US Army Corps of Engineers®
Portland District

WATER QUALITY REPORT

JOHN DAY DAM, LAKE UMATILLA
COLUMBIA RIVER BASIN
COLUMBIA RIVER, OREGON AND WASHINGTON

John Day Dam, Lake Umatilla

Water Quality Report
September 2020

EXECUTIVE SUMMARY

John Day Lock and Dam was authorized by Section 201 of the Rivers and Harbors Act of 1950 (Public Law 81-516) for flood control, hydropower, and navigation. Fish and wildlife conservation, recreation, and irrigation have been added as project purposes since the original authorization. Construction on John Day Lock and Dam began in 1958, and the first generator came online in 1968. John Day is a concrete gravity storage dam located at Columbia River Mile (RM) 215.6 (Figure 1-1), 24 miles upstream from The Dalles Lock and Dam. It is 281 feet high and 5,543 feet long. It features a powerhouse, spillway, navigation lock, and fish passage facilities. The John Day powerhouse has 16 turbine generating units with a combined hydraulic capacity of 322,000 cfs. The spillway is 1,252 feet long with 20 spillbays; the spillway design capacity is 2,250,000 cfs.

Unlike other dams on the lower Columbia River and those on the lower Snake River, John Day Dam is operated for flood risk management. Lake Umatilla is the portion of the Columbia River upstream of the John Day Dam that stretches to the McNary Dam (RM 292), and was created with the completion of John Day Dam. Lake Umatilla can be lowered to provide space for approximately 500,000 acre-feet of floodwaters when needed.

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ACRONYMS

Acronym	Description
µg/L	Micrograms Per Liter
µS/cm	Microsiemens Per Centimeter
ALK	Alkalinity
$CaCO_3$	Calcium Carbonate
CHL	Chlorophyll A
COND	Conductivity
Corps	U.S. Army Corps of Engineers
DART	Data Access in Real Time
Detects	Detections
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FC	Fecal Coliform Bacteria
HARD	Hardness
HUC	Hydrologic Unit Code
ICP-MS	Inductively Coupled Plasma-Mass Spectrometry
JDA	John Day Dam Forebay Monitoring Station; RM 216.5
JDY	John Day Dam Forebay Monitoring Station; RM 215.7
JHAW	John Day Dam Tailwater Monitoring Station; RM 214.7; USGS Station 454249120423500
KM	Kaplan-Meier
max	Maximum
MCPW	Mcnary Dam Tailwater Monitoring Station; RM 290.7; USGS Station 14019240
med	Median
mg/L	Milligrams Per Liter
min	Minimum
mmHg	Millimeters of Mercury
MPN	Most Probable Number
mV	Millivolts
N/A	Not Applicable
ND	Non-Detection
ng/L	Nanograms Per Liter
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPCC	Northwest Power and Conservation Council
NTU	Nephelometric Turbidity Unit
Obs	Observations
ODEQ	Oregon Department of Environmental Quality
OHA	Oregon Health Authority
OP_DIS	Soluble Reactive Phosphorus
PCB	Polychlorinated Biphenyl
PRESS	Barometric Pressure
Q1	First Quartile
Q3	Third Quartile
RM	River Mile
SD	Secchi Disk Depth
SUSSOL	Suspended Solids
TCDD	Tetrachlorodibenzo-P-Dioxin

TDG	Total Dissolved Gas
TEMP	Temperature
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorus
TP_P	Total Phosphorus
TSI	Trophic State Index
TURB	Turbidity
USGS	U.S. Geological Survey

SECTION 1 - INTRODUCTION

1.1 STUDY AREA

The Columbia River Basin is one of the world's great river basins in terms of its land area and river volume, as well as its environmental and cultural significance (U.S. Environmental Protection Agency [EPA] 2009). The Columbia River Basin drains about 259,000 square miles across seven U.S. states and British Columbia, Canada. Of that total, about 219,400 square miles, or 85 percent of the Pacific Northwest region, are in the United States; the remaining 39,500 square miles are in Canada (Pacific Northwest River Basins Commission 1979). The Basin's rivers and streams carry the fourth largest volume of runoff in North America. The Columbia River begins at Columbia Lake in the Canadian Rockies and travels 1,243 miles over 14 dams to reach the Pacific Ocean 100 miles downstream from Portland, Oregon. The Columbia River's final 300 miles from the border between Washington and Oregon. The Snake River is the largest tributary of the Columbia River, with a drainage area of 108,500 square miles, or 49 percent of the U.S. portion of the watershed. There are more than 370 major dams on tributaries of the Columbia River Basin (Bonneville Power Administration, U.S. Army Corps of Engineers [Corps], and Bureau of Reclamation 2001). With its many major Federal and non-Federal hydropower dams, the Columbia River is one of the most intensive hydroelectric developments in the world. About 65 percent (approximately 33,000 megawatts) of the Pacific Northwest's generating capacity comes from hydroelectric dams. Under normal precipitation, the dams produce about three-quarters (16,200 average megawatts) of the region's electricity. Some of the other major uses of the multi-purpose dams on the Columbia and Snake Rivers include flood control, commercial navigation, irrigation, and recreation (Northwest Power and Conservation Council [NPCC] 2000).

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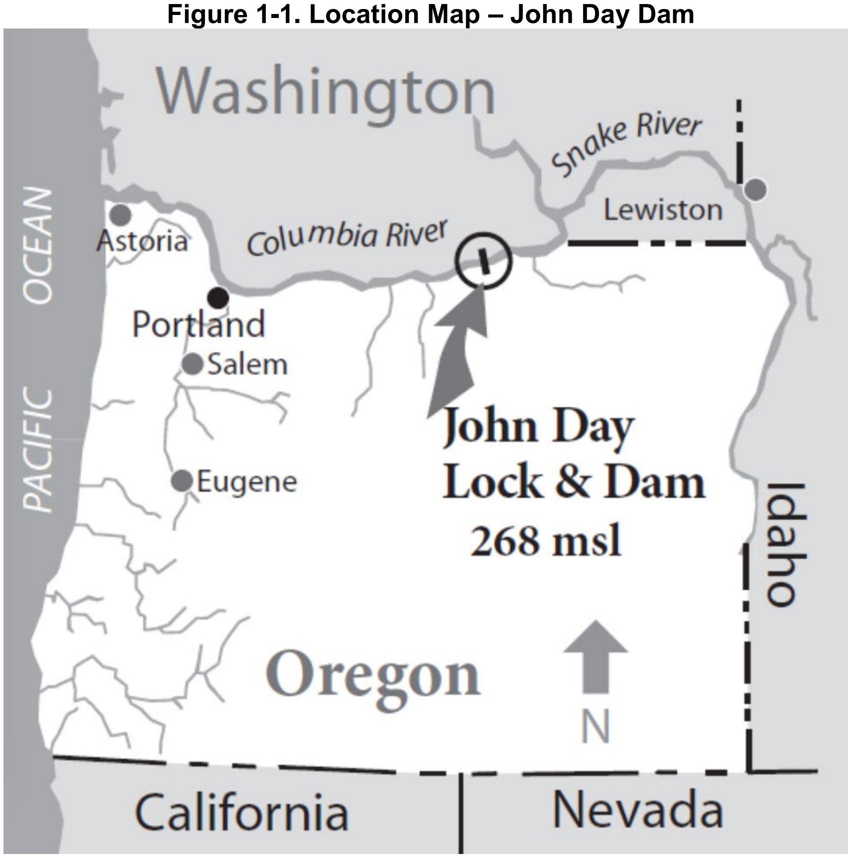
Unlike other dams on the lower Columbia River and those on the lower Snake River, John Day Dam is operated for flood risk management. Lake Umatilla is the portion of the Columbia River upstream of the John Day Dam that stretches to the McNary Dam (RM 292), and was created with the completion of John Day Dam. Lake Umatilla can be lowered to provide space for approximately 500,000 acre-feet of floodwaters when needed.

In order to accommodate tribal treaty fishing in the lower Columbia River, John Day, The Dalles, and Bonneville Dams are operated within a 1.5-foot range during the tribal fishing season. Additionally, from April 10 through September 30, John Day Dam is operated to minimize water travel time for downstream-migrating juvenile salmonids. This is done by operating the forebay within the minimum irrigation pool range (262.5 to 264 feet above mean sea level), which is the lowest possible operation for irrigation withdrawals.

Figure 1-1. Location Map – John Day Dam



1.2 PREVIOUS STUDIES

The Washington Department of Ecology (Ecology) monitors nearly 100 river and stream locations throughout Washington to understand the health of the waterways. The monitoring program offers residents and policymakers credible data to make informed choices for the rivers and streams of the state. Twenty-four-hour data for dissolved oxygen (DO), temperature, pH, and specific conductivity are collected in many of these rivers and streams. Additionally, monthly data on bacteria, pH, phosphorus, and more is collected. The data is useful for establishing long-term trends in stream health and contributes to watershed studies and water quality improvement plans. Rope and weighted containers are used to collect single surface-grab samples from highway bridges or, depending on accessibility, from the stream bank. Temperature is measured in stream using a long-line thermistor or electronic tracking device. Water quality parameters are either measured in the field or are processed at an environmental laboratory. In addition, streamflow is measured at some long-term stations. Publications associated with this monitoring program date back to 1973, and can be accessed online (Ecology 2018).

The Oregon Department of Environmental Quality (ODEQ) is responsible for keeping Oregon's waters safe and healthy for many uses, such as drinking, recreation, and agriculture, as well as for ensuring fish populations are able to thrive. To monitor the water quality status, ODEQ regularly collects water samples at over 130 sites on more than 50 rivers and streams across the state. The Water Quality Monitoring Program provides critical information for understanding how well water quality goals are being met and for identifying emerging water quality concerns, planning wastewater and industrial permit limits, assessing compliance with environmental regulations, developing effective watershed pollution reduction strategies, and understanding trends in water quality statewide. ODEQ's Water Quality Monitoring Program meets these needs by planning and coordinating environmental data collection efforts, collecting representative and valid data, managing environmental data to ensure availability, and analyzing and interpreting water quality–related data to produce reports that identify water quality conditions and any threats to water quality. Further information about ODEQ's Water Quality Monitoring Program and associated data and reports can be accessed online (ODEQ 2017a).

The National Marine Fisheries Service (NFMS) conducted limnological sampling of the John Day Reservoir from April 1994 to September 1995 (NMFS 2000). The study was initiated to acquire baseline data prior to reservoir drawdown, which was under consideration at the time, principally as a means of reducing travel times of juvenile migrant salmonids passing through the reservoir. Although drawdown did not occur as had been considered, the NFMS limnological sampling produced an extensive set of baseline physical, chemical, and biological data. The sampling effort was concentrated at five upper-reservoir stations within the Blalock Islands area, because much the expected habitat loss due to the proposed drawdown would have occurred in that area. These stations were characterized by water depths of 5 to 7 meters and were located along the main river channel. Less intensive sampling was conducted at lower- and mid-reservoir stations where the sampling depths ranged from 30 to 40 meters. At each sampling location, field measurements were made of physical variables, including temperature, turbidity, and Secchi disk visibility. Water samples were taken and preserved for laboratory determination of chemical variables including alkalinity, nutrients, and major ions. Other chemical variables (pH, DO, and specific conductivity were monitored directly using a multifunction meter. Biological variables included chlorophyll a, zooplankton, benthic invertebrates, and resident and migrant fish.

The Corps monitors the water quality of reservoir releases at projects throughout the Columbia River Basin to manage fish pass spill operations at the fish passage projects on the lower Snake and lower Columbia Rivers, as well as to manage system wide water quality. The Corps completes water quality monitoring of total dissolved gas (TDG) and temperature at the 12 Corps dams in the Columbia River Basin (Bonneville, The Dalles, John Day, McNary, Chief Joseph, Ice Harbor, Lower Monumental, Little Goose, Lower Granite, Dworshak, Libby, and Albeni Falls Dams). The Corps prepares annual reports to address responsibilities related to the ODEQ TDG modification, the

Ecology TDG criteria adjustment, and the 2002 and 2003 TDG total maximum daily loads (TMDLs) for the lower Columbia and lower Snake Rivers (e.g, Corps 2016b). TDG and temperature are monitored throughout the Columbia River Basin via 43 fixed monitoring stations. The Corps operates 25 of these stations: Portland District operates eight stations on the lower Columbia River from John Day Dam to Camas-Washougal; the Seattle District is responsible for two monitoring stations in the Upper Columbia River Basin (at Chief Joseph Dam); and the Walla Walla District is responsible for 15 monitoring stations in the lower Snake and Clearwater River Basins, and at McNary Dam on the Columbia River. Chemical runoff data from dam turbine, generation machinery, and from the dam deck is not available.

The University of Washington (UW), through their Columbia River Data Access in Real Time (DART) webpage, provides an interactive data resource designed for research and management purposes relating to the Columbia Basin salmon populations and river environment. Columbia River DART focuses on the Columbia Basin Dams and fish passage. Detailed information is brought in daily from federal, state, and tribal databases to provide a comprehensive information tool. Daily and historic information dating back to 1878 is available online.

1.3 WATER QUALITY DATA USED FOR THIS ANALYSIS

Recent water quality data used for the analysis of existing conditions originates from the following sources:

- Ecology water quality monitoring station 31A070 – Columbia River at Umatilla. Monthly data is available from 1968 through the present (Ecology 2017a). The station is located at RM 290.5.
- ODEQ water quality monitoring stations (listed in Section 2.2.3). Vertical profiles of specific conductivity, DO, oxidation-reduction potential, pH, temperature, and turbidity were collected, along with single analyses of other constituents. This data was obtained through instructions provided on the ODEQ webpage (ODEQ 2017a).
- NMFS. Limnological sampling of the John Day Reservoir was completed from April 1994 to September 1995 (NMFS 2000). The data from the NMFS study is included in Section 4.
- Corps/U.S. Geological Survey (USGS) TDG/temperature monitoring stations JDY (John Day Dam forebay; RM 215.7; USGS Station 454314120413701), JDA (John Day Dam forebay; RM 216.5), MCPW (McNary Dam tailwater; RM 290.7; USGS Station 14019240), and JHAW (John Day Dam tailwater; RM 214.7; USGS Station 454249120423500).
- Secchi depth measurements of the John Day forebay from 2008 – 2009 were available via the UW Columbia River DART webpage (Columbia River DART, 2018).

Ecology, ODEQ, and Corps monitoring station locations are shown in Figure 1-2. The station names corresponding to the station numbers are given in Table 1-1. The NMFS sampling locations are available in the referenced report (NMFS 2000).

Figure 1-2. Locations of Sampling/Monitoring Stations – John Day Dam and Lake Umatilla

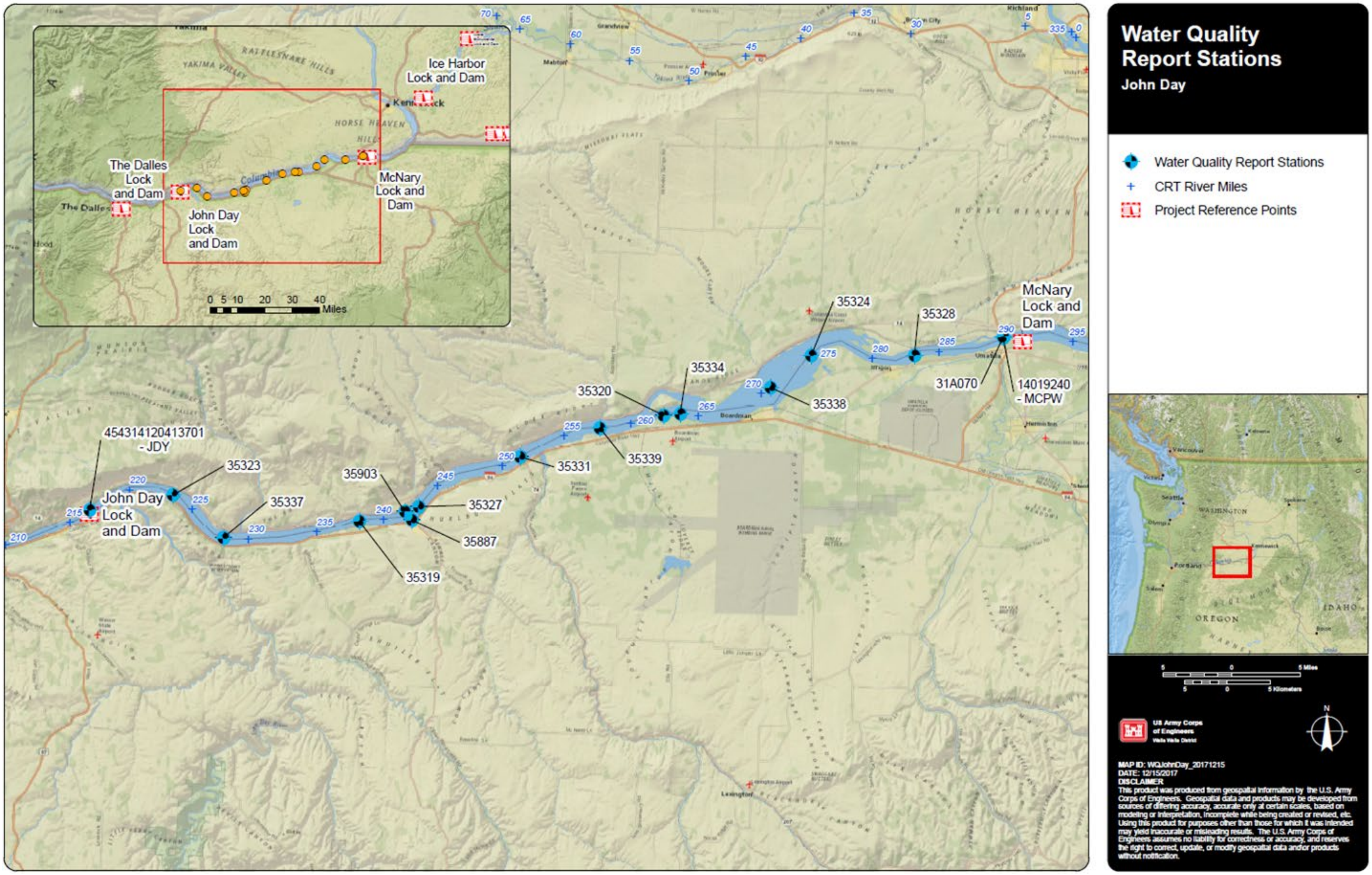


Table 1-1. Sampling and Monitoring Locations Used for this Analysis

Entity	Station Number	Station Name
ODEQ	35328	Columbia R at Irrigon Channel Marker 64 St Mi 284.3
ODEQ	35324	Columbia R at Big Blalock Island St Mi 276.2
ODEQ	35338	Columbia R at Lake Umatilla N Channel Blalock Islands St Mi 272
ODEQ	35334	Columbia R at Crow Butte Channel Marker 35 St Mi 264.6
ODEQ	35320	Columbia R at Crow Butte Powerline St Mi 263.3
ODEQ	35339	Columbia River DS of Sixmile Canyon RM 258.5
ODEQ	35331	Columbia R at Hepner Jct 1.25 Mi DS of Willow Cr. St Mi 252.2
ODEQ	35327	Columbia R at Arlington Channel Marker 21 St Mi 243.5
ODEQ	35319	Columbia R Lake Umatilla at Channel Marker 18 St Mi 238.7
ODEQ	35337	Columbia R at Lake Umatilla 0.6 Mi US Channel Marker 10 St Mi 228.3
ODEQ	35323	Columbia R at Lake Umatilla Channel Marker 6 St Mi 223.4
ODEQ	35887	Columbia River at Arlington Launch Site below Grain Mill
ODEQ	35903	Columbia River at Roosevelt Park Launch Site (WA)
Ecology	31A070	Columbia River at Umatilla
Corps	454314120413701 – JDY	Columbia River at John Day navigation lock, Washington
Corps	14019240 – MCPW	McNary Dam Tailwater, WA
Corps	454249120423500 - JHAW	Columbia River, right bank, near Cliffs, Washington (John Day tailwater)
Corps	JDA	John Day Dam forebay

SECTION 2 - WATER QUALITY

2.1 GENERAL DESCRIPTION

The John Day reach is defined as the stretch of the Columbia River beginning immediately downstream of the John Day Dam at RM 216 upstream to McNary Lock and Dam at RM 292. The most notable tributary in the John Day reach is the John Day River (Oregon). There are other smaller tributaries that flow into this reach from both Oregon and Washington.

In the John Day reach, the Columbia River sits at an approximate elevation of 267 feet above mean sea level (USGS 2018). The geological formations through which the Columbia River passes in the western portion of the John Day reach are primarily igneous, basalt formations that were deposited at various times during the middle Miocene (13.6 to 16 million years ago) (Huntting et al. 1961; Walker and MacLeod 1991). Towards the middle of the reach and eastward to McNary Dam, the river is flanked by unconsolidated sedimentary formations that were laid down during the Pleistocene (between 11.7 thousand years ago and 2.5 million years ago) or more recently. These formations are wind deposited loess, river deposited alluvium, and lacustrine sediments deposited during glacial flooding episodes on the Columbia River during the late Pleistocene.

This portion of the lower Columbia River is notable for its commercial navigation as well as recreational activities, including fishing. There are also significant tribal treaty–reserved fisheries that occur during many months of the year on the Columbia River between McNary and Bonneville dams. These tribally regulated fisheries use many different fishing methods, including drift and set nets or fishing from platforms that are built on the banks of the river. The United States Supreme Court as well as lower Federal courts have upheld Columbia River tribal fishing rights on multiple occasions. Extensive tribal fisheries also occur in tributaries to the Columbia and elsewhere on the mainstem Columbia River where salmon and steelhead (Oncorhynchus mykiss) are present.

Interstate 84 in Oregon and Highway 14 in Washington parallel the Columbia River along this segment of river.

Regional climate information for the Northwest Climate Region (Washington, Oregon, and Idaho) was obtained from the National Oceanic and Atmospheric Administration (NOAA) National Centers for Climate Information Climate at a Glance webpage (NOAA 2018). The average monthly air temperature in the Northwest Climate Region for the last 30 years (1987 through 2018) is shown in Figure 2-1. The average annual temperature for the last 30 years is shown in Figure 2-2. Within the last 30 years, the average annual temperature was above the mean temperature from 1901 to 2017 in all but 3 years. Based on air temperature data from 1895 through 2017, average annual temperatures in the Northwest Climate Region are increasing at a rate of 0.2 degrees Fahrenheit (0.11 degrees Celsius) per decade. The average monthly precipitation in the

Northwest Climate Region for the last 30 years (1987 through 2018) is shown in Figure 2-3. The average annual precipitation for the last 30 years is shown in Figure 2-4. Based on precipitation data from 1895 through 2017, average annual precipitation in the Northwest Climate Region is increasing at a rate of 0.11 inch per decade.

Monthly flow data from Ecology Station 31A070 – Columbia River at Umatilla is presented in Figure 2-5 and summarized in Table 2-1. Flow ranged from 71,617 to 501,633 cfs, and averaged 198,484 cfs. With the limited available data, flows generally appear seasonal, with higher flows occurring in the spring/summer and lower flows occurring during the winter/fall. Water particle travel time has been estimated to range from 3.8 days at flows of 300,000 cfs to 11.2 days at 100,000 cfs (Corps 1992). River conditions associated with flow greater than the 7Q10 flow (average peak annual flow for 7 consecutive days that has a recurrence interval of 10 years) are exempt from state water quality standards since it is impossible for dam operators to lower the TDG saturation of these natural origin flows. The 7Q10 flow rate identifies the upper flow limit for which state TDG standards are applicable and therefore represents the "worst case" for TDG generation (Corps 2016a). The John Day 7Q10 flow criteria for 2000 to 2016 was 454,000 cfs, and was updated for 2017 and the future to be 441,000 cfs. There were 36 exceedences of the 7Q10 flow criteria in 2011, and 9 in 2017; there were no execeedences in other years since 2008 (Corps 2008 to 2011, 2012b, 2013 to 2015, 2016b).

The most recent state water quality classifications for Washington and Oregon are shown in Table 2-2 and Table 2-3, respectively (Ecology 2017b; ODEQ 2017a). Category 5 listings are those that are on the Clean Water Act 303(d) list; Category 4A listings are those that have an approved TMDL that is actively being implemented. In Lake Umatilla, temperature, mercury, and polychlorinated biphenyls (PCBs) are on the 303(d) list. Dioxin (2,3,7,8-TCDD) and TDG have TMDLs in at least some portion of this reach. ODEQ's 303(d) list does not distinguish the media (i.e., water, tissue, sediment) that serves as the basis for the water quality evaluation. Based on characteristics of the substances, it is assumed that the mercury, PCB, and dioxin 303(d) listings are based on tissue or sediment rather than water.

