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Seepage Investigation for Selected River Reaches in the Chehalis River Basin, Washington

Scientific Investigations Report 2008-5180

U.S. Department of the Interior
U.S. Geological Survey

Cover: Photograph of Chehalis River near Independence, Washington. (Photograph taken by Matt Ely, U.S. Geological Survey, August 30, 2007.)

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Suggested citation:
Ely, D.M., Frasl, K.E., Marshall, C.A., and Reed, Fred, 2008, Seepage investigation for selected river reaches in the Chehalis River basin, Washington: U.S. Geological Survey Scientific Investigations Report 2008-5180, 12 p.

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Conversion Factors and Datums

Conversion Factors

Multiply	By	To obtain
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
foot (ft)	0.3048	meter (m)
inch (in.)	2.54	centimeter (cm)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)

Datums

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above the vertical datum.

Seepage Investigation for Selected River Reaches in the Chehalis River Basin, Washington

By D. Matthew Ely, Kenneth E. Frasl, Cameron A. Marshall, and Fred Reed

Abstract

A study was completed in September 2007 in the Chehalis River basin to determine gain or loss of streamflow by measuring discharge at selected intervals within various reaches along the Chehalis River and its tributaries. Discharge was measured at 68 new and existing streamflow sites, where gains and losses were determined for 36 stream reaches. Streamflow gains were measured for 22 reaches and losses were measured for 13 reaches. No gain or loss was measured at the Chehalis River between the Newaukum and Skookumchuck Rivers. The Chehalis River exhibited a pattern of alternating gains and losses as it entered the area of wide, gentle relief known as the Grand Mound Prairie. The general pattern of tributary ground- and surface-water interaction was discharge to streams (gaining reaches) in the upper reaches and discharge to the ground-water system (losing reaches) as the tributaries entered the broad, flat Chehalis River valley.

Introduction

In recent years, increasing demands for water for municipal, agricultural, industrial, and recreational uses in watersheds of Washington State has created concern that insufficient water resources remain for fish and other uses. The Chehalis River basin currently is one of many watersheds in Washington where local citizens and governments have elected to coordinate with Tribes and State agencies to develop a watershed management plan, according to the guidelines outlined in the Watershed Management Act of 1998 (Washington State Engrossed Substitute House Bill 2514). The Chehalis Basin Partnership (CBP) currently is working to implement a long-range sustainable watershed plan to meet the needs of current and future water demands within the basin, while also working to protect and improve its natural resources. The ground-water flow system and its interaction with surface-water features is not understood well enough on a watershed scale to effectively plan and manage the use of the water resources.

Purpose and Scope

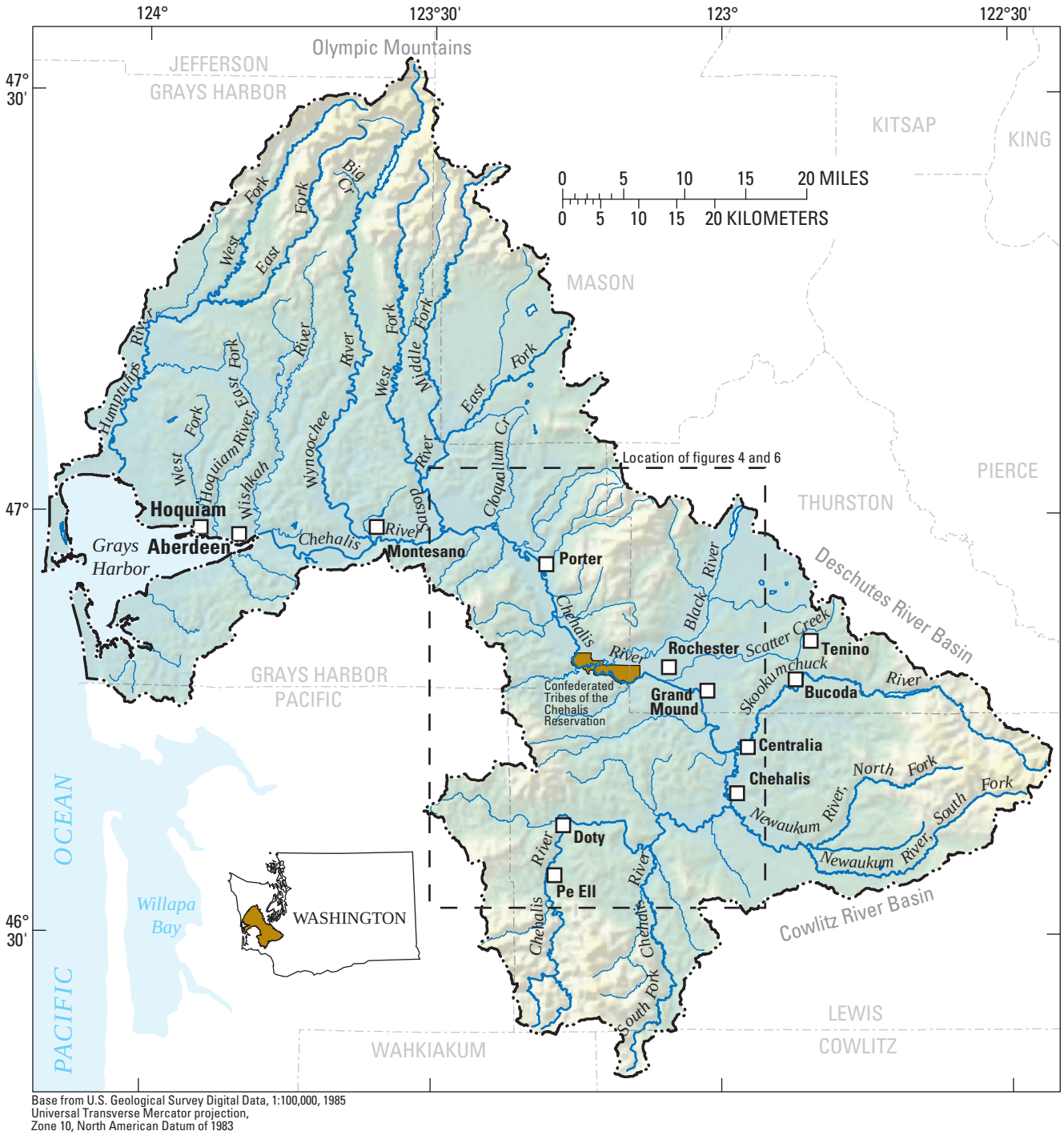
The purpose of the seepage investigation was to determine gain or loss of streamflow by measuring discharge at selected intervals within various reaches along the Chehalis River and its tributaries. This information on ground-water/surface-water interaction is needed by managers to make informed water-resource decisions.

