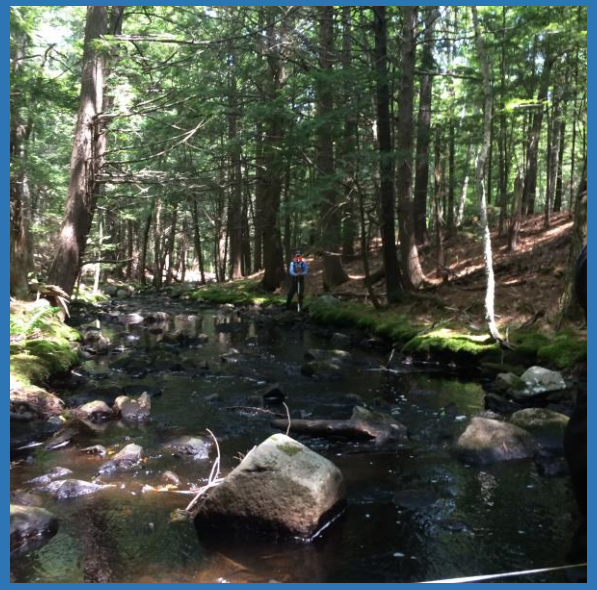
Stream Dynamics in Headwaters of Postglacial Watershed Systems

Brett Gerard and Sean Smith

March 29, 2018

Geomorphic Setting

Source: Colorado Plateau Geosystems

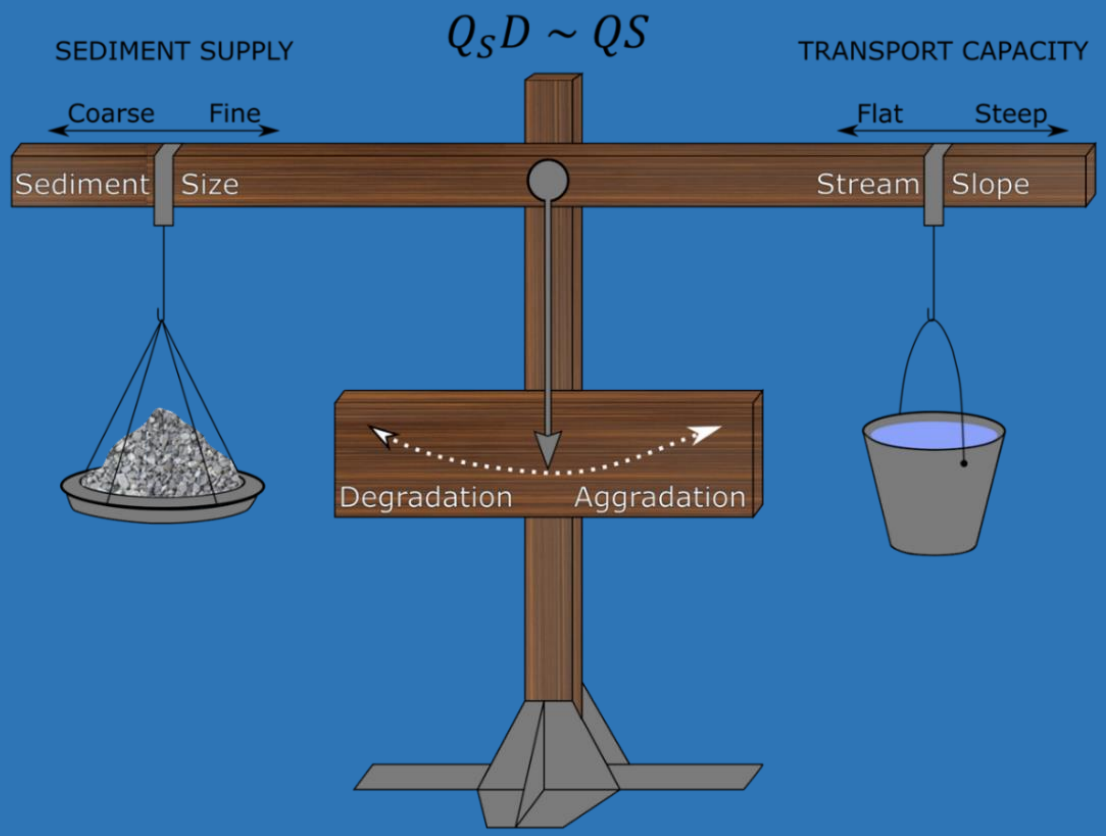
Human Intervention

OBJECTIVES

1. Examine and “describe” watershed conditions related to hydrologic processes.

2. Examine surface flow regimes under varied climate conditions.

3. Evaluate channel characteristics relative to watershed setting (and hydrology).



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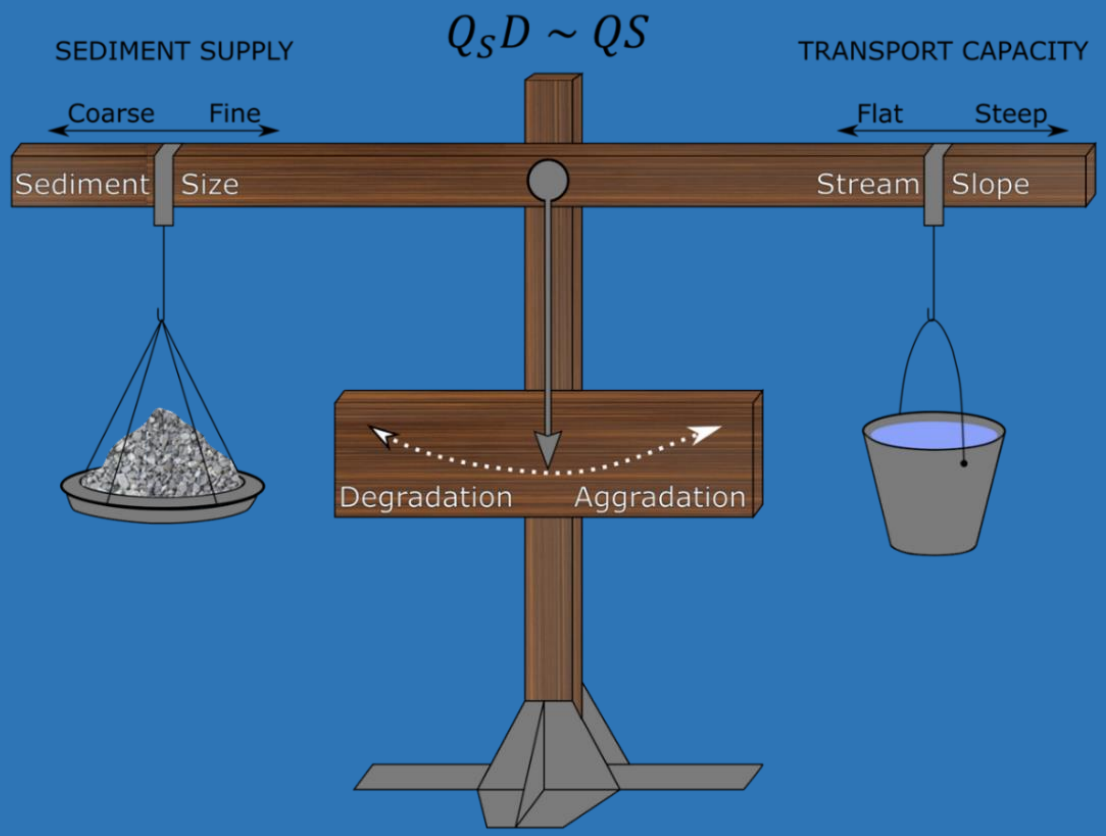
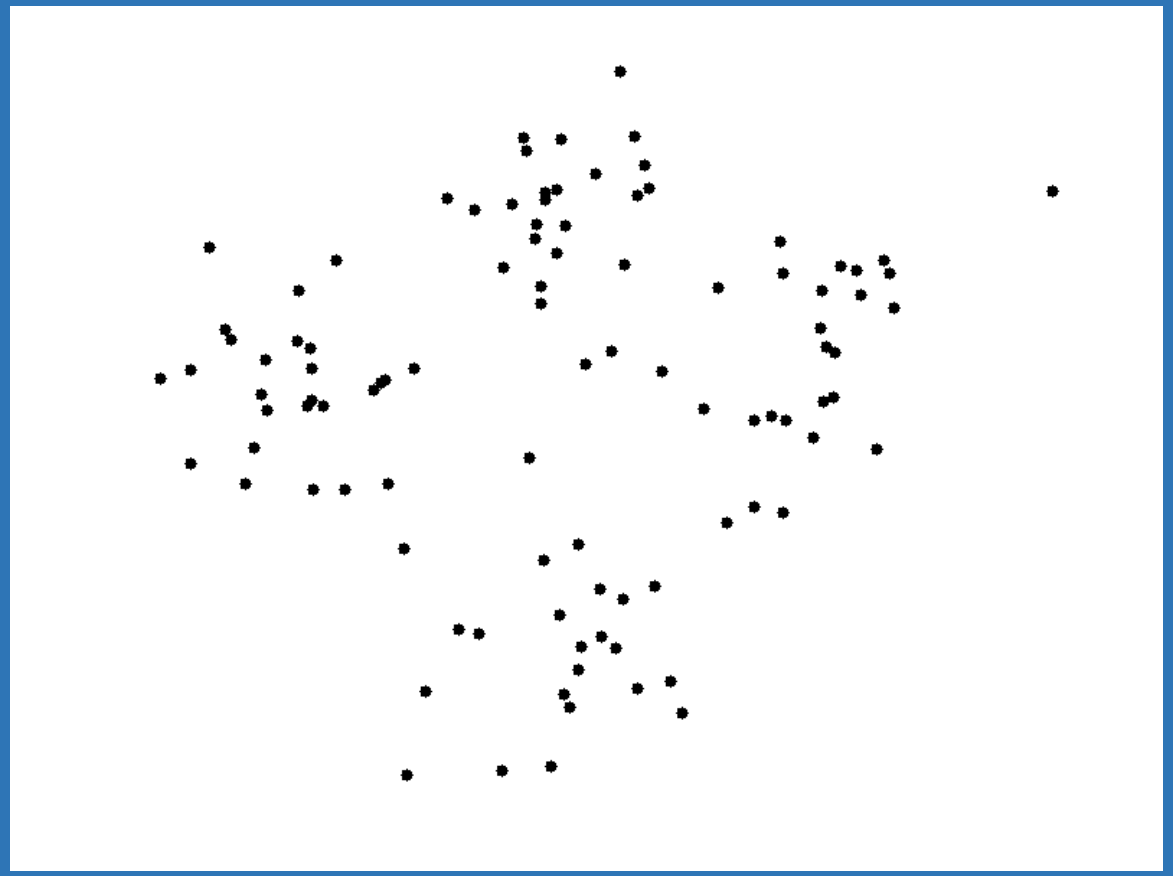