Figure 2-1. Average Monthly Temperatures in the Northwest Climate Region from 1987 through 2018

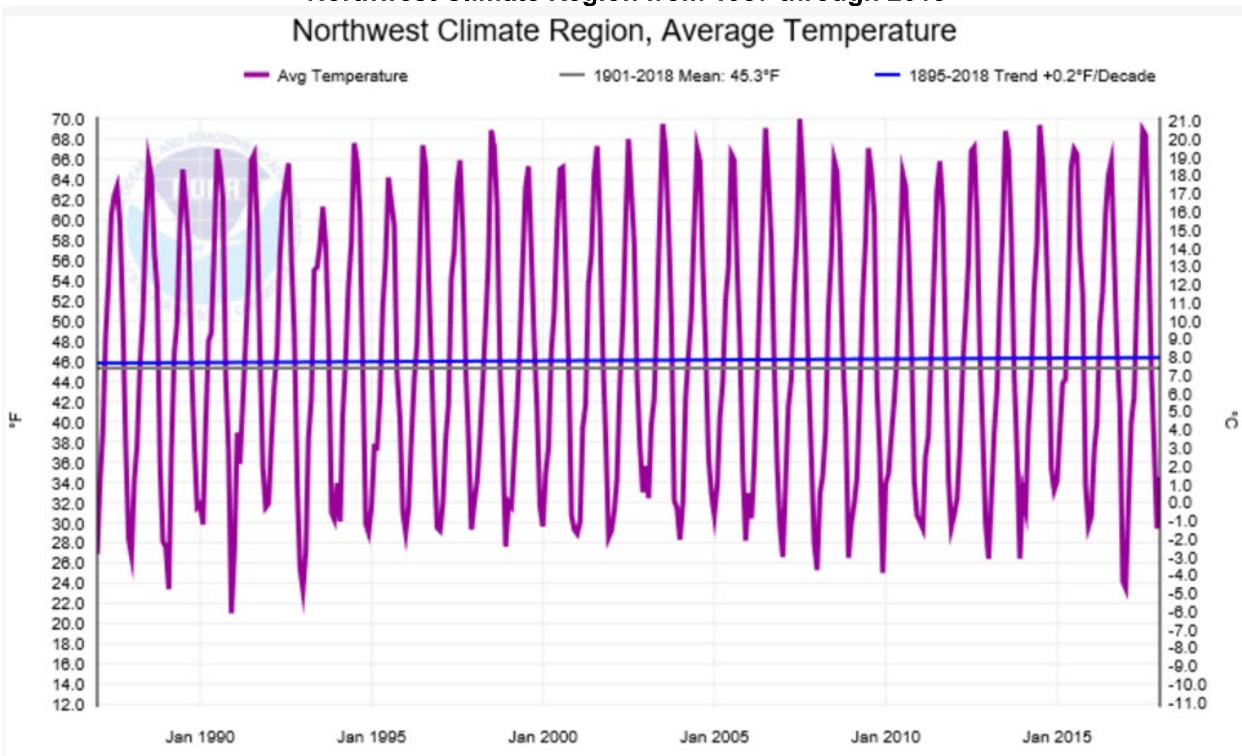


Figure 2-2. Average Annual Temperatures in the Northwest Climate Region from 1987 through 2018

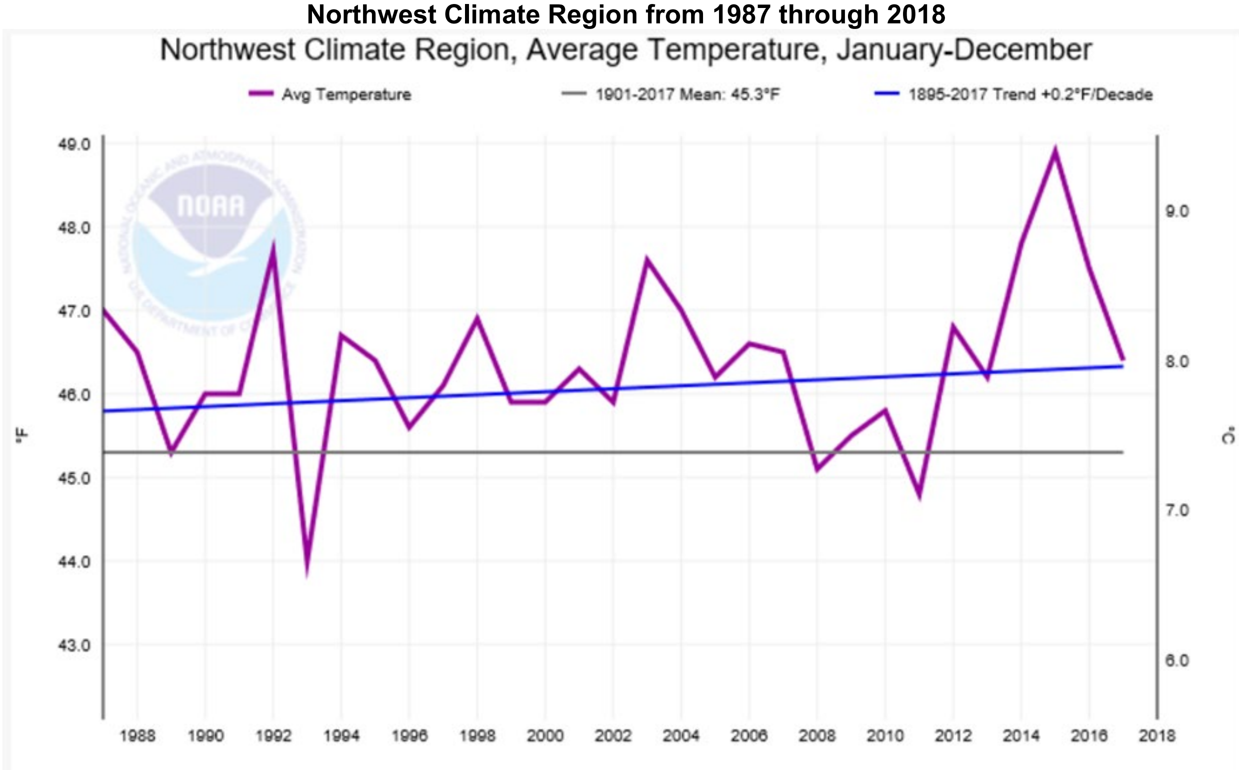


Figure 2-3. Average Monthly Precipitation in the Northwest Climate Region from 1987 through 2018

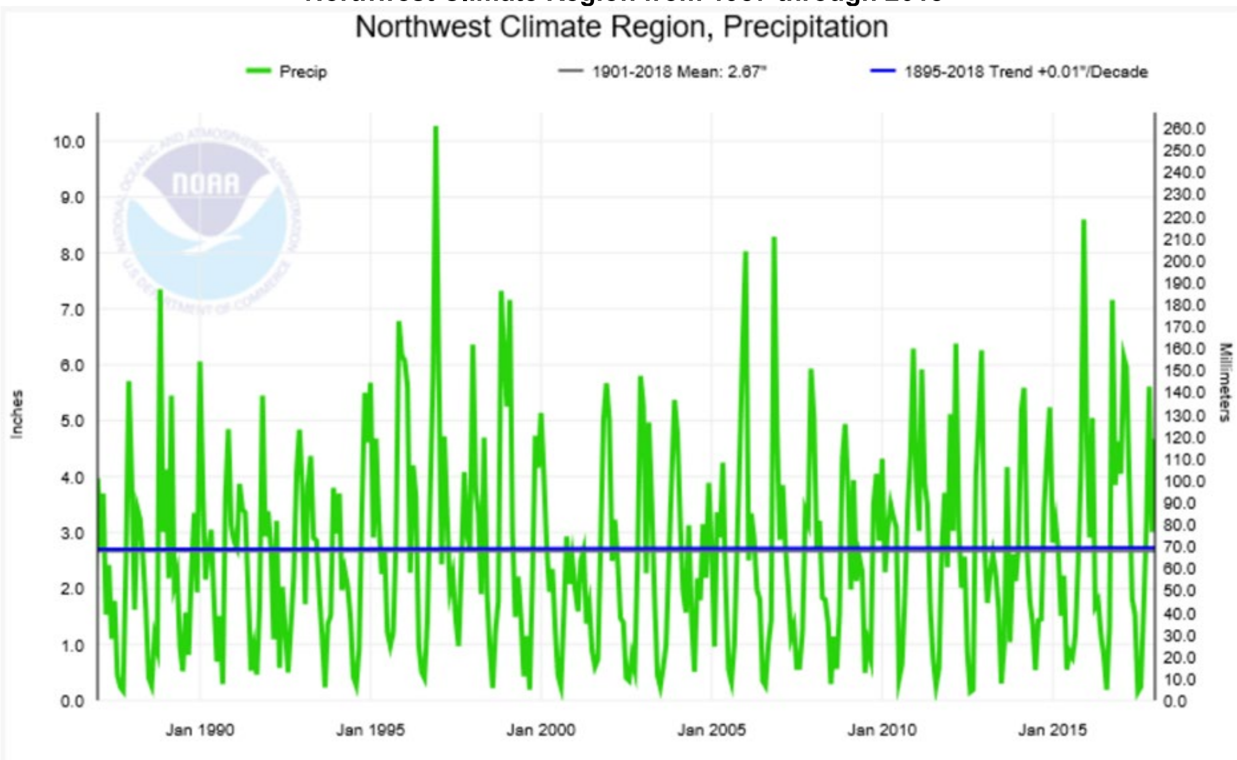


Figure 2-4. Average Annual Precipitation in the Northwest Climate Region from 1987 through 2018

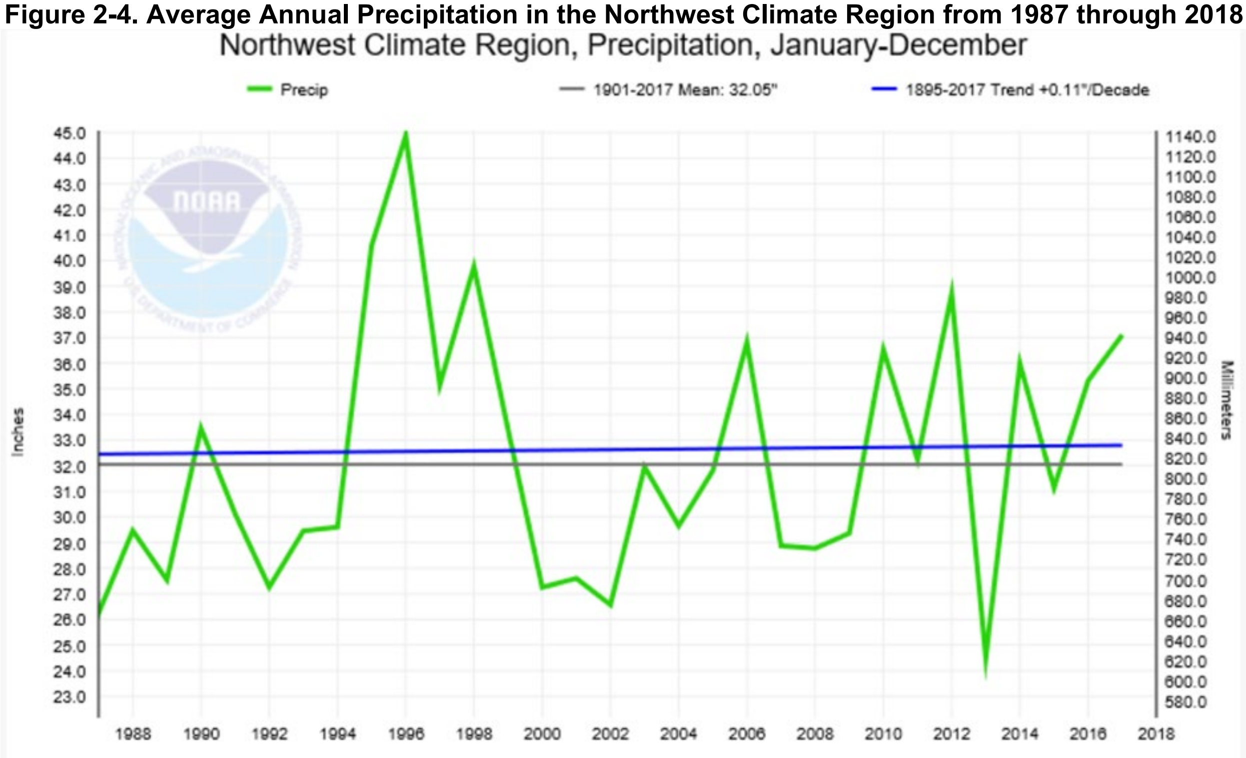


Figure 2-5. Flow at Ecology Station 31A070 – Columbia River at Umatilla, 2007 to 2015

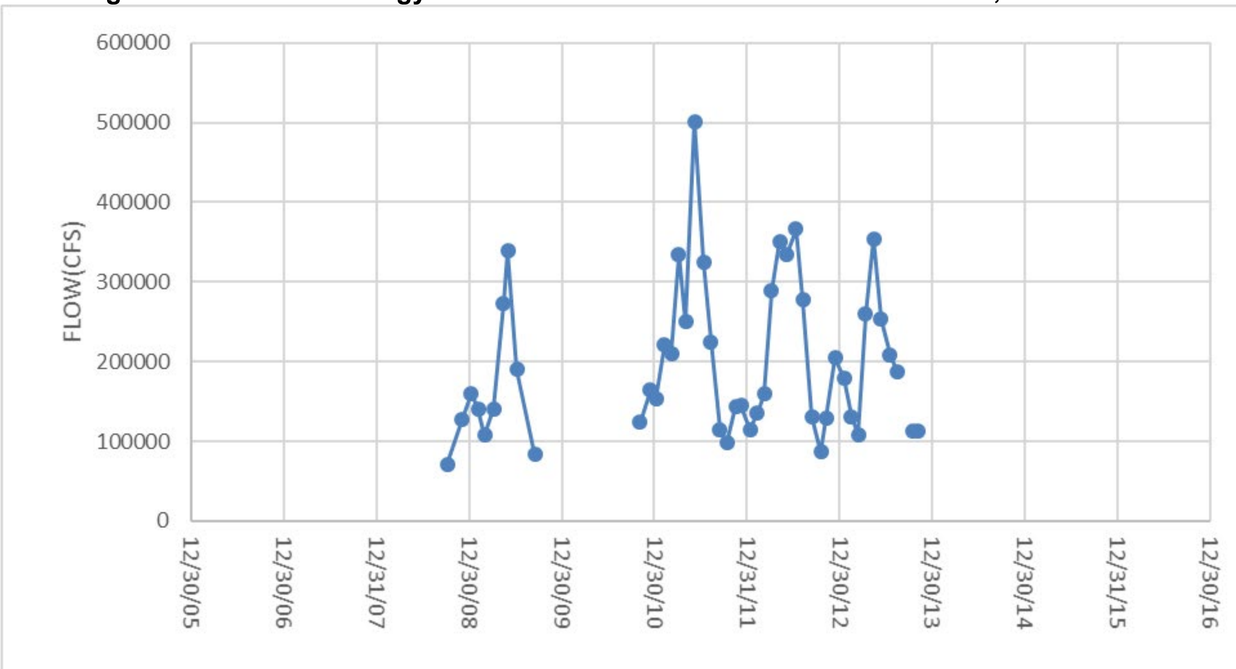


Table 2-1. Data Summary at Ecology Station 31A070 – Columbia River at Umatilla, 2007 to 2015

Type	Parameter	Start Date	End Date	# of Obs	# of Detects	% of NDs	Min ND Value	Max ND Value	KM Mean	Min[1/]	Max[1/]	Mean[1/]	Med[1/]	Q1	Q3
Physical	Flow (cfs)	10/6/2008	11/5/2013	46	46	0%	N/A	N/A	198,484	71,617	501,633	198,484	162,116	128,171	257,796
Physical	Temperature (°C)	1/9/2007	9/16/2015	102	102	0%	N/A	N/A	11.88	1.6	21.92	11.88	11.8	6.025	17.78
Physical	DO (mg/L)	1/9/2007	9/16/2015	101	101	0%	N/A	N/A	11.53	8.1	14.8	11.53	11.7	10	12.8
Physical	Barometric Pressure (mmHg)	1/9/2007	9/16/2015	102	102	0%	N/A	N/A	758	737.4	773.9	758	757.4	753.3	762.4
Physical	pH	1/9/2007	9/16/2015	102	102	0%	N/A	N/A	8.118	7.73	8.47	8.118	8.1	8.03	8.19
Physical	Specific Conductivity (uS/cm)	1/9/2007	9/16/2015	102	102	0%	N/A	N/A	153	102	231	153	153	138.3	165
Chemical	Alkalinity (mg/L)	10/22/2007	8/11/2008	6	6	0%	N/A	N/A	64.55	51.3	74.7	64.55	65.75	57.48	72.75
Chemical	Hardness (mg/L as $CaCO_3$)	10/22/2007	8/11/2008	6	6	0%	N/A	N/A	68.87	53.8	82.5	68.87	71.8	58.65	77.23
Chemical	Turbidity (NTU)	1/9/2007	9/16/2015	102	102	0%	N/A	N/A	2.335	0.8	14	2.335	1.75	1.3	2.625
Chemical	Suspended Solids (mg/L)	1/9/2007	9/16/2015	102	101	1%	1	1	3.333	1	13	3.356	3	2	4
Chemical	Nitrate + Nitrite as Nitrogen (mg/L)	1/9/2007	9/16/2015	102	102	0%	N/A	N/A	0.221	0.051	0.658	0.221	0.226	0.108	0.291
Chemical	Ammonia as Nitrogen (mg/L)	1/9/2007	9/16/2015	101	28	72%	0.01	0.01	0.0115	0.01	0.03	0.0155	0.014	0.01	0.01
Chemical	Total Persulfate Nitrogen (mg/L)	1/9/2007	9/16/2015	102	102	0%	N/A	N/A	0.283	0.112	0.714	0.283	0.28	0.18	0.345
Chemical	Total Phosphorus (mg/L)	10/22/2007	9/16/2015	93	93	0%	N/A	N/A	0.0184	0.0092	0.0522	0.0184	0.0166	0.0136	0.0205
Chemical	Total Phosphorus by ICP-MS (mg/L)	1/9/2007	9/12/2007	9	9	0%	N/A	N/A	0.0102	0.0062	0.0231	0.0102	0.0087	0.0075	0.0098
Chemical	Soluble Reactive Phosphorus (mg/L)	1/9/2007	9/16/2015	101	96	5%	0.003	0.003	0.00833	0.003	0.0227	0.00861	0.00695	0.005	0.0111
Chemical	Dissolved Organic Carbon (mg/L)	9/14/2010	8/10/2011	6	6	0%	N/A	N/A	1.617	1.1	2.3	1.617	1.55	1.5	1.675
Chemical	Total Organic Carbon (mg/L)	9/14/2010	8/10/2011	6	6	0%	N/A	N/A	1.85	1.4	2.3	1.85	1.75	1.625	2.175
Biological	Chlorophyll a (ug/L)	6/8/2010	9/16/2015	60	60	0%	N/A	N/A	3.957	0.8	16.2	3.957	3.35	2.2	4.625
Biological	Fecal Coliform Bacteria (#/100 mL)	1/9/2007	9/16/2015	102	75	26%	1	1	3.804	1	120	4.813	2	1	3

Notes: Obs = observations; Detects = detections; ND = non-detection; Min = minimum; Max = maximum; KM = Kaplan-Meier; Med = median; Q1 = first quartile; Q3 = third quartile.
$CaCO_3$ = calcium carbonate; ICP-MS = inductively coupled plasma-mass spectrometry; N/A = not applicable; NTU = Nephelometric Turbidity Unit.
1/ These summary statistics are based on only the detected values.

Table 2-2. 2017 Washington State Water Quality Classifications and Clean Water Act 303(d) Listings

Assessment Unit ID; Description	Listing ID	Category	Medium	Parameter
170701010601_01_01; just downstream of McNary Dam near Plymouth, Washington	6300	5	Water	Temperature
170701010601_01_01	7965	4A	Water	TDG
170701010601_01_01	11093	2	Water	Mercury
170701010601_01_01	11095	2	Water	pH
170701010601_01_01	11086	1	Water	Ammonia-N
170701010601_01_01	11092	1	Water	Arsenic
170701010601_01_01	16782	1	Water	Bacteria
170701011403_01_01; near Roosevelt, Washington	73854	2	Water	Temperature
170701011408_01_01; just upstream of John Day Dam	7964	5	Water	Temperature
170701011408_01_01	8801	2	Water	Arsenic

Table 2-3. 2017 Oregon State Water Quality Classifications and Clean Water Act 303(d) Listings

USGS HUC	Record ID	River Miles	Category	Parameter
17070101; 17070105; 17080001; 17080003; 17080006; 17090012	13288	0 to 303.9	5	Temperature
17070101; 17070105; 17080001; 17080003; 17080006; 17090012	21819	0 to 303.9	3B	Phosphate phosphorus
17070101; 17070105; 17080001; 17080003; 17080006; 17090012	20002	0 to 303.9	3	Barium
17070101; 17070105; 17080001; 17080003; 17080006; 17090012	20006	0 to 303.9	3	Chloride
17070101; 17070105; 17080001; 17080003; 17080006; 17090012	20007	0 to 303.9	3	Chlorophyll a
17070101; 17070105; 17080001; 17080003; 17080006; 17090012	20008	0 to 303.9	3	Chlorophyll a
17070101; 17070105; 17080001; 17080003; 17080006; 17090012	20026	0 to 303.9	3	Nitrates
17070101; 17070105; 17080001; 17080003; 17080006; 17090012	20035	0 to 303.9	3	Thallium
17070101; 17070105; 17080001; 17080003; 17080006; 17090012	19999	0 to 303.9	2	Ammonia
17070101; 17070105; 17080001; 17080003; 17080006; 17090012	25982	0 to 303.9	2	Chromium
17070101; 17070105; 17080001; 17080003; 17080006; 17090012	20010	0 to 303.9	2	Copper
17070101; 17070105; 17080001; 17080003; 17080006; 17090012	21103	0 to 303.9	2	DO
17070101; 17070105; 17080001; 17080003; 17080006; 17090012	20025	0 to 303.9	2	Nickel
17070101; 17070105; 17080001; 17080003; 17080006; 17090012	20032	0 to 303.9	2	Selenium
17070101; 17070105; 17080001; 17080003; 17080006; 17090012	20036	0 to 303.9	2	Zinc
17070101; 17070105; 17080001; 17080003; 17090012	19998	34.5 to 303.9	2	Alkalinity
17070101; 17070105; 17080001	20024	137.1 to 303.9	2	Manganese
17070101; 17070105	26018	142 to 287.1	5	Mercury
17070101; 17070105	9284	142 to 287.1	5	PCBs

USGS HUC	Record ID	River Miles	Category	Parameter
17070101; 17070105	25983	142 to 303.9	3	Arsenic
17070101; 17070105	25986	142 to 303.9	3	Cadmium
17070101; 17070105	20020	142 to 303.9	3	Iron
17070101; 17070105	25985	142 to 303.9	3	Lead
17070101; 17070105	25984	142 to 303.9	3	Silver
17070101; 17070105	26027	142 to 303.9	2	pH
17070101; 17070105	26025	188.6 to 303.9	3	pH
17070101	44	213.7 to 287.1	4A	Dioxin (2,3,7,8-TCDD)
17070101	43	213.7 to 287.1	4A	Dioxin (2,3,7,8-TCDD)
17070101	26	213.7 to 287.1	4A	TDG
17070101	45	287.1 to 303.9	4A	Dioxin (2,3,7,8-TCDD)
17070101	46	287.1 to 303.9	4A	Dioxin (2,3,7,8-TCDD)
17070101	27	287.1 to 303.9	4A	TDG

Note: HUC = Hydrologic Unit Code.

2.2 EXISTING WATER QUALITY CONDITIONS

Monthly physical, chemical, and biological water quality parameters (2007 to 2015) at Ecology Station 31A070 – Columbia River at Umatilla were summarized in Table 2-1.

A set of physical, chemical, and biological water quality parameters were collected by ODEQ during an 8-day period in September of 2009 at several locations along this reach. Table 2-4 identifies these monitoring stations. Depth profiles of physical parameters from these ODEQ stations are summarized in Table 2-5. The other physical, chemical, and biological parameters obtained during the surface water sampling event (depth 0.2 meter) were analyzed together because the parameter values, for the most part, were similar. The summary of this data is presented in Table 2-6. There were two other stations with ODEQ data within the same time range (Table 2-7). Each of these stations had only two observations for specific conductivity and temperature during August 2008; Table 2-8 summarizes that data.

Table 2-4. Oregon Department of Environmental Quality Monitoring Stations with Data in September 2009

Station	Station Name
35328	Columbia R at Irrigon Channel Marker 64 St Mi 284.3
35324	Columbia R at Big Blalock Island St Mi 276.2
35338	Columbia R at Lake Umatilla N Channel Blalock Islands St Mi 272
35334	Columbia R at Crow Butte Channel Marker 35 St Mi 264.6
35320	Columbia R at Crow Butte Powerline St Mi 263.3
35339	Columbia River DS of Sixmile Canyon RM 258.5
35331	Columbia R at Hepner Jct 1.25 Mi DS of Willow Cr. St Mi 252.2
35327	Columbia R at Arlington Channel Marker 21 St Mi 243.5
35319	Columbia R Lake Umatilla at Channel Marker 18 St Mi 238.7
35337	Columbia R at Lake Umatilla 0.6 Mi US Channel Marker 10 St Mi 228.3
35323	Columbia R at Lake Umatilla Channel Marker 6 St Mi 223.4

The National Marine Fisheries Service (NFMS) conducted limnological sampling of the John Day Reservoir from April 1994 to September 1995 (NMFS 2000). Field measurements were made of physical variables, including temperature, turbidity, and Secchi disk visibility. Water samples were taken and preserved for laboratory determination of chemical variables including alkalinity, nutrients, and major ions. Other chemical variables (pH, DO, and specific conductivity were monitored directly using a multifunction meter. Biological variables included chlorophyll a, zooplankton, benthic invertebrates, and resident and migrant fish. The data from the NMFS study is included in Section 3.

Daily average water temperature and hourly TDG data from Corps/USGS temperature/TDG monitoring stations JDY (John Day Forebay; RM 215.7), JHAW (John Day Tailwater; RM 214.7), and MCPW (McNary Dam Tailwater; RM 290.7) back to 2007 was also available. Hourly temperature data at different depths was also available from station JDA from June to October 2012. TDG exceedences are briefly discussed as summarized in TDG reports from 2007 through 2016 (Corps 2007 to 2011, 2012b, 2013 to 2015, 2016b).

