APPENDIX B TEMPERATURE DATA COMPILATION, QUALITY ASSURANCE AND ANALYSIS

Technical Memorandum

Subject: **Columbia and Snake River Data Analysis: Existing Conditions and Water Quality Criteria Exceedances for Temperature**

Prepared For: US EPA Region 10 Columbia-Snake Temperature TMDL Team

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Date: April 15, 2020

Introduction

In this memorandum, we summarize available data to examine current temperature conditions in the Columbia and Snake River Basin within the geographic scope (Figure 1) of EPA's Columbia-Snake River Temperature Total Maximum Daily Load (TMDL). In addition, we evaluate the extent to which current conditions exceed applicable numeric temperature water quality criteria (WQC) within EPA approved state and tribal water quality standards (WQS) and identify warming patterns throughout the basin (Figure 2).

All figures and tables in this document were generated from data accessed through the Columbia Basin Research website administered by the University of Washington's School of Aquatic & Fishery Sciences. The website features the Columbia River Data Access in Real Time (DART) database, a public database that compiles and summarizes a broad range of environmental, fish, and climatic data in the Columbia River Basin. DART provides hourly data measurements at a variety of locations along the Columbia and Snake Rivers, including the forebay (upstream) and tailrace (downstream) of the major dams within the study area (Figure 1).

Data Analysis Approach

The current analysis relies on tailrace data because data collected in the tailrace represents the well-mixed temperature of the river. Forebay data can be less representative of cross-sectional average temperature –it can be impacted by the limited stratification in Columbia and Snake River reservoirs and the inconsistent depth of forebay temperature sensors (Appendix C). Forebay data were utilized at Wells Dam, however, because tailrace data are not available at this site.

In addition to utilizing data from all the dam tailrace sites within the project domain, data from other water quality monitoring stations were used to bolster the analysis. To inform boundary conditions, data from the Canadian Border (Columbia River upstream boundary) and Anatone, WA (Snake River upstream boundary) were included in the analysis. To further inform the Snake River upstream boundary conditions and the impact of the Clearwater River confluence, two water quality monitoring stations outside of the project domain were utilized: the Dworshak Dam tailrace station and the Clearwater River station. To better understand the confluence of the Snake River with the Columbia River, a station near the city of Pasco, WA –just upstream of the Snake confluence –was included.

For each of the twenty DART water quality monitoring sites examined (Table of Contents; Figure 1), temperature data were downloaded from the DART website (http://www.cbr.washington.edu/dart/query/wqm_hourly) as hourly measurements for the years 2011-2016.

All analyses were conducted in Microsoft Excel™. In accordance with applicable numeric temperature WQC, summarized in EPA's 2020 draft compilation of the Columbia and Snake temperature WQS's (EPA 2020; Figure 2), the hourly temperature data were translated into the averaging period(s) corresponding to the numeric temperature WQC that apply at that location (EPA 2020; Figure 2). For instance, the applicable numeric WQC at

the Rock Island Dam Tailrace is Washington's 17.5°C seven-day average of the daily maximum (7-DADM), so the raw hourly data from Rock Island Dam were converted into 7-DADM values, enabling the equivalent comparison of current conditions to the applicable WQC. The 7-DADM temperatures were calculated by averaging the daily maximum temperature for a given day with the daily maximum temperature values of the previous three days and the following three days, as specified in the Washington WQS. For each DART site examined, plots were generated to illustrate the 2011-2016 river temperature plotted against the applicable WQC; the plots show individual years in color, the average temperature in black, and the applicable numeric WQC in red and/or purple (Figures 3-28). The variation within and between years is illustrated in these plots visually, as well as the extent and frequency of WQC exceedances.

Current condition exceedances of the applicable numeric WQC were also calculated quantitatively for each DART site examined. The number of exceedances were calculated as days per year and percent of year. These metrics were also generated for the warm months of July, August, September and October individually. Further, the magnitude of exceedance was calculated as a maximum temperature above the applicable WQC, and as the average magnitude above the WQC (Tables 1-45). The annual average and maximum temperatures were also calculated quantitatively for each DART site examined, along with these metrics specifically for the warm months of July, August, September and October.

In summary, for each DART station utilized for this analysis, the following plots and metrics are included:

- Daily maximum temperature (DM) and/or 7-day average of the daily maximum temperature (7-DADM) plotted against the applicable WQC
- Average and maximum temperature calculated annually and during the months of July - October.
- Frequency of current condition temperature exceedances (days/year & % of year) above the applicable WQC annually and during the months of July- October.
- Maximum and average exceedances above the applicable WQC annually and during the months of July - October.

This document also includes figures that illustrate temperature changes between water quality stations. For these plots, the 2011-2016 average of the daily maximum temperatures for a given location are plotted against the same metric at a downstream location (Figures 29-33).

Quality Assurance

The hourly temperature data utilized for this analysis had a range of data issues requiring an extensive quality assurance review. In general, the goal of this quality assurance effort was to retain all data judged to accurately represent river temperatures. First, we identified and removed spurious data, where it was clear, based on the best professional judgement of the authors, that given values were not representative of river conditions (e.g. sensor out of the water measuring air temperatures, sensor error, other reasons unknown to the authors) (Appendix A). We also identified numerous data gaps–in some cases data are missing for part of a day or consecutive days; in other cases, data are missing for substantial portions of the year (Appendix B).

In instances where hourly temperature data were available for part of a given day, best professional judgement was used to determine if the daily maximum was likely captured and if the average of the available data would be representative. Generally, if 12 or more hourly temperature values were present for a given day, the maximum and average were calculated and utilized in the analysis. In addition, if four or more daily maximum values were present within a seven-day window, the average was calculated and assumed to reasonably represent the 7-DADM. To calculate the 2011-2016 average annual temperature regime, values from those 6

individual years were averaged; if data from only 4 years exists for a given date, those values were averaged and identified as the average over the six-year period.

Our QA process carries forward to the results tables to allow data users to distinguish between values based on complete and incomplete data. Generally, if the average temperature is calculated over a given month for which there are less than 15 usable daily average values, the monthly average calculation was omitted from the table and replaced with an 'NA'. Similarly, if the average temperature is calculated over a given year for which there are less than 10 months of usable data, the annual average calculation was omitted from the table and replaced with an 'NA'. If the average calculated over a given month or year is based on more data than the thresholds described above (15 days/month & 10 months/year) but is still incomplete, the cell is highlighted orange to indicate an incomplete dataset that still offers a reasonable indication of true river conditions.

Prior to our QA process, the WQC exceedance frequency and magnitude calculations, including percent exceedance, also reflected the quality of the underlying data. Similar to the QA process described in the previous paragraph for the average and maximum calculations, our QA process allows data users to distinguish between exceedance values based on incomplete data from exceedance values based on complete data that represents river conditions. Exceedance values were calculated annually and for July through October, when river conditions are likely to exceed WQC. In instances where the necessary underlying data is completely absent or inadequate during this timeframe, data is omitted from the table. In instances where the data are incomplete but may still have value, the cell within the table was highlighted orange.

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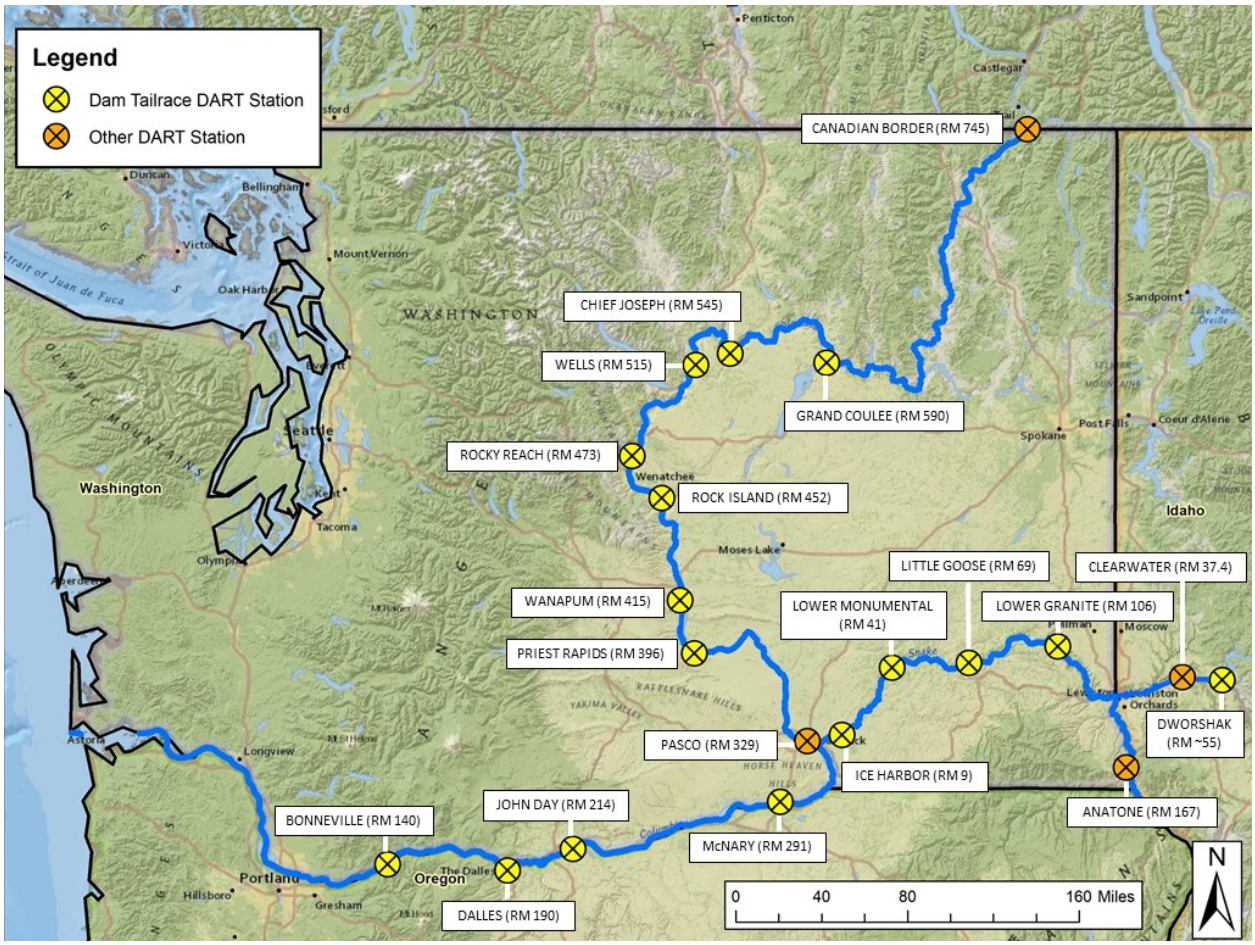

Figure 1. The Columbia and Snake Rivers in Washington and Oregon within the scope of EPA's Temperature TMDL currently under development. Data Source: Department of Ecology Large Dams and River Miles datasets.

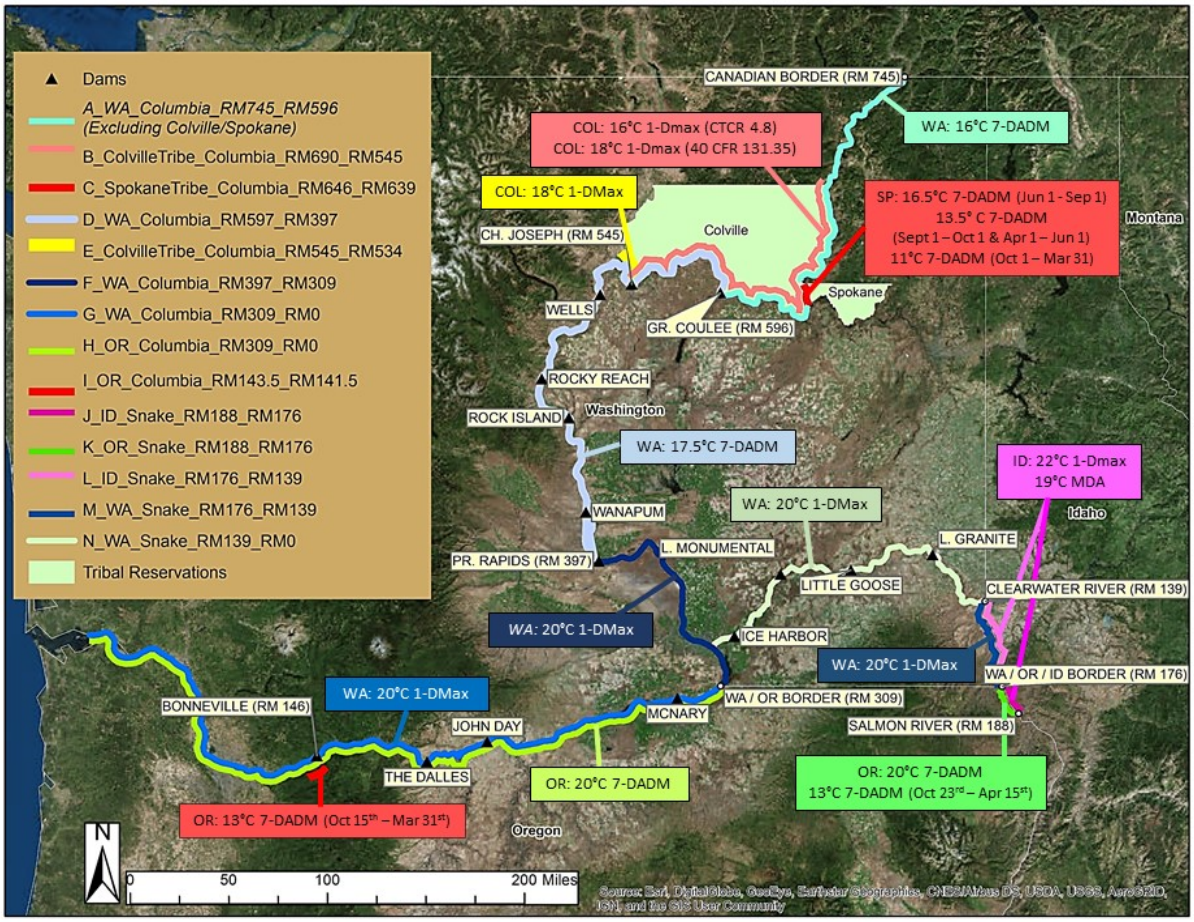

Figure 2. Numeric temperature water quality criteria on the Columbia and Lower Snake Rivers. Data Source: EPA Temperature WQC Compilation 2018.

COLUMBIA RIVER

Water Quality Monitoring Station	DART ID	River Mile	Dates
Canadian Border	CIBW	745	2011-2016

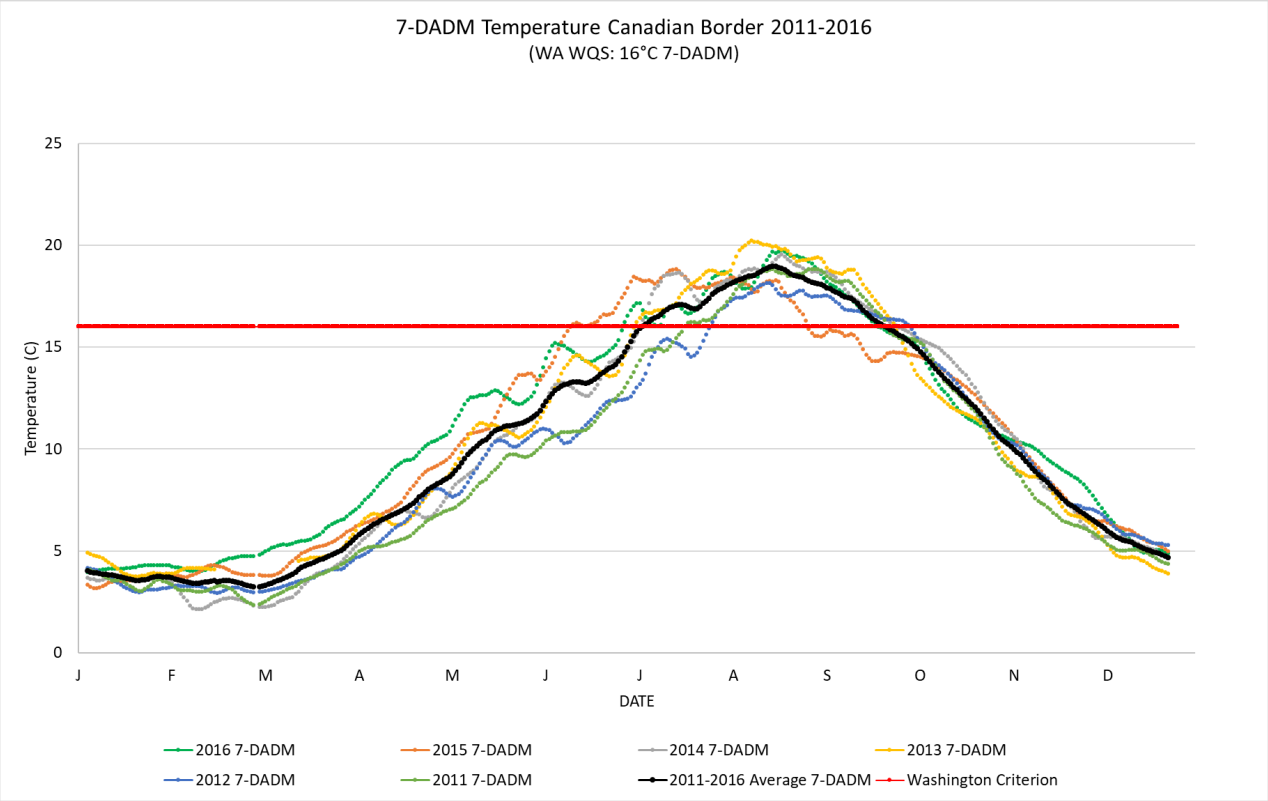

Figure 3. 7-DADM river temperature at the Canadian Border for the years 2011-2016, plotted against the Washington numeric WQC of 16°C 7-DADM.

Table 1. Average and maximum temperature values calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Average and Maximum Temperature (°C) at Canadian Border 2011-2016							
	2016	2015	2014	2013	2012	2011	Average
ANNUAL Average	10.59	10.20	9.74	10.34	9.29	9.09	9.88
ANNUAL Maximum	20.22	19.28	19.80	20.50	18.50	19.10	19.57
JULY Average	16.45	17.80	17.03	16.86	14.31	15.05	16.25
JULY Maximum	18.78	19.28	19.10	19.30	16.70	16.70	18.31
AUGUST Average	18.27	17.12	18.00	18.71	16.75	17.78	17.77
AUGUST Maximum	20.22	19.00	19.80	20.50	18.50	19.10	19.52
SEPTEMBER Average	16.55	14.49	16.84	17.22	16.24	16.89	16.37
SEPTEMBER Maximum	19.11	16.28	18.80	19.70	17.70	19.10	18.45
OCTOBER Average	12.56	13.18	13.87	12.10	13.18	12.96	12.97
OCTOBER Maximum	15.5	14.61	15.8	14.6	16.3	15.5	15.39

Table 2. Canadian Border river temperature exceedances of the Washington numeric WQC of 16°C 7-DADM calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Canadian Border 7-DADM Temperature Exceedance of 16°C							
	2016	2015	2014	2013	2012	2011	Average
DAYS / YEAR	84	78	85	86	66	66	78
% EXCEED / YEAR	23%	21%	23%	24%	18%	18%	21%
Mean Exceedance (°C)	1.80	1.67	2.04	2.43	1.13	1.79	1.81
Maximum Exceedance (°C)	3.71	2.80	3.53	4.20	2.11	2.80	3.19
DAYS / JULY	31	31	26	28	3	11	22
% EXCEED / JULY	100%	100%	84%	90%	10%	35%	70%
Mean Exceedance (°C)	0.97	2.24	1.80	1.49	0.45	0.31	1.21
Maximum Exceedance (°C)	2.52	2.80	2.61	2.74	0.70	0.74	2.02
DAYS / AUG	31	29	31	31	31	31	31
% EXCEED / AUG	100%	94%	100%	100%	100%	100%	99%
Mean Exceedance (°C)	2.89	1.80	2.79	3.55	1.58	2.30	2.48
Maximum Exceedance (°C)	3.71	2.38	3.53	4.20	2.11	2.79	3.12
DAYS / SEPT	21	0	28	27	30	24	22
% EXCEED / SEPT	70%	0%	93%	90%	100%	80%	72%
Mean Exceedance (°C)	1.49	0.00	1.43	2.11	0.81	1.80	1.27
Maximum Exceedance (°C)	2.89	0.00	2.69	3.39	1.50	2.80	2.21
DAYS / OCT	0	0	0	0	2	0	0
% EXCEED / OCT	0%	0%	0%	0%	6%	0%	0%
Mean Exceedance (°C)	0	0	0	0	0.11	0	0
Maximum Exceedance (°C)	0	0	0	0	0.17	0	0

Water Quality Monitoring Station	DART ID	River Mile	Dates
Grand Coulee Dam Tailrace (6 miles downstream)	GCGW	590	2011-2016

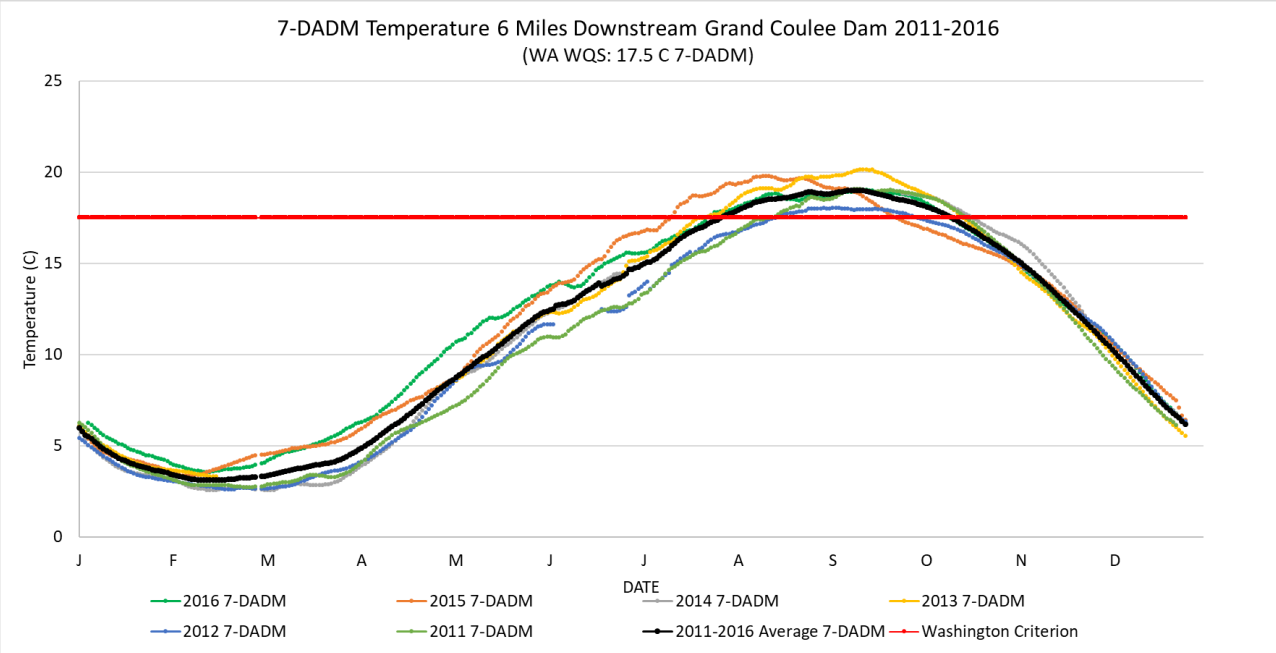

Figure 4. 7-DADM river temperature at the Grand Coulee Dam for the years 2011-2016, plotted against the Washington numeric WQC of 17.5°C 7-DADM.

