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AN ALLETE COMPANY

Via Electronic Filing

October 19, 2020

Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, N.E.
Washington, D.C. 20426

Subject: Grand Rapids Hydroelectric Project (FERC No. 2362)
Prairie River Hydroelectric Project (FERC No. 2361)
Initial Study Report and Virtual Webex Meeting

Dear Secretary Bose:

ALLETE, Inc., doing business as Minnesota Power (MP or Applicant), is the Licensee, owner, and operator of the Grand Rapids Hydroelectric Project (FERC No. 2362), and the Prairie River Hydroelectric Project (FERC No. 2361), collectively, the "Projects." The Grand Rapids Project is a 2.1 megawatt (MW), run-of-river (ROR) facility located on the Mississippi River in the City of Grand Rapids in Itasca County, Minnesota. The Prairie River Project is a 1.1 MW, ROR facility located on the Prairie River, near the City of Grand Rapids in Arbo Township, Itasca County, Minnesota.

The existing Federal Energy Regulatory Commission (FERC) licenses for the Projects expire on December 31, 2023. Accordingly, MP is pursuing a new license for the Grand Rapids Project and a subsequent license for the Prairie River Project pursuant to FERC's Integrated Licensing Process (ILP), as described at 18 Code of Federal Regulations (CFR) Part 5. Although these are separate processes, due to the proximity of the Projects to each other, MP is conducting the processes concurrently with combined documents, meetings, and overall relicensing schedules.

MP has conducted studies as provided in the September 23, 2019 Revised Study Plan (RSP) and approved in FERC's October 16, 2019 Study Plan Determination (SPD) for the Projects, with the exception of the Recreation Resources Study for both Projects[1]. In accordance with 18 CFR §5.15 of FERC's regulations, MP is hereby filing the Initial Study Report (ISR) with FERC. The ISR describes MP's overall progress in implementing the study plans and schedule, summarizes available data, and describes any variances from the study plans and schedule approved by FERC.

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[1] On April 10, 2020, MP filed a notification to conduct the Recreation Resources Study for both Projects during the 2021 study season instead of 2020 citing COVID-19 restrictions. MP intends to include the Recreation Resources Study results to date in the filing of the Draft License Application (DLA) and will file final study reports with FERC once the studies and analyses are complete.

FERC's regulations at 18 CFR §5.15(c) require MP to hold a meeting with participants and FERC staff within 15 days of filing the ISR[2]. Accordingly, MP will hold an ISR Meeting via Webex from 2 PM to 4 PM (eastern time) on Thursday, October 29, 2020.

To allow for adequate planning, MP respectfully requests that those planning on joining the ISR Webex Meeting RSVP by emailing Nora Rosemore at NRosemore@mnpower.com on or before close of business Thursday, October 22, 2020.

MP is filing the ISR with FERC electronically and is distributing this letter to the parties listed on the attached distribution list. For parties who have provided an email address, MP is distributing this letter via email; otherwise, MP is distributing this letter via U.S. mail. One paper copy of the ISR is being sent to the Minnesota State Historic Preservation Office. All parties interested in the relicensing process may obtain a copy of the ISR electronically through FERC's eLibrary at https://elibrary.ferc.gov/idmws/search/fercgensearch.asp under docket numbers P-2362 and P-2361 or on MP's website www.mnpower.com/Environment/Hydro. If any stakeholder would like a CD copy of the ISR, please contact me at nrosemore@mnpower.com.

Our relicensing team looks forward to working with FERC's staff, resource agencies, Indian Tribes, local governments, non-governmental organizations, and members of the public, in developing license applications for these renewable energy facilities. If there are any questions regarding the ISR or the overall relicensing process for the Projects, please do not hesitate to contact me at (218) 725-2101 or at the email address above.

Sincerely,

Nora Rosemore

Nora Rosemore
Hydro Operations Superintendent
Minnesota Power

Attachments:
Distribution List
ISR

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[2] According to the process plan and schedule included in Scoping Document 2, the ISR is scheduled to be filed on or by October 23, 2020 with the ISR meeting to take place on or by November 7, 2020. Early filings or issuances will not result in changes to the deadlines.

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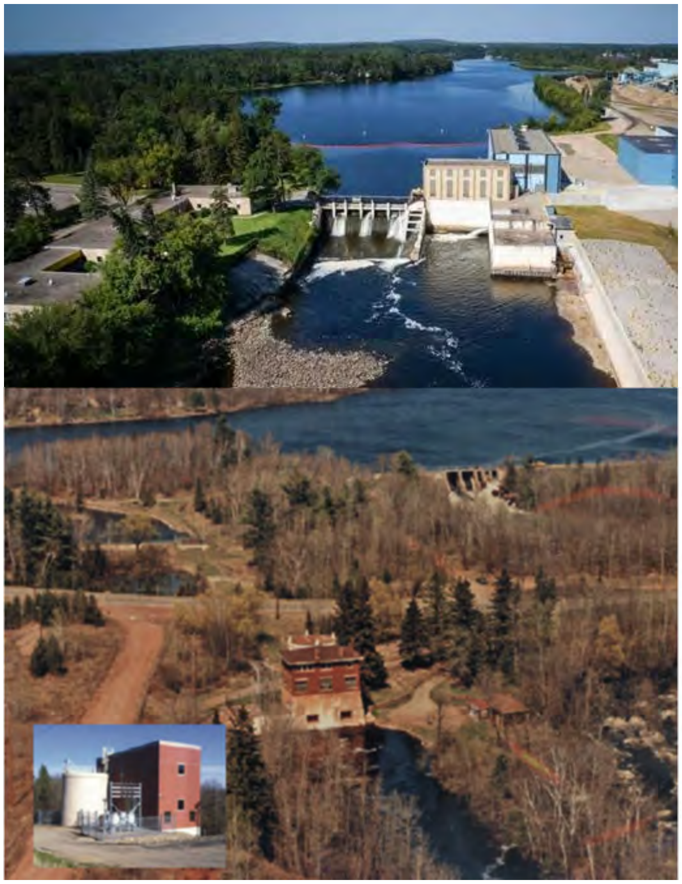

Initial Study Report

Grand Rapids Hydroelectric Project
(FERC No. 2362)

Prairie River Hydroelectric Project
(FERC No. 2361)

October 19, 2020

Prepared by:

HDR

Prepared for:

Minnesota Power

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List of Acronyms

°C	degrees Celsius
APE	Area of Potential Effects
CFR	Code of Federal Regulations
cfs	cubic feet per second
DLA	Draft License Application
DO	dissolved oxygen
ECPS	Electric Consumers Protection Act
FERC	Federal Energy Regulatory Commission
ILP	Integrated Licensing Process
ISR	Initial Study Report
mg/L	milligram per liter
MP	Minnesota Power
MW	megawatt
MWh	megawatt hours
NEPA	National Environmental Policy Act
NOI	Notice of Intent
NRHP	National Register of Historic Places
PAD	Pre-Application Document
PM&E	protection, mitigation, and enhancement
POR	period of record
PSP	Proposed Study Plan
RC%	Relative Composition
ROR	run-of-river
RSP	Revised Study Plan
SD1	Scoping Document 1
SD2	Scoping Document 2

SHPO	State Historic Preservation Office
SPD	Study Plan Determination
USACE	United States Army Corp of Engineers
USC	United States Code
USR	Updated Study Report

1 Introduction and Background

1.1 Introduction

ALLETE Inc., doing business as Minnesota Power ("MP" or "Licensee"), is the Licensee, owner, and operator of the Grand Rapids Hydroelectric Project (FERC No. 2362) and the Prairie River Hydroelectric Project (FERC No. 2361). The Grand Rapids Project is a 2.1 megawatt (MW), run-of-river (ROR) facility located on the Mississippi River in the City of Grand Rapids in Itasca County, Minnesota. The Prairie River Project is a 1.1 MW, ROR facility located on the Prairie River, near the City of Grand Rapids in Arbo Township, Itasca County, Minnesota.

The Grand Rapids Project consists of a 21-foot-high concrete dam, a 465-acre reservoir, a powerhouse containing two generating units, a short transmission line extending from the powerhouse to the Blandin Paper Mill, and other appurtenances. The original construction on the Project dam started in May 1901 by Grand Rapids Power and Boom Company and came online in 1902. Blandin Paper Company sold the Project to MP in 2000. The Grand Rapids Project primarily serves to supplement the power supply for the Blandin Paper Mill, an important economic asset and employment base in Grand Rapids. The Project generates approximately 6,000 megawatt hours (MWh) annually of renewable energy.

The Grand Rapids Project is operated as ROR with the upstream pool maintained at a target elevation of 1,268.2 feet. License Article 402 specifies ROR operations and that under normal operating conditions, reservoir fluctuations are limited to ±0.1 feet, as measured at Blandin Dam. Inflow to the Project is controlled by the United States Army Corps of Engineers (USACE) by releases from the USACE's Pokegama Dam, located three miles upstream of the Grand Rapids Project.

The Prairie River Project consists of a 17-foot-high concrete dam; a 1,305-acre reservoir; a forebay; a 450-foot-long by 10-foot-diameter, reinforced-concrete penstock extending from the forebay to a surge tank and on to the powerhouse; a powerhouse with two generating units; and appurtenant facilities. The Project dam was constructed in 1920 by Prairie River Power Company, and MP purchased the Project from Blandin Paper Company in 1982. The Project generates approximately 3,000 MWh annually of renewable energy.

The Prairie River Project is operated as ROR with the upstream pool maintained at a target elevation of 1,289.4 feet. License Article 401 specifies ROR operations and that under normal operating conditions, reservoir fluctuations are limited to ±0.1 feet, as measured at the dam. Article 401 and the Project Monitoring and Operation Plan also specify that during periods of high inflow (>500 cubic feet per second [cfs]), reservoir elevation must be maintained at 1,289.4 ±0.5 feet. As specified in License Article 404, MP provides a minimum of 75 cfs flow into the Prairie River bypass reach during the months of April and May and a minimum of 50 cfs during June.

The Grand Rapids and Prairie River Projects share important common characteristics. As noted above, both Projects operate solely as ROR facilities, with reservoir fluctuations under normal conditions limited to ±0.1 feet, limiting the potential for either Project to influence adjacent habitats or resources. Additionally, both Projects were relicensed in the 1990s following the passage of the Electric Consumers Protection Act (ECPA), which directed the Federal Energy Regulatory Commission (FERC) to balance hydropower and other interests when considering license conditions, including environmental protection and recreation. As a result, FERC developed comprehensive National Environmental Policy Act (NEPA) documents in support of their orders for issuing the existing Grand Rapids and Prairie River licenses. During this process, extensive protection, mitigation, and enhancement (PM&E) measures were developed and mandated by FERC and federal and state resource agencies to achieve the balance required by ECPA.

MP is pursuing a new license for the Grand Rapids Project and subsequent license for the Prairie River Project using the Commission's Integrated Licensing Process (ILP) as defined in 18 Code of Federal Regulations (CFR) Part 5.

In accordance with 18 CFR §5.15, MP has initiated studies and information-gathering activities as provided in the study plan and schedule approved by the Commission. This Initial Study Report (ISR) describes the Licensee's overall progress in implementing the study plan and schedule, the data collected, and any variances from the study plan and schedule.

The Commission's regulations at 18 CFR §5.15(c) require MP to hold a meeting with participants and FERC staff within 15 days of filing the ISR[1]. **Accordingly, MP will hold an ISR Meeting via Webex from 2 PM to 4 PM (eastern time) on Thursday, October 29, 2020. An agenda for the ISR Meeting is presented in** Error! Reference source not found. **to this ISR.**

To allow for adequate planning, MP respectfully requests that those planning on joining the ISR Webex Meeting RSVP by emailing Nora Rosemore at NRosemore@mnpower.com on or before close of business Thursday, October 22, 2020.

1.2 Background

On December 13, 2018, MP initiated the ILP by filing a Pre-Application Document (PAD) and Notice of Intent (NOI) with the Commission. Major ILP milestones completed to date are presented in Table 1.2-1.

Table 1.2-1. Major ILP Milestones Completed

Date	Milestone
12/13/2018	PAD and NOI Filed
02/11/2019	Scoping Document 1 (SD1) Issued by FERC
03/06-03/07/2019	FERC Agency and Public Scoping Meetings Conducted
03/06/2019	Project Site Visit Held
05/27/2019	Scoping Document 2 (SD2) Issued by FERC

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[1] According to the process plan and schedule included in Scoping Document 2, the ISR is scheduled to be filed on or by October 23, 2020 with the ISR meeting to take place on or by November 7, 2020. Early filings or issuances will not result in changes to the deadlines.

Date	Milestone
05/27/2019	Proposed Study Plan (PSP) Filed
06/26/2019	PSP Meeting Conducted
09/23/2019	Revised Study Plan (RSP) Filed
10/16/2019	FERC Issued Study Plan Determination (SPD)
10/16/2020	ISR

No comments were received on MP's RSP, which was approved by FERC on October 16, 2019, with the issuance of FERC's SPD.

1.3 Study Plan Implementation

On October 16, 2019, the Commission issued a SPD for the Project. The SPD directed MP to conduct eight studies, including four studies for the Grand Rapids Project and four studies for the Prairie River Project, comprising of the same studies for each project:

1. Water Quality Study
2. Fish Entrainment and Impingement Study
3. Recreation Resources Study
4. Cultural Resources Study

On April 10, 2020, MP filed a notification to conduct the Recreation Resources Study for both Projects during the 2021 study season instead of 2020 citing COVID-19 restrictions. MP intends to include the Recreation Resources Study results to date in the filing of the Draft License Application (DLA) and will file final study reports with FERC once the studies and analyses are complete.

MP initiated the approved studies, with the exception of the Recreation Resources Studies as noted above, in accordance with the schedule and methods described in the RSP and SPD. Section 2 of this ISR describes MP's overall progress implementing the study plan and schedule, the data collected, and any variances from the study plan and schedule. All the studies have been completed and technical study reports are attached as appendices to this ISR.

1.4 Proposals to Modify Ongoing Studies or for New Studies

With the exception of moving the Recreations Resources Study to 2021 due to COVID - 19 considerations, MP is not proposing any modifications to the studies approved in the Commission's October 16, 2019, SPD or any new studies. As described above, MP will hold an ISR Meeting via Webex on October 29, 2020. MP will file an ISR Meeting Summary with the Commission within 15 days of the ISR Meeting date listed within SD2 (on or before November 22, 2020).

After review of the ISR Meeting Summary, stakeholders may file disagreements with the meeting summary, request modifications to studies, or request new studies. Disagreements with the ISR Meeting Summary and any requests to amend the study plan to include new or modified studies must be filed with the Commission no later than 30 days after the filing of the ISR Meeting Summary (December 22, 2020). In requesting modifications to studies or new studies, stakeholders must take into account the following criteria:

- *Criteria for Modification of Approved Study (18 CFR 5.15(d))*. Any proposal to modify a study must be accompanied by a showing of good cause why the proposal should be approved, and must include, as appropriate to the facts of the case, a demonstration that:
  (1) Approved studies were not conducted as provided for in the approved study plan; or
  (2) The study was conducted under anomalous environmental conditions or that environmental conditions have changed in a material way.
- *Criteria for New Study (18 CFR 5.15(e)).* Any proposal for new information gathering or studies must be accompanied by a showing of good cause why the proposal should be approved, and must include, as appropriate to the facts of the case, a statement explaining:
  (1) Any material changes in the law or regulations applicable to the information request;
  (2) Why the goals and objectives of any approved study could not be met with the approved study methodology;
  (3) Why the request was not made earlier;
  (4) Significant changes in the project proposal or that significant new information material to the study objectives has become available; and
  (5) Why the new study request satisfies the study criteria in 18 CFR §5.9(b).

MP will have 30 days to respond to any disagreements or requests to amend the study plan (January 21, 2021). The Commission's Director of the Office of Energy Projects will resolve any disagreement and amend the approved study plan, as appropriate, within 30 days of the due date for MP's response (February 20, 2021).

2 Status and Summaries of Studies

This section describes MP's overall progress implementing the study plan and schedule, the data collected, and any variances from the study plan and schedule. Study methods and available study results are summarized for each of the six total studies performed in 2020 and approved in the Commission's SPD.

2.1 Grand Rapids Project Water Quality Study

2.1.1 Study Status

MP has completed the Grand Rapids Project Water Quality Study in accordance with the RSP and the Commission's SPD. The technical report including the results of the Grand Rapids Water Quality Study is included as Appendix B to this ISR.

2.1.2 Summary of Study Methods and Results

In accordance with the study plan approved in the Commission's SPD, MP conducted a Water Quality Study in the Grand Rapids Project's reservoir and downstream area.

Water temperature and dissolved oxygen (DO) were measured in the Project impoundment and immediately downstream at the following locations:

1. Blandin Reservoir – log boom corner;
2. Blandin Reservoir – turbine intake area;
3. Tailrace near retaining wall; and
4. Upstream of Highway 169 Bridge (adjusted for safety reasons to downstream of bridge).

Measurements for DO and temperature at the upstream dam sampling locations were collected at 1-meter intervals from the surface to bottom of the water. For the tailrace area near the retaining wall and upstream of Highway 169 Bridge sampling locations, measurements of DO and temperature were taken at the surface, middle, and bottom of the water column and included corresponding depth measurements.

Eleven bi-weekly water quality monitoring events took place in the summer 2020 monitoring season. The dates of the sampling events and associated flow conditions on each date are provided in Table 2.1-1.

Table 2.1-1. Water Quality Sampling Dates

Date	Flow[1]
May 12, 2020	1370
May 20, 2020	1040
June 2, 2020	902
June 16, 2020	1000
June 30, 2020	633
July 14, 2020	595
July 28, 2020	1150
August 11, 2020	1520
August 25, 2020	1850
September 8, 2020	1400
September 22, 2020	1340

1. Discharge data was obtained from USGS site 05211000 Mississippi River at Grand Rapids, MN.

Sampling was completed using a YSI 6920 V2 with 6560 Cond/Temp Probe & 6150 ROX Optical DO Probe. The meter was calibrated according to manufacturer instructions at the start of each day prior to beginning field monitoring. A summary of mean water temperature and DO at the Grand Rapids Project in 2020 is provided in Table 2.1-2.

Table 2.1-2. Summary of Water Quality Monitoring at the Grand Rapids Project

Sampling Location	DO (mg/L)	Water Temperature (°C)	Number of Observations
Log Boom Corner	7.38	19.7	71
Turbine Intake Area	7.58	19.8	72
Tailrace Near Retaining Wall	7.55	19.9	32
Downstream of Hwy 169 Bridge	7.71	19.8	33

The Grand Rapids Project operates in a ROR mode. Overall, the observed readings were typical of well-mixed warmwater rivers in Minnesota. Water temperature generally increased at all sites from May 12 through July 14, 2020 then decreased for the remainder of the monitoring period apart from an increase in water temperature on August 25, 2020. DO readings at all stations were above the Minnesota Class 2B stream standards of 5.00 mg/L for 10 of the 11 sampling events. On August 25, 2020, the DO readings at all sampling stations were below the 5.0 mg/L state standard ranging from 4.18 – 4.57 mg/L.

2.1.3 Variances from FERC-Approved Study Plan

The only variance from the FERC-approved study plan is the timing of the first sampling event. The event was scheduled for May 5, 2020; however, there was an issue accessing the sampling locations at the Blandin Paper site. This resulted in the first sampling event being delayed until May 12, 2020. The small modification from the sampling plan is that sampling events #1 and #2 were only one week apart and not two. This modification is not expected to impact sampling results, as both sampling events met state water quality criteria. The remainder of the sampling events have been completed on a bi-weekly basis.

2.2 Grand Rapids Project Desktop Entrainment and Impingement Study

2.2.1 Study Status

MP has completed the Grand Rapids Project Desktop Entrainment and Impingement Study in accordance with the RSP and the Commission’s SPD. The technical report including the results of the Grand Rapids Entrainment and Impingement Study is included as Appendix C to this ISR.

2.2.2 Summary of Study Methods and Results

In accordance with the study plan approved in the Commission’s SPD, MP conducted a Desktop Fish Entrainment and Impingement Study at the Grand Rapids Project to determine the likelihood that impingement and entrainment of fish will occur and whether this could have an adverse effect on resident fish populations.

Results of the existing fisheries information (MP 2018, MDNR 2018) were used to describe the fish communities that may be susceptible to turbine entrainment. Monthly quantitative entrainment estimates were derived for a list of recreational and ecologically important target species using a literature review. This included an analysis of empirical entrainment rate data collected at various hydroelectric projects, species periodicities, and their average Relative Composition (RC%) in the Project's pools. The potential for trashrack exclusion and vulnerability to impingement/entrainment was assessed by incorporating the trashrack clear spacing, intake velocities, swimming speeds, and body scaling factors. Additionally, a literature review of turbine mortality field studies conducted at other hydroelectric projects was performed to compile fish survival rates applicable to the Project. A blade strike analysis was performed to calculate turbine mortality rates at the Project.

The average annual estimate of target species expected to become entrained at the Project is 14,661 fish (rounded to nearest fish) based on a normal water year for the period of record (POR). For dry and wet water years, this number could range from approximately 4,133 to 20,285 fish, respectively. The majority of the entrainment estimates are small fish in the 0- to 4-inch length groups. Yellow Perch and centrarchids (sunfishes) represented a large majority of entrainment, particularly in the summer and fall months.

Fish mortality rates through the Project's Francis unit are relatively low and are very low for the larger propeller unit, particularly for small fish that make up the majority of all entrained fish. Average blade strike survival rates were multiplied by target species seasonal entrainment estimates to determine immediate turbine mortality estimates of the target species. This study included all size classes of fish as the 4-inch and 3-inch trashracks currently in place at the Project do not exclude most fish within Blandin Reservoir. According to this assessment, the annual average number (rounded to the nearest fish) of target species expected to suffer immediate turbine-related mortality at the Project is estimated to be 3,568 fish based on a normal water year for the POR. For dry and wet water years, this number could range from approximately 1,004 to 4,896 fish, respectively. These mortality estimates assume that all fish entrained went through just one unit and, therefore, encompass the range of possible mortality values. Entrainment mortalities will likely be the highest in the summer and fall months when fish are most active.

2.2.3 Variances from FERC-Approved Study Plan

There are no variances from the Grand Rapids Project Desktop Entrainment and Impingement Study Plan.

2.3 Grand Rapids Project Cultural Resources Study

2.3.1 Study Status

MP has completed the Grand Rapids Project Cultural Resources Study in accordance with the RSP and the Commission's SPD. The technical report including the results of the Grand Rapids Cultural Resources Study will be filed as privileged under separate cover.

2.3.2 Summary of Study Methods and Results

In accordance with the study plan approved in the Commission's SPD, MP conducted a Cultural Resources Study at the Grand Rapids Project to identify potential historic properties within the Project's Area of Potential Effects (APE) and assess the potential effects of continued Project operations and maintenance activities on historic and cultural resources.

MP conducted background research and an archival review to inform the specific research design and the historic and environmental contexts. The literature review revealed four previous cultural resource inventories were conducted within the Project vicinity and study area between 1995 and 2008. In addition, a total of seven previously recorded archaeological resources were identified within the one-mile study area. Of these, five resources were within or near the Project APE. A total of 90 previously recorded architectural resources were identified within the one-mile study area, but none were located within the Project APE.

A Phase I cultural resource investigation was conducted between June 15 and July 10, 2020, by In Situ Archaeological Consulting as contracted by MP. A visual inspection was conducted along the shoreline of the reservoir via boat. A pedestrian survey was also used to survey landforms with slopes less than 20 degrees and a surface visibility of 25 percent or greater. Last, a shovel test method was used to sample subsurface contexts along the shoreline that had slopes with less than 20 degrees, ground visibility of less than 25 percent, and evidence of active erosion from the reservoir. No new archaeological resources were identified during the Phase I investigation. One newly recorded architectural resource was observed near the APE of the Project. Of the five previously identified archaeological resources within the APE, three were previously determined to be ineligible for the National Register of Historic Places (NRHP), and two were unevaluated. In Situ inspected the locations of these sites during the Phase I investigation. No Project-related impacts to those sites were observed as they all have stable shorelines with no evidence of active erosion. Due to these factors, In Situ recommended that no further work is necessary for these sites. However, if there are changes to the operations or management of the Project area that has a potential to cause shoreline erosion, then the sites should be monitored to document any impacts to the sites. If the episode does impact the site, MP will evaluate the site for eligibility status.

As a component of the Phase I investigation, In Situ also evaluated the NRHP-eligibility of Project facilities. The Blandin Dam and Powerhouse were constructed in 1901-02 to supply the energy needs to the Itasca Paper Company, later known as the Blandin Paper Company. The powerhouse was replaced following a dam break that occurred in 1948, and the dam and spillway were modified. For these reasons, the dam and powerhouse had previously been determined to be ineligible for the NRHP. In Situ concurred with the previous eligibility finding and recommended the Blandin Dam and Powerhouse as ineligible for the NRHP.

Overall, the investigation was concluded with a finding of No Historic Properties Affected within the Project APE and recommended no further work is needed.

2.3.3 Variances from FERC-Approved Study Plan

There are no variances from the Grand Rapids Project Cultural Resources Study Plan.

2.4 Prairie River Project Water Quality Study

2.4.1 Study Status

MP has completed the Prairie River Project Water Quality Study in accordance with the RSP and the Commission's SPD. The technical report including the results of the Prairie River Water Quality Study is included as Appendix E to this ISR.

2.4.2 Summary of Study Methods and Results

In accordance with the study plan approved in the Commission's SPD, MP conducted a Water Quality Study in the Prairie River Project's reservoir, bypass reach, and downstream area.

Water temperature and DO were measured in the Project impoundment and immediately downstream at the following locations:

1. Upstream of the coarse trashrack;
2. Tailrace area; and
3. Bypass reach (upstream of the road to avoid influence).

Measurements of DO and temperature upstream of the coarse trashrack sampling location were collected and recorded at 1-meter intervals. For the tailrace area and bypass reach locations, measurements of DO and temperature were taken at the surface, middle, and bottom of the water column and included corresponding depth measurements.

Eleven bi-weekly water quality monitoring events took place in the summer 2020 monitoring season. The dates of the sampling events and associated flow conditions on each date are provided in Table 2.4-1.

Table 2.44-1. Water Quality Sampling Dates

Date	Flow[1]
May 12, 2020	212
May 20, 2020	180
June 2, 2020	164
June 16, 2020	443
June 30, 2020	141
July 14, 2020	114
July 28, 2020	150
August 11, 2020	147
August 25, 2020	506
September 8, 2020	228
September 22, 2020	132

1. Discharge data was obtained from Prairie River Dam staff.

Sampling was completed using a YSI 6920 V2 with 6560 Cond/Temp Probe & 6150 ROX Optical DO Probe. The meter was calibrated at the start of each day prior to beginning field monitoring. A summary of water temperature and DO at the Prairie River Project in 2020 is provided in Table 2.4-2.

Table 2.4-2. Summary of Water Quality Monitoring at the Prairie River Project

Sampling Location	DO (mg/L)	Water Temperature (°C)	Number of Observations
Upstream of Coarse Trash Rack	8.43	20.4	37
Bypass Reach	8.77	20.5	32
Tailrace Area	8.18	20.0	33

The Prairie River Project is operated in a ROR mode. Overall, the observed readings were typical of well-mixed, warmwater rivers in Minnesota. Water temperature generally increased at all sites until August, then decreased during the September monitoring events. All readings were above the 5.0 mg/L state standard for DO for all stations during all monitoring events.

2.4.3 Variances from FERC-Approved Study Plan

The only variance from the FERC-approved study plan is the timing of the first sampling event. It was scheduled for May 5, 2020; however, there was an issue accessing the sampling locations at the Blandin Paper site. This resulted in the first event of both Grand Rapids and Prairie River sampling being delayed until May 12, 2020. This small modification from the sampling plan is that sampling events #1 and #2 were only one week apart and not two. This modification is not expected to impact sampling results, as both sampling events met state water quality criteria. The remainder of the sampling events have been completed on a bi-weekly basis.

2.5 Prairie River Project Desktop Entrainment and Impingement Study

2.5.1 Study Status

MP has completed the Prairie River Project Desktop Entrainment and Impingement Study in accordance with the RSP and the Commission’s SPD. The technical report including the results of the Prairie River Entrainment and Impingement Study is included as Appendix F to this ISR.

2.5.2 Summary of Study Methods and Results

In accordance with the study plan approved in the Commission’s SPD, MP conducted a Desktop Fish Entrainment and Impingement Study at the Prairie River Project to determine the likelihood that impingement and entrainment of fish will occur and whether this could have an adverse effect on resident fish populations.

The methodology used to assess entrainment and impingement at the Prairie River Project was the same as the Grand Rapids Project (Section 2.2.2).

According to MP's assessment, the average annual number of target species expected to become entrained at the Project is 3,320 fish (rounded to the nearest fish) based on an average water year for the POR. For dry and wet water years, this number could range from approximately 1,086 to 5,994 fish, respectively. The majority of the entrainment estimates are small fish in the 0- to 4-inch length cohort. Yellow Perch represented the largest component of entrainment, followed by the centrarchids (sunfishes). Combined, these species/guilds represented approximately 88 percent of all fish entrained. Very few fish in the larger size classes were estimated to be entrained because most are large enough to be excluded by the 1.5-inch clear-spaced trashracks in front of the combined intake for Units 1 and 2 currently in place at the Project.

The annual average number (rounded to the nearest fish) of target species expected to suffer immediate turbine-related mortality at the Project ranged from 237 to 593 fish based on an average water year for the POR. For dry and wet water years, this number could range from approximately 79 to 197 fish and 445 to 1,113 fish, respectively. Yellow Perch showed the highest mortality due to high entrainment rates in the spring and fall months, and relatively high RC% in the Project reservoir followed by centrarchids (largely made up of the sunfishes). Entrainment mortalities will likely be the highest in the spring and fall months when fish are most active.

2.5.3 Variances from FERC-Approved Study Plan

There are no variances from the Prairie River Project Desktop Entrainment and Impingement Study Plan.

2.6 Prairie River Project Cultural Resources Study

2.6.1 Study Status

MP has completed the Prairie River Project Cultural Resources Study in accordance with the RSP and the Commission's SPD. The technical report including the results of the Prairie River Cultural Resources Study will be filed as privileged under separate cover.

2.6.2 Summary of Study Methods and Results

In accordance with the study plan approved in the Commission's SPD, MP conducted a Cultural Resources Study at the Prairie River Project to identify potential historic properties within the Project's APE and assess the potential effects of continued Project operations and maintenance activities on historic and cultural resources.

MP conducted background research and an archival review to inform the specific research design and the historic and environmental contexts. The literature review revealed four previous cultural resource inventories were conducted in this area between 1991 and 1995 within the study area. Additionally, a total of 20 previously recorded archaeological resources were identified within the one-mile study area. Of these, 19 resources were within or near the Project. The literature review also revealed a total of three previously recorded architectural resources within the one-mile study area. Of these, there is one previously recorded architectural resource within the APE for this Project (IC-ARB-002).

A Phase I cultural resource investigation was conducted between June 15 and July 10, 2020, by In Situ Archaeological Consulting as contracted by MP. A visual inspection was conducted along the shoreline of the reservoir via boat. A pedestrian survey was also used to survey landforms with slopes less than 20 degrees and a surface visibility of 25 percent or greater. Last, a shovel test method was used to sample subsurface contexts along the shoreline that had slopes with less than 20 degrees, ground visibility of less than 25 percent, and evidence of active erosion from the reservoir. Of the 19 previously identified archaeological resources within or near the APE, eight were previously determined to be eligible for the NRHP, six were determined to be ineligible, and five were unevaluated. In Situ inspected the locations of these sites during the Phase I investigation. No Project-related impacts to those sites were observed as they all have stable shorelines with no evidence of active erosion. In Situ also identified four new archaeological resources, including three single artifact finds and one depressional feature site. In Situ recommended these new resources as ineligible for the NRHP.

Based on the results of the Phase I investigation, In Situ recommended that no further work is necessary for the identified archaeological sites at the Project. However, if there are changes to the operations or management of the Project area that has a potential to cause shoreline erosion, then the sites should be monitored to document any impacts to the sites. If the episode does impact the site, MP will evaluate the site for eligibility status.

The Phase I investigation determined that 10 archaeological sites are not eligible for the NRHP and no further work is necessary. The investigation suggests 5 archaeological sites are unevaluated for the NRHP, and 8 archaeological sites are eligible for the NRHP. During the investigation, all the sites were observed to have stable shoreline with no evidence of active erosion or impacts from Project operation.

As a component of the Phase I investigation, In Situ also evaluated the NRHP eligibility of architectural resources within the APE, including the Prairie River Power Plant, Prairie River Dam, and a ca. 1935 wood-frame cabin. The Prairie River Power Plant was previously determined to be ineligible for the NRHP, and In Situ concluded that the Prairie River Dam and the wood-frame cabin did not meet the NRHP eligibility criteria. For these reasons, In Situ recommended the power plant, dam, and the cabin as ineligible for the NRHP.

A finding of *No Historic Properties Affected* was determined within the Project APE and recommend no further work or annual monitoring for these sites. However, monitoring efforts may be deemed necessary if significant fluctuations of the water level of the reservoir occur outside of the operating band.

2.6.3 Variances from FERC-Approved Study Plan

There are no variances from the Prairie River Project Cultural Resources Study Plan.

3 Upcoming ILP Milestones and Study Reporting

Table 3.0-1 presents upcoming ILP milestones.

Table 3.0-1. Upcoming Major ILP Milestones

Date	Milestone
10/29/2020[1]	ISR Meeting
11/22/2020	File ISR Meeting Summary
12/22/2020	Stakeholders file disagreements with ISR Meeting Summary and/or requests for modified/new studies
01/21/2021	MP files response to disagreements with ISR Meeting Summary and/or requests for modified/new studies
02/20/2021	FERC Director of the Office of Energy Projects makes a determination on disputes/amendments to the approved study plan
2021	Conduct Second Year of Studies
10/23/2021	File Updated Study Report (USR), if necessary
11/07/2021	USR Report Meeting
11/22/2021	File USR Meeting Summary
08/03/2021	File Draft License Application (DLA)
11/01/2021	Comments on DLA Due
12/31/2021	File Final License Application

Note: According to the process plan and schedule included in Scoping Document 2, the ISR is scheduled to be filed on or by October 23, 2020 with the ISR meeting to take place on or by November 7, 2020. Early filings or issuances will not result in changes to the deadlines.

4 Notice of Intent to File Draft License Application

As required by 18 CFR §5.16(c), MP hereby advises the Commission of its intent to file a DLA, which will include the contents of a license application, rather than a Preliminary Licensing Proposal. The DLA will be filed no later than August 3, 2021.

5 Literature Cited

Minnesota Power (MP). 2018. Pre-Application Document, Volume I of II, Grand Rapids Hydroelectric Project (FERC Project No. 2362) Prairie River Hydroelectric Project

(FERC Project No. 2361). Prepared by HDR Engineering, Inc. for Minnesota Power. December 13, 2018.

Minnesota Department of Natural Resources (MDNR). 2018. Fisheries Lake Surveys: Blandin. Online: [URL] https://www.dnr.state.mn.us/lakefind/showreport.html?downum=31053300.

Appendix A. ISR Meeting Agenda

Initial Study Report Meeting Agenda

Grand Rapids Hydroelectric Project and Prairie River Hydroelectric Project

October 29, 2020, 2pm – 4pm EST

1. Welcome and Introductions

2. Overview of Study Scoping Process

3. Grand Rapids Hydroelectric Project Studies Overview
    - Water Quality Study
    - Desktop Entrainment and Impingement Study
    - Cultural Resources Study

4. Prairie River Hydroelectric Project Studies Overview
    - Water Quality Study
    - Desktop Entrainment and Impingement Study
    - Cultural Resources Study

5. Next Steps

6. Questions and Comments

Appendix B. Grand Rapids Project Water Quality Study

WENCK File #B000959-20-082
October 2020

Grand Rapids Hydroelectric Project (FERC No. 2362)

Prepared for:

Minnesota Power

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1.0 Introduction and Background

1.1 INTRODUCTION

ALLETE Inc., doing business as Minnesota Power ("MP" or "Licensee"), is the Licensee, owner, and operator of the Grand Rapids Hydroelectric Project (FERC No. 2362). The Grand Rapids Hydroelectric Project (Project) is licensed by the Federal Energy Regulatory Commission ("FERC" or "Commission") under the authority granted to FERC by Congress through the Federal Power Act (FPA), 16 United States Code (USC) §791(a), et seq., to license and oversee the operation of non-federal hydroelectric projects on jurisdictional waters and/or federal land. There are no federal lands associated with the Project. The Project previously underwent licensing in the early 1990s, and the current operating license for the Project expires on December 31, 2023. Accordingly, MP is pursuing a new license for the Grand Rapids Project pursuant to FERC's Integrated Licensing Process (ILP), as described at 18 Code of Federal Regulations (CFR) Part 5.

This report describes the methods and results of the approved Water Quality Study conducted as part of obtaining a new license for the Project.

1.2 BACKGROUND

The Grand Rapids Project is a 2.1-megawatt (MW), run-of-river (ROR) facility located on the Mississippi River in the City of Grand Rapids in Itasca County, Minnesota. On December 13, 2018, MP initiated the ILP by filing a Pre-Application Document (PAD) and Notice of Intent (NOI) with the Commission. Major ILP milestones to-date are presented in **Table 1-1**.

Table 1-1. Major ILP milestones to-date.

Date	Milestone
12/13/2018	PAD and NOI Filed
02/07/2019	Scoping Document 1 (SD1) Issued by FERC
03/06-03/07/2019	FERC Agency and Public Scoping Meetings Conducted
03/06/2019	Project Site Visit Held
05/16/2019	Scoping Document 2 (SD2) Issued by FERC
05/28/2019	Proposed Study Plan (PSP) Filed
06/20/2019	PSP Meeting Conducted
09/23/2019	Revised Study Plan (RSP) Filed
10/16/2019	FERC Issues Study Plan Determination (SPD)

2.0 Study Goals and Objectives

The water quality study collected information and established recent baseline information on temperature and dissolved oxygen (DO) concentrations in the vicinity of the Project to further expand on the data that has been collected historically. The study employed standard methodologies that are consistent with the scope and level of effort of water quality monitoring conducted at hydropower projects in the region. The specific details and methods included in this study were outlined in the Revised Study Plan (RSP) which was approved by FERC in October 2019. The information collected by this study will be used to determine the Project's potential effects on water quality and provide water quality data sufficient to determine compliance with applicable water quality standards (Minnesota Statute Chapter 7050) and designated uses.

The State of Minnesota has established water quality standards (Minnesota Statute Chapter 7050) to protect water resources for uses such as fishing, swimming, and other recreation, and to sustain aquatic life. These rules are administered by the MPCA, who is the lead 401 Water Quality Certification Agency. The Minnesota Department of Natural Resources (MDNR), Minnesota Board of Soil and Water Resources (BWSR), and local agencies also play a role in water quality protection (MPCA undated).

3.0 Study Area

The Project impounds the Mississippi River at Blandin Dam in Grand Rapids, Minnesota. DO and water temperature data were collected at four locations at the Project (Figure 3-1). Sampling locations and their GPS coordinates included:

- Blandin Reservoir – Log Boom Corner; 47.231989, -93.532224
- Blandin Reservoir – Turbine Intake Area; 47.231837, -93.5321717
- Tailrace Near Retaining Wall; 47.232017, -93.530990
- Downstream of Highway 169 Bridge; 47.232936, -93.5277858

These four sampling locations match the general location of the four sampling locations identified in the FERC approved RSP (2019). The stations include conditions representative of both the slower pool conditions of the Blandin Reservoir and the flowing channel conditions associated with the Mississippi River channel downstream of the dam. Habitat types at both sites within the Blandin Reservoir are characterized as pools. The habitat condition for the Tailrace Near Retaining Wall is characterized as a riffle and the condition at the site Downstream of Highway 169 Bridge is characterized as a run.

The station shown as Downstream of Highway 169 Bridge was adjusted from the location in the RSP (Upstream of Highway 169 Bridge) because it was not possible to access the shoreline at this location for field surveys. The sampling location was moved downstream of the bridge where it was safer for field staff to access the river channel. The Mississippi River channel and habitat conditions at the adjusted sampling location Downstream of Highway 169 Bridge are consistent with the conditions immediately upstream of the bridge at the planned sampling location.

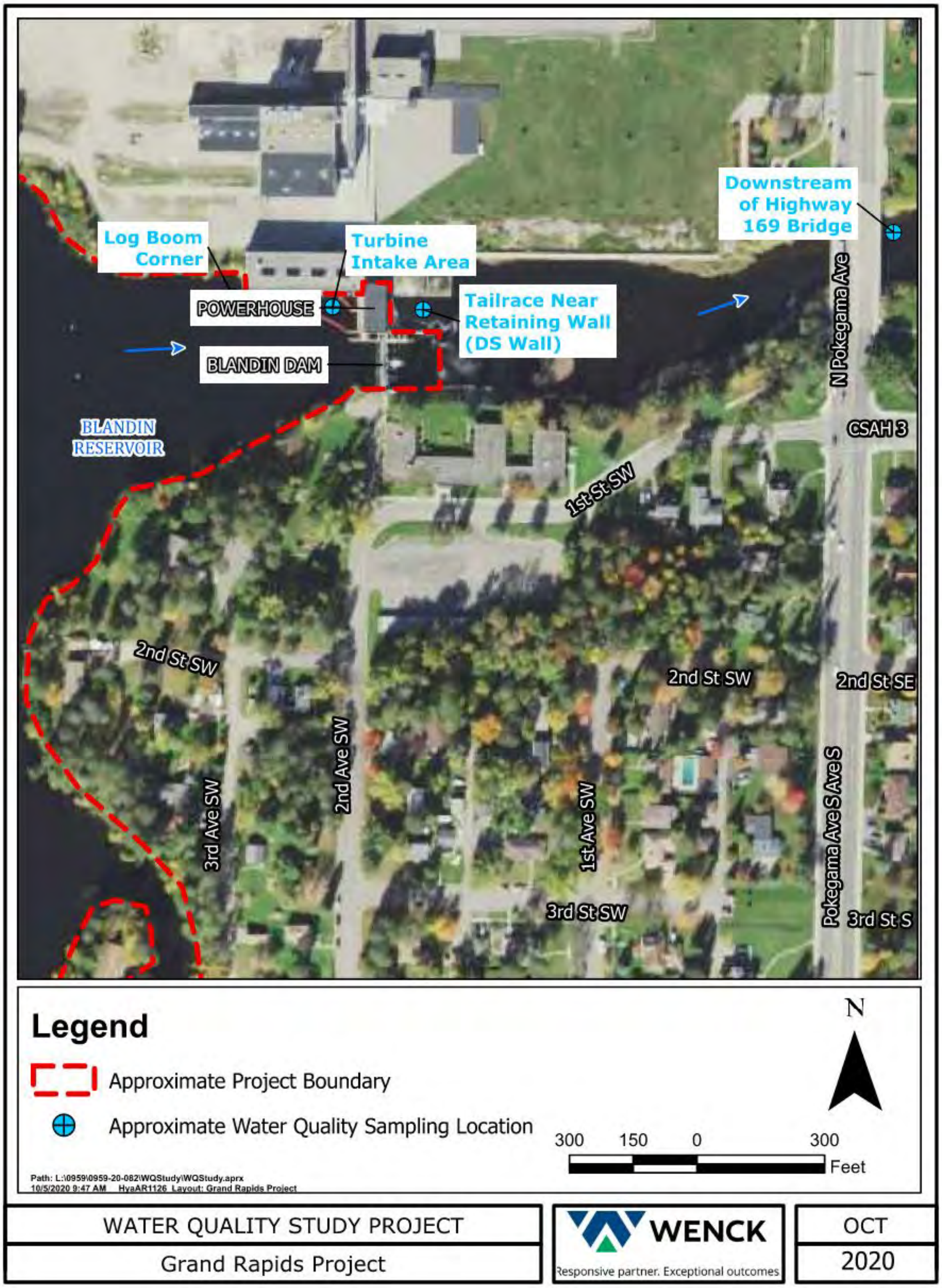

Figure 3-1. Water quality sampling locations at the Grand Rapids Project site.

4.0 Methodology

Following the procedures outlined in the RSP (2019), DO and temperature measurements were made at four locations at the Grand Rapids Project site as displayed on Figure 3-1 above. All sampling locations are on the Mississippi River in Grand Rapids, Minnesota. There were 11 total sampling events from May–September 2020. Sampling events occurred approximately every two weeks throughout the monitoring period. The specific sampling events occurred on the dates listed:

- May 12th, 2020
- May 20th, 2020
- June 2nd, 2020
- June 16th, 2020
- June 30th, 2020
- July 14th, 2020
- July 28th, 2020
- August 11th, 2020
- August 25th, 2020
- September 10th, 2020
- September 22nd, 2020

DO concentration and temperature were measured on the surface and at multiple depths at each sampling location. DO and temperature upstream of the dam (the Log Boom Corner and Turbine Intake Area sites) were collected at 1-meter intervals from the surface to the bottom of the water column. For sampling stations with a total depth of approximately two meters or less, DO and temperature were collected at the surface, middle, and bottom of the water column. This included the two sites downstream from the dam (the Tailrace Near Retaining Wall and Downstream of Highway 169 Bridge sites). Corresponding depth measurements were recorded at each site. A YSI 6920 V2 data sonde with 6560 Conductivity/Temperature Probe & 6150 ROX Optical DO Probe was used for all sampling events except for September 10th and September 22nd, 2020. For the September sampling events, a YSI 5560 Conductivity/Temperature Probe and Pro2002 Galvanic DO Sensor was used. The DO probe was calibrated in the morning before each sampling event. The calibration method used was a percent saturation air calibration method specified in YSI's 6150 & 6450 Optical Dissolved Oxygen Sensors Description and Instructions for Use Manual.

Additional data that was recorded during each sampling event included river discharge and reservoir elevation. Discharge was obtained from the USGS site 05211000 Mississippi River at Grand Rapids, MN website and reservoir elevation was obtained from Minnesota Power staff. Habitat type at each sampling location was noted during the water quality study. The field sampling sheets are provided in this report as Appendix A. Site photos from the study are provided in Appendix B and calibration records are provided in Appendix C.

5.0 Study Results

DO and temperature profiles, river discharge (flow), and reservoir elevation data were collected 11 times over the course of the study. River discharge during the Grand Rapids Project ranged from 633–1,850 cubic feet per second (cfs) over the monitoring period. Water elevation at Blandin Dam ranged from 1,268.16 ft –1,268.23 ft above sea level. The Log Boom Corner and Turbine Intake Area sites were deeper sites and measurements were collected at 1-meter intervals. The Downstream Wall and Downstream of Highway 169 Bridge sites were typically less than two meters deep and measurements were collected at the surface, middle, and bottom of the water column. See Appendix A: Raw Data for all data points collected during the study and used in this report.

Mean DO concentration across sites ranged from 7.38–7.71 mg/L and mean water temperature ranged from 19.7–19.9 degrees Celsius (Table 5-1). Differences in DO between sites were minimal. The highest mean DO concentration occurred at the Downstream of Highway 169 Bridge site downstream of the dam and the lowest mean DO concentration occurred at the Log Boom Corner site upstream of the dam. Differences in temperature between sites were also minimal, but mean water temperature was highest at the Tailrace Near Retaining Wall site. Mean water temperature was lowest at the Log Boom Corner site. Over the course of the study, mean DO concentration at all sites generally decreased from May 12th 2020 to August 25th 2020 (Figure 5-1).

Table 5-1. Mean dissolved oxygen concentration and water temperature at each sampling location for 11 sampling events. Number in parentheses is one standard error of the mean.

Sampling Location	Dissolved oxygen (mg/L)	Water Temperature (degrees C)	Number of observations
Log Boom Corner	7.38 (0.21)	19.7 (0.57)	71
Turbine Intake Area	7.58 (0.21)	19.8 (0.57)	72
Tailrace Near Retaining Wall	7.55 (0.33)	19.9 (0.83)	32
Downstream of Hwy 169 Bridge	7.71 (0.30)	19.8 (0.83)	33

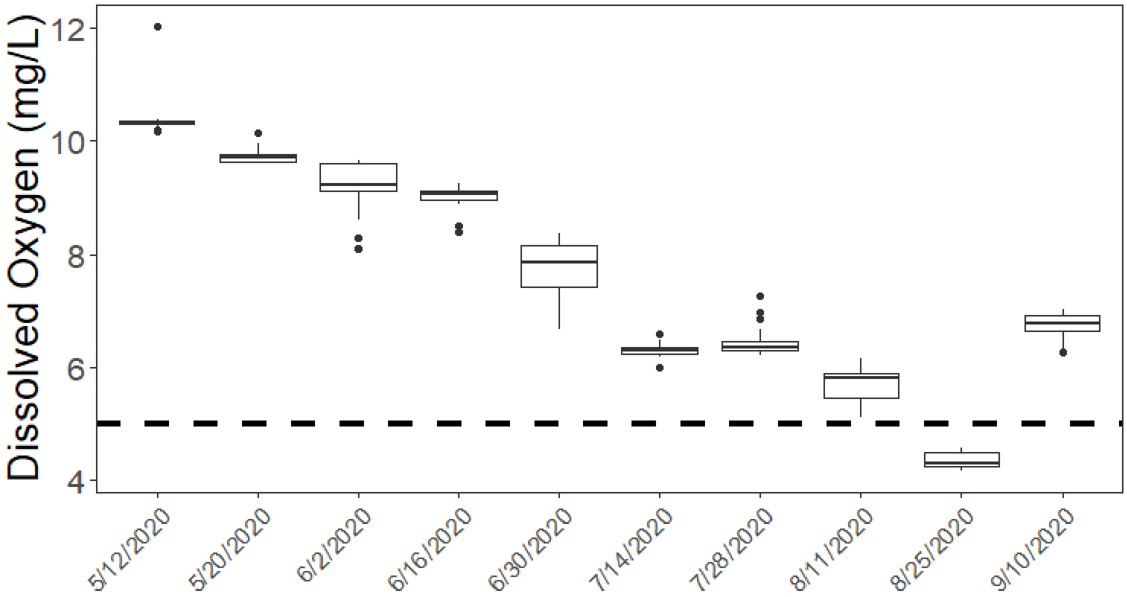

Figure 5-1. Boxplot showing DO summary statistics for all sampling locations at the Grand Rapids Project. The center line in each box represents the median, the lower and upper hinges correspond to the first and third quartiles, and outliers are represented by black points. Data points were considered outliers if they fell outside 1.5 times the inner quartile range. Dotted black line represents the Minnesota Class 2B warmwater stream standard of 5.00 mg/L.

5.1 LOG BOOM CORNER

The Log Boom Corner is a deep site upstream of Blandin Dam. Temperature and DO measurements were taken up to 6 m below the water surface during the study. Water temperature measurements at the Log Boom Corner site ranged from 10.1–25.7 degrees C. Water temperature generally increased over the course of the study until mid-July (Figure 5-2) corresponding to an increase in air temperatures over the summer months. Water temperatures decreased over the final five sampling events except for a short spike in temperature on August 25th, 2020.

DO measurements at the Log Boom Corner site ranged from 4.24–10.4 mg/L with the lowest readings on August 25th, 2020. DO measurements generally decreased from May to the end of August (Figure 5-3). DO measurements were all above the Class 2B warmwater stream standard except on one occasion, August 25th, 2020, when they fell slightly below 5.00 mg/L. On this date DO measurements ranged from 4.42–4.52 mg/L. Measurements of temperature and DO were generally taken at the same depths at each station during all 11 sampling events (Figure 5-4).

DO and temperature measurements were slightly higher on the surface and decreased with depth on several occasions (Figure 5-5, Figure 5-6).

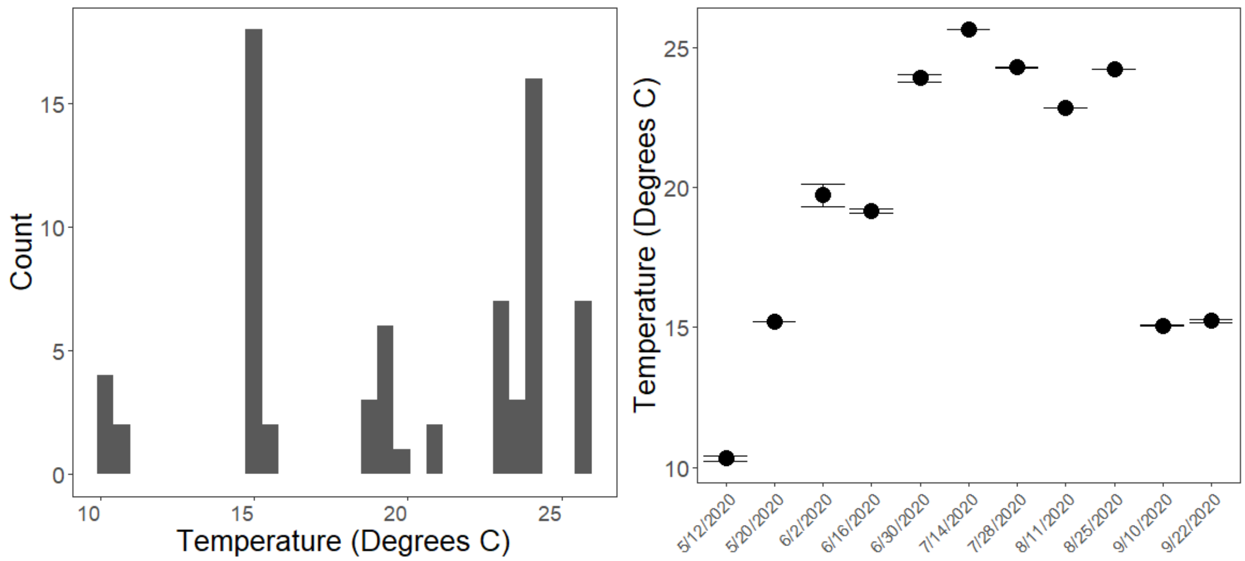

Figure 5-2. Histogram of temperature measurements (left) and mean temperature for each sampling event (right) at the Log Boom Corner site. Whiskers represent standard error.

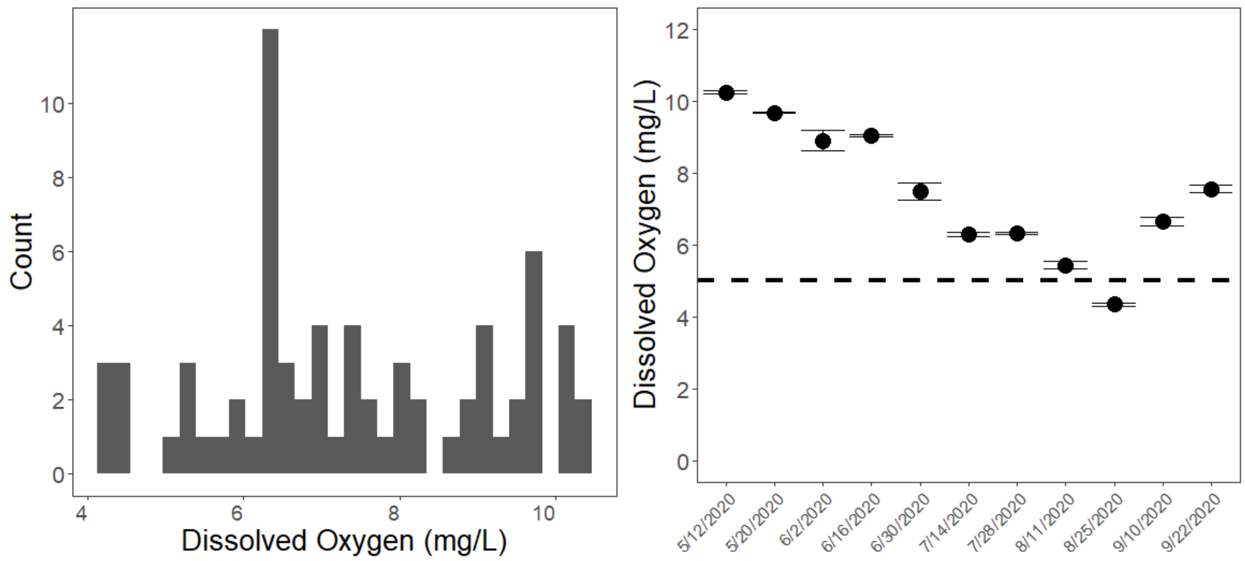

Figure 5-3. Histogram of dissolved oxygen measurements (left) and mean dissolved oxygen concentration (mg/L) for each sampling event (right) at the Log Boom Corner site. Whiskers represent standard error and dotted black line represents the Minnesota Class 2B (warmwater) stream standard of 5.00 mg/L.

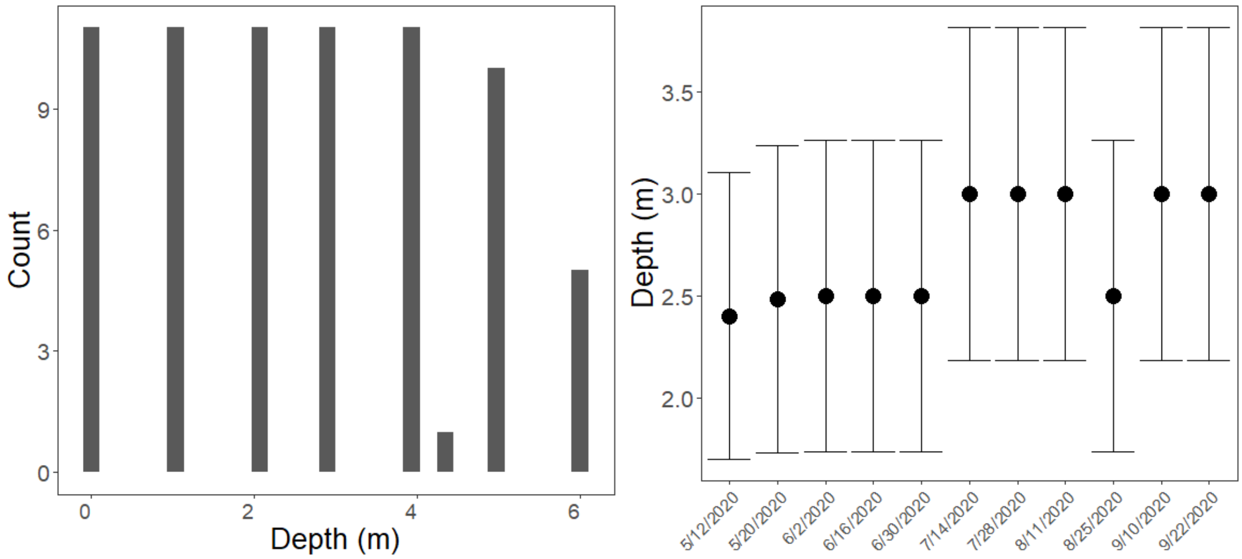

Figure 5-4. Histogram of depth measurements (left) and depth (m) for each sampling event (right) at the Log Boom Corner site. Whiskers represent standard error.

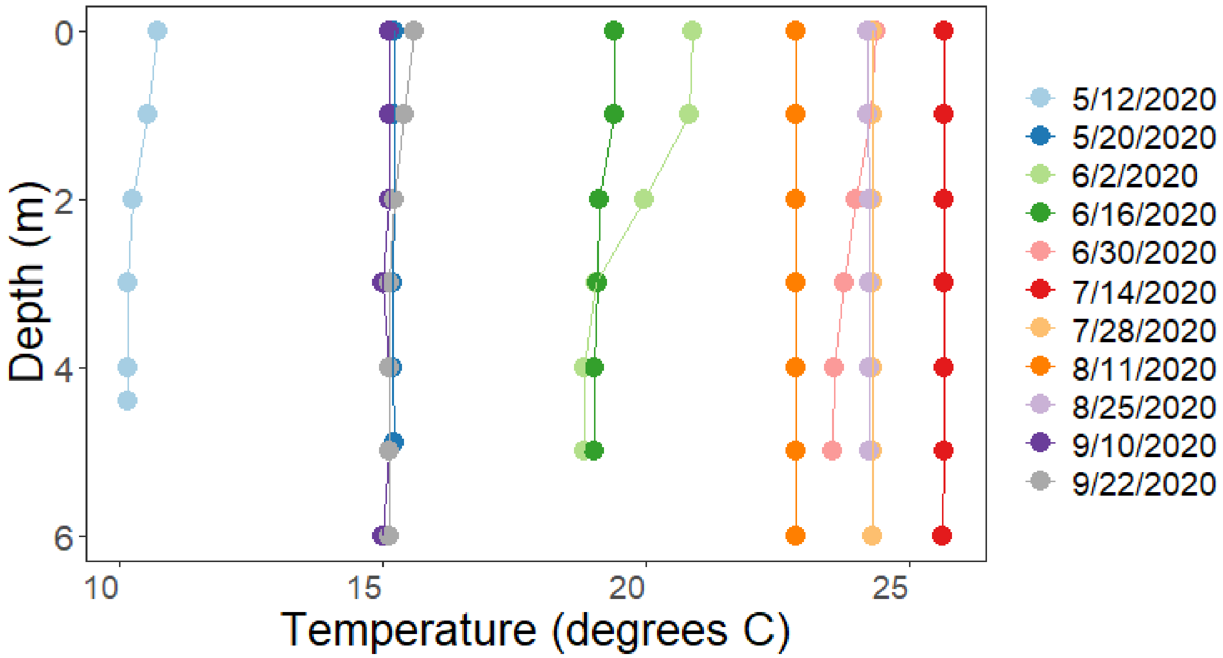

Figure 5-5. Temperature profiles at the Log Boom Corner site for each sampling event.

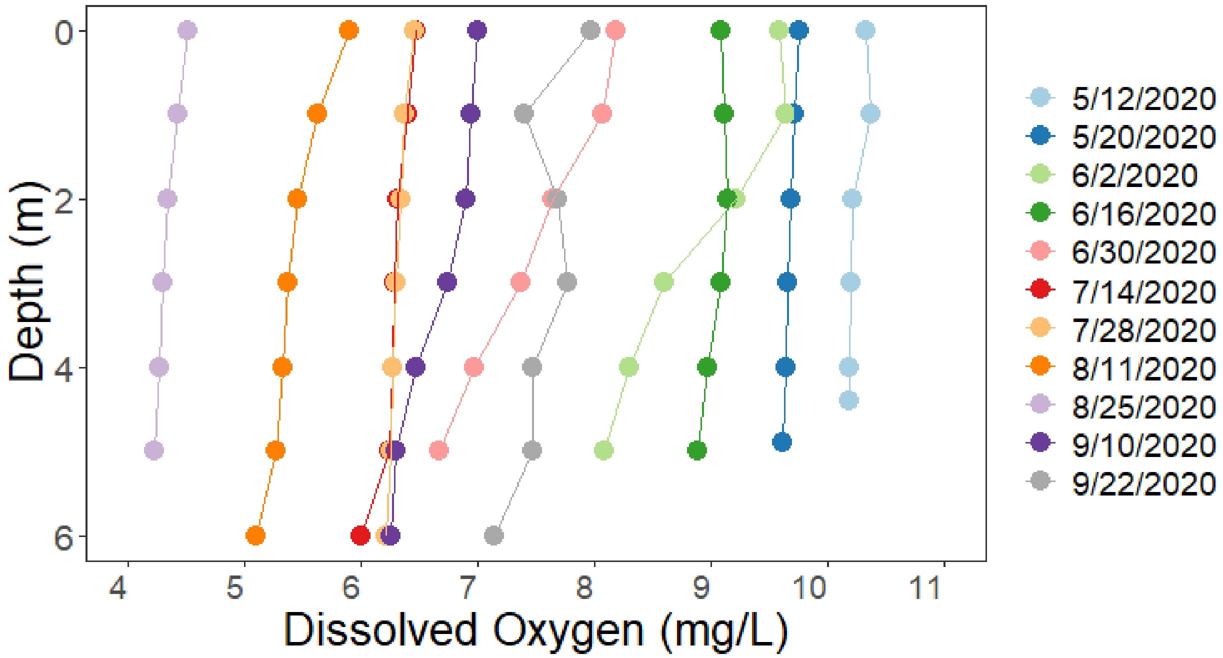

Figure 5-6. Dissolved oxygen profiles at the Log Boom Corner site for each sampling event.

5.2 TURBINE INTAKE AREA

The Turbine Intake Area is a deep site upstream of Blandin Dam. Temperature and DO measurements were taken up to 6 m below the water surface during the study. Water temperature measurements at the Turbine Intake Area site ranged from 10.6–25.6 degrees C. Water temperature generally increased over the course of the study until mid-July (Figure 5-7) corresponding to an increase in air temperatures over the summer months. Water temperatures reached a maximum during the July 14th, 2020 sampling event. Water temperatures decreased over the final five sampling events except for a short spike in temperature on August 25th, 2020.

DO measurements at the Turbine Intake Area site ranged from 4.18–10.4 mg/L with the lowest readings on August 25th, 2020. DO measurements generally decreased over the course of the study until the end of August (Figure 5-8). DO measurements were all above the Class 2B stream standard except on one occasion, August 25th, 2020, when they fell slightly below 5.00 mg/L. On this date DO measurements ranged from 4.18–4.55 mg/L. Measurements of temperature and DO were generally taken at the same depths at each station during all 11 sampling events (Figure 5-9).

DO and temperature profiles taken during each sampling event show a well-mixed site except on September 22nd, 2020 when DO concentrations were higher on the surface than the rest of the water column (Figure 5-10, Figure 5-11).

