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Popular Myths about Flooding in Western Washington

Floods are the most destructive natural hazard in the Nation, causing more deaths and financial loss in the 20th century than any other natural disaster. The most significant 20 riverine floods of the 20th century for which data are available have killed more than 1,843 people and caused more than $50 billion (uninflated) in damages (Perry, 2000). One of the most common means of describing the severity of a flood is a comparison to the "100-year flood." In the last decade, increasing attention has been paid to the fact that some regions, notably the Pacific Northwest, have experienced numerous so-called "100-year" floods in the span of a few years. Part of the confusion stems from the statistical nature of the "100-year flood" (Greene, 1996); however, another part of the confusion is the fact that the statistics are calculated for specific sites (streamgages) on specific rivers, rather than for a region as a whole. Scientists with the U.S. Geological Survey have begun to investigate how the likelihood of flooding may be determined on a regional basis (Troutman and Karlinger, 2003).

MYTH: *A "100-year" flood only happens once every 100 years on average somewhere in western Washington.*

FACT: *A "100-year" flood happens about once every 4½ years on at least one western Washington river draining to Puget Sound.*

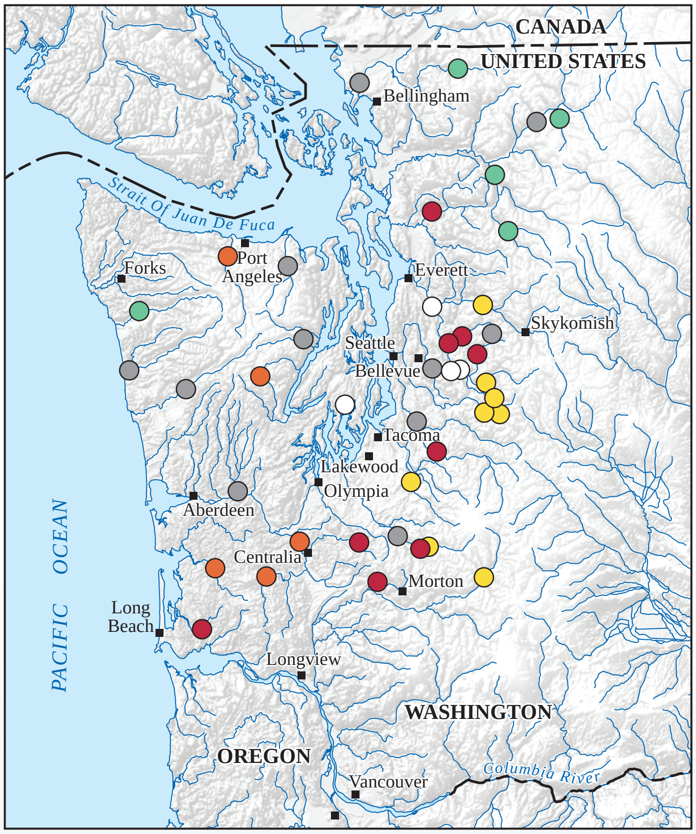
MYTH: *Flooding occurs randomly in time and location across western Washington.*

FACT: *Floods cluster in time and location.*

MYTH: *Rain-on-snow and wet soils are required to cause severe flooding.*

FACT: *Rainfall INTENSITY and DURATION are responsible for ALL major floods in western Washington regardless of conditions prior to the event.*

Flood waters of Dillenbough Creek cover Exit 77 of U.S. Interstate 5, January 8, 2009, in Chehalis, Washington.



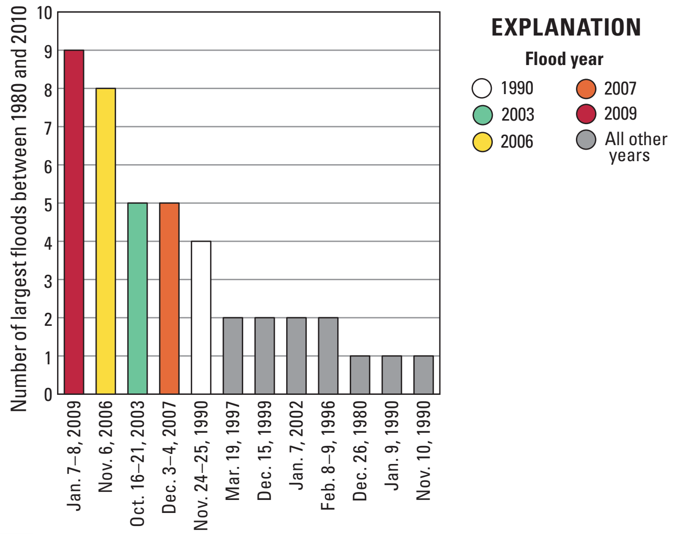


Figure 1. Locations and number of largest floods between 1980 and 2010 for unregulated streams with continuous records, colored by date of storm.

