October 2017
USACE Walla Walla District Biological Services

McNary Dam Annual Temperature Report, 2017

Prepared for U.S. Army Corps of Engineers

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Prepared for
U.S Army Corps of Engineers
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ABBREVIATIONS

ESA	Endangered Species Act
JFF	Juvenile Fish Facility
kcfs	kilo cubic feet per second
mph	miles per hour
NOAA	National Oceanic and Atmospheric Administration

Acknowledgements

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 Hannah Begley of the Pacific States Marine Fisheries Commission for providing suggestions and assisting with equipment deployment. Thank you also to Anchor QEA, LLC, staff Jaqi Walt for her assistance in daily tasks and Kristi Geris and Carolyn Roper for their advice and support over the season.

1 Introduction

Fall Chinook salmon typically begin seaward migration within months of emergence as subyearlings (Healey 1991). 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 Chinook salmon migrating through McNary Dam, though smaller numbers of Endangered Species Act (ESA)-listed Snake River fall Chinook salmon stock also navigate the dam.

Migration of juvenile fall Chinook salmon typically peak in summer months when water temperatures tend to be at their seasonal maximum. High water temperatures may have adverse effects on migrating salmonids, the nature of which is dependent on the magnitude and duration of the exposure as well as the acclimation status of the fish (Richter and Kolmes 2005). High rates of juvenile salmonid mortality have been associated with high water temperatures at McNary Dam in the past (Hoffarth 2000).

During the summer, forebay surface temperatures are warmed by solar radiation and warm air temperatures, though deeper forebay water may remain cooler (Haskell et al. 2004). Moderate wind speeds (greater than 3 miles per hour [mph]) can mix water in the forebay and decrease surface water temperature. Warm, windless days typically experienced in July and August allow surface water to warm unabated.

Juvenile salmonids passing at the powerhouse may follow a juvenile bypass system through the dam to the Juvenile Fish Facility (JFF) and the tailrace. Fish entering the bypass system from the forebay are guided into turbine gatewells (3 for each turbine — 42 in total) and away from turbine intakes by extended-length submersible bar screens. In the gatewells, 12-inch orifices lead into a collection channel and a full-flow system that delivers fish to the JFF outfall pipe that exits channel center in the tailwater approximately 1,100 feet downstream of the dam. Every other day, the system is switched to secondary bypass operations. Water from the collection channel is diverted over a 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. A portion (0.5 to 25 percent) of the fish passing are diverted, held for up to 24 hours for examination to determine their species make-up and health, and then released to the tailrace.

High water temperatures in the juvenile bypass route through the powerhouse can be mitigated through powerhouse operations. Using a turbine operational strategy that balances turbines in operational mode and stand-by mode across the powerhouse decreases the magnitude of the temperature and temperature gradients. Turbines in operational mode draw in warmer surface water while stand-by turbines allow cooler, deeper water at the orifice depth passively into the gatewells from the forebay. This warm water turbine management pattern can decrease the temperature of water along bypass routes.

The objective of the 2017 Temperature Monitoring Program at McNary Dam was to monitor water temperature patterns in fish 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.

2 Methods

Water temperatures were measured at half-hour intervals (0000 and 0030) from 0700 hours on June 15 to 0700 hours on August 31, 2017. 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. The Hobo loggers are also used in the adult fishway temperature monitoring program.

The temperature probes were deployed at 28 locations throughout the McNary Dam powerhouse including the forebay, gatewells, and collection channel as well as the JFF and JFF outfall pipe 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); in approximately 10 feet of water.
- Gatewells, in the center of each "B" slot at each unit (14 total) in approximately 3 feet of water
- Collection channel, downstream of gatewell orifices 12B and 8B, and upstream of the incline dewatering screen, south of Unit 1
- JFF, in the fish separator underneath the bars in the "B" section, the sample tank "B" in approximately 2 feet of water
- JFF outfall pipe, approximately 40 feet from the exit in 10 feet of water (This logger was not deployed until July 6 due to high river flows prior to this date that precluded pipe access.)

In previous years, 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. The tailrace loggers at Units 1 and 14 and the transportation barge dock were incorporated into the adult fishway temperature monitoring program. The logger placed at the JFF outfall pipe has replaced the tailrace navigation lock wing wall. The spillway was not monitored this year.

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 Pro 2 data station positioned at the JFF near the separator. The station recorded average air temperature, wind velocity over a half-hour period, wind direction, and maximum half-hour wind velocity. The anemometer at the JFF became fouled with spider webs and stopped functioning properly on August 17. The anemometer was cleaned and repaired on August 23. Wind data for 0000 hours August 17 to 1700 hours August 23 were obtained from a National Oceanic and Atmospheric Administration (NOAA) monitoring station at the Hermiston, Oregon airport. The data from this station is not included in the analysis for this report, but included in Appendix A.

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 2017 unless noted otherwise.

3 Results

3.1 Weather Conditions

The air temperature peaked between 1430 and 2000 hours daily. The daily minimum air temperatures (Table 1 below) were measured between 0230 and 0700 hours. The maximum air temperature, 103.3 °F, was measured at 1900 hours on July 6 (Figure 1 below). Heavy smoke from August 2 to Aug 12 may have reduced the solar radiation reaching the water in the forebay despite these days being cloudless with little to no wind.

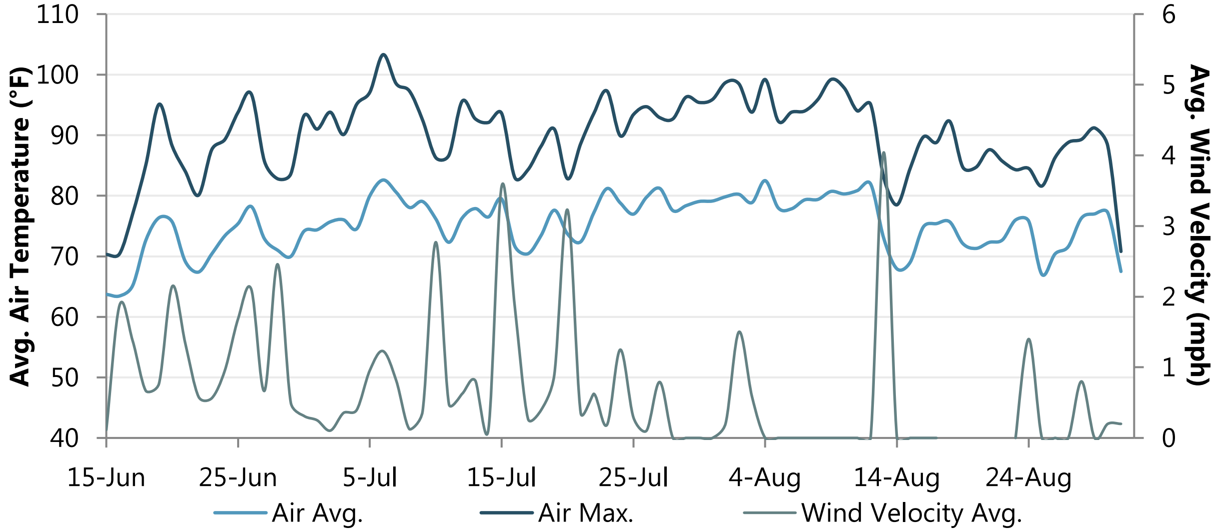
Wind, when present, was highly variable throughout the day. June experienced the highest average wind velocity. August had the lowest average wind velocity. The highest average daily wind velocity was August 13 with a daily average wind speed of 4.0 miles per hour.

