

**Ghost Watershed
Water Monitoring Program
CABiN Project
2024**



BIOTA CONSULTANTS

A division of Aspen Croft Holdings Ltd.

March 2025

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Water Monitoring Program
CABiN Project
2024

Unpublished report submitted to:
Ghost Watershed Alliance Society
Cochrane, Alberta

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March 2025

Acknowledgements

Funding for this project was provided by the Department of Fisheries and Oceans Canada - Habitat Stewardship Program, Land Stewardship Centre, and Forest Resource Improvement Association - Forest Resource Improvement Program, which is sponsored by Bow River Basin Council and West Fraser Cochrane. The Executive Director of the Ghost Watershed Alliance Society, Marina Krainer, provided administrative and logistical support.

Professional and technical support was provided by Cordillera Consulting for the benthic macroinvertebrate taxonomic analysis. Equipment support was provided by Oak Environmental Inc. (Calgary, Alberta).

The field work could not have been completed without the help of volunteers. Special thanks to Emma Chong, Cal Hill, Anne Holcroft-Weerstra, Brooke Kapeller, Marina Krainer, Karen Laustsen, Carol Maichle, Bob McAlpine and Karoliina Munter.

We are very grateful to those who reviewed the draft report and provided helpful comments and suggestions, namely Cal Hill, Sharlene Fritz, Bob McAlpine and Karoliina Munter. Editing services were provided by Anne Holcroft-Weerstra.

Cover photo credit: Cal Hill – Waiparous Creek, looking upstream from WAP03 site

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Suggested citation:

Biota Consultants. 2025. Ghost Watershed Water Monitoring Program CABiN Project 2024. Report to Ghost Watershed Alliance Society, Cochrane, Alberta. 71 pp.

Executive Summary

The Ghost Watershed Alliance Society (GWAS) began a water monitoring program in 2020 to aid in determining aquatic ecosystem health. This followed a recommendation in the *Ghost River State of the Watershed Report 2018* to sample aquatic invertebrates using the Canadian Aquatic Biomonitoring Network (CABiN) protocols, and using Ephemeroptera, Plecoptera and Trichoptera (EPT) ratios as a proxy for water quality.

In 2019, GWAS began participation in the STREAM (Sequencing the Rivers for Environmental Assessment and Monitoring) three-year pilot project, which uses CABiN methods to collect samples to identify benthic macro-invertebrates using environmental DNA (eDNA). GWAS then developed a multi-year water monitoring plan that incorporated the STREAM pilot project as well as the traditional CABiN sampling for morphological analysis. The latter provided data on benthic macro-invertebrate abundance, required to determine the EPT ratio, among other metrics. The STREAM project ended in 2023, and no samples were collected in 2024 for eDNA analysis.

The water monitoring program began in the fall of 2020 when Biota Consultants was contracted to oversee the sampling of ten sites, eight along Waiparous Creek and two on the Ghost River. In the second year of the program, the focus was the Ghost River, but included one site on Johnson Creek (JOH01), whose headwaters had been affected by the Devil's Head/Black Rock wildfire in fall, 2020. In addition, two sites on Waiparous Creek below and above the confluence with Johnson Creek, WAP02 and WAP03, were resampled.

In 2022, the focus of the sampling program was tributaries of Waiparous Creek. This included resampling the Johnson Creek site from 2021, as well as sites WAP02 and WAP03. Human disturbance to the channel precluded sampling WAP02 at exactly the same location as in previous years. Instead a site slightly upstream was sampled and referred to as WAP02a. In 2023 and 2024, key sites were resampled, and additional sites were added. Another focus in 2024 was sampling further potential reference sites to be used in a reference model.

Based on lab analyses and direct measurements, water quality in 2024 was within the parameters acceptable to benthic macroinvertebrates and fish. The chemical and physical attributes were within the guidelines for the protection of freshwater aquatic life. Dissolved nitrogen and nitrate have risen at JOH01 over the four years of sampling, which may suggest

nutrient loading. At the Aura Creek site there was a steady increase in total suspended solids, turbidity, carbonates and alkalinity, and a slight increase in phosphorus and dissolved nitrogen, that could be attributed to the logging activity upstream. There was also an increase in embeddedness in 2024, and an overall decrease in particle size, suggesting greater sediment.

The Hilsenhoff Biotic Index suggests there was possible slight organic enrichment at all but one site (water quality rating of very good). The Lost Knife Creek site (LOS01) was rated as fair with an index of 5.89, suggesting fairly substantial organic enrichment is likely. This corresponds to the stream substrate, since organic material is more easily stored in finer substrates.

The Simpson's Index of Diversity and the Shannon-Wiener Index indicate the sites were diverse in their community composition. The EPT ratio suggests high water quality at most of the sites, with EPT species more abundant than the pollution-tolerant chironomid family. The ratio remained moderate at JOH01 (0.61) but increased from previous years at JOH02 and LES02. The anomaly again was LOS01, at only 0.13; however, this may be related more to stream characteristics than water quality. Lost Knife Creek was very different from any of the other creeks sampled. It was very narrow, with a largely silty bottom and overhanging vegetation. Few EPT species are adapted to sandy and silty substrates, whereas many chironomid species are. On a positive note, none of the few Trichoptera at LOS01 were the more tolerant Hydropsychidae and a low percentage of the Ephemeroptera were the more tolerant Baetidae.

The proportion of functional feeding groups (FFGs) varied among the sites, reflecting the habitat and adjacent riparian vegetation. Scrapers dominated or were prominent in Aura Creek and Waiparous Creek, suggesting more algae; collector-gatherers were prominent at LES02, LOS01, WAP02a, WAP03 and the Johnson Creek sites, suggesting greater sediment; shredders were highest at the Lesueur Creek sites, suggesting greater leaf litter.

Conditions at the lower Lesueur Creek site (LES02) raised potential concerns in 2023; however, total suspended solids and turbidity were lower in 2024, and the EPT ratio increased. Also, water quality with respect to organic enrichment or pollution improved slightly. There was also a decline in carbonates and alkalinity and a slight increase in nitrogen, which may warrant monitoring.

The Johnson Creek sites also raised concerns in 2023. The EPT ratio rose at JOH02, but remained moderate at JOH01. Both sites had a high proportion of the more tolerant Baetidae (within the order Ephemeroptera), and a low proportion (or none) of the more tolerant Hydropsychidae (within the order Trichoptera).

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1.0 Introduction

1.1 Background

The mission of the Ghost Watershed Alliance Society (GWAS) is to protect the integrity of the Ghost Watershed. One means of accomplishing this is to monitor water quality to determine aquatic ecosystem health. This was a recommendation in the *Ghost River State of the Watershed Report 2018* (ALCES and GWAS 2018), specifically sampling aquatic invertebrates as per the Canadian Aquatic Biomonitoring Network (CABiN) protocols, and using Ephemeroptera, Plecoptera and Trichoptera (EPT) ratios as a proxy for water quality. CABiN methods include assessing physical and chemical parameters, and collecting benthic macroinvertebrates for morphological analysis to determine species abundance and diversity.

One site on Waiparous Creek was sampled as part of the field course in July, 2019 (WAP01). During the spring and summer of 2020, the GWAS CABiN team developed a strategic multi-year plan (*GWAS Water Monitoring Program Plan 2020*) to obtain information on the health of water courses within the Ghost River watershed. The intent was to augment existing information and to assist public land managers and other organizations tasked with water management responsibilities. This plan is a living document and continues to be updated. It adopts water quality indicators as per the CABiN protocol, using the *CABiN Field Manual – Wadeable Streams* (Environment Canada 2012).

The water monitoring program began in the fall of 2020 when ten sites were sampled, eight along Waiparous Creek (WAP02 to WAP09) and two on the Ghost River (GHO01 and GHO02). In this first year of the plan, the focus was mainly on sites above and below creek tributaries and other possible point source sites that might affect water quality as a result of land use activities (see Biota Consultants 2022a). In the second year (2021), the focus was the Ghost River (sites GHO03 to GHO07), with a slight modification due to the Devil’s Head/Black Rock wildfire (CWF-156-2020)¹, which occurred in the fall of 2020 (see Biota Consultants 2022b). Since the fire encroached on the southwest fork of the headwaters of Johnson Creek, which is in the Waiparous Creek sub-basin, it was decided to sample this creek above its confluence with Waiparous Creek (JOH01). In 2022, tributaries to Waiparous Creek were sampled: Aura Creek (AUR01), Meadow Creek (MEA01), Lookout Creek (LOO01) and Margaret Creek (MAR01). In addition, Johnson Creek (JOH01) was resampled. In 2023, the focus was to add to the inventory

¹ Code assigned by Alberta Agriculture and Forestry.

of sites and to resample key sites to provide further monitoring data and information on variability. These sites included GHO06, AUR01, WAP02/02a and WAP03. The latter two sites, located below and above the confluence with Johnson Creek, had also been resampled in 2021 and 2022.

1.2 Field Plan

The water monitoring program in 2024 had a number of objectives. One was to resample key sites again, specifically WAP02/02a, WAP03/03a, JOH01, JOH02 and AUR01. A second objective was to sample above and below another point source that might affect water quality as a result of land use activities, specifically a random campsite on Lesueur Creek. A third objective was to sample above and below a reclamation site by a bridge over Waiparous Creek. Lastly, there was an effort in 2024 to sample potential reference sites, i.e., sites where little or no human activity affected the site, to be used in a reference model (see section 1.3). Only one new site potentially met these criteria, on Lost Knife Creek, which was added to the sampling sites for the year.

In previous years, samples were taken for morphological analysis and additional samples were taken for environmental DNA (eDNA) analysis as part of the STREAM (Sequencing the Rivers for Environmental Assessment and Monitoring) pilot project. The STREAM samples were sent to the Hajibabaei Lab at the Centre for Biodiversity Genomics (University of Guelph). Rather than quantifying abundance, eDNA testing determines the presence or absence of benthic macroinvertebrate species. The pilot project ended in 2023, therefore in 2024, samples were only collected for morphological analysis.

1.3 Reference Sites and Reference Model

Unless otherwise indicated, the information in this section is taken from Module 1 - *Introduction to CABIN* of the 2019 CABiN training course.

Two types of sites are sampled in CABiN, reference sites and test sites. Ideally, reference sites are at least minimally affected by human (post-European) activities, whereas the health of test sites is suspected to be compromised by human activities. Reference sites, therefore, represent healthy ecosystems with which test sites can be compared to determine if they are within the natural range of environmental variability, or are likely affected by anthropogenic impacts. Reference sites should represent the range of natural conditions (biota and habitat) in the area being sampled.

In some areas, such as the Ghost River watershed, the only sites with little or no anthropogenic impacts tend to be at higher elevations, and it is difficult to find undisturbed sites at lower elevations with which to compare test sites. It may then be justifiable to use sites with less intense impacts as reference sites, representing “best available” or “least disturbed” conditions.

Reference sites are used to create a CABiN reference condition model. This predictive model requires a large number of reference sites that represent the variety of ecoregions or physiographic zones within the study area. In 2024, the Miistakis Institute was contracted by the Oldman Watershed Council on behalf of the Eastern Slopes Collaborative² to identify areas within the eastern slopes of Alberta where reference conditions potentially exist (Sinnatamby and Sanderson 2024). Watersheds were divided according to the designated national ecoregion (Ecological Stratification Working Group 1995), and human activity gradient (HAG) scores were calculated and placed into ten categories. Recent wildfires were taken into account, along with anthropogenic point sources within 100 m of a stream or river. Potential sites were further refined by accepting HAG scores no higher than 4. With this information, the members of the Eastern Slopes Collaborative could focus their search for potential reference sites within each of their watersheds.

Potential reference sites previously had been identified and sampled in the GWAS Water Monitoring Program, including JOH02 which was above most OHV activity near Johnson Creek. The uppermost site on Waiparous Creek, WAP09, also was considered a potential site, as was the uppermost site on the Ghost River, GHO06, which was above the extent of the Devil's Head/Black Rock wildfire and is located within the Ghost River Wilderness Area. None of these three sites were within polygons identified by Sinnatamby and Sanderson (2024) containing acceptable levels of disturbance. However, four sites previously sampled were within these polygons, with HAG scores of 1 to 4, including AUR01. The recent clearcuts above AUR01 would clearly disqualify it now, apart from nearby OHV activity. Therefore it was recognized that the Miistakis Institute report should be used only as a guideline, since those familiar with the watershed are better able to make final judgements. Unfortunately, many potential reference sites are difficult or expensive to access, reducing the number that can be sampled.

² The Eastern Slopes Collaborative is a consortium of Watershed Planning and Advisory Councils, watershed stewardship groups (including GWAS), First Nations land managers and other interested parties who seek to improve the watershed through education, monitoring, planning and action. Working together, a community-based aquatic monitoring program was developed across the eastern slopes using the CABiN sampling protocol to assess local community needs, share expertise and resources, and secure additional resources as required. The collaborative also is tasked with developing a reference model for the eastern slopes that can be used for assessing test sites using the Reference Condition Approach.

2.0 Methods

2.1 Field Sampling

The field sampling followed the same CABiN protocols as in 2020, described in *Ghost Watershed Water Monitoring Program CABiN/STREAM Project 2020* (Biota Consultants 2022a). A YSI-DSS multimeter again was rented from Oak Environmental Inc., who calibrated it prior to field use, to measure water temperature, dissolved oxygen, specific conductance and pH. Other water properties were measured in the lab by Bureau Veritas in Calgary, Alberta.

Field sampling occurred between August 27th and September 6th when there was low stream flow and mainly stable sunny weather conditions. The CABiN Field Sheet is included in Appendix A. Site locations are mapped in Figure 1, and site name codes, date of sampling, and geographic locations are presented in Table 1. Air and water temperatures at the time of sampling are provided.

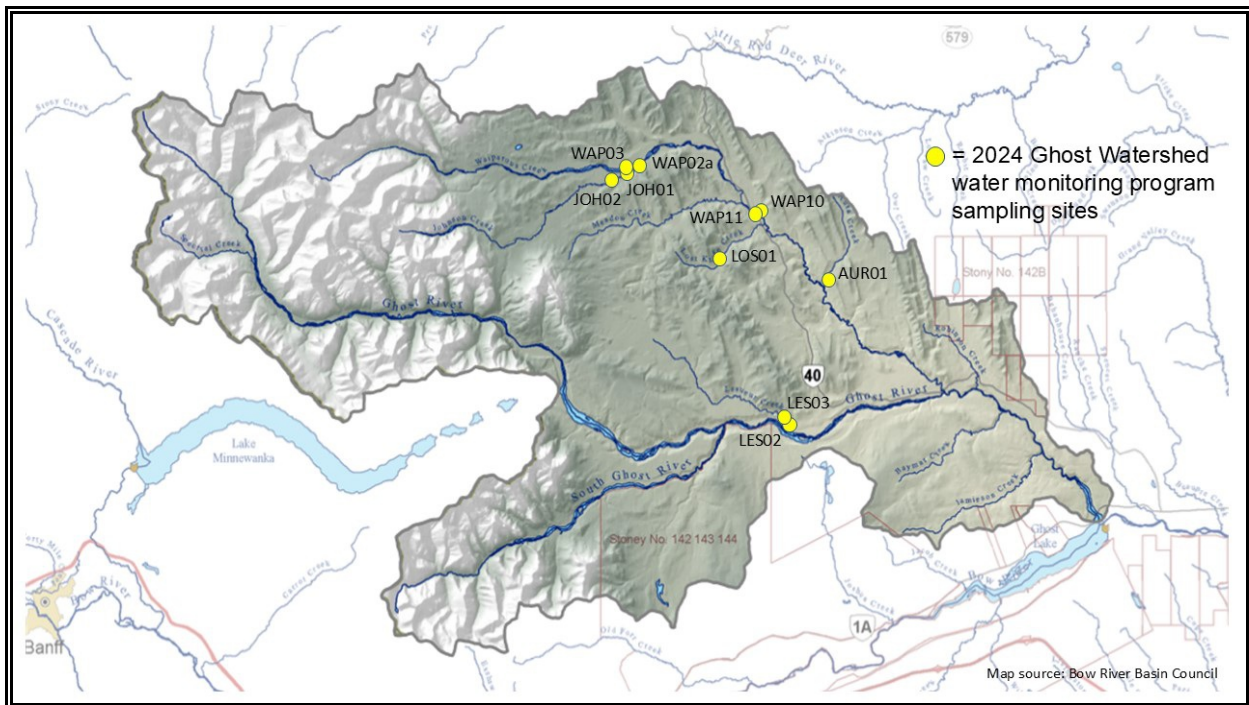


Figure 1. Sampling locations in 2024 within the Ghost River watershed.

Table 1. Location of sites sampled in 2024, plus sampling date, time of day, and conditions.

Code/ Date	Latitude	Longitude	Elevation (m)	Comments
WAP02a Aug. 27	51.39415°	-115.085950°	1560	Waiparous Creek below confluence with Johnson Creek Sampled in morning Sun and cloud, air temperature 21.0°C, water temperature 12.4°C
WAP03 Aug. 27	51.39254°	-115.08916°	1557	Waiparous Creek above confluence with Johnson Creek Sampled in afternoon Sun and cloud, air temperature 20.5°C, water temperature 13.2°C
JOH01 Aug. 27	51.39151°	-115.08939°	1561	Johnson Creek above confluence with Waiparous Creek Sampled in afternoon Sun and cloud, air temperature 19.5°C, water temperature 12.2°C
JOH02 Aug. 30	51.38666°	-115.10658°	1583	Johnson Creek above former "Johnson bog" Sampled in morning Mostly cloudy, air temperature 16.5°C, water temperature 6.2°C
LOS01 Sept. 3	51.34673°	-115.01988°	1509	Lost Knife Creek south (upstream) of bridge on OHV trail Sampled in afternoon Sunny, air temperature 22.0°C, water temperature 9.2°C
AUR01 Sept. 4	51.33436°	-114.93511°	1380	Aura Creek above confluence with Waiparous Creek Sampled in morning Cloudy, air temperature 16.5°C, water temperature 11.4°C
WAP10 Sept. 5	51.36885°	-114.98969°	1432	Waiparous Provincial Recreation Area, downstream of Hwy 40 bridge and upstream of OHV bridge Sampled in morning Sunny, air temperature 24.0°C, water temperature 9.5°C
WAP11 Sept. 5	51.36783°	-114.99341°	1432	Across highway from Waiparous Provincial Recreation Area, upstream of Hwy 40 bridge Sampled in afternoon Sunny, air temperature 23.0°C, water temperature 13.6°C
LES02 Sept. 6	51.26537°	-114.96748°	1364	Lesueur Creek above confluence with Ghost River Sampled in morning Sunny, air temperature 13.0°C, water temperature 9.1°C
LES03 Sept. 6	51.26757°	-114.96709°	1373	Lesueur Creek upstream of TransAlta Road bridge Sampled in afternoon Sunny, air temperature 26.0°C, water temperature 13.5°C

In 2022, WAP02 could not be sampled in the exact location as the previous two years and a site slightly upstream was sampled instead, referred to as WAP02a. This new site was sampled in subsequent years. In 2023, the same issue arose with WAP03 due to natural fluvial action and low stream flow, and the upstream site sampled was labelled WAP03a. In 2024, further natural fluvial action allowed the original WAP03 site to be sampled (see section 3.1.4).

When sampling the paired sites on Waiparous Creek and the two sites on Johnson Creek, the downstream site (i.e., WAP02a, WAP10, JOH01) was sampled prior to the upstream site (i.e., WAP03, WAP11, JOH02) to ensure the downstream site was not disturbed by upstream activities (although JOH02 was sampled three days after JOH01).

