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Historical Streamflow and Stage Data Compilation for the Lower Columbia River, Pacific Northwest

Open-File Report 2020–1138

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

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Contents

Figures

Tables

Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)

Datums

Vertical coordinate information is referenced to various vertical reference datums and primarily to the North American Vertical Datum of 1988 (NAVD 88).

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

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

Abbreviations

CRD	Columbia River Datum
GMT	Greenwich Mean Time
LCR	Lower Columbia River
NFDA	National Federal Data Archive
NOAA	National Oceanic and Atmospheric Administration
NWIS	National Water Information System
OWRD	Oregon Water Resources Department
PDT	Pacific Daylight Time
PNNL	Pacific Northwest National Laboratory
PST	Pacific standard time
PSU	Portland State University
STND	Station Datum
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WA-DOE	Washington Department of Ecology

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Abstract

The U.S. Geological Survey (USGS) mined data from a variety of national and state agencies including USGS, Oregon Water Resources Department, National Oceanic and Atmospheric Administration, Washington Department of Ecology, Pacific Northwest National Laboratory, Portland State University, and U.S. Army Corps of Engineers (USACE). A comprehensive dataset of streamflow, stage, and tidal elevations for the Lower Columbia River basin was compiled. Data were compiled from gaging stations in Oregon and Washington along the Columbia River from Astoria to The Dalles and along the Willamette River from Salem to Portland. Tidal gages along the Washington, Oregon, and California coasts were also compiled. Seasonal maximum values were calculated for both streamflow and stage for the winter (November–March) and spring (April–July) flow seasons, as well as for the full water year when underlying data were available. The aggregated datasets are available at https://doi.org/10.5066/P9R6RT0Z.

Introduction

The U.S. Geological Survey (USGS) supported the U.S. Army Corps of Engineers in compilation of streamflow and stage data along with quality assurance of acquired data to be used by USACE in a reanalysis of the current flood profiles for the Lower Columbia River (LCR) basin. Flood profiles, also known as “stage-frequency curves,” are defined as the annual probability the water level at a given river mile will exceed a specific elevation. The use of accurate flood profiles is important for floodplain management and levee risk assessments. The flood profiles currently used for the Lower Columbia and Willamette Rivers were first developed in 1990 as part of the Columbia River and Tributaries Study 1963 (U.S. Army Corps of Engineers, 1991).

Purpose and Scope

The purpose of this study was to compile an up-to-date dataset of daily mean streamflow, annual peak streamflow, stage, and tidal elevations that will allow for USACE to reanalyze flood profiles and update estimates of uncertainty. The updated profiles will support the mission of the U.S. Army Corps of Engineers (USACE) and other public agencies in the study area involved with the mitigation of flood impacts. All findings are summarized in this report with data published in Boudreau and others (2021). Additionally, three USGS stations were analyzed to provide additional information for future hydrologic modeling efforts in the study area.

Study Area

The LCR basin includes all watersheds draining into the Columbia River from its mouth to downstream of the Bonneville Dam (river mile 146). While much of the study area was in the LCR basin, a few additional areas, upstream of Bonneville Dam to the Dalles along with some tidal stations along the California, Oregon, and Washington coasts, were included. Tidal stations were included for this study in order to look at potential effects from tides and surges on the interior gages. The study area (fig. 1) includes the Columbia River from Astoria to The Dalles, the Willamette River from Salem to Portland, and portions of the California, Oregon, and Washington coasts. For easier viewing, the study area (fig. 1) was divided into sub-regions, which included gages from all data sources for the designated regions: Coastal Washington and Oregon (fig. 2), Lower Columbia River Estuary (fig. 3), Upper Columbia River Estuary (fig. 4), Longview to Portland (fig. 5), Willamette River Coastal (fig. 6), Willamette River Cascades (fig. 7), and Troutdale to The Dalles (fig. 8) gages. Figures 2 through 8 depict the individual sub-regions.

Figures 1–8. Figures 1–8 are located at this back of the report.

Methodology

Streamflow data were gathered as daily-mean streamflow and annual peak streamflow along the Columbia River from The Dalles to Astoria and along the Willamette River from Salem to Portland. Data were not collected from stations that did not contain sufficient period of record length or were not in locations needed for future modeling efforts. When available, finer-resolution streamflow data (sub-daily) were collected for a selection of historic flooding events that occurred on December 1933, December 1964, January 1974, February 1982, February 1986, February 1996, January 1997, and January 2006. Stage data were gathered at a finer resolution (sub-daily) from available locations on the Columbia River below Bonneville Dam and along the Willamette River below Willamette Falls. Hourly tidal data were gathered from sites along the Oregon and Washington coasts as well as from sites on the Columbia River from Vancouver, Washington, to Astoria, Oregon (fig. 2).

All data were compiled in a HEC-DSSVue (U.S. Army Corps of Engineers, 2018a) database file. HEC-DSSVue is a java-based program allowing the user to both visualize and manipulate data in the database file format (.dss). Each dataset is saved in HEC-DSSVue with an associated pathname that follows the format /A/B/C/D/E/F. The various parts, A–F, are described in more detail in table 1, along with pathname examples in table 2.

Table 1. HEC-DSSVue database file pathname parts and descriptions.

Part	Description
A	Project, river, or basin name
B	Location or station identifier
C	Data parameter
D	Time frame of data
E	Time interval
F	Additional user-defined information

Table 2. Three examples of HEC-DSSVue database file pathnames, following a /A/B/C/D/E/F format.

[/A/B/C/D/E/F, Project river or basin name/Location or station identifier/Data parameter/Time frame of data/Time interval/Additional user-defined information]

Example	File pathname
1	/WILLAMETTE RIVER AT NEWBERG, OR/14197900/FLOW-DAILY MEAN/01JAN2001-01JAN2018/1DAY/USGS-NWIS/
2	/WILLAMETTE RIVER AT NEWBERG, OR/14197900/ELEV-NAVD88/01OCT2001-01MAR2018/IR-MONTH/USGS-AQ-CALCULATED/
3	/WILLAMETTE RIVER AT NEWBERG, OR/14197900/FLOW-2006/01DEC2005-01JAN2006/30MIN/USGS-NWIS/

Pathname parts A or B could be blank if a river name or station identifier/location were not available from the data source. Names were not added to these records in order to avoid future confusion when referencing the original data. For part C, the data parameter, see table 3 for explanations of the abbreviations used and their expanded descriptions. In some instances, part D, the data time range, could differ slightly in the pathname versus the actual dataset if the original data file was edited after upload. The time interval, part E, abbreviations are explained in table 3*B*. Part F, the additional user-defined information, was used to note the source where the data were retrieved from for this study. Table 3 describes the abbreviated part F sources with an expanded description.

Table 3. Abbreviations and detailed explanations for the HEC-DSSVue database pathname parts.

[**Abbreviations**: NAVD 88, North American Vertical Datum of 1988; USACE, U.S. Army Corps of Engineers]

Abbreviation	Description
HEC-DSSVue pathname part C: Data parameter	
ELEV-NAVD88	Elevation in NAVD 88
ELEV-NAVD88-MAX	Daily maximum elevation in NAVD 88
ELEV-NAVD88-MEAN	Daily mean elevation in NAVD 88
ELEV-NAVD88-MIN	Daily minimum elevation in NAVD 88
ELEV-STND	Elevation in Station Datum (an arbitrarily established fixed elevation)
ELEV-TAILWATER	Elevation tailwater (below dam structures)
FLOW	Streamflow (digitized from paper file post-flood reports)
FLOW-1933	Streamflow from the 1933 flooding event
FLOW-1964	Streamflow from the 1964 flooding event
FLOW-1974	Streamflow from the 1974 flooding event
FLOW-1982	Streamflow from the 1982 flooding event
FLOW-1986	Streamflow from the 1986 flooding event
FLOW-1996	Streamflow from the 1996 flooding event
FLOW-1997	Streamflow from the 1997 flooding event
FLOW-2006	Streamflow from the 2006 flooding event
FLOW-ANNUAL PEAK	Annual peak streamflow
FLOW-DAILY MEAN	Daily mean streamflow
FLOW-OUT	Calculated streamflow output below structures (calculated by USACE based on hydraulic tables for gate openings)
STAGE	Stage (local datum)
STAGE-DAILY MAX	Daily maximum stage
STAGE-DAILY MEAN	Daily mean stage
STAGE-DAILY MIN	Daily minimum stage
STAGE-EVENT MAX	Event maximum stage values

Abbreviation	Description
STAGE-SPING ANNUAL MAX	Spring peak stage values (digitized from USACE drawings)
STAGE-WINTER ANNUAL MAX	Winter peak stage values (digitized from USACE drawings)
HEC-DSSVue pathname part E: Time Interval	
15MIN	15-minute time stamp interval
1DAY	Daily time stamp interval
1YEAR	Annual time stamp interval
2HOUR	2-hour time stamp interval
30MIN	30-minute time stamp interval
IR-CENTURY	Irregular, varying time interval on a century time block. Associated only with the Annual Peak Streamflow datasets.
IR-MONTH	Irregular, varying time interval on a month time block.
IR-YEAR	Irregular, varying time interval on a year time block.
15MIN	15-minute time stamp interval
HEC-DSSVue pathname part F: Data Source	
1943 POST-FLOOD REPORT	Digitized paper files from the 1943 USACE post-flood report
1948 POST-FLOOD REPORT	Digitized paper files from the 1948 USACE post-flood report
1954 POST-FLOOD REPORT	Digitized paper files from the 1954 USACE post-flood report
1956 POST-FLOOD REPORT	Digitized paper files from the 1956 USACE post-flood report
1961 POST-FLOOD REPORT	Digitized paper files from the 1961 USACE post-flood report
1964 POST-FLOOD REPORT	Digitized paper files from the 1964 USACE post-flood report
1965 POST-FLOOD REPORT	Digitized paper files from the 1965 USACE post-flood report
1974 POST-FLOOD REPORT	Digitized paper files from the 1974 USACE post-flood report
1996 POST FLOOD REPORT	Digitized paper files from the 1996 USACE post-flood report
CL -03-112, CL -03-116	Digitized data from USACE drawings CL -03-112 and CL -03-116
COMBINED-DQ-NOAA	Data files combined with USACE Dataquery data supplementing NOAA data
COMBINED-DQ-USGS	Data files combined with USACE Dataquery data supplementing USGS data
COMBINED-DQ-USGS-CALCULATED	Data files combined with USACE Dataquery data supplementing USGS data, converted to elevation in NAVD 88
DATAQUERY	Data files supplied by USACE Dataquery database
DATAQUERY-CALCULATED	Data files supplied by USACE Dataquery database, converted to NAVD 88
NOAA	National Oceanic and Atmospheric Administration
OWRD	Oregon Water Resources department
PNNL	Pacific Northwest National Laboratory
PSU	Portland State University
PSU-NOAA	NOAA data retrieved by Portland State University
PSU-NOAA-CORRECTED	Portland State University determined datum correction to NOAA dataset
USACE POST-FLOOD REPORTS	Digitized paper files from various USACE post-flood reports
USGS-AQ-CALCULATED	USGS data retrieved from the internal NWIS database, converted to elevation in NAVD 88
USGS-ARCHIVES	USGS data retrieved from the National Federal Data Archive
USGS-NWIS	USGS data retrieved from the National Water Information System
USGS-NWIS-CALCULATED	USGS stage data retrieved from the National Water Information System, converted to elevation in NAVD 88
USGS-OWRD	Stations previously operated by USGS and currently operated by OWRD
WA-DOE	Washington Department of Ecology

Data Sources

This section summarizes sources from which data were compiled. Gages were not identified as being tidally influenced or regulated during this data compilation.

United States Geological Survey (USGS)

Data from 65 USGS gages were compiled for this study (table 4; figs. 4, 5, 6, 7, and 8). Multiple sources were used when compiling data from USGS stations. The USGS National Water Information System (NWIS) website was used for both historical and recent readily available data (U.S. Geological Survey, 2018). The USGS internal NWIS database was used to download stage data which has historically not been available on NWIS. Historical data that were not available in NWIS or electronic format were requested from the National Federal Data Archive (NFDA). An inventory of available data was searched, and a request made to the NFDA for temporary use of the archived records of interest. These records included pre-digital, analog recordings of gage height, such as mechanical stage recorders, paper copies of daily flow values, historic gage documentation, and paper copies of stage-discharge rating tables. Some historical stage-discharge rating tables (table 5) were recreated in the internal USGS database so they could be expanded to determine streamflow from historic stage data. For the historic flooding events of interest, 45 USGS gages had at least 1 flooding event where finer resolution (sub-daily) data were retrieved. Table 6 details the USGS sites and corresponding flooding event dates compiled. All datasets were compiled in Pacific standard time (PST). The gage datum used for the compiled stage data varied. Recorded datums were Columbia River Datum (CRD), National Geodetic Vertical Datum of 1929 (NGVD 29), USGS datum, or North American Vertical Datum of 1988 (NAVD 88).

Table 4. U.S. Geological Survey gaging station list for data compiled in this report.

[**Map no. (number)** may not be in numerical order based on how stations were grouped by sources during map creation. **Period of record** may not be continuous. **Abbreviations**: Ab, above; Bl, below; Cr, Creek; Nr, near; OR, Oregon; R, river; WA, Washington]

Map no.	Station identifier	Station name	Latitude (decimal degrees)	Longitude (decimal degrees)	Period of record	Data compiled
1	14105700	Columbia River at The Dalles, OR	45.60827778	-121.1899167	June 1, 1878–March 5, 2018[1]	Daily mean streamflow, annual peak streamflow
2	14113000	Klickitat River Near Pitt, WA	45.75651098	-121.2100714	July 1, 1909–March 5, 2018[1]	Daily mean streamflow, annual peak streamflow
3	14113200	Mosier Creek Near Mosier, OR	45.649008	-121.3772951	April 17, 1963–March 5, 2018[1]	Daily mean streamflow, annual peak streamflow
4	14120000	Hood River at Tucker Bridge, Near Hood River, OR	45.6545	-121.5488	October 20, 1897–March 5, 2018[1]	Daily mean streamflow, annual peak streamflow
5	14123500	White Salmon River Near Underwood, WA	45.7520637	-121.5270176	November 1, 1912–March 5, 2018[a]	Daily mean streamflow, annual peak streamflow
6	14125500	Little White Salmon River Near Cook, WA	45.72345147	-121.6339631	October 1, 1956–October 5, 1977	Daily mean streamflow, annual peak streamflow
7	14128500	Wind River Near Carson, WA	45.7267837	-121.794799	October 1, 1934–October 14, 1980	Daily mean streamflow, annual peak streamflow
52	14128870	Columbia River Below Bonneville Dam, OR	45.63305556	-121.9608333	September 30, 1986–April 16, 2018[b]	Stage
8	14128910	Columbia River at Warrendale, OR	45.6123396	-122.0275838	October 27, 1971–September 29, 1987	Stage (daily max, min, mean)
9	14137000	Sandy River Near Marmot, OR	45.3995642	-122.1373068	September 1, 1911–March 5, 2018[a]	Daily mean streamflow, annual peak streamflow
10	14141500	Little Sandy River Near Bull Run, OR	45.41539777	-122.1714746	May 1, 1911–March 5, 2018[1]	Daily mean streamflow, annual peak streamflow
11	14142500	Sandy River Blw Bull Run River, Nr Bull Run, OR	45.4490094	-122.2450885	October 1, 1910–March 5, 2018[1]	Daily mean streamflow, annual peak streamflow
12	14143500	Washougal River Near Washougal, WA	45.6231733	-122.2975912	October 1, 1944–October 29, 1981	Daily mean streamflow, annual peak streamflow
13	14144000	Little Washougal River Near Washougal, WA	45.614007	-122.358425	July 1, 1951–November 30, 1955	Daily mean streamflow, annual peak streamflow
14	14142800	Beaver Creek at Troutdale, OR	45.5192866	-122.3889798	October 1, 1999–March 5, 2018[1]	Daily mean streamflow, annual peak streamflow

Map no.	Station identifier	Station name	Latitude (decimal degrees)	Longitude (decimal degrees)	Period of record	Data compiled
58	14144700	Columbia River at Vancouver, WA	45.62067265	-122.6734306	October 1, 1963–March 5, 2018[1]	Daily mean streamflow, stage
15	14191000	Willamette River at Salem, OR	44.9442863	-123.0428742	October 1, 1909–March 5, 2018[1]	Daily mean streamflow, annual peak streamflow
68	14192500	S Yamhill R Nr Willamina, OR	45.04742	-123.504292	May 1, 1934–September 29, 1993	Daily mean streamflow, annual peak streamflow
69	14193000	Willamina Cr Nr Willamina, OR	45.143242	-123.494639	June 1, 1934–October 29, 1991	Daily mean streamflow, annual peak streamflow
16	14194150	South Yamhill River at Mcminnville, OR	45.2056719	-123.1826047	October 1, 1994–March 5, 2018[1]	Daily mean streamflow, annual peak streamflow
70	14194300	N Yamhill R Nr Fairdale, OR	45.364959	-123.3793	October 1, 1958–October 29, 1991	Daily mean streamflow, annual peak streamflow
17	14198400	Bull Creek Near Wilhoit, OR	44.9609	-122.385	March 31, 1993–March 5, 2018[1]	Daily mean streamflow, annual peak streamflow
18	14198500	Molalla R Ab Pc Nr Wilhoit, OR	45.00956696	-122.480362	October 1, 1935–September 29, 1993	Daily mean streamflow, annual peak streamflow
19	14199000	Molalla River Near Molalla, OR	45.11928929	-122.534531	October 1, 1905–October 29, 1951	Daily mean streamflow, annual peak streamflow
20	14197000	North Yamhill R at Pike, OR	45.36928017	-123.2553867	October 1, 1948–September 29, 1973	Daily mean streamflow, annual peak streamflow
21	14197900	Willamette River at Newberg, OR	45.2845625	-122.9614893	October 1, 2001–March 5, 2018[1]	Daily mean streamflow, annual peak streamflow, Stage
22	14198000	Willamette River at Wilsonville, OR	45.2990086	-122.7512055	October 1, 1948–July 31, 1973	Daily mean streamflow, annual peak streamflow
23	14200000	Molalla River Near Canby, OR	45.24428767	-122.687314	August 1, 1928–March 5, 2018[1]	Daily mean streamflow, annual peak streamflow
24	14200100	Drift Creek Near Silverton, OR	44.97680556	-122.830111	May 21, 2014–February 5, 2018	Daily mean streamflow, annual peak streamflow
25	14200300	Silver Creek at Silverton, OR	45.0092878	-122.7887014	October 1, 1963–February 5, 2018	Daily mean streamflow, annual peak streamflow
26	14200700	Abiqua Creek at Silverton, OR	45.03145	-122.7908306	June 12, 2014–March 6, 2018[1]	Daily mean streamflow, annual peak streamflow
27	14201500	Butte Creek at Monitor, OR	45.1015099	-122.7462019	January 1, 1936–March 5, 2018[1]	Daily mean streamflow, annual peak streamflow
28	14201300	Zollner Creek Near Mt Angel, OR	45.10039816	-122.8217596	September 1, 1993–March 6, 2018[a]	Daily mean streamflow, annual peak streamflow

