Montana Department of Environmental Quality

WETLAND RESTORATION EFFECTIVENESS MONITORING PROJECT PLAN

Project ID: WET-EFF-MON

APPROVALS:

/s/ Galen Steffens	5/13/2022
Galen Steffens: Water Quality Planning Bureau Chief	Date
/s/ Eric Trum	5/23/2022
Eric Trum: Nonpoint Source and Wetland Section Supervisor	Date
/s/ Katie Makarowski	5/19/2022
Katie Makarowski: Quality Assurance Officer	Date
/s/ Stephen Carpenedo	5/24/2022
Steve Carpenedo: Technical Review	Date
Hannah Riedl	05/19/2022
Hannah Riedl: Project Coordinator	Date

Prepared by Hannah Riedl, project lead, and Steve Carpenedo, program lead

Nonpoint Source and Wetland Section, Water Quality Planning Bureau

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1.0. Introduction

Nationwide, the acreage of freshwater vegetated wetlands has declined by approximately 50% between 2004 and 2009 (Dahl, 2011). In Montana, Dahl (1989) estimates 1/3rd of original wetlands have been lost since EuroAmerican settlement in the mid-1800s. Since 1989, the Montana Wetland Program goal has been "no overall net loss of the state's remaining wetland resource base and an overall increase in the quality and quantity of wetlands in Montana" (Montana DEQ, 2013). Success towards this goal is mixed. Between the 1980s and 2005, wetland acreage and associated functions in the Gallatin watershed increased (Newlon and Burns, 2009b). During the same period, wetland acreage in the Flathead Valley slightly decreased and lost 38% loss of hydrologic functions (Newlon and Burns, 2009a), and in the Bitterroot, there was no net change in wetland acreage (Kudray and Schemm, 2008). At two reaches along Yellowstone River Corridor, wetland acreage decreased approximately 9% between the mid-1900s and late-1990s (Kudray and Schemm, 2006). Studies on the Yellowstone and in the Bitterroot found large increases in small human-made pond acreage, which skews these results and emphasizes a need to quantify changing wetland function.

Functional wetlands throughout the landscape provide increased water storage for late season flows, recharge groundwater, cycle nutrients, retain sediment, stabilize land erosion, and provide habitat for most Montana's plants and wildlife (Tiner, 2003). Estimates of nutrient attenuation by wetlands varies widely but is reported to be as high as 80% (EPA, 2005; Trepel and Palmeri, 2002; Crumpton *et al.*, 1993).

DEQ has determined that, respectively, 35 and 40% of river miles that have been assessed (or 12 and 14% of total perennial stream miles in the state) are impaired by nutrients or sediment (Montana DEQ, 2021). Nonpoint sources of nutrient pollution need to reduce nutrient loading by 70% to achieve the average nutrient Total Maximum Daily Loads.

Montana's Nonpoint Source Management Plan (Watershed Protection Section, 2017) recognizes the need to restore and protect wetlands and includes in the list of applicable best management practices: restoring wetlands and their natural hydrologic function, restricting development in floodplains, and constructing wetlands for stormwater management. Nonpoint sources are inherently widely dispersed, and because their impacts are cumulative, detecting water quality improvement due to individual projects is extremely difficult. Demonstrating water quality improvements often requires widespread adoption of best management practices. Nonetheless, demonstrating the effectiveness of nonpoint source pollution reduction projects is essential for continued or increased financial support and landowner buy-in. Monitoring pollutant load reductions will ensure these projects are implemented effectively and at the appropriate scale to improve water quality.

Pollutant load reductions are traditionally estimated using models that rely on assumptions and literature values that are not site specific (Lintern *et al.*, 2020). For example, the Bank Erosion Hazard Index is often used to estimate sediment load reductions associated with streambank stabilization and floodplain restoration projects. Riedl *et al.* (2018) found that retreat rates provided in Near Bank Stress score tables typically underestimated retreat rates estimated via aerial imagery and therefore BEHI likely underestimates sediment load reductions. Nutrient load reductions are often estimated using a livestock deposition model. This approach uses literature values to estimate the amount of animal waste derived nutrients excluded from surface water, but it does not account for a potential increase in wetland function by excluding livestock.