The U.S. Geological Survey (USGS) in cooperation with Washington State Department of Ecology and the CBP completed a study in September 2007 to measure the ground-water/surface-water interaction of the Chehalis River basin. This report documents the data collection effort that included synoptic discharge measurements needed to evaluate gaining and losing reaches of the Chehalis River and selected tributaries.

Study Area

The Chehalis River flows about 125 mi from southwestern Washington east to the city of Chehalis and then north-northwesterly to Grays Harbor and the Pacific Ocean, draining an area of about 2,600 mi^2 (fig. 1). The basin is bounded on the west by the Pacific Ocean, on the east by the Deschutes River basin, on the north by the Olympic Mountains, and on the south by the Cowlitz River basin. Land surface altitudes range from 0 ft at the Pacific Ocean to about 5,000 ft at Capitol Peak in the Olympic Mountains. The Chehalis River basin is predominately forests and shrubs (74 percent) with some developed areas (7 percent), wetlands (6 percent), and agriculture (5 percent; Homer and others, 2004). The Chehalis River basin is divided into two Water Resource Inventory Areas (WRIAs). The upper Chehalis basin (WRIA 23) is upstream of the town of Porter and the lower Chehalis basin (WRIA 22) is downstream of the town of Porter.

The Chehalis River basin includes parts of Grays Harbor, Lewis, Mason, Pacific, and Thurston Counties and the cities of Aberdeen, Centralia, Chehalis, and Hoquiam, and the Confederated Tribes of the Chehalis Reservation. The Chehalis River basin is home to Coho and fall Chinook salmon and steelhead trout and the lakes, ponds, and reservoirs support various fish and wildlife species.



Base from U.S. Geological Survey Digital Data, 1:100,000, 1985
Universal Transverse Mercator projection,
Zone 10, North American Datum of 1983

Figure 1. Location of the Chehalis River basin, Washington.

Mean annual precipitation for the upper basin ranges from 40 in. near the city of Chehalis, to more than 120 in. near the headwaters of the Chehalis River (Garrigues and others, 1998). Mean annual precipitation for the lower basin ranges from 55 in. near the town of Porter, to more than 220 in. near the headwaters of the Wynoochee and Humptulips River in the Olympic Mountains (Garrigues and others, 1998).

Methods

A reconnaissance of the Chehalis River basin was done in August 2007 to locate potential measurement sites and obtain landowner permissions. Seventy discharge measurements were made over a 3-day period in September 2007 at 68 sites (59 new or existing miscellaneous streamflow sites and

9 active streamflow-gaging stations) along the Chehalis, Newaukum, Skookumchuck, and Black Rivers, Scatter Creek, and smaller selected tributaries.

Discharge measurements made during the low-flow season, usually August–September (fig. 2), were used to capture baseflow conditions. The measurements were concentrated in the upper Chehalis basin (WRIA 23) partly because of the concentration of development in the upper basin, but also because the Chehalis River is tidally influenced downstream of the Satsop River.

Gains to or losses from the Chehalis River were determined by establishing a series of measurement (transect) sites along the river channel and measuring discharge at upstream and downstream locations during 1 day. The transect sites were located at river cross sections with a uniform shape and free flowing conditions. Stream depth and velocity measurements were made using two methods—a Price AA meter with top setting rod or an acoustic Doppler current profiler (ADCP). Discharge of the Chehalis River remained fairly constant during the 3-day period (fig. 3).

Discharge was measured with a Price AA meter according to standardized techniques of the USGS (Rantz, 1982). The USGS rates the accuracy of discharge measurements based on the equipment, character of the measurement section, number of observation verticals, stability of stage, wind and accuracy of depth, and velocity measurements (Rantz, 1982, p. 179). Accuracy ratings of "good" indicate that the measurements are within 5 percent of true values and "fair" indicate the measurements are within 8 percent of true values. All discharge measurements were rated "good" or "fair," except six measurements that were rated "poor" (greater than 8 percent of true values), primarily due to aquatic growth in the streams.

An ADCP uses sonar to measure and record water current velocities over a range of depths. A complete description of the ADCP and the discharge measurement methods is provided by Oberg and others (2005). Two ADCPs were deployed using several methods, including mounted on a motor boat, towed behind a kayak, and pulled across the stream transect from riverbanks and bridges.