Map no.	Station identifier	Station name	Latitude (decimal degrees)	Longitude (decimal degrees)	Period of record	Data compiled
29	14201340	Pudding River Near Woodburn, OR	45.15123137	-122.80426	October 1, 1997–March 6, 2018[1]	Daily mean streamflow, annual peak streamflow
30	14202000	Pudding River at Aurora, OR	45.23317586	-122.7500933	October 1, 1928–March 6, 2018[1]	Daily mean streamflow, annual peak streamflow
31	14202500	Tualatin R Nr Gaston, OR	45.4366684	-123.1688843	October 1, 1940–February 25, 1985	Daily mean streamflow, annual peak streamflow
71	14202850	Scoggins Cr Ab Henry Hagg Lake Nr Gaston, OR	45.499942	-123.251188	October 1, 1972–October 29, 1976	Daily mean streamflow, annual peak streamflow
72	14202920	Sain Cr Nr Gaston, OR	45.480803	-123.245886	October 1, 1972–October 29, 1976	Daily mean streamflow, annual peak streamflow
73	14202980	Scoggins Cr Bl Henry Hagg Lake Nr Gaston, OR	45.471756	-123.197467	January 1, 1975–October 1, 2006	Daily mean streamflow, annual peak streamflow
32	14203500	Tualatin River Near Dilley, OR	45.4748365	-123.124274	October 1, 1939–March 6, 2018[1]	Daily mean streamflow, annual peak streamflow
33	14205400	East Fork Dairy Creek Near Meacham Corner, OR	45.68233568	-123.069553	May 8, 2002–March 6, 2018[1]	Daily mean streamflow, annual peak streamflow
74	14206500	Tualatin River at Farmington, OR	45.44983918	-122.9512138	October 1, 1939–October 29, 1976	Daily mean streamflow, annual peak streamflow
34	14206950	Fanno Creek at Durham, OR	45.403452	-122.7548185	October 1, 1993–March 6, 2018[1]	Daily mean streamflow, annual peak streamflow
35	14207500	Tualatin River at West Linn, OR	45.35067559	-122.6762044	August 1, 1928–March 6, 2018[1]	Daily mean streamflow, annual peak streamflow
54	14207740	Willamette River Above Falls, at Oregon City, OR	45.348454	-122.6200918	September 30, 1986–3/29/2018[1]	Stage
55	14207770	Willamette River Below Falls, at Oregon City, OR	45.35762066	-122.610925	September 30, 1988–6/18/2018[1]	Stage
36	14211010	Clackamas River Near Oregon City, OR	45.3792874	-122.5773134	June 1, 2001–March 6, 2018[1]	Daily mean streamflow, annual peak streamflow, stage
37	14210000	Clackamas River at Estacada, OR	45.29984346	-122.3539746	April 1, 1908–March 6, 2018[1]	Daily mean streamflow, annual peak streamflow
38	14211315	Tryon Creek Near Lake Oswego, OR	45.43067476	-122.6737057	August 1, 2001–March 6, 2018[1]	Daily mean streamflow, annual peak streamflow
39	14211500	Johnson Creek at Sycamore, OR	45.47745556	-122.5080194	October 1, 1940–March 6, 2018[1]	Daily mean streamflow, annual peak streamflow
40	14211550	Johnson Creek at Milwaukie, OR	45.452897	-122.6431496	April 22, 1989–March 6, 2018[1]	Daily mean streamflow, annual peak streamflow, stage

Map no.	Station identifier	Station name	Latitude (decimal degrees)	Longitude (decimal degrees)	Period of record	Data compiled
56	14211720	Willamette River at Portland, OR	45.5175	-122.6691667	October 1, 1972–March 6, 2018[1]	Daily mean streamflow, annual peak streamflow, stage
41	14211814	Fairview Creek at Glisan St Near Gresham, OR	45.52761968	-122.4487024	May 1, 1992–March 6, 2018[1]	Daily mean streamflow, annual peak streamflow
42	14211820	Columbia Slough at Portland, OR	45.63900515	-122.763155	October 14, 1988–October 2, 2017[1]	Daily mean streamflow, annual peak streamflow, stage
43	14211902	Burnt Bridge Creek Near Mouth at Vancouver, WA	45.66122778	-122.6689866	October 1, 1998–11/12/2012	Daily mean streamflow, annual peak streamflow
44	14222500	East Fork Lewis River Near Heisson, WA	45.8367809	-122.4662083	October 1, 1929–March 6, 2018[1]	Daily mean streamflow, annual peak streamflow
45	14220500	Lewis River at Ariel, WA	45.9517789	-122.5639899	July 1, 1909–March 6, 2018[1]	Daily mean streamflow, annual peak streamflow
53	14222880	Columbia River at Columbia City, OR	45.8945588	-122.8076038	October 14, 1971–December 1, 1981	Stage (Daily max, min, mean)
46	14223000	Kalama River Near Kalama, WA	46.01705847	-122.7323262	July 1, 1911–October 29, 1932	Daily mean streamflow, annual peak streamflow
47	14223500	Kalama River Below Italian Creek Near Kalama, WA	46.044836	-122.8153843	October 1, 1946–September 12, 1982	Daily mean streamflow, annual peak streamflow
57	14243000	Cowlitz River at Castle Rock, WA	46.2748332	-122.9145587	December 12, 1926–March 6, 2018[a]	Daily mean streamflow, annual peak streamflow, stage
48	14246000	Abernathy Creek Near Longview, WA	46.2026102	-123.1553978	May 1, 1949–December 31, 1957	Daily mean streamflow, annual peak streamflow
49	14246900	Columbia River at Port Westward, Near Quincy, OR[2]	46.18122136	-123.1834539	May 1, 1968–March 6, 2018[1]	Daily mean streamflow, annual peak streamflow, stage
50	14247000	Clatskanie River Near Clatskanie, OR	46.048445	-123.1234489	October 1, 1949–October 29, 1954	Daily mean streamflow, annual peak streamflow
51	14247500	Elochoman River Near Cathlamet, WA	46.2212209	-123.3423492	October 1, 1940–October 12, 1971	Daily mean streamflow, annual peak streamflow

[1]Station still active at the time of data compilation

[2]Station previously named Columbia River at Beaver Army Terminal, near Quincy, Oregon

Table 5. Historical paper rating tables that were recreated within the internal U.S. Geological Survey database to expand and determine instantaneous discharge for flooding events.

[**Rating number**: Rating numbers were historically labeled as the date they were implemented, but the U.S. Geological Survey later switched to labeling them by numeral. Dates are in month–day–year. **Abbreviations**: blw, below; nr, near; OR, Oregon; WA, Washington]

Station identification number	Station name	Rating number	Applied to flooding event
14120000	Hood River at Tucker Bridge, near Hood River, OR	15	1986
14137000	Sandy River near Marmot, OR	1–30–1935	1933
		1–31–1935	1933
		15	1974
14141500	Little Sandy River near Bull Run, OR	2–27–1935	1933
		16	1974
14142500	Sandy River blw Bull Run River, nr Bull Run, OR	11–21–1933	1933
14191000	Willamette River at Salem, OR	14	1974
		15	1974
		17	1986
14200300	Silver Creek at Silverton, OR	1	1965
		2	1965
14202000	Pudding River at Aurora, OR	3–15–1934	1933
		3–11–1935	1933
		3–3–1949	1933
14203500	Tualatin River near Dilley, OR	14	1974
		15	1974
14207500	Tualatin River at West Linn, OR	3–24–1934	1933
		7	1964
		9	1974
		10	1974
14210000	Clackamas River at Estacada, OR	13	1974
		14	1974
14211500	Johnson Creek at Sycamore, OR	8	1974
14243000	Cowlitz River at Castle Rock, WA	9	1974

Oregon Water Resources Department (OWRD)

Twelve OWRD gages were compiled for this study (table 7; fig. 6). Data were downloaded for the stations of interest from the OWRD website (Oregon Water Resources Department, 2018a). Data prior to approximately 2016 could be downloaded from Historical Streamflow and Lake Level Data web application (Oregon Water Resources Department, 2018b), while more recent data could be found on the Near Real Time Hydrographics Data web application (Oregon Water Resources Department, 2018c). Daily-mean flows were available and retrieved from all 12 of the stations of interest. Annual peak flow files were available for 11 of the stations. All data were compiled in local standard time (PST).

Table 6. Summary of U.S. Geological Survey historic flood data compiled in this report.

[Dates shown as month–day–year. **Abbreviations**: Ab, above; Bl, below, Cr, creek; Mt, Mount; N, North; Nr, near; OR, Oregon; Pc, Pine Creek; R, river; S, South; St, street; WA, Washington; ×, flood data available that year; –, no data available]

Station identifier	Station name	Station begin date	Station end date	Flooding events of interest							
				1933	1964	1974	1982	1986	1996	1997	2006
14105700	Columbia River at The Dalles, OR	6–1–1878	[1]3–5–2018	–	–	–	–	–	x	–	x
14113000	Klickitat River Near Pitt, WA	7–1–1909	[1]3–5–2018	–	–	–	–	–	x	x	x
14113200	Mosier Creek Near Mosier, OR	4–17–1963	[1]3–5–2018	–	–	–	–	–	–	–	x
14120000	Hood River at Tucker Bridge, Near Hood River, OR	10–20–1897	[1]3–5–2018	–	x	–	x	x	x	x	x
14123500	White Salmon River Near Underwood, WA	11–1–1912	[1]3–5–2018	–	–	x	–	x	–	–	x
14125500	Little White Salmon River Near Cook, WA	10–1–1956	10–5–1977	–	–	x	–	–	–	–	–
14137000	Sandy River Near Marmot, OR	9–1–1911	[1]3–5–2018	x	x	x	–	x	x	x	x
14141500	Little Sandy River Near Bull Run, OR	5–1–1911	[1]3–5–2018	x	x	x	–	x	x	x	x
14142500	Sandy River Bl Bull Run River, Nr Bull Run, OR	10–1–1910	[1]3–5–2018	x	x	–	–	x	x	x	x
14142800	Beaver Creek at Troutdale, OR	10–1–1999	[1]3–5–2018	–	–	–	–	–	–	–	x
14191000	Willamette River at Salem, OR	10–1–1909	[1]3–5–2018	–	x	x	x	x	x	x	x
14194150	South Yamhill River at Mcminnville, OR	10–1–1994	[1]3–5–2018	–	–	–	–	–	x	x	x
14198400	Bull Creek Near Wilhoit, OR	3–31–1993	[1]3–5–2018	–	–	–	–	–	–	x	x
14198500	Molalla R Ab Pc Nr Wilhoit, OR	10–1–1935	9–29–1993	–	x	x	–	x	–	–	–
14197000	North Yamhill R at Pike, OR	10–1–1948	9–29–1973	–	x	–	–	–	–	–	–
14197900	Willamette River at Newberg, OR	10–1–2001	[1]3–5–2018	–	–	–	–	–	–	–	x
14198000	Willamette River at Wilsonville, OR	10–1–1948	7–31–1973	–	x	–	–	–	–	–	–
14200000	Molalla River Near Canby, OR	8–1–1928	[1]3–5–2018	–	x	x	–	–	–	–	x
14200300	Silver Creek at Silverton, OR	10–1–1963	2–5–2018	–	x	x	–	–	–	–	–
14201500	Butte Creek at Monitor, OR	1–1–1936	[1]3–5–2018	–	–	x	–	–	–	–	–
14201300	Zollner Creek Near Mt Angel, OR	7–1–1993	[1]3–6–2018	–	–	–	–	–	–	–	x
14201340	Pudding River Near Woodburn, OR	10–1–1997	[1]3–6–2018	–	–	–	–	–	–	–	x
14202000	Pudding River at Aurora, OR	10–1–1928	[1]3–6–2018	x	–	–	–	–	x	x	x
14203500	Tualatin River Near Dilley, OR	10–1–1939	[1]3–6–2018	–	x	x	–	x	x	x	x
14205400	East Fork Dairy Creek Near Meacham Corner, OR	5–8–2002	[1]3–6–2018	–	–	–	–	–	–	–	x
14206950	Fanno Creek at Durham, OR	10–1–1993	[1]3–6–2018	–	–	–	–	–	–	–	x
14207500	Tualatin River at West Linn, OR	8–1–1928	[1]3–6–2018	x	x	x	–	x	x	x	x
14211010	Clackamas River Near Oregon City, OR	6–1–2001	[1]3–6–2018	–	–	–	–	–	–	–	x
14210000	Clackamas River at Estacada, OR	4–1–1908	[1]3–6–2018	–	x	x	–	x	x	x	x
14211315	Tryon Creek Near Lake Oswego, OR	8–1–2001	[1]3–6–2018	–	–	–	–	–	–	–	x
14211500	Johnson Creek at Sycamore, OR	10–1–1940	[1]3–6–2018	–	x	x	–	x	x	x	x
14211550	Johnson Creek at Milwaukie, OR	4–22–1989	[1]3–6–2018	–	–	–	–	–	x	x	x

Station identifier	Station name	Station begin date	Station end date	Flooding events of interest							
				1933	1964	1974	1982	1986	1996	1997	2006
14211720	Willamette River at Portland, OR	10–1–1972	[1]3–6–2018	–	–	–	–	–	–	–	x
14211814	Fairview Creek at Glisan St Near Gresham, OR	5–1–1992	[1]3–6–2018	–	–	–	–	–	x	x	x
14222500	East Fork Lewis River Near Heisson, WA	10–1–1929	[1]3–6–2018	–	–	–	–	–	x	–	x
14220500	Lewis River at Ariel, WA	7–1–1909	[1]3–6–2018	–	–	–	–	–	–	–	x
14243000	Cowlitz River at Castle Rock, WA	12–10–1926	[1]3–6–2018	–	–	x	–	–	x	x	x
14246900	Columbia River at Port Westward, Near Quincy, OR	5–1–1968	[1]3–6–2018	–	–	–	–	–	–	–	x
14192500	S Yamhill R Nr Willamina, OR	5–1–1934	9–29–1993	–	x	x	–	x	–	–	–
14193000	Willamina Cr Nr Willamina, OR	6–1–1934	9–29–1991	–	x	–	–	x	–	–	–
14194300	N Yamhill R Nr Fairdale, OR	10–1–1958	9–29–1991	–	x	x	–	x	–	–	–
14202500	Tualatin R Nr Gaston, OR	10–1–1940	2–25–1985	–	–	–	x	–	–	–	–
14202920	Sain Cr Nr Gaston, OR	10–1–1972	9–29–1976	–	–	x	–	–	–	–	–
14202850	Scoggins Cr Ab Henry Hagg Lake Nr Gaston, OR	10–1–1972	9–29–1976	–	–	x	–	–	–	–	–
14202980	Scoggins Cr Bl Henry Hagg Lake Nr Gaston, OR	1–1–1975	10–1–2006	–	–	–	–	x	x	x	x
14105700	Columbia River at The Dalles, OR	6–1–1878	[1]3–5–2018	–	–	–	–	–	x	–	x
14113000	Klickitat River Near Pitt, WA	7–1–1909	[1]3–5–2018	–	–	–	–	–	x	x	x
14113200	Mosier Creek Near Mosier, OR	4–17–1963	[1]3–5–2018	–	–	–	–	–	–	–	x

[1]Station still active at the time of data compilation

Table 7. Oregon Water Resources Department gaging station list for data compiled in this report.

