Missouri-Madison Project no. 2188 Water Quality and Biological Monitoring Plan

For the years 2022-2040

Final Version – 12/16/2021

NorthWestern® Energy

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Section 1.0 – Introduction

Northwestern Energy (formerly PPL Montana) filed a Water Quality and Biological Monitoring Plan on June 15, 2001 with the Federal Energy Regulatory Commission (FERC) as required by Article 404 of the Project 2188 License. On January 16, 2002, the FERC approved the plan with the requirement that an updated water quality monitoring plan will be provided to the Montana Department of Environmental Quality for its approval and to other specified agencies for their comments by May 15, 2011, which was extended to December 30, 2011 by FERC order of May 19, 2011.

The Water Quality and Biological Monitoring Plan for the Years 2012 -2021 ([Plan], PPLMT, 2011) incorporated recommendations from the 2011 Water Quality and Biological Monitoring Trend Analysis – Missouri-Madison Water Monitoring Program (PBS&J, 2011) and reviewing agencies. The overall objectives of the monitoring plan include:

- Identify long-term trends and spatial variation of water quality and biological parameters in the study area.

- Evaluate the effects of the operation and maintenance of hydroelectric facilities along the Madison and upper Missouri rivers.

The study area covered by the Plan extends from the headwaters of the Madison River in Yellowstone National Park through the upper reaches of the Missouri River, confluence of the Madison, Jefferson, and Gallatin rivers, and downstream of Morony Dam in Great Falls (**Figure 1-1**). Included in the study area are nine hydroelectric facilities operated by Northwestern Energy plus one dam operated by the Bureau of Reclamation, Canyon Ferry Dam. The Northwestern Energy dams include Hebgen and Madison dams on the Madison River, and Hauser, Holter, and the five Great Falls dams (Black Eagle, Rainbow, Cochrane, Ryan, and Morony) on the upper Missouri River. In addition to documenting the water quality and biological conditions for stations that bracket (upstream-downstream) these hydroelectric facilities, the Plan outlined a comprehensive statistical analysis approach to evaluate the downstream effects of these facilities, and other watershed influences, over time.

Monitoring objectives for the study area were previously identified by the Montana Department of Environmental Quality (MDHES 1993), the 2188 Water Quality Technical Committee, and by the terms of the license issued by FERC. These objectives have been combined into the following:

- Provide a statistical analysis of long-term trends in water quality and biological data.

- Evaluate the potential influence of dam facilities on water quality and biological parameters with upstream-downstream comparisons.

- Monitor the effects of operation and maintenance of dam facilities on water quality and biological parameters.

- Evaluate the status of the entire system with respect to water quality and biological parameters.

- Determine whether the effects measured above indicate an improvement or deterioration of water quality, biological integrity, and ecological health of the Madison and Missouri river system.

The duration of the monitoring program detailed in the current Plan is ten years, and per the Water Quality Plan approved by FERC, a comprehensive analysis of water quality and biological data is to be provided every five years. The first analysis report summarized the monitoring data and statistical analyses of the data collected from 1997 through 2006 (PBS&J 2011) and the second report from 2006 through 2016 (GEI 2017). In order to align the ten year period with the approved Plan, a ten-year analysis was again performed for 2011 to 2020 (GEI 2021).

As the current FERC-issued license to operate the Missouri-Madison dams is set to expire on August 31, 2040, this plan serves to outline the water quality and biological monitoring that NWE plans to conduct throughout the remainder of the license term.

Section 1.1 – Purpose

This plan details a comprehensive monitoring program that incorporates the findings and recommendations of several years of water quality and biological pilot phase data collection and 20 years of Monitoring Program implementation. This monitoring plan is intended to provide statistically rigorous approach to characterize and identify trends in water quality and biological parameters. Baseline data and continuing monitoring data will be analyzed to assess the potential influence of hydroelectric facilities on the Madison and upper Missouri rivers.

In addition to meeting FERC relicensing needs, this monitoring plan will generate reliable data appropriate for eventual application to Total Maximum Daily Load (TMDL) or other water quality initiatives within the basin.

The duration of the monitoring program detailed in this plan is for the remainder of the license term set to end on August 31, 2040. A comprehensive analysis of water quality will be undertaken at the end of the first ten-year period (2032) and again at the end of the license term (2040).

Section 1.2 – Monitoring Locations

The monitoring locations have been selected to provide data sufficient to evaluate the potential impacts of dams on the Madison and Missouri rivers. These monitoring locations are considered adequate for meeting the objectives of this plan. Sampling locations differ slightly for the water quality and biological monitoring in some instances due to physical requirements for collecting representative samples.

The monitoring locations comprise 10 water quality and biological monitoring stations (**Figure 1-2**). The water quality and biological monitoring locations include:

- Hebgen Dam (Madison River):
  - **YNP**: above Hebgen Lake, in Yellowstone National Park ([B1] macroinvertebrates only).
  - **HWY 287**: above Hebgen Lake, Highway 287 ([1] water quality only).
  - **Hebgen**: below dam ([2, B2] water quality and biological).

- Madison Dam (Madison River):
  - **Varney**: above Ennis Lake, at Varney Bridge ([3] water quality only).
  - **Ennis**: above Ennis Lake, at Ennis Campground ([B3] biological only).
  - **Madison**: below dam ([4, B4] water quality and biological).

- Canyon Ferry Dam (Missouri River):
  - **Toston**: above Canyon Ferry Lake, at Toston Bridge ([5, B5] water quality and biological).
  - **Canyon Ferry**: below dam, above Hauser Lake ([6] water quality only).

- Hauser Dam (Missouri River):
  - **Hauser**: below dam, above Holter Lake ([7, B7] water quality and biological).

- Holter Dam (Missouri River):
  - **Holter**: below dam ([8, B8] water quality and biological).

- Great Falls Dams (Missouri River):
  - **Black Eagle**: above Black Eagle reservoir ([9] water quality only), also known as Central Ave/G. Falls.
  - **Morony**: below Morony Dam ([10, B10] water quality and biological).

In addition to the above monitoring locations, macroinvertebrate data is collected at three additional sites on the Madison River as a part of NWE's Madison River Flushing Flow Program. These sites are:

- **Kirby**: above Ennis Lake, at the Kirby Ranch USGS gage ([F1] macroinvertebrates only).
- **Norris**: below Ennis Lake, downstream of Hot Springs Creek ([F3] macroinvertebrates only).
- **Greycliff**: below Ennis Lake, upstream of the Three Forks confluence ([F4] macroinvertebrates only).

Three of these locations, including sites above Hebgen Lake (YNP and HWY 287) and Toston are located on relatively "unregulated" reaches of the Madison and upper Missouri rivers. These sites are intended to establish natural background variability in water quality where little or no effect from reservoir discharges upstream would be expected.

The exact location of each site, as well as a list of water quality parameters measured at each site can be found in **Table 1-1 in Appendix A**. Monitoring locations may be modified during the course of this monitoring program if data evaluation suggests that monitoring objectives would still be met.

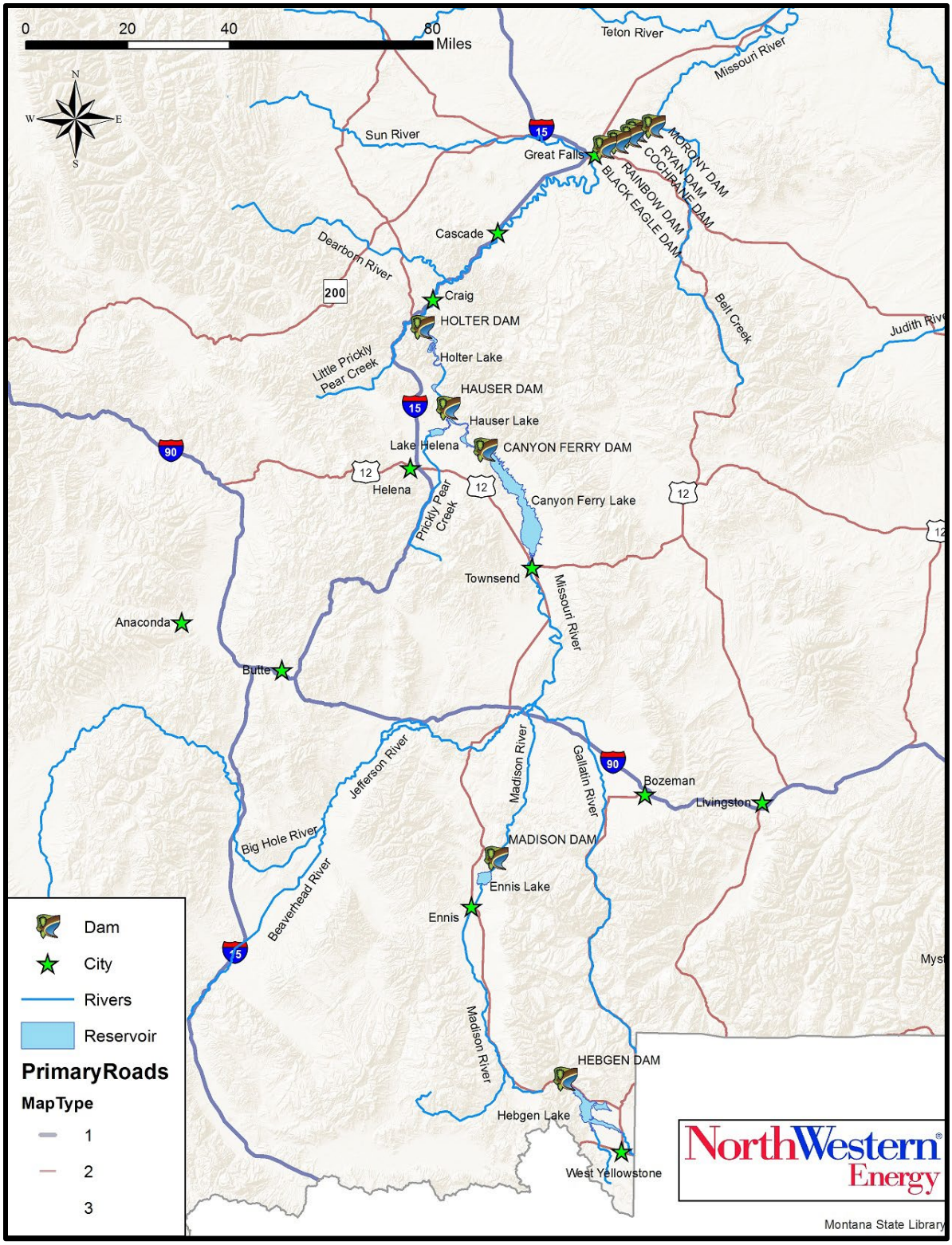

Figure 1-1. Study area from West Yellowstone downstream to Great Falls, Montana.