Table 1
Air Temperatures and Wind Velocity at McNary Dam from June 15 to August 31, 2017

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*	71.2	85.2	59.3	70.3 – 96.8	52.2 – 67.9	4	1.1	15
July	77.0	92.4	64.6	82.8 – 103.3	57.0 – 71.1	23	0.8	23
August	75.6	89.6	63.7	70.8 – 99.2	53.5 – 74.6	14	0.4***	7***

Notes:
* Monitoring occurred June 15 to June 30
** Count of days with highs exceeding 90 °F
***Wind data omitted 0000 hours August 17 to 1700 hours August 23 due to anemometer malfunction. Data recorded at the Hermiston, OR airport for the omitted time period is included in Appendix A.
† Days with at least 1 half-hour period with wind velocity exceeding 3 miles per hour (mph)

Figure 1
Average and Maximum Daily Air Temperature and Average Wind Velocity from June 15 to August 31, 2017

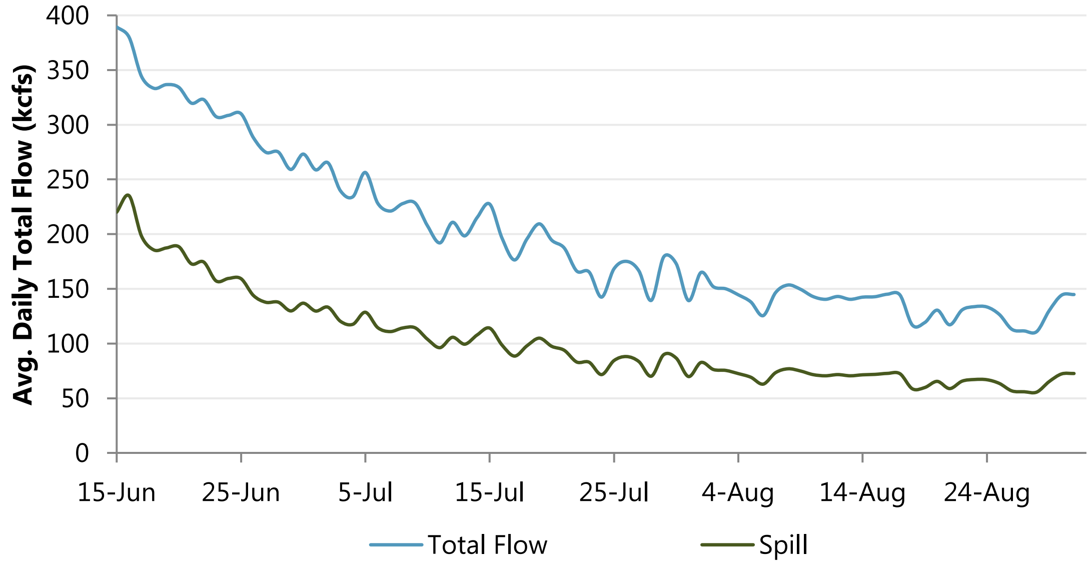


Notes:
mph: miles per hour
Wind velocity data from 0000 hours August 17 to 1700 hours August 23 omitted due to anemometer malfunction.

3.2 River Flow and Spill

High spring run-off was preceded by above average winter precipitation. Total river flow during the monitoring period from June 15 to August 31 averaged 198.3 kilo cubic feet per second (kcfs). The peak average daily total river flow (389.4 kcfs) was recorded on June 15. The minimum average daily total river flow (110.9 kcfs) was recorded on August 28 (Figure 2 below). Monthly average total river flow over the monitoring period in June (15 to 30), July, and August was 316.1 kcfs, 199.5 kcfs, and 136.4 kcfs, respectively. Monthly average spill for the same period in June, July, and August was 170.3 kcfs, 100.1 kcfs, and 68.4 kcfs, respectively. Spill comprised 53.9, 50.1, and 50.1 percent of total flow for June, July, and August, respectively.

Figure 2
Total River Flow and Spill from June 15 to August 31, 2017



Note:
kcfs: kilo cubic feet per second

3.3 Powerhouse Forebay and Gatewell Temperatures

Daily temperature patterns in the forebay and gatewells trended with air temperatures and wind velocity. Daily maximum average forebay temperatures were recorded between 1300 hours and 0130 hours and most frequently recorded at 1800 hours. Daily minimum average forebay temperatures were recorded between 0330 hours 1230 hours and most frequently recorded at 0700 and 0730 hours.

Forebay temperatures began reaching 68 °F at 1600 hours on June 26 at Units 10 and 12. The average temperature across the forebay began reaching 68 °F on June 27 for short periods of time after 1200 hours (Figure 3 below). The forebay average was consistently above 68 °F starting on July 7. McNary operations were advised to begin warm water turbine operation on July 8. The forebay reached seasonal maximum average temperatures on July 31. The maximum temperature recorded in the forebay was 82.5 °F at 1730 hours on July 31 at Unit 1. The average forebay temperature was 79.2 °F at that time. The maximum average forebay temperature of 80.1 °F was recorded at 1800 hours on July 31 (Table 2 below).

The average temperature gradient across the forebay was 2.1 °F from June 15 to August 31 (Figure 4 below) and ranged from 0.1 °F to 10.6 °F. The largest gradients across the forebay formed between

1400 and 2100 hours daily. The largest temperature gradient across the forebay was 10.6 °F at 1400 hours on July 5.

