Valley-scale Landscape Structure as a Component of Hydrologic Response

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Null Hypothesis: *underlying landscape structure is not a significant element in characterizing the hydrologic regime of mountain watersheds*

Valley-scale Landscape Structure as a Component of Hydrologic Response

- Context
- What are we looking for and how is it useful?
- What is surprising about this research?
- Research design
- Preliminary results
- Conclusion

Context: A simplified look at how this research intersects with hydrological science in scale and focus

- **Large-scale streamflow hydrology-climate models - climate forcing:** water supply, prediction

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- **Valley scale characterization - run-off and storage mechanisms produced by coupled hillslope, fluvial and glacial processes:** 1 km^2 to 40 km^2 sub-basins – stream management for the sustainability of biotic ecosystems

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- **Plot-scale:** ~1 m^2 to 50m^2 – experimental research to trace actual surface/groundwater flowpaths – basis of hydrological science

Context: Relationship between spatial scale, geomorphological influence and biological attributes

Spatial Scale	Climate, Topography, Geology	Biological Attributes
Regional/ Physiographic Province	Climate, Topography, Geology	Community Type
Valley Segment/ Channel Reach	***Routing of Sediment, Water and Organic Matter Disturbance Regimes***	***Community Composition/ Species Abundance***
Channel Unit or Patch	Local Factors/ Disturbance History	Habitat Use by Individuals

Montgomery, 1999

Differences in groundwater storage

What are we looking for and how is it useful?

Understanding streamflow ***patterns*** *fundamental to successful monitoring of aquatic biota in undisturbed ecosystems*

- Range of variability important for evolutionary potential of aquatic ecosystems.
- The *natural flow regime* of a functioning aquatic ecosystem is characterized by the seasonal timing and patterning of flows.
- Data from undisturbed sites allow managers to maintain or restore the range of natural flow variability.
- Various recent articles define stream type by snow, rain-on-snow, etc. Given the variability of such events in one sub-basin over time, structure might be more useful to characterize stream type.

What is surprising about this research?

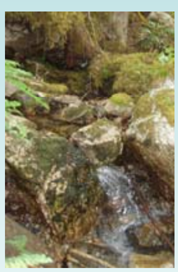
- Many people believe that headwater streamflow patterns are homogenous when they have similar climate, bedrock type and hardness, topographical range, drainage area, soils and vegetation.
- Research suggests that adjoining sub-basins with similar characteristics can produce very different patterns in their hydrologic response.

Research Design

What are some different patterns of hydrologic response and how did we find them?

Experimental Organization

All 8 NOCA sites have similar climate, bedrock type and hardness, slope, topographical range, drainage area and proximity.
Groupings according to scale and presence or absence of glaciers



4th of July	**Devil's Club**	**#6**

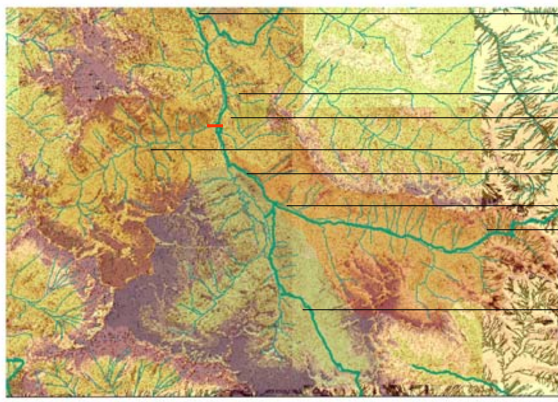
Mean slope range: 10-15%
Drainage area: 22-32 mi2
Topographical range: 8000' – 2000'
Bedrock: Skagit gneiss

Fisher Creek	**MacAllister Creek**	**Thunder Creek**

Mean slope range: 43-45%
Drainage area: .8-.9 mi2
Topographical range: 6000' – 1400'
Bedrock: Skagit gneiss

