Bighorn Lake and Bighorn River

WATER QUALITY MONITORING
Sampling and Analysis Plan - 2024

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Bighorn River Alliance
Billings, Montana

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We approve this Sampling and Analysis Plan, to go into effect on ______________________

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Abbreviations

ASL	Above Sea Level
BHRA	Bighorn River Alliance
BOR	Bureau of Reclamation
CEPA	Crow Environmental Protection Agency
CPR	Cardiopulmonary Resuscitation
DO	Dissolved Oxygen
FAS	Fishing Access Site
FNU	Formazin Nephelometric Units
FSP	Field Safety Plan
GPS	Global Positioning System
HDPE	High Density Polyethylene
IQR	Interquartile Range
MDEQ	Montana Department of Environmental Quality
MFWP	Montana Fish, Wildlife, and Parks
MT	Montana
NPS	National Park Service
PFD	Personal Flotation Device
QA/QC	Quality Assurance and Quality Control
SAP	Sampling and Analysis Plan
SC	Specific Conductance
SD	Standard Deviation
USB	Universal Serial Bus
USCG	United States Coast Guard
USGS	United States Geologic Survey
WDEQ	Wyoming Department of Environmental Quality
WS	Water Surface

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1 Introduction and Background Information

The Bighorn River Alliance (BHRA) recognizes that the long-term health of the Bighorn River fishery is dependent upon the ecological integrity of the entire watershed. To better understand how the Bighorn River ecosystem responds to natural and human factors, the BHRA developed a Research Initiative (August 2018) outlining several studies to closely examine the biology (aquatic and terrestrial plant and animal life), hydrology, water quality, and channel geomorphology of the river. The underlying premise is that an interdisciplinary information base is crucial in meeting BHRA's objectives to support the long-term health of the river.

The study area at this time is Bighorn Lake and the Bighorn River from Afterbay Dam to its confluence with the Yellowstone River. This section of river flows for approximately 72 km (45 mi) through the Crow Nation Tribal Reservation and is monitored by the Crow Environmental Protection Agency (CEPA), Montana Fish, Wildlife and Parks (MFWP), and the National Park Service (NPS) before leaving Crow lands north of Hardin, MT where it is monitored by Montana Department of Environmental Quality (MDEQ) and MFWP for the remaining approximately 63 km (39 mi). This study also includes three major tributaries to the Bighorn River: Soap Creek, Rotten Grass Creek, and the Little Bighorn River to identify their influences on the physiochemistry of the Bighorn River.

Within the Montana portion of the basin rangeland composed of grassland and shrubland is the most prevalent land use covering 75.3% of the basin. Agriculture composed of cultivated crops, hay, and pasture is the next most prevalent land use covering 11.7 % of the land. Within the basin livestock are grazed in established pastures and on open rangeland so an estimate of land used for grazing is not possible. Forests are limited to the steeper hillslopes covering 6.6% of the basin and are almost exclusively evergreen. Riparian woody wetlands, herbaceous wetlands, and open water cover 5.2% of the land in the basin extending laterally from the channels and filling the valley bottoms. Development within the basin is minimal, impacting 1.1% of the land with most of that being concentrated near Hardin, MT. The primary anthropogenic land use disturbances within the Montana portion of the Bighorn Basin are agricultural or agricultural support. There is no known mineral mining or hard rock quarry activity within the Montana portion of the basin. There is one known operational oil field in the Soap Creek sub-basin and a natural gas field north of Hardin that was known to be operational as recently as 1955 but current operation is unknown.

The Bighorn River below Yellowtail Dam is a world-renowned trout fishing destination. It is one of the largest cold water fisheries in the state of Montana and hypolimnetic releases from Yellowtail Dam maintain cold water during the summer when many fisheries in the state are placed on Hoot Owl restrictions due to high temperatures, which prohibit fishing each day between 2 p.m. and midnight. As such it is of economic and recreational importance to the state of Montana but has limited water quality monitoring. The BHRA Research Initiative in cooperation with the CEPA, MDEQ, and MFWP will conduct water quality monitoring to develop a long-term dataset for the assessment of conditions within the river and to inform future projects which will investigate specific aspects of the physiochemistry in the Bighorn River.

2 Objectives

BHRA's Research Initiative identifies water quality as a major study to determine how the river's water quality interrelates with other river features (i.e. hydrology, fisheries, benthic macroinvertebrates, riparian forest, etc.) and to better understand how natural and human drivers are influencing river health and function. This project is designed to monitor the Bighorn Lake, Bighorn River, and select tributaries, and to develop a long-term dataset. The results of this consistent dataset can then be used to discover spatial and temporal patterns of interest and direct future projects.

3 Water Sampling Parameters

Chlorophyll α: Chlorophyll is bound within cells of algae and other phytoplankton found in surface water. Chlorophyll α is the most abundant form of chlorophyll. Monitoring of chlorophyll levels is an indirect way of estimating algal growth by monitoring plankton and algal spores or cells in the drift before they settle on the substrate and begin to grow. Chlorophyll measurements can be utilized as an indirect indicator of bioavailable nutrient levels, generally phosphorus and nitrogen, and suspended solids/turbidity.

Dissolved Oxygen (DO): Dissolved oxygen in the Bighorn River is essential for a healthy aquatic ecosystem. The need for oxygen depends on the species and life stage; cold-water fish on the upper river require higher concentrations than warm water species further downstream. DO is greatly influenced by aeration from the Yellowtail Dam and Afterbay releases. Additionally, it comes directly from the atmosphere and from photosynthesis by aquatic plants during the day. Deceases in DO occur from aquatic plant respiration at night and plant decomposition in the autumn.

Nutrients – Nitrogen and Phosphorus: Nitrogen and phosphorus are essential nutrients for plants and small amounts are an important component of healthy rivers. Large inputs of nutrients often lead to excessive growth of aquatic plants and/or algae that can degrade fish habitat, and alter flows and water chemistry. Low concentrations of dissolved oxygen and high water temperatures can increase the availability of nutrients to aquatic plants.

pH: pH is the amount of free Hydrogen present in the water, with low values indicating acidic conditions and high values being basic. Natural waters show little variation in pH, but it is an important early warning parameter, as it can indicate the presence of acid rain or accidental spills from industrial or agricultural operations and can directly impair the health of aquatic life by disturbing homeostasis of organisms or interfering with the mineralization of shell and bone.

Specific Conductance (SC): Specific conductance is a measure of the water's capability to pass electrical current that is directly related to the amount of dissolved salts and inorganic materials in the water. It is an early indicator of change in water quality affected by dam releases, tributary inflows, agricultural run-off, geologic effects, etc. High levels of dissolved solids will lower dissolved oxygen which adversely affects fish and other aquatic life. SC levels often determine aquatic species present on a certain section of river due, in part, to their level of tolerance to dissolved salts.

Transparency (Secchi Depth in the lake): Transparency is a direct measure of water clarity and can serve as an indirect indication of suspended solids (sediment and/or algae) in the water or dissolved materials (iron, sulfur, tannins, etc.) which can change the color of the water. Low water transparency limits the success of visual predators, leads to increased water temperature, low dissolved oxygen, and other impairments to aquatic life.

Turbidity: Turbidity is another direct measure of water clarity which is far more sensitive than Transparency, particularly at high values; but which only detects suspended solids, not coloration from dissolved materials. It is additionally measured from a much smaller volume of water, allowing it to be installed on the sonde and conducted with the depth profile in the lake.

Water Temperature: Water temperature is one of the most important characteristics of an aquatic system. Water temperature is affected by air temperature, tributary inputs, groundwater, agricultural runoff, and especially releases out of Yellowtail Dam. Water temperatures vary widely along the Bighorn River, both spatially and temporally. Temperature is stable near the Afterbay due to hypolimnetic releases from Yellowtail Dam. Further downstream from Yellowtail Dam, water temperatures fluctuate significantly between day and night (diurnal temperature changes), and between summer and winter (annual temperature changes). Temperature is also important because of its influence on water chemistry. Higher water temperatures can dissolve more salts and minerals causing the specific conductivity to rise. Conversely, warm water holds less dissolved oxygen than cold water.

4 Water Sampling Locations and Protocols

4.1 *Bighorn Lake*

The water quality of the Bighorn River is primarily determined by Yellowtail Dam releases from Bighorn Lake. To understand spatial and temporal changes in the chemical, physical, and biological properties of the Bighorn River, it is important to understand how the distribution and stratification of key water quality parameters in Bighorn Lake change throughout the year.

4.1.1 Bighorn Lake Monitoring Site Location

The monitoring site near Yellowtail Dam will provide water quality data for the full depth profile and will be used to characterize the northern portion of the lake (Table 1, Figure 1). Supplemental data will be collected with grab samples

__Table 1:__ Location of sampling site on Bighorn Lake. The elevation of the water surface fluctuates throughout the year as the Bureau of Reclamation fills or drains the lake in response to fluctuations in inflows and hydroelectric generation demand.