Figure 3
Average Temperatures of 8 Forebay and 14 Gatewell Locations from June 15 to August 31, 2017

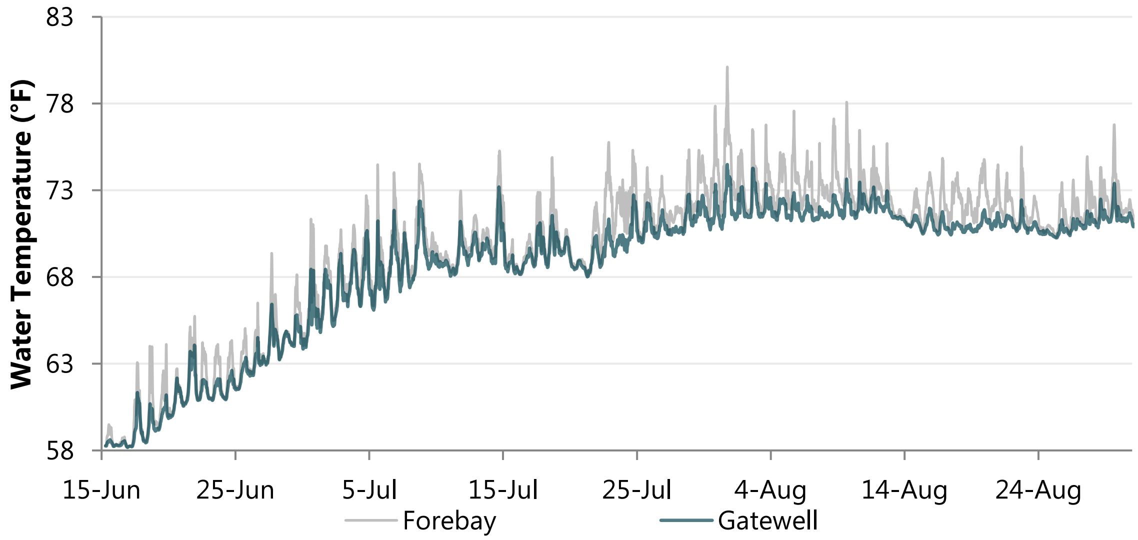
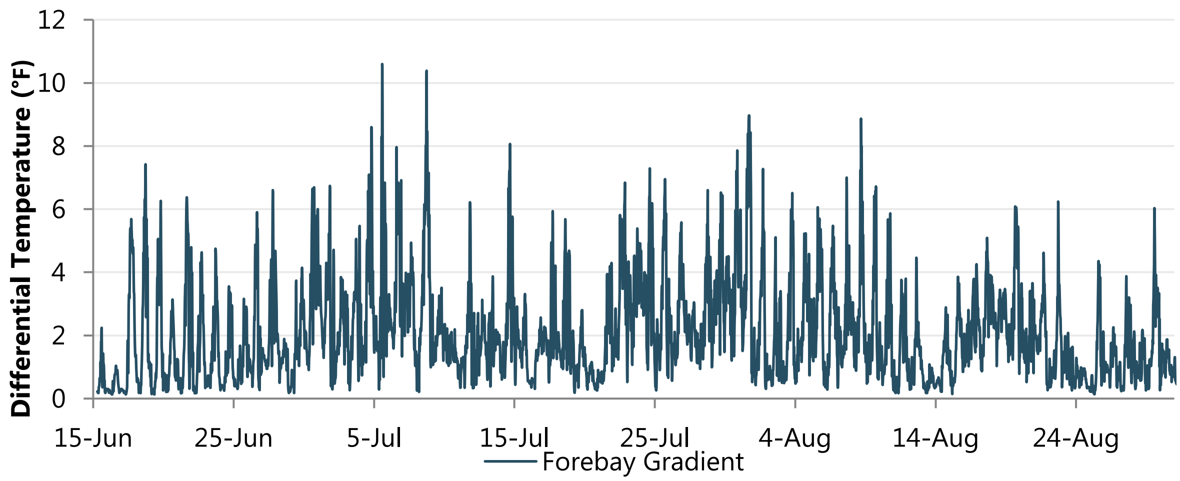


Table 2
Average Forebay and Gatewell Temperatures in June, July, and August 2017

Location	June*	July	August
Forebay	62.3 °F	70.4 °F	72.5
Gatewell	61.7 °F	69.5 °F	71.4

Note:
* June 15 to June 30

Figure 4
Temperature Gradient Between Minimum and Maximum Temperature Recorded Across 8 Forebay Positions for Each Half-hour Period from June 15 to August 31, 2017



Gatewell temperatures trended with forebay temperatures, but did not reach the same extremes observed in the forebay. The average gatewell temperatures began reaching 68 °F on June 30 for short periods of time, and gatewell temperatures were consistently above 68 °F after July 8. The gatewell reached a seasonal maximum average temperature of 74.5 °F at 1800 hours on July 31. The maximum temperature recorded in the gatewells was 78.5 °F at 1600 hours on August 9 at Unit 12. The forebay at Unit 12 was 79.9 °F at that time. The average temperature gradient across the gatewells was 2.7 °F from June 15 to August 31 (Figure 5 below) and ranged from 0.2 °F to 8.8 °F. The largest temperature gradient across the gatewell was 8.8 °F at 2030 hours on July 6.

The temperature between the forebay and gatewells differed by 1.2 °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 temperature gradients between the forebay and gatewell were observed between the forebay and units in stand-by mode. The maximum temperature differential was 12.7 °F at 1730 hours on July 31 at Unit 1. Unit 1 was in stand-by mode. The number of units in stand-by mode increased once the warm water operational pattern began on July 8. However, smolts were most likely not passing at these units due to lack of attractive water flow. The warm water operational pattern is most helpful for introducing cooler water into the bypass system as gatewells passively pass water from lower, cooler depths of the forebay through the orifices to the collection channel.

Figure 5
Temperature Gradient Between Minimum and Maximum Temperature Recorded Across 14 Gatewell Positions for Each Half-hour Period from June 15 to August 31, 2017

