Puget Lowland Rivers and Streams

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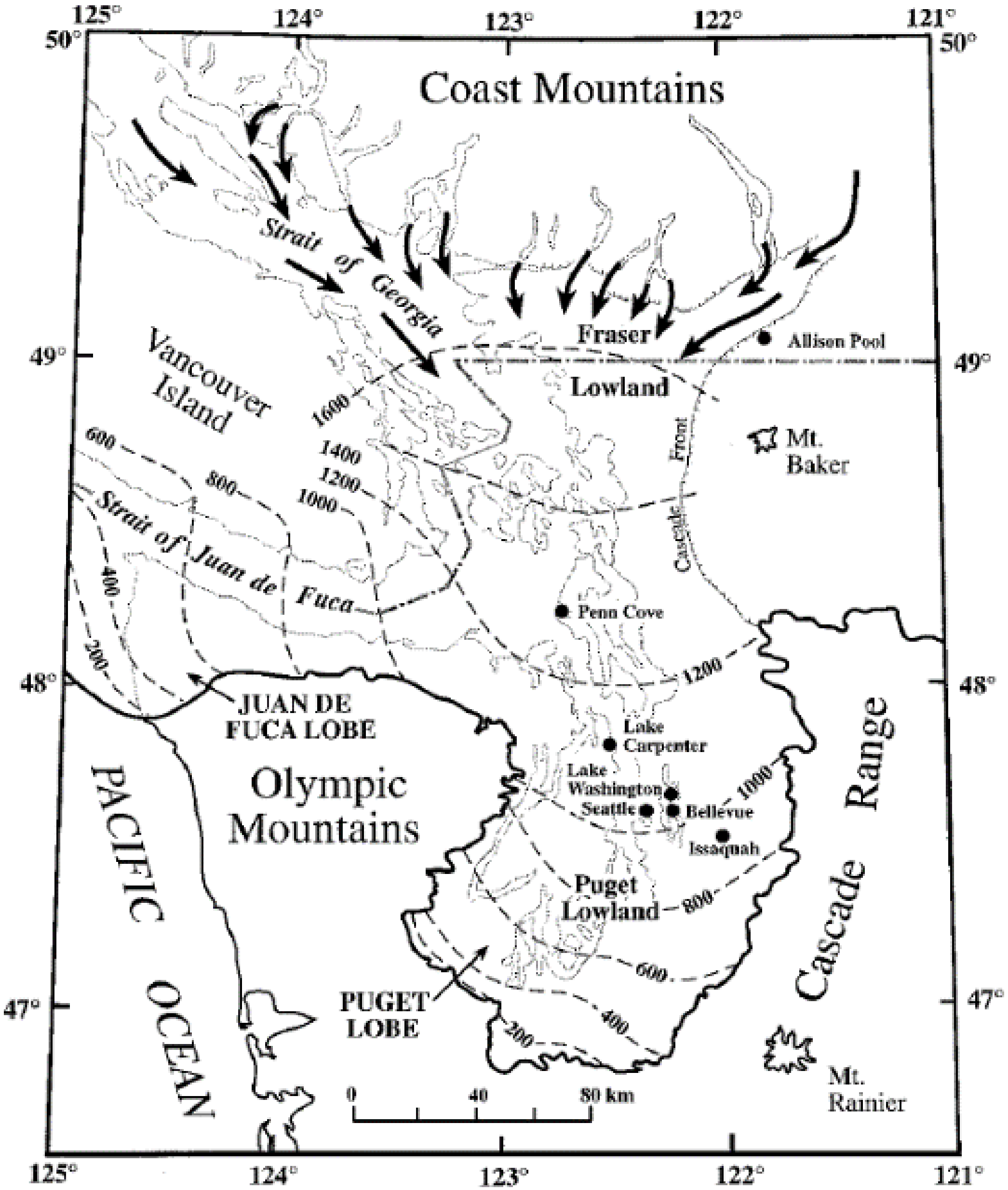
Outline

- Geology/Glacial History
- Watersheds/River Systems
- Natural Morphology and Processes
  - Plan/Profile/Cross-Section
  - Geomorphic Change
- Human Modification
  - Hydrology/Sediment/Wood/Connectivity

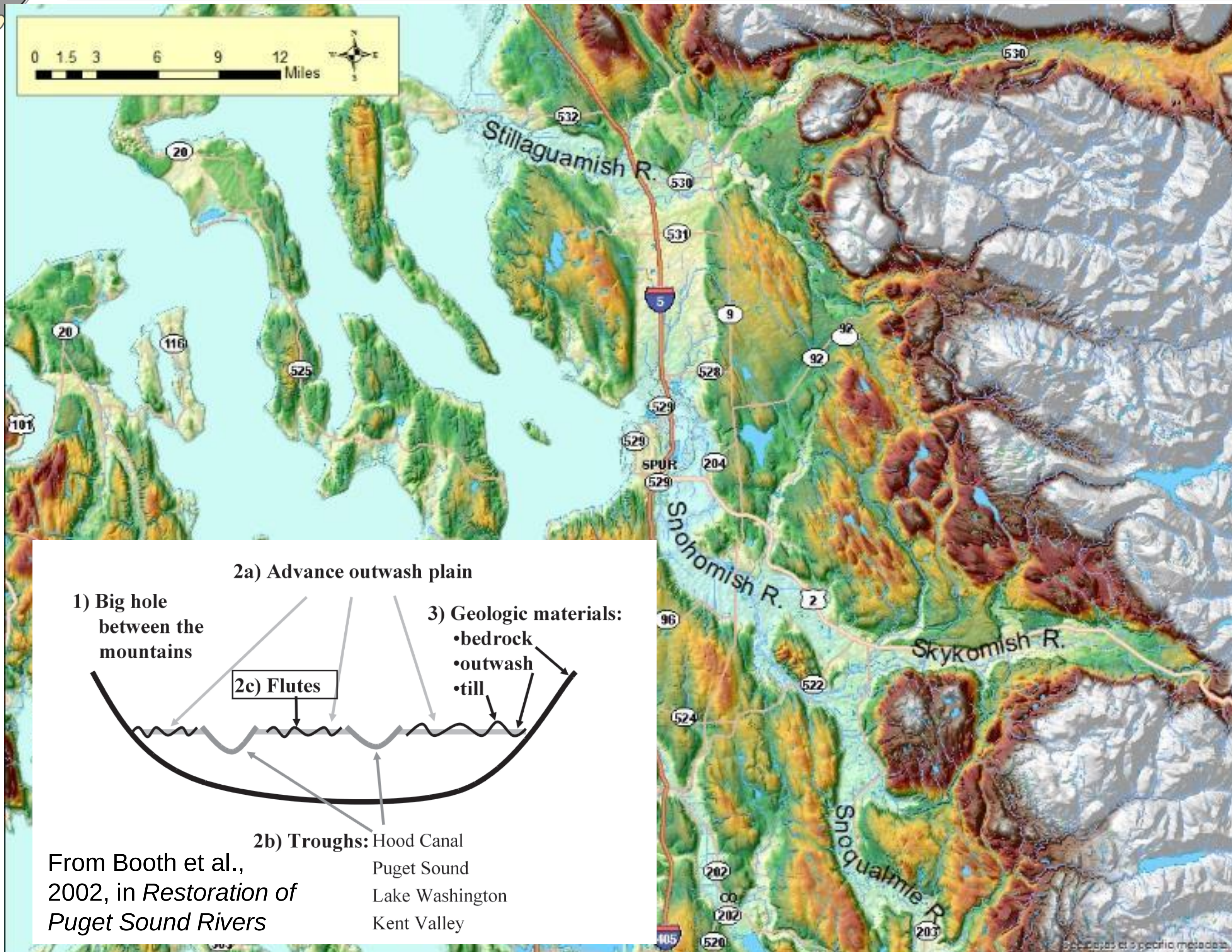
Regional Pleistocene History: Vashon Ice Sheet

- Maximum glaciation ~17,000 years ago
- Occurred AFTER alpine glaciers retreated high into mountains
- Seattle covered by ice for only about 1000 years
- Ice sheet blocked mountain valleys



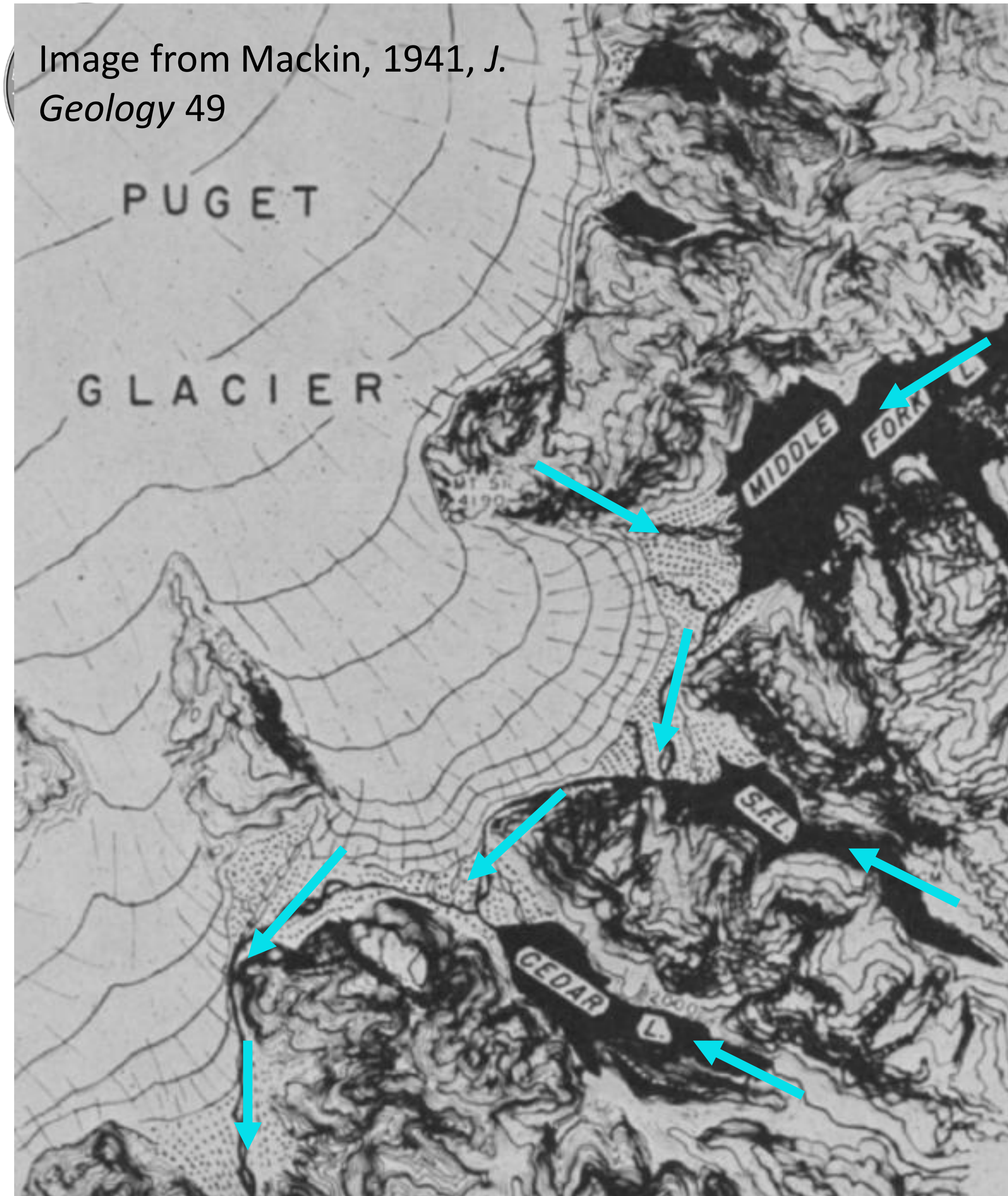
From Porter and Swanson, 1998, *Quaternary Research* 50

Regional Sub-Glacial Terrain



From Booth et al., 2002, in *Restoration of Puget Sound Rivers*

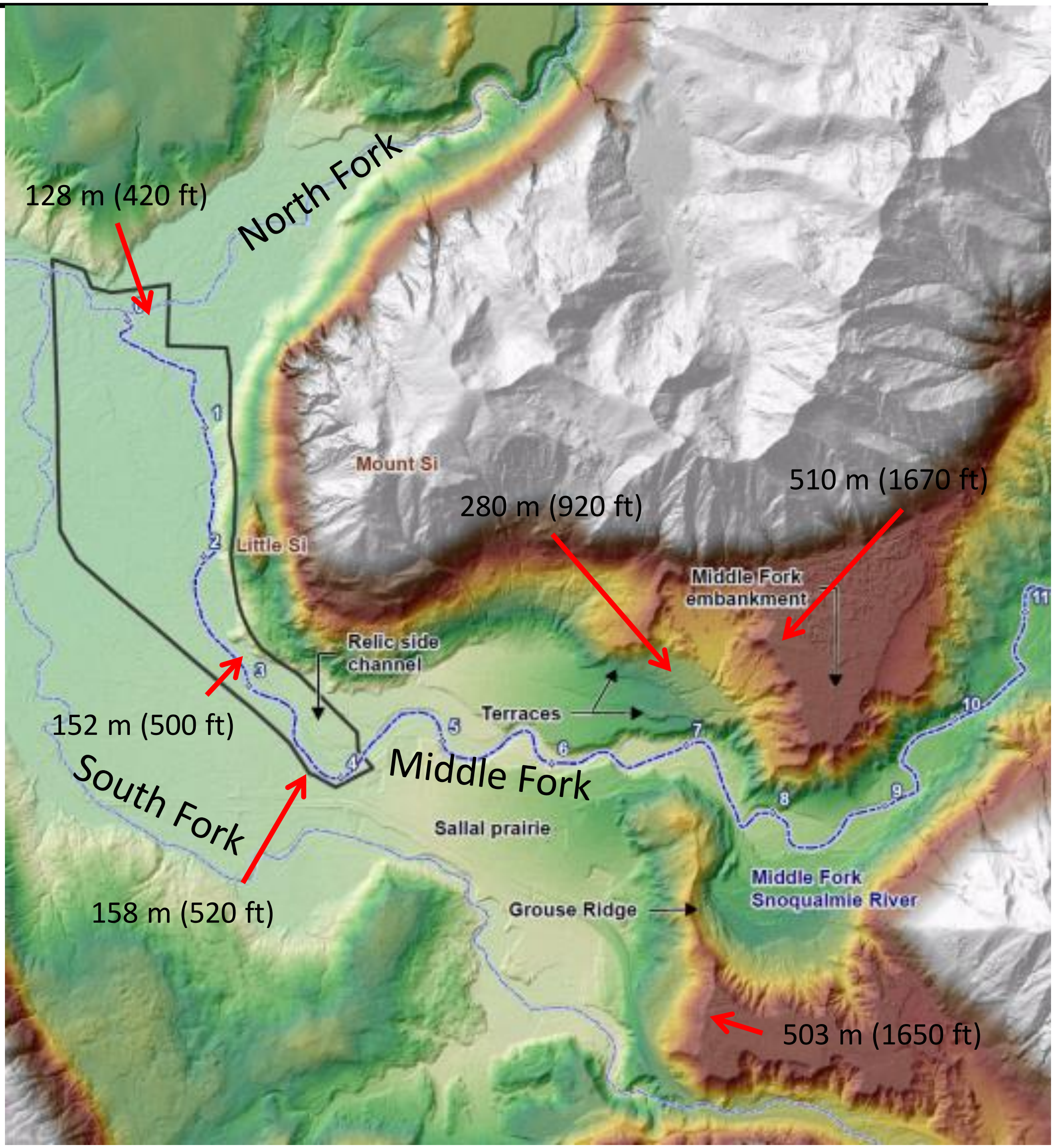
Pro-glacial Lakes



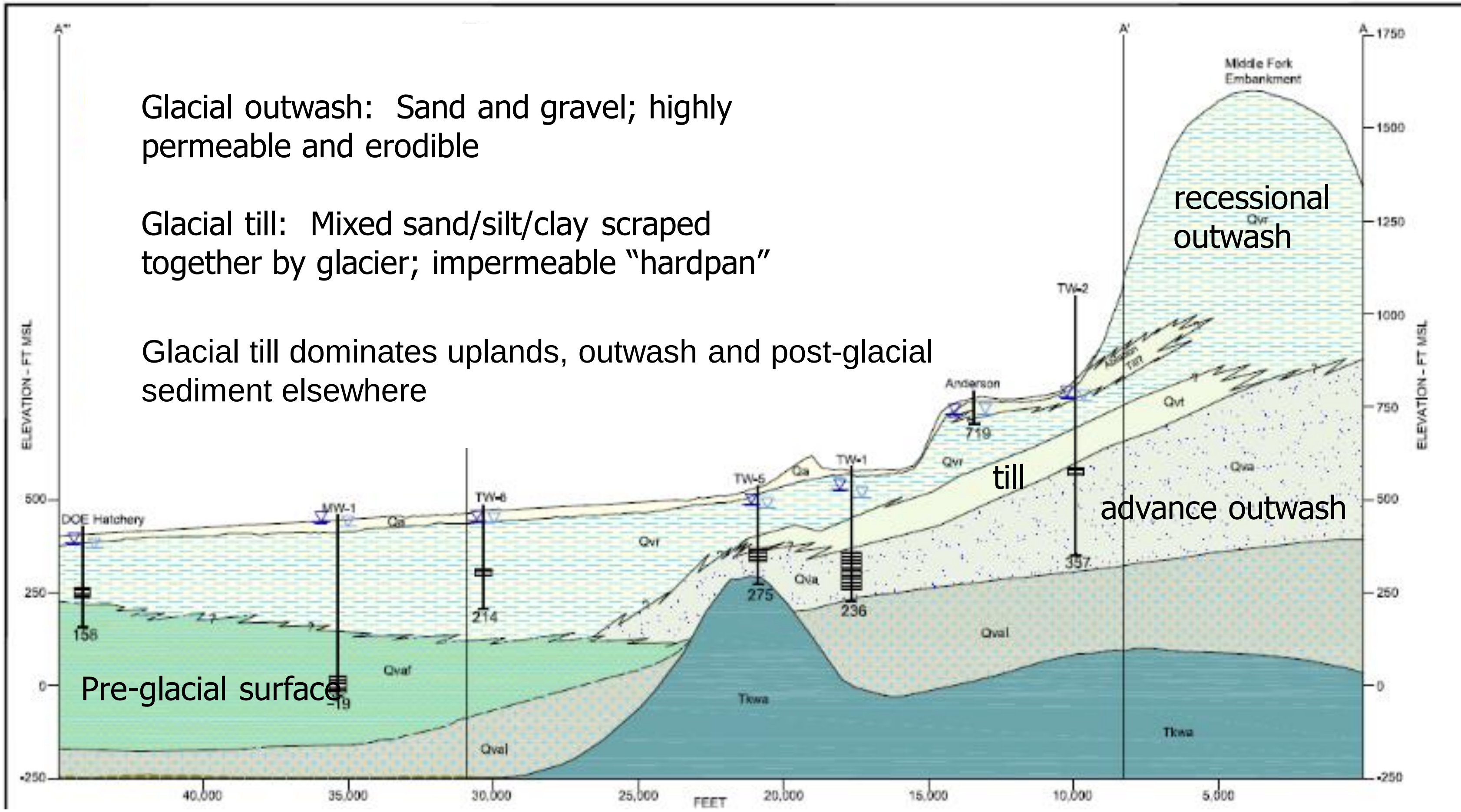
- Gravely delta moraines formed at edge of ice
- Lakes extended up valley

