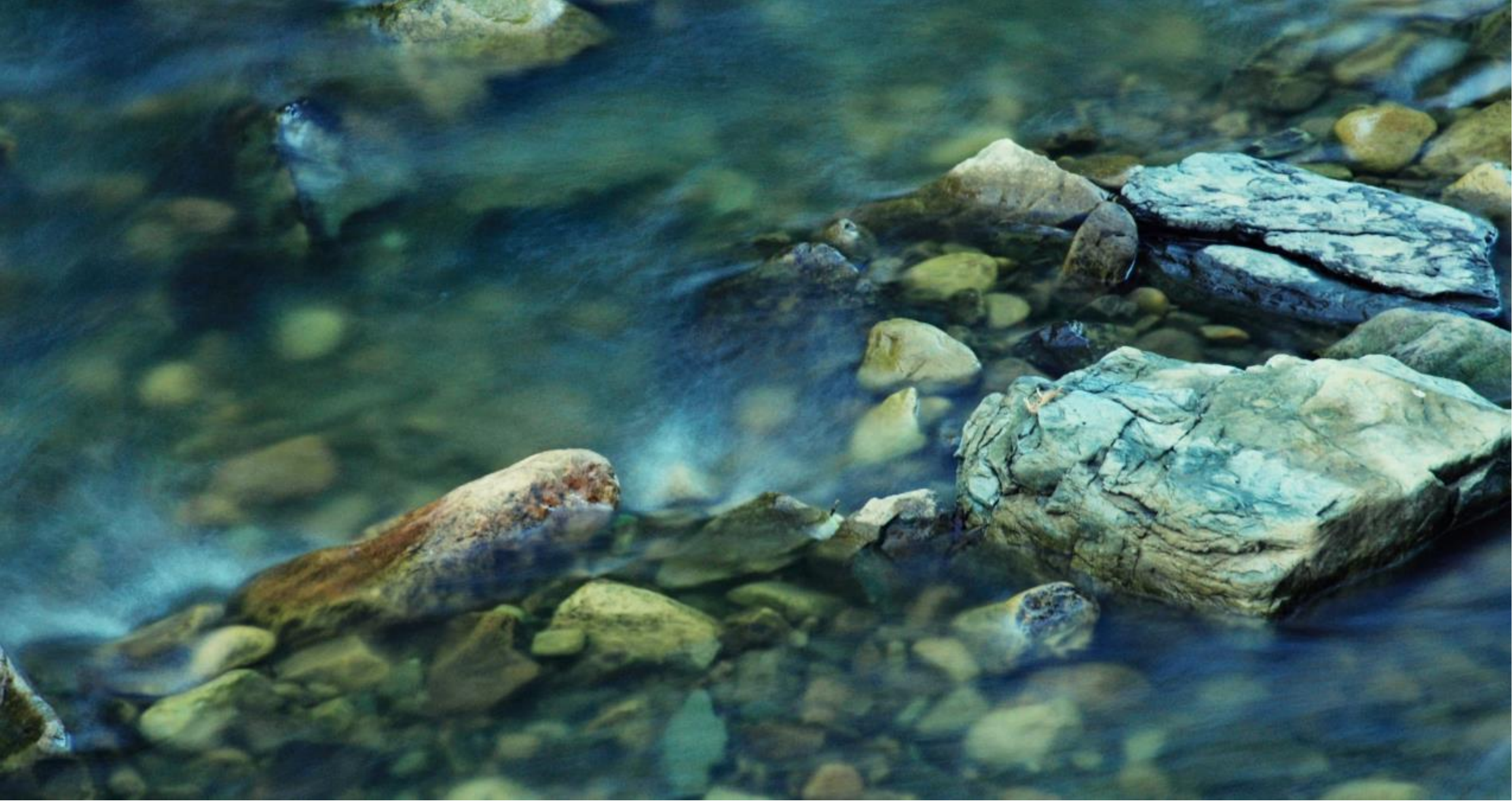

October 2018
USACE Walla Walla District Biological Services

McNary Dam Annual Temperature Report, 2018

Prepared for U.S. Army Corps of Engineers

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Prepared for
U.S. Army Corps of Engineers
201 N Third Avenue
Walla Walla, Washington 99362

Prepared by
Michelle Bahnick and Ben Hagood
Anchor QEA, LLC
23 S Wenatchee Ave, Suite 220
Wenatchee, Washington 98801

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APPENDICES

Appendix A Temperature Logger Problems

ABBREVIATIONS

JFF	Juvenile Fish Facility
kcfs	kilo cubic feet per second
mph	miles per hour

1 Introduction

McNary Dam, located at river mile 292, is the first dam encountered by Columbia River fall Chinook salmon originating from the Hanford Reach and Priest Rapids Hatchery. These fish comprise the largest component of subyearling fall Chinook salmon migrating through McNary Dam, though smaller numbers of Endangered Species Act-listed Snake River fall Chinook salmon also navigate the dam.

The migration of juvenile fall Chinook salmon typically peak in summer months when water temperatures are the highest of the season. High water temperatures may have adverse effects on migrating salmonids. High rates of juvenile salmonid mortality have been associated with high water temperatures at McNary Dam in the past.

During the summer, forebay surface temperatures are warmed by solar radiation and warm air temperatures, though deeper forebay water may remain cooler. Moderate wind speeds (greater than 3 miles per hour [mph]) can mix water in the forebay and decrease surface water temperature. Warm, windless days are typically experienced in July and August and allow surface water to warm unabated.

A portion (0.5% to 25%) of the juvenile salmonids passing McNary are diverted, held for up to 24 hours for examination to determine species composition and condition, and then released to the tailrace. Fish entering the bypass system from the forebay are guided into turbine gatewells (3 gatewells for each of the 14 turbines, totaling 42 gatewells) and away from turbine intakes by extended-length submersible bar screens. In the gatewells, 12-inch orifices lead into the collection channel and the full-flow bypass system that delivers fish to the JFF during secondary bypass operations. Water from the collection channel is diverted over the wet separator at the JFF where smolts and smaller fish are separated from adults and larger fish. While in secondary bypass, most of the separated fish are passed through the JFF system and to the JFF outfall pipe.