[All stations were still active at the time of data compilation. **Map no.**: Map number. **Station identifier**: Names are presented with abbreviated terms as they are in the National Water Information System. **Abbreviations**: Ab, above; Bl, below; Cr, creek; Nr, near; OR, Oregon; R, river; Rd, road; rte, route; WA, Washington]

Map no.	Station identifier	Station name	Latitude	Longitude	Period of record	Data compiled
68	14192500	South Yamhill R Nr Willamina, OR	45° 2′ 50.712″	-123° 30′ 15.451″	Sept. 30, 1993–Mar. 1, 2018	Daily mean streamflow, annual peak streamflow
69	14193000	Willamina Cr Nr Willamina, OR	45° 8′ 35.671″	-123° 29′ 40.7″	Sept. 30, 1991–Mar. 1, 2018	Daily mean streamflow, annual peak streamflow
70	14194300	North Yamhill R Nr Fairdale, OR	45° 21′ 53.852″	-123° 22′ 45.48″	Sept. 30, 1991–Mar. 1, 2018	Daily mean streamflow, annual peak streamflow
63	14202450	Tualatin R Bl Lee Falls Nr Cherry Grove, OR	45° 27′ 37.699″	-123° 16′ 45.419″	Jan. 2, 2008–Mar. 1, 2018	Daily mean streamflow, annual peak streamflow
71	14202850	Scoggins Cr Ab Henry Hagg Lake Nr Gaston, OR	45° 29′ 59.791″	-123° 15′ 4.277″	Sept. 30, 1976–Mar. 1, 2018	Daily mean streamflow, annual peak streamflow
72	14202920	Sain Cr Nr Gaston, OR	45° 28′ 50.891″	-123° 14′ 45.19″	Sept. 30, 1976–Mar. 1, 2018	Daily mean streamflow, annual peak streamflow
73	14202980	Scoggins Cr Bl Henry Hagg Lake Nr Gaston, OR	45° 28′ 18.322″	-123° 11′ 50.881″	Oct. 2, 2006–Mar. 1, 2018	Daily mean streamflow, annual peak streamflow
64	14204530	Gales Cr At Route 47 At Forest Grove, OR	45° 30′ 38.801″	-123° 6′ 55.829″	Jan. 1, 2008–Mar. 1, 2018	Daily mean streamflow, annual peak streamflow
65	14204800	Tualatin R at Golf Course Rd Nr Cornelius, OR	45° 30′ 7.549″	-123° 3′ 22.061″	Jan. 1, 2008–Jan. 25, 2018	Daily mean streamflow, annual peak streamflow
66	14206200	Dairy Cr At Rte 8 Nr Hillsboro, OR	45° 31′ 12.41″	-123° 0′ 41.08″	Feb. 23, 2008–Jan. 1, 2018	Daily mean streamflow
67	14206295	Tualatin R at Rood Bridge At Hillsboro, OR	45° 29′ 23.86″	-122° 57′ 5.558″	Jan. 1, 2008–Jan. 25, 2018	Daily mean streamflow, annual peak streamflow
74	14206500	Tualatin R at Farmington, OR	45° 26′ 57.71″	-122° 57′ 2.588″	Sept. 30, 1976–Jan. 25, 2018	Daily mean streamflow, annual peak streamflow

National Oceanic and Atmospheric Administration (NOAA)

Of the 12 long-term NOAA tidal gages compiled for this study, 6 were coastal locations in Washington, Oregon, and California, and 6 were river locations in the Columbia and Willamette Rivers (table 8; fig. 2). Data were downloaded for each station from the NOAA tides and currents webpage (National Oceanic and Atmospheric Administration, 2018a). All data were compiled in local standard time (PST) and in station datum (STND), an arbitrary fixed base elevation.

Table 8. National Oceanic and Atmospheric Administration gaging station list for data compiled in this report.

[All stations were still active at time of data compilation. **Map no.**: Map number. **Period of record** may not be continuous. **Abbreviations**: CA, California; OR, Oregon; St, street; WA, Washington]

Map no.	Station identifier	Station name	Latitude	Longitude	Period of record	Data compiled
			Coastal locations			
75	9443090	Neah Bay, WA	48°22.2'N	124°36.1'W	July 1934–Dec. 2017	Hourly elevation
76	9440910	Toke Point, WA	46°42.5'N	123°58'W	Nov. 1972–Dec. 2017	Hourly elevation
86	9439040	Astoria, OR	46°12.4'N	123°46.1'W	Jan. 1925–Dec. 2017	Hourly elevation
77	9435380	South Beach, OR	44°37.5'N	124°32.7'W	Jan. 1967–Dec. 2017	Hourly elevation
78	9432780	Charleston, OR	43°20.7'N	124°19.3'W	Mar. 1970–Dec. 2017	Hourly elevation
79	9419750	Crescent City, CA	41°44.7'N	124°11.1'W	Apr. 1933–Dec. 2017	Hourly elevation
			River locations			
80	9440569	Skamokawa, WA	46°16.2'N	123°27.4'W	Mar. 2002–Dec. 2017	Hourly elevation
82	9440422	Longview, WA	46°6.4'N	122°57.2'W	Mar. 2002–Dec. 2017	Hourly elevation
83	9439201	St. Helens, OR	45°51.8'N	122°47.8'W	Mar. 2002–Dec. 2017	Hourly elevation
84	9440083	Vancouver, WA	45°37.9'N	122°41.8'W	Mar. 2002–Dec. 2017	Hourly elevation
85	9439099	Wauna, OR	46°9.7'N	123°24.5'W	Mar. 2002–Dec. 2017	Hourly elevation
81	9439221	Portland Morrison St Bridge, OR	45°30.6'N	122°40.4'W	Mar. 2002–Jan. 2009	Hourly Elevation

Washington Department of Ecology (WA-DOE)

Thirteen WA-DOE gages were compiled for this study (table 9; figs. 3, 4, 5, and 8). Data were downloaded from each available year of data from the WA-DOE Flow Monitoring Network webpage (Department of Ecology State of Washington, 2018). Daily-mean streamflow values were retrieved from 12 of the gages, and 15-minute stage data were retrieved from 6 of the gages. All gages were established after January 2000; therefore, only the January 2006 flooding event was available and retrieved from six of the gages. All data were compiled in local standard time (PST) and all stage data were compiled at an arbitrary datum.

Pacific Northwest National Laboratory (PNNL)

Thirty-nine PNNL elevation gages were compiled for this study (table 10; figs. 3, 4, 5, and 8). Data were supplied by the U.S. Army Corps of Engineers (USACE) in a Microsoft Excel data file (R. Cahill, U.S. Army Corps of Engineers, written commun., April 26, 2018). Elevation data were available in either 30-minute or hourly increments. The original datasets were supplied in Greenwich Mean Time (GMT) with a gage datum of NAVD 88 in meters.

Table 9. Washington Department of Ecology gaging station list for data compiled in this report.

[**Map no**.: Map number. **Period of record:** Station still active at the time of data compilation; may not be continuous. **Abbreviations**: blw, below; Cr, creek; Dr, Drive; EF, East Fork; nr, near; R, river; Rd, road; St, street]

Map no.	Station identifier	Station name	Latitude	Longitude	Period of record	Data compiled
87	30C070	Little Klickitat R nr Wahkiacus	45° 50' 35.00061"	-121° 3' 28.98743"	June 2004–Sept. 2017[1]	Daily mean streamflow, 2006 flood event 15-min streamflow
88	29C100	Wind R at Stabler	45° 48' 27.36"	-121° 54' 32.04"	June 2004–Sept. 2017[1]	Daily mean streamflow
89	29A070	Rock Cr at Stevenson	45° 41' 55.31982"	-121° 54' 17.28149"	June 2008–Sept 2013	Daily mean streamflow
90	28B080	Washougal R at Hathaway Park	45° 35' 2.04"	-122° 20' 35.88"	Jan. 2005–Sept. 2017[1]	Daily mean streamflow, 15-min stage, 2006 flood event 15-min Streamflow
91	27D090	EF Lewis R nr Dollar Corner	45° 48' 51.12"	-122° 35' 30.12"	Jan. 2005–Sept 2013	Daily mean streamflow, 2006 flood event 15-min Streamflow
92	26C075	Coweeman R nr Kelso	46° 7' 41.16486"	-122° 50' 17.8894"	Sept. 2006–Sept. 2017[1]	Daily mean streamflow, 15-min Stage
93	25F060	Mill Cr at Mouth	46° 11' 26.16486"	-123° 10' 42.94739"	June 2004–Sept. 2017[1]	Daily mean streamflow, 15-min stage, 2006 flood event 15-min streamflow
94	25E060	Abernathy Cr nr Mouth[2]	46° 11' 43.0838"	-123° 9' 56.1731"	June 2004–Sept. 2017[1]	Daily mean streamflow, 15-min stage
95	25D050	Germany Cr at Mouth	46° 11' 29.03503"	-123° 7' 30"	June 2004–Sept. 2017[1]	Daily mean streamflow, 15-min stage, 2006 flood event 15-min Streamflow
96	25C060	Elochoman R at Monroe Dr	46° 13' 32.16431"	-123° 21' 32.40417"	Dec. 2014–Sept. 2017[1]	Daily mean streamflow
97	25B060	Grays R nr Mouth	46° 21' 15.11444"	-123° 34' 53.03284"	Jan. 2005–Sept. 2013[2]	Daily mean streamflow, 2006 flood event 15-min Streamflow
98	24N100	Chinook R nr Houchen St	46° 16' 4.8"	-123° 55' 24.96"	Dec. 2014–Sept. 2017[1]	Daily mean streamflow
99	24N070	Chinook R at Chinook Valley Rd	46° 17' 0.6"	-123° 56' 15"	Dec. 2014–Sept. 2017[1]	15-min stage

[1]Website states station still active but no additional data is available online after Sept. 2013 at the time of data compilation.

[2]Station was moved to another location on same creek starting June 28, 2006.

Table 10. Pacific Northwest National Laboratory gaging station list for data compiled in this report.

[**Map no.**: Map number. **Period of record** may not be continuous]

Map no.	Station identifier	Station name	Latitude (decimal degrees)	Longitude (decimal degrees)	Period of record	Data compiled
100	BBM-HOBO	Baker Bay Marsh hobo	46.300657	-124.04549	Apr. 2011–Feb. 2017	Hourly elevation
101	BIM-HOBO	Burke Island Marsh Hobo sensor	45.939161	-122.790358	July 2011–May 2012	Hourly elevation
102	BSM-HOBO	Bradwood Slough Marsh Hobo sensor	46.203008	-123.445919	July 2009–Aug. 2010	Hourly elevation
103	CCR-HOBO	Coal Creek Riparian Wetland Hobo sensor	46.167735	-123.038533	July 2008–Aug. 2009	Hourly elevation
104	CCS-HOBO	Crooked Creek Swamp hobo	46.294423	-123.672489	Aug. 2007–June 2010	30-min elevation
105	CHM-HOBO	Chinook River Marsh hobo	46.298528	-123.96906	Aug. 2008–Aug. 2009	Hourly elevation
106	CI1-HOBO	Cottonwood Island 1 hobo	46.080391	-122.876356	Mar. 2009–Aug. 2010	Hourly elevation
107	CLM-HOBO	Cunningham Lake Marsh Hobo sensor	45.807547	-122.805071	July 2009–Feb. 2017	Hourly elevation
108	CRM-HOBO	Clatskanie River Marsh Hobo sensor	46.13337	-123.233933	Aug. 2008–July 2009	Hourly elevation
109	CS1-HOBO	Campbell Slough Marsh Hobo sensor	45.784739	-122.753966	July 2008–Feb. 2017	Hourly elevation
110	DSC-HOBO	Dibblee Slough Marsh hobo	46.114992	-122.995492	Mar. 2009–Aug. 2010	Hourly elevation
111	FCB-HOBO	Ft. Clatsop Dike-breach Marsh hobo	46.131636	-123.878962	Aug. 2008–June 2009	30-min elevation
112	FLM-HOBO	Franz Lake Marsh Hobo sensor	45.60062	-122.102936	July 2008–July 2017	Hourly elevation
113	GCR-HOBO	Gee Creek Riparian Wetland Hobo sensor	45.847913	-122.778405	Aug. 2009–July 2010	Hourly elevation
114	GIC-HOBO	Goat Island Marsh Hobo sensor	45.932088	-122.815116	Aug. 2008–Aug. 2012	Hourly elevation
115	GIM-HOBO	Grant Island Marsh Hobo sensor	46.123443	-123.804429	June 2009–June 2010	Hourly elevation
116	GOM-HOBO	Government Island Marsh Hobo sensor	45.591347	-122.561208	Nov. 2011–Nov. 2012	Hourly elevation
117	HCM-HOBO	Hardy Creek Marsh Hobo sensor	45.629163	-122.006155	July 2008–July 2009	Hourly elevation
118	HIB-HOBO	Haven Island Dike-breach Marsh Hobo sensor	46.117643	-123.81049	June 2009–June 2010	Hourly elevation
119	KIB-HOBO	Karlson Island Dike-breach Marsh hobo	46.203357	-123.613757	Aug. 2007–July 2008	30-min elevation
120	KIS-HOBO	Karlson Island Swamp hobo	46.188787	-123.600257	Aug. 2007–July 2008	30-min elevation
121	LI2-HOBO	Lord Island Marsh 2 Hobo sensor	46.135579	-123.029157	Aug. 2008–July 2009	Hourly elevation
122	LRI-HOBO	Little Ryan Island Hobo Sensor	46.197455	-123.403081	April 2014–Feb. 2015	Hourly elevation
123	OWM-HOBO	Washougal River (Old) Marsh Hobo sensor	45.580987	-122.394679	Nov. 2011–Nov. 2012	Hourly elevation
124	PIM-HOBO	Pierce Island Marsh Hobo sensor	45.620655	-122.010976	July 2008–July 2009	Hourly elevation
125	RI2-HOBO	Reed Island Slough Marsh Hobo sensor	45.555386	-122.298962	Nov. 2001–Oct 2012	Hourly elevation
126	RIM-HOBO	Ryan Island Marsh Hobo sensor	46.207838	-123.414729	July 2009–Aug. 2010	Hourly elevation
127	SIM-HOBO	Sand Island (Rooster Rock) Marsh Hobo sensor	45.553465	-122.212189	July 2008–July 2009	Hourly elevation
128	SRM-HOBO	Secret River Marsh Hobo sensor	46.304789	-123.694938	July 2007–Aug. 2016	Hourly elevation
129	SSC-HOBO	Sauvie Willow Bar Marsh Hobo sensor	45.736777	-122.77199	July 2009–July 2010	Hourly elevation
130	SSS-HOBO2	Seal Slough Swamp Hobo sensor 2	46.326466	-123.661548	Feb. 2010–June 2010	30-min elevation
131	WAC-HOBO	Wallace Island West Marsh Hobo sensor	46.140476	-123.282894	July 2009–July 2010	Hourly elevation
132	WHC-HOBO	Whites Island Marsh Hobo sensor	46.159321	-123.338159	July 2009–Feb. 2017	Hourly elevation

Map no.	Station identifier	Station name	Latitude (decimal degrees)	Longitude (decimal degrees)	Period of record	Data compiled
133	WI2-HOBO	Welch Island Marsh hobo	46.255479	-123.484440	Dec. 2011–Feb. 2017	Hourly elevation
134	WIM-HOBO	Welch Island Marsh Slough hobo	46.253	-123.481181	July 2008–Aug. 2009	Hourly elevation
135	WR2-HOBO	Walluski River Marsh Hobo sensor	46.133571	-123.782039	June 2008–June 2009	Hourly elevation
136	WRB-HOBO	Walluski River Dike-breach Marsh Hobo sensor	46.133577	-123.782054	June 2008–June 2009	Hourly elevation
137	WRM-HOBO	Walluski River Mouth Marsh Hobo sensor[1]	46.14398	-123.789197	July 2009–July 2010	Hourly elevation
138	WSS-HOBO	Westport Slough Shrub Hobo sensor	46.121457	-123.345692	Aug. 2009–July 2010	Hourly elevation

[1]Site named "Washogal River Mouth Marsh Hobo sensor" in original data file. Adjusted to "Walluski River Mouth Marsh Hobo sensor" based on latitude/longitude coordinates.

Table 11. Portland State University gaging station list for data compiled in this report.

[**Map no.**: Map number. **Period of record** may not be continuous. OR, Oregon; –, stations not given identifier numbers]

Map no.	Station identifier	Station name	Latitude	Longitude	Period of record	Data compiled
141	–	Astoria	46° 11' 26.16" N	123° 49' 48.5682" W	Jan. 1855–Oct. 1876	Elevation
139	9439026	Astoria Youngs Bay, OR	46° 10.3'N	123° 50.5'W	Mar. 1931–Feb. 1943	Elevation
86	9439040	Astoria Tongue Point, OR	46° 12.4' N	123° 46.1' W	[1]Jan. 1925– Aug. 2018	Elevation
140	–	Portland, OR	45° 31' 3.579" N	122° 40' 13.296" W	Jan. 1876– Dec. 1964	Elevation

[1]Station still active at the time of data compilation

Portland State University (PSU)

Data were provided by PSU (Dr. Stefan Talke, Portland State University, written commun., September 24, 2018) from a recently published paper (Talke and Jay, 2017). Data from four elevation gaging stations were compiled for this study (table 11; figs. 2, 3, and 7). Data directly retrieved from the NOAA webpage were used to populate the Astoria Tongue Point, OR station (9439026). The corrected data file for 9439026 includes a stage datum correction applied to documented instability of BM1 noted in Burgette and others (2009). The data were supplied in Greenwich Mean Time (GMT) with a gage datum of NAVD 88 in meters.

United States Army Corps of Engineers (USACE) Dataquery

Data (table 12; figs. 2, 4, 5, 7, and 8) to supplement and (or) extend data records at five sites were provided by the USACE in the form of HEC-DSS files that were retrieved from the Dataquery/Corps Water Management System (U.S. Army Corps of Engineers, 2018b). Table 13 details a selection of digitized paper files from post-flood report data compiled by USACE that were also included as part of this data compilation (U.S. Army Corps of Engineers, 1943, 1949, 1956, 1957, 1963, 1966, and 1975; Columbia Basin Inter-Agency Committee, 1966; Northwest Hydraulic Consultants and others, 1997). Seasonal peak stages (winter and spring) for Willamette at Portland (PRTO) and Columbia at Vancouver (VANW) were digitized from USACE drawing CL-03-112 and CL-03-116. USACE also operates a network of stage gages on the Lower Cowlitz River since the mid-2000s, these were not included in this analysis because they are located on the tributary and not the main stem along with the shorter period of record. High-water marks along the Columbia for the 1948, 1956, and 1996 floods exist in USACE records, but are not included here because they representative of the whole river and are not tied to a specific gage. Additional daily data from Dataquery containing maximum, mean, and minimum stage at VANW are also included (1974–2003), though other datasets should take precedence during periods of overlap due to uncertainty about the source of these data.

Table 12. U.S. Army Corps of Engineers gaging station list for data compiled in this report.

[**Period of record**: may not be continuous.]

Map no.	Station identifier	Station name	Latitude	Longitude	Period of record	Data Compiled
62	BON	Bonneville Lock and Dam	45°37'59" N	121°57'39" W	Sept. 30, 1960–Oct. 2, 2018[1]	Tailwater elevation, Streamflow
59	BON-PH1	Bonneville Powerhouse 1	45°38'22" N	121°56'51" W	Nov. 29, 1966–Oct. 2, 2018[1]	Tailwater elevation
60	TDA	The Dalles	45°36'48" N	121° 8'4" W	Nov. 29, 1966–Aug. 2, 2018[1]	Streamflow
53	COCO	Columbia at Columbia City	45° 54' 0" N	122° 48' 0" W	Oct. 1, 1974–Mar. 30, 1982	Elevation
61	CAMW	Columbia River at Camas	45° 34' 48" N	122° 25' 12" W	Oct. 2, 1974–May 19, 1987	Stage

[1]Station still active at the time of data compilation

Table 13. U.S. Army Corps of Engineers post-flood report data compiled for this report.