Site Name	River km	River mi	Latitude	Longitude	Elevation	Channel Location
Yellowtail Dam	139.2	86.5	45.3014	-107.9642	*variable*	Impoundment

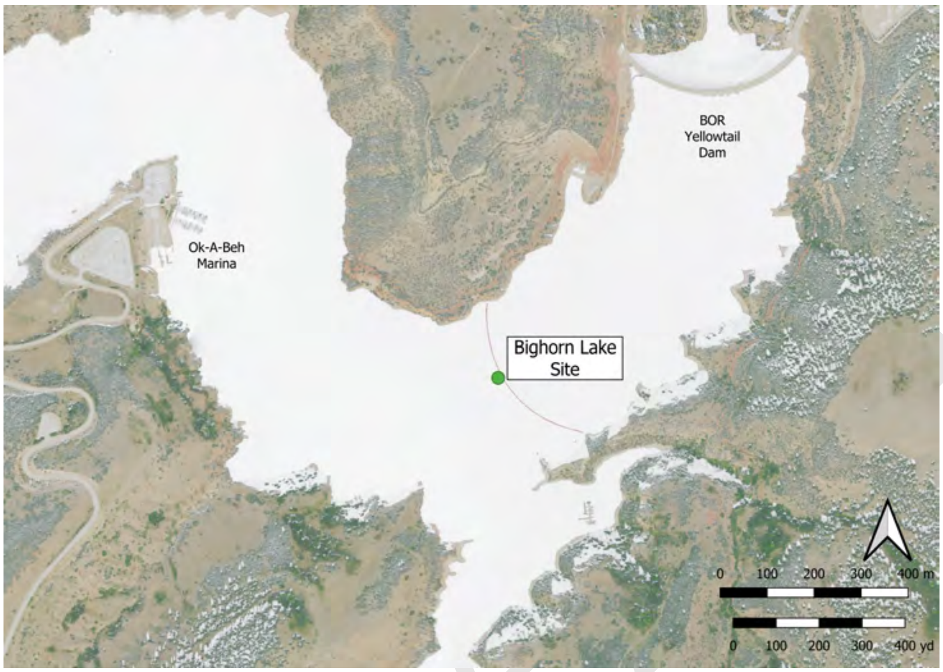

__Figure 1:__ Satellite imagery showing the location of the sampling site in relation to the Yellowtail Dam and Ok-A-Beh Marina. The sampling site is outside of the restricted access area near the dam.

for laboratory analysis at key gate elevations on the dam (Table 2). The Yellowtail Dam site is not within the restricted access zone and will not require access permissions from the Bureau of Reclamation.

4.1.2 Bighorn Lake In Situ Measurements - Depth Profile

Methods: The reservoir depth at the sampling site is approximately 120 meters (400 feet). The depth profile will be completed using a calibrated YSI EXO1 sonde that will continuously record data from the surface to near the reservoir bottom. The sonde will be attached to a cable then lowered/raised using a downrigger and electric winch. While the depth profile is being taken, the boat's position will be maintained using an automated GPS locating system connected to an electric trolling motor. Once collected, the data will be downloaded to a laptop/tablet (software not compatible with Apple products) via Bluetooth or a direct USB connection. Calibration of the sonde will be completed in the lab/office prior to each field trip and relative depths of outflow gates calculated from the the water surface elevation on the day of data collection. Surface measurements will be collected with an air thermometer and secchi disk.

Frequency/Schedule: Monthly throughout the warm months and in winter as conditions allow. The access road is not maintained during the winter and snow drifts or icy conditions may limit access. Winter ice cover is seldom a concern on Bighorn Lake. The YSI multiparameter sonde minimum operating temperature is -5 °C (23 °F), so winter work will be restricted to warm days above this temperature. Lake and river sampling should be performed on the same day or on two consecutive days to capture conditions at outlet gates and river conditions as close to simultaneously as possible.

Depth Parameters: Depth in m, Dissolved Oxygen in mg/L, % Saturation, and % Calibrated Barometer, pH (unitless), Specific Conductance in μS/cm, Turbidity in Formazin Nephelometric Units (FNU), and Water Temperature in °C.

Table 2: *Elevations of release gates through the Yellowtail Dam. *Water samples are not collected at the true surface of the water, that information is used to calculate the depth to collection sites.*

Site Name	Elevation (m ASL)	Elevation (ft ASL)	Depth (m)	Depth (ft)
Water Surface (WS)*	*variable*	*variable*	*N/A*	*N/A*
Surface Sample	*WS Elevation* - 1	*WS Elevation* - 3	1	3
Spillway	1095	3593	*WS Elevation* - 1095	*WS Elevation* - 3593
Powerplant	1050	3444	*WS Elevation* - 1050	*WS Elevation* - 3444
River Outlet	1005	3297	*WS Elevation* - 1005	*WS Elevation* - 3297

Surface Parameters: Ambient air Temperature in °C, Barometric Pressure in mmHg, Secchi Depth in meters, qualitative notes on weather conditions, and qualitative description of water color. Air temperature will be measured in a shaded area with good air circulation and allowed to stabilize for approximately 15 minutes. In situ measurements of the lake surface will be made with the YSI to assess stability and calibration before deployment and recorded onto a field form for redundancy and archival (Form 1).

4.1.3 Bighorn Lake Water Sample Collection

Method: Water quality sample sets will be collected in sterilized bottles provided by Energy Laboratories (Billings, MT). Two bottles will be necessary per sample set. Sample sets will be collected at four depths and two additional sets will be needed for field duplicates and field blanks. Precautions should be made to avoid bias or contamination:

- The collection of water samples at Yellowtail Dam will be done using a Van Dorn water sampler. Individual sample sets will be collected at four depths: one meter (3 feet) below the surface, and at the elevations corresponding to the spillway, powerplant penstock, and river outlet (See Table 2 in Section 4.1.1). Sample duplicates will also be collected, and field blanks made, according to Quality Assurance and Quality Control requirements outlined in Section 6.
- Rinse the sample bottles and lids three times with collected water and completely fill the fourth time.
- Preservative will be added to the appropriate bottles in the sample set and the lid tightly secured. Sample labels will be filled out and placed on each bottle for proper identification in the field and for tracking in the laboratory. Samples will be stored in a cooler with ice until delivered to the lab within 2-3 days.
- All sample deliveries to the laboratory will be accompanied by a chain-of-custody form. Chain of custody forms will be used to identify the contents of each shipment and maintain the custodial integrity of the samples.

Frequency/Schedule: Quarterly, collected with the depth profile. Winter conditions may affect collection, see caveats in Section 4.1.2.

Parameters: Chlorophyll α in mg/m^3, Nitrate + Nitrite in mg/L, and Total Phosphorus in mg/L.

Sample Handling Procedures: Field samples will be collected and preserved in accordance with the specifications outlined in MDEQ's Field Procedures Manual for Water Quality Assessment Monitoring (2012a) (Table 3).

Table 3: *Field collection containers and preservation methods for the three physiochemical parameters measured from grab samples. Nitrogen and phosphorus are both measured from the same acidified sample.*

Parameter	Bottle Size	Container	Preservation	Storage	Holding Time
Chlorophyll α	1000 mL	Amber Glass bottle	None	ice	28 Days
Nitrate + Nitrite	250 mL	HDPE bottle	None	ice	28 Days
Total Phosphorus	250 mL	HDPE bottle	H_2SO_4	ice	28 Days

4.2 *Bighorn River*

The water quality of the Bighorn River is primarily determined by Yellowtail Dam releases, and also influenced by tributary inflows, irrigation return flows, and river corridor management. To understand the spatial and temporal changes in the chemical, physical, and biological properties of the Bighorn River, and to identify sources that influence water quality and aquatic habitat conditions, a network of strategically located sample sites from below the Afterbay Dam to the Yellowstone River confluence will be established (Table 4, Figure 2).

Table 4: *Locations of river and tributary sampling sites used for long term water quality monitoring project. River distances for tributary streams are reported at the confluence of that stream and the mainstem Bighorn River. *The Three Rivers site is located on Schneiders Channel, a major side channel comparable in size to the main channel.*

Site Name	River km	River mi	Latitude	Longitude	Elevation (m ASL)	Elevation (ft ASL)	Channel Location
Below Afterbay	134.5	83.6	45.3170	-107.9183	967	3171	Mainstem
Three Rivers	121.0	75.2	45.3778	-107.8093	946	3103	Mainstem*
Soap Creek	119.1	74.0	45.3738	-107.7903	956	3137	Tributary
Bighorn FAS	115.6	71.8	45.4164	-107.7898	936	3071	Mainstem
Rotten Grass Creek	107.2	66.6	45.4615	-107.7284	931	3056	Tributary
Mallards Landing	101.4	63.0	45.5208	-107.7281	914	2998	Mainstem
Two Leggins	83.7	52.0	45.6444	-107.6581	896	2940	Mainstem
Little Bighorn River	67.6	42.0	45.7355	-107.5575	883	2897	Tributary
Arapooish	65.3	40.6	45.7561	-107.5652	877	2877	Mainstem
Manuel Lisa	2.9	1.8	46.1446	-107.4643	825	2707	Mainstem

4.2.1 Water Chemistry Site Location, Description, and Rationale

Below Afterbay: This site is located directly downstream from the Yellowtail Afterbay Dam at the same location as the joint United States Geological Survey (USGS) gaging station and United States Bureau of Reclamation (BOR) hydrolab on river right (Figure 3). The water quality data collected will complement the water quality data that the BOR is collecting. The data collected at the Below Afterbay site will be compared with the water quality released from Bighorn Lake through Yellowtail Dam.

