# Submersed Aquatic Vegetation Survey 2019, Upper Missouri River, Montana

## Prepared for:

## The Upper Missouri Watershed Alliance (UMOWA)

**AMARUQ ENVIRONMENTAL SERVICES LLC**
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## DISCLAIMER



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May 2020

Prepared for the Upper Missouri Watershed Alliance.

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The author would be remiss if he did not thank the members of the board of directors of the Upper Missouri Watershed Alliance who funded the entirety of this study; Even when they didn't know what it was going to look like in the end, they knew it was going to benefit *The* River and that is what mattered. The author would specifically like to mention the UMOWA Scientific Committee members Sherri Meador, Dave Stagliano and Dr. Alan Shaw, UMOWA President; All of whom provided support, counsel, gentle encouragement to actually compile this report, and some of whom even went so far as to provide temporary shelter during study intervals. All due thanks as well to Montana Fish, Wildlife and Parks who conducted the initial survey back in 2010 which provided a foundation upon which to base this study.

# EXECUTIVE SUMMARY

Submersed aquatic vegetation surveys of the Upper Missouri River; from Holter Dam to Cascade, Montana and spanning portions of both Lewis & Clark and Cascade Counties, were conducted in May and in August 2019. These surveys utilized multi-band sonar, in conjunction with point-intercept sampling, and were conducted as a pilot assessment of submersed aquatic vegetation presence and spatial location; relative abundance and diversity and provided a characterization of river-bottom substrate composition. The goal of these surveys was to document inter-seasonal variation of submersed aquatic vegetation communities and hydrologic impact of spring-runoff discharge operations at Holter Dam (Lewis and Clark County, Montana), to Cascade, Montana, 55 kilometers downriver.

Nearly the entirety of the surveyed area; some 8.25 square kilometers, would be considered suitable for aquatic plant growth as the surveyed area is predominantly comprised of extensive gravel bars and larger cobble beds, interspersed throughout with soft substrate zones conducive to aquatic plant growth. While deep areas (≥10 meters) exist within the study area, the calculated average depth of ±2.5 meters, is well suited to providing adequate sunlight to the river bottom in most locations. During the initial spring 2019 survey, the dominant submersed aquatic vegetation species was Northern milfoil (*Myriophyllum sibiricum*) followed by Leafy pondweed (*Potamogeton foliosus*) and Common watermoss (*Fontinalis antipyretica*). 99% of all recorded submersed aquatic plants occurred at depths ≤4 meters and the majority, 85%, were found at depths of 0-1 meter. Minor populations of the invasive (noxious; 2B)[a] species Curlyleaf pondweed (*Potamogeton crispus*) were noted along with extensive, incipient stands of filamentous algae (likely *Lyngbya* or *Cladophora* species).

During the follow-up survey conducted in August of 2019, the submersed aquatic vegetation population composition remained nearly the same, species was Northern milfoil (*Myriophyllum sibiricum*) followed by Leafy pondweed (*Potamogeton foliosus*) and Common watermoss (*Fontinalis antipyretica*). Mirroring the May survey, 99% of all surveyed SAV were detected at depths ≤ 5m and the majority (93%) occurring within the top meter of the water column. Unlike

[a] https://agr.mt.gov/Weeds

the May survey, SAV populations increased dramatically below the surface with 36% occurring at -1-2m and 13% respectively occurring deeper than 2 meters.While the previously noted stands of *P. crispus* were still present, their life cycle was near completion at this time and so were much less extensive. In contrast, during this later survey extensive, nearly monotypic stands of a relatively cosmopolitan algae species, *Ulva intestinalis* (formerly *Enteromorpha intestinalis*), which was formerly thought to occur only rarely within Montana, were noted throughout the study area. Downstream of the confluence of the Dearborn River (47° 7'41.87"N 111°54'41.30"W), SAV was relatively absent, as compared to upstream river mile segments, and were dominated nearly in their entirety by filamentous and macrophytic algal species; primarily *U. intestinalis*.

Combined data from both survey events was used to confirm the presence of at least nine of eleven previously reported (2010, unpublished) submersed and floating aquatic species collected by Montana Fish, Wildlife and Parks. As this data set only encompasses a single season, limited inferences may be made about the potential effects of inter-seasonal peak discharge regime at Holter Dam; However, preliminary data suggests that the impacts on submersed aquatic vegetation are limited to within the first few kilometers of the river downstream from Holter Dam. Interestingly, the effect of gravel contribution to the Upper Missouri River from the Dearborn River appears to be quite extensive as rooted submersed plants only occurred in the river channel periphery. Submersed plant population occurrence and density was less than 50% of that found per river mile surveyed upstream of the Dearborn-Upper Missouri confluence; SAV and overall (includes moss and algae counts) species count was also significantly less than what was detected upstream, suggesting that seasonal discharge from the unmanaged Dearborn might provide an adequate model of the Missouri River study area were the Bureau of Reclamation Projects at Canyon Ferry and Holter not present.

A second season of hydroacoustic surveys, coupled with point-intercept and random sampling methods will be conducted during the 2020 water season with the intention of capturing river channel bathymetry, bottom composition, and SAV occurrence and distribution both PRE- and POST- peak seasonal discharge is planned. Combined data from the 2019 and 2020 data sets will be analyzed and reported during the winter 2020-21.

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| km | kilometer |
| m | meter |
| $m^3/s^{-1}$ | cubic meters per second |
| USGS | United States Geological Service |
| BOR | Bureau of Reclamation |
| FAS | Fishing Access Station |
| SAV | Submersed Aquatic Vegetation |
| MT FWP | Montana Fish, Wildlife, and Parks |
| PRE- | Preemergent |
| POST- | Postemergent |
| CHIRP | Compressed High-Intensity Radiated Pulse |
| Km/h | Kilometers per hour |
| GPS | Geographic Positioning System |
| Cm | centimeters |
| GIS | Geographic Information Systems |
| pH | per hydronium |
| °C | Degrees Celsius |

# 1.0 Introduction

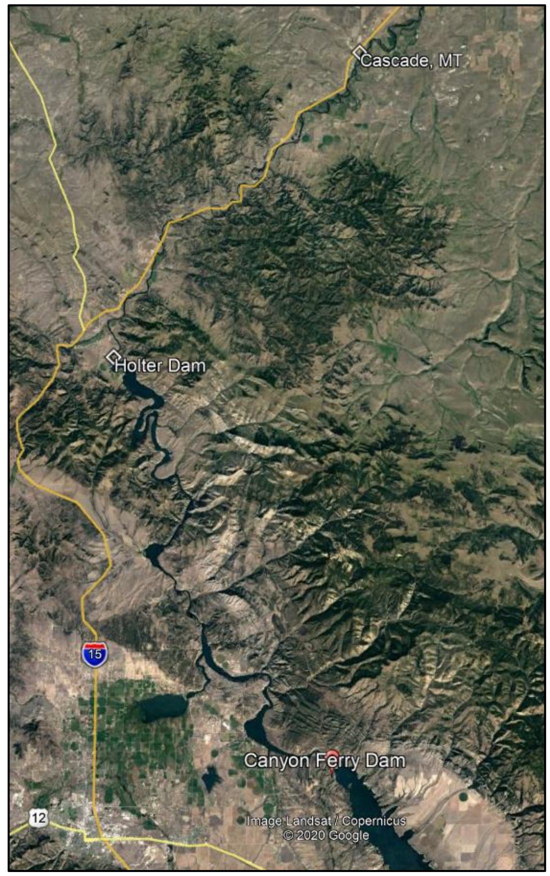
The 2019 study area (**Image 1**) delineation started at the foot of Holter Dam (46° 59’30.35 N 112° 0’21.04 W NAD83) near Wolf Creek, Lewis and Clark County, Montana and ran north-by-northeast approximately 55 river kilometers (40km, linear) to the Craig Fishing Access Station (FAS) in Cascade, Cascade County, Montana (47° 16’49.73 N 111° 41’23.78 W NAD83). Satellite imagery analysis was used to determine an average width at river’s surface to be 135 meters and an average depth of 2.5 meters. A seasonal mean discharge of 193 cubic meters per second ($m^3/s^{-1}$) (**Figure 1**) was measured at the United States Geological Service (USGS) National Water Information System (NWIS) Station 06074000[2] in Cascade, Montana.