Deglaciation

- Occurred over hundreds of years
- Rapid pro-glacial lake drainage
- Slow rebound of land surface (highest in north)
- Very slow valley filling thereafter



Typical Sediment Package, Snoqualmie Valley near North Bend



Similar Stratigraphy in Oso Landslide Deposits

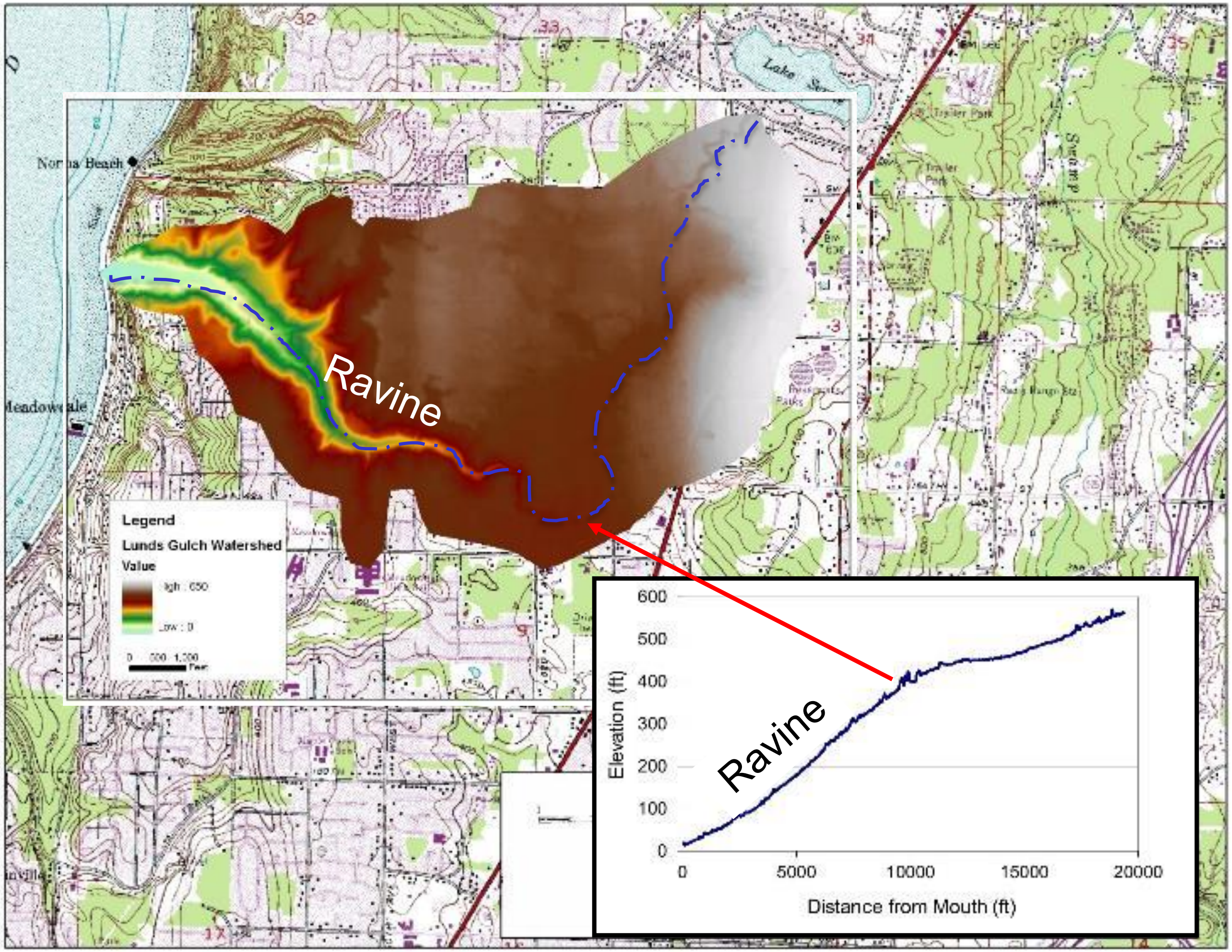
Geotechnical Extreme Events Reconnaissance (GEER) report, Keaton et al., 2014

http://www.geerassociation.org/administrator/components/com_geer_reports/geerfiles/GEER_Oso_Landslide_Report.pdf

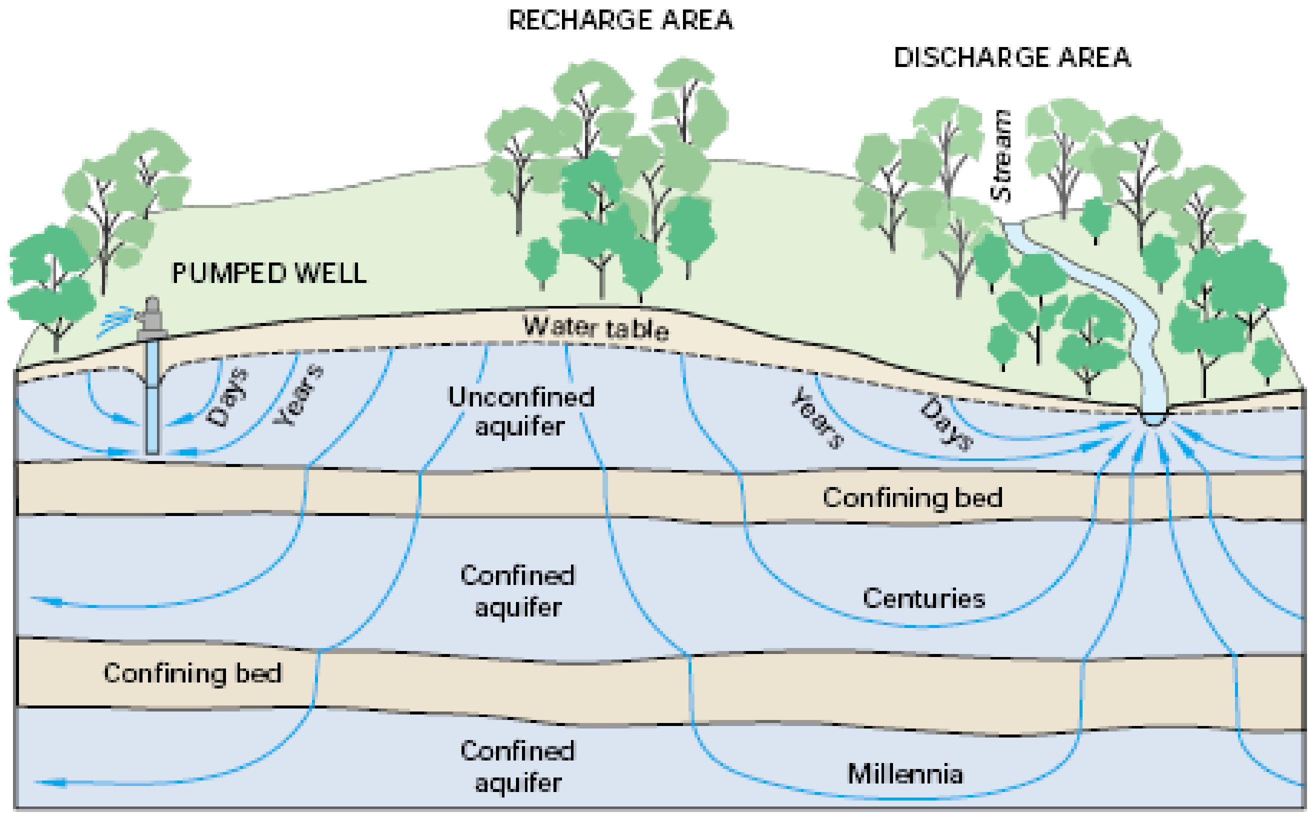
Exercise 1 (in small groups)

- Install Google Earth Pro (available at https://www.google.com/earth/versions/#earth-pro)
  - (if you have trouble, use online version at https://earth.google.com/web/, but this will not allow use of add-ins)
- Install add-in here: (https://ge-map-overlays.appspot.com/world-maps/maps-for-free-relief)
  - You may need to log in first. Hopefully, I can share the file with you over Zoom.
- Zoom to the region where each of you in your group lives. Do you think you are located on glacial till, outwash, or post-glacial valley fill?

Post-Glacial Drainage Reorganization



Surface Water—Ground Water



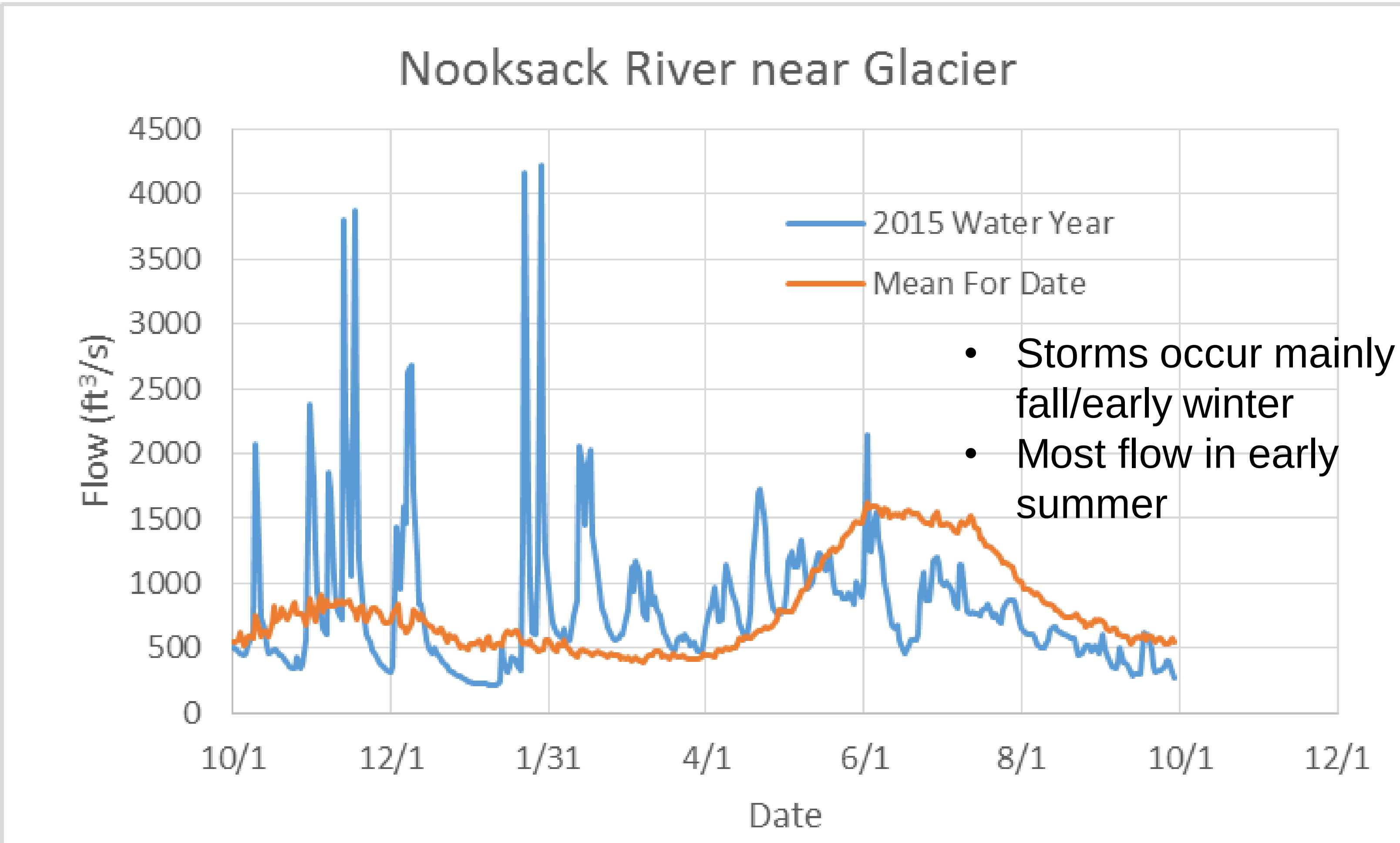
Take-away points from natural history

- Larger rivers pass through glacial valleys that have filled with sediment during the past several thousand years.
- Small streams on uplands generally pass across glacial till, then move across steep zone before entering river valley or sound.
- Glacial deposits play an important role in groundwater hydrology.

River Dynamics and Morphology

- Basic Hydrology
  - Large Rivers (Snowmelt/Rainfall/Transitional)
  - Flow/flood statistics
  - Lowland Streams
- River/Valley Morphology
- Processes of Geomorphic Change

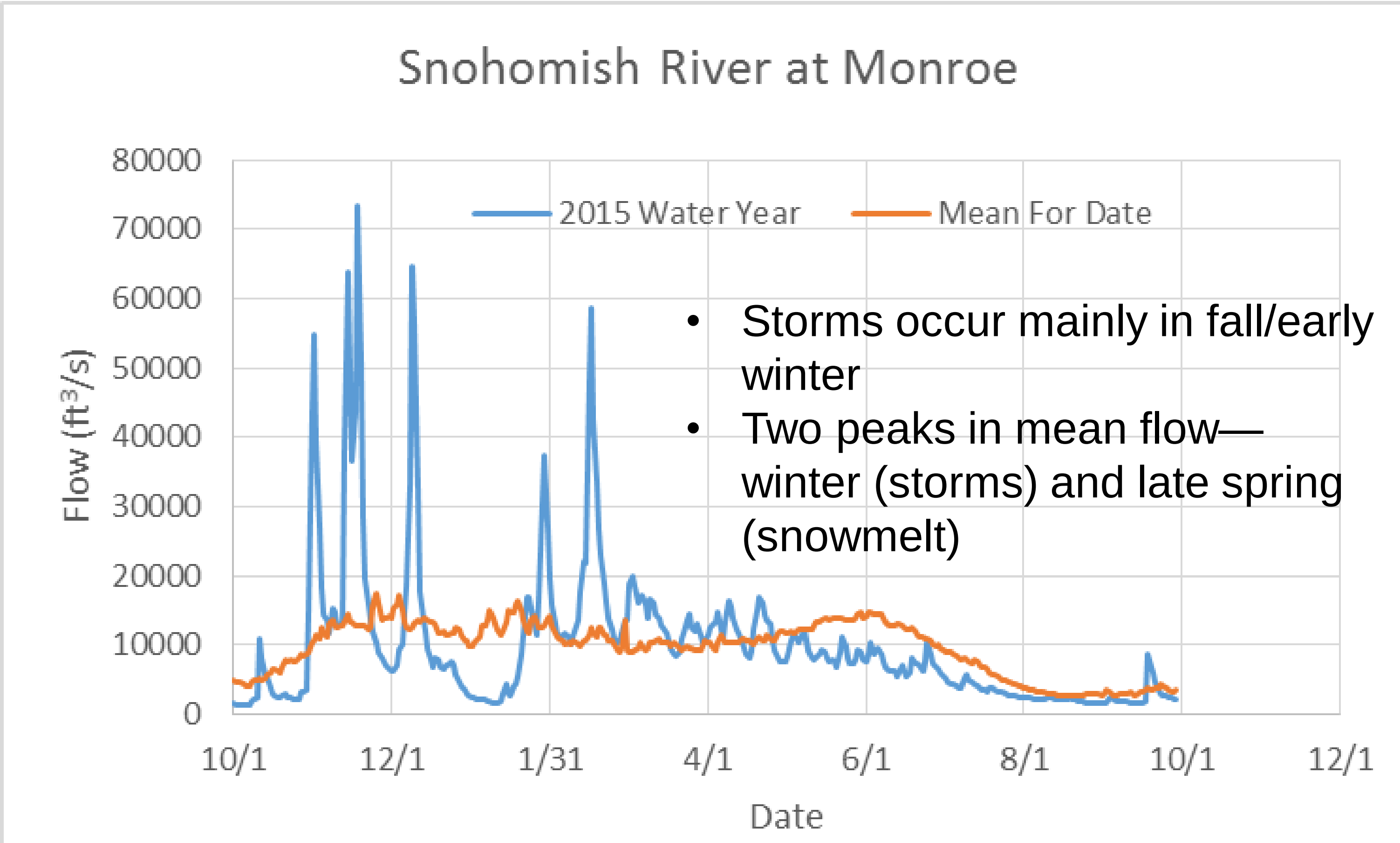
Basic Hydrology for Puget Sound: Snowmelt



- Storms occur mainly in fall/early winter
- Most flow in early summer

Most high-elevation rivers in Washington are like this.