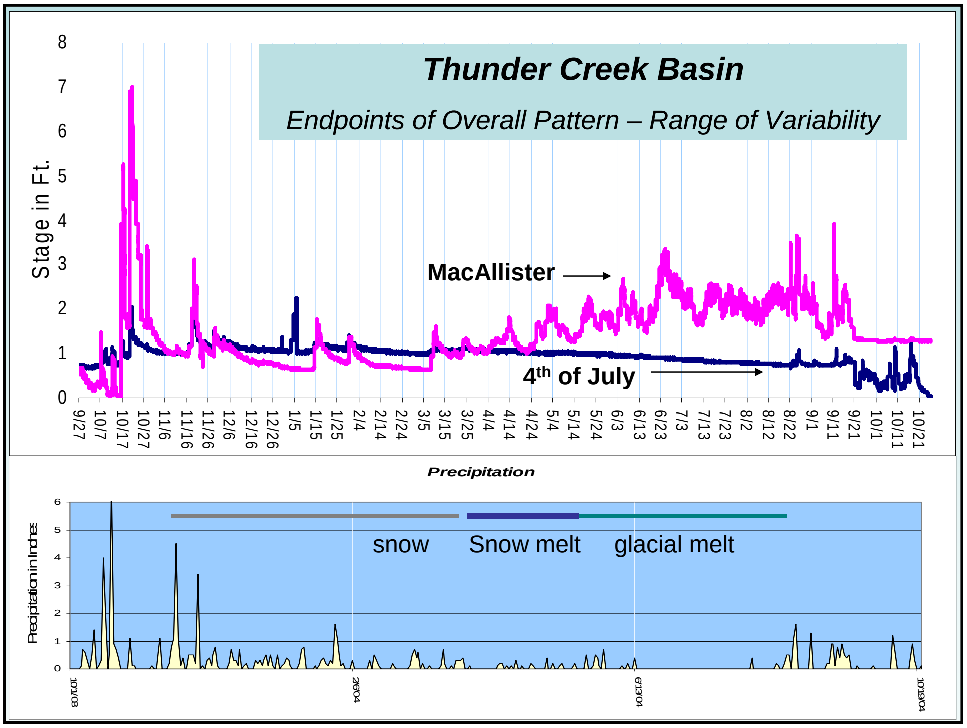
Where is the research located?

North Cascades National Park
Thunder Creek Basin Stream Gage Sites



Sites Grouped by Potential Storage Mechanisms and Dominant Processes

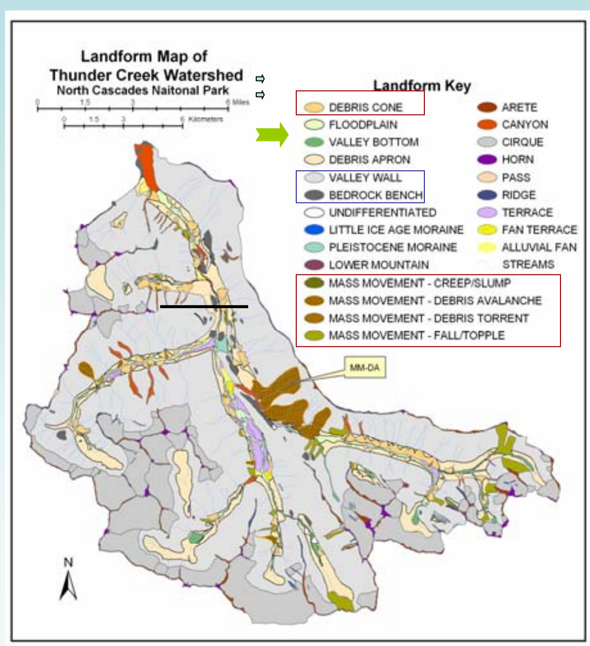
Stream/ subwatershed	***Dominate processes***	***Hydrogeological flow regimes***	***Valley scale classification***	***Storage type***
Fisher Creek	Glacial Debris flow Fluvial	Snow Rain and snow Stable groundwater Runoff	Glacial valley	Mass movement debris
MacAllister Creek	Glacial Debris flow Fluvial	Snow Rain and snow Stable groundwater Runoff	Glacial valley	Glacial fill
Thunder Creek	Glacial Debris flow Fluvial	Snow Rain and snow Stable groundwater Runoff	Glacial valley	Wetland
4th of July	Colluvial Debris flow	Stable groundwater Rain on snow Rain	Colluvial	Mass movement debris
Devils Club	Colluvial Debris flow	Intermittent Stable groundwater Rain on snow Rain	Colluvial	Mass movement debris
#6	Bedrock	Runoff Rain on snow Rain	Bedrock	



