Water Quality Studies

Final Report

Gorge 2nd Tunnel Phase 1 and Phase 2 Design Services

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Appendix

USGS Temperature and Flow Data

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1.0 Introduction

In 1918, the federal government granted the City of Seattle permission to start developing hydroelectric generating facilities on the Skagit River. The following year, the City's electrical utility, Seattle City Light (SCL), began constructing the Gorge timber crib dam, the Gorge Powerhouse, and a tunnel to convey water from the dam to the powerhouse. In 1927, the Federal Power Commission, later called the Federal Energy Regulatory Commission (FERC), issued the first license to the City of Seattle for its facilities on the Skagit, thereafter called Project 553.

The original license has been amended by FERC several times, and the entire Skagit Project 553 was relicensed in 1991. The Gorge operation was most significantly modified in 1949, when SCL increased power generation capacity by installing another generator and adding 88 feet of head on the turbines by building High Gorge Dam. These improvements increased the Gorge Powerhouse's output as intended, but they also sped up the water velocity in the power tunnel, and the corresponding growth of frictional head loss lowered the efficiency of the powerhouse. The full generating capacity of the facility cannot be achieved because of headloss through the existing power tunnel. SCL has determined that a second power tunnel is necessary to reduce system headloss and increase generating efficiency.

A study of a second tunnel began in 2006, concurrent with the approval of Initiative I-937 by Washington State voters, also called the Energy Independence Act (Chapter 19.285 RCW). The Energy Independence Act requires large utilities, such as SCL, to obtain 15% of the energy they sell from renewable sources by 2015. The new energy that the Gorge 2nd Tunnel produces will count towards SCL's commitment to renewable energy and will reduce the amount of energy produced by fossil fuels that the utility currently has to buy to meet its customers' needs.

This report describes the current water quality in the Skagit River near the project site, the construction and operation of the Gorge 2nd Tunnel Project, the expected water quality impacts from the project, and avoidance and minimization measures proposed to reduce any potential water quality impacts.

The findings of the water quality studies will be used to:

- Support an application for a 401 Water Quality Certification;
- Assess potential impacts to the beneficial uses of the Skagit River from the construction and operation of the second tunnel; and
- Support National Environmental Policy Act (NEPA) documentation for the project.

2.0 Project Study Area

The Gorge Hydroelectric Project is located in the Upper Skagit watershed and utilizes the following waterbodies (Figure 1):

- Gorge Lake (river mile [RM] 96.5 to RM 100.9)
- Upper Skagit River (RM 92.8 to RM 94.3)

The proposed Gorge 2nd Tunnel Project will involve tunnel construction between the Gorge Dam tunnel intake and the existing powerhouse at Newhalem, WA (Figure 1).

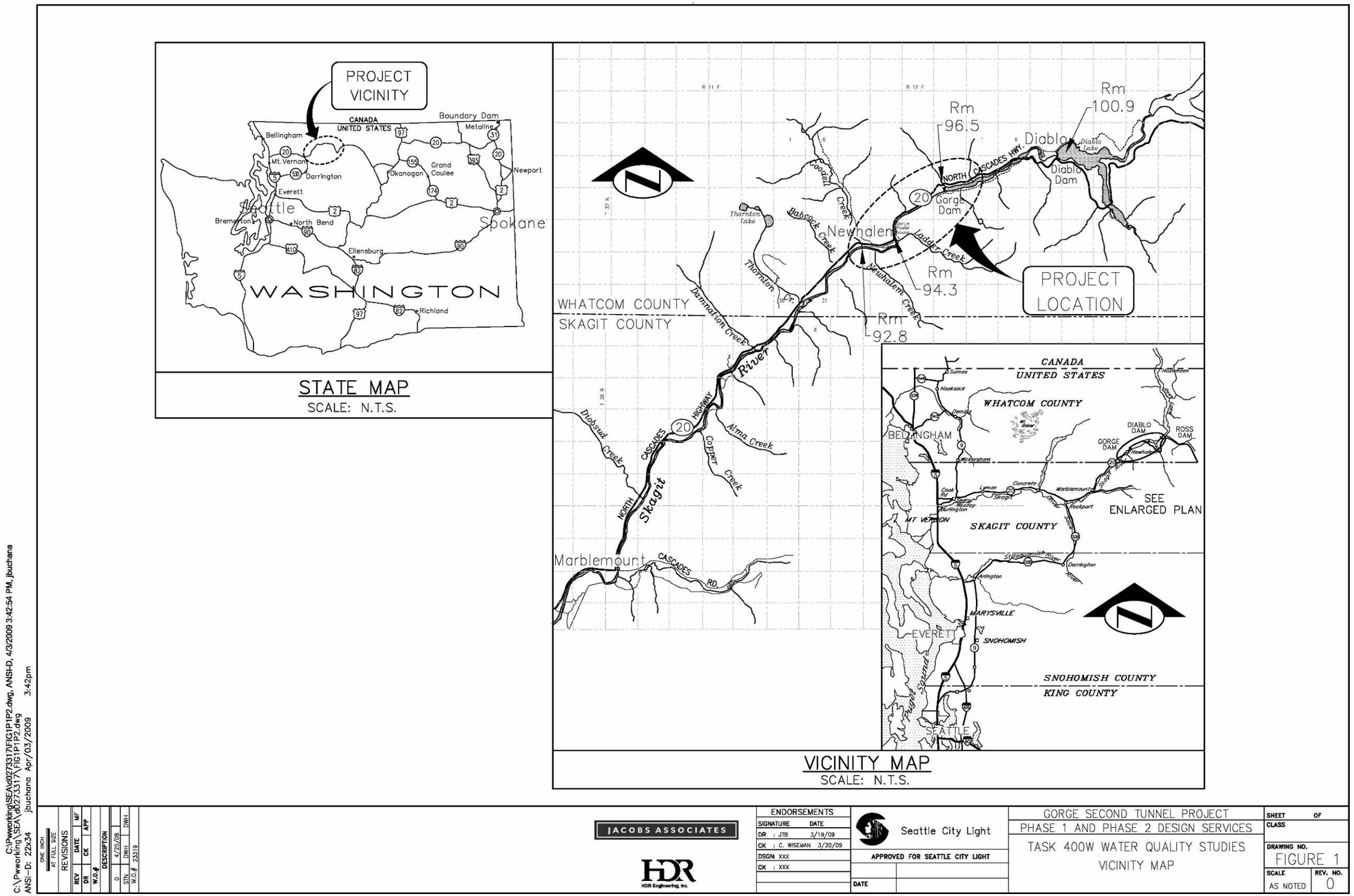

Figure 1. Vicinity map of Gorge 2nd Tunnel Project.

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3.0 Upper Skagit River Watershed (adapted from Smith 2001)

The Skagit River originates near Allison Pass in Canada, 35 miles north of the U.S.-Canada border (Phinney and Williams 1975). From the Canadian border to Newhalem, the Skagit River flows south through the rugged landforms of the Cascade Mountain Range. Three dams have been constructed in this region—the Ross (RM 105.1), Diablo (RM 100.9), and Gorge (RM 96.5)—but all are upstream of the natural anadromous salmonid distribution. The upper extent of anadromous salmonid distribution in the Skagit River is near Newhalem at RM 94.3 (Cutler 2001) near the Gorge Powerhouse. Chinook, chum, coho, pink, and sockeye salmon, steelhead, anadromous char, and cutthroat trout have been documented in the mainstem Skagit River (Cutler 2001).

Between Newhalem and Marblemount, the Skagit River flows through a narrow valley. The Skagit River mainstem has been classified as an unconfined, low-gradient channel in this area, but the tributaries entering the Skagit River are much steeper and more confined. The upper Skagit River mainstem is the primary spawning site for the most abundant Chinook stock in the Skagit Basin, the Upper Skagit Summer Chinook (Washington Department of Fish and Wildlife and Western Washington Treaty Indian Tribes 1994). Forestry is the primary land use in this sub-basin with agriculture and residences in the valleys. A large area (from Bacon Creek upstream and in the upper Cascade River watershed) is within the North Cascades National Park.

The Skagit Basin has a maritime climate with mild winters and drier summers. In the mountains, precipitation can exceed 140 inches per year, while the lowlands average less than 80 inches of annual rainfall (Drost and Lombard 1978). Most (75%) of the precipitation occurs from October through March.

4.0 Existing Facilities

The Gorge Power Plant is one of three generating facilities operated by SCL on the Skagit Hydroelectric Project. The Gorge Powerhouse is capable of generating 176 MW (megawatts) at a gross head of 380 feet. The nameplate generating capacity is 207.5 MW. The powerhouse has four turbine-generator units. Three of the units were installed in the 1920s, and the fourth unit was installed in 1951. The assumed maximum flow through the powerhouse is approximately 7,700 cfs (cubic feet per second).

5.0 Proposed Activities

The proposed Gorge 2nd Tunnel Project will increase the Gorge Powerhouse's efficiency by reducing frictional head loss during tunnel conveyance, raising the head pressure at the turbine, increasing the torque on the generator, and producing more power for any given flow. With the Gorge 2nd Tunnel Project completed, the facility will generate hydroelectric power approaching the nameplate capacity of the plant.

A tunnel boring machine (TBM) will be used to excavate rock to construct a new power tunnel between the Gorge Dam and Gorge Powerhouse (Figure 2). The tunnel will parallel the existing power tunnel. The TBM will be launched from a portal/ access adit located within the portal construction site next to the powerhouse. Access to the site is via the existing steel Gorge Powerhouse Bridge across the Skagit River. This construction site is constrained by the powerhouse on the south, the Skagit River on the west, and steep, near-vertical rock slopes on the north and east. The construction duration of the Gorge 2nd Tunnel project will be about 2 years.

Several key work activities are necessary to construct the project. Key activities include:

- Demolition/vegetation removal
- Portal development
- Tunnel excavation
- Tunnel connection
- Spoils disposal
- Site restoration

5.1 Demolition/Vegetation Removal

With the exception of the line of maples that separate the lower and upper parking lots, all vegetation, structures, and pavements in the portal area between the trees at the top of the river bank and the toe of the rock face will be removed. This includes the greenhouse and rearing sheds. SCL will determine which plants will be saved and transplanted.

On arriving at the site, the contractor will remove the vegetation that SCL did not transplant, demolish the nursery structures if necessary for space requirements, remove and install fencing where necessary, replace the lawn with crushed rock, build the turning radius at the end of the Gorge Powerhouse Bridge, install erosion-control structures, and set up temporary offices, job shacks, and worker facilities. A permanent shop building will also be constructed.

5.2 Portal Development

The contractor will excavate the first 100 feet or so of the portal access/adit by drilling and blasting methods. This tunnel, referred to as a starter tunnel, is used to launch the TBM. The rock slope around the portal will be stabilized before the starter tunnel is constructed. Loose rock will need to be scaled off the surface and the material hauled away. The contractor will secure the blocks of larger, more-stable surface rock. While preparing the portal site, the contractor will install collection, treatment, and disposal systems for both onsite storm runoff and tunnel discharge water. The contractor will then construct a tunneling shop building that will be subsequently converted to a storage building after the project is complete.

Site drainage and stormwater runoff will be generated during storms, which are expected to occur primarily from October through April. A preliminary arrangement of the flow and treatment of onsite drainage and stormwater is shown in Figure 3 and described in detail in the Water Management Plan (SCL 2009). Site drainage will be managed using a suite of source control best management practices (BMPs) to reduce the burden on treatment BMPs.

Tunneling discharge water will be generated at the portal site from groundwater seeping into the tunnel and smaller amounts of TBM process water. The flow and treatment of discharge water from the tunnel is shown in Figure 3 and described in detail in the Water Management Plan (SCL 2009).

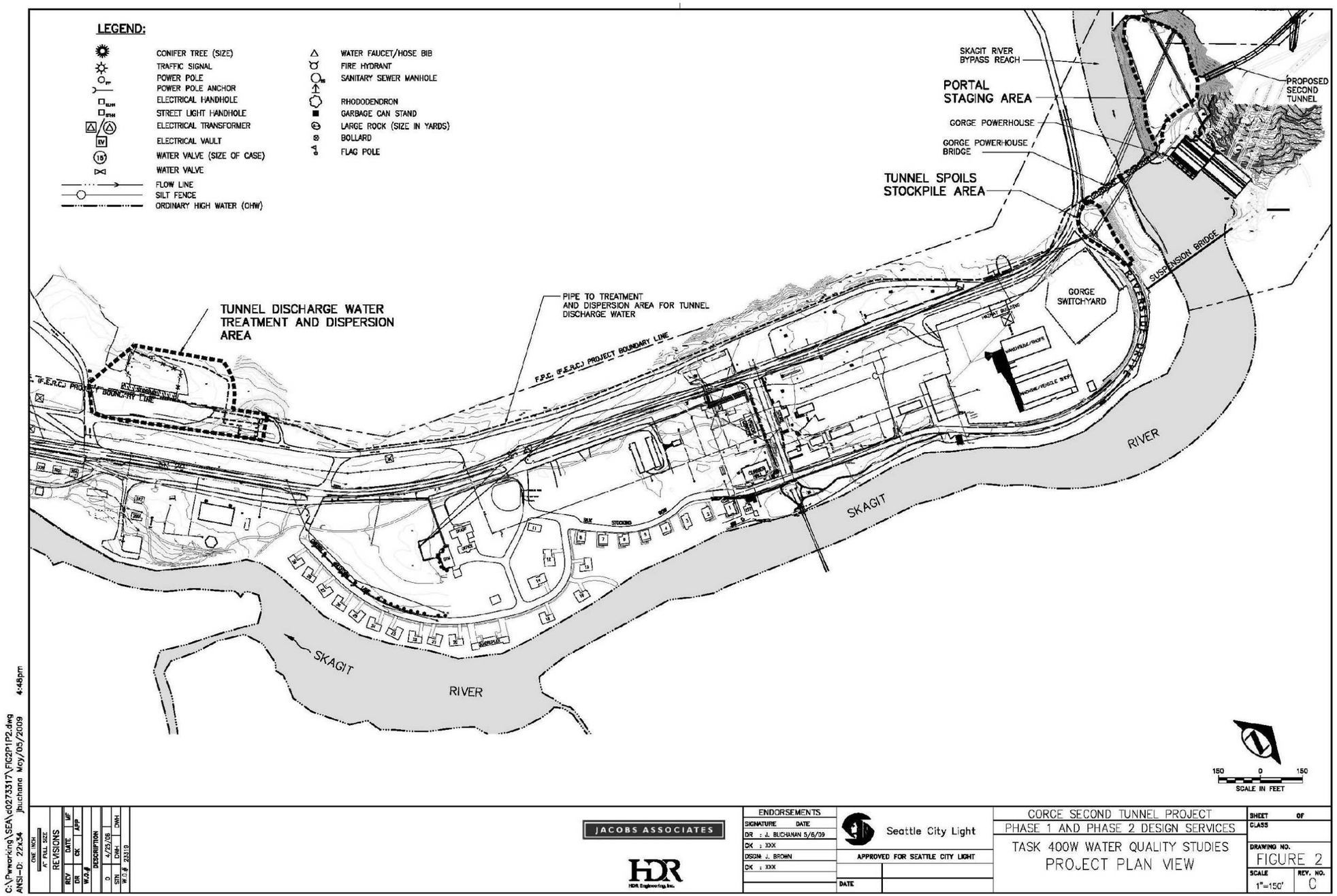


Figure 2. Gorge 2nd Tunnel Project plan view.