In addition to the Project Plan, data collection activities under this SAP are supported by the Water Quality Planning Bureau Quality Assurance Project Plan (DEQ, 2022), the Nonpoint Source Management

Plan (Watershed Protection Section, 2017), and the FY20-FY22 Wetland Program Development Grant (DEQ, 2020).

2.0. Project Objectives

The primary goal of this Project Plan is to define a methodology for quantifying site-specific nutrient and sediment load reductions associated with wetland restoration. This includes quantifying effectiveness through time (i.e., short-term and long-term effectiveness) and through a variety of stream flow conditions (i.e., baseflow and stormflow or spring runoff) and associated wetland hydroperiods. In general, summertime stormflows should be the priority over spring runoff because that is when vegetation can better uptake nutrients and attenuate sediment. Prioritization of capturing stormflow versus spring runoff conditions will often be dictated by how heavily irrigated the watershed containing the project area is. Stormflow in heavily irrigated watersheds may be dampened by impoundments and irrigation canals, and in these project areas, spring runoff would be the sampling timeframe to prioritize.

Objectives inherently associated with this goal are to:

- Compare quantified load reductions to the more typically reported modelled load reduction estimates, if methods for load reduction estimates exist
- Track effectiveness by Cowardin wetland types
  - Palustrine emergent temporarily flooded – PEMA
  - “” seasonally flooded – PEMC
  - “” semipermanently flooded – PEMF
  - Palustrine aquatic bed semipermanently flooded – PABF
- Improve designs of future wetland restoration projects
- Inform potential future nutrient trading programs
- Provide more accurate load reduction information for future Total Maximum Daily Load development

This project is *not* intended to influence wetland mitigation crediting, which is an established process primarily under the jurisdiction of the Army Corp of Engineers.

Wetland restoration or mitigation projects have been evaluated for effectiveness previously in Montana, however, these studies did not consider nutrient or sediment water quality. For example, Brissette (2017) found that restored reaches of the historically placer mined Ninemile Creek were effective at storing groundwater and providing additional late season stream flow compared to degraded reaches. USGS has collected data in partnership with MDT since 1992 to determine if project sites can be replaced with a wetland, and after the wetland is created, ensure that the wetland maintains its integrity. Monitoring at these many of these mitigated wetlands has been long term, though almost exclusively focused on hydrology (one site, an exception for tracking water quality data, has been monitored for total dissolved solids)[*].

3.0. Project Scope & Rationale

Site-specific, quantitative effectiveness monitoring would ideally occur at all restoration and mitigation projects. The lessons learned by conducting such monitoring would greatly improve the effectiveness of future projects. However, such intensive monitoring is not feasible with current resources. Additionally,

[*] S. Lawlor, USGS Montana Wyoming Science Center, personal communication, April 8, 2022, and see https://www.usgs.gov/centers/wyoming-montana-water-science-center/science/hydrologic-characterization-potential-sites?qt-science_center_objects=4#qt-science_center_objects

the effort to complete quantitative monitoring on every project could hinder the important pace and scale of implementing future projects. While other entities are encouraged to adopt this project plan and develop their own SAPs, the DEQ Nonpoint Source and Wetland Program prioritizes staff resources for wetland restoration effectiveness monitoring based on the following project characteristics:

- No site-specific effectiveness monitoring has yet occurred or is planned to occur
- At least one year of pre-project data is possible to acquire
- Restoration occurred in a Nonpoint Source Program "Focus Watershed". These are the lower Gallatin, Bitterroot, Deep Creek, and Camp and Godfrey watersheds at the time of this writing.
- Funded wholly or partially with §319 grant funding or in lieu fee compensatory wetland mitigation
- Project activities are limited to typical best management practices funded by §319 grants, including:
  - Riparian fencing for excluding or implementing high density, short duration grazing
  - Floodplain reconnection and restoration
  - Re-establishing historic stream channels by plugging channelized reaches and repurposing them as wetlands
- Project supports a nutrient trade
- The project occurs on a tributary to tribal lands

