US Army Corps
of Engineers®
Portland District

WATER QUALITY REPORT

ICE HARBOR RESERVOIR, LAKE SACAJAWEA
COLUMBIA RIVER BASIN
SNAKE RIVER, WASHINGTON

Ice Harbor Reservoir, Lake Sacajawea

Water Quality Report
August 2020

EXECUTIVE SUMMARY

Lake Sacajawea is a run-of-river reservoir created by Ice Harbor Dam located at Snake River Mile (RM) 9.7 (Figure 1-1). The reservoir extends 31.9 miles upstream to Lower Monumental Dam. Authorized purposes include power generation and inland navigation. Other uses include fishery and recreation. Table 1-1 summarizes some key elements of the Ice Harbor Dam project.

CONTENTS

TABLES

FIGURES

ACRONYMS

Acronym	Description
µg/L	Micrograms per Liter
μm^3/L	Cubic Micrometers per Liter
µS/cm	Microsiemens per Centimeter
biOp	Biological Opinion
Bonneville	Bonneville Power Administration
CFU/100 mL	Colony Forming Units per 100 Milliliters
Corps	U.S. Army Corps of Engineers
EPA	U.S. Environmental Protection Agency
GOES	Geostationary Operational Environmental Satellite
IQR	Interquartile Range
mg $^{12}C/m^3$/hr	Milligrams Carbon-12 Per Cubic Meter Per Hour
mg/L	Milligrams per Liter
msl	Mean Sea Level
NOAA	National Oceanic and Atmospheric Administration
NTU	Nephelometric Turbidity Unit
ortho-P	Orthophosphorus
RM	River Mile
SNR-2	Lake Wallula Sampling Station at Snake River Mile 2
SNR-6	Lake Wallula Sampling Station at Snake River Mile 6
SNR-18	Lake Sacajawea Sampling Station at Snake River Mile 18
TDG	Total Dissolved Gas
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
Total-P	Total Phosphorus
TSI	Trophic State Index

SECTION 1 - INTRODUCTION

1.1 STUDY AREA

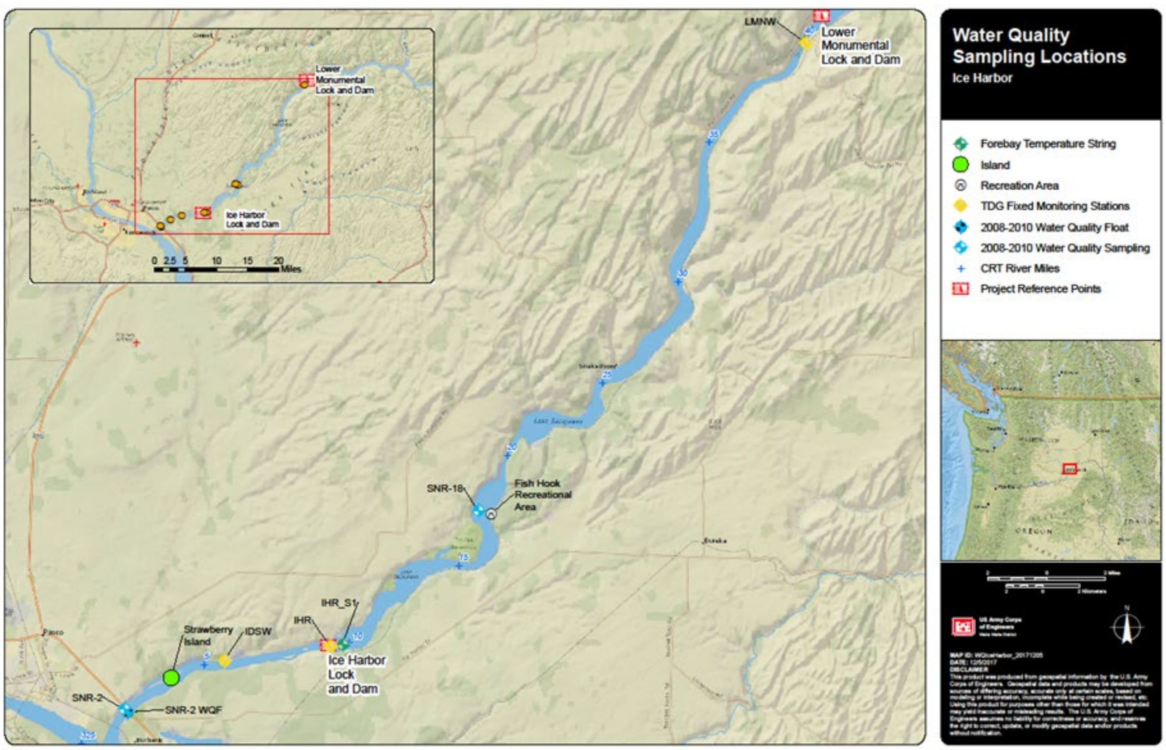
The Snake and Clearwater Rivers are the two primary sources of flow into Lower Granite Lake. The Snake River originates in western Wyoming at Yellowstone National Park and flows approximately 1,000 miles through the states of Idaho, Washington, and Oregon. The Clearwater River originates in the Bitterroot Mountains near the Montana border and flows west to where it joins the Snake River at Lewiston, Idaho. The two drainage basins have a combined area of approximately 93,884 square miles upstream of the confluence at Lewiston, Idaho, and Clarkston, Washington. The topography within the basin ranges from steep mountainous areas, mainly in the upper headwater areas, to extensive volcanic plateaus and plains that have been deeply incised by the river over geologic time. The Snake River flows through several different physiographic provinces including the Columbia Plateau/Basalt Plain, which extends east from the foothills of the Cascade Range in Washington and Oregon to western Idaho; the Snake River Plain, which extends from southeastern Oregon, across southern Idaho and northern Nevada and Utah; the Blue Mountains province, which extends from southeastern Washington to central Oregon; and the Northern Rocky Mountains province, which encompasses much of Idaho and Wyoming (Bonneville Power Administration [Bonneville] 1995). Elevations range from approximately 500 feet above mean sea level (msl) along the gorges of the lower Snake River in the Columbia Plateau physiographic province to more than 10,000 feet above msl in the mountains (Bonneville 1995). The geology primarily consists of basaltic and granitic rocks, and to a lesser extent, consolidated sedimentary rocks and alluvium. Soils within the drainage area of the Snake River generally consist of young alluvial materials along the lower terraces of the river and a fine wind-deposited loess in large areas of the uplands in the Columbia Plateau. In addition, areas of glacial outwash and lake-bed silts caused by past glacial activity can be found in the Columbia Plateau. Soils within the Rocky Mountain province include a variety of parent materials, including metamorphic rock, as well as deposits of glacial drift, outwash, and alluvium (Bonneville 1995). The basin is exposed to Pacific weather systems with precipitation ranging from 8 inches at Pasco, Washington, to more than 90 inches at the higher elevations, much of which falls as snow (Sustainable Communities Initiative 2010).

Lake Sacajawea is a run-of-river reservoir created by Ice Harbor Dam located at Snake River Mile (RM) 9.7 (Figure 1-1). The reservoir extends 31.9 miles upstream to Lower Monumental Dam. Authorized purposes include power generation and inland navigation. Other uses include fishery and recreation. Table 1-1 summarizes some key elements of the Ice Harbor Dam project.

Table 1-1. Selected Characteristics of the Ice Harbor Dam Project

Parameter	Metric
Location	RM 9.7
Year first completed	1961
Reservoir name	Lake Sacajawea
Normal operating range	437 to 440 feet above mean sea level
Storage capacity below elevation 440 feet	406,165 acre-feet
Pool length	31.9 miles
Average reservoir width	0.4 mile
Maximum reservoir width	1.0 mile
Reservoir area at elevation 440 feet	8,375 acres
Shoreline length	80 miles
Maximum depth	112 feet
Mean depth	48.6 feet

Figure 1-1. Locations of the 2008 to 2010 Ice Harbor Related Water Quality Sampling Stations



1.2 PREVIOUS STUDIES

Water quality data collection occurred on the lower Snake River prior to completion of Ice Harbor Dam. The Washington State Department of Ecology (Ecology) began collecting monthly water quality data from the Snake River at the U.S. Highway 12 bridge in 1960 at Station 33A050. Data was collected through 1966, skipped a year, resumed in 1968 for one year, and was activated again in 1973. No data was collected until 1991, but monthly sampling has been consistent from 1991 to 2017. The U.S. Geological Survey (USGS) also completed periodic water quality monitoring at the same location from 1973 through most of 2000. Water quality monitoring in Lake

Sacajawea was included sampling program that was completed by Washington State University and the University of Idaho in the 1970s. This program was funded by the U.S. Army Corps of Engineers (Corps) and continued until about 1977 (Falter et al. 1973; Funk, Falter, and Lingg 1979). In 1994, the Corps initiated an extensive sampling program throughout the lower Snake River Basin with the assistance of research teams from Washington State University, National Marine Fisheries Service, and the University of Idaho. The primary goal of this sampling program was to provide a more complete synopsis of the existing limnological and biological productivity conditions above, below, and throughout the lower Snake River reach and to assess the effects, if any, that the dams have on water quality. Sampling was conducted both in the impoundments and in the “free-flowing” reaches and major tributaries. Initially, in 1994 and 1995, data was collected on a monthly or biweekly basis within the lower Snake River system (Juul 1998a, 1998b). The sampling frequency was increased in 1997 to biweekly monitoring through the growing season. An extensive suite of parameters was sampled during these investigations, including many of the same conventional parameters used in the long-term monitoring studies such as pH, alkalinity, specific conductivity, dissolved oxygen, nutrients, total suspended solids, and turbidity. Various anions and cations were also monitored including chloride, silica, sulfate, calcium, magnesium, sodium, and potassium. In addition, biochemical oxygen demand was also measured at selected locations, as well as various biological parameters including chlorophyll *a*, phytoplankton, zooplankton, attached benthic algae, and other primary productivity indicators (Juul 1998a, 1998b, 1999; NAI 1999; Corps 2002).

1.3 WATER QUALITY DATA USED FOR THIS ANALYSIS

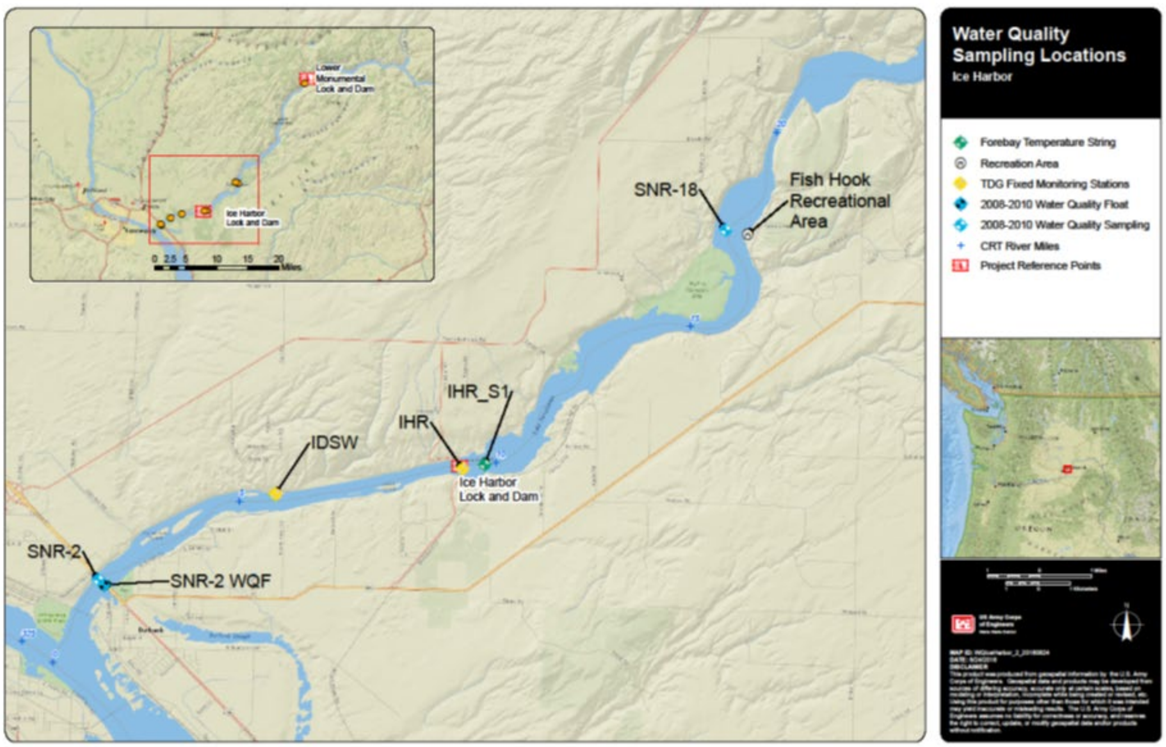
Extensive temperature data is available for Lake Sacajawea. The Corps has collected scrollcase temperature data at the project since 1962, which is discussed in Section 2. The Corps has also operated fixed-monitoring stations in the forebay and tailwater of the project where water temperature and total dissolved gas (TDG) are measured hourly since 1994. The tailwater station operates year-round, and the forebay station collects data from April 1 through August 31. Finally, the Corps installed a forebay temperature string in 2004 that measures water temperatures at 10 depths hourly during the entire year. All USGS and Corps data are transmitted real-time via the Geostationary Operational Environmental Satellite (GOES) system.

Existing water quality conditions of the lower Snake River were evaluated with data from a sampling program that began in April 2008 and ended in October 2010 (Corps, 2014). One sampling station was located in Lake Sacajawea at Snake RM 18 (SNR-18), and one was located downstream from the dam at SNR-2 (Figure 1-1). The stations were visited monthly. Field measurements included water column profiles for temperature, dissolved oxygen, pH, specific conductivity, turbidity, and Secchi disk measurements. Water samples were collected at selected depths for chemical analyses that included alkalinity, chloride, sulfate, inductively coupled plasma metals scan, nitrate plus nitrite-nitrogen, ammonia nitrogen, total nitrogen, orthophosphate, total phosphorus, and total suspended solids. Chlorophyll a, phytoplankton, and zooplankton samples were also retrieved from the photic zone.

One water-quality monitoring float was also deployed to measure temperature, dissolved oxygen, pH, specific conductivity, and turbidity during the 2008 to 2010 period (Figure 1-2). The data was transmitted via a cellular phone to a website on an hourly basis. The station was located near the Highway 12 bridge and consisted of one multi-parameter sonde positioned at approximately mid-depth in the water column.

A temperature string with 10 sensors was installed in the forebay in 2004 near the boat restricted zone. This string measures hourly data that is transmitted via the GOES system to the Corps Northwestern Division's database (https://pweb.crohms.org/ftppub/water_quality/tempstrings/) throughout the year.

Figure 1-2. Locations of the Water Quality Float and Sampling Stations in Lake Sacajawea



SECTION 2 - WATER QUALITY

2.1 Water Quality Standards

The State of Washington use designations for Lake Sacajawea include salmonid spawning, rearing, and migration; primary contact recreation; and domestic, industrial, agricultural, and stock water uses. These designations determine the criteria applied to temperature, dissolved oxygen, TDG, and pH (Table 2-1). Detailed descriptions of the water quality standards are located on the State of Washington Department of Ecology website (https://ecology.wa.gov/Water-Shorelines/Water-quality/Water-quality-standards).

Table 2-1. Summary of Selected Washington Water Quality Standards

Parameter	Standard
Temperature	≤ 20 ºC
Dissolved oxygen	≥ 8 mg/L
Total dissolved gas	≤ 110% [a] ≤ 115% and ≤ 120% [b] ≤ 125% [c]
pH	6.5 – 8.5 units

Notes: [a] During the non-fish spill season when river flows are < 7Q10 (defined in Section 2.2.1.1)
[b] Average 115% forebay and 120% tailwater allowance during voluntary fish spill season
[c] Maximum one-hour average

Various parts of the reach are on Washington State's 303(d) list category 5 for temperature, total phosphorus, and dissolved oxygen. There are two total maximum daily loads (TMDLs) in place, one for dioxin (U.S. Environmental Protection Agency [EPA] 1991) and one for total dissolved gas (Ecology 2003). A draft temperature TMDL was completed by the EPA in 2003 but never finalized. Blue-green algal blooms also occur periodically in the reservoir, especially in the forebay and swim areas (NAI 1999), but have not been tested for toxins such as anatoxin, saxitoxin, and microcystin.

2.2 EXISTING WATER QUALITY CONDITIONS

The following sections provide a synopsis of the relevant hydrologic, physical, chemical, and biological parameters that can be used to characterize water quality conditions within the area of interest.

2.2.1 Physical

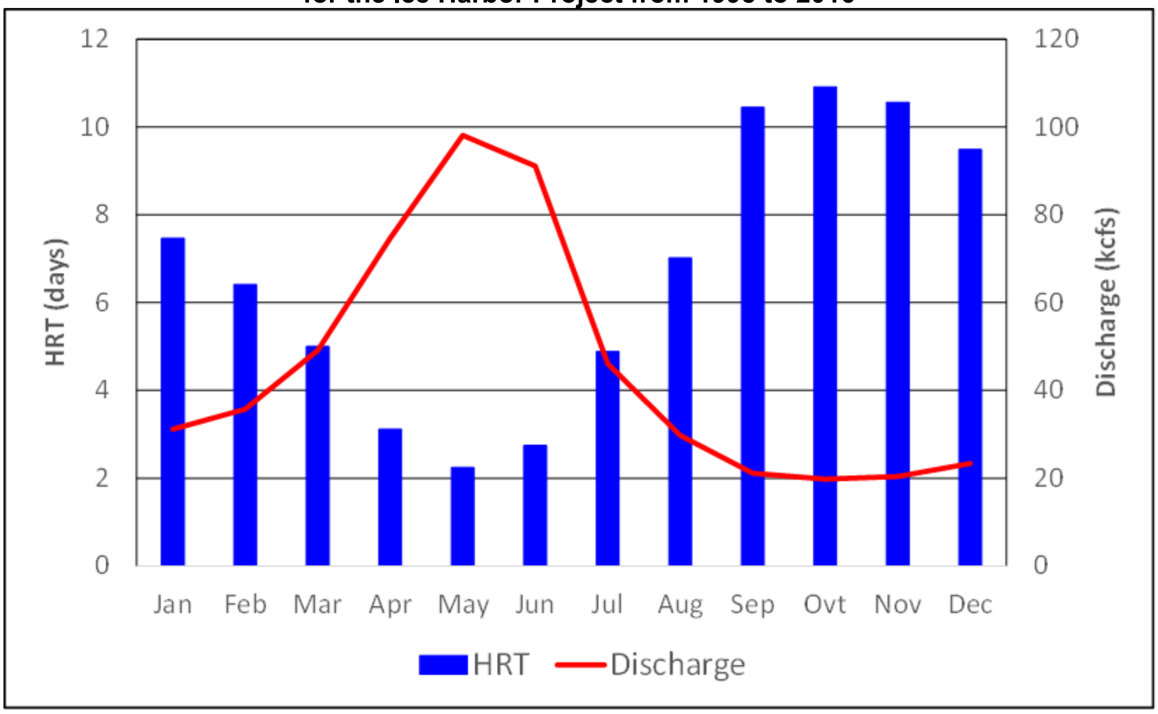
2.2.1.1 *Hydrologic Characteristics*

Because Ice Harbor is a run-of-river project, the long-term minimum, maximum, and average flows are similar to the ones determined for the three upstream Lower Snake River projects. Based on the project outflow data for 1974 through 2017, the minimum average monthly flow is 22.8 kcfs in October, the maximum average monthly flow is 104.0 kcfs, and the average annual flow is 49.1 kcfs.

