Multi-Year Habitat Monitoring at Johnsons Mill Dam Removal – 2025 Annual Report

STONE ENVIRONMENTAL

PROJECT NO.

19-093

REVIEWED BY:

APH

PREPARED FOR:

Lauren Weston / *District Manager*
Franklin County Natural Resources Conservation District
50 S. Main St.
Ste B20
St. Albans / VT / 05478

SUBMITTED BY:

Meghan Arpino / *Project Hydrologist*
Stone Environmental, Inc.
535 Stone Cutters Way
Montpelier / VT / 05602
marpino@stone-env.com

Multi-Year Habitat Monitoring at Johnsons Mill Dam Removal 2025 Annual Monitoring Report

Cover Photo: Imagery captured via UAV of eroding river right bank through project site and house at 2159 Witchcat Road, Bakersfield, Vermont.

Contents

List of Figures

List of Tables

1. Introduction

The Johnsons Mill dam removal was completed in August 2021. Prior to full removal, the dam was partially breached during a 100-year storm event that occurred on October 31, 2019. The dam was constructed of stone and concrete, and was located along the Bogue Branch in Bakersfield, Vermont. The Bogue Branch is a tributary to the Tyler Branch which flows into the Missisquoi River. The watershed area draining to the Johnsons Mill Dam location (44.83141, -72.75578) is 8.63 mi^2 (StreamStats, 2019). A majority of the watershed is forested, with only 2% considered developed land (StreamStats, 2019).

Stone Environmental, Inc. (Stone), in conjunction with Whiteout Solutions (Whiteout) and the Franklin County Natural Resources Conservation District (FCNRCD) completed four years of annual post-dam removal monitoring along the Bogue Branch from 2022 to 2025. These monitoring events aimed to improve our understanding of aquatic organism habitat following dam removal and address knowledge gaps related to a removal design that had a minimal amount of sediment removed from the upstream impoundment prior to dam removal. Monitoring data collection included streambed characterization and analysis, topographic and bathymetric surveying, woody debris evaluation, plant survival and coverage assessment, algal analysis, and macroinvertebrate analysis. This report summarizes the final year of monitoring in 2025 and uses the monitoring data to assess changes in stream habitat over time and increase our understanding of post-dam removal stream dynamics. A separate final project report includes a complementary assessment of sediment transport over the monitoring period to further inform how minimal sediment excavation during dam removal impacted change observed on the site during the first four years post-removal.

2. Monitoring Data Collection & Analysis Methods

This project includes a monitoring area of interest (AOI) encompassing the entire area of topographic and bathymetric data and drone imagery collection. The 84-acre AOI extends from Witchcat Road near the intersection with Joyal Road to just north of 1505 Witchcat Road, as shown in Figure 1. This area is subdivided into three sub-reaches numbered from upstream to downstream. Reach 2 correlates to the limits of disturbance during dam removal (Figure 1, Figure 2). Data were entered into ESRI Field Maps and Survey123 field forms. 2025 monitoring data was collected in accordance with the project Quality Assurance Project Plan (QAPP) with the following exceptions:

- Spring aerial imagery was not collected in 2025. UAV data collection completed by Whiteout Solutions was delayed until August 2025. Stone did not collect additional Summer 2025 aerial imagery since it would be redundant with the Whiteout Solutions UAV data acquisition.
- Whiteout Solutions collected remote sensing data using sensors attached to a helicopter rather than a UAV in 2025. The same types of remote sensing data were collected.
- Macroinvertebrate and algal community data were collected in 2025; however, insufficient data had been collected in prior monitoring years.

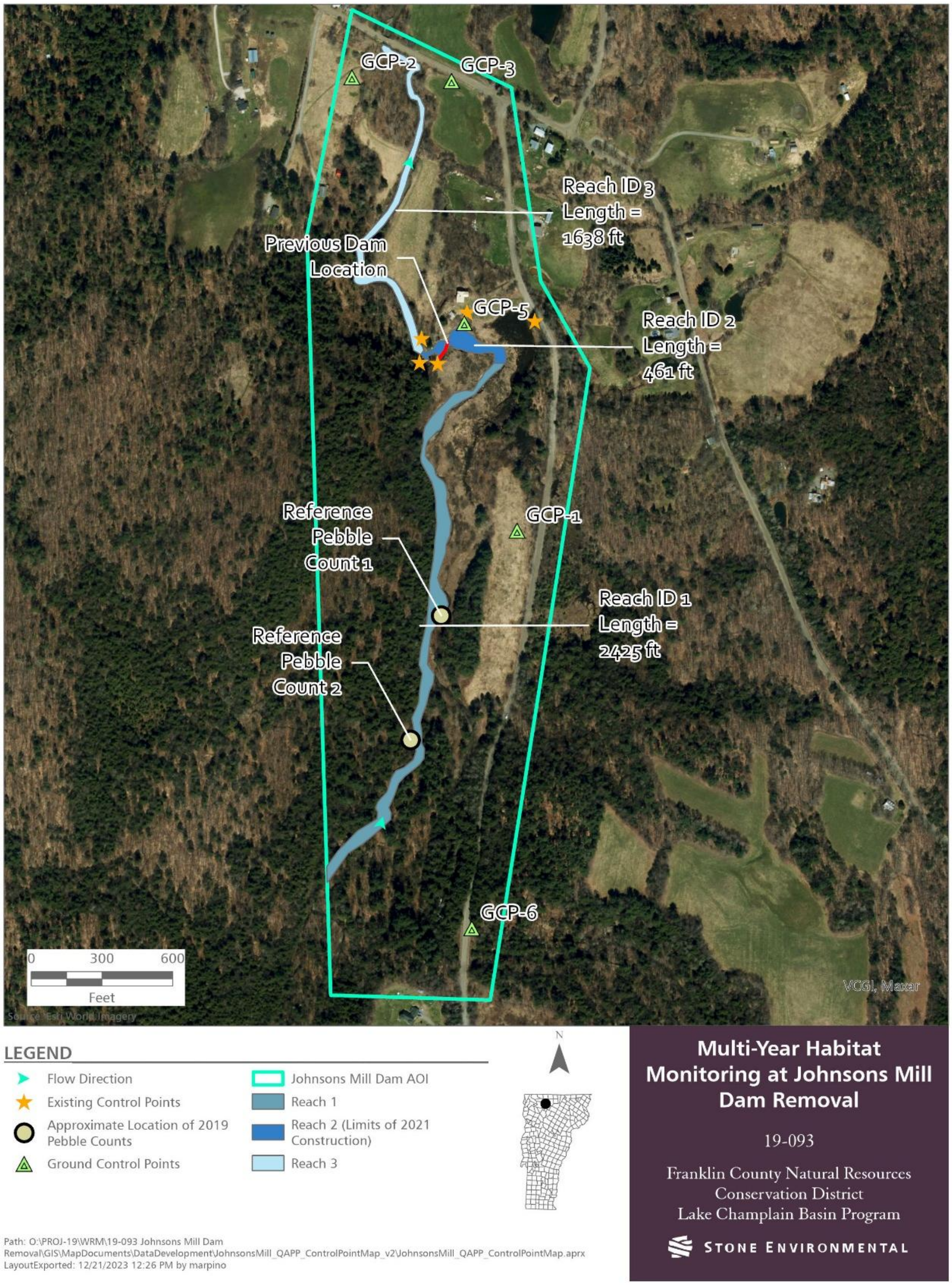


Figure 1. AOI and monitoring reaches identified for multi-year monitoring.

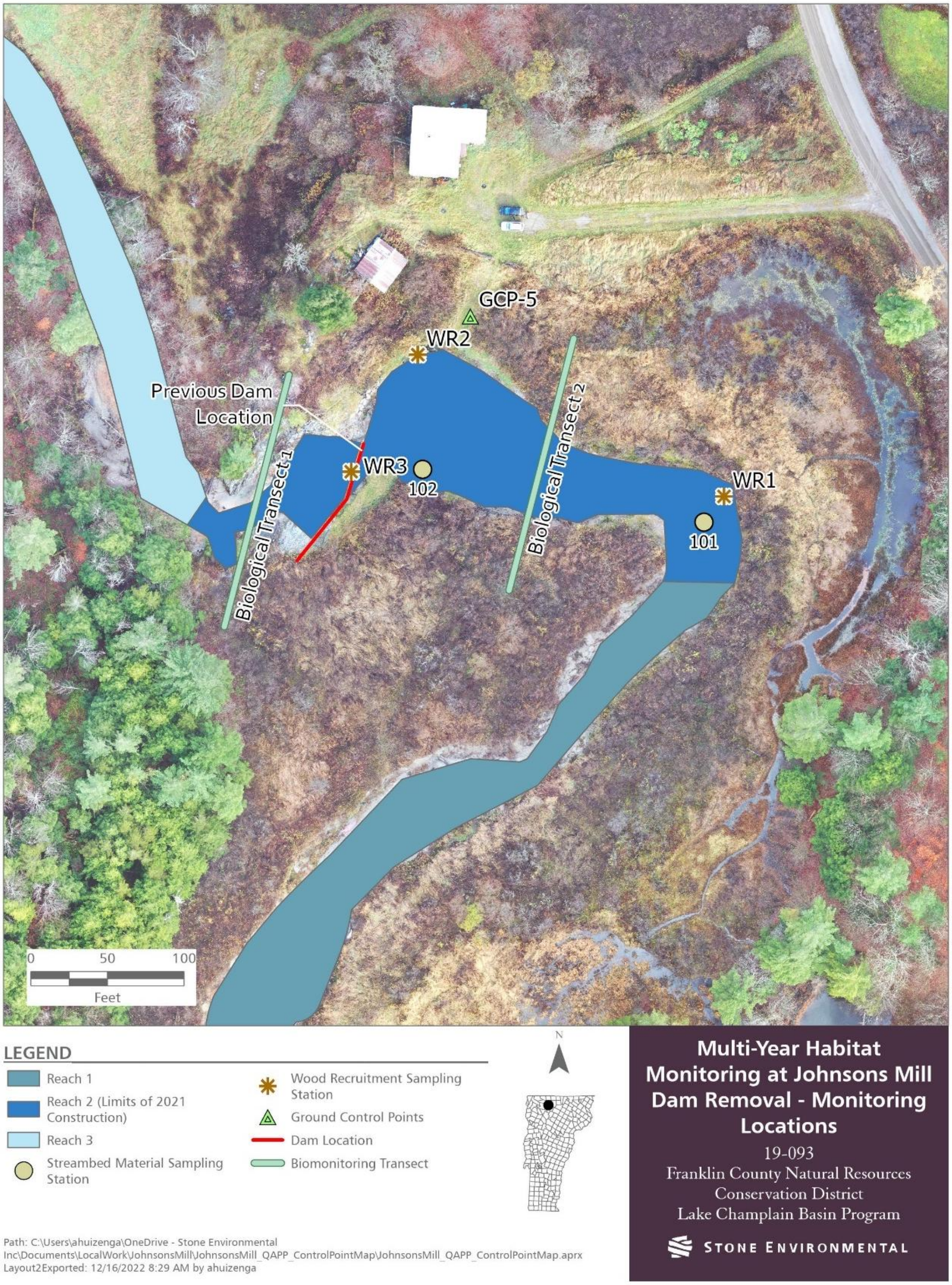


Figure 2. Wood recruitment, sediment sampling, and biological sampling locations established during Year One (2022) monitoring and revisited during subsequent monitoring events.

2.1. Streambed Material Analysis

Sites 101 and 102 were identified for repeated streambed material analysis, representing different habitat types at the time of selection (see Figure 2 for locations). The same locations were assessed every year, though due to the changes experienced on the site, the habitat type did not remain the same throughout the monitoring period. At each location, Stone staff completed pebble counts using the Wolman pebble count method to determine grain size distributions. After pebble counts were completed, visual and tactile assessment methods were used to determine relative percentages of material beneath the surficial armor layer at one location toward the center of the channel at each streambed monitoring site. Each monitoring location was inspected for key roughness features and if present, dimensions and angularity were recorded. Photos were taken of each station. Data were processed in MS Excel to determine grain size distributions and approximate percentage of materials.

2.2. Evaluation of Wood Recruitment

Initial monitoring plans for wood recruitment in Reach 2 consisted of assessing recruitment at the rootwad installations completed during construction. These installations were made along two meander bends within Reach 2 and are identified as WR1 (upstream) and WR2 (downstream) in Figure 2. Channel migration and incising that occurred in 2022 following dam removal resulted in the disconnection of the downstream rootwad installation (WR2) from the main channel and suspension of the upstream rootwad installation (WR1) above the water surface. As a result, a third monitoring location (WR3) was identified while in the field on November 2, 2022. WR3 is located directly upstream of the prior dam location and consists of a timber cribbing that was uncovered following dam removal and has begun to recruit wood.

The following data were collected for each wood recruitment monitoring station:

- Embeddedness in bank (distance from tag to bank) (only applicable for installed rootwads at WR1 and WR2)
- Tag ID
- General condition
- Count, length, diameter, and tag ID of recruited wood
- Photos

Natural woody debris and timber logs greater than 3” in diameter within bankfull width were also tagged, measured, and recorded in ESRI Field Maps and Survey123. Blue metal tags were affixed near the collar of the rootwads or one end of a timber log using nails (Figure 3 and Figure 4). Qualitative notes regarding the potential source of woody debris were recorded (i.e., natural recruitment vs timber log). The total count and distribution of wood length and diameters were quantified in MS Excel. In 2025, Stone staff made additional wood recruitment and transport observations in the upper extent of Reach 3, approximately 500 downstream of the original dam location.

Figure 3. Stone staff tagging and collecting GPS locations of wood at monitoring station WR3.

Figure 4. Image of an installed rootwad at WR2 with the blue metal tag highlighted with a blue circle.

2.3. Evaluation of Plant Survival and Coverage

Plant communities were initially assessed on November 2, 2022, and reassessed during each subsequent monitoring event. Stone staff walked from the prior dam location upstream to the beginning of Reach 1 to identify plant communities, tree stands, and individual trees within 30 feet of the channel along river left and river right. Plant and tree stands (vegetation stands) found during the first monitoring season, were revisited and a representative photograph and vegetation record was collected. The following data were recorded as appropriate for each stand and individual tree:

- Leaf condition
- Stem condition
- Evidence of pests and/or disease
- Species composition
- GPS coordinates
- Photos

The main stands identified were "Planted Willow" (willows planted as part of the stream restoration project), "Natural Willow," "Mature Tree," and "Goldenrod/Grass." Mature trees were marked as individual stands so that their health could be monitored independently of the surrounding stand. Health was assessed using the criteria listed above, with a general score of "Good", "Fair", or "Poor".

2.4. Aerial Imagery

Each monitoring year, Stone staff collected aerial imagery of the AOI during the winter, summer, and fall seasons. This imagery provides data on changes that may occur between the annual geospatial data collection completed by Whiteout Solutions and described in Section 2.5. Stone staff collected aerial imagery using a DJI Mavic 2 Pro drone flown at an elevation of approximately 350 ft. Images were processed and orthorectified using DroneDeploy. The resulting orthomosaics and digital terrain models (DTM) have been shared with FCNRCD and are presented in maps within this report.

2.5. Topographic, Bathymetric, and Vegetation Indices Surveys

2.5.1. Data Collection

Beginning in Year 2 (2023), Whiteout Solutions collected geospatial data using an unmanned aerial vehicles (UAV) or helicopter. The geospatial data collected included topographic, bathymetric, and vegetation indices (including NDVI imagery) for the 84-acre area of interest (AOI) shown in Figure 1.

Prior to collecting geospatial data with UAVs, Stone staff established ground control points (GCP) GCP-1, GCP-2, GCP-3, GCP-5, and GCP-6 as seen in Figure 1. At the start of each drone flight, Whiteout Solutions reestablished these GCPs to establish the vertical and horizontal datum. Ground control points are 24" lengths of 3/8" rebar driven into the ground with an orange cap flush at existing ground elevation. Grade stakes with survey flagging were also driven next to the ground control points to aid in locating the control in the future.

2.5.2. Topographic and Bathymetric Data Analysis

The availability of topographic and bathymetric data from multiple points in time pre- and post-dam removal makes it possible to assess changes over time at the Johnsons Mill site. However, the available data collected prior to 2023 were not all collected in the same datum, for the same extent, or using the same methods. The available datasets are summarized in Table 1.