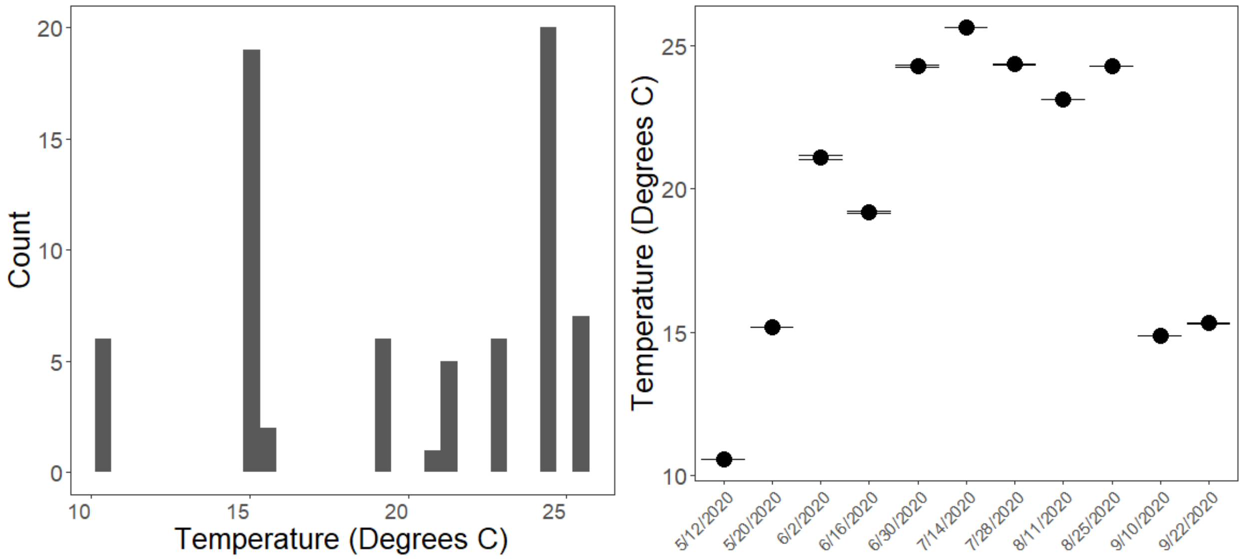

Figure 5-7. Histogram of temperature measurements (left) and mean temperature for each sampling event (right) at the Turbine Intake Area site. Whiskers represent the standard error.

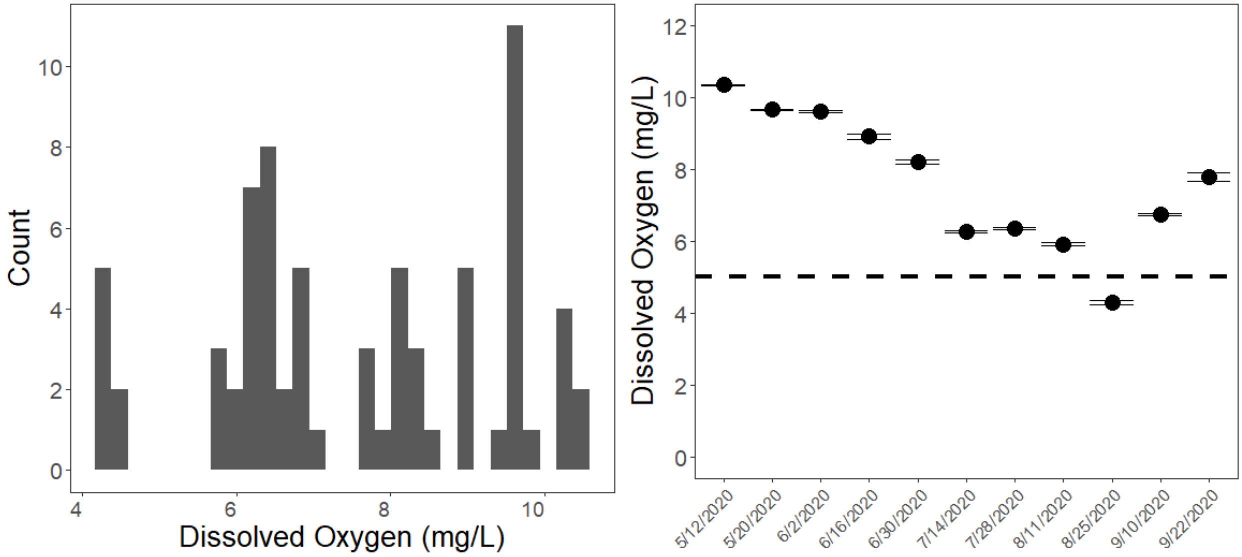

Figure 5-8. Histogram of dissolved oxygen measurements (left) and mean dissolved oxygen concentration (mg/L) for each sampling event (right) at the Turbine Intake Area site. Whiskers represent standard error and dotted black line represents the Minnesota Class 2B stream standard of 5.00 mg/L.

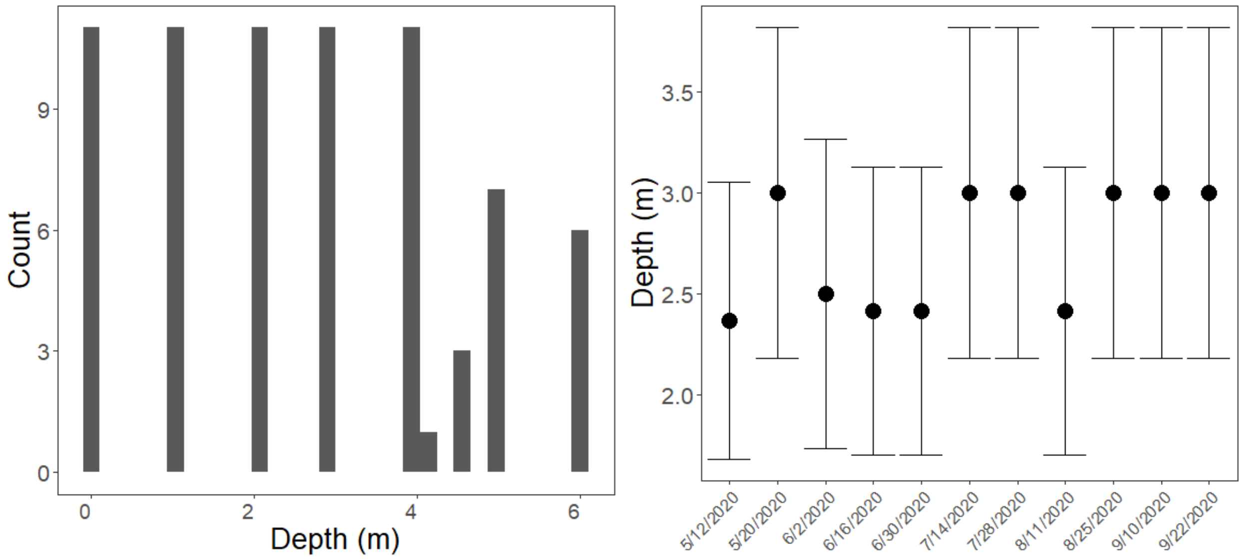

Figure 5-9. Histogram of depth measurements (left) and depth (m) for each sampling event (right) at the Turbine Intake Area site. Whiskers represent standard error.

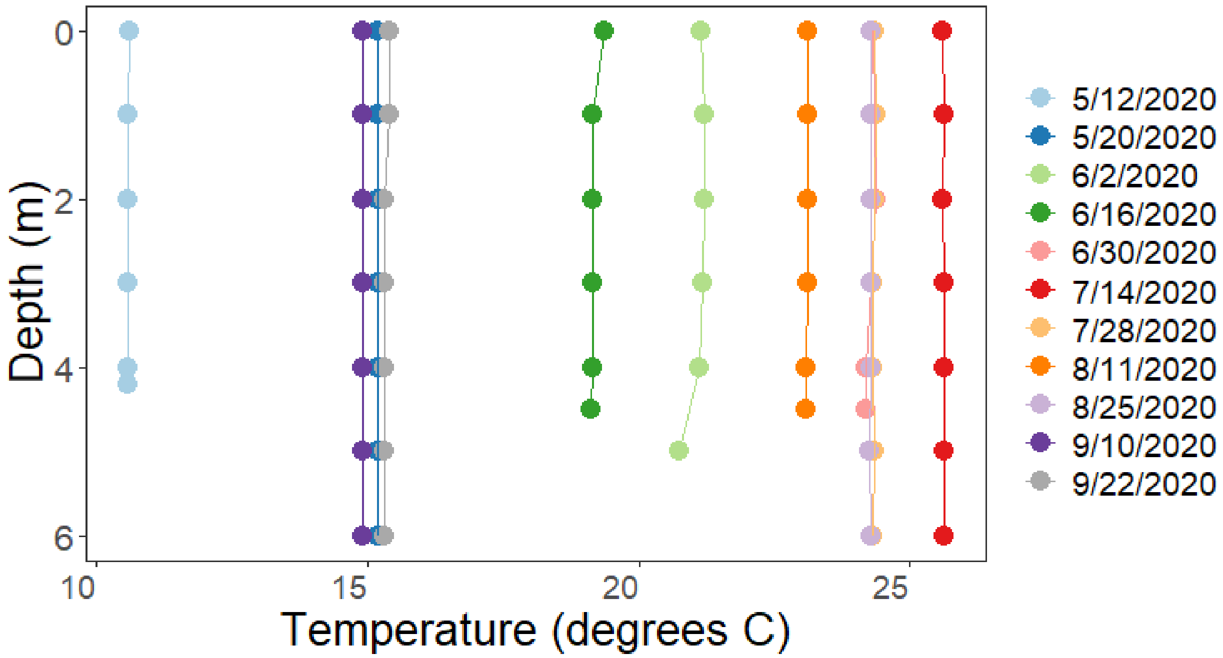

Figure 5-10. Temperature profiles at the Turbine Intake Area site for each sampling event.

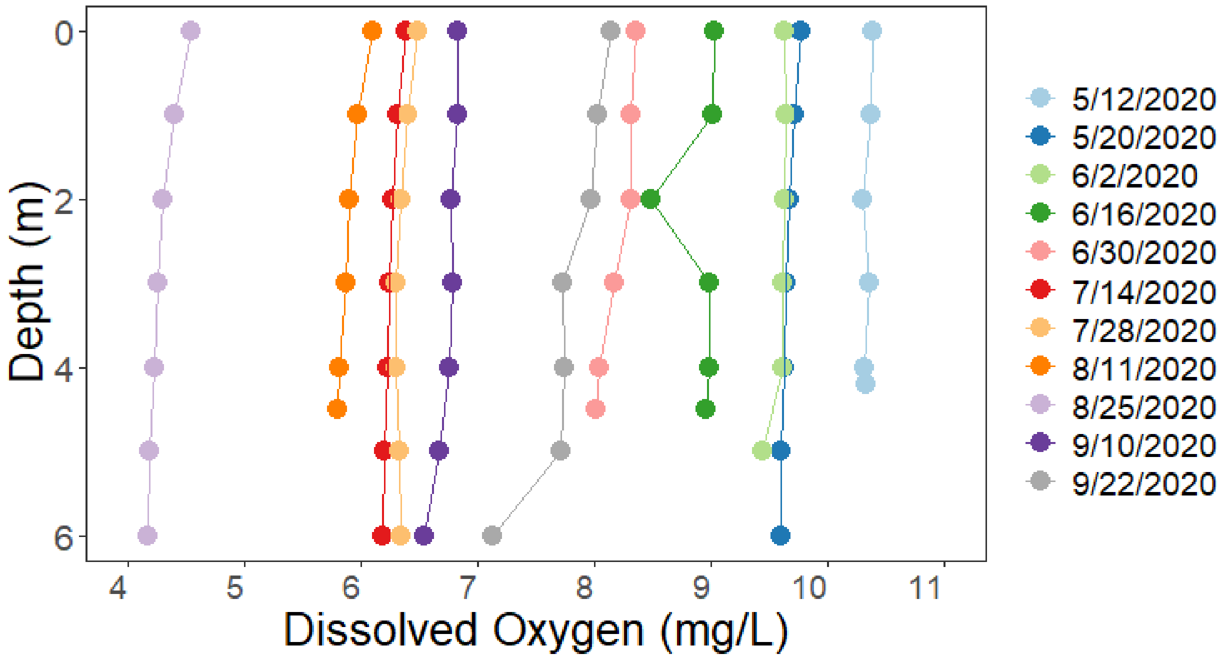

Figure 5-11. Dissolved oxygen profiles at the Turbine Intake Area site for each sampling event.

5.3 TAILRACE NEAR RETAINING WALL

The Tailrace Near Retaining Wall site is a shallow site just downstream of Blandin Dam. Water temperature and DO measurements were taken up to 2 m below the water surface during the study. Water temperature measurements at the Tailrace Near Retaining Wall site ranged from 10.3–25.6 degrees C. Water temperature generally increased over the course of the study until mid-July (Figure 5-10) corresponding to an increase in air temperatures over the summer months. Water temperatures reached a maximum during the July 14th, 2020 sampling event. Water temperatures decreased over the final five sampling events except for a short spike in temperature on August 25th, 2020.

DO measurements at the Tailrace Near Retaining Wall site ranged from 4.24–12.0 mg/L and the lowest readings occurred on August 25th, 2020. DO measurements generally decreased over the course of the study until the end of August (Figure 5-13). DO measurements were all above the Class 2B stream standard except on one occasion, August 25th, 2020, when they fell below the 5.00 mg/l standard. On this date DO measurements ranged from 4.24–4.40 mg/L. Measurements of temperature and DO were generally taken at the same depths at each station during all 11 sampling events (Figure 5-14).

Temperature and DO profiles taken during each sampling event show a well-mixed water column except on May 12th, July 14th and 28th, and August 11th, 2020 when DO concentrations were slightly higher on the surface than the rest of the water column (Figure 5-15, Figure 5-16).

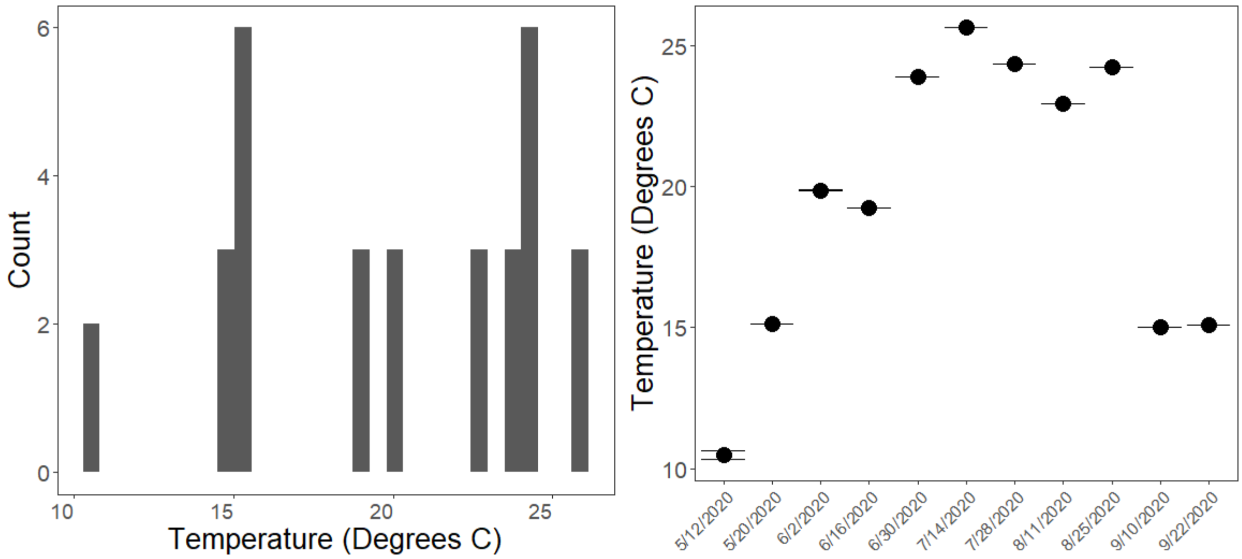

Figure 5-12. Histogram of temperature measurements (left) and mean temperature for each sampling event (right) at the Tailrace Near Retaining Wall site. Whiskers represent standard error.

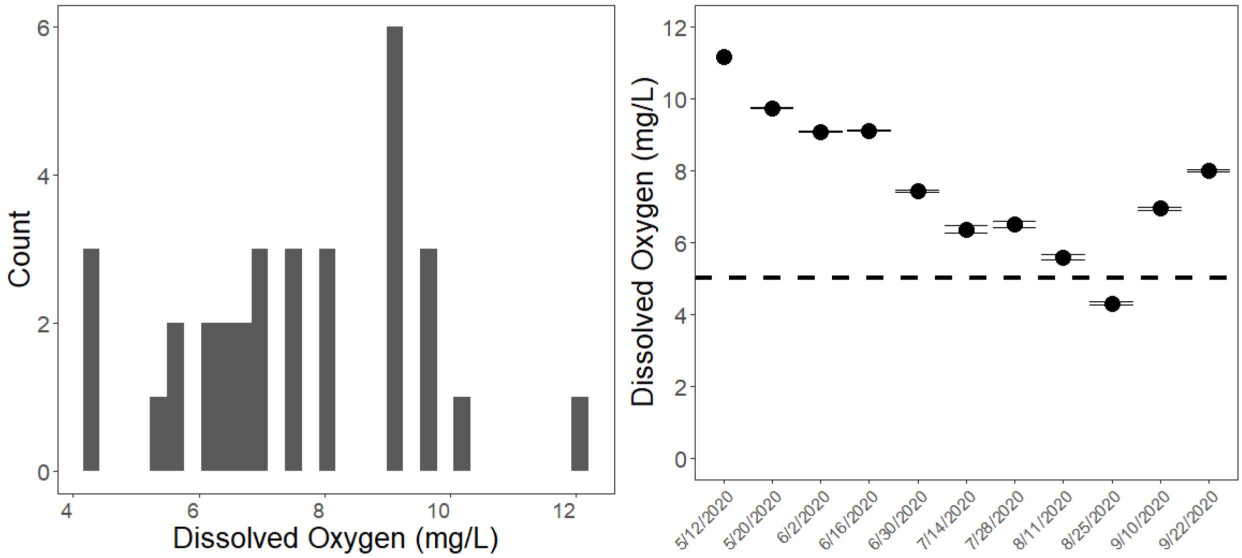

Figure 5-13. Histogram of dissolved oxygen measurements (left) and mean dissolved oxygen concentration (mg/L) for each sampling event (right) at the Tailrace Near Retaining Wall site. Whiskers represent standard error and dotted black line represents the Minnesota Class 2B stream standard of 5.00 mg/L.

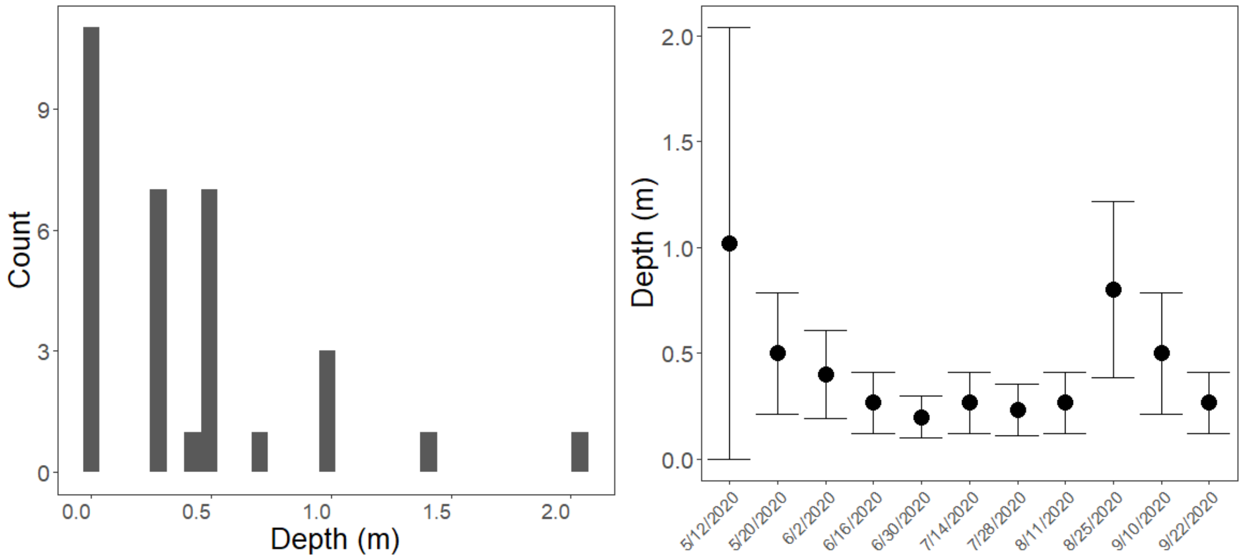

Figure 5-14. Histogram of depth measurements (left) and depth (m) for each sampling event (right) at the Tailrace Near Retaining Wall site. Whiskers represent standard error.

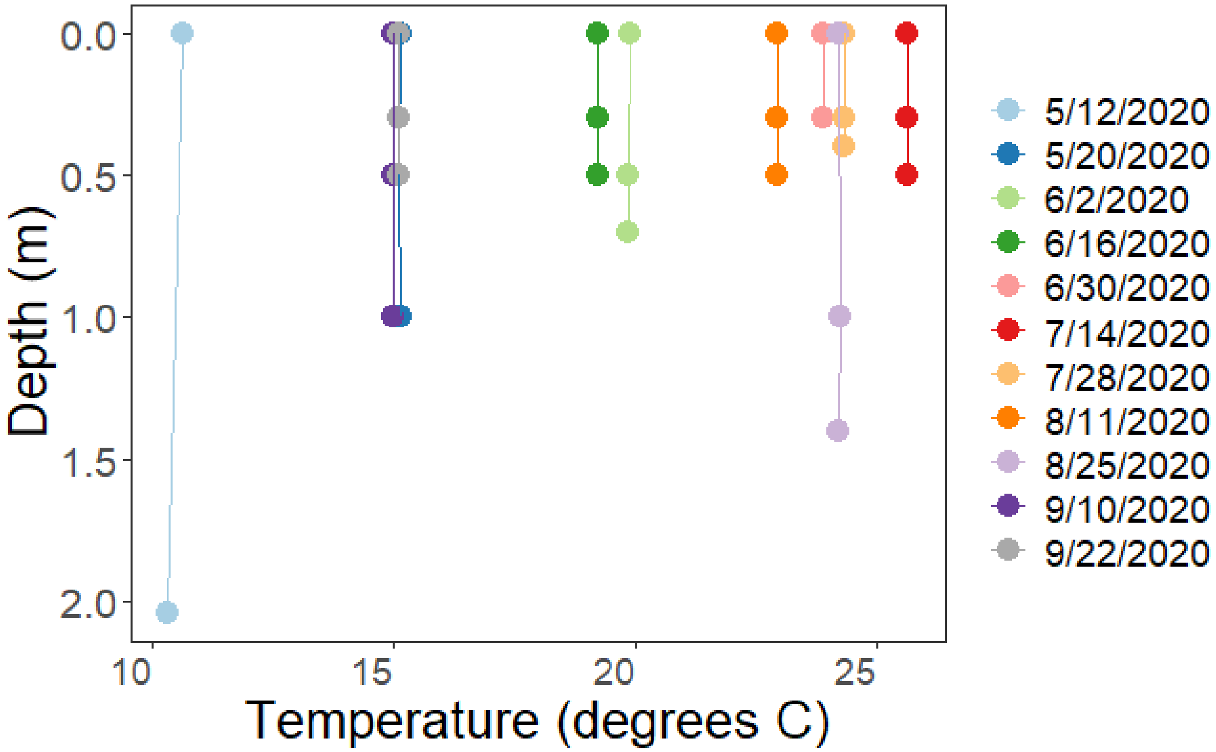

Figure 5-15. Temperature profiles at the Tailrace Near Retaining Wall site for each sampling event.

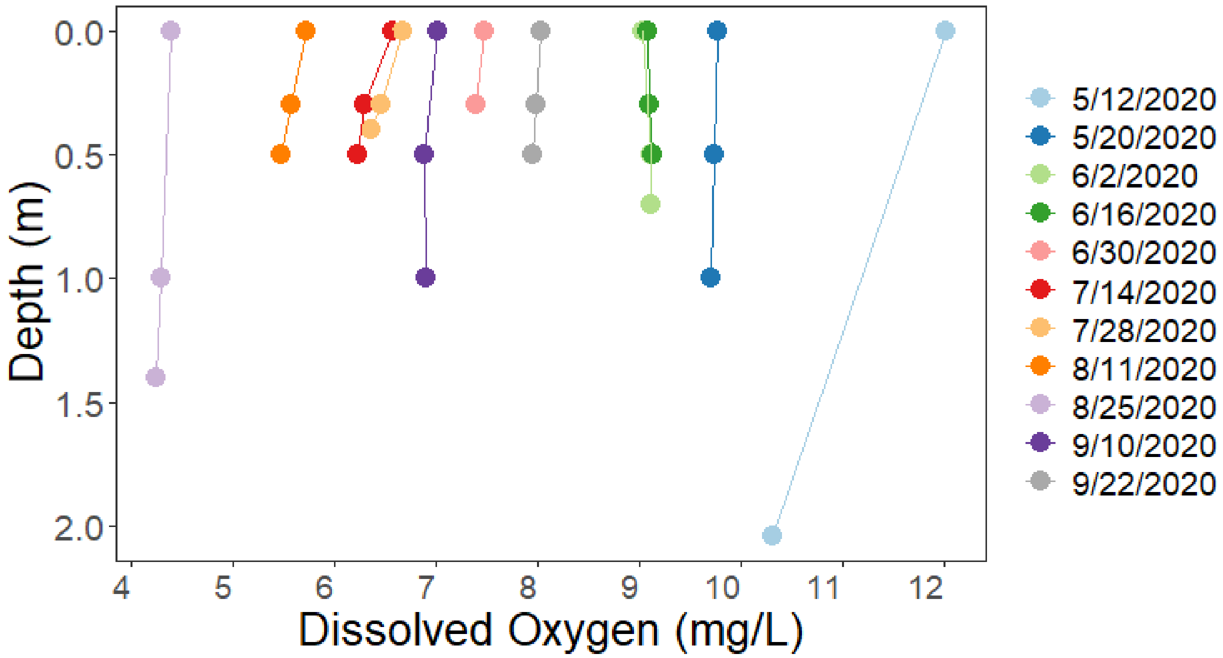

Figure 5-16. Dissolved oxygen profiles at the Tailrace Near Retaining Wall site for each sampling event.

5.4 DOWNSTREAM OF HIGHWAY 169 BRIDGE

The Downstream of Highway 169 Bridge site is a shallow site downstream of Blandin Dam. Water temperature and DO measurements were taken up to 0.6 m below the water surface during the study. Water temperature measurements at the site ranged from 10.6–25.6 degrees C. Water temperature generally increased over the course of the study until mid-July (Figure 5-17) corresponding to an increase in air temperatures over the summer months. Water temperatures reached a maximum during the July 14th, 2020 sampling event. Water temperatures decreased over the final five sampling events except for a short spike in temperature on August 25th, 2020.

DO measurements at the Downstream of Highway 169 Bridge site ranged from 4.55–10.3 mg/L and the lowest readings occurred on August 25th, 2020. DO measurements generally decreased over the course of the study until the end of August (Figure 5-18). DO measurements were all above the Class 2B stream standard except on one occasion, August 25th, 2020 when they fell slightly below 5.00 mg/L. On this date DO measurements ranged from 4.55–4.57 mg/L. Measurements of temperature and DO were generally taken at the same depths at each station during all 11 sampling events (Figure 5-19).

Temperature and DO profiles taken during each sampling event show a well-mixed site except on May 20th, June 30th, and July 28th when DO was slightly higher on the surface than the rest of the water column (Figure 5-20, Figure 5-21).

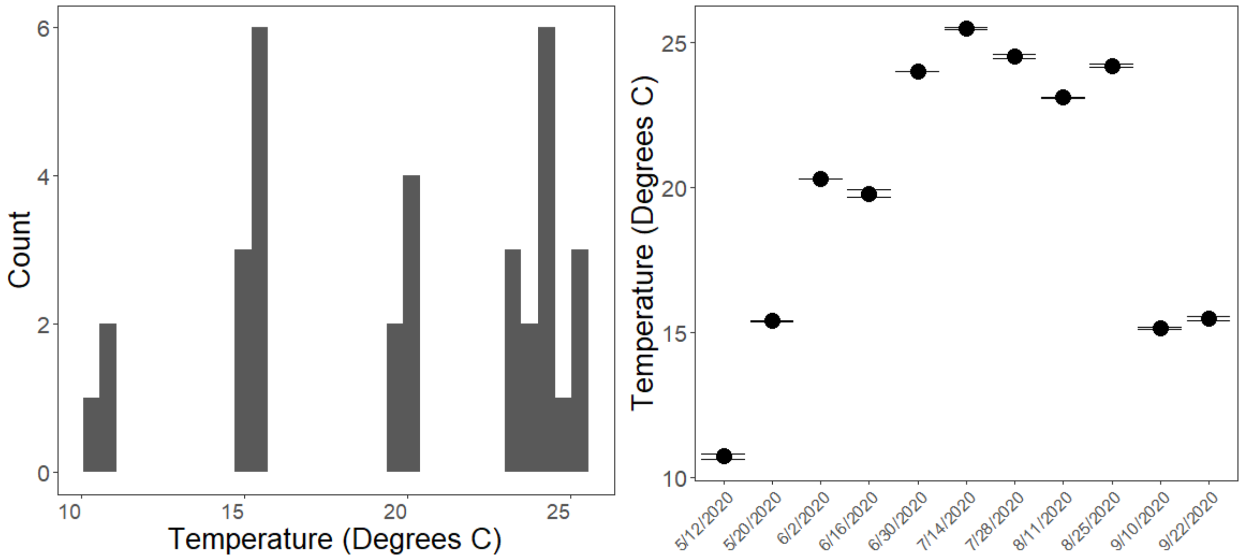

Figure 5-17. Histogram of temperature measurements (left) and mean temperature for each sampling event (right) at the Downstream of Highway 169 Bridge site. Whiskers represent standard error.

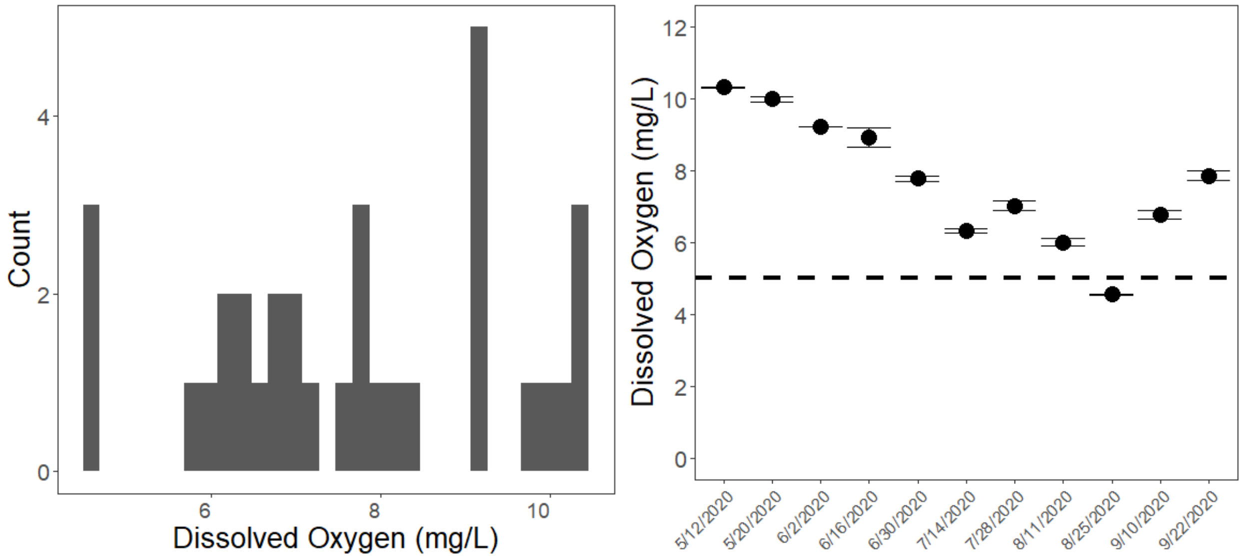

Figure 5-18. Histogram of dissolved oxygen measurements (left) and mean dissolved oxygen concentration (mg/L) for each sampling event (right) at the Downstream of Highway 169 Bridge site. Whiskers represent standard error and dotted black line represents the Minnesota Class 2B stream standard of 5.00 mg/L.

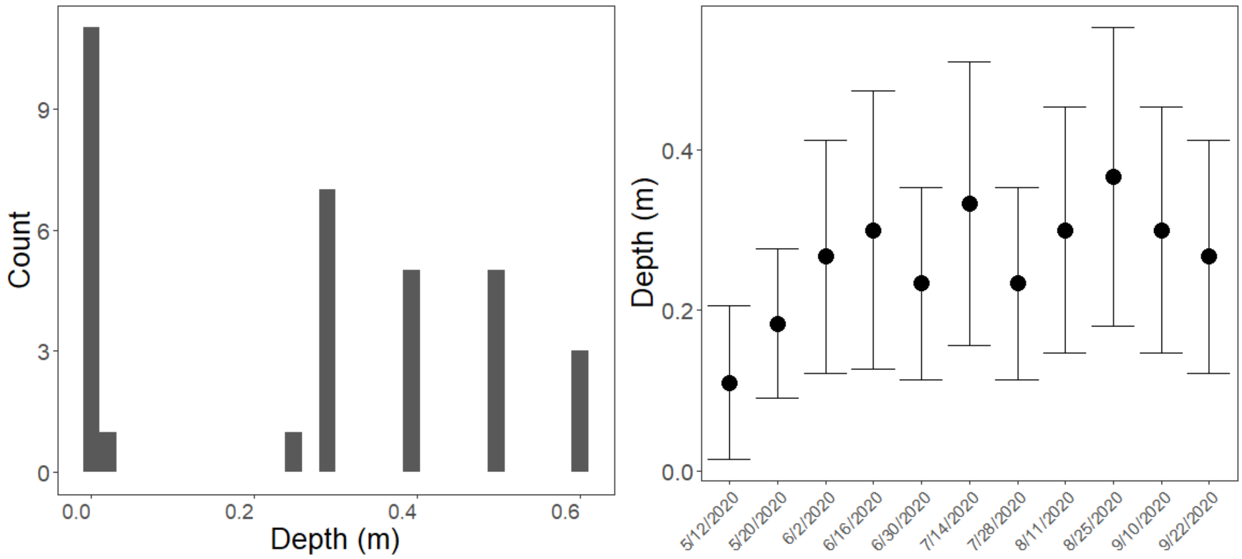

Figure 5-19. Histogram of depth measurements (left) and depth (m) for each sampling event (right) at the Downstream of Highway 169 Bridge site. Whiskers represent standard error.

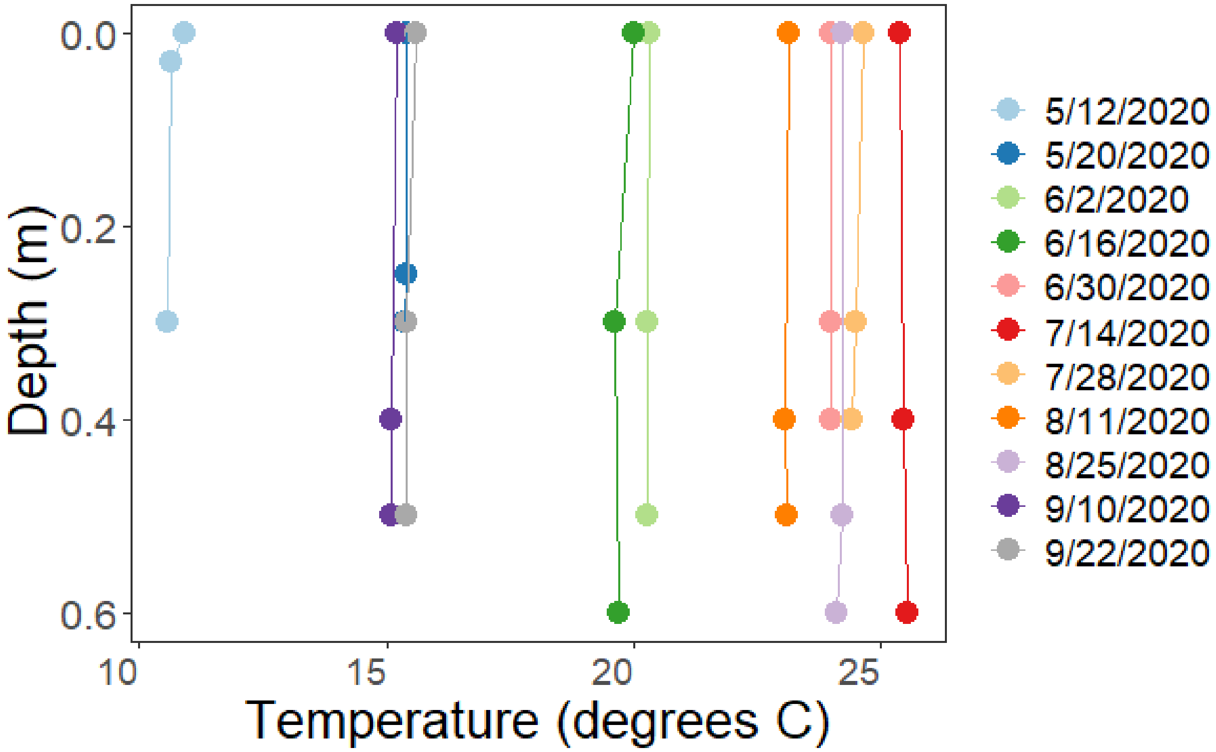

Figure 5-20. Temperature profiles at the Downstream of Hwy 169 Bridge site for each sampling event.

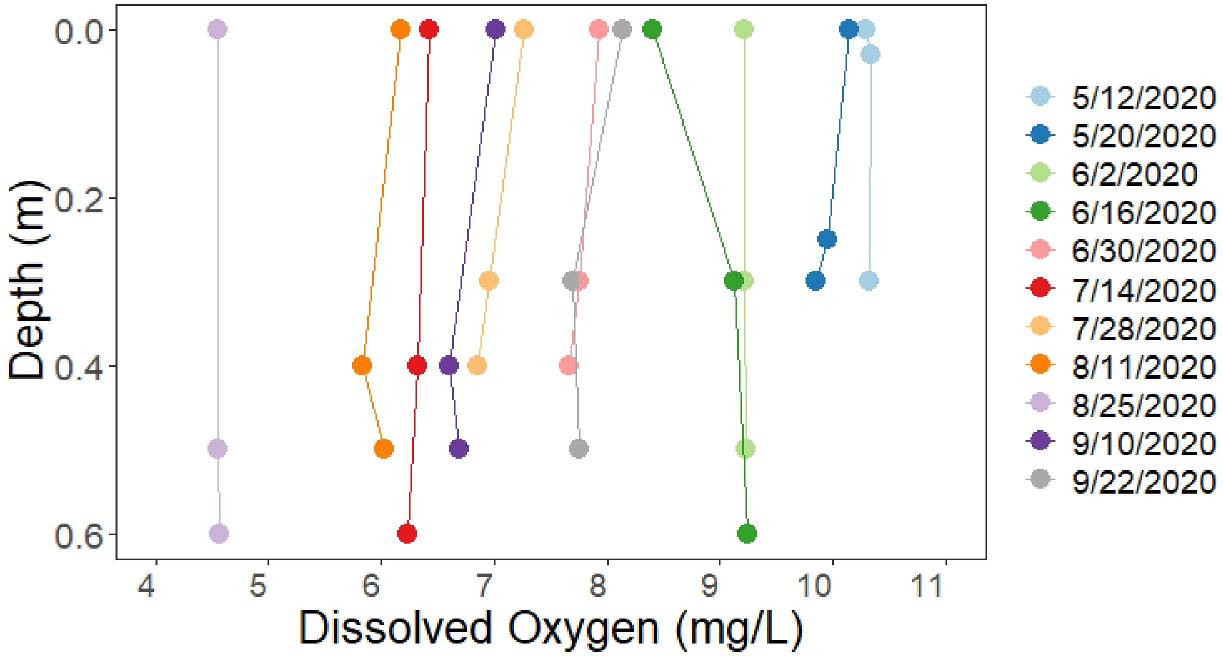

Figure 5-21. Dissolved oxygen profiles at the Downstream of Highway 169 Bridge site for each sampling event.

6.0 Summary

A total of 219 DO and water temperature readings were collected over the course of the study at the Grand Rapids Project.

Overall, the observed readings were typical of well-mixed, warmwater rivers in Minnesota. Water temperature generally increased at all sites from May 12th–July 14th, 2020 then decreased for the remainder of the monitoring period apart from a spike in water temperature on August 25th, 2020. DO readings at all stations were above the Minnesota Class 2B stream standard of 5.00 mg/L for 10 of the 11 sampling events. On August 25th, 2020 the DO readings at all sampling stations were below the 5.00 mg/L state standard. During this event, DO readings ranged from 4.18–4.57 mg/L.

There were a few instances of DO and temperature stratification at the monitored sites, but stratification was not strong and was not a consistent occurrence.

7.0 References

Minnesota Power (2019). Revised Study Plan: Grand Rapids Hydroelectric Project (FERC No. 2362) and Prairie River Hydroelectric Project (FERC No. 2361). Prepared by HDR Engineering, Inc. for Minnesota Power. September 23, 2019.

8.0 Appendix A: Raw Data

Table A-1. Water quality data from all stations at the Grand Rapids Project site for all sampling events**.**

Site	Station	Date	Time	Depth (m)	Temperature (degrees C)	Dissolved oxygen (mg/L)	Dissolved oxygen (percent saturation)
Grand Rapids	Log Boom Corner	5/12/2020	11:26	0	10.71	10.33	-
Grand Rapids	Log Boom Corner	5/12/2020	11:26	1	10.52	10.37	-
Grand Rapids	Log Boom Corner	5/12/2020	11:26	2	10.23	10.22	-
Grand Rapids	Log Boom Corner	5/12/2020	11:26	3	10.15	10.2	-
Grand Rapids	Log Boom Corner	5/12/2020	11:26	4	10.15	10.19	-
Grand Rapids	Log Boom Corner	5/12/2020	11:26	4.4	10.13	10.18	-
Grand Rapids	Turbine Intake Area	5/12/2020	11:10	0	10.61	10.38	-
Grand Rapids	Turbine Intake Area	5/12/2020	11:10	1	10.58	10.37	-
Grand Rapids	Turbine Intake Area	5/12/2020	11:10	2	10.58	10.3	-
Grand Rapids	Turbine Intake Area	5/12/2020	11:10	3	10.57	10.36	-
Grand Rapids	Turbine Intake Area	5/12/2020	11:10	4	10.57	10.32	-
Grand Rapids	Turbine Intake Area	5/12/2020	11:10	4.2	10.58	10.33	-
Grand Rapids	Tailrace Near Retaining Wall	5/12/2020	11:48	0	10.65	12.02	-
Grand Rapids	Tailrace Near Retaining Wall	5/12/2020	11:48	2.04	10.33	10.31	-
Grand Rapids	Hwy 169 Bridge	5/12/2020	12:26	0	10.9	10.3	-

Grand Rapids	Hwy 169 Bridge	5/12/2020	12:26	0.03	10.65	10.33	-
Grand Rapids	Hwy 169 Bridge	5/12/2020	12:26	0.3	10.58	10.32	-
Grand Rapids	Log Boom Corner	5/20/2020	9:43	0	15.2	9.76	-
Grand Rapids	Log Boom Corner	5/20/2020	9:43	1	15.21	9.72	-
Grand Rapids	Log Boom Corner	5/20/2020	9:43	2	15.2	9.69	-
Grand Rapids	Log Boom Corner	5/20/2020	9:43	3	15.19	9.66	-
Grand Rapids	Log Boom Corner	5/20/2020	9:43	4	15.19	9.64	-
Grand Rapids	Log Boom Corner	5/20/2020	9:43	4.9	15.2	9.61	-
Grand Rapids	Turbine Intake Area	5/20/2020	10:10	0	15.18	9.77	-
Grand Rapids	Turbine Intake Area	5/20/2020	10:10	1	15.18	9.71	-
Grand Rapids	Turbine Intake Area	5/20/2020	10:10	2	15.18	9.67	-
Grand Rapids	Turbine Intake Area	5/20/2020	10:10	3	15.19	9.64	-
Grand Rapids	Turbine Intake Area	5/20/2020	10:10	4	15.18	9.63	-
Grand Rapids	Turbine Intake Area	5/20/2020	10:10	5	15.18	9.6	-
Grand Rapids	Turbine Intake Area	5/20/2020	10:10	6	15.18	9.6	-
Grand Rapids	Tailrace Near Retaining Wall	5/20/2020	10:25	0	15.13	9.78	-
Grand Rapids	Tailrace Near Retaining Wall	5/20/2020	10:25	0.5	15.12	9.74	-
Grand Rapids	Tailrace Near Retaining Wall	5/20/2020	10:25	1	15.13	9.71	-
Grand Rapids	Hwy 169 Bridge	5/20/2020	10:50	0	15.41	10.15	-
Grand Rapids	Hwy 169 Bridge	5/20/2020	10:50	0.25	15.4	9.95	-
Grand Rapids	Hwy 169 Bridge	5/20/2020	10:50	0.3	15.35	9.85	-
Grand Rapids	Log Boom Corner	6/2/2020	11:27	0	20.89	9.58	107.4

Grand Rapids	Log Boom Corner	6/2/2020	11:27	1	20.81	9.65	107.9
Grand Rapids	Log Boom Corner	6/2/2020	11:27	2	19.96	9.22	101.2
Grand Rapids	Log Boom Corner	6/2/2020	11:27	3	19.05	8.6	92.8
Grand Rapids	Log Boom Corner	6/2/2020	11:27	4	18.82	8.3	89.1
Grand Rapids	Log Boom Corner	6/2/2020	11:27	5	18.81	8.09	86.1
Grand Rapids	Turbine Intake Area	6/2/2020	11:48	0	21.16	9.63	108.5
Grand Rapids	Turbine Intake Area	6/2/2020	11:48	1	21.2	9.64	108.7
Grand Rapids	Turbine Intake Area	6/2/2020	11:48	2	21.21	9.63	108.5
Grand Rapids	Turbine Intake Area	6/2/2020	11:48	3	21.18	9.62	108.4
Grand Rapids	Turbine Intake Area	6/2/2020	11:48	4	21.12	9.61	108.1
Grand Rapids	Turbine Intake Area	6/2/2020	11:48	5	20.76	9.45	105.6
Grand Rapids	Tailrace Near Retaining Wall	6/2/2020	12:03	0	19.88	9.03	99.2
Grand Rapids	Tailrace Near Retaining Wall	6/2/2020	12:03	0.5	19.87	9.11	100
Grand Rapids	Tailrace Near Retaining Wall	6/2/2020	12:03	0.7	19.84	9.12	100.1
Grand Rapids	Hwy 169 Bridge	6/2/2020	12:34	0	20.31	9.22	102.2
Grand Rapids	Hwy 169 Bridge	6/2/2020	12:34	0.3	20.27	9.21	101.8
Grand Rapids	Hwy 169 Bridge	6/2/2020	12:34	0.5	20.28	9.23	102.7
Grand Rapids	Log Boom Corner	6/16/2020	10:09	0	19.39	9.08	98.6
Grand Rapids	Log Boom Corner	6/16/2020	10:09	1	19.38	9.12	99.1
Grand Rapids	Log Boom Corner	6/16/2020	10:09	2	19.1	9.14	98.8
Grand Rapids	Log Boom Corner	6/16/2020	10:09	3	19.06	9.08	98.1
Grand Rapids	Log Boom Corner	6/16/2020	10:09	4	19.02	8.97	96.9

Grand Rapids	Log Boom Corner	6/16/2020	10:09	5	19.01	8.88	95.8
Grand Rapids	Turbine Intake Area	6/16/2020	10:25	0	19.38	9.03	98.1
Grand Rapids	Turbine Intake Area	6/16/2020	10:25	1	19.16	9.02	97.6
Grand Rapids	Turbine Intake Area	6/16/2020	10:25	2	19.14	8.49	97.3
Grand Rapids	Turbine Intake Area	6/16/2020	10:25	3	19.15	8.98	97.2
Grand Rapids	Turbine Intake Area	6/16/2020	10:25	4	19.15	8.98	97.1
Grand Rapids	Turbine Intake Area	6/16/2020	10:25	4.5	19.13	8.96	97
Grand Rapids	Tailrace Near Retaining Wall	6/16/2020	10:45	0	19.23	9.08	98.4
Grand Rapids	Tailrace Near Retaining Wall	6/16/2020	10:45	0.3	19.22	9.1	98.6
Grand Rapids	Tailrace Near Retaining Wall	6/16/2020	10:45	0.5	19.23	9.13	98.9
Grand Rapids	Hwy 169 Bridge	6/16/2020	11:15	0	20.01	8.4	98.4
Grand Rapids	Hwy 169 Bridge	6/16/2020	11:15	0.3	19.63	9.12	99.5
Grand Rapids	Hwy 169 Bridge	6/16/2020	11:15	0.6	19.71	9.25	101.2
Grand Rapids	Log Boom Corner	6/30/2020	9:58	0	24.35	8.19	98.11
Grand Rapids	Log Boom Corner	6/30/2020	9:58	1	24.27	8.08	96.6
Grand Rapids	Log Boom Corner	6/30/2020	9:58	2	23.97	7.65	91
Grand Rapids	Log Boom Corner	6/30/2020	9:58	3	23.75	7.37	87.4
Grand Rapids	Log Boom Corner	6/30/2020	9:58	4	23.56	6.97	82.3
Grand Rapids	Log Boom Corner	6/30/2020	9:58	5	23.55	6.67	78.6
Grand Rapids	Turbine Intake Area	6/30/2020	10:12	0	24.32	8.36	101
Grand Rapids	Turbine Intake Area	6/30/2020	10:12	1	24.34	8.31	99.5

Grand Rapids	Turbine Intake Area	6/30/2020	10:12	2	24.38	8.31	99.5
Grand Rapids	Turbine Intake Area	6/30/2020	10:12	3	24.28	8.17	97.6
Grand Rapids	Turbine Intake Area	6/30/2020	10:12	4	24.19	8.05	96.1
Grand Rapids	Turbine Intake Area	6/30/2020	10:12	4.5	24.18	8.02	95.6
Grand Rapids	Tailrace Near Retaining Wall	6/30/2020	10:27	0	23.87	7.48	88.7
Grand Rapids	Tailrace Near Retaining Wall	6/30/2020	10:27	0.3	23.89	7.4	87.9
Grand Rapids	Tailrace Near Retaining Wall	6/30/2020	10:27	0.3	23.89	7.39	87.7
Grand Rapids	Hwy 169 Bridge	6/30/2020	11:04	0	24.01	7.93	94.2
Grand Rapids	Hwy 169 Bridge	6/30/2020	11:04	0.3	23.98	7.76	92.4
Grand Rapids	Hwy 169 Bridge	6/30/2020	11:04	0.4	23.98	7.67	91.1
Grand Rapids	Log Boom Corner	7/14/2020	10:14	0	25.65	6.48	79.3
Grand Rapids	Log Boom Corner	7/14/2020	10:14	1	25.66	6.41	78.6
Grand Rapids	Log Boom Corner	7/14/2020	10:14	2	25.66	6.32	77.4
Grand Rapids	Log Boom Corner	7/14/2020	10:14	3	25.66	6.29	77.1
Grand Rapids	Log Boom Corner	7/14/2020	10:14	4	25.65	6.28	76.9
Grand Rapids	Log Boom Corner	7/14/2020	10:14	5	25.65	6.24	76.5
Grand Rapids	Log Boom Corner	7/14/2020	10:14	6	25.64	6	73.6
Grand Rapids	Turbine Intake Area	7/14/2020	10:31	0	25.62	6.39	78.3
Grand Rapids	Turbine Intake Area	7/14/2020	10:31	1	25.64	6.32	77.5
Grand Rapids	Turbine Intake Area	7/14/2020	10:31	2	25.62	6.28	76.9
Grand Rapids	Turbine Intake Area	7/14/2020	10:31	3	25.63	6.25	76.6

Grand Rapids	Turbine Intake Area	7/14/2020	10:31	4	25.64	6.23	76.3
Grand Rapids	Turbine Intake Area	7/14/2020	10:31	5	25.64	6.21	76.1
Grand Rapids	Turbine Intake Area	7/14/2020	10:31	6	25.64	6.19	75.9
Grand Rapids	Tailrace Near Retaining Wall	7/14/2020	10:47	0	25.63	6.58	80.7
Grand Rapids	Tailrace Near Retaining Wall	7/14/2020	10:47	0.3	25.64	6.3	77.2
Grand Rapids	Tailrace Near Retaining Wall	7/14/2020	10:47	0.5	25.64	6.23	76.4
Grand Rapids	Hwy 169 Bridge	7/14/2020	11:10	0	25.4	6.42	78.3
Grand Rapids	Hwy 169 Bridge	7/14/2020	11:10	0.4	25.46	6.32	77.3
Grand Rapids	Hwy 169 Bridge	7/14/2020	11:10	0.6	25.55	6.23	76.2
Grand Rapids	Log Boom Corner	7/28/2020	9:33	0	24.3	6.46	77.2
Grand Rapids	Log Boom Corner	7/28/2020	9:33	1	24.3	6.38	75.3
Grand Rapids	Log Boom Corner	7/28/2020	9:33	2	24.3	6.34	75.8
Grand Rapids	Log Boom Corner	7/28/2020	9:33	3	24.29	6.3	75.3
Grand Rapids	Log Boom Corner	7/28/2020	9:33	4	24.29	6.28	75.1
Grand Rapids	Log Boom Corner	7/28/2020	9:33	5	24.28	6.26	74.8
Grand Rapids	Log Boom Corner	7/28/2020	9:33	6	24.28	6.22	74.4
Grand Rapids	Turbine Intake Area	7/28/2020	9:49	0	24.36	6.49	77.6
Grand Rapids	Turbine Intake Area	7/28/2020	9:49	1	24.37	6.41	76.8
Grand Rapids	Turbine Intake Area	7/28/2020	9:49	2	24.36	6.35	76.1
Grand Rapids	Turbine Intake Area	7/28/2020	9:49	3	24.33	6.31	75.5
Grand Rapids	Turbine Intake Area	7/28/2020	9:49	4	24.33	6.3	75.4

Grand Rapids	Turbine Intake Area	7/28/2020	9:49	5	24.34	6.33	75.9
Grand Rapids	Turbine Intake Area	7/28/2020	9:49	6	24.33	6.34	75.9
Grand Rapids	Tailrace Near Retaining Wall	7/28/2020	10:02	0	24.32	6.67	79.9
Grand Rapids	Tailrace Near Retaining Wall	7/28/2020	10:02	0.3	24.33	6.46	77.3
Grand Rapids	Tailrace Near Retaining Wall	7/28/2020	10:02	0.4	24.33	6.36	76.2
Grand Rapids	Hwy 169 Bridge	7/28/2020	10:28	0	24.63	7.27	87.6
Grand Rapids	Hwy 169 Bridge	7/28/2020	10:28	0.3	24.48	6.96	83.5
Grand Rapids	Hwy 169 Bridge	7/28/2020	10:28	0.4	24.43	6.85	82.1
Grand Rapids	Log Boom Corner	8/11/2020	9:33	0	22.85	5.9	68.9
Grand Rapids	Log Boom Corner	8/11/2020	9:33	1	22.85	5.64	65.6
Grand Rapids	Log Boom Corner	8/11/2020	9:33	2	22.85	5.46	63.5
Grand Rapids	Log Boom Corner	8/11/2020	9:33	3	22.85	5.37	62.4
Grand Rapids	Log Boom Corner	8/11/2020	9:33	4	22.85	5.33	62
Grand Rapids	Log Boom Corner	8/11/2020	9:33	5	22.85	5.27	61.3
Grand Rapids	Log Boom Corner	8/11/2020	9:33	6	22.85	5.1	59.4
Grand Rapids	Turbine Intake Area	8/11/2020	9:48	0	23.11	6.1	71.4
Grand Rapids	Turbine Intake Area	8/11/2020	9:48	1	23.12	5.98	69.9
Grand Rapids	Turbine Intake Area	8/11/2020	9:48	2	23.11	5.9	69.1
Grand Rapids	Turbine Intake Area	8/11/2020	9:48	3	23.12	5.87	68.7
Grand Rapids	Turbine Intake Area	8/11/2020	9:48	4	23.1	5.82	68.1
Grand Rapids	Turbine Intake Area	8/11/2020	9:48	4.5	23.1	5.8	67.8

Grand Rapids	Tailrace Near Retaining Wall	8/11/2020	10:59	0	22.94	5.72	66.7
Grand Rapids	Tailrace Near Retaining Wall	8/11/2020	10:59	0.3	22.94	5.57	64.9
Grand Rapids	Tailrace Near Retaining Wall	8/11/2020	10:59	0.5	22.93	5.48	63.9
Grand Rapids	Hwy 169 Bridge	8/11/2020	11:22	0	23.13	6.17	72.3
Grand Rapids	Hwy 169 Bridge	8/11/2020	11:22	0.5	23.1	6.03	70.5
Grand Rapids	Hwy 169 Bridge	8/11/2020	11:22	0.4	23.06	5.84	68.3
Grand Rapids	Log Boom Corner	8/25/2020	9:27	0	24.2	4.52	54.2
Grand Rapids	Log Boom Corner	8/25/2020	9:27	1	24.21	4.44	53.1
Grand Rapids	Log Boom Corner	8/25/2020	9:27	2	24.23	4.35	51.9
Grand Rapids	Log Boom Corner	8/25/2020	9:27	3	24.23	4.3	51.3
Grand Rapids	Log Boom Corner	8/25/2020	9:27	4	24.22	4.28	51.1
Grand Rapids	Log Boom Corner	8/25/2020	9:27	5	24.22	4.24	50.7
Grand Rapids	Turbine Intake Area	8/25/2020	9:39	0	24.28	4.55	54.6
Grand Rapids	Turbine Intake Area	8/25/2020	9:39	1	24.28	4.4	52.6
Grand Rapids	Turbine Intake Area	8/25/2020	9:39	2	24.28	4.3	51.4
Grand Rapids	Turbine Intake Area	8/25/2020	9:39	3	24.28	4.26	50.9
Grand Rapids	Turbine Intake Area	8/25/2020	9:39	4	24.27	4.23	50.5
Grand Rapids	Turbine Intake Area	8/25/2020	9:39	5	24.26	4.19	50
Grand Rapids	Turbine Intake Area	8/25/2020	9:39	6	24.27	4.18	50
Grand Rapids	Tailrace Near Retaining Wall	8/25/2020	9:52	0	24.21	4.4	52.5

Grand Rapids	Tailrace Near Retaining Wall	8/25/2020	9:52	1	24.23	4.29	51.2
Grand Rapids	Tailrace Near Retaining Wall	8/25/2020	9:52	1.4	24.22	4.24	50.7
Grand Rapids	Hwy 169 Bridge	8/25/2020	10:23	0	24.24	4.55	54.4
Grand Rapids	Hwy 169 Bridge	8/25/2020	10:23	0.5	24.23	4.55	54.4
Grand Rapids	Hwy 169 Bridge	8/25/2020	10:23	0.6	24.09	4.57	54.5
Grand Rapids	Log Boom Corner	9/10/2020	10:05	0	15.1	7.01	-
Grand Rapids	Log Boom Corner	9/10/2020	10:05	1	15.1	6.95	-
Grand Rapids	Log Boom Corner	9/10/2020	10:05	2	15.1	6.91	-
Grand Rapids	Log Boom Corner	9/10/2020	10:05	3	15	6.75	-
Grand Rapids	Log Boom Corner	9/10/2020	10:05	4	15.1	6.48	-
Grand Rapids	Log Boom Corner	9/10/2020	10:05	5	15.1	6.3	-
Grand Rapids	Log Boom Corner	9/10/2020	10:05	6	15	6.26	-
Grand Rapids	Turbine Intake Area	9/10/2020	10:29	0	14.9	6.83	-
Grand Rapids	Turbine Intake Area	9/10/2020	10:29	1	14.9	6.83	-
Grand Rapids	Turbine Intake Area	9/10/2020	10:29	2	14.9	6.78	-
Grand Rapids	Turbine Intake Area	9/10/2020	10:29	3	14.9	6.79	-
Grand Rapids	Turbine Intake Area	9/10/2020	10:29	4	14.9	6.76	-
Grand Rapids	Turbine Intake Area	9/10/2020	10:29	5	14.9	6.67	-
Grand Rapids	Turbine Intake Area	9/10/2020	10:29	6	14.9	6.54	-
Grand Rapids	Tailrace Near Retaining Wall	9/10/2020	10:43	0	15	7.02	-
Grand Rapids	Tailrace Near Retaining Wall	9/10/2020	10:43	0.5	15	6.89	-

Grand Rapids	Tailrace Near Retaining Wall	9/10/2020	10:43	1	15	6.91	-
Grand Rapids	Hwy 169 Bridge	9/10/2020	11:14	0	15.2	7.01	-
Grand Rapids	Hwy 169 Bridge	9/10/2020	11:14	0.4	15.1	6.6	-
Grand Rapids	Hwy 169 Bridge	9/10/2020	11:14	0.5	15.1	6.69	-
Grand Rapids	Log Boom Corner	9/22/2020	11:00	0	15.6	7.98	80.2
Grand Rapids	Log Boom Corner	9/22/2020	11:00	1	15.4	7.4	74
Grand Rapids	Log Boom Corner	9/22/2020	11:00	2	15.2	7.69	76.6
Grand Rapids	Log Boom Corner	9/22/2020	11:00	3	15.1	7.77	77.5
Grand Rapids	Log Boom Corner	9/22/2020	11:00	4	15.1	7.48	74.3
Grand Rapids	Log Boom Corner	9/22/2020	11:00	5	15.1	7.47	74.3
Grand Rapids	Log Boom Corner	9/22/2020	11:00	6	15.1	7.14	71.2
Grand Rapids	Turbine Intake Area	9/22/2020	11:19	0	15.4	8.15	81.7
Grand Rapids	Turbine Intake Area	9/22/2020	11:19	1	15.4	8.03	80.4
Grand Rapids	Turbine Intake Area	9/22/2020	11:19	2	15.3	7.98	79.8
Grand Rapids	Turbine Intake Area	9/22/2020	11:19	3	15.3	7.73	77.3
Grand Rapids	Turbine Intake Area	9/22/2020	11:19	4	15.3	7.75	77.4
Grand Rapids	Turbine Intake Area	9/22/2020	11:19	5	15.3	7.72	77.1
Grand Rapids	Turbine Intake Area	9/22/2020	11:19	6	15.3	7.13	71.3
Grand Rapids	Tailrace Near Retaining Wall	9/22/2020	11:32	0	15.1	8.03	80
Grand Rapids	Tailrace Near Retaining Wall	9/22/2020	11:32	0.3	15.1	7.99	79.4
Grand Rapids	Tailrace Near Retaining Wall	9/22/2020	11:32	0.5	15.1	7.96	79.2

Grand Rapids	Hwy 169 Bridge	9/22/2020	11:50	0	15.6	8.13	81.7
Grand Rapids	Hwy 169 Bridge	9/22/2020	11:50	0.3	15.4	7.7	77.3
Grand Rapids	Hwy 169 Bridge	9/22/2020	11:50	0.5	15.4	7.75	77.4

Table A-2. Reservoir elevation and discharge at the Grand Rapids Project site. Discharge data was obtained from USGS site 05211000 Mississippi River at Grand Rapids, MN.

Site	Station	Date	Flow (cfs)	Elevation (ft)
Grand Rapids	Grand Rapids Reservoir	5/12/2020	1370	1268.18
Grand Rapids	Grand Rapids Reservoir	5/20/2020	1040	1268.16
Grand Rapids	Grand Rapids Reservoir	6/2/2020	902	1268.17
Grand Rapids	Grand Rapids Reservoir	6/16/2020	1000	1268.2
Grand Rapids	Grand Rapids Reservoir	6/30/2020	633	1268.21
Grand Rapids	Grand Rapids Reservoir	7/14/2020	595	1268.2
Grand Rapids	Grand Rapids Reservoir	7/28/2020	1150	1268.23
Grand Rapids	Grand Rapids Reservoir	8/11/2020	1520	1268.21
Grand Rapids	Grand Rapids Reservoir	8/25/2020	1850	1268.22
Grand Rapids	Grand Rapids Reservoir	9/10/2020	1400	1268.23
Grand Rapids	Grand Rapids Reservoir	9/22/2020	1340	1268.19

Prairie River Hydroelectric Project
FERC License No. 2361
DO and Temp. Study Measurements

Date: 5/12/2020

Weather Conditions and Outside Temp: 52°, sunny, wind 6mph, humidity 24%

Flow Conditions (Observations and flow from MP): (see below) Wendy Gomez

Temp and DO Meter Model & Calibration Start time:

Name of Person Collecting Data measurements: 131 units, 83 thru waste gates

Comments: Upstream of trash rack, I wasn't able to get the sensor more than ~4 feet from shore with extender pole → lowest reading at 1.839 meters.

Upstream of Coarse Trash Rack
Time: 1:51

GPS: 47.287098, -93.500178

Depth (meters)		Temp (C)	DO (mg/L)
Surface		12,501	9.77
1 m	0,997	11,446	9.58
2 m	1.839	11.508	9,58
3 m			
4 m			
5 m			
6 m			

Tailrace Area
Time: 1:30

GPS: 47.284471, -93.499681

Depth (meters)		Temp (C)	DO (mg/L)
Surface	0.00	12,414	9.59
Mid	.168	12,443	9.88
Bttm	0.442	12.464	9.89

Bypass Reach
Time: 2:21

GPS: 47.2854610, -93.4980522

Depth (meters)		Temp (C)	DO (mg/L)
Surface	0.136	12.155	10.39
Mid	0.141	12,132	10.40
Bttm	0.151	12.136	10.39

Prairie River Hydroelectric Project
FERC License No. 2361
DO and Temp. Study Measurements

Date: 5/20/2020

Weather Conditions and Outside Temp: Sunny, 77° F, Winds SSE at 10-20 mph.

Flow Conditions (Observations and flow from MP): Unit 101 ~~[illegible]~~ waste gates = 79 total stn flow - 180

Temp and DO Meter Model & Calibration Start time: 9:25 am, 56° F at G.R Dam.