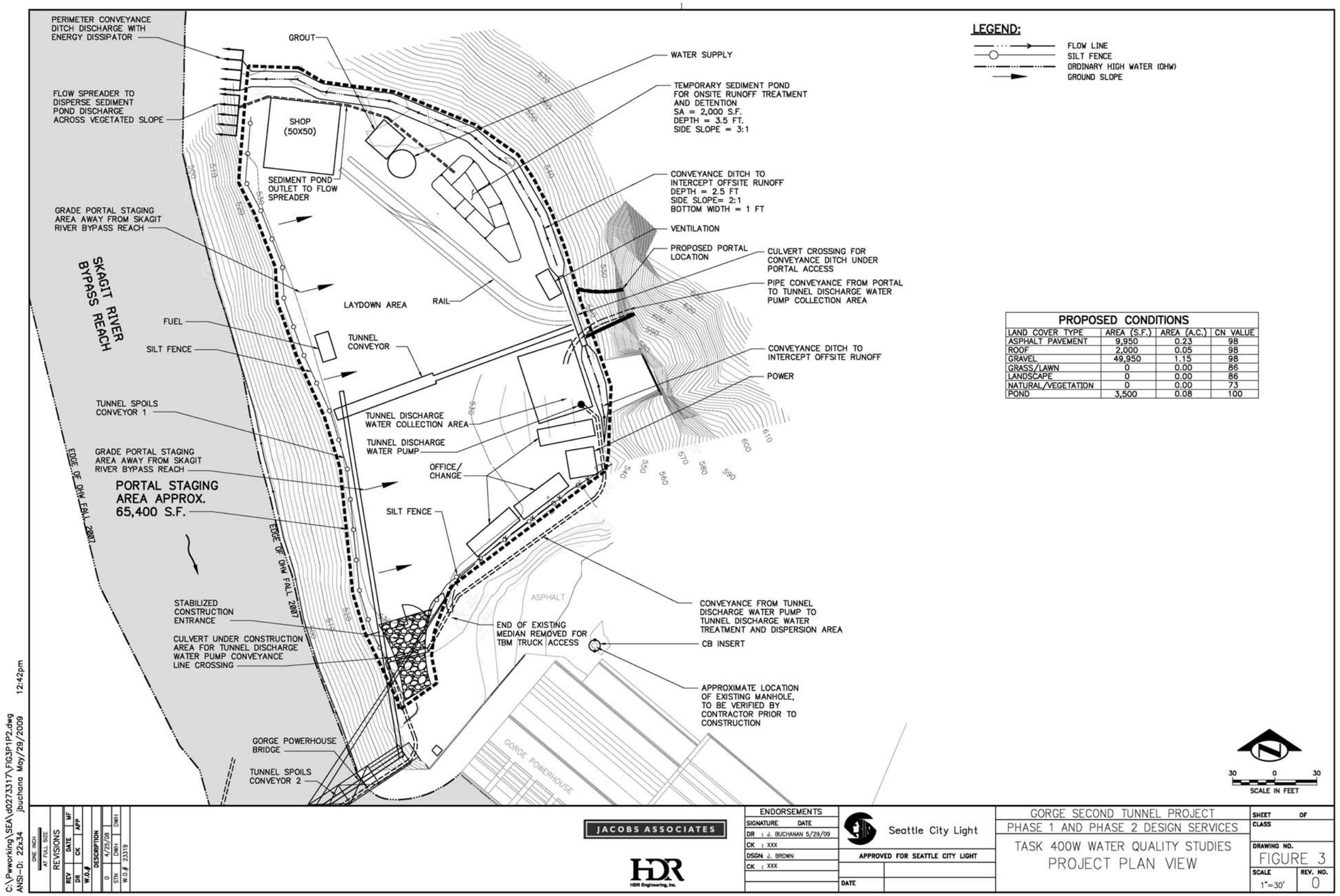


Figure 3. Tunnel discharge water and portal stormwater management plan view (PRELIMINARY).

5.3 Tunnel Excavation

After the tunnel portal and starter tunnel have been constructed, the TBM will be assembled and launched. It is anticipated that an “open,” main beam TBM will be used. This type of machine is advanced by hydraulic rams supported by grippers between the main beam of the machine and the rock wall. The initial support system will generally consist of various combinations of rock bolts, mesh and steel ribs depending on the ground conditions. The initial supports will be installed directly behind the cutterhead. The tunnel will be excavated through Skagit Gneiss. This material is believed to contain less than 1% sulfide minerals (pyrite, marcasite, and pyrrohotite) based on bedrock observations during the 1954 geologic investigation for the Gorge High Dam (SCL 1954).

5.4 Tunnel Connection

When tunnel excavation is nearly complete and connection to the existing tunnel is underway, the Gorge facility will need to go off line. During this time, the flow will be directed to a spillway at the Gorge Dam, where it will enter into the Skagit River channel directly below the dam. When the new facility is ready to go back on-line, the spillway will be closed and the water will be redirected into the tunnels.

5.5 Spoils Disposal

Excavation during tunnel construction will generate loose (that is, bulked) materials. These bulked materials are referred to as spoils. Spoils will consist of fine material from crushing and rock chips, about 2 to 3 inches long, from fracturing. Lesser amounts of gravel-sized material will also be present in the tunnel spoils. The spoils will have very low moisture content and may have to be dampened to control dust. The two standard methods of spoils removal out of a TBM tunnels are rail-mounted cars, and a horizontal continuous conveyor belt. The choice of spoils transportation methods will be primarily based on contractor preference and equipment. The spoils will be transported across the Skagit River on an enclosed conveyor. Once across the river, the spoils will be temporarily stockpiled and loaded into trucks. The trucks will transport the spoils to the Bacon Creek mitigation site. The Bacon Creek mitigation site is an old rock quarry. The spoils will be used as fill to implement the restoration grading plan.

5.6 Site Restoration

After the new tunnel has been commissioned and the temporary facilities have been removed, the contractor will grade off the portal area, rebuild the upper parking lot, and re-sod the rest of the staging area. The contractor or SCL will replant the shrubs and trees removed before construction. The contractor’s tunneling shop building will be left in place and converted to a storage building for the powerhouse.

6.0 Protection of Receiving Waters

6.1 Beneficial Uses and Surface Water Quality Standards

The Upper Skagit Watershed is predominantly forested National Park and National Forest ownership. For this reason, the water quality in the Upper Skagit River is good. The regulatory framework that protects the water quality in the Upper Skagit River is based on specific *beneficial uses* and the associated water quality standards that support those beneficial uses (see Table 1 and Table 2). Under the federal Clean Water Act, beneficial uses must be designated for all surface waters within a state or tribal jurisdiction. Washington State has met this requirement with its regulation Water Quality Standards for Surface Waters of the State of Washington. These standards are in Washington Administrative Code (WAC) 173-201A. The Upper Skagit River has the following beneficial-use designations (Table 1).

Table 1. Beneficial uses designated for the Upper Skagit River.

Beneficial-Use Designations
Core Summer Habitat
Extraordinary Primary Contact
Domestic Water
Industrial Water
Agricultural Water
Stock Water
Wildlife Habitat
Harvesting
Commerce/ Navigation
Boating
Aesthetics

The surface water quality standards that support these beneficial uses are defined in Table 2. These water quality standards and the antidegradation provisions constitute the policy goals of the construction stormwater National Pollutant Discharge Elimination System (NPDES) permit and 401 Water Quality Certification.

Table 2. Surface water quality standards that support the beneficial uses designated for the Upper Skagit River.

Parameter	Statistic	Surface Water Quality Standards	Mixing Zone
Temperature	7-day average of the daily maximum temperatures	16 degrees Celsius	NA
Dissolved oxygen	Lowest 1-day minimum	9.5 mg/L	NA
Turbidity	NA	5 NTU over background	300 ft
Total dissolved gases	NA	110% of saturation*	NA
pH	NA	6.5 to 8.5, with a human-caused variation within the above range of less than 0.2 unit	NA

* Applies to flows below the 7-day, 10-year-frequency flood. There are conditional criteria for hydropower operations.

mg/L = milligrams per liter

NTU = nephelometric turbidity units

6.2 Antidegradation Policy

The Clean Water Act requires that state water quality standards protect existing beneficial uses by establishing the maximum level of pollutants allowed in state waters. The standards also protect waters from unnecessary lowering of water quality. Washington State's antidegradation policy follows the federal regulation and has three tiers of protection.

- **Tier I** is used to ensure that existing and designated uses are maintained and protected. Tier I focuses on fully applying the water quality criteria and correcting problems using the Washington State Department of Ecology's (WDOE) existing regulatory and total maximum daily load (TMDL) processes.
- **Tier II** is used to ensure that waters of a higher quality than the criteria assigned in the standards are not degraded unless such lowering of water quality is necessary and is in the overriding public interest. Tier II applies only to new or expanded sources of pollution from specific types of activities directly regulated by WDOE.
- **Tier III** is used when high-quality water is designated as "outstanding resource water." The water quality and uses of these waters must be maintained and protected against all sources of pollution.

Since the Upper Skagit River does not currently have any 303(d) listings, the Tier II antidegradation standards apply to a 401 water quality review of the Gorge 2nd tunnel. Actions that are expected to cause a measurable change in the quality of the water cannot be allowed unless WDOE determines that lowering water quality is necessary and is in the overriding public interest. A measurable change is defined as any of the following criteria at the edge of a chronic mixing zone:

- Temperature increase of 0.3 degrees Celsius or greater
- Dissolved oxygen decrease of 0.2 mg/L or greater
- Bacteria level increase of 2 cfu [colony-forming unit]/100 mL or greater
- pH change of 0.1 unit or greater
- Turbidity increase of 0.5 NTU or greater
- Any detectable increase in the concentration of a toxic or radioactive substance

7.0 Existing Surface Water Quality Data

7.1 Data Inventory

Existing surface water quality and flow data were compiled from all relevant and credible sources (Table 3). Data were collected immediately downstream of the Gorge Powerhouse at Newhalem, WA (RM 93.7), and 15 miles downstream at Marblemount, WA (RM 78.7).

Table 3. Summary of relevant historical data available to describe existing water quality in the Skagit River below the Gorge Powerhouse.

Source	Station Name	Station ID	Period of Record	Flow	Temperature	Dissolved Oxygen	Turbidity	Total Dissolved Gases	pH
WDOE	Skagit River at Newhalem	04A140	1974–1977	X	X	X	X		X
WDOE	Skagit River at Marblemount	04A100	1978–2009	X	X	X	X		X
U.S. Geological Survey (USGS)	Skagit River at Newhalem	12178000	1999–2009	X	X				

7.2 Temperature

Continuous water temperature has been measured at long-term USGS station 12178000 at Newhalem, WA, at the Gorge tailrace. Ten years of data collection show that the water temperature at the tailrace is well below the 16-degree-Celsius surface water quality standard (Figure 4). The rolling 7-day average of daily temperature maxima are plotted by year in Appendix A. The typical temperature range at this station has been between 4 and 12 degrees Celsius. Data from WDOE's historical ambient station at Newhalem generally concurs with this temperature range (Figure 5). WDOE's long-term ambient station at Marblemount shows that this temperature regime has been in place for most of the latter half of the 20th century (Figure 6).

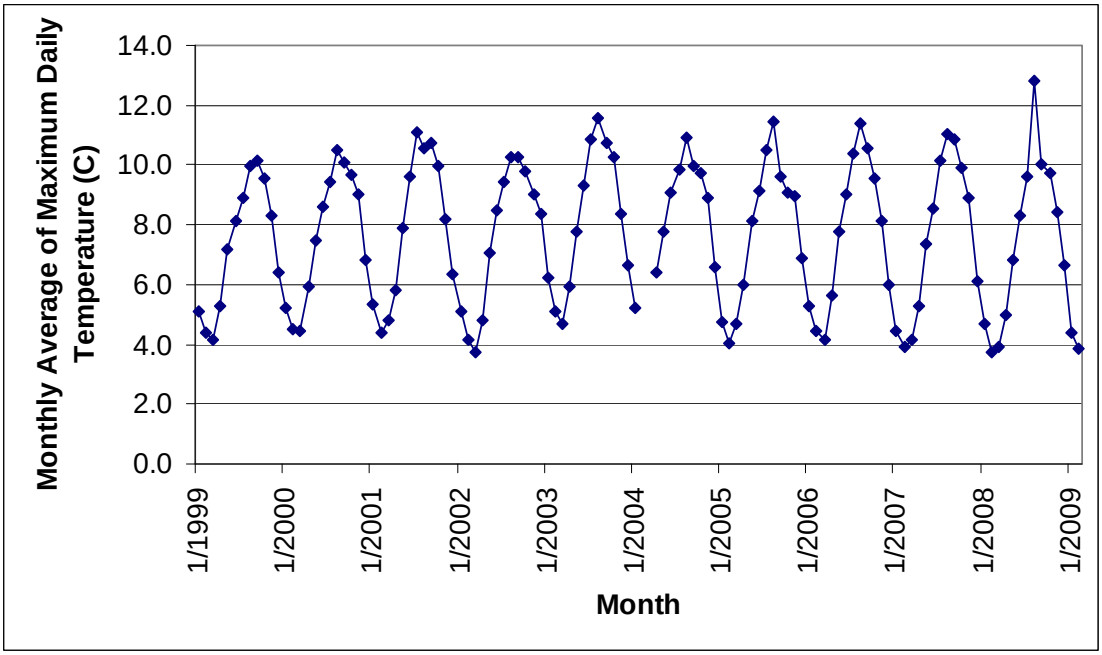


Figure 4. Monthly average of maximum daily river temperature at USGS station 12178000 at Newhalem, WA, at the Gorge tailrace.

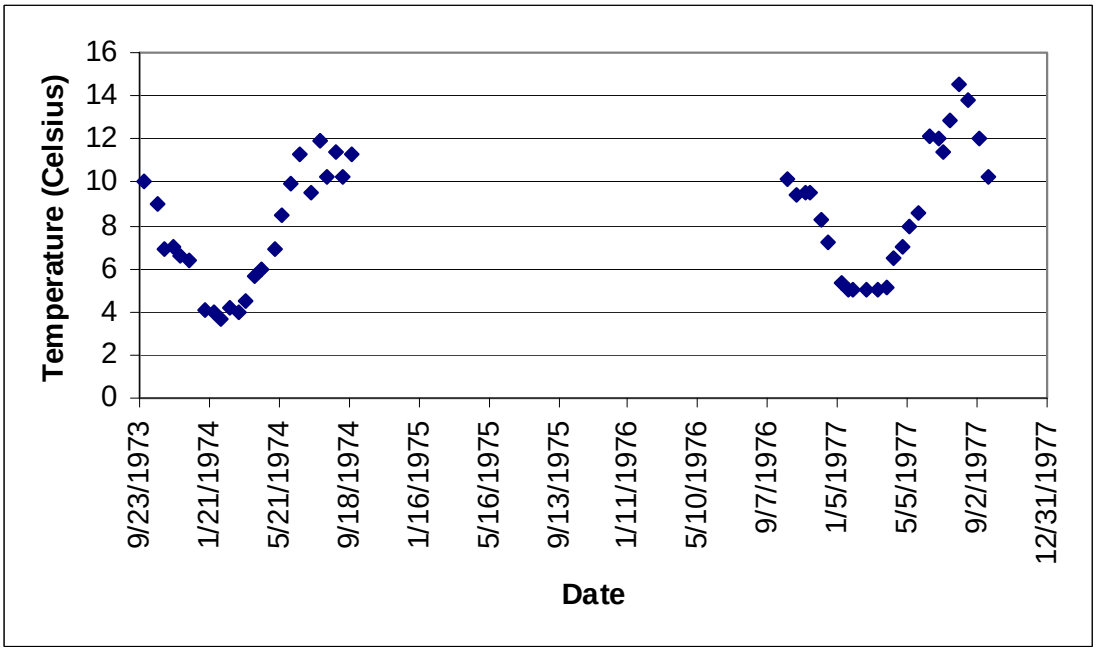


Figure 5. Instantaneous (grab) temperature measurements at WDOE station 04A140 at Newhalem, WA.

