Lecture 17: Floods

Key Questions
1. What defines a drainage basin?
2. What is stream discharge?
3. What is stage height?
4. What is a rating curve?
5. What is a hydrograph?
Flooding effects about 75 million people per year

An aerial view of the flooded I-5 overpass looking south Flooding in Chehalis (December 04, 2007)
In the USA, 50% of the flood related deaths occur in vehicles.

A driver attempts to drive through the flood zone on 171st Street in Woodinville. (December 03, 2007)
FLOODS are usually caused by heavy rains and/or rapid snow melt—their severity is controlled by the WATERSHED characteristics.
Water flows into the Green River from the 48-year-old Howard Hanson Dam dam which is upriver from Kent, Renton, Auburn, Tukwila, located in South King County.

On occasion, there is a flood caused by a dam burst.
On occasion, there is a flood caused by a dam burst

Water seeping through Howard Hanson Dam. Engineers are concerned the dam could fail, creating catastrophic flooding in the valley below.
**Watershed:** The area of land that drains to a single outlet and is separated from other watersheds by a topographic drainage divide. Also known as a catchment, river basin, drainage basin.
Watersheds can be large

Columbia River Basin
260,462 sq-miles
Columbia River Basin
260,462 sq-miles
The Puget Sound watershed covers nearly 42,800 square kilometers and consists of over ten thousand rivers and streams that drain into the Sound.
Nooksack River Basin

About 2000 square kilometers or 780 square miles

### Table 5-1
Lower Nooksack Watershed Subbasin Characteristics

<table>
<thead>
<tr>
<th>Item</th>
<th>North Fork</th>
<th>Middle Fork</th>
<th>South Fork</th>
<th>Lower Nooksack</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Land Use</td>
<td>Commercial Forestry</td>
<td>Commercial Forestry</td>
<td>Commercial Forestry</td>
<td>Commercial Agriculture</td>
</tr>
<tr>
<td>Total Subbasin Size (sq. mi.)</td>
<td>293</td>
<td>103</td>
<td>181</td>
<td>204</td>
</tr>
<tr>
<td>Area in BC (sq. mi.)</td>
<td>4.5</td>
<td>0</td>
<td>0</td>
<td>35</td>
</tr>
<tr>
<td>Elevation Range (ft.)</td>
<td>300 – 10,780</td>
<td>290 – 10,780</td>
<td>220 – 6,930</td>
<td>0 – 1,800</td>
</tr>
<tr>
<td>Avg. Precipitation (in./yr.)</td>
<td>67</td>
<td>67</td>
<td>67</td>
<td>36</td>
</tr>
<tr>
<td>Avg. Runoff (ac.-ft./yr.)</td>
<td>1,190,000</td>
<td>470,800</td>
<td>785,000</td>
<td>283,000</td>
</tr>
<tr>
<td>Avg. Runoff (ac-ft/sq. mi./yr.)</td>
<td>4,061</td>
<td>4,571</td>
<td>4,337</td>
<td>1,387</td>
</tr>
</tbody>
</table>

Watersheds can be small

Lake Whatcom Watershed

- Area is 36,270 acres (57 sq mi)
- Lake is about 5000 acres (252 billion gallons)
Watersheds can be small

Austin Creek Watershed
(8.3 square miles)
Streamflow is the heartbeat of a watershed

Austin Creek Watershed
(8.3 square miles)

Austin Creek Hydrograph
$Q = \text{volume of water passing a plane in a unit of time}$

$Q = \text{stream discharge}$

watershed
\[ Q = \text{average velocity} \times \text{cross sectional area} \]
Q = average velocity \times \text{cross sectional area} = \text{ft}^3/\text{s}

velocity is in feet/second (ft/s)

area is in square feet (ft^2)
A hydrograph is a plot of stream discharge as a function of time.
Base Flow is sustained “lower” flow in between rain events.
$Q = \text{stream discharge}$
$Q = \text{stream discharge}$

Hydrograph

$Q \text{ (cfs)}$

Time

receding flow

rain stops
Base Flow is sustained “lower” flow in between rain events
Real Time Hydrographs are used to monitoring stream flow for flood forecasting
\[ Q = \text{average velocity} \times \text{cross sectional area} \]
Stream Discharge Measurement

**VERY NICE WORK!**

Summary of Discharge Data for this Hypothetical River

<table>
<thead>
<tr>
<th>Vertical Number</th>
<th>Width (meters)</th>
<th>Depth (meters)</th>
<th>Average Velocity (m/sec)</th>
<th>Area of Vertical (sq m)</th>
<th>Discharge of Vertical (cubic m/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.75</td>
<td>1.70</td>
<td>0.48</td>
<td>1.28</td>
<td>0.612</td>
</tr>
<tr>
<td>2</td>
<td>0.75</td>
<td>1.74</td>
<td>0.77</td>
<td>1.31</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>0.75</td>
<td>1.69</td>
<td>0.73</td>
<td>1.27</td>
<td>0.925</td>
</tr>
<tr>
<td>4</td>
<td>0.75</td>
<td>1.65</td>
<td>0.69</td>
<td>1.24</td>
<td>0.85</td>
</tr>
<tr>
<td>5</td>
<td>0.75</td>
<td>1.55</td>
<td>0.62</td>
<td>1.163</td>
<td>0.721</td>
</tr>
<tr>
<td>6</td>
<td>0.75</td>
<td>1.47</td>
<td>0.56</td>
<td>1.103</td>
<td>0.617</td>
</tr>
<tr>
<td>7</td>
<td>0.75</td>
<td>1.27</td>
<td>0.41</td>
<td>0.953</td>
<td>0.391</td>
</tr>
<tr>
<td>8</td>
<td>0.75</td>
<td>1.04</td>
<td>0.28</td>
<td>0.700</td>
<td>0.218</td>
</tr>
<tr>
<td>9</td>
<td>0.75</td>
<td>0.68</td>
<td>0.12</td>
<td>0.510</td>
<td>0.061</td>
</tr>
<tr>
<td>10</td>
<td>0.75</td>
<td>0.54</td>
<td>0.08</td>
<td>0.405</td>
<td>0.032</td>
</tr>
</tbody>
</table>