Name of Person Collecting Data measurements: Wendy Gomez

Comments: Bottom level at trash rack was 2m,

Upstream of Coarse Trash Rack
Time: 12:02
GPS: 47.2869760, -93.5001175

Depth (meters)	Temp (C)	DO (mg/L)
Surface .2	15.54	9.85
1 m	14.90	9.47
2 m	~~6.~~ 14.48	9.43
3 m		
4 m		
5 m		
6 m		

Tailrace Area
Time: 11:45
GPS: 47.2846038, -93.4997819

Depth (meters)		Temp (C)	DO (mg/L)
Surface	.2	14.75	9.71
Mid	.33	14.75	9.62
Bttm	.6	14.73	9.52

Bypass Reach
Time: 12:25 Lots of mosquitoes!
GPS: 47.2854813, -93.498034

Depth (meters)		Temp (C)	DO (mg/L)
Surface	.2	15.14	9.95
Mid	.25	14.78	9.99
Bttm	.3	14.71	9.97

Prairie River Hydroelectric Project #2361
Water Quality Study – Data Collection

Date: 6/2/2020

Data Collector: Wendy Gong

Weather: ☐ Sunny ☒ Rainy sprinkles ☐ Party Cloudy ☒ Mostly Cloudy ☐ Windy/Significant Wave Action

☐ Recent storm event – When: ________ ☐ Other ________

Temperature: ~~80~~° F 76° F light rain/sprinkles

Flow: Call Hydro Control Room at (218) 725-~~2101~~. 2110

Total Station Flow 164 cfs / Bypass Flow 66 cfs / Unit Flow 108 cfs

Flow Observations: quiet, calm

Temp and DO Meter Calibration Start Time: 10:49, 81° F

Comments: mosquitos

Upstream of Coarse Trash Rack

Time: 1:51

GPS: 47.2869807, -93.5002355

Depth (meters)	Temp (C)	DO (mg/L)	DO%
Surface	21.82	9.06	103.3
1m	21.87	9.07	103.4
~~2m~~ 1.3	21.61	9.04	102.7
3m			
4m			
5m			
6m			

Trailrace Area

Time: 1:25 pm 13:25

GPS: 47.2844981, -93.4997517

Depth (meters)	Temp (C)	DO (mg/L)	DO%
Surface	21.64	8.87	100.8
Mid .3	21.57	8.81	99.9
Bottom .5	~~21.5~~ 21.65	8.86	100.7

Bypass Reach

Time: 2:07

GPS: 47.2854087, -93.4978614

Depth (meters)	Temp (C)	DO (mg/L)	DO%
Surface	20.52	9.09	101.1
Mid	20.54	9.06	100.7
Bottom	20.51	9.05	100.6

**utilize military time HH:MM*

Prairie River Hydroelectric Project #2361
Water Quality Study – Data Collection

Date: 6/16/2020

Data Collector: Wendy Gomez

Weather: ☐ Sunny ☐ Rainy ☒ Party Cloudy ☐ Mostly Cloudy ☐ Windy/Significant Wave Action

☒ Recent storm event – When: ~a week ☐ Other

Temperature: 78°

Flow: Call Hydro Control Room at (218) 725-~~2101~~ 2110

Reservoir elevation: 1289.43

Called again to verify - there was a rain storm about a week ago

Total Station Flow 443 cfs / Bypass Flow 291 cfs / Unit Flow 152 cfs

tail 1249.42

Flow Observations: rushing water -

Temp and DO Meter Calibration Start Time: 9:50 am 74°

Comments: water is deeper - spilling into road, rushing current larg rock is covered now

Upstream of Coarse Trash Rack

Time: ~~12:15~~ 1245

GPS: ~~47.2845581, -93.4997413~~ error w GPS

Depth (meters)	Temp (C)	DO (mg/L)	DO%
Surface	19.39	95.5	8.79
1m	19.28	95.5	8.81
2m	19.05	95.6	8.85
3m 2.	19.05	95.0	8.80
4m	—	—	—
5m	—	—	—
6m	—	—	—

max depth was about 2.3 m

Trailrace Area

Time: 12:15

GPS: 47.2845581, -93.4997413

Depth (meters)	Temp (C)	DO (mg/L)	DO%
Surface	19.33	95.3	8.78
Mid	19.32	95.6	8.81
Bottom	19.34	96.1	8.86

surface depth, .25 m mid depth 0.5 m, bottom 0.9m

Upstream of Trash Rack GPS: 47.2869901, -93.5001745

Bypass Reach

Time: 13:05

GPS: 47.2854761, -93.4981269

Depth (meters)	Temp (C)	DO (mg/L)	DO%
Surface	19.27	99.7	9.20
Mid	19.26	100.7	9.30
Bottom	19.13	101.4	9.38

surface depth 0.25 m, mid depth 0.4 m, bottom 1.2m

**utilize military time HH:MM*

Prairie River Hydroelectric Project #2361
Water Quality Study – Data Collection

Date: 6/30/2020 Data Collector: Wendy Gomez

Weather: ☐ Sunny ☐ Rainy ☐ Party Cloudy ☒ Mostly Cloudy ☐ Windy/Significant Wave Action

☐ Recent storm event – When: ______ ☐ Other ______

Temperature: 75°

Flow: Call Hydro Control Room at (218) 725-2110

Total Station Flow 141 cfs / Bypass Flow 51 cfs / Unit Flow 90 cfs

Flow Observations: ______

Temp and DO Meter Calibration Start Time: 68° 937 am Reservoir Elevation: 1289.43

Comments: no people at tailrace area - but a fire with wood & ashes still hot broken glass & cans

Upstream of Coarse Trash Rack many black ants

Time: 12:07

GPS: 47.2876125, -93.4982359

Depth (meters)	Temp (C)	DO%	DO (mg/L)
Surface .25	25.02	107.7	8.89
1m 0.4	24.54	106.4	8.86
2m 0.6	24.40	105.8	8.84
3m			
4m			
5m			
6m			

Trailrace Area a car with 4 people pulled up - towels + swimming suits

Time: 11:39

GPS: 47.2846093, -93.4996967

Depth (meters)	Meters	Temp (C)	DO%	DO (mg/L)
Surface	0.25	24.28	97.6	8.17
Mid	0.4	24.32	98.5	8.34
Bottom	0.6	24.32	98.9	8.27

Bypass Reach

Time: 12:20

GPS: 47.2855056, -93.4980364

Depth (meters)	Meters	Temp (C)	DO%	DO (mg/L)
Surface	.25	23.65	100.3	8.50
Mid	.3	23.59	100.7	8.54
Bottom	.3	23.59	101.1	8.57

utilize military time HH:MM

Prairie River Hydroelectric Project #2361
Water Quality Study – Data Collection

Date: 7/14/2020 , Data Collector: Wendy Gomez

Weather: ☐ Sunny ☒ Rainy ☐ Party Cloudy ☐ Mostly Cloudy ☐ Windy/Significant Wave Action

☐ Recent storm event – When: ______ ☐ Other ______

Temperature: 62° F

Flow: Call Hydro Control Room at (218) 725-2110

Total Station Flow 114. cfs / Bypass Flow 111 cfs / Unit Flow 3.0 cfs

Flow Observations: control room operator said flow was basically "off" just a little flow through the wicket gates

Temp and DO Meter Calibration Start Time: 66°, 945 am Reservoir Elevation: 1289.49

Comments: 2 people walking

Upstream of Coarse Trash Rack

Time: 12:34

GPS: 47.2870110, -93.4999136

Depth (meters)	Temp (C)	DO%	DO (mg/L)
Surface	25.03	93.92.2	7.61
1m	25.02	91.1	7.53
2m 1.6	24.94	91.3	7.55
3m			
4m			
5m			
6m			

Trailrace Area

Time: 12:14

GPS: 47.2843694, -93.4996125

Depth (meters)	Meters	24.53 Temp (C)	DO%	DO (mg/L)
Surface	.25	24.53	71.4	5.94
Mid	0.4	24.56	69.7	5.80
Bottom	0.5	24.53	67.9	5.65

Bypass Reach

Time: 12:50

GPS: 47.2853496, -93.4980143

Depth (meters)	Meters	Temp (C)	DO%	DO (mg/L)
Surface	.25	24.61	94.7	7.87
Mid	0.3	24.93	95.4	7.89
Bottom	0.3	24.78	95.2	7.88

**utilize military time HH:MM*

Prairie River Hydroelectric Project #2361
Water Quality Study – Data Collection

Date: 7/28/2020 Data Collector: Wendy Gomez

Weather: ☐ Sunny ☐ Rainy ☒ Party Cloudy ☐ Mostly Cloudy ☐ Windy/Significant Wave Action

☐ Recent storm event – When: ________ ☐ Other ________

Temperature: 75° F

Flow: Call Hydro Control Room at (218) 725-2110

Total Station Flow 150 cfs / Bypass Flow 150 cfs / Unit Flow – off-line cfs

Flow Observations: water is quiet – unit is offline today.

Temp and DO Meter Calibration Start Time: 69° 9:15 am. Reservoir Elevation: 1289.36

Comments: by the tailrace area, lots of aquatic insects on the water surface. (person in parking lot.

Upstream of Coarse Trash Rack

Time: 11:36

GPS: 47.2870633, -93.5000880

Depth (meters)	Temp (C)	DO%	DO (mg/L)
Surface .25	24.88	1044	8.64
1m 1.0	24.78	103.9	8.61
2m 2.0	24.49	101.4	8.45
3m 3.0	24.51	99.9	8.33
4m 8			
5m			
6m			

Trailrace Area

Time: 11:11

GPS: 47.2844244, -93.4996327

Depth (meters)	Meters	Temp (C)	DO%	DO (mg/L)
Surface	.25	23.92	84.10	7.08
Mid	0.5	23.92	85.3	7.19
Bottom	1.0	23.83	83.6	7.05

Bypass Reach

Time: 11:55

GPS: 47.2851417, -93.4979774

Depth (meters)	Meters	Temp (C)	DO%	DO (mg/L)
Surface	.25	24.92	99.5	8.23
Mid	.30	24.68	99.6	8.27
Bottom	.40	24.68	99.3	8.25

**utilize military time HH:MM*

Prairie River Hydroelectric Project #2361
Water Quality Study – Data Collection

Date: 8/11/2020

Data Collector: Wendy Gomez

Weather: ☐ Sunny ☐ Rainy ☒ Party Cloudy ☐ Mostly Cloudy ☐ Windy/Significant Wave Action

☐ Recent storm event – When: ______ ☐ Other ______

Temperature: 75° F

Flow: Call Hydro Control Room at (218) 725-2110

Total Station Flow 147 cfs / Bypass Flow 2 cfs / Unit Flow 145 cfs

Flow Observations: ______

Temp and DO Meter Calibration Start Time: 9:10 68°F

Reservoir Elevation: 1289.37

Comments: 1 person fishing by tailrace area, a family by the bypass reach

Several crayfish & frogs/older tadpoles

water looked low near bypass reach.

Upstream of Coarse Trash Rack

Time: 12:32

GPS: 47.2869887, -93.5001906

.25

Depth (meters)	Temp (C)	DO%	DO (mg/L)
Surface	23.23	90.8	7.75
1m	23.15	89.4	7.64
2m	23.11	88.1	7.53
3m	23.14	87.2	7.45
4m	23.12	86.6	7.41
5m			
6m			

Trailrace Area

Time: 12:16

GPS: 47.2844874, -93.4988137

Depth (meters)	Meters	Temp (C)	DO%	DO (mg/L)
Surface	.25	23.10	91.3	7.81
Mid	0.4	23.10	90.0	7.70
Bottom	1.2	23.10	88.6	7.58

Bypass Reach

Time: 12:51

GPS: 47.2855015, -93.4980730

.25

Depth (meters)	Meters	Temp (C)	DO%	DO (mg/L)
Surface	.25	24.40	92.9	7.76
Mid	.25	25.21	94.8	7.80
Bottom	0.30	24.4	93.2	7.77

51

**utilize military time HH:MM*

Prairie River Hydroelectric Project #2361
Water Quality Study – Data Collection

Date: 8/25/20

Data Collector: Wendy Gomez

Weather: ☐ Sunny ☐ Rainy ☒ Party Cloudy ☐ Mostly Cloudy ☐ Windy/Significant Wave Action

☐ Recent storm event – When: ______ ☐ Other ______

Temperature: 69°F

Flow: Call Hydro Control Room at (218) 725-2110

Total Station Flow ~~509~~ 506 cfs / Bypass Flow ~~356~~ 353 cfs / Unit Flow 153 cfs

Flow Observations: ______

Temp and DO Meter Calibration Start Time: 61°F, 8:56am Reservoir Elevation: 1289.35

Comments: 2 vehicles - 1 grp of 3 carrying fishing poles, 1 single person
2 adults, 1 child

Upstream of Coarse Trash Rack

Time: 11:46

GPS: 47.2869612, -93.5000652

Depth (meters)	Temp (C)	DO%	DO (mg/L)
.25 Surface	23.83	90.1	7.60
1m	23.82	89.6	7.56
2m	23.74	88.5	7.48
3m	—	—	—
4m	—	—	—
5m	—	—	—
6m	—	—	—

Trailrace Area

Time: 11:22

GPS: 27.2844533

Depth (meters)	Meters	Temp (C)	DO%	DO (mg/L)
Surface	.25	23.77	88.5	7.48
Mid	1.0	23.77	87.9	7.42
Bottom	1.5	23.77	87.6	7.40

Bypass Reach

Time: ~~14:22~~ 12:01

GPS: 47.2854720, -93.4980257

Depth (meters)	Meters	Temp (C)	DO%	DO (mg/L)
Surface	0.25	23.95	99.6	8.38
Mid 0.50	~~0.40~~	23.93	99.2	8.36
Bottom	~~0.30~~ 0.30	23.95	98.2	8.27

*utilize military time HH:MM

Prairie River Hydroelectric Project #2361
Water Quality Study – Data Collection

Date: 9/10/2020 Data Collector: Wendy Gomez

Weather: ☒ Sunny ☐ Rainy ☐ Party Cloudy ☐ Mostly Cloudy ☐ Windy/Significant Wave Action

☐ Recent storm event – When: ______ ☐ Other ______

Temperature: 53 °

Flow: Call Hydro Control Room at (218) 725-2110

Total Station Flow 228 cfs / Bypass Flow 72 cfs / Unit Flow 156 cfs

Flow Observations: ______

Temp and DO Meter Calibration Start Time: 9:45 52° Reservoir Elevation: 1289.39

Comments: 1 car parked in area. – 1 person fishing

Upstream of Coarse Trash Rack

Time: 12:06

GPS: 47.2845131, -93.4997403

	Depth (meters)	**Temp (C)**	**DO%**	**DO (mg/L)**
.25	Surface	16.1	77.4	7.62
	1m ✓	16.1	75.5	7.44
	2m ✓	16.0	74.6	7.36
	3m			
	4m			
	5m			
	6m			

Trailrace Area

Time: 11:51

GPS: 47.2845131, -93.4997403

Depth (meters)	**Meters**	**Temp (C)**	**DO%**	**DO (mg/L)**
Surface	0.25	16°	80.0	7.90
Mid	0.75	16°	77.8	7.68
Bottom	1.0	16°	75.8	7.47

Bypass Reach

Time: 12:18

GPS: 47.2854504, -93.4980233

Depth (meters)	**Meters**	**Temp (C)**	**DO%**	**DO (mg/L)**
Surface	0.25	16.3	89.5	8.77
Mid	0.3	16.3	88.8	8.72
Bottom	0.3	16.2	89.2	8.76

Took the average of these two measurements that were taken at the same depth for entry in spreadsheet, KK 9/11/20

**utilize military time HH:MM*

Prairie River Hydroelectric Project #2361
Water Quality Study – Data Collection

Date: 9/22/2020

Data Collector: Wendy Gomez

Weather: ☒ Sunny ☐ Rainy ☐ Party Cloudy ☐ Mostly Cloudy ☐ Windy/Significant Wave Action

☐ Recent storm event – When: ____________ ☐ Other ____________

Temperature: 71°

Flow: Call Hydro Control Room at (218) 725-2110

Total Station Flow 132 cfs / Bypass Flow 0 cfs / Unit Flow 132 cfs

Flow Observations: ____________

Temp and DO Meter Calibration Start Time: 62° @ 10:49

Reservoir Elevation: 1289.38

Comments: one truck with 2 people arrived w/ fishing gear

Upstream of Coarse Trash Rack

Time: 12:33

GPS: 47.2845392, -93.4997926

Depth (meters)	Temp (C)	DO%	DO (mg/L)
Surface	16.3	87.3	8.61
1m	15.9	86.8	8.58
2m	15.9	86.0	8.50
3m			
4m			
5m			
6m			

Trailrace Area

Time: 12:22

GPS: 47.2845392, -93.49979926.

Depth (meters)	Meters	Temp (C)	DO%	DO (mg/L)
Surface	0.25	16.1	92.9	9.15
Mid	0.50	16.0	87.0	8.58
Bottom	0.60	16.0	86.7	8.55

Bypass Reach

Time: 12:43

GPS: 47.2845392, -93.4997926

Depth (meters)	Meters	Temp (C)	DO%	DO (mg/L)
Surface	.25	19.3	89.8	8.38
Mid	.25	19.3	86.6	7.98
Bottom	.40	18.3	88.3	8.29

**utilize military time HH:MM*

9.0 Appendix B: Site Photos

Figure B-1. Site photos from the Log Boom Corner. Photos taken on 6/16/2020 (left) and 8/11/2020 (right) by Wendy Gomez.

Figure B-2. Sites photos from the Turbine Intake Area. Photos taken on 6/30/2020 (left) and 8/11/2020 (right) by Wendy Gomez.

Figure B-3. Site photos from the Downstream Wall. Photos take on 6/16/2020 (left) and 8/11/2020 (right) by Wendy Gomez.

Figure B-4. Site photos from the Hwy 169 Bridge sampling location. Taken 6/16/2020 by Wendy Gomez.

10.0 Appendix C: Calibration Records

CALIBRATION WORK SHEET

Date of Calibration: 5/12/2020

Sonde ID: Wenck YSI 6920 V2 with 6560 Cond/Temp Probe & 6150 ROX Optical DO Probe

Technician: Wendy Gomez

RP DO membrane changed? Y N

RP DO membrane o-ring changed? Y N

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y N

ROX DO wiper changed? Y [✓ N]

BGA-PC wiper changed? Y N

Chlorophyll wiper changed? Y N

BGA-PE wiper changed? Y N

Rhodamine wiper changed? Y N

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: ________________ (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant _____________ Range 5.0 ± .45

Integrated conductivity cell constant_________ Range 5.0 ± .70

pH mv Buffer 7 _____________ Range 0 ± 50 mv

pH mv Buffer 4 _____________ Range +180 ± 50 mv*

pH mv Buffer 10 _____________ Range -180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only) _____________ Range 25 to 75

DO gain _____________ Range 0.7 to 1.4

ODO gain mg/L % sat 1.05 Range 0.85 to 1.15

Turbidity standard used in calibration ________________________

Manufacturer and part number ________________________________

Barometric Pressure: 732.7 mmHg (from 650 handheld internal barometer)

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	________	____Sonde
Conductivity	________	____/____
pH 7	________	____/____
pH 4	________	____/____
pH 10	________	____/___
ORP	________	____/___
Turbidity	________	____/____
Turbidity	________	____/____
Turbidity 0.5	________	____/____
Chlorophyll	________	____/____
Chlorophyll	________	____/____
DO RP	________	____/____
DO ROX	100% H20 sat. air	mg/L % sat 96.4 / 100.0
BGA PE/PC	________	____/____
BGA PE/PC	________	____/____
Rhodamine	________	____/____

Depth Calibration - If zero was entered, record barometric pressure at time of calibration _____________mmHg

Depth Calibration - If offset depth was entered, record value ____________ meters/feet and pressure ____________ mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 ____________________

Notes: True BP in mm Hg = [Corrected BP in mm Hg] - [2.5 * (Local Altitude in Feet Above Sea Level/100]
mm Hg = in Hg * 25.4

Barometric Pressure Reading from Local Weather Station ____________________ (corrected)

Barometric Pressure Reading from Local Weather Station ____________________ (uncorrected)

Weather Station Used ____________________ Date/Time ________________

CALIBRATION WORK SHEET

Date of Calibration: 5/20/2020 9:25
Sonde ID: Wenck YSI 6920 V2 with 6560 Cond/Temp Probe & 6150 ROX Optical DO Probe
Technician: Wendy Gomez

RP DO membrane changed? Y [✓ N]
RP DO membrane o-ring changed? Y [✓ N]

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y N
ROX DO wiper changed? Y [✓ N]
BGA-PC wiper changed? Y N
Chlorophyll wiper changed? Y N
BGA-PE wiper changed? Y N
Rhodamine wiper changed? Y N

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.4 V (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant ______ Range 5.0 ± .45

Integrated conductivity cell constant ______ Range 5.0 ± .70

pH mv Buffer 7 ______ Range 0 ± 50 mv

pH mv Buffer 4 ______ Range +180 ± 50 mv*

pH mv Buffer 10 ______ Range -180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only) ______ Range 25 to 75

DO gain ______ Range 0.7 to 1.4

ODO gain mg/L % sat 3.0 % Range 0.85 to 1.15

Turbidity standard used in calibration ______

Manufacturer and part number ______

Barometric Pressure: 731.6 mmHg (from 650 handheld internal barometer)

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal	
Temperature	19.25	Sonde	
Conductivity		/	
pH 7		/	
pH 4		/	
pH 10		/	
ORP		/	
Turbidity		/	
Turbidity		/	
Turbidity 0.5		/	
Chlorophyll		/	
Chlorophyll		/	
DO RP		/	
DO ROX	100% H20 sat. air	mg/L % sat 8.75 94.7%	pre-cal
~~BGA PE/PC~~		↓ /	post-cal
BGA PE/PC		/	
Rhodamine		9.01 / 97.7	

Depth Calibration - If zero was entered, record barometric pressure at time of calibration ______ mmHg

Depth Calibration - If offset depth was entered, record value ______ meters/feet and pressure ______ mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 ______

Notes: True BP in mm Hg = [Corrected BP in mm Hg] - [2.5 * (Local Altitude in Feet Above Sea Level/100]

Barometric Pressure Reading from Local Weather Station 30.18 in → 767 mmHg (corrected)

Barometric Pressure Reading from Local Weather Station 767 - (2.5*(1356/100)= 733.1 mmHg (uncorrected)

Weather Station Used GR- Itasca Co Airport-Gordon Newstrom Field Date/Time 9:21 am, 5/20/2020

CALIBRATION WORK SHEET

Date of Calibration: 6/2/2020

Technician: Wendy Gomez

Sonde ID: Wenck YSI 6920 V2 with 6560 Cond/Temp Probe & 6150 ROX Optical DO Probe

RP DO membrane changed? Y N

RP DO membrane o-ring changed? Y N

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y N

ROX DO wiper changed? Y [✓ N]

BGA-PC wiper changed? Y N

Chlorophyll wiper changed? Y N

BGA-PE wiper changed? Y N

Rhodamine wiper changed? Y N

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: ______________ (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant		Range	5.0 ± .45
Integrated conductivity cell constant		Range	5.0 ± .70
pH mv Buffer 7		Range	0 ± 50 mv
pH mv Buffer 4		Range	+180 ± 50 mv*
pH mv Buffer 10		Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)		Range	25 to 75
DO gain		Range	0.7 to 1.4
ODO gain mg/L % sat	1.6 %	Range	0.85 to 1.15

Turbidity standard used in calibration ______________________

Manufacturer and part number ______________________

Barometric Pressure: 728.4 mmHg (from 650 handheld internal barometer)

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature		Sonde
Conductivity		/
pH 7		/
pH 4		/
pH 10		/
ORP		/
Turbidity		/
Turbidity		/
Turbidity 0.5		/
Chlorophyll		/
Chlorophyll		/
DO RP		/
DO ROX	100% H20 sat. air	mg/L % sat 94.5 96.1 %
BGA PE/PC		/
BGA PE/PC		/
Rhodamine		/

Depth Calibration - If zero was entered, record barometric pressure at time of calibration ____________ mmHg

Depth Calibration - If offset depth was entered, record value ___________ meters/feet and pressure ___________ mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 ______________

True = 759 – 2.5 (1355 ft/100)

Notes: True BP in mm Hg = [Corrected BP in mm Hg] - [2.5 * (Local Altitude in Feet Above Sea Level/100]

Barometric Pressure Reading from Local Weather Station 29.87" = 759 mm Hg (corrected) 29.87" x 25.4 mm/in

Barometric Pressure Reading from Local Weather Station 725 mmHg (uncorrected)

Weather Station Used Grand Rapids/Itasca Co. Airport Date/Time 11:00 am,

i

CALIBRATION WORK SHEET

Date of Calibration: 6/10/2020

Technician: Wendy Gomez

Sonde ID: Wenck YSI 6920 V2 with 6560 Cond/Temp Probe & 6150 ROX Optical DO Probe

RP DO membrane changed? Y N

RP DO membrane o-ring changed? Y N

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y N

ROX DO wiper changed? Y [✓ N]

BGA-PC wiper changed? Y N

Chlorophyll wiper changed? Y N

BGA-PE wiper changed? Y N

Rhodamine wiper changed? Y N

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.4 V (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant ______ Range 5.0 ± .45

Integrated conductivity cell constant ______ Range 5.0 ± .70

pH mv Buffer 7 ______ Range 0 ± 50 mv

pH mv Buffer 4 ______ Range +180 ± 50 mv*

pH mv Buffer 10 ______ Range -180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only) ______ Range 25 to 75

DO gain ______ Range 0.7 to 1.4

ODO gain mg/L % sat ______ **Range 0.85 to 1.15**

Turbidity standard used in calibration ______

Manufacturer and part number ______

30.10 in weather stn.

Barometric Pressure: 753.6 mmHg (from 650 handheld internal barometer)

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	______	____Sonde
Conductivity	______	___/___
pH 7	______	___/___
pH 4	______	___/___
pH 10	______	___/___
ORP	______	___/___
Turbidity	______	___/___
Turbidity	______	___/___
Turbidity 0.5	______	___/___
Chlorophyll	______	___/___
Chlorophyll	______	___/___
DO RP	______	___/___
DO ROX	100% H20 sat. air	mg/L 8.1 % sat 7.09 / 96.7
BGA PE/PC	______	___/ 7.32
BGA PE/PC	______	___/___
Rhodamine	______	___/___

Depth Calibration - If zero was entered, record barometric pressure at time of calibration ______ mmHg

Depth Calibration - If offset depth was entered, record value ______ meters/feet and pressure ______ mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 ______

True = 765 - 2.5 (1355/100) = 731

Notes: True BP in mm Hg = [Corrected BP in mm Hg] - [2.5 * (Local Altitude in Feet Above Sea Level/100]

Barometric Pressure Reading from Local Weather Station 30.10 in = 765 mmHg (corrected)

Barometric Pressure Reading from Local Weather Station 731 mmHg (uncorrected)

Weather Station Used GR/Itasco Co Airpot Date/Time 9:55 am

CALIBRATION WORK SHEET

Date of Calibration: 6/30/2020
Technician: Wendy Gomez

Sonde ID: Wenck YSI 6920 V2 with 6560 Cond/Temp Probe & 6150 ROX Optical DO Probe

RP DO membrane changed? Y N
RP DO membrane o-ring changed? Y N

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y N
ROX DO wiper changed? Y [✓ N]
BGA-PC wiper changed? Y N
Chlorophyll wiper changed? Y N
BGA-PE wiper changed? Y N
Rhodamine wiper changed? Y N

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.3 V (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant		Range 5.0 ± .45
Integrated conductivity cell constant		Range 5.0 ± .70
pH mv Buffer 7		Range 0 ± 50 mv
pH mv Buffer 4		Range +180 ± 50 mv*
pH mv Buffer 10		Range -180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)		Range 25 to 75
DO gain		Range 0.7 to 1.4
ODO gain mg/L % sat	11.5% 0.55 mg/L	Range 0.85 to 1.15

Turbidity standard used in calibration ____________

Manufacturer and part number ____________

Barometric Pressure: 726 mmHg (from 650 handheld internal barometer)

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature		Sonde
Conductivity		/
pH 7		/
pH 4		/
pH 10		/
ORP		/
Turbidity		/
Turbidity		/
Turbidity 0.5		/
Chlorophyll		/
Chlorophyll		/
DO RP		/
DO ROX	100% H20 sat. air	mg/L % sat 86.8% / 98.3% 7.16 mg/L / 7.71 mg/L
BGA PE/PC		7.16 /
BGA PE/PC		/
Rhodamine		/

Depth Calibration - If zero was entered, record barometric pressure at time of calibration ____________ mmHg

Depth Calibration - If offset depth was entered, record value ____________ meters/feet and pressure ____________ mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 ____________

Notes: True BP in mm Hg = [Corrected BP in mm Hg] - [2.5 * (Local Altitude in Feet Above Sea Level/100]
mm Hg = in Hg * 25.4 29.86(25.4) = 758

Barometric Pressure Reading from Local Weather Station 758 (corrected)

Barometric Pressure Reading from Local Weather Station 724 (uncorrected)

Weather Station Used GR airport Date/Time 6/30/2020 9:38

CALIBRATION WORK SHEET

Date of Calibration: 7/14/2020

Technician: Wendy Gomez

Sonde ID: Wenck YSI 6920 V2 with 6560 Cond/Temp Probe & 6150 ROX Optical DO Probe

RP DO membrane changed? Y N

RP DO membrane o-ring changed? Y N

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y N

ROX DO wiper changed? Y [✓ N]

BGA-PC wiper changed? Y N

Chlorophyll wiper changed? Y N

BGA-PE wiper changed? Y N

Rhodamine wiper changed? Y N

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.4 V (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant		Range 5.0 ± .45
Integrated conductivity cell constant		Range 5.0 ± .70
pH mv Buffer 7		Range 0 ± 50 mv
pH mv Buffer 4		Range +180 ± 50 mv*
pH mv Buffer 10		Range -180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)		Range 25 to 75
DO gain		Range 0.7 to 1.4
ODO gain mg/L % sat		Range 0.85 to 1.15

Turbidity standard used in calibration

Manufacturer and part number

Barometric Pressure: 725.6 mmHg (from 650 handheld internal barometer)

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature		Sonde
Conductivity		/
pH 7		/
pH 4		/
pH 10		/
ORP		/
Turbidity		/
Turbidity		/
Turbidity 0.5		/
Chlorophyll		/
Chlorophyll		/
DO RP		/
DO ROX	100% H20 sat. air	mg/L 8.96 / 8.12 % sat 101.6 / 95.5
BGA PE/PC		/
BGA PE/PC		/
Rhodamine		/

Depth Calibration - If zero was entered, record barometric pressure at time of calibration ______ mmHg

Depth Calibration - If offset depth was entered, record value ______ meters/feet and pressure ______ mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15

29.92 ~1355

Notes: True BP in mm Hg = [Corrected BP in mm Hg] - [2.5 * (Local Altitude in Feet Above Sea Level/100]
mm Hg = in Hg * 25.4 ≈ 760.0

Barometric Pressure Reading from Local Weather Station 760.0 (corrected)

Barometric Pressure Reading from Local Weather Station 726.1 (uncorrected)

Weather Station Used GR airport Date/Time 9:45am 7/14

CALIBRATION WORK SHEET

Date of Calibration: 7/28/2020
Technician: Wendy Gomez

Sonde ID: Wenck YSI 6920 V2 with 6560 Cond/Temp Probe & 6150 ROX Optical DO Probe

RP DO membrane changed? Y N
RP DO membrane o-ring changed? Y N

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y N
ROX DO wiper changed? Y [✓ N]
BGA-PC wiper changed? Y N
Chlorophyll wiper changed? Y N
BGA-PE wiper changed? Y N
Rhodamine wiper changed? Y N

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.4V (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant ________ Range 5.0 ± .45
Integrated conductivity cell constant ________ Range 5.0 ± .70
pH mv Buffer 7 ________ Range 0 ± 50 mv
pH mv Buffer 4 ________ Range +180 ± 50 mv*
pH mv Buffer 10 ________ Range -180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only) ________ Range 25 to 75
DO gain ________ Range 0.7 to 1.4
ODO gain mg/L 0.1 mg/L % sat 1.3 % Range 0.85 to 1.15

Turbidity standard used in calibration ________
Manufacturer and part number ________

Barometric Pressure: 724.1 mmHg (from 650 handheld internal barometer)
DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature		Sonde
Conductivity		/
pH 7		/
pH 4		/
pH 10		/
ORP		/
Turbidity		/
Turbidity		/
Turbidity 0.5		/
Chlorophyll		/
Chlorophyll		/
DO RP		/
DO ROX	100% H20 sat. air	mg/L 7.72 / 7.82 mg/L % sat 94.2 / 95.5 %
BGA PE/PC		/
BGA PE/PC		/
Rhodamine		/

Depth Calibration - If zero was entered, record barometric pressure at time of calibration ________ mmHg
Depth Calibration - If offset depth was entered, record value ________ meters/feet and pressure ________ mmHg
Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 ________

Corrected BP = 29.90 × 25.4 = 759.46

Notes: True BP in mm Hg = [Corrected BP in mm Hg] - [2.5 * (Local Altitude in Feet Above Sea Level/100]
mm Hg = in Hg * 25.4 759.46 − 2.5 × 1296/100

Barometric Pressure Reading from Local Weather Station 759.46 (corrected)

Barometric Pressure Reading from Local Weather Station 727.1 (uncorrected)

Weather Station Used Grand Rapids Airport Date/Time 7/28/2020

CALIBRATION WORK SHEET

Date of Calibration: 8/11/2020

Technician: Wendy Gomez

Sonde ID: Wenck YSI 6920 V2 with 6560 Cond/Temp Probe & 6150 ROX Optical DO Probe

RP DO membrane changed? Y N

RP DO membrane o-ring changed? Y N

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y N

ROX DO wiper changed? Y [✓ N]

BGA-PC wiper changed? Y N

Chlorophyll wiper changed? Y N

BGA-PE wiper changed? Y N

Rhodamine wiper changed? Y N

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.4 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant		Range 5.0 ±.45
Integrated conductivity cell constant		Range 5.0 ±.70
pH mv Buffer 7		Range 0 ±50 mv
pH mv Buffer 4		Range +180 ±50 mv*
pH mv Buffer 10		Range -180 ±50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)			Range 25 to 75
DO gain			Range 0.7 to 1.4
ODO gain	mg/L	0.35 mg/L	
	% sat	4.3 % sat	Range 0.85 to 1.15

Turbidity standard used in calibration

Manufacturer and part number

Barometric Pressure: 726.9 mmHg (from 650 handheld internal barometer)

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature		Sonde
Conductivity		/
pH 7		/
pH 4		/
pH 10		/
ORP		/
Turbidity		/
Turbidity		/
Turbidity 0.5		/
Chlorophyll		/
Chlorophyll		/
DO RP		7.65 8.00 mg/L
DO ROX	100% H20 sat. air	mg/L % sat 91.5 95.8 % sat
BGA PE/PC		/
BGA PE/PC		/
Rhodamine		/

Depth Calibration - If zero was entered, record barometric pressure at time of calibration ____ mmHg

Depth Calibration - If offset depth was entered, record value ____ meters/feet and pressure ____ mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 ____

Notes: True BP in mm Hg = [Corrected BP in mm Hg] - [2.5 * (Local Altitude in Feet Above Sea Level/100)] 1280

mm Hg = in Hg * 25.4 29.92 in x 25.4

Barometric Pressure Reading from Local Weather Station = 760 (corrected)

Barometric Pressure Reading from Local Weather Station 728 (uncorrected)

Weather Station Used GR/Itasca Co Airport Date/Time 9:22 am

CALIBRATION WORK SHEET

Date of Calibration: 8/25/20

Technician: Wendy Gomez

Sonde ID: Wenck YSI 6920 V2 with 6560 Cond/Temp Probe & 6150 ROX Optical DO Probe

RP DO membrane changed? Y N

RP DO membrane o-ring changed? Y N

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y N

ROX DO wiper changed? Y [✓ N]

BGA-PC wiper changed? Y N

Chlorophyll wiper changed? Y N

BGA-PE wiper changed? Y N

Rhodamine wiper changed? Y N

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.3 Volt (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant ______ Range 5.0 ± .45

Integrated conductivity cell constant ______ Range 5.0 ± .70

pH mv Buffer 7 ______ Range 0 ± 50 mv

pH mv Buffer 4 ______ Range +180 ± 50 mv*

pH mv Buffer 10 ______ Range -180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only) ______ Range 25 to 75

DO gain ______ Range 0.7 to 1.4

ODO gain mg/L 0.27 mg/L % sat 7.5 % sat Range 0.85 to 1.15

Turbidity standard used in calibration ______

Manufacturer and part number ______

Barometric Pressure: 730.9 mmHg (from 650 handheld internal barometer)

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature		Sonde
Conductivity		/
pH 7		/
pH 4		/
pH 10		/
ORP		/
Turbidity		/
Turbidity		/
Turbidity 0.5		/
Chlorophyll		/
Chlorophyll		/
DO RP		/
DO ROX	100% H20 sat. air	mg/L 7.86 / 8.13 % sat 88.6 / 96.1
BGA PE/PC		/
BGA PE/PC		/
Rhodamine		/

Depth Calibration - If zero was entered, record barometric pressure at time of calibration ______ mmHg

Depth Calibration - If offset depth was entered, record value ______ meters/feet and pressure ______ mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 ______

30.06 inch × 25.4 = 763.5

Notes: True BP in mm Hg = [Corrected BP in mm Hg] - [2.5 * (Local Altitude in Feet Above Sea Level/100)]
mm Hg = in Hg * 25.4

1355 ft above sea level

Barometric Pressure Reading from Local Weather Station 763.5 (corrected)

Barometric Pressure Reading from Local Weather Station 729.6 (uncorrected)

Weather Station Used GR/Itasca Co. Arpt Date/Time 8:56 am 8/25/20

CALIBRATION WORK SHEET

Date of Calibration: 9/10/2020

Technician: Wendy Gomez

Sonde ID: Wenck YSI 6920 V2 with 6560 Cond/Temp Probe & 6150 ROX Optical DO Probe

RP DO membrane changed? Y N

RP DO membrane o-ring changed? Y N

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y N

ROX DO wiper changed? Y [✓ N]

BGA-PC wiper changed? Y N

Chlorophyll wiper changed? Y N

BGA-PE wiper changed? Y N

Rhodamine wiper changed? Y N

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: __________ (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant		Range 5.0 ± .45
Integrated conductivity cell constant		Range 5.0 ± .70
pH mv Buffer 7		Range 0 ± 50 mv
pH mv Buffer 4		Range +180 ± 50 mv*
pH mv Buffer 10		Range -180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)		Range 25 to 75
DO gain		Range 0.7 to 1.4
ODO gain mg/L % sat	0.34 mg/L	Range 0.85 to 1.15

% not given for initial reading

Turbidity standard used in calibration __________

Manufacturer and part number __________

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature		Sonde
Conductivity		/
pH 7		/
pH 4		/
pH 10		/
ORP		/
Turbidity		/
Turbidity		/
Turbidity 0.5		/
Chlorophyll		/
Chlorophyll		/
DO RP		/ 9.30
DO ROX	100% H20 sat. air	mg/L 8.96 / 93.6% % sat / ~~94.1%~~
BGA PE/PC		/
BGA PE/PC		/
Rhodamine		/

Barometric Pressure: 739 mmHg (from 650 handheld internal barometer)

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Depth Calibration - If zero was entered, record barometric pressure at time of calibration __________ mmHg

Depth Calibration - If offset depth was entered, record value __________ meters/feet and pressure __________ mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 __________

30.45 in x 25.4 = 773

1280

Notes: True BP in mm Hg = [Corrected BP in mm Hg] - [2.5 * (Local Altitude in Feet Above Sea Level/100]
mm Hg = in Hg * 25.4

Barometric Pressure Reading from Local Weather Station 773 (corrected)

Barometric Pressure Reading from Local Weather Station 741 (uncorrected)

Weather Station Used GR Airport Date/Time 9:45 9/10/2020

CALIBRATION WORK SHEET

Date of Calibration: 9/22/20
Sonde ID: Wenck YSI 6920 V2 with 6560 Cond/Temp Probe & 6150 ROX Optical DO Probe
Technician: Wendy Gomez

RP DO membrane changed? Y N
RP DO membrane o-ring changed? Y N

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y N
ROX DO wiper changed? Y [✓ N]
BGA-PC wiper changed? Y N
Chlorophyll wiper changed? Y N
BGA-PE wiper changed? Y N
Rhodamine wiper changed? Y N

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: ______________ (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant ____________ Range 5.0 ± .45
Integrated conductivity cell constant ________ Range 5.0 ± .70
pH mv Buffer 7 ____________ Range 0 ± 50 mv
pH mv Buffer 4 ____________ Range +180 ± 50 mv*
pH mv Buffer 10 ____________ Range -180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv
Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only) ____________ Range 25 to 75
DO gain ____________ Range 0.7 to 1.4
ODO gain mg/L % sat 4.5 % Range 0.85 to 1.15
0.40 mg/L.

Turbidity standard used in calibration ______________________
Manufacturer and part number ______________________

Barometric Pressure: 731 mmHg (from 650 handheld internal barometer)
DO % Calculated – (BARO mmHg divided by 7.6) = % saturation
Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature		Sonde
Conductivity		/
pH 7		/
pH 4		/
pH 10		/
ORP		/
Turbidity		/
Turbidity		/
Turbidity 0.5		/
Chlorophyll		/
Chlorophyll		102.7 / 98.2
DO RP		8.79 / ~~83.9~~
DO ROX	100% H20 sat. air	mg/L ~~8.54~~ % sat ~~111.2~~ / ~~90.7~~ 8.39
BGA PE/PC		/
BGA PE/PC		/
Rhodamine		/

Depth Calibration - If zero was entered, record barometric pressure at time of calibration ____________ mmHg
Depth Calibration - If offset depth was entered, record value ____________ meters/feet and pressure ____________ mmHg
Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 ____________

30.13" x 25.4 = 735.30 mmHg. 1280 ft

Notes: True BP in mm Hg = [Corrected BP in mm Hg] - [2.5 * (Local Altitude in Feet Above Sea Level/100)]
mm Hg = in Hg * 25.4

Barometric Pressure Reading from Local Weather Station 735.3 (corrected)

Barometric Pressure Reading from Local Weather Station 733.3 (uncorrected)

Weather Station Used GR Itasca Co Airport Date/Time 9:34

WENCK

Responsive partner.
Exceptional outcomes.

Appendix C. Grand Rapids Project Desktop Entrainment and Impingement Study

Fish Entrainment and Impingement Study

Grand Rapids Hydroelectric Project (FERC No. 2362)

October 2020

Prepared for:

Minnesota Power

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Appendix E. Monthly and Annual Entrainment Rates for Target/Surrogate Fish Species Derived from EPRI (1997a)
Appendix F. Blade Strike Results (Franke et al. 1997)

List of Acronyms

°F	degrees Fahrenheit
CFR	Code of Federal Regulations
cfs	cubic feet per second
CPUE	catch per unit effort
EPRI	Electronic Power Research Institute
FERC	Federal Energy Regulatory Commission
FPA	Federal Power Act
ft	feet
ft/s	feet per second
ILP	Integrated Licensing Process
MDNR	Minnesota Department of Natural Resources
MW	megawatt
MWh	megawatt hours
NOI	Notice of Intent
PAD	Pre-Application Document
POR	period of record
PSP	Proposed Study Plan
RC	relative composition
ROR	run of river
rpm	rotations per minute
RSP	Revised Study Plan
SD1	Scoping Document 1
SD2	Scoping Document 2
SPD	Study Plan Determination
USC	United States Code
USGS	United States Geological Survey

1 Introduction and Background

1.1 Introduction

ALLETE Inc., doing business as Minnesota Power ("MP" or "Licensee"), is the Licensee, owner, and operator of the Grand Rapids Hydroelectric Project (FERC No. 2362).

The Grand Rapids Project (Project) is licensed by the Federal Energy Regulatory Commission ("FERC" or "Commission") under the authority granted to FERC by Congress through the Federal Power Act (FPA), 16 United States Code (USC) §791(a), et seq., to license and oversee the operation of non-federal hydroelectric projects on jurisdictional waters and/or federal land. There are no federal lands associated with the Project. The Project previously underwent licensing in the early 1990s, and the current operating license for the Project expires on December 31, 2023. Accordingly, MP is pursuing a new license for the Grand Rapids Project pursuant to FERC's Integrated Licensing Process (ILP), as described at 18 Code of Federal Regulations (CFR) Part 5.

This report describes the methods and results of the FERC approved Fish Entrainment and Impingement Study conducted as part of obtaining a new license for the Project.

1.2 Background

The Grand Rapids Project is a 2.1 megawatt (MW), run-of-river (ROR) facility located on the Mississippi River in the City of Grand Rapids in Itasca County, Minnesota. On December 13, 2018, MP initiated the ILP by filing a Pre-Application Document (PAD) and Notice of Intent (NOI) with the Commission. Major ILP milestones to-date are presented in Table 1.

Table 1. Major ILP Milestones Completed

Date	Milestone
12/13/2018	PAD and NOI Filed
02/07/2019	Scoping Document 1 (SD1) Issued by FERC
03/06-03/07/2019	FERC Agency and Public Scoping Meetings Conducted
03/06/2019	Project Site Visit Held
05/16/2019	Scoping Document 2 (SD2) Issued by FERC
05/28/2019	Proposed Study Plan (PSP) Filed
06/20/2019	PSP Meeting Conducted
09/23/2019	Revised Study Plan (RSP) Filed
10/16/2019	FERC Issued Study Plan Determination (SPD)

2 Study Goals and Objectives

The goals of the Fish Entrainment and Impingement Study are to

1. Describe the physical characteristics of the powerhouse and intake structures including location, dimensions, turbine specifications, trashrack spacing, and field collection or calculation of average intake velocities that could influence entrainment.
2. Describe the local fish community and compile a target species list for entrainment analysis.
3. Use intake velocities, trashrack spacing, target fish swim speeds, and other Project specifications to conduct a desktop impingement assessment.
4. Conduct a desktop analysis that incorporates the impingement assessment, Project specifications, and hydrology to quantify turbine entrainment and mortality at the Project.

3 Study Area

The Grand Rapids Hydroelectric Project is located at river mile 1,182 on the Mississippi River in the City of Grand Rapids in Itasca County, Minnesota. The Project facilities are located on the Mississippi River in Itasca County, Minnesota (see Figure 1). The Project layout is shown in Figure 2.

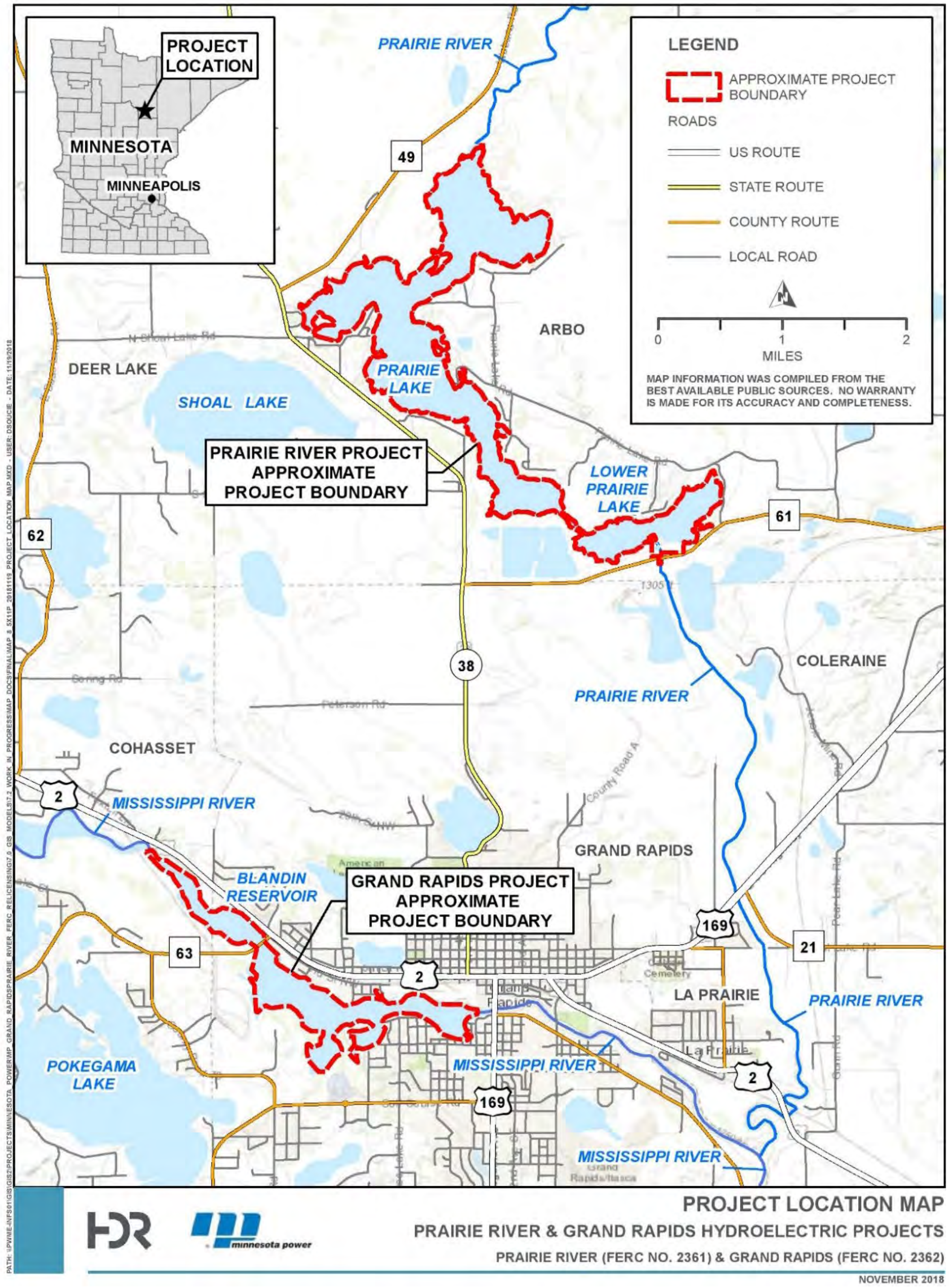

Figure 1. Grand Rapids Project Facilities

Figure 2. Grand Rapids Project Boundary and Layout

4 Methodology

4.1 Project Understanding, Fish Community, and Background Information Used in Methods

Operation of hydroelectric projects can result in the sporadic/episodic impingement and entrainment of fish. Impingement refers to the potential for fish to become trapped against the trashracks due to velocity conditions at the intake. Entrainment refers to the passage of fish into the powerhouse intakes and through the turbine units. Fish passing through the turbines can be subjected to the risk of injury or mortality. The number of fish impinged or entrained at a project is related to a variety of physical factors near the dam and powerhouse, such as flow rate, intake depth, intake approach velocities, trashrack spacing, and proximity to fish habitat. Biotic factors also affect entrainment, including diurnal and/or seasonal patterns of fish migration and dispersal, fish size and swimming capabilities, life history requirements, and density-dependent influences (e.g., resource availability) on fish populations in upstream habitats.

In addition, survival of turbine-entrained fish depends on the physical characteristics of the turbine system, such as head, turbine size and design, runner speed, wicket gate openings, number of runner blades, runner blade angle, gap size, and water flow through the turbine. Many of these factors can be causes of mechanical injury, and studies suggest that survival probability primarily depends on the size of the fish, species, and type of turbine.

During the past 30 years, owners of hydroelectric facilities, mostly applicants for FERC relicensing, have conducted numerous field studies to assess impingement, entrainment, and turbine survival at many small-to-medium-sized projects. Over 50 site-specific studies of resident fish entrainment and mortality at hydroelectric sites in the United States have been performed to date. The projects studied vary by location, size, operation patterns, fish presence, reservoir characteristics, and intake features such as trashrack spacing and intake velocities. Similarly, these studies contain extensive turbine survival data for a range of turbine types and physical characteristics. In recent years, this extensive empirical database has been successfully used to conduct desktop assessments of fish impingement, entrainment, and turbine survival at many projects throughout the country. This approach is currently accepted by the FERC, as well as other federal agencies and most state fisheries agencies nationwide.

The Project may have an effect on potential entrainment and mortality that will vary with river flow, fish species, season, and fish size/life stage. The majority of entrained fish species will likely be percids (perch family), centrarchids (sunfish/bass family), and to a lesser degree ictalurids (catfish family), and young life stages of all species, including eggs, fry, juveniles, and some young adults incapable of intake avoidance or exclusion by the trashracks. Monthly quantitative entrainment estimates were derived for a list of recreational and ecologically important target species. This included an analysis of empirical entrainment rate data collected at various hydroelectric projects, species periodicities, and their average Relative Composition (RC%) in the Project’s pools.

Blandin Dam, which impounds water at the Grand Rapids Project, consists of a concrete and rock-filled timber crib, timber piles, and steel sheetpile structures founded on natural soils consisting primarily of sand and gravel deposits. Beginning on the right side of the structure (looking downstream) the dam consists of an abutment and retaining wall, gated spillway, and a powerhouse. The gated spillway consists of 6 stop log gates, 3 slide gates, and 1 Tainter gate. Stop log gates 1, 2, and 9 are approximately 7 feet wide by 8.5 feet high; stop log gates 7 and 8 are approximately 6.5 feet wide by 8 feet high; and stop log gate 10 is approximately 7.5 feet wide by 8.5 feet high. The south slide gate is approximately 9.5 feet wide by 8 feet high; the center slide gate is approximately 12 feet wide by 8 feet high; and the north slide gate is approximately 9 feet wide by 8 feet high, all over a sill at elevation 1,260.6 feet. The Tainter gate is approximately 12 feet wide by 14 feet high over a sill elevation of 1,254.1 feet.

The intake and outlet works are integral with the powerhouse. Unit No. 4 has a 29-foot-wide by approximately 16.5-foot-high intake and Unit No. 5 has a 19-foot-wide by approximately 16.5-foot-high intake. Steel trashracks protect the intakes to both turbines. The 3/8-inch vertical trashrack bars have 4 inches and 3 inches of clear spacing on Units 4 and 5, respectively. The adjacent mill water intake structure (a non-Project facility) is equipped with a separate trashrack and a traveling wire mesh screen (Blandin Paper Company 1991).

The Project includes one vertical-shaft Francis unit (Unit 4) and one fixed-blade propeller unit (Unit 5) and has a total installed capacity of 2.1 megawatts (MW) and a total maximum hydraulic capacity of 1,600 cubic feet per second (cfs) (600 cfs for Unit No. 4 and 1,000 cfs for Unit No. 5). The Project Boundary and layout are shown in Figure 1 and Figure 2. Additional Project specifications relevant to the entrainment assessment are provided in Table 2.

As detailed in the Pre-Application Document (PAD) prepared for the Project (MP 2018a), the Mississippi River flow exceedances obtained from the United States Geological Survey (USGS) stream gages were used to determine the hydrologic variability and amount of water available for generation. As discussed below, the hydraulic capacity of the Project and the historical hydrological data were used to estimate monthly flow volume potentially used for generation.

Table 2. Grand Rapids Hydroelectric Project Specifications

Parameter	Specification
Installed Capacity (MW)	2.1
Operating Mode	Run of River
Unit Type	Francis / Propeller
Unit Orientation	Vertical
Number of Units	2
Max. Hydraulic Capacities of Each Unit (cfs)	600 / 1,000
Min. Hydraulic Capacities of each Unit (cfs)	270 / 450

Parameter	Specification
Turbine Efficiency Maximum	0.94%
Generator Efficiency	0.94%
Runner Diameter (inches)	68 / 84
Runner Hub Diameter (feet [ft])	6.42
Runner Speed (rotations per minute [rpm])	120 / 150
Number of Blades	11 / 4
Turbine Rated Head (ft)	19
Trashrack Spacing (inches)	4 (Unit 4) / 3 (Unit 5)
Trashrack Dimensions (L X H) (ft)	29 X 16.5 / 19 X 16.5
Intake Width (ft)	48
Intake Depth with Reservoir at Normal Pool Elevation (ft)	0-15.5
Maximum Operating Flow (cfs)	1,600
Minimum Operating Flow (cfs)	270
Maximum Intake Velocity for Unit 5 (feet per second [ft/s])	1.91
Maximum Intake Velocity for Unit 4 (ft/s)	2.08

4.2 Fish Community

The Grand Rapids Project is located in the Prairie-Willow watershed within the larger Upper Mississippi River Basin. The Upper Mississippi River Basin includes 15 separate watersheds and covers approximately 20,100 square miles (12,864,000 acres) of the State of Minnesota. The Mississippi River headwaters are in Itasca State Park in Itasca County, and from there the river runs a general northeasterly course to Bemidji, then turns eastward to Grand Rapids, before turning south and running through Brainerd, Little Falls, St. Cloud, and the Twin Cities metropolitan area (Minneapolis and St. Paul) before it combines with the St. Croix River at Lock and Dam 2 near Hastings, Minnesota. The Upper Mississippi River Basin drains 15 of the 80 major watersheds in Minnesota and all or parts of 21 counties (MPCA 2017).

The Prairie-Willow watershed is located in the Northern Lakes and Forest ecoregion of Minnesota. This largely forested watershed is 1,316,102 acres in size. Approximately 45 percent of the Prairie-Willow watershed falls within Itasca County, equating to approximately 592,826 acres. The average elevation in the Prairie-Willow watershed is 1,313 feet above sea level, with the highest values occurring in the Northwestern portions of the watershed and lower values in the Southwestern and central regions. Precipitation in the watershed ranges from 25 to 29 inches annually (NRCS 2008). The Mississippi River floodplain is generally wide in the Prairie-Willow watershed as the river meanders through numerous shallow lakes, wetlands, and areas of low topographic relief (NRCS 2008).

The Grand Rapid Project's reservoir, Blandin Reservoir, is a 465-acre reservoir of the Mississippi River with 366 acres of littoral area, 35 miles of shoreline, and a maximum depth of 38 feet (MP 2018a). The lake is classified as an Ecological Class 35, generally describing lakes with a high percentage of littoral area, moderate alkalinity, and moderate transparency and productivity with a trophic state index of 47.7 (meso- to meso-eutrophic productivity) (Carlson 1977 and MDNR 2013a). The majority of the substrate types within Blandin Reservoir are sand, gravel, silt, and muck (FERC 1993). The littoral zone provides excellent fish habitat with a diversity of aquatic and wetland plant species (MDNR 2013a).

The Mississippi River upstream and downstream of Blandin Reservoir is characterized as a slow-moving, narrow, and deep single channel river (FERC 1993). The dominant substrate within this portion of the river consists of sand and silt. River width at this section of the river ranges from 100 to 300 feet, with a maximum depth of 12 feet, and an average stream gradient of 0.48 feet per mile (FERC 1993). This section of the Mississippi River also has few islands and rapids, though cut-off oxbows are common.

Dam tailwaters, where flow velocities are higher, provide the most diverse habitat and fish assemblage, while pools contain a more lake-like warmwater fishery (FERC 1988).

Blandin Reservoir contains a variety of forage species and popular sportfish species, such as Largemouth Bass (*Micropterus* spp.), Black Crappie (*Pomoxis nigromaculatus*), sunfish (*Lepomis* spp.), bullheads (*Ameirus* spp.), pikes (*Esox* spp.), perch (*Perca*) Walleye, redhorses (*Moxostoma* spp.), and others (MDNR 2018a). The following sections provide an overview of studies and surveys characterizing the fish community in Blandin Reservoir (MP 2018a).

The prevailing habitat, and warmwater fish assemblage with no catadromous or anadromous species, would be expected to result in little seasonal or temporal variations in the communities. Potadromous species may relocate to other pools, tributaries, and lakes for spawning, foraging, or overwintering. Some species may temporarily relocate to cooler waters with higher velocities and dissolved oxygen concentrations during the summer low flow period (FERC 1988).

2016-2017 Impingement Study at Rapids Energy Center

An impingement characterization study was performed in 2017 by Minnesota Power on the traveling water screen of the cooling water intake structure for the Rapids Energy Center located near Blandin Dam for compliance with Section 316 (b) of the Clean Water Act. The Rapids Energy Center intake supplies cooling water to the adjacent mill and is separate from the Grand Rapids Project. This intake is located just upstream of the trashracks for the Project on the embankment wall. The study provides insight as to what species are within the vicinity of the Rapids Energy Center cooling water intake structure and Blandin Dam (MP 2018a). Fish were collected on several dates from May 2016 to May 2017. Ninety-three fish representing four species of two families were collected in

May, June, August, October, and November 2016, and May 2017. Approximately 94 percent of the total collection comprised fish species belonging to the family Centrarchidae, and 6 percent from Percidae. The collection was dominated by Bluegill (*Lepomis macrochirus*, 52%) and Black Crappie (*Pomoxis nigromaculaus* 41%), followed by Yellow Perch (*Perca flavescens*, 6%) and Largemouth Bass (*Micropterus salmoides*, 1%) (MP 2018a).

The Minnesota Department of Natural Resources (MDNR) has performed periodic fish surveys using gill and trap nets at the Grand Rapids Project in Blandin Reservoir since 1973, with the addition of electrofishing in 2012 to target Largemouth and Smallmouth Bass (MDNR 2018b). In general, fish populations and species distributions have been stable throughout this time (MDNR 2006). Catch per unit effort (CPUE) reported by species and gear type is presented below for the top 95 percent of species by relative abundance (Table 3). Several species dominated catches by both passive gear types, including Yellow Perch, Pumpkinseed (*Lepomis gibbosus*), Bluegill, Black Bullhead (*Ameiurus melas*), Yellow Bullhead (*A. natalis*), White Sucker (*Catostomus commersonii*), and Black Crappie, suggesting these species are in higher abundance in Blandin Reservoir. A greater number of fish were collected with gill nets than trap nets in all years except 1973 and 1978; however, trap nets were not used in 1987, one of the largest total collections made by gill nets. Larger centrarchids such as Largemouth Bass and Smallmouth Bass are not well represented by the passive gear types. Yellow Perch (gill nets), Pumpkinseed (gill nets), and Bluegill (trap nets) generally exhibit the highest CPUE across years, as well as in 2012 (MP 2018a).

Table 3. CPUE for the top 95% of species collected using gill nets, trap nets, and electrofishing at Blandin Reservoir, 1973-2012[1] (Source: MDNR 2018b)

Species	1973	1978	1983	1987	1990	1996	2004	2012
Gill Nets								
Yellow Perch	1.5	4.8	2.6	10.3	2.3	5.1	5.9	3.6
Pumpkinseed	--	5.9	2.4	7.9	6.6	0.7	3.3	3.6
Black Bullhead	--	5.1	0.7	2.6	5.0	--	--	--
Northern Pike	2.5	3.8	2.6	2.1	2.9	1.6	2.4	1.8
Rock Bass	2.0	1.3	2.4	2.0	0.7	4.8	1.7	1.2
Walleye	1.5	2.0	0.6	1.1	2.9	1.8	0.6	1.1
Yellow Bullhead	--	2.6	0.6	0.5	3.3	0.2	1.1	0.3
Bluegill	--	0.7	0.1	0.6	2.6	0.1	2.4	1.0
Shorthead Redhorse	--	0.6	0.3	1.0	1.6	0.6	1.5	0.8
Black Crappie	--	1.1	--	0.6	0.6	0.2	1.3	0.2
White Sucker	--	1.0	0.9	0.6	0.7	1.0	0.3	0.1
Total Fish Collected[2]	**15**	**270**	**96**	**247**	**215**	**150**	**220**	**136**

Species	1973	1978	1983	1987	1990	1996	2004	2012
Standard Trap Nets								
Bluegill	3.6	8.3	1.9	--	4.0	1.2	1.8	1.9
Pumpkinseed	0.4	5.6	1.9	--	0.5	1.0	0.3	2.3
Black Bullhead	--	2.8	0.5	--	--	--	--	--
Yellow Bullhead	--	5.3	--	--	0.4	0.4	0.1	0.8
Black Crappie	0.8	3.3	--	--	--	0.4	0.2	--
Yellow Perch	2.2	2.3	1.5	--	0.1	0.6	0.6	0.4
Brown Bullhead	1.4	1.9	--	--	0.1	--	--	0.1
Northern Pike	1.4	2.2	0.4	--	0.1	1.0	0.3	0.1
White Sucker	0.4	2.0	0.5	--	0.3	--	--	0.1
Bowfin	--	1.4	0.3	--	0.4	0.2	0.1	0.3
Total Fish Collected[3]	**55**	**437**	**61**	**0**	**49**	**48**	**32**	**50**
Electrofishing								
Largemouth Bass	--	--	--	--	--	--	--	21.33
Smallmouth Bass	--	--	--	--	--	--	--	1.33
Total Fish Collected	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**34**

1 Species are ordered from greatest to least overall relative abundance.
2 Other species collected include Largemouth Bass, Bowfin, Brown Bullhead, Smallmouth Bass, Silver Redhorse, Cisco, hybrid sunfish, and Muskellunge.
3 Other species collected include Rock Bass, Largemouth Bass, Walleye, and hybrid sunfish.

Sample collections in 2012 at Blandin Reservoir were dominated by the centrarchids (sunfish and Largemouth Bass) family for both gear types, followed by percids (Perch and Walleye) and esocids (pikes) by gill nets, and ictalurids (bullhead) and percids by trap nets (Figure 3). The overall composition of fish collections at Blandin Reservoir is consistent with historical data and with the trophic status and ecological classification of this waterbody (Schupp 1992, MDNR 2006). Therefore, for the purposes of this study, the catches from gill net and trap net surveys were combined across all years to determine the RC for species/guilds of interest.

