WASHINGTON STATE DEPARTMENT OF ECOLOGY

Flow Summary at Three Seasonal Gaging Stations on the Little Klickitat River

Abstract

Between June and November 2000, the Washington State Department of Ecology (Ecology) measured flows and developed continuous stage records at three sites on the Little Klickitat River. The uppermost station was located west of Hwy 97 just north of Goldendale, the middle station was at the Olson Road crossing southwest of Goldendale, and the lower station was located alongside Hwy 142 (M.P. 19) approximately 1/4 mile above the confluence with the Klickitat River.

Monitoring was conducted in support of a Temperature Total Maximum Daily Load (TMDL) study developed by Ecology. The purpose of this TMDL was to characterize water temperature and to establish load and wasteload allocations for heat sources in order to meet water quality standards for surface water temperature in the basin.

Continuous stage height recorders and staff gages were installed, and four to six instantaneous discharge measurements were taken at all three sites. Discharge rating curves were developed for each site by relating various stage height values to their corresponding instantaneous discharge measurements. Doing so related the river stage to a corresponding instantaneous discharge measurement. These rating curves were then applied to the continuous records of each station to predict daily average discharge values. Measured discharge of the Little Klickitat River ranged from 3 cfs above the city of Goldendale to 58 cfs near the mouth. Predicted discharge values based on continuous records ranged from 1.5 cfs above Goldendale to 70 cfs near the mouth. The r^2 values for regressions of discharge against transducer values ranged from 0.90 to 0.99. The lower r^2 of 0.90 may be the result of vandalism at one of the stations

By Christopher Evans
March 2001

Publication No. 01-03-006
Waterbody No. WA-30-1020 (AY21LB)

Publication Information

This report is available on the Department of Ecology home page on the World Wide Web at http://www.ecy.wa.gov/biblio/0103006.html

For additional copies of this report, contact the Department of Ecology Publications Distribution Office and refer to publication number 01-03-006
E-mail: ecypub@ecy.wa.gov
Phone: (360) 407-7472
Address: PO Box 47600, Olympia WA 98504-7600

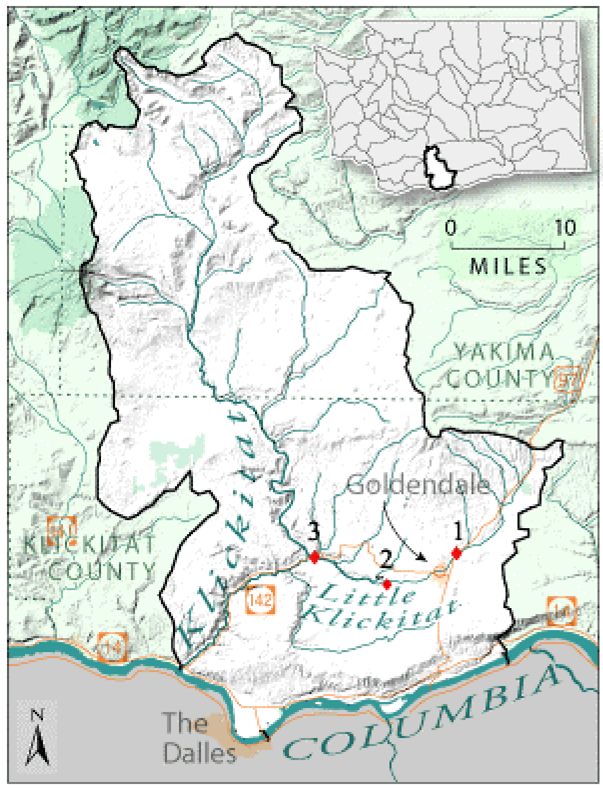
Author: Christopher Evans
Washington State Department of Ecology
Environmental Assessment Program
Stream Hydrology Unit
Phone: (360) 407-6052
Address: PO Box 47600, Olympia WA 98504-7600

Introduction

Between June and November 2000, the Environmental Assessment Program of the Washington State Department of Ecology measured flows on the mainstem Little Klickitat River. Monitoring was conducted in support of a Temperature Total Maximum Daily Load (TMDL) study developed by the Environmental Assessment Program. The purpose of this TMDL was to characterize water temperature in the basin and establish load and wasteload allocations for heat sources in order to meet water quality standards for surface water temperature (Brock, 2000). The study was initiated because of 303(d) listings for temperature of river segments in the Little Klickitat Watershed (Brock, 2000).