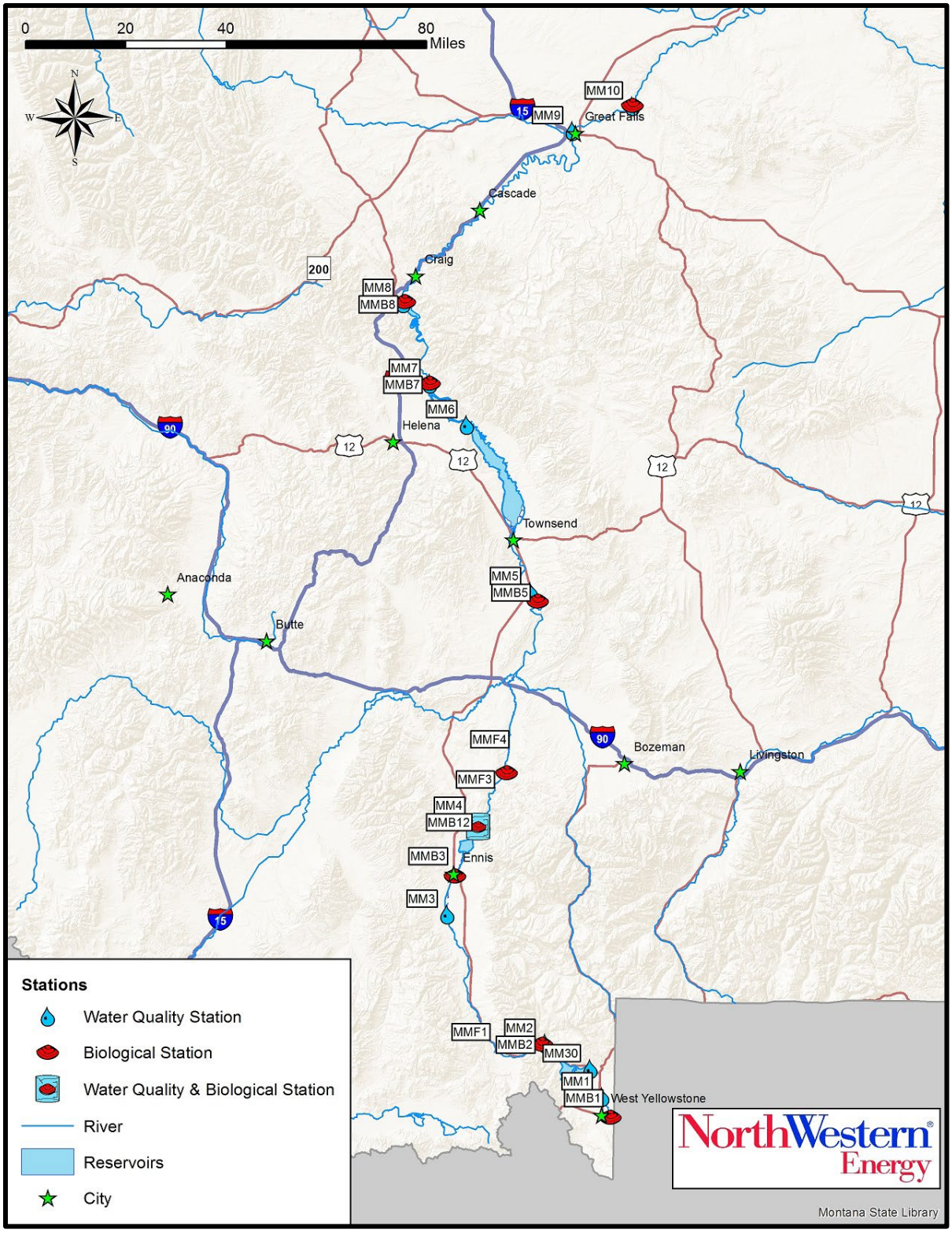

Figure 1-2. Water quality and biology monitoring stations on the Madison-Missouri River for 2022 to 2040.

Section 1.2.1 – Hebgen Dam

Hebgen Reservoir, formed by the completion of Hebgen Dam in 1915, is located about 22 miles northwest of West Yellowstone, Montana. The reservoir intercepts a drainage area of about 930 square miles. The earth filled dam is 85 feet high and 721 feet long, with a broad crested weir spillway on the right bank that is 50 feet wide. The dam stores 386,000 acre-ft at the normal full pool elevation of 6534.87 feet. Releases from the dam are made through intake gates with a single vertical opening of 13 feet by 9 feet high, centered at elevation 6495.87, and then through a 10'-8" diameter discharge pipe located 68 feet below full pool.

The depth of the reservoir is 75 feet near the dam and 81 feet maximum (about a mile upstream), with a mean depth of 27 feet. At full pool, the reservoir surface area is 19.8 square miles. The mean water retention time in the reservoir is 172 days.

The biological monitoring station above Hebgen Reservoir (Station B1, YNP) is located approximately 2 miles East of West Yellowstone **(Figure 1-3**). The water quality monitoring station above the reservoir (Station 1, HWY 287) is located at the Highway 287 bridge (**Figure 1-4**) and the method used to collect samples at this site is a depth integrated, equal width increment composite. These stations are considered control stations because they are located on a relatively "unregulated" reach of the Madison River and are intended to establish natural background variability in biological and water quality data where no effect from reservoir discharges upstream occurs. The water quality monitoring station below Hebgen Dam (Station 2, Hebgen) is roughly 0.3 miles below the dam, at the United States Geological Survey (USGS) gaging station #6038500 on the right bank (**Figure 1-5**). The sampling method at this site is a depth integrated point sample. The biological monitoring station downstream from Hebgen Dam (Station B2, Hebgen) is located about 1.25 miles downstream of the facility on the right bank (**Figure 1-6**Error! Reference source not found.). A flushing flow monitoring station (Station F1, Kirby) is also located about 16 miles downstream of Hebgen Dam (**Figure 1-7**).

Figure 1-3. Station B1, YNP on the Madison River.

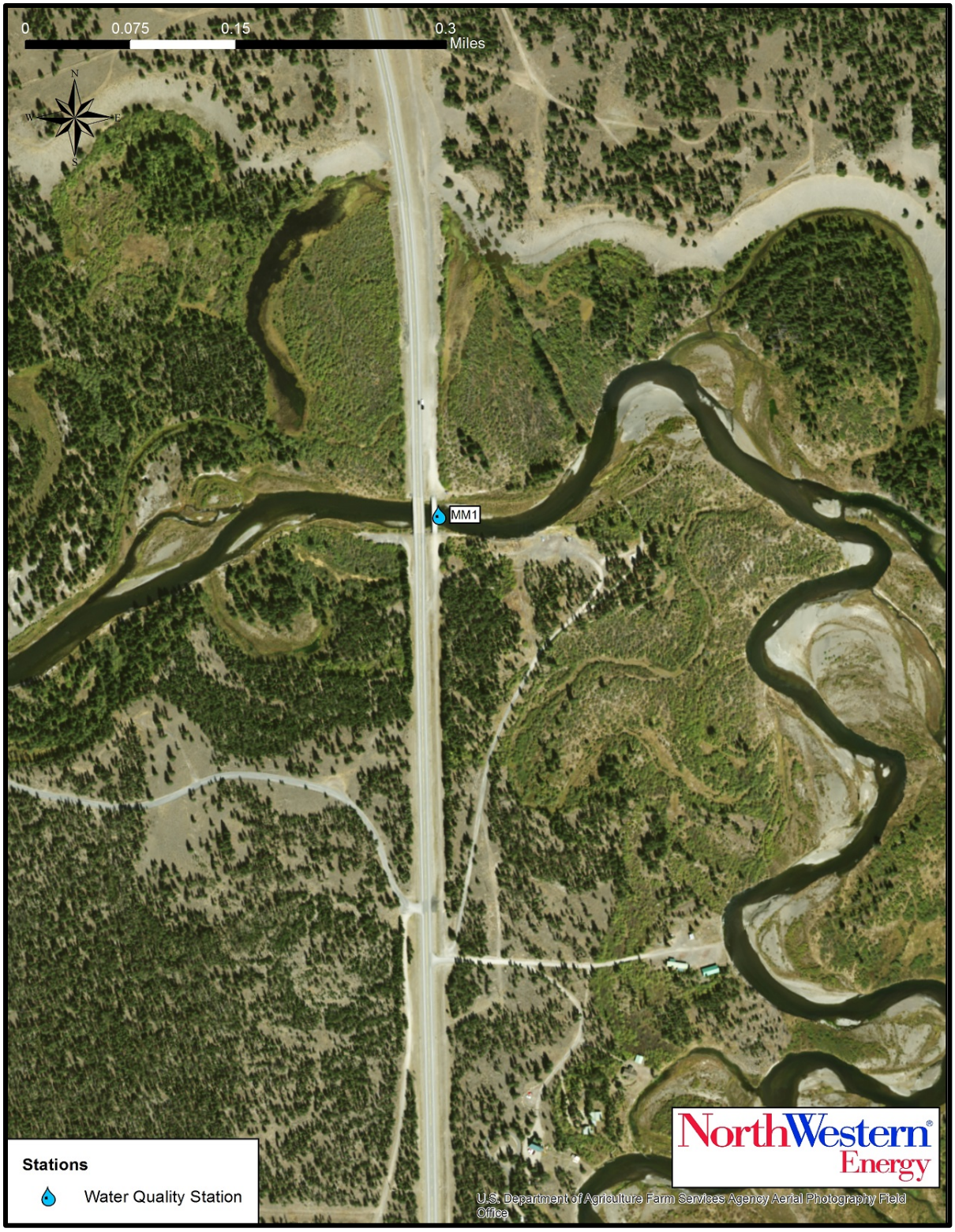

Figure 1-4. Station 1, HWY 287 on the Madison River.

Figure 1-5. Station 2, Hebgen on the Madison River.

Figure 1-6. Station B2, Hebgen on the Madison River.

Figure 1-7. Station F1, Kirby on the Madison River.

Section 1.2.2 – Madison Dam

Ennis Lake is located roughly 5 miles northeast of Ennis, Montana. Madison dam is located 68.8 miles downstream of Hebgen Dam, and 40.2 miles upstream of the Missouri River headwaters at Three Forks, Montana. The reservoir intercepts a drainage area of about 2,181 square miles. The dam is a 38.5-foot high rock-filled crib structure that is operated primarily as a run-of-the river facility. The dam impounds 39,115 acre-feet of useable storage between elevations 4,826 and 4,841 feet.

A concrete intake structure, 26 feet deep in front of the dam, provides water to a 13-foot diameter flow line which extends 7,500 feet down the canyon to the powerhouse. NorthWestern Energy is currently implementing a project to replace all four turbine generator units in the Madison powerhouse which is scheduled to be completed in 2022. The upgraded powerhouse will have a hydraulic capacity of 1,600 cfs. Maximum depth of the reservoir is 32 feet near the dam, with a mean depth of 12 feet. Mean water residence time in the reservoir is 15 days.

The water quality monitoring station (Station 3, Varney) is located at the Varney Bridge and the sampling method for this site is a depth integrated, equal width interval composite (**Figure 1-8**). The biological monitoring station (Station B3, Ennis) is at Ennis Campground and is also a flushing flow program monitoring station (**Figure 1-9**). The biological and water quality monitoring stations below Ennis Lake (Station 4, Madison) are at the same location (**Figure 1-10**). The sampling method at this water quality monitoring station is a depth integrated, single point sample composite of the turbine and bypass channel at the footbridge and the biological monitoring station is located downstream from the junction of the powerhouse and bypass channel. Two flushing flow program monitoring stations are also located approximately 11 miles (Station F3, Norris; **Figure 1-11**) and approximately 21 miles (Station F4, Greycliff; **Figure 1-12**) downstream of the Madison Powerhouse.

Figure 1-8. Station 3, Varney on the Madison River.

Figure 1-9. Station B3, Ennis on the Madison River.

Figure 1-10. Station 4, Madison on the Madison River.