Table 3. Average and maximum temperature values calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Average and Maximum Temperature (°C) at Grand Coulee Dam 2011-2016							
	2016	2015	2014	2013	2012	2011	Average
ANNUAL Average	11.58	11.47	NA	12.73	10.37	10.34	11.30
ANNUAL Maximum	19.22	19.89	NA	20.40	18.20	19.20	19.38
JULY Average	16.02	17.09	NA	16.21	14.58	14.50	15.68
JULY Maximum	18.00	19.50	NA	17.90	16.90	16.30	17.72
AUGUST Average	17.81	19.13	NA	18.66	17.06	17.16	17.96
AUGUST Maximum	19.11	19.89	NA	19.90	18.20	18.80	19.18
SEPTEMBER Average	18.44	18.13	NA	19.40	17.60	18.40	18.40
SEPTEMBER Maximum	19.22	19.28	NA	20.40	18.20	19.20	19.26
OCTOBER Average	17.09	15.97	NA	17.41	16.53	17.47	16.89
OCTOBER Maximum	18.70	17.11	NA	19.10	17.70	18.80	18.28

Table 4. Grand Coulee Dam river temperature exceedances of the Washington numeric WQC of 17.5°C 7-DADM calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Grand Coulee 7-DADM Temperature Exceedance of 17.5°C							
	2016	2015	2014	2013	2012	2011	Average
DAYS / YEAR	79	74	NA	84	46	63	62
% EXCEED / YEAR	22%	20%	NA	23%	13%	17%	17%
Mean Exceedance (°C)	0.98	1.48	NA	1.60	0.36	1.03	1.05
Maximum Exceedance (°C)	1.52	2.27	NA	2.61	0.53	1.53	1.63
DAYS / JULY	5	18	NA	6	0	0	5
% EXCEED / JULY	16%	58%	NA	19%	0%	0%	16%
Mean Exceedance (°C)	0.24	1.04	NA	0.17	0	0	0.24
Maximum Exceedance (°C)	0.31	1.71	NA	0.37	0	0	0.40
DAYS / AUG	31	31	NA	31	14	15	20
% EXCEED / AUG	100%	100%	NA	100%	45%	48%	66%
Mean Exceedance (°C)	0.94	2.04	NA	1.57	0.30	0.63	0.91
Maximum Exceedance (°C)	1.32	2.27	NA	2.23	0.47	1.13	1.24
DAYS / SEPT	30	25	NA	30	30	30	25
% EXCEED / SEPT	100%	83%	NA	100%	100%	100%	82%
Mean Exceedance (°C)	1.30	1.11	NA	2.29	0.40	1.35	1.29
Maximum Exceedance (°C)	1.52	1.73	NA	2.61	0.53	1.53	1.54
DAYS / OCT	13	0	20	17	2	18	12
% EXCEED / OCT	42%	0%	65%	55%	6%	58%	38%
Mean Exceedance (°C)	0.61	0	0.81	0.94	0.04	0.82	0.54
Maximum Exceedance (°C)	1.12	0	1.25	1.60	0.07	1.29	0.89

Water Quality Monitoring Station	DART ID	River Mile	Dates
Chief Joseph Dam Tailrace	CHQW	545	2011-2016

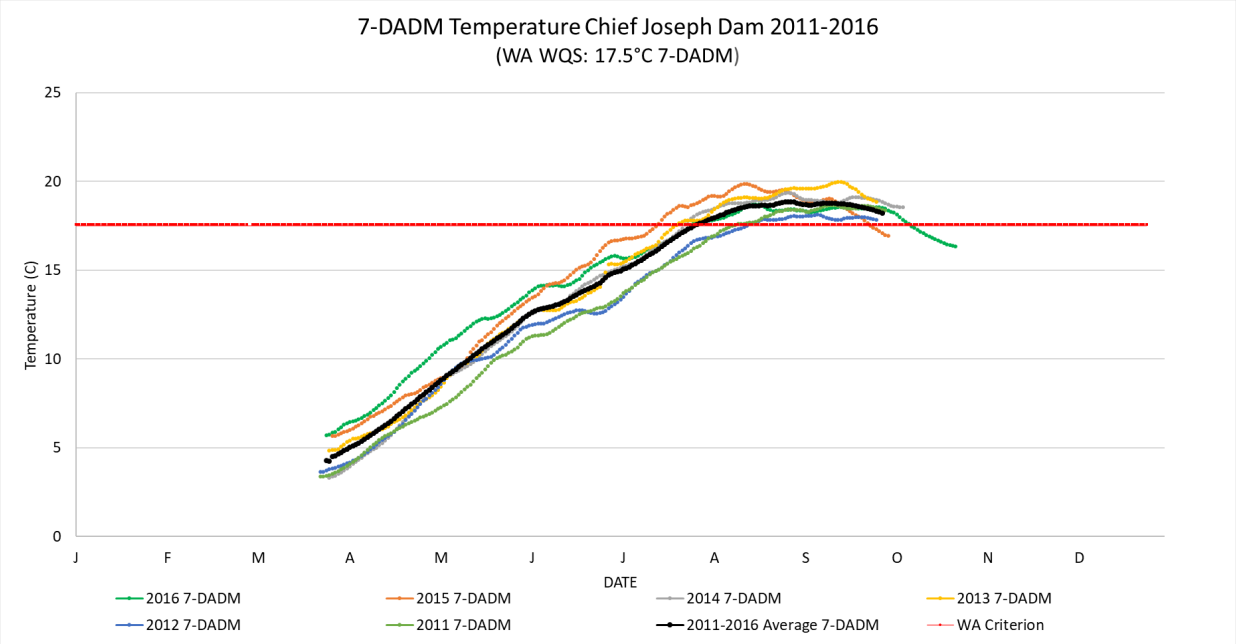

Figure 5. 7-DADM river temperature at Chief Joseph Dam for the years 2011-2016, plotted against the Washington numeric WQC of 17.5°C 7-DADM.

Table 5. Average and maximum temperature values calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Average and Maximum Temperature (°C) at Chief Joseph Dam 2011-2016							
	2016	2015	2014	2013	2012	2011	Average
ANNUAL Average	NA	NA	NA	NA	NA	NA	NA
ANNUAL Maximum	18.83	20.00	19.60	20.10	18.20	18.80	19.26
JULY Average	16.25	17.38	16.14	16.41	14.76	14.66	15.94
JULY Maximum	17.94	18.89	18.30	17.90	16.90	16.40	17.72
AUGUST Average	18.02	19.28	18.65	18.77	17.25	17.35	18.22
AUGUST Maximum	18.83	20.00	19.60	19.60	18.10	18.40	19.09
SEPTEMBER Average	18.24	18.26	18.74	19.39	17.81	18.31	18.46
SEPTEMBER Maximum	18.70	19.17	19.20	20.10	18.20	18.80	19.03
OCTOBER Average	17.15	16.77	18.44	NA	17.57	18.27	17.64
OCTOBER Maximum	18.5	17.06	18.9	NA	17.7	18.4	18.11

Table 6. Chief Joseph Dam river temperature exceedances of the Washington numeric WQC of 17.5°C 7-DADM calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Chief Joseph 7-DADM Temperature Exceedance of 17.5°C							
	2016	2015	2014	2013	2012	2011	Average
DAYS / YEAR	74	72	NA	NA	44	NA	64
% EXCEED / YEAR	20%	20%	NA	NA	12%	NA	18%
Mean Exceedance (°C)	0.76	1.40	NA	NA	0.39	NA	1.01
Maximum Exceedance (°C)	1.18	2.33	NA	NA	0.60	NA	1.58
DAYS / JULY	3	15	6	9	0	0	6
% EXCEED / JULY	10%	48%	19%	29%	0%	0%	18%
Mean Exceedance (°C)	0.18	0.87	0.40	0.20	0	0	0.28
Maximum Exceedance (°C)	0.24	1.30	0.69	0.27	0	0	0.42
DAYS / AUG	31	31	31	31	15	20	27
% EXCEED / AUG	100%	100%	100%	100%	48%	65%	85%
Mean Exceedance (°C)	0.73	1.91	1.30	1.41	0.29	0.43	1.01
Maximum Exceedance (°C)	1.18	2.33	1.83	2.06	0.50	0.88	1.46
DAYS / SEPT	30	26	30	29	29	30	29
% EXCEED / SEPT	100%	87%	100%	97%	97%	100%	97%
Mean Exceedance (°C)	0.92	1.10	1.43	2.02	0.43	0.96	1.14
Maximum Exceedance (°C)	1.05	1.68	1.74	2.41	0.60	1.13	1.44
DAYS / OCT	10	0	8	0	0	2	3
% EXCEED / OCT	32%	0%	26%	0%	0%	6%	11%
Mean Exceedance (°C)	0.58	0	1.11	0	0	0.84	0.21
Maximum Exceedance (°C)	0.96	0	1.31	0	0	0.86	0.30

Water Quality Monitoring Station	DART ID	River Mile	Dates
Wells Dam Forebay	WEL	515	2011-2016

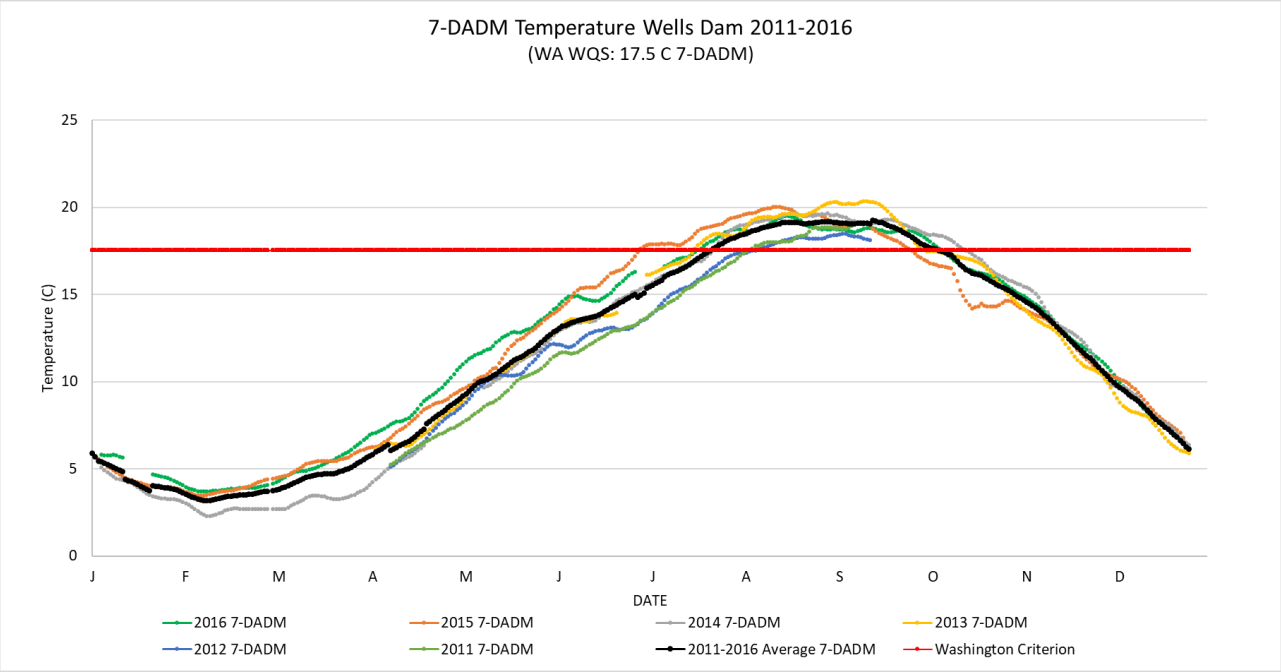

Figure 6. 7-DADM river temperature at Wells Dam for the years 2011-2016, plotted against the Washington numeric WQC of 17.5°C 7-DADM.

Table 7. Average and maximum temperature values calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Average and Maximum Temperature (°C) at Wells Dam 2011-2016							
	2016	2015	2014	2013	2012	2011	Average
ANNUAL Average	11.87	11.68	11.23	NA	NA	NA	11.59
ANNUAL Maximum	19.67	20.11	19.80	20.40	18.60	NA	19.66
JULY Average	17.16	18.03	16.58	17.07	15.18	14.95	16.50
JULY Maximum	18.94	19.28	18.70	18.60	17.40	16.80	18.29
AUGUST Average	18.73	19.51	19.11	19.22	17.72	17.77	18.68
AUGUST Maximum	19.67	20.11	19.80	20.20	18.40	18.90	19.51
SEPTEMBER Average	18.41	18.37	18.94	19.63	NA	NA	18.84
SEPTEMBER Maximum	19.11	19.44	19.80	20.40	NA	NA	19.69
OCTOBER Average	16.72	15.15	17.33	16.67	NA	NA	16.47
OCTOBER Maximum	18.5	17.33	18.7	17.6	NA	NA	18.03

Table 8. Wells Dam river temperature exceedances of the Washington numeric WQC of 17.5°C 7-DADM calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Wells 7-DADM Temperature Exceedance of 17.5°C							
	2016	2015	2014	2013	2012	2011	Average
DAYS / YEAR	80	90	83	77	NA	NA	83
% EXCEED / YEAR	22%	25%	23%	21%	NA	NA	23%
Mean Exceedance (°C)	1.13	1.37	1.47	1.76	NA	NA	1.43
Maximum Exceedance (°C)	1.96	2.49	2.14	2.81	NA	NA	2.35
DAYS / JULY	11	31	6	13	0	0	10
% EXCEED / JULY	35%	100%	19%	42%	0%	0%	33%
Mean Exceedance (°C)	0.67	0.80	0.74	0.70	0	0	0.48
Maximum Exceedance (°C)	1.14	1.82	1.16	0.94	0	0	0.84
DAYS / AUG	31	31	31	31	23	26	29
% EXCEED / AUG	100%	100%	100%	100%	74%	84%	93%
Mean Exceedance (°C)	1.45	2.17	1.82	1.88	0.52	0.66	1.42
Maximum Exceedance (°C)	1.96	2.49	2.14	2.61	0.74	1.30	1.88
DAYS / SEPT	30	28	30	30	NA	NA	30
% EXCEED / SEPT	100%	93%	100%	100%	NA	NA	98%
Mean Exceedance (°C)	1.14	1.11	1.67	2.25	NA	NA	1.54
Maximum Exceedance (°C)	1.27	1.75	2.10	2.81	NA	NA	1.98
DAYS / OCT	8	0	16	3	0	0	5
% EXCEED / OCT	26%	0%	52%	10%	0%	0%	14.5%
Mean Exceedance (°C)	0.54	0	0.71	0.13	0	0	0.23
Maximum Exceedance (°C)	0.93	0	1.14	0.27	0	0	0.39

Water Quality Monitoring Station	DART ID	River Mile	Dates
Rocky Reach Dam Tailrace	RRDW	473	2011-2016

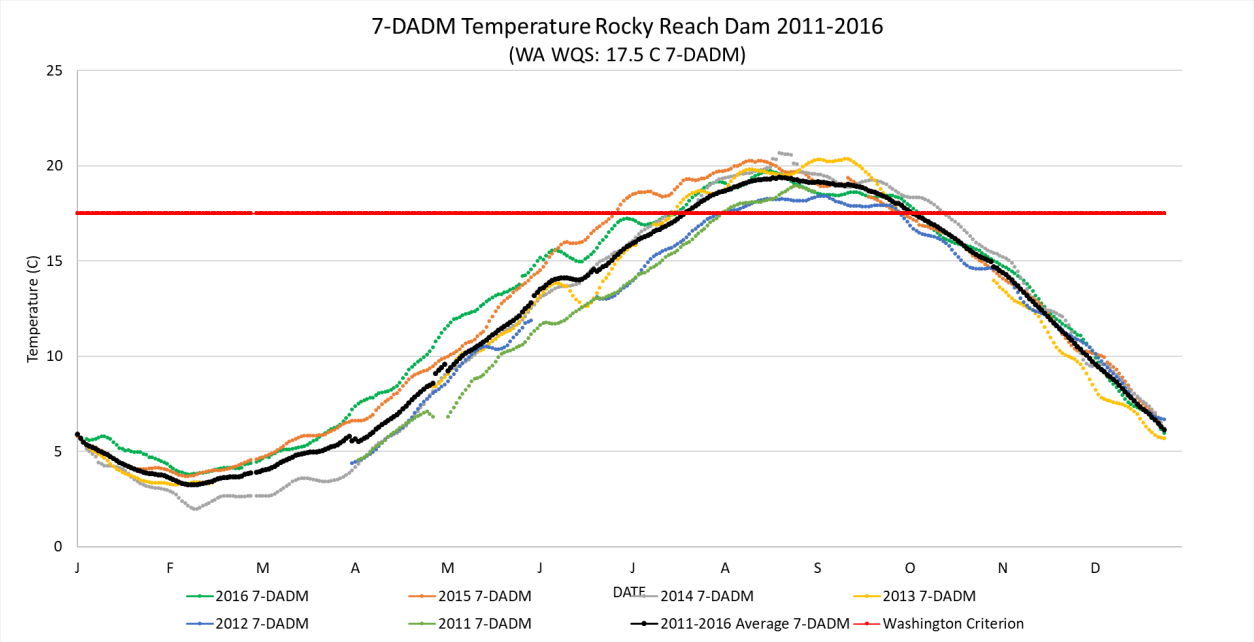

Figure 7. 7-DADM river temperature at Rocky Reach Dam for the years 2011-2016, plotted against the Washington numeric WQC of 17.5°C 7-DADM.

Table 9. Average and maximum temperature values calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Average and Maximum Temperature (°C) at Rocky Reach Dam 2011-2016							
	2016	2015	2014	2013	2012	2011	Average
ANNUAL Average	12.03	12.01	11.23	NA	NA	NA	11.76
ANNUAL Maximum	19.78	21.22	22.70	20.50	18.50	NA	20.28
JULY Average	17.46	18.63	16.99	NA	15.29	15.05	16.68
JULY Maximum	19.00	19.61	19.10	18.80	17.20	17.10	18.47
AUGUST Average	19.14	19.79	19.50	19.28	17.83	17.99	18.92
AUGUST Maximum	19.78	20.61	22.70	19.90	18.30	19.00	20.05
SEPTEMBER Average	18.41	18.59	19.12	19.67	17.96	NA	18.75
SEPTEMBER Maximum	18.90	21.22	19.70	20.50	18.50	NA	19.60
OCTOBER Average	16.57	16.21	17.31	17.42	15.84	NA	16.67
OCTOBER Maximum	18.5	18.11	18.7	17.6	17.8	NA	18.14

Table 10. Rocky Reach Dam river temperature exceedances of the Washington numeric WQC of 17.5°C 7-DADM calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Rocky Reach 7-DADM Temperature Exceedance of 17.5°C							
	2016	2015	2014	2013	2012	2011	Average
DAYS / YEAR	81	95	92	75	60	NA	81
% EXCEED / YEAR	22%	26%	25%	21%	16%	NA	22%
Mean Exceedance (°C)	1.20	1.59	1.52	1.84	0.51	NA	1.33
Maximum Exceedance (°C)	2.21	2.74	3.14	2.84	0.89	NA	2.36
DAYS / JULY	12	31	14	13	0	0	12
% EXCEED / JULY	39%	100%	45%	42%	0%	0%	38%
Mean Exceedance (°C)	0.82	1.25	0.48	0.85	0	0	0.57
Maximum Exceedance (°C)	1.53	1.98	1.46	1.17	0	0	1.02
DAYS / AUG	31	31	31	31	28	27	30
% EXCEED / AUG	100%	100%	100%	100%	90%	87%	96%
Mean Exceedance (°C)	1.73	2.40	2.29	1.92	0.50	0.76	1.60
Maximum Exceedance (°C)	2.21	2.74	3.14	2.41	0.73	1.41	2.11
DAYS / SEPT	30	30	30	30	30	NA	30
% EXCEED / SEPT	100%	100%	100%	100%	100%	NA	100%
Mean Exceedance (°C)	0.98	1.26	1.68	2.24	0.54	NA	1.34
Maximum Exceedance (°C)	1.30	2.00	2.11	2.84	0.89	NA	1.83
DAYS / OCT	8	2	17	1	0	0	5
% EXCEED / OCT	26%	6%	55%	3%	0%	0%	16.1%
Mean Exceedance (°C)	0.52	0.06	0.69	0.32	0	0	0.29
Maximum Exceedance (°C)	0.86	0.09	1.14	0.32	0	0	0.44

Water Quality Monitoring Station	DART ID	River Mile	Dates
Rock Island Dam Tailrace	RIGW	452	2011-2016

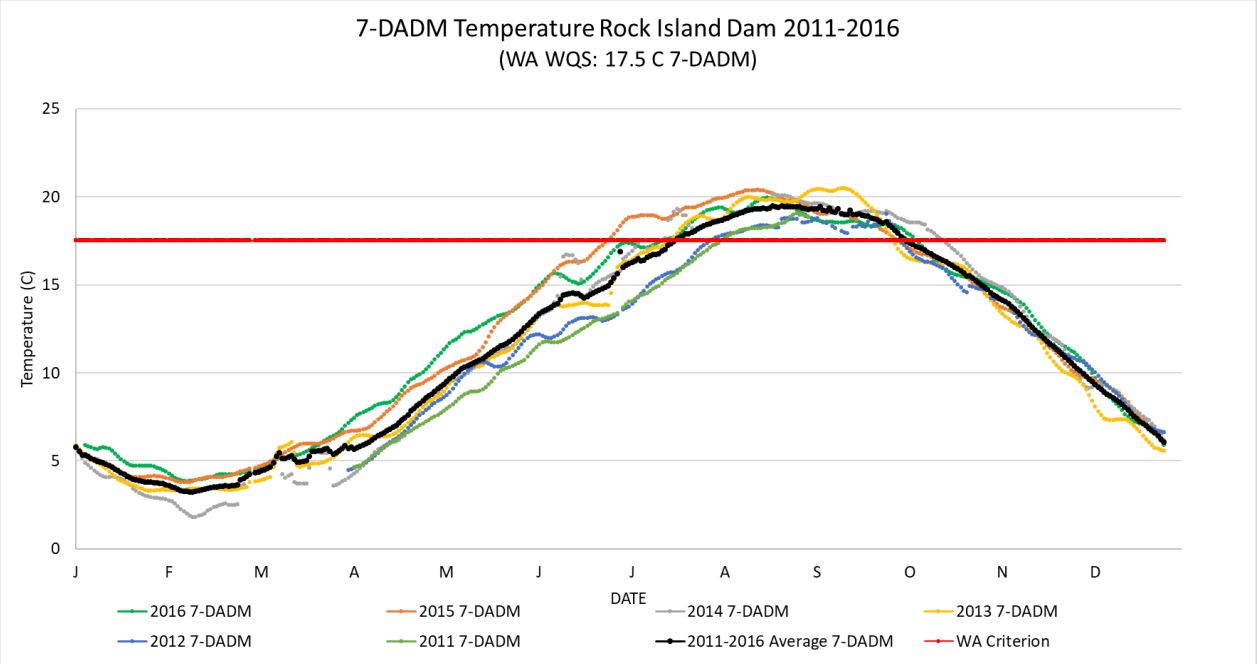

Figure 8. 7-DADM river temperature at Rock Island Dam for the years 2011-2016, plotted against the Washington numeric WQC of 17.5°C 7-DADM.