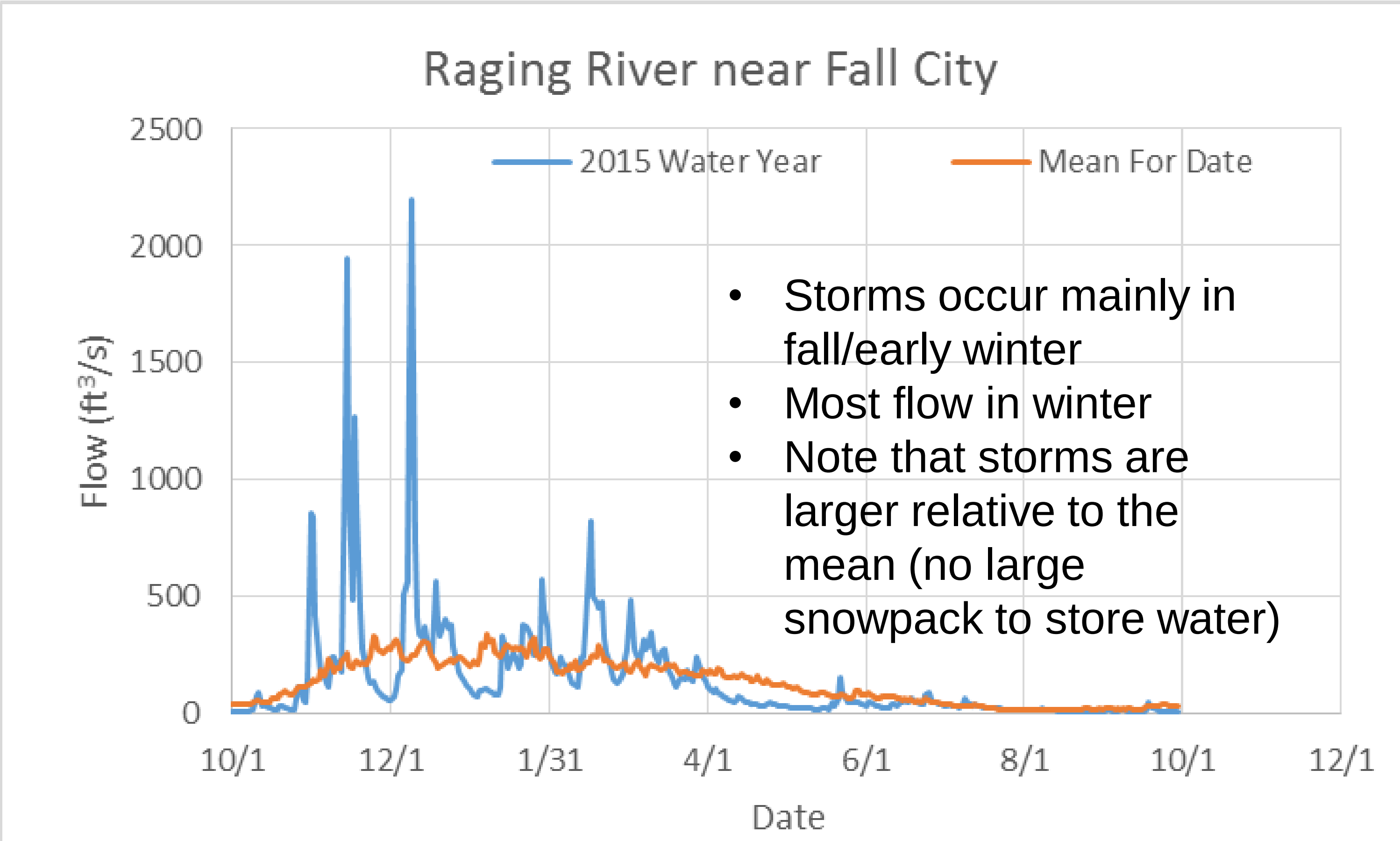
Basic Hydrology for Puget Sound: Transitional



- Storms occur mainly in fall/early winter
- Two peaks in mean flow—winter (storms) and late spring (snowmelt)

Most lowland rivers in Puget Sound are something like this.

Basic Hydrology for Puget Sound: Rainfall Dominated



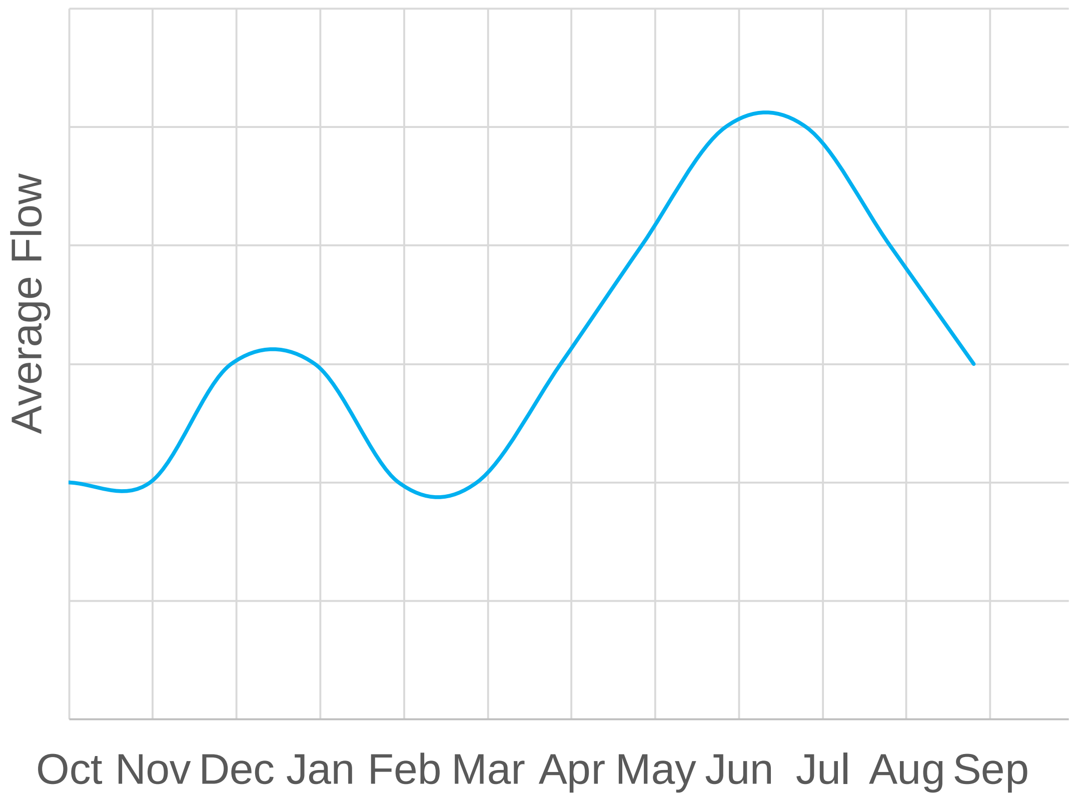
- Storms occur mainly in fall/early winter
- Most flow in winter
- Note that storms are larger relative to the mean (no large snowpack to store water)

Most small lowland streams in the Puget Sound region are like this, but more exaggerated.

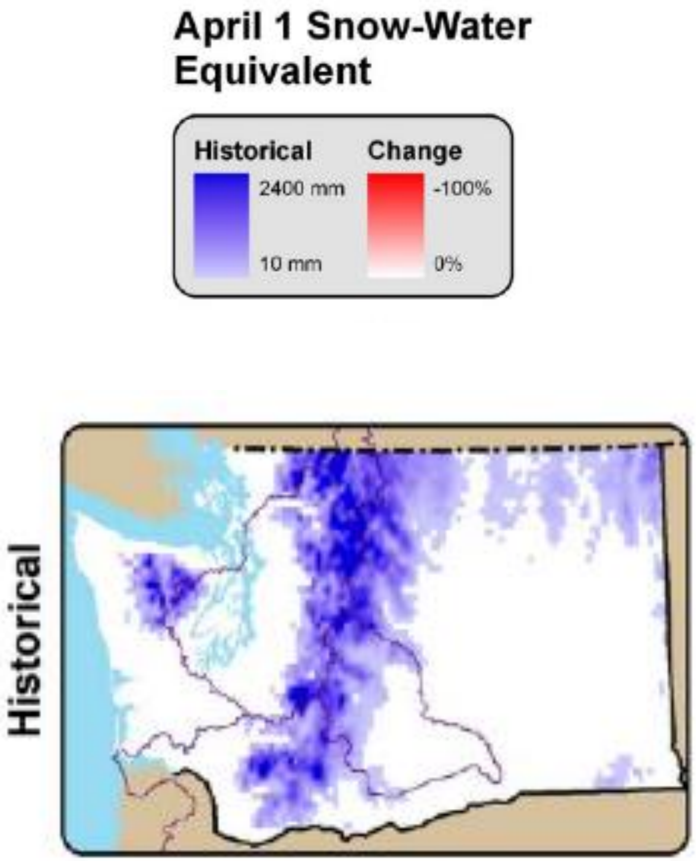
Snowline and Climate Change

Hydrograph Change Activity

In new groups, sketch what you think a future average annual hydrograph would look like in a snowmelt-dominated watershed. If you have time, discuss how the actual hydrograph in a given year would differ from the annual average.

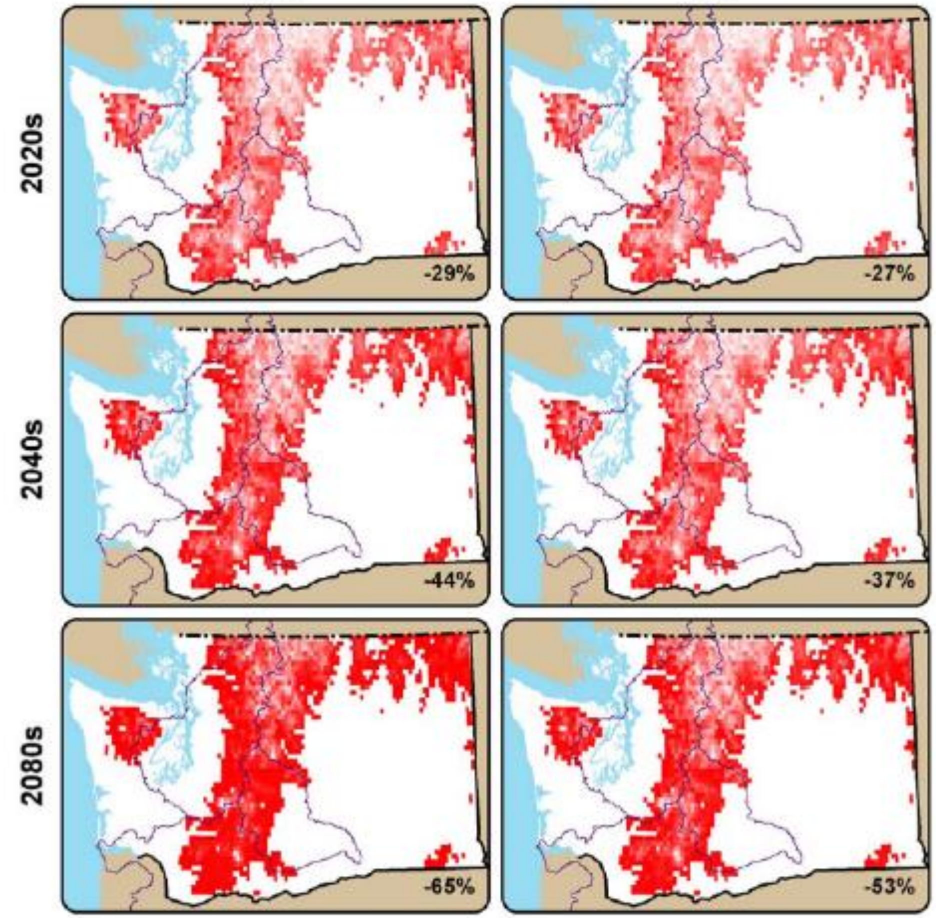


Climate Change: Most pronounced effect is change in snowpack and time of year when snowmelt dominates hydrograph



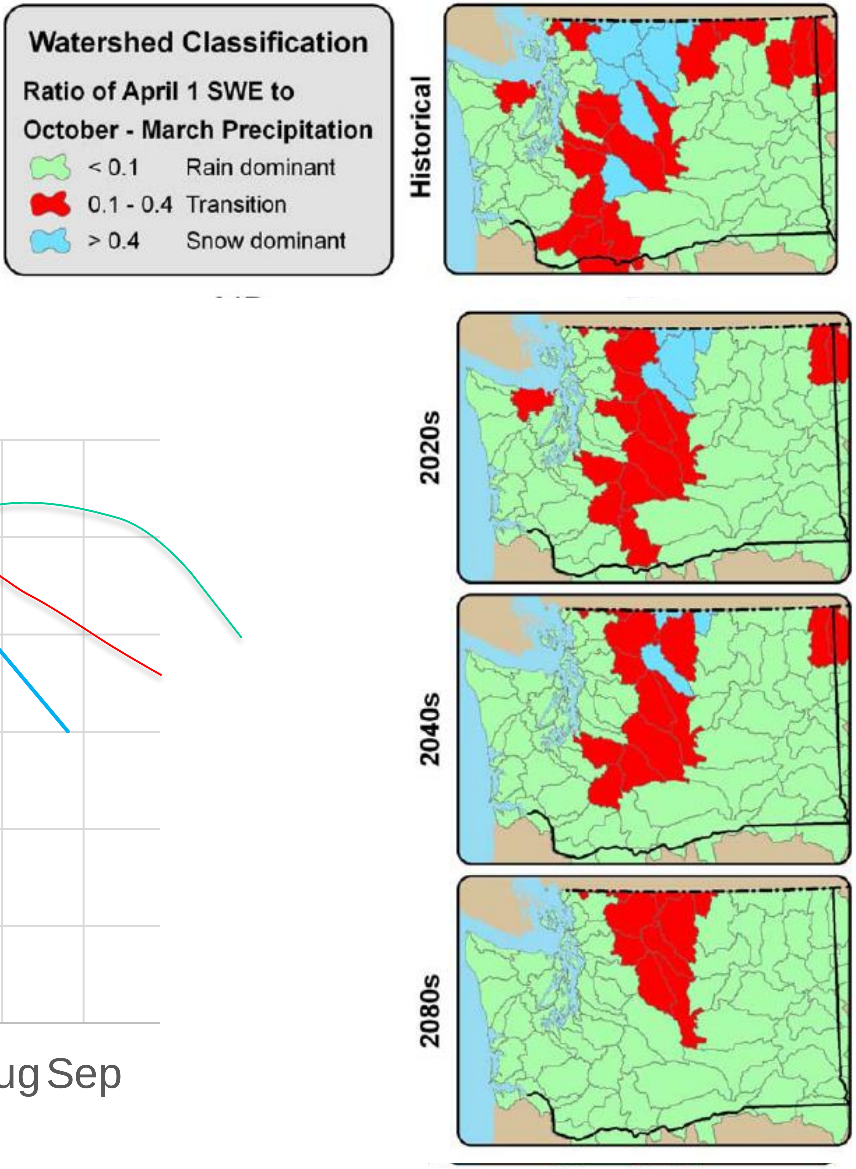
High Warming Scenario

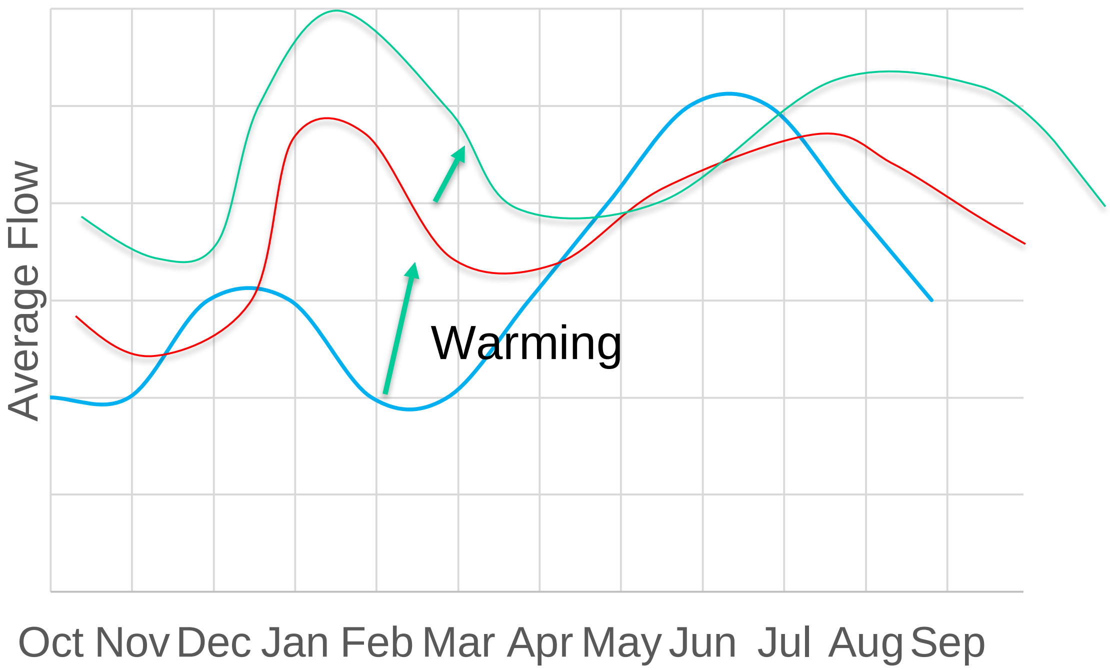
Low Warming Scenario



Elsner et al., 2010

Reduction in snowmelt and change in stream temperatures will change hydrograph timing

