Flow Summary for Gaging Stations on the Wenatchee River and Selected Tributaries

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Flow Summary for Gaging Stations on the Wenatchee River and Selected Tributaries

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June 2005

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Abstract

From May 2002 through May 2004, the Washington State Department of Ecology conducted a streamflow assessment on the Wenatchee River and selected tributaries. The project was divided into two study years. The first year focused on the mainstem Wenatchee River and upper-watershed tributaries, and the second year focused on lower-watershed tributaries.

The streamflow assessment was conducted in support of a Total Maximum Daily Load (TMDL) study for temperature, dissolved oxygen, pH, and fecal coliform. The purpose of the study was to evaluate temperature, pH, dissolved oxygen, fecal coliform, and other ancillary parameters to form the basis for a proposal to set instream water quality targets to meet water quality standards and allocate contaminant loads to sources.

Continuous stage height recorders and staff gages were installed at four sites during each of the two study years, and at least four discharge measurements were taken at each site. Discharge rating curves were developed for each site by relating various stage height values to corresponding discharge measurements. Applying these rating curves over the range of stage height enabled a continuous record of discharge to be developed at each site. Rating curves were developed at five additional sites during year one of the study. No continuous monitoring took place at these sites.

Ten of the fourteen sites monitored in this study produced discharge data that are accurate to within 10 percent. Aquatic weed growth and sedimentation were the primary causes of error in discharge data.

Introduction

Between May 2002 through May 2004, the Environmental Assessment Program of the Washington State Department of Ecology (Ecology) conducted a streamflow assessment on the Wenatchee River and several tributaries in support of a Total Maximum Daily Load (TMDL) study for temperature, dissolved oxygen, pH, and fecal coliform developed by the Environmental Assessment Program. The purpose of the study was to evaluate temperature, pH, dissolved oxygen, fecal coliform, and other ancillary parameters to form the basis for a proposal to set instream water quality targets to meet water quality standards and allocate contaminant loads to sources (Bilhimer et al., 2002).

Sites

The Wenatchee River basin (WRIA 45) encompasses 878,423 acres in central Washington. The basin is bounded on the west by the Cascade Mountains, on the north by the Entiat Mountains, and on the South by the Wenatchee Mountains. The Wenatchee River is a tributary to the Columbia River, with the confluence at the City of Wenatchee (Bilhimer et al 2002).

This study was divided into two separate study years. The first focused on the mainstem Wenatchee River above the City of Leavenworth, and on mid-basin tributaries. The second year focused on low-basin tributaries.

For year one, four sites were monitored using continuous monitoring equipment; one on the mainstem Wenatchee River, and three on mid-basin tributaries to the mainstem. On Icicle Creek, a tributary to the mainstem at river mile 25.6, the station was located approximately 200 yards upstream of the confluence (Figure 1, Site 1). On Chiwaukum Creek, a tributary to the mainstem at river mile 35.9, the station was located approximately 100 yards upstream of the confluence (Site 2). On Nason Creek, a tributary to the mainstem at river mile 53.6 just below Lake Wenatchee, the station was located at the Cedar Brae Road crossing (Site 3). On the mainstem, the station was located at Highway 207, below the confluence with Nason Creek (Site 4).

In addition, five sites were monitored using discrete staff gage observations; two on the mainstem Wenatchee River, and three on tributaries. On the mainstem, the lower station was located on Icicle Road in the City of Leavenworth, at river mile 26.4 (Site 5). The upper mainstem station was located at the head of Tumwater Canyon, on Highway 2, at river mile 35.5 (Site 6). On the Chiwawa River, a mainstem tributary at river mile 48.4, the station was located at Chiwawa Loop Road at river mile 0.4 (Site 7). On the White River, a tributary to Lake Wenatchee, the station was located on Forest Road 6500, at river mile 7.8 (Site 8). On the Little Wenatchee River, another tributary to Lake Wenatchee, the station was located on property owned by Two Rivers Sand & Gravel Company, at river mile 6.4 (Site 9).

For year two of the study, four stations were installed on three low-basin tributaries. On Mission Creek, a mainstem tributary at river mile 10.5, the station was located on the south end of the town of Cashmere, at Binder Road (Site 10). On Brender Creek, a tributary to Mission Creek at river mile 0.1, two stations were installed. The lower station was located above Pioneer Drive, near the confluence with Mission Creek (Site 11). The upper station on Brender Creek was located approximately one mile below Brender Canyon, on private orchard property (Site 12). On Peshastin Creek, a mainstem tributary at river mile 17.9, the station was located above Tronsen Creek near Forest Road 7320 (Site 13).

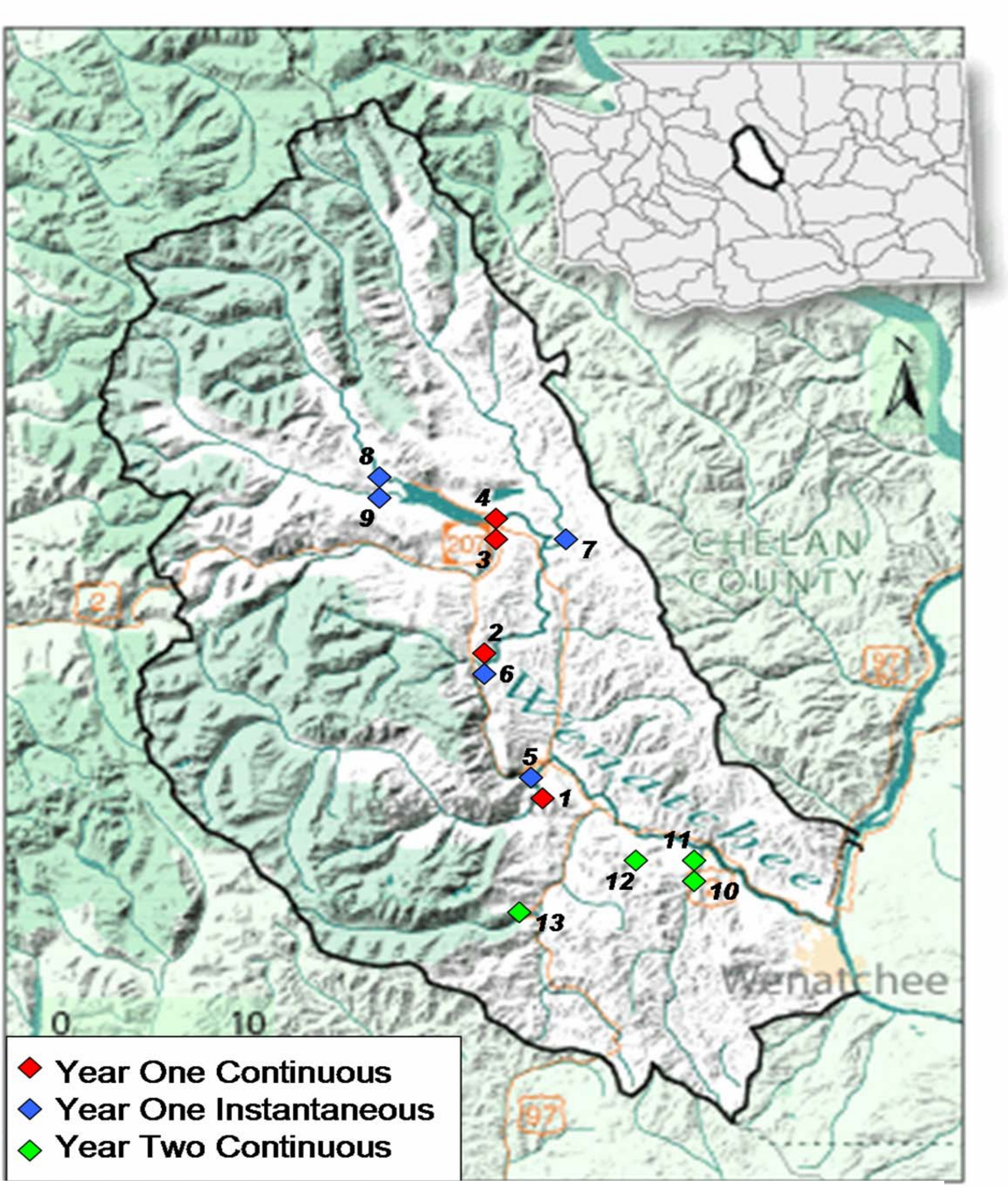

Figure 1: Map of Wenatchee TMDL Study Sites.

Methods

Each of the four continuous gaging stations, in both years of the study, was equipped with a pressure transducer and datalogger that recorded river stage height and temperature at 15-minute intervals from May to October 2002 for year one stations, and May 2003 to May 2004 for year two stations. Four to six discharge measurements were taken at each station to establish rating curves used to calculate the average daily discharges.

At each of the five instantaneous flow monitoring stations during year one of the study, a stage index was established using either an in situ staff gage or a reference point at a bridge crossing. These stage references were used in conjunction with four to six discrete discharge measurements at each station to develop discharge rating curves for each.

Discharge measurements were made following the United States Geological Survey (USGS) mid-section method. Ecology has made minor modifications to the USGS method to accommodate its measurement equipment (Hopkins, 1999). The flow measurement cross sections were established by driving re-bar into opposing banks perpendicular to the streamflow. This allowed field staff to return to the same cross-section at different stage heights and added to the reliability of the measured discharge data. In general, the cross-sections were divided into approximately 20 cells so that no more than 10 percent of the total discharge passed through any single cell. The width of the individual cells varied in keeping with the 10 percent discharge criteria. Velocity measurements were taken at 60 percent of the stream depth when the total stream depth was less than 1.5 ft and at 20 percent and 80 percent of the stream depth when the depth was greater than 1.5 ft (Hopkins, 1999). The instream velocity measurements were taken using a standard USGS top set wading rod fitted for Swoffer type optical sensors and propellers. Stream discharge was calculated in the office using an in-house specialized discharge calculation software program.

Time of Travel Analyses

Several of the stations monitored for year one of this study were upstream or downstream of streamflow stations monitored by the US Geological Survey. For these stations, time of travel analyses were conducted to determine the travel time between upstream and downstream stations at different discharge levels. For these analyses, the average velocities obtained from discrete flow measurements at each site were regressed against the stages at which those discharge measurements were taken. The relationship between stage and velocity was then used to estimate the average velocities for interpolative and extrapolative stages that were not physically measured. Travel times were then calculated based on the distance between stations. Time of travel tables for these stations are in Appendix D.

Quality Assurance

Quality assurance measures were taken in this study to address both error in stage height record produced by the dataloggers, and error inherent in instream discharge measurements.

Discharge Measurements

Because the largest potential source of error involved with a discharge measurement is in the velocity measurement itself, site selection and equipment calibration are of high importance. In this study, the measured cross-sections were rated between excellent and poor, according to best professional judgment based on physical conditions encountered at each site. An excellent cross-section assumes an error of up to 2 percent and a poor cross-section assumes an error of over 8 percent. Depending on the selected cross-section, a minimum of the assigned error is assumed and carried forward to the final discharge calculation. An additional source of error in velocity measurements is the calibration of the Swoffer instruments. The ideal calibration value of a Swoffer propeller is 186, which means that for every 186 revolutions of the propeller, 10 lineal feet of water have passed the measurement point. The Swoffer meters used during this project were pre- and post-calibrated with values ranging from 183 to 189. A calibration value of 183 overestimates the discharge measurement by 1.6 percent. Similarly, a calibration value of 189 underestimates the discharge measurement by 1.6 percent.

Once a discharge rating curve was established for a site, discharge measurements were tracked by comparing the measured discharge values to the discharge values predicted by the rating curve at the same stage. The combination of propeller variations, poor cross-sectional characteristics, aquatic weed growth, and high bottom roughness due to low-flow conditions contributed to the measured and predicted discharge differences ranging from 0.05 percent to 100 percent. This range of differences between measured and predicted discharge demonstrates the ability of the rating curves to predict stream discharge for each site.

Pressure Transducers and Staff Gages

Based on manufacturer specifications, the theoretical precision of the pressure transducers is less than or equal to 0.02 percent of the full-scale output. For the transducers used by Ecology, this precision is considered linear from 0 to 15 pounds per square inch (psi), or 0 to 34.6 ft (Fletcher, 2.6). During the study period, the accuracy of each transducer was addressed by using staff gage versus transducer regressions. The r^2 values for the regressions of transducer against staff gage readings ranged from 0.42 to 1.0.

Results

This study was designed as a summer low-flow assessment of the Wenatchee River basin. The year one stations operated from May through October 2002. The year two stations were originally scheduled to operate from May through October 2003, however, due to an extension in water quality sampling, the stations were extended through May 2004.

Year One Study Stations (May – October 2002)

Site 1: Icicle Creek near mouth (45B050)

The average daily discharge for Site 1 ranged from under 48 cfs in late-September to nearly 6,000 cfs during peak snowmelt in mid-June. Peak flow during the study period was 6,450 cfs on June 16 (Figure 2). Daily discharge averages are presented in Appendix A, Table 1. Due to the lack of nearby bridge crossings, and thus the difficulty in measuring high flows at Site 1, the rating curve encompassed only 16 percent of the range of discharge, with flow measurements ranging from 72 to 1,140 cfs (Figure 3). Discharge exceeded the rating curve approximately 25 percent of the time over the duration of the study (Figure 4). Flows greater than 1,140 cfs were modeled using the established relationships between stage, velocity, and cross-sectional area at this site (see Appendix B).

Within the range of measured flows, the fit of the rating curve was very good. All four discharge measurements taken at Site 1 were within 2 percent of the flow predicted by the rating curve. Before corrective adjustments were made to the continuous stage data to compensate for pressure transducer drift, a linear regression of manual staff gage readings against pressure transducer readings showed a perfect correlation ($r^2 = 1.0$), indicating that any drift in the pressure transducer readings was inconsequential (Figure 5). Since there were no nearby bridge crossings, no secondary stage reference was established to perform quality assurance checks on the manual staff gage readings. However, due to placement of the staff gage at Site 1 in a low velocity pool, manual staff gage readings should be accurate to within 0.01 ft.

Within the measured range of flows at Site 1, the overall margin of error for discharge data is estimated at 5 percent. Overall margin of error for flows greater than 1,200 cfs is estimated at 20 percent due to the limitations of extrapolative modeling at this site.

The US Geological Survey operates a gaging station 5.5 miles upstream from this station, above Snow Creek. Mean daily discharge at the USGS gage is estimated to be 0.97(x) + 36 cfs, where x is mean daily discharge at this station, based on data collected during this study. This relationship breaks down severely in flows greater than 1,000 cfs. For instantaneous flow comparisons, see the time of travel tables in Appendix D.

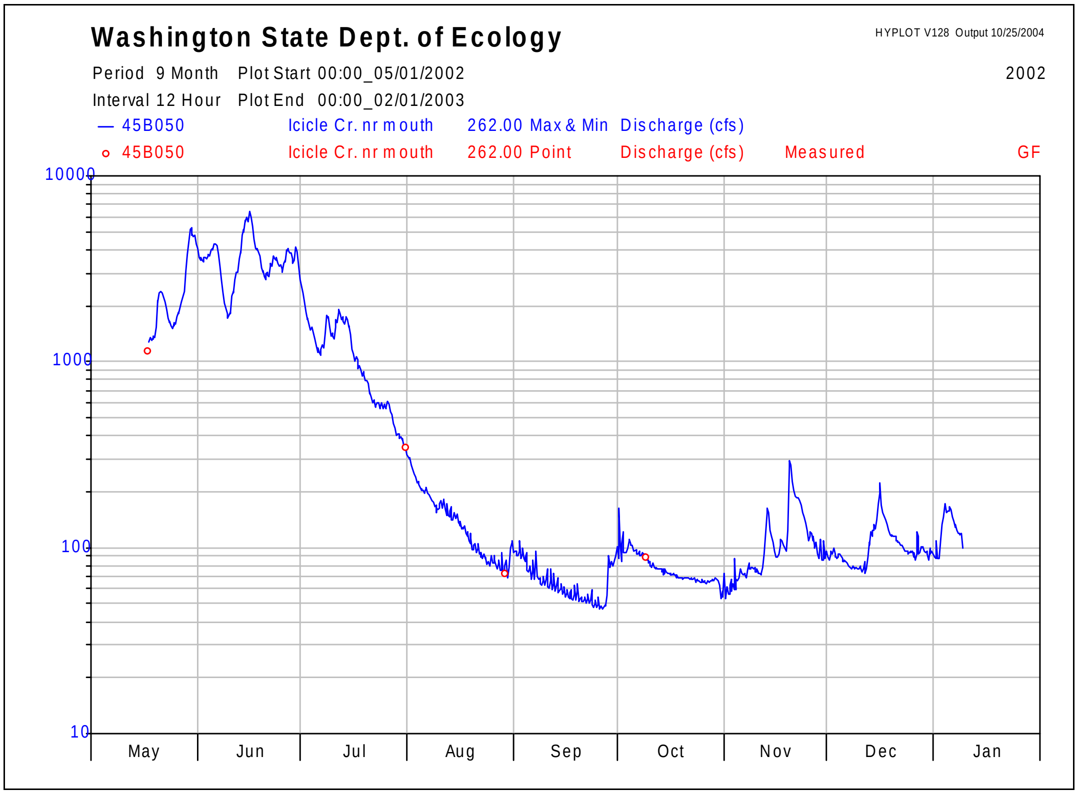

Figure 2: Discharge hydrograph for Site 1.

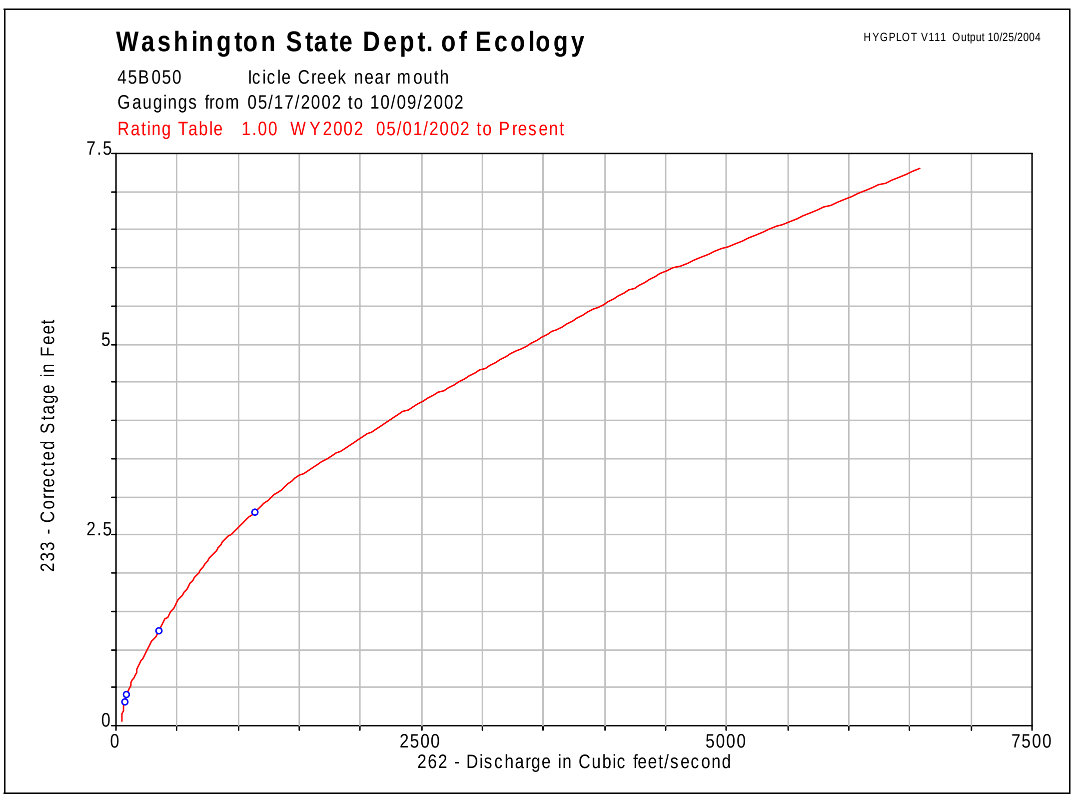

Figure 3: Discharge rating curve for Site 1.

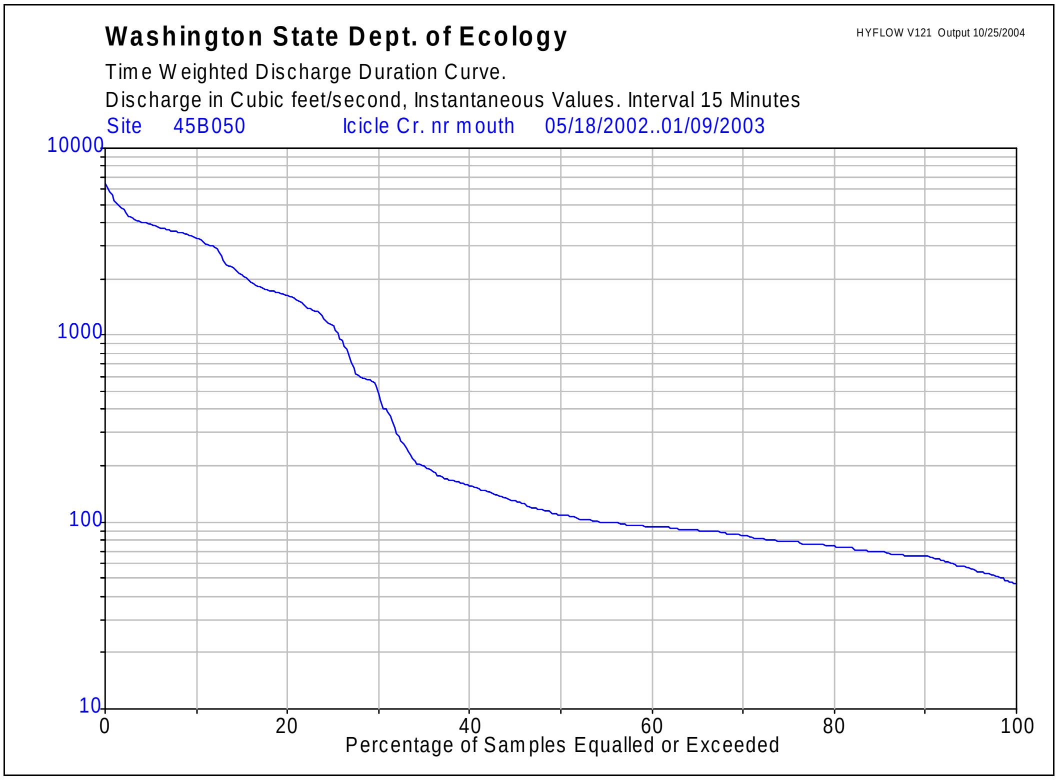

Figure 4: Discharge exceedence graph for Site 1.

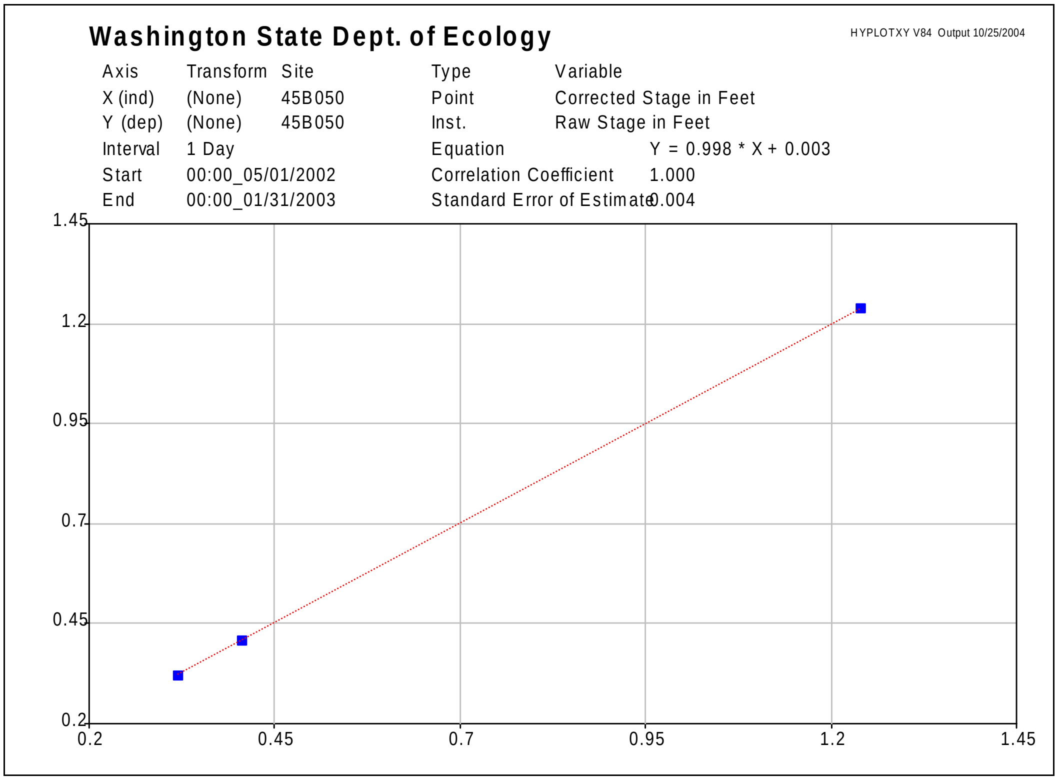

Figure 5: Linear regression of staff gage versus pressure transducer readings for Site 1.