**Image 1.** UMOWA Study Area, 2019, showing known tributary outfalls to the Missouri River.


[2] https://waterdata.usgs.gov/nwis/inventory?/?site_no=06074000

NWIS Station 06066500[3] at Holter Dam (**Figure 3**) is a pass-through facility managed by the Bureau of Reclamation; the discharge at Holter Dam being determined by BOR releases at Canyon Ferry Dam (USGS 0605800) [4] in Canyon Ferry, Montana, 43.8 km upstream from Holter Dam.

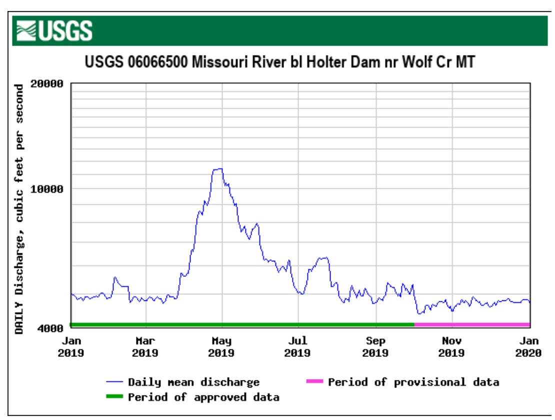
**Image 2.** 2019 UMOWA Study Area, relative to Holter and Canyon Ferry Canyon Ferry Dams.




Propoerty ownership trhoughout the study area described is diverse; with privately-owned homes and ranches; city, county, state, and federal lands all having frontage somewhere along the river. Numerous state-maintained Fishing Access Stations (FAS) for public access are located throughout the study area (**Image 4**) and are referenced as waypoints in this document.

The Missouri River varies greatly in depth throughout the study area, with a maximum detected depth of 12.2 meters and an average depth of 2.3 meters (**Appendix A**). This relatively shallow depth is adequate to support rooted, submerged plants, provided adequate sunlight reaches the river bottom and adequate sediment accumulates in the river cobble during the season of establishment and subsequent growth. While many submersed aquatic plant species have preferential depths of occurrence, most commonly encountered species in the lower 48 contiguous United States are capable and have

**Figure 1.** USGS Discharge (cfs) as measured at USGS 06066500 at Wolf Creek; 01JAN2019-01JAN2020.




[3] https://waterdata.usgs.gov/nwis/inventory/?site_no=06066500
[4] https://waterdata.usgs.gov/nwis/inventory/?site_no=06058000

been documented growing to depths of 12[5] to 20[6] meters, though this last measure may be considered an extreme maximum depth of occurrence and may not representative of typical conditions on a large river (*author; personal opinion*). As such, nearly the entirety of the study area would be considered suitable to support SAV populations, given limited disturbances to the river sediments in-season, adequate sunlight penetration, and suitable substrate.

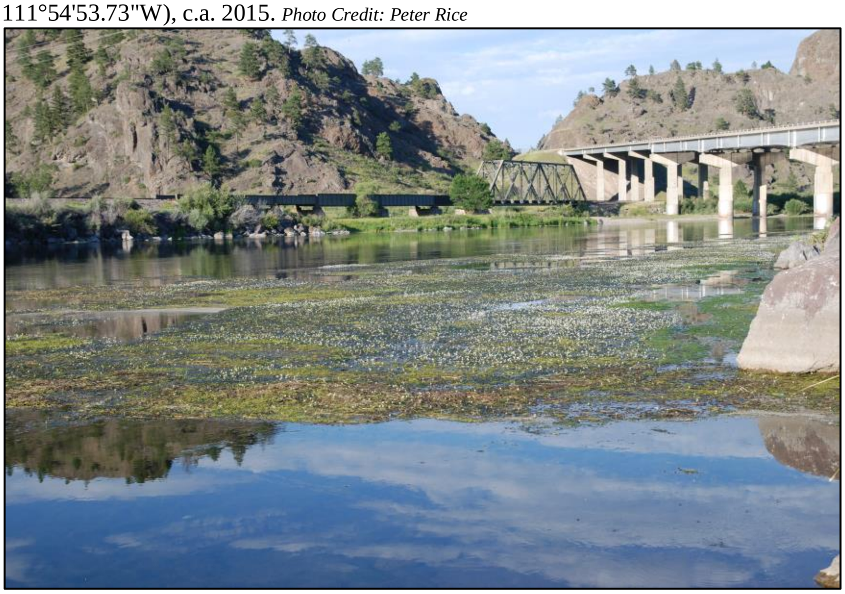
**Table 1.** Initial Species Survey, Upper Missouri River, as conducted by MT FWP, 2010.

| Common_Name | Count | % Occurrence | Scientific_Name |
|---|---|---|---|
| White waterbuttercup | 110 | 30.1 | *Ranunculus aquatilis* |
| Leafy pondweed | 66 | 18.1 | *Potamogeton foliosus* |
| Chara spp. | 39 | 10.7 | *Chara spp.* |
| Curlyleaf pondweed | 36 | 9.9 | *Potamogeton crispus* |
| Canada waterweed | 31 | 8.5 | *Elodea canadensis* |
| Sago pondweed | 29 | 7.9 | *Stuckenia pectinatus* |
| Northern watermilfoil | 24 | 6.6 | *Myriophyllum sibiricum* |
| None | 10 | 2.7 | Unidentified |
| Common water moss | 9 | 2.5 | *Fontinalis antipyretica* |
| Coontail | 5 | 1.4 | *Ceratophyllum demersum* |
| Northern arrowhead | 4 | 1.1 | *Sagittaria cuneata* |
| Duckweed | 2 | 0.5 | *Lemna spp.* |
| | 365 | 100 | |

Where % Occurrence = (Species Count/ Total Count)* 100

A vegetation survey was conducted in 2010 by MT FWP (unpublished) along a smaller portion of this study area, recording presence/absence and provided identification to the taxa level and documented 9 submersed and floating aquatic plants, White water buttercup (*Ranuncuclus aquatilis;*); Leafy pondweed (Potamogeton foliosus); *Chara* spp., a macrophytic algae species; Curlyleaf pondweed (*Potamogeton crispus*); Canadian waterweed (*Elodea canadensis*); Sago pondweed (*Stuckenia pectinatus*); Northern milfoil (*Myriophyllum sibiricum*); Common watermoss (*Fontinalis antipyretica*); Coontail (*Ceratophyllum demersum*); Northern Arrowhead (*Sagittaria cuneata*); and Duckweed (*Lemna* spp.) (**Table 1**). Species were listed in order of greatest to least occurrence. Anecdotal evidence in the decade following this study has suggested widespread

**Image 3.** White water buttercup infestation at Dearborn FAS (47°7'39.70"N 111°54'53.73"W), c.a. 2015. *Photo Credit: Peter Rice*



[5] Sheldon, Richard B., and Charles W. Boylen. "Maximum Depth Inhabited by Aquatic Vascular Plants." The American Midland Naturalist, vol. 97, no. 1, 1977, pp. 248–254. JSTOR, www.jstor.org/stable/2424706. Accessed 15 May 2020.
[6] https://duluthmn.gov/media/8081/predicting-submerged-aquatic-vegetation-cover.pdf

expansion of nuisance SAV throughout the region, and a brief inspection during the summer of 2015 found many areas above and below Craig, Montana to be completely infested with White water buttercup (**image 3**).