The 7Q10 is the average peak annual flow for seven consecutive days that has a recurrence interval of 10 years. The calculated values for Lake Sacajawea are the same as the ones determined for Lower Granite Lake: 214 kcfs as determined by the Washington State Department of Ecology (Ecology 2003) and 211 kcfs calculated by Walla Walla District.

Because the volume of Lake Sacajawea is smaller than Lower Granite Lake and Lake Bryan, but larger than Lake Herbert G. West, the calculated hydrologic residence times are intermediate. The long-term average, based on 1998 through 2016 project outflow data is 6.7 days. However, the calculated values follow a cyclic pattern throughout the year (Figure 2-1). The shortest retention time occurs in May when the average is 2.2 days and is greatest in October at 10.9 days. The maximum 7-day moving average ranged from 10.8 days to 16.1 days and did not reach or exceed 20 days in any of the years considered.

Figure 2-1. Average Monthly Hydrologic Residence Time and Discharge for the Ice Harbor Project from 1998 to 2016



2.2.1.2 *Water Temperature*

Temperature represents one of the most important characteristics of river water. It affects other physical properties, such as dissolved oxygen and TDG, and also influences the chemical and biological reactions that take place in aquatic systems.

Recent and historical water temperature data was evaluated to quantify water temperature conditions through the reservoir. The primary sources of information included the hourly data collected at the tailwater fixed monitoring station and the forebay temperature string.

Water Temperatures in Lake Sacajawea. Lake Sacajawea does not stratify thermally to the extent that Dworshak Reservoir and other deep lakes do. Significant temperature differences between the surface and bottom waters are generally rare in running waters. A frequently used rule-of-thumb is that a water body has to have a mean depth greater than 33 feet and a mean annual hydrologic residence time in excess of 20 days before strong thermal stratification develops. The mean depth of the reservoir is greater than 33 feet, but the average annual residence time, based on 1998 to 2016 data, is 6.7 days. The calculated retention time can exceed 10 days during the summer and fall of low-flow years, but it still remains less than 20 days. Consequently, vertical temperature differences due to incoming solar radiation are minimal since wind- and flow-induced turbulent diffusion, along with convective mixing, prevents the formation of a thermal gradient most of the time.

A relatively small vertical thermal gradient does occur in Lake Sacajawea as a consequence of the summer cold water releases from Dworshak Dam. However, since this reservoir is the farthest downstream project on the Lower Snake River, the summer forebay thermal gradient is less apparent than in the upstream reservoirs. Based on hourly data recorded between July 15 through August 31 from 2005 to 2016 at the forebay temperature sting, the temperature difference between a depth of 3.3 feet (1 meter) and 98.4 feet (30 meters) ranged from 1.3°F (0.7°C) in 2011 to 3.8°F (2.1°C) in 2005. The average for the 12-year period was 2.7°F (1.5°C).

Water Temperatures at Ice Harbor Dam Tailwater. Summer tailwater temperatures at the Ice Harbor Dam tailwater station were higher than at the upstream locations (Figure 2-2). The 1995 through 2016 trace shows that the average of the daily maximum temperatures recorded at the Ice Harbor fixed monitoring system station were higher than at the three upstream projects, exceeding 69.8°F (21°C) from July 20 through August 29. The frequency distribution for the July 1 through September 15 daily maximum temperatures (Figure 2-3) shows that the 68°F (20°C) threshold was exceeded every year between 1995 and 2016. Annual values ranged from a low of 51 percent in 2008 to greater than 80 percent in 1998, 2001, 2003 to 2007, 2009, and 2013 to 2015.

Figure 2-2. Comparison of Average Daily Maximum Temperatures at the Ice Harbor Tailwater Station and at the Three Upstream Projects from 1995 to 2016

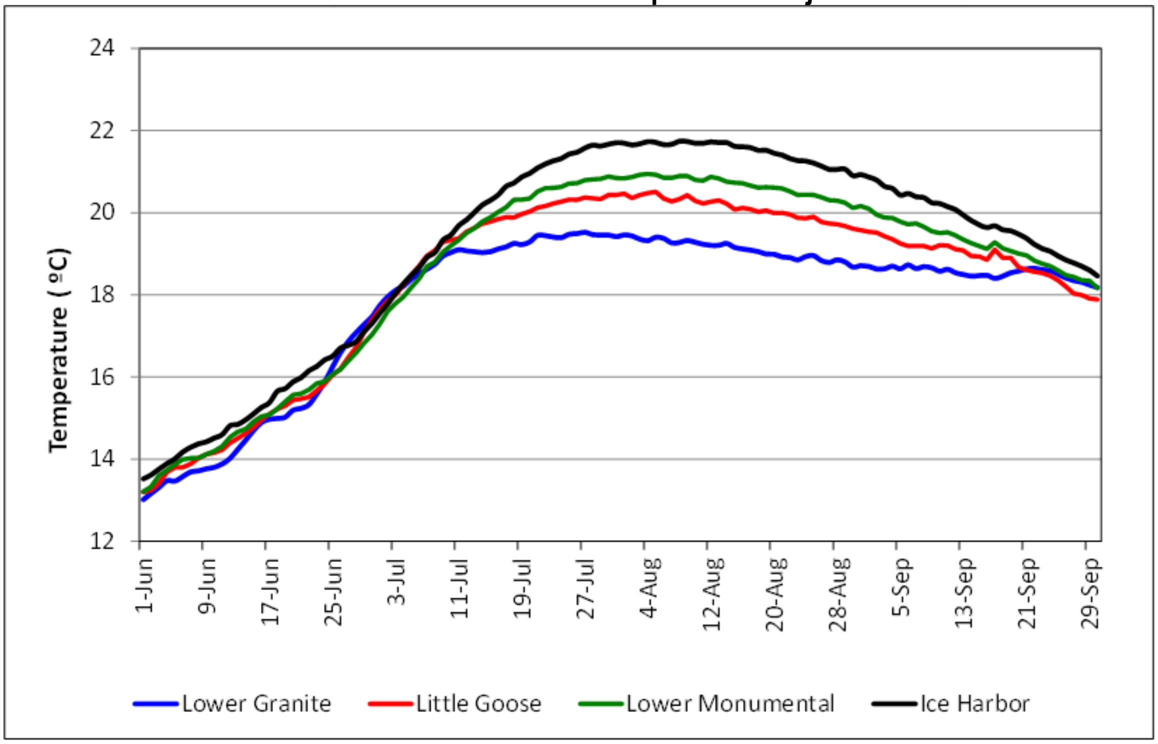
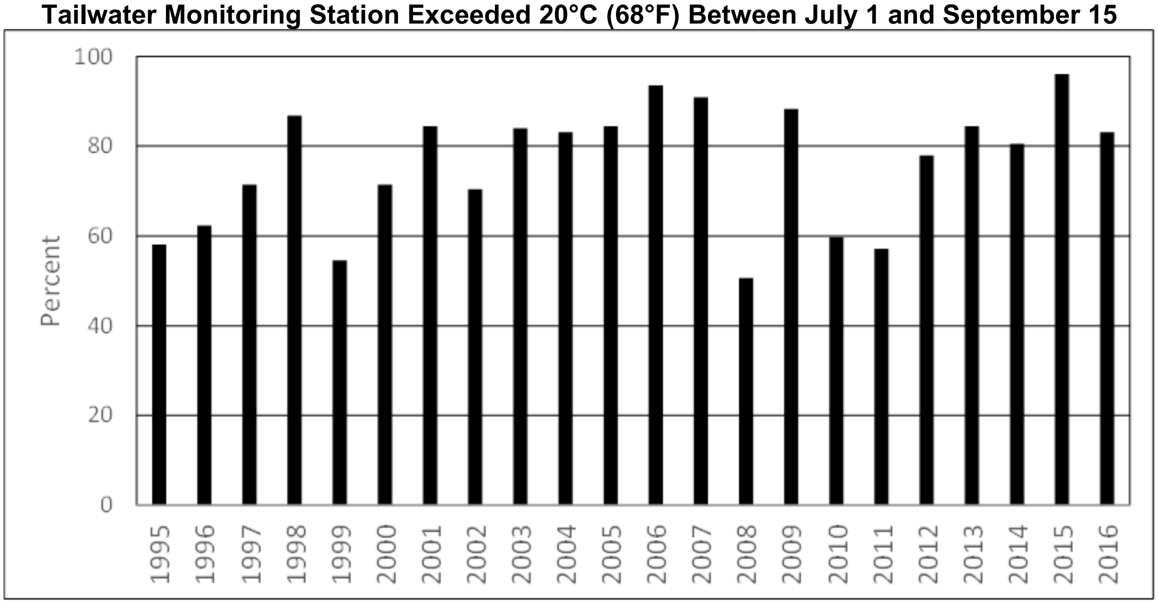


Figure 2-3. Percent of Days When the Daily Maximum Water Temperature at the Ice Harbor Dam Tailwater Monitoring Station Exceeded 20°C (68°F) Between July 1 and September 15



2.2.1.3 *Dissolved Oxygen*

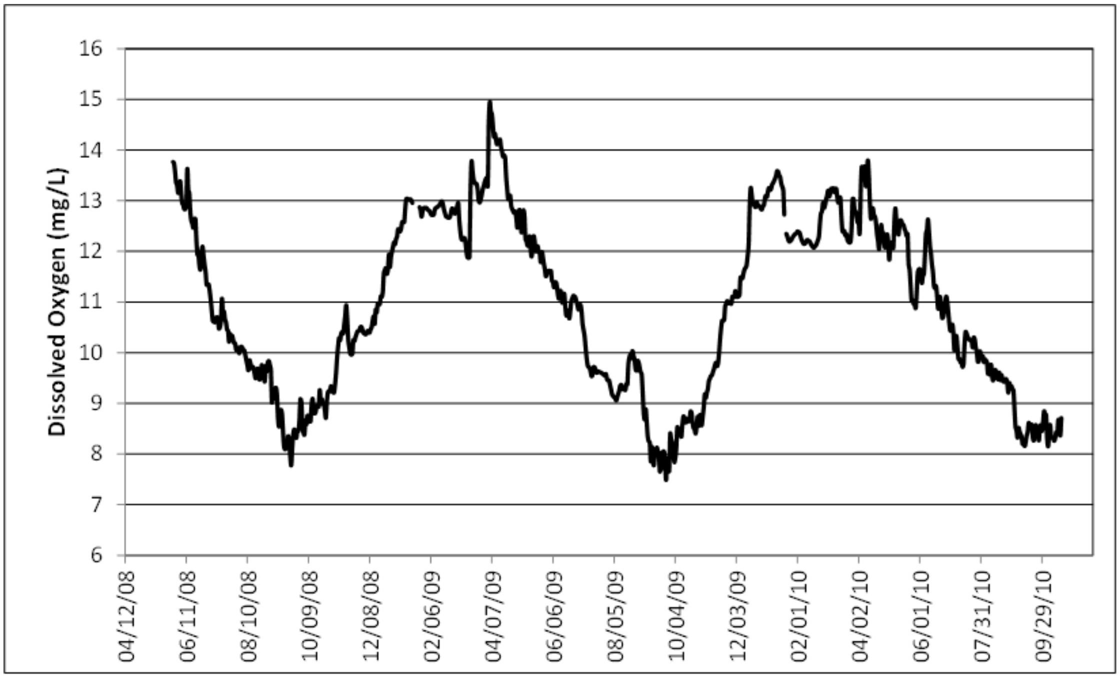
Dissolved oxygen is critical to the ecology of both riverine and reservoir systems and sustains most biological life. Nearly as important, oxygen is the key element in many chemical processes in water. Through oxidation and reduction reactions, the concentration of oxygen has the ability to influence the concentration of many dissolved substances in water. These chemical processes include the decomposition of organic matter, the cycling of nutrients, and the transformation and transport of substances within the water column and between the sediments and the water column.

The biochemical processes of photosynthesis and respiration by living organisms provide a means by which the aquatic community can regulate the amount of oxygen in the aquatic environment, within limits. Most organisms cannot survive with too little oxygen while the solubility of oxygen generally limits the maximum amount that can be dissolved in water under most conditions. Super saturation of water with oxygen does occur during periods of intense photosynthetic activity and as a result of dissolution of oxygen under high hydrostatic pressure in the plunge pools of high head dams (Bowie *et al.* 1985). Both of these situations occur, at times, in the lower Snake River.

Dissolved oxygen profiles were completed during each sampling event at SNR-18 during the 2008 to 2010 sampling period. Water column averages were higher during the winter and spring when water temperatures were lower and typically exceeded 12 milligrams per liter (mg/L). Calculated average water column averages occurred in September and October but were still greater than 8 mg/L with the exception of October 2010, when the calculated average was 7.8 mg/L. Oxygen super-saturation in the upper strata of the water column occurred between February and August, depending on the year. Maximum concentrations occurred in the upper 5 meters of the water column and exceeded 120 percent saturation during May 2010.

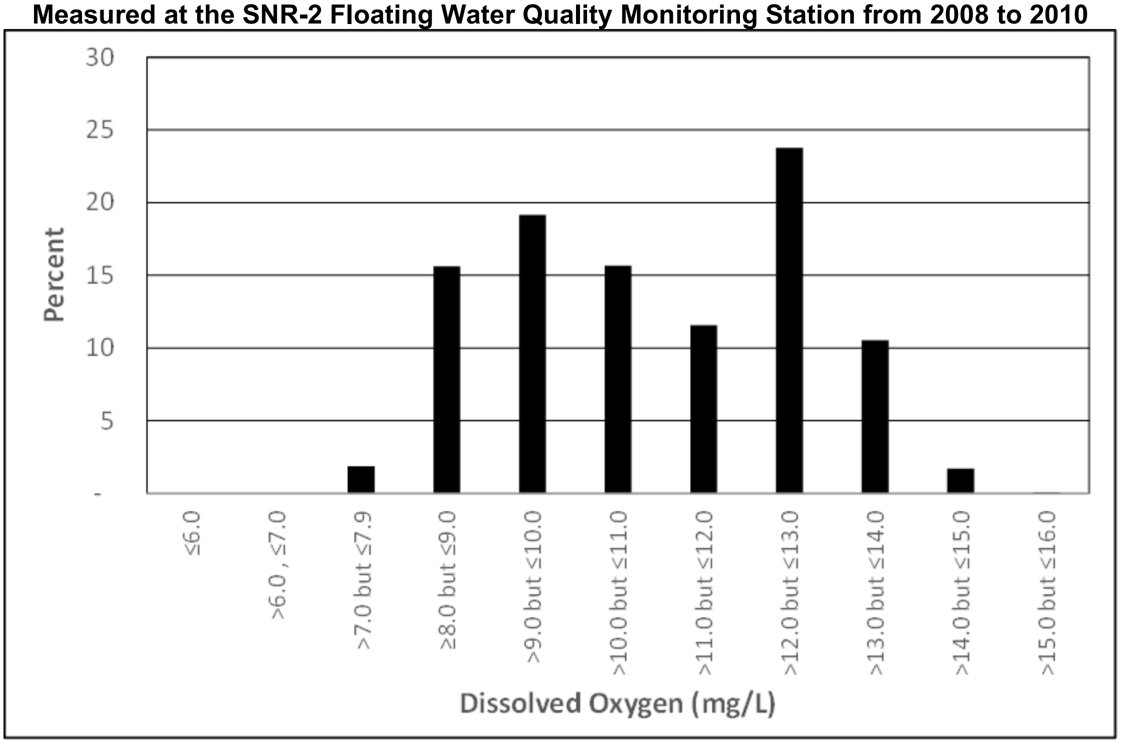
Dissolved oxygen concentrations were also recorded hourly at the water quality float located at SNR-2 during the 2008 to 2010 sampling period. The plot of daily averages (Figure 2-4) shows that the magnitude of the annual minimum and maximum values differed from year to year. Minimum concentrations occurred in September and October and were usually near 8.0 mg/L. The timing of daily maximums varied between years but generally occurred between January and April with daily averages ranging from 13.0 to 15.0 mg/L.

Figure 2-4. Annual Cycle for the Dissolved Oxygen Concentrations Measured at SNR-2 from 2008 to 2010



The frequency distribution for the hourly dissolved oxygen concentrations measured at SNR-2 are shown in Figure 2-5. None of the hourly data points was less than 6 mg/L, and only 1.9 percent were less than 8 mg/L. Ninety-six of the hourly values were between 8 mg/L and 14 mg/L.

Figure 2-5. Frequency Distributions for the Hourly Dissolved Oxygen Concentrations Measured at the SNR-2 Floating Water Quality Monitoring Station from 2008 to 2010



2.2.1.4 *Total Dissolved Gas*

Nitrogen, oxygen, and argon compose about 78 percent, 21 percent, and 1 percent, respectively, of the elemental gases in dry air. When the pressure of every gas in the atmosphere reaches equilibrium with its dissolved form in water, the water is saturated. The pressures of gases in the air make up atmospheric pressure, and its counterpart in water is the TDG pressure. If the TDG pressure is greater than atmospheric pressure, the water is supersaturated.

