CONTINUED MONITORING OF DO, pH, AND TURBIDITY IN THE WELLS FOREBAY AND LOWER OKANOGAN RIVER
(DO, pH and Turbidity Study)

WELLS HYDROELECTRIC PROJECT

FERC NO. 2149

FINAL REPORT
NOT REQUIRED BY FERC

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ABSTRACT

The current Wells Hydroelectric Project (Wells Project) license will expire on May 31, 2012. As part of the Wells Project relicensing process, the Public Utility District No. 1 of Douglas County (Douglas PUD) is required to obtain a water quality certificate pursuant to Section 401 of the Clean Water Act. As part of the 401 certification process, the Washington State Department of Ecology (Ecology) must determine whether the Wells Project meets state water quality standards, including the numeric standards, for dissolved oxygen (DO), pH, and turbidity.

The Aquatic Resource Work Group (Aquatic RWG), which is comprised of interested parties (including Ecology) and Douglas PUD, was formed for the purpose of identifying issues that may require study during the Wells Project relicensing. The Aquatic RWG proposed a study to collect additional DO, pH, and turbidity data from within the Wells Project. The goal of this study was to obtain required DO, pH, and turbidity information for the Wells Dam forebay and lower Okanogan River, both above and within the Wells Project boundary. The information gathered from this monitoring effort will assist Ecology in determining whether the Project, as proposed to be operated under the new license, will meet the numeric criteria for DO, pH and turbidity.

A Quality Assurance Project Plan (QAPP), revised to incorporate review comments from Ecology, identified the organization, schedule, data quality objectives, sampling design, field and laboratory procedures, quality control, and data management and reporting parameters required to implement the DO, pH, and turbidity study proposed by the Aquatic RWG (Parametrix, 2008a).

Three Hydrolab Minisonde5 instruments equipped with DO, pH, and turbidity sensors were installed throughout the lower Okanogan River and began recording data at 30-minute intervals on May 5, 2008. Protective instrument housings were attached to pilings at the Malott Bridge (River Mile [RM] 17.0, above the Project boundary), Monse Bridge (RM 5.0) and Highway 97 Bridge (RM 1.3). Similar instrumentation, operating in the Wells Dam forebay at RM 515.6, began recording DO and pH measurements at 1-hour intervals on May 30, 2008, and a Global Water WQ750 sensor began monitoring turbidity at 5-minute intervals on June 3, 2008. These forebay instruments complete the network of four continuous water quality monitoring locations that were operated until late October 2008.

Twelve Okanogan River instrument servicing events were conducted over the monitoring period. Each servicing event involved downloading data, calibrating and performing maintenance on the instruments, performing quality control checks (including Winkler titrations for dissolved oxygen determination) and replacing batteries. High river flows and woody debris accumulations at times precluded access to some of the instruments in the Okanogan River during two of the twelve servicing events. Battery failures and an electrical short in a data logger also caused some data gaps.

In general, DO measurements in the Okanogan River remained above the 8.0 mg/L water quality criterion throughout the monitoring season, with infrequent recordings (28 of 165 days at

Highway 97) below 8.0 mg/L occurring in July and August as snowmelt runoff receded and both air and water temperatures increased. The lowest minimum daily DO on the Okanogan River during this period was observed most frequently at Malott upstream of the Wells Project boundary. Project effects on DO concentrations in the Okanogan River were not evident as incoming DO concentrations closely resemble those within the inundated portions of the Okanogan River. Changes in background minimum DO levels at Malott have a strong and significant linear relationship ($P < .0001$) with minimum values recorded at both Monse and the Highway 97 Bridge (R^2 of 0.92 and 0.72, respectively). These results indicate that there is no statistically significant difference between minimum DO measurements collected above the Project (Malott) and within the Project (lower Okanogan River). Further, there is no statistical difference among DO measurements by location. Median DO levels during the peak months of concern (July, August, and September) are equal to or greater than background values observed at Malott.

DO concentrations at Wells Dam forebay monitoring station decreased from June through mid-August, although concentrations remained well above the minimum numeric water quality criterion until early October when a brief and minor excursion, thought to be instrument related, below 8.0 mg/L was recorded over an 4 day period (7.8 mg/L minimum value overall average).

The majority of observed pH exceedances were within + 0.3 units of the criteria (6.5 to 8.5) and occurred at Malott (18 of 123 days, or 14.6%), above the Wells Project boundary. There were nine excursions of pH above the 6.5 to 8.5 range of water quality criteria and no excursion below the standard. On all but one of the nine exceedance event (May 6th), the pH was higher at Malott, upriver from the Project's influence, compared to Monse or Highway 97. On May 6th, the pH at Monse exceeded readings at Malott, but only by 0.06 units, well within the water quality allowance for human caused conditions.

It is not clear what effect, if any, the Wells Project may have had on turbidity. No turbidity data from the Wells forebay are available from this study, due to instrumentation failure. Limited data availability from locations upstream of the Wells Project boundary prevented comparisons to incoming waters on the Okanogan River during high turbidity events. However, given that elevated turbidity values coincided with increasing spring temperatures, river flow and precipitation, these observations are believed to be a product of annual snowmelt and runoff. Turbidity levels exceeding 5 NTU (over background when the background is 50 NTU or less) at Malott were inconsistent with readings collected at both Monse (5 of 122 comparable days, or 4%) and Highway 97 (8 of 165 comparable days, or 5%), suggesting that such events are not widespread or persistent within the Wells Project.

1.0 INTRODUCTION

1.1 General Description of the Wells Hydroelectric Project

The Wells Hydroelectric Project (Wells Project) is located at river mile (RM) 515.6 on the Columbia River in the State of Washington (Figure 1.1-1). Wells Dam is located approximately 30 river miles downstream from the Chief Joseph Hydroelectric Project, owned and operated by the United States Army Corps of Engineers (COE); and 42 miles upstream from the Rocky Reach Hydroelectric Project owned and operated by Public Utility District No. 1 of Chelan County (Chelan PUD). The nearest town is Pateros, Washington, which is located approximately 8 miles upstream from the Wells Dam.

The Wells Project is the chief generating resource for Public Utility District No. 1 of Douglas County (Douglas PUD). It includes ten generating units with a nameplate rating of 774,300 kW and a peaking capacity of approximately 840,000 kW. The design of the Wells Project is unique in that the generating units, spillways, switchyard, and fish passage facilities were combined into a single structure referred to as the hydrocombine. Fish passage facilities reside on both sides of the hydrocombine, which is 1,130 feet long, 168 feet wide, with a top of dam elevation of 795 feet above mean sea level (msl).

The Wells Reservoir is approximately 30 miles long. The Methow and Okanogan rivers are tributaries of the Columbia River within the Wells Reservoir. The Wells Project boundary extends approximately 1.5 miles up the Methow River and approximately 15.5 miles up the Okanogan River. The surface area of the reservoir is 9,740 acres with a gross storage capacity of 331,200 acre-feet and usable storage of 97,985 acre feet at the normal maximum water surface elevation of 781 (Figure 1.1-1).

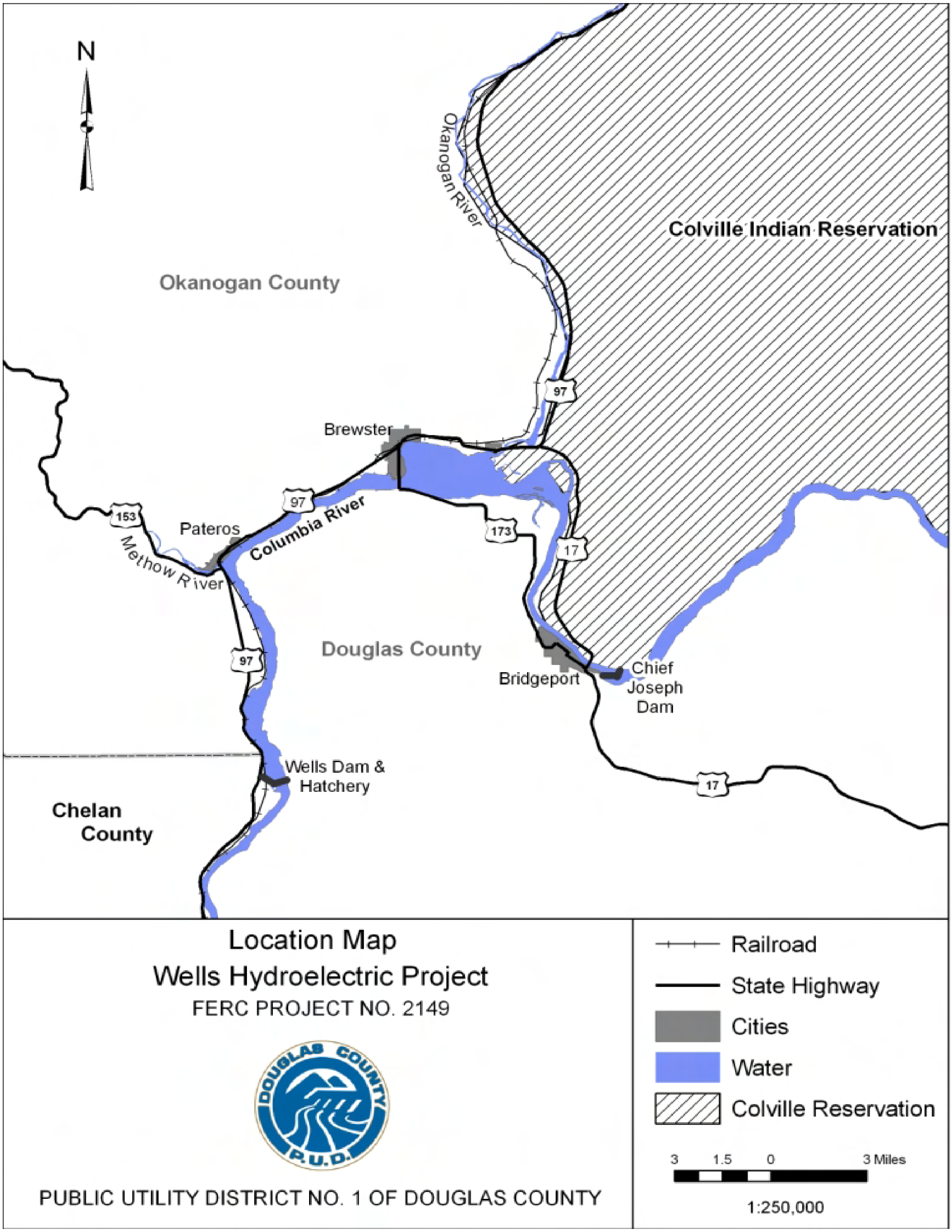


Figure 1.1-1 Location Map of the Wells Project

1.2 Relicensing Process

The current Wells Project license will expire on May 31, 2012. Douglas PUD is using the Integrated Licensing Process (ILP) promulgated by Federal Energy Regulatory Commission (FERC) Order 2002 (18 CFR Part 5). Stakeholders, including representatives from state and federal agencies, tribes, local governments, non-governmental organizations and the general public have participated in the Wells Project ILP, from a very early stage, to identify information needs related to the relicensing of the Wells Project.

In August 2005, Douglas PUD initiated a series of Resource Work Group (RWG) meetings with stakeholders regarding the upcoming relicensing of the Wells Project. This voluntary effort was initiated to provide stakeholders with information about the Wells Project, to identify resource issues, and to develop preliminary study plans prior to filing the Notice of Intent (NOI) and Pre-Application Document (PAD). The RWGs were formed to discuss issues related to the Wells Project and its operations, identify information needs, and develop agreed-upon study plans.