Sites

The Little Klickitat River is located in south central Washington State. It flows from the southwest flank of the Simco Mountains, west across the Munson Prairie, and through the Little Klickitat canyon to its confluence with the Klickitat River (Brock, 2000). Ecology established continuous stage height recorders at three locations within this drainage. The uppermost station (Site 1) was located alongside (west) of Hwy 97 just north of Goldendale. The middle station (Site 2) was located at the Olson Road crossing southwest of Goldendale. The lower station (Site 3) was located alongside Hwy 142 (M.P. 19) approximately 1/4 mile above the confluence with the Klickitat River.



Washington State Department of Ecology
Continuous Stage Height Recorders
June 2000 -November 2000 ♦

Methods

Each station was equipped with a pressure transducer and a datalogger that recorded stage height and temperature at 15-minute intervals from June to November 2000. The dataloggers used by Ecology are Design Analysis H-510s with H-310 SDI-12 pressure transducers. Four to six wading measurements were taken at each station to establish rating curves used to calculate the daily average discharges.

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 stream flow. 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 5% to 10% of the total discharge passed through any single cell. The width of the individual cells varied in keeping with the 5% to 10% discharge criteria. Velocity measurements were taken at 0.6 ft of the stream depth when the total stream depth was less than 1.5 ft, and at 0.2 ft and 0.8 ft 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 software program.

Quality Assurance

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 good and poor. Based on physical conditions encountered at each site, a good cross-section assumes an error of up to 5% and a poor cross-section assumes an error of up to 8%. 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. The Swoffer propellers used during this project were pre- and post-calibrated with values ranging from 186 to 182. A calibration rating of 186 means that for every 186 revolutions of the propeller, 10 ft of water have passed the measurement point. A calibration value of 182 underestimates the discharge measurement by 2%. Once a rating curve was established, discharge measurements were tracked by comparing the measured discharge values to the predicted discharge values at the same stage. The combination of propeller variations, poor cross-sections, and low-flow conditions contributed to the measured and predicted discharge differences ranging from less than 1% to just over 15%. This range of difference between the measured and the predicted discharge demonstrates the ability of the rating curve to predict stream discharge for each site.

Pressure Transducers and Staff Gages

Based on manufacture specifications, the theoretical precision of the pressure transducers is less than or equal to 0.02% of the full-scale output. For the transducers used by Ecology, this precision is considered linear from 0 to15 psi or 0 to 34.6 ft (Fletcher, 2.6). During the study period, the accuracy of each probe was addressed by using staff gage versus transducer regressions. The r^2 values for the regressions of transducer versus staff gage readings ranged from 0.80 to 0.99.

Results

Site 1

The daily average discharge, based on the rating curve, ranged from 26.3 cubic feet per second (cfs) at the beginning of the project in June to 1.2 cfs near the end of August. The rating curve encompassed most of this range with four actual measurements between 2 cfs and 19 cfs. The polynomial regression of discharge versus the pressure transducer used to predict the daily discharge averages had an r^2 of 0.99 (Figure 1). The linear regression of pressure transducer versus staff gage was also strong with an r^2 of 0.99 (Figure 2). Daily discharge averages are presented in Table 1.

Throughout the study period, the Site 1 continuous record demonstrated an unusual daily fluctuation in discharge (Figure 3). The range was near 10 cfs at the beginning of the study, and then diminished to near 5 cfs as the daily average discharge decreased near the end of the summer. According to the continuous record, every morning at 6:00 a.m. the stage would be the lowest and every evening shortly after 6:00 p.m. the stage would peak (Figure 3). Ecology staff always visited the site before 12:00 p.m. Unfortunately, this caused staff to miss making a measurement at the peaks. Based on the continuous record, it was determined the overall range of stage during the study period was just over 0.50 ft. The recurring daily fluctuations in discharge were represented by less than 0.10 psi or .23 ft of stage.

It was originally believed that this fluctuation was related to the city of Goldendale's water supply system. However, representatives from the city have said that the water supply system by-pass returns below Goldendale. One possible source of this fluctuation is a temperature introduced bias of the pressure transducer. In an effort to address this question, temperature was plotted against the corresponding psi value at 18:00 hours for each day of the continuous record. The time was selected because it was nearest the daily discharge peaks. If temperature influenced the psi values, a correlation would be evident near these daily peaks. The regression of psi versus temperature produced an r^2 of 0.02, demonstrating no definable relationship (Figure 4). This leaves the daily fluctuations recorded at the station unexplained to the author.

