NWE-2188-4178

Ms. Kimberly D. Bose
Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington, DC 20426

December 20, 2022

Re: NorthWestern Energy filing year one of fisheries monitoring results and mitigation efforts related to the November 30, 2021 Hebgen Dam gate failure

Dear Secretary Bose,

On November 30, 2021, a gate failure at Hebgen Dam caused a rapid decrease in water levels in the Madison River, resulting in a deviation from NorthWestern Energy's (NorthWestern) Project 2188 Article 403 requirements. NorthWestern self-reported this deviation in a letter transmitted to the Federal Energy Regulatory Commission (Commission or FERC) on December 9, 2021. NorthWestern also submitted an Incident Report, per section 12.10(a) of the Commission's regulations, 18 C.F.R. § 12.10(a), to the Commission's Division of Dam Safety and Inspection – Portland Regional Office (Regional Engineer) on December 13, 2021. The Regional Engineer responded to the Incident Report on December 23, 2021, providing comments and requesting a plan and schedule for addressing those comments within 14 days.

NorthWestern filed a response to the Regional Engineer's request on January 5, 2022. FERC's Division of Hydropower Administration and Compliance (DHAC) responded on January 19, 2022, with a request for information in addition to that requested by the Regional Engineer on December 23, 2021. On March 23, 2022 NorthWestern provided DHAC additional information regarding convening an advisory group with representatives from Montana Fish, Wildlife & Parks (FWP), Forest Service (USFS), and Fish Wildlife Service (FWS).

The advisory group discussed existing fisheries data, potential effects from the gate failure, agreed on monitoring plan and a schedule to complete them, and developed mitigation measures to benefit the Madison River fishery. The advisory group agreed on the following monitoring plan:

1. Continue developing population estimates in the Pine Butte section (a longstanding electrofishing survey area) on an annual basis to gain information on species ratios and to track cohorts;

2. Conduct backpack electrofishing surveys in the side channels and margins of the mainstem Madison River (but possibly as far downstream as Kirby) to determine the

presence or absence of young-of-the-year, 1-, and 2-year-old salmonids during the summer of 2022;

3. Conduct electrofishing surveys between Hebgen Dam and Quake Lake to determine catch-per-unit-effort data and population structure information (provided that electrofishing remains safe in the swift currents) in 2022 and 2025; and,

4. Conduct fall redd counts between Hebgen Dam and Quake Lake to identify key areas of fish use 2022 through 2025.

Additionally the advisory group agreed on pursuing mitigation measures to benefit the Madison River fishery, with a focus on improving embryo or young-of-year survival, developing or enhancing spawning habitat, and or protecting key habitats from Hebgen Dam to Lyons Bridge. Recommended measures include the installation of fencing in two areas to improve aquatic habitat to support embryo and young-of-the-year survival, and development of an alternative analysis and preliminary engineering report to evaluate alternatives to improve spawning habitat, gravel recruitment, and embryo survival within the affected reach of the mainstem Madison River.

On August 18, 2022, FERC responded to NorthWestern's filing and agreed with the advisory committee's recommendation on monitoring and mitigation actions. Further, FERC required that an annual PM&E implementation report on the monitoring plan and status of mitigation projects be filed annually, with the first due by December 31, 2022.

NorthWestern has worked with FWP to provide funding and assistance to complete the first year of the monitoring plan. The four tasks of the monitoring plan, as stated above have been completed. A summary of those was prepared by FWP and is attached to this filing. In general, the first year monitoring supports the preliminary conclusion that the gate failure did not eliminate an entire year class of salmonids and that there was documented survival of age 1, 2, and 0 young-of the-year brown and rainbow trout located throughout the upper river.

In conjunction with the monitoring, a literature review to evaluate the hypothesis that the impact from this flow deviation did not result in a total loss of the population or individual age class is being completed. A working draft of this review is currently being prepared. NorthWestern and FWP will collectively finalize this document in 2023, and will file with the Commission by December 31, 2023 along with the second year of the monitoring results.

Three potential mitigation measures were identified during the January 2022 advisory group meeting that would assist in improving young salmonid survival and enhance spawning habitat for trout in the upper Madison River. NorthWestern's March 23, 2022 letter conveying additional information described these potential measures, and NorthWestern committed to pursue and support them.

Two tributaries were discussed as potentially needing fencing to reduce cattle grazing impacts and improve riparian health. One of the tributaries is on land managed by the United States Forest Service (USFS). NorthWestern, FWP, and USFS biologists conducted a field visit in the summer of 2022 to view the current conditions on site. The location of interest showed previous grazing impacts, however riparian and stream conditions appeared to be in good and improving condition. There was no evidence of recent grazing and biologists agreed that fencing or planting would not improve embryo or young-of-year survival. Alternative

opportunities and locations for mitigation that would improve embryo or young-of-year survival are being discussed with resource agencies.

The other tributary identified is located on private land and numerous field trips and reviews were conducted by FWP during 2022. Based on site visits and initial discussions with the landowners, restoration actions to decrease riparian grazing impacts, reduce stream sedimentation, and improve spawning substrate and habitat complexity are needed. A suite of actions targeting these issues is being assessed. NorthWestern and FWP have requested that a restoration consulting firm develop a Proposal. NorthWestern intends to work with FWP, other stakeholders, the consulting firm, and the landowners to develop a scope for restoration at this site and implement a contract to improve young salmonid survival and spawning habitat through restoration actions.

