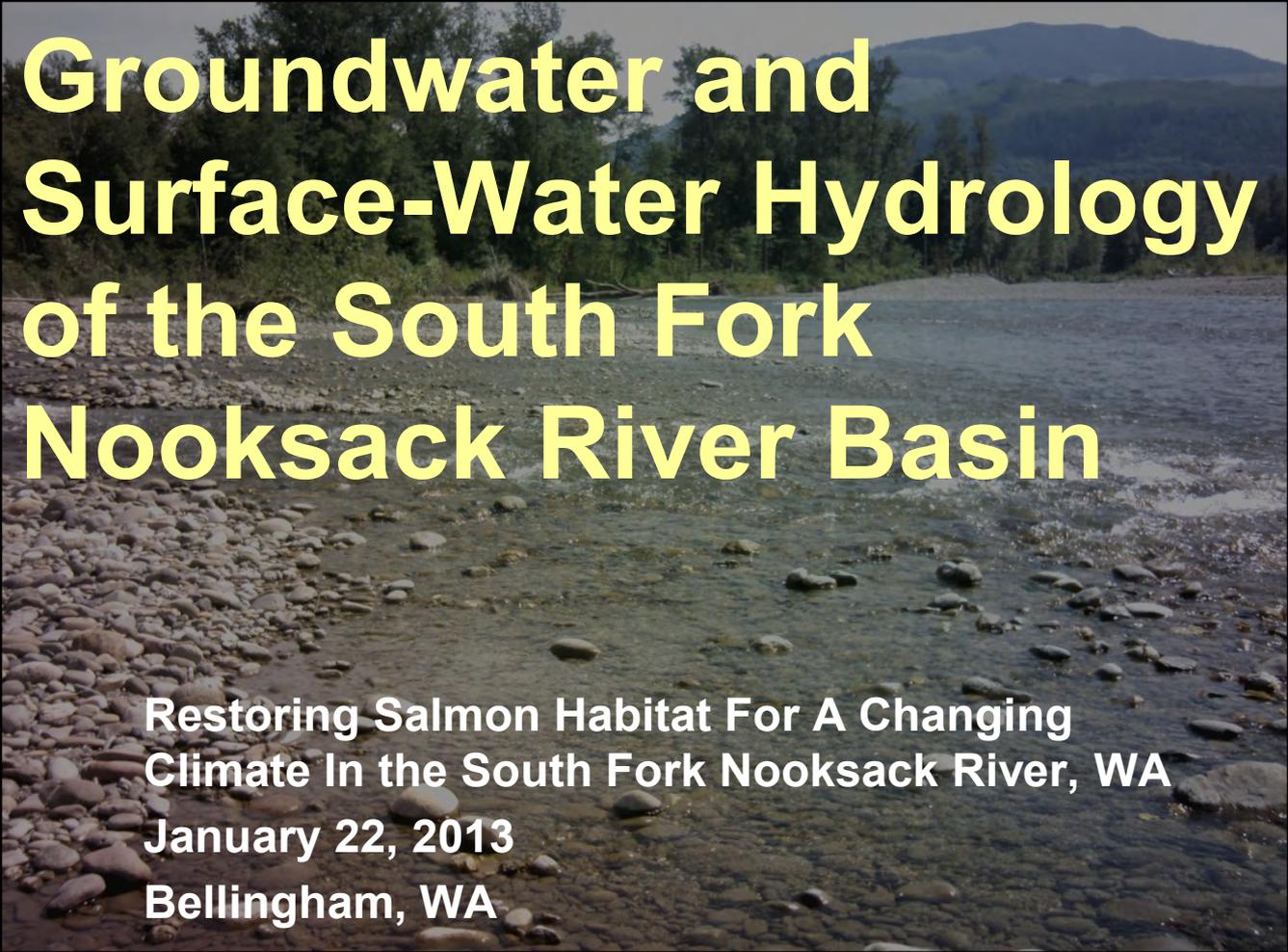


US EPA ARCHIVE DOCUMENT

The background image shows a wide, shallow river with a rocky, pebbly bank in the foreground. The water is clear and flows over the rocks. In the distance, there are green hills and mountains under a clear sky.

Groundwater and Surface-Water Hydrology of the South Fork Nooksack River Basin

**Restoring Salmon Habitat For A Changing
Climate In the South Fork Nooksack River, WA**

January 22, 2013

Bellingham, WA

USGS Groundwater/Surface Water Interaction Study 2012 - 2013

- Characterize relationship between groundwater flow system and surface waters including wetlands and streams
- Help inform salmon restoration activities



Outline

- **Surface Water Hydrology**
 - Precipitation Patterns & Snowpack
 - Flow Regime
 - Temperature Regime
 - **Groundwater Hydrology**
 - Geologic History
 - Hydrogeologic Framework
 - Groundwater Model
 - **Groundwater/Surface-Water Interactions**
 - Seepage Run
 - Longitudinal Temperature Profiles
 - Fine-Scale Stream Temperature Distribution
-