Site 2: Chiwaukum Creek at mouth (45G060)

The average daily discharge for Site 2 ranged from just over 11 cfs in late-October to over 640 cfs during peak snowmelt in early June. Peak discharge during the study was 684 cfs on May 29, and again on June 6 and 15 (Figure 6). Daily discharge averages are presented in Appendix A, Table 2. Due to the lack of nearby bridge crossings, and thus the difficulty of measuring high flows at Site 2, the rating curve encompassed only 26 percent of the range of discharge, with flow measurements ranging from 11.8 to 191 cfs (Figure 7). Discharge exceeded the rating curve nearly 40 percent of the time over the duration of the study (Figure 8). Flows greater than 191 cfs were modeled using the established relationships between stage, velocity, and cross-sectional area at this site (see Appendix B).

Within the range of measured flows, the fit of the rating curve was very good. All five discharge measurements taken at Site 2 were within 5 percent of the flow predicted by the rating curve. Before corrective adjustments were made to the continuous stage data to compensate for pressure transducer drift, a linear regression of manual staff gage readings against pressure transducer readings had an r^2 of 0.992, indicating minor drift in the raw pressure transducer readings (Figure 9). Any transducer drift resulting in a difference in predicted discharge greater than 5 percent was corrected. Since there were no nearby usable bridge crossings, no secondary stage reference was established to perform quality assurance checks on the manual staff gage readings. There were no pool conditions present at Site 1, so the staff gage and pressure transducer were both placed in the deepest available glide. Due to the wave action created by flow velocity under these conditions, staff gage readings can be considered accurate to within 0.03 ft.

Within the measured range of flows at Site 1, the overall margin of error for discharge data is estimated at 10 percent. However, overall margin of error for flows greater than 200 cfs is estimated at 20 percent due to the limitations of extrapolative modeling at this site.

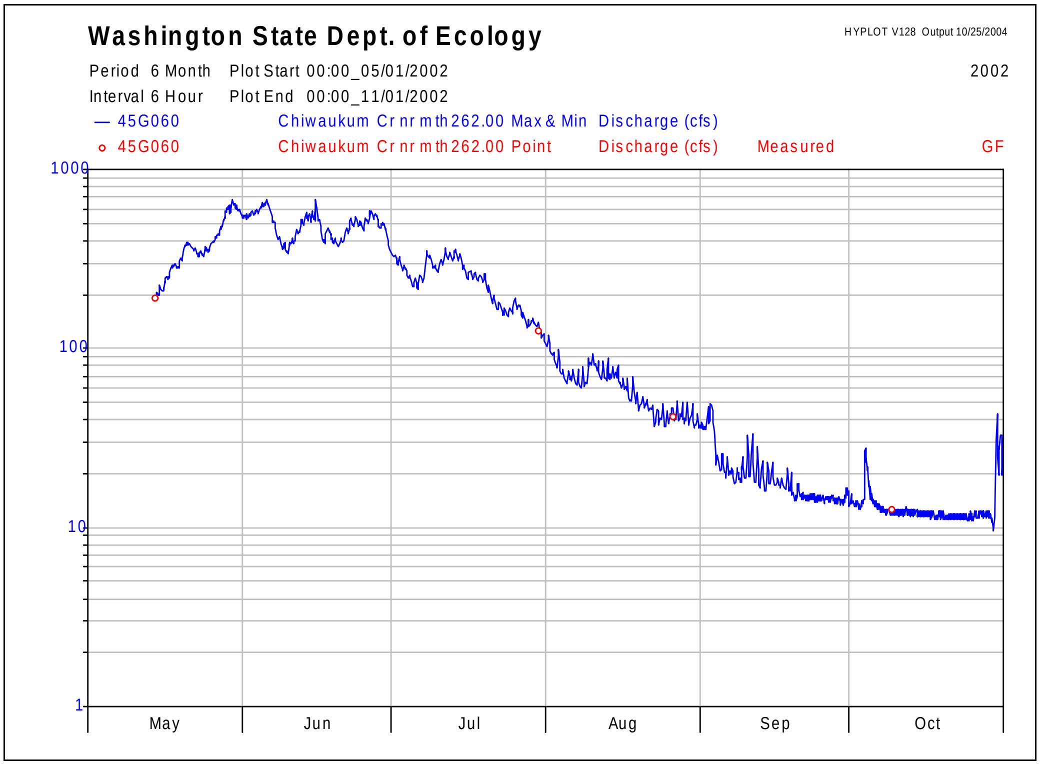

Figure 6: Discharge hydrograph for Site 2.

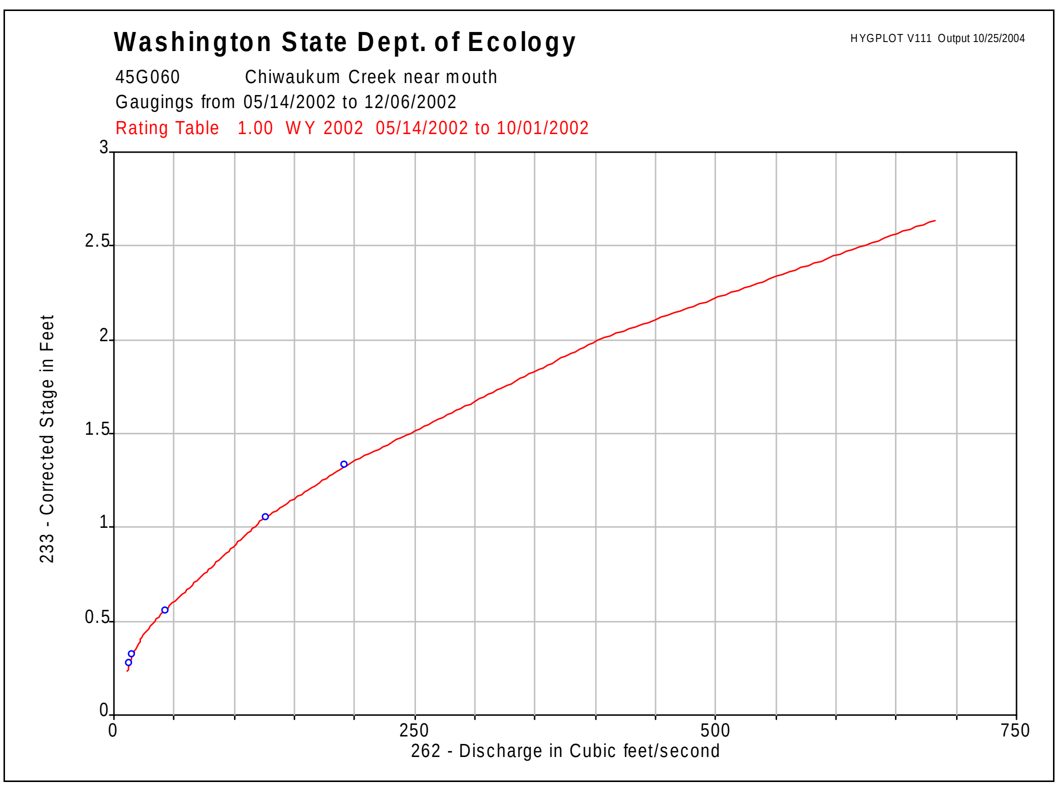

Figure 7: Discharge rating curve for Site 2.

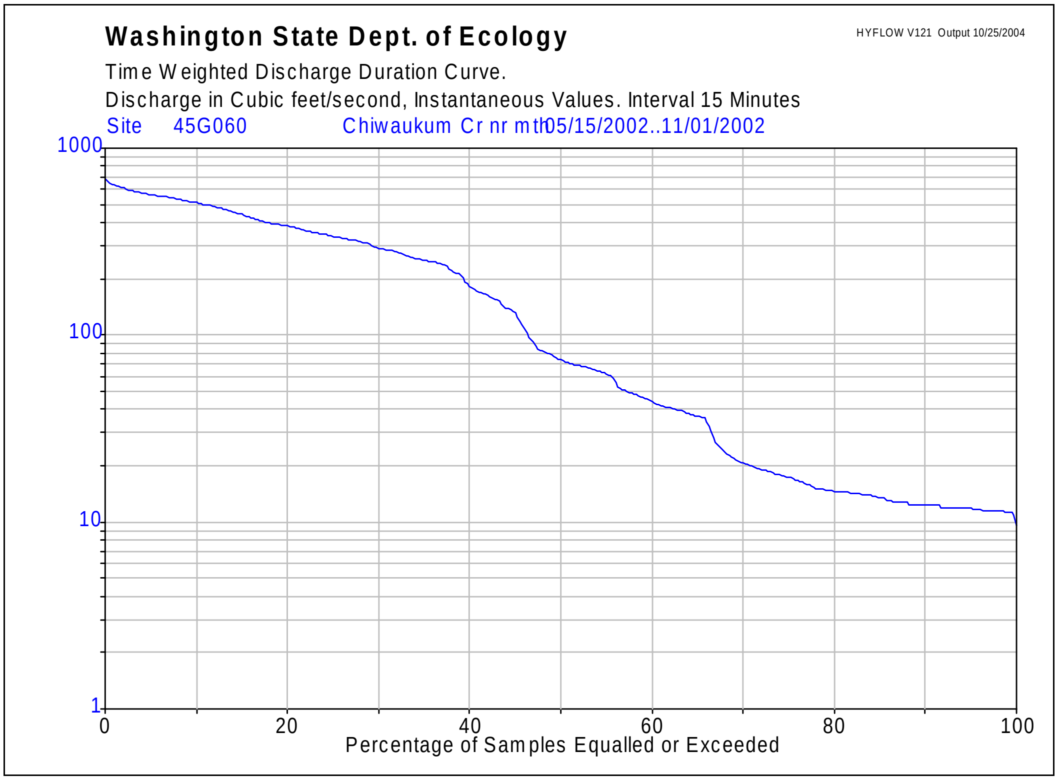

Figure 8: Discharge exceedence graph for Site 2.

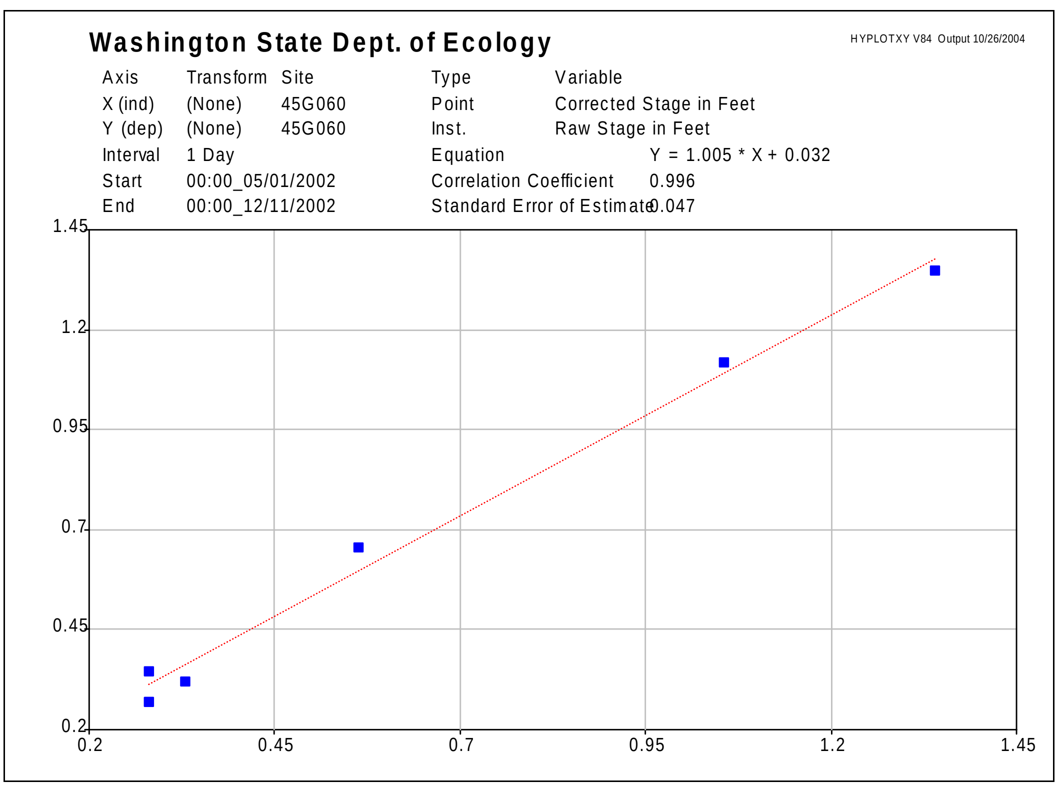

Figure 9: Linear regression of staff gage versus pressure transducer readings for Site 2.

Site 3: Nason Creek near mouth (45J070)

The average daily discharge for Site 3 ranged from over 31 cfs in late-September to nearly 2,200 cfs during peak snowmelt in mid-June. Peak flow during the study period was 2,390 cfs on June 15 (Figure 10). Daily discharge averages are presented in Appendix A, Table 3. The rating curve encompassed less than 50 percent of the range of discharge, with flow measurements ranging from 63 to 1,170 cfs (Figure 11). However, discharge exceeded the rating curve less than 1 percent of the time over the duration of the study (Figure 12). Flows greater than 1,200 cfs were modeled using the established relationships between stage, velocity, and cross-sectional area at this site (see Appendix B).

Within the range of measured flows, the fit of the rating curve was very good. All five discharge measurements taken at Site 3 were within 1 percent of the flow predicted by the rating curve. Before corrective adjustments were made to the continuous stage data to compensate for pressure transducer drift, a linear regression of manual staff gage readings against pressure transducer readings showed a perfect correlation ($r^2 = 1.0$), indicating any drift in the pressure transducer readings was inconsequential (Figure 13). No secondary stage reference was established to perform quality assurance checks on the manual staff gage readings. However, due to placement of the staff gage at Site 3 in a fairly low velocity pool, manual staff gage readings should be accurate to within 0.02 ft.

Within the measured range of flows at Site 3, the overall margin of error for discharge data is estimated at 5 percent. Overall margin of error for flows greater than 1,200 cfs is estimated at 15 percent.

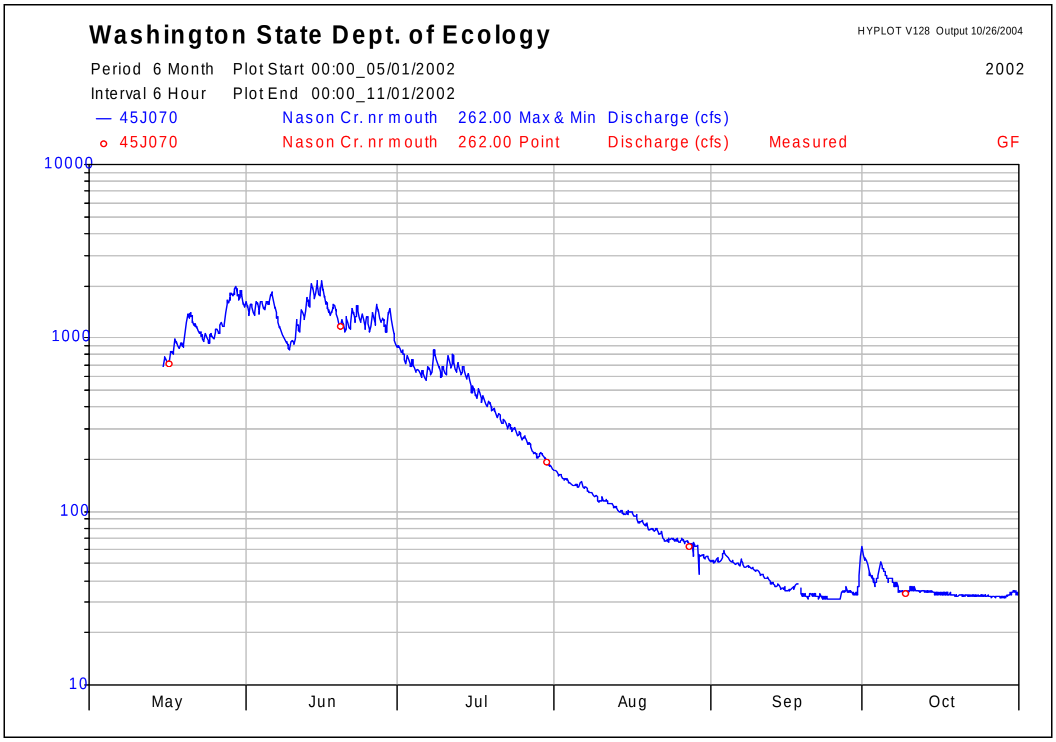

Figure 10: Discharge hydrograph for Site 3.

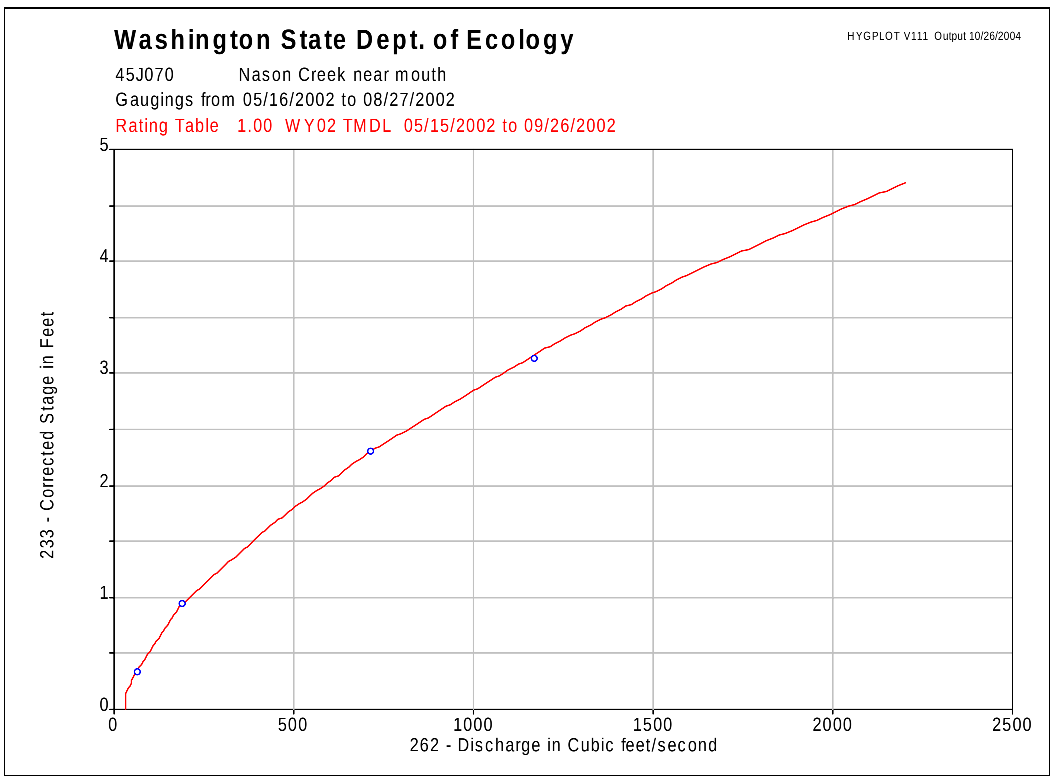

Figure 11: Discharge rating curve for Site 3.

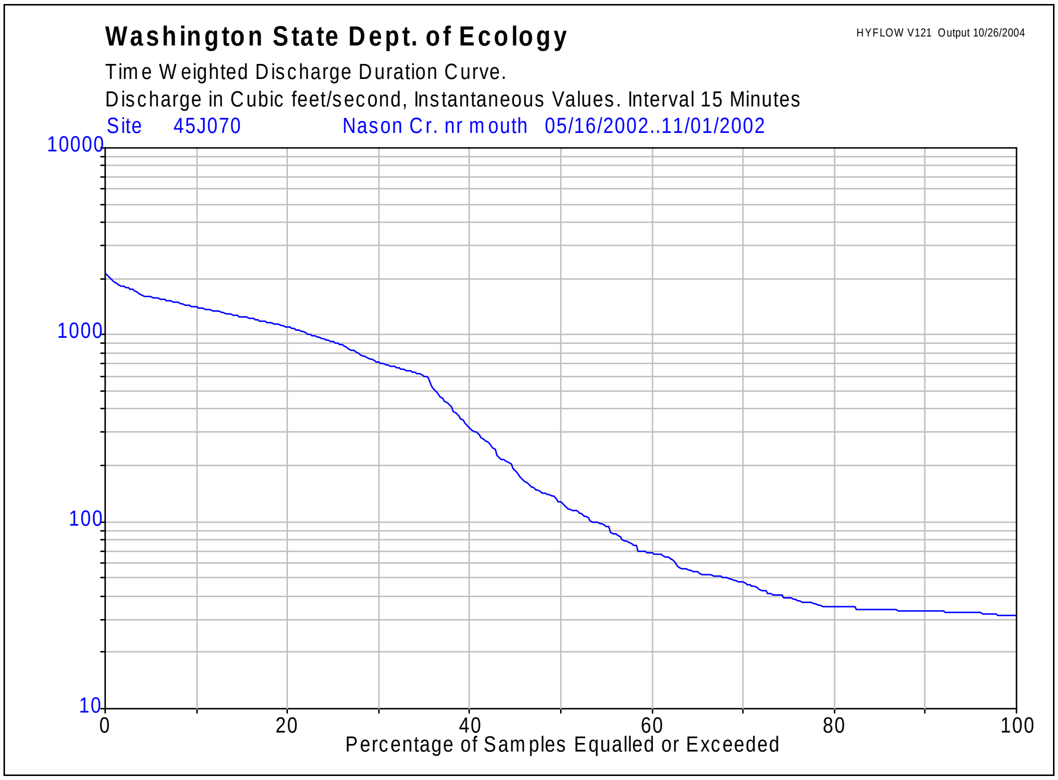

Figure 12: Discharge exceedence graph for Site 3.

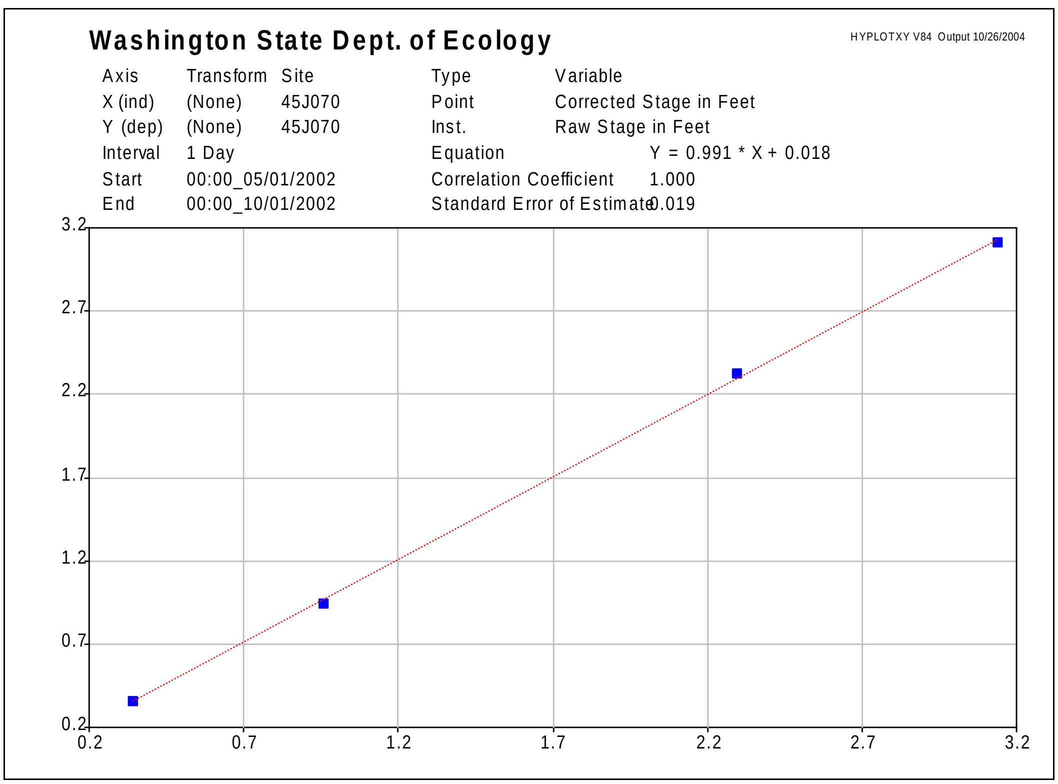

Figure 13: Linear regression of staff gage versus pressure transducer readings for Site 3.

Site 4: Wenatchee River below Lake Wenatchee (45A240)

The average daily discharge for Site 4 ranged from just over 160 cfs in late-October to over 9,300 cfs in mid-June. Peak flow during the study period was 9,580 cfs on June 16 (Figure 14). Daily discharge averages are presented in Appendix A, Table 4. The rating curve encompassed approximately 55 percent of the range of flows encountered during the study, with flow measurements ranging from 515 cfs to 6,370 cfs (Figure 15). However, discharge exceeded the rating curve less than 10 percent of the time over the duration of the study (Figure 16). Flows greater than 6,370 cfs were modeled using the established relationships between stage, velocity, and cross-sectional area at this site (see Appendix B).

Within the measured range of flows, the fit of the rating curve was very good. All three discharge measurements taken at Site 4 were within 1 percent of the flow predicted by the rating curve. Before corrective adjustments were made to the continuous stage data to compensate for pressure transducer drift, a linear regression of manual staff gage readings against pressure transducer readings showed a perfect correlation ($r^2 = 1.0$), indicating any drift in the pressure transducer readings was inconsequential (Figure 17). No secondary stage reference was established to perform quality assurance checks on the manual staff gage readings. However, due to placement of the staff gage at Site 4 near the bank, in moderately low velocities, manual staff gage readings should be accurate to within 0.02 ft.