Numerous small unmeasured tributaries and surface-water diversions and returns are in this system, and their omission would present some error in the calculation of gains and losses. Quantifying the rates of all tributary inflows and surface-water diversions and returns was beyond the scope of this study, but unmeasured diversions and inflows would influence the net seepage results. Diversions might mask or reduce measured streamflow gains along gaining reaches and artificially increase measured streamflow losses along naturally losing reaches. Similarly, unmeasured tributaries and return flows might mask or reduce streamflow losses along a losing reach and artificially increase streamflow gains along naturally gaining reaches. Gain or loss of streamflow, as described in this report, refers to a cumulative or "gross" gain or loss.

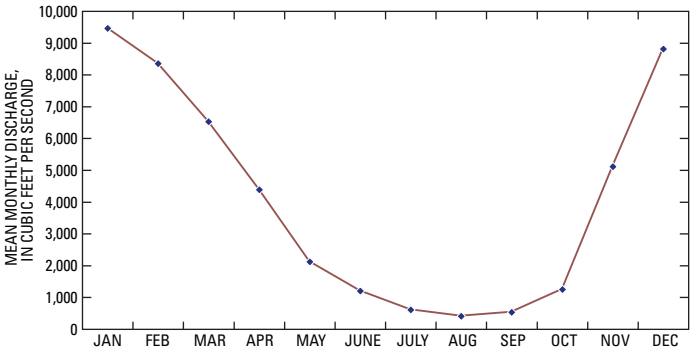


Figure 2. Mean monthly discharge for the period of record (1953–2006) for U.S. Geological Survey streamflow-gaging station 12031000, Chehalis River at Porter, Chehalis River Basin, Washington.

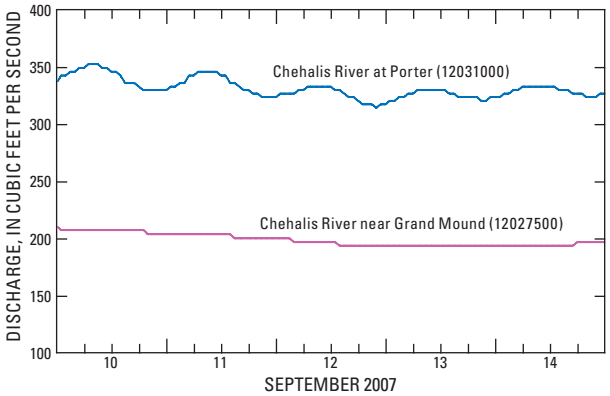


Figure 3. Discharge for September 10-14, 2007, for two U.S. Geological Survey streamflow-gaging stations, Chehalis River Basin, Washington.

Discharge was not measured at Elk and Lincoln Creeks. Discharge at these creeks was estimated using a historical relation between the creek and a nearby USGS streamflow-gaging station (appendix A). The estimates were considered "poor" due to the level of uncertainty.

No measurements were made at Chehalis River at Galvin (12026700) on the same day measurements were made at streamflow sites immediately upstream and downstream. The discharge at this site was adjusted upward by 9 ft^3/s (192 to 201 ft^3/s), the difference in the daily mean discharge from September 11, 2007 and September 13, 2007 at the streamflow-gaging station at Chehalis River near Grand Mound (12027500) (fig. 3). Error in the associated gain/loss was considered minimal.

Records of daily mean discharge and miscellaneous measurements for Washington are available by water year at http://wdr.water.usgs.gov/ (U.S. Geological Survey, 2008).

Seepage Investigation

The results of the 3-day seepage investigation are presented in table 1. An interactive Google Maps™ image shows the location of the discharge measurement sites and the gaining and losing reaches (http://wa.water.usgs.gov/projects/chehalis/seepage_run.htm). The reach name is shown on the map when the cursor is over a reach. Clicking on any measurement point will display more detailed information of the site. Gains and losses, in cubic feet per second, and gains and losses, in cubic feet per second per mile, are shown when the cursor is placed over any section of the reach.

Measurements of gains and losses for 36 stream reaches were identified. Gaining reaches indicate a strong connection to a local or regional aquifer and losing reaches identify possible recharge zones to a local or regional aquifer. Of the 36 reaches, 22 (61 percent) were gaining reaches (gain from the ground-water system) and 13 (36 percent) were losing reaches (loss to the ground-water system). No gain or loss in streamflow was measured at the Chehalis River between the Newaukum and Skookumchuck Rivers. This does not indicate a lack of ground- and surface-water interaction, but rather the cumulative gains and losses between measurement sites equal 0 ft^3/s. Pitz and others (2005) measured the same reach in September 2003 and reported a net loss of 17 ft^3/s (including a 2 ft^3/s discharge to the river). Their piezometer data indicated that the measured loss occurred over the lower 2 mi of the reach.

Headwaters of the tributary streams tended to be gaining reaches. Losses to the ground-water system were measured as the tributaries entered the broad, gentle relief of the main Chehalis River valley. Figure 4 shows gaining and losing reaches along the Chehalis River. Figure 5 shows the cumulative gain and loss, by river mile.

Gain/loss per mile can be a more useful statistic than total gain/loss from or to the ground-water system. Measurements were not made at regular intervals due the lack of accessibility and suitability of a discharge measurement site. Dividing the gain/loss by the approximate length of the measured stream reach identifies locations of greater ground-water/surface-water interaction. Gains greater than 10 ft^3/s-mi were measured in four reaches and losses greater than 10 ft^3/s-mi were measured in three reaches. Similar to the large gains and losses shown in figure 5, all seven reaches are on the Chehalis River between river miles 20 and 60. The first reach occurs as the Chehalis River enters the topographic feature known as the Grand Mound Prairie, a wide area of gentle relief. The pattern of alternating gains and losses along the Chehalis River downstream of Centralia indicates that this is an area of greater interaction between the ground- and surface-water systems.