Each individual SAP developed under this Project Plan (**Table 3.1**) shall contain site specific project area information including but not limited to:

- 8-digit HUC or higher
- Ecoregion(s)
- Anticipated Cowardian wetland type
- Receiving water
  - use class
  - impairment status
  - impairment causes
  - load reductions required if applicable
- Proposed monitoring locations

Table 3.1. SAPs and restoration project areas covered under this project plan

SAP Document ID	Years Monitored	Project Area
WQDNPSSAP-06	2022	Teller Wildlife Refuge
		Upper East Gallatin River
TBD	2023+	Teller Wildlife Refuge
		Upper East Gallatin River

4.0. Sampling Design

Three groups of samples will be collected for each restoration project:

- Upstream and downstream surface water grab samples, both in the receiving water and from the wetland prior to surface water entering the receiving water, of nutrients and total suspended solids (TSS) and field meter measurements
- Groundwater well continuous data loggers, grab samples of nutrients and TSS, and field meter measurements from a matrix of locations in the wetland area
- Sediment accumulation from sediment traps in a matrix of locations in the wetland area

For more information about specific parameters and sites, see the most recently updated SAP. Parameters must adhere to the analytical methods described in DEQ (2022) Section 2.4, and quality control must adhere to Section 2.5.

For each restoration site evaluated, a "before" and "after" sampling design should be followed, with each timeframe being relative to the restoration activities (see an example schematic in **Figure 4.1**). Note that inclusion of an upstream receiving water grab sample location somewhat fulfills the gold standard before-after-control-impact (BACI) study design (Smith, 2002). However, establishing "control" locations for the wetland matrix samples would prohibitively increase the scope of the project. For rare cases where no "before" data exists (see prioritization factors in **Section 3.0**), the minimum sampling design for each restoration project must include a full (i.e., with receiving water and wetland matrix samples) control site for comparison with the restoration ("impact") site.