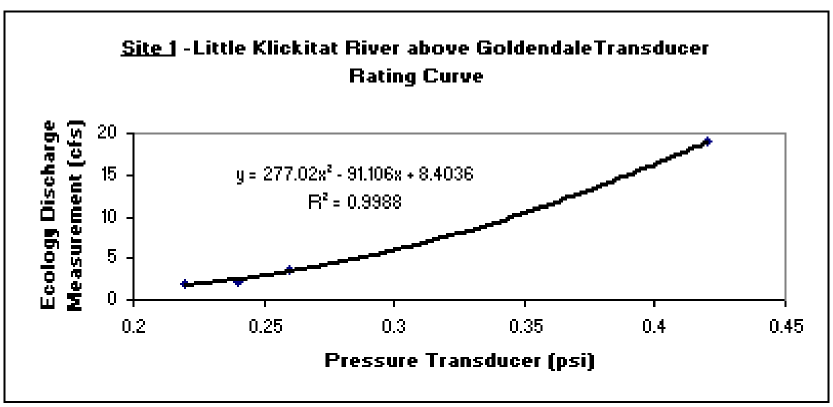


Figure 1. Site 1 pressure transducer versus discharge measurement rating curve used to calculate the daily average discharges.

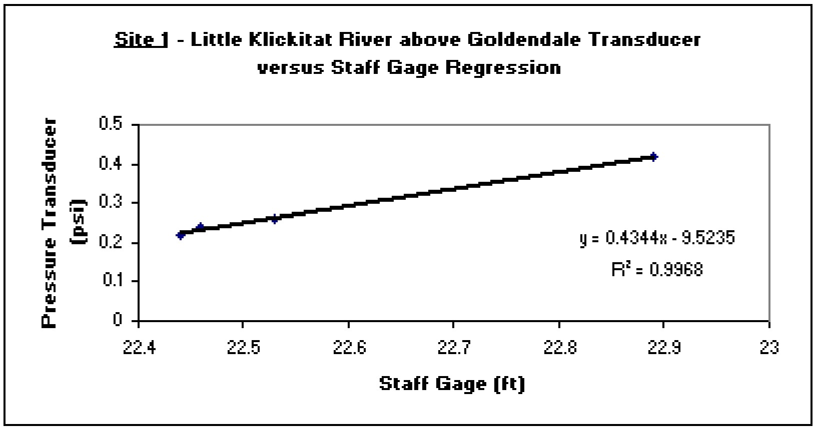


Figure 2. Site 1 staff gage versus pressure transducer.