The reported gains and losses also include unmeasured surface-water diversions from the reaches and surface-water discharges to the reaches. The Department of Ecology's Water Rights Tracking System (WRTS) provided the approximate location for certificated surface-water diversions along the measured stream reaches (M. Lynum, Washington State Department of Ecology, written commun., 2008). WRTS locates surface-water diversion rates by township, range, and section, resulting in more than one diversion at some locations (fig. 6). The total discharge rate of certificated surface-water diversions is 263 ft^3/s, not including two diversions designated for power generation, and an average permitted rate of 0.6 ft^3/s at each diversion. Actual rates of surface-water diversions during the seepage measurements are unknown, but likely were considerably less than the full surface-water right.

Information on permitted surface-water discharges into the Chehalis and Black Rivers and Scatter Creek from the National Pollutant Discharge Elimination System (Section 402 of the Clean Water Act) provided average daily discharge rates for the low-flow period for three fish hatcheries, three municipal sewage and wastewater treatment facilities, and one commercial operation (fig. 6). The total average daily discharge to the Chehalis River from the municipal sewage and wastewater treatment facilities, and dairy operation is 9.5 ft^3/s.

Two fish hatcheries in the study area withdraw ground water and discharge surface water to Black River (fig. 6). One hatchery is permitted to discharge as much as 8 ft^3/s to the Black River by percolation from a terminal pond; however, discharge was not measured for this study. Another hatchery discharges to a swamp bordering Black River. No permitted discharge limits could be found for this hatchery but Das (1993) reported that the average effluent rate over four weirs was 4 ft^3/s during an inspection in September 1991. A third hatchery near Scatter Creek discharges from settling ponds into Scatter Creek (fig. 6). A discharge of 19 ft^3/s was reported to the Washington State Department of Ecology on September 1, 2007. This discharge largely explains the measured 20.7 ft^3/s gain along the reach of Scatter Creek between Case Road (12028020) and Sargent Road (12028040) (table 1). Except for the gain at Scatter Creek, the surface-water diversions and return flows are thought to be small relative to ground-water/surface-water exchange.

Table 1. Evaluation of gains and losses, with error analysis measurements for the seepage investigation, Chehalis River basin, Washington, September 2007.

[Measurement sites are shown at http://wa.water.usgs.gov/projects/chehalis/seepage_run.htm. **Abbreviations**: ft^3/s, cubic foot per second; <, less than; e, estimated; –, no data]

