counts species level identifications when species and genus level eDNA sequences are found in the eDNA sample.

3.4.1 Rise and Shine Creek Nov 2022 to April 2024

The Rise and Shine Creek catchment has twelve or less macroinvertebrate taxa present at any site in the eDNA samples (Figure 32, Table 9). *Deleatidium* mayflies and *Hudsonema* caddisflies were the common taxa detected and no other mayflies nor any stoneflies were detected. Four different genera of caddisfly were detected giving rise to a maximum number of EPT taxa of five and earthworms, flatworms and *Potamopyrgus* snails were the most common taxa detected. The MCI scores derived from the eDNA samples range from 104 to 78 with the lowest MCI score downstream of the Rise and Shine dam. The most downstream Rise and Shine site also had the lowest TICI score with higher scores in the upstream tributaries.

3.4.1 Rise and Shine Creek September 2024

The September 2024 eDNA sampling found that in the Rise and Shine catchment the Mt Moka Stream was the highest quality location (Table 10) and all three other sites had macroinvertebrate communities associated with low quality habitat. Mt Moka Stream supports a relatively diverse macroinvertebrate community with over 50% of the taxa being EPT taxa.

TICI scores indicate the macroinvertebrates and freshwater ecosystem are in good to excellent condition, but still shows the downstream sites are in poorer condition that the upstream sites. As the TICI assesses more than just the macroinvertebrate taxa present and includes eDNA from a suite of flora and fauna detected and the low range of scores indicates that the general ecosystem in Rise and Shine Creek, unlike the eMCI, was not showing a large variation in quality.

Table 9: Summary indices for macroinvertebrates in eDNA samples from Rise and Shine Creek (Nov 2022 to April 2024).

Parameter	Rise & Shine u/s Mt Moka	Mt Moka Stream	Mt Moka Stream	Rise and Shine d/s pond
Number of taxa detected	10	8	6	12
Number of EPT taxa detected	5	3	2	2
Number of EPT taxa detected minus Hydrophidiae	5	3	2	2
MCI score	104	97.5	90	78
MCI interpretation (hard bottomed streams)	Good	Fair	Fair	Poor
NPS-FM (2020) MCI attribute band	C	C	C	D
TICI	113.1	112.4	111.7	106.2
Quality class (TICI)	Excellent	Excellent	Excellent	Good

Table 10: Summary indices for macroinvertebrates in eDNA samples from Rise and Shine Creek (September 2024).

Parameter	Rise & Shine u/s Mt Moka	Mt Moka Stream	Rise & Shine u/s pond and road	Rise and Shine d/s pond
Number of taxa detected	8	12	5	5
Number of EPT taxa detected	1	7	1	1
Number of EPT taxa detected minus Hydrophidiae	1	7	1	1
MCI score	57.5	103.3	60	64
MCI interpretation (hard bottomed streams)	Poor	Good	Poor	Poor
NPS-FM (2020) MCI attribute band	D	C	D	D
TICI	107.9	113.11	110.44	106.89
Quality class (TICI)	Good	Excellent	Excellent	Good

3.4.2 Bendigo Creek

The taxa richness at individual sites in Bendigo Creek is high and the taxa richness amongst all the samples is higher as ten taxa were only detected at single sites (Table 11). Bendigo Creek at the waterfall is a site part way down a cascade system and is well aerated with good habitat. A sample was also collected from upstream of the brown trout populations and this site has the highest number of taxa and highest number of EPT taxa. However, the MCI scores are similar across the four sites with the only score below 110 at lower Bendigo Creek in December. This also reflected in the lowest number of EPT taxa at this site. However, the TICI scores across the four sites indicate the downstream lower Bendigo site is in better condition that the two upstream sites with the lower site scoring 4-6 points higher than the upstream sites, although all sites are in the excellent category range.

Table 11: Summary indices for macroinvertebrates in eDNA samples from Bendigo Creek (Nov 2022 to April 2024).

Parameter	Upper Bendigo	Bendigo waterfall	Lower Bendigo (Dec 22)	Lower Bendigo (Nov 22)
Number of taxa detected*	21	25	20	22
Number of EPT taxa detected	13	15	10	12
Number of EPT taxa detected minus Hydrophidiae	12	14	9	12
MCI score	112.4	112	92	110
MCI interpretation (hard bottomed streams)	Good	Good	Fair	Good
NPS-FM (2020) MCI attribute band	B	B	C	C
TICI	110.1	111.8	114.7	116.0
Quality class (TICI)	Excellent	Excellent	Excellent	Excellent

3.4.3 Clearwater Creek

The upper reaches of Clearwater Creek, upstream of the Rise and Shine Creek confluence had a high number of macroinvertebrate taxa (Table 12) and high number of EPT taxa. The EPT taxa are dominated by caddisflies, and the stream also has the most diverse mayfly and stonefly communities. Both the MCI and TICI scores are high showing upper Clearwater Creek has high habitat and water quality. Mid and lower Clearwater Creek has noticeably lower MCI and TICI scores and this is due to the progressive decline in the EPT taxa with no stoneflies and loss of three of the four mayfly species present in the upper reaches with only *Deleatidium* present at the lower Clearwater Creek sampling site.

Table 12: Summary indices for macroinvertebrates in eDNA samples from Clearwater Creek (Nov 2022 to September 2024).

Parameter	Lower Clearwater (Nov 2024)	Mid Clearwater (Sep 2024)	Upper Clearwater (Mar 2024)	Upper Clearwater (Mar 2024)	Upper most Clearwater (Mar 20240
Number of taxa detected*	13	15	22	22	27
Number of EPT taxa detected	7	8	13	16	16
Number of EPT taxa detected minus Hydrophidiae	5	8	13	16	15
MCI score	89.2	102.67	121.8	131.8	108.1
MCI interpretation (hard bottomed streams)	Fair	Good	Excellent	Excellent	Good
NPS-FM (2020) band	D	C	B	A	C
TICI	110.1	113.95	120.1	121.0	119.1
Quality class (TICI)	Excellent	Excellent	Pristine	Pristine	Excellent

3.4.4 Threatened aquatic macroinvertebrates

A total of 28 aquatic macroinvertebrate taxa were identified to species level in the eDNA sampling. All the detected species are listed as not threatened in the Department of Conservation threat ranking classification for aquatic macroinvertebrates (Grainger et al 2018).

3.4.5 Koura and kākahi

The electric fishing, eDNA sampling and the stream walks all failed to detect any koura (freshwater crayfish) and kākahi (freshwater mussels). For koura this is consistent with the absence of koura in any sub-catchment of the Clutha River / Mata Au upstream of Cromwell. The absence of kākahi is also consistent with the life history requirement for kākahi. The larval phase of kākahi is parasitic on fish and the absence of fish from most of the study area means kākahi cannot complete their life cycle and are therefore absent.

3.4.6 Introduced aquatic macroinvertebrates

A single introduced mollusc, *Physella acuta*, was the only introduced aquatic macroinvertebrate detected in the eDNA sampling, and it was detected at a very low level in the lower perennial reaches of Shepherds Creek. This macroinvertebrate has no biosecurity threat status and can be found throughout New Zealand.

3.5. Stream State Assessment – present day

3.5.1 Stock access and damage

The stream reaches with and without stock access to water courses were mapped and the level of stock damage to physical habitat was visually assessed (Figure 33). Hoof damage and cattle faeces along the stream edges were used as a guide to impact.

There is no stock exclusion fencing in the Shepherds Creek and Rise and Shine Creek catchments. Shepherds Creek had nearly continuous hoof damage to varying degrees along its full length (Figure 33). There was a reduction in damage where dense riparian vegetation restricted access to the water course. Damage also was more noticeable in areas that had cattle present during the Shepherds Creek survey. The stock damage included both the mainstream and the small spring fed tributaries and their springheads. With cattle grazing along the water courses, faecal deposits were also common right to the stream edge. Many of the springheads in the Shepherds Creek catchment have been manually dug out to create small pool areas for cattle to drink from. This has created large sparsely vegetated springheads with significant hoof damage.

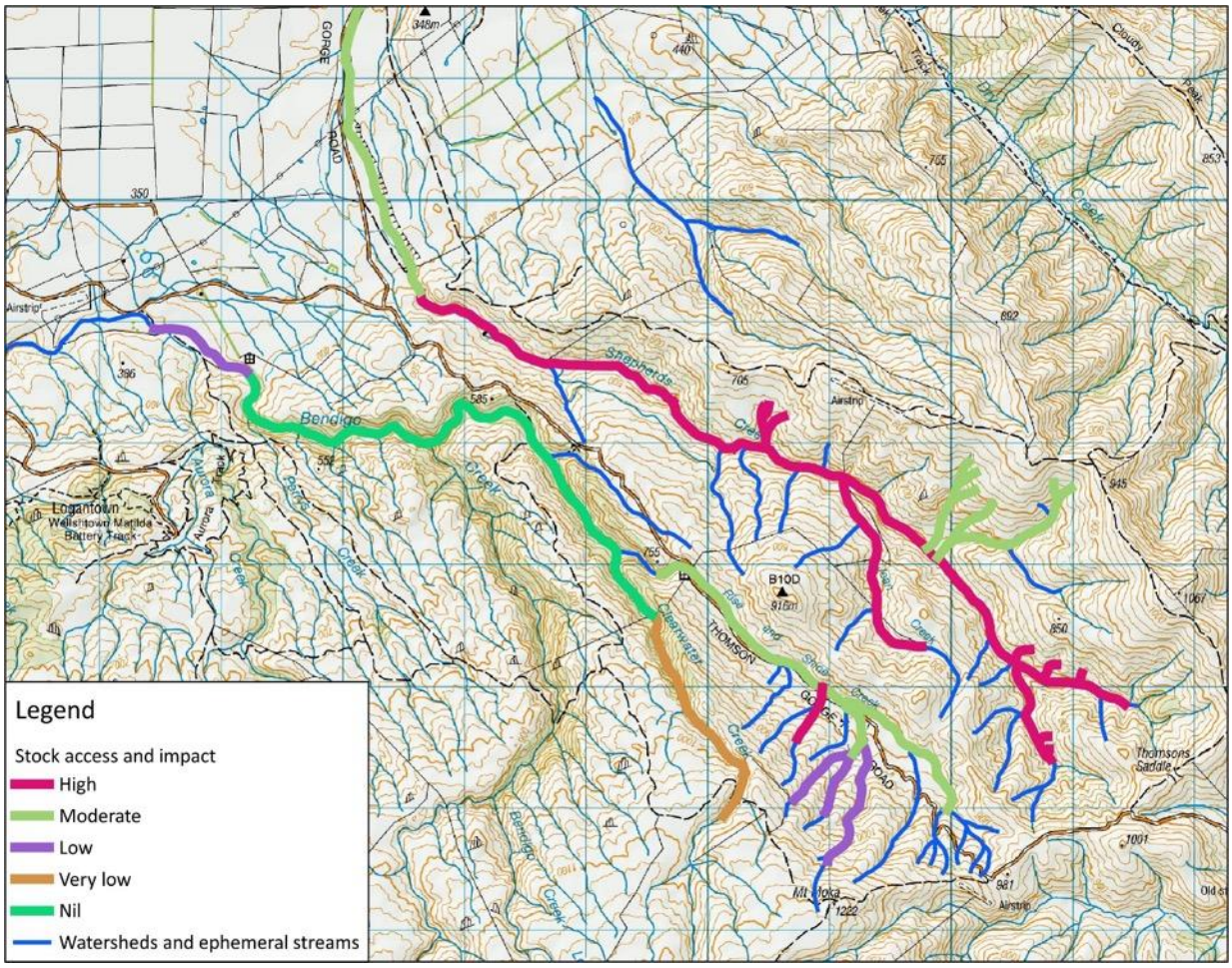

Figure 33: The stock impacted reaches of Bendigo and Shepherds Creeks.

In Jean Creek cattle and sheep damage was present in all perennial and intermittent flow areas. The single spring found was damaged by stock (Figure 34). Secondly, stock were using the dry/near dry stream channel as a pathway to move under the matagouri grey scrub (Figure 35). The channel was mud over bedrock with hoof prints and faecal matter on the dry or damp streambed being very common.

Figure 34: Stock hoof damage at the Jean Creek spring.

Figure 35: A stock track along Jean Creek under the matagouri and coprosma shrubs.

Rise and Shine Creek had low to moderate levels of stock impact in the upper reaches. Grazing, during the mapping period, was mainly sheep in the intermittent and ephemeral upper reaches. A fence line part way down the valley separated the upper reach area of lower impact from a higher impact area that extended downstream past the Rise and Shine Creek pond. The cattle damage extended upslope

along the small tributaries and included some localised areas of high damage associated with cattle at the small springs (Figure 36) and their resting areas (Figure 37). The wetland valley floor was less intensively impacted as cattle did not appear to graze the wetland area as intensively as the drier pasture grass hillslopes.

Figure 36: A spring in the Rise and Shine Creek catchment with cattle damage

Figure 37: A cattle resting area in a watershed area of the Rise and Shine Creek catchment

The un-named Lindis River tributaries to the north of Shepherds Creek had a high level of cattle hoof damage in the flowing reach of one branch up to the spring source that was also heavily impacted. The other branch had more moderate evidence of stock hoof damage along the stream, although grazing, possibly more by sheep was occurring along the stream riparian edge.

Common across these heavily stock damaged areas was the presence of both very recent stock impacts and sites with evidence of previous damage that are showing some recovery as stock grazing varies over time in area (Figure 38).

Clearwater Creek upstream of the historic reserve appears to be very lightly grazed, and there was almost no evidence of stock damage (Figure 39). In the headwaters near to the access track there were very rare deposits of cattle faecal matter, but hoof damage did not appear to be present. The pasture in this area was much less intensively grazed than in all the other areas that were surveyed.

Figure 38: A small stream channel showing some recovery from stock damage.

Figure 39: Sites in mid-Clearwater Creek (top photo) and upper Clearwater Creek (bottom photo) showing little evidence of grazing and stock damage.

In summary, the area typically has moderate levels of stock damage with pockets of high damage associated with stock accessing water sources. Common across these heavily damaged areas was the presence of very recent stock impacts. Sites with evidence of previous damage are showing some

recovery as stock grazing varies over time in area (Figure 38). Where there is dense riparian vegetation or stock are grazing less intensively there is noticeably less damage.

3.5.2 Stream channel modifications

The stream mapping noted channel modifications in Shepherds Creek, Rise and Shine Creek and the un-named Lindis River tributaries (Figure 40).

In Shepherds Creek there is online pond. The pond dam wall is partially broken, and the water impounded in the pond is limited. Upstream of the pond there is the stock water take point and occasional farm track crossings.

Rise and Shine Creek appears to be heavily modified. There is a small pond downstream of the Thomson Gorge Road. Upstream of this, the stream flows on a broad valley floor that is at least partially created by sediment deposition from historic gold mining activity. In this area there are water race channels along the valley edge and small dam structures extending across the valley floor and areas where the stream channel has been straightened or modified to flow through old dam structures. Modification extends upstream into the lower 500 m of the Mt Moka Stream with farm track crossing points and more historic gold mining effects.