Regional Flood Probabilities

MYTH: *A "100-year" flood only happens once every 100 years on average somewhere in western Washington.*

FACT: *A "100-year" flood happens about once every 4 ½ years on at least one western Washington river draining to Puget Sound.*

An important use of flow data from streamgages is to obtain an estimate of how frequently large floods will occur *at that streamgage*. The frequency of large floods is often expressed in terms of "recurrence intervals." Consider, for example, floods with a 100-year recurrence interval, or the "100-year flood." The definition of a 100-year flood is the streamflow that has a probability of 1/100, or 1 percent (%), of being exceeded at a given point in any given year (Holmes and Dinicola, 2010). This means that a flow at least this large will occur at that given point or site *on average* every 100 years. For a group of sites, the regional flood probability (RFP) of a 100-year flood is the probability that at least one site will experience a 1%-chance flood for that site. The RFP varies with the number of sites (streamgages) in the region and with the degree of correlation between them (how closely flows at one streamgage are related to flows at another). For example, two streamgages near each other on the same river are highly correlated and the RFP for those two sites is close to the same 1-in-100 chance as either streamgage alone. If two sites are far enough apart for flows to be uncorrelated, say one in Texas and one in Washington, the chance of a 1%-chance flood at either is 1-in-50, or a 2% RFP—exactly twice as likely. Troutman and Karlinger (2003) determined that the RFP for the 193 streamgages on rivers draining to Puget Sound is 22% or the equivalent of 4 ½ years on average. Although this is certainly more informative than the "100-year flood myth," it may be improved by selecting streamgages on some basis other than streamgages that "drain to Puget Sound." For example, if urban areas were the only areas of concern, the selected streamgages could be limited to those located in urban areas. Other criteria for selecting subsets of sites might be those near industrial facilities, in National Parks, or near vulnerable populations, such as schools and hospitals.

Timing and Locations of Floods Occur in Clusters

MYTH: *Flooding occurs randomly in time and location across western Washington.*

FACT: *Floods cluster in time and location.*

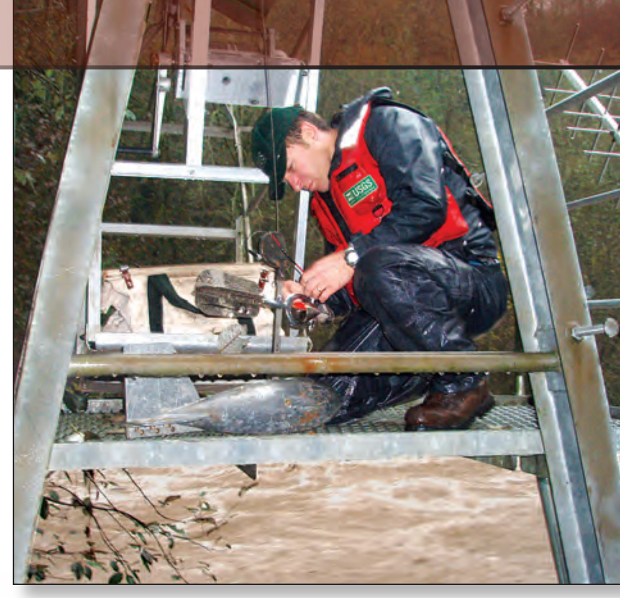
If flows at the 193 streamgages on rivers that drain to the Puget Sound were completely uncorrelated, as in the example of one site in Texas and one in Washington, the likelihood of a 1%-chance flood at any site (the RFP) would approach near certainty. The reason the RFP is 22% for the 193 streamgages on rivers that drain to Puget Sound is because the flows at those streamgages are correlated. The map and graph in figure 1 show how large floods are correlated both in time and location. The map shows where the largest floods between 1980 and 2010 occurred at streamgages that have a complete history of flow and no effects from dams or canals (unregulated). The colors identify peaks that occurred during the same storm event, except gray, which are all storms that produced only one or two largest floods at a streamgage between 1980 and 2010. Note that the locations for "all other years" are fairly randomly distributed, while the largest floods that occurred during the same storm are clustered both in time (color) and location. The graph shows that 31 of the 42 largest floods over the 30-year period occurred as a result of just five storms.

Atmospheric Rivers *(locally known as "Pineapple Express")*

MYTH: *Rain-on-snow and wet soils cause severe flooding.*

FACT: *Rainfall INTENSITY and DURATION are responsible for ALL major floods in western Washington regardless of conditions prior to the event.*

The reason for this correlation between flows at streamgages in the Puget Lowlands is that *all* of the largest floods in western Washington are caused by intense precipitation due to atmospheric rivers (AR's) (Schick, 2008). An AR is a narrow band of concentrated low-level water vapor that, when encountering mountain ranges such as the Cascade Range, produces large amounts of rain. Should an AR linger over an area for a day or more, extreme flooding commonly results. The direction of the AR's storm track may affect how the flooding is distributed. Schick and Pattee (2010) noted that the floods of 2006 (yellow dots) and 2009 (red dots) had similar orientations that show up in the map of peak flows in figure 1.



USGS hydrologist prepares to make a streamflow measurement.