The USGS Gage Station below the Afterbay Dam is designated: USGS 06287000 Bighorn River near St. Xavier, MT. The gage station records continuous flow data that will supplement the sampling data.

Three Rivers: This site is located on Schneiders Channel and is intended as an upstream bracket to the inflow from Soap Creek approximately 1.9 km (1.2 mi) downstream (Figure 4). Schneiders Channel is a major side channel and is comparable in size to the main channel across Schneiders Island. The side channel is not expected to run dry except in severe drought or to have differing chemistry to the main channel due to size.

The USGS Gage Station designated: USGS 06287000 Bighorn River near St. Xavier, MT below the Afterbay Dam will be used to estimate flows when samples are collected. The gage station is located approximately 13.5 km (8.4 mi) upstream from the site with no significant tributaries in that reach.

Soap Creek: This site is located immediately downstream of the Highway 313 bridge across Soap Creek (Figure 5). It is intended to directly monitor the tributary and identify any causes for concern within that sub-basin.

There is no gage on Soap Creek.

Bighorn FAS: Samples will be taken upstream from the Bighorn Fishing Access Site (FAS) boat ramp (Figure 6). This site provides a spatial sampling of the Bighorn River that captures the influence of Soap Creek inflows (3.5 km (2.2 mi) upstream) and provides an upstream bracket for Rotten Grass Creek (8.4 km (5.2 mi) downstream).

The USGS Gage Station designated: USGS 06287800 Bighorn River at bridge, at St. Xavier, MT at the St. Xavier Bridge will be used to estimate flows when samples are collected. The gage station is located approximately 6.3 km (3.9 mi) downstream from the site.

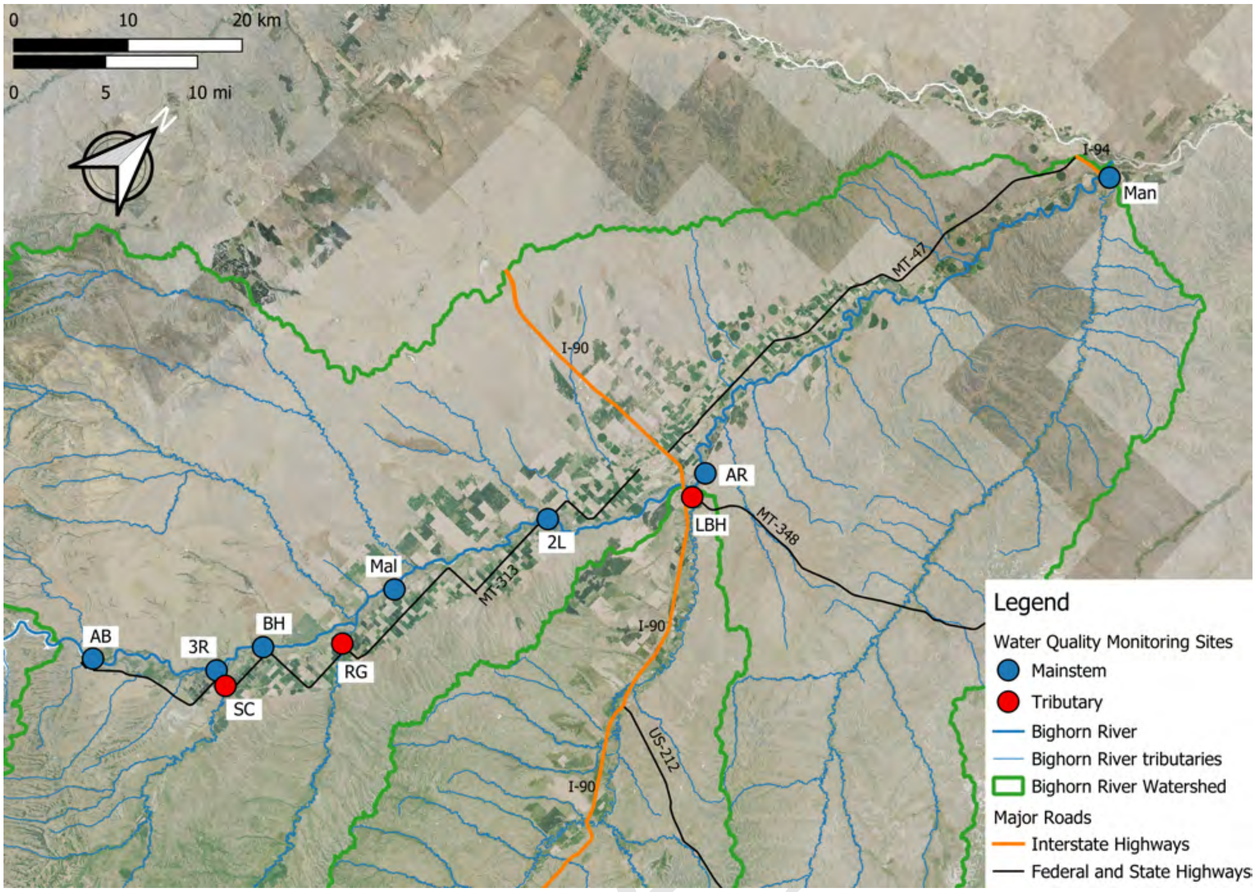

Figure 2: *Relative locations of sites used for the long term water quality monitoring project. The Bighorn River in the study area flows from the Yellowtail Dam in the south to the confluence with the Yellowstone River in the north. Seven of the ten sites are located on the mainstem of the Bighorn River, three are located on tributaries to the Bighorn River. From upstream to downstream the sites are Below Afterbay (AB, Mainstem), Three Rivers (3R, Mainstem), Soap Creek (SC, Tributary), Bighorn FAS (BH, Mainstem), Rotten Grass Creek (RG, Tributary), Mallards Landing (Mal, Mainstem), Two Leggins (2L, Mainstem), Little Bighorn River (LBH, Tributary), Arapooish (AR, Mainstem), and Manuel Lisa (Man, Mainstem).*

Rotten Grass Creek: This site is located downstream of the Highway 91 bridge on the grounds of the Pretty Eagle Catholic Academy (Figure 7). It is intended to directly monitor the tributary and identify any causes for concern within that sub-basin.

There is no gage on Rotten Grass Creek.

Mallards Landing: This site is intended to bracket the influence of Rotten Grass Creek that enters the Bighorn River approximately 5.8 km (3.6 mi) upstream (Figure 8). Measurements and samples will be collected approximately 180 meters (200 yards) upstream of the boat ramp to avoid influence from an irrigation return.

Flows will be estimated from the USGS Gage Station designated: USGS 06287800 Bighorn River at bridge, at St. Xavier, MT located at the St. Xavier Bridge located approximately 7.9 km (4.9 mi) upstream.

Two Leggins: Samples will be taken at the Two Leggins Fishing Access Site immediately upstream from the Highway 313 bridge (Figure 9). This site is near the end of the cold-water reach and 16.1 km (10.0 mi) upstream from the Little Bighorn River confluence. It provides an end-point site to evaluate spatial trends on the upper cold-water reach. In combination with Arapooish, this site will bracket the Little Bighorn River confluence to determine its influence on the Bighorn River below Hardin.

The USGS Gage Station designated: USGS 06288400 Bighorn River at Two Leggins Bridge, near Hardin, MT will provide flow when samples are collected.