The primary goals of the RWGs were to identify resource issues and potential study needs in advance of Douglas PUD filing the NOI and PAD. Through 35 meetings, each RWG cooperatively developed a list of Issue Statements, Issue Determination Statements and Agreed-Upon Study Plans. An Issue Statement is an agreed-upon definition of a resource issue raised by a stakeholder. An Issue Determination Statement reflects the RWGs' efforts to apply the FERC's seven study criteria to mutually determine the applicability of each individual Issue Statement. Agreed-Upon Study Plans are the finished products of the informal RWG process.

Douglas PUD submitted the NOI and PAD to the FERC on December 1, 2006. The PAD included the RWGs' 12 Agreed-Upon Study Plans. The filing of these documents initiated the relicensing process for the Wells Project under the FERC's regulations governing the ILP.

On May 16, 2007, Douglas PUD submitted a Proposed Study Plan (PSP) Document. The PSP Document consisted of the Applicant's Proposed Study Plans, Responses to Stakeholder Study Requests, and a schedule for conducting the Study Plan Meeting. The ILP-required Study Plan Meeting was conducted on June 14, 2007. The purpose of the Study Plan Meeting was to provide stakeholders with an opportunity to review and comment on Douglas PUD's PSP Document, to review and answer questions related to stakeholder study requests and to attempt to resolve any outstanding issues with respect to the PSP Document.

On September 14, 2007, Douglas PUD submitted a Revised Study Plan (RSP) Document. The RSP Document consisted of a summary of each of Douglas PUD's RSPs and a response to stakeholder comments on the PSP Document.

On October 11, 2007, the FERC issued its Study Plan Determination based on its review of the RSP Document and comments from stakeholders. The FERC's Study Plan Determination required Douglas PUD to complete 10 of the 12 studies included in its RSP Document. The Dissolved Oxygen (DO), pH, and Turbidity Study was not required by the FERC. However, Douglas PUD has opted to complete this study to better prepare for the 401 Water Quality Certification process conducted by the Washington State Department of Ecology (Ecology) and to fulfill its commitment to the RWGs who collaboratively developed the 12 Agreed-Upon Study Plans with Douglas PUD. On October 15, 2008, Douglas PUD filed with the FERC the ISR Document that contained final reports for eight of the 12 studies and contained interim progress reports for four of the 12 studies. The ISR Document included results from all ten of the studies required by the FERC in the October 11, 2007 Study Plan Determination. The ISR Document also included results from two studies voluntarily conducted by Douglas PUD for the reasons stated above. On November 24, 2008, Douglas PUD filed a letter correcting a water temperature figure within the original ISR Document. On December 2, 2008, Douglas PUD filed the final Traditional Cultural Property Study for the Wells Project, which was prepared by the Confederated Tribes of the Colville Reservation under a contract with Douglas PUD.

The deadline for stakeholder comment on the ISR Document was December 15, 2008 pursuant to the approved Process Plan and Schedule for the Wells Project. Comments were filed by the City of Pateros on November 7, 2008 and by the City of Brewster on December 5, 2008.

On January 14, 2009, Douglas PUD filed a letter containing its responses to the comments from the cities on the ISR Document and proposed revisions to the schedule for the Wells ILP. On February 4, 2009, the FERC issued a determination on the requests for modification to the Wells Study Plan and on Douglas PUD's proposed revisions to the schedule. The FERC concluded that there was no need to modify the Wells Study Plan. The FERC also approved Douglas PUD's proposed modifications to the Wells ILP schedule.

This study was conducted voluntarily by Douglas PUD based on the agreed-upon study plan filed with the FERC in the Revised Study Plan. This report provides the final results from the DO, pH and Turbidity Study collected from May 5 through October 29, 2008.

This report is the final report for the DO, pH and Turbidity Study.

2.0 GOALS AND OBJECTIVES

The goal of this study was to obtain required DO, pH, and turbidity information for the Wells Dam forebay and lower Okanogan River, both above and within the Wells Project boundary. The information gathered from this monitoring effort will assist Ecology in determining whether the Project, as proposed to be operated under the new license, will meet the numeric criteria for DO, pH and turbidity.

3.0 STUDY AREA

The study area consists of waters within the Wells Project with a particular emphasis on the Wells Dam forebay and the lower Okanogan River from its confluence with the Columbia River up to RM 17.0 (Figure 1.1-1).

4.0 BACKGROUND AND EXISTING INFORMATION

DO levels are a critical variable for aquatic life and affect the chemical dynamics of a water body. DO levels are influenced by a suite of factors including the level of biological activity in the water, turbulence, and temperature (EES Consulting, 2006).

The term pH is used to describe the acidity or hydrogen ion content of a liquid. Factors influencing the pH of a water body include the chemical composition of soils in the watershed, photosynthetic activity, pollutants, and respiration of organisms (EES Consulting, 2006). Levels of pH which are extremely acidic or basic can adversely impact aquatic life and may indicate that other pollutants are present within a watershed.

Turbidity is the measure of the light scattering from suspended particles in water that reduce its transparency. After light enters water, it is absorbed, reflected or refracted by dissolved organic substances, pigmented (phytoplankton) and colored particulates, inorganic particulates, and by the water itself. Transparency also regulates primary productivity and trophic dynamics which ultimately can affect fish populations. There is a direct relationship between turbidity, water transparency and the depth at which macrophytes grow (EES Consulting, 2006). Factors and activities affecting water quality in the Wells Project include: (1) nonpoint source pollution from agricultural runoff and irrigation return flow,(2) point source pollution from mines, municipal and industrial sources upriver and outside of the Wells Project boundary, (3) depletion of in-stream flows from water diversions and consumptive uses, (4) watershed management in the tributaries and Upper Columbia River above Wells Dam, (5) the operation of large water storage facilities located upriver of Wells Dam on the mainstem Columbia and in the Okanogan watershed, (6) effects related to operations of the Wells Project, and (7) elevated sediment concentrations due to rain and snowmelt runoff.

Under section 303(d) of the Clean Water Act (CWA), states are required to list all water body segments that do not meet the state water quality standards. Within the Wells Project boundary, specific water reaches are on the state’s 303(d) list for various parameters. However, no river segments within the Project boundary are on Ecology’s current 303(d) list for DO, pH or turbidity (Ecology, 2008a).

Douglas PUD and state and federal agencies have implemented water quality monitoring programs to collect information within or adjacent to the Wells Project. The programs collect a variety of biological, chemical, and physical water quality parameters and typically include the three parameters of interest (DO, pH, and turbidity). Data collected from these monitoring activities have indicated that waters within the Wells Project are generally in compliance with the state standards. During the infrequent times when Wells Project waters do not meet numeric criteria for these parameters, waters entering the Wells Project are typically out of compliance (EES Consulting 2006).

4.1 Aquatic Resource Work Group

As part of the relicensing process for the Wells Project, Douglas PUD established an Aquatic RWG which began meeting informally in November, 2005. This voluntary effort was initiated to provide stakeholders with information about the Wells Project, to collaboratively identify potential resource issues related to Project operations and relevant to relicensing, and to develop preliminary study plans to be included in the PAD (DCPUD, 2006).

Through a series of meetings, the Aquatic RWG cooperatively developed a list of Issue Statements, Issue Determination Statements and Agreed-Upon Study Plans. An Issue Statement is an agreed-upon definition of a resource issue raised by a stakeholder. An Issue Determination Statement reflects the RWG's efforts to review the existing project information and to determine whether an issue met the FERC's seven criteria and would be useful in making future relicensing decisions. Agreed-Upon Study Plans are the finished products of the informal RWG process.

The Issue Statement and Issue Determination Statement described below were included in the PAD (section number included) filed with the FERC on December 1, 2006:

4.1.1 Issue Statement (PAD Section 6.2.1.7)

Project operations may affect compliance with DO, pH and turbidity standards in the Wells Project.

4.1.2 Issue Determination Statement (PAD Section 6.2.1.7)

The Wells Project may have an effect on compliance with the standards for DO, pH and turbidity. Currently, Douglas PUD has collected water quality data toward the evaluation of meeting the numeric criteria for these parameters. Initial data collected during the 2005 baseline limnological assessment indicates that Douglas PUD is in compliance with the Washington State standard for these parameters. However, additional monitoring is required to make a final determination.

The resource work group agreed that a study during the two-year ILP study period would be valuable. The study was to focus on the collection of DO, pH and turbidity in the Wells Project especially focusing on data collection from the Okanogan River and at Wells Dam.

4.2 Project Nexus

Ecology is responsible for the protection and restoration of the state's waters. Ecology has adopted water quality standards that set limits on pollution in lakes, rivers, and marine waters in order to protect water quality. On July 1, 2003, Ecology completed the first major overhaul of the state's WQS in a decade. A significant revision presented in the 2003 water quality standards classifies fresh water by actual use, rather than by class as was done in the 1997 standards. These revisions were adopted in 2003 and are maintained in the current 2006 standards in order to make the standards less complicated to interpret and provide future flexibility as the uses of a water body evolve.

Under the 2006 WQS, the Wells Project includes designated uses for spawning/rearing (aquatic life), primary contact recreation, and all types of water supply and miscellaneous uses (Ecology, 2006). Numeric criteria to support the protection of these designated uses consist of various physical, chemical, and biological parameters, including the water quality indicators that are the subject of this study: dissolved oxygen (DO), pH, and turbidity. The 2006 WQS for DO, pH, and turbidity are presented below in Section 4.4.

The information resulting from continued monitoring of DO, pH, and turbidity will assist Ecology during the development of any needed licensing requirements resulting from the 401 water certification process.

4.3 Water Quality Standards

Congress passed the CWA in 1972, and designated the U.S. Environmental Protection Agency (EPA) as the administering federal agency. This federal law requires that a state's WQS protect the surface waters of the U.S. for beneficial or designated uses, such as recreation, agriculture, domestic and industrial use, and habitat for aquatic life. Any state WQS, or amendments to these standards, do not become effective under the CWA until they have been approved by EPA. Ecology is responsible for the protection and restoration of the State's waters. Ecology establishes WQS that set limits on pollution in lakes, rivers, and marine waters in order to protect water quality and specified designated and potential uses of such water bodies. These standards are found at WAC 173-201A.

4.3.1 Water Quality Standards for the Project

The Wells Project includes the mainstem Columbia River above Wells Dam, one mile of the mainstem Columbia River below Wells Dam, the Methow River (up to RM 1.5) and the Okanogan River (up to RM 15.5).

Under the 2006 WQS, the Project includes designated uses for spawning/rearing (aquatic life), primary contact recreation, and all types of water supply and miscellaneous uses (Ecology, 2006). Numeric criteria to support the protection of these designated uses consist of various physical, chemical, and biological parameters, including the water quality indicators that are the subject of this study: dissolved oxygen, pH, and turbidity.

4.3.1.1 Dissolved Oxygen

Dissolved Oxygen criteria are measured in milligrams per liter (mg/L). Based upon criteria developed by Ecology, DO concentrations shall not be under the 1-day minimum of 8.0 mg/L, this being defined as the lowest DO reached on any given day.

When DO in a waterbody is lower than the 8.0 mg/L criteria (or within 0.2 mg/L of the criteria) and that condition is due to natural conditions, then human actions considered cumulatively may not cause the DO of that water body to decrease more than 0.2 mg/L.

Concentrations of DO are not to fall below 8.0 mg/L at a probability frequency of more than once every ten years on average.

DO measurements should be taken to represent the dominant aquatic habitat of the monitoring site. This typically means samples should:

(A) be taken from well mixed portions of rivers and streams.