High water temperatures in the juvenile bypass system can be mitigated through powerhouse operations. Using a turbine operational strategy that balances the turbines in operation and those in standby across the powerhouse can decrease the magnitude of the temperature and temperature gradients. Turbines in operation draw in warmer surface water while turbines in standby allow cooler, deeper water at orifice depth to passively enter the gatewells. This warm water turbine management pattern can decrease the temperature of water along bypass routes.

The objective of the 2018 Temperature Monitoring Program at McNary Dam was to monitor water temperature patterns in juvenile salmonid passage areas, including the powerhouse, gatewells, collection channel, the JFF, and the JFF outfall pipe. The daily temperatures were analyzed in these areas to identify temperature conditions that might contribute to increased mortality of bypassing fish.

Thank you to the staff at the McNary Dam Juvenile Fish Facility for their advice and support. Bobby Johnson, Denise Griffith, and the U.S. Army Corps of Engineers staff at the Juvenile Fish Facility provided invaluable assistance during each phase of this work. Thank you to Thomas VanNice and Kathleen Carter of Pacific States Marine Fisheries Commission for providing suggestions and assisting with equipment deployment. Thank you also to Anchor QEA, LLC, staff Kristi Geris and Carolyn Roper for their advice and support over the season.

2 Methods

Water temperatures were measured at 0.5-hour intervals (0000 and 0030) from 0700 hours on June 15 to 0700 hours on August 31, 2018. Measurements were taken using Onset Hobo U22-001 data loggers with an accuracy of ±0.38°F and a precision of 0.04°F. The Onset Hobo loggers were purchased in 2017 prior to the start of the temperature monitoring season to replace the aging MadgeTech temperature probes used in prior years. A total of 168.5 hours of water temperature data were lost during the 2018 temperature monitoring season due to ten loggers failing in the field (Appendix A). The Hobo loggers are also used in the adult fishway temperature monitoring program, the data for which can be found in the Juvenile Fish Collection and Bypass Report.

The temperature probes were deployed at 27 locations throughout the McNary Dam project including the forebay, gatewells, collection channel, and the JFF as follows:

- Powerhouse forebay (referred to herein as forebay), near elevation 335 feet in the trolley pipes fitted to the "C" pier nose of Units 1, 3, 5, 7, 8, 10, 12, and 14 (8 total); submerged to a depth of approximately 10 feet below the forebay water surface
- Gatewells, in the center of each "B" slot at each unit (14 total); submerged to a depth of approximately 3 feet below the water surface in the gatewell
- Collection channel, downstream of gatewell orifices 12B and 8B, and upstream of the incline dewatering screen south of Unit 1; submerged to a depth of approximately 2 feet below the water surface in the collection channel
- JFF, in the fish separator underneath the bars in the "B" section and in the "B" sample tank; submerged to a depth of 2 feet below the water surface

Prior to 2017, water temperature loggers were deployed along the spillway and in the tailrace at Units 1 and 14, on the transportation barge dock, and the tailrace navigation lock wing wall. In 2017 the tailrace loggers at Units 1 and 14 and the transportation barge dock were incorporated into the adult fishway temperature monitoring program. A logger placed at the JFF outfall pipe has replaced the tailrace navigation lock wing wall since 2016; however, the JFF outfall pipe was not accessible this year due to damage from high flows. The spillway has not been monitored since 2016.

Daily water temperatures were also recorded at 0700 hours in sample tank "B" using a Fluke 52-2 digital thermometer with a precision of 0.1°F and an accuracy of ±0.54°F. The daily temperature value was reported to McNary Dam biologists as part of the Smolt Monitoring Program. The temperatures recorded at 0700 hours are considered a minimum daily temperature and do not reflect any diurnal fluctuation that may occur.

Weather data was obtained from a Davis Vantage Vue data station positioned at the JFF near the separator and installed before temperature monitoring began, replacing the previous Davis Vantage Pro 2. The station recorded average air temperature, wind velocity over a 0.5-hour period, wind direction, and maximum 0.5-hour wind velocity. The anemometer at the JFF periodically became fouled with spider webs after August 3, which caused it to stop recording wind data. Wind data were periodically obtained from a National Oceanic and Atmospheric Administration monitoring station at the Hermiston, Oregon, airport when the JFF anemometer was not functioning. The data from the Hermiston Airport station is not included in the average wind velocities (Table 1 and Figure 1, below) or the count of days with wind velocities above 3 mph (Table 1, below) for this report.

Daily temperature reports were compiled using water temperatures and weather data collected from 0700 hours of the previous day to 0700 hours of the current day. This time frame coincided with sampling activities at the JFF. Subsequent dates in this report refer to data collected in 2018 unless noted otherwise.

3 Results

3.1 Weather Conditions

The air temperature peaked between 1800 and 2030 hours daily. The daily minimum air temperatures (Table 1) were measured between 0700 and 0900 hours. The maximum air temperature, 107.4°F, was measured at 1830 hours on July 16 (Figure 1, below).