Biological sampling followed the CABiN/STREAM protocols used in 2020 (Biota Consultants 2022a), with a minor modification. As in 2021 and following years, the sample jars were sealed by winding a strip of parafilm tightly around the outside of the jar and lid. The description of physical attributes of each site and the collection of water chemistry data followed the same protocols described by Biota Consultants (2022a).

2.2 Data Entry

All of the data, except the benthic macroinvertebrate community structure information, were entered into the CABiN database by the Project Manager. To reduce potential errors, the morphologic consultant (Cordillera Consulting Inc.) uploaded the benthic macroinvertebrate community data into the database.

3.0 Results and Discussion

3.1 Physical Characteristics

The physical characteristics of the ten sample sites are presented in Table 2, ordered from downstream to upstream within the watershed. Substrate embeddedness refers to how deeply the dominant substrate is buried in the surrounding finer particles. Five categories of substrate embeddedness³ were used. In areas modified by streamside activities (anthropogenic land uses), increased erosion can result in the accumulation of fine material in the interstitial spaces. The more embedded the substrate, the fewer interstitial spaces for macroinvertebrates to occupy, which can reduce productivity (Environment Canada 2012).

³ Embedded Categories: 1) Completely embedded: 100% embedded; 2) 75% embedded; 3) 50% embedded; 4) 25% embedded; 5) 0% embedded

Table 2. Physical characteristics of the 2024 sample sites.

Attributes	Site									
	LES02	LES03	AUR01	LOS01	WAP10	WAP11	WAP02a	WAP03	JOH01	JOH02
Elevation (m)	1364	1373	1380	1509	1432	1432	1560	1560	1561	1583
Bankfull width (m)	6.32	5.16	5.20	1.26	19.90	19.44	16.20	19.20	9.10	7.34
Wetted width (m)	3.80	4.57	2.53	1.08	17.80	16.80	8.72	9.40	5.69	5.42
Bankfull wetted depth (cm)	6.1	15.6	23.3	14.5	39.0	25.2	14.0	27.5	23.0	33.0
Maximum channel depth (cm)	12.5	12.8	6.8	23.6	28.5	36.5	37.5	31.6	28.2	21.2
Average channel depth (cm)	8.0	9.8	4.8	22.4	20.6	21.3	26.7	21.8	20.7	17.8
Maximum velocity (m/s)	0.6419	0.5050	0.5050	0.2426	1.2291	1.1803	1.4285	1.3214	1.2606	1.1968
Average velocity (m/s)	0.4039	0.4175	0.4137	0.0957	1.0080	1.0455	1.2244	0.9192	1.0300	0.9910
Slope (m/m)	0.0165	0.0033	0.0231	0.0020	0.0082	0.0038	0.0092	0.0650	0.0120	0.0556
Substrate embeddedness (%)	50	25	50	0	0	0	25	25	25	0
Dominant substrate (cm)	1.6-3.2	3.2-6.4	1.6-3.2	<0.1	1.6-3.2	1.6-3.2	3.2-6.4	3.2-6.4	6.4-12.8	3.2-6.4
2 nd dominant substrate (cm)	3.2-6.4	6.4-12.8	3.2-6.4	0.2-1.6	3.2-6.4	3.2-6.4	6.4-12.8	6.4-12.8	3.2-6.4	1.6-3.2
Surrounding material (cm)	0.2-1.6	0.2-1.6	0.2-1.6	<0.1	0.1-0.2	0.1-0.2	0.2-1.6	0.2-1.6	0.1-0.2	0.1-0.2
Geometric median particle size (cm)	3.6	3.8	2.8	0.2	2.5	3.1	6.3	6.4	6.3	3.5
% Silt/clay	0	0	0	60	0	0	0	0	0	0
% Sand	0	0	0	0	0	0	0	0	0	0
% Gravel	11	8	12	37	17	11	2	2	4	6
% Pebble	61	62	81	1	78	79	50	48	41	83
% Cobble	27	28	7	2	3	10	45	42	54	11
% Boulder	0	1	0	0	0	0	3	4	1	0
% Bedrock	1	1	0	0	2	0	0	4	0	0

Note: Sand = fine sand, silt or clay (<0.1 cm), coarse sand (0.1 - 0.2 cm); Gravel = 0.2 - 1.6 cm; Pebble = small (1.6 - 3.2 cm), large (3.2 - 6.4 cm); Cobble = small (6.4 - 12.8 cm), large (12.8 - 25.6 cm); Boulder = >25.6 cm.

The Lost Knife Creek site, LOS01, had the lowest width and velocity of all sites sampled to date, and the finest substrate. In the following sections, those sites that have been sampled more than once are discussed.

3.1.1 Lesueur Creek

The lowermost site on Lesueur Creek (LES02) was situated approximately 95 m downstream of the TransAlta Road bridge and 500 m above the confluence with the Ghost River. A random campsite was on the north side of the bridge beside the creek, and another was near the sampling site on the south side of the creek. LES02 was sampled in both 2023 and 2024. The location of the tape, when it was stretched across the creek to determine the physical attributes, was not exactly the same in 2024, which will have contributed to the variation in data between years (Table 3). The lower water depth in 2023, however, would be related, at least in part, to drought conditions that year. Particle size was reduced in 2024, with less cobble-sized substrate and more pebble and gravel (Table 3). Algae were prominent on the substrate in both years and were identified in 2024 as pennate diatoms, likely of the genus *Flagilaria* (R. McAlpine, pers. comm.). *Flagilaria* are found in oligotrophic waters, especially streams, lake margins and bogs (Bellinger and Sigeo 2015), suggesting high water quality.

LES03 was approximately 170 m upstream of the TransAlta Road bridge, to the north of a random campsite. Embeddedness was less than at LES02 (Table 2).

Table 3. Comparison of physical attributes of the Lesueur Creek site, LES02, in 2023 and 2024.

Attributes	Site and Date of Sampling	
	LES02	
	Sept. 6, 2023	Sept. 6, 2024
Elevation (m)	1370	1364
Bankfull width (m)	7.80	6.32
Wetted width (m)	4.90	3.80
Bankfull wetted depth (cm)	21.0	6.1
Maximum channel depth (cm)	5.7	12.5
Avg channel depth (cm)	4.1	8.0
Maximum velocity (m/s)	0.6106	0.6419
Avg velocity (m/s)	0.3699	0.4039
Slope (m/m)	0.0079	0.0165
Substrate embeddedness (%)	50	50
Dominant substrate (cm)	6.4-12.8	1.6-3.2
2nd dominant substrate (cm)	3.2-6.4	3.2-6.4
Surrounding material (cm)	0.2-1.6	0.2-1.6
Geometric median particle size (cm)	6.5	3.6
% Sand	0	0
% Gravel	0	11
% Pebble	44	61
% Cobble	56	27
% Boulder	0	0
% Bedrock	0	1

3.1.2 Aura Creek

Aura Creek is a small tributary of Waiparous Creek. The Aura Creek site, situated just upstream of the Waiparous Creek flood plain, was sampled previously in 2022, before logging had occurred immediately upstream, but after logging in the watershed had begun (in 2020). AUR01 was sampled again in 2023. Prior to the sampling date in 2023, clearcuts were confined to the upper reaches of the creek. Lower reaches had been logged over the winter of 2023/2024, including immediately upstream of the sampling site.

AUR01 had one of the lowest wetted widths of all sites sampled over the five years of the project, at 2.53 m in 2024, with an average channel depth of only 4.8 cm (Table 4). It also had comparatively low velocity. As with LES02, the exact location where the various bank and channel measurements were made differed among years, which will have contributed to some of the variability. There was an increase in embeddedness in 2024, and an overall decrease in particle size.

Table 4. Comparison of physical attributes of the Aura Creek site (AUR01) from 2022 to 2024.

Attributes	Site and Date of Sampling		
	AUR01		
	Sept. 12, 2022	Aug. 29, 2023	Sept. 4, 2024
Elevation (m)	1379	1379	1380
Bankfull width (m)	4.70	3.25	5.20
Wetted width (m)	2.19	2.00	2.53
Bankfull wetted depth (cm)	35.0	17.5	23.3
Maximum channel depth (cm)	7.2	7.5	6.8
Avg channel depth (cm)	5.9	4.5	4.8
Maximum velocity (m/s)	0.4202	0.3431	0.5050
Avg velocity (m/s)	0.2007	0.2341	0.4137
Slope (m/m)	0.0269	0.0275	0.0231
Substrate embeddedness (%)	25	25	50
Dominant substrate (cm)	3.2-6.4	3.2-6.4	1.6-3.2
2nd dominant substrate (cm)	1.6-3.2	1.6-3.2	3.2-6.4
Surrounding material (cm)	0.2-1.6	0.2-1.6	0.2-1.6
Geometric median particle size (cm)	3.1	3.9	2.8
% Sand	0	0	0
% Gravel	20	5	12
% Pebble	63	71	81
% Cobble	16	24	7
% Boulder	1	0	0
% Bedrock	0	0	0

3.1.3 Johnson Creek

The location of JOH01 was approximately 155 m upstream from its confluence with Waiparous Creek. It also was sampled the previous three years, and again, the exact location where the various bank and channel measurements were made differed slightly among years. Variations in physical attributes tend to be relatively subtle among years, although velocity had increased (Table 5).

JOH02 was approximately 1.5 km upstream of JOH01. There was little variation in physical attributes between the two years of sampling (Table 5). It had lower embeddedness than JOH01 but smaller particle size.

Table 5. Comparison of physical attributes of the Johnson Creek sites (JOH01 and JOH02) from 2021 to 2024, and 2023 to 2024, respectively.

Attributes	Site and Date of Sampling					
	JOH01				JOH02	
	Sept. 7 2021	Aug. 30 2022	Aug. 31 2023	Aug. 27 2024	Aug. 31 2023	Aug. 30 2024
Elevation (m)	1569	1569	1569	1561	1588	1583
Bankfull width (m)	6.66	6.20	7.00	9.10	8.00	7.34
Wetted width (m)	5.64	5.40	5.80	5.69	5.50	5.42
Bankfull wetted depth (cm)	23.0	7.4	12.0	23.0	24.3	33.0
Maximum channel depth (cm)	23.5	23.8	26.3	28.2	18.0	21.2
Avg channel depth (cm)	18.5	21.8	22.1	20.7	15.6	17.8
Maximum velocity (m/s)	0.8287	0.7799	0.9078	1.2606	1.4353	1.1968
Avg velocity (m/s)	0.5658	0.6798	0.6712	1.0300	1.0042	0.9910
Slope (m/m)	0.0085	0.0085	0.0085	0.0120	0.0071	0.0556
Substrate embeddedness (%)	25	25	25	25	0	0
Dominant substrate (cm)	6.4-12.8	6.4-12.8	6.4-12.8	6.4-12.8	3.2-6.4	3.2-6.4
2nd dominant substrate (cm)	12.8-25.6	3.2-6.4	3.2-6.4	3.2-6.4	1.6-3.2	1.6-3.2
Surrounding material (cm)	0.2-1.6	0.1-0.2	0.2-1.6	0.1-0.2	0.2-1.6	0.1-0.2
Geometric median particle size (cm)	9.6	7.1	8.5	6.3	3.6	3.5
% Sand	0	0	0	0	0	0
% Gravel	0	1	2	4	7	6
% Pebble	29	44	33	41	82	83
% Cobble	67	50	59	54	11	11
% Boulder	4	5	6	1	0	0
% Bedrock	0	0	0	0	0	0

3.1.4 Waiparous Creek

2024 was the fifth consecutive year that sites below and above the confluence with Johnson Creek were sampled. Despite attempts to select reach locations at these two sites with similar stream channel characteristics, the heterogeneous nature of the stream channel, along with annual fluvial action, and human interference altering the stream channel, made this impossible. In 2022, human interference below the confluence with Johnson Creek was so great that the original WAP02 location no longer contained riffle habitat. As a result, the sampling site was moved slightly upstream to WAP02a. These sites bordered random campsites. In all four years, alteration of stream flow occurred from placement of rock dams at the edge of the creek and/or across the creek. The WAP02a site was again sampled in 2024.

The velocity at the slightly upstream location of WAP02a had been less than the location of WAP02 (Table 6), which was attributed to the full or partial rock dams upstream. The velocity was much higher at WAP02a in 2024, with fewer rock dams and no full dams. The geometric median particle size of the substrate had been declining each year, corresponding to the decline in velocity. In 2024, however, the velocity was substantially higher and the particle size was greater.

In 2023, natural fluvial action and low stream flow had altered the original WAP03 site enough to eliminate riffle habitat, therefore sampling occurred slightly upstream and the site was named WAP03a. Further natural fluvial action altered the reach again, resulting in more appropriate habitat in 2024 at the original WAP03 site, although the channel had shifted slightly to the south. Therefore, WAP03 was resampled and, as would be expected, physical attributes differed among years (Table 7). Similarly, substrate measurements have varied over the five years.

Table 6. Comparison of physical attributes of Waiparous Creek sites, WAP02/WAP02a, from 2020 to 2024.

Attributes	Site and Date of Sampling				
	WAP02		WAP02a		
	Sept. 1 2020	Sept. 2 2021	Sept. 7 2022	Aug. 30 2023	Aug. 27 2024
Elevation (m)	1554	1554	1559	1559	1560
Bankfull width (m)	17.00	12.02	15.30	14.50	16.20
Wetted width (m)	9.60	10.35	7.78	14.20	8.72
Bankfull wetted depth (cm)	26.5	17.0	32.7	21.2	14.0
Maximum channel depth (cm)	27.0	21.2	42.6	28.1	37.5
Avg channel depth (cm)	17.4	17.2	23.8	16.8	26.7
Maximum velocity (m/s)	1.2528	1.3065	1.0759	1.0293	1.4285
Avg velocity (m/s)	0.8760	0.8630	0.7192	0.5841	1.2244
Slope (m/m)	0.0138	0.0110	0.0233	0.0008	0.0092
Substrate embeddedness (%)	25	25	25	0	25
Dominant substrate (cm)	6.4-12.8	3.2-6.4	6.4-12.8	3.2-6.4	3.2-6.4
2nd dominant substrate (cm)	12.8-25.6	6.4-12.8	3.2-6.4	6.4-12.8	6.4-12.8
Surrounding material (cm)	0.2-1.6	0.1-0.2	0.2-1.6	0.2-1.6	0.2-1.6
Geometric median particle size (cm)	10.3	6.9	5.3	5	6.3
% Sand	0	0	0	0	0
% Gravel	1	0	2	3	2
% Pebble	23	49	50	62	50
% Cobble	68	51	46	35	45
% Boulder	8	0	0	0	3
% Bedrock	0	0	2	0	0

Table 7. Comparison of physical attributes at Waiparous Creek sites, WAP03/WAP03a, from 2020 to 2024.

Attributes	Site and Date of Sampling				
	WAP03			WAP03a	WAP03
	Sept. 3 2020	Sept. 2 2021	Sept. 7 2022	Aug. 30 2023	Aug. 27 2024
Elevation (m)	1560	1560	1560	1565	1560
Bankfull width (m)	15.00	21.90	18.50	11.50	19.20
Wetted width (m)	6.90	8.90	4.18	7.60	9.40
Bankfull wetted depth (cm)	56.0	57.0	55.0	34.5	27.5
Maximum channel depth (cm)	22.0	24.2	32.8	23.4	31.6
Avg channel depth (cm)	16.4	15.2	26.8	18.2	21.8
Maximum velocity (m/s)	1.1293	1.0850	1.2838	1.0575	1.3214
Avg velocity (m/s)	0.8650	0.7305	1.0052	0.8191	0.9192
Slope (m/m)	0.0150	0.0087	0.0087	0.0133	0.0650
Substrate embeddedness (%)	25	25	0	0	25
Dominant substrate (cm)	3.2-6.4	3.2-6.4	6.4-12.8	6.4-12.8	3.2-6.4
2nd dominant substrate (cm)	6.4-12.8	6.4-12.8	12.8-25.6	3.2-6.4	6.4-12.8
Surrounding material (cm)	0.2-1.6	0.2-1.6	0.2-1.6	0.2-1.6	0.2-1.6
Geometric median particle size (cm)	5.9	5.8	10	7.7	6.4
% Sand	0	0	0	0	0
% Gravel	1	1	1	0	2
% Pebble	56	57	21	39	48
% Cobble	41	37	67	58	42
% Boulder	2	2	11	3	4
% Bedrock	0	3	0	0	4

3.2 Land Use

Forest habitat (or shrubland in the case of JOH02) was present at all sites and was the dominant adjacent land use, or one of the dominants, at most sites (Table 8). The dominant adjacent land uses at WAP02a and WAP03 were random camping, day-use and off-highway vehicle (OHV) use, whereas camping and OHV use were dominant at WAP10. Day-use and random camping, along with forest, were the dominant activities in the area surrounding LES03. OHV use occurred upstream of all sites to varying degrees. Livestock grazing was a dominant upstream activity at the Lesueur Creek sites. Logging was dominant both adjacent and upstream of AUR01, and was a dominant land use above WAP11.

Table 8. Land uses adjacent and upstream of each site. Xs in bold indicate dominant land use(s).

Site	Land Use Location	Land Use							
		Forest/ Shrubland	Grazing	Logging	OHV	Day-use	Camping	Shooting	Commercial/ Youth Camp(s)
LES02	Adjacent	x			x	x	x		
	Upstream	x	x	x	x	x	x	x	x
LES03	Adjacent	x	x		x	x	x		
	Upstream	x	x	x	x	x	x	x	x
AUR01	Adjacent	x		x	x				
	Upstream	x	x	x	x				
LOS01	Adjacent	x	x		x				
	Upstream	x	x		x				
WAP10	Adjacent	x	x		x	x	x		
	Upstream	x	x	x	x	x	x	x	x
WAP11	Adjacent	x			x				
	Upstream	x	x	x	x	x	x	x	x
WAP02a & WAP03	Adjacent	x			x	x	x		
	Upstream	x			x	x	x	x	x
JOH01	Adjacent	x			x	x			
	Upstream	x			x				
JOH02	Adjacent	x			x				
	Upstream	x			x				

3.3 Water Attributes and Chemical Analysis

The chemical attributes (i.e., pH, dissolved oxygen, anions, nutrients) of water samples, along with the physical attributes (i.e., total suspended solids, turbidity, specific conductance, temperature), are presented for each site in Table 9. The chemical analysis suggests that the water quality at the time of sampling was within the parameters acceptable for benthic macroinvertebrates and fish (Government of Alberta 2018). The surface water quality guidelines and criteria, including brief narratives, are presented in Table 10.

Table 9. Chemical and physical attributes of water samples at each site.