The 2008 National Oceanic and Atmospheric Administration (NOAA) Federal Columbia River Power System Biological Opinion (BiOp) relies on spill operations at Corps mainstem projects to benefit Endangered Species Act–listed juvenile salmon (*Oncorhynchus tshawytscha and O. nerka*) and steelhead (*O. mykiss*) passage. Currently, the spill operations during the juvenile fish passage season (generally early April into August) at Corps dams are consistent with court-ordered operations and the adaptive management provisions in the 2008 NOAA BiOp as implemented through the Adaptive Management Implementation Plan. The intent of the spill operations is to help meet juvenile fish survival performance standards identified in the BiOp. These fish passage spills may result in the generation of TDG supersaturation in the lower Snake River at levels above current state and federal water quality standards. The State of Washington has authorized exceptions to these standards as long as the elevated TDG levels provide for improved fish passage through the spillway without causing more harm to fish populations than through other passage routes.

The general approach for TDG abatement activities focuses on limiting the entrainment of air into the water column, the water flow rate that encounters the bubble plume, and the effective depth of the air that does become entrained. Spillway flow deflectors, commonly referred to as flip lips, redirect the spill jet from a plunging flow that transports air bubbles deep into the stilling basin to a horizontal jet that maintains entrained air much closer to the water surface. The influence of spillway flow deflectors is also to transport highly aerated flow conditions well downstream of the stilling basin into the tailrace channel, promoting the exchange of atmospheric gasses at shallow depths. The effectiveness of spillway flow deflectors in abating TDG production has been consistently demonstrated at Corps projects on the Columbia and Snake Rivers. Spillway flow deflectors were not included in the original design of Ice Harbor Dam, but were installed on all 10 spillways over a three period from 1997 to 1999, resulting in significant reductions in TDG generation. Other methodologies to reduce TDG loading below mainstem dams involve minimizing the use of spillways for involuntary spill. Limiting the entrainment of powerhouse flows into the turbulence bubbly flow in the stilling basin can also be an effective method of TDG enhancement. A spill pattern that widely distributes spillway flows uniformly across the entire spillway has been found to lower TDG exchange rates.

The Ice Harbor project includes two TDG fixed-monitoring stations: one at the project forebay, and one downstream from the dam. The tailwater station records data on an hourly basis throughout the year, while the forebay station is maintained throughout the fish passage season (April 1 through August 31). All of the data is transmitted in near real-time via the GOES system and can be accessed at the Corps' Northwestern Division's website (http://pweb.crohms.org/ftppub/water_quality/tdg/).

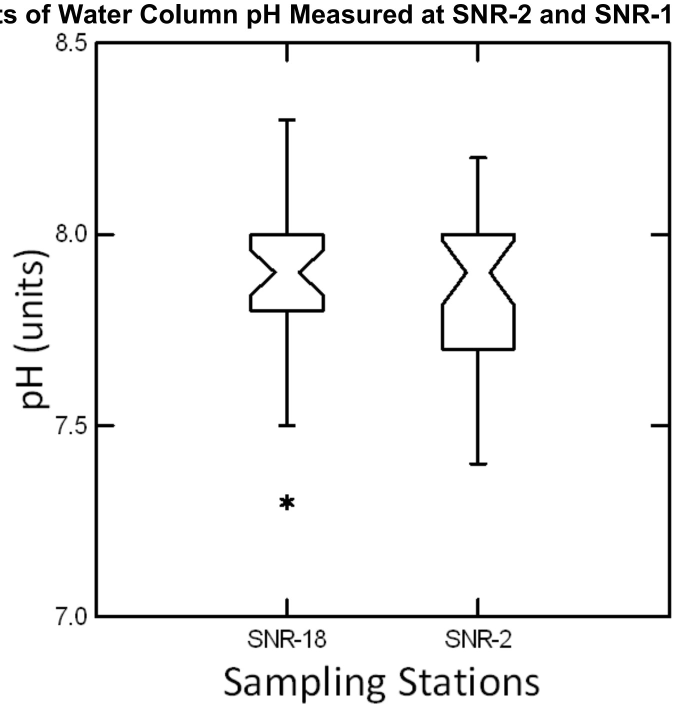
Annual TDG and temperature reports are available at the Corps Northwestern Division's website (https://www.nwd.usace.army.mil/Missions/Water/Columbia/Water-Quality/). These reports are comprehensive and include information such as the fish operations plan for each year, quality assurance summaries from each Corps district, and required court reports. The number of times when the TDG concentrations exceeded water quality standards in any of the years between 1999 and 2016 at the forebay station ranged from zero in 2001 to 70 in 2011, and an overall median of 42 per year. Exceedances were less frequent at the tailwater station, ranging from zero in 2001, 2007, and 2016 to 57 in 2011. The calculated median at the tailwater station was four per year.

2.2.1.5 *pH*

The acidity or basicity of an aqueous solution is measured by pH. Solutions with a pH less than 7 units are considered acidic, and solutions with a pH greater than 7 units are basic or alkaline.

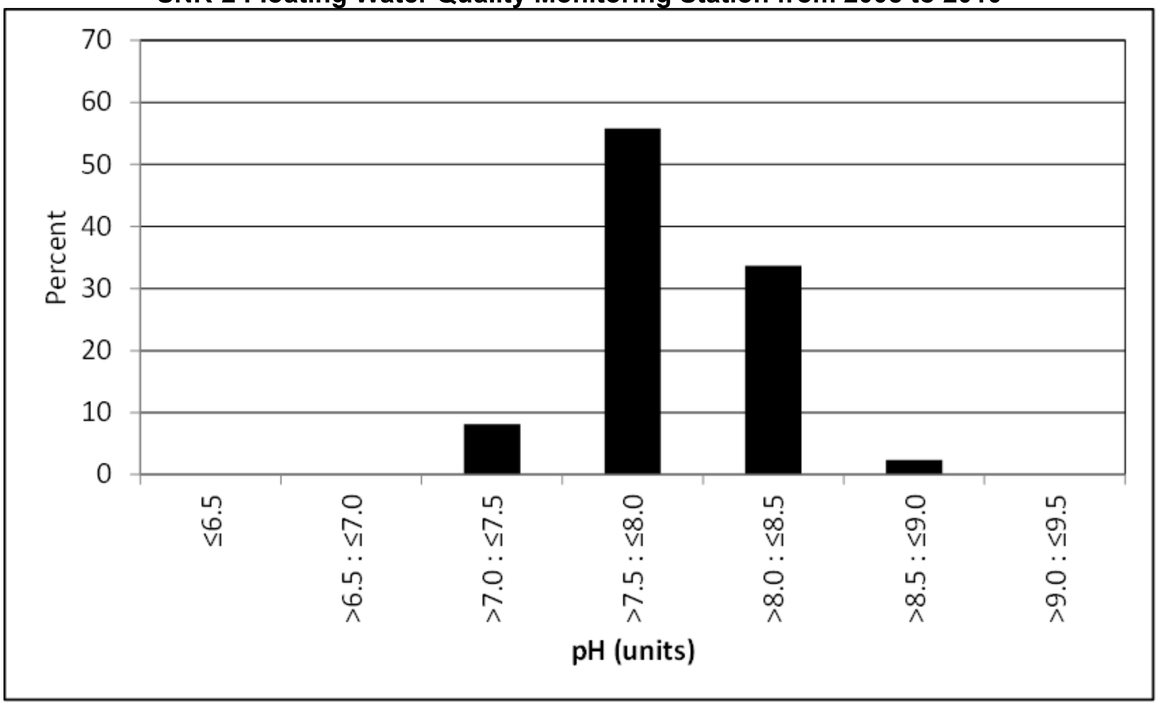
Water column profile measurements were recorded at SNR-18 and SNR-2 during each sampling event. The overall medians for both stations were essentially the same, 7.9 units at SNR-18 and 7.8 units at SNR-2 (Figure 2-6). The differences between maximum and minimum point measurements during an individual sampling event ranged from 0.0 to 0.3 units at both locations. The lowest pH values were recorded during May at both locations, while the highest values occurred during either March or April.

Figure 2-6. Box Plots of Water Column pH Measured at SNR-2 and SNR-18 from 2008 to 2010



Frequency distributions of the hourly data set available from the water quality monitoring float that was located at SNR-2 provide additional information. The average for the 2008 to 2010 sampling period was also 7.9 units. No hourly values less than 6.5 units were recorded (Figure 2-7), and 97.6 percent of the data points were between pH 7.0 and 8.5. The remaining 2.4 percent were greater than 8.5 pH units. Most of these occurrences were recorded during the second half of August 2009.

Figure 2-7. Frequency Distribution for the Hourly pH Measured at the SNR-2 Floating Water Quality Monitoring Station from 2008 to 2010

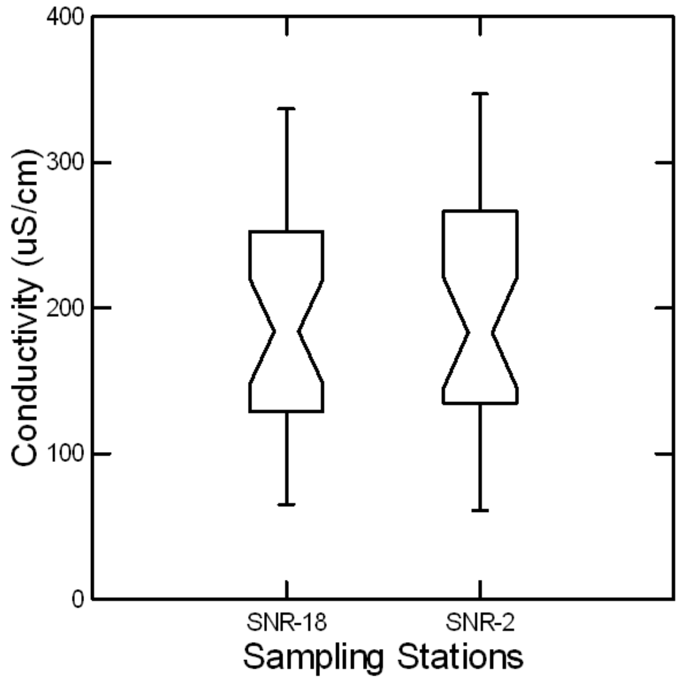


2.2.1.6 *Specific Conductivity*

Specific conductivity is the reciprocal of resistance and is a measure of the waters ability to conduct an electric current. It varies both with the number and type of ions in solution.

Water-column specific conductivity was measured during each 2008 to 2010 sampling event. Minimum values occurred at both locations during May, June, and July 2008 when field measurements ranged from 65 to 80 microsiemens per centimeter (µS/cm). Maximum specific conductivity was measured during the fall and winter months and exceeded 300 µS/cm between November 2009 and March 2010. Measurements within the water column during a given sampling event only differed by a maximum of 2 µS/cm. The calculated 2008 to 2010 median at the two sampling stations were essentially the same, 166 µS/cm at SNR-18 and 166 µS/cm at SNR-2 (Figure 2-8).

Figure 2-8. Box Plots of Water-Column Specific Conductivity Measured at SBR-2 and SNR-18 from 2008 to 2010



The hourly specific conductivity measurements recorded at SNR-2 provide a similar, but more detailed, picture of the annual cycle. Figure 2-9 shows that minimum values occurred in May or June each year, and the magnitude changed each year with lows of 57, 67, and 86 μS/cm in 2008, 2009, and 2010, respectively. Values greater than 300 μS/cm were also more common in 2009 and 2010 than in 2008. In 2008, less than 10 hourly measurements were greater than 300 μS/cm during the latter part of November, yet during the following year, 129 measurements exceeded this threshold between early November 2009 and the beginning of April 2010. An analysis of the frequency distribution shows that 11 percent (2,300 measurements) of the values were less than 100 μS/cm and less than 1 percent, or only 5 hourly measurements, were greater than 350 μS/cm (Figure 2-10).

Figure 2-9. Annual Cycle for the Specific Conductivity Measured at SNR-2

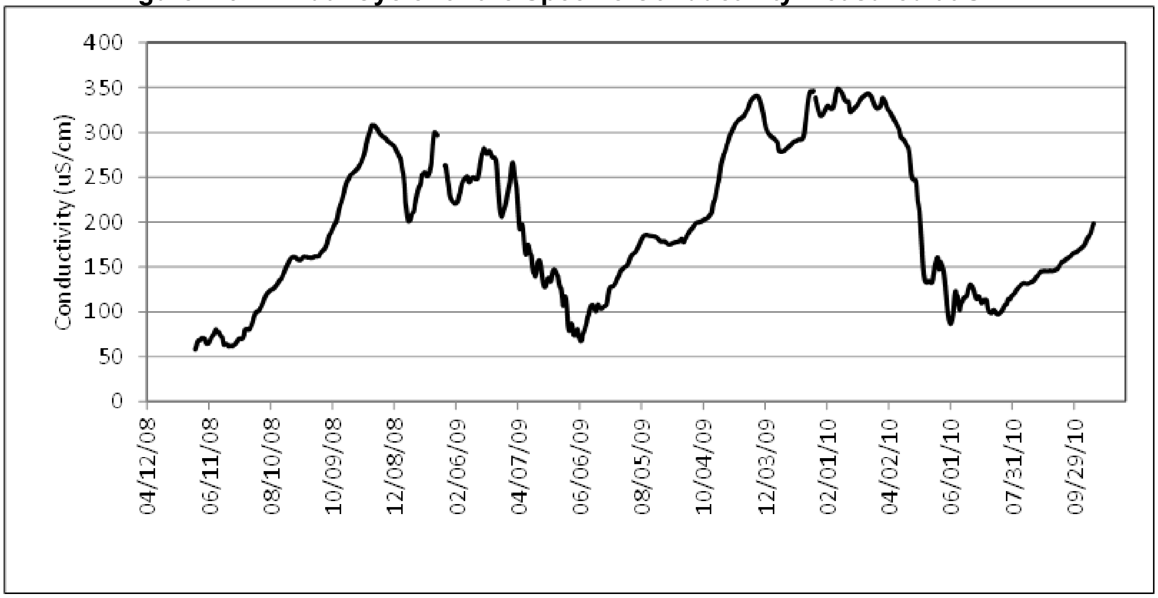
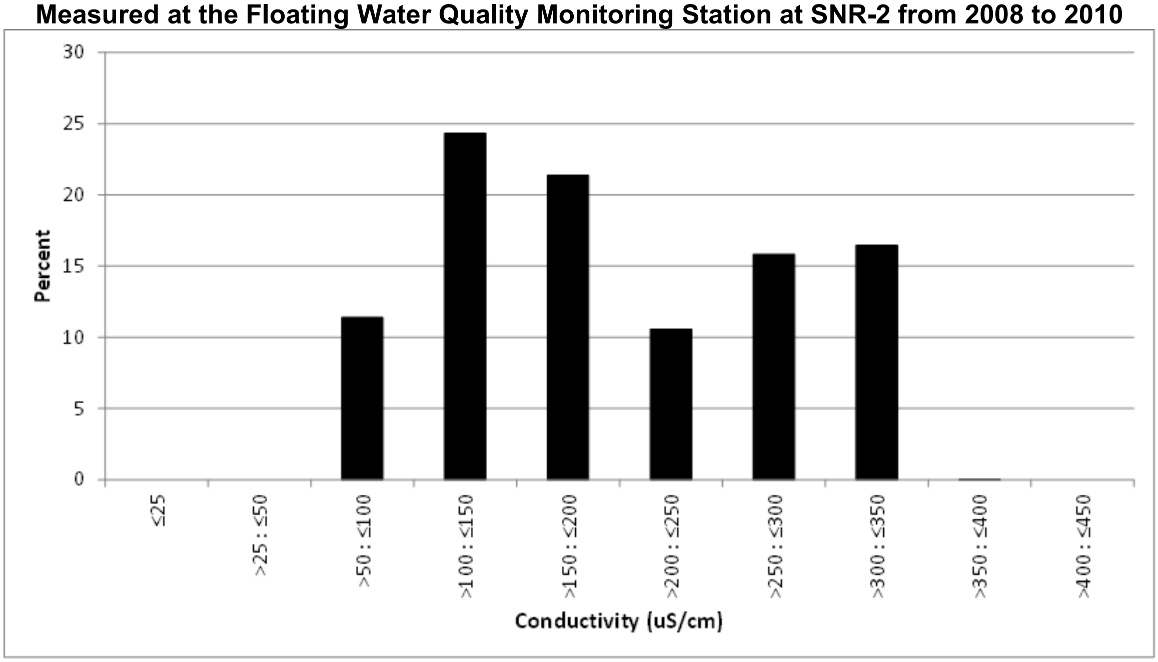


Figure 2-10. Frequency Distributions for the Hourly Specific Conductivity Measured at the Floating Water Quality Monitoring Station at SNR-2 from 2008 to 2010



2.2.2 Chemical

2.2.2.1 *Major Ions, Alkalinity, and Hardness*

Since the specific conductivity of the water is dependent on ionic constituents, it is not surprising that the annual fluctuations in the concentrations of individual ions mimicked the one set by specific conductivity. The median concentrations of the major ions, along with alkalinity and hardness, in the water are presented in Table 2-2. The median concentrations determined for SNR-2 and SNR-18 were very similar. The calculated median hardness value is indicative of moderately hard water but can range from slightly hard to hard depending on the time of year. Calcium, sodium, and sulfate were the three ions that were present in the greatest concentrations.

Table 2-2. Median Concentrations (mg/L) of the Major Ions, Alkalinity, and Hardness Analyzed from 2008 to 2010 for the SNR-2 and SNR-18 Water Samples

Parameter	SNR-2	SNR-18
Alkalinity	68	69
Hardness	74	75
Calcium	19.0	19.0
Chloride	6.2	6.9
Iron	0.14	0.18
Magnesium	6.3	6.6
Potassium	2.3	2.4
Silicon	7.5	7.7
Sodium	15.0	15.0
Sulfate	18.0	19.0
Sulfur	6.3	6.1

2.2.2.2 *Other Inorganic Constituents*

A suite of additional inorganic compounds that are typically present in smaller concentrations than the major ions were also analyzed quarterly during the 2008 to 2010 sampling period. All of the median concentrations shown in Table 2-3 are low and often equal to instrument detection limits. Additionally, in the instances where EPA National Primary Drinking Water Regulations have been established to protect public health, the analytical results from both sampling stations are lower.