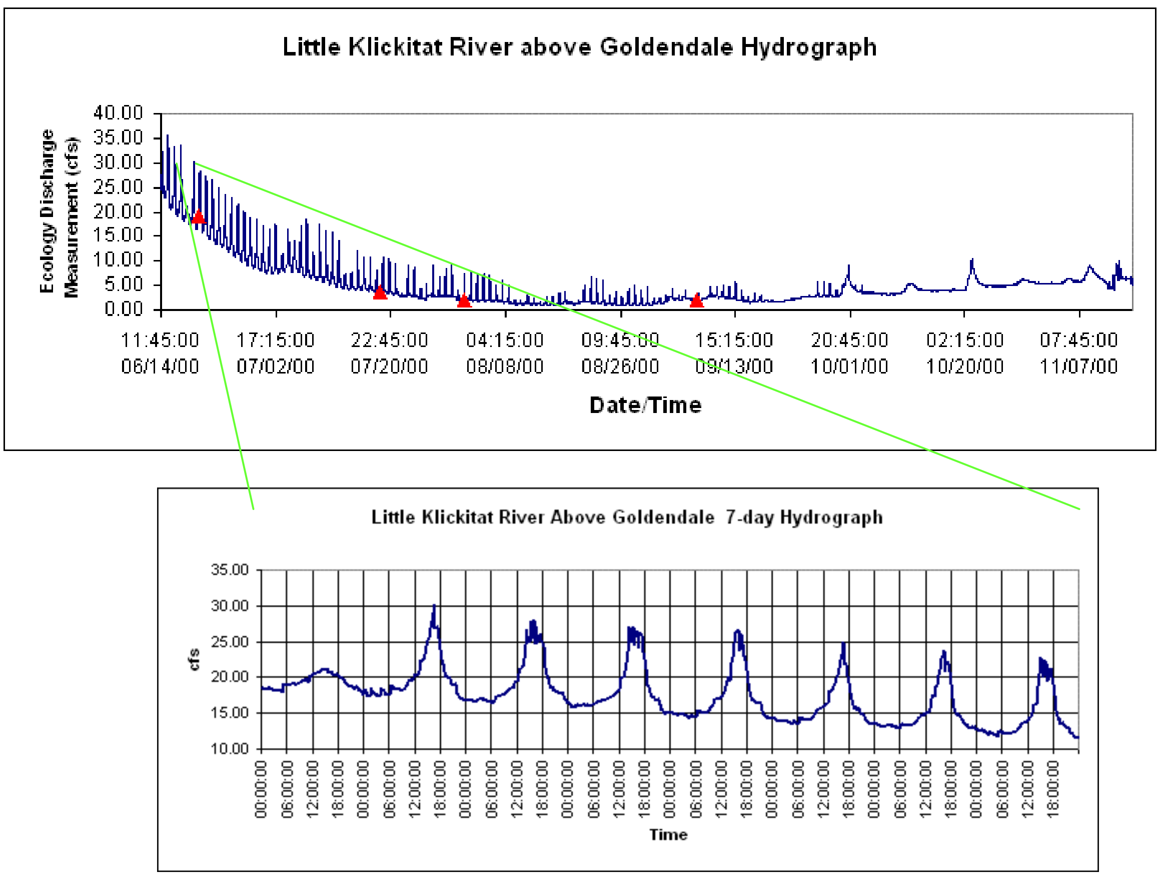


Figure 3. Site 1 hydrograph. Inset reflects pattern of daily stage fluctuations during seven days in the middle of June. This pattern continued into the late summer when the range of stage fluctuation diminished to near zero. Triangles represent actual discharge measurements.

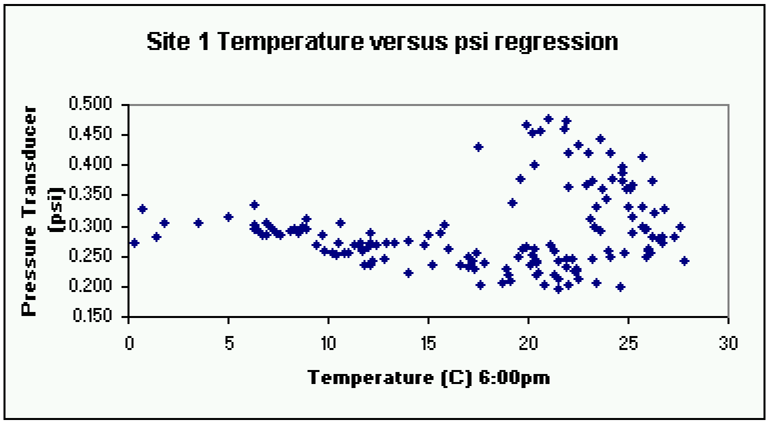


Figure 4. Site 1 pressure transducer psi versus temperature values regression at 6:00 p.m. of each study day. Psi is not correlated to recorded temperature.

Site 2

Because of a bedrock substrate, Ecology was unable to install a staff gage at this site. Subsequently, the stage was tracked by measuring from an established reference point on the bridge. These tapedown measurements were then compared to the transducer readings to track the continuous recorder performance. Site 2 did not provide an ideal spot to measure flow, and the selected cross-section was rated as poor. This poor cross-section rating assumes an error of over 8%, which should be considered in the calculated discharge values for the station.

The calculated discharge ranged from 33 cfs at the beginning of the study to near 7.5 cfs in mid September. The rating curve encompassed most of this with six instream wading measurements ranging from 7 to 27 cfs. The polynomial regression of discharge versus pressure transducer used to predict the daily discharge averages produced an r^2 of 0.98 (Figure 5). The linear regression of tapedown versus pressure transducer produced an r^2 of 0.988 (Figure 6). Daily discharge averages are presented in Table 2. From June 14 to 30, the continuous record reflects a pattern that resembles a daily input to the river (Figure 7). This pattern ceases at the end of June and was not seen again during the study period. Between this time and the end of the study, the stage displayed typical low-flow conditions.