Table 1. Summary of Available Datasets

Surface No.	Collection Details	Type	Description
0	October 2019, Stone Environmental	Total Station Survey	Pre-dam breach existing conditions surface
1	January 2020, Stone Environmental	Total Station Survey	Post-dam breach existing conditions surface
2	August 2021, Stone Environmental	Total Station Survey	As-built survey data used to create a DEM
3	April 2022, University of Vermont	Topographic Lidar Only	Post-dam removal lidar for entire 84-acre AOI
4	June 2023, Whiteout Solutions	Topographic and Bathymetric Lidar	Monitoring geospatial data collection via UAVs for the entire 84-acre AOI
5	June 2024, Whiteout Solutions	Topographic and Bathymetric Lidar	Monitoring geospatial data collection via UAVs for the entire 84-acre AOI
6	August 2025, Whiteout Solutions	Topographic and Bathymetric Lidar	Monitoring geospatial data collection via helicopter for the entire 84-acre AOI

These datasets were processed in ArcGIS Pro to assess vertical and lateral channel adjustments to the longitudinal profiles and channel extents. One limitation of this comparison is the represented extent as the survey data does not extend upstream of the former impoundment. This analysis is discussed in more detail in Section 3.5.

2.6. Algal Analysis

Methods for algal community data collection and analysis are covered in separate reports and data packages from Avacal Biological Consultants and FCNRCD and EcoAnalysts for years monitoring was completed.

2.7. Macroinvertebrate Analysis

Methods for macroinvertebrate community data collection and analysis are covered in separate reports and data packages from Avacal Biological Consultants and FCNRCD and EcoAnalysts for years monitoring was completed.

3. Monitoring Results

3.1. Streambed Material Analysis

Overall, monitoring results show that stream bed material is generally increasing in coarseness through the former dam impoundment. Figure 5 includes photos from each sampling location in 2025. The grain size distribution plots created using the pebble count data collected during each year of monitoring are presented in Figure 6 and Figure 7 for Site 101 and Site 102, respectively . In monitoring Year 1, the stream habitat type at Site 101 was a pool and at Site 102 was a riffle. These habitat types have changed over time with continued channel adjustment. In Year 2 (2023), these were still the dominant stream habitat types at these locations, by Year 3 (2024) the Site 101 was located in a riffle and Site 102 in a pool, and in Year 4 of monitoring (2025) Site 1 remained in a riffle and Site 102 was in a run.

These observations are compared to reference reach pebble counts were completed in a part of Reach 1 on October 21, 2019, prior to the dam removal (Figure 6 and Figure 7).Figure 1 includes the approximate locations of the reference reach pebble counts. In 2022 and 2023, the dominant particle size in the pool (Site 101) was sand (<2 mm) and silt (<0.0625 mm), and in 2024 the dominant particle size in the pool (Site 102) was still sand (<2mm) but there was less silt content than the previous years.

No key roughness features were seen at Site 101 or Site 102 during Year 4 (2025) monitoring. Key roughness feature observations from prior years are summarized in those annual monitoring reports.

Results of the visual and tactile assessment of sediment beneath the surficial layer are summarized in Table 2 and presented in photographs in Figure 8 and Figure 9.

Figure 5. Streambed material analysis locations Site 101 (left) and Site 102 (right).

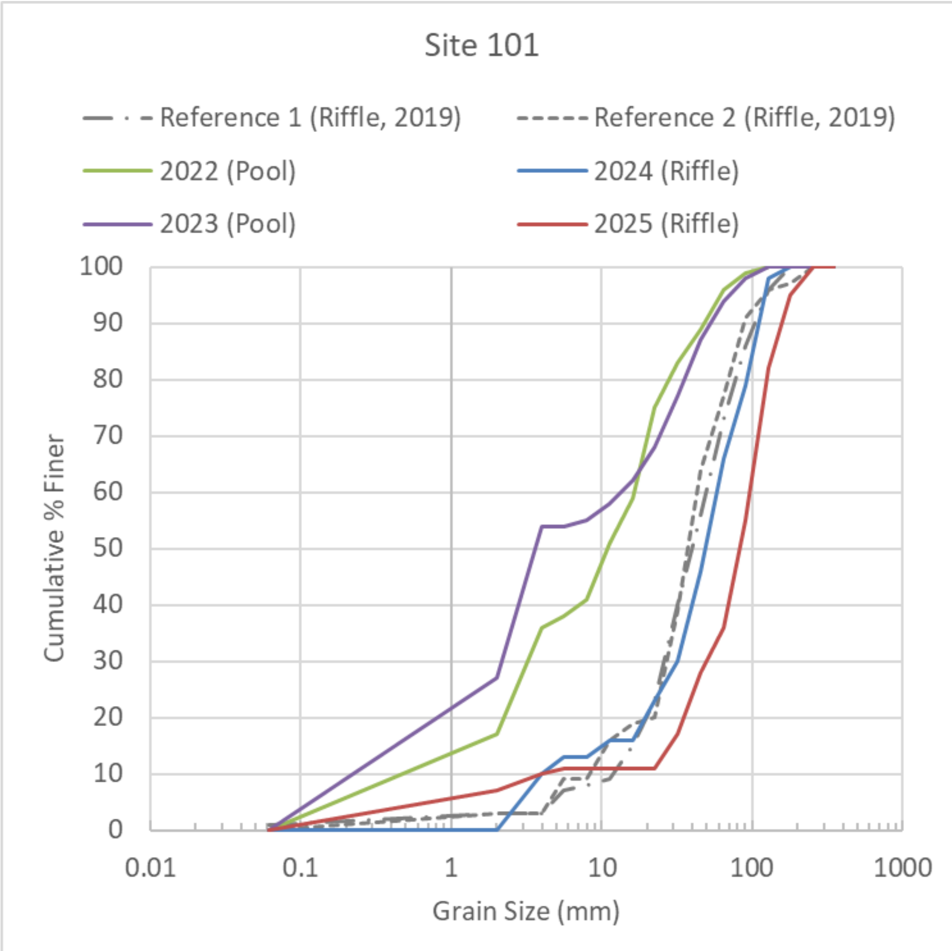


Figure 6. Post-dam removal cumulative grain size distributions measured at Site 101 in monitoring Reach 2 compared to reference reach grain size distributions developed using pre-dam removal data collected in 2019. Note, pre-removal (2019) pebble counts were completed in the upstream reference reach (see Figure 1 for approximate location) and not at the same locations as the sediment sampling stations established for multi-year monitoring.

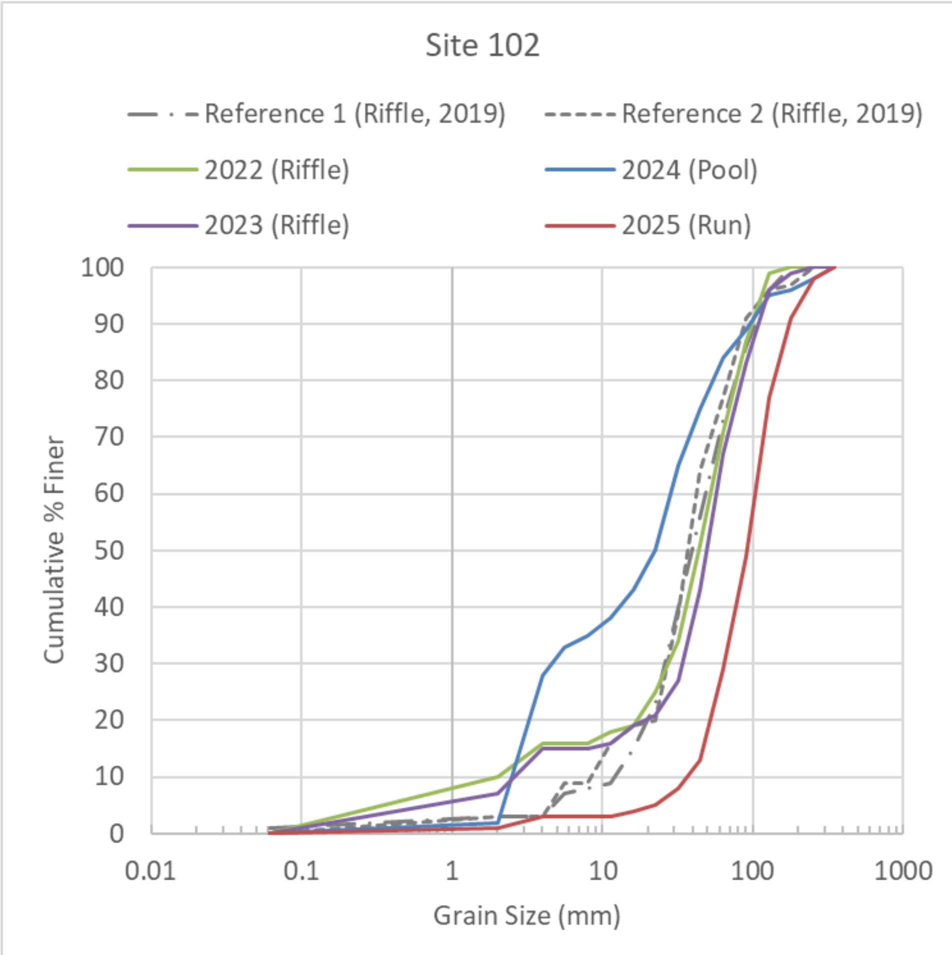


Figure 7. Post-dam removal cumulative grain size distributions measured at Site 101 in monitoring Reach 2 compared to reference reach grain size distributions developed using pre-dam removal data collected in 2019. Note, pre-removal (2019) pebble counts were completed in the upstream reference reach (see Figure 1 for approximate location) and not at the same locations as the sediment sampling stations established for multi-year monitoring.

Figure 8. Sediment below surficial layer, Site 101.

Figure 9. Sediment below surficial layer, Site 102.

Table 2. Summary of visual and tactile assessment results for sediment below the surficial layer.

Year	Location	Gravel (%)	Sand (%)	< Sand (%)
2022	Pool (Site 101)	75	20	5
	Riffle (Site 102)	70	10	20
2023	Pool (Site 101)	33	33	33
	Riffle (Site 102)	50	25	25
2024	Riffle (Site 101)	90	5	5
	Pool (Site 102)	15	80	5
2025	Riffle (Site 101)	45	50	5
	Run (Site 102)	60	30	10

3.2. Evaluation of Wood Recruitment

Evaluation of wood recruitment included assessing installed rootwads and naturally recruited woody debris within the channel. In 2023, Stone staff observed that all the rootwads from WR1 had been dislodged from the bank and only three of the five rootwads were found downstream within the monitoring reach, with the remaining two assumed to have been carried downstream beyond the monitoring reach. In 2025, There was little to no change at WR2 from Year 1 through Year 4 due to the disconnection of these rootwads from the main channel.

Figure 10 compares the spatial distribution of tagged woody debris and rootwads within Reach 2 in Year 1 (2022) to Year 3 (2025).

Table 3 summarizes large woody debris observations by year, including total number of large woody debris observed, unrecovered previously tagged large woody debris not recovered, and newly tagged large woody debris. One limitation of the tagging methodology selected for this study is that the tag could become obscured if a given piece of wood rotated, moved downstream, or became partially buried, potentially leading to that piece of wood being incorrectly identified as uncovered and retagged as a new piece of wood. Where possible, Stone staff used comparisons to the previous year's photos, notes, and GPS location to determine whether a piece of wood had been recorded in prior years. During the Year Four (2025) monitoring effort, the downstream reach (Reach 3) was also walked to identify previously tagged woody debris that moved downstream.

Table 4 presents the migration distances of tagged woody debris observed the monitoring period. Figure 11 through Figure 13 summarize the dimensions and general locations of the woody debris greater than 3 inches in diameter. The total volume of the recruited wood observed in 2025 equaled approximately 17 cubic yards (CY), including two rootwads that are now located in the channel. Woody debris was primarily recruited along the river left bank (looking downstream) or on the point bar located at the meander bend upstream of the former dam location. Much of the tagged woody debris pieces were timber logs that had previously been buried under the dam impoundment and may have been part of timber cribbing or other structures associated with the dam. These timber logs became exposed following dam removal and the subsequent channel adjustment.

Table 3. Summary of woody debris observations by year.

Year	Woody Debris Observations (count)	Total Volume (CY)
2022	14	9
2023	16	13
2024	27	15
2025	26	17

Figure 10. Annual woody debris and rootwad spatial and size distribution observations, with observed movement is shown with red arrows.

Table 4. Tagged woody debris IDs, length, diameter, and year(s) recorded.

Tag ID	Length (ft)	Diameter (in)	2022	2023	2024	2025
107	22.0	16.0	X	X	X	X
108	16.0	33.0	-	X	X	X
109	12.0	17.0	X	X	Unrecovered	Unrecovered
110	8.3	5.5	X	X	X	X
111	13.0	7.5	X	X	Unrecovered	Unrecovered
117	6.0	10.0	X	X	X	X
118	30.0	16.0	X	X	X	Unrecovered
119	9.8	12.0	X	Unrecovered	Unrecovered	Unrecovered
120	22.0	21.0	X	X	X	X
121	13.0	7.0	X	Unrecovered	Unrecovered	Unrecovered
122	9.5	13.0	X	X	X	Unrecovered
123	7.5	10.0	X	X	X	Unrecovered
124	13.0	12.0	X	X	X	Unrecovered
125	16.0	12.0	X	X	X	Unrecovered
126	8.7	28.0	X	X	X	Unrecovered
127	13.0	12.0	-	X	Unrecovered	Unrecovered
128	12.4	9.0	-	X	X	Unrecovered
129	20.0	17.0	-	X	X	X
130	10.5	7.0	-	-	X	Unrecovered
131	22.0	11.0	-	-	X	Unrecovered
132	10.5	13.0	-	-	X	Unrecovered
133	10.0	10.0	-	-	X	Unrecovered
134	9.0	8.0	-	-	X	X
135	7.0	11.0	-	-	X	Unrecovered
136	11.0	7.0	-	-	X	X
137	8.0	9.0	-	-	X	X
138	10.0	9.0	-	-	X	Unrecovered
139	10.0	6.0	-	-	X	X
140	28.5	15.0	-	-	X	Unrecovered
141	6.0	5.0	-	-	X	Unrecovered
142	20.0	15.0	-	-	X	X
143	10.0	8.0	-	-	X	Unrecovered
144	8.7	28.0	-	-	-	X
145	12.0	18.0	-	-	-	X
146	10.3	7.0	-	-	-	X
147	2.0	8.0	-	-	-	X
148	10.0	10.0	-	-	-	X
149	4.0	12.0	-	-	-	X
150	4.0	10.0	-	-	-	X
151	6.5	20.0	-	-	-	X
152	7.0	8.0	-	-	-	X
153	10.5	15.0	-	-	-	X
154	15.0	14.0	-	-	-	X
155	20.5	11.0	-	-	-	X
156	11.0	8.5	-	-	-	X
157	11.0	20.0	-	-	-	X
158	21.5	7.0	-	-	-	X

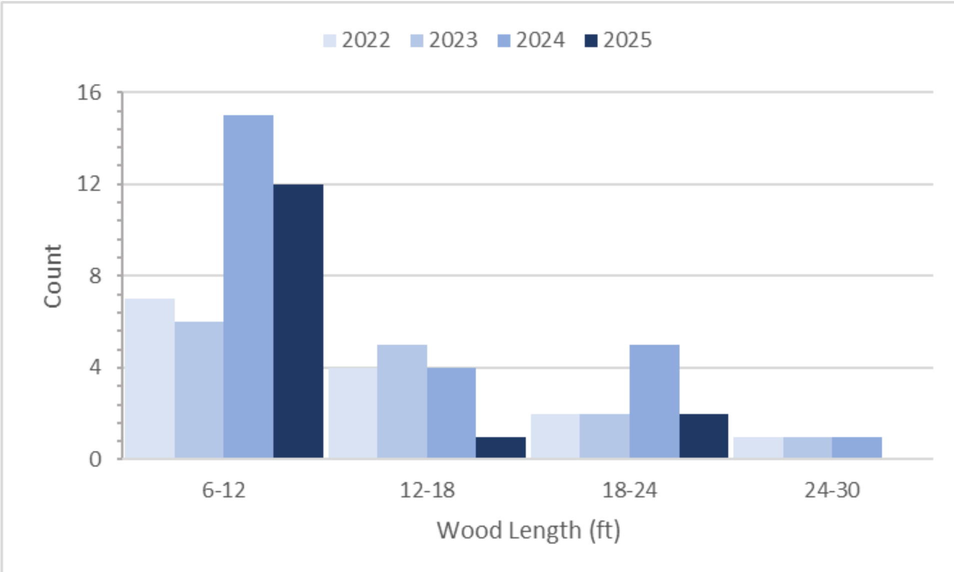


Figure 11. Summary of wood length within the monitoring reach of the Bogue Branch.