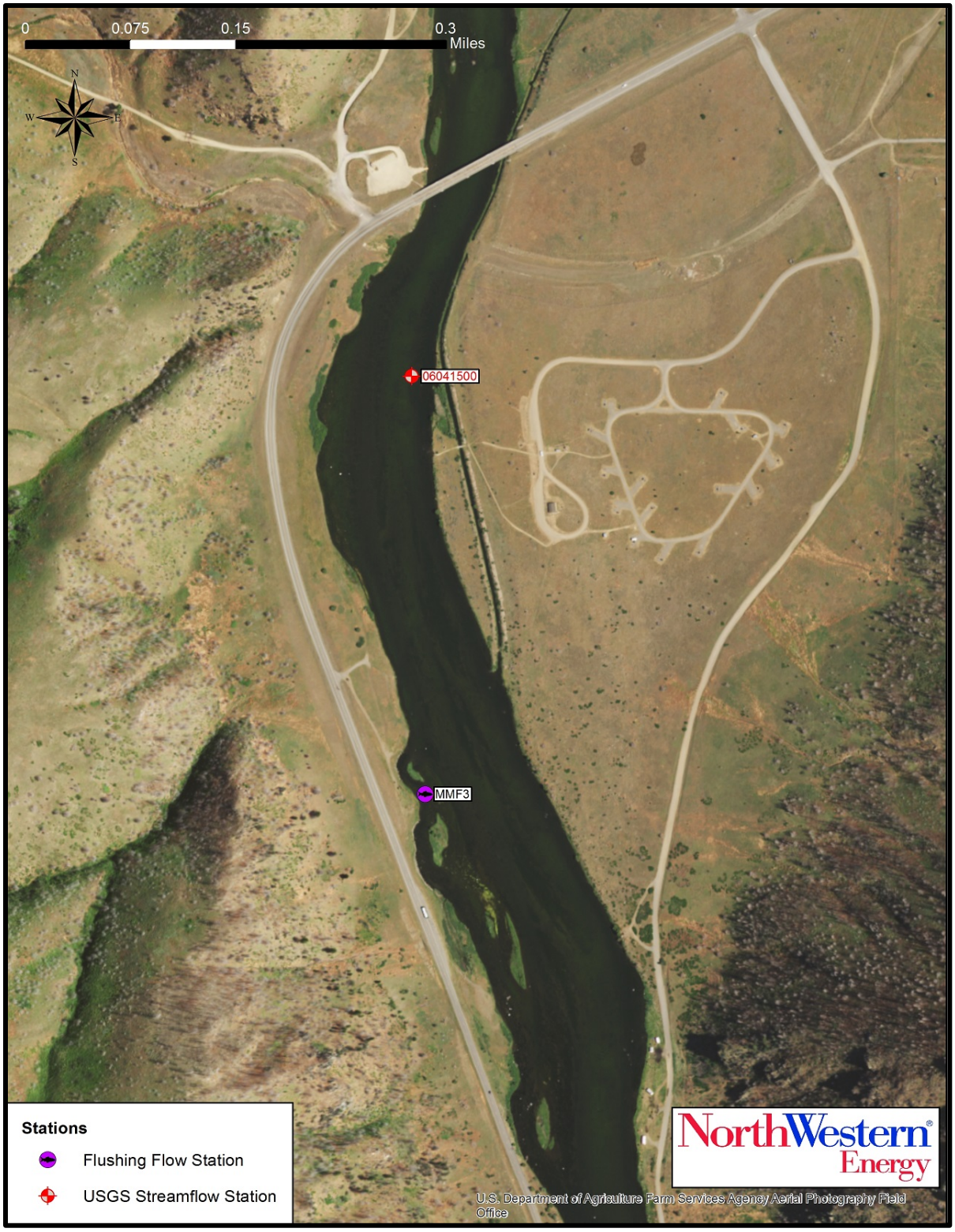

Figure 1-11. Station F3, Norris on the Madison River.

Figure 1-12. Station F4, Greycliff on the Madison River.

Section 1.2.3 – Canyon Ferry Dam

Canyon Ferry Dam is owned and operated by the Bureau of Reclamation and was built between 1949 and 1954. The facility is used for flood control, power supply, irrigation, and recreation. The dam is constructed of concrete and is roughly 1,000 feet long and 225 feet high. The reservoir storage capacity is 2,050,900 acre-ft (at an elevation of 3800 ft).

The biological monitoring station above Canyon Ferry Lake (Station B5, Toston) is located approximately 3 miles upstream of the Hwy 287 Bypass bridge in Toston on the left bank (**Figure 1-13**). The water quality monitoring station (Station 5, Toston) is located at the bridge (**Figure 1-14**), and the sampling method for this site is a depth integrated, equal width interval composite. These stations are considered control stations because they are located in a relatively “unregulated” reach of the Missouri River and are intended to establish natural background variability in water quality and biological data where little or no effect from reservoir discharges upstream would be expected. The water quality monitoring station below the dam (Station 6, Canyon Ferry) is located at the penstock discharge, and the sampling method for this site is a single point, depth integrated sample (**Figure 1-15**). It is not possible to proportionally sample spill/turbine flow, and high flow samples are limited to turbine discharge only. No biological monitoring station is located below the dam.

Figure 1-13. Station B5, Toston on the Missouri River.

Figure 1-14. Station 5, Toston on the Missouri River.

Figure 1-15. Station 6, Canyon Ferry on the Missouri River.

Section 1.2.4 – Hauser Dam

Hauser Reservoir is located about 14 miles northeast of Helena, Montana and 14 miles downstream of Canyon Ferry Dam. The reservoir intercepts a drainage area of about 16,876 square miles. The dam is a concrete gravity structure with a 445-foot long overflow spillway and non-overflow sections at each abutment.

The reservoir is comprised of two connected bodies of water. The main water body, Hauser Reservoir, has a useable storage of 52,893 acre-ft. A smaller water body, Lake Helena, has 11,360 acre-ft of useable storage. Mean depth of the reservoir is 25.8 feet at full pool with a mean water residence time of about 9 days.

The monitoring station below Canyon Ferry Dam (Station 6, Canyon Ferry; **Figure 1-15**) is used to define water quality parameters above Hauser Reservoir. The water quality monitoring station below Hauser Dam (Station 7, Hauser) is approximately 0.1 miles below the power plant on the left bank (**Figure 1-16**), and the sample methodology for this site is a single point, depth integrated sample . The biological monitoring station (Station B7, Hauser) is approximately 0.2 miles below the power plant (**Figure 1-16**).

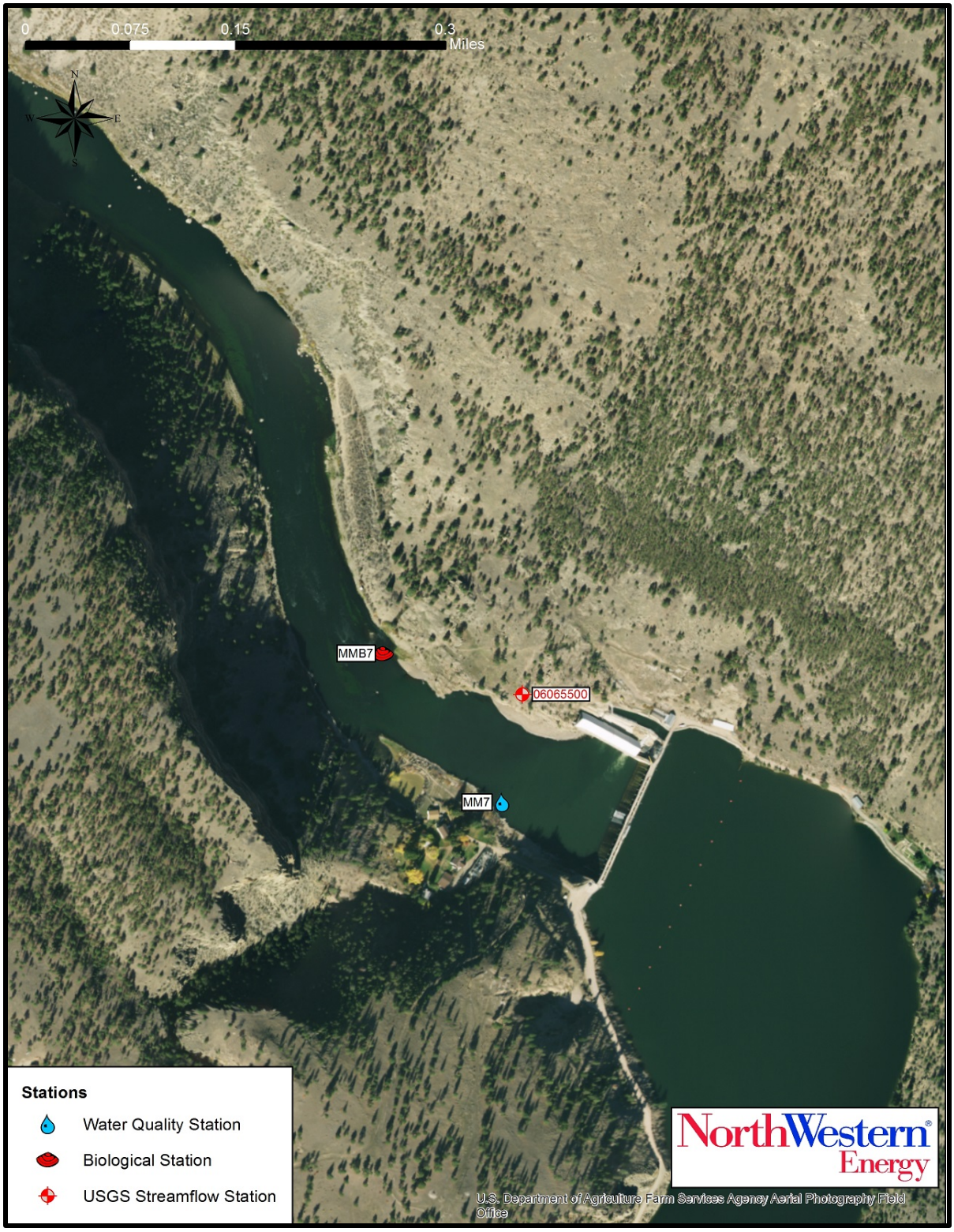

Figure 1-16. Stations 7 and B7, Hauser on the Missouri River.

Section 1.2.5 – Holter Dam

Holter Reservoir is located about 27.7 miles downstream of Hauser Dam, and 43 miles northeast of Helena, Montana. The reservoir intercepts a drainage area of about 17,150 square miles. The dam is a 124-foot high, straight concrete gravity structure with an ogee spillway section that is 682 feet long. The dam impounds 81,920 acre-ft of useable storage with a surface area of 4,550 acres and is operated primarily as a run-of-the river facility. Mean water residence time in the reservoir is 22 days.

The monitoring point below Hauser Dam (Hauser) is used to define water quality and the monitoring station below Hauser Dam (Station B7, Hauser; **Figure 1-16**) is used to define water quality above Holter Reservoir. The water quality monitoring station below Holter Dam (Station 8, Holter) is approximately 0.4 miles below the power plant on the left bank (**Figure 1-17**), and the sampling methodology for this site is a single point, depth integrated sample. The biological monitoring station (Station B8, Holter) is approximately 0.9 miles below the power plant (**Figure 1-17**).