Within the measured range of flows at Site 4, the overall margin of error for discharge data is estimated at 5 percent. Overall margin of error for flows greater than 6,370 cfs is estimated at 15 percent.

The US Geological Survey operates a gaging station 7.4 miles downstream from this station, near the town of Plain. Mean daily discharge at the USGS gage is estimated to be $1.3(x) + 64$ cfs, where x is mean daily discharge at this station, based on data collected during this study. For instantaneous flow comparisons, see the time of travel tables in Appendix D.

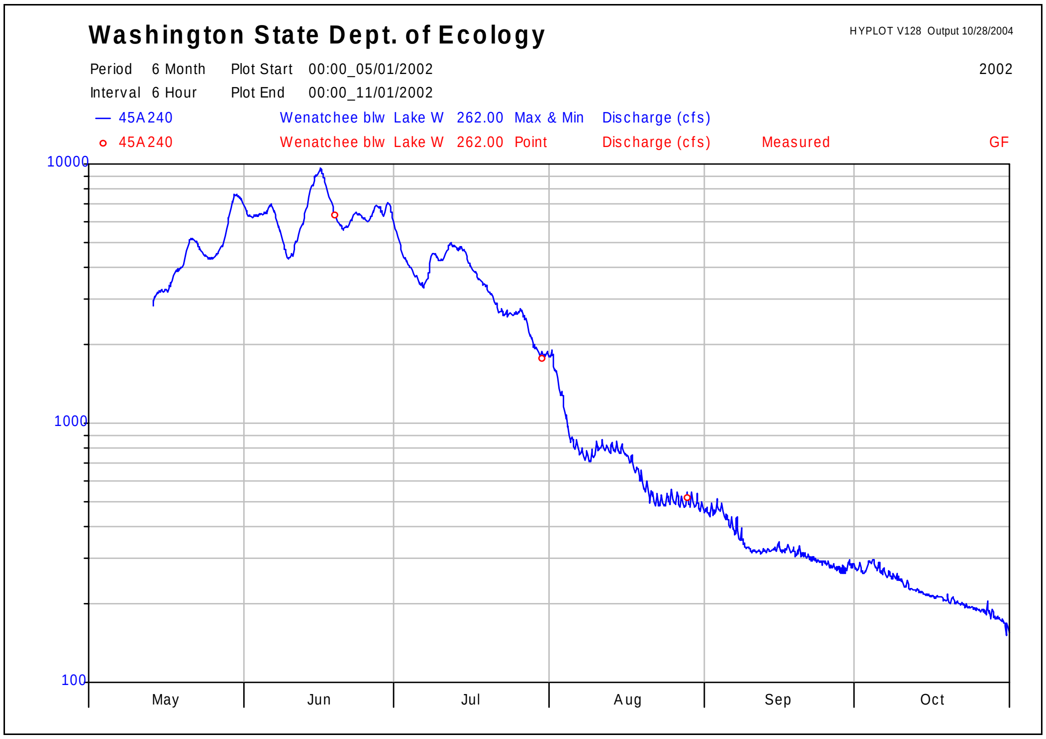

Figure 14: Discharge hydrograph for Site 4.

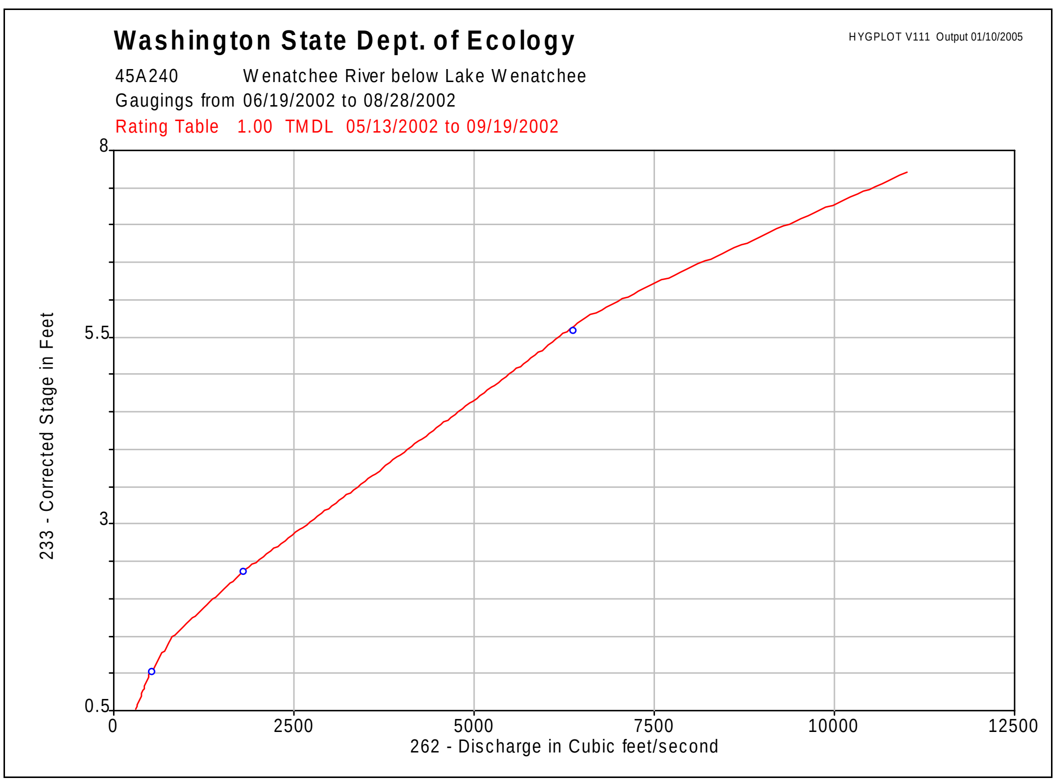

Figure 15: Discharge rating curve for Site 4.

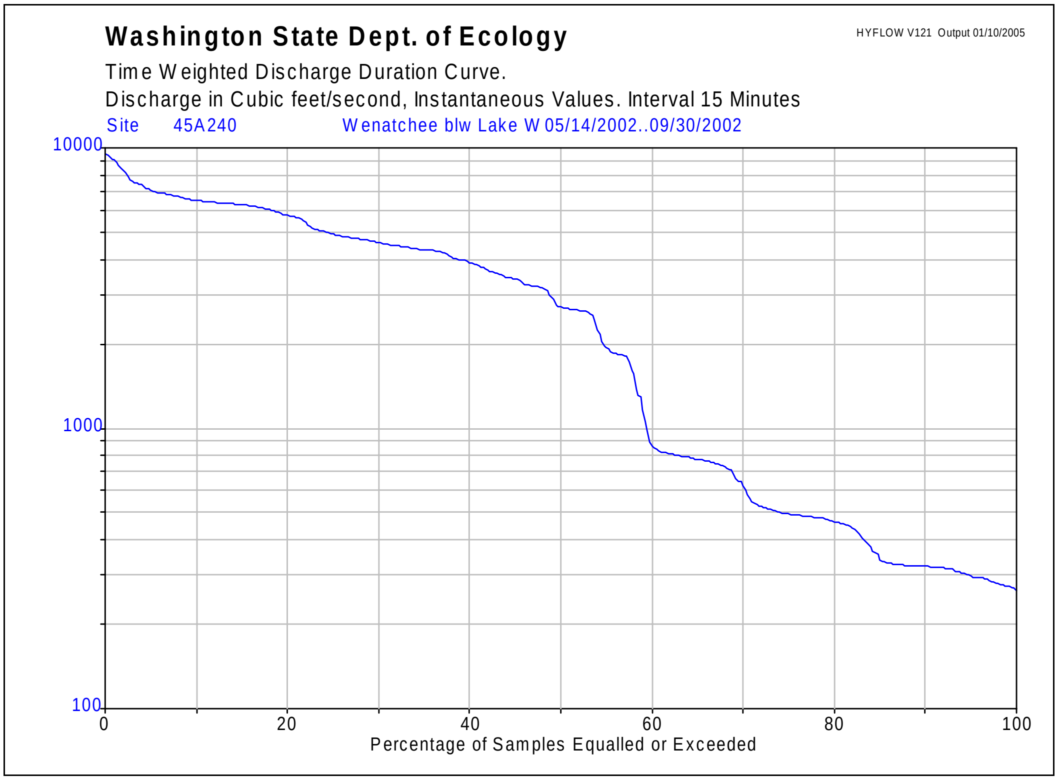

Figure 16: Discharge exceedence curve for Site 4.

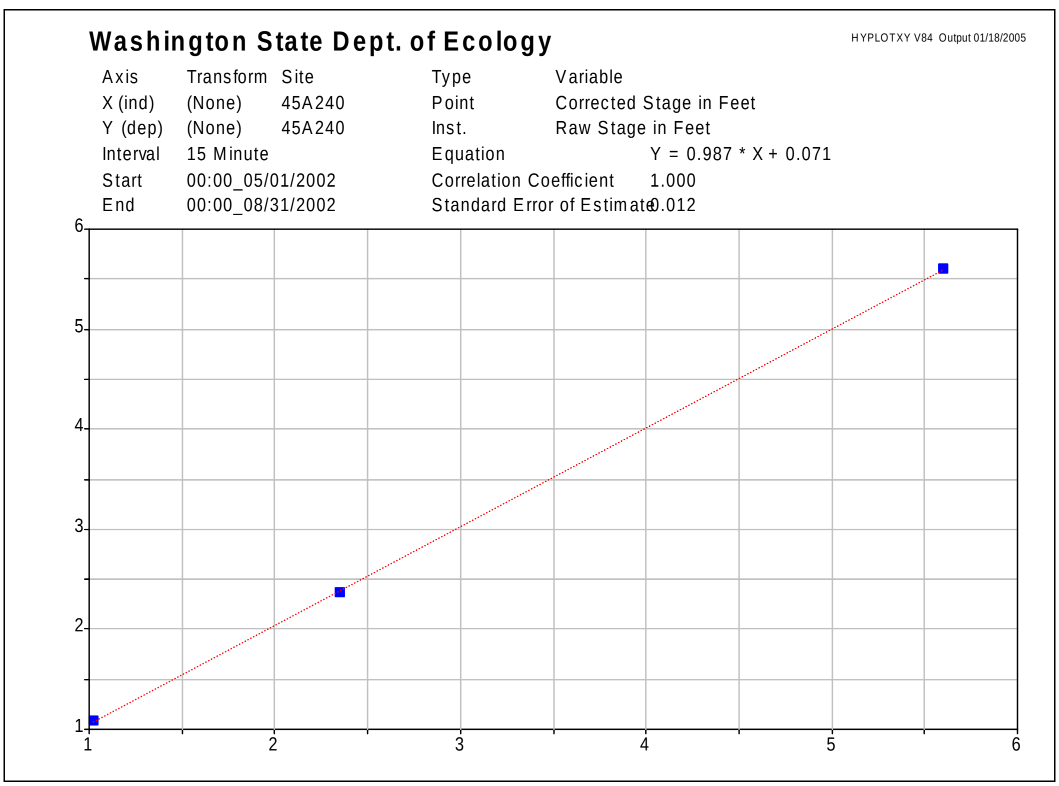

Figure 17: Linear regression of staff gage versus pressure transducer readings for Site 4.

Site 5: Wenatchee River at Leavenworth (45A100)

Continuous data collection was not conducted at Site 5. Instead, a rating curve was developed, and used to derive flows from manual stage readings taken during temperature sampling visits by Watershed Ecology Section staff. The stage index for this site was derived from a reference point established on a bridge over the river. River stage readings were taken by measuring from the reference point down to the water surface. Thus, as the river rose, the distance from the reference point to the water surface would decrease, and vice versa. Flows encountered during the study period ranged from 386 cfs in mid-October to over 18,000 cfs in late-June (Figure 18). The rating curve encompassed over 90 percent of the range of flows encountered during the study period, with flow measurements ranging from 386 cfs to 16,400 cfs (Figure 19). All five discharge measurements conducted at the site during the study period were within 5 percent of the flow predicted by the rating curve.

Within the measured range of flows at Site 5, the overall margin of error for discharge data is estimated at 5 percent. Overall margin of error for flows greater than 16,400 cfs is estimated at 10 percent.

The US Geological Survey operates a gaging station 7.4 miles downstream from this station, at the town of Peshastin. Mean daily discharge at the USGS gage is estimated to be 0.88(*x*) + 235 cfs, where *x* is discharge at this station, based on data collected during this study. For instantaneous flow comparisons, see the time of travel tables in Appendix D.

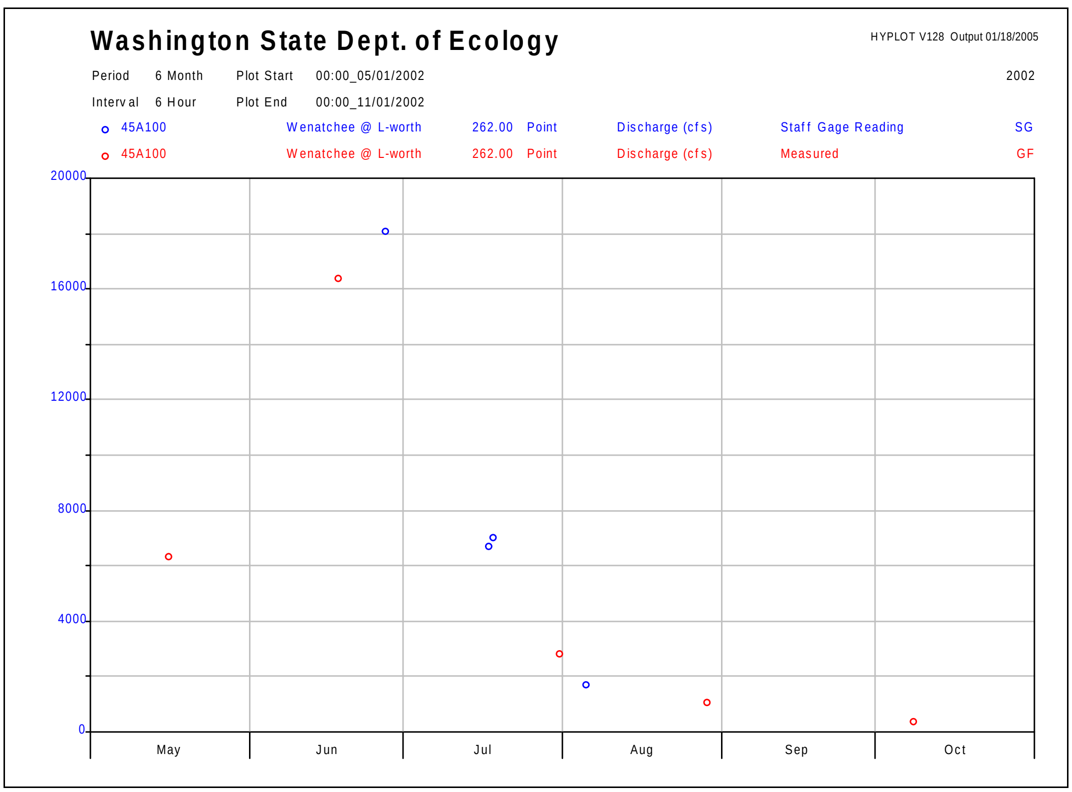

Figure 18: Discrete flow hydrograph for Site 5.

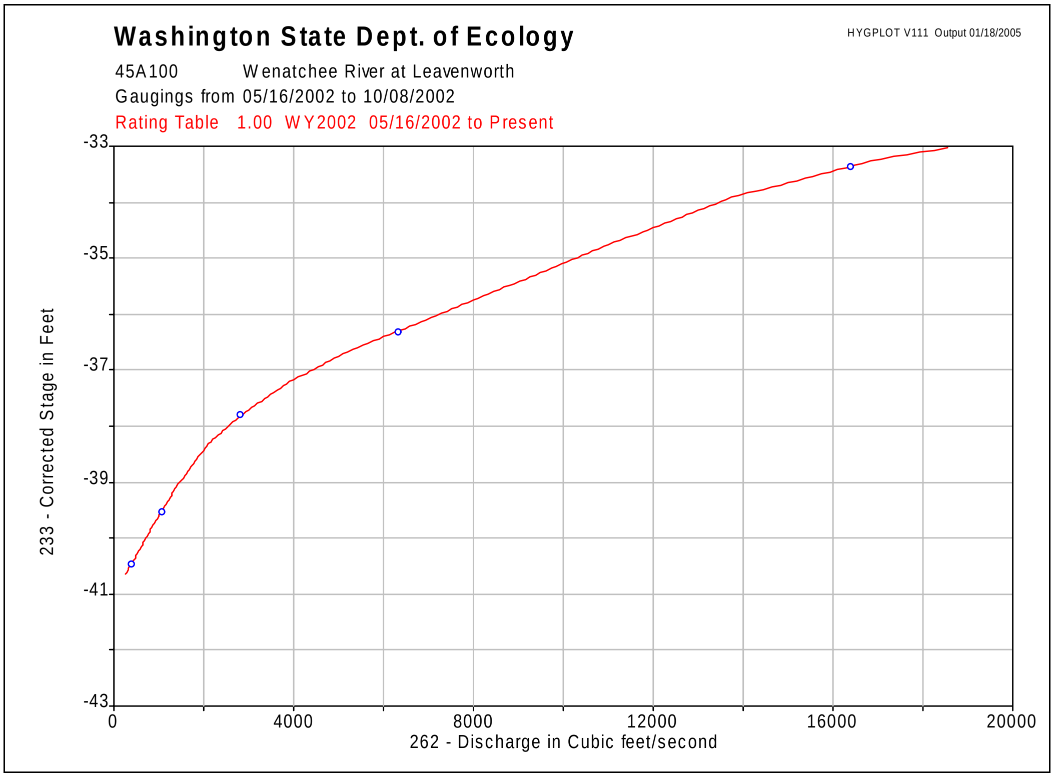

Figure 19: Discharge rating curve for Site 5.

Site 6: Wenatchee River near Leavenworth (45A110)

Continuous data collection was not conducted at Site 6. Instead, a rating curve was developed, and used to derive flows from manual stage readings taken during temperature sampling visits by Watershed Ecology Section staff. The stage index for this site was derived from a reference point established on a bridge over the river. River stage readings were taken by measuring from the reference point down to the water surface. Thus, as the river rose, the distance from the reference point to the water surface would decrease, and vice versa. Flows encountered during the study period ranged from 420 cfs in mid-October to over 11,200 cfs in late-June (Figure 20). The rating curve encompassed over 75 percent of the range of flows encountered during the study period, with flow measurements ranging from 420 cfs to 10,300 cfs (Figure 21). All five discharge measurements conducted at the site during the study period were within 2 percent of the flow predicted by the rating curve.

Within the measured range of flows at Site 6, the overall margin of error for discharge data is estimated at 5 percent. Overall margin of error for flows greater than 10,300 cfs is estimated at 10 percent.

The US Geological Survey operates a gaging station 10.6 miles upstream from this station, at the town of Plain. Mean daily discharge at the USGS gage is estimated to be $0.66(x) + 90$ cfs, where x is discharge at this station, based on data collected during this study. For instantaneous flow comparisons, see the time of travel tables in Appendix D.

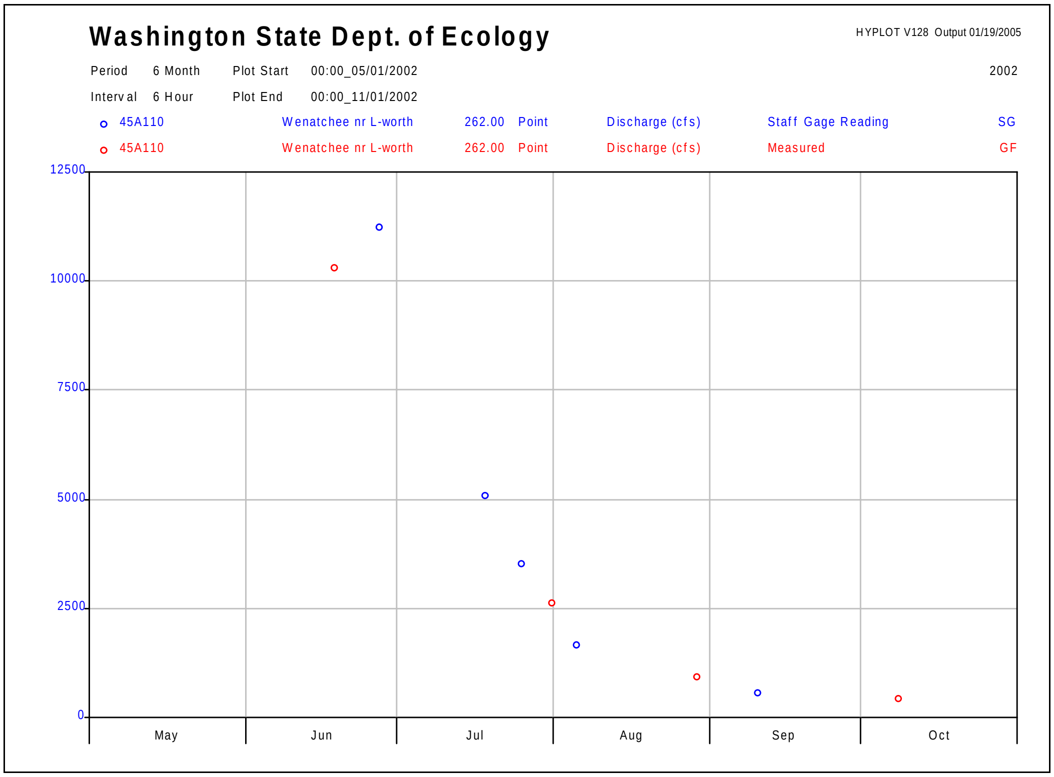

Figure 20: Discrete flow hydrograph for Site 6.

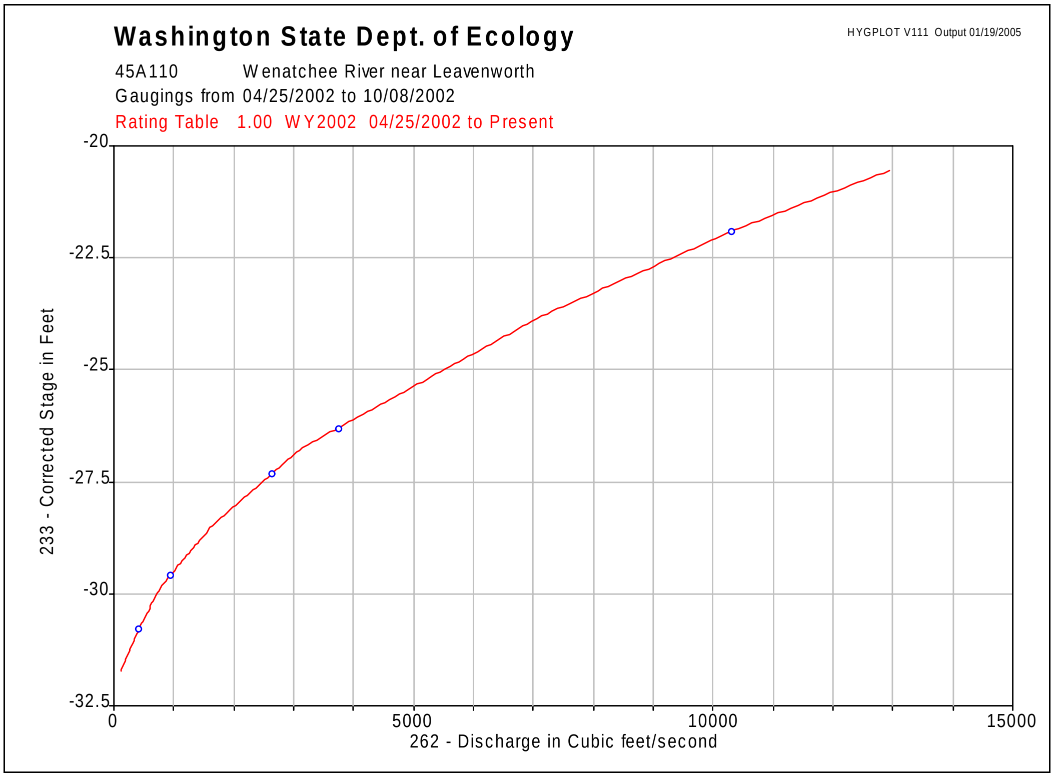

Figure 21: Discharge rating curve for Site 6.

Site 7: Chiwawa River at Schugart Flat (45H060)

Continuous data collection was not conducted at Site 7. Instead, a rating curve was developed, and used to derive flows from manual stage readings taken during temperature sampling visits by Watershed Ecology Section staff. The stage index for this site was derived from a reference point established on a bridge over the river. River stage readings were taken by measuring from the reference point down to the water surface. Thus, as the river rose, the distance from the reference point to the water surface would decrease, and vice versa. Flows encountered during the study period ranged from 115 cfs in mid-October to 2,050 cfs in late-June (Figure 22). The rating curve encompassed the entire range of flows encountered during the study period (Figure 23). All five discharge measurements conducted at the site during the study period were within 1 percent of the flow predicted by the rating curve.

For the entire encountered range of flows at Site 7, the overall margin of error for discharge data is estimated at 5 percent.