Measurement sites and No.	Measured streamflow (ft^3/s)	Date	Assumed measurement error (percent)	Gain or loss (ft^3/s)	Error-adjusted minimum streamflow (ft^3/s)	Error-adjusted maximum streamflow (ft^3/s)	Net gain or loss uncertainty range (cumulative measurement error; ft^3/s)
Chehalis River near Doty (12020000)	17.8	09-11-2007	5		16.9	18.7	
Chehalis River at Elk Creek Road near Doty (12020050)	18.7	09-11-2007	5	0.9	17.8	19.6	-0.9 to 2.7
Chehalis River at Dryad (12020565)	43.5	09-11-2007	5	[1]18.0	41.3	45.7	14.1 to 21.8
Hope Creek near Dryad (12020595)	<1e	09-11-2007	11		.9	1.1	
Chehalis River near Meskill (12020625)	35.7	09-11-2007	8	-7.8	32.8	38.6	-12.8 to -2.7
Chehalis River near Ceres (12020700)	35.6	09-11-2007	5	-.1	33.8	37.4	-4.7 to 4.5
South Fork Chehalis River near Wildwood (12020800)	3.18	09-11-2007	8		2.9	3.4	
South Fork Chehalis River near Klaber (12021600)	11.2	09-11-2007	8	8.0	10.3	12.1	6.8 to 9.1
South Fork Chehalis River near Curtis (12021750)	12.4	09-11-2007	5	1.2	11.8	13.0	-0.3 to 2.7
Chehalis River near Adna (12021800)	49.4	09-11-2007	8	1.4	45.4	53.4	-4.9 to 7.7
Chehalis River near Littell (12022300)	46.5	09-11-2007	5	-2.9	44.2	48.8	-9.1 to 3.3
South Fork Newaukum River near Onalaska (12024000)	19.9	09-11-2007	5		18.9	20.9	
South Fork Newaukum River at Forest (12024100)	20.8	09-11-2007	5	.9	19.8	21.8	-1.1 to 2.9
North Fork Newaukum River above Bear Creek near Forest (12024400)	9.86	09-11-2007	5		9.4	10.4	
North Fork Newaukum River at Forest (12024820)	10.5	09-11-2007	5	.6	10.0	11.0	-0.3 to 1.6
Newaukum River at Jackson Hwy near Forest (12024830)	30	09-11-2007	8	-1.3	27.6	32.4	-5.2 to 2.6
Newaukum River near Chehalis (12025000)	31.7	09-11-2007	5	1.7	30.1	33.3	-2.2 to 5.6
Newaukum River at Chehalis (12025020)	32.8	09-11-2007	5	1.1	31.2	34.4	-2.1 to 4.3
Chehalis River below Newaukum River near Chehalis (12025025)	93	09-11-2007	5	13.7	88.4	97.7	5 to 22.3
Salzer Creek at Airport Road near Centralia (12025400)	.96	09-11-2007	11		.9	1.1	
Skookumchuck River near Bucoda (12026400)	99.9	09-11-2007	5		94.9	104.9	
Skookumchuck River at mouth near Centralia (12026620)	103	09-11-2007	8	3.1	94.8	111.2	-10.1 to 16.3
Chehalis River at Fort Borst Park near Centralia (12026625)	197	09-11-2007	8	.0	181.2	212.8	
Chehalis River at Galvin (12026700)	192	09-13-2007	8		176.6	207.4	
Chehalis River at Galvin (12026700)	[2]201	09-11-2007	11	[2]4.0	178.9	223.1	-33.8 to 41.8
Chehalis River near Grand Mound (12027500)	201	09-11-2007	5	[1]2.2	191.0	211.1	-34.6 to 30.2
Prairie Creek near Grand Mound (12027540)	0	09-11-2007			.0	.0	
Scatter Creek at Case Road near Grand Mound (12028020)	0	09-11-2007			.0	.0	
Scatter Creek at Sargent Road near Rochester (12028040)	20.7	09-11-2007	8	20.7	19.0	22.4	19 to 22.3
Scatter Creek at James Road near Rochester (12028055)	18.1	09-11-2007	8	-2.6	16.7	19.5	-5.7 to 0.5
Chehalis River near Rochester (12028060)	296	09-11-2007	11	76.9	263.4	328.6	32.8 to 120.9
	289	09-12-2007	8		265.9	312.1	
Chehalis River near Independence (12028080)	242	09-12-2007	5	-47.0	229.9	254.1	-82.2 to -11.7
Chehalis River above Black River near Oakville (12028300)	237	09-12-2007	8	-5.0	218.0	256.0	-36 to 26
Black River below Salmon Creek near Littlerock (12028330)	10.5	09-12-2007	11		9.3	11.7	
Blooms Ditch below Littlerock Road near Littlerock (12028360)	.45	09-12-2007	8		.4	.5	
Black River near Littlerock (12028440)	13.2	09-12-2007	8	2.3	12.1	14.3	0 to 4.4
Wadell Creek near Littlerock (12028500)	3.68	09-12-2007	5		3.5	3.9	
Black River at Littlerock (12029000)	12.8	09-12-2007	5	-4.1	12.2	13.4	-5.9 to -2.2
Beaver Creek near Maytown (12029025)	.59	09-12-2007	8		.5	.6	
Beaver Creek at Littlerock (12029060)	3.02	09-12-2007	8	2.4	2.8	3.3	2.1 to 2.7
Unnamed tributary to Black River near Mima (12029090)	0	09-12-2007	0		.0	.0	
Mima Creek near Mima (12029160)	2.39	09-12-2007	8		2.2	2.6	
Unnamed tributary to Black River near Gate (12029175)	.61	09-12-2007	11		.5	.7	
Black River at Gate (12029180)	70.2	09-12-2007	11	51.4	62.5	77.9	42.5 to 60.2

Table 1. Evaluation of gains and losses, with error analysis measurements for the seepage investigation, Chehalis River basin, Washington, September 2007.—Continued

[Measurement sites are shown at http://wa.water.usgs.gov/projects/chehalis/seepage_run.htm. **Abbreviations**: ft^3/s, cubic foot per second; <, less than; e, estimated; –, no data]

Measurement sites and No.	Measured streamflow (ft^3/s)	Date	Assumed measurement error (percent)	Gain or loss (ft^3/s)	Error-adjusted minimum streamflow (ft^3/s)	Error-adjusted maximum streamflow (ft^3/s)	Net gain or loss uncertainty range (cumulative measurement error; ft^3/s)
Black River near Oakville (12029200)	50.8	09-12-2007	8	-19.4	46.7	54.9	-31.1 to -7.6
Willamette Creek near Howanut Road near Oakville (12029201)	<.1e	09-12-2007	11		.1	.1	
Black River near mouth near Oakville (12029210)	72.1	09-12-2007	8	21.2	66.3	77.9	11.3 to 31
Garrard (Garrod) Creek near Oakville (12029500)	<1e	09-12-2007	11		.9	1.1	
Chehalis River near Oakville (12029700)	363	09-12-2007	8	52.9	334.0	392.0	36.9 to 68.8
Davis Creek near Oakville (12029780)	0	09-12-2007	0		.0	.0	
Chehalis River near Cedarville (12029800)	297	09-12-2007	5	-66.0	282.2	311.9	-109.8 to -22.1
	292	09-13-2007	5		277.4	306.6	
Rock Creek near Cedarville (12030020)	.92	09-13-2007	8		.8	1.0	
Cedar Creek near Cedarville (12030505)	8.28	09-13-2007	8		7.6	8.9	
Gibson Creek near Porter (12030550)	1.63	09-13-2007	5		1.5	1.7	
Chehalis River near Porter (12030600)	331	09-13-2007	5	28.2	314.5	347.6	-3.7 to 60.1
Gaddis Creek near Porter (12030650)	0	09-13-2007			.0	.0	
Porter Creek at U.S. Highway 12 at Porter (12030950)	8.63	09-13-2007	8		7.9	9.3	
Chehalis River at Porter (12031000)	330	09-13-2007	8	-9.6	303.6	356.4	-53.2 to 34
Chehalis River near Malone (12031020)	352	09-13-2007	5	22.0	334.4	369.6	-22 to 66
Eaton Creek at Rony (12031050)	.41	09-13-2007	11		.4	.5	
Delezene Creek near Saginaw (12031860)	2.4	09-13-2007	8		2.2	2.6	
Cloquallum Creek at Elma (12032500)	25.2	09-13-2007	5		23.9	26.5	
Chehalis River near South Elma (12033100)	379	09-13-2007	8	-1.0	348.7	409.3	-50.4 to 48.4
Chehalis River above Satsop River at Fuller (12033305)	423	09-13-2007	8	44.0	389.2	456.8	-20.1 to 108.1
Satsop River near Satsop (12035000)	277	09-13-2007	5		263.2	290.9	

[1] Tributary streamflow (not shown) calculated by MOVE methods (Hirsch, 1982).

