Preliminary flow records from small, mountainous channels on the Olympic Peninsula, Washington State

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Abstract

Channels and the water they convey control the spatial extent of aquatic ecosystems and the evolution of landscapes. Over geologic time scales (millions of years), flow rates have varied with changes in climate, glacial extent and tectonics; however, over shorter time scales, flow rates have remained stable enough to permit the establishment of unique ecosystems that depend on and interact with specific flow and sediment transport regimes. On the Olympic Peninsula, that relative stability was altered when humans converted vast areas of old-growth forest to tree plantations during the 20th century; however, because of the remote location and unstable nature of the channels affected by the tree farms, exactly how stream flow has changed is unknown. This study presents preliminary flow observations in the Olympic Experimental State Forest (OESF), a 110,000 ha block of public land on the west side of the Olympic Peninsula that is presently being managed for both timber and ecosystem values. Through repeat flow measurements and channel surveys and the installation of pressure transducers and staff gages, we are developing a long-term record of flow in small, (basin area 50 to 700 ha) step-pool to cascade channels that transport pulses of sediment and violently swing between low and high flows. Preliminary flow observations indicate that the geologic setting of the basin plays a large role in hydrograph characteristics and that picking out a vegetation signal in the flow record may be difficult. Nonetheless, the long-term goal of these observations is to quantify flow trends and help humans (The Washington State Department of Natural Resources) better understand how past and present tree harvests on the Olympic Peninsula may be altering natural hydrologic and geomorphic processes. Monitoring techniques we are using to measure flow in these small, dynamic streams, including the use of BaRatin (Le Coz et al., 2013) to develop rating curves, are presented. Future monitoring goals and plans to use the flow records for geomorphic and hydrologic modeling studies are also discussed.

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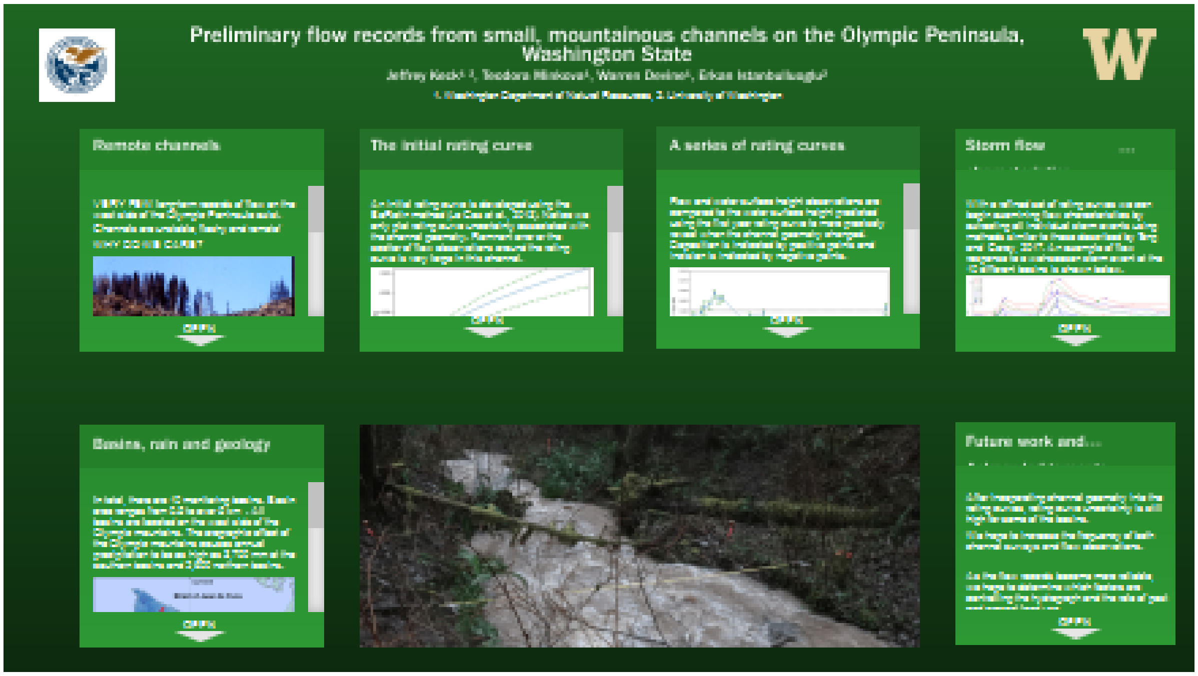

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REMOTE CHANNELS

VERY FEW long-term records of flow on the west side of the Olympic Peninsula exist.

Channels are unstable, flashy and remote!

WHY DO WE CARE?

In the 20th century, large areas of the original forest were cleared.

Vegetation removal extended into steep, headwater channels.