[—, stations not given identifier numbers]

Station identifier	Station name	Latitude	Longitude	Post flood report data compiled
—	Clackamas at Clackamas	45°23'50" N	122°33'27" W	1974 streamflow
—	Columbia at Fort Stevens	Unknown	Unknown	1956 stage
LONW	Columbia at Longview	46°6.4'N	122°57.2'W	1948 daily max& daily min stage, 1956 stage, 1964 peak stage, 1974 peak stage
SHNO	Columbia at St Helens	45°51.8'N	122°47.8'W	1956 stage, 1964 peak stage
VANW	Columbia at Vancouver	45°37′13.409″ N	122°40′28.346″ W	1943 peak stage, 1948 daily max& daily min stage, 1956 stage, 1965 stage, 1974 stage
14202000	Pudding at Aurora	45°14′0.437″ N	122°45′0.326″ W	1964 streamflow
14194000	South Yamhill near Whiteson	45°10'08" N	123°12'25" W	1964 streamflow, 1974 streamflow, 1996 streamflow
ORC	Willamette at Oregon City	45°20′53.428″ N	122°37′16.341″ W	1943 stage, 1955 flow, 1961 stage, 1964 flow, 1974 flow
PRTO	Willamette at Portland	45°31′5.426″ N	122°40′8.346" W	1943 peak stage, 1948 stage, 1956 stage, 1964 flow, 1974 stage

Review and Quality Assurance/Quality Control (QA/QC) of Acquired Datasets

General Data Review

HEC-DSS software was used to review data for accuracy, and any points deemed erroneous, based on hydrologic judgement, were removed (fig. 9). Nearby gages, if available, were also used for comparison to help evaluate areas of uncertainty where the data appeared to deviate from the general trend. If erroneous data were removed from a dataset, the source file was duplicated to maintain an unaltered file. Both the original and final datasets were published as HEC-DSS database files (Boudreau and others, 2021). The time datum of all data compiled were reviewed and adjusted when needed to get all datasets consistently in the PST time datum. The gage elevation datums were also reviewed and adjusted when possible to get all datasets into a consistent datum (NAVD 88).

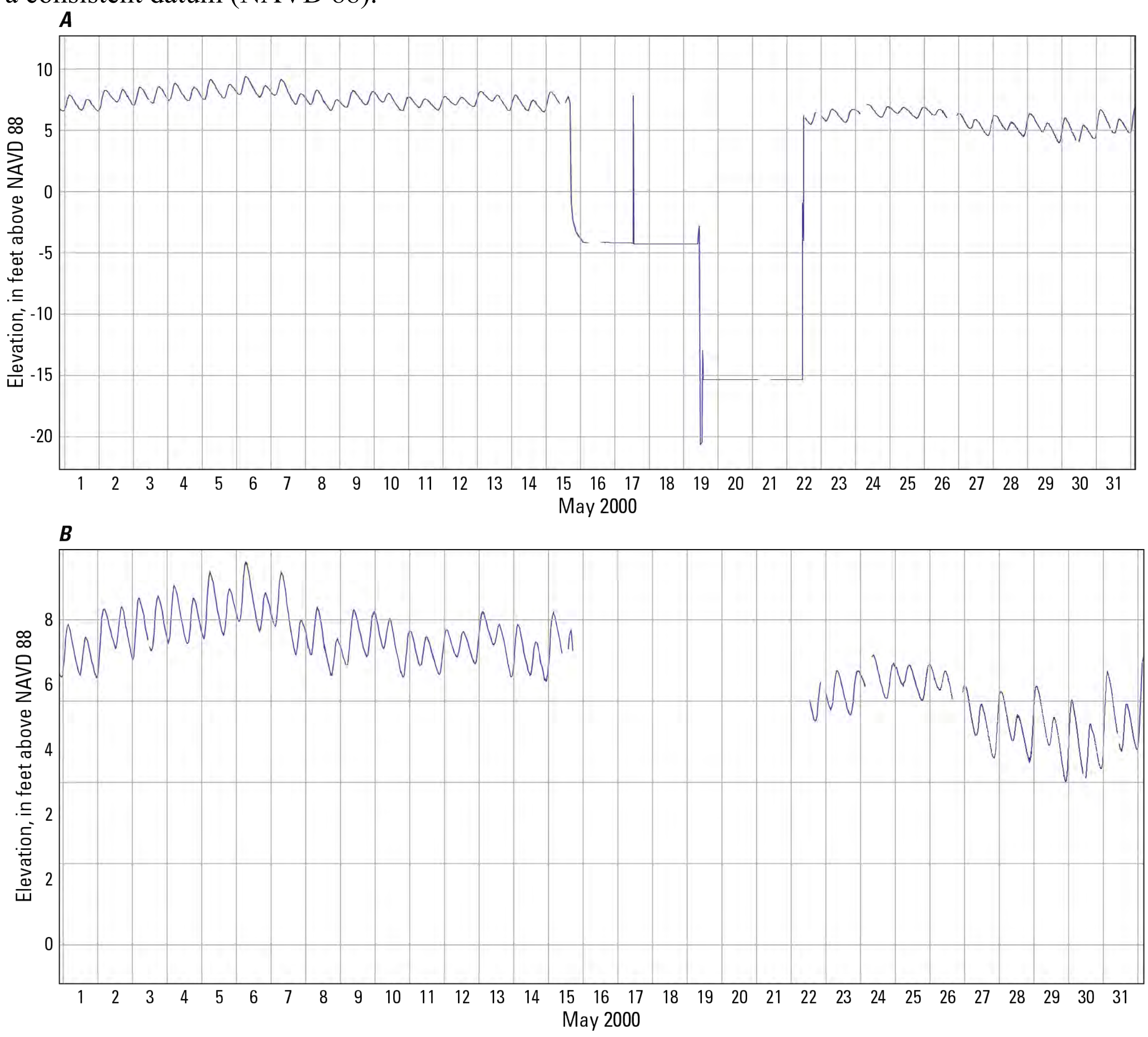

Figure 9. Raw elevation data that included an example of erroneous data (*A*) and the edited dataset with the erroneous data removed (*B*), St. Helens, Oregon. May 2000. NAVD 88, North American Vertical Datum of 1988.

Time Datum Adjustments

For this study, most data were collected in or shifted to Pacific Standard Time (PST). The data from both PNNL and PSU were obtained in GMT and shifted accordingly, including date adjustments where needed. The USACE Dataquery files were supplied in local time, both PST and Pacific Daylight Time (PDT). USACE data in PDT were not shifted because the one-hour time difference was surmised to have negligible impact on the calculated summary maximums.

Vertical Gage Datum Adjustments

Most data were collected in or adjusted to North American Vertical Datum of 1988 (NAVD 88) in feet (ft). The data from both PNNL and PSU had gage heights obtained in NAVD 88 in meters. A conversion factor of 3.281 was used to convert data from meters to feet. NOAA tidal stage data were obtained in Station Datum (STND), an arbitrarily established fixed base elevation, and are converted to NAVD 88 using conversion values from Bondurant (2019). WA-DOE gage height data were referenced to an arbitrary datum and left as is. USGS data were found in multiple datums: Columbia River Datum (CRD), NGVD 29, and NAVD 88. Data in CRD and NGVD 29 were converted to NAVD 88 using VERTCON 2.0 software downloaded from National Oceanic and Atmospheric Administration (2018b). The values determined by VERTCON 2.0 are supplied in table 14.

Table 14. Conversion values used to adjust gage datums to North American Vertical Datum of 1988.

[**Abbreviations**: CRD, Columbia River Datum; ft, feet; NA, not applicable; NAVD 88, North American Vertical Datum of 1988; NGVD 29, National Geodetic Datum of 1929; NOAA, National Oceanic and Atmospheric Administration; OR, Oregon; St, street; USGS, U.S. Geological Survey; WA, Washington]

Operator	Station identifier	Station name	Original station datum	Conversion to NGVD 29 if needed (in feet)	VERTCON conversion factor from NGVD 29 to NAVD 88 (in feet)	Conversion from gage datum to NAVD 88 (in feet)	Notes
USGS	14144700	Columbia River at Vancouver, WA	CRD	Add 1.82	3.45	5.27	2018 resurvey of USGS gage. CRD to NAVD 88 is 5.26[a]
USGS	14197900	Willamette River at Newberg, OR	NGVD 29	NA	3.38	3.38	USGS gage notes
USGS	14211010	Clackamas River at Oregon City. OR	NGVD 29	NA	3.47	3.47	USGS gage notes
USGS	14211550	Johnson Creek at Milwaukie, OR	NGVD 29	NA	3.47	3.47	USGS gage notes
USGS	14211720	Willamette River at Portland, OR	1.48 ft above NGVD 29[2]	Add 1.48	3.48	4.96	2018 resurvey of USGS gage. Agrees with Bondurant (2019).
USGS	14246900	Columbia River at Port Westward, near Quincy, OR	CRD	Subtract 1.00	3.07	2.07	USGS gage notes. USACE identified uncertainty in gage datum before October 1, 2006.
USGS	14211820	Columbia Slough at Portland, OR	1.53 ft above NGVD 29	Add 1.53	3.39	4.92	USGS gage notes
USGS	14207740	Willamette River above Falls at Oregon City, OR	NGVD 29	NA	3.5	3.5	USGS gage notes
USGS	14207770	Willamette River below Falls, at Oregon City, OR	NGVD 29	NA	3.49	3.49	USGS gage notes
USGS	14128870	Columbia River below Bonneville Dam, OR	NGVD 29	NA	3.34	3.34	USGS gage notes
USGS	14128910	Columbia River at Warrendale, OR	NGVD 29	NA	3.35	3.35	USGS gage notes

Operator	Station identifier	Station name	Original station datum	Conversion to NGVD 29 if needed (in feet)	VERTCON conversion factor from NGVD 29 to NAVD 88 (in feet)	Conversion from gage datum to NAVD 88 (in feet)	Notes
USGS	14222880	Columbia River at Columbia City, OR	0.79 ft above NGVD 29	Add 0.79	3.33	4.12	USGS gage notes
NOAA	9439040	Astoria, OR	Station datum	NA	3.37	-2.02	NOAA Tides and Currents (present-day)
NOAA	9440569	Skamokawa, WA	Station datum (0.06 ft above CRD)[3]	NA	3.1	1.01	CRD to NAVD 88 is [1]0.95
NOAA	9439099	Wauna, OR	Station datum (0.14 ft above CRD)[3]	NA	3.5	1.62	CRD to NAVD 88 is [1]1.48
NOAA	9440422	Longview, WA	Station datum (0.27 ft below CRD)[3]	NA	3.2	2.59	CRD to NAVD 88 is [1]2.86
NOAA	9439201	St. Helens, OR	Station datum (0.02 ft below CRD)[3]	NA	3.3	4.13	CRD to NAVD 88 is [1]4.15
NOAA	9440083	Vancouver, WA	Station datum (0.17 ft above CRD)[3]	NA	3.44	5.31	CRD to NAVD 88 is [1]5.15
NOAA	9439221	Portland Morrison St Bridge, OR	Station datum (likely CRD)	NA	3.48	5.38	CRD to NAVD 88 is [1]5.38

[1]CRD to NAVD 88 values determined by Bondurant (2019).

[2]Previously noted as 1.55ft above NGVD 29 before USGS resurvey in 2018.

[3]Value above or below CRD determined from NOAA website (National Oceanic and Atmospheric Association, 2018a).

Of the 12 USGS stage datasets compiled for this study, only Cowlitz River at Castle Rock, WA (14243000), needed additional adjustments. The stage data at 14243000 were collected in NAVD 88 for most of the record except for the period of May 23, 1980, to June 29, 1997, where the USGS datum notes stated the water-stage recorder was at present site at datum, 23.65 ft higher. For the period in question, 23.65 ft was added to the gage datum to create a continuous NAVD 88 dataset.

Data Review by Data Source

Stage and streamflow data were scanned for erroneous periods and data were removed when deemed necessary. Erroneous data, often referred to as “data spikes,” were removed based on hydrologic judgement. Nearby stations, if available, were also used to support the decision to remove the data spikes. The following sections detail the edits made, if needed, to each of the sources of data compiled for this study.

U.S. Geological Survey (USGS)

Historically, the USGS published streamflow data but not stage data. Because stage data were not published and were only used as an intermediate step in the calculation of streamflow, historical stage records did not undergo the same level of editorial clean-up and may contain some erroneous data. Erroneous data could have resulted from instances where the equipment used to measure stage failed or due to environmental conditions. If this occurred, the streamflow data may have been estimated or calculated without the use of the standard relationship between stage and streamflow. In such instances, the stage data might not reflect the true stage of the stream for that period-of-time. Specific edits to records are detailed below.

For the 1974 flooding event, Butte Creek at Monitor, OR (14201500), stage data, used to compute the sub-daily streamflow record, contained a string of repetitive stage values on the recession of the streamflow flooding event peak, suggesting the stage data were erroneous. It was determined this was the result a stage recorder malfunction and the corresponding streamflow data were removed. The 1982 flooding event at Tualatin River near Gaston, OR (14202500), also had signs of a stage recorder malfunction on the recession of the streamflow flooding event peak. The corresponding streamflow during the time of stage recorder malfunction was also removed from the record.

Erroneous stage-data spikes were removed from the record in 1990, 1991, 1992, and 1998 at Columbia River below Bonneville Dam (14128870). Cowlitz River at Castle Rock (14243000) had erroneous stage data spikes removed from the record in the following years: 1989, 1990, and 1995. For the stage data at Willamette River above the Falls, at Oregon City (14207740), the stage recorder appeared to be failing during two periods of data, one in 1991 and one in 1994, the data were removed from the record. Erroneous data points were removed from the stage record at Willamette River below the Falls, at Oregon City (14207770) in 1990, 1994, and 1996.

Due to changes in rounding values over time, as well as the subjective process of visual interpretation of stage values from paper tape chart line plots, the recreated sub-daily streamflow data for flooding events may not match the historically computed daily records. Stage values were physically read off the paper tape chart line plots, so a certain degree of uncertainty could be related to those stage values “picked off the line” and the corresponding streamflow.

Oregon Water Resources Department (OWRD)

OWRD data were reviewed for erroneous data. No edits were deemed necessary.

National Oceanic and Atmospheric Administration (NOAA)

NOAA tidal data were reviewed for erroneous data. No edits were deemed necessary.

Washington Department of Ecology (WA-DOE)

Data from WA-DOE were reviewed for erroneous data, and edits were made as deemed necessary. Data collection during high flow events is not the primary mission of WA-DOE. Therefore, field measurements are often not taken during high flow events, reducing the accuracy of the rating curves and flow data for large events. Edits and review documentation are detailed below broken into sub-sections for stage and streamflow. WA-DOE provided a list of defined codes that were used when qualifying the stage and streamflow data (J. Shedd, WA-DOE, written communication, May 11, 2020). These codes were considered when analyzing the data for data edits.

Stage

The early portion of data from Chinook River at Chinook Valley Road (24N070), collected from December 2014 to July 2015 and from August to October 2015, diverged significantly from the rest of the record. After an email response from WA-DOE staff, it was determined that during this period the tide gates were fully raised so that a contractor could install a lid on a culvert on highway 101. During this period, the gage infrastructure was modified so that all tidal changes would be recorded (J. Shedd, WA-DOE, written commun., July 13, 2018). During some periods of 2015, missing data had been coded as “below instrument threshold” by WA-DOE.

From October 2005 to June 2006, there was a large portion of data missing from Abernathy Creek near Mouth (25E060). These data had been coded by WA-DOE as “estimated data-unreliable” and were therefore removed from the record by WA-DOE. The stage data during low flow periods prior to June 2006 appears lower than the stage data after it. The station had been moved to a new location on June 28, 2006, which accounted for this change in the stage values observed. No adjustments were made to the stage data to account for the station moving.

At Mill Creek at Mouth (25F060), two periods (May 14, 2011–July 19, 2011 and March 31, 2012–May 9, 2012) were coded by WA-DOE as “backwater flow conditions” and, therefore, no data were reported by WA-DOE. From March to June 2017, stage data differ from the surrounding periods with a more pronounced oscillation. The Mill Creek stage data were plotted against a nearby site, Coweeman River at Kelso (26C075), and the oscillations were not observed there. The data were coded as “good quality provisional data” by WA-DOE. This period also coincides with backwater conditions when the Columbia River stage was high. To stay consistent with previous periods where WA-DOE had removed backwater effected areas these data were also removed.

In February 2012 a period of data that had been coded as “questionable estimate” by WA-DOE was removed from the dataset at Washougal River at Hatahway Park (28B080). It deviated from the general trend, and similar patterns were not observed at nearby sites Coweeman River at Kelso and Mill Creek at Mouth. Additional periods of missing data were noted in March 2012; there were two periods coded by WA-DOE as “instrument impaired,” but the data in-between was coded as "good quality provisional data." The "good quality provisional data" did not follow the trends of nearby sites and was removed as potentially suspect.

Streamflow

Chinook River near Houchen Street (24N100) had a few streamflow peaks which appeared to be outliers. During these periods, December 2014, January 2015, and November 2016, the data were coded by WA-DOE as "above rating, over 2x." The data were compared with a nearby USGS gage, Naselle River near Naselle, WA (12010000), these higher peaks corresponded to similar peaks of differing magnitudes at the USGS gage and were therefore kept in the record.

Some high streamflow peaks were also observed at Grays River near Mouth (25B060) during 2006–09. For the periods in question the data were coded by WA-DOE as "above rating, over 2x." The data were again compared with USGS gage 12010000 with similar corresponding peaks, of differing magnitude, being present. Notes were also found in WA-DOE documentation that USGS gage Chehalis River near Doty, WA (12020000), stage data had occasionally been used to compute streamflow when stage data were missing at Grays River near Mouth. The streamflow at 12020000 was found to have similar high flow peaks supporting the peaks at 25B060, and they remain in the record. High flow peaks were not present from the end of 2009 through 2013 as the data had been deleted by WA-DOE with the data being coded as "estimated data – unreliable."