2.2.2.3 *Turbidity*

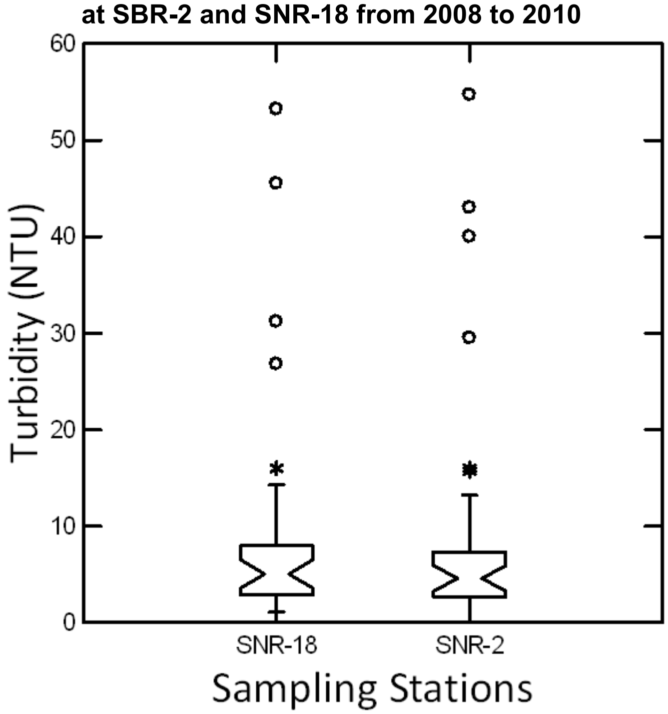
Turbidity is the cloudiness or haziness of a fluid caused by individual particles (suspended solids) that are generally invisible to the naked eye, similar to smoke in air. Fluids can contain suspended solid matter consisting of particles of many different sizes. While some suspended material will be large enough and heavy enough to settle rapidly to the bottom of the container if a liquid sample is left to stand (the settable solids), very small particles will settle only very slowly or not at all if the sample is regularly agitated or the particles are colloidal. These small solid particles cause the liquid to appear turbid.

Turbidity profiles were also completed at SNR-2 and SNR-18 during the 2008 to 2010 sample period. The calculated medians for the entire sample period were 5.2 Nephelometric Turbidity Units (NTU) at SNR-18 and 4.9 NTU at SNR-2 (Figure 2-11), with a range of 1 to 50 NTU within the profile during individual sample trips. The highest turbidity values were measured during May and June during elevated runoff events, and during January when there was an associated increase in total suspended solids. The median difference the maximum and minimum measurements within in a profile was 1.5 NTU, but it did reach 31 NTU during the May 2008 sampling event.

Table 2-3. Detection Limits and Median Concentrations (mg/L) for Minor Inorganic Chemicals Determined for the Water Samples Collected at SNR-2 and SNR-18 from 2008 to 2010

Parameter	Detection Limit	SNR-2	SNR-18
Aluminum	0.01	0.16	0.21
Antimony	0.01	0.01	0.01
Arsenic	0.01	0.01	0.01
Barium	0.0005	0.02	0.02
Beryllium	0.0005	0.0005	0.0005
Boron	0.05	0.05	0.05
Cadmium	0.0005	0.0005	0.0005
Chromium	0.001	0.001	0.001
Cobalt	0.001	0.001	0.001
Copper	0.001	0.002	0.002
Lead	0.01	0.01	0.01
Lithium	0.005	0.009	0.009
Manganese	0.0005	0.010	0.013
Mercury	0.01	0.01	0.010
Molybdenum	0.005	0.005	0.005
Nickel	0.005	0.005	0.005
Selenium	0.01	0.01	0.010
Silver	0.01	0.01	0.010
Strontium	0.0005	0.116	0.121
Thallium	0.01	0.01	0.01
Tin	0.005	0.005	0.005
Titanium	0.001	0.009	0.011
Vanadium	0.005	0.005	0.005
Yttrium	0.0005	0.0005	0.0005
Zinc	0.001	0.004	0.003

Figure 2-11. Box Plots of Water Column Turbidity Measured at SBR-2 and SNR-18 from 2008 to 2010



Hourly turbidity data was recorded at a mean depth of 3.6 meters (11.8 feet) at SNR-2 from June 2008 through October 2010. A plot of the daily average data (Figure 2-12) shows the spring and January peaks noted at the upstream SNR-18 reservoir station. The graph also illustrates that there was a greater incidence of measurements greater than 10 NTU during the first 7 months of 2009. This data is consistent with the information gathered at the floating platforms in Lower Granite Lake and likely attributed to the shape of the hydrograph that year. A frequency distribution of the hourly data shows that 57 percent of the measured values were less than 5 NTU, and 78 percent were less than 10 NTU (Figure 2-13). Less than 6 percent of the data points were greater than 20 NTU.

Figure 2-12. Mean Daily Turbidity Measured at the Floating Water Quality Monitoring Station at SNR-2

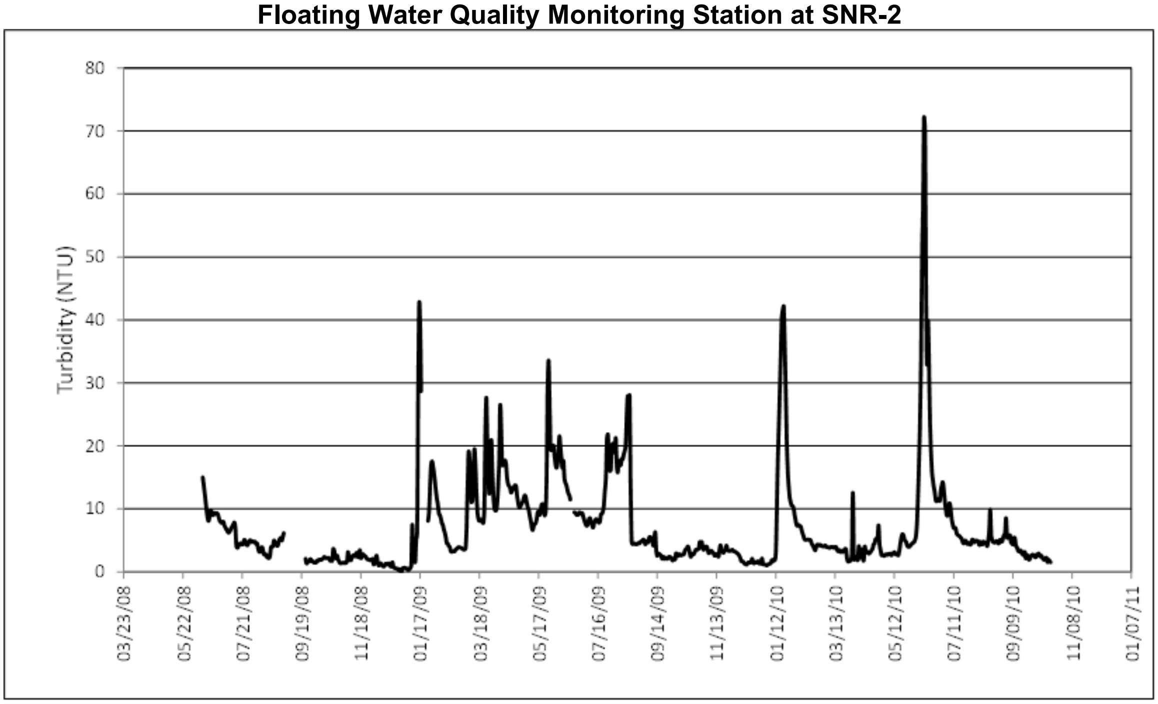
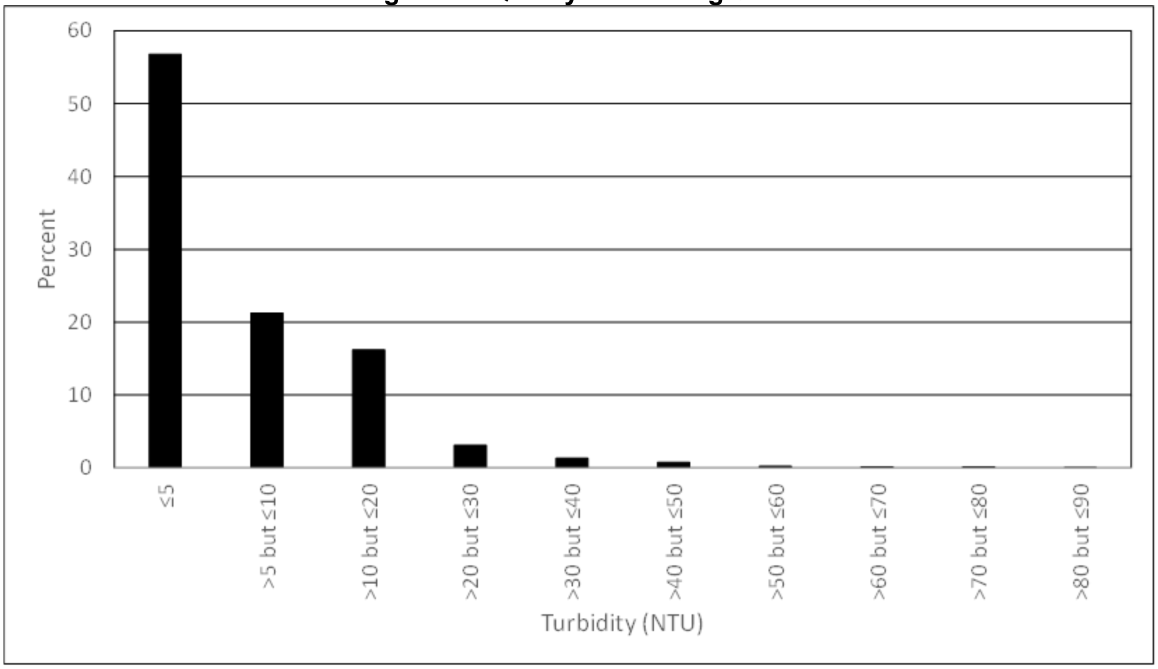


Figure 2-13. Frequency Distributions for the Hourly Turbidity Measured at the Floating Water Quality Monitoring Station at SNR-2

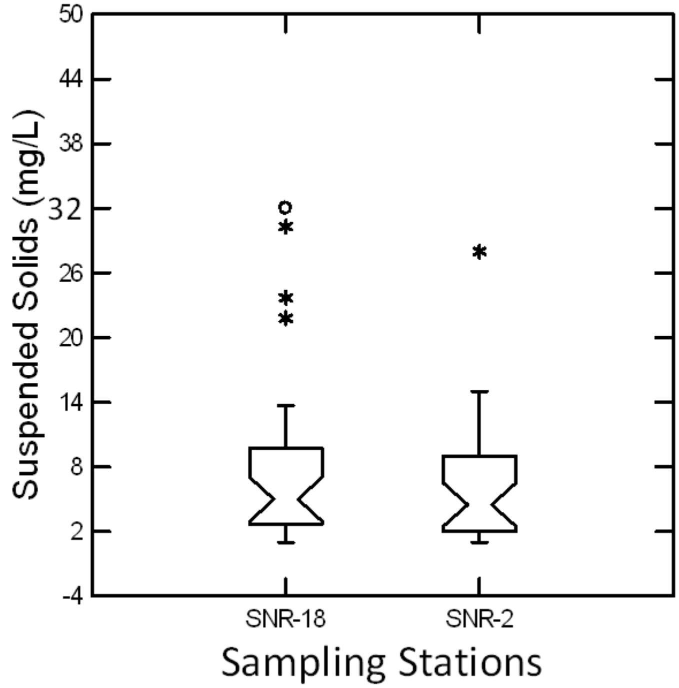


2.2.2.4 *Total Suspended Solids*

Total suspended solids are solid materials, organic and inorganic, that are suspended in the water and can include silt, plankton, and urban wastes. The general consensus of previous lower Snake River investigations is that larger particles transported by the rivers settle out in the transition zone in the vicinity of Lewiston, Idaho/Clarkston, Washington, and downstream in Lower Granite Lake. Finer material that passes Lower Granite Dam remains suspended. The highest concentrations are generally observed at deeper sampling depths, but elevated concentrations occasionally occur near the surface in the reservoirs as a result of localized algal blooms, port operations, and tributary inflows.

Total suspended solids concentrations displayed several similarities, and some differences, with the turbidity data. The median water-column concentration at both SNR-18 and SNR-2 was 5 mg/L (Figure 2-14). Approximately 80 percent of the data was less than or equal to 10 NTU at both locations, and 60 to 65 percent was less than or equal to 6 NTU.

Figure 2-14. Box Plot of Water-Column Total Suspended Solids Measured at SNR-2 and SNR-18 from 2008 to 2010



2.2.2.5 *Light Attenuation*

Light attenuation in the water column is dependent on the type and quantity of dissolved or suspended material. One of the traditional field methods for determining this parameter is Secchi disk depth. The median Secchi disk depths determined for SNR-2 and SNR-18 were very similar, 2.1 and 2.3 meters, respectively (Figure 2-15). Though there were exceptions, the general trend was for greatest light penetration from late fall through early spring and minimum values during the summer (Figure 2-16).

Figure 2-15. Box Plots of the Secchi Disk Depths Determined at SNR-2 and SNR-18 from 2008 to 2010

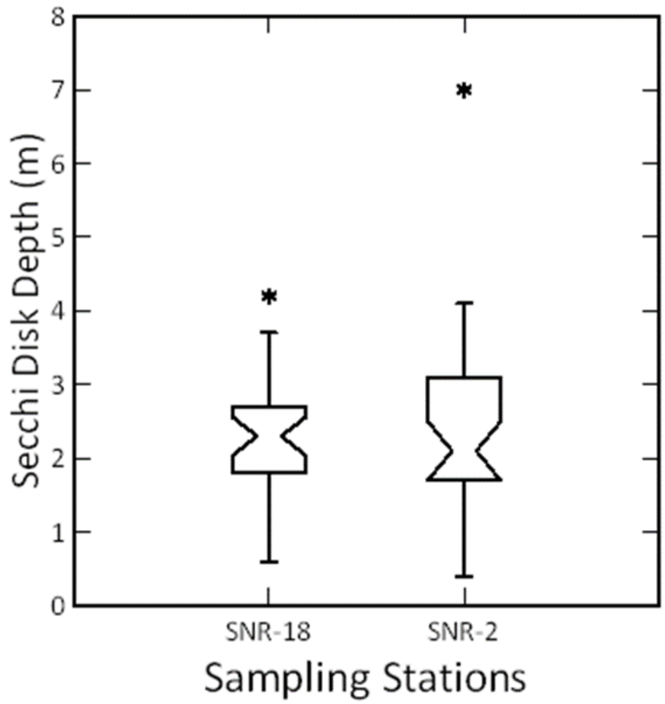
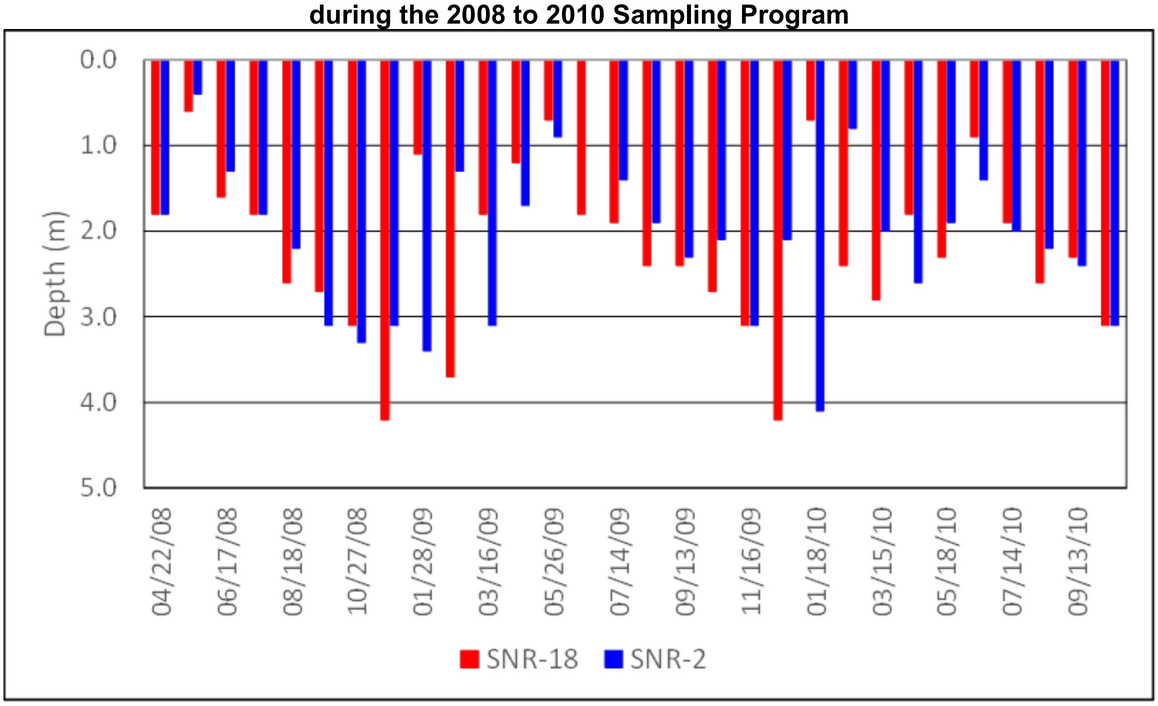


Figure 2-16. Secchi Disk Depths Recorded at SNR-2 and SNR-18 during the 2008 to 2010 Sampling Program

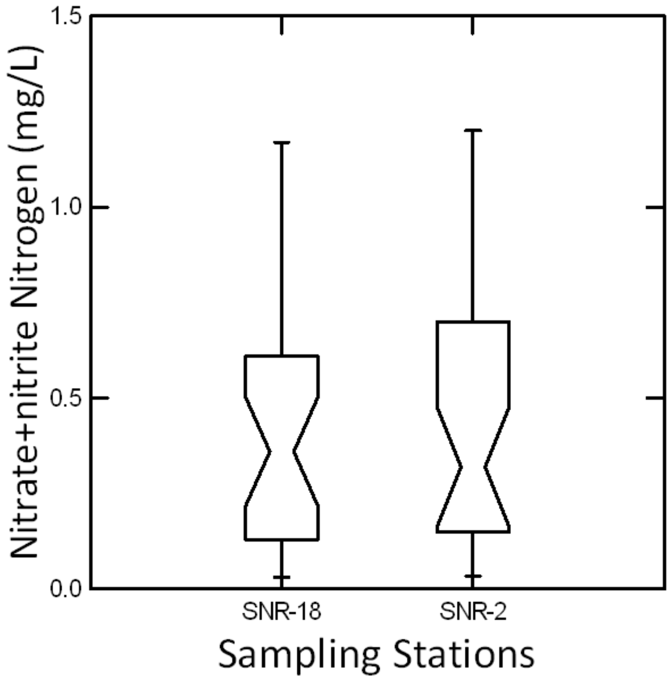


2.2.2.6 *Nitrogen and Phosphorus*

Nitrogen. Nitrate plus nitrite-nitrogen (NO_3+NO_2-N), hereafter referred to as nitrate, was the principal inorganic nitrogen component identified in the water samples comprising

96 percent of the soluble fraction at SNR-2 and SNR-18. The concentrations at SNR-2 and SNR-18 were not significantly different (Figure 2-17), with median concentrations of 0.32 and 0.37 mg/L, respectively. There was also a pronounced seasonal distribution with the highest concentrations occurring during the winter and low concentrations during the summer growing season as shown in the example for SNR-2 (Figure 2-18).