The third mitigation action is to develop an alternative analysis and preliminary engineering report to evaluate alternatives to improve spawning habitat, gravel recruitment, and embryo survival within the affected reach of the mainstem Madison River. A request for proposal is being developed and will be reviewed by stakeholders before being sent to qualified consultants to provide a plan and alternatives analysis. NorthWestern anticipates a contract will be in place by early spring 2023 to begin this work.

Monitoring actions for the first year have been completed, and mitigation efforts are in progress to comply with FERC's August 18, 2022 letter. NorthWestern will continue completing these monitoring and mitigation actions as designed through 2025 and will report annually to resource agencies at the Madison Fisheries TAC meeting and in an end of the year report to FERC.

Sincerely,

Mary Gail Sullivan
Director, Environmental and Lands

CC:
Andy Welch, NWE
John Tabaracci, NWE
Jeremy Clotfelter, NWE
Jon Hanson, NWE
Trevor Watson, FWP
Matt Jaeger, FWP
Mike Duncan, FWP
Dale Olson, USFS
Monica Berreman, USFS
James Boyd, FWS
Keenan Storrar, DEQ
Chris Boone, BLM

Madison River Fishery Monitoring related to the Hebgen Dam Gate Failure

Compliance Report 2022

Prepared by

Travis Lohrenz, Jenna Dukovcic, Mike Duncan, Matt McCormack and Matt Jaeger

For

NorthWestern Energy

Introduction

On November 30, 2021, a mechanical failure of the Hebgen Dam gate resulted in an abrupt decrease in the stage of the Madison River. Within 15 minutes of the failure, Madison River flows between Hebgen Dam and Quake Lake declined 370 cfs, from 648 cfs to 278 cfs (Figure 1). From Quake Lake to Lyons Bridge (a 13-mile reach; Figure 1), the decline was more protracted with flows decreasing 381 cfs, from 780 cfs to 399 cfs in roughly a 48-hour period. The rate and volume of water reduction resulted in deviations from NorthWestern Energy's (NWE) Project 2188 Article 403 requirements: (1) maintain…a continuous minimum flow of 600 cfs at USGS Gauge No. 6-388 near the Kirby Ranch and (3) limit changes in the outflow from Hebgen Dam to no more than 10 percent per day for the entire year.

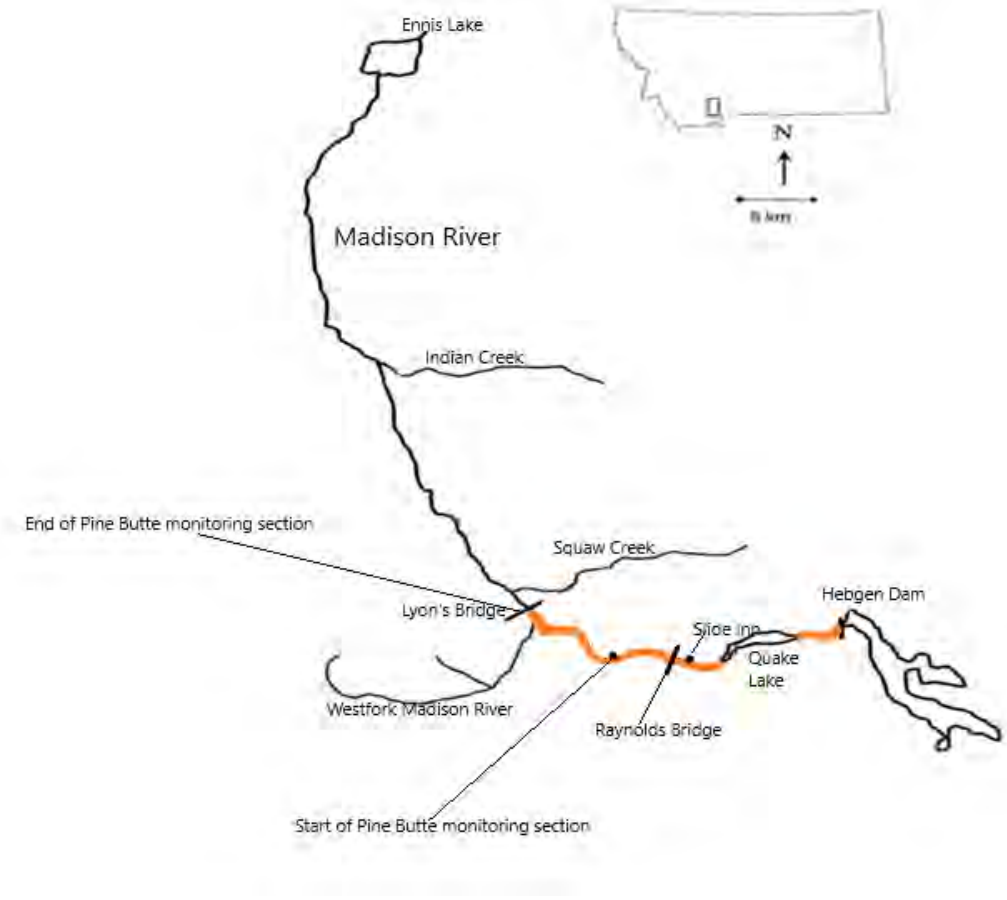

Figure 1. Areas of the Madison River affected by the Hebgen Dam gate failure on November 30, 2021. Orange segments indicate the areas of greatest concern and the focal area of 2022 monitoring.

