Prepared in cooperation with the U.S. Army Corps of Engineers and the Bureau of Reclamation

Preliminary Flood-Duration Frequency Estimates Using Naturalized Streamflow Records for the Willamette River Basin, Oregon

Open-File Report 2018–1020

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

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U.S. Geological Survey
William H. Werkheiser, Deputy Director
exercising the authority of the Director

U.S. Geological Survey, Reston, Virginia: 2018

Suggested citation:
Lind, G.D., and Stonewall, A.J., 2018, Preliminary flood-duration frequency estimates using naturalized streamflow records for the Willamette River Basin, Oregon: U.S. Geological Survey Open-File Report 2018-1020, 17 p., https://doi.org/10.3133/ofr20181020.

ISSN 2331-1258 (online)

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Flow	
cubic feet per second (ft^3/s)	0.0283	cubic meter per second (m^3/s)

Datums

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

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

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

Abbreviations

USACE	U.S. Army Corps of Engineers
AEP	annual exceedance probability
Reclamation	Bureau of Reclamation
BPA	Bonneville Power Administration
EMA	Expected Moments Algorithm
MOVE	maintenance of variance extension
NRNI	no-regulation no-irrigation
NWIS	National Water Information System
PILF	potentially influential low flow
SREF	streamflow record extension facilitator
EPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey

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Abstract

In this study, “naturalized” daily streamflow records, created by the U.S. Army Corps of Engineers and the Bureau of Reclamation, were used to compute 1-, 3-, 7-, 10-, 15-, 30-, and 60-day annual maximum streamflow durations, which are running averages of daily streamflow for the number of days in each duration. Once the annual maximum durations were computed, the flood-duration frequencies could be estimated. The estimated flood-duration frequencies correspond to the 50-, 20-, 10-, 4-, 2-, 1-, 0.5-, and 0.2-percent probabilities of their occurring or being exceeded each year. For this report, the focus was on the Willamette River Basin in Oregon, which is a subbasin of the Columbia River Basin. This study is part of a larger one encompassing the entire Columbia Basin.

Introduction

Flood-frequency estimates provide information used to design, maintain, and operate structures that convey or retain large volumes of streamflow. For structures such as bridges and culverts, the flood-frequency predictions of most interest are annual exceedance probabilities (AEP). An AEP (also known as the “annual peak-flow prediction”) is the estimated probability that a certain instantaneous streamflow will be equaled or exceeded for any given year. A recurrence interval of 100 years, also known as a “100-year event,” has an AEP of 1/100 (or 1 percent).

AEP of flood-durations is important to consider for public agencies or private companies operating water-retention structures such as dams and levees. Flood-durations are running averages of daily streamflow during selected time periods, usually described as “N-days” where “N” refers to the number of days contained by a particular duration. Flood-duration frequency estimates are required to effectively and safely operate dams and reservoirs, especially if their primary purpose is for flood control.

Most Federal agencies involved with flood-frequency studies follow the guidelines of Bulletin 17B, which was issued by the Interagency Committee on Water Data, Hydrology Subcommittee (Interagency Advisory Committee on Water Data, 1982). The method recommended by Bulletin 17B to predict flood frequencies is fitting a log-Pearson type III (LP3) probability distribution to streamflow data. The data are logarithmically (base 10) transformed, which usually results in a more linear fit than plotting flood-flow data on an arithmetic scale using the original untransformed data. Fitting an LP3 distribution to streamflow data uses three sample moments: mean, standard deviation, and skew coefficient. Skew coefficients are a determinant of the shapes of the LP3 fitted curves, which can significantly affect the magnitudes of flood estimates.

Purpose and Scope

This report presents provisional, "naturalized" flood-duration frequencies corresponding to the 50-, 20-, 10-, 4-, 2-, 1-, 0.5-, and 0.2-percent probabilities of their occurring or being exceeded each year at 26 regulated stream sites in the Willamette River Basin. The Willamette River Basin analysis discussed in this report is part of a larger study, done in cooperation with the U.S. Army Corps of Engineers (USACE), that encompasses the entire Columbia River. One goal of the overall study is to estimate AEPs for 1-, 3-, 7-, 10-, 15-, 30-, and 60-day flood-duration frequencies, which will be used by the USACE to safely and effectively operate and maintain dams and reservoirs along the Columbia River system.

Another goal of the study is to develop 1-, 3-, 7-, 10-, 15-, 30-, and 60-day regional skew models for the Columbia River Basin. Currently, no N-day flood duration regional skew models have been developed for the entire basin. As recommended by Bulletin 17B, a regional skew is used to weight a station skew to make a particular site more representative of the region. Regional skew values can also be used to increase accuracies of flood-frequency predictions at ungaged locations within a basin. This would be valuable to public agencies and private companies that operate dams in areas where streamflow records do not exist.

Description of Study Area

The Willamette River Basin (fig. 1) is located in northwestern Oregon and has a drainage area of 11,500 mi^2. The Coast Range bounds the basin on the west and the Cascade Range flanks the east; between these two mountain ranges lies the Willamette Valley. The Willamette River Basin includes parts of five ecoregions that are defined by a combination of geology, topography, climate, and other ecological considerations. These five ecoregions include Coast Range, Valley Foothills, Valley Plains, Western Cascades, and High Cascades (Omernik and Gallant, 1986; Clarke and others, 1991; Clarke and Bryce, 1997; Pater and others, 1998; Uhrich and Wentz, 1999; Watershed Professionals Network, 1999; Thiele and others, 2006).