The US Geological Survey operates a gaging station 5.8 miles upstream from this station, in the Wenatchee National Forest. Mean daily discharge at the USGS gage is estimated to be 1.4(x) - 151 cfs, where x is discharge at this station, based on data collected during this study. For instantaneous flow comparisons, see the time of travel tables in Appendix D.

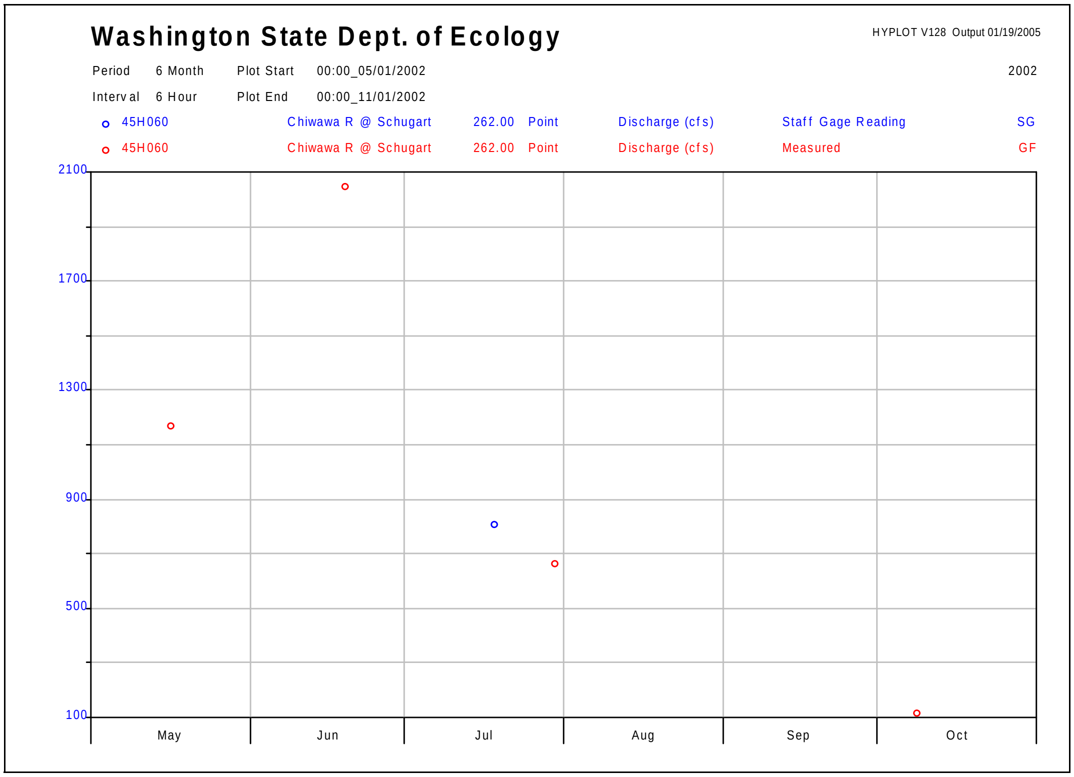

Figure 22: Discrete flow hydrograph for Site 7.

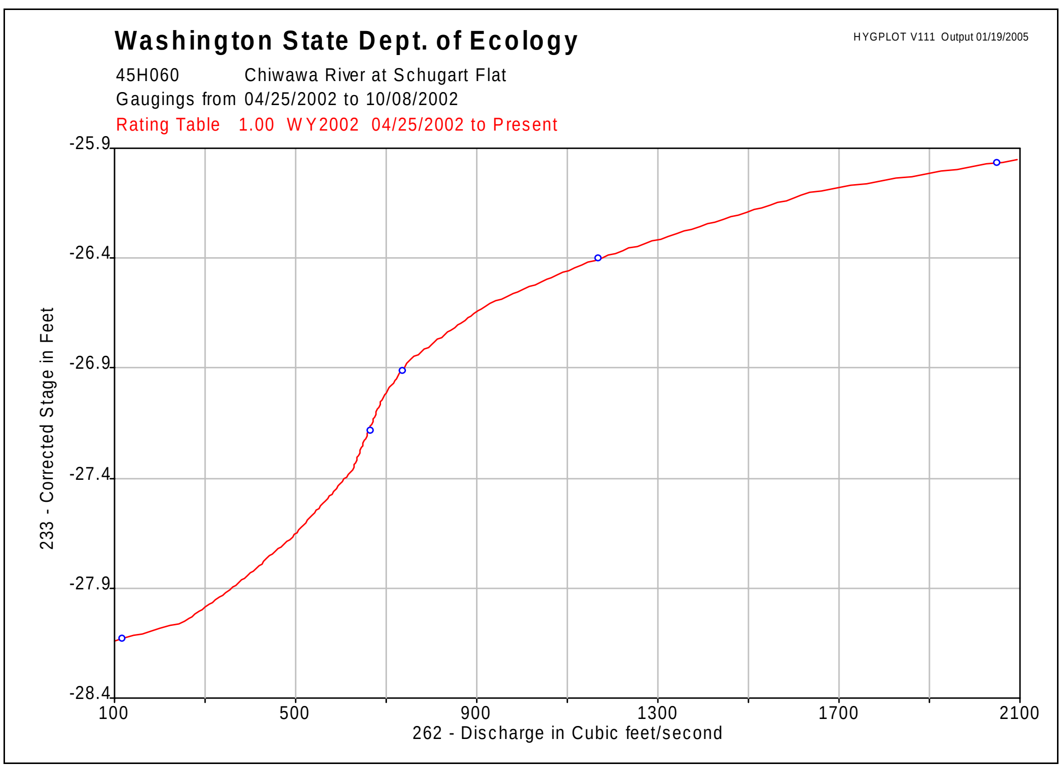

Figure 23: Discharge rating curve for Site 7.

Site 8: White River near the mouth (45K070)

Continuous data collection was not conducted at Site 8. Instead, a rating curve was developed, and used to derive flows from manual stage readings taken during temperature sampling visits by Watershed Ecology Section staff. The stage index for this site was derived from a reference point established on a bridge over the river. River stage readings were taken by measuring from the reference point down to the water surface. Thus, as the river rose, the distance from the reference point to the water surface would decrease, and vice versa. Flows encountered during the study period ranged from 103 cfs in mid-October to over 3,650 cfs in late-June (Figure 24). The rating curve encompassed nearly 85 percent of the range of flows encountered during the study period, with flow measurements ranging from 103 cfs to 3,100 cfs (Figure 25). Two of the six discharge measurements were within 5 percent of the flow predicted by the rating curve, and all six were within 10 percent.

Within the measured range of flows at Site 6, the overall margin of error for discharge data is estimated at 10 percent. Overall margin of error for flows greater than 3,100 cfs is estimated at 15 percent.

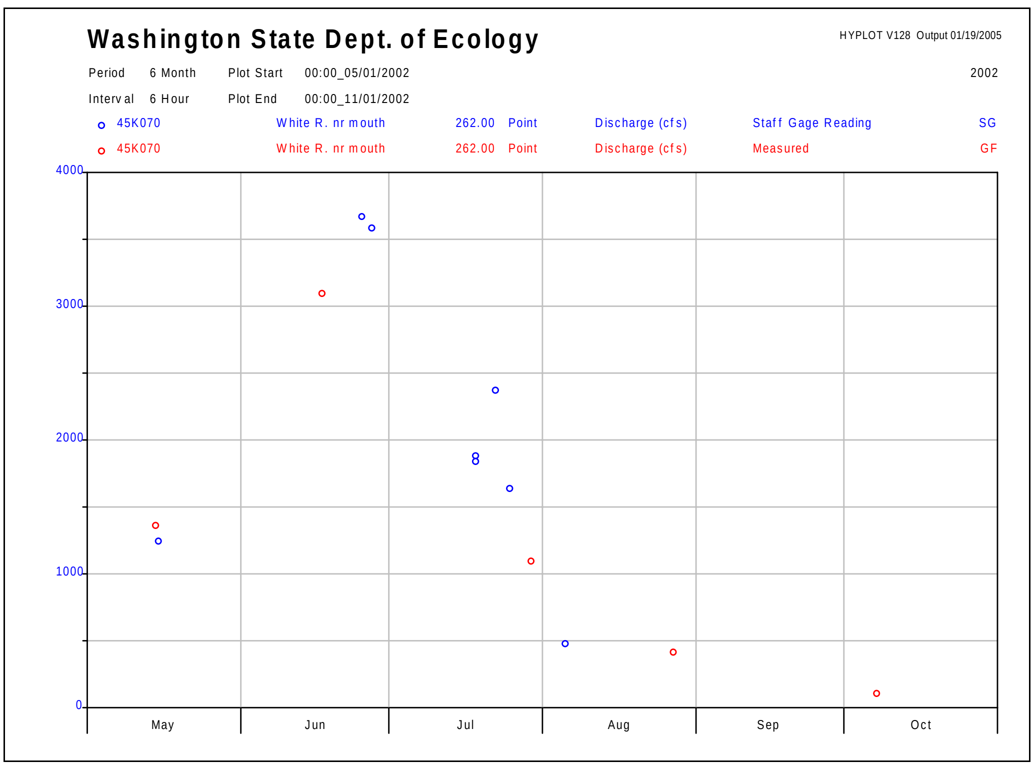

Figure 24: Discrete flow hydrograph for Site 8.

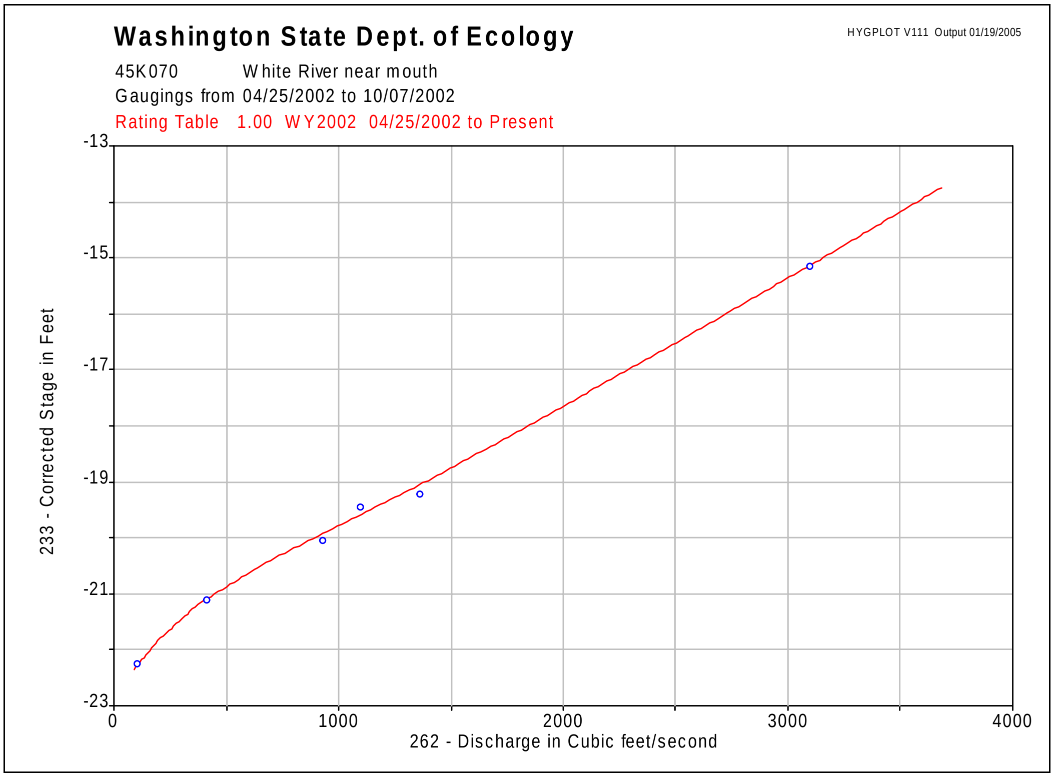

Figure 25: Discharge rating curve for Site 8.

Site 9: Little Wenatchee River near the mouth (45L070)

Continuous data collection was not conducted at Site 9. Instead, a rating curve was developed, and used to derive flows from manual stage readings taken during temperature sampling visits by Watershed Ecology Section staff. The stage index for this site was derived from a staff gage anchored in the river. Flows encountered during the study period ranged from 42 cfs in mid-September to nearly 4,500 cfs in late-June (Figure 26). Due to the lack of nearby bridge crossings, and thus the difficulty in measuring high flows at Site 9, the rating curve encompassed only 6 percent of the range of flows encountered during the study period, with flow measurements ranging from 53 cfs to 310 cfs (Figure 27). Flows greater than 310 cfs were modeled using the established relationships between stage, velocity, and cross-sectional area at this site (See Appendix B). Two of the four discharge measurements were within 5 percent of the flow predicted by the rating curve, and three were within 10 percent.

Within the measured range of flows at Site 9, the overall margin of error for discharge data is estimated at 10 percent. Overall margin of error for flows greater than 310 cfs is estimated at 25 percent.

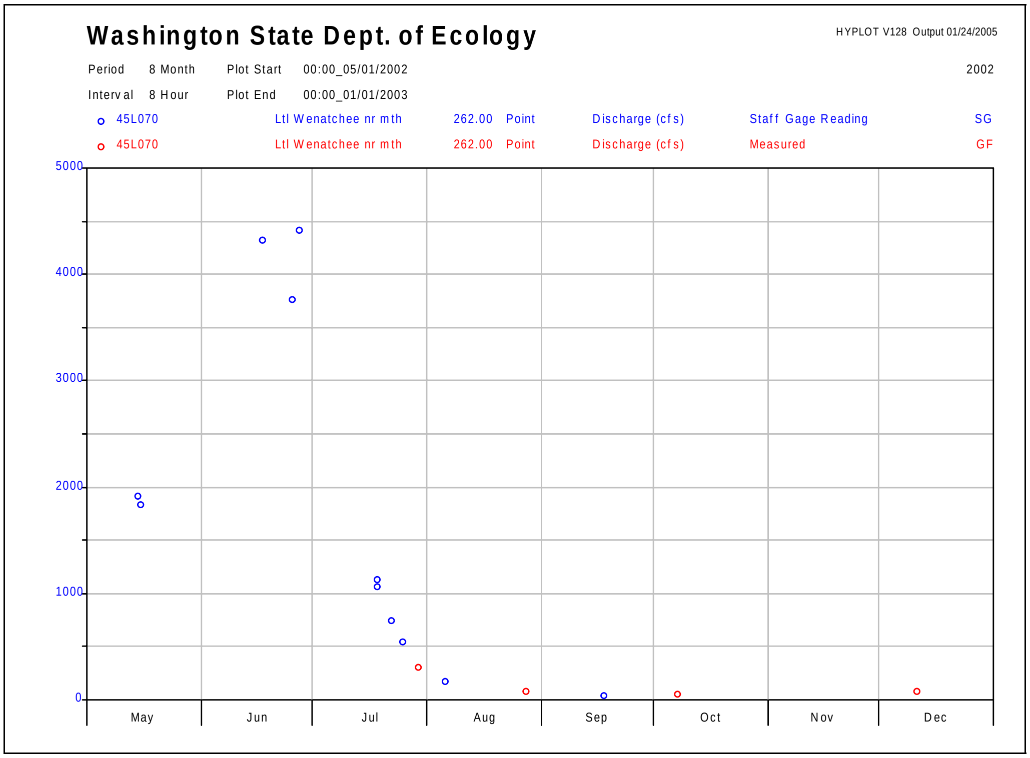

Figure 26: Discrete flow hydrograph for Site 9.

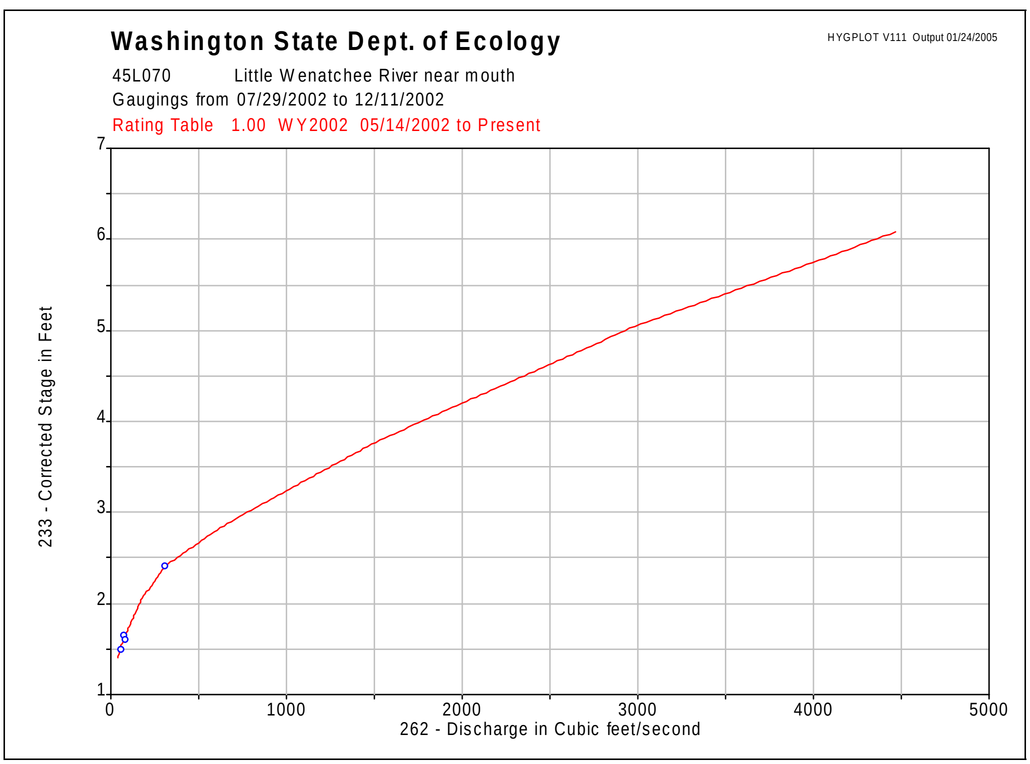

Figure 27: Discharge rating curve for Site 9.

Year Two Study Stations (July 2003 – May 2004)

Site 10: Mission Creek at Binder Road (45E100)

The average daily discharge for Site 10 ranged from 0 cfs in mid-September to over 76 cfs in early-March. Peak flow during the study period was 93.6 cfs on March 9, 2004 (Figure 28). Daily discharge averages are presented in Appendix A, Table 5. During five seperate periods from November 2003 through January 2004, channel and/or bank ice conditions impeded flow, compromising the relationship between stage and discharge. Data for these periods has been excluded from this analysis. Due to the "flashy" nature of Mission Creek, the rating curve encompassed only 53 percent of of the range of discharge, with flow measurments ranging from 0.004 cfs to 49 cfs (Figure 29). However, discharge exceeded the rating curve less than 5 percent of the time over the duration of the study (Figure 30). Flows greater than 49 cfs were modeled using the established relationships between stage, velocity, and cross-sectional area at the site (see Appendix B).

Within the range of measured flows, the fit of the rating curve was fairly good. Six of the eight discharge measurements taken at Site 10 were within 5 percent of the flow predicted by the rating curve. The other two measurements exceeded 20 percent error. Before corrective adjustments were made to the continuous stage data to compensate for pressure transducer drift, a linear regression of manual staff gage readings against pressure transducer readings had an r^2 of 0.988, with a standard error of 0.06 ft, indicating a moderate level of drift in the raw pressure transducer readings (Figure 31). Drift at this site is predominantly due to sedimentation in and around the pressure transducer's stilling pipe. Any transducer drift resulting in a difference in predicted discharge greater than 5 percent was corrected. A secondary stage reference was established on the Binder Road bridge, from which depth to water surface measurements were taken during each visit to the site. A linear regression of staff gage readings versus depth to water surface readings had an r^2 of 0.994, indicating a low potential for physical movement of the staff gage. The regression had a standard error of 0.037 ft, indicating a moderate level of error in the staff gage and/or depth to water surface readings.

This segment of Mission Creek had a very shallow and uniform channel. As a result, the only place with adequate depth to monitor stage height during low flows was in the thalweg of the creek. Over the course of the study, large amounts of debris accumulated on the staff gage and stilling pipe numerous times, likely adding error to the stage record. For the last two months of the study data from a downstream station (45E070 – Mission Cr. nr Cashmere) was used to estimate the continuous stage record for this site.

Within the measured range of flows at Site 1, the overall margin of error for discharge data is estimated at 20 percent. Overall margin of error for flows greater than 49 cfs is estimated at 30 percent.

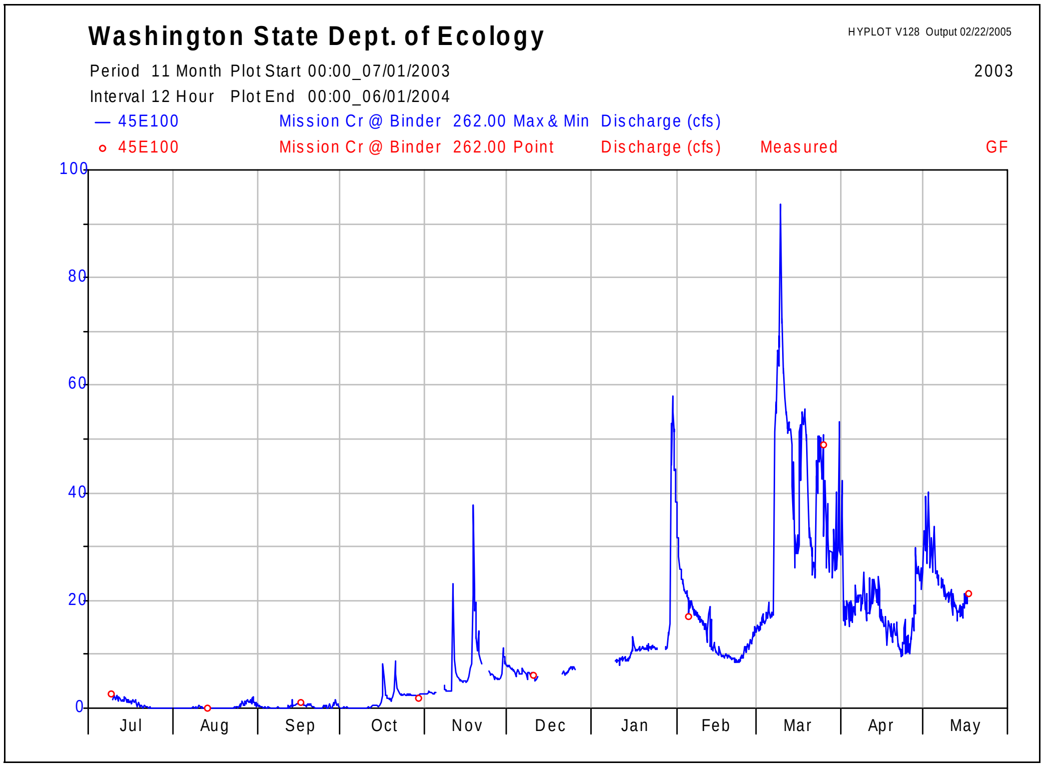

Figure 28: Discharge hydrograph for Site 10.

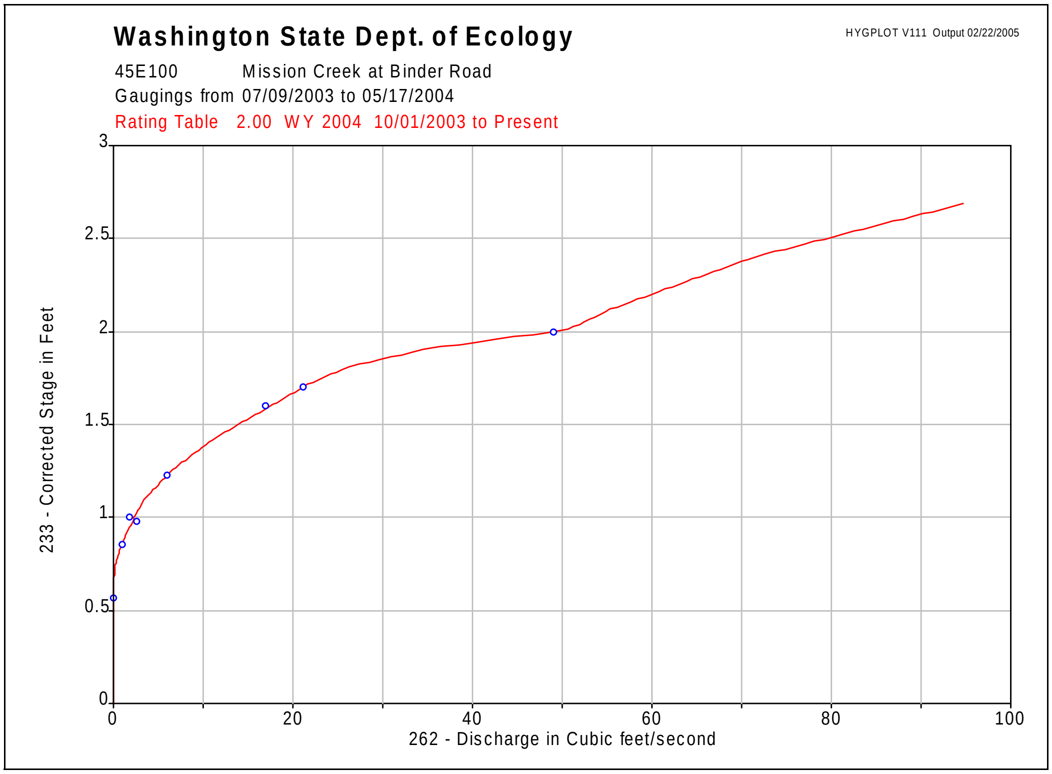

Figure 29: Discharge rating curve for Site 10.