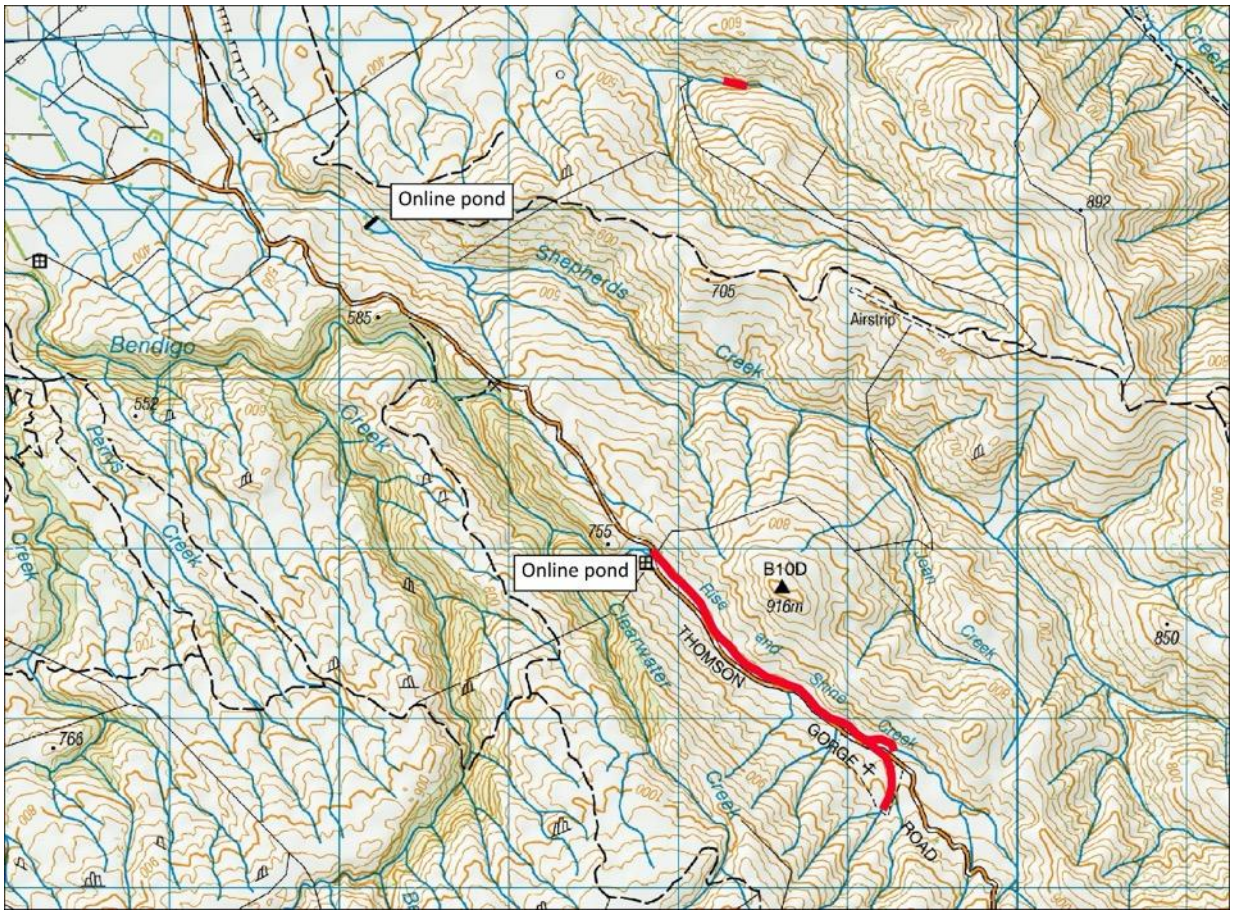

Figure 40: Stream modification locations.

In the un-named Lindis River tributaries a section of stream had been modified for what appeared to be a now disused water abstraction site or to create a very small pond for drinking water (Figure 41).

Figure 41: Small constructed pool on the un-named Lindis River tributary

3.5.1 Water abstraction affected reaches

Three consented water abstractions occur in the project area, two from Shepherd Creek and one from Bendigo Creek (Figure 42). The upstream take in Shepherd Creek is an abstraction for stock water with an estimated take rate of between 1-2 L/s and the downstream abstraction (Figure 44) is an abstraction for irrigation. The downstream abstraction takes all of flow during summer and has probably created the ephemeral reach from the Lindis River to Shepherd Creek at this take point. When no abstraction is occurring (e.g. during winter) the flow does extend downstream of the take for a few hundred metres but still did not flow to the Lindis River when surveyed in September 2024.

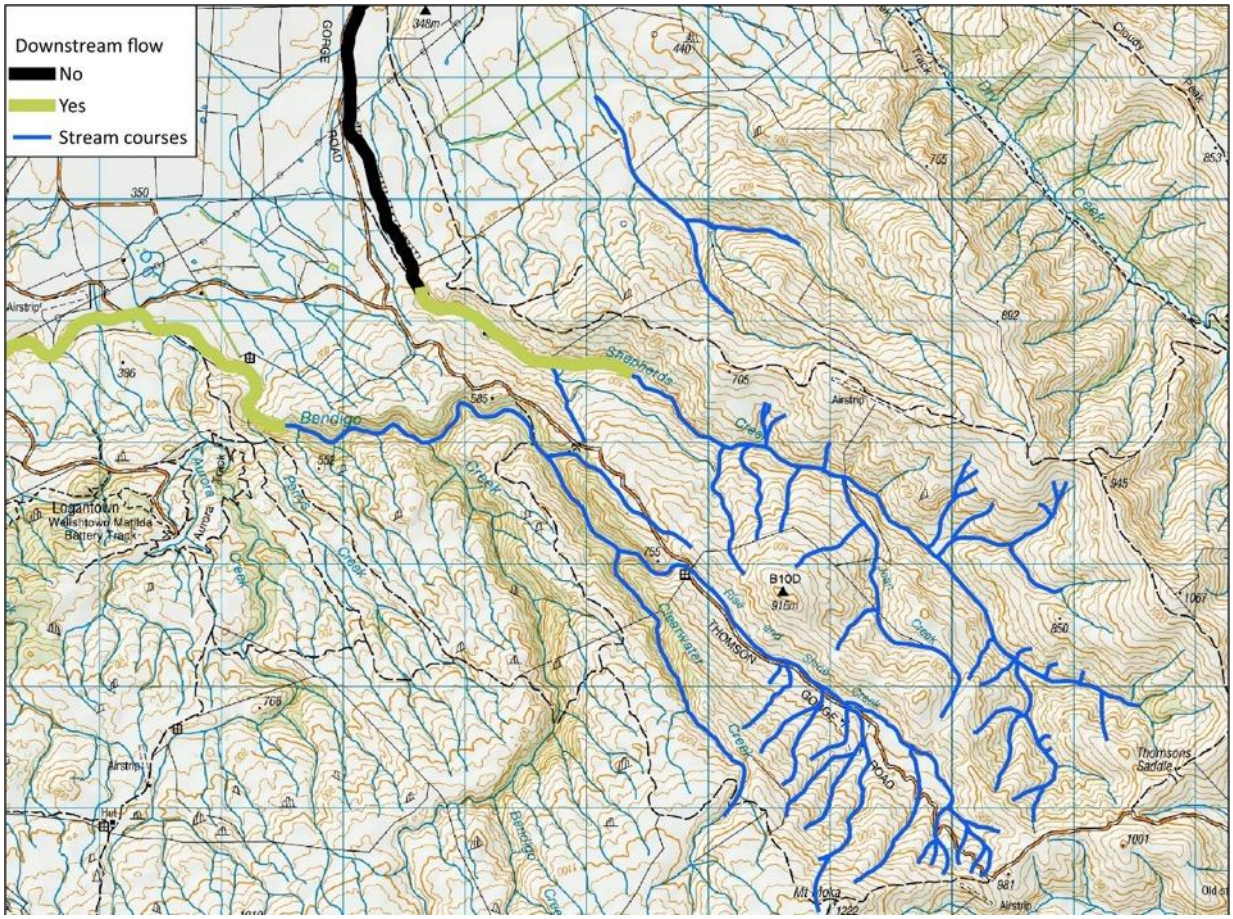

Figure 42: The water abstraction affected reaches of Bendigo and Shepherds Creeks.

Figure 43: The stock water intake structure in Shepherds Creek.

Figure 44: The main water abstraction intake in Shepherds Creek.

In Bendigo Creek perennial flow is present downstream of the water abstraction although flow is lost as the stream crosses the alluvial outwash zone in its lower reaches. The Bendigo abstraction occurs through a screened intake pipe in a deep pool and the abstraction would not impede upstream and downstream fish passage (Figure 45).

Figure 45: The Bendigo Creek water abstraction intake.

3.5.2 Fish passage barriers

The large Shepherds Creek water take is an upstream and downstream fish passage barrier as all the water is abstracted for much of the year and even when no abstraction is occurring the structure is unlikely to provide fish passage. In addition, the 4.8 km Shepherds Creek downstream of the abstraction point is an ephemeral reach and fish passage would only rarely be provided under natural flow conditions.

One natural fish passage barrier was located in Bendigo Creek that prevents upstream passage for brown trout (Figure 46). This waterfall is not a barrier to upstream movement by koaro. The other fish passage barrier is the Shepherds Creek water abstraction that creates a dry reach downstream of the intake and the intake structure is also a barrier to passage. This barrier is effectively both an upstream and downstream fish passage barrier.

Figure 46: The brown trout barrier waterfall in Bendigo Creek.

The lower ephemeral reach of Bendigo Creek is another partial fish passage barrier. Fish passage is available along the lower 5.5 km of the stream when there is surface flow to the confluence with the Clutha River / Mata Au. However, for much of the year this reach is dry, and fish passage is not available. The reach of Bendigo Creek between State Highway 8 and the Bendigo Loop Road has also been extensively developed between 2011 and 2023 (Figure 47 and Figure 48 respectively), with the construction of spray irrigation pasture and channel works along Bendigo Creek and aerial images show terrestrial vegetation colonising the stream bed, leading to possible changes in fish passage when flow is present.

Figure 47: Lower Bendigo Creek and SH 8, Dec 2011.

Figure 48: Lower Bendigo Creek and SH 8, Feb 2023.

3.5.3 Crack willow

Crack willow trees occur in both the Bendigo and Shepherds Creek catchments (Figure 49). These trees can form dense stands along the stream margins creating logjams and scour holes around trunks in the riverbed. The root mats can extend across the bed of small streams burying the natural stream bed substrate. The trees are easily spread downstream as branches that break from the trees can take root in damp ground and establish new stands of crack willow.

Crack willow in Shepherds Creek is limited to an area around the dam and downstream to about 300 m past the main water take. In this reach there is crack willow control that is preventing the spread of

crack willow. There are occasional small crack willows trees establishing themselves in the reach from the pond to the water intake that have also been subjected to control work. A cluster of mature crack willows occurs further downstream at the upstream end of the ephemeral reach.

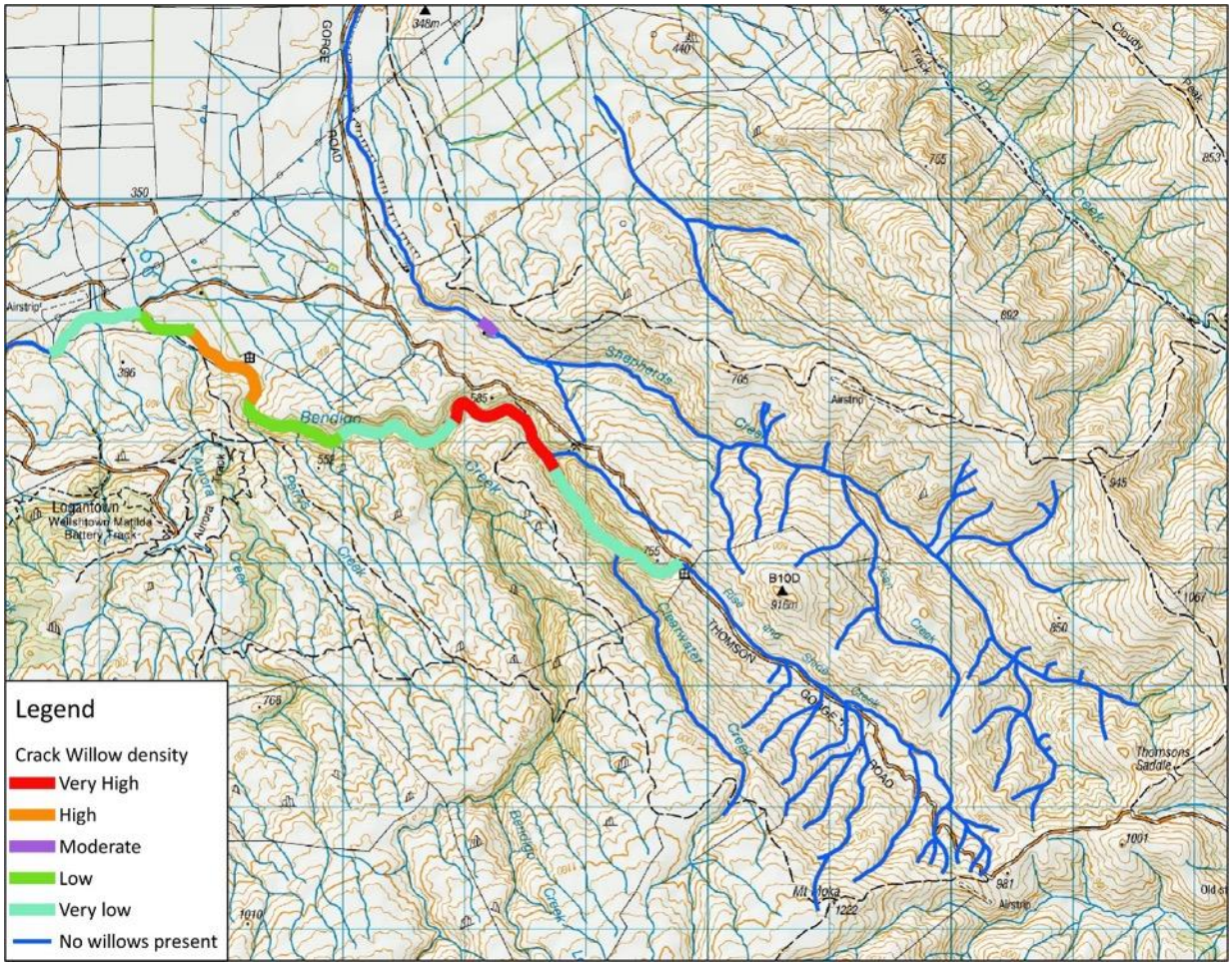

Figure 49: The crack willow reaches of Bendigo and Shepherds Creeks.