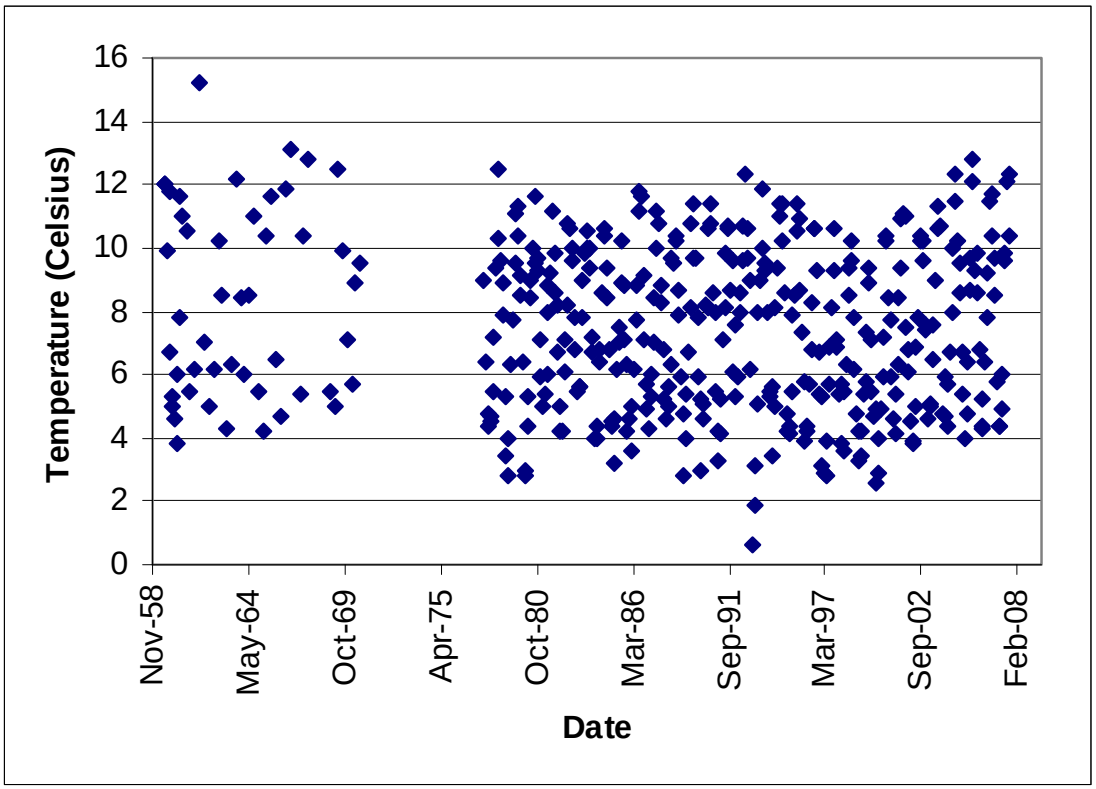


Figure 6. Instantaneous (grab) temperature measurements at WDOE station 04A100 at Marblemount, WA.

7.3 Turbidity

WDOE measured turbidity at their Newhalem, WA, station immediately downstream from the Gorge Powerhouse during the 1973–1974 water year. Turbidity was very low with an average value of 3.7 NTU and a range of 0.6–15.2 NTU (Figure 7). The long-term record at Marblemount, WA, also indicated low turbidity with an average value of 2.3 NTU and a range of 0.2–39.0 NTU (Figure 8). These turbidity data could be used to define the background surface water quality standard.

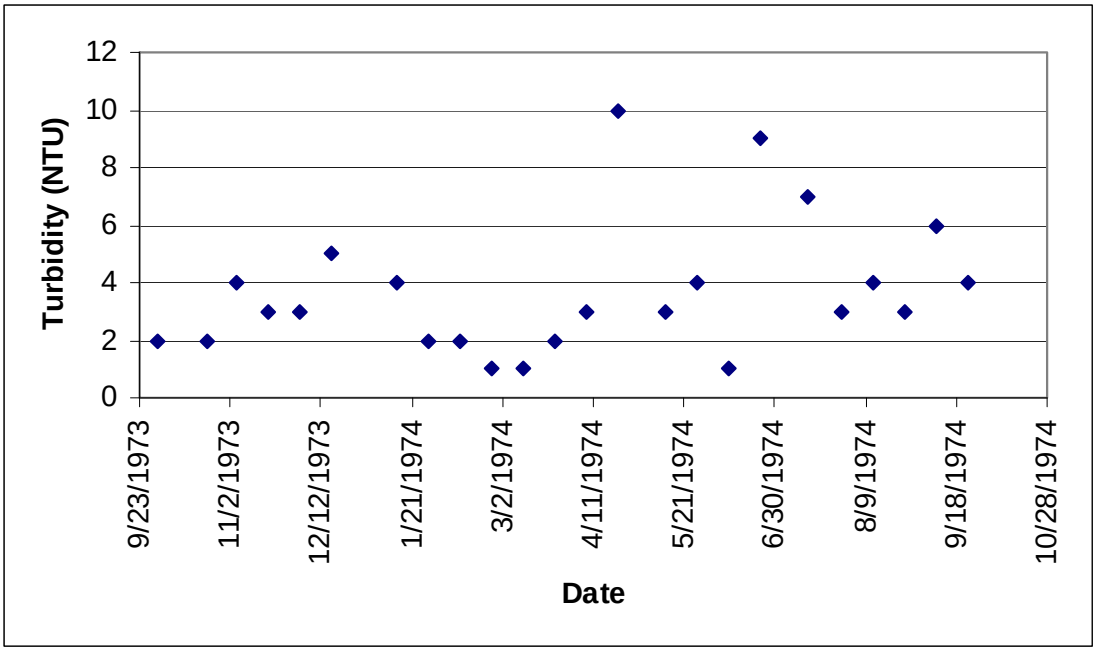


Figure 7. Instantaneous (grab) turbidity measurements at WDOE station 04A140 at Newhalem, WA.

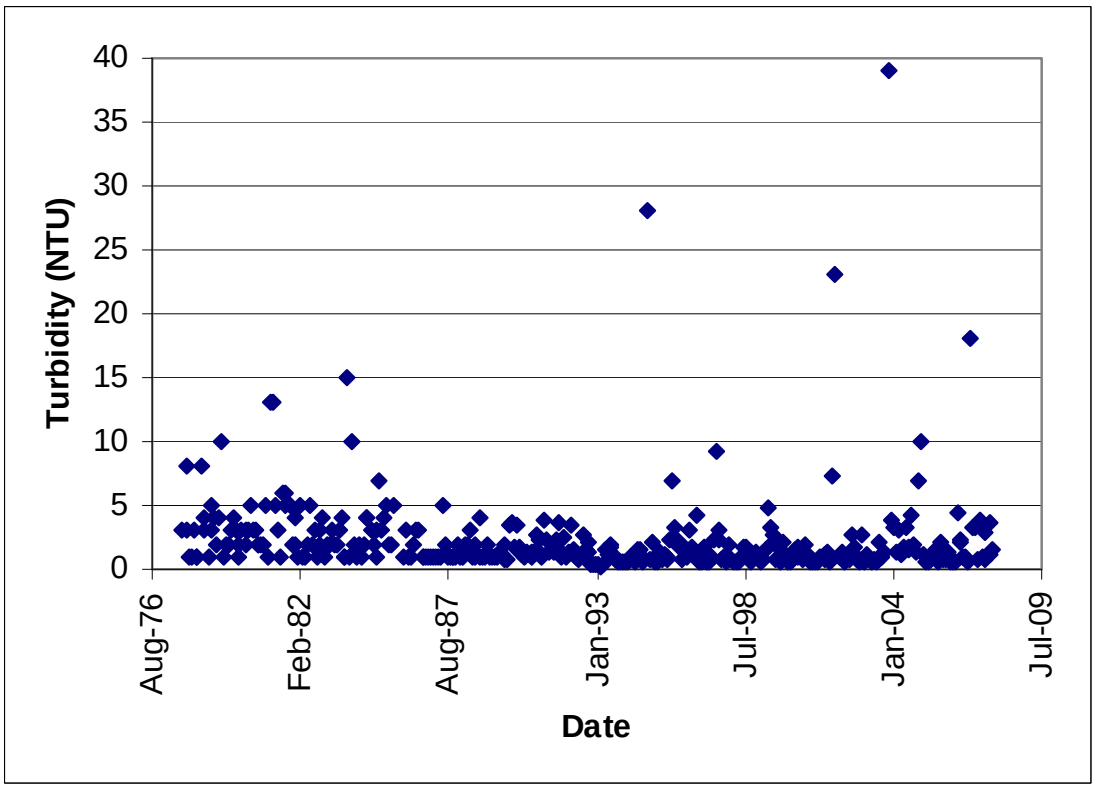


Figure 8. Instantaneous (grab) turbidity measurements at WDOE station 04A100 at Marblemount, WA.

7.4 Total Dissolved Gas

Total dissolved gas (TDG) was not measured at any of the stations.

7.5 pH

WDOE measured pH at their Newhalem, WA, station immediately downstream from the Gorge Powerhouse during the 1973–1974 and 1976–1977 water years. The pH was within standards with an average value of 7.3 and a range of 6.8–7.6 (Figure 9). The long-term record at Marblemount, WA, had an average pH of 7.4 and a range of 6.6–9.4 units (Figure 10). One measurement above the surface water quality standard is an outlier in the large data set, and is most likely a spurious result. The datum was collected by WDOE in the 1970s, and the department did not determine that it warranted a 303(d) listing.

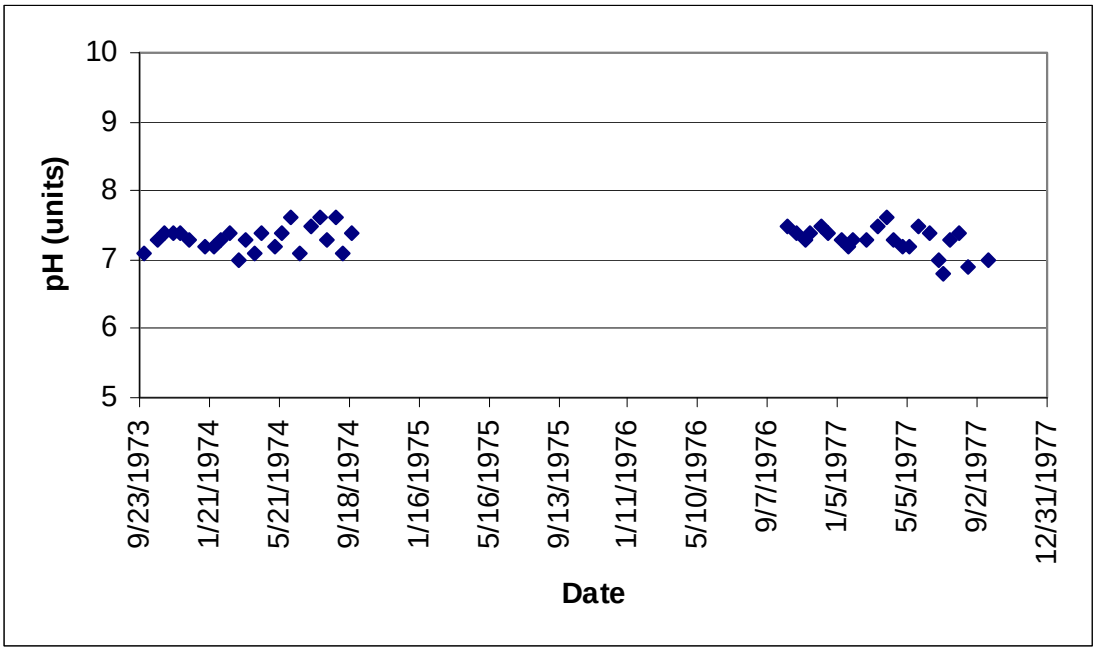


Figure 9. Instantaneous (grab) pH measurements at WDOE station 04A140 at Newhalem, WA.

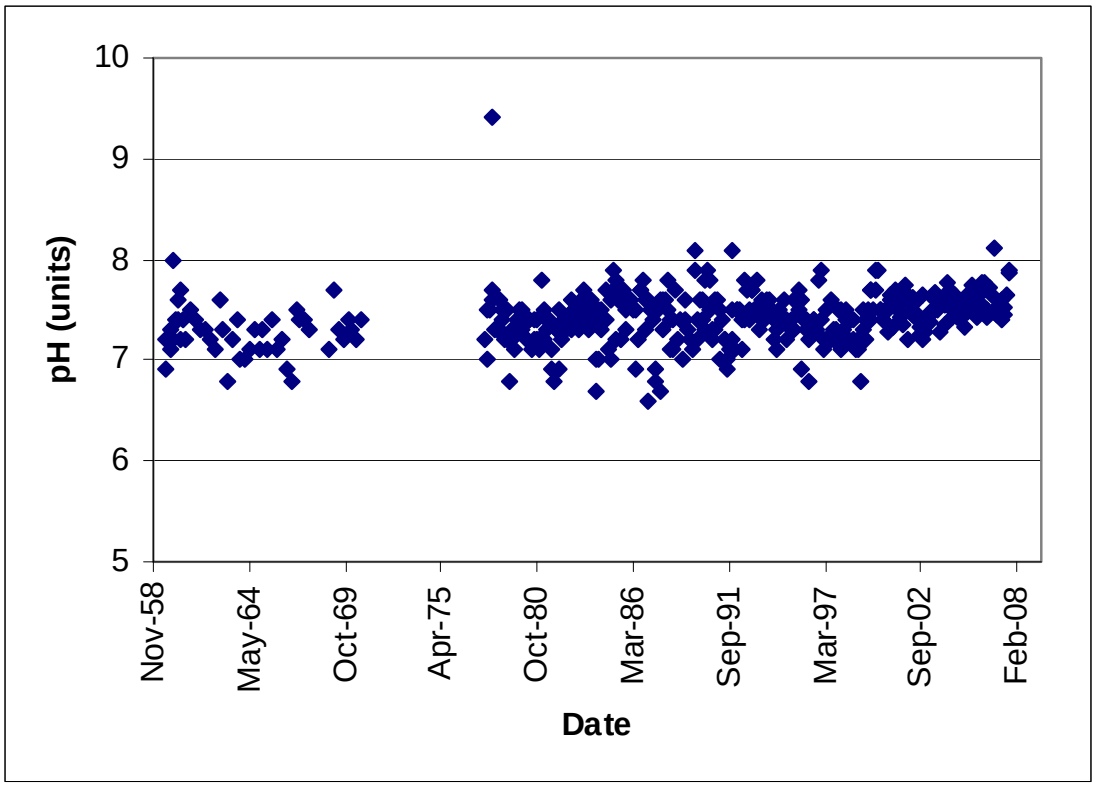


Figure 10. Instantaneous (grab) pH measurements at WDOE station 04A100 at Marblemount, WA.