[2] Streamflow adjusted to date of downstream measurement site.

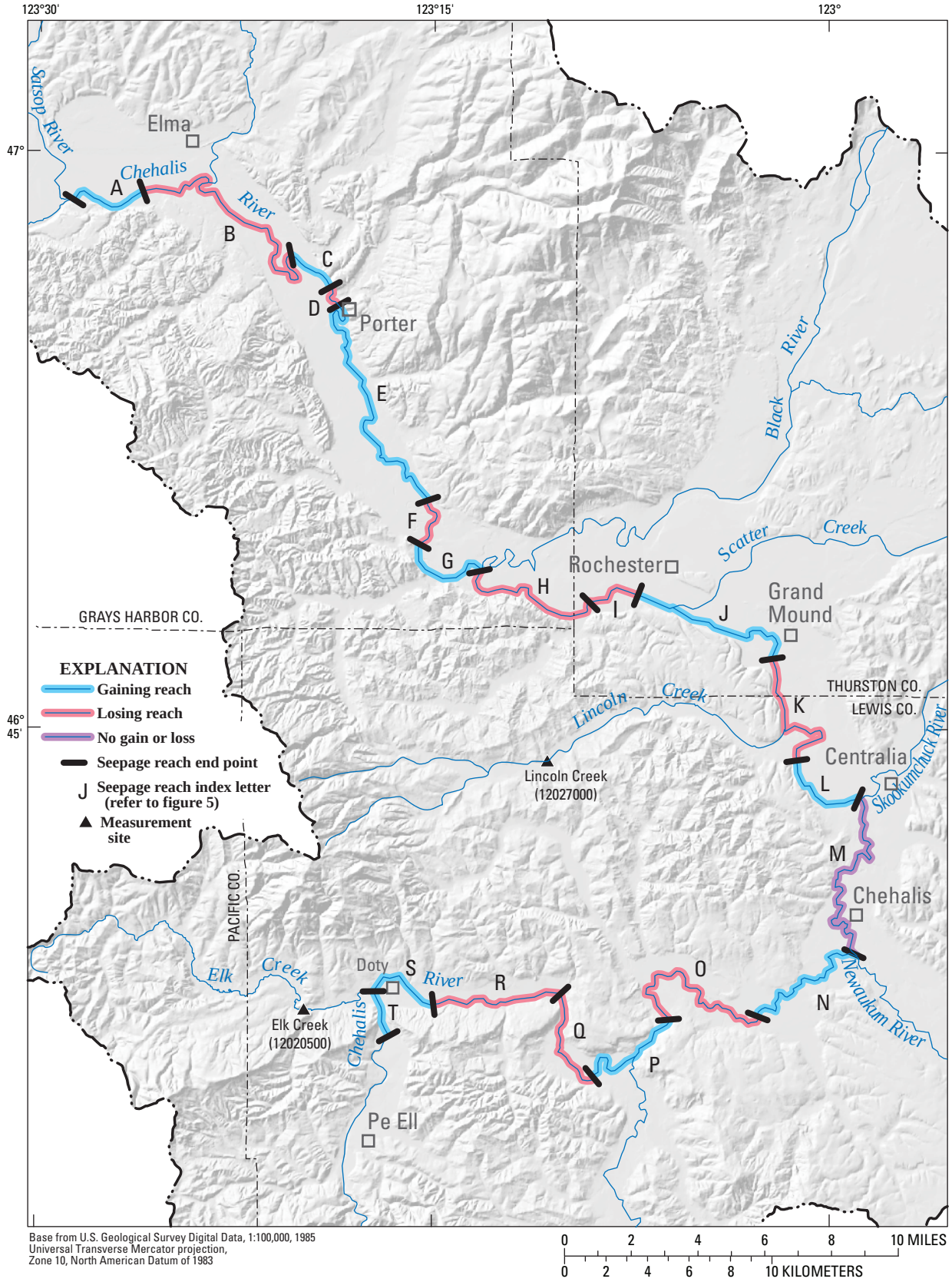


Figure 4. Discharge gains and losses in reaches along the Chehalis River, Washington.