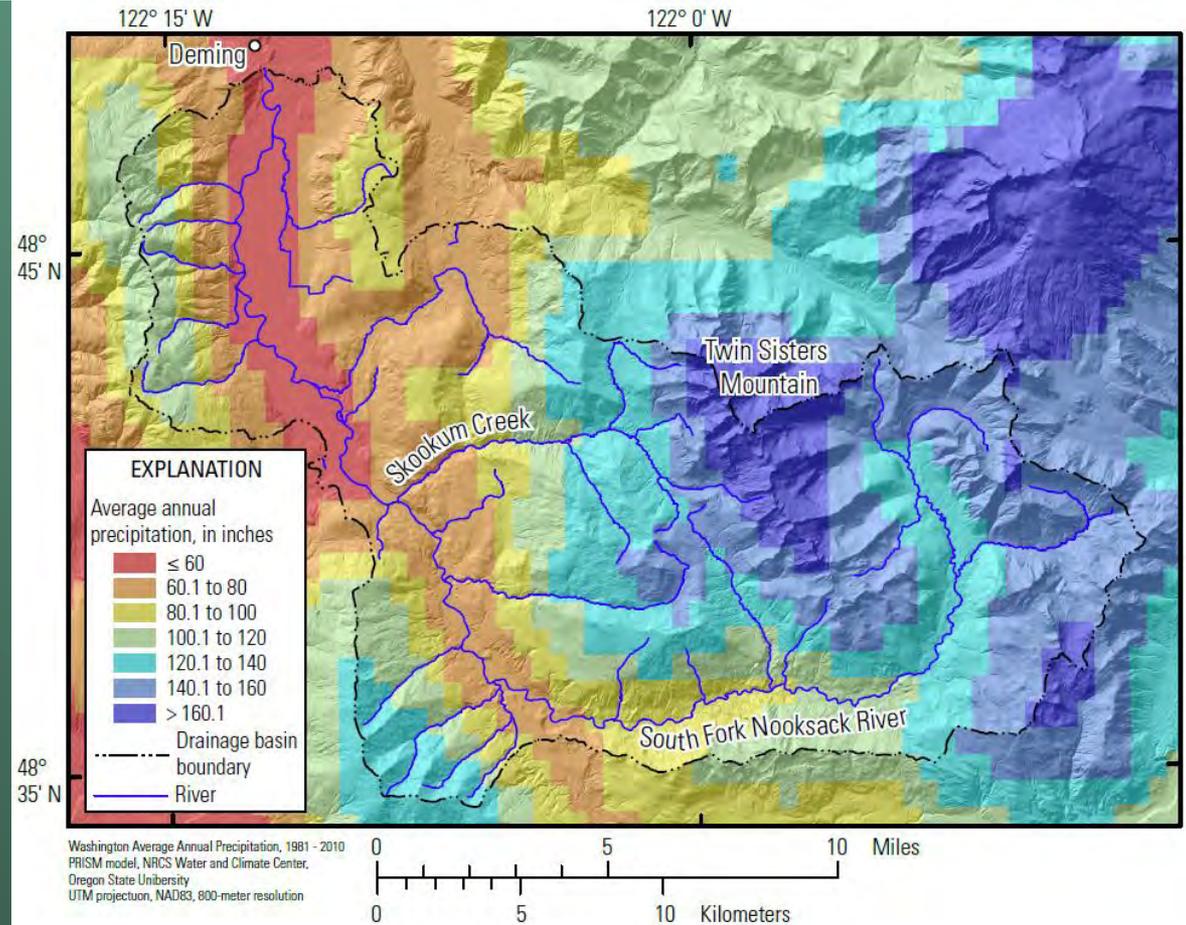
Surface Water Hydrology

- Spatial and Temporal Precipitation Patterns
- Peak-Flow and Annual Hydrology
- Stream Temperature



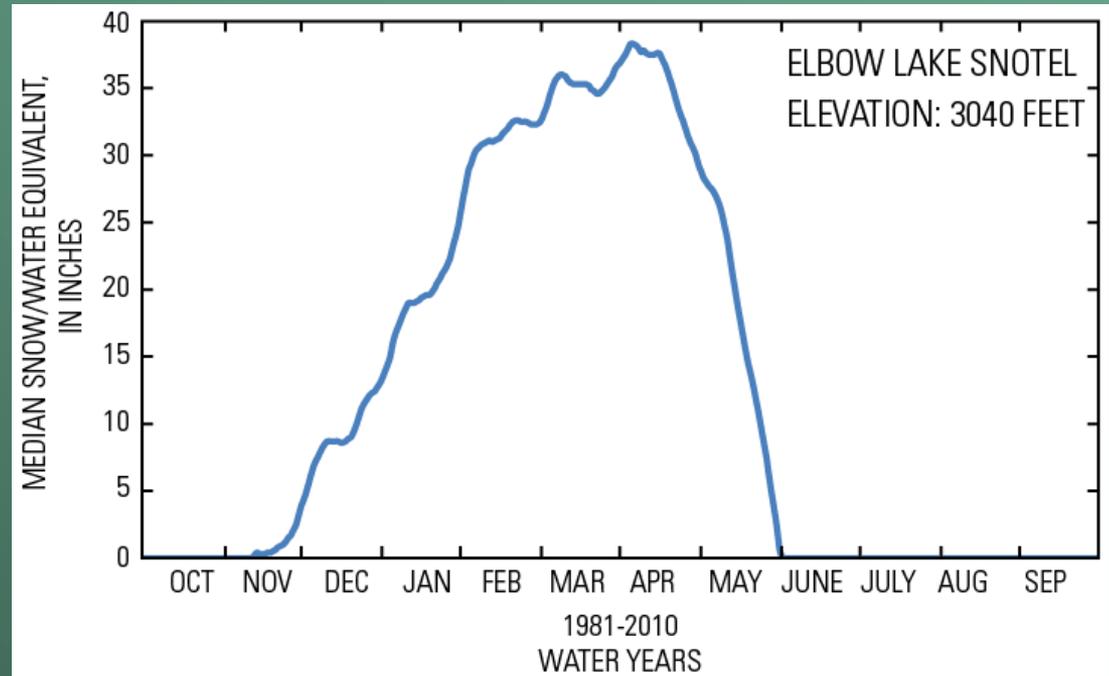
PRISM Climate Data

- Large precipitation gradient between high topography in headwaters and low topography in the lower basin
- Most precipitation falls during the Fall and Winter



Historical SNOTEL Data: Elbow Lake

- Snowpack builds between November and April
- Rapid melting during April and May



