VERMILION RIVER

2015 AQUATIC ECOSYSTEM ASSESSMENT

Prepared for: North Saskatchewan Watershed Alliance

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Executive Summary

The North Saskatchewan Watershed Alliance (NSWA) is responsible for making watershed management recommendations to the Government of Alberta. The North Saskatchewan River (NSR) watershed is comprised of 12 sub-watersheds, one of which drains toward the Vermilion River (VR). Although the VR watershed covers a relatively large (14%) portion of the total NSR watershed, information regarding the aquatic ecosystem is not readily available. On behalf of the NSWA, CPP Environmental (CPPENV) completed an aquatic ecosystem assessment of the VR including aquatic habitat, vegetation, macroinvertebrates, and fish.

The VR is located in the east central part of Alberta in the Parkland Natural Region. The predominant land use is agriculture. The watershed has a population of approximately 57,000 people whom are concentrated in Vegreville, Vermilion, and Two Hills. Drainage works have occurred throughout the watershed, particularly in the upper reaches of the watershed (i.e., the Holden Drainage District) and in a 40+ km stretch of the VR near Two Hills. Two dams hold back the VR flow: the Morecambe Dam near Two Hills, and the Town of Vermilion dam which creates a reservoir next to the town. The river is fed by localized runoff from areas strongly associated with the riparian areas, precipitation, as well as the regional groundwater system. By late summer, most of the river reaches can cease to flow. At this time, the river's hydraulic behavior is similar to that of a shallow open water wetland or small lake. Indeed, the Vermilion Lakes complex, near Two Hills, is part of the river channel.

Seven sampling stations were surveyed from August to September in 2015, which corresponds to the locations visited in 2014 for water quality sampling. In late summer of 2015, flow was either non-existent or detected in trace amounts at all stations, except for the downstream-most station VER6. At each station, 5 transects were established, spaced 50m apart, representing a 200m reach. Habitat metrics measured at each transect included stream shading, aquatic plant cover, bank undercutting, habitat diversity, and bank stability. In addition to this, water quality sampling was completed to represent the chemical environment. These metrics were scored and converted into a Habitat Quality Index (USEPA 1997). Based on this index, station VER6 stood out with the best score, largely driven by high habitat diversity and better water quality. VER1 and 05EE010, representing the middle reaches in between Two Hills and the Town of Vermilion, had the second-highest habitat quality scores for different reasons. These three stations (VER6, VER1 and 05EE010) had the highest habitat scores and the highest aquatic plant species richness. The three stations representing the upper reaches of the VR (moving upstream from 05EE010: TWO2A, MIN2A, BEA1) had some of the lowest habitat quality due to a low diversity of habitat types (TWO2A), poor water quality (all 3), and little aquatic plant coverage (BEA1). VER3, downstream of the Town of Vermilion, had the lowest habitat quality due to low oxygen levels (below short-term guidelines for the protection of aquatic life) and an overabundance of aquatic vegetation. Water substantially improves in quality after passing through the Vermilion River lakes complex, which acts as an important sink of nutrients and drives results in aquatic ecosystem health.

To capture a representative sample of the fauna of the VR, macroinvertebrate and fish sampling was completed in each 200m reach. Macroinvertebrates were sampled by "jabbing" and "sweeping" submerged macrophytes, vegetated banks and snags 20 times in proportion to the abundance of these habitat types as per the USEPA multi-habitat approach for slow moving streams. Based on the Family Biotic Index (FBI) calculated from macroinvertebrate data, all reaches in the VR were classified as "substantial organic pollution". Differences in macroinvertebrate captures among stations reflect habitat quality and predation. Fish were sampled through a combination of backpack electrofishing and minnow trapping. The percentage of the fish catch classified as omnivores, which is a highly tolerant functional group, followed patterns in habitat quality, with a high percentage of omnivores at stations with low habitat scores. VER6 was the only reach that contained fish that were intolerant of poor environmental conditions.

In summary, the VR is characteristic of a small, slow-moving mud-bottom prairie river in Alberta. Except for the lowest reach, the river ceases to flow in mid to late summer, which dictates many ecosystem processes. As demonstrated by the poor macroinvertebrate FBI score, the Vermilion River generally is an unhealthy system, which is consistent with the widespread degradation of riparian areas and wetlands. Aquatic ecosystem health is much improved near the mouth of the VR (VER6) due to the presence of physical habitat diversity, improved hydraulic connectivity with the regional fish species pool (i.e., the North Saskatchewan River), and improved water quality linked to the presence of instream flows that can flush the system. Other places that show significant improvement are reaches downstream from the VR Lakes complex, which acts as a nutrient sink. Upstream of the VR lakes, the aquatic ecosystem is in a very poor state in late summer. Recommendations are provided in the report to conserve such a regionally important environmental resource.

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Acknowledgements

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1.1 Introduction

Aquatic ecological health is the ability of a river or wetland to maintain ecological structure and function over time and in a manner that is similar to the natural or undisturbed ecosystem of the region's past (Alberta Environment 2005). The Vermilion River (VR) watershed has been identified as one of the most altered of the North Saskatchewan River sub-watersheds. Over the past century, the VR has been altered by extensive wetland drainage, riparian degradation, organic pollution, channelization and other water management structures such as dams (NSWA 2012). These human alterations have had an impact on watershed hydrology; however there is limited historic documentation of the aquatic life in the (VR). The goal of this project is to document aquatic ecosystems on seven reaches in the VR. The scope of the aquatic surveys included the following components:

Aquatic Habitat

An ecosystem is "a community of living organisms and their physical and chemical environment, linked by the flows of energy and nutrients" (RAMP 2016). Physical and chemical metrics, which together represent the habitat of the VR, were measured. These data were synthesized in a multi-metric index of habitat health (Barbour et al. 1999, USEPA 1997).

River Morphometry & Aquatic Vegetation

The size and shape of the river (river morphometry) and types of macrophytes (aquatic vegetation) can strongly influence the presence or absence of aquatic organisms (Wallace and Webster 1996). These components are presented through visual cross sections of the underwater habitat with plant community descriptions of diversity and abundance. Overall these attributes help in understanding the species distribution and ecology among the stations in the VR.

Macroinvertebrate Surveys

Macroinvertebrate surveys were completed to understand the intermediate trophic level of the ecosystem (Alberta Environment 2006). Macroinvertebrates are ideal candidates for biomonitoring because they can reveal past and present water quality issues, unlike the physical and chemical conditions that indicate a river condition only at the time of sampling (Anderson 1990).

Fish Surveys

Fish surveys were completed to understand the third trophic level of the aquatic ecosystem. Through their ability to move through ecosystems, the presence or absence of fish can act as good indicators of overall environmental health or stress (Karr and Chu 1999).

2.0 Background

The VR is located in the Parkland Natural Region of eastern central Alberta. The hydrology is typical of the central Canadian Prairies (Pomeroy et al. 2012) - it is a small river fed by local runoff, precipitation and the regional groundwater flow system. The hydrograph closely follows patterns in precipitation such that by August, most of the river ceases to flow and behaves similarly to a series of shallow open water wetlands or small lakes (Figure 1). The lower reach of the river is an exception, where flow typically occurs year-round because of the low topographical position of the site in relation to the regional groundwater flow system. Most of the watershed does not contribute to surface runoff under average runoff conditions (Figure 2) due to areas draining toward lakes and wetlands that do not drain externally (LaBaugh et al. 1998). The portions of the watershed that do contribute to runoff are closely related to riparian areas and wetlands that border the Vermilion River channel, highlighting the importance of these components to the system as a whole.

The VR has a gross drainage area of approximately 7,860 km^2 that is predominantly covered by agricultural land uses (e.g., annual/perennial croplands, pasture; Figure 3). Urban land uses are primarily associated with the populated centers of Vegreville, Vermilion, and Two Hills. Drainage works have primarily occurred in the upper reaches of the watershed (i.e., the Holden Drainage District) and instream channelization was completed in a 40 km stretch of river near Two Hills and the Vermilion Lakes chain (Figure 5).

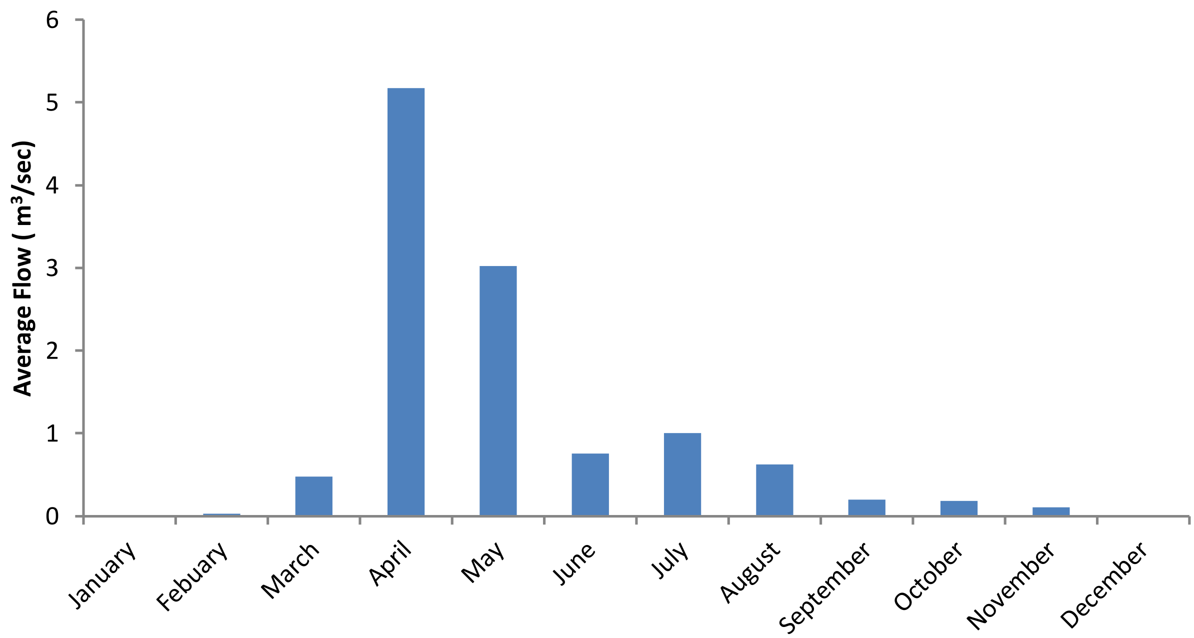


Figure 1: Average monthly flow (m^3/sec) on the Vermilion River from 1979-2012 at the Water Survey of Canada hydrometric station near Marwayne.

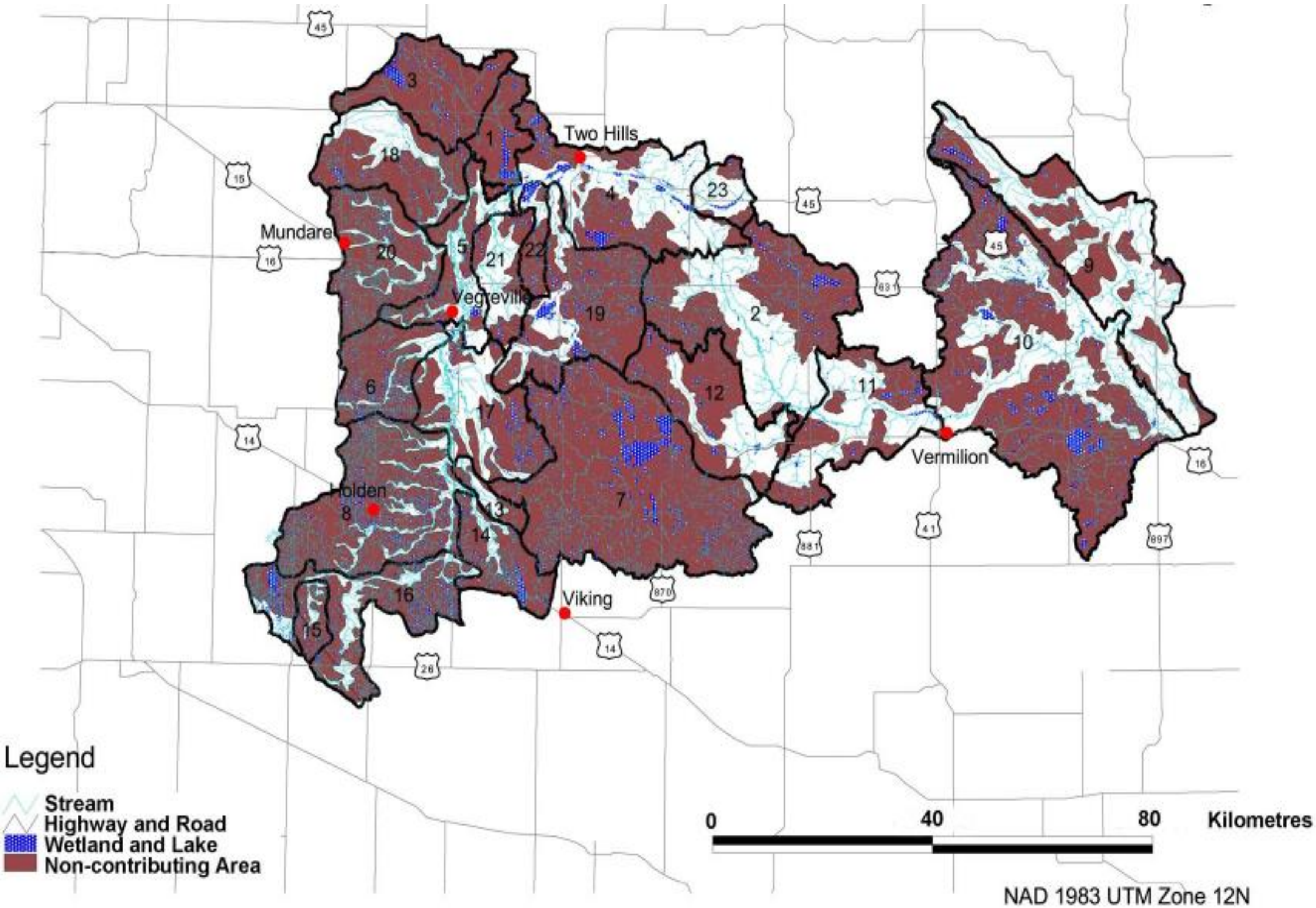


Figure 2: Vermilion River watershed non-contributing areas (Pomeroy et al. 2012).

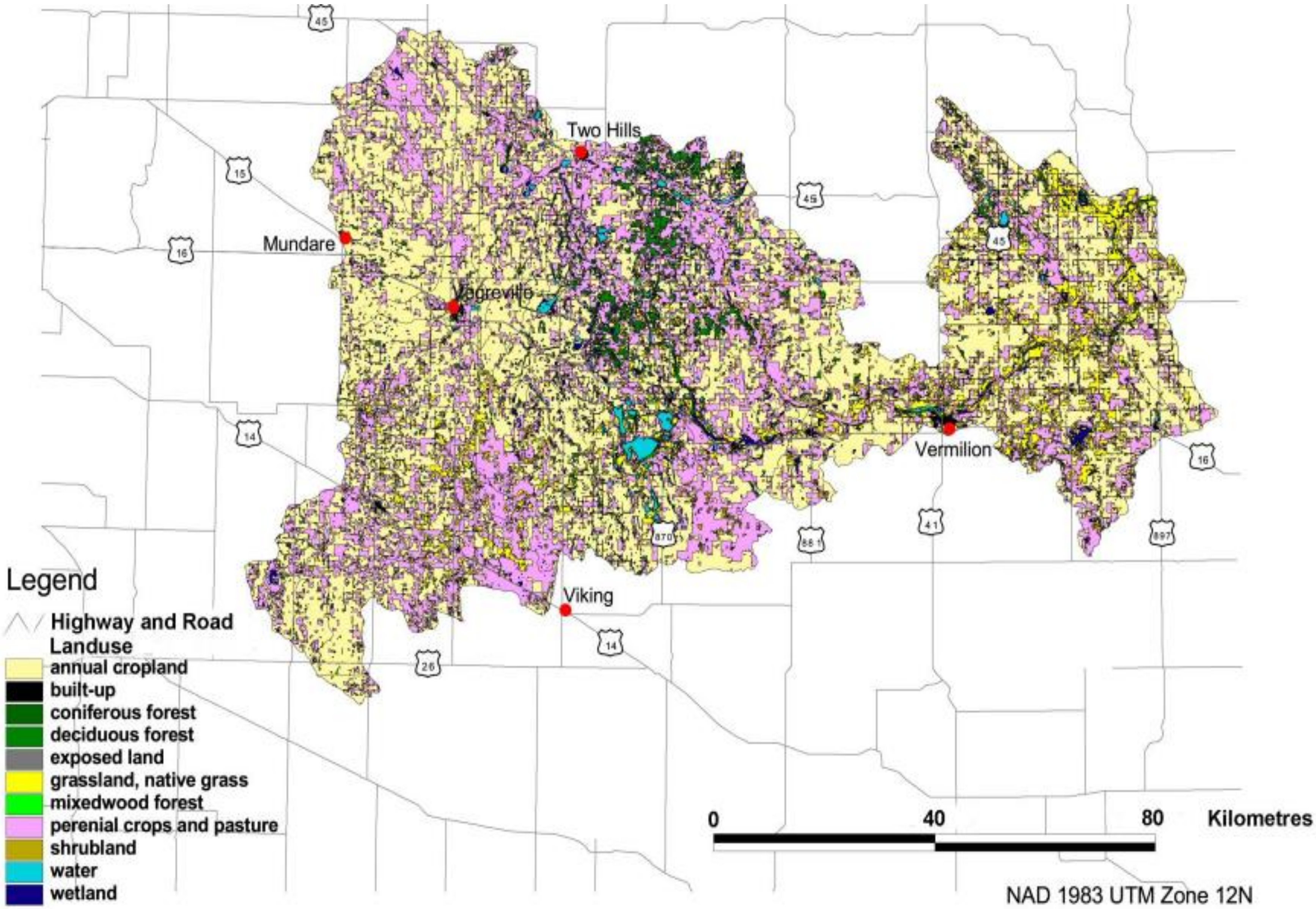


Figure 3: Vermilion River watershed land use (Pomeroy et al. 2012).

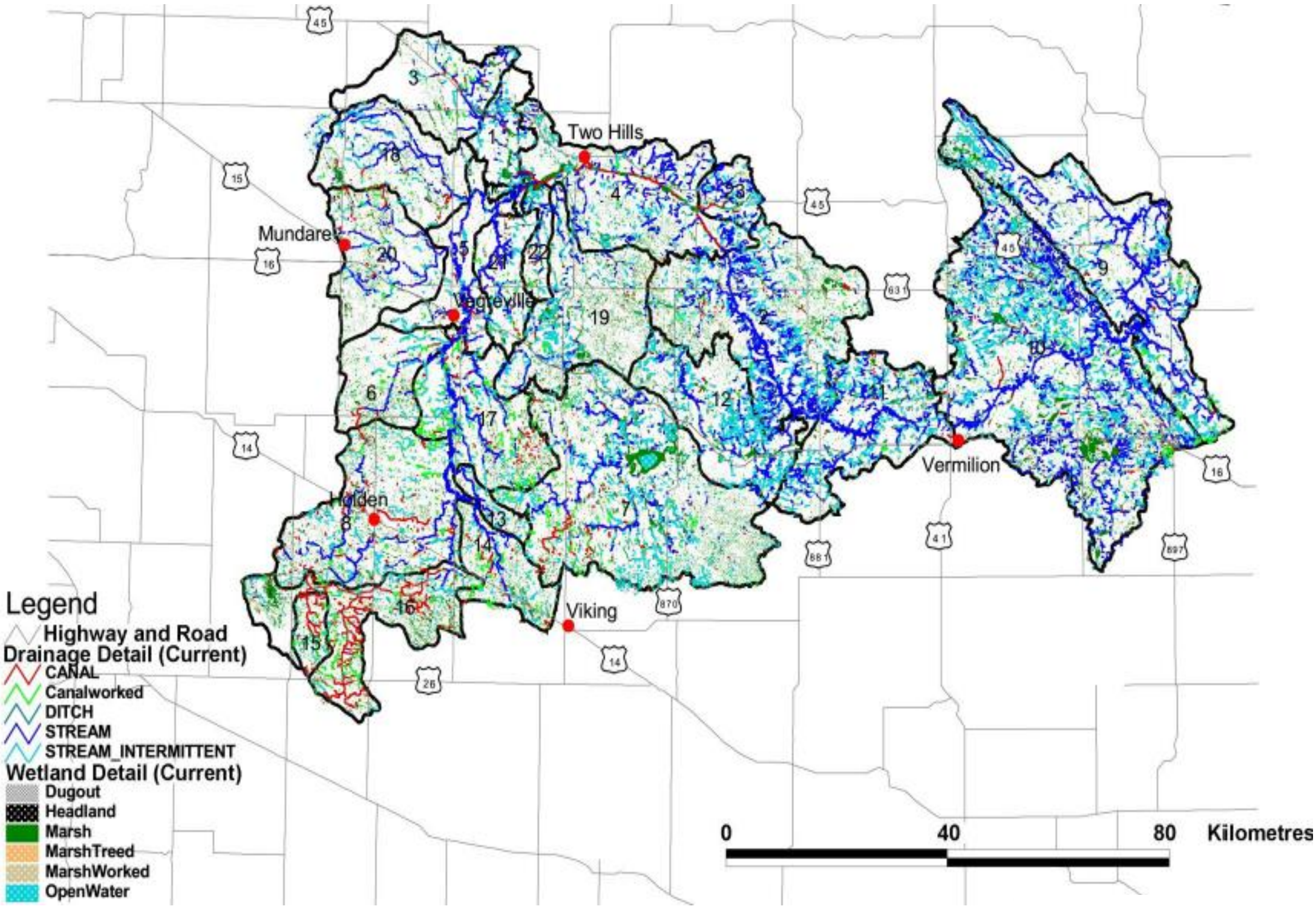


Figure 4: Vermilion River watershed drainage network (Pomeroy et al. 2012).

3.0 Sampling Stations

The VR was surveyed at seven stations distributed throughout the length of the river. These locations were pre-determined according to water quality sampling by NSWA in 2014, which coincided with Water Survey of Canada historical water level monitoring stations and river access points (Figure 5). The human footprint in the effective watershed areas of each station is similar from station to station, ranging from 79% to 86% (Table 1). Thus total land use in contributing areas was very similar from one station to the next.

At each station, 5 transects were established 50 meters apart to allow the characterization of habitat and vegetation along a 200m reach. Water quality, vegetation, fish, and macroinvertebrate surveys took place within each river reach. All stations were accessed at bridge crossings and transects were placed 100m upstream of crossings and any other barriers such as fords or beaver dams. Figures 6 to 12 show the individual stations and transects surveyed in 2015. The pictures associates with the figures were taken by CPP Environmental during the survey events. All figures are organized from the upstream station (BEA1) and follow consecutive order to the final downstream station (VER6).

Table 1: Human footprint in the effective watershed area of each sampling station. From ABMI Human Footprint Inventory, which includes the land uses associated with the energy, forestry, agriculture industries, as well as urban development.

Water Quality Station	% Human Footprint
BEA1	83.5
MIN2A	86.0
TWO2A	82.4
05EE10	79.6
VER1	79.1
VER3	79.2
VER6	80.4

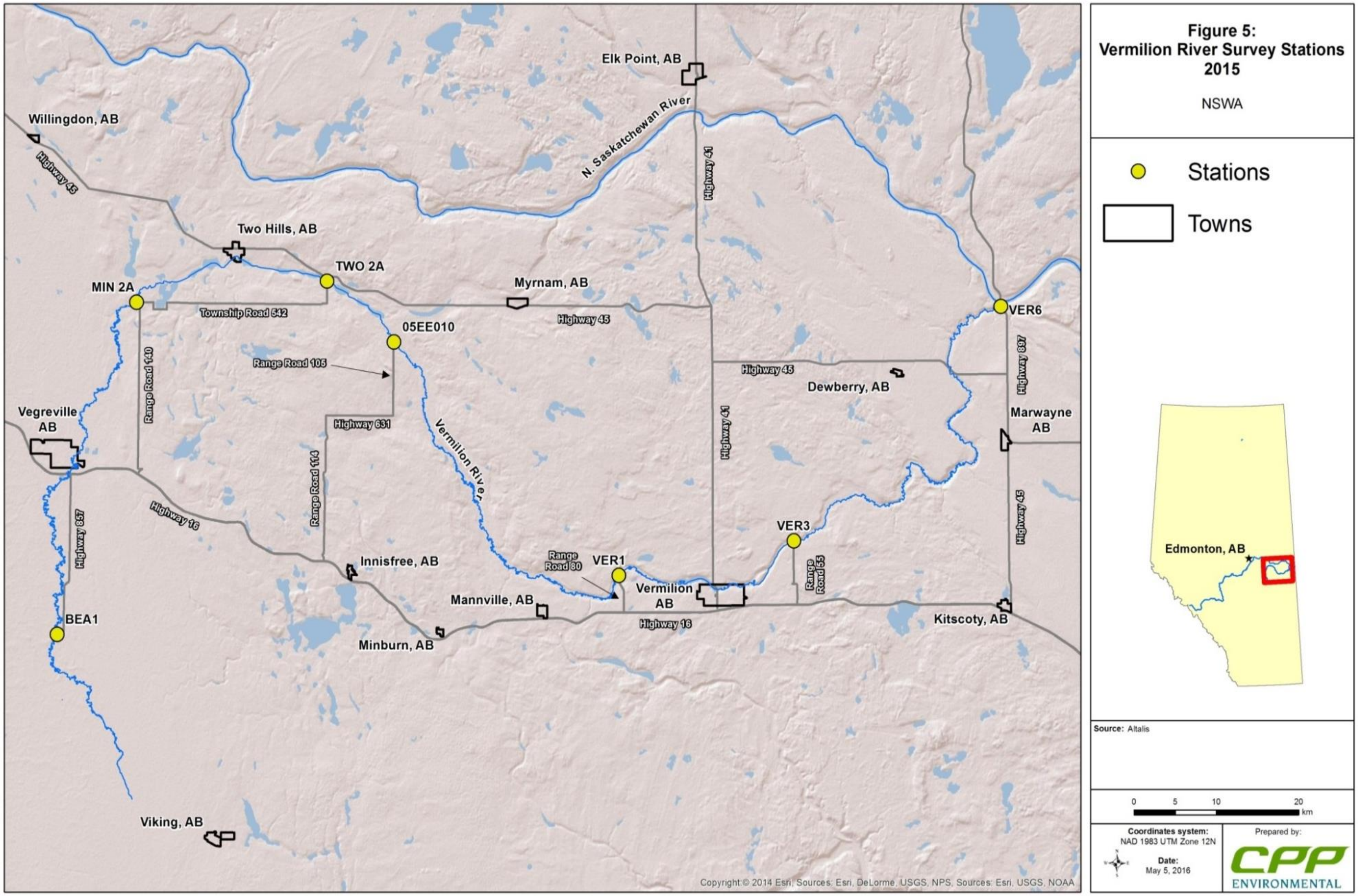


Figure 5:
Vermilion River Survey Stations
2015
NSWA
Stations
Towns
Elk Point, AB
N. Saskatchewan River
Willingdon, AB
Highway 45
Highway 41
Two Hills, AB
TWO 2A
MIN 2A
Myrnam, AB
Township Road 542
Highway 45
05EE010
VER6
Range Road 105
Range Road 140
Highway 45
Dewberry, AB
Highway 897
Vegreville AB
Highway 631
Vermilion River
Highway 41
Marwayne AB
Range Road 114
Highway 16
Highway 857
VER3
Highway 45
Innisfree, AB
Range Road 80
VER1
Vermilion AB
Range Road 55
Mannville, AB
Kitscoty, AB
BEA1
Highway 16
Minburn, AB
Edmonton, AB
Viking, AB
Source: Altalis
0 5 10 20 km
Coordinates system: NAD 1983 UTM Zone 12N
Date: May 5, 2016
Prepared by:
CPP ENVIRONMENTAL
Copyright:© 2014 Esri, Sources: Esri, DeLorme, USGS, NPS, Sources: Esri, USGS, NOAA

a) Location of transects

b) Transect 4 facing downstream

c) Transect 4 facing upstream

Figure 6: Station BEA1 transects (a) and site photos (b & c).

a) Location of transects

b) Transect 4 facing downstream

c) Transect 4 facing upstream

Figure 7: Station MIN2A transects (a) and site photos (b & c).

a) Location of transects

b) Transect 3 facing downstream

c) Transect 3 facing upstream

Figure 8: Station TWO2A transects (a) and site photos (b & c).

a) Location of transects.

b) Transect 5 facing downstream

c) Transect 5 facing upstream

Figure 9: Station 05EE0010 transects (a) and site photos (b & c).

a) Location of transects

b) Transect 3 facing downstream

c) Transect 3 facing upstream

Figure 10: Station VER1 transects (a) and site photos (b & c).

a) Location of transects.

b) Transect 2 facing downstream

c) Transect 2 facing upstream

Figure 11: Station VER3 transects (a) and site photos (b & c).

a) Location of transects.

b) Transect 1 facing downstream

c) Transect 1 facing upstream

Figure 12: Station VER6 transects (a) and site photos (b & c).

4.0 Aquatic Habitat

CPPENV surveyed physical habitat characteristics and collected water quality data to determine the overall habitat quality of each station. These metrics are useful since they provide a link between the physical environment and its inhabitants (USEPA 1997). The goal of the habitat assessment was to collect qualitative metrics that support aquatic life and categorize them to create quantitative measures that represent each station as a habitat value.

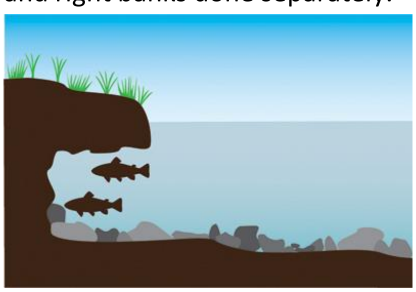
4.1 Methods

The habitat assessment occurred during low flows, from August 31st to September 15th, 2015. Metrics and procedures followed the Alberta Biodiversity Monitoring Institute's Alberta-based stream field protocols (ABMI 2007) and the United States Environmental Protection Agency's procedures for low gradient streams (Barbour et al. 1999).

4.1.1 Habitat Survey

Habitat metrics were measured at all five transects, representing a 200m reach for each sampling station. Metrics included percent of bank undercutting, macrophyte coverage, substrate composition, shading and habitat diversity. These physical features support habitat diversity and provide shelter for aquatic life, as follows:

- Bank undercutting: an estimation of undercut banks (%) for 10m upstream of the transect; left and right banks done separately.



View of an undercut bank (left), which provides shelter for aquatic life (Google Images).

- Macrophyte coverage: the percent cover of aquatic vegetation within the transect; quantity of rooted aquatic plants or free floating. Aquatic vegetation provides shelter for aquatic life and some organisms are specialized for these types of environments.
- Substrate composition: percent cover of substrate materials (boulder, cobble, gravel, sand and organic matter). During the field surveys all substrate materials were categorized; however, for the purposes of the habitat assessment scores, organic matter is the only metric analyzed for substrate cover. In the VR, organic matter dominated at the majority of stations and its presence affects the diversity of aquatic organisms since areas with dominant organic matter are related to areas of dense aquatic vegetation.
- Shading: percent coverage of the water surface that is shaded. Shade is an important factor when considering aquatic habitat since it can help regulate stream temperatures.

- Habitat Diversity of stream channel morphometry: total percent of straight run, riffles and pools and the amount of snags and logs. Each of these habitat types provide feeding, resting or spawning areas for aquatic life and the more diversity the better for aquatic life functions. Each area was scored based on the quantity of habitat types:
    - Excellent = 4 habitat types
    - Good = 3 habitat types
    - Fair = 2 habitat type
    - Poor = 1 habitat type

4.1.2 Water Quality Sampling

Water quality samples were taken at each station from September 10th to 15th, 2015. Water sampling consisted of two methods; 1) a water probe (YSI Multi-Probe) measurement and; 2) a water sample sent to a lab. The following chemical metrics are included in habitat assessment scoring due to their effect on aquatic life:

- Oxygen: Aquatic biota requires a minimum amount of dissolved oxygen (DO) for survival. DO is controlled by physical and biological processes that affect its solubility (i.e. temperature, wind mixing, bacterial activity, photosynthesis). The saturation concentration of DO is quickly achieved at the air-water interface and in rivers like the VR that are shallow it is relatively consistent throughout the water column. Alberta guidelines suggest a minimum of 5.0 mg/L for short-term exposure (1 day) and 6.5 mg/L for long-term exposure (AESRD 2014).
- Nutrients: Nitrogen and phosphorus provide an indication of the fertility of the ecosystem. High nutrients indicate eutrophication (increased plant/algae growth), which can have a negative impact on biodiversity and desirable fish species (CCME 2004).

4.1.3 Data Analysis

Total habitat health scores for physical and chemical metrics were computed by ranking each metric into numerical categories (USEPA 1997). All physical habitat metrics were scored based on USEPA protocols and chemical metrics were scored based on 25th percentiles (Appendix A).

<u>Physical habitat</u> metrics were scored as follows:

Step 1: At each transect, we assigned a score number from 1 (Poor) to 4 (Excellent) for each metric (Table 2). For example, station BEA1 had 0-5% shade cover at transect 1 and therefore would score a 1.

Table 2: The habitat assessment categories for scoring metrics at each station (USEPA 1997).

Physical Metrics	Excellent (Score=4)	Good (Score=3)	Fair (Score=2)	Poor (Score=1)
Shade (%)	51+	26- 50	6- 25	0-5
Macrophyte (%)	76-100	51-75	26 - 50	0- 25
Undercut Banks (%)	76-100	51- 75	25- 50	0- 25
Organic Substrate (%)	0– 25	25-50	51– 75	76-100
Habitat Diversity	Excellent	Good	Fair	Poor

Step 2: The values of all individual transects were totaled to obtain a "total score" for each station. Values ranged from 5 (5 transects with a score of 1) to 20 (5 transects with a score of 4) for the majority of physical metrics. Bank undercutting ranged from 10 to 40 since measurements were completed on both river banks. Total scoring for all physical metrics and the original habitat assessment data is available in Appendix A: Table A-1.

Step 3: The total tally of all 5 transects were separated into 4 categories for final score, as per Table 3.

Chemical habitat metrics were scored as follows:

Step 4: The water quality data was separated into 4 categories using 25th percentiles from the combined 2014 and 2015 water quality dataset (Appendix A: Table A-2), as follows:

- "1" represents chemistry values (see Table 3 for values) between 0 and the 25th percentile;
- "2" represents chemistry values greater than the 25th percentile and up to the 50th percentile;
- "3" represents chemistry values greater than the 50th percentile and up to the 75th percentile;
- "4" represents chemistry values greater than the 75th percentile and up to the 100th percentile.

A total habitat health score was created as follows:

Step 5: Each physical habitat and chemical metric was assigned a value from 1 to 4, using Table 3.

Step 6: Values were totaled by sampling station to obtain a total habitat health score.

Table 3: Physical and chemical metrics and the final scoring categories.