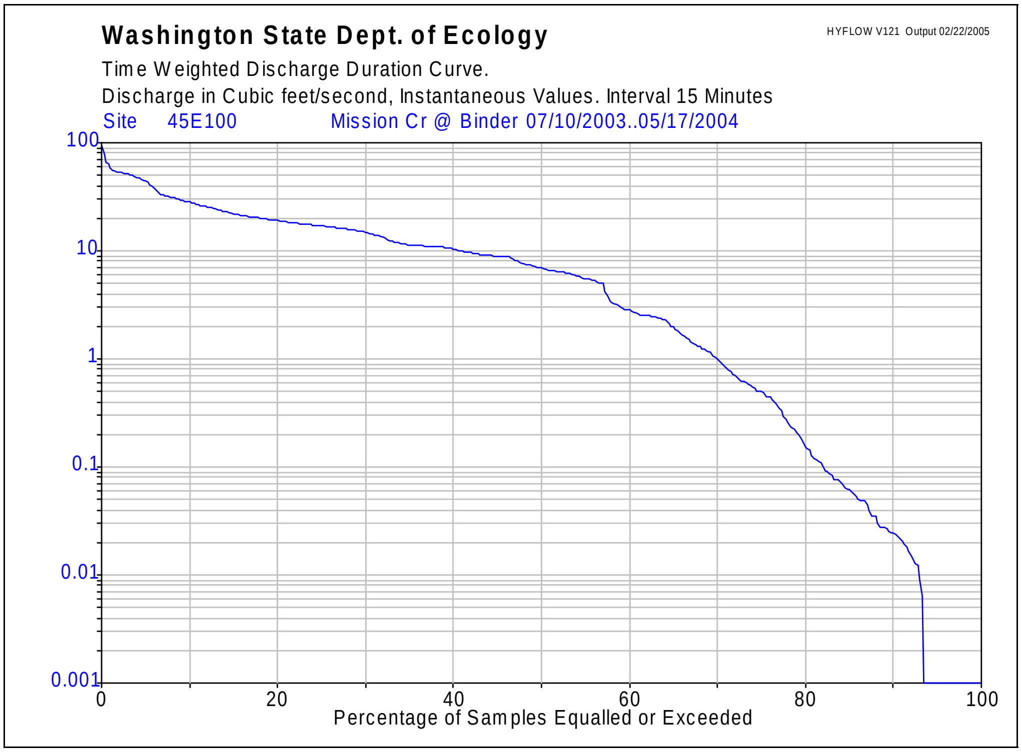

Figure 30: Discharge exceedence graph for Site 10.

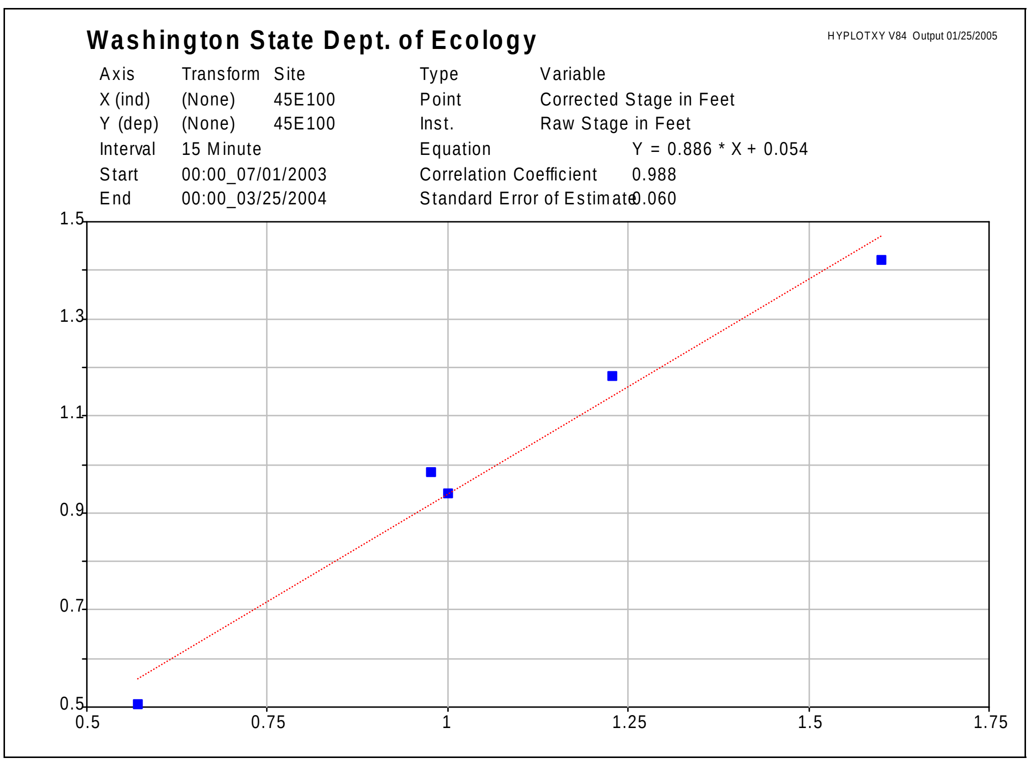

Figure 31: Linear regression of staff gage versus pressure transducer readings for Site 10.

Site 11: Brender Creek above Noname Creek (45D080)

The average daily discharge for Site 11 ranged from 1.4 cfs in early-August to 11.8 cfs in mid-September. Peak flow during the study period was 12.8 cfs on September 19 (Figure 32). Daily discharge averages are presented in Appendix A, Table 6. The rating curve encompassed 60 percent of the range of discharge, with flow measurements ranging from 1.4 cfs to 8.4 cfs (Figure 33). However, discharge exceeded the rating curve less than 5 percent of the time over the duration of the study (Figure 34). High irrigation return flows in September 2003 caused substrate scouring at the site, which resulted in a substantial change in the relationship between stage and discharge. The rating curve was shifted effective October 1, 2003, to reflect this change. No flow modeling was necessary for high flows at this site.

Within the range of measured flows, the fit of the rating curve was fairly good. Six of the eight discharge measurements taken at Site 11 were within 5 percent of the flow predicted by the rating curve. The other two measurements, taken in October and December 2003, deviated from the rating by 18 percent and 45 percent respectively. This is likely due to rampant reed-canary grass growth on the banks and in the stream channel, which temporarily altered the relationship between stage and discharge. Data from mid-September 2003 to early-February 2004 were qualified as estimates, and the two discharge measurements taken during this period were discarded from the analysis. Before corrective adjustments were made to the continuous stage data to compensate for pressure transducer drift, a linear regression of manual staff gage readings against pressure transducer readings had an r^2 of 0.42, indicating extreme drift in pressure transducer readings (Figure 35). This was likely caused by constant fine sediment deposition at this site, due to low gradient and extensive aquatic weed growth. Since the nearest bridge crossing was too far downstream to correlate depth to water surface readings with the staff gage readings taken at the site, no secondary stage reference was established to perform quality assurance checks on the manual staff gage readings. However, due to the low gradient and very low velocities at Site 11, manual staff gage readings should be accurate to within 0.01 ft.

Due to the extensive aquatic weed growth at Site 11 from September 2003 to February 2004, coupled with the extreme level of drift that occurred in the pressure transducer, the overall margin of error for discharge data for this site is estimated at 25 percent.

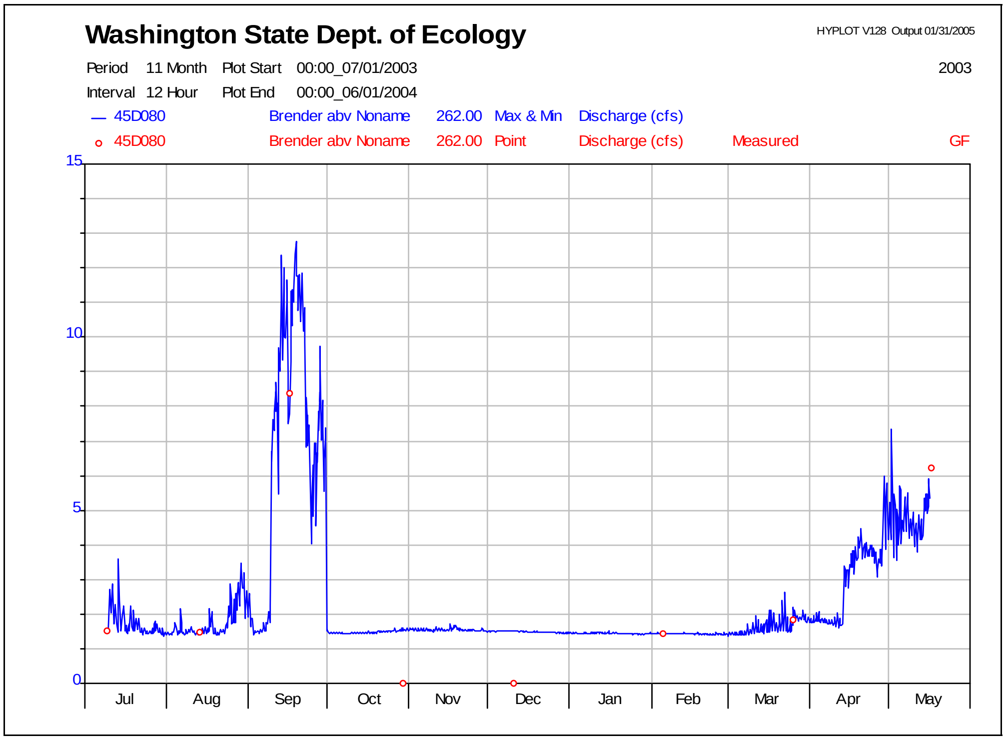

Figure 32: Discharge hydrograph for Site 11.

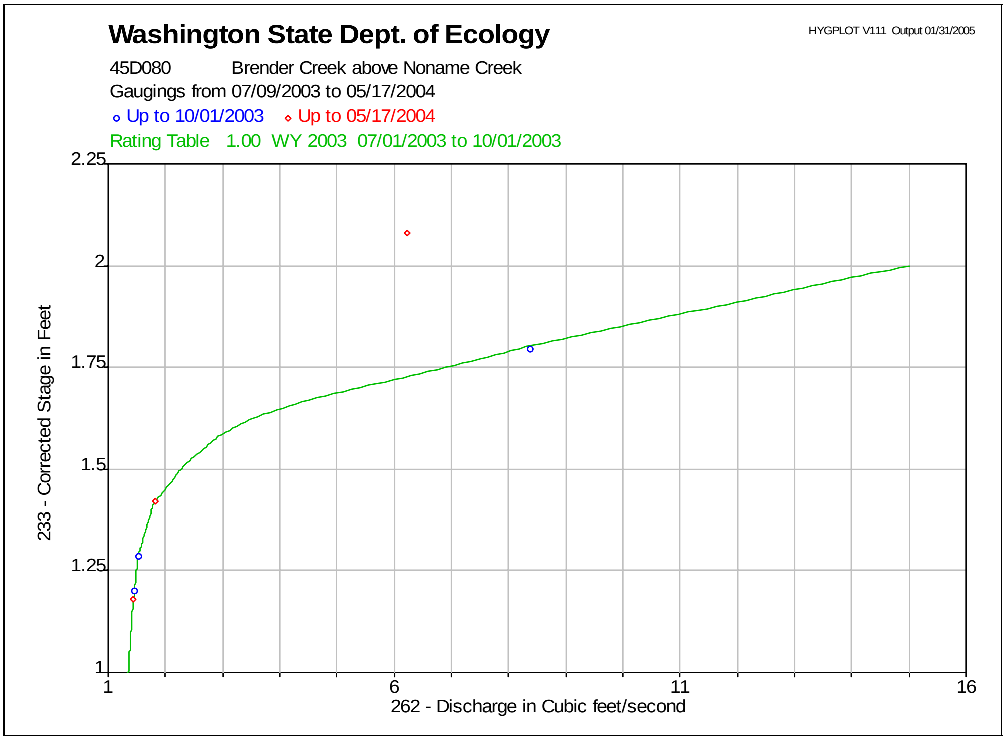

Figure 33: Discharge rating curve for Site 11.

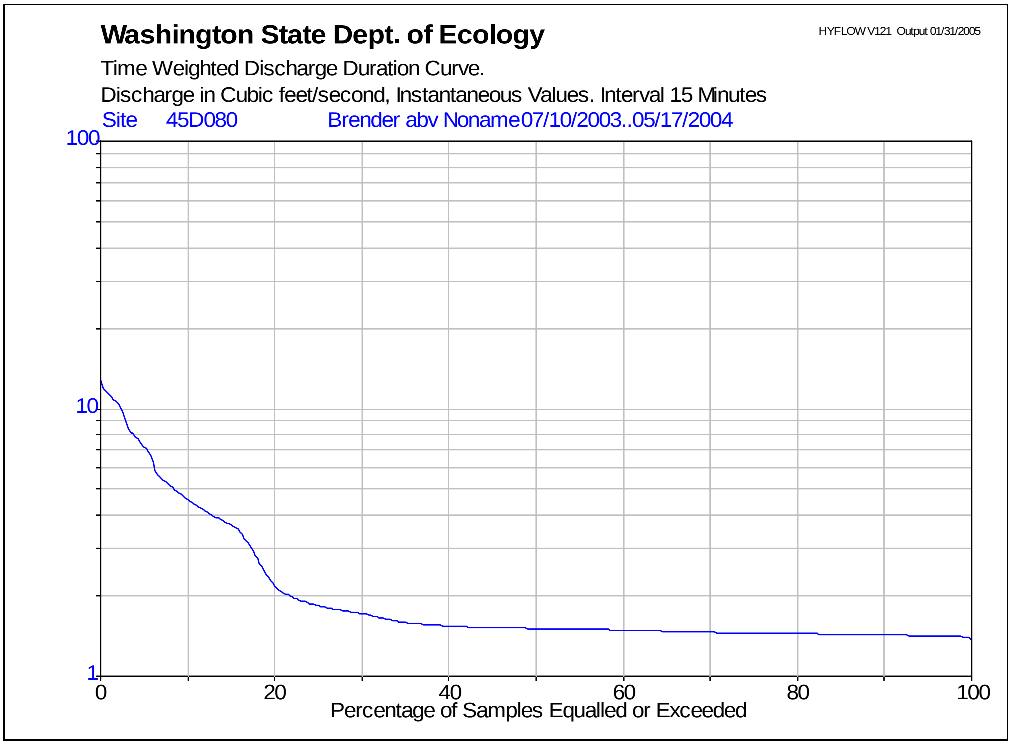

Figure 34: Discharge exceedence graph for Site 11.

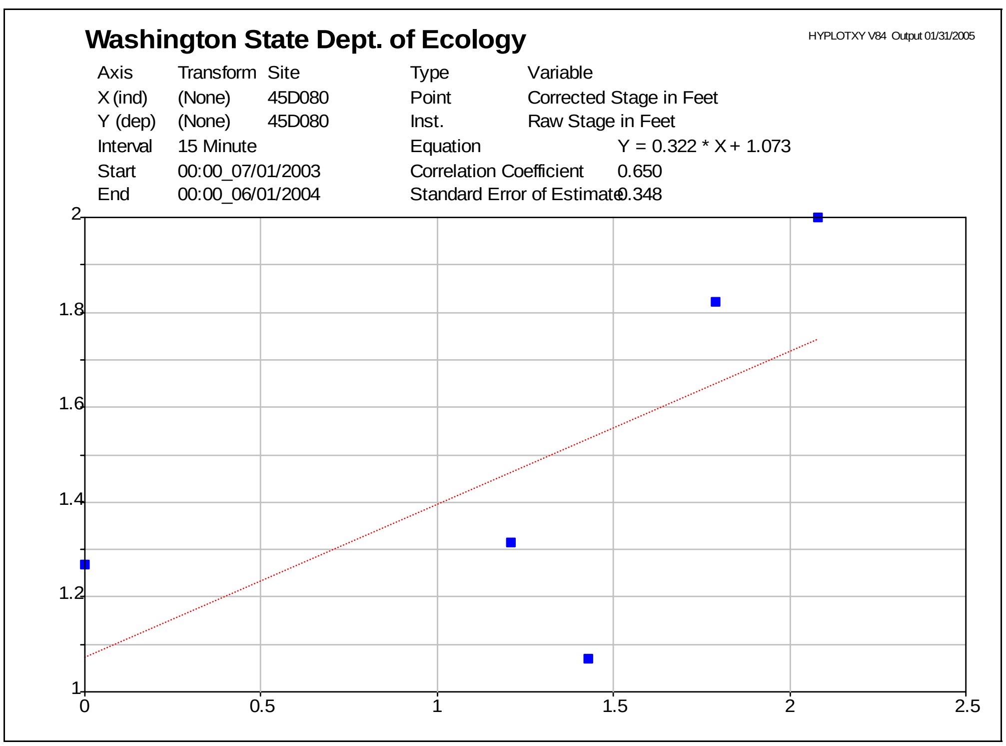

Figure 35: Linear regression of staff gage versus pressure transducer readings for Site 11.

Site 12: Brender Creek below Brender Canyon (45D150)

The average daily discharge for Site 12 ranged from 0.02 cfs during several periods during the fall and winter to 10.3 cfs in mid-September 2003. Peak flow during the study period was 11.7 cfs on September 13 (Figure 36). Daily discharge averages are presented in Appendix A, Table 7. During four distinct periods from November 2003 to February 2004, bank and/or channel ice conditions impeded flow, compromising the relationship between stage and discharge. Data for these periods have been excluded from the analysis. The rating curve covered 60 percent of the range of discharge, with flow measurements ranging from 0.04 cfs to 7.2 cfs (Figure 37). However, discharge exceeded the rating curve less than 5 percent of the time over the duration of the study (Figure 38). High irrigation return flows in September 2003 caused substrate scouring at the site, which resulted in a substantial change in the relationship between stage and discharge. The rating curve was shifted effective October 1, 2003 to reflect this change. No high flow modeling was necessary for this site.

Within the range of measured flows, the fit of the rating curve was fairly good. Five of the seven discharge measurements taken at Site 12 were within 5 percent of the flow predicted by the rating curve. The other two measurements, which were both low flow measurements taken during Fall 2003, deviated 50 percent and 100 percent respectively from the rating curve. Both of these measurements were 0.10 cfs or less in total discharge, and the variability is largely due to aquatic weed growth, and a lack of sensitivity in stage height as a predictor of discharge during low flow conditions at this site. Before corrective adjustments were made to the continuous stage data to compensate for pressure transducer drift, a linear regression of manual staff gage readings against pressure transducer readings had an r^2 of 0.998, indicating that a nominal amount of drift occurred in the pressure transducer readings (Figure 39). Any transducer drift resulting in a difference in predicted discharge greater than 5 percent was corrected. Since there were no nearby usable bridge crossings, no secondary stage reference was established to perform quality assurance checks on the manual staff gage readings. However, due to placement of the staff gage at Site 12 in a low-velocity glide, staff gage readings can be considered accurate to within 0.01 ft.

Within the measured range of flows at Site 12, the over all margin of error for discharge data above 0.5 cfs is estimated at 10 percent. Due to extreme difficulties in measuring the lowest flows at this site, flows less than 0.5 cfs are considered accurate to within 50 percent. Flows greater than 7.2 cfs are considered accurate to within 15 percent.

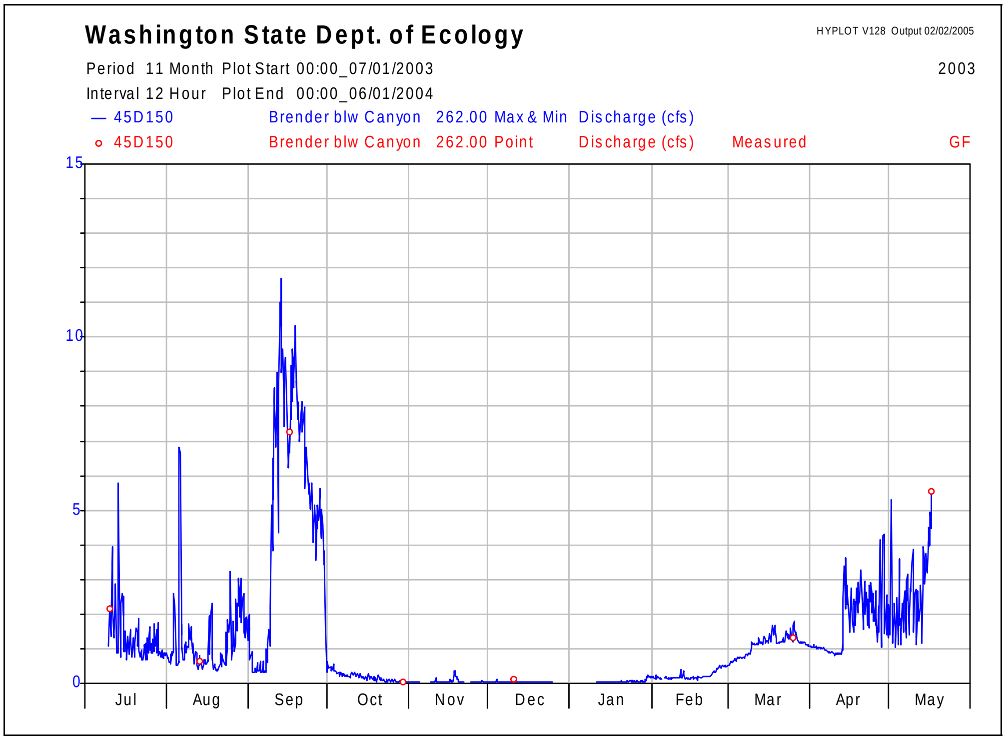

Figure 36: Discharge hydrograph for Site 12.

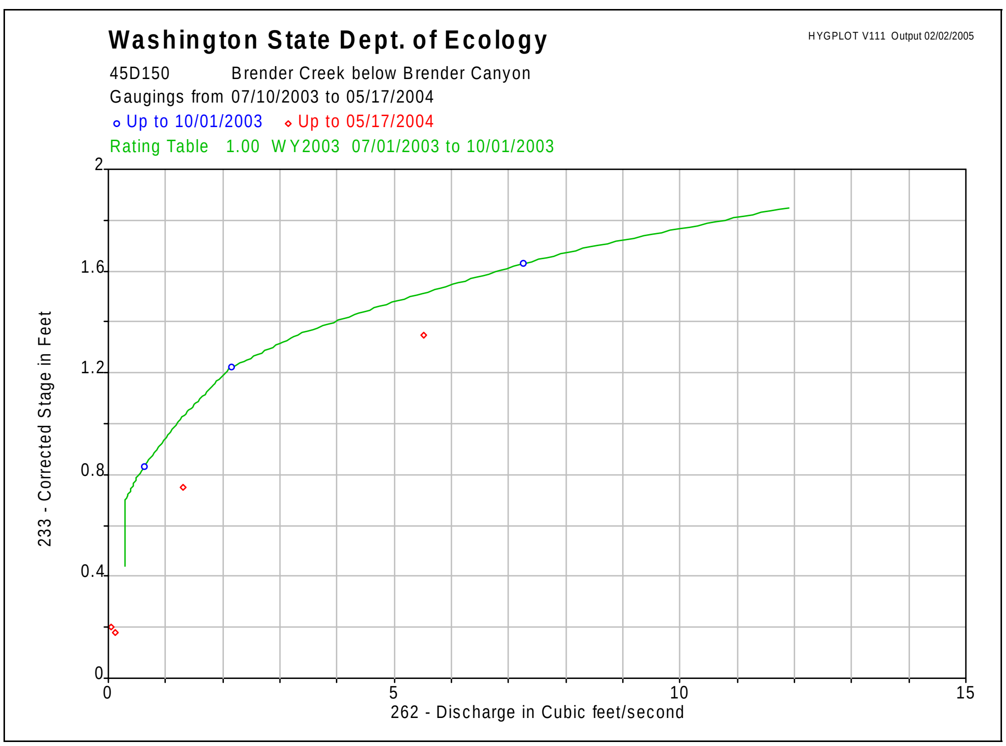

Figure 37: Discharge rating curve for Site 12.

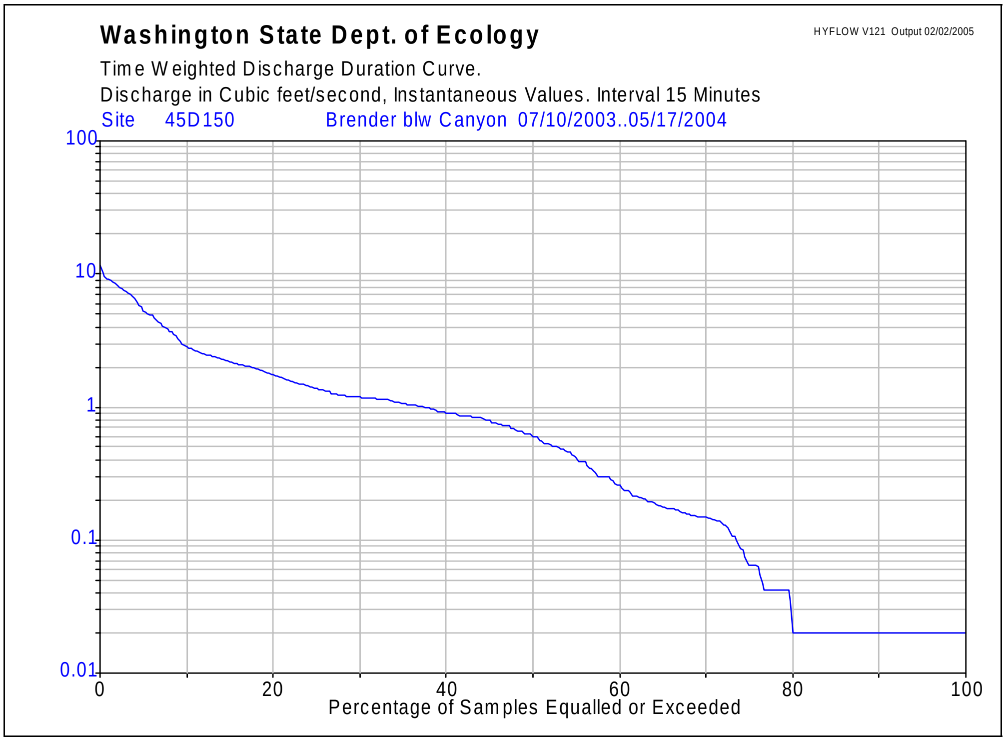

Figure 38: Discharge exceedence graph for Site 12.