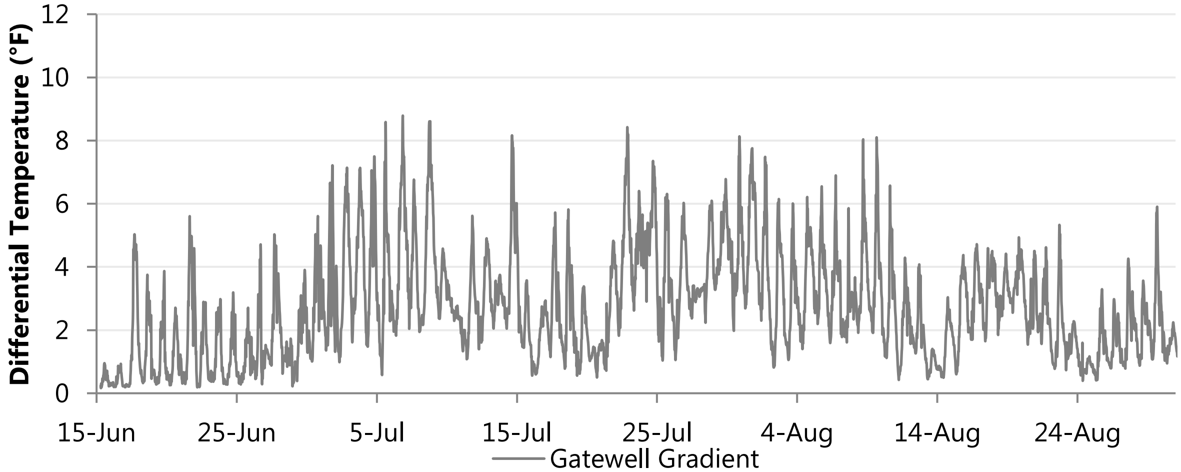
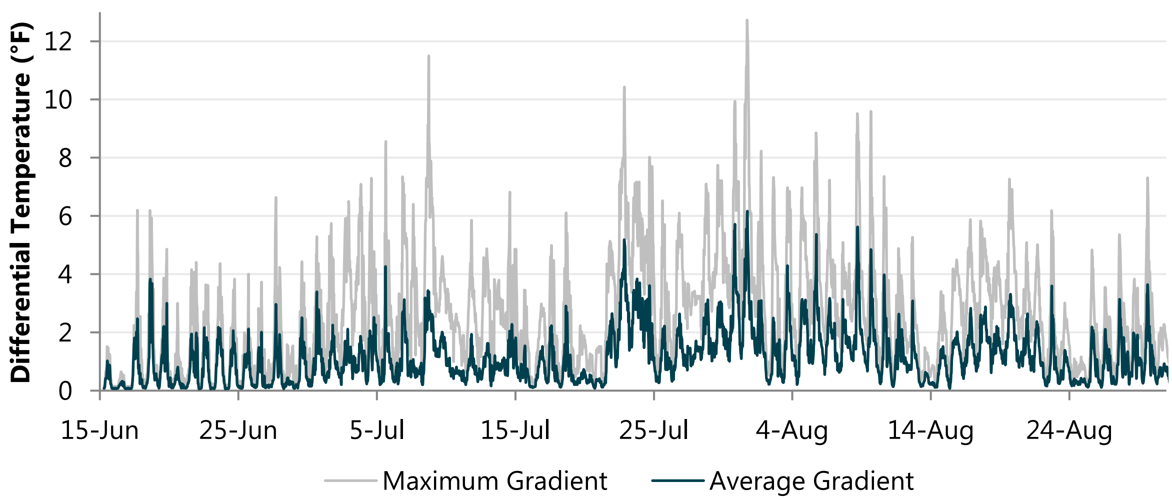


Figure 6
Maximum and Average Temperature Gradient Recorded Between the Forebay and Gatewells for Each Half-hour Period from June 15 to August 31, 2017



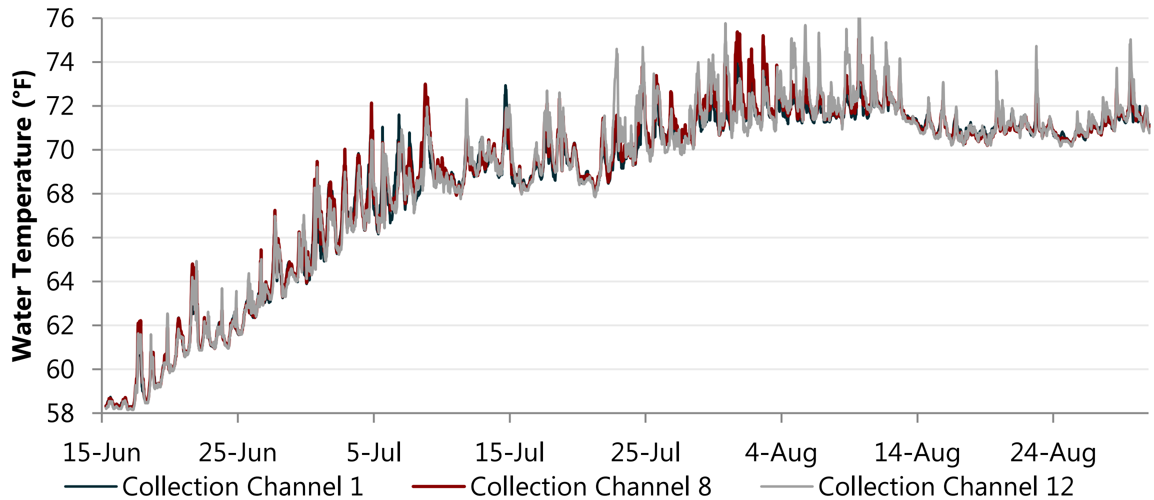
3.4 Collection Channel

Water temperatures in the collection channel were less variable than in the forebay and gatewells. Water temperatures across the collection channel averaged 68.7 °F from June 15 to August 31 (Table 3 below). Collection channel temperatures reached an average of 68 °F on June 30 for short periods of time and were continuously exceeding 68 °F after July 8 (Figure 7 below). The maximum temperature of 76.5 °F was measured at 1630 on August 9 at Unit 12.

Table 3
Water Temperatures in the Collection Channel from June 15 to August 31, 2017

Average (°F)	Maximum (°F)	Date
68.7	76.5	9-Aug

Figure 7
Water Temperatures for Three Collection Channel Locations from June 15 to August 31, 2017



The average temperature gradient between the gatewells and the collection channel was 0.8 °F from June 15 to August 31 (Figure 8 below) and ranged from less than 0.1 °F to 5.5 °F. Typically, the gatewell was warmer than the collection channel at Unit 8 and Unit 12 and cooler than the collection channel at Unit 1. Unit 1 was in stand-by mode for much of the monitoring period and therefore, drawing cooler water from the forebay. The maximum temperature gradient was 5.5 °F at 1800 hours on July 8 at Unit 1, with the gatewell being cooler than the collection channel. The average temperature gradient between the collection channel at Unit 12 and Unit 1 was 0.5 °F from June 15 to August 31 (Figure 9 below). The maximum temperature gradient between the collection channel at Unit 12 and Unit 1 was 3.9 °F at 2100 hours on July 22, 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 22 days between June 15 and August 31 for short periods of time, typically between 1600 and 1930 hours.