Table 11. Average and maximum temperature values calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Average and Maximum Temperature at Rock Island Dam 2011-2016							
	2016	2015	2014	2013	2012	2011	Average
ANNUAL Average	12.03	12.02	NA	11.18	NA	NA	11.78
ANNUAL Maximum	20.00	20.89	NA	20.70	21.70	NA	20.68
JULY Average	17.61	18.88	NA	17.31	15.31	15.10	16.83
JULY Maximum	19.22	20.00	NA	19.10	17.40	17.10	19.09
AUGUST Average	19.32	19.89	NA	19.38	17.98	17.99	19.04
AUGUST Maximum	20.00	20.50	NA	20.40	21.70	19.10	20.55
SEPTEMBER Average	18.41	18.60	19.02	19.68	17.34	NA	18.61
SEPTEMBER Maximum	18.90	20.89	19.70	20.70	21.60	NA	20.36
OCTOBER Average	16.34	16.13	17.14	15.96	NA	NA	16.39
OCTOBER Maximum	18.5	17.61	20.2	17.4	NA	NA	18.43

Table 12. Rock Island Dam river temperature exceedances of the Washington numeric WQC of 17.5°C 7-DADM calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Rock Island 7-DADM Exceedance of 17.5°C							
	2016	2015	2014	2013	2012	2011	Average
DAYS / YEAR	85	96	NA	75	57	NA	78
% EXCEED / YEAR	23%	26%	NA	21%	16%	NA	21%
Mean Exceedance (°C)	1.28	1.74	NA	1.95	0.80	NA	1.44
Maximum Exceedance (°C)	2.42	2.88	NA	2.94	1.52	NA	2.44
DAYS / JULY	16	31	NA	14	0	0	12
% EXCEED / JULY	52%	100%	NA	45%	0%	0%	39%
Mean Exceedance (°C)	0.82	1.53	NA	0.95	0	0	0.66
Maximum Exceedance (°C)	1.75	2.21	NA	1.39	0	0	1.07
DAYS / AUG	31	31	NA	31	31	27	30
% EXCEED / AUG	100%	100%	NA	100%	100%	87%	97%
Mean Exceedance (°C)	1.96	2.55	NA	2.09	0.73	0.82	1.63
Maximum Exceedance (°C)	2.42	2.88	NA	2.53	1.47	1.55	2.17
DAYS / SEPT	30	30	30	30	24	NA	29
% EXCEED / SEPT	100%	100%	100%	100%	80%	NA	96%
Mean Exceedance (°C)	1.03	1.32	1.74	2.28	0.90	NA	1.45
Maximum Exceedance (°C)	1.45	2.05	2.14	2.94	1.52	NA	2.02
DAYS / OCT	8	1	16%	0	2	0	5
% EXCEED / OCT	26%	3%	52%	0%	6%	0%	15%
Mean Exceedance (°C)	0.48	0.10	0.86	0	0.67	0	0.35
Maximum Exceedance (°C)	0.85	0.10	1.37	0	0.73	0	0.51

Water Quality Monitoring Station	DART ID	River Mile	Dates
Wanapum Dam Tailrace	WANW	415	2011-2016

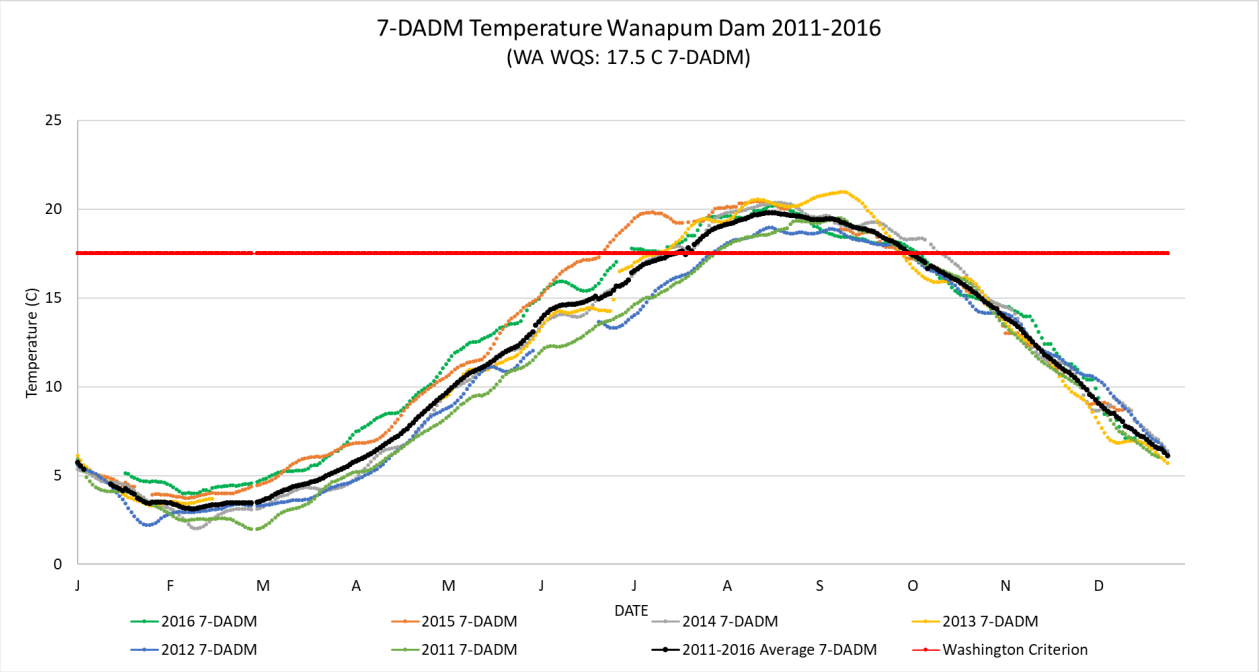

Figure 9. 7-DADM river temperature at Wanapum Dam for the years 2011-2016, plotted against the Washington numeric WQC of 17.5°C 7-DADM.

Table 13. Average and maximum temperature values calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Average and Maximum Temperature (°C) at Wanapum Dam 2011-2016							
	2016	2015	2014	2013	2012	2011	Average
ANNUAL Average	12.33	11.51	11.29	NA	10.70	10.53	11.27
ANNUAL Maximum	20.28	20.56	20.43	21.06	19.10	19.59	20.17
JULY Average	18.15	19.30	17.27	17.83	15.47	15.43	17.24
JULY Maximum	19.78	19.94	19.34	19.56	17.62	17.56	18.97
AUGUST Average	19.65	20.05	19.87	19.90	18.35	18.36	19.36
AUGUST Maximum	20.28	20.56	20.43	20.69	19.10	19.56	20.10
SEPTEMBER Average	18.31	NA	19.03	20.01	18.26	18.80	18.88
SEPTEMBER Maximum	19.50	NA	19.79	21.06	19.03	19.59	19.79
OCTOBER Average	16.31	16.16	17.01	16.04	15.91	16.33	16.29
OCTOBER Maximum	18.2	17.33	18.4	17.79	17.98	17.93	17.94

Table 14. Wanapum Dam river temperature exceedances of the Washington numeric WQC of 17.5°C 7-DADM calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Wanapum 7-DADM Temperature Exceedance of 17.5°C							
	2016	2015	2014	2013	2012	2011	Average
DAYS / YEAR	95	NA	91	82	66	63	80
% EXCEED / YEAR	26%	NA	25%	22%	18%	17%	22%
Mean Exceedance (°C)	1.25	NA	1.61	2.16	0.86	1.18	1.48
Maximum Exceedance (°C)	2.67	NA	2.84	3.45	1.41	1.97	2.54
DAYS / JULY	27	29	17	19	1	0	16
% EXCEED / JULY	87%	94%	55%	61%	3%	0%	50%
Mean Exceedance (°C)	0.69	1.94	0.56	1.06	0.01	0	0.71
Maximum Exceedance (°C)	2.03	2.31	1.79	1.91	0.01	0	1.34
DAYS / AUG	31	25	31	31	31	30	30
% EXCEED / AUG	100%	81%	100%	100%	100%	97%	96%
Mean Exceedance (°C)	2.26	2.70	2.50	2.53	0.96	1.04	2.00
Maximum Exceedance (°C)	2.67	2.90	2.84	3.01	1.41	1.81	2.44
DAYS / SEPT	30	NA	30	30	30	30	30
% EXCEED / SEPT	100%	NA	100%	100%	100%	100%	100%
Mean Exceedance (°C)	0.92	NA	1.68	2.61	0.86	1.41	1.50
Maximum Exceedance (°C)	1.85	NA	2.11	3.45	1.34	1.97	2.14
DAYS / OCT	7	1	13	2	4	3	5
% EXCEED / OCT	23%	3%	42%	6%	13%	10%	16%
Mean Exceedance (°C)	0.35	0.13	0.69	0.12	0.28	0.26	0.31
Maximum Exceedance (°C)	0.60	0.13	1.01	0.24	0.44	0.35	0.46

Water Quality Monitoring Station	DART ID	River Mile	Dates
Priest Rapids Dam Tailrace	PRXW	396	2011-2016

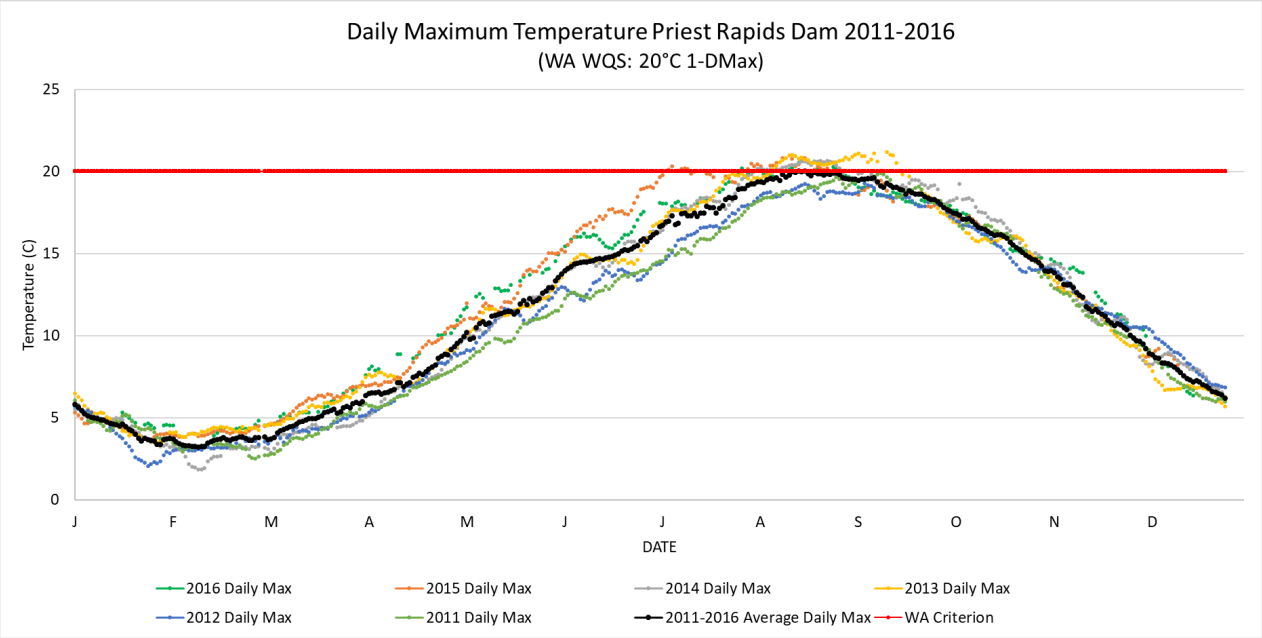

Figure 10. Daily maximum river temperature at Priest Rapids Dam for the years 2011-2016, plotted against the Washington numeric WQC of 20°C DM.

Table 15. Average and maximum temperature values calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Average and Maximum Temperature at Priest Rapids Dam 2011-2016							
	2016	2015	2014	2013	2012	2011	Average
ANNUAL Average	NA	NA	11.53	11.54	10.93	10.75	11.19
ANNUAL Maximum	NA	NA	20.62	21.15	19.24	19.85	20.22
JULY Average	NA	NA	17.64	17.98	15.89	15.50	16.75
JULY Maximum	NA	NA	19.61	19.83	17.84	17.51	18.70
AUGUST Average	NA	NA	20.10	20.17	18.50	18.61	19.34
AUGUST Maximum	NA	NA	20.62	20.98	19.19	19.63	20.11
SEPTEMBER Average	NA	NA	19.11	19.79	18.25	18.85	19.00
SEPTEMBER Maximum	NA	NA	19.98	21.15	19.24	19.85	20.06
OCTOBER Average	NA	NA	16.90	15.91	15.64	16.24	16.17
OCTOBER Maximum	NA	NA	19.19	17.48	17.88	18.17	18.18

Table 16. Priest Rapids Dam river temperature exceedances of the Washington numeric WQC of 20°C DM calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Priest Rapids Daily Maximum Temperature Exceedance of 20°C							
	2016	2015	2014	2013	2012	2011	Average
DAYS / YEAR	NA	NA	26	38	0	0	16
% EXCEED / YEAR	NA	NA	7%	10%	0%	0%	4%
Mean Exceedance (°C)	NA	NA	0.35	0.68	0	0	0.26
Maximum Exceedance (°C)	NA	NA	0.62	1.15	0	0	0.44
DAYS / JULY	NA	NA	0	0	0	0	0
% EXCEED / JULY	NA	NA	0%	0%	0%	0%	0%
Mean Exceedance (°C)	NA	NA	0	0	0	0	0
Maximum Exceedance (°C)	NA	NA	0	0	0	0	0
DAYS / AUG	NA	NA	26	23	0	0	12
% EXCEED / AUG	NA	NA	84%	74%	0%	0%	40%
Mean Exceedance (°C)	NA	NA	0.35	0.58	0	0	0.23
Maximum Exceedance (°C)	NA	NA	0.62	0.98	0	0	0.40
DAYS / SEPT	NA	NA	0	15	0	0	4
% EXCEED / SEPT	NA	NA	0%	50%	0%	0%	13%
Mean Exceedance (°C)	NA	NA	0	0.84	0	0	0.21
Maximum Exceedance (°C)	NA	NA	0	1.15	0	0	0.29
DAYS / OCT	0	0	0	0	0	0	0
% EXCEED / OCT	0%	0%	0%	0%	0%	0%	0%
Mean Exceedance (°C)	0	0	0	0	0	0	0
Maximum Exceedance (°C)	0	0	0	0	0	0	0

Water Quality Monitoring Station	DART ID	River Mile	Dates
Pasco, WA	PAQW	329	2011-2016

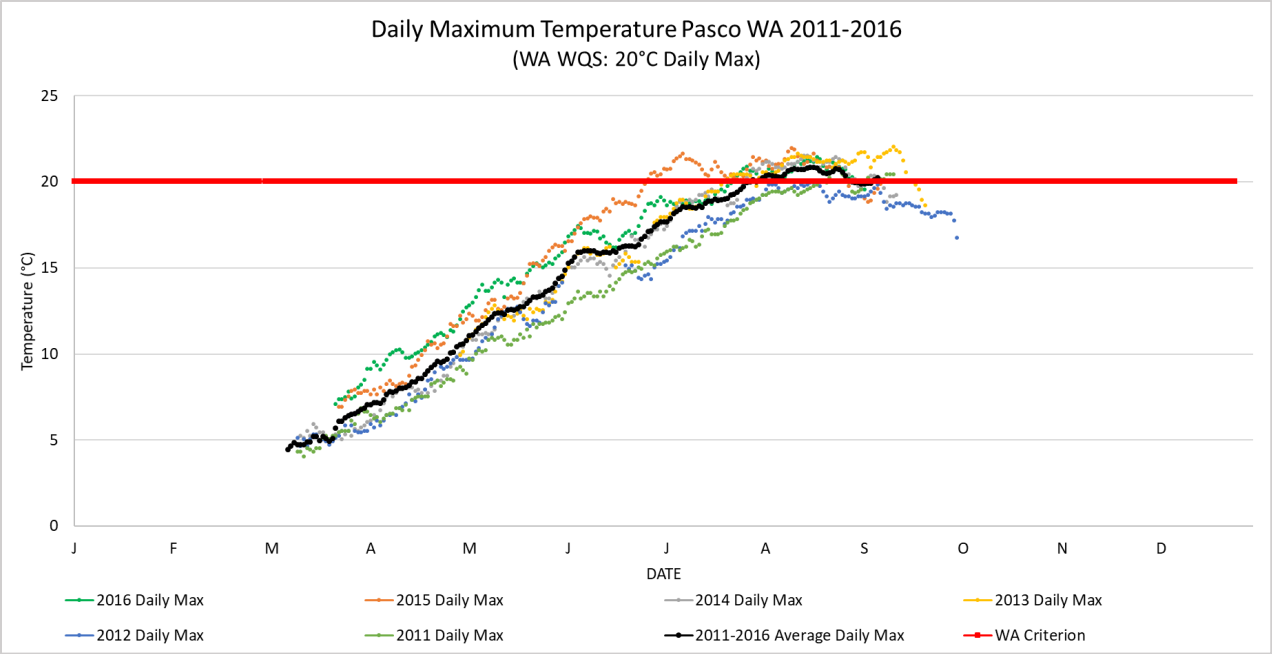

Figure 11. Daily maximum river temperature at Pasco, WA for the years 2011-2016, plotted against the Washington numeric WQC of 20°C DM.

Table 17. Average and maximum temperature values calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Average and Maximum Temperature (°C) at Pasco 2011-2016							
	2016	2015	2014	2013	2012	2011	Average
ANNUAL Average	NA	NA	NA	NA	NA	NA	NA
ANNUAL Maximum	21.39	21.94	21.50	22.00	19.90	20.40	21.19
JULY Average	19.05	20.50	18.48	18.84	16.75	16.43	18.34
JULY Maximum	20.83	21.61	20.40	20.40	18.90	18.70	20.14
AUGUST Average	20.51	20.85	20.82	20.77	19.23	19.31	20.25
AUGUST Maximum	21.39	21.94	21.50	21.60	19.90	20.40	21.12
SEPTEMBER Average	NA	NA	NA	20.75	18.48	NA	NA
SEPTEMBER Maximum	NA	NA	NA	22.00	19.80	NA	NA
OCTOBER Average	NA	NA	NA	NA	NA	NA	NA
OCTOBER Maximum	NA	NA	NA	NA	NA	NA	NA

Table 18. Pasco, WA river temperature exceedances of the Washington numeric WQC of 20°C DM calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Pasco Daily Maximum Temperature Exceedance of 20°C							
	2016	2015	2014	2013	2012	2011	Average
DAYS / YEAR	38	63	39	55	0	9	34
% EXCEED / YEAR	10%	17%	11%	15%	0%	2%	9%
Mean Exceedance (°C)	0.68	0.88	0.86	1.06	0	0.26	0.62
Maximum Exceedance (°C)	1.39	1.94	1.50	2.00	0	0.40	1.21
DAYS / JULY	6	31	2	8	0	0	8
% EXCEED / JULY	19%	100%	6%	26%	0%	0%	25%
Mean Exceedance (°C)	0.53	0.72	0.30	0.34	0	0	0.31
Maximum Exceedance (°C)	0.83	1.61	0.40	0.40	0	0	0.54
DAYS / AUG	31	30	31	29	0	3	21
% EXCEED / AUG	100%	97%	100%	94%	0%	10%	67%
Mean Exceedance (°C)	0.72	1.09	1.03	1.03	0	0.23	0.68
Maximum Exceedance (°C)	1.39	1.94	1.50	1.60	0	0.40	1.14
DAYS / SEPT	1	0	6	24	0	6	6
% EXCEED / SEPT	3%	0%	20%	80%	0%	20%	21%
Mean Exceedance (°C)	0.22	0	0.18	1.43	0	0.27	0.35
Maximum Exceedance (°C)	0.22	0	0.30	2.00	0	0.40	0.49
DAYS / OCT	NA	NA	NA	NA	NA	NA	NA
% EXCEED / OCT	NA	NA	NA	NA	NA	NA	NA
Mean Exceedance (°C)	NA	NA	NA	NA	NA	NA	NA
Maximum Exceedance (°C)	NA	NA	NA	NA	NA	NA	NA

Water Quality Monitoring Station	DART ID	River Mile	Dates
McNary Dam Tailrace	MCPW	291	2011-2016

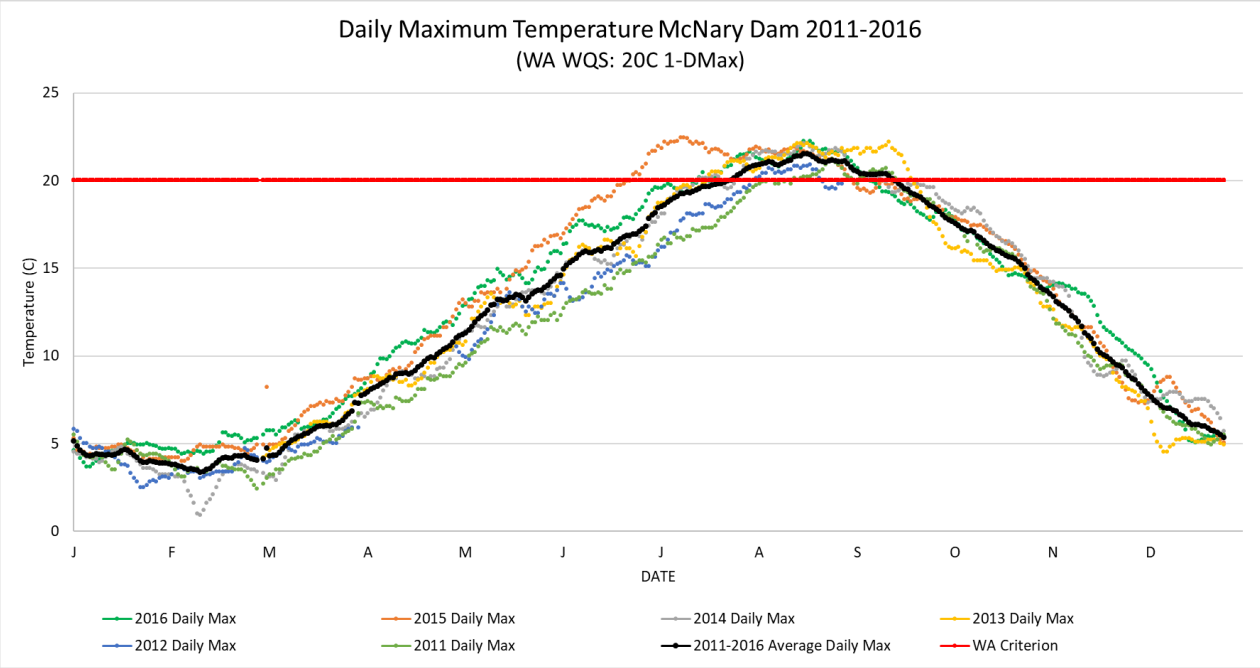

Figure 12. Daily maximum river temperature at McNary Dam for the years 2011-2016, plotted against the Washington numeric WQC of 20°C DM.