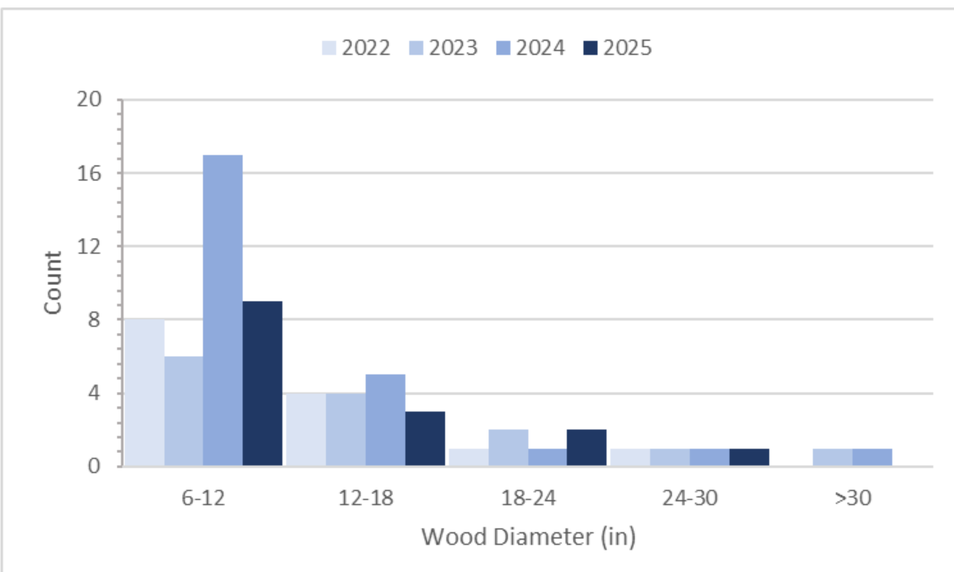


Figure 12. Summary of wood diameter within the monitoring reach of the Bogue Branch.

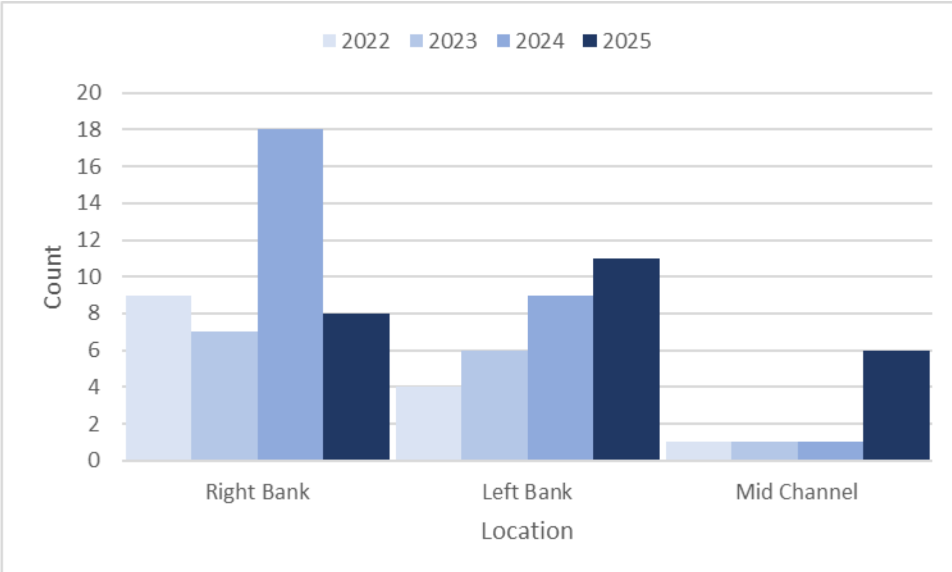


Figure 13. Summary of wood location within the monitoring reach of the Bogue Branch.

3.3. Evaluation of Plant Survival and Coverage

Plant survival and coverage were qualitatively assessed using the initial 2022 assessment as a baseline along with field observations and review of remotely sensed vegetation indices data. Each vegetation stand and mature tree identified in 2022 was revisited and assessed for plant health in, 2023, 2024, and 2025. Delineated stands are shown compared to aerial imagery and Normalized Difference Vegetative Index (NDVI) data in Figure 14 and Figure 15, respectively.

One of the primary drivers in changes observed at the vegetation and individual mature tree level was the loss of overbank land due to erosion of the stream banks. In 2025, Stand 20 experienced the most loss due to erosion followed by Stand 3. However, small stands of healthy vegetation were beginning to grow on the point bar on the inside of the meander bend that cut through Stand 20. While not specifically identified as a new stand during field data collection, these pockets of healthy vegetation are shown in green on the point bar between Stand 5 (S5) and Stand 20 (S20) in Figure 14 and Figure 15.

Significant draining of the wetland on river right was observed in 2025 due to erosion undercutting the wetland outlet. While there has been limited die off in wetland plants, less standing water may begin to shift the wetland plant community. The wetland also appears to have reduced in surface area and a new plant, arrow-leaved tear thumb, was identified on the outer edges. Vines such as virgin's bower and bindweed continue to be prevalent on the river left floodplain area, but no major health issues were noted in the vegetation. Stand 9 (S9), a mature American Elm, is now a standing dead tree with significant insect damage.

With the exception of vegetation loss due to erosion, the health of the vegetation communities in the monitoring reach remained good in 2025. Additionally, no significant dieback of the willow and alder stands was noted in 2025.

NDVI imagery collected from each monitoring year is presented in Appendix A, with two areas of vegetation changes overserved in the field that align well with the NDVI assessment of vegetation health circled.

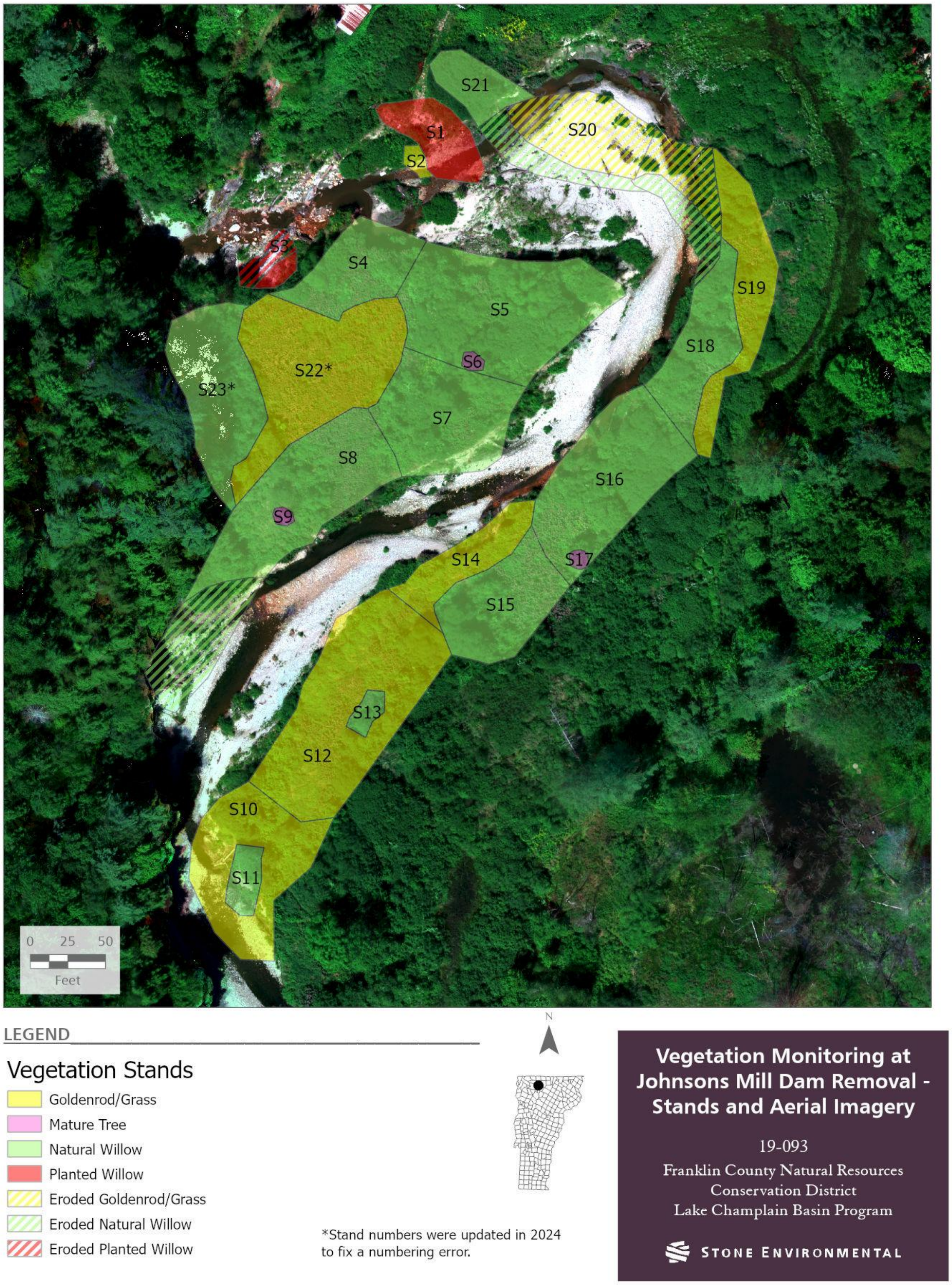


Figure 14. Map of vegetation stands originally delineated in 2022 over aerial imagery from summer 2025.

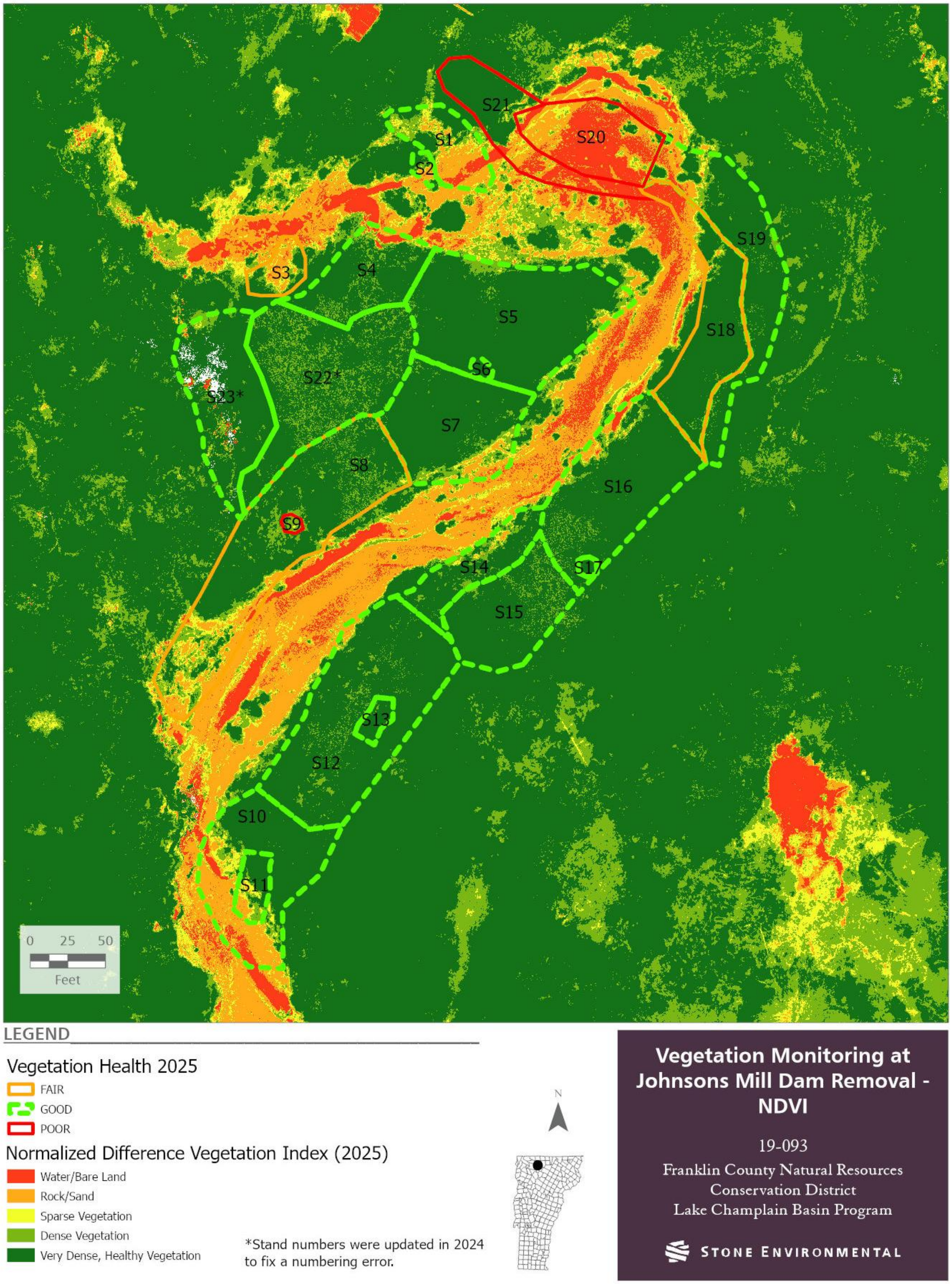


Figure 15. Vegetation monitoring stands assessed in September 2024 shown with NDVI data collected in August 2025.

Figure 16. Looking upstream from Stand 8 in 2025.

Figure 17. Photo taken from river right bank on meander bend migrating towards driveway looking at point bar with newly established vegetation and vegetated steep banks on river left.

3.4. Aerial Imagery

Aerial imagery was collected in winter, summer, and fall 2025 and is compiled in Attachment 1.

3.5. Topographic and Bathymetric Comparisons

The significant lateral adjustments of the channel within the monitoring reach complicates the year-over-year longitudinal profile comparison. The stream is increasing in sinuosity which changes the stream's total length within the monitoring reach and means thalwegs cannot be compared at the same location. The longitudinal profile comparison completed in prior monitoring years was not completed in 2025 due to significant channel change in the former dam impoundment that increased overall stream length. Rather, overall channel slope through the former dam impoundment was calculated for the 2025 data and compared to the overall channel slope from prior monitoring years. This comparison is shown in Table 5. A comprehensive comparison of topographic and bathymetric data collected over the course of the project is provided in the project Sediment Transport Analysis Report.

Table 5. Channel slope calculated from lidar data collected during monitoring years for the reach extending from the former dam location upstream to a location on the streambed parallel to ground control point 1 (GCP1 in Figure 1).

Year	Channel Length (ft)	Channel Slope
2023	1266	1.2%
2024	1357	0.9%
2025	1335	0.9%

The DEMs generated from lidar data collected during monitoring years were also compared to assess lateral channel migration over time. These comparisons are shown in Figure 18 and depict the lateral migration of the channel centerline for 2023 through 2025.