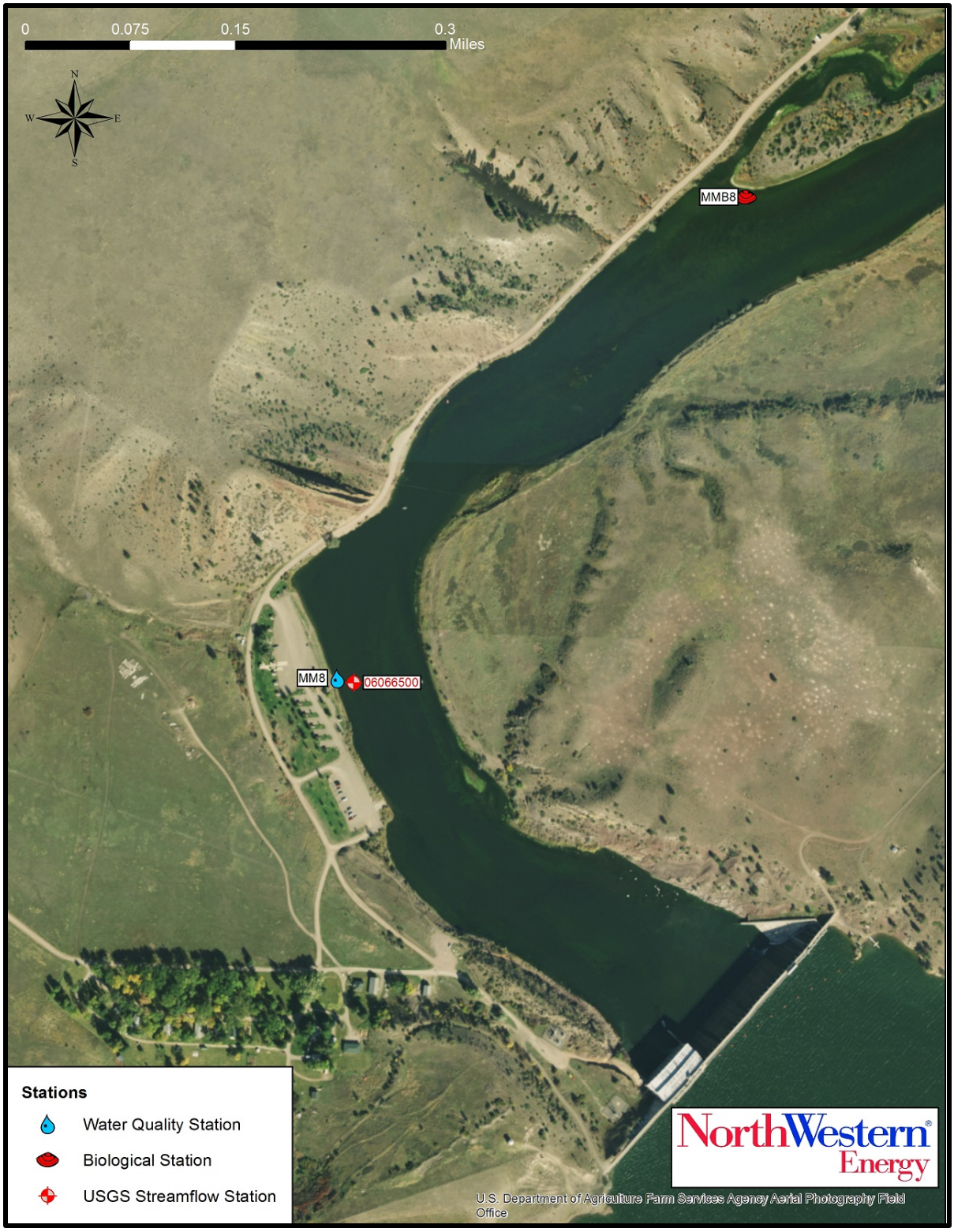

Figure 1-17. Stations 8 and B8, Holter on the Missouri River.

Section 1.2.6 – Great Falls Dams

The Great Falls dams consist of a series of five hydroelectric developments within a 12.1-mile section of the Missouri River. The cumulative effects of the five Great falls dams (Black Eagle, Rainbow, Cochrane, Ryan, and Morony) are evaluated using monitoring points above Black Eagle and below the Morony dams. Brief descriptions of each of the dams are presented below, along with a description of the monitoring points for this study.

Black Eagle Dam is located in Great Falls, 93 miles downstream from Holter Dam. The Sun River empties into Black Eagle Reservoir 3.8 miles upstream from Black Eagle Dam. The reservoir intercepts a drainage area of about 22,100 square miles. The dam is operated as a run-of-the river facility. The dam impounds 1,710 acre-ft of useable storage between elevations 3,279 and 3,290 feet, with a surface area of 402 acres.

The Rainbow Development is located 6 miles northeast of Great Falls, 3.2 miles downstream from Black Eagle Dam. The reservoir intercepts a drainage area of about 22,920 square miles. The dam is operated as a base load, run-of-the river project and maintains the elevation of Rainbow Reservoir near its normal full pool elevation of 3,224 feet. The dam impounds 1,170 acre-ft of useable storage, with a surface area of 126 acres.

The Cochrane Development is located northeast of Great Falls, 3.2 miles downstream from Rainbow Dam. The reservoir intercepts a drainage area of about 23,270 square miles. The dam is operated to provide base load generation, short-term generation reserves, and load-following generation on a coordinated basis with the Ryan and Morony developments. The dam impounds 4,503 acre-ft of useable storage, with a surface area of 249 acres.

The Ryan Development is located northeast of Great Falls, 1.9 miles downstream from Cochrane Dam. The reservoir intercepts a drainage area of about 23,080 square miles. The dam is operated to provide base load generation, short-term generation reserves, and load-following generation on a coordinated basis with the Cochrane and Morony developments. The dam impounds 3,653 acre-ft, of which 2,440 acre-ft is useable storage, with a surface area of 168 acres.

The last of the five dams, Morony Dam, is located northeast of Great Falls, 3.9 miles downstream from Ryan Dam. The reservoir intercepts a drainage area of about 23,292 square miles. The dam is operated as base load project with outflows approximately equal to inflows into the Great Falls developments upstream. The dam impounds 7,595 acre-ft of useable storage, with a surface area of 304 acres.

The Great Falls dams and reservoirs are treated as one unit for water quality monitoring purposes. Water quality parameters are monitored above the dams at the Central Avenue Bridge in Great Falls (**Figure 1-18,** Station 9) and sampling methodology at this site is comprised of 12 equal width, depth integrated samples that are composited to create one sample. Both water quality and biological parameters are monitored downstream of the Great Falls dams at Stations 10 and B10. The water quality monitoring point (Morony) is located off the penstock discharge structure of the Morony Dam (**Figure 1-19,** Station 10), and the water sampling methodology for this site is a single point depth-integrated sample. The biological location (**Figure 1-19,** Station B10) is 0.2 miles downstream of the dam on the left bank.

Figure 1-18. Station 9, Black Eagle/Central Ave Bridge on the Missouri River.


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Stations
Water Quality Station
Biological Station
USGS Streamflow Station
NorthWestern Energy
U.S. Department of Agriculture Farm Services Agency Aerial Photography Field Office

Section 2.0 – Monitoring Objectives

The overall objectives of this Missouri-Madison Water Quality and Biological Monitoring Program include the following:

- Provide a statistical analysis of long-term trends in water quality and biological data;
- Evaluate the potential influence of dam facilities on water quality and biological parameters with above/below comparisons;
- Monitor the effects of operation and maintenance of dam facilities on water quality and biological parameters;
- Evaluate the status of the entire system with respect to water quality and biological parameters; and
- Determine whether the effects measured above suggest an improvement or deterioration of water quality, biological integrity, and ecological health of the Madison and Missouri river system.

Section 2.1 – Water Quality Monitoring Objectives

Monitoring objectives are outlined in formal structure below and are summarized in **Table 2-1 in Appendix A**. Referenced statistical methodologies are outlined in **Section 5.3.1**.

Long-term Trend Identification

MANAGEMENT GOAL:	Maintain or improve water quality.
MONITORING GOAL:	Detect significant temporal (10 year) trends in water quality parameters.
DEFINITION OF WATER QUALITY:	Analysis of nutrient, metals, and other parameters defined in Error! Reference source not found. **in Appendix A**.
DEFINITION OF TREND:	Correlation between concentration and time at the 0.05 significance level.
STATISTICAL METHODOLOGY:	Kendall non-parametric test applied to flow and seasonally adjusted data as appropriate.
STATISTICAL HYPOTHESIS:	No trend exists.
DATA ANALYSIS RESULT:	Conclusions regarding presence and nature of trends (statistical significance of +- correlation); provide estimate of trend magnitude (Sen slope estimate).
INFORMATION PRODUCT:	Management goal met when no trend exists, or indicates improvement in water quality (e.g. decreasing trend for nutrient concentration).

Parameter Correlation

MANAGEMENT GOAL:	Optimize monitoring program, define covariate behavior.
MONITORING GOAL:	Detect significant correlations between water quality parameters.
DEFINITION OF WATER QUALITY:	Analysis parameters defined in Error! Reference source not found. **in Appendix A**.
DEFINITION OF EFFECT:	Correlation between parameters, 0.05 significance level.
STATISTICAL METHODOLOGY:	Spearman's non-parametric correlation applied to paired parameter data.
STATISTICAL HYPOTHESIS:	No correlation exists.
DATA ANALYSIS RESULT:	Conclusions regarding potential use of surrogates to optimize monitoring. Conclusions regarding covariate behavior of parameters.
INFORMATION PRODUCT:	Management goal met when no benefits would result from modifications to monitoring program. Improved understanding of inter-relationships between water quality measures.

Dam Baseline Evaluation, Routine Operations

MANAGEMENT GOAL:	Maintain or improve water quality downstream of dam facilities.
MONITORING GOAL:	Detect and quantify significant differences in parameters upstream-downstream of each dam. Determine if differences suggest dam-related improvement or impact on water quality.
DEFINITION OF WATER QUALITY:	Analysis parameters defined in Error! Reference source not found. **in Appendix A**.
DEFINITION OF EFFECT:	Differences in median response, 0.05 significance level.
STATISTICAL METHODOLOGY:	Kruskal-Wallis non-parametric test applied to paired parameter data, seasonally stratified as appropriate.
STATISTICAL HYPOTHESIS:	No differences in median values exist.
DATA ANALYSIS RESULT:	Conclusions regarding presence and nature of facility effects.
INFORMATION PRODUCT:	Management goal met when no upstream-downstream differences exist, or results indicate stability or improvement in water quality over time.

Dam Evaluation, Non-Routine Operations

MANAGEMENT GOAL:	Minimize any detrimental dam operation effects on water quality.
MONITORING GOAL:	Detect significant correlations between dam operations and water quality parameters. Determine if effects vary with magnitude/duration or timing of operation event.
DEFINITION OF WATER QUALITY:	Analysis parameters defined in Error! Reference source not found. **in Appendix A**.
DEFINITION OF EFFECT:	Correlation between parameters and dam operations, 0.05 significance level.
STATISTICAL METHODOLOGY:	Spearman's non-parametric correlation applied to paired parameter/operation data.
STATISTICAL HYPOTHESIS:	No correlation exists.
DATA ANALYSIS RESULT:	Conclusions regarding the effect (magnitude/duration) of operation events on water quality. This analysis may employ additional statistical methods such as multivariate analysis to evaluate water quality effects.
INFORMATION PRODUCT:	Management goal met if operation effects are not statistically significant, or are deemed to be within acceptable levels.

Section 2.2 – Biological Monitoring Objectives

The objectives of the biological monitoring portion of this plan are presented below and follow the format presented in **Table 2-1 in Appendix A**.

