APPENDIX D

Review of Nisqually River Hydrology

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OBJECTIVE

The Nisqually River is one of four major rivers in Pierce County, Washington. The river forms the southern boundary of Pierce County with Thurston and Lewis Counties. This Technical Information Memorandum (TIM) was prepared for Pierce County Surface Water Management as part of the Nisqually River Basin Plan. The objective of this TIM is to evaluate current hydrologic information for the Nisqually River and make recommendations regarding updated hydrologic studies that will be used for future flood hazard mapping and flood mitigation projects on the Nisqually River.

BACKGROUND

The Nisqually River originates from the Nisqually Glacier on the south slope of Mount Rainier and flows approximately 78 miles, west-northwest, to the Nisqually Estuary, where it flows into South Puget Sound. The watershed covers an area of approximately 760 square miles (see Figure 1). La Grande Canyon, at RM 40, divides the Nisqually River watershed into two distinct physiographic areas. Below the canyon, the watershed consists of low hills and prairie plains of glacial outwash. Above the canyon, volcanic rock and steeper mountainous terrain dominate the area. Major tributaries include Mineral Creek, Little Nisqually River, Mashel River, Ohop Creek, Tanwax Creek, and Muck Creek.

Overview of Hydrologic Conditions

Mean annual precipitation within the Nisqually watershed generally increases as elevation increases. On average, the lower portions of the watershed receive from 33 to 50 inches of precipitation per year. The higher portions of the watershed receive greater than 70 inches of precipitation annually. The wettest months are November through January, and the driest months are June, July, and August. Precipitation typically cycles over periods of decades from warm/dry periods to wet/cool periods and back again. The climatic cycles are important in interpreting data on water availability. The lower portion of the watershed has a rain-dominated hydrologic regime, and the upper portion of the basin has a rain-on-snow dominated hydrologic regime.

Flow Controls and River Modifications

There are two hydroelectric facilities on the Nisqually River: the Nisqually Hydroelectric Project, which includes two major dams (La Grande and Alder), and the Yelm Hydroelectric Project, which includes a small diversion dam. Flows in the lower Nisqually River (below River Mile [RM] 42.5) are influenced by La Grande and Alder Dams. Diversions at RM 26.2

influence flows for a 13 mile reach of the river. The locations of these dams are shown in Figure 1. The following sections describe the two hydroelectric projects.

Nisqually Hydroelectric Project

The Nisqually Hydroelectric Project is owned by the City of Tacoma and operated by Tacoma's hydroelectric utility, Tacoma Power. Flows in the lower reaches of the Nisqually River are regulated in part by the Nisqually Hydroelectric Project, which is comprised of La Grande Dam at RM 42.4 and Alder Dam approximately 2 miles upstream at RM 44.2. The original La Grande Dam was built in 1912. This dam was replaced in 1945 and Alder Dam, and its associated reservoir, was added that same year.

La Grande Dam is 192 feet high and has an impoundment storage capacity of 2,700 acre-feet. River flow is diverted at the dam to the powerhouse located approximately 1.7 miles downstream. The diverted water re-enters the Nisqually River downstream of the powerhouse. Water is also released from the impoundment to the Nisqually River to maintain a continuous flow. Alder Dam is 285 feet high and has an impoundment storage capacity of 231,900 acre-feet (Alder Lake). The powerhouse is located at the base of the dam.

In addition to providing hydroelectric power, the Nisqually River Project provides recreational benefits. Alder Lake and its associated parks are used for fishing, camping, picnicking, swimming, water skiing, and boating. The impoundment behind La Grande Dam is not publicly accessible because of the steep topography.

The Nisqually Hydroelectric Project is operated under a license issued by the Federal Energy Regulatory Commission (FERC). The 40-year FERC license (No. 1862) was issued on March 7, 1997. This license contains articles pertaining to operational requirements, including minimum instream flows and reservoir water levels. There are no requirements for flood control or flood storage.

According to Tacoma Power – the operator of the dams – the dams do provide some incidental attenuation of flood flows; however, **there are no flood control requirements for the Nisqually Hydroelectric Project.** When possible and consistent with federal mandate, Tacoma Power voluntarily uses the available storage space to help reduce the downstream crest of the flood. However, Tacoma Power will do so only when these operations remain consistent with prudent operation of the project and the requirements of its federal license (personal communication with Todd Lloyd, Tacoma Power, October 2006).

Yelm Hydroelectric Project

The Centralia Diversion Dam is part of a 12 megawatt run-of-the-river hydroelectric project located at RM 26. The project is owned by City of Centralia Light Department and provides electricity to the citizens on Centralia. The project is operated under a 40-year FERC license (No. 10703-001) issued on March 7, 1997. The diversion dam was constructed in 1930, expanded in 1955, and reconstructed in 1985. The dam is a low head structure that diverts water into a 9.1-mile canal that conveys water to a powerhouse downstream at RM 12.6.

There is no impoundment at the diversion dam, which is a concrete gravity dam with a structural height of 20 feet, but a hydraulic height of only 4 feet at low stages. During high stages the dam is almost completely submerged, with a difference between headwater and tailwater of less than 1 foot (Golder, 2003).

Available Flow Data

The United States Geological Survey (USGS) has collected flow data at numerous stream gauges in the Nisqually River watershed (see Figure 2). The primary active gauges on the Nisqually River include:

- USGS Station No. 12082500 – Located upstream of Alder Dam near the community of National (RM 57.8).
- USGS Station No. 12086500 – Located downstream of La Grande Dam (RM 40.4).
- USGS Station No. 12089500 – Located just downstream of the State Route 507 Bridge on the south bank, left bank looking downstream (RM 21.8).

All of these are real-time stream gauging stations. Two additional real-time gauging stations are operated in the watershed: one on Mineral Creek (USGS Station No. 12083000) and one on the Centralia Diversion Canal (USGS Station No. 12089208). There are two active, non-real-time gauges operated on tributaries: USGS Station No. 12088000 on Ohop Creek and USGS Station No. 12087000 on the Mashel River. USGS also operates gauges at La Grande Dam (No. 12085500) and Alder Dam (No. 12085000), but these record only reservoir stage, not flow. Figure 3 shows a map and schematic of the current USGS stream gauging system in the Nisqually River Watershed.

Figure 4 is a graph showing the available years of peak instantaneous annual discharge data available for all USGS gauges in the Nisqually River Basin.