	Excellent=4	Good=3	Fair=2	Poor=1
Physical Habitat Metrics				
Shade Cover	15-20	10-15	5-10	1-5
Macrophyte Cover	11-14	6-10	1-5	15-20
Bank Undercutting	34-40	26-33	18-25	10-17
Organic Substrate	17-20	13-16	9-12	5-8
Habitat Diversity	17-20	13-16	9-12	5-8
Chemistry Metrics				
Total Phosphorus (mg/L)	0 – 0.16	0.17 – 0.39	0.40 – 0.45	0.46 – 0.56
Total Nitrogen (mg/L)	0 – 1.7	1.8 – 2.4	2.5 – 2.8	2.9 - 4.8
Dissolved Oxygen (mg/L)	8.99 -9.69	8.01 – 8.98	7.16 – 8.00	0 – 7.15

Habitat diversity at station VER6 (left) showing 'excellent' diversity including riffles, runs and pools with snags and logs, and station VER3 (right) showing 'poor' diversity including a straight run and overabundance of aquatic vegetation (CPPENV 2015).

4.4 Results

4.4.1 Habitat Quality

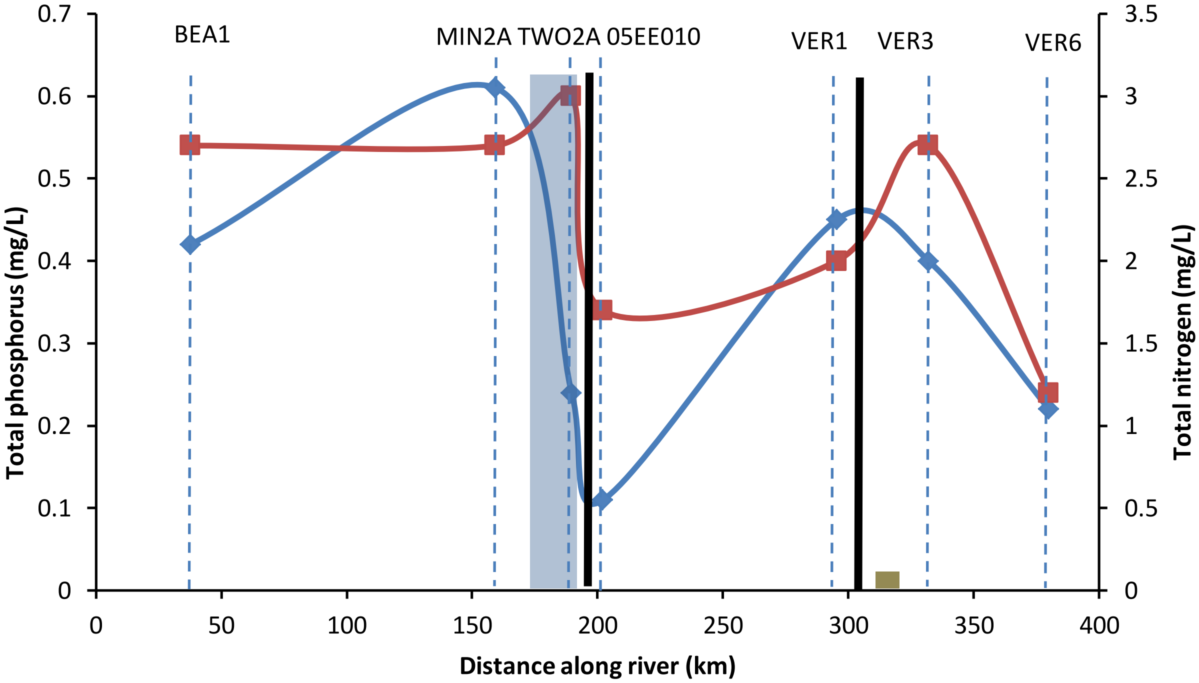
Habitat health scores are presented in Table 4. Station VER6 had the highest overall station health score relative to the other stations, largely a result of high habitat diversity and water quality. Station 05EE010 had the second-highest overall health score and good water quality, especially in comparison to station TWO2A, which is 12km upstream. The Vermilion Lakes chain is also located between stations TWO2A and 05EE010 and is likely retaining some of the nutrients, improving water quality at station 05EE010. Station VER1 had the third best score due to relatively good scores for the majority of categories, however it had low diversity in substrate (predominantly organic), and low water quality (high total phosphorus and low dissolved oxygen). MIN2A scored amongst the highest in habitat diversity and contains a high percentage of undercut banks, which provides shelter for aquatic organisms. TWO2A and BEA1 were among the lowest overall health scores. BEA1 had fair habitat diversity and offered diverse substrate types but water quality was poor and there was little to no macrophyte coverage. TWO2A had an overabundance of macrophyte cover and was not diverse in habitat characteristics. VER3 had the lowest health score, with the lowest oxygen levels and an overabundance of aquatic vegetation.

Table 4: Final metric scores for the habitat assessment; the total score represents the station health.

Metric	BEA1	MIN2A	TWO2A	05EE010	VER1	VER3	VER6
Shade	2	3	1	2	3	1	3
Macrophyte Cover	2	3	1	4	3	1	3
Bank Undercutting	2	3	1	1	3	1	1
Organic Substrate	3	1	1	3	3	1	4
Habitat Diversity	2	3	1	2	3	1	4
Total Phosphorus	1	1	3	4	2	2	4
Total Nitrogen	1	3	1	4	3	2	4
Dissolved Oxygen	3	2	3	4	1	1	4
Overall Station Health Score	**16**	**19**	**12**	**24**	**21**	**10**	**27**

4.4.2 Water Quality

Over the past 100 years, extensive changes to the natural landscape, such as riparian zone alterations and river channelization, have influenced water quality and habitat of the VR. Point sources in the VR include municipal wastewater lagoons and a mechanical waste water treatment plant at the Town of Vermilion. Non-point sources involve the overland runoff from agricultural field crops and rangeland, urban and rural centers and roads. Figure 13 shows the water quality of the VR stations from upstream to downstream. This data represents total phosphorus and total nitrogen averages from the 2014 and 2015 water quality sampling events.



Legend

Total phosphorus

Total Nitrogen

Station Location

Dam Location (Morecambe & Vermilion)

Vermilion Lakes Chain

Town of Vermilion Waste Water Treatment Plant

Figure 13: Water quality (2014-2015 averages) at the VR stations; upstream to downstream.

Overall, total phosphorus and nitrogen concentrations improve from the headwaters at station BEA1, to the confluence at station VER6. Water quality is substantially improved after the Vermilion Lakes and Morecambe Dam complex, likely due to nutrient settling and retention (Rice et al. 2012, Omelia 1998). The Town of Vermilion dam and lake reservoir does not appear to have the same effect. The reservoir can act as a settling basin (Omelia 1998); however the continuous nutrient input from the Town of Vermilion waste water treatment plant upstream of station VER3 would mask any nutrient reductions caused by the impoundment. Other than the headwater stations, VER3 has the poorest water quality in the VR.

4.4.3 Other Metrics

The habitat survey involved the characterization of other physical and chemical features that were not included in the metric scoring but are essential components of aquatic health, including:

- Bank stability: assessment of eroded banks through the amount of exposed soil that shows recent scouring, disturbance or failure. Recorded as stable (>90% vegetated banks), moderate (50-90%), low (25-50%), or unstable (<25). Results of bank erosion at each station are included in Appendix A: Table A-3.
- Streamside vegetation: the percent cover of grasses, shrubs and trees. Streamside vegetation mostly comprised of grass or shrubs at all VR stations. Results of the streamside vegetation assessment are included in Appendix A: A-4.
- Bottom type: determination of the type of bottom as: hard (sand or gravel), soft (easy to walk), very soft (hard to walk), not wadeable (deep). Results of bottom types are included in Appendix A: A-4.
- Substrate embeddedness: assessment of a 10m section of stream centered on each transect, estimation of the embeddedness as one of 4 categories, based on the extent to which the predominant substrate material is embedded in fines or sands. Due to the dominance of organic material at the majority of stations, this measurement was only applicable at stations BEA1, 05EE010 and VER6. Results are presented in Appendix A: A-4.
- Periphyton coverage on substrate: The degrees to which rocks are covered in algae was only applicable at stations with rocks, see Appendix A: A-4.
- Other water quality measurements included pH, temperature, conductivity and other results from the laboratory analysis. A summary of these and all other water quality results are available in Appendix A: Table A-4.

5.0 River Morphometry & Aquatic Vegetation

River morphometry and aquatic vegetation provide the physical structure that aquatic fauna depend on for life processes (Barbour et al. 1999). Vegetation is affected by channel slope, flow and ecosystem productivity. In this section we describe the physical environment and aquatic plant community at each station on the VR.

5.1 Methods

5.1.1 Fieldwork

River morphometry and aquatic vegetation surveys were completed from August 31st to September 3rd and September 8th to 10th 2015. Transects were surveyed by using a rope stretched across the width of the river. The rope contained markings to delineate 1m x 1m quadrats and every quadrat was assessed for plant identification, percent coverage of each plant species, water depth, and dominant and secondary substrate types. A rake was used to collect submerged vegetation not visible at the surface and based on the volume collected an estimation of percent cover was applied. The data collected during the vegetation survey is available in Appendix B.

Field crew identifying vegetation at station VER6. This station was wadeable; at stations that were not, we used a boat for access.

5.1.2 Data Analysis

Visual cross sections of station transects were created using Excel spreadsheets. The cross sections are designed to represent total percent coverage of the various vegetation types identified in the river and are a true representation of the wetted width and depth. Depth is recorded as a negative value for the purposes of visual display.

To summarize the overall physical structures of the entire river reach, river morphometry data was processed by averaging data from all 5 transects at each station. Species diversity for aquatic vegetation was calculated by measuring species richness and applying a modified Shannon-Wiener Index. This modified approach to the Shannon-Wiener Index is an approximation for diversity meant to represent patterns in diversity and it does not represent true diversity values.

The plant community was analyzed as follows:

- The Shannon-Wiener Index is an equation that shows the community composition and abundance of aquatic species present within a stream reach. The Shannon index is commonly used in ecological studies and is calculated using the following formula:

$$\text{Shannon-wiener index (H)} = -\sum Pi \log_n Pi$$

- Where *Pi* is the proportion of individuals found of species i. The estimated proportion of *Pi* = ni/N, where ni is the number of individuals in species i, and N is the total number of individuals in the community. Since by definition the P*i* will all be between zero and one, the natural log makes all of the terms of the summation negative, which is why the inverse of the sum is used. The Shannon-Wiener index increases as both the richness and the evenness of the community increase. The Shannon-Wiener index is typically calculated using individual plant species counts; however this information was not collected during the vegetation survey. Instead the total percent cover was estimated for each individual species within a quadrant. As means of estimating diversity, for the purpose of comparing the stations, total percent coverage was ranked in one of the four classes, as follows:

Total Percent Cover	Cover Class Rank
1-25	1
25-50	2
50-75	3
75-100	4

- Species evenness is calculated by dividing the result of the Shannon-Wiener index by the species richness to show the distribution of species abundance. Ultimately, it quantifies how equal the community is numerically (e.g. if there are 40 coontail and 1000 common duckweed plants, then the community is not even). The results will always be between 0 to 1, with 0 signifying no evenness and 1 as complete evenness.
- Species richness is the number of plant species at each station.
- Species abundance was calculated by dividing the total sum of all cover class ranks per station by the total sum of all cover class ranks in the VR.

5.2 Results

5.2.1 Overall Results

River morphometry and aquatic vegetation varied in diversity and abundance at each site. Stream channel width is largest at station TWO2A (50.9m), due to channelization, and smallest in the headwaters at station BEA1 (8.2m) (Table 5). Overall the physical conditions of the VR are ideal for aquatic vegetation growth due to relatively shallow water depths and finer material in the substrate. Shallow water depths allow for sufficient light penetration, and the finer, nutrient-rich substrate allows roots to take anchorage and the stimulation of plant growth (Lahring 2003). The following parameters were measured during the river morphometry surveys:

- Bankfull width is the horizontal width of the channel from right bank to left bank; the bank ends at the point where over-bank flow begins during a flooding event.
- Wetted width is the horizontal width of the channel containing water.
- Bankfull wetted depth is a vertical measurement from the surface of the water to the top of the stream bank; it represents the potential wetted depth if the stream channel was filled to its greatest depth.
- Water depth was recorded during the vegetation surveys in each 1m x 1m quadrant; for the purpose of this table only the maximum & minimum depths are represented.

Table 5: River morphometry at VR stations.

Station Name	Average			Max Depth (cm)	Min Depth (cm)
	Bankfull Width (m)	Wetted Width (m)	Bankfull Wetted Depth (cm)		
BEA1	8.2	6.4	73.6	92	6
Min2A	11.9	10.7	172	232	30
Two2A	50.9	42.32	57	100	15
05EE010	19.6	14.9	146	106	5
Ver1	14.8	11.5	178	176	12
Ver3	26.8	17.6	110	69	5
Ver6	17.2	13.1	198	95	6

The aquatic vegetation surveys documented a total of 28 native species. Dominant species include Northern water milfoil (*Myriophyllum exalbescens*), Common duckweed (*Lemna turionifera*), Sago pondweed (*Stuckenia pectinata*) and Richardson's pondweed (*Pontamogeton richardsonii)* (Table 6). The station with the highest plant species diversity was VER1, and the least diverse is station BEA1.

View of station VER1, which had the highest plant diversity.

Table 6: Aquatic vegetation results including species richness, evenness, abundance, diversity, and top three dominant plant species at each station.

Station	Species Richness	Species Evenness	Species Abundance	Community Diversity	3 Most Dominant Species
BEA1	5	0.92	0.01	1.48	Northern water milfoil, Common duckweed, Richardson's pondweed
MIN2A	7	0.90	0.05	1.75	Common Duckweed, Sago Pondweed, Northern water milfoil
TWO2A	8	0.86	0.41	1.78	Northern water milfoil, Richardson's Pondweed, Coontail
05EE010	12	0.67	0.14	1.66	Richardson's pondweed, Sago pondweed, Northern water milfoil
VER1	16	0.80	0.07	2.23	Giant Bur reed, Common duckweed, Richardson's pondweed
VER3	9	0.73	0.25	1.61	Sago pondweed, Common duckweed, Richardson's pondweed
VER6	19	0.75	0.07	2.17	Northern water milfoil, Sago pondweed, Stolen grass

5.2.2 Visual Cross Sections of Stations

Visual cross sections were created to represent the vegetation surveys and river morphometry. Cross sections represent one transect out of the five measured and are true to the surveyed information (plant species and density, water depth and wetted width).

Station BEA1 had the least amount of aquatic vegetation, likely due to the low clarity of water (total suspended solids was 68 mg/L). The turbid conditions created light limitation for plant growth, which is reflected in the stations lowest species richness and abundance. Steep slopes on the right bank prevented proper establishment of plants and growth is thus limited to the opposing side. Transect 4 of station BEA1 is good representation of the station's vegetation and river morphometry (Figure 14). The substrate is varied and contains boulders, cobble, gravels and organics.

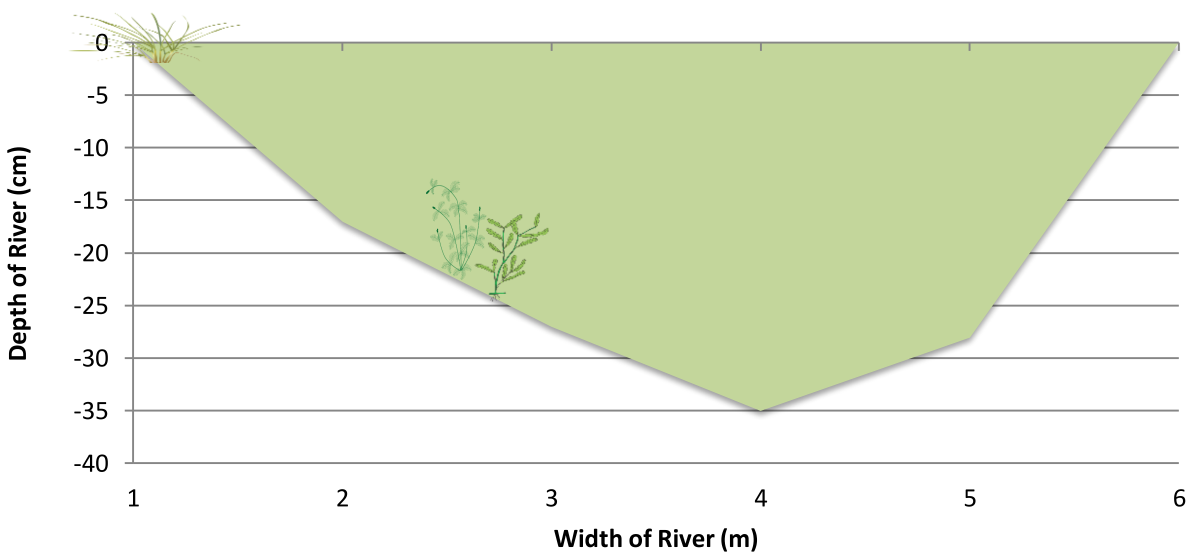


Figure 14: Cross-section of station BEA1, transect 4.

Table 7: Vegetation survey data collected at transect 4 (station BEA1) on August 31, 2015.

Quadrat	Water Depth (cm)	Dominant Substrate	Second Substrate	Plant Species	Percent Cover
0-1	6	organic	cobble	Water sedge	1-25
1-2	25	organic	gravel	no veg	-
2-3	23	cobble	organic	Northern water milfoil	1-25
				Richardson's pondweed	1-25
3-4	27	cobble/gravel	none	no veg	-
4-5	35	gravel	organic	no veg	-
5-6	29	gravel	organic	no veg	-

Station MIN2A had the second lowest abundance of aquatic plants with the main distribution occurring on the right streamside (Figure 15). The opposing side was steep and in many areas piles of woody debris were present, which looked to be old beaver lodges. This station had the deepest wetted depth with a maximum depth of 232cm. The substrate was comprised of finer and organic materials (Table 8).

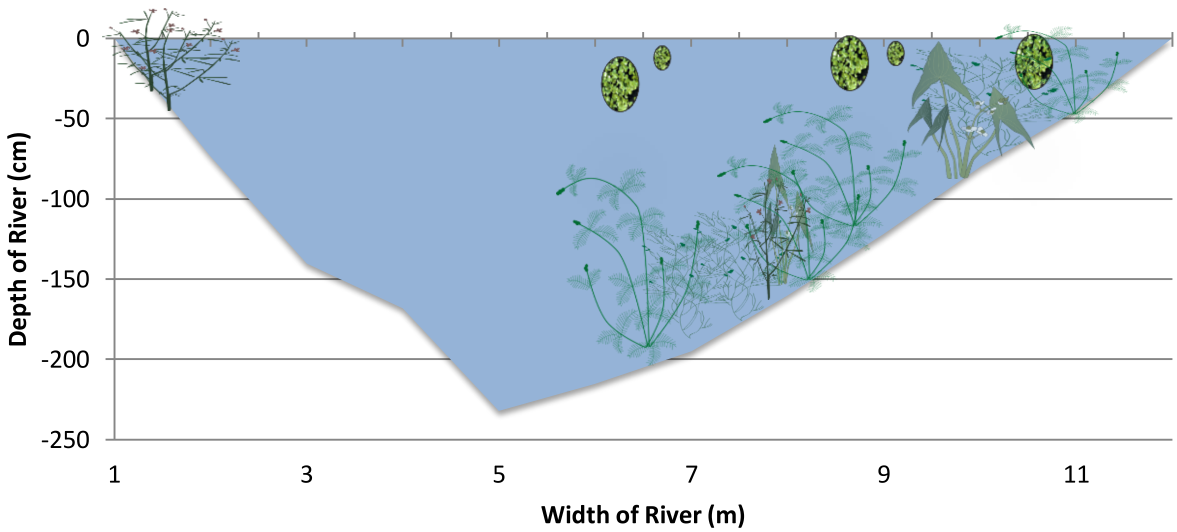


Figure 15: Cross-section of station MIN2A, transect 4.

Table 8: Vegetation survey data collected at transect 4 (station MIN2A) on September 1, 2015.

Quadrat	Water Depth (cm)	Dominant Substrate	Second Substrate	Plant Species	Percent Cover
0-1	73	organic	-	Slender pondweed	25-50
1-2	140	organic	-	no veg	-
2-3	168	organic	-	no veg	-
3-4	169	organic	-	no veg	-
4-5	230	unknown	-	no veg	-
5-6	232	unknown	-	no veg	-
6-7	215	unknown	-	no veg	-
7-8	195	unknown	-	no veg	-
8-9	141	organic	-	Northern water milfoil	25-50
				Common Duckweed	25-50
				Sago pondweed	25-50
9-10	122	organic	-	Arum-leaved arrowhead	1-25
				Common Duckweed	25-50
				Northern water milfoil	25-50
				Slender pondweed	50-75
10-11	80	organic	-	Common Duckweed	1-25
				Northern water milfoil	25-50
				Arum-leaved arrowhead	1-25
11-12	45	organic	-	Sago pondweed	50-75
				Common Duckweed	25-50
				Arum-leaved arrowhead	1-25

Station TWO2A had the shallowest wetted depth and widest bankfull width extending over 40m (Figure 16). The reach was also nutrient rich, which provided ideal growing conditions for aquatic vegetation. In fact, the station had the highest abundance of aquatic vegetation but a low diversity when compared to the other stations. Substrate was comprised entirely of organic matter and the shorelines were dominated by Common cattails (*Typha latifolia*), which are typically found in wetlands with fluctuating water levels (Table 9).

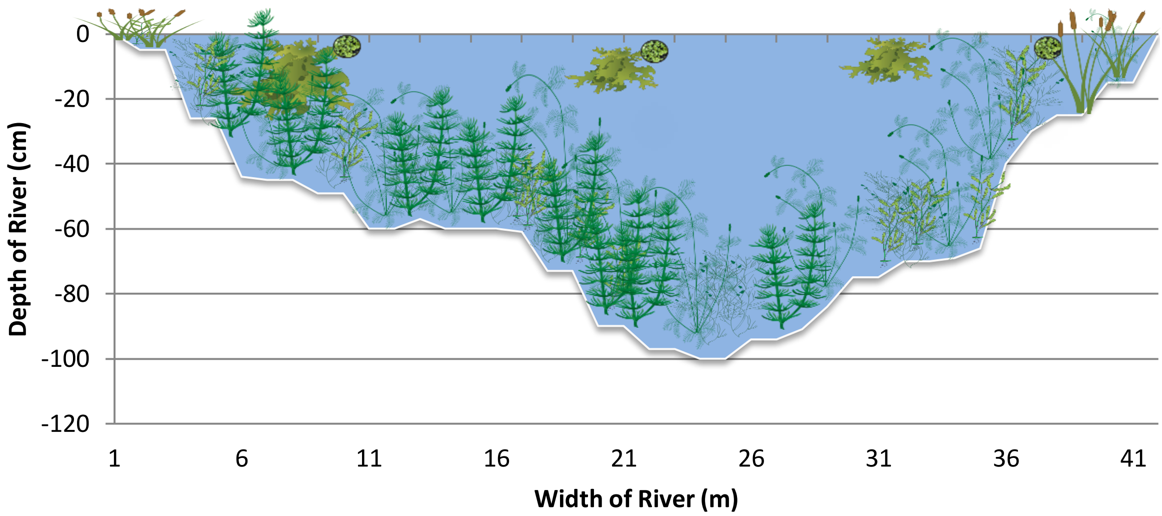


Figure 16: Cross-section of station TWO2A, transect 1.

Table 9: Vegetation survey data collected at transect 1 (station TWO2A) on September 10, 2015.

Quadrat	Water Depth (cm)	Dominant Substrate	Plant Species	Percent Cover
0-1	0	organic	Common Cattail	25-50
1-2	5	organic	Sago Pondweed	25-50
			Northern water milfoil	25-50
			Coontail	1-25
			Ivy-leaved duckweed	1-25
			Common duckweed	1-25
3-4	26	organic	Sago Pondweed	1-25
			Ivy-leaved duckweed	1-25
			Common duckweed	1-25
5-6	44	organic	Ivy-leaved duckweed	25-50
			Coontail	1-25
			Northern water milfoil	1-25
			Common duckweed	1-25
7-8	45	OM	Ivy-leaved duckweed	1-25
			Slender pondweed	1-25
			Coontail	1-25
			Richardson's Pondweed	1-25
			Northern water milfoil	1-25
			Common duckweed	1-25
9-10	49	OM	Northern water milfoil	25-50
			Sago Pondweed	1-25
			Ivy-leaved duckweed	1-25
			Common duckweed	1-25
11-12	60	OM	Ivy-leaved duckweed	1-25
			Coontail	1-25
			Northern water milfoil	1-25
			Sago Pondweed	1-25

*OM =organic matter

Table 9: Continued

Quadrat	Water Depth (cm)	Dominant Substrate	Plant Species	Percent Cover
13-14	57	OM	Sago Pondweed	25-50
			Northern water milfoil	1-25
			Ivy-leaved duckweed	1-25
			Slender pondweed	1-25
			Coontail	1-25
			Common duckweed	1-25
15-16	60	OM	Northern water milfoil	50-75
			Sago Pondweed	1-25
			Ivy-leaved duckweed	1-25
			Common duckweed	1-25
17-18	61	OM	Sago Pondweed	25-50
			Northern water milfoil	50-75
			Ivy-leaved duckweed	1-25
19-20	61	OM	Sago Pondweed	25-50
			Richardson's Pondweed	1-25
			Northern water milfoil	25-50
			Filamentous algae	1-25
			Ivy-leaved duckweed	1-25
			Coontail	1-25
			Slender pondweed	1-25
21-22	73	OM	Northern water milfoil	1-25
			Sago Pondweed	1-25
			Ivy-leaved duckweed	1-25
			Slender pondweed	1-25
23-24	73	OM	Northern water milfoil	1-25
			Ivy-leaved duckweed	1-25
25-26	90	OM	Northern water milfoil	1-25
			Sago Pondweed	1-25
			Coontail	1-25
			Ivy-leaved duckweed	1-25
			Slender pondweed	1-25
27-28	97	OM	Northern water milfoil	1-25
			Slender pondweed	1-25
			Coontail	1-25
			Ivy-leaved duckweed	1-25
			Coontail	1-25
			Common duckweed	1-25
29-30	100	OM	Northern water milfoil	1-25
			Ivy-leaved duckweed	25-50
			Coontail	1-25
			Common duckweed	1-25
31-32	94	OM	Sago Pondweed	1-25
			Ivy-leaved duckweed	1-25
			Coontail	1-25
			Northern water milfoil	1-25
33-34	91	OM	Northern water milfoil	1-25
			Sago Pondweed	1-25
			Slender pondweed	1-25
			Coontail	1-25
			Ivy-leaved duckweed	1-25
35-36	84	OM	Coontail	1-25
			Ivy-leaved duckweed	1-25
			Richardson's Pondweed	1-25
37-38	75	OM	Northern water milfoil	25-50
			Richardson's Pondweed	1-25
			Ivy-leaved duckweed	1-25
39-40	70	OM	Northern water milfoil	50-75
			Richardson's Pondweed	1-25
			Slender pondweed	1-25
			Ivy-leaved duckweed	1-25
			Coontail	1-25
41-42	25	OM	Northern water milfoil	50-75
			Common duckweed	1-25
			Slender pondweed	1-25
			Richardson's Pondweed	1-25
42-43	15	OM	Common Cattail	25-50
			Slender pondweed	1-25
			Northern water milfoil	25-50
			Richardson's Pondweed	1-25
			Common duckweed	1-25
			Ivy-leaved duckweed	1-25

*OM= organic matter

Station 05EE010 ranked 3rd in species abundance and diversity was considered average in comparison to the other stations. Species abundance was evenly distributed on both sides of the channel; however, the evenness measure is the lowest at 0.67, indicating uneven distribution of plant species. Dominant species include Richardson's and Sago pondweed (Figure 17). The substrate was diverse comprising of cobbles, sands, gravels and organic materials.

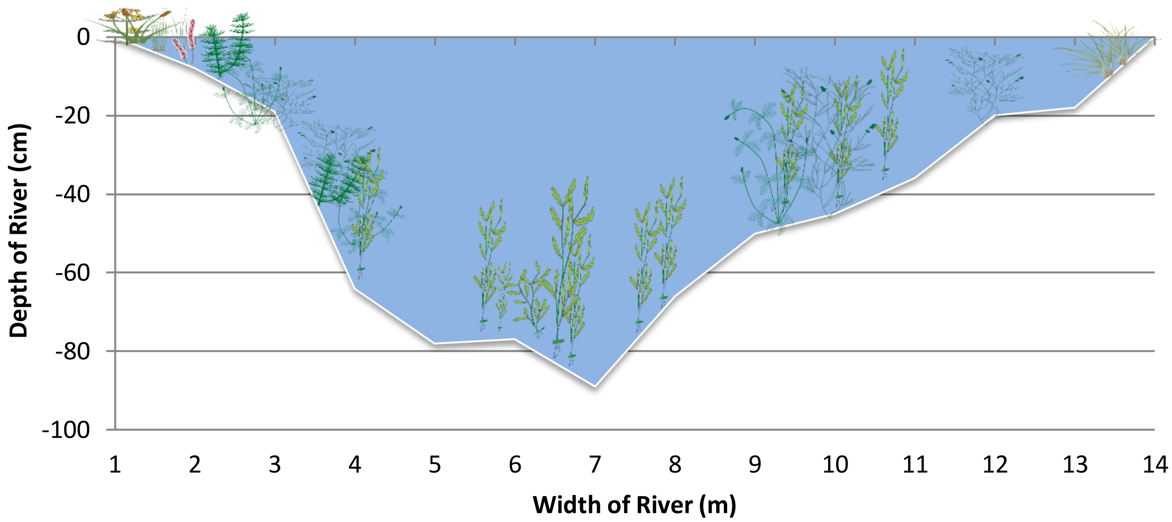


Figure 17: Cross-section of station 05EE010, transect 1.

Table 10: Vegetation survey data collected at transect 1 (station 05EE010) on September 3, 2015.

Quadrat	Water Depth (cm)	Dominant Substrate	Second Substrate	Plant Species	Percent Cover
0-1	8	organic	-	Nodding beggar ticks	1-25
				Common Cattail	1-25
				Creeping spike rush	25-50
				Coontail	25-50
				Northern water milfoil	1-25
				Richardson's pondweed	1-25
				Water smartweed	1-25
1-2	19	organic	-	Sago pondweed	50-75
				Richardson's pondweed	1-25
				Northern water milfoil	25-50
3-4	64	sand/gravel	-	Richardson's pondweed	25-50
				Northern water milfoil	1-25
				Coontail	1-25
5-6	78	gravel/sand		Richardson's pondweed	25-50
7-8	77	gravel/sand	-	Richardson's pondweed	1-25
9-10	89	cobble	sand/gravel	Richardson's pondweed	1-25
				Northern water milfoil	1-25
11-12	66	cobble	gravel/sand	Richardson's pondweed	1-25
12-13	36	cobble	gravel/sand	Northern water milfoil	1-25
				Richardson's pondweed	1-25
13-14	18	organic	sand/gravel	Grasses	1-25

Station VER1 ranked highest in species diversity. Due to the steepness of the left bank, vegetation growth occurred mostly on the opposing side (Figure 18). Giant bur-reed dominated the shorelines and in some areas, extended into the center of the channel. The station river morphometry is unique due to oxbows located on both sides of the river. There is also a relatively healthy riparian area located on the south side of the river, which shades the river.

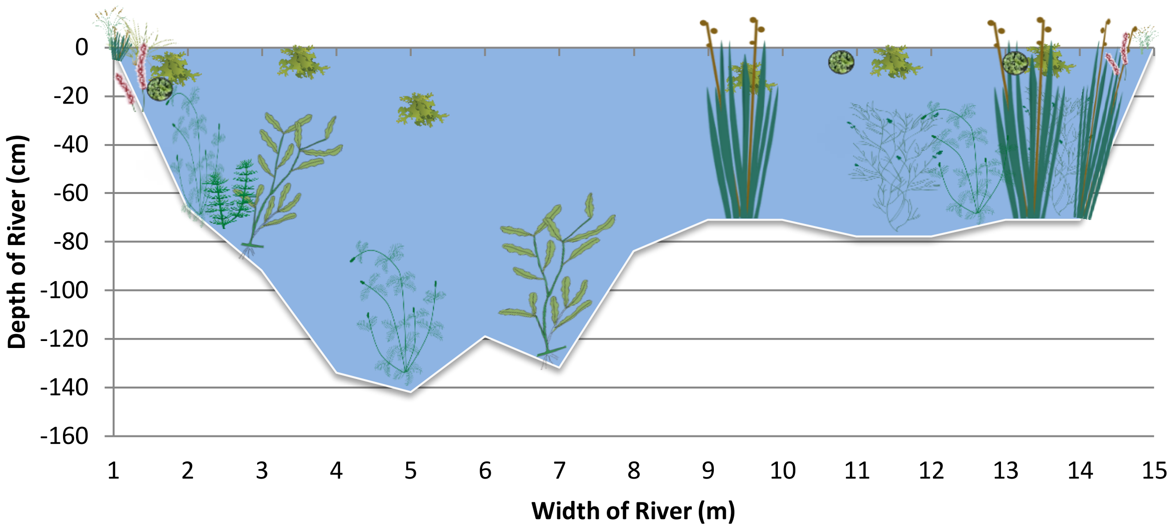


Figure 18: Cross-section of VER1, transect 5.

Table 11: Vegetation survey data collected at transect 5 (station VER1) on September 8, 2015.

Quadrat	Water Depth (cm)	Dominant Substrate	Plant Species	Percent Cover
0-1	66	gravel, cobble, sand, OM	Bulrush	1-25
			Sedges	1-25
			Common duckweed	1-25
			Water parsnip	1-25
1-2	92	gravel, cobble, OM, sand	Giant Bur reed	1-25
			Filamentous algae	1-25
3-4	134	OM/sand	Richardson's pondweed	1-25
			Filamentous algae	1-25
5-6	142	gravel	Filamentous algae	1-25
7-8	119	gravel	Richardson's pondweed	1-25
			Filamentous algae	1-25
9-10	132	OM/sand	Richardson's pondweed	1-25
			Giant Bur reed	1-25
			Filamentous algae	1-25
11-12	84	OM/Sand	Sago pondweed	1-25
			Common duckweed	1-25
			Filamentous algae	1-25
13-14	71	OM/sand	Giant Bur reed	1-25
			Filamentous algae	1-25
			Common duckweed	1-25
			Northern water milfoil	1-25
			Sago pondweed	1-25
14-15	78	OM	Northern water milfoil	1-25
			Sago pondweed	1-25
			Giant Bur reed	1-25
			Sedge spp.	1-25

*OM=organic matter

Station VER3 has the second highest abundance of plants and is quite similar to station TWO2A (Figure 19). Both have Richardson's pondweed as a dominant species, relatively large bankfull widths and shallow wetted depths. Aquatic vegetation occurred in all quadrats at station VER3 and the abundance of vegetation indicates the area is rich in nutrients. The substrate was entirely comprised of organic material and water depth was less than 70 cm (Table 12).