Periphyton Long-term Trend Identification

MANAGEMENT GOAL:	Maintain or improve periphyton integrity.
MONITORING GOAL:	Detect significant trends in periphyton standing crop. Determine if trends suggest dam related improvement or deterioration of water quality.
DEFINITION OF WATER QUALITY:	Chlorophyll-a, various metrics.
DEFINITION OF TREND:	Correlation between parameter and time to the 0.10 significance level.
STATISTICAL METHODOLOGY:	Kendall non-parametric test applied to seasonal or covariate-adjusted data as necessary.
STATISTICAL HYPOTHESIS:	No trend exists.
DATA ANALYSIS RESULT:	Conclusions regarding presence and nature of trends in periphyton biomass or metrics, and provide estimate of trend magnitude(s).
INFORMATION PRODUCT:	Management goal met when no trend exists, or indicates improvement (i.e. a reduction in biomass for most sites).

Periphyton Targets

MANAGEMENT GOAL:	Maintain or improve periphyton integrity.
MONITORING GOAL:	Evaluate annual compliance with site specific targets.
DEFINITION OF WATER QUALITY:	Analysis of metrics defined in **Section** Error! Reference source not found..
DEFINITION OF TREND:	Comparison of median values with target limits established by baseline monitoring.
STATISTICAL METHODOLOGY:	Comparison of median values to baseline targets.
STATISTICAL HYPOTHESIS:	Median values are within one standard deviation of baseline.
DATA ANALYSIS RESULT:	Conclusions regarding compliance with respect to periphyton biomass targets.
INFORMATION PRODUCT:	Management goal met when annual periphyton measures are within baseline targets.

Macroinvertebrate Long-term Trend Identification

MANAGEMENT GOAL:	Maintain or improve macroinvertebrate integrity.
MONITORING GOAL:	Detect significant trends in composite ("multimetric") measures of macroinvertebrates. Determine if trends suggest an improvement or deterioration of water quality.
DEFINITION OF WATER QUALITY:	Multimetric scores.
DEFINITION OF TREND:	Correlation between parameter and time to the 0.10 significance level.
STATISTICAL METHODOLOGY:	Kendall non-parametric test applied to seasonal or covariate-adjusted data (as necessary).
STATISTICAL HYPOTHESIS:	No trend exists.
DATA ANALYSIS RESULT:	Conclusions regarding presence and nature of trends. Provide estimate of trend magnitude.
INFORMATION PRODUCT:	Management goal met when no trend exists, or indicates improvement in benthic community integrity.

Macroinvertebrate Targets

MANAGEMENT GOAL:	Maintain or improve macroinvertebrate community integrity.
MONITORING GOAL:	Compare annual results with site specific targets established by baseline monitoring.
DEFINITION OF WATER QUALITY:	Analysis of metrics defined in **Section** Error! Reference source not found..
DEFINITION OF TREND:	Comparison of annual values with target limits for individual macroinvertebrate metrics.
STATISTICAL METHODOLOGY:	Numerical comparison of annual to baseline targets.
STATISTICAL HYPOTHESIS:	Median values are within one standard deviation of baseline.
DATA ANALYSIS RESULT:	Conclusions regarding achievement of targets with respect to macroinvertebrate metric targets.
INFORMATION PRODUCT:	Management goal met when macroinvertebrate metrics measures are within baseline targets.

Fish Tissue Biocontaminants

MANAGEMENT GOAL:	Maintain or improve (i.e. reduce) biocontaminant levels in fish tissue.
MONITORING GOAL:	Detect significant differences in biocontaminant levels over 10-year period[1].
DEFINITION OF WATER QUALITY:	Analysis of organochlorine and metal parameters defined in **Section** Error! Reference source not found..
DEFINITION OF TREND:	Detect a 40% difference in mean or median concentrations at 80% power, 90% confidence.
STATISTICAL METHODOLOGY:	Wilcoxon rank sum test (or Kruskal-Wallis), confidence level set at 0.10.
STATISTICAL HYPOTHESIS:	No statistical difference exists between mean or median values.
DATA ANALYSIS RESULT:	Conclusions regarding potential changes in biocontaminant levels in fish tissue.
INFORMATION PRODUCT:	Management goal met when no statistically significant increases occur in biocontaminant levels.

1. Trace metals are sampled every five years; organochlorine compounds every ten years

Section 3.0 – Previous Water Quality and Biological Studies

Water quality and biological data collection have been ongoing since the first pilot program studies in 1994. Conclusions from these previous studies are used to determine if the water quality and biological objectives of the monitoring plan are being met, and to guide future water quality and biological monitoring plan development. Results from prior Missouri-Madison water quality and biological studies are detailed in the following reports:

- Water Quality Statistical Analysis, Missouri-Madison Basin (Land And Water, 2000)
- 1997-2006 Water Quality and Biological Monitoring Trend Analysis (PBS&J, 2011)
- 2007-2016 Water Quality and Biological Monitoring Trend Analysis (GEI 2017)
- 2011-2020 Water Quality and Biological Monitoring Trend Analysis (GEI 2021)

Section 4.0 – Data Collection and Sample Analysis

This section outlines the methodology for the collection of water quality and biological samples, sample analysis, and the measurement of dam operation parameters. These components of the monitoring program are discussed separately below, along with a schedule for the sampling.

Section 4.1 – Sample Collection

Sample collection methodology for water quality and biological sampling was refined during previous monitoring studies and is summarized below and in **Tables 2-2, 2-3, and 2-4 in Appendix A**.

Section 4.1.1 – Water Quality

The water quality sampling will consist of the collection of either single point depth integrated samples, or depth integrated, equal width increment composites at each monitoring location. Grab samples will be collected from the riverbank, a bridge, or the downstream side of a dam structure in a well-mixed portion of the river. Sample bottles will be rinsed with native water (or filtered native water) prior to sampling. Samples will be taken in the upstream direction to avoid entrainment of sediment disturbed by wading. During sampling, the sampling device should be drawn through the water column once, carefully avoiding any disturbance of bottom sediments.

Samples will be transferred to a decontaminated Teflon churn splitter and sealed in an insulated secure container (wrapped in plastic in a soft cooler) until processing. Processing and splitting of sample aliquots into sample bottles will occur at the end of each day. Filtration with a 0.45um filter for dissolved parameters will be done as a batch process within 8 hours of sampling. All sample bottles will be virgin polyethylene bottles supplied by Energy Labs.

Samples will be clearly labeled with a waterproof marker or preprinted labels. Label information will include the site identification, date and time, sample type, and preservative if applicable. Field notebooks will be completed for each location along with appropriate chain-of-custody forms. All samples will be immediately placed in a cooler chilled to 4°C for transport to the lab.

Quality control samples will also be analyzed for water quality parameters. These samples consist of one replicate for every ten samples or sampling event, and one equipment blank for each sampling event. The replicate is a sequential sample taken at one of the locations as a control measure of field variability, sample processing procedures, and laboratory methodology. The equipment blank is a deionized water sample run through the sampling apparatus after standard decontamination procedures and analyzed for the full suite of water quality parameters. The blank primarily represents a quality control measure of lab methodology, but also integrates procedural aspects such as decontamination and sample handling.

The sampling methodology described above conforms to current standard operating procedures described in the document “Sample Collection for Chemistry Analysis: Water Sediment, and Biological Tissue”, available online at the Montana Department of Environmental Quality web site (MDEQ, 2019).

Special site-specific studies will be conducted on an as-needed basis in addition to routine monitoring, and additional short term intensive studies may be implemented to investigate findings of interest from the monitoring program.

Section 4.1.2 – Biological Monitoring

Chlorophyll-*a* sampling methodology will consist of collecting 6 replicate samples that represent the range of crops that are present at each site. Whole rock samples of 4-6 rocks per sample will be collected. A composite periphyton sample will also be scraped from all microhabitats and preserved with Lugol's to provide a representative sample for species composition analysis.

Macroinvertebrate sampling methods were initially identified in the Biological Monitoring Plan (MDHES, 1993). These methods were modified after field testing (McGuire, 1997). The modified sampling consists of collecting five replicate samples enclosing 0.25 m^2 at each site. The samples are collected using a fine 560 micron mesh kick net, and the entire sample (macroinvertebrates, vegetation, sediment, and debris) are preserved in 90% ETOH. Bottle labeling will be similar to that specified for water quality sampling.

Fish tissue biocontaminants will be evaluated for both predator species (rainbow trout or walleye), and bottom dwellers (longnose sucker or white sucker). An effort will be made to obtain a sample of 4 individuals of similar size class (length within 25%) for analysis as filets (predators) or whole body samples (bottom dwellers). Approximately 560 grams of tissue will be required for each analysis; this may require a composite of multiple fish if size classes do not allow provide enough tissue from individuals. Fish will be captured with electrofishing equipment, weighed, measured, wrapped in aluminum foil, and placed in double plastic bags. Fish will be placed on ice in the field, frozen as soon as practicable, and remain frozen until chemical analyses are performed by the laboratory.

Section 4.2 – Sample Analyses

Sample analysis methodologies for the water quality and biological samples are summarized below. The sampling and analysis methodology is also summarized in **Tables 2-2, 2-3, and 2-4 in Appendix A**. The methodologies presented were refined during the pilot monitoring studies.

Section 4.2.1 – Water Quality

Water quality samples will be analyzed for various parameters both in the field and laboratory. The parameters, analysis methods, holding times, and detection limits (**Table 2-2 in Appendix A)** correspond to the pilot study analyses. The complete list of total and dissolved metals will be analyzed for samples from Black Eagle and Morony stations. Total and recoverable arsenic will be analyzed for all stations. Parameter correlations will be reviewed periodically to determine if surrogates can be used effectively to estimate some parameters, potentially reducing analysis costs. Analytical sampling will continue to confirm surrogate suitability throughout the program.

Section 4.2.2 – Biological Monitoring

Periphyton sample analysis will consist of measurement of chlorophyll-*a*, diatom species count, and identification of soft bodied algae. The methodology for these will follow EPA guidance (Barbour et. al.1999). Chlorophyll-*a* is measured using a spectrophotometer or fluorometer on a sample extracted in acetone. The pilot study recommended measuring the chlorophyll optical density both before and after acidification to correct for the error associated with degraded Chlorophyll-*a*. In addition, the sample analysis will consist of a diatom species count that will be used to develop the metrics described in **Section 5.3.2**.

The sample processing for macroinvertebrates was described by McGuire (McGuire, 1999) and follows EPA guidance (Plafkin et. al.,1989). This process consists of obtaining a subsample consisting of approximately 300 organisms using RBP III techniques (Plafkin et al., 1989). The sample is placed in a US Standard #30 sieve and rinsed with water, and the entire sample is evenly distributed in a gridded enamel pan (9" x 12" or 14" x 20"). All macroinvertebrates in a randomly selected grid square are removed. This process is repeated until 270 to 330 have been picked. The total number of macroinvertebrates in the sample is estimated from the percentage of sample used to obtain 300 organisms. Rare taxa, which might be missed by subsampling, are removed from the remainder of the sample to determine taxa richness and EPT richness for the entire sample. Macroinvertebrates in the subsample are then identified to taxonomic levels specified in the Montana DEQ Sample Collection, Sorting, Taxonomic Identification, and Analysis of Benthic Macroinvertebrate Communities Standard Operating Procedure manual and enumerated (MDEQ, 2012).

Fish tissue samples will be analyzed for a suite of trace elements, organochlorine compounds, and PCB's as detailed in **Table 4-1 in Appendix A**. This list of analytes conforms to reporting requirements of the USFWS. Laboratory analysis will be conducted by Energy Laboratories, or a suitable alternative. Fish will be analyzed as either individual whole-body samples for bottom dwelling species or fillets for predator species, and composited from multiple fish and reported on a wet weight basis. Because organochlorines were largely undetected during preliminary sampling, sampling will be limited to once every 10 years rather than once every 5 years (i.e. for trace metals).