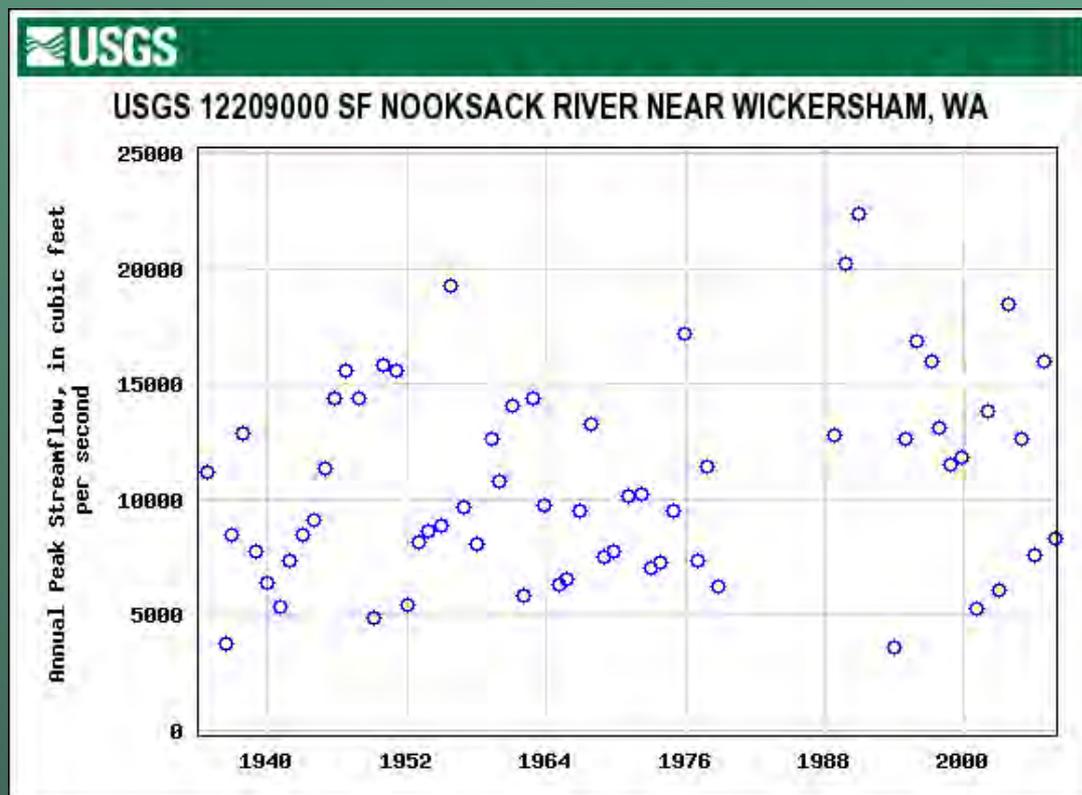
USDA-NRCS

<http://www.wcc.nrcs.usda.gov/nwcc/site?sitenum=910&state=wa>



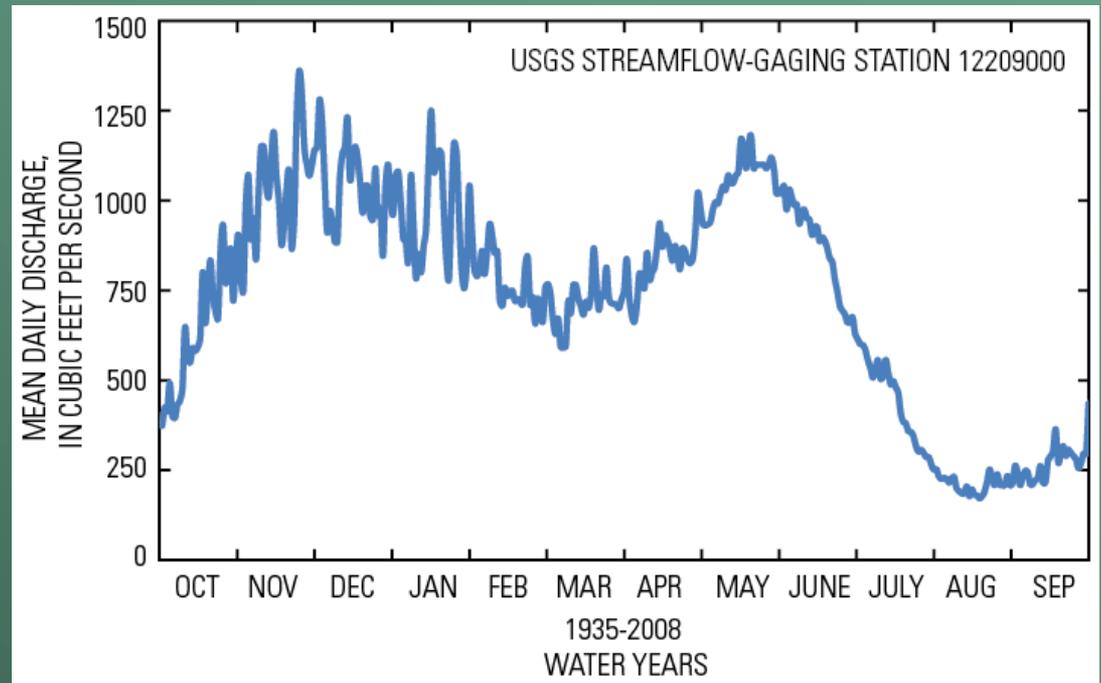
Surface-Water Hydrology – Peak Streamflow

- Peak flow of record: 11/23/90
22,400 cfs
- Most peak flow events occurred between October and February



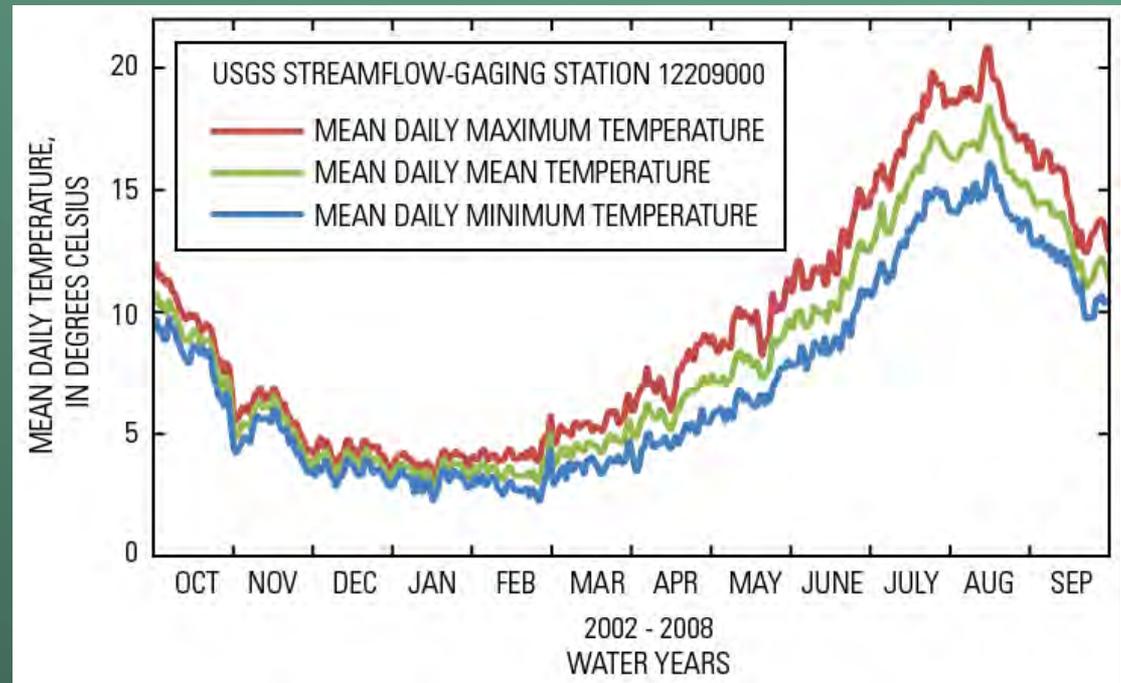
Historical Streamflow Data: SF Nooksack River Near Wickersham

- High flows during winter storms (Nov. – Jan.) and spring snowmelt (May – June)
- Low flows during Aug. and Sept.