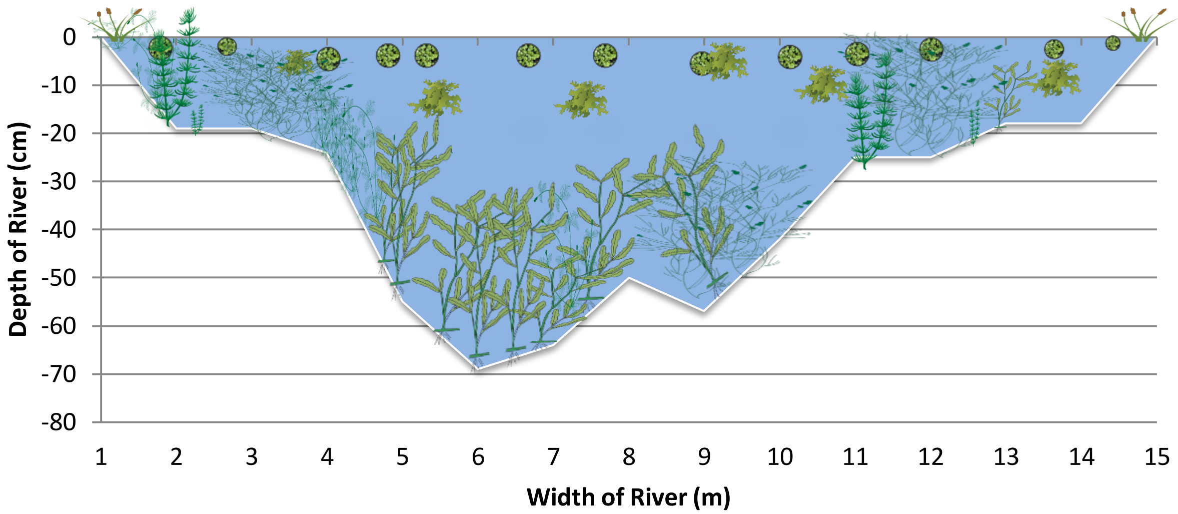


Figure 19: Cross-section of Station Ver3, transect 3.

Table 12: Vegetation survey data collected at transect 3 (station VER3) on September 3, 2015.

Quadrat	Water Depth (cm)	Dominant Substrate	Plant Species	Percent Cover
0-1	19	OM	Common duckweed	1-25
			Sago pondweed	50-75
			Coontail	1-25
			Northern water milfoil	1-25
			Common cattail	1-25
1-2	24	OM	Northern water milfoil	75-100
			Sago pondweed	25-50
			Common duckweed	1-25
			Coontail	1-25
3-4	55	OM	Filamentous Algae	1-25
			Sago pondweed	1-25
			Northern water milfoil	1-25
			Common duckweed	1-25
5-6	69	OM	Sago pondweed	1-25
			Filamentous Algae	1-25
			Common duckweed	1-25
			Richardson's Pondweed	1-25
7-8	64	OM	Richardson's Pondweed	25-50
			Northern water milfoil	25-50
			Sago pondweed	25-50
			Common duckweed	1-25
			Slender pondweed	1-25
			Filamentous Algae	1-25
9-10	57	OM	Sago pondweed	75-100
			Common duckweed	1-25
			Richardson's Pondweed	1-25
			Filamentous Algae	1-25
11-12	42	OM	Richardson's Pondweed	1-25
			Sago pondweed	75-100
			Coontail	1-25
			Filamentous Algae	1-25
			Common duckweed	1-25
13-14	25	OM	Richardson's Pondweed	1-25
			Sago pondweed	25-50
			Duckweed	1-25
			Coontail	1-25
14-15	18	OM	Sago pondweed	25-50
			Common cattail	1-25
			Common duckweed	1-25

*OM=organic matter

Station VER6 ranked second highest in species diversity and highest in species richness. It was unique from the other stations since the substrate composition was mostly comprised of cobbles. The physical environment at this station is influenced by flow, which occurs from April to October, thereby restricting root anchorage in the runs and riffles. The dominant species at this station was Northern water milfoil *(Myriophyllum sibiricum)*, which was confined to pools (Figure 20). The diversity of substrate composition is important for the communities of fish and macro-invertebrates (Table 13).

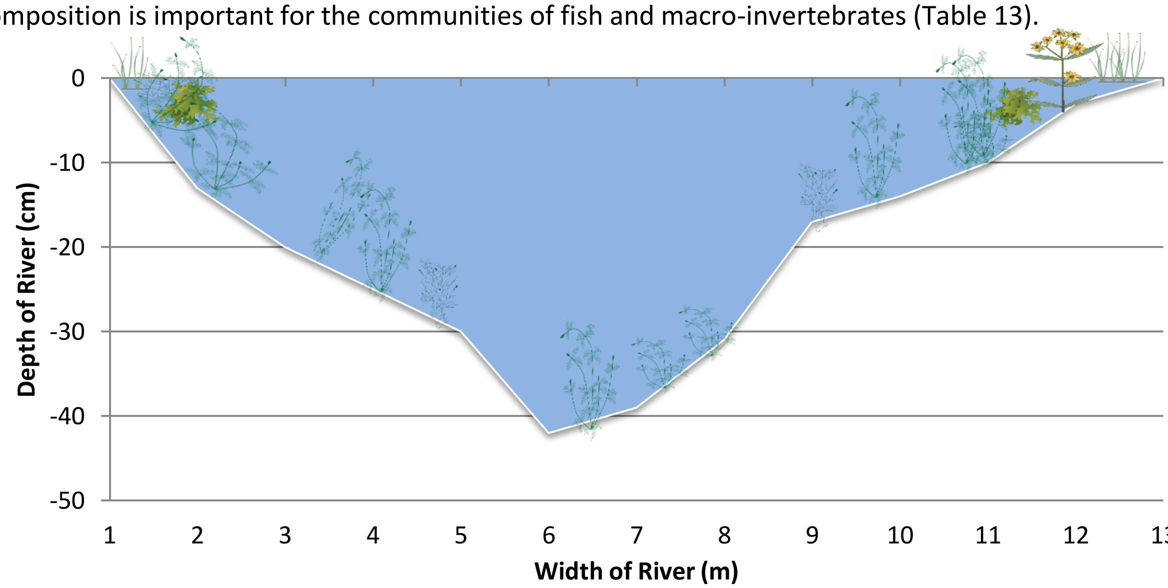


Figure 20: Cross-section of station VER6, transect 1.

Table 13: Vegetation survey data collected at transect 1 (station VER6) on September 9, 2015.

Quadrat	Water Depth (cm)	Dominant Substrate	Second Substrate	Plant Species	Percent Cover
0-1	13	gravel/fines	-	Northern water milfoil	1-25
1-2	25	gravel/fines	boulder/cobble	Sago pondweed	1-25
				Northern water milfoil	1-25
				Filamentous algae	1-25
3-4	42	fines/gravel	cobble	Northern water milfoil	1-25
				Sago pondweed	1-25
5-6	39	fine/gravel	cobble	Northern water milfoil	1-25
7-8	31	cobble/gravel/fine	-	Northern water milfoil	1-25
9-10	17	cobble/fines/gravel	boulder	Northern water milfoil	25-50
				Sago pondweed	1-25
11-12	14	cobble/gravel/fines	boulder	Northern water milfoil	25-50
				Sago pondweed	1-25
12-13	3	cobble/fines	gravel	Nodding beggar ticks	1-25
				Common mare's-tail	1-25
				Common scouring rush	1-25
				Filamentous algae	1-25
				Filamentous algae	1-25

6.0 Macro-Invertebrates

Macroinvertebrates are important biomonitoring subjects since they reflect the interaction of various factors within their environment including water quality (Clifford 1991). They also represent the middle trophic level, between plants and fish. The main objective of the field collection was to capture and document species presence and abundance for the purpose of biomonitoring (Plafkin et al. 1989).

6.1 Methods

6.1.1 Fieldwork

Macroinvertebrate sampling was completed at all seven river reaches of the VR from September 10th to 11th and September 14th to 15th, 2015. Sampling protocols followed the United States Environmental Protection Agency (USEPA) protocols for a multi-habitat approach (Barbour et al 1999). The multi-habitat approach was ideal for the VR since every station varies in substrate type and vegetation cover. The habitat types sampled included snags, vegetated banks, undercut banks, and submerged macrophytes. Macroinvertebrates were collected systematically from all available habitats by jabbing the area with a D-frame dip net. A total of 20 jabs were conducted at each station in proportion to the abundance of habitat types. For example, if submerged macrophytes comprised 50% of the reach, and snags comprised the other 50%, then 10 jabs would be conducted in each habitat type. Sampling efforts began at transect one and proceeded upstream until all 20 jabs were completed.

After each jab, the samples were transferred from the net into a 500 µm sieve. The sieve was used to rinse the macroinvertebrates of sediments and vegetation. The samples were then transferred to a labelled jar containing 95% ethanol for preservation. The jar was then labelled and sealed for shipment to be identified by a trained taxonomist (Nancy Serediak, Streamside Consulting Inc.). Identification of invertebrates was completed under microscope using the *Aquatic Invertebrates of Alberta: An Illustrated Guide* (Clifford 1991) as the main reference.

6.1.2 Data Analysis

Two different biomonitoring techniques were implemented to analyze the results: functional feeding groups and the Family Biotic Index.

Functional Feeding Groups

A functional feeding group (FFG) is a classification approach that is based on behavioral mechanisms of food acquisition (Merritt and Cummins 1996). Individuals were categorized into one of five feeding groups:

1. scrapers (grazers): consume algae
2. shredders: consume leaf litter or other coarse particulate organic matter (CPOM), including wood
3. collectors: gather fine particulate organic matter (FPOM) from the stream bottom
4. filterers: gather FPOM from the water column using a variety of filters

5. predators: feed on other aquatic invertebrates and in some cases small-bodied fish

It should be noted that many organisms shift from one feeding class to another as they advance through their respective life stages and some may be considered in two or more categories. For the purpose of this study, organisms with multiple feeding groups are represented by their dominant feeding group.

Family Biotic Index (FBI)

The Family Biotic Index (FBI) (Hilsenhoff, 1988) is a useful tool for understanding species distribution in relation to organic pollution. The FBI is an equation that estimates the overall tolerance of the invertebrate community, weighed by the relative abundance of each taxonomic group. The first step in calculating the FBI involved assigning tolerance values from 0 (very intolerant) to 10 (highly tolerant) for each family (Mandaville 2002). The FBI was calculated using the following equation: $\text{FBI} = \sum \frac{(ni)(ai)}{Nt}$

Where ni is the number of individuals in family i, ai is the pollution tolerance value of family i, and Nt is the total number of individuals in the sample (Hilsenhoff 1988). FBI values quantified the extent of organic pollution (Table 14).

Table 14: Water quality and the degree of organic pollution corresponding to the calculated FBI range (Hilsenhoff 1988).

Biotic Index	Water Quality	Extent of Organic Pollution
<3.75	Excellent	Pollution Likely
3.76 - 4.25	Very Good	Possible Slight Pollution
4.26-5.00	Good	Some Pollution Probable
5.01 - 5.75	Fair	Fairly Substantial Pollution Likely
5.76 - 6.50	Fairly Poor	Substantial Pollution Likely
6.51-7.25	Poor	Very Substantial Pollution
7.26-10.00	Very Poor	Severe pollution likely

The above photos illustrate the macro-invertebrate sampling; (left) rinsing the collected samples in the sieve, (middle) a Giant water bug (*Lethocerus americanus*) and (right) the sample prior to preservation. These photographs were taken at station VER6 on September 11, 2015.

6.2 Results

Sampling resulted in 16 306 captures, identified to twelve orders that represent the VR communities (Figure 21) (Appendix C: Table C-1).

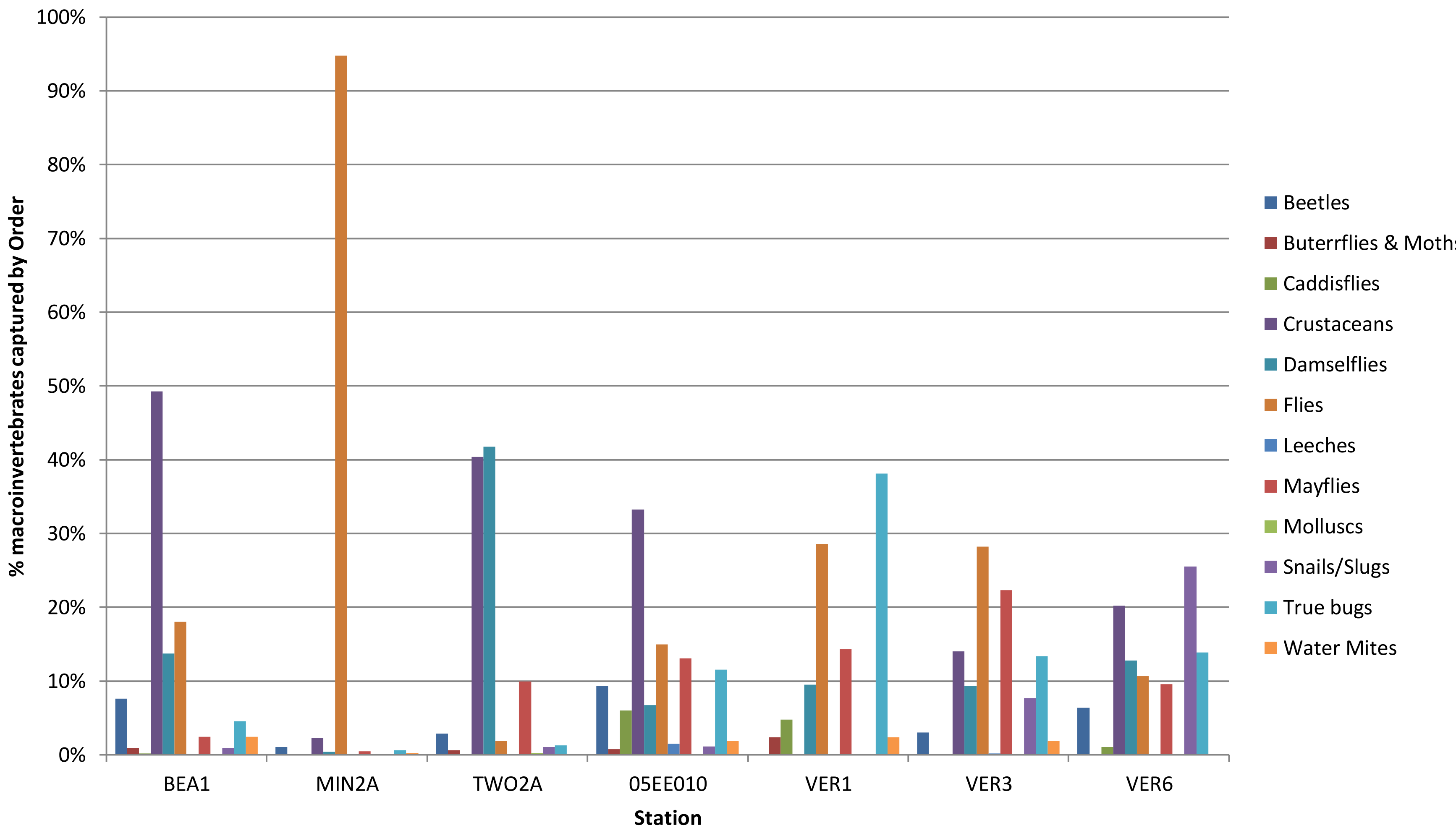


Figure 21: Total percent of macro-invertebrate captured at each station, by Order.

6.2.1 Functional Feeding Groups

Collectors

Collectors accounted for 90% of the entire captures in the VR and dominated at the majority of stations. Station MIN2A had the highest percent of collectors, which represented 97% of the population. Collectors are usually the most abundant river macro-invertebrate group and primarily feed on fine particles (<1mm diameter) (Wallace and Webster 1996). The group is represented by the Amphipoda (Crustacea) and Diptera (Fly) orders, which have high tolerances to polluted water. The Crustacea order is mostly composed of the Hyalellidae and Gammaridae families and the Fly order is represented by the Chironomidae (non-biting midges) family. Both orders are diverse and important food sources for predators such as sticklebacks, waterfowl and beetles (Clifford 1991).

View of a species in the Crustacean order, commonly known as scuds (Google Images).

View of a species in the Fly order and Chironomidae family (Google Images).

Predators

Predators accounted for 8% of the entire VR captures at all stations and dominated at station VER1 (50%). Predators are also a fairly dominant species at station TWO2A (44%). At all other stations they occupy > 20% of species feeding groups. As in other ecosystems, predators in rivers have top-down effects on their prey through direct consumption and reduction of prey populations (Wallace and Webster 1996). The tolerance of predators varies amongst individuals including the Odonata (damselflies), Coleptera (beetle), Diptera (flies), Hemiptera (true bugs) and Hydrachnidia (water mites) orders. These predators are important members of the aquatic community because in addition to direct mortality (population control), their impacts include nonlethal effects on prey feeding activities, growth rate, fecundity and behavior (Wallace et al. 1996).

View of a damselfly larva (Google Images)

View of a marsh fly in the Sciomyzidae family. The fly order is diverse and families are represented in all FFG. This family in particular feeds on snail eggs and clams.

Shredders

Shredders accounted for 2% of the VR invertebrate population at all stations. Shredders fluctuated throughout the stations but had the highest percentage at station MIN2A. Shredders feed on coarse particulate organic matter (CPOM) from terrestrial litter inputs (Ramp 2016). Hence, a large proportion of terrestrial liter is transformed into fine particulate organic matter (FPOM), an important function in the food web of making materials more available for other types of consumers (Wallace and Webster 1996). Shredder species rely on riparian shrubs and trees for terrestrial litter input and therefore are sensitive to riparian disturbance (Plafkin et. al 1989). Shredders also promote wood decomposition by gouging wood and these activities expose further microbial colonization and decomposition. The shredder orders are Coleoptera (beetles), Diptera (flies), Lepidoptera (butterflies and moths) and Trichoptera (caddisflies).

View of a caddisfly in the family Phryganeidae (Google Images)

View of moth larva in the family Pyralidae (Google Images)

Scrapers

Scrapers accounted for 1% of the VR invertebrate captures. At individual stations, scrapers commonly represented <3% of the captures except at station VER6, where they occupied 26% of the functional feeding groups. The majority of scraper species in the VR are represented by the order Gastropoda (Snail) and some beetle larvae and flies pupae. Scrapers are adapted to graze or scrape materials (periphyton or algae) from mineral and organic substrates. Algal primary production is lower when scrapers are present (Webster et al. 1996).

View of a snail in the Physidae family (CPPENV 2015)

Filterers

Filterers were rarely captured in the VR, accounting for 0.7% of the entire VR invertebrate captures. Filter feeders are specialized for water column feeding and remove particles from suspension. The majority (1.8%) of the population resided at station MIN2A, which was the deepest out of all stations and thus had the most amount of open water. The filtering species include the Diptera and Bivalvia orders. Filter-feeding invertebrates constitute important pathways for energy flow and are important in the productivity of aquatic environments (Wallace et al. 1996). Due to their sensitivity, filtering invertebrates usually are the first group to decrease when exposed to pollution (high TSS, nutrients and other organics) (Plafkin et al. 1989).

View of a fly larva in the Dixidae family (Google Images).

Overview of Functional Feeding Groups

The most dominant feeding group in the VR was collectors (90%), which gather fine particulate organic matter (FPOM) from the stream bottom and the least abundant, were filterers (0.7%), which gather FPOM from the water column using a variety of filters (Figure 22). This is typical of a prairie mud bottom stream where fine organic matter is abundant. Station MIN2A was a major contributor to the collector feeding group, due to a high captures (12 412) of flies (chironomids). Station VER1 was the only station were collectors were not dominant (Figure 23).

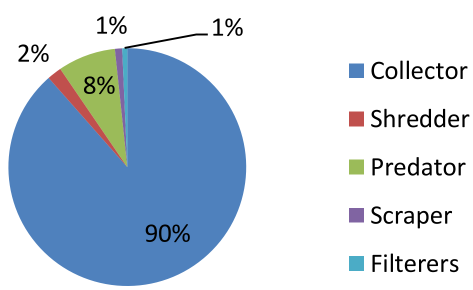


Figure 22: Macro-invertebrate functional feeding groups (%) in the VR; data from all stations.

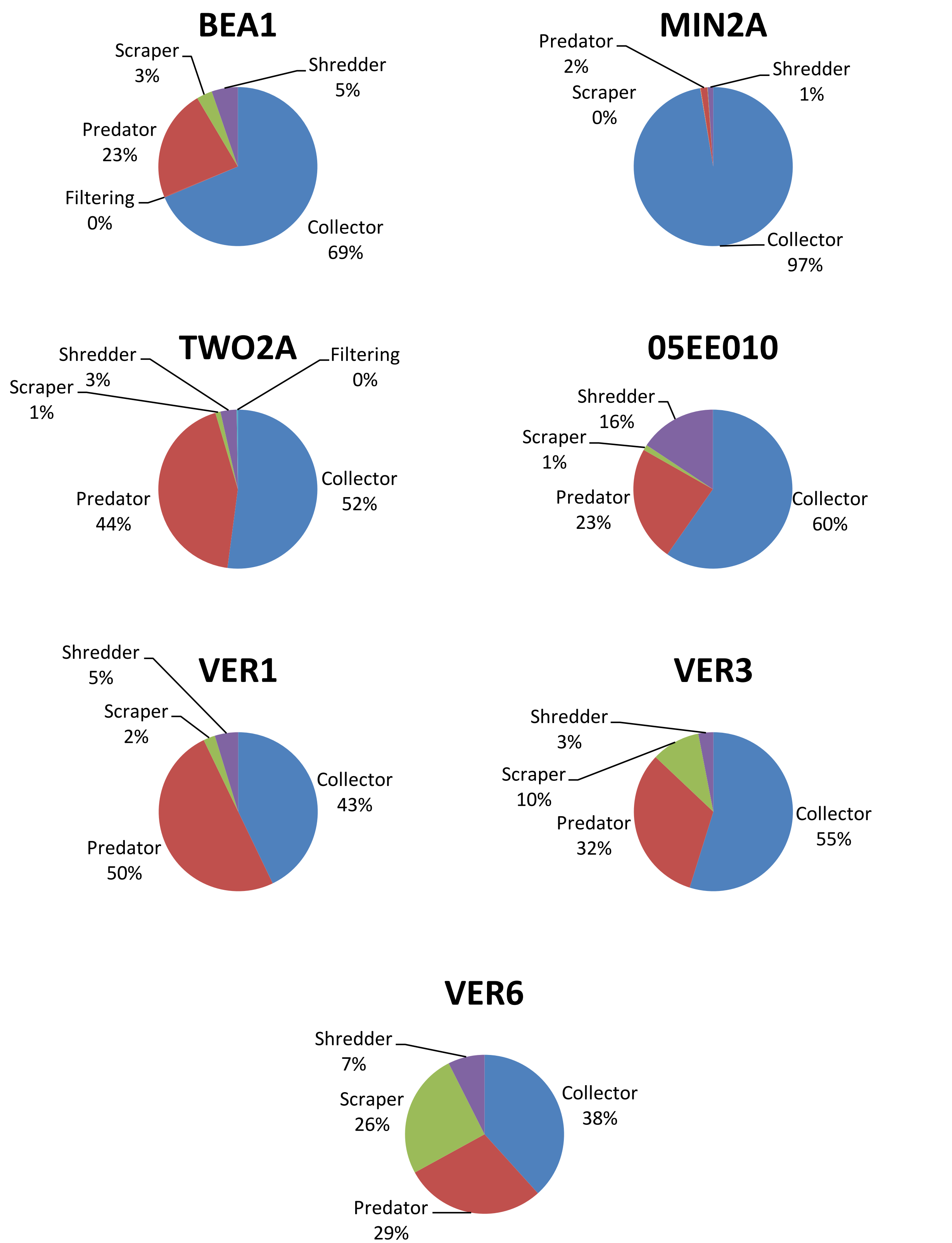


Figure 23: Proportion of macroinvertebrates at each station in each functional feeding group.

6.2.2 Family Biotic Index

FBI values indicate organic pollution at all stations (Table 15). The FBI was consistently above 6 (i.e. 'poor') for all stations, with the highest FBI value at stations above the Vermilion Lakes (TW02A, MIN2A, and BEA1; Figure 24).

Table 15: FBI results at each station and the associated water quality score (Hilsenhoff 1988).

Station	Biotic Index	Water Quality	Extent of Organic Pollution
BEA1	7.45	Very poor	Severe pollution likely
MIN2A	7.93	Very Poor	Very Substantial Pollution
TWO2A	7.60	Very poor	Substantial Pollution Likely
05EE010	6.95	Poor	Very Substantial Pollution
VER1	6.21	Fairly Poor	Substantial Pollution Likely
VER3	6.73	Poor	Very Substantial Pollution
VER6	7.09	Poor	Very Substantial Pollution

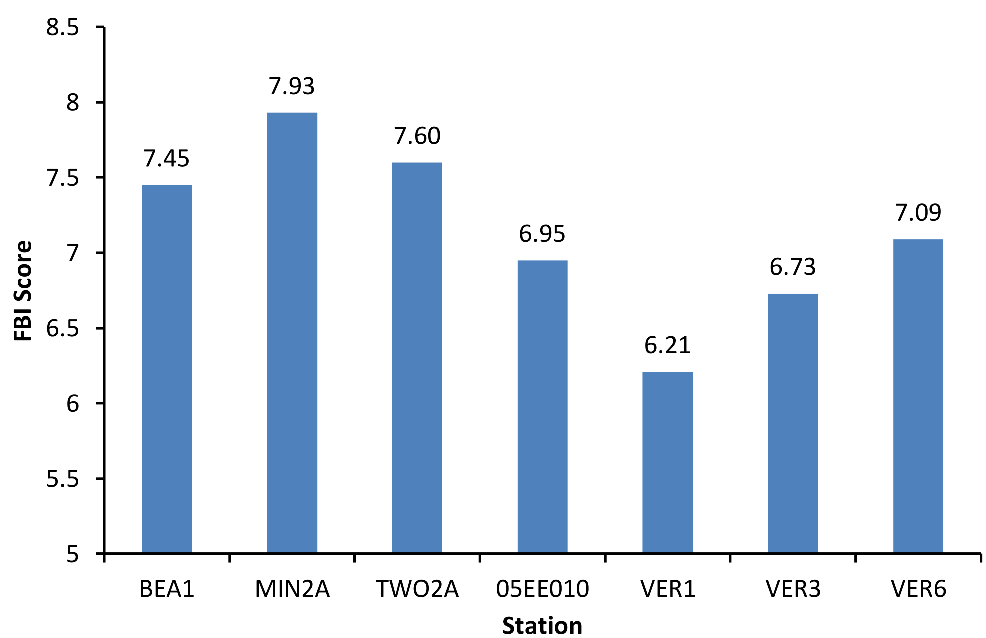


Figure 24: Station Family Biotic Index (FBI) scores indicating degree of organic pollution.

7.0 Fish

Fish are good indicators of ecological status since they occupy a range of ecological niches (Karr and Chu 1999). The main objective of the fish survey was to measure species abundance in relation to environmental factors at each station.

7.1 Methods

7.1.2 Fieldwork

Fish surveys were completed at the seven stations on the VR in August 2015. Fish sampling occurred through a combination of electro-fishing and minnow trapping. Electrofishing was conducted using a Smith-Root LR-24 Backpack Electrofisher. Minnow trapping involved setting Gee traps, which are capable of capturing specimens with a fork length up to 12 cm. Fish surveys were conducted under a valid Fish Research License (FRL License #15-6034) and operations followed best management practices for sampling small bodied fish and streams in Alberta (AESRD 2013). Electrofishing occurred in all habitat types and involved single sweep passes moving upstream in a zig zag pattern.

Despite efforts for consistent electrofishing times at each station, environmental factors caused issues at some stations, thereby reducing efficiency. For the majority of stations, electrofishing occurred for 200m up- and down-stream of the bridges at each station, except for BEA1 and TWO2A. At station BEA1, the high turbidity, slippery rocks, and physical river barriers reduced backpack electrofishing efforts. Electrofishing was less successful at station TWO2A, since vegetation growth was too dense to capture fish with a dip net. MIN2A was shocked for the entire 400m. However, due to deep areas (>2m), successful captures mainly occurred in shallow areas. Despite the limitations of electrofishing at some of the VR stations, minnow trapping yielded good results to represent the fish data for these stations. Refer to Appendix D: Fish Surveys for all original capture data.

For all captured fish, we identified species and recorded fork length. We also examined fish for DELTS: deformities, diseases, fin erosion, lesions and tumors.

The Smith Root LR-24 Backpack Electrofisher (Source: Google 2015)

A minnow trap (Source: Google 2015)

7.1.2 Data Analysis

Metrics for determining the ecological state of rivers was first proposed by Karr (1981) in the *Assessment of Biotic Integrity Using Fish Communities*. Since then, multiple studies have implemented multi-metric variables for assessing the health of aquatic ecosystems (Stevens and Council 2008). This study utilizes five metrics to determine the ecological state:

- Percent of invertivores (Cyprinids & benthic) are expected to decline with increase in human influence
- Percent of omnivores are expected to increase as river quality declines
- Percent of intolerant individuals are expected to be the first species to decline with increasing anthropogenic influence
- Percent of individuals with DELTS (deformities, disease, parasites, fin erosion, lesions or tumours) can reflect stress

7.2 Results

In total, 149 minutes of electrofishing and one event of minnow trapping at all 7 stations resulted in the capture of 774 fish. Fish captures were within 4 families and 8 species (Table 16). Historically, nine species have been documented in the VR by the Alberta Environment and Parks FWMIS database (Fish and Wildlife Mapping Tool). Of the 9 species historical known to occur in the VR, 7 species were captured in the following proportions: Brook stickleback (*Culaea inconstans,* 26%), Fathead minnow (*Pimephales promelas,* 23%), Emerald shiner (*Notropis atherinoides,* 21%), Lake chub (*Couesius plumbeus,* 18%), Longnose dace (*Rhinichthys cataractae,* 8%), Pearl dace (*Margariscus margarita,* 2%) and White suckers (*Catostomus commersoni,* 1%) (Figure 24). Trout-perch (*Percopsis omiscomaycus*) is not recorded in the historical database but one specimen was captured at station VER6. For more information on captured fish species, refer to Appendix E: Fish Facts.

Table 16: Species of fish caught in the VR in 2015.

Family	Common Name	Scientific Name	Abbreviation
Cyprinidae	Fathead minnow	*Pimephales promelas*	FTMN
	Lake chub	*Couesius plumbeus*	LKCH
	Pearl dace	*Margariscus margarita*	PRDC
	Longnose dace	*Rhinichthys cataractae*	LNDC
	Emerald shiner	*Notropis atherinoides*	EMSH
Gasterosteidae	Brook stickleback	*Culaea inconstans*	BRST
Percopsidae	Trout-perch	*Percopsis omiscomaycus*	TRPR
Catostomidae	White sucker	*Catostomus commersoni*	WHSC

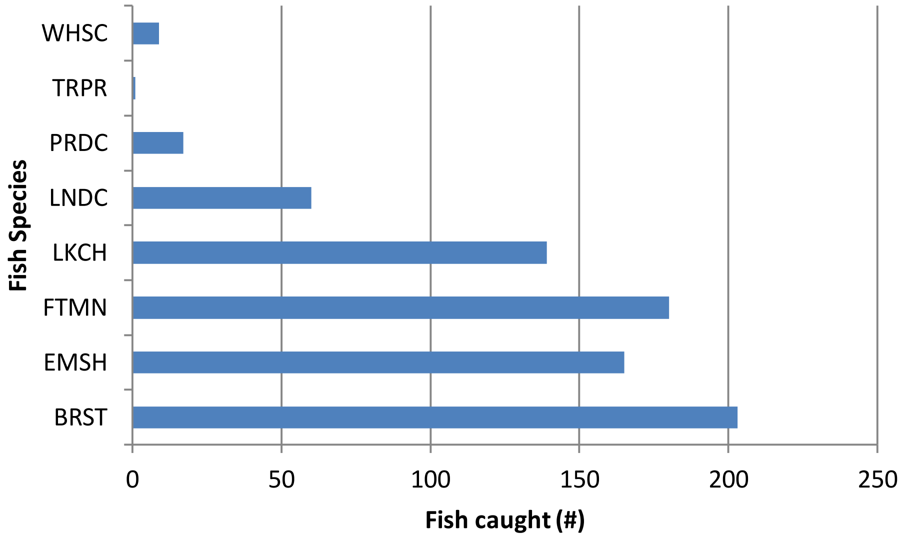


Figure 25: Total Fish captured in the VR by species.

The two species historically recorded in the VR that were not captured in the 2015 surveys were Northern pike (*Esox lucius*) and Spottail shiner (*Notropis hudsonius*). There is no further information regarding the Spottail shiner, but phone interviews with local landowners reveal that Northern pike are or were caught in the VR. Anglers reported Northern pike in the canal immediately downstream of the Vermilion Dam Reservoir. Surveys by Lakeland College in the Vermilion reservoir resulted in no Northern pike captures (Dr. Vytenis (Vee) Gotceitas, personal communication). A 2009 Vermilion Standard article discussed fish deaths occurring in the area due to high summer temperatures, increased algal blooms and decreased oxygen levels (Vermilion Standard 2009). Northern pike and White sucker were among the dead fish that washed ashore under the highway 41 bridge. In 2015, many dead or dying minnows were observed at the surface of the water in the same area, as shown in the picture below.

Fish deaths in July 2009 (left) and in August 2015 (right).

7.2.1 Invertivores

Invertivores accounted for 47% of the entire VR catch effort and represent fish that feed on invertebrates (Simon 1999). Invertivores include: Lake chub, Emerald shiner and Longnose dace (Stevens and Council 2008, Royal Alberta Museum (RAM) 2006). The majority of these captures were Lake chub (47%), which were recorded at all stations except VER6. Emerald shiners accounted for 38% of the invertivore captures and were trapped during a one hour event at station VER6. Longnose dace also were only captured at station VER6 (via electrofishing) and accounted for 16% of the invertivore captures. Trout-perch (*Percopsis omiscomaycus*) represent 0.3% of the invertivore catch, involving one specimen at station VER6. Invertivores were not captured at stations MIN2A and TWO2A.