The following sites had minor data gaps throughout the period of record: Elochoman River at Monroe Drive (25C060), Germany Creek at Mouth (25D050), Abernathy Creek near Mouth (25E060), Mill Creek at Mouth (25F060), EF Lewis near Dollar Corner (27D090), Rock Creek at Stevenson (29A070), and Wind River at Stabler (29C070). These gaps were associated with data flags of "rating table exceeded (data will not be reported)," "incomplete day," or "estimated data –unreliable." Mill Creek at Mouth also had a few small gaps in 2011 and 2012 associated with a data flag of "backwater flow conditions."

Coweeman River at Kelso (26C075) had streamflow peaks which appeared to be outliers during 2006–09. These peaks corresponded to data periods flagged as "above rating, over 2x" by WA-DOE. A nearby USGS gage, Cowlitz River at Castle Rock, WA (14243000), was used as a comparison site and found corresponding similar peaks, at differing magnitudes, were present. This supported keeping the peaks at 26C075 in the record.

Washougal River at Hathaway Park (28B080) had a combination of some higher flows in 2006 and 2009 associated with data coded as "modeled flow–calibrated results exceed 20 percent of measured flow." A nearby USGS gage, Sandy River near Marmot, OR (14137000), was used for comparison and displayed similar high flow peaks of differing magnitudes, this provided the support for keeping the peaks in the record. Due to not knowing the methods WA-DOE uses to model flow at this station, calculated streamflow values were assumed accurate and retained. Minor periods of missing data were associated with data coded as either "rating table exceeded (data will not be reported)," "incomplete day," "bankfull discharge exceeded," or "estimated data–unreliable."

A few periods of high flow were observed at Little Klickitat near Wahkiacus (30C070) in 2007, 2009, 2011, 2012, and 2017. These are all associated with data coded as "modeled flow." Data from 2017 were also coded as "estimated from another station, same variable." Similar high flow peaks at the USGS gage Klickitat River near Pitt, WA (14113000), were found to correspond, at differing magnitudes, to the higher flows observed at 30C070. This provided the support for keeping the higher flows for 30C070 in the record. Various data throughout the period were missing and associated to codes “instrument impaired,” “rating table exceeded,” and “ice impacted data.”

Pacific Northwest National Laboratory (PNNL)

The following stations had erroneous points, in the form of data spikes, that were removed from the elevation records using hydrologic judgement: Baker Bay Marsh, Bradwood Slough Marsh, Burke Island Marsh, Clatskanie River Marsh, Cunningham Lake Marsh, Fort Clatsop Dike-Breach Marsh, Gee Creek Riparian Wetland, Karlson Island Dike-Breach Marsh, Reed Island Slough Marsh, Sauvie Willow Bar Marsh, Walluski River Dike-Breach Marsh, Walluski River Marsh, Welch Island Marsh Slough, and Whites Island Marsh. Stations were compared to others in the area for evaluating when to remove spikes.

Data were typically recorded in 30-minute or 1-hour increments, and typically recorded on the hour. Three stations had hourly data but on slightly differing recording marks: Chinook River Marsh (CHM-HOBO) on the 20-minute mark, Lord Island Marsh 2 (LI2-HOBO) on the 45-minute mark, and Walluski River Dike-Breach Marsh (WRB-HOBO) on the 14-minute mark. Times were not adjusted for these stations.

The snap to time function was used within the HEC-DSS software when the data files from PNNL appeared to have a slight time offset during various deployment periods. This allowed the irregular time series to be adjusted to a regular time series. The time shifts were anywhere from 1 to 13 minutes. The following sites had time shifts applied: Crooked Creek Swamp (CCS-HOBO), Goat Island Marsh (GIC-HOBO), and Seal Slough Swamp (SSS-HOBO2). The first deployment period for the Secret River Marsh (SRM-HOBO) was set to 30-minute data. and all other deployments were set to 1 hour. The 30-minute data were snapped to hourly data to create a regular complete final dataset at a 1-hour interval. The original 30-minute dataset was retained as an unaltered file.

Portland State University (PSU)

Data provided by PSU had been reviewed by their staff and were assigned a quality assurance level of “good,” based on a qualitative scale of “light,” “good,” or “excellent.” Datasets were qualitatively reviewed for this study, and no edits were deemed necessary.

The Portland water-level data provided by PSU was collected on the Willamette River in downtown Portland. This data covers several staff gage locations over time and does not have a defined station identifier. Table 15 lists the time periods and locations of the Portland staff gage (Bondurant, 2019).

Table 15. Staff gage locations over time in Portland, Oregon.

Time frame	Staff gage location	Latitude	Longitude	Time frame
1876–96	Stark Street Bridge	45°31'09"	122°40'14"	1876–1896
1896–05	1st Morrison Street Bridge	45°31'02"	122°40'18"	1896–1905
1905–58	2nd Morrison Street Bridge	45°31'05"	122°40'16"	1905–1958
1958–Present	3rd Morrison Street Bridge	45°31'03"	122°40'09"	1958–Present

U.S. Army Corps of Engineers (USACE)

Data provided by USACE via Dataquery files in HEC-DSS format were typically in local standard time. Some data supplied by USACE from Dataquery were found to have stage values off exactly by a factor of 10. In such instances, stage values were divided by 10 to match the stage from periods either before or after the period in question. USACE staff confirmed (R. Cahill, USACE, written commun., October 18, 2018) this approach. Erroneous data points were removed from the supplied records using hydrologic judgement and by comparing data from nearby locations. The following stations each had some data where this manipulation was needed to correct the data back to within reason: Bonneville (BON), Columbia at Columbia City (COCO), Columbia River at Camas (CAMW), Wauna (WAUO/9439099), Willamette River above the falls, at Oregon City (ORC/14207740), and Willamette River below the falls, at Oregon City (ORCO/14207770).

Combining Data from Multiple Sources

On a few occasions, data from the same station were available from multiple data sources (table 16). When possible, the data were combined to extend the dataset and form a continuous period of record. The primary and secondary data sources are listed in table 13. In all instances, the primary data source is presented in Pacific Standard Time and the secondary data source is in local standard time. These 1-hour discrepancies in time were deemed to be inconsequential for the purpose of this project compilation; therefore, no time adjustments were made to the secondary data source.

Table 16. Gaging stations where data were combined from a secondary data source to extend the record or fill in some missing time periods.

[**Abbreviations**: NOAA, National Oceanic and Atmospheric Administration; OR, Oregon; USACE, U.S. Army Corps of Engineers; USGS, U.S. Geological Survey; WA, Washington]

Gaging station name	Primary data source	Primary station identifier	Secondary data source	Secondary station identification
Willamette River at Portland, OR	USGS	14211720	Dataquery USACE	PRTO
Columbia River at Vancouver, WA	USGS	14144700	Dataquery USACE	VANW
Cowlitz River at Castle Rock, WA	USGS	14243000	Dataquery USACE	CASW
Willamette River above Falls, at Oregon City, OR	USGS	14207740	Dataquery USACE	ORC
Willamette River below Falls, at Oregon City, OR	USGS	14207770	Dataquery USACE	ORCO
Longview, WA	NOAA	9440422	Dataquery USACE	LONW
St. Helens, OR	NOAA	9439201	Dataquery USACE	SHNO
Vancouver, WA	NOAA	9440083	Dataquery USACE	VAPW
Wauna, OR	NOAA	9439099	Dataquery USACE	WAUO

The elevation data were combined at the Willamette River at Portland, OR, gage between USACE Dataquery (PRTO) and USGS (14211720) data files. The Dataquery file was used exclusively from 14:00 on October 1, 1976, to 18:00 on September 30, 1988, to extend the station dataset further back in time from where the USGS data began. An observable time difference of approximately 10 hours with the Dataquery file from October 1976 to December 1992 was visible in the overlapping portions of the two datasets. During four additional time periods where USGS data were currently unavailable, the Dataquery files were used to fill in missing periods: January–April 1993, July–September 1994, March–May 1995, and November

1995. During these time periods, the data were found to coincide well with only the slight 1-hour time difference noted.

Columbia River at Vancouver elevation data were extended as a combination of Dataquery (VANW) and USGS (14144700) files. There was a small period of overlap between the two datasets where the time datum lined up. Dataquery files from 15:00 on November 1, 1974, to 15:00 on February 4, 1998, were used to extend the NOAA dataset back further in time.

For the Cowlitz River at Castle Rock, WA, gage, a Dataquery file was used for the early portion of the elevation dataset from 13:30 on October 31, 1988, to 12:15 on July 29, 1997. The remainder of the dataset from 12:30 on July 29, 1997, to present is from the USGS.

Willamette River above the Falls, at Oregon City USGS (14207740), elevation data were extended further back in time with a single Dataquery (ORC) file. The Dataquery file from 15:00 on November 1, 1974, to 23:00 on September 30, 1986, was used directly as received from USACE. The remainder of the dataset from 24:00 on September 30, 1986, to present, is from the USGS.

Willamette River below the Falls, at Oregon City USGS (14207770), elevation data were extended further back in time with two additional Dataquery (ORCO) files. The first Dataquery file from 14:00 on October 1, 1976, to 15:00 on March 31, 1980, was used directly as received from USACE. The second Dataquery file was off by a factor of 10 and needed to be divided by 10 to match the time periods both before and after it. The second Dataquery file covered the period from 14:00 on April 1, 1980, to 14:00 on September 30, 1988. The remainder of the dataset from 24:00 on September 30, 1988, to present is from the USGS.

The following NOAA tidal elevation gages were combined with additional data provided by USACE Dataquery: Longview (LONW/9440422), Vancouver (VAPW/9440083), Wauna (WAUO/9439099), and St Helens (SHNO/9439201).

The Longview gage dataset was extended back in time with a Dataquery file from 15:00 on November 1, 1974, to 19:46 on March 26, 2002. The NOAA data covers the period from 20:00 on March 26, 2002, to present.

Two Dataquery files were used to extend the St Helens gage dataset. The first file from 24:00 on March 10, 1986, to 24:00 on December 31, 1990, and the second file from 01:00 on January 1, 1991, to 14:00 on March 26, 2002. The second Dataquery file continued to overlap with the original NOAA data file through May 2004. There were varying discrepancies noted in both the elevation values as well as the time datum shifts for the second Dataquery file, these were left as is. The NOAA data covers the period from 17:00 on March 26, 2002, to present.

The Wauna gage was extended with two additional Dataquery files. A combination of the first and second Dataquery files, from 24:00 on March 10, 1986, to 16:54 on March 26, 2002, were used to extend the NOAA period further back in time. Two portions of the second Dataquery file were used to fill in two sections, from 10:06 on April 17, 2003, to 18:00 on March 4, 2004, and from 10:00 on November 23, 2004, to 12:00 on June 3, 2005, which were missing from the NOAA dataset.

The Vancouver gage was extended with one additional Dataquery file. The first period, from 24:00 on March 10, 1986, to 19:00 on March 26, 2002, was used to extend the NOAA dataset back in time. The second portion of the Dataquery file was used to fill in one section, from 12:00 on December 2, 2004, to 16:00 on May 31, 2005, which was missing from the NOAA dataset.

Seven gages are currently being operated by OWRD after being previously operated by USGS. Those datasets were combined between the two sources to form a continuous record for both daily mean streamflow and the annual peak streamflow at the gages involved. Table 17 details the USGS gages now operated by OWRD and the corresponding time periods of each agency's operation of the gage.

Table 17. Current Oregon Water Resources Department gaging stations that were previously run by U.S. Geological Survey.

[All stations were still active at time of data compilation. **Dates USGS operated** and **Dates OWRD operated** periods may not have been continuous. **Abbreviations**: Ab, above; Bl, below; Cr, creek; Nr, near; Or, Oregon; OWRD, Oregon Water Resources Department; R, river; USGS, U.S. Geological Survey]

Station identifier	Station name	Latitude	Longitude	Dates USGS operated	Dates OWRD operated
14192500	South Yamhill R Nr Willamina, OR	45° 2′ 50.712″	-123° 30′ 15.451″	May 1, 1934-September 29, 1993	September 30, 1993-March 1, 2018
14193000	Willamina Cr Nr Willamina, OR	45° 8′ 35.671″	-123° 29′ 40.7″	June 1, 1934-October 29, 1991	September 30, 1991-March 1, 2018
14194300	North Yamhill R Nr Fairdale, OR	45° 21′ 53.852″	-123° 22′ 45.48″	October 1, 1958-October 29, 1991	September 30, 1991-March 1, 2018
14202850	Scoggins Cr Ab Henry Hagg Lake Nr Gaston, OR	45° 29′ 59.791″	-123° 15′ 4.277″	October 1, 1972-October 29, 1976	September 30, 1976-March 1, 2018
14202920	Sain Cr Nr Gaston, OR	45° 28′ 50.891″	-123° 14′ 45.19″	October 1, 1972-October 29, 1976	September 30, 1976-March 1, 2018
14202980	Scoggins Cr Bl Henry Hagg Lake Nr Gaston, OR	45° 28′ 18.322″	-123° 11′ 50.881″	January 1, 1975-October 1, 2006	October 2, 2006-March 1, 2018
14206500	Tualatin R at Farmington, OR	45° 26′ 57.71″	-122° 57′ 2.588″	October 1, 1939-October 29, 1976	September 30, 1976-January 25, 2018

Maximum Stage and Streamflow Statistics

R was used to compute each gage's maximum stage and streamflow statistics. Water-year (October 1–September 30) maximum stage and streamflow were computed. Seasonal maximum statistics were computed for the typical high-flow seasons of the LCR basin, winter (November–March) and spring (April–July). Typical low-flow season (summer–autumn) statistics were not computed for this study. All maximum statistic results are available at Boudreau and others (2021).

Supplemental Information

In addition to aggregating a comprehensive streamflow and elevation dataset for the study area, additional analysis was provided for three USGS stations within the study area. These stations are briefly summarized here and available as Appendix 1 and 2 below.

The USGS does not have an established rating for computing streamflow at Willamette River above Falls, at Oregon City (14207740). Appendix 1 describes the history and reasoning behind why continuous streamflow has not been part of the historical record at the gage and discusses two methods that could be used to produce a record of continuous streamflow.

An evaluation of the gage data at Willamette River at Portland (14211720) and Columbia River at Vancouver (14144700) was completed along with a re-survey at each gage location to associated benchmarks (Appendix 2). The USGS gage datum at 14211720, which had previously been described as 1.55 ft above NGVD29, has since been adjusted to 1.48 ft above NGVD29 or 4.96 ft above NAVD88. The vertical gage datum at 14144700 is CRD, and the reported conversion was previously described as 1.82 ft above NGVD29. This datum has since been updated to 1.77 ft above NGVD29 or 5.22 ft above NAVD88.

Summary

A total of 402 datasets from 7 national and state agencies were compiled into a HEC-DSSVue database file. These included daily streamflow, annual peak streamflow, streamflow from various historic flooding events, along with elevation and stage data. The datasets were reviewed for any potential erroneous data before being accepted into the final database. The database files are available at Boudreau and others (2021).

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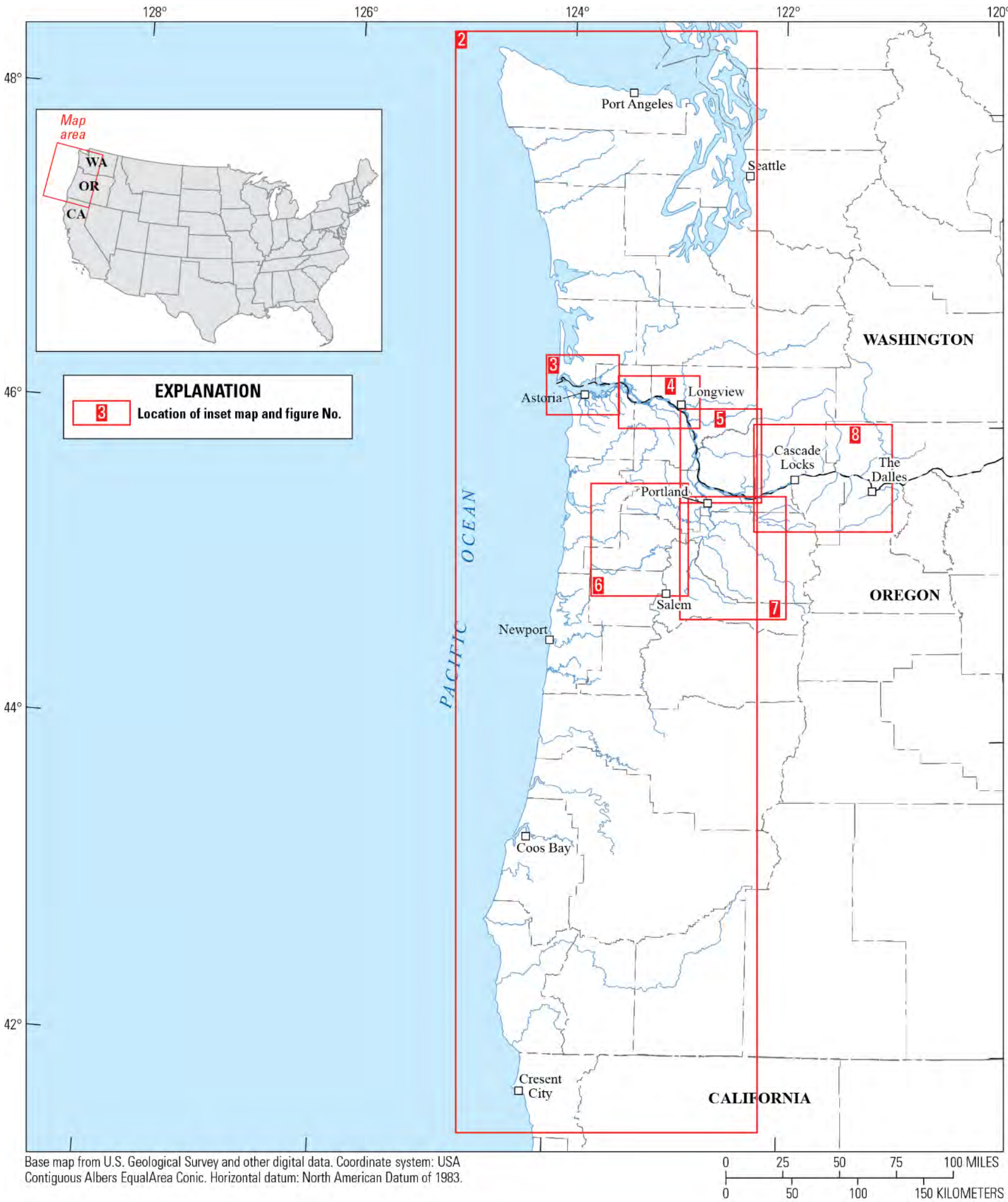


Figure 1. The Lower Columbia River flood profile study area with sub-regions. [2, Coastal Washington and Oregon; 3, Lower Columbia River Estuary; 4, Upper Columbia River Estuary; 5, Longview to Portland; 6, Willamette River Coastal; 7, Willamette River Cascades; 8, Troutdale to The Dalles.]