Figure 8
Gradient Recorded Between Three Gatewells and Corresponding Collection Channel locations (Gatewell minus Collection Channel) for Each Half-hour Period from June 15 to August 31, 2017

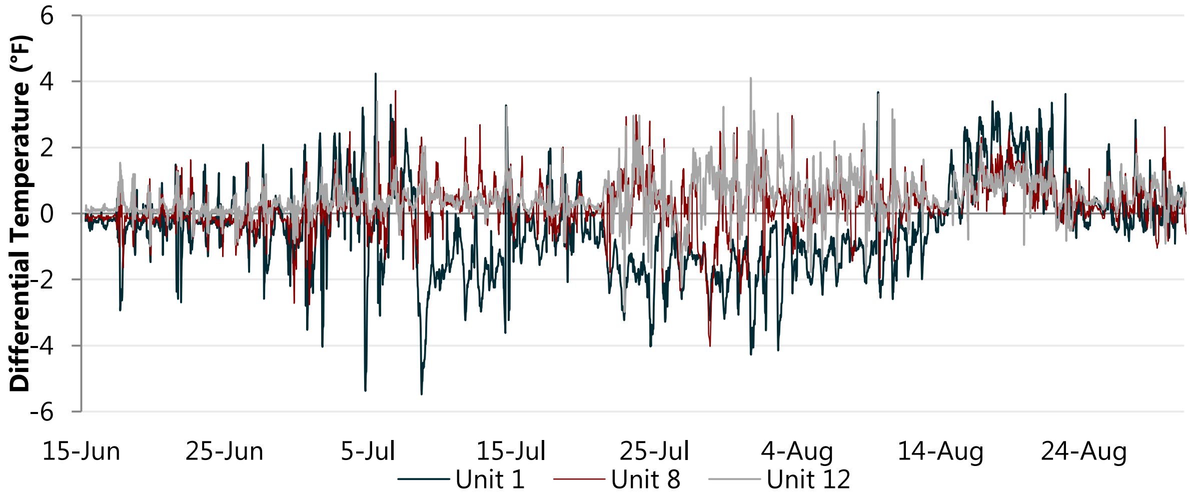
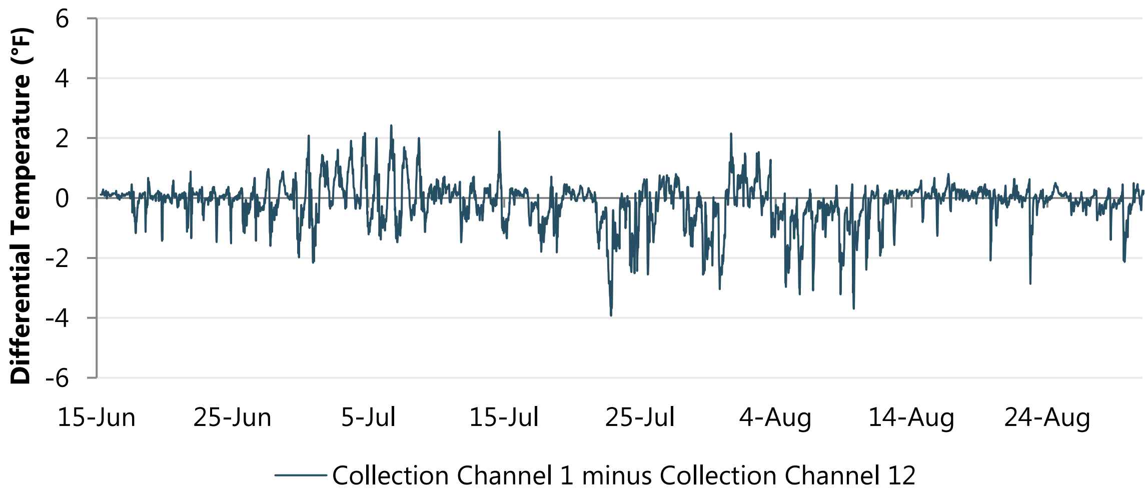


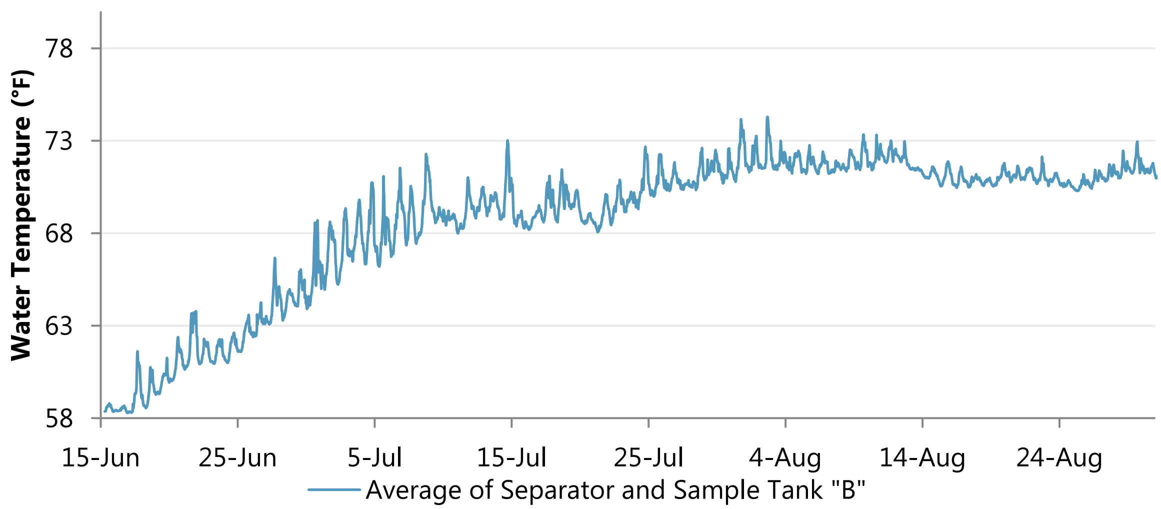
Figure 9
Gradient Recorded Between Water at Collection Channel 1 and Collection Channel 12 from June 15 to August 31, 2017