Impacts to the fishery immediately following gate failure were greatest between Hebgen Dam and Quake Lake where Brown Trout redds were dewatered along channel margins and within side channels. Adult and juvenile salmonids and sculpins were stranded in disconnected side channels and pools (Figure 2). From Quake Lake to Lyons Bridge, some Brown Trout redds in shallow side channels were partially dewatered and juvenile salmonids and sculpin were stranded; however, no stranding of adult fish was observed in this reach. There was minimal change in the river stage downstream of Lyon's Bridge and no dewatered Brown Trout redds or stranded fish were observed in this reach during initial surveys (Figure 1).

Figure 2. The left panel shows a Brown Trout redd that was dewatered, and the right panel shows stranded juvenile salmonids in the Madison River between Hebgen Dam and the Quake Lake inlet following the rapid reduction in flow and stage during the Hebgen gate failure.

Figure 3. A partially dewatered Brown Trout redd in a side channel of the Madison River near Lyon's Bridge.

Assessment of impacts:

To assess the potential impacts of the Hebgen Dam gate failure to the Madison River fishery, the Madison Technical Advisory Committee, comprised of NWE, Montana Fish, Wildlife & Parks (FWP), United States Forest Service, United States Fish and Wildlife Service, and the Bureau of Land Management suggested the following monitoring plan, which was approved by the Federal Energy Regulatory Commission (FERC) on August 18, 2022.

1. Continue developing population estimates in the Pine Butte section (a longstanding electrofishing survey area) on an annual basis to gain information on species ratios and to track cohorts;
2. Conduct backpack electrofishing surveys in the side channels and margins of the mainstem Madison River (but possibly as far downstream as Kirby) to determine the presence or absence of young-of-the-year (YOY), 1-, and 2-year-old salmonids during the summer of 2022;
3. Conduct electrofishing surveys between Hebgen Dam and Quake Lake to determine catch-per-unit-effort (C/f) and population structure information (provided that electrofishing remains safe in swift currents) in 2022 and 2025; and,
4. Conduct fall redd counts in the Madison River between Hebgen Dam and Quake Lake to identify and document key areas of fish use from 2022 through 2025.

Additionally, a literature review to evaluate whether impacts from the low flows could have resulted in a total loss of the population or an individual age class will be prepared and mitigation measures to benefit the Madison River fishery, with a focus on improving embryo or young-of-the-year survival, developing or enhancing spawning habitat, and/or protecting key habitats from Hebgen Dam to Lyons Bridge (e.g., tributary habitat improvement, alternative analysis to evaluate improvements to spawning habitat, gravel recruitment, and embryo survival), will be developed.

This report summarizes the monitoring completed in 2022 related to the Hebgen Gate failure.

1) Pine Butte Cohort Recruitment and Species Ratios

FWP estimated trout abundances using mark-recapture techniques in the Pine Butte monitoring section to evaluate the influence of modified project operations at Hebgen Dam and the gate failure (Figure 1). Trout were collected by electrofishing from a drift boat-mounted mobile anode system. Fish captured during the marking run were weighed (g) and measured (mm), marked with a fin clip, observed for hooking scars, and released. After seven days, FWP conducted a second trip (recapture run) where fish were examined for marks, measured, and unmarked fish weighed. Species ratios and length-specific mark-recapture log-likelihood closed population abundance estimates by age group were generated and standardized to stream mile for Brown and Rainbow Trout using an R-based proprietary FWP fisheries database and analysis tool. Age classifications were adopted from scale data previously summarized for the Madison River fishery as follows: age-1 (152.0mm-276.9mm), age-2 (277.0mm-376.9mm), and age-3+ (>377mm; Vincent 1973).

The ratio of Brown to Rainbow Trout was lower than average and age-1 Rainbow Trout comprised the largest proportion of the total combined trout population in 2022. Brown and Rainbow Trout are typically found in similar abundances in the Pine Butte Section; however, 73% of the trout captured in 2022 were Rainbow Trout (Table 1). Age-1 Rainbow Trout made up 53% of the total trout captured, age-2 9%, and age-3+ 10%. Age-1 Brown Trout comprised 14%, age-2 5%, and age-3+ 9% (Table 1). The proportion of Age-1 Rainbow was 18% higher and the proportion of age-1 Brown Trout 10% lower than the 20-year average. Similarly, the proportion of age-2 Brown and Rainbow Trout and age-3+ Brown Trout were 1%, 5%, and 4% lower than the 20-year average, respectively, while age-3+ Rainbow Trout was 3% higher than the 20-year average (Table 1).

Future monitoring will improve inference about potential effects of the Hebgen gate failure on the trout population. Brown Trout abundances were below the 20-year averages for all ages (Figure 4). The high abundance of age-1 Brown Trout in 2021 did not translate into a strong age-2 cohort in 2022; however, difficult sampling conditions (high water temperatures and crew inexperience) in the fall of 2021 led to unreliable abundance estimates and inferences should be cautious. It is presently unclear whether the apparent decrease in abundance of that cohort is attributable to the 2021 Hebgen gate failure, given the uncertainty in the 2021 estimate and the observed relative decline in age 2 Brown Trout in previous years. Age 2 Brown Trout have been

below the 20-year average since 2018, indicating other factors may also affect brown trout abundance in the upper Madison River. Continued monitoring in 2023 will provide more insight into the effects of the gate failure on YOY Brown Trout as fish from the 2022 cohort that were eggs in the gravels of spawning redds during the dam failure will have recruited to electrofishing surveys. The estimated above average abundance of age 1 Rainbow Trout suggests the gate failure did not have a major negative effect on that cohort (Figure 4). The 2020 cohort declined on a relative basis from average abundances of 2021 age-1 fish to below average abundances of 2022 age-2 fish. However, the previous cohort of rainbow trout followed a similar pattern without being subjected to gate failure (Figure 4). To ascertain the effects of the 2021 gate failure on the trout population, tracking of cohorts and species ratios in the Pine Butte reach will be continued for the next four years and new length-at-age data from otoliths will improve aging precision.