7.6 Dissolved Oxygen

WDOE measured dissolved oxygen at their Newhalem, WA, station immediately downstream from the Gorge Powerhouse during the 1973–1974 and 1976–1977 water years. Dissolved oxygen was within standards with an average value of 13.1 mg/L and a range of 11.4–15.4 mg/L (Figure 11). The long-term record at Marblemount, WA, had an average value of 12.0 and a range of 9.6–15.0 mg/L (Figure 12).

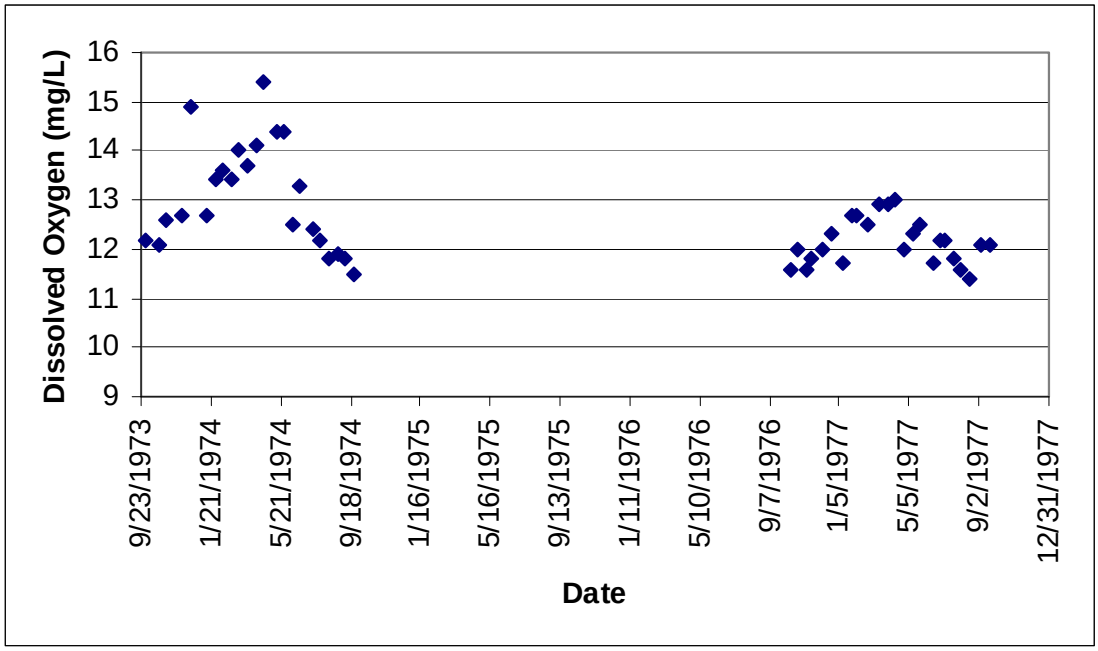


Figure 11. Instantaneous (grab) dissolved oxygen measurements at WDOE station 04A140 at Newhalem, WA.

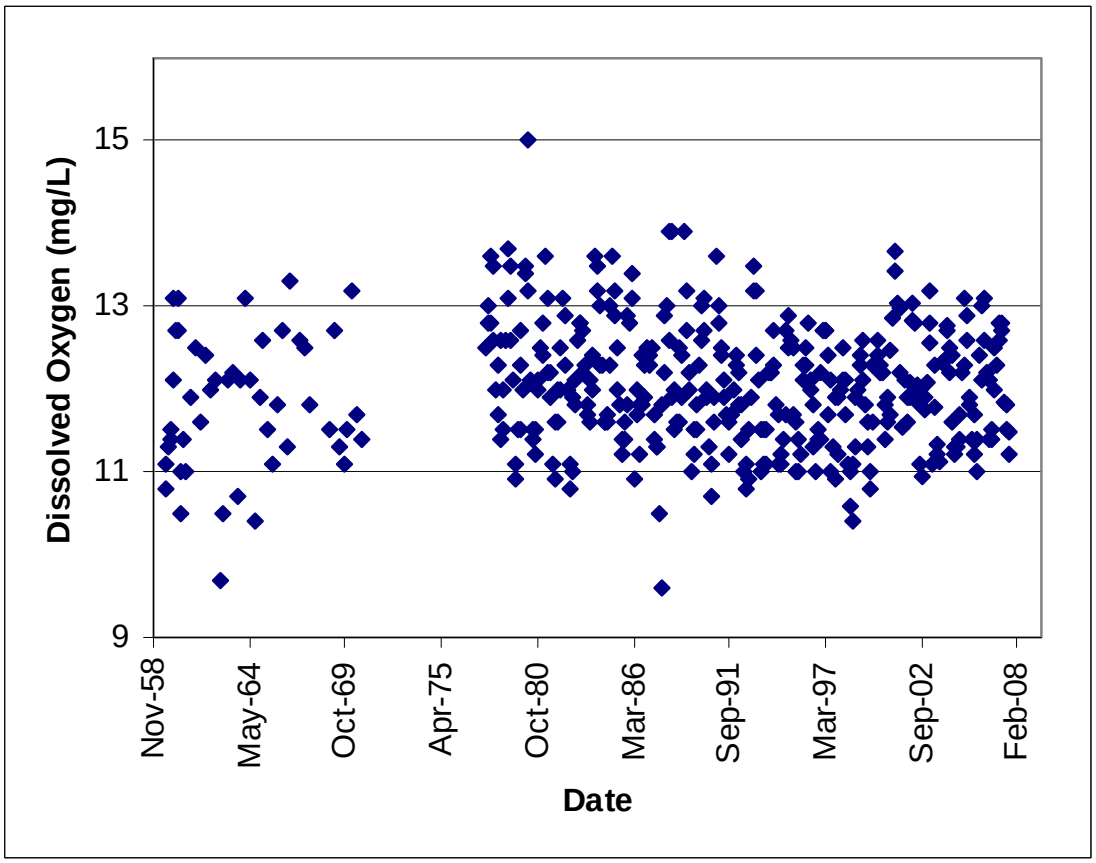


Figure 12. Instantaneous (grab) dissolved oxygen measurements at WDOE station 04A100 at Marblemount, WA.

7.7 Flow

The three Skagit Hydroelectric Project facilities, including the Gorge facility, are hydraulically coordinated to supply about one-fourth of SCL's power requirements while maintaining instream flows beneficial to salmon reproduction and rearing. The flow regime in the Skagit River under the 1991 Settlement Agreement (FERC 1991) and 1996 rehearing order provides eggs and embryos with high levels of protection from dewatering by imposing greater constraints on maximum flows during the salmon spawning period and by sustaining higher minimum flows during the incubation period. If flows are relatively high during the spawning period, then higher flows will be released from the project storage (provided by Ross Lake) during the fish incubation period. The flow provided by the project during low-flow periods is determined by modeling to provide dewatering protection to eggs and embryos. The effective protection levels range from 90% to 100% depending on tributary inflow conditions.

Minimum flow levels in the Skagit River have significantly increased as a result the Settlement Agreement (Connor and Pflug 2004). During the biologically critical salmon incubation period, minimum flows have increased in almost all years compared to flows before the agreements were implemented (that is, before 1981). Minimum flows during the Chinook salmon incubation period have increased from 1,300 cfs under pre-agreement conditions to 2,100 cfs under the final negotiated settlement (see Figure 13 and Figure 14 for recent flows). During the pink salmon incubation period, minimum flows have increased from 1,400 cfs under pre-agreement conditions to 2,100 cfs under the final negotiated settlement. Flow improvements are greatest for the incubation period of chum salmon with minimum incubation flows increasing from 1,600 cfs under pre-agreement conditions to 2,600 cfs under the final negotiated settlement.

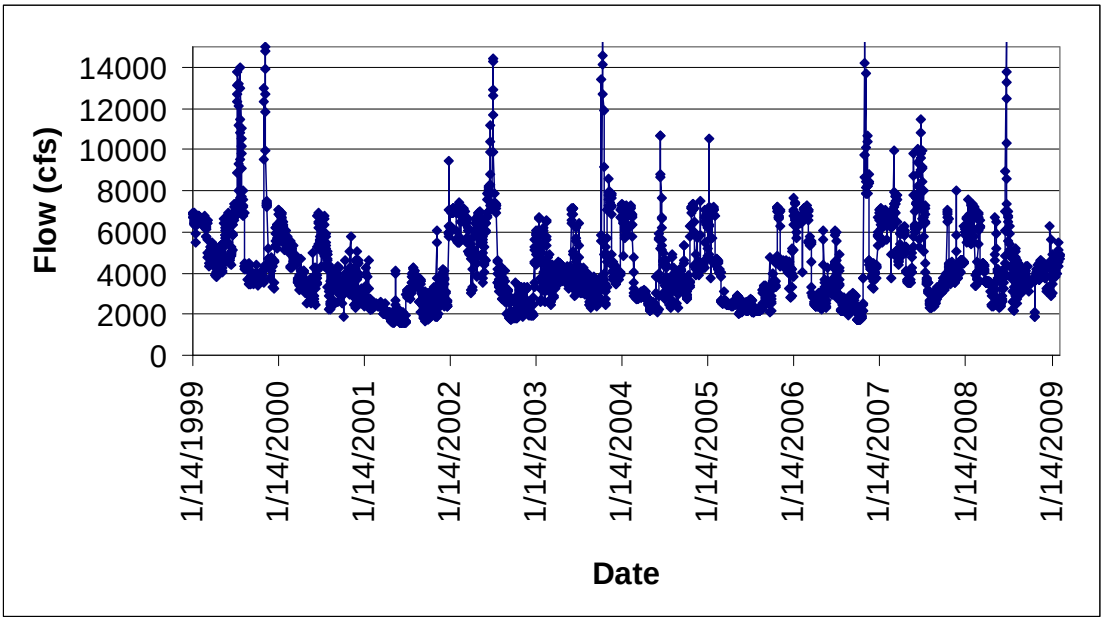


Figure 13. Average daily flow at USGS station 12178000 at Newhalem, WA, at the Gorge tailrace during the entire period of record, 1999 to the present. Flows greater than 15,000 cfs have been truncated.

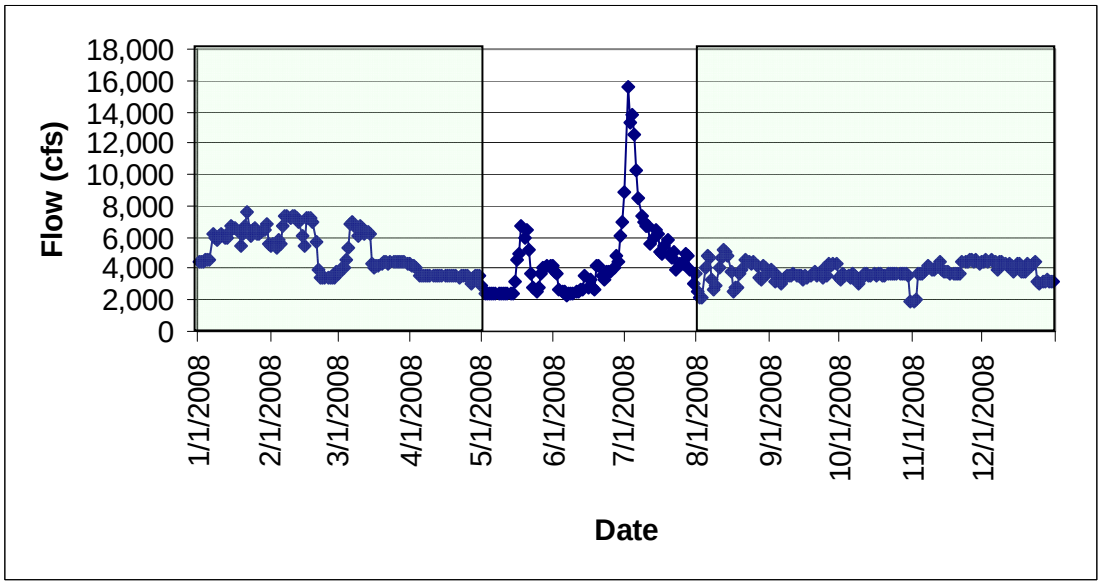
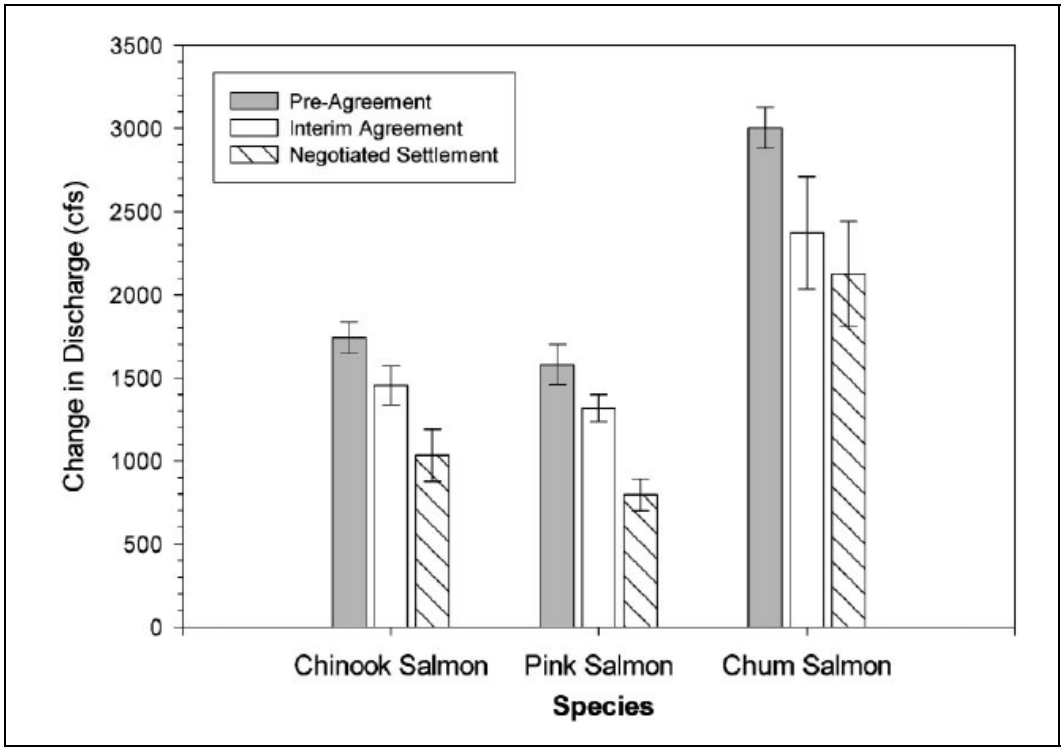


Figure 14. Average daily flow at USGS station 12178000 at Newhalem, WA, at the Gorge tailrace during 2008. The shaded area indicates critical fish incubation periods when minimum in-stream flows are in effect.