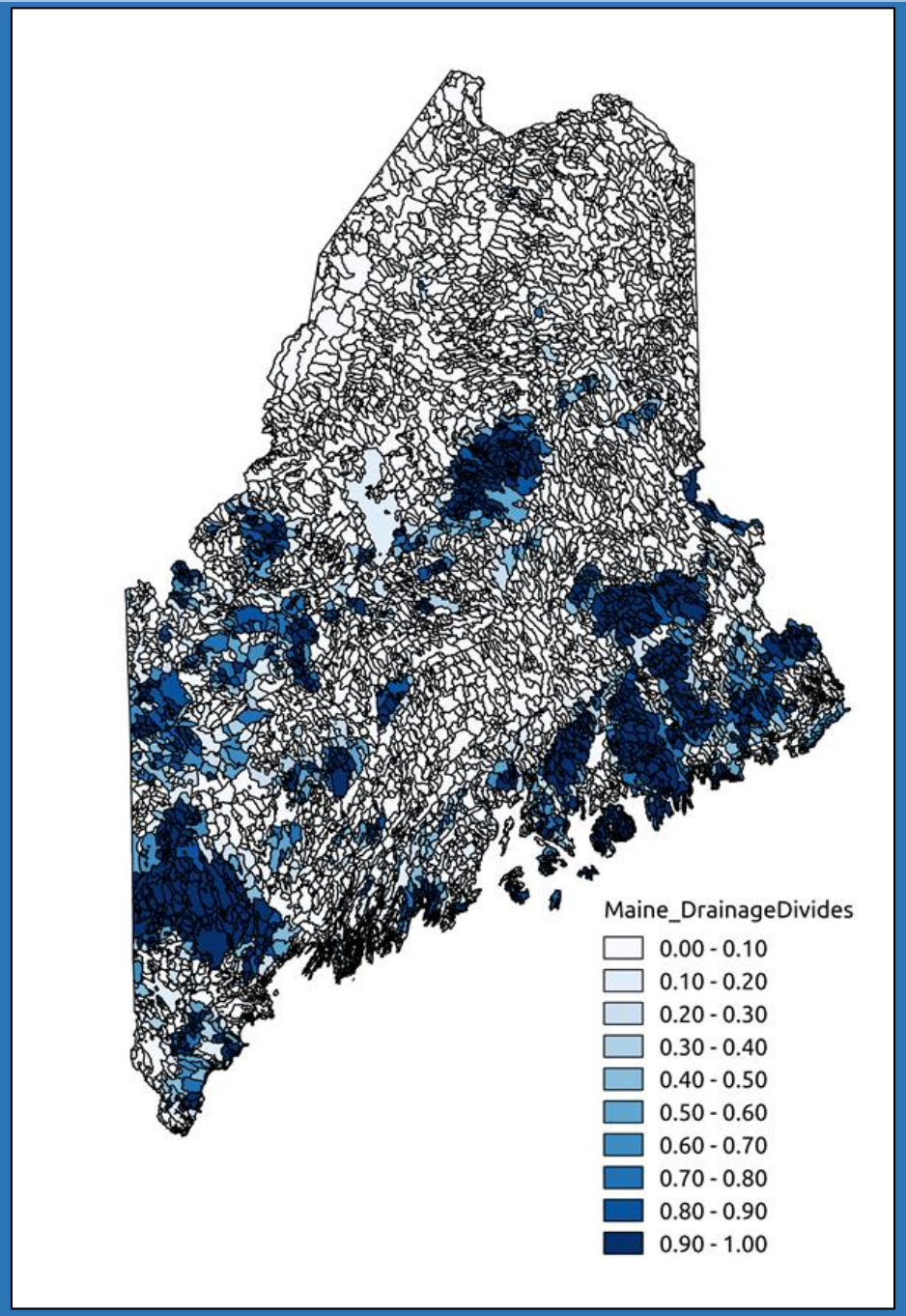
CLUSTER ANALYSIS

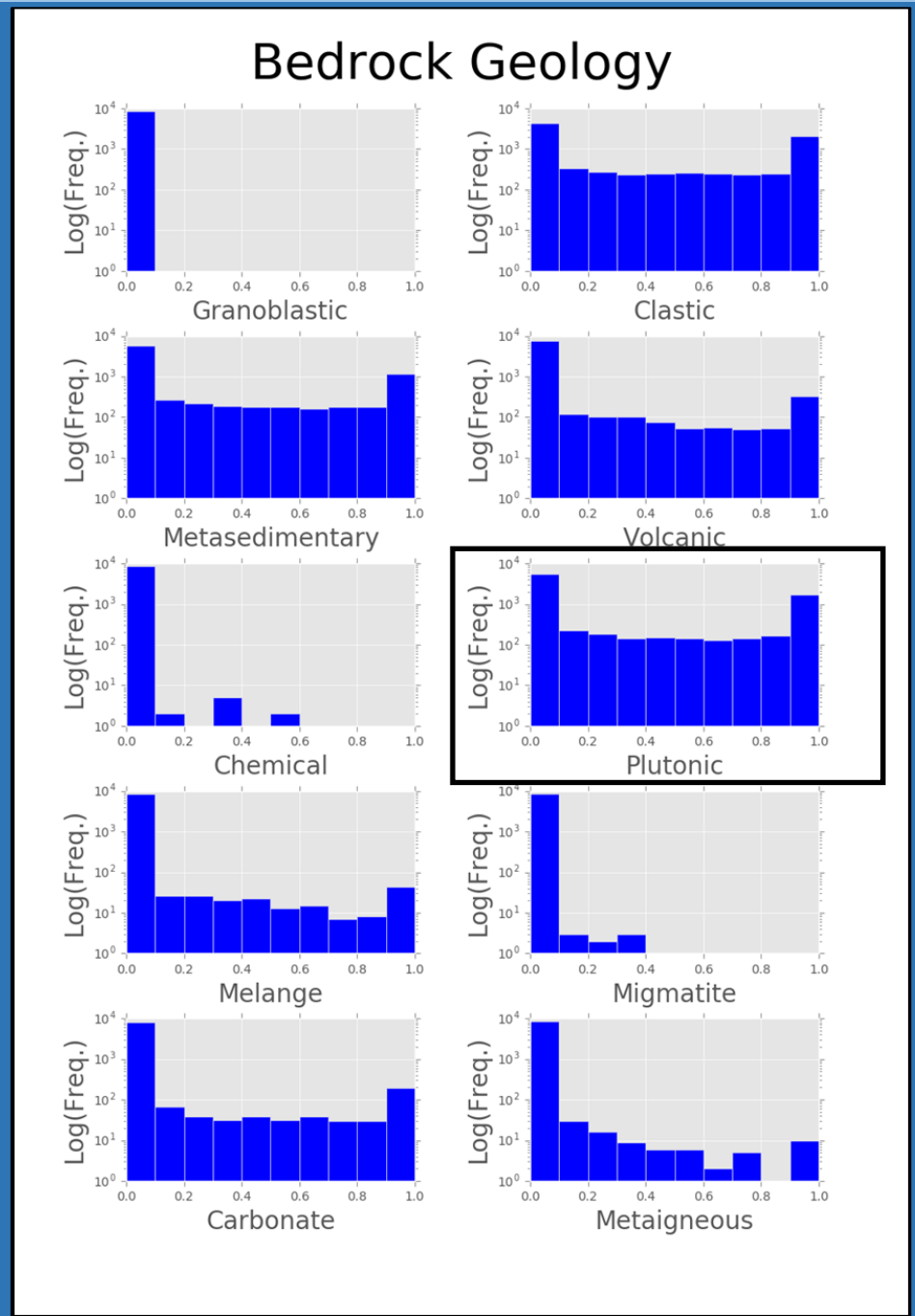
- Minimize within cluster sums of squares
- Iterative process
- K clusters defined by user

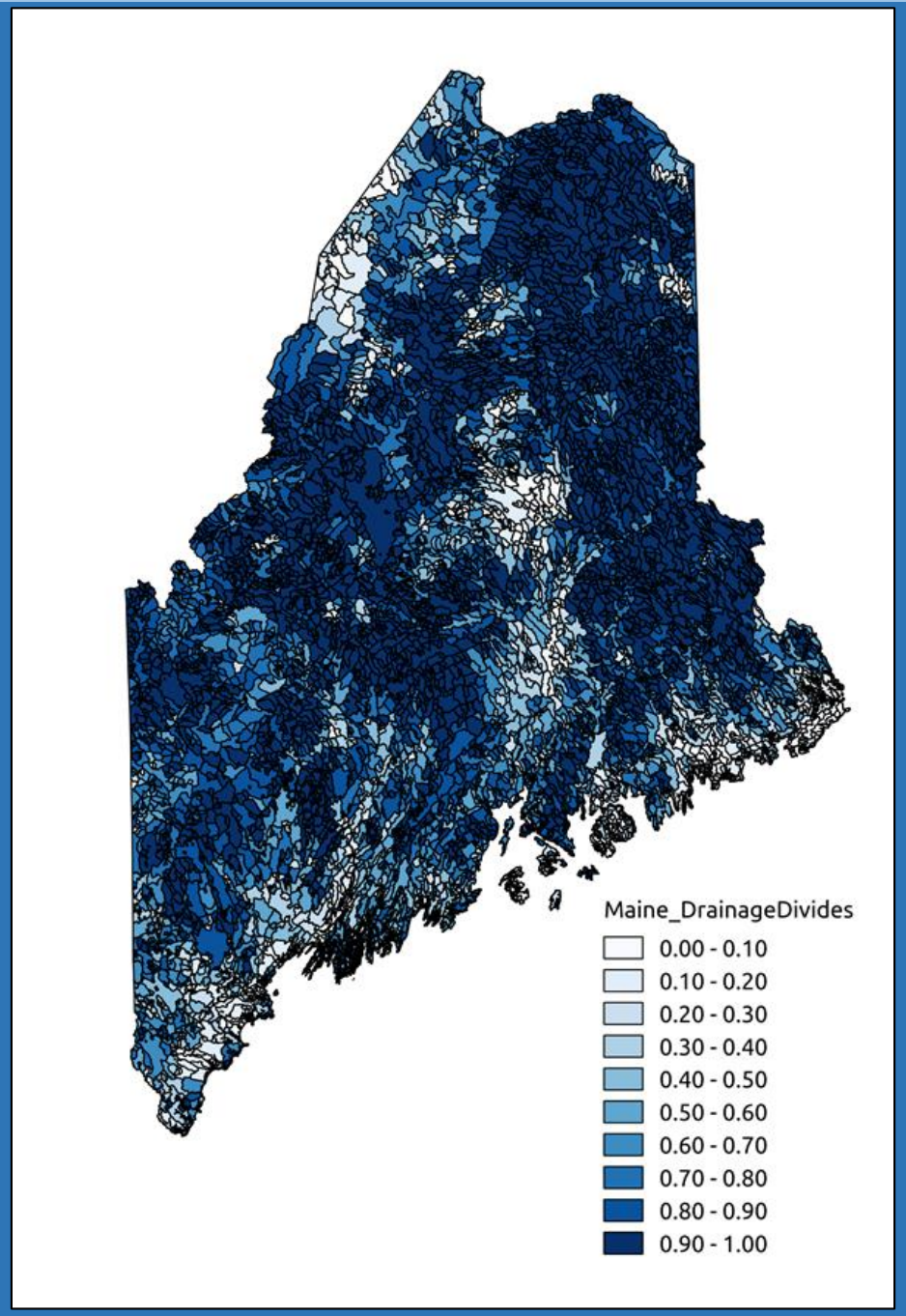


DouglasDuhaim.com

Crawley (2007)


Maine_DrainageDivides
0.00 - 0.10
0.10 - 0.20
0.20 - 0.30
0.30 - 0.40
0.40 - 0.50
0.50 - 0.60
0.60 - 0.70
0.70 - 0.80
0.80 - 0.90
0.90 - 1.00


Bedrock Geology
Log(Freq.)
Granoblastic
Clastic
Metasedimentary
Volcanic
Chemical
Plutonic
Melange
Migmatite
Carbonate
Metaigneous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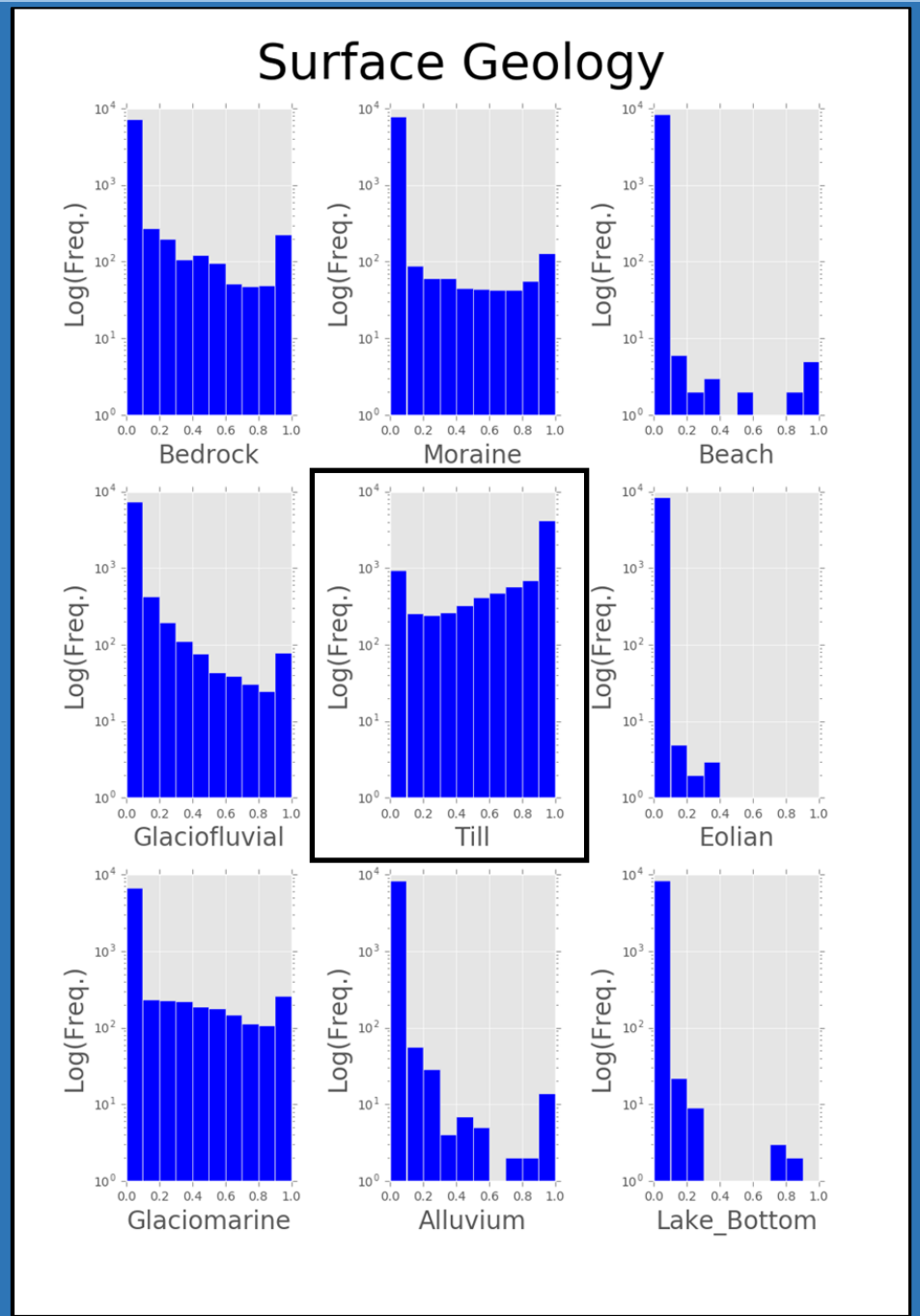
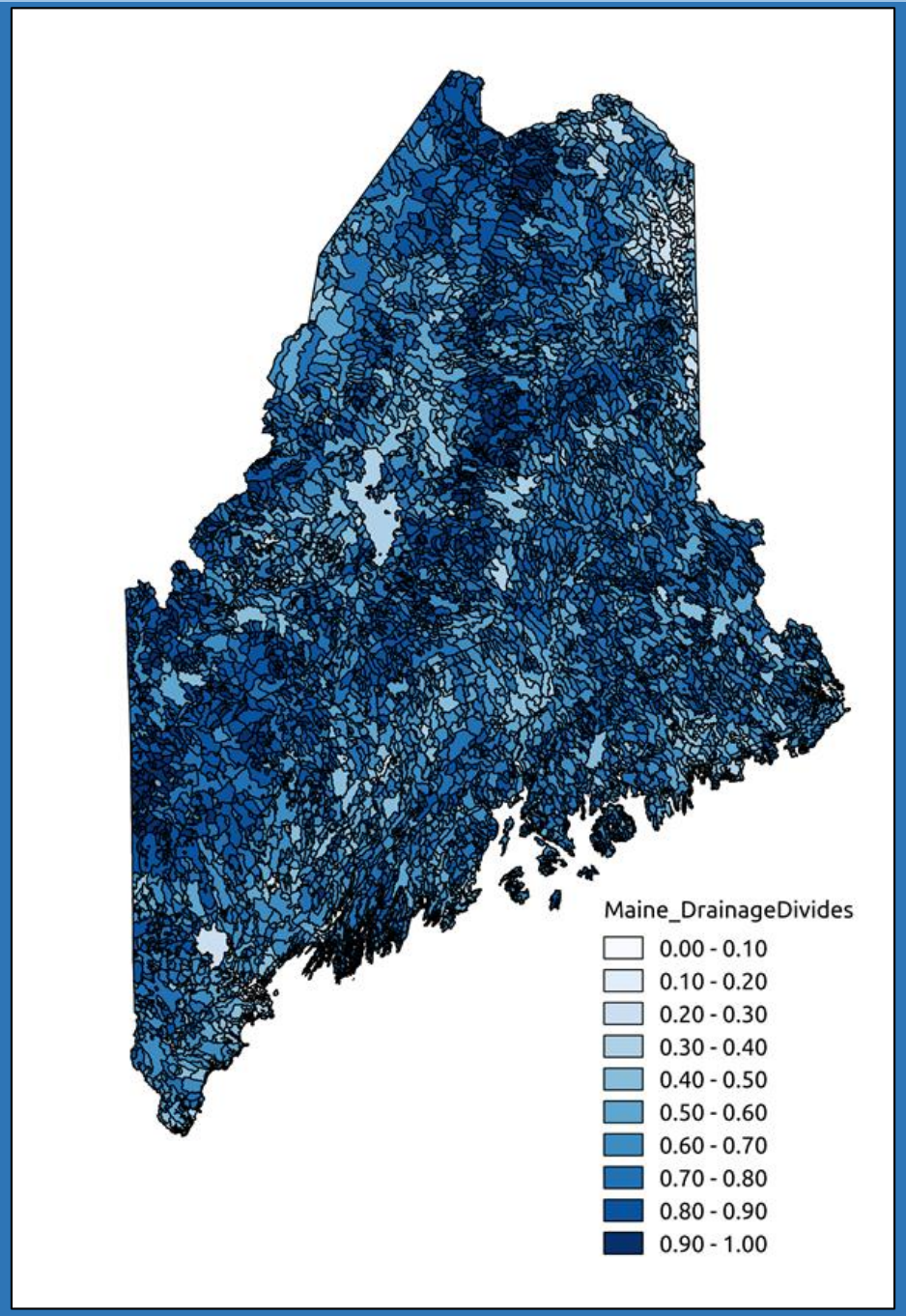