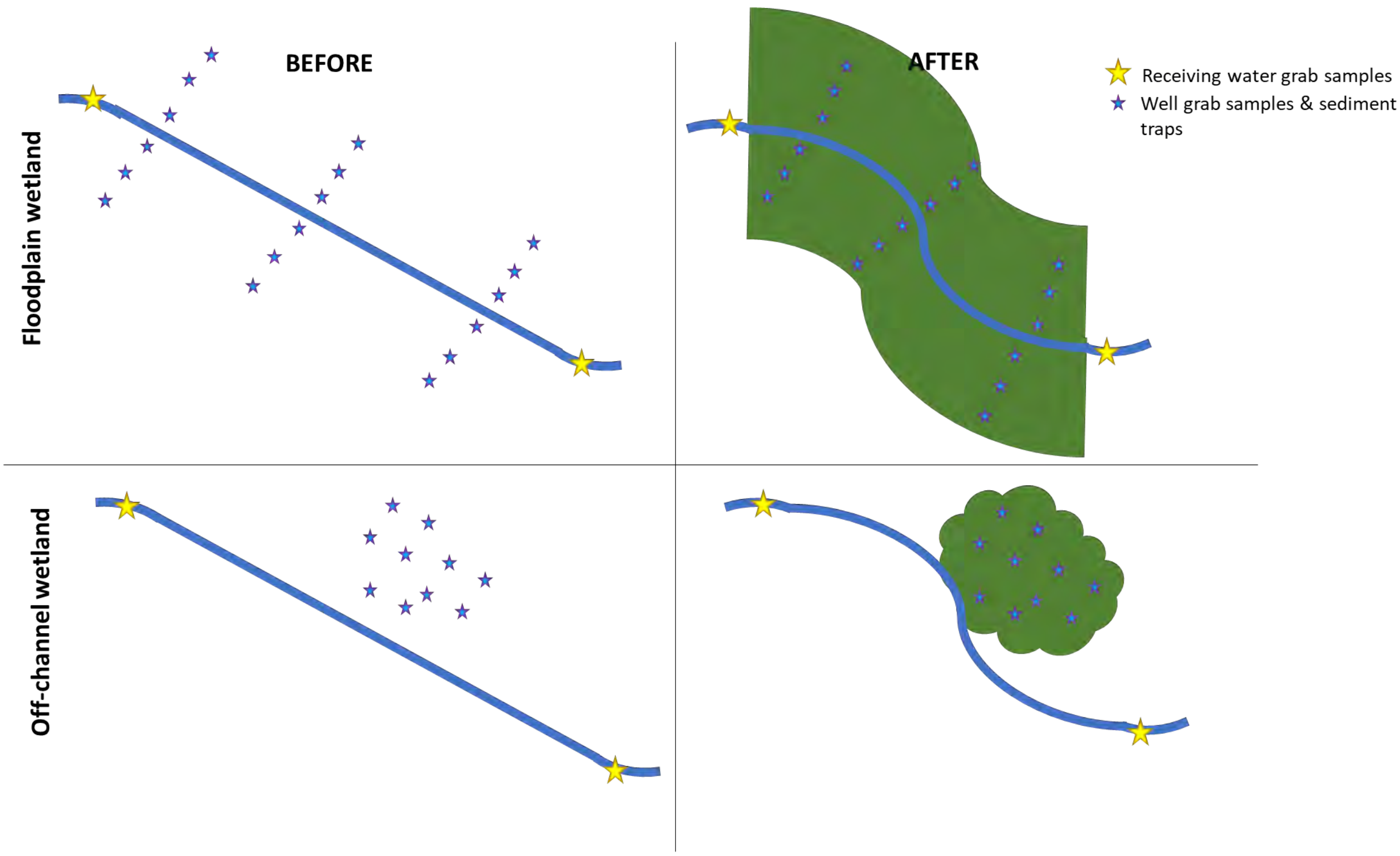

Figure 4.1. A generalized schematic of sampling locations for two types of typical wetland restoration projects.

All wetland and receiving water sample locations should be selected ahead of time via desktop analysis based on the guidance provided in the following paragraphs and best professional judgement. Sampling locations should be reviewed via reconnaissance in the field and adjusted as conditions require.

For each restoration project, a minimum of one upstream and one downstream receiving water grab sample location will be established. More upstream and downstream sites may be required if there are different source waters or drainage areas of the wetland. These sites are intended to quantify the impact of the wetland restoration on the receiving water.

For floodplain wetland restoration projects, a minimum of three groundwater well and sediment trap transects will be established, at 25, 50, and 75% of the upstream to downstream distance. At minimum, individual groundwater wells and sediment traps should be placed at 25, 50, and 75% of the distance, perpendicular to flow, from bankfull to the expected extent of the restored floodplain from each bank. If the stream channel will be realigned as part of restoration activities, these wells and traps will need to be reset accordingly. This results in a total of 18 groundwater well and sediment trap sampling locations. Continuous data loggers should be randomly placed within 1/3rd of the groundwater wells, ensuring that each transect and distance from bankfull is equally represented.

For off-channel wetland restoration projects, a minimum of four groundwater well and sediment trap locations should be randomly established across the wetland area, or one location per hectare (i.e., 107,639 square feet, or 0.0039 square miles, or 2.47 acres), whichever is larger. If there are a variety of wetland restoration treatments or excavation depths included in the restoration designs, locations should be stratified to represent each treatment type equally. If earthmoving during restoration alters groundwater well and sediment trap locations, these locations will need to be reset after construction. The post-restoration matrix of wetland sampling locations should be equal distance from bankfull of the receiving water as in pre-restoration conditions. This means that if the receiving water will be realigned as part of the restoration treatment, wells and traps will need to be shifted accordingly post-restoration.