(B) not be taken from shallow stagnant backwater areas, within isolated thermal refuges, at the surface, or at the water's edge.

4.3.1.2 pH

The pH of a water body is defined as the negative logarithm of the hydrogen ion concentration. Under the WQS, pH measurements shall be in the range of 6.5 to 8.5, with a human-caused variation within the above range of less than 0.5 units.

4.3.1.3 Turbidity

Turbidity is measured in nephelometric turbidity units (NTUs). Turbidity shall not exceed 5 NTU over background when the background is 50 NTU or less; or a 10% increase in turbidity when the background turbidity is more than 50 NTU.

4.4 Douglas PUD Monitoring Activities

In August, 2005, Douglas PUD began monitoring DO and pH in the Wells Dam forebay during the season when the possibility of low DO levels occurring was highest. The results of this monitoring effort indicated that DO levels were not below 8.0 mg/L and pH levels were not outside of the specified range of 6.5 to 8.5, which are the state water quality numeric criteria (Ecology, 2006). In response to requests made by Ecology, Douglas PUD implemented seasonal monitoring for these parameters at hourly intervals at the Wells Dam forebay. Monitoring at the forebay in 2008 began on May 30. The monitoring is performed using a Hydrolab Minisonde deployed at depths that have ranged from 5.08 to 7.76 meters through the 2008 monitoring period.

At Wells Dam, Secchi disk readings are also taken to measure water transparency, which is inversely correlated to turbidity. Sampling occurs daily during the adult fish passage assessment period of May 1 to November 15. Measurements are recorded in feet of visibility and reliable information adhering to a standard protocol has been collected since 1998. During the monitoring period, Secchi disk readings ranged from 2 feet during spring run-off to 16 feet by late summer.

In 2005, Douglas PUD contracted with EES Consulting to conduct a comprehensive limnological investigation of Wells Project waters (EES Consulting, 2006). The year-long study was conducted at nine sites (seven sites in the Columbia River and one site in both the Methow and Okanogan rivers) in order to characterize water quality and seasonal trends in the Wells Project. Water quality sampling was scheduled seasonally with one sample event scheduled for each season. Spring sampling was conducted in May, fall monitoring was conducted in October, and winter sampling occurred in February 2006. Summer sampling was conducted more frequently when water quality exceedances would be more likely and temporal changes more dynamic (July, August and September). Results of the study found DO levels at 1m depth in Wells Project waters increased from upriver to downriver at the sites sampled; the average difference (May through October) was 1.07 mg/L. All surface water measurements had DO values greater than 8.0 mg/L and pH for Wells Project waters generally varied between 7.5 and 8.25, which is slightly above neutral. There were no measured exceedances of the water quality criteria for pH. Turbidity in the Wells Reservoir showed relatively little seasonal variation with an annual average of 0.98 NTUs. Longitudinal variation in turbidity was also minimal. Low turbidity in the reservoir was attributed partially to the large upriver storage reservoir capacity that allows fines to settle out. Turbidity in the Okanogan River was consistently higher than in the Wells Reservoir. Turbidity in the Methow River was higher than in the Wells Reservoir in May (due to sediment load) and in August due to phytoplankton growth. The only turbidity reading over 5 NTUs was in the Methow River during May (EES Consulting 2006).

4.5 Ecology Monitoring Activities

Ecology has conducted monthly water quality monitoring at locations on the Okanogan River near Malott (station 49A070) upriver of the Wells Project boundary at approximately RM 17 and on the Methow River near Pateros (station 48A070) upriver of the Wells Project boundary at approximately RM 5. Both stations are considered "long-term" stations by Ecology and provide reliable information for the quality of water entering the Wells Reservoir from tributary inflow. It is important to note that data collected from these stations are representative of water quality conditions of waters entering the Wells Project boundary. Data are typically collected as grab samples on a monthly basis. A variety of water quality parameters including DO, pH, and turbidity information as well as site compliance are available at http://www.ecy.wa.gov/programs/eap/fw_riv/rv_main.html. Table 4.5-1 provides the range of values for the parameters of interest observed at the Okanogan River long-term monitoring station since 2001 (Ecology 2008b).

Table 4.5-1 The range of DO, pH and turbidity values observed from monthly grab samples collected upriver of the Wells Project on the Okanogan (RM 17). Data from Ecology long-term monitoring stations 2001-2008.

	DO (mg/L)	pH	Turbidity (NTU)
2001	7.32 to 13.87	7.87 to 8.45	0.8 to 5.5
2002	8.80 to 13.63	7.83 to 8.39	1.0 to 19
2003	8.32 to 13.30	7.81 to 8.35	0.8 to 22
2004	8.16 to 14.08	7.48 to 8.55	0.9 to 75
2005	7.24 to 14.11	7.85 to 8.44	0.8 to 7.8
2006	7.89 to 13.53	8.09 to 8.58	<0.5 to 26
2007	7.43 to 13.13	7.94 to 8.45	1.6 to 85
2008*	7.80 to 13.08	7.93 to 8.39	1.0 to 27

* preliminary data for January through October

4.6 United States Geological Survey (USGS) Monitoring Activities

The USGS monitors surface water quality in cooperation with local and state governments and with other federal agencies. Monitoring programs consist of collection, analysis and data archiving and dissemination of data and information describing the quality of surface water resources. Similar to Ecology, the USGS has monitoring stations on both the Okanogan (12447200) and Methow (122449950) rivers near Malott and Pateros, respectively. However, the data collected at the Malott station since 1994 has been limited to stage, discharge and water temperature; therefore the USGS is a very limited source of water quality data for the Okanogan River. USGS data can be accessed via the Internet at: http://nwis.waterdata.usgs.gov/wa/nwis/qwdata.

5.0 METHODOLOGY

A Quality Assurance Project Plan (QAPP), revised to incorporate review comments from Ecology, identified the organization, schedule, data quality objectives, sampling design, monitoring locations, field procedures, quality control, and data management and reporting associated with implementing the DO, pH, and turbidity study proposed by the RWG (Parametrix, 2008a).

5.1 Monitoring Locations

In order to collect information related to the effects of Wells Project operations on the water quality parameters of interest and whether these parameters are in compliance with the Washington State water quality standards, monitoring instrumentation was installed in the following locations:

- Okanogan River above the Project boundary at Malott (RM 17.0);
- Okanogan River near Monse (RM 5.0);
- Okanogan River upriver of the confluence with the Columbia River (RM 1.3);
- Wells Dam forebay (RM 516).

The Okanogan River monitoring instruments are installed on pilings with bridge locations shown on Figures 5.1-1 and 5.2-1.

Figure 5.1-1 Water quality monitoring instrument housing mounted on the downriver side of a Monse Bridge piling.

5.2 Study Design

At each of the three stations located in the lower Okanogan River and at the station in the Wells Dam forebay, dissolved oxygen, pH, and turbidity were measured continuously using Hydrolab Minisonde5 instrumentation. Instruments are calibrated prior to each field visit according to the manufacturer's specifications. Winkler titrations are performed during each field event to ensure the dissolved oxygen probes are functioning properly, and the probes are re-calibrated if the result of the Winkler titration and probe reading differ by more than 0.2 mg/L.

The following sampling and analysis components were designed to address the water quality monitoring objectives:

- Multiprobe water quality instruments capable of continuous monitoring of DO, pH, and turbidity were installed at the three Okanogan River locations to supplement the existing Wells Dam forebay monitoring station. The instruments are deployed in locked housings mounted to bridge pilings near midstream at each Okanogan River location.

- Parametrix and Douglas PUD conducted a reconnaissance of each site in April 2008 to determine the best available location for deploying monitoring instruments, take measurements and determine the hardware needed for constructing and mounting the instrument housings.
- Housings were designed and constructed to protect continuous monitoring instrumentation at the three new locations identified above, and installed to allow the monitoring probes to be approximately 1 meter below the water surface during low flows.
- The instrument housings and multi-probe meters were installed and began recording measurements on May 5 and 6, 2008. The instruments were calibrated and programmed to record DO, pH, and turbidity at 30-minute intervals. They continued to record measurements until removed on October 29, 2008.
- The Wells Dam forebay multi-probe meter recorded DO and pH at one-hour intervals between May 30 and October 27, 2008; and a separate sensor recorded turbidity at the dam at 5-minute intervals beginning on June 3, 2008.
- Monitoring instruments were retrieved, calibrated, and maintained, and data downloaded every 2 to 4 weeks, depending on battery life and river conditions affecting accessibility and safety.
- Data were downloaded to a meter and transferred to a personal computer in the field. Backup copies of the data were recorded on a CD or flash drive while still in the field.
- A separate quality assurance/quality control (QA/QC) instrument was calibrated before each downloading event and used for comparisons to the fixed instrument readings. Winkler titrations were performed to verify the accuracy of the DO sensor readings.

Figure 5.2-1 Locations of bridges with water quality monitoring instrumentation on the lower Okanogan River.

5.3 Data Quality Objectives

Because the Okanogan and Columbia rivers are generally well-mixed riverine environments, the field-located sites are expected to be representative of water quality conditions in the monitored reaches. The same type of instruments and monitoring were used to collect data at each Okanogan River site to ensure data comparability between monitoring locations.

The primary instrument for measurement of in situ DO, pH, and turbidity was the Hydrolab Minisonde5 equipped with DO, pH, and turbidity sensors. Turbidity data was collected in the Wells Dam forebay using a Global Water WQ750 turbidity sensor. Both types of sensors are susceptible to fouling by debris, sediment, and growth of organisms (algae, etc.) during continuous deployment. Therefore, luminescent dissolved oxygen (LDO) and self-cleaning turbidity sensors were employed at all four sites because they are resistant to fouling or configured to retard fouling. The LDO sensor is not affected by fouling or other debris, unless the growth is an organism that locally consumes or produces oxygen, such as algae growing directly on the sensor cap. The self-cleaning turbidity sensor offers a wiper mechanism to reduce the effects of fouling.

The primary QA/QC instrument was a Hydrolab® Datasonde4a coupled with a Surveyor4a (SVR4a) display and recording unit (Figure 5.3-1). This unit was also equipped with DO, pH, and turbidity sensors as well as conductivity and temperature sensors. The Datasonde4a was used in the field to verify the accuracy of the continuously deployed Minisonde5 sensors. The SVR4a display and recording unit was used to download data from the Minisondes during data retrieval events.

Accuracy objectives for water quality field measurements are presented in Table 5.3-1. The monitoring data completeness goal was 90 percent.

Figure 5.3-1 Downloading data from a Hydrolab MiniSonde5, located within its protective casing, using a Surveyor4a, at the Highway 97 Bridge.

Table 5.3-1 Measurement quality objectives for dissolved oxygen, conductivity, pH, turbidity, temperature, and depth.

Parameter	Method	Duplicate Samples Relative Standard Deviation (RSD)	Method Reporting Limit and/or Resolution
Dissolved Oxygen[1]	Hydrolab® Datasonde 5	5% RSD	0.01 mg/L
Dissolved Oxygen[2]	Winkler Titration	+/- 0.1 mg/L	0.01 mg/L
Specific Conductivity[3]	Hydrolab® Datasonde 5	+/- 0.5%	0.01 µS/cm
pH[3]	Hydrolab® Datasonde 5	0.05 s.u.[4]	± 0.01 s.u.
Turbidity[5]	Hydrolab® Datasonde 5	+/- 1% (0 to 100 NTU[6]) +/- 3% (100 to 400 NTU)	0.1 NTU (0-400 NTU)
Water Temperature[3]	Hydrolab® Datasonde 5	+/- 0.1° C	0.01° C
Depth[3,7]	Hydrolab® Datasonde 5	± 0.05 meters	0.01 meters

[1] Luminescent Dissolved Oxygen Sensor
[2] As units of measurement, not RSD or percentages
[3] As percentage of reading, not RSD
[4] Standard Units
[5] Self-cleaning Turbidity Sensor
[6] NTU = Nephelometric Turbidity Unit
[7] Non-vented 0 -100 meter Depth Sensor

5.4 Quality Control Procedures

All sondes and the SVR4a were performance-tested and evaluated (PT&E) by the manufacturer before the initial deployment for continuous monitoring. Required factory calibrations and maintenance, as well as necessary repairs, take place during the PT&E event. Should a sonde or the SVR4a be damaged during deployment and monitoring, a replacement is obtained from the manufacturer while the damaged unit is being repaired.