3.5 Juvenile Fish Facility

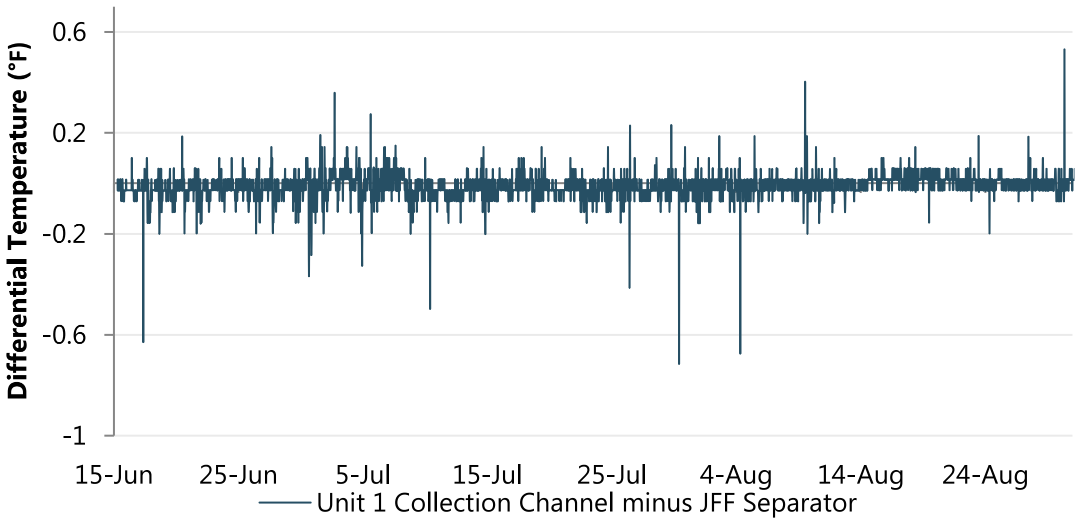
The average temperature at the JFF from June 15 to August 31 was 68.7 °F. Average temperatures began reaching 68 °F on June 30 (Figure 10 below) for short periods of time during the day. Water temperatures were continuously exceeding 68 °F after July 8. The maximum temperature of 74.3 °F was measured between 1600 to 1630 hours on August 2 at the separator and sample tank "B".

Figure 10
Average Water Temperatures for Two Juvenile Fish Facility Locations from June 15 to August 31, 2017



The temperature gradient between the collection channel at Unit 1 and the separator at the JFF averaged less than 0.1 °F and ranged from 0 °F to 0.7 °F (Figure 11 below). The separator was typically warmer than the collection channel. The temperature gradient across the separator and sample tank "B" averaged less than 0.1 °F. The maximum difference between the two JFF locations was 1.1 °F at 1000 hours on June 26 and 0730 on July 29. Sample tank "B" was warmer on both occasions.

Figure 11
Gradient Recorded Between the Collection Channel at Unit 1 and Juvenile Fish Facility Separator from June 15 to August 31, 2017



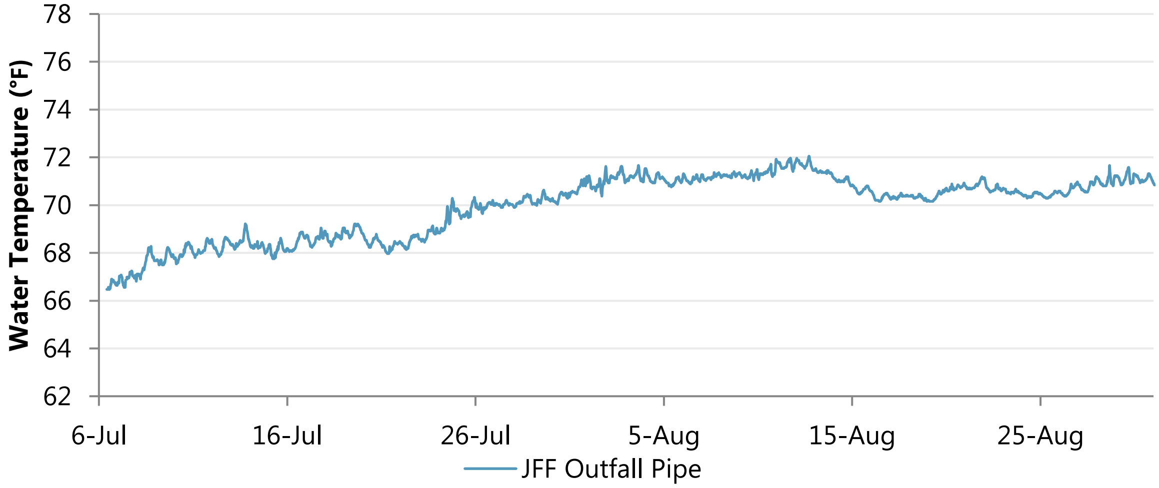
Note:
JFF: Juvenile Fish Facility

3.6 Outfall Pipe

The tailwater at the outfall pipe experienced very little of the diurnal fluctuations observed in other monitored areas (Figure 12 below). The average water temperature at the outfall pipe was 69.9 °F from July 6 to August 31. The outfall pipe temperature logger was deployed when the end of the outfall pipe became accessible after river flows reduced. Tailwater temperature at the outfall pipe reached 68 °F on July 8 for short periods and was continuously over 68 after July 15. The maximum temperature of 72.1 °F was measured at 1700 hours on August 12.

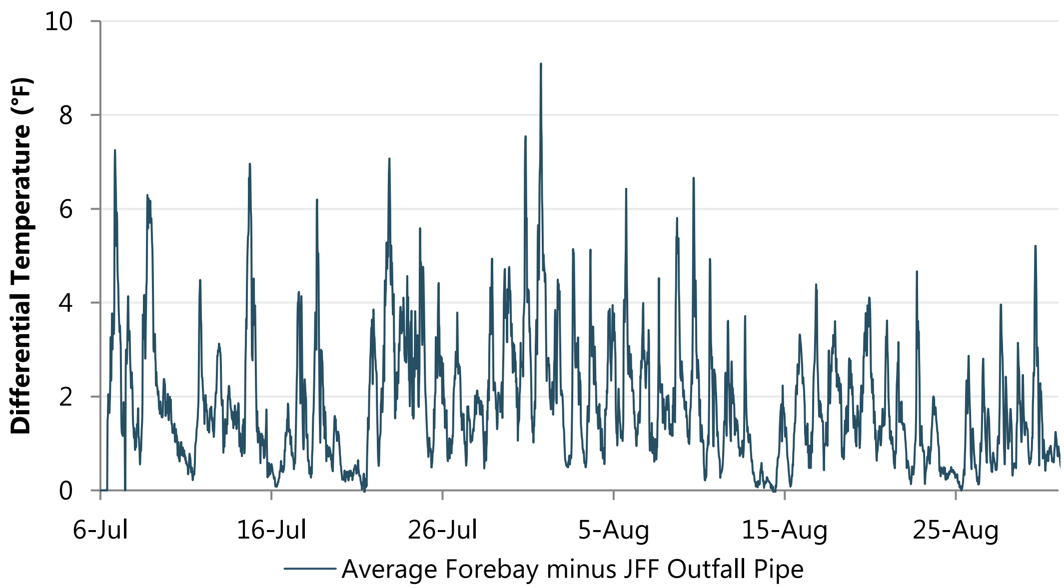
The average temperature gradient between the forebay and the outfall pipe was 1.9 °F. The forebay was typically warmer than the outfall pipe (Figure 13 below). The largest gradient between the two locations was 9.1 °F at 1800 hours on July 31. The temperature gradient between the separator at the JFF and the outfall pipe was 0.8 °F on average between July 6 and August 31. The largest temperature gradient between the separator and the outfall pipe was 4.7 °F at 2030 hours on July 6 (Figure 14 below).