5.0. SAMPLING PARAMETERS

Parameter[*]	Collection Approach	Justification for Collecting
	Surface water and groundwater samples	
Total persulfate nitrogen (TN) and total phosphorus (TP)	Upstream/downstream receiving water, wetland surface water, and groundwater well grab samples for laboratory analysis	Wetlands should be effective at reducing nutrients. These parameters are total amount of organic and inorganic nutrients. Systems are often either TN or TP limited. Primary indicator for assessing nutrient impairment.
Nitrate + nitrite nitrogen (NO2+NO3-N)		Along with ammonia, indicates total amount of nitrogen available for biological uptake. Indicative of septic pollution in groundwater.
Ammonia nitrogen (NH3+NH4-N)		Indicative of wastewater pollution in surface water, and toxicity to aquatic life. Combined with NO2+NO3-N, indicates total amount of nitrogen available for biological uptake (Total Soluble Inorganic Nitrogen).
Soluble reactive phosphorus (SRP)		Indicative of wastewater and other sources of pollution in surface water, and available phosphorus for biological uptake.
Total suspended solids (TSS)	Upstream/downstream receiving water and inlet/outlet wetland surface water grab samples for laboratory analysis	Wetlands should be effective at reducing sediment and particulates. Nutrients, especially phosphorus, is closely linked to suspended sediment.
Bioavailable phosphorus[†]	Upstream/downstream wetland surface water grab samples for laboratory analysis	Phosphorus is often the limiting nutrient for algal growth. SRP does not fully capture the bioavailable phosphorus fraction. Demonstrating wetland restoration effectiveness at removing bioavailable phosphorous from surface water would make wetland restoration highly marketable for nutrient trading programs.
Dissolved Oxygen (DO)	In situ field meter measurement at groundwater and receiving water sample locations	Indicative of biological activity and mixing with the environment.
pH		Can vary because of restoration and ranges will influence nitrogen and phosphorus cycling.
Temperature		Restoration can cause temperature to vary based on groundwater and surface water reconnection and changes in residence time.
	Groundwater well in situ *meters*	
Groundwater level, recharge rate	In situ field meter measurement at groundwater wells	Successful wetland restoration would be indicated by an increase in groundwater level and recharge rate.
	Groundwater well continuous data loggers	
Groundwater level fluctuation	Rugged TROLL 100 continuous data logger, 30-minute intervals	The magnitude of diurnal groundwater level fluctuations is an indicator of vegetative health (i.e., evapotranspiration) and therefore nutrient attenuation.
	Sediment trap samples	
Sediment load via organic content by loss-on-ignition	Wetland sediment traps	Properly functioning wetlands accumulate organic material. To estimate sediment load reduction, organic material must be subtracted from mass collected in sediment traps.
	Flow estimates	
Upstream/downstream receiving water flow volume	In situ field meter measurement at cross section or, for non-wadeable rivers, extrapolation from nearby stream gages and StreamStats	Provides inference about stream flow condition and water reaching floodplain or off channel wetlands. Important for calculating load for source assessment purposes.

[*] See most recent sampling an analysis plan for up-to-date analytical methods

[†] See Suplee (2021). Due to labor and expenses associated with this sample type, this parameter likely will only be included in post-project SAPs. Additionally, wetland surface water is typically only available in post-restoration conditions.

6.0. Sampling Schedule

Samples should be collected according to the following general schedule (for a detailed schedule, see the most recently updated SAP):

- One to two summers pre-project
- Two to three summers post-project, then alternating summers through 10 years post-project, then every 5 years post-project as funding allows
- For systems unlikely to be influenced by storm events (e.g., heavily irrigated watersheds):
    - May-October monthly surface water grab samples and field meter measurements
    - One high flow, one low flow, and one after irrigation season groundwater grab sampling and field meter measurement event
    - Sediment trap sample collection after high flow season, then at least once before the end of the year's sampling
    - No stormflow sampling
- For flashy systems influenced by storm events:
    - July-September twice monthly surface water grab samples and field meter measurements
    - One stormflow and one low flow groundwater grab sampling and field meter measurement event
    - Sediment trap sample collection after high flow season, once after a storm event, then at least once before the end of the year's sampling
    - At least one set of stormflow surface water and groundwater grab samples and field meter measurements during the storm. Ideally include one set per day of the storm event, plus the preceding and following days. Monthly grab sampling events may substitute the day's samples preceding the storm event.