Peak flows have been collected at National (USGS Station No. 12082500) for over 64 years beginning in 1943. Additional data are available from a gauge that was installed at Alder (USGS Station No. 12084000), approximately 10 miles downstream, recorded from 1932 to 1944. Peak discharges at the Alder gauge were 72% and 76% higher than the National gauge for the 2 years with overlapping records: 1943 and 1944, respectively. Historic peak annual instantaneous discharges are listed in Attachment A and shown in Figure 5.

Peak flow data have been collected at La Grande (USGS Station No. 12086500) since 1907. Four years of data were collected before the first La Grande Dam was built in 1912. Another 12 years of data were collected from 1920 to 1931. Flow records began again in 1945 (after the new La Grande and Alder Dams had been built) and have continued to present day. A total of 78 years of peak flow data are available at this gauge; 62 of those years came after La Grande and Alder Dams were completed. Historic peak annual instantaneous discharges are listed in Attachment A and shown in Figure 5.

Flow measurement at the McKenna gauge began in 1947 and has continued to present day. However, flow data were not collected between 1968 and 1977. During the 1968-77 data gap there was an active USGS gauge upstream of McKenna near RM 33 (USGS Station No. 12088400); data are available at this location from 1942 to 1979. Gauge data at No. 12088400 could be used to augment the data at the McKenna gauge to create a larger or more continuous period of record. Historic peak annual instantaneous discharges are listed in Attachment A and shown in Figure 5.

Current FEMA Study

The Federal Emergency Management Agency (FEMA) conducted a Flood Insurance Study (FIS) of unincorporated Pierce County in 1987 (FEMA, 1987). A detailed hydrologic analysis of the Nisqually River was conducted for the FIS. Table B-1 lists peak discharges for several locations along the River as published in the FIS.

Table D-1. Flood Frequency for the Nisqually River (FEMA, 1987)

Location on Nisqually River	Drainage Area (sq.mi.)	Peak Discharges (cfs)			
		10-Year	50-Year	100-Year	500-Year
At Mouth[1]	711	21,500	29,000	33,000	45,000
Upstream of Horn Creek[1,2]	488	21,000	28,000	32,000	44,000
Upstream of Tanwax Creek[1]	446	20,500	27,000	31,000	43,000
At Skate Creek Road	79	6,250	9,080	10,400	13,600
At Mt. Rainier National Park	66	5,400	7,910	9,040	11,900

1. Discharges reflect regulated conditions.

2. The community of McKenna is located downstream of the Horn Creek confluence.

The FIS does not specify which USGS stream gauges were used in the hydrologic analysis, nor does it specify the period of historical records used. However, the latest year that could have been included is 1987. At minimum, there is an additional 20 years of flow records that have been collected since the publication of the FIS. Included in these recent flow records is the largest peak discharge on record for the Nisqually River, which occurred in 1996, when there was an estimated flood flow of 50,000[1] cubic feet per second (cfs) at the McKenna gauge (No.

[1] Discharge for the February 1996 event was estimated by extrapolation because the recorded stage exceeded the available rating curve.

12089500). Not only is this peak discharge substantially larger than the 100-year discharge listed in Table B-1, but exceeds even the 500-year discharge.

A preliminary analysis was performed to examine flood flow frequency at the McKenna gauge (USGS Station No. 12089500) and approximate the relative change in the discharge-frequency curve that would result from adding the most recent 20 years of flow data. A log-Pearson Type III regression analysis was performed on peak annual discharge records from 1948 to 1987[2] using simply a station skew. This yielded similar results to the discharge frequency data in Table B-1. The log-Pearson Type III regression analysis was then repeated using records from 1948 to 2006. Peak discharge estimates increased between approximately 10 percent and 20 percent for the 10-year to 100-year events when the additional 20 years of data was included (see Figure 6).

RECOMMENDED HYDROLOGIC STUDIES

As discussed in the previous section, over 20 years of additional stream flow data have been collected since the FIS was published in 1987, and a preliminary analysis shows that including these 20 years of data in and updated study could change peak discharges by 10 to 20 percent. Therefore, a new updated hydrologic study is warranted, and should be completed for use in any future flood hazard mapping or flood mitigation studies.

There are various methods for conducting hydrologic analyses. Specific objectives should be defined for the study before determining the most appropriate methodology. The recommendations provided herein are based on the following objective: *An updated hydrologic analysis will be conducted to provide peak discharge-frequency estimates for various points along the Nisqually River, such that the results can be used in hydraulic modeling to develop flood hazard mapping*. Delineated flood hazards zones will consist of both the floodway[3] and flood fringe as defined by Pierce County Code, and should be developed in accordance with FEMA guidelines for map revisions.

The following sections describe specific recommendations.

Flood Flow Frequency Analysis (Bulletin 17B)

All relevant hydrologic analyses from previous studies should be collected and reviewed, particularly those studies completed by FEMA or USGS. An updated flood flow frequency analysis should be performed using historical stream flow data. Historical flow data should be obtained from available USGS stream gauging records as follows:

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[2] Note this did not include any data for 1968 to 1977 for which no data is available. Data could possibly be translated from an upstream gauge; however, including data from the upstream gauge is not expected to have a considerable effect on the flood frequency results.

[3] "Floodway" consists of the FEMA floodway and deep and/or fast flowing water.

- Nisqually River near National (USGS Station No. 12082500): All recorded annual maximum instantaneous peak discharge data on record, which should include approximately 64 data points from 1942 to 2006 (see Figure 5).
- Nisqually River near Alder (USGS Station No. 12084000): All peak annual maximum instantaneous peak discharge data on record, which should include approximately 13 data points from 1931 to 1944. These data could be used to augment the annual series at USGS Station No. 12082500 by proportionally adjusting for drainage area (see Figure 5).
- Nisqually River at La Grande (USGS Station No. 12086500): Annual maximum instantaneous peak discharge data recorded after 1945 (subsequent to the construction of La Grande and Alder Dams), which should consist of a continuous record of 62 data points from 1945 to 2006 (see Figure 5).
- Nisqually River at McKenna (USGS Station No. 12089500): All annual maximum instantaneous peak discharge data on record, all of which was recorded after 1945 (subsequent to the construction of La Grande and Alder Dams). These data should include approximately 50 data points recorded from 1948 to 1968 and from 1978 to 2006 (see Figure 5). Discharges are affected by regulation and diversion. Flow data should also be obtained for the Centralia Power Canal (USGS Station No. 12089208) to examine the relative diversion rates and determine whether any adjustments need to be made to the peak discharges at the McKenna gauge.
- Nisqually River above Powell Creek near McKenna (USGS Station No. 12088400) combined with Nisqually River near McKenna (USGS Station No. 12088500): Historical data for these two gauges has been combined by USGS. Annual maximum instantaneous peak discharge data recorded after 1945 could be used to augment the annual series at USGS Station No. 12089500. A total of 28 data points are available, 11 of which cover years not covered by gauge No. 12089500 (see Figure 5) by proportionally adjusting for drainage area. Discharges are affected by regulation and diversion.