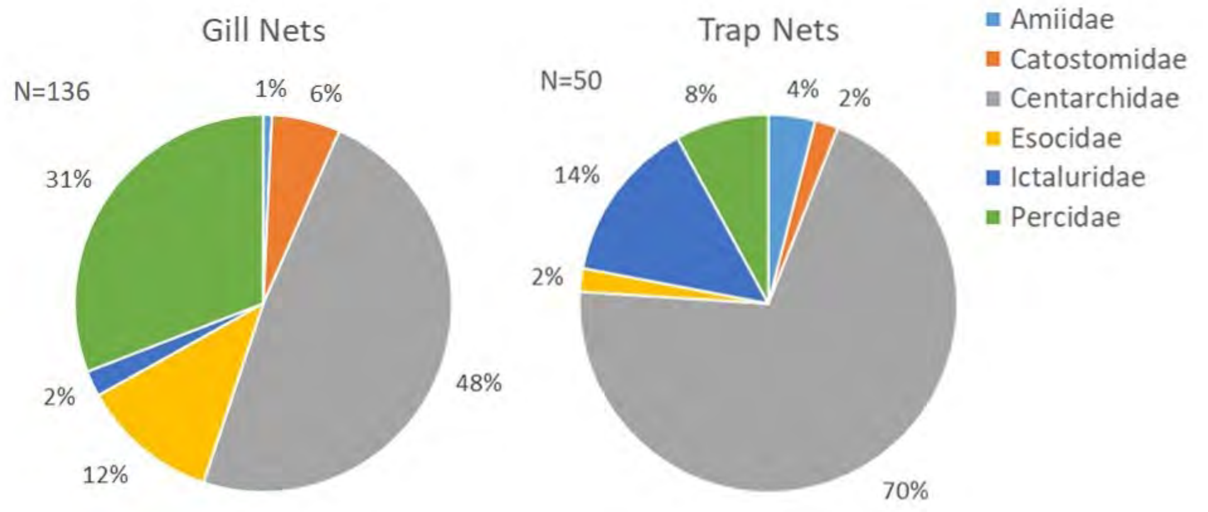

Figure 3. Relative abundance of fish collection by family in Blandin Reservoir, 2012 (Pooled gill and trap net)

Blandin Reservoir has primarily been stocked with Walleye and Muskellunge since 1971 (MDNR 2013a). Approximately 281 adult Muskellunge (*Esox masquinongy*) and 32,000 Walleye fingerlings have been stocked in Blandin Reservoir since 2008. Walleye in Blandin Reservoir have been stocked by both MDNR and private citizens/sporting groups and will continue on a biennial basis (MDNR 2013a). If long-term goals set for the Walleye population are not met after the next population assessment, stocking may be discontinued (MP 2018a).

Table 4 includes a list of fish species that have been documented from fisheries surveys conducted throughout the Project vicinity since 1973. The list includes each species percent RC, which is used below in the entrainment assessment.

Blandin Reservoir supports a variety of non-migratory forage species and popular sportfish species such as Largemouth Bass, Black Crappie, Sunfish, Perch, Pike, Walleye, and others. The MDNR has performed periodic fish surveys in Blandin Reservoir for over 30 years. The overall composition of fish collections in Blandin Reservoir is consistent with historical data and with the trophic status and ecological classification of the waterbody.

No Endangered Species Act or state-listed fish or aquatic species have been identified in the vicinity of the Project.

4.3 Target Fish Species

Typically, a subset of fish species is selected from a complete species list when conducting desktop entrainment assessments. The selection process typically includes those species of highest abundance; game and forage species; species of conservation concern, including any rare, threatened, or endangered species; obligate migrants (i.e., those species requiring migration to complete a life cycle); and representatives of several different habitat-use guilds to provide ecological variability. Often, species selected for entrainment analyses may not be represented in available entrainment databases. In such instances, one or more species, or a group of species (e.g., guild, genus, or family), are typically used as a surrogate(s). As discussed below, this approach was employed for this analysis. Species were selected according to the above-referenced criteria and surrogates were used when specific species were not represented in the Electric Power Research Institute (EPRI) database.

Table 4 includes the target species or pooled guilds/families of similar species (and their RC%) selected for analysis at the Project. These six species/guilds represent approximately 98 percent of the total species composition of Blandin Reservoir. As described below, species composition was used to adjust (based solely on RC%) entrainment estimates to make them specific to the target fishery. Species such as Walleye, Muskellunge and Northern Pike, represent games species, while Yellow Perch and the sunfishes (centrarchids) were used to represent forage species. Yellow Perch are an important forage species in this reservoir (MDNR 2018b). Spawning and early life stage periodicities, along with life history descriptions in Appendix B, are provided as general information regarding habitat use and seasonal life stage presence.

Table 4. All fish species and their percent RC from MDNR gill and trap net survey data

Fish Species	Blandin Reservoir	
	N (number of individuals)	RC%
Bluegill	271	13.0
Pumpkinseed	368	17.7
Black crappie	85	4.08
Rock bass	143	6.9
Hybrid Sunfish	2	.096
Largemouth bass	30	1.4
Smallmouth bass	16	.01
Black Bullhead	144	6.9
Brown Bullhead	48	2.3
Yellow Bullhead	148	7.1
Northern Pike	198	9.5
Muskellunge	1	.04
Bowfin	44	2.1
Cisco	2	.096
Shorthead redhorse	53	2.5
Silver redhorse	2	.001
White sucker	71	3.4

Fish Species	Blandin Reservoir	
	N (number of individuals)	RC%
Walleye	91	4.3
Yellow Perch	364	17.5

Table 5. Target species and polled families for entrainment analysis and their percent RC

Target Species or Family	RC%
Yellow Perch	17.49
Walleye	4.37
Centrarchids (Sunfish/Bass)	43.97
Esocids (Pike)	9.56
Ictalurids (Pooled Bullheads)	16.34
Catastomids (Suckers)	6.05
Total	**97.78**

4.4 Impingement, Turbine Entrainment, and Survival

4.4.1 Overview

The potential for fish to become entrained or impinged at a hydroelectric facility is dependent on a variety of factors such as fish life history, size, and swimming ability, along with water quality, operating regimes, inflow, and intake/turbine configurations (Cada et al. 1997). Impingement may occur when a fish does not pass through the trashrack (entrained), but is instead held or impinged on the screens due to forces created by the intake velocities Entrainment may occur when fish are pulled through or volitionally pass through the trashrack and into the intakes. Early life stages of fish such as eggs, larvae, fry, and juveniles are most vulnerable to entrainment due to their small size which allows passage through trashracks and limited swimming ability which does not allow them to overcome intake velocities. Larger life stages of fish such as larger juveniles, sub adults, and adults become vulnerable to impingement when they are large enough to span trashrack openings in and avoid direct entrainment through the racks, Impingement potential is also related to the intake velocities and if fish have the burst swimming capabilities to overcome intake velocities. A gradient of potential exists both temporally and spatially, where smaller-sized fish may be in higher abundances during certain portions of the year, thus increasing their potential for entrainment. In addition, diurnal and seasonal movements of both small and large fish may bring them in close proximity to intake structures. Physical and operational characteristics of a given project, including trashrack bar spacing, intake velocities, intake depth, stratification, and intake proximity to feeding and rearing habitats also affect the potential for a fish to become entrained. These factors and several others are used to make general assessments of entrainment and impingement potential at hydroelectric projects using a desktop study approach.

The size of trashrack bar spacing is a significant factor to consider when designing intake structures for operating efficiency and successful exclusion of woody debris and other objects that could damage turbines. Analyses by FERC (1995a) and Winchell et al. (2000) found no consistent relationship between trashrack clear spacing and the size of fish entrained. The majority of fish entrained were small in size and similar size distributions were found among sites with widely varying trashrack spacing, which indicates that the entrainment potential for larger lifestages is not solely influenced by trashrack spacing.

This assessment evaluates impingement/intake avoidance using the existing 4-inch and 3-inch clear spacing at the Project. The assessment compares available target fish swim speeds with calculated intake velocities, as well as estimating minimum fish lengths for the target fish species that would either be excluded (too large) or impinged by the existing trashrack spacing. Representative swim speed data for the target species/guilds were available in scientific literature, while surrogate species were used to represent target species where the literature does not provide sound swim speed data. (Appendix D). A scaling factor relating fish body width to total length is used for the impingement assessment to determine minimum sizes of the target fish species that would physically be excluded by the trashracks (Smith 1985). This is done by dividing the trashrack clear spacing by the scaling factor to determine the minimum size of fish that would be excluded.

4.4.2 Empirical Entrainment Rate Data

An extensive literature review was conducted on entrainment studies previously completed for various hydroelectric facilities throughout the United States. Recent FERC relicensing entrainment studies (HDR Engineering, Inc. 2019, 2017, 2016, 2013a, 2013b, 2012a, 2012b, 2012c, 2011, 2010a, 2010b, 2010c; HDR|DTA 2010a, 2010b; GeoSyntec Consultants [GeoSyntec] 2005; Normandeau Associates Inc. [Normandeau] 2008, 2009) have utilized desktop approaches for such assessments, where data compiled by EPRI (1992, 1997a, 1997b) and FERC (1995a, 1995b) has most commonly been used for comparative purposes. These reports have detailed trends and correlations between fish community characteristics, entrainment rates, mortality, and passage with hydroelectric plant design and operation. Findings from field trials conducted at these projects and their transferability across the hydroelectric spectrum have eliminated the need for costly and time-consuming survival/netting studies at FERC hydroelectric projects (EPRI 1997a).

The EPRI (1997a) entrainment database provides results from field trials conducted at 43 hydroelectric facilities east of the Mississippi River using full-flow tailrace netting. Full-flow tailrace netting is the most preferred (and costly) entrainment study methodology as opposed to partial-flow tailrace netting, intake gallery netting, and/or hydroacoustics. This involves the placement of a conical net in the immediate tailrace to collect the entire discharge on a seasonal or monthly basis. This results in relatively accurate entrainment rates (fish/volume of water if recorded, or fish/hour/cfs of sampled unit capacity), including the number, species, and size of entrained fish. Most of the studies adjusted data based on net collection efficiencies realized during sampling, although studies conducted at the Buzzards Roost, Gaston Shoals, Hollidays Bridge, Ninety-Nine Islands, and Saluda projects did not. The results from these projects were excluded from this assessment. Other potential sources of error in the database include net intrusion of fish in the tailrace. Larger fish will often enter the draft tube before the net is installed, thus potentially allowing for net intrusion of fish that actually did not pass through the turbines. Larger fish possess swim speeds that would be capable of escaping the intake velocities reported for the Project, and certain trashrack spacings at the EPRI projects suggest larger fish collected in nets were not physically capable of passing through the trashracks. The impingement and avoidance analysis discussed herein is based on the 4-inch and 3-inch clear spacing currently existing at the Project and shows the minimum size of fish physically excluded from such spacing, in addition to expected burst swim speeds.

Since only approximately half of the studies in the EPRI database recorded volume of water sampled, the number of fish per hour per 1,000 cfs of unit capacity was used in this assessment. This allowed for the standardization of the data and a larger sample size in the EPRI database from which to draw. All of the projects/studies in the database recorded hours sampled, as well as provided the hydraulic capacity of the sampled units. These rates were determined for 10 size groups for each species as provided in EPRI (1997a).

Entrainment rates derived from 37 of the EPRI (1997a) sites were used in this entrainment and survival assessment. Characteristics from each site (Appendix D) and associated entrainment netting study results were used to draw comparisons with current and proposed Project operations and entrainment potential. This involved analysis of Project/turbine specifics, hydrology, operations, and the calculation of monthly entrainment rates for the target or surrogate species.

Some desktop entrainment studies have only used a few projects from the EPRI database that most closely resemble the facility being evaluated. Projects are often selected based on similarities in hydraulic capacity, operations, reservoir size, species compositions, and regional proximity; however, this method is subjective and can reduce the application of the database in terms of target species representation and monthly entrainment rate data. Fish populations are very dynamic and can change from year to year within and between projects, depending on certain biotic (recruitment and year class strength) and abiotic (flow and temperature) interactions. For example, high recruitment in a given year may increase a species' potential for entrainment based on density alone. Although certain projects used may not exactly match the specifications of the project being evaluated, it is our opinion that using as many projects as possible from the EPRI database accounts for the variability of aquatic ecosystems and fish populations, while providing a robust database for calculating average monthly entrainment rates for a wide range of species and sizes. As discussed herein, the rates are then applied to the hydrology and project operations to obtain an entrainment estimate specific to the target project. Entrainment estimates for each species result from this calculation, which are then adjusted by their RC% to make them specific to the projects' fishery.

4.4.3 Project Turbine Entrainment Estimates

Average monthly entrainment rates (fish per hour per 1,000 cfs unit capacity) were calculated for each target species or guild. Using the period of record (POR) (1883-2018), flow data was used to determine the monthly entrainment rates in a dry (90% flow exceedance), average (50% flow exceedance), and wet (10% flow exceedance) year. Flow data and Project operations were reviewed to provide conservative estimated monthly generation amounts in terms of flow (1,000 cfs-hours) (Appendix A). Monthly entrainment rates for the target species were then multiplied by the monthly generation amounts to obtain a monthly entrainment estimate for four size groups per species/guild. Monthly entrainment estimates were then adjusted based on each species' RC% for a given hydroelectric project, as provided in Table 5. This allowed for entrainment estimates that are specific to the fishery composition found in the Project's reservoir.

As an example, the following steps were taken to estimate monthly/annual entrainment rates:

(1) Monthly entrainment rates (fish/hr/1,000 cfs of unit capacity) were determined from the EPRI database for four size groups of each target/surrogate species.

(2) These monthly rates for each species or guild/size group were then multiplied by the monthly flow amounts determined for an average, dry, and wet water year that would have been passed through the Project. For example, using the POR June generation amount 825 $_{1,000}$ cfs-hours) and June yellow perch (0-4 in) entrainment rate (6.943), the following entrainment estimate resulted: **6.943 fish/hr/1,000 cfs of unit capacity x 825 $_{1,000}$cfs-hours = ~5,730 fish.**

(3) This value was then multiplied by yellow perch RC% in the Project reservoir (17.5%): **5,730x 0.1749 = ~1,000 fish**. This methodology was conducted for each species, month, and size group (Appendix F) with the resulting number of fish summed to obtain combined annual entrainment estimates.

4.4.4 Turbine Survival

Fish may suffer immediate or latent mortality during entrainment through a hydropower plant. This could be caused by a number of factors related to mechanical injuries, sheer stress, pressure changes, cavitation, and/or turbulence (Odeh 1999; Cada et al. 1997). Immediate mortalities typically occur from mechanical injuries, where blade strikes can completely sever fish or cause blunt force trauma. Other physical injuries such as grinding, abrasions, and cuts may make fish more susceptible to disease and predation, thus causing latent mortality. Fish with open wounds and abrasions are more susceptible to bacterial and viral diseases due to loss of their skin's mucous layer, while physical injuries may limit fish mobility and predator avoidance (Jenkins and Burkhead 1993).

Pressure changes, particularly in those fish with closed swim bladders (physoclistous), may often cause latent mortality. Shear stress, or parallel surface pressure, can also lead to latent or immediate mortalities. Injuries sustained from shear stress could include the removal of skin mucous and loss of eyeballs and mouth parts (Cada et al. 1997). Turbulence occurs at different scales while a hydroelectric turbine is operating, often leading to pressure and shear-stress-related injuries. However, turbulence may also disorient fish after passage, potentially creating higher predation potential. Cavitation, or the formation of gas bubbles in areas of low pressure (i.e., downstream of a turbine blade), is another form of injury that can cause both latent and immediate mortality. These types of pressure-related injuries, however, most often occur at dams with >100 feet of head. It is presumed that injuries/mortalities related to pressure/cavitation will not occur at the Project due to an operating head of approximately equal to or less than 19 feet. Some disorientation may occur related to turbulence during turbine passage, but it is not expected to cause immediate or latent mortalities.

4.4.5 Blade Strike Analysis

A predictive blade strike model was used to estimate turbine survival for fish passing through the Project's turbines. The Advance Hydro Turbine model (Franke et al. 1997) is a blade strike probability model developed by the U.S. Department of Energy program to develop more "fish-friendly" turbines. Franke et al. (1997) refined the original Von Raben Model (cited by Bell 1981) to account for the effect of tangential projection of fish length and flow angle on operating head and discharge parameters.

It has been suggested that the majority of fish mortalities at low head dams (<100 feet) are caused by fish striking a blade or other component of the turbine unit (Franke et al. 1997). The probability of blade strike in the model is based on several factors, including the number of runner blades, fish length, runner blade speed, turbine type, runner diameter, turbine efficiency, and total discharge.

Model predictions were made for four fish length increments for both the francis and turbine units. For the propeller unit, three *r* values were used to estimate blade strike probability at three different points along the runner radius where fish enter the turbine. These included the edge of the hub (40% of the runner radius), mid-blade between the turbine hub and the discharge ring (65% of the runner radius), and blade tip (95% of the runner radius).

A correlation factor (lambda) was added to each equation to account for the fact that a fish may not always lie in a plane of revolution, as well as the fact that the strike location on the fish (head) may be more detrimental than other less-sensitive locations (tail). Von Raben (cited by Bell 1981) incorporated the correlation factor to adjust the predictive turbine strike results to more closely match empirical results. Franke et al. (1997) suggested correlation factors between 0.1 and 0.2, based on test results using Pacific salmonids. In this assessment, correlation factors of 0.10, 0.15, and 0.20 were used, or in other words 10 percent, 15 percent, and 20 percent of strikes are lethal.

Blade strike probabilities for the Francis unit currently at the Project were calculated for each correlation factor with the associated model input parameters. Survival was calculated by subtracting the predicted strike estimate from 100 for each size class. Average survival was calculated for each turbine passage route, and an overall average was calculated from all correlation factor combinations for all 1-inch groups. Average survival rates were then calculated for each size group expected to be entrained for each target species based on the impingement/exclusion assessment. These survival rates were then multiplied by the seasonal entrainment estimates to derive a fish mortality estimate.

The following equations (Franke et al. 1997) were used for a Francis horizontal and pit-type Kaplan turbine unit to calculate blade strike probability and survival at the Project under maximum turbine flow efficiency:

Francis Turbine Formula:

$$P = \lambda \frac{N \cdot L}{D} \cdot \left[\frac{\sin \alpha_t \cdot \frac{B}{D_1}}{2 Q_{\omega d}} + \frac{\cos \alpha_t}{\pi} \right]$$

Descriptions of the variables in the equation are:

P = Probability of strike
N = Number of turbine blades
L = Fish length
D = Runner diameter
D_1 = Diameter of runner at inlet
λ = Strike mortality correlation factor
B = Runner height at inlet
Q_{wd} = Discharge coefficient
α_t = Angle to tangential of absolute flow upstream of runner

The equation for predicted survival, S, is:

$S = 1 - P$

The discharge coefficient, Q_{wd}, is derived by the following equation:

$Q_{wd} = Q \div (\omega D^3)$

Descriptions of the additional variables in the discharge coefficient equation are:

Q = Maximum turbine flow rate
ω = Rotational speed

The angle to tangential of absolute flow upstream of the runner is derived by the following equation:

$$\tan(90 - \alpha_t) = \frac{2\pi E_{\omega d} \cdot \eta}{Q_{\omega d}} \cdot \frac{B}{D_1} + \frac{\pi \cdot 0.707^2}{2 Q_{\omega d}} \frac{B}{D_1} \left(\frac{D_2}{D_1} \right)^2 - 4 \cdot 0.707 \cdot \tan \beta \frac{B}{D_1} \frac{D_1}{D_2}$$

An additional variable in the angle to tangential of absolute flow equation is:

E_{wd} = Energy coefficient

The energy coefficient is derived by the following equation:

$$E_{wd} = \frac{g \cdot H}{(\omega \cdot D)^2}$$

In the energy coefficient equation, *g* is acceleration of gravity and *H* is the net head of the turbine.

Also, included in the angle to tangential of absolute flow equation is the following variable:

B = Relative flow angle at runner discharge

The relative flow angle at runner discharge is calculated by the following equation:

$$\tan\beta = \frac{0.707 \cdot \frac{\pi}{8}}{\xi \cdot Q_{\omega d}opt\left(\frac{D_1}{D_2}\right)^3}$$

The additional variables in the relative flow angle equation are:

ξ = Ratio between Q with no exit swirl and Qopt
Qopt = Turbine discharge at best efficiency
D_2 = Diameter of runner at discharge

Propeller Turbine Formula:

$$P = \lambda \frac{N \cdot L}{D} \cdot \left[\frac{\cos\alpha_a}{8 \cdot Q_{wd}} + \frac{\sin\alpha_a}{\pi \cdot \frac{r}{R}}\right]$$

$$\alpha_a = \tan^{-1}\left[\frac{\pi \cdot E_{wd} \cdot \eta}{2 \cdot Q_{wd} \cdot \frac{r}{R}}\right]$$

$$R = \frac{D}{2}$$

$$E_{wd} = \frac{g \cdot H}{(\omega \cdot D)^2}$$

$$Q_{wd} = \frac{Q}{\omega \cdot D^3}$$

$$\omega = RPM \cdot \frac{2\pi}{60}$$

$$S = 1 - P$$

Where:

P = Predicted strike
S = Predicted survival
N = Number of turbine blades
L = Fish length

D = Runner diameter
λ = Strike mortality correlation factor (lambda)
R = Radius of runner = (D/2)
r = Location along radius that a given fish enters the turbine (passage route)
η = Turbine efficiency at maximum flow rate (Q)
E_{wd} = Head coefficient or energy coefficient (see above equation)
Q_{wd} = Discharge coefficient (see above equation)
α_a = Angle to axial of absolute flow upstream of runner (see above equation)
g = Acceleration of gravity
H = Turbine net head
ω = Rotational speed $= RPM \cdot \frac{2\pi}{60}$
RPM = Revolutions per minute
Q = Maximum turbine flow rate

5 Study Results

5.1 Impingement, Trashrack Spacing, and Intake Avoidance

Calculated intake velocities at the Project are provided in Table 2. Burst swim speeds are the theoretical speeds used by fish to escape predation; maneuver through high flows; or in this case, escape intake velocities and avoid entrainment. In general, and based on other studies, most fry and small juvenile burst swim speeds are slightly slower than the maximum intake velocities (1.91 ft/s to 2.09 ft/s) calculated for the Project. Small fish often make up the majority of entrainment samples, likely due to their lack of directed swimming and inability to escape, high densities, and/or tendency to disperse (EPRI 1997a; EPRI 1992; Cada et al. 1997); however, they also possess higher survival rates through turbines. With the exception of Bluegill juvenile, Largemouth Bass fry/juvenile, Smallmouth Bass fry, and Northern Pike juvenile, target species and life stages have burst speeds greater than Project intake velocities which indicates that most species and life stages would be able to avoid impingement. Appendix C includes the swim speed references and raw data used to calculate burst speeds (unless provided in the reference) for the target/surrogate species (Table 6).

Table 6. Target species burst swim speeds

Species	Life Stage	Total Length (in)	Burst/Startle Swim Speed (ft/s)
Bluegill[1]	Juvenile	2.01-2.13	1.84
	Adult	3.94-5.91	2.44
	Adult	6.02	4.3

Species	Life Stage	Total Length (in)	Burst/Startle Swim Speed (ft/s)
Largemouth bass	Fry	0.79-0.87	1.56-2.04
	Juvenile	2.05-5.04	1.84-3.28
	Juvenile	5.91-10.63	3.02-4.34
Northern Pike	Juvenile	4.7[3]	0.9
	Adult	37.8[4]	13.0
Longnose sucker	Juvenile/Adult	3.9-16.0	4.0-8.0
Smallmouth bass	Fry	0.55-0.98	<1.78
	Juvenile	3.58-3.66	2.6-3.6
	Adult	10.3-14.9	3.2-7.8
Walleye	Juvenile	3.15 (Fork Length)	2.48
	Juvenile	6.30 (Fork Length)	6.02
	Adult	13.78-22.44 (Fork Length)	5.48-8.57
Yellow Perch	Juvenile	3.5	2.0
	Adult	9.6	5.6

[1] Used to represent centrarchids.
[2] Used to represent catastomids.
[3] Represents Minimum size length.
[4] Represents maximum size length.
NOTE: Burst/Startle swim speeds calculated at 50% greater than Prolonged/Critical speeds in Appendix D table based on Bell (1991) unless burst speed provided in the literature.

Proportional estimates of body width to total length (scaling factor) were compiled by Smith (1985) for most of the species in this study. This proportional measurement was used to determine the minimum length of each species excluded from the intake by the trashracks (Table 7). Surrogates or groups/guilds of fish were used to represent certain target species if data was not available in Smith (1985). The trashrack spacing (4 inches for Unit 4 and 3 inches for Unit 5) was divided by the scaling factor to get the minimum length of a given species that would be physically excluded. The minimum size of exclusion for all species is either larger than the species are capable of growing, or larger than were documented in fisheries resources. For the purposes of this analysis, it is assumed that the existing trashrack spacing would not exclude any fish from the intakes.

Findings from FERC (1995a) and Winchell et al. (2000) suggest that the majority of fish size classes entrained at hydroelectric projects is much smaller than the minimum length of fish physically excluded by a certain clear spacing, and that length frequencies of entrainment compositions are similar among sites with differing trashrack spacing. It has been suggested that larger fish collected in entrainment samples may have been in the draft tubes prior to tailrace net deployment and/or they may have entered through gaps in the nets once they were deployed (EPRI 1992, 1997b). Such findings indicate that the lack of larger fish in entrainment compositions may be related to their increased swimming performance and ability to avoid intake velocities as they approach a dam. However, entrainment may occur regardless of their swimming performance if the intake openings and resulting intake velocities are the only available attractant flow for downstream migrating fish, particularly in riverine environments (FERC 1995a; EPRI 1997b).

Table 7. Estimated minimum lengths (inch) of each target species excluded by the 4 inch and 3 inch trashrack clear spacing

Common Name	Scaling Factor for Body Width[1]	Minimum Size Excluded[3] by a Trashrack Clear Spacing of 4 inches*	Minimum Size Excluded[3] by a Trashrack Clear Spacing of 3 inches*
Bluegill	0.132	**30.3**	**22.7**
Pumpkinseed	0.13	**30.8**	**23.1**
Rock bass	0.156	**25.6**	**19.2**
Smallmouth bass	0.128	**31.3**	23.4
Largemouth Bass	0.134	**29.9**	22.4
Black crappie	0.085	**47.1**	**35.3**
Yellow Bullhead	0.166	**24.1**	**18.1**
Brown Bullhead	0.166	**24.1**	18.1
Chain Pickerel[2]	0.078	**51.3**	38.5
Smallmouth redhorse	0.127	**31.5**	**23.6**
White Sucker	0.146	**27.4**	20.5
Walleye	0.125	**32.0**	24.0
Yellow Perch	0.114	**35.1**	**26.3**

* 4-inch clear spaced trashracks are located in front of Unit 4 and 3-inch clear spaced trashracks are located in front of Unit 5.

[1] Scaling factor expresses body width as a proportion of total length based on proportional measurements for the target/surrogate species in Smith (1985).

[2] Surrogate for Northern Pike and Muskellunge.

[3] Bolded and underlined minimum sizes of exclusion represent sizes that are larger than the species can attain or are likely to attain in the Project reservoir; in these instances a given species would not be excluded from the project intake by the existing trashrack.

5.2 Empirical Entrainment Rate Data and Species Composition

5.2.1 Species Composition

Sunfish were the majority of species entrained at 42 of the 43 developments included in the EPRI (1997a) entrainment database studies, representing on average 30 percent of the netted species compositions. Sunfish are also fairly common in the Project's pools, representing the second greatest percentage of fish family composition in Blandin Reservoir. This family, as well as Yellow Perch, have the highest potential for entrainment based solely on density.

5.2.2 EPRI (1997a) Monthly/Seasonal Entrainment Rates

Average monthly entrainment rates for four size groups of each target (surrogate/group) species are provided in Appendix E. Entrainment rates for all target species increase in the summer and fall months, likely due to increased activity related to foraging and reproduction resulting in increased juvenile and young-of-year abundances (GeoSyntec 2005; EPRI 1997a; Jenkins and Burkhead 1993). On average, fish measuring less than 2.1 to 4 inches constituted the majority of fish entrainment field trial compositions compiled in EPRI (1997a).

5.3 Project Entrainment Estimates

Analysis of USGS flow data and the Project's minimum and maximum operating flows were used to estimate monthly generation amounts (1,000 cfs-hours) for the POR, a dry year, and a wet year. As a run-of-river (ROR) Project, generation amounts were determined by reviewing the monthly flow duration curves and applying the monthly flow to the maximum possible generation for each month. No minimum flows were assumed for generation, which is a conservative assumption that likely overestimates the amount of generation. Flows in excess of the maximum generation capacity were not considered to have the potential for generating unit entrainment or impingement. Entrainment estimates were calculated for the Project, resulting in monthly and annual generation amounts for the POR, dry, and wet water years.

5.3.1 Grand Rapids Hydroelectric Project

The total annual generation (in terms of flow) estimated at the Project for an average water year (POR) was 9,420 (1,000 cfs-hours), with a range of 3,805 to 14,016, based on the dry and wet years, respectively (Table 8). This resulted in the monthly/annual number of fish estimated to become entrained (Table 9 through Table 11). These values represent Project-specific entrainment estimates, which have been multiplied by the target species' RC% in the Project reservoir. The number of 1,000 cfs hours of potential generation per month was estimated by dividing the monthly average river discharge by 1,000 and multiplying by the number of hours in an average month (730).

As an example, the following steps were taken to estimate monthly/annual entrainment rates:

(1) Monthly entrainment rates (fish/hr/1,000 cfs of unit capacity) were determined from the EPRI database for four size groups of each target/surrogate species.

(2) These monthly rates for each species or guild/size group were then multiplied by the monthly flow amounts determined for an average, dry, and wet water year that would have been passed through the Project. For example, using the June generation amount in a normal year (50% flow exceedance) for (825 $_{1,000}$ cfs hours) and June Yellow Perch (0-4 in) entrainment rate (6.943 fish/hr), the following entrainment estimate resulted:
6.943 fish/hr/1,000 cfs of unit capacity x 825 $_{1,000}$cfs-hours = ~5,730 fish.

(3) This value was then multiplied by Yellow Perch RC% in the Project reservoir (17.49%): **5,730 x .1749 = ~1000 fish**. This methodology was conducted for each target species/family, month, and size group (Appendix E) with the resulting number of fish summed to obtain combined annual entrainment estimates.

Table 8. Estimated generation (1,000 cfs-hours) at the Grand Rapids Hydroelectric Project

	Month	Monthly Generation (1,000 cfs-hours)
LOW FLOW YEAR (90% EXCEEDANCE)	January	218
	February	226
	March	193
	April	185
	May	231
	June	249
	July	253
	August	180
	September	210
	October	283
	November	278
	December	271
	Annual	2,778

	Month	Monthly Generation (1,000 cfs-hours)
NORMAL FLOW YEAR (50% EXCEEDANCE)	January	679
	February	666
	March	593
	April	518
	May	667
	June	825
	July	942
	August	913
	September	956
	October	1059
	November	891
	December	712
	Annual	9,420
WET FLOW YEAR 10 % EXCEEDANCE)	January	1168
	February	1168
	March	1168
	April	1168
	May	1168
	June	1168
	July	1168
	August	1168
	September	1168
	October	1168
	November	1168
	December	1168
	Annual	14,016

Table 9. Monthly low flow year entrainment estimates for target species at the Grand Rapids Hydroelectric Project

Month	Centrarchids	Yellow Perch	Walleye	Pike and Muskellunge	Bullheads	Suckers
January	34	39	2	0	3	12
February	35	44	0	1	6	13
March	15	24	0	3	4	6
April	183	392	1	7	18	11
May	56	51	3	1	6	2
June	101	311	13	6	13	15
July	194	255	18	8	110	20
August	128	22	3	2	10	1
September	213	114	3	2	7	2
October	309	801	4	2	8	140
November	153	18	1	2	9	33
December	64	23	1	1	2	18
Annual	**1,486**	**2,094**	**49**	**36**	**195**	**273**
TOTAL = 4,133						

Table 10. Monthly normal flow year entrainment estimates for target species at the Grand Rapids Hydroelectric Project

Month	Centrarchids	Yellow Perch	Walleye	Pike and Muskellunge	Bullheads	Suckers
January	105	121	7	0	9	39
February	103	129	1	4	18	38
March	46	74	0	11	12	19
April	512	1,096	3	20	51	30
May	162	146	9	4	17	6
June	335	1,030	44	21	44	51
July	724	952	69	31	409	75
August	652	112	14	9	53	7
September	969	517	12	9	33	7
October	1,156	2,994	14	8	29	523
November	489	57	3	6	28	104
December	169	62	2	2	4	47
Annual	**5,422**	**7,289**	**178**	**123**	**704**	**945**
TOTAL = 14,661						

Table 11. Monthly wet flow year entrainment estimates for target species at the Grand Rapids Hydroelectric Project

Month	Centrarchids	Yellow Perch	Walleye	Pike and Muskellunge	Bullheads	Suckers
January	181	207	11	0	15	67
February	181	226	2	8	31	67
March	90	145	0	21	23	37
April	1,153	2,469	6	44	115	69
May	283	256	16	6	30	11
June	475	1,459	62	29	62	72
July	898	1181	86	39	507	93
August	834	143	18	11	67	9
September	1,184	632	14	11	40	8
October	1,276	3,304	15	9	32	577
November	641	74	4	8	36	137
December	278	101	3	3	7	77
Annual	**7,473**	**10,198**	**239**	**188**	**965**	**1,222**
TOTAL = 20,285						

According to this assessment, the average annual number of target species expected to become entrained at the Grand Rapid Project is approximately 14,661 fish (rounded to the nearest hundred). Based on water year, this number could range from approximately 4,133 to 20,285 fish. The majority of the entrained fish in the 0- to 4-inch length groups (Appendix F). Centrarchids and Yellow Perch represent the majority of the entrained taxa.

It should be noted that this is likely an overestimate of entrainment, as entrainment avoidance (using burst swim speeds) of the target species was not factored into these estimates due to uncertainty in relative extent of potential volitional entry, but should be taken into consideration when assessing entrainment potential in general. Additionally, physical exclusion was also not factored into the entrainment and survival estimates due to the size of the trashrack spacing that either not exclude or only exclude individuals larger than those documented in historical fisheries studies in the Project area.

5.3.2 Grand Rapids Hydroelectric Project Blade Strike Analysis

An average blade strike survival rate for each unit was determined for each of the four size groups analyzed in the entrainment assessment. For example, the estimated average survival rate of the 0- to 4-inch length group at Unit 5 was 96.97 percent. This was calculated by averaging the individual blade strike survival rates for the 0- to 4 -inch fish length groups and all possible passage routes (edge of hub, mid-blade, and blade tip) and position in the plane of revolution (correlation factor 0.1, 0.15, and 0.2). This was performed for each generating unit at the Project. It has been suggested that fish turbine mortality is more related to fish size than the type of species (Franke et al. 1997;

Winchell et al. 2000); therefore, the survival rates determined for each length group was deemed transferable across species. In other words, when conducting the blade strike analysis, a 6-inch Yellow Perch has the same survival rate as a 6-inch White Sucker.

Survival of target species through the Project is expected to be high based on this analysis and the size groups of fish expected to become entrained. The majority of entrained fish are in the 0- to 4-inch length groups (Appendix F), which show relatively high survival rates through the Francis-type generating unit and even higher survival rates through the larger propeller unit which also has fewer blades.

Average blade strike mortality rates were multiplied by target species annual entrainment estimates by size class to determine immediate turbine mortality estimates for the Project (Table 12 and Table 13). This analysis was performed for each of the two units to determine the full range of potential blade strike mortalities. Each calculation was performed under the assumption that all entrained fish passed through just one of the units.

According to this assessment, the annual average number (rounded to the nearest hundred) of target species expected to experience immediate turbine-related mortality at the Project is between approximately 800 and 2,800 fish based on a normal flow year. Based on a dry and wet year, these numbers could range from approximately 200 to 800 fish and 1,100 to 3,800 fish, respectively. Unit 5 consists of a propeller turbine with four blades and has a larger diameter than the Unit 4 Francis turbine with 11 blades and a smaller diameter. As would be expected, blade strike mortality rates through Unit 5 were lower than Unit 4, particularly for larger size classes of fish.

Table 12. Annual immediate turbine mortality estimates at Unit 4 & 5 of the Grand Rapids Hydroelectric Project based on a normal water year.

Size Class (in)	Unit 4 Average Blade Strike Mortality Estimate All Species	Unit 5 Average Blade Strike Mortality Estimate All Species	Unit 4 Average Blade Strike Mortality Rate	Unit 5 Average Blade Strike Mortality Rate
<4	974	283	10.42%	3.02%
4-8	1,540	447	31.26%	9.07%
8-15	205	59	59.91%	17.21%
>15	44	17	98.32%	38.54%
Total	**2,763**	**805**	-	-

Note: These blade strike mortality estimates assume that all fish entrained went through one unit and, therefore, encompass the range of possible mortality values.

Table 13. Annual immediate turbine mortality estimates at Unit 4 & 5 of the Grand Rapids Hydroelectric Project based on a low and high water year.

	Size Class (in)	Unit 4 Average Blade Strike Mortality Estimate All Species	Unit 5 Average Blade Strike Mortality Estimate All Species	Unit 4 Average Blade Strike Mortality Rate	Unit 5 Average Blade Strike Mortality Rate
LOW FLOW YEAR (90% EXCEEDANCE)	<4	279	81	10.42%	3.02%
	4-8	418	121	31.26%	9.07%
	8-15	61	18	59.91%	17.21%
	>15	21	5	98.32%	38.54%
	Total	**779**	**225**	-	-
HIGH FLOW YEAR (10% EXCEEDANCE	<4	1,374	399	10.42%	3.02%
	4-8	2,035	590	31.26%	9.07%
	8-15	309	89	59.91%	17.21%
	>15	72	28	98.32%	38.54%
	Total	**3,790**	**1,106**	-	-

Note: These blade strike mortality estimates assume that all fish entrained went through one unit and, therefore, encompass the range of possible mortality values.

5.4 Flow Routing and Potential Spillway Mortality

Entrainment and survival potential at the Project will also vary based on the quantity and route of river flow, which at times may include the spillway, powerhouse, and/or stop-log gates, Tainter gates, or slide gates. Passage through routes other than the generating units was considered for this study. As a ROR Project, all flows in excess of turbine capacity are passed through alternative routes. All flow in excess of the maximum turbine capacity of 1,600 cfs was not considered for the fish entrainment or blade strike analysis. In a low water and normal water year, the monthly average discharge remained below 1,600 cfs for all months. In a high water year, the monthly average discharge was between roughly 2,000 and 2,600 cfs, indicating consistent spill throughout the year. In a normal and low water year there is limited potential for spill and it would likely be limited to brief and isolated events. In higher water years there is a significant potential for spillway passage.

There is potential for some mortality to occur through the alternate routes, particularly under lower spill flow scenarios. Empirical data exists from 16 tests at six hydroelectric facilities, which estimated the survival of fish passing over spillways and through bypass sluices using the HI-Z Turb'N Tag methodology (Heisey et al. 1992). These studies found survival rates ranging from 88.3 percent to 100 percent depending on the species and the specifications of the projects and flows evaluated (Table 14). The 48-hour survival of juvenile herring passed over the spillway at the Crescent Project was 88.3 percent. This rate is likely lower than would be observed at the Project, as juvenile herring are much less hardy and succumb to mortality more easily than the majority of those species present in the Project reservoir.

It is also important to note that the spillway survival rates of the other projects with much higher heads than the Grand Rapids Project had higher survival rates than the Crescent Project, several of which were 100 percent survival. Fish passing over the spillways at these traditional hydroelectric facilities are typically exposed to concrete aprons or other rough surfaces before reaching a downstream pool. It is likely that higher flows/lower gross head at the Project’s spillway would allow fish to plunge into the next downstream pool without injury. As flows recede and gross head increases, spill mortality potential may slightly increase due to the greater plunge distance and strike velocities, as well as the potential for abrasion or scraping.

Table 14. Spillway survival rates from 16 tests at 6 hydroelectric facilities (Heisey et al. 1992)

Project	Year	Passage Route	Species	Temp. (°C)	Head (ft)	Spill Flow Rate (cfs)	48 h Survival (%)	Injured		Injury Type
								No.	(%)	
Crescent, NY	1991	Spillway	Juv. herring	14-17	13	400	88.3	0	(0.0)	N/A
Garvin Falls, NH	2005	Bypass/ collector	Juv. Atlantic salmon	13	30	800	100	0	(0.0)	N/A
Little Falls Hydro, NY	1996	Bypass Pipe	Adult herring	18-19	44	100	98.7	3	(3.7)	Bruises
Little Falls Hydro, NY	1996	Bypass Pipe	Adult herring	18-19	44	50	100	1	(2.9)	Bruises
Rock Island, WA	1997	Spillway[b,c]	Juv. Chinook salmon	4	41	1,900	95.1	11	(4.5)	Int injuries
Rock Island, WA	1997	Spillway[b]	Juv. Chinook salmon	4	41	1,000	98.4	3	(1.2)	Dmg/hem eye
Rock Island, WA	1999	Spillway[b]	Juv. Chinook salmon	13-14	41-49	2,500	99.5	0	(0.0)	None
Rock Island, WA	1999	Spillway[b]	Juv. Chinook salmon	13-14	41-49	1,000	99.5	1	(0.5)	Int hem
Rock Island, WA	2000	Spillway[a,b,d]	Juv. Chinook salmon	14-15	40-43	2,500	99.0	0	(0.0)	N/A
Rock Island, WA	2000	Spillway[a,b,e]	Juv. Chinook salmon	14-15	40-44	2,500	100.0	0	(0.0)	N/A
Rock Island, WA	2001	Spillway[a,b,d]	Juv. Chinook salmon	9-10	39-43	2,500	99.0	3	(1.5)	Dmg/hem eye
Rock Island, WA	2001	Spillway[a,b,e]	Juv. Chinook salmon	9-10	39-43	2,500	100.0	3	(1.5)	Dmg/hem eye
Vernon, VT/NH	1995	"Fish tube" (Sluice)	Juv. Atlantic salmon	16-18	27	400	93.3	0	(0.0)	N/A

Project	Year	Passage Route	Species	Temp. (°C)	Head (ft)	Spill Flow Rate (cfs)	48 h Survival (%)	Injured		Injury Type
								No.	(%)	
Wilder, VT	1992	Sluice	Juv. Atlantic salmon	9-16	52	200	97.0	31	(31.0)	Bruises
Wilder, VT	1992	Sluice	Juv. Atlantic salmon	9-16	52	300	91.0	12	(27.3)	Bruises
Wilder, VT	1992	Sluice	Juv. Atlantic salmon	9-16	52	500	97.0	14	(14.1)	Bruises

[a] Spillway with flow deflector.

[b] Overflow weir or spill to attract surface-oriented juvenile salmonids.

[c] Spill directed onto concrete slab.

[d] Periphery release location.

[e] Off-center release.

6 Discussion and Analysis

The Grand Rapids Project has little potential for impingement due to intake velocities that do not exceed the burst swimming capabilities of nearly all fish species and lifestages that are large enough to be impinged. The Project has the potential to create some degree of entrainment that will vary with river flow, species, season, and fish size/life stage. The majority of entrained fish will likely be centrarchids, percids, and young life stages of all species, including eggs, fry, juveniles, and some young adults incapable of intake avoidance or exclusion by the trashracks. Most larval (yolk-sac) fish can only adjust their vertical position in the water column and drift with river flow (Jenkins and Burkhead 1993). Fry (no yolk-sac) and juvenile fish possess escape or burst swim speeds capable of avoidance; however, adults are more successful in avoiding intake structures and, thus, comprise the minority of entrained fish at a given system.

Entrainment risk of the target species will vary by a number of factors at the Project, including species, life stage, season, swim speed, the flow regime, and hydropower operations. The quantitative entrainment estimates provided in this report utilized target species empirical entrainment rate data collected at various hydroelectric projects, species periodicities, and their average RC in the Project reservoir. According to this assessment (reference Table 9 through Table 11), the average annual estimate of target species expected to become entrained at the Project is 14,661 fish (rounded to nearest fish) based on a normal water year for the POR. For dry and wet water years, this number could range from approximately 4,133 to 20,285 fish, respectively. These mortality estimates assume that all fish entrained went through one unit and, therefore, encompass the range of possible mortality values. The majority of the entrainment estimates are small fish in the 0- to 4-inch length groups. Yellow Perch and centrarchids (sunfish) represented a large majority of entrainment, particularly in the summer and fall months.

Fish mortality rates through the Project's Francis unit are relatively low, and are very low for the larger propeller unit, particularly for small fish that make up the majority of all entrained fish. Average blade strike survival rates were multiplied by target species monthly entrainment estimates to determine immediate turbine mortality estimates of the target species (reference Table 12 and Table 13). This study included all size classes of fish as the 4-inch and 3-inch trashracks currently in place at the Project do not exclude most fish within Blandin Reservoir. According to this assessment, the annual average number (rounded to the nearest fish) of target species expected to suffer immediate turbine-related mortality at the Project is estimated to be 3,568 fish based on a normal water year for the POR. For dry and wet water years, this number could range from approximately 1,004 to 4,896 fish, respectively. Entrainment mortalities will likely be the highest in the summer and fall months when fish are most active.

7 Literature Cited

Beamish, F. W. H. 1978. Swimming capacity. Fish Physiology, Vol. VII: 101-187.

Beecham, R. V., P. R. Pearson, S. B. Labarre, and C. D. Minchew. 2009. Swimming Performance and Metabolism of Golden Shiners. North American Journal of Aquaculture. 71:59-63.

Bell, M. C. 1981. Updated compendium on the success of passage of small fish through turbines. Prepared for U.S. Army Corps of Engineers, North Pacific Division, Portland, OR.

———. 1991. Fisheries Handbook of Engineering Requirements and Biological Criteria. Prepared for U.S. Army Corps of Engineers, North Pacific Division, Fish Passage Development and Evaluation Program, Portland, OR. Third Edition.

Blandin Paper Company. 1991. Application for New License for Major Water Power Project 5 Megawatts or Less, FERC Project No. 2362, Blandin Hydroelectric Project. December.

Bunt, Christopher M., C. Katopodis, and R.S. McKinley. 1999. Attraction and Passage Efficiency of White Suckers and Smallmouth Bass by Two Denil Fishways. North American Journal of Fisheries Management 19:793-803.

Cada, G. F., C. C. Coutant, and R. R. Whitney. 1997. Development of biological criteria for the design of advanced hydropower turbines. DOE/ID-10578. Prepared for the U.S. Department of Energy, Idaho Operations Office, Idaho Falls, Idaho.

Carlander, K.D. 1977. Handbook of Freshwater fishery biology, Volume 2. The Iowa State University Press. Ames, Iowa. 1977.

Carlson, D.M. 1977. A Trophic State Index for Lakes. Limnology and Oceanography 22(2): 361-369.

_____. 1992. Lower Oswegatchie River: a warm-water fish survey. New York State Department Environmental Conservation, Watertown.

Deng, Z., M. C. Richmond, G. R. Guensch, and R. P. Mueller. 2004. Study of fish response using particle image velocimetry and high-speed, high-resolution imaging. Prepared for U.S. Department of Energy by Pacific Northwest National Laboratory, Richland, Washington.

Drucker, E. G. and G. V. Lauder. 1999. Locomotor forces on a swimming fish: three-dimensional vortex wake dynamics quantified using digital particle image velocimetry. J. Exp. Biol. 202, 2393-2412.

Electric Power Research Institute (EPRI). 1992. Fish entrainment and turbine mortality review and guidelines. Prepared by Stone & Webster Environmental Services, Boston, Massachusetts. EPRI Report No. TR-101231, Project 2694-01. September 1992.

———. 1997a. Turbine entrainment and survival database – field tests. Prepared by Alden Research Laboratory, Inc., Holden, Massachusetts. EPRI Report No. TR-108630. October 1997.

———. 1997b. Guidelines for hydro turbine fish entrainment and survival studies. Prepared by Alden Research Laboratory, Inc., Holden, Massachusetts. EPRI Report No. TR-107299. July 1997.

Federal Energy Regulatory Commission (FERC). 1988. Hydroelectric Development in the Upper Ohio River Basin Final Environmental Impact Statement. FERC Docket No. EL85-19-114.

_____. 1993. Order Issuing New License (Major Project), FERC No. 2362-002, Blandin Paper Company. Issued February 26.

_____. 1995a. Preliminary assessment of fish entrainment at hydropower projects, a report on studies and protective measures, volumes 1 and 2 (appendices). FERC Office of Hydropower Licensing, Washington, D.C. Paper No. DPR-10. June 1995 volume 1) and December 1994 (volume 2).

———. 1995b. Final environmental assessment for hydropower license, Stevens Creek Hydroelectric Project, FERC Project No. 2535-South Carolina, Georgia. FERC Office of Hydropower Licensing, Washington, D.C. November 7, 1995.

Franke, G. F., D. R. Webb, R. K. Fisher, Jr., D. Mathur, P. N. Hopping, P. A. March, M. R. Headrick, I. T. Laczo, Y. Ventikos, and F. Sotiropoulos. 1997. Development of environmentally advanced hydropower turbine system design concepts. Prepared for U.S. Department of Energy, Idaho Operations Office, Contract DE-AC07-94ID13223.

Gardner, A. N., G. D. Jennings, W. F. Hunt, and J. F. Gilliam. 2006. Non-anadromous fish passage through road culverts. Paper No. 067034, Annual Meeting, American Society of Agricultural and Biological Engineers, St. Joseph, MI.

GeoSyntec Consultants. 2005. Fish entrainment evaluation. Catawba-Wateree Project (FERC No. 2232). Prepared for Devine Tarbell and Associates.

HDR Engineering, Inc. 2010a. Fish entrainment and mortality study. BOST3 Hydroelectric Project (FERC No. 12756). Prepared for Nelson Energy and BOST3 Hydroelectric LLC, Golden Valley, Minnesota. June 2010.

———. 2010b. Fish entrainment and mortality study. BOST4 Hydroelectric Project (FERC No. 12757). Prepared for Nelson Energy and BOST4 Hydroelectric LLC, Golden Valley, Minnesota. June 2010.

———. 2010c. Fish entrainment and mortality study. BOST5 Hydroelectric Project (FERC No. 12758). Prepared for Nelson Energy and BOST5 Hydroelectric LLC, Golden Valley, Minnesota. June 2010.

———. 2011. Turbine entrainment and mortality report. York Haven Hydroelectric Project (FERC No. 1888). Prepared for York Haven Power Company, LLC, York Haven Pennsylvania. April 2011.

———. 2012a. Fish entrainment report. Muskingum River Hydroelectric Projects (FERC Nos. P-13412, P-13408, P-13411, P-13406, P-13404, P-13407, and P-13405). Prepared for Free Flow Power Corporation, Boston, Massachusetts. March 2012.

———. 2012b. Fish entrainment report. Williams Hydroelectric Project (FERC No. P-13346). Prepared for Free Flow Power Corporation, Boston, Massachusetts. June 2012.

———. 2012c. Fish entrainment and survival assessment. Braddock Locks and Dam Hydroelectric Project (FERC No. 13739). Prepared for Hydro Green Energy, LLC, Westmont, Illinois. August 2012.

———. 2013a. Fish entrainment study report. Yazoo River Basin Hydroelectric Projects (FERC Nos. P-13702, P-13703, P-13701, and P-13704). Prepared for Free Flow Power Corporation, Boston, Massachusetts. June 2013.

———. 2013b. Fish entrainment study report. Hogansburg Projects (FERC No. P-7518). Prepared for Erie Boulevard Hydropower, L.P. Fulton, New York. 2013.

———. 2016. Colliersville Hydroelectric Project (FERC No. 2788) Final License Application. Appendix B – Study Reports. Section 6 – Fish Passage and Protection Study. Prepared for Goodyear Lake Hydro, LLC. Andover, Massachusetts.

———. 2017. Fish Entrainment Evaluation Study Report. Bear Swamp Project (FERC No. P-2699). Prepared for Bear Swamp Power Company, LLC, Rowe, Massachusetts. 2017.

———. 2019. Fish Passage and Protection Study Report. Mongaup River Hydroelectric Projects: Swinging Bridge Hydroelectric Project (FERC No. 10482), Mongaup Falls Hydroelectric Project (FERC No. 10481, and Rio Hydroelectric Project (FERC No. 9690). Prepared for Eagle Creek Hydro Power, LLC; Eagle Creek Water Resources, LLC; and Eagle Creek Land Resources, LLC. 2019.

HDR|DTA. 2010a. Fish entrainment and impingement. Sutton Hydroelectric Project (FERC No. 12693). Prepared for Brookfield Renewable Power, Marlborough, Massachusetts. June 2010.

———. 2010b. Fish entrainment and survival assessment. Price Dam Hydroelectric Project (FERC No. 12187). Prepared for Brookfield Renewable Power Inc., Syracuse, New York. August 2010.

Heisey, P. G., D. Mathur, and T. Rineer. 1992. A reliable tag-recapture technique for estimating turbine passage survival: application to young-of-the-year American shad (*Alosa sapidissima*). Can. Jour. Fish. Aquat. Sci. 49:1826-1834.

Hocutt, C. H. 1973. Swimming performance of three warmwater fishes exposed to a rapid temperature change. Chesapeake Science 14(1):11–16.

Hoover, J. J., K. J. Killgore, D. G. Clarke, H. Smith, A. Turnage, and J. Beard. 2005. Paddlefish and sturgeon entrainment by dredges: Swimming performance as an indicator of risk. DOER Technical Notes Collection (ERDC TN-DOER-E22), U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Houde, E. D. 1963. Sustained swimming ability of larvae of walleye (*Stizostedion vitreum vitreum*) and yellow perch (*Perca flavescens*). J. Fish. Res. Bd. Canada 26:1647-1659.

Jenkins, R. E. and N. M. Burkhead. 1993. Freshwater fishes of Virginia. American Fisheries Society, Bethesda, Maryland.

Jones, D. R., J. W. Kiceniuk, and O. S. Bamford. 1974. Evaluation of the swimming performance of several fish species from the Mackenzie River. J. Fish. Res. Bd.

King, L. R. 1969. Swimming speed of the channel catfish, white crappie, and other warm water fishes from Conowingo Reservoir, Susquehanna River, PA. Ichthyological Associates, Bulletin No. 4.

Larimore R. W. and M. J. Duever. 1968. Effects of temperature acclimation on the swimming ability of small-mouth bass fry. Trans Am Fish Soc 97:175–184.

Layher, W. G. 1993. Determining swimming speeds for darters of the genera Etheostoma and two cyprinid fishes. Final Report. Challenge cost-share grant between the Ouchita National Forest U.S.D.A. Forest Service and the University of Arkansas at Pine Bluff.

Leavy, Tracy R. and Timothy H. Bonner. 2009. Relationships among Swimming Ability, Current Velocity Association and Morphology for Freshwater Lotic Fishes. North America Journal of Fisheries Management 29:72-83.

Lee, L. A. and J. W. Terrell. 1987. Habitat suitability index models: Flathead Catfish. U.S. Fish and Wildlife Service Biological Report 82(10.152). 39 pp.

Muth, R. T. and J. C. Schmulbach. 1984. Downstream transport offish larvae in a shallow prairie river. Transactions of the American Fisheries Society 113:224-230.

Minnesota Department of Natural Resources (MDNR). 2006. Draft Environmental Impact Statement for the UPM/Blandin Paper Mill Thunderhawk Project. Prepared by HDR. Grand Rapids, MN. January 2006.

_____. 2013a. Lake Management Plan for Blandin Reservoir. Region 2 Grand Rapids F216, D.O.W. No. 31-0533.

_____. 2013b. Lake Management Plan for Prairie Lake. Region 2 Grand Rapids 216, D.O.W. No. 31-0384.

_____. 2018a. Lake Finder: Blandin. Online: [URL] https://www.dnr.state.mn.us/lakefind/lake.html?id=31053300.

_____. 2018b. Fisheries Lake Surveys: Blandin. Online: [URL] https://www.dnr.state.mn.us/lakefind/showreport.html?downum=31053300.

Minnesota Pollution Control Agency (MPCA). 2017. Our Upper Mississippi River. Large River and Basin Restoration and Protection Strategies. Wq-ws4-38b. June 2017.

Minnesota Power (MP). 2018a. Pre-Application Document Volume I of II. Grand Rapids Hydroelectric Project (FERC Project No. 2362). Prairie River Hydroelectric Project (FERC Project No. 2361). Prepared for: Minnesota Power. Prepared by HDR Engineering, Inc. 2018. 178 pp.

_____. 2018b. Rapids Energy Center NPDES Permit Renewal, 316(b) Submittal. February 28, 2018.

National Resources Conservation Service (NRCS). 2008. Rapid Watershed Assessment: Prairie-Willow (MN) HUC: 07010103. NRCS. USDA. Online: [URL] https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_021558.pdf. Accessed on October 10, 2018.

Normandeau Associates, Inc. 2008. Desktop fish entrainment and impingement assessment. Prepared for Appalachian Power Company. Smith Mountain Project (FERC Project No. 2210). 49 pp.

———. 2009. Fish entrainment and impingement assessment. Claytor Hydroelectric Project (FERC Project No. 739). Prepared for Appalachian Power Company. 52 pp.

Odeh, M. 1999. A summary of environmentally friendly turbine design concepts. U.S. Department of Energy, Idaho Operations Office, DOE/ID/13741. July 1999. Olson et al. 1988.

Peake, S., R. S. McKinley, and D. A. Scruton. 2000. Swimming performance of walleye (Stizostedion vitreum). Can. J. Zool. 78:1686-1690.

Schuler, V. J. 1968. Progress report of swim speed study conducted on fishes of Conowingo Reservoir. Ichthyological Associates, Progress Report 1B.

Smiley, P. and G. R. Parsons. 1997. Effects of photoperiod and temperature on the swimming performance of white crappie. Transactions of the American Fisheries Society, 126:495-499.

Smith, C. L. 1985. The inland fishes of New York State. The New York State Department of Environmental Conservation, Albany, New York.

University of Iowa. 2010. Upstream passage, fish swimming speeds: determination of the need for fish passage at the proposed project. IIHR Hydroscience and Engineering. Iowa City, Iowa. February 2010: Page 7.

Webb, P. W. 1998. Swimming. In The Physiology of Fishes (ed. D. H. Evans), pp.3 -24. Boca Raton: CRC Press.

Werner, R.G. 1980. Freshwater Fishes of New York: A Field Guide. Syracuse University Press. Syracuse, New York. 186 pp.

_____. 1985. Freshwater Fishes of New York State: A Field Guide. Syracuse University Press.

Winchell, F., S. Amaral, and D. Dixon. 2000. Hydroelectric turbine entrainment and survival database: an alternative to field studies. HydroVision Conference, August 8-11, 2000, Charlotte, North Carolina.

Appendix A.
Monthly Generation Estimates (1,000 Cfs-Hrs) and Flow Routing Data

% Exceedance	Annual	January	Febuary	March	April	May	June	July	August	September	October	November	December
100.00%	0	1	103	64	38	21	31	20	50	22	0	42	42
99.00%	115	157	145	127	95	97	168	140	88	89	95	146	154
98.00%	148	170	152	135	111	154	189	180	119	133	117	174	175
97.00%	171	195	173	138	122	178	200	200	155	157	156	199	199
96.00%	194	209	188	153	135	190	206	206	182	192	191	214	235
95.00%	206	218	214	171	148	201	226	220	197	211	200	246	263
94.00%	224	236	235	191	162	215	259	240	205	229	252	290	282
93.00%	247	253	260	207	188	244	293	277	216	239	282	309	300
92.00%	273	276	281	226	201	277	311	301	224	251	317	342	322
91.00%	291	289	290	246	220	295	327	317	232	266	367	366	357
90.00%	305	298	310	265	254	317	341	346	246	288	388	381	371
89.00%	328	312	337	283	274	348	357	366	270	308	399	390	377
88.00%	352	350	361	294	286	367	369	373	288	330	414	400	383
87.00%	369	365	371	302	294	379	377	384	309	352	436	406	389
86.00%	378	374	378	311	302	386	383	390	330	379	472	414	393
85.00%	385	378	382	326	313	390	388	397	349	390	530	426	397
84.00%	391	383	386	342	326	394	393	404	362	400	580	450	400
83.00%	396	388	389	360	341	397	398	413	382	409	600	494	406
82.00%	400	391	393	371	360	400	403	421	395	421	616	504	411
81.00%	406	394	396	377	370	405	408	433	408	434	653	525	416
80.00%	412	397	400	382	377	410	414	463	424	465	710	559	420
79.00%	418	400	402	390	382	414	422	486	438	488	734	581	427
78.00%	427	403	407	396	386	418	447	522	468	498	755	596	444
77.00%	440	408	412	400	390	424	488	578	491	542	788	608	466
76.00%	462	413	415	404	394	433	523	599	520	569	812	630	474
75.00%	482	417	420	407	397	443	551	620	572	585	839	661	488
74.00%	499	424	425	410	401	463	570	663	600	601	868	694	495
73.00%	515	436	433	414	405	488	588	710	624	616	900	708	500
72.00%	543	449	444	418	409	508	610	771	667	635	934	732	506
71.00%	566	473	459	422	414	533	635	792	705	685	971	755	517
70.00%	586	482	473	429	419	554	669	821	744	713	1,000	779	531
69.00%	604	490	484	437	424	571	711	856	780	746	1,030	795	554
68.00%	624	501	490	447	430	587	739	880	803	773	1,060	816	576
67.00%	650	512	498	461	441	606	766	900	854	798	1,080	832	596
66.00%	688	534	507	482	455	622	797	916	892	833	1,100	847	609
65.00%	716	554	528	500	467	648	819	937	926	875	1,130	865	626
64.00%	746	567	562	517	478	680	849	962	952	914	1,150	883	650
63.00%	775	593	574	528	495	705	872	984	968	946	1,170	905	693
62.00%	797	610	607	544	514	719	893	996	982	972	1,180	927	741
61.00%	817	622	630	559	536	738	903	1,000	999	999	1,200	948	770
60.00%	840	670	662	571	550	760	924	1,020	1,010	1,040	1,210	970	786
59.00%	864	722	700	586	570	785	954	1,040	1,020	1,080	1,224	985	802
58.00%	889	750	713	611	584	800	980	1,053	1,040	1,130	1,240	1,000	814
57.00%	910	779	761	630	596	810	996	1,080	1,070	1,180	1,261	1,020	832
56.00%	938	795	789	651	606	825	1,000	1,100	1,100	1,200	1,280	1,060	844
55.00%	968	810	804	678	621	835	1,010	1,140	1,130	1,210	1,300	1,100	854
54.00%	995	833	830	696	635	852	1,020	1,160	1,160	1,220	1,350	1,120	876
53.00%	1,010	853	847	726	652	869	1,050	1,190	1,190	1,230	1,380	1,150	888
52.00%	1,040	873	869	746	669	887	1,070	1,210	1,210	1,250	1,400	1,170	912
51.00%	1,070	900	886	781	687	900	1,110	1,240	1,230	1,280	1,430	1,200	930
50.00%	1,100	930	912	813	710	914	1,130	1,290	1,250	1,310	1,450	1,220	975
49.00%	1,140	960	1,000	848	731	927	1,160	1,308	1,280	1,350	1,470	1,260	1,000
48.00%	1,170	1,060	1,050	890	752	952	1,180	1,347	1,300	1,380	1,490	1,300	1,060
47.00%	1,200	1,100	1,088	929	778	977	1,190	1,370	1,340	1,410	1,500	1,310	1,100
46.00%	1,210	1,200	1,120	949	800	994	1,210	1,410	1,380	1,430	1,510	1,330	1,130
45.00%	1,240	1,222	1,180	990	820	1,000	1,220	1,430	1,420	1,460	1,520	1,360	1,192
44.00%	1,270	1,270	1,200	1,040	842	1,010	1,244	1,460	1,460	1,480	1,540	1,400	1,200
43.00%	1,300	1,300	1,220	1,060	869	1,030	1,290	1,480	1,480	1,490	1,560	1,410	1,259
42.00%	1,330	1,310	1,240	1,080	895	1,060	1,320	1,500	1,490	1,500	1,580	1,430	1,300
41.00%	1,370	1,380	1,260	1,100	915	1,100	1,360	1,500	1,500	1,510	1,610	1,460	1,320
40.00%	1,400	1,400	1,290	1,130	942	1,140	1,400	1,510	1,500	1,520	1,640	1,500	1,350
39.00%	1,440	1,432	1,300	1,152	989	1,170	1,440	1,520	1,510	1,540	1,660	1,520	1,392
38.00%	1,470	1,460	1,350	1,200	1,010	1,200	1,460	1,540	1,530	1,560	1,690	1,550	1,421
37.00%	1,490	1,500	1,399	1,220	1,040	1,220	1,490	1,560	1,550	1,590	1,710	1,600	1,450
36.00%	1,500	1,510	1,410	1,240	1,070	1,250	1,500	1,590	1,580	1,620	1,740	1,640	1,500
35.00%	1,530	1,540	1,450	1,290	1,100	1,280	1,520	1,620	1,610	1,650	1,760	1,670	1,516
34.00%	1,550	1,580	1,490	1,300	1,140	1,330	1,550	1,650	1,640	1,680	1,790	1,700	1,550
33.00%	1,590	1,600	1,530	1,330	1,170	1,373	1,580	1,700	1,670	1,710	1,820	1,720	1,570
32.00%	1,610	1,600	1,570	1,361	1,203	1,431	1,620	1,740	1,710	1,740	1,850	1,750	1,600
31.00%	1,640	1,620	1,600	1,400	1,240	1,480	1,660	1,760	1,730	1,760	1,890	1,788	1,610
30.00%	1,670	1,650	1,600	1,450	1,273	1,508	1,700	1,780	1,750	1,790	1,928	1,800	1,638
29.00%	1,700	1,680	1,620	1,490	1,310	1,540	1,720	1,800	1,770	1,810	1,960	1,830	1,660
28.00%	1,720	1,700	1,640	1,520	1,350	1,570	1,760	1,820	1,790	1,830	1,980	1,850	1,680
27.00%	1,750	1,710	1,670	1,553	1,400	1,620	1,800	1,840	1,810	1,850	1,990	1,890	1,700
26.00%	1,780	1,740	1,700	1,580	1,450	1,650	1,830	1,890	1,840	1,890	2,000	1,923	1,700
25.00%	1,800	1,770	1,700	1,600	1,500	1,690	1,870	1,930	1,860	1,930	2,010	1,970	1,720
24.00%	1,820	1,800	1,714	1,640	1,570	1,720	1,920	1,970	1,900	1,962	2,020	2,000	1,750
23.00%	1,850	1,800	1,740	1,690	1,620	1,760	1,960	2,000	1,930	2,000	2,050	2,010	1,780
22.00%	1,890	1,820	1,756	1,700	1,650	1,800	2,000	2,040	1,970	2,010	2,070	2,040	1,800
21.00%	1,910	1,840	1,780	1,730	1,680	1,820	2,020	2,070	2,000	2,037	2,100	2,070	1,800
20.00%	1,950	1,860	1,800	1,750	1,720	1,880	2,050	2,140	2,022	2,090	2,120	2,090	1,830
19.00%	1,990	1,880	1,820	1,800	1,760	1,930	2,100	2,200	2,060	2,140	2,150	2,120	1,850
18.00%	2,000	1,899	1,840	1,819	1,800	2,000	2,150	2,230	2,090	2,180	2,190	2,160	1,870
17.00%	2,020	1,900	1,870	1,850	1,850	2,060	2,200	2,260	2,110	2,207	2,240	2,190	1,900
16.00%	2,060	1,916	1,900	1,890	1,890	2,130	2,240	2,300	2,160	2,270	2,276	2,230	1,900
15.00%	2,100	1,940	1,950	1,910	1,910	2,194	2,290	2,360	2,200	2,320	2,314	2,250	1,924
14.00%	2,140	1,970	1,960	1,940	1,960	2,310	2,330	2,410	2,250	2,380	2,370	2,280	1,960
13.00%	2,190	1,990	2,000	1,971	2,006	2,400	2,360	2,470	2,310	2,440	2,420	2,310	2,000
12.00%	2,230	2,000	2,000	2,000	2,050	2,480	2,400	2,510	2,370	2,501	2,470	2,340	2,000
11.00%	2,280	2,010	2,000	2,010	2,100	2,510	2,460	2,538	2,440	2,580	2,500	2,360	2,020
10.00%	2,330	2,050	2,040	2,080	2,160	2,550	2,500	2,580	2,480	2,641	2,530	2,400	2,040
9.00%	2,390	2,060	2,060	2,120	2,220	2,600	2,520	2,670	2,520	2,700	2,610	2,450	2,080
8.00%	2,450	2,100	2,100	2,190	2,280	2,663	2,580	2,730	2,580	2,760	2,690	2,500	2,150
7.00%	2,500	2,120	2,120	2,240	2,340	2,760	2,656	2,801	2,620	2,820	2,750	2,530	2,200
6.00%	2,570	2,160	2,150	2,280	2,440	2,800	2,720	2,870	2,680	2,900	2,840	2,600	2,270
5.00%	2,660	2,190	2,200	2,320	2,540	2,890	2,816	2,960	2,798	2,940	2,918	2,730	2,310
4.00%	2,780	2,210	2,280	2,360	2,610	2,970	2,950	3,060	2,870	3,020	2,986	2,840	2,400
3.00%	2,920	2,300	2,360	2,390	2,865	3,100	3,090	3,150	3,000	3,110	3,120	2,985	2,490
2.00%	3,080	2,370	2,410	2,453	3,240	3,250	3,220	3,290	3,450	3,500	3,350	3,080	2,580
1.00%	3,450	2,450	2,509	2,622	3,931	3,662	3,770	3,472	3,720	3,810	3,510	3,300	2,682
0.10%	4,624	2,500	3,000	3,758	5,082	4,291	4,290	4,275	4,780	5,209	4,268	3,750	3,040
0.00%	8,900	2,860	3,200	4,070	5,220	4,570	4,590	4,760	5,020	8,900	4,600	3,850	3,070

Appendix B.
Target Fish Species Accounts

Bluegill

The Bluegill is a common type of sunfish in the family Centrarchidae and a popular game fish. They are a widespread species, originally found in a region that extended from the St. Lawrence River south to Georgia and then west to Texas and Minnesota, but has since been introduced to areas beyond this range (Smith 1985). Bluegills have the typical deep and laterally compressed body type represented in most *Lepomis* species. They have several sharp dorsal fin spines, and is often greenish-blue to brown in color with vertical bars sometimes present along the sides of the body with an orange breast. A black spot located on the posterior base of the soft dorsal fin is a useful identification characteristic (Smith 1985).