Figure 2-17. Box Plots of the Nitrate Plus Nitrite-Nitrogen Concentrations Measured at SNR-2 and SNR-18 from 2008 to 2010



Ammonia (NH_3-N) concentrations were consistently lower than nitrate values, often by an order of magnitude. Median concentrations at SNR-2 and SNR-18 were both 0.01 mg/L. Maximum concentrations determined for the same sampling stations were both near 0.10 mg/L, and only occurred once during the sampling period.

Total nitrogen (TN) includes inorganic and organic components. The median concentrations determined for SNR-2 and SNR-18 were 0.51 and 0.52 mg/L, respectively, and not significantly different for the duration latest sampling period (Figure 2-19). The seasonal pattern of TN concentrations at SNR-2 is shown in Figure 2-18 and is representative of both stations. The annual cycle is very similar to the one displayed for NO_3+NO_2-N, and in fact NO_3+NO_2-N comprises 67 to 68 percent of the total nitrogen at SNR-2 and SNR-18, respectively. Minimum concentrations ranged from 0.10 to 0.29 mg/L and occurred during the summer, while the highest values during the winter typically ranged from 1.0 to 1.5 mg/L.

Figure 2-18. Seasonal Distribution of the Total-N, Ammonia-N, and Nitrate+Nitrite-N Concentrations Determined at SNR-2 during the 2008 to 2010 Sampling Program

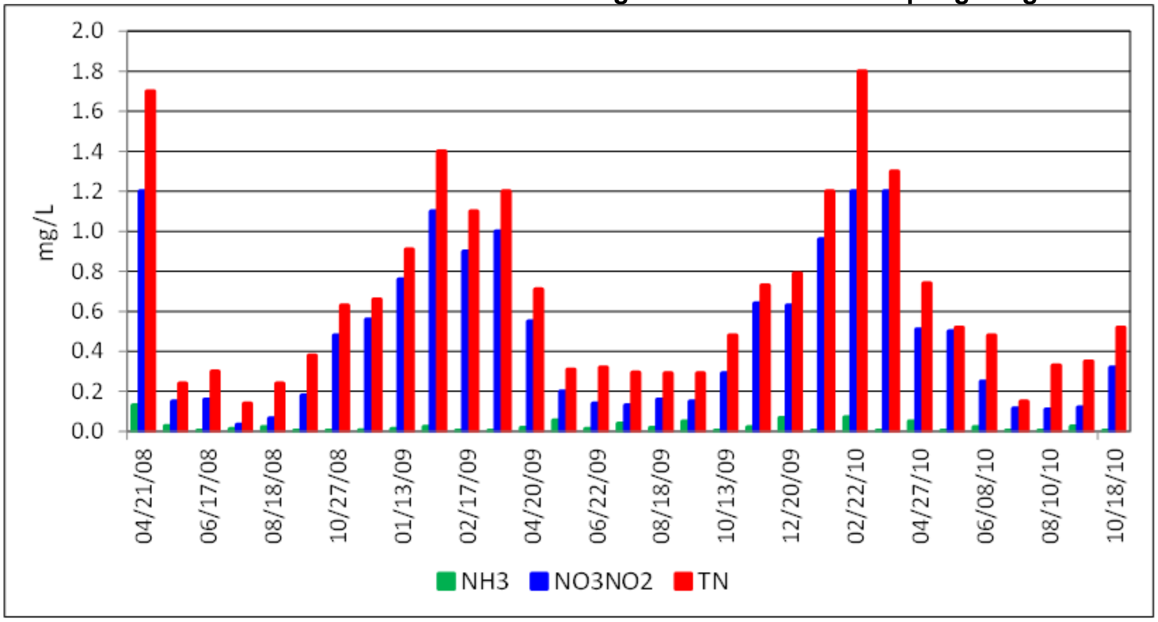
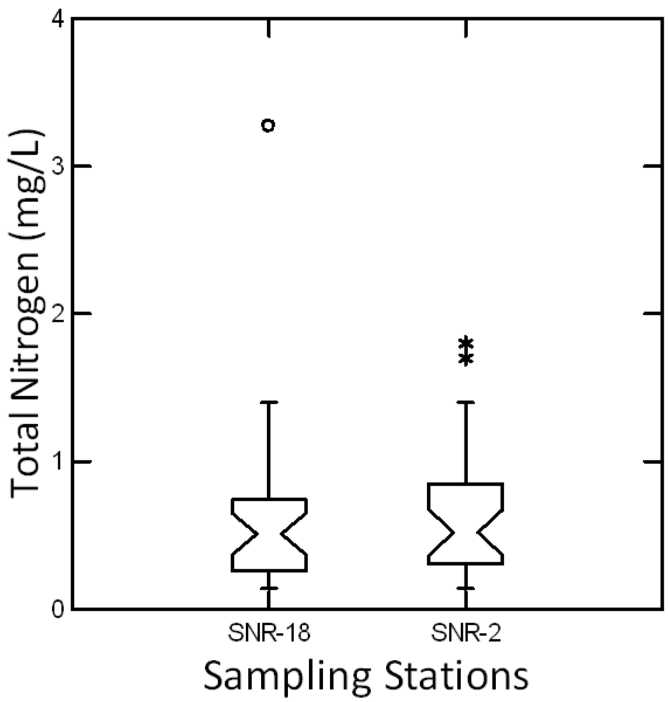


Figure 2-19. Box Plots of the Total Nitrogen Concentrations Measured at SNR-2 and SNR-18 from 2008 to 2010



<u>Phosphorus.</u> Phosphorus is generally expressed in terms of total phosphorus (total-P) and orthophosphorus (ortho-P). Ortho-P represents the inorganic soluble fraction of the total phosphorus in water and is generally considered to be more readily available for biological uptake than is total-P. Total-P consists of both the soluble fraction and that portion adsorbed to sediments or tied up with biological materials in the water column.

Since phosphorus readily attaches to and travels with sediments, adsorbed or biological quantities usually represent the largest portion of total-P. Phosphorus is often the limiting nutrient for plant growth in freshwater systems (Wetzel 2001).

Ortho-P concentrations above and below Ice Harbor Dam tend to be highest in the fall and winter, with relatively low concentrations in the summer. The calculated study period median for both sample locations was 0.023 mg/L (Figure 2-20). Summer concentrations were typically less than 0.010 mg/L and likely influenced by biological uptake by aquatic plants and algal growth. As plant growth diminished in the fall due to less uptake and biological senescence, the orthophosphorus concentrations increased to between 0.03 and 0.07 mg/L (Figure 2-21).

Figure 2-20. Box Plots of the Orthophosphorus Concentrations Measured at SNR-2 and SNR-18 from 2008 to 2010

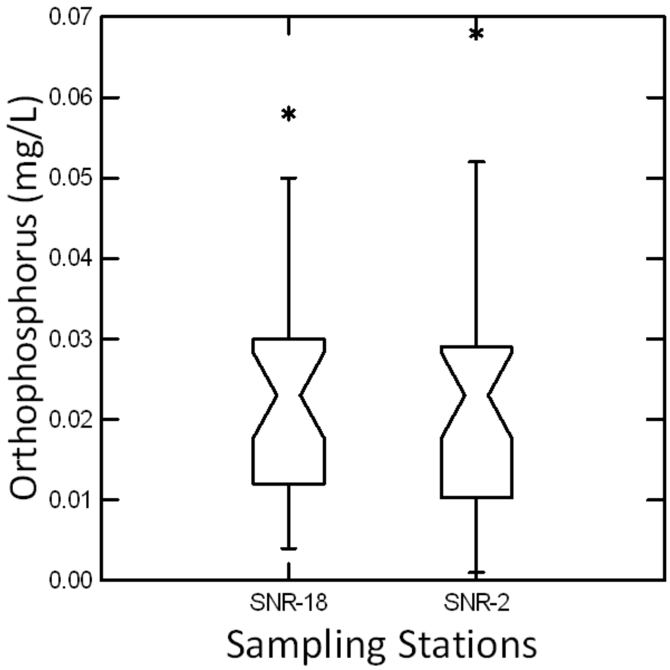
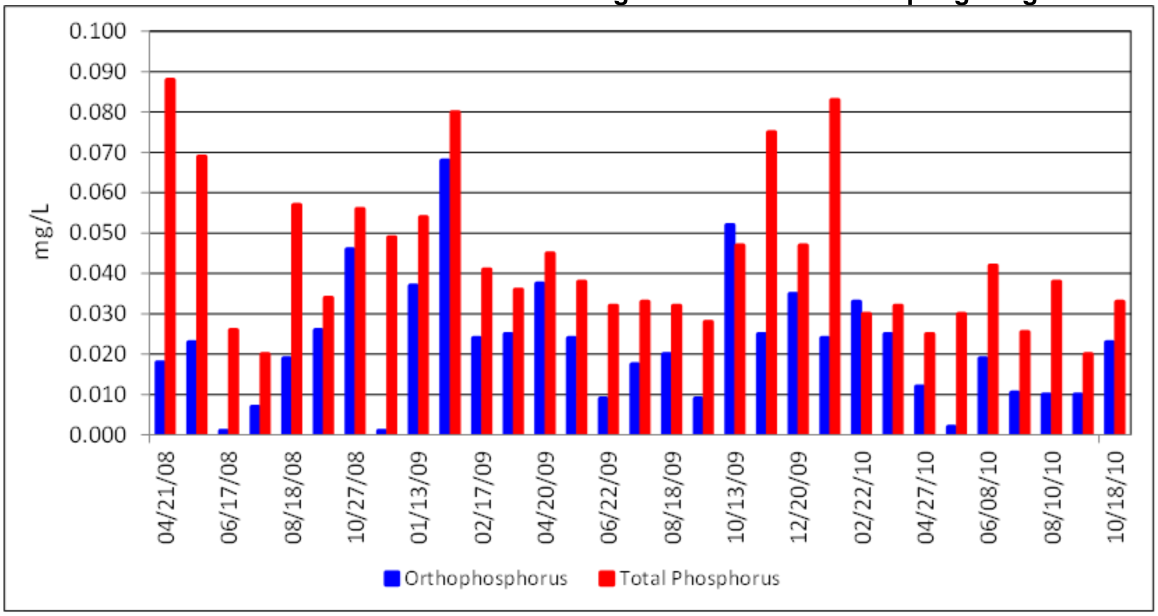
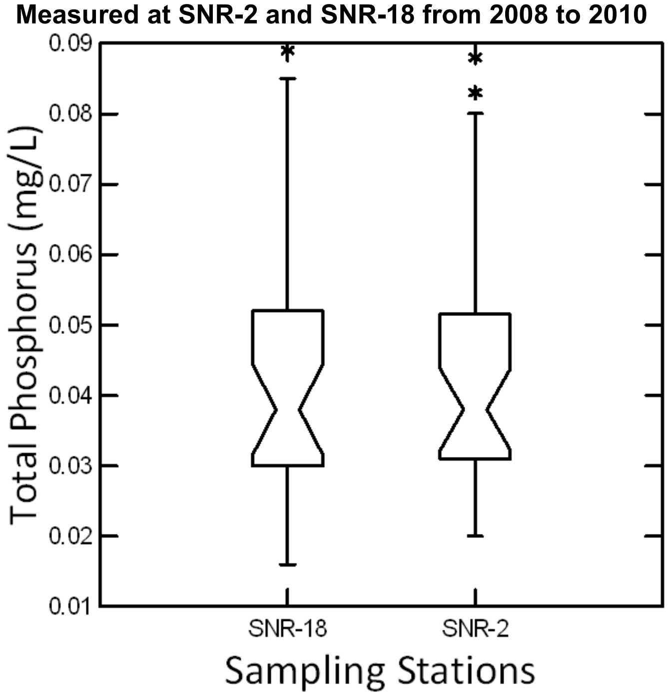


Figure 2-21. Seasonal Distribution of the Orthophosphorus and Total Phosphorus Concentrations Determined at SNR-2 during the 2008 to 2010 Sampling Program



Total-P concentrations generally followed the temporal pattern set by ortho-P (Figure 2-21). Approximately 50 percent of total-P consisted of the soluble ortho-P at both stations. The median water-column total-P concentrations were also very similar, 0.037 and 0.038 mg/L, at the upstream and downstream stations (Figure 2-22). The highest total-P concentrations generally occurred during the fall and winter when the concentrations of most ions increased due to less dilution, and during runoff events when suspended solids concentrations increased.

Figure 2-22. Box Plots of the Total Phosphorus Concentrations Measured at SNR-2 and SNR-18 from 2008 to 2010



2.2.2.7 *Organic Compounds*

Water samples from Lake Sacajawea have not been routinely analyzed for organic compounds.

2.2.3 Biological

2.2.3.1 *Chlorophyll a*

Chlorophyll a is a specific form of chlorophyll used in oxygenic photosynthesis. It absorbs most of its energy from wavelengths of the violet-blue and orange-red light range. It is essential for photosynthesis in most algae and green plants and is often used as a trophic state indicator and as an indirect measure of phytoplankton biomass.

Chlorophyll a concentrations displayed some differences between the reservoir and downstream transition zone sampling station. The overall calculated median for the SNR-2 data was 2.8 μg/L, which is less than the 3.9 μg/L determined for SNR-18 (Figure 2-23). When only the June through September data is considered, the differences were greater: 4.2 micrograms per liter (μg/L) at SNR-18 and 2.9 μg/L at SNR-2 (Figure 2-24).

Figure 2-23. Box Plots of the Chlorophyll a Concentrations Measured at SNR-2 and SNR-18 from 2008 to 2010

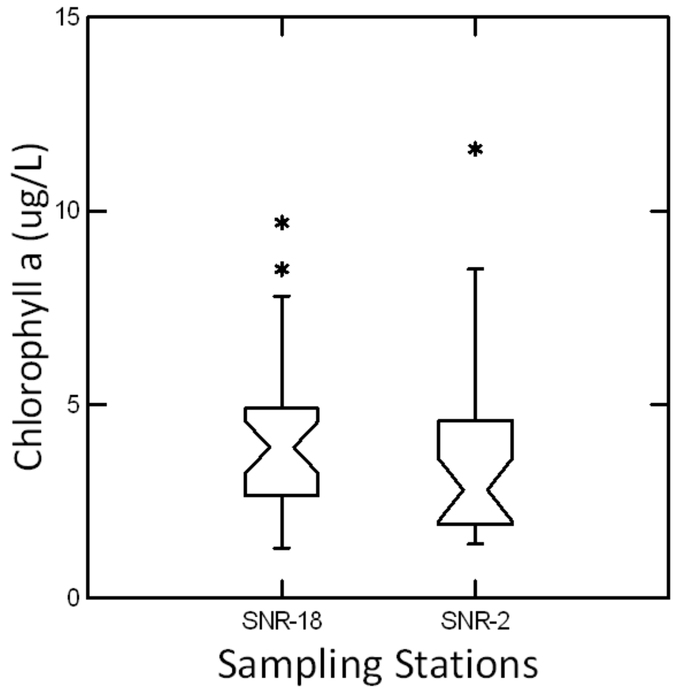
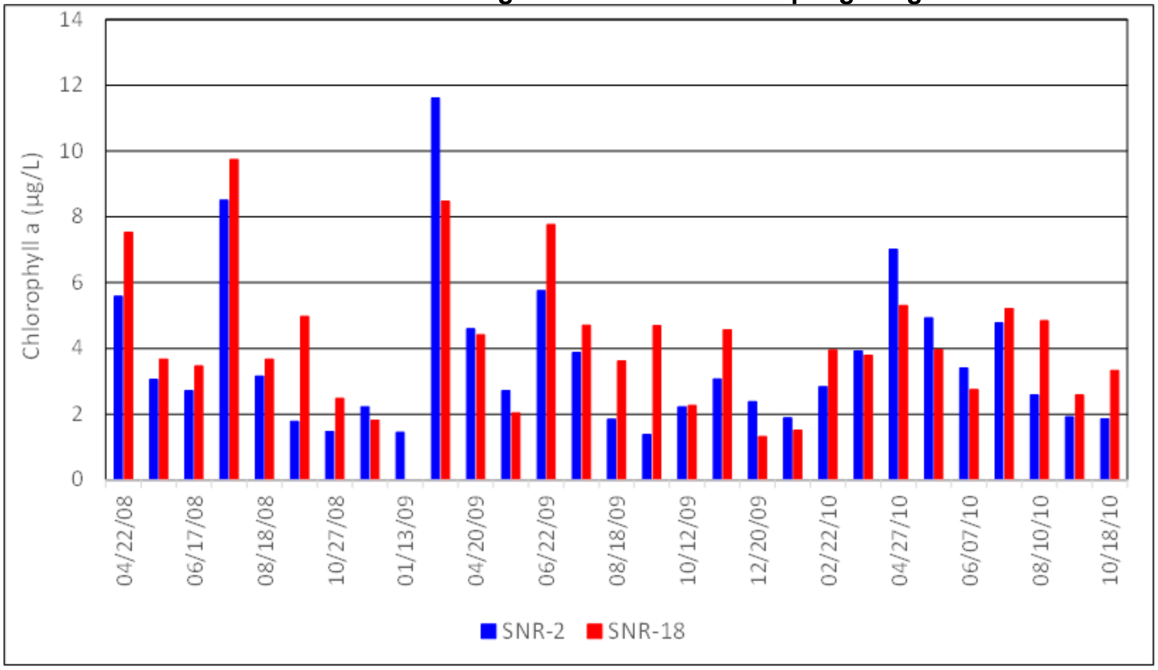


Figure 2-24. Chlorophyll a Concentrations Determined for SNR-2 and SNR-18 during the 2008 to 2010 Sampling Program



2.2.3.2 *Phytoplankton*

Phytoplankton, also called algae, are small, photosynthetic organisms found floating in the water column. They lack any roots, stems, or leaves, thereby separating them from higher plants. Planktonic algae are found in unicellular, colonial, or filamentous forms and range in size from 5 micrometers across to over 100 micrometers in diameter. They are found in all lakes, slow-flowing rivers, estuaries, and oceans. Their role as primary producers makes them an important part of aquatic ecosystem. Algae use inorganic compounds to make complex organic molecules through the photosynthetic process, and are an essential link to higher trophic levels of the food web. As necessary as they are to the aquatic system, phytoplankton can also be a nuisance. If conditions in a body of water shift to favor a particular species, algal blooms of 5 to 50 million cells per liter can occur. This sometimes results in lower water quality, specifically poor taste, odor, and color (Horne and Goldman 1994).