The gauge data described above should be used to compile a continuous series of annual maximum instantaneous peak discharges at each of three primary gauge sites: 1) near National, 2) just downstream of La Grande Dam, and 3) near McKenna. Discharge-frequency analyses should be conducted in accordance with Bulletin 17B guidelines (Interagency Advisory Committee, 1982), which could be performed using public domain software such as HEC-SSP or USGS PeakFQ. Bulletin 17B methodology is used to fit logarithms of annual peak discharges to a Pearson Type III distribution. This method includes options for improving the estimates using a regional skew coefficient, weighing stations and generalized skew to reflect relative gauge accuracy, and adjustments for outliers and gaps in records. Results are used to estimate the magnitude of flood discharges for various recurrence intervals (annual probabilities). Flood flow frequency data could be translated to other points along the Nisqually River by adjusting proportionally to contributing drainage area.

In a regulated river, runoff volume estimates are often more reliable than peak discharge estimates. Flow regulation should be examined with respect to historical dam operations and by comparing peak flows with mean daily flows.

Addressing Climate Change

According to the Intergovernmental Panel on Climate Change (IPCC) – a scientific body established by the World Meteorological Organization (WMO) and by the United Nations Environment Programme (UNEP) – global mean surface temperature has increased over the past 100 years, and projections indicate that the warming trend will continue in the 21st Century (IPCC, 2001). Projections also indicate that some areas will see increases in precipitation, more frequent and intense events, which are likely to lead to increased flooding (IPCC, 2001). Local studies agree with these projections.

A 1997 report by the Environmental Protection Agency (EPA) estimates that by 2100, temperatures in Washington could increase on average by about 5^{o}F in winter and summer, and 4^{o}F in spring and fall (EPA, 1997). The EPA report states that in that same period, precipitation in Washington is projected to change little in spring, summer, and fall, but increase by about 10% in winter.

The Climate Impacts Group (CIG) at the University of Washington completed a study on the impacts of climate change on the Pacific Northwest. The CIG study concluded that temperatures and precipitation in the region will increase (Mote, et al., 1999). Projections show that the increase in mean annual precipitation would be relatively small, but the seasonal variation would be greater with wetter winters and drier summers (Mote, et al., 1999). In addition, the warmer temperatures are predicted to cause snow levels to rise to higher elevations leading to less snowpack and less precipitation falling as snow. Spring runoff will shift becoming earlier and lower, while winter runoff will increase; a change that is likely to lead to increased flooding especially in lower elevations (Mote, et al., 1999).

Projected changes in the regional climate could have a considerable effect on hydrology in the Nisqually River basin. The upper portion of the Nisqually River watershed is high elevation, mountainous terrain, and the headwaters are located high on the south slopes of Mount Rainier. Several glaciers are located near the top of the basin, and large areas are covered with a substantial snowpack in winter. Warming trends could reduce the size and number of glaciers, as well as reduce the overall snowpack in upper elevations. In addition to the above-mentioned shift to earlier spring runoff and larger winter runoff, higher temperatures could cause large winter precipitation events that previously fell as snow to fall as rain over a larger area. These changes could lead to more frequent downstream flooding.

Until recently, standard practice for hydrologic analyses has been to assume that past conditions are representative of future conditions. However, climate change studies suggest that this assumption is not valid. Many agencies have already begun planning for the potential impacts of climate change on natural resources. More recently, agencies have begun recognizing the potential effect on natural hazards. Researchers are still working to develop high-resolution modeling that will project the effects of climate change in Washington relating to the frequency and intensity of storms.

It is recommended that the hydrologic study for the Nisqually River review the latest information related to regional climate change, and make considerations for the potential effects on future flooding conditions.

Coordination with FEMA

An updated hydrologic study for the Nisqually River would be used primarily for updated flood hazard mapping. As such, the new analysis must meet all NFIP requirements. Coordination with FEMA will be necessary to ensure the updated hydrologic analysis will be accepted as a revision to the flood discharges currently published in the effective FIS. Ultimately, FEMA will need to review the updated hydrologic analysis as part of the map revision process.

Considerations for Additional Studies

The recommended hydrologic analysis in Sections 3.1 was based on the objective stated at the beginning of this section. If additional objectives or considerations were identified the hydrologic analysis could be modified or additional studies could be conducted. The following are two suggestions for additional studies:

Creating Administrated Floods of Selected Recurrence Intervals for Alternative Analysis

The flood flow frequency analysis in Section 3.1 only estimates peak discharges. If complete flood flow hydrographs were developed an unsteady-flow hydraulic analysis could evaluate the effects of floodplain storage and attenuation of flood flows along the river channel. In addition, modeling results would provide more detailed depth and velocity data for use in delineating the DFF floodway.

Building on the flood flow frequency analysis, complete design-event flood hydrographs could be developed. Selected historical events would be assigned to a specific recurrence interval and scaled such that the magnitude and duration match the results for that frequency. The design flood hydrograph would be constructed using an *n*-day flood volume method as follows:

1. Assign a recurrence interval to selected historical events for hydraulic analysis.
2. Scale historical events to match the estimated flood quartile, considering both intensity and duration.
3. Create design flood event based on n-day flood volumes (Balocki and Burges, 1994).

Reservoir Simulation

The flood flow frequency analysis in Section 3.1 assumes operations at the dams have remained constant and will not change in the future. A more detailed hydrologic analysis would be required to investigate changes in dam operations. Such an analysis would require additional data such as stage-storage information for the reservoirs, gate/spillway discharge relations, operating rules, and mean daily flow data. Historical stream flow records could be used to develop inflow time series for use in a reservoir simulation model such as HEC-ResSim, which could be used to simulate changes in dam operations and generate outflow time series.