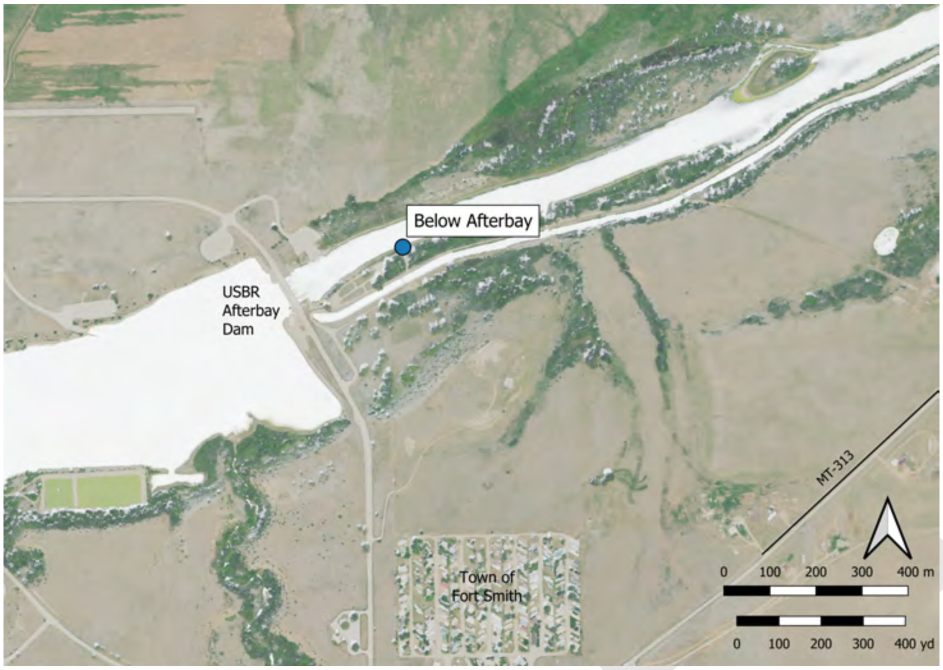

Figure 3: *Location of the Below Afterbay monitoring site. Data are collected on river right at the same location as the BOR Hydromet data collections.*

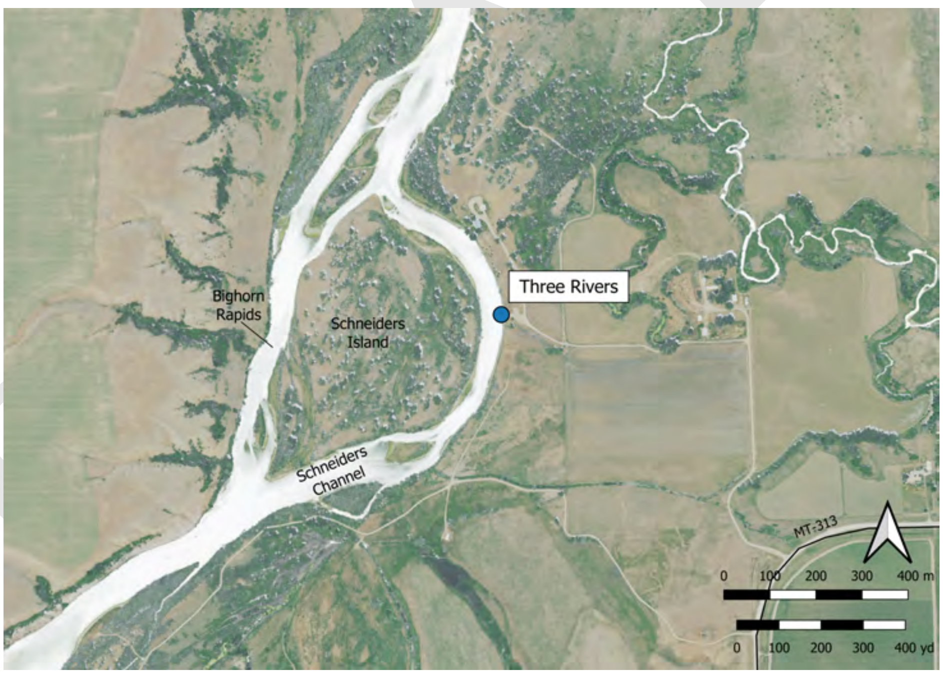

Figure 4: *Three Rivers is located on the right bank of Schneiders Channel.*

Little Bighorn River: This site is located near the USGS Gage Station next to the Sarpy Creek Road Bridge, 1.3 km (0.8 mi) upstream from the Bighorn River confluence (Figure 10). This site will characterize the Little Bighorn River water quality contribution to the Bighorn River.

Figure 5: *Data are collected from Soap Creek downstream of the Montana Highway 313 high water bridge.*

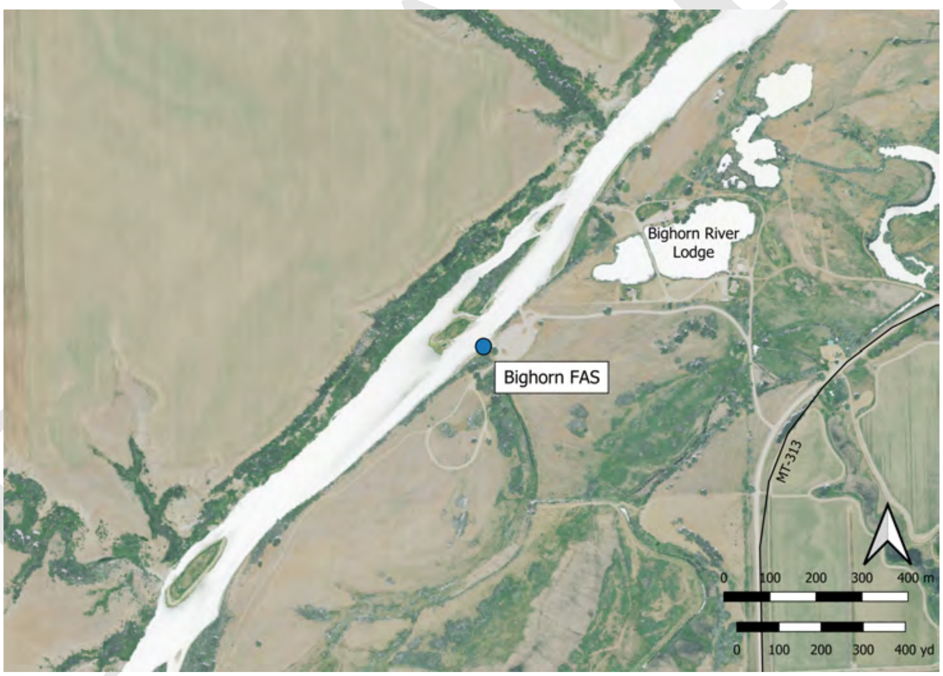

Figure 6: *The Bighorn FAS site is located at the Montana FWP access site and collected from upstream of the confluence with a small tributary.*

The Crow Tribe has periodically monitored water quality at this site as part of their long-term water quality monitoring program. The BHRA and the Crow Tribe should work cooperatively to coordinate future water quality monitoring to avoid duplicating efforts and to share information.

The USGS Gage Station designated: USGS 06294000 Little Bighorn River near Hardin, MT., located at this site provides continuous flow measurements.

Figure 7: The Rotten Grass Creek site is located downstream of the Pryor Cutoff high water bridge. Highway digitization by USGS.

Figure 8: *The site at Mallards Landing is located approximately 180 meters (200 yards) upstream of the boat ramp in order to collect data upstream of the confluence with an irrigation return.*

Arapooish: This site is located at the Arapooish Fishing Access Site approximately 2.3 km (1.4 mi) downstream from the Little Bighorn River confluence (Figure 11). It serves as the downstream bracket of the Little Bighorn River in combination with the site at Two Leggins FAS. The site provides water quality data on the Bighorn River reflecting its transition to a warm-water ecosystem that approaches historic conditions.

Figure 9: *The specific sampling location at the Two Leggins FAS is variable, data should be collected wherever water levels will allow for safe wading. The marker is located on a small rip rap jetty downstream of the boat ramp that is frequently used.*

Figure 10: *Data collection at the Little Bighorn River is conducted immediately upstream of the Montana Highway 348 high water bridge.*

There is no USGS Gage Station near this site, but discharge will be estimated by combining discharges recorded at the USGS Gage Stations at Two Leggins and the lower Little Bighorn River.

Manuel Lisa: This site is located at the Manuel Lisa Fishing Access Site approximately 2.3 km (1.4 mi) upstream from the Yellowstone River confluence (Figure 12). It serves as the lowermost spatial trend site for the Bighorn River and a characterization of the river's water quality contribution to the Yellowstone River.

Figure 11: Data at Arapooish are collected immediately upstream of the boat ramp at the Arapooish FAS.

Montana DEQ and the USGS have been monitoring water quality at this site as part of their Statewide Monitoring Network to document biological and water quality conditions and temporal change.

The USGS Gage Station designated: USGS 06294500 Bighorn River above Tullock Creek near Bighorn, MT., located 3.5 km (2.2 mi) upstream from Manuel Lisa will provide flow measurements.