Historical Temperature Data: SF Nooksack River Near Wickersham

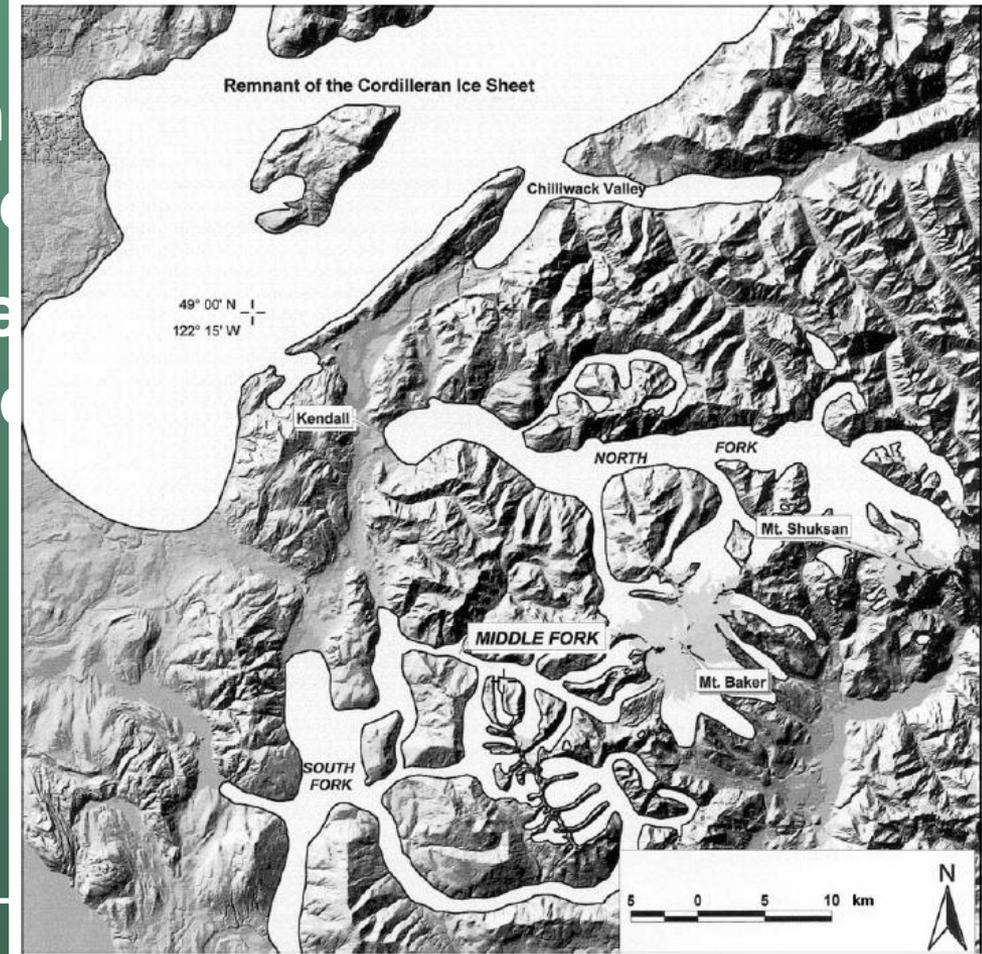
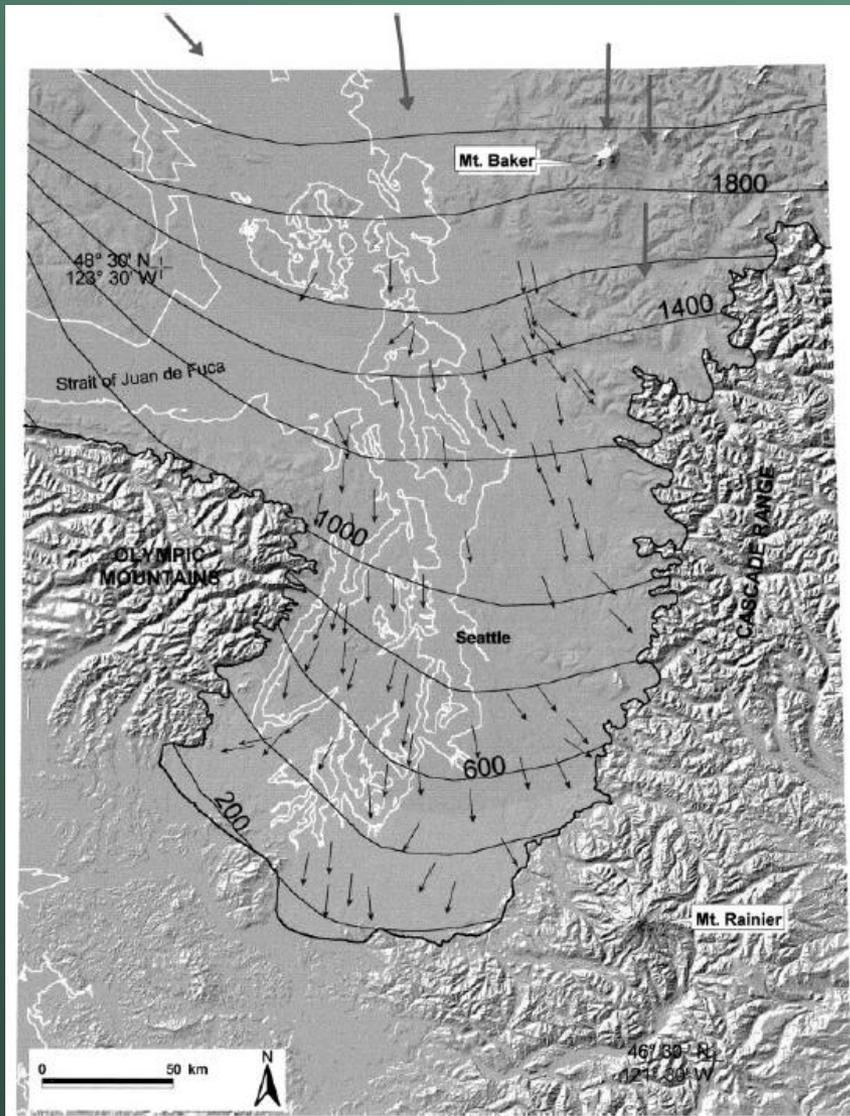
- Temperature measured continuously at SF Nooksack Gages since WY 2002
- Low stream temperature and diurnal variability during winter
- Highest stream temperature and diurnal variability in July and August



Groundwater Hydrology

- **Geologic History**
- **Geologic Units**
- **Hydrogeologic Units**
- **Groundwater Flow Modeling - MODFLOW**