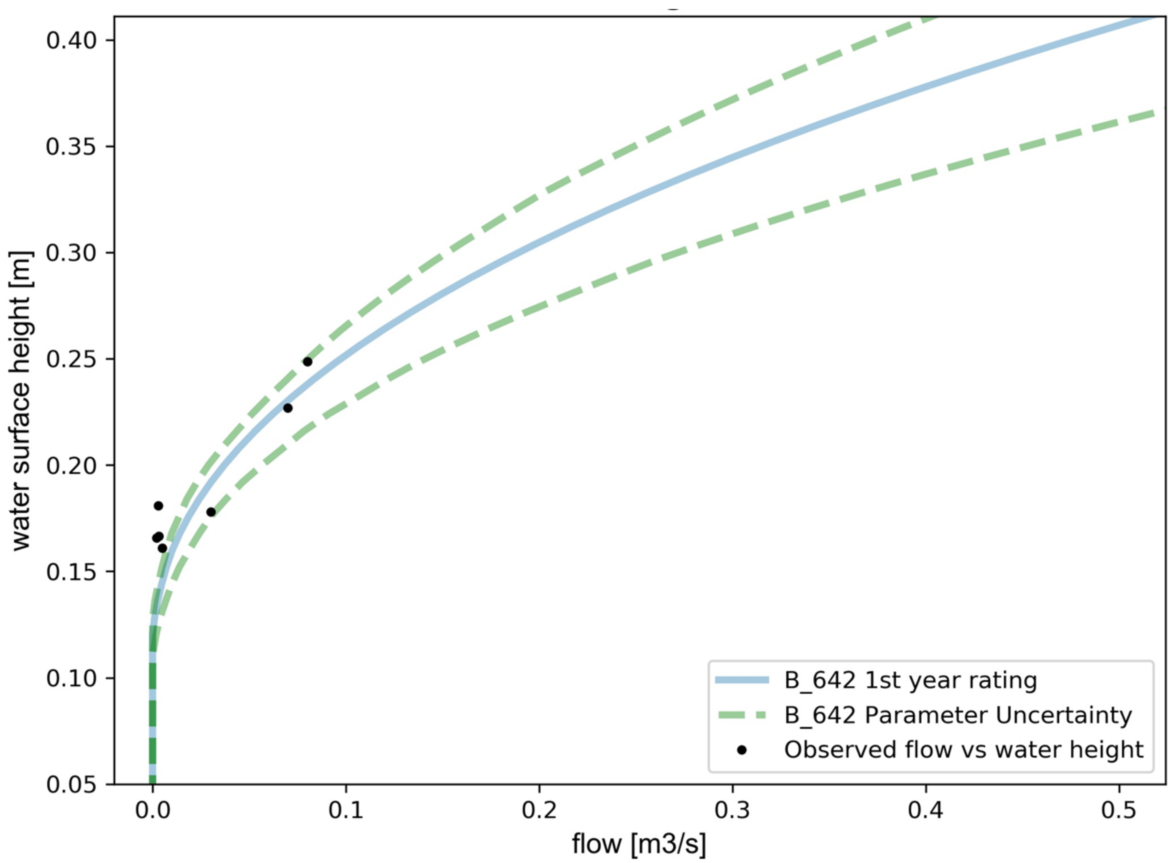
Today, much of that same area is still managed as tree farms.

But regulations restrict harvests within the channel.

We want to establish a record of flow that can be used to assess the current impact of the tree farms on channel hydrology and geomorpholgy

THE INITIAL RATING CURVE

An initial rating curve is developed using the BaRatin method (Le Coz et al., 2013). Notice we only plot rating curve uncertainty associated with the channel geometry. Remnant error or the scatter of flow observations around the rating curve is very large in this channel.



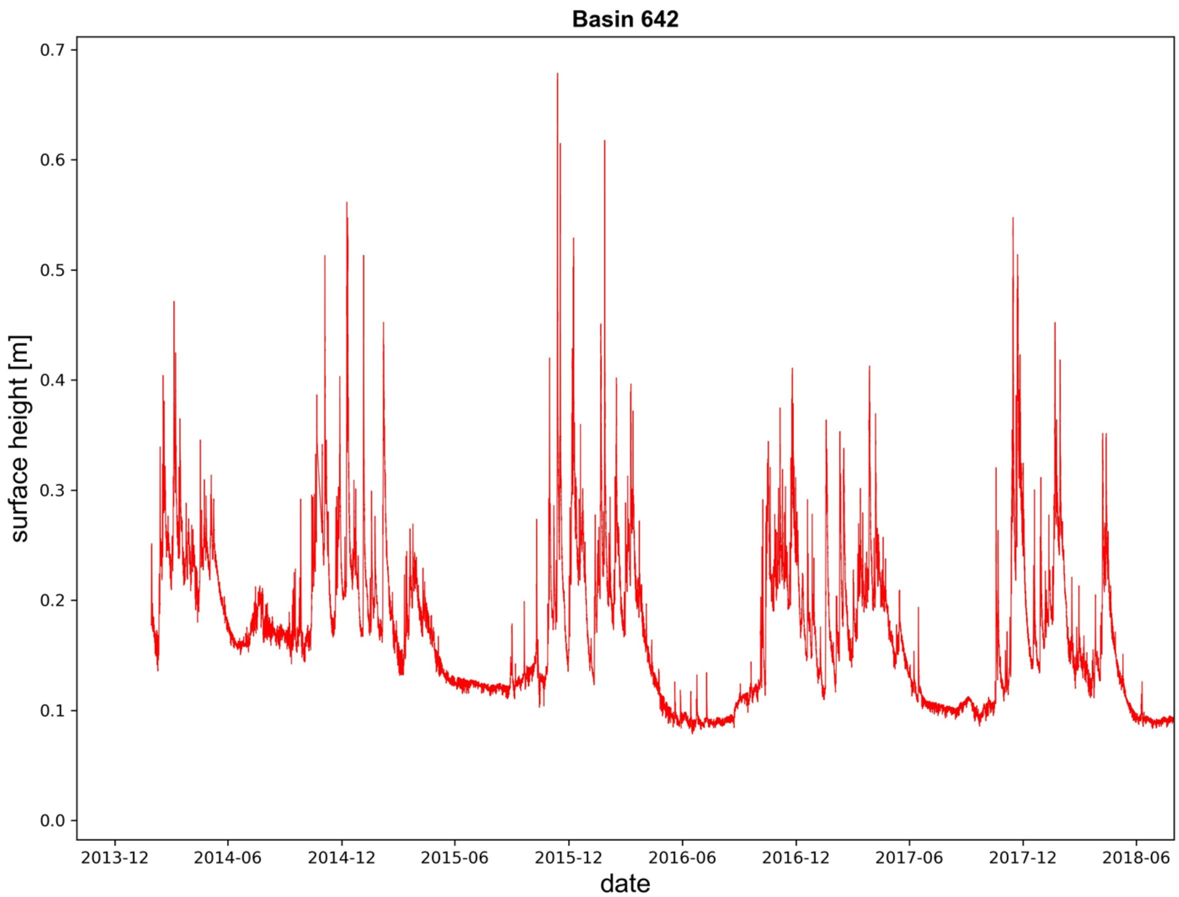
A survey of the channel geometry and water surface slope and estimate of survey uncertainty are used to develop a prior estimate of the coefficients of the power function that describes the relation between flow and the height of the water surface.