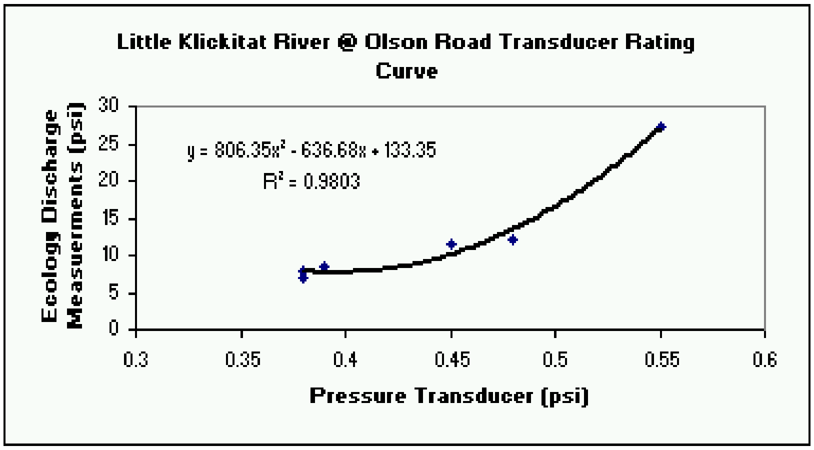


Figure 5. Site 2 discharge versus pressure transducer rating curve used to develop continuous record.

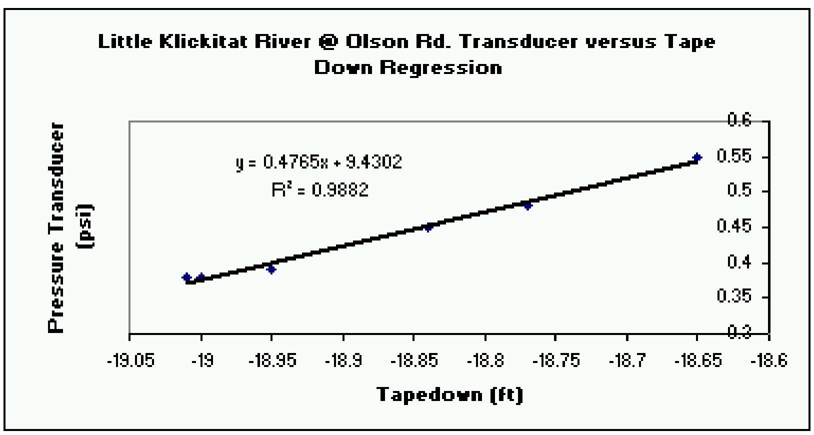


Figure 6. Site 2 pressure transducer versus tapedown regression used to track performance of station.

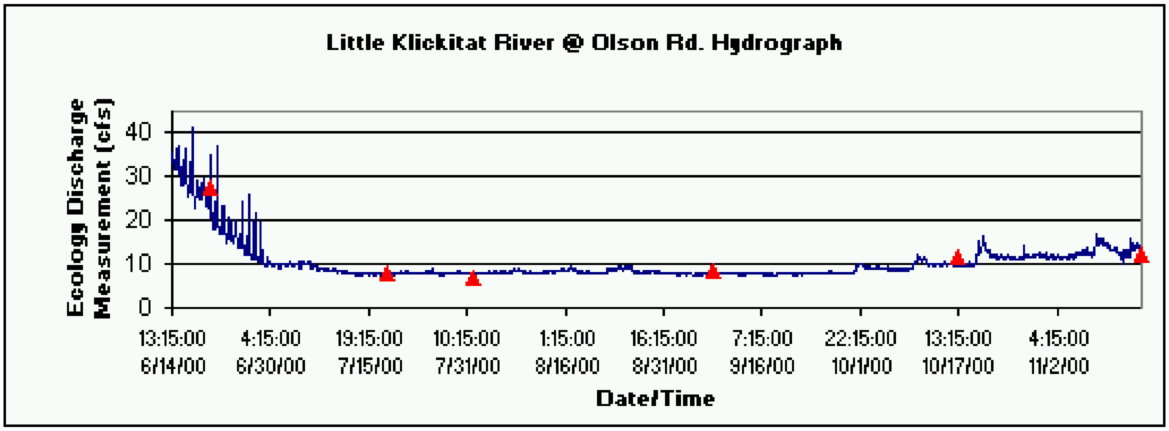


Figure 7. Site 2 hydrograph. Fluctuations at beginning and end of graph correspond to the Goldendale wastewater treatment plant discharge schedule.