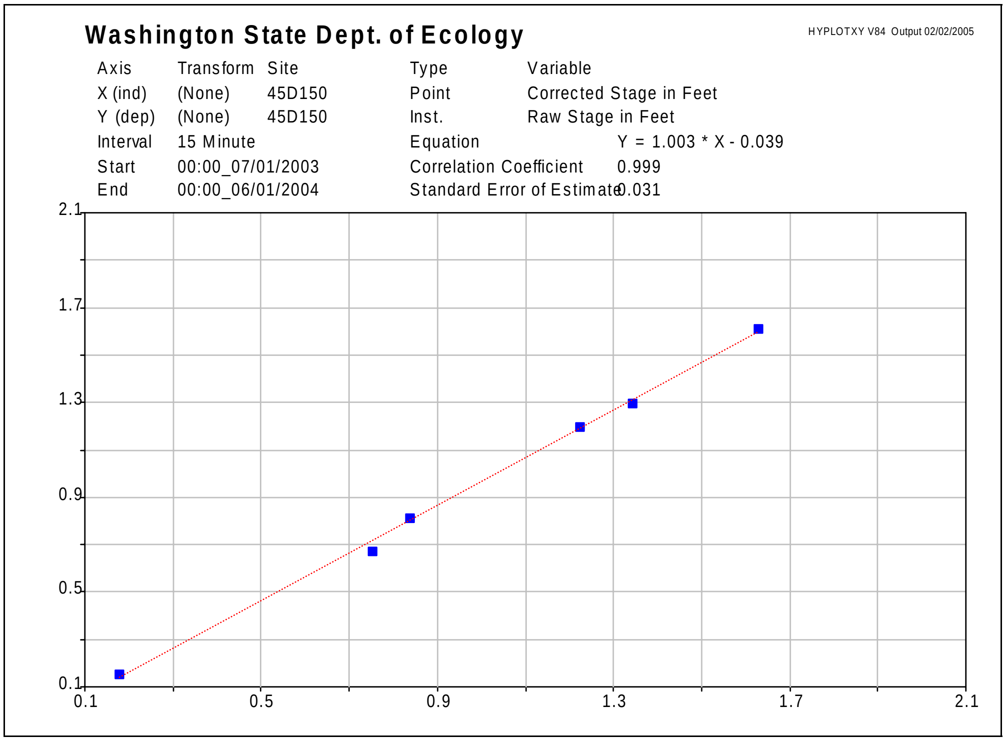

Figure 39: Linear regression of staff gage versus pressure transducer readings for Site 12.

Site 13: Peshastin Creek above Tronsen Creek (45F150)

The average daily discharge for Site 13 ranged from 0.3 cfs in early-September to over 92 cfs during peak snowmelt in mid-March. Peak discharge during the study was 101 cfs on March 9 (Figure 40). Daily discharge averages are presented in Appendix A, Table 8. During two distinct periods from December 2003 to January 2004, channel and/or bank ice impeded flow, compromising the relationship between stage and discharge. Data for these periods have been excluded from the analysis. The rating curve encompassed 61 percent of the range of discharge, with flow measurements ranging from 0.5 cfs to 62 cfs (Figure 41). However, discharge exceeded the rating curve only 5 percent of the time over the duration of the study (Figure 42). No high flow modeling was necessary for this site.

Within the range of measured flows, the fit of the rating curve was very good. Five of the eight discharge measurements taken at Site 13 were within 2 percent of the flow predicted by the rating curve, and all eight were within 5 percent. Before corrective adjustments were made to the continuous stage data to compensate for pressure transducer drift, a linear regression of manual staff gage readings against pressure transducer readings showed a perfect correlation ($r^2 = 1$), indicating that any drift in the pressure transducer readings was inconsequential (Figure 43). A secondary stage reference was established on the Forest Road bridge, from which depth to water surface measurements were taken during each visit to the site. A linear regression of staff gage readings versus depth to water surface readings had an r^2 of 0.978, indicating a fairly low potential for physical movement of the staff. The regression had a standard error of 0.094 ft, indicating a moderately high level of error in the staff gage and/or depth to water surface readings. The error is most likely in the depth to water surface readings due to the difficulty in taking those readings at this site.

Within the measured range of flows at Site 1, the overall margin of error for discharge data is estimated at 5 percent. Overall margin of error for flows greater than 62 cfs is estimated at 10 percent.

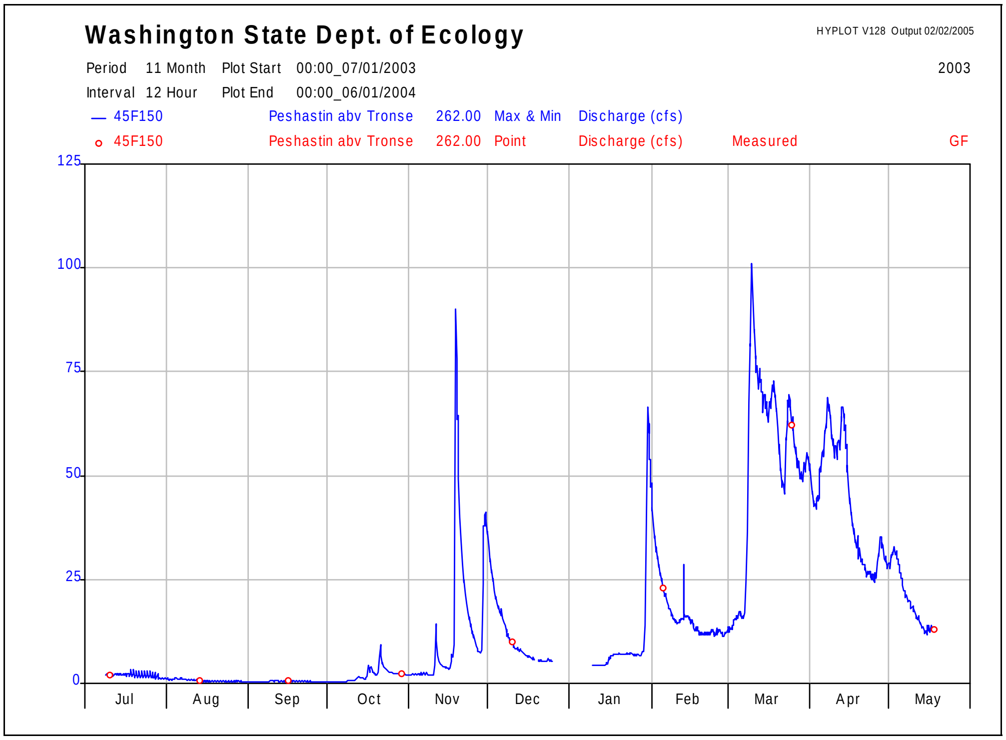

Figure 40: Discharge hydrograph for Site 13.

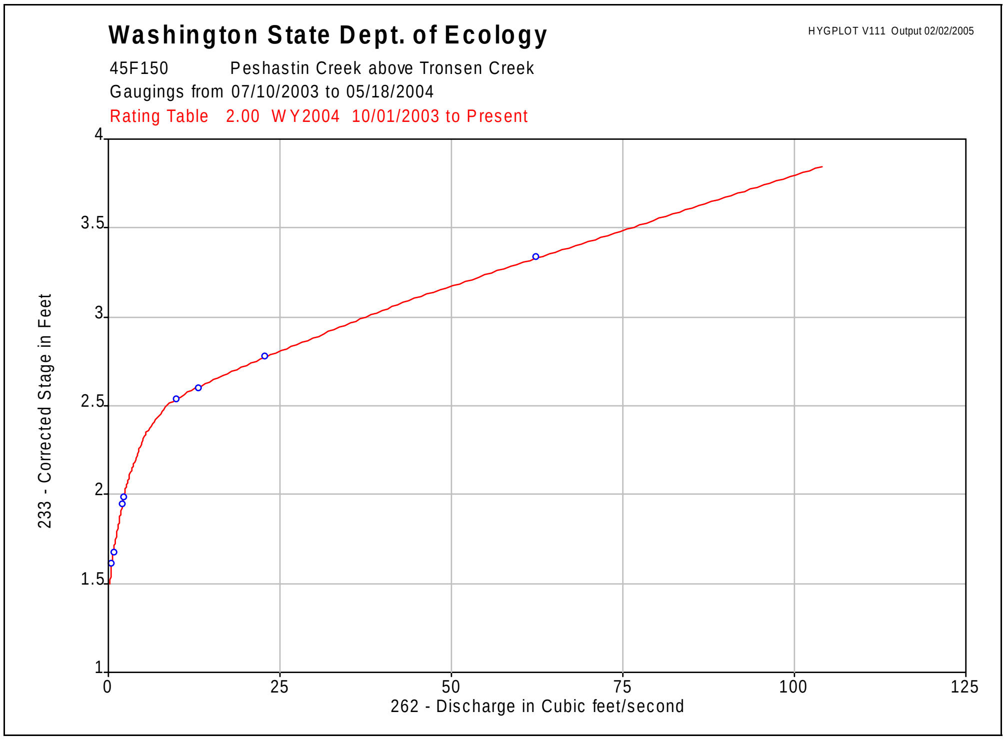

Figure 41: Discharge rating curve for Site 13.

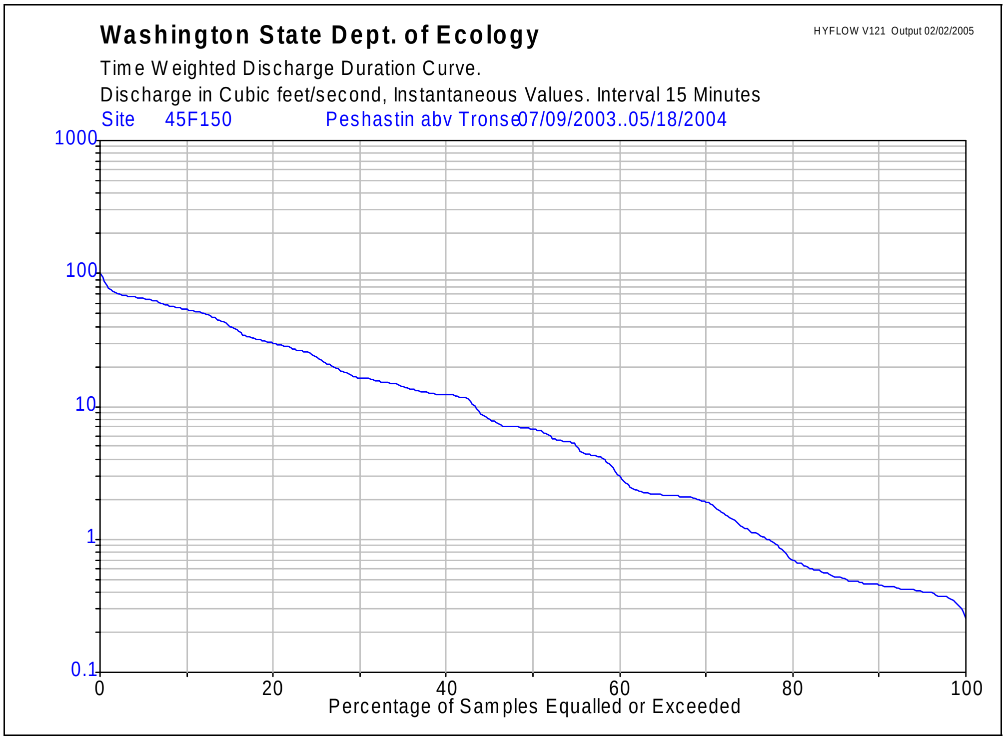

Figure 42: Discharge exceedence graph for Site 13.

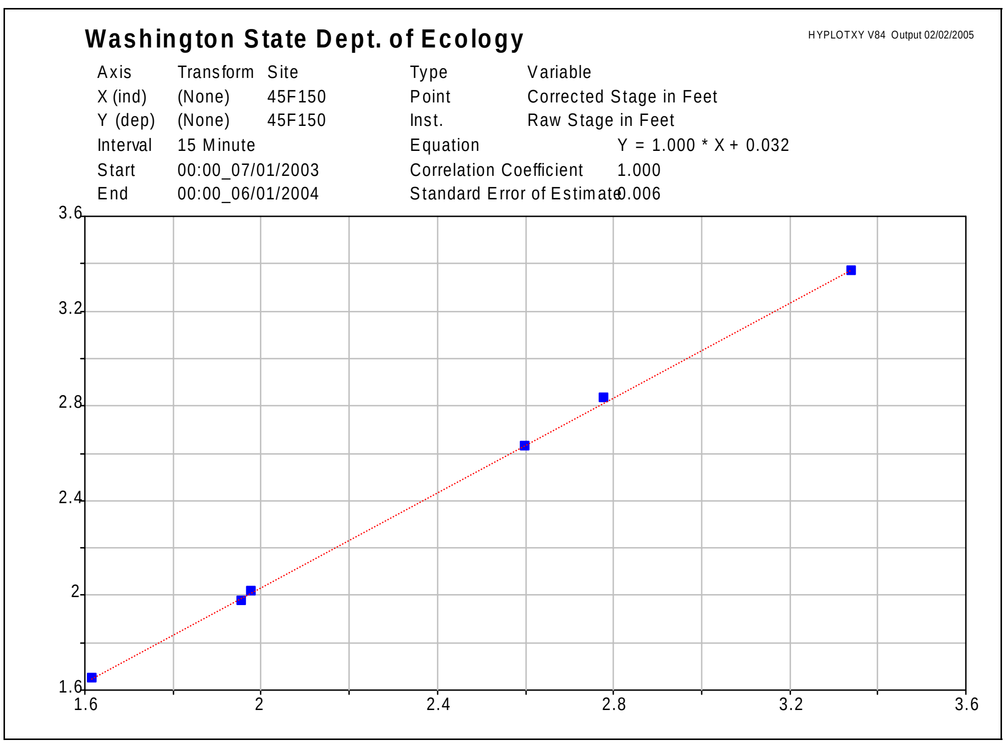

Figure 43: Linear regression of staff gage versus pressure transducer readings for Site 13.

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Appendix A: Average Daily Discharge Tables

Table 1: Icicle Cr. near mouth (Site 1) Daily Data for 2002

Day	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1	[]	3730J	2370J	299	93.8	113	57.8B	90.7	93.3
2	[]	3540J	1870A	263	93.9	100	59.0B	94.3	94.8
3	[]	3620J	1590A	239	90.2	95.6	61.2B	92.9	130
4	[]	3780J	1430A	215	85.5	106	65.1B	89.9	159
5	[]	4080J	1220A	203	74.8	101	69.5B	87.8	159
6	[]	4140J	1130A	203	71.2B	96.8	73.2	84.0	147
7	[]	3260J	1230A	189	79.2B	93.1	71.9	80.5	131
8	[]	2380J	1710A	174	66.9B	91.1	78.7	78.3	121
9	[]	1850A	1530A	164	65.3B	89.2	78.1	77.2	[]
10	[]	1880A	1400A	167	66.3B	82.2	75.8	77.5	[]
11	[]	2400J	1670A	168	65.1B	79.4	73.0	79.3	[]
12	[]	3090J	1800A	158	62.7B	77.2	79.2	79.2	[]
13	[]	4000J	1670A	150	60.7B	76.6	138	106	[]
14	[]	5160J	1660A	146	58.7B	74.7	127	124	[]
15	[]	5940J	1370A	145	56.9B	73.3	105	145	[]
16	[]	5950J	1090	133	55.3B	72.3	91.0	186	[]
17	[]	4600J	1000	126	54.5B	71.4	103	153	[]
18	1320A	3980J	902	114	54.8B	69.8	103	132	[]
19	1370A	3280J	842	106	55.8B	69.1	145	119	[]
20	2040A	2920J	752	99.3	52.3B	69.0B	269	115	[]
21	2330J	3000J	644	97.0	51.6B	69.1	205	109	[]
22	2080A	3390J	600	90.9	51.6B	68.0B	186	105	[]
23	1740A	3630J	585	85.9	52.5B	67.3B	167	99.6	[]
24	1580A	3410J	581	82.1	49.1B	66.5B	145	94.5	[]
25	1630A	3210J	574	84.2	49.1B	66.1B	122	93.9	[]
26	1840A	3540J	576	83.2	47.6B	65.7B	116	90.5	[]
27	2120J	3950J	510	79.3	49.1B	65.7B	105	100	[]
28	3090J	3620J	433	79.7	81.2B	66.1B	96.2	98.2	[]
29	4460J	3950J	401	74.9	80.7	67.7B	94.8	96.4	[]
30	4910J	3350J	378	80.6	90.0	65.8B	94.9	92.9	[]
31	4340J		343	101		57.9B		94.7	[]
Mean	2490J	3620J	1090J	142	65.5B	78.3B	109B	102	129
Median	2060J	3580J	1090J	133	61.7B	72.3B	95.6B	94.5	130
Max.Daily Mean	4910J	5950J	2370J	299	93.9	113	269	186	159
Min.Daily Mean	1320J	1850J	343	74.9	47.6B	57.9B	57.8B	77.2	93.3
Inst.Max	5250J	6450J	2740J	317	110	165	295	224	171
Inst.Min	1270J	1720J	317	69.2	47.1B	53.5B	53.5B	72.9	87.9
Missing Days	17	0	0	0	0	0	0	0	23

------------------ Notes -------------------
All recorded data is continuous and reliable
except where the following tags are used...
A ... Above Rating, reliable extrapolation
B ... Below rating, reliable extrapolation
J ... Estimated Data
[ ] Data Not Recorded

Table 2: Chiwaukum Cr. near mouth (Site 2) Daily Data for 2002

Day	May	Jun	Jul	Aug	Sep	Oct
1	[]	550J	332A	105	36.7	13.9
2	[]	558J	307A	90.9	39.2	13.4
3	[]	574J	280A	83.5	42.7	13.5
4	[]	603J	252A	71.4	25.4	21.8
5	[]	643J	236A	67.9	22.3	14.9
6	[]	608J	236A	68.8	21.0	13.4
7	[]	494J	267A	66.2	19.9	12.9
8	[]	401J	330A	65.1	19.1	12.4B
9	[]	363A	290A	74.5	20.1	12.3B
10	[]	372J	285A	83.7	22.5	12.4B
11	[]	410J	323A	76.9	22.0	12.2B
12	[]	465J	330A	71.6	20.2	12.4B
13	[]	521J	328A	71.4	18.9	12.3B
14	[]	544J	329A	72.3	18.7	12.2B
15	211A	570J	289A	70.2	18.9	12.0B
16	233A	515J	259A	62.2	17.6	12.0B
17	265A	419J	257A	58.8	17.6	11.9B
18	289A	448J	251A	55.8	17.8	11.7B
19	302A	398J	248A	50.4	16.1	11.8B
20	366A	391J	215A	49.6	15.4	11.6B
21	378A	421J	185A	48.3	15.0	11.6B
22	353A	481J	173	43.2	14.6	11.6B
23	339A	508J	161	40.7	14.4	11.6B
24	347A	500J	160	41.4	14.4	11.5B
25	367A	498J	172	39.4	14.7	11.5B
26	408J	538J	171	42.7	14.6	11.7B
27	453J	562J	152	43.0	14.6	12.1B
28	544J	501J	136	43.2	14.2	11.9B
29	616J	482J	141	42.3	14.0	11.4B
30	636J	381J	132	42.5	15.2	25.4B
31	585J		115	38.1		27.7
Mean	394J	491J	237A	60.7	19.9	13.5B
Median	366J	499J	251A	62.2	18.2	12.2B
Max.Daily Mean	636J	643J	332A	105	42.7	27.7
Min.Daily Mean	211J	363J	115	38.1	14.0	11.4B
Inst.Max	684J	684J	363A	119	49.5	43.2
Inst.Min	198J	341J	106	35.7	13.2	9.66B
Missing Days	14	0	0	0	0	0

------------------ Notes -------------------
All recorded data is continuous and reliable
except where the following tags are used...
A ... Above Rating, reliable extrapolation
B ... Below rating, reliable extrapolation
J ... Estimated Data
[ ] Data Not Recorded

Table 3: Nason Cr. near mouth (Site 3) Daily Data for 2002

Day	May	Jun	Jul	Aug	Sep	Oct
1	[]	1620A	902	168	51.7B	54.6
2	[]	1630A	785	159	52.1B	44.0
3	[]	1680A	737	151	56.2B	39.6
4	[]	1700A	679	144	54.0B	46.5
5	[]	1790A	626	141	51.0B	44.5
6	[]	1790A	615	142	49.9B	40.8
7	[]	1350A	669	134	49.6B	38.3
8	[]	1080	805	126	47.9B	34.7
9	[]	938	651	119	46.8B	34.1
10	[]	1060A	673	116	44.9B	35.4
11	[]	1300A	738	114	42.3B	34.9
12	[]	1570A	699	109	40.2B	34.8
13	[]	1860A	657	104	38.1B	34.6
14	[]	2100A	629	98.5	37.0B	34.1
15	[]	2180A	538	98.2	35.8B	34.0
16	747	1960A	487	96.9	35.2B	33.8
17	880	1580A	461	90.8	36.7B	33.8L
18	961	1620A	427	86.0	[]	33.4
19	986	1350A	403	81.9	33.2B	33.2
20	1400A	1280A	369	78.3	32.7U	32.9L
21	1380A	1360A	343	77.4	32.9B	33.0
22	1210A	1500A	321	71.8	32.2U	33.0
23	1080	1500A	303	68.2	32.0U	33.0
24	1050	1350A	289	69.0	31.5U	32.7
25	1090	1320A	273	68.1	31.5U	32.6
26	1190	1460A	258	67.4	31.8U	32.5
27	1330A	1470A	234	66.4	34.5	32.4
28	1780A	1290A	212	62.5B	34.3	32.4
29	2010A	1460A	213	59.9B	33.5	32.7
30	2010A	1050	196	55.1B	45.4	33.8
31	1830A		180	53.7B		33.9
Mean	1310A	1510A	496	99.3B	40.5U	35.9L
Median	1200A	1490A	487	96.9B	37.0U	33.9L
Max.Daily Mean	2010A	2180A	902	168	56.2	54.6
Min.Daily Mean	747	938	180	53.7B	31.5U	32.4
Inst.Max	2190A	2390A	951	173	62.9	62.9
Inst.Min	696	880	171	43.7B	31.5U	31.7
Missing Days	15	0	0	0	1	0

------------------ Notes -------------------
All recorded data is continuous and reliable
except where the following tags are used...
A ... Above Rating, reliable extrapolation
B ... Below rating, reliable extrapolation
L ... Linear interpolation across gap in data
U ... Unknown flow, less than value shown
[ ] Data Not Recorded

Table 4: Wenatchee R. blw Lake Wenatchee (Site 4) Daily Data for 2002

Day	May	Jun	Jul	Aug	Sep	Oct
1	[]	6590A	5470	1810	459B	278B
2	[]	6270	4690	1540	457B	272B
3	[]	6310	4210	1290	474B	277B
4	[]	6410	3940	1030	463B	291B
5	[]	6530A	3640	856	428B	279B
6	[]	6830A	3420	812	400B	269B
7	[]	6170A	3570	771	387B	261B
8	[]	5280	4310	741	358*	257B
9	[]	4550	4380	741	332*	254B
10	[]	4430	4260	788	323*	246B
11	[]	4980	4610	819	320*	237B
12	[]	5750	4870	796	319*	229B
13	[]	6700A	4740	793	321*	226B
14	3110	8110A	4710	794	324*	222B
15	3220	9010A	4420	788	329*	219B
16	3240	9330A	4000	748	323L	215B
17	3470	8190A	3740	712	328*	213B
18	3850	7060A	3520L	653	323*	212B
19	3990	6200L	3350	610	315*	210B
20	4580	5730	3120	556	316	207B
21	5120	5710	2840	516B	307B	202B
22	4980	6090	2680	496B	301B	200B
23	4620	6410	2620	493B	296B	197B
24	4390	6280	2640	503B	291B	195B
25	4320	6080	2650	510B	287B	192B
26	4460	6290A	2670	507B	280B	189B
27	4780	6820A	2460	490B	275B	189B
28	5590	6580A	2110	498B	272B	184B
29	6780A	6800A	1940	496B	277B	177B
30	7560A	6510A	1840	490B	283B	173B
31	7260A		1840	471B		163B
Mean	4740A	6470L	3520L	746B	339L	224B
Median	4520A	6360L	3570L	741B	322L	215B
Max.Daily Mean	7560A	9330	5470	1810	474	291B
Min.Daily Mean	3110	4430	1840	471B	272	163B
Inst.Max	7680A	9580	5990	1920	509	298B
Inst.Min	2960	4300	1790	456B	264	151B
Missing Days	13	0	0	0	0	0