Table 2-5. Depth Profiles for Oregon Department of Environmental Quality Monitoring Stations with Data in September 2009

Station Number	Station Name	River Mile	Profile Date	Sample Depth (m)	Specific Conductivity (µS/cm @ 25°C)	DO (% Saturation)	DO (mg/L)	Oxidation Reduction Potential (mV)	pH	Temperature (°C)	Turbidity (NTU)
35328	Columbia R at Irrigon Channel Marker 64 St Mi 284.3	284.3	9/1/2009	0.2	152	102	9	236	8.4	21.4	1
35328	Columbia R at Irrigon Channel Marker 64 St Mi 284.3	284.3	9/1/2009	2.5	152	102	8.9	258	8.4	21.4	N/A
35328	Columbia R at Irrigon Channel Marker 64 St Mi 284.3	284.3	9/1/2009	5	152	102	8.9	270	8.4	21.4	N/A
35324	Columbia R at Big Blalock Island St Mi 276.2	276.2	9/1/2009	0.2	152	110	9.7	280	8.3	21.4	1
35324	Columbia R at Big Blalock Island St Mi 276.2	276.2	9/1/2009	3	151	110	9.7	296	8.3	21.1	N/A
35324	Columbia R at Big Blalock Island St Mi 276.2	276.2	9/1/2009	6	152	110	9.7	301	8.3	21	N/A
35338	Columbia R at Lake Umatilla N Channel Blalock Islands St Mi 272	272	9/1/2009	0.2	151	110	9.4	288	8.4	22.8	2
35338	Columbia R at Lake Umatilla N Channel Blalock Islands St Mi 272	272	9/1/2009	3	153	106	9.4	290	8.4	21.5	N/A
35338	Columbia R at Lake Umatilla N Channel Blalock Islands St Mi 272	272	9/1/2009	6	155	105	9.3	291	8.3	21	N/A
35334	Columbia R at Crow Butte Channel Marker 35 St Mi 264.6	264.6	9/2/2009	0.2	149	122	10.4	213	8.4	22.9	<1
35334	Columbia R at Crow Butte Channel Marker 35 St Mi 264.6	264.6	9/2/2009	1	149	122	10.4	214	8.4	22.8	<1
35334	Columbia R at Crow Butte Channel Marker 35 St Mi 264.6	264.6	9/2/2009	3	149	120	10.3	214	8.4	22.5	<1
35334	Columbia R at Crow Butte Channel Marker 35 St Mi 264.6	264.6	9/2/2009	5	149	119	10.2	216	8.4	22.4	<1
35320	Columbia R at Crow Butte Powerline St Mi 263.3	263.3	9/2/2009	0.2	149	115	9.9	298	7.8	22.5	<1
35320	Columbia R at Crow Butte Powerline St Mi 263.3	263.3	9/2/2009	1	149	115	9.9	287	7.9	22.7	<1
35320	Columbia R at Crow Butte Powerline St Mi 263.3	263.3	9/2/2009	3	149	115	9.9	279	7.9	22.3	<1
35320	Columbia R at Crow Butte Powerline St Mi 263.3	263.3	9/2/2009	6	149	109	9.5	275	7.8	21.4	<1
35339	Columbia River DS of Sixmile Canyon RM 258.5	258.5	9/2/2009	0.2	152	112	9.6	210	8.4	22.7	2
35339	Columbia River DS of Sixmile Canyon RM 258.5	258.5	9/2/2009	2.5	152	109	9.5	230	8.4	21.5	N/A
35339	Columbia River DS of Sixmile Canyon RM 258.5	258.5	9/2/2009	5	151	105	9.2	242	8.3	21.4	N/A
35339	Columbia River DS of Sixmile Canyon RM 258.5	258.5	9/2/2009	7	152	99	8.8	248	8.1	21.1	N/A
35331	Columbia R at Hepner Jct 1.25 Mi DS of Willow Cr. St Mi 252.2	252.2	9/2/2009	0.2	154	109	9.4	324	8.4	22.1	3
35331	Columbia R at Hepner Jct 1.25 Mi DS of Willow Cr. St Mi 252.2	252.2	9/2/2009	2.5	154	106	9.2	344	8.4	21.7	N/A
35331	Columbia R at Hepner Jct 1.25 Mi DS of Willow Cr. St Mi 252.2	252.2	9/2/2009	5	154	104	9	350	8.3	21.6	N/A
35331	Columbia R at Hepner Jct 1.25 Mi DS of Willow Cr. St Mi 252.2	252.2	9/2/2009	8	153	101	8.9	358	8.1	21.3	N/A
35327	Columbia R at Arlington Channel Marker 21 St Mi 243.5	243.5	9/9/2009	0.2	149	103	9.1	229	8.2	20.7	<1
35327	Columbia R at Arlington Channel Marker 21 St Mi 243.5	243.5	9/9/2009	1	149	103	9.2	229	8.2	20.7	<1
35327	Columbia R at Arlington Channel Marker 21 St Mi 243.5	243.5	9/9/2009	3	149	103	9.1	230	8.2	20.7	1
35327	Columbia R at Arlington Channel Marker 21 St Mi 243.5	243.5	9/9/2009	5	149	102	9	231	8.2	20.7	1
35327	Columbia R at Arlington Channel Marker 21 St Mi 243.5	243.5	9/9/2009	8	149	101	9	232	8.2	20.7	1
35319	Columbia R Lake Umatilla at Channel Marker 18 St Mi 238.7	238.7	9/3/2009	0.2	154	103	8.9	198	8.3	21.9	2
35319	Columbia R Lake Umatilla at Channel Marker 18 St Mi 238.7	238.7	9/3/2009	2.5	154	106	9.2	241	8.4	21.8	N/A
35319	Columbia R Lake Umatilla at Channel Marker 18 St Mi 238.7	238.7	9/3/2009	4.4	154	105	9.1	243	8.3	21.8	N/A
35337	Columbia R at Lake Umatilla 0.6 Mi US Channel Marker 10 St Mi 228.3	228.3	9/8/2009	0.2	150	105	9	165	8.1	22.3	<1
35337	Columbia R at Lake Umatilla 0.6 Mi US Channel Marker 10 St Mi 228.3	228.3	9/8/2009	1	150	106	9.2	167	8.1	22.1	<1
35337	Columbia R at Lake Umatilla 0.6 Mi US Channel Marker 10 St Mi 228.3	228.3	9/8/2009	3	150	103	9.1	169	8.1	22.1	<1
35337	Columbia R at Lake Umatilla 0.6 Mi US Channel Marker 10 St Mi 228.3	228.3	9/8/2009	6	150	95	8.4	174	7.9	20.9	2
35337	Columbia R at Lake Umatilla 0.6 Mi US Channel Marker 10 St Mi 228.3	228.3	9/8/2009	8	150	95	8.4	175	7.9	20.9	3
35323	Columbia R at Lake Umatilla Channel Marker 6 St Mi 223.4	223.4	9/3/2009	0.2	155	99	8.6	410	7.8	21.6	3
35323	Columbia R at Lake Umatilla Channel Marker 6 St Mi 223.4	223.4	9/3/2009	2.5	154	100	8.7	361	7.8	21.6	N/A
35323	Columbia R at Lake Umatilla Channel Marker 6 St Mi 223.4	223.4	9/3/2009	5	154	100	8.7	361	7.9	21.6	N/A

Table 2-6. Data Summary for Oregon Department of Environmental Quality Monitoring Stations with Data in September 2009

Type	Parameter	Start Date	End Date	# of Obs	# of Detects	% of NDs	Min ND Value	Max ND Value	KM Mean	Min1/	Max1/	Mean1/	Med1/	Q1	Q3
Physical	Specific Conductivity (µS/cm @ 25°C)	9/1/2009	9/9/2009	11	11	0.00%	N/A	N/A	151.5	149	155	151.5	152	149.5	153
Physical	DO (% Saturation)	9/1/2009	9/9/2009	11	11	0.00%	N/A	N/A	108.2	99	122	108.2	109	103	111
Physical	DO (mg/L)	9/1/2009	9/9/2009	11	11	0.00%	N/A	N/A	9.364	8.6	10.4	9.364	9.4	9	9.65
Physical	Oxidation Reduction Potential (mV)	9/1/2009	9/9/2009	11	11	0.00%	N/A	N/A	259.2	165	410	259.2	236	211.5	293
Physical	pH	9/1/2009	9/9/2009	11	11	0.00%	N/A	N/A	8.227	7.8	8.4	8.227	8.3	8.15	8.4
Physical	Temperature (°C)	9/1/2009	9/9/2009	11	11	0.00%	N/A	N/A	22.03	20.7	22.9	22.03	22.1	21.5	22.6
Physical	Turbidity (NTU)	9/1/2009	9/9/2009	11	7	36.36%	1	1	1.636	1	3	2	2	1	2
Chemical	Calcium (mg/L)	9/1/2009	9/9/2009	11	11	0.00%	N/A	N/A	17.45	17.2	17.7	17.45	17.4	17.35	17.6
Chemical	Magnesium (mg/L)	9/1/2009	9/9/2009	11	11	0.00%	N/A	N/A	4.843	4.74	4.94	4.843	4.82	4.8	4.905
Chemical	Sulfate (mg/L)	9/1/2009	9/9/2009	11	11	0.00%	N/A	N/A	10.88	10.7	11.1	10.88	10.9	10.8	10.95
Chemical	Alkalinity as $CaCO_3$ (mg/L)	9/1/2009	9/9/2009	11	11	0.00%	N/A	N/A	60.55	60	62	60.55	60	60	61
Chemical	Hardness as $CaCO_3$ (mg/L)	9/1/2009	9/9/2009	11	11	0.00%	N/A	N/A	63.48	62.6	64.3	63.48	63.6	63.2	63.75
Chemical	Antimony, Total Recoverable (µg/L)	9/1/2009	9/9/2009	11	0	100.00%	2	2	N/A	N/A	N/A	N/A	N/A	2	2
Chemical	Arsenic, Total Recoverable (µg/L)	9/1/2009	9/9/2009	11	0	100.00%	2	2	N/A	N/A	N/A	N/A	N/A	2	2
Chemical	Barium, Total Recoverable (µg/L)	9/1/2009	9/9/2009	11	11	0.00%	N/A	N/A	28.26	27.7	28.9	28.26	28.1	27.95	28.6
Chemical	Beryllium, Total Recoverable (µg/L)	9/1/2009	9/9/2009	11	0	100.00%	0.3	0.3	N/A	N/A	N/A	N/A	N/A	0.3	0.3
Chemical	Cadmium, Total Recoverable (µg/L)	9/1/2009	9/9/2009	11	0	100.00%	0.3	0.3	N/A	N/A	N/A	N/A	N/A	0.3	0.3
Chemical	Chromium, Total Recoverable (µg/L)	9/1/2009	9/9/2009	11	0	100.00%	1	1	N/A	N/A	N/A	N/A	N/A	1	1
Chemical	Cobalt, Total Recoverable (µg/L)	9/1/2009	9/9/2009	11	0	100.00%	0.2	0.2	N/A	N/A	N/A	N/A	N/A	0.2	0.2
Chemical	Copper, Total Recoverable (µg/L)	9/1/2009	9/9/2009	11	0	100.00%	1.5	1.5	N/A	N/A	N/A	N/A	N/A	1.5	1.5
Chemical	Lead, Total Recoverable (µg/L)	9/1/2009	9/9/2009	11	0	100.00%	0.2	0.2	N/A	N/A	N/A	N/A	N/A	0.2	0.2
Chemical	Molybdenum, Total Recoverable (µg/L)	9/1/2009	9/9/2009	11	0	100.00%	3	3	N/A	N/A	N/A	N/A	N/A	3	3
Chemical	Nickel, Total Recoverable (µg/L)	9/1/2009	9/9/2009	11	0	100.00%	1	1	N/A	N/A	N/A	N/A	N/A	1	1
Chemical	Selenium, Total Recoverable (µg/L)	9/1/2009	9/9/2009	11	0	100.00%	2	2	N/A	N/A	N/A	N/A	N/A	2	2
Chemical	Silver, Total Recoverable (µg/L)	9/1/2009	9/9/2009	11	0	100.00%	0.1	0.1	N/A	N/A	N/A	N/A	N/A	0.1	0.1
Chemical	Thallium, Total Recoverable (µg/L)	9/1/2009	9/9/2009	11	0	100.00%	0.1	0.1	N/A	N/A	N/A	N/A	N/A	0.1	0.1
Chemical	Uranium, Total Recoverable (µg/L)	9/1/2009	9/9/2009	11	11	0.00%	N/A	N/A	0.718	0.68	0.75	0.718	0.71	0.71	0.73
Chemical	Vanadium, Total Recoverable (µg/L)	9/1/2009	9/9/2009	11	0	100.00%	4	4	N/A	N/A	N/A	N/A	N/A	4	4
Chemical	Zinc, Total Recoverable (µg/L)	9/1/2009	9/9/2009	11	0	100.00%	3	3	N/A	N/A	N/A	N/A	N/A	3	3
Chemical	Mercury, Dissolved (ng/L)	9/1/2009	9/9/2009	11	0	100.00%	0.5	0.5	N/A	N/A	N/A	N/A	N/A	0.5	0.5
Chemical	Mercury, Total Recoverable (ng/L)	9/1/2009	9/9/2009	11	8	27.27%	0.5	0.5	0.58	0.549	0.772	0.61	0.587	0.525	0.602
Chemical	Methyl Mercury, Dissolved (ng/L)	9/1/2009	9/9/2009	11	0	100.00%	0.049	0.049	N/A	N/A	N/A	N/A	N/A	0.049	0.049
Chemical	Methyl Mercury, Total (ng/L)	9/1/2009	9/9/2009	11	0	100.00%	0.049	0.049	N/A	N/A	N/A	N/A	N/A	0.049	0.049
Chemical	Total Suspended Solids (mg/L)	9/1/2009	9/9/2009	11	9	18.18%	1	1	1.727	1	3	1.889	2	1	2
Chemical	Secchi Disk Depth (m)	9/1/2009	9/9/2009	10	10	0.00%	N/A	N/A	2.72	1.9	3.5	2.72	2.65	2.35	3.25
Chemical	Nitrate/Nitrite as Nitrogen (mg/L)	9/1/2009	9/9/2009	11	11	0.00%	N/A	N/A	0.058	0.0205	0.0825	0.058	0.0609	0.046	0.0718
Chemical	Ammonia as Nitrogen (mg/L)	9/1/2009	9/9/2009	11	0	100.00%	0.02	0.02	N/A	N/A	N/A	N/A	N/A	0.02	0.02
Chemical	Total Phosphorus (mg/L)	9/1/2009	9/9/2009	11	11	0.00%	N/A	N/A	0.0236	0.02	0.03	0.0236	0.02	0.02	0.03
Chemical	Orthophosphate as Phosphorus (mg/L)	9/1/2009	9/9/2009	11	3	72.73%	0.005	0.005	0.00518	0.005	0.007	0.00567	0.005	0.005	0.005
Chemical	Total Organic Carbon (mg/L)	9/1/2009	9/9/2009	11	11	0.00%	N/A	N/A	2	2	2	2	2	2	2
Chemical	Dissolved Organic Carbon (mg/L)	9/1/2009	9/9/2009	11	11	0.00%	N/A	N/A	2	2	2	2	2	2	2
Biological	Chlorophyll a (µg/L)	9/1/2009	9/9/2009	10	10	0.00%	N/A	N/A	4.46	1.7	11.9	4.46	3.95	2.65	4.875
Biological	Pheophytin a (µg/L)	9/1/2009	9/9/2009	10	10	0.00%	N/A	N/A	1.4	0.6	2.6	1.4	1.1	1	1.75
Biological	E. coli (MPN/100 mL)	9/1/2009	9/9/2009	11	1	90.91%	1	1	1	1	1	1	1	1	1

Note: 1/ These summary statistics are based on only the detected values.

Table 2-7. Oregon Department of Environmental Quality Monitoring Stations with Data in August 2008

Station Number	Station Description
35887	Columbia River at Arlington Launch Site below Grain Mill
35903	Columbia River at Roosevelt Park Launch Site (WA)

Table 2-8. Data Summary for Oregon Department of Environmental Quality Monitoring Stations with data in August 2008

Site	Parameter	Date Range		# of Obs	# of Detects	% of NDs	Min ND Value	Max ND Value	KM Mean	Min[1/]	Max[1/]	Mean[1/]	Med[1/]	Q1	Q3
35887 – Columbia River at Arlington Launch Site below Grain Mill	Specific Conductivity (µS/cm @ 25°C)	8/14/2008	8/16/2008	2	2	0%	N/A	N/A	133.4	132.5	134.3	133.4	133.4	132.5	134.3
35887 – Columbia River at Arlington Launch Site below Grain Mill	Temperature (°C)	8/14/2008	8/16/2008	2	2	0%	N/A	N/A	23.2	23.1	23.3	23.2	23.2	23.1	23.3
35903 – Columbia River at Roosevelt Park Launch Site (WA)	Specific Conductivity (µS/cm @ 25°C)	8/14/2008	8/16/2008	2	2	0%	N/A	N/A	137	135.6	138.4	137	137	135.6	138.4
35903 – Columbia River at Roosevelt Park Launch Site (WA)	Temperature (°C)	8/14/2008	8/16/2008	2	2	0%	N/A	N/A	23.6	23.3	23.9	23.6	23.6	23.3	23.9

Note: 1/ These summary statistics are based on only the detected values.

2.2.1 Physical

2.2.1.1 *Temperature*

The temperature-related characteristics of water have a large effect on water quality and the ecology of lakes. As lake water warms in the spring and summer it becomes less dense and floats on top of colder water. In the absence of sufficient energy (i.e., wind or high inflows) to mix the water and equilibrate the temperature, a lake will thermally stratify and form two separate temperature layers. Thermal stratification produces a warm water upper layer, called the epilimnion, and a cold water bottom layer, called the hypolimnion. The transition zone between these two layers is called the metalimnion or thermocline, and is marked by rapid changes in water temperatures from top to bottom. Typical direct thermal stratification is apparent when the temperature in this transition zone decreases at least 1 degree Celsius for every 1-meter increase in depth. Because of the temperature difference in a stratified lake, there is little mixing of water between the epilimnion and hypolimnion until the lake de-stratifies in the fall and winter, resulting in a uniform temperature throughout the water column.

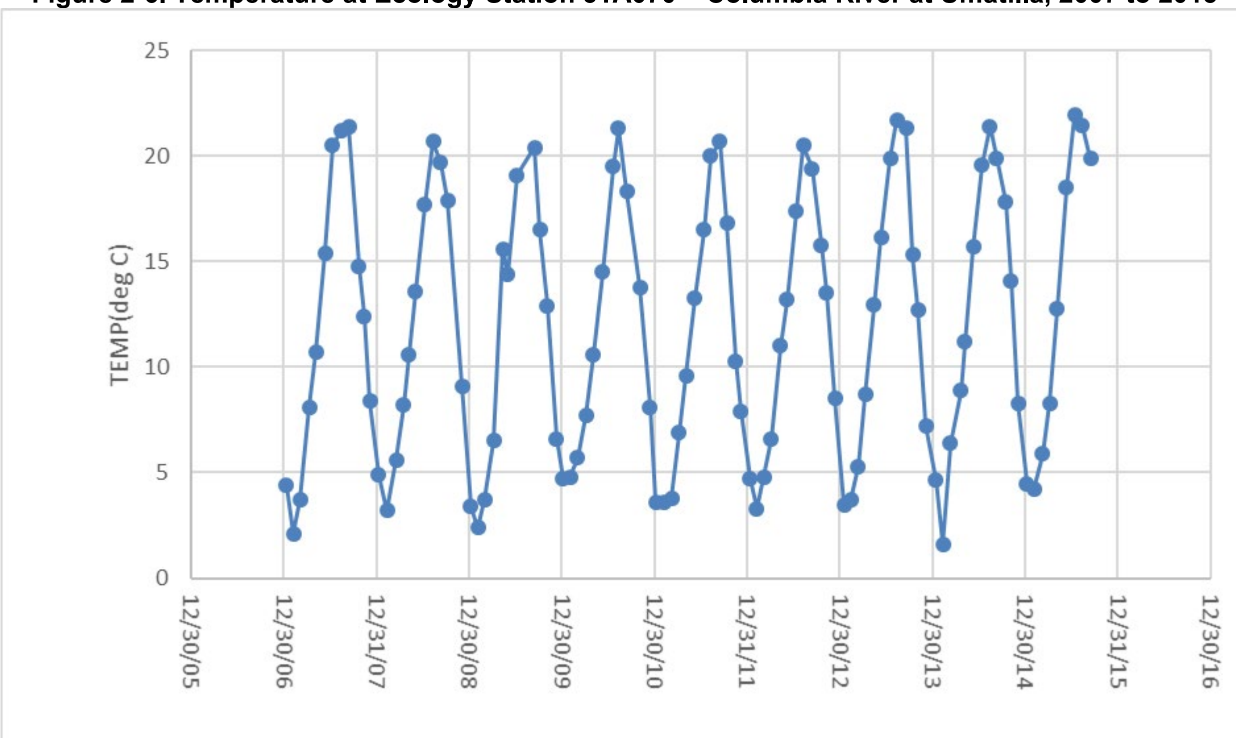
Elevated temperatures affect multiple life history stages in anadromous fish including migration, gametogenesis, gamete viability, egg incubation, timing of emergence, predator exposure, growth, migration, maturation, and ultimate survival of individuals and overall population productivity. For example, adult fallback over and through dam turbines and screen bypass systems after adults have migrated through fish ladders can be substantial and could be caused by warm water temperatures in the fish ladders or at other places within the project boundaries (Wagner and Hillison 1991). Additionally, warm water temperatures in reservoirs cause severe temperature stresses, including a higher risk of disease and increased susceptibility to parasites, e.g., the *Neascus* spp. (aka “blackspot”) infection. The combination of infestation by the parasite and exposure to high temperatures leads to more fish die-offs. Higher stream temperatures have also been shown to increase sensitivity of subyearling Chinook salmon (Oncorhynchus tshawytscha) in the Columbia River Basin to pesticides (EPA 2014). Corps-funded studies of adult salmon and steelhead passage indicate that warm water temperatures in fish ladders such as those at John Day Dam may impede adult migration (Keefer et al. 2004).

Additionally, the run timing of steelhead and Chinook salmon overlap with the period of high summer temperatures in the Lower Columbia (Palmer, 2017). Accordingly, steelhead and fall Chinook are the species that most often encounter warm Columbia River temperatures, and are the species that use cold water refuges to escape the warm Columbia River temperatures. In the Lower Columbia River, these cold water refuges are primarily where cooler tributary rivers flow into the Columbia River. Protecting and restoring cold water refuges is likely to be important for the recovery of salmon and steelhead populations in the Columbia River Basin. The importance of protecting and restoring these cold water refuges may take on more significance due to climate change, which is expected to increase the water temperatures in both the tributaries and the Columbia River.

The Washington state water temperature criteria is a 68°F (20°C) daily maximum. The Oregon state water temperature criterion is a 68°F (20°C) 7-day moving average of daily maximum.

Monthly temperature data from Ecology Station 31A070 – Columbia River at Umatilla is presented in Figure 2-6 and summarized in Table 2-1. From 2007 to 2015, temperature ranged from 1.6 to 21.92°C, and averaged 11.88°C. Temperature is seasonal, with the highest temperatures occurring in the mid- to late summer (and often exceeding the Washington state daily maximum standard of 20°C) and lowest temperatures occurring during the mid- to late winter.

Figure 2-6. Temperature at Ecology Station 31A070 – Columbia River at Umatilla, 2007 to 2015



Depth profiles obtained by ODEQ in September 2009 (Table 2-5) suggest that there was weak to no thermal stratification; in none of the profiles was there a 1-degree-Celcius decrease per meter in depth. Temperature during the 2009 ODEQ sampling event (Table 2-6) ranged from 20.7 to 22.9°C, and averaged 22.03°C.

Comparisons of water temperatures in the NMFS data during the April to September periods in 1994 and 1995 showed little difference between the 2 years. Minimum and maximum temperatures were 3.4°C in January and February 1995 and 21.8°C in August 1994. Vertical temperature profiles at lower- and mid-reservoir stations in 1994 showed declining temperatures from the surface to depths of 10 to 15 meters, and then relatively stable ones from 15 meters to the bottom. However, in none of the profiles was there a 1-degree-Celcius decrease per meter in depth. In contrast, slight temperature decreases at upper-reservoir stations were only in the top meter of water (only one profile at one of nine locations had a greater than 1-degree-Celcius decrease per meter). These vertical temperature profiles suggest surface warming or weak thermal stratification in the John Day Reservoir.

From January 2007 through May 2017, maximum daily temperatures from Corps monitoring station MCPW (McNary Dam tailwater) exceeded the Washington state daily maximum criteria on 502 days (Figure 2-7); on average, about 50 days per year when ignoring the 2017 calendar year for which summer temperatures had not been reported at the time this document was written. Over the same period, maximum daily temperatures from Corps monitoring station JDY (John Day Dam forebay) exceeded the Washington state daily maximum criteria on 600 days (Figure 2-8); on average, about 60 days per year. Station JDY does not have data from late summer/early fall through late winter/early spring. Also, maximum daily temperatures from Corps monitoring station JHAW (John Day Dam tailwater) exceeded the Washington state daily maximum criteria on 627 days (Figure 2-9); on average, about 63 days per year. Summaries of maximum daily temperatures are provided for stations MCPW, JDY, and JHAW in Table 2-9, Table 2-10, and Table 2-11, respectively. Maximum daily water temperatures at station JHAW are typically slightly higher than at station MCPW, particularly during the summer months, indicating that temperature increases slightly as water travels through the reservoir. Temperature data from every 15 minutes at station JDA (John Day Dam forebay) in a depth profile from 0.5 to 40 meters from April to August of 2004 is shown in Figure 2-10. Hourly temperature data at different depths (from 1 to 80 meters) from station JDA from June to October of 2012 is shown in Figure 2-11. In 2004, there were 153 instances where a 1-degree-Celcius decrease per meter of depth was observed, all observed within the top 5 meters; there were no instances in 2012. Thermal stratification was infrequent in 2004 and 2012 JDA depth profiles, but some surface warming was occasionally observed.