## 2.0 Objectives

The purpose of this submersed aquatic vegetation (SAV) survey was as a feasibility study of large-scale river assessment. Specific objectives included:

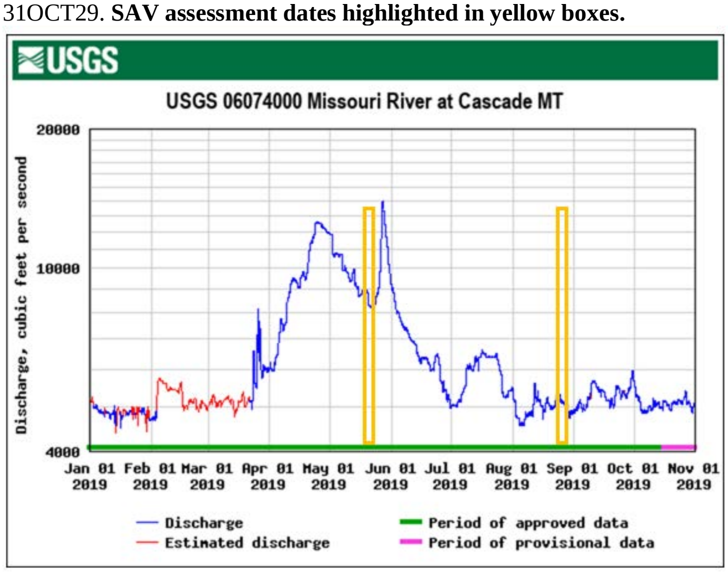
- **1.** Confirm prior MT FWP data regarding overall species presence;
- **3.** Conduct point-intercept survey along same track to estimate SAV presence, speciation to the taxa level where possible, and estimate taxon frequencies and relative densities;
- **2.** Conduct multi-band hydroacoustic survey to roughly follow the Upper Missouri River thalweg from Holter Dam to Cascade, Montana;
- **4.** Conduct sequential SAV surveys following spring discharge at Holter Dam to determine potential impacts on river channel geomorphology; coarse-level changes to the river structure and sediment composition and distribution following same;
- **5.** Compare PRE- and POST- flushing flow discharge data to establish correlations between seasonal impacts of fluvial activity and SAV occurrence and densities;
- **6.** Develop distribution maps for identified SAV taxa

## 3.0 Materials & Methods

### 3.1 Spring Survey 2019

As a pilot program, this study maintained an initial course heading to follow the Upper Missouri River thalweg, as indicated by sonar at the time of survey in May 2019, as opposed to the river centerline; this was done so as to survey the areas where spring runoff induced discharge

**Figure 2.** USGS NWIS Station 06074000 Discharge (cfs), 01JAN19 to 31OCT29. **SAV assessment dates highlighted in yellow boxes.**



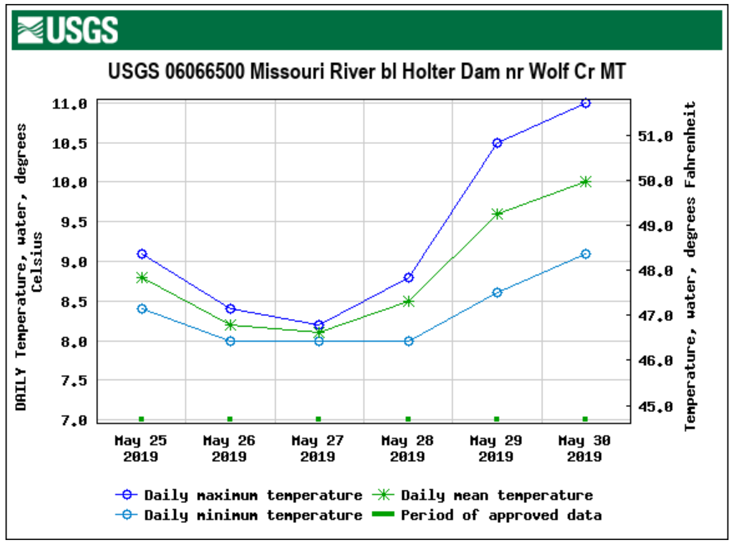


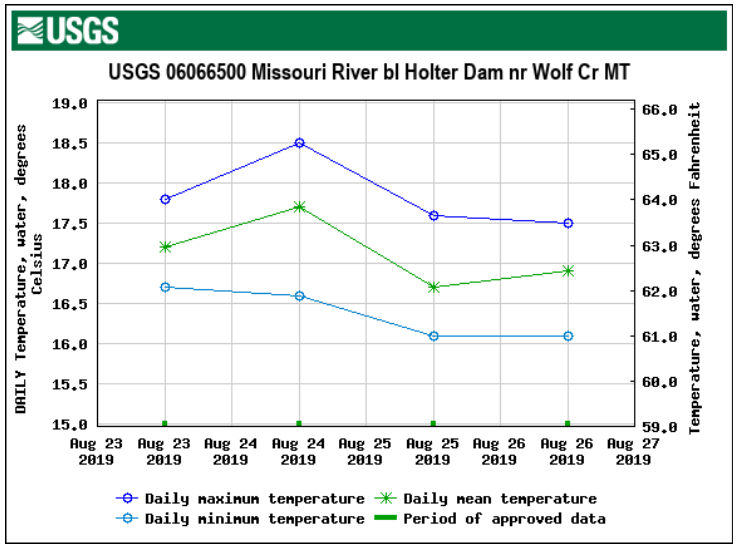

**Figure 3.** USGS NWIS Station 06074000 Water Temperature, 25MAY – 30MAY19.

would have greatest souring effect during the intervals between surveys, 2019. The first survey occurred 24-26MAY2019 at a recorded discharge at Holter Dam of 184 $m^3s^{-1}$ (**Figure 2**) and water temperatures averaged 8.4°C during the survey period (**Figure 3**). Individual data parameters collected and recorded in continuous intervals during the survey included depth, bottom hardness, SAV height above bottom, SAV presence/absence, and relative biomass density. This data was collected via Duplicate Lowrance®[7] HDS 9 (Gen 3) fish finders with 83/200 KHz Compressed High-Intensity Radiated Pulse (CHIRP) and 455/800 kHz TotalScan™ HST-WSBL transducers ($22^{\circ}$ beam width) mounted underneath the transom of a 4.9 meter fiberglass epoxy flat-bottom fishing boat manufactured by Clackacraft™[8] Drift Boats, and was of the type of watercraft common to areas with shoal waters. Negative depth correction was measured from the top of the transponder to the water surface when the boat was first floated with full survey weight on board. This correction provides a zero reference between the transponder and river bottom and provides a reference for accurate assessment of sonar signatures height above ground and below the transducers.