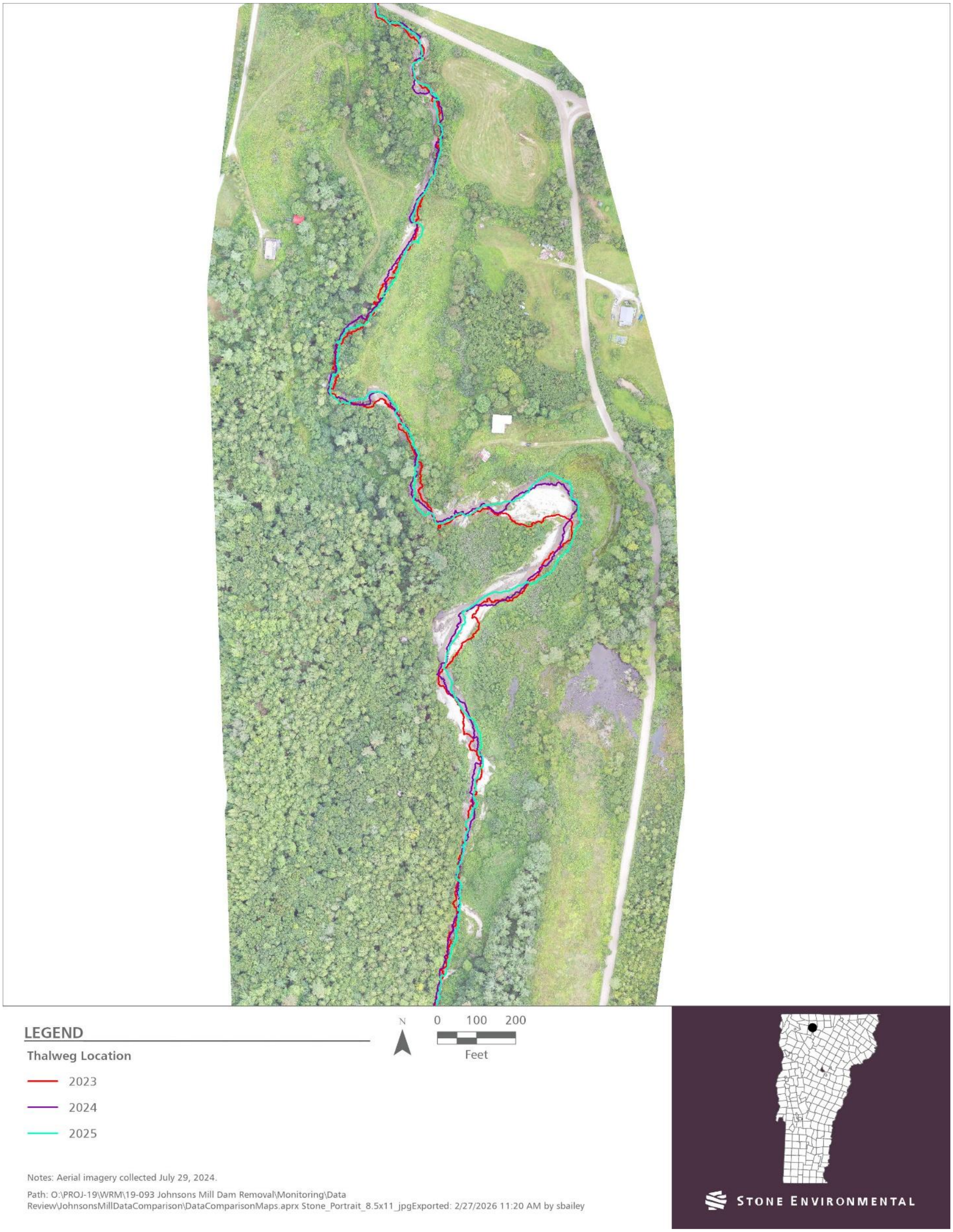


Figure 18. Channel thalweg lateral migration over the course of monitoring Year 2 through Year 4 when topobathymetric lidar data were collected for the project AOI.

3.6. Algal Analysis

Results of the algal analysis were summarized and provided in a separate report and data package.

3.7. Macroinvertebrate Analysis

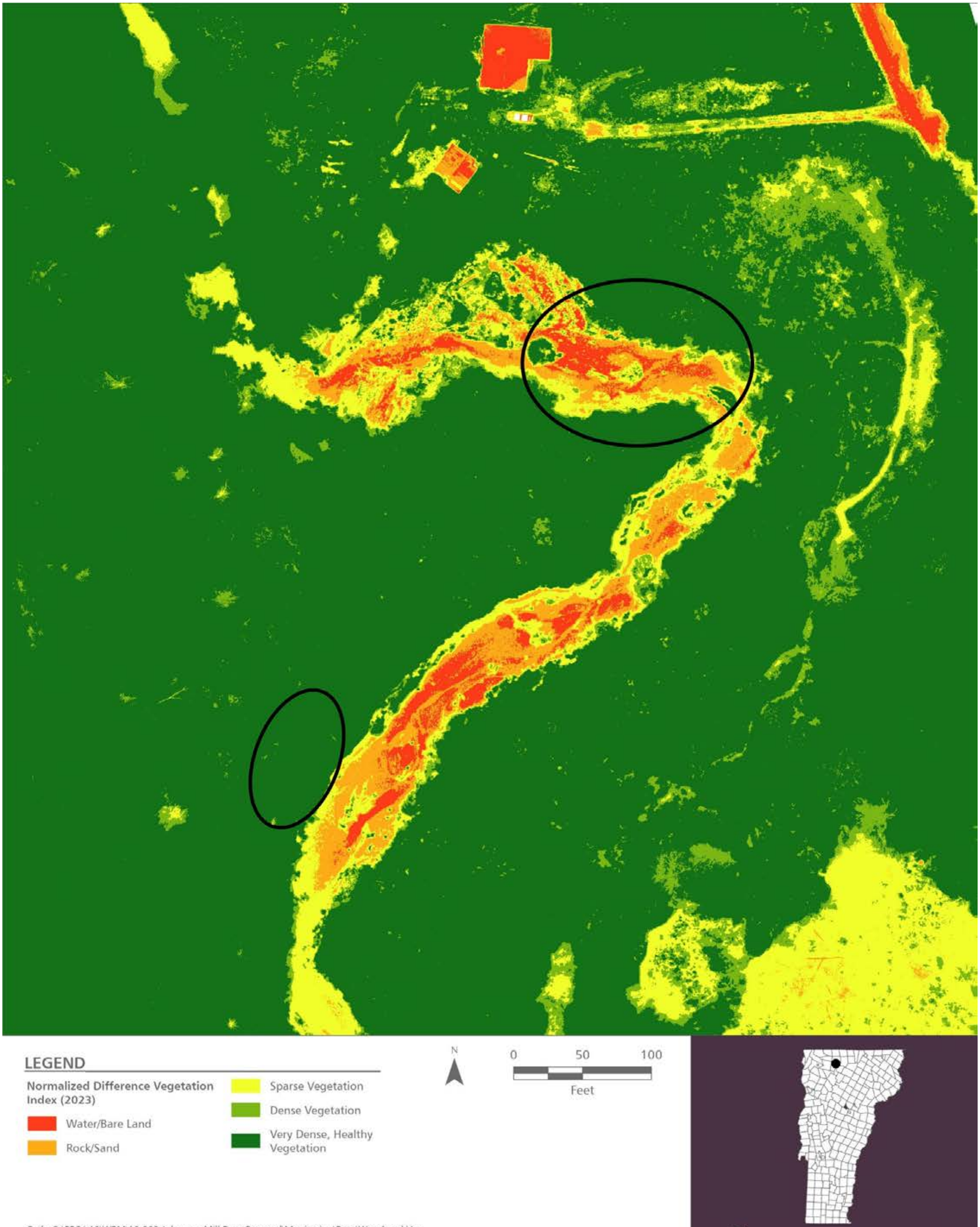
Results of the algal analysis were summarized and provided in a separate report and data package.

4. Conclusions

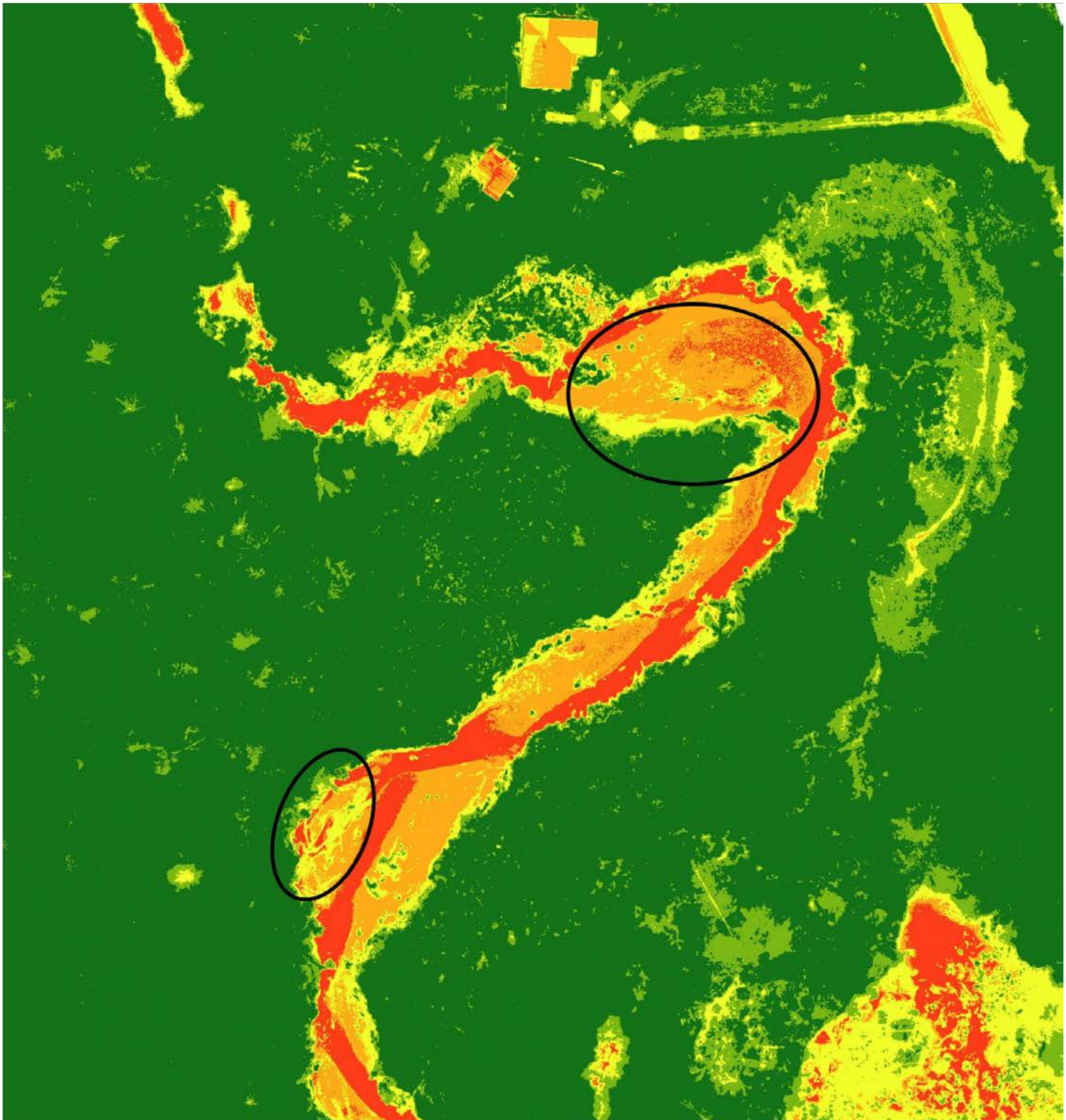
The 2025 monitoring data indicates that the Bogue Branch is continuing to adjust in and beyond the vicinity of the former Johnsons Mill Dam and dam removal project extents. These changes are attributable to the dam removal and pilot channel responses to significant flooding events, such as the Halloween 2021, July and December 2023, and July 2024 floods along with natural channel evolution processes restored following the dam removal. In Year 1, incision was the primary factor contributing to adjustment observed at the project site. In Years 2-4, continued bank failure along with the formation of lateral channel bars indicate that this reach of the Bogue Branch is continuing to widen and beginning to form floodplain features, such as the point bar being to vegetate on the bank opposite the driveway. As mentioned in the Year 2 (2023) monitoring report, the installed rootwads at both locations (WR1 and WR2) were no longer functioning as intended and while this continued through Year 4 the remaining rootwads have become roughness and habituated features on the newly formed floodplain. Overall, natural wood recruitment was observed during each year of monitoring. Woody debris and the formation of pools are providing habitat for aquatic organisms in the former impoundment. A separate report will provide analysis of sediment transport for the entire study period. Overall, initial comparisons of streambed elevations show signs of deposition downstream of the former dam location, indicating that the restoration of natural sediment transport processes may be providing a source of sediment for a previously sediment starved reach of Bogue Branch.

Future monitoring efforts at this site should continue plant community observations of the abandoned floodplain, particularly the wetland on river right. The establishment of in-channel vegetation on point bars and river banks should also be monitored to track if native species are able to regenerate or if invasives take advantage of the exposed soils. It is also recommended that any future monitoring efforts include established monitoring locations further downstream and upstream of the former dam impoundment.

Appendix A. NDVI Imagery



Path: O:\PROJ-19\WRM\19-093 Johnsons Mill Dam Removal\Monitoring\Data\Wood and Veg Maps\2023MonitoringMaps.aprx Stone_Portrait_8.5x11_jpgExported: 2/27/2026 10:13 AM by sbailey



LEGEND

Normalized Difference Vegetation Index (2024)

- Water/Bare Land
- Rock/Sand
- Sparse Vegetation
- Dense Vegetation
- Very Dense, Healthy Vegetation

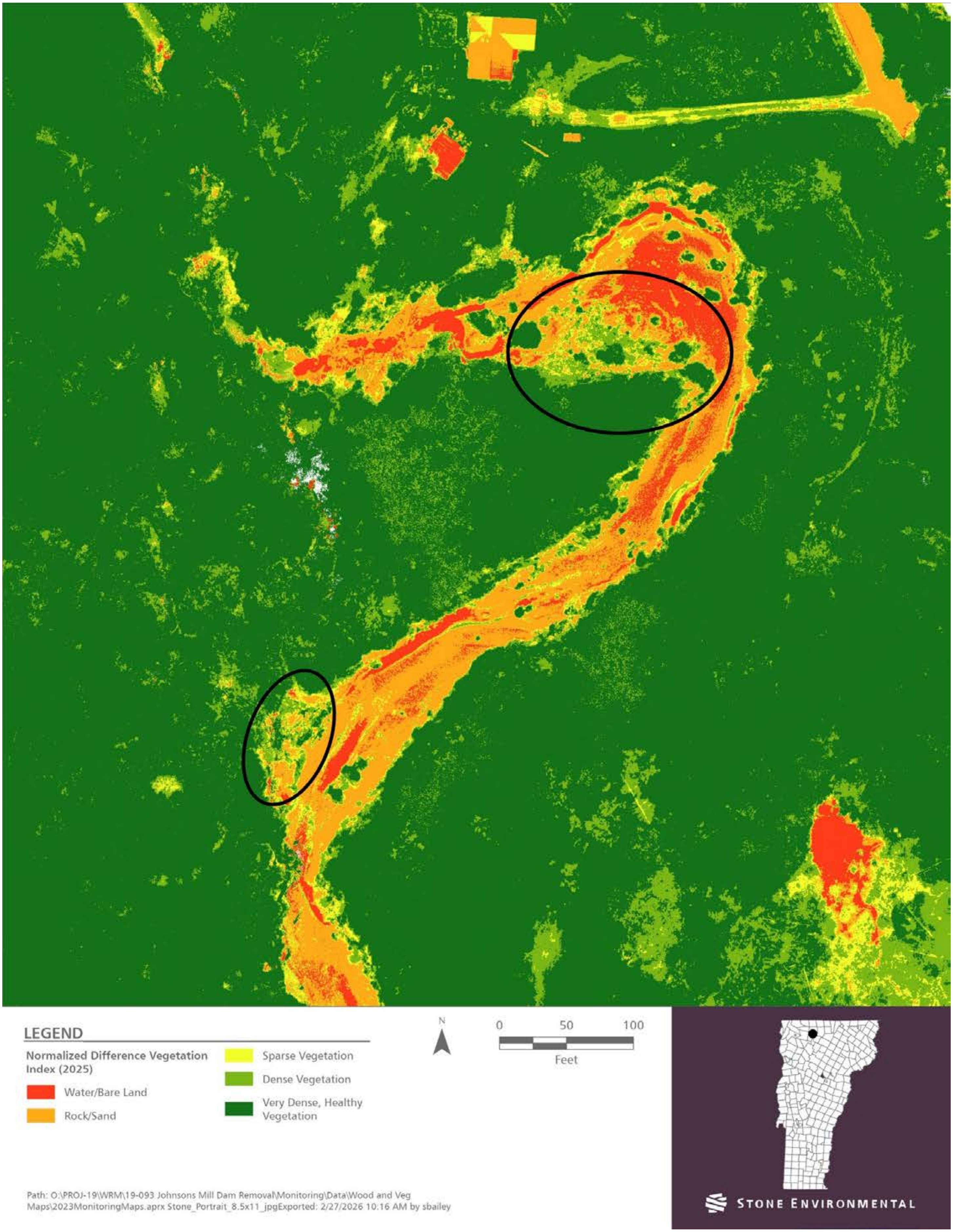
N

0 50 100

Feet

STONE ENVIRONMENTAL

Path: O:\PROJ-19\WRM\19-093 Johnsons Mill Dam Removal\Monitoring\Data\Wood and Veg Maps\2023MonitoringMaps.aprx Stone_Portrait_8.5x11_jpgExported: 2/27/2026 10:05 AM by sbailey