Bluegill are colonial and tend to occupy more open habitat near vegetative cover while building nests, spawning, and rearing in littoral zones. Males construct and defend the nest in shallow areas with sand and gravel substrates, often within inches of neighboring nests. Spawning occurs in late spring and into the summer. (Smith 1985; Jenkins and Burkhead 1993).

Bluegills are generalist and opportunistic feeders. Fry leave the nest to an open area to feed on zooplankton when they are 1/4 to 1/3 inches in length. At approximately 1-inch in length, young Bluegill return to the littoral habitats to feed on zooplankton and begin to feed on insects, invertebrates, and occasionally on small fish as they further develop. Throughout their lives, juveniles and adults will often make forays to deep water habitats during the day to feed on zooplankton, returning to littoral zone habitats at night to rest or feed on insects. In rivers, they are found in low velocity, marginal, and backwater habitats (Smith 1985; Jenkins and Burkhead 1993).

The species is often fairly abundant where it occurs due to high reproductive and growth rates, represents an important forage fish for Black Bass and other piscivorous species, and can live as long as 11 years (Smith 1985).

Smallmouth Bass

Smallmouth Bass are commercially and economically important game fish, and are similar in appearance to Largemouth Bass, but are differentiated by their smaller mouth and browner coloration with dark vertical lines. Other distinctive characteristics include the jaw ending below the middle of the eye and juveniles with orange and black bands on the base of their tails. This species is common in the north-central United States and southern Canada from Minnesota and the Dakotas to the St. Lawrence River drainage and south to the Mississippi Valley, the Ozarks, and northern Alabama (Smith 1985).

Smallmouth Bass can be found in almost all manner of aquatic habitat but are most abundant in cool large rivers and lakes. They prefer slow to moderate current and select areas of rocky shorelines. Like the Yellow Perch, Smallmouth Bass are opportunistic feeders and generally feed during daylight hours on aquatic invertebrates, crustaceans, and small fish (Smith 1985). Smallmouth Bass sexually mature at age 3 to 6 years. Spawning usually occurs in late spring/early summer when water temperatures reach 62 degrees Fahrenheit (°F) to 65°F. Spawning occurs in 2 to 20 feet of water but average spawning depth is approximately 3 feet. Males build and maintain a nest in gravelly substrate until the fry emerge and disperse. Multiple females may visit a nest over a 30- to 36-hour period. Eggs hatch between 7 and 21 days, depending on the water temperature (Smith 1985).

Walleye

Walleye usually occur in large rivers and lakes and prefer a bottom of loose aggregates. They are generally found in deeper waters during the day and tend to move into shallower areas during heavy cloud cover and at night for feeding. They can be sensitive to low pH levels (Carlson 1992). Walleye are opportunistic predators, beginning on crustaceans and aquatic invertebrates as juveniles and moving to fish and other larger vertebrates and invertebrates as they mature (Smith 1985).

Male Walleye mature at age 2 to 3, while females mature at age 4 to 5. They spawn in the spring following ice out when water temperatures reach 35 °F to 44°F. Walleye prefer to spawn over substrates ranging in size from sand to boulders, but preferably select cobble to rock-size substrate in water generally 2 to 4 feet deep. Walleye are not nest builders, instead they broadcast their eggs along the substrate. Eggs hatch between 7 and 26 days, depending on the water temperature (Smith 1985). Generally, less than 20 percent of the eggs survive to hatching and more commonly only 5 percent under natural conditions. While males tend to remain in the area following spawning, no parental care is undertaken.

Largemouth Bass

Largemouth Bass are mostly found in warm and weedy portions of lakes, bays, and some rivers and prefer a much softer bottom substrate. Similar to the Smallmouth Bass, the Largemouth Bass are opportunistic feeders and generally feed during daylight hours on aquatic invertebrates, crustaceans, and small fish or anything that moves on or under the surface of the water.

Largemouth Bass sexually mature at age 5 years. Spawning usually occurs in late spring/early summer when water temperatures reach 60°F (Smith 1985).

Spawning occurs in shallow water from 1 to 4 feet. Spawning behavior is very similar to the Smallmouth Bass, but the two species rarely compete for spawning areas due to differing depth and substrate preferences. Males build and maintain a nest in a siltier substrate until the fry emerge and disperse. Multiple females may visit the Largemouth Bass nest. Eggs hatch between 3 and 5 days, depending on the water temperature (Werner 1980).

Yellow Perch

Yellow Perch can be found in almost all types of aquatic habitat, but are most abundant in large rivers and lakes with no preferred substrate. Larger Yellow Perch are commonly found in deeper waters, while juveniles and younger perch are found in shallower waters. They are opportunistic feeders and feed exclusively during the day on crustaceans, aquatic invertebrates, and small fish. At night, Yellow Perch remain motionless, hovering close to the substrate.

Yellow Perch sexually mature at age 3 to 4 years. Spawning usually occurs following Walleye when water temperatures reach 45°F to 52°F. Spawning occurs in 5 to 10 feet of water and no nests are built. Females are followed by multiple males in a circuitous pattern until the female distributes a long gelatinous string of eggs (2 to 7 feet long) over a variety of substrates. Eggs hatch between 7 and 10 days, depending on the water temperature (Werner 1985).

Black Crappie

The Black Crappie, from the family Centrarchidae, closely resemble the White Crappie with its laterally compressed body shape, but differs in the number of dorsal spines and the base of the dorsal fin is noticeably longer. The Black Crappie is a silvery color on the sides and the belly with darker gray/green blotches and marbling generally on the upper half of the body.

Black Crappie are not tolerant of poor water quality as they prefer less turbid waters, are less tolerant of silt, and are generally found in clear weedy waters. Feeding habits of young fish are focused on zooplankton and insect larvae, switching to a diet of small fish and crustaceans as they reach adulthood (Smith 1985).

Black Crappie usually spawn in May to July when water temperatures are in excess of 68°F. Nests are usually constructed on sandy bottoms in weedy areas, 8-9 inches in diameter, and 5-6 feet apart. These community nesters fan depressions in water with depths of 1-2 feet (Smith 1985). The Black Crappie was included as a target species in this study due to its economical/recreational importance as a game species.

Northern pike

Northern Pike will usually inhabit clear, small lakes and ponds; shallow-vegetated areas of larger lakes, marshes, and creeks; and small-to-large rivers. Adults will move to deeper or cooler water in summer months and spawn in shallow-vegetated areas found in river backwaters, oxbows, and side channels; in similar areas near lakes or in the inlet streams associated with those lakes; and flooded-terrestrial vegetation at a reservoir's edge will also be used (Smith 1985). After hatching, the larval fish will remain in the spawning habitat for several weeks. Northern Pike spawn in vegetated floodplains adjacent to rivers, marshes, and bays where they reside in early spring when average water temperatures are approximately 9°C (Smith 1985). This species was chosen for this analysis for being a popular game fish species and a top predator in the ecosystem.

Brown Bullhead (***Ictalurus nebulosus)***

The Brown Bullhead is the most common catfish species in New York and is found between southern Canada to the southern Gulf Coast states. Brown Bullhead range from olive to blackish in color along the sides and back and pale white to yellow along the belly. They commonly range between 8 and 14 inches when adults (Smith 1985).

Brown Bullheads are found in various habitat types, such as large rivers and lakes, small ponds, and lower areas in small streams. Adults spawn in late May and June when water temperatures reach 27°C and build nests or burrow under banks, logs, or boulders. Young are guarded in the nests until they reach 2 inches in length and rapidly reach 5 inches by the end of their first summer. Brown Bullheads mature at age two and typically live for 6 to 7 years. The most common prey items of Brown Bullhead include crustaceans and chironomids (Smith 1985). This species was included in the study for being relatively common in the Project reservoir and is a popular game species.

Appendix C.
Target Fish Swim Speeds

Species	Life Stage	TL/FL (in)	Swim Speed (ft/s)			Tested Temperature (C)	Time (min)	References
			Maximum Sustained	Prolonged (P) or Critical (C)	Burst (B) or Startle (S)			
American shad[1]	Juvenile	1.0-3.0		1.25-1.75	1.8-2.5			Bell (1991)
	Adult	12.0-14.0		3.0-7.0	8.0-13.5			
Emerald shiner	Adult	2.5		2	4			Bell (1991)
Bluegill	Juvenile	0.98-1.57	0.3-0.75			>15.5		Schuler (1968)
	Juvenile	1.54-1.73	0.48-0.52			26.1-29.4		King (1969)
	Juvenile	2.01-2.13		0.92		21		Beamish (1978)
	Adult	3.94-5.91		1.22 (C)			10	Gardner et al. (2006)
	Adult	6.02			4.3 (B)		0.15	Webb (1978)
	Adult	7.99	1					Deng et al. (2004)
	Adult		0.98					Drucker and Lauder (1999)
Blue sucker[2]	Adult	26.2		4.36	19.51			Brett 1964 cited in The University of Iowa 2010; Brainbridge 1961 cited in The University of Iowa 2011
Herring[1]	Fry	0.4-0.8			0.0-1.0			Bell (1991)
	Juvenile/Adult	6.0-11.0	0.0-3.0	3.0-5.0	5.0-7.0			
Hybrid catfish (Female Channel catfish x Male Blue catfish[3]	Juvenile	6.30-9.06	1.31	3.94 (P)		19-22		Beecham et al. (2009)
Ghost shiner	Adult	1.39		1.47	2.93			Leavy and Bonner (2009)
Greenside darter[4]	Adult	4.0-6.8		0.51-1.32	1.02-2.64			Layher (1993) unpublished
Largemouth bass[5]	Fry	0.79-0.87		0.78-1.02 (P)		30-Oct		Larimore and Deuver (1968) cited in Beamish (1978)
	Juvenile	2.05-2.52	0.5	1.63 (C)		30, 15-35		Hocutt (1973)
	Juvenile	2.05-2.52		8.08L/sec		30		Hocutt (1973) - relative swim speed
	Juvenile	2.05-2.52		1.64 (C)		25		Farlinger and Beamish (1977) cited in Beamish (1978)
	Juvenile	2.24		1.01 (P)		20		Larimore and Deuver (1968) cited in Beamish (1978)
	Juvenile	2.95-3.35	1.21-1.34					Dahlberg et al. (1968) cited in Carlander (1977)
	Juvenile	3.66-5.04		1.60 (C)		15-19	2	Kolok (1991)
	Juvenile	3.66-5.04		0.92 (C)		5	2	Kolok (1991)
	Juvenile	3.94		1.15 (C)		10		Otto and Rice (1974) cited in Beamish (1978)
	Juvenile	4.02		1.50 (C)		25		Farlinger and Beamish (1977) cited in Beamish (1978)
	Juvenile	5.91	0.79			10		Beamish (1970) cited in Carlander (1977)
	Juvenile	5.91	1.57			30		Beamish (1970) cited in Carlander (1977)
	Juvenile	5.91-10.63		1.80-2.17 (P)		30		Beamish (1970) cited in Beamish (1978)
	Juvenile	9.84	1.51			10		Beamish (1970) cited in Carlander (1977)
	Juvenile	9.84	2.07			30		Beamish (1970) cited in Carlander (1977)
Longnose sucker[2]	Juvenile/Adult	3.9-16.0			4.0-8.0			Bell (1991)
Mimic shiner	Adult	1.39		1.43	2.86			Leavy and Bonner (2009)
Paddlefish	Juvenile	3.54		0.98-1.87	3.54	1.87-2.46		Hoover (2005)
	Adult	47.2			47.2	32.8		Brett 1964 cited in The University of Iowa 2010; Brainbridge 1961 cited in The University of Iowa 2011
Smallmouth bass	Fry	0.55		13-19 L/sec (P)				Larimore and Deuver (1968) cited in Carlander (1977) and Houde (1963)
	Fry	0.55		0.60-0.87 (P)				
	Fry	0.79-0.98		<0.89				
	Juvenile	3.58-3.66		1.3-1.8 (C)		13-23	2	Webb (1998)
	Adult	10.3-14.9		1.6-3.9 (C)		15-20	10	Bunt et al. (1999)
Striped bass[6]	Fry	0.5-1.0			0.4-1.0			Bell (1991)
	Juvenile	2.0-5.0			1.0-5.0			
Walleye	Fry	0.47	0.16			18.3		Houde (1963)
	Fry	0.78	0.25			13		Houde (1963)
	Juvenile	3.15 (FL)		1.24 (C)		18.0-20.0	10	Jones et al. (1974)
	Juvenile	6.3 (FL)			6.02 (S)			Peake et al. (2000)
	Adult	13.78 (FL)			7.20 (S)			Peake et al. (2000)
	Adult	14.96 (FL)		2.74 (C)				Peake et al. (2000)
	Adult	22.44 (FL)			8.57 (S)			Peake et al. (2000)
White crappie	Juvenile	.17-3.94 (FL	0.50-0.75			21.1-28.3		Schuler (1968)
	Juvenile	.95-3.19 (FL	0.54-0.61			24.4-26.1		King (1969)
	Juvenile	3.03	-	0.52 (C)		25	60	Smiley and Parsons (1997)
	Juvenile	3.03	-	0.18 (C)		5	60	Smiley and Parsons (1997)

[1] Used to represent skipjack herring and mooneye

[2] Used to represent smallmouth redhorse

[3] Used to represent channel catfish and flathead catfish

[4] Used to represent target darter species

[5] Used to represent spotted bass

[6] Used to represent white bass

NOTE: Burst/Startle speed calculated at 50% greater than Prolonged/Critical speeds in Appendix D table based on Bell (1986) unless burst speed provided in the literature.

Appendix D.
Thirty-Seven Hydroelectric Projects Used in the Entrainment Assessment
(EPRI 1997a; FERC 1995a, 1995b)

Site Name	State	River	Reservoir		Total Plant Capacity (cfs)	Hydraulic Capacity of Sampled Units (cfs)	No. Units	Operating Mode	Avg. Velocity at Trashrack (ft/sec)	Trashrack Clear Spacing (in)
			Area (ac)	Volume (ac-ft)						
Belding	MI	Flat	-	-	416	416	2	-	-	2.00
Bond Falls	MI	W.B. Ontonagon	-	-	900	450	2	PK	-	3.00
Brule	WI	Brule	545	8,880	1,377	916	3	PK-partial	1.00	1.62
Caldron Falls	WI	Peshtigo	1,180	-	1,300	650	2	PK	-	2.00
Centralia	WI	Wisconsin	250	-	3,640	550	6	ROR	2.30	3.50
Colton	NY	Raquette	195	620	1,503	450	3	PK	-	2.00
Crowley	WI	N.F. Flambeau	422	3,539	2,400	1,200	2	ROR	1.40	2.38
E. J. West	NY	Sacandaga	25,940	792,000	5,400	5,400	2	-	-	4.50
Feeder Dam	NY	Hudson	-	-	5,000	2,000	5	PK	-	2.75
Four Mile Dam	MI	Thunder Bay	1,112	2,500	1,500	500	3	ROR	-	2.00
Grand Rapids	MI/WI	Menominee	250	-	3,870	2,216	5	ROR	-	1.75
Herrings	NY	Black	140	-	3,610	1,203	3	ROR	-	4.13
High Falls - Beaver River	NY	Beaver	145	1,058	900	300	3	-	0.70	1.81
Higley	NY	Raquette	742	4,446	2,045	2,045	3	PK	-	3.63
Hillman Dam	MI	Thunder Bay	988	1,600	270	270	1	ROR	-	3.25
Johnsonville	NY	Hoosic	450	6,430	1,288	1,288	2	PK	-	2.00
Kleber	MI	Black	270	3,000	400	400	2	ROR	1.41	3.00
Lake Algonquin	NY	Sacandaga	-	-	750	750	1	-	-	1.00
Minetto	NY	Oswego	350	4,730	7,500	4,500	5	PULSE	2.40	2.50
Moshier	NY	Beaver	365	7,339	660	660	2	PK	-	1.50
Ninth Street Dam	MI	Thunder Bay	9,884	2,600	1,650	550	3	ROR	-	1.00
Norway Point Dam	MI	Thunder Bay	10,502	3,800	1,775	575	2	ROR	-	1.69
Potato Rapids	WI	Peshtigo	288	-	1,380	500	3	ROR	-	1.75
Raymondville	NY	Raquette	50	264	1,640	1,640	1	PK	-	2.25
Richard B. Russell	GA/SC	Savannah	31,770	1,297,513	60,000	7,200	8	PK	-	8.00
Sandstone Rapids	WI	Peshtigo	150	-	1,300	650	2	PK	-	1.75
Schaghticoke	NY	Hoosic	164	1,150	1,640	1,640	4	ROR	-	2.13
Shawano	WI	Wolf	155	1,090	850	850	1	ROR	-	5.00
Sherman Island	NY	Hudson	305	6,960	6,600	4,950	4	PK	-	3.13
Thornapple	WI	Flambeau	295	1,000	1,400	700	2	ROR-mod	1.22	1.69
Tower	MI	Black	102	620	404	404	2	ROR	0.82	1.00
Townsend Dam	PA	Beaver	-	-	4,400	4,400	2	ROR	-	5.50
Twin Branch	IA	St. Joseph	1,065	-	3,200	1,200	-	ROR	-	3.00
Warrensburg	NY	Schroon	-	-	1,350	1,350	1	-	-	-
White Rapids	MI/WI	Menominee	435	5,155	3,994	3,994	3	PK-partial	1.90	2.50
Wisconsin River Division	WI	Wisconsin	240	1,120	5150	5,150	10	ROR	1.40	2.19
Youghiogheny	PA	Youghiogheny	2,840	149,300	1,600	1,600	2	ROR	0.70	10.00

Appendix E.

Monthly and Annual Entrainment Rates for Target/Surrogate Fish Species Derived from EPRI (1997a)

Centrarchidae				
Month	Avg. No. Fish/hr/1000 cfs			
	<4	4-8	8-15	>15
Jan	0.3017	0.0449	0.0021	0.0044
Feb	0.3007	0.0509	0.0004	0.0000
Mar	0.0535	0.1062	0.0148	0.0000
Apr	1.2508	0.9548	0.0382	0.0007
May	0.3493	0.1767	0.0246	0.0007
Jun	0.4644	0.4278	0.0322	0.0002
Jul	1.3950	0.3376	0.0168	0.0000
Aug	0.6617	0.9385	0.0240	0.0001
Sep	0.5240	1.7588	0.0219	0.0002
Oct	0.5982	1.8628	0.0198	0.0033
Nov	0.6324	0.6037	0.0116	0.0000
Dec	0.3544	0.1835	0.0028	0.0000

Yellow Perch				
Month	Avg. No. Fish/hr/1000 cfs			
	<4	4-8	8-15	>15
Jan	0.5908	0.4189	0.0055	0.0000
Feb	0.6409	0.4628	0.0048	0.0000
Mar	0.3983	0.3062	0.0056	0.0001
Apr	11.0413	0.9722	0.0717	0.0000
May	0.8240	0.4085	0.0221	0.0000
Jun	6.9463	0.1848	0.0098	0.0000
Jul	5.6341	0.1378	0.0095	0.0000
Aug	0.4632	0.2261	0.0096	0.0000
Sep	2.2040	0.8570	0.0319	0.0000
Oct	13.1352	3.0206	0.0148	0.0000
Nov	0.2062	0.1506	0.0068	0.0000
Dec	0.1607	0.3324	0.0025	0.0000

Walleye				
Month	**Avg. No. Fish/hr/1000 cfs**			
	<4	**4-8**	**8-15**	**>15**
Jan	0.0159	0.0218	0.1816	0.0000
Feb	0.0091	0.0295	0.0044	0.0022
Mar	0.0000	0.0024	0.0070	0.0000
Apr	0.0009	0.0334	0.0742	0.0060
May	0.0039	0.1399	0.1693	0.0049
Jun	1.0143	0.0757	0.1277	0.0056
Jul	1.4364	0.1237	0.0884	0.0265
Aug	0.0893	0.1977	0.0689	0.0039
Sep	0.0470	0.1745	0.0449	0.0127
Oct	0.0071	0.1738	0.1070	0.0043
Nov	0.0090	0.0318	0.0247	0.0073
Dec	0.0017	0.0454	0.0205	0.0000

Northern Pike				
Month	**Avg. No. Fish/hr/1000 cfs**			
	<4	**4-8**	**8-15**	**>15**
Jan	-	-	-	-
Feb	0.0000	0.0000	0.0000	0.0673
Mar	0.0000	0.0569	0.1290	0.0000
Apr	0.0000	0.0206	0.1522	0.2241
May	0.0076	0.0040	0.0352	0.0108
Jun	0.1681	0.0388	0.0402	0.0134
Jul	0.0704	0.2504	0.0254	0.0025
Aug	0.0015	0.0850	0.0118	0.0000
Sep	0.0000	0.0098	0.0208	0.0674
Oct	0.0000	0.0060	0.0231	0.0477
Nov	0.0000	0.0099	0.0567	0.0047
Dec	0.0000	0.0000	0.0058	0.0201

Brown Bullhead				
Month	Avg. No. Fish/hr/1000 cfs			
	<4	4-8	8-15	>15
Jan	0.0344	0.0000	0.0000	0.0000
Feb	0.0380	0.0000	0.0716	0.0000
Mar	0.0326	0.0041	0.0000	0.0000
Apr	0.0265	1.1046	0.3826	0.0000
May	0.1585	0.0896	0.0292	0.0003
Jun	0.0679	0.3635	0.4137	0.0103
Jul	0.0427	2.0200	0.2183	0.0001
Aug	0.1813	1.2160	0.0660	0.0000
Sep	0.0355	0.3935	0.0611	0.0000
Oct	0.0100	0.0494	0.0334	0.0000
Nov	0.0277	0.0529	0.0055	0.0003
Dec	0.0135	0.0000	0.0000	0.0000

Yellow Bullhead				
Month	Avg. No. Fish/hr/1000 cfs			
	<4	4-8	8-15	>15
Jan	0.013158	0.036995	0.023359	0
Feb	0.263538	0.022979	0	0
Mar	0.066948	0.00899	0.002429	0
Apr	0.065951	0.011987	0.028172	0
May	0.010926	0.004433	0.012275	0
Jun	0.046658	0.022716	0.029729	0
Jul	4.861348	0.024251	0.028396	0
Aug	0.152667	0.032991	0.007131	0
Sep	0.139824	0.015965	0.001604	0
Oct	0.072897	0.030205	0.019514	0
Nov	0.191708	0.068841	0.015231	0
Dec	0.034477	0	0	0

Black Bullhead				
Month	**Avg. No. Fish/hr/1000 cfs**			
	<4	**4-8**	**8-15**	**>15**
Jan	0.085499	0	0.009109	0
Feb	0.033636	0.009109	0.009109	0
Mar	0.018965	0.097878	0.074544	0
Apr	0.493329	0.244902	0.070682	0.001571
May	0.05953	0.069165	0.124411	0
Jun	0.114121	0.188409	0.076263	0
Jul	0.242956	0.054969	0.162928	0
Aug	0.057623	0.016652	0.057947	0.013838
Sep	0.091391	0.018028	0.050723	0.00621
Oct	0.147408	0.0154	0.079788	0
Nov	0.068336	0.041446	0.02429	0
Dec	0.021368	0	0.021645	0

Suckers (Catostomidae)				
Month	**Avg. No. Fish/hr/1000 cfs**			
	<4	**4-8**	**8-15**	**>15**
Jan	0.1764	0.5277	0.2398	0.0000
Feb	0.1948	0.7171	0.0310	0.0053
Mar	0.0756	0.4104	0.0335	0.0000
Apr	0.2571	0.2013	0.4092	0.1014
May	0.0434	0.0237	0.0716	0.0136
Jun	0.9150	0.0490	0.0504	0.0056
Jul	1.2443	0.0377	0.0267	0.0033
Aug	0.0986	0.0111	0.0106	0.0026
Sep	0.0571	0.0260	0.0303	0.0064
Oct	0.1062	7.6390	0.3869	0.0237
Nov	0.0667	1.1638	0.6975	0.0024
Dec	0.0342	0.8515	0.2036	0.0000

Appendix F.
Blade Strike Results (Franke et al. 1997)

GRAND RAPIDS UNIT 4

Fish Length (inches)	0.10	0.15	0.20
1	96.53%	94.79%	93.05%
2	93.05%	89.58%	86.11%
3	89.58%	84.37%	79.16%
4	86.11%	79.16%	72.21%
5	82.63%	73.95%	65.27%
6	79.16%	68.74%	58.32%
7	75.69%	63.53%	51.37%
8	72.21%	58.32%	44.43%
9	68.74%	53.11%	37.48%
10	65.27%	47.90%	30.54%
11	61.79%	42.69%	23.59%
12	58.32%	37.48%	16.64%
13	54.85%	32.27%	9.70%
14	51.37%	27.06%	2.75%
15	47.90%	21.85%	0.00%
16	44.43%	16.64%	0.00%
17	40.95%	11.43%	0.00%
18	37.48%	6.22%	0.00%
19	34.01%	1.01%	0.00%
20	30.54%	0.00%	0.00%
21	27.06%	0.00%	0.00%
22	23.59%	0.00%	0.00%
23	20.12%	0.00%	0.00%
24	16.64%	0.00%	0.00%
25	13.17%	0.00%	0.00%
26	9.70%	0.00%	0.00%
27	6.22%	0.00%	0.00%
28	2.75%	0.00%	0.00%
29	0.00%	0.00%	0.00%
30	0.00%	0.00%	0.00%
31	0.00%	0.00%	0.00%
32	0.00%	0.00%	0.00%
33	0.00%	0.00%	0.00%
34	0.00%	0.00%	0.00%
35	0.00%	0.00%	0.00%
36	0.00%	0.00%	0.00%

GRAND RAPIDS UNIT 5

Fish Length (inches)	Edge of Hub= 0.4			Mid Blade=0.65			Blade Tip=0.95			Average
	0.1	0.15	0.2	0.1	0.15	0.2	0.1	0.15	0.2	
1	98.61%	97.91%	97.21%	99.08%	98.62%	98.16%	99.29%	98.94%	98.59%	98.49%
2	97.21%	95.82%	94.43%	98.16%	97.23%	96.31%	98.59%	97.88%	97.17%	96.98%
3	95.82%	93.73%	91.64%	97.23%	95.85%	94.47%	97.88%	96.82%	95.76%	95.47%
4	94.43%	91.64%	88.85%	96.31%	94.47%	92.62%	97.17%	95.76%	94.34%	93.95%
5	93.03%	89.55%	86.07%	95.39%	93.08%	90.78%	96.46%	94.69%	92.93%	92.44%
6	91.64%	87.46%	83.28%	94.47%	91.70%	88.93%	95.76%	93.63%	91.51%	90.93%
7	90.25%	85.37%	80.49%	93.54%	90.32%	87.09%	95.05%	92.57%	90.10%	89.42%
8	88.85%	83.28%	77.71%	92.62%	88.93%	85.24%	94.34%	91.51%	88.68%	87.91%
9	87.46%	81.19%	74.92%	91.70%	87.55%	83.40%	93.63%	90.45%	87.27%	86.40%
10	86.07%	79.10%	72.14%	90.78%	86.16%	81.55%	92.93%	89.39%	85.85%	84.89%
11	84.67%	77.01%	69.35%	89.85%	84.78%	79.71%	92.22%	88.33%	84.44%	83.37%
12	83.28%	74.92%	66.56%	88.93%	83.40%	77.86%	91.51%	87.27%	83.02%	81.86%
13	81.89%	72.83%	63.78%	88.01%	82.01%	76.02%	90.80%	86.21%	81.61%	80.35%
14	80.49%	70.74%	60.99%	87.09%	80.63%	74.17%	90.10%	85.15%	80.19%	78.84%
15	79.10%	68.65%	58.20%	86.16%	79.25%	72.33%	89.39%	84.08%	78.78%	77.33%
16	77.71%	66.56%	55.42%	85.24%	77.86%	70.48%	88.68%	83.02%	77.37%	75.82%
17	76.32%	64.47%	52.63%	84.32%	76.48%	68.64%	87.98%	81.96%	75.95%	74.31%
18	74.92%	62.38%	49.84%	83.40%	75.10%	66.80%	87.27%	80.90%	74.54%	72.79%
19	73.53%	60.29%	47.06%	82.48%	73.71%	64.95%	86.56%	79.84%	73.12%	71.28%

Fish Length (inches)	Edge of Hub= 0.4			Mid Blade=0.65			Blade Tip=0.95			Average
	0.1	0.15	0.2	0.1	0.15	0.2	0.1	0.15	0.2	
20	72.14%	58.20%	44.27%	81.55%	72.33%	63.11%	85.85%	78.78%	71.71%	69.77%
21	70.74%	56.11%	41.48%	80.63%	70.95%	61.26%	85.15%	77.72%	70.29%	68.26%
22	69.35%	54.02%	38.70%	79.71%	69.56%	59.42%	84.44%	76.66%	68.88%	66.75%
23	67.96%	51.93%	35.91%	78.79%	68.18%	57.57%	83.73%	75.60%	67.46%	65.24%
24	66.56%	49.84%	33.13%	77.86%	66.80%	55.73%	83.02%	74.54%	66.05%	63.73%
25	65.17%	47.75%	30.34%	76.94%	65.41%	53.88%	82.32%	73.47%	64.63%	62.21%
26	63.78%	45.66%	27.55%	76.02%	64.03%	52.04%	81.61%	72.41%	63.22%	60.70%
27	62.38%	43.57%	24.77%	75.10%	62.64%	50.19%	80.90%	71.35%	61.80%	59.19%
28	60.99%	41.48%	21.98%	74.17%	61.26%	48.35%	80.19%	70.29%	60.39%	57.68%
29	59.60%	39.39%	19.19%	73.25%	59.88%	46.50%	79.49%	69.23%	58.97%	56.17%
30	58.20%	37.30%	16.41%	72.33%	58.49%	44.66%	78.78%	68.17%	57.56%	54.66%
31	56.81%	35.21%	13.62%	71.41%	57.11%	42.81%	78.07%	67.11%	56.15%	53.14%
32	55.42%	33.13%	10.83%	70.48%	55.73%	40.97%	77.37%	66.05%	54.73%	51.63%
33	54.02%	31.04%	8.05%	69.56%	54.34%	39.13%	76.66%	64.99%	53.32%	50.12%
34	52.63%	28.95%	5.26%	68.64%	52.96%	37.28%	75.95%	63.93%	51.90%	48.61%
35	51.24%	26.86%	2.47%	67.72%	51.58%	35.44%	75.24%	62.86%	50.49%	47.10%
36	49.84%	24.77%	-0.31%	66.80%	50.19%	33.59%	74.54%	61.80%	49.07%	45.59%

Appendix D. Grand Rapids Project Cultural Resources Study

(Filed as Privileged)

Appendix E. Prairie River Project Water Quality Study

WENCK File #B000959-20-082
October 2020

Prairie River Hydroelectric Project (FERC No. 2361)

Prepared for:

Minnesota Power

Minnesota Power
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1.0 Introduction and Background

1.1 INTRODUCTION

ALLETE Inc., doing business as Minnesota Power ("MP" or "Licensee"), is the Licensee, owner, and operator of the Prairie River Hydroelectric Project (FERC No. 2361).
The Prairie River Hydroelectric Project (Project) is licensed by the Federal Energy Regulatory Commission ("FERC" or "Commission") under the authority granted to FERC by Congress through the Federal Power Act (FPA), 16 United States Code (USC) §791(a), et seq., to license and oversee the operation of non-federal hydroelectric projects on jurisdictional waters and/or federal land. There are no federal lands associated with the Project. The Project previously underwent licensing in the early 1990s, and the current operating license for the Project expires on December 31, 2023. Accordingly, MP is pursuing a subsequent license for the Prairie River Project pursuant to FERC's Integrated Licensing Process (ILP), as described at 18 Code of Federal Regulations (CFR) Part 5.

This report describes the methods and results of the approved Water Quality Study conducted as part of obtaining a subsequent license for the Project.

1.2 BACKGROUND

The Prairie River Project is a 1.1-megawatt (MW), run-of-river (ROR) facility located on the Prairie River, near the City of Grand Rapids in Arbo Township, Itasca County, Minnesota. On December 13, 2018, MP initiated the ILP by filing a Pre-Application Document (PAD) and Notice of Intent (NOI) with the Commission. Major ILP milestones to-date are presented in Table 1-1.

Table 1-1. Major ILP milestones completed.

Date	Milestone
12/13/2018	PAD and NOI Filed
02/07/2019	Scoping Document 1 (SD1) Issued by FERC
03/06-03/07/2019	FERC Agency and Public Scoping Meetings Conducted
03/06/2019	Project Site Visit Held
05/16/2019	Scoping Document 2 (SD2) Issued by FERC
05/28/2019	Proposed Study Plan (PSP) Filed
06/20/2019	PSP Meeting Conducted
09/23/2019	Revised Study Plan (RSP) Filed
10/16/2019	FERC Issues Study Plan Determination (SPD)

2.0 Study Goals and Objectives

The water quality study collected information and established recent baseline information on temperature and dissolved oxygen (DO) concentrations in the vicinity of the Project to further expand on the data that has been collected historically. The study employed standard methodologies that are consistent with the scope and level of effort of water quality monitoring conducted at hydropower projects in the region. The specific details and methods included in this study were outlined in the Revised Study Plan (RSP) which was approved by FERC in October 2019. The information collected by this study will be used to determine the Project's potential effects on water quality and provide water quality data sufficient to determine compliance with applicable water quality standards (Minnesota Statute Chapter 7050) and designated uses.

The State of Minnesota has established water quality standards (Minnesota Statute Chapter 7050) to protect water resources for uses such as fishing, swimming, and other recreation and to sustain aquatic life. These rules are administered by the MPCA, who is the lead 401 Water Quality Certification Agency. The Minnesota Department of Natural Resources (MDNR), Minnesota Board of Soil and Water Resources (BWSR), and local agencies also play a role in water quality protection (MPCA undated).

3.0 Study Area

The Project impounds water at the Prairie River Dam on the Prairie River in Arbo Township, Minnesota. DO and water temperature data were collected at three locations at the Project (Figure 3-1). Sampling locations and their GPS coordinates included:

- Upstream of Coarse Trash Rack; 47.287098, -93.500178
- Bypass Reach; 47.2854610, -93.4980522
- Tailrace Area; 47.284471, -93.499681

These three sampling locations match the general location of the three sampling locations identified in the FERC approved RSP (2019). The stations include conditions representative of both the slower pool conditions of the Prairie River Reservoir and the flowing channel conditions associated with the Prairie River channel downstream of the dam. The habitat type of the Upstream of Coarse Trash Rack site is characterized as a pool. The Bypass Reach site is characterized as a riffle, and the Tailrace Area site is characterized as a run.

Figure 3-1. Water quality sampling locations at the Prairie River Project site.

4.0 Methodology

Following the procedures outlined in the RSP (2019), DO and temperature measurements were made at three locations at the Prairie River Project site as displayed on Figure 3-1. All sampling locations are on the Prairie River in Arbo Township, Minnesota. There were 11 total sampling events from May–September 2020. Sampling events occurred approximately every two weeks throughout the monitoring period. The specific sampling events occurred on the dates listed:

- May 12th, 2020
- May 20th, 2020
- June 2nd, 2020
- June 16th, 2020
- June 30th, 2020
- July 14th, 2020
- July 28th, 2020
- August 11th, 2020
- August 25th, 2020
- September 10th, 2020
- September 22nd, 2020

DO concentration and temperature were measured on the surface and at multiple depths at each sampling location. DO and temperature upstream of the dam were collected at the Upstream of Coarse Trash Rack site and measurements were collected at 1-meter intervals from surface to the bottom of the water column. For sampling stations with a total depth of approximately two meters or less, DO and temperature were collected at the surface, middle, and bottom of the water column. This included the two sites downstream of the dam (the Bypass Reach and Tailrace Area sites). Corresponding depth measurements were recorded. A YSI 6920 V2 data sonde with 6560 Conductivity/Temperature Probe and 6150 ROX Optical DO Sensor was used for all sampling events except for September 10th and September 22nd, 2020. For the September sampling events, a YSI 5560 Conductivity/Temperature Probe and Pro2002 Galvanic DO Sensor was used. The DO probe was calibrated in the morning before each sampling event. The calibration method used was a percent saturation air calibration method specified in YSI's 6150 & 6450 Optical Dissolved Oxygen Sensors Description and Instructions for Use Manual.

Additional data that was recorded during each sampling event included reservoir discharge flows and elevation. Discharge and reservoir elevation were obtained directly from Minnesota Power staff. Habitat type at each sampling location was noted during the water quality study. The field sampling sheets are included in this report as Appendix A. The site photos are included in Appendix B and the calibration records are included in Appendix C of this report.

5.0 Study Results

DO and temperature profiles, discharge (total station flow), and reservoir elevation data were collected 11 times over the course of the study. Discharge at the Prairie River Project ranged from 114–506 cubic feet per second (cfs). Water elevation in the Prairie River Reservoir ranged from 1289.35–1289.49 ft above sea level. The Upstream of Coarse Trash Rack site was deeper and measurements were collected at 1-meter intervals. The Bypass Reach and Tailrace Area sites were shallow and measurements were collected at the surface, middle, and bottom of the water column. See Appendix A: Raw Data for all data points collected during the study and used in this report.

Mean DO concentration across sites ranged from 8.18–8.77 mg/L and mean water temperature ranged from 20.0–20.5 degrees C (Table 5-1). Differences in DO between sites were minimal, but the highest mean DO concentration occurred at the Bypass Reach site downstream of the dam and the lowest mean DO concentration occurred at the Tailrace Area site. Differences in temperature between sites were also minimal, but mean water temperature was highest at the Bypass Reach site. Mean water temperature was lowest at the Tailrace Area site. Over the course of the study, mean DO concentration at all sites generally decreased from May 12th, 2020 to August 25th, 2020 (Figure 5-1).

Table 5-1. Mean dissolved oxygen concentration and temperature for each site and 11 sampling events. Number in parentheses is one standard error of the mean.

Sampling Location	Dissolved oxygen (mg/L)	Temperature (degrees C)	Number of observations
Upstream of Coarse Trash Rack	8.43 (0.13)	20.4 (0.72)	37
Bypass Reach	8.77 (0.15)	20.5 (0.76)	32
Tailrace Area	8.18 (0.20)	20.0 (0.75)	33

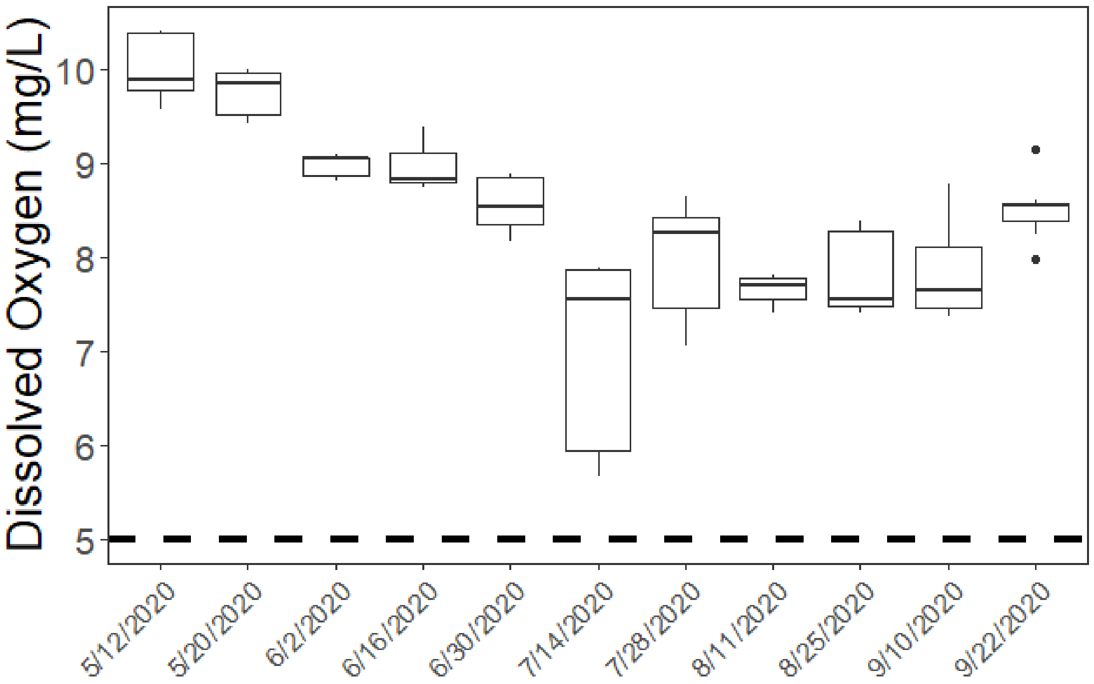

Figure 5-1. Boxplot showing DO summary statistics for all sampling locations at the Prairie Rapids Project. The center line in each box represents the median, the lower and upper hinges correspond to the first and third quartiles, and outliers are represented by black points. Data points were considered outliers if they fell outside 1.5 times the inner quartile range. Dotted black line represents the Minnesota Class 2B (warmwater) stream standard of 5.00 mg/L.

5.1 UPSTREAM OF COARSE TRASH RACK

The Upstream of Coarse Trash Rack site is a deep site upstream of the Prairie River Dam. Temperature and DO measurements were taken up to 4 m below the water surface during the study. Water temperature measurements at the site ranged from 11.5–25.0 degrees C. Water temperature generally increased over the course of the study until mid-July (Figure 5-2) corresponding to an increase in air temperatures over the summer months. Water temperatures decreased over the final five sampling events except for a short spike in temperature on August 25th, 2020.

DO measurements at the site ranged from 7.36–9.85 mg/L with the lowest readings September 10th, 2020. DO measurements generally decreased from May–September 10th, 2020 except for a short spike on July 28th (Figure 5-3). All DO measurements were above the Class 2B warmwater stream standard of 5.00 mg/L. Measurements of temperature and DO were generally taken at the same depths at each station during all 11 sampling events (Figure 5-4).

DO and temperature measurements were higher at the surface and decreased with depth on several occasions (Figure 5-5, Figure 5-6).

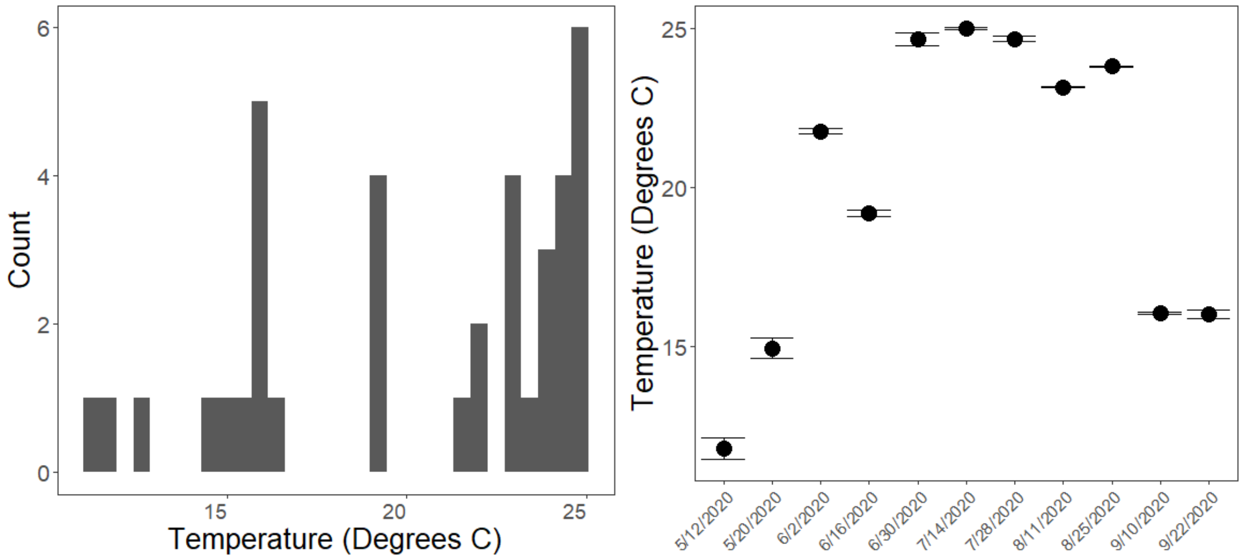

Figure 5-2. Histogram of temperature measurements (left) and mean temperature for each sampling event (right) at the Upstream of Coarse Trash Rack site. Whiskers represent standard error.

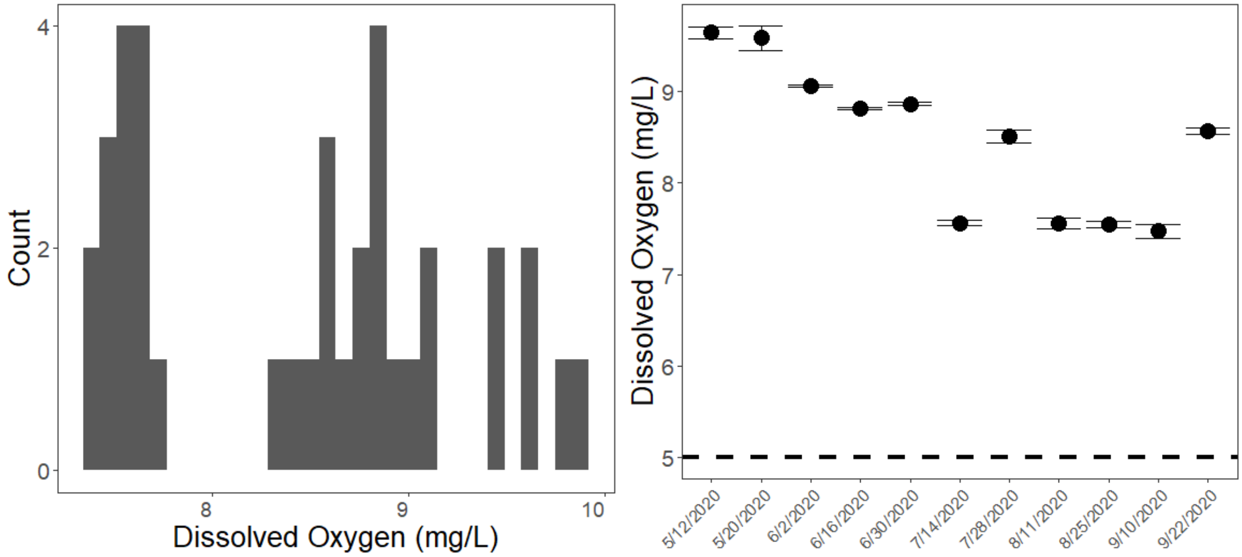

Figure 5-3. Histogram of dissolved oxygen measurements (left) and mean dissolved oxygen concentration (mg/L) for each sampling event (right) at the Upstream of Coarse Trash Rack site. Whiskers represent standard error and dotted black line represents the Minnesota Class 2B stream standard of 5.00 mg/L.

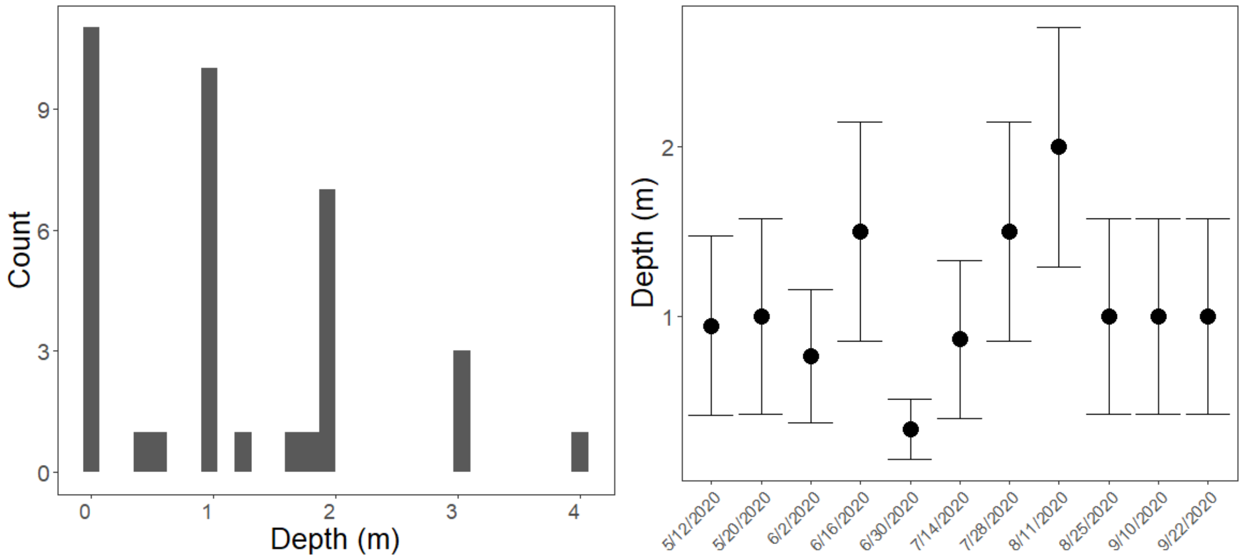

Figure 5-4. Histogram of depth measurements (left) and depth (m) for each sampling event (right) at the Upstream of Coarse Trash Rack site. Whiskers represent standard error.

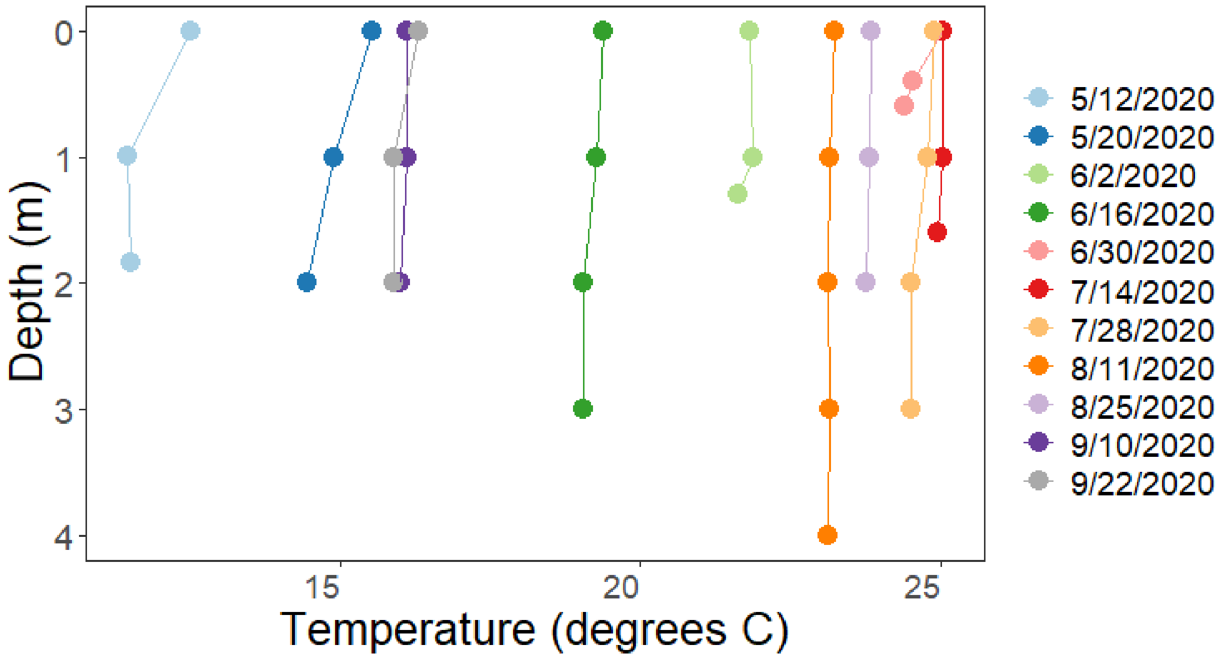

Figure 5-5. Temperature profiles at the Upstream of Coarse Trash Rack site for each sampling event.

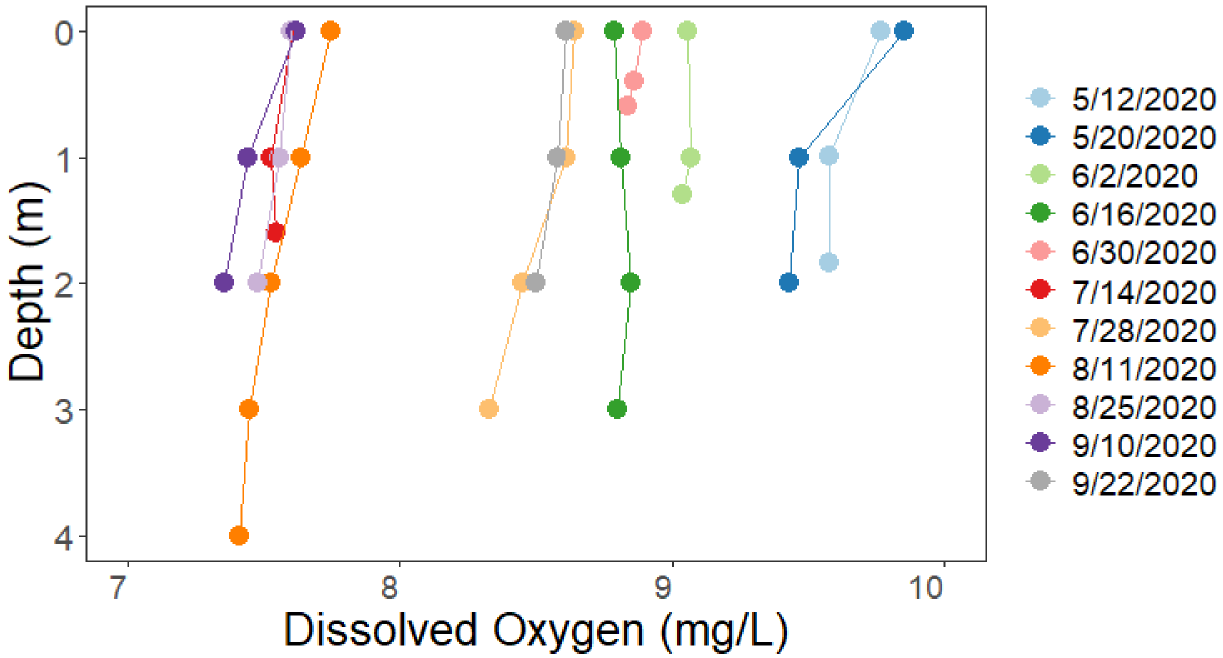

Figure 5-6. Dissolved oxygen profiles at the Upstream of Coarse Trash Rack site for each sampling event.

5.2 BYPASS REACH

The Bypass Reach site is a shallow site downstream of the Prairie River Dam. Temperature and DO measurements were taken up to 1.2 m below the water surface during the study. Water temperature measurements at the site ranged from 12.1–25.2 degrees C. Water temperature generally increased over the course of the study until August (Figure 5-7) corresponding to an increase in air temperatures over the summer months. Water temperatures decreased in September.

DO measurements at the site ranged from 7.76–10.4 mg/L with the lowest readings August 11th, 2020. DO measurements generally decreased until mid-August (Figure 5-8). All DO measurements were above the Class 2B warmwater stream standard of 5.0 mg/L. Measurements of temperature and DO were generally taken at the same depths at each station during all 11 sampling events, except on June 16th when the deepest measurement was made at 1.2 m (Figure 5-9).

The site was well-mixed with no observable pattern of higher temperature or DO on the surface (Figure 5-10, Figure 5-11). On June 2nd, 2020 measurements of DO and temperature were made at the surface, middle, and bottom of the water column; however, the depth of the middle and bottom measurement were not recorded. Only the surface water measurement is included in the profiles for this date.

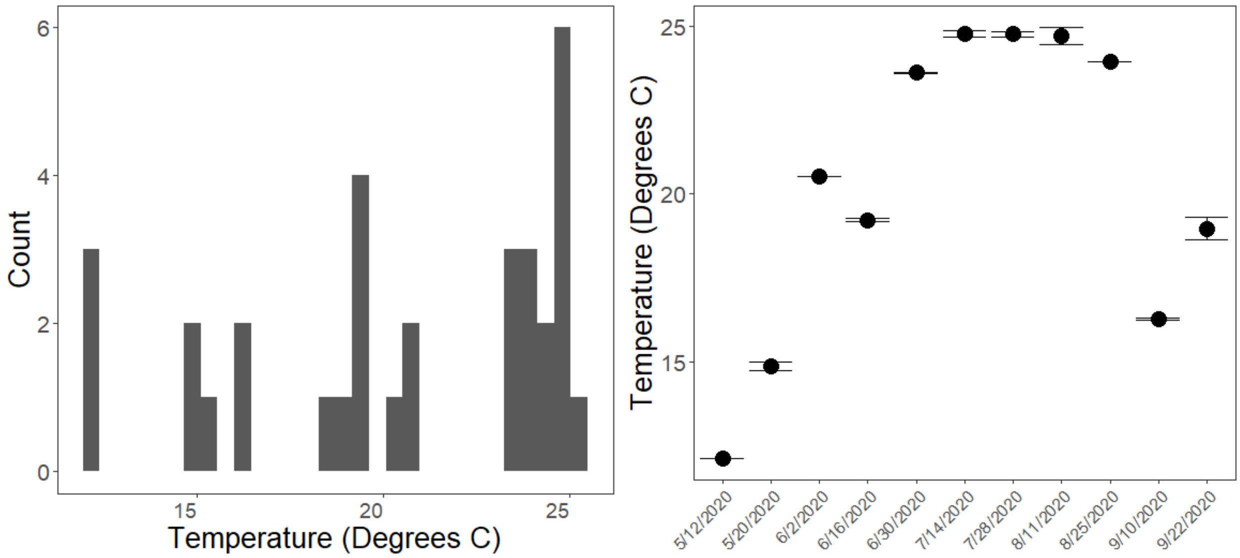

Figure 5-7. Histogram of temperature measurements (left) and mean temperature for each sampling event (right) at the Bypass Reach site. Whiskers represent standard error.

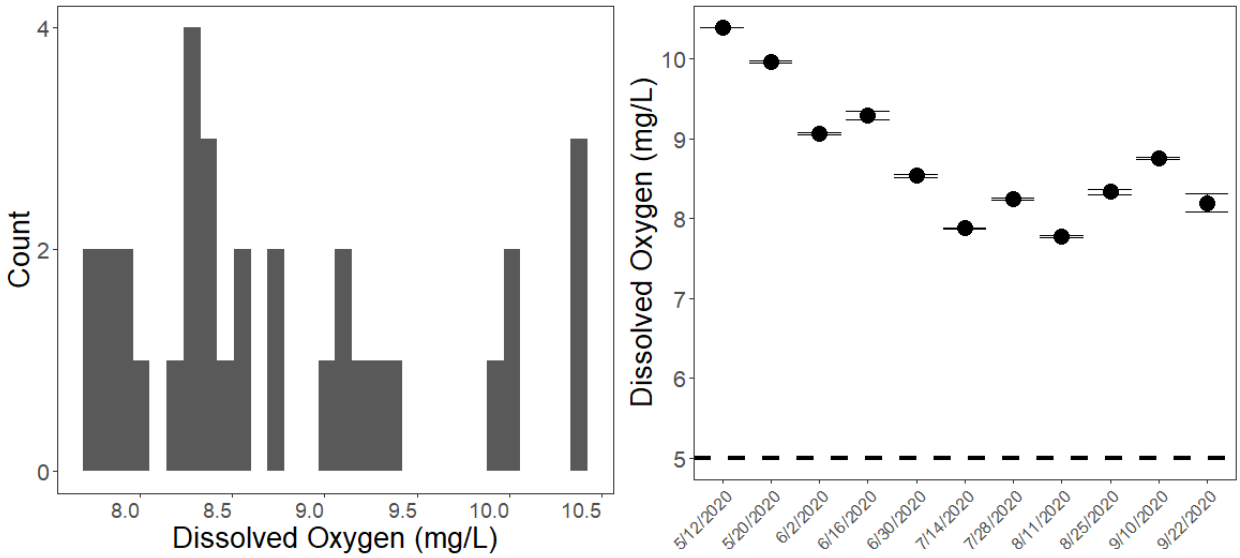

Figure 5-8. Histogram of dissolved oxygen measurements (left) and mean dissolved oxygen concentration (mg/L) for each sampling event (right) at the Bypass Reach site. Whiskers represent standard error and dotted black line represents the Minnesota Class 2B warmwater stream standard of 5.00 mg/L.

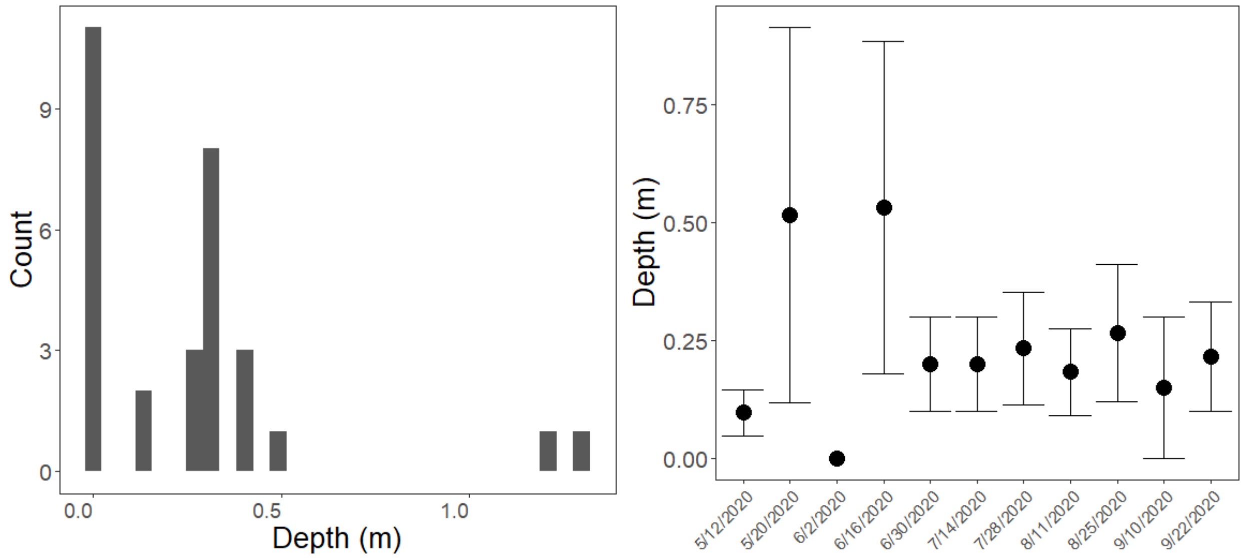

Figure 5-9. Histogram of depth measurements (left) and depth (m) for each sampling event (right) at the Bypass Reach site. Whiskers represent standard error.