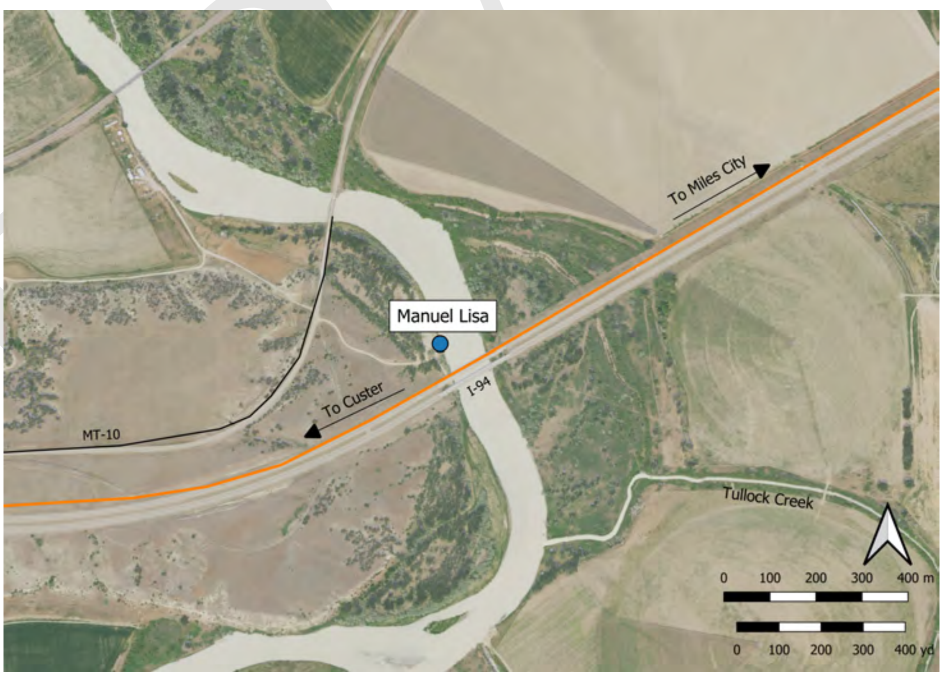

Figure 12: Data at Manuel Lisa are collected immediately upstream of the boat ramp at the Manuel Lisa FAS.

4.2.2 Bighorn River In Situ Measurements

Methods: Field measurements will be collected in situ at each monitoring site using a calibrated YSI EXO1 sonde, air thermometer, and Eisco 120 cm (48 in) transparency tube. Measurements will be taken prior to the collection of water samples or other physical disturbances to the water column or channel substrate. After the data are collected, they will be downloaded to a laptop/tablet (software not compatible with Apple products) via Bluetooth or a direct USB connection. Data will also be recorded onto a field form for redundancy and archival (Form 2).

Frequency/Schedule: Monthly during the warm period of the year, and as conditions allow in the winter. Most of the access roads to the sites will be maintained in the winter, and tire chains or snowshoes will allow for access through the winter to unmaintained sites. An ice auger will allow access to open water through ice cover during the winter where unfrozen riffles are not accessible. The YSI multiparameter sonde minimum operating temperature is -5 °C (23 °F), so winter work will be restricted to warm days above this temperature. River and lake sampling should be performed on the same day or on two consecutive days to capture river conditions and conditions at outlet gates as close to simultaneously as possible. All river sites should be visited on the same day in a randomly determined direction from upstream to down or from downstream to up to account for daily variability in parameters.

Parameters: Ambient Air Temperature in °C, Barometric Pressure in mmHg, Dissolved Oxygen as mg/L, % Saturation, and % Calibrated Barometer, pH, Specific Conductance in μS/cm, Transparency in cm, Turbidity in FNU, Water Temperature in °C, and qualitative notes on weather conditions. Air temperature will be measured in a shaded area with good air circulation and allowed to stabilize for approximately 15 minutes.

4.2.3 Bighorn River Water Sample Collection

Parameters: Chlorophyll α in mg/m^3, Nitrate + Nitrite in mg/L, and Total Phosphorus in mg/L..

Method: Water quality sample sets will be collected in sterilized bottles provided by Energy Laboratories (Billings, MT). Precautions should be made to avoid bias or contamination:

- Wade into the river as far as safely possible before collecting the samples. A water sampling extension pole may be used to help collect samples, especially during high flows.
- Avoid upstream disturbances. Walk upstream to the sample location and take the samples facing upstream.
- Do not take surface water. Collect sample sets 8 to 16 cm (3 to 6 in) below the surface, rinse the sample bottles and lids three times with ambient water and completely fill the fourth time.
- Be sure there is thorough mixing of river water. Do not sample immediately downstream of irrigation returns, drainage ditches, or tributary inflows.
- After each sample set has been collected, add the appropriate preservative and secure the lids tightly. Sample labels will be filled out. Sample sets will be stored in a cooler with ice until delivered to the lab within 2-3 days.
- Refer to Table 3 in Section 4.1.3 for a list of monitoring parameters, bottle size and type needed, preservatives used (if applicable), sample storage method, and holding times.
- Chain of custody forms will be completed for all sample sets collected submitted to the lab.

Frequency/Schedule: Quarterly, collected with in situ measurements. Winter conditions may affect collection, see caveats in Section 4.2.2.

Sample Handling Procedures: Refer to Section 4.1.3.

4.2.4 Bighorn River Real-Time Parameters

The BOR has established three continuous water quality monitoring stations associated with the Afterbay Dam. Stations are installed to monitor the Afterbay Reservoir and the left and right banks of the Bighorn River below the Afterbay Dam. Each station has a Hydrolab MS5 multiparameter water quality instrument, atmospheric barometer, and data collection platform. The water quality parameters collected at each site include Barometric Pressure in mmHg, Dissolved Gas Pressure in mmHg, Dissolved Oxygen in % Saturation, pH, Specific Conductance in μS/cm, and Water Temperature in °F. Hourly data is transmitted via satellite telemetry to the Bureau of Reclamation's Hydromet database. The main objective for these stations is to monitor Total Gas Supersaturation (PSAT – computation using barometric pressure and total dissolved gas) and differentiate the effects of the sluice gate (right bank) and the radial gates (mid-channel and left bank) that release water from the Afterbay Reservoir into the Bighorn River.

The USGS maintains a gaging station at the BOR Hydrolab station, at the St. Xavier bridge, at the Two Leggins bridge, and below Tullock Creek on the Bighorn River; and at the Sarpy Creek Rd. bridge on the Little Bighorn River. The BHRA funds real-time collection of Water Temperature in °F at the St. Xavier bridge gaging station.

4.3 *Bighorn Lake Tributaries*

The Shoshone and Bighorn Rivers are the principal tributaries into Bighorn Lake and are together responsible for the majority of physiochemical parameters of Bighorn Lake and the Bighorn River downstream (Figure 13). The BHRA Sampling and Analysis Plan does not include water quality monitoring of the Shoshone and Bighorn River inflows to Bighorn Lake, but the BHRA should maintain close communication with the Wyoming Department of Environmental Quality (WDEQ) and USGS on their monitoring activities. Data collection following the procedures outlined in Sections 4.2.2 and 4.2.3 may be implemented in the future and this document will be updated or an amendment will be added to reflect this change.

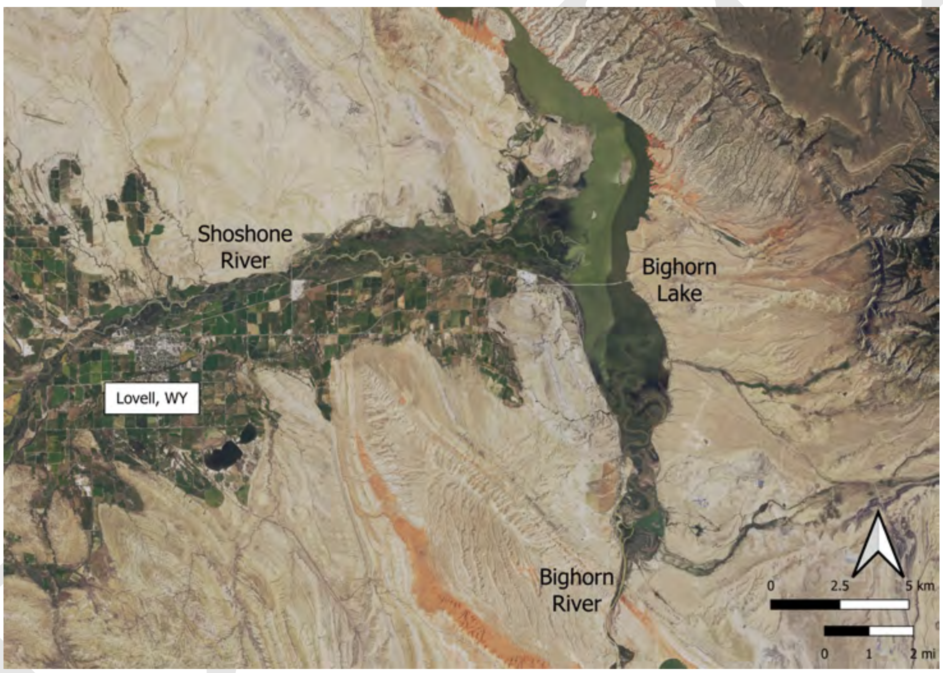

Figure 13: *The major tributaries to Bighorn Lake near Lovell, Wyoming. No work is currently planned for either tributary.*

Each river has a USGS gage station located near their confluences with the lake that currently records discharge and gage height in real-time (15 minute intervals). Discharge records for the Shoshone River gage station near Lovell, WY run from 1966 to present and records from the Bighorn River near Kane, WY run from 1928 to present. Water quality sensors are not deployed at either gage station at the present time.