LEGEND
Normalized Difference Vegetation Index (2025)
Water/Bare Land
Rock/Sand
Sparse Vegetation
Dense Vegetation
Very Dense, Healthy Vegetation
N
0
50
100
Feet
Path: O:\PROJ-19\WRM\19-093 Johnsons Mill Dam Removal\Monitoring\Data\Wood and Veg Maps\2023MonitoringMaps.aprx Stone_Portrait_8.5x11_jpgExported: 2/27/2026 10:16 AM by sbailey
STONE ENVIRONMENTAL

Appendix B. Aerial Imagery

Orthoimagery from March 14, 2025

Orthoimagery from August 2025

Orthoimagery from March 19, 2025

FRANKLIN COUNTY
NATURAL RESOURCES
CONSERVATION DISTRICT

Johnsons Mill Dam Macroinvertebrate and Algae Assessment Post-Dam Removal

Project Overview

The Johnsons Mill Dam in Bakersfield, Vermont was removed in 2021 due to the levels of degradation and aggradation. The goal of the dam removal project was to restore the stream; the goal of the associated monitoring project was to help fill knowledge gaps of dam removal to better understand how the ecosystem will respond. Between the 1970s and 2017 roughly 1,100 dams had been removed across the nation, and only 130 of those had ecological and geomorphic assessments (Foley et al., 2017). Most dams have outlived their operational timeline and are structurally challenged, no longer economically viable, or perceived to have negative impacts on stream health (Mahan et al., 2021). Among the organisms impacted by dams are macroinvertebrates and algae, which are important bioindicators of water quality.

As part of the ecological assessment at Johnsons Mill Dam, macroinvertebrate samples were collected and analyzed in 2023 by Avacal Biological Consulting and collected by FCNRCD and processed by EcoAnalysts in September 2025 upstream and downstream of where the dam was removed. Algae samples were also collected and analyzed by Avacal Biological Consulting in 2022 and 2023, and again by FCNRCD with processing done by EcoAnalysts in September 2025. No data was collected in 2024 due to cold temperatures. This report serves to compile and compare results across the sampling years for both bioindicators with emphasis on downstream and upstream impacts.

Importance of Bioindicators

Macroinvertebrates

Macroinvertebrates serve as important links in trophic levels, being influenced by both bottom-up and top-down forces. The functional roles they serve include grazers, scrapers, collectors (filter and gatherer), and predators, while also being important food sources for other organisms (Wallace and Webster, 1996). Nutrient recycling, fine particulate organic material filtering (FPOM), control of algae and biofilm populations, and control of other macroinvertebrate or insect populations are among some of the niches they fill; all of which influence stream health.

They represent local physical and chemical features within the system in a straightforward manner (Carlson et al., 2018), which is why they serve as bioindicators. Due to species' sensitivities, water quality can be inferred of the system from community assemblage. These sensitives include factors such as flow rate, dissolved oxygen levels, sedimentation, presence of organic pollution, nutrient enrichment, heavy metals, and pesticides. Their low mobility lends to fine-scale assessment of stream quality and restoration progress (Mahan et al., 2021). Macroinvertebrates are key indicators of stream health and are used to assess the success of dam removals.

Algae

Algae are important primary producers that contribute to nutrient cycling, carbon sequestration, and serve as important food sources. Algae–especially periphyton and diatoms—are widely used as bioindicators for water quality. Their ecological characteristics and sensitivities make them valuable for evaluating chemical, physical, and biological indices.

They have short life cycles and generation times; therefore, they respond quickly to environmental changes. Flow variability, sediment transport, light availability, and nutrient concentrations are some of the factors they are used to assess. Community composition is greatly impacted by nutrient availability, particularly phosphorus and nitrogen (Bellinger & Sigee, 2010; Lobo et al., 2016). Increases in nutrient loading result in changes in abundance and composition, which indicate eutrophication or nutrient enrichment (Barinova & Mamanazarova, 2021; Bellinger & Sigee, 2010). Excess nutrients can lead to harmful algal blooms that result in trophic disturbances (e.g. major fish deaths), public safety hazards (e.g., drinking water contamination, recreation impacts), and chemical changes to water. Furthermore, algae can indicate sediment disturbances due to taxa sensitivities to turbidity, burial, and substrate instability. Short- and long-term changes in sediment loads can be inferred from algal community shifts (Lobo et al, 2016).

Dam Removal Impacts

Macroinvertebrates

Dam removal alters macroinvertebrate habitat by restoring lotic flow regimes. This impacts substrate composition, changes thermal conditions, and oxygen levels (Poulos et al., 2019). Sediment redistribution and release also greatly impact community structure and can have negative impacts initially. Smothering benthic macroinvertebrates, disrupting feeding, and reduction in habitat heterogeneity are some of the potential consequences (Bellmore et al., 2019). As community structure reorganizes, so does functional group relative abundances due to changes in organic matter dynamics, flow rates, and food sources (Poulos et al., 2019).

Research indicates that dam removal causes initial declines in macroinvertebrate abundance, density, richness, and sensitive taxa (especially Ephemeroptera, Plecoptera, and Trichoptera [EPT], which are the most common bioindicators). This is due to sediment redistribution, altered water flow, and temperature changes (Mahan et al., 2021). This is sometimes referred to as a “pulse disturbance” because abundance and richness have shown to stabilize to pre-dam removal levels or increase gradually within 15 to 20 months in some cases (Carlson et al., 2018; Ohio State University). However, in other studies, community stabilization has ranged from 1 to 4 years (Mahan et al., 2021; Cleason et al., 2016; Piscart et al., 2024). Drivers of macroinvertebrate response include catchment characteristics (e.g., discharge rates, land use), sample distance from dam, sediment flushing efficiency (Carlson et al., 2018), and seasonal variances (Sullivan and Manning, 2017).

In a New England case study, community assemblage (structure and composition) took three years to reorganize and had not fully recovered to pre-removal levels. Major shifts occurred both upstream and downstream. Functional group abundances and diversity were influenced by site location (upstream vs. downstream) and stage of removal. Sedimentation and deposition have impacts for years on community structure, abundance, and richness. Overtime, the communities were becoming more similar and continued stabilizing. This study emphasizes that community reorganization is site-specific and can demonstrate that upstream and downstream responses to dam removal are variable (Poulos et al., 2019).

Algae

Dam removal restores natural channel morphology and hydrology which directly affects algal communities. Typical dam removal impacts include higher current velocity, increased substrate movement, increased coarse substrate exposure, and improved riffle habitat.

Immediately after removal, high sediment disturbance typically reduces algal diversity and increases dominance of tolerant taxa. Diatom assemblages often shift from slow-water taxa to flow-adapted species. During recovery, diversity increases, sensitive diatoms return, and periphyton communities stabilize (Lobo et al., 2016).

Downstream versus Upstream Responses

Macroinvertebrates

Downstream and upstream assemblages have asymmetric ecological responses due to preexisting differences of assemblage stability prior to dam removal (Poulos et al., 2019) (i.e., upstream impoundments versus downstream sediment-affected areas). Though both experience changes in habitat quality and quantity, the mechanisms, timing, and recovery timelines differ.

Upstream responses are typically habitat-transition driven while downstream is more disturbance driven. Upstream is typically converted from lentic to lotic conditions, meaning water velocity increases, channels incise and narrow, substrate becomes coarser, and oxygen levels increase. Typical response of macroinvertebrate assemblage is the reduction of lentic and burrowing taxa (e.g., Chironomidae, Oligochaeta) and an increase in lotic species (EPT). Furthermore, there is a shift towards grazers and scrapers as periphyton increases (Carlson et al., 2018). These areas often show greater ecological improvements.

Downstream is typically more impacted due to the extent of changes from sedimentation (length of accumulation), water velocity, riverbed gradient, and the specific techniques used to remove the dam (Carlson et al., 2018). Downstream differences can last for years, especially where legacy sediments and geomorphology persist (Malm-Renöfält et al., n.d.). Common short-term impacts show reduced density, declines in EPT, increased drift, and shifts towards tolerant taxa (Sullivan and Manning, 2017; Cleason et al., 2015). Distance from the dam is an important factor as effects diminish further from the dam removal site. Recovery downstream can take longer than upstream but typically takes 1 to 3 years (Mahan et al., 2021; Cleason et al., 2016; Piscart et al., 2024).

There is still little research to provide a general probability of assemblage timelines following dam removals. Ongoing monitoring and research to provide clearer methods, records, and models are becoming increasingly necessary as dam removal becomes a more common tool for restoration.

Algae

Prior to dam removal, assemblages downstream often have reduced benthic algal biomass compared to natural riffle habitats due to the trapping of sediments and nutrients by the dam, alterations of substrate from sediment scour, and altered light and temperatures (Doyle et al., 2005; Gregory et al., 2002; Tullos, 2016). Immediately after dam removal, there is a short-term reduction in algae abundance and richness. Sediment released from upstream smothers algae and increases turbidity (limiting light) (Bellmore et al., 2017). Within 1-3 years, algal communities increase once the flow, light, and temperature regimes stabilize. Periphyton biomass increases, and food webs shift towards algal-based production. Downstream impacts are typically stronger and last slightly longer than upstream impacts from dam removal (Bellmore et al., 2017; Doyle et al., 2005; Major et al., 2012).

Upstream communities prior to dam removal typically have higher pelagic algal biomass because stream velocity is slower and pools, the water is warmer, and more light is available (Doyle et al., 2005; Gregory et al., 2002). Following removal, algal community biomass decreases from sediment pulses and increased turbidity. Previously stable substrates are dislodged and disrupt abundance and richness. Communities typically stabilize within three years of dam removal (Major et al., 2012; Tullos, 2016). A shift from pelagic algae to a more diverse combination of pelagic and benthic algae happens once the system stabilizes and substrate diversity increases (Bellmore et al., 2017; Doyle et al., 2005; Stanley & Doyle, 2002; Tullos, 2016).

Project Sample Results

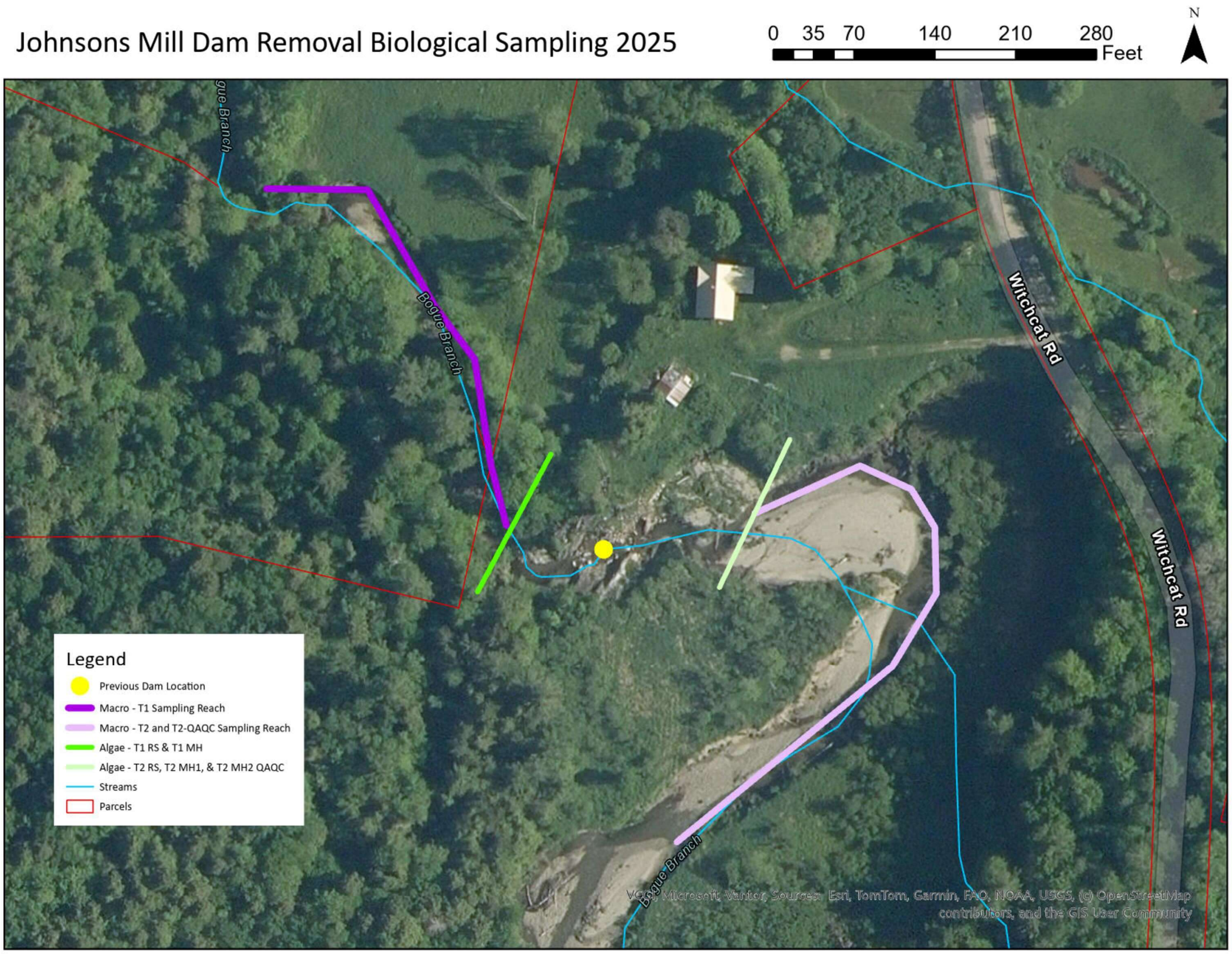


Figure 1: Map of sample collections at Transect 1 and Transect 2 for macroinvertebrates and algae above and below the Johnson Mill dam.

Sample methods used by FCNRCD follow the procedures described in Field Methods Manual, sections 6.5.1 and 6.5.7, written by the Watershed Management Division of the Vermont Department of Environmental Conservation (Vermont Agency of Natural Resources, Department of Environmental Conservation, Watershed Management Division, 2022). Each sample was collected along the transect (following the direction of water flow for macroinvertebrates and across stream width for algae samples) from four riffle habitats within the reach of each transect. Riffle habitats were not sampled more than once.

Habitat conditions and pebble counts taken at each transect during the day of sampling can be seen in Appendix 1.

Macroinvertebrate Results

Macroinvertebrate samples were taken downstream (Transect1 [T1]) and upstream (Transect2 [T2] and Transect2 QAQC [T2 QAQC]) in 2025 after dam removal. A second sample was completed upstream for quality assurance and quality control (T2 QAQC) (Figure 1). Following removal, Avacal Biological Consulting took samples in 2023 and are compared to FCNRCD/EcoAnalyst data collected in 2025. No data was collected in 2022 or 2024. All results will be discussed in this section.

Once collected in 2025 by FCNRCD staff, samples were evenly spread into trays with 24 square sections to sort the macroinvertebrates by type. A section of six squares were randomly chosen to become the subsample. Macroinvertebrates were sorted within the six squares to collect the minimum 300 specimens (if more were within the six squares; they were also sorted). If 300 specimens were not within six squares, more squares were opened until the minimum is met. T1 required 18 squares to meet the minimum while both T2 and T2 QAQC samples only required the initial six squares.