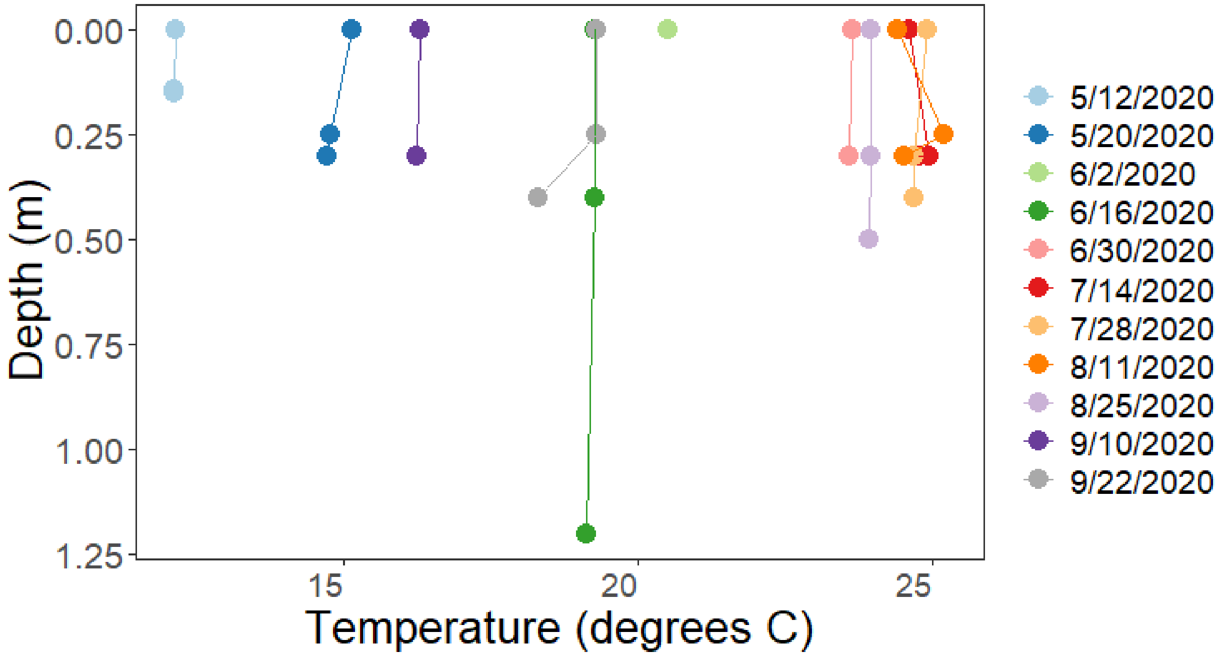

Figure 5-10. Temperature profiles at the Bypass Reach site for each sampling event.

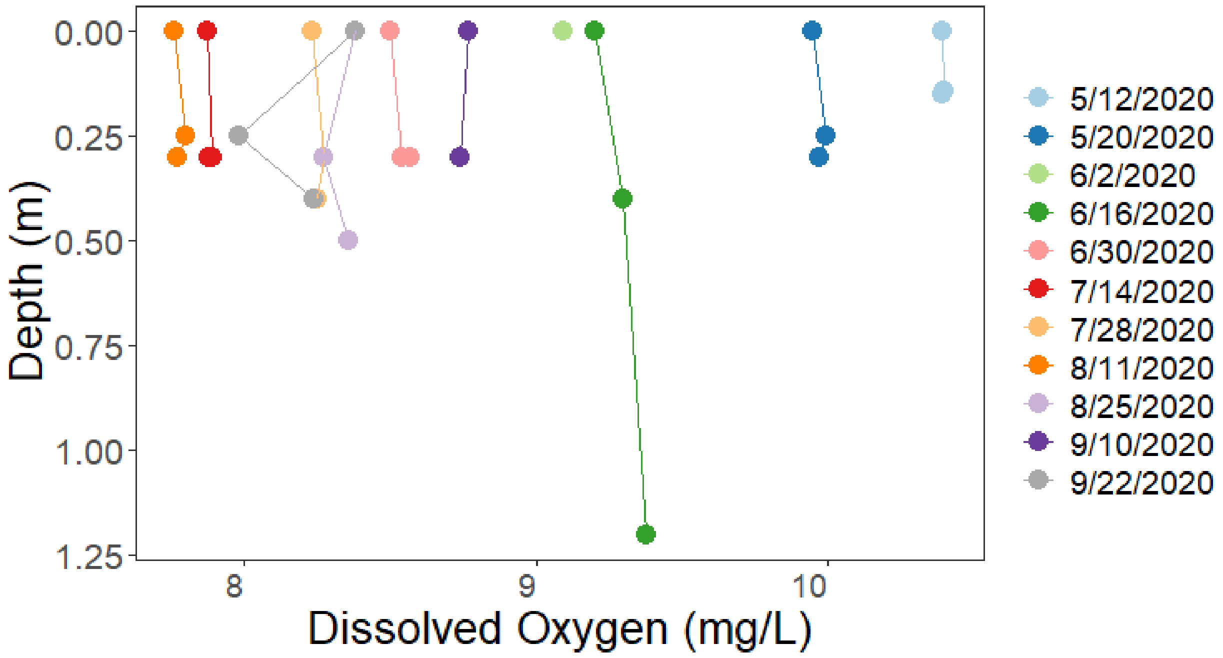

Figure 5-11. Dissolved oxygen profiles at the Bypass Reach site for each sampling event.

5.3 TAILRACE AREA

The Tailrace Area site is a shallow site downstream of the Prairie River Dam. Temperature and DO measurements were taken up to 1.5 m below the water surface during the study. Water temperature measurements at the site ranged from 12.4–24.6 degrees C. Water temperature generally increased over the course of the study until August (Figure 5-12) corresponding to an increase in air temperatures over the summer months. Water temperatures decreased in September.

DO measurements at the site ranged from 5.65–9.97 mg/L with the lowest readings on July 14th, 2020. DO measurements generally decreased until mid-August (Figure 5-13). All DO measurements were above the Class 2B warmwater stream standard. Measurements of temperature and DO were taken at various depths depending on the water level during the 11 sampling events (Figure 5-14).

Temperature was not stratified during any event (Figure 5-15). DO was higher on the surface than below the surface on May 20th, July 14th, August 11th, August 25th, and September 22nd, 2020 (Figure 5-16).

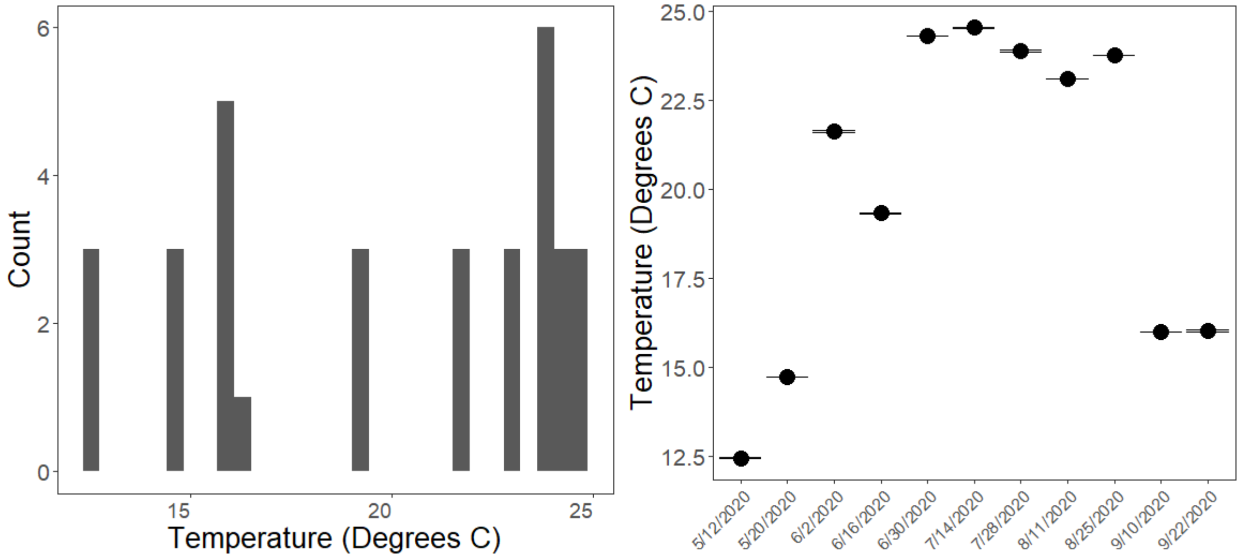

Figure 5-12. Histogram of temperature measurements (left) and mean temperature for each sampling event (right) at the Tailrace Area site. Whiskers represent standard error.

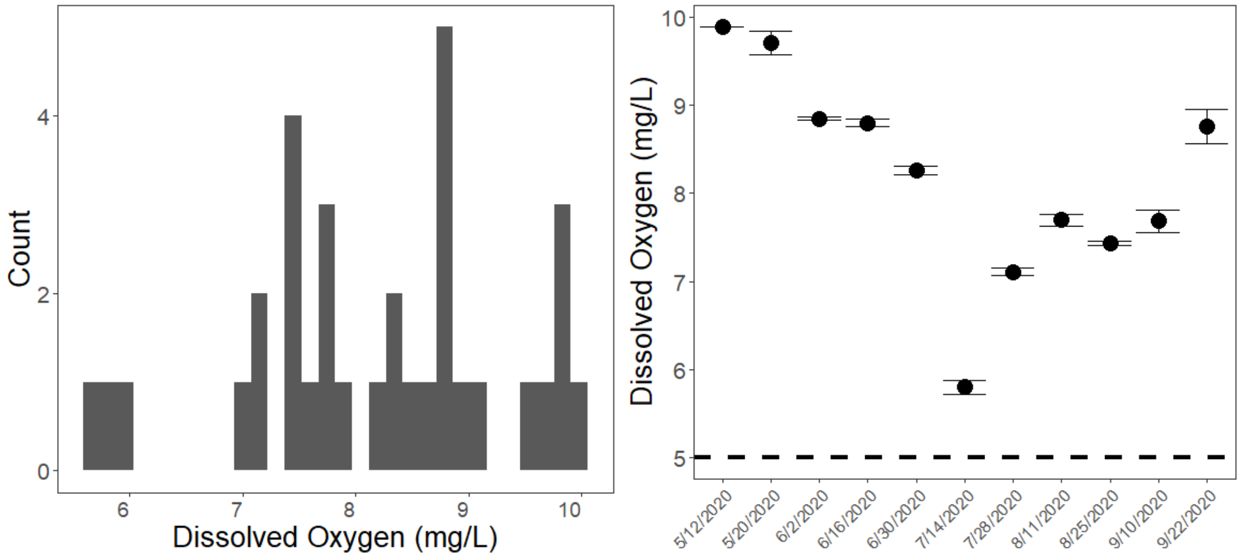

Figure 5-13. Histogram of dissolved oxygen measurements (left) and mean dissolved oxygen concentration (mg/L) for each sampling event (right) at the Tailrace Area site. Whiskers represent standard error and dotted black line represents the Minnesota Class 2B stream standard of 5.00 mg/L.

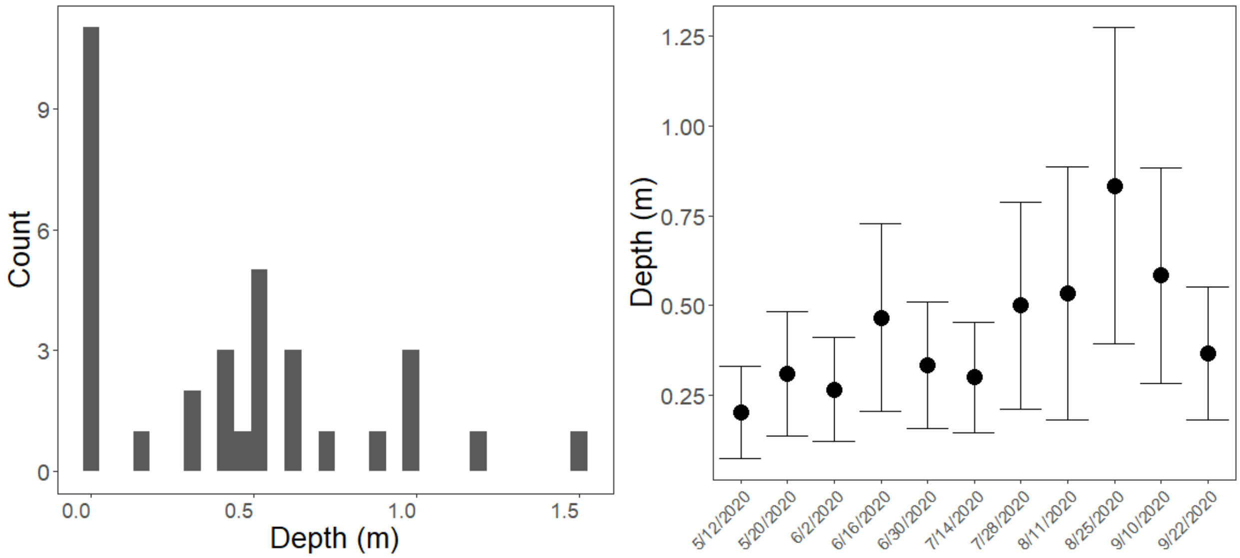

Figure 5-14. Histogram of depth measurements (left) and depth (m) for each sampling event (right) at the Tailrace Area site. Whiskers represent standard error.

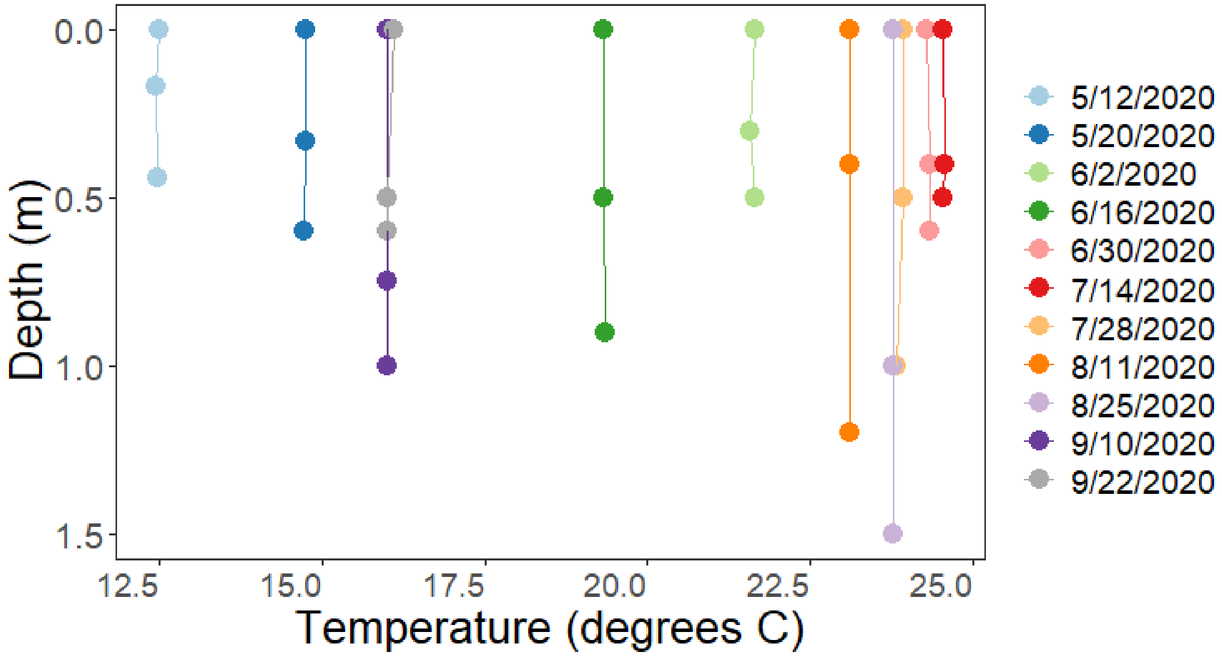

Figure 5-15. Temperature profiles at the Tailrace Area site for each sampling event.

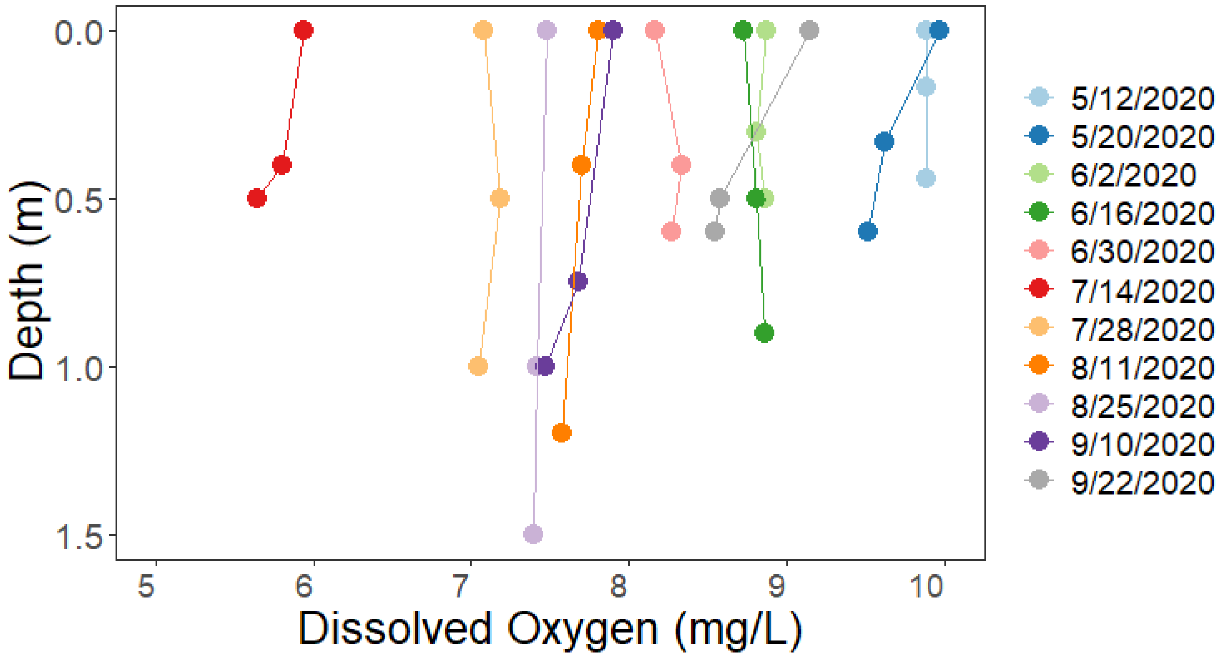

Figure 5-16. Dissolved oxygen profiles at the Tailrace Area site for each sampling event.

6.0 Summary

A total of 102 measurements of DO and water temperature readings were collected over the course of the study at the Prairie River Project.

Overall, the observed readings were typical of well-mixed, warmwater rivers in Minnesota. Water temperature generally increased at all sites until August, then decreased during the September monitoring events. Dissolved oxygen measurements made at all sites during this project were above the Minnesota Class 2B warmwater stream standard of 5.00 mg/L. Mean DO generally decreased from May through July and then began to increase over the rest of the monitoring period until the final sampling on September 22nd, 2020.

There were a few instances where DO and temperature were higher on the surface than at depths below the surface at the monitored sites, a typical occurrence for surface waters in Minnesota in the summer. Differences in DO and temperature in the water column were not a consistent occurrence.

7.0 References

Minnesota Power (2019). Revised Study Plan: Grand Rapids Hydroelectric Project (FERC No. 2362) and Prairie River Hydroelectric Project (FERC No. 2361). Prepared by HDR Engineering, Inc. for Minnesota Power. September 23, 2019.

8.0 Appendix A: Raw Data

Table A- 1. Water quality data from all stations at the Grand Rapids Project site for all sampling events.

Site	Station	Date	Time	Depth (m)	Temperature (degrees C)	Dissolved oxygen (mg/L)	Dissolved oxygen (percent saturation)
Prairie River	Upstream of Coarse Trash Rack	5/12/2020	13:51	0	12.501	9.77	-
Prairie River	Upstream of Coarse Trash Rack	5/12/2020	13:51	0.997	11.446	9.58	-
Prairie River	Upstream of Coarse Trash Rack	5/12/2020	13:51	1.839	11.508	9.58	-
Prairie River	Tailrace Area	5/12/2020	13:30	0	12.494	9.89	-
Prairie River	Tailrace Area	5/12/2020	13:30	0.168	12.443	9.88	-
Prairie River	Tailrace Area	5/12/2020	13:30	0.442	12.464	9.89	-
Prairie River	Bypass Reach	5/12/2020	14:21	0	12.155	10.39	-
Prairie River	Bypass Reach	5/12/2020	14:21	0.141	12.132	10.4	-
Prairie River	Bypass Reach	5/12/2020	14:21	0.151	12.136	10.39	-
Prairie River	Upstream of Coarse Trash Rack	5/20/2020	12:02	0	15.54	9.85	-
Prairie River	Upstream of Coarse Trash Rack	5/20/2020	12:02	1	14.9	9.47	-
Prairie River	Upstream of Coarse Trash Rack	5/20/2020	12:02	2	14.45	9.43	-
Prairie River	Tailrace Area	5/20/2020	11:45	0	14.75	9.97	-
Prairie River	Tailrace Area	5/20/2020	11:45	0.33	14.75	9.62	-
Prairie River	Tailrace Area	5/20/2020	11:45	0.6	14.73	9.52	-
Prairie River	Bypass Reach	5/20/2020	12:25	0	15.14	9.95	-

Prairie River	Bypass Reach	5/20/2020	12:25	0.25	14.78	9.99	-
Prairie River	Bypass Reach	5/20/2020	12:25	0.3	14.71	9.97	-
Prairie River	Upstream of Coarse Trash Rack	6/2/2020	13:51	0	21.82	9.06	103.2
Prairie River	Upstream of Coarse Trash Rack	6/2/2020	13:51	1	21.87	9.07	103.4
Prairie River	Upstream of Coarse Trash Rack	6/2/2020	13:51	1.3	21.61	9.04	102.7
Prairie River	Tailrace Area	6/2/2020	13:25	0	21.64	8.87	100.8
Prairie River	Tailrace Area	6/2/2020	13:25	0.3	21.57	8.81	99.9
Prairie River	Tailrace Area	6/2/2020	13:25	0.5	21.65	8.86	100.7
Prairie River	Bypass Reach	6/2/2020	14:07	0	20.52	9.09	101.1
Prairie River	Bypass Reach	6/2/2020	14:07	-	20.54	9.06	100.7
Prairie River	Bypass Reach	6/2/2020	14:07	-	20.51	9.05	100.6
Prairie River	Upstream of Coarse Trash Rack	6/16/2020	12:45	0	19.39	8.79	95.5
Prairie River	Upstream of Coarse Trash Rack	6/16/2020	12:45	1	19.28	8.81	95.5
Prairie River	Upstream of Coarse Trash Rack	6/16/2020	12:45	2	19.05	8.85	95.6
Prairie River	Upstream of Coarse Trash Rack	6/16/2020	12:45	3	19.05	8.8	95
Prairie River	Tailrace Area	6/16/2020	12:15	0	19.33	8.73	95.3
Prairie River	Tailrace Area	6/16/2020	12:15	0.5	19.32	8.81	95.6
Prairie River	Tailrace Area	6/16/2020	12:15	0.9	19.34	8.86	96.1
Prairie River	Bypass Reach	6/16/2020	13:05	0	19.27	9.2	99.7
Prairie River	Bypass Reach	6/16/2020	13:05	0.4	19.26	9.3	100.7
Prairie River	Bypass Reach	6/16/2020	13:05	1.2	19.13	9.38	101.4
Prairie River	Upstream of Coarse Trash Rack	6/30/2020	12:07	0	25.02	8.89	107.7

Prairie River	Upstream of Coarse Trash Rack	6/30/2020	12:07	0.4	24.54	8.86	106.4
Prairie River	Upstream of Coarse Trash Rack	6/30/2020	12:07	0.6	24.4	8.84	105.8
Prairie River	Tailrace Area	6/30/2020	11:39	0	24.28	8.17	97.6
Prairie River	Tailrace Area	6/30/2020	11:39	0.4	24.32	8.34	98.5
Prairie River	Tailrace Area	6/30/2020	11:39	0.6	24.32	8.27	98.9
Prairie River	Bypass Reach	6/30/2020	12:20	0	23.65	8.5	100.3
Prairie River	Bypass Reach	6/30/2020	12:20	0.3	23.59	8.54	100.7
Prairie River	Bypass Reach	6/30/2020	12:20	0.3	23.59	8.57	101.1
Prairie River	Upstream of Coarse Trash Rack	7/14/2020	12:34	0	25.03	7.61	92.2
Prairie River	Upstream of Coarse Trash Rack	7/14/2020	12:34	1	25.02	7.53	91.1
Prairie River	Upstream of Coarse Trash Rack	7/14/2020	12:34	1.6	24.94	7.55	91.3
Prairie River	Tailrace Area	7/14/2020	12:14	0	24.53	5.94	71.4
Prairie River	Tailrace Area	7/14/2020	12:14	0.4	24.56	5.8	69.7
Prairie River	Tailrace Area	7/14/2020	12:14	0.5	24.53	5.65	67.9
Prairie River	Bypass Reach	7/14/2020	12:50	0	24.61	7.87	94.7
Prairie River	Bypass Reach	7/14/2020	12:50	0.3	24.93	7.89	95.4
Prairie River	Bypass Reach	7/14/2020	12:50	0.3	24.78	7.88	95.2
Prairie River	Upstream of Coarse Trash Rack	7/28/2020	11:36	0	24.88	8.64	104.4
Prairie River	Upstream of Coarse Trash Rack	7/28/2020	11:36	1	24.78	8.61	103.9
Prairie River	Upstream of Coarse Trash Rack	7/28/2020	11:36	2	24.49	8.45	101.4
Prairie River	Upstream of Coarse Trash Rack	7/28/2020	11:36	3	24.51	8.33	99.9
Prairie River	Tailrace Area	7/28/2020	11:11	0	23.92	7.08	84.1

Prairie River	Tailrace Area	7/28/2020	11:11	0.5	23.92	7.19	85.3
Prairie River	Tailrace Area	7/28/2020	11:11	1	23.83	7.05	83.6
Prairie River	Bypass Reach	7/28/2020	11:55	0	24.92	8.23	99.5
Prairie River	Bypass Reach	7/28/2020	11:55	0.3	24.68	8.27	99.6
Prairie River	Bypass Reach	7/28/2020	11:55	0.4	24.68	8.25	99.3
Prairie River	Upstream of Coarse Trash Rack	8/11/2020	12:32	0	23.23	7.75	90.8
Prairie River	Upstream of Coarse Trash Rack	8/11/2020	12:32	1	23.15	7.64	89.4
Prairie River	Upstream of Coarse Trash Rack	8/11/2020	12:32	2	23.11	7.53	88.1
Prairie River	Upstream of Coarse Trash Rack	8/11/2020	12:32	3	23.14	7.45	87.2
Prairie River	Upstream of Coarse Trash Rack	8/11/2020	12:32	4	23.12	7.41	86.6
Prairie River	Tailrace Area	8/11/2020	12:16	0	23.1	7.81	91.3
Prairie River	Tailrace Area	8/11/2020	12:16	0.4	23.1	7.7	90
Prairie River	Tailrace Area	8/11/2020	12:16	1.2	23.1	7.58	88.6
Prairie River	Bypass Reach	8/11/2020	12:51	0	24.4	7.76	92.9
Prairie River	Bypass Reach	8/11/2020	12:51	0.25	25.21	7.8	94.8
Prairie River	Bypass Reach	8/11/2020	12:51	0.3	24.51	7.77	93.2
Prairie River	Upstream of Coarse Trash Rack	8/25/2020	11:46	0	23.83	7.6	90.1
Prairie River	Upstream of Coarse Trash Rack	8/25/2020	11:46	1	23.82	7.56	89.6
Prairie River	Upstream of Coarse Trash Rack	8/25/2020	11:46	2	23.74	7.48	88.5
Prairie River	Tailrace Area	8/25/2020	11:22	0	23.77	7.48	88.5
Prairie River	Tailrace Area	8/25/2020	11:22	1	23.77	7.42	87.9
Prairie River	Tailrace Area	8/25/2020	11:22	1.5	23.77	7.4	87.6
Prairie River	Bypass Reach	8/25/2020	12:01	0	23.95	8.38	99.6

Prairie River	Bypass Reach	8/25/2020	12:01	0.5	23.93	8.36	99.2
Prairie River	Bypass Reach	8/25/2020	12:01	0.3	23.95	8.27	98.2
Prairie River	Upstream of Coarse Trash Rack	9/10/2020	12:06	0	16.1	7.62	77.4
Prairie River	Upstream of Coarse Trash Rack	9/10/2020	12:06	1	16.1	7.44	75.5
Prairie River	Upstream of Coarse Trash Rack	9/10/2020	12:06	2	16	7.36	74.6
Prairie River	Tailrace Area	9/10/2020	11:51	0	16	7.9	80
Prairie River	Tailrace Area	9/10/2020	11:51	0.75	16	7.68	77.8
Prairie River	Tailrace Area	9/10/2020	11:51	1	16	7.47	75.8
Prairie River	Bypass Reach	9/10/2020	12:18	0	16.3	8.77	89.5
Prairie River	Bypass Reach	9/10/2020	12:18	0.3	16.25	8.74	89
Prairie River	Upstream of Coarse Trash Rack	9/22/2020	12:33	0	16.3	8.61	87.3
Prairie River	Upstream of Coarse Trash Rack	9/22/2020	12:33	1	15.9	8.58	86.8
Prairie River	Upstream of Coarse Trash Rack	9/22/2020	12:33	2	15.9	8.5	86
Prairie River	Tailrace Area	9/22/2020	12:22	0	16.1	9.15	92.9
Prairie River	Tailrace Area	9/22/2020	12:22	0.5	16	8.58	87
Prairie River	Tailrace Area	9/22/2020	12:22	0.6	16	8.55	86.7
Prairie River	Bypass Reach	9/22/2020	12:43	0	19.3	8.38	89.8
Prairie River	Bypass Reach	9/22/2020	12:43	0.25	19.3	7.98	86.6
Prairie River	Bypass Reach	9/22/2020	12:43	0.4	18.3	8.24	88.3

Table A- 2. Reservoir elevation and discharge at the Prairie River Project site. Discharge and reservoir elevation obtained from Prairie River Dam staff.

Site	Station	Date	Flow (cfs)	Elevation (ft)
Prairie River	Prairie River Reservoir	6/16/2020	443	1289.43
Prairie River	Prairie River Reservoir	5/12/2020	212	1289.36
Prairie River	Prairie River Reservoir	5/20/2020	180	1289.35
Prairie River	Prairie River Reservoir	6/2/2020	164	1289.42
Prairie River	Prairie River Reservoir	6/30/2020	141	1289.43
Prairie River	Prairie River Reservoir	7/14/2020	114	1289.49
Prairie River	Prairie River Reservoir	7/28/2020	150	1289.36
Prairie River	Prairie River Reservoir	8/11/2020	147	1289.37
Prairie River	Prairie River Reservoir	8/25/2020	506	1289.35
Prairie River	Prairie River Reservoir	9/10/2020	228	1289.39
Prairie River	Prairie River Reservoir	9/22/2020	132	1289.38

Prairie River Hydroelectric Project
FERC License No. 2361
DO and Temp. Study Measurements

Date: 5/12/2020

Weather Conditions and Outside Temp: 52°, sunny, wind 6mph, humidity 24%

Flow Conditions (Observations and flow from MP): (see below) Wendy Gomez

Temp and DO Meter Model & Calibration Start time:

Name of Person Collecting Data measurements: 131 units, 83 thru waste gates

Comments: Upstream of trash rack, I wasn't able to get the sensor more than ~4 feet from shore with extender pole → lowest reading at 1.839 meters.

Upstream of Coarse Trash Rack
Time: 1:51

GPS: 47.287098, -93.500178

Depth (meters)		**Temp (C)**	**DO (mg/L)**
Surface		12,501	9,77
1 m	0,997	11,446	9.58
2 m	1.839	11.508	9,58
3 m			
4 m			
5 m			
6 m			

Tailrace Area
Time: 1:30

GPS: 47.284471, -93.499681

Depth (meters)		**Temp (C)**	**DO (mg/L)**
Surface	0.00	12,414	9.59
Mid	.168	12,443	9.88
Bttm	0.442	12.464	9.89

Bypass Reach
Time: 2:21

GPS: 47.2854610, -93.4980522

Depth (meters)		**Temp (C)**	**DO (mg/L)**
Surface	0.136	12.55	10.39
Mid	0.141	12,132	10.40
Bttm	0.151	12,136	10.39

Prairie River Hydroelectric Project
FERC License No. 2361
DO and Temp. Study Measurements

Date: 5/20/2020

Weather Conditions and Outside Temp: Sunny, 77° F, Winds SSE at 10-20 mph.

Flow Conditions (Observations and flow from MP): Unit 101 ~~[illegible]~~ waste gates = 79 total str flow-180

Temp and DO Meter Model & Calibration Start time: 9:25 am, 56° F at G.R Dam.

Name of Person Collecting Data measurements: Wendy Gomez

Comments: Bottom level at trash rack was 2m,

Upstream of Coarse Trash Rack
Time: 12:02

GPS: 47.2869760, -93.5001175

Depth (meters)	Temp (C)	DO (mg/L)
Surface .2	15.54	9.85
1 m	14.90	9.47
2 m	~~6.~~ 14.48	9.43
3 m		
4 m		
5 m		
6 m		

Tailrace Area
Time: 11:45

GPS: 47.2846038, -93.4997819

Depth (meters)		Temp (C)	DO (mg/L)
Surface	.2	14.75	9.71
Mid	.33	14.75	9.62
Bttm	.6	14.73	9.52

Bypass Reach
Time: 12:25 Lots of mosquitos!

GPS: 47.2854813, -93.498034

Depth (meters)		Temp (C)	DO (mg/L)
Surface	.2	15.14	9.95
Mid	.25	14.78	9.99
Bttm	.3	14.71	9.97

Prairie River Hydroelectric Project #2361
Water Quality Study – Data Collection

Date: 6/2/2020 Data Collector: Wendy Gong

Weather: ☐ Sunny ☒ Rainy sprinkles ☐ Party Cloudy ☒ Mostly Cloudy ☐ Windy/Significant Wave Action

☐ Recent storm event – When: ☐ Other

Temperature: ~~80°~~ F 76° F light rain/sprinkles

Flow: Call Hydro Control Room at (218) 725-~~2101~~ 2110

Total Station Flow 164 cfs / Bypass Flow 66 cfs / Unit Flow 108 cfs

Flow Observations: quiet, calm

Temp and DO Meter Calibration Start Time: 10:49, 81° F

Comments: mosquitos

Upstream of Coarse Trash Rack

Time: 1:51

GPS: 47.2869807, -93.5002355

Depth (meters)	Temp (C)	DO (mg/L)	DO%
Surface	21.82	9.06	103.3
1m	21.87	9.07	103.4
~~2m~~ 1.3	21.61	9.04	102.7
3m			
4m			
5m			
6m			

Trailrace Area

Time: 1:25 pm 13:25

GPS: 47.2844981, -93.4997517

Depth (meters)	Temp (C)	DO (mg/L)	DO%
Surface	21.64	8.87	100.8
Mid .3	21.57	8.81	99.9
Bottom .5	~~21.5~~ 21.65	8.86	100.7

Bypass Reach

Time: 2:07

GPS: 47.2854087, -93.4978614

Depth (meters)	Temp (C)	DO (mg/L)	DO%
Surface	20.52	9.09	101.1
Mid	20.54	9.06	100.7
Bottom	20.51	9.05	100.6

**utilize military time HH:MM*

Prairie River Hydroelectric Project #2361
Water Quality Study – Data Collection

Date: 6/16/2020

Data Collector: Wendy Gomez

Weather: ☐ Sunny ☐ Rainy ☒ Party Cloudy ☐ Mostly Cloudy ☐ Windy/Significant Wave Action

☒ Recent storm event – When: ~a week ☐ Other

Temperature: 78°

Flow: Call Hydro Control Room at (218) 725-~~2101~~ 2110 Reservoir elevation: 1289.43

Called again to verify - the was a rain storm about a week ago

Total Station Flow 443 cfs / Bypass Flow 291 cfs / Unit Flow 152 cfs tail 1249.42

Flow Observations: rushing water -

Temp and DO Meter Calibration Start Time: 9:50 am 74°

Comments: water is deeper - spilling into road, rushing current larg rock is covered now

Upstream of Coarse Trash Rack

Time: ~~12:15~~ 1245

GPS: ~~47.2845581, -93.4997413~~ error w

Depth (meters)	Temp (C)	DO (mg/L)	DO%
Surface	19.39	95.5	8.79
1m	19.28	95.5	8.81
2m	19.05	95.6	8.85
3m 2.	19.05	95.0	8.80
4m	–	–	–
5m	–	–	–
6m	–	–	–

max depth was about 2.3 m

Trailrace Area

Time: 12:15

GPS: 47.2845581, -93.4997413

Depth (meters)	Temp (C)	DO (mg/L)	DO%
Surface	19.33	95.3	8.78
Mid	19.32	95.6	8.81
Bottom	19.34	96.1	8.86

surface depth, .25 m mid depth 0.5 m, bottom 0.9m

Upstream of Trash Rack GPS: 47.2869901, -93.5001745

Bypass Reach

Time: 13:05

GPS: 47.2854761, -93.4981269

Depth (meters)	Temp (C)	DO (mg/L)	DO%
Surface	19.27	99.7	9.20
Mid	19.26	100.7	9.30
Bottom	19.13	101.4	9.38

surface depth 0.25 m, mid depth 0.4 m, bottom 1.2m

**utilize military time HH:MM*

Prairie River Hydroelectric Project #2361
Water Quality Study – Data Collection

Date: 6/30/2020

Data Collector: Wendy Gomez

Weather: ☐ Sunny ☐ Rainy ☐ Party Cloudy ☒ Mostly Cloudy ☐ Windy/Significant Wave Action

☐ Recent storm event – When: ______ ☐ Other ______

Temperature: 75°

Flow: Call Hydro Control Room at (218) 725-2110

Total Station Flow 141 cfs / Bypass Flow 51 cfs / Unit Flow 90 cfs

Flow Observations: ______

Temp and DO Meter Calibration Start Time: 68° 937 am Reservoir Elevation: 1289.43

Comments: no people at tailrace area - but a fire with wood & ashes still hot broken glass & cans

Upstream of Coarse Trash Rack many black ants

Time: 12:07

GPS: 47.2876125, -93.4982359

Depth (meters)	Temp (C)	DO%	DO (mg/L)
Surface .25	25.02	107.7	8.89
1m 0.4	24.54	106.4	8.86
2m 0.6	24.40	105.8	8.84
3m			
4m			
5m			
6m			

Trailrace Area a car with 4 people pulled up + towels + swimming suits

Time: 11:39

GPS: 47.2846093, -93.4996967

Depth (meters)	Meters	Temp (C)	DO%	DO (mg/L)
Surface	0.25	24.28	97.6	8.17
Mid	0.4	24.32	98.5	8.34
Bottom	0.6	24.32	98.9	8.27

Bypass Reach

Time: 12:20

GPS: 47.2855056, -93.4980364

Depth (meters)	Meters	Temp (C)	DO%	DO (mg/L)
Surface	.25	23.65	100.3	8.50
Mid	.3	23.59	100.7	8.54
Bottom	.3	23.59	101.1	8.57

**utilize military time HH:MM*

Prairie River Hydroelectric Project #2361
Water Quality Study – Data Collection

Date: 7/14/2020 , Data Collector: Wendy Gomez

Weather: ☐ Sunny ☒ Rainy ☐ Party Cloudy ☐ Mostly Cloudy ☐ Windy/Significant Wave Action

☐ Recent storm event – When: ______ ☐ Other ______

Temperature: 62° F

Flow: Call Hydro Control Room at (218) 725-2110

Total Station Flow 114. cfs / Bypass Flow 111 cfs / Unit Flow 3.0 cfs

Flow Observations: control room operator said flow was basically "off" just a little flow through the wicket gates

Temp and DO Meter Calibration Start Time: 66°, 945 am Reservoir Elevation: 1289.49

Comments: 2 people walking

Upstream of Coarse Trash Rack

Time: 12:34

GPS: 47.2870110, -93.4999136

Depth (meters)	Temp (C)	DO%	DO (mg/L)
Surface	25.03	93.92.2	7.61
1m	25.02	91.1	7.53
2m 1.6	24.94	91.3	7.55
3m			
4m			
5m			
6m			

Trailrace Area

Time: 12:14

GPS: 47.2843694, -93.4996125

Depth (meters)	Meters	24.53 Temp (C)	DO%	DO (mg/L)
Surface	.25	24.58	71.4	5.94
Mid	0.4	24.56	69.7	5.80
Bottom	0.5	24.53	67.9	5.65

Bypass Reach

Time: 12:50

GPS: 47.2853496, -93.4980143

Depth (meters)	Meters	Temp (C)	DO%	DO (mg/L)
Surface	.25	24.61	94.7	7.87
Mid	0.3	24.93	95.4	7.89
Bottom	0.3	24.78	95.2	7.88

**utilize military time HH:MM*

Prairie River Hydroelectric Project #2361
Water Quality Study – Data Collection

Date: 7/28/2020 Data Collector: Wendy Gomez

Weather: ☐ Sunny ☐ Rainy ☒ Party Cloudy ☐ Mostly Cloudy ☐ Windy/Significant Wave Action

☐ Recent storm event – When: ______ ☐ Other ______

Temperature: 75° F

Flow: Call Hydro Control Room at (218) 725-2110

Total Station Flow 150 cfs / Bypass Flow 150 cfs / Unit Flow – off-line cfs

Flow Observations: water is quiet - unit is offline today.

Temp and DO Meter Calibration Start Time: 69° 9:15 am. Reservoir Elevation: 1289.36

Comments: by the tailrace area, lots of aquatic insects on the water surface. (person in parking lot.

Upstream of Coarse Trash Rack

Time: 11:36

GPS: 47.2840633, -93.5000880

Depth (meters)	Temp (C)	DO%	DO (mg/L)
Surface .25	24.88	1044	8.64
1m 1.0	24.78	103.9	8.61
2m 2.0	24.49	101.4	8.45
3m 3.0	24.51	99.9	8.33
4m			
5m			
6m			

Trailrace Area

Time: 11:11

GPS: 47.2844244, -93.4996327

Depth (meters)	Meters	Temp (C)	DO%	DO (mg/L)
Surface	.25	23.92	84.10	7.08
Mid	0.5	23.92	85.3	7.19
Bottom	1.0	23.83	83.6	7.05

Bypass Reach

Time: 11:55

GPS: 47.2851417, -93.4979774

Depth (meters)	Meters	Temp (C)	DO%	DO (mg/L)
Surface	.25	24.92	99.5	8.23
Mid	.30	24.68	99.6	8.27
Bottom	.40	24.68	99.3	8.25

utilize military time HH:MM

Prairie River Hydroelectric Project #2361
Water Quality Study – Data Collection

Date: 8/11/2020 Data Collector: Wendy Gomez

Weather: ☐ Sunny ☐ Rainy ☒ Party Cloudy ☐ Mostly Cloudy ☐ Windy/Significant Wave Action

☐ Recent storm event – When: ____ ☐ Other ____

Temperature: 75° F

Flow: Call Hydro Control Room at (218) 725-2110

Total Station Flow 147 cfs / Bypass Flow 2 cfs / Unit Flow 145 cfs

Flow Observations: ____

Temp and DO Meter Calibration Start Time: 9:10 68° F Reservoir Elevation: 1289.37

Comments: 1 person fishing by tailrace area, a family by the several crayfish & frogs/older tadpoles bypass reach water looked low near bypass reach. 4

Upstream of Coarse Trash Rack

Time: 12:32

GPS: 47.2869887, -93.5001906

	Depth (meters)	Temp (C)	DO%	DO (mg/L)
.25	Surface	23.23	90.8	7.75
	1m	23.15	89.4	7.64
	2m	23.11	88.1	7.53
	3m	23.14	87.2	7.45
	4m	23.12	86.6	7.41
	5m			
	6m			

Trailrace Area

Time: 12:16

GPS: 47,2844874, -93.4988137

Depth (meters)	Meters	Temp (C)	DO%	DO (mg/L)
Surface	,25	23.10	91.3	7.81
Mid	0.4	23.10	90.0	7.70
Bottom	1.2	23.10	88.6	7.58

Bypass Reach

Time: 12:51

GPS: 47.2855015, -93.4980730

	Depth (meters)	Meters	Temp (C)	DO%	DO (mg/L)
,25	Surface	,25	24.40	92.9	7.76
	Mid	,25	25.21	94.8	7.80
	Bottom	0.30	24.4	93.2	7.77

51

**utilize military time HH:MM*

Prairie River Hydroelectric Project #2361
Water Quality Study – Data Collection

Date: 8/25/20

Data Collector: Wendy Gomez

Weather: ☐ Sunny ☐ Rainy ☒ Party Cloudy ☐ Mostly Cloudy ☐ Windy/Significant Wave Action

☐ Recent storm event – When: ______ ☐ Other ______

Temperature: 69°F

Flow: Call Hydro Control Room at (218) 725-2110

Total Station Flow ~~507~~ 506 cfs / Bypass Flow ~~356~~ 353 cfs / Unit Flow 153 cfs

Flow Observations: ______

Temp and DO Meter Calibration Start Time: 61°F, 8:56am Reservoir Elevation: 1289.35

Comments: 2 vehicles - 1 grp of 3 carrying fishing poles, 1 single person on
2 adults, 1 child

Upstream of Coarse Trash Rack

Time: 11:46

GPS: 47.2869612, -93.5000652

.25

Depth (meters)	Temp (C)	DO%	DO (mg/L)
Surface	23.83	90.1	7.60
1m	23.82	89.6	7.56
2m	23.74	88.5	7.48
3m	—	—	—
4m	—	—	—
5m	—	—	—
6m	—	—	—

Trailrace Area

Time: 11:22

GPS: 27.2844533

Depth (meters)	Meters	Temp (C)	DO%	DO (mg/L)
Surface	.25	23.77	88.5	7.48
Mid	1.0	23.77	87.9	7.42
Bottom	1.5	23.77	87.6	7.40

Bypass Reach

Time: ~~14:22~~ 12:01

GPS: 47.2854720, -93.4980257

Depth (meters)	Meters	Temp (C)	DO%	DO (mg/L)
Surface	0.25	2395	99.6	8.38
Mid 0.50	~~0.40~~	2393	99.2	8.36
Bottom	~~0.30~~ 0.30	2395	98.2	8.27

**utilize military time HH:MM*

Prairie River Hydroelectric Project #2361
Water Quality Study – Data Collection

Date: 9/10/2020

Data Collector: Wendy Gomez

Weather: ☒ Sunny ☐ Rainy ☐ Party Cloudy ☐ Mostly Cloudy ☐ Windy/Significant Wave Action

☐ Recent storm event – When: ______ ☐ Other ______

Temperature: 53°

Flow: Call Hydro Control Room at (218) 725-2110

Total Station Flow 228 cfs / Bypass Flow 72 cfs / Unit Flow 156 cfs

Flow Observations: ______

Temp and DO Meter Calibration Start Time: 9:45 52°

Reservoir Elevation: 1289.39

Comments: 1 car parked in area. — 1 person fishing

Upstream of Coarse Trash Rack

Time: 12:06

GPS: 47.2845131, -93.4997403

.25

Depth (meters)	Temp (C)	DO%	DO (mg/L)
Surface	16.1	77.4	7.62
1m ✓	16.1	75.5	7.44
2m ✓	16.0	74.6	7.36
3m			
4m			
5m			
6m			

Trailrace Area

Time: 11:51

GPS: 47.2845131, -93.4997403

Depth (meters)	Meters	Temp (C)	DO%	DO (mg/L)
Surface	0.25	16°	80.0	7.90
Mid	0.75	16°	77.8	7.68
Bottom	1.0	16°	75.8	7.47

Bypass Reach

Time: 12:18

GPS: 47.2854504, -93.4980233

Depth (meters)	Meters	Temp (C)	DO%	DO (mg/L)
Surface	0.25	16.3	89.5	8.77
Mid	0.3	16.3	88.8	8.72
Bottom	0.3	16.2	89.2	8.76

Took the average of these two measurements that were taken at the same depth for entry in spreadsheet, KK 9/11/20

utilize military time HH:MM

Prairie River Hydroelectric Project #2361
Water Quality Study – Data Collection

Date: 9/22/2020

Data Collector: Wendy Gomez

Weather: ☒ Sunny ☐ Rainy ☐ Party Cloudy ☐ Mostly Cloudy ☐ Windy/Significant Wave Action

☐ Recent storm event – When: ______ ☐ Other ______

Temperature: 71°

Flow: Call Hydro Control Room at (218) 725-2110

Total Station Flow 132 cfs / Bypass Flow 0 cfs / Unit Flow 132 cfs

Flow Observations: ______

Temp and DO Meter Calibration Start Time: 62° @ 10:49

Reservoir Elevation: 1289.38

Comments: one truck with 2 people arrived w fishing gear

Upstream of Coarse Trash Rack

Time: 12:33

GPS: 47.2845392, -93.4997926

Depth (meters)	Temp (C)	DO%	DO (mg/L)
Surface	16.3	87.3	8.61
1m	15.9	86.8	8.58
2m	15.9	86.0	8.50
3m			
4m			
5m			
6m			

Trailrace Area

Time: 12:22

GPS: 47.2845392, -93.4997926.

Depth (meters)	Meters	Temp (C)	DO%	DO (mg/L)
Surface	0.25	16.1	92.9	9.15
Mid	0.50	16.0	87.0	8.58
Bottom	0.60	16.0	86.7	8.55

Bypass Reach

Time: 12:43

GPS: 47.2845392, -93.4997926

Depth (meters)	Meters	Temp (C)	DO%	DO (mg/L)
Surface	.25	19.3	89.8	8.38
Mid	.25	19.3	86.6	7.98
Bottom	.40	18.3	88.3	8.29

**utilize military time HH:MM*

9.0 Appendix B: Site Photos

Figure B- 1. Upstream of Coarse Trash Rack 5/11/20 and 8/25/20.

Figure B- 2. Bypass reach 5/12/20 and 6/30/20.

Figure B- 3. Tailrace Area 6/16/20 and 7/28/2020.

10.0 Appendix C: Calibration Records

CALIBRATION WORK SHEET

Date of Calibration: 5/12/2020 Sonde ID: Wenck YSI 6920 V2 with 6560 Cond/Temp Probe & 6150 ROX Optical DO Probe

Technician: Wendy Gomez

RP DO membrane changed? Y N

RP DO membrane o-ring changed? Y N

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y N

ROX DO wiper changed? Y [✓ N]

BGA-PC wiper changed? Y N

Chlorophyll wiper changed? Y N

BGA-PE wiper changed? Y N

Rhodamine wiper changed? Y N

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: ________________ (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant ____________ Range 5.0 ± .45

Integrated conductivity cell constant_________ Range 5.0 ± .70

pH mv Buffer 7 ____________ Range 0 ± 50 mv

pH mv Buffer 4 ____________ Range +180 ± 50 mv*

pH mv Buffer 10 ____________ Range -180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only) ____________ Range 25 to 75

DO gain ____________ Range 0.7 to 1.4

ODO gain mg/L % sat 1.05 Range 0.85 to 1.15

Turbidity standard used in calibration ______________________

Manufacturer and part number ______________________________

Barometric Pressure: 732.7 mmHg (from 650 handheld internal barometer)

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature		____Sonde
Conductivity		____/____
pH 7		____/____
pH 4		____/____
pH 10		____/___
ORP		____/___
Turbidity		____/____
Turbidity		____/____
Turbidity 0.5		____/____
Chlorophyll		____/____
Chlorophyll		____/____
DO RP		____/____
DO ROX	100% H20 sat. air	mg/L % sat 96.4 / 100.0
BGA PE/PC		____/____
BGA PE/PC		____/____
Rhodamine		____/____

Depth Calibration - If zero was entered, record barometric pressure at time of calibration ____________mmHg

Depth Calibration - If offset depth was entered, record value ____________ meters/feet and pressure ____________ mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 ____________________

Notes: True BP in mm Hg = [Corrected BP in mm Hg] - [2.5 * (Local Altitude in Feet Above Sea Level/100]
mm Hg = in Hg * 25.4

Barometric Pressure Reading from Local Weather Station ____________________ (corrected)

Barometric Pressure Reading from Local Weather Station ____________________ (uncorrected)

Weather Station Used ____________________ Date/Time ________________

CALIBRATION WORK SHEET

Date of Calibration: 5/20/2020 9:25

Sonde ID: Wenck YSI 6920 V2 with 6560 Cond/Temp Probe & 6150 ROX Optical DO Probe

Technician: Wendy Gomez

RP DO membrane changed? Y [✓ N]

RP DO membrane o-ring changed? Y [✓ N]

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y N

ROX DO wiper changed? Y [✓ N]

BGA-PC wiper changed? Y N

Chlorophyll wiper changed? Y N

BGA-PE wiper changed? Y N

Rhodamine wiper changed? Y N

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.4 V (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant ______ Range 5.0 ± .45

Integrated conductivity cell constant ______ Range 5.0 ± .70

pH mv Buffer 7 ______ Range 0 ± 50 mv

pH mv Buffer 4 ______ Range +180 ± 50 mv*

pH mv Buffer 10 ______ Range -180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only) ______ Range 25 to 75

DO gain ______ Range 0.7 to 1.4

ODO gain mg/L % sat 3.0 % Range 0.85 to 1.15

Turbidity standard used in calibration ______

Manufacturer and part number ______

Barometric Pressure: 731.6 mmHg (from 650 handheld internal barometer)

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	19.25	Sonde
Conductivity		/
pH 7		/
pH 4		/
pH 10		/
ORP		/
Turbidity		/
Turbidity		/
Turbidity 0.5		/
Chlorophyll		/
Chlorophyll		/
DO RP		/
DO ROX	100% H20 sat. air	mg/L % sat 8.75 94.7 % pre-cal
~~BGA PE/PC~~		↓ / post-cal.
BGA PE/PC		/
Rhodamine		9.01 / 97.7

Depth Calibration - If zero was entered, record barometric pressure at time of calibration ______ mmHg

Depth Calibration - If offset depth was entered, record value ______ meters/feet and pressure ______ mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 ______

Notes: True BP in mm Hg = [Corrected BP in mm Hg] - [2.5 * (Local Altitude in Feet Above Sea Level/100]

Barometric Pressure Reading from Local Weather Station 30.18 in → 767 mmHg (corrected)

Barometric Pressure Reading from Local Weather Station 767 - (2.5*(1356/100)= 733.1 mmHg (uncorrected)

Weather Station Used GR- Itasca Co Airport-Gordon Newstrom Field Date/Time 9:21 am, 5/20/2020

CALIBRATION WORK SHEET

Date of Calibration: 6/2/2020

Technician: Wendy Gomez

Sonde ID: Wenck YSI 6920 V2 with 6560 Cond/Temp Probe & 6150 ROX Optical DO Probe

RP DO membrane changed? Y N

RP DO membrane o-ring changed? Y N

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y N

ROX DO wiper changed? Y [✓ N]

BGA-PC wiper changed? Y N

Chlorophyll wiper changed? Y N

BGA-PE wiper changed? Y N

Rhodamine wiper changed? Y N

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: ______________ (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	________	Range	5.0 ± .45
Integrated conductivity cell constant	________	Range	5.0 ± .70
pH mv Buffer 7	________	Range	0 ± 50 mv
pH mv Buffer 4	________	Range	+180 ± 50 mv*
pH mv Buffer 10	________	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	________	Range	25 to 75
DO gain	________	Range	0.7 to 1.4
ODO gain mg/L % sat	1.16 %	Range	0.85 to 1.15

Turbidity standard used in calibration ______________

Manufacturer and part number ______________

Barometric Pressure: 728.4 mmHg (from 650 handheld internal barometer)

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	________	____Sonde
Conductivity	________	____/____
pH 7	________	____/____
pH 4	________	____/____
pH 10	________	____/____
ORP	________	____/____
Turbidity	________	____/____
Turbidity	________	____/____
Turbidity 0.5	________	____/____
Chlorophyll	________	____/____
Chlorophyll	________	____/____
DO RP	________	____/____
DO ROX	100% H20 sat. air	mg/L % sat 94.5 96.1 %
BGA PE/PC	________	____/____
BGA PE/PC	________	____/____
Rhodamine	________	____/____

Depth Calibration - If zero was entered, record barometric pressure at time of calibration __________ mmHg

Depth Calibration - If offset depth was entered, record value __________ meters/feet and pressure __________ mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 __________

True = 759 – 2.5 (1355 ft/100)

Notes: True BP in mm Hg = [Corrected BP in mm Hg] - [2.5 * (Local Altitude in Feet Above Sea Level/100]

Barometric Pressure Reading from Local Weather Station 29.87" = 759 mm Hg (corrected) 29.87" x 25.4 mm/in

Barometric Pressure Reading from Local Weather Station 725 mmHg (uncorrected)

Weather Station Used Grand Rapids/ Itasca Co. Airport Date/Time 11:00 am,

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CALIBRATION WORK SHEET

Date of Calibration: 6/10/2020 Sonde ID: Wenck YSI 6920 V2 with 6560 Cond/Temp Probe & 6150 ROX Optical DO Probe

Technician: Wendy Gomez

RP DO membrane changed? Y N *Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)*

RP DO membrane o-ring changed? Y N

Turbidity wiper changed? Y N Chlorophyll wiper changed? Y N

ROX DO wiper changed? Y [✓ N] BGA-PE wiper changed? Y N

BGA-PC wiper changed? Y N Rhodamine wiper changed? Y N

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.4 V (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	______	Range	5.0 ± .45
Integrated conductivity cell constant	______	Range	5.0 ± .70
pH mv Buffer 7	______	Range	0 ± 50 mv
pH mv Buffer 4	______	Range	+180 ± 50 mv*
pH mv Buffer 10	______	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	______	Range	25 to 75
DO gain	______	Range	0.7 to 1.4
ODO gain mg/L % sat	______	**Range**	**0.85 to 1.15**

Turbidity standard used in calibration ______

Manufacturer and part number ______

30.10 in weather Stn.