Site 3

Site 3 was located alongside Hwy 142 at milepost 19. This site is below the Little Klickitat Canyon and about 1/4 of a mile above the confluence with the Klickitat River. Site 3 provided a good rated cross-section for flow measurement. A good rated cross-section assumes an error of up to 5%. The calculated daily discharges ranged from 70 cfs at the beginning of the project to 29 cfs in July and August. The rating curve encompassed most of this range with actual measurements ranging from 26 to 59 cfs.

Sometime in mid July this site was vandalized. Subsequently, about two weeks of data were lost before a new station could be installed. Replacing the station shifted the height of the transducer. To determine the amount of shift, staff gage and psi values were recorded before and after the station replacement. By comparing staff gage readings that were similar to readings before the station was moved to readings that were taken after the new station was installed, Ecology was able to determine the shift in the transducer placement. For example, assume the staff gage read 1.00 ft and the psi was 0.43 before the station was moved, and the staff gage read 1.00 ft and the psi read 0.86 after the station was moved. This means the transducer is now .43 psi or 1.00 ft deeper than before it was moved. The continuous record was then shifted to adjust for this change in the transducer position.

In addition, a psi value for a flow measurement taken while the station was damaged was resurrected by calculating the psi from the next closest staff gage reading. Assuming that the next closest staff gage reading was correct and knowing that 0.01 ft is equal to 0.0043 psi, Ecology was able to calculate the missing psi by converting the difference in staff gage values in feet to psi. By doing so, Ecology was able to include this point in the rating curve used to develop the average daily discharges. To fill in the continuous record that was lost while the station was being replaced, Ecology had to look at what the record was doing before and after the station was moved. It was determined that the record preceding the station being damaged was relatively stable and showed a slow downward trend.

The period directly following the reinstallation of the station showed the discharge remaining stable at just below 30 cfs. To provide a data overlap, it was determined that beginning July 18 the record should be corrected to the point of the station reinstallation on August 8.

Because it appears the stage was stabilizing near 30 cfs during the period when the station was not logging, a straight line was drawn between the two dates. This method produces a representative continuous record for the data gap but does not include any fluctuation in stage that may have occurred during the time period (Figure 8). So, for this period the daily averages are estimated at 28 cfs. This value is halfway between what the record was estimating before and after the station was down (30 cfs) and the wading measurement that was taken in the middle of the down time (26 cfs). These values are only estimates and are flagged as such in the daily averages table (Table 3).

The polynomial regression of discharge versus pressure transducer used to develop the continuous record produced an r^2 of 0.90 (Figure 9). The linear regression of staff gage versus pressure transducer used to track the transducer performance produced an r^2 of 0.805 (Figure 10). The lower r^2 for the staff gage versus pressure transducer regression may be a result of the station vandalism, which may have included movement of the staff gage.

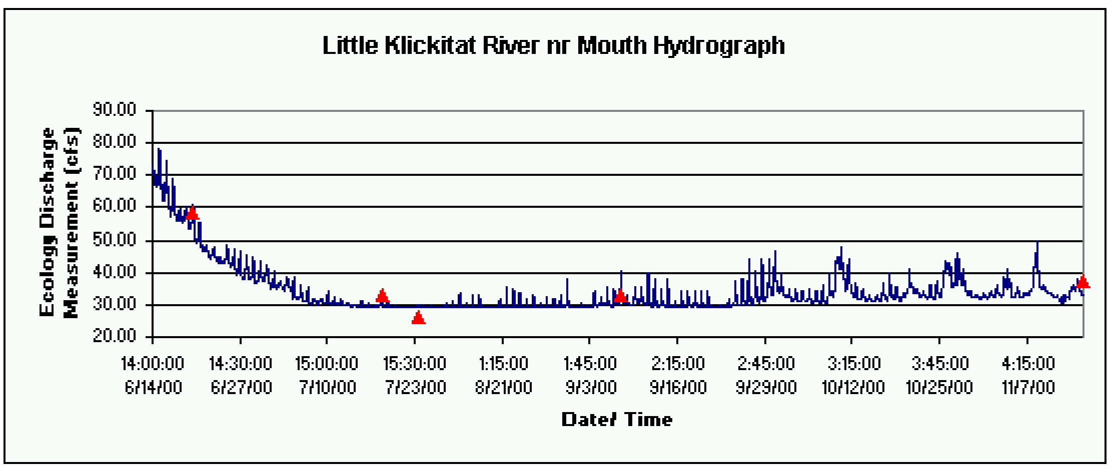


Figure 8. Site 3 hydrograph. The period between the last week of July and the first week of August are estimates based on the established daily patterns preceding that time. The triangles represent instream discharge measurements.