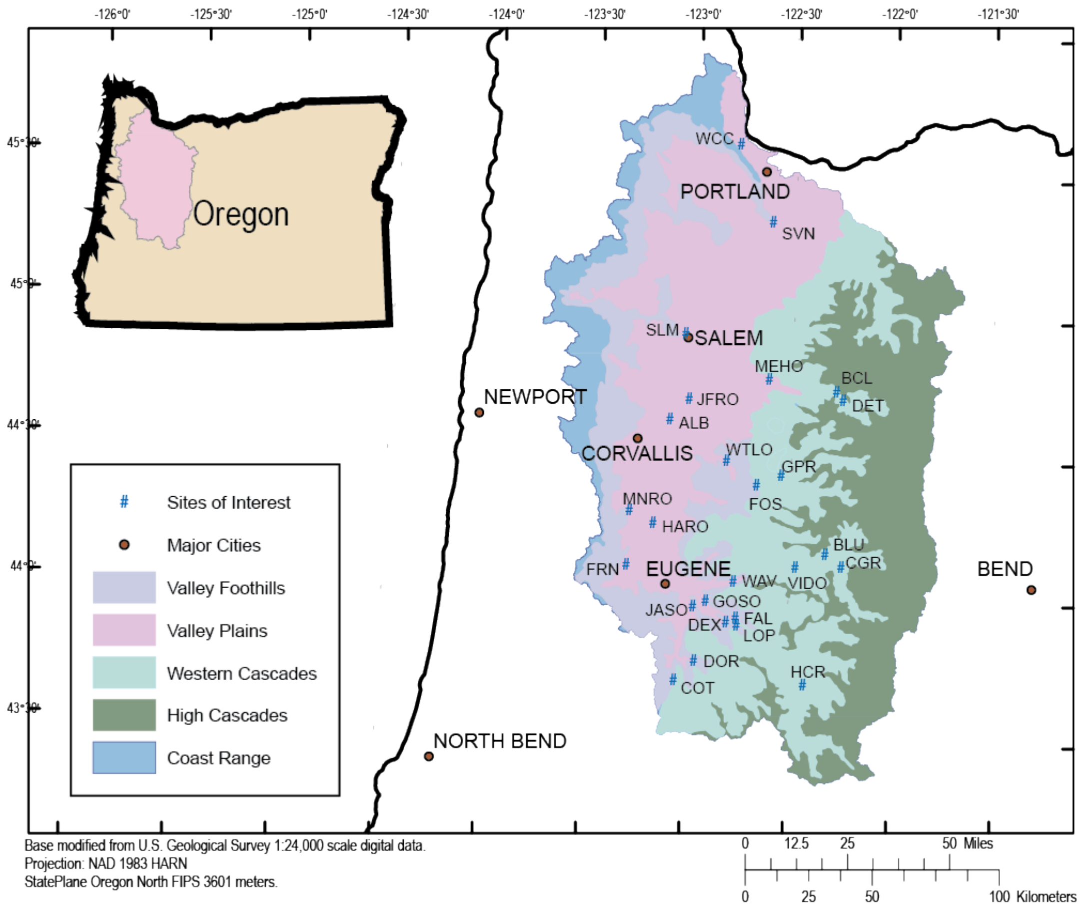

Figure 1. Map showing locations of 5 ecoregions and 26 selected streamflow sites in the Willamette River Basin, Oregon.

The Coast Range is made up of a combination of volcanic and sedimentary rock, the latter having two prominent forms, siltstone and sandstone (Pater and others, 1998). The topography is diverse, with steep slopes in the headwaters and more gradual gradients in lower lying areas. Elevations usually range from 1,500 to 2,000 ft, with the highest elevations reaching 3,000 ft. The annual precipitation is from 70 in. in the lower elevations to 200 in. at the crest of the range, the majority falling in winter (Watershed Professionals Network, 1999; Miller, 2002). Rainstorms during the winter account for the highest sustained monthly flows and the largest peak flows during the year (Miller, 2002).

The foothills surrounding the Willamette Valley are primarily composed of basalt and sandstone. Mostly comprising rolling hills, the slopes are moderate in the Valley Foothills. Elevations are typically in the range of 1,000–2,000 ft, with annual precipitations generally ranging from 40 to 60 inches, but up to 90 inches at higher elevations (Watershed Professionals Network, 1999; Miller, 2002). Like the Coastal Mountains, the majority of precipitation falls in winter months. Usually the highest sustained monthly flows take place in the winter, but snowmelt during the spring can also increase monthly flows. Winter storms with intense precipitation (often generated from atmospheric rivers) and rain-on-snow events are responsible for the largest peak flows.

The Valley Plains consist of fluvial deposits resulting from the ancient Missoula Floods, and much of the land is taken up by agriculture. Being in a lowland area, the valley has very little gradient or change in topology, with elevations ranging only from 100 to 300 ft. The annual precipitation is usually between 40 and 50 in., reaching up to 70 in. at higher elevations, with the majority falling in winter (Watershed Professionals Network, 1999; Miller, 2002). Winter rain produces the highest monthly flows and the largest peaks for streams with watersheds that are entirely encompassed within this region.