Observations of flow and the height of the water surface are then combined with the prior rating curve to develop a posterior estimate using Bayes theorem.

A pressure sensor is installed at the flow observation location to obtain a continuous record of the water surface height.

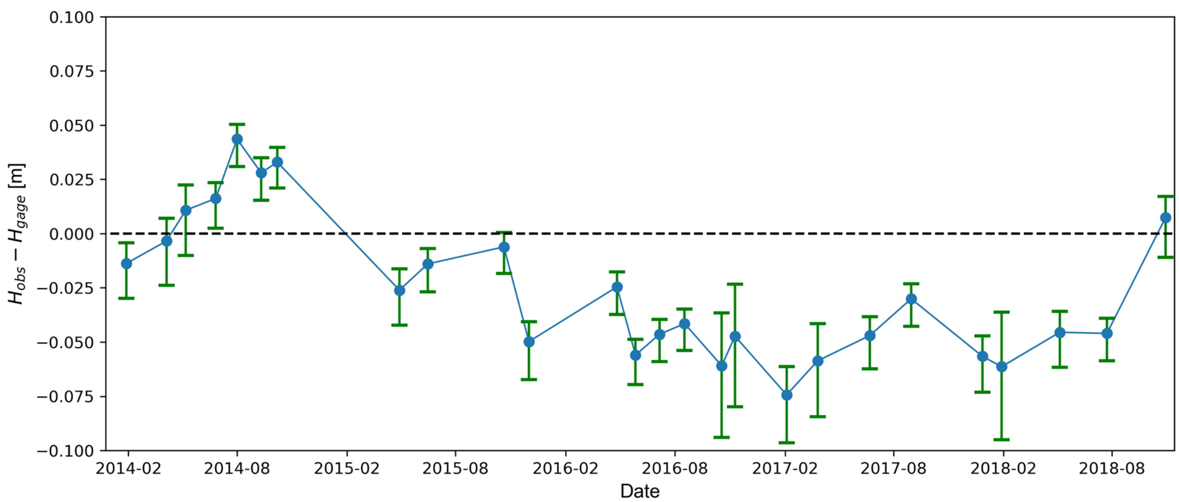
As shown below, the water surface elevation recorded by the pressure sensor is highly variable during the wet season and stable when base flow controls in the dry season. Note how the elevation of base flow changes during the first three years of the record. The geometry of the channel changed!

Before converting the time series of water height to flow, a series of rating curves must be developed.