Table 1. Percent composition of Brown Trout (LL) and Rainbow Trout (RB) for the 2022 total combined trout estimate and the total combined trout estimated 20-year average by age group in the Pine Butte section.

	Age Group			
Species	1	2	3+	Total
LL 2022	14%	5%	9%	28%
RB 2022	53%	9%	10%	72%
LL 20-year average	24%	10%	13%	47%
RB 20-year average	35%	11%	7%	53%

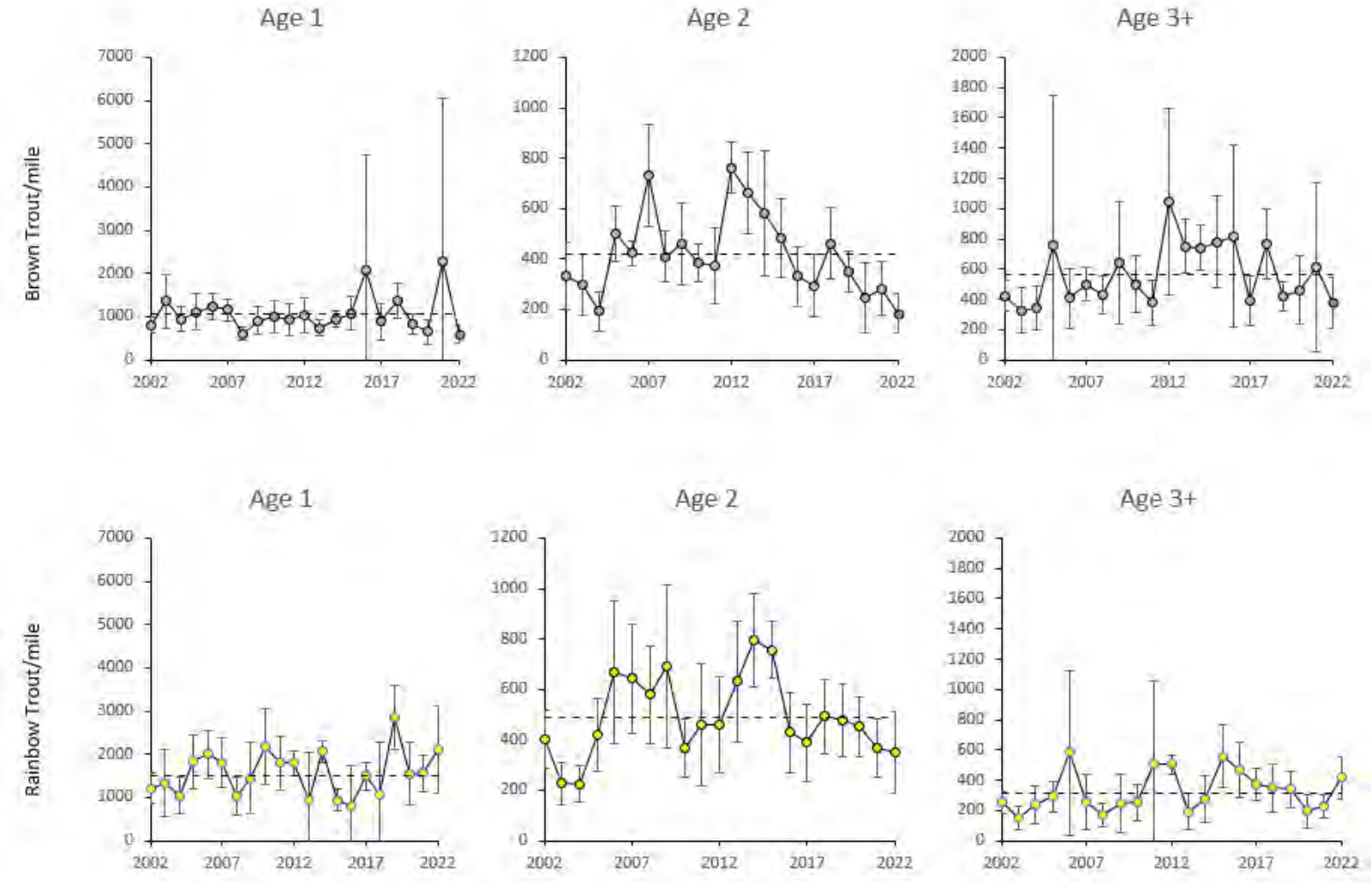

Figure 4. Estimated abundances of Brown and Rainbow Trout by age group in the Pine Butte monitoring section. Dashed lines are the 20-year averages (2002-2022), and error bars are the 95% confidence intervals. Note that the y-axis is not on the same scale.