Surface Geology
Log(Freq.)
Bedrock
Moraine
Beach
Glaciofluvial
Till
Eolian
Glaciomarine
Alluvium
Lake_Bottom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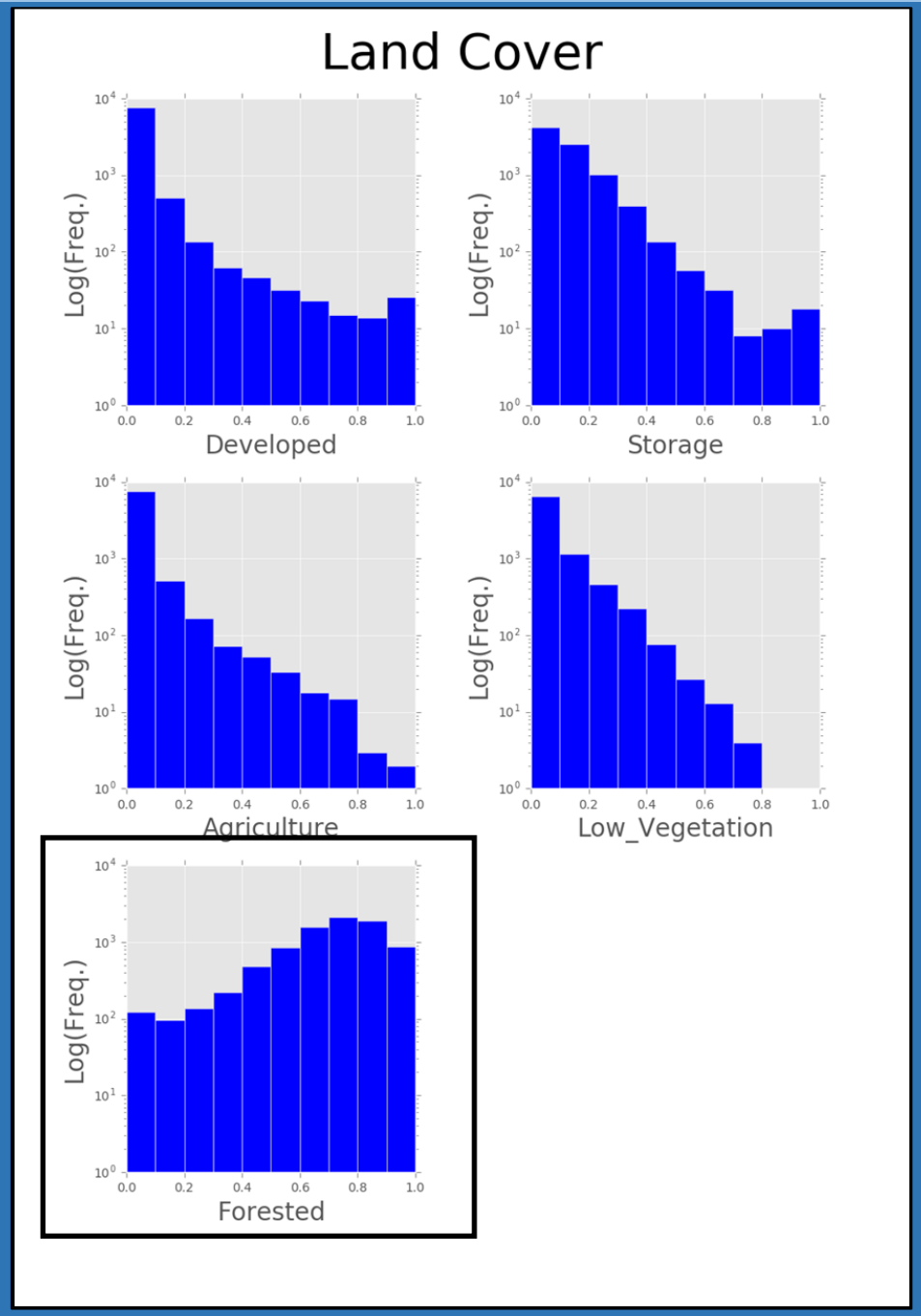
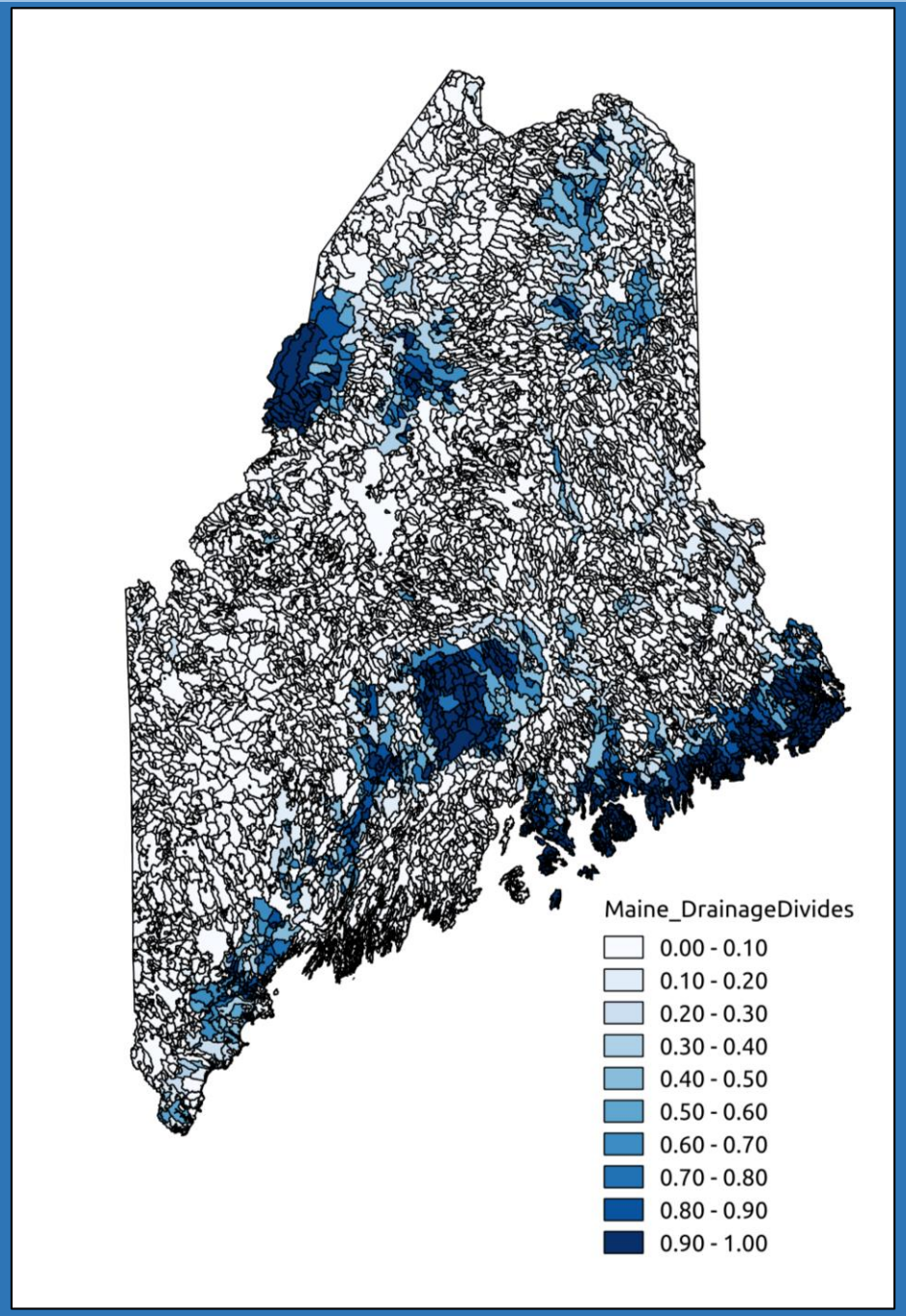

Land Cover
Log(Freq.)
Developed
Storage
Agriculture
Low_Vegetation
Forested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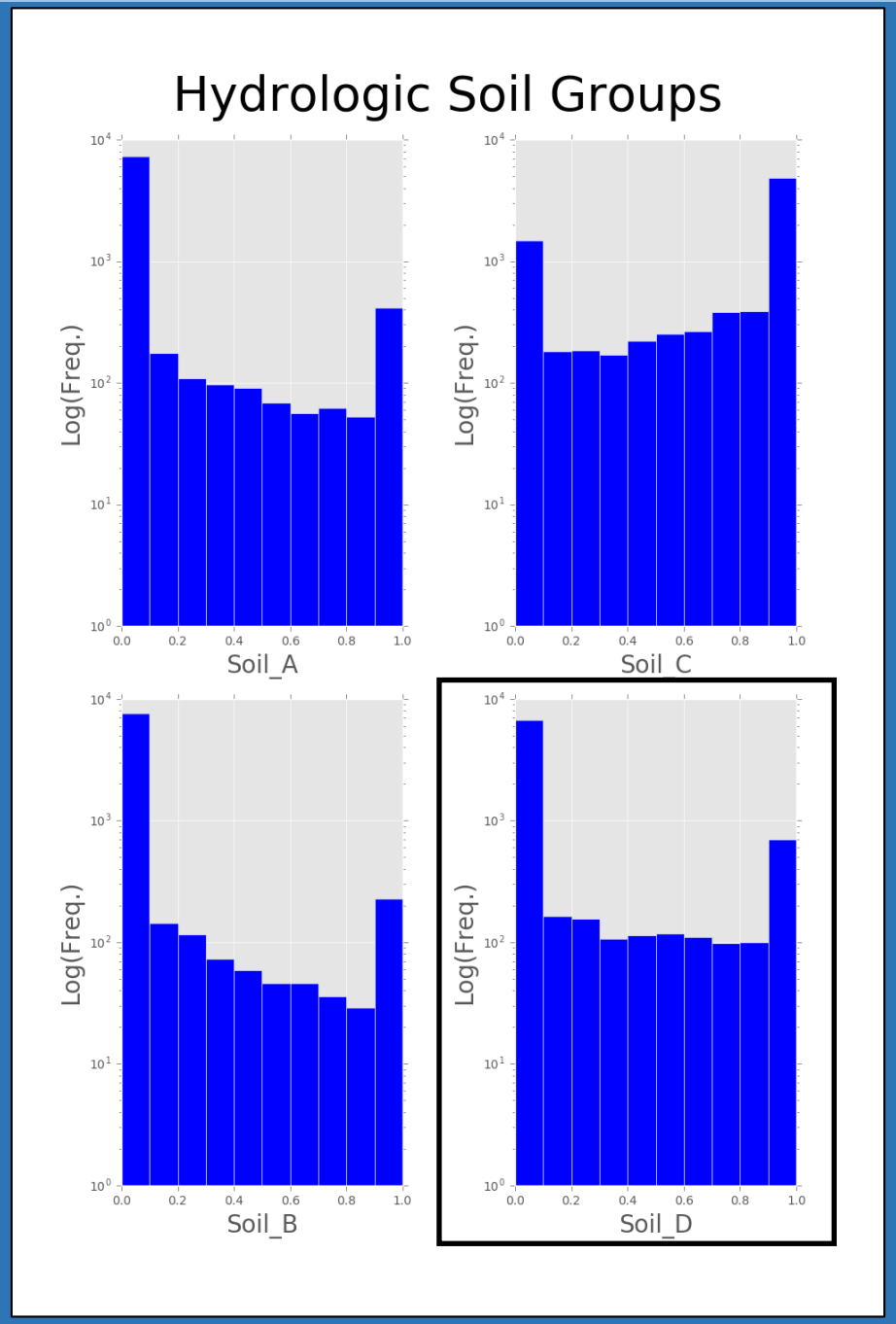
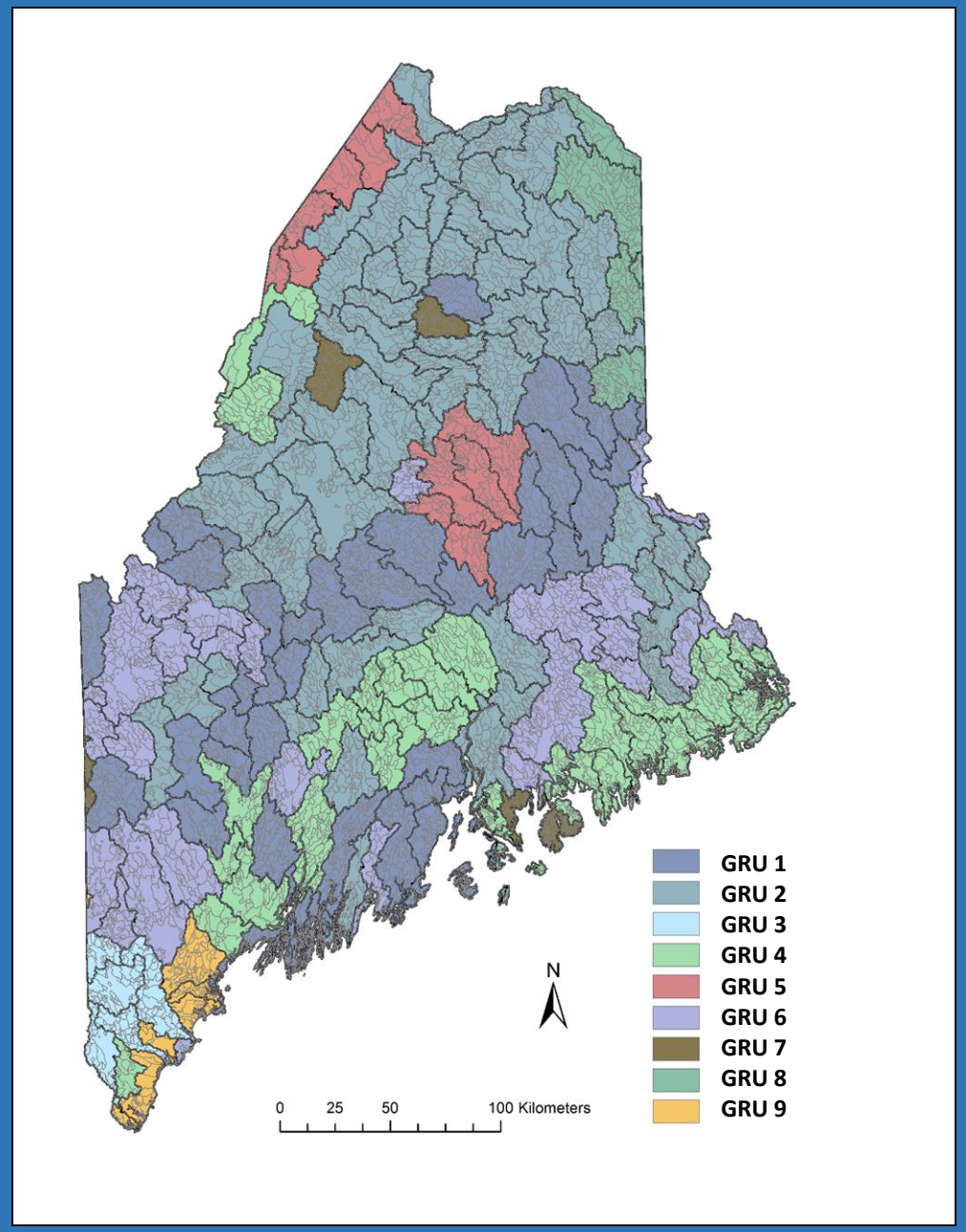

Hydrologic Soil Groups
Log(Freq.)
Soil_A
Soil_C
Soil_B
Soil_D

Geomorphic Response Units (GRUs)

- **GRU 1:** Metased., C Soils, Till
- **GRU 2:** Clastic bedrock, Till
- **GRU 3:** A Soils, Glaciofluvial
- **GRU 4:** Poorly Drained
- **GRU 5:** C Soils, Moraines
- **GRU 6:** Relief, Till, Plutonic
- **GRU 7:** High Relief, Bedrock
- **GRU 8:** B Soils, Carbonate, Agricultural
- **GRU 9:** Developed, Glaciomarine