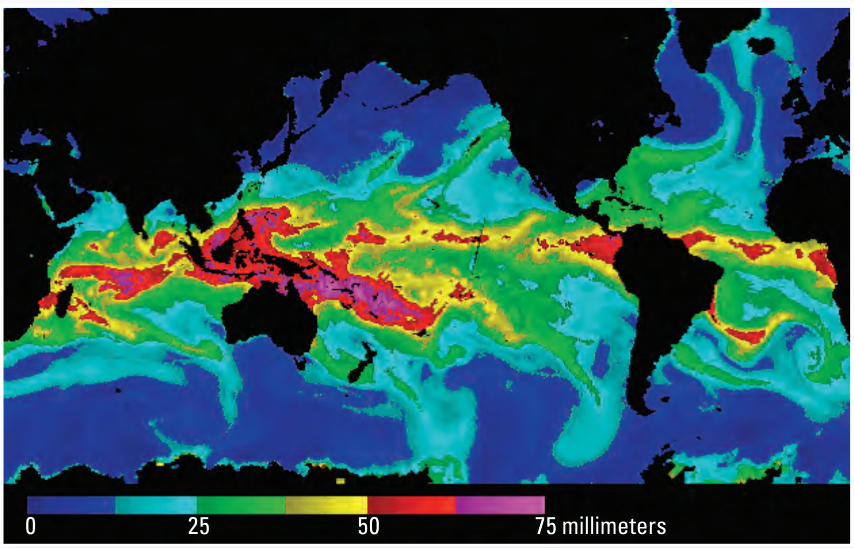


Figure 2. Global water vapor distribution on January 7, 2009. Image is from the Defense Meteorological Satellite Program Special Sensor Microwave/Imager (SSM/I).

Figure 2 shows the water content in the air above the oceans of the World (black areas are continents where no data are shown). The red areas show where the warm moist tropical air is and the narrow green arms (ARs) show how and where this warm moist tropical air can be conveyed to higher latitudes. This image in particular shows the January 2009 AR that caused record flooding in Washington, including 9 of the 42 record peaks shown in figure 1. Although the spatial cluster of these peaks was not as "tight" as some of the other AR-caused flood peaks, their orientation reflects the linear nature of these types of intense systems. The presence of substantial lowland snowpack that could be quickly melted by a blast of warm wind and rain can add a small percentage to the peak flows, but it is the rainfall intensity and duration brought by AR's that create the largest floods.

Flooding across U.S. Interstate 5 near Centralia, Washington, January 8, 2009.

Flooded home near Chehalis, Washington.

So What?

Showing that the so-called “100-year” flood is really more like the 4 ½ year flood can help emergency managers enhance public awareness of how often flooding truly occurs in a region. This perspective also could help convince those people that are in harm’s way that preparedness is more urgent than many may currently feel, and that, when asked to evacuate, they should. Additionally, these regional flood probability calculations could be re-cast to estimate probabilities between local and regional scales or for particular types of development. For example, an Urban Flood Probability could be calculated using only sites in urban areas to refine the hazard estimate for a particular urban area. The fact that flooding clusters in time and by location due to atmospheric rivers may help emergency responders position equipment and plan access routes knowing that flooding is more likely to occur along the path of the atmospheric river rather than randomly.

Road washout near Blewett Pass, Washington.

References Cited:

Greene, K.E., 1996, The “100-year flood”: U.S. Geological Survey Fact Sheet 229-96, 2 p., accessed October 17, 2011, at http://pubs.usgs.gov/fs/FS-229-96/.

Holmes, R.H., and Dinicola, K.E., 2010, 100-year flood—It’s all about chance: Haven’t we already had one this century?: U.S. Geological Survey General Information Product 106, 4 p.

Perry, C.A., 2000, Significant floods in the United States during the 20th century—USGS measures a century of floods: U.S. Geological Survey Fact Sheet 024-00, 4 p., accessed October 17, 2011, at http://ks.water.usgs.gov/pubs/fact-sheets/fs.024-00.html.

Schick, L.J., 2008, Flood fight: The Pineapple Express and flooding in Western Washington: Proceedings, Whistler 2008 International Snow Science Workshop, p. 1078-1082, accessed October 17, 2011, at http://arc.lib.montana.edu/snow-science/objects/P__8070.pdf.

Schick, L.J., and Pattee, S., 2010, Influence of recent major atmospheric river events on snowpack in western Washington, 2010: Proceedings, Western Snow Conference 2010, accessed October 17, 2011, at http://www.westernsnowconference.org/proceedings/pdf_Proceedings/2010/Schick.Influence%20of%20Recent%20Major%20Atmospheric%20River%20Events%20on%20Snowpack.pdf.

Troutman, B.M., and Karlinger, M.R., 2003, Regional flood probabilities: Water Resources Research, v. 39, no. 4, 1095, doi:10.1029/2001WR001140, accessed October 17, 2011, at http://www.agu.org/pubs/crossref/2003/2001WR001140.shtml.

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