The Lowrance HDS 9 sonar records GPS position approximately once a second and then averages acoustic data (5-30 pings/$s^{-1}$) between positional reports for each coordinate point. Hydroacoustic data were recorded using twin transducers, mounted underneath the boat transom of the boat (-15 cm under water surface) and the boat was driven down the entire study area at speeds ranging from 3.5 to 7.5 km/h. Lowrance 3-in-1 wide-beam HST-WSBL transducers have a minimum height above SAV and the river bottom hardpan of 0.73 m from the transducer face and 0.37 m for depth determination.

[7] https://www.lowrance.com/lowrance/type/fishfinders-chartplotters/hds-9-live-amer-xd-ai-3-in-1/
[8] https://www.clacka.com/boats/16-big-eddy/

**Figure 4.** USGS NWIS Station 06074000 Water Temperature, 23AUG – 27AUG19.




Following the methods described by Madsen (1999), submersed aquatic vegetation was sampled via rake-toss methodology; wherein a macrophyte rake (35×12 cm with 2 cm spacing) was thrown three times per sample event and visually assessed for SAV presence/ absence, species identification to the taxa level where possible, and an estimate given for taxa-specific percent biomass, relative to the entire rake sample. Percent biomass was estimated and assessed on an arbitrary scale of 0 to 5; 0 being no SAV detected, 1 being less than 10% of the total sample and 5 being a sample comprised of a single species. Hydroacoustic data was transferred from the sonar array to computer via .sl2 file type and uploaded to BioBase™ by CMAP[9] and the data is subjected to quality control analyses. Data output is in Geographic Information System (GIS) raster layers of depth, vegetation biovolume where;

$$\textit{Biovolume} = \frac{\textit{Transducer height above ground- macrophyte height}}{\textit{Transducer-measured depth of water column}}$$

Bottom hardness, as a measure of relative amounts of soft sediments through which CHIRP frequencies pass, as a percentage over hard rock cobble which reflect CHIRP frequencies and is quantified through acoustic reflection.

### 3.2 Summer Survey 2019

A summer survey was conducted 23-25AUG2019 during a recorded discharge at Holter Dam of 136 $m^3s^{-1}$ **(Figure 2)**. Water temperatures averaged 17.13°C during the survey period (**Figure**

[9] https://www.biobasemaps.com/Solutions/AquaticPlants

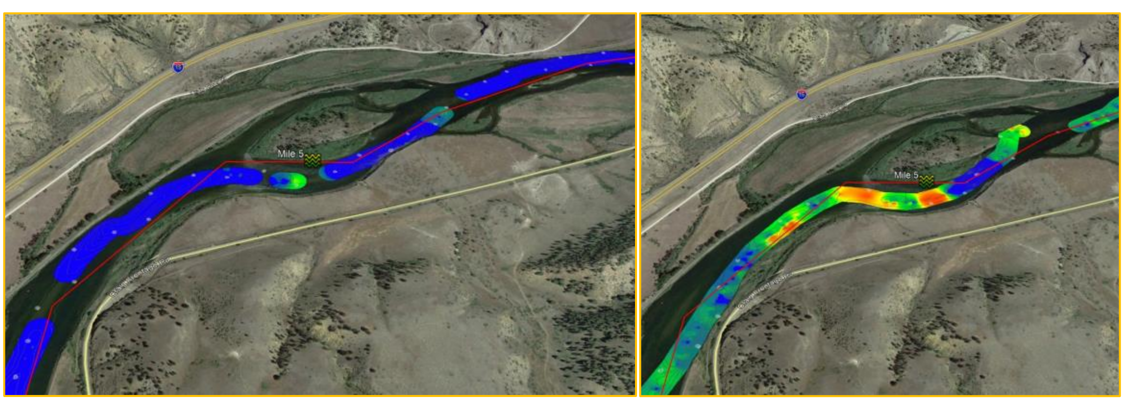
**4**) and roughly followed the same path utilizing Geographic Positioning System (GPS) waypoints set during the previous survey.

**Image 4.** Total (0-100%) Submersed Aquatic Vegetation Densities at Holter Dam, in May (left) and then in August (right) following seasonal peak discharge 2019. *Photo Credit: Amaruq Environmental Services*


## 4.0 Data Processing and Statistical Analysis

Post-survey data processing was required to correlate sonar reflectance values to plant canopy height where distance between transducer and the top of plant canopy intercepted by the transducer acoustic cone was subtracted from transducer height-over-ground to obtain a reliable measurement of plant canopy height, biovolume as a percent of the water column occupied by

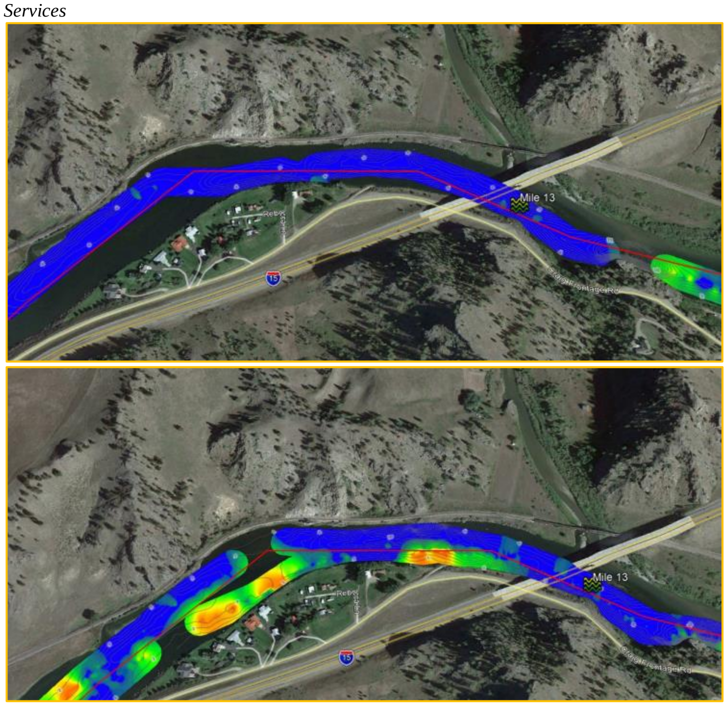
**Image 5.** Total (0-100%) Submersed Aquatic Vegetation Densities five miles downstream of Holter Dam, in May (left) and then in August (right) following seasonal peak discharge 2019. *Photo Credit: Amaruq Environmental Services*



plant or algal biomass. Plant heights were averaged across all pings within a GPS coordinate point, and plant heights that together averaged less than 5% of the depth were considered not vegetated to minimize false detections by bottom detritus or other debris. The Biobase by CMAPS™ platform also discards 2% of the deepest coordinate points registering vegetation to prevent bottom debris or other phenomena from generation of false vegetation detections. Regression analysis removed outlier data generally associated with transducer minimal height over ground in shallow waters (<0.3m). As 2019 was a pilot study and did not have successive data sets to allow for statistical interpretation, data analysis following the completion of survey in 2020 will include: mean (depth), median (bottom hardness), Vegetation percent biovolume; species composition (presence/absence and percent sample composition).

Hydroacoustic and point-sample data were compared using 1.6 km transects as experimental blocks within the study area. For point-sample data, frequency of occurrence was calculated for each species as the number of sites in which a species occurred divided by the total number of sample sites. The average density of plants, calculated as total rake sample (percent fullness, %) by species and per rake sample was calculated as the estimated percentage density, by species, divided by total estimated density percentage of aquatic vegetation captured in a single rake sample. Species occurrence and relative density were then compared to total sample count (*n= 340)* to determine overall species composition by river segment.