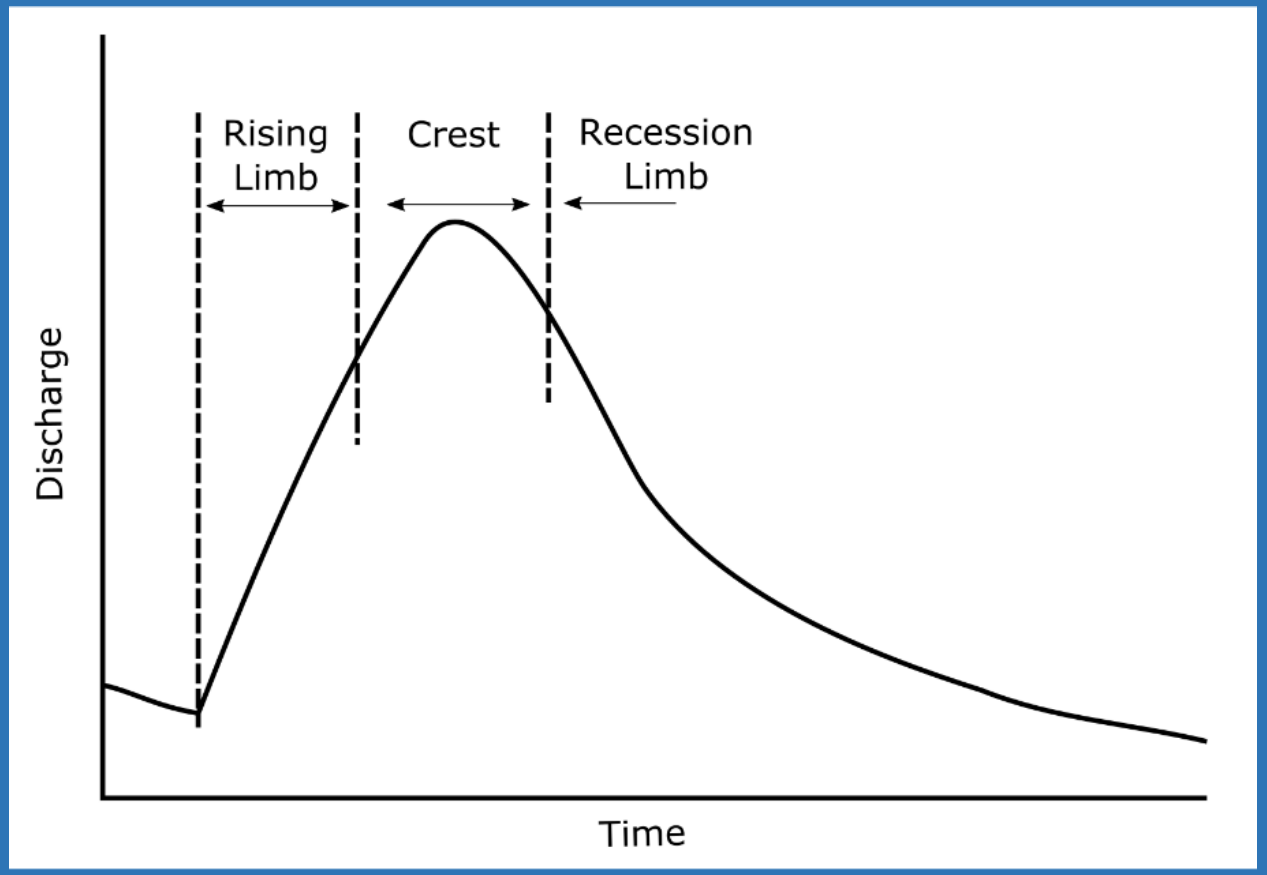


HYDROLOGIC CHARACTERIZATION

- Linear Reservoir Theory:
  - Discharge (Q) is linearly related to the storage (S) by a constant (K).[1,2]

$$Q\left[\frac{length^3}{time}\right] = K\left[\frac{1}{time}\right] \times S\left[\frac{length^3}{1}\right]$$

  - Form of function can be estimated from streamflow analysis.[3]



Adapted from Gupta (2008)

1: Chow (1969); 2: DHI (2012); 3: Kirchner (2009)

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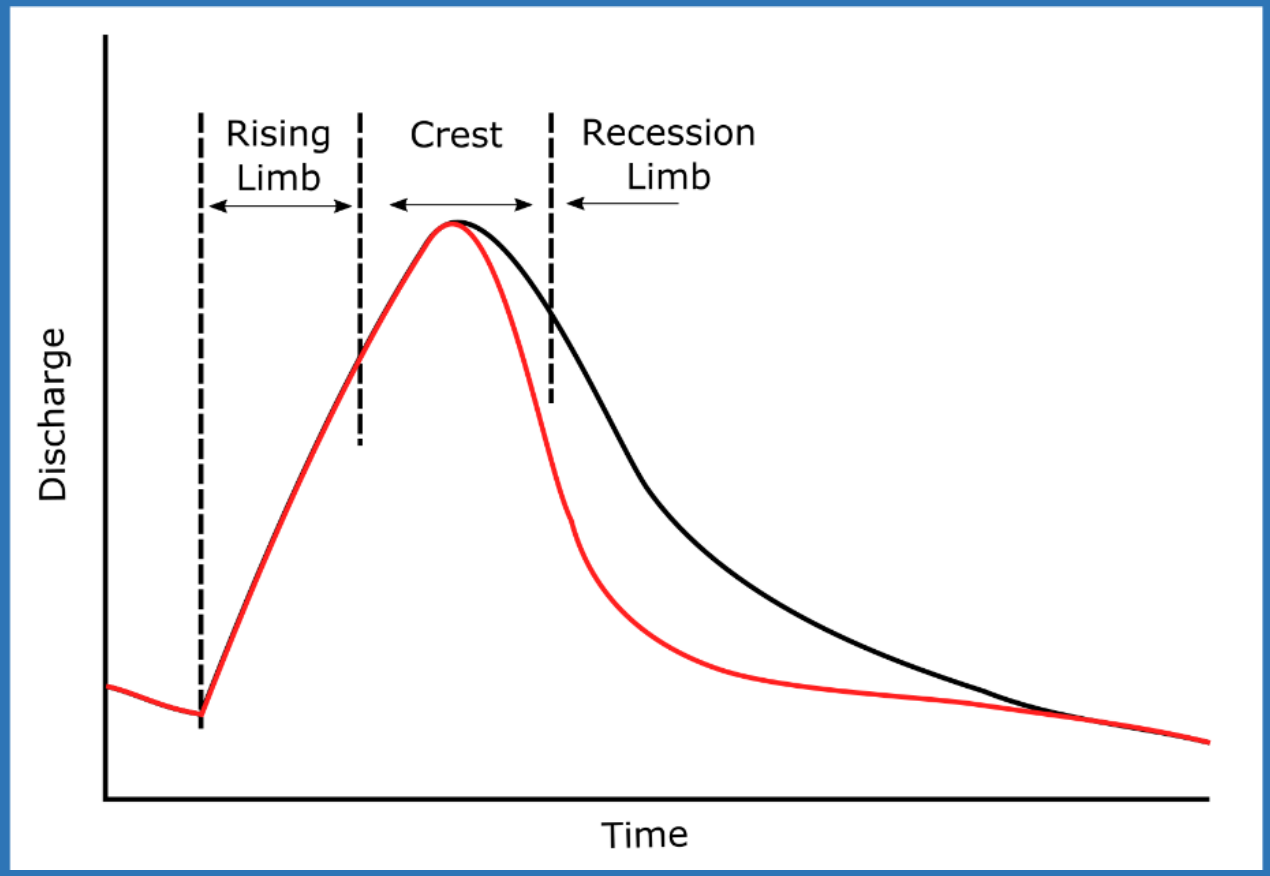

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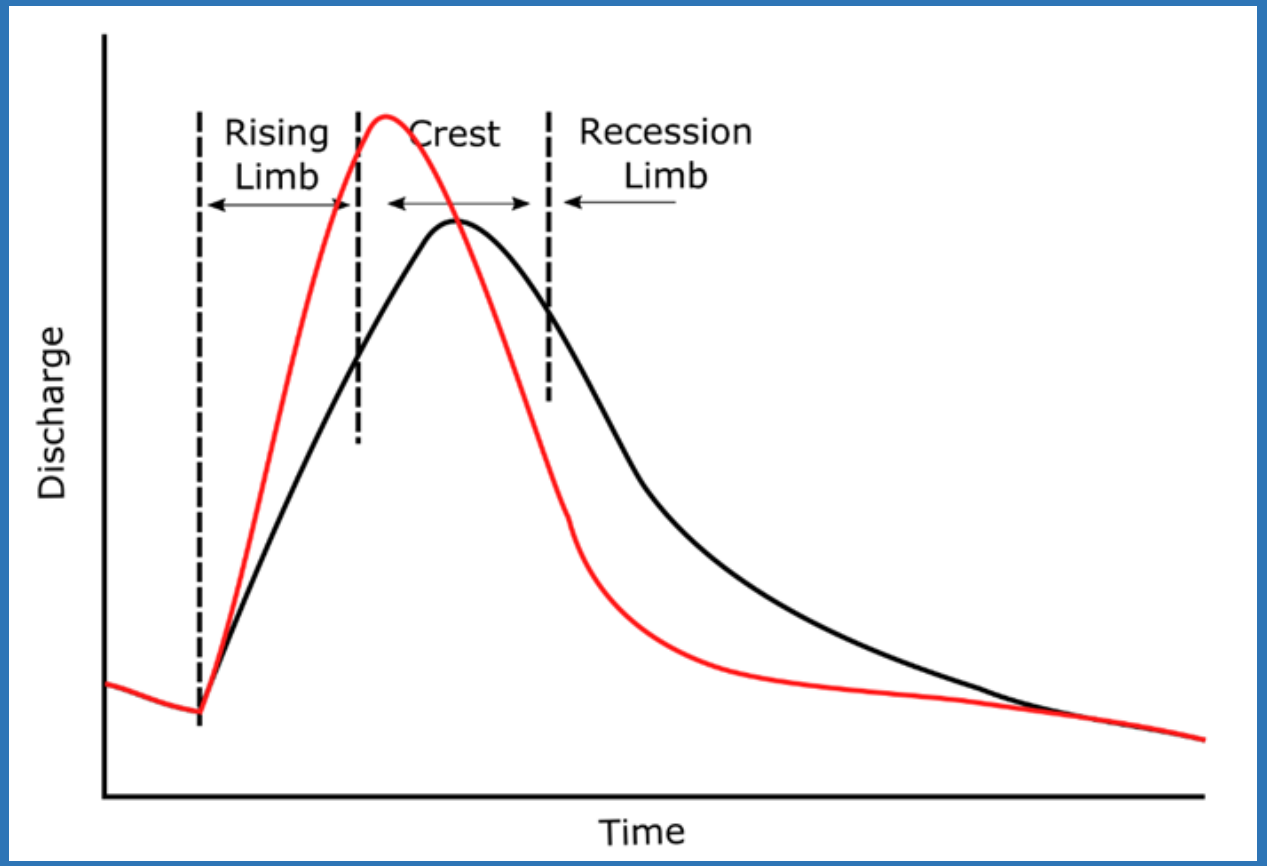

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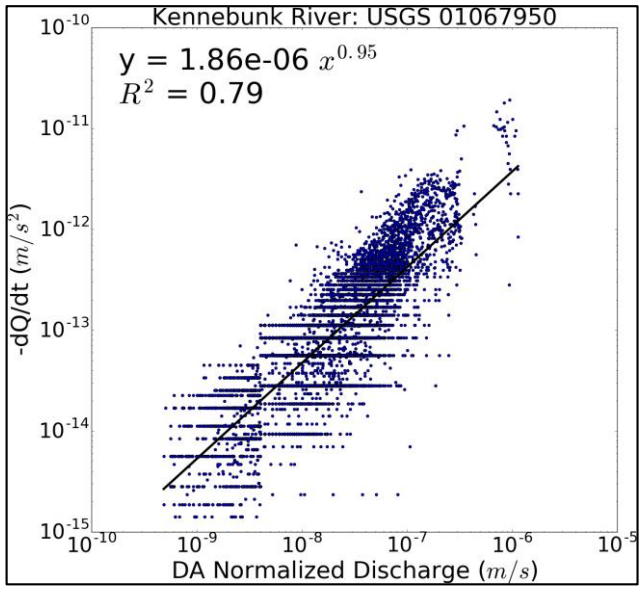
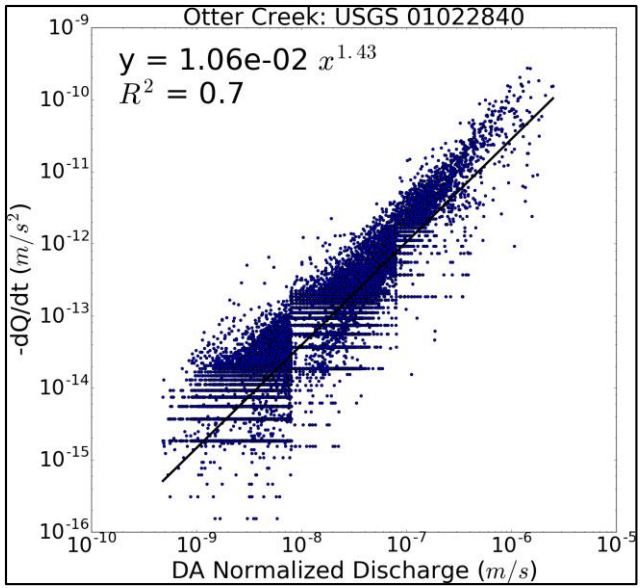
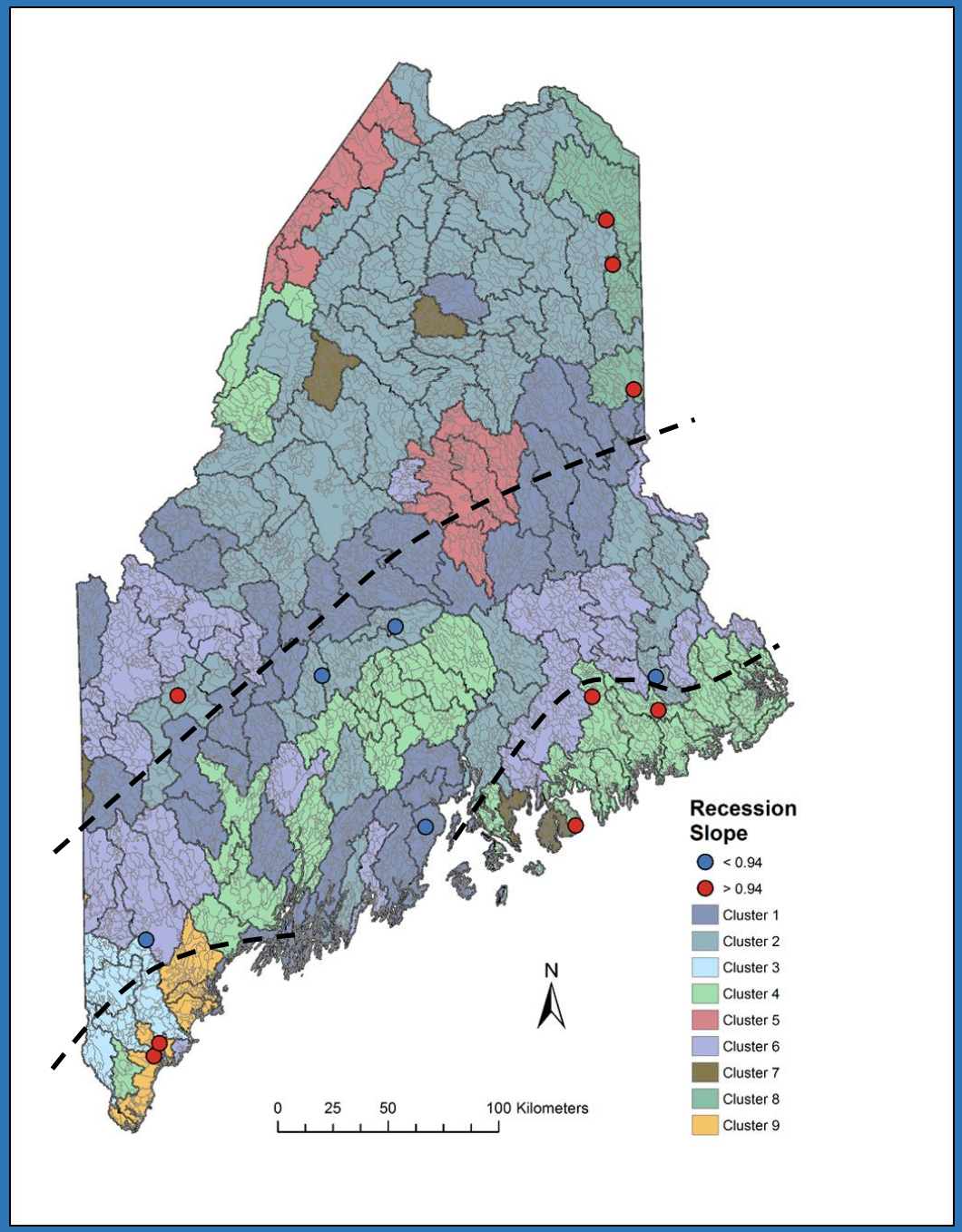
- USGS gauges (14)
  - Currently operational
  - Continuous Discharge measurements
  - Drainage Area less than 100 km^2
- Limited dataset, but some spatial trends observable.