The sensors of each Minisonde were calibrated before deployment and in the field during instrument servicing/data retrieval events. The QA/QC Datasonde was calibrated before each data retrieval event and used for comparisons to the fixed instruments readings. The Datasonde was also re-calibrated on return from the field. This post-event calibration verifies that the Datasonde was functioning correctly and that the accuracy of the sensors has not deteriorated. Winkler titrations are performed to verify the accuracy of the QA/QC instrument DO sensor readings and, in the field, at each monitoring location to verify Minisonde DO sensor readings.

A calibration log was maintained to document the dates and times of sonde calibration, and any calibration problems and corrective actions taken (e.g., replacing electrolyte solution in the pH probe). This log was kept with the filling and calibration solutions and spare parts that were taken to the field. The calibration log will be retained in the project files.

Datasonde maintenance and replacement of filling solutions occur before each data retrieval event, as necessary. Minisonde maintenance and replacement of filling solutions occurred in the field, as necessary, during data retrieval mobilizations. Calibration standards followed and buffers were replaced based on manufacturers' recommendations.

6.0 RESULTS

Complete monitoring results from the four study sites are available in CD format from Douglas PUD or may be viewed in hard copy at the office in East Wenatchee, Washington.

6.1 Monitoring Instrument Performance

Hydrolab Minisonde5 instruments equipped with DO, pH, and turbidity sensors were installed at lower Okanogan River locations in protective housings and activated on May 5, 2008. Through the 2008 monitoring period the deployment depth ranged from 3.0 to 5.9 meters at Highway 97, 1.0 to 3.2 meters at Monse, and 1.5 to 5.1 meters at Malott. There were 12 instrument servicing events through October 29, with each event including downloading data, instrument calibration and maintenance, performing quality control checks (e.g., Winkler titrations), and replacing batteries. A similar instrument deployed in the Wells Dam forebay was serviced bi-monthly. High river flows and woody debris accumulations sometimes limited access to instruments and resulting battery failures caused data gaps from one or more sensors.

Douglas PUD staff reported problems with the self-cleaning mechanism on the Global Water WQ750 turbidity sensor deployed in the Wells Dam forebay. Although there were frequent manual cleanings of the sensor window, problems with instrument fouling persisted. Data collected in 2008 by this instrument were judged to be unreliable and were rejected as unusable.

6.2 Dissolved Oxygen Results

Lower Okanogan River DO concentrations followed changes in water temperatures in a typical seasonal pattern. Minimum daily DO concentrations of at least 9 mg/L were recorded early in the monitoring season (May through June). In general, DO measurements in the Okanogan River remained above 8 mg/L. However, starting in early July, DO concentrations measured in the Okanogan River, both above and within Project boundary, dropped to below the 8.0 mg/L water quality criterion (Figure 6.2-1). In late August the river began to cool and DO increased, with no measurements below 8.0 mg/L recorded after August 26.

At the Wells forebay, DO concentrations steadily dropped from early June through mid-August (Figure 6.2-1). DO concentrations at this monitoring site generally declined through the summer as the river warmed, but remained above 8.0 mg/L at least through mid-August when the instrument was lost due to vandalism. In early October, a new DO instrument was installed in the Wells forebay. DO measurements below 8.0 mg/L at the Wells Dam were recorded immediately after the new instrument was installed during the first week of October. DO then began an increasing trend that coincided with continued cooling of the reservoir.

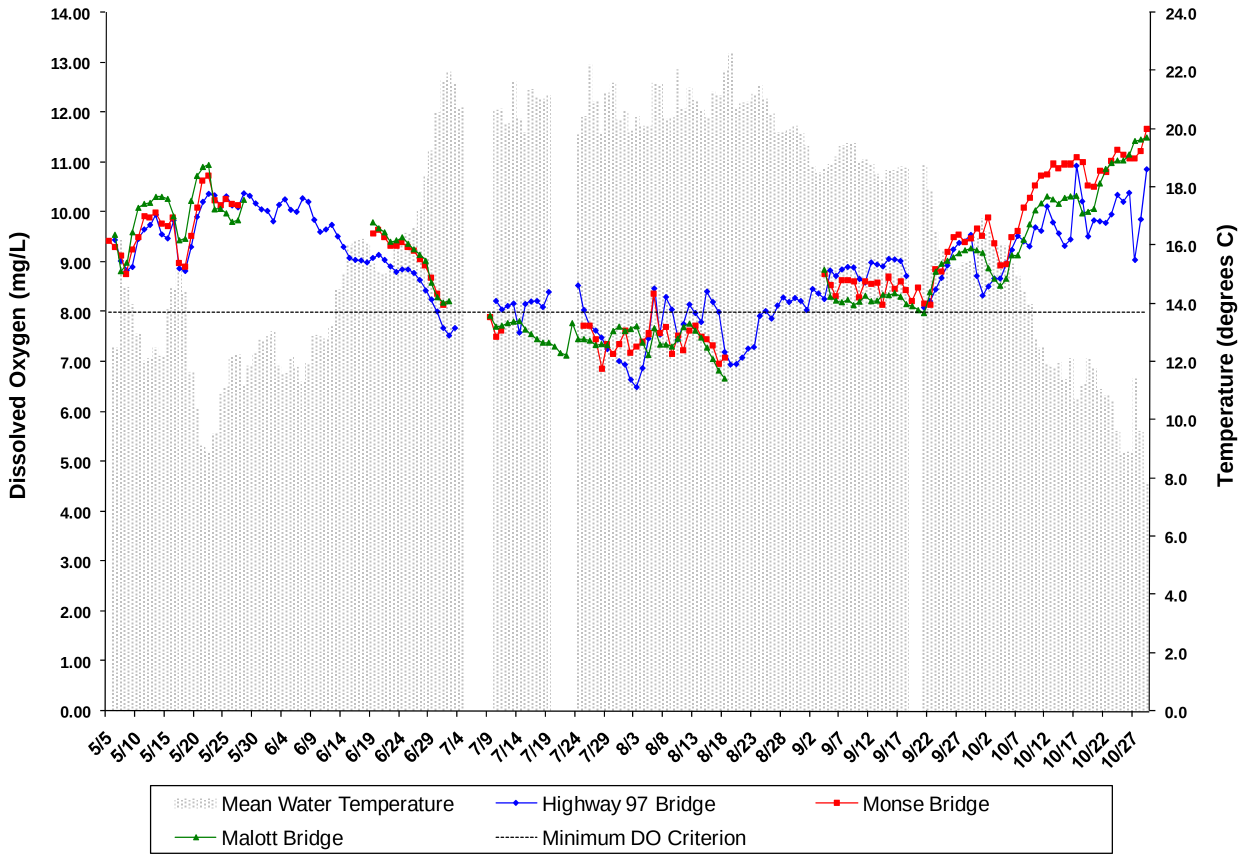


Figure 6.2-1 Daily minimum DO concentrations.

Minimum daily DO concentrations were measured below 8.0 mg/L at Malott and Monse from early July until late August with the lowest measurement of 6.67 mg/L on August 18 at Malott and 6.87 mg/L recorded on July 28 at Monse (Figures 6.2-2 and 6.2-3). Though less pronounced than at Highway 97, there were also much larger diurnal fluctuations in DO concentrations at Malott and to a lesser degree at Monse beginning in mid to late July, as illustrated by greater differences between daily minima and maxima.

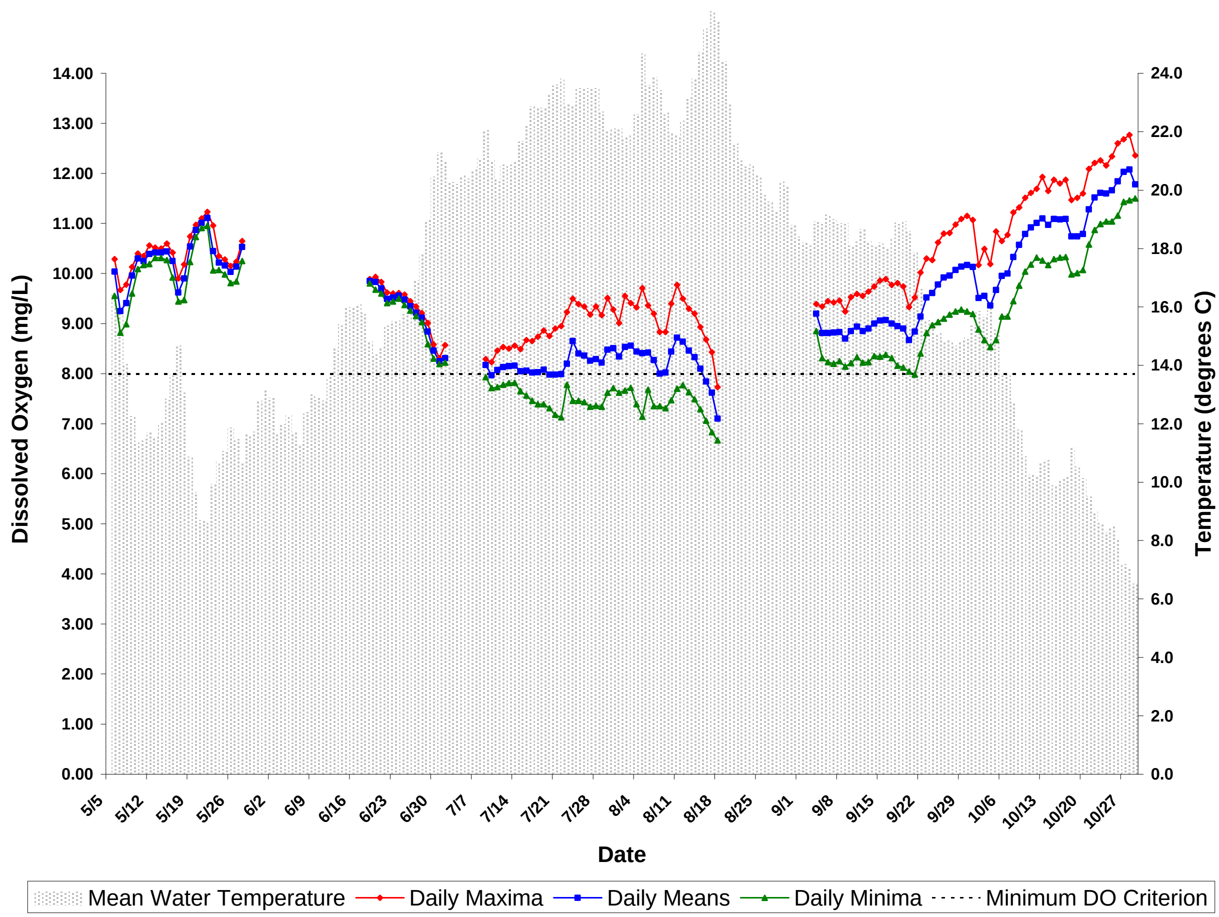


Figure 6.2-2 Daily minimum, mean and maximum DO measurements at Malott Bridge, with daily mean temperatures.