Section 4.3 – Dam Operational Plans and Monitoring

In addition to regularly scheduled monitoring data, more intensive data collection efforts will be conducted during maintenance or drawdown events at the dams.

A summary of dam operation data collection methodology is presented in **Table 2-3 in Appendix A**. Data collected during these events will include reservoir elevation, turbidity, discharge, and/or water quality samples. Data will be collected prior to the event to establish baseline conditions, and during the non-routine operational event. The frequency of the data collection will depend upon the duration of the event, with data collected preferentially during times of change (drawdown and refill). The frequencies shown on **Table 4-2 in Appendix A** may be adjusted on a case by case basis, subject to review by the Technical Advisory Committee.

Section 4.4 – Sampling and Data Collection Schedule

The schedule for collecting water quality and biological samples is presented in **Table 4-3 in Appendix A**. The schedule consists of the following:

- Routine water quality sampling conducted on a quarterly schedule;
- Routine biological sampling conducted annually;
- Dam non-routine operations data collected over the course of a non-routine operational event, as needed; and
- Potential extreme event sampling if unusual runoff or other conditions dictate.

The routine sampling for water quality parameters will be conducted on a schedule of quarterly sampling. Biological macroinvertebrate and periphyton sampling is planned on an annual basis.

The timing of periphyton sampling will fall within the early August “window” as defined by the pilot studies. Fish tissue biocontaminant sampling will occur in two reservoirs a year (until all reservoirs are sampled), and rotate throughout the basin so that a complete sampling cycle is obtained every 5 years. Sampling will be limited to once at each site every 10 years for organochlorine compounds. The sampling frequencies may be modified if routine monitoring suggests anomalous levels of any compounds, especially if concentrations are detected above levels established for human health or environmental criteria.

Water quality samples may also be collected at additional sites to address site-specific evaluations. These events will be conducted on an as-needed basis, depending on study needs.

Time series water quality sampling will be also be conducted coincident with dam operation events. Dam operation data collection will consist of project level monitoring efforts during maintenance events. This monitoring will include pre-event baseline data, periodic sampling during the event, and post event data collection. The frequency of data collection and parameter suite will be determined on a case-specific basis.

Lastly, water quality samples may be collected coincident with extreme events such as icing or extraordinary flow conditions. The need for this sampling will be determined on a case by case basis, taking into consideration river and climatic conditions, and the potential for water quality effects. This type of sampling is not expected to be a routine component of the water quality program.

Section 5.0 – Data Management and Analysis Methodology

Data quality control, management, and analysis methods crucial to the success of this monitoring effort are summarized below.

Section 5.1 – Data QA/QC

Data quality assurance and quality control (QA/QC) will be accomplished under this plan using methods described in the Montana DEQ publication: Sample Collection for Chemistry Analysis: Water Sediment, and Biological Tissue (MDEQ, 2019). These methods include:

- Validation: Reviewing analytical laboratory techniques including lab duplicate, matrix spikes, blanks, and surrogate recoveries to determine if the methods are within acceptable limits.

- Replicates: Each sampling event will include the collection of one replicate per ten samples for water quality, and the collection of replicate samples for the biological monitoring. Replicate variability will be analyzed using standard methods with objective of obtaining Relative Percent Differences ("RPD's") within 10% for values greater than 5 times the method detection limit.

- Splits: Splits will be collected using a churn splitter to achieve equal aliquots, and samples will be analyzed for the full suite of parameters.

- Field methodology: Field blanks will be collected for each water quality event to monitor field methodology. Methods and field sampling forms will be reviewed to assure consistency.

- Individual data which fails to achieve QA/QC objectives will be flagged with appropriate qualifiers in the database.

- If QA/QC review suggests widespread problems with QA/QC for a sampling run, the sampling run (or individual samples) may be repeated at the discretion of the project manager.

Quality control measures will also be employed for the statistical analyses. These measures will include:

- Testing the data for normality and adjusting for seasonal and flow effects.

- For water quality, assigning one-half the detection limit to non-detect values and evaluating the methodology/detection limits to assure the analyses are valid.

- Addressing missing values and trend analyses in a consistent manner that avoids biasing the results.

Section 5.2 – Database and STORET

The water quality data collected to date has been assembled into a Microsoft Access database. Water quality data is merged into the database through the electronic transmittal of data from the analytical laboratory. This database includes a function to generate a data file for uploading the data to Montana DEQ's MT-eWQX database and STORET.

Biological and dam operation data will also be incorporated in the Microsoft Access database. This database will provide an easily accessible repository for the Missouri-Madison system which will facilitate future analyses.

Section 5.3 – Data Analysis and Statistical Approach

The statistical approach used for data analysis will vary for water quality and biological parameters. These methods are designed to meet the objectives noted above, and have been presented in previous data evaluations (Land & Water, 1999; Bahls, 1999b, McGuire, 1999).

Statistical analyses will evaluate whether changes in parameters or metrics indicate improving or deteriorating water quality. Analyses will evaluate changes in water quality and biological conditions at each site, between upstream and downstream pairs at each dam, and for the study area as a whole.

The methods employed will identify statistically significant temporal and spatial variability. Observed differences may be related to dam operations if the change is not accompanied by an equivalent response above the dam. Similar change identified concurrently at multiple sites may be considered as indicators of systemic or basin-wide effects. Biological results will also be compared to reference streams in the same ecoregion to assign ratings of biological integrity (excellent to poor) and corresponding use-support status (full, partial, and non-support).

Inter-correlations of parameters and metrics will also be valuable in identifying those factors that behave in a similar fashion (i.e. covariates). This information is useful for interpreting water quality response, and also for streamlining the program by optimizing the sample collection with key indicator parameters or metrics.

Section 5.3.1 – Water Quality

The water quality statistical analysis methodology is summarized in **Table 5-1 in Appendix A**. The magnitude of a trend that can be detected is a function of inherent data variability and sample size. As sample size increases with continued monitoring, the power to detect trends will improve.

Data will generally have non-detect values set to one-half the detection limit for purposes of statistical analysis. Tests for normality will be conducted using the Kolmogorov-Smirnov (K-S) test, to the 0.05 significance level to determine the suitability of parametric or non-parametric statistical techniques. Non-normal datasets and data with high levels of left censored data (i.e. below detection limit) will generally be analyzed using non-parametric approaches.

Previous evaluations have documented a relationship of certain parameters to discharge. These data will need to be normalized to flow to account for the effects of variable discharge and allow trend evaluation of residuals. Raw data will be tested for correlation to discharge using

Spearman's non-parametric analysis. Those showing significant positive correlations will be adjusted using power functions, and those with significant negative correlations will be adjusted using inverse functions. Trend analysis will include both raw and discharge adjusted data series.

Seasonal variability beyond discharge related effects have also been noted for some parameters. Both discharge adjusted data and data for those parameters not correlated to discharge will be tested for correlation to seasonality. The data will be stratified into seasonal groups and tested for significant differences between the groups using Kruskall-Wallis non-parametric ANOVA tests. Parameters with statistically significant seasonal effects will be de-seasonalized by subtracting the appropriate seasonal mean from each data point and adding the overall pooled mean of the data series.

The datasets that will result from this processing include:

- Raw data sets;
- Datasets normalized to discharge;
- Datasets with seasonality removed; and
- Datasets normalized to discharge and with seasonality removed.

Once the data has been processed, trends, correlations, and comparisons will be evaluated. This will be accomplished as follows:

- Long-Term Trend Identification:
  - Statistical trend analysis of concentration over time at each location using Kendall or seasonal Kendall non-parametric method and linear function for trend magnitude.
  - Correlation analysis between parameters at each location using Spearman's non-parametric method.
- Dam Effect Evaluation:
  - Statistical comparison of parameter data for paired upstream-downstream locations using Mann Kendall non-parametric method.
- Operational Effect Evaluation:
  - Correlation analysis between parameters and dam operation data using Spearman's non-parametric method.

Section 5.3.2 – Biological Data

Data analysis methods for evaluating the periphyton and macroinvertebrate data are summarized below. Separate sections are provided for detailing the preparation of the periphyton and macroinvertebrate data for analysis. Both periphyton and macroinvertebrate data will be analyzed using a common approach, which is summarized in a third section below and in **Table 5-2 in Appendix A**.

Biological data is typically evaluated using a reference site either on the same river or within the same region. The reference site(s) represents a least impaired condition with which monitored locations can be compared. The periphyton pilot study assigned ratings of biological integrity (good, fair, poor) and corresponding use-support status (full, partial, non-support) using reference sites in the region. However, because there is some question as to the suitability of

the reference streams (i.e. smaller wadeable rivers), a simple comparison of the site data to site-specific baseline median values was recommended.

Due to the inherent challenge of identifying appropriate reference conditions, the evaluation of biological data will be based on data trends relative to the baseline data. Multimetric assessments will use the range of data collected during the pilot phase (baseline) to assign scores for the various metrics and allow comparison between monitored locations. The development of the scoring strategy is based on procedures outlined by the EPA (EPA, 1998), with the exception that the baseline data serves as the basis for the reference site.

Periphyton Data Preparation

Periphyton data will processed according to procedures developed during the pilot study. The data will be organized into the following categories:

- Biomass or standing crop:
  - Chlorophyll-*a* (mg/m^2). Chlorophyll a ranges from 0.5-2% of total algal biomass, depending on taxonomy, light, and nutrients (Barbour et al., 1999). Generally, chlorophyll-*a* levels less than 125 mg/m^2 will protect fish and aquatic life.

- Diatom metrics
  - Shannon Diversity (Weber, 1973). Based on taxa richness and distribution of individuals among taxa (evenness).

  - Pollution Tolerance Index or PTI. Resembles Hilsenhoff Biotic Index (described below for macroinvertebrates). PTI is a sum of values assigned to three categories of diatoms based on their pollution tolerance. Values range from 1 (most polluted) to 3 (least polluted).

  - Siltation Index. Based on the difference between dry mass and AFDM.

  - Percent Community Similarity, or PCS (Whittaker, 1958). Referred to as the Floristic Similarity Index in the pilot study. This metric measures the similarity of community composition between two sites, and is calculated for all possible station pairings. PCS is 100% when all taxa are present in exactly the same proportion at each site.

  - Disturbance Index. Percentage of generalist diatom species that are often pioneer species at scour or polluted locations (Barbour et al. 1999).

  - Number of Species Counted (Species Richness). Number of species per sample is indicative of water quality. Loss of most sensitive species to any stress will affect index.

  - Percent Abundance of the Dominant Species. A measure similar to species richness. The greater the stress the higher the percentage of the dominant (tolerant) species.

  - Percentage of Abnormal Cells. Percent of diatoms that have anomalies in striae patterns or frustile shape. This metric has been positively correlated with heavy metals contamination (Barbour et al., 1999).

The biomass or standing crop data consists of the laboratory measured median values for chlorophyll-*a*. The metrics listed generally follow recommended metrics (EPA, 1998 and Barbour et al., 1999).

During the course of this monitoring program, a multimetric assessment may be developed similar to that listed below for macroinvertebrates as a means to combine the metrics into a single measure. The multimetric assessment (**Table 5-3 in Appendix A**) would be a composite of scores for individual metrics, similar to that used for macroinvertebrates. The scores would be based on the range of values at study sites during the baseline monitoring period.

Macroinvertebrate Data Preparation

The macroinvertebrate taxa and species count data, expressed in terms of median values of the replicate samples, will be used to develop various metrics. A total of 10 metrics were deemed appropriate in the pilot study for evaluating changes in macroinvertebrate assemblages associated with water quality and flow regimes below the dams (McGuire, 1999). These metrics generally follow EPA guidance (Plafkin et al., 1989), and include:

- Taxa Richness. Number of taxa per sample is indicative of water quality. Loss of most sensitive species to any stress will affect index.