Sensitivity Function Kennebunk River Example



Sensitivity Function Otter Creek Example



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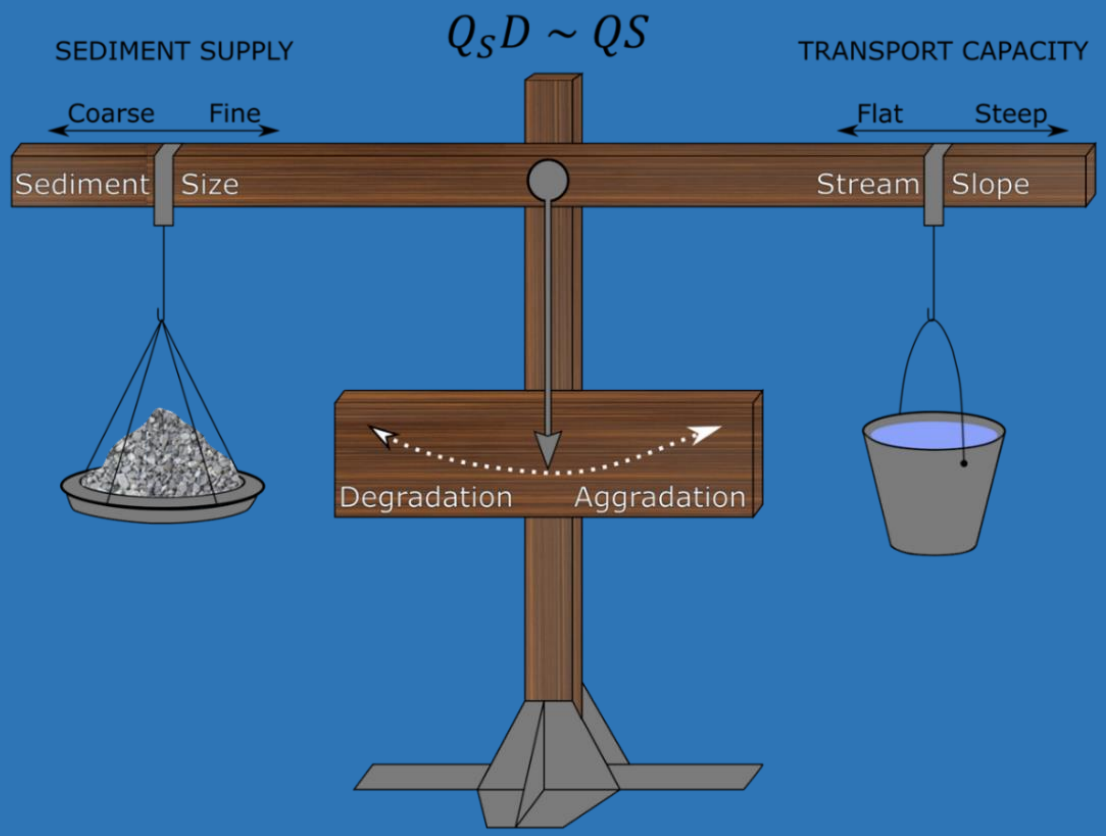
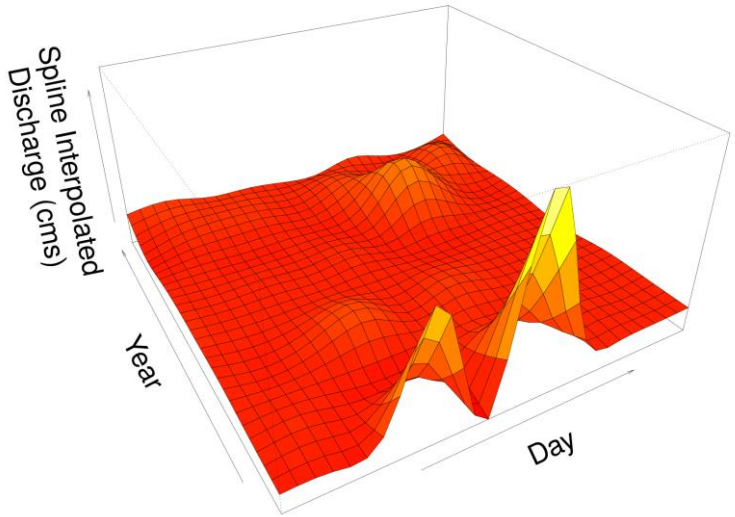
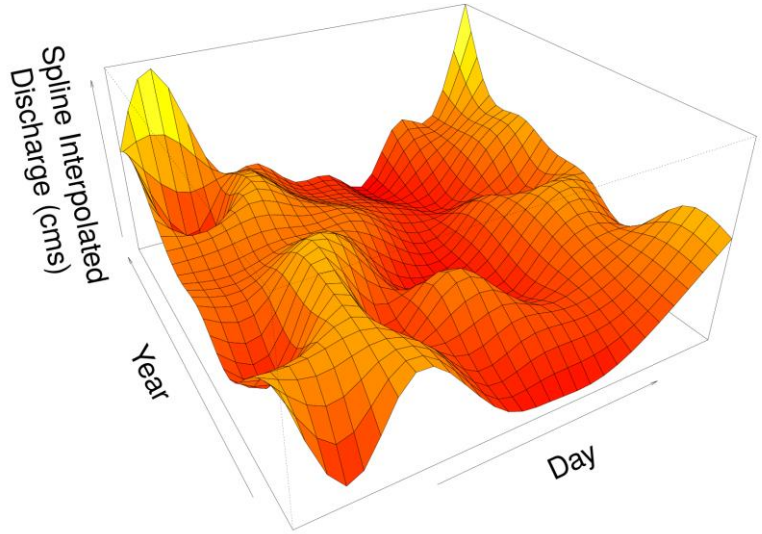


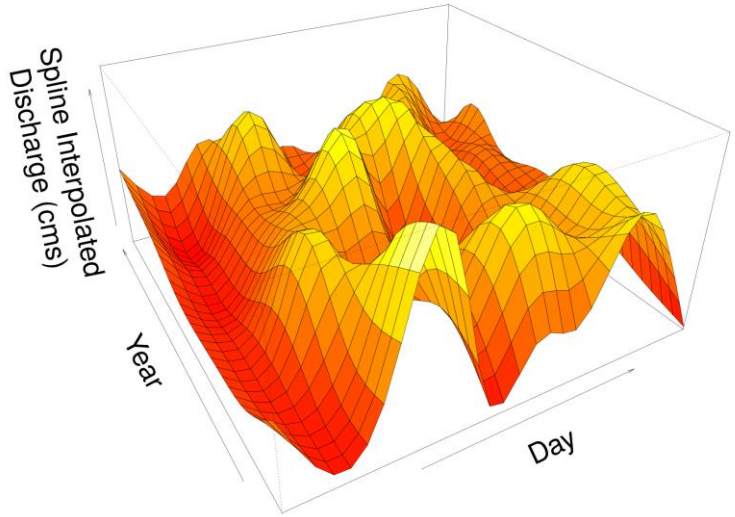
North Fork Eagle Creek
Alto, NM

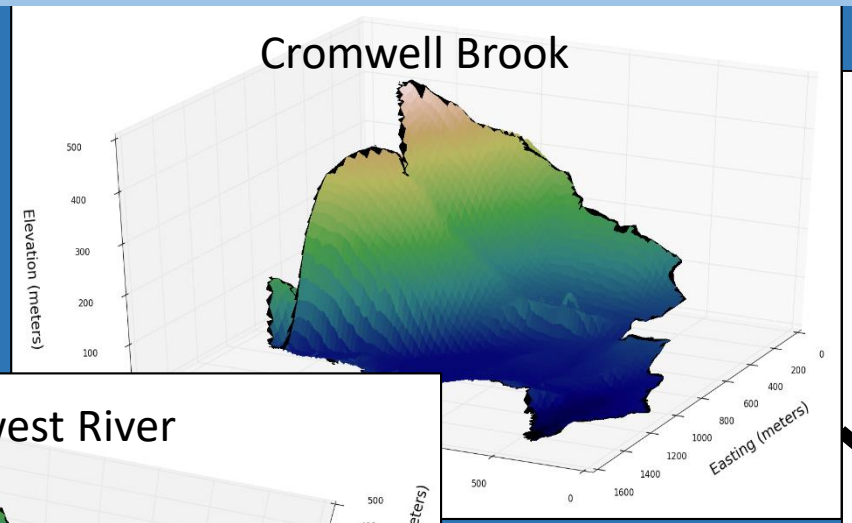


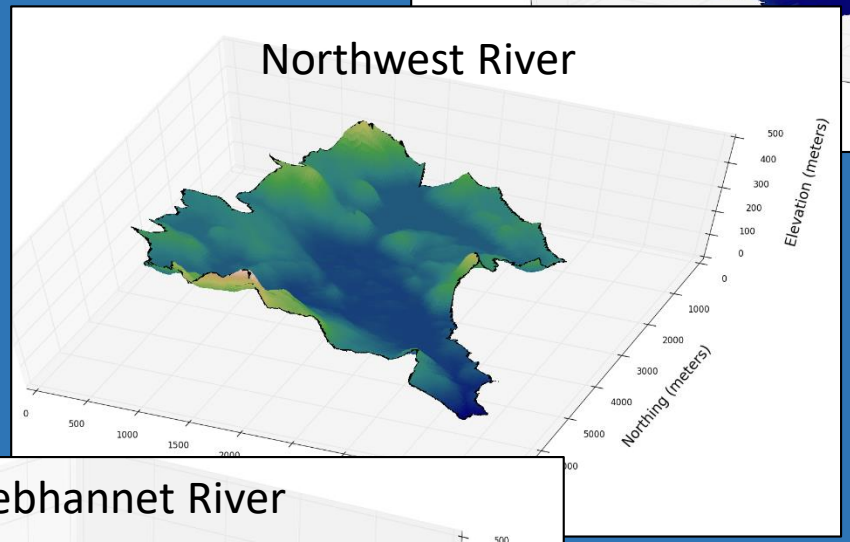
Otter Creek
Bar Harbor, ME

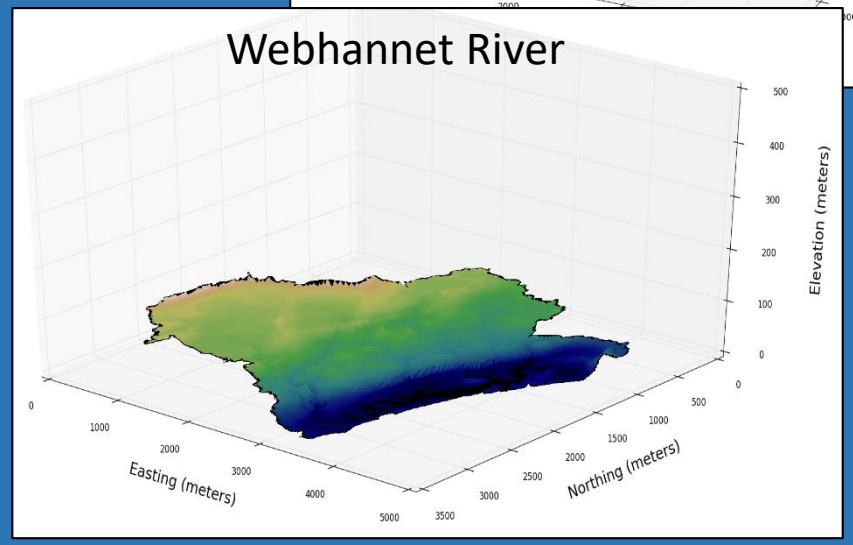


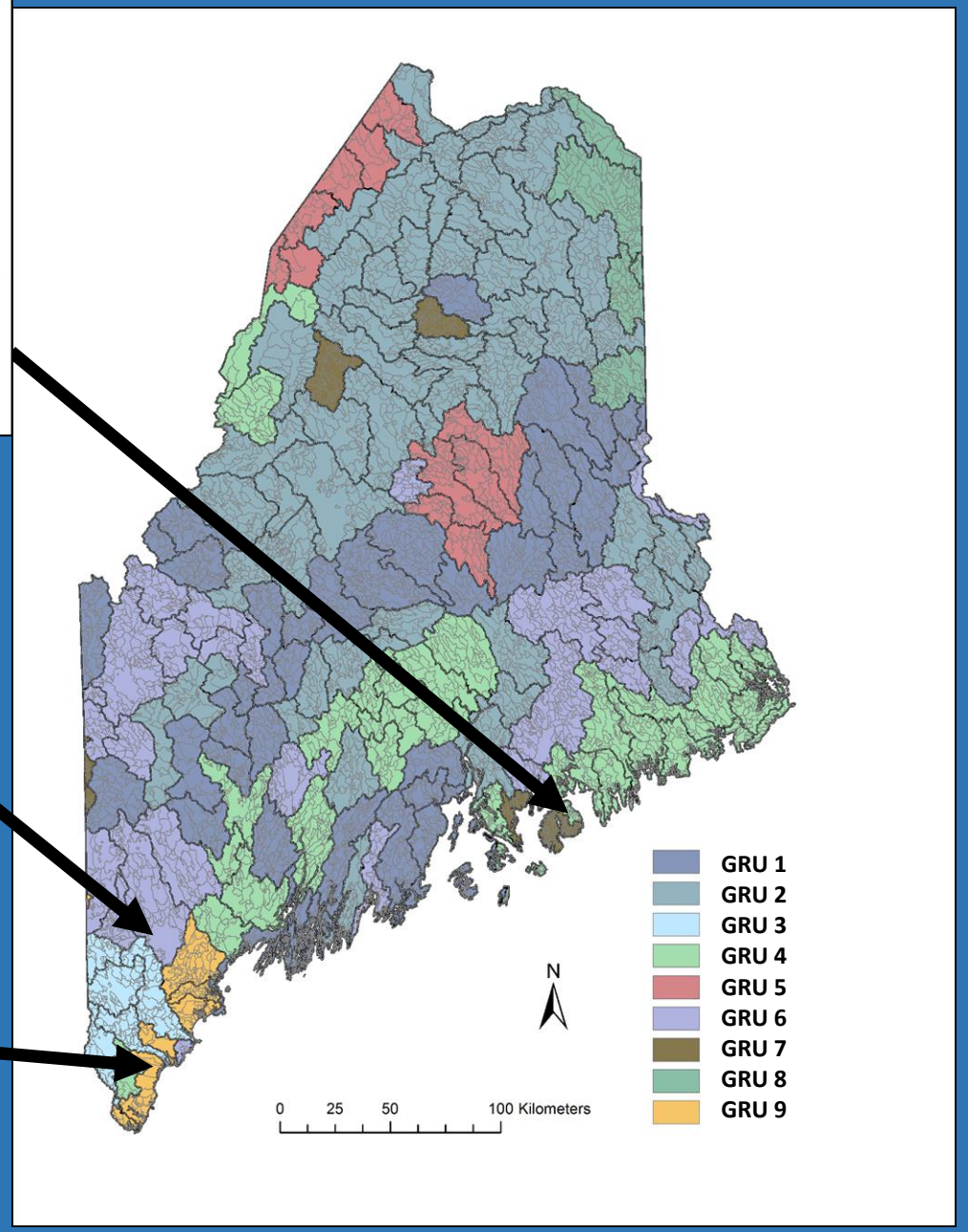
Cromwell Brook (Modelled)
Bar Harbor, ME