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FIGURES

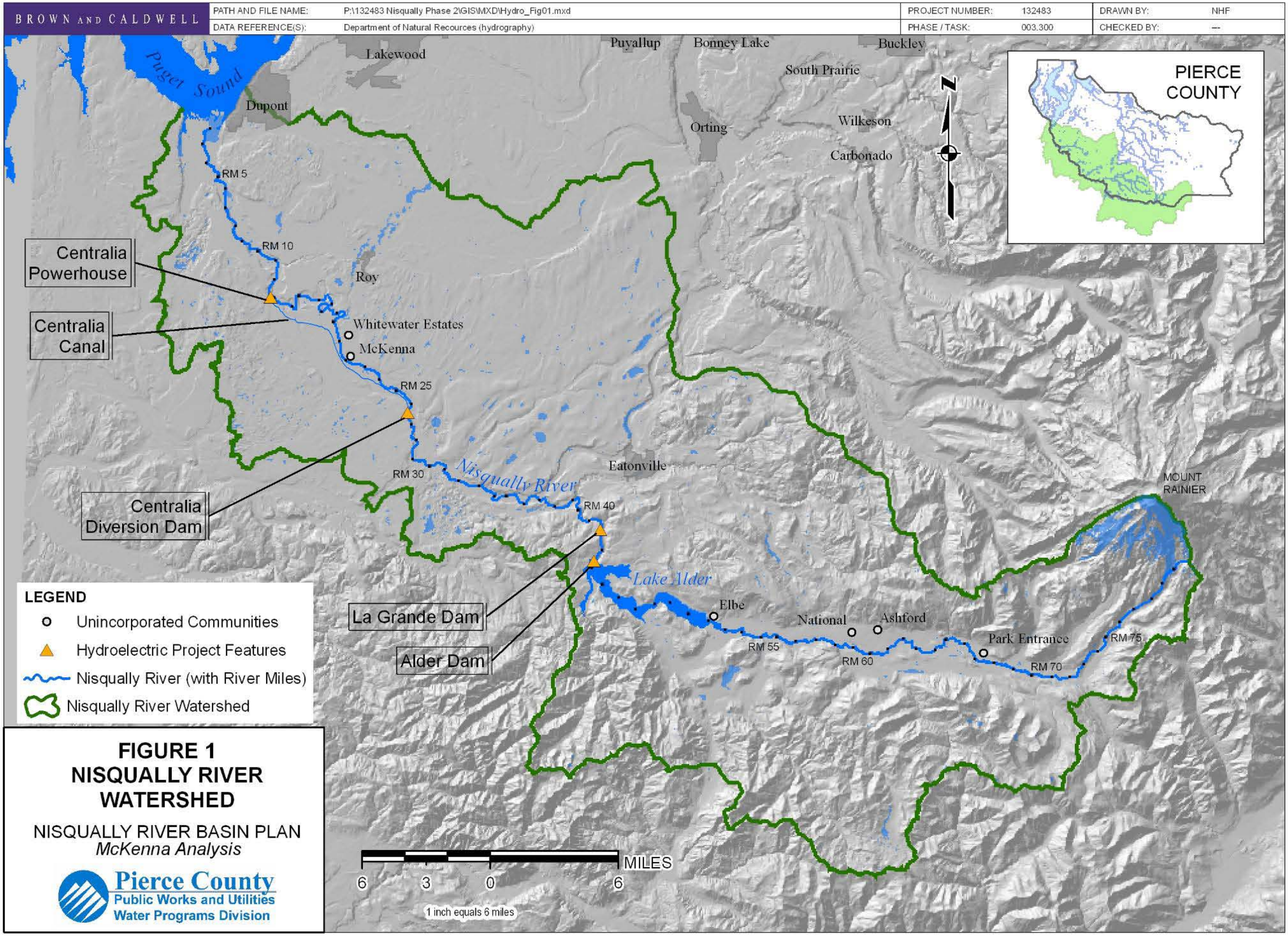

FIGURE 1
NISQUALLY RIVER WATERSHED

NISQUALLY RIVER BASIN PLAN
McKenna Analysis

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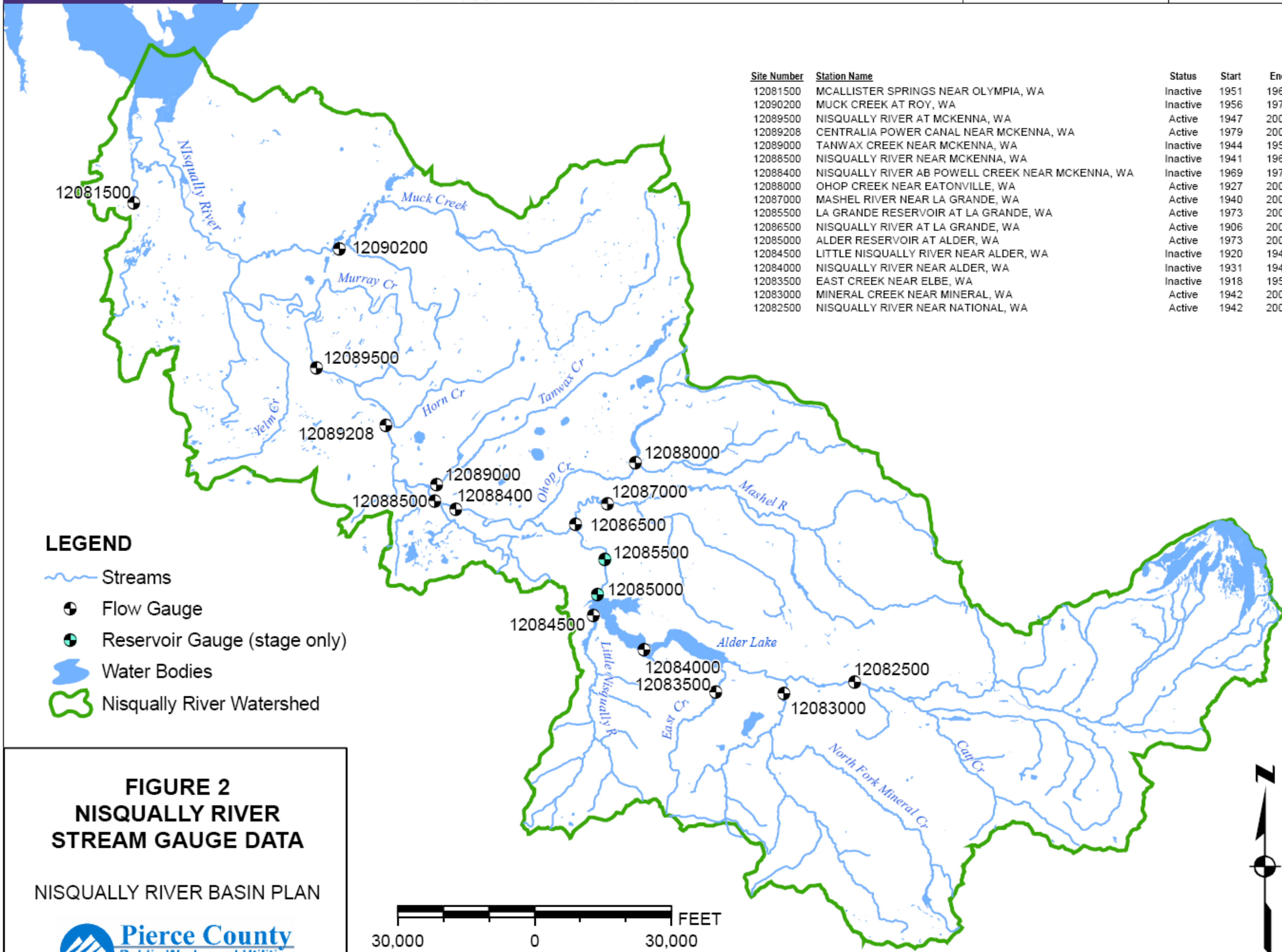
	DATA REFERENCE(S):	U.S. Geological Survey (gages), Pacific Northwest Hydrography Framework	PHASE / TASK:	003.300	CHECKED BY:	---