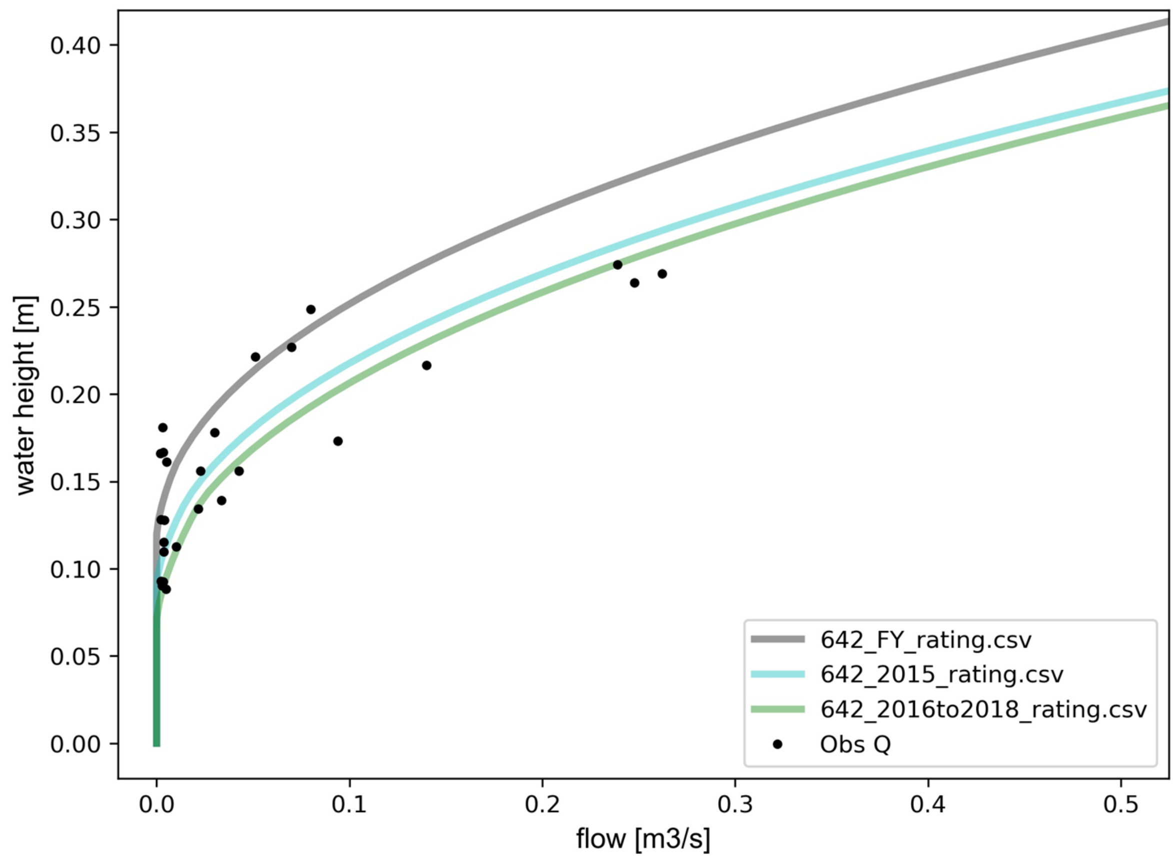


A SERIES OF RATING CURVES

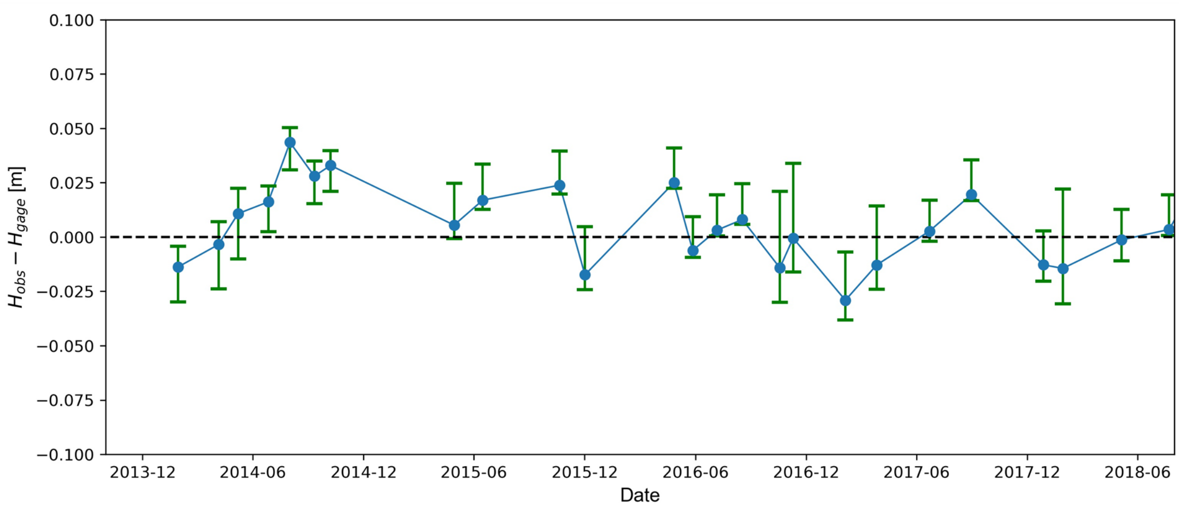
Flow and water surface height observations are compared to the water surface height predicted using the first year rating curve to more precisely reveal when the channel geometry changed. Deposition is indicated by positive points and incision is indicated by negative points.



Periods of relatively constant difference between observed water surface and that predicted by the initial rating curve are used to define 3 separate rating curve periods.

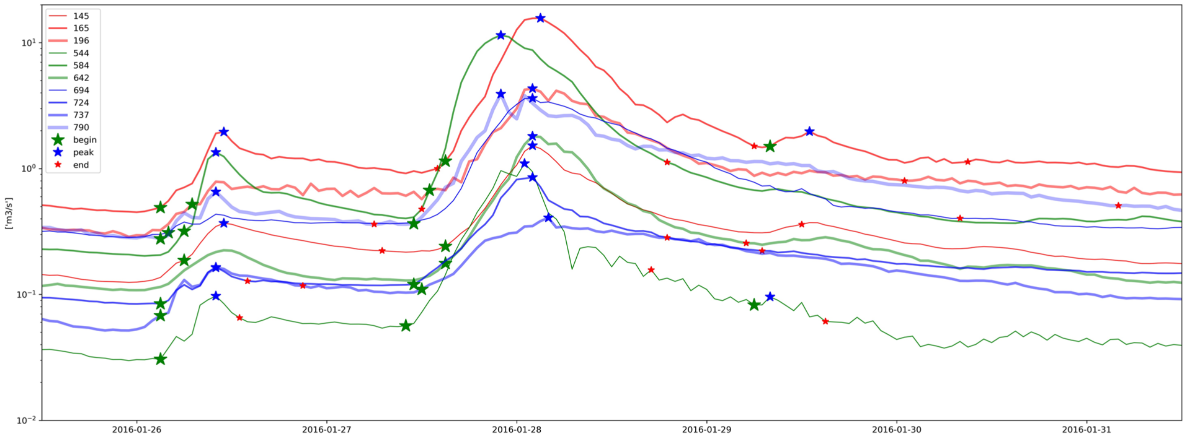


Again comparing observed flow and water surface height to the height predicted by the series of rating curves, the average difference between observed and predicted water surface is closer to zero.