Clearwater Creek in the Bendigo catchment has a 1.3 km long dense continuous stand of crack willow that appears to be restricted to part of the Department of Conservation historic reserve. Upstream for another 1.4 km crack willow are occasionally present, then there are no more. The low-density crack willow trees also extend up into the lower reaches of Rise and Shine Creek with crack willows occasionally present up to the farm pond.

Downstream of the dense crack willow reach, crack willows continue to occur as occasional trees for 1.0 km before the density increases again. Downstream of the Bendigo water abstraction intake crack willow trees become common and, in the lower 1 km of the perennial reach crack, willow is one of the dominant woody plants in the riparian zone. However, large crack willow trees are uncommon in the lowest 500 m of this reach indicating this lower section may have recently been colonised by crack willows.

Figure 50: Live and dead crack willows trees around the dam pond in Shepherds Creek.

Figure 51: Small and large crack willows in Clearwater Creek.

Figure 52: Crack willow establishing in the lower intermittent reach of Bendigo Creek.

3.5.4 Introduced fauna

Two introduced species, brown trout and the snail *Physella acuta* have been detected in Bendigo Creek and Shepherds Creek respectively (Figure 53). Both species appear to be limited to the lower reaches of the streams in the perennial reaches just upstream of the ephemeral or intermittent lower reaches. The distribution of brown trout in Bendigo Creek has been accurately mapped but *Physella acuta* has only been detected in the eDNA sampling and the full range is unknown but the lack of detections (aside from at the most downstream eDNA sample site and none in Surber samples (E3 Scientific 2023) indicates it has a limited distribution in Shepherds Creek.

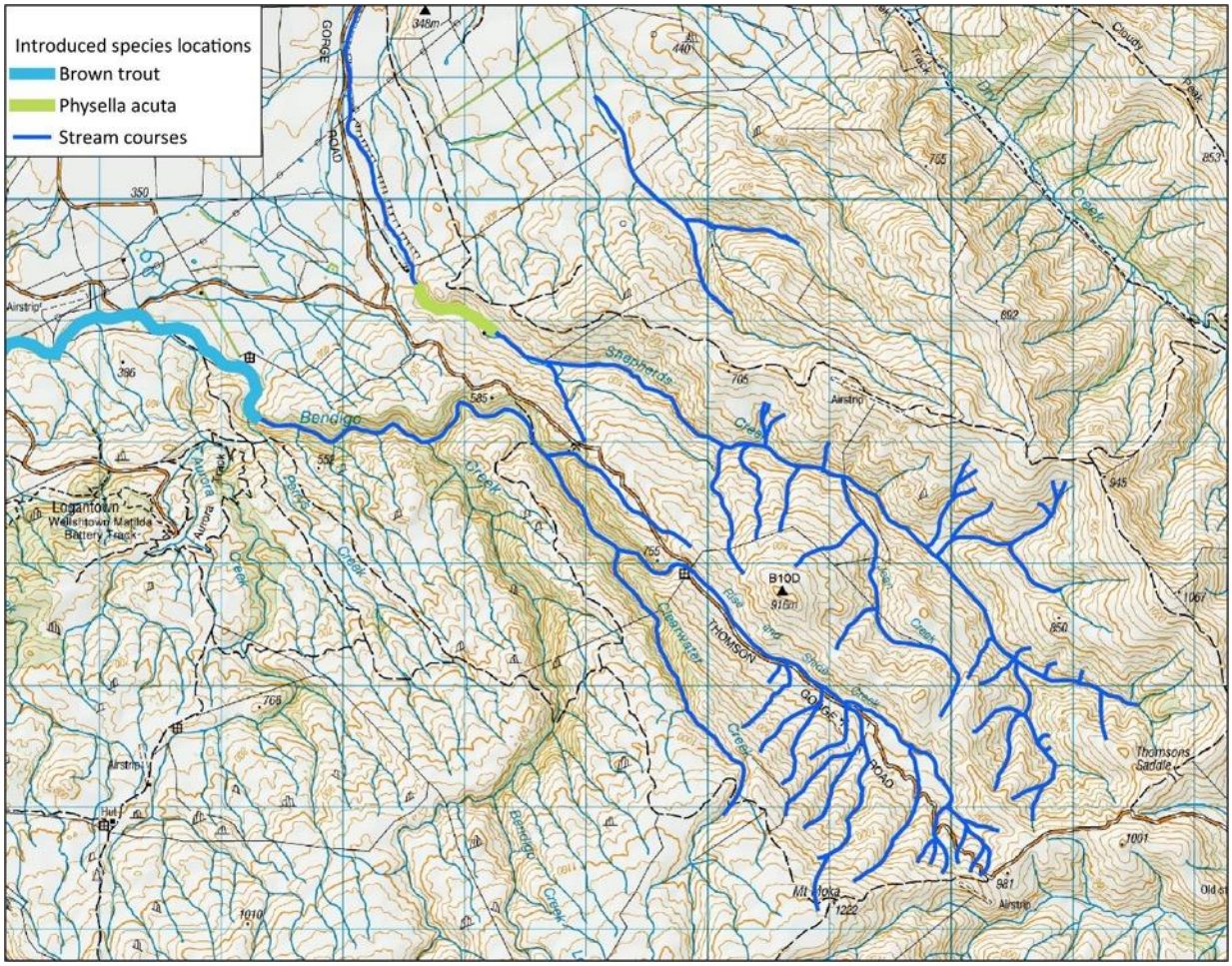

Figure 53: The distributions of introduced aquatic fauna in Shepherds and Bendigo creeks.

4. DISCUSSION

4.1. Fish Communities

The fish communities in the study area are very limited with only two species, koaro and brown trout reported and only from lower Bendigo Creek. No koaro have been caught and it is most likely that the population is small as it is limited by recruitment. Elsewhere along the Dunstan and Pisa ranges koaro are occasionally reported, but often fish surveys report only one to two individuals were present at survey sites (NZFFD, Allibone pers. obs.).

The brown trout population also has a very limited distribution due to the intermittent downstream reach and the waterfall preventing upstream fish passage limiting their permanent habitat. The population does not appear to have any sports fishery value as the trout are generally small, and the stream is hard to access and so small it is unlikely to attract sport fishing interest.

The NZFFD, E3 scientific (2023) and Allibone (2020) all report fish surveys in Bendigo Creek and Shepherds Creek and only brown trout have been reported from the lower intermittent reach of Bendigo Creek and E^3 Scientific (2023) had an eDNA detection of koaro in lower Bendigo Creek. The NZFFD has had a record for brown trout in the upper reaches of Rise and Shine Creek. This record was checked with the submitter from the Department of Conservation and the record had been placed in the wrong location and has been relocated to the correct site in Thomson Creek. Therefore, aside from the fish records for lower Bendigo Creek there are no fish records in Bendigo or Shepherds creek catchments.

The eDNA sampling in Rise and Shine, Clearwater, upper Bendigo and Shepherds Creeks did not detect any fish species. Most importantly there is no evidence of the threatened fish, the Clutha flathead (*Galaxias* spD), a nationally critical threatened fish (Dunn et al 2018) that is present in streams to the north and west being present in the project area. The nearest reported population of Clutha flathead, that is now thought to be extirpated, was in Wainui Creek, a Lindis River tributary that is 6 km to the north along the Dunstan Mountains.

4.2. Macroinvertebrate Communities

4.2.1 Shepherds Creek

The eDNA sampling showed the macroinvertebrate communities differ along Shepherds Creek. Species characteristic of ponds, low gradient stream and poor habitat or water quality are present in lower Shepherds Creek. These include molluscs and damselflies and a much higher detection rate for Oligochates. The presence of *Corynoneura scutellate* is often an indicator of high algae abundance and elevated nutrients and this species was only detected in lower Shepherds Creek. The detection of Hydroptilidae (the purse case caddisflies, *Oxyethira* and *Paraoxyethira*) eDNA in lower Shepherds Creek, but not in the upper Shepherds Creek sites, is another indicator of a reduction in habitat or water quality in the lower reaches of Shepherds Creek.

The samples of eDNA from the upper reaches of Shepherds Creek had several good habitat and or good water quality indicator species including two stoneflies, *Spaniocerca longicauda* and *Taraperla* sp. and the caddisfly *Oeconesus*. Common, poor water or habitat quality indicator taxa, such as the purse case caddisflies and *Corynoneura*, present in lower Shepherds Creek were absent from upper Shepherds Creek.

The differences between the upper and lower reaches of Shepherds Creek are reflected in the MCI scores calculated from the eDNA data within upper Shepherds Creek (106, 112) being 20-40 points higher than the downstream Shepherds Creek MCI (77, 86). A kick net macroinvertebrate sample previously collected from lower Shepherds Creek (E^3 Scientific, 2023) had an MCI score of 80. E^3 Scientific (2023) had two sites upstream towards the Jean Creek confluence, downstream of the eDNA samples in this study and they had MCI scores of 90 and 92, again indicating an upstream improvement. The most upstream eDNA sites may also gain some ecological benefit from the upstream Department of Conservation reserve. The TICI scores calculated from eDNA have a small range of 102 to 107, while showing the same trend of lower scores in a downstream direction.

E^3 scientific (2023) also found lower Jean Creek was flowing, but reported it as intermittent, and this site had an MCI score of 83.

Shepherds Creek has tributaries that, aside from Jean Creek, can be divided into two groups, the perennial flowing spring fed streams and the ephemeral streams that have very short duration flow periods. The ephemeral streams do not retain any aquatic macroinvertebrates as the streams flow for very short periods (hours or days) and cannot be successfully colonised by macroinvertebrates. The macroinvertebrate faunas of the spring fed streams have not been rigorously sampled, but eDNA sampling was undertaken in the lower reaches of a spring fed tributary (Site eDNA6). An additional eDNA sample was taken from the ephemeral stream flowing across the RAS pit footprint (site eDNA4). This stream was flowing for an extended period due to ground water flowing from a test bore hole at the stream edge that provided more permanent flow than would naturally occur. Both these eDNA samples detected very few taxa, six and five respectively, and only one EPT taxa, *Hudsonema*. The eDNA derived MCI scores were also very low indicating poor habitat. There are four factors that will be limiting the occurrence of diverse macroinvertebrate faunas in these small spring fed streams are the:

- Very small flow in these streams (Figure 54);
- the stock damage along most of the water course;
- the stream bed substrates dominated by mud, sand and gravel that provide little habitat for many macroinvertebrates; and
- the low habitat diversity.

Figure 54: A springhead (left) and spring fed stream (right) in the Shepherds Creek catchment.

4.2.2 Rise and Shine Creek

The macroinvertebrate fauna detected by the eDNA sampling was relatively sparse with between 6 and 10 taxa detected at the four sites. All sites were characterised by a lack of stoneflies and the only mayfly detected was *Deleatidium.* The small size of the Mt Moka tributary (20-50 cm wide) is likely limiting the number of resident taxa due to a limited array of available habitat types. The MCI scores from the eDNA detections found that the most downstream site below the dam had a low MCI of 78 indicating poor habitat. The species detected in this sample included *Xanthocnemis zealandica,* a damsel fly and the detection rate for *Potamopyrgus* was very high probably due to the upstream wetland areas and pond habitat providing still or slow flowing water that is suitable for these species. Conversely, there was no riffle habitat that is suitable for many mayflies and caddisflies near the downstream eDNA site.

The samples upstream in the perennial flowing Mt Moka tributary and from Rise and Shine Creek immediately upstream of the confluence with the Mt Moka tributary had higher MCI scores of between 90 and 104 respectively. The taxa diversity was still low and the high-quality habitat demanding species were rare or absent.

The two E^3 Scientific (2023) macroinvertebrate samples from Rise and Shine Creek found the same results with the site downstream of the dam site having pollution tolerant species and an MCI score of 70 and a site 250 m downstream from the Mt Moka tributary/ Rise and Shine confluence having an MCI of 93.

The TICI scores, 113 to 106 for Rise and Shine Creek sites had a smaller range than the MCI scores, However, the TICI scores had the same trend as the MCI scores with them decreasing in a downstream direction.

The upper reaches of Rise and Shine Creek were mapped as intermittent or ephemeral. The intermittent reaches will retain some macroinverterbrates that tolerate the no flow conditions. The ephemeral reaches are not expected to retain any macroinvertebrates.

4.2.3 Bendigo Creek

Bendigo Creek, at all the three sites sampled for eDNA, had relatively diverse macroinvertebrate communities with between 20 and 25 taxa detected. Caddisfly and mayfly diversity is high and EPT taxa made up 50% or more of the taxa detected at all sites. The intermittent reach was sampled in November and December and the December eDNA sample showed a marked increase in DNA detections, although caddisfly diversity did drop between the two sampling periods. The MCI scores are 112 for the two upstream sites in the perennial flow reaches. In the intermittent reach the MCI dropped from 110 in November to 92 in December reflecting a loss of caddisflies and a small increase in the midge taxa detected. In general, the macroinvertebrate community is of good but not high quality, and this is reflected in the limited stonefly fauna. Stoneflies are often the community component most sensitive to environmental conditions and, therefore, absent when some environmental conditions are limiting.

The TICI scores for Bendigo Creek are all in a small range being 111 to 116 with the two samples from the lower intermittent reach having the highest scores (114, 116). This may be due to eDNA being dispersed downstream from the perennial reach, that occurs about 200 m upstream. As such this sample site reflects upstream conditions and does not represent the stream condition when dry.

4.2.4 Clearwater Creek

Clearwater Creek has two distinct macroinvertebrate communities. The eDNA detected diverse high-quality communities in the three upper reach samples. The eDNA detections indicate abundant

mayfly and caddisfly communities, and a relatively diverse stonefly fauna. The total number of taxa detected was also high with 22 to 27 taxa found, of which more than 50% were EPT taxa at the three upper sites. The MCI scores ranged from 108 to 131, indicating good to excellent instream conditions. The upper Clearwater is only subject to some low intensity grazing and there was no stock damage visible along the stream edges. The instream habitat was also good with no evidence of sediment deposits and the stream has good habitat diversity with runs, riffles and pools.

The single lower Clearwater Creek sample came from downstream of the Rise and Shine Creek confluence. At this location the macroinvertebrate community has declined to 13 detected taxa and MCI of 89 indicating a significant drop in the instream conditions. The TICI scores also show that the lower Clearwater site scores poorly with a score of 110 when compared with the three upstream sites with scores of 119-121. The reason for the decline is unknown; However, further downstream once Clearwater Creek joins Bendigo Creek the macroinvertebrate community improves indicating the decline is possibly due to a localised effect.

4.3. Water Quality

The existing water quality has been sampled and reported by E^3 scientific (2023), and interpretation of the results is not part of this assessment. However, for the description of the present stream state it is important to note that E^3 Scientific detected an increase in nitrogen concentration in a downstream direction in Shepherds Creek. This is most likely an effect associated with the agricultural activity in the catchment. The maximum concentration of N detected was below a level expected to have large detrimental effects on the stream community.

Water quality sampling by E^3 scientific (2023) has also detected that the existing levels of heavy metals in Shepherds Creek and Rise and Shine Creek including elevated levels of arsenic and copper that may be either due to naturally elevated levels due to the nature of the underlying rock or possibly the result of the releases of metals from previous mining activity, or both.