7.0. PROJECT ORGANIZATION, ROLES & RESPONSIBILITIES

See the most recently updated SAP for specific individuals and external partners assigned to each role.

Affiliation	Roles	Responsibilities
DEQ Nonpoint Source and Wetland Section	Project leader	Develop SAP Oversee field personnel and training Review field forms Lab coordination Fill field personnel role as available Data analysis Final reporting, after post-project data is collected)
DEQ Wetland Program	Program leader	Provide expertise Finalize SAP Lead initial training Pursue future grant funding Assist with data analysis and reporting Fill field personnel role as available
DEQ Nonpoint Source and Wetland Section	Section supervisor	Approve QA documents and final reports Pursue future funding
DEQ External partners	Field personnel	Data collection Review field forms Ship or deliver samples
DEQ Monitoring and Assessment Section DEQ Wetland Program	Equipment technician	Calibrate and maintain equipment
DEQ Monitoring and Assessment Section	Database manager	Validate and upload data into EQuIS QA review data
External partners	External partners	Landowner coordination Fill field personnel role as available
External partners		

8.0. PROJECT ANALYSIS, OUTCOMES & DOCUMENTATION

Data collected under this project plan must be stored according to DEQ (2022) Section 2.10.

Data validation and usability should be assessed via a QA/QC document specific to each year according to DEQ (2022) Section 4.0.

For each year that Wetland Program Development grants (or any other grant) support this project, annual reporting must be completed. These annual reports typically summarize activities completed and grant funds expended.

After at least one year of pre-project and one year of post-project data has been collected, the DEQ Nonpoint Source and Wetland Program will analyze data and publish a final report. With subsequent years of post-project data collection, the data analysis and final reporting shall be updated accordingly.

Some data manipulation must occur prior to analysis:

- Nondetect values should never be replaced with, for example, ½ the detection limit (e.g., Helsel, 2013). Use the detection limit rather than assume the actual value. If there are varying detection limits across years for individual parameters, use the highest detection limit.[†]
- The sum of nitrate + nitrite (NO2+NO3-N) and ammonia (NH3+NH4-N) shall be presented and analyzed as bioavailable nitrogen rather than their individual parameters.
- Calculate an average groundwater level, recharge rate, and daily fluctuation for each sampling event. Besides displaying heatmaps of individual sample sites, averages shall be used for short- and long-term data analyses.
- The difference between dry weight and loss-on-ignition mass shall be presented an analyzed as sediment mass in addition to moisture content (%).
- Time periods during which groundwater well grab sampling occurred should be deleted from the continuous data logger logs.
- To calculate overall sediment load reduction, extrapolate all site's sediment trap dry weight across the total project area, using an average or post-project treatment type weighted average. Retain individual site's dry weight for heat maps and statistical analyses. Surface water TSS samples are analyzed separately and there is no assumed relationship between sediment mass in traps and in TSS samples.

Final reports must address all applicable objectives addressed in **Section 2.0**, with the primary goal being **quantifying the site-specific nutrient and sediment load reductions associated with wetland restoration**. Final reports must include the following graphics and results differentiated by timeframe (pre- and post-restoration) and flow condition/hydroperiod (summer growing season, typically July – September though it depends on ecoregion, and each month outside of the growing season):

- For all parameters—Boxplots (or time series plots for continuous data loggers) and summary statistics (sample size, data range, median, mean, standard deviation) of all parameters.
- For sediment trap and groundwater quality and quantity parameters—Heat maps of average sampling results throughout the wetland complex. These visuals may either be summarized across the entire sampling period or summarized by season, whichever is most informative.
- For wetland restoration effectiveness of groundwater quantity, groundwater quality, and sediment attenuation:
    - Friedman test[‡]: evaluate each response variable (i.e., water quality parameter) separately[§] (*Ho* = no difference between pre- and post-restoration) for significant ($p > 0.05$) difference, with flow conditions/hydroperiods (i.e., growing season/baseflow, individual outside growing season months, and stormflow if applicable) as the blocking factor and timeframe (i.e., pre- and post-restoration) as the treatment. Each wetland type (i.e., restoration treatment) will need to be tested separately. Note that this

[†] If there are a substantial number of nondetect samples (e.g., >1/3rd), consider using percent lower-than-detection-level as the response variable instead of raw values for statistical analysis. If this approach is taken in once, it must be used in all subsequent years of data analysis.