Site Number	Station Name	Status	Start	End	Years
12081500	MCALLISTER SPRINGS NEAR OLYMPIA, WA	Inactive	1951	1964	11
12090200	MUCK CREEK AT ROY, WA	Inactive	1956	1971	15
12089500	NISQUALLY RIVER AT MCKENNA, WA	Active	1947	2007	47
12089208	CENTRALIA POWER CANAL NEAR MCKENNA, WA	Active	1979	2007	25
12089000	TANWAX CREEK NEAR MCKENNA, WA	Inactive	1944	1950	6
12088500	NISQUALLY RIVER NEAR MCKENNA, WA	Inactive	1941	1963	22
12088400	NISQUALLY RIVER AB POWELL CREEK NEAR MCKENNA, WA	Inactive	1969	1979	11
12088000	OHOP CREEK NEAR EATONVILLE, WA	Active	1927	2007	46
12087000	MASHEL RIVER NEAR LA GRANDE, WA	Active	1940	2007	29
12085500	LA GRANDE RESERVOIR AT LA GRANDE, WA	Active	1973	2007	34
12086500	NISQUALLY RIVER AT LA GRANDE, WA	Active	1906	2007	77
12085000	ALDER RESERVOIR AT ALDER, WA	Active	1973	2007	34
12084500	LITTLE NISQUALLY RIVER NEAR ALDER, WA	Inactive	1920	1943	23
12084000	NISQUALLY RIVER NEAR ALDER, WA	Inactive	1931	1944	13
12083500	EAST CREEK NEAR ELBE, WA	Inactive	1918	1950	5
12083000	MINERAL CREEK NEAR MINERAL, WA	Active	1942	2007	61
12082500	NISQUALLY RIVER NEAR NATIONAL, WA	Active	1942	2007	61

LEGEND

- Streams
- Flow Gauge
- Reservoir Gauge (stage only)
- Water Bodies
- Nisqually River Watershed

30,000 0 30,000 FEET

1 inch equals 30,000 feet

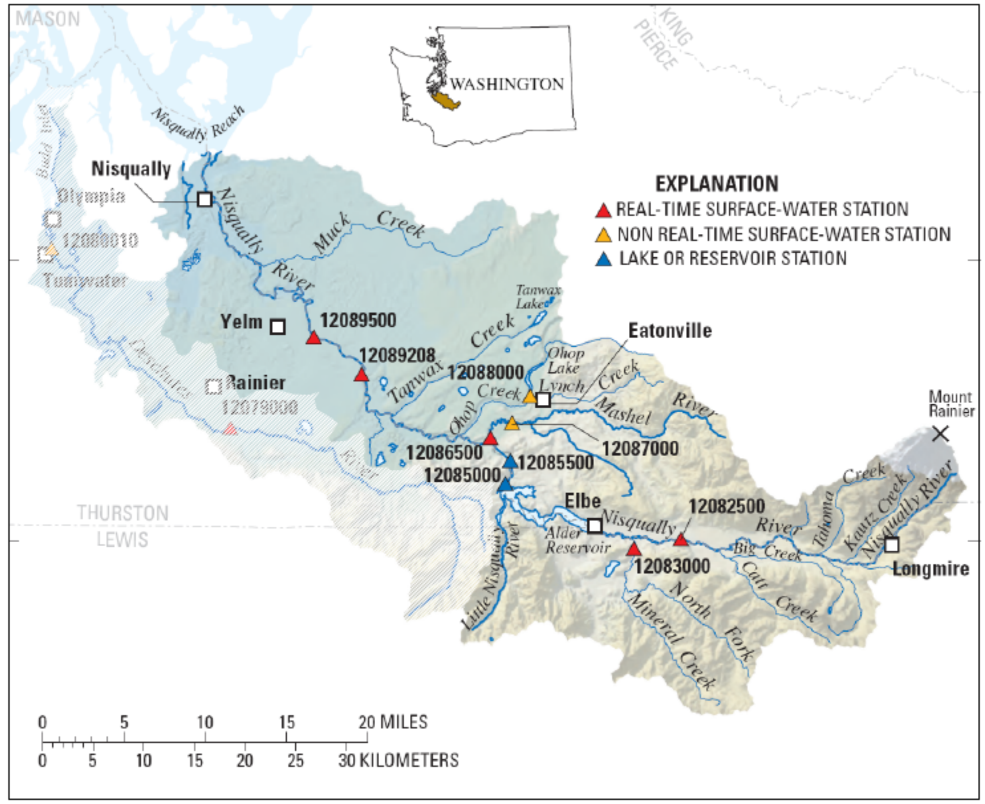
FIGURE 2
NISQUALLY RIVER STREAM GAUGE DATA

NISQUALLY RIVER BASIN PLAN

Pierce County
Public Works and Utilities
Water Programs Division

BROWN AND CALDWELL	PATH AND FILE NAME:	P:\132483 Nisqually Phase 2\GIS\MXD\Hydro_Fig03.mxd	PROJECT NUMBER:	132483	DRAWN BY:	NHF
	DATA REFERENCE(S):	United States Geological Survey	PHASE / TASK:	003.300	CHECKED BY:	--

Map and Schematic obtained from USGS:
http://wa.water.usgs.gov/data/realtime/adr/interactive/maps/NisquallySC_basin.pdf
http://wa.water.usgs.gov/data/realtime/adr/interactive/schematics/Nisqually.pdf