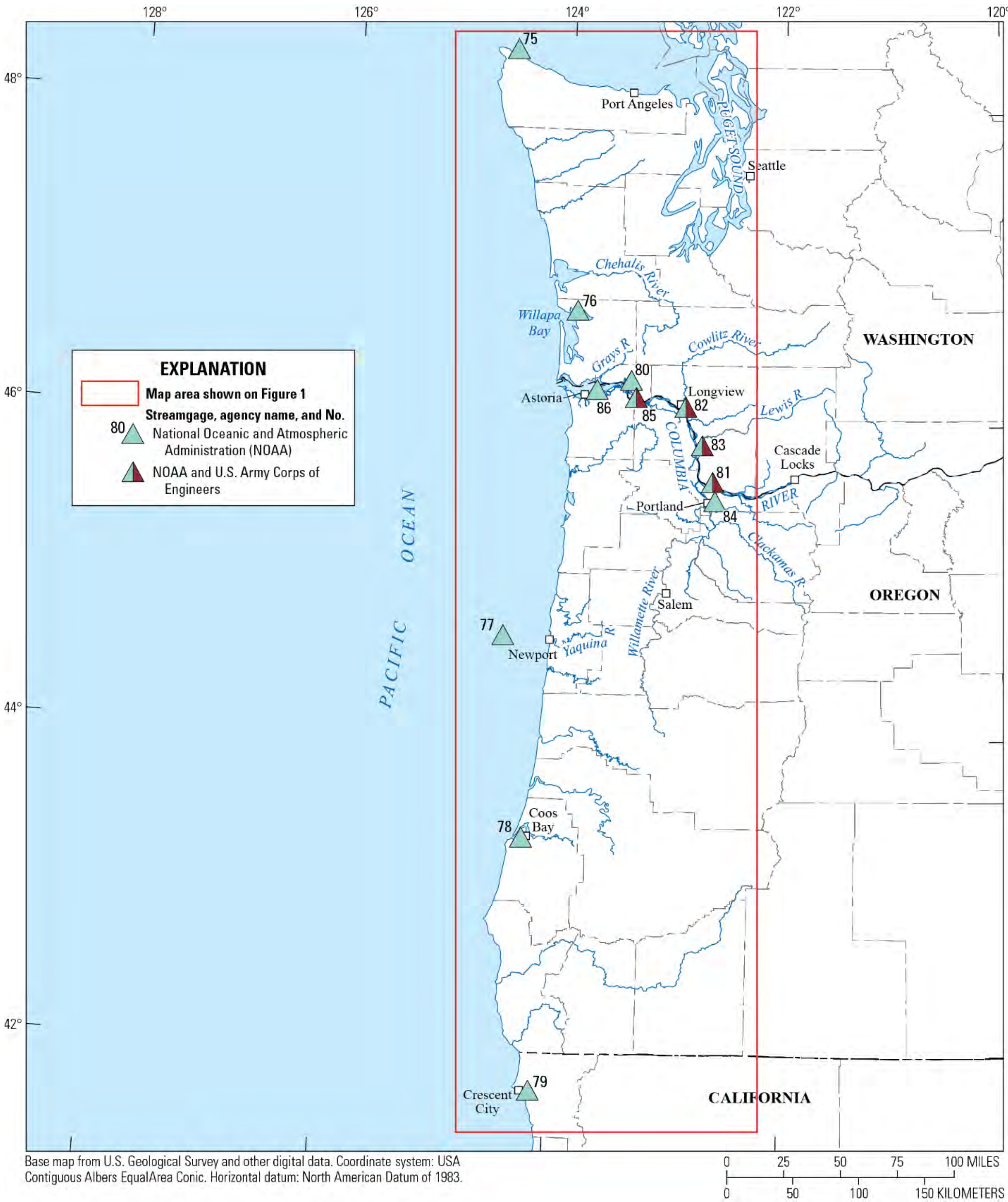


Figure 2. The coastal Washington, Oregon, and California sub-region of the Lower Columbia River flood profile study area. [The gaging stations are depicted as triangles, with the color signifying the agency/agencies that collected the data. Stations are numbered and correspond to station information provided in table 5.]

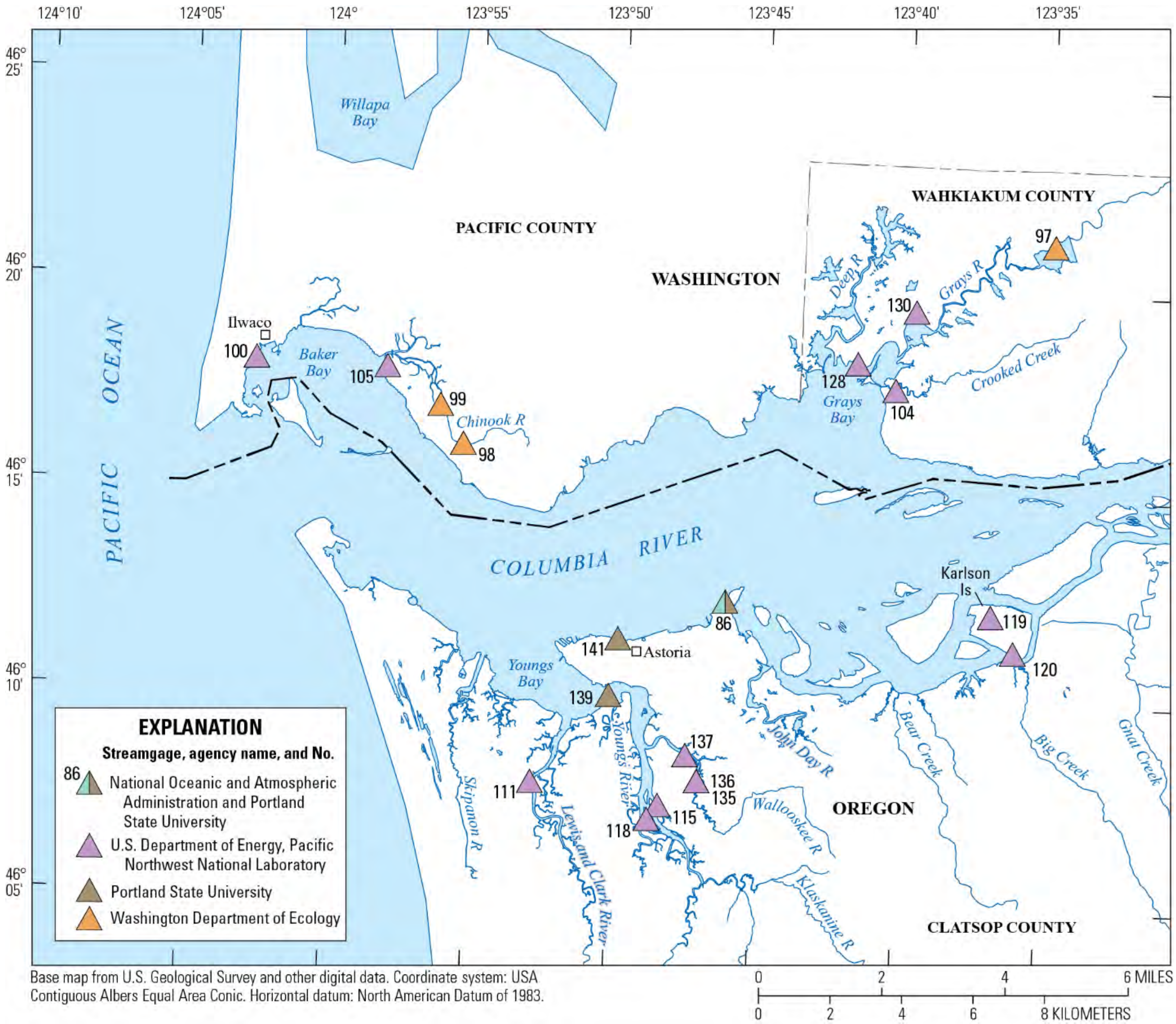


Figure 3. The Lower Columbia River Estuary sub-region of the Lower Columbia River flood profile study area, Washington and Oregon. [The gaging stations are depicted as triangles, with the color signifying the agency/agencies that collected the data. The circles depict elevation only monitoring stations. Stations are numbered and correspond to station information provided in tables 5, 6, 7, and 8.]

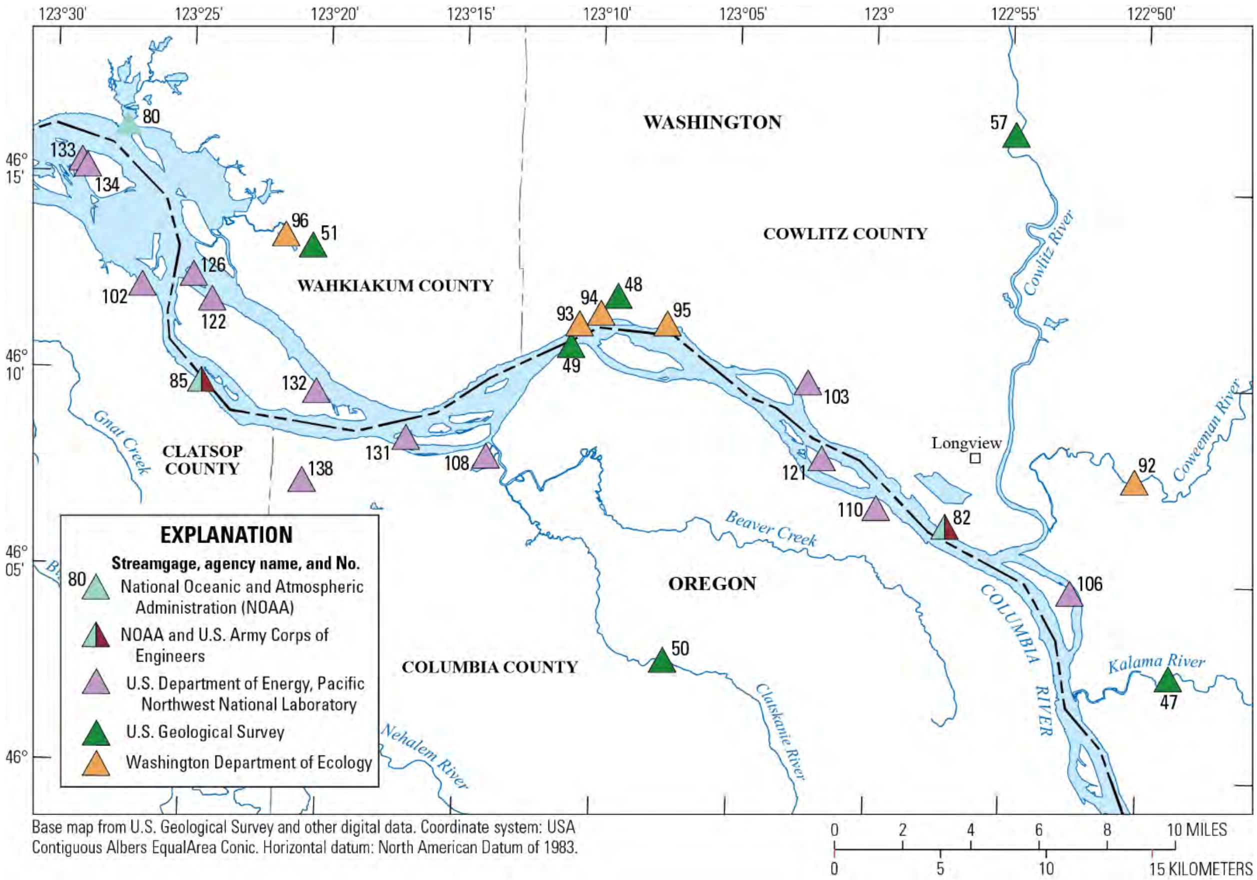
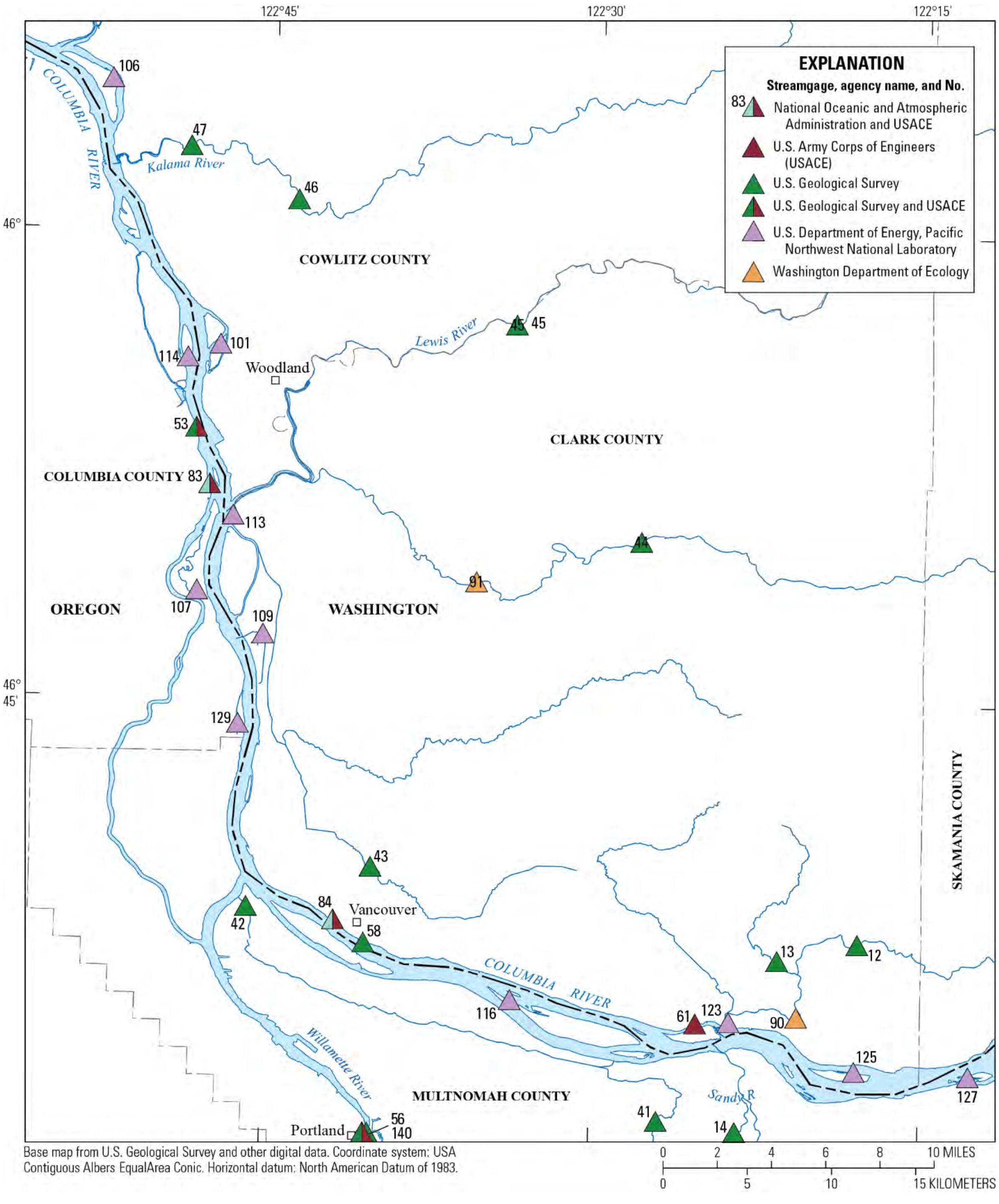


Figure 4. The Upper Columbia River Estuary sub-region of the Lower Columbia River flood profile study area, Washington and Oregon. [The gaging stations are depicted as triangles, with the color signifying the agency/agencies that collected the data. The circles depict elevation only monitoring stations. Stations are numbered and correspond to station information provided in tables 2, 5, 6, and 7.]



Base map from U.S. Geological Survey and other digital data. Coordinate system: USA Contiguous Albers EqualArea Conic. Horizontal datum: North American Datum of 1983.

Figure 5. The Longview to Portland sub-region of the Lower Columbia River flood profile study area, Washington and Oregon. [The gaging stations are depicted as triangles, with the color signifying the agency/agencies that collected the data. The circles depict elevation only monitoring stations. Stations are numbered and correspond to station information provided in tables 2, 5, 6, 7, and 9.]