Types of Processes and Landforms Found in the Thunder Basin

Fluvial Valley

Glacial Valleys



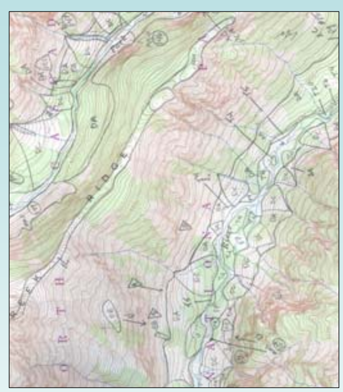
Thunder Creek Landform Areas

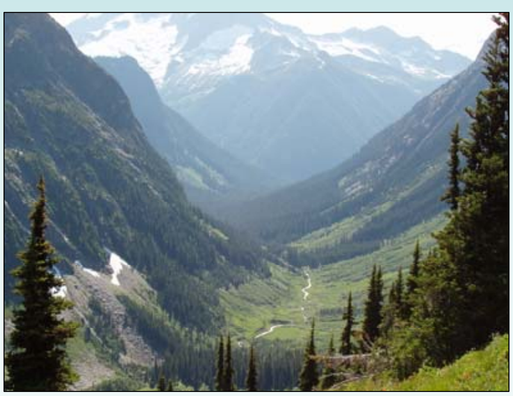
Landform Type	Area	%
Valley Wall	165	55
Cirque	57	19
Debris Apron	28	9
Debris Cone	7.8	2.6
Debris Avalanche	6.3	5.6
Floodplain	5.6	1.8

Thunder Creek Landforms

Valley Wall (VW)

- Too steep to hold a significant amount of slope debris
- Largest single mapping unit in each watershed
- Lower elevation boundary is typically debris cone (break in slope)
- Heavily vegetated or exposed bedrock





Glacial melt is the dominant influence during the summer months

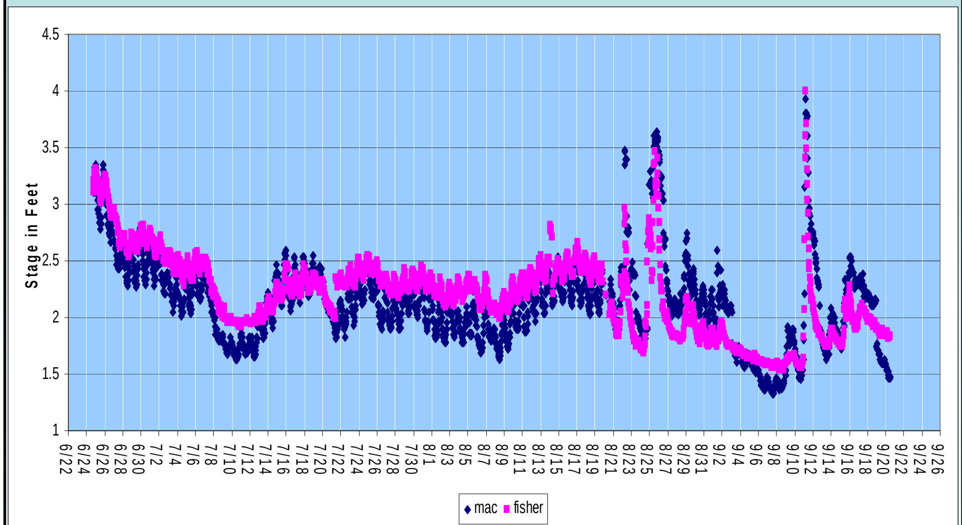
Klawatti Glacier,
Thunder Basin

Thunder Creek Landforms:
Alternating Canyon and Glacial Valley Morphology
Found within Sub-Basins