T2 and T2 QAQC had dissimilarities in abundance and dominance of species indicating localized habitat conditions varied (Figure 1). The samples were not collected from the same riffle habitats but were within the same reach of the transect. The presence of cyanobacteria and iron precipitates contributed to these differences. These contaminants were avoided to prioritize surveyor safety. Cyanobacteria can cause serious health issues from the hepatotoxins and nephrotoxins they produce. These can include mild symptoms such as headaches, fever, and rashes to more severe symptoms such as acute hepatitis and jaundice, liver damage, or failure, and even death (Centers for Disease Control and Prevention, 2025).

Major differences between T2 and T2 QAQC presented in total abundance and dominant species. However, richness, community composition, and functional group composition did not have significant differences. Only slight variation existed between these metrics. This indicates that though the samples taken in T2 were lower in abundance, the community structure was similar to T2 QAQC. Samples of this area upstream may show more impacted water quality than downstream due to these pockets. Slight differences can still indicate water quality differences and will be discussed for each transect.

Abundance

Abundance was divided by the number of subsample squares required to meet the minimum number of macroinvertebrates. The Vermont Department of Environmental Conservation declares a minimum of 300 specimens for healthy streams (2017). Abundance measures (Table 1) along the stream averaged 55.33 at T1 downstream and 316 at T2 and 741 at T2 QAQC upstream per subsample. EPT average abundance per subsample was 53.33 at T1, 215 at T2, and 369 at T2 QAQC. The presence of these sensitive taxa at 60% downstream and 68% at T2 and 50% at T2 QAQC indicates healthy conditions. Overall, abundance, above the 300 threshold, indicates that the habitat is good; there is sufficient dissolved oxygen, and stable flow conditions. Lower abundance downstream may be due to the longer impact time typical after dam removal, high amounts of ongoing sediment erosion, bank failures, or a combination of these factors. Difference between T2 and T2 QAQC could be due to the aforementioned safety precautions.

Table 1: Macroinvertebrate Abundance Measures

Abundance Measures	Transect 1	Transect 2	Transect 2 QAQC	Average
Number of subsamples squares	18.00	6.00	6.00	10.00
Abundance / subsample	81.33	316.00	741.00	379.44
EPT Abundance / subsample	55.33	215.00	369.00	213.11

Dominance

Dominant taxa (Table 2) downstream (T1) include *Hydropsyche sparna* (63), *Ephemerella* spp. (28), and *Hydropsyche betteni* (25) indicating good water quality. *H. sparna* and H. *betteni* are also the top two abundant taxa downstream and upstream. This indicates good water quality as these species are highly sensitive to nutrient and organic pollution, heavy metals, pesticides, and low dissolved oxygen levels and would not be present if water conditions were not adequate (Friends of Kootenay Lake Stewardship Society, 2022). *Ephemerella* spp. sensitivities include low dissolved oxygen, excessive siltation, and heavily polluted water: another indication that downstream waters are of good quality after dam removal.

Upstream (T2 and T2 QAQC) dominant taxa include *H. betteni (*67), *Glossosoma* spp. (39), *H. sparna* (28) (T2) and *Cricotopus bicinctus* (68), *Neoleptophlebia* spp. (49), and *Mircotendipes pedellus* (48) (T2 QAQC). *Glossosoma* spp. and *Neoleptophlebia* spp.. This indicates that sedimentation, siltation, and pollution are low while dissolved oxygen levels are adequate (Friends of Kootenay Lake Stewardship Society, 2022). *Cricotopus bicinctus* also indicates that these factors are low, and that excessive nutrient enrichment is not occurring. *Microtendipes pedellus* dominance can indicate that nutrient enrichment or mild pollution may be impacting water quality as they are very tolerant to these factors. High abundance of this species alone typically indicates these issues (Friends of Kootenay Lake Stewardship Society, 2022). However, in the presence of the other dominant and abundant taxa, it is indicated that these influences are not impeding water quality. Dominant taxa indicate good water quality overall.

Table 2: Macroinvertebrate Dominance Measures

Dominance Measures	Transect 1	Transect 2	Transect 2 QAQC
Dominant Taxon	*Hydropsyche sparna*	*Hydropsyche betteni*	*Cricotopus bicinctus* gr.
Dominant Abundance	63.00	67.00	68.00
2nd Dominant Taxa	*Ephemerella* spp.	*Glossosoma* spp.	*Neoleptophlebia* spp.
2nd Dominant Abundance	28.00	39.00	49.00
3rd Dominant Taxa	*Hydropsyche betteni*	*Hydropsyche sparna*	*Microtendipes pedellus* gr.
3rd Dominant Abundance	25.00	28.00	48.00
% Dominant Taxon	25.82	21.20	9.18
% 2 Dominant Taxa	37.30	33.54	15.79
% 3 Dominant Taxa	47.54	42.41	22.27

Richness

Richness of the stream (Table 3) measured 27 species at T1 (T1), 42 species at T2, and 52 species at T2 QAQC upstream. EPT richness was 14 at T1 and 21 at T2 and T2 QAQC. Specific group richness can be seen in Table 3. Across the group richness measures, downstream has less richness compared to upstream. This could be due to downstream reorganization still in process post-dam removal, differing sedimentation impacts, changes in hydrology, or longer recovery time typical of downstream areas. Upstream transects are higher in sensitive taxa (EPT) and are more taxonomically diverse, which indicate better habitat quality/complexity or lower stress relative to downstream.

Table 3. Macroinvertebrate Richness Measures.

Richness Measures	T1	T2	T2 QAQC	Average
Species Richness	27.00	42.00	52.00	40.33
EPT Richness	14.00	21.00	21.00	18.67
Ephemeroptera Richness	2.00	9.00	8.00	6.33
Plecoptera Richness	6.00	7.00	4.00	5.67

Trichoptera Richness	6.00	5.00	9.00	6.67
Chironomidae Richness	8.00	15.00	20.00	14.33
Orthocladiinae Richness	5.00	8.00	9.00	7.33
Chironomini Richness	0.00	2.00	3.00	1.67
Oligochaeta Richness	1.00	1.00	2.00	1.33
Non-Chiro. Non-Olig. Richness	18.00	26.00	30.00	24.67
Rhyacophila Richness	1.00	0.00	1.00	0.67

Community Composition

Community composition (Table 4), or percentage of taxa per transect, shows %EPT is high for all transects (68.03% T1; 68.04% T2; 49.80% T2 QAQC). A %EPT higher than 50% indicates good water quality (Lewin et al. 2013).

- Ephemeroptera comprised 14.75% of the community at T1, 12.34% at T2, and 16.73% at T2 QAQC.
- Plecoptera accounted for 9.43% at T1, 8.23% at T2, and 7.56% at T2 QAQC.
- Trichoptera represented the largest proportion of the EPT assemblage, contributing 43.85% at T1, 47.47% at T2, and 25.51% at T2 QAQC.

The %EPT indicates that water quality is high, there is adequate dissolved oxygen, good flow, and there is suitable habitat and substrate. It should be noted that the lower %EPT at T2 QAQC could indicate localized disturbance, low pollution, or increased sedimentation in this area, though not severe.

Community Composition also showed:

- Hydropsychidae percentages were moderate across all transects (36.07% at T1, 35.13% at T2, and 19.57% at T2 QAQC).
- Diptera and Chironomidae are present downstream (25% and 19.26% respectfully) and upstream (27.22% at T2 and 43.32% at T2 QAQC). These orders are typically more tolerant to pollution and organic enrichment (Friends of Kootenay Lake Stewardship Society, 2022). T2 QAQC had a 43.32% Diptera which indicates that this area likely has a slightly higher input of pollution, enrichments, or finer sediment, which coincides with the transect's lower %EPT. There is possible stress but not impairment as other metrics indicate good water quality.
- Orthicladiinae percentage was 17.62% at T1, 15.82% at T2, and 24.56% at T2 QAQC.
- Sensitive taxa such as Perlidae and Pteronarcyidae are present (though in low percentages), indicating cold, well-oxygenated water (U.S. Environmental Protection Agency, n.d.).

- Low percentages of Oligochaeta mean that the stream is not heavily polluted and is well oxygenated as these species are highly adapted to organic pollution and low oxygen (U.S. Environmental Protection Agency, n.d.).
- Low percentages of Baetidae, Odonata, Tanyarsini, and others may be natural and do not indicate good or bad water quality.

Overall, macroinvertebrate community composition indicates that water quality is moderate to high across the stream. The domination of sensitive taxa suggests that the system is clean, well-oxygenated, and has stable substrate, habitat complexity, and adequate flow. Increased Diptera and Chironomidae downstream suggest minor localized disturbance, but overall EPT abundance indicates healthy stream conditions.

Table 4. Macroinvertebrate Community Composition.

Community Composition	Transect 1	Transect 2	Transect 2 QAQC
% Ephemeroptera	14.75	12.34	16.73
% Plecoptera	9.43	8.23	7.56
% Trichoptera	43.85	47.47	25.51
% EPT	68.03	68.04	49.80
% Coleoptera	4.51	4.11	5.67
% Diptera	25.00	27.22	43.32
% Oligochaeta	2.46	0.32	1.08
% Baetidae	0.00	2.53	1.48
% Brachycentridae	0.00	0.00	0.00
% Chironomidae	19.26	26.58	41.03
% Orthocladiinae	17.62	15.82	24.56
% Chironomini	0.00	7.59	9.04
% Tanytarsini	1.23	2.85	4.59
% Chironomus	0.00	0.00	0.00
% Tanytarsus	0.00	0.00	1.48
% Dicrotendipes	0.00	0.00	0.00
% Ephemerellidae	11.48	7.28	7.83
% Hydropsychidae	36.07	35.13	19.57
% Odonata	0.00	0.32	0.13
% Perlidae	1.23	0.95	0.94
% Pteronarcyidae	1.64	0.32	0.00
% Simuliidae	4.10	0.00	0.00
% Crustacea	0.00	0.00	0.00
% Mollusca	0.00	0.00	0.00

Functional Group Composition

Functional group composition (Table 5 and Table 6) results show that filterers and gatherers dominate the community. This indicates that both upstream and downstream have high fine particulate organic material food sources. The secondary dominant groups are shredders and scrapers, which feed on coarse particulate organic material (woody debris and plants, biofilm, algae, and diatoms). Predators are also present but in lower percentages. Piecer-herbivores are not present across the system (only found in T2 QAQC at 0.13%). Most of the trophic links are present, indicating a healthy flow of nutrient cycling, filtering of organic matter, control of algal blooms and biofilms, and control from top-down predators (Wallace and Webster, 1996).

Table 5. Macroinvertebrate Functional Group Composition.

Functional Group Composition	Transect 1	Transect 2	Transect 2 QAQC	Average
% Filterers	40.98	41.46	28.34	36.93
% Gatherers	32.38	25.00	30.77	29.38
% Predators	6.15	8.86	10.12	8.38
% Scrapers	10.25	17.09	10.26	12.53
% Shredders	7.79	6.01	18.89	10.90
% Piercer-Herbivores	0.00	0.00	0.13	0.04
% Unclassified	0.00	1.27	0.00	0.42
Filterer Richness	5.00	6.00	9.00	6.67
Gatherer Richness	8.00	18.00	22.00	16.00
Predator Richness	6.00	8.00	8.00	7.33
Scraper Richness	2.00	4.00	4.00	3.33
Shredder Richness	5.00	4.00	6.00	5.00
Piercer-Herbivore Richness	0.00	0.00	1.00	0.33
Unclassified	0.00	1.00	0.00	0.33

Table 6. Macroinvertebrate Functional Group and Common Name per Taxa

Taxa	Functional Role	Common Name
Hydropsyche sparna	Collector-Filterer	Spotted sedge, Buttoned net-spinning caddisfly
Hydropsyche betteni	Collector-Filterer	Common net-spinner caddisfly
Microtendipes pedellus gr.	Collector-Filterer	small red midge
Hydropsyche slossonae	Collector-Filterer	Slossan's net spinning caddisfly
Hydropsyche bronta	Collector-Filterer	thundering net-spinning caddisfly

Cheumatopsyche spp.	Collector-Filterer	little sister sedge, little sister net-spinning caddisfly
Tanytarsus spp.	Collector-Filterer	non-biting midge
Simulium spp.	Collector-Filterer	black fly
Naididae	Collector-Filterer	sludge worm, detritus worm
Rheotanytarsus exiguus gr.	Collector-Filterer	non-biting midge
Corynoneura spp.	Collector-Filterer	non-biting midge
Rheocricotopus spp.	Collector-Filterer	non-biting midge
Dolophilodes spp.	Collector-Filterer	finger-net caddisfly
Psychomyia flavida	Collector-Filterer	dinky net-tube caddisfly
Micropsectra spp.	Collector-Filterer	non-biting midge
Potthastia longimanus gr.	Collector-Filterer	non-biting midge
Ephemerella spp.	Collector-Gatherer	spint crawler mayfly
Cricotopus spp.	Collector-Gatherer	non-biting midge
Tvetenia bavarica gr.	Collector-Gatherer	non-biting midge, buzzer
Parametriocnemus spp.	Collector-Gatherer	non-biting midge, orthoclad
Polypedilum aviceps	Collector-Gatherer	non-biting midge
Cladotanytarsus spp.	Collector-Gatherer	non-biting midge, green nimitti
Baetis flavistriga	Collector-Gatherer	yellow-streaked small minnow mayfly
Baetisca spp.	Collector-Gatherer	armored mayfly
Stempellinella spp.	Collector-Gatherer	non-biting midge
Eukiefferiella pseudomontana gr.	Collector-Gatherer	non-biting midge
Acentrella turbida	Collector-Gatherer	tiny blue-winged olive
Antocha spp.	Collector-Gatherer	crane fly
Baetis tricaudatus	Collector-Gatherer	blue-winged olive
Eukiefferiella devonica gr.	Collector-Gatherer	non-biting midge
Isogenoides spp.	Predator	springfly
Sweltsa spp.	Predator	sallflies, green stonefly
Thienemannimyia gr. spp.	Predator	non-biting midge
Perlodidae	Predator	stonefly
Ceratopogoninae	Predator	biting midge
Agnetina capitata	Predator	northern stonefly
Hexatoma spp.	Predator	hexatoma crane fly
Acroneuria spp.	Predator	golden stone
Paragnetina immarginata	Predator	beautiful stonefly
Isoperla spp.	Predator	striped tails, yellow sallies
Rhyacophila fuscula	Predator	dusky free-living caddisfly

Gomphidae	Predator	clubtail dragonfly
Aeshna spp.	Predator	hawker dragonflies
Glossosoma spp.	Scraper/Grazer	saddle-case caddisfly
Cricotopus bicinctus gr.	Scraper/Grazer	non-biting midge
Neoleptophlebia spp.	Scraper/Grazer	prong-gilled mayfly, blue gills
Optioservus spp.	Scraper/Grazer	riffle beetle
Eukiefferiella claripennis gr.	Scraper/Grazer	non-biting midge, bloodworm (larvae)
Thienemanniella spp.	Scraper/Grazer	non-biting midge
Eurylophella spp.	Scraper/Grazer	spint crawler mayfly
Oulimnius spp.	Scraper/Grazer	riffle beetle
Synorthocladius spp.	Scraper/Grazer	non-biting midge
Lumbriculidae	Scraper/Grazer	blackworm
Sublettea spp.	Scraper/Grazer	non-biting midge
Cricotopus/Orthocladius spp.	Scraper/Grazer	non-biting midge
Rhithrogena spp.	Scraper/Grazer	flathead mayfly
Maccaffertium spp.	Scraper/Grazer	flathead mayfly
Psephenus herricki	Scraper/Grazer	water penny
Acerpenna pygmaea	Scraper/Grazer	mayfly
Plauditus spp.	Scraper/Grazer	minnow mayfly
Baetidae	Scraper/Grazer	minnow mayfly
Nilothauma spp.	Scraper/Grazer	non-biting midge
Hydroptila spp.	Scraper/Grazer	microcaddisfly, purse-case caddisfly
Stenacron spp.	Scraper/Grazer	Stenacron mayfly
Helichus spp.	Scraper/Grazer	long-toed water beetles
Leuctra spp.	Shredder	needlefly, needle stonefly, rolled-winged stonefly
Tipula spp.	Shredder	crane fly
Pteronarcys biloba	Shredder	knobbed salmonfly
Limnephilidae	Shredder	caddisfly

Biotic Indices

Table 7 includes the biotic indices calculated by EcoAnalyst.