Tests	Site									
	LES02	LES03	AUR01	LOS01	WAP10	WAP11	WAP02a	WAP03	JOH01	JOH02
Air Temperature (°C)	13.0	26.0	16.5	22.0	24.0	23.0	21.0	20.5	19.5	16.5
Water Temperature (°C)	9.1	13.5	11.4	9.2	9.5	13.6	12.4	13.2	12.2	6.2
Dissolved Oxygen (mg/L)	9.30	8.66	9.43	8.03	8.49	8.38	8.91	8.42	8.42	9.49
Specific Conductance (µS/cm)	412.6	410.9	445.4	370.5	355.3	356.8	350.4	356.6	334.0	331.9
pH	8.23	8.45	8.42	7.68	8.20	8.32	8.13	8.32	8.40	8.17
Total Suspended Solids (mg/L)	<1.0	<1.0	5.5	4.1	<1.0	<1.0	<1.0	<1.0	<1.0	2.5
Turbidity (lab) (NTU)	<0.10	0.12	6.60	5.00	0.40	0.39	0.24	0.21	0.24	0.90
<u>Anions (mg/L)</u>										
Alkalinity (Total as CaCO ₃)	230	230	250	200	160	160	140	130	160	180
Alkalinity (PP as CaCO ₃)	<1.0	5.1	13.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	4.6
Bicarbonate (HCO ₃)	290	270	270	250	190	190	170	160	190	200
Carbonate (CO ₃)	<1.0	6.1	16.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	5.5
Hydroxide (OH)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<u>Nutrients (mg/L)</u>										
Total Phosphorus (P)	<0.0030	<0.0030	0.01	0.01	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030
Dissolved Nitrogen (N)	0.24	0.20	0.56	0.35	0.21	0.21	0.27	0.22	0.41	0.33
Dissolved Nitrate (N)	<0.050	<0.050	<0.010	0.23	0.16	0.16	0.24	0.18	0.33	0.37
Dissolved Nitrite (N)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Dissolved Total Kjeldahl Nitrogen	0.24	0.20	0.56	0.11	0.049	0.054	0.021	0.047	0.079	<0.020

Note: Lab analyses by Bureau Veritas Laboratories, Calgary, Alberta.

Table 10. Surface water quality guidelines and criteria for protection of freshwater aquatic life.

Water Quality Variable (Substance or Condition)	Short-term (Acute)	Long-term (Chronic)	Notes and Direction
Alkalinity (as CaCO ₃) (mg/L)	-	20	A minimum value, unless natural conditions are less, in which case the guideline cannot be lower than 25% of the natural level.
Bicarbonate (HCO ₃)	-	-	
Carbonate (CO ₃)	-	-	
Hydroxide (OH)	-	-	
Nitrate – N (mg/L)	>124	>3.0	As N. For protection from toxicity. Does not consider eutrophication effects.
Nitrite – N (mg/L)	Varies	Varies	As N. Varies with chloride.
Nitrogen – total (inorganic + organic)	-	Narrative	Nitrogen (total) and phosphorus concentrations should be maintained to prevent detrimental changes to algal and aquatic plant communities, aquatic biodiversity, oxygen levels and recreational quality. Where priorities warrant, develop site-specific nutrient objectives and management plans.
Dissolved Oxygen (mg/L) (Minimum values)	5	6.5	See Alberta Environmental Protection (1997) for guidance when natural conditions do not meet guidelines. Long-term is 7 day mean, short-term is instantaneous value.
	-	8.3	For mid-May to end of June, to protect mayfly emergence.
	-	9.5	For areas and times where and when larval fish develop within gravel beds.
Total Phosphorous (mg/L)	-	Narrative	For major rivers and for surface waters not covered by specific guidelines, nitrogen (total) and phosphorus concentrations should be maintained to prevent detrimental changes to algal and aquatic plant communities, aquatic biodiversity, oxygen levels, and recreational quality. Where priorities warrant, develop site-specific nutrient objectives and management plans.

Table 10. Continued

Water Quality Variable (Substance or Condition)	Short-term (Acute)	Long-term (Chronic)	Notes and Direction
pH (Safe range)		6.5 - 9.0	Not to be altered by more than 0.5 units from background.
Total Suspended Solids (TSS) (mg/L)	Narrative	Narrative	<p><u>During clear flows or for clear waters:</u> Maximum increase of 25 mg/L from background for any short-term exposure (e.g., 24 hr period). Maximum average increase of 5 mg/L from background levels for longer term exposures (greater than 24 hr).</p> <p><u>During high flow or for turbid waters:</u> Maximum increase of 25 mg/L from background levels at any time when background levels are between 25 and 250 mg/L. Should not increase more than 10% of background levels when background is ≥ 250 mg/L.</p>
Specific Conductance	-	-	
Turbidity (NTU)	Narrative	Narrative	<p><u>For clear waters:</u> Maximum increase of 8 NTU from background for any short-term exposure (e.g., 24 hr period). Maximum average increase of 2 NTU from background levels for longer term exposures (greater than 24 hr).</p> <p><u>For high flow or turbid waters:</u> Maximum increase of 8 NTU from background levels at any time when background levels are between 8 and 80 NTU. Should not increase more than 10% of background levels when background is >80 NTU.</p>

Source: Government of Alberta (2018)

The water quality guidelines for Alberta surface waters (Government of Alberta 2018) do not provide values for specific conductivity or for three main anions: bicarbonate (HCO_3^-), carbonate (CO_3^{2-}) and hydroxide (HO^-). Further discussion is provided below on specific conductivity and on the relationship of the three anions to alkalinity and inorganic carbon.

3.3.1 Alkalinity, Inorganic Carbon, Hardness and pH

A full description of alkalinity, inorganic carbon, hardness and pH is given in the report on the 2020 monitoring program (Biota Consultants 2022a).

Alkalinity, as expressed by the total CaCO_3 , was lowest at WAP03 (130 mg/L) and highest at AUR01 (250 mg/L) (Table 9). These values are well above the minimum 20 mg/L level indicated in Table 10. The hardness of a water body is regulated largely by the levels of calcium and magnesium salts. Hard water contains cations with a charge of 2+, especially Ca^{2+} and Mg^{2+} (Casiday and Frey 1998). The water at sites LES02, LES03, AUR01 and LOS01 would be classified as very hard according to the USGS Water Science School (2018a) classification, whereas water at the other sites would be classified as hard:

Soft = 0 to 60 mg/L CaCO_3

Moderately hard = >60 to 120 mg/L CaCO_3

Hard = >120 to 180 mg/L CaCO_3

Very hard = >180 mg/L CaCO_3

The pH of the samples varied from 7.68 to 8.45, which is in the safe range for acute toxicity according to Government of Alberta (2018) criteria (Table 10).

3.3.2 Specific Conductance (Conductivity)

Specific conductance (conductivity) is a numerical expression of water's ability to conduct an electrical current, usually expressed in microsiemens per centimetre ($\mu\text{S}/\text{cm}$). Specific conductance is measured at, or corrected to, 25°C (Miller *et al.* 1988). Since conductivity increases with temperature, reporting conductivity at the reference temperature of 25°C allows data to easily be compared (FEI 2014a). The lowest specific conductance value was at JOH02 (331.9 $\mu\text{S}/\text{cm}$), while the highest value occurred at AUR01 (445.4 $\mu\text{S}/\text{cm}$) (Table 9).

There is no set standard for the conductivity of water (Table 10) because conductivity can differ regionally and between neighbouring streams if there is enough difference in the surrounding geology, or if one source has a separate inflow (FEI 2014a). Freshwater that runs through granite bedrock will have a very low conductivity value, whereas clay- and limestone-derived soils can contribute to higher conductivity values (LCRA 2014). Despite the lack of standards and the fact that the surrounding environment can affect conductivity, there are approximate values that can be expected based on the source of the water. Freshwater streams vary from 100 to 2,000 $\mu\text{S}/\text{cm}$ whereas industrial wastewater is in the order of 10,000 $\mu\text{S}/\text{cm}$ (American Public Health Assoc. *et al.* 1999, as cited in FEI 2014a; Clean Water Team 2004).

A full discussion on specific conductance is provided in Biota Consultants (2022a). Specific conductance is one of the most useful and commonly measured water quality parameters (Miller *et al.* 1988). It is the basis of most salinity and total dissolved solids calculations, and is an early indicator of change in a water body. Most water bodies maintain a fairly constant conductivity that can be used as a baseline for future comparisons (EPA 2012, as cited in FEI 2014a). Therefore, conductivity is a useful tracer of point source discharges (Environment Canada 2012). A significant change in conductivity, whether due to natural flooding, evaporation or man-made pollution, can be detrimental to water quality, hence to aquatic insects (FEI 2014a). The 2020 to 2024 data provide baseline measurements for comparison in the future.

3.3.3 Total Suspended Solids, Turbidity and Dissolved Oxygen

3.3.3.1 Total Suspended Solids

Total suspended solids (TSS) were <1.0 mg/L at most of the sites and up to 5.5 mg/L at AUR01 (Table 9), but were still within the guidelines. A TSS measurement of less than 20 mg/L generally appears clear, while levels over 40 mg/L may begin to appear cloudy (Michigan Department of Environmental Quality n.d., as cited in FEI 2014b).

Particles in the water column that are larger than 2 microns comprise TSS. Anything smaller (average filter size) is considered to be a dissolved solid. Most suspended solids are made up of inorganic materials such as sand and silt; however, bacteria, algae, plankton, and organic particles from decaying plants and animals can also contribute to the TSS concentration, i.e., anything drifting or floating in the water (Murphy 2007; EPA 2012, as cited in FEI 2014b). Water clarity is significantly affected, declining as the amount of solids increases. Water temperature then increases, which reduces dissolved oxygen (FEI 2014b).

Suspended solids can adversely affect aquatic organisms in several ways:

- Clog the filtering systems of fish and some immature stages of insects (e.g., caddisfly larvae);
- Cause physical injury to delicate eye and gill membranes by abrasion;
- Restrict food availability to fish, affecting growth rates;
- Restrict normal movements and migrations of fish; and
- Inhibit egg development (Alabaster and Lloyd 1984, as cited in CCME 1999).

For further information on suspended and settleable solids, please see Biota Consultants (2022a).

3.3.3.2 Turbidity

Turbidity is often reported as nephelometric turbidity units (NTU) and is a measure of relative water clarity. Turbid water can appear cloudy, murky, hazy, muddy, coloured or opaque. At 5 NTU, water appears clear, at 55 NTU it is obviously cloudy, and at 500 NTU, it appears completely opaque (USGS Water Science School 2018b). The majority of sites had turbidity values ranging from <0.1 NTU to 0.9 NTU (Table 9), which are considered very low (Table 10). The highest values were still relatively low at 6.60 NTU (AUR01) and 5.00 NTU (LOS01).

Turbidity in water results from the presence of suspended matter such as clay, silt, finely divided inorganic and decaying organic material, soluble coloured organic compounds, and living organisms that are held in suspension by turbulent flow (McNeely *et al.* 1979, as cited in CCME 2008). Coloured dissolved organic matter, also known as humic stain, also can cause turbidity. This is produced from decaying underwater vegetation and the release of tannins and other molecules. Water will appear red or brown, depending on the type of flora present. These dissolved substances may be too small to be considered suspended solids, but they contribute to turbidity by affecting water clarity (FEI 2014b).

By blocking sunlight, turbidity can inhibit photosynthesis, thereby reducing plant growth, which in turn reduces dissolved oxygen. If the turbidity blocks enough sunlight to kill aquatic vegetation, aquatic organisms that rely on underwater plants also will decline (FEI 2014b).

Turbidity and TSS are related, as both reduce water clarity; however, turbidity is not a direct measurement of suspended materials in water. It is often used to indicate changes in the TSS concentration without providing an exact measurement of solids (EPA 2012, as cited in FEI 2014b). Since the correlation between turbidity and the weight of suspended (or total suspended) and settleable solids is often tenuous, both should be assessed.

3.3.3.3 Dissolved Oxygen and Temperature

The dissolved oxygen values were within acceptable limits, ranging from 8.03 to 9.49 mg/L (Table 9). Dissolved oxygen (DO) is the concentration of free oxygen (O₂) present in water or other liquids and is usually measured in mg/L. An O₂ level that is too low or too high can affect water quality, harming aquatic life (FEI 2013). The amount of O₂ dissolved in water primarily depends on temperature, atmospheric (barometric) pressure and salinity, and can be introduced through turbulence (e.g., rapids, waterfalls, waves) (FEI 2013). Temperature is the main factor, as cold water can hold more oxygen (Environment Canada 2012). Therefore, water temperature and the amount of DO are important in assessing water quality due to their influence on organisms within a body of water. Please see Biota Consultants (2022a) for a further discussion on factors influencing DO and the effects of DO on aquatic fauna.

3.3.4 Comparison of Sites Among Years

A comparison among years of the physical and chemical attributes of the water samples at sites that have been sampled more than once are presented in Tables 11 to 14. There were slight variations among years at each site, but all were within the guidelines. This variation is expected in a natural environment.

Total suspended solids and turbidity were less at LES02 compared to the previous year (Table 11). In 2023, there were regular flushes of sediment from a puddle on the bridge just 95 m upstream. Whenever the puddle was hit by a vehicle travelling at a high enough speed, water from the puddle splashed into the creek. There was no similar puddle in 2024, however, which may explain the lower TSS and turbidity. There was a decline in carbonates and alkalinity (PP as CaCO_3)⁴ and a slight increase in nitrogen, which may warrant monitoring.

Total suspended solids and turbidity have continued to increase at AUR01 from 2022 to 2024 (Table 11), which may be related to land uses upstream, such as logging. The higher measurements did not affect the level of DO; however, further monitoring would be prudent.

Carbonate and alkalinity (PP as CaCO_3) values have also climbed over the three years of sampling, and there have been slight increases in phosphorous and dissolved nitrogen (Table 11). The increase in carbonates is likely due to a proportional increase in groundwater contribution, or from decay of organic materials (i.e., leaves, twigs, soil, etc.) that cause release of CO_2 in the stream, which combines to make Ca/Mg carbonates or bicarbonates (R. McAlpine, pers. comm.). This is supported by the increase in phosphorus and organic nitrogen over the years. Such increases can result from forestry activities or fire (R. McAlpine, pers. comm.).

⁴ Phenolphthalein alkalinity is a measure of the buffering capacity (i.e., changes in pH) of water. It specifically measures the presence of hydroxide ions in a solution, indicating the presence of strong bases. It is determined by adding an acid to the water sample until the pink colour of the phenolphthalein indicator disappears. In comparison, total alkalinity measures the sum of all alkaline substances in a solution, including hydroxides, carbonates and bicarbonates. While phenolphthalein alkalinity focuses on strong bases, total alkalinity provides a more comprehensive measure of all alkaline substances present in the solution. (Source: <https://thisvsthat.io/phenolphthalein-alkalinity-vs-total-alkalinity>)

Table 11. Comparison among years of physical and chemical attributes of water samples at Lesueur Creek (LES02) and Aura Creek (AUR01) sites.

Tests	Site and Date of Sampling				
	LES02		AUR01		
	Sept. 6 2023	Sept. 6 2024	Sept. 12 2022	Aug. 29 2023	Sept. 4 2024
Air Temperature (°C)	14.0	13.0	14.0	25.0	16.5
Water Temperature (°C)	11.3	9.1	8.1	13.4	11.4
Dissolved Oxygen (mg/L)	9.75	9.30	9.53	9.40	9.43
Specific Conductance (µS/cm)	366.3	412.6	459.4	456.7	445.4
pH	8.20	8.23	8.24	8.35	8.42
Total Suspended Solids (mg/L)	1.6	<1.0	<1.0	2.2	5.5
Turbidity (NTU)	3.20	<0.10	2.50	4.60	6.60
<u>Anions (mg/L)</u>					
Alkalinity (Total as CaCO ₃)	220	230	260	260	250
Alkalinity (PP as CaCO ₃)	5.4	<1.0	<1.0	5.0	13.0
Bicarbonate (HCO ₃)	260	290	320	310	270
Carbonate (CO ₃)	6.5	<1.0	<1.0	6.0	16.0
Hydroxide (OH)	<1.0	<1.0	<1.0	<1.0	<1.0
<u>Nutrients (mg/L)</u>					
Total Phosphorus (P)	<0.0030	<0.0030	<0.0030	0.0040	0.0060
Dissolved Nitrogen (N)	0.13	0.24	0.36	0.46	0.56
Dissolved Nitrate (N)	<0.010	<0.050	0.010	<0.010	<0.010
Dissolved Nitrite (N)	<0.010	<0.010	<0.010	<0.010	<0.010
Dissolved Total Kjeldahl Nitrogen	0.127	0.240	0.347	0.455	0.560

Dissolved nitrogen and dissolved nitrate have gradually increased at JOH01 over the four years of sampling (Table 12), which might be related to nutrient loading (R. McAlpine, pers. comm.). Further monitoring would be beneficial. The outflow from Johnson Creek may have influenced the chemical attributes of Waiparous Creek below the confluence. The consistently higher dissolved nitrogen and dissolved nitrate at WAP02/02a versus WAP03/03a in the last three years (Tables 13 and 14) possibly resulted from the even higher dissolved nitrogen and dissolved nitrate at JOH01, although these differences are within the range of natural variation.

Table 12. Comparison among years of physical and chemical attributes of water samples at Johnson Creek (JOH01) sites.

Tests	Site and Date of Sampling					
	JOH01				JOH02	
	Sept. 7 2021	Aug. 30 2022	Aug. 31 2023	Aug. 27 2024	Aug. 31 2023	Aug. 30 2024
Air Temperature (°C)	16.0	21.0	14.0	19.5	17.5	16.5
Water Temperature (°C)	6.2	9.8	8.2	12.2	8.4	6.2
Dissolved Oxygen (mg/L)	10.24	9.61	9.76	8.42	9.97	9.49
Specific Conductance (µS/cm)	335.8	323.1	392.2	334.0	324.9	331.9
pH	8.21	8.23	8.17	8.40	8.18	8.17
Total Suspended Solids (mg/L)	<1.0	<1.0	1.5	<1.0	1.1	2.5
Turbidity (NTU)	0.11	0.40	0.11	0.24	0.11	0.90
<u>Anions</u> (mg/L)						
Alkalinity (Total as CaCO ₃)	150	170	140	160	160	180
Alkalinity (PP as CaCO ₃)	<1.0	<1.0	<1.0	<1.0	<1.0	4.6
Bicarbonate (HCO ₃)	190	210	180	190	200	200
Carbonate (CO ₃)	<1.0	<1.0	<1.0	<1.0	<1.0	5.5
Hydroxide (OH)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
<u>Nutrients</u> (mg/L)						
Total Phosphorus (P)	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030
Dissolved Nitrogen (N)	0.16	0.29	0.35	0.41	0.34	0.33
Dissolved Nitrate (N)	0.17	0.24	0.32	0.33	0.33	0.37
Dissolved Nitrite (N)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Dissolved Total Kjeldahl Nitrogen	-	0.055	0.030	0.079	<0.020	<0.020

Table 13. Comparison among years of physical and chemical attributes of water samples at the Waiparous Creek sites, WAP02/WAP02a.

Tests	Site and Date of Sampling				
	WAP02		WAP02a		
	Sept. 1 2020	Sept. 2 2021	Sept. 7 2022	Aug. 30 2023	Aug. 27 2024
Air Temperature (°C)	22.5	10.5	21.5	22.5	21.0
Water Temperature (°C)	15.0	7.4	12.7	12.2	12.4
Dissolved Oxygen (mg/L)	8.97	9.92	8.04	9.05	8.91
Specific Conductance (µS/cm)	316.6	336.8	333.7	341.7	350.4
pH	8.18	8.29	8.04	8.24	8.13
Total Suspended Solids (mg/L)	1.2	<1.0	<1.0	<1.0	<1.0
Turbidity (NTU)	<0.10	0.22	0.30	0.54	0.24
<u>Anions (mg/L)</u>					
Alkalinity (Total as CaCO ₃)	150	140	160	160	140
Alkalinity (PP as CaCO ₃)	<1.0	<1.0	<1.0	<1.0	<1.0
Bicarbonate (HCO ₃)	180	170	200	190	170
Carbonate (CO ₃)	<1.0	<1.0	<1.0	<1.0	<1.0
Hydroxide (OH)	<1.0	<1.0	<1.0	<1.0	<1.0
<u>Nutrients (mg/L)</u>					
Total Phosphorus (P)	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030
Dissolved Nitrogen (N)	0.26	0.13	0.23	0.22	0.27
Dissolved Nitrate (N)	0.12	0.13	0.19	0.23	0.24
Dissolved Nitrite (N)	<0.010	<0.010	<0.010	<0.010	<0.010
Dissolved Total Kjeldahl Nitrogen	0.140	-	0.040	<0.020	0.021

Table 14. Comparison among years of physical and chemical attributes of water samples at the Waiparous Creek sites, WAP03/WAP03a.