Volcanic rock and sediments make up the Western Cascades, which have elevations from 3,000 to 6,000 ft. Slopes are gradual in lower lying areas and steep in upper elevations. Annual precipitation generally ranges from 60 to 90 in. and can reach up to 110 in. in the highest elevations (Watershed Professionals Network, 1999; Miller, 2002). Most of the precipitation occurs during the winter. The highest sustained monthly flows take place during the spring snowmelt, and the largest peak flows occur in the winter from rain storms or rain-on-snow events.

The High Cascades comprise mostly lava flows and pyroclastic deposits along with some glacial deposits. Topographic gradients are moderate in the volcanic plateaus and steep in the upper elevations. The annual precipitation is typically in the range of 70–90 in. and up to 120 in. or more at higher elevations with most occurring in winter (Watershed Professionals Network, 1999; Miller, 2002). Spring snowmelt results in the highest sustained monthly streamflow whereas the largest peak flows in this subregion take place during the winter as a result of rain on snow events.

In 1996, heavy flooding occurred in the Willamette River Basin as a result of heavy rainfall and rapid snowmelt. It has been estimated that the damages caused by the floods of February 6−11, 1996, were reduced by 3.2 billion dollars through effective operations of flood control dams along the Columbia and Willamette River systems (American Institute of Hydrology, 1997).

Selected Streamflow Sites

For the purposes of this report, 26 streamflow sites of interest were selected for the Willamette River Basin (fig.1; table 1). Most of these sites are located at existing USACE reservoirs. Ten of these sites are located within the valley—nine are in the foothills, and the remaining seven are in the Western Cascade Mountains. Headwater sites are in locations that do not have upstream dams. Nine of the 26 sites are headwater sites, and 17 are sites downstream of one or more dams.

Table 1. Twenty-six selected streamflow sites in the Willamette River Basin, Oregon.

[Site locations shown in figure 1. NRNI, no-regulation no-irrigation; USGS, U.S. Geological Survey]

NRNI site ID	Stream	Location	USGS station No.
ALB	Willamette River	Albany	14174000
BCL	North Santiam River	Big Cliff Dam	14181500
BLU	Blue River	Blue River Dam	14162200
CGR	South Fork Mckenzie River	Cougar Dam	14159500
COT	Coast Fork Willamette River	Cottage Grove Dam	14153500
DET	North Santiam River	Detroit Dam	14181500
DEX	Middle Fork Willamette River	Dexter Lake	14150000
DOR	Row River	Dorena Dam	14155500
FAL	Fall Creek	Fall Creek Dam	14151000
FOS	South Santiam River	Foster Dam	14187200
FRN	Long Tom River	Fern Ridge Dam	14169000
GOSO	Coast Fork Willamette River	Goshen	14157500
GPR	Middle Fork Santiam River	Green Peter Dam	14186200
HARO	Willamette River	Harrisburg	14166000
HCR	Middle Fork Willamette River	Hills Creek Dam	14145500
JASO	Middle Fork Willamette River	Jasper	14152000
JFRO	Santiam River	Jefferson	14189000
LOP	Middle Fork Willamette River	Lookout Point Dam	14150000
MEHO	North Santiam River	Mehama	14183000
MNRO	Long Tom River	Monroe	14170000
SLM	Willamette River	Salem	14191000
SVN	Willamette River	T.W. Sullivan Power Plant	14207740
VIDO	McKenzie River	Vida	14162500
WAV	Mckenzie River	Walterville	14163900
WCC	Willamette River	Columbia Confluence	14211720
WTLO	South Santiam River	Waterloo	14187500

Methods

An important consideration for site selection in flood-frequency studies is whether or not the river or stream is affected by flow regulations. Heavily regulated streamflow results in a departure from the natural flow regime. A regulated stream may have truncated or attenuated streamflow peaks as a result of retaining water in an upstream reservoir during flood events, or conversely, during naturally occurring low periods the streamflow may be augmented by dam releases. Since a goal of flood-frequency studies is to predict natural streamflow events, the use of streamflow records from rivers or streams with regulated streamflow would violate the assumptions of flood frequency analysis. One way to handle this potential issue is to reconstruct the altered streamflow record to one that more closely represents the natural streamflow record, or the streamflow record that would exist if it were unregulated.

All sites used in this study had regulation upstream. In order to account for this, the records were reconstructed in an attempt to remove regulatory effects, such as diversions or reservoir storage. The U.S. Army Corps of Engineers (ACOE), Bureau of Reclamation (Reclamation), and the Bonneville Power Administration (BPA) provided reconstructed, or naturalized, daily no-regulation no-irrigation (NRNI) streamflow records from 1928 to 2008 (Bonneville Power Administration, 2011; U.S. Army Corps of Engineers, 2014; K. Duffy, U.S. Army Corps of Engineers, written commun., 2017). The NRNI streamflow records are a modification of the 2010 Level Streamflow records (Bonneville Power Administration, 2011). Both datasets and their accompanying reports are available at https://www.bpa.gov/power/streamflow/default.aspx.

As a major objective of this study, the reconstructed NRNI streamflow records were reviewed and rated based on the quality of each record. If the source of data was a USGS streamgage, its accuracy was checked by comparing data downloaded from the National Water Information System (NWIS) (U.S. Geological Survey, 2016) for the streamgage corresponding with the NRNI streamflow data. Calculations made to datasets during the process of naturalizing the records were verified for accuracy using the equations provided by the USACE. Evaporation and water-use data from outside sources, such as the National Oceanic and Atmospheric Administration and the Oregon Water Resources Department, were used to compare with NRNI components for evaporation and depletion. As a check for consistency, NRNI datasets were plotted along with the measured datasets of regulated streamflow and visually inspected. After a record was reviewed, the quality of the streamflow data was determined. Records determined to be usable were given a rating of “excellent,” “good,” “fair,” or “poor.”