Project operations have been modified to minimize stranding of salmon and steelhead fry along the gravel bars in the Skagit River below the project. Before flow measures were implemented under the Settlement Agreement, many salmon fry were stranded along the river after project downramping events (reductions in flow). SCL commissioned the University of Washington Fisheries Research Institute to examine the relationships between daily flow

fluctuations and fry stranding and to identify specific flow measures that would reduce stranding and resulting mortality to fish.

These studies, which began in the mid-1970s, found that few salmon fry were stranded when project downramping rates were less than 3,000 cfs per hour and when downramping occurred during the night. Salmon and steelhead fry were more often stranded during daylight downramping events, since the fry move into gravel beds during the day to avoid predators. Based on the results of these studies, a maximum downramping rate of 3,000 cfs per hour was established under the Settlement Agreement and are limited to periods of darkness (Figure 15; Table 4). This has greatly reduced fry stranding in the Skagit River below the project.



Source: Connor and Pflug 2004

Figure 15. Average change in river discharge before the Settlement Agreement, during the interim Settlement Agreement, and after the final (negotiated) Settlement Agreement.

Table 4. Progression of operational changes at Skagit Hydroelectric Project[1]

Conditions	Number of Downramping Events	Daytime Downramping Events (%)	Average Downramping Amplitude (cfs)	Average Downramping Rate (cfs/h)
Pre-agreement	186	89	1762	583
Interim agreement	151	40	1760	718
Final agreement	90	3	1760	950

Source: Connor and Pflug 2004

cfs/h = cubic feet per second per hour

1Operational changes resulting from the pre-agreement to the interim and final agreements negotiated during Federal Energy Regulatory Commission relicensing (FERC 1991).

7.8 Data Gaps

The turbidity, pH, and dissolved oxygen data collected immediately below the Gorge Powerhouse are from the 1970s. Total dissolved gas data have not been collected immediately below the Gorge Powerhouse. Recent data for all of these parameters are desirable. However, new data for permitting the Gorge 2nd Tunnel Project might not be necessary for two reasons. First, a long-term and current record of water quality has been collected 15 miles downstream at Marblemount. Water quality at this station has been very good. Second, two tunnels at the Gorge facility will have the same operational effect on water quality as the current single tunnel. The following section describes the risk of water quality impacts to the Skagit River during construction and operation of the Gorge 2nd Tunnel Project.

8.0 Water Quality Impact Analysis

The Gorge 2nd Tunnel Project will have very little risk to water quality in the Skagit River because there will be no work in the river itself.

- All construction work will occur above the ordinary high-water mark (OHWM).
- The facility's operations will not change, except that a second tunnel will help convey water more efficiently to the powerhouse.
- Maximum flow out of the powerhouse will not increase because maximum flow is limited by the turbine-generator capacity.
- Actual flow and ramping rates are less than the maximum flow capacity and are governed by a multi-stakeholder settlement agreement.

In order to comprehensively evaluate the risk to water quality, this section addresses all potential water quality risks from hydropower projects in general. A comprehensive list of potential water quality impacts is defined in a WDOE guidance manual (WDOE 2004). This guidance manual lists all possible causes of water quality impairments from a wide variety of hydropower projects. Most of these possible causes are beyond the scope of the proposed project. However, when a possible cause is within the scope of the proposed project, this section discusses the risk and measures to minimize the risk.

8.1 Total Dissolved Gases

No increased risk of TDG supersaturation is expected from operation of the proposed project. (Table 5). Spills over the Gorge Dam will not increase in frequency or duration during operation of the Gorge facility. Water from the proposed second tunnel will combine with water from the pre-existing tunnel before the water enters the powerhouse, and other operations (for example, wicket operation, ramping rates, powering up and down, maintenance) will remain the same. Therefore, the possible causes of impairment in Table 5 are absent. During construction, it will be necessary to take the existing tunnel off line and allow water to enter the Skagit River from the Gorge Dam Spillway. Water will spill into a 200 ft long plunge-pool, where supersaturation of gases is possible. The reach immediately downstream of the plunge-pool is a gorge with continuous rapids. Any supersaturated water from the plunge-pool should off-gas very quickly.

Table 5. Possible causes of total dissolved gas impairment from hydropower projects.

Possible Cause of Impairment from Hydropower Projects	Risk from Second Tunnel
Spill over the dam pushes air deep into a plunge pool where, under pressure, the air is forced into solution.	**Possible**
Air is injected into the turbines during power up or power down (ramping) to avoid/reduce cavitation at the turbine blades. These usually small amounts of supersaturated gas can remain for long periods of time if found in slow-moving water below the dam.	No change
Air is injected to spin the turbines with no water and no power generation. The wicket gates are closed, but water leaks into the turbine area where air is being injected. Under the headwater above the dam, this air is pressurized, and leaking wicket gate water is gassed and collects in the draft tubes.	No change
Air enters from ventilation during powering up or powering down turbines.	No change
Other operations creating plunging spills such as continuous fish bypass spills and opening trash sluiceways.	No change

Source: WDOE 2004

8.2 Temperature

The proposed project is not expected to increase water temperature. The possible causes of temperature impairments in Table 6 are based on a change in water management from the reservoir to the tailrace. Since the water will move out of the reservoir to the powerhouse at the same rate and from the same location, the proposed project will not cause any changes in solar warming, tailrace temperature fluctuations, or groundwater inputs. The in-stream flow agreements made during and after FERC relicensing regulate in-stream flow and, therefore, water temperature.

Finally, fish ladders are not incorporated into the Gorge Dam facility, and flow through the diversion reach will not change. Therefore, the temperature in local areas of water will not increase as a result of the proposed project.

Table 6. Possible causes of temperature impairment from hydropower projects.

Possible Cause of Impairment from Hydropower Projects	Risk from Second Tunnel
Decreasing the flow in the diversion reach, leading to increased warming during the hotter months. The water in the diversion reach is shallower and there is less of it than there would be without the diversion.	No change
Withdrawing cooler subsurface water from a thermally stratified reservoir immediately upstream of the dam and routing this water through the penstocks and turbines back into the river downstream of the dam. Even if there is only moderate surface warming, subsurface withdrawal can too quickly cool the river downstream.	No change
Spilling warmer surface water.	No change
Changing flow release quantities to respond to power demands. This can cool or heat downstream waters, sometimes almost instantaneously, especially when the reservoir behind the dam is stratified. Rapid fluctuations in river levels can strand fish in pockets of water, which can heat to lethal levels on hot days.	No change
Impounding the river behind the dam. Some reservoirs generally heat more during the summer than a free-flowing river because of slower-moving water and more surface area exposed to solar and air temperature influence.	No change
Diverting small volumes of river water into fish ladders to aid in upstream movement of fish. Because of the small volumes, these diverted streams of water tend to heat rapidly, especially if uncovered and exposed to the sun.	No change
Blocking groundwater inputs to the river, because the impounded water keeps the river at higher elevations than pre-dam elevations (especially during the summer low-water season). Local groundwater inflows to rivers can create cold-water refuge areas for fish and other aquatic organisms.	No change
Eliminating spring flood flows. In some rivers, cold, high spring runoff saturates the banks of the river, recharging the local aquifer. Relatively cool groundwater then seeps out during warmer, lower-flow months and provides cold-water refugia for aquatic organisms.	No change

Source: WDOE 2004

8.3 Turbidity

Since the reservoir and flow-management regime will remain the same, all potential causes of turbidity impairment will remain the same, except for construction activities (Table 7). Construction activities will be relatively low risk, because all work will occur above the ordinary high-water mark. TBM process water and groundwater from tunnel fissures will discharge to the tunnel entrance at the portal site. This water will carry suspended sediments out of the tunnel onto the portal site. Stormwater could carry suspended sediments and other pollutants from the portal site to the Skagit River. A water-management plan will address tunnel discharge water and stormwater at the portal site. Construction equipment and materials will also be managed to minimize the risk of pollutants entering the Skagit River.

Table 7. Possible causes of turbidity impairment from hydropower projects.

Mechanisms of Turbidity Impairment from Hydropower Projects	Risk from Second Tunnel
Construction activities.	**Possible**
Erosion of downstream channels due to excessive, unnatural flows from dam releases.	No change
Erosion of the reservoir shoreline caused by fluctuations in the level of the reservoir.	No change
Erosion of areas exposed during drawdown, including sheet erosion of denuded banks and down cutting of tributaries into deposited sediment.	No change
Mass wasting due to wetting and drying of the soils on the reservoir shore.	No change
Effects of watershed development stimulated by the dam and reservoir.	No change
Sediment settling in the reservoir, which can make discharge water in the river below unnaturally clear with corresponding losses of fish productivity.	No change

Source: WDOE 2004

8.4 pH

Since the reservoir and flow-management regime will remain the same, all potential causes of pH impairment will remain the same except for construction activities (Table 8). Parts of the tunnel wall might need to be grouted with concrete. Since this material cannot be pre-cast, the tunnel discharge water generated from the TBM process water and groundwater could have high pH. This discharge water will be collected at the portal site and treated according to the water-management plan. Grouting materials will be managed at the portal site with practices that will minimize the risk of stormwater contact.

Control of high pH will also serve to limit arsenic solubility. Arsenic occurs naturally in some sulfide minerals that are present in the Skagit Gneiss along the Gorge Second Tunnel alignment. The Skagit River already flows across the Skagit Gneiss bedrock and is expected to contain background levels of dissolved arsenic. Arsenic can have toxic effects in its soluble form. Arsenic is relatively soluble in reducing, high-pH (>7.5) conditions but is relatively insoluble in oxidizing, neutral- to lower-pH (<7.5) conditions. The oxidizing environments in the spoils and tunnel groundwater will also minimize arsenic solubility. Spoils and tunnel groundwater will be tested prior to discharge to confirm low arsenic concentrations and neutral pH conditions. If these or other naturally occurring contaminants are found at elevated levels, the water and spoils will be treated prior to land infiltration (water) or application as fill (spoils).

Table 8. Possible causes of pH impairment from hydropower projects.

Possible Cause of Impairment from Hydropower Projects	Risk from Second Tunnel
Reduced flow in reservoirs and the creation of shallow flooded areas allows plants to maintain a foothold at the edges of the reservoir as well as allowing the growth of phytoplankton. Increased photosynthesis can drive pH in these areas above 8.5–9.0 due to the absorption of CO_2 in the form of carbonic acid.	No change
Nutrients (usually phosphorus) from lakeshore development can contribute to increased productivity.	No change
Chemical discharges, most commonly wet concrete, can affect pH. Other chemicals used at the project might increase or decrease pH, either through use or due to a spill. Possible chemicals include alkaline cleaners or acid washing.	**Possible**
Decay of organic material, such as in wetlands or in the anoxic bottom layers of a lake, can affect pH.	No change
Steady, reduced flow in the bypass reach can contribute to excessive plant growth.	No change

Source: WDOE 2004

8.5 Dissolved Oxygen

Since the reservoir and flow-management regime will remain the same, all potential causes of dissolved oxygen (DO) impairment will remain the same (Table 9). No sources of biological oxygen demand (BOD) are associated with the Gorge 2nd Tunnel Project. The management of the Gorge reservoir will remain the same.

Table 9. Possible causes of dissolved oxygen/biological oxygen demand impairment from hydropower projects.

Possible Cause of Impairment from Hydropower Projects	Risk from Second Tunnel
A dam project can increase BOD if there are associated wastewater sources, such as a sewage treatment plant for workers or for an associated recreation facility.	No change
The project can also exacerbate problems from other BOD sources because of reduced aeration in the reservoir or low flows below the dam.	No change
Increased macrophyte and algae growth can lead to increased daily swings in DO with very high levels during daylight and sags after dark.	No change
Thermal stratification can occur in reservoirs, when warmer water stays near the surface and cooler, denser water sinks to the bottom. This can lock up a deeper layer of colder water where DO commonly reaches very low levels.	No change
Deep releases from a stratified reservoir are likely to show very low oxygen levels, causing fish kills and foul odors.	No change
All of these problems can combine: high algal biomass can use up the oxygen in the lower levels of a reservoir. Ammonia inputs can both exert BOD by oxidizing and serve as a nutrient source for algae.	No change

Source: WDOE 2004

8.6 Oil and Grease

Since the operational regime of the gorge facility will remain the same, all potential causes of oil and grease impairment will remain the same except for construction activities (Table 10). The TBM and other heavy equipment at the portal site could release small amounts of oil and hydraulic fluid. Best management practices associated with equipment management will help control these pollutants. The water-management plan will contain provisions to treat any pollutants that are in the tunnel wastewater stream or that come from portal stormwater.

Table 10. Possible causes of oil and grease impairment from hydropower projects.

Possible Cause of Impairment from Hydropower Projects	Risk from Second Tunnel
Grease and heavy oil used for lubrication and hydraulics can escape from construction equipment	**Possible**
Servomotors leak oils to the bottom of the turbine pit.	No change
Wicket gates lubricants can leak directly into the water.	No change
Turbine guide bearing oil can leak. This is usually stored in large tanks on site. Gravity brings most of the lubricant into a sump where it is pumped back into the lubrication system. Leakage occurs and oil from other sources collects to be pumped to large sumps before being discharged to the river.	No change
Lubricants from spill gate mechanisms, turbine gate mechanisms, etc. can leak.	No change
Most transformers have been purged of PCB oil and now contain “mineral” oils. Low levels of PCBs can still be found in purged transformers due to incomplete purging or desorption from transformer materials.	No change
The mineral oil used in transformers typically is less refined than the store-bought variety and contains low levels of contaminants, such as metals and organic contaminants that accumulate during use.	No change
Oil leaked from vehicles onto facility pavement is likely to contaminate stormwater if untreated. Washing equipment can also cause an oily discharge, if untreated.	**Possible**
Vehicle and boat use in the watershed is likely to increase due to recreation and development encouraged by the reservoir behind the dam. Increased vehicle use can cause increased oil levels in stormwater. Studies have shown recreational boats to be a major source of oil discharges from spills, leakage, and engine pass-through.	No change

Source: WDOE 2004

8.7 Flow

Since the reservoir and flow-management regime will remain the same, all potential causes of flow impairment will remain the same (Table 11). The Gorge 2nd Tunnel project will have no effect on the operation and management of flow. Maximum flow capacity out of the powerhouse will not increase because maximum flow is limited by the turbine-generator capacity. Actual flow and ramping rates are less than the maximum flow capacity and are governed by a multi-stakeholder settlement agreement.

Table 11. Possible causes of fish habitat and flow impairment from hydropower projects.