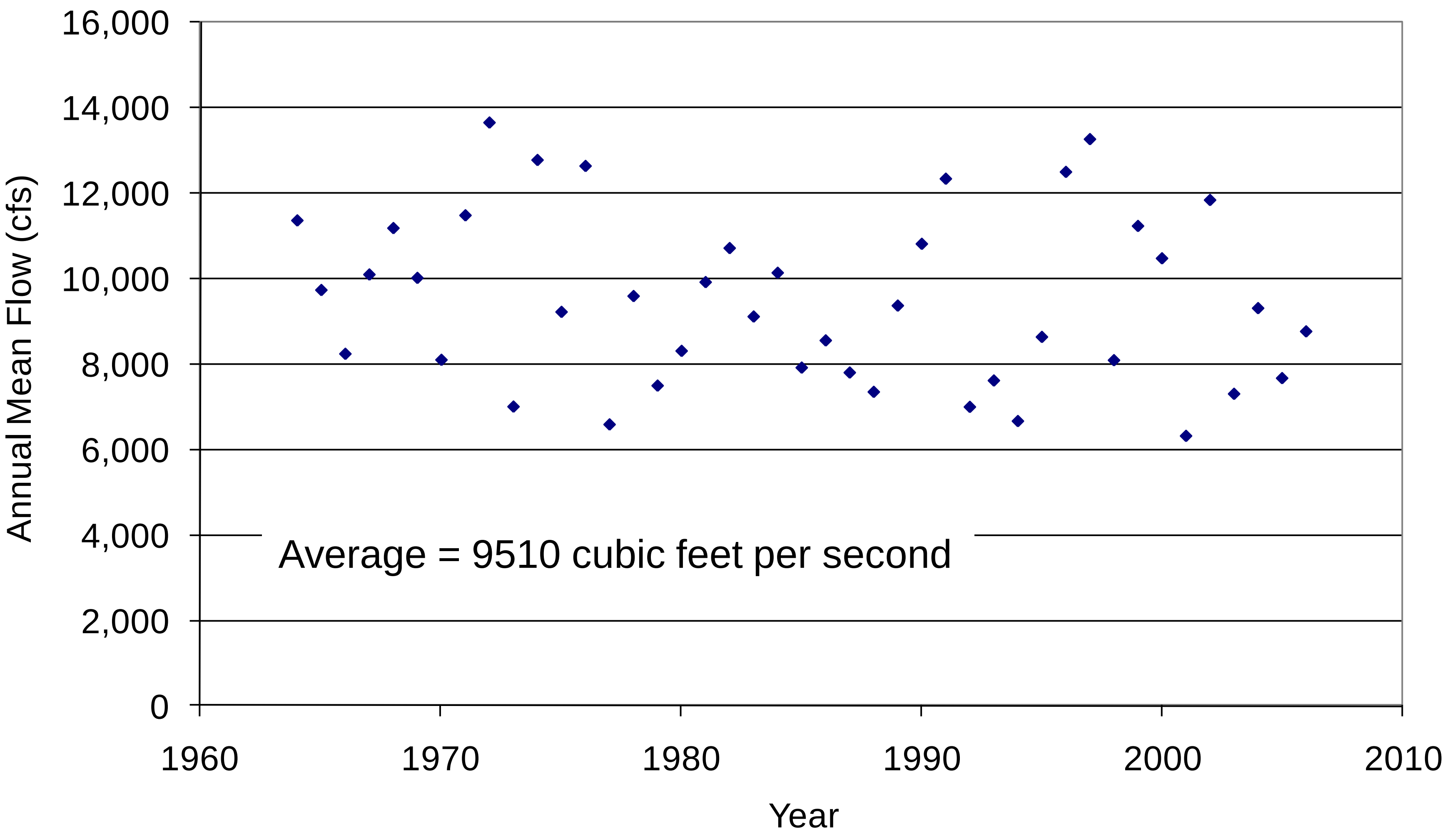




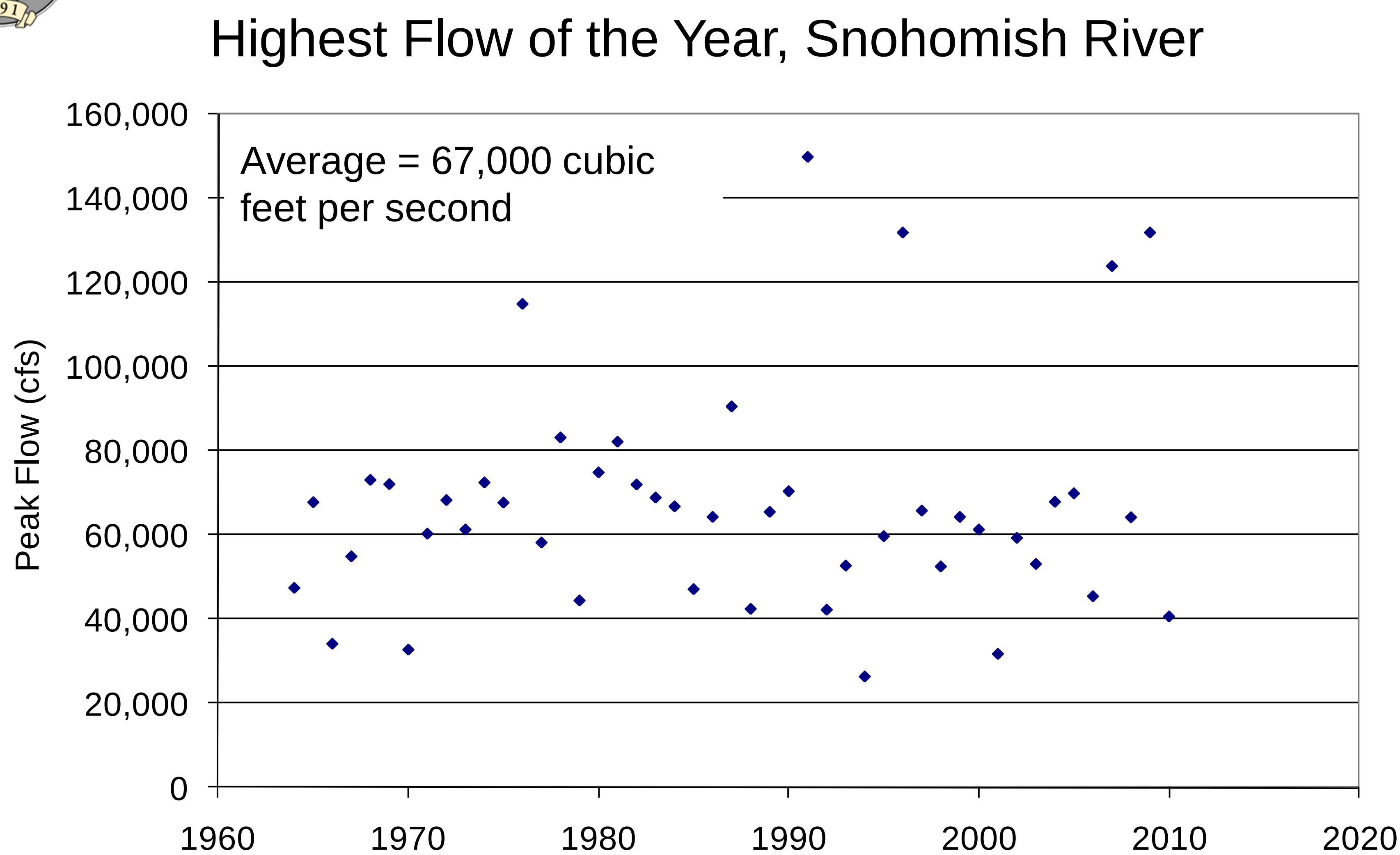
Elsner et al., 2010

Year to Year Variability

Average Flow for the Year, Snohomish River

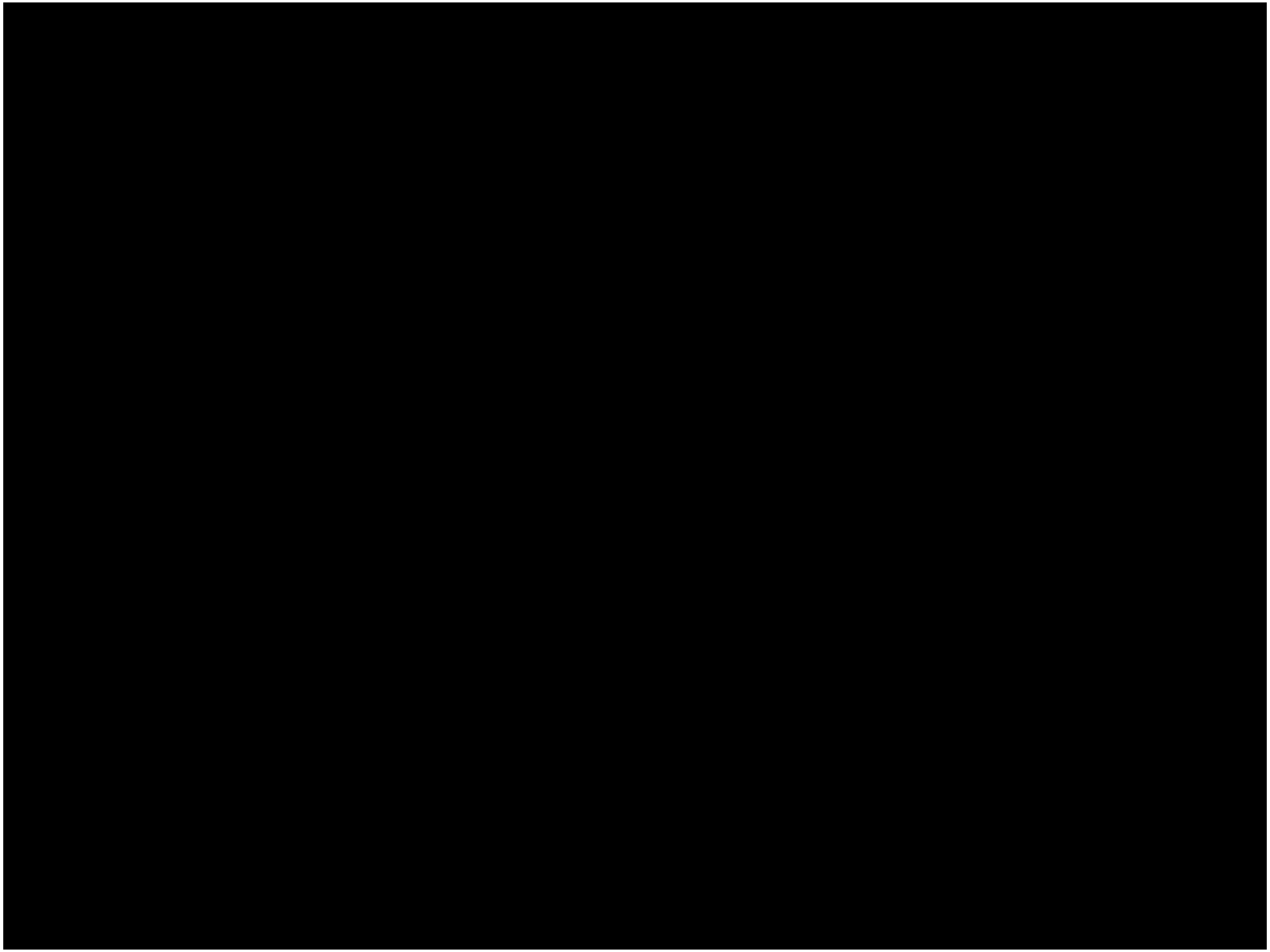


Year to Year Variability



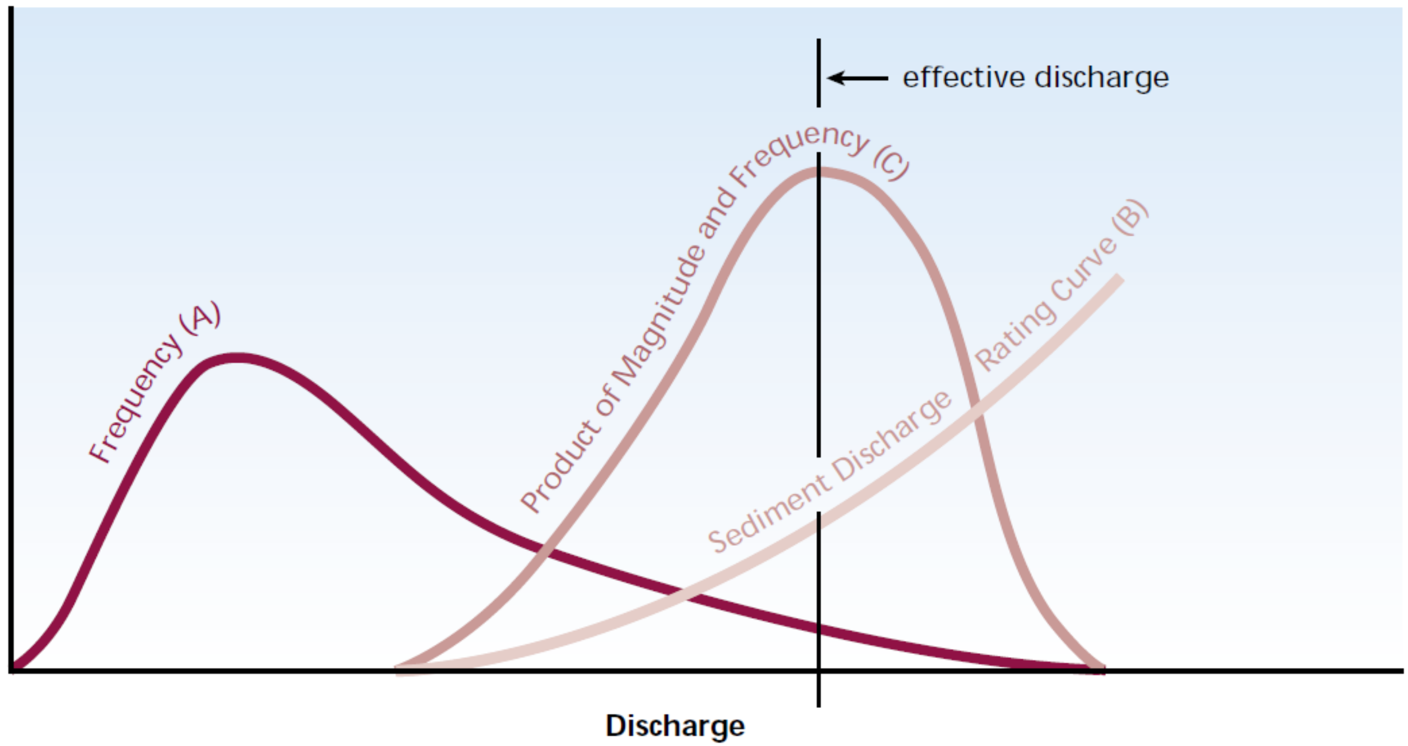
Median or 50th Percentile of these floods has a 50% chance of being equaled or exceeded each year, so it is exceeded on average every other year. We call it the 2-year flood.

February 8, 2015 Flooding, Middle Elwha River



Which flood is most important?

Rivers tend to adjust their geometries to flows that happen relatively frequently (every few years)



From Federal Interagency Stream Restoration Working Group, 2001, Stream Corridor Restoration: Principles, Processes, and Practices

Natural rivers flood (i.e., inundate vegetated surfaces) every year or two.

Ecological Effects of Flood Regime

Benefits

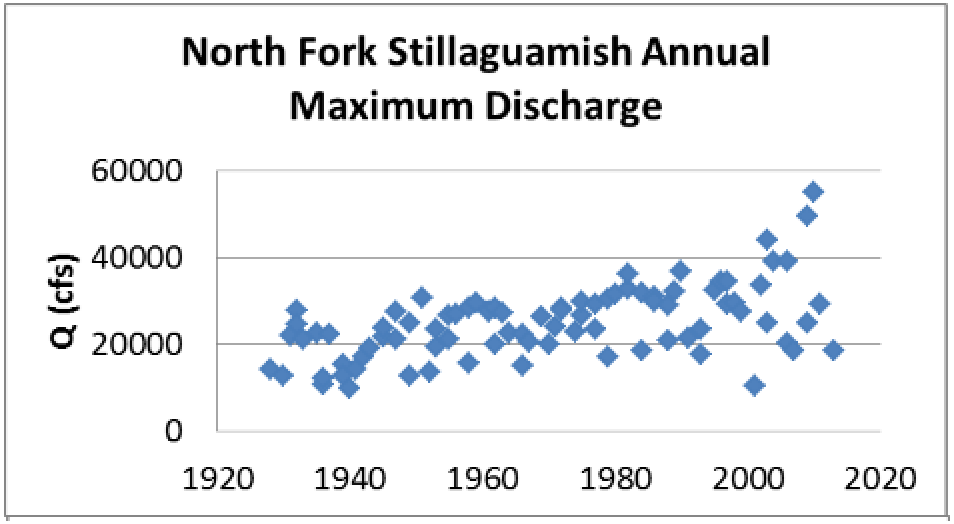
- Re-sets geomorphic system
- Moves (and cleans) sediment
- Creates variability that becomes habitat
- Disturbs ecosystem, but native species are resilient and require the disturbance

Drawbacks

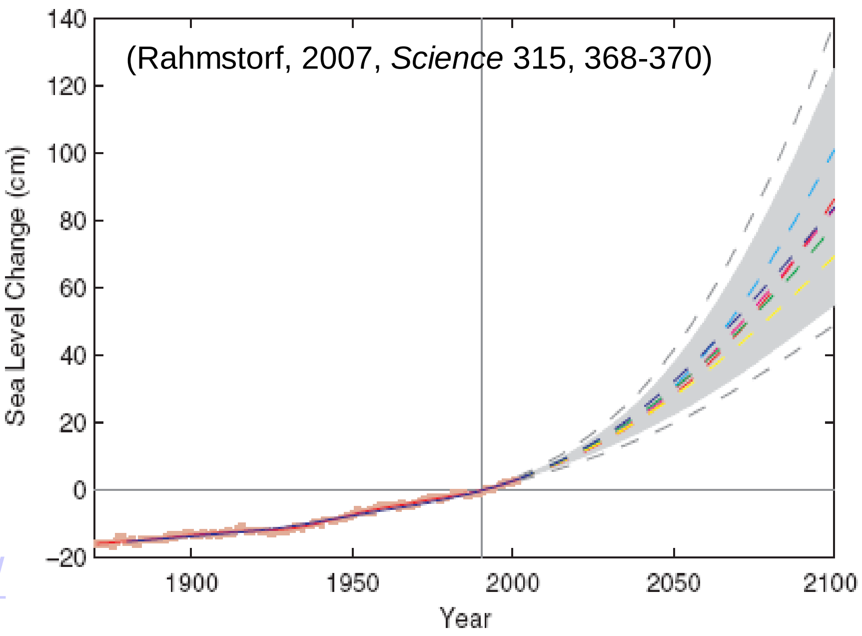
- Unnaturally large floods can cause excessive erosion/scour
- Especially where river banks are straightened/armored, flood velocities can be too high and sweep organisms away