Tests	Site and Date of Sampling				
	WAP03			WAP03a	WAP03
	Sept. 3 2020	Sept. 2 2021	Sept. 7 2022	Aug. 30 2023	Aug. 27 2024
Air Temperature (°C)	17.5	19.0	23.0	25.5	20.5
Water Temperature (°C)	12.8	10.2	15.7	15.9	13.2
Dissolved Oxygen (mg/L)	8.77	9.28	8.27	8.27	8.42
Specific Conductance (µS/cm)	320.2	336.7	339.0	352.0	356.6
pH	8.38	8.38	8.27	8.18	8.32
Total Suspended Solids (mg/L)	2.0	<1.0	<1.0	<1.0	<1.0
Turbidity (NTU)	<0.10	0.11	0.20	0.19	0.21
<u>Anions</u> (mg/L)					
Alkalinity (Total as CaCO ₃)	140	130	140	140	130
Alkalinity (PP as CaCO ₃)	1.4	<1.0	<1.0	<1.0	<1.0
Bicarbonate (HCO ₃)	160	160	180	180	160
Carbonate (CO ₃)	1.7	<1.0	<1.0	<1.0	<1.0
Hydroxide (OH)	<1.0	<1.0	<1.0	<1.0	<1.0
<u>Nutrients</u> (mg/L)					
Total Phosphorus (P)	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030
Dissolved Nitrogen (N)	0.25	0.13	0.14	0.12	0.22
Dissolved Nitrate (N)	0.068	0.130	0.110	0.140	0.180
Dissolved Nitrite (N)	<0.010	<0.010	<0.010	<0.010	<0.010
Dissolved Total Kjeldahl Nitrogen	0.190	-	0.032	<0.020	0.047

3.4 Benthic Macroinvertebrate Morphological Analysis

In addition to measuring chemical and physical parameters, CABiN uses benthic macroinvertebrates as indicators of aquatic ecosystem health (Environment Canada 2012). Organisms in natural aquatic systems are continuously exposed to fluctuations in their environment. Some species adapt to these changes, whereas other species cannot (CCME 2008).

The orders Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) (EPT) are taxa that tend to be sensitive to pollution or degraded aquatic environments. The EPT index is the proportion of these taxa in the benthic invertebrate community. In contrast, the family Chironomidae (non-biting midges) in the order Diptera are generally tolerant of degraded waterbodies. Therefore, determining the ratio of chironomids to EPT species can be a good indicator of water quality, depending on the habitat present. Monitoring the ratio over time can be used to determine whether the community is changing, either because of anthropogenic influences (using test sites) or naturally-caused influences (using reference condition sites). Metric indices using the data collected in GWAS's water monitoring program can provide information on the abundance, richness, diversity and evenness of the community.

The community/population data and analyses are presented in the appendices. Appendix B contains the common names of the orders and families of the benthic macroinvertebrates that were identified in this study. Appendix C contains the entire raw data set of the benthic macroinvertebrates identified based on morphological characteristics. Appendix D contains this taxonomic data at the family level. Appendix E contains the metric indices for the entire 2024 taxonomic data to the genus/species level based on morphological identification.

Within CABiN, the metrics are classified into four main groups: measurements of richness, measurements of abundance or community composition, functional group measures and biotic indices. A description of these taxonomic data analyses is provided in the report on the 2020 monitoring program (Biota Consultants 2022a). All of the metric results are presented in Appendix E, and key results are summarized below.

3.4.1 Richness Measurements

The number of different species present is a measure of richness. This can be the total number of species at a site, or the number within a taxon(s), or the number within a functional group (i.e., predators, shredder-herbivores, collector-gatherers, scrapers, collector-filterers, omnivores, parasites, piercer-herbivores or unclassified types). Species richness does not take into account the number of individuals of each species present. Rather, it gives as much weight to those species represented by very few individuals as to those represented by many individuals.

Diversity/evenness measurements take into account the abundance and distribution among the taxa present (e.g., Simpson’s Diversity/Evenness Index and Shannon-Wiener Diversity Index). Diverse communities are indicators of “good” water quality.

The Simpson’s Index of Diversity indicates that the community composition of most sites sampled in 2024 were highly diverse (Figure 2). WAP10 had the lowest diversity with a value of 0.58. Similarly, values for the Shannon-Wiener Diversity Index were lowest for WAP10 (1.48). Of those sites sampled more than once, Simpson’s Index of Diversity was similar among years except at WAP02/02a, when there was a drop in 2021 (Figure 2).

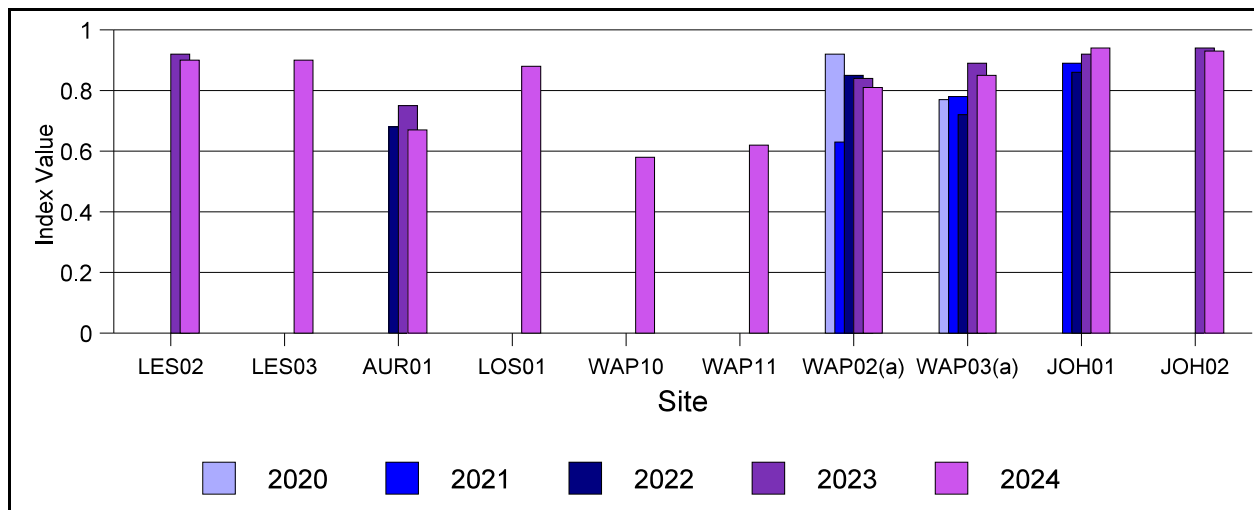


Figure 2. Simpson’s Index of Diversity (1-D) for each site.

3.4.2 Abundance and Compositional Measures

Abundance can be expressed as the sum of all organisms present at a selected taxonomic level or within a specified group. Composition of taxa within the population can be expressed numerically or as a percentage of the population. Shifts within the population can alter the structure at various trophic levels, as certain species increase or decrease due to changes in the aquatic environment. The abundance and compositional measures presented include:

- EPT ratio: EPT/(chironomids+ EPT): the abundance of EPT individuals divided by the abundance of chironomids plus the EPT individuals (expressed as a value from 1 to 0).
- % Diptera that are Chironomidae: Chironomidae tend to be more tolerant than other families of Diptera.
- % Trichoptera that are Hydropsychidae: Hydropsychidae tend to be more tolerant than other families of Trichoptera.
- % Ephemeroptera that are Baetidae: Baetidae tend to be more tolerant than other families of Ephemeroptera.

The following graphs illustrate the relationship among the Ephemeroptera, Plecoptera, Trichoptera (Figure 3) and Diptera at each site (Figure 4). Of the EPT species, the Ephemeroptera dominated at five of the sites (Aura Creek and Waiparous Creek sites). Plecoptera dominated at LES03, but not at LES02, as in 2023 (Biota Consultants 2024). Trichoptera were very low in abundance (<2%). Note the abundance at LOS01 was 0.30%, which is barely noticeable in Figure 3.

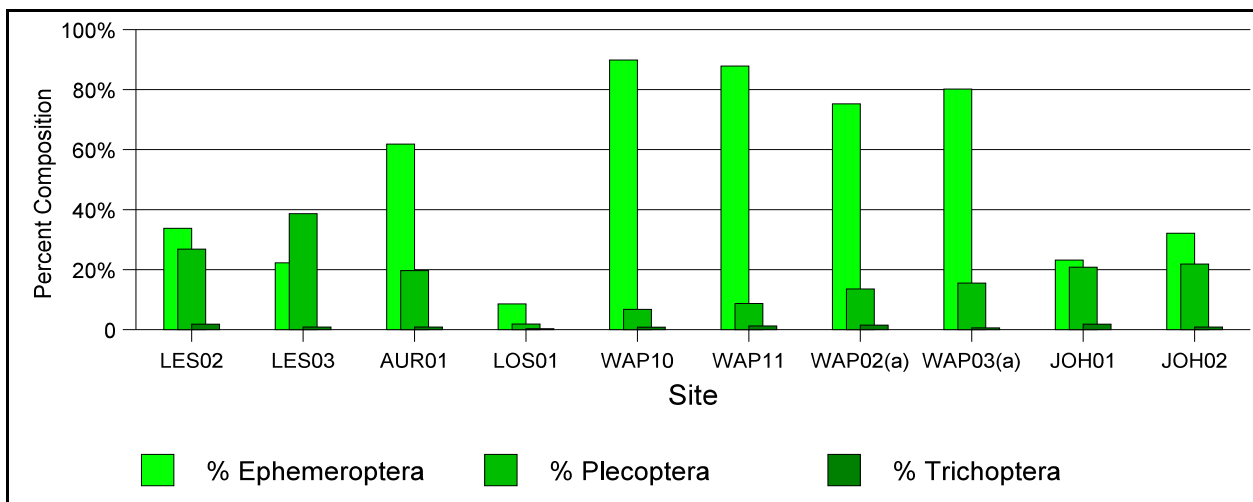


Figure 3. Percent composition of EPT orders at each site.

The EPT species were more prevalent than the Diptera species at all sites except LOS01, but were close in abundance at JOH01 (45.83% and 36.98%, respectively) (Figure 4). In the previous four years, the EPT species have consistently been much more abundant than Diptera and chironomids at WAP02/02a and WAP03/03a (Biota Consultants 2024), a pattern that continued in 2024. Chironomid flies comprised over 70% of the Diptera species at half of the sites (Figure 5). They were noticeably lower at WAP02/02a, WAP03/03a and JOH02 than in past years.

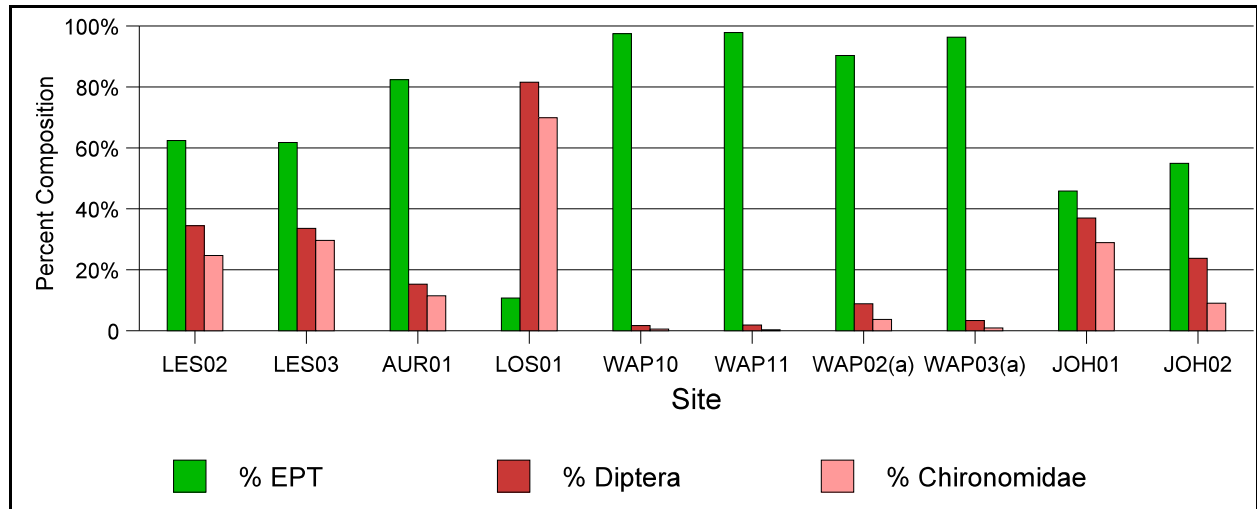


Figure 4. Percent composition of EPT orders, Diptera order and chironomid family at each site.

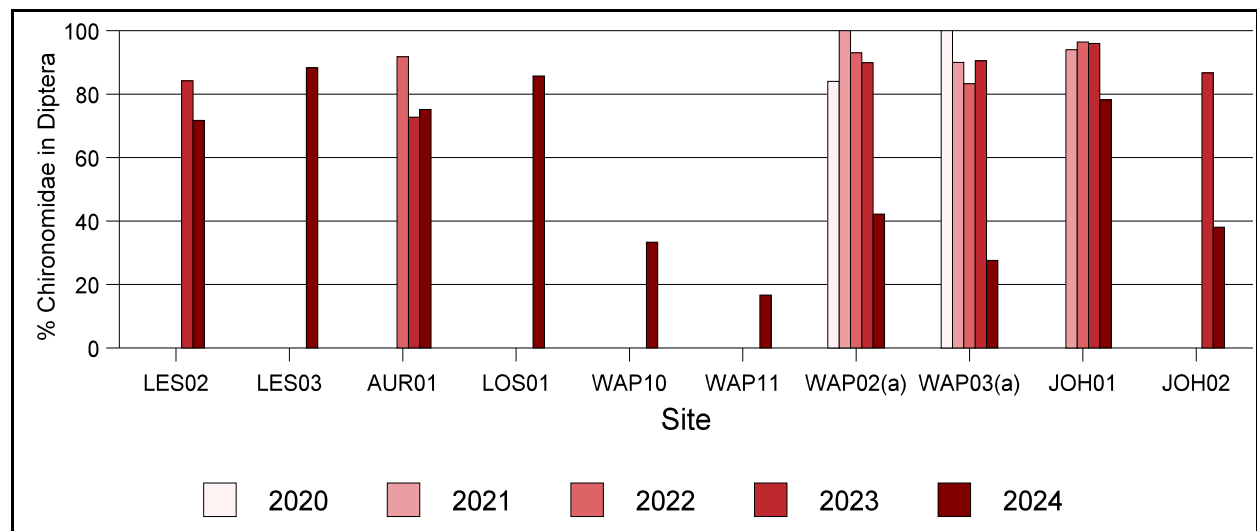


Figure 5. Percent of Diptera that were chironomid flies at each site.

The EPT ratio puts these findings into perspective (Figure 6). The value at LOS01 was extremely low, at 0.13, the lowest of any site over the five years of sampling. The ratio remained moderate at JOH01 but increased from previous years at JOH02 and LES02. The very high values at the Waiparous Creek sites suggest good water quality. In all five years, values were slightly lower below the confluence with Johnson Creek, although not enough to clearly suggest the inflow from Johnson Creek influenced these values.

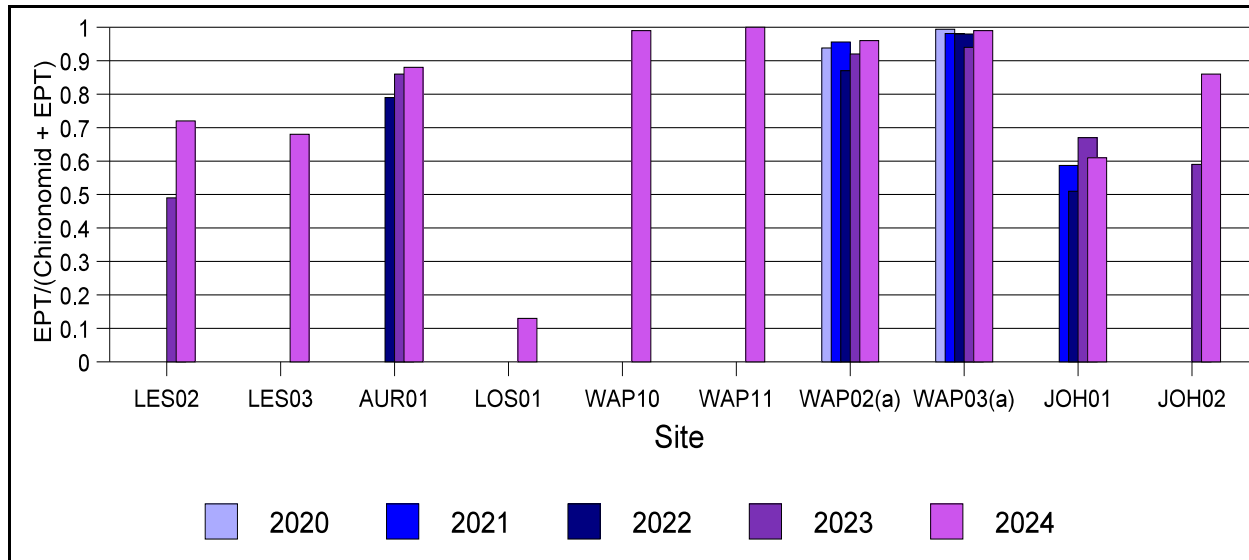


Figure 6. EPT/(chironomid + EPT) ratio for each site using percent community composition.

Based on the first four years of the water monitoring program, LES02 and the two Johnson Creek sites were of most concern with respect to the benthic macroinvertebrate community. In 2024, the EPT ratio improved at LES02 and JOH02, and remained moderate at JOH01. However, the ratio was the lowest to date at LOS01, at only 0.13, with a very high chironomid population of almost 70%. This does not necessarily equate to low water quality, however. The stream substrate at LOS01 was largely silt. Fine substrates like sand and silt provide a unique habitat for benthic macroinvertebrates where specialist taxa dominate. EPT have few taxa that are well suited to fine substrates whereas Chironomidae and other invertebrates are more common. This may explain why the EPT ratio differed from the cobble/pebble sites, reflecting the stream characteristics rather than indicating poor water quality (A. Martens, pers. comm.).

The low EPT ratio at LES02 in 2023 was potentially related to regular flushes of sediment from a puddle on the bridge just 95 m upstream. This happened whenever the puddle was hit by a vehicle travelling at a high enough speed to make water from the puddle splash into the creek.

There was no puddle in 2024, however, so this was not a factor affecting water quality. Livestock grazing and recreational use (largely including random camping and OHV use) upstream of both Lesueur Creek sites continued to be factors.

The Devil’s Head/Black Rock fire may be at least partially responsible for the lower EPT ratios at the Johnson Creek sites, but no data were collected prior to the fire for comparison. There is high OHV activity on some upstream sections of Johnson Creek, but these are below JOH02. If the forest fire did affect the benthic communities, it is possible the higher EPT of JOH02 reflects recovery from this event.