Figure 2-7. Maximum Daily Temperature at U.S. Army Corps of Engineers Station MCPW from January 1, 2007, to May 31, 2017

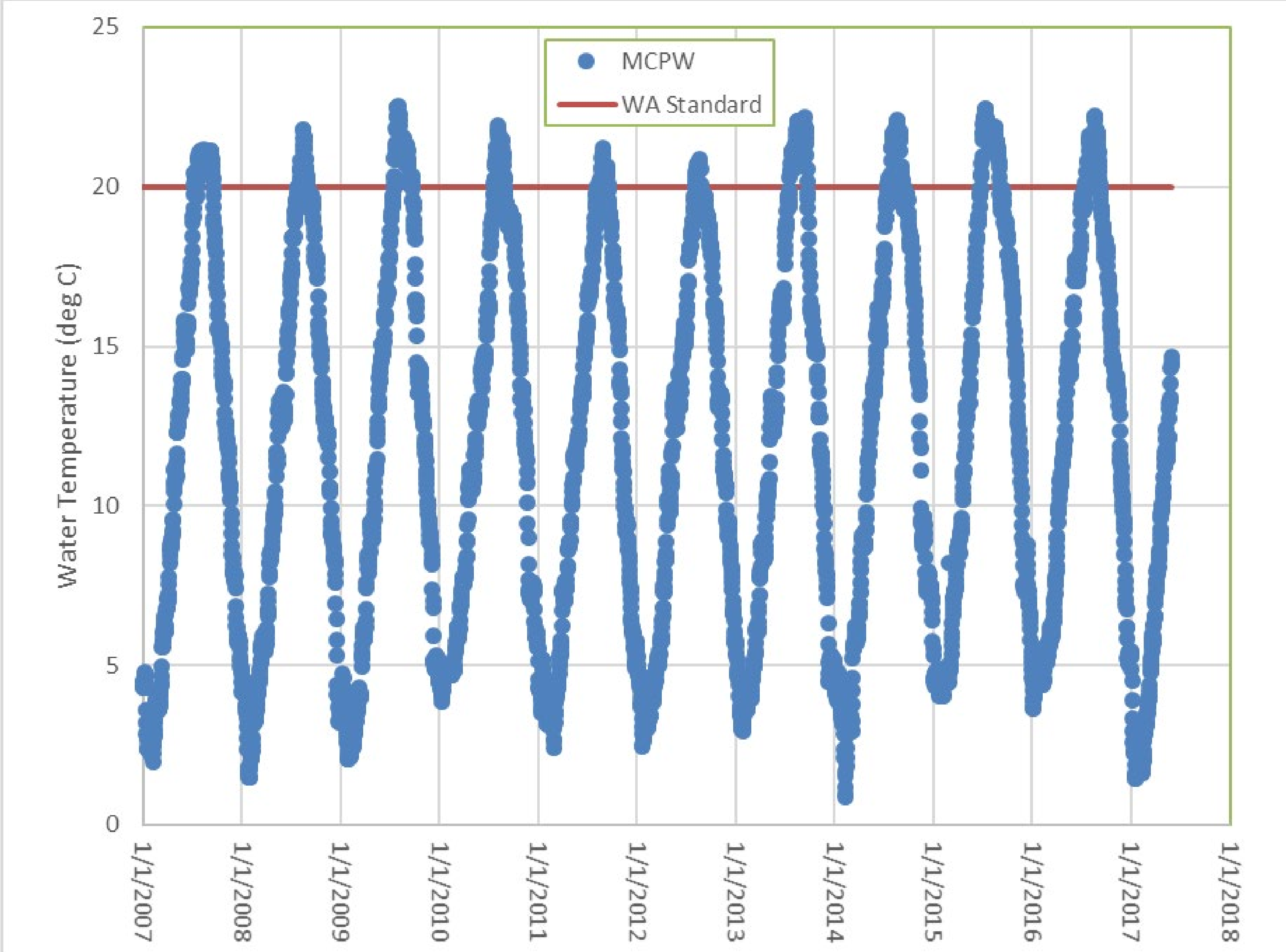


Figure 2-8. Maximum Daily Temperature at U.S. Army Corps of Engineers Station JDY from January 1, 2007, to May 31, 2017

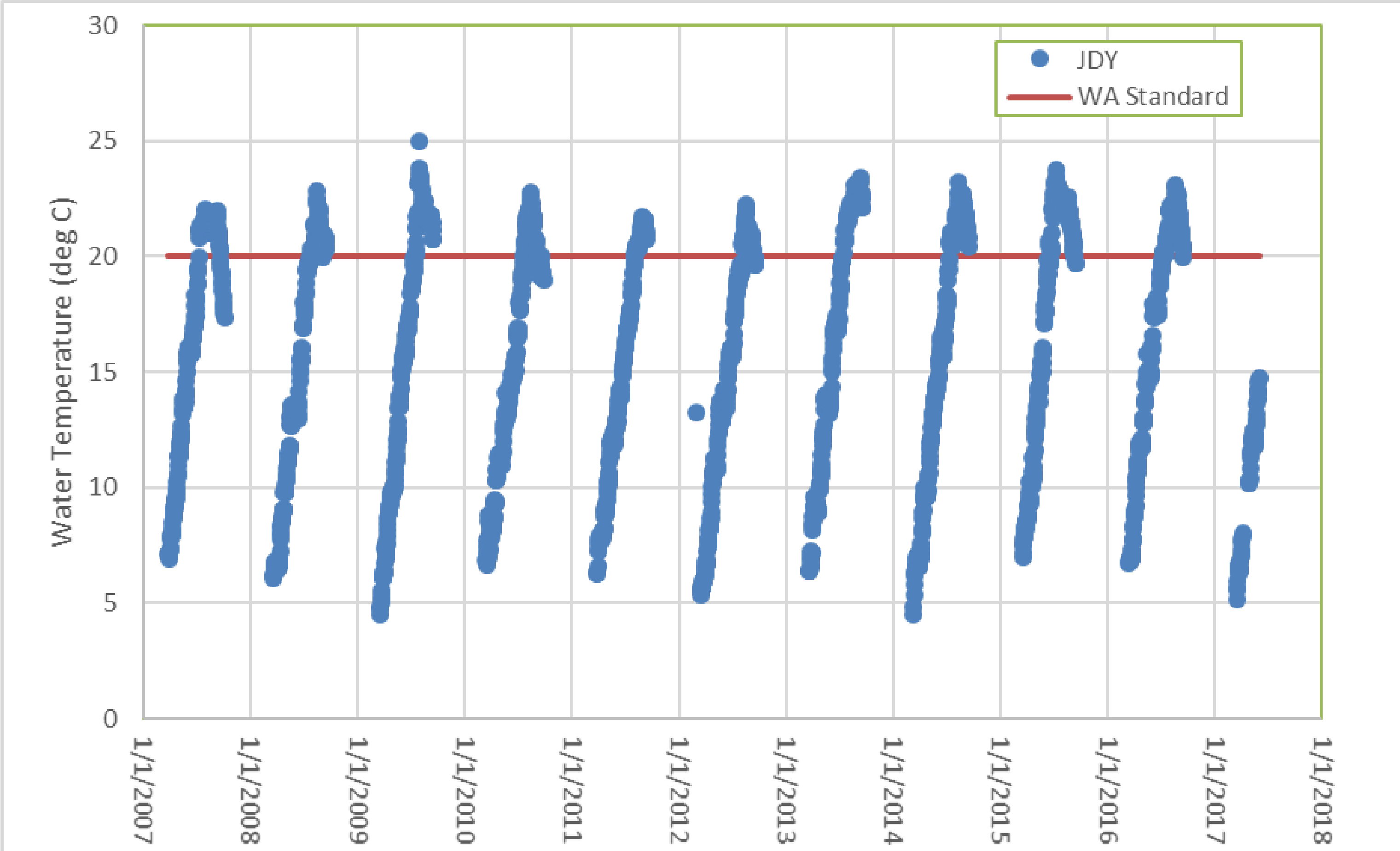


Figure 2-9. Maximum Daily Temperature at U.S. Army Corps of Engineers Station JHAW from January 1, 2007, to May 31, 2017

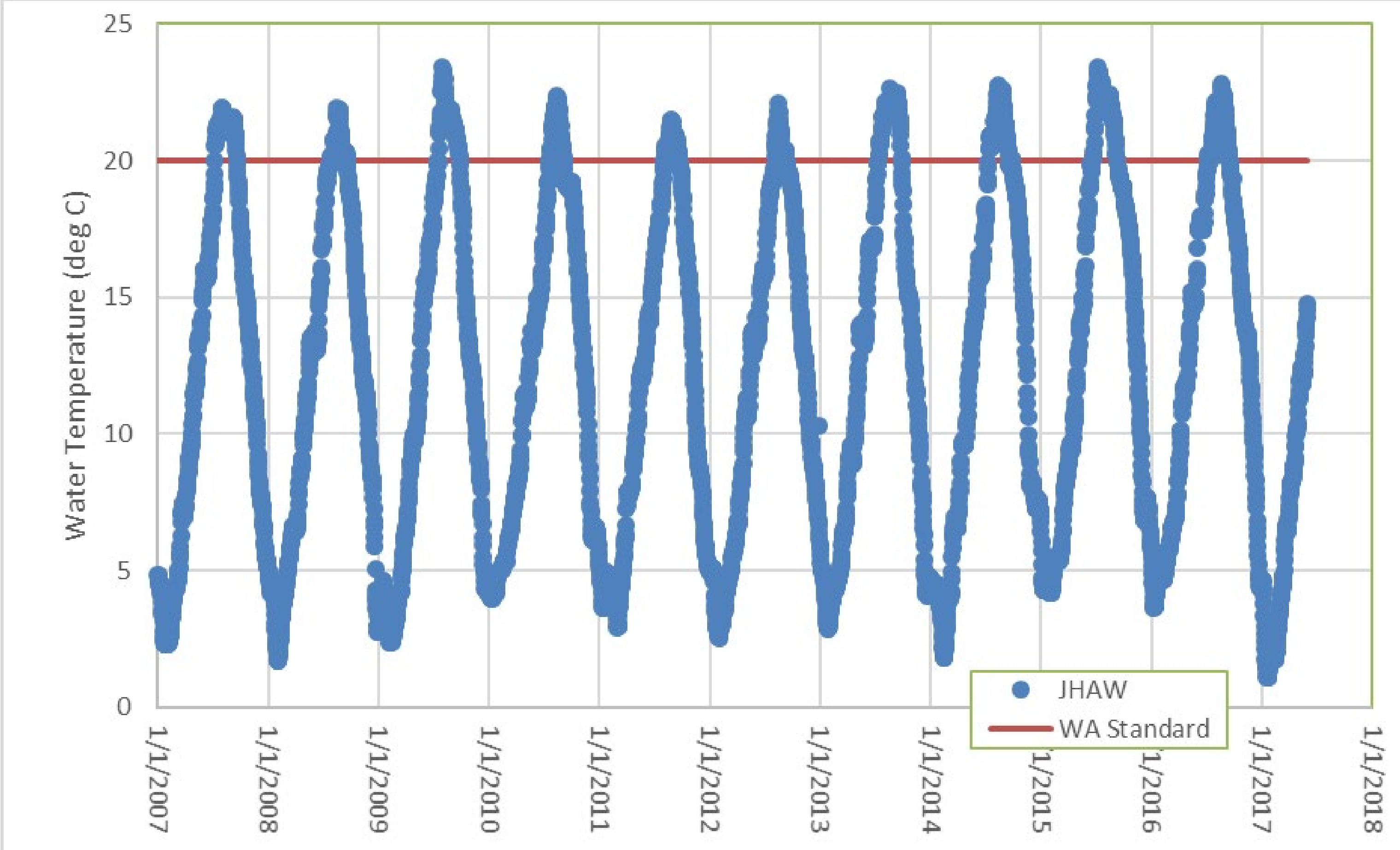


Figure 2-10. Temperature (°C) at Corps Station JDA at Different Depths (in meters) in 2004

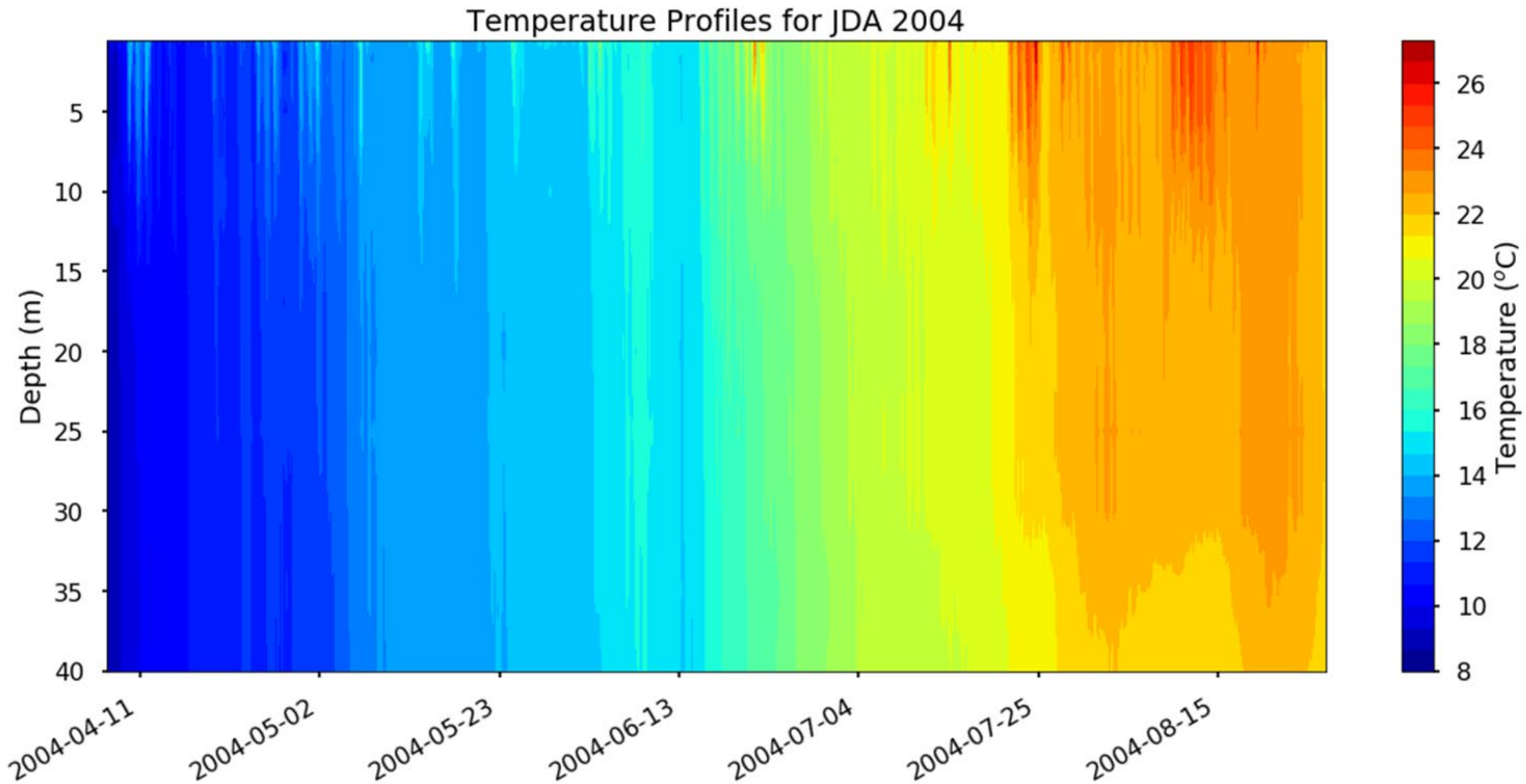


Figure 2-11. Temperature (°C) at Corps Station JDA at Different Depths (in meters) in 2012

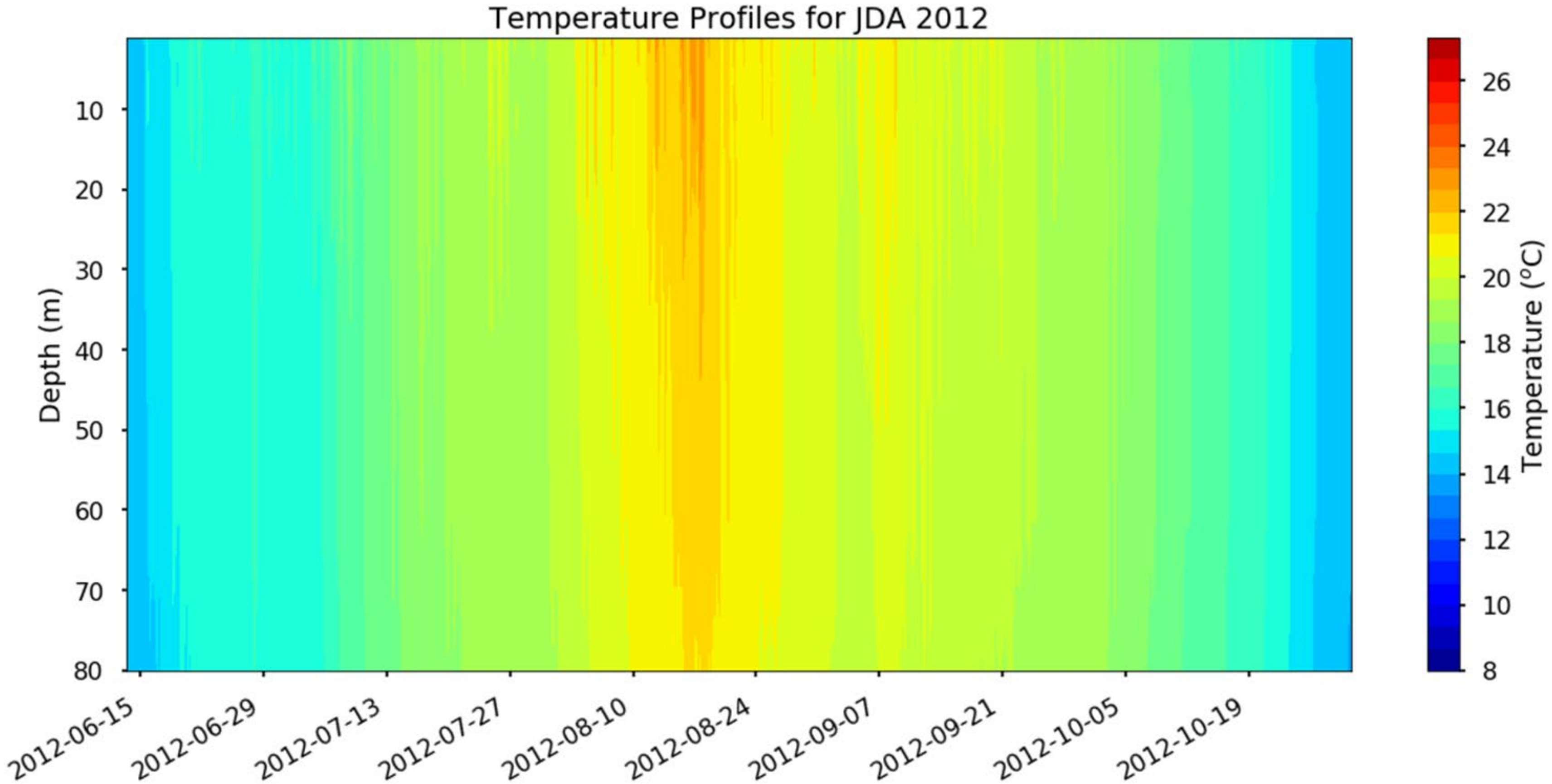


Table 2-9. Annual Summary of Maximum Daily Water Temperature Data (°C) from U.S. Army Corps of Engineers Station MCPW from 2007 to 2016

Year	Minimum	Maximum	Average	Median
2007	2.0	21.2	11.9	12.1
2008	1.5	21.8	11.5	12.2
2009	2.0	22.5	11.8	11.3
2010	3.9	21.9	12.2	12.0
2011	2.4	21.2	11.3	11.2
2012	2.5	20.9	11.7	12.4
2013	2.9	22.2	12.1	12.3
2014	0.9	22.1	12.2	12.6
2015	4.0	22.5	13.2	13.2
2016	3.7	22.2	12.9	13.9

Table 2-10. Annual Summary of Maximum Daily Water Temperature Data (°C) from U.S. Army Corps of Engineers Station JDY from 2007 to 2016

Year	Minimum	Maximum	Average	Median
2007	6.9	22.1	16.6	17.9
2008	6.1	22.8	15.0	14.8
2009	4.5	25.0	15.6	16.7
2010	6.7	22.8	15.5	15.4
2011	6.3	21.7	14.8	14.9
2012	5.4	22.2	14.6	14.8
2013	6.4	23.4	16.3	16.9
2014	4.5	23.2	15.5	16.0
2015	7.0	23.8	17.3	19.7
2016	6.7	23.1	16.5	17.8

Table 2-11. Annual Summary of Maximum Daily Water Temperature Data (°C) from U.S. Army Corps of Engineers Station JHAW from 2007 to 2016

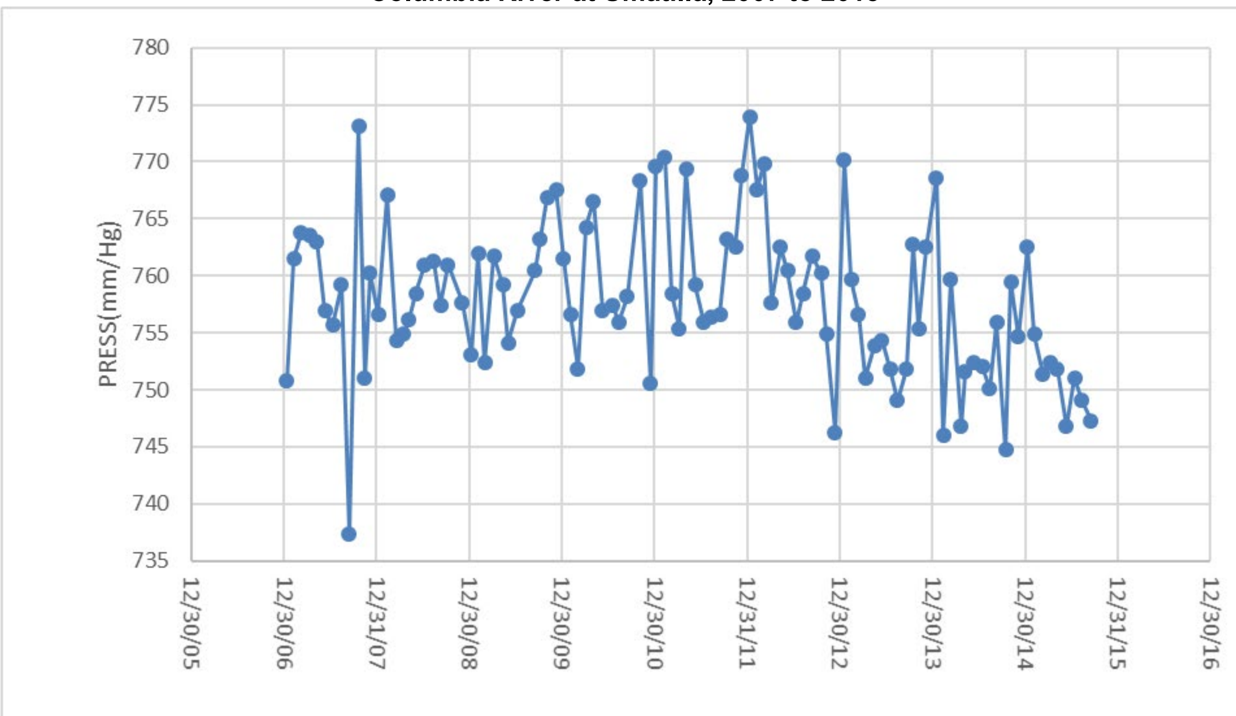
Year	Minimum	Maximum	Average	Median
2007	2.3	22.0	12.3	12.5
2008	1.7	21.9	11.9	11.9
2009	2.4	23.4	12.0	11.5
2010	4.0	22.4	12.4	12.4
2011	2.9	21.5	11.7	11.9
2012	2.5	22.1	12.1	12.7
2013	2.9	22.7	12.5	12.6
2014	1.8	22.8	12.6	12.9
2015	4.2	23.4	13.6	13.8
2016	3.6	22.8	13.2	13.8

2.2.1.2 *Barometric Pressure*

Barometric pressure, also known as the air pressure, is the weight of the overlying air pressing down on the earth. Barometric pressure has important effects on water chemistry and weather conditions. It affects the amount of gas, such as oxygen, that can dissolve in water. More gas can dissolve in water under higher air pressure than when under lower air pressure. One atmosphere of pressure is equal to 760 mmHg. Barometric pressure is used in the calculation of TDG saturation.

Monthly barometric pressure data from Ecology Station 31A070 – Columbia River at Umatilla is presented in Figure 2-12 and summarized in Table 2-1. Barometric pressure ranged from 737.4 to 773.9 mmHg, and averaged 758 mmHg. There is no easily discernible trend in the barometric pressure data.

Figure 2-12. Barometric Pressure at Ecology Station 31A070 Columbia River at Umatilla, 2007 to 2015



2.2.1.3 *Total Dissolved Gas*

TDG is a measure of air dissolved into water. TDG is usually discussed in terms of TDG saturation which is the percent of TDG saturation in the water body. The TDG saturation is calculated by dividing the TDG pressure by the barometric pressure times 100. When fish and other aquatic species are exposed to elevated TDG, the excess gas can build up in their bloodstream and tissues, causing a condition called gas bubble trauma, with symptoms ranging from minor injuries to death depending on the TDG concentration. When water plunges into a pool, it takes air bubbles with it. The high pressure causes the bubbles to dissolve into the water and the water becomes supersaturated with gases, primarily nitrogen. High spill levels at the dams can increase TDG in the water below the dam because as water flows over the spillway, air becomes trapped by the spill flow. As a result, the water that flows over the spillway increases in TDG in proportion to the increase in flow, most of the time, but certain dams have flow deflectors, including John Day Dam, that are capable of removing TDG from the water, resulting in lower TDG levels with increased spill. Generally, the background TDG is unchanged after the water goes through the dam turbines. TDG generation at a dam is a function of many factors such as structural configurations, spill operations, operational policies, state TDG standards, spill priority list order, spill patterns, total river flow rate, background TDG properties, powerhouse capacity, water temperature, and wind. This comprehensive set of factors results in different TDG productions estimates at each dam. The number of instances where TDG at stations MCPW (McNary Dam tailwater) and JDY (John Day Dam forebay) exceeds water quality standards from 2007 through 2016 are summarized in Table 2-12. The McNary Tailwater averaged 21 TDG exceedances per year, while the John Day Dam forebay only averaged 10 exceedances per year. Hourly TDG percent saturations for stations MCPW and JDY are shown in Figure 2-13 and Figure 2-14.