**Image 6.** Total (0-100%) Submersed Aquatic Vegetation Densities 13 miles downstream of Holter Dam, just south of the confluence of the Missouri and Dearborn Rivers in May (left) and then in August (right) following seasonal peak discharge 2019. *Photo Credit: Amaruq Environmental Services*



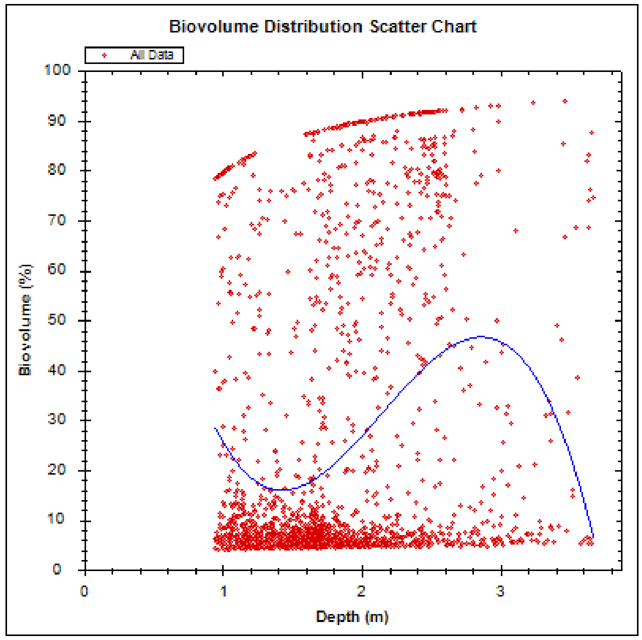
## 5.0 Results & Discussion

Results for the spring and summer surveys will be presented sequentially, starting with the spring 2019 survey. Differences between the two surveys will then be compared.

## 5.1 Spring Survey 2019

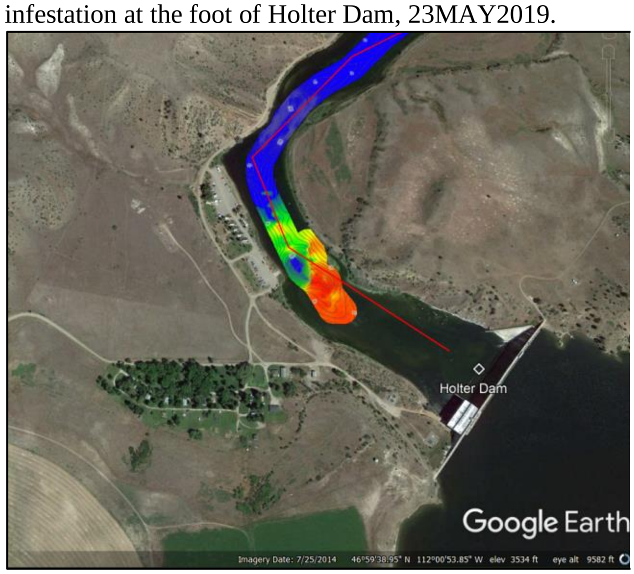
Survey data collected 24-26MAY19 detected only three species of SAV within the 55km length of the study area; Northern milfoil (*Myriophyllum sibiricum*, **section 5.1.1**), Leafy pondweed (*Potamogeton foliosus*; **section 5.1.2**), and Curlyleaf pondweed (*Potamogeton crispus*; **section 5.1.4**). During this time period, none of the SAV localities surveyed were in excess of 40% by rake-sample volume and of a total of 340 sample points, most samples returned less than 5% "full" for any species. Biovolume distribution data was parsed to remove data collected where hydroacoustic transducer height-over-ground was ≤0.3m to remove errors associated with insufficient height over biomass (**Figure 5**).

**Figure 5.** Biovolume Distribution Scatter Chart, MAY2019.




The presence of large, incipient (defined as averaging ≤15cm in length or less per sample) beds of Common watermoss (*Fontinalis antipyretica*; **Section 5.1.3**) were also noted occurring throughout the study area, though no sample containing this species rated higher than 5% sample density, likely a result of a lack of above-ground biomass at time of sampling. Significant populations of Common watermoss were found growing within the first 0.5 km of the survey area. (**image 7**). Curlyleaf pondweed was first detected approximately 8.5km from Holter Dam; co-occurring with Northern Milfoil (25% and 30% sample density, respectively). This was the only find of this invasive species during this sample period. At approximately 19 kilometers downstream of Holter Dam, Common watermoss was no longer detected and total SAV population surveyed was comprised entirely of Northern milfoil, average population density ~14%; and Leafy

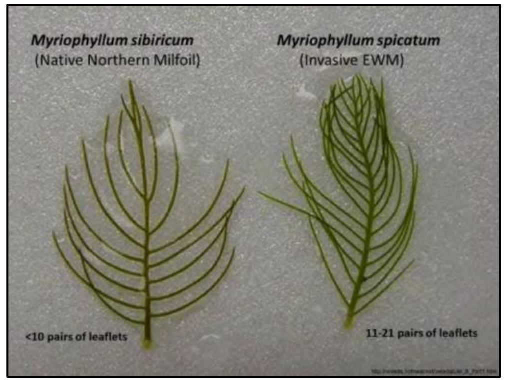
**Image 7.** Common watermoss (*Fontinalis antipyretica*) infestation at the foot of Holter Dam, 23MAY2019.



pondweed, average population density ~15%, both of which were in very early stages seasonal growth. Downstream of the confluence of the Dearborn River (21km from Holter Dam), SAV populations dropped to less than 5% for all samples taken and only Northern milfoil and Leafy pondweed were detected in measurable quantities. Growth by species had a high degree of variability, with sample values ranging from <5% to 45% for all species found; including Northern milfoil. Common watermoss was seen throughout the lower half of the study area but was not recovered in recordable (≥5%) quantities anywhere downstream of this point.

***5.1.1*** Northern milfoil *(Myriophyllum sibiricum);* Northern milfoil, also known as Shortspike watermilfoil, is a native species endemic to nearly all continental North America[10], however, it is not commonly found in the Southeastern United States as a likely result of warmer temperatures being inhospitable to this species. Northern milfoil can be found in depths of 1-10 m in lacustrine systems and low-energy areas of riverine systems, and like many aquatic plant species, can tolerate a wide spectrum of conditions, and has been documented to occur in brackish water. This species is frequently found in calcareous waters common to the Western United States. Also, like many congeners, *M. sibiricum* flourishes in areas that experience frequent inter- and intra-seasonal disturbances associated with spring runoff in the Western United States as well as anthropogenic activities that result in plant fragmentation and dispersal.

**Image 8.** Northern milfoil foliage syn.. Siberian milfoil (*Myriophyllum sibiricum*). Showing typical leaf count (<10) versus the invasive Eurasian watermilfoil (*M. spicatum*) which typically has 11-21 pairs of subdivided leaflets. *Photo- John Halpop, Montana State University Extension*




*M. sibiricum* is a perennial that flowers twice a year, typically mid-June and late-July, followed by auto-fragmentation of the plant after each flowering. Northern milfoil typically goes dormant during the late fall; though standing vegetation may be found throughout the winter season in minimally disturbed areas. Winter mortality, while not common with this species, may occur if the seedbed lies in seasonally exposed areas, but unless the root system-hosting sediment bed is exposed to temperatures below 0°C for extended intervals of time, the root system is likely to overwinter. Regrowth begins early the following spring once water temperatures reach about 15°C (Smith and Barko 1990), though actively growing plants have been observed within the study area as late as October and as early as March (*author, personal observations*).