Total Discharge: 5.427 cu m/sec
191.65 cu ft/sec

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**Virtual River Certificate of Completion**

This certifies that

Robert Mitchell
Eastern Washington University
Rehoboth, Maryland
Thursday, May 07, 2009

has successfully completed the RIVER DISCHARGE exercise
and will now be an expert Virtual Hydrologist.

Robert Mitchell
Geology

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Note: Adapted content for clarity and readability.
Real Time Hydrographs are used to monitoring stream flow for flood forecasting
Streamflow Stage Height Measurement

Austin Creek Stream Gauge
Streamflow Stage Height Measurement

Austin Creek Stream Gauge

<table>
<thead>
<tr>
<th>Time</th>
<th>Stage (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:15</td>
<td>1.15</td>
</tr>
<tr>
<td>10:30</td>
<td>1.16</td>
</tr>
<tr>
<td>10:45</td>
<td>1.17</td>
</tr>
</tbody>
</table>
Stilling Well: float and chart recorder
Austin Creek Stage Height: 2007 Water Year

Stage Height (feet)

Oct 1  Apr 1  Sep 30
Time | Stage (feet)  
---|---
10:15 | 1.15

Measure the discharge at a specific stage height
highest stream velocity

energy lost due to friction along the stream channel

lowest stream velocity
Stream Discharge Measurement

Austin Creek Rating Curve

\[ Q = 25.643x^2 - 10.68x - 0.1558 \]
Rating Curve Equation

\[ Q = 25.643s^2 - 10.68s - 0.1558 \]
Hydrologic Modeling with the Distributed-Hydrology-Soils-Vegetation Model (DHSVM)

DHSVM was developed by researchers at the University of Washington and the Pacific Northwest National Lab.

GIS grid-based representation (30 m x 30 m)
What determines the magnitude and timing of runoff and streamflow in a watershed?

1. Basin size
2. Precipitation characteristics
3. Vegetation type and distributions
4. Soil type and thickness
5. Groundwater discharge
6. Topography
7. Artificial controls (dams)

\[ Q = \text{stream discharge} \]
1. Basin size affects streamflow
PNW Rivers

\[ Q = -0.0045A^2 + 8.6322A - 8.3014 \]
2. Rainfall spatial and temporal variability affect streamflow
City of Bellingham Rain Gauge Locations
North Shore Meteorological (MET) Station
Brannian Creek Rain Gauge
Geneva Rain Gauge
Bloedel Donovan Rain Gauge
Geneva Hyetograph: 2007 Water Year

Daily Rainfall (inches)
Orographic Effect

air pressure decreases with altitude

expanding balloon
Orographic Effect

A decrease in air pressure causes the clouds to expand.
Orographic Effect

Cloud temperatures drop as they expand.
Orographic Effect

- Clouds expand as they rise.
- Clouds cool when they expand.
- Water vapor condenses when it cools, which produce rain.
Puget Sound Watershed

http://courses.washington.edu/uwtoce06/puget%20sound%20watershed.jpg
Average Annual Precipitation

Washington

Legend (in inches):
- Red: Under 30
- Orange: 30 to 60
- Yellow: 60 to 90
- Green: 90 to 120
- Blue: 120 to 150
- Pink: 150 to 180
- Purple: 180 to 210
- Purple: 210 to 240
- Purple: Above 240

Period: 1961-1990

This map is a plot of 1961-1990 annual average precipitation contours from NOAA Cooperative stations and (where appropriate) USDA-NRCS SNOTEL stations. Christopher Daly used the PRISM model to generate the gridded estimates from which this map was derived. The modeled grid was approximately 4x4 km latitude/longitude, and was resampled to 2x2 km using a Gaussian filter.

Mapping was performed by Jenny Weisburg. Funding was provided by USDA-NRCS National Water and Climate Center.
January 6-9 storm event, 2009

Legend
- Approximate location of landslide
- County boundaries
- Transportation:
  - Interstate
  - U.S.
  - State
  - Local

High: 20.79 inches
Low: 0.04 inches

Updated January 30, 2009
1:2,500,000

Compiled by Isabelle Sarikhan
Elizabeth Thompson
Anne Heinitz
3. Vegetation type and distribution affect streamflow
Vegetation intercepts and stores precipitation
Vegetation removes water from soils and **transpires** it to the atmosphere.

(stomata)
Evapotranspiration (ET) is a term used to quantify all evaporative losses in a watershed.

1) Evaporation of water intercepted and stored by vegetation
2) Water transpired by vegetation
3) Water evaporated from soil

ET accounts for about 60 to 70% of the water loss from a slope.
Vegetation and Landcover

NOAA Landcover

- Deciduous
- Mixed Forest
- Closed Shrub
- Grassland
- Bare
- Urban
- Water
- Coastal Conifer