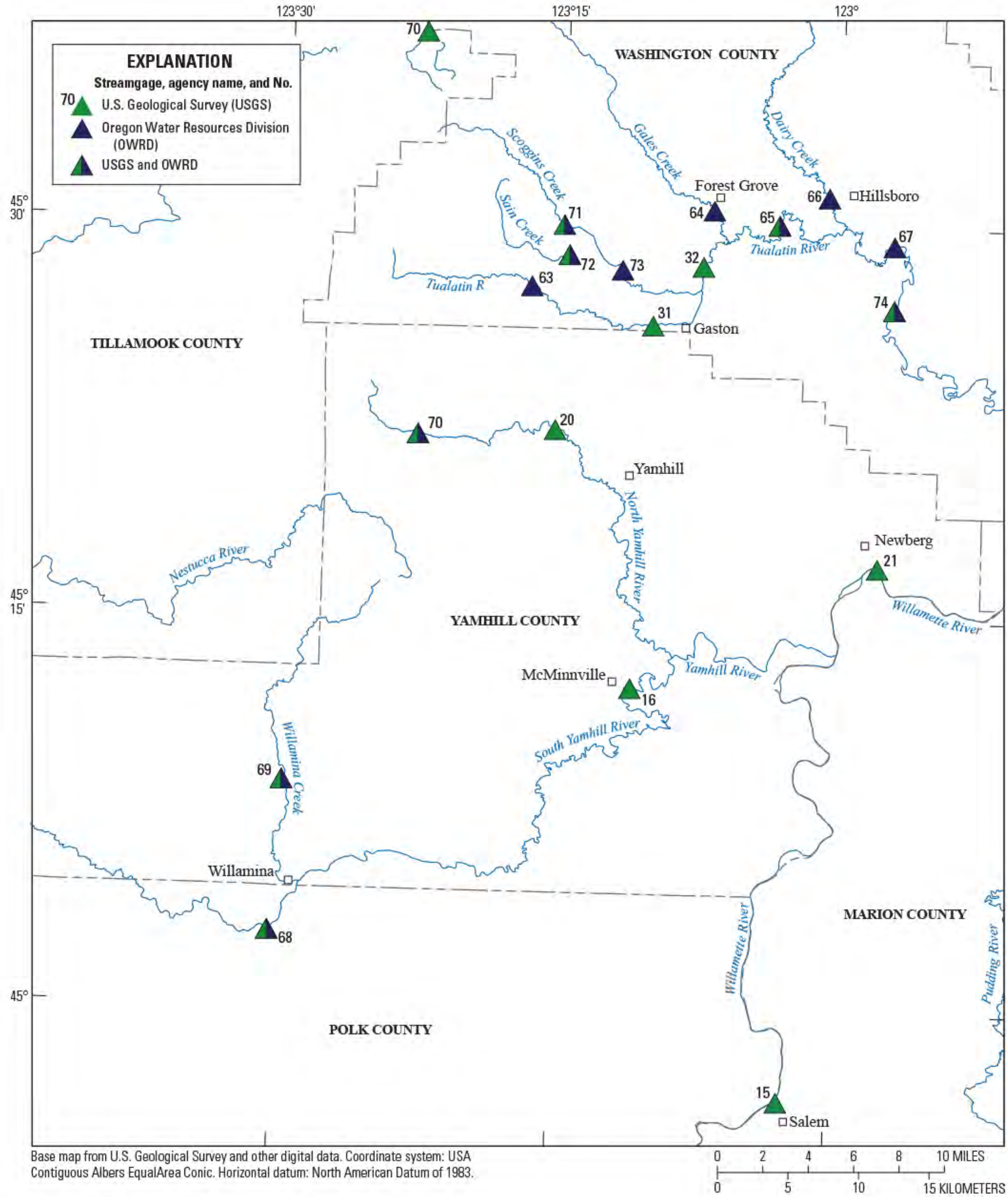


Figure 6. The Willamette River Coastal sub-region of the Lower Columbia River flood profile study area, Oregon. [The gaging stations are depicted as triangles, with the color signifying the agency/agencies that collected the data. Stations are numbered and correspond to station information provided in tables 2 and 4.]

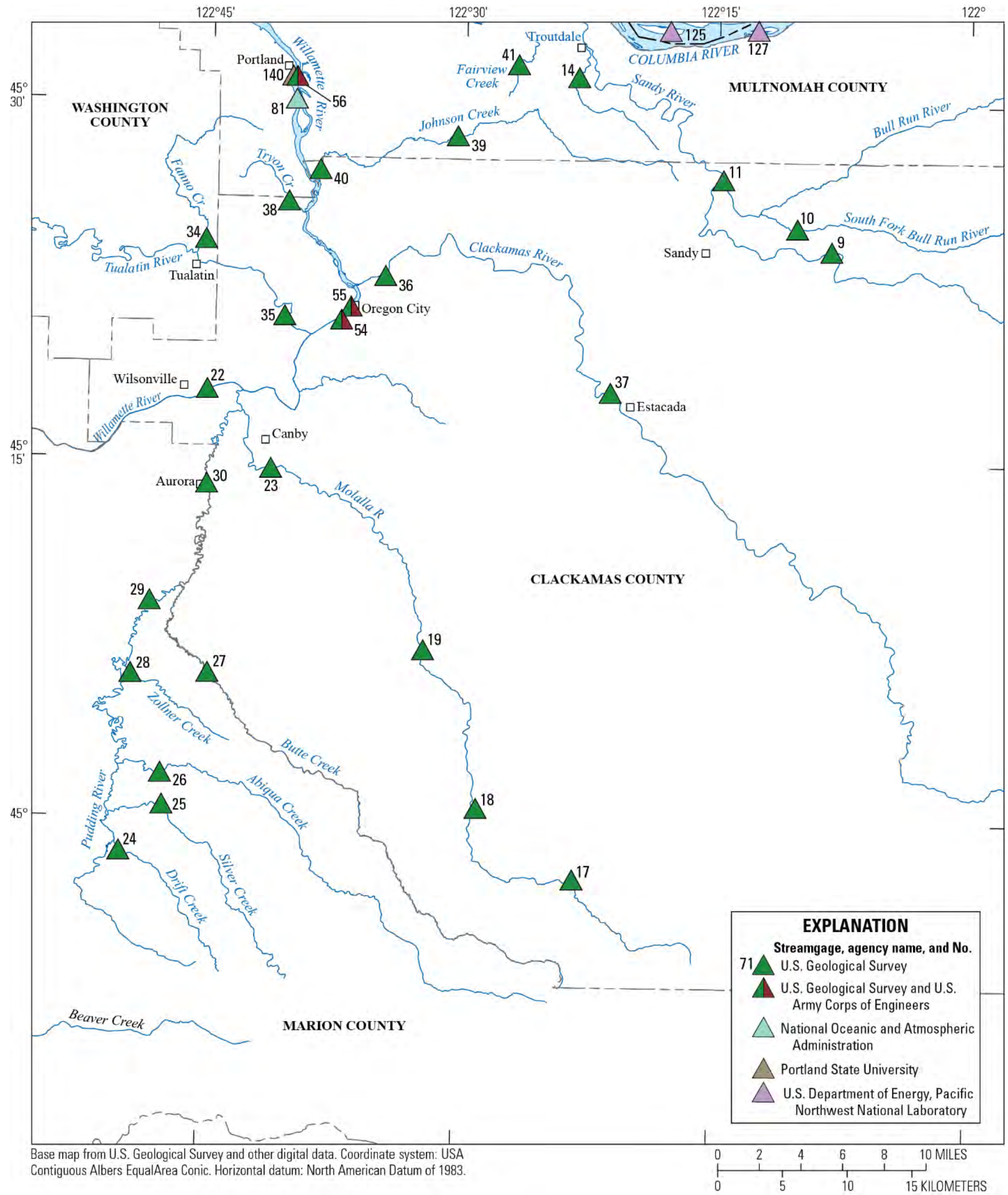


Figure 7. The Willamette River Cascades sub-region of the Lower Columbia River flood profile study area, Washington and Oregon. [The gaging stations are depicted as triangles, with the color signifying the agency/agencies that collected the data. The circles depict elevation only monitoring stations. Stations are numbered and correspond to station information provided in tables 2, 5, and 8.]

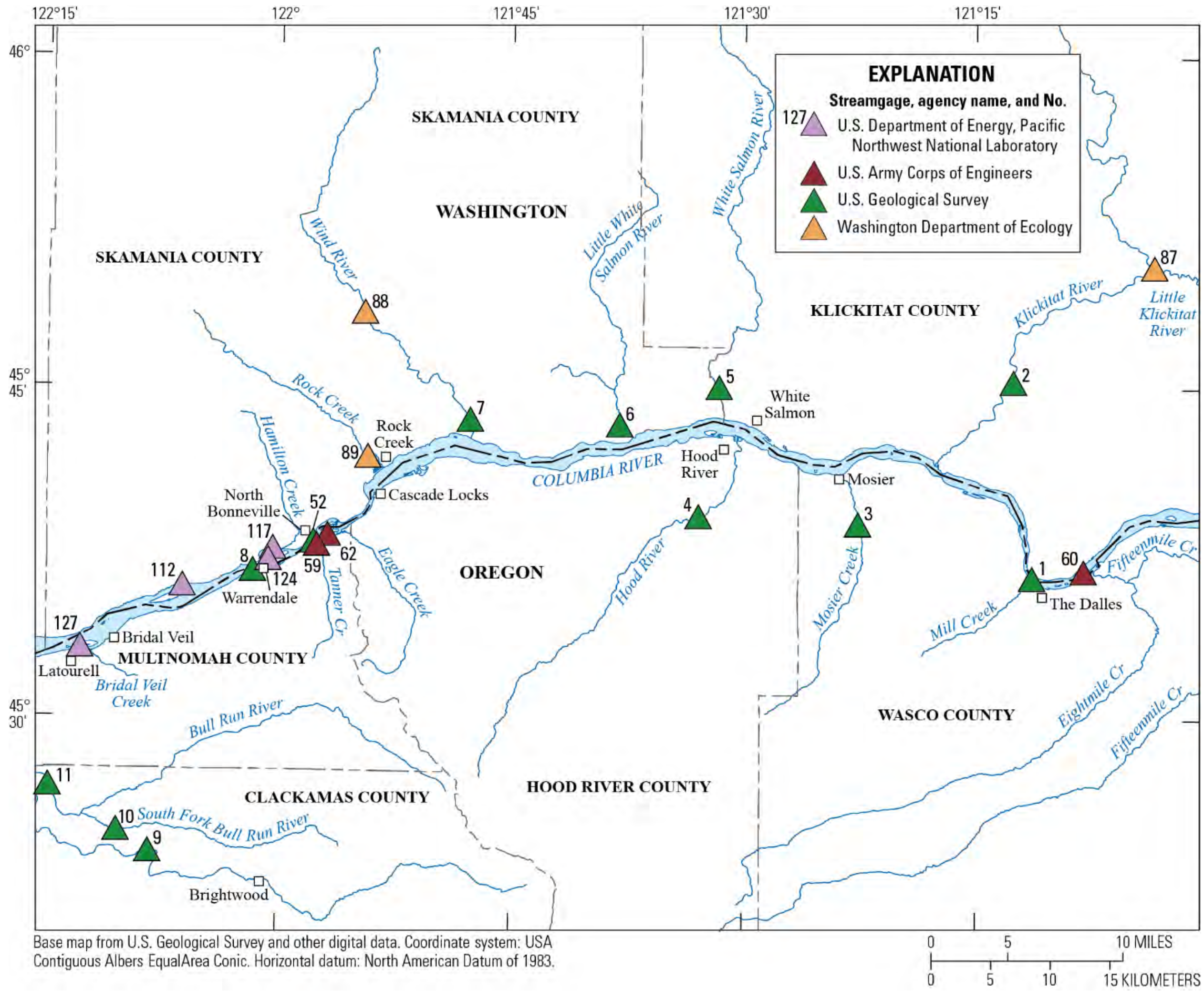


Figure 8. The Troutdale to The Dalles sub-region of the Lower Columbia River flood profile study area, Washington and Oregon. [The gaging stations are depicted as triangles, with the color signifying the agency/agencies that collected the data. The circles depict elevation only monitoring stations. Stations are numbered and correspond to station information provided in tables 2, 6, 7, and 9.]

Appendix 1. Examination of Gaging and Feasibility of Streamflow Ratings at Willamette Falls

By Marc A. Stewart and Carrie L. Boudreau

The Willamette Falls are situated about 26 river miles upstream from the confluence of the Willamette River and the Columbia River. The normal operating range of the river above Willamette Falls, based on U.S. Geological Survey (USGS) data, is 54 feet (ft), National Geodetic Vertical Datum of 1929 (NGVD 29) in the summer to 58 ft (NGVD 29) in the winter. The river is free flowing over Willamette Falls except for the use of flashboards and a bladder system.

Flashboards have been used to manipulate water level in the river above Willamette Falls in some form since at least 1908. The boards are typically installed annually between June and early July (fig. 1.1) and remain in place until the first high flow event in early fall. The bladders were introduced in 2008 and aid in directing the flow for fish passage. (D. Cramer, Portland General Electric, written communication, July 2, 2018). Historical water levels, above Willamette Falls, were potentially influenced by U.S. Army Corps of Engineers (USACE) navigational lock operations during summer months. That system is non-operational since December 2011 (U.S. Army Corps of Engineers, 2018).

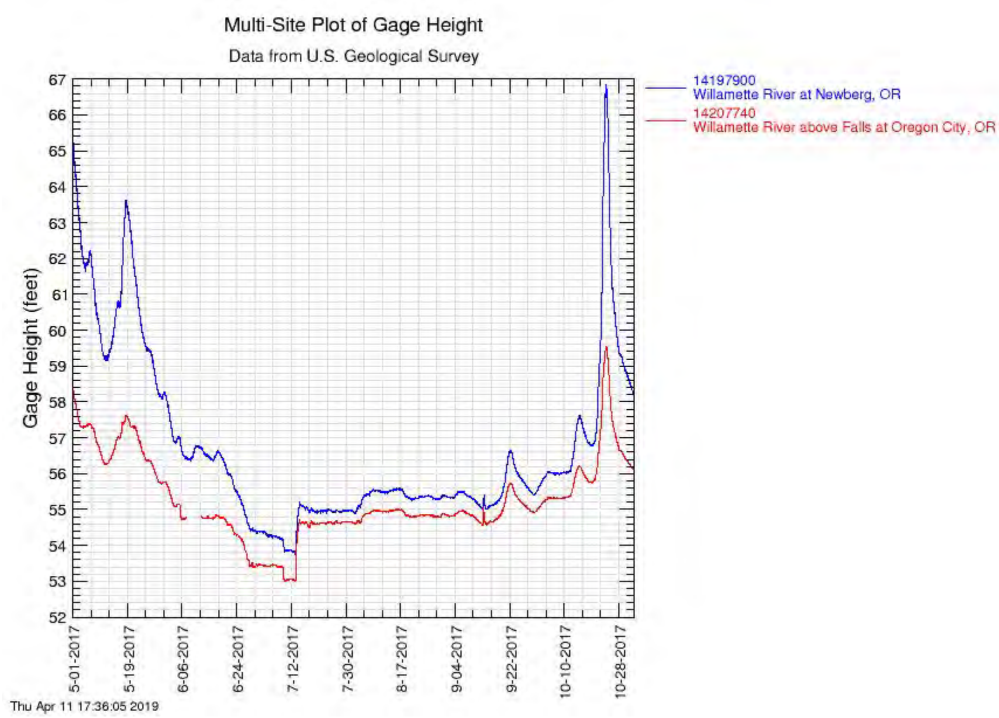


Figure 1.1. Gage height data at Willamette River above the Falls at Oregon City, Oregon, and Willamette River at Newberg, Oregon, illustrating the effect of the flashboards for summer 2017 in which the flashboards were installed in mid-July.

Summary of Key Gaging activities at Willamette Falls

From 1909 to 1912 the USGS published daily water level data furnished by Portland Railway, Light and Power Company, a precursor to Portland General Electric (PGE). In the USGS's early Water Supply reports and archived files at the USGS office in Portland, the location was simply referred to as Willamette River at Oregon City. The gage locations were described as below Willamette Falls at a "vertical staff at the foot of the locks" or "vertical staff gage on the left bank about 1 mile above Willamette Falls." Values were published from both locations.

During 1909–12, streamflow measurements were made by the USGS on the Willamette River either below the mouth of the Clackamas River, about 1.4 miles downstream of Willamette Falls, or at the historical location of a railroad bridge 7 miles downstream of Willamette Falls. Measurements were made by boat, and inflows were subtracted as necessary, so the results represented river discharge at Willamette Falls.

The U.S. Department of Agriculture and the Weather Bureau, a precursor to the National Weather Service (NWS) also recorded water levels at this location. Their readings were made from the staff plate located below the locks (USGS files).

In 1927, the USGS, at the request of the U.S. Army Corps of Engineers made 18 streamflow measurements as well as velocity verification measurements for the turbines. More recently between 1992 and 2001, the USGS made 14 streamflow measurements above the Willamette Falls and above the Tualatin River.

The USGS has recorded water levels at both Willamette River above the Falls at Oregon City (14207740) and Willamette River Below the Falls at Oregon City (14207770) since 1976. Continuous streamflow was not computed for either of these locations. The gage above Willamette Falls is located on the right bank (from the reference frame looking downstream), 0.2 mi upstream from Willamette Falls, 1.6 mi downstream from Tualatin River, and at river mile 26.8. The gage below Willamette Falls is located on the right bank, 0.5 mi downstream from Willamette Falls, 1.4 mi upstream from Clackamas River, and at river mile 26.2

Streamflow Ratings and Streamflow

Upstream of the Willamette Falls a stage-streamflow relationship is unreliable due to backwater caused by the installation of flashboards and bladders. It appears early efforts to measure streamflow (1909–12 and 1927) were made downstream due to dangerous boating conditions above Willamette Falls. The measurements from 1992–2001 were made above the Tualatin River during non-flood conditions.

Downstream of Willamette Falls, the Willamette River is tidally influenced (fig. 1.2), preventing the development of an accurate stage-streamflow rating required to compute streamflow. Developed stage-streamflow ratings would have limited use outside of flood conditions.