Other Important Human Impacts

Changes in Flood Frequency

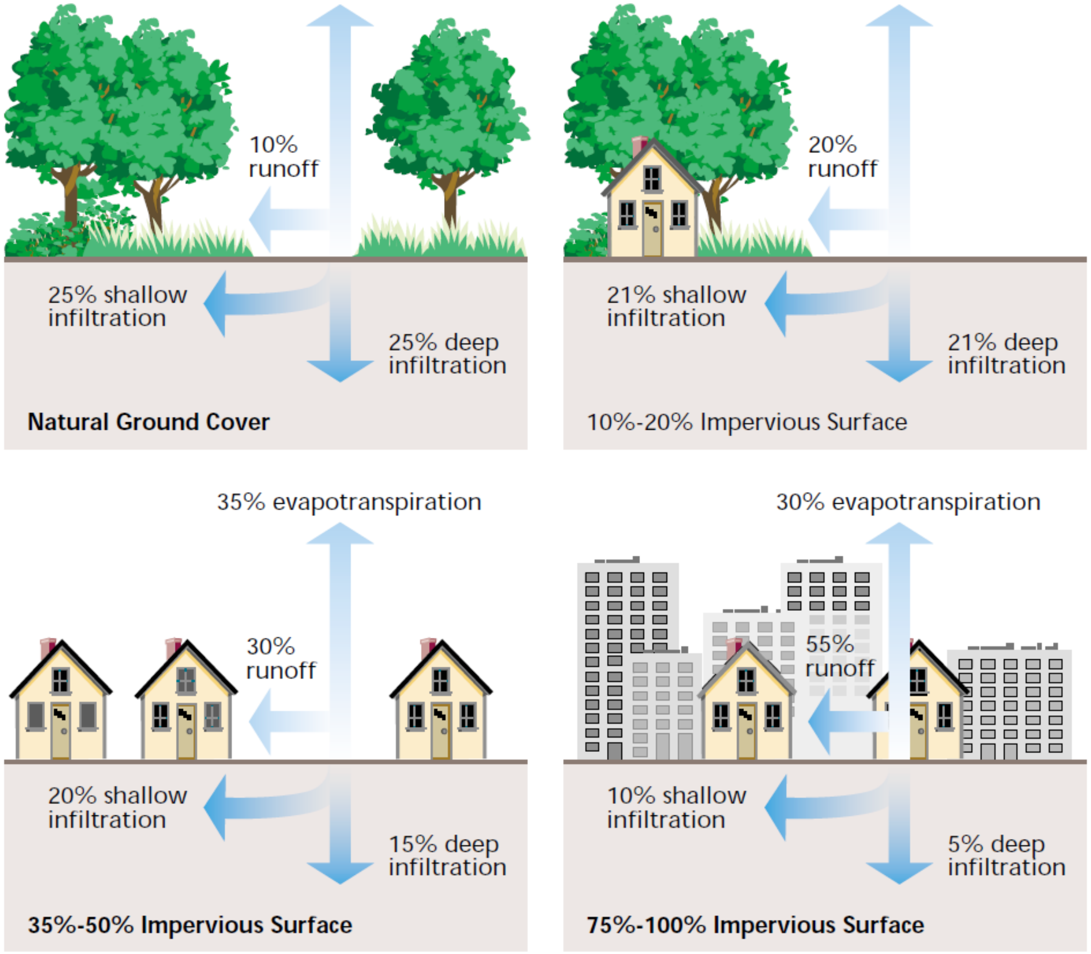


Changes in Sea Level



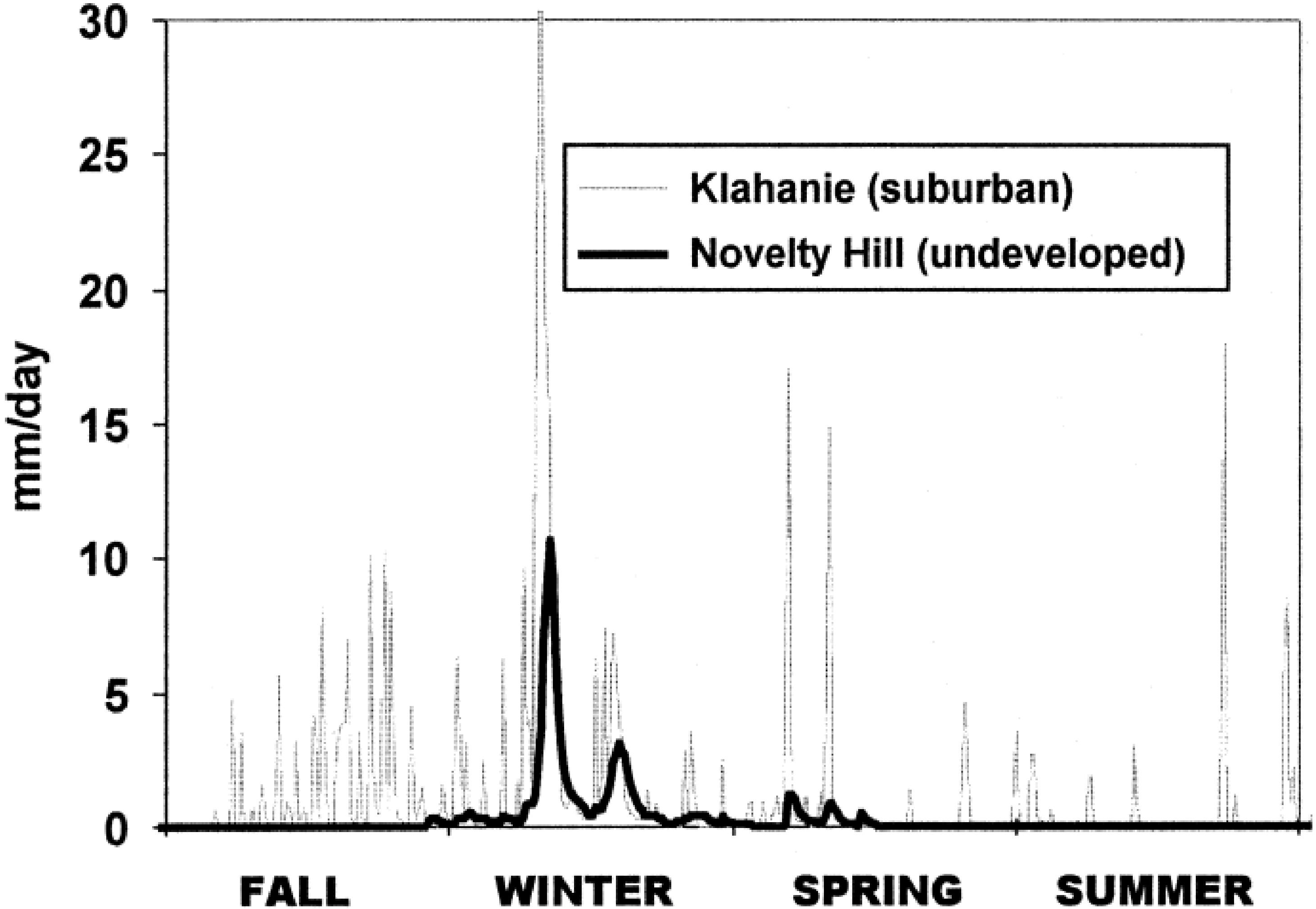
For more on climate, see National Climate Assessment: https://nca2018.globalchange.gov/

Urbanization Impact on Storm Flow



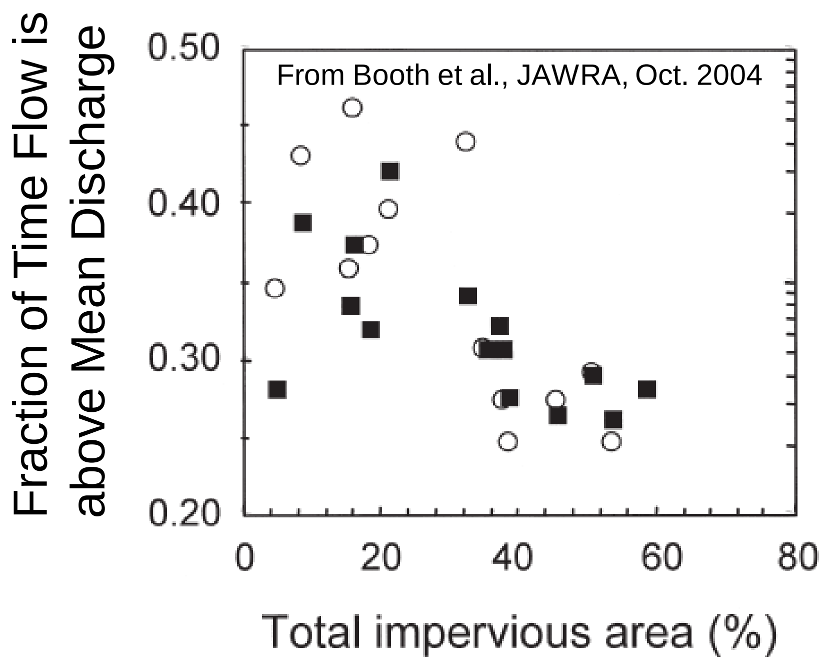
From Federal Interagency Stream Restoration Working Group, 2001, Stream Corridor Restoration: Principles, Processes, and Practices

Small Stream Hydrology



From Booth et al., 2007, *J. Am. Water. Res. Assoc.* 38.

Effect of Impervious Surfaces on Hydrology



A lower number means a larger fraction of flow leaves watershed in large flow events. In other words, for low numbers, when it floods, it REALLY floods (and is pretty dry the rest of the time). This is associated with poor stream health.

Basic problem is also important in any developing area, E.G. Hagley Gap, Jamaica


Runoff flows overland,
eventually must enter channel

Typical Erosion Problem Where Flow Re-enters Channel


Main source of runoff is new construction along road, not necessarily runoff from pervious surfaces.

Culverts under roadway are temporary solution, but additional development could lead to excessively high flows.

Take-away points from hydrology

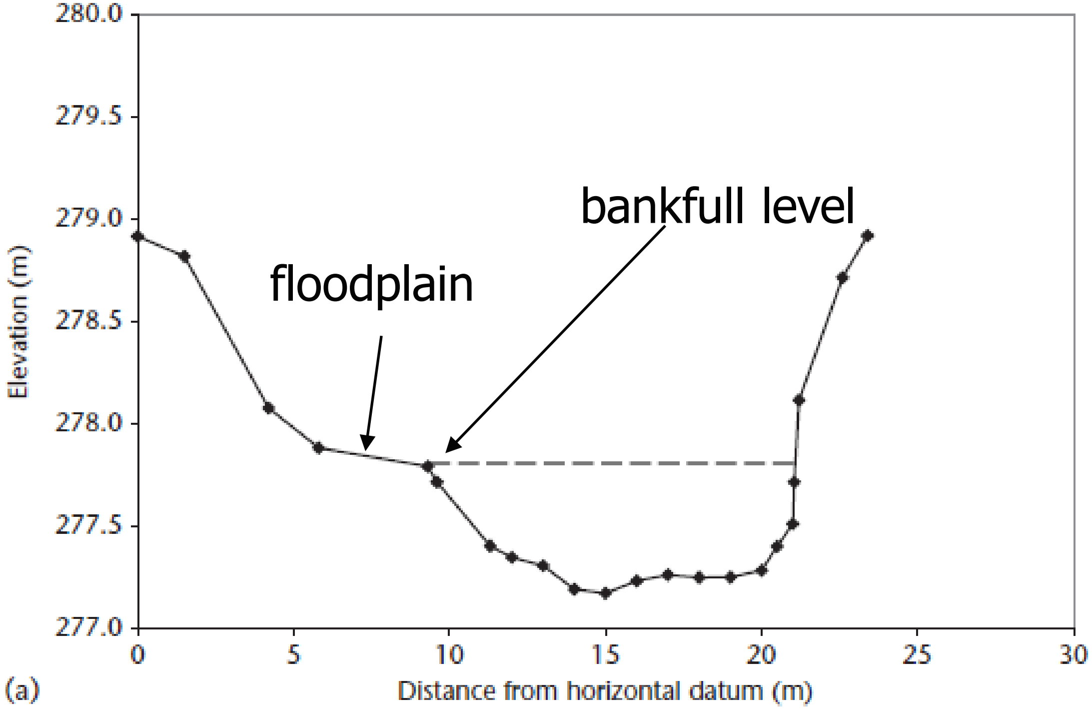
- Large lowland rivers are affected by both winter floods and snowmelt while smaller streams are affected mainly by winter floods.
- Natural rivers and streams are strongly affected over time by “ordinary” flood flows.
- Because urbanization affects flood flows significantly, urbanization can have strongly negative impacts on the morphology and ecology of these systems.

Geomorphology and Sediment Transport

- Types of Sediment Transport
  - Suspended Load: Sediment is well-mixed throughout the water column
  - Bed Load: Sediment hops or rolls along the bed
- Sediment Origin
  - Mass wasting (landslides, etc.)
  - Surface erosion
  - Bank erosion

Channel Cross-Sectional Geometry

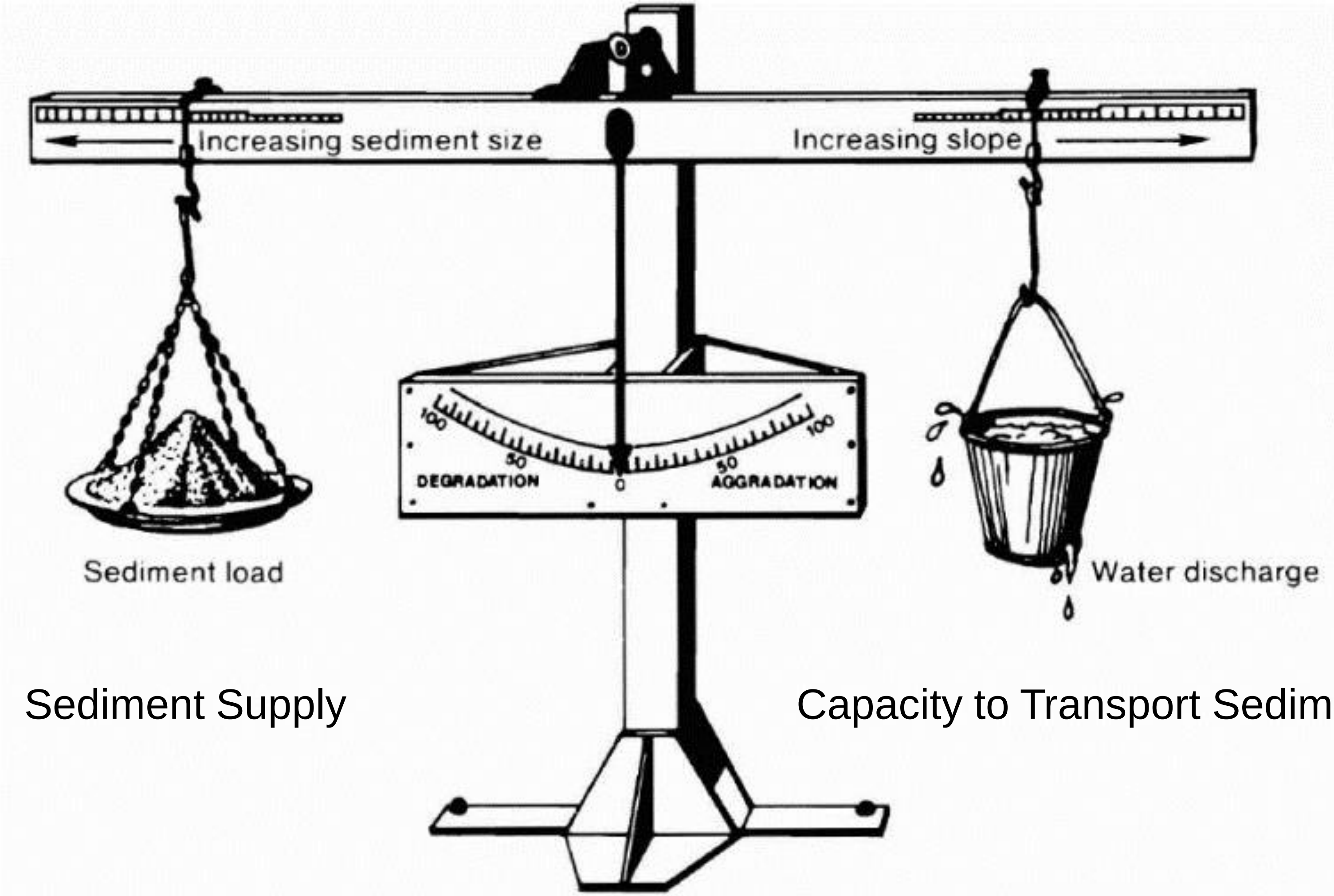
Rivers tend to adjust their slope, grain-size, or cross-sections until they are capable of transporting their sediment given their flood regime.