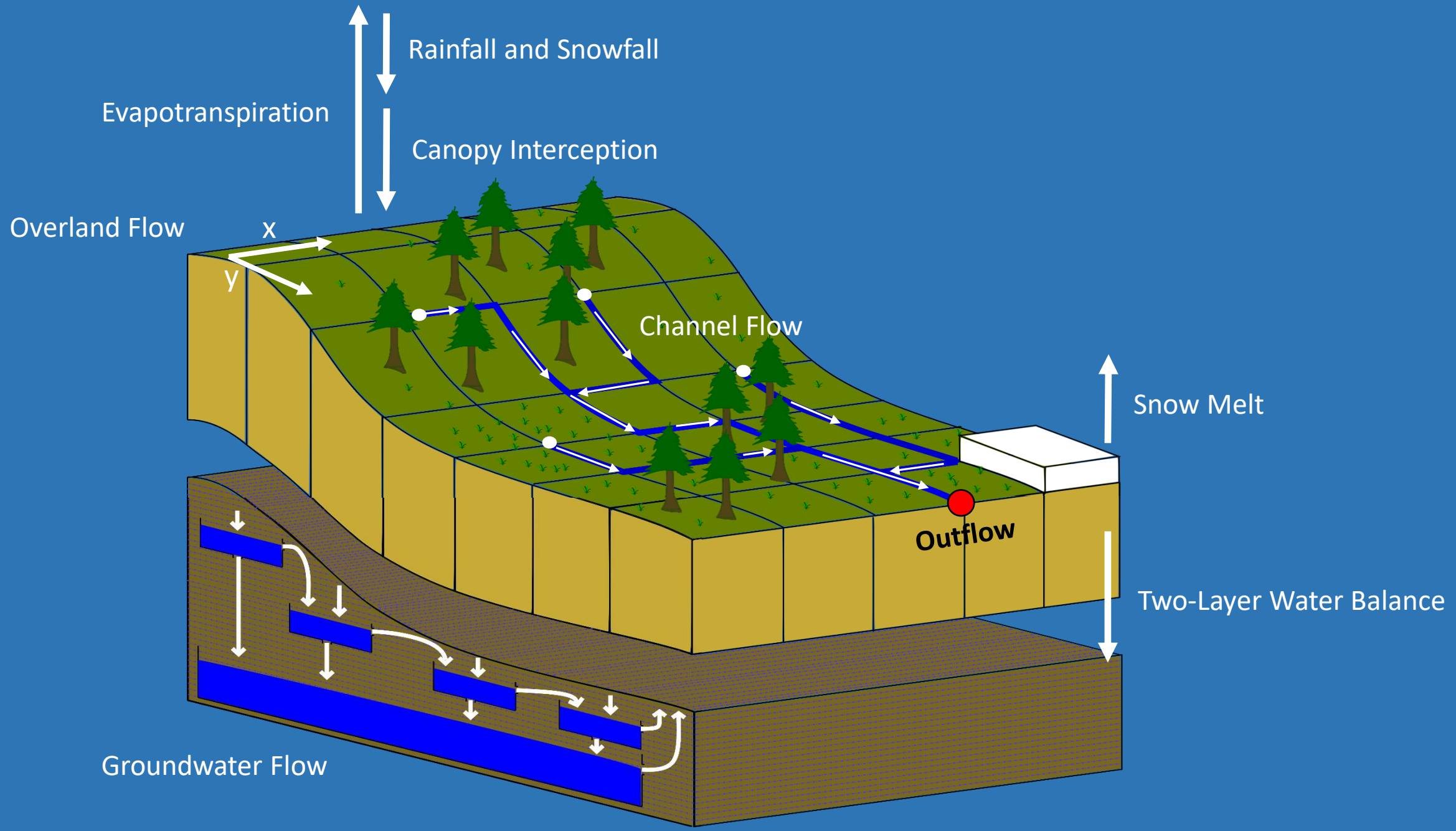



Cromwell Brook
Elevation (meters)
Easting (meters)

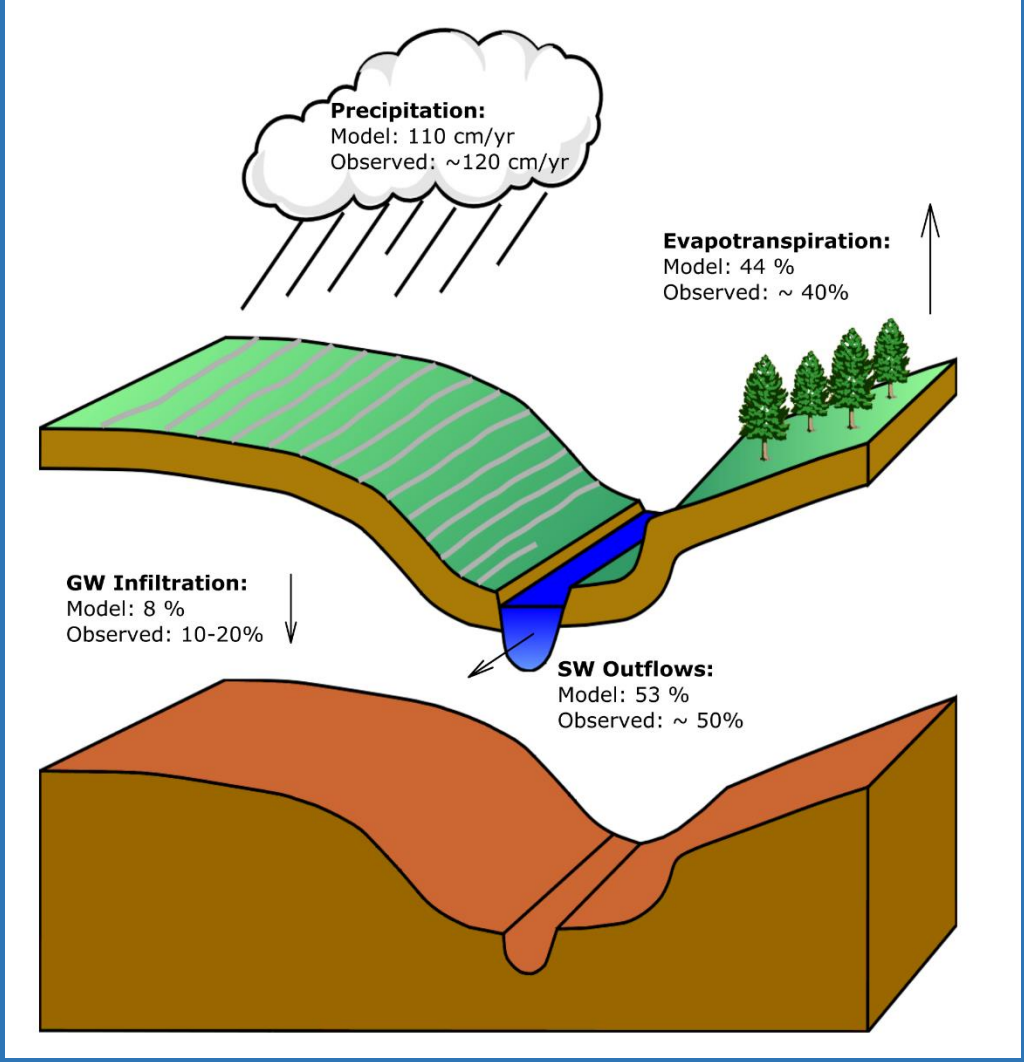

Northwest River
Elevation (meters)
Northing (meters)

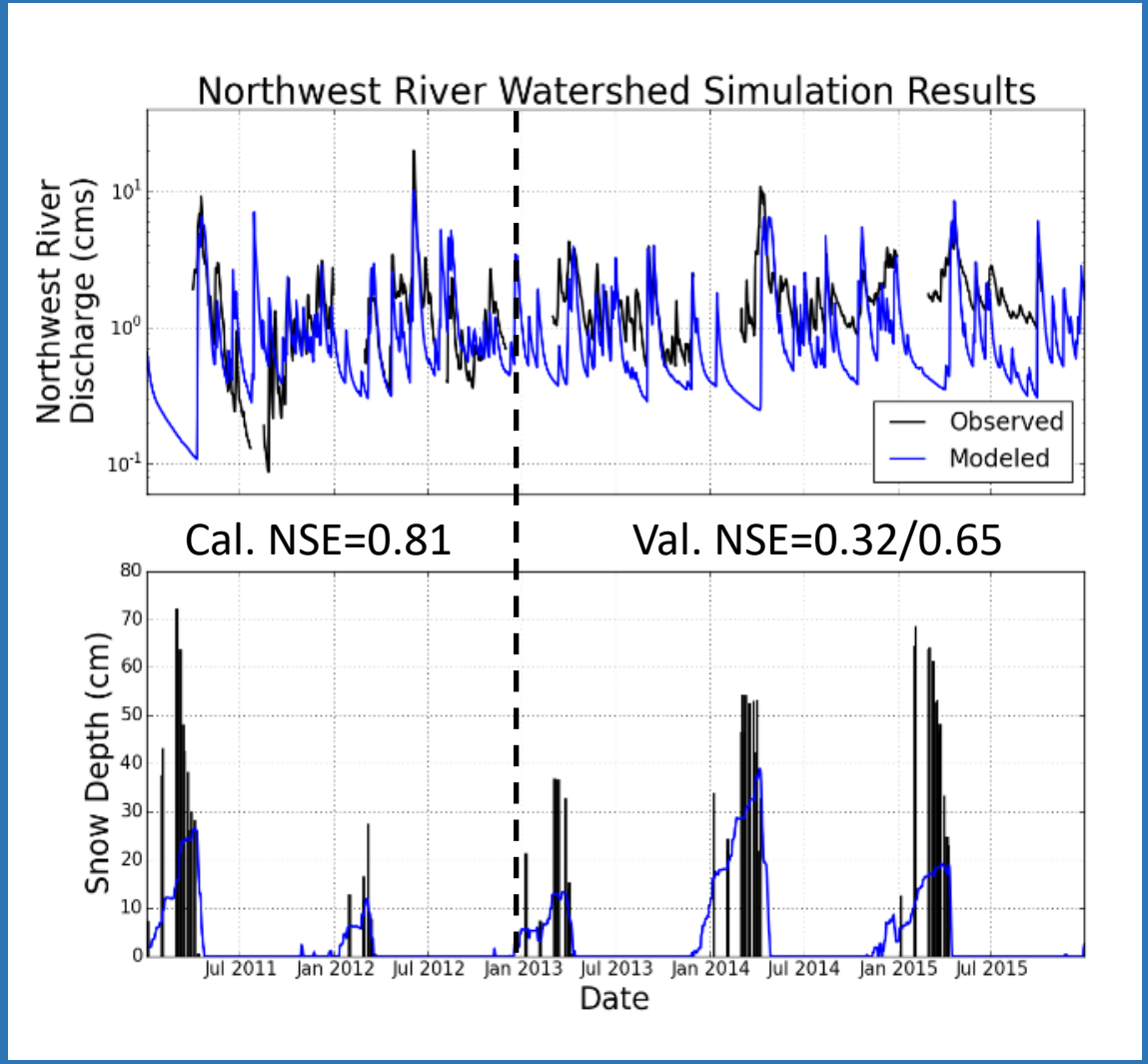

Webhannet River
Elevation (meters)
Easting (meters)
Northing (meters)


GRU 1
GRU 2
GRU 3
GRU 4
GRU 5
GRU 6
GRU 7
GRU 8
GRU 9
N
0 25 50 100 Kilometers


Rainfall and Snowfall
Evapotranspiration
Canopy Interception
Overland Flow
x
y
Channel Flow
Snow Melt
Outflow
Two-Layer Water Balance
Groundwater Flow

WATERSHED MODELING



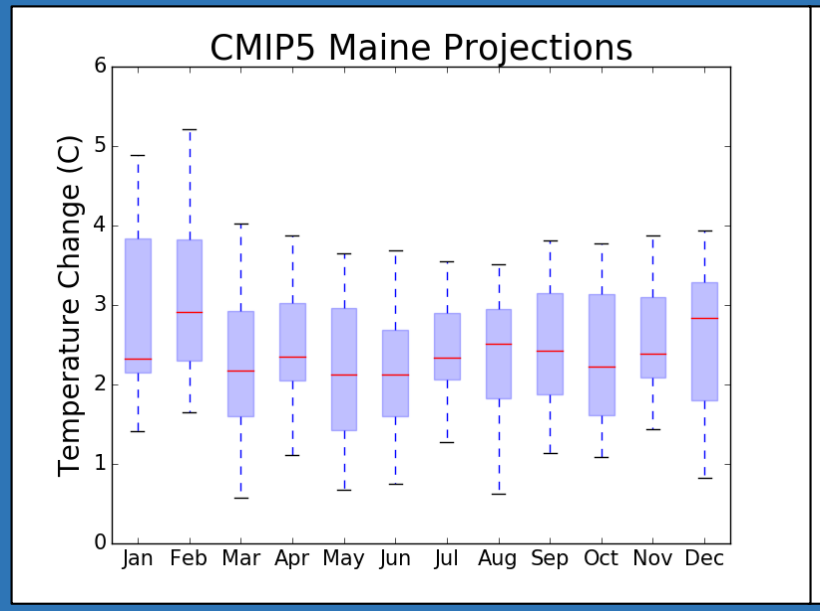


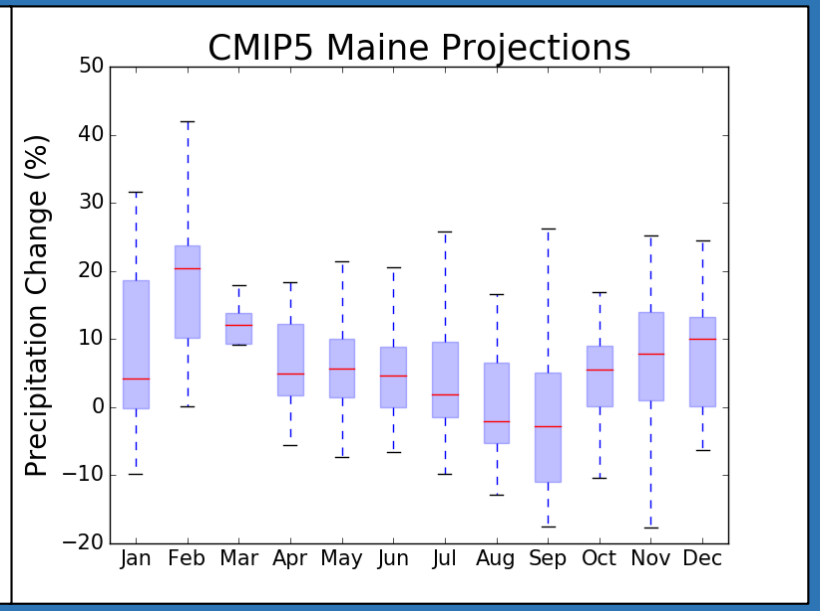
Climate Projections: Coupled Model Intercomparison Project (CMIP5)

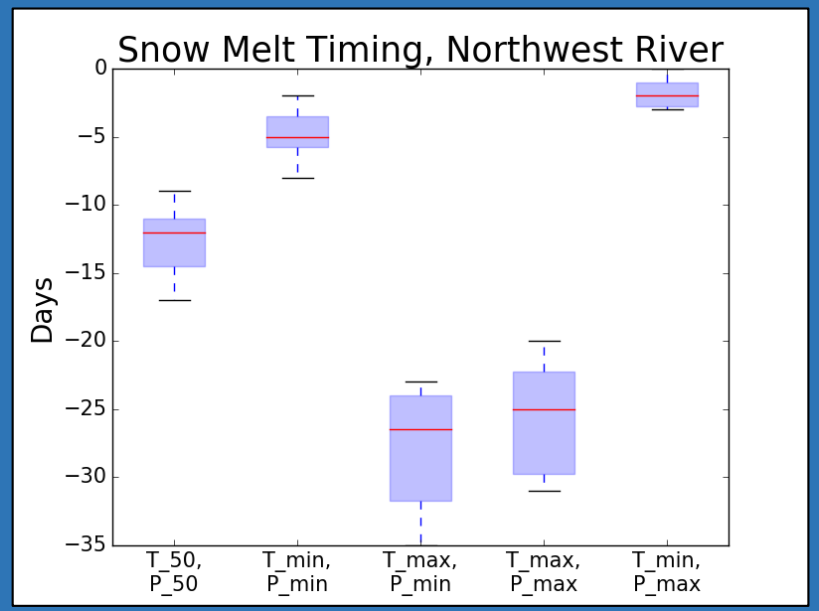
- A1B Conditions- Rapid economic growth with the global population peaking mid-century and declining thereafter. Rapid introduction of new and more efficient technologies balanced across all sources.