[10] https://plants.usda.gov/core/profile?symbol=MYSI

**Image 9.** Northern milfoil (*M. sibiricum*) inflorescence.
*Photo: Vernon Smith, 2012.*

Like other members of the genera *Myriophyllum*, *M. sibiricum* produces turions, or reproductive vegetative structures, in order to overwinter. Seed production does occur but is minimal in contrast to the ease with which this species disperses through vegetative fragmentation and propagation. Northern milfoil has thin stems, which can be appear green, brown, or pinkish white depending on growth stage and ambient growth conditions. There are typically four feather-like, deeply-dissected leaves (**image 8**) whorled around the stems with 10 (or less) subdivided leaflets per stem, and the inconspicuous, pink to yellow four-parted flowers (**image 9**) rise 5-10 cm above the surface of the water from the terminal spike. Northern milfoil is often confused with the non-native and invasive Eurasian milfoil (*M. spicatum*); though the latter species most often has ≥14 leaflet pairs per leaf. It is worth noting that Northern milfoil readily hybridizes with the invasive species, Eurasian milfoil, and the resultant hybrid (Hybrid water milfoil or *M. sibricum x spicatum*), may be indistinguishable from either parent without the use of genetic analysis.

***5.1.2*** *Leafy pondweed (Potamogeton foliosus);*

**Image10.** Leafy pondweed (*P. foliosus*) foliage and seed cluster.
*Photo: https://www.illinoiswildflowers.info/wetland/plants/leafy_pondweed.html*

Leafy pondweed (*Potamogeton foliosus)*, is a native species endemic to all continental North America[11] and may be found in lacustrine and riverine systems, and like many other aquatic plant species, is tolerant of a wide range of growing conditions to include swings in pH, salinity, and sediment composition. Leafy pondweed has branching, leafy stems ≤0.75 m long, and the stems are typically ≤1 mm in diameter (**Image 10**) Foliage often appears pale green to yellowish green, depending on seasonal conditions and time of year. Leaves occur in an alternating pattern along unbranched areas of the stems, while either alternate or opposite leaves occur where the stems divide. Leaves are up to 6 cm. long and about 1.5 mm. across; are dark to olive green, linear and smooth along their margins, and taper to flat tips, and are often grassy in appearance, relatively soft, and flexible. Submerged, nondescript floral spikes develop from some of the leaf junctions (**image 11**), usually in mid-to-late summer, and are present for some 3 weeks. Leafy Pondweed is common throughout Montana and is known to be better adapted than many other members of the Pondweed Family to shallow waters: however, this species does require standing water cover throughout the year to stay active.

**Image 11.** Leafy pondweed (*P. foliosus*) inflorescence.
*Photo:http://science.halleyhosting.com/nature/basin/aquatic/potamogeton/foliosus.html*


[11] https://plants.usda.gov/core/profile?symbol=POFO3

Leafy pondweed may be encountered at depths of 1-10 m in lacustrine systems and low-energy areas of riverine systems, and like many aquatic plant species, can tolerate a wide spectrum of conditions, and has been documented to occur in brackish water. Also, like many members of the Pondweed family, *Potamogetonacea*, Leafy pondweed flourishes in areas that experience frequent inter- and intra-seasonal disturbances associated with spring runoff in the Western United States as well as anthropogenic activities that result in plant fragmentation and dispersal. This species is frequently encountered in the State of Montana within ponds, lakes and irrigation conveyance systems, though within the latter, *P. foliosus* occurs with less regularity than Curlyleaf pondweed (*P. crispus;* **see section *4.2.4***), and distant relatives Horned pondweed (*Z. palustris*; **see section *4.2.1***) and Sago pondweed (*Stuckenia pectinata;* **see section *4.2.5***), (*author, personal observations*).

**5.1.3** Common watermoss (*Fontinalis antipyretica*); Common watermoss (*Fontinalis antipyretica* also known as Robust Fountain Moss[12]. Common water moss is a dark green underwater plant that attaches to rocks or logs in flowing water, or floats loose or attached in still water and is one of only a few truly aquatic mosses (*Bryophyta* species) in the Pacific Northwest. The leaves are sharply pointed, ridged, overlapping, and arranged in 3 rows along the entire length of the stems which may grow ≥ 60 cm long. These stems appear triangular in cross section. Common water moss does not produce flowers, reproducing by stolons, plant fragments, or spores instead. It is often found dried and dormant above water in the summer. *Fontinalis*, like many members of *Bryophyta* is widespread throughout the northern hemisphere and is found in both lacustrine and riverine systems. *Fontinalis* is known to form extensive and dense monoclonal colonies, and as such, becomes an important habitat for stream invertebrates and even a protective site for fish eggs.

**Image 12.** Common watermoss (*F. antipyretic*) foliage. *Photo: ©2012 calbryos group*

[12] http://fieldguide.mt.gov/speciesDetail.aspx?elcode=NBMUS2X070

Common watermoss may be an indicator of clean water; however, it also occurs in highly turbid, nutrient rich waters as well. This species may be sensitive to alkaline waters, preferring a pH range of 4-5.5 and will generally not tolerate temperatures in excess of 20°C which induces dormancy in this species until temperatures return to an optimum of 10°C. This species occurs in both lacustrine and riverine systems and is well adapted to living in fast moving water conditions, such as may be found across shallow gravel bars throughout the study area. Fontinalis leaves are toothed at the leaf apex and leaves exhibit a slight roll.

As a member of Family *Fontinalaceae*, reproduces via spores, though this is thought to be infrequent, with primary dispersal being through vegetative fragmentation of leaves and stolons. Common watermoss produces numerous root-like structures that enable a strong hold onto substrate and may offer a means of dispersal during annual spring runoff events.

**Image 13.** Curlyleaf pondweed (*P.crispus*) foliage.
*Photo: Paul Skawinski, Aquatic Plants of the Upper Midwest*

**5.1.4** Curlyleaf pondweed (*Potamogeton crispus*); is an invasive (Noxious, 2B[13]) species introduced to Montana, circa 1973 and was listed as a noxious species by the State of Montana in 2010. Curlyleaf pondweed may be encountered in lacustrine or riverine systems as an extensive, and deeply-rooted perennial system that can quickly form dense, monoclonal stands to the detriment of native flora and fauna that depend on open gravel for reproduction. This species may be found in depths like other submersed aquatic weed species described herein; and is most commonly found growing at depths of 1 to 3 meters. While perennial, Curlyleaf pondweed is notable for having a unique lifecycle wherein established stands appear to go dormant mid-season, only to reoccur later in season. This mid-season dieback may result in localized dissolved oxygen levels in lacustrine systems but is generally not seen in riverine systems and in areas with high water volume turnover. The unique seasonal growth of Curlyleaf pondweed differentiates this species from other submersed aquatic plants found in North American waters. In the colder regions of its range, turions break dormancy in the fall when water temperatures drop. Curlyleaf pondweed overwinters as whole, intact leafy plants (even under thick ice and snow cover) quickly emerging in early spring when water temperatures are still quite cool (10-15°C). In early June plants flower, fruit, and form turions, and then plants senesce by mid-July throughout most of its range.