The NPS, USGS, WDEQ, and others have collected numerous physical, chemical, and biological field samples at or near the Shoshone and Bighorn River gage stations. Flow-sediment relationships have been established for both rivers, however a detailed temporal and correlation analysis of the other water quality parameters has not been done.

4.4 *Yellowstone River*

The Bighorn River is the principal tributary to the Yellowstone River, and monitoring of the Yellowstone River near the confluence with the Bighorn River would provide valuable information about the wider watershed, the contributions of the Bighorn River to the Yellowstone, and information for comparison of the two rivers. The BHRA Sampling and Analysis Plan does not currently include water quality monitoring of the Yellowstone River, but the BHRA is in the early planning phase of adding limited monitoring near the confluence. Data collection following the procedures outlined in Sections 4.2.2 and 4.2.3 may be implemented in the future and this document will be updated or an amendment will be added to reflect this change.

5 Macroinvertebrate Collection

Benthic macroinvertebrates will be collected from the Bighorn River as part of the water quality monitoring project. In situ and grab samples of water chemistry provide an instantaneous value for water quality. Aquatic organisms which live in the water are exposed for longer and so can serve as a proxy for time-averaged water quality for the course of their life spans using published tolerance values for the ability of a species to tolerate pollution. Many benthic macroinvertebrates live for less than one year, with some living as long as 2-3 years. Their contribution to the water quality monitoring program will allow for investigation of medium to long term changes in water and habitat quality. Sampling of benthic macroinvertebrates will be conducted at 8 sites along the mainstem of the Bighorn River to monitor spatial patterns and to maintain interoperability and comparability with previous collections (Table 5, Figure 14)

Table 5: *Locations of benthic macroinvertebrate collection sites used for long term biological monitoring component of water quality monitoring project. River distances for tributary streams are reported at the confluence of that stream and the mainstem Bighorn River. Agency refers to the original sampler at this location.*

Site Name	River km	River mi	Latitude	Longitude	Elevation (m ASL)	Elevation (ft ASL)	Agency
Upper Brammer	132.1	82.1	45.3286	-107.8985	960	3150	MSU
Lower Brammer	120.7	75.0	45.3823	-107.8125	943	3095	MSU
Bighorn FAS	115.6	71.8	45.4164	-107.7898	936	3071	BHRA
Mallards Landing	101.4	63.0	45.5208	-107.7281	914	2998	MDEQ
Two Leggins	83.7	52.0	45.6444	-107.6581	896	2940	BHRA
Arapooish	65.3	40.6	45.7561	-107.5652	877	2877	BHRA
Grant Marsh	50.5	31.4	45.8441	-107.5829	864	2833	BHRA
Manuel Lisa	2.9	1.8	46.1446	-107.4643	825	2707	MDEQ

5.1 Macroinvertebrate Site Location, Description, and Rationale

Upper and Lower Brammer: These sites were first utilized by Brammer (1991) during his graduate research at Montana State University (MSU) to investigate the effects of dissolved gas supersaturation below the Yellowtail Afterbay Dam (Figures 15 and 16). Macroinvertebrate data collected from these sites will allow for long-term comparisons to investigate how the macroinvertebrate communities have changed since the 1980s when the first samples were collected.

Grant Marsh: This site was originally located at the General Custer FAS to capture the community between Arapooish and Manuel Lisa, however it was moved following the 2023 high water event and the destruction of the riffle at that location (Figure 17).

Bighorn FAS, Mallards Landing, Two Leggins, Arapooish, and Manuel Lisa: The remaining macroinvertebrate sites are also water chemistry sites, see descriptions and large scale maps in Section 4.2.1. Mallards Landing and Manuel Lisa had previous qualitative data collected by MDEQ for analysis with a longer dataset. Bighorn FAS, Two Leggins, and Arapooish are new sites added in 2020.

5.2 Methods

Water Chemistry Methods: In situ water chemistry data will be collected concurrently each macroinvertebrate collection following the procedure described in Section 4.2.2. These measurements will be collected prior to disturbances

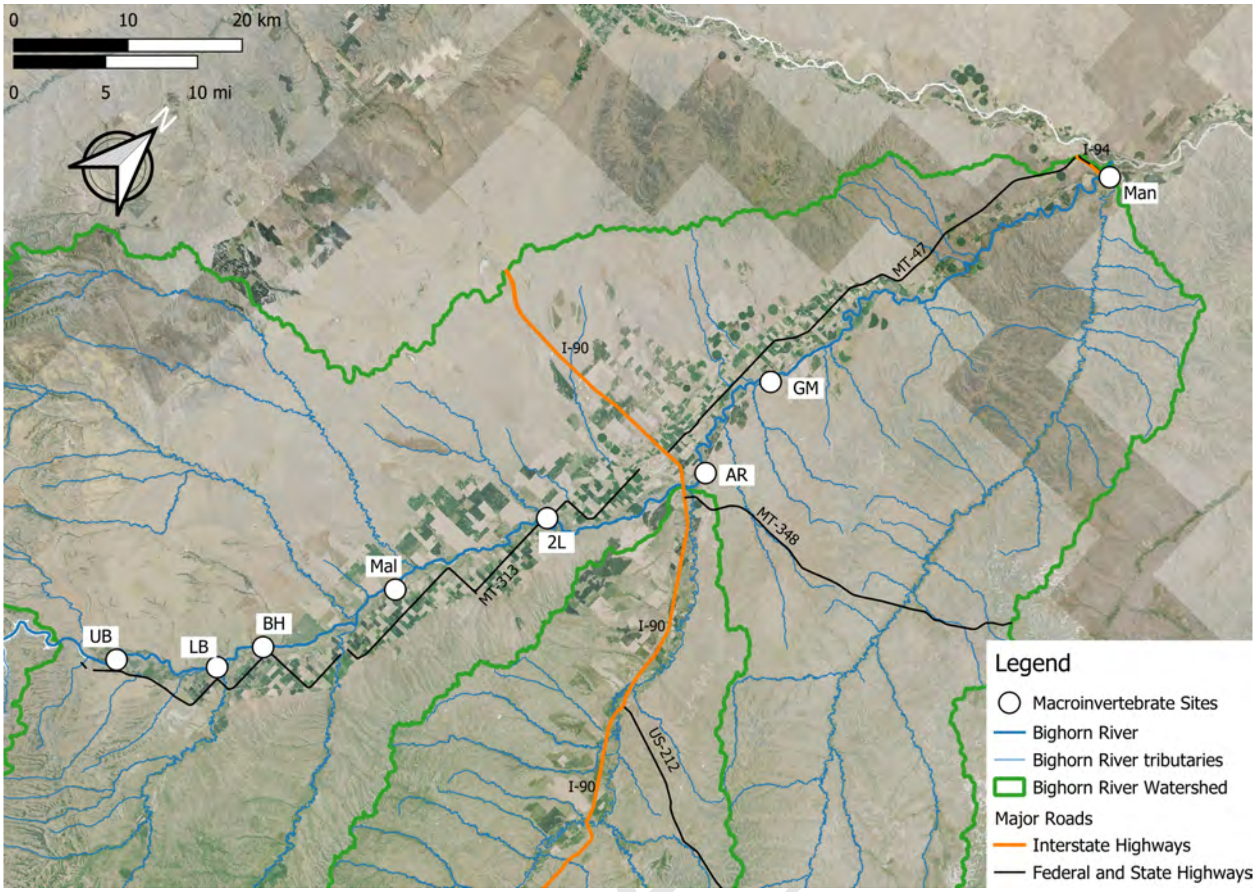

Figure 14: *Relative locations of sites used for the macroinvertebrate component of the long term water quality monitoring project. The Bighorn River in the study area flows from the Yellowtail Dam in the south to the confluence with the Yellowstone River in the North. From upstream to downstream the sites are Upper Brammer (UB), Lower Brammer (LB), Bighorn FAS (BH), Mallards Landing (Mal), Two Leggins (2L), Arapooish (AR), Grant Marsh (GM), and Manuel Lisa (Man).*

to the water column or substrate during macroinvertebrate sampling, with the exception of Mallards Landing. At Mallards Landing the macroinvertebrate riffle is located downstream of an irrigation return, macroinvertebrates should be collected before moving upstream of the irrigation return to collect water chemistry data.

Macroinvertebrate Collection Methods: Three replicate Hess (33 cm diameter, 500 μm mesh) samples will be collected within a designated riffle at each site. At each sampling point, the Hess sampler will be pushed into the stream bottom to form an effective seal and all cobbles ($>$ 64 mm) within the sampler will be scrubbed clean of organisms and removed; then the entire area within the sample frame will be raked for one minute until all organic matter is flushed into the collection net of the Hess sampler. The raw sample will be elutriated into a 500 μm sieve and transferred to labeled collection containers filled with 95% ethanol. Inorganic materials remaining following elutriation will be thoroughly examined for Trichoptera cases before being discarded.