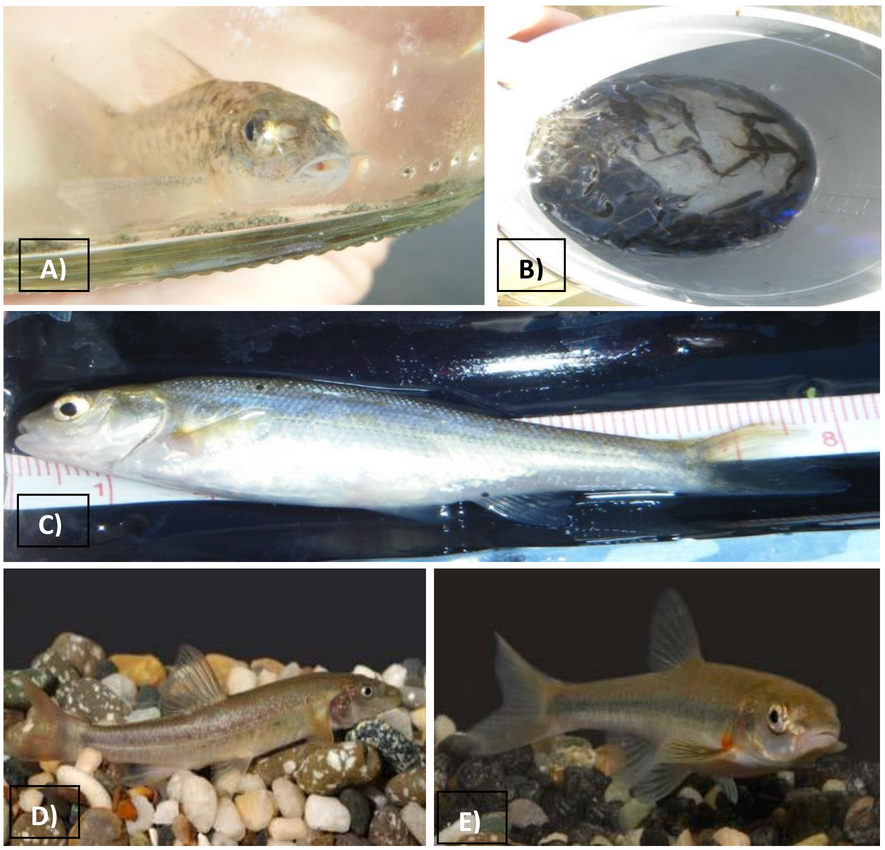


Photo A: Trout-perch captured at station VER6 (CPPENV 2015)

Photo B: Bucket of Emerald shiners; all captured in one minnow trapping event at station VER6 (CPPENV 2015)

Photo C: Emerald shiner captured at station VER6 (CPPENV 2015)

Photo D: Longnose dace captured at station VER6 (RAM 2015)

Photo E: Lake chub captured at stations BEA1, 05EE010, VER1, VER3 & VER6 (RAM 2015).

7.2.2 Omnivores

Omnivores accounted for 53% of VR captures and represent fish species that will eat plant material, insect larvae, zooplankton and invertebrates. Omnivores include Brook stickleback, Fathead minnow, Pearl dace and White sucker (Stevens & Council 2008, RAM 2006). Brook sticklebacks were captured at all stations and were the most abundant species representing 50% of the omnivore catch. Fathead minnows were also highly abundant (44% of the omnivore catch), although they were not captured at all stations. Pearl dace were captured at stations 055EE010 and VER3 and represent 17% of omnivore captures. White suckers were among the least abundant captured fish species (9%) and were most abundant downstream of the Vermilion dam. Omnivores were most abundant at stations with low habitat scores (Figure 26).

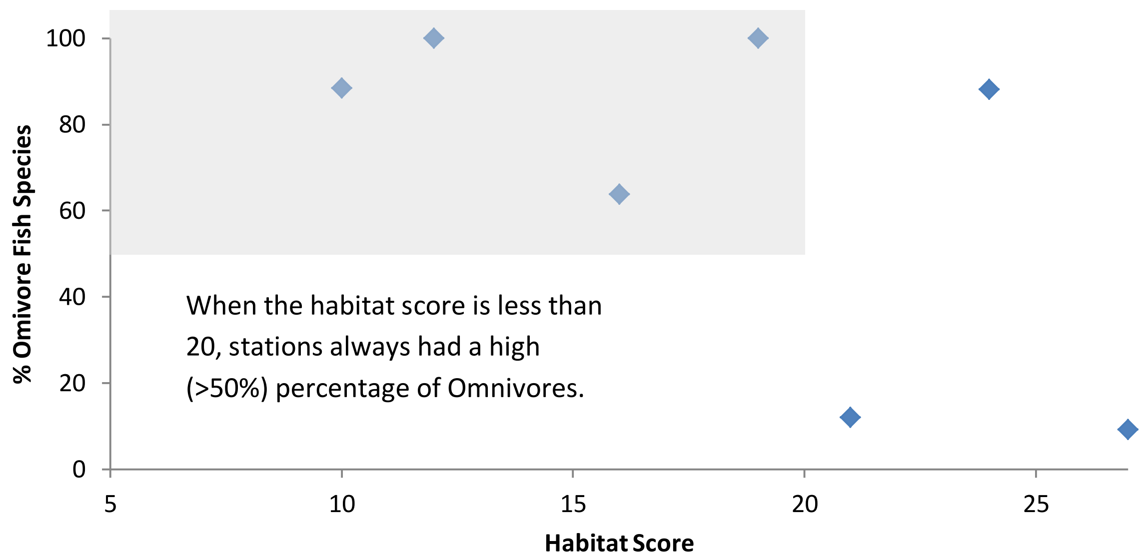


Figure 26: Total percent of captured omnivores in relation to habitat scores (VER3=10, TWO2A=12, BEA1=16, MIN2A=19, VER1=21, 05EE010=24 & VER6=27).

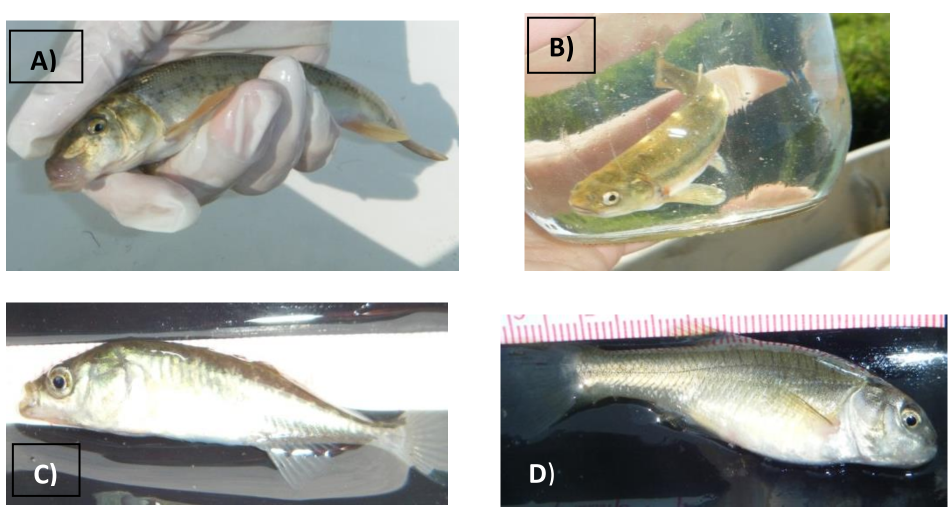


Photo A: White sucker captured at station 05EE010 (CPPENV 2015)

Photo B: Pearl dace captured at station 05EE010 (CPPENV 2015)

Photo C: Brook stickleback captured at station BEA1 (CPPENV 2015)

Photo D: Fathead minnow captured at station BEA1 (CPPENV 2015)

7.2.3 Tolerant species

Most fish captured were tolerant species (71%) including Brook stickleback (37% of captures), Fathead minnow (33%), Lake chub (25%), White sucker (2%) and Pearl dace (3%). Tolerant species are defined by their ability to withstand low oxygen levels, high pH values, and low flows (Nelson & Paetz 1992; RAM 2006; Stewart et al. 2007; Stevens & Council 2008). These species were abundant at all stations on the VR except station VER6 (Figure 27).

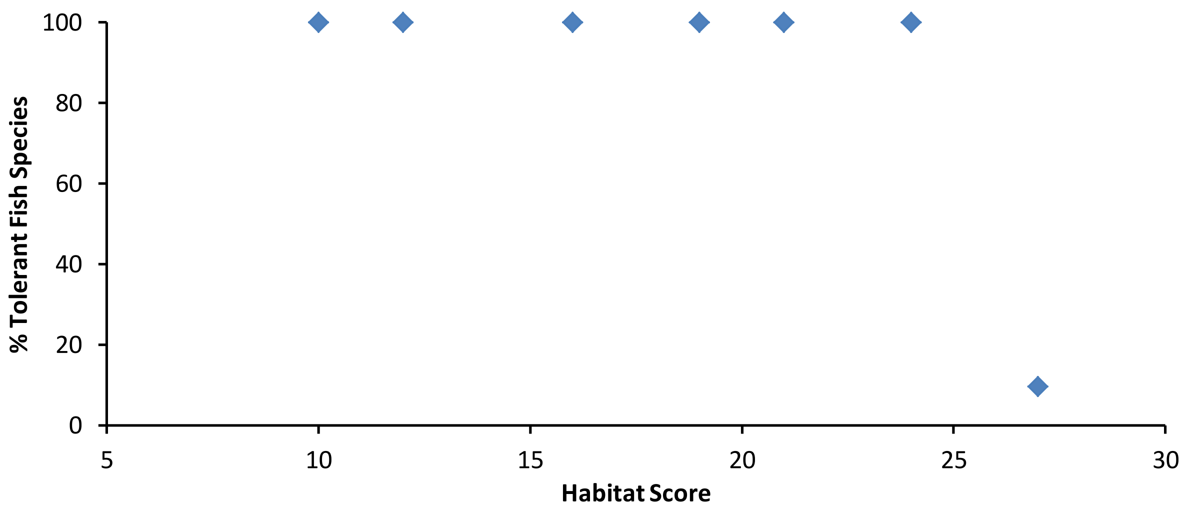


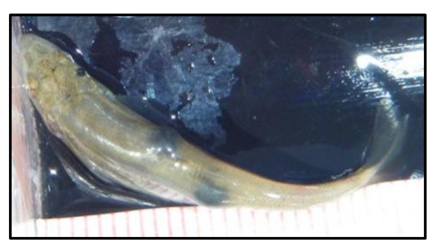
Figure 27: Total percent of tolerant species in relation to habitat assessment score (Ver3=10, TWO2A=12, BEA1=16, MIN2A=19, VER1=21, 05EE010=24 & VER6=27).

7.2.4 Intolerant species

Intolerant species account for 29% of the VR captures and represent species that prefer specific habitat features (Nelson & Paetz 1992; Stevens and Council 2008; Spafford 1999). Intolerant species include: Emerald shiners (73% of captures), Longnose dace (27%) and Trout-perch (0.4%). All of these species were only captured at station VER6.

7.2.5 DELTS

DELTS (deformities, erosion, lesions or tumours) were visible on 21% of the captured fish. Blackspot parasite (*Neascus spp.)* was the DELT most frequently observed and it affected two stations: 055EE010 and VER6. The majority of fish with Blackspot occurred at station 05EE010 (81%). Blackspot disease is relatively common in Alberta and mostly occurs in shallow warm waters (AESRD 2013).



Longnose dace with Black spots, captured at station VER6 (CPPENV 2015).

Other DELTS included lesions on numerous White suckers that were observed dead during other aquatic surveys (approximately 10 White suckers at stations BEA1, Two2A and VER3).

8.0 Summary and Discussion

The Vermilion River is characteristic of a small, slow-moving, mud-bottom prairie river in Alberta. Except for the lowest reach, the river ceases to flow in mid to late summer, which provides the context for many ecosystem processes. All sites that were surveyed had a macroinvertebrate FBI score reflecting a system that is polluted with organics (Hilsenhoff 1988, Figure 28). Aquatic ecosystem health is much improved near the mouth of the Vermilion River (VER6) than at all other sites due to the presence of physical habitat diversity, improved hydraulic connectivity with the North Saskatchewan River, and improved water quality linked to the presence of instream flows can flush the system. Important nutrient sinks include the lakes and reservoirs that function in the same way as settling ponds, and are integral components of the Vermilion River channel. Riparian areas and wetlands immediately adjacent to the river channel can also be important sinks for nutrients, particularly since areas that contribute runoff neighbour the river (see Section 2.0). These key habitat features are described and summarized by station in the following sections.

Photo of Water smartweed (*Persicaria amphibia*; foreground) and Common duckweed (*Lemna minor*; floating in the background) (CPPENV 2015).

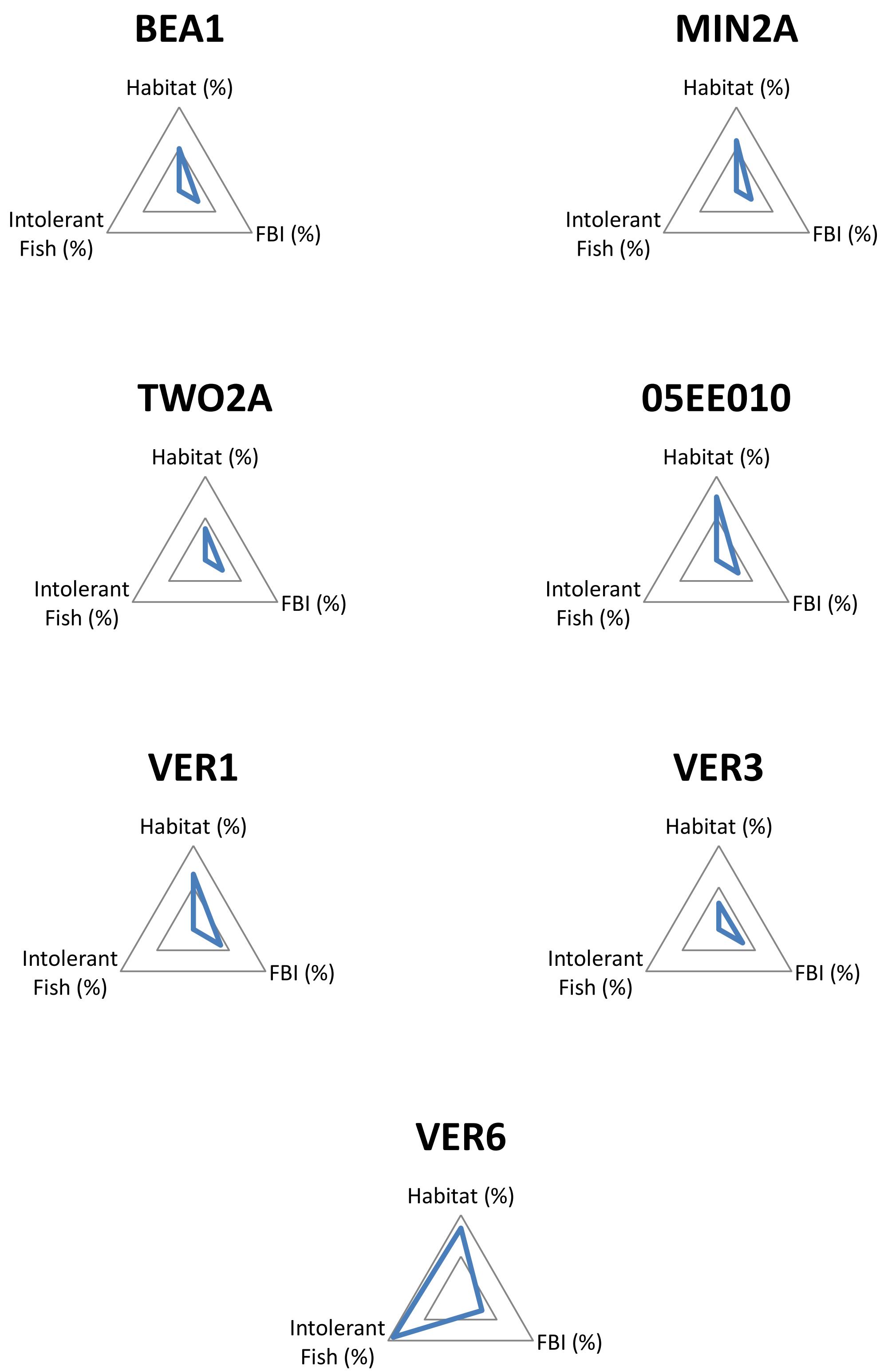


Figure 28: Integrated aquatic ecosystem health assessment at VR stations. The middle of the triangle represents 0% and the tips are 100%. The larger the area of the blue triangle, the greater is the overall health of the site. **Note: The FBI scores were inversed and expressed as a percentage so that high values represent improved conditions.**

8.1 Bea1

Station BEA1 is located at the headwaters of the VR, approximately 21km south of Vegreville. It ranked 5th in the habitat assessment and had the best physical habitat features including diverse substrate cover and undercut banks, which provide sufficient shelter for aquatic life. However, the station scored poorly for water quality and riparian health.

Water quality problems are visually apparent at this station; the water was thick green due to high algal productivity. This observation is consistent with high concentrations of nitrogen, phosphorous and total suspended solids (TSS). High levels of TSS can be toxic to fish and macroinvertebrates by causing clogs and abrasion of gills, behavioral effects (i.e. impaired movement for species that are heavily reliant on sight), resistance to disease, the formation of physical constraints disabling proper egg and fry development, reduced feeding, blanketing of spawning gravels and other habitat changes (CCME 2002). The high levels of TSS within the reach are a direct result of algae blooms, which limit plant growth due to limited light penetration. The abundant algae growth can create problems for the aquatic ecosystem by diminishing oxygen levels and increases pH levels. During the sampling event, dissolved oxygen levels were good; however pH levels were above surface water quality guidelines. High pH values can cause stress to the ecosystem due to its magnifying effect on the toxicity of certain chemical elements (e.g., unionized ammonia; CCME 2010).

Another factor causing habitat degradation was fragmentation by ford crossings (Figure 29). The ford crossings are above the natural streambed and are blocking flow, thereby blocking fish passage and contravening provincial and federal legislation (Government of Alberta Transportation 2009, page 5-3). Algae blooms favor these conditions where water movements is slow and nutrient and temperatures levels are high (RAMP 2016). The surrounding riparian areas are 'poor' to 'fair', which is consistent with the habitat assessment in this study (high erosion and poor shading scores) (Figure 30).

Figure 29: A ford (left) blocking stream channel (right) (CPPENV 2015).

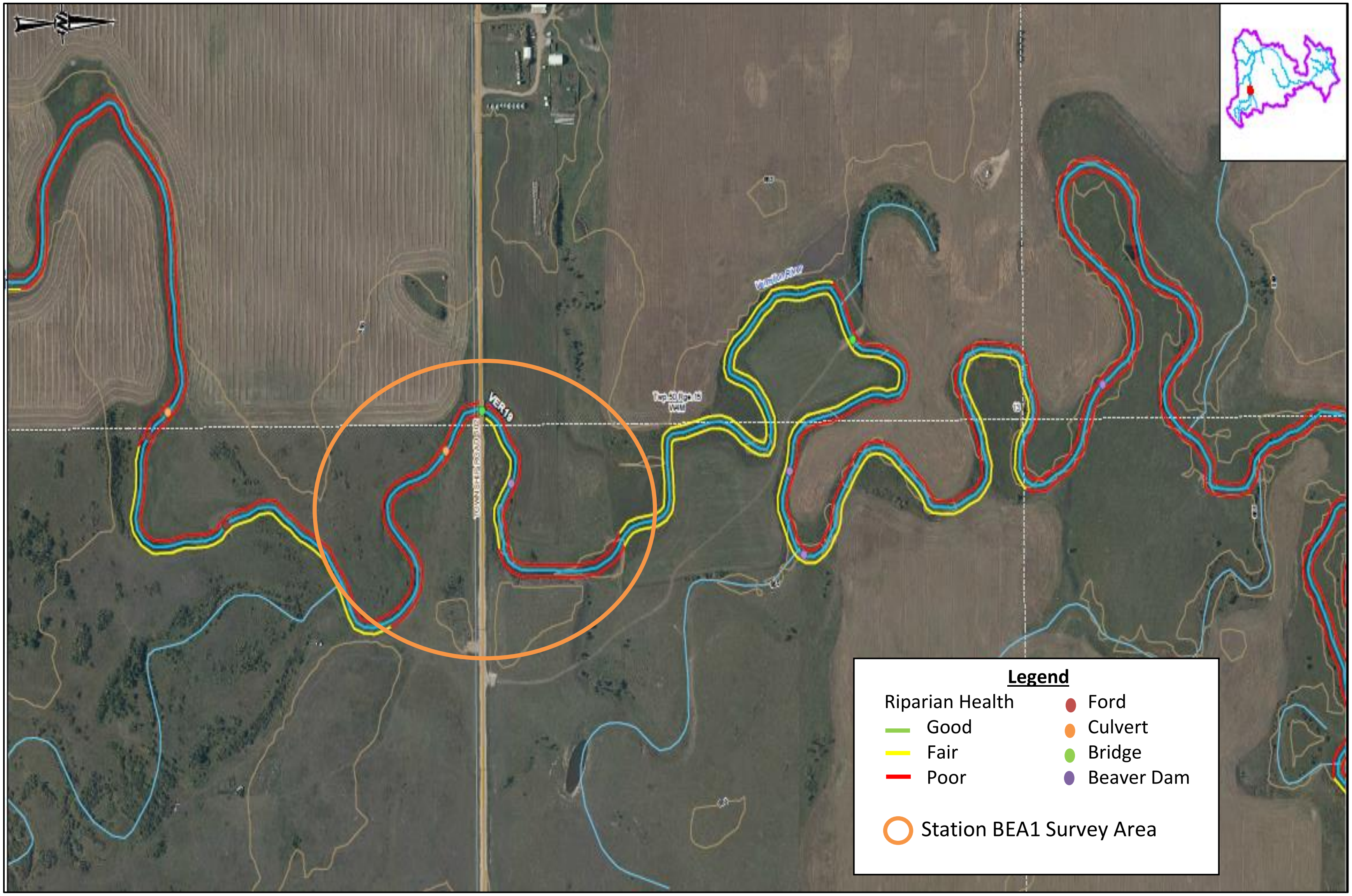


Figure 30: Riparian health at station BEA1 (Golder 2016).

The biological surveys of station BEA1 revealed populations that are adapted to survive in poor environmental conditions. The macroinvertebrate FBI is second highest at 7.45, indicating severe organic pollution is likely. Currently the macroinvertebrate populations are dominated by the functional feeding group collectors, including crustaceans and the highly tolerant Chironomidae family (flies). Due to their broad tolerances, the fly family Chironomidae is the most widely distributed and most frequently abundant group of insects in freshwater (Armitage et al. 1995). Fish surveys revealed the same type of information with tolerant species being dominant. Electrofishing was problematic at this station due to the high turbidity, but minnow trapping was successful. The population was comprised of 64% omnivore including Fathead minnows and Brook stickleback and 34% invertivore, including Lake chub. White suckers were also observed during other surveys, except they were dead, which is indicative of biological stress (Nelson & Paetz 1992). Despite these observations, white suckers are known to enhabit the upper reaches of the VR. Spawning activity was documented in the Town of Vegreville in the spring of 2016 (David Berry, personal communication). Other wildlife sightings at station BEA1 include the Great Blue Heron (*Ardea herodias)* and Mallard ducks (*Anas platyrhynchos*). Recent beaver (*Castor canadensis)* activity also was noted.

8.2 MIN2A

Station MIN2A is located downstream of Vegreville, prior to Bens Lake. This station was unique from the others due to the high vegetated slopes. These slopes provide good shade cover for the river ecosystem, helping to regulate water temperatures. Station MIN2A ranked 4th in the habitat assessment and no visually apparent water quality concerns were recorded. It had the deepest recorded water depths out of all stations and had good habitat features to support aquatic life.

View of old beaver lodge and woody debris at station MIN2A (CPPENV 2015).

Habitat features included undercut banks and an abundance of woody debris on the shorelines. Some of the wood debris appears to be old beaver lodges, and a large beaver dam indicated that beavers are active in the area (Figure 31). The beaver dam is maintaining an old oxbow as a wetland area, which provides ecological diversity (Fitch and Ambrose 2003). Beavers were not observed during surveying events. However, muskrats (*Ondatra zibethicus)* were observed taking advantage of the beaver activity on numerous occasions.

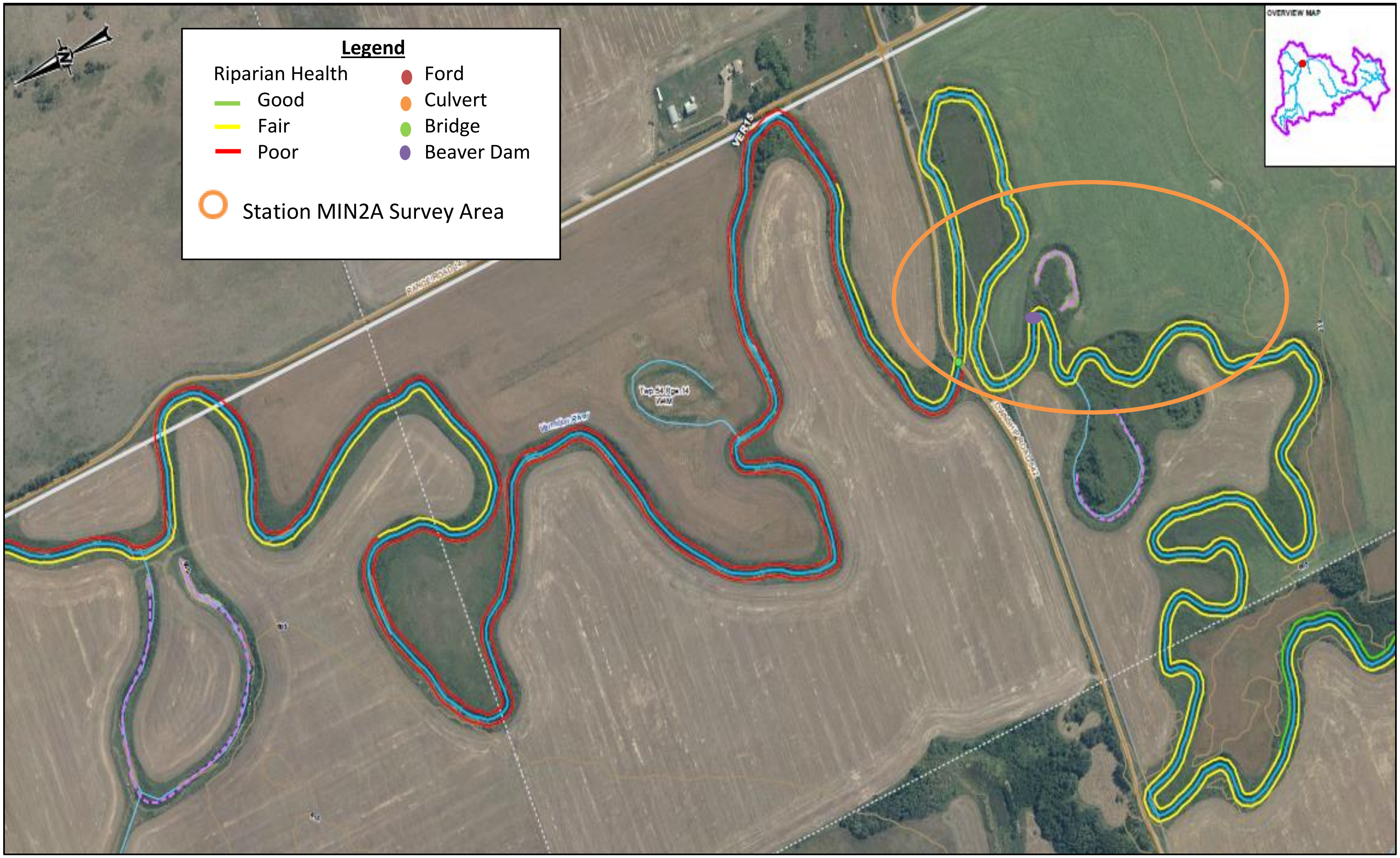


Figure 31: Riparian health at station MIN2A (Golder 2016).

Macro-invertebrate surveys documented the most abundant capture of the Chironomidae family, which accounted for 95% of the stations catch and 76% of the entire VR macro-invertebrate captures. The fly family Chironomidae is the most widely distributed and can occupy a wide range of gradients and, in highly polluted environments, may be the only insect present (Armitage et al. 1995). This station also had the highest abundance of the Coleoptera (Beetles) family, which accounted for 49% of all beetle captures. Most beetle species are within the shredding functional group, which is a reflection of the surrounding riparian zone since shredders feed on coarse particulate organic matter (CPOM) from terrestrial litter inputs (RAMP 2016), making them sensitive to riparian disturbance (Plafkin et. al 1989). Overall, the composition of the macroinvertebrate community at MIN2A indicated the poorest water quality with an FBI of 7.93.

Fish surveys revealed a population dominated by Brook stickleback. Brook stickleback are omnivores but are physiologically restricted to what they can eat due to a small mouth. Brook stickleback cannot eat large beetles but are the prey of choice for predatory beetles. The habitat is well suited to Northern pike that prefer spawning in flooded marsh areas, such as the old oxbow areas surrounding MIN2A (Harvey 2009). However, ours and previous efforts (VR Operations Review 2000) captured no pike in the VR to Bens Lake area. Electrofishing at this station was not effective due to the unexpected water depth. The site is ideal for boat electrofishing; however, access is extremely difficult due to the steep slopes. Continued monitoring may reveal a better access site upstream of the large beaver dam, and interviews with local landowners may provide more information in relation to large bodied fish in the MIN2A area.


Muskrats were a common sighting at the majority of stations on the VR, especially MIN2A. They primarily feed on aquatic vegetation, as well as small fish, mussels and frogs. Stacked piles of mussel shells were noted on the shoreline of MIN2A, indicating muskrat feeding. The picture to the right shows floating stems, most likely dislodged by muskrat feeding activity (CPPENV 2015).

8.3 TWO2A

Station TWO2A is located in the middle of the Vermilion Lakes chain, which historically has been channelized for flood mitigation purposes. As a result, this reach is a straight run that is over 40m wide. The habitat assessment ranked this station 6th as a result of poor habitat diversity. However, the water depth is shallow and provides excellent growing space for aquatic vegetation that in turn provides shelter for macro-invertebrates.

Station TWO2A had the most abundant macroinvertebrate captures in three orders, including Amphipoda (Crustacean 41%), Ephemeroptera (Mayflies 76%) and Odonata (damselflies 76%). These species are widely distributed throughout Alberta and are an environmentally sensitive species with low tolerances to pollution (Clifford 1991). This station's FBI of 7.6 is the second highest out of all the stations and indicates substantial organic pollution. Overall, the macro-invertebrate populations provide an ample supply of food for predators including Brook stickleback and many bird species. Only Brook stickleback were captured in the 2015 survey, however historical sampling in the Vermilion Lakes found White suckers and minnows with few Northern pike in the reach from Bens Lake to Vermilion chain lakes (VR Operations Review 2000).Thus, the potential for large bodied fish does exist.

Migratory birds were noted during every site visit, and likely were benefitting from abundant prey populations. Historical initiatives of building a larger river width and piling sediment to make islands has improved nesting habitat and the area is valuable for many species of birds. Species of observed birds include the American Bittern (*Botaurus lentiginosus*), Great Blue Heron (*Ardea herodias*), Common Sandpiper (*Actitis hypoleucos),* Double-crested Cormorant (*Phalacrocorax auritus*) and the Red-necked Grebe (*Podiceps grisegena*). Local landowners have also noted the presence of American White Pelican (*Pelecanus erythrorhynchos*) during the migratory season. The diversity of waterfowl makes this station a significant wildlife corridor and initiatives to protect these ecological services should be maintained.

"Buck for Wildlife" sign designating the area as a zone of value for restoration projects initiated in the early 70's (CPP ENV 2015).

The site was included in the "Buck for Wildlife" campaign initiated by the Alberta Government in the early 1970's. As a part of this initiative to protect areas for fish and wildlife, trees were planted and fences were installed to prevent erosion from cattle access. The conservation initiatives over the years have diminished at this site and the fences are no longer in place. Erosion is a contributing problem to water quality and the degradation of aquatic habitat. Due to the ecological services at this station, there exists a good opportunity to re-initiate conservation programs such as those offered by the Alberta Riparian Habitat Management Society.

As with other upstream stations, water quality sampling revealed high nitrogen and phosphorus concentrations. The riparian health in the surveyed section is fair to poor, with good riparian health located down and upstream (Figure 32) (Golder 2016). Overall, the Vermilion Lakes chain provides valuable habitat and the aquatic life offers significant food sources for migratory birds. The station is ideal for wetland restoration and land conservation.

Field crews did not witness pelicans on the VR, however a farmer reported hundreds in May at station TWO2A. Field crews saw large flocks of pelicans on Bens Lake (SW of Two Hills) in August (Google Images 2015).

The American bittern (*Botaurus lentiginosus*) was spotted at station TWO2A on September 10th, 2015 at 9am. They are wading birds that eat fish, amphibians and invertebrates (Google Images 2015).

The Redneck Grebe, (*Podiceps grisegena)* spotted at station TWO2A on September 10th, 2015, eats fish and invertebrates (CPPENV 2015).

The Double-crested Cormorant (*Phalacrocorax auritus*) spotted flying away at station TWO2A on September 10th 2015 (CPPENV 2015).

Common sandpipers (*Actitis hypoleucos*) spotted at station TWO2A on August 26th 2015, foraging for insects, crustaceans and invertebrates (CPPENV 2015).

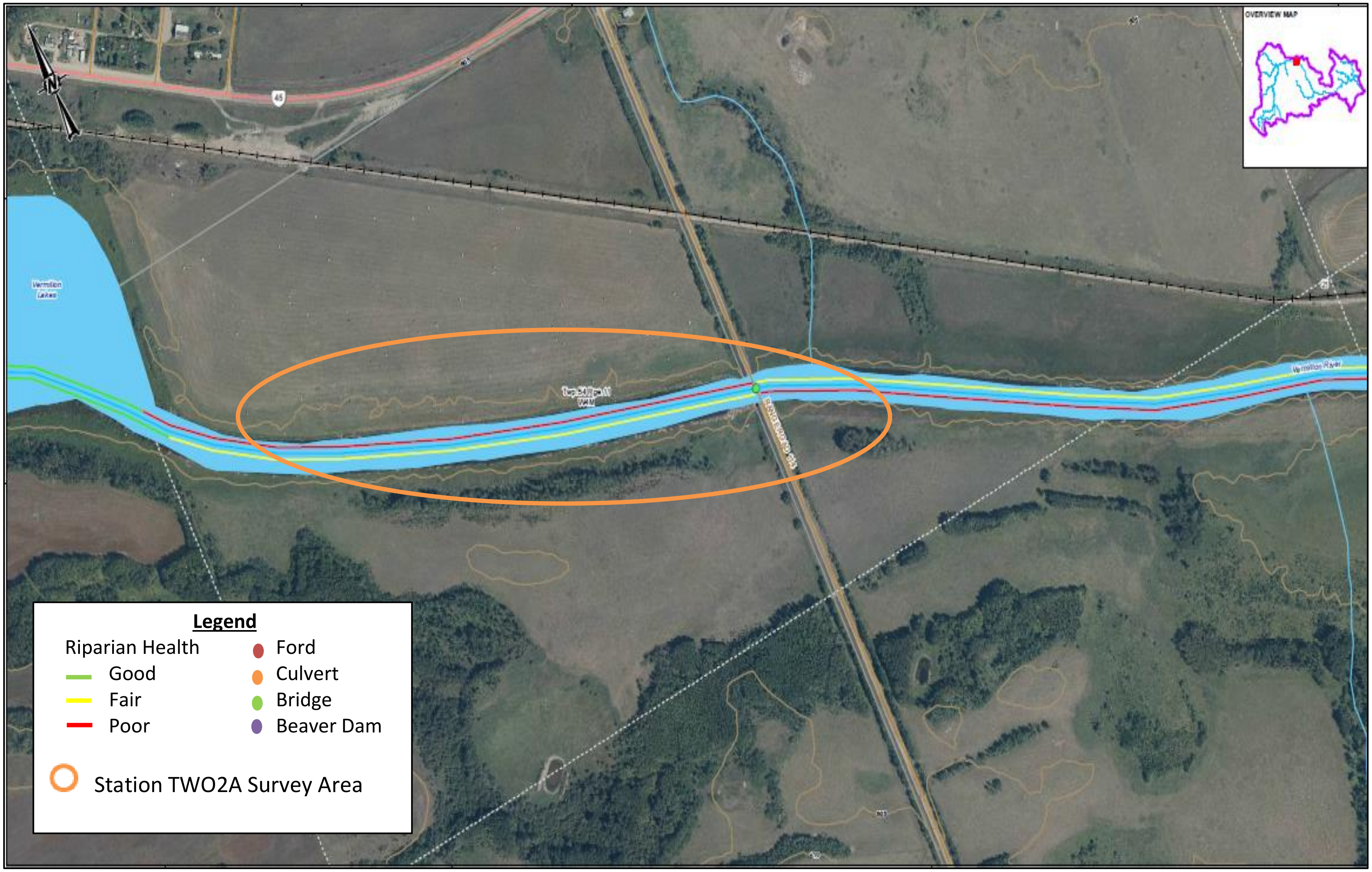


Figure 32: Riparian health at station Two2A (Golder 2016).