(a)

Modes of Adjustment

Load X Grainsize ~ Discharge X Slope

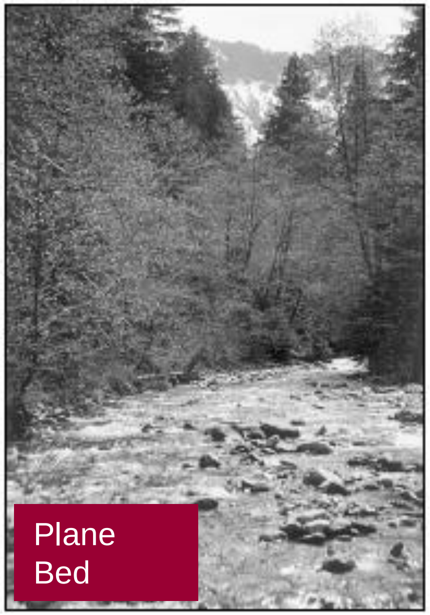


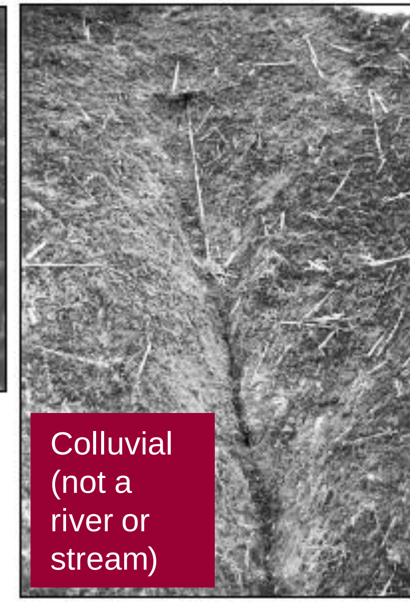
Sediment Supply

Capacity to Transport Sediment

Borland (1960) illustration of Lane's 1955 balance

Profile Types



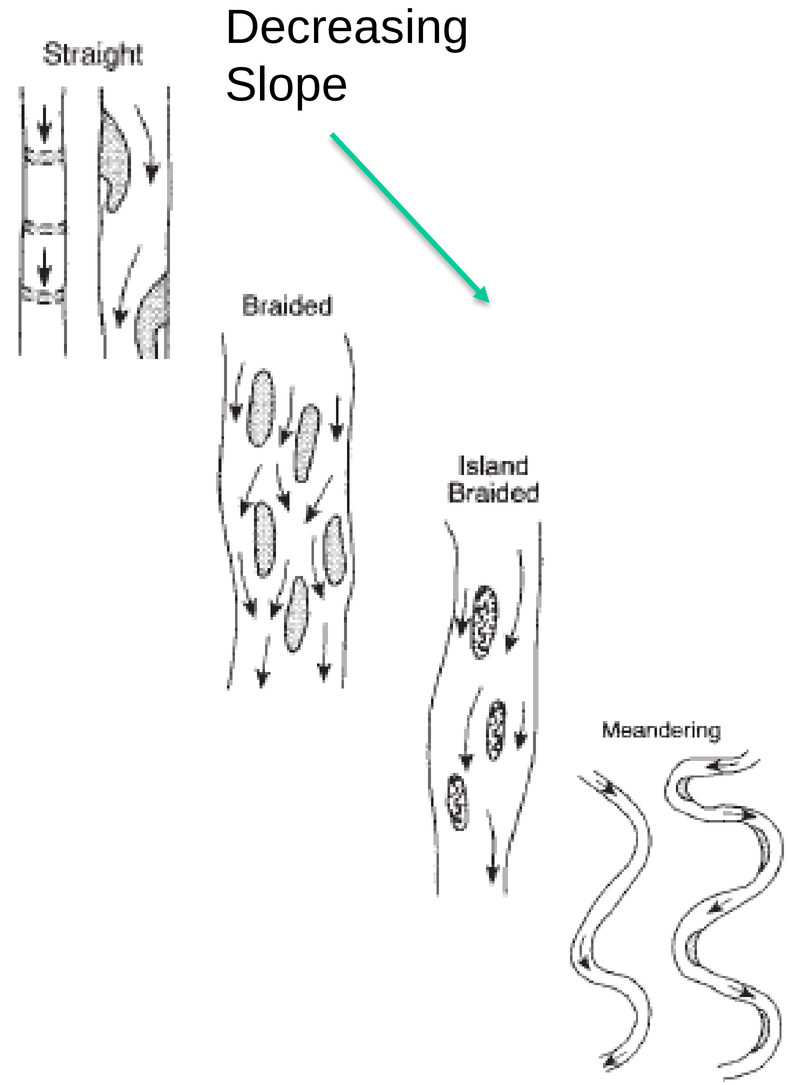


Decreasing
Slope

From Montgomery and
Buffington (1997)

River Planform Types

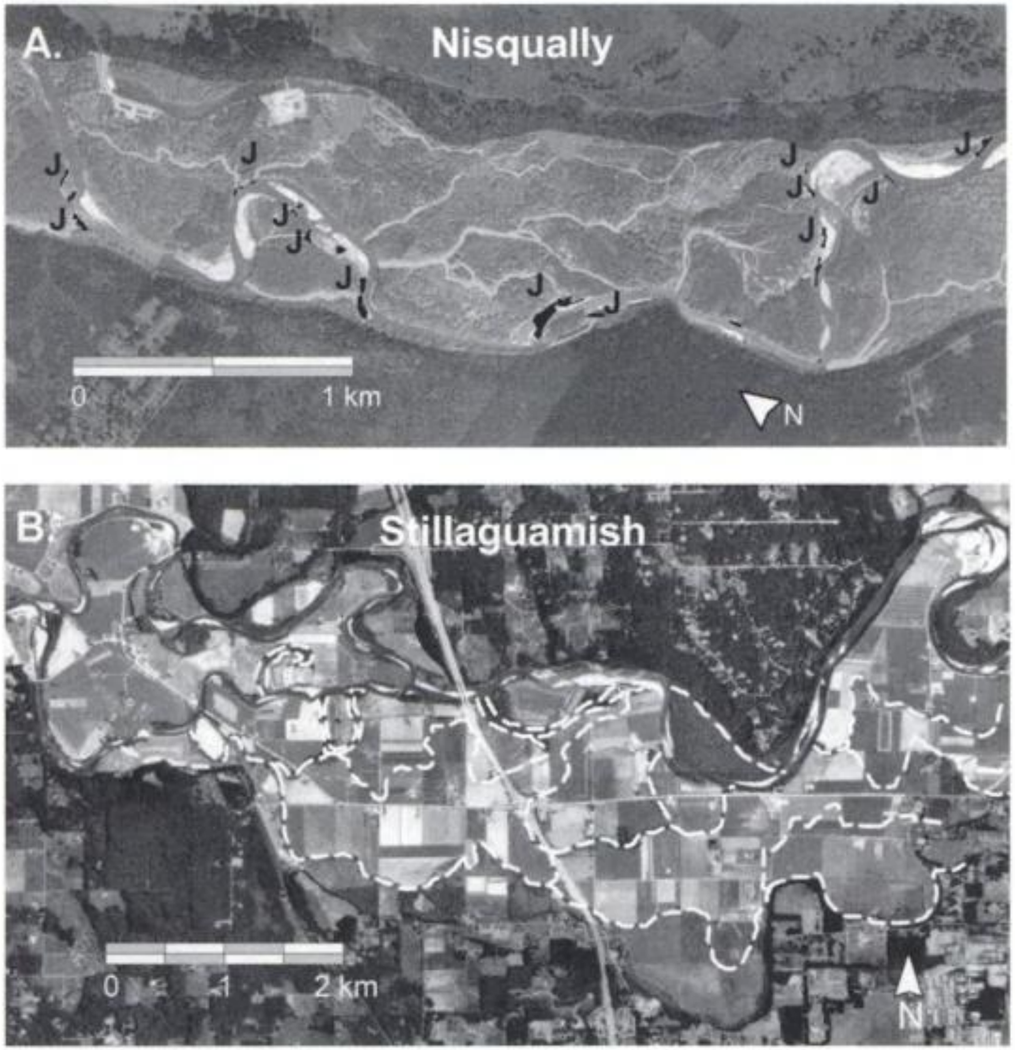
- **Straight**: No obvious curvature—but often occurs where bedrock controls valley walls
- **Braided**: Many converging/diverging channels or flow paths
- **Island Braided (a.k.a. Wandering or Anastamosing)**: Braided, but with permanently vegetated islands
- **Meandering**: Sinuous single channel



From Schumm, 1985

Typical Historic Change in Planform, Puget Sound

- ► Many lowland Puget Sound naturally included multiple channels
- ► May have been maintained by wood in channel (log jams)
- ► Side channels were populated by Beaver
- ► Channelization has simplified most large rivers in Washington

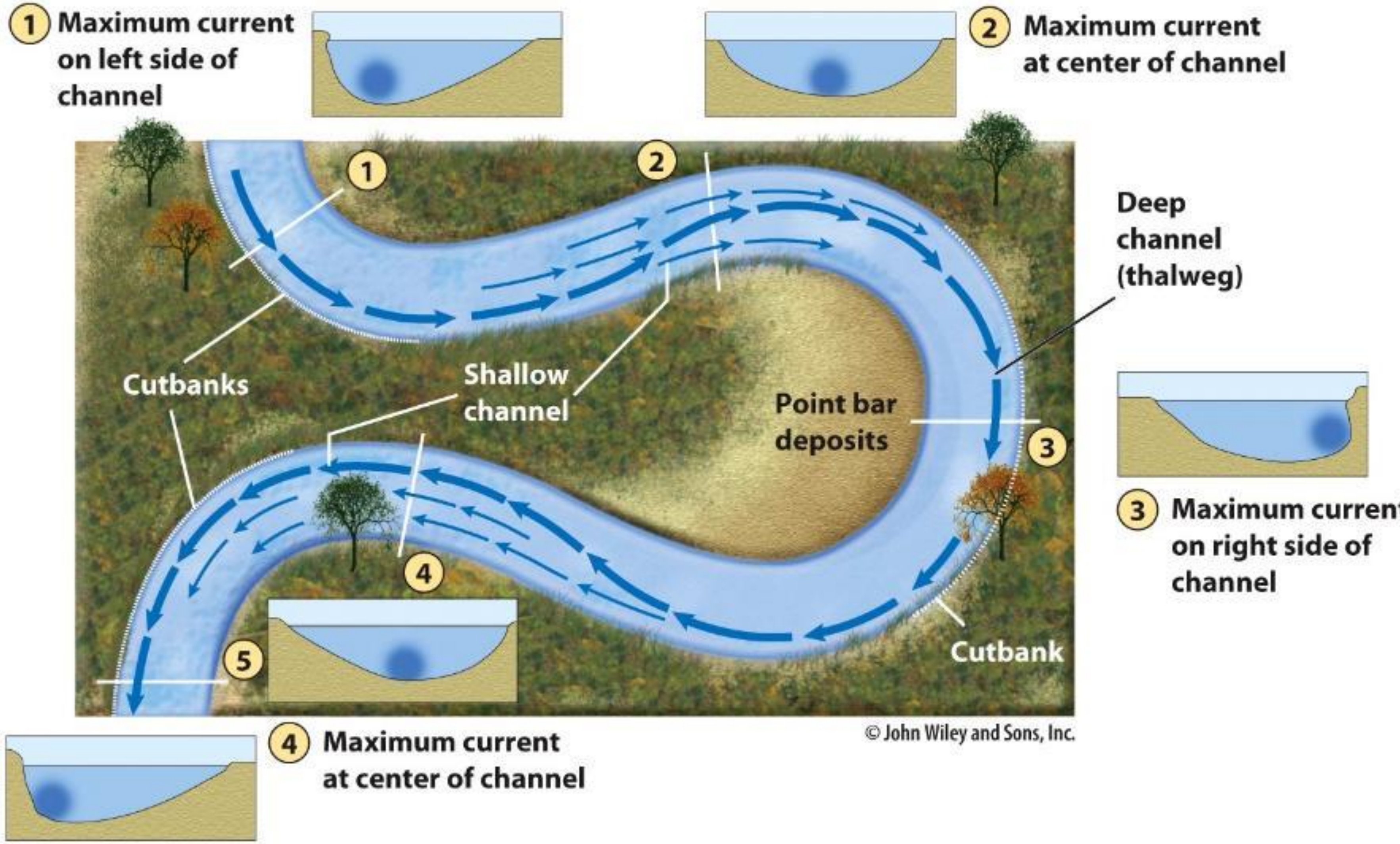


From Collins, Montgomery, and Sheik, 2003

Take-away points from morphology

- Rivers in the Northwest typically had complex valley and profile morphologies and could be:
  - Braided
  - Meandering
  - Anabranching or “Wandering”
- River profiles vary characteristically with slope, with various processes setting the position of pools, bends, etc.

Planform Change through Bend Migration

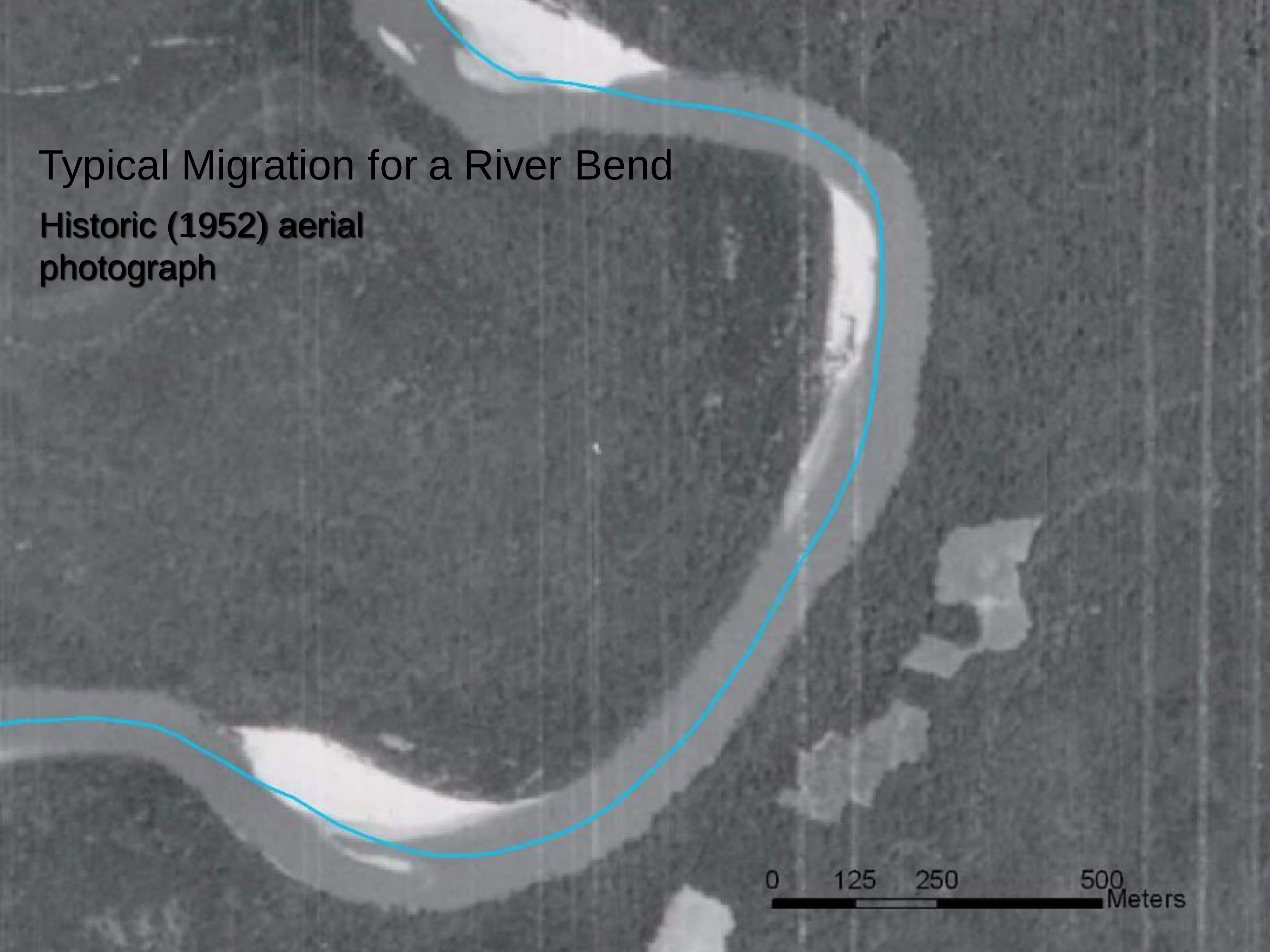


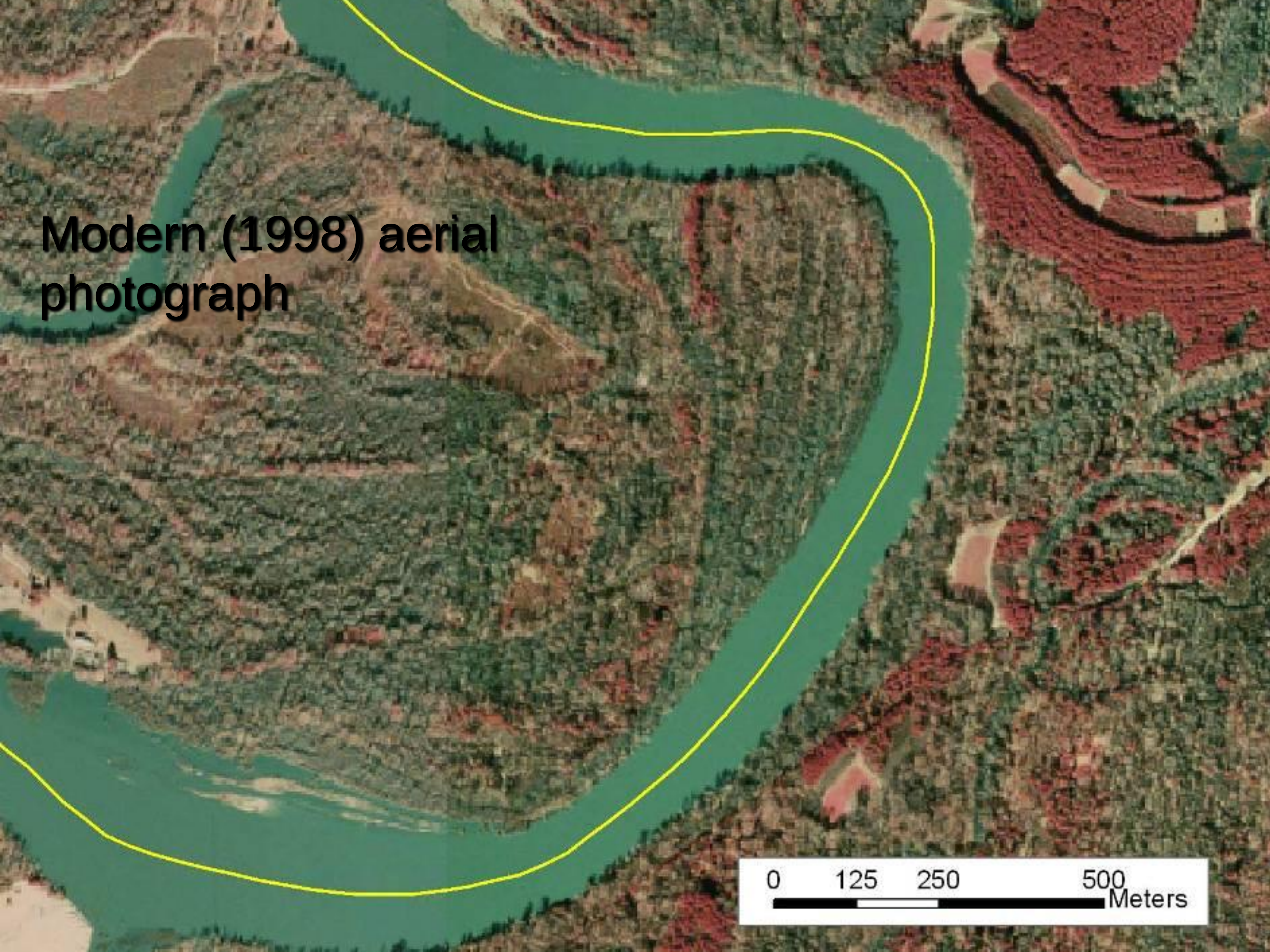
From Arbogast, 2014, *Discovering Physical Geography*