STORM FLOW CHARACTERISTICS

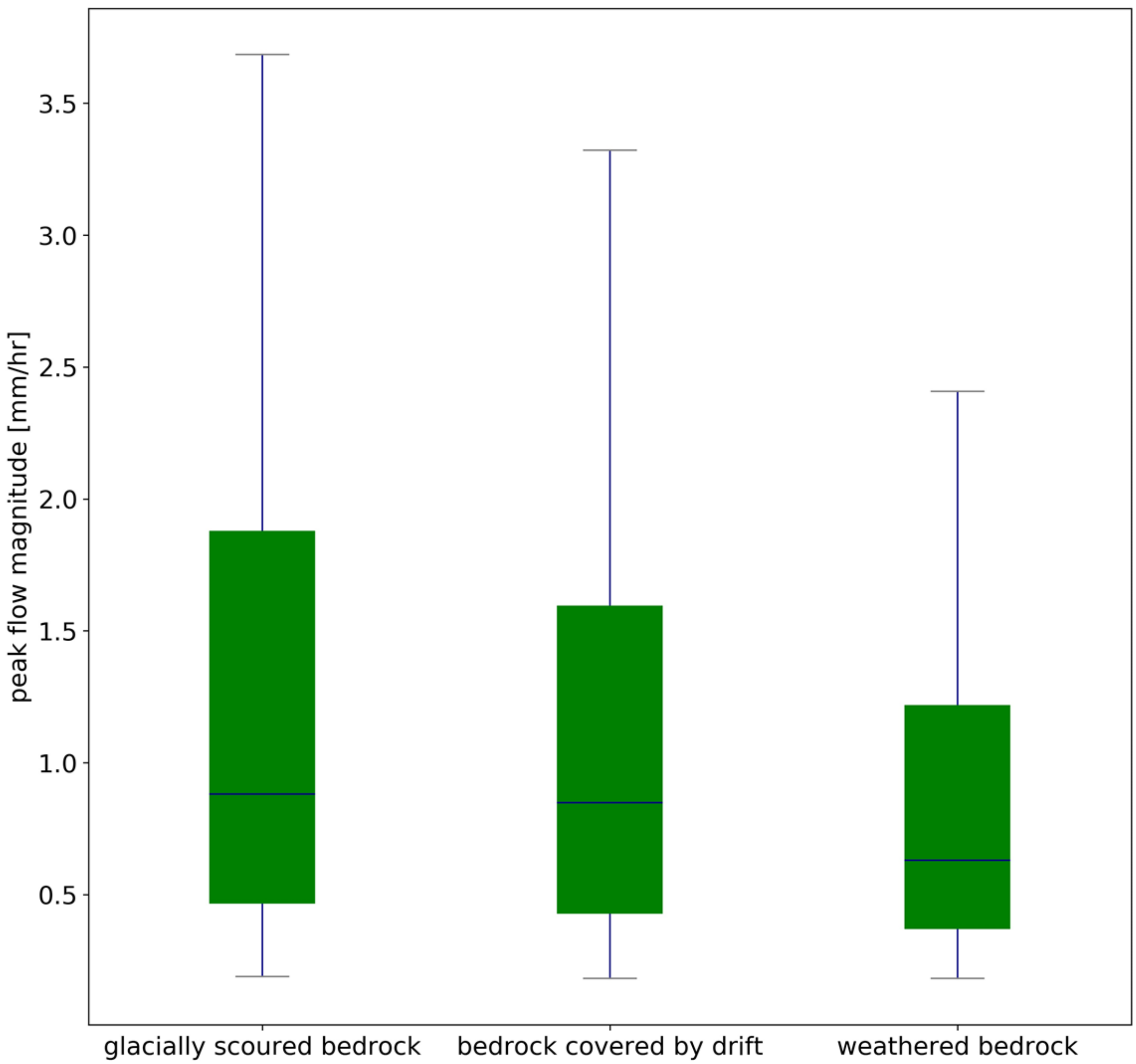
With a refined set of rating curves we can begin examining flow characteristics by extracting all individual storm events using methods similar to those described by Tang and Carey, 2017. An example of flow response to a wet-season storm event at the 10 different basins is shown below.