2) Juvenile Salmonid Presence-Absence Survey

FWP conducted backpack electrofishing surveys in the side channels and margins of the mainstem Madison River between Hebgen Dam and Lyons Bridge to determine the presence or absence of YOY, age-1, and age-2 salmonids during the summer of 2022 (Figure 5). Four monitoring reaches were selected using satellite imagery: Between the Lakes (BTL)was from Hebgen Dam to the Quake Lake inlet (Figure 6), Upper (U) was from the Slide Inn to below Raynolds Bridge (Figure 7), Middle (M) was from below Raynolds Bridge to the Pine Butte primitive boat launch (Figure 8), Lower (L) was from the Pine Butte primitive boat launch to Lyons Bridge (Figure 9). Side channels that had a minimum of 300 feet of island shoreline and did not have a wetted width greater than one-third of the total wetted width of the mainstem river were identified within each reach. Those criteria were based on previous observations of spawning gravel recruitment and juvenile salmonid habitat use. Twenty-five side channels were identified among the four sampling reaches (9 BTL, 8 U, 9 M, and 8 L; Table 2). Four side channels were randomly selected from each reach with the exception of BTL. All but one of the side channels in BTL were sampled (side channel 5 was dry) because the effects of the gate failure were likely greatest in this reach due to the rapid decline in discharge. Sampling occurred on June 7-8 and July 25-26 following emergenceof YOY Brown and Rainbow Trout, respectively (Downing 2001). Side channels were sampled in an upstream direction with a backpack electrofisher focusing on shorelines and habitat features used by juvenile salmonids such as woody debris, pools, and backwaters. The ages of captured fish were assigned in the field based on length; YOY (< 152mm), age-1 (152.0mm-276.9mm), and age-2 salmonids (277.0mm-376.9mm; Vincent 1973). Sampling continued until one of each species and age class was observed or the entire side channel was sampled. Additionally, about 100 YOY salmonids were collected from each side channel, preserved in ethanol, and identified in the laboratory (Weisel 1966; Figure 10).

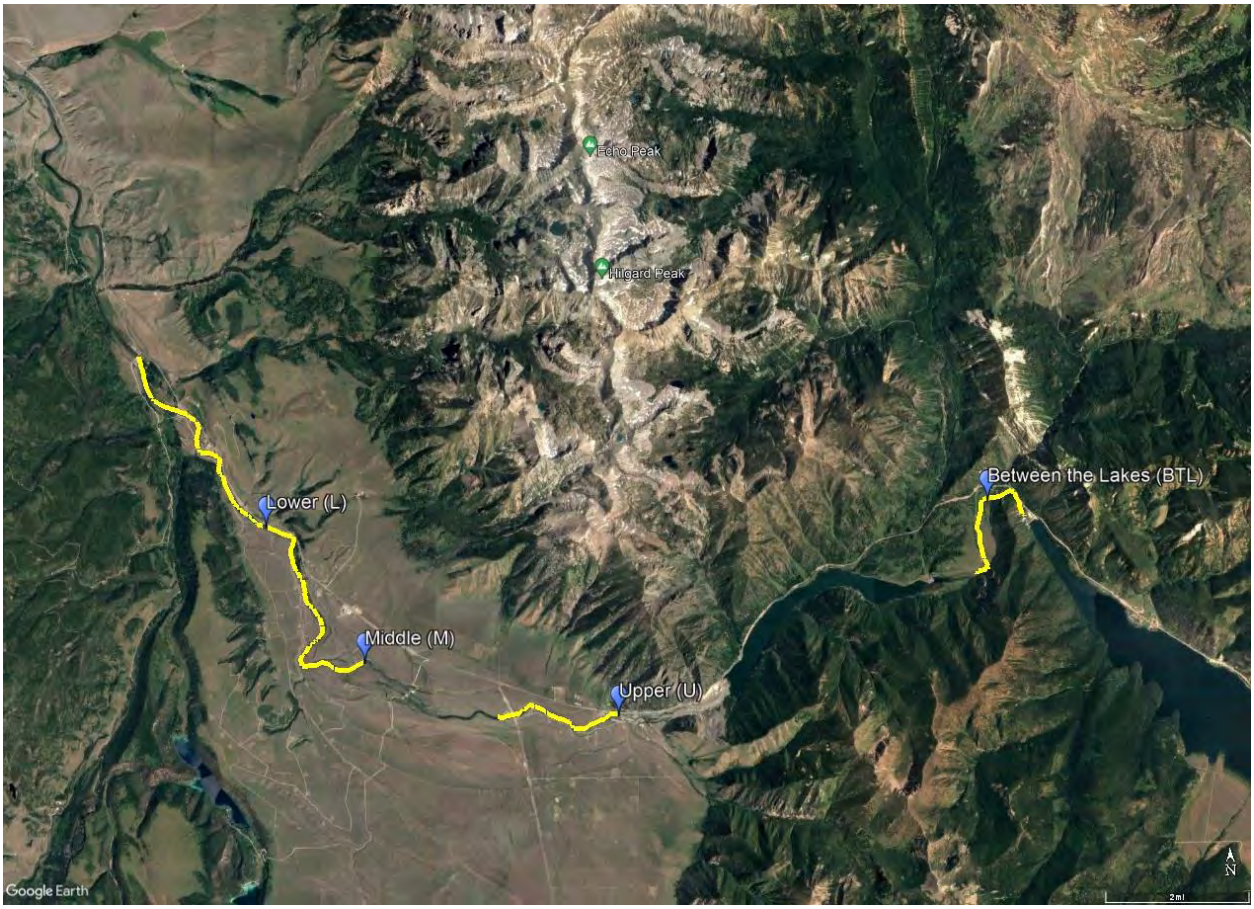

Figure 5.Madison River sections selected for juvenile presence/absence surveys.