Table 19. Average and maximum temperature values calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Average and Maximum Temperature (°C) at McNary Dam 2011-2016							
	2016	2015	2014	2013	2012	2011	Average
ANNUAL Average	12.81	13.04	12.09	13.58	NA	11.13	12.53
ANNUAL Maximum	22.22	22.44	22.10	22.20	NA	21.20	21.84
JULY Average	19.91	21.67	19.24	19.64	17.55	16.94	19.16
JULY Maximum	21.44	22.44	20.80	21.10	19.60	19.00	20.73
AUGUST Average	21.33	21.38	21.49	21.31	20.14	20.04	20.95
AUGUST Maximum	22.22	21.89	22.10	22.10	20.90	21.20	21.74
SEPTEMBER Average	19.17	19.21	19.82	20.65	NA	19.72	19.71
SEPTEMBER Maximum	21.44	20.61	21.40	22.20	NA	20.70	17.73
OCTOBER Average	16.03	16.77	17.12	15.29	NA	15.97	16.23
OCTOBER Maximum	18.3	18.5	19	17.2	NA	18	18.2

Table 20. McNary Dam river temperature exceedances of the Washington numeric WQC of 20°C DM calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

McNary Daily Maximum Temperature Exceedance of 20°C							
	2016	2015	2014	2013	2012	2011	Average
DAYS / YEAR	53	70	53	65	NA	30	49
% EXCEED / YEAR	15%	19%	15%	18%	NA	8%	13%
Mean Exceedance (°C)	1.16	1.52	1.08	1.36	NA	0.46	1.02
Maximum Exceedance (°C)	2.22	2.44	2.10	2.20	NA	1.20	1.84
DAYS / JULY	14	31	10	12	0	0	11
% EXCEED / JULY	45%	100%	32%	39%	0%	0%	36%
Mean Exceedance (°C)	0.66	1.82	0.24	0.78	0	0	0.58
Maximum Exceedance (°C)	1.44	2.44	0.80	1.10	0	0	0.96
DAYS / AUG	31	31	31	31	21	15	27
% EXCEED / AUG	100%	100%	100%	100%	68%	48%	86%
Mean Exceedance (°C)	1.49	1.49	1.60	1.45	0.55	0.55	1.19
Maximum Exceedance (°C)	2.22	1.89	2.10	2.10	0.90	1.20	1.74
DAYS / SEPT	8	3	12	22	NA	15	12
% EXCEED / SEPT	27%	10%	40%	73%	NA	50%	40%
Mean Exceedance (°C)	0.76	0.32	0.44	1.57	NA	0.37	0.69
Maximum Exceedance (°C)	1.44	0.61	1.40	2.20	NA	0.70	1.27
DAYS / OCT	0	0	0	0	0	0	0
% EXCEED / OCT	0%	0%	0%	0%	0%	0%	0%
Mean Exceedance (°C)	0	0	0	0	0	0	0
Maximum Exceedance (°C)	0	0	0	0	0	0	0

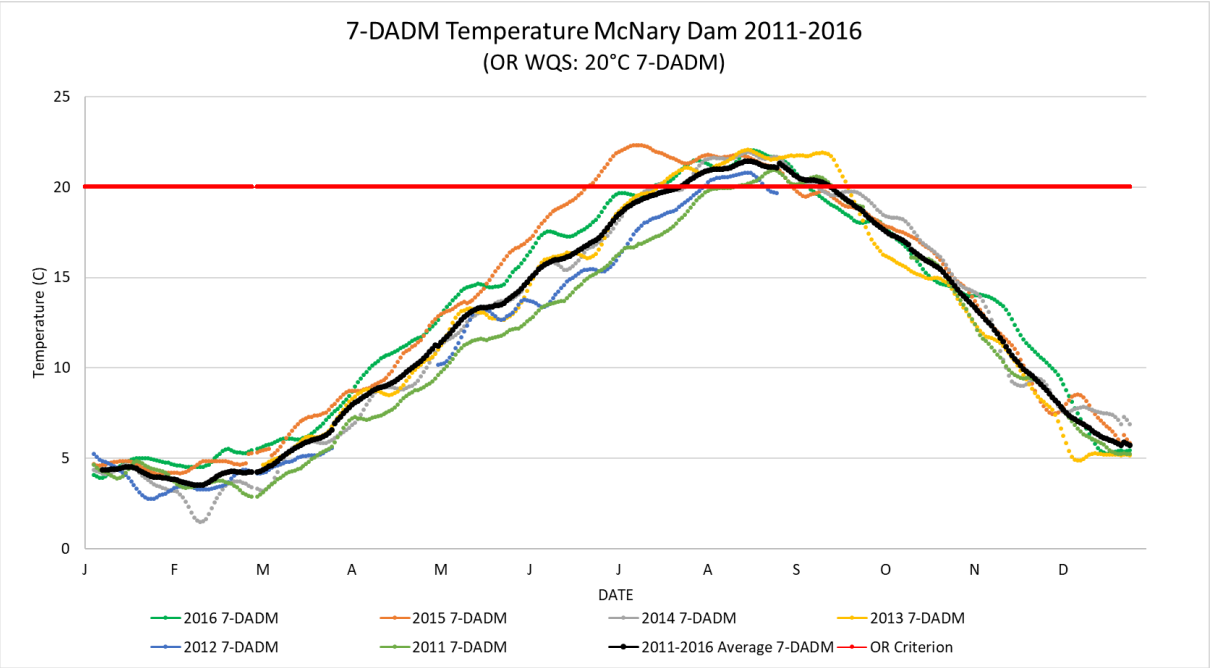

Figure 13. 7-DADM river temperature at McNary Dam for the years 2011-2016, plotted against the Oregon numeric WQC of 20°C 7-DADM.

Table 21. McNary Dam river temperature exceedances of the Oregon numeric WQC of 20°C 7-DADM calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

McNary 7-DADM Temperature Exceedance of 20°C							
	2016	2015	2014	2013	2012	2011	Average
DAYS / YEAR	53	71	50	66	NA	33	49
% EXCEED / YEAR	15%	19%	14%	18%	NA	9%	13%
Mean Exceedance (°C)	1.14	1.49	1.12	1.33	NA	0.39	1.00
Maximum Exceedance (°C)	1.99	2.29	1.90	2.03	NA	0.91	1.65
DAYS / JULY	14	31	8	13	0	0	11
% EXCEED / JULY	45%	100%	26%	42%	0%	0%	35%
Mean Exceedance (°C)	0.63	1.80	0.23	0.66	0	0	0.55
Maximum Exceedance (°C)	1.42	2.29	0.70	1.04	0	0	0.91
DAYS / AUG	31	31	31	31	21	16	27
% EXCEED / AUG	100%	100%	100%	100%	68%	52%	87%
Mean Exceedance (°C)	1.47	1.47	1.57	1.46	0.51	0.48	1.16
Maximum Exceedance (°C)	1.99	1.75	1.90	2.03	0.77	0.91	1.56
DAYS / SEPT	8	3	11	22	NA	17	12
% EXCEED / SEPT	27%	10%	37%	73%	NA	57%	41%
Mean Exceedance (°C)	0.76	0.28	0.50	1.54	NA	0.31	0.68
Maximum Exceedance (°C)	1.37	0.49	1.24	1.86	NA	0.54	1.10
DAYS / OCT	0	0	0	0	0	0	0
% EXCEED / OCT	0%	0%	0%	0%	0%	0%	0%
Mean Exceedance (°C)	0	0	0	0	0	0	0
Maximum Exceedance (°C)	0	0	0	0	0	0	0

Water Quality Monitoring Station	DART ID	River Mile	Dates
John Day Dam Tailrace	JHAW	214	2011-2016

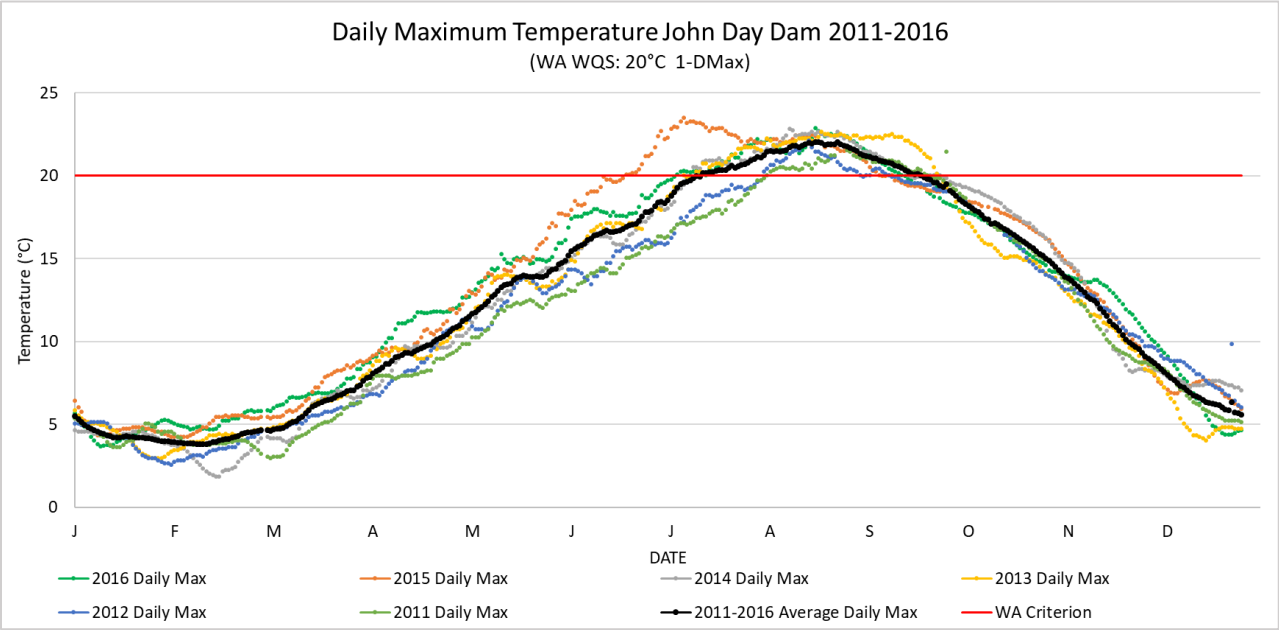

Figure 14. Daily maximum river temperature at John Day Dam for the years 2011-2016, plotted against the Washington numeric WQC of 20°C DM.

Table 22. Average and maximum temperature values calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Average and Maximum Temperature (°C) at John Day Dam 2011-2016							
	2016	2015	2014	2013	2012	2011	Average
ANNUAL Average	13.15	13.48	12.55	12.39	12.05	11.58	12.53
ANNUAL Maximum	22.83	23.44	22.80	22.60	22.10	21.50	22.55
JULY Average	20.38	22.51	19.93	20.14	17.97	17.48	19.73
JULY Maximum	21.94	23.44	21.40	21.70	19.40	19.30	21.20
AUGUST Average	21.92	21.87	22.09	22.05	20.79	20.47	21.53
AUGUST Maximum	22.83	22.44	22.80	22.60	22.10	21.50	22.38
SEPTEMBER Average	19.88	19.64	20.41	21.49	19.60	20.36	20.23
SEPTEMBER Maximum	21.90	21.28	21.80	22.50	20.40	21.40	21.55
OCTOBER Average	16.38	17.54	18.00	15.65	16.45	16.73	16.79
OCTOBER Maximum	18.11	18.90	19.5	18.9	18.9	19.2	18.92

Table 23. John Day Dam river temperature exceedances of the Washington numeric WQC of 20°C DM calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

John Day Daily Maximum Temperature Exceedance of 20°C							
	2016	2015	2014	2013	2012	2011	Average
DAYS / YEAR	69	79	68	76	35	47	62
% EXCEED / YEAR	19%	22%	19%	21%	10%	13%	17%
Mean Exceedance (°C)	1.37	1.97	1.48	1.78	0.90	0.71	1.37
Maximum Exceedance (°C)	2.83	3.44	2.80	2.60	2.10	1.50	2.55
DAYS / JULY	24	31	20	19	0	0	16
% EXCEED / JULY	77%	100%	65%	61%	0%	0%	51%
Mean Exceedance (°C)	0.74	2.68	0.79	1.01	0.00	0.00	0.87
Maximum Exceedance (°C)	1.94	3.44	1.40	1.70	0.00	0.00	1.41
DAYS / AUG	31	31	31	31	29	24	30
% EXCEED / AUG	100%	100%	100%	100%	94%	77%	95%
Mean Exceedance (°C)	2.05	1.96	2.21	2.15	1.03	0.70	1.68
Maximum Exceedance (°C)	2.83	2.44	2.80	2.60	2.10	1.50	2.38
DAYS / SEPT	14	7	17	26	6	23	16
% EXCEED / SEPT	47%	23%	57%	87%	20%	77%	52%
Mean Exceedance (°C)	0.94	0.73	0.97	1.91	0.27	0.73	0.93
Maximum Exceedance (°C)	1.90	1.28	1.80	2.50	0.40	1.40	1.55
DAYS / OCT	0	0	0	0	0	0	0
% EXCEED / OCT	0%	0%	0%	0%	0%	0%	0%
Mean Exceedance (°C)	0	0	0	0	0	0	0
Maximum Exceedance (°C)	0	0	0	0	0	0	0

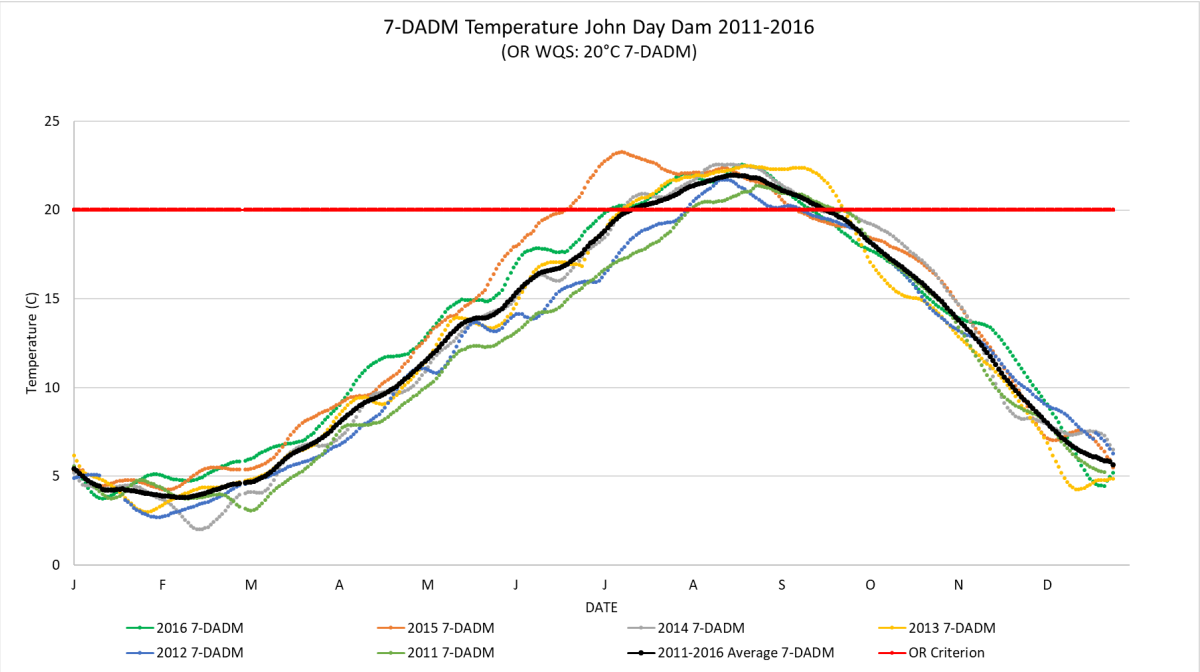

Figure 15. 7-DADM river temperature at John Day Dam for the years 2011-2016, plotted against the Oregon numeric WQC of 20°C 7-DADM.

Table 24. John Day Dam river temperature exceedances of the Oregon numeric WQC of 20°C 7-DADM calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

John Day 7-DADM Temperature Exceedance of 20°C							
	2016	2015	2014	2013	2012	2011	Average
DAYS / YEAR	71	80	69	77	40	52	65
% EXCEED / YEAR	19%	22%	19%	21%	11%	14%	18%
Mean Exceedance (°C)	1.32	1.94	1.45	1.75	0.76	0.68	1.32
Maximum Exceedance (°C)	2.52	3.23	2.54	2.47	1.69	1.33	2.30
DAYS / JULY	25	31	20	20	0	0	16
% EXCEED / JULY	81%	100%	65%	65%	0%	0%	52%
Mean Exceedance (°C)	0.70	2.65	0.77	0.95	0	0	0.84
Maximum Exceedance (°C)	1.90	3.23	1.20	1.69	0	0	1.34
DAYS / AUG	31	31	31	31	29	28	30
% EXCEED / AUG	100%	100%	100%	100%	94%	90%	97%
Mean Exceedance (°C)	2.04	1.96	2.19	2.15	1.00	0.71	1.67
Maximum Exceedance (°C)	2.52	2.36	2.54	2.47	1.69	1.33	2.15
DAYS / SEPT	15	9	18	26	11	24	17
% EXCEED / SEPT	50%	30%	60%	87%	37%	80%	57%
Mean Exceedance (°C)	0.89	0.59	0.92	1.89	0.14	0.64	0.84
Maximum Exceedance (°C)	1.89	1.22	1.81	2.34	0.20	1.19	1.44
DAYS / OCT	0	0	0	0	0	0	0
% EXCEED / OCT	0%	0%	0%	0%	0%	0%	0%
Mean Exceedance (°C)	0	0	0	0	0	0	0
Maximum Exceedance (°C)	0	0	0	0	0	0	0

Water Quality Monitoring Station	DART ID	River Mile	Dates
The Dalles Dam Tailrace	TDDO	190	2011-2016

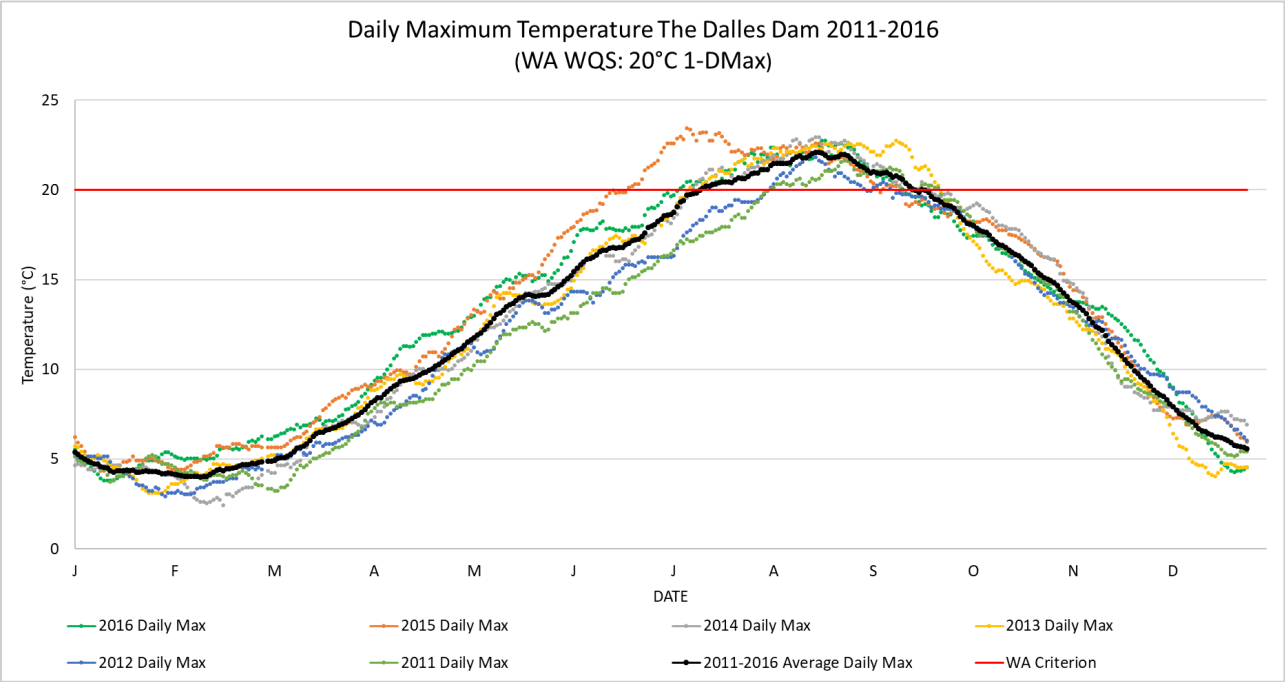

Figure 16. Daily maximum river temperature at the Dalles Dam for the years 2011-2016, plotted against the Washington numeric WQC of 20°C DM.