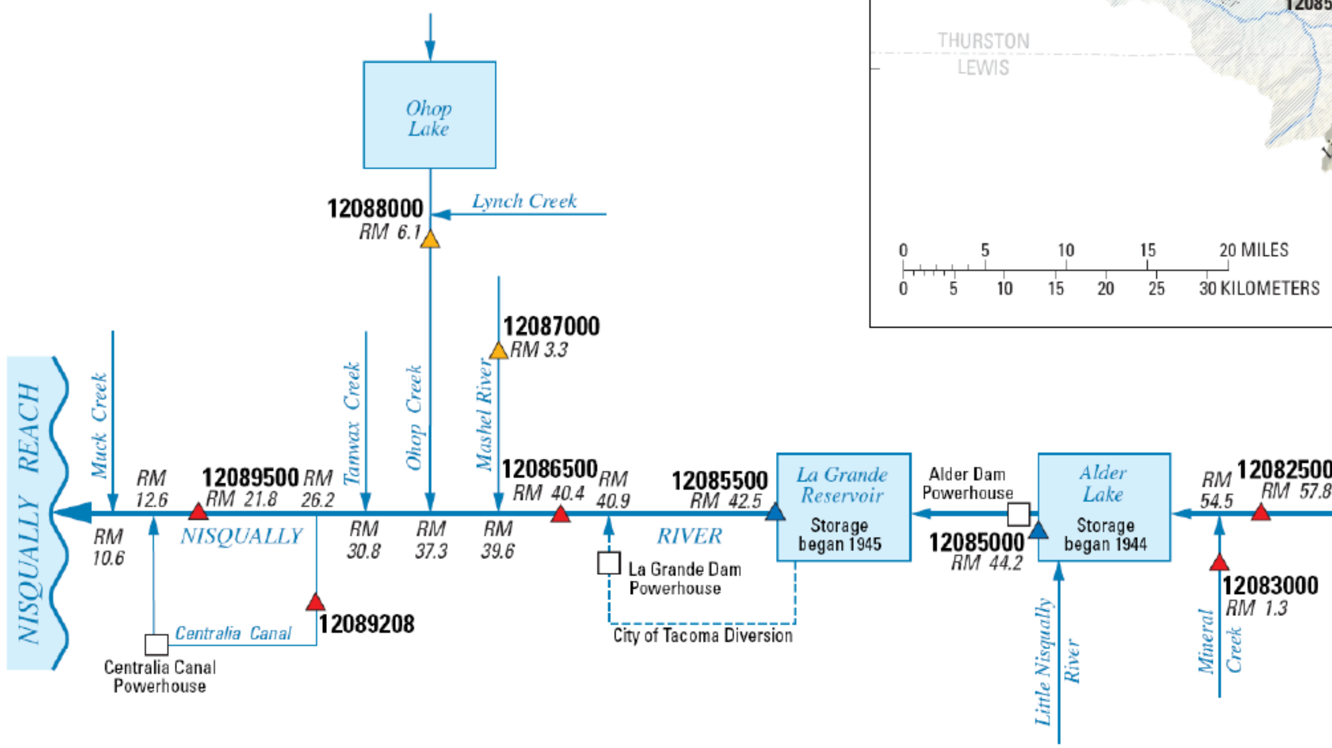


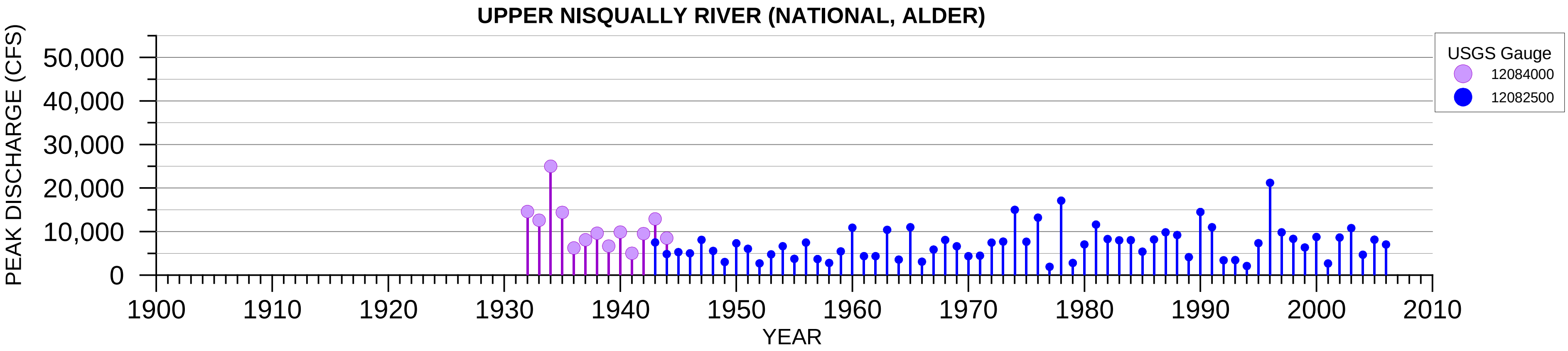
FIGURE 3
USGS SCHEMATIC AND MAP ACTIVE NISQUALLY GAUGES