5. STREAM ECOSYSTEM ASSESSMENT

5.1. Shepherds Creek

5.1.1 Stream flow

Using the stream flow monitoring data, Shepherds Creek can be divided into three distinct reaches: lower, mid and upper. The lower reach downstream of the major water abstraction is highly modified due to the water abstraction and agricultural development. This lower 4.8 km reach is at best an ephemeral water course although in the very lower reaches there is no evidence a water course exists. This reach does not support any permanent aquatic life.

The mid reach of Shepherd Creek reach has permanent flow with the summer low flow in the mainstem being less than 5 L/s. The instream flow is provided, from the headwaters in the Ardgour Conservation Area and by a series of springs on the hillslopes above Shepherds Creek. The springs and the small streams they feed are modified by stock and often modified to provide a stock water drinking source.

The other source of flow and third reach is the headwater catchment in the Department of Conservation Ardgour Conservation Area. This upper reach has no agricultural activity nor is it subject to water abstraction, the effects of introduced species or historical alteration due to mining and can

be considered an un-modified freshwater ecosystem, although possibly still recovering from pre-reserve status agricultural effects.

When considering flow and existing impacts the stream is easily divided into a high value headwater in the Ardgour Conservation Area, the permanently flowing agricultural impact reach with moderate to good ecological value and the very low value ephemeral reach downstream of the main water abstraction.

5.1.2 Ecological Value

The three reaches of Shepherds Creek are easily categorized in terms of their freshwater ecological state and value. The headwater reaches in Ardgour Conservation Area are of high value ecosystems. The absence of grazing, introduced aquatic species and water abstraction means this reach is close to a natural state. However, the TICI values are not the highest observed in this study nor are they in the range Wilkson et al 2024 classify as pristine. The macroinvertebrate fauna also indicates these upper reaches are either naturally limited by the habitat present or are still recovering from the historic grazing impacts. However, within the Shepherds Creek catchment the headwaters are still the most ecological intact ecosystem.

The lower reach of Shepherds Creek below the irrigation water abstraction point has almost no freshwater ecological value. It is an ephemeral flow path and provides no permanent freshwater habitat. The reach supports no freshwater species and much of it is highly modified to such a degree that its course is no longer apparent in the very lower part of the reach. This reach has very low ecological value.

The mid-reach of Shepherds Creek from the Ardgour Conservation Area boundary to the irrigation water take is an impacted perennial stream reach. The major alteration to this reach is that it is accessed by stock, and stock grazing and hoof damage is present along the whole reach. Water quality data also indicates that the stock are likely to be contributing to a nitrogen concentration increase in the stream (E^3 scientific 2023). However, aside from the presence of stock most of the reach remains in a near natural state as water abstraction via the small stock water take, and the presence of introduced species, e.g., crack willow only occurs in the lower part of the reach. The absence of salmonids from the stream is another ecological positive feature as salmonids can impact freshwater fauna and salmonid free streams are relatively rare. Therefore, most of the reach has a natural flow regime and has a native only fauna.

The TICI scores are good but show a small downstream direction decline from the Ardgour Conservation Area boundary to the water take that is likely due to the cumulative downstream effect of stock. The macroinvertebrate community assessment (e.g. MCI scores) shows a low-quality macroinvertebrate community is present in some areas of Shepherds Creek, especially in the lower part of the perennial mid-reach. This is likely to be driven by habitat rather than water quality. The natural summer low flows, the lack of cobble and boulder substrates, the rarity of riffle habitat and the presence of almost soft bottomed stream ecosystems will be influencing the quality of the macroinvertebrate community. Therefore, this mid-reach can be considered of moderate ecological value. It is representative of a low impact agricultural stream that has naturally limited habitat diversity.

A short 719 m gorge section has a cobble and boulder substrate and good riffle habitat and a more habitat or water quality sensitive EPT taxa that upstream or downstream reaches. This section of the stream has a reduced level of stock damage due to more limited access and the boulder and bedrock on the stream edge providing some protection from hoof damage. This short section provides some

ecological diversity to the Shepherds Creek ecosystem and is important when considering the diversity in the mid-reach.

Therefore, the state of Shepherds Creek upstream of the main water abstraction can be summarised as having a moderately diverse macroinvertebrate fauna, that is composed of a broad range of insects, molluscs and worms. It includes pollution sensitive EPT taxa, but also pollution tolerant snails and worms. The stream has no threatened macroinvertebrates and no freshwater fish. Only one introduced macroinvertebrate has been detected in the lower part of this reach. Problematic introduced species, such as brown trout are absent and crack willow is well controlled, so the stream fauna has a very high level of naturalness but has no fauna values that indicate it has high conservation value.

In the wider Dunstan Mountains stream setting Shepherds Creek supports moderately diverse macroinvertebrate fauna but is lacking some of the diversity of EPT taxa that are present in streams with more suitable EPT habitat, such as Clearwater Creek and Bendigo Creek. The instream habitat is limited in terms of diversity and provides relatively low-quality riffle habitat that is a limiting factor. Therefore, Shepherds Creek is considered representative of a low gradient Dunstan Mountains perennial small stream. Other such streams are present in the tributaries of the Lindis River and most or all are also in agricultural landuse and have water abstractions (Allibone pers. obs.).

Shepherds Creek does provide a perennial stream habitat that is absent from some other Dunstan Mountains streams (e.g., Dry Stream, and the adjacent un-named Lindis River tributaries).

Shepherds Creek can be considered representative of the small perennial streams that drain the Dunstan Mountains. The extent of modification is limited to the effects of agricultural activity such as stock grazing, and water abstraction; however, the absence of introduced fish and the limited range of other introduced species suggests most of the stream is currently subject to low to moderate impacts. The presence of the Ardgour Conservation Area in the headwaters provides a clean water supply to the stream and there is only a low level of nitrogen increase in the farmed perennial reach of Shepherds Creek indicating that stock impacts are more limited to physical damage than to declines in water quality.

This assessment indicates that the upper reaches of Shepherd Creek from the Ardgour Conservation Area boundary downstream to at last the downstream end of the gorge section has moderate to high ecological value. The extent of modification is limited to stock impacts, and this reach has good water quality, habitat diversity and no introduced species. Downstream of the gorge section the section can be considered of moderate value as the extent of habitat modification increases with water abstraction and channel modifications (e.g., the dam), crack willow appears, and stock impacts are marginally more noticeable.

5.2. Jean Creek

Jean Creek is an intermittent stream that is colonized by aquatic macroinvertebrates during extended wet periods, but this community is extinguished when the stream dries. A small 20 m reach at the one spring in this catchment appears to be the only permanent wetted habitat. This small section has been modified to provide drinking water for stock and is further impacted by stock access.

Therefore, this stream is assessed as having very low aquatic ecosystem systems value.

5.3. Rise and Shine Creek

Rise and Shine Creek can be divided into four sections. There is an upper section that is comprised of a series of intermittent or ephemeral tributaries in the headwaters near Thompson Gorge Road. The spring fed tributary catchment draining Mt Moka is a second reach. These upper two reaches combine at their confluence to create a third reach, the perennially flowing Rise and Shine Creek on the main valley floor. This reach extends to just downstream of the pond. Downstream of the pond the stream enters a gorge reach that has a steeper gradient and dense riparian scrub restricting access to the stream.

All four sections are fishless, and faunal values are restricted to the macroinvertebrate fauna.

For the upper intermittent and ephemeral reaches the aquatic communities are limited by the flow duration. In the intermittent areas the stream fauna can survive some low or no flow periods in areas that retain surface water. The ephemeral reaches do not provide any refuge habitat. Stock grazing occurs in this area, but the stock damage is low. The eDNA sampling at the downstream end of this reach indicates a low diversity (8 taxa detected) dominated by the snail, *Potamopyrgus antipodarum.* The intermittent or ephemeral flow, and low-quality macroinvertebrate faunas, but low stock impact and absence of introduced species, gives this upper catchment area a low to moderate ecological value.

The Mt Moka streams have permanent flow and in the steeper headwater reaches some boulder cobble riffle and run habitat is present. These upper areas have very little modification and habitat macroinvertebrate communities in the Mt Moka stream are of moderate to high quality with 12 taxa detected with 7 EPT taxa present. The eMCI and TICI both indicate good to high quality conditions in the stream. The stream survey also detected relatively low levels of stock impacts, and the stream retains a gray scrub riparian zone until altitude limitations change the gray scrub to tussock vegetation. This stream has the highest quality macroinvertebrate fauna in the upper Rise and Shine catchment and is considered a high-quality habitat area, aside from the lower 200 m where historic and present modifications occur.

Rise and Shine Creek downstream of the Mt Moka Stream confluence is a perennial stream but the reach is modified by historic gold mining structures and present grazing activity. The macroinvertebrate fauna is of low quality, and this is reflected in low eMCI and TICI scores. However, the area has no introduced species, and the flow regime is not impacted by water abstraction. Therefore, the aquatic community and habitat while poor and somewhat modified does retain important natural features. The reach is considered to have low to moderate ecological value.

The gorge reach of Rise and Shine Creek has not been assessed but will retain a higher degree of naturalness than the upstream reach as gold mining has not altered the habitat in this reach. The reach does retain the key features of natural flow and no introduced species. The rockier nature of the stream with a high stream gradient will also provide more riffle habitat, a key macroinvertebrate habitat. Therefore, this reach is considered to have at least moderate value.

6. ASSESSMENT OF EFFECTS

6.1. Introduction

Four general categories of potential adverse effects are expected from the BOGP:

- Complete loss of habitat that is either buried or excavated;

- diversion of streams;
- changes to stream flow; and
- water quality changes.

These effects are not spread evenly across the water courses in the project area. Any impacts on a perennial stream habitat has the largest effect. Whereas the impacts on intermittent water course will have a lesser effect on aquatic communities as these streams have a limited ability to retain aquatic taxa for long durations or communities are limited to those that survive periods of no flow. The loss of ephemeral streams and watershed areas will affect water flow paths but will not lead to the direct loss of habitat used by aquatic species. Therefore, the assessment of effects has assessed the effect on stream course habitat for each stream category separately.

There are also four general categories of stream improvement:

- Exclusion of stock from water courses;
- Removal of crack willow;
- Restoration of natural flow with removal of stock water abstraction; and
- Habitat improvement.

The benefit of these actions is assessed according to the nature of the water course with more benefit gained for improvement in perennial water courses and less to intermittent and ephemeral. One caveat to this is that the effect of stock removal has two aspects: one the physical benefit of removing stock from streams and grazing the riparian zone that is more significant in perennial streams; and two the benefit of reducing stock effluent runoff into water courses where the benefit is derived from the overall reduction in stock across a catchment with general improvement in water quality across all aquatic systems. Description and evaluation of any stream improvement works will be provided elsewhere once improvement actions have been determined.

6.2. Adverse Effects on Stream Habitat

6.2.1 Assessment method

For each part of the BOGP, GIS files of the location of the various features were overlaid on the stream network that had been mapped using GIS. The effected length of stream reaches for each part of the BOGP was determined from the overlay of the mine feature on the stream network. To account for some uncertainty in the final location and size of some of the mine features buffer zones of between 20 m and 50 m were placed around the design footprints for features of concern to allow for some changes in the final size and locations of features. Other features that have their size and location constrained had no buffers in the GIS analysis. The stream effects were divided into two categories, stream loss where a stream is buried or excavated and impacted were the stream is modified but generally remains in or near its existing course.

6.2.2 Tailing Storage Facility (TSF), Engineered Land Form (ELF) and sediment and sump ponds

There are four overlapping components of the BOGP in the upper part of Shepherds Creek; the TSF, ELF, a runoff collection sump and a silt collection pond. As these features overlap the effect on Shepherds Creek for each component separately overestimates the total effect stream habitat. The assessment has calculated the lost and/or impact each component has on stream habitat and then the combined lost and impacted reaches.

The TSF is in the head waters of Shepherds Creek and will fill the valley to an altitude of approximately 700 m. The TSF has two parts, the main tailings storage area (TSF) and a wall feature at the downstream end that forms the downstream end of the TSF, i.e. the TSF wall. These two features combined create a single area for the TSF. The TSF size will be constrained by the construction of the clean water drains that run around the hillsides above the TSF. Therefore, the TSF is not expected to increase as this would infill the clean water drains. For this reason, no buffer zone has been used for the TSF when the stream loss was determined.

TSF is the largest area of stream habitat loss in the project footprint. The mapped footprint for the storage facility will also cover predominately perennial stream courses with a smaller area of ephemeral and watershed lost (Figure 55, Table 13).

Table 13: Length of stream lost under TSF in Shepherds Creek.

Stream type	Ephemeral	Intermittent	Minor perennial streams	Perennial 2nd order +	Watershed
Stream length	248 m		630 m	3,182 m	310 m

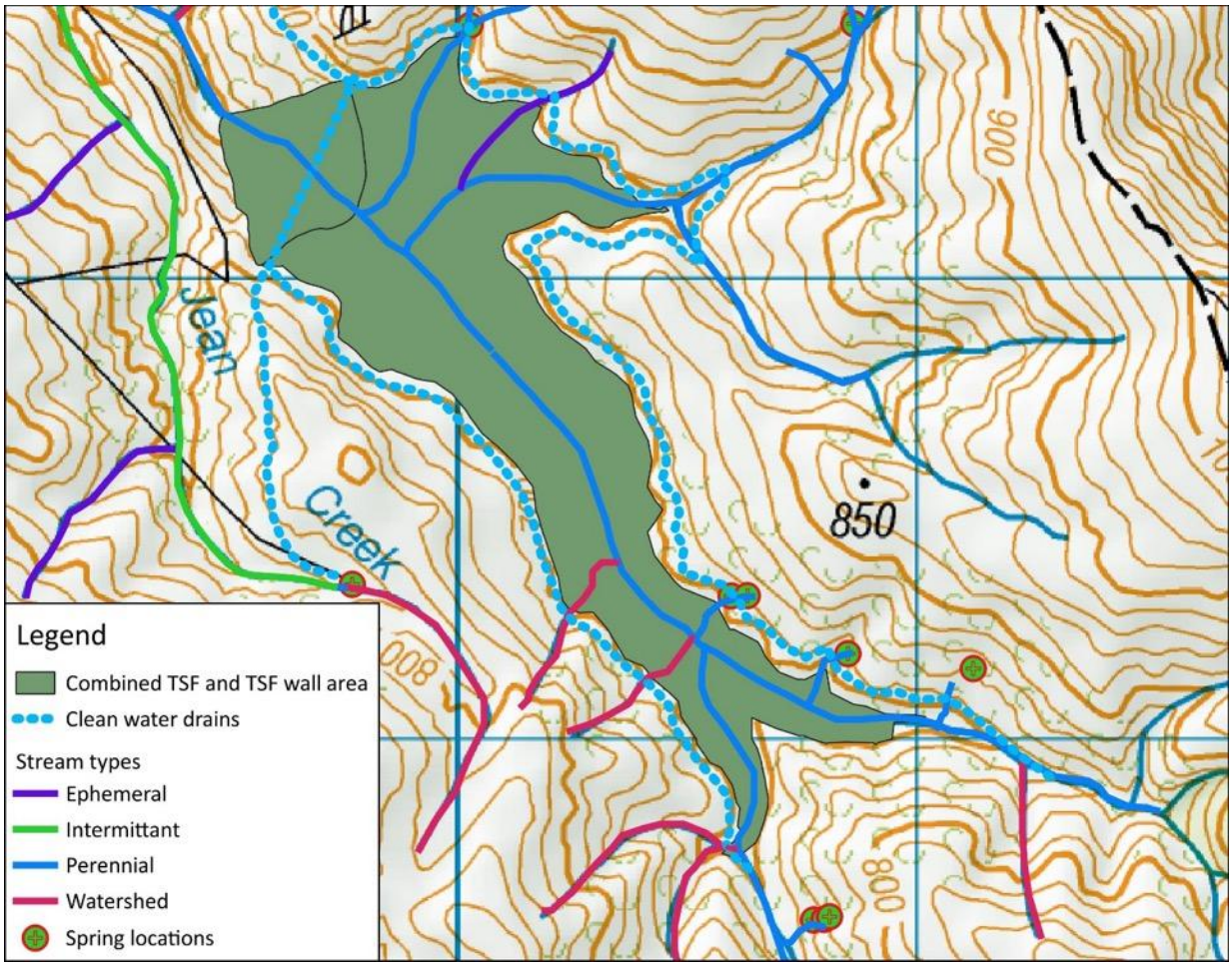

Figure 55: The area of Shepherds Creek covered by the TSF with stream types shown.