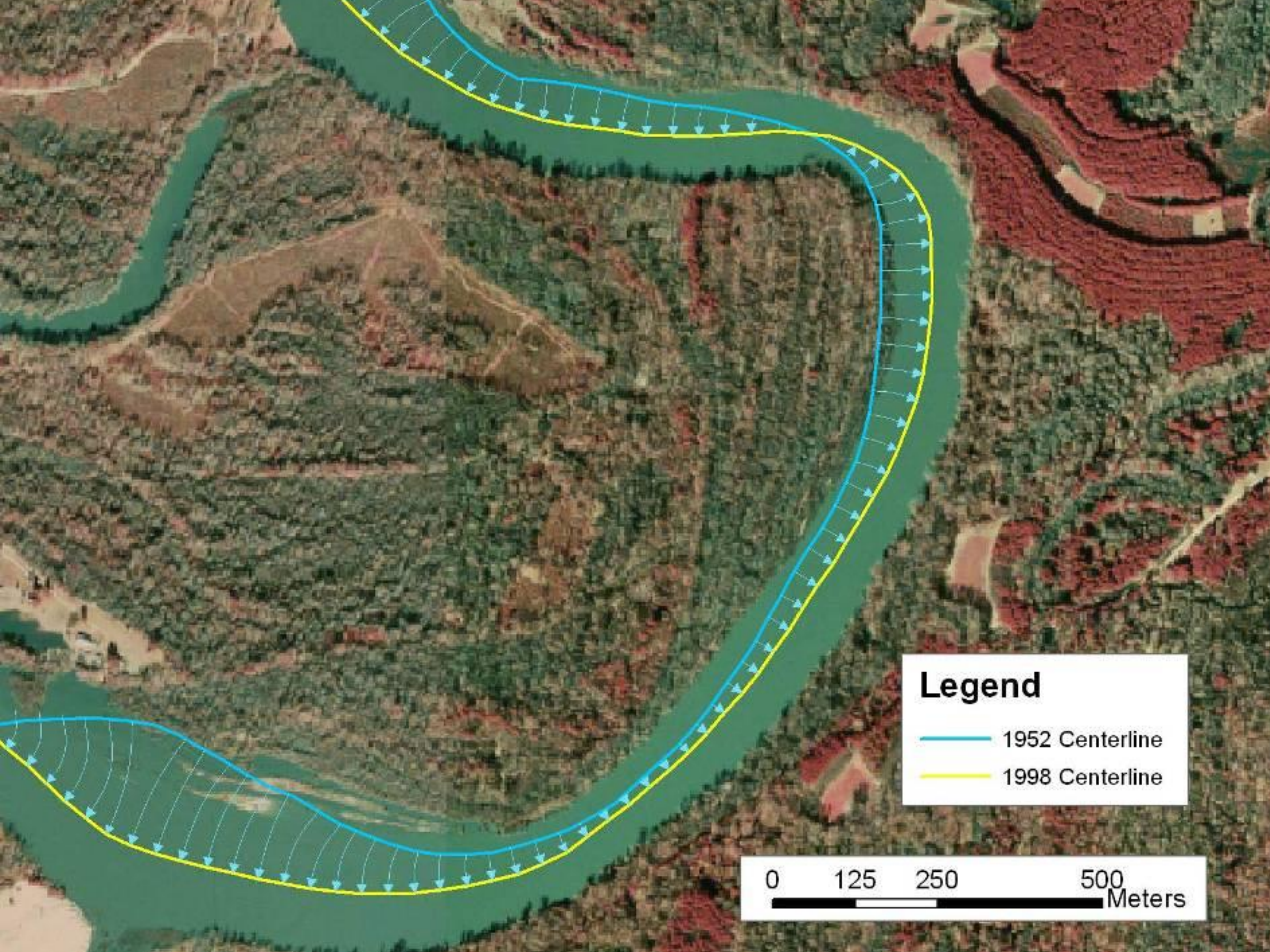
Strickland River, Papua New Guinea

Typical Migration for a River Bend

Historic (1952) aerial photograph

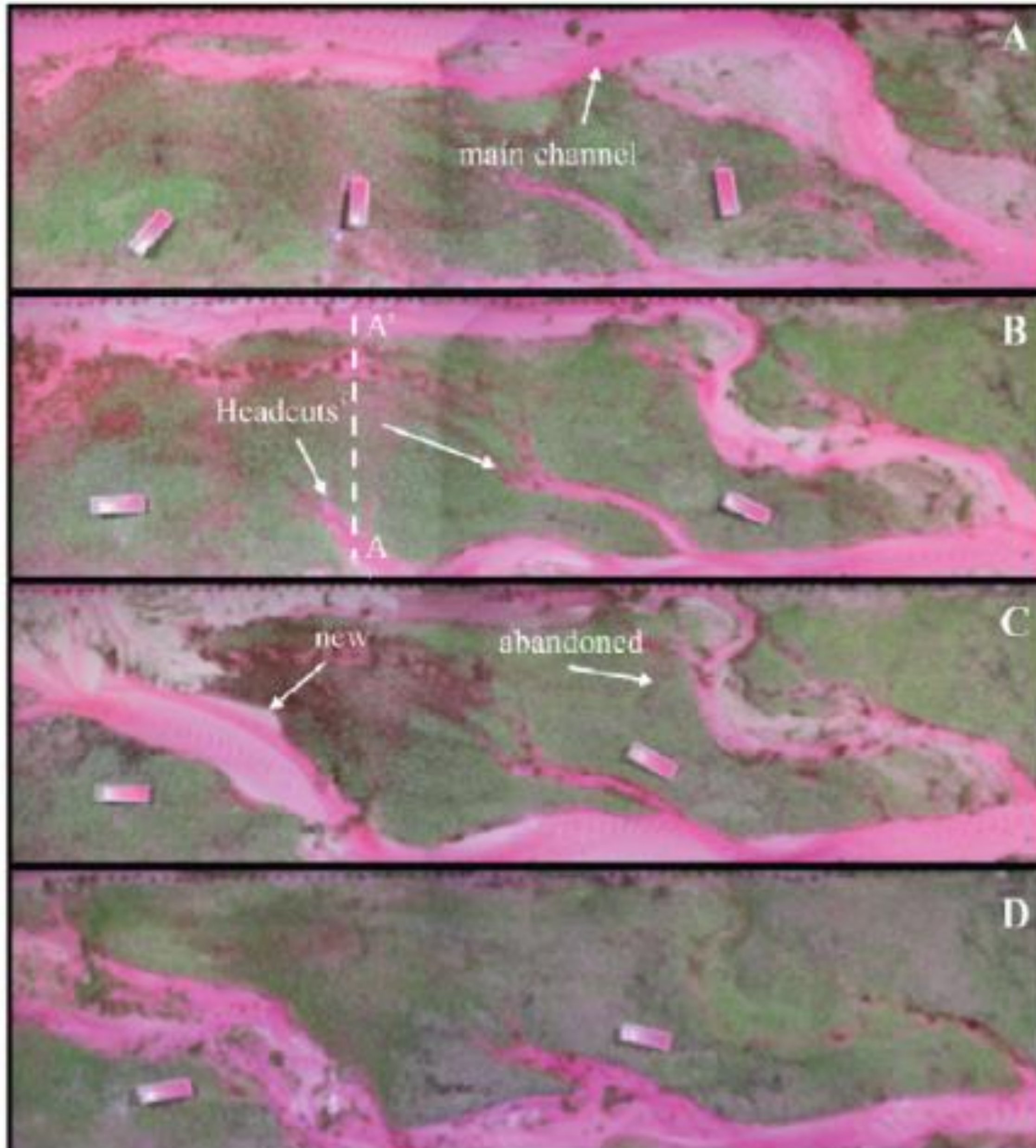



Modern (1998) aerial photograph
0
125
250
500
Meters


Legend
1952 Centerline
1998 Centerline
0 125 250 500
Meters

Avulsion: Large-scale redirection of flow into new course

These photos show how a river (in a laboratory) can change course



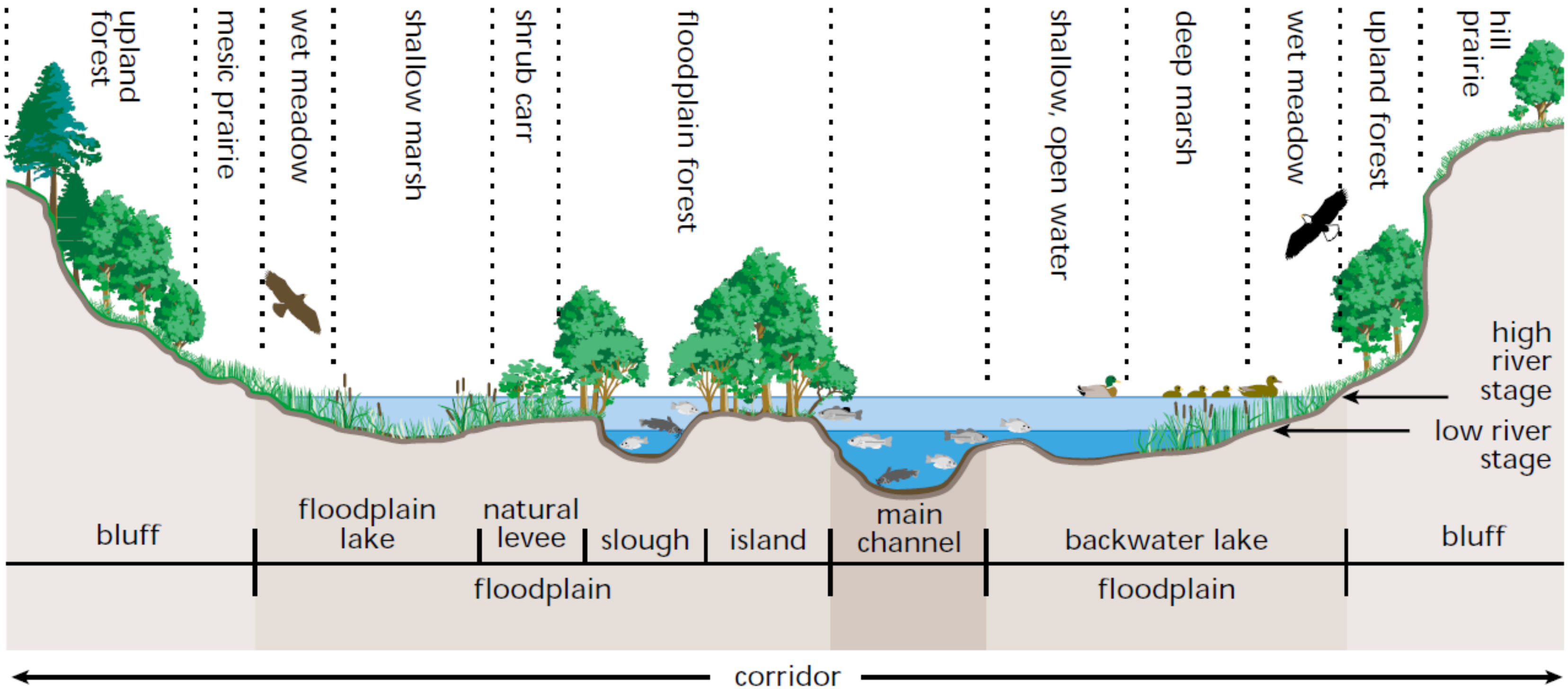
Exercise (Time Permitting)

- Visit https://earthengine.google.com/timelapse/, and pan/zoom around until you can find an example of geomorphic change on a river.
- Be prepared to share your screen when you find a good one, and comment on whether the river is meandering, braided, or island-braided.

- If you want to start in Washington, use this link (I'll share over Zoom): https://earthengine.google.com/timelapse#v=48.30092,-122.72574,6.995,latLng&t=2.9&ps=50&bt=19840101&et=20181231&startDwell=0&endDwell=0

Typical River Valley Cross Section

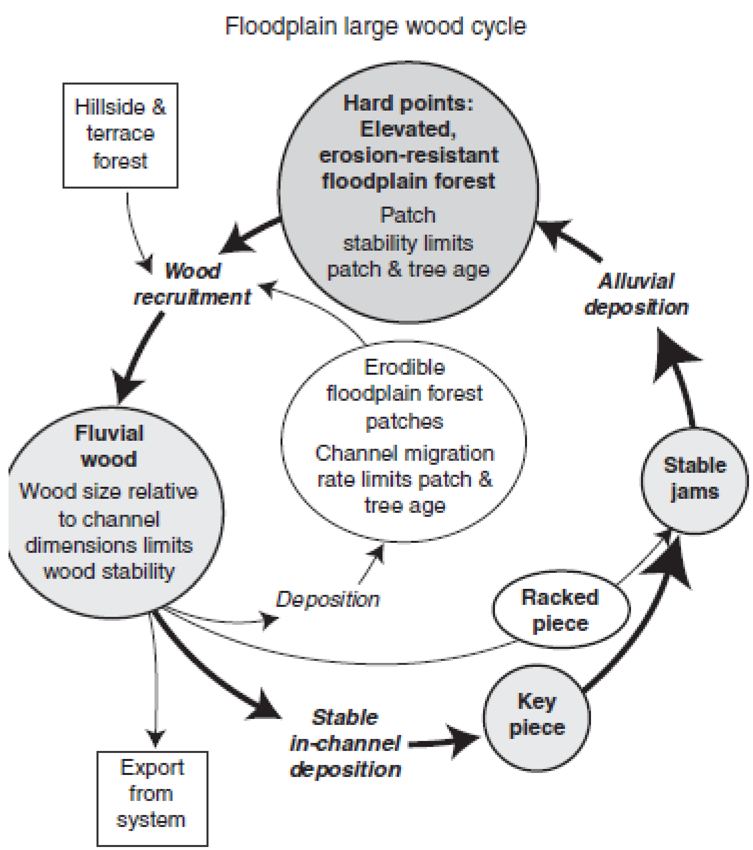
Notice that the complexity here is probably a function of active geomorphic process. Most river restoration focuses on these processes.



From Federal Interagency Stream Restoration Working Group, 2001, Stream Corridor Restoration: Principles, Processes, and Practices

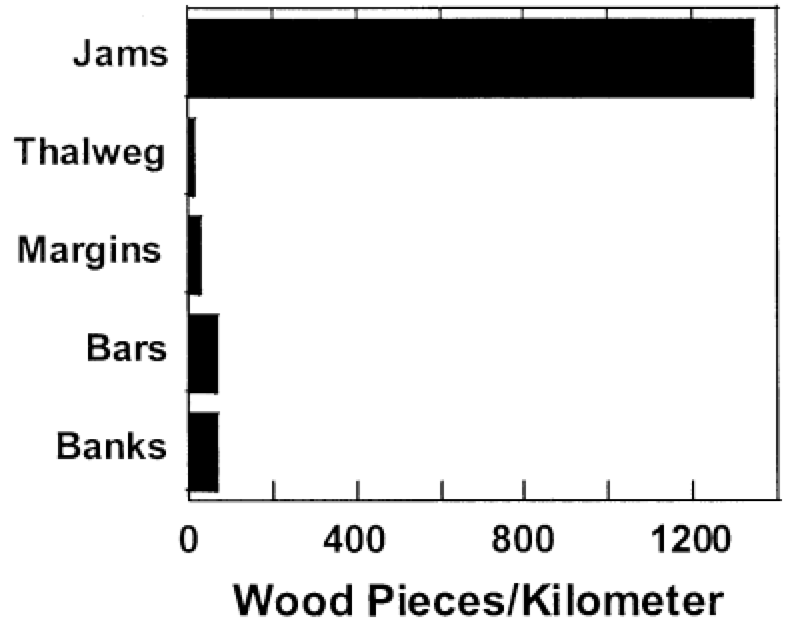
Role of Wood: Creates stable points, and redirects flow/sediment

Basic Point of Hypothesis: Large wood lasts a very long time, pushes system toward anabranching or wandering state because of stability caused by large "key" pieces.



Most wood is/was in the form of logjams

General Land Office Plat Map of Skagit River near Mt. Vernon, ca. 1905. Note depiction of log jams spanning channel.