Table 2-12. Number of Total Dissolved Gas Instances Exceeding Water Quality Standards from 2007 to 2016

Year	McNary Dam Tailwater	John Day Dam Forebay
2007	1	0
2008	28	14
2009	5	9
2010	23	1
2011	54	18
2012	74	40
2013	5	7
2014	14	10
2015	6	0
2016	1	4
Average	21	10

Figure 2-13. Total Dissolved Gas at U.S. Army Corps of Engineers Station MCPW

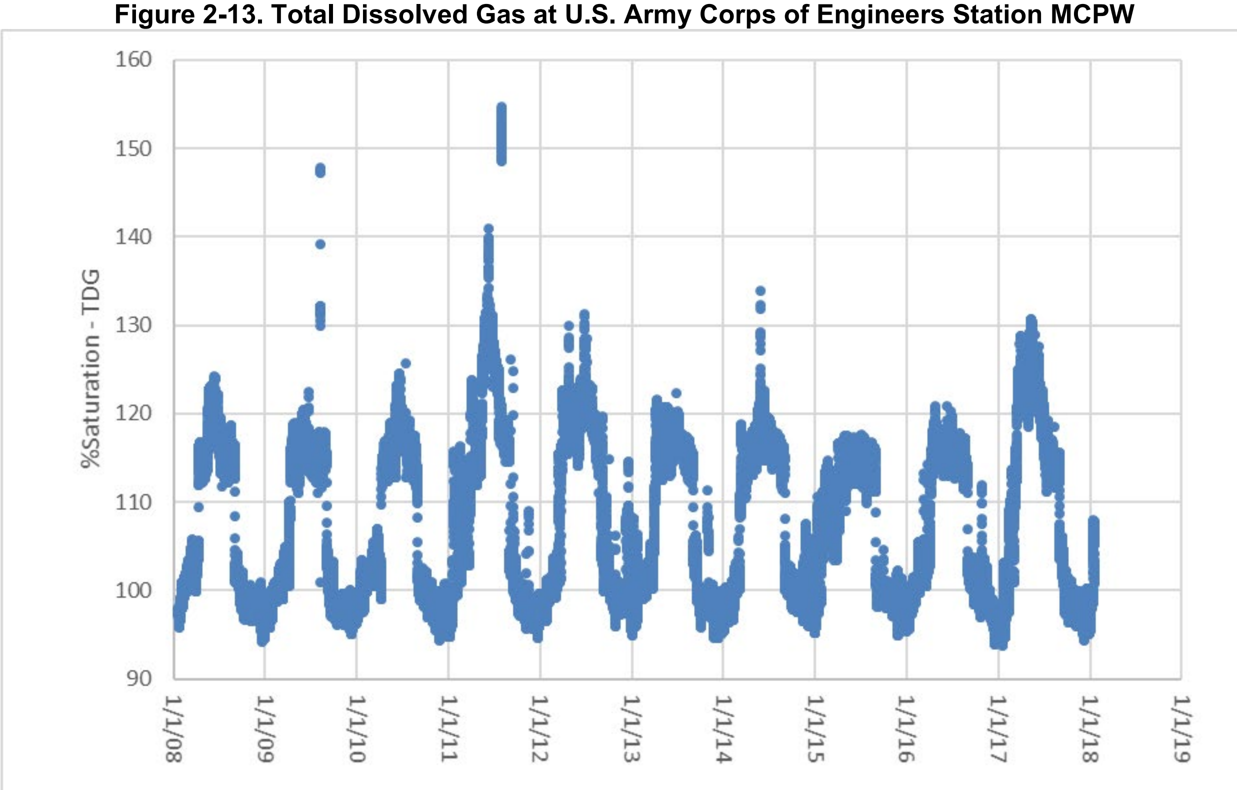
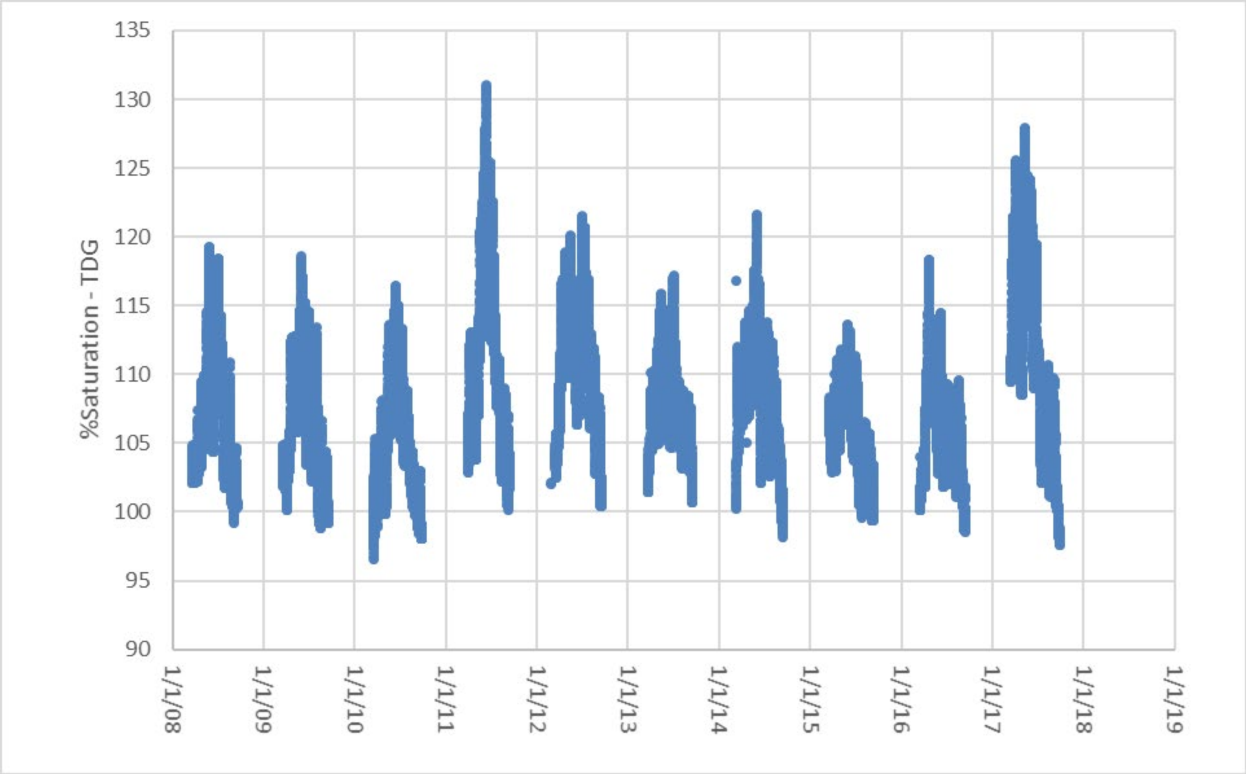


Figure 2-14. Total Dissolved Gas at U.S. Army Corps of Engineers Station JDY

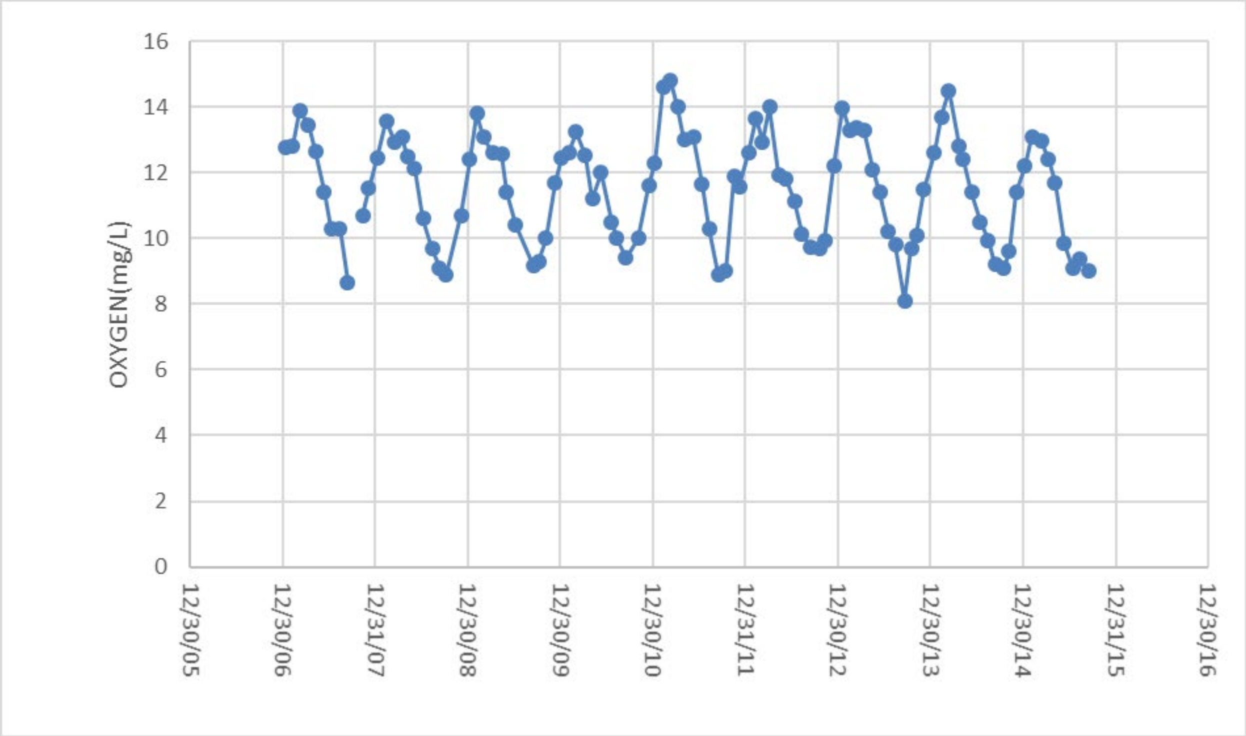


Dissolved Oxygen

DO is the amount of oxygen dissolved in water. Higher forms of aquatic life require oxygen for survival, and the DO determination is used widely in evaluations of the biochemistry of streams and lakes. This oxygen comes from sources such as the atmosphere, aeration, and photosynthesis. The DO concentration may be depleted by processes that consume dissolved, suspended, or precipitated organic matter. Due to photosynthesis, DO typically follows a diurnal pattern rising and falling during daytime and nighttime processes. Photosynthesizing biota can also produce DO values above equilibrium concentrations.

Monthly DO data from Ecology Station 31A070 – Columbia River at Umatilla is presented in Figure 2-15 and is summarized in Table 2-1. DO is seasonal, with the highest concentrations occurring in the late winter to early spring and lowest concentrations occurring during the late summer to early fall. In general, aquatic life depends on DO concentrations of greater than 5.0 mg/L. As shown in Figure 2-15, DO levels measured in John Day Reservoir ranged from 8 to 15 mg/L, indicating supersaturation for much of the time. The supersaturated levels of DO are likely attributable to McNary Dam operations and the use of the spillway, which is known to produce excess TDG through the aeration and plunging of water as it is released over the spillway.

Figure 2-15. Dissolved Oxygen at Ecology Station 31A070
Columbia River at Umatilla, 2007 to 2015



Depth profiles from the September 2009 ODEQ dataset (Table 2-5) suggest that DO does not vary much with depth. DO concentrations during the 2009 ODEQ sampling event (Table 2-6) ranged from 8.6 to 10.4 mg/L, and averaged 9.4 mg/L, indicating supersaturation at some locations during this sampling period.

In the NMFS dataset, DO levels varied from 8.4 to 12.8 mg/L during the 1994–1995 sampling period. Differences were typically minimal between stations sampled on the same date. The extent of oxygen decline from spring to fall was slight, amounting to only about 0.5 mg/L in profiles covering 20- to 30-meter depths.

pH

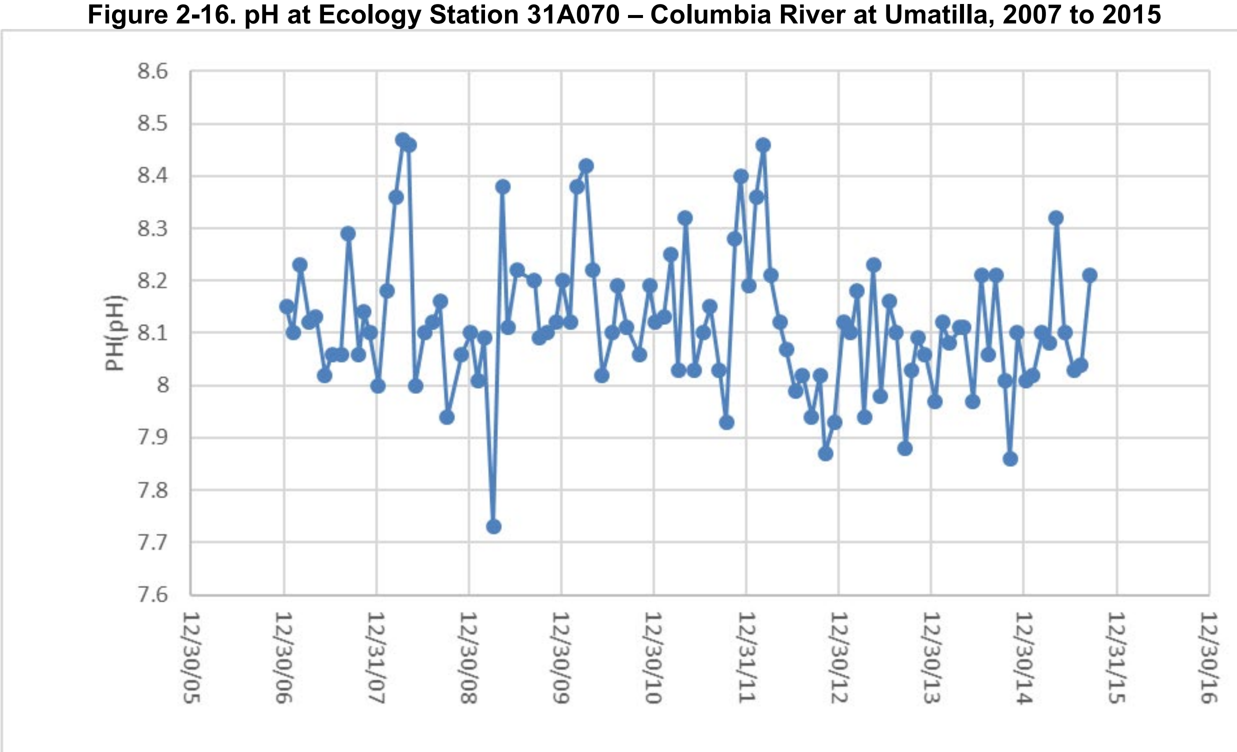
pH is used to indicate the acidity of water and is based on a scale of 0 to 14. Values of less than 7 mean the water is acidic or has a higher concentration of hydrogen ions. A reading of higher than 7 means the water is basic or alkaline and has a higher ability to neutralize acids. During photosynthesis, plants use the energy from the sun to convert carbon dioxide (CO_2) to oxygen and sugar, causing an uptake of hydrogen and increase in the pH of the water. The process of respiration and carbon dioxide production releases hydrogen ions, leading to lower pH. Because photosynthesis happens during daylight hours, pH levels may fluctuate from day to night as well as throughout the seasons, and with depth.

A reduction in pH, or acidification, has a negative effect on the reproduction of many aquatic organisms, such as mollusks, zooplankton, and fish species. Aquatic species have different tolerances for life in low pH conditions, and although conditions may not lead to death for an individual, it may mean reduced ability to reproduce or grow.

Monthly pH data from Ecology Station 31A070 – Columbia River at Umatilla is presented in Figure 2-16 and summarized in Table 2-1. pH ranged from 7.73 to 8.47, and averaged 8.12. There is no easily discernible trend in pH the data. Depth profiles from the September 2009 ODEQ dataset (Table 2-5) suggest that pH does not vary much with depth. pH during the 2009 ODEQ sampling event (Table 2-6) ranged from 7.8 to 8.4, and averaged 8.2.

In the NMFS dataset, pH ranged from 7.7 to 8.6 during the 1994–1995 sampling period. Differences were typically minimal between stations sampled on the same date; there were no clear differences in pH between upper-, mid-, and lower-reservoir sampling stations. Variation of pH with depth was about 0.1 at the lower- and mid-reservoir sampling stations, and slightly less than 0.1 at upper-reservoir stations. Seasonal pH variation was characterized by the highest values in January and February and the lowest values in mid-September.

Figure 2-16. pH at Ecology Station 31A070 – Columbia River at Umatilla, 2007 to 2015



Specific Conductivity

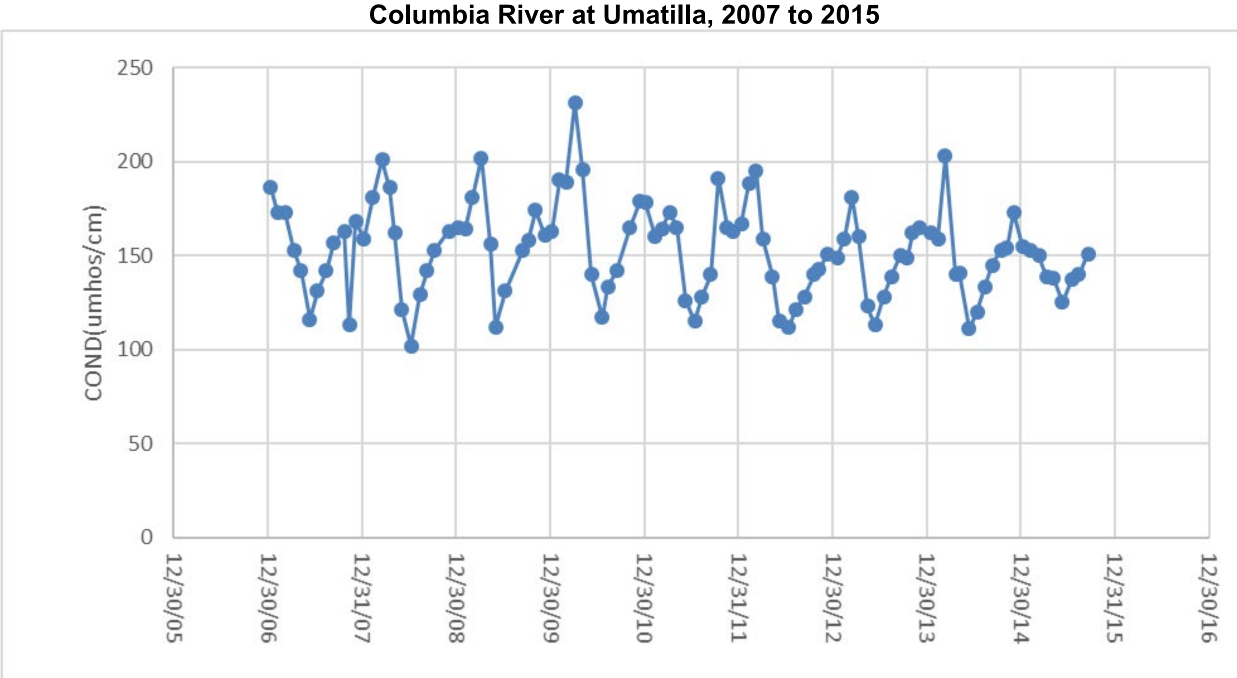
Specific conductivity is a measurement of a solution's ability to conduct electricity and is often used as an indicator of the amount of dissolved ions present since specific conductivity increases with an increase in dissolved ions.

Monthly specific conductivity data from Ecology Station 31A070 – Columbia River at Umatilla is presented in Figure 2-17 and summarized in Table 2-1. Specific Conductivity ranged from 102 to 231 µS/cm, and averaged 153 µS/cm. Generally, specific conductivity appears seasonal, with higher conductivity occurring in the late winter/early spring and lower specific conductivity occurring during the summer. Specific conductivity does not appear to be increasing or decreasing in the long term.

Depth profiles from the September 2009 ODEQ dataset (Table 2-5) suggest that specific conductivity does not vary much with depth. Specific conductivity during the 2009 ODEQ sampling event (Table 2-6) ranged from 149 to 155 µS/cm, which suggests little variability in specific conductivity along this reach.

In the NMFS dataset, specific conductivity ranged from 112 to 191 µS/cm during the 1994–1995 sampling period. The lowest specific conductivity values coincided with periods of high runoff and the highest values were observed during low runoff periods. Specific conductivity values differed only slightly within the reservoir in samples taken during the same week. Depth profiles showed minimal variation in specific conductivity with depth.

Figure 2-17. Specific Conductivity (µS/cm) at Ecology Station 31A070 Columbia River at Umatilla, 2007 to 2015



Water Transparency

Water transparency was measured in Lake Umatilla using a Secchi disk, which is an 8-inch disk with alternating black and white quadrants. The depth at which the disk can no longer be seen in the water is called the Secchi disk depth. This depth is a relative measure of water transparency that can be used to look at changes in water clarity over time and between sampling stations. Water clarity is an important parameter when determining the trophic status of a lake because the amount of algae suspended in the water column (phytoplankton) directly impacts transparency. Other factors that can affect transparency include turbidity from suspended matter, soil particles, and natural water color.

Secchi disk depth measured at 10 locations in this reach during the 2009 ODEQ sampling event (Table 2-6) ranged from 1.9 to 3.5 meters, and averaged 2.7 meters.

In the NMFS dataset, Secchi disk visibility ranged from 0.2 meters (associated with a runoff event) to 4.4 meters, and generally increased from April to September. Variability in Secchi disk depth was largely seasonal, reflecting higher turbidity during systemwide runoff in winter and spring and maximum clarity during winter periods when runoff and algae abundance were at a minimum. Station to station differences in Secchi disk depth were observed, but were usually due to local influences such as turbid water from nearby tributaries or from wind-generated waves causing resuspension of fine sediments at nearshore stations.

Secchi disk depth in the John Day forebay is also reported on the University of Washington Columbia River Data Access in Real Time (DART) webpage (Columbia River DART 2018). Though it is described on the page as turbidity, it is measured with a Secchi disk. Daily Secchi disk depth measurements for the John Day forebay from 2008 and 2009 are shown in Figure 2-18 and Figure 2-19 (Secchi disk depth was not reported after 2009).

Figure 2-18. Secchi Disk Depth in John Day Forebay in 2008

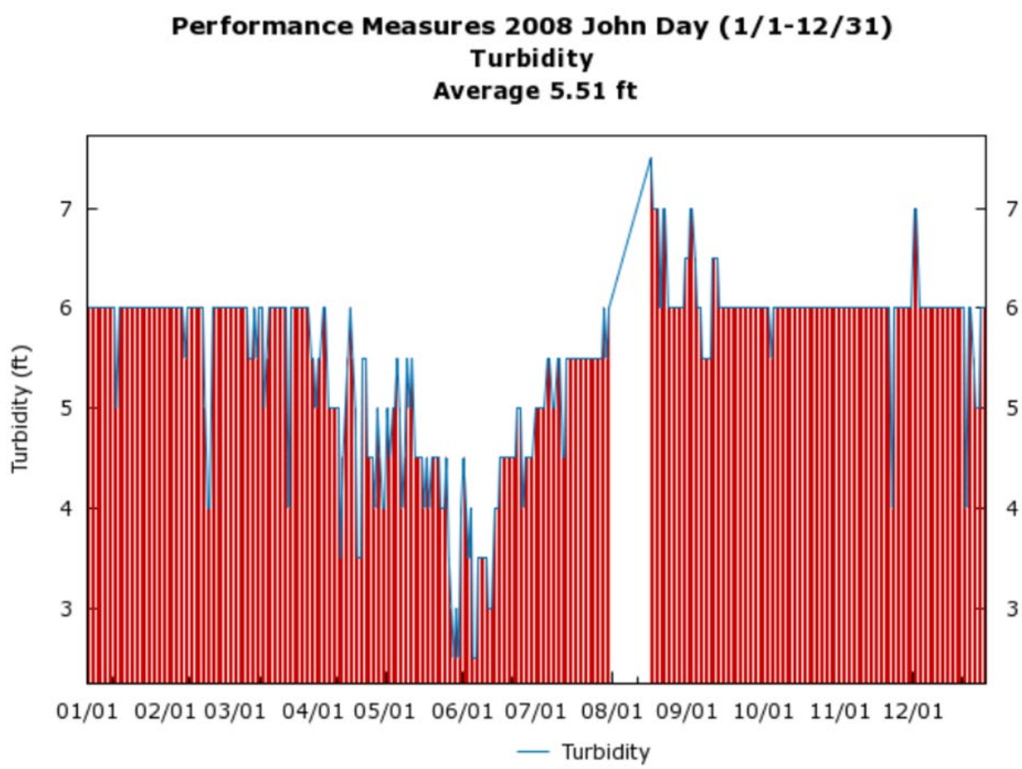
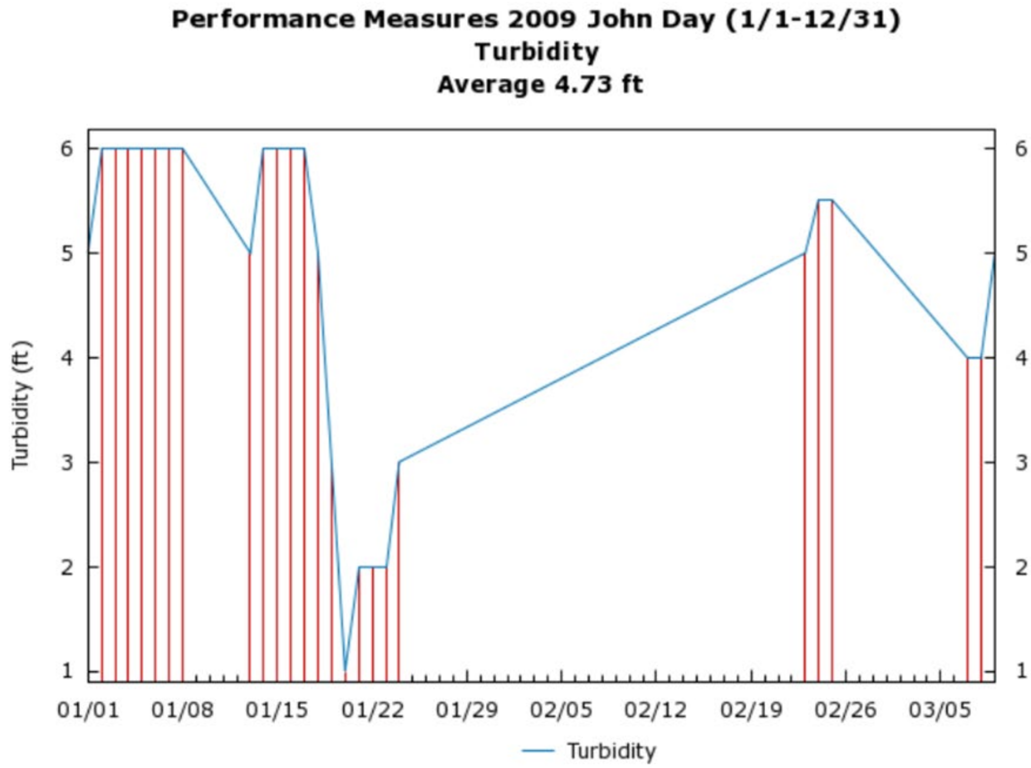


Figure 2-19. Secchi Disk Depth in John Day Forebay in 2009



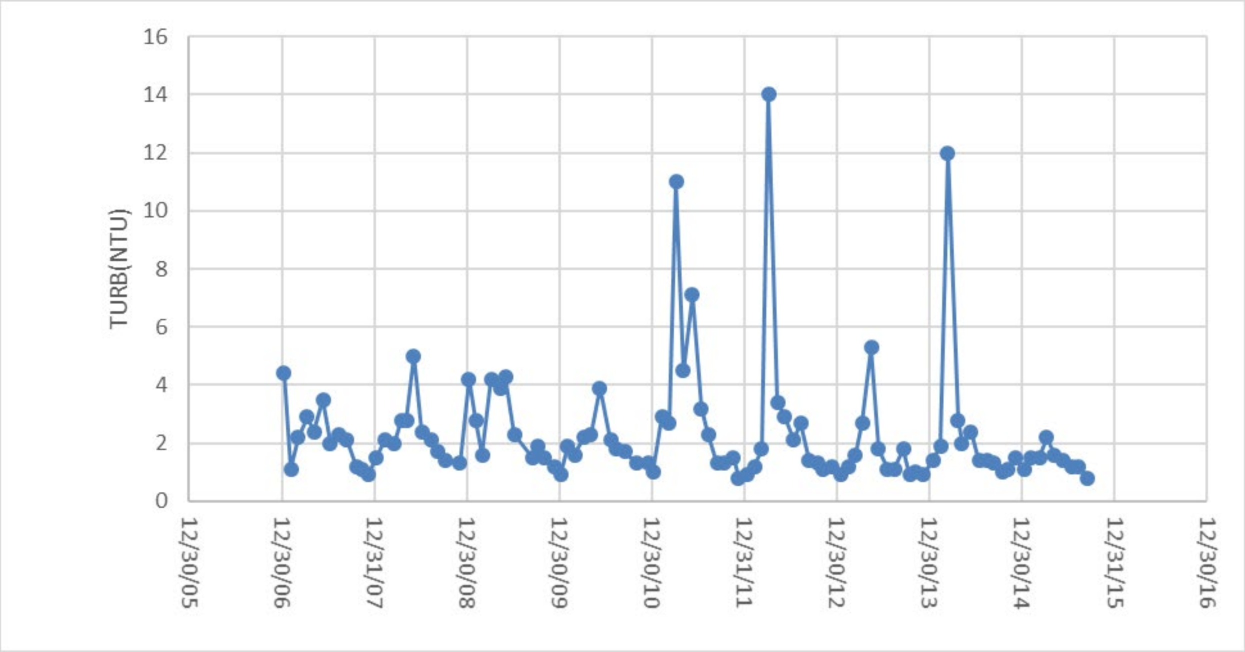
2.2.2 Chemical

2.2.2.1 *Turbidity*

Turbidity is a measure of the cloudiness of water and can provide an estimate of total suspended solids and sediments in water such as clay, silt, organic matter, and plankton. Turbidity levels of greater than 10 NTUs may lead to stress of aquatic life while turbidity levels of greater than 100 NTUs are unsafe levels for most aquatic life. However, a certain degree of turbidity is a key water quality parameter affecting juvenile salmon, as it decreases their visibility to piscivorous predators. The presence of the dam and reservoir decreases turbidity and Junge and Oakley (1966) reported that salmon productivity decreased in the river as a result of dam and reservoir construction. Turbidity and suspended solids are measures of sediment transport, an important geophysical function of rivers that provides diversity in hydraulic geometry and key nutrients to ecological systems (Vannote et al. 1980; Williams et al. 1996).