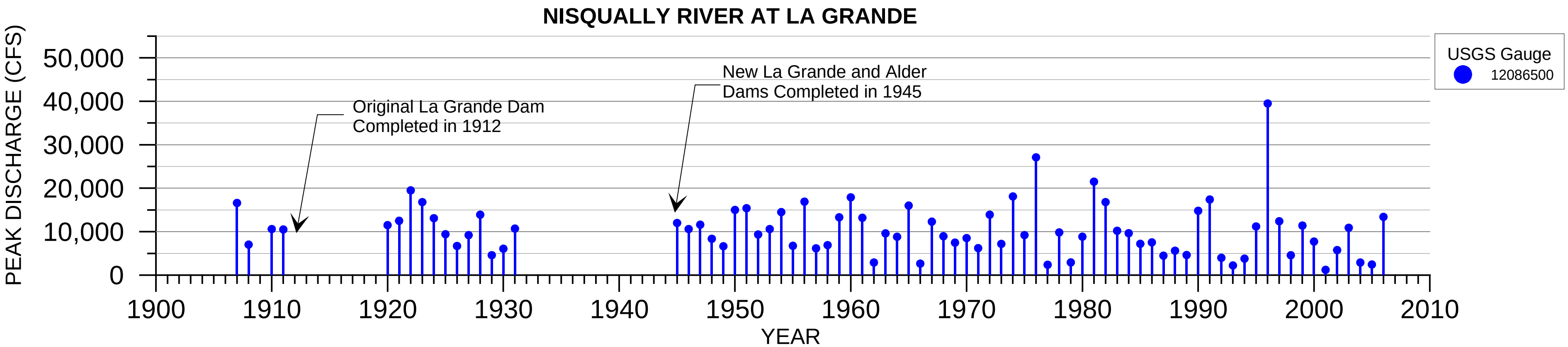
NISQUALLY RIVER BASIN PLAN

Pierce County
Public Works and Utilities
Water Programs Division

FIGURE 4 – USGS Gauge Records for Nisqually River Watershed

Site Number	Station Name	1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2006	No. of Q_{peak}	Drainage Area	River Mile
12090200	MUCK CREEK AT ROY, WA		21	86.8	
12089500	NISQUALLY RIVER AT MCKENNA, WA		50	517.0	21.8
12089208	CENTRALIA POWER CANAL NEAR MCKENNA, WA		12	*diversion flow*	
12089000	TANWAX CREEK NEAR MCKENNA, WA		6	26.0	
12088500	NISQUALLY RIVER NEAR MCKENNA, WA		22	445.0	
12088400	NISQUALLY RIVER AB POWELL CREEK NEAR MCKENNA, WA		32	431.0	
12088000	OHOP CREEK NEAR EATONVILLE, WA		52	34.5	6.1
12087000	MASHEL RIVER NEAR LA GRANDE, WA		32	80.7	3.3
12086500	NISQUALLY RIVER AT LA GRANDE, WA		78	292.0	40.4
12084500	LITTLE NISQUALLY RIVER NEAR ALDER, WA		23	28.0	
12084000	NISQUALLY RIVER NEAR ALDER, WA		13	252.0	
12083000	MINERAL CREEK NEAR MINERAL, WA		64	75.2	1.3
12082500	NISQUALLY RIVER NEAR NATIONAL, WA		64	133.0	57.8
12085500	LA GRANDE RESERVOIR AT LA GRANDE, WA		*stage only*	289.0	42.5
12085000	ALDER RESERVOIR AT ALDER, WA		*stage only*	286.0	44.2
12081990	TAHOMA CREEK AT HIGHWAY BRIDGE NEAR ASHFORD, WA		*no data available on-line*		
12081900	KAUTZ CREEK (UPPER SITE) NEAR LONGMIRE, WA		*no data available on-line*		
12081590	NISQUALLY RIVER AB DEAD HORSE CR AT PARADISE, WA		*no data available on-line*		