- Hilsenhoff Biotic Index (HBI) values less than 5 indicate good water quality (4.26 at T1, 4.29 at T2, and 4.68 at T2 QAQC) (New York State Department of Environmental

Conservation, 2018). T2 QAQC value may indicate localized stress as mentioned before for other metrics.

- Metal Tolerance index (MTI) indicates that the taxa present are not tolerant of metal and pollution (3.92 at T1, 3.02 at T2, and 4.40 at T2 QAQC). T2 QAQC has slightly more tolerant taxa meaning that there could be pockets of metal pollution, though not severe. Non-tolerant taxa present means that water quality is good (Puget Sound Stream Bentos, n.d.).
- Fine Sediment Biotic Index (FSBI) shows that macroinvertebrates in this system require clean, coarse substrate with high oxygen and flowing water (30 at T1, 51 at T2, and 55 at T2 QAQC) (Reltea, Minshall, & Danehy, 2012). Higher value at T2 QAQC may indicate some localized sediment accumulation.
- Temperature Preference Metric (TPM) indicates macroinvertebrates' thermal preference. Lower values across transect mean more cool-water taxa are present, and the stream supports these macroinvertebrates.

Table 7. Macroinvertebrate Biotic Indices.

Biotic Indices	Transect 1	Transect 2	Transect 2 QAQC
% Indiv. w/ HBI Value	93.85	96.84	91.09
Hilsenhoff Biotic Index	4.26	4.29	4.68
% Indiv. w/ MTI Value	32.38	30.06	44.26
Metals Tolerance Index	3.92	3.02	4.40
% Indiv. w/ FSBI Value	31.97	34.49	31.85
Fine Sediment Biotic Index	30.00	51.00	55.00
FSBI - average	1.11	1.21	1.06
FSBI - weighted average	4.08	4.84	4.41
% Indiv. w/ TPM Value	39.75	43.99	48.72
Temp. Pref. Metric - average	2.33	2.12	1.60
TPM - weighted average	5.95	5.50	4.22

Algae Results

Algae samples were taken at two transects, downstream at T1 and upstream at T2 (Figure 1), in 2025, four years after dam removal. A second sample was taken at T2 as a quality assurance and quality control measure (T2 MH2 QAQC). At each transect, multihabitat (MH) and rock scraping (RS) samples were collected. Total results across transects and downstream versus upstream comparisons will be discussed. No samples were collected before or during dam removal. Following removal, Avacal Biological Consulting took samples in 2022 and 2023 and will be compared to FCNRCD/EcoAnalyst data collected in 2025. No data was collected in 2024. Cells and Cell/mL were used to analyze data.

Abundance

Abundance measures (Table 8) and comparisons were calculated using the sum of cells and the sum of cells/mL. Abundance of algae species totaled 2208 cells from 1506 natural units across the stream. *Fragilaria* spp. (441 cell, 25,136.04 cell/mL), *Pseudanabaena* spp. (257, 19,946.57 cell/mL), Unknown *Pennate* spp. (185 cells, 11,214.34 cell/mL), *Nitzschia* spp. (163, 10,229.69 cell/mL) and *Encyonema* spp. (143 cells, 10,618.25 cells/mL) were the top five most abundant species across the stream. The average abundance per taxon ranged from 10.56 downstream to 19.73 upstream.

Pseusdanabaena spp., *Fragilaria* spp., *Encyonema* spp., Unknown *Pennate* spp., and *Nitzchia* spp. abundances were the top five species downstream and upstream. *Pseudanabaena* spp. thrive in low-velocity water and indicate there are some nutrient influences and potential for algal blooms. However, the abundance of *Fragilaria* spp. and *Encyonema* spp. show that conditions are cool, well-oxygenated, and there is good flow. *Nitzchia* spp. and *Pennate* spp. indicate moderate to low nutrient levels, stable substrates, and moderate water flow (Bellinger & Sigee, 2010).

Abundance of these species above and below the dam suggests moderate productivity with some nutrient influences, consistent with mesotrophic conditions. Overall, adequate flow, good oxygen levels, and stable substrates are indicated through these bioindicators (Bellinger & Sigee, 2010; Wehr & Kociolek, 2015).

Table 8: Algal Abundance Measures

Abundance Measures (Cells)	T1 RS	T1 MH	T2 MH1	T2 MH2 QAQC	T2 RS
Abundance	380.00	416.00	513.00	424.00	475.00
Average Abundance (per Taxon)	10.56	11.24	19.73	11.78	13.97

Acronyms: T1- Transect 1, T2- Transect 2; MH-Multihabitat sample, RS- Rock Scraping sample

Dominance

The dominant species' cells/mL were summed across T1 and T2 and compared downstream versus upstream. Dominant species, at both T1 and T2, (Table 9) include *Pseudanabaena* spp. (8,924 cell/mL), *Fragilaria* spp. (8,258 cell/mL), *Achnanthidium* spp. (8,119 cells/ mL), *Encyonema* spp. (6,260 cells/mL), and *Nitzchia* spp. (4,928 cells/mL). The dominant species indicate a mixed algal community with characteristics of both nutrient tolerant species (*Nitzchia* spp., *Fragilaria* spp. *Pseudanabaena* spp.) and moderate water quality species. Diatoms dominate 70% of collected samples across the stream, meaning that flow is adequate. Cyanobacteria influences, though present (18%), do not dominate the system. Taxa associated with good oxygen and stable substrates are present (*Achnanthidium* spp., *Encyonema* spp.) (Bellinger & Sigee, 2010; Stevenson & Lowe, 1996).

Differences in dominate species downstream versus upstream are minimal but should be noted. Overall, downstream has higher cells/mL per species mentioned before than upstream. Furthermore, *Navicula* spp. and *Desmodesmus* spp. are within the 2,000-4,000 cells/mL range downstream. These species indicate moderate nutrient availability, mixed pockets of riffle habitat, and slow-moving pools (Kociolek & Spaulding, 2003). Upstream dominant species also include *Glaucospira* spp. (not dominant downstream). *Glaucospira* spp. (2,261.61 cells/mL) indicates longer water residence time, low physical disturbance, and nutrient conditions favorable to filamentous cyanobacteria growth (Kociolek & Spaulding, 2003).

Table 9: Algal Dominance Measures

Dominance Measures (Cells)	T1 RS	T1 MH	T2 MH1	T2 MH2	T2 RS
Dominant Taxon	*Fragilaria* spp.	*Pseudanabaena* spp.	*Fragilaria* spp.	*Pseudanabaena* spp.	*Pseudanabaena* spp.
Dominant Abundance	97.00	67.00	102.00	78.00	112.00
2nd Dominant Taxa	*Nitzschia* spp.	*Fragilaria* spp.	*Glaucospira* spp.	*Fragilaria* spp.	*Fragilaria* spp.
2nd Dominant Abundance	47.00	62.00	88.00	76.00	104.00
3rd Dominant Taxa	Unknown *Pennate* spp.	*Encyonema* spp.	*Tribonema* spp.	Unknown *Pennate* spp.	Unknown *Pennate* spp.
3rd Dominant Abundance	42.00	47.00	83.00	48.00	43.00
% Dominant Taxon	25.50	16.10	19.90	18.30	23.60
% 2 Dominant Taxa	12.40	14.90	17.20	17.90	21.90
% 3 Dominant Taxa	11.00	11.30	16.20	11.30	9.05

Acronyms: T1- Transect 1, T2- Transect 2; MH-Multihabitat sample, RS- Rock Scaping sample

Richness

Richness measures were calculated using unique taxon name counts. Downstream richness is 51 unique taxa while upstream richness is 56. Algal richness greater than 50 is relatively high for temperate stream systems and, when considered alongside community composition (e.g. overall diatom dominance and low cyanobacteria abundance; discussed other sections of this report), suggests good habitat heterogeneity and moderate nutrient conditions (moderate richness = 30-50 taxa, high richness = > 50 taxa; Bellinger & Sigee, 2010; Stevenson & Lowe, 1996; Wher & Kociolek, 2015). The stream post dam removal is functioning and biologically active. Upstream shows greater habitat heterogeneity and slightly higher richness post dam removal as compared to downstream. Specific class richness per transect can be seen in Table 10. Though there are some nutrient influences, the system is not degraded.

- Bacillariophyceae richness was 29 in T1 and 24 in T2. High diatom presences indicated well-oxygenated water, stable substrates, habitat heterogeneity, and consistent flow conditions (Stevenson & Lowe, 1996; Wehr & Kociolek, 2015).
- Chlorophyceae richness (13 in T1 and T2) is the second most diverse class. These taxa are associated with productive systems, adequate light, and nutrient availability (Bellinger & Sigee, 2010; Wehr & Kociolek, 2015).
- Cyanobacteria richness (3 in T1, 5 in T2) is relatively low compared to diatoms and green algae, their presence means there is slightly high nutrient availability (particularly phosphorous and nitrogen). There are moderate nutrients in the stream, and it is not dominated by bloom-forming cyanobacteria (Barinova & Mamanazarova, 2021; Bellinger & Sigee, 2010).
- Zygnematophyceae richness (2 in T1, 4 in T2) indicates relatively clean water and no major nutrient influences, as these species are sensitive to these factors (Bellinger & Sigee, 2010; Wehr & Kociolek, 2015).
- Chrysophyceae (1 in T1, 3 inT2), Cryptophyceae (2 in T1, 3 in T2), Trebouxiophyceae (1 in T1), Xanthophyceae (1 in T2) and Euglenophyceae (1 in T2) are low, which is typical of benthic streams. Euglenophyceae are associated with organic enrichment, indicating that the stream post dam removal is not experiencing organic pollution (Barinova & Mamanazarova, 2021; Bellinger & Sigee, 2010).

High diatom richness, moderate green algae richness, low cyanobacteria richness, and presence of sensitive taxa indicates a diverse, functioning ecosystem (well-oxygenated water, stable substrates, habitat heterogeneity, and consistent flow conditions) with moderate nutrient availability.

Table 10. Algal Richness Measures.

Richness Measures (Cells)	**T1 RS**	**T1 MH**	**Downstream Total**	**T2 MH1**	**T2 MH2**	**T2 RS**	**Upstream Total**
Bacillariophyceae Richness (diatoms)	20.00	19.00	**29.00**	17.00	20.00	19.00	**24.00**
Chlorophyceae Richness	8.00	9.00	**13.00**	6.00	9.00.	8.00	**13.00**

Chrysophyceae Richness	0.00	1.00	**1.00**	0.00	1.00	0.00	**3.00**
Cryptophyceae Richness	1.00	1.00	**2.00**	0.00	1.00	2.00	**3.00**
Cyanophyceae Richness	2.00	2.00	**3.00**	2.00	3.00	3.00	**5.00**
Euglenophyceae Richness	0.00	0.00	**0.00**	0.00	1.00	0.00	**1.00**
Trebouxiophyceae Richness	0.00	1.00	**1.00**	0.00	0.00	0.00	**0.00**
Xanthophyceae Richness	0.00	0.00	**0.00**	0.00	1.00	0.00	**1.00**
Zygnematophyceae Richness	1.00	2.00	**2.00**	1.00	2.00	2.00	**4.00**
Totals	**32.00**	**35.00**	***51.00***	**26.00**	**38.00**	**34.00**	***52.00***

Acronyms: T1- Transect 1, T2- Transect 2; MH-Multihabitat sample, RS- Rock Scaping sample
*Note: Total richness is lower than the sum of each transects because shared taxa are only counted once when samples are combined into downstream and upstream categories.

Community Composition

Total algal density sum is 134,624 cells/mL across the stream. Densities greater than 100,000 cells/mL often indicate highly productive and potentially nutrient rich systems (Bellinger & Sigee, 2010). Table 11 describes community composition based on division per transect. Community composition is dominated both downstream and upstream by Heterokonphyta (Bacillariophyceae; diatoms). However, downstream shows a stronger dominance of diatoms, including more uniform and stable environmental conditions. Heterokonphyta (~70% overall; ~72% downstream and ~60% upstream) typically dominate benthic communities in flowing systems. They are associated with well-oxygenated water, stable substrates, and moderate nutrient conditions. In contrast to downstream dominance of diatoms, upstream exhibits even distribution among algal divisions, with higher abundance of Cyanophyta and other minor divisions. This suggests greater habitat heterogeneity and potential nutrient enrichment in localized areas. The moderate proportion of cyanobacteria suggests some nutrient enrichment, but not a system dominated by harmful algal blooms. Chlorophyta (11%) are a smaller but significant part of the ecosystem. They are good indicators of adequate light availability within the system (Lobo & Schuch, 2016). Their presence shows active primary production and suitable conditions for algal growth.

Table 11. Algal Community Composition.

Division	T1 RS	T1 MH	T2 MH1	T2 MH2	T2 RS	Total Cells/mL	% of Total Community
Heterokonphyta	12543.97	37961.46	9815.31	13371.04	20481.53	94,173.00	70.10

Cyanobacteria	278.75	9457.07	2312.51	3699.32	8219.56	23,967.00	17.90
Cholorphyta	2269.86	7192.7	976.39	1470.81	2762.31	14,672.00	10.90
Cryptista	39.82	266.40	0.00	222.85	202.12	731.00	0.54
Charophyta	0.00	266.40	51.39	89.14	202.12	609.00	0.45
Euglenophyta	0.00	0.00	0.00	44.57	67.37	112.00	0.08
Total	**15132.40**	**55144.03**	**13155.60**	**18897.73**	**31935.01**	**134,264.00**	**99.97**

Acronyms: T1- Transect 1, T2- Transect 2; MH-Multihabitat sample, RS- Rock Scaping sample

Multiyear Comparisons

Macroinvertebrate Comparisons by Year

Data was collected and analyzed by Avacal Biological Consulting in 2023, two years following dam removal. No data was collected in 2022 due to cold temperatures or in 2024. Comparing the 2023 results to the 2025 results can provide insight into changes over time following dam removal.

2023

Findings from 2023 indicate that the density of macroinvertebrates was low downstream and upstream. Richness was very low across the stream with Lepidoptera, Plecoptera, Trichoptera and Coleoptera present upstream and mainly Plecoptera present downstream. Downstream results were more impacted by flooding and high rain events than upstream.

Samples were too small to calculate any other measures. However, based on what was collected, there were indications of clean water and environmentally sensitive species were present. It is likely that macroinvertebrate populations were not able to recolonize adequately by the time of sampling due to flooding and high rain events. Iron oxide mixing from anaerobic groundwater and aerobic surface water (Princeton Hydro, 2023) and high siltation levels further prevented adequate recolonization.

2025

In 2025, there is a dramatic increase in density, richness, and abundance. Both upstream and downstream had increases in diversity and community composition. Further calculations were possible with the increase in sample size. Time since flooding and reduced siltation has allowed for increased recolonization compared to past years. However, full recolonization and stream recovery has not yet occurred. Regular bank failures, movement of sediment, and erosion continue to have impacts on the stream's water quality and the organisms within it. Though silt and clay particles have passed further downstream, larger particles such as pebbles and sand are still working through the impacted system.

Algae Comparisons by Year

Following dam removal, data was collected and analyzed by Avacal Biological Consulting in 2022 and 2023. No data was collected in 2024. 2025 data was collected by FCNRCD and analyzed by EcoAnalysts.

2022-2023

In 2022, there was no indication of toxic pollution or acidity impacts. Low levels of organic pollution, slight to moderate levels of overall pollution impacts (downstream and upstream respectively), and severe salinity impacts were present. Furthermore, there were indications of minor siltation impacts across the stream. The same results were concluded in 2023.

Moreover, the samples showed low generic richness both downstream and upstream. The number of divisions were also low in both years. In 2022, the stream had higher amounts of siltation and elevated iron oxide levels (caused by mixing of anaerobic groundwater and aerobic surface water post dam removal; Princeton Hydro, 2023), whereas in 2023, flooding and high rain events occurred throughout the season. These factors are likely the reason for the lack of adequate recolonization of algal populations within the first two years post dam removal. Sensitive diatoms were not present downstream within the first two years but were present upstream. Cyanobacteria were not found within samples in 2022 or 2023.