Barometric Pressure: 733.6 mmHg (from 650 handheld internal barometer)

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	______	____Sonde
Conductivity	______	___/___
pH 7	______	___/___
pH 4	______	___/___
pH 10	______	___/___
ORP	______	___/___
Turbidity	______	___/___
Turbidity	______	___/___
Turbidity 0.5	______	___/___
Chlorophyll	______	___/___
Chlorophyll	______	___/___
DO RP	______	___/___
DO ROX	100% H20 sat. air	mg/L 8.1 % sat 7.09 / 96.7
BGA PE/PC	______	___/ 7.32
BGA PE/PC	______	___/___
Rhodamine	______	___/___

Depth Calibration - If zero was entered, record barometric pressure at time of calibration ______ mmHg

Depth Calibration - If offset depth was entered, record value ______ meters/feet and pressure ______ mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 ______

True = 765 - 2.5 (1355/100) = 731

Notes: True BP in mm Hg = [Corrected BP in mm Hg] - [2.5 * (Local Altitude in Feet Above Sea Level/100]

Barometric Pressure Reading from Local Weather Station 30.10 in = 765 mmHg (corrected)

Barometric Pressure Reading from Local Weather Station 731 mmHg (uncorrected)

Weather Station Used GR/Itasco Co Airpot Date/Time 9:55 am

CALIBRATION WORK SHEET

Date of Calibration: 6/30/2020

Technician: Wendy Gomez

Sonde ID: Wenck YSI 6920 V2 with 6560 Cond/Temp Probe & 6150 ROX Optical DO Probe

RP DO membrane changed? Y N

RP DO membrane o-ring changed? Y N

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y N

ROX DO wiper changed? Y [✓ N]

BGA-PC wiper changed? Y N

Chlorophyll wiper changed? Y N

BGA-PE wiper changed? Y N

Rhodamine wiper changed? Y N

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.3 V (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant		Range 5.0 ± .45
Integrated conductivity cell constant		Range 5.0 ± .70
pH mv Buffer 7		Range 0 ± 50 mv
pH mv Buffer 4		Range +180 ± 50 mv*
pH mv Buffer 10		Range -180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)		Range 25 to 75
DO gain		Range 0.7 to 1.4
ODO gain mg/L % sat	11.5% 0.55 mg/L	Range 0.85 to 1.15

Turbidity standard used in calibration

Manufacturer and part number

Barometric Pressure: 726 mmHg (from 650 handheld internal barometer)

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature		Sonde
Conductivity		/
pH 7		/
pH 4		/
pH 10		/
ORP		/
Turbidity		/
Turbidity		/
Turbidity 0.5		/
Chlorophyll		/
Chlorophyll		/
DO RP		/
DO ROX	100% H20 sat. air	mg/L % sat 86.8% / 98.3% ~~7.16~~ mg/L / 7.71 mg/L
BGA PE/PC		/
BGA PE/PC		7.16 /
Rhodamine		/

Depth Calibration - If zero was entered, record barometric pressure at time of calibration mmHg

Depth Calibration - If offset depth was entered, record value meters/feet and pressure mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15

Notes: True BP in mm Hg = [Corrected BP in mm Hg] - [2.5 * (Local Altitude in Feet Above Sea Level/100]

mm Hg = in Hg * 25.4 29.86(25.4) = 758

Barometric Pressure Reading from Local Weather Station 758 (corrected)

Barometric Pressure Reading from Local Weather Station 724 (uncorrected)

Weather Station Used GR airport Date/Time 6/30/2020 9:38

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CALIBRATION WORK SHEET

Date of Calibration: 7/14/2020

Technician: Wendy Gomez

Sonde ID: Wenck YSI 6920 V2 with 6560 Cond/Temp Probe & 6150 ROX Optical DO Probe

RP DO membrane changed? Y N

RP DO membrane o-ring changed? Y N

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y N

ROX DO wiper changed? Y [✓ N]

BGA-PC wiper changed? Y N

Chlorophyll wiper changed? Y N

BGA-PE wiper changed? Y N

Rhodamine wiper changed? Y N

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.4 V (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant		Range 5.0 ± .45
Integrated conductivity cell constant		Range 5.0 ± .70
pH mv Buffer 7		Range 0 ± 50 mv
pH mv Buffer 4		Range +180 ± 50 mv*
pH mv Buffer 10		Range -180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)		Range 25 to 75
DO gain		Range 0.7 to 1.4
ODO gain mg/L % sat		Range 0.85 to 1.15

Turbidity standard used in calibration

Manufacturer and part number

Barometric Pressure: 725.6 mmHg (from 650 handheld internal barometer)

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard		Pre Cal / Post Cal
Temperature			Sonde
Conductivity			/
pH 7			/
pH 4			/
pH 10			/
ORP			/
Turbidity			/
Turbidity			/
Turbidity 0.5			/
Chlorophyll			/
Chlorophyll			/
DO RP			/
DO ROX	100% H20 sat. air	mg/L	8.46 / 8.12
		% sat	101.6 / 95.5
BGA PE/PC			/
BGA PE/PC			/
Rhodamine			/

Depth Calibration - If zero was entered, record barometric pressure at time of calibration ____ mmHg

Depth Calibration - If offset depth was entered, record value ____ meters/feet and pressure ____ mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 ____

29.92 ~1355

Notes: True BP in mm Hg = [Corrected BP in mm Hg] - [2.5 * (Local Altitude in Feet Above Sea Level/100]
mm Hg = in Hg * 25.4 ≈ 760.0

Barometric Pressure Reading from Local Weather Station 760.0 (corrected)

Barometric Pressure Reading from Local Weather Station 726.1 (uncorrected)

Weather Station Used GR airport Date/Time 9:45 am 7/14

CALIBRATION WORK SHEET

Date of Calibration: 7/28/2020

Technician: Wendy Gomez

Sonde ID: Wenck YSI 6920 V2 with 6560 Cond/Temp Probe & 6150 ROX Optical DO Probe

RP DO membrane changed? Y N

RP DO membrane o-ring changed? Y N

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y N

ROX DO wiper changed? Y [✓ N]

BGA-PC wiper changed? Y N

Chlorophyll wiper changed? Y N

BGA-PE wiper changed? Y N

Rhodamine wiper changed? Y N

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.4V (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant		Range	5.0 ± .45
Integrated conductivity cell constant		Range	5.0 ± .70
pH mv Buffer 7		Range	0 ± 50 mv
pH mv Buffer 4		Range	+180 ± 50 mv*
pH mv Buffer 10		Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)		Range	25 to 75
DO gain		Range	0.7 to 1.4
ODO gain mg/L % sat	0.1 mg/L 1.3 %	Range	0.85 to 1.15

Turbidity standard used in calibration

Manufacturer and part number

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature		Sonde
Conductivity		/
pH 7		/
pH 4		/
pH 10		/
ORP		/
Turbidity		/
Turbidity		/
Turbidity 0.5		/
Chlorophyll		/
Chlorophyll		/
DO RP		/
DO ROX	100% H20 sat. air	mg/L 7.72 / 7.82 mg/L % sat 94.2 / 95.5 %
BGA PE/PC		/
BGA PE/PC		/
Rhodamine		/

Barometric Pressure: 724.1 mmHg (from 650 handheld internal barometer)

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Depth Calibration - If zero was entered, record barometric pressure at time of calibration ____ mmHg

Depth Calibration - If offset depth was entered, record value ____ meters/feet and pressure ____ mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15

Corrected BP = 29.90 × 25.4 = 759.46

Notes: True BP in mm Hg = [Corrected BP in mm Hg] - [2.5 * (Local Altitude in Feet Above Sea Level/100]

mm Hg = in Hg * 25.4 759.46 – 2.5 × 1296/100

Barometric Pressure Reading from Local Weather Station 759.46 (corrected)

Barometric Pressure Reading from Local Weather Station 727.1 (uncorrected)

Weather Station Used Grand Rapids Airport Date/Time 7/28/2020

CALIBRATION WORK SHEET

Date of Calibration: 8/11/2020

Technician: Wendy Gomez

Sonde ID: Wenck YSI 6920 V2 with 6560 Cond/Temp Probe & 6150 ROX Optical DO Probe

RP DO membrane changed? Y N

RP DO membrane o-ring changed? Y N

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y N

ROX DO wiper changed? Y [✓ N]

BGA-PC wiper changed? Y N

Chlorophyll wiper changed? Y N

BGA-PE wiper changed? Y N

Rhodamine wiper changed? Y N

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.4 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant ________ Range 5.0 ±.45

Integrated conductivity cell constant ________ Range 5.0 ±.70

pH mv Buffer 7 ________ Range 0 ±50 mv

pH mv Buffer 4 ________ Range +180 ±50 mv*

pH mv Buffer 10 ________ Range -180 ±50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only) ________ Range 25 to 75

DO gain Range 0.7 to 1.4

ODO gain mg/L 0.35 mg/L

% sat 4.3 % sat Range 0.85 to 1.15

Turbidity standard used in calibration ________

Manufacturer and part number ________

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	____	____Sonde
Conductivity	____	___/___
pH 7	____	___/___
pH 4	____	___/___
pH 10	____	___/___
ORP	____	___/___
Turbidity	____	___/___
Turbidity	____	___/___
Turbidity 0.5	____	___/___
Chlorophyll	____	___/___
Chlorophyll	____	___/___
DO RP	____	7.65 8.00 mg/L
DO ROX	100% H20 sat. air	mg/L % sat 91.5 95.8 % sat
BGA PE/PC	____	___/___
BGA PE/PC	____	___/___
Rhodamine	____	___/___

Barometric Pressure: 726.9 mmHg (from 650 handheld internal barometer)

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Depth Calibration - If zero was entered, record barometric pressure at time of calibration ________ mmHg

Depth Calibration - If offset depth was entered, record value ________ meters/feet and pressure ________ mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 ________

Notes: True BP in mm Hg = [Corrected BP in mm Hg] - [2.5 * (Local Altitude in Feet Above Sea Level/100] 1280

mm Hg = in Hg * 25.4 29.92 in × 25.4

Barometric Pressure Reading from Local Weather Station = 760 (corrected)

Barometric Pressure Reading from Local Weather Station 728 (uncorrected)

Weather Station Used GR/Itasca Co Airport Date/Time 9:22 am

CALIBRATION WORK SHEET

Date of Calibration: 8/25/20
Technician: WendyGomez

Sonde ID: Wenck YSI 6920 V2 with 6560 Cond/Temp Probe & 6150 ROX Optical DO Probe

RP DO membrane changed? Y N
RP DO membrane o-ring changed? Y N

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y N
ROX DO wiper changed? Y [✓ N]
BGA-PC wiper changed? Y N
Chlorophyll wiper changed? Y N
BGA-PE wiper changed? Y N
Rhodamine wiper changed? Y N

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.3 Volt (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant		Range	5.0 ± .45
Integrated conductivity cell constant		Range	5.0 ± .70
pH mv Buffer 7		Range	0 ± 50 mv
pH mv Buffer 4		Range	+180 ± 50 mv*
pH mv Buffer 10		Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)		Range	25 to 75
DO gain		Range	0.7 to 1.4
ODO gain mg/L % sat	0.27 mg/L 7.5 % sat	Range	0.85 to 1.15

Turbidity standard used in calibration

Manufacturer and part number

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature		Sonde
Conductivity		/
pH 7		/
pH 4		/
pH 10		/
ORP		/
Turbidity		/
Turbidity		/
Turbidity 0.5		/
Chlorophyll		/
Chlorophyll		/
DO RP		/
DO ROX	100% H20 sat. air	mg/L 7.86 / 8.13 % sat 88.6 / 96.1
BGA PE/PC		/
BGA PE/PC		/
Rhodamine		/

Barometric Pressure: 730.9 mmHg (from 650 handheld internal barometer)

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Depth Calibration - If zero was entered, record barometric pressure at time of calibration ______ mmHg

Depth Calibration - If offset depth was entered, record value ______ meters/feet and pressure ______ mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15

30.06 inch × 25.4 = 763.5

Notes: True BP in mm Hg = [Corrected BP in mm Hg] - [2.5 * (Local Altitude in Feet Above Sea Level/100)]
mm Hg = in Hg * 25.4

1355 ft above sea level

Barometric Pressure Reading from Local Weather Station 763.5 (corrected)

Barometric Pressure Reading from Local Weather Station 729.6 (uncorrected)

Weather Station Used GR/Itasca Co. Airport Date/Time 8:56 am 8/25/20

CALIBRATION WORK SHEET

Date of Calibration: 9/10/2020

Technician: Wendy Gomez

Sonde ID: Wenck YSI 6920 V2 with 6560 Cond/Temp Probe & 6150 ROX Optical DO Probe

RP DO membrane changed? Y N

RP DO membrane o-ring changed? Y N

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y N

ROX DO wiper changed? Y [✓ N]

BGA-PC wiper changed? Y N

Chlorophyll wiper changed? Y N

BGA-PE wiper changed? Y N

Rhodamine wiper changed? Y N

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: ______________ (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	________	Range 5.0 ± .45
Integrated conductivity cell constant	________	Range 5.0 ± .70
pH mv Buffer 7	________	Range 0 ± 50 mv
pH mv Buffer 4	________	Range +180 ± 50 mv*
pH mv Buffer 10	________	Range -180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	________	Range 25 to 75
DO gain	________	Range 0.7 to 1.4
ODO gain mg/L % sat	0.34 mg/L	Range 0.85 to 1.15

% not given for initial reading

Turbidity standard used in calibration ____________________

Manufacturer and part number ____________________

Barometric Pressure: 739 mmHg (from 650 handheld internal barometer)

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	________	____Sonde
Conductivity	________	____/____
pH 7	________	____/____
pH 4	________	____/____
pH 10	________	____/____
ORP	________	____/____
Turbidity	________	____/____
Turbidity	________	____/____
Turbidity 0.5	________	____/____
Chlorophyll	________	____/____
Chlorophyll	________	____/____
DO RP	________	____/____
DO ROX	100% H20 sat. air	mg/L 8.96 / 9.30 % sat ____/ 93.6% ~~94.1%~~
BGA PE/PC	________	____/____
BGA PE/PC	________	____/____
Rhodamine	________	____/____

Depth Calibration - If zero was entered, record barometric pressure at time of calibration ____________ mmHg

Depth Calibration - If offset depth was entered, record value ____________ meters/feet and pressure ____________ mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 ________________

30.45 in x 25.4 = 773

1280

Notes: True BP in mm Hg = [Corrected BP in mm Hg] - [2.5 * (Local Altitude in Feet Above Sea Level/100)]
mm Hg = in Hg * 25.4

Barometric Pressure Reading from Local Weather Station 773 (corrected)

Barometric Pressure Reading from Local Weather Station 741 (uncorrected)

Weather Station Used GR Airport Date/Time 9:45 9/10/2020

CALIBRATION WORK SHEET

Date of Calibration: 9/22/20 Sonde ID: Wenck YSI 6920 V2 with 6560 Cond/Temp Probe & 6150 ROX Optical DO Probe
Technician: Wendy Gomez

RP DO membrane changed? Y N
RP DO membrane o-ring changed? Y N

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y N
ROX DO wiper changed? Y [✓ N]
BGA-PC wiper changed? Y N
Chlorophyll wiper changed? Y N
BGA-PE wiper changed? Y N
Rhodamine wiper changed? Y N

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: ______________ (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant ____________ Range 5.0 ± .45
Integrated conductivity cell constant ________ Range 5.0 ± .70
pH mv Buffer 7 ____________ Range 0 ± 50 mv
pH mv Buffer 4 ____________ Range +180 ± 50 mv*
pH mv Buffer 10 ____________ Range -180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv
Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only) ____________ Range 25 to 75
DO gain ____________ Range 0.7 to 1.4
ODO gain mg/L % sat 4.5 % Range 0.85 to 1.15
0.40 mg/L.

Turbidity standard used in calibration ______________________
Manufacturer and part number ______________________________

Barometric Pressure: 731 mmHg (from 650 handheld internal barometer)
DO % Calculated – (BARO mmHg divided by 7.6) = % saturation
Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

Standard		Pre Cal / Post Cal
Temperature	________	____Sonde
Conductivity	________	____/____
pH 7	________	____/____
pH 4	________	____/____
pH 10	________	____/____
ORP	________	____/____
Turbidity	________	____/____
Turbidity	________	____/____
Turbidity 0.5	________	____/____
Chlorophyll	________	____/____
Chlorophyll	________	102.7 / 98.2
DO RP	________	8.79 / ~~83.9~~
DO ROX 100% H20 sat. air	mg/L % sat	~~8.54~~ / 8.39 ~~112~~ / ~~90.7~~
BGA PE/PC	________	____/____
BGA PE/PC	________	____/____
Rhodamine	________	____/____

Depth Calibration - If zero was entered, record barometric pressure at time of calibration ____________ mmHg
Depth Calibration - If offset depth was entered, record value ____________ meters/feet and pressure ____________ mmHg
Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 ______________

30.13" x 25.4 = 735.30 mmHg. 1280 Ft

Notes: True BP in mm Hg = [Corrected BP in mm Hg] - [2.5 * (Local Altitude in Feet Above Sea Level/100]
mm Hg = in Hg * 25.4

Barometric Pressure Reading from Local Weather Station 735.3 (corrected)

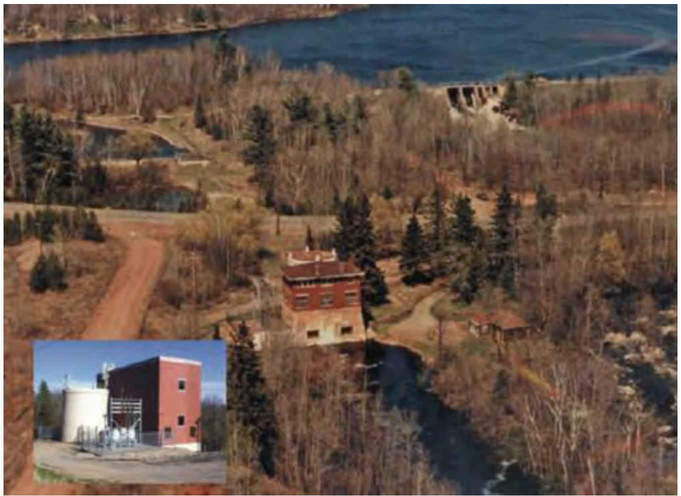
Barometric Pressure Reading from Local Weather Station 733.3 (uncorrected)

Weather Station Used GR Itasca Co Airport Date/Time 9:34

WENCK

Responsive partner.
Exceptional outcomes.

Appendix F. Prairie River Project Desktop Entrainment and Impingement Study



Fish Entrainment and Impingement Study

Prairie River Hydroelectric Project (FERC No. 2361)

October 2020

Prepared for:

Minnesota Power

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List of Acronyms

°F	degrees Fahrenheit
CFR	Code of Federal Regulations
cfs	cubic feet per second
CPUE	catch per unit effort
EPRI	Electronic Power Research Institute
FERC	Federal Energy Regulatory Commission
FPA	Federal Power Act
ft	feet
ft/s	feet per second
ILP	Integrated Licensing Process
MDNR	Minnesota Department of Natural Resources
MW	megawatt
MWh	megawatt hours
NOI	Notice of Intent
PAD	Pre-Application Document
POR	period of record
PSP	Proposed Study Plan
RC	relative composition
ROR	run of river
rpm	rotations per minute
RSP	Revised Study Plan
SD1	Scoping Document 1
SD2	Scoping Document 2
SPD	Study Plan Determination
TBSA	Turbine Blade Strike Analysis
UFSWS	U.S. Fish and Wildlife Service
USC	United States Code
USGS	United States Geological Survey

1 Introduction and Background

1.1 Introduction

ALLETE Inc., doing business as Minnesota Power (“MP” or “Licensee”), is the Licensee, owner, and operator of the Prairie River Hydroelectric Project (FERC No. 2361).

The Prairie River Project (Project) is licensed by the Federal Energy Regulatory Commission (“FERC” or “Commission”) under the authority granted to FERC by Congress through the Federal Power Act (FPA), 16 United States Code (USC) §791(a), et seq., to license and oversee the operation of non-federal hydroelectric projects on jurisdictional waters and/or federal land. There are no federal lands associated with the Project. The Project previously underwent licensing in the early 1990s, and the current operating license for the Project expires on December 31, 2023. Accordingly, MP is pursuing a subsequent license for the Prairie River Project pursuant to FERC’s Integrated Licensing Process (ILP), as described at 18 Code of Federal Regulations (CFR) Part 5.

This report describes the methods and results of the approved Fish Entrainment and Impingement Study conducted as part of obtaining a subsequent license for the Project.

1.2 Background

The Prairie River Project is a 1.1 megawatt (MW), run-of-river (ROR) facility located on the Prairie River, near the City of Grand Rapids in Arbo Township, Itasca County, Minnesota. On December 13, 2018, MP initiated the ILP by filing a Pre-Application Document (PAD) and Notice of Intent (NOI) with the Commission. Major ILP milestones to-date are presented in Table 1.

Table 1. Major ILP Milestones Completed

Date	Milestone
12/13/2018	PAD and NOI Filed
02/07/2019	Scoping Document 1 (SD1) Issued by FERC
03/06-03/07/2019	FERC Agency and Public Scoping Meetings Conducted
03/06/2019	Project Site Visit Held
05/16/2019	Scoping Document 2 (SD2) Issued by FERC
05/28/2019	Proposed Study Plan (PSP) Filed
06/20/2019	PSP Meeting Conducted
09/23/2019	Revised Study Plan (RSP) Filed
10/16/2019	FERC Issued Study Plan Determination (SPD)

2 Study Goals and Objectives

The goal of the Fish Entrainment and Impingement Study are to:

1. Describe the physical characteristics of the powerhouse and intake structures including location, dimensions, turbine specifications, trashrack spacing, and field collection or calculation of average intake velocities that could influence entrainment.
2. Describe the local fish community and compile a target species list for entrainment analysis.
3. Use intake velocities, trashrack spacing, target fish swim speeds, and other Project specifications to conduct a desktop impingement assessment.
4. Conduct a desktop analysis that incorporates the impingement assessment, Project specifications, and hydrology to quantify turbine entrainment and mortality at the Project.

3 Study Area

The Project facilities are located on a tributary to the Mississippi River at river mile 6.3 on the Prairie River in Itasca County, Minnesota, approximately 4.0 miles outside of the City of Grand Rapids. Figure 1 provides the location of the Prairie River Hydroelectric Project. The Project Boundary and layout are shown in Figure 2.

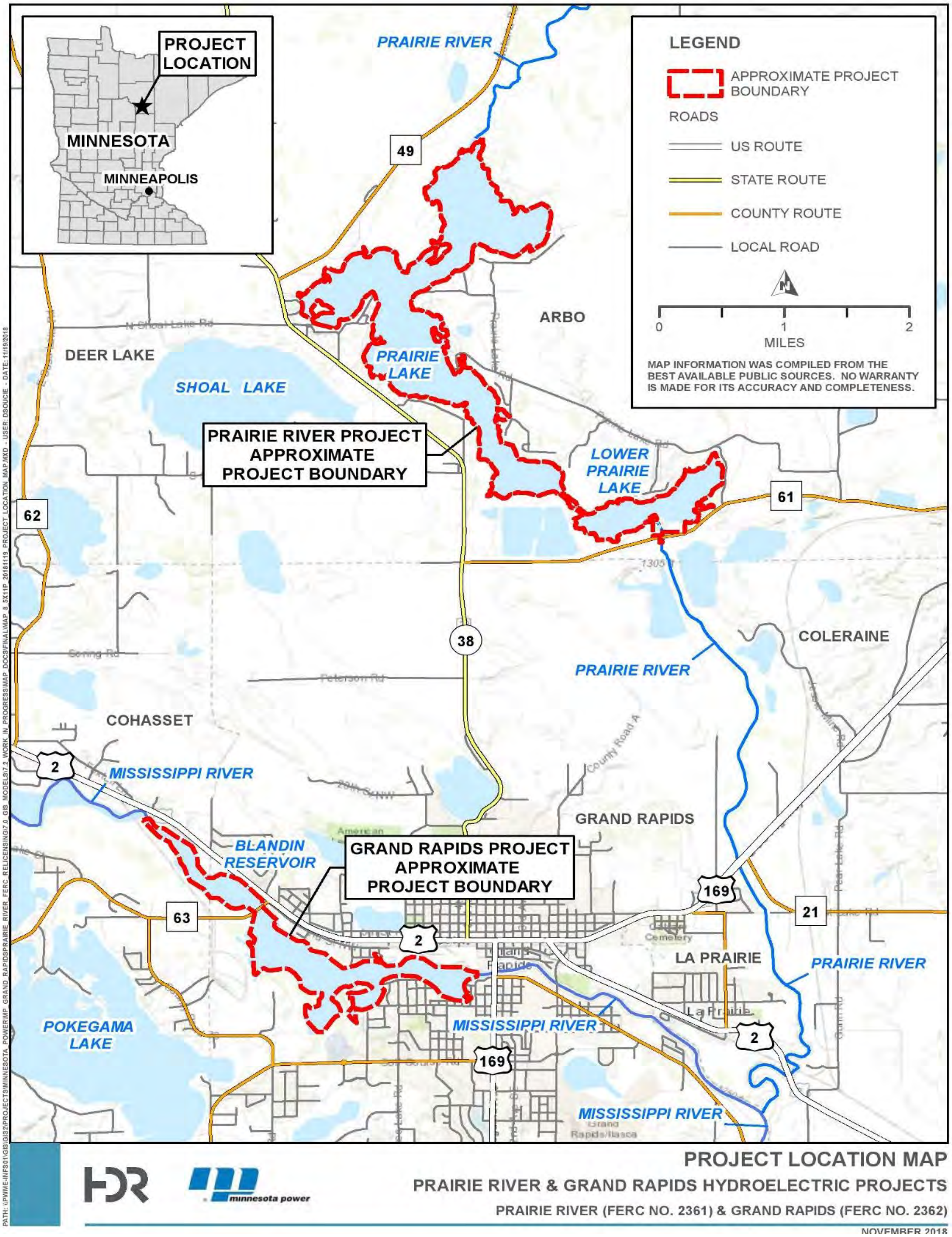

Figure 1. Prairie River Project Facilities

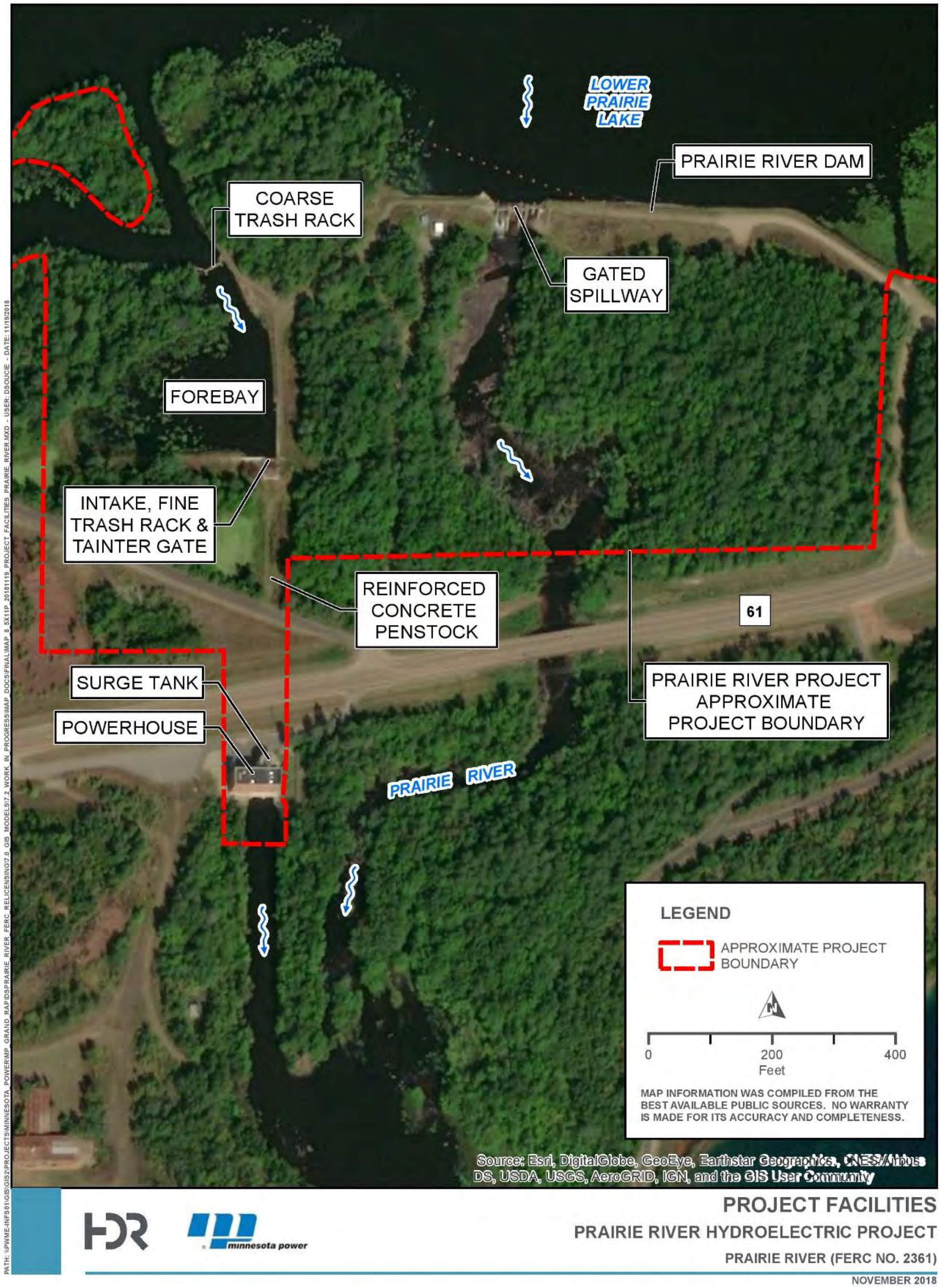

Figure 2. Prairie River Project Boundary and Layout

4 Methodology

4.1 Project Understanding, Fish Community, and Background Information Used in Methods

Operation of hydroelectric projects can result in the sporadic/episodic impingement and entrainment of fish. Impingement refers to the potential for fish to become trapped against the trashracks due to velocity conditions at the intake. Entrainment refers to the passage of fish into the powerhouse intakes and through the turbine units. Fish passing through the turbines can be subjected to the risk of injury or mortality. The number of fish impinged or entrained at a project is related to a variety of physical factors near the dam and powerhouse, such as flow rate, intake depth, intake approach velocities, trashrack spacing, and proximity to fish habitat. Biotic factors also affect entrainment, including diurnal and/or seasonal patterns of fish migration and dispersal, fish size and swimming capabilities, life history requirements, and density-dependent influences (e.g., resource availability) on fish populations in upstream habitats.

In addition, survival of turbine-entrained fish depends on the physical characteristics of the turbine system, such as head, turbine size and design, runner speed, wicket gate openings, number of runner blades, runner blade angle, gap size, and water flow through the turbine. Many of these factors can be causes of mechanical injury, and studies suggest that survival probability primarily depends on the size of the fish and type of turbine.

During the past 30 years, owners of hydroelectric facilities, mostly applicants for FERC relicensing, have conducted numerous field studies to assess impingement, entrainment, and turbine survival at many small-to-medium-sized projects. Over 50 site-specific studies of resident fish entrainment and mortality at hydroelectric sites in the United States have been performed to date. The projects studied vary by location, size, operation patterns, fish presence, reservoir characteristics, and intake features such as trashrack spacing and intake velocities. Similarly, these studies contain extensive turbine survival data for a range of turbine types and physical characteristics. In recent years, this extensive empirical database has been successfully used to conduct desktop assessments of fish impingement, entrainment, and turbine survival at many projects throughout the country. This approach is currently accepted by the FERC, as well as other federal agencies and most state fisheries agencies nationwide.

The Project may have an effect on potential entrainment and mortality that will vary with river flow, fish species, season, and fish size/life stage. The majority of entrained fish species will likely be percids (perch family), centrarchids (sunfish family), and young life stages of all species, including eggs, fry, juveniles, and few young adults incapable of intake avoidance or exclusion by the trashracks. Monthly quantitative entrainment estimates were derived for a list of recreational and ecologically important target species. This included an analysis of empirical entrainment rate data collected at various hydroelectric projects, species periodicities, and their average relative composition (RC%) in the Project reservoir.

Prairie River Dam, consisting of non-overflow sections, an emergency spillway, and a gated spillway, is approximately 1,120 feet long.

The gated spillway consists of two large (Gates 1 and 2) and one small (Gate 3) Tainter gate bays, and two slide gate bays (Gates 4 and 5). Tainter Gates 1 and 2 measure approximately 16.0 feet wide by 10.0 feet high over sills at elevation 1,280.2 feet. Tainter Gate 3 is approximately 6.0 feet wide by 8.0 feet high over a sill at elevation 1,284.0 feet. The two slide gates are each approximately 7.0 feet wide by 6.5 feet high over a sill at elevation 1,283.7 feet.

The powerhouse consists of a reinforced-concrete substructure containing two sets of turbine intakes, scroll cases, draft tubes, and discharge pits. The steel superstructure with precast-concrete-panel walls shelters the two generators and switch gear. A steel-lined, reinforced-concrete surge tank is located immediately upstream and built integral with the powerhouse. The current powerhouse was constructed following a station-destroying fire in 2008; subsequent reconstruction efforts included a new powerhouse and generator replacement.

The forebay consists of an inlet channel from the main reservoir, an earth dam, a concrete retaining dam, an intake structure, and a penstock. A coarse trashrack is located at the downstream end of the inlet channel between the main reservoir and the forebay pond. The pond is formed by concrete gravity walls and earth embankments along the south and east sides. At the intersection of the concrete gravity walls, at the southeast corner of the forebay pond, is the penstock intake structure. The intake structure consists of reinforced-concrete headwall and retaining walls with a 20-foot-wide by 13-foot-high steel Tainter gate to control discharge into the penstock. A fine trashrack, spaced 1.5 inch on center, is located immediately upstream of the Tainter gate. A hand-operated lifting mechanism and an operator's bridge are in place on the penstock intake structure. The 450-foot-long penstock, extending from the forebay to the powerhouse, consists of a reinforced-concrete conduit approximately 10 feet in diameter covered with an earth embankment.

The Project includes two vertical-shaft Francis units (Units 1 and 2) and has a total installed capacity of 1.1 MW and a total maximum hydraulic capacity of 470 cubic feet per second (cfs) (302 cfs for Unit No. 1 and 168 cfs for Unit No. 2). Additional project specifications relevant to the entrainment assessment are provided in Table 2.

The Prairie River bypass reach is approximately 2,500 feet long, generally consisting of a high-gradient stream channel (approximately 34 feet per mile) including multiple sections of stepped pools.

Table 2. Prairie River Hydroelectric Project Specifications

Parameter	Specification
Installed Capacity (MW)	1.1
Operating Mode	Run of River
Unit Type	Francis
Unit Orientation	Vertical
Number of Units	2

Parameter	Specification
Max. Hydraulic Capacities of Each Unit (cfs) (unit 1 / unit 2)	302 / 168
Min. Hydraulic Capacities of each Unit (cfs) (unit 1 / unit 2)	156 / 85
Turbine Efficiency Maximum	0.85%
Generator Efficiency	0.94%
Runner Diameter (inches)	45
Runner Hub Diameter (feet[ft])	4.16
Runner Speed (rotations per minute [rpm]) (unit 1 / unit 2)	225 / 277
Number of Blades	12
Turbine Rated Head (ft)	35
Trashrack Spacing (inches)	1.5
Trashrack Dimensions (L X H) (ft)	18 X 20
Intake Width (ft)	20
Intake Depth with Reservoir at Normal Operating Elevation (ft)	13
Maximum Operating Flow (cfs)	470
Minimum Operating Flow (cfs)	85
Combined Maximum Intake Velocity (feet per second [ft/s])	1.31
Bypass Flow (cfs)	0-75 cfs seasonal

4.2 Fish Community

The Prairie River Project is located in the Prairie-Willow watershed, within the larger Upper Mississippi River Basin. The Upper Mississippi River Basin includes 15 separate watersheds and covers approximately 20,100 square miles (12,864,000 acres) of the State of Minnesota. The Mississippi River headwaters are in Itasca State Park in Itasca County, and from there the river runs a general northeasterly course to Bemidji, then turns eastward to Prairie River before turning south and running through Brainerd, Little Falls, St. Cloud, and the Twin Cities metropolitan area (Minneapolis and St. Paul) before it combines with the St. Croix River at Lock and Dam 2 near Hastings, Minnesota. The Upper Mississippi River Basin drains 15 of the 80 major watersheds in Minnesota and all or parts of 21 counties (MPCA 2017).

The Prairie-Willow watershed is located in the Northern Lakes and Forest ecoregion of Minnesota. This largely forested watershed is 1,316,102 acres in size. Approximately 45 percent of the Prairie-Willow watershed falls within Itasca County, equating to approximately 592,826 acres. The average elevation in the Prairie-Willow watershed is 1,313 feet above sea level, with the highest values occurring in the Northwestern portions of the watershed and lower values in the Southwestern and central regions. Precipitation in the watershed ranges from 25 to 29 inches annually (NRCS 2008). The Mississippi River floodplain is generally wide in the Prairie-Willow watershed as the river meanders through numerous shallow lakes, wetlands, and areas of low topographic relief (NRCS 2008).

The Prairie River Project's reservoir, Prairie River Reservoir, is a 1,305-acre lake with 853 acres of littoral area, 21 miles of shoreline, and a maximum depth of 31 feet (MDNR 2013b). Prairie River Reservoir is part of the Prairie River system, which originates at Long Lake and flows through Lawrence Lake and Prairie River Reservoir chains, entering the Mississippi River approximately five miles south of Prairie River Dam, approximately 2.8 miles downstream of Blandin Dam. The Prairie River Reservoir is classified as an Ecological Class 35, exhibiting a high percentage of littoral area, moderate alkalinity, and moderate productivity (Carlson 1977 and MDNR 2013b).

The Prairie River Project includes a bypass reach east of Prairie River Dam. The bypass reach is a high-gradient stream (approximately 34 feet per mile) approximately 2,500 feet long that includes multiple sections of stepped pools. The bypass reach is primarily of seasonal use to fish. Fish presence in the bypass reach drops substantially after the spring spawning season as the fish move downstream into the Mississippi River.

Dam tailwaters, where flow velocities are higher, provide the most diverse habitat and fish assemblage, while pools contain a more lake-like warmwater fishery (FERC 1988).

Prairie River Reservoir contains a variety of forage species and popular sportfish species, such as Largemouth Bass (*Micropterus* spp.), Black Crappie (*Pomoxis nigromaculatus*), sunfish (*Lepomis* spp.), bullheads (*Ameirus* spp.), pike (*Esox* spp.), perch (*Perca*) Walleye, Redhorses (*Moxostoma* spp.), and others (MDNR 2018a, 2018b). The following sections provide an overview of studies and surveys characterizing the fish community in Prairie River Reservoir (MP 2018a).

The prevailing habitat, and warmwater fish assemblage with no catadromous or anadromous species, would be expected to result in little seasonal or temporal variations in the communities. Potadromous species may relocate to other pools, tributaries, and lakes for spawning, foraging, or overwintering; however, no specific studies documenting such movement for species in the Project area were identified. Some species may temporarily relocate to cooler waters with higher velocities and dissolved oxygen concentrations during the summer low flow period (FERC 1988).

The Minnesota Department of Natural Resources' (MDNR) periodic summer fish surveys in Prairie River Reservoir date back to 1955 (MDNR 2018b). This range of survey data remains applicable as it is consistent with historical catch data. The surveys consisted of deploying standard gill and trap nets.

Table 3. Catch per unit effort (CPUE) for the top 95% of species collected using gill nets and trap nets at Prairie River Reservoir, 1955-2012 (Source: MDNR 2018b)

Species[1]	1955	1975	1980	1985	1990	1995	2000	2006	2012
Gill Nets									
Yellow Perch	21.0	18.6	3.6	9.1	5.1	12.0	5.9	5.7	2.4
Black Crappie	2.8	25.0	3.0	13.1	9.4	5.5	4.7	8.5	9.1
Northern Pike	4.8	2.2	1.5	4.3	4.8	3.6	4.5	5.1	4.5
Walleye	3.6	3.2	2.3	1.5	2.3	2.4	1.8	1.9	0.6
White Sucker	4.2	1.9	1.9	1.7	2.5	1.1	1.4	0.9	0.7
Shorthead Redhorse	0.9	--	--	--	3.5	0.7	0.9	1.2	1.7
Bluegill	--	--	--	0.5	1.4	0.5	1.1	1.9	3.1
Redhorse	--	0.9	1.0	2.6	--	--	--	--	--
Pumpkinseed	0.3		0.1	0.5	0.6	--	0.1	0.7	1.4
Total No. Collected[2]	**457**	**469**	**164**	**417**	**373**	**399**	**327**	**448**	**392**
Standard trap nets									
Bluegill	4.2	4.6	13.3	5.9	4.5	10.2	4.8	7.9	8.0
Black Crappie	4.8	3.6	1.3	1.9	3.8	1.9	1.9	1.1	2.7
Pumpkinseed	3.5	0.8	1.6	1.5	1.8	1.0	1.1	0.5	0.7
Brown Bullhead	0.4	1.7	1.9	0.6	0.4	0.1	0.9	0.7	0.7
White Sucker	0.6	1.1	3.1	0.5	0.3	0.7	0.3	0.3	0.2
Yellow Perch	1.1	0.1	0.5	0.8	1.1	1.9	0.2	0.3	0.3
Northern Pike	0.2	0.4	1.3	0.5	1.1	0.4	0.4	0.9	0.8
Yellow Bullhead	--	--	0.8	--	0.5	0.2	0.4	2.1	0.7
Rock Bass	1.9	0.7	0.5	0.1	0.3	0.3	0.1	--	0.1
Golden Redhorse	--	--	--	--	0.1	0.4	--	1.9	0.4
Total No. Collected[3]	**214**	**242**	**199**	**95**	**110**	**247**	**176**	**256**	**230**

[1] Species are ordered from greatest to least overall relative abundance.

[2] Other species collected include Rock Bass, Yellow Bullhead, Brown Bullhead, Smallmouth Bass, Bowfin, Black Bullhead, Golden Redhorse, Largemouth Bass, Silver Redhorse, and Tubillee (Cisco).

[3] Other species collected include Bowfin, Redhorse, Shorthead Redhorse, Walleye, Silver Redhorse, Largemouth Bass, Black Bullhead, and Golden Shiner.

Other species collected in 2012 using active sampling techniques (in addition to the most abundant species collected using gill and trap nets) included Blackchin Shiner (*Notropis* *heterodon*), Johnny Darter (*Etheostoma nigrum*), Burbot (*Lota lota*), Central Mudminnow (*Umbra limi*), Mottled Sculpin (*Cottus bairdii*), Tadpole Madtom (*Noturus gyrinus*), and Iowa Darter (*Etheostoma exile*).

Sample collections in 2012 at Prairie River Reservoir were dominated by catostomids (suckers) and centrarchids, followed by ictalurids, percids, and others (Figure 3). Gill nets and trap nets collected the same families except gill nets collected a salmonid (Cisco [*Coregonus artedi*]). Like that seen at Blandin Reservoir, the overall composition of fish collections at Prairie River Reservoir is consistent with historical data and with the trophic status and ecological classification of this waterbody (Schupp 1992).

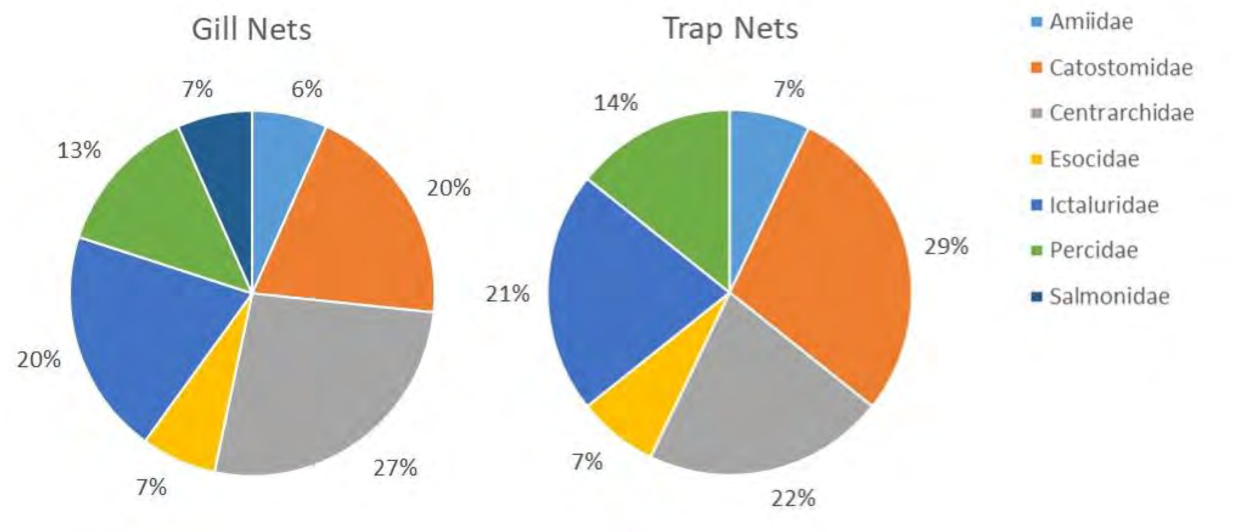

Figure 3. Relative abundance of fish collection by family and gear type at Prairie River Reservoir, 2012

For the Prairie River Project, the Minnesota Department of Natural Resources (MDNR 2018b) reported fish survey data from 2000 and 2015 upstream and downstream of Prairie River Reservoir. Twenty-seven species of fish were collected during the three surveys, consisting of up to seven piscivore species, four pollution-intolerant species, and up to nine sportfish species. All Index of Biotic Integrity ratings were within the “good” range (**Error! Reference source not found.** and Table 5).

Overall, there is a relative similarity and continuity in the fish community upstream and downstream of the Project area, comprising many sportfish species, predators, and forage fish.

In Prairie River Reservoir, approximately 14,000 Walleye fingerlings were stocked by the MDNR from 2008 to 2012. However, due to failure to achieve management goals set for Prairie River Reservoir, the Walleye stocking program was recommended for discontinuation in 2013 (MDNR 2013b).

No Endangered Species Act or state-listed fish or aquatic species have been identified in the vicinity of the Project.

4.3 Target Fish Species

Typically, a subset of fish species is selected from a complete species list when conducting desktop entrainment assessments. The selection process typically includes those species of highest abundance; game and forage species; species of conservation concern, including any rare, threatened, or endangered species; obligate migrants (i.e., those species requiring migration to complete a life cycle); and representatives of several different habitat-use guilds to provide ecological variability. Often, species selected for entrainment analyses may not be represented in available entrainment databases. In such instances, one or more species, or a group of species (e.g., guild, genus, or family), are typically used as a surrogate(s). As discussed below, this approach was employed for this analysis. Species were selected according to the above-referenced criteria and surrogates were used when specific species were not represented in the Electric Power Research Institute (EPRI) database.

Table 4 includes the target species or combined guilds/families of similar species (and their RC%) selected for analysis at the Project. These six species/guilds represent nearly 99 percent of the total species composition of Prairie River Reservoir. As described below, species composition was used to adjust (based solely on RC%) entrainment estimates to make them specific to the target fishery. Species such as Walleye (*Sander vitreus*), Muskellunge (*Esox masquinongy*) and Northern Pike (*Esox Lucius*), represent games species, while Yellow Perch (*Perca flavescens*) and the sunfishes (centrarchids) were used to represent forage species. Yellow Perch are an important forage species in this reservoir (MDNR 2018b). Life history descriptions in Appendix B, are provided as general information regarding habitat use and seasonal life stage presence.

Table 4. All fish species and their percent RC from MDNR gill and trap net survey data

Fish Species	Prairie River Reservoir	
	N (Number of individuals)	RC%
Bluegill	1,628	26.35
Black Crappie	1,266	20.49
Yellow Perch	1,158	18.74
Northern Pike	541	8.76
White Sucker	280	4.53
Walleye	259	4.19
Pumpkinseed	218	3.53
Shorthead Redhorse	142	2.30
Brown Bullhead	122	1.97
Rock Bass	116	1.88
Yellow Bullhead	105	1.70

Fish Species	Prairie River Reservoir	
	N (Number of individuals)	RC%
Largemouth Bass	98	1.59
Redhorse	79	1.28
Golden Redhorse	48	0.78
Bowfin (Dogfish)	45	0.73
Smallmouth Bass	19	0.31
Silver Redhorse	16	0.26
Black Bullhead	11	0.18
Golden Shiner	7	0.11
Johnny Darter	4	0.06
Mottled Sculpin	4	0.06
Central Mudminnow	3	0.05
Blackchin Shiner	2	0.03
Burbot	2	0.03
Iowa Darter	2	0.03
Hybrid Sunfish	1	0.02
Tadpole Madtom	1	0.02
Total	**6,178**	**100.00**

Table 5. Target species and pooled families for entrainment analysis and their percent RC

Target Species or Family	RC%
Centrarchids	54.16
Yellow Perch	18.74
Catastomids	9.15
Esocids	8.76
Walleye	4.19
Ictalurids (Pooled Bullheads)	3.87
Total	**98.87***

[*] Total does not equal 100% due to minimal representation of additional species.

4.4 Impingement, Turbine Entrainment, and Survival

4.4.1 Overview

The potential for fish to become entrained or impinged at a hydroelectric facility is dependent on a variety of factors such as fish life history, size, and swimming ability, along with water quality, operating regimes, inflow, and intake/turbine configurations (Cada et al. 1997). Impingement may occur when a fish does not pass through the intake trashrack, but is instead held or impinged on the trashracks due to forces created by the intake velocities. Entrainment may occur when fish are pulled through or volitionally pass through the trashrack and into the intakes. Early life stages of fish such as eggs, larvae, fry, and juveniles are most vulnerable to entrainment due to their small size which allows passage through intake racks and limited swimming ability which does not allow them to overcome intake velocities. Larger life stages of fish such as larger juveniles, sub adults, and adults become vulnerable to impingement when they are large enough to span trashrack openings in and avoid direct entrainment through the racks, Impingement potential is also related to the intake velocities and if fish have the burst swimming capabilities to overcome intake velocities A gradient of potential exists both temporally and spatially, where smaller-sized fish may be in higher abundances during certain portions of the year, thus increasing their potential for entrainment. In addition, diurnal and seasonal movements of both small and large fish may bring them in close proximity to intake structures making them more susceptible to impingement and entrainment. Physical and operational characteristics of a given project, including trashrack bar spacing, intake velocities, intake depth, stratification, and intake proximity to feeding and rearing habitats also affect the potential for a fish to become entrained or impinged. These factors and several others are used to make general assessments of entrainment and impingement potential at hydroelectric projects using a desktop study approach.

The size of trashrack bar spacing is a significant factor to consider when designing intake structures for operating efficiency and successful exclusion of woody debris and other objects that could damage turbines. Analyses by FERC (1995a) and Winchell et al. (2000) found no consistent relationship between trashrack clear spacing and the size of fish entrained. The majority of fish entrained were small in size and similar size distributions were found among sites with widely varying trashrack spacing, which indicates that the entrainment potential for larger lifestages is not solely influenced by trashrack spacing.

However, trashrack spacing can have an effect on impingement where smaller screen sizes would be expected to have greater impingement. The Project’s existing 1.5-inch clear spacing trashrack was included in this assessment to understand impingement/intake avoidance. This process involved comparing available target fish swim speeds with calculated intake velocities, as well as estimating minimum fish lengths for the target fish species that would be excluded or impinged by the existing trashrack spacing. Representative swim speed data for the target species/guilds were available in scientific literature, while surrogate species were used to represent target species where the literature does not provide sound swim speed data. (Appendix C). A scaling factor relating fish body width to total length is used for the impingement assessment to determine minimum sizes of the target fish species that would physically be excluded by the trashracks (Smith 1985). This is done by dividing the trashrack clear spacing by the scaling factor to determine the minimum size of fish that would be excluded. Table 6 provides the minimum fish size for each target species that would be physically excluded by a trashrack clear spacing of 1.5 inches.

Table 6. Estimated minimum lengths (inches) of each target species excluded by the 1.5-inch trashrack clear spacing

Common Name	Scaling Factor for Body Width[1]	Minimum Size Excluded by a Trashrack Clear Spacing of 1.5 in
Bluegill	0.132	11.4
Pumpkinseed	0.13	11.5
Rock Bass	0.156	9.6
Smallmouth Bass	0.128	11.7
Largemouth Bass	0.134	11.2
Black Crappie	0.085	17.6
Yellow Bullhead	0.166	9.0
Brown Bullhead	0.166	9.0
Chain Pickerel[2]	0.078	19.2
Smallmouth Redhorse	0.127	11.8
White Sucker	0.146	10.3
Walleye	0.125	12.0
Yellow Perch	0.114	13.2

[1] Scaling factor expresses body width as a proportion of total length based on proportional measurements for the target/surrogate species in Smith (1985).
[2] Surrogate for Northern Pike and Muskellunge.

4.4.2 Empirical Entrainment Rate Data

An extensive literature review was conducted on entrainment studies previously completed for various hydroelectric facilities throughout the United States. Recent FERC relicensing entrainment studies (HDR Engineering, Inc. 2019, 2017, 2016, 2013a, 2013b, 2012a, 2012b, 2012c, 2011, 2010a, 2010b, 2010c; HDR|DTA 2010a, 2010b; GeoSyntec Consultants [GeoSyntec] 2005; Normandeau Associates Inc. [Normandeau] 2008, 2009) have utilized desktop approaches for such assessments, where data compiled by EPRI (1992, 1997a, 1997b) and FERC (1995a, 1995b) has most commonly been used for comparative purposes. These reports have detailed trends and correlations between fish community characteristics, entrainment rates, mortality, and passage with hydroelectric plant design and operation. Findings from field trials conducted at these projects and their transferability across the hydroelectric spectrum have eliminated the need for costly and time-consuming survival/netting studies at FERC hydroelectric projects (EPRI 1997a).

The EPRI (1997a) entrainment database provides results from field trials conducted at 43 hydroelectric facilities east of the Mississippi River using full-flow tailrace netting. Full-flow tailrace netting is the most preferred (and costly) entrainment study methodology as opposed to partial-flow tailrace netting, intake gallery netting, and/or hydroacoustics. This involves the placement of a conical net in the immediate tailrace to collect the entire discharge on a seasonal or monthly basis. This results in relatively accurate entrainment rates (fish/volume of water if recorded, or fish/hour/cfs of sampled unit capacity), including the number, species, and size of entrained fish. Most of the studies adjusted data based on net collection efficiencies realized during sampling, although studies conducted at the Buzzards Roost, Gaston Shoals, Hollidays Bridge, Ninety-Nine Islands, and Saluda projects did not. However, the results from these projects were not used in this assessment.

Other potential sources of error in the database include net intrusion of fish in the tailrace. Larger fish will often enter the draft tube before the net is installed, thus potentially allowing for net intrusion of fish that actually did not pass through the turbines. Larger fish possess swim speeds that would be capable of escaping the intake velocities reported for the Project, and certain trashrack spacings at the EPRI projects suggest larger fish collected in nets were not physically capable of passing through the trashracks. The impingement and avoidance analysis discussed herein is based on the 1.5-inch clear spacing currently existing at the Project and shows the minimum size of fish physically excluded from such spacing, in addition to expected burst swim speeds.

Since only approximately half of the studies in the EPRI database recorded volume of water sampled, the number of fish per hour per 1,000 cfs of unit capacity was used in this assessment. This allowed for the standardization of the data and a larger sample size in the EPRI database from which to draw. All of the projects/studies in the database recorded hours sampled, as well as provided the hydraulic capacity of the sampled units. These rates were determined for 4 size groups for each species or species cohort as provided in EPRI (1997a).

Entrainment rates derived from 37 of the EPRI (1997a) sites were used in this entrainment and survival assessment. Characteristics from each site (Appendix D) and associated entrainment netting study results were used to draw comparisons with current Project operations and entrainment potential. This involved analysis of project/turbine specifics, hydrology, operations, and the calculation of mean monthly and annual entrainment rates for the target or surrogate species.

Some desktop entrainment studies have only used a few projects from the EPRI database that most closely resemble the facility being evaluated. Projects are often selected based on similarities in hydraulic capacity, operations, reservoir size, species compositions, and regional proximity; however, this method is subjective and can reduce the application of the database in terms of target species representation and monthly entrainment rate data. Fish populations are very dynamic and can change from year to year within and between projects, depending on certain biotic (recruitment and year class strength) and abiotic (flow and temperature) interactions. For example, high recruitment in a given year may increase a species' potential for entrainment based on density alone. Although certain projects used may not exactly match the specifications of the project being evaluated, it is our opinion that using as many projects as possible from the EPRI database accounts for the variability of aquatic ecosystems and fish populations, while providing a robust database for calculating average monthly entrainment rates for a wide range of species and sizes. As discussed herein, the rates are then applied to the hydrology and project operations to obtain an entrainment estimate specific to the target project. Entrainment estimates for each species result from this calculation, which are then adjusted by their RC% to make them specific to the projects' fishery.

4.4.3 Project Turbine Entrainment Estimates

Average monthly entrainment rates (fish per hour per 1,000 cfs unit capacity) were calculated for each target/surrogate species or guild. Using the period of record (POR) (1967-2018), flow data was used to determine the monthly entrainment rates in a dry (90% flow exceedance), average (50% flow exceedance), and wet (10% flow exceedance) year. Flow data and Project operations were reviewed to provide conservative estimated monthly generation amounts in terms of flow (1,000 cfs-hours). Monthly entrainment rates for the target species were then multiplied by the monthly generation amounts to obtain a monthly entrainment estimate for four size groups per species/guild. Monthly entrainment estimates were then adjusted based on each species' RC% for a given hydroelectric project, as provided in Table 6. This allowed for entrainment estimates that are specific to the fishery composition found in the Project's reservoir.

As an example, the following steps were taken to estimate monthly/annual entrainment rates:

(1) Monthly entrainment rates (fish/hr/1,000 cfs of unit capacity) were determined from the EPRI database for four size groups of each target/surrogate species.

(2) These monthly rates for each species or guild/size group were then multiplied by the monthly flow amounts determined for an average, dry, and wet water year that would have been passed through the Project. For example, using the POR January generation amount (72 $_{1000}$cfs-hours) and January yellow perch (0-4 in) entrainment rate (0.5908 fish), the following entrainment estimate resulted: **0.5908 fish/hr/1,000 cfs of unit capacity x 72 $_{1000}$cfs-hours = 43 fish.**

(3) This value was then multiplied by yellow perch RC% in the Project reservoir (17.5%): **43 x 0.1749 = 7.5 fish (rounded to 8 fish)**. This methodology was conducted for each species, month, and size group (Appendix F) with the resulting number of fish summed to obtain combined annual entrainment estimates.

4.4.4 Turbine Survival

Fish may suffer immediate or latent mortality during entrainment through a hydropower plant. This could be caused by a number of factors related to mechanical injuries, sheer stress, pressure changes, cavitation, and/or turbulence (Odeh 1999; Cada et al. 1997).

Immediate mortalities typically occur from mechanical injuries, where blade strikes can completely sever fish or cause blunt force trauma. Other physical injuries such as grinding, abrasions, and cuts may make fish more susceptible to disease and predation, thus causing latent mortality. Fish with open wounds and abrasions are more susceptible to bacterial and viral diseases due to loss of their skin's mucous layer, while physical injuries may limit fish mobility and predator avoidance (Jenkins and Burkhead 1993).

Pressure changes, particularly in those fish with closed swim bladders (physoclistous), may often cause latent mortality. Shear stress, or parallel surface pressure, can also lead to latent or immediate mortalities. Injuries sustained from shear stress could include the removal of skin mucous and loss of eyeballs and mouth parts (Cada et al. 1997). Turbulence occurs at different scales while a hydroelectric turbine is operating, often leading to pressure and shear-stress-related injuries. However, turbulence may also disorient fish after passage, potentially creating higher predation potential. Cavitation, or the formation of gas bubbles in areas of low pressure (i.e., downstream of a turbine blade), is another form of injury that can cause both latent and immediate mortality. These types of pressure-related injuries, however, most often occur at dams with >100 feet of head. It is presumed that injuries/mortalities related to pressure/cavitation will not likely occur at the Project due to an operating head of approximately 35 feet. Some disorientation may occur related to turbulence during turbine passage, but it is not expected to cause immediate or latent mortalities.

4.4.5 Blade Strike Analysis

A predictive blade strike model was used to estimate turbine survival for fish passing through the Project's turbines. The Advance Hydro Turbine model (Franke et al. 1997) is a blade strike probability model developed by the U.S. Department of Energy program to develop more "fish-friendly" turbines. Franke et al. (1997) refined the original Von Raben Model (cited by Bell 1981) to account for the effect of tangential projection of fish length and flow angle on operating head and discharge parameters.

It has been suggested that the majority of fish mortalities at low head dams (<100 feet) are caused by fish striking a blade or other component of the turbine unit (Franke et al. 1997). The probability of blade strike in the model is based on several factors, including the number of runner blades, fish length, runner blade speed, turbine type, runner diameter, turbine efficiency, and total discharge.

Model predictions were made for four fish length increments. Three *r* values were used to estimate blade strike probability at three different points along the runner radius where fish enter the turbine. These included the edge of the hub (40% of the runner radius), mid-blade between the turbine hub and the discharge ring (65% of the runner radius), and blade tip (95% of the runner radius).

A correlation factor (lambda) was added to each equation to account for the fact that a fish may not always lie in a plane of revolution, as well as the fact that the strike location on the fish (head) may be more detrimental than other less-sensitive locations (tail). Von Raben (cited by Bell 1981) incorporated the correlation factor to adjust the predictive turbine strike results to more closely match empirical results. Franke et al. (1997) suggested correlation factors between 0.1 and 0.2, based on test results using Pacific salmonids. In this assessment, correlation factors of 0.10, 0.15, and 0.20 were used, or in other words 10 percent, 15 percent, and 20 percent of strikes are lethal.

Blade strike probabilities for the Francis units currently at the Project were calculated for each combination of *r* value and correlation factor with the associated model input parameters. Survival was calculated by subtracting the predicted strike estimate from 100 for each size class. Average survival was calculated for each turbine passage route, and an overall average was calculated from all *r* values and correlation factor combinations for all 1-inch groups. Average survival rates were then calculated for each size group cohort expected to be entrained for each target species based on the impingement/exclusion assessment. These survival rates were then multiplied by the monthly entrainment estimates to derive a fish mortality estimate.

The following equations (Franke et al. 1997) were used for a Francis turbine unit to calculate blade strike probability and survival at the Project under maximum turbine flow efficiency:

Francis Turbine Formula:

$$P = \lambda \frac{N \cdot L}{D} \cdot \left[\frac{\sin \alpha_t \cdot \frac{B}{D_1}}{2 Q_{\omega d}} + \frac{\cos \alpha_t}{\pi} \right]$$

Descriptions of the variables in the equation are:

P = Probability of strike
N = Number of turbine blades
L = Fish length
D = Runner diameter
D_1 = Diameter of runner at inlet
λ = Strike mortality correlation factor
B = Runner height at inlet
Q_{wd} = Discharge coefficient
α_t = Angle to tangential of absolute flow upstream of runner

The equation for predicted survival, S, is:

$$S = 1 - P$$

The discharge coefficient, Q_{wd}, is derived by the following equation:

$$Q_{wd} = Q \div (\omega D^3)$$

Descriptions of the additional variables in the discharge coefficient equation are:

Q = Maximum turbine flow rate
ω = Rotational speed

The angle to tangential of absolute flow upstream of the runner is derived by the following equation:

$$\tan(90-\alpha_1)=\frac{2\pi E_{\omega d}\cdot\eta}{Q_{\omega d}}\cdot\frac{B}{D_1}+\frac{\pi\cdot 0.707^2}{2Q_{\omega d}}\frac{B}{D_1}\left(\frac{D_2}{D_1}\right)^2-4\cdot 0.707\cdot\tan\beta\frac{B}{D_1}\frac{D_1}{D_2}$$

An additional variable in the angle to tangential of absolute flow equation is:

E_{wd} = Energy coefficient

The energy coefficient is derived by the following equation:

$$E_{wd}=\frac{\text{g}\cdot H}{(\omega\cdot D)^2}$$

In the energy coefficient equation, *g* is acceleration of gravity and *H* is the net head of the turbine.

Also, included in the angle to tangential of absolute flow equation is the following variable:

B = Relative flow angle at runner discharge

The relative flow angle at runner discharge is calculated by the following equation:

$$\tan\beta=\frac{0.707\cdot\frac{\pi}{8}}{\xi\cdot Q_{\omega d}opt\left(\frac{D_1}{D_2}\right)^3}$$

The additional variables in the relative flow angle equation are:

ξ = Ratio between Q with no exit swirl and Qopt
Qopt = Turbine discharge at best efficiency
D_2 = Diameter of runner at discharge

Propeller Turbine Formula:

$$P=\lambda\frac{N\cdot L}{D}\cdot\left[\frac{\cos\alpha_a}{8\cdot Q_{wd}}+\frac{\sin\alpha_a}{\pi\cdot\frac{r}{R}}\right]$$

$$\alpha_a=\tan^{-1}\left[\frac{\pi\cdot E_{wd}\cdot\eta}{2\cdot Q_{wd}\cdot\frac{r}{R}}\right]$$

$$R=\frac{D}{2}$$

$$E_{wd} = \frac{g \cdot H}{(\omega \cdot D)^2}$$

$$Q_{wd} = \frac{Q}{\omega \cdot D^3}$$

$$\omega = RPM \cdot \frac{2\pi}{60}$$

$$S = 1 - P$$

Where:

P = Predicted strike
S = Predicted survival
N = Number of turbine blades
L = Fish length
D = Runner diameter
λ = Strike mortality correlation factor (lambda)
R = Radius of runner = (D/2)
r = Location along radius that a given fish enters the turbine (passage route)
η = Turbine efficiency at maximum flow rate (Q)
E_{wd} = Head coefficient or energy coefficient (see above equation)
Q_{wd} = Discharge coefficient (see above equation)
α_a = Angle to axial of absolute flow upstream of runner (see above equation)
g = Acceleration of gravity
H = Turbine net head
ω = Rotational speed $= RPM \cdot \frac{2\pi}{60}$
RPM = Revolutions per minute
Q = Maximum turbine flow rate

The estimated average survival rate of the 0- to 4-inch length group at Unit 1 of the Project is 93 percent. This was calculated by averaging the individual blade strike survival rates for the 0 to 4 -inch fish length groups and position in the plane of revolution (correlation factor 0.1, 0.15, and 0.2) for each generating unit. This was performed for each generating unit at the Project. It has been suggested that fish turbine mortality is more related to fish size than the type of species (Franke et al. 1997; Winchell et al. 2000); therefore, the survival rates determined for each length group was deemed transferable across species. In other words, when conducting the blade strike analysis, a 6-inch Yellow Perch has the same survival rate as a 6-inch Catfish.

5 Study Results

5.1 Impingement, Trashrack Spacing, and Intake Avoidance

Calculated intake velocities at the Project are provided in Table 2. Burst swim speeds are considered to be the theoretical speeds used by fish to escape predation, maneuver through high flows, or in this case, escape intake velocities and avoid entrainment. In general, and based on other studies, most fry and small juvenile burst swim speeds are faster than the maximum intake velocity (1.31 ft/s) calculated for the Project. With the exception of Northern Pike juveniles, target species and life stages have burst speeds greater than Project intake velocities which indicates that nearly all species and life stages would be able to avoid impingement. Target species/guild swim speed data available in the scientific literature referenced for this study are included in Appendix C, these data were used to calculate burst speeds for the target species/guild (Centrarchids (sunfishes), the most abundant cohort in the Project area (54%), have burst swim speeds from 1.84 ft/s (juvenile) to 4.3 ft/s (adult). Burst swim speed for centrarchids are above the maximum calculated intake velocity at the Project (1.31 ft/s). Therefore, Centrarchids, regardless of age class of this abundant forage species, would likely be able to avoid impingement and entrainment at the Project. Most of the other abundant target species, including most or all life stages of walleye, suckers, bass, and catfishes also have burst speeds greater than 1.31 ft/s and are therefore likely to avoid impingement and entrainment at the Project.

Table 7).

Centrarchids (sunfishes), the most abundant cohort in the Project area (54%), have burst swim speeds from 1.84 ft/s (juvenile) to 4.3 ft/s (adult). Burst swim speed for centrarchids are above the maximum calculated intake velocity at the Project (1.31 ft/s). Therefore, Centrarchids, regardless of age class of this abundant forage species, would likely be able to avoid impingement and entrainment at the Project. Most of the other abundant target species, including most or all life stages of walleye, suckers, bass, and catfishes also have burst speeds greater than 1.31 ft/s and are therefore likely to avoid impingement and entrainment at the Project.

Table 7. Target species burst swim speeds

Species	Life Stage	Total Length (in)	Burst/Startle Swim Speed (ft/s)
Bluegill[1]	Juvenile	2.01-2.13	1.84
	Adult	3.94-5.91	2.44
	Adult	6.02	4.3
Blue sucker[2]	Adult	26.2	19.51
Yellow Perch	Juvenile/Adult	3.9-9.6	2.0-9.6
Hybrid catfish[3]	Juvenile	6.30-9.06	7.88
Largemouth bass[1]	Fry	0.79-0.87	1.56-2.04
	Juvenile	2.05-5.04	1.84-3.28
	Juvenile	5.91-10.63	3.02-4.34
Longnose sucker[2]	Juvenile/Adult	3.9-16.0	4.0-8.0
Northern Pike	Juvenile	4.73	0.9
	Adult	37.84	13.0
Smallmouth bass[2]	Fry	0.55-0.98	<1.78
	Juvenile	3.58-3.66	2.6-3.6

	Adult	10.3-14.9	3.2-7.8
Walleye	Juvenile	3.15 (Fork Length)	2.48
	Juvenile	6.30 (Fork Length)	6.02
	Adult	13.78-22.44 (Fork Length)	5.48-8.57
Yellow Perch	Juvenile	3.5	2.0
	Adult	9.6	5.6

[1] Used to represent centrarchids (the sunfishes and basses).
[2] Used to represent catostomids (suckers).
[3] Used to represent ictalurids (bullhead and catfish).
NOTE: Burst/Startle swim speeds calculated at 50% greater than Prolonged/Critical speeds in Appendix C table based on Bell (1991) unless burst speed provided in the literature.

Proportional estimates of body width to total length (scaling factor) were compiled by Smith (1985) for the species in this study. This proportional measurement was used to determine the minimum length of each species excluded from the intake by the trashracks (Table 8). Surrogates or groups/guilds of fish were used to represent certain target species if data was not available in Smith (1985). The trashrack spacing (1.5 inches) was divided by the scaling factor to get the minimum length of a given species that would be physically excluded from entrainment at the Project. The minimum size of exclusion for all species is either larger than the species are capable of growing, or larger than were documented in fisheries resources.

As mentioned, physical exclusion of certain size classes of target species will occur due to the 1.5-inch clear trashrack spacing. The calculated average survival rate of all length groups and correlation factors at the Prairie River Hydroelectric Project excluding the >15 inch cohort (all fish greater than 15 inches with the exception of Black Crappie and Chain Pickerel are excluded by the 1.5-inch trashracks) is 77 percent (41 - 96%).

Regardless of the potential of exclusion by the existing trashracks, all fish were considered to be entrained for this analysis and for the calculation of the blade strike analysis.

Findings from FERC (1995a) and Winchell et al. (2000) suggest that the majority of fish size classes entrained at hydroelectric projects is much smaller than the minimum length of fish physically excluded by a certain clear spacing, and that length frequencies of entrainment compositions are similar among sites with differing trashrack spacing. It has been suggested that larger fish collected in entrainment samples may have been in the draft tubes prior to tailrace net deployment and/or they may have entered through gaps in the nets once they were deployed (EPRI 1992, 1997b). Such findings indicate that the lack of larger fish in entrainment compositions may be related to their increased swimming performance and ability to avoid intake velocities as they approach a dam. However, entrainment may occur regardless of their swimming performance if the intake openings and resulting intake velocities are the only available attractant flow for downstream migrating fish, particularly in riverine environments (FERC 1995a; EPRI 1997b).

Table 8. Target species minimum size excluded by 1.5-inch clear spaced trashracks

Common Name	Scaling Factor for Body Width[1]	Minimum Size Excluded by a Trashrack Clear Spacing of 1.5 in*
Bluegill	0.132	11.4
Pumpkinseed	0.13	11.5
Rock Bass	0.156	9.6
Smallmouth Bass	0.128	11.7
Largemouth Bass	0.134	11.2
Black Crappie	0.085	17.6
Yellow Bullhead	0.166	9.0
Brown Bullhead	0.166	9.0
Chain Pickerel[2]	0.078	19.2
Smallmouth Redhorse	0.127	11.8
White Sucker	0.146	10.3
Walleye	0.125	12.0
Yellow Perch	0.114	13.2

[1] Scaling factor expresses body width as a proportion of total length (TL) based on proportional measurements for the target/surrogate species in Smith (1985).

[2] Surrogate for Northern Pike and Muskellunge

5.2 Empirical Entrainment Rate Data and Species Composition

5.2.1 Species Composition

Centrarchids (sunfish) were the majority of taxa entrained at the 42 of 43 developments included in the EPRI (1997a) entrainment database studies used in this analysis, representing on average 30 percent of the netted taxa compositions. Sunfish are also common in the Project's Reservoir, and Centrarchids are the second-most dominant family in Prairie River Reservoir. This family, as well as Yellow Perch, have the highest potential for entrainment based solely on density.