Sampling of macroinvertebrates from a non-wadeable stream such as the Bighorn River requires a non-standard procedure. Hess Samples cannot be randomly located on the substrate due to water depth in mid-channel, so samples will be collected from near-bank habitats where water depth is shallow enough to employ the Hess Sampler. Samples will be collected in a line staggered as much as possible without overtopping the sampler from downstream to upstream so as not to disturb the habitat before sampling and will be sited on suitable substrate determined to be both representative of the habitat present and accessible.

Frequency/Schedule: Macroinvertebrates will be collected in the middle of April before spring runoff and at the end of September after runoff and the summer growing season.

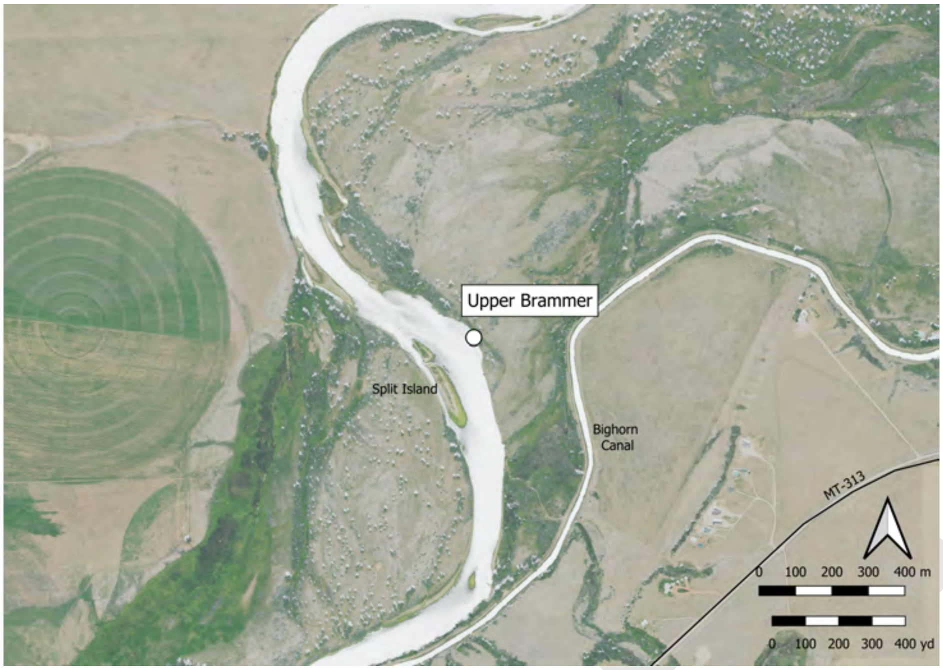

Figure 15: *Upper Brammer is located on river right across from Split Island.*

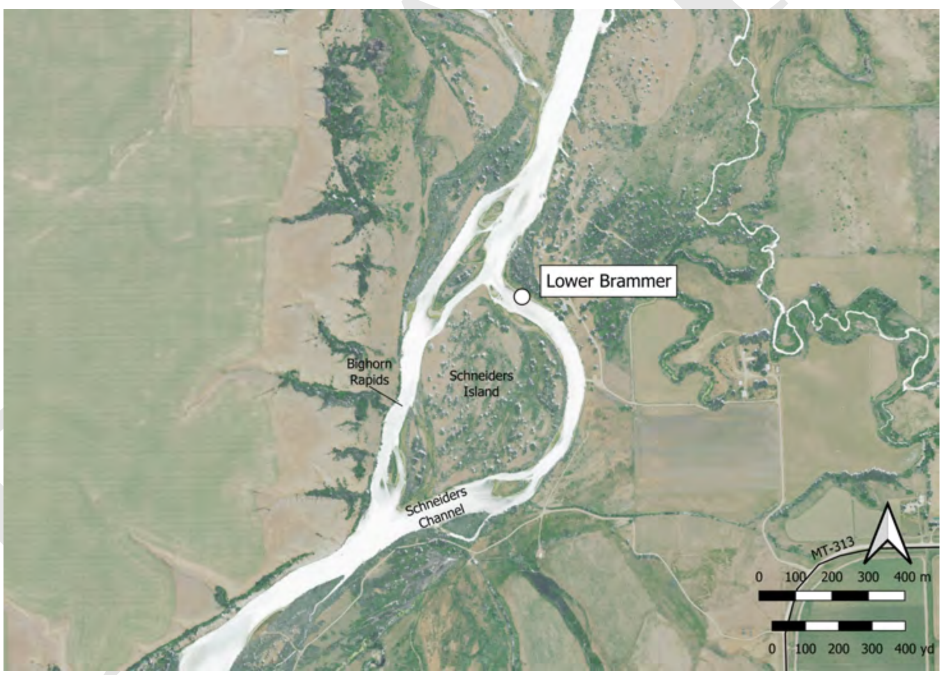

Figure 16: *Lower Brammer is located on river right just upstream of the end of Schneiders Channel.*

Laboratory Processing Methods: Macroinvertebrates will be picked from the samples on a randomized grid pattern until 500-600 individuals are reached, placed in vials, and identified to the lowest taxonomic level possible (usually genus or species) following MDEQ (2012b) protocols. Processing will be performed by the BHRA and/or by independent contractors. Contractors will deliver raw count and identification data to the BHRA for analysis.

Figure 17: The Grant Marsh site is located on river left upstream of the boat ramp at the Grant Marsh FAS and WMA.

6 Quality Assurance and Quality Control

Quality Assurance and Quality Control (QA/QC) are control measures to demonstrate the accuracy and precision of the sampling and analytical procedures. The water quality data must be of sufficient quality to be comparable both spatially and temporally. The QA/QC requirements include:

- YSI Sonde Calibration: Calibration of the YSI EXO1 will be completed in the office/lab prior to each field trip (Figure 18). The accuracy and precision of the sonde are verified by certified control standards. All calibrations, reading checks, and maintenance will be recorded and archived (Form 3). YSI specifies an operaing temperature range of -5 to 50 °C (23 to 122 °F). The device will not be used outside of this range, and sampling frequency will be adjusted as necessary to collect data within the operating parameters of the device.

Figure 18: Battery powered sonde with four sensors installed attached to handheld data recorder and data display. The batteries in the sonde allow for remote deployment during the lake depth profiling.

- Field Duplicate Samples: To assess precision associated with all steps in the water sample collection and laboratory analysis process, field duplicates will be collected. A field duplicate is a duplicate water sample at the same place and same time as other samples are taken. Sampling locations for duplicate samples will be randomly selected for each field trip from among the sampling sites. A duplicate sample will be collected for each parameter for each sampling trip. Field duplicate samples will be collected, preserved, stored, and handled in the same manner described for the regular samples. A separate sample number and site number will be assigned to each duplicate and submitted as “blind” samples to the lab.

- Field Blanks: To assess laboratory accuracy, field blanks will be collected and analyzed. Field blanks are deionized water which are treated as samples. They are used to identify errors or contamination in sample collection and analysis. The river field blank will be prepared in the field at the same site where the field duplicate is collected. The lake field blank will be prepared while on the boat over the sampling location at any time during or immediately after the retrieval of samples from depth. One field blank will be prepared for each parameter for each sampling trip. A separate sample number and site number will be assigned to each blank and submitted as “blind” samples to the lab.

- Temperature Blanks: To verify sample storage conditions each cooler provided by Energy Labs will contain a bottle marked ”Temperature Blank” that will be used by the sample custodian to check the temperature of samples upon delivery to Energy Labs.

- Duplicate Macroinvertebrate Collection: To assess efficacy of macroinvertebrate collection and accuracy in identification a duplicate three replicate Hess sample will be collected. The sampling location for duplication will be randomly selected for each field trip from among the sampling sites. Field duplicate samples will be collected, preserved, stored, and handled in the same manner described for the regular samples. A separate sample number and site number will be assigned to each duplicate and submitted as “blind” samples to the taxonomist.

- Data Quality Assurance/Data Validity: All data collected by BHRA will undergo a series of checks to ensure that the data are of sufficient quality and conform to project objectives. Soon after receipt of data deliverables from the lab, data verification and validation should occur. The BHRA Researcher is responsible for verifying that the laboratory data deliverables are complete and consistent with the requirements established in this Sampling Analysis Plan (SAP).

7 Data Management and Analysis

Site conditions, weather, photo numbers/descriptions, pertinent comments, etc. will be recorded on a field form concurrent with data collection (Form 1, Form 2). Field forms will be archived in the care of the BHRA Researcher for audit and data redundancy.