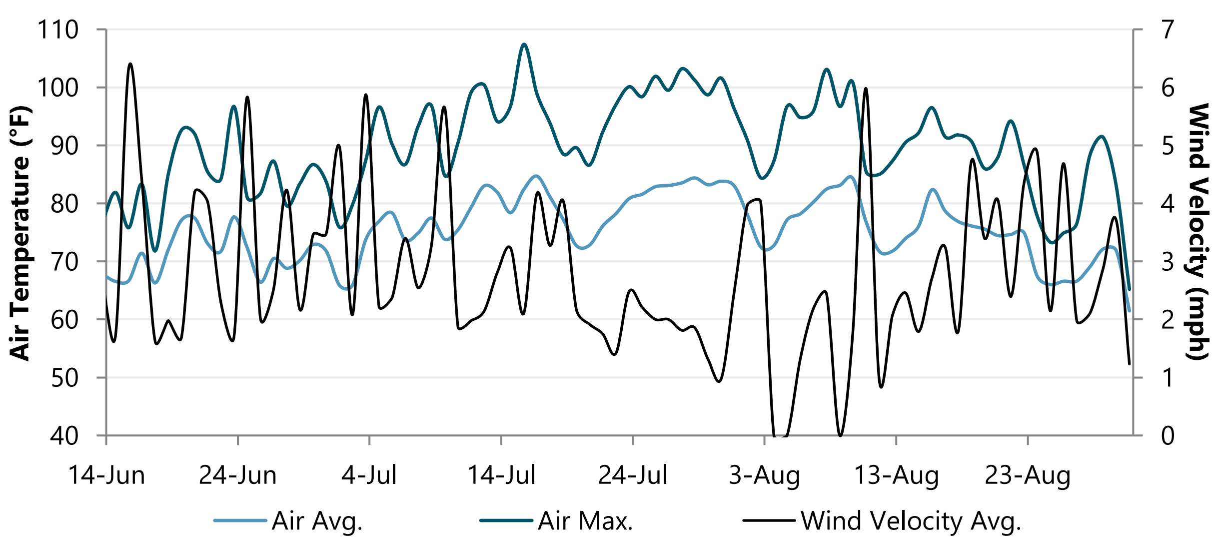
Wind velocity was highly variable throughout the day. June experienced the highest average wind velocity. August had the lowest average wind velocity. The highest average daily wind velocity was June 16 with a daily average wind speed of 21.0 mph.

Table 1
Air Temperatures and Wind Velocity at McNary Dam from 0700 on June 14 to 0700 on August 31, 2018

Month	Daily Avg. (°F)	Daily Max. Avg. (°F)	Daily Min. Avg. (°F)	Max. Range (°F)	Min. Range (°F)	Days >90°F*	Wind Avg. (mph)	Days >3 mph**
June†	71.1	83.8	58.8	71.8–96.7	52.2–68.7	3	3.11	17
July	78.0	94.0	63.6	75.9-107.4	52.1-70.6	22	2.69	31
August	74.7	88.5	62.6	65.2-103.1	53.4-71.4	16	2.64	28

Notes:
* Count of days with highs exceeding 90°F
** Days with at least one 0.5-hour period with wind velocity exceeding 3 mph
† Monitoring occurred June 15 to June 30

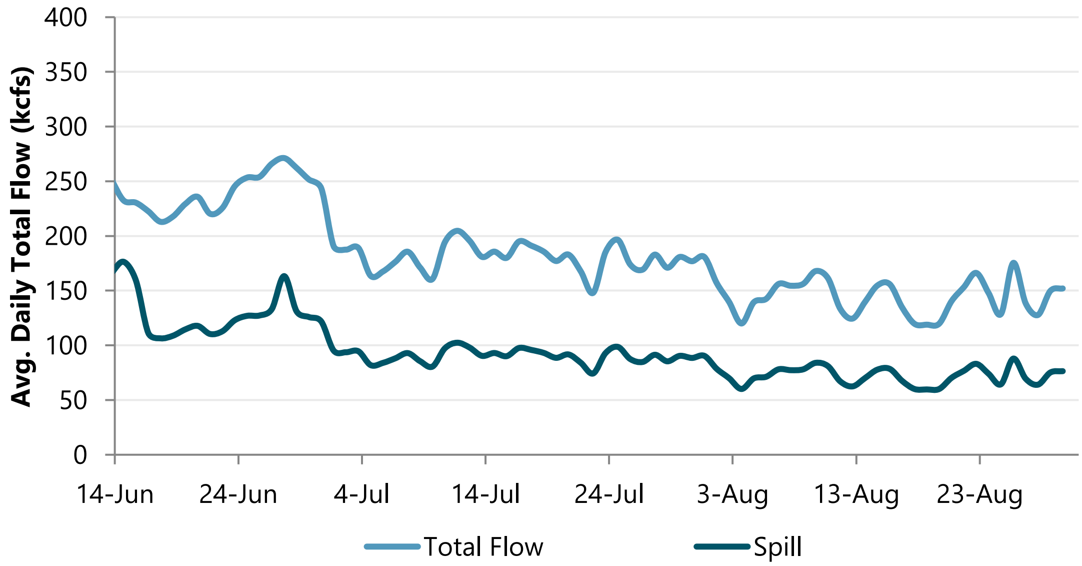
Figure 1
Average and Maximum Daily Air Temperatures and Average Wind Velocity from 0700 on June 14 to 0700 on August 31, 2018



3.2 River Flow and Spill

Total river flow during the monitoring period from June 15 to August 31 averaged 179.2 kilo cubic feet per second (kcfs). The peak average daily total river flow (271.2 kcfs) was recorded on June 28. The minimum average daily total river flow (118.9 kcfs) was recorded on August 19 (Figure 2, below). Monthly average total river flow over the monitoring period in June, July, and August was 239.5 kcfs, 182.6 kcfs, and 144.6 kcfs, respectively. Monthly average spill for the same period in June, July, and August was 128.0 kcfs, 91.4 kcfs, and 72.5 kcfs, respectively. Spill constituted 53.5%, 50.1%, and 50.1% of total flow for June, July, and August, respectively.

Figure 2
Total River Flow and Spill from 0700 on June 14 to 0700 on August 31, 2018



3.3 Powerhouse Forebay and Gatewell Temperatures

Daily water temperature patterns in the forebay and gatewells trended with air temperatures and wind velocity. Daily maximum average forebay water temperatures were recorded between 1300 and 0130 hours and most frequently recorded at 1830 hours. Daily minimum average forebay water temperatures were recorded between 0300 and 1200 hours and most frequently recorded at 0700 and 0730 hours.

Forebay water temperatures reached 68°F at 1930 hours on June 15 at Unit 12. The average water temperature across the forebay reached 68°F on June 20 for short periods of time (Figure 3, below). The forebay average was consistently above 68°F starting on July 11. McNary dam began warm water turbine operations on July 8. The forebay reached seasonal maximum average water temperatures on June 20. The maximum water temperature recorded in the forebay was 80.6°F at 1800 hours on July 26 at Unit 5. The average forebay water temperature was 76.7°F at that time. The maximum average forebay water temperature of 77.7°F was recorded at 1830 hours on July 16 (Table 2, below).