After the review was completed, it was decided that all 26 of the Willamette River Basin sites had usable records. All but four of these records had identical lengths of 80 years (July 1, 1928–September 30, 2008). The remaining four sites, Jefferson, Harrisburg, Jasper, and Goshen, had 73 years of record (water years 1936–2008). Records were extended for the shorter periods by a USGS approved technique called the Maintenance of Variance Extension (MOVE) using the Streamflow Record Extension Facilitator (SREF version 1.0), a software package developed by the USGS (Granato, 2009). MOVE uses one or more longer records, from similar stations, to extend a shorter period of record at a station of interest. A correlation matrix was made using daily streamflow values from all 26 sites in the Willamette River Basin to determine which sites were the most similar to each other. The sites with longer records, which were found to have the highest correlations to the sites with shorter records, were used for the MOVE technique. SREF employs two versions of MOVE: type 1 (MOVE 1) and type 3 (MOVE 3). For high streamflow, which is the focus of this study, MOVE 1 is recommended over MOVE 3 (Granato, 2009). SREF was run for the four sites with shorter records and for each of the seven N-day flood durations, using both MOVE types. Based on the root mean-square error reported by the SREF output files, MOVE 1 performed better than MOVE 3 for all four sites receiving record extensions and for all seven N-day flood durations. It was decided to use MOVE 1 when extending the period of record for the four sites to 80 years.

Bulletin 17B recommends weighting station skews with a regional skew because the resultant weighted skews may be more accurate and representative of a particular basin, especially when records are short and of unequal length. Regional skews have been developed in various parts of the country based on hydrologically significant basin characteristics. Currently, no regional skew models for N-day flood duration frequencies have been developed for the Willamette River Basin. A sample size of 26 sites may be too small to accurately represent a basin as large and diverse as the Willamette River Basin. Bulletin 17B states that it may be reasonable to give more weight to station skews instead of weighting station skews with regional skew values if the stations being analyzed have relatively long record lengths. Since the records being used have identical lengths of 80 years (including the extended records), it was decided that using the station skews for these flood-duration frequency estimates without regional skew weighting would be adequate for this analysis.

GW Toolbox is a USGS-developed software package that allows users the option to compute selected N-day flood durations after inputting a daily mean streamflow record (Barlow and others, 2014). The program will output the maximum selected N-day flood duration for each complete water year from the input record. Using the previously reviewed and approved naturalized daily streamflow records, furnished by the ACOE and the Reclamation, GW Toolbox was used to compute the N-day flood durations. An Excel® template was also created to compute the N-day flood durations as a check against the GW Toolbox output files. The two methods compared well.

There have been numerous recommendations for improvements to Bulletin 17B since it was published (Cohn and others, 1997, 2001; England and others, 2003; Griffis and others, 2004; Stedinger and Griffis, 2008). One potential area of improvement is in the treatment of low-flow outliers. Low-flow outliers are not the only low flows that can significantly affect the LP3 curve (Cohn and others, 2013). Any low flows, whether outliers or not, that extensively affect the LP3 curve are termed potentially influential low flows (PILFs). For this reason, the focus of flood frequency analysis has shifted from outliers to PILFs when considering which low flows should be of a concern.

Bulletin 17B recommends using the Grubbs-Beck test to treat PILFs. One of the shortfalls of the Grubbs-Beck test is that, when numerous PILFs exist, the test is limited in its ability to remove or treat all of them. The Multiple Grubbs-Beck test has been recommended as a more robust test in cases where multiple PILFs exist (Grubbs and Beck, 1972). If PILFs are not removed or properly adjusted for, they can significantly affect the LP3 fitted curve, especially at the upper end. Since flood frequency studies are concerned with high flows, PILFs must be treated correctly to avoid inaccurate high flow predictions.

Another suggested update to Bulletin 17B is the Expected Moments Algorithm (EMA) to fit the LP3 curve (Cohn and others 1997, 2001; Griffis and others, 2004). Bulletin 17B recommends using the method of moments when fitting a frequency curve to observed streamflow data. The EMA has been shown to provide a better fit for the LP3 curve when PILFs have been censored than the method of moments (Stedinger and Griffis, 2008). Another advantage of using the EMA is its ability to calculate the mean-square error of a station skew. The EMA and Multiple Grubbs-Beck test have been incorporated into Bulletin 17C, which will soon replace Bulletin 17B (England and others, in press).

PeakFQ (version 7.1) (Flynn and others, 2006), a USGS software package used to predict flood frequencies, was used for this report. The defaults for the PeakFQ program follow Bulletin 17B guidelines. However, PeakFQ allows users the option to use the Multiple Grubbs-Beck test in place of the Grubbs-Beck test. PeakFQ can also be run using the EMA option as opposed to the method of moments. It was decided to use PeakFQ using the Multiple Grubbs-Beck test and the EMA options for this analysis.