Copies of laboratory analytical reports and electronic data spreadsheets will be provided by Energy Labs to the BHRA Researcher. A quality assurance/data validity review of field and analytical data will be completed following receipt of the laboratory data. Data generated during the project will be maintained by BHRA and entered into a Microsoft Excel spreadsheet and/or database to be determined. If a cooperative agreement is forged between MDEQ and BHRA, the maintenance and analysis of data will be jointly done.

Processing and analysis of water quality data will be an ongoing task of the BHRA Researcher. At the conclusion of each water year, the Researcher will be responsible for completing a report that summarizes the annual data, contextualizes the long term dataset, and recommends future projects based on the findings from the dataset. Submission of the report will be followed by an annual presentation to the BHRA Board of Directors and other stakeholders.

Results will be presented graphically as mean and standard deviation (SD) plotted against river kilometer as a continuous variable, and as median and interquartile range (IQR) plotted against site as a categorical variable. Differences in the value of water quality parameters between sites, and the influence of seasonality on these differences, will be analyzed using linear models fit in the R statistical programming language. The validity of model assumptions (i.e. normality of residuals, heteroskedasticity) will be assessed by examining the residuals of initial models. Water quality parameters may then be transformed to meet model assumptions when necessary. Statistical support for differences between sites or between seasons will be considered strong at a threshold of $P \leq 0.05$. Statistical interactions between site and season (indicating seasonal influence on differences between sites) will be assessed for ecological significance if $P \leq 0.1$, and considered strongly supported if $P \leq 0.05$.

8 Adaptive Management

Adaptive management is an iterative approach to review and adjust the SAP as monitoring results and ecological relationships on the Bighorn River become better understood. This process is also important if BHRA research objectives and priorities change over time.

The effectiveness of adaptive management relies upon the participation of people, organizations, and agencies who use, manage, and have an interest in the Bighorn River. The BHRA will participate in the annual Bighorn Technical Working Group meeting to discuss previous monitoring results, spatial and temporal trends, water quality drivers, SAP adjustments, and the coordination of water quality monitoring for the coming year; as well as hear reports from other agencies involved with the management of Bighorn Lake and the Bighorn River to keep abreast of other research being conducted in the basin.

Conditions in the field may vary, and it may become necessary to implement modifications to sampling as presented in this plan. If modifications are required, they will be documented by field personnel and brought to the attention of the Research Committee at the earliest convenience. If field modifications will become permanent alterations to this SAP, then this document will be updated or an ammendment added to reflect this change.

9 Field Health and Safety Procedures

Accountability of field personnel will be maintained by all field personnel by recording all planned field trips in the company calendar listing the project and approximate field area, and by alerting at least one emergency contact outside of the BHRA of the same information. Inclement weather clothing and equipment will be at the discretion of field personnel based on actual and expected weather conditions during field work, and competency in use of equipment. High-visibility traffic vests will be worn by all field personnel at the Soap Creek and Little Bighorn River sites due to their location along state highway right-of-ways. High-visibility traffic vests or blaze orange hunting vests are recommended to be worn by all field personnel at Mallards Landing during hunting season. United States Coast Guard (USCG) approved Type II or Type III inherently buoyant or inflatable personal flotation devices (PFD)s will be worn by all personnel at all times while on board any motororized watercraft utilized for BHRA research activities, or when solo on board any watercraft utilized for BHRA research activities.

The nearest medical facility to all sites along the Bighorn River is the Big Horn Hospital in Hardin, MT, located roughly halfway along the study section of the Bighorn River. Ground-based medical response may be extedended as distance from Hardin increases. First Responder level of care is available from NPS Rangers at Bighorn Canyon National Recreation Area, and a helicopter landing zone is present near Ok-A-Beh marina. Current First Aid and Cardiopulmonary Resuscitation (CPR) training is required for all field crew leaders and recommended for all field personnel. A satellite communication device for contacting emergency services is recommended for all field crews due to limited cell phone reception in the study area.

A Field Safety Plan (FSP) is in development for BHRA research activities. Upon completion see that document for further details regarding field safety.

10 References

Brammer, J. A. (1991). (thesis). *The Effects of SUpersaturation of Dissolved Gases on Aquatic Invertebrates of the Bighorn River Downstream of Yellowtail Afterbay Dam.*

Montana Department of Environmental Quality (2012a). Water Quality Planning Bureau Field Procedures Manual for Water Quality Assessment Monitoring. Helena, MT. Report WQPBWQM-020

Montana Department of Environmental Quality (2012b). Sample Collection, Sorting, Taxonomic Identification, and Analysis of Benthic Macroinvertebrate Communities Standard Operating Procedure. Helena, MT. Report WQPBWQM-009

11 Further Reading

Bureau of Reclamation (2019). Hydromet Data System. Website at: https://www.usbr.gov/gp/hydromet/

Crow Tribe, Crow Environmental Protection Program. Sampling and Analysis Plan for 2017 – Surface Water Quality Monitoring Program for Long-Term Baseline Trend Monitoring and NPS Projects of the Reservation.

Montana Department of Environmental Quality (2018). Clark Canyon Reservoir and Beaverhead River Turbidity Monitoring – 2018: Water Quality Monitoring. Helena, MT. Sample and Analysis Plan. Document Number: M01MASSAP-07

Montana Department of Environmental Quality (2018). Watershed Characterization Monitoring: Yellowstone Project - 2018. Helena, MT. Sampling and Analysis Plan Y01MASSAP=02

BIGHORN RIVER ALLIANCE LAKE CHEMISTRY MONITORING FIELD FORM

Sampling Location: Latitude: 45.301372, Longitude: -107.964172

Participants			**Date**		
Time Start		**Time End**		**Sonde ID**	

Surface Values to Assess Sonde Stability Before Deployment

Water Temperature	______	°C	Barometric Pressure	______	mmHg
Dissolved Oxygen	______	% Sat	Dissolved Oxygen	______	mg/L
Dissolved Oxygen	______	% CB	Specific Conductance	______	µS/cm
Turbidity	______	FNU	pH	______	*unitless*
Secchi Depth	______	m	Sample logged in YSI handheld [ ]		

Administrative

Surface Sample Depth	3	ft	Lake Surface Elevation	______	ft
Spillway Depth	______	ft	Spillway Elevation	3593	ft
Penstock Depth	______	ft	Penstock Elevation	3444	ft
River Outlet Depth	______	ft	River Outlet Elevation	3297	ft
Bighorn Lake Inflows	______	ft^3/s	Yellowtail Outflows	______	ft^3/s

Location:	Surface	Spillway	Penstock	Outlet	Duplicate:	______	______
Time:	______	______	______	______	Blank:	N/A	______
						Location	*Time*

Weather Conditions

Air Temperature ________ °C

Comments

Water Color ________________

DRAFT

BIGHORN RIVER ALLIANCE RIVER CHEMISTRY MONITORING FIELD FORM

Site Name				**Date**	
Participants		**Sonde ID**		**Time**	

Water Temperature	________	°C	Barometric Pressure	________	mmHg
Dissolved Oxygen	________	% Sat	Dissolved Oxygen	________	mg/L
Dissolved Oxygen	________	% CB	Specific Conductance	________	µS/cm
Turbidity	________	FNU	pH	________	*unitless*
Transparency	________	cm	Sample logged in YSI handheld [ ]		

Water Samples Collected (Yes / No) TIME:_________ - Field Duplicate (Yes / No / NA) TIME:_________

Weather Conditions: Air Temperature ________ °C

Comments:

Site Name				**Date**	
Participants		**Sonde ID**		**Time**	

Water Temperature	________	°C	Barometric Pressure	________	mmHg
Dissolved Oxygen	________	% Sat	Dissolved Oxygen	________	mg/L
Dissolved Oxygen	________	% CB	Specific Conductance	________	µS/cm
Turbidity	________	FNU	pH	________	*unitless*
Transparency	________	cm	Sample logged in YSI handheld [ ]		

Water Samples Collected (Yes / No) TIME:_________ - Field Duplicate (Yes / No / NA) TIME:_________

Weather Conditions: Air Temperature ________ °C

Comments:

BIGHORN RIVER ALLIANCE SONDE CALIBRATION FORM

Technician		**Date**	
Sonde ID		**Last Cal.**	

Analog Temp. Reading	°C	Billings (Corrected) Barometric Pressure (BP)*	mmHg
		True BP = Corrected BP - [2.5 * (elevation (ft) / 100)] = CBP - 91.6	mmHg

Note: Weather Service or Airport readings are correted to sea level. Value must be uncorrected before use. KBIL elevation 3662.3 ft.

Parameter	Pre Cal. Value	Post Cal. Value	Temperature	QC Score	Cal. Status
Barometer	mmHg	mmHg	°C		
Specific Conductance	µS/cm	µS/cm	°C		
pH 7			°C	N/A	N/A
pH 10			°C		
pH 4 (optional)			°C		
Dissolved Oxygen %CB	%	%	°C		
Turbidity 0	FNU	FNU	°C	N/A	N/A
Turbidity 124	FNU	FNU	°C		

Comments