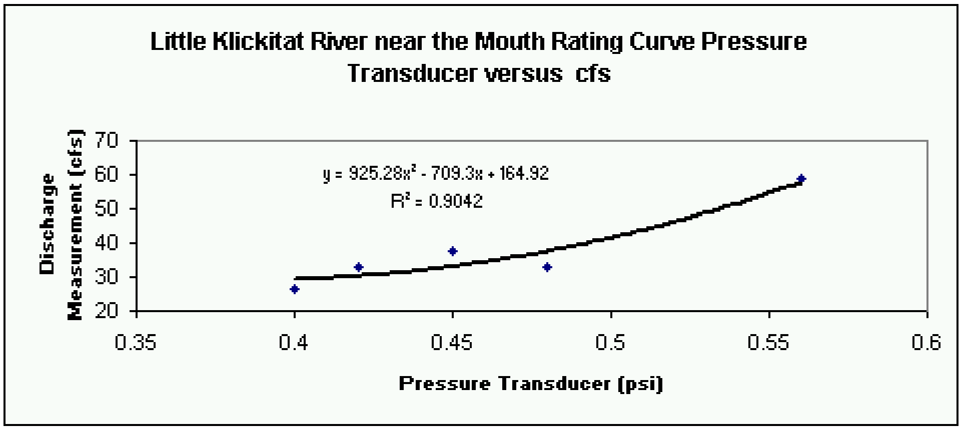


Figure 9. Site 3 discharge versus pressure transducer rating curve used to predict the continuous record.

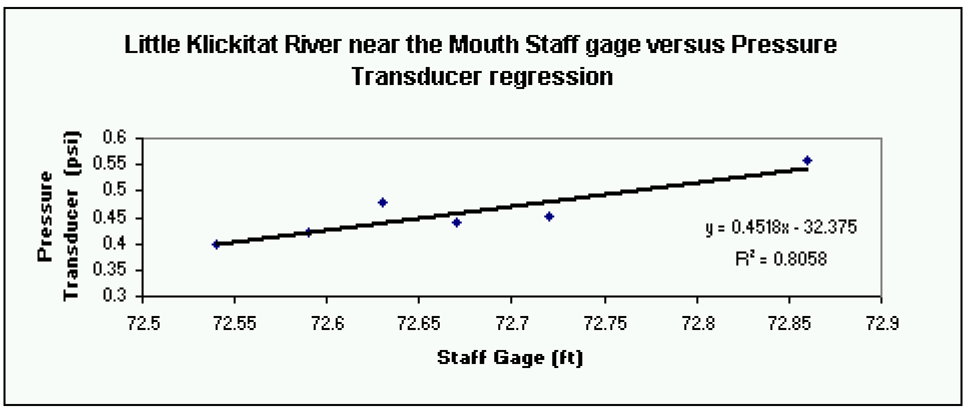


Figure 10. Site 3 staff gage versus pressure transducer used to track the reliability of the station data.

Table 1. Little Klickitat River Above Goldendale (Site 1) Daily Discharge Averages (cfs).

	June	July	August	September	October	November
1	-	9.4	2.7	1.6	6.3	5.4
2	-	9.3	2.7	1.8	4.5	5.4
3	-	8.6	2.6	2.5	3.8	5.4
4	-	10.0	2.6	2.3	3.5	5.6
5	-	9.6	2.5	2.7	3.4	6.3
6	-	9.6	2.2	2.2	3.3	5.9
7	-	9.0	2.1	2.2	3.2	5.9
8	-	7.7	2.0	2.2	3.2	7.8
9	-	8.1	1.4	2.9	3.4	7.8
10	-	7.8	1.3	2.9	4.2	6.5
11	-	7.2	1.6	2.9	5.2	5.6
12	-	6.6	1.4	2.8	4.4	5.1
13	-	5.1	1.3	2.8	4.1	7.6
14	26	4.9	1.4	2.3	3.9	6.4
15	25	5.7	1.3	1.8	3.9	-
16	23	5.3	1.4	1.9	4.0	-
17	22	4.9	1.7	2.0	3.9	-
18	19	4.4	1.4	1.9	4.1	-
19	20	4.7	1.4	1.7	4.1	-
20	19	4.6	2.0	1.7	5.7	-
21	18	4.2	2.2	1.9	8.0	-
22	17	3.0	2.0	2.1	5.4	-
23	16	3.7	1.9	2.3	5.0	-
24	15	3.5	1.4	2.6	4.9	-
25	14	2.7	1.4	2.8	4.9	-
26	13	2.8	1.2	3.2	4.9	-
27	13	3.6	1.6	3.3	5.0	-
28	11	3.2	1.6	3.3	5.5	-
29	11	3.5	1.6	3.0	6.2	-
30	10	3.7	1.5	4.0	5.8	-
31	-	2.5	1.2	-	5.5	-