The sets of seven annual N-day flood durations generated by the GW Toolbox program were formatted so they could be run in the PeakFQ batch mode. The resulting LP3 fitted curves were visually inspected for reasonableness. The removal of outliers was visually inspected to determine whether they were treated in a reasonable manner. Sites with 25 percent or more of the streamflow record containing PILFs that were removed were visually inspected. Two sites had more PILFs censored from the streamflow records than the other sites. The Coast Fork Willamette River at Cottage Grove Dam, OR (USGS streamgage 14153599) site had 26 PILFs removed from the 1-day duration data set that was run through Peak FQ, which amounts to 30 percent of the total record. The other site, Coast Fork Willamette River at Goshen, OR (USGS streamgage 14157500), also had 30 percent of the PILFs removed from the set of 1-day durations. For both sites, all the other N-day flood durations had less than 30 percent of their original records removed after running PeakFQ. After visually inspecting these sites, the removal of PILFs seemed reasonable, and further adjustments were not necessary.

When N-day flood duration AEPs are predicted, one area of concern is whether curve crossover occurs. For instance, curve crossover occurs when the predicted 7-day, 100-year flood is larger than the 3-day, 100-year flood estimate, which is unlikely statistically because shorter duration floods should be at least as high in magnitude as the longer duration floods. Usually, they will be higher. A similar concern exists for recurrence intervals, so that a 100-year event should always be as large, or more often larger, than a 50-year event. All predicted N-duration floods were inspected for any crossovers. No crossovers were found for the predicted flood durations at any of the 26 sites, and no adjustments were deemed necessary. Tables of the estimated sets of N-day flood duration AEPs are shown in table 2 (at back of report).

Summary

Flood-duration frequency predictions provide valuable information used to safely and effectively operate and maintain dams and reservoirs. A major assumption of flood frequency analysis is that sites are unregulated. In this study, all selected sites had regulated streamflow. Reconstructed naturalized daily streamflow records, most of them provided by the USACE, were reviewed to determine if they were usable. Twenty-six naturalized daily streamflow records, all 73 or more years, were used for this study.

Four of the 26 daily streamflow records were extended, using the MOVE 1 method, resulting in all 26 records having the same length of 80 years. Bulletin 17B recommends using an estimated regional skew with the computed station skew which should result in a more representative weighted skew. However, because all the records used in this study had the same length of 80 years it was decided to use the individual station skews for this analysis.

The desired N-day flood durations were computed from the naturalized streamflow records using the USGS GW Toolbox software. The annual exceedance probabilities (AEPs) and three moments of the LP3 distribution where determined using the USGS PeakFQ software. PeakFQ was run using the Multiple Grubbs-Beck test and the Expected Moments Algorithm options.

The 1-, 3-, 7-, 10-, 15-, 30-, and 60-day flood durations are presented at AEP intervals coinciding with the 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year events or the 50-, 20-, 10-, 4-, 2-, 1-, 0.5-, and 0.2-percent probabilities, respectively. These flood predictions are provided on a preliminary basis because this study is part of a larger study encompassing the entire Columbia River Basin. With future analyses planned for both the Willamette and Columbia River Basins, revisions to these predictions may be warranted as further information is gained during the progression of this study.

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Table 2. Flood-duration frequency estimates for sites in the Willamette River Basin, Oregon, for the 50-, 20-, 10-, 4-, 2-, 0.5-, and 0.2-percent annual exceedance probabilities.

[NRNI Site ID, no-regulation no-irrigation site identification]

	Percent annual exceedance probability of 1-day flood-duration streamflow (cubic feet per second)							
NRNI Site ID	**50-percent**	**20-percent**	**10-percent**	**4-percent**	**2-percent**	**1-percent**	**0.5-percent**	**0.2-percent**
ALB	100,000	147,000	176,000	212,000	237,000	261,000	284,000	314,000
BCL	17,300	25,000	30,000	37,100	42,400	47,800	53,300	60,800
BLU	5,240	7,650	9,390	11,700	13,600	15,500	17,500	20,400
CGR	6,320	9,530	11,800	14,700	17,000	19,300	21,600	24,800
COT	3,220	4,950	5,970	7,120	7,860	8,530	9,130	9,830
DET	17,300	25,000	30,300	37,100	42,400	47,800	53,300	60,800
DEX	24,700	37,700	46,500	57,600	65,900	74,100	82,200	93,000
DOR	9,140	13,600	16,300	19,700	22,000	24,200	26,200	28,900
FAL	6,570	9,410	11,200	13,300	14,800	16,300	17,600	19,400
FOS	26,800	38,300	46,700	58,200	67,400	77,200	87,600	103,000
FRN	6,600	10,700	13,600	17,400	20,200	23,100	26,000	29,900
GOSO	18,300	30,000	36,600	43,500	47,800	51,300	54,200	57,400
GPR	17,200	24,600	29,900	37,300	43,200	49,500	56,200	65,800
HARO	91,000	134,000	161,000	193,000	215,000	236,000	256,000	281,000
HCR	9,510	15,000	18,800	23,900	27,800	31,700	35,800	41,300
JASO	34,900	52,400	64,300	79,600	91,100	103,000	114,000	130,000
JFRO	73,200	105,000	129,000	162,000	190,000	219,000	251,000	298,000
LOP	24,700	37,700	46,500	57,600	65,900	74,100	82,200	93,000
MEHO	29,200	42,400	51,600	63,900	73,400	83,300	93,600	108,000
MNRO	9,850	15,700	19,600	24,600	28,200	31,700	35,200	39,700
SLM	156,000	223,000	268,000	326,000	370,000	415,000	460,000	522,000
SVN	201,000	281,000	336,000	409,000	465,000	523,000	583,000	666,000
VIDO	23,500	33,600	40,400	48,900	55,200	61,400	67,700	76,000
WAV	26,800	38,100	45,700	55,200	62,200	69,300	76,400	85,900
WCC	225,000	314,000	376,000	458,000	521,000	585,000	653,000	746,000
WTLO	29,900	42,600	51,200	62,500	71,000	79,700	88,600	101,000