Scenarios: Delta Method

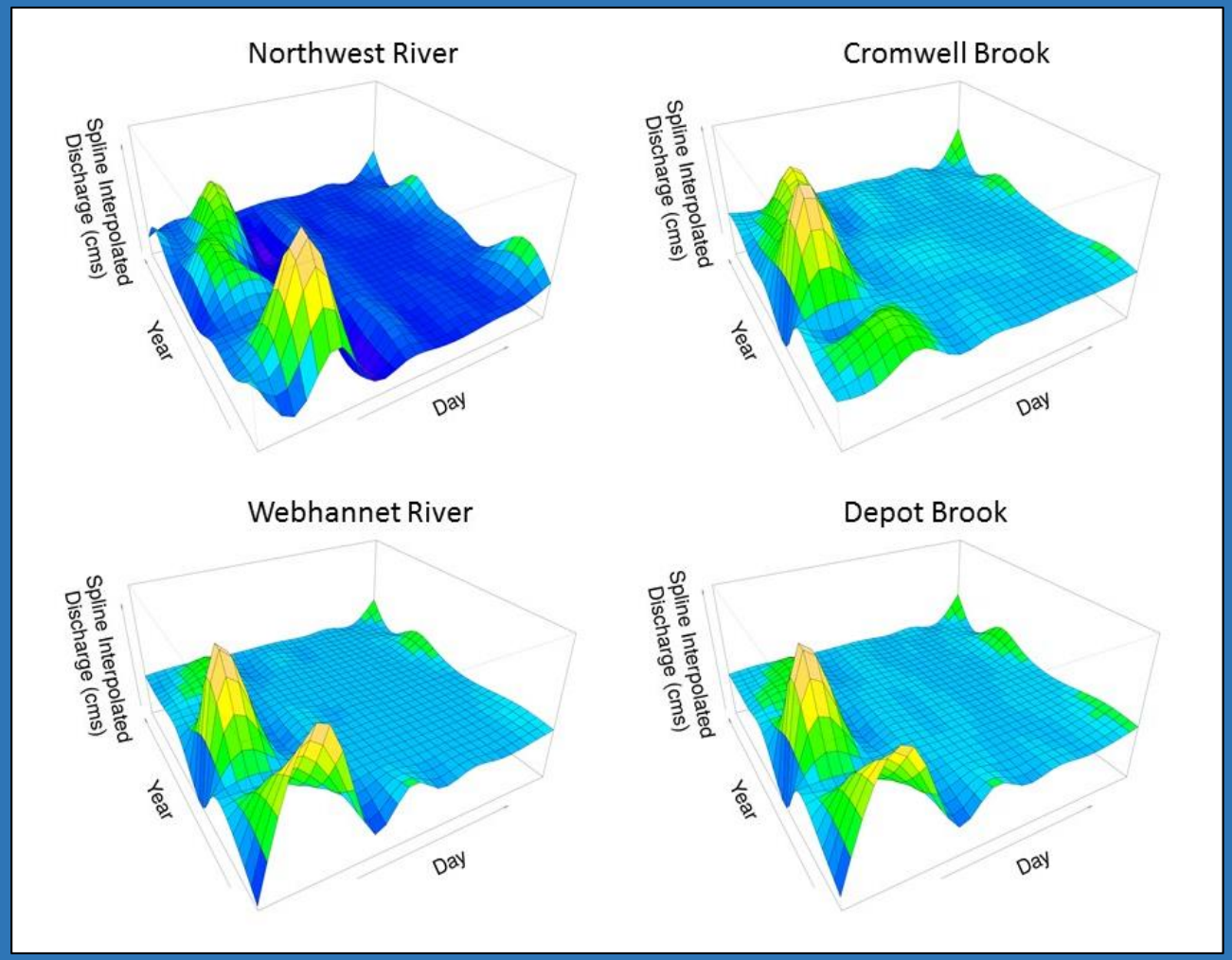
- August Airport Weather Station
  - Current: 1987-2017
  - Future: 2070-2100



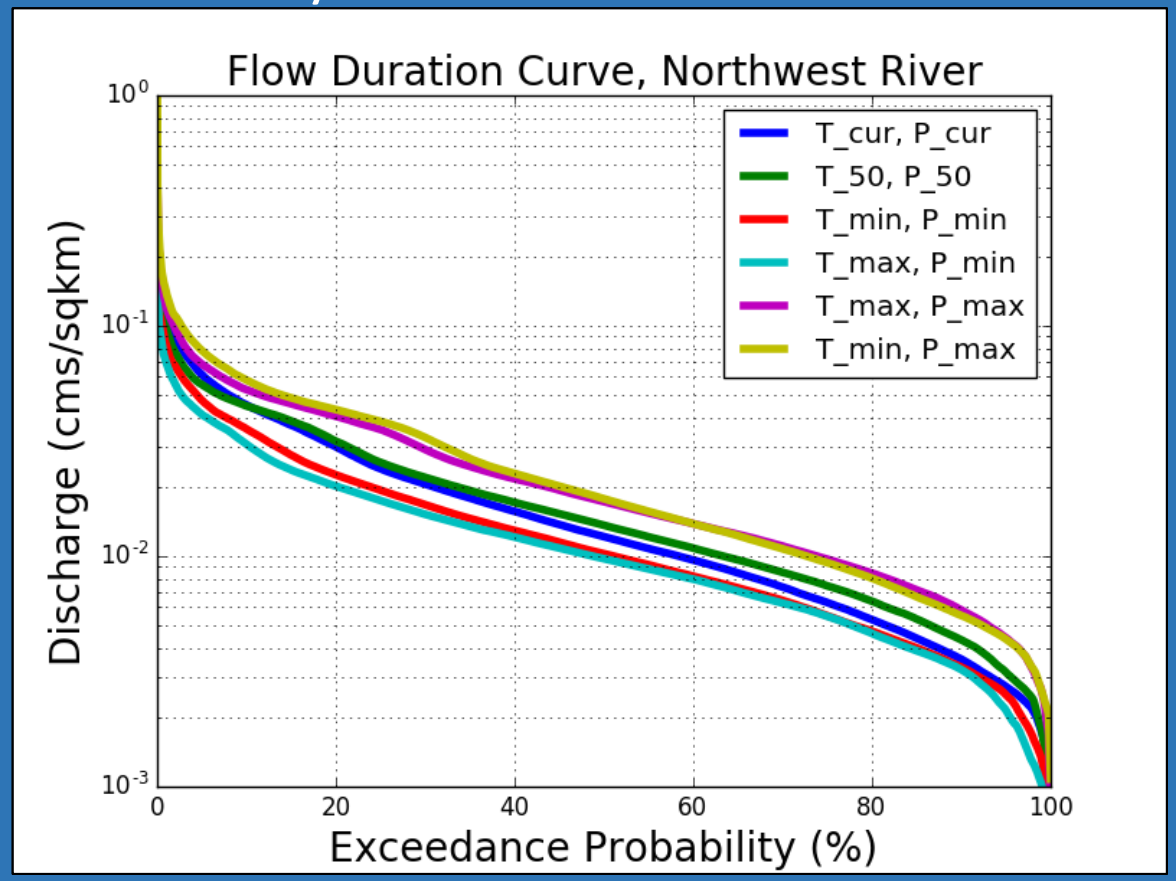




Hydrologic Fingerprint Residuals: Most visibly significant change is in snow melt timing and magnitude.



Changes in flow dynamics within and across study watersheds.



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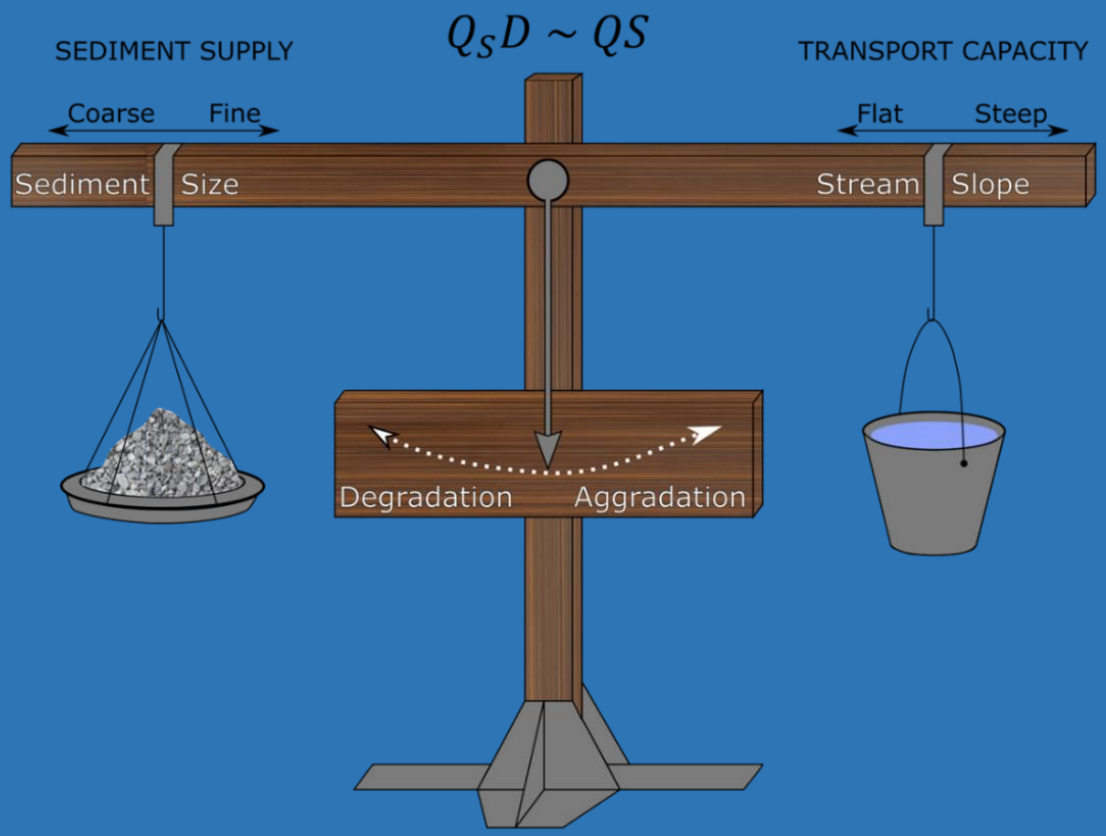
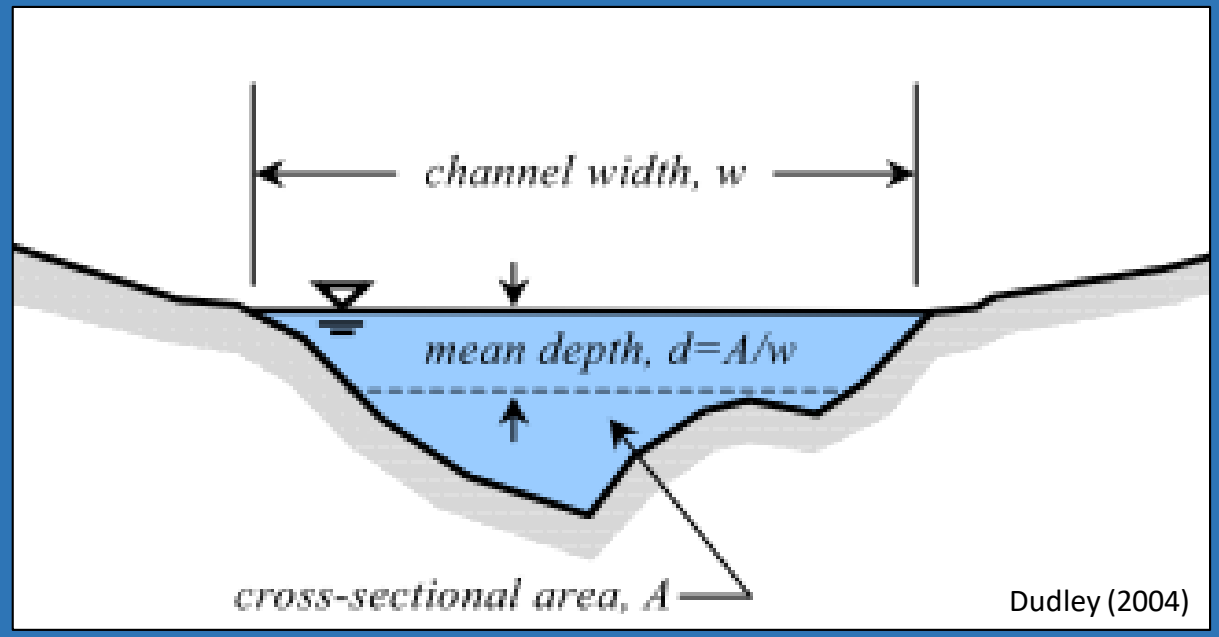
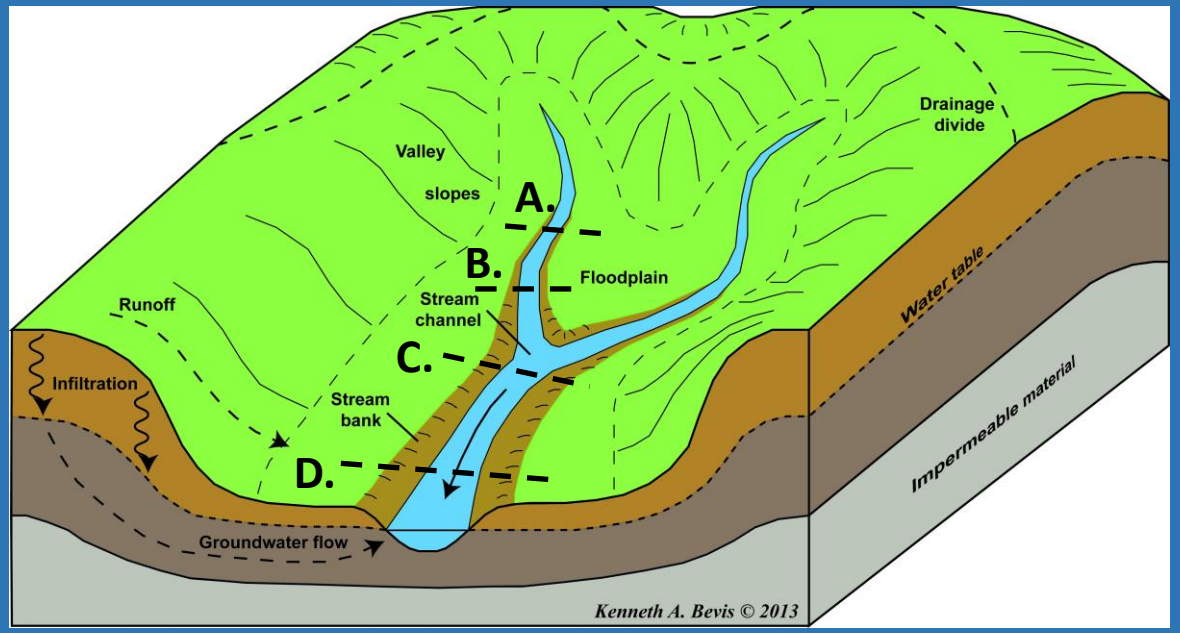


HYDRAULIC GEOMETRY

- At-A-Station:
  - How velocity, *depth*, and *width* vary in a channel cross section as a function of discharge.
- Downstream Geometry:
  - How cross section dimensions change as a function of drainage (contributing) area.