5.2.2 EPRI (1997a) Monthly/Annual Entrainment Rates

Average monthly entrainment rates for four size cohorts of each target (surrogate/guild) species are provided in Appendix E. Entrainment rates for all target species increase in the summer and fall months, likely due to increased activity related to foraging and reproduction resulting in increased juvenile and young-of-year abundances (GeoSyntec 2005; EPRI 1997a; Jenkins and Burkhead 1993). Fish measuring less than four inches constituted the majority of fish entrainment field trial compositions compiled in EPRI (1997a).

5.3 Project Entrainment Estimates

Analysis of 51-year Prairie River flow data (1967-2018) and the Project's' minimum and maximum operating flows were used to estimate monthly generation amounts (1,000 cfs-hours) for the (Period of Record) POR, the 10% and 90% exceedance values representing a dry and wet year. As a run-of-river (ROR) project, generation amounts were determined by reviewing the monthly flow duration curves and applying each monthly flow to the maximum possible generation for each month. No minimum flows were assumed for generation, which is a conservative assumption that likely overestimates the amount of generation. Flows in excess of the maximum generation capacity were not considered to have the potential for generating unit entrainment or impingement. Entrainment estimates were calculated for the Project, resulting in monthly and annual generation amounts for the POR, dry and wet water years.

5.3.1 Prairie River Hydroelectric Project

The total annual generation (in terms of flow) estimated at the Project for an average water year (POR) was 1,766 (1,000 cfs-hours), with a range of 711 to 3,061 based on the dry and wet years, respectively (Table 9). This resulted in the monthly/annual number of fish estimated to become entrained (Table 10) for a normal water year (POR), a dry water year (Table 11), and a wet water year (Table 12). These values represent project-specific entrainment estimates, which have been multiplied by the target species' RC% in the Project reservoir.

Table 9. Estimated generation (1,000 cfs-hours) at the Prairie River Hydroelectric Project

	Month	Monthly Generation (1,000 cfs hours)
PERIOD OF RECORD (1993-2018) 50% EXCEEDANCE	January	72
	February	66
	March	80
	April	343
	May	343
	June	239
	July	141
	August	75
	September	76
	October	98
	November	141
	December	92
	Annual	**1,766**
DRY YEAR 90% EXCEEDANCE	January	47
	February	43
	March	58
	April	83
	May	135
	June	92
	July	48
	August	27
	September	27
	October	30
	November	62
	December	58
	Annual	**711**

	Month	Monthly Generation (1,000 cfs hours)
WET YEAR 10% EXCEEDANCE	January	343
	February	104
	March	93
	April	196
	May	343
	June	343
	July	343
	August	343
	September	211
	October	232
	November	343
	December	313
	Annual	**3,061**

Table 10. Monthly and annual fish entrainment estimates at the Prairie River Hydroelectric Project based on the POR (1963-2018)

Month	Centrarchids	Yellow Perch	Walleye	Esocids	Ictalurids	Catostomids
January	14	14	1	0	0	6
February	13	14	0	0	0	6
March	8	11	0	1	0	4
April	417	777	2	12	10	30
May	102	81	5	2	45	5
June	120	320	12	5	24	22
July	133	153	10	4	16	17
August	66	10	1	1	3	1
September	95	44	1	1	1	1
October	132	296	1	1	1	73
November	95	10	0	1	1	25
December	27	9	0	0	0	9
Annual	**1,222**	**1,739**	**33**	**28**	**101**	**199**
TOTAL = 3,322						

Table 11. Monthly and annual fish entrainment estimates at the Prairie River Hydroelectric Project based for a dry water year (90% exceedance)

Month	Centrarchids	Yellow Perch	Walleye	Esocids	Ictalurids	Catostomids
January	9	9	0	0	0	4
February	8	9	0	0	0	4
March	6	8	0	1	0	3
April	101	189	0	3	2	7
May	40	32	2	1	18	2
June	46	123	5	2	9	9
July	46	52	3	1	5	6
August	24	4	0	0	1	0
September	34	16	0	0	0	0
October	40	91	0	0	0	22
November	42	4	0	0	0	11
December	17	5	0	0	0	6
Annual	**413**	**542**	**10**	**8**	**35**	**74**
TOTAL = 1,082						

Table 12. Monthly and annual fish entrainment estimates at the Prairie River Hydroelectric Project based for a wet water year (10% exceedance)

Month	Centrarchids	Yellow Perch	Walleye	Esocids	Ictalurids	Catostomids
January	20	20	1	0	0	9
February	18	19	0	1	1	8
March	18	26	0	3	1	9
April	417	777	2	12	10	30
May	102	81	5	2	45	5
June	172	459	18	8	34	32
July	325	372	24	10	39	41
August	186	28	3	2	7	2
September	290	135	3	2	3	3
October	462	1040	4	2	2	256
November	212	21	1	2	2	55
December	57	18	1	0	1	19
Annual	2,279	2,996	62	44	145	469
TOTAL = 5,995						

The average annual number fish expected to become entrained from the assessed target species at the Prairie River Project is 3,320 fish. Based on water year, this number could range from approximately 1,086 to 5,994 fish. The majority of entrained fish are represented by the 0- to 4-inch length groups (Appendix E). Yellow Perch and centrarchids represent the majority of entrained taxa. Small fish often make up the majority of entrainment samples, likely due to their lack of directed swimming and inability to escape, high densities, and/or tendency to disperse (EPRI 1997a; EPRI 1992; Cada et al. 1997); however, they also possess higher survival rates through turbines.

It should be noted that this is likely an overestimate of entrainment, as entrainment avoidance (use of burst swim speeds) of the target species was not factored into these estimates, but should be taken into consideration when assessing entrainment potential in general. Likewise, due to the low numbers of fish being entrained at the Project, for this analysis those individual fish that would likely be excluded by the 1.5-inch clear spaced trashracks were not removed from the total number of fish entrained, providing a conservative estimate of entrainment and potential fish mortality.

5.3.2 Prairie River Hydroelectric Project Blade Strike Analysis

An average blade strike survival rate for each unit was determined for each of the four size groups analyzed in the entrainment assessment.

Survival of target species through the Project is expected to be high based on this analysis and the size groups of fish expected to become entrained. The majority of entrained fish will likely fall into the 0- to 4-inch length groups (Appendix E), which show relatively high survival rates through the Francis-type generating units (Figure 5-3).

Average blade strike survival rates were multiplied by target species monthly entrainment estimates to determine immediate turbine mortality estimates of the target species (Table 13 through Table 15).

According to this assessment, the annual average number (rounded to the nearest fish) of target species expected to experience immediate turbine-related mortality at the Project is between approximately 350 and 440 fish for an average water year based on the POR. Based on a dry and wet year, this number could range from approximately 118 to 830 fish. Yellow Perch showed the highest mortality due to their RC% in the Project area and their entrainment rate being higher relative to the other entrained species/cohorts at the Project.

Table 13. Annual immediate turbine mortality estimates at the Prairie River Hydroelectric Project based on the POR (1963-2018)

Size Class (in)	Unit 1 Average Blade Strike Mortality Estimate All Species	Unit 2 Average Blade Strike Mortality Estimate All Species	Unit 1 Average Blade Strike Mortality Rate	Unit 2 Average Blade Strike Mortality Rate
<4	142	**178**	6.16%	7.71%
4-8	167	**209**	18.49%	23.14%
8-15	33	**41**	35.45%	44.35%
>15	11	**13**	79.70%	88.66%
Total	**354**	**441**	-	-

Table 14. Annual immediate turbine mortality estimates at the Prairie River Hydroelectric Project based for a dry water year (90% exceedance)

Size Class (in)	Unit 1 Average Blade Strike Mortality Estimate All Species	Unit 2 Average Blade Strike Mortality Estimate All Species	Unit 1 Average Blade Strike Mortality Rate	Unit 2 Average Blade Strike Mortality Rate
<4	46	**57**	6.16%	7.71%
4-8	57	**72**	18.49%	23.14%
8-15	12	**15**	35.45%	44.35%
>15	3	**4**	79.70%	88.66%
Total	**118**	**147**	-	-

Table 15. Annual immediate turbine mortality estimates at the Prairie River Hydroelectric Project based for a wet water year (10% exceedance)

Size Class (in)	Unit 1 Average Blade Strike Mortality Estimate All Species	Unit 2 Average Blade Strike Mortality Estimate All Species	Unit 1 Average Blade Strike Mortality Rate	Unit 2 Average Blade Strike Mortality Rate
<4	240	**300**	6.16%	7.71%
4-8	359	**449**	18.49%	23.14%
8-15	52	**65**	35.45%	44.35%
>15	15	**16**	79.70%	88.66%
Total	**665**	**830**	-	-

5.4 Flow Routing and Potential Spillway Mortality

Entrainment and survival potential at the Project will also vary based on the quantity and route of river flow, which at times may include the bypass reach flow through the gated spillway's Tainter gates or slide gates and the powerhouse flow/leakage. Passage through routes other than the generating units was considered for this study. As a run-of-river Project, all flows in excess of turbine capacity are passed through alternative routes. Although the flow distribution analysis conducted can be used to determine the percentage of river flow passing through alternate routes, for this analysis all flow in excess of maximum turbine capacity was not considered for fish entrainment or for the blade strike analysis. The Project contains a bypass reach with a seasonal minimum flow requirement of 75 cfs in April and May and 50 cfs in June. In addition, the Project is required to follow the licensed ramping rate regime when implementing, reducing, or ceasing the minimum flow requirements. Flows can be reduced 50 cfs per hour for flows between 200-400 cfs, 25 cfs for flows between 75-200 cfs, and 15 cfs per hour for flows below 75 cfs.

There is potential for some mortality to occur through the alternate routes, particularly under lower spill flow scenarios. Empirical data exists from 16 tests at six hydroelectric facilities, which estimated the survival of fish passing over spillways and through bypass sluices using the HI-Z Turb'N Tag methodology (Heisey et al. 1992). These studies found survival rates ranging from 88.3 percent to 100 percent depending on the species and the specifications of the projects and flows evaluated (Table 16). However, the head differentials of most of these projects are all more than that existing at the Project. Only the Crescent (13 feet) project has an operating head similar to that at the Project. The 48-hour survival of juvenile herring passed over the spillway at Crescent was 88.3 percent. This rate is likely lower than would be observed at the Project, as juvenile herring are much less hardy and succumb to mortality more easily than the majority of those species present in the Project reservoir.

It is also important to note that the spillway survival rates of the other projects with much higher heads than the Prairie River Project had higher survival rates than the Crescent Project, several of which were 100 percent survival. Fish passing over the spillways at these traditional hydroelectric facilities are typically exposed to concrete aprons or other rough surfaces before reaching a downstream pool. It is likely that higher flows/lower gross head at the Project spillway would allow fish to plunge into the next downstream pool without injury. As flows recede and gross head increases, spill mortality potential may slightly increase due to the greater plunge distance and strike velocities, as well as the potential for abrasion or scraping.

Table 16. Spillway survival rates from 16 tests at 6 hydroelectric facilities (Heisey et al. 1992)

Project	Year	Passage Route	Species	Temp. (°C)	Head (ft)	Spill Flow Rate (cfs)	48 h Survival (%)	Injured		Injury Type
								No.	(%)	
Crescent, NY	1991	Spillway	Juv. herring	14-17	13	400	88.3	0	(0.0)	N/A
Garvin Falls, NH	2005	Bypass/collector	Juv. Atlantic salmon	13	30	800	100	0	(0.0)	N/A
Little Falls Hydro, NY	1996	Bypass Pipe	Adult herring	18-19	44	100	98.7	3	(3.7)	Bruises
Little Falls Hydro, NY	1996	Bypass Pipe	Adult herring	18-19	44	50	100	1	(2.9)	Bruises
Rock Island, WA	1997	Spillway[b,c]	Juv. Chinook salmon	4	41	1,900	95.1	11	(4.5)	Int injuries
Rock Island, WA	1997	Spillway[b]	Juv. Chinook salmon	4	41	1,000	98.4	3	(1.2)	Dmg/hem eye
Rock Island, WA	1999	Spillway[b]	Juv. Chinook salmon	13-14	41-49	2,500	99.5	0	(0.0)	None
Rock Island, WA	1999	Spillway[b]	Juv. Chinook salmon	13-14	41-49	1,000	99.5	1	(0.5)	Int hem
Rock Island, WA	2000	Spillway[a,b,d]	Juv. Chinook salmon	14-15	40-43	2,500	99.0	0	(0.0)	N/A
Rock Island, WA	2000	Spillway[a,b,e]	Juv. Chinook salmon	14-15	40-44	2,500	100.0	0	(0.0)	N/A
Rock Island, WA	2001	Spillway[a,b,d]	Juv. Chinook salmon	9-10	39-43	2,500	99.0	3	(1.5)	Dmg/hem eye
Rock Island, WA	2001	Spillway[a,b,e]	Juv. Chinook salmon	9-10	39-43	2,500	100.0	3	(1.5)	Dmg/hem eye
Vernon, VT/NH	1995	"Fish tube" (Sluice)	Juv. Atlantic salmon	16-18	27	400	93.3	0	(0.0)	N/A
Wilder, VT	1992	Sluice	Juv. Atlantic salmon	9-16	52	200	97.0	31	(31.0)	Bruises

Project	Year	Passage Route	Species	Temp. (°C)	Head (ft)	Spill Flow Rate (cfs)	48 h Survival (%)	Injured		Injury Type
								No.	(%)	
Wilder, VT	1992	Sluice	Juv. Atlantic salmon	9-16	52	300	91.0	12	(27.3)	Bruises
Wilder, VT	1992	Sluice	Juv. Atlantic salmon	9-16	52	500	97.0	14	(14.1)	Bruises

a Spillway with flow deflector.
b Overflow weir or spill to attract surface oriented juvenile salmonids.
c Spill directed onto concrete slab.
d Periphery release location.
e Off-center release.

6 Discussion and Analysis

The Prairie River Project has little potential for impingement due to intake velocities that do not exceed the burst swimming capabilities of nearly all fish species and life stages that are large enough to be impinged. The Project has the potential to create some degree of entrainment that will vary with river flow, species, season, and fish size/life stage. The Project intake is located in a small a forebay, that is isolated from the main basin of the lake by a narrow constriction and a coarse trashrack. It is possible that the separation of the forebay from the main lake basin, would limit the exposure of fish in the main reservoir to entrainment. The majority of entrained fish will likely be centrarchids, percids, and young life stages of all species, including eggs, fry, juveniles, and some young adults incapable of intake avoidance or exclusion by the trashracks. Most larval (yolk-sac) fish can only adjust their vertical position in the water column and drift with river flow (Jenkins and Burkhead 1993). Fry (no yolk-sac) and juvenile fish possess escape or burst swim speeds capable of avoidance; however, adults are more successful in avoiding intake structures, and thus comprise the minority of entrained fish at a given system.

Entrainment risk of the target species will vary by a number of factors at the Project, including species, life stage, season, swim speed, the flow regime, and hydropower operations. The quantitative entrainment estimates provided in this report utilized target species empirical entrainment rate data collected at various hydroelectric projects and fish species average relative composition in the Project reservoir. According to this assessment (reference Table 10 through Table 12), the average annual number of target species expected to become entrained at the Project is 3,320 fish (rounded to the nearest fish) based on an average water year for the POR. For dry and wet water years, this number could range from approximately 1,086 to 5,994 fish, respectively. The majority of the entrainment estimates are small fish in the 0- to 4-inch length cohort. Yellow Perch represented a largest component of entrainment, followed by the sunfishes (centrarchids). Combined, these species/guilds represented approximately 88 percent of all fish entrained. Very few fish in the larger size classes were estimated to be entrained because most are large enough to be excluded by the 1.5-inch clear-spaced trashracks in front of the combined intake for Units 1 and 2 currently in place at the Project.

Fish survival rates through the Project's Francis turbine units appear to be relatively high, particularly for small fish that make up the majority of all entrained fish. Average blade strike survival rates were multiplied by target species seasonal entrainment estimates to determine immediate turbine mortality estimates of the target species (reference Table 13 through Table 15). The entrainment and mortality estimates for the Prairie River Project included all size classes regardless of larger fish being physically excluded from passing through the 1.5-inch trashracks currently in place to provide the most conservative estimate of entrainment at the Project.

According to this assessment, the annual average number (rounded to the nearest fish) of target species expected to suffer immediate turbine-related mortality at the Project ranged from 237 to 593 fish based on an average water year for the POR. For dry and wet water years, this number could range from approximately 79 to 197 fish and 445 to 1,113 fish, respectively. Yellow Perch showed the highest mortality due to high entrainment rates in the spring and fall months, and relatively high RC% in the Project reservoir followed by centrarchids (largely made up of the sunfishes). Entrainment mortalities will likely be the highest in the spring and fall months when fish are most active.

7 Literature Cited

Beamish, F. W. H. 1978. Swimming capacity. Fish Physiology, Vol. VII: 101-187.

Beecham, R. V., P. R. Pearson, S. B. Labarre, and C. D. Minchew. 2009. Swimming Performance and Metabolism of Golden Shiners. North American Journal of Aquaculture. 71:59-63.

Bell, M. C. 1981. Updated compendium on the success of passage of small fish through turbines. Prepared for U.S. Army Corps of Engineers, North Pacific Division, Portland, OR.

———. 1991. Fisheries Handbook of Engineering Requirements and Biological Criteria. Prepared for U.S. Army Corps of Engineers, North Pacific Division, Fish Passage Development and Evaluation Program, Portland, OR. Third Edition.

Blandin Paper Company. 1991. Application for New License for Major Water Power Project 5 Megawatts or Less, FERC Project No. 2362, Blandin Hydroelectric Project. December.

Bunt, Christopher M., C. Katopodis, and R.S. McKinley. 1999. Attraction and Passage Efficiency of White Suckers and Smallmouth Bass by Two Denil Fishways. North American Journal of Fisheries Management 19:793-803.

Cada, G. F., C. C. Coutant, and R. R. Whitney. 1997. Development of biological criteria for the design of advanced hydropower turbines. DOE/ID-10578. Prepared for the U.S. Department of Energy, Idaho Operations Office, Idaho Falls, Idaho.

Carlander, K.D. 1977. Handbook of Freshwater fishery biology, Volume 2. The Iowa State University Press. Ames, Iowa. 1977.

Carlson, D.M. 1977. A Trophic State Index for Lakes. Limnology and Oceanography 22(2): 361-369.

_____. 1992. Lower Oswegatchie River: a warm-water fish survey. New York State Department Environmental Conservation, Watertown.

Deng, Z., M. C. Richmond, G. R. Guensch, and R. P. Mueller. 2004. Study of fish response using particle image velocimetry and high-speed, high-resolution imaging. Prepared for U.S. Department of Energy by Pacific Northwest National Laboratory, Richland, Washington.

Drucker, E. G. and G. V. Lauder. 1999. Locomotor forces on a swimming fish: three-dimensional vortex wake dynamics quantified using digital particle image velocimetry. J. Exp. Biol. 202, 2393-2412.

Electric Power Research Institute (EPRI). 1992. Fish entrainment and turbine mortality review and guidelines. Prepared by Stone & Webster Environmental Services, Boston, Massachusetts. EPRI Report No. TR-101231, Project 2694-01. September 1992.

———. 1997a. Turbine entrainment and survival database – field tests. Prepared by Alden Research Laboratory, Inc., Holden, Massachusetts. EPRI Report No. TR-108630. October 1997.

———. 1997b. Guidelines for hydro turbine fish entrainment and survival studies. Prepared by Alden Research Laboratory, Inc., Holden, Massachusetts. EPRI Report No. TR-107299. July 1997.

Federal Energy Regulatory Commission (FERC). 1988. Hydroelectric Development in the Upper Ohio River Basin Final Environmental Impact Statement. FERC Docket No. EL85-19-114.

_____. 1993. Order Issuing New License (Major Project), FERC No. 2362-002, Blandin Paper Company. Issued February 26.

_____. 1995a. Preliminary assessment of fish entrainment at hydropower projects, a report on studies and protective measures, volumes 1 and 2 (appendices). FERC Office of Hydropower Licensing, Washington, D.C. Paper No. DPR-10. June 1995 volume 1) and December 1994 (volume 2).

———. 1995b. Final environmental assessment for hydropower license, Stevens Creek Hydroelectric Project, FERC Project No. 2535-South Carolina, Georgia. FERC Office of Hydropower Licensing, Washington, D.C. November 7, 1995.

Franke, G. F., D. R. Webb, R. K. Fisher, Jr., D. Mathur, P. N. Hopping, P. A. March, M. R. Headrick, I. T. Laczo, Y. Ventikos, and F. Sotiropoulos. 1997. Development of environmentally advanced hydropower turbine system design concepts. Prepared for U.S. Department of Energy, Idaho Operations Office, Contract DE-AC07-94ID13223.

Gardner, A. N., G. D. Jennings, W. F. Hunt, and J. F. Gilliam. 2006. Non-anadromous fish passage through road culverts. Paper No. 067034, Annual Meeting, American Society of Agricultural and Biological Engineers, St. Joseph, MI.

GeoSyntec Consultants. 2005. Fish entrainment evaluation. Catawba-Wateree Project (FERC No. 2232). Prepared for Devine Tarbell and Associates.

HDR Engineering, Inc. 2010a. Fish entrainment and mortality study. BOST3 Hydroelectric Project (FERC No. 12756). Prepared for Nelson Energy and BOST3 Hydroelectric LLC, Golden Valley, Minnesota. June 2010.

———. 2010b. Fish entrainment and mortality study. BOST4 Hydroelectric Project (FERC No. 12757). Prepared for Nelson Energy and BOST4 Hydroelectric LLC, Golden Valley, Minnesota. June 2010.

———. 2010c. Fish entrainment and mortality study. BOST5 Hydroelectric Project (FERC No. 12758). Prepared for Nelson Energy and BOST5 Hydroelectric LLC, Golden Valley, Minnesota. June 2010.

———. 2011. Turbine entrainment and mortality report. York Haven Hydroelectric Project (FERC No. 1888). Prepared for York Haven Power Company, LLC, York Haven Pennsylvania. April 2011.

———. 2012a. Fish entrainment report. Muskingum River Hydroelectric Projects (FERC Nos. P-13412, P-13408, P-13411, P-13406, P-13404, P-13407, and P-13405). Prepared for Free Flow Power Corporation, Boston, Massachusetts. March 2012.

———. 2012b. Fish entrainment report. Williams Hydroelectric Project (FERC No. P-13346). Prepared for Free Flow Power Corporation, Boston, Massachusetts. June 2012.

———. 2012c. Fish entrainment and survival assessment. Braddock Locks and Dam Hydroelectric Project (FERC No. 13739). Prepared for Hydro Green Energy, LLC, Westmont, Illinois. August 2012.

———. 2013a. Fish entrainment study report. Yazoo River Basin Hydroelectric Projects (FERC Nos. P-13702, P-13703, P-13701, and P-13704). Prepared for Free Flow Power Corporation, Boston, Massachusetts. June 2013.

———. 2013b. Fish entrainment study report. Hogansburg Projects (FERC No. P-7518). Prepared for Erie Boulevard Hydropower, L.P. Fulton, New York. 2013.

———. 2016. Colliersville Hydroelectric Project (FERC No. 2788) Final License Application. Appendix B – Study Reports. Section 6 – Fish Passage and Protection Study. Prepared for Goodyear Lake Hydro, LLC. Andover, Massachusetts.

———. 2017. Fish Entrainment Evaluation Study Report. Bear Swamp Project (FERC No. P-2699). Prepared for Bear Swamp Power Company, LLC, Rowe, Massachusetts. 2017.

———. 2019. Fish Passage and Protection Study Report. Mongaup River Hydroelectric Projects: Swinging Bridge Hydroelectric Project (FERC No. 10482), Mongaup Falls Hydroelectric Project (FERC No. 10481, and Rio Hydroelectric Project (FERC No. 9690). Prepared for Eagle Creek Hydro Power, LLC; Eagle Creek Water Resources, LLC; and Eagle Creek Land Resources, LLC. 2019.

HDR|DTA. 2010a. Fish entrainment and impingement. Sutton Hydroelectric Project (FERC No. 12693). Prepared for Brookfield Renewable Power, Marlborough, Massachusetts. June 2010.

———. 2010b. Fish entrainment and survival assessment. Price Dam Hydroelectric Project (FERC No. 12187). Prepared for Brookfield Renewable Power Inc., Syracuse, New York. August 2010.

Heisey, P. G., D. Mathur, and T. Rineer. 1992. A reliable tag-recapture technique for estimating turbine passage survival: application to young-of-the-year American shad (*Alosa sapidissima*). Can. Jour. Fish. Aquat. Sci. 49:1826-1834.

Hocutt, C. H. 1973. Swimming performance of three warmwater fishes exposed to a rapid temperature change. Chesapeake Science 14(1):11–16.

Hoover, J. J., K. J. Killgore, D. G. Clarke, H. Smith, A. Turnage, and J. Beard. 2005. Paddlefish and sturgeon entrainment by dredges: Swimming performance as an indicator of risk. DOER Technical Notes Collection (ERDC TN-DOER-E22), U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Houde, E. D. 1963. Sustained swimming ability of larvae of walleye (*Stizostedion vitreum vitreum*) and yellow perch (*Perca flavescens*). J. Fish. Res. Bd. Canada 26:1647-1659.

Jenkins, R. E. and N. M. Burkhead. 1993. Freshwater fishes of Virginia. American Fisheries Society, Bethesda, Maryland.

Jones, D. R., J. W. Kiceniuk, and O. S. Bamford. 1974. Evaluation of the swimming performance of several fish species from the Mackenzie River. J. Fish. Res. Bd.

King, L. R. 1969. Swimming speed of the channel catfish, white crappie, and other warm water fishes from Conowingo Reservoir, Susquehanna River, PA. Ichthyological Associates, Bulletin No. 4.

Larimore R. W. and M. J. Duever. 1968. Effects of temperature acclimation on the swimming ability of small-mouth bass fry. Trans Am Fish Soc 97:175–184.

Layher, W. G. 1993. Determining swimming speeds for darters of the genera Etheostoma and two cyprinid fishes. Final Report. Challenge cost-share grant between the Ouchita National Forest U.S.D.A. Forest Service and the University of Arkansas at Pine Bluff.

Leavy, Tracy R. and Timothy H. Bonner. 2009. Relationships among Swimming Ability, Current Velocity Association and Morphology for Freshwater Lotic Fishes. North America Journal of Fisheries Management 29:72-83.

Lee, L. A. and J. W. Terrell. 1987. Habitat suitability index models: Flathead Catfish. U.S. Fish and Wildlife Service Biological Report 82(10.152). 39 pp.

Muth, R. T. and J. C. Schmulbach. 1984. Downstream transport offish larvae in a shallow prairie river. Transactions of the American Fisheries Society 113:224-230.

Minnesota Department of Natural Resources (MDNR). 2006. Draft Environmental Impact Statement for the UPM/Blandin Paper Mill Thunderhawk Project. Prepared by HDR. Grand Rapids, MN. January 2006.

_____. 2013a. Lake Management Plan for Blandin Reservoir. Region 2 Grand Rapids F216, D.O.W. No. 31-0533.

_____. 2013b. Lake Management Plan for Prairie Lake. Region 2 Grand Rapids 216, D.O.W. No. 31-0384.

_____. 2018a. Lake Finder: Blandin. Online: [URL] https://www.dnr.state.mn.us/lakefind/lake.html?id=31053300.

_____. 2018b. Fisheries Lake Surveys: Blandin. Online: [URL] https://www.dnr.state.mn.us/lakefind/showreport.html?downum=31053300.

Minnesota Pollution Control Agency (MPCA). 2017. Our Upper Mississippi River. Large River and Basin Restoration and Protection Strategies. Wq-ws4-38b. June 2017.

Minnesota Power (MP). 2018a. Pre-Application Document Volume I of II. Grand Rapids Hydroelectric Project (FERC Project No. 2362). Prairie River Hydroelectric Project (FERC Project No. 2361). Prepared for: Minnesota Power. Prepared by HDR Engineering, Inc. 2018. 178 pp.

_____. 2018b. Rapids Energy Center NPDES Permit Renewal, 316(b) Submittal. February 28, 2018.

National Resources Conservation Service (NRCS). 2008. Rapid Watershed Assessment: Prairie-Willow (MN) HUC: 07010103. NRCS. USDA. Online: [URL] https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_021558.pdf. Accessed on October 10, 2018.

Normandeau Associates, Inc. 2008. Desktop fish entrainment and impingement assessment. Prepared for Appalachian Power Company. Smith Mountain Project (FERC Project No. 2210). 49 pp.

———. 2009. Fish entrainment and impingement assessment. Claytor Hydroelectric Project (FERC Project No. 739). Prepared for Appalachian Power Company. 52 pp.

Odeh, M. 1999. A summary of environmentally friendly turbine design concepts. U.S. Department of Energy, Idaho Operations Office, DOE/ID/13741. July 1999. Olson et al. 1988.

Peake, S., R. S. McKinley, and D. A. Scruton. 2000. Swimming performance of walleye (Stizostedion vitreum). Can. J. Zool. 78:1686-1690.

Schuler, V. J. 1968. Progress report of swim speed study conducted on fishes of Conowingo Reservoir. Ichthyological Associates, Progress Report 1B.

Schupp, D.H. 1992. An Ecological Classification of Minnesota Lakes with Associated Fish Communities. Minnesota Department of Natural Resources Investigational Report 417: 1-27.

Smiley, P. and G. R. Parsons. 1997. Effects of photoperiod and temperature on the swimming performance of white crappie. Transactions of the American Fisheries Society, 126:495-499.

Smith, C. L. 1985. The inland fishes of New York State. The New York State Department of Environmental Conservation, Albany, New York.

University of Iowa. 2010. Upstream passage, fish swimming speeds: determination of the need for fish passage at the proposed project. IIHR Hydroscience and Engineering. Iowa City, Iowa. February 2010: Page 7.

Webb, P. W. 1998. Swimming. In The Physiology of Fishes (ed. D. H. Evans), pp.3 -24. Boca Raton: CRC Press.

Werner, R.G. 1980. Freshwater Fishes of New York: A Field Guide. Syracuse University Press. Syracuse, New York. 186 pp.

_____. 1985. Freshwater Fishes of New York State: A Field Guide. Syracuse University Press.

Winchell, F., S. Amaral, and D. Dixon. 2000. Hydroelectric turbine entrainment and survival database: an alternative to field studies. HydroVision Conference, August 8-11, 2000, Charlotte, North Carolina.

Appendix A.
Period of Record (1967-2018) Flow Exceedances for the Prairie River

% Exceedance	Annual	January	February	March	April	May	June	July	August	September	October	November	December
100.00%	11	24	39	45	70	45	38	28	18	16	11	16	18
99.00%	22	28	42	54	78	64	56	34	24	17	14	18	20
98.00%	30	34	43	63	82	77	72	39	26	20	15	18	21
97.00%	37	42	45	64	84	89	81	47	29	23	16	24	24
96.00%	42	42	46	67	88	106	92	51	29	24	27	46	48
95.00%	45	45	49	74	93	115	97	53	30	26	34	51	60
94.00%	49	53	50	75	96	126	101	55	32	26	36	61	68
93.00%	53	63	55	76	99	149	105	57	33	29	37	75	74
92.00%	57	63	57	79	105	164	111	61	34	32	39	79	76
91.00%	61	63	58	79	112	179	119	63	36	35	40	82	78
90.00%	63	64	59	80	114	185	126	66	37	37	41	85	80
89.00%	66	66	60	82	116	192	130	71	40	40	42	87	82
88.00%	69	67	63	83	119	199	134	74	42	42	44	91	82
87.00%	72	68	63	84	123	209	138	78	42	43	46	93	83
86.00%	75	71	65	84	125	218	143	83	44	45	50	95	83
85.00%	78	72	68	85	129	232	146	86	46	46	52	96	84
84.00%	80	75	72	85	131	243	150	91	47	47	54	97	87
83.00%	82	79	74	86	132	254	157	95	49	47	56	99	89
82.00%	83	81	75	87	134	259	160	101	50	49	60	100	91
81.00%	84	82	76	87	138	266	164	104	51	52	63	102	91
80.00%	85	82	78	88	141	274	170	108	53	53	64	105	92
79.00%	87	83	78	89	145	279	175	112	54	54	68	109	95
78.00%	89	84	79	90	147	284	178	115	57	55	71	113	96
77.00%	91	84	79	91	151	292	183	118	58	57	75	117	97
76.00%	92	85	80	92	155	299	188	121	60	58	76	119	97
75.00%	93	85	80	93	162	303	193	124	62	60	77	120	100
74.00%	95	87	81	94	171	308	200	125	64	61	79	123	101
73.00%	96	87	82	95	181	309	207	129	66	62	80	128	103
72.00%	97	89	82	95	195	314	213	132	67	63	82	131	103
71.00%	99	89	82	96	213	318	220	134	68	63	84	137	104
70.00%	100	90	83	97	242	322	226	137	69	65	88	139	104
69.00%	101	91	83	97	252	325	230	139	71	66	91	142	105
68.00%	103	92	84	97	263	330	233	143	72	67	92	146	105
67.00%	104	92	84	99	268	337	237	146	73	69	94	149	106
66.00%	105	92	84	99	281	347	242	149	74	71	96	151	108
65.00%	107	92	85	100	292	354	246	151	76	73	96	153	108
64.00%	108	93	85	101	308	362	249	154	79	75	97	155	109
63.00%	110	93	85	101	318	370	254	157	80	77	99	158	111
62.00%	112	93	85	101	335	374	263	158	82	80	100	159	111
61.00%	114	93	86	103	350	380	268	160	85	82	101	160	114
60.00%	117	94	86	103	362	392	274	163	87	84	102	163	115
59.00%	118	95	87	105	375	403	280	166	88	85	105	164	116
58.00%	121	95	87	105	386	408	287	168	89	86	108	168	117
57.00%	123	95	88	105	393	418	295	170	92	88	111	174	119
56.00%	125	95	88	105	405	426	296	172	93	91	113	179	120
55.00%	129	96	88	105	432	431	303	175	96	94	115	182	121
54.00%	132	96	89	107	458	441	306	179	97	97	118	185	122
53.00%	133	96	89	107	472	453	313	183	99	99	124	187	124
52.00%	137	97	90	108	489	466	317	185	100	100	128	189	125
51.00%	139	97	91	108	507	481	322	190	101	101	130	192	125
50.00%	142	98	91	109	525	502	328	193	103	104	134	193	126
49.00%	145	99	92	110	540	514	334	196	104	106	138	196	129
48.00%	149	99	93	110	570	529	345	201	105	108	141	197	131
47.00%	151	100	93	111	579	548	354	204	107	110	145	200	132
46.00%	157	100	93	112	587	564	359	205	109	113	148	201	133
45.00%	160	101	93	112	602	588	370	208	110	117	155	204	134
44.00%	164	101	95	113	618	602	380	213	112	122	161	207	137
43.00%	168	102	95	113	642	610	388	218	113	125	167	208	138
42.00%	174	103	96	114	655	620	400	221	116	128	170	210	139
41.00%	179	103	97	116	674	638	409	226	117	132	173	213	142
40.00%	184	104	97	116	690	653	416	232	120	135	178	214	143
39.00%	189	104	99	117	712	667	431	235	122	139	180	216	145
38.00%	195	105	99	118	727	676	450	241	125	143	185	217	145
37.00%	200	105	99	118	751	700	460	245	129	146	188	218	146
36.00%	205	107	100	121	770	716	476	251	134	151	189	222	148
35.00%	212	107	100	122	784	728	497	259	138	154	192	225	150
34.00%	218	108	101	124	814	746	508	266	143	159	196	229	151
33.00%	226	110	103	125	830	772	521	270	150	162	200	232	154
32.00%	234	112	103	127	857	789	529	277	153	165	201	234	155
31.00%	243	114	104	129	866	816	544	285	158	167	207	239	157
30.00%	251	116	105	132	898	842	552	289	162	172	208	241	158
29.00%	262	117	105	133	922	860	566	296	169	176	213	247	160
28.00%	272	118	106	135	938	873	583	302	175	180	218	251	162
27.00%	283	119	107	137	959	887	596	310	180	187	226	255	164
26.00%	295	121	108	139	967	905	614	313	184	193	233	263	167
25.00%	305	121	109	141	984	922	624	322	189	196	242	277	170
24.00%	314	124	110	143	999	931	638	325	193	197	250	281	172
23.00%	325	125	112	146	1,021	950	671	334	199	203	258	289	175
22.00%	342	127	113	148	1,042	974	684	342	204	209	263	296	176
21.00%	358	129	116	151	1,065	993	693	358	209	213	279	303	179
20.00%	374	131	117	154	1,103	1,017	713	373	214	221	293	308	181
19.00%	395	132	118	157	1,117	1,038	755	386	219	226	304	310	184
18.00%	416	132	118	160	1,159	1,058	764	408	224	235	321	318	187
17.00%	441	133	118	167	1,220	1,081	789	419	233	241	348	327	191
16.00%	466	134	120	177	1,257	1,111	808	438	243	249	370	334	201
15.00%	499	137	121	184	1,312	1,130	823	456	247	253	389	345	214
14.00%	530	138	121	197	1,374	1,154	846	476	258	263	412	355	229
13.00%	566	138	122	207	1,429	1,186	866	499	263	274	433	368	240
12.00%	605	141	125	224	1,524	1,213	894	517	271	287	455	388	250
11.00%	647	142	126	249	1,631	1,244	925	538	280	299	475	406	250
10.00%	691	143	128	268	1,697	1,273	946	547	289	318	545	429	268
9.00%	747	145	130	281	1,763	1,315	969	596	297	341	598	460	295
8.00%	809	147	135	315	1,849	1,355	1,008	630	306	368	627	494	317
7.00%	877	151	137	345	1,914	1,421	1,044	707	321	406	669	518	341
6.00%	940	159	139	363	2,091	1,473	1,087	770	345	437	694	556	360
5.00%	1,011	174	141	383	2,265	1,513	1,141	870	381	458	723	586	374
4.00%	1,106	183	145	457	2,441	1,580	1,230	988	402	483	830	622	408
3.00%	1,245	191	159	546	2,780	1,631	1,320	1,070	427	512	888	652	456
2.00%	1,437	200	164	649	3,021	1,824	1,442	1,243	457	544	959	723	506
1.00%	1,842	217	182	1,107	3,450	2,182	1,963	1,447	488	689	1,079	987	647
0.10%	3,475	284	552	1,986	4,209	3,141	4,079	1,980	654	906	1,473	1,329	785
0.00%	4,262	299	564	2,052	4,262	3,209	4,170	2,355	706	912	1,486	1,329	785

Appendix B.
Target Fish Species Accounts

Bluegill

The Bluegill is a common type of sunfish in the family Centrarchidae and a popular game fish. They are a widespread species, originally found in a region that extended from the St. Lawrence River south to Georgia and then west to Texas and Minnesota, but has since been introduced to areas beyond this range (Smith 1985). Bluegills have the typical deep and laterally compressed body type represented in most *Lepomis* species. They have several sharp dorsal fin spines, and is often greenish-blue to brown in color with vertical bars sometimes present along the sides of the body with an orange breast. A black spot located on the posterior base of the soft dorsal fin is a useful identification characteristic (Smith 1985).

Bluegill are colonial and tend to occupy more open habitat near vegetative cover while building nests, spawning, and rearing in littoral zones. Males construct and defend the nest in shallow areas with sand and gravel substrates, often within inches of neighboring nests. Spawning occurs in late spring and into the summer. (Smith 1985; Jenkins and Burkhead 1993).

Bluegills are generalist and opportunistic feeders. Fry leave the nest to an open area to feed on zooplankton when they are 1/4 to 1/3 inches in length. At approximately 1-inch in length, young Bluegill return to the littoral habitats to feed on zooplankton and begin to feed on insects, invertebrates, and occasionally on small fish as they further develop. Throughout their lives, juveniles and adults will often make forays to deep water habitats during the day to feed on zooplankton, returning to littoral zone habitats at night to rest or feed on insects. In rivers, they are found in low velocity, marginal, and backwater habitats (Smith 1985; Jenkins and Burkhead 1993).

The species is often fairly abundant where it occurs due to high reproductive and growth rates, represents an important forage fish for Black Bass and other piscivorous species, and can live as long as 11 years (Smith 1985).

Smallmouth Bass

Smallmouth Bass are commercially and economically important game fish, and are similar in appearance to Largemouth Bass, but are differentiated by their smaller mouth and browner coloration with dark vertical lines. Other distinctive characteristics include the jaw ending below the middle of the eye and juveniles with orange and black bands on the base of their tails. This species is common in the north-central United States and southern Canada from Minnesota and the Dakotas to the St. Lawrence River drainage and south to the Mississippi Valley, the Ozarks, and northern Alabama (Smith 1985).

Smallmouth Bass can be found in almost all manner of aquatic habitat but are most abundant in cool large rivers and lakes. They prefer slow to moderate current and select areas of rocky shorelines. Like the Yellow Perch, Smallmouth Bass are opportunistic feeders and generally feed during daylight hours on aquatic invertebrates, crustaceans, and small fish (Smith 1985). Smallmouth Bass sexually mature at age 3 to 6 years. Spawning usually occurs in late spring/early summer when water temperatures reach 62 degrees Fahrenheit (°F) to 65°F. Spawning occurs in 2 to 20 feet of water but average spawning depth is approximately 3 feet. Males build and maintain a nest in gravelly substrate until the fry emerge and disperse. Multiple females may visit a nest over a 30- to 36-hour period. Eggs hatch between 7 and 21 days, depending on the water temperature (Smith 1985).

Walleye

Walleye usually occur in large rivers and lakes and prefer a bottom of loose aggregates. They are generally found in deeper waters during the day and tend to move into shallower areas during heavy cloud cover and at night for feeding. They can be sensitive to low pH levels (Carlson 1992). Walleye are opportunistic predators, beginning on crustaceans and aquatic invertebrates as juveniles and moving to fish and other larger vertebrates and invertebrates as they mature (Smith 1985).

Male Walleye mature at age 2 to 3, while females mature at age 4 to 5. They spawn in the spring following ice out when water temperatures reach 35°F to 44°F. Walleye prefer to spawn over substrates ranging in size from sand to boulders, but preferably select cobble to rock-size substrate in water generally 2 to 4 feet deep. Walleye are not nest builders, instead they broadcast their eggs along the substrate. Eggs hatch between 7 and 26 days, depending on the water temperature (Smith 1985). Generally, less than 20 percent of the eggs survive to hatching and more commonly only 5 percent under natural conditions. While males tend to remain in the area following spawning, no parental care is undertaken.

Largemouth Bass

Largemouth Bass are mostly found in warm and weedy portions of lakes, bays, and some rivers and prefer a much softer bottom substrate. Similar to the Smallmouth Bass, the Largemouth Bass are opportunistic feeders and generally feed during daylight hours on aquatic invertebrates, crustaceans, and small fish or anything that moves on or under the surface of the water.

Largemouth Bass sexually mature at age 5 years. Spawning usually occurs in late spring/early summer when water temperatures reach 60°F (Smith 1985).

Spawning occurs in shallow water from 1 to 4 feet. Spawning behavior is very similar to the Smallmouth Bass, but the two species rarely compete for spawning areas due to differing depth and substrate preferences. Males build and maintain a nest in a siltier substrate until the fry emerge and disperse. Multiple females may visit the Largemouth Bass nest. Eggs hatch between 3 and 5 days, depending on the water temperature (Werner 1980).

Yellow Perch

Yellow Perch can be found in almost all types of aquatic habitat, but are most abundant in large rivers and lakes with no preferred substrate. Larger Yellow Perch are commonly found in deeper waters, while juveniles and younger perch are found in shallower waters. They are opportunistic feeders and feed exclusively during the day on crustaceans, aquatic invertebrates, and small fish. At night, Yellow Perch remain motionless, hovering close to the substrate.

Yellow Perch sexually mature at age 3 to 4 years. Spawning usually occurs following Walleye when water temperatures reach 45°F to 52°F. Spawning occurs in 5 to 10 feet of water and no nests are built. Females are followed by multiple males in a circuitous pattern until the female distributes a long gelatinous string of eggs (2 to 7 feet long) over a variety of substrates. Eggs hatch between 7 and 10 days, depending on the water temperature (Werner 1985).

Black Crappie

The Black Crappie, from the family Centrarchidae, closely resemble the White Crappie with its laterally compressed body shape, but differs in the number of dorsal spines and the base of the dorsal fin is noticeably longer. The Black Crappie is a silvery color on the sides and the belly with darker gray/green blotches and marbling generally on the upper half of the body.

Black Crappie are not tolerant of poor water quality as they prefer less turbid waters, are less tolerant of silt, and are generally found in clear weedy waters. Feeding habits of young fish are focused on zooplankton and insect larvae, switching to a diet of small fish and crustaceans as they reach adulthood (Smith 1985).

Black Crappie usually spawn in May to July when water temperatures are in excess of 68°F. Nests are usually constructed on sandy bottoms in weedy areas, 8-9 inches in diameter, and 5-6 feet apart. These community nesters fan depressions in water with depths of 1-2 feet (Smith 1985). The Black Crappie was included as a target species in this study due to its economical/recreational importance as a game species.

Northern pike

Northern Pike will usually inhabit clear, small lakes and ponds; shallow-vegetated areas of larger lakes, marshes, and creeks; and small-to-large rivers. Adults will move to deeper or cooler water in summer months and spawn in shallow-vegetated areas found in river backwaters, oxbows, and side channels; in similar areas near lakes or in the inlet streams associated with those lakes; and flooded-terrestrial vegetation at a reservoir’s edge will also be used (Smith 1985). After hatching, the larval fish will remain in the spawning habitat for several weeks. Northern Pike spawn in vegetated floodplains adjacent to rivers, marshes, and bays where they reside in early spring when average water temperatures are approximately 9°C (Smith 1985). This species was chosen for this analysis for being a popular game fish species and a top predator in the ecosystem.

Brown Bullhead

The Brown Bullhead is the most common catfish species in New York and is found between southern Canada to the southern Gulf Coast states. Brown Bullhead range from olive to blackish in color along the sides and back and pale white to yellow along the belly. They commonly range between 8 and 14 inches when adults (Smith 1985).

Brown Bullheads are found in various habitat types, such as large rivers and lakes, small ponds, and lower areas in small streams. Adults spawn in late May and June when water temperatures reach 27°C and build nests or burrow under banks, logs, or boulders. Young are guarded in the nests until they reach 2 inches in length and rapidly reach 5 inches by the end of their first summer. Brown Bullheads mature at age two and typically live for 6 to 7 years. The most common prey items of Brown Bullhead include crustaceans and chironomids (Smith 1985). This species was included in the study for being relatively common in the Project reservoir and is a popular game species.

Appendix C.
Target Fish Swim Speeds

Species	Life Stage	TL/FL (in)	Swim Speed (ft/s)			Tested Temperature (C)	Time (min)	References
			Maximum Sustained	Prolonged (P) or Critical (C)	Burst (B) or Startle (S)			
American shad[1]	Juvenile	1.0-3.0		1.25-1.75	1.8-2.5			Bell (1991)
	Adult	12.0-14.0		3.0-7.0	8.0-13.5			
Emerald shiner	Adult	2.5		2	4			Bell (1991)
Bluegill	Juvenile	0.98-1.57	0.3-0.75			>15.5		Schuler (1968)
	Juvenile	1.54-1.73	0.48-0.52			26.1-29.4		King (1969)
	Juvenile	2.01-2.13		0.92		21		Beamish (1978)
	Adult	3.94-5.91		1.22 (C)			10	Gardner et al. (2006)
	Adult	6.02			4.3 (B)		0.15	Webb (1978)
	Adult	7.99	1					Deng et al. (2004)
	Adult		0.98					Drucker and Lauder (1999)
Blue sucker[2]	Adult	26.2		4.36	19.51			Brett 1964 cited in The University of Iowa 2010; Brainbridge 1961 cited in The University of Iowa 2011
Herring[1]	Fry	0.4-0.8			0.0-1.0			Bell (1991)
	Juvenile/Adult	6.0-11.0	0.0-3.0	3.0-5.0	5.0-7.0			
Hybrid catfish (Female Channel catfish x Male Blue catfish[3]	Juvenile	6.30-9.06	1.31	3.94 (P)		19-22		Beecham et al. (2009)
Ghost shiner	Adult	1.39		1.47	2.93			Leavy and Bonner (2009)
Greenside darter[4]	Adult	4.0-6.8		0.51-1.32	1.02-2.64			Layher (1993) unpublished
Largemouth bass[5]	Fry	0.79-0.87		0.78-1.02 (P)		30-Oct		Larimore and Deuver (1968) cited in Beamish (1978)
	Juvenile	2.05-2.52	0.5	1.63 (C)		30, 15-35		Hocutt (1973)
	Juvenile	2.05-2.52		8.08L/sec		30		Hocutt (1973) - relative swim speed
	Juvenile	2.05-2.52		1.64 (C)		25		Farlinger and Beamish (1977) cited in Beamish (1978)
	Juvenile	2.24		1.01 (P)		20		Larimore and Deuver (1968) cited in Beamish (1978)
	Juvenile	2.95-3.35	1.21-1.34					Dahlberg et al. (1968) cited in Carlander (1977)
	Juvenile	3.66-5.04		1.60 (C)		15-19	2	Kolok (1991)
	Juvenile	3.66-5.04		0.92 (C)		5	2	Kolok (1991)
	Juvenile	3.94		1.15 (C)		10		Otto and Rice (1974) cited in Beamish (1978)
	Juvenile	4.02		1.50 (C)		25		Farlinger and Beamish (1977) cited in Beamish (1978)
	Juvenile	5.91	0.79			10		Beamish (1970) cited in Carlander (1977)
	Juvenile	5.91	1.57			30		Beamish (1970) cited in Carlander (1977)
	Juvenile	5.91-10.63		1.80-2.17 (P)		30		Beamish (1970) cited in Beamish (1978)
	Juvenile	9.84	1.51			10		Beamish (1970) cited in Carlander (1977)
	Juvenile	9.84	2.07			30		Beamish (1970) cited in Carlander (1977)
Longnose sucker[2]	Juvenile/Adult	3.9-16.0			4.0-8.0			Bell (1991)
Mimic shiner	Adult	1.39		1.43	2.86			Leavy and Bonner (2009)
Paddlefish	Juvenile	3.54		0.98-1.87	3.54	1.87-2.46		Hoover (2005)
	Adult	47.2			47.2	32.8		Brett 1964 cited in The University of Iowa 2010; Brainbridge 1961 cited in The University of Iowa 2011
Smallmouth bass	Fry	0.55		13-19 L/sec (P)				Larimore and Deuver (1968) cited in Carlander (1977) and Houde (1963)
	Fry	0.55		0.60-0.87 (P)				
	Fry	0.79-0.98		<0.89				
	Juvenile	3.58-3.66		1.3-1.8 (C)		13-23	2	Webb (1998)
	Adult	10.3-14.9		1.6-3.9 (C)		15-20	10	Bunt et al. (1999)
Striped bass[6]	Fry	0.5-1.0			0.4-1.0			Bell (1991)
	Juvenile	2.0-5.0			1.0-5.0			
Walleye	Fry	0.47	0.16			18.3		Houde (1963)
	Fry	0.78	0.25			13		Houde (1963)
	Juvenile	3.15 (FL)		1.24 (C)		18.0-20.0	10	Jones et al. (1974)
	Juvenile	6.3 (FL)			6.02 (S)			Peake et al. (2000)
	Adult	13.78 (FL)			7.20 (S)			Peake et al. (2000)
	Adult	14.96 (FL)		2.74 (C)				Peake et al. (2000)
	Adult	22.44 (FL)			8.57 (S)			Peake et al. (2000)
White crappie	Juvenile	2.17-3.94 (FL	0.50-0.75			21.1-28.3		Schuler (1968)
	Juvenile	2.95-3.19 (FL	0.54-0.61			24.4-26.1		King (1969)
	Juvenile	3.03	-	0.52 (C)		25	60	Smiley and Parsons (1997)
	Juvenile	3.03	-	0.18 (C)		5	60	Smiley and Parsons (1997)

[1] Used to represent skipjack herring and mooneye

[2] Used to represent smallmouth redhorse

[3] Used to represent channel catfish and flathead catfish

[4] Used to represent target darter species

[5] Used to represent spotted bass

[6] Used to represent white bass

NOTE: Burst/Startle speed calculated at 50% greater than Prolonged/Critical speeds in Appendix D table based on Bell (1986) unless burst speed provided in the literature.

Appendix D.

Thirty-Seven Hydroelectric Projects Used in the Entrainment Assessment

(EPRI 1997a; FERC 1995a, 1995b)

Site Name	State	River	Reservoir		Total Plant Capacity (cfs)	Hydraulic Capacity of Sampled Units (cfs)	No. Units	Operating Mode	Avg. Velocity at Trashrack (ft/sec)	Trashrack Clear Spacing (in)
			Area (ac)	Volume (ac-ft)						
Belding	MI	Flat	-	-	416	416	2	-	-	2.00
Bond Falls	MI	W.B. Ontonagon	-	-	900	450	2	PK	-	3.00
Brule	WI	Brule	545	8,880	1,377	916	3	PK-partial	1.00	1.62
Caldron Falls	WI	Peshtigo	1,180	-	1,300	650	2	PK	-	2.00
Centralia	WI	Wisconsin	250	-	3,640	550	6	ROR	2.30	3.50
Colton	NY	Raquette	195	620	1,503	450	3	PK	-	2.00
Crowley	WI	N.F. Flambeau	422	3,539	2,400	1,200	2	ROR	1.40	2.38
E. J. West	NY	Sacandaga	25,940	792,000	5,400	5,400	2	-	-	4.50
Feeder Dam	NY	Hudson	-	-	5,000	2,000	5	PK	-	2.75
Four Mile Dam	MI	Thunder Bay	1,112	2,500	1,500	500	3	ROR	-	2.00
Grand Rapids	MI/WI	Menominee	250	-	3,870	2,216	5	ROR	-	1.75
Herrings	NY	Black	140	-	3,610	1,203	3	ROR	-	4.13
High Falls - Beaver River	NY	Beaver	145	1,058	900	300	3	-	0.70	1.81
Higley	NY	Raquette	742	4,446	2,045	2,045	3	PK	-	3.63
Hillman Dam	MI	Thunder Bay	988	1,600	270	270	1	ROR	-	3.25
Johnsonville	NY	Hoosic	450	6,430	1,288	1,288	2	PK	-	2.00
Kleber	MI	Black	270	3,000	400	400	2	ROR	1.41	3.00
Lake Algonquin	NY	Sacandaga	-	-	750	750	1	-	-	1.00
Minetto	NY	Oswego	350	4,730	7,500	4,500	5	PULSE	2.40	2.50
Moshier	NY	Beaver	365	7,339	660	660	2	PK	-	1.50
Ninth Street Dam	MI	Thunder Bay	9,884	2,600	1,650	550	3	ROR	-	1.00
Norway Point Dam	MI	Thunder Bay	10,502	3,800	1,775	575	2	ROR	-	1.69
Potato Rapids	WI	Peshtigo	288	-	1,380	500	3	ROR	-	1.75
Raymondville	NY	Raquette	50	264	1,640	1,640	1	PK	-	2.25
Richard B. Russell	GA/SC	Savannah	31,770	1,297,513	60,000	7,200	8	PK	-	8.00
Sandstone Rapids	WI	Peshtigo	150	-	1,300	650	2	PK	-	1.75
Schaghticoke	NY	Hoosic	164	1,150	1,640	1,640	4	ROR	-	2.13
Shawano	WI	Wolf	155	1,090	850	850	1	ROR	-	5.00
Sherman Island	NY	Hudson	305	6,960	6,600	4,950	4	PK	-	3.13
Thornapple	WI	Flambeau	295	1,000	1,400	700	2	ROR-mod	1.22	1.69
Tower	MI	Black	102	620	404	404	2	ROR	0.82	1.00
Townsend Dam	PA	Beaver	-	-	4,400	4,400	2	ROR	-	5.50
Twin Branch	IA	St. Joseph	1,065	-	3,200	1,200	-	ROR	-	3.00
Warrensburg	NY	Schroon	-	-	1,350	1,350	1	-	-	-
White Rapids	MI/WI	Menominee	435	5,155	3,994	3,994	3	PK-partial	1.90	2.50
Wisconsin River Division	WI	Wisconsin	240	1,120	5150	5,150	10	ROR	1.40	2.19
Youghiogheny	PA	Youghiogheny	2,840	149,300	1,600	1,600	2	ROR	0.70	10.00

Appendix E.
Monthly and Annual Entrainment Rates for Target/Surrogate Fish Species Derived From EPRI (1997a)

Centrarchidae				
Month	Avg. No. Fish/hr/1000 cfs			
	<4	4-8	8-15	>15
Jan	0.3017	0.0449	0.0021	0.0044
Feb	0.3007	0.0509	0.0004	0.0000
Mar	0.0535	0.1062	0.0148	0.0000
Apr	1.2508	0.9548	0.0382	0.0007
May	0.3493	0.1767	0.0246	0.0007
Jun	0.4644	0.4278	0.0322	0.0002
Jul	1.3950	0.3376	0.0168	0.0000
Aug	0.6617	0.9385	0.0240	0.0001
Sep	0.5240	1.7588	0.0219	0.0002
Oct	0.5982	1.8628	0.0198	0.0033
Nov	0.6324	0.6037	0.0116	0.0000
Dec	0.3544	0.1835	0.0028	0.0000

Yellow Perch				
Month	Avg. No. Fish/hr/1000 cfs			
	<4	4-8	8-15	>15
Jan	0.5908	0.4189	0.0055	0.0000
Feb	0.6409	0.4628	0.0048	0.0000
Mar	0.3983	0.3062	0.0056	0.0001
Apr	11.0413	0.9722	0.0717	0.0000
May	0.8240	0.4085	0.0221	0.0000
Jun	6.9463	0.1848	0.0098	0.0000
Jul	5.6341	0.1378	0.0095	0.0000
Aug	0.4632	0.2261	0.0096	0.0000
Sep	2.2040	0.8570	0.0319	0.0000
Oct	13.1352	3.0206	0.0148	0.0000
Nov	0.2062	0.1506	0.0068	0.0000
Dec	0.1607	0.3324	0.0025	0.0000

Walleye				
Month	**Avg. No. Fish/hr/1000 cfs**			
	<4	**4-8**	**8-15**	**>15**
Jan	0.0159	0.0218	0.1816	0.0000
Feb	0.0091	0.0295	0.0044	0.0022
Mar	0.0000	0.0024	0.0070	0.0000
Apr	0.0009	0.0334	0.0742	0.0060
May	0.0039	0.1399	0.1693	0.0049
Jun	1.0143	0.0757	0.1277	0.0056
Jul	1.4364	0.1237	0.0884	0.0265
Aug	0.0893	0.1977	0.0689	0.0039
Sep	0.0470	0.1745	0.0449	0.0127
Oct	0.0071	0.1738	0.1070	0.0043
Nov	0.0090	0.0318	0.0247	0.0073
Dec	0.0017	0.0454	0.0205	0.0000

Northern Pike				
Month	**Avg. No. Fish/hr/1000 cfs**			
	<4	**4-8**	**8-15**	**>15**
Jan	-	-	-	-
Feb	0.0000	0.0000	0.0000	0.0673
Mar	0.0000	0.0569	0.1290	0.0000
Apr	0.0000	0.0206	0.1522	0.2241
May	0.0076	0.0040	0.0352	0.0108
Jun	0.1681	0.0388	0.0402	0.0134
Jul	0.0704	0.2504	0.0254	0.0025
Aug	0.0015	0.0850	0.0118	0.0000
Sep	0.0000	0.0098	0.0208	0.0674
Oct	0.0000	0.0060	0.0231	0.0477
Nov	0.0000	0.0099	0.0567	0.0047
Dec	0.0000	0.0000	0.0058	0.0201

Brown Bullhead				
Month	Avg. No. Fish/hr/1000 cfs			
	<4	4-8	8-15	>15
Jan	0.0344	0.0000	0.0000	0.0000
Feb	0.0380	0.0000	0.0716	0.0000
Mar	0.0326	0.0041	0.0000	0.0000
Apr	0.0265	1.1046	0.3826	0.0000
May	0.1585	0.0896	0.0292	0.0003
Jun	0.0679	0.3635	0.4137	0.0103
Jul	0.0427	2.0200	0.2183	0.0001
Aug	0.1813	1.2160	0.0660	0.0000
Sep	0.0355	0.3935	0.0611	0.0000
Oct	0.0100	0.0494	0.0334	0.0000
Nov	0.0277	0.0529	0.0055	0.0003
Dec	0.0135	0.0000	0.0000	0.0000

Yellow Bullhead				
Month	Avg. No. Fish/hr/1000 cfs			
	<4	4-8	8-15	>15
Jan	0.013158	0.036995	0.023359	0
Feb	0.263538	0.022979	0	0
Mar	0.066948	0.00899	0.002429	0
Apr	0.065951	0.011987	0.028172	0
May	0.010926	0.004433	0.012275	0
Jun	0.046658	0.022716	0.029729	0
Jul	4.861348	0.024251	0.028396	0
Aug	0.152667	0.032991	0.007131	0
Sep	0.139824	0.015965	0.001604	0
Oct	0.072897	0.030205	0.019514	0
Nov	0.191708	0.068841	0.015231	0
Dec	0.034477	0	0	0

Black Bullhead				
Month	**Avg. No. Fish/hr/1000 cfs**			
	<4	**4-8**	**8-15**	**>15**
Jan	0.085499	0	0.009109	0
Feb	0.033636	0.009109	0.009109	0
Mar	0.018965	0.097878	0.074544	0
Apr	0.493329	0.244902	0.070682	0.001571
May	0.05953	0.069165	0.124411	0
Jun	0.114121	0.188409	0.076263	0
Jul	0.242956	0.054969	0.162928	0
Aug	0.057623	0.016652	0.057947	0.013838
Sep	0.091391	0.018028	0.050723	0.00621
Oct	0.147408	0.0154	0.079788	0
Nov	0.068336	0.041446	0.02429	0
Dec	0.021368	0	0.021645	0

Suckers (Catostomidae)				
Month	**Avg. No. Fish/hr/1000 cfs**			
	<4	**4-8**	**8-15**	**>15**
Jan	0.1764	0.5277	0.2398	0.0000
Feb	0.1948	0.7171	0.0310	0.0053
Mar	0.0756	0.4104	0.0335	0.0000
Apr	0.2571	0.2013	0.4092	0.1014
May	0.0434	0.0237	0.0716	0.0136
Jun	0.9150	0.0490	0.0504	0.0056
Jul	1.2443	0.0377	0.0267	0.0033
Aug	0.0986	0.0111	0.0106	0.0026
Sep	0.0571	0.0260	0.0303	0.0064
Oct	0.1062	7.6390	0.3869	0.0237
Nov	0.0667	1.1638	0.6975	0.0024
Dec	0.0342	0.8515	0.2036	0.0000

Appendix F.
Blade Strike Results (Franke et al. 1997)

Prairie River Unit 1

Fish Length (inches)	0.1	0.15	0.2
1	97.95%	96.92%	95.89%
2	95.89%	93.84%	91.78%
3	93.84%	90.75%	87.67%
4	91.78%	87.67%	83.56%
5	89.73%	84.59%	79.45%
6	87.67%	81.51%	75.34%
7	85.62%	78.42%	71.23%
8	83.56%	75.34%	67.12%
9	81.51%	72.26%	63.01%
10	79.45%	69.18%	58.90%
11	77.40%	66.09%	54.79%
12	75.34%	63.01%	50.68%
13	73.29%	59.93%	46.57%
14	71.23%	56.85%	42.46%
15	69.18%	53.76%	38.35%
16	67.12%	50.68%	34.24%
17	65.07%	47.60%	30.13%
18	63.01%	44.52%	26.02%
19	60.96%	41.43%	21.91%
20	58.90%	38.35%	17.80%
21	56.85%	35.27%	13.69%
22	54.79%	32.19%	9.58%
23	52.74%	29.10%	5.47%
24	50.68%	26.02%	1.36%
25	48.63%	22.94%	0.00%
26	46.57%	19.86%	0.00%
27	44.52%	16.77%	0.00%
28	42.46%	13.69%	0.00%
29	40.41%	10.61%	0.00%
30	38.35%	7.53%	0.00%
31	36.30%	4.44%	0.00%
32	34.24%	1.36%	0.00%
33	32.19%	0.00%	0.00%
34	30.13%	0.00%	0.00%
35	28.08%	0.00%	0.00%
36	26.02%	0.00%	0.00%

Prairie River Unit 2

Fish Length (inches)	0.1	0.15	0.2
1	97.43%	96.14%	94.86%
2	94.86%	92.29%	89.72%
3	92.29%	88.43%	84.58%
4	89.72%	84.58%	79.43%
5	87.15%	80.72%	74.29%
6	84.58%	76.86%	69.15%
7	82.00%	73.01%	64.01%
8	79.43%	69.15%	58.87%
9	76.86%	65.29%	53.73%
10	74.29%	61.44%	48.58%
11	71.72%	57.58%	43.44%
12	69.15%	53.73%	38.30%
13	66.58%	49.87%	33.16%
14	64.01%	46.01%	28.02%
15	61.44%	42.16%	22.88%
16	58.87%	38.30%	17.73%
17	56.30%	34.45%	12.59%
18	53.73%	30.59%	7.45%
19	51.16%	26.73%	2.31%
20	48.58%	22.88%	0.00%
21	46.01%	19.02%	0.00%
22	43.44%	15.16%	0.00%
23	40.87%	11.31%	0.00%
24	38.30%	7.45%	0.00%
25	35.73%	3.60%	0.00%
26	33.16%	0.00%	0.00%
27	30.59%	0.00%	0.00%
28	28.02%	0.00%	0.00%
29	25.45%	0.00%	0.00%
30	22.88%	0.00%	0.00%
31	20.31%	0.00%	0.00%
32	17.73%	0.00%	0.00%
33	15.16%	0.00%	0.00%
34	12.59%	0.00%	0.00%
35	10.02%	0.00%	0.00%
36	7.45%	0.00%	0.00%

Appendix G. Prairie River Project Cultural Resources Study

(Filed as Privileged)