The ELF at the downstream end of the TSF will overlap with the TSF, but will cover additional areas of Shepherds Creek and Jean Creek with the loss of ephemeral, intermittent and perennial streams (Figure 56, Table 14). The ELF has less constraints on its final form, so a 50 m buffer has been applied to its boundary. The ELF with the 50 m buffer, assessed as a stand-alone feature will cover 4,646 m of

water course, split amongst ephemeral, intermittent, minor and 2nd order + perennial water streams (Table 14).

Table 14: Length of stream lost under ELF (+50 m buffer) in Shepherds Creek.

Stream type	Ephemeral	Intermittent	Minor perennial streams	Perennial 2nd order +	Watershed
Stream length	1,182m	1,631m	301 m	1,531 m	292 m

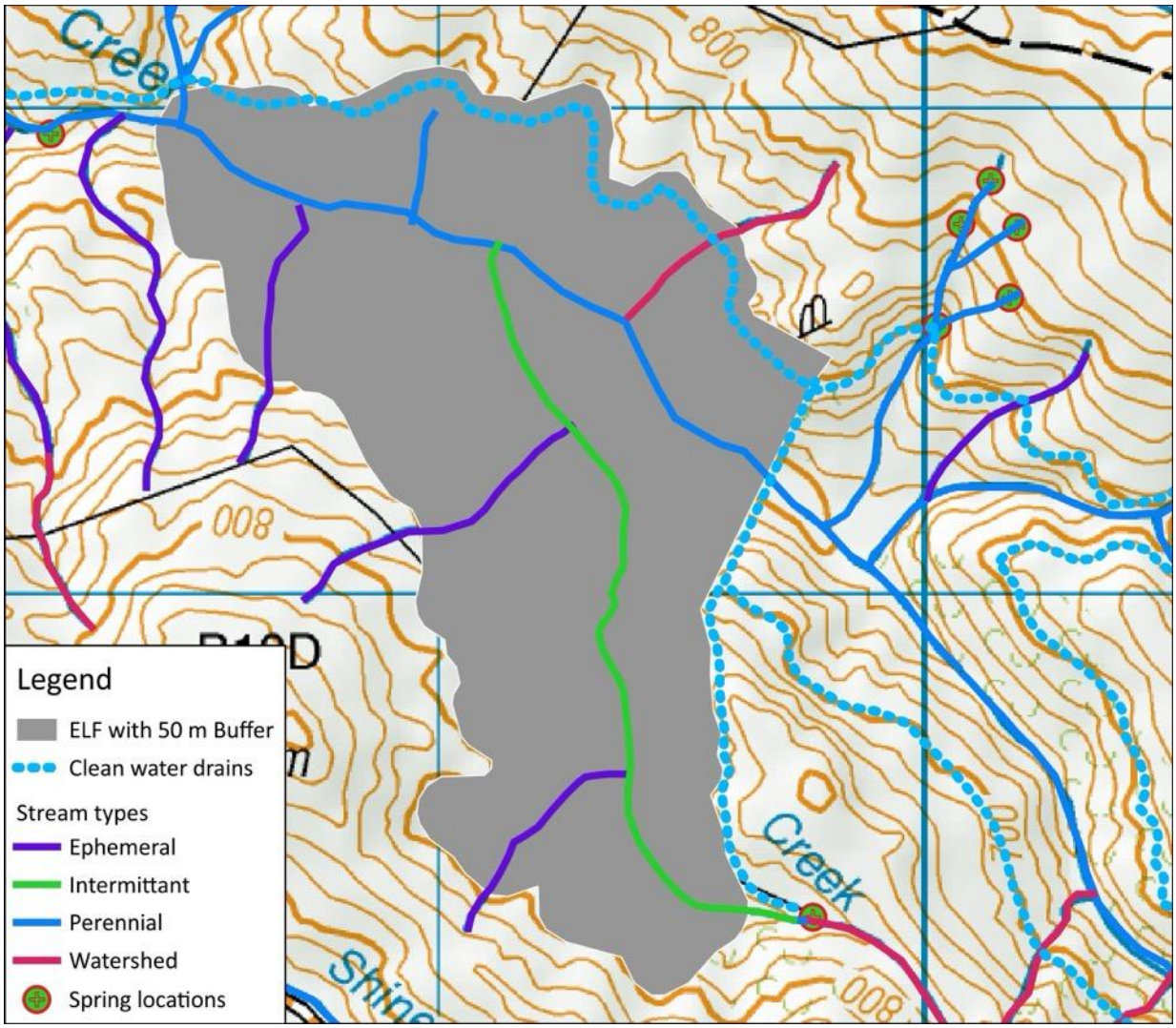

Figure 56: The area of Shepherds Creek covered by the ELF (+50 m buffer) with stream types shown.

Downstream of the ELF a silt collection pond and a seepage collection sump will be constructed on the toe of the ELF and downstream of the ELF to capture silt run off and to collect water seepage from the TSF and ELF. The silt collection pond lies downstream of the sump along the Shepherds Creek valley floor and will cover Shepherds Creek for 442 m downstream of the toe of the ELF (Figure 57, Table 15). This 442 m silt pond reach includes 87 m of the high ecological value cobble bolder habitat in Shepherds Creek. The pond will also overlay the confluence zones of two tributaries, 65 m of an ephemeral tributary and 42 m of a minor perennial tributary of Shepherds Creek (Figure 57).

Table 15: Length of stream lost under silt retention and collection sump ponds in Shepherds Creek.

Stream type	Ephemeral	Intermittent	Minor perennial order	Perennial 2nd order +	Watershed
Stream length	72 m	0 m	42 m	366 m	0 m

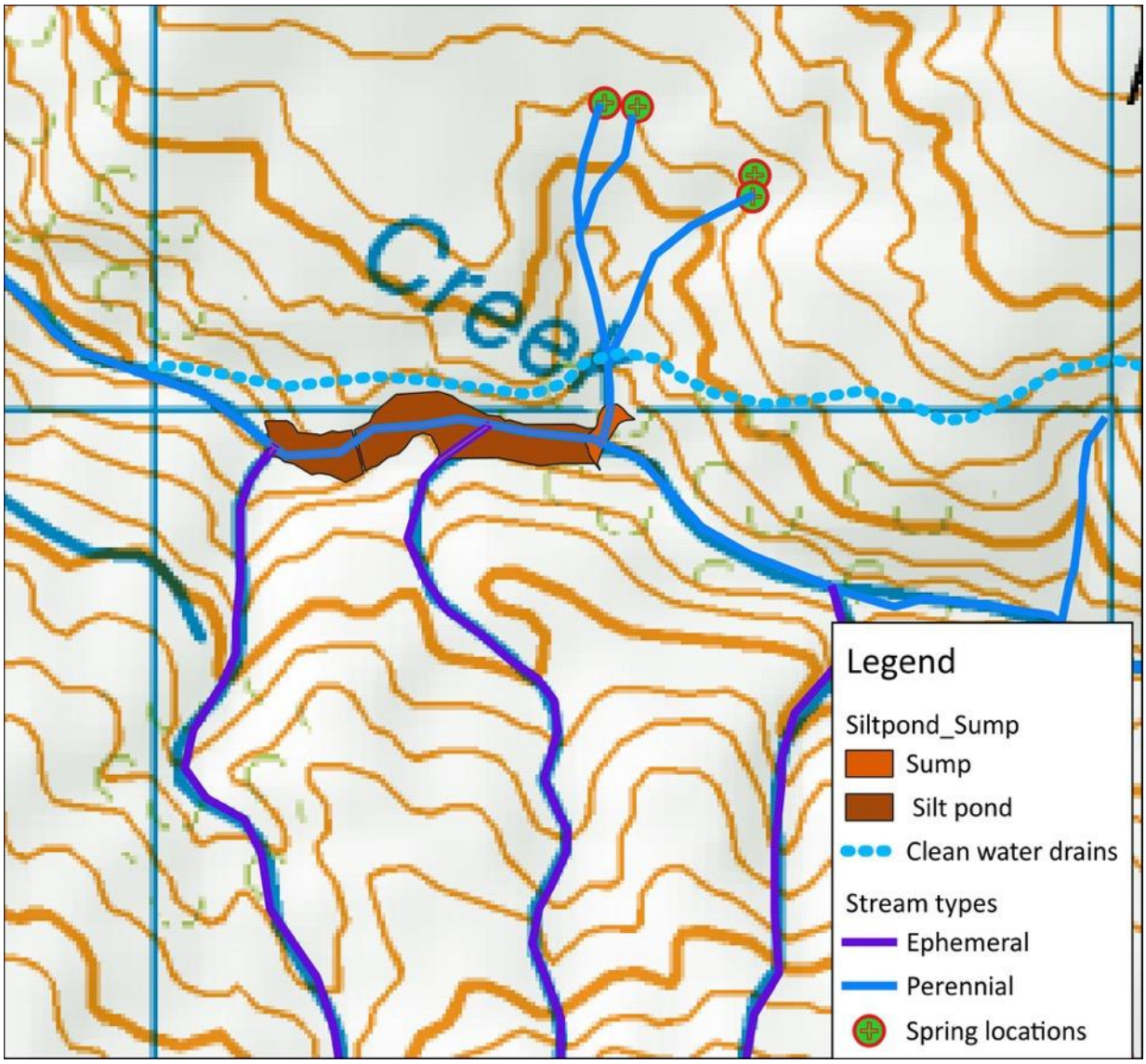

Figure 57: The area of Shepherds Creek covered by the silt pond and seepage sump with stream types shown.

The total stream loss under the TSF, TSF wall, ELF, runoff sump and the silt collection pond is less than the total area for each component due to the overlapping nature of these features. The combined stream loss for these four components is split amongst perennial, intermittent, ephemeral streams and watersheds (Figure 58, Table 16). The overlap amongst these combined features reduces the loss of Perennial 2nd order + streams when compared to the losses for individual features by 268 m.

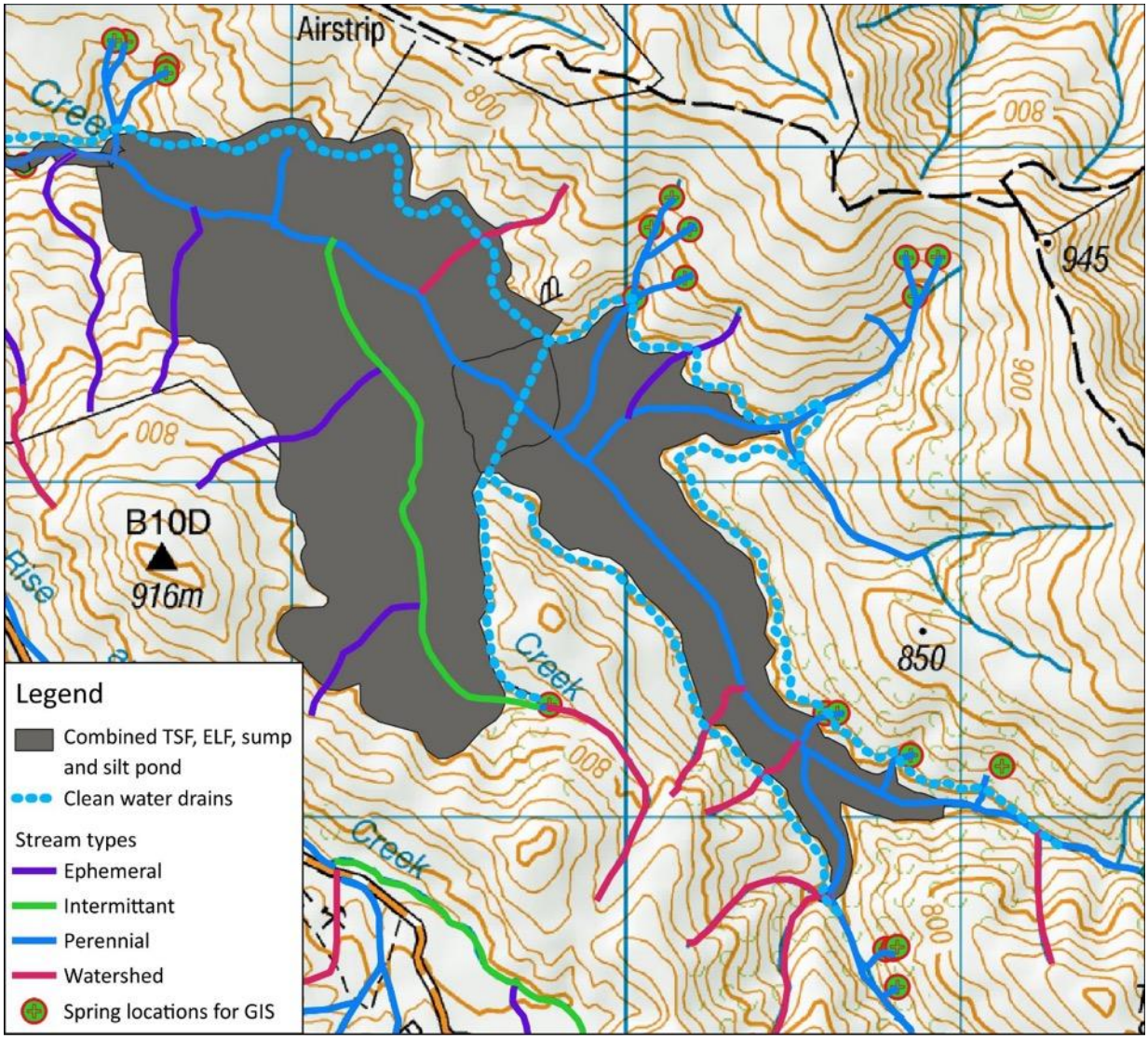

Figure 58: The area of Shepherds Creek covered by the combined TSF, ELF (+50 m buffer) silt settling pond and runoff sump with stream types shown.