------------------ Notes -------------------
All recorded data is continuous and reliable
except where the following tags are used...
* ... Data estimated based on other stations
A ... Above Rating, reliable extrapolation
B ... Below rating, reliable extrapolation
L ... Linear interpolation across gap in data

[ ] Data Not Recorded

Table 5: Mission Cr. at Binder Road (Site 10) Daily Data for 2003

Day	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
1	[]	0.01J	0.44	0.01B	2.66	8.05	[ ]I	31.8	14.6	27.2*	30.9*
2	[]	0.02J	0.16B	0.03B	2.85	7.59	[ ]I	25.8	15.1	17.2*	31.7*
3	[]	0.04J	0.10B	0.09B	2.90	7.16	[ ]I	23.1	16.4	17.1*	31.9*
4	[]	0.04J	0.07	0.07B	2.86	6.57	[ ]I	21.4	16.6	17.7*	27.7*
5	[]	0.02J	0.03B	0.03B	[ ]I	6.79	[ ]I	20.0	17.4	17.2*	[]
6	[]	0.02J	0.06	0.02B	[ ]I	7.01	[ ]I	19.2	17.3	19.9*	24.2*
7	[]	0.01J	0.04B	0.02B	[ ]I	6.66	[ ]I	18.0	22.0A	20.3*	[]
8	[]	0.08J	0.11	0.04B	3.53	6.10	[ ]I	17.3	57.6A	19.8*	22.5*
9	[]	0.11J	0.03B	0.05B	3.17	6.24	[ ]I	16.5	76.1A	20.8*	21.3*
10	1.95	0.24J	0B	0.07B	3.17	6.28	8.95	15.9	73.4A	18.7*	20.8*
11	1.85	0.12J	0.07B	0.11	11.1	5.44	8.96	15.3	58.1A	18.8*	19.5*
12	1.61	0J	0.43	0.21	6.97	[ ]I	9.11	15.0	52.8A	20.9*	19.5*
13	1.47	0.02B	0.71	0.50	5.59	[ ]I	9.04	14.4	51.6A	21.9*	17.9*
14	1.66	0B	0.61	0.44	5.03	[ ]I	9.16	11.2	43.9	21.2*	17.9*
15	1.35	0.01B	0.81	0.66	4.95	[ ]I	10.1	10.7	36.0	18.5*	17.7*
16	1.14	0.01B	0.97	3.46	5.22	[ ]I	11.5	10.3	35.4A	16.5*	19.7*
17	1.21	0.01L	0.79	3.38	7.05	[ ]I	10.9	9.84	51.3A	15.6*	[]
18	1.05	0.02B	0.49	1.97	19.3	[ ]I	11.0	9.73	54.0A	14.9*	[]
19	0.70	0.01B	0.68	1.60	17.9	[ ]I	11.2	9.63	48.7A	13.9*	[]
20	0.30J	0.05L	0.55	2.20	11.6	[ ]I	11.0	9.34	33.4	14.5*	[]
21	0.37J	0.02L	0.20	5.18	8.91	[ ]I	11.2	9.01	27.9	14.1*	[]
22	0.18J	0B	0.07B	3.09	[ ]I	6.44	11.3	8.89	29.1	11.1*	[]
23	0.06J	0.10L	0.04B	2.52	[ ]I	6.82	11.3	8.89	44.5	10.7*	[]
24	0.05J	0.17	0.10B	2.45	[ ]I	7.60	11.1	9.31	48.8	13.3*	[]
25	0.01J	0.52L	0.43	2.46	6.22	7.37	[ ]I	10.1	43.1*	12.1*	[]
26	0.04J	0.90	0.19B	2.49	5.75	[ ]I	[ ]I	11.2	33.2*	11.4*	[]
27	0.03J	0.99	0.23B	2.48	5.42	[ ]I	[ ]I	11.8	31.4*	15.5*	[]
28	0.04J	1.36	0.30	2.38	5.75	[ ]I	11.7	12.6	27.5*	24.3*	[]
29	0.01J	1.28	0.80	2.34	8.82	[ ]I	19.7A	14.2	27.5*	25.2*	[]
30	0.04J	1.41	0.45	2.61	8.59	[ ]I	53.1A		29.9*	24.4*	[]
31	0.02J	0.61		2.58		[ ]I	44.5A		39.6*		[]
Mean	0.69J	0.26L	0.33B	1.47B	6.89	6.81	15.0A	14.5	37.9*	17.8*	23.1*
Median	0.34J	0.04L	0.22B	1.60B	5.67	6.79	11.1A	12.6	35.4*	17.4*	21.0*
Max.Daily Mean	1.95J	1.41	0.97	5.18	19.3	8.05	53.1A	31.8	76.1A	27.2*	31.9*
Min.Daily Mean	0.01J	0	0B	0.01B	2.66	5.44	8.95	8.89	14.6	10.7*	17.7*
Inst.Max	2.45J	2.09	1.71	8.84	37.8	8.09	58.0A	38.4	93.6A	42.3*	40.1*
Inst.Min	0J	0	0B	0B	2.55	5.09	8.09	8.59	14.0	9.57*	16.3*
Missing Days	9	0	0	0	6	16	12	0	0	0	17

------------------ Notes -------------------
All recorded data is continuous and reliable
except where the following tags are used...

- * ... Data estimated based on other stations
- A ... Above Rating, reliable extrapolation
- B ... Below rating, reliable extrapolation
- I ... Ice-impacted data
- J ... Estimated Data
- L ... Linear interpolation across gap in record
- [ ] Data Not Recorded

Table 6: Brender Cr. abv Noname Cr. (Site 11) Daily Data for 2003

Day	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
1	[]	1.43B	2.21	1.48J	1.57J	1.50J	1.45J	1.44J	1.42B	1.81	4.76
2	[]	1.40B	1.70	1.45J	1.56J	1.50J	1.45J	1.44J	1.43B	1.83	5.18A
3	[]	1.49B	1.46B	1.45J	1.54J	1.50J	1.45J	1.44J	1.43B	1.87	4.65
4	[]	1.60	1.49	1.44J	1.54J	1.50J	1.44J	1.43J	1.42B	1.86	4.48
5	[]	1.45B	1.49	1.44J	1.54J	1.51J	1.44J	1.43J	1.44B	1.80	4.93
6	[]	1.74	1.59	1.44J	1.55J	1.51J	1.45J	1.44	1.43B	1.79	4.44
7	[]	1.45B	1.56	1.43J	1.55J	1.51J	1.45J	1.44	1.44B	1.77	4.89
8	[]	1.48	1.84	1.44J	1.52J	1.51J	1.45J	1.43	1.46B	1.76	4.83
9	[]	1.49	3.14	1.44J	1.51J	1.51J	1.45J	1.44	1.45B	1.75	4.46
10	2.24	1.55	7.47	1.44J	1.51J	1.52J	1.45J	1.43	1.51	1.76	4.47
11	2.35	1.46B	8.12A	1.45J	1.56J	1.51J	1.45J	1.43	1.57	1.77	4.28
12	1.96	1.43B	8.08A	1.45J	1.55J	1.51J	1.45J	1.43	1.53	1.71	4.46
13	1.88	1.45B	10.5A	1.44J	1.55J	1.51J	1.45J	1.43	1.54	1.98	4.42
14	1.83	1.51	10.3A	1.44J	1.54J	1.50J	1.45J	1.43	1.54	3.13	4.94
15	1.99	1.50	10.4A	1.45J	1.54J	1.49J	1.46J	1.43B	1.57	3.07	5.25
16	1.55	1.50	8.36J	1.47J	1.58J	1.49J	1.45J	1.43B	1.63	3.39	5.53
17	1.55	1.74	10.8J	1.47J	1.58J	1.49J	1.45J	1.43B	1.64	3.60	[]
18	1.87	1.76	11.5J	1.47J	1.63J	1.49J	1.45J	1.44	1.63	3.57	[]
19	1.75	1.48B	11.8J	1.47J	1.57J	1.50J	1.44J	1.42B	1.57	3.96	[]
20	1.67	1.43B	11.1J	1.49J	1.56J	1.49J	1.44J	1.42B	1.62	4.09	[]
21	1.67	1.48B	11.1J	1.49J	1.53J	1.48J	1.44J	1.42B	1.74	3.83	[]
22	1.49B	1.49	9.22J	1.49J	1.53J	1.48J	1.44J	1.42B	1.82	3.80	[]
23	1.50B	1.61	7.59J	1.49J	1.52J	1.48J	1.45J	1.41B	1.59	3.78	[]
24	1.46	2.02	5.87J	1.51J	1.52J	1.48J	1.43J	1.41B	1.55	3.87	[]
25	1.49	2.22	5.52J	1.51J	1.52J	1.47J	1.43J	1.42B	1.67	3.71	[]
26	1.49	1.97	6.29J	1.52J	1.51J	1.46J	1.43J	1.43B	2.03	3.53	[]
27	1.62	2.21	7.42J	1.51J	1.51J	1.46J	1.42J	1.42B	1.90	3.60	[]
28	1.59	2.61	8.34J	1.53J	1.54J	1.46J	1.43J	1.42B	1.88	3.84	[]
29	1.50	2.98	7.21J	1.56J	1.52J	1.46J	1.43J	1.41B	1.95	4.93	[]
30	1.46B	2.55	5.11J	1.54J	1.51J	1.45J	1.44J		1.87	5.19	[]
31	1.42B	2.25		1.55J		1.45J	1.44J		1.85		[]
Mean	1.70B	1.73B	6.62J	1.48J	1.54J	1.49J	1.44J	1.43J	1.62B	2.94	4.75A
Median	1.60B	1.50B	7.44J	1.47J	1.54J	1.49J	1.45J	1.43J	1.57B	3.26	4.71A
Max.Daily Mean	2.35	2.98	11.8J	1.56J	1.63J	1.52J	1.46J	1.44J	2.03	5.19	5.53A
Min.Daily Mean	1.42B	1.40B	1.46B	1.43J	1.51J	1.45J	1.42J	1.41B	1.42B	1.71	4.28
Inst.Max	3.58	3.48	12.8J	1.61J	1.71J	1.53J	1.51J	1.48J	2.62	6.00	7.34A
Inst.Min	1.37B	1.38B	1.41B	1.42J	1.49J	1.44J	1.42J	1.39B	1.37B	1.60	3.57
Missing Days	9	0	0	0	0	0	0	0	0	0	15

------------------ Notes ------------------
All recorded data is continuous and reliable
except where the following tags are used...
A ... Above Rating, reliable extrapolation
B ... Below rating, reliable extrapolation
J ... Estimated Data
[   ] Data Not Recorded

Table 7: Brender Cr. blw Brender Canyon (Site 12) Daily Data for 2003

Day	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
1	[]	0.74	1.43	0.49	0.03U	0.02U	[ ]I	0.17	0.56	1.07	1.87
2	[]	0.72	0.49U	0.41	0.02U	0.02U	[ ]I	0.17	0.62	1.05	2.46
3	[]	1.21	0.33U	0.39	0.02U	0.02U	[ ]I	0.16	0.67	1.04	1.68
4	[]	1.21B	0.40U	0.32	0.02U	0.02U	[ ]I	0.15	0.69	1.04	1.73
5	[]	1.29B	0.41U	0.28	[ ]I	0.02U	[ ]I	[ ]I	0.73	1.01	2.05
6	[]	2.14	0.38U	0.26	[ ]I	0.02U	[ ]I	0.16	0.74	0.98	1.85
7	[]	0.87	0.45U	0.24	[ ]I	0.02U	[ ]I	0.16	0.78	0.94	2.28
8	[]	1.02	1.07	0.22	[ ]I	0.02U	[ ]I	0.16	0.83	0.91	2.38
9	[]	1.38	2.52	0.21	0.02U	0.02U	[ ]I	0.16	0.86	0.89	2.69
10	1.68	1.31	5.75A	0.27*	0.02U	0.02U	[ ]I	0.16	1.14	0.86	2.64
11	2.08	0.82	7.65A	0.26*	0.04U	0.02U	0.02U	0.15	1.12	0.86	1.87
12	1.96	0.59B	8.45A	0.23*	0.02U	0.02U	0.02U	0.20	1.17	0.86	2.09
13	2.19	0.53B	10.3A	0.20*	0.02U	0.02U	0.02U	0.21	1.18	1.35	2.24
14	1.51	0.50B	8.83A	0.17*	0.02U	0.02U	0.02U	0.14	1.20	2.63	3.20
15	1.99	0.61	7.98A	0.15*	0.02U	0.02U	0.02U	0.14	1.21	2.45	3.59
16	0.95	0.67	6.83A	0.20*	0.04U	0.02U	0.02U	0.16	1.25	2.18	4.26
17	0.92	1.35	8.63A	0.16*	0.06U	0.02U	0.02U	0.16	1.35	2.13	[]
18	1.12	1.05B	9.22A	0.13*	0.30	0.02U	0.02U	0.18	1.55	2.15	[]
19	0.99	0.47B	8.87A	0.10*	0.10	0.02U	0.02U	0.18	1.30	2.43	[]
20	1.27	0.40B	7.38A	0.15*	0.03U	0.02U	0.02U	0.19	1.18	2.71	[]
21	1.15	0.57B	7.69A	0.11*	0.02U	0.02U	0.02U	0.21	1.21	2.35	[]
22	0.80	0.68	6.74A	0.09*	[ ]I	0.02U	0.03U	0.20	1.27	2.24	[]
23	0.86	0.82B	6.06	0.07*	[ ]I	0.02U	0.05	0.22	1.40	2.09	[]
24	0.92	1.41	5.37	0.08*	[ ]I	0.02U	0.06	0.29	1.36	2.42	[]
25	1.18	1.57	4.77	0.06*	0.02U	0.02U	0.05	0.36	1.36	2.10	[]
26	1.03	1.26	4.54	0.06U	0.02U	[ ]I	0.05	0.45	1.59	1.86	[]
27	1.27	1.85	4.95	0.02U	0.02U	[ ]I	0.04	0.48	1.30	2.53	[]
28	1.20	2.36	4.96	0.03U	0.04U	[ ]I	0.05	0.50	1.19	3.29	[]
29	0.83	2.38	4.31	0.04U	0.02U	[ ]I	0.06	0.50	1.18	2.62	[]
30	0.84	1.80	1.99U	0.04U	0.02U	[ ]I	0.16		1.15	1.81	[]
31	0.85	1.63		0.04U		[ ]I	0.19		1.11		[]
Mean	1.25	1.14B	4.96U	0.18U	0.04U	0.02U	0.05U	0.23	1.10	1.76	2.43
Median	1.14	1.05B	5.17U	0.16U	0.02U	0.02U	0.02U	0.18	1.18	1.98	2.26
Max.Daily Mean	2.19	2.38	10.3	0.49	0.30	0.02U	0.19	0.50	1.59	3.29	4.26
Min.Daily Mean	0.80	0.40B	0.33U	0.02U	0.02U	0.02U	0.02U	0.14	0.56	0.86	1.68
Inst.Max	5.77	6.82	11.7	0.64	0.36	0.11U	0.24	0.53	1.81	4.29	5.29
Inst.Min	0.66	0.37B	0.30U	0.02U	0.02U	0.02U	0.02U	0.07	0.51	0.81	1.04
Missing Days	9	0	0	0	7	6	10	1	0	0	15

------------------ Notes -------------------
All recorded data is continuous and reliable
except where the following tags are used...
* ... Data estimated based on other stations
A ... Above Rating, reliable extrapolation
B ... Below rating, reliable extrapolation
I ... Ice-impacted data
U ... Unknown flow, less than value shown
[ ] Data Not Recorded

Table 8: Peshastin Cr. abv Tronsen Cr. (Site 13) Daily Data for 2003

Day	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
1	[]	1.01	0.37B	0.42B	2.14	32.9	[ ]I	42.3	13.0	48.9	28.9
2	[]	0.97	0.36B	0.42B	2.17	27.0	[ ]I	35.4	13.5	43.9	31.5
3	[]	1.01	0.34B	0.43B	2.16	22.6	[ ]I	30.4	14.9	43.0	32.0
4	[]	1.04	0.34B	0.43B	2.15	19.3	[ ]I	26.4	15.9	46.5	30.0
5	[]	1.02	0.33B	0.43B	2.27	17.1	[ ]I	22.9	16.6	52.5	27.0
6	[]	1.12	0.35B	0.43B	2.16	15.9	[ ]I	20.7	16.2	56.9	23.7
7	[]	0.99	0.37B	0.47B	2.14	13.8	[ ]I	18.8	18.2	63.6A	21.4
8	[]	0.93	0.42B	0.61	2.09	11.8	[ ]I	17.0	40.7A	66.7A	20.1
9	2.06	0.84	0.53B	0.70	2.08	10.5	[ ]I	15.6	84.4A	60.4A	18.9
10	1.95	0.75	0.57	0.68	2.39	9.78	4.36	14.8	93.0A	55.9	17.9
11	2.02	0.69	0.61	0.78	8.72	8.52	4.32	14.7	79.1A	56.0	16.3
12	2.09	0.68	0.57B	1.35	5.40	8.23	4.27	15.4	73.4A	59.6A	15.3
13	2.09	0.62	0.48B	1.36	4.40	7.90	4.18	18.0	72.5A	65.3A	14.0
14	2.08	0.56B	0.45B	1.17	3.96	7.28	4.34	16.1	67.6A	61.7A	12.7
15	2.07	0.52B	0.44B	1.30	3.73	6.72	5.18	15.4	67.2A	52.2	12.7
16	2.03	0.52B	0.47B	3.15	3.98	6.46	6.30	14.7	65.1A	44.0	12.8
17	1.97	0.54B	0.52B	3.31	6.68	6.03	6.71	13.5	68.4A	38.5	13.0
18	1.98	0.52B	0.51B	2.62	63.8A	5.72	6.98	13.0	71.2A	34.4	[]
19	1.87	0.51B	0.49B	2.12	63.7A	[ ]I	7.08	12.1	65.7A	31.2	[]
20	1.78	0.48B	0.51B	2.96	40.4	5.53	7.08	11.8	56.5	30.3	[]
21	1.79	0.46B	0.51B	6.69	28.9	5.36	7.08	12.1	49.2	28.7	[]
22	1.75	0.49B	0.50B	4.10	21.7	5.29	7.08	12.1	50.0	26.7	[]
23	1.69	0.50B	0.47B	3.21	17.2	5.46	7.18	12.1	63.7A	26.5	[]
24	1.69	0.45B	0.46B	2.81	13.8	5.56	7.14	12.2	67.7A	26.1	[]
25	1.67	0.43B	0.42B	2.52	11.3	5.40	6.90	12.3	63.4A	25.5	[]
26	1.56	0.44B	0.41B	2.35	8.94	[ ]I	6.77	12.5	57.5	26.8	[]
27	1.44	0.46B	0.39B	2.25	7.78	[ ]I	6.67	12.1	54.0	31.8	[]
28	1.32	0.46B	0.40B	2.18	11.0	[ ]I	7.25	11.8	50.8	33.7	[]
29	1.11	0.42B	0.40B	2.22	35.9	[ ]I	18.2	12.3	50.1	30.9	[]
30	1.08	0.38B	0.40B	2.21	38.5	[ ]I	60.6A		52.7	28.7	[]
31	1.06	0.37B		2.14		[ ]I	54.1		53.6		[]
Mean	1.75	0.65B	0.45B	1.87B	14.0A	11.3	11.4A	17.2	52.4A	43.2A	20.5
Median	1.79	0.52B	0.45B	2.12B	6.04A	8.07	6.94A	14.7	56.5A	43.5A	18.9
Max.Daily Mean	2.09	1.12	0.61	6.69	63.8A	32.9	60.6A	42.3	93.0A	66.7A	32.0
Min.Daily Mean	1.06	0.37B	0.33B	0.42B	2.08	5.29	4.18	11.8	13.0	25.5	12.7
Inst.Max	3.45	1.26	0.67	9.36	90.1A	36.5	66.5A	48.1	101A	68.7A	33.0
Inst.Min	0.87	0.30B	0.26B	0.38B	1.84	5.29	4.18	11.3	12.4	24.4	11.7
Missing Days	8	0	0	0	0	7	9	0	0	0	14

------------------ Notes -------------------
All recorded data is continuous and reliable
except where the following tags are used...
A ... Above Rating, reliable extrapolation
B ... Below rating, reliable extrapolation
I ... Ice-impacted data
[   ] Data Not Recorded

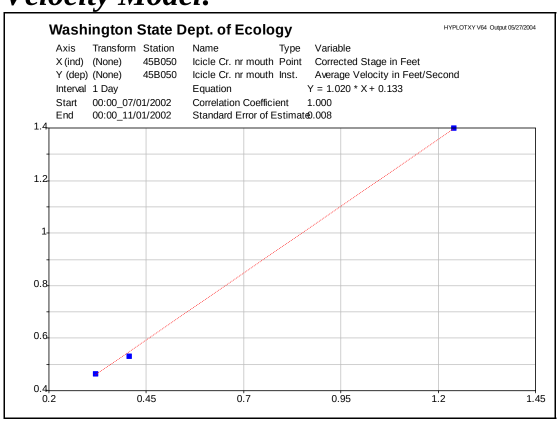
Appendix B: Discharge Models

Site 1: Icicle Creek near mouth (45B050)

This flow model was developed to estimate high flows in Icicle Creek during the spring snowmelt in 2002. The highest measured flow during this period occurred as a stage height of 2.79 ft. During peak snowmelt, the stage height reached 7.30 ft. This model uses the relationships established from known (measured) flows between river stage, velocity and cross-sectional area. The model was applied to stages at which discharge was physically measured to assess interpolative accuracy, and was then used to extrapolate high flows encountered at the site but not physically measured. The model assumes a consistent bank slope up to the highest stage used. This is a reasonable assumption for this site.

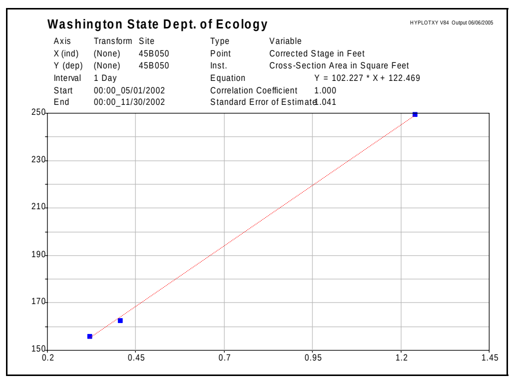
The interpolative accuracy of the model was very good (0.2-6.5% error). Given the potential for error inherent in extrapolative modeling, the accuracy of the model is estimated to be within 15 percent.

Velocity Model:



(velocity) = 1.02 * (stage) + 0.133

Cross-Sectional Area Model



(x-area) = 102.227 * (stage) + 122.469

Discharge Model:

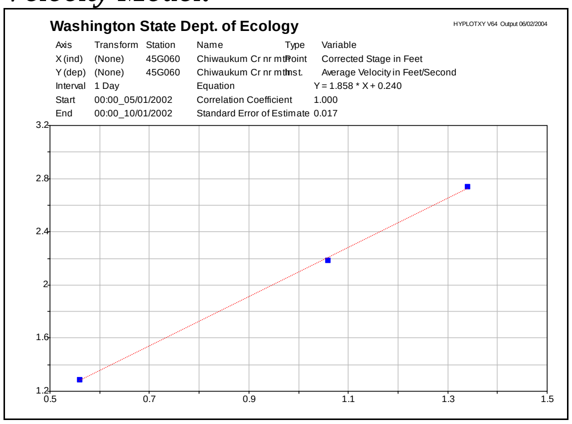
Stage (ft)	*Mod. Vel. (ft/sec)*	*Meas. Vel. (ft/sec)*	*Mod. Area (ft^2)*	*Meas. Area (ft^2)*	*Mod. Flow (cfs)*	*Meas Flow (cfs)*	*% Diff.*
0.32	0.46	0.46	155	156	71	72.5	1.7
0.40	0.55	0.54	164	163	89	88.2	-1.5
1.24	1.40	1.40	249	249	348	349	0.2
2.79	2.98	2.88	408	429	1210	1140	-6.5
4.13	4.35		545		2370		
7.30	7.58		869		6580		

Site 2: Chiwaukum Creek near mouth (45G060)

This flow model was developed to estimate high flows in Chiwaukum Creek during the spring snowmelt in 2002. The highest measured flow during this period occurred at a stage height of 1.34 ft. During peak snowmelt, the stage height reached 2.65 ft. This model uses the relationships established from known (measured) flows between river stage, velocity and cross-sectional area. The model assumes that the transect slope at the banks of the creek remains constant as stage rises from 1.34 ft to 2.65 ft. Given the channel geometry at the site, this is a fairly reasonable assumption. The model may underestimate cross-sectional area if the bank slope decreases with increasing stage height. However, it may overestimate average velocity as the near-bank flow reaches riparian vegetation.