Figure 12
Water Temperatures for Each Half-hour Period at the Outfall Pipe from July 6 to August 31, 2017



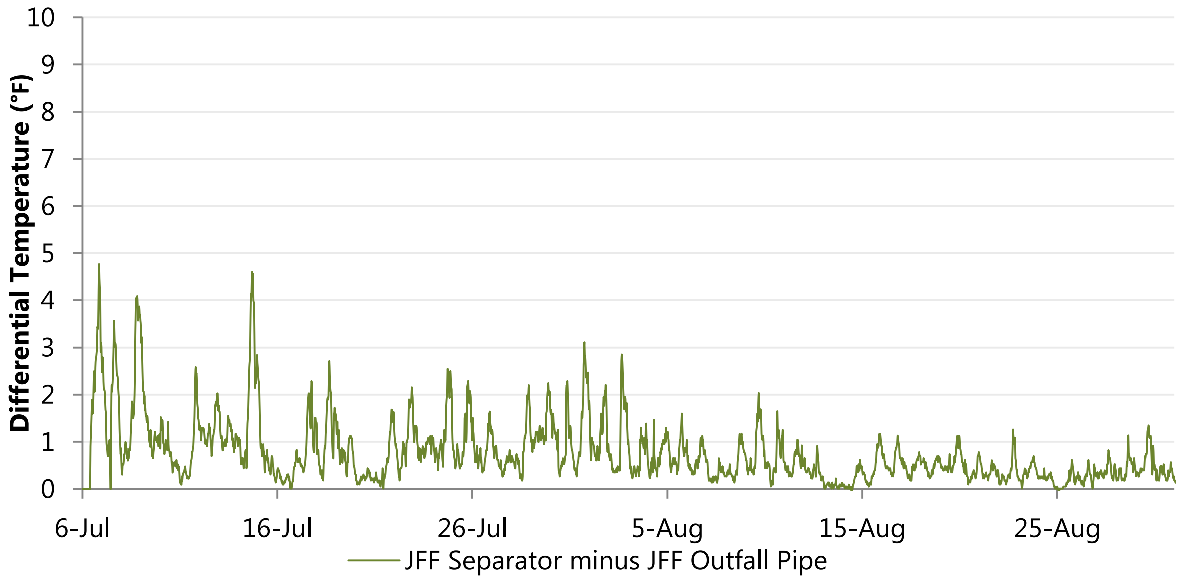
Note:
JFF: Juvenile Fish Facility

Figure 13
Temperature Gradient Recorded Between Water at the Forebay and the Outfall Pipe from July 6 to August 31, 2017



Note:
JFF: Juvenile Fish Facility

Figure 14
Temperature Gradient Recorded Between Water at the Separator and the Outfall Pipe from July 6 to August 31, 2017



Note:
JFF: Juvenile Fish Facility

3.7 Fish Passage and Mortality

A total of 889,307 juvenile salmonids passed McNary Dam during the monitoring period from June 15 to August 31. Subyearling Chinook salmon comprised 99.8 percent of the total during this period. The majority of these fish passed McNary Dam in June and early July (Table 4 below). By July 26, 90 percent 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 less than 0.1 percent of bypassed fish over the monitoring period (subyearling Chinook salmon, 82 mortalities; all other species combined, 1 mortality).

Mortalities among fish sampled from the bypassing population and held for up to 24 hours may be an indicator of the health status of the larger bypassing cohort. Sample mortalities for subyearling Chinook salmon alone was 0.6 percent of sampled fish during the monitoring period (subyearling Chinook salmon, 43 sample mortalities; all other species combined, 0 mortalities).

Table 4
Collection, Mortality, and Passage for Juvenile Salmonids, 2016 and 2017

Year	System			Sample			Passage			
	Collection	Mortality	% Mortality	Sample	Sample Mortality	% Mortality	25%	50%	75%	90%
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
2016*	1,858,570	83	<0.1%	7,779	36	0.5%	24-Jun	26-Jun	28-Jun	2-Jul
	Sample Tank "B" Temperature (°F)**						63.3	63.8	65.0	67.8

Notes:
* Values for 2016 include data recorded June 15 to August 31.
** Sample tank temperature was taken at 0700 daily

4 Recommendations

Continue to employ the warm water turbine operation strategy. Balancing turbine operation continues to be an effective tool in mitigating high water temperatures and 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 purchasing a new weather station for the JFF. The current weather station was purchased prior to 2006. The software and hardware are no longer supported by manufacturer. The current sensors are deployed on a poll between the separator booth and the public viewing walkway and are difficult to access. This year, the anemometer became fouled with spider webs during a period of little to no wind. Cleaning and repair was accomplished after several days when the sensors could be accessed by U.S. Army Corps of Engineers staff. Newer weather stations have wireless capability which would allow the sensors to be deployed in a more accessible location. This would allow for more regular maintenance and for the sensors to be removed and stored when not in use.

5 References

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Appendix A

Table A-1
National Oceanic and Atmospheric Administration Wind Data Recorded at the Hermiston, Oregon Airport, 0053 hours August 17 to 1653 hours August 23, 2017

Date	Wind Speed (miles per hour)	Wind Gusts* (miles per hour)	Wind Direction**
8/17/2017 0:53	13		SW
8/17/2017 1:53	11		SW
8/17/2017 2:53	10		SW
8/17/2017 3:53	11		WSW
8/17/2017 4:53	9		SW
8/17/2017 5:53	8		SW
8/17/2017 6:53	9		WSW
8/17/2017 7:53	11		WSW
8/17/2017 8:53	10		WSW
8/17/2017 9:53	8		WSW
8/17/2017 10:53	7		WSW
8/17/2017 11:53	9		SW
8/17/2017 12:53	9		WSW
8/17/2017 13:53	11		W
8/17/2017 14:53	8		W
8/17/2017 15:53	5		NW
8/17/2017 16:53	3		
8/17/2017 17:53	3		WNW
8/17/2017 18:53	5		N
8/17/2017 19:53	3		ENE
8/17/2017 20:53	6		SSE
8/17/2017 21:53	10		SSW
8/17/2017 22:53	9		SSW
8/17/2017 23:53	8		SW
8/18/2017 0:53	8		SW
8/18/2017 1:53	7		SSE
8/18/2017 2:53	7		SSW
8/18/2017 3:53	7		S
8/18/2017 4:53	3		ESE
8/18/2017 5:53	5		ESE
8/18/2017 6:53	6		S
8/18/2017 7:53	5		S