The loss of watershed and ephemeral water courses will not cause any direct loss of aquatic flora and fauna as these areas do not support aquatic life. The first order perennial streams are heavily modified by existing stock and the eDNA indicates a limited macroinvertebrate fauna is present in these small water courses. The loss of 2nd order and higher order water course at 4,811 m will occur in the upper and mid reaches of Shepherds Creek, including areas close to the boundary with the upstream Ardgour Conservation Area. This area of Shepherds Creek is subject to the lowest cumulative impact of agricultural activity and is not subjected to water abstraction, and no introduced species (e.g. brown trout and crack willow) are present, so this is the high-quality reach of Shepherds Creek outside of the Ardgour Conservation Area.

Table 16: Length of stream lost under the TSF, ELF silt pond and runoff sump in Shepherds Creek.

	Ephemeral	Intermittent	Minor perennial 1st order	Perennial 2nd order +	Watershed
	1,524 m	1,631	931 m	4,811 m	602 m

6.2.3 Mine pits

Rise and Shine Pit (RAS pit)

The RAS Pit (with 100 m buffer) will intersect with several ephemeral water courses in the Shepherds Creek catchment and also the mainstem of Rise and Shine Creek (Figure 59, Table 17). In the Shepherds Creek catchment 1,504 m of ephemeral stream and 394 m of watershed will be lostthe pit footprint. This will create no direct loss for aquatic habitat in the Shepherds Creek catchment as these water courses do not support aquatic life. In the Rise and Shine catchment, 606 m of the Rise and Shine Creek mainstem will be lost and an additional 410 m of an ephemeral tributary. The section of Rise and Shine Creek within the pit boundary includes the modified section with the pond.

SRX Pit

The SRX pit and its associated ELF sits in the Rise and Shine Creek catchment and they intersect a combination of perennial, ephemeral and watershed water courses (Figure 59, Table 17). The key stream loss in this site is the perennial Mt Moka stream as this stream provides continuous flow for Rise and Shine Creek and this stream is also the highest quality habitat in the Rise and Shine Creek catchment. The Mt Moka stream reaches lost can be divided across the two tributaries. The 305 m in the more westerly stream is lower quality than the habitat in easterly stream. In the easterly tributary stream, the lower 160 m in the pit footprint is lower quality due to the presence of farm track crossings, stock access and historic mine works. The upper 326 m of the stream is high quality habitat. The pit also intersects the main stem of Rise and Shine Creek, and 86 m of this perennial section will be lost. Therefore, the perennial stream loss can be split into 465 m of moderate to low quality stream and 412 m of high-quality stream.

Come in Time Pit (CIT pit)

The CIT pit sits on the ridge line between the Shepherds Creek and Rise and Shine Creek catchments. No streams in the Rise and Shine catchment are within the mine footprint. The mine will remove 336 m of the upper reaches of an ephemeral stream in the Shepherds Creek catchment (Figure 59, Table 17).

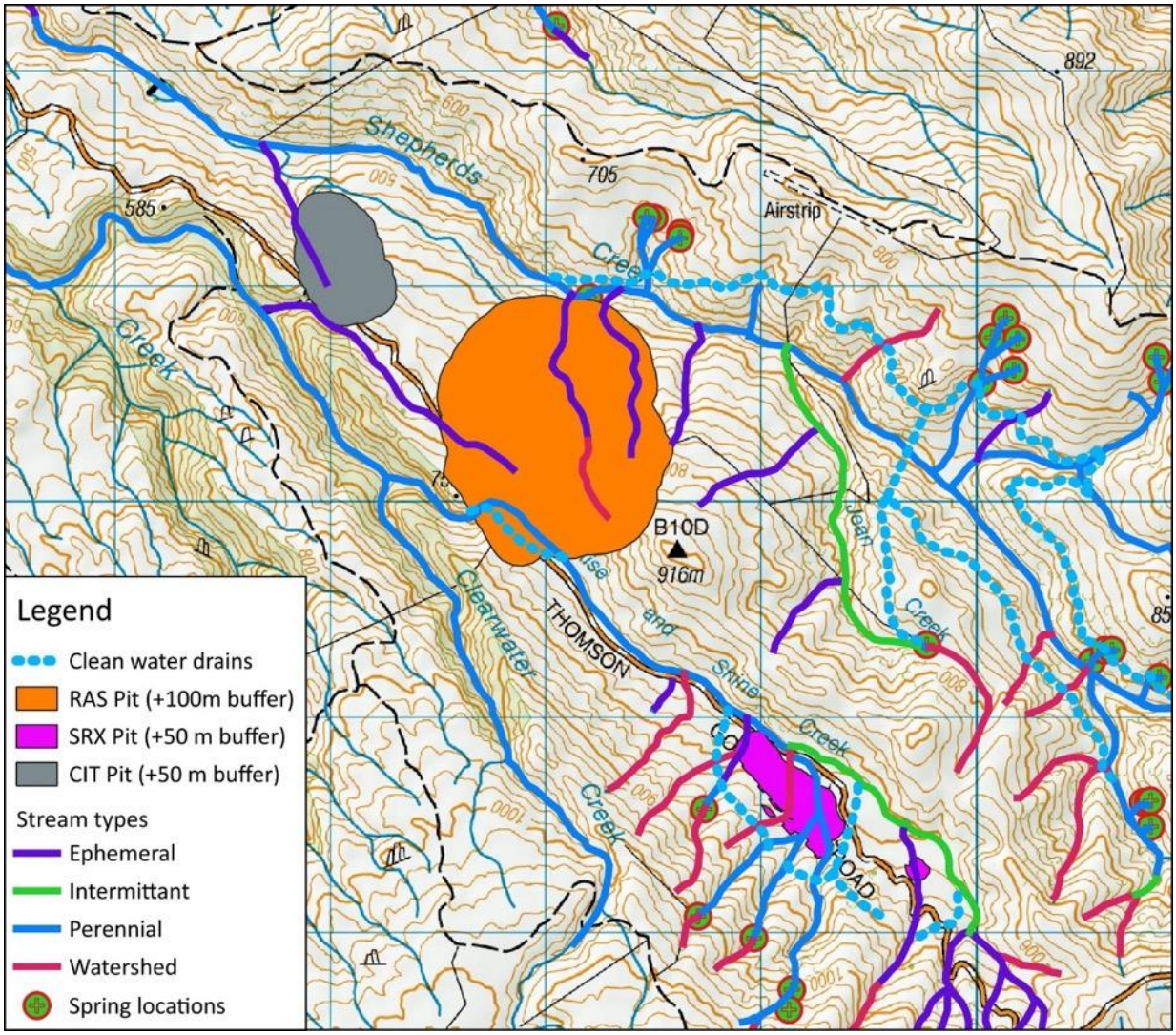

Figure 59: The stream reaches within the three mine pit footprints with stream types shown.

Table 17: Length of stream lost under the three mine pits in Shepherds Creek and Rise and Shine Creek.

Mine pit	Ephemeral	Intermittent	Minor perennial 1st order	Perennial 2nd order +	Watershed
RAS	1,914 m			606 m	394 m
CIT	336 m				
SRX	343 m		305 m	486 m	442 m
SRX ELF	357* m				

* Total is minus 108 m to account for loss in the small eastern SRX pit

SRX Engineered land form (SRX ELF)

An ELF will be constructed over the small western section of the SRX pit and extend over an ephemeral tributary of Rise and Shine Creek. The SRX pit removes 108 m of the ephemeral stream, but this small pit will then be covered by the ELF. The ELF adds another 357 m of ephemeral stream loss in the Rise and Shine Creek catchment (Figure 60, Table 17).

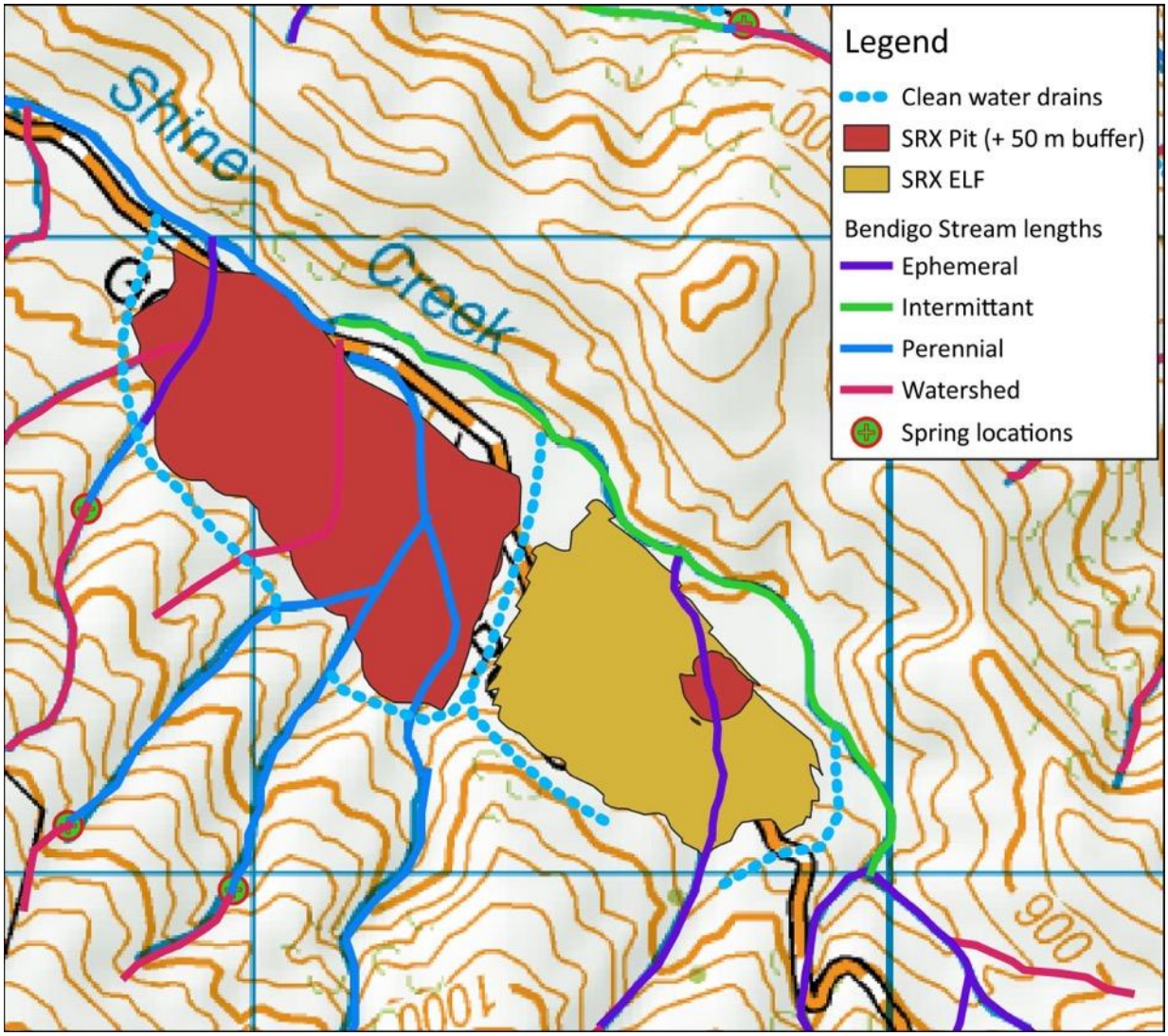

Figure 60: Stream reaches in the SRX pit and SRX ELF with stream types shown.

6.2.4 Topsoil Storage areas

The topsoil storage areas have been mapped with 20 m buffers to allow for some change in store area. Some of the topsoil storage areas will be placed in ephemeral water courses, watershed areas and intermittent stream courses (Figure 61, Table 18). One short section of perennial stream in Jean Creek will also be affected by the topsoil storage. However, all the topsoil stored at these sites will be used during site rehabilitation, so permanent stream loss is not expected to occur at the topsoil storage areas.

Table 18: Length of stream temporarily lost under topsoil storage areas in Shepherds Creek and Clearwater Creek.

Catchment	Ephemeral	Intermittent	Minor perennial 1st order	Perennial 2nd order +	Watershed
Shepherds	122 m	97 m	19 m		312 m
Clearwater	550 m				

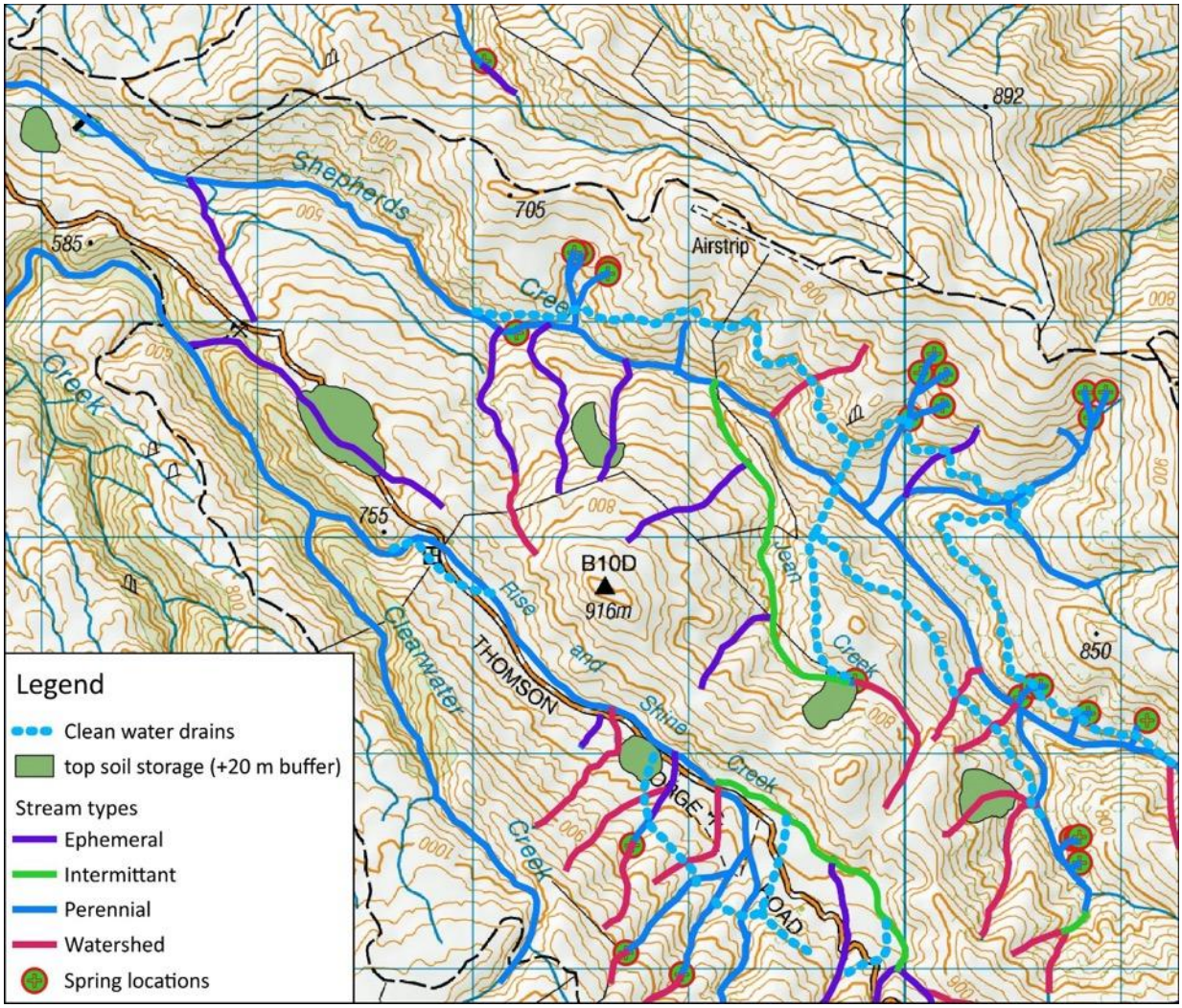

Figure 61: The location of topsoil storage area that overlay stream courses.