Phytoplankton are the most important primary producer in the lower Snake River. At the foundation of the food web, they transform light and nutrients into energy for herbivores such as zooplankton, which in turn support higher trophic levels. Phytoplankton grow best in low-velocity waters with warm temperatures and high nutrient availability, particularly phosphorus. Phytoplankton growth is generally limited in stream or riverine systems that have much greater flow velocities. In evaluating phytoplankton data, a relative increase in species diversity or richness under similar habitat conditions is often considered a positive indication of improving ambient water quality conditions. In contrast, the dominance of certain robust species, such as some species of blue-green algae, can often be indicative of poor water quality conditions. To evaluate the importance of phytoplankton as a food source, the volume or quantity of algae available for consumption is often the most critical parameter to be considered. For this reason, phytoplankton data is typically expressed in terms of overall biovolume (*i.e.,* cubic micrometers per liter [$\mu m^3/L$]) as well as species composition.

The phytoplankton biovolume determined for the SNR-2 and SNR-18 sampling stations is shown in Figure 2-25. The calculated median for SNR-2 was 4.08×10^9 $\mu m^3/L$ compared to 5.18×10^9 $\mu m^3/L$ at SNR-18. These values, though not the same, are not considered to be significantly different.

The phytoplankton biovolume and species composition at SNR-2 and SNR-18 were similar. Bacillariophyta (diatoms) were the dominant component and comprised greater than 97 percent of the biovolume, followed by about one percent each of Chlorophyta (green algae) and Cryptophytes (Figure 2-26, Figure 2-27 and Figure 2-28; Table 2-4). The greatest median diatom biovolume determined for the most recent investigation at both locations was attributed to *Aulascoseira* spp. (primarily *Aulascoseira granulata*) at 1.57×10^9 $\mu m^3/L$ at SNR-18 and 8.54×10^8 $\mu m^3/L$ at SNR-2. Their abundance did not show a definite annual cycle, but there were times when they accounted for almost 70 percent of the diatom biovolume at SNR-2 and from 70 to 90 percent at SNR-18. The overall biovolume attributed to *Stephanodiscus* spp. (primarily *S. niagarae,* and to a lesser extent, *S. hantzschii* and *S. parvus*) was less than that of *Aulascoseira* spp. at both locations. The median biovolume of this genus for the study period was 6.42×10^8 $\mu m^3/L$ at SNR-18 and 5.08×10^8 $\mu m^3/L$ at SNR-2. Maximum values did exceed 1.5×10^{10} $\mu m^3/L$ during individual sampling trips, though at different times of the year. *Synedra* spp. (primarily *Synedra ulna*) was more prevalent at SNR-2 than at the upstream reservoir location. During the two-year study their calculated median biovolume at SNR-2 was 1.73×10^8 $\mu m^3/L$, or 2.9 percent, while at SNR-18 it was 1.25×10^8 $\mu m^3/L$, or 5.7 percent of the total diatom biovolume. *Fragilaria* spp. biovolume (primarily due to *Fragilaria crotonensis)* was very similar at both stations. The calculated median for SNR-2 was 8.31×10^7 $\mu m^3/L$ compared to 7.70×10^7 $\mu m^3/L$ at SNR-18. In both cases, this accounted for a little over 3 percent of the total for the diatoms. As with the other genera, there were months when their contribution to the total was between 20 to 50 percent, but they generally accounted for less than 5 percent during any sampling event.

Figure 2-25. Box Plots of the Phytoplankton Biovolume Determined for the Samples Collected at SNR-2 and SNR-18 from 2008 to 2010

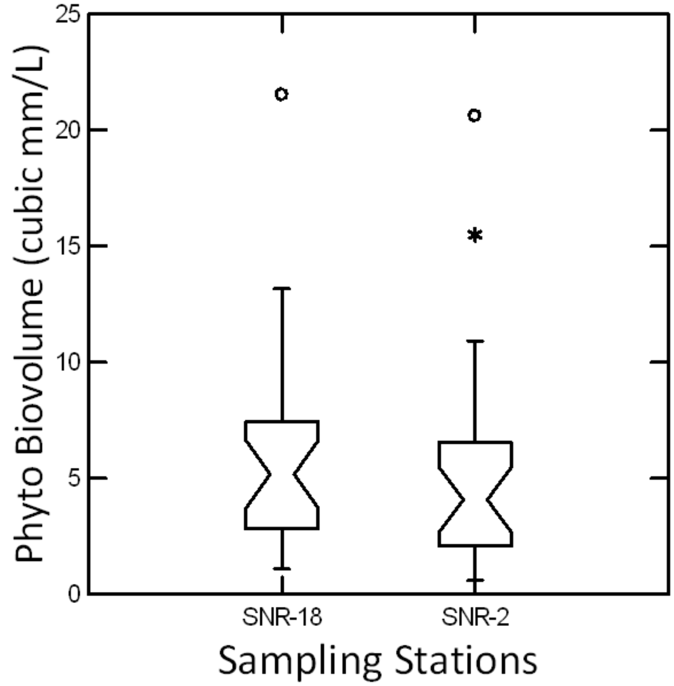


Figure 2-26. Phytoplankton Assemblage Percent Composition at the SNR-2 and SNR-18 Sampling Stations from 2008 to 2010

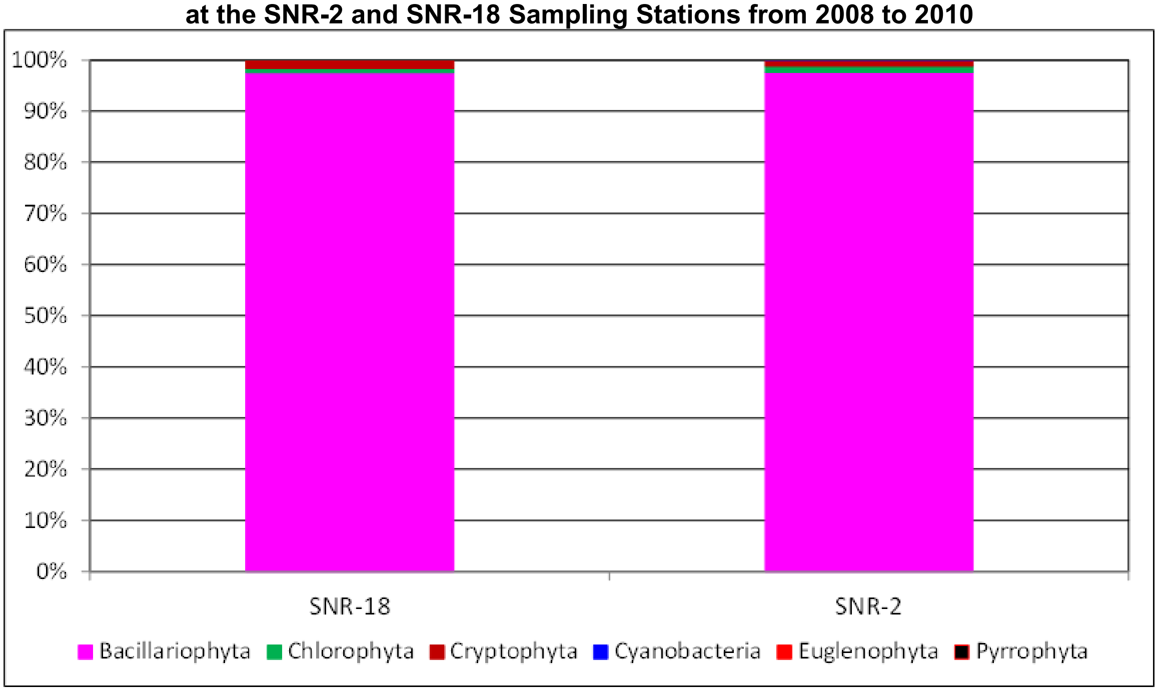


Figure 2-27. Median Biovolume for the Major Phytoplankton Divisions at SNR-2 and SNR-18 during the 2008 to 2010 Sampling Program

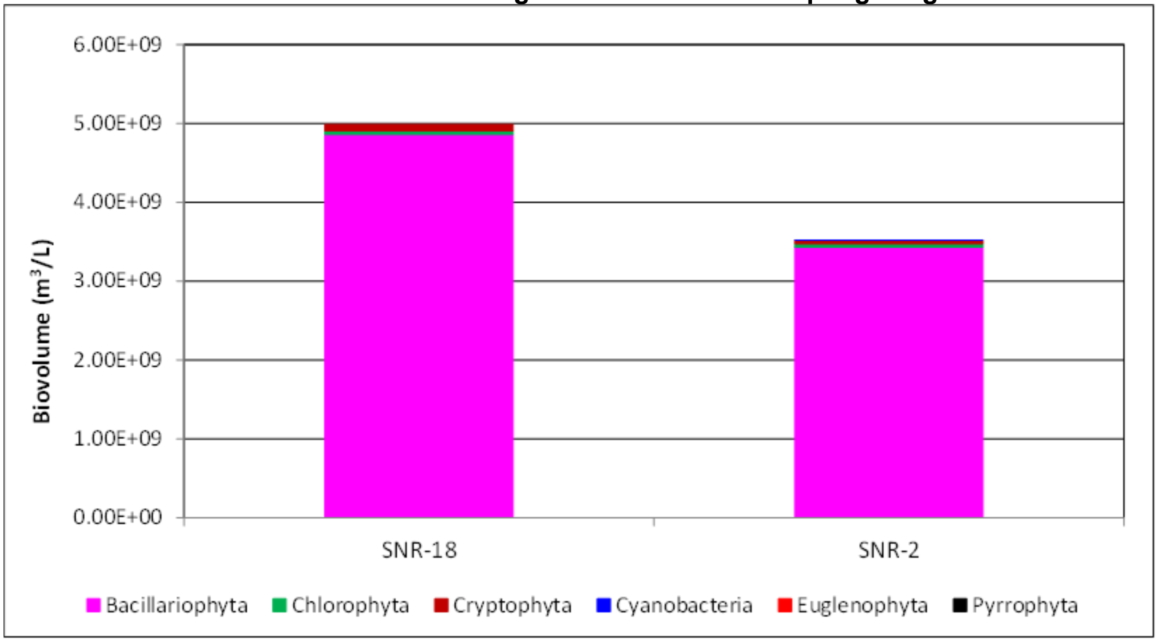


Figure 2-28. Time-Series Biovolume Plots for the Major Phytoplankton Groups Identified at SNR-2 and SNR-18 during the 2008 to 2010 Study

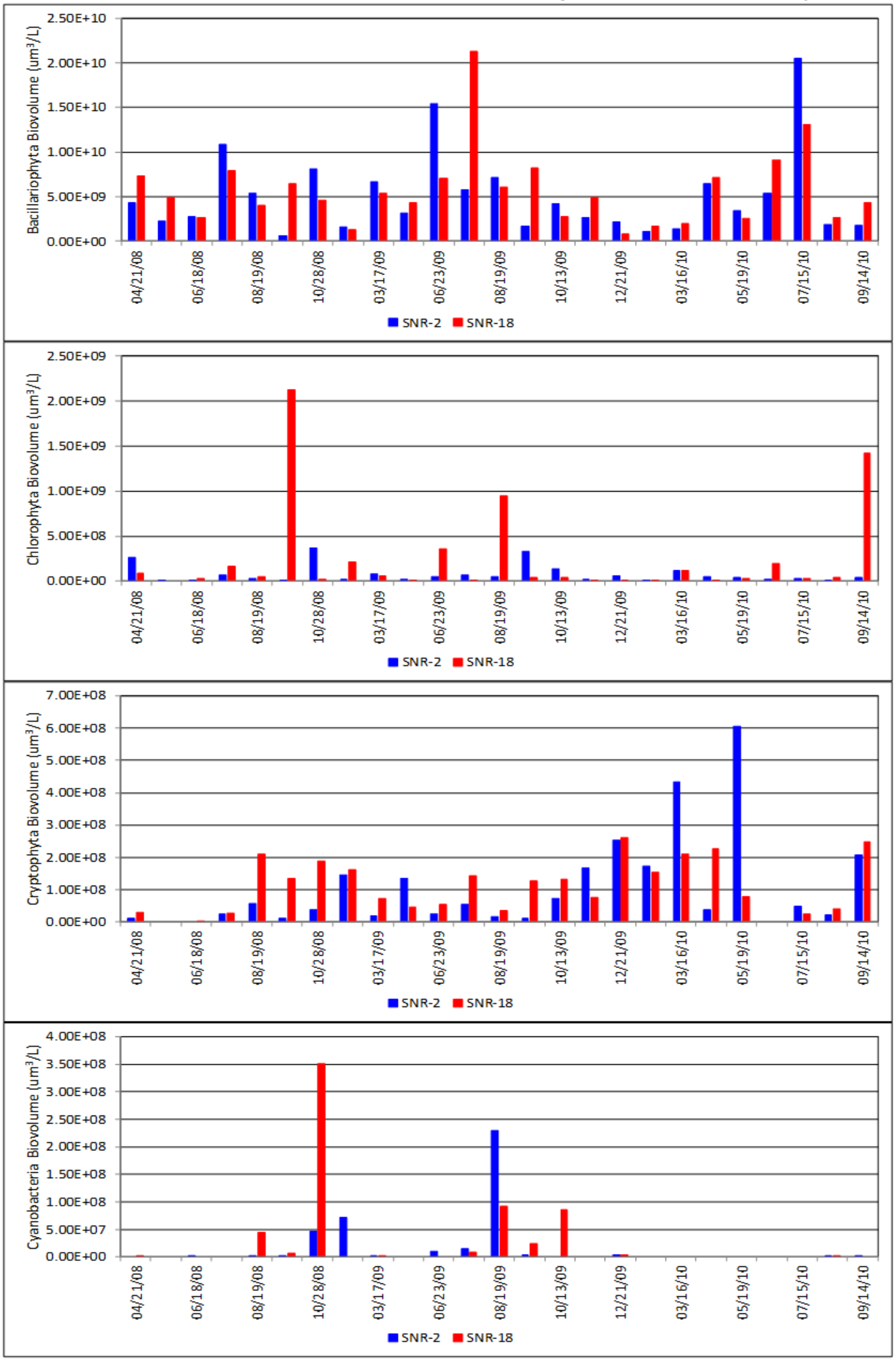


Table 2-4. Median Biovolume (µm3/L) Estimates for the Major Bacillariophytes, Chlorophytes, and Cryptophytes Identified in the 2008 to 2010 SNR-2 and SNR-18 Samples

Type	Station	SNR-18	SNR-2
Bacillariophyta	Total	4.86 x 109	3.43 x 109
Bacillariophyta	Aulacoseira	1.57 x 109	8.54 x 108
Bacillariophyta	Fragilaria	7.70 x 107	8.31 x 107
Bacillariophyta	Melosira	1.90 x 107	4.53 x 107
Bacillariophyta	Stephanodiscus	6.42 x 108	5.08 x 108
Bacillariophyta	Synedra	1.25 x 108	1.73 x 108
Chlorophyta	Total	4.47 x 107	4.64 x 107
Cryptophyta	Total	8.02 x 107	3.94 x 107

The median Chlorophyte biovolume above and below Ice Harbor Dam was less than 1 percent of the total algal biovolume (Table 2-5). *Pyramimonas tetrarhynchus* was the species most consistently present with a 2008 to 2010 median of 2.77 x 10^7 µm^3/L (71 percent of the green algae biovolume) at SNR-18 and 2.02 x 10^7 µm^3/L at SNR-2 (54 percent of the green algae biovolume). *Selenastrum* spp., *Chlamydomonas* spp., *Sphaerocystis schroeteri*, and *Pediastrum duplex* were additional species that were periodically the primary species identified, but not on a consistent basis.

Rhodomonas spp. was the dominant Cryptophyte at both locations. The median study period biovolume at SNR-18 was 8.02 x 10^7 µm^3/L, and, on average, accounted for 98 percent of the Cryptophyte biovolume. The median biovolume of *Rhodomonas* spp. at SNR-2 was lower at 3.81 x 10^7 µm^3/L, or 96 percent of the Cryptophyte total. However, during 68 percent of the sample trips at SNR-2, and 60 percent of the sample trips SNR-18, they constituted less than 2 percent of the total biovolume.