8.4 05EE010

Station 05EE010 is located approximately 4km downstream of the Morecambe dam structure. The station ranked second in the habitat assessment due to 'good' habitat diversity and fair water quality. Habitat diversity included good shade cover on one side of the river from steep vegetated slopes, diverse substrate composition and good cover of macrophytes. Total phosphorus was the lowest of the sites sampled (0.025 mg/L). These results were surprising considering the poor riparian health surrounding the area (Figure 33).

The water quality at station 05EE010 supported the highest diversity of fish recorded in the upstream reaches of the VR. Until this station, Brook stickleback, Lake chub and/or Fathead minnows have been the dominant fish species. These species were still dominant at this station, and new additions include the Pearl Dace and living White suckers (other stations had dead White suckers). These species are considered tolerant omnivores and station 05EE010 offers ideal habitat for them. This station had the highest percent of fish affected by Black spot disease, which is a relatively common parasitic disease in shallow mud-bottom waters (AESRD 2014).

The macroinvertebrate data at station 05EE010 also reflected better water quality, relative to the other stations. Although the macroinvertebrate community indicates "substantial organic pollution" (FBI=6.95), it has the highest percent of Caddisflies (Trichoptera), a pollution sensitive family. They are within the functional feeding group of shredders and are thereby reliant on the nearby riparian vegetation for terrestrial inputs, which adds value to the small riparian area documented at this station (RAMP 2016). The station is dominated by tolerant crustaceans and flies, which are valuable food sources for fish. The significant water quality improvements from the Vermilion Lakes chain to the Morecambe dam were measureable and had a significant positive affect on the aquatic ecosystem.

White sucker (*Catostomus commersoni*) captured during fish surveys (CPPENV 2015).

Water scorpion (*Ranatra chinensis*) captured during macro-invertebrate surveys (CPPENV 2015).

Great Blue Heron and unidentified ducklings sited at station 05EE010 (CPPENV 2015).

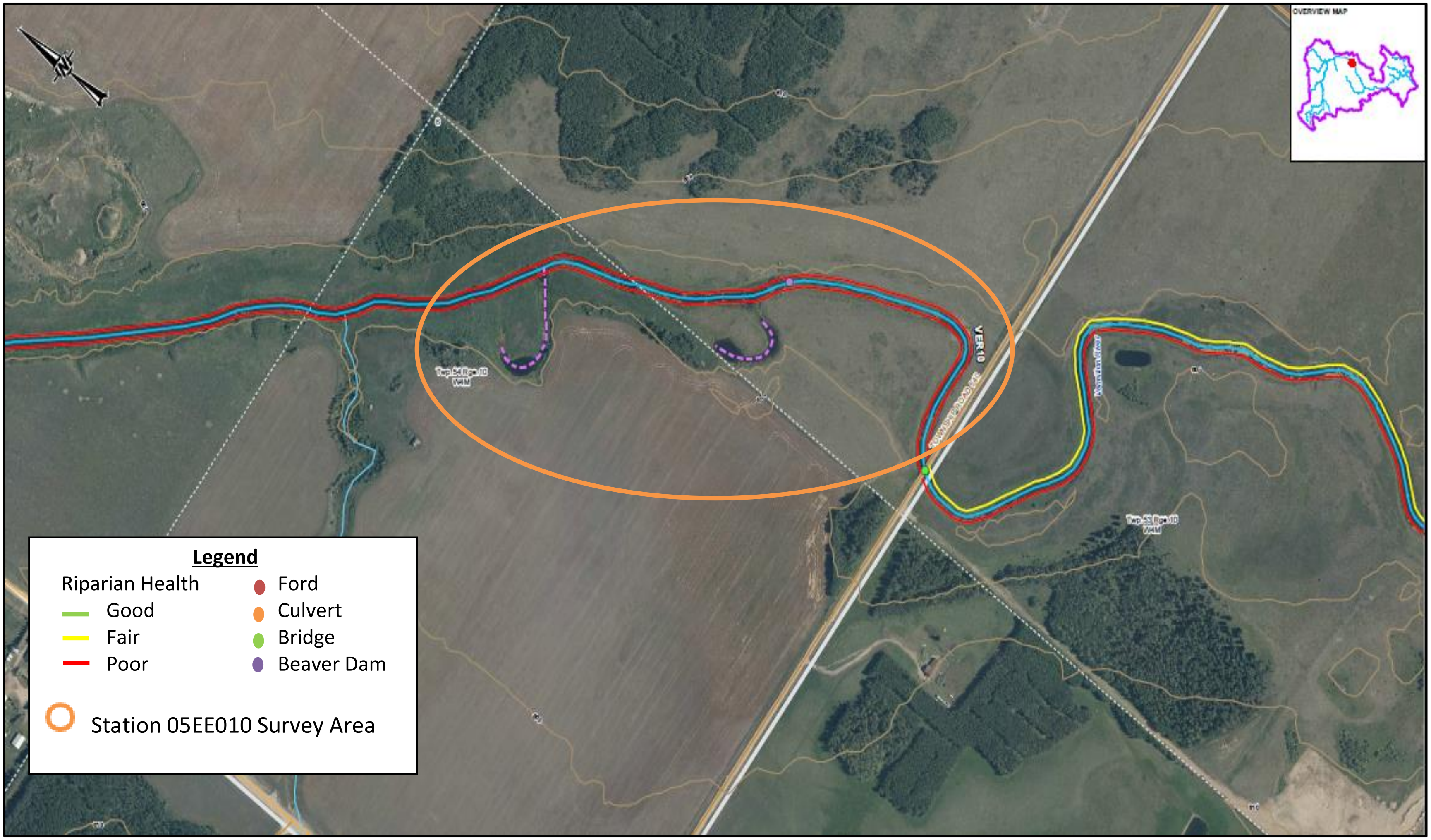


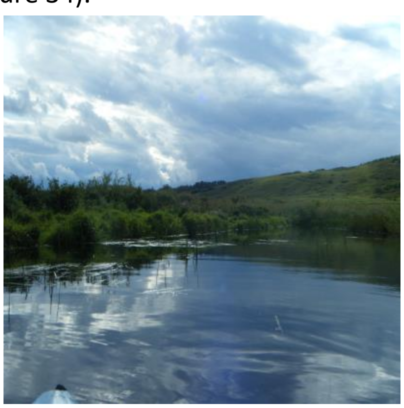
Figure 33: Riparian health at station 05EE010 (Golder 2016).

8.5 VER1

Station VER1 is located approximately 15km upstream of the Vermilion Reservoir. The habitat assessment revealed good riparian coverage for one side of the river and a large proportion of bank undercutting. The station is ranked as 3rd best in the habitat assessment and had the lowest FBI value (6.21). Riparian areas are an important feature for macro-invertebrate shredders, which was highest at station VER1 (5%) in comparison to the other stations that contained <3% of shredder families. Despite the good habitat features, aquatic surveys revealed the lowest percent capture of macro-invertebrates, which may be an indication of the higher concentration of predator invertebrates and invertivore fish. The predator macroinvertebrate feeding group is greatest (50%) at this station. The predator group is represented by true bug order within the Corixidae family, commonly known as water boatmen. Other predators include damselflies and fish such as the Lake chub, an invertivore that was at its highest (%) capture at station VER1. The station is also suitable for Northern pike, a top predator of aquatic ecosystems. Northern pike were not captured during the fish survey; however, the station has oxbow channels and smaller stream channels that are suitable for spawning and rearing juveniles. The VR reservoir is located approximately 8km downstream of station VER1, connecting valuable habitat for migrating fish.

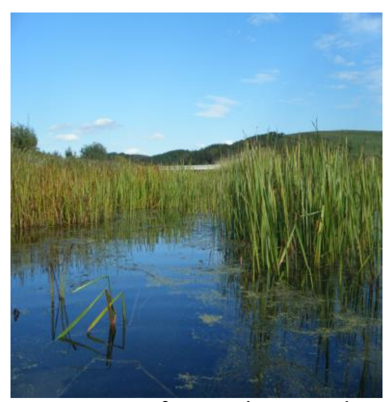
The macroinvertebrate community was unique at station VER1 in comparison to the others, due to the absence of crustaceans. Crustaceans are typically common invertebrates and were amongst the dominant captures at all other stations in the VR. Another possible reason for low macroinvertebrate captures is the river morphometry. The vegetation surveys revealed a steep slope from shore to the center of the stream, which confined macrophyte growth to the shorelines. Thus, limited shelter may be contributing to the low macro-invertebrate populations.

The water quality at this station was rated as ‘good’. Total phosphorus and nitrogen concentrations were 0.24 mg/L (‘good’) and 1.3 mg/L (‘excellent’) respectively. The lowest score for water quality was the concentration of dissolved oxygen at 7.03 (‘poor’) which was the second lowest measurement out of all the VR stations. The riparian health is poor on the north east side but good on the opposite bank (Figure 34).



View of good riparian health on the left stream side (CPPENV 2015).

View of poor riparian health on the right stream side (CPPENV 2015).



View of Giant bur-reed (*Sparganium eurycarpum*), the dominant plant species at station VER1 (CPPENV 2015).

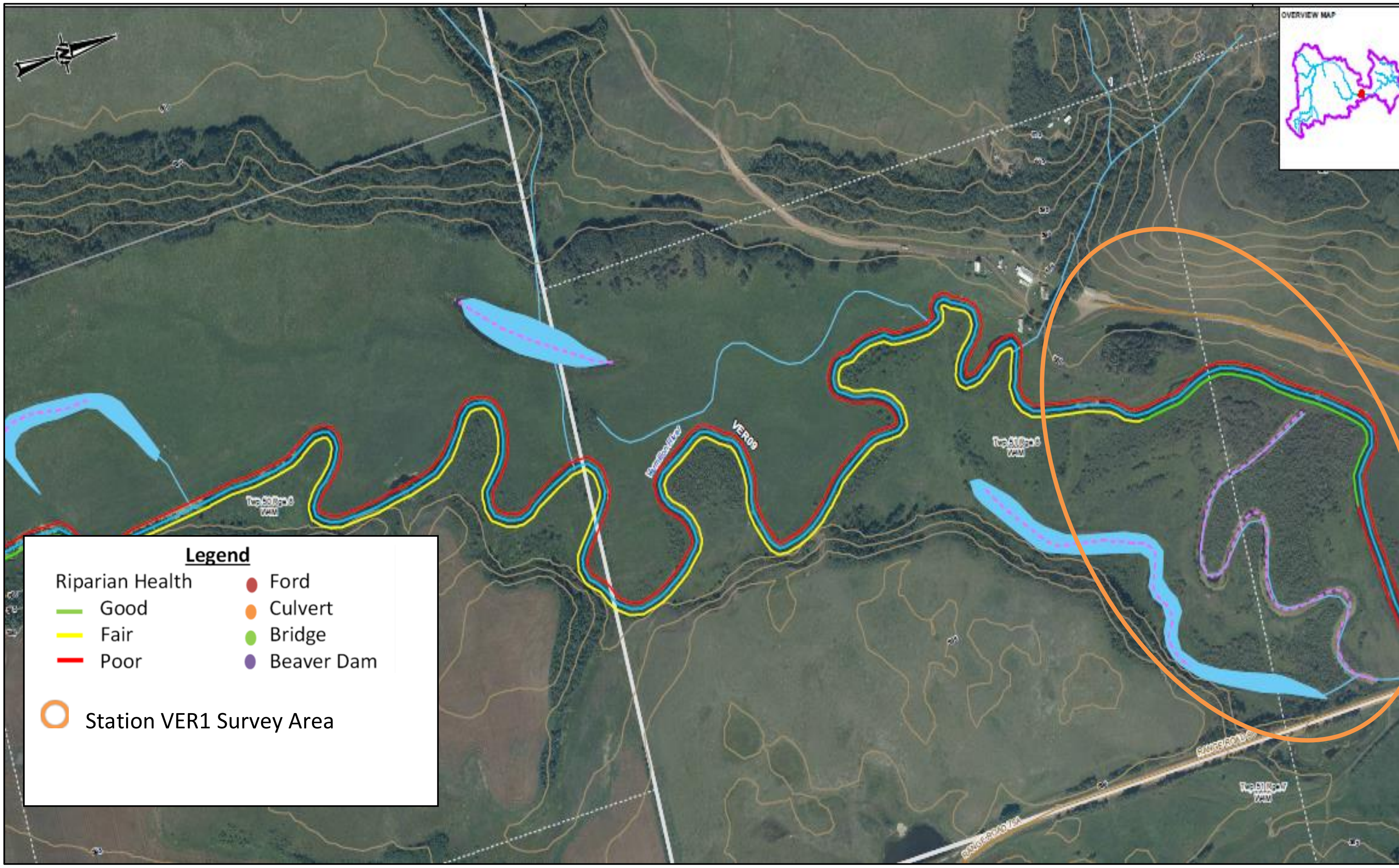


Figure 34: Riparian health at station VER1 (Golder 2016).

8.6 VER3

Station VER3 is located approximately 10km downstream of the Vermilion dam and reservoir. The habitat assessment ranked this station as the unhealthiest station in the VR. Uniform habitat features make this station similar to TWO2A and both have an overabundance of aquatic vegetation. Despite similar habitat features, aquatic assemblages varied at each site. The FBI score of 6.73 indicates that very substantial organic pollution is likely. Total phosphorus (0.42 mg/L) and nitrogen (2.4 mg/L) are high in general, and dissolved oxygen is the lowest of all stations. Riparian health surrounding the station is also poor (Golder 2016, Figure 35).

Macroinvertebrate sampling yielded an abundant population of Chironomidae (flies) and Caenidae (mayfly) families. It had the highest abundance of in the Gastropoda order, commonly known as snails and slugs. The station yielded 40% of all captured snails and slugs in the 2015 VR surveys, which are capable of tolerating low levels of dissolved oxygen, which was lowest at station VER3.

The concentration of dissolved oxygen (DO; 4.49 mg/L) was below short-term guidelines for the protection of aquatic life (AESRD 2014). Fish injury and mortality are associated with low DO and the overabundances of aquatic vegetation combined with low velocities are contributing to this problem. Northern pike begin seeking higher oxygen levels at concentrations less than 4 mg/L (Harvey 2009). Fish surveys at this station revealed a dominance of tolerant species and omnivores, primarily in the minnow family. Fish captures were difficult due to the abundance of aquatic vegetation and most stunted specimens were able to escape through the dense cover. Recent surveys completed by Lakeland College revealed similar species assemblages in the Vermilion Reservoir (Dr. Vytenis (Vee) Gotceitas, personal communication).

Station VER3 is an ideal site for aquatic vegetation growth since it is shallow (<80cm) and nutrient loading is available from nearby point sources (Town of Vermilion waste water treatment plant) and non-point sources (agricultural and urban runoff). The shallow water is susceptible to warmer water temperatures. Warm water temperatures, high oxygen demand from organics and respiration from primary consumers are likely the cause for low oxygen concentrations in the water (Golder 2007). Aquatic vegetation and algal growth can exert considerable oxygen demand during summer nights and during the winter when biomass decays (Goater et al. 2007). DO levels are also associated with water temperature (oxygen becomes less soluble at increased temperatures) and in shallow waters it is relatively consistent throughout the water column (CCME 1999).

Station VER3 yielded the highest % capture rate for snails and slugs, which are known to tolerate low dissolved oxygen levels by floating to the surface to breathe oxygen from the air (CCME 1999).

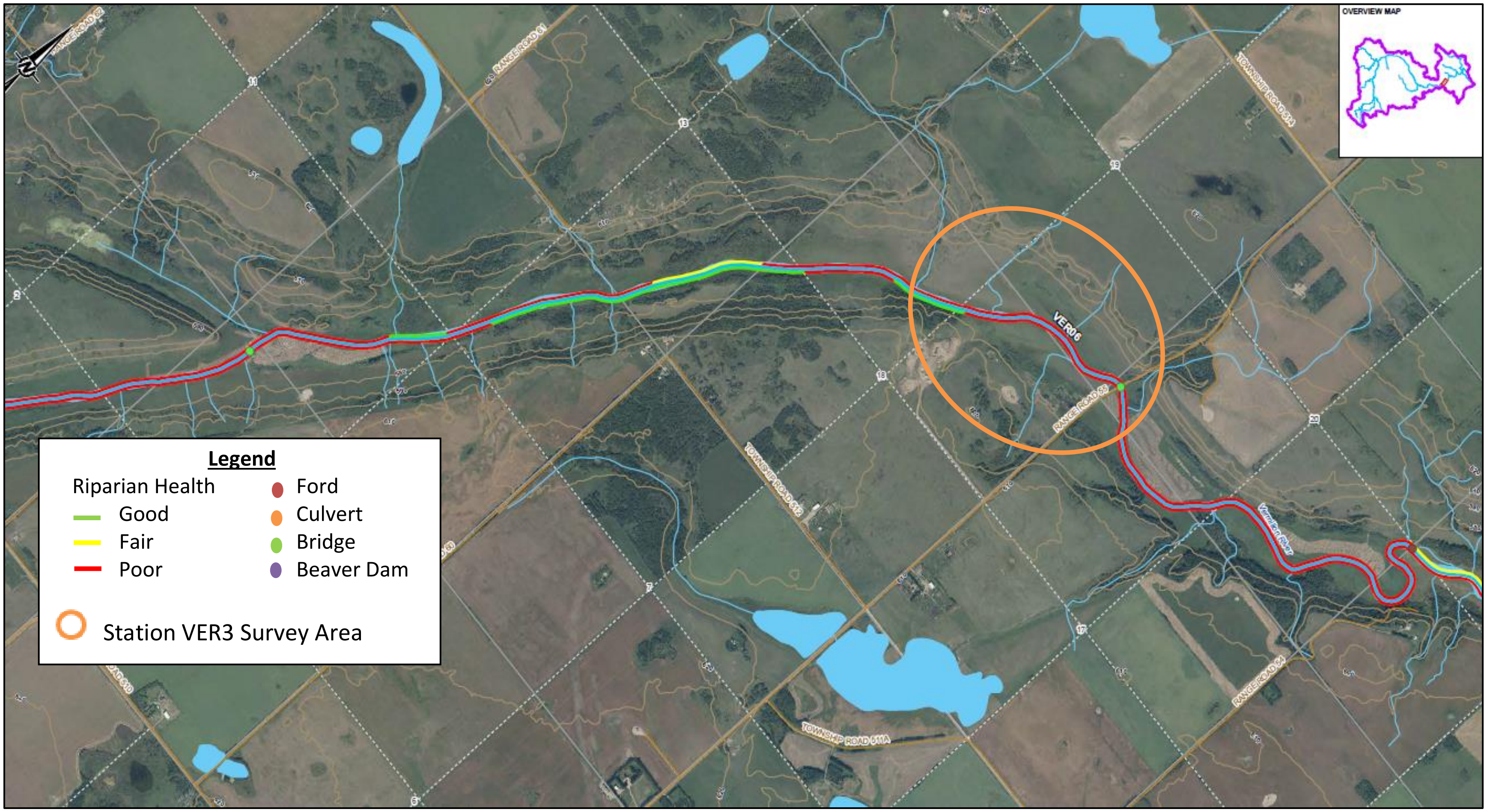


Figure 35: Riparian health at station VER3 (Golder 2016).

In late summer, flows were present in trace amounts at station VER3. Higher flows can reduce the impacts of nutrient loading from anthropogenic sources largely through dilution and transport to downstream areas. Higher flows dislodge organic sediments and aquatic vegetation and as a result will reduce oxygen demand (Goater et al. 2007). The management of the Vermilion Dam is critical for maintaining flow and fish habitat in the downstream sections.

The VR has a long history of water management in relation to water quality and fish populations (VR Operations Review 2000). Alberta Environment and Parks have responded to committee concerns by considering recommendations and committing to operate the VR dam to maximize benefits to the entire river system. The commitment to protect aquatic ecosystems has been expressed, however, it is unclear how management is occurring with respect to maintaining instream flow needs (IFN) (Weing et al. 2006). A requirement for maintaining or restoring healthy aquatic ecosystems is the protection or re-establishment of natural flow regimes. Determination of IFN may help manage streamflow to protect aquatic life (Goater et al. 2007).

View of the abundant aquatic vegetation at station VER3 (CPPENV 2015).

8.7 VER6

Station VER6 is furthest downstream on the VR and is located at the confluence with the North Saskatchewan River. It was ranked as the healthiest station due to diverse habitat features, including the presence of riffles and pools, abundant streamside vegetation and diverse substrate composition. The sequences of riffles and pools create significant fish habitat and--with the close proximity to the North Saskatchewan River-- the area offers significant fish spawning and rearing habitat not present at any other station.

Unlike the other VR stations, flow is present at VER6 during late summer. The activity of flow, presence of riffles and density of cobble substrate has created different fish assemblages not recorded at any other station. VER6 is ideal for specialized species such as the Longnose dace, Emerald shiner and Trout perch. All of these species have specialized adaptations for the type of habitat available such as the presence of velocity and riffles. Fish assemblage at station VER6 shifts from dominant tolerant species to intolerant species, which is most likely a result of more diverse habitat features and the proximity of the North Saskatchewan River to this station.

This station had the highest percentage of scrapers, which graze or scrape materials (periphyton) from mineral and organic substrates. Periphyton is the mixture of algae, cyanobacteria and detritus that is attached to the submerged rock surfaces and is also a food source for other species of invertebrates, fish and tadpoles (Plafkin et al 1989). Due to the active flow, finer substrates get dislodged downstream and the surface of larges cobbles is exposed to accumulate periphyton (Goater et al. 2007).

View of the abundant periphyton coverage over the cobble substrate at station VER6.

Overall, the total % capture of macro-invertebrates was low, likely as a result of high predation. The Northern Crayfish (*Orconectes virilis*), which was observed at station VER6, is known to contribute to lower macro-invertebrate populations. This may have resulted in in higher periphyton abundance (Lodge et al. 1994). Invertivore fish populations were also highest at this station and may also be a contributing factor in the low macro-invertebrate populations.

There is a large distance and a noticeable difference in water quality between stations VER3 and VER6. This reflects the internal cleansing function of the Vermilion River, but it also reflects the considerable amount of healthy riparian areas in the vicinity of VER6 (Figure 36).

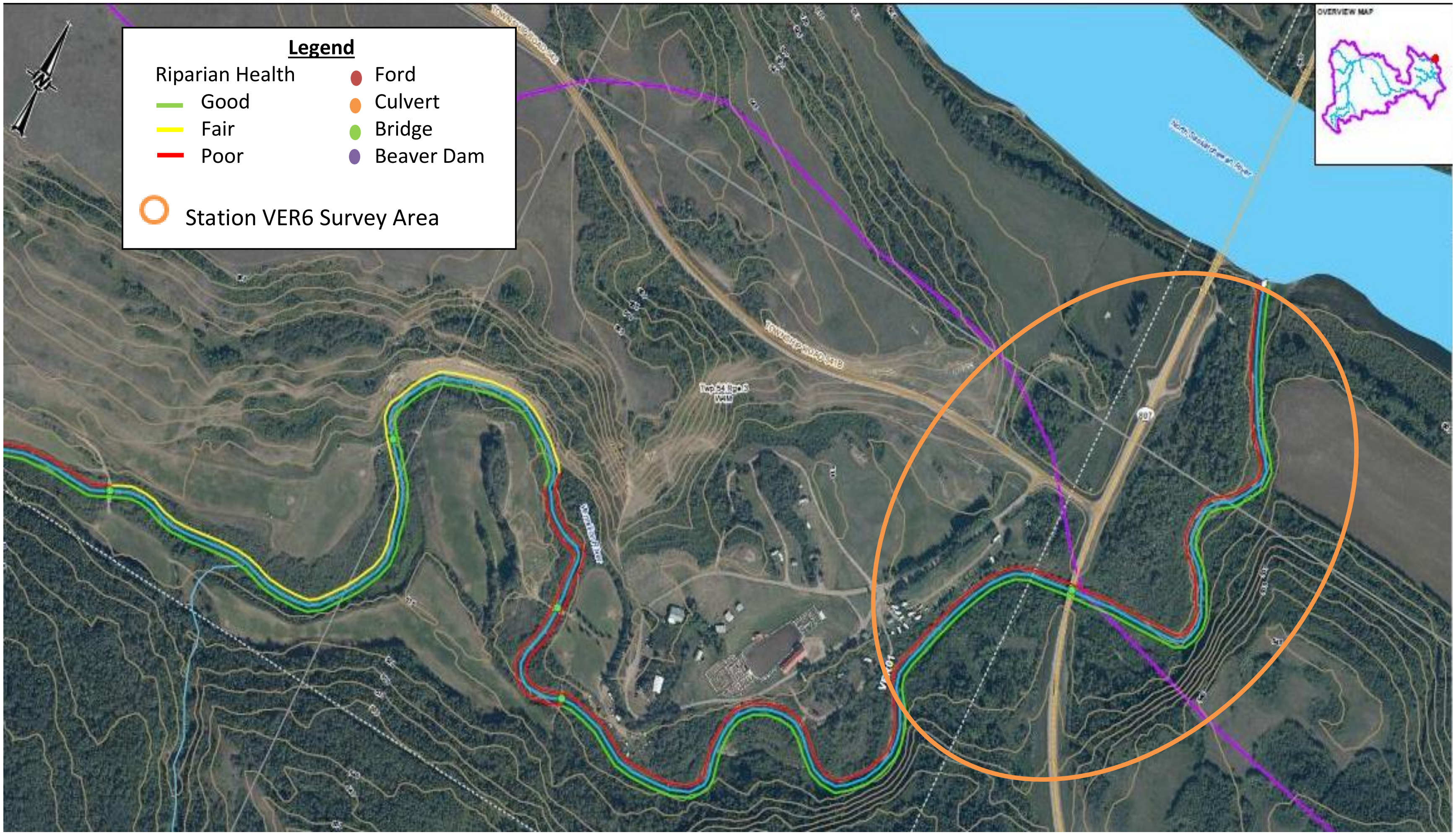


Figure 36: Riparian health at station VER6 (Golder 2016).

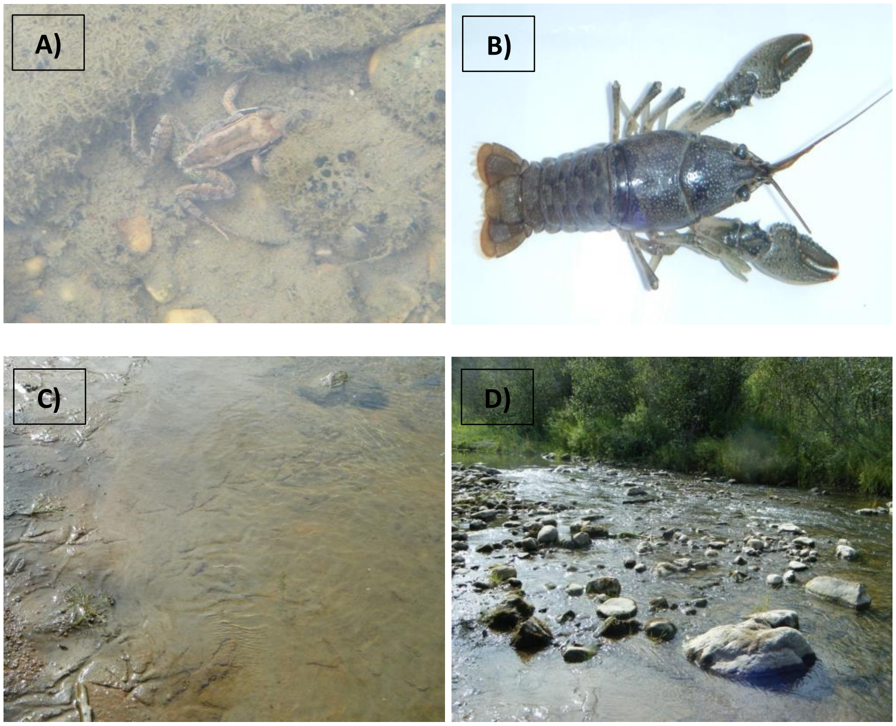


Photo A: Wood frog (*Lithobates sylvaticus)*

Photo B: Northern Crayfish (*Orconectes virilis)*; many were observed during electrofishing.

Photo C: Great Blue Heron tracks

Photo D: Diverse substrate at station VER6 with healthy riparian area surrounding stream

(All photos taken by CPPENV 2015)

9.0 Recommendations

This study is the first of its kind - documenting the aquatic ecosystem of the Vermilion River. However, it is a snapshot in time. We don't have a good understanding of aquatic ecosystem health in seasons other than late summer. We recommend further study of the river, in all seasons, to build off this report. Water quality sampling throughout the year would document the changes in the chemical environment as flows peak and drop in the spring and summer, respectively. Water quality sampling under ice in late winter would inform managers about the susceptibility of the ecosystem to winterkill due to low oxygen concentrations. Fish surveys in the spring would provide information about the importance of the river from a fish spawning perspective. This information will be critical for supporting the mandate of the Vermilion River Watershed Alliance's mandate of management planning of the Vermilion River Watershed.

Other recommendations are as follows:

1. Riparian areas and wetlands immediately adjacent to the river channel are very important to the health of the Vermilion River, particularly since areas that are sources of water (contributing areas) neighbour the river (see Section 2). These riparian areas and palustrine wetlands are generally in a poor state (Golder 2016), thereby providing little buffer to the nutrients and other pathogens produced by surrounding land uses. At most stations, cattle have direct access to the river, which can degrade riparian areas and contribute nutrients directly to the river. These

observations offer opportunities for the restoration and conservation of riparian areas around the Vermilion River.

2. We particularly recommend conservation of the lower portion (from the mouth up to the Town of Vermilion) of the Vermilion River. This section may be regionally important as fish spawning and rearing habitat for the North Saskatchewan River. Additionally, this section of the river has recreational and aesthetic significance with local residents.
3. Fragmentation of the Vermilion River has been documented by our study and by a recent assessment of riparian health (Golder, 2016). Barriers exist in the form of manmade ford crossings and dams. Culverts are also documented, but their state is currently unknown. Any opportunity to improve the connectivity of the river would be beneficial for aquatic ecosystem health. Fish populations are particularly sensitive to such barriers in flow. To have a healthy fish population, fish must be allowed to migrate to/from the regional fish species pool (i.e., the North Saskatchewan River) and to escape negative environmental conditions such as low oxygen concentrations (Danylchuk and Tonn, 2003).
4. Our study indicates that discharge from the City of Vermilion Wastewater Treatment Plant (WWTP) has a negative effect on the river in the form of nutrient enrichment, eutrophication, and critically low oxygen. We recommend that further water quality testing upstream and downstream of the WWTP be conducted to fully document the issue. Site specific water quality objectives for treatment could be derived using this data, which can then inform discussions on wastewater treatment management.

Finally, as management recommendations are implemented and improvements are made, we recommend re-sampling the aquatic ecosystems in the VR to measure progress. If the aquatic habitat quality assessment and scoring is completed using the same methods as those in this report, our data suggests that a score of 20 could be used as a target in the future. Although validation of this value would require a substantial sampling effort, which was beyond the scope of this study, a habitat score of 20 would be considered good habitat and an improvement overall. Aquatic habitat quality can be directly and indirectly improved through riparian management (which will improve shade, undercut banks, habitat diversity, and water quality), wetland restoration, and reductions in point and non-point nutrient loading to the river.

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Appendix A: Habitat Assessment

Table A-1: Physical metrics scoring from the habitat assessment at all five transects and total scores calculated to represent each station.

Station Name	Transect #	Shading		Macrophyte		Bank Undercutting				Organic Substrate		Habitat Diversity	
		% Cover	Score	% Cover	Score	Left	Score	Right	Score	% Cover	Score	Observation	Score
Bea1	1	6-25	2	0-25	1	>75	4	0-25	1	30	3	Fair	2
	2	0-5	1	0-25	1	25-50	2	0-25	1	20	4	Fair	2
	3	6-25	2	0-25	1	51-75	3	>75	4	30	3	Fair	2
	4	6-25	2	0-25	1	0-25	1	0-25	1	50	3	Poor	1
	5	0-5	1	0-25	1	25-50	2	0-25	1	45	3	Fair	2
Total Scores			8		5		12		8		16	Fair	9
Min2A	1	6-25	2	0-25	1	>75	4	>75	4	80	1	Good	3
	2	6-25	2	0-25	1	>75	4	>75	4	70	2	Fair	2
	3	6-25	2	0-25	1	>75	4	>75	4	80	1	Good	3
	4	6-25	2	26-50	2	25-50	2	0-25	1	80	1	Good	3
	5	6-25	2	0-25	1	25-50	2	0-25	1	80	1	Fair	2
Total Scores			10		6		16		14		6	Good	13
Two2A	1	0-5	1	76-100	4	0-25	1	0-25	1	100	1	Poor	1
	2	0-5	1	76-100	4	0-25	1	0-25	1	100	1	Poor	1
	3	0-5	1	76-100	4	0-25	1	0-25	1	100	1	Poor	1
	4	0-5	1	76-100	4	0-25	1	0-25	1	100	1	Poor	1
	5	0-5	1	76-100	4	0-25	1	0-25	1	100	1	Poor	1
Total Scores			5		20		5		5		5	Fair	5
05EE010	1	0-5	1	0-25	1	0-25	1	0-25	1	30	3	Poor	1
	2	0-25	1	26-50	2	0-25	1	0-25	1	40	3	Good	3
	3	6-25	2	26-50	2	0-25	1	0-25	1	20	4	Fair	2
	4	26-50	3	76-100	4	0-25	1	0-25	1	60	2	Good	3
	5	0-5	1	76-100	4	0-25	1	0-25	1	80	1	Poor	1
Total Scores			8		13		5		5		13	Good	10

Table A-1: Physical metric scoring continued

Station Name	Transect #	Shading		Macrophyte		Bank Undercutting				Organic Substrate		Habitat Diversity	
		% Cover	Score	% Cover	Score	Left	Score	Right	Score	% Cover	Score	Observation	Score
Ver1	1	26-50	3	51-75	3	26-50	2	26-50	2	50	3	Fair	2
	2	6-25	2	26-50	2	25-50	2	51-75	3	50	3	Fair	2
	3	26-50	3	26-50	2	51-75	3	51-75	3	50	3	Good	3
	4	26-50	3	0-25	1	51-75	3	>75	4	50	3	Good	3
	5	6-25	2	0-25	1	51-75	3	51-75	3	75	2	Good	3
Total Scores			13		9		13		15		14	Good	13
Ver3	1	0-5	1	76-100	4	0-25	1	0-25	1	100	1	Poor	1
	2	0-5	1	76-100	4	0-25	1	0-25	1	100	1	Poor	1
	3	0-5	1	76-100	4	0-25	1	0-25	1	100	1	Poor	1
	4	0-5	1	76-100	4	0-25	1	0-25	1	80	1	Poor	1
	5	0-5	1	76-100	4	0-25	1	0-25	1	80	1	Poor	1
Total Scores			5		20		5		5		5	Fair	5
Ver6	1	26-50	3	0-25	1	0-25	1	26-50	3	5	4	Good	3
	2	6-25	2	0-25	1	0-25	1	0-25	1	30	3	Good	3
	3	6-25	2	26-50	2	0-25	1	0-25	1	25	4	Excellent	4
	4	6-25	2	26-50	2	0-25	1	0-25	1	0	4	Good	3
	5	26-50	3	26-50	2	0-25	1	0-25	1	0	4	Excellent	4
Total Scores			12		8		5		7		19	Good	17

Table A-2: Total phosphorus, total nitrogen and dissolved oxygen average concentrations from 2014-2015 (Aug, Sept, Oct) in the VR, including percentages and ranges used for habitat index scoring.