Percent annual exceedance probability of 3-day flood-duration streamflow (cubic feet per second)								
NRNI Site ID	**50-percent**	**20-percent**	**10-percent**	**4-percent**	**2-percent**	**1-percent**	**0.5-percent**	**0.2-percent**
ALB	88,500	127,000	153,000	185,000	208,000	231,000	254,000	284,000
BCL	13,200	19,100	23,200	28,600	32,700	36,900	41,100	47,000
BLU	3,900	5,590	6,730	8,190	9,280	10,400	11,500	13,000
CGR	4,840	7,240	9,030	11,500	13,500	15,700	18,000	21,400
COT	2,380	3,460	4,150	4,990	5,580	6,150	6,700	7,400
DET	13,200	19,100	23,200	28,600	32,700	36,900	41,100	47,000
DEX	18,400	27,600	34,200	43,100	50,000	57,200	64,800	75,400
DOR	6,550	9,490	11,400	13,600	15,200	16,700	18,200	20,100
FAL	4,770	6,660	7,860	9,300	10,300	11,300	12,300	13,500
FOS	20,100	28,500	34,000	40,800	45,700	50,600	55,500	61,900
FRN	5,560	8,560	10,500	13,000	14,700	16,400	18,100	20,200
GOSO	14,200	20,700	25,000	30,200	34,000	37,600	41,200	45,900
GPR	12,700	18,100	21,700	26,300	29,800	33,200	36,700	41,300
HARO	70,000	102,000	122,000	146,000	164,000	180,000	196,000	217,000
HCR	6,980	10,800	13,600	17,500	20,600	23,900	27,400	32,400
JASO	26,200	38,600	47,500	59,500	69,000	79,000	89,400	104,000
JFRO	55,700	79,500	95,500	116,000	131,000	146,000	161,000	182,000
LOP	18,400	27,600	34,200	43,100	50,000	57,200	64,800	75,400
MEHO	21,900	31,400	37,700	45,900	52,000	58,200	64,400	72,800
MNRO	8,170	12,500	15,300	18,600	20,900	23,200	25,300	28,000
SLM	144,000	202,000	241,000	290,000	326,000	363,000	400,000	450,000
SVN	188,000	261,000	311,000	377,000	427,000	479,000	533,000	607,000
VIDO	18,400	26,300	31,900	39,100	44,700	50,400	56,300	64,400
WAV	21,400	30,200	36,300	44,000	49,800	55,800	61,800	70,100
WCC	211,000	292,000	349,000	422,000	479,000	537,000	597,000	680,000
WTLO	22,400	31,500	37,500	45,000	50,500	56,000	61,400	68,600

	Percent annual exceedance probability of 7-day flood-duration streamflow (cubic feet per second)							
NRNI Site ID	50-percent	20-percent	10-percent	4-percent	2-percent	1-percent	0.5-percent	0.2-percent
ALB	68,100	94,800	113,000	137,000	155,000	174,000	193,000	219,000
BCL	9,500	13,200	15,700	18,800	21,100	23,400	25,800	28,900
BLU	2,680	3,710	4,360	5,140	5,690	6,230	6,760	7,430
CGR	3,510	4,990	6,030	7,430	8,520	9,650	10,800	12,500
COT	1,620	2,330	2,770	3,310	3,680	4,040	4,380	4,820
DET	9,500	13,200	15,700	18,800	21,100	23,400	25,800	28,900
DEX	12,900	18,600	22,500	27,600	31,500	35,400	39,500	45,000
DOR	4,400	6,130	7,290	8,770	9,880	11,000	12,100	13,700
FAL	3,230	4,390	5,140	6,050	6,700	7,340	7,970	8,800
FOS	14,100	18,900	22,200	26,400	29,700	33,000	36,500	41,200
FRN	4,150	6,050	7,210	8,540	9,450	10,300	11,100	12,000
GOSO	9,700	13,900	16,600	19,800	22,200	24,500	26,800	29,700
GPR	8,810	11,900	14,000	16,700	18,700	20,800	22,900	25,800
HARO	50,700	69,700	83,000	101,000	114,000	129,000	144,000	165,000
HCR	4,890	7,240	8,930	11,200	13,000	14,900	17,000	19,800
JASO	18,700	26,400	31,400	37,600	42,100	46,400	50,700	56,400
JFRO	39,800	53,600	63,400	76,400	86,600	97,300	109,000	124,000
LOP	12,900	18,600	22,500	27,600	31,500	35,400	39,500	45,000
MEHO	15,800	21,700	25,400	29,800	33,000	36,000	38,900	42,600
MNRO	6,080	8,790	10,500	12,500	13,900	15,200	16,400	18,000
SLM	115,000	158,000	186,000	222,000	250,000	277,000	304,000	342,000
SVN	155,000	211,000	249,000	296,000	331,000	367,000	403,000	451,000
VIDO	13,800	18,800	22,200	26,400	29,600	32,800	36,000	40,300
WAV	16,100	21,800	25,400	30,000	33,400	36,700	40,100	44,500
WCC	174,000	237,000	279,000	332,000	371,000	411,000	451,000	506,000
WTLO	15,800	21,000	24,600	29,200	32,700	36,300	40,000	45,100