6.2.5 Processing Plant and Services Corridor

The gold processing plant and associated infrastructure is to be placed in the lower part of the Shepherds Creek valley. The majority of the valley from the toe of the Shepherds Silt Pond to the western end of Shepherds Gorge will receive engineered fill (overburden from the RAS pit) to create a level platform for the establishment of the process plant, buildings, underground services (power, water, communications fibre), tailings pipeline and return water and light vehicle traffic. Shepherds Creek will be diverted to the north side of the valley floor as an engineered diversion channel – Shepherds Creek Diversion Channel (Figure 62). Approximately 2960 m of the mainstem of Shepherds Creek and small reaches of ephemeral streams near their confluences with Shepherds Creek lie in the realignment reach. The realignment will provide the beneficial actions of the complete removal of crack willow from Shepherds Creek and the removal of the existing online modifications, the damaged dam and small upstream pond on Shepherds Creek (Figure 62).

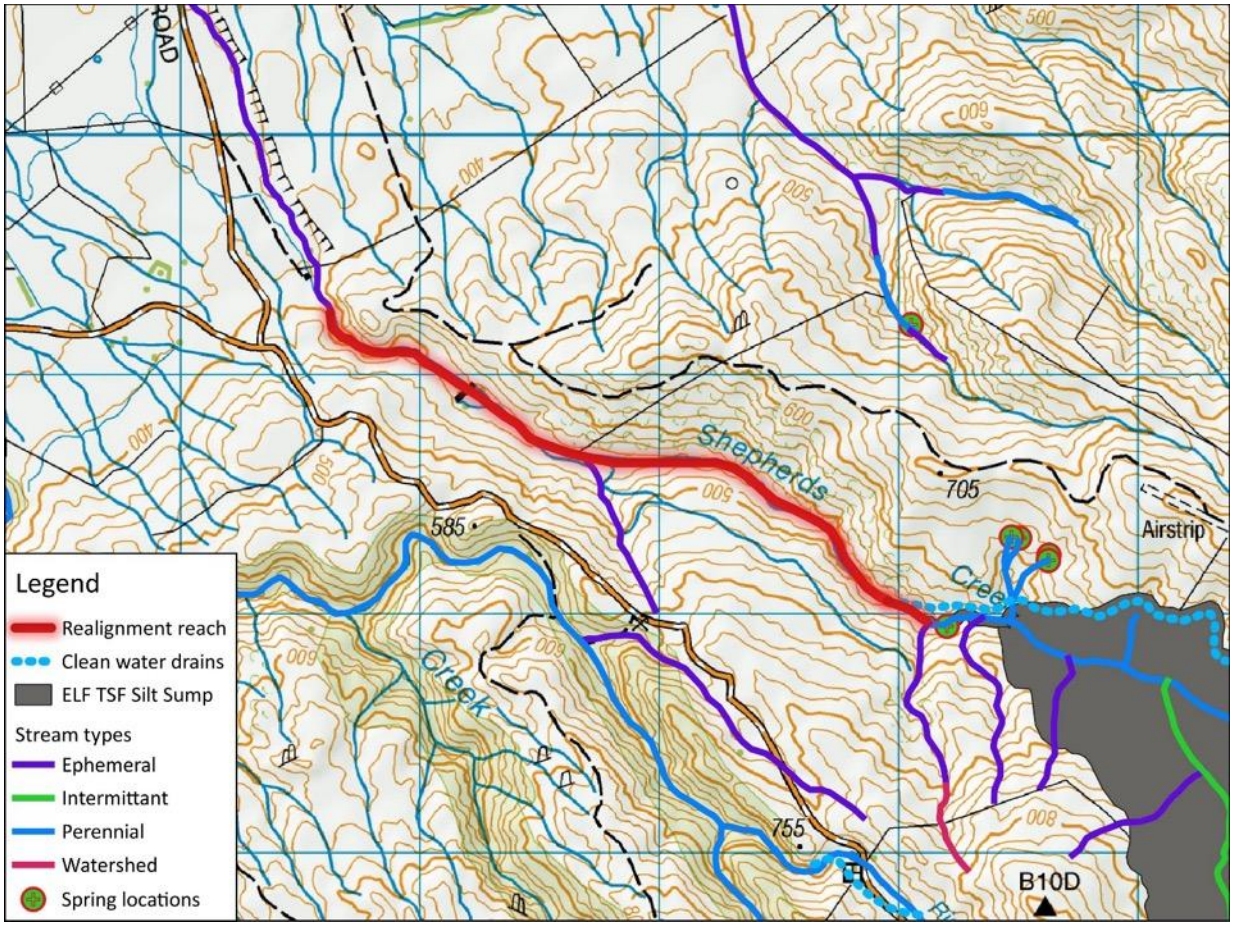

Figure 62: The sections of Shepherds Creek to be realigned.

Stream Habitat Loss Summary

The total stream habitat loss in Shepherds Creek in the TSF, ELF, and mine pits amounts to 13,244 m of water course excluding watersheds (Table 19) and of this 7,139 m is perennial water course. An additional 2,960 m of 2nd order + perennial stream will be realigned to accommodate the process plant and services corridor in Shepherds Creek. This gives rise to direct impacts on 10,099 m of perennial stream.

Table 19: Summary of the length of stream lost or modified in the BOGP footprint.

Stream type	Ephemeral	Intermittent	Minor perennial order	Perennial 2nd order +	Watershed
Stream length lost Shepherd Creek	4,474 m	1,631 m	1,236 m	5,903 m	1,438 m
Stream length realigned, Shepherds Creek	0 m	0 m	0 m	2,960 m	0 m
Stream length lost, Rise and Shine Creek	700 m	0 m	305 m	1,092 m	0 m
Non-permanent stream length loss at soil storage sites	672 m	97 m	19 m	0 m	312 m

6.3. Stream flow, Dewatering Halos and Ephemeral Flow Path Loss

There are three areas of mine activity that can potentially lead to additional impacts to surface flow:

- Mine pit dewatering
- Loss of water in stream diversions; and
- Loss of flow via the ephemeral streams.

These three factors can affect both low and high flow states of the streams.

Each mine pit will have a ground water dewatering operation to remove water from the pit. The connection between surface and ground water means that some surface flow can be lost (temporarily) as the pumping of ground water creates dewatering halos around each pit where surface will infiltrate into the ground to fill void space left by ground water removal. This can lead to the reduction or the loss of surface flow in streams that are flowing over the dewatering halos e.g. creating intermittent streams rather than retaining perennial streams. This impacts both on the habitat in the stream reaches around the mine and further downstream. The diversion of surface water around the mines can help address this issue if water is collected upstream of the dewatering halo, conveyed around the mines and discharged back into the stream downstream of the dewatering halo. This is proposed for the SRX pit which has a relatively short mine life of approximately 2 years.

The stream diversions aim to transfer all the clean water from upstream flow sources around the infrastructure and discharge it into downstream water courses. Quality control during construction and regular inspections during operations should ensure leakage in the diversion pipelines or constructed water courses is avoided. This will be necessary to ensure instream flows are maintained in the perennial streams.

The loss of flow from the ephemeral streams that are lost in mine development can reduce the magnitude and duration of high flow events and may also reduce ground water infiltration. This will be most prominent in the Shepherds Creek catchment, where the majority of these water courses are located. The high flow events are important habitat and aquatic community structuring events and a reduction in flow can reduce stream bed and algal scouring, factors that are important for retaining good instream ecosystem condition. During mining effects of loss of flow from ephemeral streams to Shepherds Creek will be minimised through diversions to capture the water and transfer it back into the creeks.

7. CONCLUSION

The aim of this study was to characterise the streams, aquatic fauna in and adjacent to the Ophir Gold Project (BOGP), to assess the effects of the proposed BOGP- and associated infrastructure on these streams, in particular Shepherds Creek and Rise and Shine Creek. In general, the study found that the ecological value of the Shepherds and Rise and Shine Creeks and associated tributaries varied from moderate-to-high in the upper reaches to moderate-to-low in the lower reaches.

Shepherds Creek

The current extent of modification is limited to the effects of agricultural activity such as stock grazing, and water abstraction. The absence of introduced fish and the limited range of other introduced species suggests most of the stream is currently subject to low to moderate impacts. The presence of

the Ardgour Conservation Area in the headwaters provides a clean water supply to the stream and there is only a low level of nitrogen increase in the farmed perennial reach of Shepherds Creek indicating that stock impacts are more limited to physical damage than to declines in water quality.

Shepherds Creek has a number of tributaries that, aside from Jean Creek, can be divided into two groups: the perennial flowing spring fed streams and the ephemeral streams that have very short duration flow periods. The ephemeral streams do not retain any aquatic macroinvertebrates as the streams flow for very short periods (hours or days) and cannot be successfully colonised by macroinvertebrates. The macroinvertebrate faunas in the small spring fed streams were of low quality and low diversity. The effects of the small stream size, stock damage, mud dominated stream bed and low habitat diversity are expected to be limiting the macroinvertebrate fauna in these spring fed streams. No fish, kourā and kākahi are present in Shepherds Creek

In the wider Dunstan Mountains stream setting Shepherds Creek supports moderately diverse macroinvertebrate fauna but is lacking some of the diversity of taxa that are present in streams with more suitable habitat, such as Clearwater Creek and Bendigo Creek.

Therefore, Shepherds Creek is considered representative of a fishless low gradient Dunstan Mountains perennial small stream. The upper reaches of the creek have moderate to high ecological value and downstream of the gorge section the aquatic values can be considered moderate to low value.

Rise and Shine Creek

The current extent of modification includes the effects of widespread effects of agricultural activity and historic mining means the stream is currently subject to catchment wide low to moderate impacts.

- The stream draining Mt Moka in the upper Rise and Shine catchment is considered a high-quality habitat area, aside from the lower 200 m where historic and present modifications occur.
- Rise and Shine Creek downstream of the Mt Moka Stream confluence is a perennial stream and is considered to have low to moderate ecological value.
- Rise and Shine Creek and its tributaries upstream of the Mt Moka Stream confluence are intermittent and ephemeral water courses.

In Rise and Shine Creek the macroinvertebrate fauna was relatively sparse. The upper reaches of Rise and Shine Creek were mapped as intermittent or ephemeral. The intermittent reaches retain some macroinverterbrates that tolerate the no flow conditions. The ephemeral reaches are not expected to retain any freshwater macroinvertebrates. The absence of any introduced fish or aquatic macroinvertebrates means that while the indigenous macroinvertebrate fauna is limited, it is unimpacted by introduced aquatic species.

By comparison, Bendigo Creek and its tributary Clearwater Creek, that are outside of the project footprint have a diverse high-quality macroinvertebrate communities that reflect the higher quality habitat in these streams.

Assessment of Effects

The total stream loss in Shepherds Creek during mining on stream courses in the proposed Tailings Storage Facility (TSF), Engineered Landforms (ELF), and mine pits amounts to 13,710 m of water course (ephemeral, intermittent and perennial) and of this 8,536 m is perennial water course (Table 19). An additional 2,090 m of 2nd order + perennial stream will be realigned to accommodate the process plant

and services corridor in Shepherds Creek. This gives rise to direct impacts on 10,626 m of perennial stream.

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9. APPENDIX A MACROINVERTEBRATES DETECTED IN EDNA SAMPLES NOV 2022 TO APRIL 2024.

Table 20: Macroinvertebrate taxa detected in eDNA samples from Shepherds Creek between Nov 2022 to April 2024.

Scientific Name	Taxonomic Rank (MCI score)	Shepherds main stem	Shepherds main trib	Shepherds @ intake (Dec)	Shepherds @ intake (Nov)
Crustaceans					
Candona candida	Species (3)	6	0	0	0
Mayflies					
Coloburiscus humeralis	Species (9)	0	0	5	0
Deleatidium	Genus (8)	893	322	1634	324
Caddisflies					
Hudsonema alienum	Species (6)	825	165	941	237
Hydrobiosis chalcodes	Species (5)	16	0	701	18
Hydroptilidae sp.	Species (2)	0	0	611	69
Oeconesus	Genus (9)	25	206	0	0
Oxyethira albiceps	Species (2)	0	0	18	0
Polyplectropus	Genus (8)	8	0	7	0
Polyplectropus puerilis	Species (8)	0	0	63	21
Pycnocentria evecta	Species (7)	9	0	0	0
Stoneflies					
Spaniocerca longicauda	Species (8)	0	27	0	0
Taraperla	Genus (7)	0	34	0	0
Zelandobius truncus	Species (5)	9	0	12	0
Diptera					
Austrosimulium australense	Species (3)	0	0	18	56
Corynoneura scutellata	Species (2)	0	0	1409	44
Cricotopus sp.	Species (2)	0	0	0	26
Limnophyes	Genus (2)	15	10	83	21
Nannochorista philpotti	Species (7)	6	5	0	0
Odonata					
Xanthocnemis zealandica	Species (5)	0	0	10	0
Molluscs					
Gyraulus corinna	Species (3)	0	0	0	6
Physella acuta	Species (3)	0	0	25	0
Potamopyrgus antipodarum	Species (4)	320	426	1863	1124
Platyhelminthes	Family (3)	43	56	142	27
Oligochates					
Chaetogaster	Genus (1)	138	211	3619	3323
Number of taxa detected*		13	10	16	13
Number of EPT taxa detected		7	5	8	5

Number of EPT taxa detected minus Hydrophidiae		7	5	6	4
MCI_{eDNA} score		106.153846	112	86.25	76.9230769

*taxa scores only include a Genus detection in the taxa count if no species of that genera were identified in the eDNA sample.