- Shannon Diversity (Weber, 1973). Based on taxa richness and distribution of individuals among taxa (evenness).

- Biotic Index (Hilsenhoff, 1988; tolerance values from Bukantis, 1996). Also known as the Modified Family Biotic Index. Based on indicator organism approach. Index on a scale of 0-10, with higher values indicating more eutrophic conditions.

- EPT Richness. Also known as EPT Index. Total number of distinct taxa in EPT Groups (Ephemeroptera, Plecoptera, and Trichoptera or mayfly, stonefly, and caddisfly taxa). Groups are primarily intolerant species. Index increases with improving water quality.

- Percent Relative Abundance of EPT. EPT commonly the most abundant species in streams with good quality. Lower abundances are indicative of stress.

- Percent Relative Abundance of Chironomidae. These are common and tolerant species. Increased abundance is indicative of stress.

- Ratio of Amphipoda to Isopoda. Amphipods need high oxygen concentrations, Isopods are tolerant of low oxygen levels. Ranges from 0 to 1, with lower values indicating more eutrophic/reduced oxygen conditions.

- Community Density. Number of organisms per 0.25 m^2 sample. Density increases in response to organic and/or nutrient enrichment and can be used as measure of trophic status.

- Ordinal Relative Abundance. A method for estimating relative abundances by counting macroinvertebrates as abundant, common or rare (Lenat 1988, Plafkin et al. 1989).

- Percent Community Similarity, or PCS (Whittaker, 1958). This metric measures the similarity of community composition between two sites, and is calculated for all possible station pairings. PCS is 100% when all taxa are present in exactly the same proportion at each site.

The first seven metrics will be used in a composite (multimetric) assessment to document trends in benthic macroinvertebrate assemblage composition and structure over time. This is accomplished by assigning a score according to the criteria shown in **Table 5-4 in Appendix A**. The scoring was developed during the pilot study and reflects the range of values at study sites for the period of 1995-1998.

Community density, ordinal relative abundances, and percent community similarity are also used to characterize and compare study area sites, but are not incorporated into the multimetric assessment.

Biological Data Statistical Analysis Methodology

Statistical analysis of periphyton, macroinvertebrate, and fish tissue data will include the following:

- Long-Term Trend Identification:
  - Statistical trend analysis of metric data over time at each location using non-parametric Kendall method. Calculate mean and CV.
  - Correlation analysis between metrics at each location using Spearman's non-parametric method.
  - Statistical comparison of metric data for paired upstream-downstream locations using non-parametric methods. Rank paired locations by magnitude of differences.

- Target Monitoring:
  - Statistical comparison of median values to baseline targets (including fish tissue).

Additional exploratory analyses may be undertaken during the monitoring program, e.g., analysis to define statistical relationships between biological parameters and water quality or other factors.

Section 6.0 – Reporting and Evaluation

Data evaluations will be completed at ten year intervals throughout the life of the program. These evaluations will include detailed summaries of the data along with comprehensive statistical analyses. The evaluations will also include a reassessment of monitoring program effectiveness, and will present revisions to the monitoring frequency, locations, and methodologies as needed to insure monitoring goals are met. The Technical Advisory Committee will be responsible for making appropriate recommendations for further study if analyses suggest that management or monitoring goals are not being accomplished. Technical documents will be reviewed by the Technical Advisory Committee and submitted to FERC every ten years.

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Appendix A – Supporting Tables

Appendix A – Supporting Tables

Table 1-1. Missouri-Madison Monitoring Locations

Dam(s)		Site Name	Data	Water Quality Sampling	Description
Hebgen	Above	YNP	Biological		Madison River, inside Yellowstone Nat. Park, near USGS sta. #6037500, left bank.
		HWY 287	Water Quality	Depth integrated 1/4 pt. composite	Madison River, at HWY 287 bridge
	Below	Hebgen	Water Quality & Biological	Depth integrated single point sample	Madison River, below dam, at USGS sta. #6038500, right bank for water quality, and approx. 1.5 miles below dam for biological.
Madison	Above	Varney	Water Quality	Depth integrated 1/4 pt. composite	Madison River, at Varney bridge,
		Ennis	Biological		Madison River, Ennis campground
	Below	Madison	Water Quality & Biological	Flow-weighted, depth integrated single pt. composite of turbine discharge and bypass channel at footbridge.	Madison River, at powerhouse

Canyon Ferry	Above	Toston	Water Quality & Biological	Depth integrated 1/4 pt. composite	Missouri River, at Toston Br. (water quality) and 3 mi. upstream (biological).
	Below	Canyon Ferry	Water Quality	Depth integrated single point sample	Missouri River, at penstock discharge.
Hauser	Above	Canyon Ferry	Water Quality	Depth integrated single point sample	Missouri River, at penstock discharge.
	Below	Hauser	Water Quality & Biological	Depth integrated single point sample.	Missouri River, below dam 0.2 miles, left bank.
Holter	Above	Hauser	Water Quality & Biological	Depth integrated single point sample.	Missouri River, below dam 0.2 miles, left bank.
	Below	Holter	Water Quality & Biological	Depth integrated single point sample.	Missouri River, 0.3 miles below power plant, left bank.
Great Falls	Above	Black Eagle	Water Quality & Biological	Depth integrated 12 pt. composite	Missouri River, Central Ave bridge in Great Falls.
	Below	Morony	Water Quality & Biological	Depth integrated single point sample at penstock discharge.	Missouri River, at Morony penstock discharge. Biological 0.2 mi. below dam.

Hydrolab Sampling: Single point at all locations except: 1/4 pt. mean at Black Eagle; and 2 pt. flow weighted value at Madison.

Table 2-1. Summary of Monitoring Objectives and Methodology

Objective	Description	Sub-Objectives	Sampling	Methodology
Long-Term Trend Identification	Change in parameters at monitoring locations over time	Identification of a trend Determine if trend is positive or negative Estimate trend magnitude Evaluate trend relationship to dam operation	Quarterly	Statistical trend analysis of parameter data over time. Analyzed for each parameter at each location.
Parameter Correlation	Relationship between parameters	Determine if relationship exists between parameters	Quarterly	Correlation analysis between parameters/metrics. Analyzed for each parameter/metric at each location.
Dam Effect Evaluation (Long Term)	Difference in parameters between paired (upstream and downstream of a dam) monitoring locations	Quantify differences Determine if differences are a function of time (season or year) Determine if differences vary spatially	Quarterly	Statistical comparison of parameter data between upstream and downstream locations. Analyzed for each parameter at each paired location for each time (quarter or annual); Statistical comparison of computed parameter differences at each location for different times. Analyzed for seasonal (water quality only) and annual variations for each parameter; Statistical comparison of computed parameter differences between paired locations. Analyzed for each parameter.

Non-Routine Operational Effect Evaluation (Short Term)	Change in parameters as a function of non-routine dam operation (e.g. drawdown)	Identify non routine dam operation effects Determine if effects are a function of magnitude or duration of event Determine if effects vary spatially	As Needed	Statistical analysis of parameter data over duration of operational event. Analyzed for each parameter at each location; Correlation analysis between parameters and dam operations (e.g. rate of drawdown). Analyzed for each parameter at each location; Comparison of trends and correlations between locations. Analyzed for each parameter.
Periphyton Long-Term Trend Identification	Change in parameters at monitoring locations over time	Identification of a trend Determine if trend is positive or negative Estimate trend magnitude	Annual	Statistical trend analysis of parameter data over time. Analyzed for each parameter at each location.
Periphyton Targets	Comparison of median values with target limits	Identification of values exceeding targets	Annual	Comparison of median values with target limits established by baseline monitoring. Analyzed for each parameter at each location.
Macroinvertebrate Long-Term Trend Identification	Change in composite measures over time	Identification of a trend Determine if trend is positive or negative Estimate trend magnitude	Annual	Statistical trend analysis of composite (multimetric) measures of macroinvertebrate data over time. Analyzed for multimetric set at each location.

Macroinvertebrate Targets	Comparison of median values with target limits	Identification of values exceeding targets	Annual	Comparison of median values with target limits established by baseline monitoring. Analyzed for each parameter at each location.
Fish Tissue Biocontaminants	Detect differences in means/medians between years	Compare differences between sampling years Compare to baseline targets Compare to Human Health Standards	Once every 3 to 9 years	Parametric or non-parametric comparison of means/medians between sample events Comparison to baseline reference values

Table 2-2. Water Quality Sample Collection and Analysis Methodology

Sub – Type	Parameter	Sample Volume	Container	Preservation	Holding Time	Analysis Method	Detection Limit (ug/L)
Field Parameters	Temperature	--------	--------	--------	--------	Field/Hydrolab	--------
	Dissolved Oxygen	--------	--------	--------	--------	Field/Hydrolab	--------
	Specific Conductance	--------	--------	--------	--------	Field/Hydrolab	--------
	pH	--------	--------	--------	--------	Field/Hydrolab	--------
	Total Dissolved Solids	--------	--------	--------	--------	Field/Hydrolab	--------
	Turbidity	50 ml	P or G	--------	--------	Field	--------
Lab Parameters	pH	25 ml	P or G (1)	None	Analyze immediately	EPA 150.1	0.1 s.u.
	Total Suspended Solids	100 ml	P or G (1)	None	7 days	EPA 160.2	10,000
	Total Dissolved Solids	100 ml	P or G (1)	None	7 days	EPA 160.1	10,000
	Potassium	500 ml	P or G (1)	None	6 months	EPA 200.7	1,000

	Sodium	500 ml	P or G (1)	None	6 months	EPA 200.7	1,000
	Calcium	500 ml	P or G (1)	None	6 months	EPA 200.7	1,000
	Magnesium	500 ml	P or G (1)	None	6 months	EPA 200.7	1,000
	Sulfate	100 ml	P or G (1)	None	28 days	EPA 300.0	1,000
	Total N-persulfate dig.	500 ml	P or G (1)	None	28 days	SM 4500N	10
	Chloride	50 ml	P or G (1)	None	28 days	EPA 300.0	1,000
	Bicarbonate as HCO3	500 ml	P or G (1)	None	14 days	SM2320B	1,000
	Total Alkalinity as CaCO3	100 ml	P or G (1)	None	14 days	SM2320B	1,000
	Nitrate+Nitrite as N	50 ml	P or G (3)	H2SO4	28 days	EPA 353.2	50
	Total Phosphorus as P	250 ml	P or G (2)	H2SO4	28 days	EPA 365.1	10
	Total recoverable Arsenic	250 ml	P or G (4)	HNO3	6 months	EPA 200.8	1[1]

	Total recoverable Cadmium[2]	250 ml	P or G (4)	HNO3	6 months	EPA 200.8	0.1[1]
	Total recoverable Copper[2]	250 ml	P or G (4)	HNO3	6 months	EPA 200.8	1[1]
	Total recoverable Iron[2]	250 ml	P or G (4)	HNO3	6 months	EPA 200.7	30
	Total recoverable Lead[2]	250 ml	P or G (4)	HNO3	6 months	EPA 200.8	2
	Total recoverable Manganese[2]	250 ml	P or G (4)	HNO3	6 months	EPA 200.8	10
	Total recoverable Zinc[2]	250 ml	P or G (4)	HNO3	6 months	EPA 200.8	10

[1] Low level analysis
[2] Only analyzed for Black Eagle and Morony stations
Containers: Plastic (P) or Glass (G); (1) 500 ml; (2) 500 ml with H2SO4; (3) 250 ml with H2SO4; (4) 250 ml with HNO3

Table 2-3. Dam Maintenance Monitoring/Reservoir Data Collection Methodology

Parameter	Location	Data Collection	Frequency
Reservoir Elevation	Above Dam	Recorded periodically in field	Hourly during change, otherwise daily
Turbidity	Above and Below Dam	Measured in field during grab sampling, or continuous monitoring using a Hydrolab	Minimum of two during significant change, otherwise daily
Discharge	At Dam	Recorded periodically in field at facility	Hourly during change, otherwise daily
Water Quality	Above and Below Dam	Grab sample from regular sampling locations	As needed

Notes: For operational events with long periods between drawdown and refill, daily sampling may be replaced with weekly sampling. Significant change (drawdown or refill) will be determined for each event. Small changes will not necessitate more frequent sampling. During drawdown or refill events spanning several days, hourly monitoring may not be conducted during all periods of the day.

