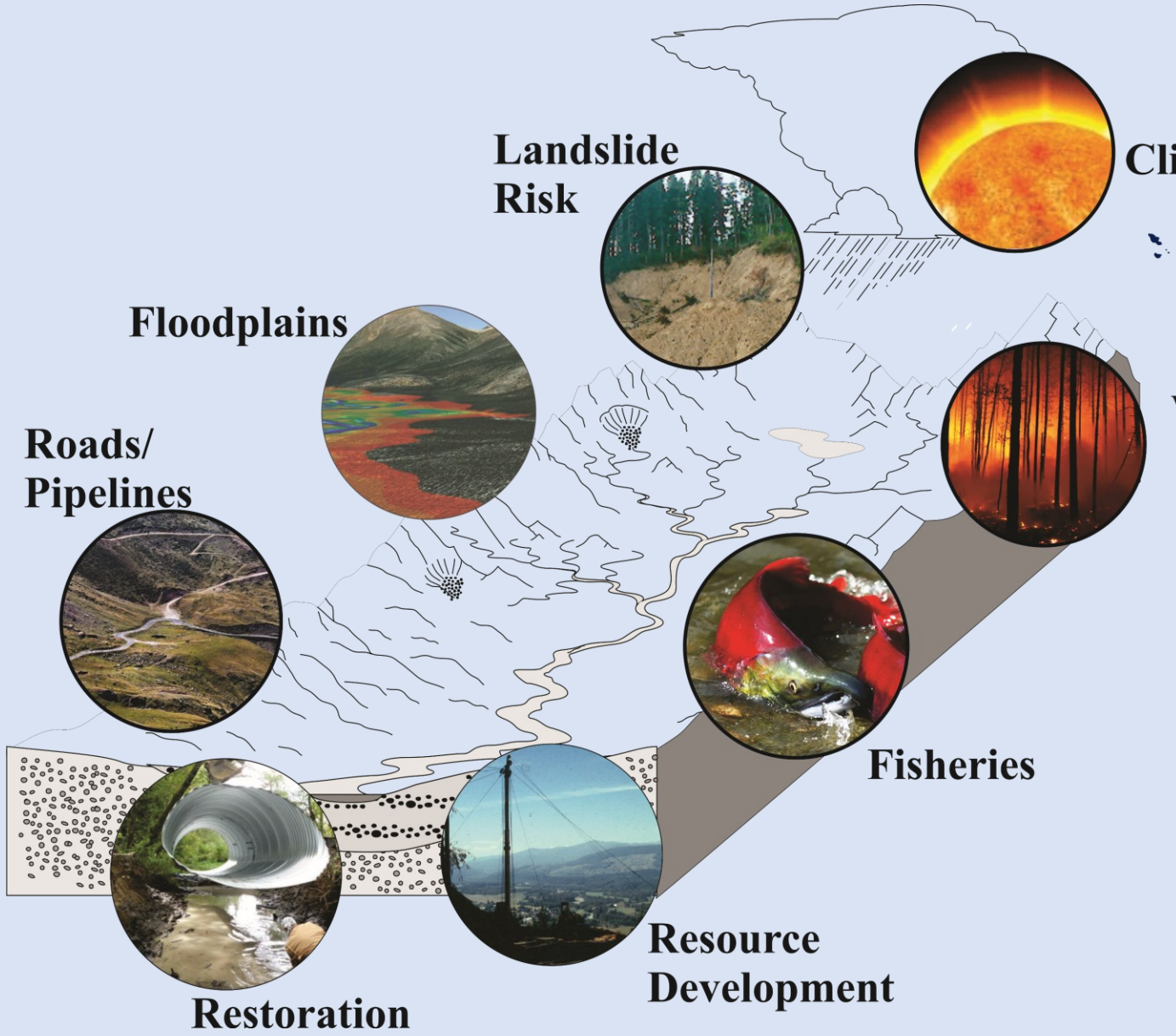
Virtual Watersheds in Alaska

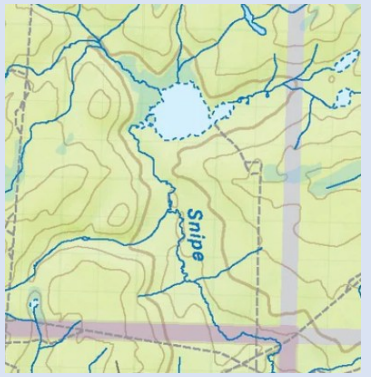


Lee Benda, Daniel Miller
Kevin Andras, TerrainWorks

End Users Questions--Applications

- Are there missing streams on maps?
- Is there missing salmon habitat?
- Where are flood-prone areas?
- Where is high landslide risk?
- Where is restoration most effective?

and many others….