Monthly turbidity data from Ecology Station 31A070 – Columbia River at Umatilla is presented in Figure 2-20 and summarized in Table 2-1. Turbidity values ranged from 0.8 to 14 NTU, with an average of 2.3 NTU. Only on three occasions did the turbidity exceed 10 NTU. It appears that there is some element of seasonality associated with turbidity; the highest values generally appear in the spring to early summer. These high values are markedly higher in more recent years than in the preceding years. Depth profiles from the September 2009 ODEQ dataset (Table 2-5) suggest that turbidity does not vary much with depth, and did not exceed 3 NTU. In the NMFS dataset, turbidity ranged from 1 to 42 NTU, though readings were mostly between 2 and 8 NTU. Turbidity readings at lower- and mid-reservoir stations generally increased with depth, whereas surface to bottom differences were minimal at the upper-reservoir stations.

Figure 2-20. Turbidity at Ecology Station 31A070 – Columbia River at Umatilla, 2007 to 2015

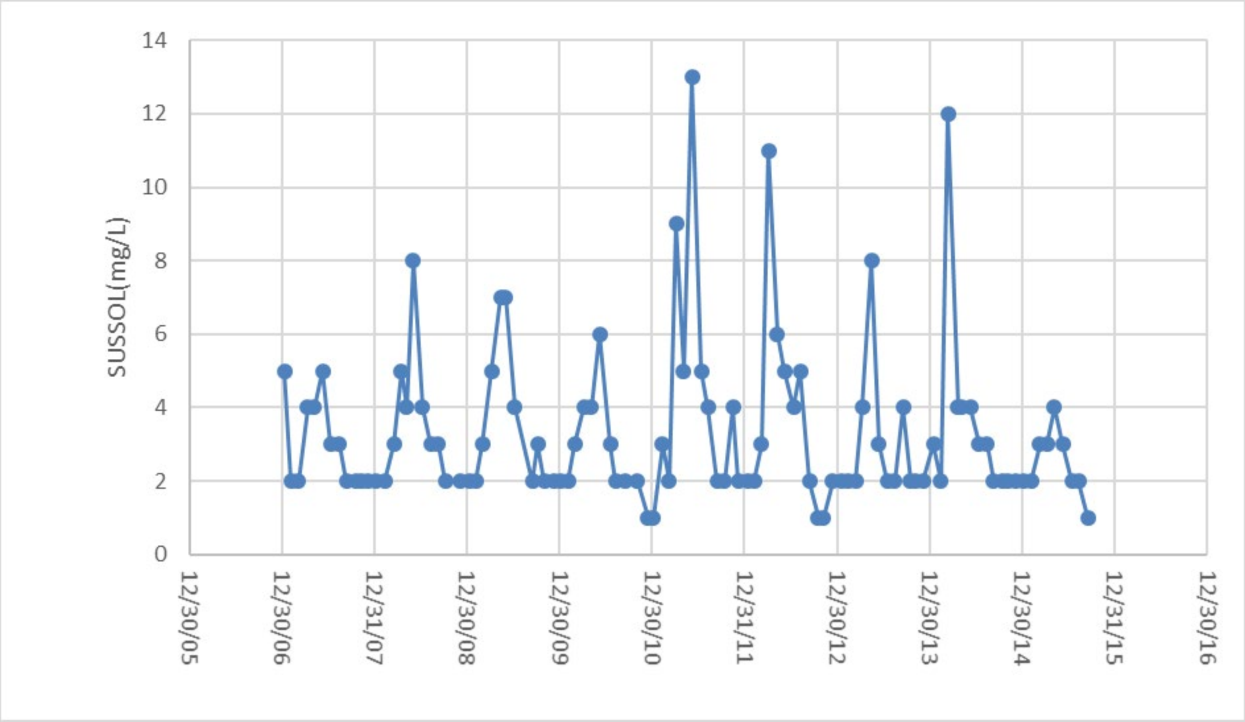


2.2.2.2 *Suspended Solids*

Suspended solids are small solid particles that remain in suspension in water as a colloid or due to the motion of the water. These solids include anything drifting or floating in the water, from sediment, silt, and sand to plankton and algae. Suspended particles can come from soil erosion, runoff, discharges, stirred bottom sediments, or algal blooms. While it is possible for streams to have naturally high levels of suspended solids, clear water is usually considered an indicator of healthy water. Stream water with a total suspended solids concentration less than an average of 50 mg/L over a 28-day period is considered healthy for fish communities. A sudden increase in suspended solids (or turbidity) in a previously clear body of water may be cause for concern. Excessive suspended sediment can impair water quality for aquatic and human life, impede navigation, and increase flooding risks.

Monthly suspended solids data from Ecology Station 31A070 – Columbia River at Umatilla is presented in Figure 2-21 and summarized in Table 2-1. Suspended solids ranged from 1 to 13 mg/L, and averaged 3.3 mg/L. Similar to turbidity, which is often related to suspended solids, it appears that there is some element of seasonality associated with suspended solids; the highest values generally appear in the spring to early summer. These high values are higher in more recent years than in the preceding years. Suspended solids during the 2009 ODEQ sampling event (Table 2-6) ranged from 1 to 3 mg/L, and averaged 1.7 mg/L, which suggests little variability in suspended solids along this reach.

Figure 2-21. Suspended Solids at Ecology Station 31A070
Columbia River at Umatilla, 2007 to 2015



2.2.2.3 *Major Cations and Anions*

The chemical compositions, in terms of major ions, of many freshwater lakes are largely derived from the weathering of soils and rocks in the drainage basin, atmospheric precipitation, and evaporation (Wetzel 1975). The ion balance of most fresh water is dominated by the major cations calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K), and the major anions carbonate (CO_3), bicarbonate (HCO_3), sulfate (SO_4), and chloride (Cl). Other elements, such as phosphorus and nitrogen, are important biologically but are typically only a minor part of the overall chemical composition of freshwater ecosystems.

Calcium concentrations during the 2009 ODEQ sampling event (Table 2-6) ranged from 17.2 to 17.7 mg/L, and averaged 17.45 mg/L. In the NMFS dataset, calcium ranged from 9.4 to 23.0 mg/L. Magnesium concentrations during the 2009 ODEQ sampling event (Table 2-6) ranged from 4.74 to 4.94 mg/L, and averaged 4.84 mg/L. In the NMFS dataset, magnesium ranged from 3.4 to 7.0 mg/L. In the NMFS dataset, sodium ranged from 3.5 to 11.2 mg/L. In the NMFS dataset, potassium ranged from 0.8 to 2.3 mg/L. Sulfate concentrations during the 2009 ODEQ sampling event (Table 2-6) ranged from 10.7 to 11.1 mg/L, and averaged 10.88 mg/L. In the NMFS dataset, sulfate ranged from 8.4 to 18.1 mg/L. In the NMFS dataset, chloride ranged from 1.4 to 4.0 mg/L.

Minimal variation was observed in major cation and anion concentrations between sampling stations or depths. Based on the major ion data in the NMFS study, the lowest concentrations of major ions coincided with periods of high runoff and the highest concentrations were observed during low-runoff periods in winter.

2.2.2.4 *Alkalinity and Hardness*

Alkalinity is a measure of the buffering capacity of water to changes in pH. In many freshwater ecosystems, alkalinity is a function of the concentration of bicarbonates, carbonates, and hydroxides (Wetzel 1975). Hardness is a measure of the amount of calcium and magnesium salts in water that are often combined with either bicarbonate or carbonate, or with anions such as sulfate or chloride (Wetzel 1975). Harder waters have greater concentrations of calcium and magnesium salts. In fresh water, hardness can be important in determining the toxicity of many metals, such as cadmium, chromium, copper, lead, and zinc. Toxicity decreases with an increase in hardness. Therefore, hardness measurements are sometimes used to calculate water quality criteria for various metals.

Monthly alkalinity data from Ecology Station 31A070 – Columbia River at Umatilla is summarized in Table 2-1, though only six data points from 2007 and 2008 are available. Monthly alkalinity ranged from 51.3 to 74.7 mg/L as $CaCO_3$, and averaged 64.6 mg/L as $CaCO_3$. Alkalinity during the 2009 ODEQ sampling event (Table 2-6) ranged from 60 to 62 mg/L as $CaCO_3$, and averaged 60.6 mg/L as $CaCO_3$, suggesting little variability in alkalinity along this reach during the brief sampling period. In the NMFS dataset, alkalinity ranged from 46 to 75 mg/L as $CaCO_3$. Alkalinity concentrations were similar across the reservoir and varied little with depth. Seasonal variation of alkalinity was characterized by the highest values occurring during low river flow in winter and low values during high river flow.

Monthly hardness data from Ecology Station 31A070 – Columbia River at Umatilla is summarized in Table 2-1, though only six data points from 2007 and 2008 are available. Monthly hardness ranged from 53.8 to 82.5 mg/L as $CaCO_3$, and averaged 68.9 mg/L as $CaCO_3$. Hardness during the 2009 ODEQ sampling event (Table 2-6) ranged from 62.6 to 64.3 mg/L as $CaCO_3$, and averaged 63.5 mg/L as $CaCO_3$, suggesting little variability in hardness along this reach during the brief sampling period.

2.2.2.5 *Nitrogen*

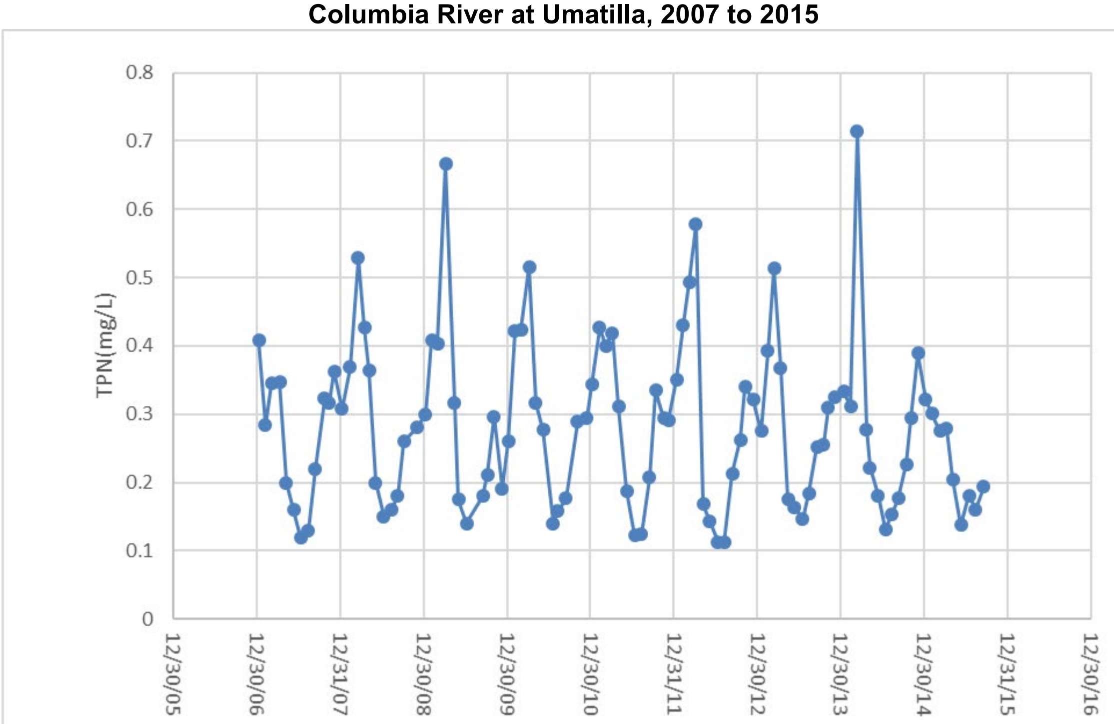
Nitrogen, like phosphorus, is essential for the growth and production of algae in fresh water. In freshwater ecosystems, nitrogen exists in many forms including dissolved molecular nitrogen, organic nitrogen, nitrite, nitrate, and ammonia. Sources of nitrogen in fresh water are varied and include atmospheric inputs via precipitation, nitrogen fixation in the water and sediments, and surface and groundwater inputs. Losses of nitrogen in the freshwater ecosystem include outflow from the system, reduction of nitrate to nitrogen via denitrification and the subsequent release of nitrogen from the water to the atmosphere, and sedimentation of inorganic and organic forms of nitrogen (Wetzel 1975). The most common forms of nitrogen used by freshwater plants for growth are the dissolved forms which include ammonia-nitrogen and nitrate-nitrogen.

Three forms of nitrogen were measured, total nitrogen (TN-N), nitrate + nitrite (NO_3 + NO_2-N), and ammonia (NH_4^+-N + NH_3-N). The dissolved inorganic forms of nitrogen, ammonia and nitrate + nitrite are all readily available for plant growth. Total nitrogen includes all inorganic plus organic forms of nitrogen, while nitrate + nitrite represents total oxidized nitrogen, with nitrite being an intermediate state between ammonia and nitrate. Nitrate is an essential plant nutrient, while nitrite can be a plant nutrient but is generally rapidly oxidized to ammonia in oxygenated waters. Ammonia nitrogen is an essential plant nutrient that is often used before nitrate. Ammonia is formed in the natural environment through the fixation of nitrogen gas, excretion by animals, and the decomposition of plants and animals. In the aquatic environment, ammonia is produced and excreted by fish. Ammonia is reported as the combined ionized (NH_4^+-N - ammonium) and unionized (NH_3-N - ammonia) forms of ammonia.

Total Nitrogen

Monthly total nitrogen (or total persulfate nitrogen, which is the total nitrogen concentration determined using an alkaline persulfate digestion method) data from Ecology Station 31A070 – Columbia River at Umatilla is presented in Figure 2-22 and summarized in Table 2-1. Total nitrogen concentrations ranged from 0.112 to 0.714 mg/L, and averaged 0.283 mg/L. Generally, total nitrogen appears to have some element of seasonality, with higher concentrations occurring in the early spring and lower concentrations occurring in the summer. Accounting for the apparent seasonality, total nitrogen concentrations do not appear to be clearly increasing or decreasing over the study period. In the NMFS dataset, total nitrogen ranged from 0.20 to 0.88 mg/L. Consistent differences associated with reservoir location or sample depth were not apparent. Total nitrogen levels were highest during winter, but declined rapidly with the onset of the growing season in April and were reduced to their lowest during the growing season.

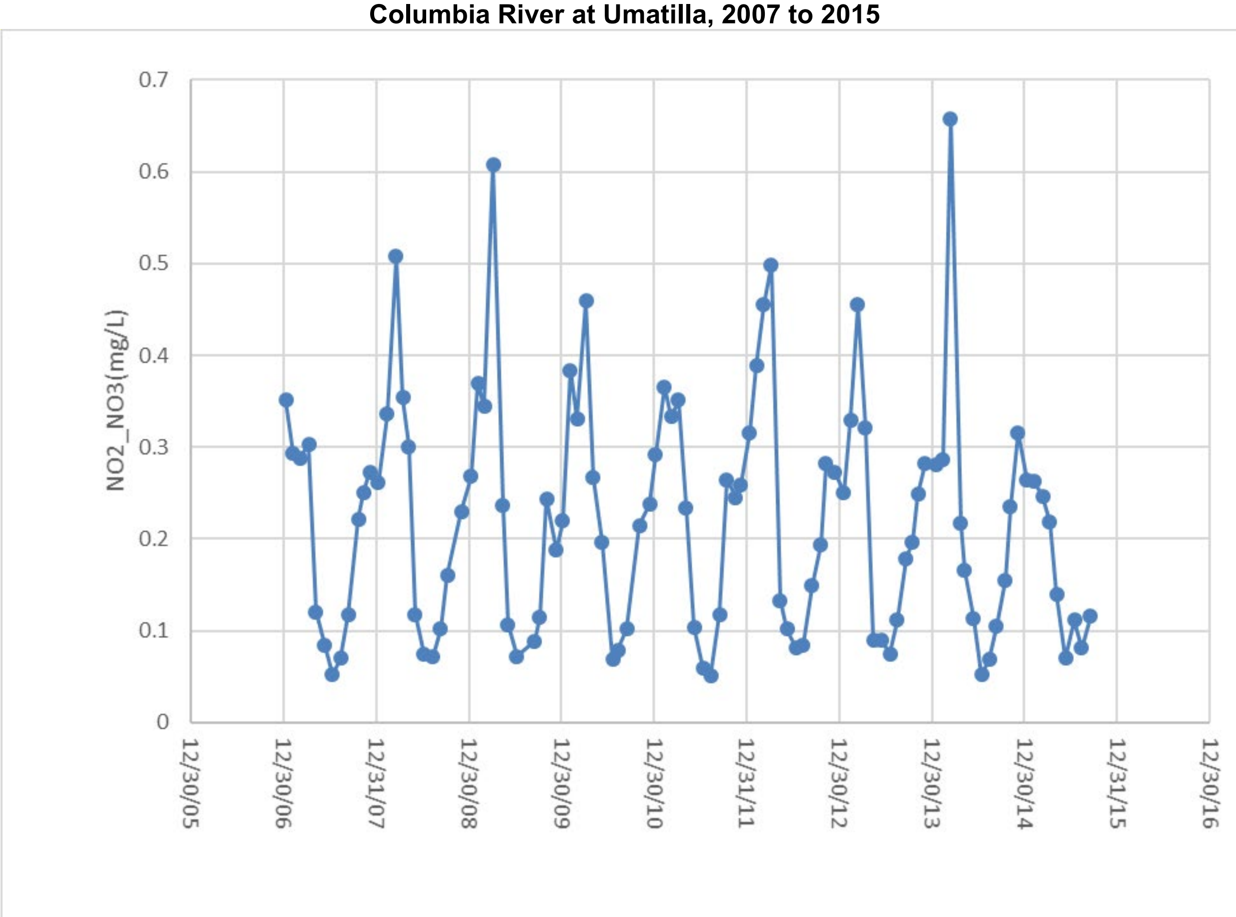
Figure 2-22. Total Persulfate Nitrogen at Ecology Station 31A070
Columbia River at Umatilla, 2007 to 2015



2.2.2.6 *Nitrate + Nitrite*

Monthly nitrate + nitrite data from Ecology Station 31A070 – Columbia River at Umatilla is presented in Figure 2-23 and summarized in Table 2-1. Nitrate + nitrite concentrations ranged from 0.051 to 0.658 mg/L as nitrogen, and averaged 0.221 mg/L as nitrogen. Generally, nitrate + nitrite appears seasonal, with higher concentrations occurring in the late winter/early spring and lower concentrations occurring during the summer. Nitrate + nitrite concentrations generally track with total nitrogen concentrations. Nitrate + nitrite concentrations during the 2009 ODEQ sampling event (Table 2-6) ranged from 0.0205 to 0.0825 mg/L as nitrogen, and averaged 0.058 mg/L as nitrogen. In the NMFS dataset, nitrate + nitrite ranged from 0.01 to 0.55 mg/L as nitrogen. Consistent differences associated with reservoir location or sample depth were not apparent. Seasonal variation in nitrate + nitrite concentrations was similar to that of total nitrogen.

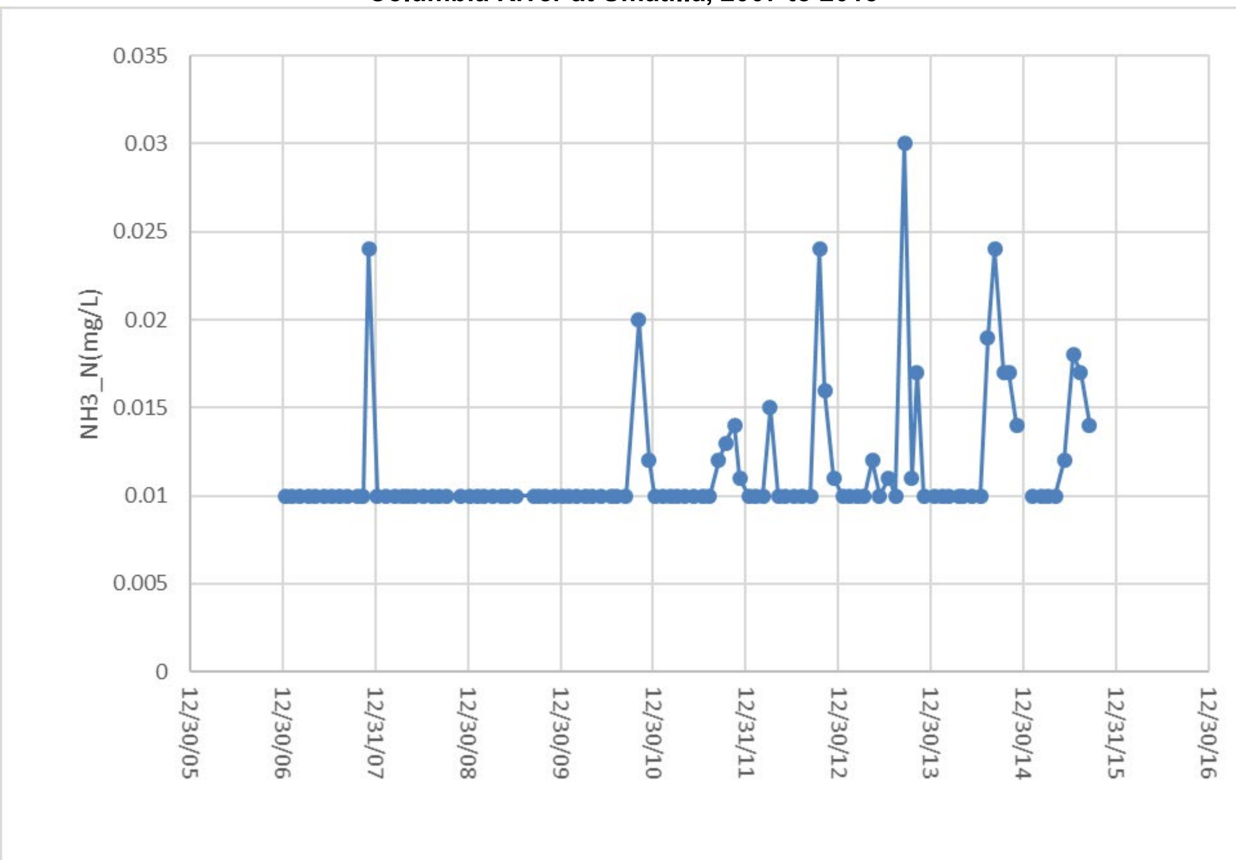
Figure 2-23. Nitrate + Nitrite (mg/L as nitrogen) at Ecology Station 31A070 Columbia River at Umatilla, 2007 to 2015



2.2.2.7 *Ammonia*

Monthly ammonia data from Ecology Station 31A070 – Columbia River at Umatilla is presented in Figure 2-24 and summarized in Table 2-1. Ammonia concentrations observed since 2007 have been low or not detected, ranging from < 0.01 to 0.03 mg/L as nitrogen, and averaging 0.0115 mg/L as nitrogen (Kaplan-Meier mean). Generally, ammonia appears to have some element of seasonality, with small ammonia peaks occurring in the late summer to fall. Ammonia peaks were not observed in 2008 or 2009. Ammonia was not detected during the 2009 ODEQ sampling event (Table 2-6). In the NMFS dataset, ammonia ranged from 0.01 to 0.06 mg/L as nitrogen. Consistent differences associated with reservoir location or sample depth were not apparent, likely due to rapid uptake by algae. Seasonal variation in ammonia was characterized by the highest levels occurring from late April through October and the lowest levels from November through early April.