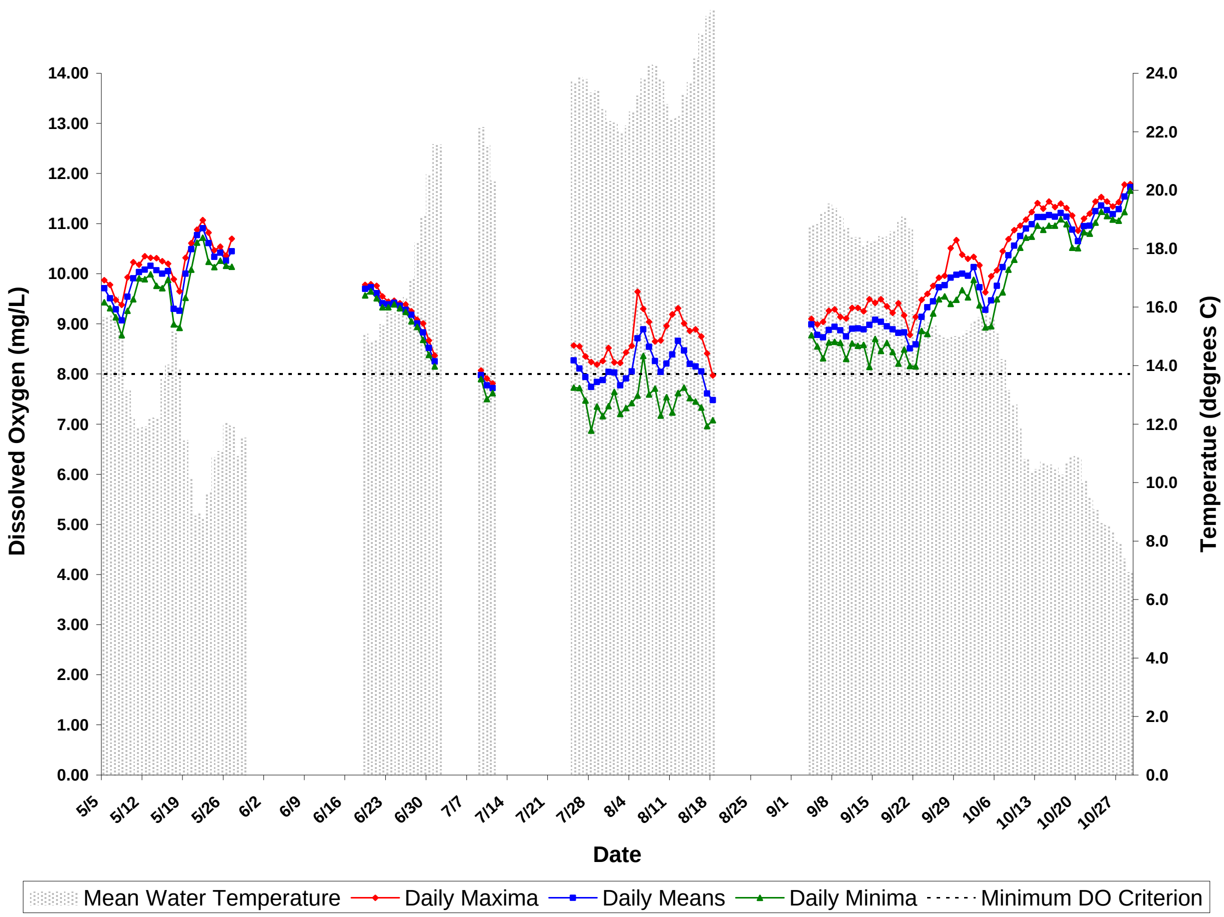


Figure 6.2-3 Daily minimum, mean and maximum DO measurements at Monse Bridge, with daily mean temperatures.

At Highway 97 the daily minimum DO began to occasionally drop below 8.0 mg/L on July 1, and was below 8.0 mg/L intermittently through August 26, with the lowest DO measurements coinciding with some of the warmest water temperatures (Figure 6.2-4). Very small differences between daily minima and maxima were observed during the high river flow season in May and June, compared with much greater daily DO fluctuation before and after the spring snowmelt runoff.

Relatively minor differences between daily minimum and maximum DO were observed at the Wells Dam forebay (Figure 6.2-5).

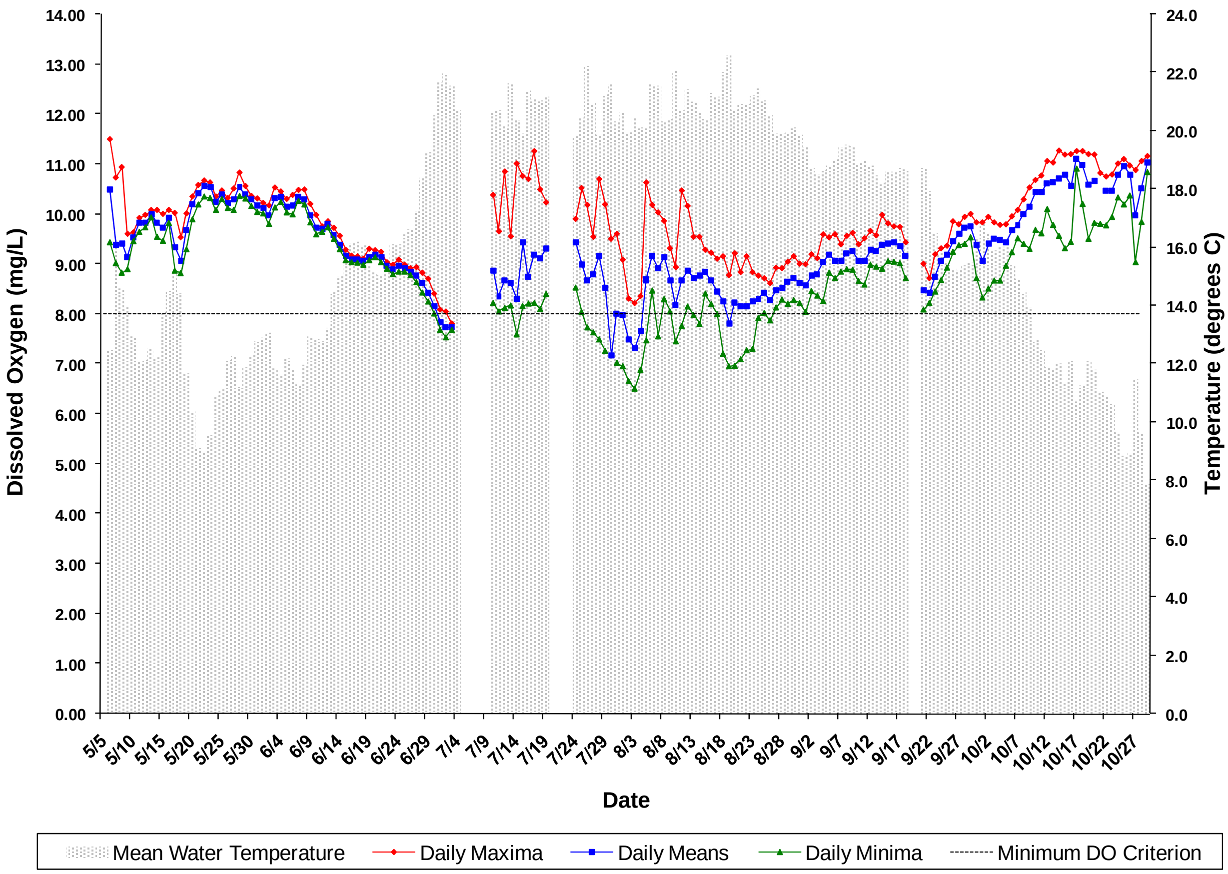


Figure 6.2-4 Daily minimum, mean and maximum DO measurements at the Highway 97 Bridge, with daily mean temperatures.