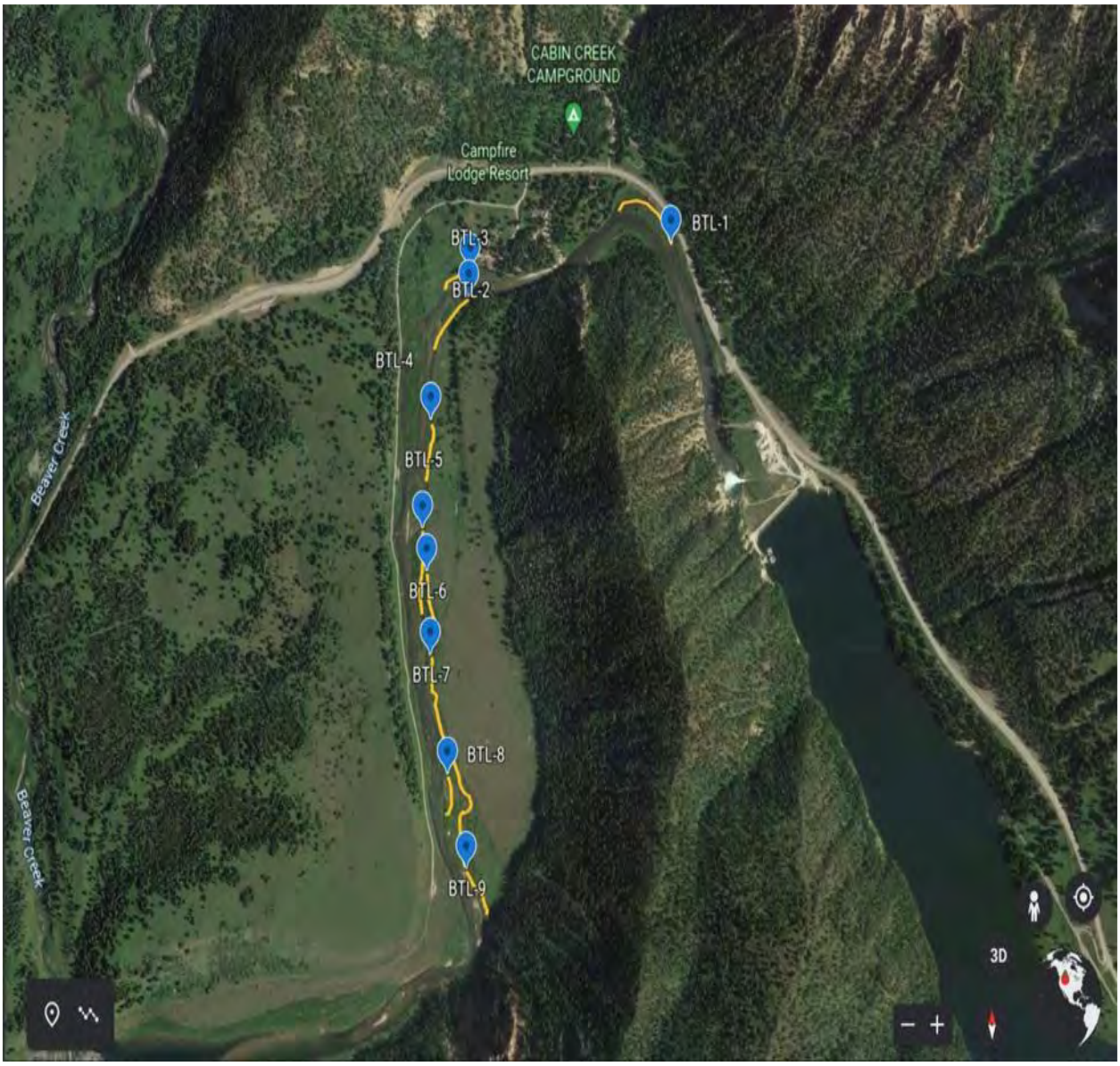

Figure 6. Selected side channels for juvenile salmonid sampling in the Between The Lakes (BTL) reach. All side channels were sampled except side channel 5.

Figure 7. Side channels in the Upper reach (U). Blue markers represent side channels not sampled and yellow markers represent side channels that were randomly selected for sampling.

Figure 8. Side channels in the middle reach (M). Blue markers represent side channels not sampled and yellow markers represent side channels that were randomly selected for sampling.

Figure 9. Side channels in the Lower reach (L). Blue markers represent side channels not sampled and yellow markers represent side channels that were randomly selected for sampling.

Table 2. Side channels selected for sampling by reach Between the Lakes (BTL), Upper (U), Middle (M), and Lower (L).

Reach	Side Channel Number	Latitude	Longitude
BTL	1	44.869701	-111.342301
BTL	2	44.869113	-111.348333
BTL	3	44.868643	-111.348551
BTL	4	44.865800	-111.348256
BTL	5	44.863263	-111.349883
BTL	6	44.863063	-111.350606
BTL	7	44.861304	-111.349335
BTL	8	44.858382	-111.348953
BTL	9	44.855846	-111.347920
U	1	44.825465	-111.459008
U	2	44.824053	-111.462250
U	3	44.825060	-111.467977
U	8	44.827633	-111.493859
M	1	44.838111	-111.529385
M	2	44.837105	-111.535760
M	6	44.853858	-111.544382
M	7	44.856010	-111.545619
L	1	44.867208	-111.558981
L	3	44.868999	-111.563532
L	6	44.888190	-111.579357
L	7	44.889932	-111.584686

Figure 10. Young-of-year salmonids collected for identification.