The blue-green algae population was ephemeral with shifts in dominant species. Their overall median contribution to the total phytoplankton biovolume was less than 1 percent, but there were some exceptions during individual sampling events. At SNR-18, *Oscillatoria* spp. comprised almost 7 percent of the total with a biovolume of 3.49 x 10^8 µm^3/L during the October 2008 sampling event. The following October, *Aphanizomenon* spp. was the primary blue-green at 7.69 x 10^7 µm^3/L, or 2.5 percent of the total. At the downstream sampling station, *Microcystis* spp. comprised 4 percent of the total with a biovolume of 7.21 x 10^7 µm^3/L during the latter part of November 2008. The next major blue-green event at the same location occurred in August 2008 when *Cylindrospermopsis raciborskii* reached a biovolume of 2.05 x 10^8 µm^3/L, or 3 percent of the total.

2.2.3.3 *Primary Productivity*

Primary productivity is a measure of the amount of carbon per unit time produced by all aquatic plants. As primary producers form the base of the food chain, the level of primary productivity ultimately dictates the productivity of the entire ecosystem. Primary productivity rates were not determined for this EIS but were evaluated during previous investigations in 1994, 1995, and 1997 (Corps 2002). Using the most recent 1997 June through October results as an example, the calculated median for SNR-18 was 12.57 milligrams carbon-12 per cubic meter per hour (mg $^{12}C/m^3$/hr) and 9.49 $^{12}C/m^3$/hr below the dam at SNR-6. Maximum productivity was determined for both stations at the beginning of July with values of 27.92 mg $^{12}C/m^3$/hr and 24.35 mg $^{12}C/m^3$/hr at SNR-18 and SNR-6, respectively.

2.2.3.4 *Zooplankton*

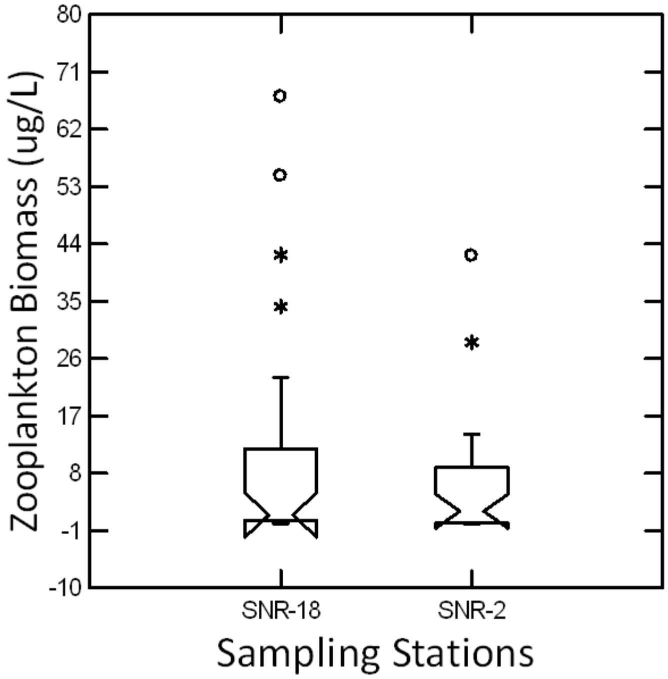
The term zooplankton refers to invertebrate animals living in the water column of freshwater bodies. These planktonic animals are typically divided into three major groups based on taxonomy: the phylum Rotifera, and two orders of the Crustacea, the Cladocera and Copepoda. Zooplankton feed by filtering 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.

The box plot of total zooplankton biomass for the two sampling stations in the vicinity of Ice Harbor Dam is presented in Figure 2-29 and Table 2-5, and the calculated median for the two locations was not significantly different. However, the maximum biomass determined at SNR-18 during any sampling event was 95.6 µg/L, which is more than twice the valued determined at SNR-2 (42.1 µg/L).

Table 2-5. Median biomass (µg/L) estimates for the Cladocera, Copepoda, and Rotifera identified in the 2008 through 2010 SNR-2 and SNR-18 samples

Location	Cladocera	Copepoda	Rotifera
SNR-2	0.033	0.689	0.199
SNR-18	0.044	0.678	0.601

Figure 2-29. Box Plots of the Zooplankton Biomass Determined for the Samples Collected at SNR-2 and SNR-18 from 2008 to 2010



Copepods comprised the majority of the zooplankton biomass at both stations, followed by the Cladocerans and Rotifers (Figure 2-30 and Figure 2-31). *Cyclopoid copepodid* and nauplii were present during most of the year but were usually more abundant during the summer and early fall (Figure 2-32). The median biomass for *Cyclopoid copepodid* at SNR-18 was 0.26 µg/L, and 0.11 µg/L at SNR-2. Maximum biomass at the reservoir station was 8.83 µg/L during September 2009 and 4.11 µg/L at SNR-2 during March 2010. Nauplii biomass was also lower at SNR-2, where the median and peak values were 0.06 and 0.80 µg/L, respectively. As with the *Cyclopoid* spp. biomass, nauplii biomass at SNR-18 was approximately two times greater with a median of 0.11 µg/L and a maximum of 2.4 µg/L. Peak abundance occurred during August and September at both stations. Additional Copepods that were more ephemeral, yet their biomass was sometimes greater than that determined for the *Cyclopoid* spp. including *Calanoid copepodid, Diacyclops thomasi, Leptodiaptomus* sicilis, and *Tropocyclops prasimus*. *Daphnia retrocurva* was the primary Cladocera at both locations, but their abundance was very ephermeral. Peak biomass at SNR-18 was 51 µg/L and much lower at 6.1 µg/L at SNR-2. Additional Cladocera that were also present periodically included *Eubosmina hagamanni*, *Eubosmina coregoni, Bosmina longirostris*, and *Camptocercus macrurus.* The median contribution of the Rotifers to the total zooplankton biomass was 18.7 percent at SNR-18 and 22.0 percent at SNR-2. Their greatest presence typically occurred during the late winter or spring when they comprised greater than 90 percent of the total biomass. These events were usually dominated by *Brachionus calyciflorus* with biomass as high as 92 µg/L at SNR-18 and 27 µg/L at SNR-2. Additional representatives of the Rotifera division that were occasionally in the majority included *Polyarthra vulgaris*, *Synchaeta pectinata*, and *Notholca acuminate*.

Figure 2-30. Median Zooplankton Assemblage Percent Composition at SNR-2 and SNR-18 during the 2008 to 2010 Sampling Program

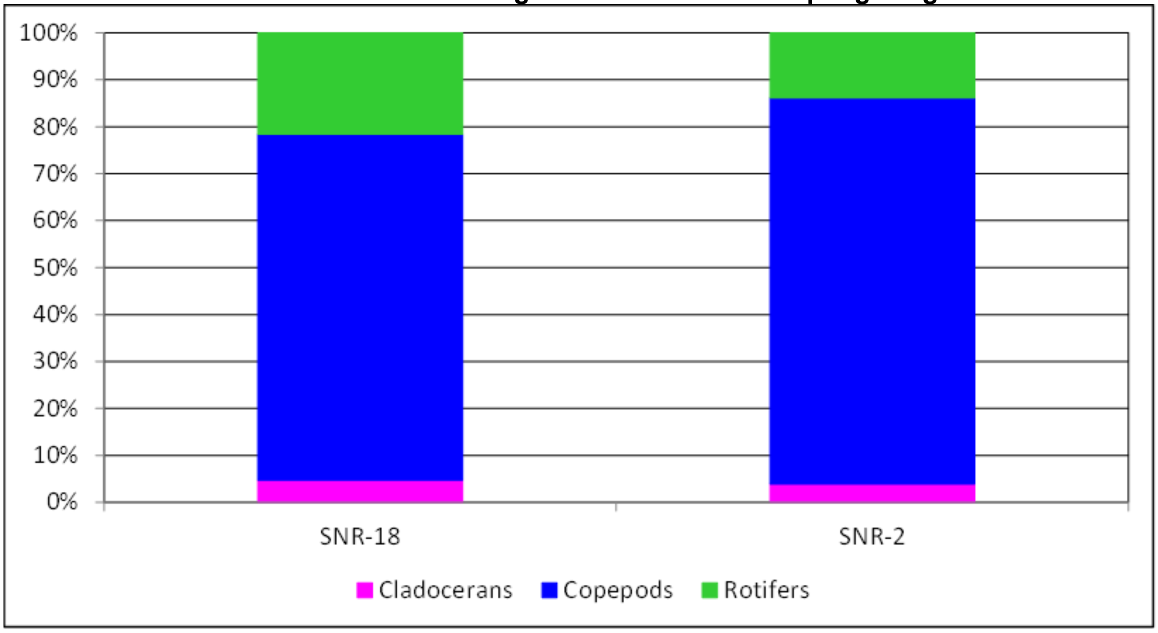


Figure 2-31. Median Biomass for the Major Zooplankton Divisions at SNR-2 and SNR-18 during the 2008 to 2010 Sampling Program

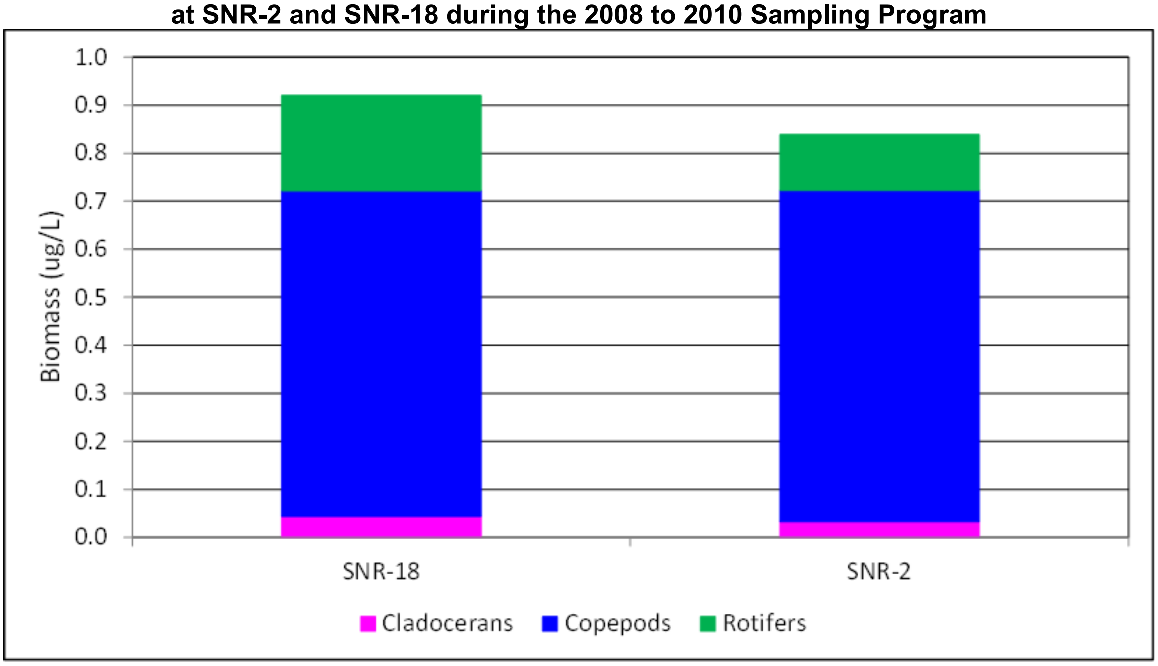
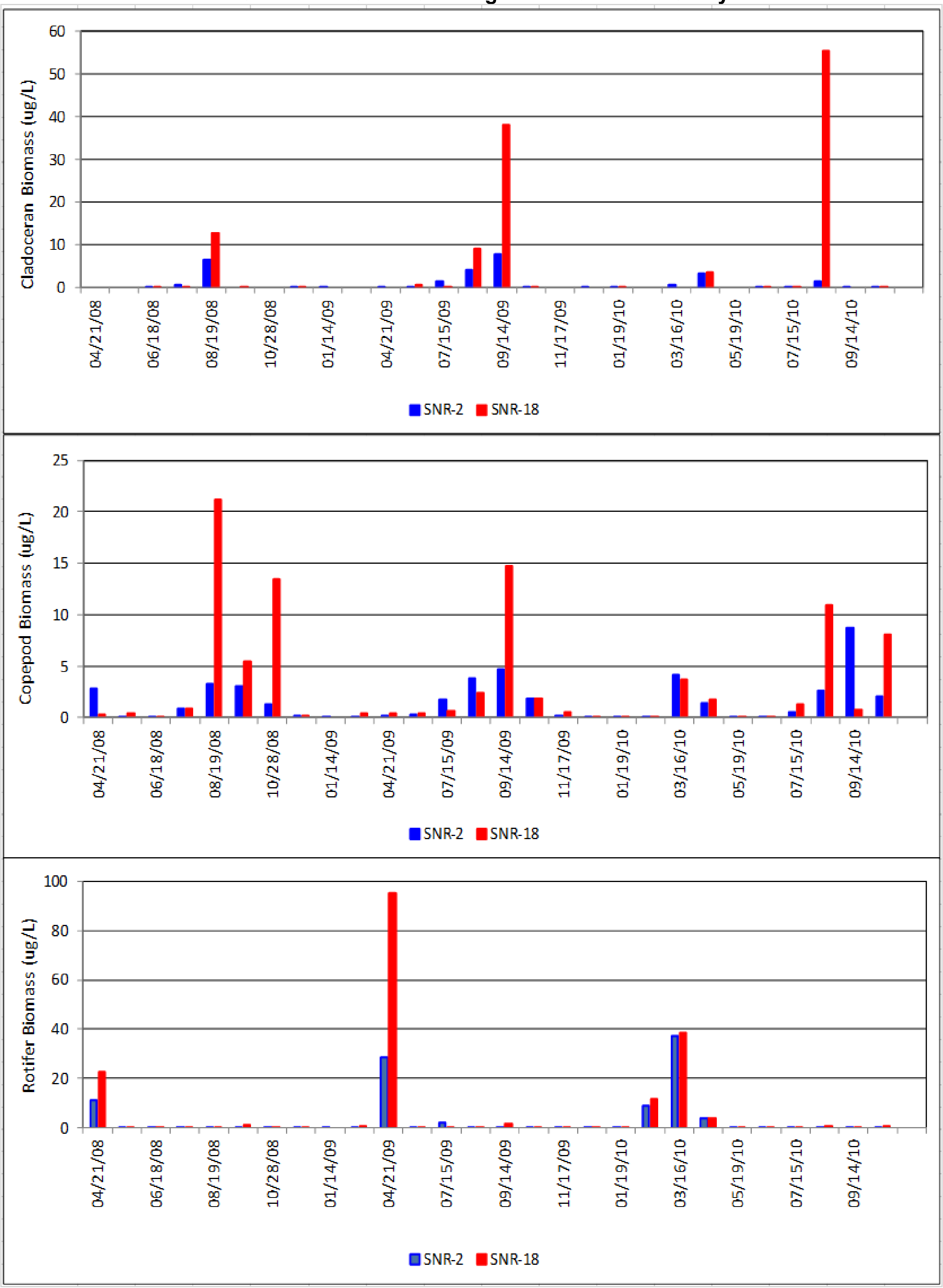


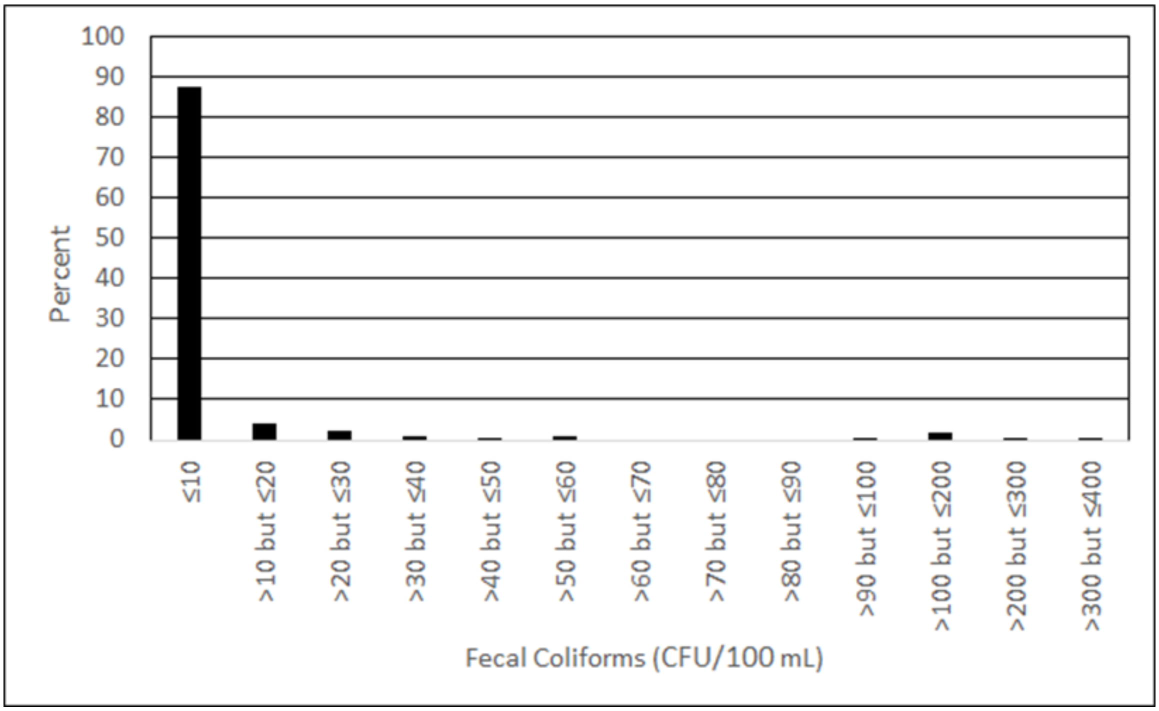
Figure 2-32. Time-Series Biomass Plots for the Major Zooplankton Groups Identified at SNR-2 and SNR-18 during the 2008 to 2010 Study



2.2.3.5 *Coliforms and Other Microbial Organisms*

Snake River water samples that were collected at the U.S. Highway 12 Bridge (Station 33A050) have been analyzed by the Washington State Department of Ecology for fecal coliforms since 1990. However, there is very little, and often no data for the period from 1967 to December 1990. Three-hundred two samples have been processed for the site, and the geometric mean for the entire dataset is 2.7 colony forming units per 100 milliliters (CFU/100 mL). A frequency distribution of the data (Figure 2-33) shows that over 87 percent of the data was less than 10 CFU/100 mL, and only 5.2 percent of the data points were greater than 30 CFU/100 mL.