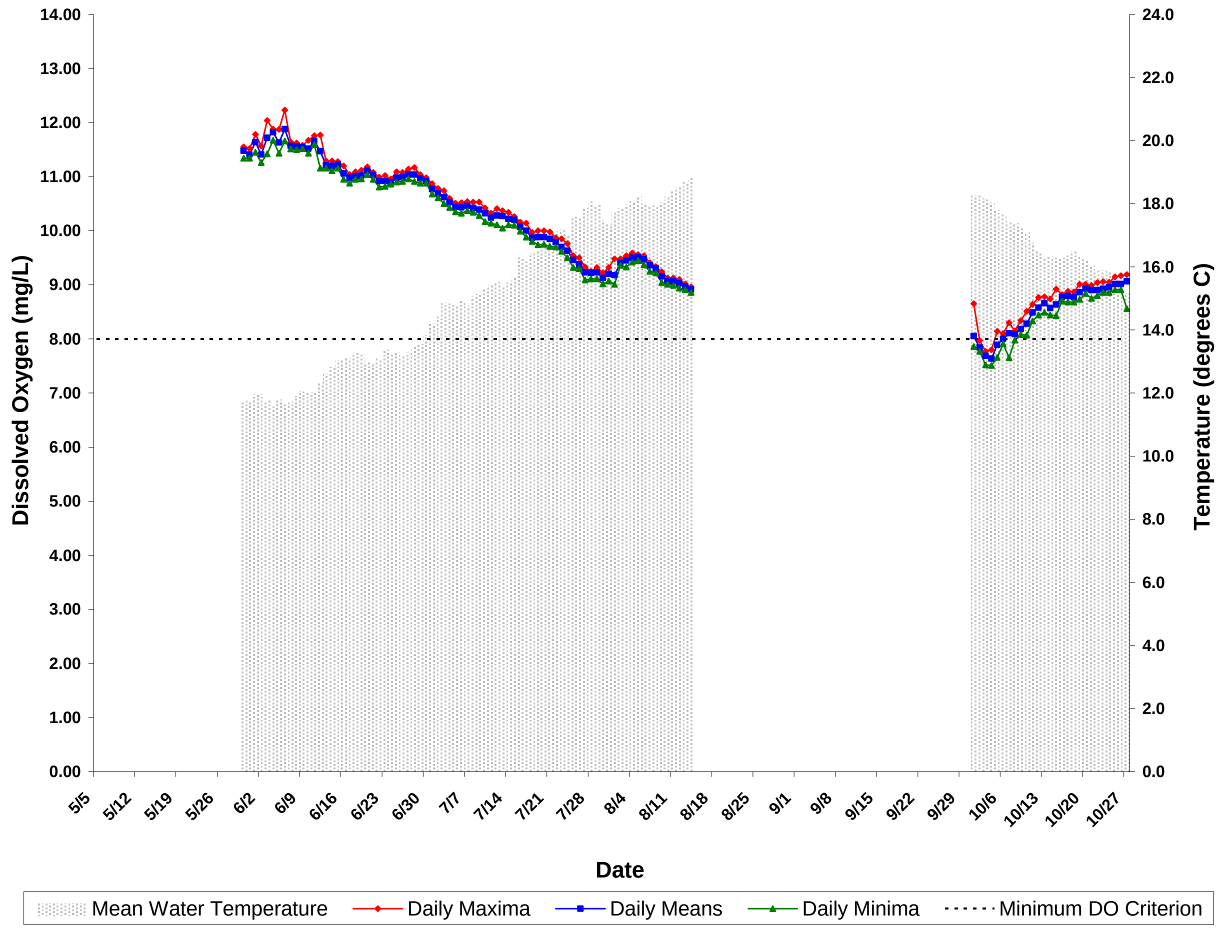
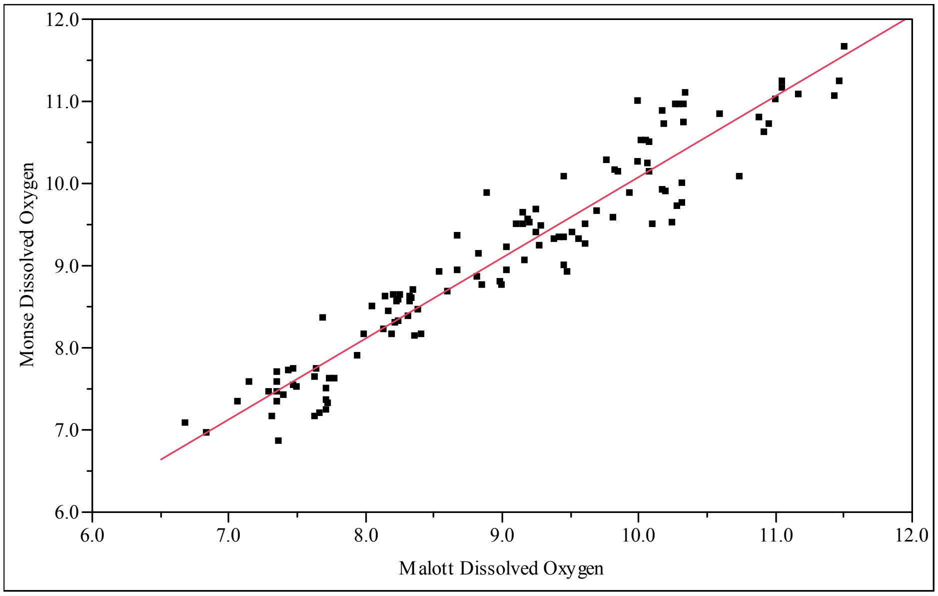
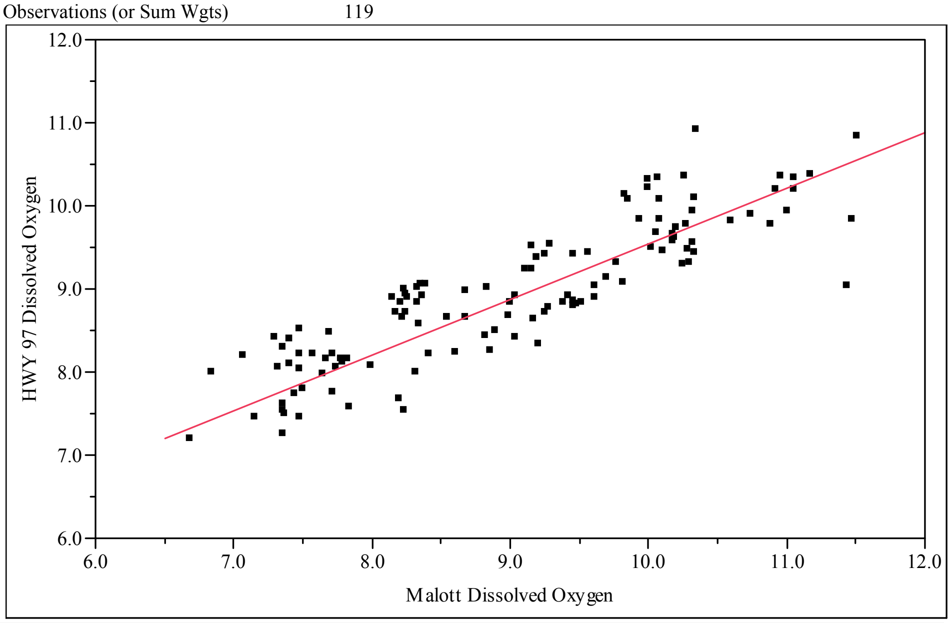


Figure 6.2-5 Daily minimum, mean and maximum DO measurements at the Wells Dam forebay, with daily mean temperatures.

Data collected from the Okanogan River sites were compared using linear regression techniques to identify the strength of the relationship between minimum DO measurements of water prior to entering the Project boundary and those observed within the Project. Changes in background minimum DO levels at Malott have a strong and significant linear relationship ($P < 0.0001$) with values recorded at both Monse and the Highway 97 Bridge (R^2 of 0.92 and 0.72, respectively). These results indicate that there is no statistically significant difference between minimum DO measurements collected from above Project (Malott) and in-Project (lower Okanogan River) locations. Further, though there is no statistical difference among DO measurements by location, median DO levels within the Project during summer months are equal to or greater than background values observed at Malott. When a linear regression is performed for summer minimum DO values (June through August) the relationship remains significant ($P < 0.0001$), and the equations at Monse and Highway 97 indicates an even greater positive influence on the DO within the Project (*Monse = 0.652 + 0.917 * Malott*, and *HWY 97 = 3.324 + 0.576 * Malott*).



Linear Fit		Analysis of Variance				
Monse = 0.2616841 + 0.9819724*Malott		Source	DF	Sum of Squares	Mean Square	F Ratio
Summary of Fit		Model	1	163.11395	163.114	1274.848
RSquare	0.915939	Error	117	14.96988	0.128	**Prob > F**
RSquare Adj	0.915221	C. Total	118	178.08383		**<.0001**
Root Mean Square Error	0.357698					
Mean of Response	9.100756					
Observations (or Sum Wgts)	119					



Linear Fit		Analysis of Variance				
HWY 97 = 2.8330135 + 0.6712533*Malott		Source	DF	Sum of Squares	Mean Square	F Ratio
Summary of Fit		Model	1	83.78590	83.7859	315.6268
RSquare	0.716313	Error	125	33.18235	0.2655	**Prob > F**
RSquare Adj	0.714044	C. Total	126	116.96825		**<.0001**
Root Mean Square Error	0.515227					
Mean of Response	8.825984					
Observations (or Sum Wgts)	127					

Figure 6.2-6 Linear regression depicting strong significant relationship between minimum DO measurements collected above Project (Malott) and within Project boundary in the Okanogan River.

6.3 pH Results

Okanogan River pH was neutral to slightly alkaline during 2008 monitoring. The pH measurements ranged from 7.23 to 8.78 at Malott Bridge, 7.07 to 8.68 at Monse Bridge, and 7.00 to 8.65 units at the Highway 97 Bridge. There were limited excursions of pH above the 6.5 to 8.5 range of water quality criteria, and on all but one of those days (May 6th), the pH was higher at Malott upriver from the Project area compared to Monse or Highway 97 (Figure 6.3-1). The most extensive periods of pH excursions occurred at the Malott Bridge between July 24 and August 15 when diurnal occurrences of higher late afternoon to nighttime pH reached up to 8.78, and again in early to mid-October when pH reached up to 8.76 (Figures 6.3-1 and 6.3-2). On May 6th, the pH at Monse exceeded readings at Malott, but only by 0.06 units – within the water quality standard. Between October 6 and 15, the pH at Monse exceeded 8.5 (Figure 6.3-3); however, this is attributed to influences upstream from the Project boundary as evidenced by the higher pH at Malott (Figure 6.3-1). On the nine days that pH exceeded 8.5 at Monse during this time frame, pH at Monse was lower than pH at Malott by 0.05 to 0.10 units (suggesting a positive influence on pH). The pH measurement at Highway 97 did not exceed 8.5 between May and mid-October (Figures 6.3-1 and 6.3-4). At no time did pH at any monitoring site approach the 6.5 minimum criterion.

Wells Dam forebay pH was also neutral to slightly alkaline during 2008 monitoring, ranging from 7.09 to 8.38 (Figure 6.3-5). All measurements were within the 6.5 to 8.5 range of water quality criteria.

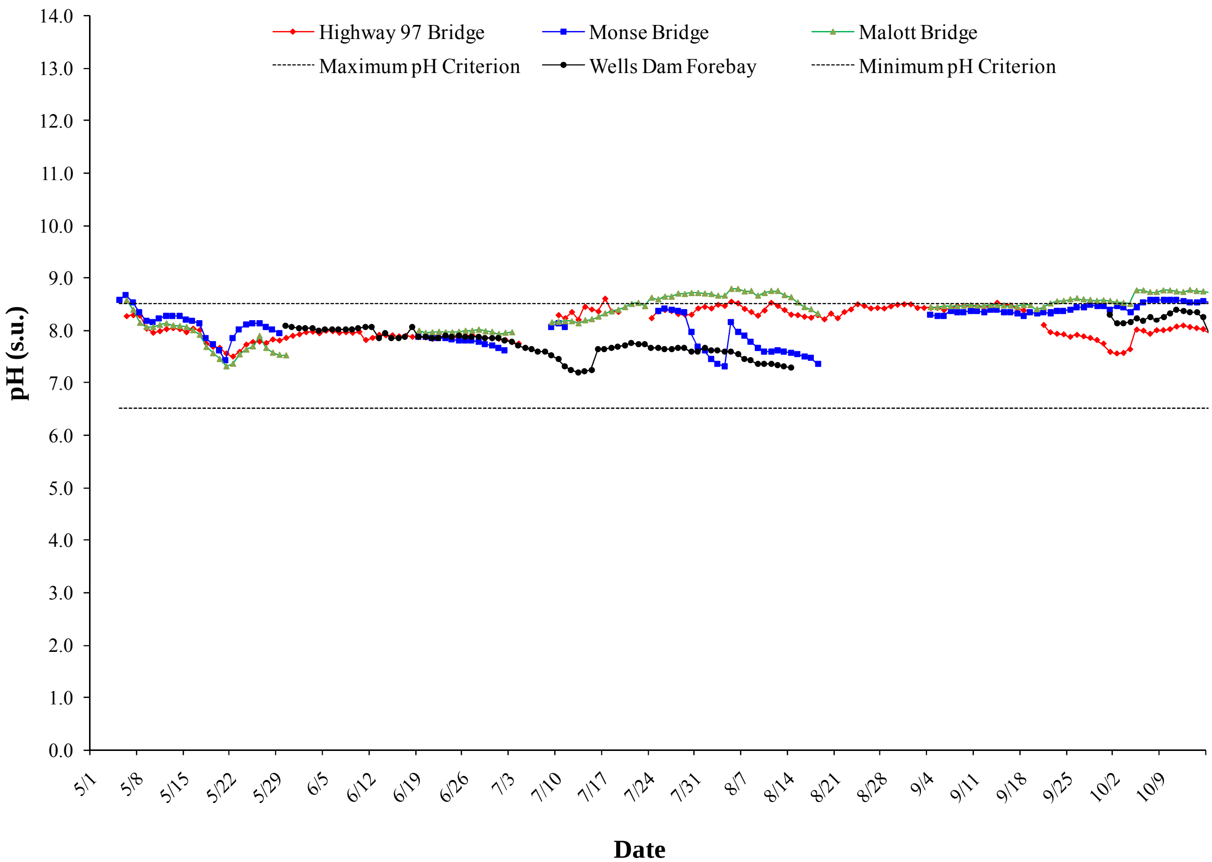


Figure 6.3-1 Daily maximum pH concentrations in the lower Okanogan River.

Figure 6.3-2 Daily minimum and maximum pH measurements at Malott Bridge.