The percentage of Trichoptera within the community at each site was very low, ranging from 0.30% to 1.82% (Figure 3). Hydropsychidae, a family within Trichoptera that is more tolerant to adverse conditions, was found at half the sites (Figure 7). At the paired sites on Waiparous Creek, a variable proportion of the Trichoptera were Hydropsychidae over the five years of sampling (Figure 7). All five Trichoptera specimens (100%) at WAP03 were Hydropsychidae. The proportion also was variable at the other sites that were sampled over more than one year. No Hydropsychidae were detected at AUR01 in 2022 and 2024, but in 2023, 9 of the 36 (25.0%) Trichoptera specimens were Hydropsychidae. All three (100%) of the Trichoptera specimens at LES02 in 2023 were Hydropsychidae, but this dropped to 66.67% in 2024.

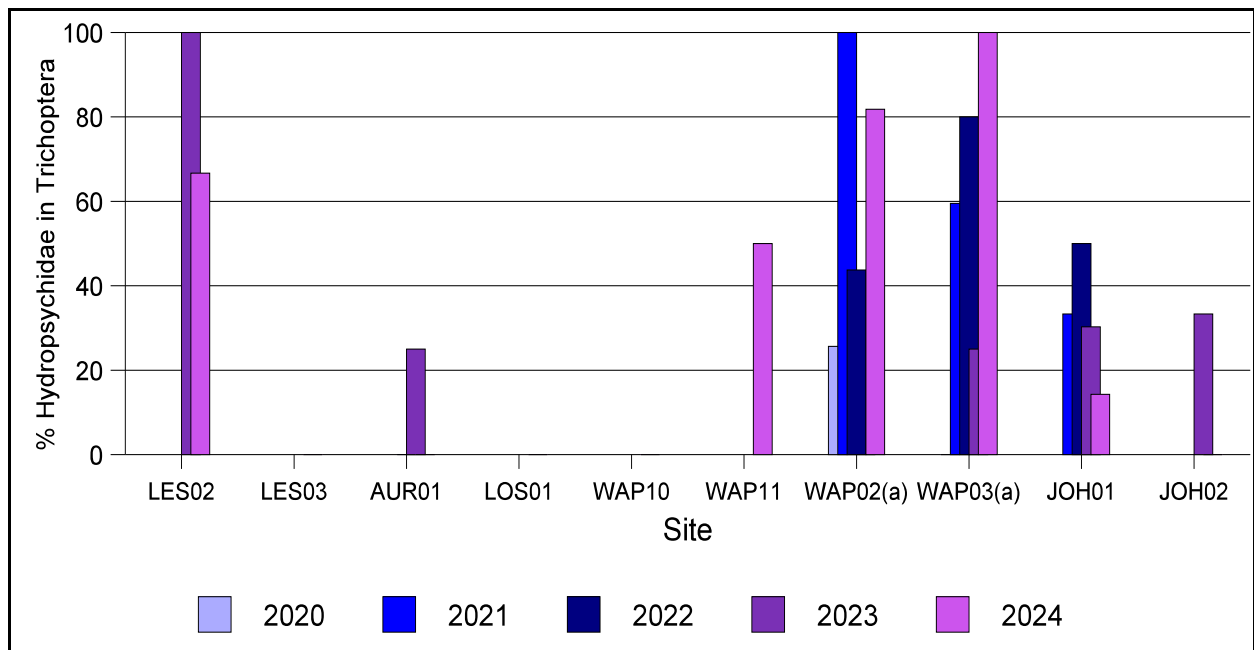


Figure 7. Percent of Trichoptera that were in the family Hydropsychidae at each site.

The percent of Baetidae, a family within Ephemeroptera that is more tolerant to adverse conditions, also was variable among the sites and between successive years at all sites except JOH02, where it remained relatively high (Figure 8). There has been a steady increase in the proportion of Baetidae at WAP02/02a and WAP03/03a since 2021, and an increase at JOH01 since 2022.

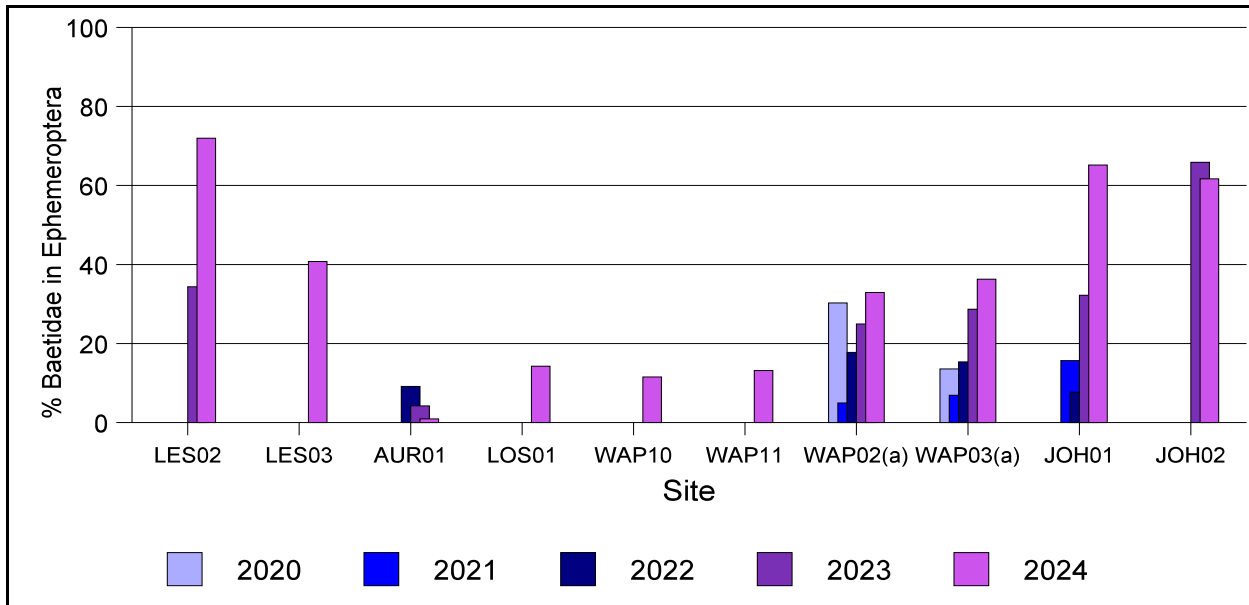


Figure 8. Percent of Ephemeroptera that were in the family Baetidae at each site.

3.4.3 Functional Feeding Groups

A functional feeding group (FFG) is a classification based on the benthic macroinvertebrate's primary method of obtaining food, and therefore can include several different taxa. There are five main groups (Cummins 1973, 2021):

- shredders, which eat leaf litter, rooted aquatic vascular plants or other coarse particulate organic matter (CPOM; >1 mm);
- scrapers/grazers, which eat algae and other associated material;
- collector-gatherers, which eat fine particulate organic matter (FPOM; ≤ 1 mm) on or in the stream sediments;
- collector-filterers, which filter fine particulate organic matter from the water column; and
- predators, which prey on live invertebrates.

Comparing FFGs in a stream is a way to simplify analyses without the need to identify all specimens to lower taxon levels (Cummins 2021). The FFGs present depend on the type of available food, which varies with stream characteristics and adjacent riparian vegetation. Their abundance will differ along the upstream to downstream continuum, with a higher proportion of shredders and lower proportion of collectors upstream versus downstream (Vannote *et al.* 1980). Min *et al.* (2019) discovered that FFG distribution was largely influenced by stream width and slope.

The presence of certain groups, or the ratio of certain groups with respect to other groups, has been shown to be related to stream health. In general, specialists (e.g., many of the shredder species) are presumed to be more sensitive and therefore associated with healthy streams, whereas generalists (e.g., many of the collector species), with their broader diet, are presumed to be more tolerant to disturbance (Cummins and Klug 1979; Barbour *et al.* 1999). Cummins (2021) determined ratios of the relative numbers of FFGs that can be used as surrogates for stream ecological conditions. For example, a 2:1 ratio of collector-filterers to collector-gatherers suggests abnormal turbidity, with an unusually high concentration of FPOM. Fu *et al.* (2014), Bhawsar *et al.* (2015) and Birara *et al.* (2020) discovered that streams with the same FFGs had similar land use patterns in their catchment areas.

Caution is advised when comparing FFGs at the same site over multiple years for several reasons. At the family level, there are often different FFGs within the same family, and at the species level, there may be different FFGs at different growth stages. In addition, data reporting changed in 2023 from having blanks for taxa where the FFG could not be specified, to having those taxa reported as "other", i.e., unclassified (S. Finlayson, pers. comm.). As a result, the "other" category tends to be larger in 2023 and 2024 versus the previous years.

3.4.3.1 Functional Feeding Groups at Lesueur Creek Sites and Sites not Previously Sampled

The graphical illustration of the FFGs at the Lesueur Creek sites and sites that were first sampled in 2024 is presented in Figure 9. Collector filterers and collector-gatherers were noticeably more abundant at LES02 versus LES03, suggesting greater sediment. Percent of shredders was higher at LES03, although leaf litter is expected to be substantial at LES02 as well from the high cover of deciduous trees and shrubs. Of those species that could be classified, collector-gatherers dominated at LOS01, where total suspended solids were higher than most sites sampled. Scrapers dominated WAP10 and WAP11 although benthic algae were not apparent at either.

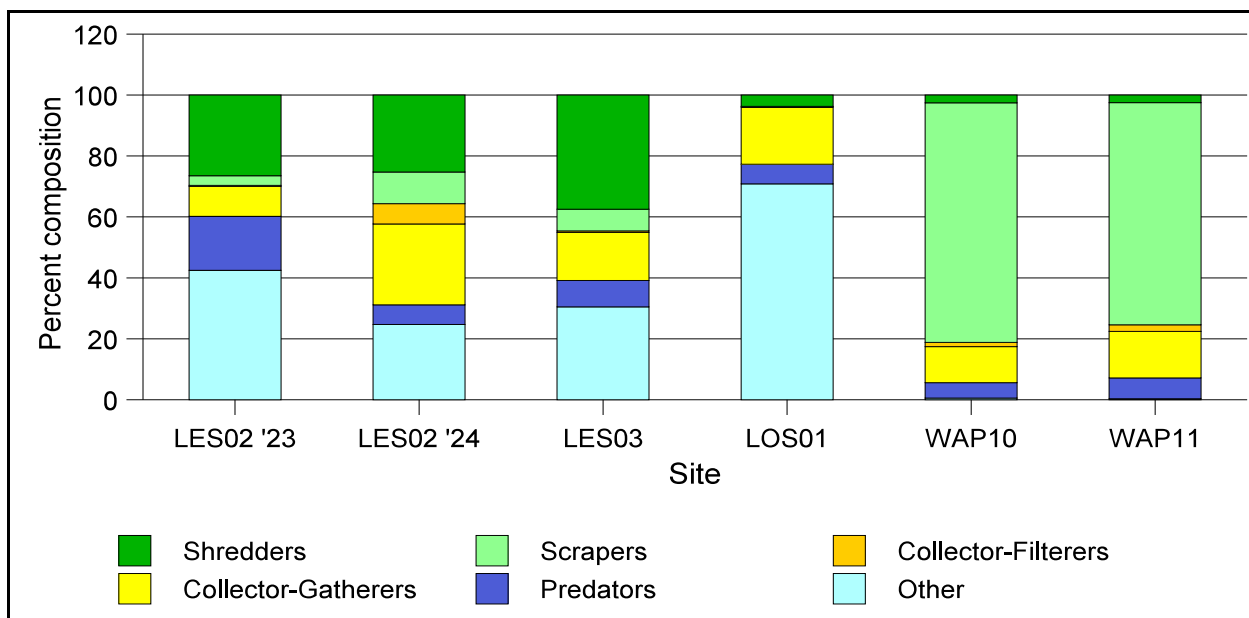


Figure 9. Percent of functional feeding groups at Lesueur Creek, Lost Knife Creek and newest Waiparous Creek sites.

3.4.3.2 Functional Feeding Groups at Aura Creek and Johnson Creek

As in previous years, the scrapers were dominant in Aura Creek (Figure 10) although benthic algae were not perceived to be any greater than at any of the other creeks. Collector-gatherers again were prominent at JOH01 and JOH02 (Figure 11), although sediment was not as noticeable at JOH02. Shredders were not as abundant at either site, but occurred at a higher percentage at JOH01. Total suspended solids were higher at JOH02 but this did not result in significantly more collector-filterers.

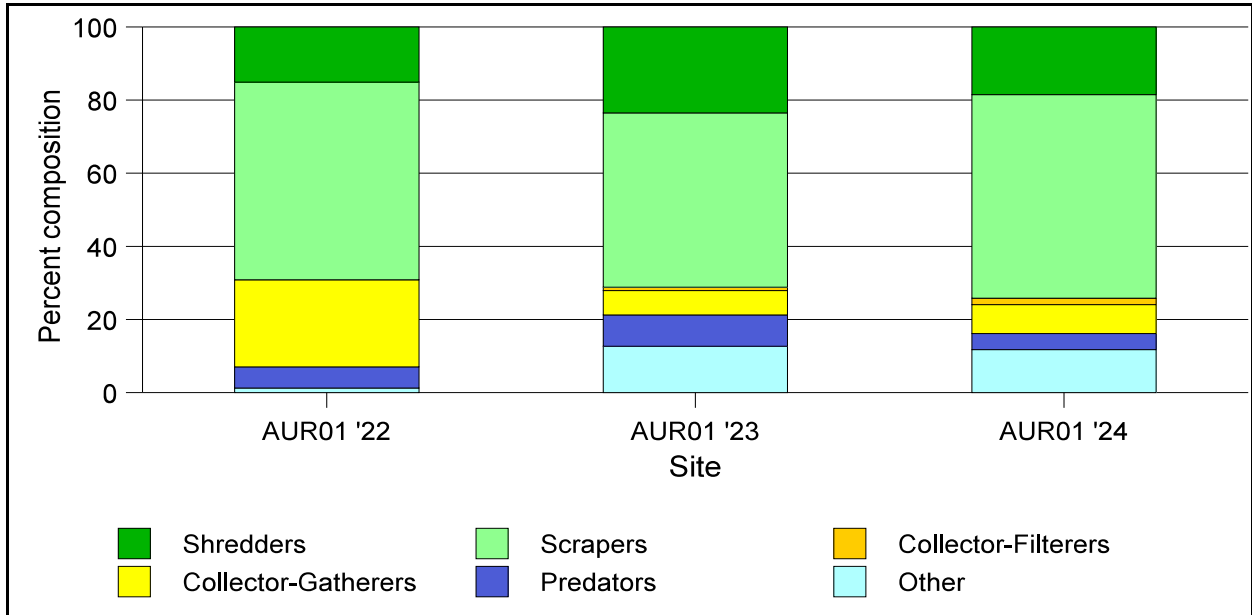


Figure 10. Percent of functional feeding groups at Aura Creek site over the three years of sampling.

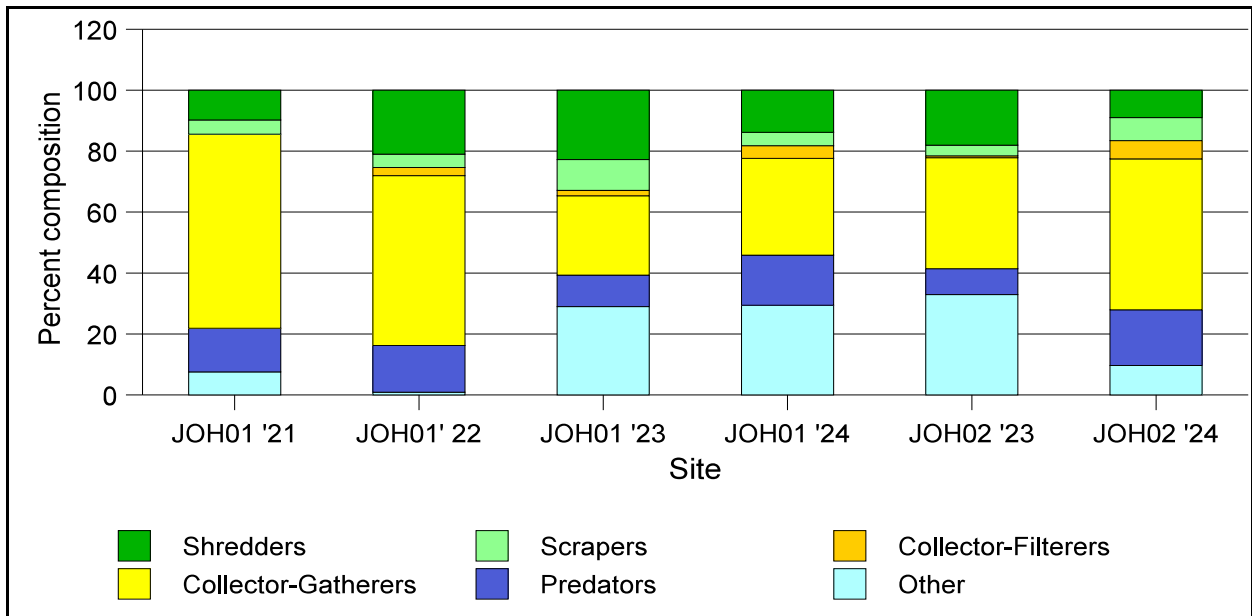


Figure 11. Percent of functional feeding groups at the Johnson Creek sites over the years of sampling.

3.4.3.3 Functional Feeding Groups at WAP02/WAP02a and WAP03/WAP03a

The five years of data at WAP02/02a and WAP03/03a show the variability in FFG communities over time (Figures 12 and 13). The scrapers at WAP02/02a became the dominant FFG, but declined slightly in 2024 (Figure 12). The shredders have declined, and the collector-gatherers have remained prominent. The collector-filterers and predators have varied in abundance. Similarly, the scrapers and collector-gatherers have become the dominant FFGs at WAP03/03a, and the shredders have declined since 2020 (Figure 13).

At both sites, natural alterations in the stream channel was evident between successive years, which may have contributed to variations in the FFG composition. In addition, the human disturbance in the stream channel at and near WAP02/02a may have had an influence, as well as the fact that WAP02a is slightly upstream of WAP02. This variability probably has more impact on the benthic macroinvertebrate population trends and community shifts than any influence from Johnson Creek.

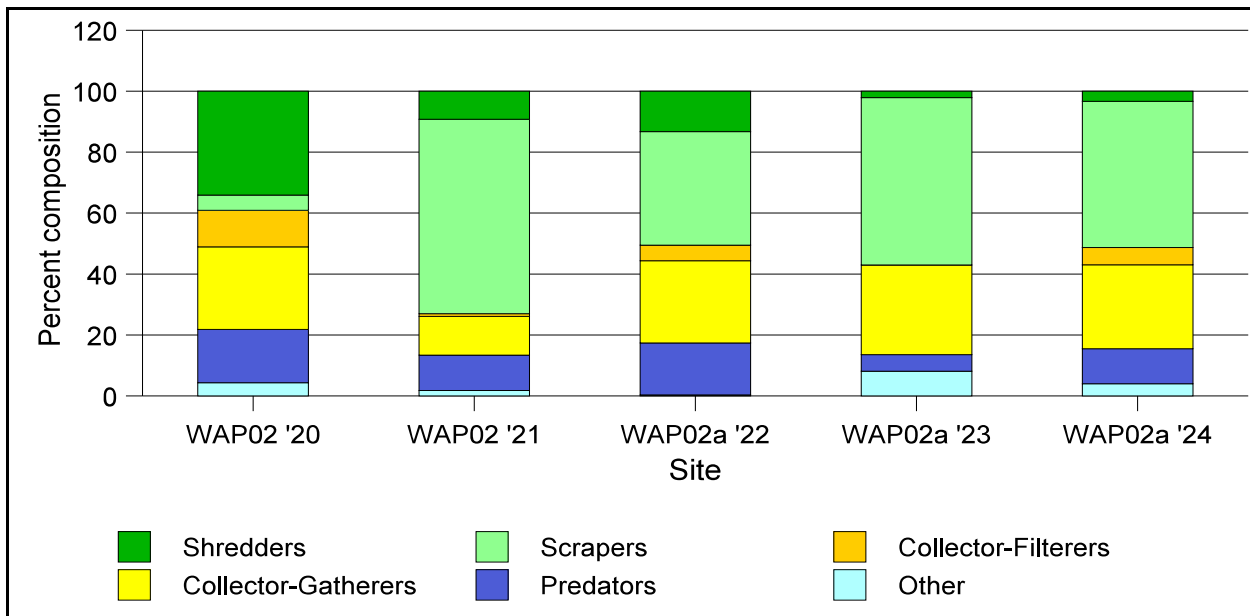


Figure 12. Percent of functional feeding groups at WAP02/WAP02a from 2020 to 2024.