Pleistocene Glacial History

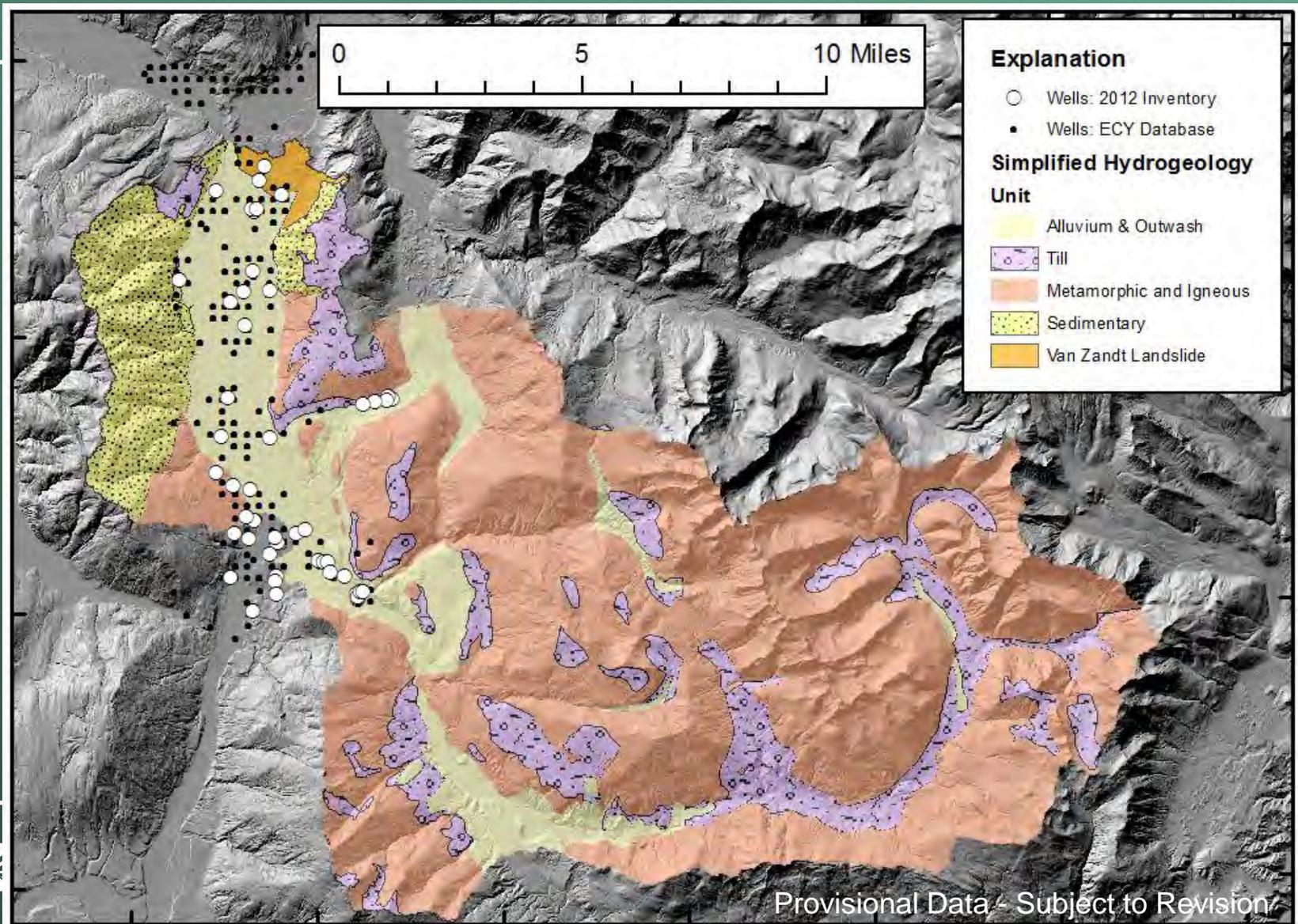


Hydrogeologic Framework: Aquifers and Confining Units

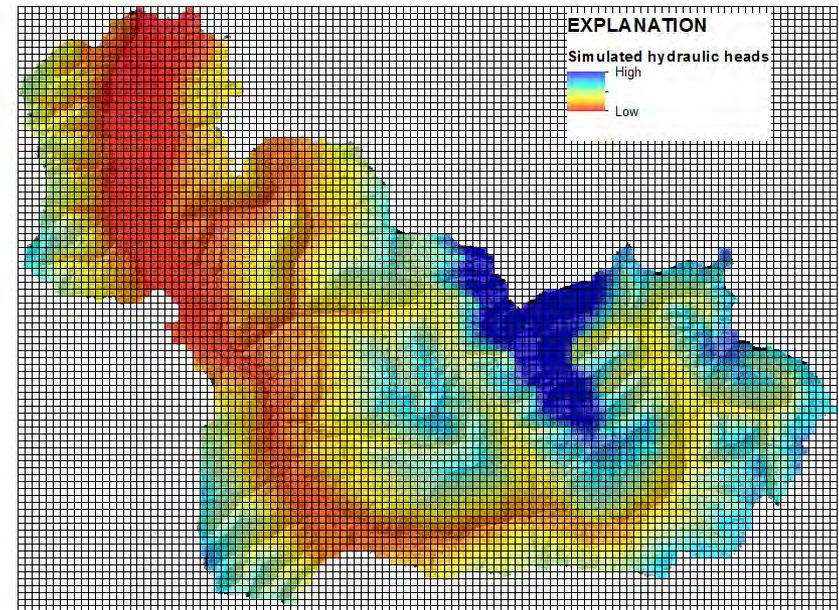
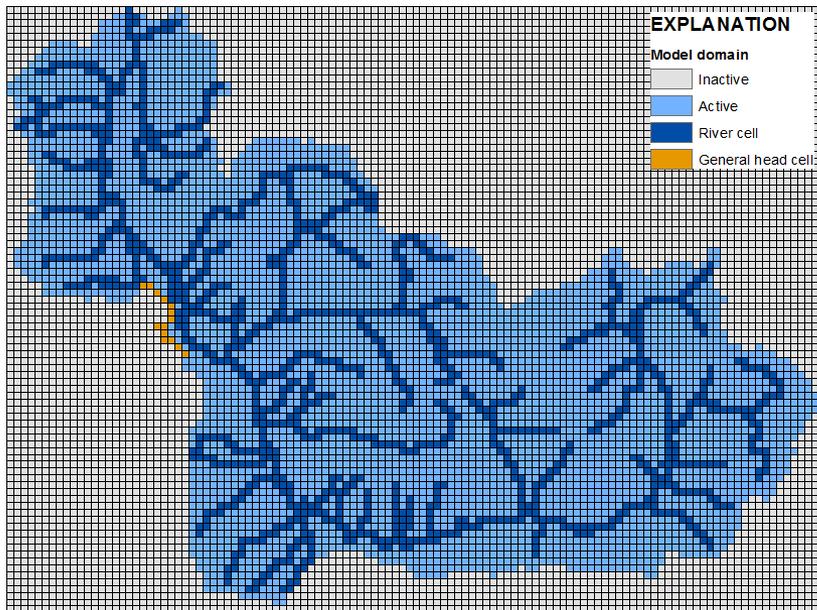
- **Bedrock (Uplands)**
 - Chuckanut Sandstone
 - Darrington Phyllite
 - Twin Sisters Dunite
- **Unconsolidated Sediments**
 - Alluvium (Aquifer)
 - Glacial Outwash (Aquifer)
 - Glacial Till (Confining Unit)
 - Glaciomarine Sediment (Confining Unit)



Hydrogeologic Framework



Next Steps: Groundwater Model

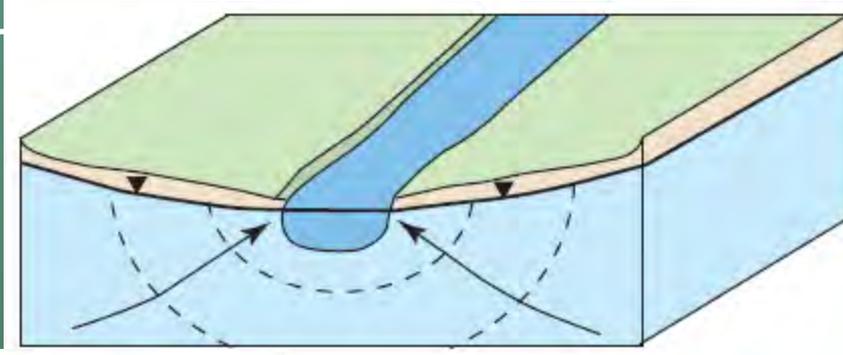


Groundwater Surface/Water Interactions

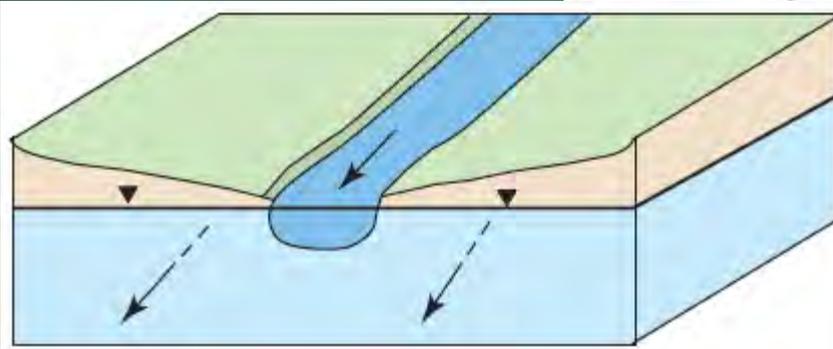
- **Bulk Seepage Gains and Losses (Seepage Runs)**
 - August/September 1998
 - September 2012
- **Temperature as a GW Tracer**
 - Longitudinal Temperature Profiling at Ambient Flow Velocity
 - Fiber-Optic Distributed Temperature Sensing
 - FLIR Thermal Imagery