Table 21: Macroinvertebrate taxa detected in eDNA samples from Bendigo Creek between Nov 2022 to April 2024.

Scientific name	Taxonomic Rank	Upper Bendigo	Bendigo waterfall	Lower Bendigo (Dec)	Lower Bendigo (Nov)
Crustaceans					
Candona candida	Species	0	5	0	0
Canthocamptidae	Family	0	0	8	8
Eucyclops	Genus	10	29	0	0
Dobsonflies					
Archichauliodes diversus	Species	8	291	41	34
Mayflies					
Austroclima jollyae	Species	32	221	25	27
Coloburiscus humeralis	Species	105	0	0	9
Nesameletus ornatus	Species	0	53	0	0
Deleatidium	Genus	552	194	72	79
Caddisflies					
Aoteapsyche colonica	Species	0	112	326	113
Hudsonema alienum	Species	235	0	0	0
Hydrobiosella stenocerca	Species	39	298	6	0
Hydrobiosis	Genus	133	191	162	27
Hydropsyche rarurarau	Species	0	0	14	0
Hydroptilidae sp.	Species	0	0	146	0
Oeconesus	Genus	18	0	0	7
Olinga feredayi	Species	10	64	249	97
Oxyethira albiceps	Species	87	28	0	0
Polyplectropus	Genus	54	251	0	12
Psilochorema bidens	Species	0	30	134	24
Psilochorema macroharpax	Species	0	7	0	0
Pycnocentria evecta	Species	96	99	253	184
Pycnocentrodes	Genus	5	79	180	59
Stoneflies					
Stenoperla	Genus	0	17	0	0
Taraperla	Genus	20	11	0	24
Diptera					
Aedes	Genus	0	17	0	0
Austrosimulium australense	Species	0	0	17	63
Chironomidae	Family	5	70	578	157

Cricotopus sp.	Species	0	17	67	38
Limnophyes	Genus	0	17	8	0
Orthocladiinae	Subfamily	0	0	8	0
Paratanytarsus grimmii	Species	494	0	0	0
Tanytarsus sp.	Species	0	39	0	19
Molluscs					
Potamopyrgus antipodarum	Species	282	230	801	332
Sphaerium novaezelandiae	Species	0	0	0	26
Platyhelminthes	Family	1826	40	53	0
Oligochates					
Chaetogaster	Genus	2543	597	4111	1439
Number of taxa detected*		21	25	20	22
Number of EPT taxa detected		13	15	10	12
Number of EPT taxa detected minus Hydrophidiae		12	14	9	12
MCI_{eDNA} score		112.4	112	92	110

Table 22: Macroinvertebrate taxa detected in eDNA samples from Rise and Shine Creek between Nov 2022 to April 2024.

Scientific Name	Taxonomic Rank	Rise & Shine u/s Mt Moka tributary	Mt Moka Stream	Mt Moka Stream	Rise and Shine d/s Dam
Crustaceans					
Canthocamptidae	Family	0	0	0	44
Harpacticoida	Order	28	13	7	0
Mayflies					
Deleatidium	Genus	266	159	62	148
Caddisflies					
Hudsonema	Genus	35	0	0	7
Hudsonema alienum	Species	38	26	14	33
Hydrobiosella stenocerca	Species	5	0	0	0
Hydrobiosis chalcodes	Species	10	0	0	0
Oeconesus	Genus	22	23	0	0
Diptera					
Austrosimulium australense	Species	0	0	0	22
Austrosimulium ungulatum	Species	0	29	0	0
Chironomidae	Family	44	0	0	54
Limnophyes	Genus	0	0	0	6
Odonata					
Xanthocnemis zealandica	Species	0	0	0	8
Molluscs					

Potamopyrgus antipodarum	Species	321	65	70	116
Platyhelminthes	Family	547	896	27	81
Oligochates					
Chaetogaster	Genus	5303	367	216	1823
Number of taxa detected*		10	8	6	10
Number of EPT taxa detected		5	3	2	2
Number of EPT taxa detected minus Hydrophidiae		5	3	2	2
MCI$_{eDNA}$ score		104	97.5	90	78

Table 23: Macroinvertebrate taxa detected in eDNA samples from Clearwater Creek between Nov 2022 to April 2024.

Scientific Name	Taxomonic Rank	Lower Clearwater	Upper Clearwater	Upper Clearwater	Upper most Clearwater
Crustaceans					
Acanthocyclops robustus	Species	6	0	0	0
Candona candida	Species	0	0	0	10
Eucyclops	Genus	0	14	0	85
Paracyclops fimbriatus	Species	36	0	0	0
Penthesilenula kohanga	Species	0	0	0	8
Dobsonfly					
Archichauliodes diversus	Species	0	108	47	31
Mayflies					
Austroclima jollyae	Species	0	1248	957	2367
Coloburiscus humeralis	Species	0	1618	1618	2029
Deleatidium	Genus	28	316	428	762
Nesameletus ornatus	Species	0	0	8	16
Caddisflies					
Aoteapsyche colonica	Species	0	529	458	396
Hudsonema alienum	Species	77	66	63	8
Hydrobiosella stenocerca	Species	0	680	833	503
Hydrobiosis	Genus	32	155	85	398
Hydroptilidae sp.	Species	9	0	0	8
Olinga	Genus	0	75	339	112
Olinga feredayi	Species	0	62	0	0
Oxyethira albiceps	Species	7	0	0	0
Polyplectropus	Genus	138	42	38	16
Psilochorema macroharpax	Species	0	0	47	0
Pycnocentria evecta	Species	21	222	296	110
Pycnocentrodes	Genus	0	34	8	8

Stoneflies					
Cristaperla waharoa	Species	0	46	187	35
Taraperla	Genus	0	0	23	9
Zelandobius	Genus	0	0	0	18
Zelandoperla fenestrata	Species	0	8	15	0
Diptera					
Austrosimulium australense	Species	0	0	0	34
Chironomidae	Family	0	0	0	9
Cricotopus sp.	Species	0	83	68	0
Culicidae	Family	0	0	0	55
Dixa	Genus	0	46	0	24
Forcipomyia	Genus	0	13	0	0
Limnophyes	Genus	9	0	0	0
Orthocladiinae	Subfamily	0	0	0	7
Tanytarsus sp.	Species	0	0	10	0
Coleoptera					
Hydraenidae	Family	0	18	17	0
Molluscs					
Potamopyrgus antipodarum	Species	61	9	0	0
Platyhelminthes	Family	105	448	232	80
Oligochates					
Chaetogaster	Genus	2248	1059	218	1059
Number of taxa detected*		13	22	22	27
Number of EPT taxa detected		7	13	16	16
Number of EPT taxa detected minus Hydrophidiae		5	13	16	15
MCI_{eDNA} score		89.2	121.8	131.8	108.1

10. APPENDIX B MACROINVERTEBRATES DETECTED IN EDNA SAMPLES SEPTEMBER 2024.

Table 24: Macroinvertebrate taxa detected in eDNA samples from lower Shepherds Creek, September 2024.

Scientific Name	Taxonomic Rank (MCI score)	Shepherds at intake B eDNA1	Shepherds u/s pond B eDNA2	Shepherds gorge B eDNA3	Shepherds Creek u/s gorge B eDNA5
Crustaceans					
Candona candida	Species (3)	0	0	0	87
Paracyclops fimbriatus	Species (3)	52	0	0	0
Eucyclops	Genus (5)	0	7	0	0
Insecta					
Dobsonflies					
Archichauliodes diversus	Species (7)	0	24	21	129
Mayflies					
Coloburiscus humeralis	Species (9)	0	0	0	62
Deleatidium	Genus (9)	331	426	1557	1429
Nesameletus ornatus	Species (9)	0	0	133	0
Caddisflies					
Aoteapsyche colonica	Species (4)	0	0	168	42
Hudsonema alienum	Species (6)	153	372	286	432
Hydrobiosis chalcodes	species (5)	38	0	0	7
Hydrobiosis	Genus (5)	0	0	92	58
Pycnocentrodes	Genus (5)	0	11	45	18
Pycnocentria evecta	species	0	23	406	207
Oeconesus	Genus (9)	0	7	150	131
Polyplectropus	Genus (8)	0	0	22	14
Stoneflies					
Taraperla	Genus (7)	0	199	225	22
Zelandobius	Genus (5)	29	11	0	40
Diptera					
Bryophaenocladius sp.	Species (2)	0	31	41	0
Chironomus	Genus (1)	1494	0	32	0
Cricotopus sp. NzeP20	Species (2)	5	38	0	14
Limnophyes	Genus (2)	14	99	8	15
Scorpion flies					
Nannochorista philpotti	Species (7)	0	9	0	53
Damselflies					
Xanthocnemis zealandica	Species (5)	17	0	0	0
Molluscs					

Potamopyrgus antipodarum	Species (4)	241	382	170	157
Flatworms					
Dugesiidae	Family (1)	187	80	445	388
Oligocheates					
Aquatic worms	Subclass 1	1	1	1	1
Number of taxa detected*		10	13	15	14
Number of EPT taxa detected		3	6	8	9
Number of EPT taxa detected minus Hydrophidiae		3	6	8	9
MCI_{eDNA} score		64.00	89.23	82.67	101.43
TICI		105.88	110.77	111.03	101.09

Table 25: Macroinvertebrate taxa detected in eDNA samples from upper Shepherds Creek and tributaries, September 2024.

Scientific Name	Taxonomic Rank (MCI score)	Shepherds Creek B eDNA8	Shepherds Creek B eDNA9	Shepherds Creek @ DOC boundary B eDNA7	Shepherds Creek RAS Pit trib B eDNA4	Shepherds Creek Spring fed trib B eDNA6
Crustaceans						
Candona candida	Species (3)	25	8	0	0	0
Paracyclops fimbriatus	Species (3)	0	0	0	27	0
Insecta						
Dobsonflies						
Archichauliodes diversus	Species (7)	0	11	0	0	0
Mayflies						
Deleatidium	Genus (9)	525	1262	975	0	5
Caddisflies						
Aoteapsyche colonica	Species (4)	0	0	0	0	0
Hudsonema alienum	Species (6)	119	346	90	18	0
Hydrobiosis chalcodes	species (5)	0	11	0	0	0
Pycnocentria evecta	species	0	10	0	0	0
Oeconesus	Genus (9)	162	132	73	0	22
Pseudoeconesus stramineus	Species (9)	37	0	187	0	0
Stoneflies						
Taraperla	Genus (7)	235	51	0	0	0

Zelandobius	Genus (5)	28	49	0	0	0
Spaniocerca longicauda	Species (8)	32	0	0	0	0
Diptera						
Bryophaenocladius sp. (Chironomidae)	Species (2)	0	21	0	0	0
Chironomus (Chironomidae)	Genus (1)	0	0	0	274	85
Austrosimulium australense	Genus (3)	0	0	0	0	22
Dixella	Genus (4)	0	0	6	0	0
Scorpion flies						
Nannochorista philpotti	Species (7)	31	13	14	0	0
Molluscs						
Potamopyrgus antipodarum	Species (4)	40	146	15	76	316
Flatworms						
Dugesiidae	Family (1)	966	323	695	0	23
Oligocheates						
Aquatic worms						
Number of taxa detected*		10	11	8	5	6
Number of EPT taxa detected		6	6	3	1	1
Number of EPT taxa detected minus Hydrophidiae		6	6	3	1	1
MCI_{eDNA} score		114.00	98.18	102.50	52.00	63.33
TICI		114.67	110.96	114.74	107.28	108.35

Table 26: Macroinvertebrate taxa detected in eDNA samples from Rise & Shine Creek and Clearwater Creek, September 2024.

Scientific Name	Taxonomic Rank (MCI score)	Clearwater d/s of Rise & Shine confluence B eDNA14	Rise & Shine d/s pond B eDNA10	Rise & Shine u/s pond and road B eDNA13	Rise & Shine Mt Moka trib B eDNA11	Rise & Shine main u/s Mt Moka B eDNA12
Crustaceans						
Acanthocyclops robustus	Species (5)	53	86	0	0	0
Candona candida	Species (3)	77	0	0	0	0
Paracyclops fimbriatus	Species (5)	22	0	0	0	0

Eucyclops	Genus (5)	72	0	0	0	0
Cryptocandona	Genus (3)	0	0	5	0	5
Allorchestes	Genus (5)	0	0	0	6	0
Dobsonflies						
Archichauliodes diversus	Species (7)	43	0	0	0	0
Mayflies						
Austroclima jollyae	Species (9)	374	0	0	0	0
Coloburiscus humeralis	Species (9)	1074	0	0	0	0
Deleatidium magnum	Species (8)	16	0	0	0	0
Deleatidium	Genus (8)	1109	0	0	1359	0
Nesameletus ornatus	Species (9)	85	0	0	0	0
Caddisflies						
Aoteapsyche colonica	Species (4)	52	0	0	0	0
Hudsonema alienum	Species (6)	150	130	150	266	0
Hudsonema	Genus (6)	0	0	102	199	9
Hydrobiosella	Genus (9)	57	0	0	0	0
Hydrobiosis chalcodes	Species (5)	0	0	0	45	0
Hydrobiosis	Genus (5)	58	0	0	0	0
Olinga feredayi	Species (9)	131	0	0	0	0
Olinga	Genus (9)	94	0	0	0	0
Pycnocentria evecta	Species (7)	484	0	0	0	0
Oeconesus	Genus (9)	201	0	0	285	0
Pseudoeconesus stramineus	Species (9)	0	0	0	47	0
Psilochorema macroharpax	Species (8)	60	0	0	0	0
Polyplectropus	Genus (8)	48	0	0	0	0
Stoneflies						
Taraperla	Genus (7)	42	0	0	13	0
Zelandobius	Genus (5)	0	0	0	15	0
Zelandoperla fenestrata	Species (10)	0	0	0	10	0
Diptera						
Bryophaenocladius sp. 8ES	Species (2)	0	0	0	15	0
Smittia sp. 8ES	Species	46	0	0	7	0
Smittia	Genus	29	0	0	0	0
Austrosimulium australense	Species (3)	0	0	0	0	23

Austrosimulium ungulatum	Species (3)	44	0	0	0	0
Limnophyes	Genus (2)	0	0	18	0	11
Dixella	Genus (4)	10	0	0	0	0
Parochlus	Genus (2)	24	0	0	27	409
Scorpion flies						
Nannochorista philpotti	Species (7)	0	0	0	30	0
Molluscs						
Potamopyrgus antipodarum	Species (4)	426	87	210	245	2166
Sphaerium novaezelandiae	Species (3)	1600	45	0	0	0
Euglesa	Genus (3)	0	0	0	0	25
Flatworms						
Dugesiidae	Family (1)	156	24	321	438	119
Number of taxa detected		15	5	5	12	8
Number of EPT taxa detected		8	1	1	7	1
Number of EPT taxa detected minus Hydrophidiae		8	1	1	7	1
MCI_{eDNA} score		102.67	64.00	60.00	103.33	57.50
TICI		113.95	106.89	110.44	113.11	107.91

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