Table 2-4. Biological Sample Collection and Analysis Methodology

Sub – Type	Parameter	Sample Volume	Container	Preservation	Analysis Method
Periphyton	Chlorophyll *a* (whole stones)	2 liters x 6	P	Ice	Spectral analysis[2]
	Diatom Species Count	250 ml	P	Lugol[1]	RBP III 300
Macroinvertebrate	Species Count	1000 ml x 5	P	90% ETOH	RBP III 300
	Taxa Count	1000 ml x 5	P	90% ETOH	RBP III 300

RBP III 300 – Rapid Bioassessment Protocol using 300 count subsampling
[1] Preservative options include Lugol's (IKI) solution, "M3" fixative, buffered 4% formalin, 2% glutaraldehyde, or other (Barbour et al, 1999)
[2] Method described in Barbour et al (1999), measured using a spectrophotometer or fluorometer on a sample extracted in acetone
Containers: Plastic (P)

Table 4-1. Practical Quantitation and Detection Limits for Organochlorine Pesticides, PCBs, and Metals (Methods E608 or SW-8081A + SW-8082 and SW-846)

Analyte	CAS No.	[1]PQL (mg/kg)	Detection Limit
Aldrin	309-00-2	0.0017	
alpha-BHC	319-84-6	0.0017	
beta-BHC	319-85-7	0.0017	
delta-BHC	319-86-8	0.0017	
gamma-BHC (Lindane)	58-89-9	0.0017	
alpha-Chlordane	5103-71-9	0.0017	
gamma-Chlordane	5103-74-2	0.0017	
4,4'-DDD	72-54-8	0.0017	
4,4'-DDE	72-55-9	0.0017	
4,4'-DDT	50-29-3	0.0017	
Dieldrin	60-57-1	0.0017	
Endosulfan I	959-98-8	0.0017	
Endosulfan II	33213-65-9	0.0017	
Endosulfan Sulfate	1031-07-8	0.0017	
Endrin	72-20-8	0.0017	
Endrin Aldehyde	7421-93-4	0.0017	

Heptachlor	76-44-8	0.0017	
Heptachlor Epoxide	1024-57-3	0.0017	
Isodrin	465-73-6	0.0017	
Kepone	143-50-0	0.0033	
Methoxychlor	72-43-5	0.0017	
Chlordane (technical)	57-74-9	0.017	
Toxaphene	8001-35-2	0.167	
Aroclor-1016	12674-11-2	0.033	
Aroclor-1221	11104-28-2	0.067	
Aroclor-1232	11141-16-5	0.033	
Aroclor-1242	53469-21-9	0.033	
Aroclor-1248	12672-29-6	0.033	
Aroclor-1254	11097-69-1	0.033	
Aroclor-1260	11096-82-5	0.033	
Aluminum			0.3 mg/kg
Arsenic			0.3 mg/kg
Cadmium			0.1 mg/kg

Chromium			0.3 mg/kg
Copper			0.3 mg/kg
Iron			1.0 mg/kg
Lead			0.1 mg/kg
Manganese			0.5 mg/kg
Mercury			0.1 mg/kg
Nickel			0.5 mg/kg
Selenium			0.1 mg/kg
Strontium			0.5 mg/kg
Zinc			0.5 mg/kg

[1]*The Practical Quantitation Limits (PQL) may be higher depending on the dilution of water in the tissue.*

Table 4-2. Sampling Schedule

Data	Event	Frequency	Dates
Water Quality	Routine	Quarterly (Feb, May, August, Nov)	Quarterly 2022-2040.
	Non-Routine Operations	As needed (e.g. during drawdown)	Variable depending upon maintenance, data collected for duration of event
	Extreme Event	As needed	During unusual icing event or flow extremes
Biological (Periphyton, Macroinvertebrates, Fish Tissue)	Routine	Annually, except fish tissue (3 year cycle for metals, 9 year cycle for organics)	Each Summer, during early August “window”, except for fish tissue to be coordinated with MTFWP gillnet sets in each reservoir.

Table 4-3. Sampling Cycle Matrix

Event	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Water Quality (quarterly)	X	X	X	X	X	X	X	X	X	X	X
Macroinvertebrates (annually)	X	X	X	X	X	X	X	X	X	X	X
Periphyton (annually)	X	X	X	X	X	X	X	X	X	X	X
Fish Tissue (metals)		X_1	X_2	X_3			X_1	X_2	X_3		
Fish Tissue (organics)		X_1	X_2	X_3							
Comprehensive Analysis/Reporting											X
FERC Reporting											X

X_1: Hebgen, Madison reservoirs
X_2: Hauser, Holter reservoirs
X_3: Black Eagle, Morony reservoirs

Table 4-3. Sampling Cycle Matrix (contd.)

Event	2033	2034	2035	2036	2037	2038	2039	2040
Water Quality (quarterly)	X	X	X	X	X	X	X	X
Macroinvertebrates (annually)	X	X	X	X	X	X	X	X
Periphyton (annually)	X	X	X	X	X	X	X	X
Fish Tissue (metals)	X_1	X_2	X_3			X_1	X_2	X_3
Fish Tissue (organics)	X_1	X_2	X_3					
Comprehensive Analysis/Reporting								X
FERC Reporting								X

X_1: Hebgen, Madison reservoirs
X_2: Hauser, Holter reservoirs
X_3: Black Eagle, Morony reservoirs

Table 5-1. Water Quality Data Statistical Analysis Methodology

Objective	Sub-Objective	Analysis	Data Processing	Methodology/Criteria
Long-Term Trend Identification	Identification of trend, summary of positive and negative trends	Statistical trend analysis of parameter data over time. Analyzed for each parameter at each location.	Flow/season adjustment if necessary[1].	Kendall test for trend (0.05 significance level); Sen slope estimate of trend magnitude.
Parameter Correlation	Evaluation of correlation between parameters	Correlation analysis between parameters. Analyzed for each parameter at each location.	Flow/season adjustment if necessary[1].	Spearman's for correlation (0.05 significance level).
Dam Effect Evaluation	Quantification of upstream and downstream differences	Statistical comparison of parameter data between up and downstream locations. Analyzed for each parameter at each paired location for each time.	Filter up and downstream samples, retain paired samples for same date.	Kruskall Wallace for correlation (0.05 significance level); Calculate differences (+,-,%) between pairs; Rank differences.
	Comparison of upstream and downstream differences for different times	Statistical comparison of parameter differences at each location for different times. Analyzed for seasonal and annual variations for each parameter.	Sort paired data by season and year.	Kruskall Wallace for correlation. Significance, test by season and by year (0.05 significance level).

Non-Routine Operational Effect Evaluation	Evaluation of effect of non-routine dam operations upon parameters.	Statistical comparison of upstream control to downstream response data over duration of operational event. Analyzed for each parameter at each location; Correlation analysis between parameters and dam operation data. Analyzed for each parameter at each location.	Filter parameter and dam operation data, create paired data.	Wilcoxon test (0.05 significance level) of paired data; Spearman for correlation significance between parameter and operation data (0.05 significance level).

[1] Flow: test using Spearman (parameter to flow), adjust those correlated (0.05 significance.); positive correlations modeled as power function ($Y=aX^b$) and negative correlations modeled as inverse functions ($Y=a+b/X$); adjust by adding mean of raw dataset to residuals from individual regressions of concentration on discharge. Season: divide data by season and test for significant (0.05 significance.) difference between groups using Kruskall-Wallis non-parametric ANOVA tests; adjust by subtracting seasonal mean from each data point and adding the overall mean.

Table 5-2. Biological Data Statistical Analysis Methodology

Objective	Sub-Objective	Analysis	Data Processing[1]	Methodology/Criteria
Long-Term Trend Identification	Identification of trend, summary of positive and negative trends	Statistical trend analysis of metric data over time. Analyzed for each metric or multimetric at each location.	Organize metric data by site.	Kendall for trend (0.05 significance level); Sen slope estimate for trend magnitude; Calculate mean and CV, 1 SD for non-significance limit.
	Evaluation of correlation between parameters	Correlation analysis between metrics. Analyzed for each metric at each location.	Group metric data by site.	Spearman's for correlation (0.05 significance level);
Dam Effect Evaluation	Quantification of upstream and downstream differences	Statistical comparison of metric data between up and downstream locations. Analyzed for each metric at each paired location for each time.	Filter up and downstream samples, retain paired samples for same date.	Wilcoxon test (0.05 significance level); Calculate differences (+,-,%) between pairs; Rank differences.
	Comparison of upstream and downstream differences for different times	Statistical comparison of metric differences at each location for different times. Analyzed for annual variations for each metric.	Sort paired data by year.	Kruskall Wallace for multiple years, Kendall for trend (0.05 significance level); Sen slope estimate for trend magnitude.

Target Monitoring	Identification of values exceeding targets	Comparison of median values with target limits established by baseline monitoring. Analyzed for each parameter at each location.	Organize parameter and metric data by site.	Compare median metric and parameter values to targets. Targets specified as within one standard deviation of baseline median values.

[1]*All analyses include processing the raw data into metrics and assigning scores to qualitative metrics*

Table 5-3. Periphyton Scoring Criteria

Metric	Scoring Criteria					
	5	4	3	2	1	0
Species diversity		>2.5	1.76-2.50	1.00-1.75	<1.00	
Pollution index		>2.5	2.01-2.50	1.50-2.00	<1.50	
Siltation index		<20	20-39	40-60	<60	
Floristic similarity index		<20	20-39	40-60	<60	
Disturbance index		<25	25-50	50-75	>75	
Number of species counted						
Percent abundance of dominant species						
Percent abnormal cells						

Table 5-4. Benthic Macroinvertebrate Assemblage Scoring Criteria

Metric	Scoring Criteria (300 count subsample)					
	5	**4**	**3**	**2**	**1**	**0**
Taxa richness	>32	32-28	27-23	22-18	17-13	<13
EPT richness	>16	16-13	12-9	8-5	4-1	0
Shannon diversity	>3.3	3.3-3.1	3.0-2.8	2.7-2.5	2.4-2.2	<2.2
Biotic index	<4.1	4.1-4.6	4.7-5.2	5.3-5.8	5.9-6.4	>6.4
% EPT	>70	70-61	60-51	50-41	40-31	<31
% Chironomidae	<21	21-25	26-30	31-35	36-40	>40
Amphipoda/(Amphipoda+Isopoda)[1]	>.52	.52-.40	.39-.27	.26-.14	.13-.01	0

[1]Not calculated when Crustaceans represent less than one percent of the fauna. Assessment score calculated as the sum of metric scores divided by the maximum possible score.