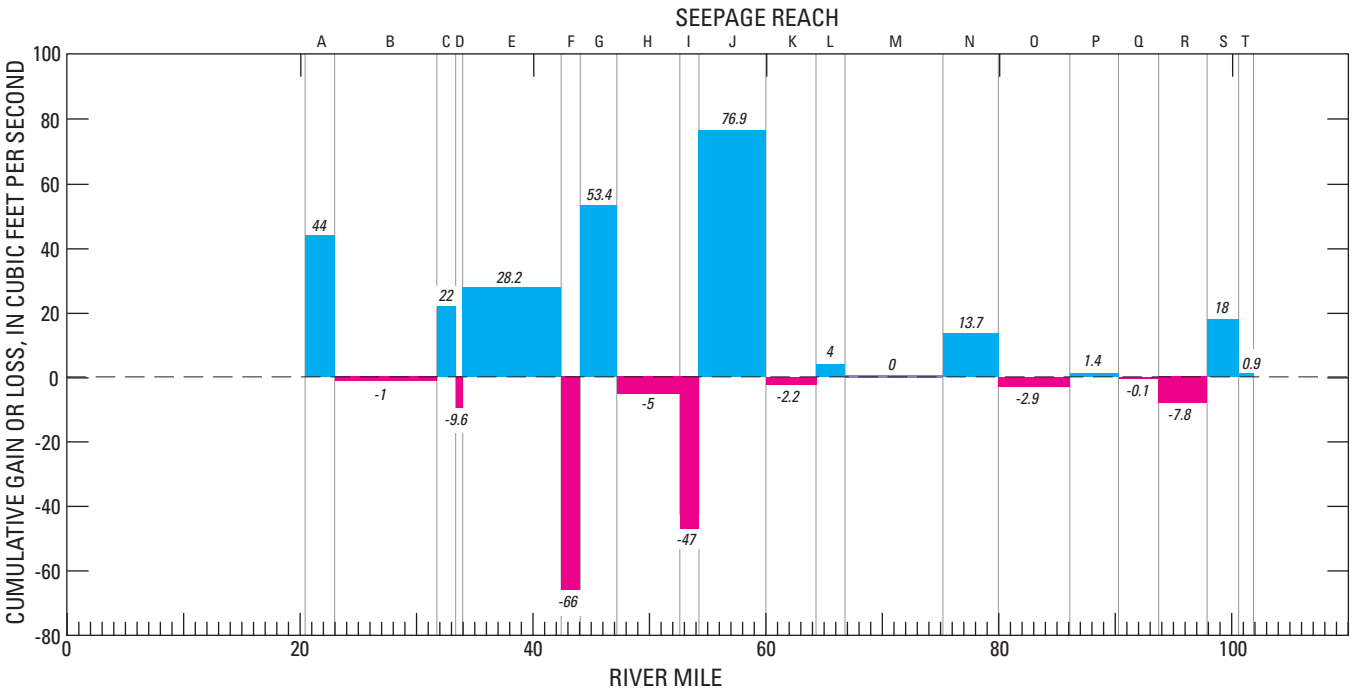


Figure 5. Cumulative discharge gains and losses by river mile, Chehalis River, Washington.