Grass Roots

10 years

Hoonah Indian Association
Federally Recognized Tribe
Since 1939

The Wilderness Society

U.S. FISH & WILDLIFE SERVICE
DEPARTMENT OF THE INTERIOR

AYK-SSI
Arctic - Yukon - Kuskokwim Sustainable Salmon Initiative

Arctic
Yukon
Kuskokwim
Sustainable
Salmon
Initiative

Terrain Works

The Nature Conservancy

UAF
UNIVERSITY OF ALASKA FAIRBANKS

USDA
United States Department of Agriculture
Natural Resources Conservation Service

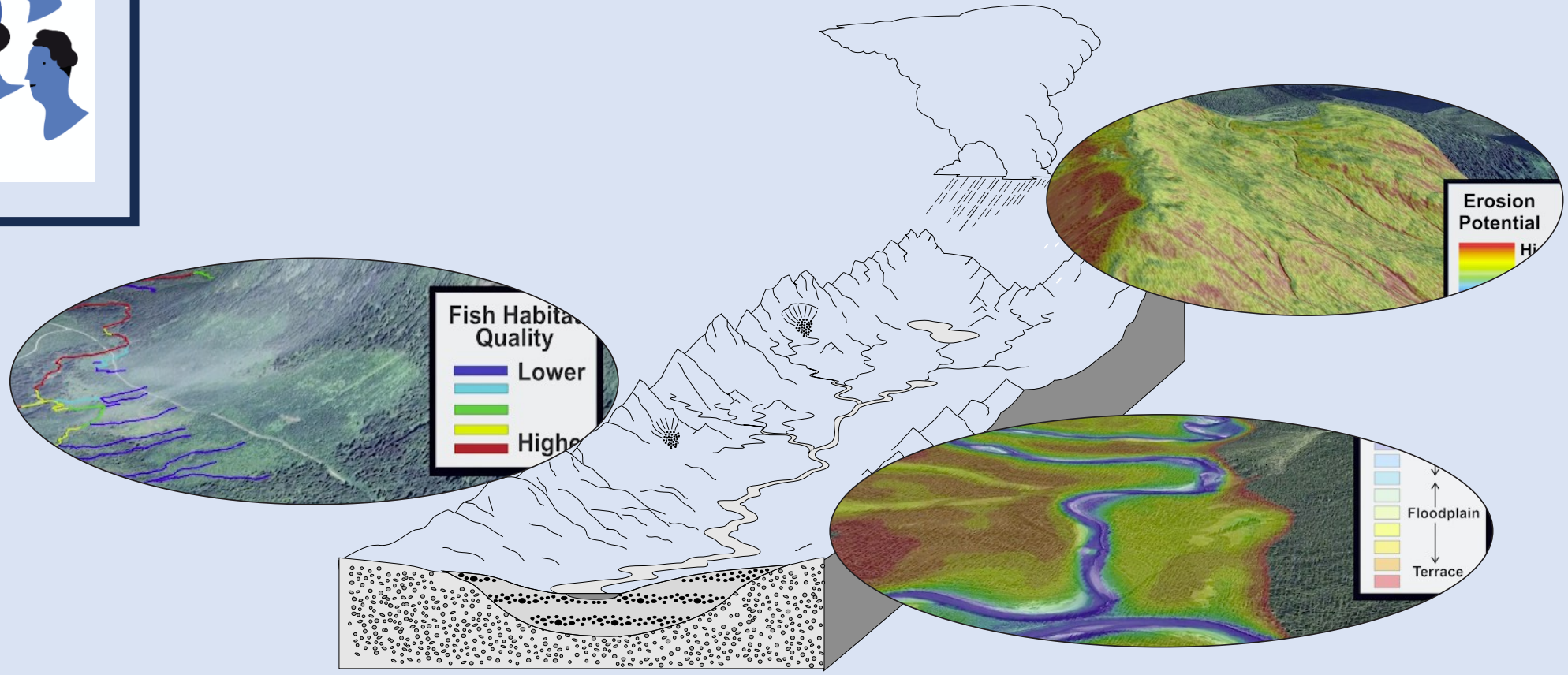
Keex' Kwáan Community Forest Partnership