Date	Wind Speed (miles per hour)	Wind Gusts* (miles per hour)	Wind Direction**
8/18/2017 8:53	7		WNW
8/18/2017 9:53	8		WSW
8/18/2017 10:53	10		WSW
8/18/2017 11:53	11		W
8/18/2017 12:53	14		W
8/18/2017 13:53	10		WSW
8/18/2017 14:53	11		W
8/18/2017 15:53	7		NW
8/18/2017 16:53	10		WSW
8/18/2017 17:53	10		W
8/18/2017 18:53	11		SW
8/18/2017 19:53	21	26	WSW
8/18/2017 20:53	9		WSW
8/18/2017 21:53	14		SW
8/18/2017 22:53	13		WSW
8/18/2017 23:53	13		WSW
8/19/2017 0:53	9		WSW
8/19/2017 1:53	10		WSW
8/19/2017 2:53	10		WSW
8/19/2017 3:53	9		WSW
8/19/2017 4:53	8		WSW
8/19/2017 5:53	13		SW
8/19/2017 6:53	15		WSW
8/19/2017 7:53	14		WSW
8/19/2017 8:53	13		W
8/19/2017 9:53	7		WSW
8/19/2017 10:53	6		NNW
8/19/2017 11:53	6		NW
8/19/2017 12:53	5		NNW
8/19/2017 13:53	5		E
8/19/2017 14:53	6		NNW
8/19/2017 15:53	5		WNW
8/19/2017 16:53	7		NNE
8/19/2017 17:53	CALM		N
8/19/2017 18:53	CALM		N
8/19/2017 19:53	3		ESE
8/19/2017 20:53	5		E

Date	Wind Speed (miles per hour)	Wind Gusts* (miles per hour)	Wind Direction**
8/19/2017 21:53	5		E
8/19/2017 22:53	9		SSE
8/19/2017 23:53	3		S
8/20/2017 0:53	CALM		N
8/20/2017 1:53	7		SSW
8/20/2017 2:53	5		SW
8/20/2017 3:53	CALM		N
8/20/2017 4:53	5		E
8/20/2017 5:53	CALM		N
8/20/2017 6:53	3		SE
8/20/2017 7:53	3		SE
8/20/2017 8:53	CALM		N
8/20/2017 9:53	5		WNW
8/20/2017 10:53	CALM		N
8/20/2017 11:53	6		WNW
8/20/2017 12:53	CALM		N
8/20/2017 13:53	5		NNE
8/20/2017 14:53	CALM		N
8/20/2017 15:53	6		NW
8/20/2017 16:53	6		
8/20/2017 17:53	CALM		N
8/20/2017 18:53	CALM		N
8/20/2017 19:53	CALM		N
8/20/2017 20:53	CALM		N
8/20/2017 21:53	6		SSE
8/20/2017 22:53	3		ESE
8/20/2017 23:53	CALM		N
8/21/2017 0:53	3		S
8/21/2017 1:53	3		SSE
8/21/2017 2:53	CALM		N
8/21/2017 3:53	CALM		N
8/21/2017 4:53	3		SE
8/21/2017 5:53	CALM		N
8/21/2017 6:53	5		SE
8/21/2017 7:53	3		SSE
8/21/2017 8:53	CALM		N
8/21/2017 9:53	3		NNW

Date	Wind Speed (miles per hour)	Wind Gusts* (miles per hour)	Wind Direction**
8/21/2017 10:53	CALM		N
8/21/2017 11:53	3		NNE
8/21/2017 12:53	8		NNE
8/21/2017 13:53	9		N
8/21/2017 14:53	9		N
8/21/2017 15:53	6		NNE
8/21/2017 16:53	CALM		N
8/21/2017 17:53	6		NNE
8/21/2017 18:53	5		NE
8/21/2017 19:53	CALM		N
8/21/2017 20:53	5		NE
8/21/2017 21:53	7		S
8/21/2017 22:53	7		S
8/21/2017 23:53	5		SSE
8/22/2017 0:53	6		ESE
8/22/2017 1:53	3		S
8/22/2017 2:53	CALM		N
8/22/2017 3:53	CALM		N
8/22/2017 4:53	3		SSE
8/22/2017 5:53	3		SE
8/22/2017 6:53	CALM		N
8/22/2017 7:53	6		SSE
8/22/2017 8:53	CALM		N
8/22/2017 9:53	3		WNW
8/22/2017 10:53	6		NW
8/22/2017 11:53	3		N
8/22/2017 12:53	3		
8/22/2017 13:53	6		WNW
8/22/2017 14:53	CALM		N
8/22/2017 15:53	3		
8/22/2017 16:53	3		
8/22/2017 17:53	3		WSW
8/22/2017 18:53	5		S
8/22/2017 19:53	3		S
8/22/2017 20:53	6		S
8/22/2017 21:53	7		S
8/22/2017 22:53	11		SSW

Date	Wind Speed (miles per hour)	Wind Gusts* (miles per hour)	Wind Direction**
8/22/2017 23:53	13		SW
8/23/2017 0:53	11		SW
8/23/2017 1:53	8		S
8/23/2017 2:53	9		SW
8/23/2017 3:53	11		SW
8/23/2017 4:53	10	20	WSW
8/23/2017 5:53	10		SW
8/23/2017 6:53	7		SSW
8/23/2017 7:53	10		WSW
8/23/2017 8:53	10		WSW
8/23/2017 9:53	8		W
8/23/2017 10:53	9		WNW
8/23/2017 11:53	9		W
8/23/2017 12:53	CALM		N
8/23/2017 13:53	CALM		N
8/23/2017 14:53	CALM		N
8/23/2017 15:53	5		E
8/23/2017 16:53	6		NE

Notes:
* Gusts are defined as a rapid change in wind speed with variations of 10 knots or more between peaks and lulls. Blanks indicate no gusts measured
**Blanks indicate no wind direction data available
Data obtained from: www.wrh.noaa.gov/mesowest/timeseries.php?sid=KHRI&num=168&wfo=pdt
N: North
NE: North East
NW: North West
NNE: North North East
NNW: North North West
E: East
ENE: East North East
ESE: East South East
S: South
S: South East
SW: South West
SSE: South South East
SSW: South South West
W: West
WNW: West North West
WSW: West South West