Table 25. Average and maximum temperature values calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Average and Maximum Temperature (°C) at The Dalles Dam 2011-2016							
	2016	2015	2014	2013	2012	2011	Average
ANNUAL Average	13.17	13.53	12.61	12.43	12.10	11.68	12.59
ANNUAL Maximum	22.72	23.39	22.90	22.70	22.00	21.60	22.55
JULY Average	20.39	22.42	20.04	20.17	18.06	17.48	19.76
JULY Maximum	22.00	23.39	21.30	21.70	19.40	19.30	21.18
AUGUST Average	21.86	21.78	22.06	22.02	20.77	20.50	21.50
AUGUST Maximum	22.72	22.56	22.90	22.50	22.00	21.60	22.38
SEPTEMBER Average	19.68	19.50	20.27	21.29	19.48	20.27	20.08
SEPTEMBER Maximum	21.61	21.00	21.70	22.70	20.40	21.20	21.44
OCTOBER Average	16.17	17.42	17.74	15.50	16.28	16.58	16.62
OCTOBER Maximum	17.94	18.83	19.2	18.4	18.8	19.3	18.75

Table 26. The Dalles Dam river temperature exceedances of the Washington numeric WQC of 20°C DM calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

The Dalles Daily Maximum Temperature Exceedance of 20°C							
	2016	2015	2014	2013	2012	2011	Average
DAYS / YEAR	68	83	70	75	34	49	63
% EXCEED / YEAR	19%	23%	19%	21%	9%	13%	17%
Mean Exceedance (°C)	1.39	1.86	1.47	1.79	0.88	0.72	1.35
Maximum Exceedance (°C)	2.72	3.39	2.90	2.70	2.00	1.60	2.55
DAYS / JULY	25	31	21	19	0	0	16
% EXCEED / JULY	81%	100%	68%	61%	0%	0%	52%
Mean Exceedance (°C)	0.83	2.62	0.84	1.05	0	0	0.89
Maximum Exceedance (°C)	2.00	3.39	1.30	1.70	0	0	1.40
DAYS / AUG	31	31	31	31	28	27	30
% EXCEED / AUG	100%	100%	100%	100%	90%	87%	96%
Mean Exceedance (°C)	2.06	1.96	2.25	2.19	1.02	0.74	1.70
Maximum Exceedance (°C)	2.72	2.56	2.90	2.50	2.00	1.60	2.38
DAYS / SEPT	12	11	18	25	6	22	16
% EXCEED / SEPT	40%	37%	60%	83%	20%	73%	52%
Mean Exceedance (°C)	0.85	0.41	0.84	1.84	0.25	0.70	0.82
Maximum Exceedance (°C)	1.61	1.00	1.70	2.70	0.40	1.20	1.44
DAYS / OCT	0	0	0	0	0	0	0
% EXCEED / OCT	0%	0%	0%	0%	0%	0%	0%
Mean Exceedance (°C)	0	0	0	0	0	0	0
Maximum Exceedance (°C)	0	0	0	0	0	0	0

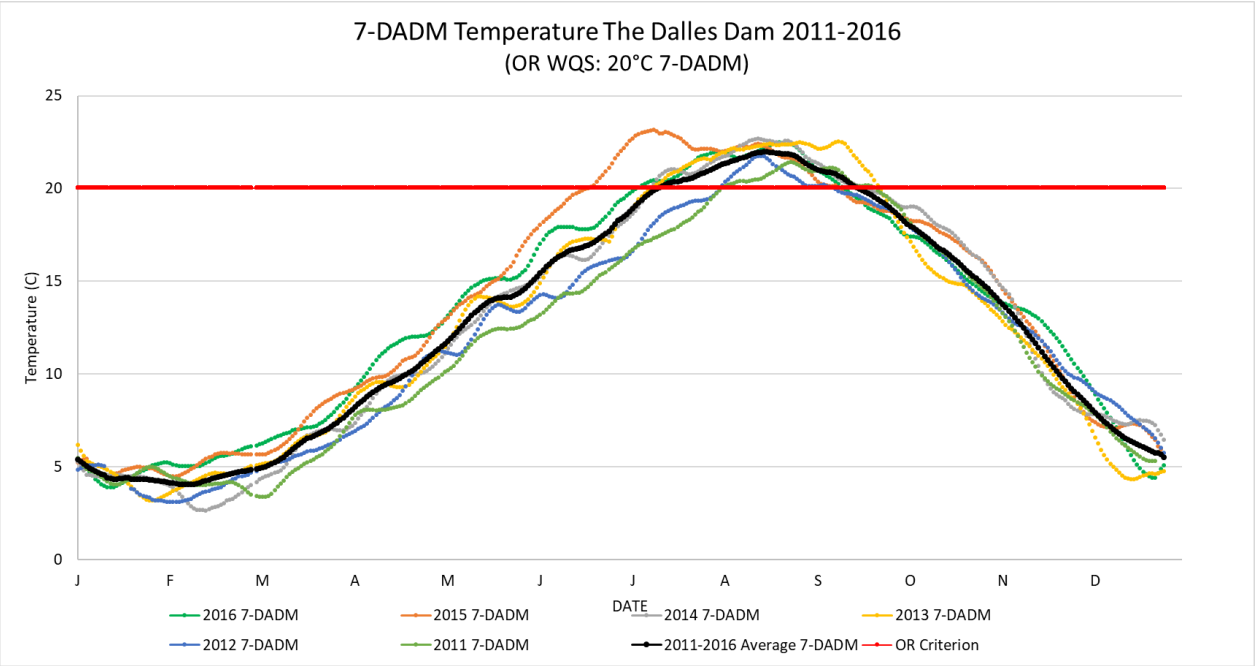

Figure 17. 7-DADM river temperature at the Dalles Dam for the years 2011-2016, plotted against the Oregon numeric WQC of 20°C 7-DADM.

Table 27. The Dalles Dam river temperature exceedances of the Oregon numeric WQC of 20°C 7-DADM calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

The Dalles 7-DADM Temperature Exceedance of 20°C							
	2016	2015	2014	2013	2012	2011	Average
DAYS / YEAR	69	84	72	76	38	50	65
% EXCEED / YEAR	19%	23%	20%	21%	10%	14%	18%
Mean Exceedance (°C)	1.36	1.83	1.41	1.75	0.76	0.69	1.30
Maximum Exceedance (°C)	2.46	3.14	2.64	2.50	1.71	1.39	2.31
DAYS / JULY	25	31	21	20	0	0	16
% EXCEED / JULY	81%	100%	68%	65%	0%	0%	52%
Mean Exceedance (°C)	0.82	2.60	0.83	0.99	0.00	0.00	0.87
Maximum Exceedance (°C)	1.86	3.14	1.36	1.59	0.00	0.00	1.32
DAYS / AUG	31	31	31	31	28	27	30
% EXCEED / AUG	100%	100%	100%	100%	90%	87%	96%
Mean Exceedance (°C)	2.04	1.96	2.24	2.19	0.99	0.72	1.69
Maximum Exceedance (°C)	2.46	2.37	2.64	2.46	1.71	1.39	2.17
DAYS / SEPT	13	12	20	25	10	23	17
% EXCEED / SEPT	43%	40%	67%	83%	33%	77%	57%
Mean Exceedance (°C)	0.80	0.35	0.76	1.82	0.11	0.65	0.75
Maximum Exceedance (°C)	1.67	0.99	1.67	2.50	0.17	1.07	1.35
DAYS / OCT	0	0	0	0	0	0	0
% EXCEED / OCT	0%	0%	0%	0%	0%	0%	0%
Mean Exceedance (°C)	0	0	0	0	0	0	0
Maximum Exceedance (°C)	0	0	0	0	0	0	0

Water Quality Monitoring Station	DART ID	River Mile	Dates

Bonneville Dam (downstream)	WRNO	140	2011-2016

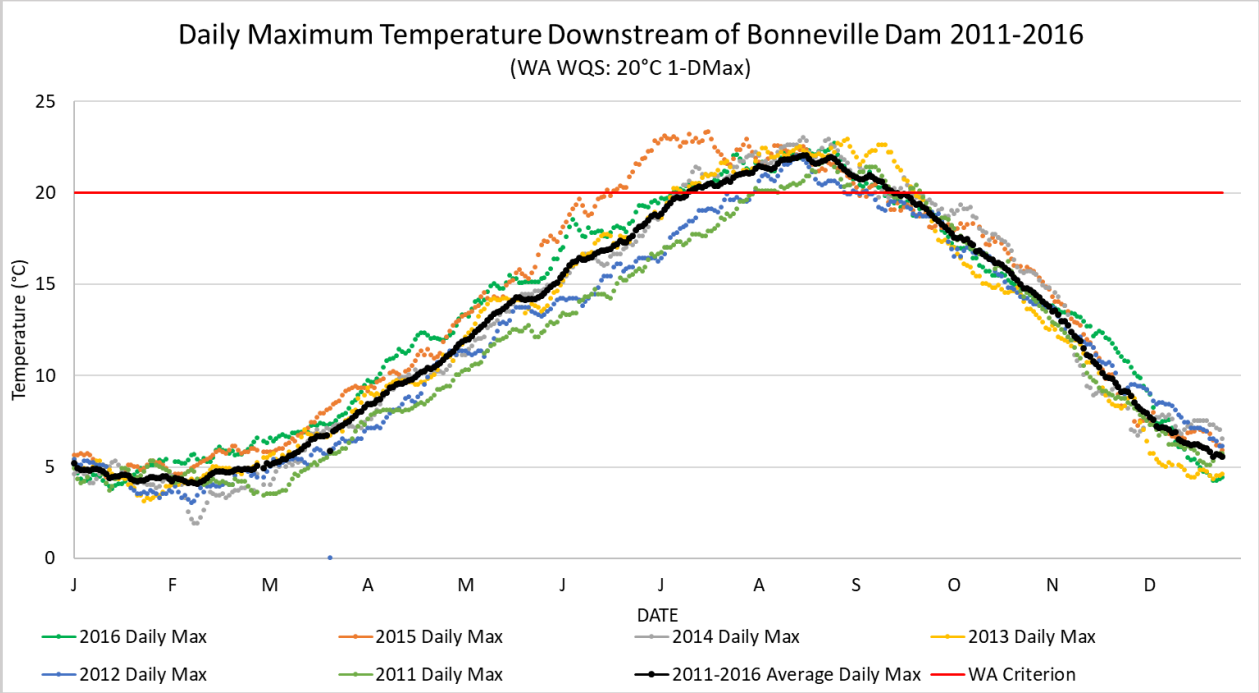

Figure 18. Daily maximum river temperature below Bonneville Dam for the years 2011-2016, plotted against the Washington numeric WQC of 20°C DM.

Table 28. Average and maximum temperature values calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Average and Maximum Temperature at Bonneville Dam 2011-2016							
	2016	2015	2014	2013	2012	2011	Average
ANNUAL Average	13.14	13.58	12.57	12.35	12.08	11.50	12.54
ANNUAL Maximum	22.67	23.33	23.00	22.90	22.00	21.60	22.58
JULY Average	20.21	22.32	20.07	20.07	18.15	17.51	19.72
JULY Maximum	22.06	23.33	21.70	21.70	19.90	19.50	21.37
AUGUST Average	21.61	21.68	21.99	21.83	20.64	20.26	21.34
AUGUST Maximum	22.67	22.89	23.00	22.70	22.00	21.60	22.48
SEPTEMBER Average	19.46	19.27	19.95	20.91	19.09	19.97	19.78
SEPTEMBER Maximum	21.44	21.17	21.80	22.90	20.10	21.40	21.47
OCTOBER Average	15.89	17.01	17.50	15.12	15.77	16.32	16.27
OCTOBER Maximum	18.4	18.39	19.3	17.4	18.8	18.6	18.48

Table 29. Bonneville Dam river temperature exceedances of the Washington numeric WQC of 20°C DM calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Bonneville Daily Maximum Temperature Exceedance of 20°C							
	2016	2015	2014	2013	2012	2011	Average
DAYS / YEAR	66	85	67	75	30	42	61
% EXCEED / YEAR	18%	23%	18%	21%	8%	12%	17%
Mean Exceedance (°C)	1.29	1.83	1.54	1.67	0.93	0.67	1.32
Maximum Exceedance (°C)	2.67	3.33	3.00	2.90	2.00	1.60	2.58
DAYS / JULY	22	31	20	21	0	0	16
% EXCEED / JULY	71%	100%	65%	68%	0%	0%	51%
Mean Exceedance (°C)	0.80	2.59	0.99	0.89	0	0	0.88
Maximum Exceedance (°C)	2.06	3.33	1.70	1.70	0	0	1.47
DAYS / AUG	31	31	31	31	28	24	29
% EXCEED / AUG	100%	100%	100%	100%	90%	77%	95%
Mean Exceedance (°C)	1.89	1.91	2.26	2.07	0.99	0.60	1.62
Maximum Exceedance (°C)	2.67	2.89	3.00	2.70	2.00	1.60	2.48
DAYS / SEPT	13	11	16	23	2	18	14
% EXCEED / SEPT	43%	37%	53%	77%	7%	60%	46%
Mean Exceedance (°C)	0.68	0.54	0.84	1.85	0.10	0.76	0.79
Maximum Exceedance (°C)	1.44	1.17	1.80	2.90	0.10	1.40	1.47
DAYS / OCT	0	0	0	0	0	0	0
% EXCEED / OCT	0%	0%	0%	0%	0%	0%	0%
Mean Exceedance (°C)	0	0	0	0	0	0	0
Maximum Exceedance (°C)	0	0	0	0	0	0	0

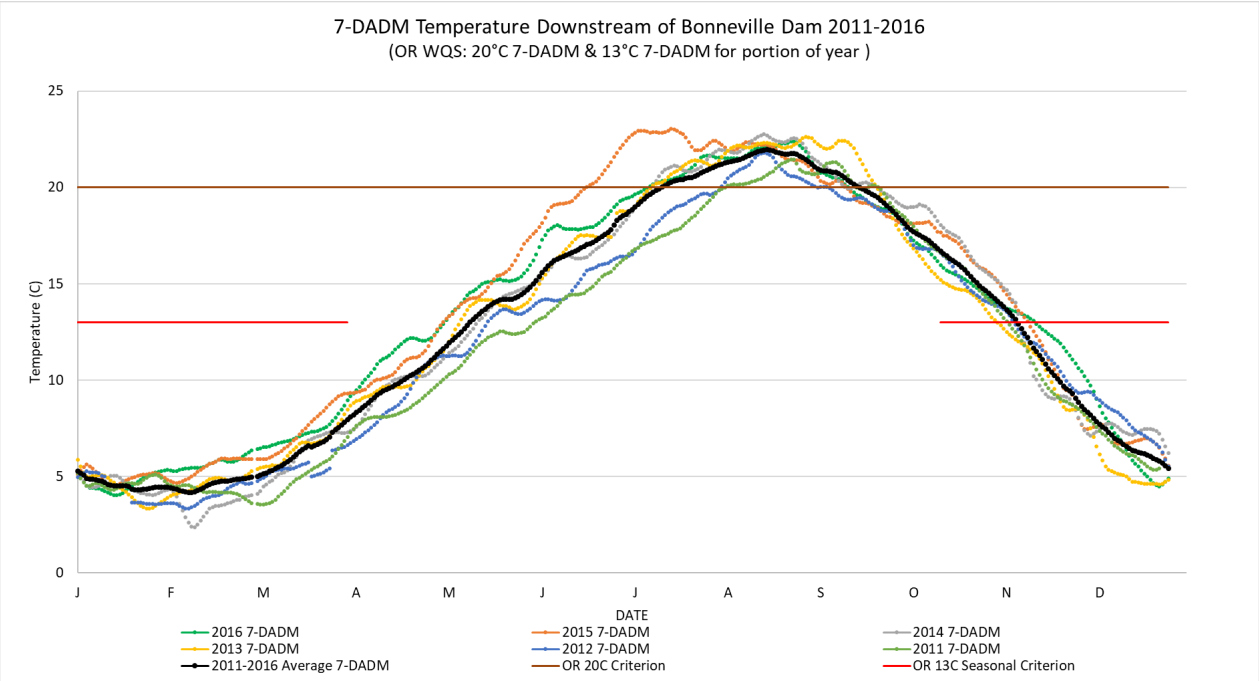

Figure 19. 7-DADM river temperature at Bonneville Dam for the years 2011-2016, plotted against the Oregon numeric WQC of 20°C 7-DADM year-round and a seasonal criterion of 13°C 7-DADM.

Table 30. Bonneville Dam river temperature exceedances of the Oregon numeric WQC of 20°C 7-DADM calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Bonneville 7-DADM Temperature Exceedance of 20°C							
	2016	2015	2014	2013	2012	2011	Average
DAYS / YEAR	66	86	71	75	32	45	63
% EXCEED / YEAR	18%	24%	19%	21%	9%	12%	17%
Mean Exceedance (°C)	1.28	1.79	1.44	1.66	0.85	0.69	1.28
Maximum Exceedance (°C)	2.35	3.01	2.71	2.59	1.74	1.40	2.30
DAYS / JULY	22	31	21	21	0	0	16
% EXCEED / JULY	71%	100%	68%	68%	0%	0%	51%
Mean Exceedance (°C)	0.77	2.58	0.94	0.87	0	0	0.86
Maximum Exceedance (°C)	1.63	3.01	1.73	1.37	0	0	1.29
DAYS / AUG	31	31	31	31	29	27	30
% EXCEED / AUG	100%	100%	100%	100%	94%	87%	97%
Mean Exceedance (°C)	1.88	1.90	2.24	2.08	0.93	0.64	1.61
Maximum Exceedance (°C)	2.35	2.39	2.71	2.59	1.74	1.40	2.20
DAYS / SEPT	13	13	19	23	3	18	15
% EXCEED / SEPT	43%	43%	63%	77%	10%	60%	49%
Mean Exceedance (°C)	0.70	0.38	0.67	1.82	0.10	0.77	0.74
Maximum Exceedance (°C)	1.55	1.06	1.76	2.56	0.19	1.29	1.40
DAYS / OCT	0	0	0	0	0	0	0
% EXCEED / OCT	0%	0%	0%	0%	0%	0%	0%
Mean Exceedance (°C)	0	0	0	0	0	0	0
Maximum Exceedance (°C)	0	0	0	0	0	0	0

Table 31. Bonneville Dam river temperature exceedances of the Oregon numeric WQC of 13°C 7-DADM (applicable October 15th- March 31st) calculated over each year 2011-2016 and from October 15th -October 31st. The right column is the 2011-2016 average of these values.

Bonneville 7-DADM Temperature Exceedance of 13°C Oct. 15th-31st							
	2016	2015	2014	2013	2012	2011	Average
DAYS / OCT	17	17	17	17	17	17	17
% EXCEED / OCT	100%	100%	100%	100%	100%	100%	100%
Mean Exceedance (°C)	2.13	3.61	3.78	1.49	2.12	2.51	2.6
Maximum Exceedance (°C)	2.92	4.63	5.01	2.16	3.57	3.60	3.65

SNAKE RIVER

Water Quality Monitoring Station	DART ID	River Mile	Dates
Anatone, WA	ANQW	167.5	2011-2016

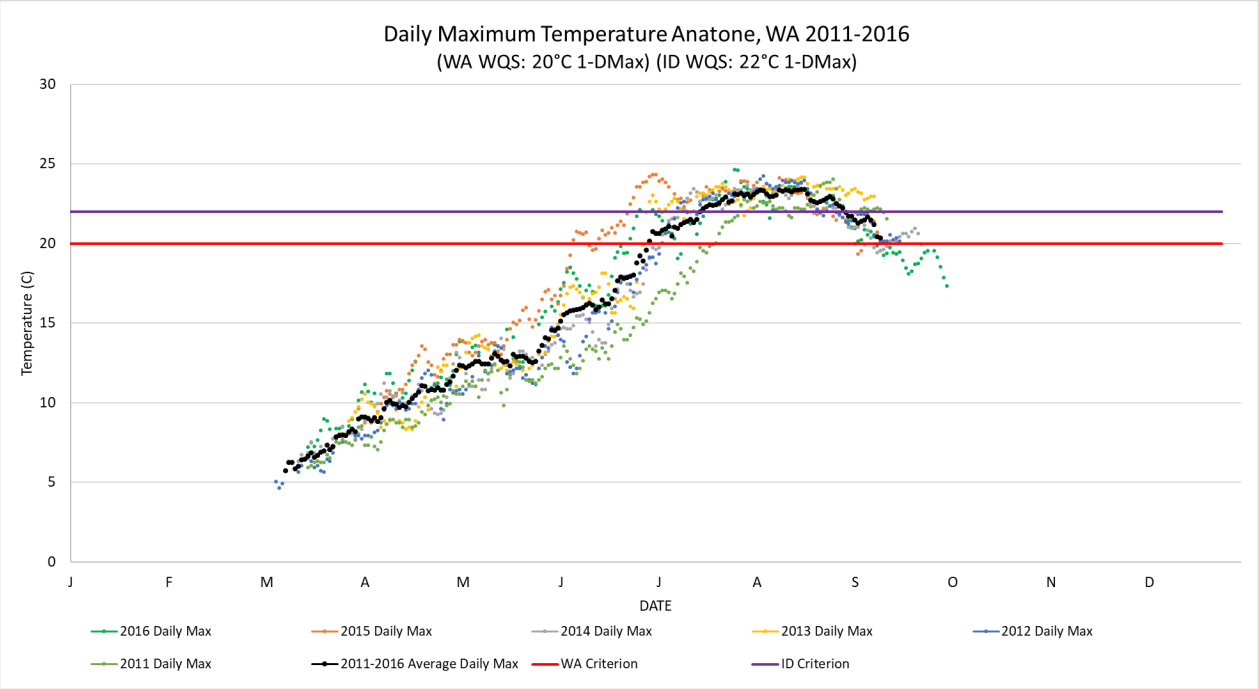

Figure 20. Daily maximum river temperature at Anatone, WA for the years 2011-2016, plotted against the Idaho WQC of 22°C DM and the Washington numeric WQC of 20°C DM.

Table 32. Average and maximum temperature values calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Average and Maximum Temperature (°C) at Anatone 2011-2016							
	2016	2015	2014	2013	2012	2011	Average
ANNUAL Average	NA	NA	NA	NA	NA	NA	NA
ANNUAL Maximum	24.61	24.28	23.70	24.10	24.20	24.00	24.15
JULY Average	21.30	22.74	21.32	22.02	21.06	18.27	21.12
JULY Maximum	24.61	24.28	23.40	23.70	23.10	22.40	23.58
AUGUST Average	22.30	22.52	22.35	22.76	22.59	22.07	22.43
AUGUST Maximum	23.50	24.06	23.70	24.10	24.20	24.00	23.93
SEPTEMBER Average	19.37	NA	19.99	NA	NA	NA	NA
SEPTEMBER Maximum	22.30	22.11	21.90	NA	NA	NA	22.30
OCTOBER Average	17.91	NA	NA	NA	NA	NA	NA
OCTOBER Maximum	19.11	NA	NA	NA	NA	NA	NA

Table 33. Anatone, WA river temperature exceedances of the Idaho numeric WQC of 22°C DM calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Anatone, WA Daily Maximum Temperature Exceedance of 22°C							
	2016	2015	2014	2013	2012	2011	Average
DAYS / YEAR	30	50	47	NA	43	NA	45
% EXCEED / YEAR	8%	14%	13%	NA	12%	NA	12%
Mean Exceedance (°C)	1.03	1.29	0.93	NA	1.14	NA	1.03
Maximum Exceedance (°C)	2.61	2.28	1.70	NA	2.20	NA	2.15
DAYS / JULY	9	25	20	25	17	1	16
% EXCEED / JULY	29%	81%	65%	81%	55%	3%	52%
Mean Exceedance (°C)	1.42	1.29	0.81	0.86	0.76	0.40	0.92
Maximum Exceedance (°C)	2.61	2.28	1.40	1.70	1.10	0.40	1.58
DAYS / AUG	19	19	27	29	26	28	25
% EXCEED / AUG	61%	61%	87%	94%	84%	90%	80%
Mean Exceedance (°C)	0.93	1.38	1.01	1.48	1.39	0.73	1.15
Maximum Exceedance (°C)	1.50	2.06	1.70	2.10	2.20	2.00	1.93
DAYS / SEPT	1	1	0	NA	0	NA	3
% EXCEED / SEPT	3%	3%	0%	NA	0%	NA	11%
Mean Exceedance (°C)	0.30	0.11	0	NA	0.00	NA	0.27
Maximum Exceedance (°C)	0.30	0.11	0	NA	0.00	NA	0.34
DAYS / OCT	NA	NA	NA	NA	NA	NA	NA
% EXCEED / OCT	NA	NA	NA	NA	NA	NA	NA
Mean Exceedance (°C)	NA	NA	NA	NA	NA	NA	NA
Maximum Exceedance (°C)	NA	NA	NA	NA	NA	NA	NA

Table 34. Anatone, WA river temperature exceedances of the Washington numeric WQC of 20°C DM calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Anatone, WA Daily Maximum Temperature Exceedance of 20°C							
	2016	2015	2014	2013	2012	2011	Average
DAYS / YEAR	55	74	76	NA	74	NA	68
% EXCEED / YEAR	15%	20%	21%	NA	20%	NA	19%
Mean Exceedance (°C)	2.11	2.57	2.20	NA	2.33	NA	2.42
Maximum Exceedance (°C)	4.61	4.28	3.70	NA	4.20	NA	4.15
DAYS / JULY	20	25	26	31	25	8	23
% EXCEED / JULY	65%	81%	84%	100%	81%	26%	73%
Mean Exceedance (°C)	2.17	3.29	2.45	2.67	2.30	1.41	2.38
Maximum Exceedance (°C)	4.61	4.28	3.40	3.70	3.10	2.40	3.58
DAYS / AUG	20	25	31	31	31	31	28
% EXCEED / AUG	65%	81%	100%	100%	100%	100%	91%
Mean Exceedance (°C)	2.87	2.99	2.87	3.37	3.15	2.63	2.98
Maximum Exceedance (°C)	3.50	4.06	3.70	4.10	4.20	4.00	3.93
DAYS / SEPT	11	4	19	NA	18	NA	13
% EXCEED / SEPT	37%	13%	63%	NA	60%	NA	43%
Mean Exceedance (°C)	0.93	1.39	0.75	NA	0.97	NA	1.51
Maximum Exceedance (°C)	2.30	2.11	1.90	NA	1.90	NA	2.30
DAYS / OCT	NA	NA	NA	NA	NA	NA	NA
% EXCEED / OCT	NA	NA	NA	NA	NA	NA	NA
Mean Exceedance (°C)	NA	NA	NA	NA	NA	NA	NA
Maximum Exceedance (°C)	NA	NA	NA	NA	NA	NA	NA