The average water temperature gradient across the forebay was 1.8°F from June 15 to August 31 (Figure 4, below) and ranged from 0.1°F to 10.3°F. The largest gradients across the forebay formed between 1430 and 2030 hours daily. The largest water temperature gradient across the forebay was 10.3°F at 1730 hours on July 26.

Figure 3
Average Water Temperatures of 8 Forebay and 14 Gatewell Locations from 0700 on June 14 to 0700 on August 31, 2018

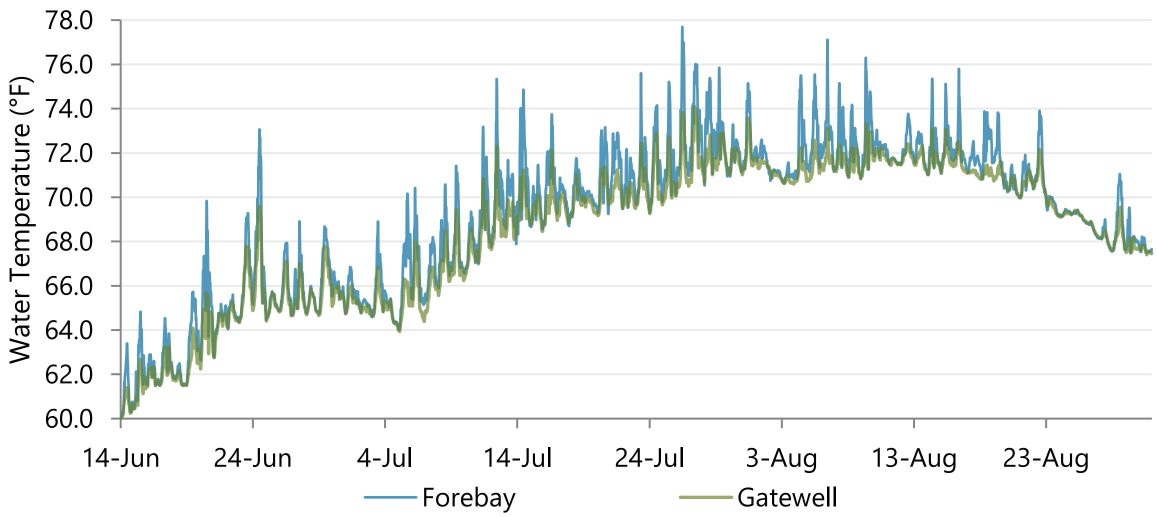
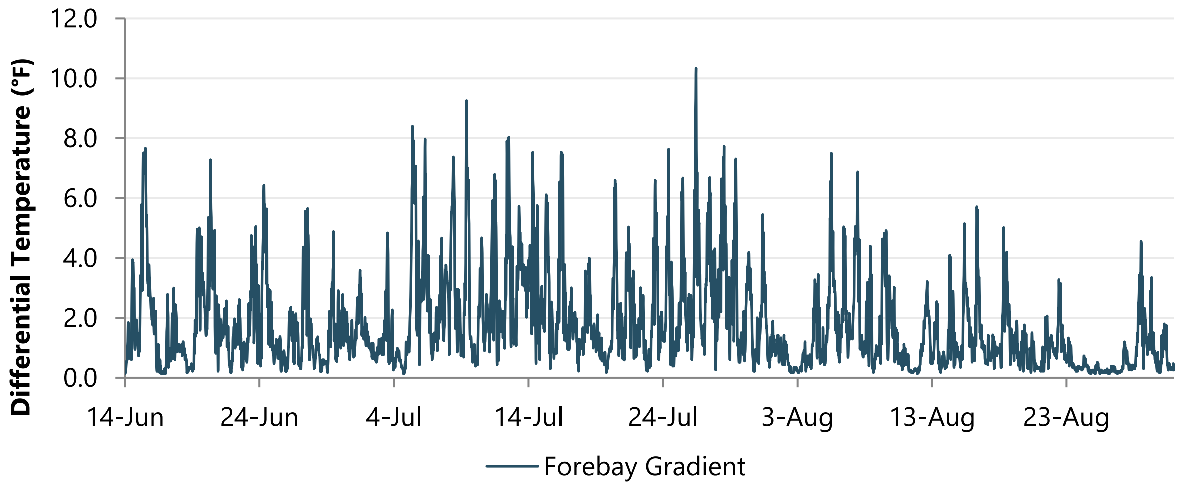


Table 2
Average Forebay and Gatewell Water Temperatures in June, July, and August 2018

Location	June*	July	August
Forebay	64.5°F	69.6°F	71.1°F
Gatewell	64.1°F	68.9°F	70.6°F

Note:
* June 15 to June 30

Figure 4
Temperature Gradient Between Minimum and Maximum Water Temperatures Recorded Across Eight Forebay Positions for Each 0.5-Hour Period from 0700 on June 14 to 0700 on August 31, 2018



Gatewell water temperatures trended with forebay water temperatures, but did not reach the same extremes observed in the forebay. The average gatewell water temperatures reached 68°F on June 24 for short periods of time, and gatewell water temperatures were consistently above 68°F after July 11. The gatewell reached a seasonal maximum average water temperature of 74.1°F at 1630 hours on July 27. The maximum water temperature recorded in the gatewells was 78.3°F at 1900 hours on July 27 at Unit 1. The forebay at Unit 1 was 78.5°F at that time. The average temperature gradient across the gatewells was 2.4°F from June 15 to August 31 (Figure 5, below) and ranged from 0.1°F to 9.3°F. The largest temperature gradient across the gatewell was 9.3°F at 1700 hours on July 9.

The water temperature between the forebay and gatewells differed by 0.8°F on average (Figure 6, below). The forebay was warmer than the corresponding gatewell on average for each unit from June 15 to August 31. The largest water temperature differences between the forebay and gatewell were observed when units were in stand-by. The maximum water temperature differential was 11.5°F at 1800 hours on July 26 at Unit 5. Unit 5 was in stand-by. The number of units in stand-by increased once warm water turbine operation began on July 8.