Station	Average of 2014-2015 (Aug, Sept, Oct)		
	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)	Dissolved Oxygen (mg/L)
BEA1	0.56	4.8	8.13
MIN2A	0.52	2.4	7.34
TWO2A	0.21	3.1	8.01
05EE010	0.09	1.5	9.69
VER1	0.40	1.9	6.95
VER3	0.40	2.6	5.71
VER6	0.10	1.1	9.31
Percentiles			
Percentile 25th	0.2	1.7	7.1
Percentile 50th	0.4	2.4	8.01
Percentile 75th	0.46	2.85	8.72
Final Ranges			
Poor (1)	0.46-0.56	2.8-4.8	≤7.15
Fair (2)	0.40-0.45	2.5-2.8	7.16-8
Good (3)	0.17-0.39	1.8-2.4	8.01-8.98
Excellent (4)	≤0.16	≤1.7	8.99-9.69

Table A-3: Bank stability assessments indicating the level of erosion at each transect on the VR.

Station Name	Transect #	Bank Stability Observation	
		Left	Right
Bea1	1	stable	moderate
	2	unstable	moderate
	3	low	moderate
	4	moderate	moderate
	5	moderate	moderate
Min2A	1	stable	stable
	2	stable	stable
	3	unstable	stable
	4	stable	unstable
	5	stable	stable
Ver1	1	moderate	stable
	2	stable	stable
	3	moderate	stable
	4	stable	moderate
	5	moderate	moderate
Ver6	1	stable	stable
	2	moderate	stable
	3	stable	low
	4	moderate	moderate
	5	moderate	stable
Two2A	1	unstable	stable
	2	stable	stable
	3	stable	stable
	4	stable	stable
	5	stable	stable
05EE010	1	low	low
	2	low	low
	3	low	stable
	4	low	stable
	5	stable	stable
Ver3	1	moderate	moderate
	2	moderate	moderate
	3	low	moderate
	4	low	moderate
	5	low	moderate

*stable = > 90% of the bank is vegetated
*moderate = 50-90% of the bank is vegetated
*low stability = <50% of the bank is covered with vegetation
*unstable = <25% of the bank is exposed and massive bank slumping is occurring

The photo above shows unstable banks on the VR caused by human and bison disturbance (Source: Google 2010).

The photo above represents slope erosion caused by natural elements and instream flows. This picture is on Transect 5 at station VER6 facing upstream (Source: CPPENV 2015).

Table A-4: Other physical metrics surveyed in the habitat assessment. Station MIN2A was too deep for visual observation, hence some metrics were not scored (N/A).

Station Name	Transect #	Streamside Vegetation (%)			Bottom Type	Substrate Embeddedness	Periphyton Coverage
		grasses	shrubs	trees			
Bea1	1	30	70	-	soft	>75	1
	2	85	15	-	hard	<25	3
	3	85	15	-	hard	25-50	2
	4	15	85	-	soft	51-75	2
	5	95	5	-	soft	51-75	2
Min2A	1	50	50	-	N/A	N/A	N/A
	2	25	75	-	N/A	N/A	N/A
	3	25	75	-	N/A	N/A	N/A
	4	50	50	-	N/A	N/A	N/A
	5	40	60	-	N/A	N/A	N/A
Two2A	1	100	0	-	V. soft	N/A	N/A
	2	100	0	-	V. soft	N/A	N/A
	3	100	0	-	V. soft	N/A	N/A
	4	100	0	-	V. soft	N/A	N/A
	5	100	0	-	V. soft	N/A	N/A
05EE010	1	100	0	-	soft	25-50	3
	2	100	0	-	soft	<25	3
	3	95	5	-	soft	25-50	3
	4	60	40	-	soft	25-50	2
	5	100	0	-	soft	<25	N/A
Ver1	1	40	60	-	soft	N/A	N/A
	2	80	20	-	soft	N/A	N/A
	3	40	70	-	soft	N/A	N/A
	4	60	40	-	soft	N/A	N/A
	5	50	50	-	soft	N/A	N/A
Ver3	1	100	0	-	V. soft	N/A	N/A
	2	100	0	-	V. soft	N/A	N/A
	3	100	0	-	V. soft	N/A	N/A
	4	100	0	-	V. soft	N/A	N/A
	5	100	0	-	V. soft	N/A	N/A
Ver6	1	53	45	2	Hard	51-75	2
	2	50	50	0	Hard	>75	2
	3	50	50	0	Hard	25-50	2
	4	40	60	0	Hard	25-50	2
	5	40	50	10	hard	51-75	2

Table A-4: Water quality results from field measurements and laboratory analyses (2015). Samples were taken September 10 -15, 2015.

Parameters		Water Quality Stations						
Field Measurements	**UNITS**	**BEA 1**	**MIN 2A**	**TWO 2A**	**05EE010**	**VER1**	**VER 3**	**VER6**
Temperature	°C	13.2	12.3	12.9	14	13.6	13.1	11.9
Conductivity	(mS/cm)	618	1069	1273	938	1287	1190	881
Oxygen	mg/L	7.48	6.16	8.59	10.47	7.03	4.49	7.94
pH	-	9.5	8.15	8.5	8.15	8.33	8.28	7.61
Misc. Inorganics								
Total Suspended Solids	mg/L	68	9.3	9.3	6	2	6	2.7
Nutrients								
Total Nitrogen	mg/L	11	1.7	3.4	1.1	1.3	2.4	0.79
Total Phosphorus	mg/L	0.97	0.25	0.13	0.025	0.24	0.42	0.045
Dissolved Nitrite	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	0.038	<0.010
Dissolved Nitrate	mg/L	<0.010	<0.010	<0.010	0.066	<0.010	0.01	<0.010
Dissolved Phosphorus	mg/L	0.39	0.15	0.081	0.009	0.22	0.34	0.012
Dissolved Nitrogen	mg/L	3.8	1.3	2.9	0.95	1.3	2	0.73

Appendix B: River Morphometry

Table B-1: Aquatic vegetation survey results at station BEA1 on August 31, 2015.

Transect	Quadrat	Water Depth (cm)	Dominant Substrate	Second Substrate	Plant Species	Percent Cover
1	0-1	6	OM	GR/CO	grass	25-50
	1-2	41	OM	GR/CO	no veg	-
	2-3	65	OM	GR/CO	no veg	-
	3-4	80	OM	GR/CO	no veg	-
	4-5	90	OM	GR/CO	no veg	-
	5-6	92	OM	GR/CO	no veg	-
	6-7	76	OM	GR/CO	no veg	-
	7-8	58	OM	GR/CO	no veg	
	8-9	35	OM	GR/CO	no veg	-
	9-10	11	OM	GR/CO	no veg	-
2	0-1	0	OM	GR/CO	no veg	-
	1-2	23	GR/CO	OM	no veg	-
	2-3	27	CO	OM	no veg	-
	3-4	30	CO	OM	no veg	-
	4-5	44	CO	OM	no veg	-
	5-6	64	CO	OM	no veg	-
	6-7	33	OM	CO	no veg	-
3	0-1	17	OM	CO	Northern water milfoil	1-25
	1-2	23	CO	OM	no veg	-
	2-3	23	CO	OM	Northern water milfoil	1-25
	3-4	27	CO/GR	-	no veg	-
	4-5	35	GR	OM	no veg	-
	5-6	28	CO/GR	OM	Water sedge	-
					Tall manna grass	-

Transect	Quadrat	Water Depth (cm)	Dominant Substrate	Second Substrate	Plant Species	Percent Cover
4	0-1	6	OM	CO	Water sedge	-
	1-2	25	OM	GR	no veg	-
	2-3	34	OM	GR	Northern water milfoil	1-25
					Richardson's pondweed	1-25
	3-4	32	OM	GR	no veg	-
	4-5	12	OM	CO	no veg	-
5	0-1	6	OM	-	Common duckweed	1-25
					Water sedge	1-25
	1-2	25	OM	GR	no veg	-
	2-3	46	OM	GR	no veg	-
	3-4	53	GR	OM	no veg	-
	4-5	57	OM/GR	-	no veg	-
	5-6	56	OM/GR	-	no veg	-
	6-7	47	OM/GR	-	no veg	-
	7-8	22	OM	GR	no veg	-

<u>Substrate Acronyms</u>

OM = Organic Matter

GR= Gravel

CO=cobble

SA= sand

Table B-2: Vegetation survey results at station MIN2A on September 1, 2015.

Transect	Quadrat	Water Depth (cm)	Dominant Substrate	Second Substrate	Plant Species	Percent Cover
1	0-1	30	OM	-	Sago pondweed	50-75
					Arum-leaved arrowhead	1-25
					Common Duckweed	1-25
	1-2	74	OM	-	Sago pondweed	25-50
					Canada waterweed	1-25
	2-3	100	OM	-	Sago pondweed	50-75
					Canada waterweed	1-25
					Common Duckweed	1-25
	3-4	114	OM	-	Canada waterweed	25-50
					Slender pondweed	1-25
	4-5	115	OM	-	Slender pondweed	1-25
	5-6	116	OM	-	Slender pondweed	1-25
	6-7	122	OM	-	Canada waterweed	1-25
	7-8	120	OM	-	no veg	-
	8-9	103	OM	-	Sago pondweed	1-25
	9-10	75	OM	-	Canada waterweed	1-25
					Common Duckweed	1-25
					Nodding beggarticks	1-25
2	0-1	82	OM	-	Common Duckweed	25-50
	1-2	110	OM	-	no veg	-
	2-3	152	OM	GR	no veg	-
	3-4	172	OM	GR	no veg	-
	4-5	145	OM	-	no veg	-
	5-6	97	OM	-	Northern water milfoil	25-50
	6-7	46	OM	-	Northern water milfoil	1-25
					Common Duckweed	1-25
3	0-1	30	OM	-	Common Duckweed	1-25
	1-2	118	OM	-	Northern water milfoil	25-50
					Common Duckweed	1-25
	2-3	145	OM		no veg	-
	3-4	170	OM	-	no veg	-
	4-5	185	OM	-	no veg	-
	5-6	183	OM	-	no veg	
	6-7	140	OM	-	no veg	-
	7-8	110	OM	-	Common Duckweed	1-25
4	0-1	73	OM	-	Slender pondweed	25-50
	1-2	140	OM	-	no veg	-
	2-3	168	OM	-	no veg	-
	3-4	169	OM	-	no veg	-
	4-5	230	unknown	-	no veg	-
	5-6	232	unknown	-	no veg	-
	6-7	215	unknown	-	no veg	-
	7-8	195	unknown	-	no veg	-
	8-9	141	OM	-	Northern water milfoil	25-50
					Common Duckweed	25-50
					Sago pondweed	25-50
	9-10	122	OM	-	Arum-leaved arrowhead	1-25
					Common Duckweed	25-50

Table B-2:MIN2A continued

Transect	Quadrat	Water Depth (cm)	Dominant Substrate	Second Substrate	Plant Species	Percent Cover
4	9-10	122	OM	-	Northern Water Milfoil	25-50
					Slender pondweed	75-100
	10-11	80	OM	-	Common duckweed	1-25
					Northern Water Milfoil	25-50
					Arum-leaved arrowhead	1-25
	11-12	45	OM	-	Sago pondweed	50-75
					Common duckweed	25-50
					Arum-leaved arrowhead	1-25
5	0-1	68	OM	-	Common Duckweed	1-25
					Arum-leaved arrowhead	1-25
					Northern water milfoil	1-25
	1-2	92	OM	-	Northern water milfoil	1-25
	2-3	112	OM	-	no veg	-
	3-4	163	OM	-	no veg	-
	4-5	165	OM	-	no veg	-
	5-6	164	OM	-	no veg	-

Table B-3: Vegetation survey results at station TWO2A on September 9, 2015. Note only transects 1, 3 & 5 were surveyed at this station.

Transect	Quadrat	Water Depth (cm)	Dominant Substrate	Second Substrate	Plant Species	Percent Cover
1	0-1	0	OM	-	Common Cattail	25-50
	1-2	5	OM	-	Sago Pondweed	25-50
					Northern water milfoil	25-50
					Coontail	1-25
					Ivy-leaved duckweed	1-25
					Common duckweed	1-25
	3-4	26	OM	-	Sago Pondweed	1-25
					Ivy-leaved duckweed	1-25
					Common duckweed	1-25
	5-6	44	OM	-	Ivy-leaved duckweed	25-50
					Coontail	1-25
					Northern water milfoil	1-25
					Common duckweed	1-25
	7-8	45	OM	-	Ivy-leaved duckweed	1-25
					Slender pondweed	1-25
					Coontail	1-25
					Richardson's Pondweed	1-25
					Northern water milfoil	1-25
					Common duckweed	1-25
	9-10	49	OM	-	Northern water milfoil	25-50
					Sago Pondweed	1-25
					Ivy-leaved duckweed	1-25
					Common duckweed	1-25
	11-12	60	OM	-	Ivy-leaved duckweed	1-25
					Coontail	1-25
					Northern water milfoil	1-25
					Sago Pondweed	1-25
	13-14	57	OM	-	Sago Pondweed	25-50
					Northern water milfoil	1-25
					Ivy-leaved duckweed	1-25
					Slender pondweed	1-25
					Coontail	1-25
					Common duckweed	1-25
	15-16	60	OM	-	Northern water milfoil	50-75
					Sago Pondweed	1-25
					Ivy-leaved duckweed	1-25
					Common duckweed	1-25
	17-18	61	OM	-	Sago Pondweed	25-50
					Northern water milfoil	50-75
					Ivy-leaved duckweed	1-25

Transect	Quadrat	Water Depth (cm)	Dominant Substrate	Second Substrate	Plant Species	Percent Cover
1	19-20	61	OM	-	Sago Pondweed	25-50
					Richardson's Pondweed	1-25
					Northern water milfoil	25-50
					Filamentous algae	1-25
					Ivy-leaved duckweed	1-25
					Coontail	1-25
					Slender pondweed	1-25
	21-22	73	OM	-	Northern water milfoil	1-25
					Sago Pondweed	1-25
					Ivy-leaved duckweed	1-25
					Slender pondweed	1-25
	23-24	73	OM	-	Northern water milfoil	1-25
					Ivy-leaved duckweed	1-25
	25-26	90	OM	-	Northern water milfoil	1-25
					Sago Pondweed	1-25
					Coontail	1-25
					Ivy-leaved duckweed	1-25
					Slender pondweed	1-25
	27-28	97	OM	-	Northern water milfoil	1-25
					Slender pondweed	1-25
					Coontail	1-25
					Ivy-leaved duckweed	1-25
	29-30	100	OM	-	Northern water milfoil	1-25
					Ivy-leaved duckweed	25-50
					Coontail	1-25
					Common duckweed	1-25
	31-32	94	OM	-	Sago Pondweed	1-25
					Ivy-leaved duckweed	1-25
					Coontail	1-25
					Northern water milfoil	1-25
	33-34	91	OM	-	Northern water milfoil	1-25
					Sago Pondweed	1-25
					Slender pondweed	1-25
					Coontail	1-25
					Ivy-leaved duckweed	1-25
	35-36	84	OM	-	Coontail	1-25
					Ivy-leaved duckweed	1-25
					Richardson's Pondweed	1-25
	37-38	75	OM	-	Northern water milfoil	25-50

Table B-3: StationTWO2A continued

Transcect	Quadrat	Water Depth (cm)	Dominant Substrate	Second Substrate	Plant Species	Percent Cover
1	37-38	75	OM	-	Ivy-leaved duckweed	1-25
					Richardson's Pondweed	1-25
	39-40	70	OM	-	Northern water milfoil	50-75
					Richardson's Pondweed	1-25
					Slender pondweed	1-25
					Ivy-leaved duckweed	1-25
					Coontail	1-25
	41-42	25	OM	GR	Northern water milfoil	50-75
					Common duckweed	1-25
					Slender pondweed	1-25
					Richardson's Pondweed	1-25
	42-43	15	OM	GR/CO	Common Cattail	25-50
					Slender pondweed	1-25
					Northern water milfoil	25-50
					Richardson's Pondweed	1-25
					Common duckweed	1-25
					Ivy-leaved duckweed	1-25
3	0-1	0	OM	-	Common Cattail	1-25
	1-2	14	OM	-	Common Cattail	1-25
					Northern water milfoil	50-75
	2-3	9	OM	-	Northern water milfoil	75-100
					Sago Pondweed	1-25
	4-5	45	OM	-	Ivy-leaved duckweed	25-50
					Northern water milfoil	50-75
					Slender pondweed	1-25
					Coontail	1-25
					Sago Pondweed	1-25
	6-7	52	OM	-	Ivy-leaved duckweed	25-50
					Northern water milfoil	1-25
					Coontail	1-25
	8-9	56	OM	-	Northern water milfoil	50-75
					Ivy-leaved duckweed	1-25
					Slender pondweed	1-25
					Richardson's Pondweed	1-25
					Coontail	1-25
	10-11	59	OM	-	Northern water milfoil	25-50
					Slender pondweed	1-25
					Ivy-leaved duckweed	1-25
					Coontail	1-25
					Filamentous algae	1-25

Transect	Quadrat	Water Depth (cm)	Dominant Substrate	Second Substrate	Plant Species	Percent Cover
3	12-13	56	OM	-	Northern water milfoil	25-50
					Slender pondweed	1-25
			OM	-	Coontail	1-25
					Ivy-leaved duckweed	1-25
	14-15	60	OM	-	Sago Pondweed	25-50
					Coontail	25-50
					Ivy-leaved duckweed	1-25
					Richardson's Pondweed	1-25
					Northern water milfoil	1-25
	16-17	60	OM	-	Northern water milfoil	25-50
					Richardson's Pondweed	1-25
					Ivy-leaved duckweed	1-25
					Coontail	25-50
	18-19	58	OM	-	Richardson's Pondweed	75-100
					Ivy-leaved duckweed	1-25
					Filamentous algae	1-25
					Coontail	25-50
					Northern water milfoil	1-25
	20-21	65	OM	-	Filamentous algae	25-50
					Richardson's Pondweed	75-100
					Northern water milfoil	50-75
					Coontail	1-25
	22-23	75	OM	-	Richardson's Pondweed	50-75
					Sago Pondweed	25-50
					Northern water milfoil	25-50
					Coontail	1-25
	24-25	80	OM	-	Richardson's Pondweed	75-100
					Northern water milfoil	25-50
					Coontail	1-25
					Filamentous algae	1-25
	26-27	92	OM	-	Sago Pondweed	1-25
					Richardson's Pondweed	25-50
					Coontail	25-50
					Filamentous algae	1-25
					Ivy-leaved duckweed	1-25
	28-29	97	OM	-	Sago Pondweed	25-50
					Richardson's Pondweed	1-25
					Northern water milfoil	1-25
					Coontail	1-25
					Ivy-leaved duckweed	1-25
	30-31	92	OM	-	Slender pondweed	1-25
					Ivy-leaved duckweed	1-25

Table B-3: Station TWO2A continued

Transect	Quadrat	Water Depth (cm)	Dominant Substrate	Second Substrate	Plant Species	Percent Cover
3	30-31	92	OM	-	Coontail	1-25
					Richardson's Pondweed	1-25
					Sago Pondweed	1-25
	32-33	98	OM	-	Sago Pondweed	1-25
					Northern water milfoil	25-50
					Ivy-leaved duckweed	1-25
					Coontail	1-25
	34-35	82	OM	-	Richardson's Pondweed	1-25
					Northern water milfoil	75-100
					Ivy-leaved duckweed	1-25
					Coontail	1-25
	36-37	63	OM	-	Northern water milfoil	25-50
					Ivy-leaved duckweed	1-25
					Richardson's Pondweed	25-50
	37-38	50	OM	-	Northern water milfoil	25-50
					Richardson's Pondweed	25-50
					Slender pondweed	1-25
	38-39	35	OM	-	Richardson's Pondweed	25-50
					Northern water milfoil	25-50
					Slender pondweed	1-25
	39-40	31	OM	-	Common Cattail	1-25
					Richardson's Pondweed	25-50
					Sago Pondweed	1-25
					Northern water milfoil	25-50
					Slender pondweed	1-25
	40-41	17	OM	-	Common Cattail	25-50
					Northern water milfoil	25-50
					Richardson's Pondweed	1-25
					Sago Pondweed	1-25
	41-42	9	OM	-	Common Cattail	50-75
					Sago Pondweed	1-25
					Richardson's Pondweed	1-25
5	0-1	20	OM	-	Richardson's Pondweed	25-50
					Sago Pondweed	25-50
					Northern water milfoil	25-50
	1-2	24	OM	-	Richardson's Pondweed	25-50
					Northern water milfoil	50-75
					Filamentous algae	25-50
					Ivy-leaved duckweed	1-25
	2-3	27	OM	-	Richardson's Pondweed	1-25
					Ivy-leaved duckweed	1-25

Transect	Quadrat	Water Depth (cm)	Dominant Substrate	Second Substrate	Plant Species	Percent Cover
5	2-3	27	OM	-	Northern water milfoil	50-75
	3-4	33	OM	-	Northern water milfoil	50-75
					Filamentous algae	50-75
					Richardson's Pondweed	25-50
					Ivy-leaved duckweed	1-25
					Coontail	1-25
	4-5	37	OM	-	Ivy-leaved duckweed	50-75
					Richardson's Pondweed	1-25
					Northern water milfoil	25-50
					Coontail	1-25
	5-6	48	OM	-	Richardson's Pondweed	50-75
					Northern water milfoil	50-75
					Ivy-leaved duckweed	25-50
					Coontail	25-50
					Filamentous algae	1-25
	6-7	47	OM	-	Richardson's Pondweed	75-100
					Coontail	1-25
					Northern water milfoil	1-25
					Ivy-leaved duckweed	1-25
					Sago Pondweed	1-25
	7-8	48	OM	-	Ivy-leaved duckweed	1-25
					Coontail	25-50
					Richardson's Pondweed	25-50
					Northern water milfoil	50-75
	8-9	55	OM	-	Coontail	25-50
					Filamentous algae	25-50
					Richardson's Pondweed	50-75
					Northern water milfoil	25-50
					Ivy-leaved duckweed	50-75
	9-10	50	OM	-	Richardson's Pondweed	50-75
					Coontail	50-75
					Northern water milfoil	25-50
					Ivy-leaved duckweed	1-25
	10-11	55	OM	-	Richardson's Pondweed	75-100
					Filamentous algae	1-25
					Northern water milfoil	25-50
					Coontail	1-25
					Ivy-leaved duckweed	1-25
	11-12	52	OM	-	Richardson's Pondweed	75-100
					Coontail	1-25
					Northern water milfoil	1-258
					Ivy-leaved duckweed	1-25

Table B-3: Station TWO2A continued

Transect	Quadrat	Water Depth (cm)	Dominant Substrate	Second Substrate	Plant Species	Percent Cover
5	11-12	52	OM	-	Sago Pondweed	1-25
	12-13	56	OM	-	Richardson's Pondweed	75-100
					Northern water milfoil	1-25
					Coontail	1-25
					Sago Pondweed	25-50
	13-14	60	OM	-	Richardson's Pondweed	50-75
					Coontail	25-50
					Northern water milfoil	50-75
					Ivy-leaved duckweed	1-25
					Filamentous algae	1-25
	14-15	60	OM	-	Ivy-leaved duckweed	1-25
					Richardson's Pondweed	50-75
					Coontail	1-25
					Northern water milfoil	25-50
	15-16	60	OM	-	Coontail	1-25
					Northern water milfoil	25-50
					Ivy-leaved duckweed	1-25
					Richardson's Pondweed	1-25
					Slender pondweed	1-25
	16-17	60	OM	-	Richardson's Pondweed	75-100
					Ivy-leaved duckweed	1-25
					Northern water milfoil	1-25
					Coontail	1-25
					Filamentous algae	1-25
	17-18	60	OM	-	Richardson's Pondweed	50-75
					Coontail	1-25
					Ivy-leaved duckweed	1-25
					Northern water milfoil	50-75
					Filamentous algae	1-25
					Sago Pondweed	1-25
	18-19	70	OM	-	Richardson's Pondweed	75-100
					Northern water milfoil	50-75
					Coontail	1-25
					Ivy-leaved duckweed	1-25
	19-20	70	OM	-	Filamentous algae	1-25
					Northern water milfoil	75-100
					Richardson's Pondweed	75-100
					Coontail	1-25
	20-21	70	OM	-	Filamentous algae	1-25
					Northern water milfoil	75-100
					Richardson's Pondweed	75-100

Transect	Quadrat	Water Depth (cm)	Dominant Substrate	Second Substrate	Plant Species	Percent Cover
5	21-22	80	OM	-	Northern water milfoil	25-50
				-	Richardson's Pondweed	25-50
					Sago Pondweed	1-25
					Sago Pondweed	1-25
	22-23	90	OM	-	Northern water milfoil	1-25
					Coontail	25-50
					Northern water milfoil	25-50
	23-24	93	OM	-	Sago Pondweed	1-25
					Ivy-leaved duckweed	1-25
					Coontail	1-25
					Filamentous algae	1-25
					Sago Pondweed	1-25
	24-25	90	OM	-	Northern water milfoil	1-25
					Coontail	1-25
					Northern water milfoil	1-25
	26-27	92	OM	-	Sago Pondweed	1-25
					Coontail	1-25
					Slender pondweed	1-25
					Sago Pondweed	1-25
	28-29	92	OM	-	Coontail	1-25
					Richardson's Pondweed	1-25
	30-31	92	OM	-	Sago Pondweed	1-25
					Coontail	1-25
					Northern water milfoil	1-25
					Slender pondweed	1-25
					Richardson's Pondweed	1-25
	32-33	93	OM	-	Slender pondweed	1-25
					Northern water milfoil	25-50
					Northern water milfoil	1-25
	34-35	93	OM	-	Ivy-leaved duckweed	1-25
					Northern water milfoil	25-50
	36-37	81	OM	-	Richardson's Pondweed	1-25
					Richardson's Pondweed	25-50
	38-39	60	OM	-	Northern water milfoil	75-100
					Slender pondweed	1-25
					Sago Pondweed	1-25
					Richardson's Pondweed	50-75
	40-41	45	OM	-	Northern water milfoil	75-100
					Slender pondweed	1-25
					Northern water milfoil	75-100
	42-43	15	OM	-	Richardson's Pondweed	50-75
					Common Cattail	1-25
					Richardson's Pondweed	1-25
	43-44	10	OM	-	Northern water milfoil	25-50
					Common Cattail	1-25

Table B-4: Vegetation survey results at station 05EE010 on September 3, 2015.

Transect	Quadrat	Water Depth (cm)	Dominant Substrate	Second Substrate	Plant Species	Percent Cover
1	0-1	8	OM	-	Nodding beggarticks	1-25
					Common Cattail	1-25
					Creeping spike-rush	25-50
					Coontail	25-50
					Northern water milfoil	1-25
					Richardson's pondweed	1-25
					Water smartweed	1-25
	1-2	19	OM	-	Sago pondweed	50-75
					Richardson's pondweed	1-25
					Northern water milfoil	25-50
	3-4	64	SA/GR	-	Richardson's pondweed	25-50
					Northern water milfoil	1-25
					Coontail	1-25
	5-6	78	GR/SA		Richardson's pondweed	25-50
	7-8	77	GR/SA	-	Richardson's pondweed	1-25
	9-10	89	CO	SA/GR	Richardson's pondweed	1-25
					Northern water milfoil	1-25
	11-12	66	CO	GR/SA	Richardson's pondweed	1-25
	12-13	36	CO	GR/SA	Northern water milfoil	1-25
					Richardson's pondweed	1-25
	13-14	18	OM	SA/GR	grasses	1-25
2	0-1	27	OM	-	Water smartweed	1-25
					Northern water milfoil	50-75
					Coontail	1-25
	1-2	48	OM	-	Northern water milfoil	25-50
					Richardson's pondweed	1-25
					Sago pondweed	1-25
					Coontail	1-25
	3-4	96	GR	SA	Coontail	1-25
					Northern water milfoil	1-25
					Richardson's pondweed	1-25
	5-6	102	GR	SA	Richardson's pondweed	1-25
					Coontail	1-25
	7-8	78	SA	GR	Nodding beggarticks	1-25
	9-10	80	GR	SA	Richardson's pondweed	25-50
	11-12	70	SA/GR	GR	Richardson's pondweed	25-50
	12-13	43	OM	GR/SA	Nodding beggarticks	1-25
					Richardson's pondweed	1-25
					Sago pondweed	1-25

Transect	Quadrat	Water Depth (cm)	Dominant Substrate	Second Substrate	Plant Species	Percent Cover
	13-14	25	OM	SA/GR	Nodding beggarticks	1-25
					Richardson's pondweed	1-25
					Northern water milfoil	25-50
					Sago pondweed	1-25
					Bulrush	1-25
3	0-1	33	GR	CO	Filamentous Algae	1-25
					Richardson's pondweed	1-25
					Northern water milfoil	1-25
	1-2	74	GR	CO	Richardson's pondweed	1-25
	3-4	83	GR	CO	Richardson's pondweed	1-25
	5-6	85	GR	CO	Richardson's pondweed	1-25
					Northern water milfoil	1-25
	7-8	63	SA	GR/CO	Richardson's pondweed	25-50
					Northern water milfoil	25-50
					Sago pondweed	1-25
					Coontail	1-25
	9-10	48	SA	GR	Sago pondweed	50-75
					Northern water milfoil	25-50
					Coontail	25-50
					Richardson's pondweed	1-25
	10-11	30	SA	GR/CO	Northern water milfoil	50-75
					Sago pondweed	50-75
					Richardson's pondweed	1-25
					Coontail	25-50
	11-12	10	OM	-	Coontail	1-25
					Ivy-leaved duckweed	1-25
					Coontail	1-25
4	0-1	38	OM	-	Filamentous Algae	1-25
					Reed canary grass	1-25
					sedges	25-50
					Richardson's pondweed	1-25
					Sago pondweed	1-25
					Coontail	1-25
					Filamentous Algae	1-25
	1-2	55	OM	-	Filamentous Algae	75-100
					Richardson's pondweed	75-100
					Sago pondweed	1-25
					Northern water milfoil	1-25

Table B-4: 05EE010 continued

Transect	Quadrat	Water Depth (cm)	Dominant Substrate	Second Substrate	Plant Species	Percent Cover
4	3-4	67	gravel	OM	Filamentous Algae	25-50
					Richardson's pondweed	50-75
	5-6	80	gravel	cobble	Filamentous Algae	50-75
					Richardson's pondweed	50-75
	7-8	73	cobble	gravel	Filamentous Algae	25-50
					Richardson's pondweed	25-50
					Coontail	1-25
	9-10	82	cobble	-	Filamentous Algae	1-25
					Richardson's pondweed	25-50
	11-12	80	OM	gravel/cobble	Richardson's pondweed	25-50
					Sago pondweed	1-25
					Northern water milfoil	25-50
					Coontail	1-25
					Filamentous Algae	1--25
	12-13	56	OM	-	Coontail	25-50
					Sago pondweed	25-50
					Northern water milfoil	25-50
					Filamentous Algae	1-25
	13-14	33	OM	-	Northern water milfoil	75-100
					Richardson's pondweed	25-50
					Filamentous Algae	1-25
					Coontail	1-25
5	0-1	16	OM	gravel	Sago pondweed	50-75
					Filamentous Algae	50-75
	1-2	34	OM	gravel	Sago pondweed	50-75
					Filamentous Algae	50-75
	3-4	74	gravel	-	Richardson's pondweed	25-50
					Sago pondweed	50-75
					Filamentous Algae	25-50
	5-6	84	organic	-	Richardson's pondweed	50-75
					Filamentous Algae	25-50
					Northern water milfoil	1-25
	7-8	75	OM	gravel	Richardson's pondweed	25-50
					Northern water milfoil	25-50
					Sago pondweed	1-25
					Filamentous Algae	1-25
	9-10	72	OM	-	Richardson's pondweed	1-25

Transect	Quadrat	Water Depth (cm)	Dominant Substrate	Second Substrate	Plant Species	Percent Cover
	9-10	72	OM	-	Northern water milfoil	1-25
					Sago pondweed	1-25
					Filamentous Algae	1-25
					Coontail	1-25
					Sago pondweed	50-75
	11-12	75	OM	gravel	Richardson's pondweed	25-50
					Coontail	1-25
					Filamentous Algae	1-25
					Sago pondweed	50-75
	13-14	72	OM	gravel	Coontail	1-25
					Richardson's pondweed	1-25
					Coontail	25-50
	14-15	62	OM	-	Richardson's pondweed	1-25
					Sago pondweed	1-25
					Filamentous Algae	25-50
	15-16	52	OM	-	Richardson's pondweed	50-75
					Sago pondweed	25-50
					Coontail	1-25

Table B-5: Vegetation survey results at station VER1 on September 9, 2015.