[‡] Nonparametric test; data do not need to meet assumptions of normality. Nonparametric tests are commonly necessitated for environmental data of small sample sizes.

[§] Principal component analysis (PCA) may help reduce the workload of analyzing each response variable and provide an interesting data visual. For PCA, each wetland type represents a point on the plot and each water quality parameter is a component that may play a role in explaining wetland type variability. Run PCA on pre- and post-restoration data to identify which water quality parameters are most responsible for changes (i.e., "shifts") in wetland type across timeframes.

approach violates assumptions of sample independence because of psuedoreplication caused by repeated measures of sites through time.
    - Mixed model[**]: If sufficient data exists (e.g., after multiple years of post-restoration data collection), consider a mixed model (Harrison *et al*., 2018). For example, a basic random intercept mixed model would include the wetland type and/or (depending on sufficient degrees of freedom) hydroperiod as random effects and the time since restoration as the fixed effect. A more complex random intercept and slope model would include the wetland type and/or hydroperiod as random effects and the time since restoration as a random effect as well as a fixed effect. The basic approach allows the evaluation of whether there has been a change in the response variable since restoration and assumes the change is similar for all wetland types or hydroperiods. The complex approach allows the evaluation of how the actual change in response variable differs between wetland types or hydroperiods. The complex approach requires more data. Both approaches evaluate the differences between groups (e.g., random effects) by examining the random effect variances in the model output.
    - Either approach will require tests for statistical significance, such as a chi-square to evaluate the outcome of the Friedman test for different groups, multiple comparison test for the Friedman test (e.g., Bonferroni) to evaluate exactly how different wetland types of hydroperiods compare in response to restoration, or a likelihood test for the mixed modeling approach.
- For wetland restoration effectiveness of surface water grab sample concentration and load parameters:
    - Friedman test[‡]: evaluate each response variable (i.e., water quality parameter) separately[§] (*Ho* = no difference between pre- and post-restoration) for significant ($p > 0.05$) difference, with flow conditions/hydroperiods (i.e., growing season/baseflow, individual outside growing season months, and stormflow if applicable) as the blocking factor and timeframe (i.e., pre- and post-restoration) as the treatment. Note that this approach violates assumptions of sample independence because of psuedoreplication caused by repeated measures of sites through time.
    - Mixed model[††]: If sufficient data exist (e.g., after multiple years of post-restoration data collection), consider a mixed model (Harrison *et al*., 2018) like the approach above for groundwater samples.
    - Either approach will require tests for statistical significance, including chi-square (Friedman), Bonferroni (Friedman), or likelihood tests (mixed model), like the analyses performed on the groundwater sample results.

Final reports shall be shared with external partners and the Montana Wetland Council. DEQ and partners may choose to promote the publication more broadly through a press release or wide-reaching methods.

For projects funded in part by the §319 grant program, resulting load reductions must be entered into the EPA's Grant Reporting and Tracking System (GRTS) and included in the contractor's final grant report.

[**] Data will need to be tested and likely transformed to ensure assumptions of normality are met.
[††] Data will need to be tested and likely transformed to ensure assumptions of normality are met.

9.0. PROJECT TIMELINE & FUNDING STRATEGY

The first and second years of sampling for this project will occur in 2022 and 2023 with funding from the Nonpoint Source Program Staffing & Support Grant and the Wetland Program Development Grant. Ideally, funding will be available to continue long-term sampling on the initial restoration projects through 10-15 years and add additional restoration projects to the rotation as they meet the **Section 3.0** priority factors. §106 Water Pollution Control and §604 Water Quality Management funding grants should also be considered for supporting this project in the long term.

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