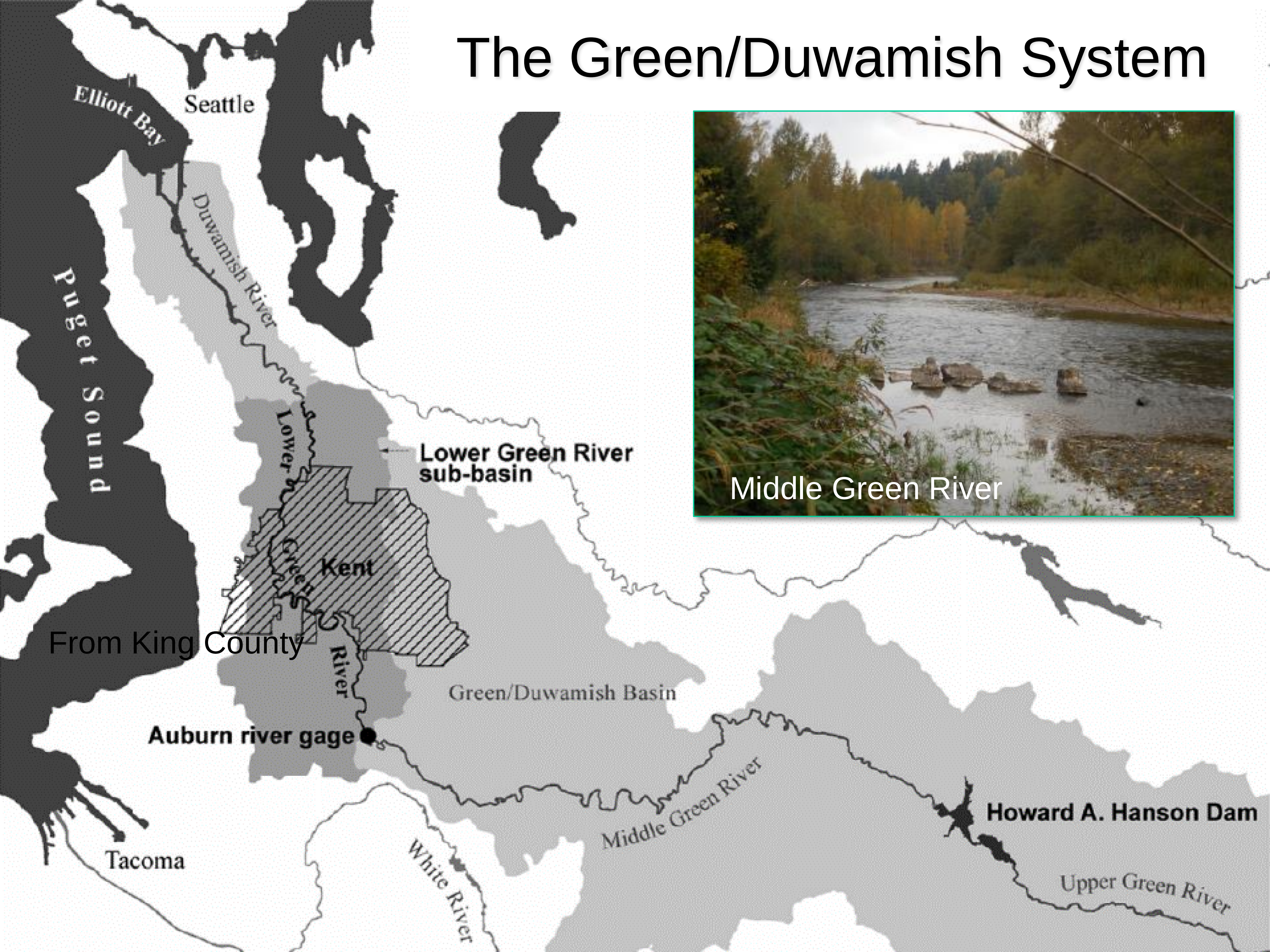
Nisqually River, Collins and Montgomery, 2002, *Restoration Ecology* 10

Take-away points about geomorphic change

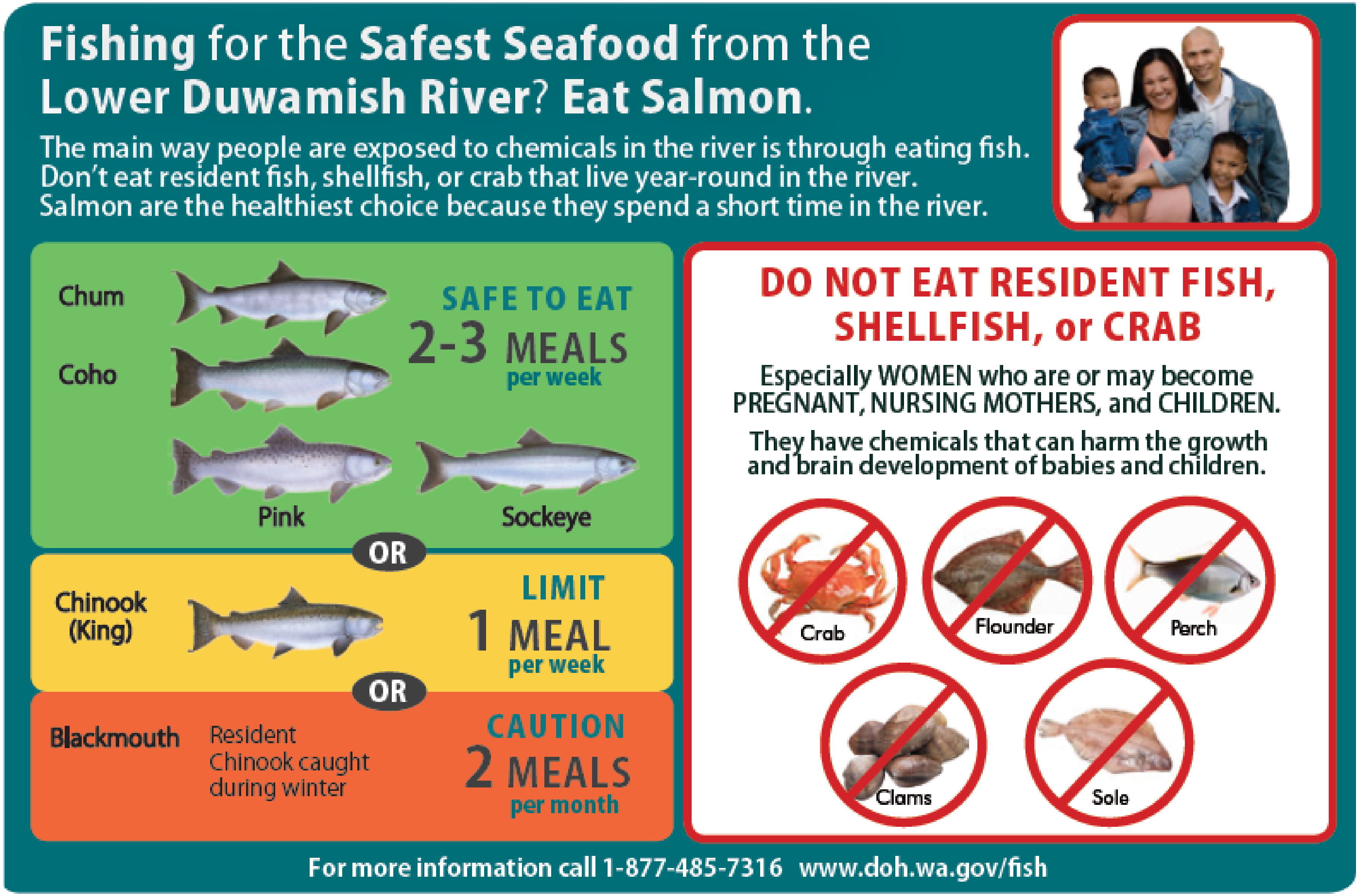
- Rivers tend to be braided (and active) where sediment loads are high
- Lowland Puget Sound rivers in glacially-carved valleys naturally migrated through progressive bend migration, leaving complex off-channel water bodies across the meander belt
- Large wood played (and plays) an important role stabilizing parts of Puget Sound systems and creating local variability
  - Tends to push “braided” or “meandering” rivers toward “Anabranching”

Human Impacts (time permitting)

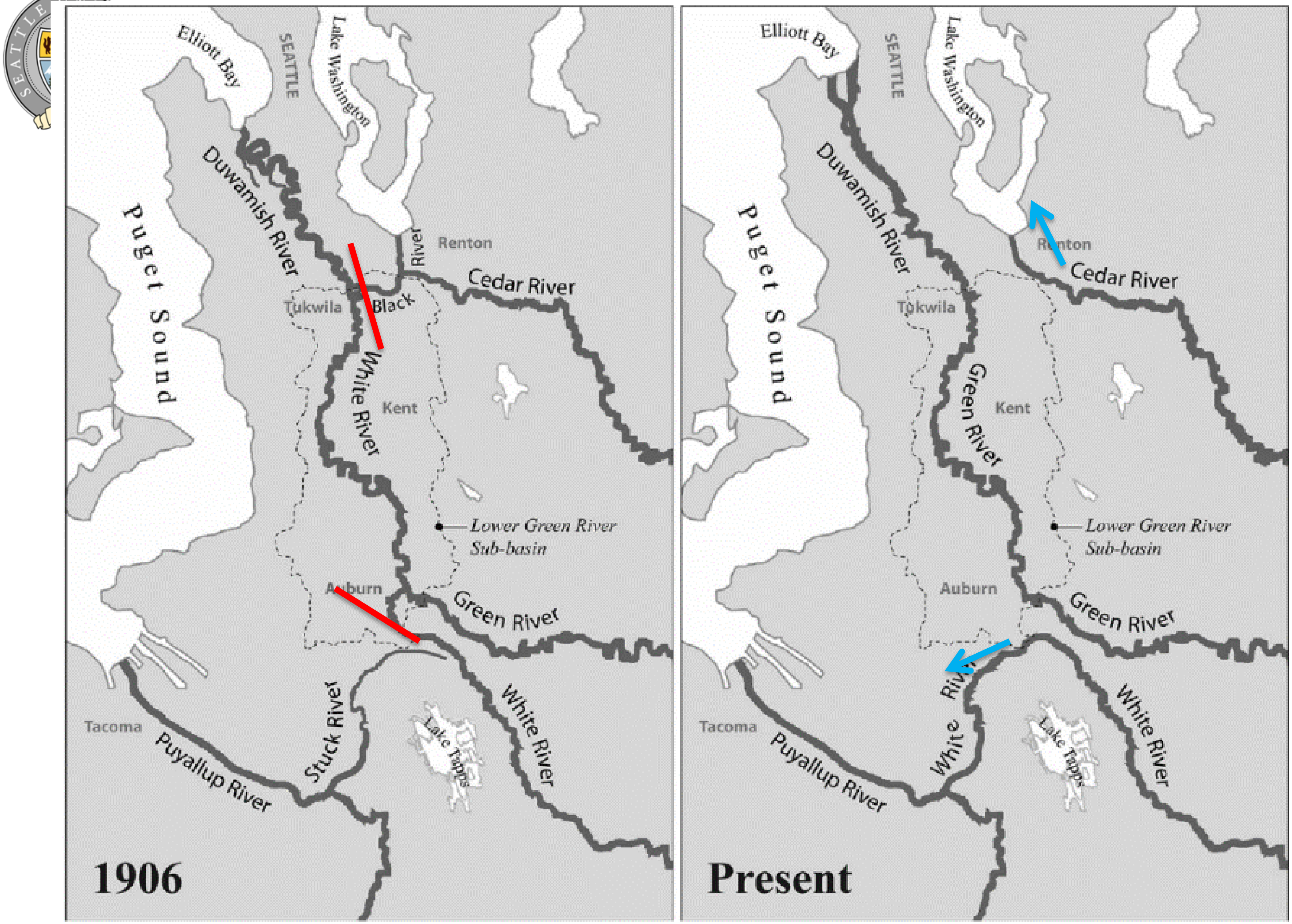
The Green/Duwamish System



From King County


Fishing for the Safest Seafood from the Lower Duwamish River? Eat Salmon.
The main way people are exposed to chemicals in the river is through eating fish.
Don't eat resident fish, shellfish, or crab that live year-round in the river.
Salmon are the healthiest choice because they spend a short time in the river.
Chum
Coho
Pink
Sockeye
SAFE TO EAT
2-3 MEALS
per week
OR
Chinook (King)
LIMIT
1 MEAL
per week
OR
Blackmouth
Resident Chinook caught during winter
CAUTION
2 MEALS
per month
DO NOT EAT RESIDENT FISH, SHELLFISH, or CRAB
Especially WOMEN who are or may become PREGNANT, NURSING MOTHERS, and CHILDREN.
They have chemicals that can harm the growth and brain development of babies and children.
Crab
Flounder
Perch
Clams
Sole
For more information call 1-877-485-7316 www.doh.wa.gov/fish

US EPA



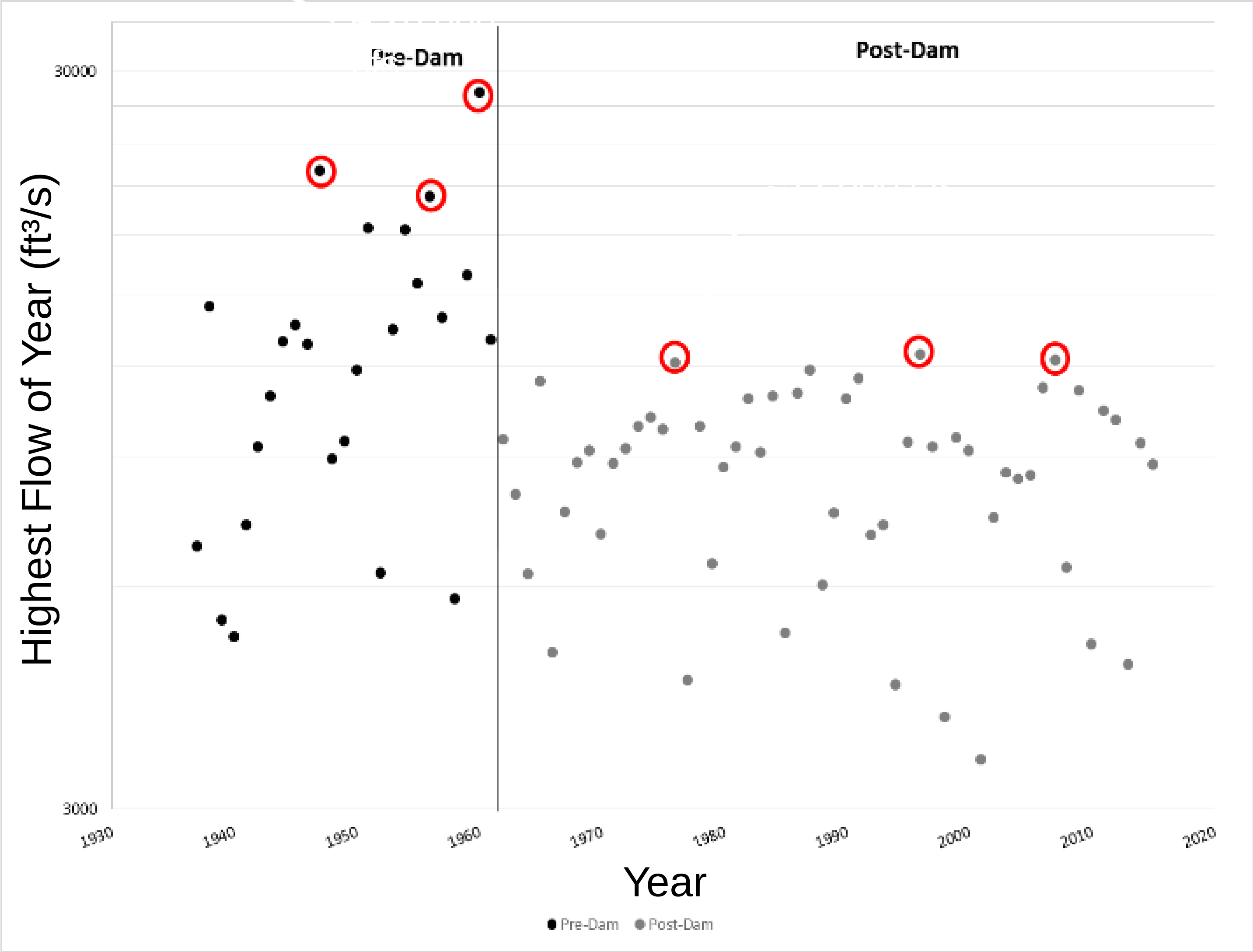
From Liao, 2014, Natural Hazards

Flood Management

From US Army Corps of Engineers

Every Puget Sound lowland river is HIGHLY modified in the lowermost reaches. The modifications have severely limited natural channel migration and riparian vegetation.

Impact of Howard Hanson Dam



Take-away points about human impacts

- Important impacts for large rivers
  - Reduction in width of alluvial corridor by channelization/levees
  - Dams
  - Removal of large wood and loss of riparian forest
  - Climate change

- Important impacts for smaller streams
  - Urbanization increases stormflow and causes pollution
  - Disruption of connectivity (e.g. culverts)
  - Loss of wood
  - Climate change

References

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- Liao, 2014, From flood control to flood adaptation: a case study on the Lower Green River Valley and the City of Kent in King County, Washington. Natural Hazards 71, 723-750.
- Montgomery, D.B., Buffington, J.M. 1997. Channel-reach morphology in mountain drainage basins. GSA Bulletin 109, 596-611.
- Mackin, J.H., 1941, Glacial Geology of the Snoqualmie-Cedar Area, Washington. *J. Geology* 49: 449-481.
- Porter, S.C., and Swanson, T.W., 1998, Radiocarbon age constraints on rates of advance and retreat of the Puget Lobe of the Cordilleran Ice Sheet during the last glaciation. *Quaternary Research* 50, 205–213.
- Schumm, S.A., 1985, Patterns of Alluvial Rivers. *Annual Review of Earth and Planetary Sciences* 13-5-27.

Additional Reading Recommendations

- Salish Sea Wiki: https://salishsearestoration.org/wiki/Welcome_to_Salish_Sea_Restoration. This is a clearing house for many of the concepts in this course. I suspect all students will be interested—my talk most closely covered the “floodplain” and “lowland watershed” parts of the system, so students interested my material might start there.

- Booth, D., Troost, K., Clague, J.J., Waitt, R.B., 2003, “The cordilleran ice sheet.” Developments in Quaternary Science 1, 17-43. Available at http://s46986.gridserver.com/resources/2004boothetal_Cordilleran.pdf: This provides a comprehensive scientific assessment of Puget Lowland glaciation and the Missoula Floods.

- Unfortunately, the Booth et al. reference above is a bit dense. I am not familiar with single book that focuses just on Puget Sound glaciation, but there is a section in Arthur Kruckeberg’s 1995 book The Natural History of Puget Sound Country (http://www.washington.edu/uwpress/search/books/KRUNAT.html) that should provide a good overview. We have learned a few things about the glacial history of the region since 1995, but I think the general story has been understood for a long time.

- For a general overview of the importance of rivers for salmon habitat, a great place to start is
- Montgomery, D., 2004, King of Fish: The Thousand-Year Run of Salmon. It’s available online and at most local bookstores.

- For an overview of Duwamish River issues, I recommend the essays in the very accessible coffee-table book by Reese, T., 2016, Once and Future River: Reclaiming the Duwamish. It is available at http://www.washington.edu/uwpress/search/books/REEDEA.html and at local bookstores.