Presence-absence surveys confirmed that YOY and juvenile salmonids occupied reaches of the river most affected by the Hebgen Dam gate failure. Brown Trout YOY were present in 90% of the side channels sampled in June and 95% in July. Young-of-year Rainbow Trout were present in 90% of the side channels sampled in July (Table 3). Rainbow Trout YOY absence from the June sample is attributable to relatively late emergence compared to brown trout (Downing 2001), which resulted in clear size differences between YOY Brown and Rainbow Trout; Brown Trout YOY were on average 20mm longer than Rainbow Trout YOY during July sampling. Age-1 Brown (70% and 75%) and Rainbow Trout (80% and 40%) were present in most side channels during both sampling periods (Table 3). Age-2 Brown (15% and 35%) and Rainbow trout (10% and 35%) were present in some of the side channels sampled. No Mountain Whitefish YOY were observed, age-1 Mountain Whitefish were present in 5% and 20% of side channels, and age-2 Mountain Whitefish were present in 5% of side channels in the respective sampling periods (Table 3). Larval drift of Mountain Whitefish may have distributed juveniles to areas of slower velocities than sampled for this report (Boyer 2016). However, YOY Mountain Whitefish are common throughout the mainstem Madison River and are frequently observed by FWP personnel during annual electrofishing surveys.

Table 3. June and July 2022 presence-absence survey of Madison River side channels Between the Lakes (BTL), Upper(U), Middle (M), and Lower (L) for young-of-the-year (YOY), age-1, and age-2, Brown Trout (LL), Rainbow Trout (RB), and Mountain Whitefish (MWF). X denotes presence. X? was a suspect Rainbow Trout later identified as a Cutthroat Trout.

Side Channel	YOY LL		Age-1 LL		Age-2 LL		YOY RB		Age-1 RB		Age-2 RB		YOY MWF		Age-1 MWF		Age-2 MWF	
	June	July	June	July	June	July	June	July	June	July	June	July	June	July	June	July	June	July
BTL1	x	x		x				x										
BTL2	x	x				x		x	x			x			x			
BTL3	x	x	x					x	x									
BTL4	x	x		x				x	x		x?	x						
BTL6	x		x	x				x	x									
BTL7	x			x				x								x		
BTL8	x	x		x				x		x						x		
BTL9	x	x	x	x				x	x							x		
U1	x	x	x	x	x	x		x	x	x	x	x						
U2		x	x			x		x	x		x	x						
U3		x	x	x					x									
U8	x	x	x	x				x	x	x								
M1	x	x	x		x	x		x	x									
M2	x	x		x		x		x		x		x					x	x
M6	x	x	x	x				x	x							x		
M7	x	x	x	x	x	x		x	x	x		x						
L1	x	x	x	x				x	x	x								
L3	x	x	x	x				x	x	x								
L6	x	x	x	x				x	x	x								
L7	x	x	x	x		x		x	x	x		x						

3) Catch-per-unit effort survey of the Madison River between Hebgen Dam and the Quake Lake inlet

FWP performed a catch-per-unit effort (C/*f*) survey to assess population structure and relative abundances of salmonids in the Madison River between Hebgen Dam and the Quake Lake inlet on September 6, 2022. Fish were collected by electrofishing from a drift boat-mounted mobile anode system, weighed (g) and measured (mm). Age-specific C/*f* estimates were generated and standardized to stream mile for Brown and Rainbow Trout, and Mountain Whitefish using an R-based proprietary FWP fisheries database and analysis tool.

Sampling between Hebgen Dam and Quake Lake showed lower C/*f* for all fish species and age classes than anticipated, which may be a result of the swift and deep river conditions throughout the section. Rainbow Trout and Mountain Whitefish comprised the majority of the fish sampled, and Brown Trout were at relatively low abundances (Table 5). The paucity of Brown Trout observed in the section may be attributable to the lack of habitat complexity (e.g.,undercut banks, large woody debris) throughout the sampling reach. As discussed previously, YOY, age-1, and age-2 Brown and Rainbow Trout were present in the side channels between Hebgen Dam and Quake Lake; however, only mainstem habitats were sampled during the C/*f* survey.

Table 5. Catch per unit effort (C/*f*) per mile by age group in millimeters for Brown Trout (LL), Rainbow Trout (RB), and Mountain Whitefish (MWF) below Hebgen Dam to the Quake Lake inlet.

	0	1	2	3+
Species	< 152	152-276	277-376	> 377
LL	1.0	1.0	0	4.7
RB	8.2	28.2	11.8	15.3
MWF	10.7	3.6	5.0	67.9

Data collected in 2022 will be compared to subsequent surveys to assess the potential effects of the Hebgen gate failure. In general, sampling conditions, normal fluctuations in abundances, and the lack of baseline data could confound our ability to attribute future changes in the trout populations to the gate failure. Estimated Brown and Rainbow trout abundances of fish 152 mm (≈ 6”) or greater in the Pine Butte Section fluctuated on average 28% and 31%, respectively, from year-to-year since 2000. Assuming the trout populations immediately downstream of Hebgen Dam possess comparable vital rates to those in the Pine Butte Section, similar fluctuations, including declines, in electrofishing C/*f* could be expected in the monitoring section between Hebgen Dam and Quake Lake regardless of potential effects caused by the dam failure. Moreover, electrofishing efforts in large rivers inherently produce abundance estimates with

notable uncertainty (i.e., relatively large confidence intervals for abundance estimates), which further inhibits our ability to statistically detect and attribute population changes to the dam failure. However, observed trends in long-term sampling reaches elsewhere that are influenced by similar environmental conditions found downstream of Hebgen Dam may be used to help explain deviations in abundances in the new monitoring section from what might be expected based on conditions in future years (i.e., are the trout populations between the lakes exhibiting different trends than tailwaters elsewhere in SW Montana).