Possible Cause of Impairment from Hydropower Projects	Risk from Second Tunnel
No flows or low flows in the river channel from diverting water from the river channel into turbines located downstream from the dam or outside the river basin altogether.	No change
Periodic no or low flows to high flows in the river channel from managing water for power generation, recreation, or flood control.	No change
Scouring flows from large releases and floods.	No change
Quickly varying flows from peaking—routing flows through the turbines mostly during periods of daily or weekly high electricity demand.	No change
Varying flows due to power generator demands, flood control, maintenance, or other operations.	No change
Flow blockages and impediments that affect upstream or downstream migration of fish.	No change
Reservoir fluctuations.	No change

Source: WDOE 2004

9.0 Avoidance and Minimization Measures

Equipment Management

Heavy equipment will be necessary for most project activities. The fueling, maintenance, and use of heavy equipment can contribute oil, grease, dirt, and other pollutants to tunnel discharge water and stormwater. To minimize the release of pollutants from these sources, the following measures will be used:

1. Areas will be designated to sort and store staging materials.
2. Boundaries of staging areas will be marked.
3. Equipment staging areas will be limited to the minimum size necessary to complete the project. To reduce the staging area and potential for contamination, only enough supplies and equipment to complete a specific task will be stored on site.
4. Accumulation of soils or debris will be removed from the drive mechanisms (wheels, tires, tracks, etc.) and the undercarriage of equipment before its use around waters of the state.
5. Enough containment will be used for any mechanical equipment on a structure over water, such as a temporary work bridge or platform, to prevent any spills and/or discharges of contaminants to waters of the state.
6. All fuel hoses, oil drums, oil or fuel transfer valves and fittings, etc. will be checked regularly for drips or leaks. Any drips or leaks will be fixed and the spilled material immediately cleaned up.
7. Machinery and equipment will be serviced, fueled, and maintained in upland contained areas.
8. Vehicles will be cleaned of mud, rock, and other material before entering a paved public highway.

Materials Management

Some materials will need to be kept and managed on site, such as tunnel grouting materials. Fuel and other petroleum products will be needed to maintain equipment. The Tunnel Boring Machine (TBM) spoils will be transported across the river on an enclosed conveyor belt. The spoils will be temporarily stockpiled, loaded into trucks, and hauled to the Bacon Creek mitigation site. The following measures will minimize the risk of pollutants entering the Skagit River:

9. Forms for any concrete/grout structure will be constructed to prevent leaching of wet concrete/grout. Impervious materials will be placed over any exposed concrete/grout not lined with the forms that will come in contact with state waters.

10. No stockpiling of soil or construction materials will occur near vegetation to be preserved.
11. Stockpiling of soil or construction materials will not occur within the drip line of vegetation to be preserved.
12. Adequate and appropriate spill-response materials will be on hand to respond to an unplanned release of petroleum products or any other material into waters of the state.
13. All concentrated waste or spilled chemicals will be disposed of after consulting with WDOE and/or the local County Health Department.
14. All oil, fuel, or chemical storage tanks or containers will be located on an impervious surface within a berm and stored under cover, such as tarpaulins or roofs.
15. Construction materials will be stockpiled in approved staging areas.
16. No contractor materials storage areas will be allowed within 300 feet of any potentially suitable wetland, stream, river, or drainage as identified by the project biologist unless site-specific review completed by the project biologist indicates that no practicable alternative exists.
17. Trash will be removed and disposed of at an approved upland disposal site.

Tunnel Discharge Water

18. Tunnel discharge water from tunnel boring activities is being addressed with a detailed water management plan. Water is required to operate the TBM. This water, along with groundwater coming out of the tunnel fissures, will flow down the tunnel to the portal site. This water may also carry fine sediments, oil, and grease from the boring activities. During grouting and concrete placement operations, this water could temporarily have a high pH. The stream of tunnel discharge water will be collected where it exits the tunnel near the powerhouse (that is, the portal staging area). Initial collection facilities will be located on the portal staging area site. Primary treatment facilities will be located “off-site” and will consist of a grit tank, large holding tanks, a backflush sand filter, an oil control device and a pH sampling area. From primary treatment, water will be discharged to a meadow area to be dispersed and infiltrated into the ground. These facilities are described in full detail in the Water Management Plan (SCL, 2009). A separate area will be established for washing down equipment where there is no possibility of the rinse water draining to surface waters.
19. Any contact water from a confined area with curing concrete either will be routed to upland areas to be treated and infiltrated or will be disposed of appropriately.

20. All saw-cut water will be controlled, contained, and disposed of in an upland location.
21. All sediment placed upland to dewater will be contained or placed in such a way that the runoff will not flow into nearby storm drains or waterbodies, including wetlands.
22. The finished second tunnel will be rinsed down to remove fine-grained boring spoils from the tunnel walls.

Construction Stormwater

Stormwater in and around the portal site is being addressed with a detailed water-management plan. A conveyance ditch will be constructed along the northern and eastern edge of the staging area site to collect and convey runoff from the steep rock slope around the site and into the Skagit River. Onsite runoff will be conveyed through ditches to an onsite temporary sediment pond to settle out particulates before the runoff is discharged to the Skagit River riparian zone. In case of a large storm, the sediment pond will have an emergency overflow into the holding tanks used for the TBM discharge so the pond doesn't overtop and spill on site or into the Skagit River. Other Temporary Erosion and Sediment Control)/Source Control measures (such as soil stabilization) will be implemented as necessary:

23. All areas disturbed or newly created by project construction will be stabilized as soon as practicable to prevent erosion. The seed mix will consist of native, annual, noninvasive plant species.
24. Sediment barriers will be placed around disturbed sites where erosion could enter the stream directly or through road ditches that are connected to the stream.

Clearing, Grubbing, Excavation, and Grading

Clearing, grubbing, and other earthwork will occur at the portal site during demolition, mobilization, portal rock stabilization, and site restoration. Since the portal site is in the Skagit River's riparian zone, the long-term impact of these activities will be minimized with the following measures:

25. Excavation or grade changes affecting the critical root zones of preserved trees will be limited. If grading within the dripline of protected trees is necessary, an arborist report will be provided to ensure tree survival.
26. Vegetation will be retained where possible to provide wildlife habitat. Existing roads or travel paths will be used whenever reasonable.
27. Sensitive areas/wetlands and buffers that are to be protected from disturbance will be clearly marked and clearly visible to equipment operators. Clearing limits, travel corridors, and stockpile sites will also be clearly marked.

28. Vegetation will be grubbed only from areas undergoing permanent alteration. No grubbing will occur in areas slated for temporary impacts.

Blasting

Blasting might be necessary to construct a starter tunnel/ adit at the portal site. The following measures will minimize risk to the Skagit River during blasting:

29. All blast material will be removed and deposited in an approved upland disposal site.
30. Methods to contain and control possible slide debris from blasting will be in place before any blasting.
31. The work area affected by the blasting will be isolated from the stream flow.

Tunnel Boring Machine Excavation

Boring will be required to excavate the second tunnel. The following measures will minimize the risk of pollutants affecting the Skagit River:

32. Boring equipment will be well maintained and in good repair to prevent the loss of lubricants, grease, and any other harmful materials.
33. Process water from boring will not be allowed to directly enter or leach into the river.

Site Restoration

After construction, the portal site will be restored. Some areas will be converted back to operation facilities, while others areas will be restored to riparian habitat. The following measures will be used to restore riparian habitat:

34. Native topsoil will be stockpiled for later use in site restoration. After the project is completed, native topsoil will be used for revegetation.
35. Before construction, affected native plants will be transplanted to other areas of the site to the extent possible. After the project is completed, woody plants, shrubs, and ground covers will be re-established in affected areas.
36. The riparian habitat damaged by construction activities will be stabilized and replanted with native vegetation during the first appropriate planting season after construction is completed.

10.0 Conclusions

Since no long-term habitat impacts or operational changes will occur, the Gorge 2nd Tunnel Project will not have any long-term operational impacts. The tunnel discharge water from tunnel excavation will likely be turbid water and will likely contain a small amount of oil and grease. The tunnel discharge water will intermittently have a high pH when the water comes in contact with grout curing in the tunnel. Treatment and infiltration will likely prevent all tunnel discharge water impacts to the Skagit River. Stormwater from the portal site could carry fine sediments and oil and grease. Best management practices will minimize pollutant concentrations in the stormwater. The stormwater will be collected and treated before it is dispersed in the Skagit River riparian zone. During final tunnel excavation, the plunge-pool at the Gorge Dam spillway could cause supersaturation of dissolved gases. However, the rapids immediately downstream will facilitate rapid off-gassing.

11.0 Literature Cited

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Appendix A: USGS Temperature and Flow Data, Station 12178000

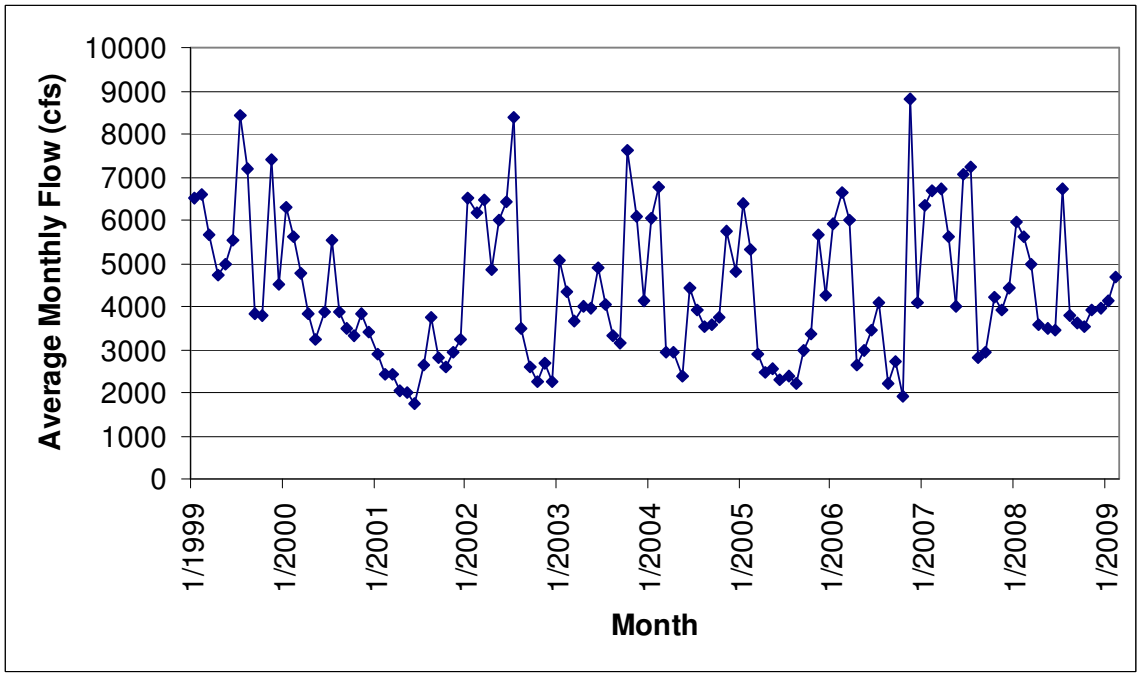

Table A-1. Average monthly flow from 1999 to 2008.

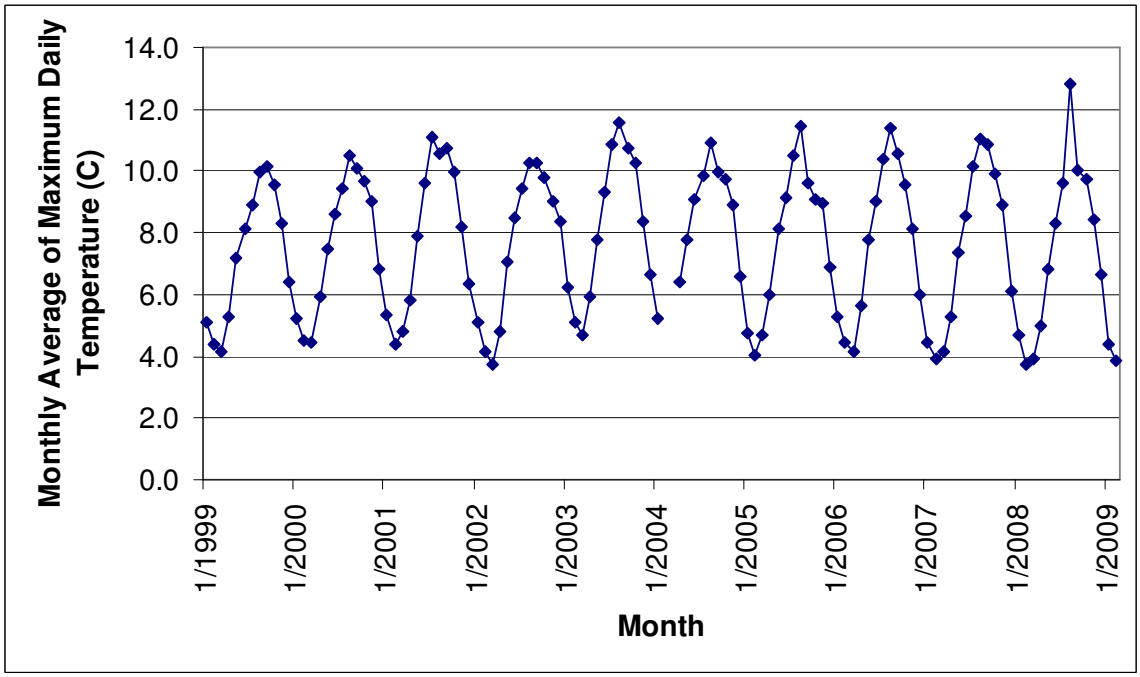

Table A-2. Average monthly maximum daily temperature from 1999 to 2009.

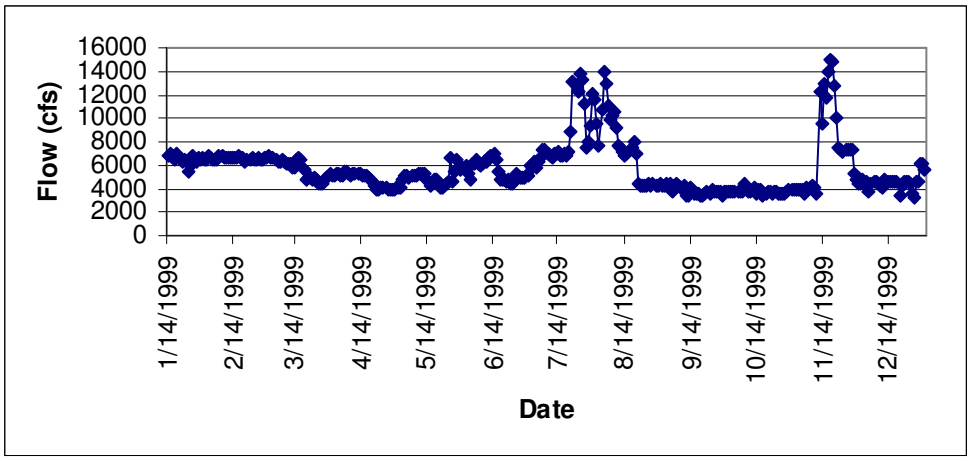

Table A-3. Daily flow during 1999.