Percent annual exceedance probability of 10-day flood-duration streamflow (cubic feet per second)								
NRNI Site ID	50-percent	20-percent	10-percent	4-percent	2-percent	1-percent	0.5-percent	0.2-percent
ALB	59,600	82,300	97,100	116,000	129,000	143,000	156,000	174,000
BCL	8,250	11,200	13,100	15,300	16,900	18,500	20,000	22,000
BLU	2,250	3,050	3,550	4,150	4,580	4,990	5,390	5,910
CGR	3,030	4,220	5,070	6,200	7,090	8,020	8,990	10,400
COT	1,390	1,970	2,310	2,710	2,980	3,240	3,470	3,760
DET	8,250	11,200	13,100	15,300	16,900	18,500	20,000	22,000
DEX	11,000	15,600	18,800	22,900	26,000	29,200	32,500	37,000
DOR	3,750	5,130	5,960	6,930	7,610	8,240	8,840	9,600
FAL	2,720	3,650	4,250	4,990	5,520	6,040	6,560	7,250
FOS	12,100	15,900	18,400	21,600	23,900	26,300	28,600	31,800
FRN	3,550	5,080	6,030	7,150	7,930	8,670	9,380	10,300
GOSO	8,270	11,600	13,600	15,900	17,500	19,000	20,400	22,100
GPR	7,600	10,100	11,600	13,500	14,800	16,000	17,300	18,800
HARO	44,100	59,800	70,800	85,700	97,400	110,000	123,000	141,000
HCR	4,180	6,080	7,430	9,230	10,600	12,100	13,600	15,700
JASO	15,900	22,200	26,400	31,700	35,600	39,500	43,400	48,700
JFRO	34,200	45,500	53,200	63,100	70,700	78,400	86,400	97,400
LOP	11,000	15,600	18,800	22,900	26,000	29,200	32,500	37,000
MEHO	13,600	18,300	21,100	24,500	26,800	29,100	31,200	33,900
MNRO	5,210	7,400	8,780	10,400	11,600	12,800	13,900	15,300
SLM	101,000	137,000	160,000	189,000	210,000	230,000	251,000	278,000
SVN	138,000	185,000	215,000	253,000	280,000	307,000	334,000	370,000
VIDO	12,100	16,200	19,000	22,400	25,000	27,600	30,300	33,900
WAV	14,100	18,800	21,800	25,600	28,400	31,200	33,900	37,600
WCC	154,000	207,000	241,000	283,000	314,000	344,000	375,000	415,000
WTLO	13,600	17,800	20,500	23,900	26,500	29,000	31,600	35,000

Percent annual exceedance probability of 15-day flood-duration streamflow (cubic feet per second)								
NRNI Site ID	**50-percent**	**20-percent**	**10-percent**	**4-percent**	**2-percent**	**1-percent**	**0.5-percent**	**0.2-percent**
ALB	51,000	69,300	80,600	94,100	104,000	113,000	121,000	133,000
BCL	6,960	9,240	10,700	12,400	13,600	14,800	16,000	17,500
BLU	1,840	2,470	2,860	3,330	3,670	3,990	4,300	4,700
CGR	2,570	3,490	4,120	4,970	5,630	6,310	7,020	8,010
COT	1,170	1,610	1,880	2,170	2,370	2,560	2,730	2,940
DET	6,960	9,240	10,700	12,400	13,600	14,800	16,000	17,500
DEX	9,260	12,700	15,200	18,500	21,100	23,900	26,800	30,900
DOR	3,120	4,200	4,850	5,590	6,090	6,570	7,010	7,560
FAL	2,280	3,010	3,470	4,030	4,430	4,830	5,220	5,730
FOS	9,980	13,000	14,900	17,400	19,300	21,200	23,100	25,600
FRN	2,970	4,160	4,870	5,670	6,210	6,710	7,160	7,720
GOSO	6,850	9,420	11,000	12,700	13,900	15,000	16,100	17,400
GPR	6,270	8,230	9,420	10,800	11,800	12,800	13,700	14,900
HARO	37,700	50,200	58,700	69,800	78,200	86,900	95,900	108,000
HCR	3,540	5,050	6,080	7,410	8,420	9,450	10,500	11,900
JASO	13,500	18,500	21,700	25,600	28,500	31,300	34,100	37,800
JFRO	28,600	37,200	43,000	50,500	56,100	61,800	67,600	75,600
LOP	9,260	12,700	15,200	18,500	21,100	23,900	26,800	30,900
MEHO	11,400	15,000	17,200	19,900	21,700	23,500	25,100	27,300
MNRO	4,360	6,100	7,140	8,330	9,140	9,890	10,600	11,500
SLM	86,000	115,000	133,000	154,000	170,000	185,000	199,000	218,000
SVN	118,000	156,000	179,000	207,000	227,000	247,000	266,000	291,000
VIDO	10,400	13,700	15,800	18,400	20,400	22,300	24,200	26,800
WAV	12,200	15,900	18,300	21,200	23,300	25,500	27,600	30,400
WCC	132,000	174,000	200,000	232,000	255,000	277,000	298,000	326,000
WTLO	11,300	14,500	16,600	19,200	21,100	23,000	25,000	27,600