4) Fall Redd Counts

FWP conducted Brown Trout redd counts on the Madison River between Hebgen Dam and Quake Lake on November 15, 2022 to identify and document key spawning areas used by Brown Trout. Discharge at the time redd counts was 689 cfs (measured at the USGS 06038500 Grayling gage below Hebgen Lake). Redd counts were completed by walking upstream and identifying streambed disturbances consistent with redd morphology (Gallagher et al. 2007). A typical redd consists of a defined pit where gravels were excavated with a mound of gravels (tail spill) immediately downstream of the pit (Figure 11). GPS coordinates were recorded and redd locations were mapped using Google Earth (Table 6; Figure 12).

Figure 11. Brown Trout redds in a side channel of the Madison River between Hebgen Dam and the Quake Lake inlet, November 2022.

Table 6. Redd locations and the number of redds observed during surveys conducted November 15, 2022 in the Madison River between Hebgen Dam and the Quake Lake.

Latitude	Longitude	Redds observed
44.85481	-111.34861	1
44.85497	-111.34633	7
44.85498	-111.34822	11
44.85529	-111.34819	19
44.85530	-111.34820	5
44.85564	-111.34840	17
44.85576	-111.34819	2
44.85575	-111.34833	2
44.85576	-111.34830	3
44.85564	-111.34840	17
44.85590	-111.34849	2
44.85616	-111.34870	1
44.85758	-111.34891	5
44.85626	-111.34940	4
44.86198	-111.35023	4
44.86239	-111.35029	6
44.86276	-111.35040	6
44.86266	-111.35058	2
44.86314	-111.35061	6
44.86953	-111.34012	5
44.86942	-111.34005	1
44.86949	-111.33990	1
44.86958	-111.33988	1
44.86957	-111.34014	1
44.86973	-111.34006	1
44.86959	-111.34045	1
44.86970	-111.34046	1
44.86979	-111.34027	1
44.86993	-111.34041	1
44.86997	-111.34054	1
44.87000	-111.34060	1
44.87002	-111.34055	1
44.87026	-111.34104	1
44.87029	-111.34102	1
44.87029	-111.34101	1
44.87035	-111.34096	1
44.87037	-111.34095	1
44.87038	-111.34104	1
44.87038	-111.34103	1
44.87043	-111.34113	1
44.87039	-111.34118	1
44.87033	-111.34119	1
44.87033	-111.34120	1
44.87042	-111.34133	1
44.87043	-111.34135	1
44.87044	-111.34142	1
44.87031	-111.34158	1
44.87039	-111.34171	1
44.87037	-111.34171	1
44.87033	-111.34171	1
44.86658	-111.35117	1
44.86577	-111.35114	1

Most Brown Trout redds between Hebgen Dam and Quake Lake occurred in side channels, which were the habitat most impacted by gate failure. Of the 165 redds identified, 151 were located in side channels and 14 were located within the main river channel (Figure 12). TGravels selected for redd construction typically have a median diameter ≤ 10% of the female's body size and can be easily excavated (Chambers et. al 1955; Kondolf and Wolman 1993). Based upon the wetted perimeter and discharge relationship curve for the Madison River below Hebgen Dam, the reduction in discharge during the gate failure dewatered an estimated 3.4 acres of nearshore mainstem habitat (FWP 1989; Figure 13). Although the graph represents a single thread channel, it demonstrates the potential effect of reduced river stage on redds in shallow or nearshore habitats and the potential for side channels within the reach tobecome disconnected. Future investigations into the relationship between stage and discharge in this section of the river would provide insight into the flows required to maintain adequate spawning conditions.

Figure 12. Locations of redds identified in the Madison River between Hebgen Dam and the Quake Lake inlet. The size of the diamond is a general representation of redd density (i.e., the larger the diamond the greater the number of redds at that location).

Feet=204+.0329(cfs)

648 cfs=225.31ft

216 cfs=211.10ft

Difference=14.22ft

Acres=(10560ft*14.22ft)/43560ft^2

3.44 acres of exposed near shore habitat

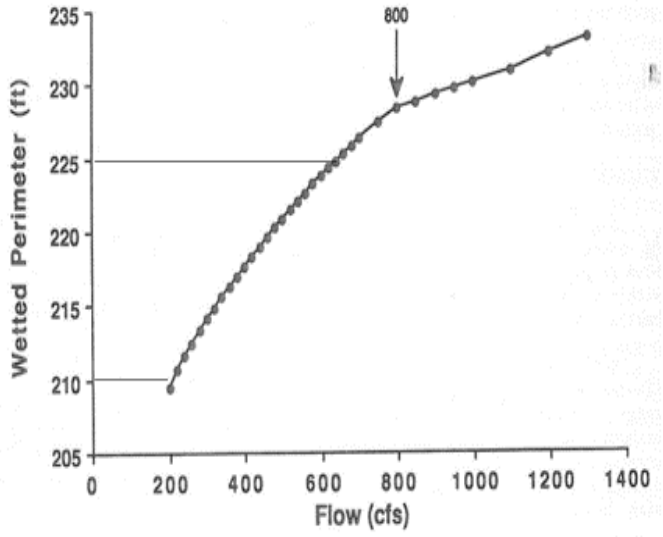

Figure 13. The wetted perimeter of the Madison River between Hebgen Dam and the Quake Lake inlet (FWP, 1989). The area of exposed nearshore habitat is estimated from the following equation: Feet=204+0.0329(cfs).

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