Upper Fisher

Upper MacAllister

Glacial-dominated Fisher – MacAllister Hydrological Pattern



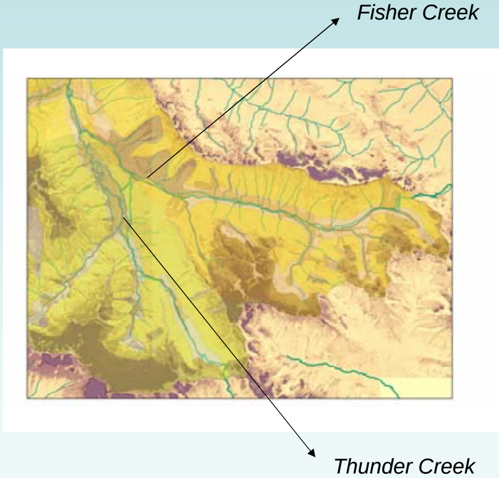
Fisher has smaller drainage and glacial contributing areas

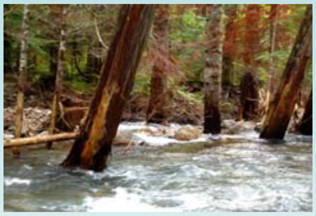
Thunder Creek Landforms

Debris Torrent (MM-DT)

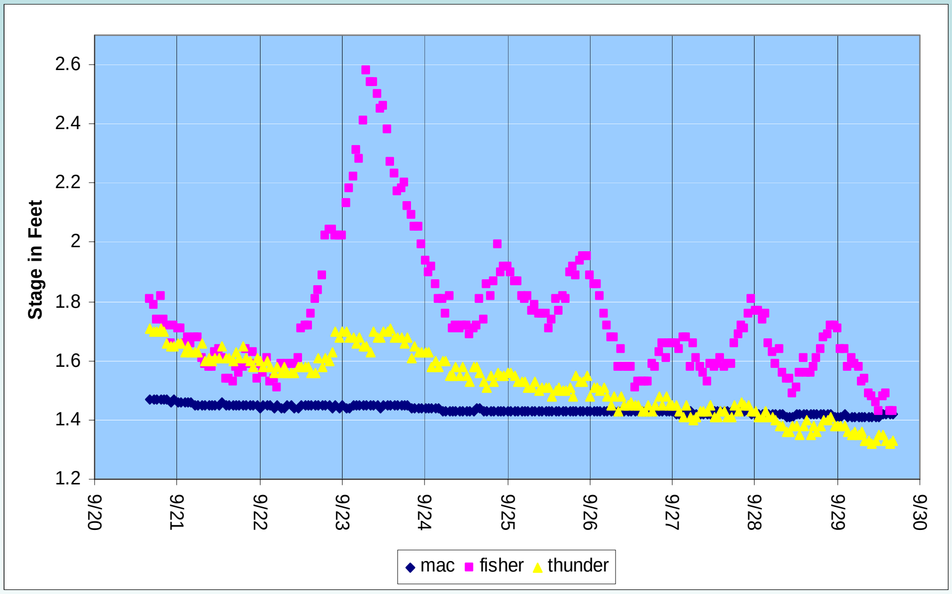
- Always within a DC, usually at the base of a river canyon, and has a fresh appearance
- Given a unique number and corresponds to the landslide inventory

Fisher and Thunder Basins – Patterns differ as a result of debris torrent activity and wetlands