	Percent annual exceedance probability of 30-day flood-duration streamflow (cubic feet per second)							
NRNI Site ID	50-percent	20-percent	10-percent	4-percent	2-percent	1-percent	0.5-percent	0.2-percent
ALB	40,800	54,000	61,500	70,000	75,600	80,700	85,400	91,100
BCL	5,380	6,920	7,930	9,200	10,100	11,100	12,100	13,400
BLU	1,410	1,880	2,150	2,480	2,700	2,910	3,110	3,360
CGR	2,040	2,680	3,120	3,690	4,120	4,560	5,020	5,650
COT	880	1,180	1,370	1,590	1,740	1,900	2,040	2,230
DET	5,380	6,920	7,930	9,200	10,100	11,100	12,100	13,400
DEX	7,430	9,990	11,600	13,600	15,000	16,500	17,800	19,700
DOR	2,380	3,170	3,640	4,180	4,550	4,890	5,220	5,620
FAL	1,770	2,310	2,640	3,040	3,320	3,580	3,840	4,170
FOS	7,700	9,930	11,400	13,200	14,500	15,800	17,200	18,900
FRN	2,200	3,000	3,480	4,030	4,410	4,760	5,090	5,510
GOSO	5,250	7,020	8,070	9,290	10,100	10,900	11,600	12,600
GPR	4,830	6,300	7,160	8,140	8,800	9,410	9,990	10,700
HARO	30,200	39,700	45,600	52,700	57,700	62,600	67,300	73,500
HCR	2,770	3,780	4,490	5,440	6,180	6,960	7,770	8,910
JASO	10,500	14,100	16,500	19,600	21,900	24,200	26,500	29,700
JFRO	22,400	28,800	32,700	37,500	41,000	44,300	47,600	51,900
LOP	7,430	9,990	11,600	13,600	15,000	16,500	17,800	19,700
MEHO	8,780	11,300	13,000	15,000	16,500	17,900	19,400	21,300
MNRO	3,230	4,440	5,180	6,040	6,640	7,210	7,740	8,420
SLM	68,000	88,000	101,000	117,000	128,000	140,000	151,000	167,000
SVN	94,000	120,000	137,000	157,000	172,000	186,000	200,000	219,000
VIDO	8,560	10,900	12,400	14,200	15,500	16,800	18,000	19,700
WAV	9,920	12,600	14,400	16,400	17,900	19,300	20,700	22,500
WCC	105,000	135,000	153,000	176,000	192,000	208,000	224,000	245,000
WTLO	8,810	11,200	12,700	14,600	16,000	17,300	18,600	20,300

NRNI Site ID	Percent annual exceedance probability of 60-day flood duration streamflow (cubic feet per second) 50-percent	20-percent	10-percent	4-percent	2-percent	1-percent	0.5-percent	0.2-percent
ALB	32,800	43,100	49,100	55,900	60,500	64,800	68,800	73,700
BCL	4,390	5,510	6,200	7,010	7,590	8,140	8,670	9,350
BLU	1,100	1,430	1,640	1,890	2,060	2,230	2,400	2,620
CGR	1,650	2,120	2,450	2,880	3,210	3,550	3,900	4,390
COT	700	929	1,060	1,220	1,320	1,420	1,510	1,630
DET	4,390	5,510	6,200	7,010	7,590	8,140	8,670	9,350
DEX	5,970	7,880	9,160	10,800	12,000	13,200	14,500	16,200
DOR	1,840	2,440	2,820	3,260	3,580	3,890	4,190	4,590
FAL	1,390	1,810	2,070	2,400	2,640	2,870	3,100	3,400
FOS	6,110	7,840	8,910	10,200	11,100	12,000	12,900	14,000
FRN	1,700	2,300	2,670	3,090	3,380	3,650	3,900	4,220
GOSO	4,110	5,470	6,270	7,210	7,840	8,440	9,010	9,720
GPR	3,780	4,880	5,560	6,370	6,940	7,500	8,050	8,750
HARO	24,400	31,900	36,500	42,100	46,000	49,800	53,600	58,400
HCR	2,250	3,020	3,530	4,190	4,680	5,180	5,690	6,370
JASO	8,450	11,200	13,100	15,500	17,300	19,100	21,000	23,500
JFRO	17,900	22,900	25,900	29,400	31,900	34,300	36,600	39,500
LOP	5,970	7,880	9,160	10,800	12,000	13,200	14,500	16,200
MEHO	7,070	8,990	10,200	11,600	12,600	13,600	14,500	15,800
MNRO	2,510	3,410	3,960	4,590	5,030	5,440	5,820	6,310
SLM	55,100	71,700	81,300	92,200	99,600	107,000	113,000	121,000
SVN	75,400	97,500	111,000	127,000	138,000	148,000	158,000	171,000
VIDO	7,130	8,920	10,100	11,500	12,600	13,600	14,700	16,100
WAV	8,220	10,300	11,700	13,400	14,600	15,900	17,100	18,800
WCC	84,500	109,000	124,000	142,000	154,000	166,000	177,000	192,000
WTLO	7,020	8,930	10,100	11,500	12,500	13,400	14,400	15,500

Publishing support provided by the U.S. Geological Survey
Science Publishing Network, Tacoma Publishing Service Center

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Lind and Stonewall—**Preliminary Flood-Duration Frequency Estimates Using Naturalized Streamflow Records for the Willamette River Basin, Oregon**—Open-File Report 2018–1020

ISSN 2331-1258 (online)
https://doi.org/10.3133/ofr20181020