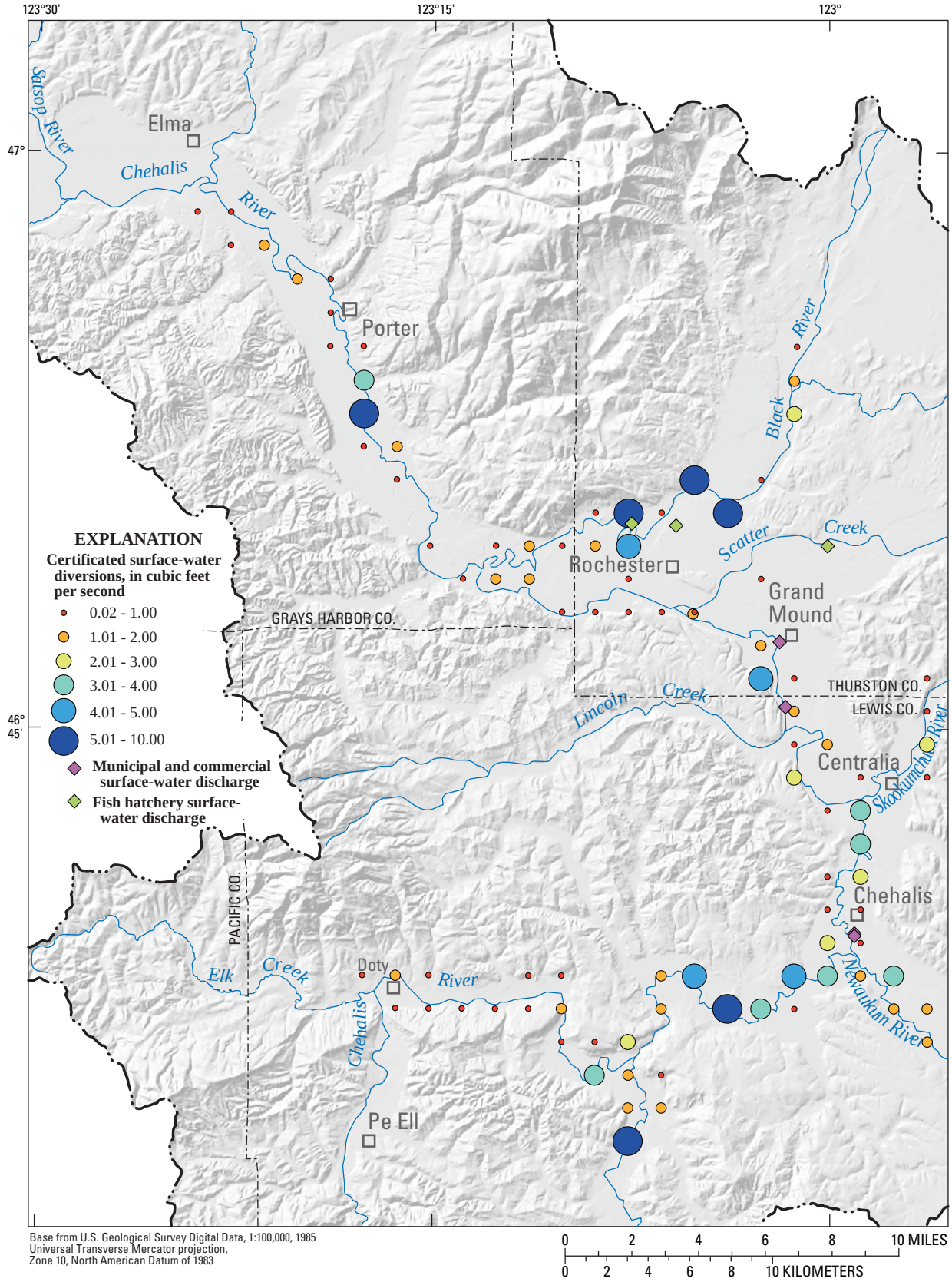


Figure 6. Approximate location of certificated surface-water diversion rates and permitted surface-water discharges along the Chehalis River, Washington.

Summary

A seepage investigation was completed in September 2007 on the Chehalis River and selected tributaries to determine the amount and spatial extent of exchange between the ground and surface-water systems. Discharge was measured at 68 new and existing streamflow sites, resulting in measured gains and losses for 36 stream reaches. Gains were measured for 22 reaches and losses were measured for 13 reaches. No gain or loss was measured at Chehalis River between the Newaukum and Skookumchuck Rivers. The Chehalis River exhibited a pattern of alternating gains and losses as it entered the area of wide, gentle relief known as the Grand Mound Prairie. The general pattern of tributary ground- and surface-water interaction was discharge to streams (gaining reaches) in the upper reaches and discharge to the ground-water system (losing reaches) as the tributaries entered the broad, flat Chehalis River valley. All gains and losses greater than 10 cubic feet per second occurred as the Chehalis River entered the Grand Mound Prairie and continued to flow downstream to the Satsop River.

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Appendix A. Details of Method to Estimate Discharge with Miscellaneous Measurements

Discharge was not measured at Elk and Lincoln Creeks. Discharge at these creeks was estimated using the maintenance of variance extension (MOVE; Hirsch, 1982) method.

$$\hat{Y}_i = \overline{Y} + \frac{s_y}{s_x}\left(X_i - \overline{X}\right) \quad (1)$$

where

$\hat{Y}_i$ is the estimated discharge at the miscellaneous site;

$\overline{Y}$ is the mean of the measured discharge at the miscellaneous site;

s_y is the standard deviation of measured discharge at the miscellaneous site;

s_x is the standard deviation of measured discharge at the index gaging station;

X_i is the measured discharge at the index gaging station for the concurrent period; and

$\overline{X}$ is the mean of the measured discharge at the index gage for the concurrent period.

The conditions for this method are not strictly met, but they did provide an adequate estimate of discharge. Using the MOVE method, a relation was calculated using the means and standard deviations of a series of miscellaneous discharge measurements collected at each creek during late summer to early autumn and daily mean discharge at established USGS streamflow-gaging stations on concurrent days. That relation was applied for the day of the seepage measurement and discharge for Elk and Lincoln Creeks (fig. 4) was estimated. Station 12020500 (Elk Creek) is 2.6 mi west of Doty and 2.5 mi from the confluence with the Chehalis River. Station 12027000 (Lincoln Creek) is 7 mi southwest of Rochester and 8.2 mi from the confluence with the Chehalis River.

Results of the discharge estimation are shown in tables A1 and A2 for Elk and Lincoln Creeks, respectively. The two locations for which discharge were estimated are not located at the confluences with the Chehalis River. It is not known what gains or losses normally occur on Elk and Lincoln Creeks between the miscellaneous site and the Chehalis River. Pitz and others (2005) measured discharges of 0.75 ft^3/s at Lincoln Creek near the mouth and 211 ft^3/s at Chehalis River near Grand Mound. This indicated that the estimated discharge presented here for the Lincoln Creek measurement site (12027000) may be an overestimation of discharge for Lincoln Creek at the confluence with the Chehalis River.

Table A1. Miscellaneous discharge measurements for Elk Creek and daily mean discharge for Chehalis River at Doty, Washington.

[**Abbreviation**: ft^3/s, cubic foot per second]

Date	Elk Creek (12020500) discharge (ft^3/s)	Chehalis River at Doty (12020500) discharge (ft^3/s)
08-16-1951	11	25
08-12-1959	16	38
08-25-1966	11	28
10-06-1966	13	31
08-03-1967	10	27
08-28-1973	13	35
09-11-2007		18
Mean	12.3	30.7
Standard deviation	2.2	5.0
Estimated streamflow	**6.8**	

Table A2. Miscellaneous discharge measurements for Lincoln Creek and daily mean discharge for Chehalis River near Grand Mound, Washington.

[**Abbreviation**: ft^3/s, cubic foot per second]

Date	Lincoln Creek (12027000) discharge (ft^3/s)	Chehalis River near Grand Mound (12031000) discharge (ft^3/s)
08-16-1951	0.42	124
07-10-1958	4.0	240
07-23-1958	2.0	181
08-04-1958	2.5	150
07-13-1959	5.9	435
07-27-1959	2.9	245
08-10-1959	1.8	192
10-02-1973	2.5	370
09-22-1944	5.9	298
10-26-1944	3.9	235
09-12-2007		192
Mean	3.2	247.0
Standard Deviation	1.8	97.3
Estimated streamflow	**2.2**	

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Manuscript approved for publication, September 25, 2008
Prepared by the USGS Publishing Network,
Publishing Service Center, Tacoma, Washington
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