Water Quality Monitoring Station	DART ID	River Mile	Dates
Clearwater Station (on Clearwater River)	PEKI	37.4	2011-2016

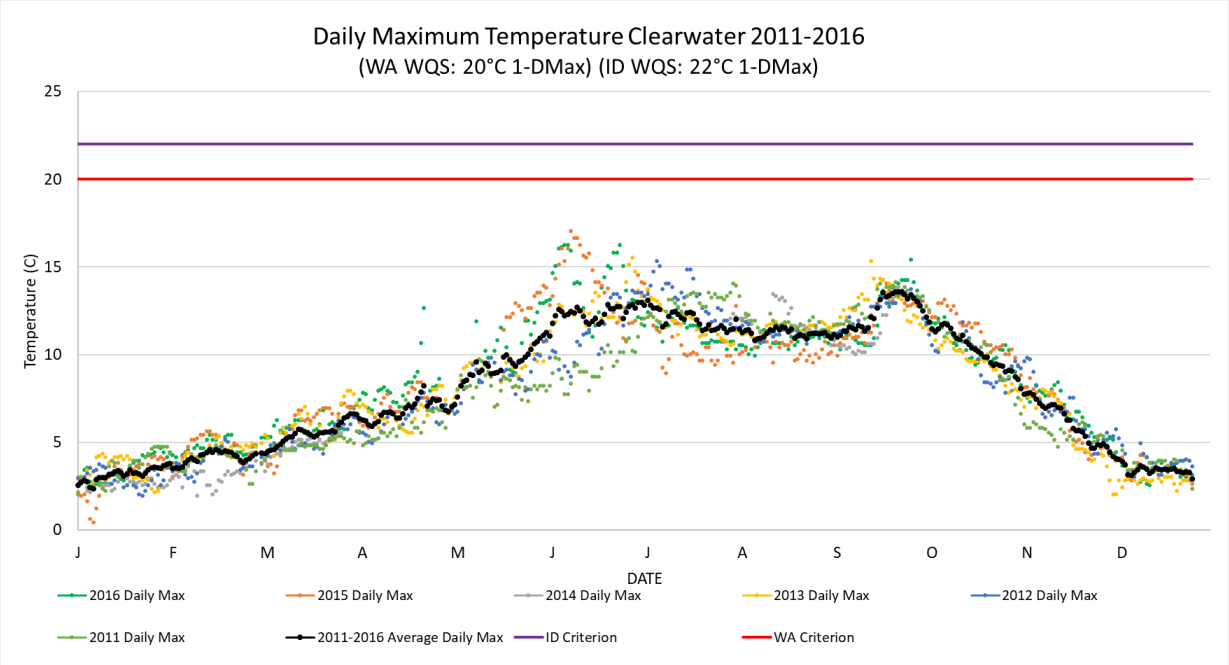

Figure 21. Daily maximum river temperature at the Clearwater station for the years 2011-2016, plotted against the Idaho numeric WQC of 22°C DM and Washington's numeric WQC of 20°C DM.

Table 35. Average and maximum temperature values calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Average and Maximum Temperature (°C) at Clearwater River 2011-2016							
	2016	2015	2014	2013	2012	2011	Average
ANNUAL Average	8.13	7.98	NA	7.70	7.57	7.38	7.50
ANNUAL Maximum	16.22	17.00	NA	15.50	15.30	14.10	15.32
JULY Average	10.90	10.13	NA	11.35	12.82	12.04	11.45
JULY Maximum	13.00	14.50	NA	14.70	15.30	13.50	14.20
AUGUST Average	10.17	9.75	NA	10.77	10.66	11.40	10.65
AUGUST Maximum	11.39	12.72	NA	11.80	11.80	14.00	12.52
SEPTEMBER Average	11.36	11.25	NA	12.39	11.67	12.05	11.57
SEPTEMBER Maximum	15.39	14.22	NA	15.30	13.70	14.10	14.42
OCTOBER Average	10.47	11.27	NA	9.58	9.61	10.42	10.27
OCTOBER Maximum	13.6	13.11	NA	12.1	13.1	13.3	13.04

*NOTE: No exceedance table generated for Clearwater – does not exceed WQC)

Water Quality Monitoring Station	DART ID	River Mile	Dates
Dworshak Dam Tailrace (on Clearwater River)	DWQI	0.5	2011-2016

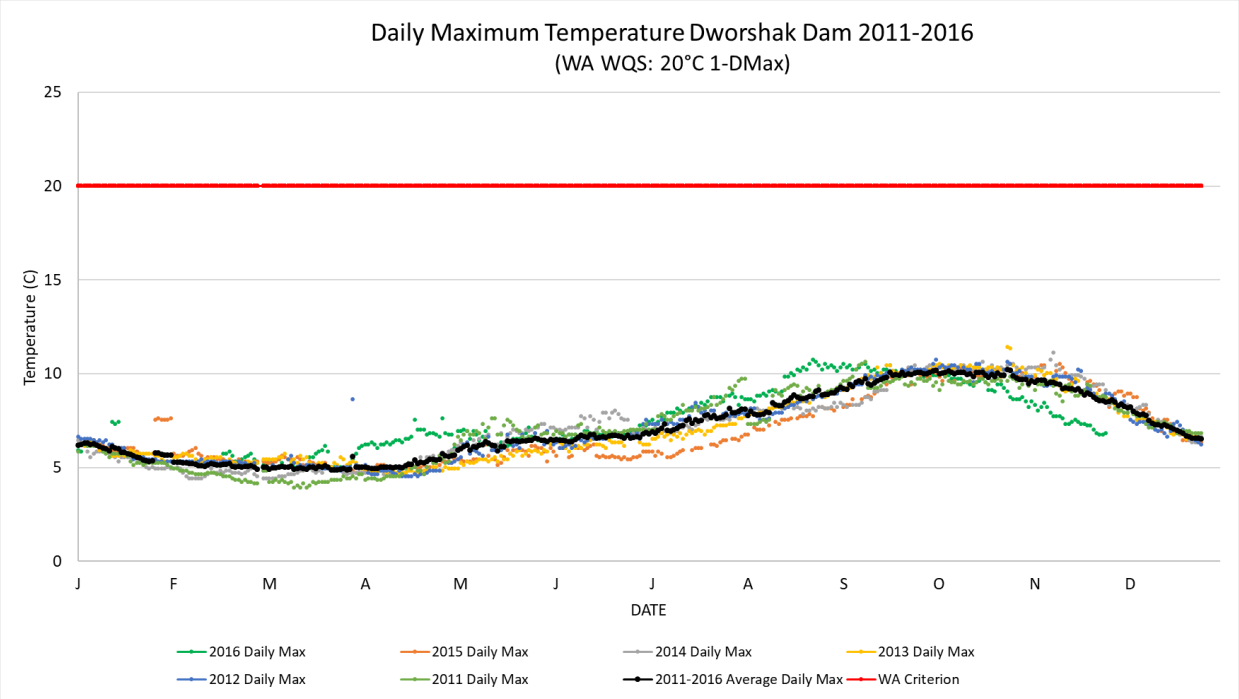

Figure 22. Daily maximum river temperature at Dworshak Dam for the years 2011-2016, plotted against the downstream Washington numeric WQC of 20°C DM.

Table 36. Average and maximum temperature values calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Average and Maximum Temperature (°C) at Dworshak Dam 2011-2016							
	2016	2015	2014	2013	2012	2011	Average
ANNUAL Average	7.40	6.50	6.96	6.86	7.00	6.91	6.94
ANNUAL Maximum	10.70	10.50	11.10	11.40	10.70	10.60	10.83
JULY Average	7.85	5.73	7.01	6.55	7.37	7.79	7.05
JULY Maximum	8.90	6.50	7.70	7.30	8.40	9.20	8.00
AUGUST Average	9.22	7.13	7.88	8.01	7.95	8.37	8.09
AUGUST Maximum	10.70	8.20	8.30	8.80	8.90	9.70	9.10
SEPTEMBER Average	9.99	8.79	8.91	9.53	9.45	9.36	9.34
SEPTEMBER Maximum	10.50	10.10	10.40	10.40	10.30	10.60	10.38
OCTOBER Average	9.36	9.67	10.07	10.03	9.96	9.33	9.74
OCTOBER Maximum	10	10.3	10.6	11.4	10.7	9.8	10.45

*NOTE: No exceedance table generated for Dworshak, does not exceed WQC)

Water Quality Monitoring Station	DART ID	River Mile	Dates
Lower Granite Dam Tailrace	LGNW	106	2011-2016

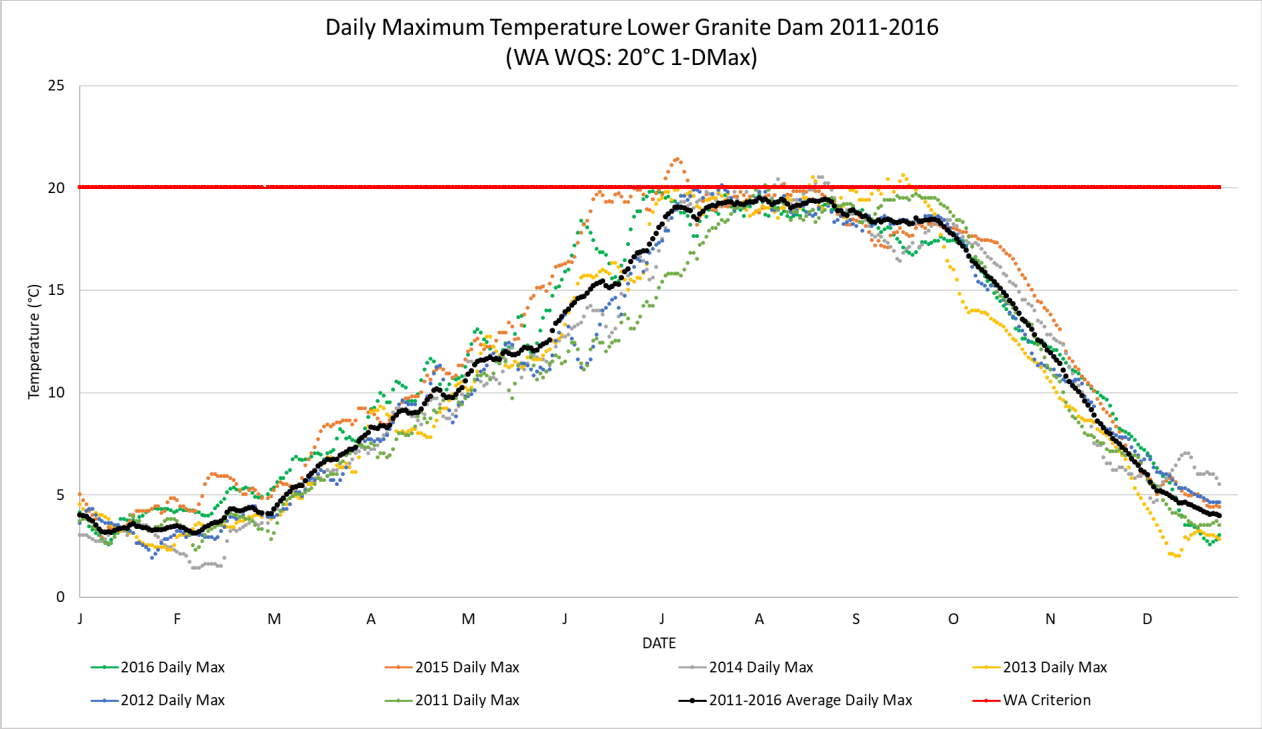

Figure 23. Daily maximum river temperature at Lower Granite Dam for the years 2011-2016, plotted against the Washington numeric WQC of 20°C DM.

Table 37. Average and maximum temperature values calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Average and Maximum Temperature (°C) at Lower Granite Dam 2011-2016							
	2016	2015	2014	2013	2012	2011	Average
ANNUAL Average	11.72	12.28	11.06	10.93	11.05	10.67	11.28
ANNUAL Maximum	19.83	21.39	20.50	20.60	20.10	20.10	20.42
JULY Average	18.82	19.44	18.59	19.17	18.83	16.75	18.60
JULY Maximum	19.83	21.39	20.00	19.90	20.10	19.10	20.05
AUGUST Average	18.72	19.30	19.43	18.94	18.85	18.95	19.03
AUGUST Maximum	19.67	20.17	20.50	20.50	19.80	20.10	20.12
SEPTEMBER Average	17.72	17.74	17.53	19.36	18.20	19.05	18.27
SEPTEMBER Maximum	19.00	18.56	18.90	20.60	18.60	19.70	19.23
OCTOBER Average	15.31	17.09	16.53	13.93	15.43	16.09	15.73
OCTOBER Maximum	17.6	18.17	18.4	18.4	18.6	19.4	18.43

Table 38. Lower Granite Dam river temperature exceedances of the Washington numeric WQC of 20°C DM calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Lower Granite Daily Maximum Temperature Exceedance of 20°C							
	2016	2015	2014	2013	2012	2011	Average
DAYS / YEAR	0	10	8	8	1	1	5
% EXCEED / YEAR	0%	3%	2%	2%	0%	0%	1%
Mean Exceedance (°C)	0	0.76	0.28	0.34	0.10	0.10	0.26
Maximum Exceedance (°C)	0	1.39	0.50	0.60	0.10	0.10	0.45
DAYS / JULY	0	8	0	0	1	0	2
% EXCEED / JULY	0%	26%	0%	0%	3%	0%	5%
Mean Exceedance (°C)	0	0.92	0	0	0.10	0	0.17
Maximum Exceedance (°C)	0	1.39	0	0	0.10	0	0.25
DAYS / AUG	0	2	8	3	0	1	2
% EXCEED / AUG	0%	6%	26%	10%	0%	3%	8%
Mean Exceedance (°C)	0	0.12	0.28	0.30	0	0.10	0.13
Maximum Exceedance (°C)	0	0.17	0.50	0.50	0	0.10	0.21
DAYS / SEPT	0	0	0	5	0	0	1
% EXCEED / SEPT	0%	0%	0%	17%	0%	0%	3%
Mean Exceedance (°C)	0	0	0	0.36	0	0	0.06
Maximum Exceedance (°C)	0	0	0	0.60	0	0	0.10
DAYS / OCT	0	0	0	0	0	0	0
% EXCEED / OCT	0%	0%	0%	0%	0%	0%	0%
Mean Exceedance (°C)	0	0	0	0	0	0	0
Maximum Exceedance (°C)	0	0	0	0	0	0	0

Water Quality Monitoring Station	DART ID	River Mile	Dates
Little Goose Dam Tailrace	LGSW	69	2011-2016

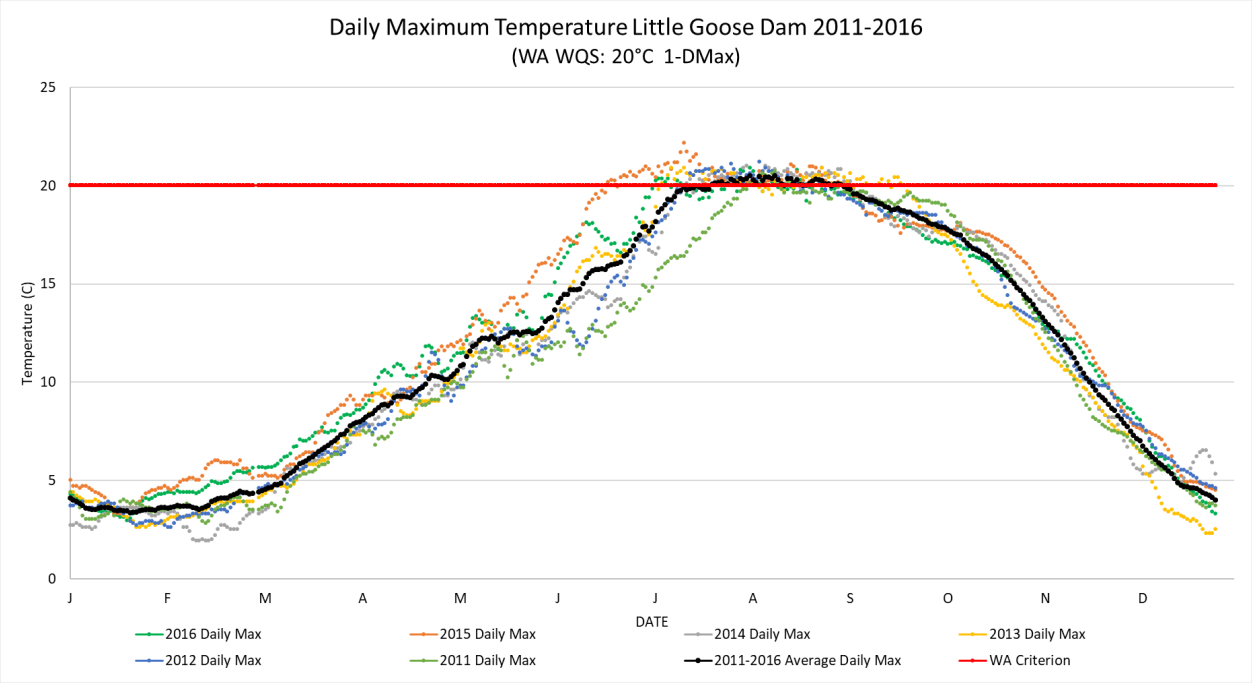

Figure 24. Daily maximum river temperature at Little Goose Dam for the years 2011-2016, plotted against the Washington numeric WQC of 20°C DM.

Table 39. Average and maximum temperature values calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Average and Maximum Temperature (°C) at Little Goose Dam 2011-2016							
	2016	2015	2014	2013	2012	2011	Average
ANNUAL Average	12.20	12.78	11.49	11.38	11.53	11.01	11.73
ANNUAL Maximum	20.89	22.17	21.00	20.90	21.20	20.70	21.14
JULY Average	19.60	20.57	19.08	19.83	19.37	16.87	19.22
JULY Maximum	20.33	22.17	20.60	20.90	21.10	19.30	20.73
AUGUST Average	19.80	20.20	20.33	19.90	19.99	19.69	19.98
AUGUST Maximum	20.89	21.06	21.00	20.90	21.20	20.70	20.96
SEPTEMBER Average	18.51	18.43	18.66	19.67	18.68	19.23	18.86
SEPTEMBER Maximum	19.72	20.17	20.80	20.60	19.60	20.00	20.15
OCTOBER Average	16.01	17.20	16.88	15.09	16.10	16.91	16.36
OCTOBER Maximum	17.2	18.60	18	17.9	18.5	19.1	18.13

Table 40. Little Goose Dam river temperature exceedances of the Washington numeric WQC of 20°C DM calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Little Goose Daily Maximum Temperature Exceedance of 20°C							
	2016	2015	2014	2013	2012	2011	Average
DAYS / YEAR	27	74	50	54	35	10	42
% EXCEED / YEAR	7%	20%	14%	15%	10%	3%	11%
Mean Exceedance (°C)	0.29	0.59	0.50	0.43	0.57	0.40	0.46
Maximum Exceedance (°C)	0.89	2.17	1.00	0.90	1.20	0.70	1.14
DAYS / JULY	12	31	15	22	16	0	16
% EXCEED / JULY	39%	100%	48%	71%	52%	0%	52%
Mean Exceedance (°C)	0.19	0.83	0.36	0.56	0.66	0	0.43
Maximum Exceedance (°C)	0.33	2.17	0.60	0.90	1.10	0	0.85
DAYS / AUG	15	30	30	17	19	10	20
% EXCEED / AUG	48%	97%	97%	55%	61%	32%	65%
Mean Exceedance (°C)	0.36	0.45	0.58	0.38	0.49	0.40	0.44
Maximum Exceedance (°C)	0.89	1.06	1.00	0.90	1.20	0.70	0.96
DAYS / SEPT	0	3	5	15	0	0	4
% EXCEED / SEPT	0%	10%	17%	50%	0%	0%	13%
Mean Exceedance (°C)	0	0.11	0.44	0.29	0	0	0.14
Maximum Exceedance (°C)	0	0.17	0.80	0.60	0	0	0.26
DAYS / OCT	0	0	0	0	0	0	0
% EXCEED / OCT	0%	0%	0%	0%	0%	0%	0%
Mean Exceedance (°C)	0	0	0	0	0	0	0
Maximum Exceedance (°C)	0	0	0	0	0	0	0

Water Quality Monitoring Station	DART ID	River Mile	Dates
Lower Monumental Dam Tailrace	LMNW	41	2011-2016

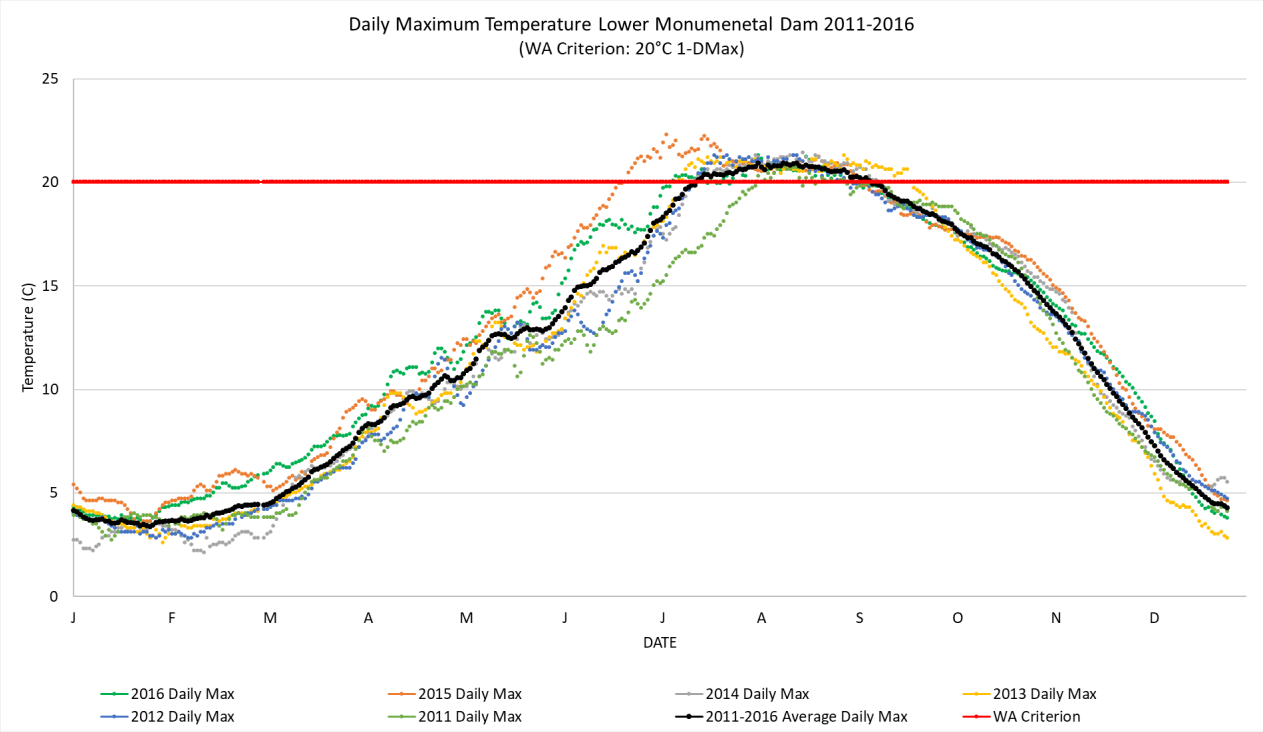

Figure 25. Daily maximum river temperature at Lower Monumental Dam for the years 2011-2016, plotted against the Washington numeric WQC of 20°C daily maximum.