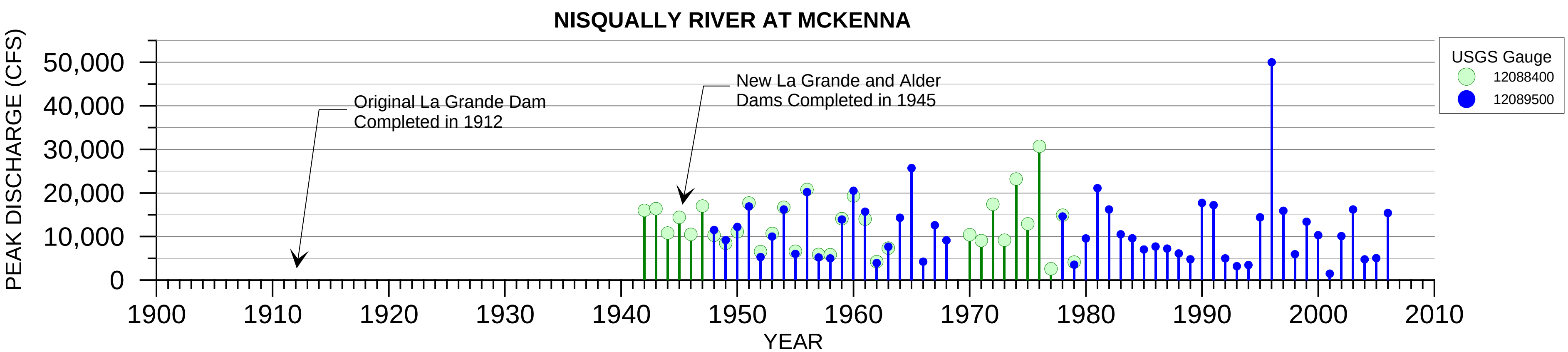


FIGURE 5. Annual Peak Discharges Recorded at the Nisqually River Gauge

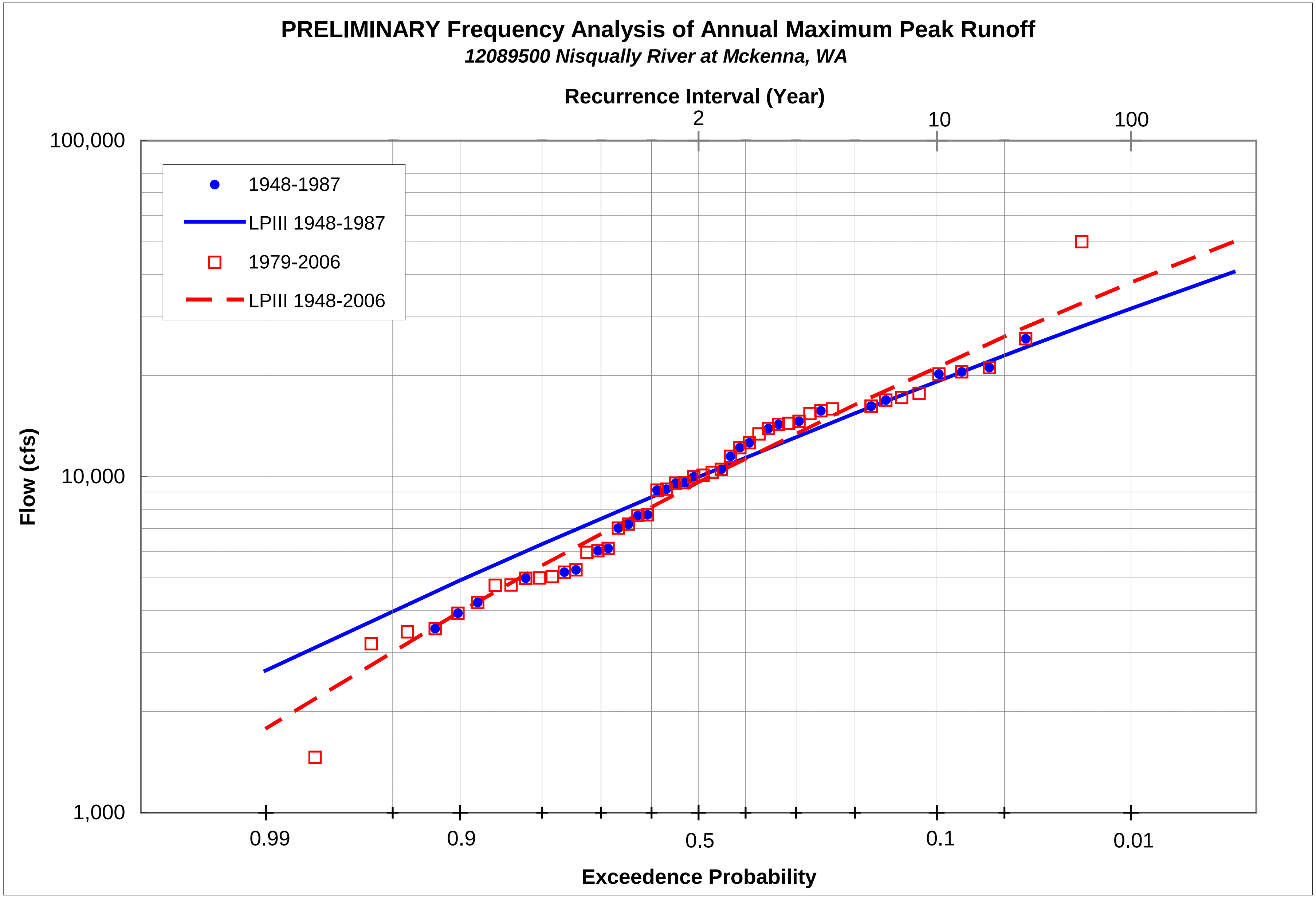


Figure 6. Preliminary Results for Frequency Analysis at McKenna Gauge

Attachment A. Historic Peak Annual Instantaneous Discharges at USGS Gauges (cfs)			
Year	Nisqually River at National: USGS Gauge No. 12082500 unless otherwise noted	Nisqually River at La Grande: USGS Gauge No. 12086500 unless otherwise noted	Nisqually River at McKenna: USGS Gauge No. 12089500 unless otherwise noted
1907	--	16,600	--
1908	--	7,020	--
1909	--	--	--
1910	--	10,600	--
1911	--	10,500	--
1912	--	--	--
1913	--	--	--
1914	--	--	--
1915	--	--	--
1916	--	--	--
1917	--	--	--
1918	--	--	--
1919	--	--	--
1920	--	11,500	--
1921	--	12,500	--
1922	--	19,500	--
1923	--	16,800	--
1924	--	13,100	--
1925	--	9,410	--
1926	--	6,700	--
1927	--	9,200	--
1928	--	13,900	--
1929	--	4,590	--
1930	--	6,070	--
1931	--	10,700	--
1932	14,600[1]	--	--
1933	12,600[1]	--	--
1934	25,000[1]	--	--
1935	14,400[1]	--	--
1936	6,230[1]	--	--
1937	8,100[1]	--	--
1938	9,620[1]	--	--
1939	6,660[1]	--	--
1940	9,880[1]	--	--
1941	5,010[1]	--	--
1942	9,520[1]	--	16,000[2]
1943	7,500	--	16,400[2]
1944	4,830	--	10,800[2]
1945	5,280	12,000	14,400[2]
1946	5,000	10,600	10,500[2]
1947	8,100	11,600	17,000[2]
1948	5,560	8,360	11,500

Attachment A. Historic Peak Annual Instantaneous Discharges at USGS Gauges (cfs)			
Year	Nisqually River at National: USGS Gauge No. 12082500 unless otherwise noted	Nisqually River at La Grande: USGS Gauge No. 12086500 unless otherwise noted	Nisqually River at McKenna: USGS Gauge No. 12089500 unless otherwise noted
1949	3,010	6,640	9,170
1950	7,310	15,000	12,200
1951	6,050	15,400	16,900
1952	2,700	9,350	5,280
1953	4,760	10,600	9,990
1954	6,640	14,500	16,200
1955	3,740	6,740	6,020
1956	7,470	16,900	20,200
1957	3,680	6,160	5,190
1958	2,790	6,900	4,980
1959	5,450	13,300	13,900
1960	10,900	17,900	20,500
1961	4,350	13,200	15,700
1962	4,350	2,900	3,920
1963	10,400	9,600	7,660
1964	3,560	8,820	14,300
1965	11,000	16,000	25,700
1966	3,080	2,650	4,220
1967	5,870	12,300	12,600
1968	8,070	8,940	9,120
1969	6,620	7,470	--
1970	4,350	8,520	10,400[2]
1971	4,460	6,210	9,070[2]
1972	7,460	13,900	17,400[2]
1973	7,700	7,190	9,160[2]
1974	15,000	18,100	23,200[2]
1975	7,660	9,210	12,900[2]
1976	13,200	27,100	30,700[2]
1977	1,910	2,380	2,590[2]
1978	17,100	9,820	14,600
1979	2,790	2,920	3,530
1980	7,050	8,840	9,560
1981	11,600	21,500	21,100
1982	8,280	16,800	16,200
1983	8,000	10,200	10,500
1984	8,020	9,640	9,590
1985	5,380	7,200	7,020
1986	8,180	7,530	7,700
1987	9,830	4,470	7,220
1988	9,200	5,620	6,110
1989	4,130	4,620	4,760
1990	14,500	14,800	17,700
1991	11,000	17,400	17,200

Attachment A. Historic Peak Annual Instantaneous Discharges at USGS Gauges (cfs)

Year	Nisqually River at National: USGS Gauge No. 12082500 unless otherwise noted	Nisqually River at La Grande: USGS Gauge No. 12086500 unless otherwise noted	Nisqually River at McKenna: USGS Gauge No. 12089500 unless otherwise noted
1992	3,410	3,980	4,990
1993	3,440	2,220	3,180
1994	2,090	3,790	3,450
1995	7,340	11,200	14,400
1996	21,200	39,500	50,000
1997	9,820	12,400	15,900
1998	8,330	4,570	5,950
1999	6,350	11,400	13,400
2000	8,750	7,720	10,300
2001	2,670	1,210	1,460
2002	8,630	5,750	10,100
2003	10,800	10,900	16,200
2004	4,680	2,900	4,750
2005	8,140	2,440	5,040
2006	7,030	13,400	15,400

1. *Data from USGS Gauge No. 12084000, Nisqually River near Alder, WA. No scaling factor has been applied to these data.*
2. *Data from USGS Gauge No. 12088400, Nisqually River AB Powell Creek near McKenna, WA. No scaling factor has been applied to these data.*