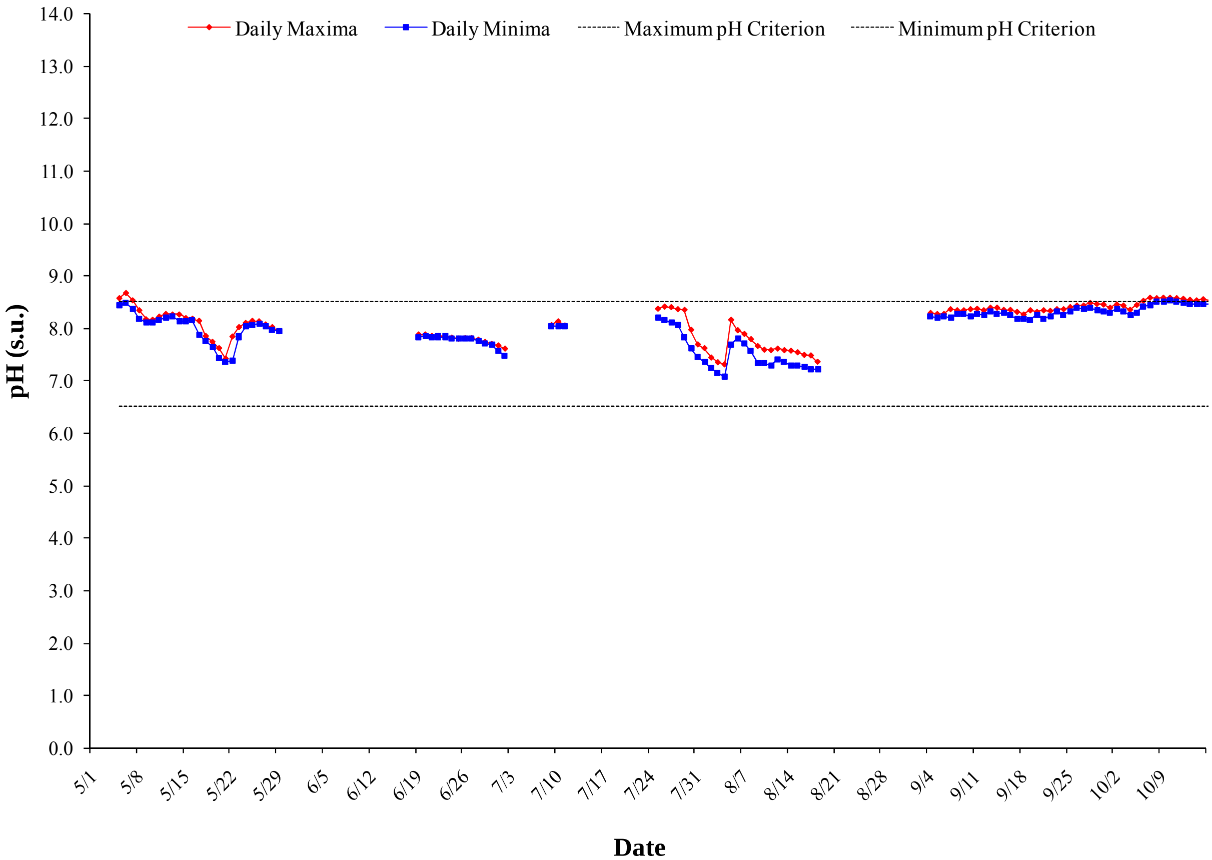


Figure 6.3-3 Daily minimum and maximum pH measurements at Monse Bridge.

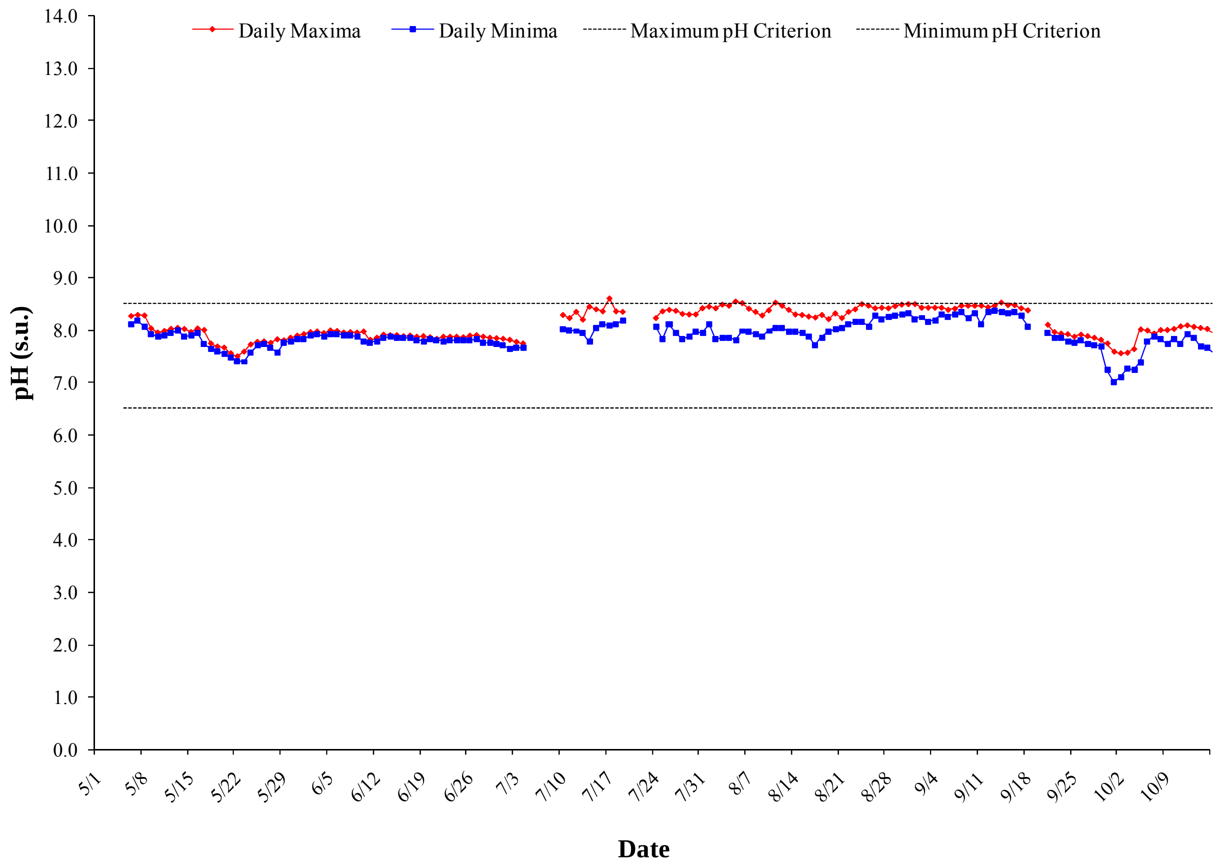


Figure 6.3-4 Daily minimum and maximum pH measurements at Highway 97 Bridge.

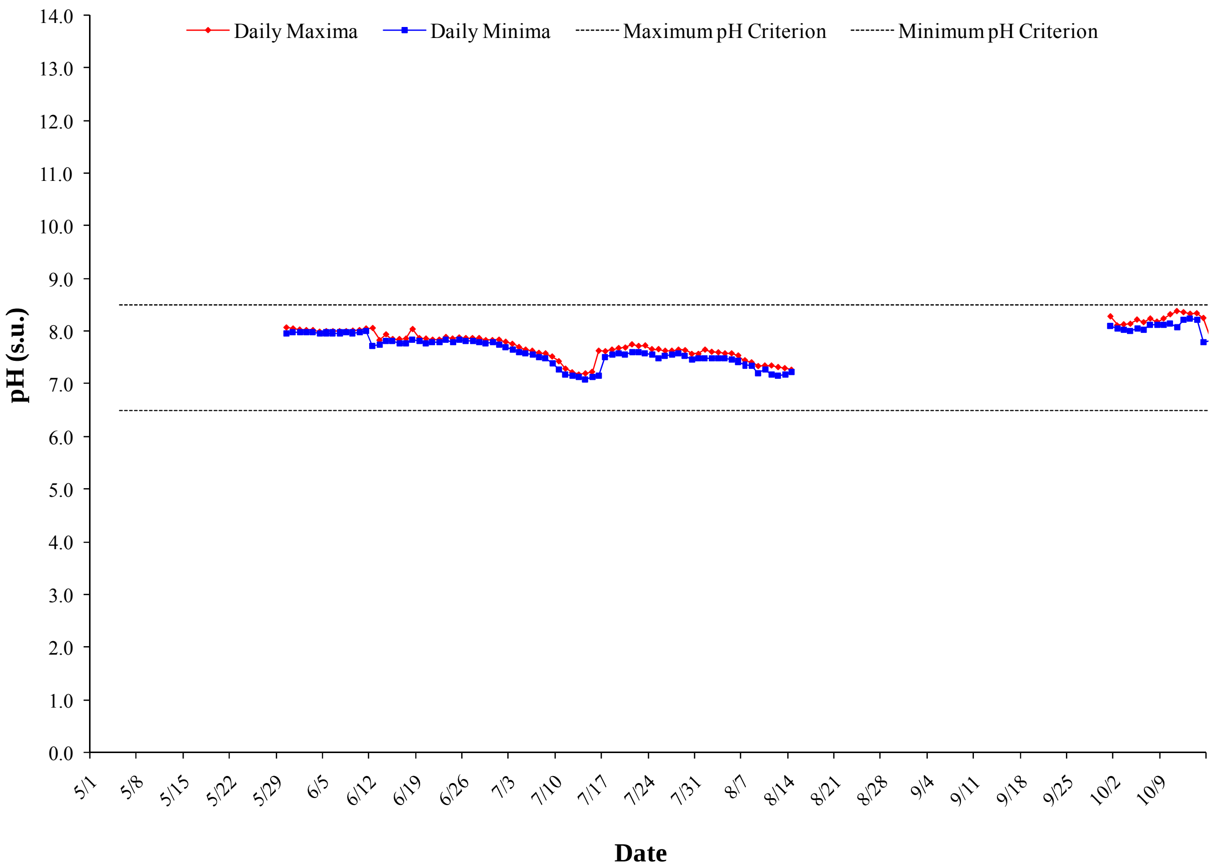


Figure 6.3-5 Daily minimum and maximum pH measurements at the Wells Dam forebay.

6.4 Turbidity Results

Lower Okanogan River turbidity increased sharply with the snowmelt runoff peak beginning on May 18, reaching peaks of 350 NTU on May 28 at Monse and 650 NTU on May 19 at Highway 97 (Figure 6.4-1). The turbidity sensor at Malott did not trigger properly when installed in early May and was inaccessible to the data monitoring crew for over a month due to flooding and a log jam on the Malott Bridge. As a result, no data were recorded at this site upriver from the Wells Project boundary to define incoming turbidity levels. Therefore, comparisons to background turbidity during the most critical time periods were limited.

A second period of high turbidity was recorded at Malott between August 9 and 16; however, those data were rejected as unreliable during quality assurance review because (1) turbidity remained low downstream at Monse and Highway 97 during this period, and (2) a review of weather records did not show any storm events on these days that might explain a spike in turbidity. It is likely that the turbidity sensor was temporarily fouled by clumps of filamentous algae that were observed floating through this river reach in late summer.

On a few occasions the turbidity at Monse (5 of 122 comparable days, or 4%) or Highway 97 (8 of 165 comparable days, or 5%) exceeded turbidity at Malott by more than 5 NTU. On two occasions in late June and early July, and again on three occasions in late September, turbidity at Monse exceeded turbidity at Malott by more than 5 NTU. Turbidity at Highway 97 exceeded Malott turbidity by more than 5 NTU on eight occasions between July 14 to August 2. These events were not widespread or persistent within the Wells Project.