Table 2. Little Klickitat River at Olson Rd (Site 2) Daily Discharge Averages (cfs).

	June	July	August	September	October	November
1	-	9.6	8.0	7.8	9.9	11.6
2	-	9.7	7.9	7.7	9.1	11.4
3	-	9.8	8.1	7.8	8.9	11.3
4	-	9.6	8.1	7.7	9.0	11.6
5	-	10.1	8.2	7.7	8.9	12.2
6	-	9.3	8.1	7.7	8.8	12.6
7	-	8.5	8.5	7.7	8.8	12.1
8	-	8.6	8.6	7.8	8.9	14.9
9	-	8.5	8.2	7.8	8.9	14.6
10	-	8.2	8.1	7.8	10.8	13.4
11	-	7.9	8.1	7.7	10.9	13.0
12	-	7.9	8.2	7.7	9.9	11.5
13	-	7.7	8.4	7.7	9.6	13.3
14	34	7.8	8.6	7.8	9.6	14.0
15	33	7.7	8.6	7.8	9.9	-
16	32	7.7	9.0	7.7	9.7	-
17	32	7.7	8.5	7.7	9.6	-
18	27	7.7	8.1	7.7	9.7	-
19	27	7.8	8.2	7.8	9.8	-
20	26	8.1	7.8	7.7	14.0	-
21	25	8.3	8.0	7.7	13.9	-
22	19	8.1	8.5	7.7	11.9	-
23	18	7.8	8.7	7.9	11.3	-
24	17	8.2	9.2	8.0	11.2	-
25	17	8.5	9.3	8.0	11.3	-
26	16	8.0	8.5	8.0	11.2	-
27	14	7.7	8.1	8.0	11.8	-
28	13	7.8	8.3	7.8	11.6	-
29	11	7.7	8.5	7.9	12.0	-
30	10	7.9	8.3	8.2	11.8	-
31	-	7.9	8.1	-	11.5	-

Table 3. Little Klickitat River Near the Mouth (Site 3) Daily Discharge Averages (cfs).

	June	July	August	September	October	November
1	-	37	28*	30	33	33
2	-	36	28*	30	32	34
3	-	36	28*	30	32	35
4	-	34	28*	31	32	33
5	-	33	28*	31	31	33
6	-	32	28*	32	32	33
7	-	31	28*	31	32	42
8	-	31	31	31	37	35
9	-	32	31	32	42	33
10	-	31	31	32	37	32
11	-	31	30	31	33	31
12	-	30	30	31	32	33
13	-	30	31	31	32	35
14	72	30	30	30	31	-
15	68	30	30	30	33	-
16	63	30	30	30	33	-
17	58	30	30	30	33	-
18	58	28*	30	30	32	-
19	56	28*	30	30	35	-
20	50	28*	30	30	34	-
21	46	28*	31	30	33	-
22	46	28*	30	30	33	-
23	43	28*	30	31	33	-
24	46	28*	30	32	36	-
25	43	28*	30	32	40	-
26	41	28*	30	33	38	-
27	40	28*	30	34	38	-
28	39	28*	30	34	33	-
29	40	28*	31	37	32	-
30	39	28*	30	35	32	-
31	-	28*	30	-	33	-

* Discharge estimate.

References

Brock, Stephanie and Anita Stohr, July 2000. *Little Klickitat River Temperature Total Maximum Daily Load, Quality Assurance Project Plan.* Washington State Department of Ecology, Olympia, Washington.

Fletcher, Terrell. *Waterlog Model H-310 Owners Manual.* Design Analysis Associates, Logan, Utah. Revision 2.6.

Hopkins, Brad, 1999. *Determination of Instantaneous Flow Measurements on Rivers and Streams.* Washington State Department of Ecology, Olympia, Washington. Draft Paper. P.6

.