Figure 2-33. Frequency Distribution of the Fecal Coliform Data Collected at SNR-2.2 from 1990 to 2017



2.2.4 Trophic State Classification

The trophic state of a lake or reservoir has been defined in various ways over the years. Three common distinctions are oligotrophic, mesotrophic, and eutrophic classifications. Oligotrophic conditions represent high-quality waters with good water clarity, low nutrient content, and low algal production, while eutrophic conditions represent high nutrient levels, excessive algal growth, and poor water clarity. Mesotrophic conditions are somewhere in the middle and typically represent moderate levels of algal production, water clarity, and light transparency.

Several metrics have also been used to express the trophic state of a water body. These indices include nutrient loading, nutrient concentration, light penetration, chlorophyll a concentration, algal or zooplankton species and abundance, oxygen concentration, aquatic vegetation, and other limnological parameters used individually or combined. The Carlson Trophic State Index (TSI) is one of the more commonly used trophic indices and is the one used by the EPA. Three independent variables can be used to calculate the Carlson TSI: Secchi disk depth, chlorophyll a concentration, and total-P concentrations. Calculated values of less than 40, 40 to 50, and 50 to 70 represent oligotrophic, mesotrophic, and eutrophic conditions, respectively (Chapra and Reckhow 1983).

The calculated Secchi disk TSI for the reservoir station was 51 when summer growing season measurements for 2008 to 2010 were used, and ranged from 49 in 2010 to 52 in 2008. Based on this method, the reservoir would be considered upper mesotrophic to lower eutrophic.

Chlorophyll a concentrations, as well as calculated Carlson TSIs, are measures of a lake or reservoirs trophic state. Published literature from some water bodies suggests that average chlorophyll *a* levels above 5.0 and 14.5 µg/L are indicative of mesotrophic and eutrophic conditions, respectively (Corps 2002). Wetzel (2001) provides broader ranges, stating that annual mean chlorophyll *a* levels between 3.0 and 11.0 µg/L indicate mesotrophic conditions, while a range of 3.0 to 78.0 µg/L represents eutrophic conditions. The calculated Carlson TSIs for SNR-18, based on integrated field samples analyzed in a laboratory, range from 43 in 2008 to 46 in 2009, with combined TSI of 45. These values suggest mesotrophic conditions.

Total-P concentrations are often used as trophic state indicators. According to the State of Washington water quality standards for lakes in the Columbia Basin Ecoregion, total-P levels greater than 0.020 to 0.035 mg/L are considered indicative of upper mesotrophic conditions, and if the concentration exceeds 0.035 mg/L, a lake–specific study should be initiated. A Carlson TSI can also be calculated using total phosphorus concentrations. The results from using summer average water column concentrations provided SNR-18 TSIs that ranged from 52 in 2008 to 54 in 2009 and 2010. Based on this metric, Lake Sacajawea would be classified as lower eutrophic.

2.2.5 Data Correlations

The non-parametric Kendall rank correlation coefficient (Kendall's tau) test was used to determine correlation coefficients between parameters. This type of analysis measures the strength and direction of a linear relationship between two variables (nonlinear relationships and those involving multiple variables are not considered). The Kendall's tau values range from -1 (a perfect downhill or negative relationship) to +1 (a perfect uphill or positive relationship), and the farther they are from zero, the stronger the relationship. It must be remembered that correlation does not imply causality, and it does not facilitate predicting a dependent variable from an independent variable. The Kendall's tau values were tested for significance at $\alpha = 0.05$ and are identified with bold font in Table 2-6 and Table 2-7.

The correlation coefficients determined for the upper 5 meters of water at SNR-18 and SNR-2 showed some similarities and differences. Flow was positively correlated with dissolved oxygen saturation (0.69) and turbidity (0.58) at both locations; 0.69 and 0.58, respectively, at SNR-2 and 0.66 and 0.62, respectively, at SNR-18. Flow was also negatively correlated with Secchi disk depth at both locations, with a stronger coefficient at SNR-18 (-0.57) than at SNR-2 (-0.40). Turbidity was also negatively correlated with Secchi disk depth at both locations; -0.68 at SNR-2 and -0.88 at SNR-18. The positive correlation between phytoplankton biovolume and chlorophyll a was essentially the same at both locations: 0.43 at SNR-2 and 0.44 at SNR-18. The remaining correlation coefficients between the phytoplankton, zooplankton, and the other parameters were either less than 0.40 or greater than -0.40 at both locations.

Table 2-6. Kendall's Tau-B Correlation Matrix for SNR-2

	Flow	Temp.	% DO	DO-mg/L	pH	Sp. Cond.	Turb.	NH_3-N	NO_3+NO_2	Total-N	PO_4-P	Total-P	TSS	Secchi	Chl a	Phyto BV	Zoop BM
Flow	1.00																
Temp.	0.08	1.00															
% DO	**0.69**	0.05	1.00														
DO-mg/L	**0.41**	**-0.45**	**0.51**	1.00													
pH	-0.12	-0.21	0.04	0.22	1.00												
Sp. Cond.	**-0.41**	**-0.41**	**-0.34**	0.01	**0.44**	1.00											
Turb.	**0.58**	-0.01	**0.48**	**0.34**	-0.12	-0.34	1.00										
NH_3-N	0.18	-0.03	0.17	0.15	0.11	-0.01	0.13	1.00									
NO_3+NO_2	-0.19	**-0.69**	-0.10	0.31	**0.42**	**0.60**	-0.09	0.03	1.00								
Total-N	-0.24	**-0.62**	-0.12	0.28	**0.45**	**0.63**	-0.11	0.02	**0.85**	1.00							
PO_4-P	-0.27	-0.31	-0.28	0.07	0.05	0.32	-0.19	0.00	**0.36**	**0.35**	1.00						
Total-P	-0.10	-0.30	-0.08	0.21	0.04	0.24	-0.05	0.07	**0.33**	0.30	**0.37**	1.00					
TSS	0.30	-0.14	0.18	0.26	-0.12	-0.10	**0.45**	0.31	0.08	0.05	0.10	0.16	1.00				
Secchi	**-0.40**	0.06	**-0.42**	**-0.36**	-0.01	0.20	**-0.68**	-0.05	0.03	0.05	0.21	0.06	-0.29	1.00			
Chl a	**0.35**	-0.09	**0.48**	**0.39**	0.27	-0.15	**0.39**	0.06	-0.01	-0.01	-0.22	-0.16	0.06	-0.41	1.00		
Phyto BV	0.25	0.21	0.26	0.11	0.12	-0.20	0.16	0.04	-0.18	-0.22	-0.03	-0.19	-0.01	-0.11	**0.43**	1.00	
Zoop BM	-0.20	0.27	-0.11	-0.22	0.18	0.03	-0.07	0.27	-0.07	-0.05	0.09	-0.15	0.01	0.05	0.02	-0.03	1.00

Table 2-7. Kendall's Tau-B Correlation Matrix for SNR-18

	Flow	Temp.	% DO	DO-mg/L	pH	Sp. Cond.	Turb.	NH_3-N	NO_3+NO_2	Total-N	PO_4-P	Total-P	TSS	Secchi	Chl a	Phyto BV	Zoop BM
Flow	1.00																
Temp.	0.09	1.00															
% DO	**0.66**	0.07	1.00														
DO-mg/L	**0.33**	**-0.48**	**0.47**	1.00													
pH	-0.23	-0.10	-0.04	0.13	1.00												
Sp. Cond.	**-0.44**	**-0.38**	**-0.36**	0.05	**0.41**	1.00											
Turb.	**0.62**	-0.07	**0.47**	**0.32**	**-0.30**	**-0.35**	1.00										
NH_3-N	0.21	0.00	0.15	0.05	0.03	-0.11	0.24	1.00									
NO_3+NO_2	-0.22	**-0.75**	-0.16	**0.36**	0.23	**0.60**	-0.07	-0.05	1.00								
Total-N	-0.28	**-0.69**	-0.14	**0.34**	0.23	**0.61**	-0.15	-0.06	**0.89**	1.00							
PO_4-P	-0.28	**-0.44**	**-0.37**	0.09	-0.09	**0.37**	-0.10	-0.03	**0.49**	**0.50**	1.00						
Total-P	-0.15	**-0.35**	-0.20	0.16	-0.01	0.28	-0.01	0.00	**0.38**	**0.37**	**0.47**	1.00					
TSS	**0.33**	-0.14	**0.30**	**0.34**	-0.23	-0.21	**0.56**	0.27	0.08	0.04	0.02	0.13	1.00				
Secchi	**-0.57**	0.08	**-0.46**	**-0.33**	**0.36**	**0.39**	**-0.88**	-0.23	0.07	0.12	0.04	0.03	**-0.60**	1.00			
Chl a	0.10	0.14	0.17	0.08	0.15	-0.18	0.16	-0.01	-0.23	-0.22	**-0.30**	**-0.36**	0.18	-0.19	1.00		
Phyto BV	0.16	**0.38**	0.09	-0.22	-0.09	**-0.31**	0.21	0.26	**-0.32**	**-0.33**	-0.21	-0.15	0.19	-0.20	**0.44**	1.00	
Zoop BM	-0.19	0.22	-0.02	-0.14	**0.33**	0.05	-0.13	0.02	-0.09	-0.05	0.04	-0.06	-0.04	0.12	0.23	0.12	1.00

SECTION 3 - SUMMARY

Lake Sacajawea is the next downstream reservoir from Lake Herbert G. West and the most downstream hydroelectric project on the lower Snake River. Because Ice Harbor Dam is also a run-of-river project, many of the water quality characteristics are very similar to the other three Lower Snake River projects. The average hydrologic residence time of the reservoir is 6.7 days but can range from less than 1 day to 25 days. June through September Secchi disk depths were similar at SNR-2 and SNR-18 with calculated median values of 2.1 meters and 1.9 meters, respectively. Median 2008 to 2010 June through September chlorophyll a concentrations were 4.2 µg/L at the reservoir station, but decreased to 2.9 µg/L at the monitoring location downstream from the dam. The total algal biovolume was predominantly comprised of diatoms that accounted for calculated median of 97 percent at both locations. *Aulacoseira* spp. and *Stephanodiscus* spp. were the primary representatives. The copepods are consistently present in the reservoir and accounted for 49 percent of the zooplankton biomass at SNR-2 and 47 percent at SNR-18 during the 2008 to 2010 study. *Calanoid* spp., *Cyclopoid* spp., *Diacyclops* spp., *Leptodiaptomus* spp., and nauplii were the species that were consistently present. However, during individual sampling events, the cladocera, primarily *Daphnia retrocurva* and *Daphnia galeata,* could surpass the combined biomass of all other zooplankters during the summer months when biomass ranged from 6 µg/L at SNR-2 to 51 µg/L at SNR-18. Carlson TSIs were calculated using summer chlorophyll a concentrations, Secchi disk depths, and total-P concentrations. The resulting metrics placed the reservoir in the upper mesotrophic to lower eutrophic category.

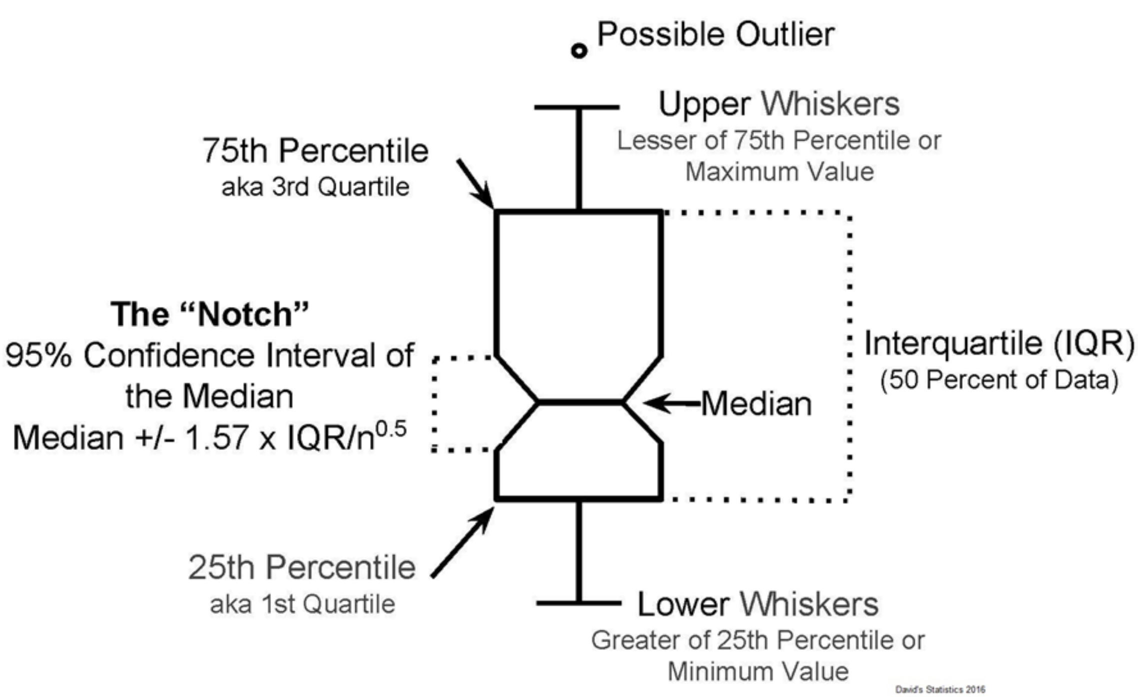
SECTION 4 - SUPPLEMENTAL INFORMATION

4.1 EXPLANATION OF BOX PLOTS

Box plots are a very useful graphic for viewing and comparing datasets (Figure 4-1).

- The box shows the interquartile range (IQR), which is the area where 50 percent of the data points fall. The upper limit is called the 75 percentile, and the lower limit is called the 25 percentile.
- The horizontal line inside the box represents the median of the data.
- The notch is the 95 percent confidence interval around the median. Although not a formal test, if the notches from two boxes do not overlap, there is strong evidence that the medians differ.
- The whiskers add 1.5 times the IQR to the 75 percentile and subtract 1.5 times the IQR from the 25 percentile. The whiskers should include 99.3 percent of the data if it is from a normal distribution.

Figure 4-1. Explanation of Box Plots



SECTION 5 - REFERENCES

Bowie, G. L., W. B. Mills, D. B. Porcella, C. L. Campbell, J. P. Pagenkopf, G. L. Rupp, K. M. Johnson, P. W. H. Chan, S. A. Gherini, and C. E. Chamberlin. 1985. Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling. 2nd edition. EPA/600/3-85/040. U.S. EPA Environmental Research Laboratory. Athens, GA.

Bonneville (Bonneville Power Administration). 1995. Columbia River System Operation Review; Final Environmental Impact Statement, Appendix M-Water Quality. DOE-EIS-0170. Produced with U.S. Army Corps of Engineers and U.S. Department of the Interior.

Chapra, S. C., and K. H. Reckhow. 1983. Engineering Approaches for Lake Management, Vol. 2. Boston: Butterworth Publishers.

Corps. 2002. Lower Snake River Juvenile Salmon Migration Feasibility Report/ Environmental Impact Statement. Appendix C, Water and Sediment Quality. Walla Walla District. Walla Walla, WA.

———. 2014. Lower Snake River Programmatic Sediment Management Plan, Final Environmental Impact Statement. Appendix I, Water Quality and Sediment Quality Reports. Walla Walla District. Walla Walla, WA.

Ecology (Washington State Department of Ecology). 2003. Total Maximum Daily Load for the Lower Snake River. Publication No. 03-03-020. Olympia, WA.

EPA (US Environmental Protection Agency). 1991. Total Maximum Daily Load (TMDL) to Limit Discharges of 2,3,7,8-TCDD (Dioxin) to the Columbia River Basin. Region 10. Seattle.

Falter, C. M., W. H. Funk D.L. Johnstone, and S.K. Bhagat 1973. Water Quality of the Lower Snake River, Especially the Lower Granite Pool Area, Idaho-Washington: Vol. 1–Main Report; Vol. 2, Appendix E–Water Quality; Vol. 3, Appendix F–Finite Element Hydrodynamic Model.

Funk, W. H., C. M. Falter, and A. J. Lingg. 1979 (Revised 1985). Limnology of an Impoundment Series in the Lower Snake River, Volume 1. Contract No. DACW68-75-C-0143 and 0144.Final Report Submitted to U.S. Army Corps of Engineers, Walla Walla District. Walla Walla, WA.

Horne, A. J., and C. R. Goldman. 1994. Linmology, 2nd edition. New York: McGraw-Hill, Inc.

Juul, S. T. J. 1998a. Water Quality Update of the Lower Snake River, Washington. Final report prepared for the U.S. Army Corps of Engineers. State of Washington Water Research Center, Washington State University. Pullman, WA.

———. 1998b. An Evaluation of Planktonic Primary Productivity and Associated Limnological Characteristics of Selected Reaches of the Clearwater River, Lower Snake River, and Columbia River During 1997. Project completion report prepared for the U.S. Army Corps of Engineers. State of Washington Water Research Center, Washington State University. Pullman, WA.

———. 1999. Completion of the Limnological Assessment of the Lower Snake River as it Relates to Primary Productivity Modeling. Project completion report prepared for Normandeau Associates Inc. State of Washington Water Research Center, Washington State University. Pullman, WA.

Kerfoot, W. C., and A. Sih. 1987. Predation: Direct and Indirect Impacts on Aquatic Communities. Hanover, NH: University Press of New England.

NAI (Normandeau Associates, inc.). 1999. Lower Snake River Water Quality and Post-Drawdown Temperature and Biological Productivity Modeling Study. Vols. 1 and 2. R-16031.011. Bedford, NH.

Pennak, R. W. 1989. Freshwater Invertebrates of the United States. New York: John Wiley and Sons.

Sustainable Communities Initiative. 2010. The Clearwater Basin Bioregional Atlas. University of Idaho. Moscow, ID.

Wetzel, R. G. 2001. Limnology. 3rd edition. San Diego: Academic Press.