Table 41. Average and maximum temperature values calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Average and Maximum Temperature (°C) at Lower Monumental Dam 2011-2016							
	2016	2015	2014	2013	2012	2011	Average
ANNUAL Average	12.56	13.03	11.71	11.70	11.67	11.18	11.97
ANNUAL Maximum	21.28	22.28	21.40	21.30	21.30	20.80	21.39
JULY Average	19.85	21.26	19.28	20.00	19.56	16.91	19.48
JULY Maximum	20.61	22.28	20.80	21.20	21.30	19.50	20.95
AUGUST Average	20.49	20.63	20.86	20.55	20.59	20.08	20.53
AUGUST Maximum	21.28	21.22	21.40	21.30	21.30	20.80	21.22
SEPTEMBER Average	18.93	18.87	19.25	20.00	18.84	19.22	19.18
SEPTEMBER Maximum	20.28	20.83	20.90	21.10	20.00	20.00	20.52
OCTOBER Average	16.20	16.98	16.85	15.50	16.26	16.96	16.46
OCTOBER Maximum	17.8	17.78	18.1	18	18.3	18.8	18.13

Table 42. Lower Monumental Dam river temperature exceedances of the Washington numeric WQC of 20°C DM calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Lower Monumental Daily Maximum Temperature Exceedance of 20°C							
	2016	2015	2014	2013	2012	2011	Average
DAYS / YEAR	54	73	58	73	45	22	54
% EXCEED / YEAR	15%	20%	16%	20%	12%	6%	15%
Mean Exceedance (°C)	0.51	1.07	0.81	0.77	0.87	0.37	0.73
Maximum Exceedance (°C)	1.28	2.28	1.40	1.30	1.30	0.80	1.39
DAYS / JULY	20	31	17	22	16	0	18
% EXCEED / JULY	65%	100%	55%	71%	52%	0%	57%
Mean Exceedance (°C)	0.31	1.46	0.55	0.87	0.96	0	0.69
Maximum Exceedance (°C)	0.61	2.28	0.80	1.20	1.30	0	1.03
DAYS / AUG	31	31	31	31	29	22	29
% EXCEED / AUG	100%	100%	100%	100%	94%	71%	94%
Mean Exceedance (°C)	0.68	0.79	1.05	0.74	0.81	0.37	0.74
Maximum Exceedance (°C)	1.28	1.22	1.40	1.30	1.30	0.80	1.22
DAYS / SEPT	3	4	10	20	0	0	6
% EXCEED / SEPT	10%	13%	33%	67%	0%	0%	21%
Mean Exceedance (°C)	0.20	0.51	0.52	0.70	0	0	0.32
Maximum Exceedance (°C)	0.28	0.83	0.90	1.10	0	0	0.52
DAYS / OCT	0	0	0	0	0	0	0
% EXCEED / OCT	0%	0%	0%	0%	0%	0%	0%
Mean Exceedance (°C)	0	0	0	0	0	0	0
Maximum Exceedance (°C)	0	0	0	0	0	0	0

Water Quality Monitoring Station	DART ID	River Mile	Dates
Ice Harbor Dam Tailrace	IDSW	9	2011-2016

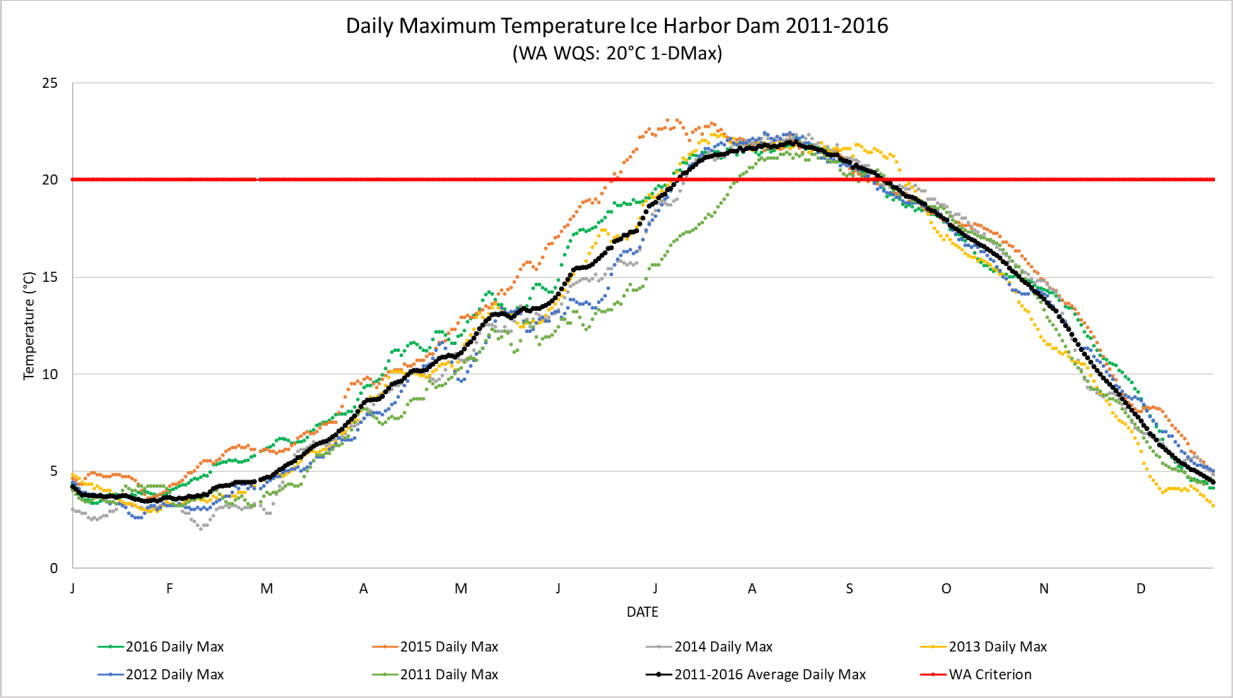

Figure 26. Daily maximum river temperature at Ice Harbor Dam for the years 2011-2016, plotted against the Washington numeric WQC of 20°C DM.

Table 43. Average and maximum temperature values calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Average and Maximum Temperature (°C) at Ice Harbor Dam 2011-2016							
	2016	2015	2014	2013	2012	2011	Average
ANNUAL Average	12.79	13.39	12.00	12.02	12.00	11.39	12.27
ANNUAL Maximum	22.22	23.06	22.30	22.30	22.40	21.40	22.28
JULY Average	20.36	22.22	19.74	20.62	20.01	17.17	20.02
JULY Maximum	21.61	23.06	21.90	22.30	22.10	19.90	21.81
AUGUST Average	21.32	21.42	21.70	21.41	21.60	20.81	21.38
AUGUST Maximum	22.22	22.28	22.30	21.90	22.40	21.40	22.08
SEPTEMBER Average	19.34	19.49	19.92	20.52	19.38	19.59	19.71
SEPTEMBER Maximum	21.10	21.44	21.80	21.80	20.90	20.90	21.32
OCTOBER Average	16.14	17.15	17.07	15.60	16.12	16.96	16.51
OCTOBER Maximum	18.22	18.28	19	17.8	18.6	18.6	18.42

Table 44. Ice Harbor Dam river temperature exceedances of the Washington numeric WQC of 20°C DM calculated over each year 2011-2016 and over the individual months of July-October. The right column is the 2011-2016 average of these values.

Ice Harbor Daily Maximum Temperature Exceedance of 20°C							
	2016	2015	2014	2013	2012	2011	Average
DAYS / YEAR	63	82	61	72	60	45	64
% EXCEED / YEAR	17%	22%	17%	20%	16%	12%	17%
Mean Exceedance (°C)	1.30	1.78	1.52	1.62	1.49	0.82	1.42
Maximum Exceedance (°C)	2.22	3.06	2.30	2.30	2.40	1.40	2.28
DAYS / JULY	21	31	17	20	18	0	18
% EXCEED / JULY	68%	100%	55%	65%	58%	0%	58%
Mean Exceedance (°C)	1.14	2.50	1.16	1.73	1.40	0	1.32
Maximum Exceedance (°C)	1.61	3.06	1.90	2.30	2.10	0	1.83
DAYS / AUG	31	31	31	31	31	31	31
% EXCEED / AUG	100%	100%	100%	100%	100%	100%	100%
Mean Exceedance (°C)	1.63	1.71	1.96	1.69	1.88	1.02	1.65
Maximum Exceedance (°C)	2.22	2.28	2.30	1.90	2.40	1.40	2.08
DAYS / SEPT	11	11	13	21	11	14	14
% EXCEED / SEPT	37%	37%	43%	70%	37%	47%	45%
Mean Exceedance (°C)	0.65	0.60	0.95	1.40	0.55	0.36	0.75
Maximum Exceedance (°C)	1.10	1.44	1.80	1.80	0.90	0.90	1.32
DAYS / OCT	0	0	0	0	0	0	0
% EXCEED / OCT	0%	0%	0%	0%	0%	0%	0%
Mean Exceedance (°C)	0	0	0	0	0	0	0
Maximum Exceedance (°C)	0	0	0	0	0	0	0

TEMPERATURE TREND ANALYSIS

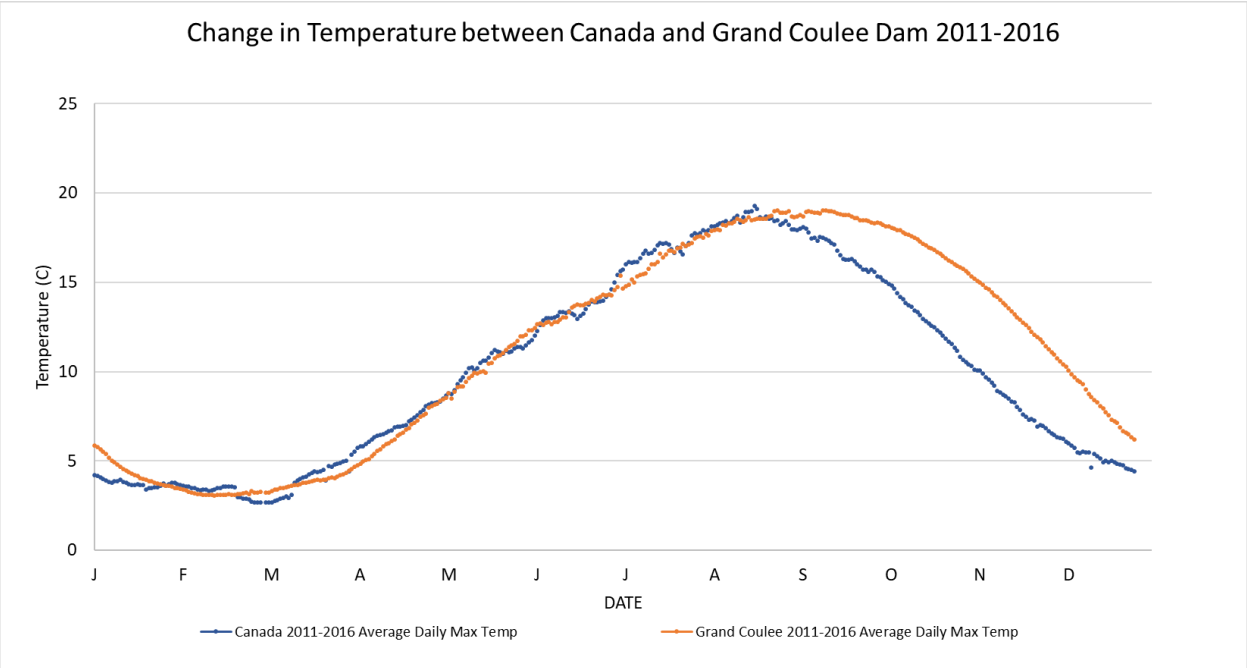

Figure 27. Canadian border 2011-2016 average maximum temperature (blue) compared with the Grand Coulee Dam 2011-2016 average maximum temperature (orange).

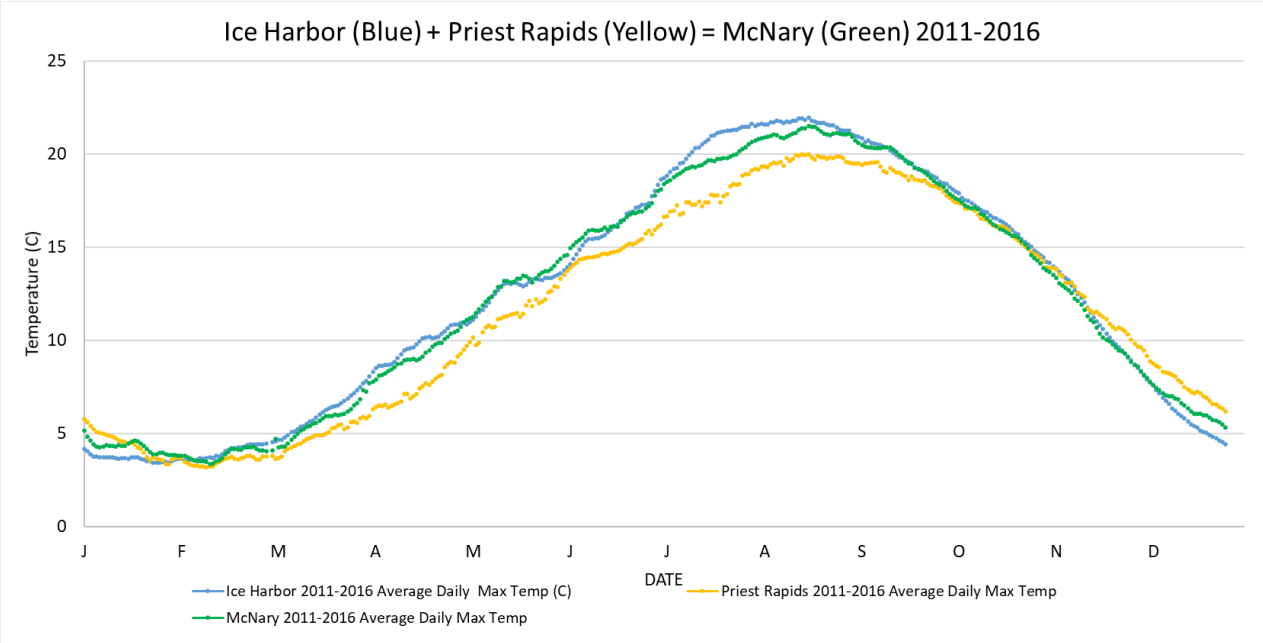

Figure 28. Ice Harbor Dam average maximum river temperature (blue) and Priest Rapids Dam average maximum river temperature (yellow) blend at the Snake confluence, leading to the average maximum river temperature at McNary Dam (green) 2011-2016.

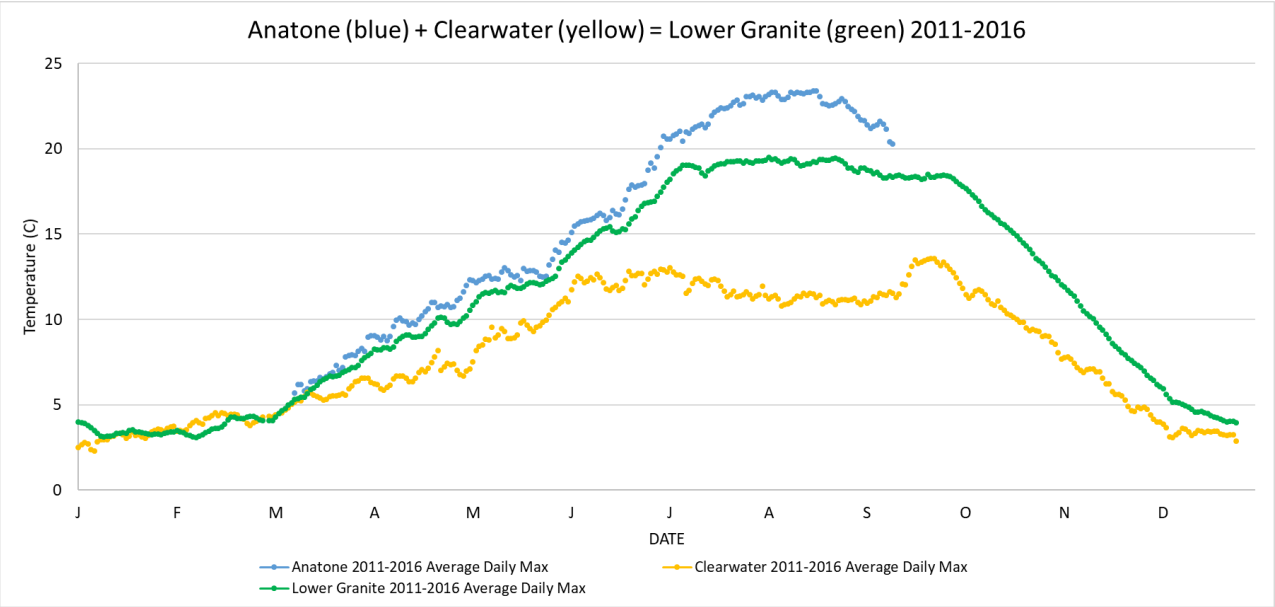

Figure 29. Anatone, WA average maximum river temperature (blue) and Clearwater River average maximum river temperature (yellow) blend at the Clearwater confluence, leading to the average maximum river temperature at Lower Granite Dam 2011-2016.

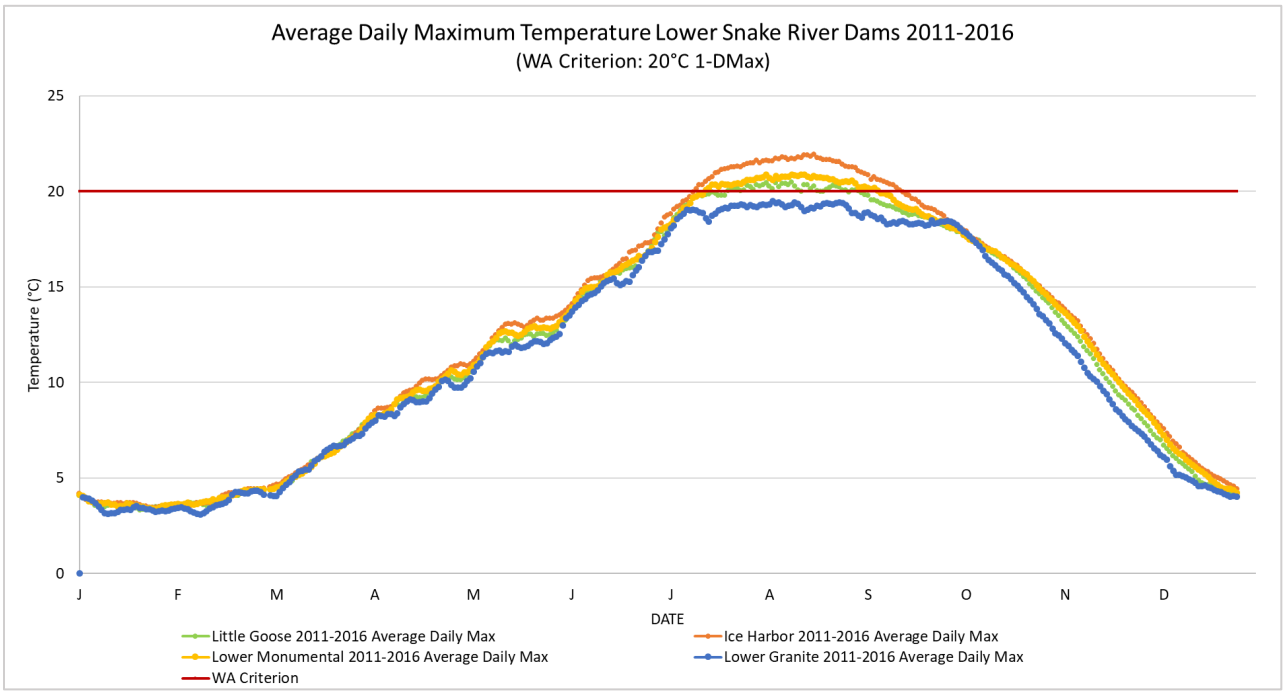

Figure 30. The Snake River 2011-2016 average maximum temperature warming between Lower Granite Dam (blue) and Ice Harbor Dam (orange); plotted against the Washington numeric WQC of 20°C daily maximum.

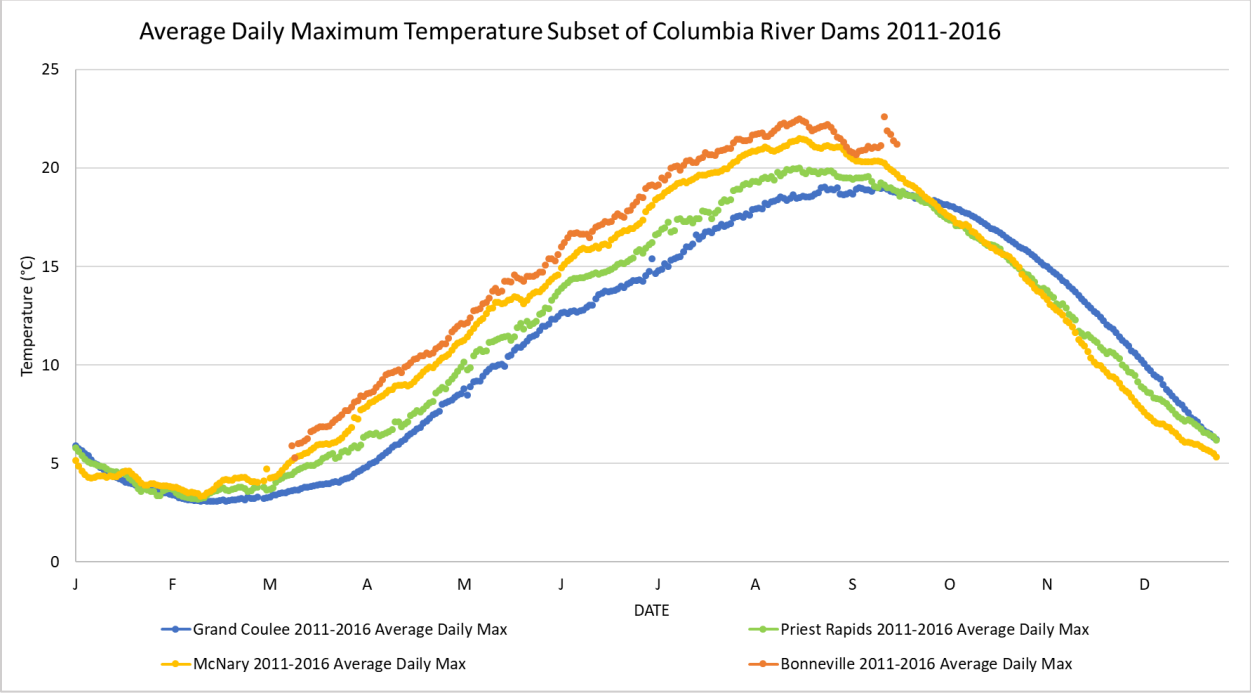

Figure 31. The Columbia River 2011-2016 average maximum temperature warming between Grand Coulee Dam (blue) and Bonneville Dam (orange) with a subset of temperature measurements in between.