Curlyleaf pondweed grows entirely as a submersed aquatic plant with no floating leaves, and plants will not live long if uncovered during periods of low water. Leaves are alternate, 4-10 cm in length and 5-10 mm wide. Leaves (**image 13**) are conspicuously toothed along leaf margins, sessile (attached directly to the stem), narrowly oblong, undulate (wavy like lasagna noodles) with a conspicuous mid-vein. Leaf tips are obtuse (rounded or blunt), olive-green to reddish-brown, and somewhat translucent. Stems are flattened, channeled, with few branches. Rhizomes are pale yellow or reddish, rooting at the nodes. Small flowers (3 mm wide), with greenish-brown or greenish-red sepals form on a terminal spike above the waterline producing 3-4 fruits per flower[14].

[13] http://fieldguide.mt.gov/speciesDetail.aspx?elcode=PMPOT03060
[14] https://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=1134

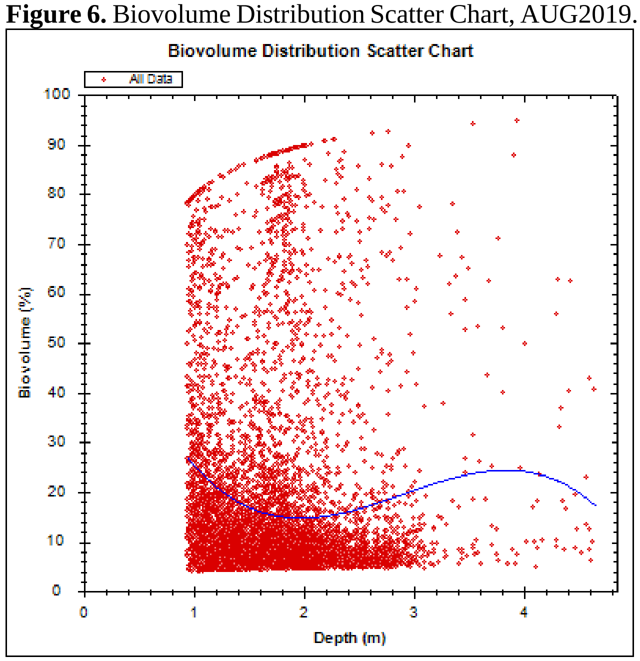
# Summer Survey 2019

Survey data collected 23-25AUG19 found both an overall increase in species diversity of SAV within the 55km length of the study area and also the appearance and proliferation of an algal species, *Ulva intestinalis*, which had previously never been documented in this section of the river nor was it known to occur in abundance in the State of Montana. Northern milfoil, Leafy pondweed, and Curlyleaf pondweed populations continued to be present though in increased density (average ~45% by sample density) from the previous survey, as could be expected given time of year and average growing conditions. A large, single population of Elodea (*Elodea canadensis*; **Section 5.1.11**) was detected just upstream of the confluence with the Dearborn River (**image 14**) and was not detected anywhere else within the study area in 2019. A total of 340 sample points were surveyed and, as was done for the Spring 2019 survey, biovolume distribution data was parsed to remove data collected where hydroacoustic transducer height-over-ground was ≤0.3m to remove errors associated with insufficient height over biomass (**Figure 6**). As was noted during the spring 2019 survey, large, dense stands of Common watermoss (100%) occurred throughout the study area, though it is interesting to note that those located during 23-25MAY19 (**image 5**) were no longer present at the foot of Holter Dam (**image 18**); possibly a result of scouring action following peak release on or before 01JUNE19.

**Image 14.** Sole Elodea (*E.canadensis*) detection location, 47° 7'12.72"N 111°56'33.82"W, 2019.


Significant populations of Northern milfoil, Leafy pondweed and Horned pondweed (*Zannichellia palustris*; **Section 5.1.5.**) first appeared around 4.75km downstream of Holter Dam. Curlyleaf pondweed, as could be expected given its life cycle and time of year, while greatly reduced from levels previously detected and was found in minor (≤10% sample density) populations to 21km downstream of Holter Dam.

**Figure 6.** Biovolume Distribution Scatter Chart, AUG2019.



Leafy pondweed and Northern milfoil maintained their dominance within the survey area, though one location with a dense stand of Sago pondweed (*Stuckenia pectinata*; **Section 5.1.9**) was found near the 38km waypoint, downstream of Holter Dam. Northern milfoil and Leafy pondweed were detected in measurable quantities. Growth by species had a high degree of variability, with sample values ranging from <5% to 45% for all species found; including Northern milfoil. Common watermoss was seen throughout the lower half of the study area but was not recovered in recordable (≥5%) quantities anywhere downstream of this point.

**Image 15.** Common watermoss (*Fontinalis antipyretica*) infestation no longer present (23AUG19), presumably following peak discharge from Holter Dam having occurred following Spring 2019 Survey.

**5.1.5** *Horned pondweed (Zannichellia palustris);* Horned pondweed is an entirely submersed aquatic perennial grass species and is native to the North American continent, including the Canadian Provinces and Alaska. Like many other aquatic weed species, Horned pondweed may be found in a wide spectrum of environments; fresh brackish and tidal wetlands, (chloride range ~185-1200 mg/l[15]) have all been documented as being adequate for establishment and survival.  This species requires flowing water to thrive. Horned pondweed is a appears as slender, thread-like branches with opposite leaves and may approach 2 meters in length; particularly when found growing within the confines of irrigation conveyance systems (**Image 16**).

**Image 16.** Horned pondweed (*Zannichellia palustris*) infestation Photo: SEINet Portal Network. 2020. http//:swbiodiversity.org/seinet/index.php. Accessed on May 19.

Horned pondweed stems are light green, glabrous, and filiform (about 0.5 mm. across). The leaves are arranged oppositely or in pseudo-whorls at intervals along these stems; they are 0.4 to 1.1cm long and 0.5-1.0 mm. across. The leaves are light to medium green, linear in shape and flattened, smooth along their margins, and glabrous, tapering to acute tips. The stems and leaves often darken with age or become brown from a coating of algae. Membranous sheaths surround the stems at the bases of the leaves; these delicate sheaths disintegrate with age. Horned Pondweed is monoecious, producing separate male and female flowers on the same plant. These inconspicuous flowers are located at the bases of the leaves, where male

**Image 17.** Horned pondweed (*Zannichellia palustris*) with distinctive "horned" seeds located in leaf axils. Photo: https://www.illinoiswildflowers.info/wetland/plants/horn_pondwd.html

[15] https://www.maine.gov/dacf/mnap/features/zanpal.htm

and female flowers often occur together. The root system is fibrous and rhizomatous. Dense, monoclonal stands of Horned pondweed will often develop from the rhizomes and seed dispersal seems to be a secondary dispersal method when compared to vegetative fragmentation. Horned pondweed will only tolerate partial shade underwater and as a result, is generally not found in water deeper than 1.5m. Distinctive fruits may be found in the leaf axils (**image 17**); However, these are only present as the plant achieves sexual maturity and may not be present to aid in identification. The seed structures are toothed along one edge and have a horn appearance averaging 1-2 mm long. Flowering and seed set may occur anytime and continuously thereafter from July through October.

***5.1.6*** *Northern milfoil (Myriophyllum sibiricum); see 4.1.1*

***5.1.7*** *Common watermoss (Fontinalis antipyretica); see 4.1.3*

***5.1.8*** *Curlyleaf pondweed (Potamogeton crispus); see 4.1.4*

**5.1.9** Sago pondweed (*Stuckenia pectinata*);

**Image 18.** Sago pondweed (*Stuckenia pectinata*) growth with terminally borne seeds. Photo:https://www.illinoiswildflowers.info/wetland/plants/sago_pondwd.htmlSEINet Portal Network. 2020. http//:swbiodiversity.org/seinet/index.php. Accessed on May 19.