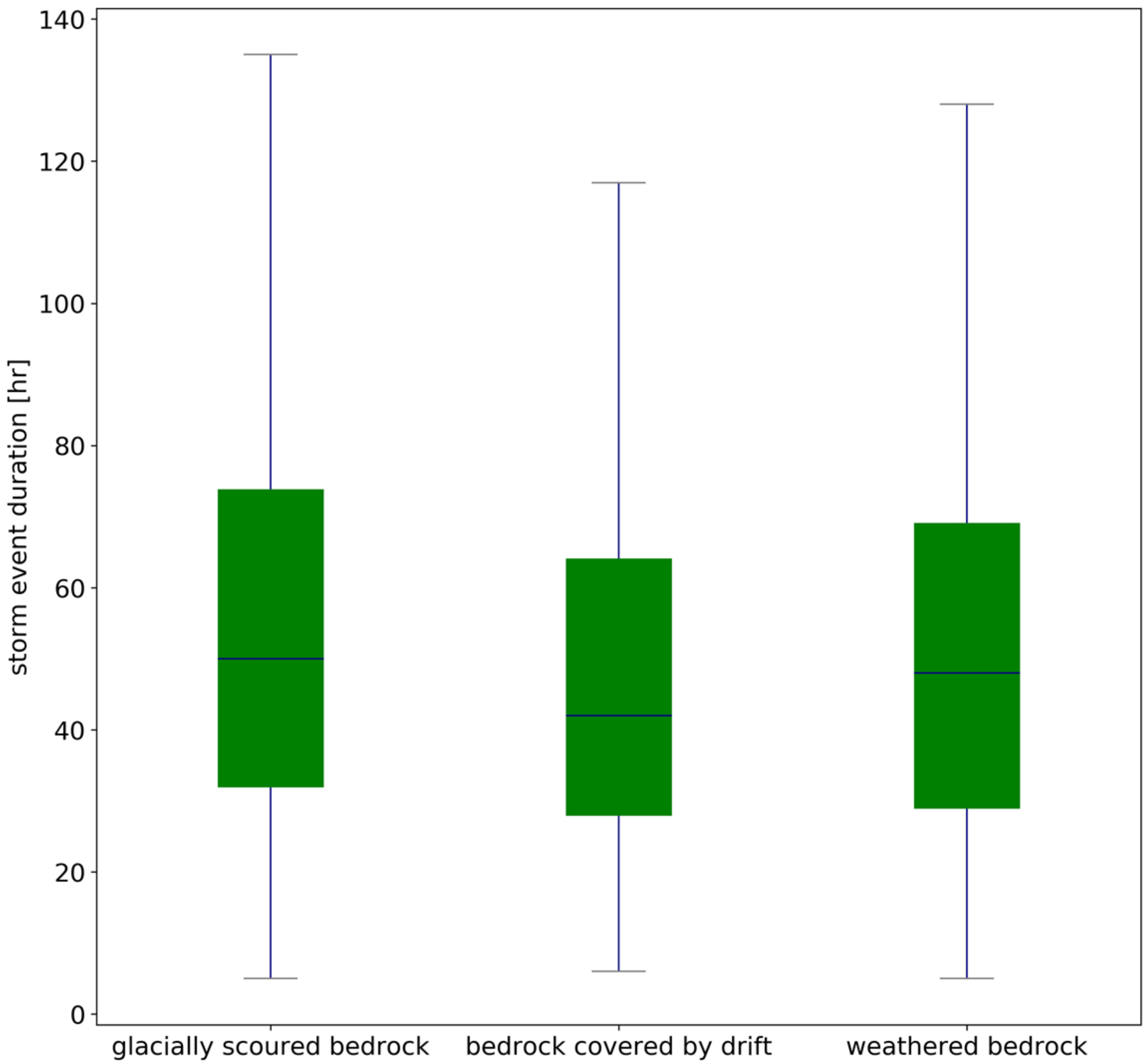
Extracting specific storms from the flow record reveals differences in storm event characteristics. The northern basins (red lines), which are underlain by glacially scoured bedrock, reach higher peak flow magnitudes and have longer storm hydrographs than the basins underlain by bedrock covered by drift (green lines) and basins underlain by weathered bedrock. These differrences may relate to underlying geology but may also be controlled by variation in precipitation or vegetation.

The plots below, which are prepared from the hydrographs of the 10 basins after normalizing by area and grouping into underlying geology, illustrate these differences.