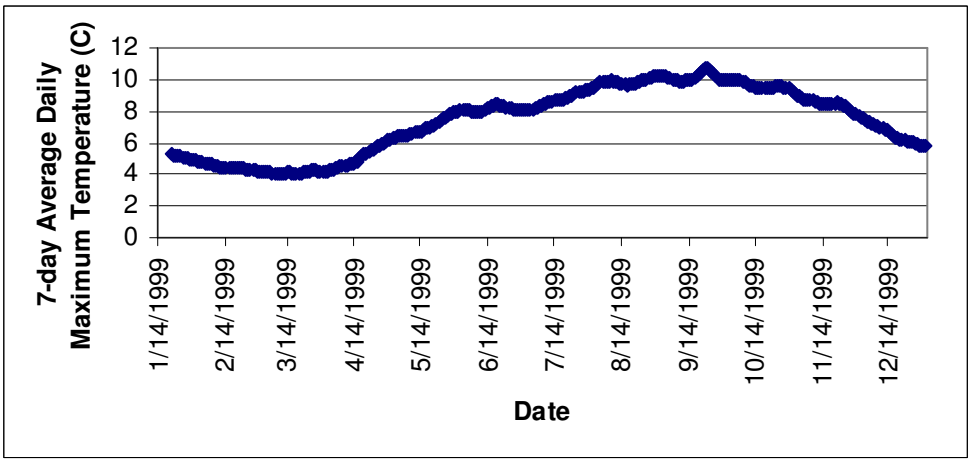

Table A-4. Seven-day average daily maximum temperature during 1999.

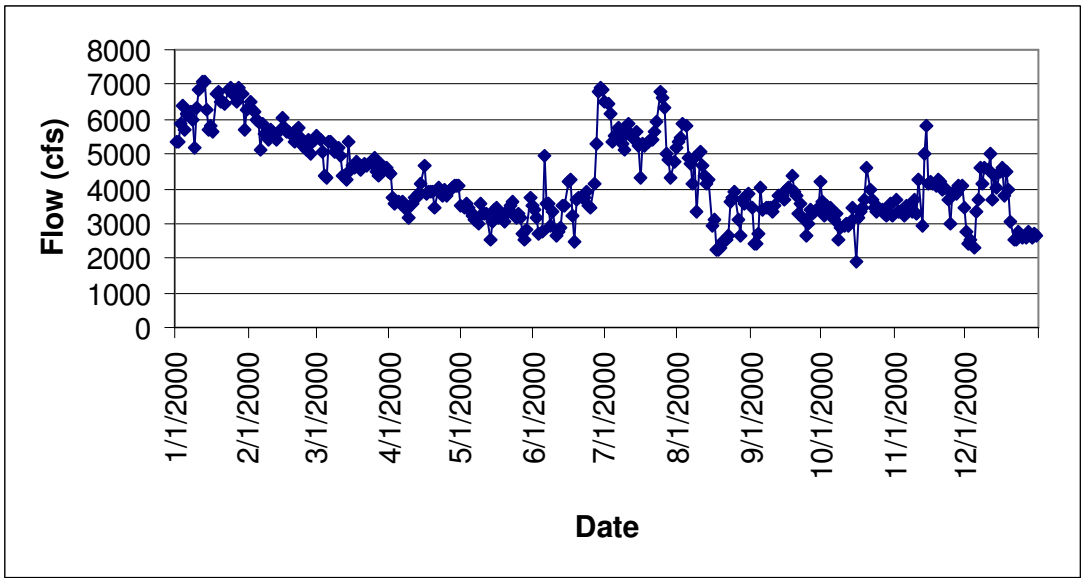

Table A-5. Daily flow during 2000.

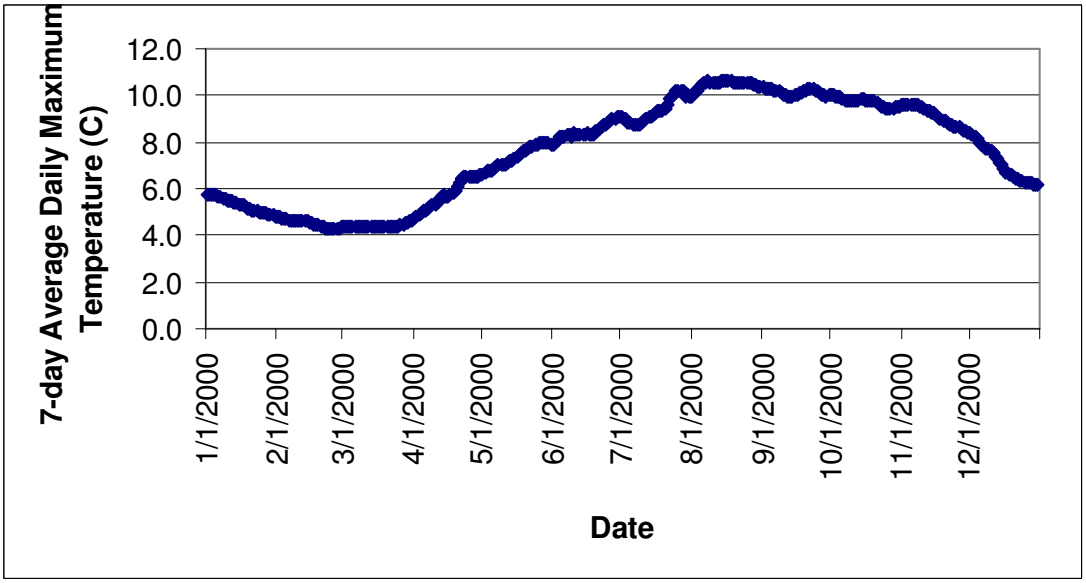

Table A-6. Seven-day average daily maximum temperature during 2000.

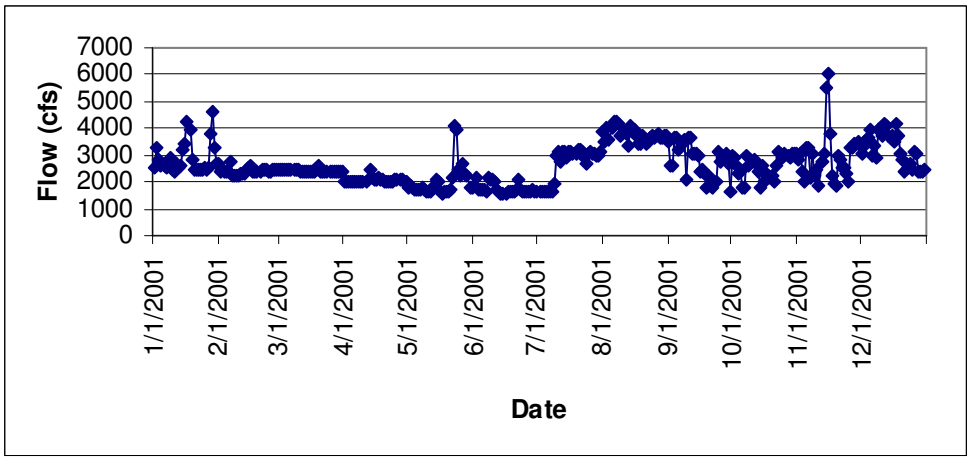

Table A-7. Daily flow during 2001.

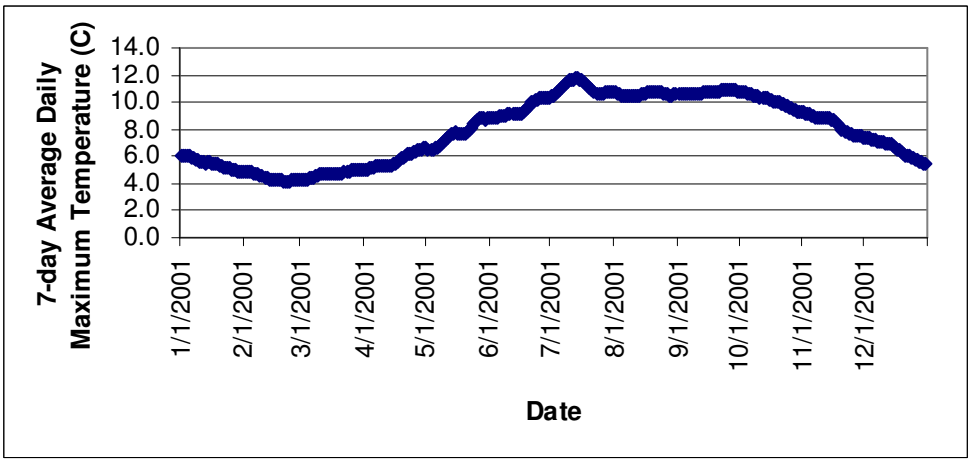

Table A-8. Seven-day average daily maximum temperature during 2001.

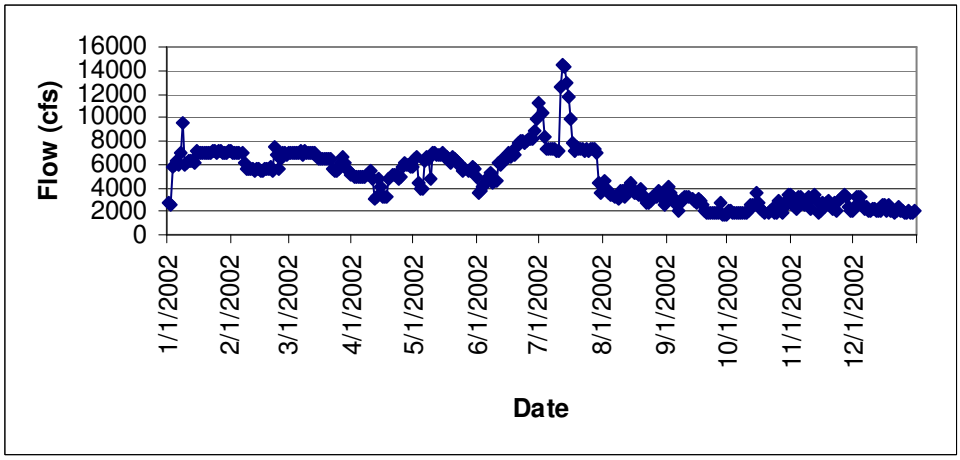

Table A-9. Daily flow during 2002.

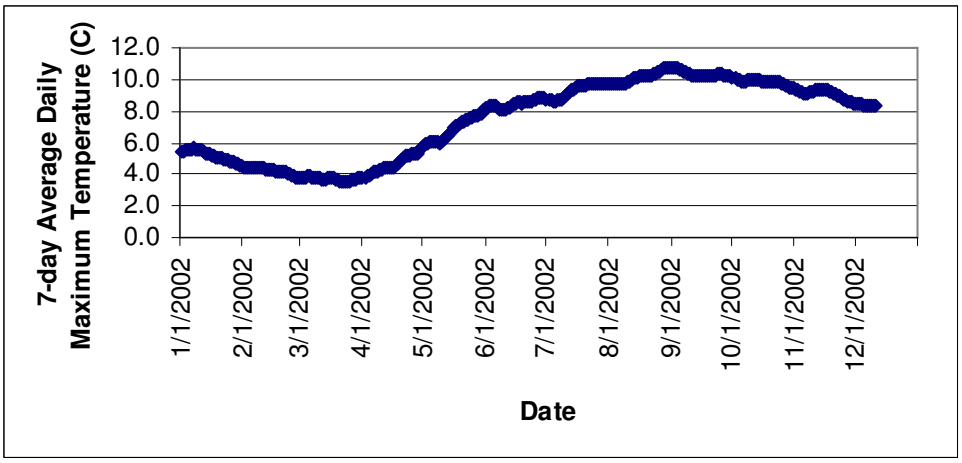

Table A-10. Seven-day average daily maximum temperature during 2002.

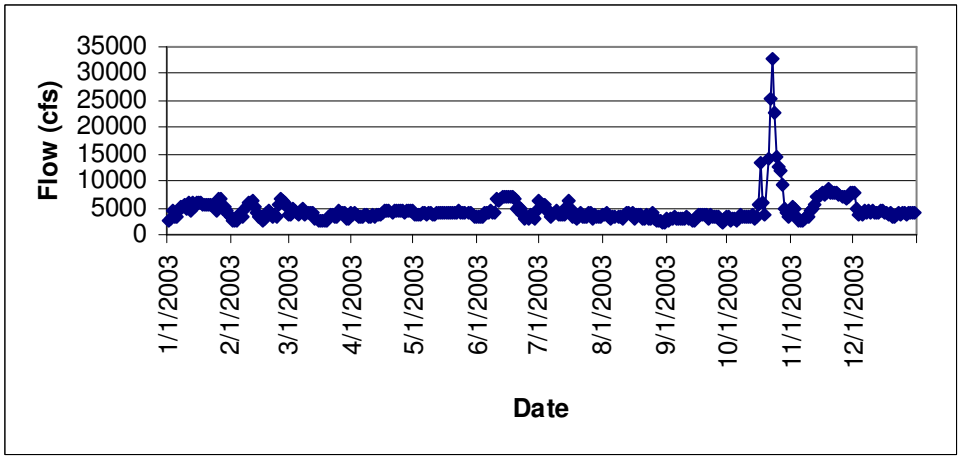

Table A-11. Daily flow during 2003.

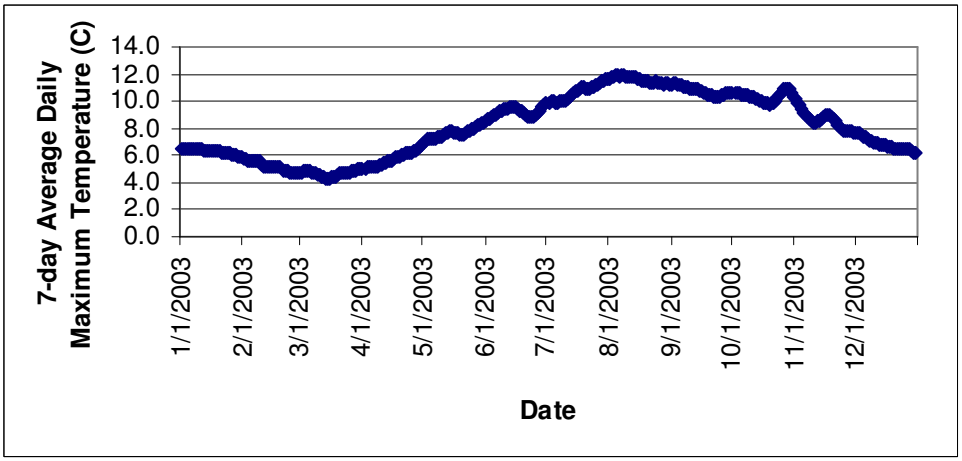

Table A-12. Seven-day average daily maximum temperature during 2003.

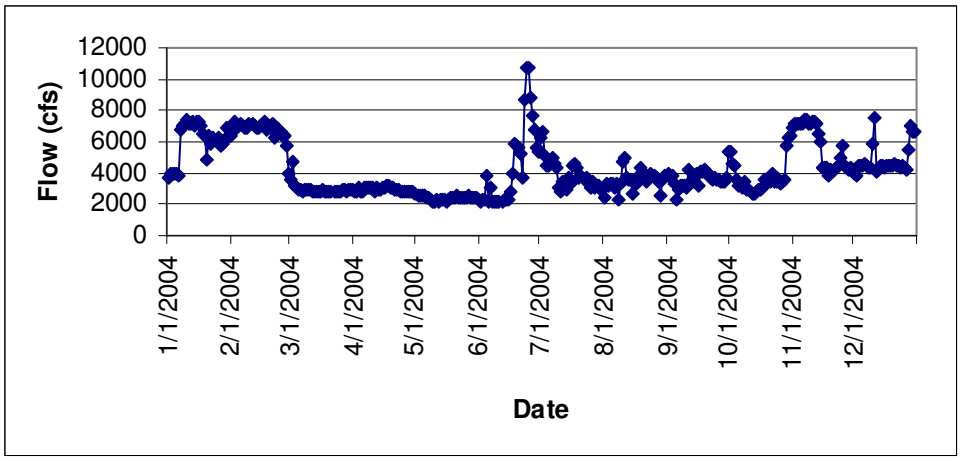

Table A-13. Daily flow during 2004.