2025

In 2025, pollution, acidity, saltation, and siltation measures were not explicitly defined using algal bioindicators. However, based on species composition, richness, and abundance, it can be inferred that toxic pollution and acidity did not have major impacts on the system. There may be influences from saltation and siltation still impacting the system. Organic pollution and nutrient influences continue to have an impacts on the algal community at low levels given the species present.

Species richness and number of divisions was moderate to high (Bellinger & Sigee, 2010; Stevenson & Lowe, 1996; Wher & Kociolek, 2015), potentially showing increased recolonization of algal species. Cyanobacteria are present at ~18% of the total stream dominance in 2025. Recolonization, warmer temperatures, and increased nutrient inputs could be the reasons for this increase. As the system continues to stabilize, algal populations are increasing in diversity and abundance. The stream composition of algae indicates a diverse and functioning ecosystem with moderate nutrient influences.

Discussion

The stream four years post-dam removal indicates moderate to high water quality and a functioning habitat for macroinvertebrates. Both upstream and downstream macroinvertebrate community assemblages indicate cool, well-oxygenated water that is not polluted (by either metals or organic matter), has ample food and habitat resources, and little sedimentation impacts. %EPT was similar upstream (68% at T2 and 49% T2 QAQC) and downstream (68% at T1), with Trichoptera dominating and sensitive taxa such as Ephemerellidae and Plecoptera present. Functional feeding groups were dominated by filterers and gatherers, with scrapers, shredders, and predators present, indicating adequate flow, habitat complexity, and availability of both fine and coarse organic matter. Biotic indices support these trends: Hilsenhoff Biotic Index values indicate low organic pollution, Metals Tolerance Index values suggest minimal metal stress, and Fine Sediment Biotic Index values show only minor localized sediment impacts.

Algal sampling results in 2025 differed between downstream and upstream transects following dam removal, reflecting variation in localized habitat conditions, flow regime, and nutrient influences. However, overall samples indicate that the stream is functioning as a moderately productive system with mesotrophic nutrient conditions. A total algal density of 134,624 cells/mL and richness measures (51 downstream and 52 upstream) suggests an active and biologically diverse community (Bellinger & Sigee, 2010).

Diatoms dominated both abundance and richness, comprising approximately 70% of the community, which is typical of well-oxygenated streams with stable substrates and consistent flow (Stevenson et al., 1996; Wehr & Sheath, 2003). Dominant taxa such as *Fragilaria* spp., *Nitzschias spp*., and *Pseudanabaena* spp. across the stream indicate some nutrient influence, while the presence of taxa associated with higher water quality, including *Achnanthidium* spp. and *Encyonema* spp., suggests that overall environmental conditions remain relatively stable (Bellinger & Sigee, 2010; Wehr & Sheath, 2003). Downstream results were characterized by a higher proportional dominance of fewer taxa, while upstream was less dominated and more even across taxa. This suggests upstream assemblages may be in a more transitional or variable state, whereas downstream is more structurally stable. These results differ from typical responses of algal populations from other dam removals in the Northeast (i.e., downstream usually has longer lasting impacts than upstream).

Upstream conditions support a broader range of algal taxa suggesting greater habitat heterogeneity (presence of Euglenophyceae and Xanthophyceae- minor taxa not found downstream) and higher nutrient influences (higher percent of Cyanobacteria). This could indicate areas of pooled water or slower recovery from previous pooling conditions. Across the stream, richness of green algae reflects adequate light and productivity, while the relatively low richness and proportion of Cyanobacteria indicate that nutrient enrichment is present but not sufficient to produce harmful algal blooms (Stevenson et al., 1996).

Additionally, the presence of sensitive groups such as Zygnematophyceae and the low occurrence of Euglenophyceae suggest limited organic pollution (Wehr & Sheath, 2003). Their absence downstream is likely due to increased water flow and reduced sediment retention following dam removal.

The observed results are mostly consistent with ecological expectations following dam removal. Downstream locations often experience increased flow, sediment transportation, and channel reorganization, which can favor diatom-dominant communities adapted to disturbance. There is a shift toward lotic conditions and potentially improving ecological stability. Atypically, these results show that upstream impacts are lasting longer than downstream impacts. Upstream areas, which were previously impounded, may be retaining characteristics of legacy conditions, such as slower water movement, higher temperatures, finer sediments, and higher nutrient availability. Upstream areas may still be recovering from dam removal.

Overall, while downstream sites exhibit a slight increase in tolerant taxa, the combined data suggest the stream is biologically healthy with only minor localized disturbances upstream and downstream. Some of these impacts could be due to the long-term recovery and reorganization processes shown from other dam removals. Sampling before, during, and after is recommended to fully track the progress of water quality impacts from dam removals to further contribute to knowledge gaps. Additionally, sampling further upstream and downstream outside of the influence of the dam removal site could provide valuable insight into stream dynamics across the riverscape setting.

FRANKLIN COUNTY
NATURAL RESOURCES
CONSERVATION DISTRICT

References

Barinova, S., & Mamanazarova, K. (2021). Diatom algae as indicators of water quality in river ecosystems. *Water*, 13(3), 358. https://doi.org/10.3390/w13030358

Bellinger, E. G., & Sigee, D. C. (2010). *Freshwater algae: Identification and use as bioindicators. Wiley-Blackwell.* John Wiley & Sons. https://books.google.com/books?id=rhMmBgAAQBAJ

Bellmore, J. R., Duda, J. J., Craig, L. S., Greene, S. L., Torgersen, C. E., Collins, M. J., & Vittum, K. (2019). Conceptualizing ecological responses to dam removal: If you remove it, what's to come? *BioScience*, 69(1), 26–39. https://doi.org/10.1093/biosci/biy152

Bellmore, J. R., Duda, J. J., Craig, L. S., Greene, S. L., Torgersen, C. E., Collins, M. J., & Vittum, K. (2017). Status and trends of dam removal research in the United States. *Wiley Interdisciplinary Reviews: Water, 4*(2), e1164. https://doi.org/10.1002/wat2.1164

Burroughs, B. A., Hayes, D. B., Klomp, K. D., Hansen, J. F., & Mistak, J. (2010). The effects of the Stronach Dam removal on fish, macroinvertebrates, and habitat in the Pine River, Michigan. *Transactions of the American Fisheries Society, 139*(6), 1595–1613. https://doi.org/10.1577/T09-200.1

Carlson, P. E., Donadi, S., & Sandin, L. (2018). Responses of macroinvertebrate communities to small dam removals: Implications for bioassessment and restoration. *Journal of Applied Ecology*, 55(4), 1896–1907. https://doi.org/10.1111/1365-2664.13102

Çelekli, A., Costa, A. B., & Schneck, F. (2024). *Determination of ecological status of streams using diatom assemblages. Environmental Science and Pollution Research*.

Centers for Disease Control and Prevention. (2025, February 24). *Clinical signs and symptoms caused by freshwater harmful algal blooms*. https://www.cdc.gov/harmful-algal-blooms/hcp/clinical-signs/symptoms-freshwater-harmful-algal-blooms.html

Claeson, S. M., & Coffin, B. (2016). Physical and biological responses to an alternative removal strategy of a moderate-sized dam in Washington, USA. *River Research and Applications*, 32(6), 1143–1152. https://doi.org/10.1002/rra.2935

Doyle, M. W., Stanley, E. H., Orr, C. H., Selle, A. R., Sethi, S. A., & Harbor, J. M. (2005). Stream ecosystem response to small dam removal: Lessons from the Heartland. *Geomorphology, 71*(1–2), 227–244. https://doi.org/10.1016/j.geomorph.2004.04.011

Friends of Kootenay Lake Stewardship Society. (2022). Macroinvertebrate Bioindicator Families Guide (Version 1.2). https://www.friendsofkootenaylake.ca/wp-content/uploads/2022/09/Macroinvertebrate-Bioindicator-Families-Guide-v1.2.pdf

Foley, M. M., Bellmore, J. R., O'Connor, J. E., Duda, J. J., East, A. E., Grant, G. E., Anderson, C. W., Bountry, J. A., Collins, M. J., Connolly, P. J., Craig, L. S., Evans, J. E., Greene, S., Magilligan, F. J., Magirl, C. S., Major, J. J., Pess, G. R., Randle, T. J., Shafroth, P. B., Torgersen, C. E., Tullos, D. D., & Wilcox, A. C. (2017). Dam removal: Listening in. *Water Resources Research*, 53(7), 5229–5246. https://doi.org/10.1002/2017WR020457

Gregory, S. V., Li, H. W., & Li, J. L. (2002). The conceptual basis for ecological responses to dam removal. *BioScience, 52*(8), 713–723. https://doi.org/10.1641/0006-3568(2002)052[0713:TCBFER]2.0.CO;2

Kociolek, J.P., & Spaulding, S.A. (2003). *Navicula*. In J.D. Wehr & R.G. Sheath (Eds.), *Freshwater algae of North America: Ecology and classification*. Academic Press.

Lewin, I., Czerniawska-Kusza, I., Szoszkiewicz, K. et al. Biological indices applied to benthic macroinvertebrates at reference conditions of mountain streams in two ecoregions (Poland, the Slovak Republic). *Hydrobiologia* **709**, 183–200 (2013). https://doi.org/10.1007/s10750-013-1448-2

Lobo, E. A., Heinrich, C., Schuch, M., & Wetzel, C. E. (2016). Diatoms as bioindicators in rivers. In *River Algae* (pp. 245–271). Springer.

Mahan, D. C., Betts, J. T., Nord, E., Van Dyke, F., & Outcalt, J. M. (2021). Response of benthic macroinvertebrates to dam removal in the restoration of the Boardman River, Michigan, USA. *PLoS ONE*, 16(5), e0245030. https://doi.org/10.1371/journal.pone.0245030

Magilligan, F. J., Sneddon, C. S., Fox, C. A., & Nislow, K. H. (2016). Dam removal and watershed resilience in New England rivers. *Elementa: Science of the Anthropocene, 4*, 000108.

Major, J. J., East, A. E., O'Connor, J. E., Warrick, J. A., Anderson, C. W., Randle, T. J., ... & Grant, G. E. (2012). Geomorphic response of the Elwha River to dam removal. *Geological Society of America Special Papers, 497*, 1–31.

Malm-Renöfält, B., Lejon, A. G. C., Jonsson, M., & Nilsson, C. (n.d.). Long-term taxon-specific responses of macroinvertebrates to dam removal in a mid-sized Swedish stream. Manuscript submitted for publication.

New York State Department of Environmental Conservation. (2018). Fact sheet on assessment of water quality impact in streams and rivers (BAP Narrative). https://extapps.dec.ny.gov/docs/water_pdf/bapnarrative18.pdf

Ohio State University. (n.d.). Dam removal – Streams, Rivers, and Estuaries (STRIVE) Lab. Retrieved February 17, 2026, from https://u.osu.edu/strive/category/damremoval/

Piscart, C., Dézerald, O., Pellan, L., Le Bris, N., Rodríguez-Pérez, H., Beauverger, T., Huteau, D., & Roussel, J.-M. (2024). Persistent disconnect between flow restoration and restoration of river ecosystem functions after the removal of a large dam on the Sélune River. *Frontiers in Environmental Science*, 12, 1250810. https://doi.org/10.3389/fenvs.2024.1250810

Princeton Hydro. (2023, April 7). *Explained: Iron oxide floc related to dam removals*. https://princetonhydro.com/explained-iron-oxide-floc-related-to-dam-removals/

Puget Sound Stream Benthos. (n.d.). Metals Tolerance Index. Puget Sound Stream Benthos. https://pugetsoundstreambenthos.org/Metals-Tolerance-Index.aspx

Poulos, H. M., Miller, K. E., Heinemann, R., Kraczkowski, M. L., Whelchel, A. W., & Chernoff, B. (2019). Dam removal effects on benthic macroinvertebrate dynamics: A New England stream case study (Connecticut, USA). *Sustainability*, 11(10), 2875. https://doi.org/10.3390/su11102875

Stanley, E. H., & Doyle, M. W. (2002). A geomorphic perspective on nutrient retention following dam removal. *BioScience, 52*(8), 693–701. https://doi.org/10.1641/0006-3568(2002)052[0693:AGPONR]2.0.CO;2

Stevenson, R. J., Bothwell, M. L., & Lowe, R. L. (Eds.). (1996). *Algal ecology: Freshwater benthic ecosystems*. Academic Press.

Sullivan, S. M. P., & Manning, D. W. P. (2017). Seasonally distinct taxonomic and functional shifts in macroinvertebrate communities following dam removal. *PeerJ*, 5, e3189. https://doi.org/10.7717/peerj.3189

Tullos, D. (2016). Dam removal and river restoration: A review of ecological responses and implications for management. *Wiley Interdisciplinary Reviews: Water, 3*(4), 437–452.

U.S. Environmental Protection Agency. (n.d.). Indicators: Benthic macroinvertebrates. https://www.epa.gov/national-aquatic-resource-surveys/indicators-benthic-macroinvertebrates

Wallace, J. B., & Webster, J. R. (1996). The role of macroinvertebrates in stream ecosystem function. *Annual Review of Entomology,* 41, 115–139. https://doi.org/10.1146/annurev.en.41.010196.000555

Wehr, J. D., & Sheath, R. G. (2003). *Freshwater algae of North America: Ecology and classification*. Academic Press.

Vermont Agency of Natural Resources. (2018). *Bug site summary report: Location ID 521582*. https://anrweb.vt.gov/DEC/IWIS/ReportViewer.aspx?Report=BugSiteSummary&LocationID=521582

Vermont Agency of Natural Resources, Department of Environmental Conservation, Watershed Management Division. (2022). *Watershed Management Division field methods manual*

(Revised January 2022). https://dec.vermont.gov/sites/dec/files/documents/WSMD-Field-Methods-Manual-2022.pdf

Vermont Department of Environmental Conservation. (2017). *Vermont water quality standards*. State of Vermont. https://dec.vermont.gov/sites/dec/files/documents/2022-Vermont-Water-Quality-Standards.pdf

Appendix 1: Habitat Characteristics

Habitat Characteristics

	Transect 1	**Transect 2**
Habitat Type	Riffle	Riffle
Bankfull Width (ft)	15	30
Wetted Width (ft)	8	4
Velocity	Medium (0.4 – 2 ft/sec)	Medium (0.4 – 2 ft/sec)
Bank Stability	Fair	Poor
Large Woody Debris	2	11
Riparian Buffer Characteristics		
Riparian Width Left (ft)	10	50
Riparian Width Right (ft)	50	15
Softwood (%)	10	0
Hardwood (%)	40	1
Woody Shrubs (%)	10	80
Herbaceous (%)	75	70
Grass (%)	0	0
Substrate Characteristics		
Embeddedness (% estimate)	50	40
Silt Rating	3	3
CPOM Rating (coarse particulate organic matter)	2	1

Pebble Counts

	Transect 1	**Transect 2**
Substrate Size Classes		
Clay (<0.002)	0	0
Silt (0.002-0.075mm)	8	2
Sand (0.075-2mm)	3	4
Gravel (2-16mm)	16	13
Coarse Gravel (16-64mm)	38	46
Cobble (64-256mm)	19	25
Boulder (>256mm)	1	0
Bedrock	0	0

Periphyton Cover			
Periphyton Type		Transect 1	Transect 2
Moss	0 (no moss present)	32	50
	1 (<5% coverage)	0	0

	2 (5-25% coverage)	0	0
	3 (>25% coverage)	0	0
Macro algae	0 (no macro algae present)	1	17
	1 (<5% coverage)	6	1
	2 (5-25% coverage)	5	11
	3 (>25% coverage)	20	27
Micro algae	0 (no micro algae present)	7	45
	1 (slimy, biofilm not visible)	24	10
	2 (thin layer of visible biofilm)	1	1
	3 (biofilm thickness 0.5-1mm)	0	0
	4 (biofilm thickness 1-5mm)	0	0
	5 (biofilm thickness 5-20mm)	0	0
Didymo presence		No	No
Iron Precipitates or Calcareous Deposits		No	No

Methods for evaluating habitat characteristics and conducting pebble counts are taken directly from the Vermont Department of Environmental Conservation's Watershed Management Division Field Methods Manual.