Groundwater/Surface-Water Interaction in Rivers

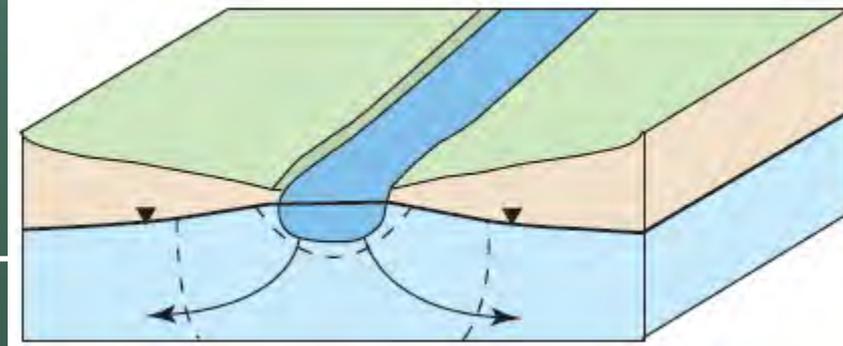
Gaining Stream



Neutral Stream



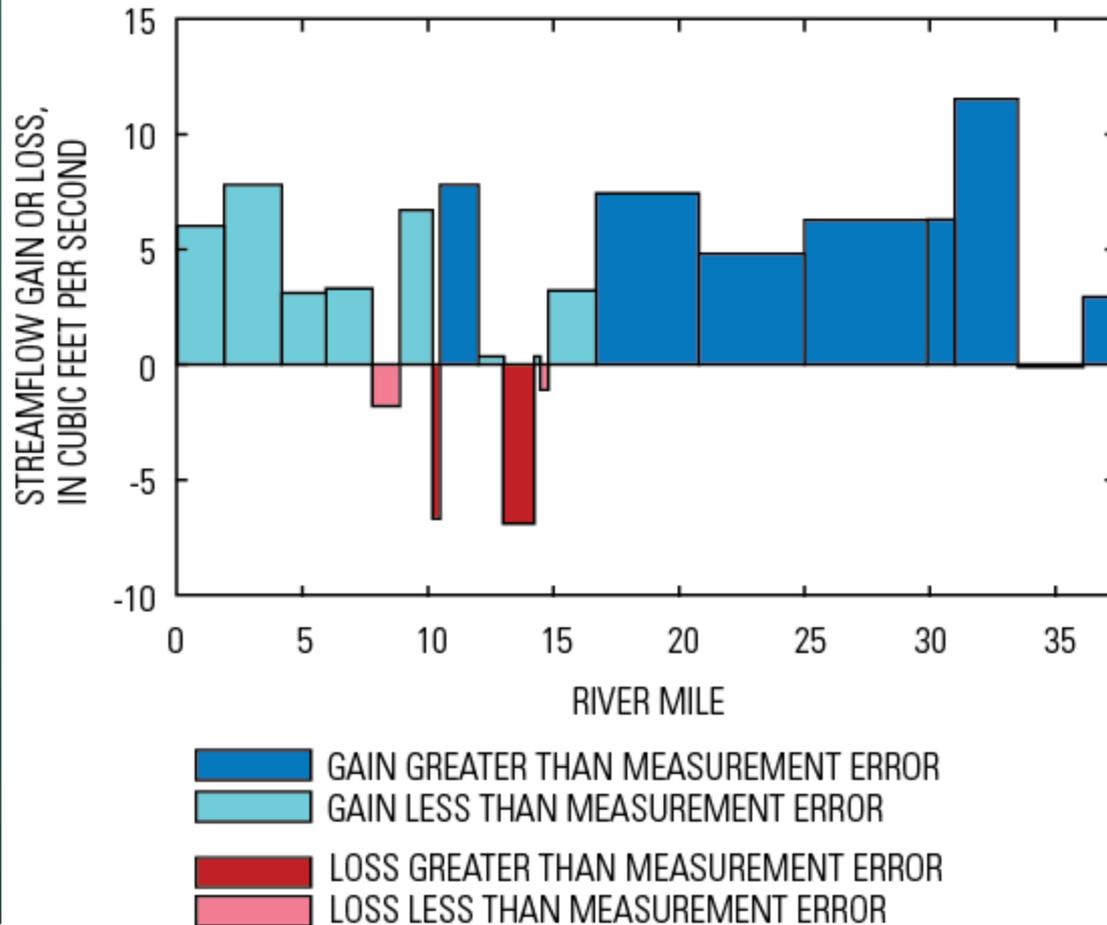
Losing Stream



Seepage Runs

- **September and August, 1998**
 - **RM 37 to the Mouth**
 - **Tributaries**
- **September, 2012**
 - **RM 15 to the Mouth**
 - **Concurrent with Mass Water-Level Measurement at ~ 50 wells**