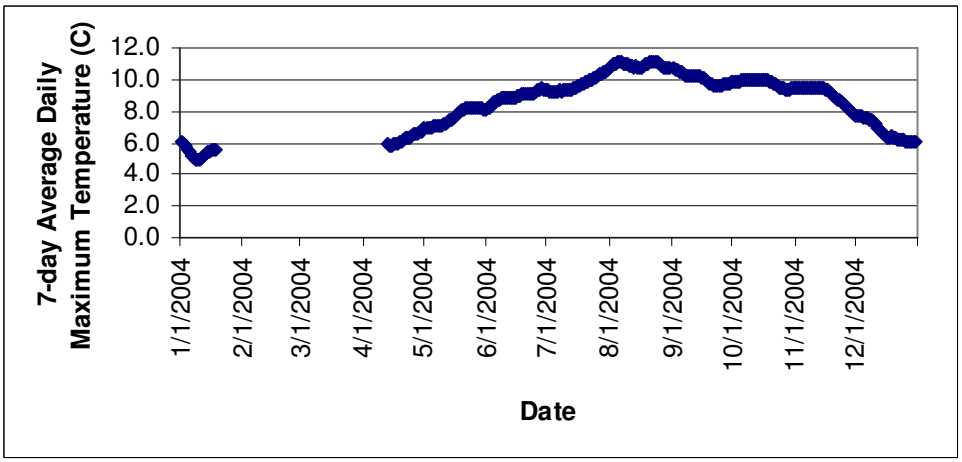

Table A-14. Seven-day average daily maximum temperature during 2004.

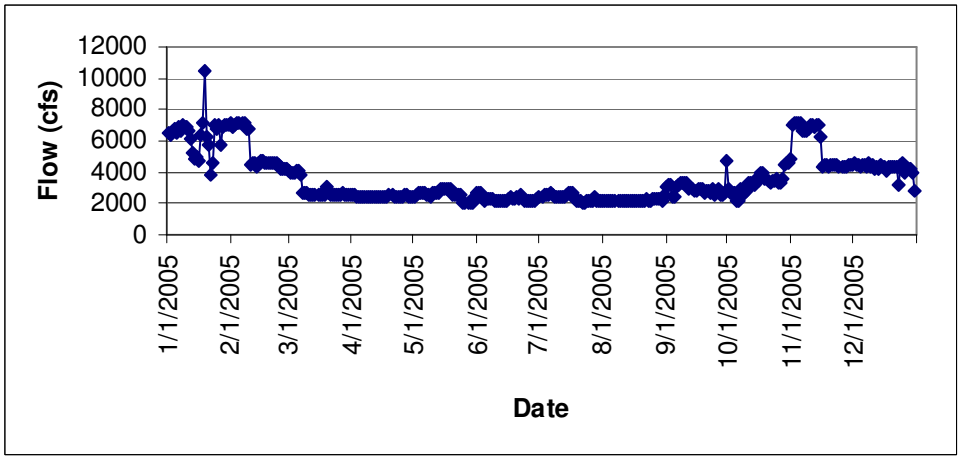

Table A-15. Daily flow during 2005.

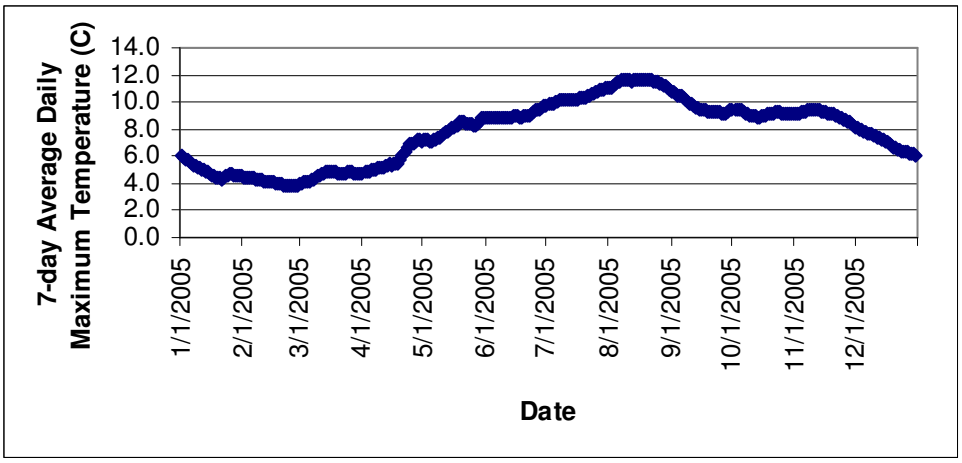

Table A-16. Seven-day average daily maximum temperature during 2005.

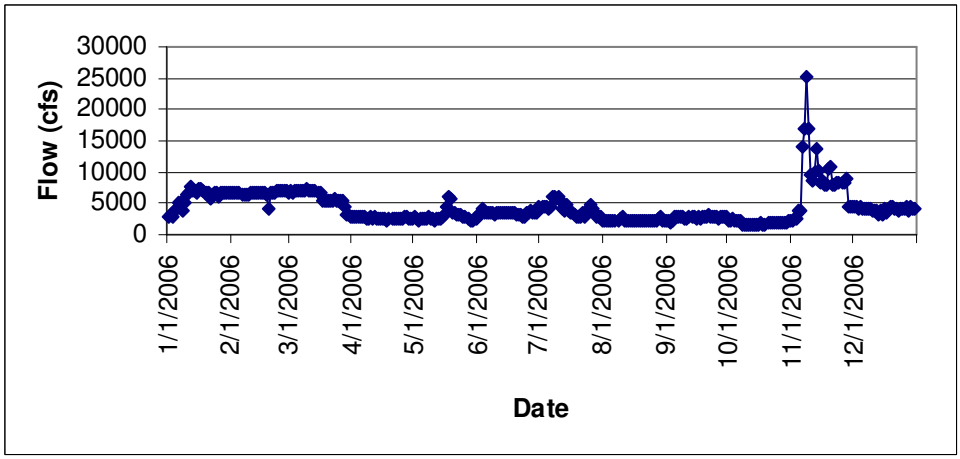

Table A-17. Daily flow during 2006.

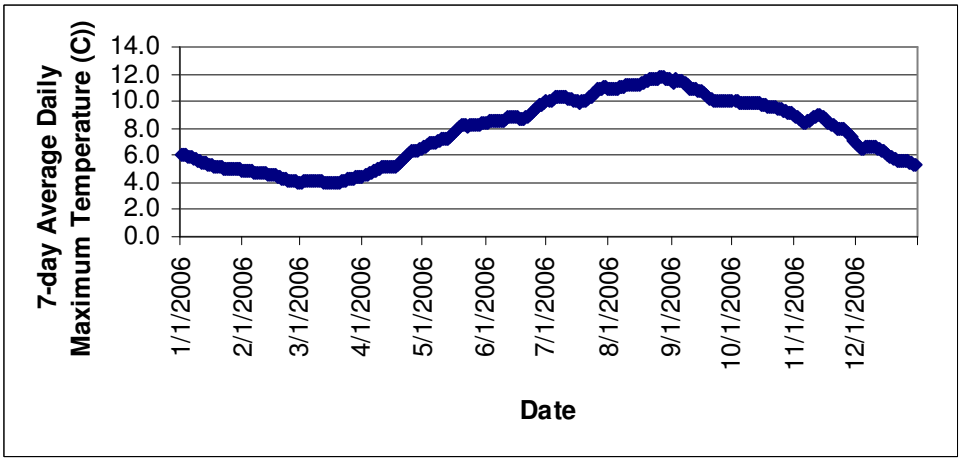

Table A-18. Seven-day average daily maximum temperature during 2006.

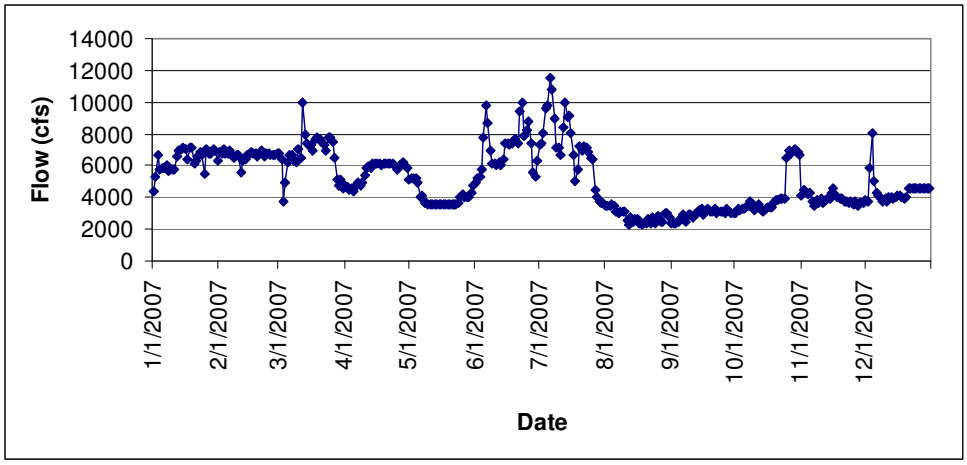

Table A-19. Daily flow during 2007.

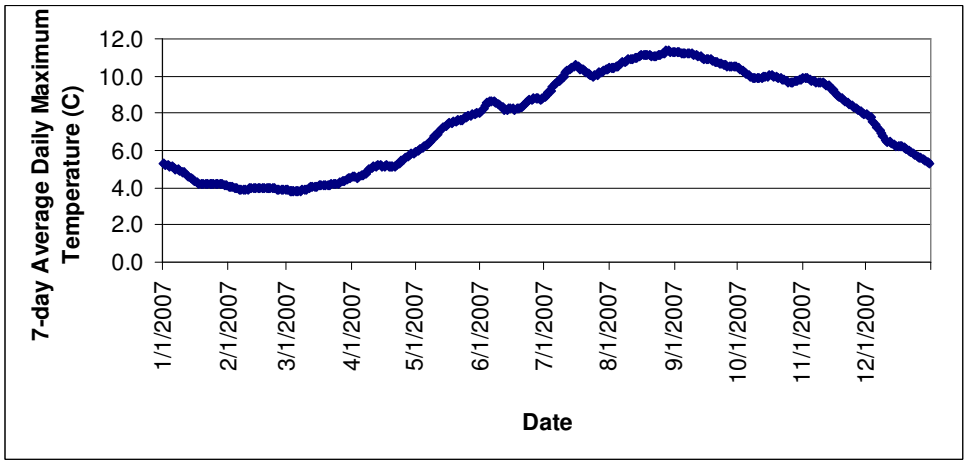

Table A-20. Seven-day average daily maximum temperature during 2007.

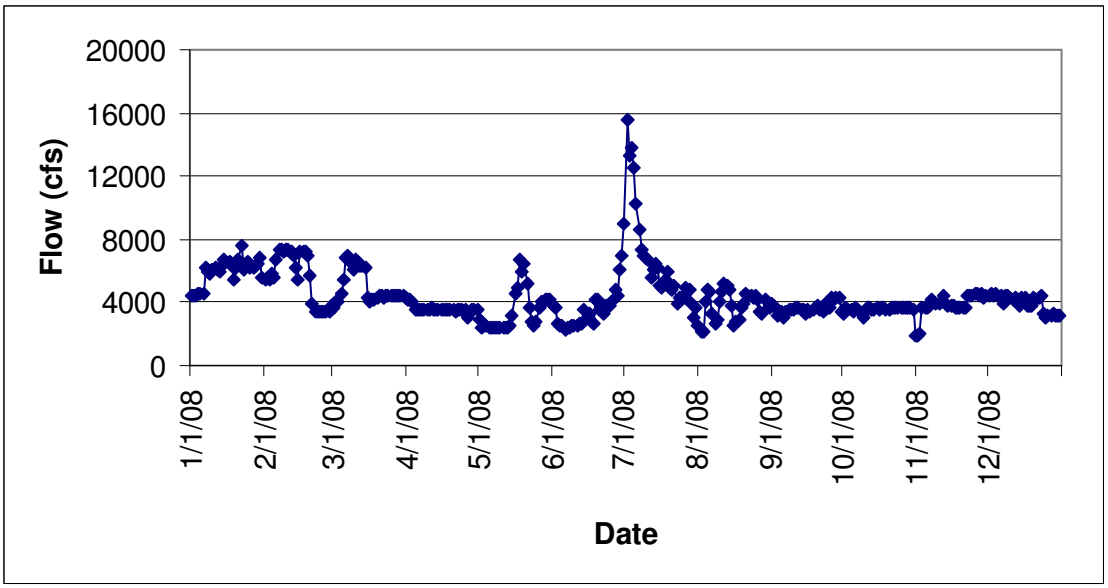

Table A-21. Daily flow during 2008.

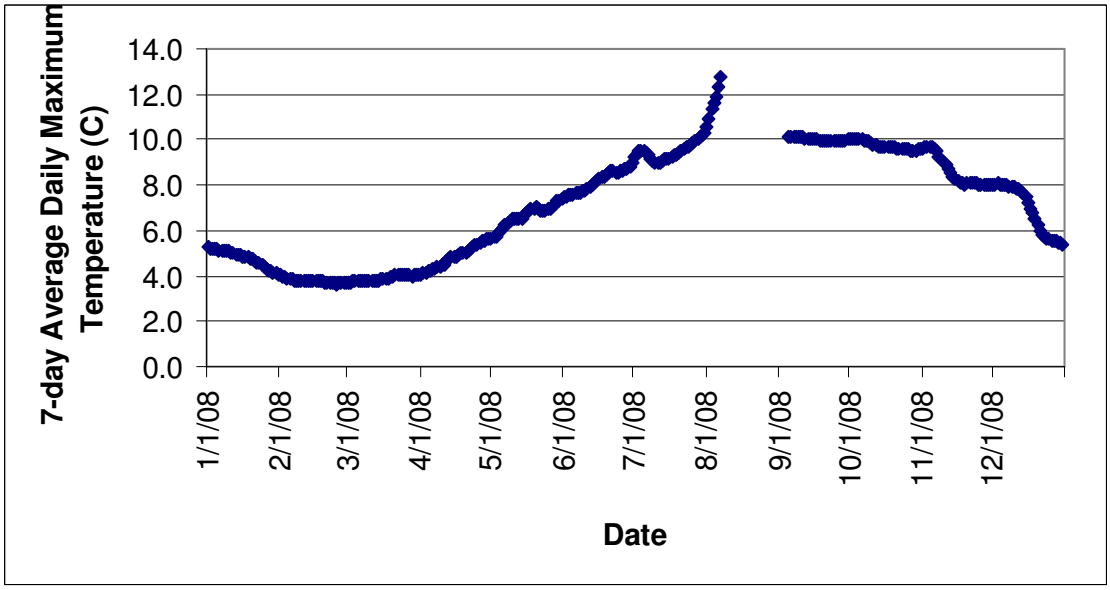

Table A-22. Seven-day average daily maximum temperature during 2008.

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