Figure 2-24. Ammonia (mg/L as nitrogen) at Ecology Station 31A070 Columbia River at Umatilla, 2007 to 2015



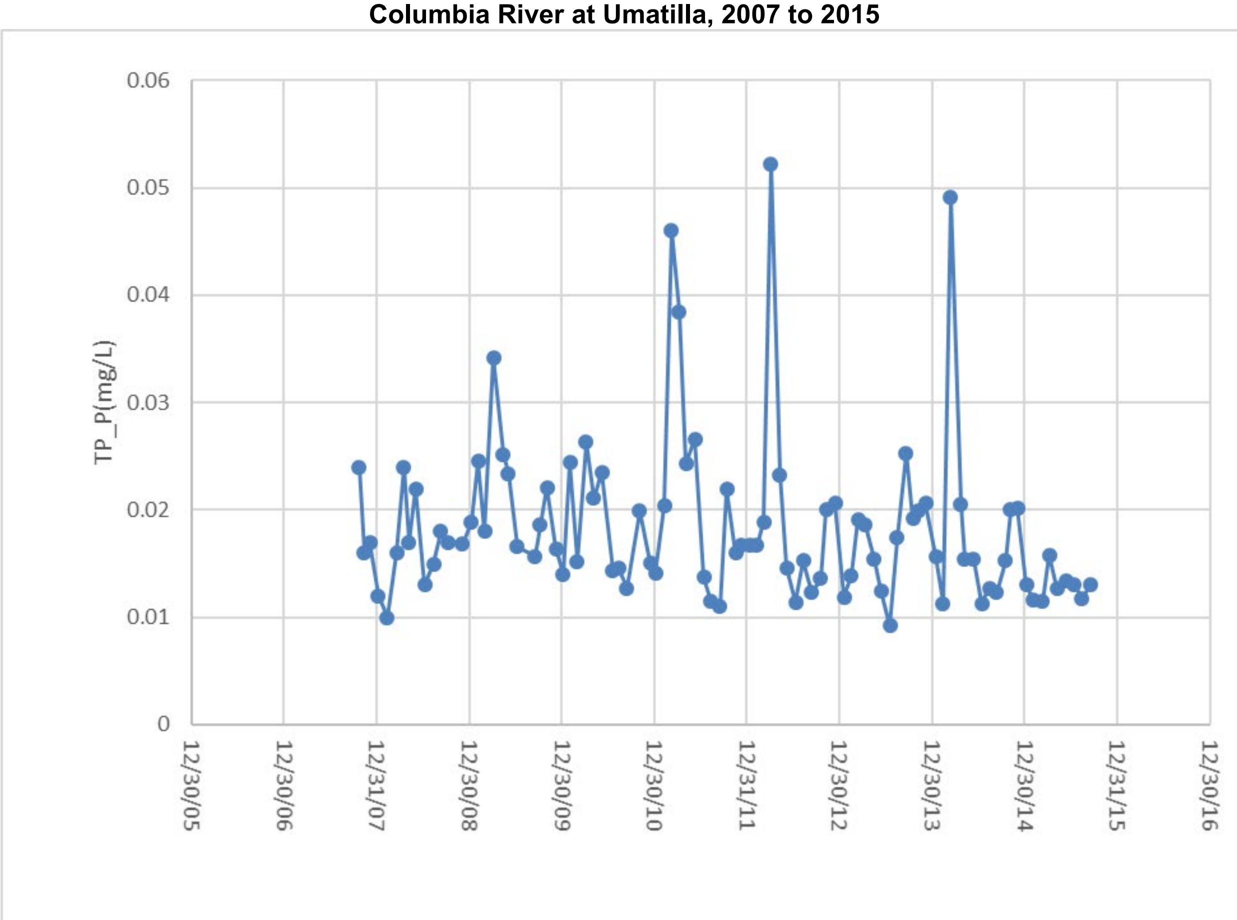
2.2.2.8 *Phosphorus*

Phosphorus, along with nitrogen, is a major nutrient required for the growth and productivity of aquatic plants. The vast majority of water quality problems in lakes are associated with an overabundance of these nutrients resulting in excessive aquatic plant growth, causing nuisance algae blooms and resulting decay. The decay of large amounts of algae can reduce oxygen concentrations to levels that have difficulty maintaining many organisms. In freshwater ecosystems, phosphorus is generally the nutrient with the smallest supply to demand ratio for aquatic plant growth. Consequently, phosphorus is often the nutrient limiting productivity in freshwater ecosystems. Increased phosphorus and nitrogen inputs to freshwater ecosystems from human activities can be attributed to numerous sources including: the discharge of detergents, runoff containing fertilizers, seepage from failing septic systems, and urban runoff and sewage discharges (Hem 1985). Phosphorus concentrations in Lake Umatilla were reported as total phosphorus and soluble reactive phosphorus.

Total Phosphorus

Total phosphorus represents all phosphorus in solution, both dissolved and particulate, including all organically combined phosphorus and all phosphate. Monthly total phosphorus data from Ecology Station 31A070 – Columbia River at Umatilla is presented in Figure 2-25 and summarized in Table 2-1. Total phosphorus concentrations ranged from 0.0092 to 0.0522 mg/L, and averaged 0.0184 mg/L. Generally, total phosphorus appears to have some element of seasonality, with higher concentrations occurring in the early spring. Total phosphorus concentrations during the 2009 ODEQ sampling event (Table 2-6) ranged from 0.02 to 0.03 mg/L, and averaged 0.0236 mg/L. In the NMFS dataset, total phosphorus ranged from 0.018 to 0.083 mg/L. Total phosphorus concentrations frequently increased with depth of sample collection. Seasonal variation in total phosphorus was characterized by the highest values occurring in winter and early spring and the minimum values in late spring and early fall. Total phosphorus varied somewhat between locations with no increasing or decreasing trends evident from upper to lower reservoir.

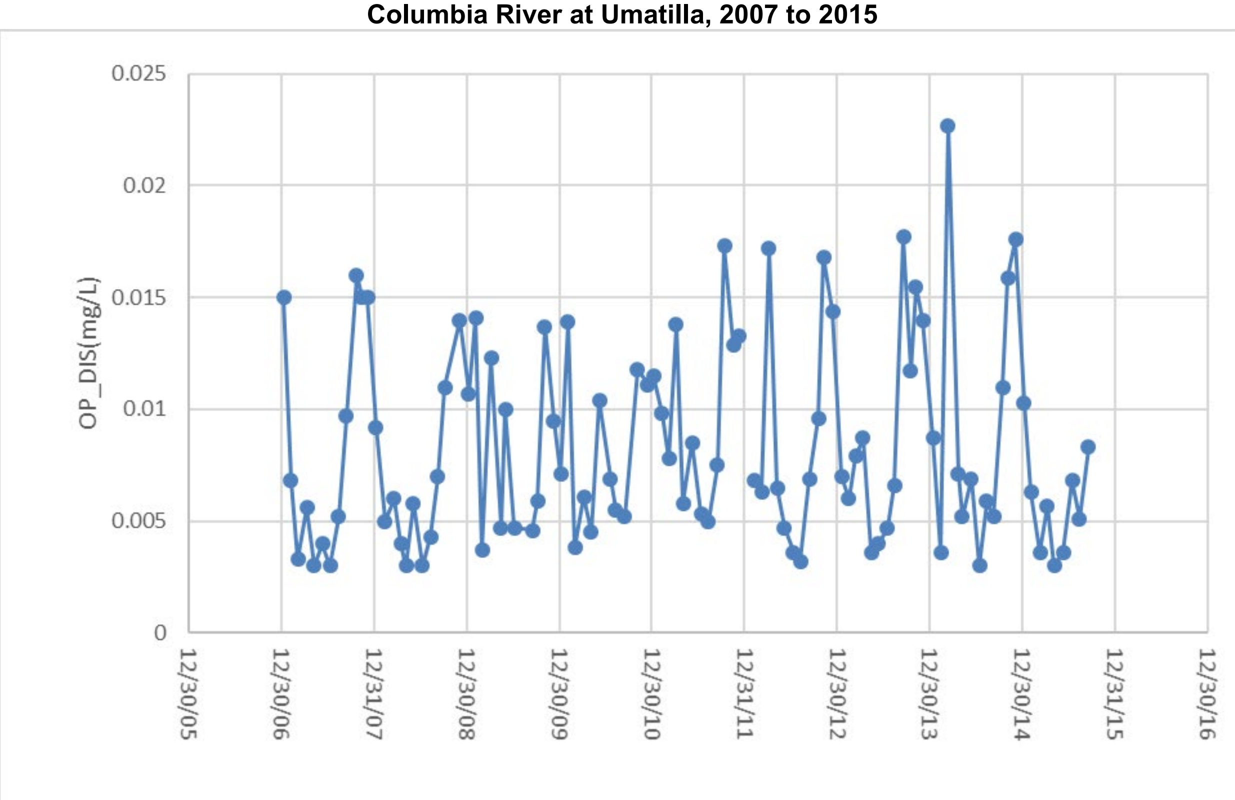
Figure 2-25. Total Phosphorus at Ecology Station 31A070 Columbia River at Umatilla, 2007 to 2015



Soluable Reactive Phosphorus

Soluble reactive phosphorus represents the dissolved form of phosphorus that is readily available for aquatic plant uptake. Monthly orthophosphate (which is the inorganic fraction of soluble reactive phosphorus) data from Ecology Station 31A070 – Columbia River at Umatilla is presented in Figure 2-26 and summarized in Table 2-1. Orthophosphate was detected in 95 percent of observations, with concentrations that ranged from < 0.003 to 0.0227 mg/L and averaged 0.00833 mg/L (Kaplan-Meier mean). There is no easily discernible trend in orthophosphate the data. Orthophosphate was only detected in 27 percent of samples during the 2009 ODEQ sampling event (Table 2-6), with concentrations that ranged from < 0.005 to 0.007 mg/L and averaged 0.00518 mg/L (Kaplan-Meier mean). The differences in total phosphorus and orthophosphate concentrations suggest that, while orthophosphate can make up a substantial portion of the total phosphorus, other phosphorus species are also present. In the NMFS dataset, orthophosphate ranged from <0.001 to 0.027 mg/L. Orthophosphate concentrations from different depths showed occasional wide variation, but no consistent increasing or decreasing trends with depth. Orthophosphate varied considerably between locations with no increasing or decreasing trends evident from upper to lower reservoir. Seasonal variation in orthophosphate was characterized by the highest values occurring in winter and early spring and the minimum values in late spring and early fall.

Figure 2-26. Soluble Reactive Phosphorus at Ecology Station 31A070
Columbia River at Umatilla, 2007 to 2015



2.2.2.9 *Trace Metals*

Of the many trace metals evaluated in the 2009 ODEQ dataset (summarized in Table 2-6), only mercury, barium, and uranium were detected. Accumulation of trace metals (including methyl mercury) in reservoirs can be a serious water quality issue. Because of the low number of sampling locations and the low frequency of recent sampling events, the observations and inferences regarding this data are of limited utility.

<u>Mercury</u>

Organomercuric compounds were widely used as biocides for treatment of seed grain and in various other applications until these uses were banned in the 1960s. A major source of mercury pollution in surface water prior to 1970 was the production of chlorine and sodium hydroxide (mercury was used in the electrolysis cells [Wershaw 1970]); the amount of mercury escaping to the environment through this source has decreased greatly since 1970. The release of mercury to the atmosphere in smelting and fossil fuel combustion have also raised the general background level of mercury in the environment substantially above its pre-industrial status (Hem 1985). Based on available data, atmospheric deposition appears to be the major pathway for mercury loading to the Columbia River Basin (EPA 2009). Mercury air deposition includes both emissions from industrial facilities within and near the basin and fallout from the pool of global mercury that has been transported from sources as far away as Asia and Europe. As of 2009, local and regional sources included a cement plant in Durkee, Oregon; several gold mines in northern Nevada; an elemental phosphorous plan in Soda Springs, Idaho; and four coal-fired power plants within or near the boundaries of the basin. Wastewater treatment plants, industrial discharges, and stormwater runoff make up a smaller but not insignificant portion of the mercury loading to the Columbia River Basin.

Elemental mercury is a liquid at normal Earth-surface temperatures, but it is also somewhat volatile at these temperatures. The stable form in most natural water systems is the free metal, Hg(aq) or aqueous mercury. The amount that would be present in water open to the atmosphere is likely to be much lower owing to mercury's tendency to escape as vapor. Mercury may form chloride or hydroxide complexes depending on pH and total chloride concentration. Organic complexes such as methyl mercury and other similar forms can be produced by methane-generating bacteria in contact with metallic mercury in lake or stream sediment (Wood et al. 1968). In this form, the element appears to be concentrated in successive biological species along aquatic food chains so that fish that live in mildly contaminated environments may contain too much mercury to be used safely for food. Concentrations of mercury in filtered natural river water generally are very small, rarely exceeding a few tenths of a microgram per liter. The amount of dissolved mercury that may occur in the form of organic complexes is uncertain, although it appears from available thermodynamic data that the concentrations of mercury occurring in solution even in water that is known to be polluted are below the solubility limits for the common inorganic forms (Hem 1970).

Due to moderate levels of mercury in fish, the Oregon Health Authority (OHA) recommends a limit of one meal per week for resident fish from the Ruckel Creek (1 mile upstream of Bonneville Dam to McNary Dam; OHA 2017). Dissolved mercury and total and dissolved methyl mercury were not detected in the 2009 ODEQ sampling effort (summarized in Table 2-6). Total recoverable mercury was detected in 73 percent of the samples during that time, ranging from 0.549 to 0.772 ng/L and averaging 0.58 ng/L (Kaplan-Meier mean). The detections of total mercury and lack of detections for dissolved mercury indicates that the majority of mercury burden is associated with suspended particulates.

Barium

Barium is an alkaline earth metal. A likely control over the concentration of barium in natural water is the solubility of barite ($BaSO_4$), which is a fairly common mineral (Hem 1985). The solubility product for barite is near 10^{-10}, so at sulfate concentrations near 10 mg/L, the corresponding equilibrium concentration of barium would be 0.14 mg/L (or 140 µg/L). Typically, high barium concentrations are associated with low sulfate concentrations (Hem 1985). Another factor that seems likely to influence the concentration of barium in natural water is adsorption to metal oxides or hydroxides. Durum and Haffty (1963) reported a median concentration of 0.045 mg/L in the larger rivers of North America.

In the September 2009 ODEQ dataset (summarized in Table 2-6), barium concentrations were rather consistent across the reach, ranging from 27.7 to 28.9 µg/L and averaging 28.26 µg/L. These barium concentrations are below both the median concentration in larger North American rivers (Durum and Haffty 1963). Additionally, these barium concentrations are lower than what would be expected with sulfate concentrations near 10 mg/L (Hem 1985), which is what was observed in the ODEQ dataset.

Uranium

Natural uranium is composed of several isotopes, of which uranium-238 is predominant. Stability and solubility diagrams published by show that reduced species (where the oxidation state is U^{4+}) are only slightly soluble, but that more highly oxidized forms (such as the uranyl ion, UO_2^{2+}) and the anionic species present at high pH are more soluble (Hem 1985). Uranium complexes with carbonate and sulfate may influence the behavior of dissolved uranium. The chemical properties of the U^{6+} state favor the wide dispersion of uranium in the oxidized portion of the Earth's crust. Uranium is present in concentrations between 0.1 and 10 picograms per liter (pg/L) in most natural water. Concentrations greater than 1 mg/L can occur in water associated with uranium ore deposits (Hem 1985).

In the September 2009 ODEQ dataset (summarized in Table 2-6), uranium concentrations ranged from 0.68 to 0.75 µg/L and averaged 0.72 µg/L. These concentrations far exceed what is typically observed in most natural water.

2.2.2.10 *Organic Carbon*

Total organic carbon is the amount of carbon found in an organic compound and is often used as a non-specific indicator of water quality. Total organic carbon in water comes from decaying natural organic matter as well as synthetic sources. Humic acid, fulvic acid, amines, and urea are examples of natural organic matter. Some detergents, pesticides, fertilizers, herbicides, industrial chemicals, and chlorinated organics are examples of synthetic sources. Dissolved organic carbon is the organic carbon remaining in a sample after filtering the sample, which removes the particulate organic carbon fraction.

Monthly total organic carbon data from Ecology Station 31A070 – Columbia River at Umatilla is summarized in Table 2-1, though only six data points from 2007 and 2008 are available. Monthly total organic carbon ranged from 1.4 to 2.3 mg/L, and averaged 1.85 mg/L. Total organic carbon during the 2009 ODEQ sampling event (Table 2-6) measured 2 mg/L at all 11 locations in the reach. Monthly dissolved organic carbon data from Ecology Station 31A070 – Columbia River at Umatilla is summarized in Table 2-1, though only six data points from 2007 and 2008 are available. Monthly dissolved organic carbon ranged from 1.1 to 2.3 mg/L, and averaged 1.62 mg/L. The similarities in the total and dissolved organic carbon concentrations indicate that the majority of organic carbon is present in the dissolved fraction. Additionally, there does not appear to be much variability in total and dissolved organic carbon along this reach.

<u>Polychlorinated Biphenyls</u>

PCBs are a family of human-made organic chemicals that were domestically produced from 1929 until 1979 when their manufacture was banned. Due to their non-flammability, chemical stability, high boiling point, and electrical insulating properties, PCBs were used in hundreds of industrial and commercial applications including:

- Electrical, heat transfer, and hydraulic equipment (e.g., transformers and capacitors, fluorescent light ballasts, cable insulation, thermal insulation)
- Plasticizers in paints, plastics, and rubber products
- Pigments, dyes, and carbonless copy paper

PCBs have been demonstrated to cause a variety of adverse health effects, including cancer and a number of serious non-cancer health effects (e.g., effects on the immune system, reproductive system, nervous system, and endocrine system). PCBs can still be released into the environment today from poorly maintained hazardous waste sites, illegal dumping of PCB waste, leaks or releases from electrical transformers containing PCBs, disposal of PCB-containing consumer products into landfills not designed to handle hazardous waste, etc. PCBs in the Columbia River tend to be associated with industrial locations where spills or poor historical handling practices were more likely to occur. Examples of know PCB disposal sites include Bradford Island at Bonneville Dam and the Alcoa Smelter in Vancouver, Washington. In addition, historically, many pieces of electrical equipment used to generate power at dams in the Columbia River Basin used cooling and insulating oil that contained PCBs. Once in the environment, PCBs do not readily break down. PCBs are not very water-soluble, and tend to adhere to organic matter and sediment particles and, therefore, have a high potential to be transported when sediment is transported. PCBs tend to concentrate in the fatty tissue of fish and other animals and can be passed from mother to young. As a result, people who ingest fish may be exposed to PCBs that have bioaccumulated in the fish they are ingesting. PCB levels have triggered fish and shellfish advisories in the lower Columbia River (EPA 2009).

PCBs were not reported in the data sources used for this analysis.

Dioxins

Dioxins are a group of highly toxic persistent organic pollutants that can cause cancer, reproductive and developmental problems, and damage to the immune system, and can interfere with hormones. Dioxins is formed in the manufacture of chlorinated organic compounds (like some herbicides), the combustion of domestic and industrial wastes, the production of chlorine-bleached wood pulp, and the burning of fuels (like wood, coal, or oil). The most studied and most toxic of all dioxins is 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD). The concern over dioxin levels in the Columbia River is related to 2,3,7,8-TCDD in effluents and treatment plant sludges at chlorine-bleaching pulp mills as well as in fish tissue below these mills (EPA 1991).

Dioxins were not reported in the data sources used for this analysis.

2.2.3 Biological

2.2.3.1 *Chlorophyll a*

Chlorophyll a is the primary photosynthetic pigment in all photosynthetic organisms requiring oxygen and is found in all freshwater phytoplankton species. This photosynthetic pigment is essential for oxygenic photosynthesis because of its role as the primary electron donor in the electron transport chain. Although there are several different forms of chlorophyll present in plants, chlorophyll a is the dominant form and is generally considered an indicator of algal biomass in freshwater ecosystems (Wetzel 1975). Thus, measurements of chlorophyll a in a waterbody can provide, in some circumstances, an indirect estimate of the amount of algal biomass; it should be noted, however, that there are circumstances where chlorophyll a does not make a good estimate (Cullen 1982).

Monthly chlorophyll a data from Ecology Station 31A070 – Columbia River at Umatilla is presented in Figure 2-27 and summarized in Table 2-1. Chlorophyll a concentrations observed since 2010 have ranged from 0.8 to 16.2 µg/L, and averaged 4 µg/L. Chlorophyll a seems somewhat seasonal, with the highest concentrations occurring in the late winter to spring and lowest values occurring in the late summer to fall. Chlorophyll a concentrations during the 2009 ODEQ sampling event (Table 2-6) ranged from 1.7 to 11.9 µg/L, and averaged 4.46 µg/L. There was substantial variation in chlorophyll a across the reach (Figure 2-28) during the sampling period.

In the NMFS dataset, chlorophyll a ranged from 1.3 to 10.6 µg/L. Chlorophyll a content of samples was highly variable between sampling stations visited on the same date, and between lower-, mid-, and upper-reservoir locations sampled during the same week. Chlorophyll a levels peaked in April and May, then declined through August, and then increased during the fall months.

Figure 2-27. Chlorophyll a (µg/L) at Ecology Station 31A070 Columbia River at Umatilla, 2007 to 2015

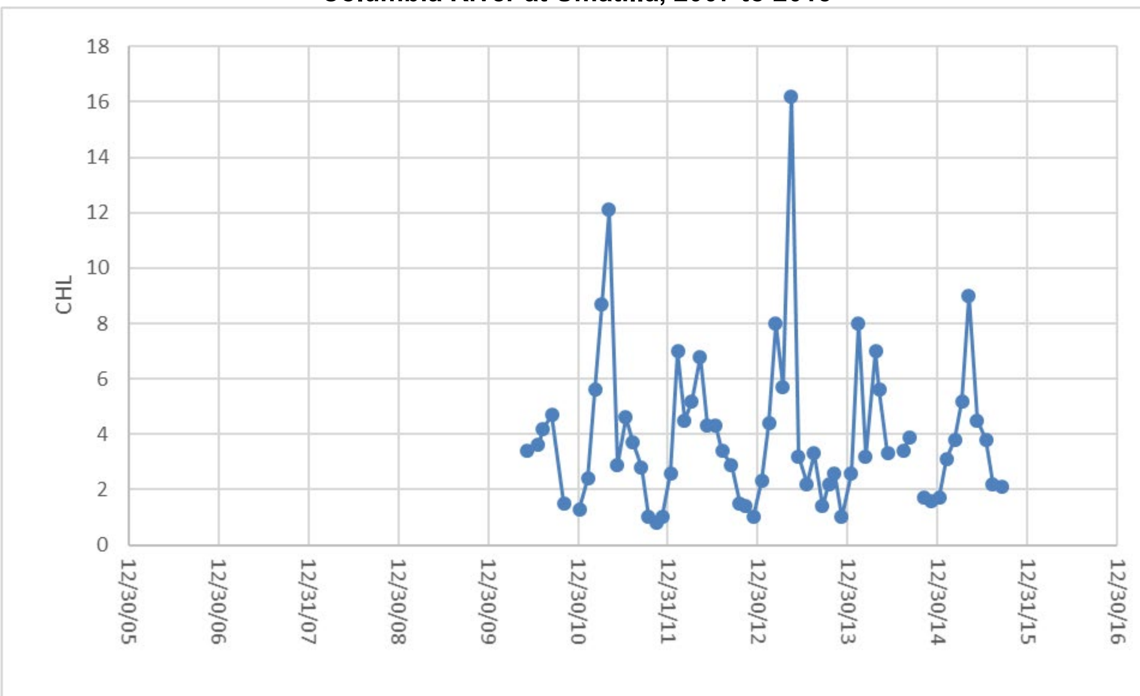
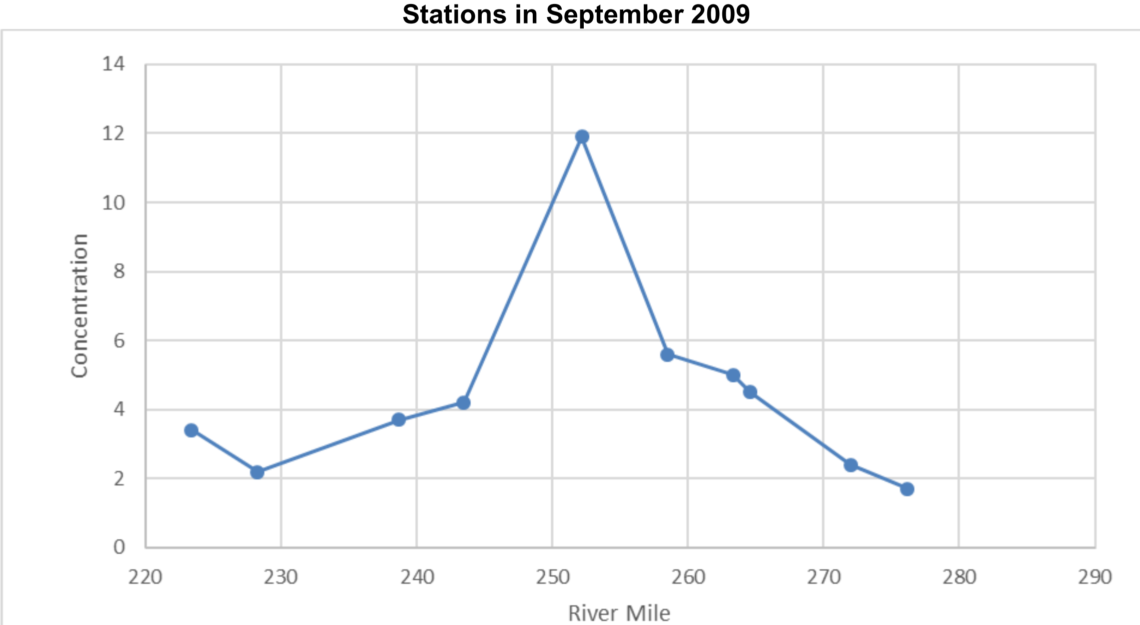


Figure 2-28. Chlorophyll a at Oregon Department of Environmental Quality Stations in September 2009



2.2.3.2 *Pheophytin A*

Pheophytin a is photosynthic pigment in green plants that is closely related to chlorophyll a. Pheophytin a is a decomposition product of chlorophyll a; biochemically, a pheophytin a molecule is a chlorophyll a molecule that lacks the central Mg^{2+} ion. Pheophytin a serves as the first electron carrier intermediate in the electron transfer pathway of oxygenic photosynthesis. Thus, like chlorophyll a, pheophytin a can be an indicator of algal biomass. The relationship of chlorophyll a and pheophytin a can be evaluated relative to water quality, but that is not assessed here.