Transect	Quadrat	Water Depth (cm)	Dominant Substrate	Second Substrate	Plant Species	Percent Cover
1	0-1	86	OM	-	Giant pondweed	25-50
					Common duckweed	1-25
					Giant Bur reed	1-25
					Richardson's pondweed	1-25
					water smart weed	1-25
	1-2	95	OM	-	Giant pondweed	1-25
					Common duckweed	1-25
					Giant Bur reed	1-25
	3-4	106	OM/SA/GR	-	Richardson's pondweed	1-25
					Giant pondweed	1-25
					Common duckweed	1-25
	5-6	104	OMSA/GR	-	Giant pondweed	25-50
					Common duckweed	1-25
					Richardson's pondweed	1-25
					Filamentous algae	1-25
	7-8	92	SA/OM	-	Common duckweed	1-25
					Giant pondweed	25-50
					Filamentous algae	1-25
	9-10	94	OM/SA	-	Common duckweed	1-25
					Giant pondweed	1-25
					Filamentous algae	1-25
	10-11	98	OM	-	Giant pondweed	25-50
					Common duckweed	1-25
					Filamentous algae	1-25
					Richardson's pondweed	1-25
	11-12	80	OM	-	water smart weed	1-25
					Common duckweed	1-25
					Giant pondweed	1-25
					Reed canary grass	1-25
2	0-1	25	OM	-	water sedge	25-50
					Common duckweed	1-25
					Northern water milfoil	1-25
					Giant Bur reed	25-50
					Nodding beggarticks	1-25
					bulrush	1-25
					water smart weed	1-25
	1-2	56	OM	-	Giant Bur reed	50-75
					Reed canary grass	1-25
					Tall manna grass	1-25
					Common duckweed	1-25
					Arum leaved arrowhead	1-25
2	3-4	93	OM	-	Northern water milfoil	1-25
					Filamentous algae	1-25
					Narrow-leaved bur-reed	1-25
					Common duckweed	1-25
	5-6	122	OM	-	Giant Bur reed	1-25
					Filamentous algae	1-25
	7-8	133	OM	-	no veg	-
	9-10	143	OM	-	no veg	-
	11-12	124	OM/SA	GR	Reed canary grass	1-25
					Filamentous algae	1-25
					Common duckweed	1-25
					Northern water milfoil	1-25
	12-13	52	OM	-	Reed canary grass	1-25
					Common duckweed	1-25
3	0-1	12	SA	-	Arum leaved arrowhead	1-25
					Wire rush	25-50
					bulrush	1-25
	1-2	56	SA	-	Arum leaved arrowhead	1-25
					Northern water milfoil	1-25
					Filamentous algae	1-25
					sago pondweed	1-25
					Richardson's pondweed	1-25
	3-4	152	SA	-	Filamentous algae	1-25
	5-6	164	OM	-	no veg	
	7-8	176	OM	-	no veg	-
	9-10	134	OM/SA	-	no veg	-
	11-12	82	GR/OM	SA	coontail	1-25
	12-13	65	GR/OM	SA	Common duckweed	1-25
					Northern water milfoil	1-25
					water smart weed	1-25
4	0-1	92	SA/OM	-	Common duckweed	1-25
					water sedge	1-25
					Filamentous algae	1-25
					bulrush	1-25
	1-2	114	SA/OM	-	Filamentous algae	1-25
					Richardson's pondweed	1-25
	3-4	152	OM/SA	-	no veg	-
	5-6	182	SA/OM	-	no veg	-
	7-8	142	OM/SA	-	no veg	-
	9-10	124	OM/SA	-	no veg	-
	10-11	103	SA/OM	GR	Filamentous algae	1-25

Table B-5: VER1 continued

Transect	Quadrat	Water Depth (cm)	Dominant Substrate	Second Substrate	Plant Species	Percent Cover
	11-12	72	SA/OM	-	Giant Bur reed	1-25
					water smart weed	1-25
					Common duckweed	1-25
5	0-1	66	GR/CO/SA	OM	bulrush	1-25
					sedges	1-25
					Common duckweed	1-25
					Willow	1-25
					water parsnip	1-25
	1-2	92	GR/CO/OM	SA	Giant Bur reed	1-25
					Filamentous algae	1-25
	3-4	134	OM/SA	-	Richardson's pondweed	1-25
					Filamentous algae	1-25
	5-6	142	GR	OM	Filamentous algae	1-25
	7-8	119	GR	OM	Richardson's pondweed	1-25
					Filamentous algae	1-25
	9-10	132	OM/SA	-	Richardson's pondweed	1-25
					Giant Bur reed	1-25
					Filamentous algae	1-25
	11-12	84	OM/SA	-	sago pondweed	1-25
					Common duckweed	1-25
					Filamentous algae	1-25
	13-14	71	OM/SA	-	Giant Bur reed	1-25
					Filamentous algae	1-25
					Common duckweed	1-25
					Northern water milfoil	1-25
					sago pondweed	1-25
	14-15	78	OM	-	Northern water milfoil	1-25
					sago pondweed	1-25
					Giant Bur reed	1-25
					sedge spp.	1-25

Table B-6: Vegetation survey results at station VER3 on September 3, 2015.

Transect	Quadrat	Water Depth (cm)	Dominant Substrate	Second Substrate	Plant Species	Percent Cover
1	0-1	5	OM	-	Common cattail	25-50
					Common duckweed	1-25
					Sago pondweed	1-25
					Coontail	1-25
	1-2	9	OM	-	Coontail	1-25
					Common duckweed	1-25
					Northern water milfoil	1-25
					Sago pondweed	1-25
	3-4	17	OM	-	Sago pondweed	1-25
					Northern water milfoil	25-50
					Common duckweed	1-25
	5-6	27	OM	-	Coontail	1-25
					Sago pondweed	1-25
					Common duckweed	1-25
	7-8	35	OM	-	Sago pondweed	50-75
					Common duckweed	1-25
					Coontail	1-25
					Filamentous Algae	1-25
	9-10	38	OM	-	Richardson's Pondweed	50-75
					Sago pondweed	75-100
					Common duckweed	1-25
					Coontail	1-25
	11-12	47	OM	-	Richardson's Pondweed	75-100
					Sago pondweed	75-100
					Filamentous Algae	1-25
					Common duckweed	1-25
	13-14	45	OM	-	Richardson's Pondweed	50-75
					Sago pondweed	75-100
					Coontail	1-25
					Common duckweed	1-25
	15-16	40	OM	-	Sago pondweed	75-100
					Richardson's Pondweed	50-75
					Filamentous Algae	1-25
	17-18	32	OM	-	Sago pondweed	1-25
					Coontail	1-25
	18-19	20	OM	-	Richardson's Pondweed	25-50
					Sago pondweed	25-50
					Coontail	1-25
					Common duckweed	1-25
					Ivy leaved duckweed	1-25

Transect	Quadrat	Water Depth (cm)	Dominant Substrate	Second Substrate	Plant Species	Percent Cover
2	0-1	11	OM	-	Sago pondweed	25-50
					Northern water milfoil	1-25
					Common cattail	1-25
					Common duckweed	1-25
					Ivy-leaved duckweed	1-25
					Coontail	1-25
					Bulrush	1-25
	1-2	19	OM	-	Sago pondweed	25-50
					Common duckweed	1-25
					Filamentous Algae	1-25
					Coontail	1-25
	3-4	40	OM	-	Sago pondweed	50-75
					Common duckweed	1-25
					Filamentous Algae	1-25
					Coontail	1-25
					Richardson's Pondweed	1-25
	5-6	61	OM	-	Richardson's Pondweed	25-50
					Sago pondweed	75-100
					Filamentous Algae	1-25
					Common duckweed	1-25
					Ivy leaved duckweed	1-25
	7-8	64	OM	-	Common duckweed	1-25
					Filamentous Algae	1-25
					Sago pondweed	75-100
					Richardson's Pondweed	25-50
	9-10	59	OM	-	Sago pondweed	75-100
					Richardson's Pondweed	1-25
					Common duckweed	1-25
					Ivy leaved duckweed	1-25
	11-12	52	OM	-	Richardson's Pondweed	1-25
					Sago pondweed	75-100
					Common duckweed	1-25
					Filamentous Algae	1-25
					Ivy leaved duckweed	1-25
	13-14	44	OM	-	Sago pondweed	50-75
					Common duckweed	1-25
					Richardson's Pondweed	1-25
					Ivy leaved duckweed	1-25
	14-15	40	OM	-	Sago pondweed	50-75
					Common duckweed	1-25
					Richardson's Pondweed	1-25
					Coontail	1-25
					Ivy leaved duckweed	1-25

Table B-6: VER3 continued

Transect	Quadrat	Water Depth (cm)	Dominant Substrate	Second Substrate	Plant Species	Percent Cover
3	0-1	19	OM	-	Common duckweed	1-25
					Sago pondweed	50-75
					Coontail	1-25
					Northern water milfoil	1-25
					Common cattail	1-25
	1-2	24	OM	-	Northern water milfoil	75-100
					Sago pondweed	25-50
					Common duckweed	1-25
					Coontail	1-25
	3-4	55	OM	-	Filamentous Algae	1-25
					Sago pondweed	1-25
					Northern water milfoil	1-25
					Common duckweed	1-25
	5-6	69	OM	-	Sago pondweed	1-25
					Filamentous Algae	1-25
					Common duckweed	1-25
					Richardson's Pondweed	1-25
	7-8	64	OM	-	Richardson's Pondweed	25-50
					Northern water milfoil	25-50
					Sago pondweed	25-50
					Common duckweed	1-25
					Slender pondweed	1-25
					Filamentous Algae	1-25
	9-10	57	OM	-	Sago pondweed	75-100
					Common duckweed	1-25
					Richardson's Pondweed	1-25
					Filamentous Algae	1-25
	11-12	42	OM	-	Richardson's Pondweed	1-25
					Sago pondweed	75-100
					Coontail	1-25
					Filamentous Algae	1-25
					Common duckweed	1-25
	13-14	25	OM	-	Richardson's Pondweed	1-25
					Sago pondweed	25-50
					Common Duckweed	1-25
					Coontail	1-25
	14-15	18	OM	-	Sago pondweed	25-50
					Common cattail	1-25
					Common duckweed	1-25
					Coontail	1-25
					Ivy-leaved duckweed	1-25

Transect	Quadrat	Water Depth (cm)	Dominant Substrate	Second Substrate	Plant Species	Percent Cover
4	0-1	10	OM	-	Richardson's Pondweed	1-25
					Filamentous Algae	1-25
					Common duckweed	25-50
					Ivy-leaved duckweed	1-25
					Coontail	25-50
					Northern water milfoil	1-25
					Common cattail	1-25
					Sago pondweed	125
					Slender pondweed	1-25
	1-2	28	OM	-	Northern water milfoil	25-50
					Filamentous Algae	50-75
					Common duckweed	1-25
					Richardson's Pondweed	25-50
					Sago pondweed	1-25
					Ivy-leaved duckweed	1-25
	3-4	35	OM	-	Filamentous Algae	75-100
					Sago pondweed	75-100
					Common duckweed	1-25
					Northern water milfoil	1-25
					Coontail	1-25
					Ivy-leaved duckweed	1-25
	5-6	38	OM	-	Sago pondweed	50-75
					Common duckweed	1-25
					Filamentous Algae	50-75
					Ivy-leaved duckweed	1-25
	7-8	85	OM	-	Sago pondweed	50-75
					Filamentous Algae	50-75
					Common duckweed	1-25
					Slender pondweed	1-25
					Coontail	1-25
	9-10	35	OM	-	Sago pondweed	50-75
					Common duckweed	1-25
					Filamentous Algae	25-50
	11-12	31	OM	-	Northern water milfoil	50-75
					Common duckweed	1-25
					Sago pondweed	75-100
					Filamentous Algae	1-25
					Slender pondweed	1-25
					Coontail	1-25
	13-14	30	OM	-	Sago pondweed	50-75
					Common duckweed	1-25
	15-16	26	OM	-	Common duckweed	25-50
					Sago pondweed	75-100

Table B-6: VER3 continued

Transect	Quadrat	Water Depth (cm)	Dominant Substrate	Second Substrate	Plant Species	Percent Cover
4	17-18	21	OM	-	Sago pondweed	75-100
					Common duckweed	50-75
					Coontail	1-25
	19-20	17	OM	-	Sago pondweed	1-25
					Common duckweed	1-25
	21-22	20	OM	-	Common duckweed	25-50
	22-23	7	OM	-	Common duckweed	25-50
					Common cattail	1-25
5	0-1	8	OM	-	Common duckweed	25-50
					Sago pondweed	75-100
	1-2	12	OM	-	Coontail	1-25
					Common duckweed	1-25
					Sago pondweed	25-50
					Northern water milfoil	1-25
					Ivy-leaved duckweed	1-25
	3-4	32	OM	-	Filamentous Algae	1-25
					Common duckweed	1-25
					Sago pondweed	75-100
					Coontail	1-25
	5-6	35	OM	-	Sago pondweed	75-100
					Filamentous Algae	25-50
					Coontail	1-25
					Common duckweed	1-25
	7-8	33	OM	-	Sago pondweed	25-50
					Filamentous Algae	1-25
					Coontail	1-25
	9-10	36	OM	-	Sago pondweed	25-50
					Richardson's Pondweed	1-25
					Coontail	1-25
					Common Duckweed	1-25
	11-12	32	OM	SA	Sago pondweed	50-75
					Common duckweed	1-25
					Coontail	1-25
					Filamentous Algae	1-25
					Richardson's Pondweed	1-25
	13-14	31	OM	SA	Sago pondweed	25-50
					Common duckweed	1-25
					Coontail	1-25
					Filamentous Algae	1-25
	15-16	27	OM	SA	Sago pondweed	75-100
					Filamentous Algae	25-50
5	15-16	27	OM	SA	Common duckweed	1-25
					Richardson's Pondweed	1-25
					Coontail	1-25
	17-18	11	OM	-	Sago pondweed	1-25
					Coontail	1-25
					Common duckweed	1-25
	18-19	10	OM	-	Coontail	1-25
					Sago pondweed	1-25
					Common cattail	1-25
					Common duckweed	1-25
					Arum-leaved arrow head	1-25
					Slender pondweed	1-25

Table B-7: Vegetation survey results at station VER6, on September 9, 2015

Transect	Quadrat	Water Depth (cm)	Dominant Substrate	Second Substrate	Plant Species	Percent Cover
1	0-1	13	GR/SA	-	Northern water milfoil	1-25
	1-2	25	GR/SA	BO/CO	Sago pondweed	1-25
					Northern water milfoil	1-25
					Filamentous algae	1-25
	3-4	42	SA/GR	CO	Northern water milfoil	1-25
					Sago pondweed	1-25
	5-6	39	SA/GR	CO	Northern water milfoil	1-25
	7-8	31	CO/GR	SA	Northern water milfoil	1-25
	9-10	17	CO/SA/GR	BO	Northern water milfoil	25-50
					Sago pondweed	1-25
	11-12	14	CO/GR/SA	BO	Northern water milfoil	25-50
					Sago pondweed	1-25
	12-13	3	CO/SA	GR	Nodding beggarticks	1-25
					Common mare's-tail	1-25
					Common scouring rush	1-25
					Filamentous algae	1-25
					Filamentous algae	1-25
2	0-1	95	SA/CO/GR	-	Northern water milfoil	1-25
					Filamentous algae	1-25
					Creeping spike rush	1-25
					Brook grass	1-25
	1-2	85	SA/CO/GR	OM/BO	Northern water milfoil	1-25
					Sago pondweed	1-25
					Filamentous algae	1-25
	3-4	63	SA	GR	Sago pondweed	1-25
					Coontail	1-25
	5-6	43	BO/SA/GR	-	Northern water milfoil	1-25
	7-8	28	BO/CO/GR	SA	Filamentous algae	1-25
	8-9	19	BO/CO/GR	SA	Sago pondweed	1-25
					Narrow-leaved bur-reed	1-25
					Filamentous algae	1-25
	9-10	17	CO/CO/SA	GR	Filamentous algae	1-25
					Scouring rush	1-25
					Northern water milfoil	1-25
					Sago pondweed	1-25
					Stolon grass	1-25
3	0-4	30	CO/SA/GR	-	brown slime	75-100
	4-7	-	-	-	upland island	-
	7-8	1	CO/GR/SA	-	Creeping spike rush	1-25
					Common mare's-tail	1-25
					Knotted rush	1-25
3	7-8	1	CO/GR/SA	-	Toad rush	1-25
					Nodding beggarticks	1-25
					Stolon grass	1-25
	8-9	1	OM/GR	SA/CO	Sago pondweed	1-25
					Nodding beggarticks	1-25
					Common mare's-tail	1-25
					Stolon grass	1-25
					Sago pondweed	25-50
	10-11	24	GR/CO/SA	-	Ivy leaved duckweed	1-25
					Northern water milfoil	1-25
					Sago pondweed	1-25
	12-13	31	SA	-	Bulrush	1-25
	14-15	17	SA	-	Common mare's-tail	1-25
					Northern water milfoil	75-100
					Sago pondweed	1-25
					Arum leaved arrowhead	1-25
					Filamentous algae	1-25
					Stolon grass	1-25
					Sago pondweed	1-25
	16-17	13	SA	-	Northern water milfoil	25-50
					Scouring rush	1-25
					Filamentous algae	1-25
					Creeping spike rush	1-25
					Stolon grass	1-25
					Sago pondweed	1-25
	17-18	4	BO/SA	-	Scouring rush	1-25
					Northern water milfoil	1-25
					Dwarf scouring rush	1-25
					Filamentous algae	50-75
4	0-1	6	CO/BO/GR	OM/SA	Stolon grass	1-25
					Filamentous algae	50-75
	1-2	5	CO/BO/GR	SA	Stolon grass	1-25
					Northern water milfoil	1-25
	3-4	31	CO/BO/GR	SA	Filamentous algae	25-50
					Slender pondweed	1-25
					Filamentous algae	1-25
	5-6	47	CO/GR	SA	Northern water milfoil	1-25
					Narrow-leaved bur-reed	1-25
	7-8	29	GR/SA	-	Northern water milfoil	1-25
					Sago pondweed	1-25
					Northern water milfoil	1-25

Table B-7: VER6 continued

Transect	Quadrat	Water Depth (cm)	Dominant Substrate	Second Substrate	Plant Species	Percent Cover
4	9-10	44	SA/GR	-	Northern water milfoil	1-25
	10-11	40	SA/GR	CO	Northern water milfoil	1-25
					Arum leaved arrowhead	1-25
	11-12	35	SA/GR	-	Northern water milfoil	1-25
					Creeping spike rush	1-25
					Sago pondweed	1-25
					Swamp horsetail	1-25
					Stolon grass	1-25
5	0-1	10	BO/CO	GR/SA	Filamentous algae	1-25
					Swamp horsetail	1-25
	1-2	17	CO/BO	GR	Northern water milfoil	1-25
					Filamentous algae	1-25
					Sago pondweed	1-25
	3-4	22	BO/CO	GR	Filamentous algae	1-25
	5-6	20	CO/BO	GR	Filamentous algae	1-25
	7-8	10	BO/CO	GR	Macrophyte algae	1-25
	9-10	6	BO/CO	GR	Filamentous algae	1-25
					Stolon grass	1-25

Appendix C: Macro-Invertebrate Surveys

Table C-1: Macro-invertebrate counts at each station on the VR.

STATION	Order	Family	Count
BEA1	Amphipoda	Gammaridae	38
	Amphipoda	Hyalellidae	285
	Coleoptera	Dytiscidae	6
	Coleoptera	Elmidae larva	14
	Coleoptera	Gyrinidae	4
	Coleoptera	Haliplidae	26
	Diptera	Ceratopogonidae	1
	Diptera	Chironomid pupa(e)	1
	Diptera	Chironomidae	110
	Diptera	Dixidae	1
	Diptera	Ephydridae	1
	Diptera	Psychodidae	1
	Diptera	Tabanidae	2
	Diptera	Tipulidae	1
	Ephemeroptera	Caenidae	16
	Gastropoda	Limnaeidae	5
	Gastropoda	Physidae	1
	Hemiptera	Corixidae	29
	Hemiptera	Notonectidae	1
	Hydrachnidia	Feltridae	15
	Hydrachnidia	Sperchonidae	1
	Lepidoptera	Pyralidae	6
	Odonata	Coenagrionidae	41
	Odonata	Coenagrionidae	49
	Trichoptera	Phryganeidae	1
MIN2A	Amphipoda	Gammaridae	11
	Amphipoda	Hyalellidae	284
	Coleoptera	Dytiscidae	14
	Coleoptera	Elmidae	69
	Coleoptera	Gyrinidae	2
	Coleoptera	Haliplidae	51
	Diptera	Chironomidae	12
	Diptera	Dixidae	13
	Diptera	Tipulidae	4
	Ephemeroptera	Caenidae	56
	Gastropoda	Planorbidae	9
	Hemiptera	Corixidae	62
	Hemiptera	Gerridae	5
	Hemiptera	Mesoveliidae	1
	Hemiptera	Hebridae	1
	Hemiptera	Notonectidae	6
	Hirundinea	Glossiphoniidae	1
	Hydrachnidia	Hygrobatidae	11
	Hydrachnidia	Unionicolidae	25
	Lepidoptera	Pyralidae	17
	Odonata	Coenagrionidae	50
	Trichoptera	Limnephiledae	4
	Trichoptera	Phryganeidae	2
TWO2A	Amphipoda	Gammaridae	251
	Amphipoda	Hyalellidae	412
	Bivalvia	Sphaeridae	4
	Coleoptera	Dytiscidae	5
	Coleoptera	Haliplidae	42
	Diptera	Chironomidae	30
	Ephemeroptera	Caenidae	163
TWO2A	Gastropoda	Planorbidae	1
	Gastropoda	Physidae	5
	Gastropoda	Limnaeidae	11
	Hemiptera	Corixidae	21
	Lepidoptera	Pyralidae	10
	Odonata	Coenagrionidae	686
	Trichoptera	Phryganeidae	2
05EE010	Amphipoda	Gammaridae	14
	Amphipoda	Hyalellidae	75
	Coleoptera	Dytiscidae	1
	Coleoptera	Elmidae	2
	Coleoptera	Haliplidae	22
	Diptera	Ceratopogonidae	2
	Diptera	Chironomidae	36
	Diptera	Tabanidae	2
	Ephemeroptera	Caenidae	35
	Gastropoda	Limnaeidae	1
	Gastropoda	Planorbidae	1
	Gastropoda	Valvatidae	1
	Hemiptera	Corixidae	30
	Hemiptera	Notonectidae	1
	Hirundinea	Erpobdellidae	4
	Hydrachnidia	Sperchonidae	3
	Hydrachnidia	Unionicolidae	2
	Lepidoptera	Pyralidae	2
	Odonata	Coenagrionidae	18
	Trichoptera	Leptoceridae	12
	Trichoptera	Limnephiledae	1
	Trichoptera	Phryganeidae	3
VER1	Diptera	Chironomidae	12
	Ephemeroptera	Caenidae	6
	Hemiptera	Corixidae	16
	Hydrachnidia	Unionicolidae	1
	Lepidoptera	Pyralidae	1
	Odonata	Aeshnidae	2
	Odonata	Coenagrionidae	2
	Trichoptera	Hydroptilidae	1
	Trichoptera	Phryganeidae	1
VER3	Amphipoda	Gammaridae	69
	Coleoptera	Dytiscidae	3
	Coleoptera	Haliplidae	12
	Diptera	Ceratopogonidae	1
	Diptera	Chironomidae	37
	Diptera	Ephydrid pupa(e)	1
	Diptera	Sciomyzidae	1
	Ephemeroptera	Caenidae	110
	Gastropoda	Limnaeidae	16
	Gastropoda	Physidae	12
	Gastropoda	Planorbidae	6
	Gastropoda	Valvatidae	4
	Hemiptera	Corixidae	65
	Hemiptera	Belostomatidae	1
	Hirundinea	Glossiphoniidae	1
	Hydrachnidia	Feltridae	1
	Hydrachnidia	Hygrobatidae	5

Table C-1: Macro-invertebrate counts continued

STATION	Order	Family	Count
VER3	Hydrachnidia	Pionidae	1
	Hydrachnidia	Sperchonidae	1
	Hydrachnidia	Unionicolidae	1
	Odonata	Aeshnidae	45
	Odonata	Coenagrionidae	1
VER6	Amphipoda	Gammaridae	18
	Amphipoda	Hyalellidae	2
	Coleoptera	Dytiscidae	2
	Coleoptera	Elmidae	2
	Coleoptera	Haliplidae	8
	Diptera	Chironomidae	2
	Diptera	Tipulidae	8
	Ephemeroptera	Caenidae	1
	Ephemeroptera	Ephemeridae	23
	Gastropoda	Physidae	1
	Gastropoda	Planorbidae	11
	Hemiptera	Corixidae	2
	Hemiptera	Belostomatidae	2
	Odonata	Aeshnidae	10
	Odonata	Coenagrionidae	1

Appendix D: Fish Survey

Table D-1: Fish Survey Results from electro-fishing (FTMN= Fathead minnow. BRST= Brook stickleback, LKCH= Lake chub, PRDC = Pearl Dace, WHSC = White sucker, LNDC = Longnose dace, TRPR= Trout-perch & EMSH=Emerald shiner).

Station	Date of Capture	Effort (sec)	Family	Fish Species	Fork Length (cm)	DELTS	Live or Dead
BEA1	27-08-15	329	Cyprinidae	FTMN	3.4	N	L
			Cyprinidae	FTMN	4.4	N	L
			Gasterosteidae	BRST	5.4	N	L
MIN2A	26-08-15	700	Gasterosteidae	BRST	4.9	N	L
			Gasterosteidae	BRST	4.1	N	L
			Gasterosteidae	BRST	4.8	N	L
			Gasterosteidae	BRST	4.6	N	L
			Cyprinidae	FTMN	1.6	N	L
			Cyprinidae	FTMN	2	N	L
			Cyprinidae	FTMN	2	N	L
			Cyprinidae	FTMN	1.6	N	L
			Cyprinidae	FTMN	1.6	N	L
TWO2A	26-08-15	629	-	-	-	-	
05EE010	25-08-15	1766	Catostomidae	WHSC	16.4	N	L
			Cyprinidae	FTMN	1.8	Y	L
			Cyprinidae	FTMN	2.1	Y	L
			Gasterosteidae	BRST	4.9	N	D
			Cyprinidae	PRDC	8.3	N	L
			Cyprinidae	FTMN	1.8	N	L
			Cyprinidae	FTMN	2.5	Y	L
			Cyprinidae	FTMN	1.9	N	D
			Cyprinidae	FTMN	1.9	N	D
			Cyprinidae	FTMN	1.8	Y	L
			Cyprinidae	FTMN	1.9	Y	L
			Cyprinidae	FTMN	1.7	Y	L
			Cyprinidae	FTMN	1.7	Y	L
			Cyprinidae	LKCH	1.6	N	L
			Cyprinidae	FTMN	1.5	N	D
			Cyprinidae	FTMN	1.9	Y	L
			Cyprinidae	FTMN	1.8	Y	L
			Cyprinidae	LKCH	2	Y	L
			Cyprinidae	LKCH	1.9	Y	L
			Cyprinidae	FTMN	2.1	Y	L
			Cyprinidae	FTMN	1.9	Y	L
			Cyprinidae	FTMN	1.9	Y	L
			Cyprinidae	FTMN	1.7	Y	L
05EE010	25-08-15	1766	Cyprinidae	FTMN	1.6	N	L
			Cyprinidae	FTMN	1.9	Y	L
			Cyprinidae	LKCH	1.9	Y	L
			Cyprinidae	LKCH	1.3	N	L
			Cyprinidae	FTMN	2	Y	L
			Cyprinidae	FTMN	1.9	Y	L
			Cyprinidae	FTMN	1.9	Y	L
			Cyprinidae	FTMN	1.9	Y	L
			Cyprinidae	FTMN	2	Y	L
			Cyprinidae	FTMN	1.7	Y	L
			Cyprinidae	FTMN	1.9	Y	L
			Cyprinidae	FTMN	2.3	Y	L
			Cyprinidae	FTMN	2.2	Y	L
			Cyprinidae	FTMN	1.7	Y	L
			Cyprinidae	FTMN	1.7	N	D
			Cyprinidae	FTMN	1.9	Y	L
			Cyprinidae	FTMN	1.9	Y	L
			Cyprinidae	FTMN	1.9	Y	L
			Cyprinidae	FTMN	2	Y	L
			Cyprinidae	FTMN	1.8	Y	L
			Cyprinidae	FTMN	2	Y	L
			Cyprinidae	FTMN	2	Y	L
			Cyprinidae	FTMN	2.1	Y	L
			Cyprinidae	FTMN	2.1	Y	L
			Cyprinidae	FTMN	2	Y	L
			Cyprinidae	LKCH	1.9	N	L
			Cyprinidae	LKCH	1.8	Y	L
			Cyprinidae	LKCH	1.9	Y	L
			Cyprinidae	FTMN	1.9	Y	L
			Cyprinidae	FTMN	1.7	N	D
			Gasterosteidae	BRST	3.7	N	L
			Cyprinidae	FTMN	2.2	Y	D
			Cyprinidae	FTMN	1.5	Y	L
			Cyprinidae	FTMN	1.9	Y	L
			Cyprinidae	FTMN	1.8	Y	L
			Cyprinidae	FTMN	1.7	Y	L
			Cyprinidae	FTMN	1.9	Y	L
			Cyprinidae	FTMN	1.7	Y	L
			Cyprinidae	FTMN	1.4	Y	L
			Cyprinidae	FTMN	1.9	Y	N
			Cyprinidae	FTMN	2	Y	L
			Cyprinidae	LKCH	1.7	Y	L

Table D-1: Electro-fishing captures continued

Station	Date of Capture	Effort (sec)	Family	Fish Species	Fork Length (cm)	DELTS	Live or Dead
05EE010	25-08-15	1766	Cyprinidae	FTMN	1.8	Y	L
			Cyprinidae	FTMN	2.2	N	L
			Cyprinidae	FTMN	1.4	N	L
			Cyprinidae	FTMN	1.5	N	L
			Cyprinidae	LKCH	2.1	Y	D
			Cyprinidae	LKCH	1.5	Y	L
			Cyprinidae	LKCH	1.7	N	L
			Cyprinidae	LKCH	1.6	N	L
			Cyprinidae	FTMN	1.9	Y	D
			Cyprinidae	FTMN	2	Y	L
			Cyprinidae	FTMN	2	Y	L
			Cyprinidae	FTMN	1.9	Y	L
			Cyprinidae	FTMN	1.8	Y	L
			Cyprinidae	FTMN	1.8	Y	L
			Cyprinidae	FTMN	2	Y	L
			Cyprinidae	FTMN	2	Y	L
			Cyprinidae	FTMN	1	Y	L
			Cyprinidae	FTMN	1.9	Y	L
			Cyprinidae	FTMN	1.6	Y	L
			Cyprinidae	FTMN	1.8	Y	L
			Cyprinidae	FTMN	1.7	Y	L
			Cyprinidae	FTMN	1.9	Y	L
			Cyprinidae	FTMN	1.6	Y	D
			Cyprinidae	FTMN	1.5	Y	D
			Cyprinidae	FTMN	1.7	N	L
			Cyprinidae	FTMN	1.9	Y	L
			Cyprinidae	FTMN	1.4	Y	L
			Cyprinidae	FTMN	1.9	Y	D
			Cyprinidae	FTMN	1.7	Y	D
			Cyprinidae	FTMN	1.9	N	L
			Cyprinidae	FTMN	1.5	Y	L
			Cyprinidae	FTMN	1.3	N	L
			Cyprinidae	FTMN	1.6	Y	D
			Cyprinidae	FTMN	1.4	Y	L
			Cyprinidae	FTMN	1.7	Y	L
			Cyprinidae	FTMN	1.6	Y	L
			Cyprinidae	FTMN	1.6	Y	L
			Cyprinidae	FTMN	1.9	Y	L
			Cyprinidae	FTMN	2.1	Y	L
			Cyprinidae	FTMN	1.7	Y	D
			Cyprinidae	FTMN	1.9	Y	L

Station	Date of Capture	Effort (sec)	Family	Fish Species	Fork Length (cm)	DELTS	Live or Dead
05EE010	25-08-15	1766	Cyprinidae	FTMN	1.7	Y	L
			Cyprinidae	FTMN	1.8	Y	L
			Cyprinidae	FTMN	1.7	Y	L
			Cyprinidae	FTMN	2.2	Y	L
			Cyprinidae	FTMN	2	Y	L
			Cyprinidae	FTMN	1.9	Y	L
			Cyprinidae	FTMN	2	Y	L
			Cyprinidae	FTMN	1.8	Y	L
			Cyprinidae	FTMN	2.1	N	L
			Cyprinidae	FTMN	1.7	Y	L
			Cyprinidae	LKCH	1.9	Y	L
			Cyprinidae	FTMN	1.5	Y	L
			Cyprinidae	LKCH	1.9	Y	L
			Cyprinidae	FTMN	1.7	N	L
			Cyprinidae	LKCH	1.9	Y	L
			Cyprinidae	LKCH	2.3	N	L
			Cyprinidae	FTMN	1.6	Y	L
			Cyprinidae	FTMN	1.7	Y	L
			Cyprinidae	FTMN	2	Y	L
			Cyprinidae	FTMN	2.3	N	L
			Cyprinidae	FTMN	2.1	Y	L
			Cyprinidae	FTMN	1.9	Y	L
			Cyprinidae	FTMN	1.8	Y	L
			Cyprinidae	FTMN	1.7	Y	L
			Cyprinidae	FTMN	2.4	Y	L
			Cyprinidae	FTMN	1.6	Y	L
			Cyprinidae	FTMN	1.9	Y	L
			Cyprinidae	FTMN	2	Y	L
			Cyprinidae	FTMN	1.8	Y	L
			Cyprinidae	FTMN	1.7	Y	L
			Cyprinidae	FTMN	1.8	Y	L
VER1	20-08-15	1649	Cyprinidae	LKCH	1.9	N	L
			Cyprinidae	LKCH	1.9	N	D
			Cyprinidae	LKCH	1.2	N	L
			Cyprinidae	LKCH	1.8	N	L
			Cyprinidae	LKCH	1.8	N	L
			Cyprinidae	LKCH	1.4	N	D
			Cyprinidae	LKCH	1.7	N	L
			Cyprinidae	LKCH	1.8	N	L
			Cyprinidae	FTMN	1.6	N	L
			Catostomidae	WHSC	10.7	N	D