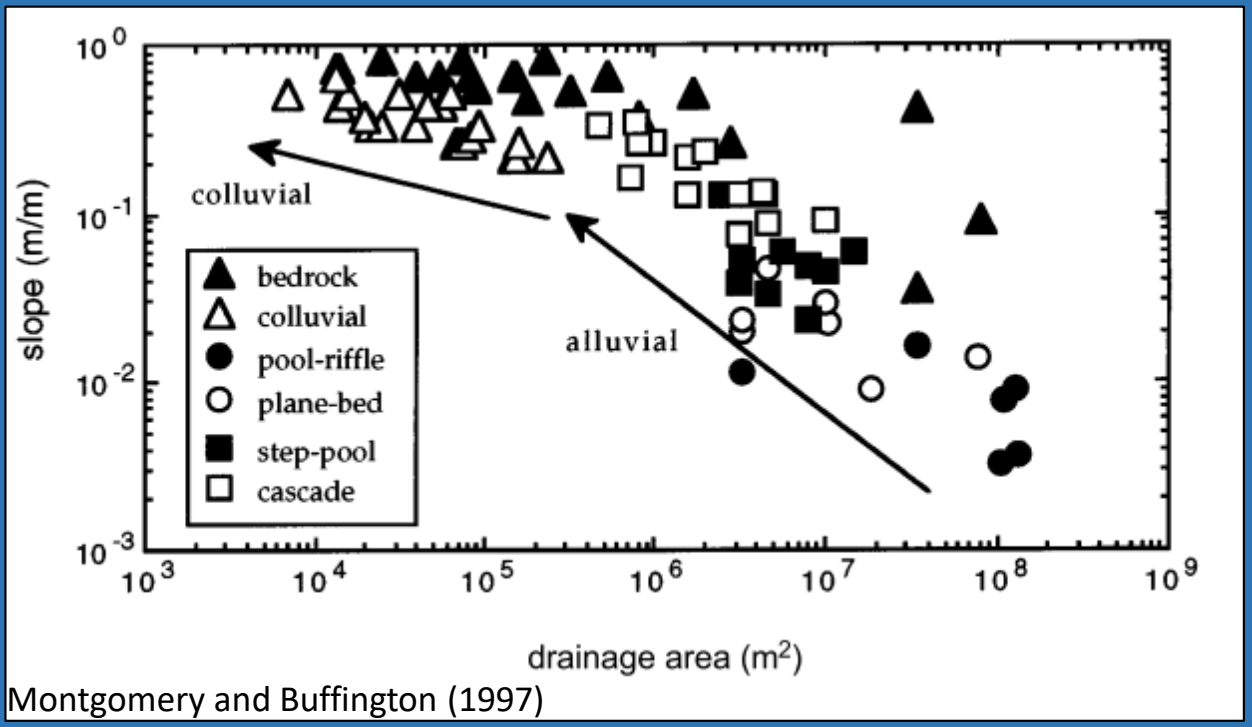
Dudley (2004)



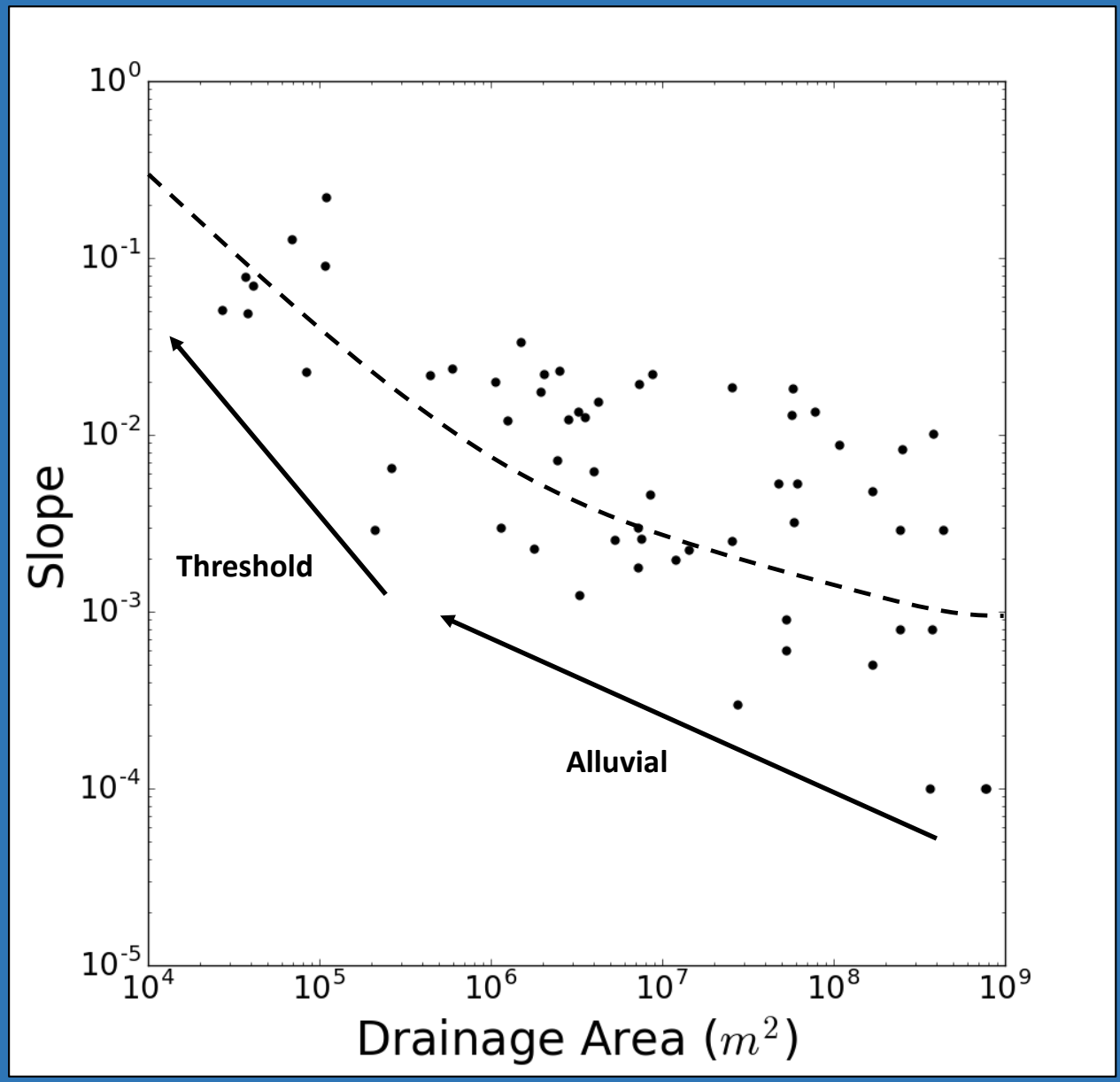
Leopold and Maddock (1953)

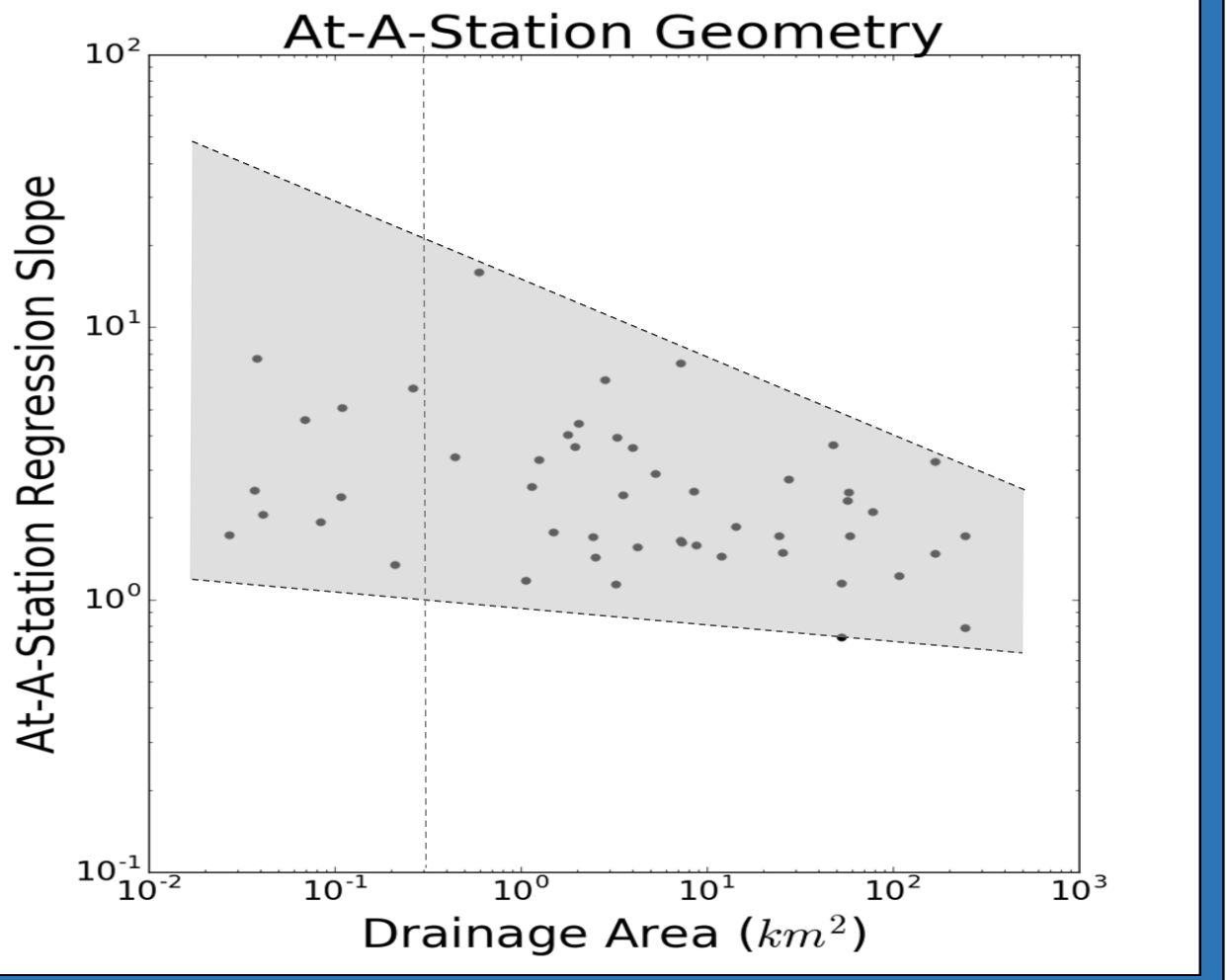
Data Collection

- Stations = 45
- Drainage Area Range = 0.03 – 170 km^2

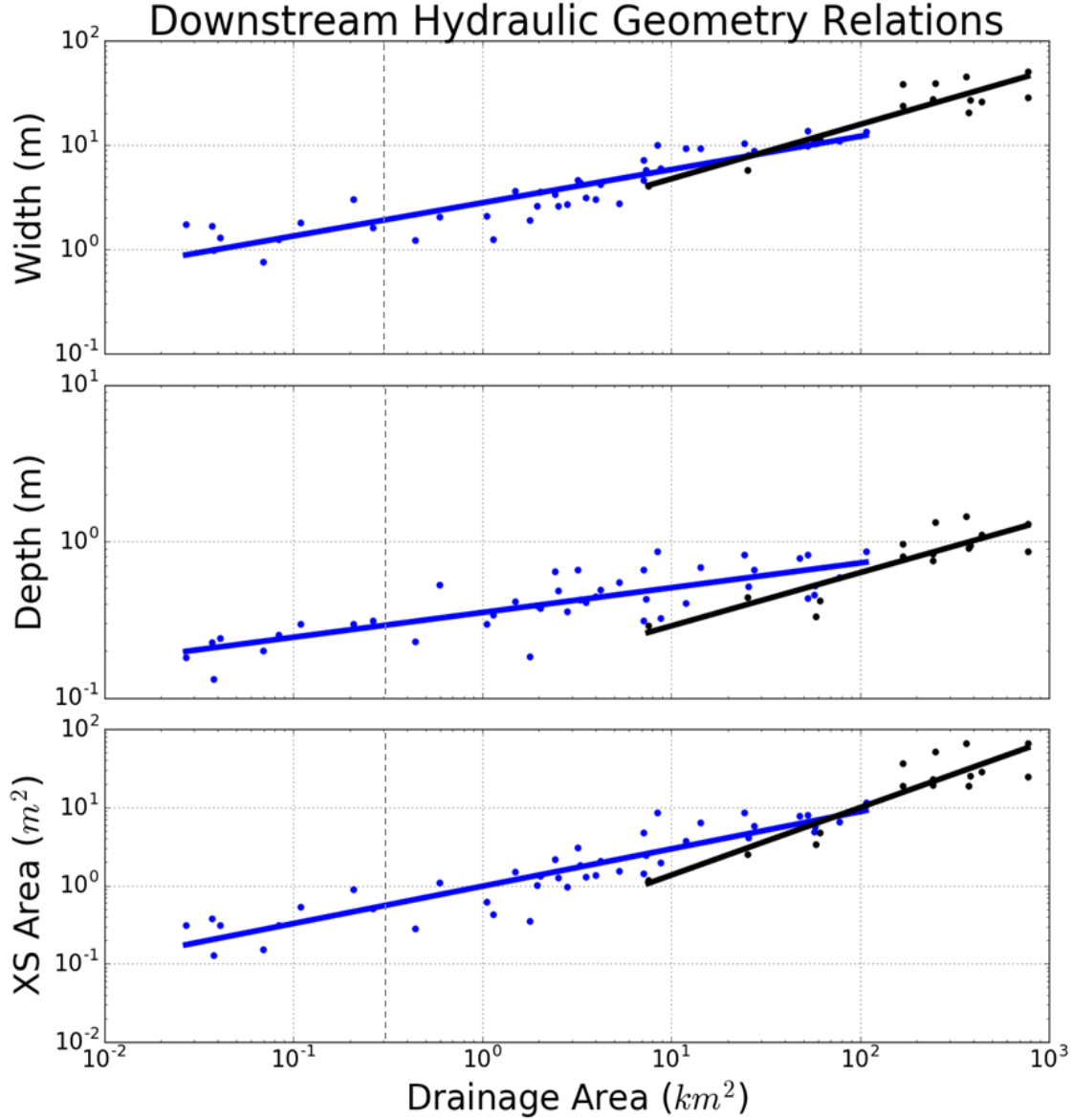


Montgomery and Buffington (1997)





Exaggeration of Channel Shape




L.E.A.
LAKES ENVIRONMENTAL ASSN.
TROUT
UNLIMITED
DEPARTMENT OF ENVIRONMENTAL PROTECTION
STATE OF MAINE
MAINE
DIRIGO
MAINE
MARINE RESOURCES

ACKNOWLEDGEMENTS

- Committee Members:
  - Dr. Sean Smith (Advisor), UMaine School of Earth and Climate Sciences
  - Dr. Andy Reeve, UMaine School of Earth and Climate Sciences
  - Dr. Damian Brady, UMaine Darling Center
  - Dr. Hamish Greig, UMaine School of Biology and Ecology
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  - Maine Agricultural and Forest Experiment Station
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  - UMaine Graduate Student Government Grants