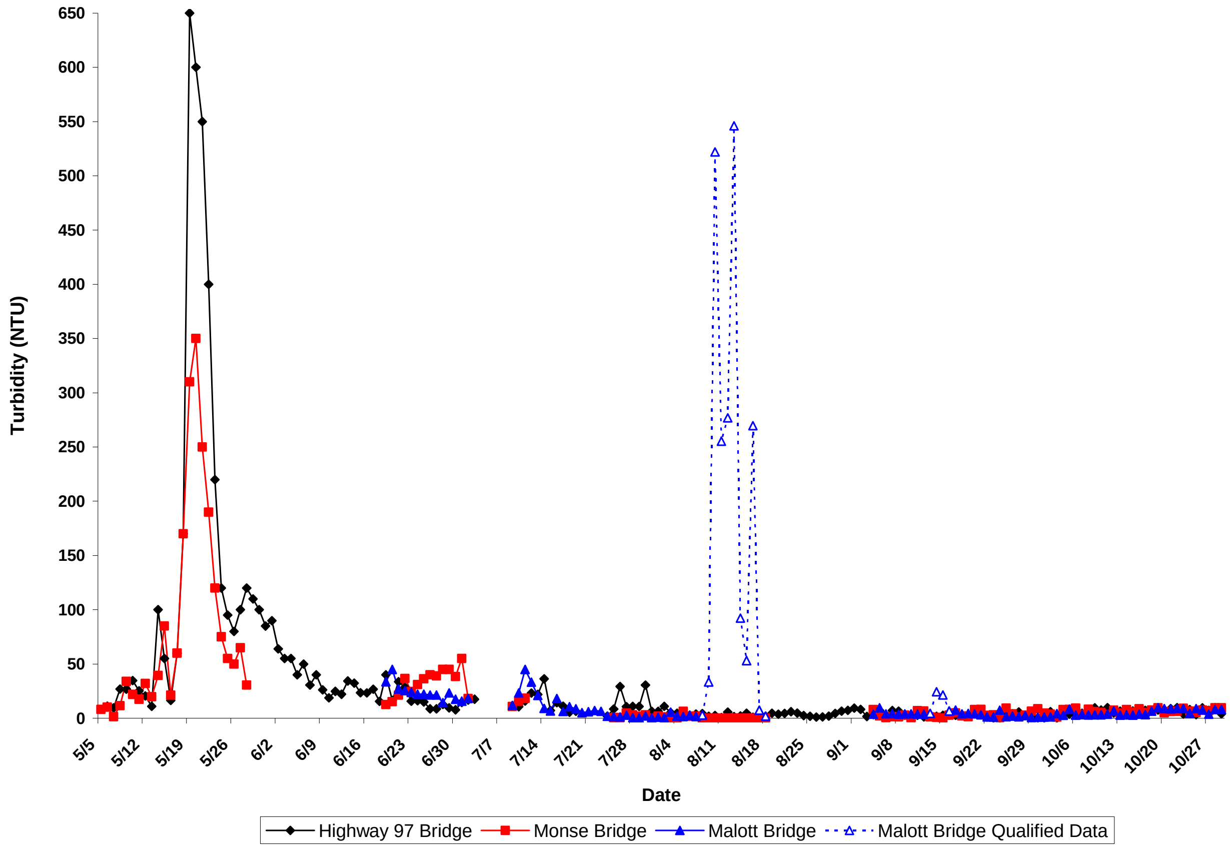


Figure 6.4-1 Daily maximum turbidity measurements (NTU) in the lower Okanogan River.

As discussed in greater detail in Section 7.1, instrument performance and maintenance issues with the Global Water WQ750 turbidity sensor at the Wells Dam forebay led to the data collected at that site to be judged unreliable and rejected as unusable. Therefore, no turbidity results are reported for that location during the 2008 study season.

6.5 Quality Assurance Results

6.5.1 Dissolved Oxygen Quality Assurance Results

The Datasonde primary instruments met data quality objectives for DO, and Winkler titrations generally confirmed DO measurements within 0.1 mg/L. Some readings from periods when the battery power was depleted were qualified as unusable. No other observable anomalous DO readings were identified. However, the DO recordings at the Wells Forebay were lower than expected immediately after installation of the replacement unit in early October, then began to rise consistent with water temperature as would be expected.

6.5.2 pH Quality Assurance Results

Datasonde pH accuracy was generally within 0.1 standard units. The pH electrode does not demand as much power as the other probes and generally did not seem to be affected by battery depletion. On two occasions the pH readings appear anomalous, the first from a five-day period in late July and early August at Monse when the pH dropped approximately one full pH unit. Because the pH at Malott and Highway 97 remained steady or increased slightly over this period, the drop in pH at Monse could not be explained and those data were qualified as questionable. The second occasion was between October 18 and 21 when pH electrode readings at Highway 97 drifted downward by more than one pH unit before servicing and re-calibration. Again the pH drift was isolated to one monitoring site and the data were qualified as questionable.

6.5.3 Turbidity Quality Assurance Results

Datasonde calibration and verification for turbidity standards were occasionally exceeded by ± 2%, though primary instruments generally met data quality objectives.

A period of high turbidity was recorded at Malott between August 9 and 16; however, those data were rejected during quality assurance review because (1) turbidity remained low downstream at Monse and Highway 97 during this period, and (2) a review of weather records did not show any storm events on those days. It is likely that the turbidity sensor was temporarily fouled by clumps of macrophytic algae that were observed floating through this river reach in late summer.

A few other data points at each lower Okanogan River station were qualified as unusable when the turbidity reading spiked up for only 30 minutes, possibly due to particle interference or temporary fouling of the probe. A few hours of anomalous data from the Highway 97 site were similarly qualified, due to battery depletion.

7.0 DISCUSSION

7.1 Dissolved Oxygen

In 2005, Douglas PUD contracted with EES Consulting to conduct a comprehensive limnological investigation of Wells Project waters. Results of the study found DO levels at 1m depth in Wells Project waters increased from upriver to downriver at the sites sampled; the average difference (May through October) was 1.07 mg/L. All surface water measurements had DO values greater than 8.0 mg/L (EES Consulting, 2006). A comparison of monthly grab samples collected by Ecology at Malott and EES in the lower Okanogan River does not indicate a reduction in DO moving downstream in the Okanogan River.

Measurements collected during the 2008 study did not identify a Project effect on DO when comparing measurements collected at Malott, Monse and Highway 97 monitoring stations. Regression analysis determined that minimum DO measurements collected within Project boundaries on the Okanogan River were statistically indistinguishable and strongly related to values recorded above the Project boundary (Malott). Strong seasonal trends in minimum DO were observed that coincided with temperature fluctuations of incoming waters from upstream of the Wells Project (e.g., above Malott). Lower DO concentrations were observed most frequently upstream of the Wells Project boundary at Malott, indicating that the source of low DO originates from upstream of the Project boundary. Daily DO and temperatures at Malott had a strong and significantly negative correlation (correlation coefficient = -0.98, $P < 0.001$). Excursions of daily minimum DO concentrations below 8.0 mg/L were observed 31% of days at Malott (42/134), 23% of days at Monse (27/120), and 17% of days at Highway 97 (28/165) indicating a lower frequency of excursions below the standard within the project despite the continued input of water that does not meet the DO standard from upstream of the Project.

Similarly, seasonal gradual declines in DO concentrations were observed with increasing temperatures in the Wells forebay (i.e., a negative correlation). Daily minimum DO concentrations remained well above 8.0 mg/L throughout the entire summer, until a brief and minor (4 days, 7.8 mg/L minimum value overall average) excursion occurred in the fall of 2008 (October 2nd to October 5th) upon the installation of a replacement instrument. These readings are likely related to instrument equilibration following installation as DO levels below 8.0 mg/L are uncharacteristic of the Columbia River and the Wells forebay, especially during periods of cooling such as October. Observed daily DO concentrations were consistently above 9.3 mg/L at all locations.

Diurnal patterns in DO concentrations were observed during the summer and early fall months at Malott, Highway 97, and, to a lesser extent, Monse. DO concentrations would reach their daily maximum values in the evenings followed by daily minima in the mornings. This was likely caused by greater daytime solar heating and fluctuation in water temperatures as spring snowmelt runoff recedes, and the diurnal photosynthesis/respiration cycle of aquatic vegetation. Diurnal fluctuations in DO concentrations were not evident at the Wells Dam forebay.

7.2 pH

Based upon results from the 2005 study, all surface water measurements for pH generally varied between 7.5 and 8.25, which is slightly above neutral. There were no measured exceedances of the water quality criteria for pH in 2005 either in the Okanogan, Methow or Columbia rivers within the Wells Project. Similarly, results collected from 2008 indicated that pH readings decreased as water moved downstream through the lower Okanogan River. The majority of higher pH readings in the Okanogan River were recorded above the Wells Project, and at no time did the daily maximum pH values from downstream monitoring locations exceed the pH at Malott by more than 0.06 units. These results indicate that pH levels of incoming water are the primary cause for any excursions above the 8.5 criterion observed within the Wells Project. All pH measurements at the Wells forebay were within the 6.5 to 8.5 water quality criteria, and at no time did pH values approach the 6.5 minimum criterion anywhere in the Wells Project. Based upon the results collected during the 2005 and 2008 studies, the Wells Project is not negatively influencing pH.

7.3 Turbidity

Based upon results from the 2005 limnological study, turbidity in the Wells Reservoir showed relatively little seasonal variation with an annual average of 0.98 NTUs. Longitudinal variation in turbidity was also minimal. Low turbidity in the reservoir was attributed partially to the large upriver storage reservoir capacity that allows fines to settle out. Turbidity in the Okanogan River was consistently higher than in the Wells Reservoir.

Based upon the results from the 2008 study, it is not clear what effect, if any, the Wells Project may have had on turbidity through the 2008 monitoring period. There are limited data available upriver from the Wells Project boundary to enable comparisons to background (Malott) during the high turbidity that accompanied the peak of snowmelt runoff in late May and early June. On only a few occasions after peak snowmelt runoff the turbidity at Monse (5 of 122 comparable days, or 4%) or Highway 97 (8 of 165 comparable days, or 5%) exceeded turbidity at Malott by more than 5 NTU, but the exceedances occurred on the same date at both monitoring sites only once. Because the events with elevated turbidity were scattered throughout the monitoring period and generally did not occur at both Monse and Highway 97 on the same days, these results are not suggestive of any widespread or persistent turbidity issues in the Wells Project.

8.0 STUDY VARIANCE

This study was not required by the FERC as part of the October 11, 2007 Study Plan Determination. This study was voluntarily conducted by Douglas PUD at the request of Ecology in support of the 401 water quality certification for the Wells Project.

Variances associated with the voluntarily conducted study for DO, pH, and Turbidity included the following:

- The upper sampling station location was changed from the Project boundary (RM 15.5) to the Malott Bridge (RM 17.0). No suitable structure could be found at RM 15.5 and as a result, the instrument housing was installed on the Malott Bridge located at RM 17.0. This change in location should have no effect on the results of this study.
- The Study Plan specified that DO monitoring would take place hourly between mid-July and mid-September when there is a greater possibility of lower DO levels occurring. In order to access the river prior to the peak of the spring hydrograph, the monitoring equipment was deployed earlier than required in the study plan. Equipment was deployed on May 5 and 6 at the Okanogan River locations and May 30 at the Wells forebay. The equipment also continued collecting data until October 15, more than a month later than required by the study plan.
- The study plan required that data be collected on an hourly basis. Battery failures and instrument inaccessibility during high flow and debris load periods caused gaps in the hourly database.
- All turbidity results for the Wells Dam forebay location were judged to be unreliable and rejected as unusable. The self-cleaning mechanism on the water quality probe was not functioning properly and became fouled frequently during the study.

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