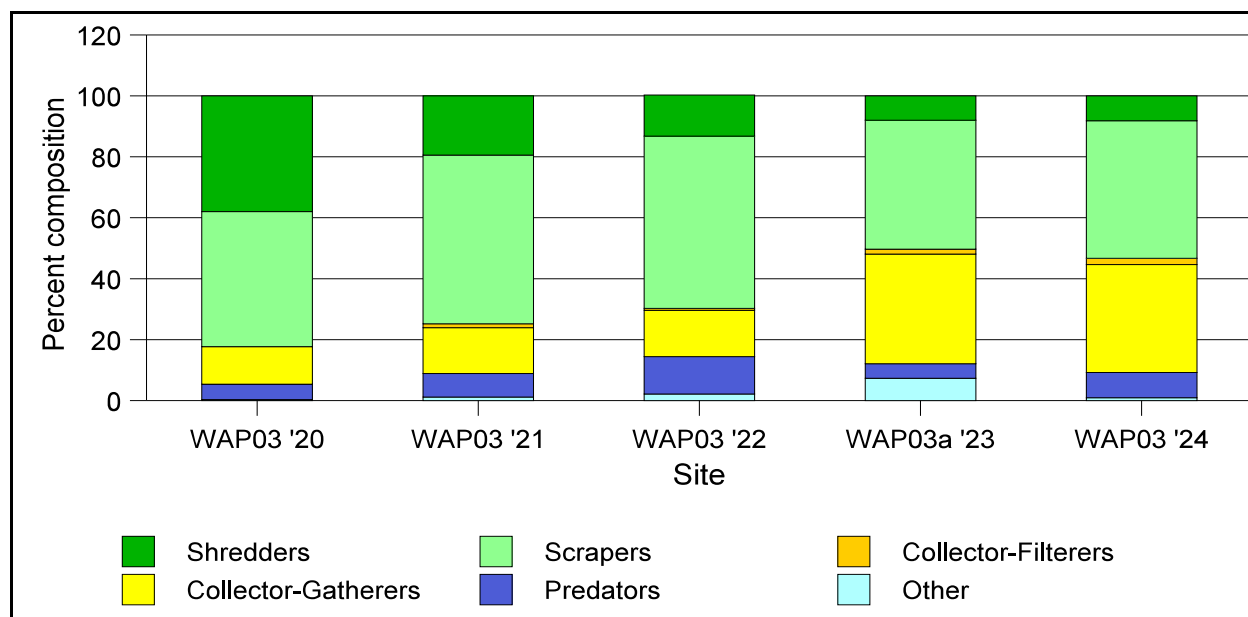


Figure 13. Percent of functional feeding groups at WAP03/WAP03a from 2020 to 2024.

3.4.4 Hilsenhoff Biotic Index

The Hilsenhoff Biotic Index (HBI) estimates organic and nutrient enrichment or pollution, which cause lower dissolved oxygen levels (Hilsenhoff 1987). Tolerance values are assigned to each taxa at the genus/species level based on their response to low dissolved oxygen and hence organic pollution, and the average for all individuals in a sample is calculated. Index scores range from 0 to 10 (Table 15). Sensitive taxa have low scores and tolerant taxa (e.g., many chironomid species) have high scores, therefore an increase in the index suggests decreased water quality due to organic enrichment or pollution (Hilsenhoff 1987).

Table 15. Hilsenhoff Biotic Index (HBI) categories.

Biotic Index	Water Quality	Degree of Organic Pollution
0.00–3.50	Excellent	Organic pollution unlikely
3.51–4.50	Very Good	Possible slight organic pollution
4.51–5.50	Good	Some organic pollution probable
5.51–6.50	Fair	Fairly substantial pollution likely
6.51–7.50	Fairly Poor	Substantial pollution likely
7.51–8.50	Poor	Very substantial pollution likely
8.51–10.00	Very Poor	Severe organic pollution likely

The water quality at the majority of the sites was rated as very good, with possible slight organic enrichment or pollution (Figure 14). In previous years, the Waiparous Creek sites have been rated as excellent, suggesting that organic enrichment increased in 2023 and remained at that level in 2024. Only Lost Knife Creek site (LOS01) was rated as fair with an index of 5.89, suggesting fairly substantial organic enrichment is likely. The stream bed was largely silt, however, and fine substrates are likely to store more carbon and nutrient material naturally than streams with larger substrates (R. McAlpine, pers. comm.). Accordingly, Hilsenhoff (1987) does not recommend using the biotic index on slow-flowing, silt-bottomed streams.

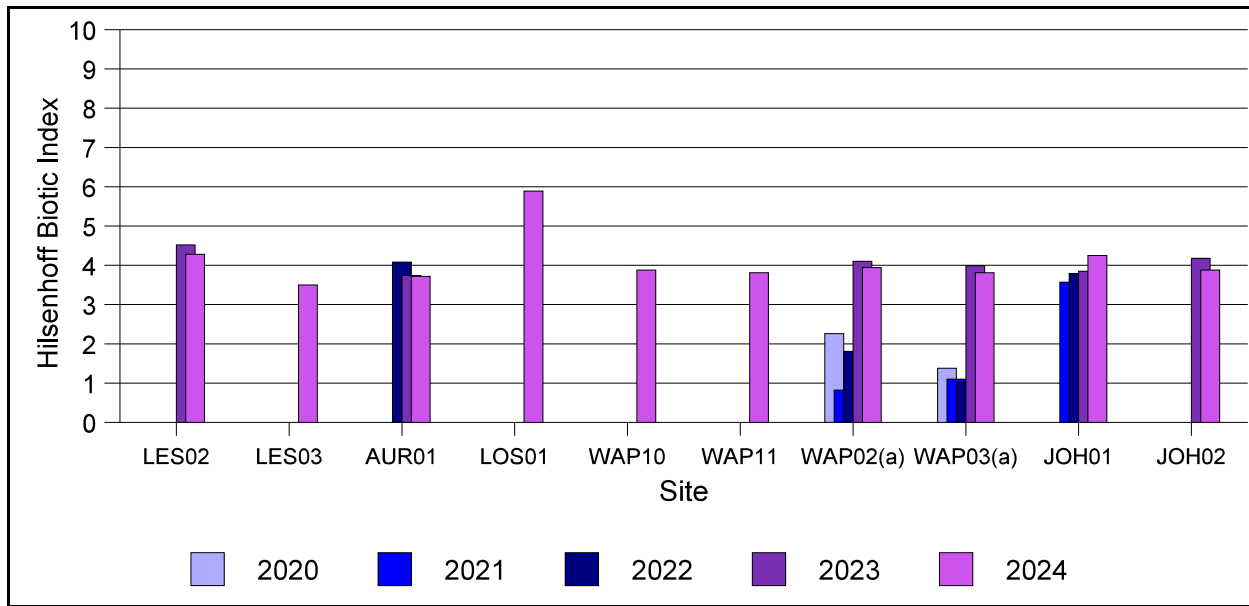


Figure 14. Hilsenhoff Biotic Index for each site.

4.0 Summary and Conclusions

4.1 Comparison of All Sites

The analyses of chemical and physical attributes of the water samples at the ten sites indicate high water quality. Water quality parameters were all within acceptable limits for benthic macroinvertebrates and fish.

Johnson Creek may be affected by nutrient loading, which might have influenced the chemical attributes of Waiparous Creek below the confluence. The higher dissolved nitrogen and nitrate at WAP02/02a versus WAP03/03a possibly was a result of the even higher dissolved nitrogen and nitrate at JOH01, although this may just be natural variation.

The Lost Knife Creek site, a potential reference site, was the anomaly in 2024. It was a much smaller creek than any sampled to date, with a largely silty bottom versus gravel and cobble, and with overhanging vegetation. In other years, water quality related to organic enrichment or pollution at the sites sampled tended to be rated as Excellent (0 – 3.50) or Very Good (3.51 – 4.50). 2024 was the first year there was a Hilsenhoff Biotic Index of Fair, at 5.89 for LOS01. Although cattle grazing is a dominant land use in the area and could contribute towards organic pollution, the index may not be applicable at this site based on the fine substrate.

The Simpson's Index of Diversity and the Shannon-Wiener Index indicate the community composition of most sites sampled in 2024 was highly diverse, above 0.88. The lowest diversity was at WAP10 (0.58), followed by WAP11 (0.62) and AUR01 (0.67).

Based on the first four years of the water monitoring program, LES02 and the two Johnson Creek sites were of most concern with respect to the benthic macroinvertebrate community. However, the EPT ratio was the lowest to date at LOS01, at only 0.13, with a very high population of the pollution-tolerant chironomid family, at almost 70%. This may not be related to water quality though, since there are few EPT taxa that are well suited to fine (sandy/silty) substrates whereas Chironomidae are more commonly found in such habitats.

The consistent high EPT values at WAP02/02a and WAP03/03a suggest good water quality, as do the values of the two new sites on Waiparous Creek, WAP10 and WAP11. The ratio at the Aura Creek site also suggests no concerns.

The percentage of the more tolerant Hydropsychidae within the Trichoptera was variable. They were present at half the sites. The Trichoptera population was very low, however, at less than 2%. Baetidae were identified at all sites but in low to relatively low abundance except at LES02, JOH01 and JOH02. None of the few Trichoptera at LOS01 were Hydropsychidae and a low percentage of Ephemeroptera were Baetidae.

The proportion of FFGs varied among the sites, largely reflecting the habitat and adjacent riparian vegetation. Scrapers dominated or were prominent in Aura Creek and Waiparous Creek, suggesting more algae; collector-gatherers were prominent at LES02, LOS01, WAP02a, WAP03, JOH01 and JOH02, suggesting greater sediment; shredders were highest at the Lesueur Creek sites, suggesting greater leaf litter.

4.2 Comparison Between Years of LES02

Channel depth was less in 2023 versus 2024 at LES02, reflecting the 2023 summer drought. Another notable difference was geometric median particle size, which was less in 2024. There was a decrease in cobble-sized substrate and an increase in pebble and gravel.

There were slight variations in physical and chemical attributes of the water samples, but all were within the guidelines. Water quality with respect to organic enrichment or pollution remained very good between years.

Diversity remained high, and the EPT ratio rose from 0.49 in 2023 to 0.72 in 2024. The percent of Hydropsychidae declined and Baetidae increased. Among the FFGs, there was a notable increase in collector-gatherers and a decrease in predators.

4.3 Comparison Among Years of Aura Creek Site

The physical characteristics of AUR01 were not markedly different among years with the exception of embeddedness, which was higher in 2024. Accordingly, total suspended solids rose each year from 2022 to 2024, as did turbidity, but not enough to cause concern. This may be related to the upstream logging that began most recently in the winter of 2020/2021. The logging may also be responsible for the rise in carbonate and alkalinity (PP as CaCO_3) values over the three years of sampling, and the slight increases in phosphorous and dissolved nitrogen, if they were caused by the decay of organic materials resulting in the release of CO_2 in the stream.

The Hilsenhoff Biotic Index suggested very good water quality in all three years.

Diversity and the EPT ratio remained relatively high, suggesting a healthy ecosystem. Hydropsychidae and Baetidae were either absent or relatively low in abundance over the three years. The proportion of FFGs differed among years, but scrapers remained the dominant FFG.

4.4 Comparison Among Years of Johnson Creek Sites

There were slight variations in physical and chemical attributes of the water samples at the Johnson Creek sites, but all were within the guidelines. There has been a gradual increase in dissolved nitrogen and dissolved nitrate at JOH01 over the four years of sampling, which may be related to nutrient loading. The Hilsenhoff Biotic Index has varied little, indicating possible slight organic enrichment with a rating of very good.

Diversity indices indicate continued highly diverse community compositions. However, the EPT ratio at JOH01 remained lower than most sites, but increased at JOH02 from 2023 to 2024. The percent of Hydropsychidae within the Trichoptera went down at JOH01 while the percent of Baetidae within the Ephemeroptera went up, reaching the same level as JOH02. Of the FFGs, collector-gatherers remained prominent at both sites.

While some health indicators suggest concerns with water quality at JOH01, others do not. Further monitoring over the years should help to determine the health of this site.

4.5 Comparison Among Years of Waiparous Creek Sites

The physical characteristics varied among years at WAP02/02a and WAP03/03a largely as a result of natural variability in the stream channel from fluvial events, and, in the case of WAP02/02a, human alteration of the stream channel. Velocity was highest in 2024, with more cobble and fewer pebbles than the previous year, possibly a result of fewer rock dams across the creek.

There were slight variations in physical and chemical attributes of the water samples, but all were within the guidelines. The Hilsenhoff Biotic Index had been in the “excellent” category, indicating organic enrichment or pollution was unlikely, but dropped to the “very good” category in 2023 and 2024, suggesting possible slight organic enrichment or pollution.

The diversity indices indicate high diversity in benthic macroinvertebrates over the five years. The EPT ratio also has been high, suggesting good water quality. The percent of Hydropsychidae within the Trichoptera and the percent of Baetidae within the Ephemeroptera has been variable at both sites.

The proportion of FFGs varied among the years. At WAP02/02a, there was a notable decline in shredders over the five years, and scrapers remained prominent. At WAP03/03a, the shredders have declined and collector-gatherers have increased, with scrapers also prominent. The variation in the stream channels may explain these differences.

4.6 Reference Sites

Lost Knife Creek was sampled because it was identified as a potential reference site by Sinnatamby and Sanderson (2024). Since it differs so much from the other sites sampled, it may not be considered representative in the Ghost River watershed; however, there may be other similar sites in adjacent eastern slopes watersheds. If so, it may still provide a valuable data point for the reference model.

5.0 General Recommendations

- Adequate annual funding for this program should be maintained.
- The *GWAS Water Monitoring Program Plan* should continue to be followed, allowing flexibility if circumstances materialize that suggest a deviation.
- The sites sampled from 2020 to 2024 should be monitored as frequently as possible, as funds will allow and as personnel are available, giving priority to those sites where water quality may be more comprised, e.g., Lesueur Creek, Johnson Creek, Lost Knife Creek. (If monitoring in successive years, three years may be considered adequate, but CABiN does not specify a frequency.)
- Consideration should be given to using drone technology as a tool for stream reconnaissance to view upstream reaches that are not easily accessed by foot or vehicle.
- If possible, at least one additional sampling site should be established on Lesueur Creek above LES01, ideally including a site above all/most OHV activity.
- Further sites on Johnson Creek would help to determine the health of the creek, ideally including a site above JOH02, above all/most OHV activity.

- Further sampling should occur at AUR01 to monitor the levels of TSS, turbidity, carbonates and alkalinity.
- Inquiries should be made of adjacent watershed groups who are part of the Eastern Slopes Collaborative to see if they have sampled sites similar to Lost Knife Creek.
- Requests should be made to modify the bridge over Lesueur Creek to prevent the introduction of sediment into the creek by vehicle traffic.
- Prior to conducting the field sampling, the survey team should read and fully understand the methodology presented in the *CABiN Field Manual – Wadeable Streams*.
- A practice run through all of the methods should be conducted prior to data collection.
- Certain tasks, such as kicknetting, should only be conducted by qualified personnel, whereas other tasks may be done by volunteers who have been trained by the CABiN-certified personnel or previously trained volunteers. Because not all of the trained volunteers may be present on each field day, they should be encouraged to try different tasks to become familiar with them in case they are required to perform them at some time.
- During the sampling, the field team must adhere to the order of events required to maintain quality assurance/quality control (QA/QC) of each sample.
- To maintain consistency, the same laboratories that were originally selected and used in from 2020 to 2024 (water chemical and benthic macroinvertebrate analysis) should continue to be used.

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7.0 Personal Communications

- | | |
|------------------|---|
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Appendix A
CABiN Field Sheet

Field Crew: _____ Site Code: _____
Sampling Date (DD/MM/YYYY): _____

Occupational Health & Safety: Site Inspection Sheet completed (see page 6)

PRIMARY SITE DATA

CABIN Study Name: _____ Local Basin Name: _____

River/Stream Name: _____ Stream Order: (map scale 1:50,000) _____

Select one: Test Site Potential Reference Site

Geographical Description/Notes:

Surrounding Land Use: (check those present) Information Source: _____

<input type="checkbox"/> Forest	<input type="checkbox"/> Field/Pasture	<input type="checkbox"/> Agriculture	<input type="checkbox"/> Residential/Urban
<input type="checkbox"/> Logging	<input type="checkbox"/> Mining	<input type="checkbox"/> Commercial/Industrial	<input type="checkbox"/> Other _____

Dominant Surrounding Land Use: (check one) Information Source: _____

<input type="checkbox"/> Forest	<input type="checkbox"/> Field/Pasture	<input type="checkbox"/> Agriculture	<input type="checkbox"/> Residential/Urban
<input type="checkbox"/> Logging	<input type="checkbox"/> Mining	<input type="checkbox"/> Commercial/Industrial	<input type="checkbox"/> Other _____

Location Data

Latitude: _____ N Longitude: - _____ W (DMS or DD)
Elevation: _____ (fast or masl) GPS Datum: GRS80 (NAD83/WGS84) Other: _____

Site Location Map Drawing

Note: Indicate north

Field Crew: _____ Site Code: _____
 Sampling Date (DD/MM/YYYY): _____

Photos

Field Sheet Upstream Downstream Across Site Aerial View
 Substrate (exposed) Substrate (aquatic) Other _____

REACH DATA (*represents 6 times bankfull width*)

1. Habitat Types: (*check those present*)

Riffle Rapids Straight run Pool/Back Eddy

2. Canopy Coverage: (*stand in middle of stream and look up, check one*)

0 % 1-25 % 26-50 % 51-75 % 76-100 %

3. Macrophyte Coverage: (*not algae or moss, check one*)

0 % 1-25 % 26-50 % 51-75 % 76-100 %

4. Streamside Vegetation: (*check those present*)

ferns/grasses shrubs deciduous trees coniferous trees

5. Dominant Streamside Vegetation: (*check one*)

ferns/grasses shrubs deciduous trees coniferous trees

6. Periphyton Coverage on Substrate: (*benthic algae, not moss, check one*)

- 1 - Thin layer, no obvious colour (< 0.5 mm thick)
- 2 - Yellow-brown to light green colour (0.5-1 mm thick)
- 3 - Patches of thicker green to brown algae (1-5 mm thick)
- 4 - Numerous large clumps of green to dark brown algae (5-20 mm thick)
- 5 - Rocks are mostly obscured by algal mat, extensive green, brown to black algal mass may have long strands (> 20 mm thick)

Note: 1 through 5 represent categories entered into the CABIN database.