Figure 5
Temperature Gradient Between Minimum and Maximum Water Temperatures Recorded Across 14 Gatewell Positions for Each 0.5-Hour Period from 0700 on June 14 to 0700 on August 31, 2018

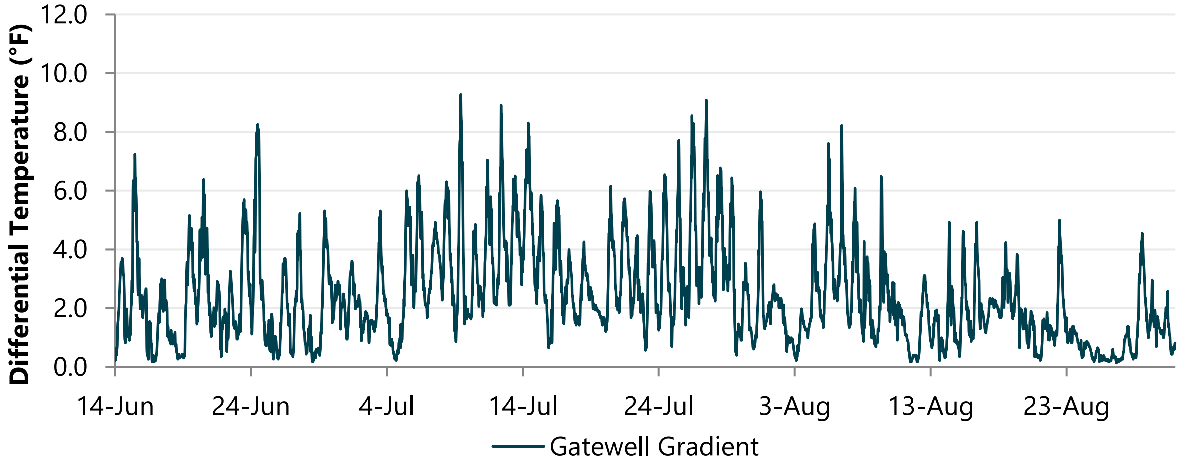
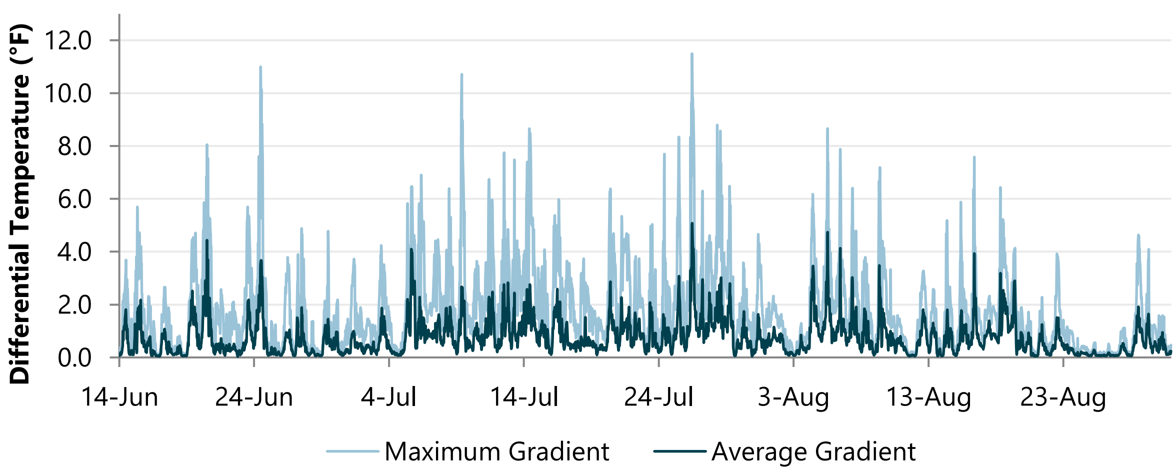


Figure 6
Maximum and Average Water Temperatures Gradient Recorded Between the Forebay and Gatewells for Each 0.5-Hour Period from 0700 on June 14 to 0700 on August 31, 2018



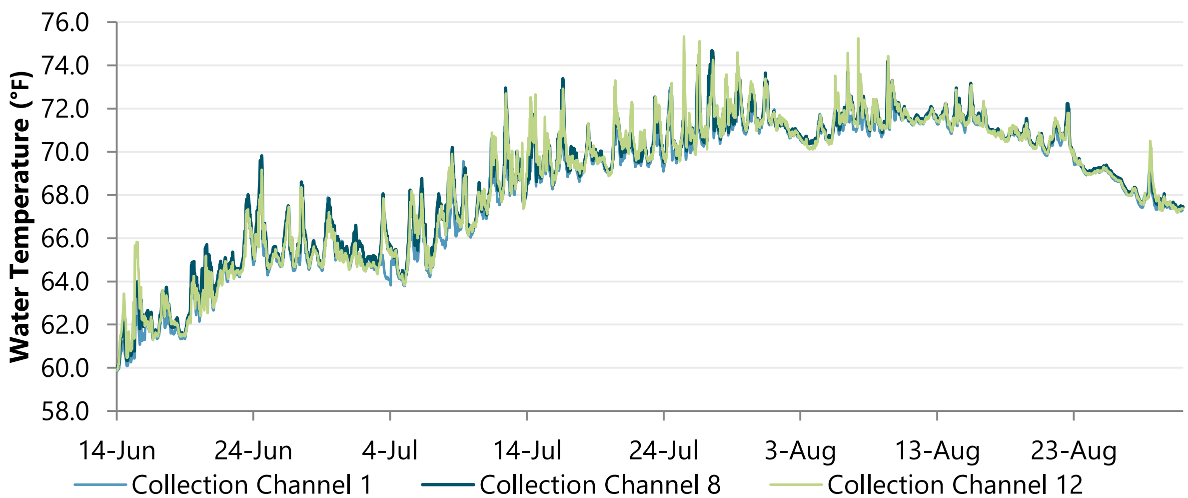
3.4 Collection Channel

Water temperatures in the collection channel were less variable than in the forebay and gatewells. Water temperatures across the collection channel averaged 68.5°F from June 15 to August 31 (Table 3, below). Collection channel water temperatures reached an average of 68°F on June 30 for short periods of time and were continuously exceeding 68°F after July 11 (Figure 7, below). The maximum water temperature of 75.3°F was measured at 1830 hours on July 25 at Unit 12.