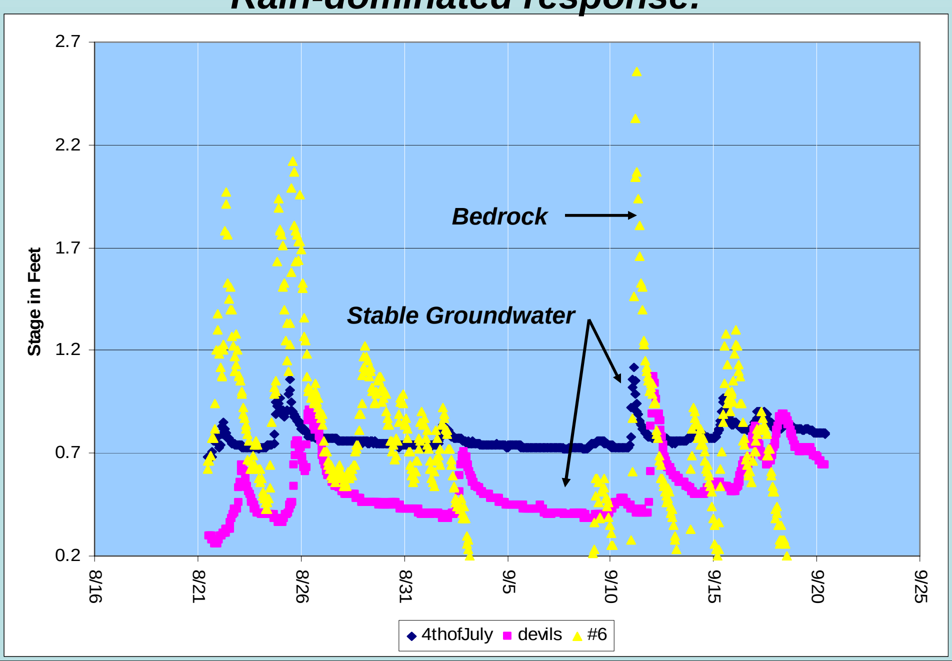
Post-glacial melt streamflow pattern



Thunder Creek Landforms

Debris Cone (DC)
- Usually covered by thick alder (young cones)
- Conical shape
- Well defined on topographic maps

Rain-dominated response:

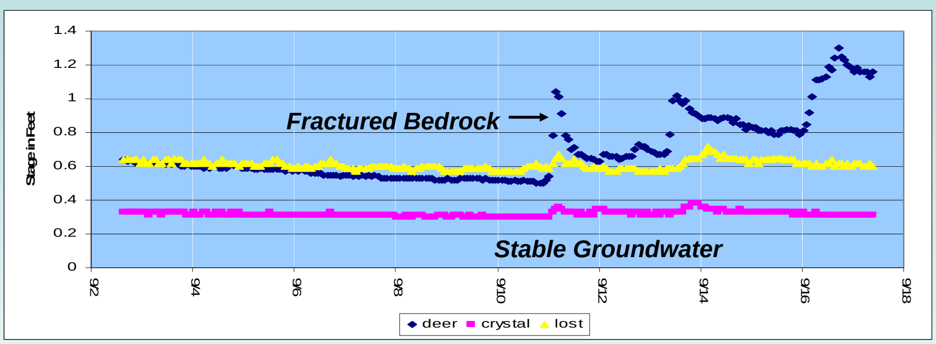


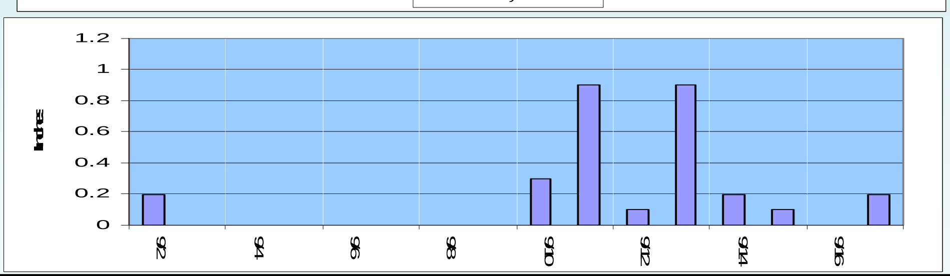
Mt. Rainier National Park Sites

Residence time, storage characteristics not complicated by glaciers

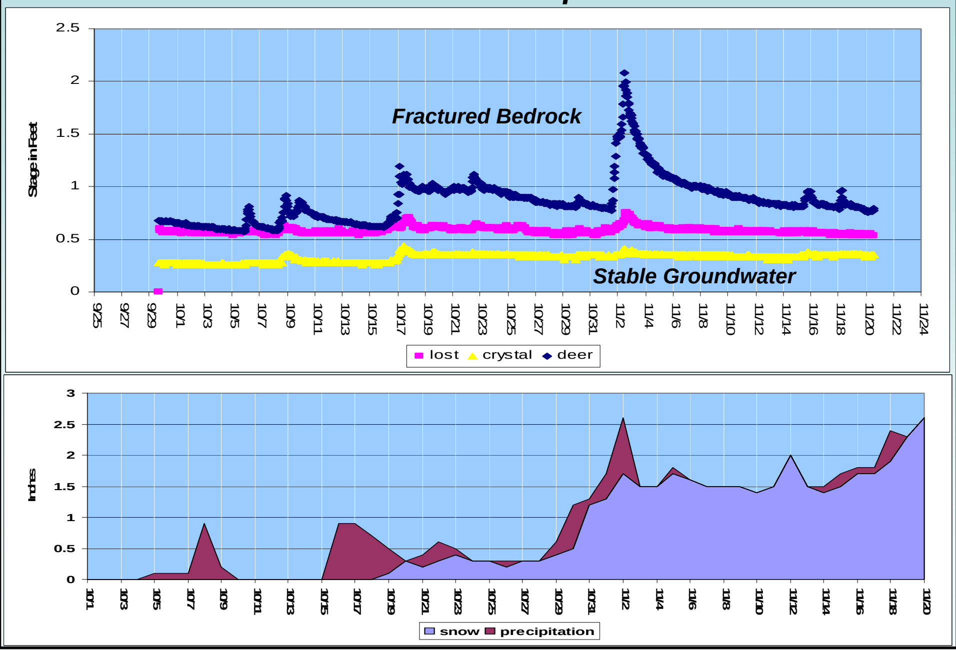
Stream/ subwatershed	*Drainage area*	*Mean slope*	*Analysis Methods*	*Dominate processes*	*Hydrogeological flow regimes*	*Valley scale classification*
Crystal	1.58	22%	Pressure Transducer Temperature ^{18}O Deuterium	Colluvial Debris flow	**Stable groundwater** Snow Rain on snow Rain	Colluvial
Lost	5.4	10%	Pressure Transducer Temperature ^{18}O Deuterium	Colluvial Debris flow	**Stable groundwater** Snow Rain on snow Rain	Colluvial
Deer	5.6	14%	Pressure Transducer Temperature ^{18}O Deuterium	Fractured bedrock	**Runoff – "Old" Water Displacement** Snow Rain on snow Rain	Bedrock
Laughingwater	5.5	9%	Pressure Transducer Temperature	Fractured bedrock	**Runoff– "Old" Water Displacement** Snow Rain on snow Rain	Bedrock

Rain-dominated response:



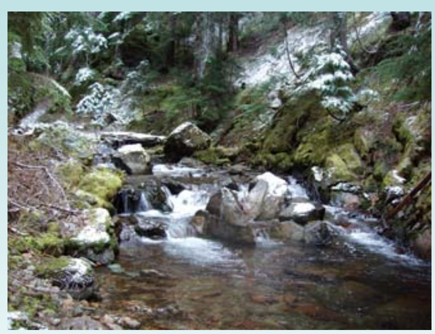


Rain-dominated response:



Preliminary Results

- Valley structure appears to be a determinant of streamflow pattern
- Residence time, groundwater storage are important in these systems
- If true, length of residence time should be evident in stable isotope signatures and temperature



How do the preliminary results apply to monitoring aquatic systems?

- If streamflow is not dominated by Hortonian overland flow, but is composed of varying ages of "old" water, the temperature and geochemical signature of these creeks will vary significantly. This is likely to affect the aquatic community found in the system.
- Hydrogeologic stream classification schemes that define stream type by snow, rain-on-snow, rain and groundwater-dominated systems will not produce meaningful stream indices in mountainous basins.

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