Table D-1: Electro-fishing captures continued

Station	Date of Capture	Effort (sec)	Family	Fish Species	Fork Length (cm)	DELTS	Live or Dead
VER1	20-08-15	1649	Cyprinidae	LKCH	2.6	N	L
			Gasterosteidae	BRST	3.1	N	L
			Cyprinidae	LKCH	2	N	L
			Cyprinidae	LKCH	2.3	N	L
			Cyprinidae	LKCH	1.8	N	L
			Cyprinidae	LKCH	1.7	N	L
			Cyprinidae	LKCH	1.9	N	L
			Cyprinidae	LKCH	1.5	N	L
			Cyprinidae	LKCH	1.4	N	L
			Cyprinidae	LKCH	2.1	N	L
			Cyprinidae	LKCH	1.8	N	L
			Cyprinidae	LKCH	1.9	N	L
			Cyprinidae	LKCH	2.5	N	L
			Cyprinidae	LKCH	1.5	N	L
			Cyprinidae	LKCH	2.3	N	L
			Cyprinidae	LKCH	2.4	N	L
			Cyprinidae	LKCH	1.6	N	L
			Cyprinidae	LKCH	1.7	N	L
			Cyprinidae	LKCH	2.1	N	L
			Cyprinidae	FTMN	1.6	N	L
			Cyprinidae	FTMN	2.1	N	L
			Cyprinidae	LKCH	1.6	N	L
			Cyprinidae	LKCH	1.5	N	L
			Cyprinidae	LKCH	1.5	N	L
			Cyprinidae	LKCH	1.3	N	L
			Cyprinidae	LKCH	1.3	N	L
			Cyprinidae	LKCH	1.4	N	L
			Cyprinidae	LKCH	1.2	N	L
			Cyprinidae	LKCH	1.3	N	L
			Cyprinidae	LKCH	1.4	N	L
			Cyprinidae	LKCH	1.8	N	L
			Cyprinidae	LKCH	1.7	N	L
			Cyprinidae	LKCH	1.5	N	L
			Cyprinidae	LKCH	1.4	N	L
			Cyprinidae	LKCH	1.9	N	L
			Cyprinidae	LKCH	1.7	N	L
			Cyprinidae	LKCH	1.7	N	L
			Cyprinidae	LKCH	1.3	N	L
			Cyprinidae	LKCH	1.6	N	L
			Cyprinidae	LKCH	1.9	N	L
			Cyprinidae	LKCH	1.5	N	L
VER1	20-08-15	1649	Cyprinidae	LKCH	1.7	N	D
			Cyprinidae	LKCH	1.6	N	D
			Cyprinidae	LKCH	1.5	N	L
			Cyprinidae	LKCH	1.5	N	L
			Cyprinidae	FTMN	1.3	N	L
			Cyprinidae	LKCH	1.5	N	L
			Cyprinidae	LKCH	1.7	N	L
			Cyprinidae	LKCH	1.2	N	L
			Gasterosteidae	BRST	1.2	N	L
			Cyprinidae	LKCH	3.2	N	L
			Cyprinidae	LKCH	2.4	N	L
			Cyprinidae	LKCH	2.8	N	L
			Cyprinidae	LKCH	2.6	N	L
			Cyprinidae	LKCH	2.7	N	L
			Cyprinidae	LKCH	1.7	N	L
			Cyprinidae	LKCH	2.7	N	L
			Cyprinidae	LKCH	1.2	N	L
			Cyprinidae	LKCH	1.9	N	L
			Cyprinidae	LKCH	1.9	N	L
			Cyprinidae	LKCH	1.8	N	L
			Cyprinidae	LKCH	1.7	N	L
			Cyprinidae	FTMN	1.5	N	L
			Cyprinidae	LKCH	1.6	N	L
VER3	18-08	769	Gasterosteidae	BRST	3.7	N	L
			Gasterosteidae	BRST	2.7	N	L
			Gasterosteidae	BRST	3.6	N	L
			Cyprinidae	PRDC	2.8	N	D
			Gasterosteidae	BRST	3.4	N	D
			Gasterosteidae	BRST	2.7	N	L
			Gasterosteidae	BRST	3.9	N	L
			Gasterosteidae	BRST	4.1	N	L
			Cyprinidae	PRDC	2.7	N	L
			Gasterosteidae	BRST	2.4	N	L
			Gasterosteidae	BRST	4.1	N	L
			Gasterosteidae	BRST	3.8	N	L
			Gasterosteidae	BRST	2.9	N	L
			Gasterosteidae	BRST	3.2	N	L

Table D-1: Electro-fishing captures continued

Station	Date of Capture	Effort (sec)	Family	Fish Species	Fork Length (cm)	DELTS	Live or Dead
VER3	18-08-15	769	Gasterosteidae	BRST	2.8	N	L
			Gasterosteidae	BRST	3	N	L
			Gasterosteidae	BRST	2.5	N	L
			Gasterosteidae	BRST	2.9	N	L
			Gasterosteidae	BRST	3.3	N	L
			Gasterosteidae	BRST	2.9	N	L
			Gasterosteidae	BRST	2.6	N	L
			Gasterosteidae	BRST	2.9	N	L
			Gasterosteidae	BRST	2.9	N	L
			Gasterosteidae	BRST	3.1	N	L
			Gasterosteidae	BRST	3.1	N	L
			Gasterosteidae	BRST	2.5	N	L
			Gasterosteidae	BRST	3.1	N	L
			Gasterosteidae	BRST	3.4	N	L
			Gasterosteidae	BRST	2.9	N	L
			Gasterosteidae	BRST	3.9	N	L
			Gasterosteidae	BRST	2.8	N	L
			Gasterosteidae	BRST	2.7	N	L
			Gasterosteidae	BRST	2.9	N	L
			Gasterosteidae	BRST	3	N	L
			Gasterosteidae	BRST	3.9	N	L
			Gasterosteidae	BRST	2.8	N	L
			Gasterosteidae	BRST	2.8	N	L
			Gasterosteidae	BRST	3.9	N	L
			Gasterosteidae	BRST	2.9	N	L
			Gasterosteidae	BRST	3	N	L
			Gasterosteidae	BRST	3.1	N	L
			Gasterosteidae	BRST	2.5	N	L
			Gasterosteidae	BRST	3	N	L
			Gasterosteidae	BRST	3	N	L
			Gasterosteidae	BRST	2.9	N	L
			Gasterosteidae	BRST	2.6	N	L
			Cyprinidae	PRDC	3.2	N	D
			Gasterosteidae	BRST	2.5	N	L
			Gasterosteidae	BRST	2.4	N	L
			Gasterosteidae	BRST	3.6	N	L
			Gasterosteidae	BRST	2.8	N	L
			Gasterosteidae	BRST	2.6	N	L
			Gasterosteidae	BRST	2.4	N	L
			Gasterosteidae	BRST	2.9	N	L
			Cyprinidae	PRDC	2.9	N	L

Station	Date of Capture	Effort (sec)	Family	Fish Species	Fork Length (cm)	DELTS	Live or Dead
VER3	18-08-15	769	Cyprinidae	PRDC	2.2	N	D
			Gasterosteidae	BRST	3.9	N	L
			Gasterosteidae	BRST	2.6	N	L
			Gasterosteidae	BRST	2.8	N	L
			Gasterosteidae	BRST	3.1	N	L
			Gasterosteidae	BRST	3.4	N	L
			Gasterosteidae	BRST	2.6	N	L
			Gasterosteidae	BRST	3.6	N	L
			Gasterosteidae	BRST	2.5	N	L
			Gasterosteidae	BRST	2.8	N	L
			Gasterosteidae	BRST	2.7	N	L
			Cyprinidae	LKCH	2.2	N	L
			Gasterosteidae	BRST	2.5	N	L
			Gasterosteidae	BRST	4.2	N	L
			Gasterosteidae	BRST	3.5	N	L
			Gasterosteidae	BRST	3.5	N	L
			Gasterosteidae	BRST	2.8	N	L
			Gasterosteidae	BRST	4.1	N	L
			Gasterosteidae	BRST	3.1	N	L
			Gasterosteidae	BRST	2.3	N	L
			Gasterosteidae	BRST	2.4	N	L
			Gasterosteidae	BRST	4.1	N	L
			Gasterosteidae	BRST	2.9	N	D
			Gasterosteidae	BRST	3.4	N	L
			Gasterosteidae	BRST	3	N	L
			Gasterosteidae	BRST	3.5	N	L
			Gasterosteidae	BRST	2.8	N	L
			Gasterosteidae	BRST	3	N	L
			Gasterosteidae	BRST	3.8	N	L
			Gasterosteidae	BRST	2.6	N	L
			Gasterosteidae	BRST	2.7	N	L
			Gasterosteidae	BRST	4.4	N	L
			Gasterosteidae	BRST	2.5	N	L
			Gasterosteidae	BRST	2.5	N	L
			Gasterosteidae	BRST	3.1	N	L
			Gasterosteidae	BRST	2.6	N	L
			Gasterosteidae	BRST	3.5	N	L
			Gasterosteidae	BRST	2.8	N	L
			Gasterosteidae	BRST	2.7	N	L
			Gasterosteidae	BRST	3.5	N	L
			Gasterosteidae	BRST	3.7	N	L

Table D-1: Electro-fishing captures continued

Station	Date of Capture	Effort (sec)	Family	Fish Species	Fork Length (cm)	DELTS	Live or Dead
VER3	18-08-15	769	Gasterosteidae	BRST	2.6	N	L
			Gasterosteidae	BRST	2.5	N	L
			Gasterosteidae	BRST	2.7	N	L
			Gasterosteidae	BRST	2.6	N	L
			Gasterosteidae	BRST	3.7	N	L
			Gasterosteidae	BRST	3.3	N	L
			Gasterosteidae	BRST	3.5	N	L
			Gasterosteidae	BRST	2.6	N	L
VER3	19-08-15	785	Gasterosteidae	BRST	2.7	N	L
			Cyprinidae	LKCH	2.4	N	D
			Cyprinidae	LKCH	2.5	N	L
			Cyprinidae	LKCH	2.1	N	L
			Cyprinidae	LKCH	2.2	N	L
			Cyprinidae	LKCH	2	N	L
			Cyprinidae	FTMN	2.1	N	L
			Cyprinidae	LKCH	2.1	N	L
			Gasterosteidae	BRST	4.8	N	L
			Cyprinidae	LKCH	2.5	N	D
			Cyprinidae	LKCH	3.3	N	L
			Gasterosteidae	BRST	4.5	N	L
			Gasterosteidae	BRST	2.4	N	L
			Gasterosteidae	BRST	2.6	N	L
			Gasterosteidae	BRST	2.6	N	L
			Gasterosteidae	BRST	3.4	N	L
			Cyprinidae	LKCH	2	N	L
			Gasterosteidae	BRST	2.4	N	L
			Gasterosteidae	BRST	2.6	N	L
			Cyprinidae	LKCH	1.9	N	L
			Gasterosteidae	BRST	2.6	N	L
			Gasterosteidae	BRST	2.4	N	L
			Cyprinidae	LKCH	2.3	N	L
			Gasterosteidae	BRST	2.6	N	L
			Gasterosteidae	BRST	2.8	N	L
			Cyprinidae	LKCH	2.7	N	L
			Gasterosteidae	BRST	2.8	N	L
			Gasterosteidae	BRST	2.6	N	L
			Gasterosteidae	BRST	4.1	N	L
			Gasterosteidae	BRST	2.9	N	L
			Gasterosteidae	BRST	2.4	N	L
			Gasterosteidae	BRST	2.8	N	L
			Gasterosteidae	BRST	2.9	N	L

Station	Date of Capture	Effort (sec)	Family	Fish Species	Fork Length (cm)	DELTS	Live or Dead
VER3	19-08-15	785	Gasterosteidae	BRST	2.7	N	L
			Gasterosteidae	BRST	2.8	N	L
			Cyprinidae	LKCH	2	N	L
			Cyprinidae	LKCH	2.2	N	L
			Cyprinidae	LKCH	2.1	N	L
			Gasterosteidae	BRST	2.3	N	L
			Gasterosteidae	BRST	2.4	N	L
			Gasterosteidae	BRST	2.6	N	L
			Gasterosteidae	BRST	2.6	N	L
			Gasterosteidae	BRST	3.5	N	L
			Gasterosteidae	BRST	2.6	N	L
			Gasterosteidae	BRST	3.2	N	L
			Cyprinidae	LKCH	2.2	N	L
			Cyprinidae	LKCH	2.1	N	L
			Gasterosteidae	BRST	3.1	N	L
			Gasterosteidae	BRST	2.4	N	L
			Gasterosteidae	BRST	2.7	N	L
			Gasterosteidae	BRST	3	N	L
			Gasterosteidae	BRST	3.5	N	L
			Gasterosteidae	BRST	2.6	N	L
			Gasterosteidae	BRST	3	N	L
			Gasterosteidae	BRST	2.9	N	L
			Gasterosteidae	BRST	2.9	N	L
			Gasterosteidae	BRST	2.5	N	L
			Gasterosteidae	BRST	2.9	N	L
			Cyprinidae	LKCH	1.8	N	D
			Gasterosteidae	BRST	2.4	N	L
VER6	14-08-15	592	Cyprinidae	LNDC	7.6	N	L
			Cyprinidae	LNDC	6.7	N	L
			Cyprinidae	LNDC	6	N	L
			Cyprinidae	LNDC	7.2	N	L
			Cyprinidae	LNDC	3.4	N	L
			Cyprinidae	LNDC	5.3	N	L
			Cyprinidae	LNDC	5.2	N	L
			Cyprinidae	LNDC	5.4	N	L
			Cyprinidae	LNDC	4.2	N	L
			Cyprinidae	LNDC	2.9	N	L
			Cyprinidae	LNDC	3.5	N	L
VER6	17-08-15	1478	Cyprinidae	EMSH	7.5	N	L
			Cyprinidae	EMSH	7.1	Y	L
			Cyprinidae	EMSH	7.6	Y	L
			Cyprinidae	EMSH	5	N	L

Table D-1: Electro-fishing captures continued

Station	Date of Capture	Effort (sec)	Family	Fish Species	Fork Length (cm)	DELTS	Live or Dead
VER6	17-08-15	1478	Cyprinidae	EMSH	6.3	N	L
			Cyprinidae	EMSH	3.4	N	L
			Catostomidae	WHSC	3.6	N	L
			Cyprinidae	EMSH	6.7	N	L
			Cyprinidae	EMSH	4.1	N	L
			Cyprinidae	EMSH	3.1	N	L
			Cyprinidae	EMSH	2.9	N	L
			Cyprinidae	LKCH	3	N	L
			Cyprinidae	LKCH	3.2	Y	L
			Cyprinidae	PRDC	3.6	N	L
			Cyprinidae	EMSH	3.3	N	L
			Cyprinidae	PRDC	3.9	N	L
			Gasterosteidae	BRST	2.4	N	L
			Cyprinidae	PRDC	2.9	N	L
			Catostomidae	WHSC	5.4	N	L
			Cyprinidae	PRDC	2.9	N	L
			Cyprinidae	PRDC	7.5	Y	L
			Cyprinidae	PRDC	4.2	Y	L
			Cyprinidae	LNDC	4.7	N	L
			Cyprinidae	PRDC	3.4	N	L
VER6	25-08-15	1222	Cyprinidae	EMSH	4.7	N	L
			Catostomidae	WHSC	3.4	N	L
			Catostomidae	WHSC	3.6	N	L
			Gasterosteidae	BRST	3.6	N	L
			Catostomidae	WHSC	4.4	N	L
			Gasterosteidae	BRST	2.4	N	L
			Cyprinidae	PRDC	2.5	Y	L
			Cyprinidae	PRDC	3.1	Y	L
			Gasterosteidae	BRST	3.9	N	L
			Cyprinidae	LNDC	3.7	Y	L
			Cyprinidae	LNDC	2.7	N	L
			Cyprinidae	LNDC	2.2	Y	L
			Cyprinidae	LNDC	2.4	Y	L
			Cyprinidae	LNDC	3.1	Y	L
			Cyprinidae	LNDC	2.9	Y	L
			Catostomidae	WHSC	2.9	N	L
			Cyprinidae	LNDC	2.4	N	L
			Cyprinidae	LNDC	2.8	Y	L
			Cyprinidae	LNDC	2.7	Y	L
			Cyprinidae	LNDC	2.9	Y	L
			Cyprinidae	LNDC	3.1	Y	L

Station	Date of Capture	Effort (sec)	Family	Fish Species	Fork Length (cm)	DELTS	Live or Dead
VER6	25-08-15	1222	Cyprinidae	LNDC	3.6	Y	L
			Cyprinidae	LNDC	3.5	Y	L
			Cyprinidae	LNDC	3.1	Y	L
			Cyprinidae	LNDC	3.3	Y	L
			Cyprinidae	LNDC	2.8	Y	L
			Cyprinidae	LNDC	2.9	Y	L
			Cyprinidae	LNDC	2.9	Y	L
			Cyprinidae	LNDC	3.3	Y	L
			Cyprinidae	LNDC	3.3	Y	L
			Cyprinidae	LNDC	2.3	Y	L
			Cyprinidae	LNDC	3.6	Y	L
			Cyprinidae	LNDC	3.3	Y	L
			Cyprinidae	LNDC	2.3	Y	L
			Percopsidae	TRPR	5.9	N	L
			Cyprinidae	LNDC	4.4	N	L
			Cyprinidae	LNDC	3.5	Y	L
			Cyprinidae	LNDC	2.8	Y	L

Table D-2: Minnow trapping results (FTMN= Fathead minnow. BRST= Brook stickleback, LKCH= Lake chub, PRDC = Pearl Dace, WHSC = White sucker, LNDC = Longnose dace & EMSH=Emerald shiner).

Station	Trap #	Set Date & Time	Check Date & Time	Family	Fish Species	Fork Length (cm)
BEA1	1	31-08-15	01-09-15	Cyprinidae	FTMN	6.4
		@ 17:00	@ 8:39	Cyprinidae	FTMN	4
				Cyprinidae	BRST	4.8
				Gasterosteidae	BRST	5.1
				Cyprinidae	FTMN	4.9
	2			Gasterosteidae	BRST	4.7
	3			Cyprinidae	FTMN	4.4
	4			None	-	-
MIN2A	1	31-08-15	01-09-15	Cyprinidae	FTMN	6.4
		@ 17:00	@ 8:39	Cyprinidae	FTMN	4
				Cyprinidae	BRST	4.8
				Gasterosteidae	BRST	5.1
				Cyprinidae	FTMN	4.9
	2			Gasterosteidae	BRST	4.7
	3			Cyprinidae	FTMN	4.4
	4			None	-	-

Station	Trap #	Set Date & Time	Check Date & Time	Family	Fish Species	Fork Length (cm)
TWO2A	1	26-08-15	27-08-15	Gasterosteidae	BRST	5.1
		@ 13:00	@ 8:00	Gasterosteidae	BRST	5.9
				Gasterosteidae	BRST	5.8
				Gasterosteidae	BRST	6
				Gasterosteidae	BRST	5.9
				Gasterosteidae	BRST	5.4
				Gasterosteidae	BRST	4.6
				Gasterosteidae	BRST	5.5
				Gasterosteidae	BRST	5.5
				Gasterosteidae	BRST	4.5
				Gasterosteidae	BRST	4.7
				Gasterosteidae	BRST	5.2
				Gasterosteidae	BRST	4.4
				Gasterosteidae	BRST	4.9
				Gasterosteidae	BRST	5.5
				Gasterosteidae	BRST	4.8
				Gasterosteidae	BRST	5.2
				Gasterosteidae	BRST	5
				Gasterosteidae	BRST	4.5
	2			none	-	-
	3			none	-	-
	4			none	-	-

Table D-2: Minnow trapping results continued

Station	Trap #	Set Date & Time	Check Date & Time	Family	Fish Species	Fork Length (cm)
05EE010	1	25-08-15	26-08-15	Cyprinidae	FTMN	6.3
		@ 2:30	@ 8:00	Cyprinidae	LKCH	6.3
				Gasterosteidae	BRST	5.4
				Cyprinidae	FTMN	5.8
				Cyprinidae	FTMN	5.7
				Cyprinidae	PRDC	7.5
				Cyprinidae	PRDC	5.5
				Cyprinidae	FTMN	5.9
				Cyprinidae	LKCH	5.4
				Cyprinidae	FTMN	5.9
				Cyprinidae	FTMN	6.5
	2			Gasterosteidae	BRST	4.5
				Gasterosteidae	BRST	5.4
				Gasterosteidae	BRST	5.9
				Gasterosteidae	BRST	5.1
				Gasterosteidae	BRST	5.1
				Gasterosteidae	BRST	5
				Gasterosteidae	BRST	5
				Gasterosteidae	BRST	5.5
				Gasterosteidae	BRST	5.2
				Cyprinidae	FTMN	6.2
				Gasterosteidae	BRST	4.1
	3			none	none	-
	4			none	none	-

Station	Trap #	Set Date & Time	Check Date & Time	Family	Fish Species	Fork Length (cm)
VER1	1	8-20-15	8-20-15	Catostomidae	WHSC	10.4
	2	17:50	7:30	none	none	-
	3			none	none	-
	4			none	none	-
VER3	-	-	-	NONE	-	-

Station	Trap #	Set Date & Time	Check Time	Family	Fish Species	Fish Species Count
VER6	1	09-09-15 @ 10:00	09-09-15 @ 12:05	Cyprinidae	EMSH	54
				Gasterosteidae	BRST	3
				Cyprinidae	LNDC	1
	2	09-09-15 @ 9:50	09-09-15 @ 12:22	Cyprinidae	LNDC	1
	3	09-09-15 @ 9:45	09-09-15 @ 12:30	Cyprinidae	LNDC	5
				Cyprinidae	EMSH	13
	4	09-09-15 @ 9:50	09-09-15 @ 12:50	Cyprinidae	EMSH	104
				Cyprinidae	LNDC	14

Appendix E: Fish Facts

Brook Stickleback (*Culaea inconstans*)

Spines are used for protection against predators (Source: Google Images)

BRST was the most captured species on the VR (Source: CPPENV 2015)

BRST nest made from twigs & other debris (Source: Google Images)

- Family: **Gasterosteidae**
- native Alberta species
- distributed throughout Canada & USA

Habitat

- generalist; found in various areas of a stream, especially areas of dense vegetation & slow moving streams

Feeding

- predominantly an insectivore; prey mainly includes insect larvae, crustaceans and fish eggs
- also eats algae and vascular plant material (omnivore)
- researchers have found stomachs empty in the winter

Spawning

- high reproductive capacity
- spawning season: May-June
- male builds a nest, courts a female into the nest who lays the eggs and then is chased out of the nest for the male to fertilize
- fecundity: 104-451 eggs. Females spawn every 3 days over a 28 day spawning period
- male guards the nest until they are hatched and then guards the fry until they are strong enough to swim away
- incubation: 8 days
- age of maturity is after one year (live until 3 years)

General Tolerance of Environmental Factors

- high tolerance of variable environmental conditions
- pH: 4.6-9.5; prefer 5.0
- temperature: 15-19°C preferred, range 4.5-22°C
- tolerant of brackish water , low oxygen levels and fragmented streams
- soft substrate, low velocity and >60% vegetation cover

[1] Stewart, D.B., Resit, JD., Carmichael, T.J., Sawatzky, C.D., and Mochnacz, N.J. 2007. Fish life history and habitat use in the Northwest Territories: brook stickleback (*Culaea inconstans*). Can. Manuscr. Rep. Fish. Aquat. Sci. 2799: vi+30p.
[2] RAM (Royal Alberta Museum). 2015. Alberta's Fish Diversity retrieved from http://royalalbertamuseum.ca/exhibits/online/fishes/family.cfm

Fathead Minnow (Pimephales promelas)

FTMN can be easily observed at the surface of water in the VR (Source: Google Images)

FTMN caught on the VR (Source: CPPENV 2015)

Spawning male (right) develops nuptial tubercles on the snout and lower jaw for territorial defense and for stimulation of females. The left side of picture shows male guarding eggs; he also develops a spongy pad on the back of the dorsal fin for cleaning & fanning of the eggs (Source Google Images)

- Family: **Cyprinidae**
- native to Alberta
- commonly distributed throughout North America

Habitat

- generalist that is found in various areas of a stream
- prefers slow moving streams with dense vegetation

Feeding

- omnivore; aquatic insect larvae, protozoans, zooplankton and algae (feeds on anything available)
- benthic feeder

Spawning

- high reproductive capacity
- male selects an area, courts a female whom then lays eggs under the surface of a rock, vegetation or wood for the male to fertilize.
- female deposits 200-500 eggs per spawn & spawning events over a season can range from 16-26 (6 800 to 10 600 eggs per female)
- incubation 7 days; male guards eggs and fans them until hatched
- age of maturity is 1-2 years (die after spawning since FTMN do not live past 2-3 years)
- juveniles grow fast reaching 45-50mm in 90 days

General Tolerance

- pH: preferred 6.6 (tolerable 4.5-8.5), although tolerant of low levels, deformities in eggs and abnormal behavior in adults has been documented
- temperatures: 10-29°C
- tolerates very low oxygen levels
- many studies have been done on FTMN, they are tolerate of environments that other fish are incapable of living in
- tolerant

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[1]Langhorne, A.L., M. Neufeld, G. Hoar, V. Bourhis, D.A. Fernet, and C.K. Minns. 2001. Life history characteristics of freshwater fishes occurring in Manitoba, Saskatchewan, and Alberta, with major emphasis on lake habitat requirements. Can. MS Rpt. Fish. Aquat. Sci. 2579: xii+170p.

[2] RAM (Royal Alberta Museum). 2015. Alberta's Fish Diversity retrieved from http://royalalbertamuseum.ca/exhibits/online/fishes/family.cfm

Emerald Shiners (Notropis atherinoides)

EMSH appears somewhat translucent in the water, acting as camouflage for surface swimming (Source: Google Images)

EMSH caught on the VR (Source: CPPENV 2015)

EMSH swim in schools and minnow trapping at Station Ver6 produced hundreds (Source: CPPENV Photos)

- Family: **Cyprinidae**
- native to Alberta and distributed across the eastern to central areas
- extends eastwards from the rocky mountains across North America

Habitat

- throughout the water column; midwater depths to surface
- primarily in large rivers and lakes
- prefers streams with pools and runs with sand and gravel substrates

Feeding

- invertivore; aquatic insects & zooplankton

Spawning

- high reproductive strategy
- June to August when water temperatures are between 20°C and 23°C
- prefers shallows areas over gravel substrate
- fecundity: 868-733 eggs per female
- open substratum spawners (scatter their eggs in the environment)
- eggs are buoyant
- age of maturity 1-2 years, lifespan is 2-4 years

General Tolerance

- no specific data on pH, temperature and oxygen levels however researchers have noted EMSH have been captured over numerous types of substrates but were never found in areas of dense aquatic vegetation
- intolerant since it is not found in dense vegetation

[1] Nelson, J.S and Paetz M.J. 1992. The freshwater fishes of Alberta, 2nd edition. University of Alberta Press, Edmonton, AB.
[2] RAM (Royal Alberta Museum). 2015. Alberta's Fish Diversity retrieved from http://royalalbertamuseum.ca/exhibits/online/fishes/family.cfm
[3] Leslie, J.K., and C.A. Timmins. 1998. Seasonality offish larvae in surf zone and tributary of Lake Erie: a comparison. Can. Tech. Rept. Fish. Aquat. Sci. 2197.

Lake Chub (Couesius plumbeus)

LKCH develop pink areas in the pectoral fins when spawning (Source: Google Images)

LKCH are the most widely distributed minnow species in Alberta (Source: Royal AB Museum)

- Family: **Cyprinidae**
- native to Alberta
- commonly distributed throughout North America

Habitat

- Water column from bottom to surface
- most distributed minnow in Alberta; found in lakes and rivers of all sized
- prefers slower moving streams

Feeding

- invertivore/planktivore; zooplankton, algae & insect larvae

Spawning

- high reproductive capacity
- June to mid-August when water temperatures reach 8°C
- substrate is variable; vegetation or rocks
- Eggs are fertilized over any substrates available including silt, detritus, gravel, cobble or boulders
- eggs hatch in ten days
- age of maturity 3-4 years, lifespan is 4-5 years

General Tolerance

- no specific environmental tolerance information thus basic CCME guidelines for aquatic life apply.
- LKCH are found in hot springs and are the only minnow species found in Alaska
- tolerant

[1] Nelson, J.S and Paetz M.J. 1992. The freshwater fishes of Alberta, 2nd edition. University of Alberta Press, Edmonton, AB.
[2] Langhorne, A.L., M. Neufeld, G. Hoar, V. Bourhis, D.A. Fernet, and C.K. Minns. 2001. Life history characteristics of freshwater fishes occurring in Manitoba, Saskatchewan, and Alberta, with major emphasis on lake habitat requirements. Can. MS Rpt. Fish. Aquat. Sci. 2579: xii+170p.
[3] RAM (Royal Alberta Museum). 2015. Alberta's Fish Diversity retrieved from http://royalalbertamuseum.ca/exhibits/online/fishes/family.cfm

Longnose Dace (Rhinichthys cataractae)

- Family: **Cyprinidae**
- native to Alberta
- commonly distributed throughout North America except the Maritimes

Habitat

- inhabit the area directly above the substrate
- prefers cool, fast flowing waters with rocky bottoms; they use the crevices in between rocks for protection of fast water during fatigue
- prefer riffles but will also utilize pools

Feeding

- invertivore; aquatic insects, worms, fish eggs, crustaceans and molluscs
- night feeder

Spawning

- high reproductive capacity; however specific environment conditions make it sensitive
- June to mid-August when water temperatures between 11°C and 24°C
- spawning occurs in the riffles of a stream
- defends territory in shallow riffles until a female enters his territory
- eggs are deposited in substrate below in between the small rock crevices
- incubation take 7-10 days
- parents will continue defending territory until eggs are hatched

General Tolerance

- turbidity tolerance is unknown but the species can tolerate temporarily turbid, murky or muddy waters
- velocity and the presence of riffles are the most importance factors for the existence of LNDC

The LNDC shape and large pectoral fins make it adapted for fast-flowing waters (Source: Google Images)

LNDC require rocky substrates and fast moving streams for survival (Source: Royal AB Museum Image)

LNDC only caught at station Ver6 on the VR (Source: CPPENV 2015)

[1] RAM (Royal Alberta Museum). 2015. Alberta's Fish Diversity retrieved from http://royalalbertamuseum.ca/exhibits/online/fishes/family.cfm

[2] Edwards, E.A., H. Li, and C.B. Schreck. 1983. Habitat suitability index models: Longnosedace. U.S. Dept. Int., Fish Wildl. Serv. Fws/OBS-82/10.33. 13pp.

Pearl Dace (Margariscus margarita)

- Family: **Cyprinidae**
- native to Alberta
- the furthest west is eastern BC, extends into the eastern and northern parts of Canada; only the northern USA with some isolated populations in the central states

Habitat

- bottom dwelling; prefers gravel or sand substrates (younger prefer surface)
- cool waters; bogs, creeks, ponds and lakes
- prefer streams feed by groundwater
- well vegetated undercut banks and often found in pools of streams

Feeding

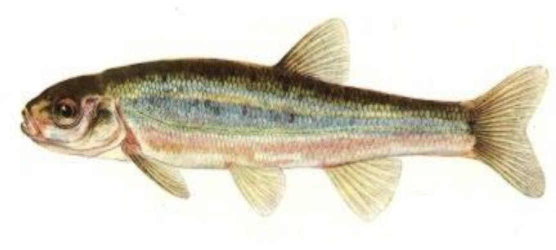
- omnivore; algae, aquatic macro-invertebrates, plant material, diptera and zooplankton
- feeds throughout winter

Spawning

- late May-June when water temperatures are 16°C to 18°C
- in depths <1m over substrates of gravel, sand, silt, clay & detritus
- males develop the red stripe during spawning that can remain until the next spawning season (left picture)
- male defends territory until female enters; eggs are distributed on the stream bottom
- fecundity: 913-2140 eggs per female
- possible hybridization between PRDC and LKCH have been recorded
- newly hatched fish are restricted to areas of dense vegetation cover for protection and they also provide zooplankton habitat; the primary diet of young fish
- age of maturity is one year; lifespan 4-5 years

General Tolerance

- will move out of an area if temperature goes above 20°C
- decreasing populations in the USA have been contributed to rising temperatures and less groundwater movement into streams due to human use



PRDC are listed as a sensitive to endangered species in various states of the USA; populations are stable throughout Canada (Source: Google Images)

Captured PRDC at station 05EE010 on the VR (Source MD photos)

PRDC are very tolerant of Canadian winters and will reside in deep pools feeding on macro-invertebrates (Source: RAM)

[1] Cunningham, G.R. (2006, September 20). Pearl Dace (Margariscus margarita): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: http://www.fs.fed.us/r2/projects/scp/assessments/pearldace.pdf [date of access].

WHSC are among Canada's most abundant and widespread fish.

WHSC are considered juvenile if less >10cm fork length (Source: RAM)

WHSC captured at station Ver3 on the VR (Source MD Photos)

White Sucker (Catostomus commersoni)

- Family: **Catostomidae**
- native to Alberta
- commonly distributed throughout North America

Habitat

- warmer shallow waters
- bottom of streams , commonly associated with large woody debris and shady areas
- substrate consists of sand, silt-clay, cobble

Feeding

- omnivore; bottom feeders that use their sub terminal mouths allow to suck up insect larvae, crustaceans, mollusc s and annelids

Spawning

- mid-May to early July or when water temperatures are 10°C
- substrate consists of gravel, sand and decaying vegetation
- prefer shallow (<1m) sections of streams and prefer gravel riffle areas of streams; in lakes along the shoreline with rocky bottoms
- at the spawning site serval males will gather around one female; their contact stimulates her to lay eggs and the males in turn fertilize them with his milt
- fecundity is from 20 000 to over 100 000 for each female over a month of spawning
- WHSC age of maturity is from 5 to 6 and they use tributaries as spawning grounds
- adults may live until 15 years of age and return to the same spawning area each year

General Tolerance

- high tolerance able to withstand turbidity, stagnant water and the alkalinity of tiny parries lakes that would kill most other species

[1] Freshwater Fishes of Canada. 1973. W. B. Scott and E. J. Crossman. Fisheries Research Board of Canada, Ottawa, Ont. Bulletin 184.

[2] Langhorne, A.L., M. Neufeld, G. Hoar, V. Bourhis, D.A. Fernet, and C.K. Minns. 2001. Life history characteristics of freshwater fishes occurring in Manitoba, Saskatchewan, and Alberta, with major emphasis on lake habitat requirements. Can. MS Rpt. Fish. Aquat. Sci. 2579: xii+170p.

Trout-Perch (Percopsis Omiscomaycus)

- Family: **Percopsidae**
- native to Alberta
- distributed throughout the USA and Canada

Habitat

- inhabits both lakes and rivers; depths range <2m to >10m
- prefer streams with sandy or rocky substrates but occasionally in areas of submergent vegetation

Feeding

- omnivore: aquatic insects, zooplankton, smaller fishes, eggs, plant material and molluscs

Spawning

- May through to August in water temperatures 15.6°C to 20°C over rocks
- two to three males will surround one female and the eggs will fall in between the rocks
- no care or guarding is given to the eggs
- fecundity is 1820-2000 eggs
- eggs hatch in 6 days at temperature ranging from 20°C to 23°C
- reach maturity at 1 to 2 years and live for 3-4 years

General Tolerance

- Needs deep pools in rivers to survive; usually over sand substrate.
- sensitive to sedimentation associated with row crop agriculture and channelization
- higher than average temperature can potentially cause die offs if no deep pools are available to cool down

TRPR gets its name from the trout like adipose fin and its perch like coloration and spines (Source: Google Images).

Only one TRPR was captured on the VR at station Ver6 (Source: MD photos)

The world record for a TRPR is 20.0cm in length but typically are from 7 to 10cm

[1] [1]Holm, Mandrak & Burridge 2009. The ROM field guide to freshwater fishes of Ontario. Royal Ontario Museum/ Toronto, Ontario; pg 312-313.
[2]Langhorne, A.L., M. Neufeld, G. Hoar, V. Bourhis, D.A. Fernet, and C.K. Minns. 2001. Life history characteristics of freshwater fishes occurring in Manitoba, Saskatchewan, and Alberta, with major emphasis on lake habitat requirements. Can. MS Rpt. Fish. Aquat. Sci. 2579: xii+170p.
[3] Alaska Department of Fish and Game (ADFG). 2005. Trout-perch. In: Our wealth maintained: a strategy for conserving Alaska's diverse wildlife and fish resources, a Comprehensive Wildlife Conservation Strategy emphasizing Alaska's nongame species. Anchorage, AK.