Table 3
Water Temperatures in the Collection Channel from 0700 on June 14 to 0700 on August 31, 2018

Seasonal Average (°F)	Seasonal Maximum (°F)	Date of Maximum
68.5	75.3	July 25

Figure 7
Water Temperatures for Three Collection Channel Locations from 0700 on June 14 to 0700 on August 31, 2018



The average water temperature gradient between the gatewells and the collection channel was 0.7°F from June 15 to August 31 (Figure 8, below) and ranged from 0.0°F to 4.2°F. Typically, the gatewell was warmer than the collection channel at Unit 1 and Unit 12 and cooler than the collection channel at Unit 8. The maximum water temperature differential was 5.9°F at 1830 hours on August 5 at Unit 1, with the collection channel being cooler than the gatewell. The average water temperature differential between the collection channel at Unit 12 and Unit 1 was 0.4°F from June 15 to August 31 (Figure 9, below). The maximum water temperature gradient between the collection channel at Unit 12 and Unit 1 was 4.0°F at 1230 hours on August 7, with the water at Unit 12 being warmer than at Unit 1. On average, the collection channel was warmer at Unit 12 than at Unit 1. Differences between the water temperatures at the two locations exceeded 2.0°F on 14 days between June 15 and August 31 for short periods of time, typically between 1600 and 1930 hours.

Figure 8
Water Temperature Gradient Recorded Between Three Gatewells and Corresponding Collection Channel Locations (Gatewell Minus Collection Channel) for Each 0.5-Hour Period from 0700 on June 14 to 0700 on August 31, 2018

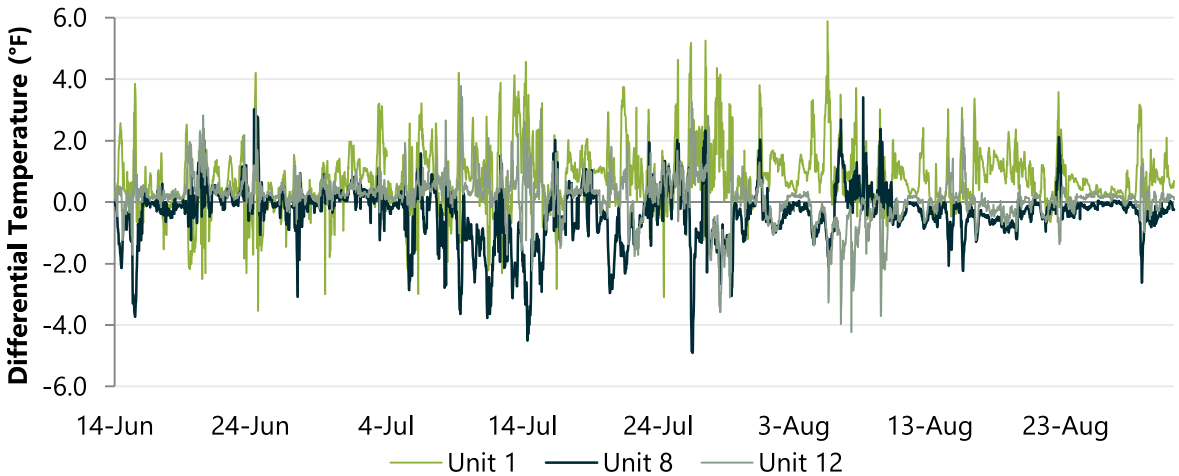
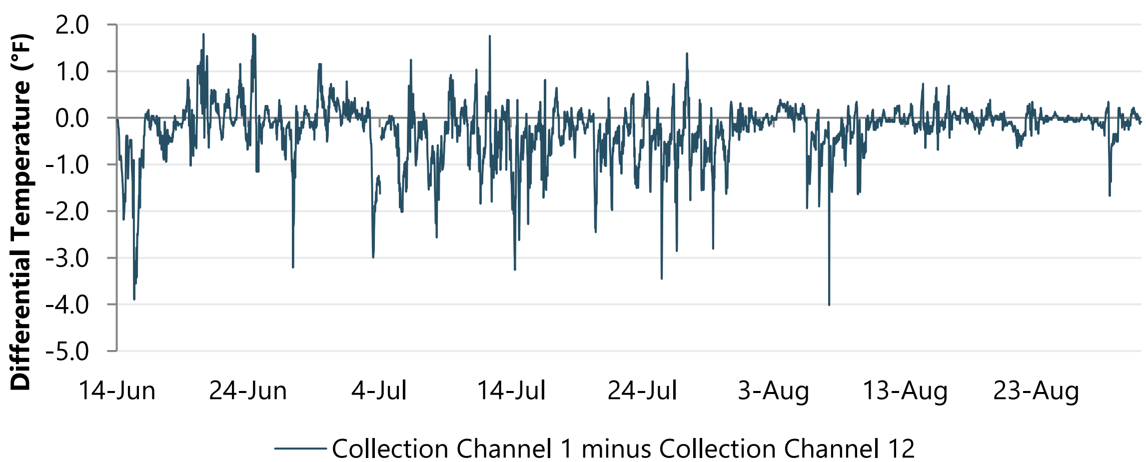