Appendix A – Spurious Data

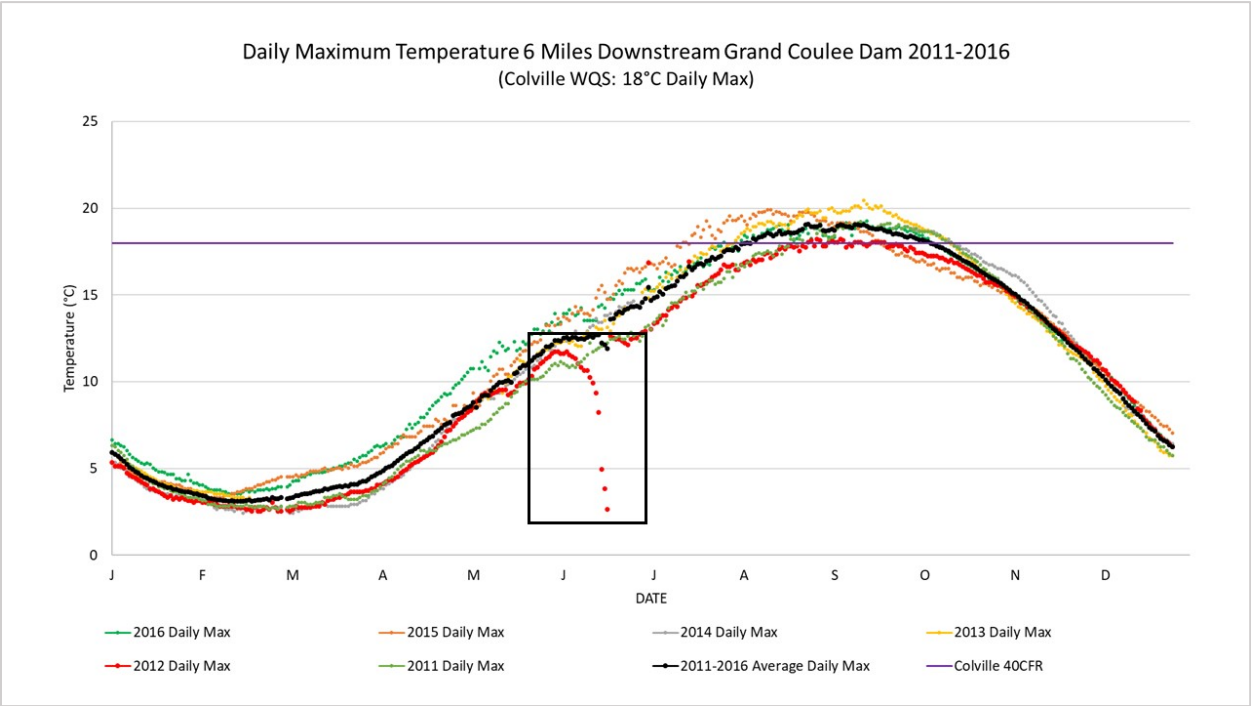

Figure A1. Example of spurious data that the authors omitted from analysis

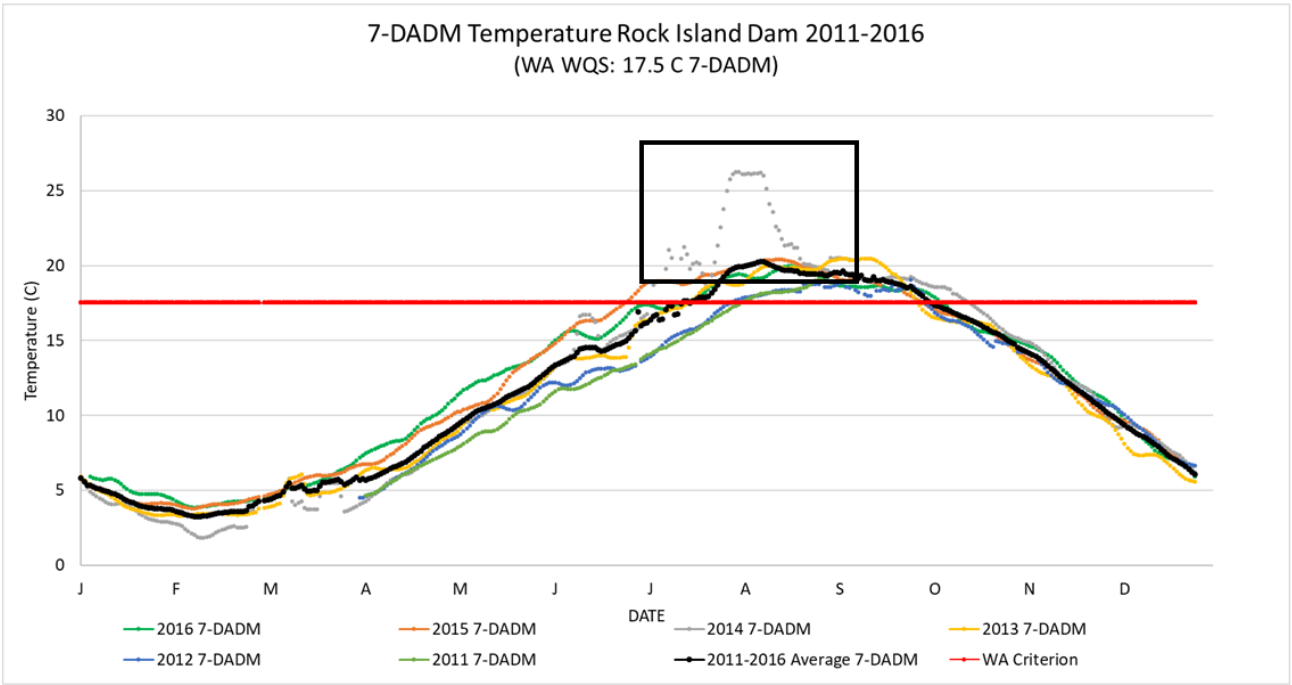

Figure A2. Example of spurious data that the authors omitted from analysis

Appendix B – Data Gaps

Table B1. Substantial Data Gaps

DART LOCATION	YEAR	EXCEEDANCE QUALITY ASSURANCE	AVERAGE & MAXIMUM QUALITY ASSURANCE	DATA GAPS
Grand Coulee (GCGW)	2014	-No annual -No monthly	-No annual -No monthly	No data late-June to early-October
Grand Coulee (GCGW)	2013		-No annual average	No data mid-February to early-May
Chief Joseph (CHQW)	2016		-No annual average	No data mid-October to mid-May
Chief Joseph (CHQW)	2015		-No annual average	No data early-October to late-May
Chief Joseph (CHQW)	2014	-No annual	-No annual average	No data early-October to late May
Chief Joseph (CHQW)	2013	-No annual	-No annual average	No data late-September to late-May
Chief Joseph (CHQW)	2012		-No annual average	No data early-October to mid-May
Chief Joseph (CHQW)	2011	-No annual	-No annual average	No data late-September to mid-May
Wells (WEL)	2013		-No annual average	No data late-December to late-May
Wells (WEL)	2012	-No annual -No September	-No annual average -No September	No data mid-September to early-April
Wells (WEL)	2011	-No annual -No September	-No annual -No September	No data mid-September to early-April
Rocky Reach (RRDW)	2013		-No annual average -No July average	No data mid-February to late-April; early-October to early-November; ~ 7 days missing in July
Rocky Reach (RRDW)	2012		-No annual average	No data early-January to early-April; month of June

DART LOCATION	YEAR	EXCEEDANCE QUALITY ASSURANCE	AVERAGE & MAXIMUM QUALITY ASSURANCE	DATA GAPS
Rocky Reach (RRDW)	2011	-No annual -No September	-No annual -No September	No data early-September to early-April
Rock Island (RIGW)	2014	-No annual -No July -No August	-No annual -No July -No August	Spotty data late-February to late-March; Spurious data mid-July to mid-August
Rock Island (RIGW)	2012		-No annual average	No data early-January to early-April
Rock Island (RIGW)	2011	-No annual -No September	-No annual -No September	No data early-September to late-April
Wanapum (WANW)	2015	-No annual -No September	-No September	No data late-August to mid-September
Wanapum (WANW)	2013		-No annual average	No data mid-February to mid-April
Wanapum (WANW)	2012		-Annual average (*)	No data in June
Priest Rapids (PRXW)	2016	-No annual -No months	-No annual -No months	~consistently spotty data throughout the year
Priest Rapids (PRXW)	2015	-No annual -No months	-No annual -No months	~consistently spotty data throughout the year
Pasco, WA (PAQW)	2016	-Annual (*) -September (*)	-No annual average -No September	No data mid-March to early-September
Pasco, WA (PAQW)	2015	-Annual (*) -September (*)	-No annual average -No September	No data mid-March to mid-September
Pasco, WA (PAQW)	2014	-Annual (*) -September (*)	-No annual average -No September	No data mid-September to mid-March
Pasco, WA (PAQW)	2013		-No annual average	No data late-Sept ember to late-April
Pasco, WA (PAQW)	2012		-No annual average	No data early-October to early-March
Pasco, WA (PAQW)	2011	-Annual (*) -September (*)	-No annual average -No September	No data mid-September to early-March

DART LOCATION	YEAR	EXCEEDANCE QUALITY ASSURANCE	AVERAGE & MAXIMUM QUALITY ASSURANCE	DATA GAPS
McNary (MCPW)	2012	-No annual -No September	-No annual -No September	No data late-March to early-May; mid-August to early-January
Anatone, WA (ANQW)	2016		-No annual average	No data early-October to mid-March
Anatone, WA (ANQW)	2015	-Annual (*) -September (*)	-No annual average -No September average	No data mid-September to early-March
Anatone, WA (ANQW)	2014		-No annual average	No data late-September to mid-March
Anatone, WA (ANQW)	2013	-No annual -No September	-No annual average -No September	No data mid-September to late-March
Anatone, WA (ANQW)	2012	-Annual (*) -September (*)	-No annual average -No September	No data mid-September to early-March
Anatone, WA (ANQW)	2011	-No annual -No September	-No annual average -No September	No data mid-September to mid-March
Clearwater (PEKI)	2014	No exceedances – no exceedance table.	-No annual -No monthly	No data late-March to early-August; late September to early-January
Dworshak (DWQI)	2016-	No exceedances – no exceedance table.	-Annual average (*)	No data mid-January to mid-February; mid-November to early-January
John Day Forebay (JDA)	2016	-Annual (*) -September (*)	-No annual average -Annual maximum (*) -No September	No data mid-September to mid-March
John Day Forebay (JDA)	2015	-Annual (*) -September (*)	-No annual average -Annual maximum (*) -No September	No data mid-September to mid-March
John Day Forebay (JDA)	2014	-No annual -No September	-No annual average -Annual maximum (*) -No September	No data mid-September to mid-March
John Day Forebay (JDA)	2013	-No annual -No September	-No annual average -Annual maximum (*) -No September	No data mid-September to mid-March
John Day Forebay (JDA)	2012	-No annual -No September	-No annual average -Annual maximum (*) -No September	No data mid-September to mid-March

DART LOCATION	YEAR	EXCEEDANCE QUALITY ASSURANCE	AVERAGE & MAXIMUM QUALITY ASSURANCE	DATA GAPS
John Day Forebay (JDA)	2011	-No annual -No September	-No annual average -Annual maximum (*) -No September	No data mid-September to late-March

Appendix C: Tailrace and Forebay Data Comparison

The forebay data available through the DART website generally have more data gaps than the tailrace data, making it challenging to use the forebay data in the current conditions temperature analysis. As an example, the plots and tables below allow for the comparison between John Day Dam tailrace and forebay data for the individual months of August and July between 2011 and 2016.

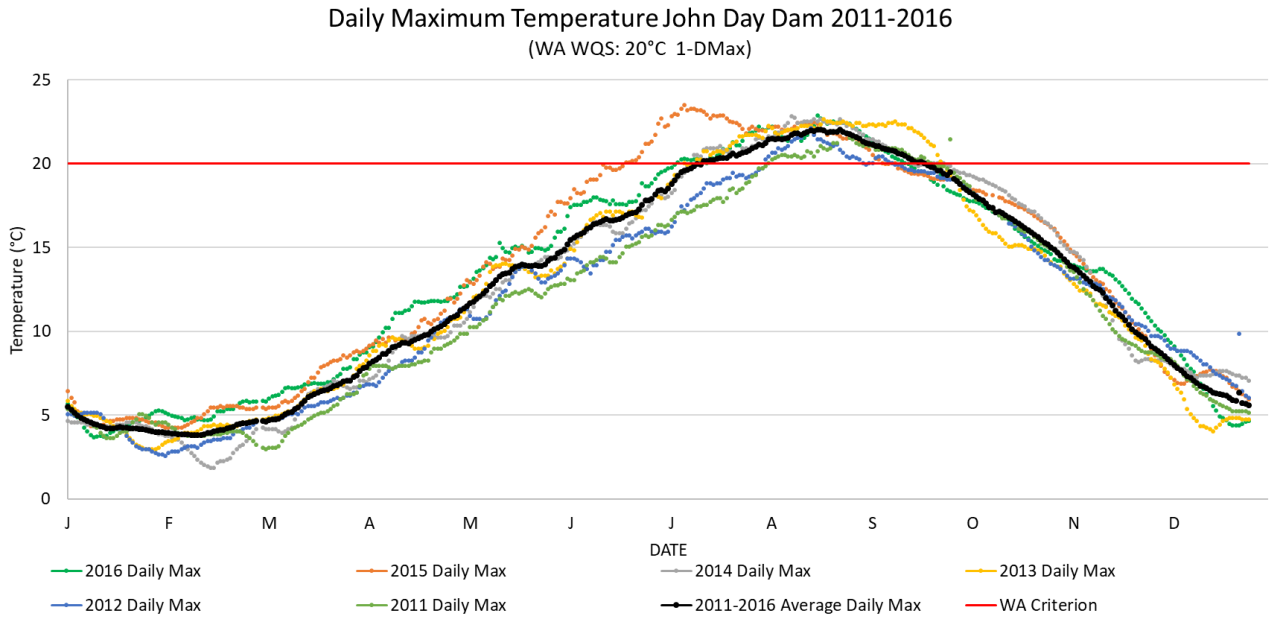

Figure C1. John Day Dam tailrace data, 2011-2016. DART ID: JHAW.

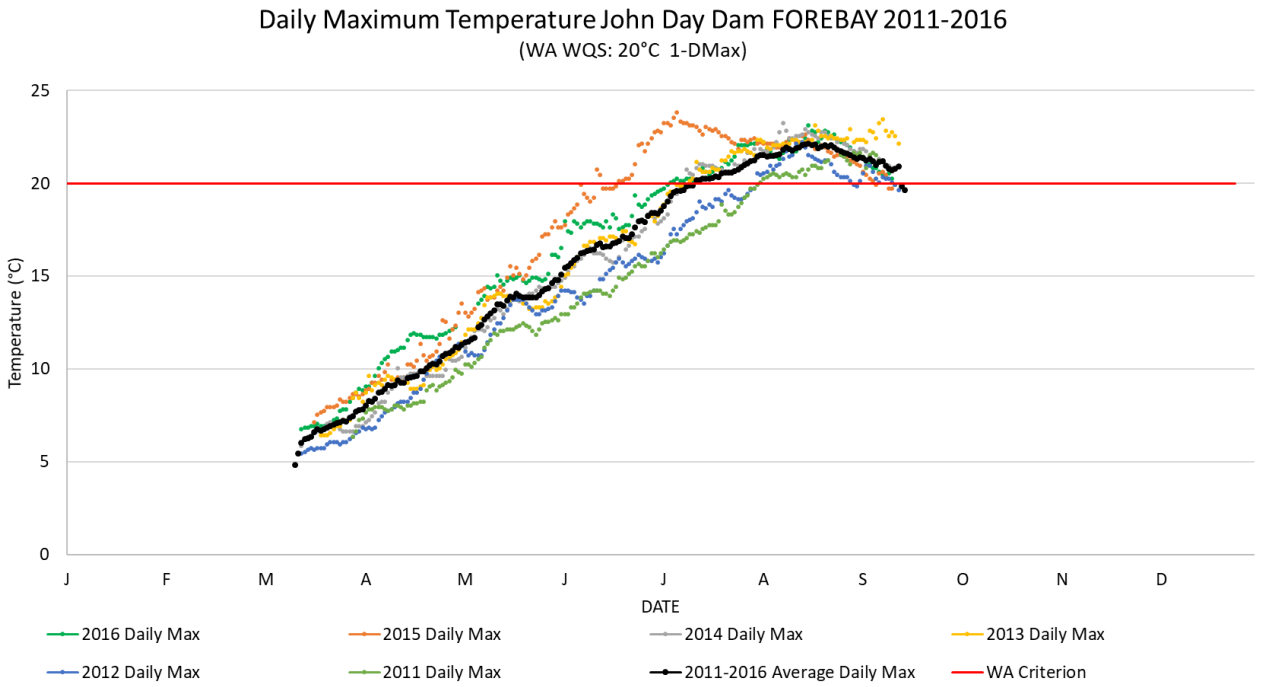

Figure C2. John Day Dam forebay (upstream) data, 2011-2016. DART ID: JDA.

Table C1. John Day Tailrace Maximum and Average Calculations

Average and Maximum Temperature at John Day Dam TAILRACE 2011-2016							
	2016	2015	2014	2013	2012	2011	Average
ANNUAL Average	13.15	13.48	12.55	12.39	12.05	11.58	12.53
ANNUAL Maximum	22.83	23.44	22.80	22.60	22.10	21.50	22.55
JULY Average	20.38	22.51	19.93	20.14	17.97	17.48	19.73
JULY Maximum	21.94	23.44	21.40	21.70	19.40	19.30	21.20
AUGUST Average	21.92	21.87	22.09	22.05	20.79	20.47	21.53
AUGUST Maximum	22.83	22.44	22.80	22.60	22.10	21.50	22.38
SEPTEMBER Average	19.88	19.64	20.41	21.49	19.60	20.36	20.23
SEPTEMBER Maximum	21.90	21.28	21.80	22.50	20.40	21.40	21.55

Table C2. John Day Forebay Maximum and Average Calculations

Average and Maximum Temperature at John Day Dam FOREBAY 2011-2016							
	2016	2015	2014	2013	2012	2011	Average
ANNUAL Average	NA	NA	NA	NA	NA	NA	NA
ANNUAL Maximum	23.10	23.80	23.20	23.40	22.20	21.60	22.88
JULY Average	20.33	22.58	19.91	20.11	17.89	17.34	19.70
JULY Maximum	22.00	23.80	21.60	21.80	19.60	19.30	21.35
AUGUST Average	21.93	21.86	22.13	22.08	20.76	20.40	21.53
AUGUST Maximum	23.10	22.60	23.20	23.10	22.20	21.50	22.62
SEPTEMBER Average	NA	NA	NA	NA	NA	NA	NA
SEPTEMBER Maximum	NA	NA	NA	NA	NA	NA	NA

Table C3. John Day Tailrace Exceedances of the WA WQC.

John Day TAILRACE Daily Maximum Temperature Exceedance of 20°C							
	2016	2015	2014	2013	2012	2011	Average
DAYS / YEAR	69	79	68	76	35	47	62
% EXCEED / YEAR	19%	22%	19%	21%	10%	13%	17%
Mean Exceedance (°C)	1.37	1.97	1.48	1.78	0.90	0.71	1.37
Maximum Exceedance (°C)	2.83	3.44	2.80	2.60	2.10	1.50	2.55
DAYS / JULY	24	31	20	19	0	0	16
% EXCEED / JULY	77%	100%	65%	61%	0%	0%	51%
Mean Exceedance (°C)	0.74	2.68	0.79	1.01	0	0	0.87
Maximum Exceedance (°C)	1.94	3.44	1.40	1.70	0	0	1.41
DAYS / AUG	31	31	31	31	29	24	30
% EXCEED / AUG	100%	100%	100%	100%	94%	77%	95%
Mean Exceedance (°C)	2.05	1.96	2.21	2.15	1.03	0.70	1.68
Maximum Exceedance (°C)	2.83	2.44	2.80	2.60	2.10	1.50	2.38
DAYS / SEPT	14	7	17	26	6	23	16
% EXCEED / SEPT	47%	23%	57%	87%	20%	77%	52%
Mean Exceedance (°C)	0.94	0.73	0.97	1.91	0.27	0.73	0.93
Maximum Exceedance (°C)	1.90	1.28	1.80	2.50	0.40	1.40	1.55

Table C4. John Day Forebay Exceedances of the WA WQC.

John Day FOREBAY Daily Maximum Temperature Exceedance of 20°C							
	2016	2015	2014	2013	2012	2011	Average
DAYS / YEAR	68	85	NA	NA	NA	NA	NA
% EXCEED / YEAR	19%	23%	NA	NA	NA	NA	NA
Mean Exceedance (°C)	1.45	1.96	NA	NA	NA	NA	NA
Maximum Exceedance (°C)	3.10	3.80	NA	NA	NA	NA	NA
DAYS / JULY	23	31	20	19	0	0	16
% EXCEED / JULY	74%	100%	65%	61%	0%	0%	50%
Mean Exceedance (°C)	0.80	2.78	0.83	1.06	0	0	0.91
Maximum Exceedance (°C)	2.00	3.80	1.60	1.80	0	0	1.53
DAYS / AUG	31	31	31	31	29	24	30
% EXCEED / AUG	100%	100%	100%	100%	94%	77%	95%
Mean Exceedance (°C)	2.15	2.00	2.31	2.23	1.08	0.68	1.74
Maximum Exceedance (°C)	3.10	2.60	3.20	3.10	2.20	1.50	2.62
DAYS / SEPT	14	11	NA	NA	NA	NA	NA
% EXCEED/SEPT	47%	37%	NA	NA	NA	NA	NA
Mean Exceedance (°C)	0.96	0.64	NA	NA	NA	NA	NA
Max Exceedance Range (°C)	1.90	1.20	NA	NA	NA	NA	NA

The July averages in the forebay are consistently within 0.15°C of the tailrace July averages for any given year during 2011-2016. The July maximum calculations are within 0.4°C of one another for any given year, with a tendency for the forebay data to capture a higher daily maximum temperature than the tailrace data. The August averages for the forebay are consistently within 0.07°C of tailrace August averages. August maximums are consistently within 0.5°C of one another, with a strong tendency for forebay data to capture higher maximums temperatures.

For the exceedance tables, the number of monthly exceedances captured in the forebay match the tailrace exceedances perfectly, except for July 2016 where one more exceedance day was captured in the tailrace data. The mean exceedances are within 0.1°C of one another in July, with the forebay data consistently capturing a higher monthly average. The July maximum exceedances are consistently within 0.4°C of one another, with the forebay data consistently capturing higher maximums. August averages are consistently within 0.01°C from one another, with a tendency for forebay data to capture higher averages. August maximums are consistently within 0.5°C of one another, with a strong tendency for forebay data to record warmer maximum temperatures.