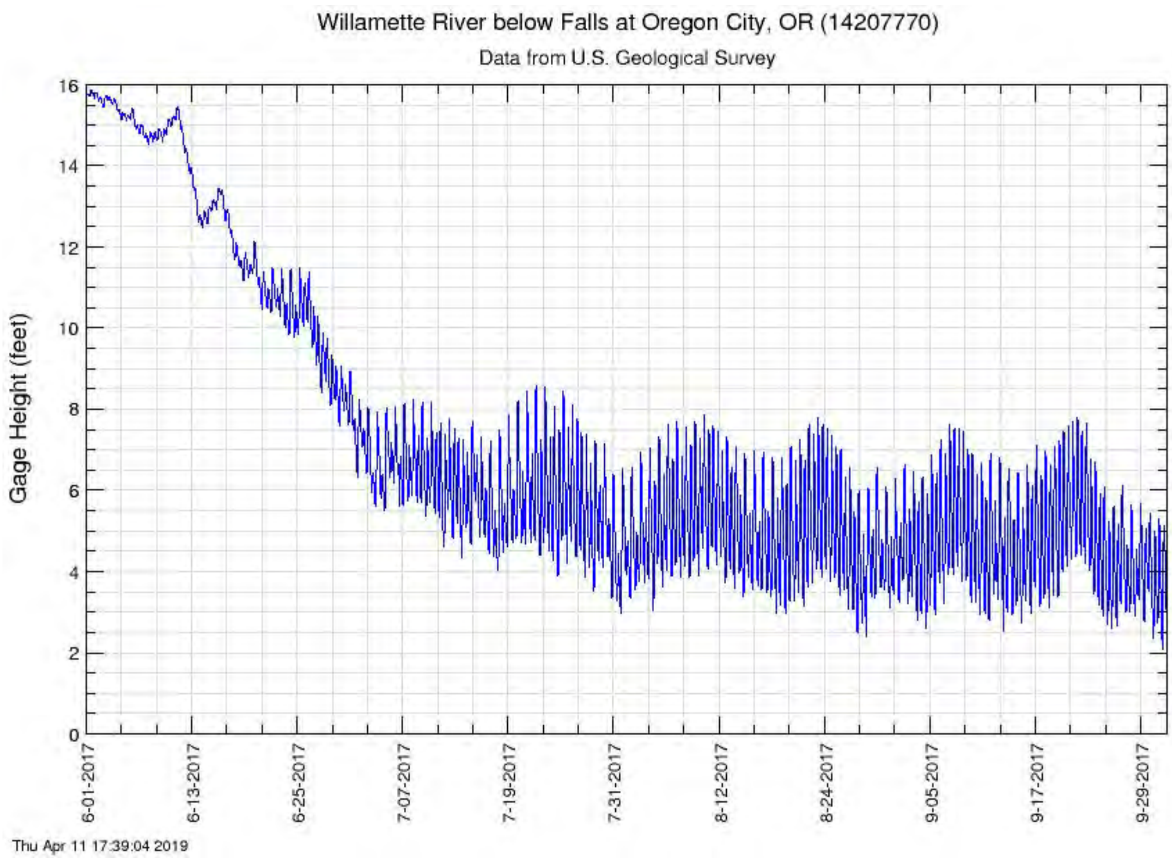


Figure 1.2. Gage height data at Willamette River below the Falls at Oregon City, Oregon; illustrating the semidiurnal tidal effect on the gage height record.

The USGS developed stage-streamflow ratings in 1912 and 1927. The ratings of data collected above Willamette Falls are only valid when flashboards are not installed due to the backwater conditions.

Of the 14 streamflow measurements made by the USGS between 1992 and 2001, 13 were correlated with available stage data from Willamette River above the Falls (14207740; fig. 1.3).

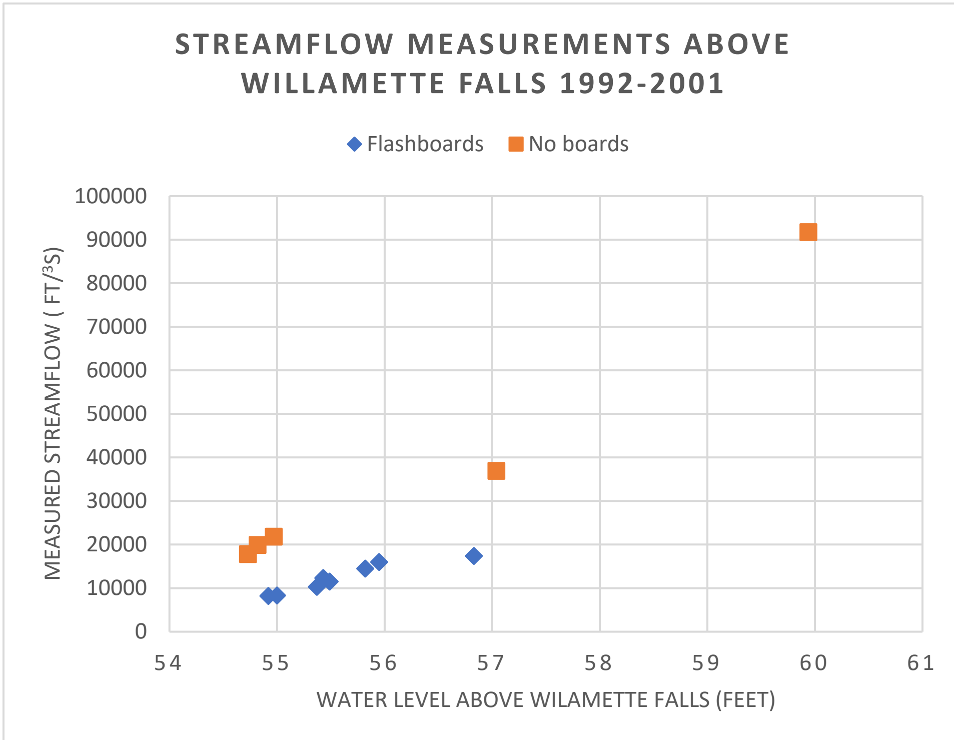


Figure 1.3. Plot of 13 streamflow measurements (cubic feet per second) and corresponding water level (feet) above the Willamette Falls.

The NWS uses a synthetic streamflow rating at Willamette Falls for internal purposes. They do not use this rating when the flashboards are in place during the summer and fall months (Stephen King, National Weather Service, written communication, Apr. 2, 2019).

The Willamette River at Newberg streamflow gage (14197900) began operation in 2001 to establish continuous streamflow data above Willamette Falls. This gage is located at river mile 50.0 and is 23.4 miles above Willamette Falls. Stage, at this location, is not affected by the flashboards or bladders.

Stage-streamflow ratings above Willamette Falls are only reliable without the flashboards or bladders. Stage-streamflow ratings below Willamette Falls are only reliable during flood conditions.

Summary of Drainage Area and Inflows between Willamette River at Newberg and Willamette Falls & Monthly Water Balance Comparisons.

The Willamette River above the Falls streamflow gage (14207740) is at river mile 26.8 with a drainage area of 10,100 square miles. The closest streamflow gage, upstream of the Willamette Falls gage, is Willamette River at Newberg (14197900). The Newberg gage is at river mile 50.0 with a drainage area of 8,350 square miles. Major inflows between the two gages consist of the Tualatin River and the Molalla River. The Tualatin River at West Linn streamflow gage (14207500), with a drainage area of 706 square miles, accounts for 99 percent of the total drainage for the river when compared to the drainage area at the mouth of Tualatin River. On the Molalla River, two upstream gages; Molalla River near Canby (14200000) and Pudding River at

Aurora (14202000), account for 91 percent of the drainage area when compared to the drainage area at the mouth of the Molalla River. The Willamette River at Newberg drainage area along with the drainage areas of the major inflow rivers (Tualatin and Molalla) together account for 98 percent of the total drainage area when compared to the Willamette River above Willamette Falls.

Directly downstream of Willamette Falls, the USGS measures water level at Willamette River below the Falls at Oregon City (14207700). The drainage area at the downstream and upstream water level gages are the same. The only mainstem streamflow gage downstream of Willamette Falls is the Willamette River at Portland (14211720), at river mile 12.8. The Clackamas River accounts for 98 percent of the contributing drainage area to the main river between the Willamette Falls and the Willamette River at Portland gage.

Streamflow is not computed at Willamette Falls. Currently a record of streamflow is available upstream at Willamette River at Newberg (14197900) and downstream at Willamette River at Portland (14211720). Streamflow records are also produced at significant inflows between the Willamette at Newberg and Willamette at Portland gages. These streamflow records make it feasible to determine an approximation of monthly streamflow at Willamette Falls by water balance.

Monthly water balance tables were created from October 2008 to October 2017 using available streamflow data from the gages described below (table 1.1). In 2003–07, the low flow period for 14211720 was estimated by a similar water balance method.

Table 1.1. Locations analyzed using monthly water balance tables and their associated drainage areas.

[**Abbreviation:** USGS, U.S. Geological Survey]

USGS station identifier or latitude, longitude (decimal degrees)	USGS station name or river location	Drainage area (square miles)
14207700	Willamette River Below the Falls, at Oregon City	10,100
14207740	Willamette River Above Falls, at Oregon City	10,100
14207500	Tualatin River at West Linn	706
45.3382, -122.65175	Near Mouth of Tualatin River	710
45.32913, -122.65913	Willamette River above Tualatin River	9,370
45.29321, -122.72089	Near Mouth of Molalla River	874
14200000	Molalla River Near Canby	323
14202000	Pudding River at Aurora	479
14197900	Willamette River at Newberg	8,350

Two methods were used to calculate streamflow at Willamette Falls. Method 1 summed monthly streamflow based on the streamflow at Willamette River at Newberg and significant inflows between Newberg and the Willamette Falls. Method 2 summed monthly streamflow by subtracting the flow of Willamette River tributaries between the Willamette Falls and the Willamette River at Portland gage (Clackamas River at Oregon City and Johnson Creek at Milwaukie) from the streamflow values calculated for the Willamette River at Portland. Monthly data from 2008 to 2017 were averaged by month and summarized in table 1.2. When the monthly data are compared, the percent difference between the two methods are typically within 5 percent except during the summer months.

Table 1.2. Summary of the differences between the two methods to estimate monthly streamflow at Willamette Falls, Oregon.

Years	Month	Method 1	Method 2	Percent difference
2008–17	January	57,639	56,138	-2.7
2008–17	February	44,937	43,426	-3.5
2008–17	March	48,745	48,813	0.1
2008–17	April	38,155	36,720	-3.9
2008–17	May	27,821	26,723	-4.1
2008–17	June	19,756	20,194	2.2
2008–17	July	9,257	10,825	14.5
2008–17	August	7,750	9,012	14
2008–17	September	9,380	9,555	1.8
2008–17	October	16,198	15,192	-6.6
2008–17	November	33,095	33,589	1.5
2008–17	December	57,038	56,218	-1.5

Efforts to determine accurate flows at Willamette Falls during low flow periods of the year could be aided by collecting a series of streamflow measurements during the summer months near Willamette Falls.

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Appendix 2. Summary of Datum for Two U.S. Geological Survey Streamflow Gages

By Marc A. Stewart and Carrie L. Boudreau

The U.S. Geological Survey (USGS) investigated the datum and history of stage data at two locations: Columbia River at Vancouver (14144700) and Willamette River at Portland (14211720). Gage-height data were collected on the north side and upstream side of the Interstate 5 (I-5) bridge for the Columbia River (fig. 2.1). The datum is Columbia River Datum (CRD), and the gage-height data can be converted to North American Vertical Datum of 1988 (NAVD 88) at this location with the addition of 5.29 feet (ft). Gage-height data at the Willamette River station were collected on the west side of the piling in the middle section of the Morrison Street Bridge (fig. 2.1). The datum of the gage is the historical USGS datum, and the water level data can be converted to NAVD 88 at this location with the addition of 4.96 ft.

U.S. Geological Survey (USGS) Procedures for Datum Control

Procedures at streamflow gages include periodic station leveling checks to ensure that gage-height measuring equipment at streamflow gages are accurately set to the established gage datum and that the relationship to the established datum is maintained over the life of the streamflow gage. Levels are run at streamflow gages, on a 1- to 3-year cycle, depending on the stability history at the location and whenever differences in gage readings are unresolved (Kenney, 2010).

The USGS term “datum of the gage” may be used to reference either a recognized datum, such as NAVD 88, National Geodetic Vertical Datum of 1929 (NGVD 29), or an arbitrary datum chosen for convenience (Kenney, 2010). Many USGS streamflow gages use an arbitrary datum plane where it is desirable for gage heights to be relatively low numbers.

Columbia River at Vancouver (14144700)

This gage is located on the I-5 Bridge. The gage datum for Columbia River at Vancouver is CRD. The CRD was established as a navigation reference plane for the Lower Columbia River (LCR) in 1912 from Astoria to Portland and extended in 1929 to the Cascade Locks on the Columbia River and up to the Willamette Falls on the Willamette River (Bondurant, 2019).

Historically, the National Weather Service (NWS) maintained and collected data at this location. Beginning in 1998, the USGS has helped with gage maintenance, data verification, and began to publish the gage-height record. Since 2002, the NWS collected data at a station approximately 1 mile downstream, referred to as Vancouver, Washington (9440083; National Oceanic and Atmospheric Administration, 2018a).

Gage-heights at USGS streamflow gages are verified by reference gage observations during site visits and the equipment is reset as necessary. The primary reference gage for this station is a staff plate mounted on the north side of the northern pier.

Gage-height data can be adjusted from station datum (CRD) to NAVD 88 with an addition of 5.29 ft.

Willamette River at Portland (14211720)

This gage is located at the Morrison Bridge. The gage datum for the Willamette River at Portland is USGS datum. The USGS datum was determined based on historical levels run in the early 1900s, by USGS and others, to tie in the LCR and are based on the “tide station at Astoria” as the basis for Mean Sea Level (Bondurant, 2019).

USGS began collecting gage-height and velocity data at this location in 1972 to produce a continuous record of streamflow in this tidally affected reach of the river. Additional details of the 1972 velocity meter installation and flow computations are documented in a USGS Open-File Report by Lanean and Smith (1982).

Gage-height readings are verified by reference gage observations during site visits and the equipment is reset as necessary. The primary reference gage for this station is a staff plate on the piling beneath the west control tower. The NWS also maintains a set of staff plates and a wire weight reference gage on the first pier from the left bank (PRTO3).

The vertical gage datum is 1.48 ft above NGVD 29, and prior to 2018, the vertical gage datum was 1.55 ft above NGVD 29. Gage-height data can be adjusted from station datum NGVD 29 to NAVD 88 with an addition of 3.48 ft (National Oceanic and Atmospheric Administration, 2018b).

The USGS gage-heights published for Willamette River at Portland are based on the USGS datum (1.48 ft above NGVD 29), where that datum can be referenced to NAVD 88 by the addition of 4.96 ft. For example, the February 1996 peak is published as 27.74 ft in USGS gage datum or 32.70 ft in NAVD 1988.

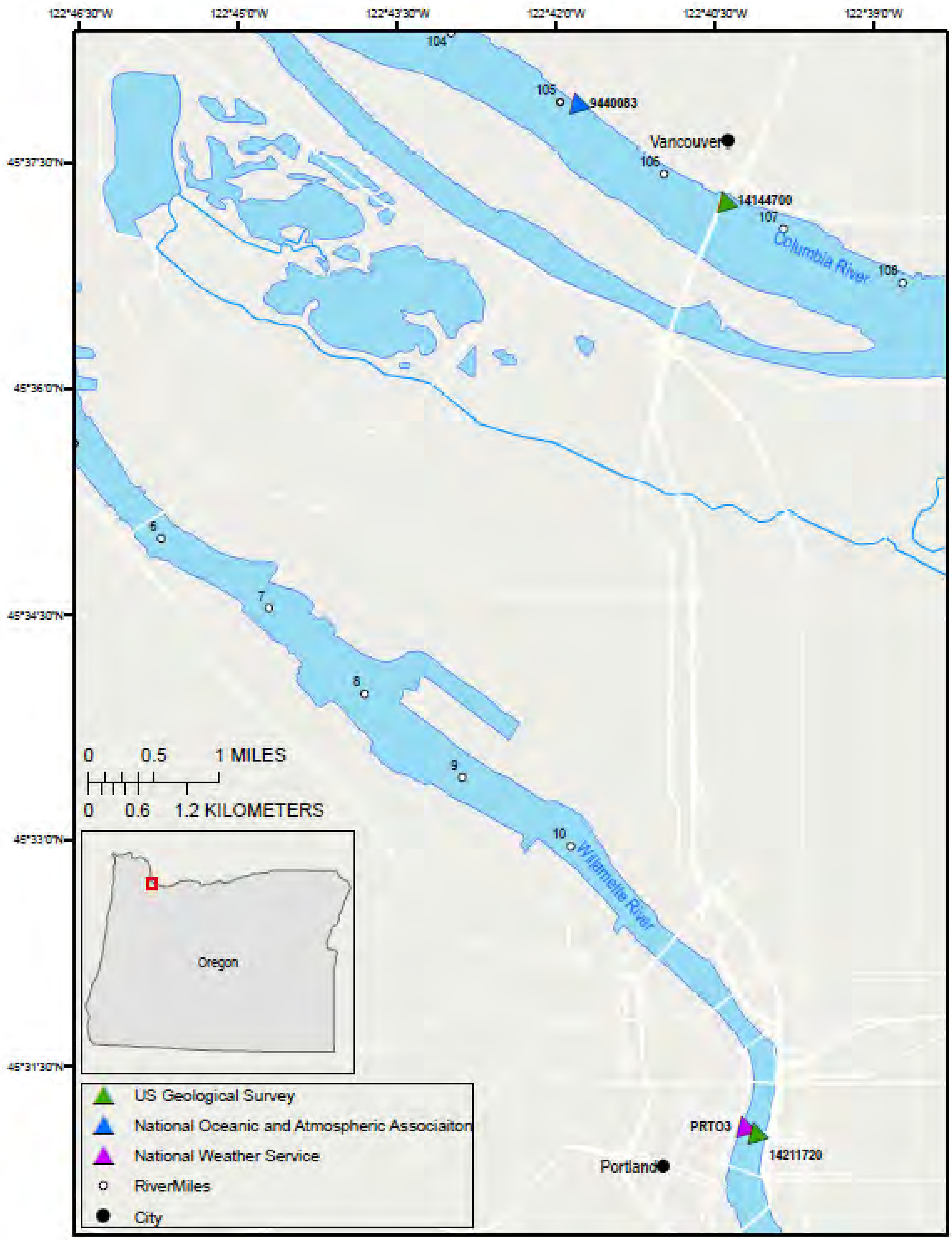

Figure 2.1. Map of the Vancouver, Washington, and Portland, Oregon, gaging station locations discussed in appendix 2. The monitoring stations are depicted as triangles, with the color signifying the agency that collected the data.

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