BENTHIC MACROINVERTEBRATE DATA

Habitat sampled (*check one*): riffle rapids straight run

400 µm mesh Kick Net *	
Person sampling	
Sampling time (i.e. 3 min.)	
No. of sample jars	
Typical depth in kick area (cm)	

Preservative used: _____

Sampled sieved on site using the "Bucket Swirling Method":

YES NO

If YES, debris collected for QA/QC

* Note: Indicate if a sampling method other than the recommended 400 µm mesh kick net is used.

Field Crew: _____ Site Code: _____
 Sampling Date (DD/MM/YYYY): _____

WATER CHEMISTRY DATA Time: _____ (24 hr clock) Time zone: _____

Air Temp: _____ (°C) Water Temp: _____ (°C) pH: _____
 Specific Conductance: _____ (µs/cm) DO: _____ (mg/L) Turbidity: _____ (NTU)

Check if water samples were collected for the following analyses:

- TSS (Total Suspended Solids)
- Nitrogen (i.e. Total, Nitrate, Nitrite, Dissolved, and/or Ammonia)
- Phosphorus (Total, Ortho, and/or Dissolved)
- Major Ions (i.e. Alkalinity, Hardness, Chloride, and/or Sulphate) Other _____

Note: Determining alkalinity is recommended, as are other analyses, but not required for CABIN assessments.

CHANNEL DATA

Slope - Indicate how slope was measured: (check one)

- Calculated from map**

Scale: _____ (Note: small scale map recommended if field measurement is not possible - i.e. 1:20,000).
 contour interval (vertical distance) _____ (m),
 distance between contour intervals (horizontal distance) _____ (m)
 slope = vertical distance/horizontal distance = _____

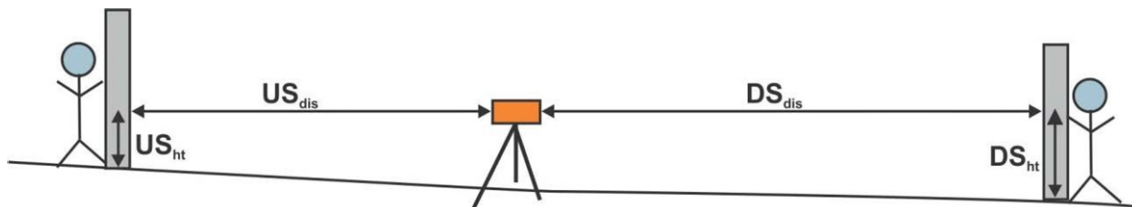
OR

- Measured in field**

Circle device used and fill out table according to device:

a. Survey Equipment b. Hand Level & Measuring Tape

Measurements	Upstream (U/S)	Downstream(D/S)	Calculation
^a Top Hairline (T)			
^a Mid Hairline (ht) OR			
^b Height of rod			
^a Bottom Hairline (B)			
^b Distance (dis) OR			US _{dis} +DS _{dis} =
^a T-B x 100	^a US _{dis} =T-B	^a DS _{dis} =T-B	
Change in height (Δht)			DS _{ht} -US _{ht} =
Slope (Δht/total dis)			



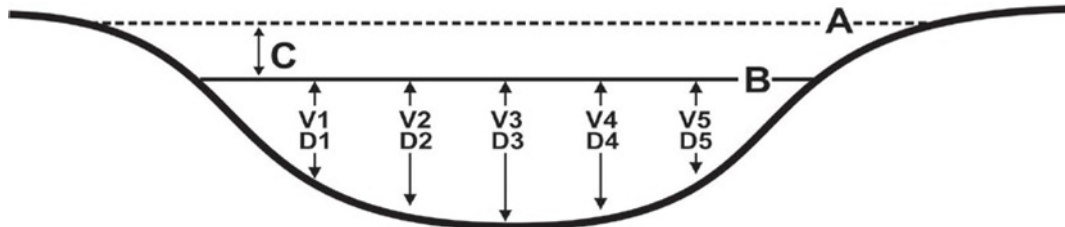
Field Crew: _____ Site Code: _____
 Sampling Date (DD/MM/YYYY): _____

Widths and Depth

Location at site: _____ (Indicate where in sample reach, ex. d/s of kick area)

A - Bankfull Width: _____ (m) B - Wetted Stream Width: _____ (m)

C - Bankfull–Wetted Depth (height from water surface to Bankfull): _____ (cm)



Note:
 Wetted widths > 5 m, measure a minimum of 5-6 equidistant locations.
 Wetted widths < 5 m, measure 3-4 equidistant locations.

Velocity and Depth

Check appropriate velocity measuring device and fill out the appropriate section in chart below. Distance from shore and depth are required regardless of method:

- Velocity Head Rod (or ruler):** Velocity Equation (m/s) = $\sqrt{[2(\Delta D/100) * 9.81]}$
- Rotary meters:** Gurley/Price/Mini-Price/Propeller (Refer to specific meter conversion chart for calculation)
- Direct velocity measurements:** Marsh-McBirney Sontek or Other _____

	1	2	3	4	5	6	AVG
Distance from Shore (m)							
Depth (D) (cm)							
Velocity Head Rod (ruler)							
Flowing water Depth (D ₁) (cm)							
Depth of Stagnation (D ₂) (cm)							
Change in depth (ΔD=D ₂ -D ₁) (cm)							
Rotary meter							
Revolutions							
Time (minimum 40 seconds)							
Direct Measurement or calculation							
Velocity (V) (m/s)							



Field Crew: _____ Site Code: _____

Sampling Date (DD/MM/YYYY): _____

SUBSTRATE DATA

1. 100 Pebble Count & Substrate Embeddedness

- Measure the intermediate axis (100 rocks) and embeddedness (10 rocks) of substrate in the stream bed.
- Indicate **B** for bedrock, **S** for sand/silt/clay (particles < 0.2 cm) and **O** for organic material.
- Embeddedness categories (**E**):
 - Completely embedded = 1
 - 75% embedded = $\frac{3}{4}$
 - 50% embedded = $\frac{1}{2}$
 - 25% embedded = $\frac{1}{4}$
 - Unembedded = 0

2. Surrounding/Interstitial Material

Circle the substrate size category for the surrounding material.

Substrate Size Class	Category
Organic Cover	0
< 0.1 cm (fine sand, silt or clay)	1
0.1-0.2 cm (coarse sand)	2
0.2-1.6 cm (gravel)	3
1.6-3.2 cm (small pebble)	4
3.2-6.4 cm (large pebble)	5
6.4-12.8 cm (small cobble)	6
12.8-25.6 cm (cobble)	7
> 25.6 cm (boulder)	8
Bedrock	9

Diameter (cm)	E	Diameter (cm)	E	Diameter (cm)	E	Diameter (cm)	E
1		26		51		76	
2		27		52		77	
3		28		53		78	
4		29		54		79	
5		30		55		80	
6		31		56		81	
7		32		57		82	
8		33		58		83	
9		34		59		84	
10		35		60		85	
11		36		61		86	
12		37		62		87	
13		38		63		88	
14		39		64		89	
15		40		65		90	
16		41		66		91	
17		42		67		92	
18		43		68		93	
19		44		69		94	
20		45		70		95	
21		46		71		96	
22		47		72		97	
23		48		73		98	
24		49		74		99	
25		50		75		100	

Note: The Wolman D50 (i.e. median diameter), Wolman Dg (i.e. geometric mean diameter) and the % composition of the substrate classes will be calculated automatically in the CABIN database using the 100 pebble data. All 100 pebbles must be measured in order for the CABIN database tool to perform substrate calculations.

Field Crew: _____ Site Code: _____
Sampling Date (DD/MM/YYYY): _____

SITE INSPECTION

Site Inspected by: _____

Communication Information

Itinerary left with contact person (include contact numbers)

Contact Person: _____ Time checked-in: _____

Form of communication: radio cell satellite hotel/pay phone SPOT

Phone number: () _____

Vehicle Safety

Safety equipment (first aid, fire extinguisher, blanket, emergency kit in vehicle)

Equipment and chemicals safely secured for transport

Vehicle parked in safe location; pylons, hazard light, reflective vests if necessary

Notes:

Shore & Wading Safety

Wading Task Hazard Analysis read by all field staff

Wading Safe Work Procedures read by all field staff

Instream hazards identified (i.e. log jams, deep pools, slippery rocks)

PFD worn

Appropriate footwear, waders, wading belt

Belay used

Notes:

CABIN Field Sheet April 2023



Appendix B
Benthic Macroinvertebrate Common Names

Order	Family	Common Name
Coleoptera		Beetles
	Dytiscidae	Predaceous diving beetles
	Elmidae	Riffle beetles
Diptera		Flies
	Ceratopogonidae	Biting midges
	Chironomidae	Non-biting midges
	Empididae	Dagger flies, balloon flies
	Psychodidae	Moth flies, sand flies
	Simuliidae	Black flies\
	Tipulidae	Craneflies
Ephemeroptera		Mayflies
	Ameletidae	Combmouthed minnow mayflies
	Baetidae	Small minnow mayflies
	Ephemerellidae	Spiny crawler mayflies
	Heptageniidae	Flat-headed mayflies
	Leptophlebiidae	Prong-gilled mayflies
Megaloptera		Alderflies, dobsonflies and fishflies
	Sialidae	Alderflies
Plecoptera		Stoneflies
	Capniidae	Small winter stoneflies
	Chloroperlidae	Green stoneflies
	Leuctridae	Rolled-winged stoneflies
	Nemouridae	Spring stoneflies
	Perlidae	Common stoneflies
	Perlodidae	Springflies
	Taeniopterygidae	Winter stoneflies
Trichoptera		Caddisflies
	Brachycentridae	Humpless casemaker caddisflies
	Hydropsychidae	Net-spinning caddisflies
	Lepidostomatidae	Bizarre caddisflies
	Phryganeidae	Giant caddisflies
	Rhyacophilidae	Free-living caddisflies
Sarcoptiformes		Mites
	Hydrozetidae	Mites
Trombidiformes		Mites
	Aturidae	Water mites

Order	Family	Common Name
	Hygrobatidae	Water mites
	Lebertiidae	Water mites
	Sperchontidae	Water mites
	Torrenticolidae	Torrent mites
Veneroida		Bivalve molluscs
	Pisidiidae	Pea clams, fingernail clams
Basommatophora		Pulmonate freshwater snails
	Lymnaeidae	Pond snails
Lumbriculida		Microdrile oligochaetes (worms)
	Lumbriculidae	Aquatic worms
Tubificida		Annelid worms
	Enchytraeidae	Microdrile oligochaetes (worms)
	Lumbricidae	Earthworms
	Naididae	Clitellate oligochaete worms

Also present: Class Copepoda (crustaceans), Class Ostracoda (seed shrimp) and Class Turbellaria (flatworms); Phylum Nemata (nematodes).

Appendix C
Benthic Macroinvertebrates Identified Using Morphological Characteristics

Taxa	Site									
	LES02	LES03	AUR01	LOS01	WAP10	WAP11	WAP02a	WAP03	JOH01	JOH02
Phylum: Arthropoda										
Subphylum: Hexapoda										
Class: Insecta										
Order: Ephemeroptera	0	0	0	0	0	0	0	0	0	0
Family: Ameletidae	0	0	0	0	0	0	0	0	0	0
<i>Ameletus</i>	6	3	0	14	0	0	5	18	80	0
Family: Baetidae	122	93	0	43	30	0	27	45	40	127
<i>Acentrella</i>	28	3	0	0	30	36	9	0	60	9
<i>Baetis</i>	294	3	22	14	130	218	127	161	1060	464
<i>Baetis fuscatus</i> gr.	0	0	0	0	40	18	9	26	0	0
<i>Baetis rhodani</i> group	0	7	0	0	140	64	7	21	0	0
Family: Ephemerellidae	0	3	211	300	0	18	0	0	40	82
<i>Drunella</i>	0	0	0	0	0	9	0	5	0	0
<i>Drunella doddsii</i>	0	0	0	0	0	45	11	26	20	0
<i>Drunella spinifera</i>	0	3	0	0	0	0	2	0	20	9
<i>Ephemerella</i>	0	3	0	0	0	0	0	0	0	0
<i>Ephemerella excrucians</i> complex	0	0	0	0	0	0	0	3	0	9
Family: Heptageniidae	161	76	2078	0	2210	1727	270	239	300	164
<i>Cinygmula</i>	0	0	22	0	0	9	11	3	40	64
<i>Epeorus</i>	0	0	0	0	0	18	5	13	0	0
<i>Rhithrogena</i>	0	0	0	0	590	364	61	137	0	0
Family: Leptophlebiidae	6	66	0	29	30	27	0	0	120	45
Order: Plecoptera	0	7	0	0	0	0	0	0	40	18
Family: Capniidae	17	110	33	0	20	27	14	39	40	27
Family: Chloroperlidae	6	0	22	0	20	27	18	5	0	109

Taxa	Site									
	LES02	LES03	AUR01	LOS01	WAP10	WAP11	WAP02a	WAP03	JOH01	JOH02
<i>Suwallia</i>	0	0	0	0	0	0	7	3	20	0
<i>Sweltsa</i>	6	7	0	14	120	127	43	53	40	145
Family: Leuctridae	0	0	0	0	0	0	0	0	0	9
Family: Nemouridae	72	17	111	43	0	0	0	0	120	27
<i>Nemoura</i>	0	0	22	0	0	0	0	0	0	0
<i>Visoka cataractae</i>	0	0	0	0	0	0	0	0	0	9
<i>Zapada</i>	0	0	0	0	0	0	0	0	40	18
<i>Zapada cinctipes</i>	372	300	511	29	10	0	0	0	640	155
Family: Perlidae	11	10	0	0	40	9	7	0	380	73
<i>Doroneuria</i>	0	0	0	0	0	0	2	0	20	27
<i>Hesperoperla</i>	0	0	0	0	0	9	2	3	240	9
Family: Perlodidae	6	0	0	0	0	0	0	0	0	0
<i>Isogenoides</i>	0	0	0	0	0	18	0	0	0	0
<i>Kogotus</i>	0	0	22	0	0	0	0	0	20	36
<i>Megarcys</i>	0	0	0	0	0	0	0	8	0	0
<i>Skwala</i>	0	0	22	0	0	0	0	0	0	0
Family: Taeniopterygidae	0	0	0	0	30	36	5	24	0	0
Order: Trichoptera	0	3	0	14	0	0	2	0	0	0
Family: Brachycentridae	11	0	0	0	10	18	0	0	40	0
<i>Brachycentrus americanus</i>	0	0	0	0	10	0	0	0	0	0
Family: Hydropsychidae	22	0	0	0	0	9	9	5	20	0
<i>Arctopsyche</i>	0	0	0	0	0	9	0	0	0	0
Family: Lepidostomatidae	0	0	0	0	0	0	0	0	0	0
<i>Lepidostoma</i>	0	7	0	0	10	0	0	0	0	0
Family: Phryganeidae	0	0	0	0	0	0	0	0	20	0
Family: Rhyacophilidae	0	0	0	0	0	0	0	0	0	0
<i>Rhyacophila betteni</i> group	0	0	33	0	0	0	0	0	0	0
<i>Rhyacophila brunnea/vemna</i> group	0	0	0	0	0	0	0	0	40	0

Taxa	Site									
	LES02	LES03	AUR01	LOS01	WAP10	WAP11	WAP02a	WAP03	JOH01	JOH02
<i>Rhyacophila narvae</i>	0	0	0	0	0	0	0	0	20	27
Order: Diptera	0	0	0	0	0	0	0	0	0	0
Family: Ceratopogonidae	0	0	0	0	0	0	0	0	0	9
<i>Dasyhelea</i>	0	3	0	0	0	0	0	0	0	0
<i>Mallochohelea</i>	0	0	0	29	0	9	0	0	0	64
Family: Chironomidae	44	41	56	57	0	9	0	0	140	0
Subfamily: Chironominae	0	0	0	0	0	0	0	0	0	0
Tribe: Chironomini	0	0	0	0	0	0	0	0	0	0
<i>Harnischia</i>	0	0	0	14	0	0	0	0	0	0
<i>Microtendipes</i>	0	31	0	0	0	0	0	0	0	0
<i>Polypedilum</i>	0	0	0	57	0	0	0	0	0	0
Tribe: Tanytarsini	0	0	0	1157	0	0	0	0	0	0
<i>Constempellina</i> sp. C	0	0	0	43	0	0	0	0	0	9
<i>Micropsectra</i>	56	34	0	314	0	0	0	0	340	64
<i>Rheotanytarsus</i>	0	3	0	0	0	0	0	0	0	0
<i>Sublettea</i>	0	0	0	0	0	0	0	0	20	0
Subfamily: Diamesinae	0	0	0	0	0	0	0	0	0	0
Tribe: Diamesini	0	0	0	0	0	0	0	0	0	0
<i>Pagastia</i>	28	3	0	0	0	0	0	0	180	9
<i>Potthastia gaedii</i> group	28	48	0	0	0	0	0	0	0	0
<i>Potthastia longimana</i> group	0	14	0	0	0	0	0	0	0	0
<i>Pseudodiamesa</i>	0	0	0	14	0	0	0	0	0	0
Subfamily: Orthoclaadiinae	0	0	0	0	0	0	0	0	0	0
<i>Brillia</i>	17	0	0	0	0	0	2	0	40	0
<i>Eukiefferiella</i>	6	0	22	0	0	0	5	8	420	64
<i>Hydrobaenus</i>	0	0	0	657	0	0	0	0	0	0
<i>Krenosmittia</i>	0	0	0	0	0	0	2	0	0	0
<i>Orthocladus</i> complex	211	93	244	0	10	0	7	0	380	55

Taxa	Site									
	LES02	LES03	AUR01	LOS01	WAP10	WAP11	WAP02a	WAP03	JOH01	JOH02
<i>Rheocricotopus</i>	0	7	0	0	0	0	0	0	80	9
<i>Thienemanniella</i>	0	0	0	14	0	0	0	0	0	0
<i>Tvetenia</i>	17	0	67	0	10	0	11	0	600	64
Subfamily: Prodiamesinae	0	0	0	0	0	0	0	0	0	0
<i>Monodiamesa</i>	0	0	0	186	0	0	0	0	0	0
Subfamily: Tanypodinae	0	0	0	43	0	0	0	0	0	0
Tribe: Macropelopiini	0	0	0	0	0	0	0	0	0	0
<i>Macropelopia</i>	0	0	0	71	0	0	0	0	0	0
<i>Radotanypus</i>	0	0	0	571	0	0	0	0	0	0
Tribe: Pentaneurini	0	0	0	0	0	0	0	0	0	0
<i>Thienemannimyia</i> group	44	72	44	57	0	0	0	0	20	0
Family: Empididae	50	7	33	0	0	0	0	0	60	0
<i>Neoplasta</i>	33	24	22	0	0	0	0	0	40	9
<i>Roederiodes</i>	6	3	0	0	0	0	0	0	0	0
Family: Psychodidae	0	0	0	0	0	0	0	0	0	0
<i>Pericoma/Telmatoscopus</i>	0	0	0	414	0	0	0	0	60	155
Family: Simuliidae	0	3	22	0	0	0	0	0	20	0
<i>Simulium</i>	89	3	44	0	20	27	32	13	240	182
Family: Tipulidae	0	0	0	0	0	0	0	0	20	0
<i>Antocha</i>	0	0	0	0	0	0	0	0	100	9
<i>Dicranota</i>	0	0	11	43	10	0	0	0	20	0
<i>Hexatoma</i>	0	3	0	0	10	9	5	8	60	18
<i>Tipula</i>	0	0	11	57	0	0	0	0	0	0
Order: Coleoptera	0	0	0	0	0	0	0	0	0	0
Family: Dytiscidae	0	0	0	0	0	0	0	0	0	0
Subfamily: Hydroporinae	0	0	0	29	0	0	0	0	0	0
Family: Elmidae	0	0	44	14	0	9	0	0	600	418
<i>Heterlimnius</i>	0	0	12	14	20	0	2	0	340	181