Sago pondweed is an entirely submersed aquatic perennial grass species and is native to the North American continent, including the Canadian Provinces and Alaska. Like many other aquatic weed species, Sago pondweed may be found in a wide spectrum of environments; fresh brackish and tidal wetlands have all been documented as being adequate for establishment and survival. This species requires flowing water to thrive. Sago pondweed is a appears as slender, thread-like branches with alternating leaves (contrast with Horned pondweed; **section 4.1.5**) and the plants generally develop more branching towards the apices, giving the plants a fan appearance in quiescent water. (**Image 18**)

Mature plants may approach 2 meters in length; particularly when found growing within the confines of irrigation conveyance systems. The stems are up to 1.0 mm. across, light green to nearly white, generally flat to flattened, 0.6 -1.4cm long, up to 1.0 mm. across, and mostly alternate. Sago pondweed flowering can occur from late spring to early fall. The root system is fibrous, rhizomatous, and tuberous. Clonal colonies of plants are often produced from the rhizomes. Sago pondweed is generally found in areas receiving full sun, is most commonly found at depths from 1 to 2m in flowing waters with deep, mucky bottom substrates. Clear, alkaline, and calcareous is preferred, but this plant adapts to a variety of conditions, including brackish water.

***5.1.10*** *Leafy pondweed (Potamogeton foliosus); see 4.1.2*

***5.1.11** Canadian waterweed (Elodea canadensis);*

Elodea is a commonly encountered submerged aquatic plant native to North America, including Canadian Provinces. Curiously, this species was not known in Alaska until the early 1980's and is now the focus of an ongoing eradication campaign active since 2014. Elodea stems may grow several meters long (**Image 19**) and these stems have distinctive whorls of 3 triangular leaves (averaging 7mm in length) arranged around the stem. The leaves are generally dark green with a glassy appearance and are finely serrated but not toothed (**image 20**). The roots are white and threadlike. This species is dioecious and typically produces small, white, and nondescript flowers (**image 21**) from June through August. This species spreads primarily through vegetative propagation of stem fragments produced by the plant throughout its lifecycle, or as a result of abiotic or anthropogenic disturbances.

**Image 19.** Elodea canadensis, or Canadian waterweed, (*Elodea canadensis*) exhibiting typical, monoclonal growth typical of the genera. 

**Image 20.** Canadian waterweed (*Elodea canadensis*) August 2019.
*Photo Credit: Amaruq Environmental Services*

**Image 21.** Elodea canadensis (*Elodea canadensis*) inflorescence. Photo: https://michiganflora.net/species.aspx?id=1447

Elodea can be found in both lacustrine and riverine systems, though often prefers calcareous waters with pH 6.5 - 10. A prerequisite for growth is the availability of reduced iron and bicarbonate as a carbon source (Spicer & Catling 1988, Larson 2003). Elodea is are commonly found in shallow water (≤3 m), but very tolerant of low light conditions, having been reported at to occur as deep as 10m in the Western united States and up to 6m in European literature, and growing nearly year-round underneath of ice cover in Alaskan rivers (*author, personal observations*). Elodea can occur in brackish water and is known to be very tolerant to cold water (10-25° C, optimum). The extensive root system will not tolerate freezing and is thus unlikely to be found in riparian zones which become seasonally exposed. Established stands of Elodea are quite capable of withstanding sub-freezing temperatures so long as the root system remains protected from freezing. Elodea and its congeners exhibit preference for firm, fine grained sediments with a high content of nutrients and is often associated with eutrophic waters, or those having elevated levels of phosphorous and nitrogen[16].

Several species of floating and emergent aquatic plants, namely Duckweed (*Lemna* spp.), Northern arrowhead (*Sagittaria cuneata*), and Water smartweed (*Polygonum amphibium*) were confirmed present within the study area, but as they are not classified as SAV, were not examined beyond confirming presence/ absence. Several genera of aquatic algae, namely Chara spp., *Ulva intestinalis* (formerly *Enteromorpha intestinalis*); and extensive beds of filamentous algae species (likely *Lyngbya* or *Cladophora*) were confirmed present within the study area, but as they are not classified as SAV, were not examined beyond confirming presence/ absence.

## 6.0 Conclusions

In this initial survey work, submersed aquatic vegetation (SAV), presence/absence, species diversity and distribution, and river channel morphology were examined to determine seasonal impacts of a current discharge regimes at Holter Dam. Stated specific objectives were to:

[16] Josefsson, M. (2011): NOBANIS - Invasive Species Fact Sheet – Elodea canadensis, Elodea nuttallii and Elodea callitrichoides – From: Online Database of the European Network on Invasive Alien Species – NOBANIS www.nobanis.org, Date of access 20MAY2020.

**6.1** Confirm prior MT FWP data regarding overall species presence;

**6.2** Conduct point-intercept survey along same track to estimate SAV presence, speciation to the taxa level where possible, and estimate taxon frequencies and relative densities;

**6.3** Conduct multi-band hydroacoustic survey to roughly follow the Upper Missouri River thalweg from Holter Dam to Cascade, Montana;

**6.4** Conduct sequential SAV surveys following spring discharge at Holter Dam to determine potential impacts on river channel geomorphology; coarse-level changes to the river structure and sediment composition and distribution following same;

**6.5** Compare PRE- and POST- flushing flow discharge data to establish correlations between seasonal impacts of fluvial activity and SAV occurrence and densities;

**6.6** Develop distribution maps for identified SAV taxa

Combined data from both survey intervals confirmed the presence of 11 of 12 submersed aquatic plant species as originally documented in 2010 by MT FWP. The only species undocumented on either survey period was White waterbuttercup (*Ranuncuclus aquatilis*) which is curious given reports from as late as 2015 noting, at least anecdotally, of stands of this species with enough biomass to effectively preclude recreational access and fishing. One new species of algae, *U. intestinalis*, was noted in abundance throughout the study area during both surveys, as were other species of macrophytic (*Chara* spp.) and filamentous algae. These latter were left unidentified as outside the scope of work for this study.

As the current dataset encompasses a single season, statistical comparisons cannot be made at this time. However, the combined dataset from 2019 will be contrasted to data captured during the 2020 water season to allow for statistical analysis of impacts following a full season within the study area. This data does allow for interpretation of current conditions within the study area and all major areas of SAV growth within the study area have been delineated and current (as of AUG 2019) river geomorphology has been mapped and GPS-referenced.

Despite a lack of sequential season data, broad assumptions may be inferred from current dataset: Sequential hydroacoustic surveys conducted in 2019 and following a peak flow of some ~13,500cfs (**Figure 2**) just prior to 01JUN2019 revealed very little change in river geomorphology or to sediment distribution composition (cobble: silt) in all areas surveyed. Significant differences to plant community composition and distribution were noted by river mile and when the study area was divided at the confluence of the Dearborn River. The effect of gravel contribution to the downstream segment of the study area is significant in both complete effect of SAV composition and distribution and distance of this effect when compared to upstream segments of the river, with ≤20% overall biomass being represented by SAV downstream from the Dearborn confluence as some 80% of all detected biomass was algal in origin. Populations of SAV, identified to the Taxa level, are being developed based on current data and will be confirmed during the 2020 season to verify or refute incipient/ transient populations from established populations as well as to examine the effect of 2019 flow regimes within the study area during the 2020 season.

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