Pheophytin a concentrations from 10 locations during the 2009 ODEQ sampling event (Table 2-6) ranged from 0.6 to 2.6 µg/L, and averaged 1.4 µg/L.

2.2.3.3 *Zooplankton*

The term zooplankton refers to invertebrate animals living in the water column of fresh water bodies. These planktonic animals are typically divided into three major groups based on taxonomy: the phylum Rotifera, and two orders of the Crustacea, the Cladocera and Copepoda. Zooplankton feed by filtering and/or grazing, and are primary consumers that feed on algae, organic detritus, and bacteria, with a few predaceous species that also prey on smaller crustaceans and rotifers (Pennak 1989). Zooplankton serve as a food base for larger crustaceans, aquatic insects, and planktivorous fish, and are therefore considered secondary producers (Kerfoot and Sih 1987; Pennak 1989). Zooplankton assemblages are expressed in terms of total biomass, population densities, or species composition. Species composition is usually determined first through enumeration and identification of the various organisms in a sample. Total biomass is then calculated through established length/width relationships for each species type.

In the 1994–1995 NFMS study, Cladoceran densities ranged from 0.08 to 25 organisms/L, with copepod densities from 0.4 to 42 organisms/L, and rotifer densities from 3 to 354 organisms/L.

Of the 10 cladoceran species identified in zooplankton samples collected at lower- and mid-reservoir stations, only *Bosmina longirostris* and *Daphnia thorata* were present at densities exceeding 1 organism/L in any month. Seventeen cladoceran species were identified from samples collected at upper-reservoir stations, including all 10 species identified at lower- and mid-reservoir stations. At upper-reservoir stations, as at lower- and mid-reservoir stations, *Bosmina longirostris* and *Daphnia thorata* were dominant. Other species typically occurred infrequently, at relatively low densities. In 1995, March to September cladoceran densities peaked at 45 organisms/L at lower- and mid-reservoir stations and 19 organisms/L at upper-reservoir stations.

Collections contained predominantly immature life stages, including nauplii and copepodids. Calanoid copepodids were presumably developmental stages of *Leptodiaptomus ashlandi*, whereas cyclopoid copepodids were probably early life stages of *Diacyclops thomasi* or *Eucyclops agilis*, since these were the only mature copepod species identified in sample collections. *Diacyclops thomasi* was numerically dominant on most sample dates. Comparison of copepod densities between lower- and mid-reservoir, and upper-reservoir locations from March to September 1995 shows slightly higher densities at lower- and mid-reservoir locations than at upper-reservoir stations

Twenty-seven rotifer taxa were identified from samples collected at lower- and mid-reservoir stations. Most taxa were rare, appearing infrequently and at very low densities. The dominant taxa, including *Keratella cochlearis*, *Polyarthra vulgaris*, and *Synchaeta pectinata,* were present at lower- and mid-reservoir stations on all sample dates. A total of 38 rotifer taxa were identified in samples collected at upper-reservoir stations. Taxa found only at upper-reservoir sites were typically present at very low densities and on only a few sample dates. *Keratella cochlearis*, *Polyarthra vulgaris*, and *Synchaeta pectinata*, the three most abundant rotifers at lower- and mid-reservoir stations, were also the dominant species at upper-reservoir stations.

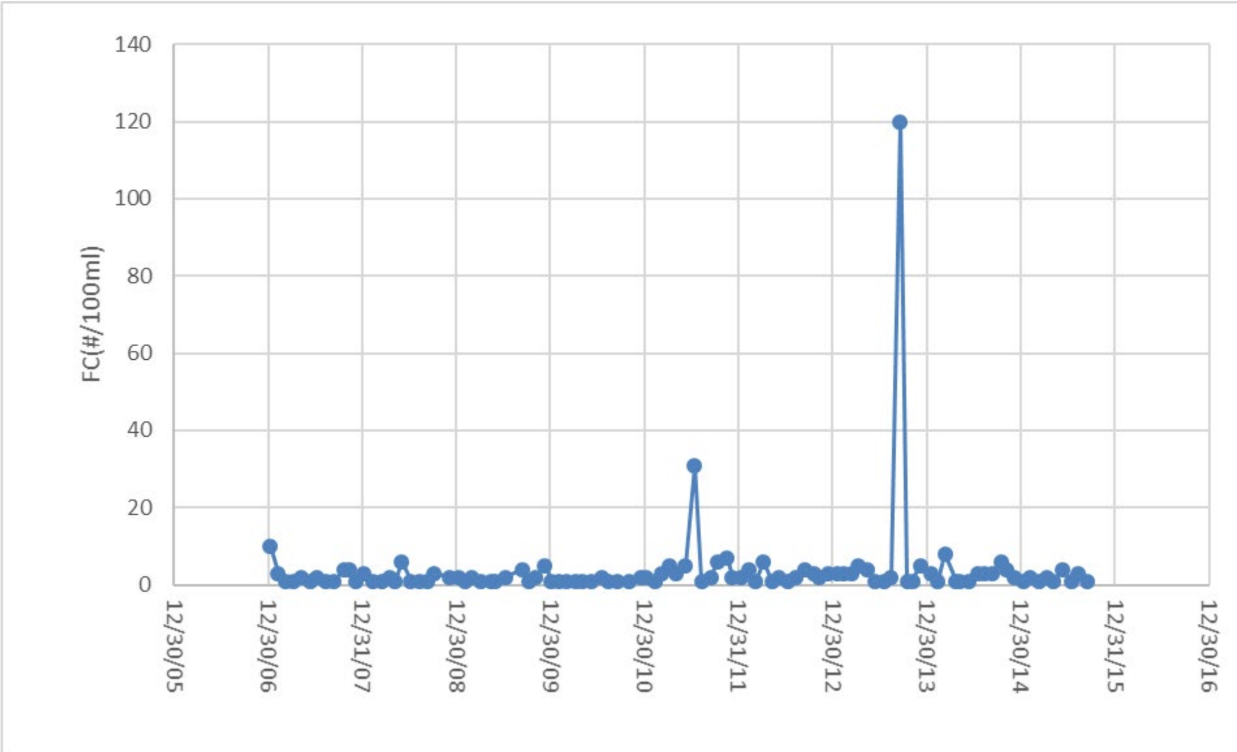
2.2.3.4 *Fecal Coliform and E. coli Bacteria*

Total coliform bacteria are commonly found in the environment and are generally harmless. Fecal coliform bacteria are a sub-group of total coliform bacteria that appear in great quantities in the intestines and feces of people and animals. The presence of fecal coliform in a water sample often indicates recent fecal contamination, meaning that there is a greater risk that pathogens are present than if only total coliform bacteria are detected. *Escherichia coli* (E. coli) is a sub-group of fecal coliform bacteria. Most E. coli bacteria are harmless, and are found in great quantities in the intestines of people and warm-blooded animals. Some strains, however, can cause illness. The presence of E. coli in a water sample usually indicates recent fecal contamination, meaning there is a greater risk that pathogens are present. Coliform data are reported in most probable number (MPN) per 100 milliliters (MPN/100 mL). The MPN is the number of organisms that are most likely to have produced the observed laboratory results in a particular test. The MPN method is used to quantify the concentration of the viable microorganisms in a sample and involves subdividing the original sample by orders of magnitude, and assessing the presence or absence of microorganisms in the multiple subdivisions.

Monthly fecal coliform data from Ecology Station 31A070 – Columbia River at Umatilla is presented in Figure 2-29 and summarized in Table 2-1. Generally, fecal coliforms are low most of the time, though there are occasionally spikes. Fecal coliform bacteria were detected 74 percent of the time, with concentrations ranging from < 1 to 120 MPN/100 mL and averaging 3.8 MPN/100 mL. Fecal coliform bacteria exceed the freshwater primary contact recreation criterion (single sample) for Washington (primary contact recreation: 200 colonies/100 mL; WAC 173-201A-200(2)(b)) in any sample.

E. coli was only detected in 1 of 11 samples during the 2009 ODEQ sampling event (Table 2-6); the singular detection was 1 MPN/100 mL. E. coli bacteria did not exceed the Oregon freshwater recreation criteria (406 E. coli organisms per 100 mL; single sample; Oregon Administrative Rule 340-041-0009(1)(a)) in any sample.

Figure 2-29. Fecal Coliform Bacteria at Ecology Station 31A070
Columbia River at Umatilla, 2007 to 2015



2.2.4 Trophic State Classification

The biological productivity, or trophic state, can be classified into three general categories: oligotrophic (low productivity), mesotrophic (moderate productivity), and eutrophic (high productivity). Lakes with low nutrient concentrations and low rates of algal productivity are classified as oligotrophic. Lakes with high nutrient concentrations and high rates of algal productivity are classified as eutrophic. Mesotrophic lakes have nutrient concentrations and algal productivity between those of eutrophic and oligotrophic lakes. The water quality parameters most often used to assess the trophic state of a lake are total phosphorus, chlorophyll a, and transparency. A useful way to group lakes by trophic state is with the trophic state index (TSI), which is based on linear regression relationships developed for total phosphorus, chlorophyll a, and transparency in lakes (Carlson 1977). Trophic state indices were computed using equations developed by Carlson, which classify a lake as oligotrophic with a TSI value less than 40, as mesotrophic with a TSI value between 40 and 50, and as eutrophic with a TSI value greater than 50. Carlson (1977) recommends using summer TSI values to classify lakes.

The Carlson TSI was calculated for Ecology Station 31A070 – Columbia River at Umatilla for each sample where total phosphorus and chlorophyll a data were available in July, August, and September, and is summarized in Table 2-13. The summer TSI for 2007 to 2015 generally indicates mesotrophic to oligotrophic conditions. Over the 10-year period, only one TSI value would be considered eutrophic, but only slightly so (TSI value of 50.74).

Table 2-13. Summary of Carlson Tropic State Indices at Ecology Station 31A070 – Columbia River at Umatilla

Statistic	TSI (TP)	TSI (CHL)	Classification
Minimum	30.46	33.90	Oligotrophic (< 30-40)
Maximum	50.74	45.78	Mesotrophic (40–50) to Eutrophic (> 50)
Mean	41.02	41.72	Mesotrophic (40–50)
Median	40.97	42.61	Mesotrophic (40–50)
Standard Deviation	3.94	3.22	

Note: CHL = chlorophyll a; TP = total phosphorus.

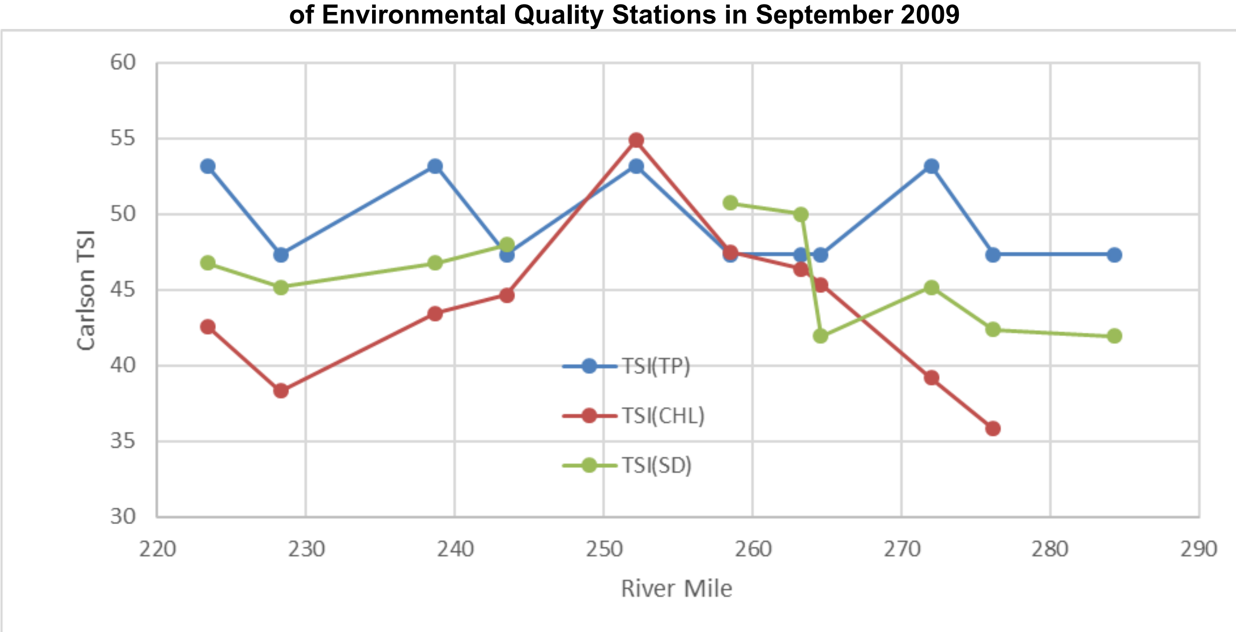
The TSI was calculated for each sample in the September 2009 ODEQ dataset where total phosphorus, chlorophyll a, and Secchi disk depth data were available, and is summarized in Table 2-14 and by river mile in Figure 2-30. The TSI for most of the reach during this period, with some exceptions, generally suggests mesotrophic conditions. Based on the chlorophyll a measures, it appears that the TSI increases with decreasing river mileage until about RM 252.2, where the TSI begins to decrease. The Secchi disk depth–based TSI calculations suggest a similar trend, though a critical data point at RM 252.2 is missing.

Table 2-14. Summary of Carlson Tropic State Indices at ODEQ Stations in September 2009

Statistic	TSI (TP)	TSI (CHL)	TSI (SD)	Classification
Minimum	47.35	35.81	41.95	Oligotrophic (< 30–40) to Mesotrophic (40–50)
Maximum	53.20	54.89	50.75	Eutrophic (> 50)
Mean	49.47	43.82	45.89	Mesotrophic (40–50)
Median	47.35	44.06	45.98	Mesotrophic (40–50)
Standard Deviation	2.95	5.41	3.18	

Note: SD = Secchi disk depth.

Figure 2-30. Carlson Trophic State Index at Oregon Department of Environmental Quality Stations in September 2009



2.2.5 Statistical Analysis

2.2.5.1 *Correlation Analysis*

Data from Ecology Station 31A070 – Columbia River at Umatilla was used for correlation analysis. Water quality correlations were evaluated using the Pearson correlation coefficient, which is a measure of linear correlation between two variables. The Pearson correlation coefficient can range from -1 to 1, with negative values indicating a negative relationship between the two parameters and positive values indicating a positive relationship. The farther a coefficient value is from 0, the stronger the relationship between the two variables. As expected, numerous relationships (both positive and negative) existed between several key water quality parameters (Table 2-15).

There are moderate to strong positive relationships between turbidity (0.59) and flow and suspended solids (0.82). These results suggest that suspended solids and turbidity are sensitive to flow, and that higher flows result in higher suspended solids concentrations and turbidity. It is, thus, somewhat intuitive that suspended solids have a strong positive relationship with turbidity (0.87), which suggests that higher turbidity is related to higher suspended solids related to higher stream flows.

Total phosphorus also has moderate to strong positive relationships with suspended solids (0.59) and turbidity (0.75), but orthophosphate does not. This result suggests that events that increase suspended solids and turbidity are likely to increase particulate-associated phosphorus, whether by transport into the system or through suspension of material within the system. Total nitrogen and total phosphorus also have a moderately strong positive relationship (0.61). Unlike total phosphorus, though, total nitrogen is negatively correlated with flow (-0.34). Further, total nitrogen has a moderate to strong negative relationship with temperature (-0.71), whereas total phosphorus only has a weak negative relationship with temperature (-0.27). These results suggest that the processes that control total phosphorus and total nitrogen concentrations may be different. Total nitrogen has a strong positive relationship with nitrate + nitrite (0.99), and ammonia and total nitrogen do not have a strong relationship (-0.06); this is further evidence that the concentration of total nitrogen is driven by nitrate and/or nitrite inputs and/or transformations.

Chlorophyll a is not strongly correlated with total phosphorus (0.12), and is negatively correlated with orthophosphate (-0.43). Similarly, chlorophyll a is also not strongly correlated with total nitrogen (0.02). These results suggest complex relationships between chlorophyll a and major nutrients.

Correlation of water quality parameters to month and year were also evaluated. Only dissolved organic carbon has a moderate to strong correlation to year, but that parameter only had data in 2 years; therefore, the usefulness of this correlation is dubious. Month had moderate to strong correlations with oxygen (-0.73) and temperature (0.61). This is intuitive because, in summer months, the water temperature is warmer; when the water temperature is warmer, less oxygen can remain dissolved in water (temperature and DO have a strong negative relationship [-0.86]).

Table 2-15. Correlation Analysis at Ecology Station 31A070 – Columbia River at Umatilla, 2007 to 2015

	Month	Year	COND	FC	FLOW	NH3_N	NO2_NO3	OP_DIS	OXYGEN	PH	PRESS	SUSSOL	TEMP	TP_P	TN	TURB	ALK	CHL	DOC	HARD	TOC
Month	1																				
Year	-0.04	1																			
COND	-0.27	-0.15	1																		
FC	0.09	0.09	-0.03	1																	
FLOW	-0.20	0.16	-0.55	0.21	1																
NH3_N	0.40	0.26	-0.03	0.49	-0.28	1															
NO2_NO3	-0.42	-0.05	0.82	-0.03	-0.33	-0.09	1														
OP_DIS	0.31	0.02	0.36	0.25	-0.31	0.33	0.46	1													
OXYGEN	-0.73	-0.05	0.40	-0.19	0.32	-0.43	0.66	-0.02	1												
PH	-0.20	-0.17	0.31	-0.19	0.04	-0.22	0.16	-0.34	0.28	1											
PRESS	-0.12	-0.26	0.30	-0.09	-0.23	-0.14	0.26	0.11	0.26	0.10	1										
SUSSOL	-0.21	-0.03	-0.11	0.10	0.82	-0.15	0.11	0.04	0.34	0.04	-0.02	1									
TEMP	0.61	0.05	-0.62	0.15	0.12	0.28	-0.77	-0.20	-0.86	-0.19	-0.32	-0.01	1								
TP_P	-0.11	-0.14	0.39	0.12	0.23	-0.02	0.57	0.53	0.40	0.00	0.15	0.59	-0.27	1							
TN	-0.39	-0.06	0.82	-0.03	-0.34	-0.06	0.99	0.48	0.62	0.17	0.24	0.14	-0.71	0.61	1						
TURB	-0.26	-0.06	0.06	0.04	0.59	-0.13	0.31	0.22	0.41	0.01	-0.02	0.87	-0.14	0.75	0.35	1					
ALK	-0.35	-0.10	0.99	-0.56	–	0.13	0.97	0.04	0.69	0.71	0.08	-0.50	-0.80	-0.18	0.94	-0.48	1				
CHL	-0.41	0.04	-0.07	-0.11	0.42	-0.28	0.00	-0.43	0.37	0.39	-0.15	0.36	-0.17	0.12	0.02	0.35	–	1			
DOC	-0.45	0.63	-0.66	0.66	0.96	-0.65	-0.29	-0.09	0.28	-0.83	0.23	0.92	0.20	0.47	-0.24	0.60	–	-0.15	1		
HARD	-0.27	-0.19	0.97	-0.57	–	0.30	0.96	0.14	0.69	0.57	0.11	-0.53	-0.87	-0.27	0.93	-0.51	0.97	–	–	1	
TOC	-0.07	0.31	-0.03	0.96	0.77	-0.07	-0.02	0.47	0.30	-0.75	-0.46	0.85	-0.04	0.75	0.01	0.84	–	0.52	0.62	–	1

Notes: COND = conductivity; FC = fecal coliform bacteria; OP_DIS = soluble reactive phosphorus; PRESS = barometric pressure; SUSSOL = suspended solids; TEMP = water temperature; TP_P = total phosphorus; TN = total nitrogen; TURB = turbidity; ALK = alkalinity; DOC = dissolved organic carbon; HARD = hardness; TOC = total organic carbon.

SECTION 3 - LIMNOLOGICAL INVESTIGATIONS IN JOHN DAY

Data from National Marine Fisheries Service Study. 2000. Limnological Investigations in John Day Reservoir Including Selected Upper Reservoir Habitats, April 1994 to September 1995. Fish Ecology Division, Northwest Fisheries Science Center.

Figure 3-1. Sampling Areas and Stations on the Columbia River.

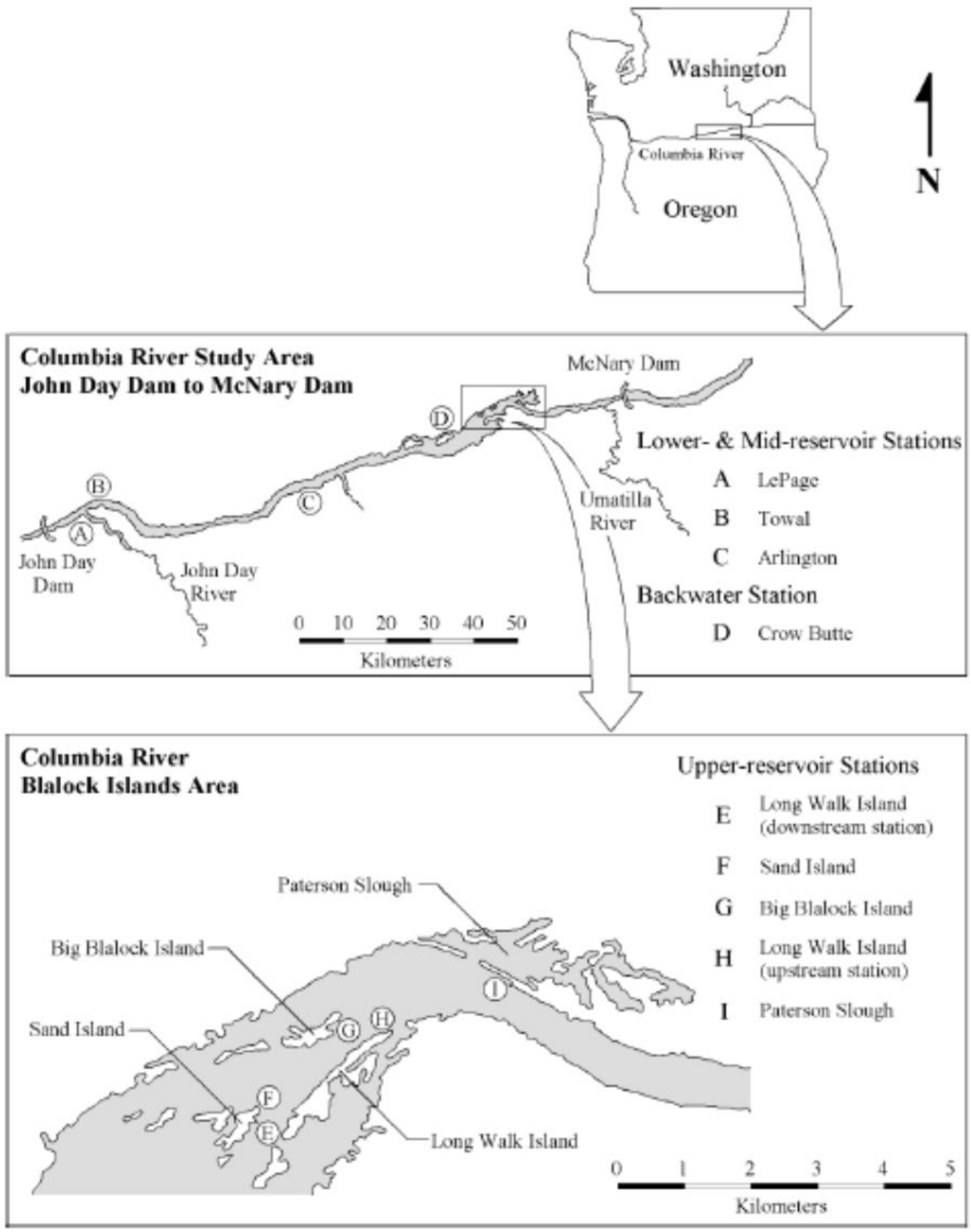


Figure 1. Sampling areas and stations on the Columbia River. John Day Reservoir limnology study, 1994-95. Locations by river kilometer (rkm) were: LePage-352; Towal-355, Arlington-390, Crow Butte-424; Long Walk Island (downstream station)-443a, Sand Island-443b, Big Blalock Island-445, Long Walk Island (upstream station)-446; Paterson Slough-449.

SECTION 4 - SUMMARY

Recent data from one monthly Ecology monitoring station, several ODEQ stations, a NMFS study, and three Corps temperature/TDG monitoring stations was available in Lake Umatilla for this analysis. Only the Ecology monitoring location provided recent long-term assessments of a fairly wide range of water quality parameters. The other monitoring locations were limited by lack of sustained sampling efforts in multiple seasons or by the number and kind of observed parameters; the ODEQ and NMFS data is old while the Corps stations are limited in the number of measured parameters (temperature and TDG).

The variations in John Day Reservoir parameters are largely temporal. Spatial variation was small across the reservoir. Vertical profiles and samples collected at different depths within the water column generally indicated uniformity from surface to bottom. Some surface warming or weak stratification was occasionally observed in the data available for the John Day Dam forebay. The relatively homogeneous nature of the reservoir water with regard to most physical, chemical, and biological parameters is likely a result of low water retention times within the reservoir. The following additional observations of the data were made:

- In Lake Umatilla, temperature, mercury, and PCBs are on the 303(d) list. Lake Umatilla has TMDLs for dioxin and TDG.
- For most parameters, there does not appear to be much variability within the reservoir during a short period.
- Water temperature appears slightly higher in the John Day Dam tailwater than in the McNary Dam tailwater, particularly in summer months. This suggests that water temperature increases within the John Day Reservoir.
- DO supersaturation and high TDG values are likely attributable to the spillway operations at McNary Dam. The spillway is used from April through August to volitionally pass juvenile salmonids downstream.
- Carlson TSI calculations suggest that the Columbia River is generally mesotrophic, but can be oligotrophic or eutrophic at a particular location or at a particular time. In addition, the classification may be different at different locations within the reservoir at the same time.
- Barium, uranium, and mercury are the only trace metals detected in the John Day Reservoir. The uranium concentrations far exceed what is typically expected in natural waters. The majority of the mercury burden is present in the particulate fraction.

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