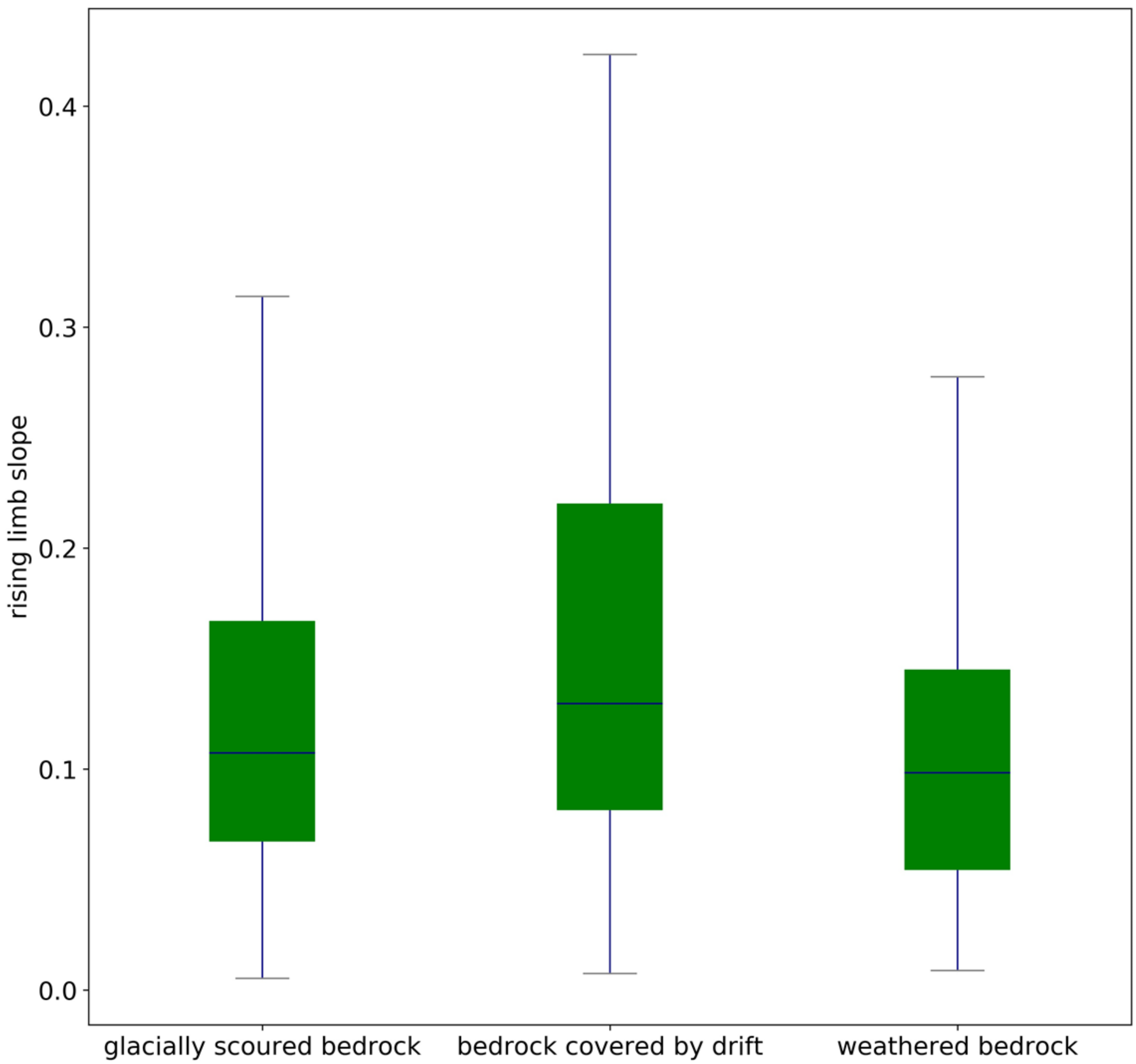
Storm peak flow rate



Storm duration

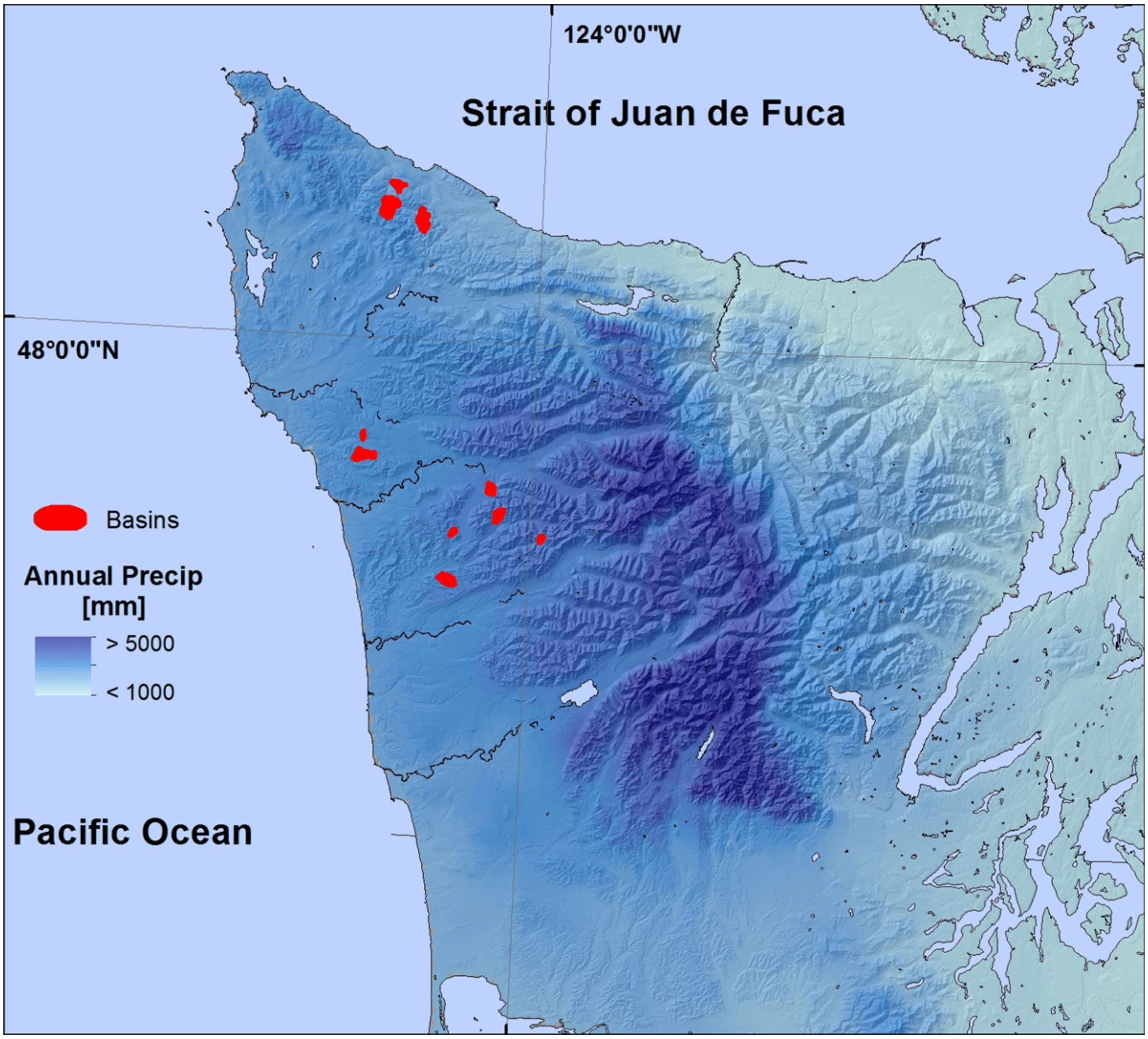


Storm rising limb slope

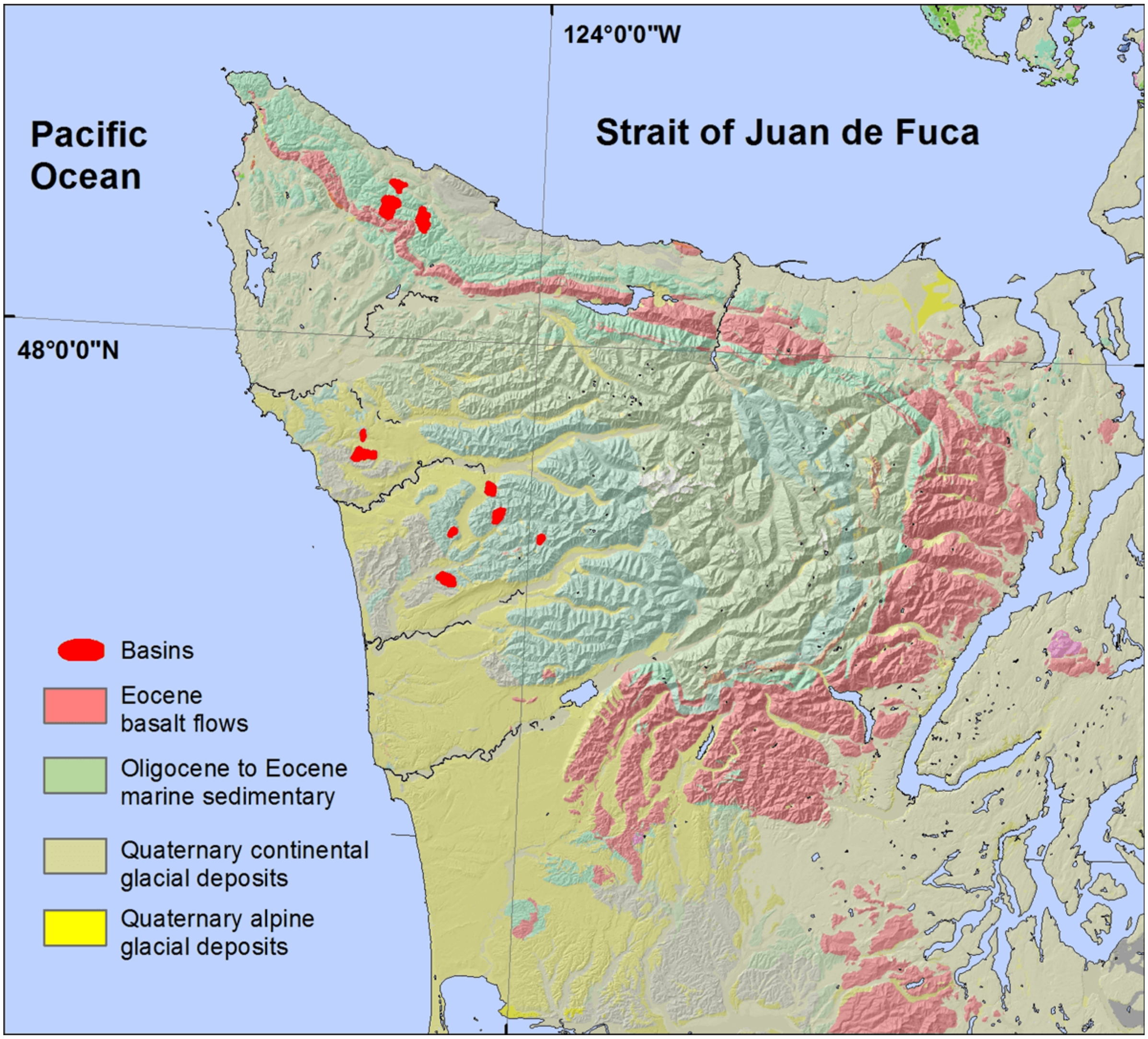

rising limb slope
0.0
0.1
0.2
0.3
0.4
glacially scoured bedrock
bedrock covered by drift
weathered bedrock

BASINS, RAIN AND GEOLOGY

In total, there are 10 monitoring basins. Basin area ranges from 0.5 to over 5 km^2. All basins are located on the west side of the Olympic mountains. The orographic effect of the Olympic mountains causes annual precipitation to be as high as 3,700 mm at the southern basins and 2,600 northern basins.



Regolith depth and permeability are highly variable as a consequence of different underlying bedrock and surficial glacial deposits. The northern basins are underlain by glacially scoured marine sedimentary bedrock while the southern basins are underlain by weathered, poorly lithified marine sedimentary rock or poorly lithified sedimentary rock covered by alpine glacial drift.


124°0'0"W
Pacific Ocean
Strait of Juan de Fuca
48°0'0"N
Basins
Eocene basalt flows
Oligocene to Eocene marine sedimentary
Quaternary continental glacial deposits
Quaternary alpine glacial deposits

FUTURE WORK AND ACKNOWLEDGEMENTS

After incoporating channel geometry into the rating curves, rating curve uncertainty is still high for some of the basins.

We hope to increase the frequency of both channel surveys and flow observations.

As the flow records become more reliable, we hope to determine which factors are controlling the hydrograph and the role of past and present land use.

Lastly, we hope to use these records as a calibratiion tool for the distributed model DHSVM and other geomorphic models that can further our understanding of how land use affects hydrologic and geomorphic processes in the basins.

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Le Coz, J., Chaleon, C., Bonnifait, L., Le Boursicaud, R., Renard, B., Branger, F., Diribarne, J., Valente, M. (2013). Bayesian analysis of rating curves and their uncertainties: The BaRatin method. Houille Blanche. 10.1051/lhb/2013048.

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