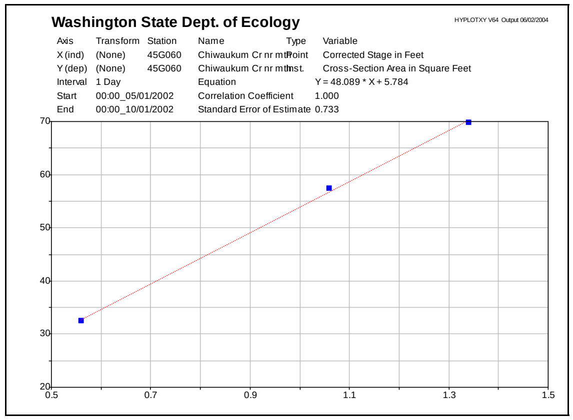
The interpolative accuracy of the model was very good (0.2% - 0.5% error). Given the potential for error inherent in extrapolative modeling, coupled with the error inherent in the assumptions of the model, the extrapolative accuracy of the model is estimated to be within 20 percent.

Velocity Model:



(velocity) = 1.858 * (stage) + 0.24

Cross-Sectional Area Model:



(x-area) = 48.089 * (stage) + 5.784

Discharge Model:

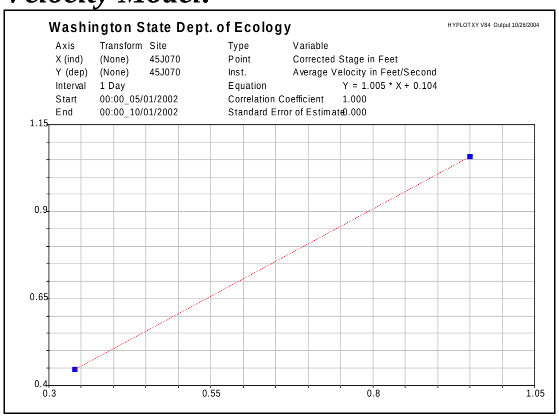
Stage (ft)	*Mod. Vel. (ft/sec)*	*Meas. Vel. (ft/sec)*	*Mod. Area (ft^2)*	*Meas. Area (ft^2)*	*Mod. Flow (cfs)*	*Meas Flow (cfs)*	*% Diff.*
0.56	1.28	1.28	32.7	32.5	41.9	41.8	-0.2
1.06	2.21	2.20	56.8	57.4	125	126	0.5
1.34	2.73	2.74	70.2	69.8	192	191	-0.4
2.00	3.96		102		403		
2.65	5.16		133		688		

Site 3: Nason Creek near mouth (45J070)

This flow model was developed to estimate high flows in Nason Creek during the spring snowmelt in 2002. The highest measured flow during this period occurred at a stage height of 3.14 ft. During peak snowmelt the stage height reached nearly 4.7 ft. The model uses the relationships established from known (measured) flows between river stage and velocity, as well as a surveyed high flow cross section. The model was applied to stages at which discharge was physically measured to assess interpolative accuracy, and was then used to extrapolate high flows encountered at the site but not physically measured. The model assumes a consistent relationship between stage and velocity up to the highest stage used. Given the low gradient and generally low velocities at this site, this is a fairly reasonable assumption.

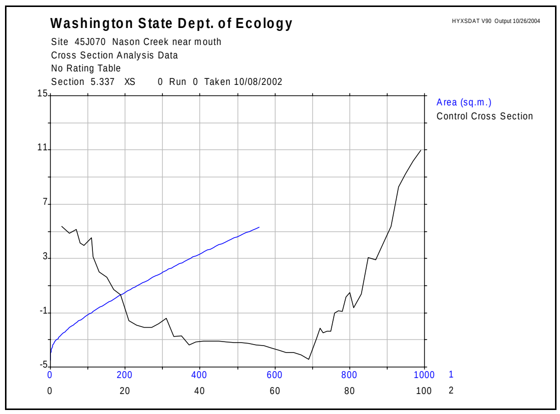
The interpolative accuracy of the model was fairly poor (20-25% error) at lower stages, but fairly good (6-8% error) at higher stages. Since this model is used to extrapolate high flows, its accuracy is estimated to be within 10 percent.

Velocity Model:



(velocity) = 1.005 * (stage) + 0.104

Cross-Sectional Area Model:



Discharge Model:

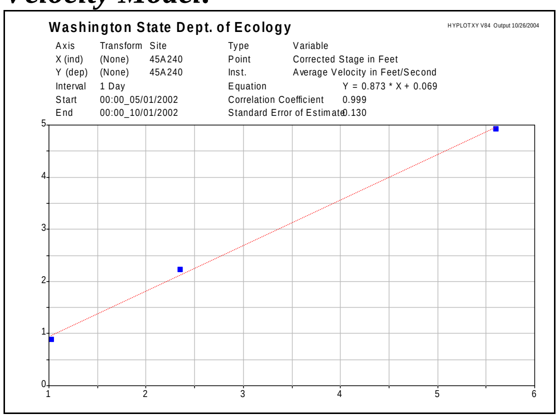
Stage (ft)	Mod. Vel. (ft/sec)	Meas. Vel. (ft/sec)	Mod. Area (ft^2)	Meas. Area (ft^2)	Mod. Flow (cfs)	Meas Flow (cfs)	% Diff.
0.34	0.44	0.45	189	140	83	63	24%
0.95	1.06	1.06	229	192	243	191	21%
2.30	2.42	2.37	323	330	782	714	8%
3.14	3.26	3.29	384	398	1250	1170	6%
3.20	3.32		389		1290		
3.90	4.02		443		1780		
4.70	4.83		507		2450		

Site 4: Wenatchee River below Lake Wenatchee (45A240)

This flow model was developed to estimate high flows in the Wenatchee River during the spring snowmelt in 2002. The highest measured flow during this period occurred at a stage height of 5.60 ft. During peak snowmelt the stage height reached 7.70 ft. The model uses the relationships established from known (measured) flows between river stage, velocity and cross-sectional area. The model was applied to stages at which discharge was physically measured to assess interpolative accuracy, and was then used to extrapolate high flows encountered at the site, but not physically measured. The model assumes a consistent relationship between stage and velocity up to the highest stage used. It also assumes a constant bank pitch above the highest measured flow. For this site, both of these assumptions should produce reasonable extrapolative estimates of flows that are within the confined channel.

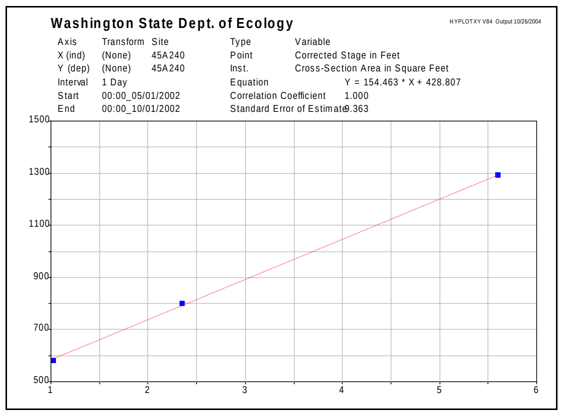
The interpolative accuracy of the model was fairly good (0.8% - 8% error). Given the potential for error inherent in extrapolative modeling, coupled with the error inherent in the assumptions of the model, the extrapolative accuracy of the model is estimated to be within 20 percent.

Velocity Model:



(velocity) = 0.873 * (stage) + 0.069

Cross-Sectional Area Model:



(x-area) = 154.463 * (stage) + 428.807

Discharge Model:

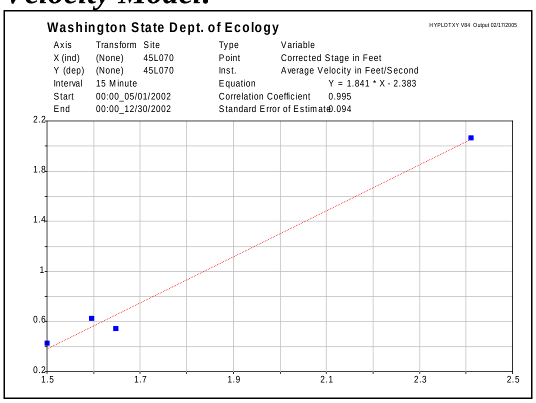
Stage (ft)	*Mod. Vel. (ft/sec)*	*Meas. Vel. (ft/sec)*	*Mod. Area (ft^2)*	*Meas. Area (ft^2)*	*Mod. Flow (cfs)*	*Meas. Flow (cfs)*	*% Diff.*
1.02	0.96	0.89	586	581	563	515	8%
2.36	2.13	2.23	793	801	1690	1790	6%
5.60	4.96	4.93	1294	1292	6420	6370	0.8%
7.00	6.18		1510		9330		
7.70	6.79		1618		11000		

Site 9: Little Wenatchee River near mouth (45L070)

This flow model was developed to estimate high flows on the Little Wenatchee River during the spring snowmelt in 2002. The highest measured flow during this period occurred at a stage height of 2.41 ft. During peak snowmelt, the highest stage recorded was 6.04 ft. This flow model uses the relationships established from known (measured) flows between river stage and velocity, as well as a surveyed high flow cross section. The model was applied to stages at which discharge was physically measured to assess interpolative accuracy, and was then used to extrapolate high flows encountered at the site but not physically measured. The model may tend to overestimate average velocity as the edge flow reaches riparian vegetation.

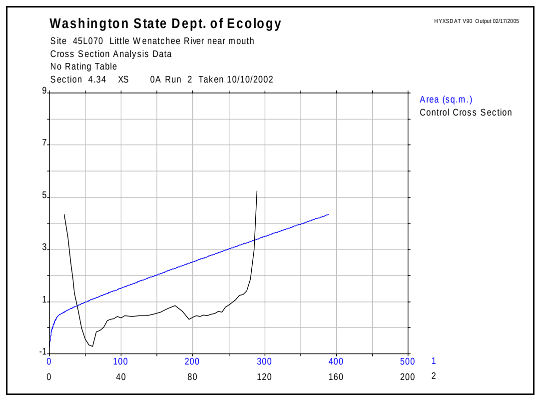
The interpolative accuracy of the model was rather poor (0-30%) due to the difficulty in measuring flows at the same cross-section at different stages. The extrapolative accuracy of the model is estimated at 30 percent.

Velocity Model:



(velocity) = 1.841 * (stage) – 2.383

Cross-Sectional Area Model:



Discharge Model:

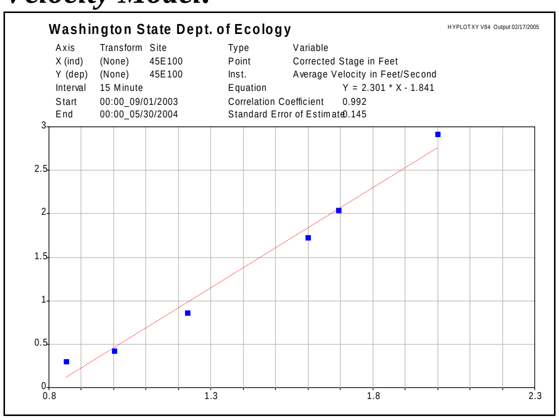
Stage (ft)	Mod. Vel. (ft/sec)	Meas. Vel. (ft/sec)	Mod. Area (ft^2)	Meas. Area (ft^2)	Mod. Flow (cfs)	Meas Flow (cfs)	% Diff.
1.50	0.38	0.43	98.3	125.0	37.4	53.6	-30.2
1.60	0.56	0.61	108.0	136.1	60.5	83.1	-27.2
1.65	0.65	0.54	112.9	135.9	73.9	73.8	0.1
2.41	2.05	2.07	188.5	150.1	387	310	24.8
2.80	2.77		228.1		632		
4.34	5.61		389.2		2180		
6.10	8.85		508.5		4500		

Site 10: Mission Cr. @ Binder Rd. (45E100)

This flow model was developed to estimate high flows in Mission Creek during the peak spring snowmelt in 2004. The highest measured flow during this period occurred at a stage height of 2.00 ft. During peak snowmelt, the stage height reached 2.67 ft. The model uses the relationships established from known (measured) flows between river stage, velocity and cross-sectional area. The model was applied to stages at which discharge was physically measured to assess interpolative accuracy, and was then used to extrapolate high flows encountered at the site, but not physically measured. The model assumes that the slope of the creek banks remains constant as stage rises from 2.00 ft to 2.67 ft. Given the channel geometry at the site, this is a fairly reasonable assumption. The model may underestimate cross-sectional area if the bank slope decreases with increasing stage height. However, it may overestimate average velocity as the edge flow reaches riparian vegetation.

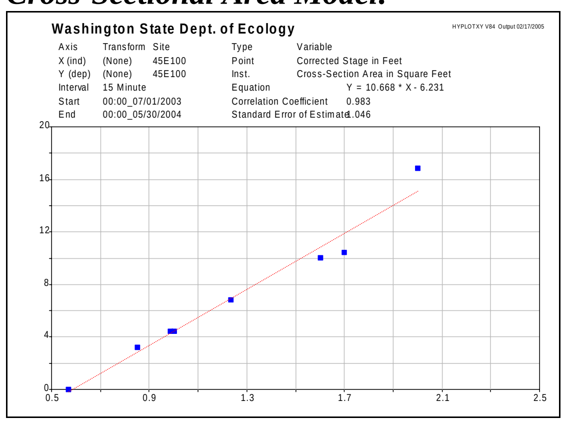
The interpolative accuracy of the model was fair (14-17%). Extrapolative accuracy is estimated at 25 percent.

Velocity Model:



(velocity) = 2.301 * (stage) – 1.841

Cross-Sectional Area Model:



(x-area) = 10.668 * (stage) – 6.231

Discharge Model:

Stage (ft)	*Mod. Vel. (ft/sec)*	*Meas. Vel. (ft/sec)*	*Mod. Area (ft^2)*	*Meas. Area (ft^2)*	*Mod. Flow (cfs)*	*Meas Flow (cfs)*	*% Diff.*
1.23	0.99	0.87	6.9	6.9	6.8	6.0	13.8
1.60	1.84	1.70	10.8	10.0	19.9	17.0	16.9
1.70	2.07	2.05	11.9	10.3	24.6	21.2	16.2
2.00	2.76	2.91	15.1	16.9	41.7	49.0	-14.9
2.20	3.22		17.2		55.5		
2.40	3.68		19.4		71.3		
2.67	4.30		22.2		95.7		

Appendix C: Discrete Discharge Points

Table 1: Wenatchee River at Leavenworth (Site 5)

DATE	TIME	FLOW (CFS)
05/16/2002	08:30	6310
06/18/2002	07:45	16400
06/27/2002	12:15	18100
07/17/2002	14:55	6730
07/18/2002	10:20	7030
07/31/2002	07:15	2810
08/05/2002	13:25	1730
08/29/2002	07:00	1050
10/08/2002	07:25	386

Table 2: Wenatchee River near Leavenworth (Site 6)

DATE	TIME	FLOW (CFS)
04/25/2002	14:40	3740
06/18/2002	12:50	10300
06/27/2002	11:50	11200
07/18/2002	10:55	5070
07/25/2002	13:40	3530
07/31/2002	14:00	2630
08/05/2002	16:55	1650
08/29/2002	12:45	933
09/10/2002	15:20	577
10/08/2002	10:20	421

Table 3: Chiwawa River at Schugart Flat (Site 7)

DATE	TIME	FLOW (CFS)
04/25/2002	11:45	734
05/16/2002	13:45	1170
06/19/2002	10:45	2050
07/18/2002	12:40	808
07/30/2002	07:30	665
10/08/2002	14:20	115

Table 4: White River near mouth (Site 8)

DATE	TIME	FLOW (CFS)
04/25/2002	08:10	932
05/14/2002	17:15	1360
05/15/2002	08:35	1240
06/17/2002	13:15	3100
06/25/2002	08:30	3670
06/27/2002	10:05	3590
07/18/2002	08:45	1890
07/18/2002	12:10	1840
07/22/2002	09:50	2370
07/25/2002	10:45	1640
07/29/2002	14:50	1090
08/05/2002	16:15	479
08/27/2002	07:50	413
10/07/2002	13:30	103
12/11/2002	10:45	96

Table 5: Little Wenatchee River near mouth (Site 9)

DATE	TIME	FLOW (CFS)
05/14/2002	16:45	1920
05/15/2002	09:00	1840
06/17/2002	12:40	4330
06/25/2002	08:05	3770
06/27/2002	09:50	4410
07/18/2002	08:35	1120
07/18/2002	12:20	1060
07/22/2002	09:30	740
07/25/2002	10:35	551
07/29/2002	13:00	310
08/05/2002	16:00	172
08/27/2002	14:00	83
09/17/2002	15:25	42
10/07/2002	12:10	54
12/11/2002	09:30	74

Appendix D: Time of Travel Tables

Table 1: Icicle Cr. @ mouth (45B050) to Icicle Cr. abv Snow Cr. nr Leavenworth (USGS 12458000)

This table details the number of hours involved for water to travel from the USGS Icicle Cr. above Snow Cr. station to the Ecology Icicle Cr. at mouth station at different stage levels. Stage values are for Icicle Cr. at mouth.

Stage (ft.)	Time (hrs)		Stage (ft.)	Time (hrs)		Stage (ft.)	Time (hrs)		Stage (ft.)	Time (hrs)
0.1	48.2		2.1	3.6		4.1	2.0		6.1	1.5
0.2	26.7		2.2	3.5		4.2	2.0		6.2	1.4
0.3	18.9		2.3	3.4		4.3	2.0		6.3	1.4
0.4	14.8		2.4	3.2		4.4	1.9		6.4	1.4
0.5	12.3		2.5	3.1		4.5	1.9		6.5	1.4
0.6	10.5		2.6	3.0		4.6	1.9		6.6	1.4
0.7	9.2		2.7	2.9		4.7	1.8		6.7	1.3
0.8	8.2		2.8	2.8		4.8	1.8		6.8	1.3
0.9	7.4		2.9	2.8		4.9	1.8		6.9	1.3
1.0	6.8		3.0	2.7		5.0	1.7		7.0	1.3
1.1	6.3		3.1	2.6		5.1	1.7		7.1	1.3
1.2	5.8		3.2	2.5		5.2	1.7		7.2	1.3
1.3	5.4		3.3	2.5		5.3	1.6			
1.4	5.1		3.4	2.4		5.4	1.6			
1.5	4.8		3.5	2.3		5.5	1.6			
1.6	4.6		3.6	2.3		5.6	1.6			
1.7	4.3		3.7	2.2		5.7	1.5			
1.8	4.1		3.8	2.2		5.8	1.5			
1.9	3.9		3.9	2.1		5.9	1.5			
2.0	3.8		4.0	2.1		6.0	1.5			

Table 2: Wenatchee R. blw Lake Wenatchee (45A240) to Wenatchee R. @ Plain (USGS 12457000)

This table details the number of hours involved for water to travel from the Ecology Wenatchee R. below Lake Wenatchee station to the USGS Wenatchee R. at Plain station at different stage levels. Stage values are for Wenatchee River below Lake Wenatchee.

Stage (ft)	Time (hrs)		Stage (ft)	Time (hrs)		Stage (ft)	Time (hrs)
0.5	24.4		2.5	4.8		4.5	2.7
0.6	20.3		2.6	4.7		4.6	2.6
0.7	17.4		2.7	4.5		4.7	2.6
0.8	15.2		2.8	4.3		4.8	2.5
0.9	13.5		2.9	4.2		4.9	2.5
1.0	12.2		3	4.0		5	2.4
1.1	11.0		3.1	3.9		5.1	2.4
1.2	10.1		3.2	3.8		5.2	2.3
1.3	9.3		3.3	3.7		5.3	2.3
1.4	8.7		3.4	3.6		5.4	2.2
1.5	8.1		3.5	3.5		5.5	2.2
1.6	7.6		3.6	3.4		5.6	2.2
1.7	7.1		3.7	3.3		5.7	2.1
1.8	6.7		3.8	3.2		5.8	2.1
1.9	6.4		3.9	3.1		5.9	2.0
2.0	6.1		4	3.0		6+	2.0
2.1	5.8		4.1	2.9			
2.2	5.5		4.2	2.9			
2.3	5.3		4.3	2.8			
2.4	5.0		4.4	2.7			

Table 3: Wenatchee R. @ Leavenworth (45A100) to Wenatchee R. @ Peshastin (USGS 12459000)

This table details the number of hours involved for water to travel from the Ecology Wenatchee R. at Leavenworth station to the USGS Wenatchee R. at Peshastin station at different stage levels. Stage values are for Wenatchee River at Leavenworth.

Stage (ft.)	Time (hrs)	Stage (ft.)	Time (hrs)	Stage (ft.)	Time (hrs)	Stage (ft.)	Time (hrs)
-33.3	0.6	-35.3	1.4	-37.3	2.9	-39.3	5.8
-33.4	0.7	-35.4	1.4	-37.4	3.0	-39.4	6.0
-33.5	0.7	-35.5	1.5	-37.5	3.1	-39.5	6.2
-33.6	0.7	-35.6	1.6	-37.6	3.2	-39.6	6.4
-33.7	0.8	-35.7	1.6	-37.7	3.3	-39.7	6.6
-33.8	0.8	-35.8	1.7	-37.8	3.4	-39.8	6.8
-33.9	0.8	-35.9	1.7	-37.9	3.6	-39.9	7.1
-34.0	0.8	-36.0	1.8	-38.0	3.7	-40.0	7.3
-34.1	0.9	-36.1	1.9	-38.1	3.8	-40.1	7.5
-34.2	0.9	-36.2	1.9	-38.2	4.0	-40.2	7.8
-34.3	0.9	-36.3	2.0	-38.3	4.1	-40.3	8.1
-34.4	1.0	-36.4	2.1	-38.4	4.2	-40.4	8.3
-34.5	1.0	-36.5	2.2	-38.5	4.4	-40.5	8.6
-34.6	1.1	-36.6	2.2	-38.6	4.5		
-34.7	1.1	-36.7	2.3	-38.7	4.7		
-34.8	1.1	-36.8	2.4	-38.8	4.9		
-34.9	1.2	-36.9	2.5	-38.9	5.0		
-35.0	1.2	-37.0	2.6	-39.0	5.2		
-35.1	1.3	-37.1	2.7	-39.1	5.4		
-35.2	1.3	-37.2	2.8	-39.2	5.6		

Table 4: Wenatchee R. nr Leavenworth (45A110) to Wenatchee R. @ Plain (USGS 12457000)

This table details the number of hours involved for water to travel from the USGS Wenatchee R. at Plain station to the Ecology Wenatchee R. near Leavenworth station at different stage levels. Stage values are for Wenatchee River near Leavenworth.

Stage (ft)	Time (hrs)	Stage (ft)	Time (hrs)	Stage (ft)	Time (hrs)	Stage (ft)	Time (hrs)	Stage (ft)	Time (hrs)
-30.7	8.4	-28.7	6.2	-26.7	4.6	-24.7	3.6	-22.7	3.2
-30.6	8.2	-28.6	6.1	-26.6	4.5	-24.6	3.6	-22.6	3.2
-30.5	8.1	-28.5	6.0	-26.5	4.5	-24.5	3.5	-22.5	3.2
-30.4	8.0	-28.4	5.9	-26.4	4.4	-24.4	3.5	-22.4	3.2
-30.3	7.9	-28.3	5.8	-26.3	4.4	-24.3	3.5	-22.3	3.2
-30.2	7.8	-28.2	5.7	-26.2	4.3	-24.2	3.5	-22.2	3.2
-30.1	7.6	-28.1	5.7	-26.1	4.2	-24.1	3.4	-22.1	3.2
-30.0	7.5	-28.0	5.6	-26.0	4.2	-24.0	3.4	-22.0	3.2
-29.9	7.4	-27.9	5.5	-25.9	4.1	-23.9	3.4	-21.9	3.2
-29.8	7.3	-27.8	5.4	-25.8	4.1	-23.8	3.4	-21.8	3.2
-29.7	7.2	-27.7	5.3	-25.7	4.0	-23.7	3.3	-21.7	3.2
-29.6	7.1	-27.6	5.2	-25.6	4.0	-23.6	3.3		
-29.5	7.0	-27.5	5.2	-25.5	3.9	-23.5	3.3		
-29.4	6.9	-27.4	5.1	-25.4	3.9	-23.4	3.3		
-29.3	6.8	-27.3	5.0	-25.3	3.8	-23.3	3.3		
-29.2	6.7	-27.2	4.9	-25.2	3.8	-23.2	3.2		
-29.1	6.6	-27.1	4.9	-25.1	3.8	-23.1	3.2		
-29.0	6.5	-27.0	4.8	-25.0	3.7	-23.0	3.2		
-28.9	6.4	-26.9	4.7	-24.9	3.7	-22.9	3.2		
-28.8	6.3	-26.8	4.7	-24.8	3.6	-22.8	3.2		

Table 5: Chiwawa R. @33 Shugart Flat (45H060) to Chiwawa R. nr Plain (USGS 12456500)

This table details the number of hours involved for water to travel from the USGS Chiwawa R. near Plain station to the Ecology Chiwawa R. at Shugart Flat station at different stage levels. Stage values are for Chiwawa R. at Shugart Flat.

Stage (ft)	Time (hrs)		Stage (ft)	Time (hrs)		Stage (ft)	Time (hrs)		Stage (ft)	Time (hrs)
-28.10	5.8		-27.50	3.8		-26.90	2.5		-26.30	1.9
-28.00	5.4		-27.40	3.5		-26.80	2.3		-26.20	1.9
-27.90	5.0		-27.30	3.3		-26.70	2.2		-26.10	1.9
-27.80	4.7		-27.20	3.0		-26.60	2.1		-26.00	1.9
-27.70	4.4		-27.10	2.8		-26.50	2.0		-25.90	2.0
-27.60	4.1		-27.00	2.7		-26.40	2.0			