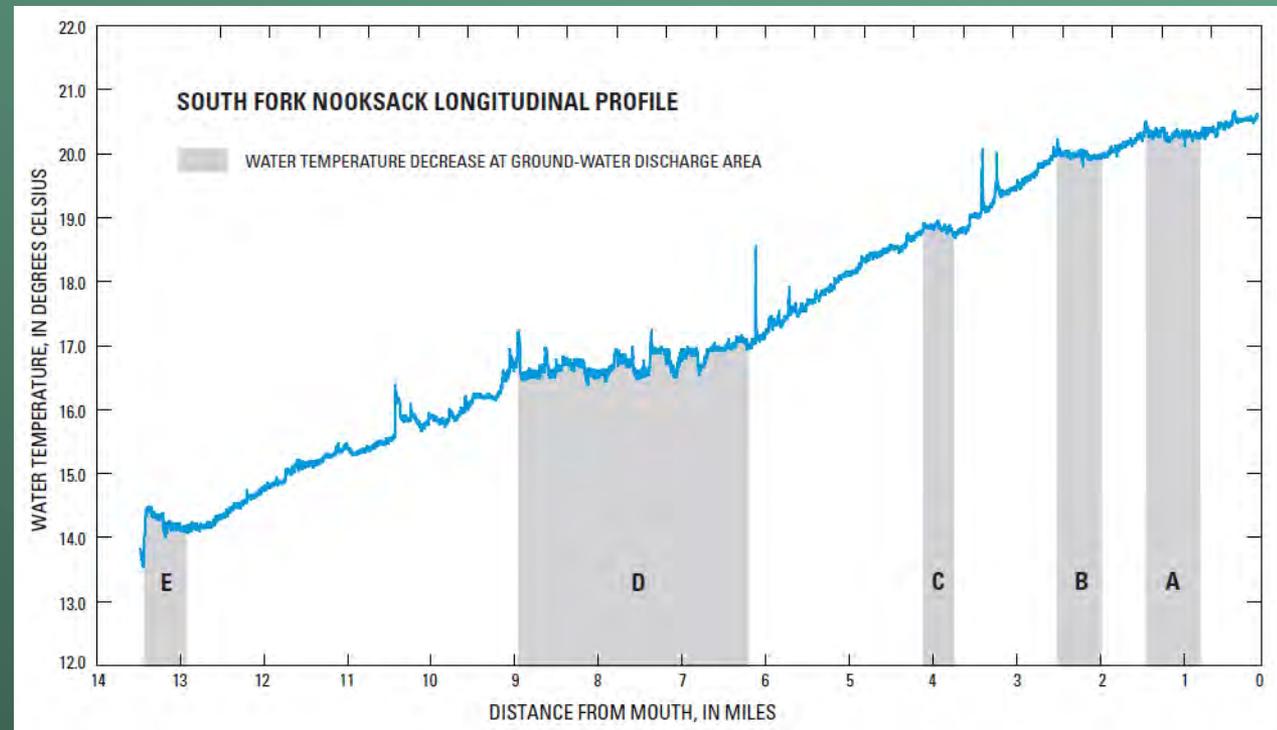
September, 1998 Seepage Run



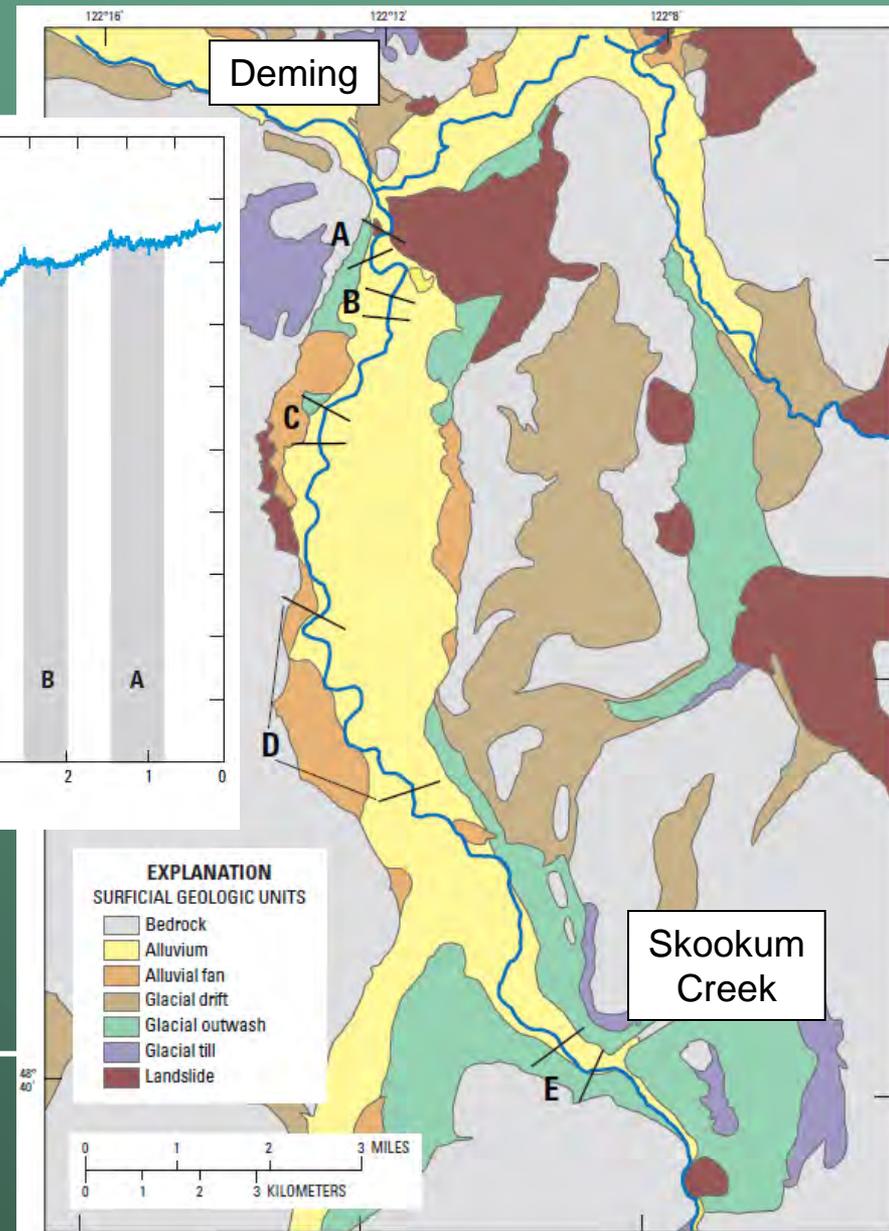
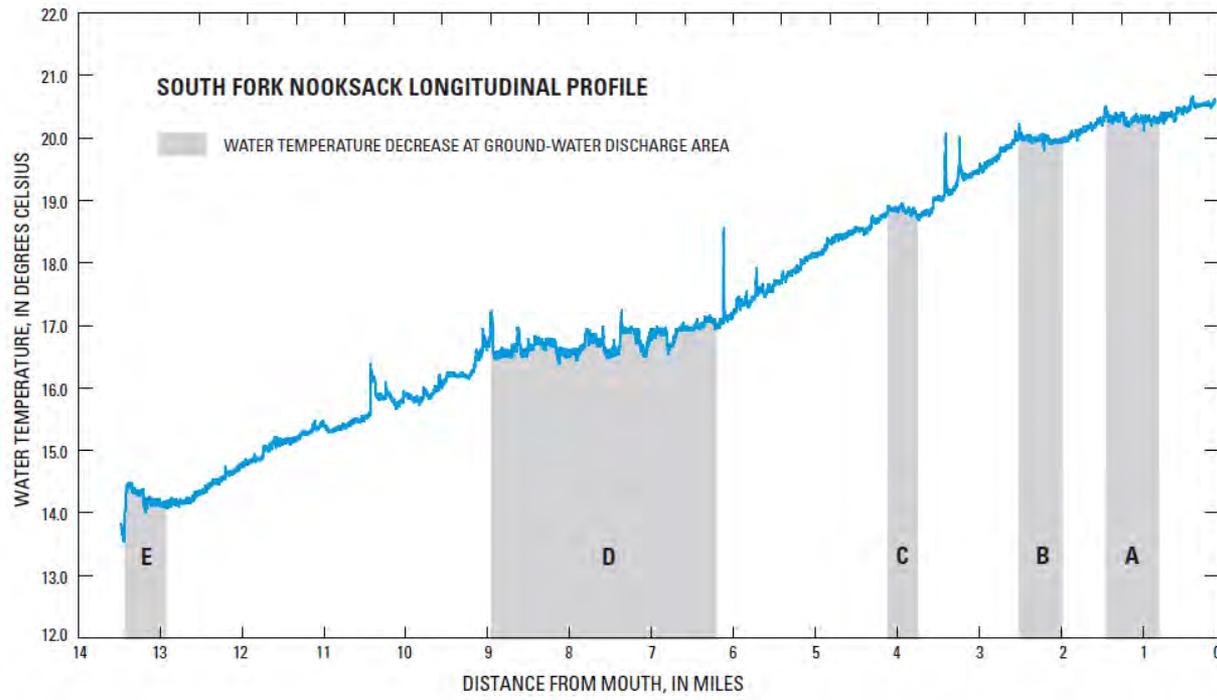
Provisional Data - Subject to Revision

Groundwater/Surface-Water Interactions – Longitudinal Temperature Profile

- Longitudinal temperature profile at ambient flow captures diurnal heating of a parcel of water
- Departures from heating reflect cool water inputs



