Incorporating Climate Change in Estimates of the 100-year Flood for Forest Road Management: Methodology and Applications to the Olympic National Forest

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Objective:

A partnership between the Olympic National Forest and Park was formed to assess the impacts of climate change on federal and to incorporate climate change projections in management practices. Road management and culvert design are key components to management in the Olympic Peninsula.

Comparing Methodologies:

Current Statistical Approach

Managers on the Olympic Peninsula use the Q_{100} (peak flow with estimated 100-year return interval) as a key design parameter. Current estimates are based on USGS regressions (http://water.usgs.gov/osw/streamstats/) using annual precipitation and basin area as explanatory variables. Note that temperature and seasonal precipitation are not used as an explanatory variable.

USGS regression and spatial application:

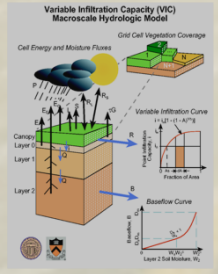
Region 1: $Q_{100}=0.745A^{0.922}P^{1.26}$

A = drainage area (mi²)
P = annual precipitation (inches)

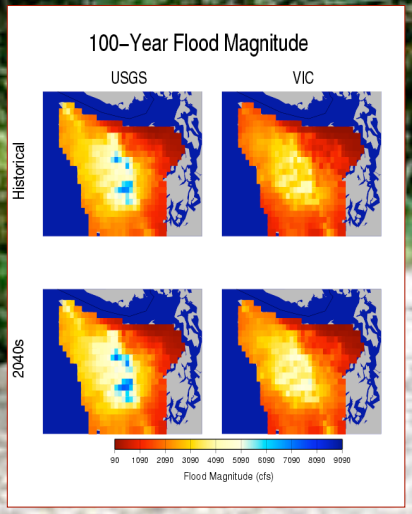
Physically Based Approach

A physically-based hydrologic model, the Variable Infiltration Capacity (VIC) model, incorporates a fully integrated snow model. The model explicitly addresses warmer temperatures, wetter winters, changing antecedent snow, and rising freezing levels in estimating daily runoff. Fitted GEV probability distributions are then used to estimate Q_{100}.

VIC schematic:



Q_{100} was estimated using the USGS regression equations and the VIC model at a spatial scale of ~30 km². Inputs to these two models were generated from historical gridded meteorological data sets and estimates of future conditions for the 2040s from downscaled GCM scenarios.

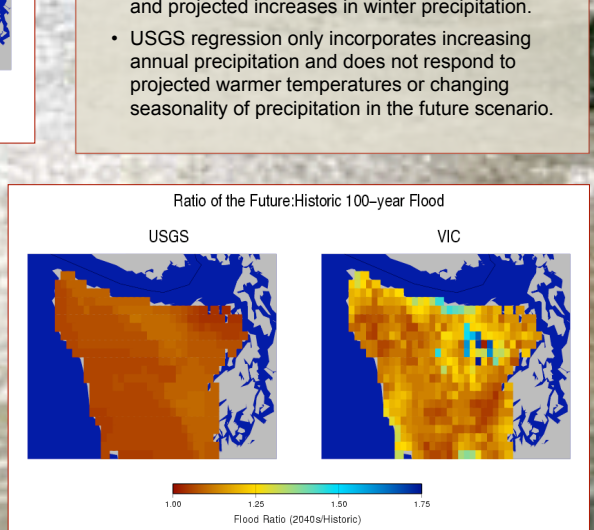


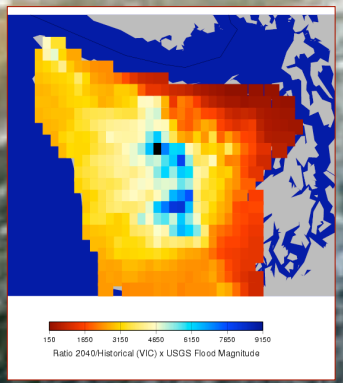
Comparing Results and Potential Applications:

- VIC model is physically-based:
  - Simulates effects of snow accumulation and melt (rain on snow) and changing freezing levels on flood risk.
  - Simulates antecedent conditions (soil moisture, snow) and their effects on extreme events
- VIC captures temporal and spatial variability of T and P from climate model scenarios
- VIC model responds explicitly to future warming and projected increases in winter precipitation.
- USGS regression only incorporates increasing annual precipitation and does not respond to projected warmer temperatures or changing seasonality of precipitation in the future scenario.

Sensitivity Maps:

The maps to the right show the ratio of the future-to-historical 100-year flood estimated by USGS (left) and VIC (right) models.
The USGS model shows low sensitivity of Q_{100} to changes in annual precipitation alone, and little spatial variability.
The VIC model results indicate a greater sensitivity of Q_{100} to warmer temperatures (changes in snow) and increases in winter precipitation.





Hybrid Approach (USGS x VIC):

The product to the left is a hybrid result which combines the spatially explicit and physically based estimate of future change from the VIC model with the historical estimate of Q_{100} from the current USGS regression approach.

Collaborators from the Olympic National Park: Kathleen O'Halloran, Luis Santoyo, Bill Shelmerdine, Robert Metzger, Robin Stoddard