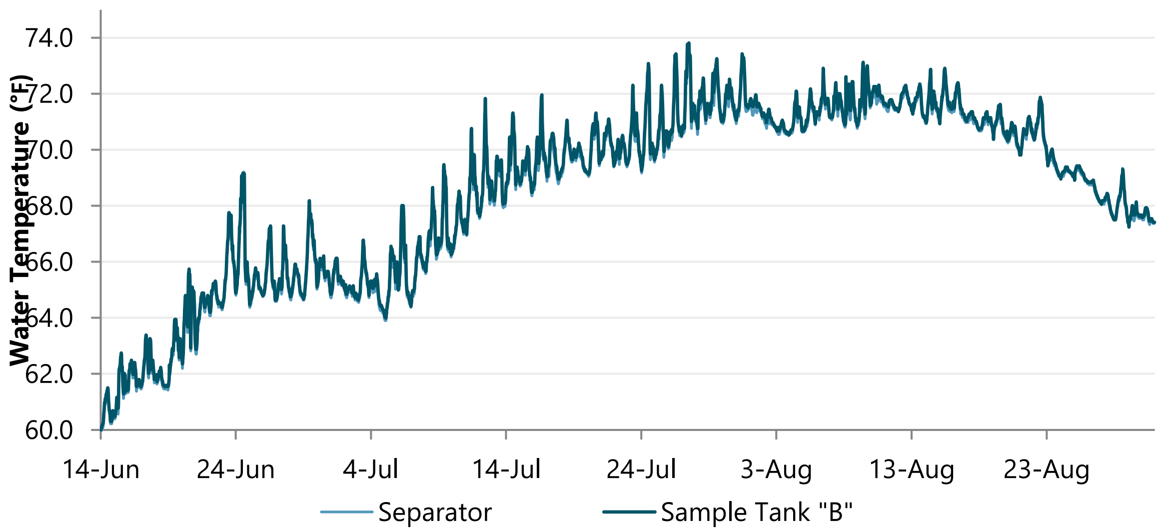
Figure 9
Gradient Recorded Between Water Temperatures at Collection Channel 1 and Collection Channel 12 from 0700 on June 14 to 0700 on August 31, 2018



3.5 Juvenile Fish Facility

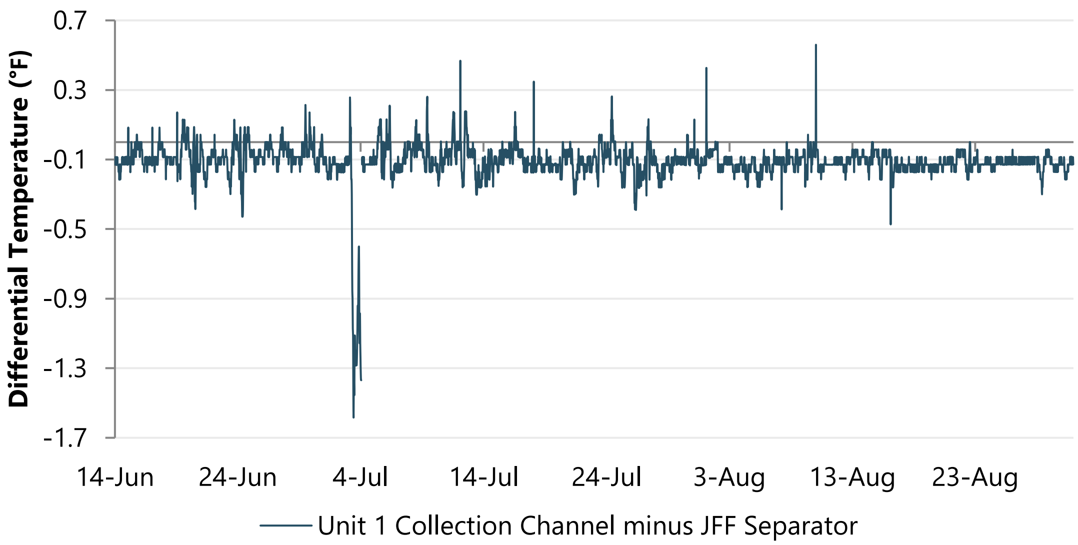
The average water temperature at the JFF from June 15 to August 31 was 68.5°F. Average water temperatures reached 68°F on June 24 (Figure 10, below) for short periods of time during the day. Water temperatures continuously exceeded 68°F after July 11. The maximum temperature of 73.8°F was measured at 1930 hours on July 27 at the sample tank "B".

Figure 10
Average Water Temperatures for Two Juvenile Fish Facility Locations from 0700 on June 14 to 0700 on August 31, 2018



The temperature gradient between the collection channel at Unit 1 and the separator at the JFF averaged 0.1°F and ranged from 0.0°F to 1.6°F (Figure 11, below). The separator was typically warmer than the collection channel. The temperature gradient across the separator and sample tank "B" averaged 0.1°F. The maximum difference between the two JFF locations was 1.5°F at 1030 hours on August 8 when sample tank "B" was warmer than the separator. There was a noticeably large differential from 1400 hours on July 3 until 0800 hours on July 4 (there was no data at collection channel 1 at 0830 or 0900 hours on July 4); the collection channel at Unit 1 was more than 0.8°F cooler than the separator and other collection channel probes. This may have been caused by cleaning of the vertical barrier screens during this time. The vertical barrier screens are cleaned in the gatewell slots by water sprayed from fire hoses, which potentially introduced colder water into the collection channel via the gatewell orifices.

Figure 11
Water Temperature Gradient Recorded Between the Collection Channel at Unit 1 and Juvenile Fish Facility Separator from 0700 on June 14 to 0700 on August 31, 2018



3.6 Outfall Pipe

The outfall pipe was inaccessible for the entire 2018 temperature monitoring season. The outfall pipe water temperature data would generally be displayed in Figures 12 (outfall water temperature over time), 13 (temperature gradient between water at the forebay and the outfall pipe), and 14 (temperature gradient between water at the separator and the outfall pipe). The last year data were collected was 2017.

3.7 Fish Passage and Mortality

A total of 665,460 juvenile salmonids passed McNary Dam during the monitoring period from June 15 to August 31. Subyearling Chinook salmon constituted 99.5% of the total during this period. The majority of these fish passed McNary Dam in July (Table 4, below). By July 19, 90% of fish migrating during the monitoring period had bypassed the dam. In previous years, high juvenile mortality at McNary has been correlated with high water temperatures and large temperature gradients along juvenile bypass routes through the powerhouse and JFF. Mortality was low during this monitoring period. Total facility mortality for subyearling Chinook salmon alone and for all salmon species combined was 0.01% of bypassed fish over the monitoring period (subyearling Chinook salmon, 62 mortalities; all other species combined, 2 mortalities).

The sample mortality rate may or may not be an indicator of the health status of the total population bypassing the facility since these fish are held for up to 24 hours and then go through the sampling process. Sample mortalities for subyearling Chinook salmon alone was 0.6% of sampled fish during the monitoring period (subyearling Chinook salmon, 32 sample mortalities; all other species combined, 1 mortality).