Groundwater/Surface-Water Interactions – Longitudinal Temperature Profile

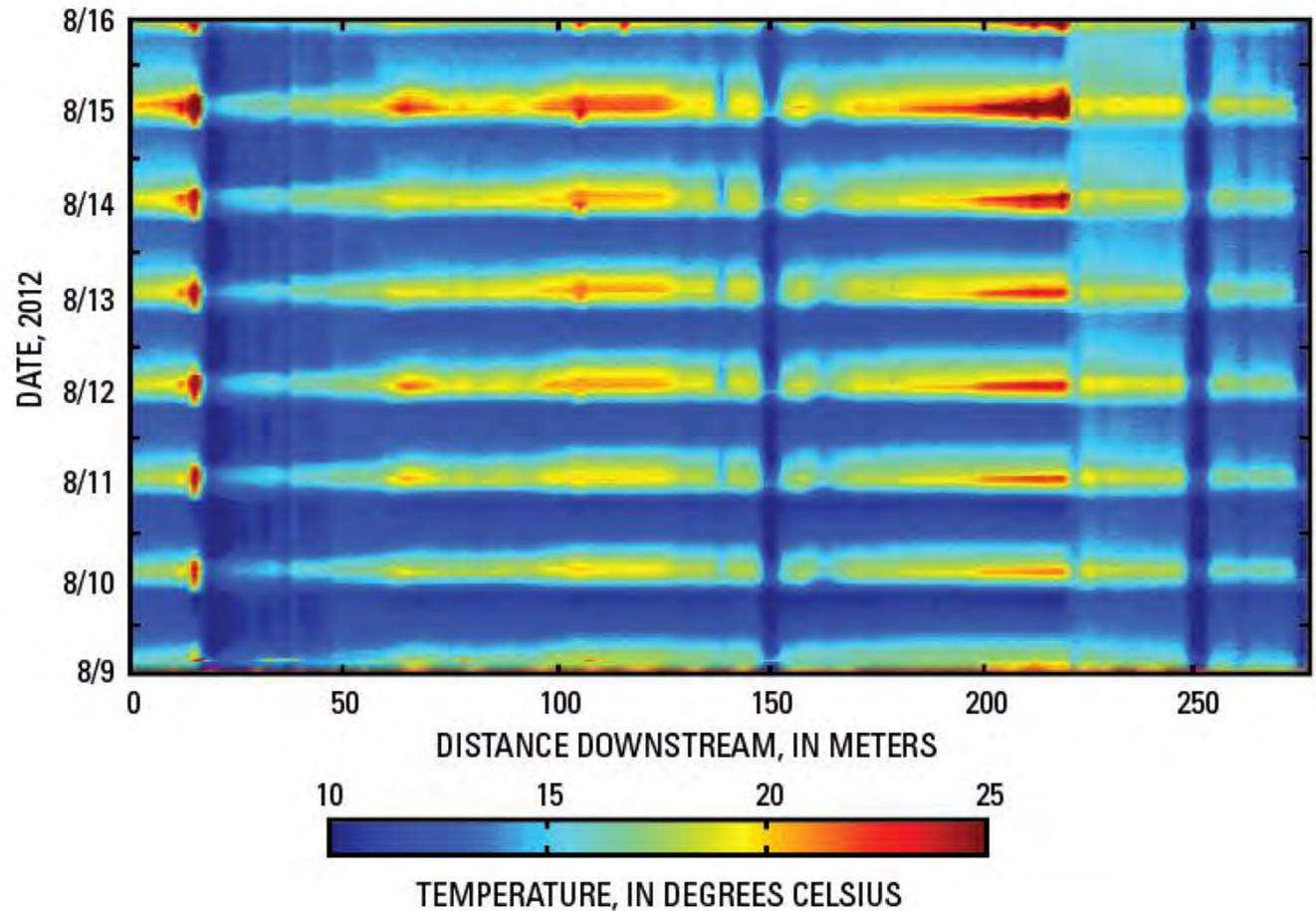


Thermal profile of the South Fork Nooksack River, Whatcom County, Washington, August 28, 2003.

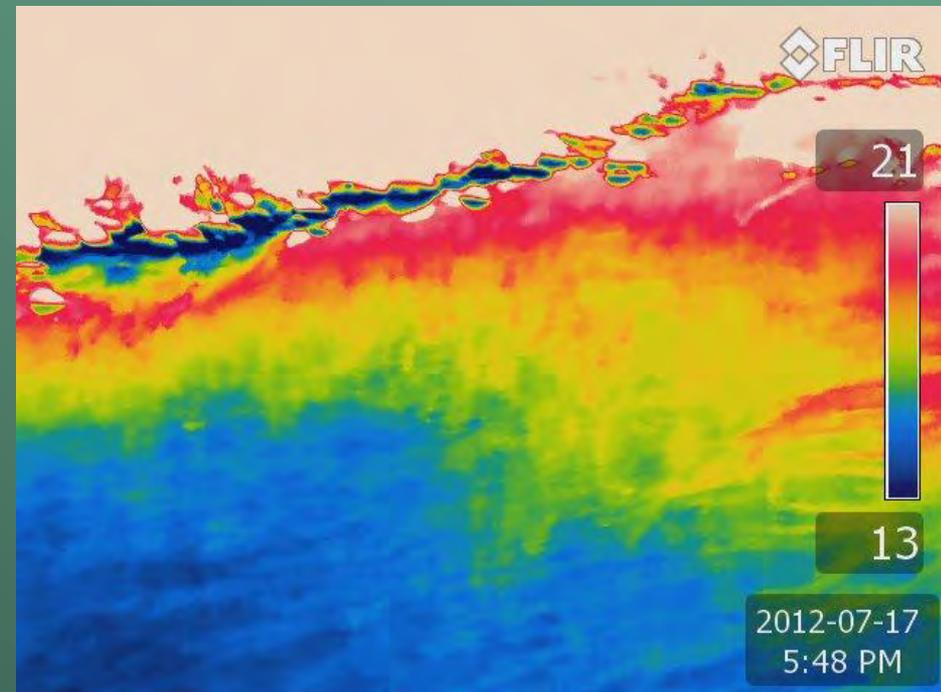


Groundwater/Surface-Water Interactions: Fiber-Optic DTS Data

- Deployed in a side channel during August 2012
- Areas of cool water with low diurnal variability

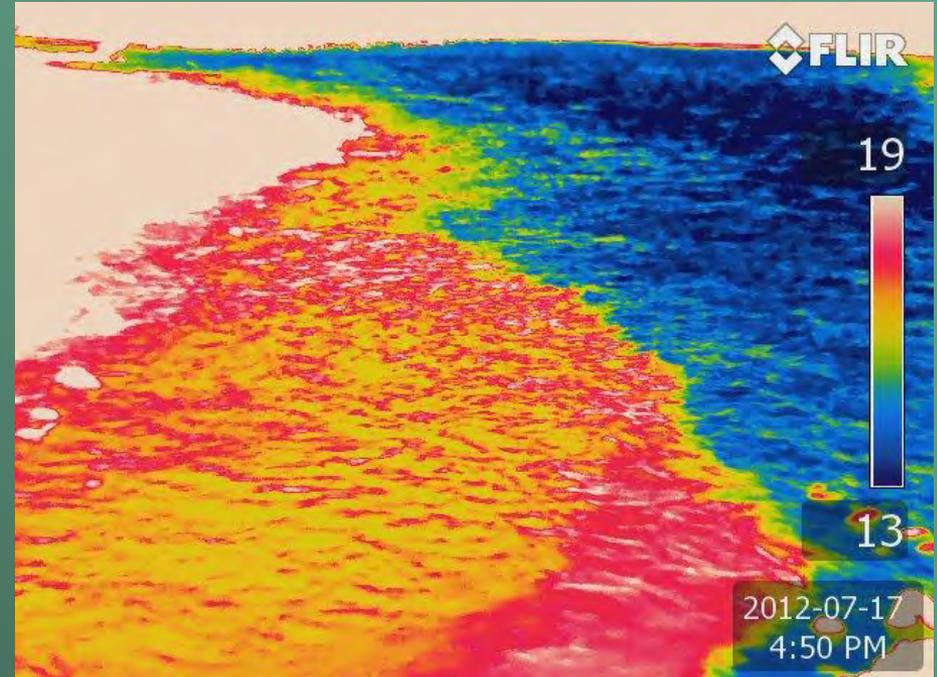


Groundwater Surface/Water Interactions: Bank Seeps



Provisional Data - Subject to Revision

Temperature Heterogeneity



References

- Cox, S.E., Simonds, F.W., Doremus, Llyn, Huffman, R.L., and Defawe, R.M., 2005, Ground water/surface water interactions and quality of discharging ground water in streams of the lower Nooksack River Basin, Whatcom County, Washington: U.S. Geological Survey Scientific Investigations Report 2005-5255, 46 p. (Also available at <http://pubs.er.usgs.gov/publication/sir20055255>.)
- Kovanen, D.J., & Easterbrook, D.J., 2001. Late Pleistocene, post-Vashon, alpine glaciation of the Nooksack drainage, North Cascades, Washington. Geological Society of America Bulletin, 113, 274–288.
- Rosenberry, D.O., and LaBaugh, J.W., 2008, Field techniques for estimating water fluxes between surface water and groundwater U.S. Geological Survey Techniques and Methods Chapter 4-D2, 128 p.