Taxa	Site									
	LES02	LES03	AUR01	LOS01	WAP10	WAP11	WAP02a	WAP03	JOH01	JOH02
Order: Megaloptera	0	0	0	0	0	0	0	0	0	0
Family: Sialidae	0	0	0	0	0	0	0	0	0	0
<i>Sialis</i>	0	0	0	29	0	0	0	0	0	0
Subphylum: Chelicerata										
Class: Arachnida										
Order: Sarcoptiformes	0	0	0	0	0	0	0	0	0	0
Family: Hydrozetidae	0	0	0	43	0	0	0	0	0	0
Order: Trombidiformes	0	3	0	14	0	0	0	0	40	0
Family: Aturidae	0	0	0	0	0	0	0	0	0	0
<i>Brachypoda</i>	0	10	0	29	0	0	0	0	0	0
Family: Hygrobatidae	0	0	0	0	0	0	0	0	0	0
<i>Atractides</i>	0	0	0	0	0	0	0	0	20	0
<i>Hygrobates</i>	0	0	0	129	0	0	0	0	0	0
Family: Lebertiidae	0	0	0	0	0	0	0	0	0	0
<i>Lebertia</i>	0	0	11	14	0	0	2	0	40	18
Family: Sperchontidae	0	0	0	0	0	0	0	0	0	0
<i>Sperchon</i>	0	0	11	0	0	0	0	0	0	0
Family: Torrenticolidae	0	0	0	0	0	0	0	0	0	0
<i>Testudacarus</i>	0	0	0	0	0	0	0	0	260	18
<i>Torrenticola</i>	0	34	0	0	0	0	2	0	20	9
Phylum: Annelida										
Subphylum: Clitellata										
Class: Oligochaeta										
Order: Lumbriculida	0	0	0	0	0	0	0	0	0	0
Family: Lumbriculidae	6	0	0	0	0	0	0	0	0	0

Taxa	Site									
	LES02	LES03	AUR01	LOS01	WAP10	WAP11	WAP02a	WAP03	JOH01	JOH02
<i>Rhynchelmis</i>	0	0	0	0	0	0	0	3	0	0
Order: Tubificida	0	0	0	0	0	0	0	0	0	0
Family: Enchytraeidae	0	0	0	0	0	0	0	0	0	0
<i>Enchytraeus</i>	22	0	0	0	0	0	0	0	0	0
Family: Naididae	0	0	0	0	0	0	0	0	0	0
<i>Rhyacodrilus</i>	0	0	11	29	0	0	0	0	0	0
Phylum: Mollusca										
Class: Bivalvia										
Order: Veneroida	0	0	0	0	0	0	0	0	0	0
Family: Pisidiidae	0	0	0	0	10	0	0	0	0	0
Class: Gastropoda	6	0	0	14	0	0	0	0	0	0
Order: Basommatophora	0	0	0	0	0	0	0	0	0	0
Family: Lymnaeidae	17	7	0	0	0	0	0	0	0	0
<i>Fossaria</i>	6	0	0	0	0	0	0	0	0	0
Totals:	1826	1167	3787	4656	3560	2905	723	869	7680	3026

Taxa present but not included:

Phylum: Arthropoda

Subphylum: Hexapoda

Class: Insecta

Order: Diptera

Family: Cecidomyiidae

Order: Homoptera

0	0	0	0	0	0	0	0	0	0	0
0	0	0	14	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0

Taxa	Site									
	LES02	LES03	AUR01	LOS01	WAP10	WAP11	WAP02a	WAP03	JOH01	JOH02
Family: Aphididae	0	0	0	14	0	0	0	0	0	0
Family: Cicadellidae	0	0	0	14	0	0	0	0	0	0
Class: Copepoda	0	0	0	14	0	0	0	0	0	0
Subphylum: Crustacea										
Class: Ostracoda	6	3	11	14	10	9	2	0	20	9
Phylum: Annelida										
Subphylum: Clitellata										
Class: Oligochaeta										
Order: Tubificida	0	0	0	0	0	0	0	0	0	0
Family: Lumbricidae	22	10	0	0	0	0	0	0	100	0
Phylum: Nemata	6	0	11	14	10	0	2	3	20	9
Phylum: Platyhelminthes										
Class: Turbellaria	6	3	0	0	10	9	0	0	0	0
Totals:	40	16	22	84	30	18	4	3	140	18

Appendix D
Benthic Macroinvertebrates Identified at the Family Level Using Morphological Characteristics

Taxa	Site									
	LES02	LES03	AUR01	LOS01	WAP10	WAP11	WAP02a	WAP03	JOH01	JOH02
Phylum: Arthropoda										
Subphylum: Hexapoda										
Class: Insecta										
Order: Ephemeroptera	0	0	0	0	0	0	0	0	0	0
Family: Ameletidae	6	3	0	14	0	0	5	18	80	0
Family: Baetidae	444	106	22	57	370	336	179	253	1160	600
Family: Ephemerellidae	0	9	211	300	0	72	13	34	80	100
Family: Heptageniidae	161	76	2100	0	2800	2118	347	392	340	228
Family: Leptophlebiidae	6	66	0	29	30	27	0	0	120	45
Order: Plecoptera	0	7	0	0	0	0	0	0	40	18
Family: Capniidae	17	110	33	0	20	27	14	39	40	27
Family: Chloroperlidae	12	7	22	14	140	154	68	61	60	254
Family: Leuctridae	0	0	0	0	0	0	0	0	0	9
Family: Nemouridae	444	317	644	72	10	0	0	0	800	209
Family: Perlidae	11	10	0	0	40	18	11	3	640	109
Family: Perlodidae	6	0	44	0	0	18	0	8	20	36
Family: Taeniopterygidae	0	0	0	0	30	36	5	24	0	0
Order: Trichoptera	0	3	0	14	0	0	2	0	0	0
Family: Brachycentridae	11	0	0	0	20	18	0	0	40	0
Family: Hydropsychidae	22	0	0	0	0	18	9	5	20	0
Family: Lepidostomatidae	0	7	0	0	10	0	0	0	0	0
Family: Phryganeidae	0	0	0	0	0	0	0	0	20	0
Family: Rhyacophilidae	0	0	33	0	0	0	0	0	60	27

Taxa	Site									
	LES02	LES03	AUR01	LOS01	WAP10	WAP11	WAP02a	WAP03	JOH01	JOH02
Order: Diptera	0	0	0	0	0	0	0	0	0	0
Family: Ceratopogonidae	0	3	0	29	0	9	0	0	0	73
Family: Chironomidae	451	346	433	3255	20	9	27	8	2220	274
Family: Empididae	89	34	55	0	0	0	0	0	100	9
Family: Psychodidae	0	0	0	414	0	0	0	0	60	155
Family: Simuliidae	89	6	66	0	20	27	32	13	260	182
Family: Tipulidae	0	3	22	100	20	9	5	8	200	27
Order: Coleoptera	0	0	0	0	0	0	0	0	0	0
Family: Dytiscidae	0	0	0	29	0	0	0	0	0	0
Family: Elmidae	0	0	55	28	20	9	2	0	940	599
Order: Megaloptera	0	0	0	0	0	0	0	0	0	0
Family: Sialidae	0	0	0	29	0	0	0	0	0	0
Subphylum: Chelicerata	0	0	0	0	0	0	0	0	0	0
Class: Arachnida	0	0	0	0	0	0	0	0	0	0
Order: Sarcoptiformes	0	0	0	0	0	0	0	0	0	0
Family: Hydrozetidae	0	0	0	43	0	0	0	0	0	0
Order: Trombidiformes	0	3	0	14	0	0	0	0	40	0
Family: Aturidae	0	10	0	29	0	0	0	0	0	0
Family: Hygrobatidae	0	0	0	129	0	0	0	0	20	0
Family: Lebertiidae	0	0	11	14	0	0	2	0	40	18
Family: Sperchontidae	0	0	11	0	0	0	0	0	0	0
Family: Torrenticolidae	0	34	0	0	0	0	2	0	280	27
Phylum: Annelida	0	0	0	0	0	0	0	0	0	0
Subphylum: Clitellata	0	0	0	0	0	0	0	0	0	0

Taxa	Site									
	LES02	LES03	AUR01	LOS01	WAP10	WAP11	WAP02a	WAP03	JOH01	JOH02
Class: Oligochaeta	0	0	0	0	0	0	0	0	0	0
Order: Lumbriculida	0	0	0	0	0	0	0	0	0	0
Family: Lumbriculidae	6	0	0	0	0	0	0	3	0	0
Order: Tubificida	0	0	0	0	0	0	0	0	0	0
Family: Enchytraeidae	22	0	0	0	0	0	0	0	0	0
Family: Naididae	0	0	11	29	0	0	0	0	0	0
Phylum: Mollusca	0	0	0	0	0	0	0	0	0	0
Class: Bivalvia	0	0	0	0	0	0	0	0	0	0
Order: Veneroida	0	0	0	0	0	0	0	0	0	0
Family: Pisidiidae	0	0	0	0	10	0	0	0	0	0
Class: Gastropoda	6	0	0	14	0	0	0	0	0	0
Order: Basommatophora	0	0	0	0	0	0	0	0	0	0
Family: Lymnaeidae	23	7	0	0	0	0	0	0	0	0
Totals:	1826	1167	3773	4656	3560	2905	723	869	7680	3026

Taxa present but not included:

Phylum: Arthropoda

Subphylum: Hexapoda

Class: Insecta

Order: Diptera

 Family: Cecidomyiidae

0	0	0	0	0	0	0	0	0	0	0
0	0	0	14	0	0	0	0	0	0	0

Order: Homoptera

 Family: Aphididae

 Family: Cicadellidae

0	0	0	0	0	0	0	0	0	0	0
0	0	0	14	0	0	0	0	0	0	0
0	0	0	14	0	0	0	0	0	0	0

Taxa	Site									
	LES02	LES03	AUR01	LOS01	WAP10	WAP11	WAP02a	WAP03	JOH01	JOH02
Class: Copepoda	0	0	0	14	0	0	0	0	0	0
Subphylum: Crustacea	0	0	0	0	0	0	0	0	0	0
Class: Ostracoda	6	3	11	14	10	9	2	0	20	9
Phylum: Annelida	0	0	0	0	0	0	0	0	0	0
Subphylum: Clitellata	0	0	0	0	0	0	0	0	0	0
Class: Oligochaeta	0	0	0	0	0	0	0	0	0	0
Order: Tubificida	0	0	0	0	0	0	0	0	0	0
Family: Lumbricidae	22	10	0	0	0	0	0	0	100	0
Phylum: Nemata	6	0	11	14	10	0	2	3	20	9
Phylum: Platyhelminthes	0	0	0	0	0	0	0	0	0	0
Class: Turbellaria	6	3	0	0	10	9	0	0	0	0
Totals:	40	16	22	84	30	18	4	3	140	18

Appendix E
Metric Indices of the Benthic Macroinvertebrates
(Genus/Species Level)

Taxa	Site									
	LES02	LES03	AUR01	LOS01	WAP10	WAP11	WAP02a	WAP03	JOH01	JOH02
Richness Measures										
Species Richness	30	36	27	35	23	26	29	22	48	39
EPT Richness	14	16	12	9	16	21	19	18	25	21
Ephemeroptera Richness	5	9	4	5	7	11	10	11	9	9
Plecoptera Richness	7	5	7	3	6	7	7	6	11	11
Trichoptera Richness	2	2	1	1	3	3	2	1	5	1
Chironomidae Richness	8	9	4	11	2	1	5	1	9	7
Oligochaeta Richness	3	1	1	1	0	0	0	1	1	0
Non-Chiro. Non-Olig. Richness	19	26	22	23	21	25	24	20	38	32
Abundance Measures										
Corrected Abundance	1826	1167	3773	4656	3560	2905	723	869	7680	3026
EPT Abundance	1140	721	3109	500	3470	2842	653	837	3520	1662
Dominance Measures										
1st Dominant Taxon	<i>Zapada cinctipes</i>	<i>Zapada cinctipes</i>	Heptageniidae Tanytarsini	Heptageniidae	Heptageniidae	Heptageniidae	Heptageniidae	Heptageniidae	<i>Baetis</i>	<i>Baetis</i>
1st Dominant Abundance	372	300	2078	1157	2210	1727	270	239	1060	464
2nd Dominant Taxon	<i>Baetis</i>	Capniidae	<i>Zapada cinctipes</i>	<i>Hydrobaenus</i>	<i>Rhithrogena</i>	<i>Rhithrogena</i>	<i>Baetis</i>	<i>Baetis</i>	<i>Zapada cinctipes</i>	Elmidae
2nd Dominant Abundance	294	110	511	657	590	364	127	161	640	418
3rd Dominant Taxon	<i>Orthocladius</i> complex	Baetidae	<i>Orthocladius</i> complex	<i>Radotanypus</i>	<i>Baetis rhodani</i> group	<i>Baetis</i>	<i>Rhithrogena</i>	<i>Rhithrogena</i>	Elmidae	<i>Simulium</i>

Taxa	Site									
	LES02	LES03	AUR01	LOS01	WAP10	WAP11	WAP02a	WAP03	JOH01	JOH02
3rd Dominant Abundance	211	93	244	571	140	218	61	137	600	182
% 1 Dominant Taxon	20.37%	25.71%	55.08%	24.85%	62.08%	59.45%	37.34%	27.50%	13.80%	15.33%
% 2 Dominant Taxon	16.10%	9.43%	13.54%	14.11%	16.57%	12.53%	17.57%	18.53%	8.33%	13.81%
% 3 Dominant Taxon	11.56%	7.97%	6.47%	12.26%	3.93%	7.50%	8.44%	15.77%	7.81%	6.01%
Percent Dominance	48.03%	43.11%	75.09%	51.22%	82.58%	79.48%	63.35%	61.80%	29.94%	35.15%
Community Composition										
% Ephemeroptera	33.79%	22.28%	61.83%	8.59%	89.89%	87.88%	75.24%	80.21%	23.18%	32.15%
% Plecoptera	26.83%	38.65%	19.69%	1.85%	6.74%	8.71%	13.55%	15.54%	20.83%	21.88%
% Trichoptera	1.81%	0.86%	0.87%	0.30%	0.84%	1.24%	1.52%	0.58%	1.82%	0.89%
% EPT	62.43%	61.78%	82.40%	10.74%	97.47%	97.83%	90.32%	96.32%	45.83%	54.92%
% Diptera	34.45%	33.59%	15.27%	81.57%	1.69%	1.86%	8.85%	3.34%	36.98%	23.79%
% Oligochaeta	1.53%	0.00%	0.29%	0.62%	0.00%	0.00%	0.00%	0.35%	0.00%	0.00%
% Baetidae	24.32%	9.08%	0.58%	1.22%	10.39%	11.57%	24.76%	29.11%	15.10%	19.83%
% Chironomidae	24.70%	29.65%	11.48%	69.91%	0.56%	0.31%	3.73%	0.92%	28.91%	9.05%
% Odonata	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
EPT ratio	0.72	0.68	0.88	0.13	0.99	1	0.96	0.99	0.61	0.86
% Chironomidae within Diptera	71.70%	88.27%	75.17%	85.70%	33.33%	16.67%	42.19%	27.59%	78.17%	38.06%
% Hydropsychidae within Trichoptera	66.67%	0.00%	0.00%	0.00%	0.00%	50.00%	81.81%	100.00%	14.29%	0.00%
% Baetidae within Ephemeroptera	71.96%	40.77%	0.94%	14.25%	11.56%	13.16%	32.90%	36.30%	65.17%	61.67%
Functional Group Composition										
% Predators	1.59%	4.46%	0.56%	1.68%	0.56%	0.83%	5.53%	3.45%	0.90%	2.12%
% Shredder-Herbivores	4.71%	10.80%	1.62%	0.11%	0.20%	0.24%	1.24%	2.76%	0.60%	0.89%
% Collector-Gatherers	8.11%	9.43%	1.46%	5.00%	1.24%	1.69%	13.28%	13.46%	2.62%	6.18%
% Scrapers	1.86%	2.06%	5.01%	0.02%	7.87%	8.02%	21.16%	17.15%	0.22%	0.83%

Taxa	Site									
	LES02	LES03	AUR01	LOS01	WAP10	WAP11	WAP02a	WAP03	JOH01	JOH02
% Macrophyte-Herbivore	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
% Collector-Filterer	1.20%	1.03%	0.16%	0.00%	0.11%	0.21%	2.49%	0.81%	0.22%	0.66%
% Omnivore	0.05%	0.17%	0.08%	0.09%	0.03%	0.00%	0.28%	0.35%	0.33%	0.26%
% Parasite	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
% Piercer-Herbivore	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
% Gatherer	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
% Unclassified	0.44%	1.29%	0.13%	0.17%	0.00%	0.03%	0.14%	0.00%	0.12%	0.07%
Functional Group Richness										
Predators Richness	9	11	10	14	5	8	10	6	19	15
Shredder-Herbivores Richness	4	4	4	2	4	2	3	2	7	6
Collector-Gatherers Richness	12	14	7	18	9	9	11	9	16	16
Scrapers Richness	4	2	2	1	2	4	4	4	2	2
MH Richness										
CF Richness	3	4	2		3	3	2	2	5	1
OM Richness	1	1	2	1	1		1	1	2	2
PA Richness										
Piercer-Herbivore Richness										
Gatherer Richness										
Unclassified	1	3	1	5		1	1		2	1
Voltinism Composition										
% Univoltine	23.44%	27.42%	15.29%	1.85%	0.84%	1.86%	2.21%	5.64%	10.68%	5.12%
% Semivoltine	0.33%	0.60%	1.17%	0.60%	3.37%	4.68%	5.95%	6.10%	8.33%	18.90%
% Multivoltine	20.97%	0.51%	1.75%	1.22%	4.21%	8.43%	21.99%	20.02%	16.93%	21.35%
Voltinism Richness										
Univoltine	3	5	4	3	3	2	2	3	5	1

Taxa	Site									
	LES02	LES03	AUR01	LOS01	WAP10	WAP11	WAP02a	WAP03	JOH01	JOH02
Semivoltine	1	1	1	2	1	2	1	1	1	2
Multivoltine	2	2	2	2	2	2	2	2	2	2
Diversity/Evenness Measures										
Shannon-Wiener H' (log 10)	1.18	1.21	0.8	1.15	0.64	0.73	1.01	1.02	1.42	1.36
Shannon-Wiener H' (log 2)	3.92	4.01	2.64	3.83	2.14	2.41	3.37	3.38	4.71	4.5
Shannon-Wiener H' (log e)	2.72	2.78	1.83	2.65	1.48	1.67	2.34	2.34	3.26	3.12
Simpson's Index (D)	0.1	0.1	0.33	0.12	0.42	0.38	0.19	0.15	0.06	0.07
Simpson's Index of Diversity (1 - D)	0.9	0.9	0.67	0.88	0.58	0.62	0.81	0.85	0.94	0.93
Simpson's Reciprocal Index	9.8	9.6	3.03	8.52	2.39	2.65	5.35	6.76	17.58	14.94
Biotic Indices										
Hilsenhoff Biotic Index	4.28	3.5	3.72	5.89	3.88	3.81	3.94	3.81	4.25	3.88