Table 4
Collection, Mortality, and Passage for Juvenile Salmonids in 2017 and 2018

Year	System			Sample			Passage			
	Collection	Mortality	% Mortality	Sample	Sample Mortality	% Mortality	25%	50%	75%	90%
2018	665,460	64	0.01%	5,266	33	0.6%	25-Jun	3-Jul	11-Jul	19-Jul
	Sample Tank "B" Temperature (°F)*						64.4	64.4	67.2	69.8
2017**	889,307	83	<0.1%	7,444	43	0.6%	28-Jun	4-Jul	14-Jul	26-Jul
	Sample Tank "B" Temperature (°F)*						63.2	66.6	68.7	70.3

Notes:
* Sample tank temperature was taken at 0700 daily.
** Values for 2017 include data recorded June 15 to August 31.

4 Recommendations

Continue to employ the warm water turbine operation strategy. Turbine operation continues to be an effective tool in mitigating high water temperatures and temperature gradients in fish passage routes through the powerhouse and the JFF. This operation plan is most effective in reducing high water temperatures from the forebay in the early season because deeper forebay water has not been warmed by prolonged high air temperatures.

Consider moving the port-a-potty from the Unit 10 "C" pier of the forebay (station F10) to another "C" pier. The port-a-potty makes it much more difficult to access the trolley pipe to deploy and collect data from the HOBO data logger.

Consider adding small buoys to the temperature deployment devices to maintain a more consistent water depth for the temperature probes. While the water levels were fairly constant, and only fluctuated a few inches at a time, such a modification could allow for the temperature collection devices to self-regulate their depth. In turn, this could increase consistency with the stated methodology than occurred during the 2018 season (the depth of each logger is currently altered manually once per day, but only if necessary changes are noticed during the temperature data collection).

Appendix A
Temperature Logger Problems

Appendix A: Temperature Logger Problems

Anchor QEA obtained 34 HOBO U22-001 submersible temperature loggers in 2017. Of these loggers, 30 were purchased from Onset Computer Corporation in April 2017 and four were previously-used loggers obtained from the USACE Walla Walla District office. During water temperature monitoring, 28 loggers continuously log temperature data throughout the McNary Dam Project (27 when the JFF outfall pipe is not accessible) leaving up to six spare temperature loggers as replacements.

During the 2017 temperature monitoring season, two of the loggers purchased from Onset stopped functioning and were replaced under warranty in July 2017 (6.7% failure rate) and six other loggers purchased from Onset had errors while collecting data (e.g., failed to collect data after offloading; Table A–1, below).

During the 2018 temperature monitoring season, ten of the remaining 28 loggers purchased from Onset in 2017 and one of the loggers obtained from the Walla Walla District office had battery failures in the field or did not function at the start of the season (a 35.7% failure rate in 2018; Table A–1, below). Nine of the failed loggers purchased in 2017 were replaced under warranty by Onset and the tenth may be replaced after the loggers returned to Onset are assessed by their technical team. As a result of temperature logger malfunctions, 168.5 hours of water temperature data in 2018 were lost between June 15 and August 31. None of the lost data have been recovered by Onset as of October 2, 2018. Additionally, out of the remaining 18 loggers purchased from Onset, five had data collection errors. Two loggers recorded “bad headers” when offloaded, one had an optical misread that caused it to begin a different logging interval, and one had its battery reset. All five of these loggers began to work normally after they were re-launched.

At the end of the 2018 temperature-monitoring season, Anchor QEA has 32 functioning HOBO U22-001 temperature loggers and two loggers that may be returned to Onset for replacements at a later date. Onset Computer Corporation is assessing the returned loggers to determine the most likely causes for the high rate of failure.

Table A–1
Water Temperature Loggers (Hobo U22-001) That Have Produced Errors Since 2017

Serial Number	Date Obtained	Date failed	Replaced?	Notes
20105949	4/1/2017	8/20/2018	Yes	Failed to offload to Shuttle. Logger failed to connect to Shuttle (dead battery) 8/27/2018.
20105951	4/1/2017	8/28/2018	Yes	Failed to offload to Shuttle.
20105953	4/1/2017	8/25/2018	Yes	Failed to connect to Shuttle.
20105956	4/1/2017	9/1/2018*	No	Failed to stop after season until the logger was relaunched.
20105957	4/1/2017	6/28/2017	Yes	Produced a corrupted file.
20105958	4/1/2017	8/15/2018*	No	Produced a "Bad Header 14" warning, but data were recovered and logger reset correctly after re-launching.
20105964	4/1/2017	2018 calibration	Yes	Did not communicate with HOBOware during calibration.**
20105965	4/1/2017	6/24/2018	Yes	Failed to connect to Shuttle.**
20105966	4/1/2017	7/2/2018*	No	Produced a "Bad Header 13" title to HOBO file, but data were recovered and logger reset correctly after re-launching.**
20105967	4/1/2017	8/31/2018	No	Failed to offload to Shuttle, log new temperature data, and to turn off. Waiting for Onset assessment of previously returned loggers before returning.
20105968	4/1/2017	2018 calibration	Yes	Failed to connect to Shuttle during calibration. **
20105969	4/1/2017	6/24/2018	Yes	Failed to connect to Shuttle.
20105970	4/1/2017	7/20/2018	Yes	Failed to record data 7/16 to 7/17, 7/19 to 7/20, and after re-launching on 7/20/2018. Continued to fail to record new temperature data.
20105976	4/1/2017	6/20/2017	Yes	Failed to offload data.
20105977	4/1/2017	8/4/2018	Yes	Failed to connect to Shuttle.**
20171665	7/17/2017	8/2/2018*	No	Began a logging interval of 18m 40s; logger reset correctly after re-launching.
10420516	2017 (from COE)	8/20/2018	No	Failed to connect to Shuttle. Outside of warranty.

Notes:
11 loggers have been replaced by Onset Computer Corporation under warranty.
* Logger had an error but the problem was resolved.
** Logger had a previous data collection problem in 2017