USGS
U.S. Geological Survey
Alaska Science Center

Grass Roots

Virtual Watersheds & Tools

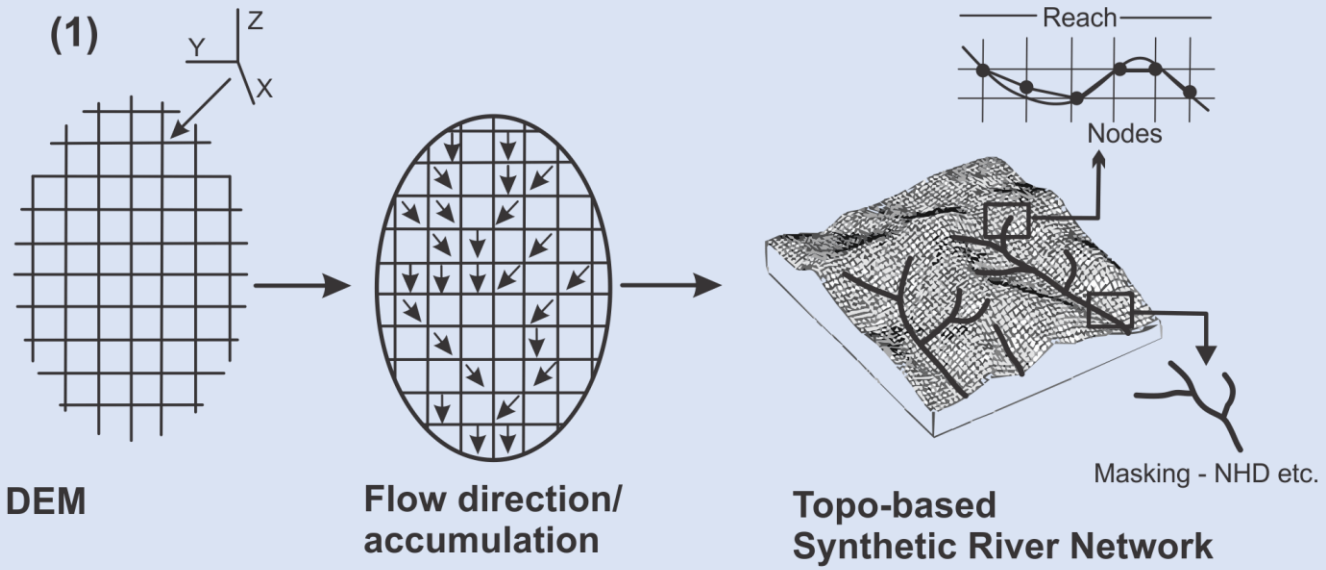
Multi-disciplinary Information and Analysis Platform

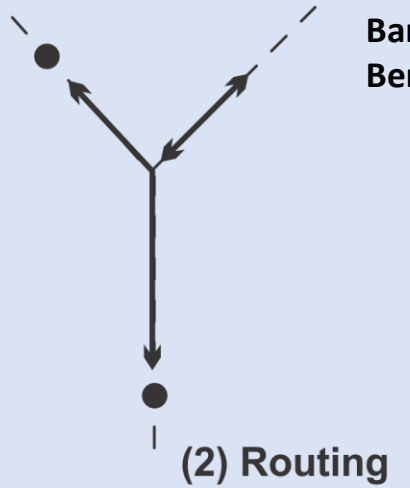


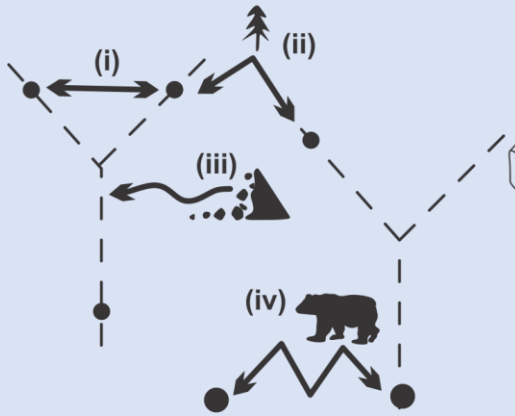
A channel network-watershed data structure that connects lotic, lentic, and terrestrial ecosystems that is designed for applications

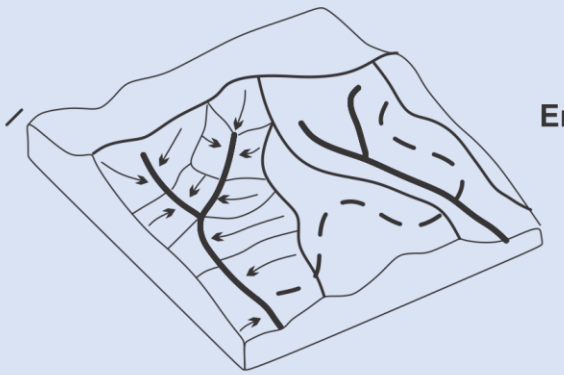
Structure of a virtual watershed (NetMap)

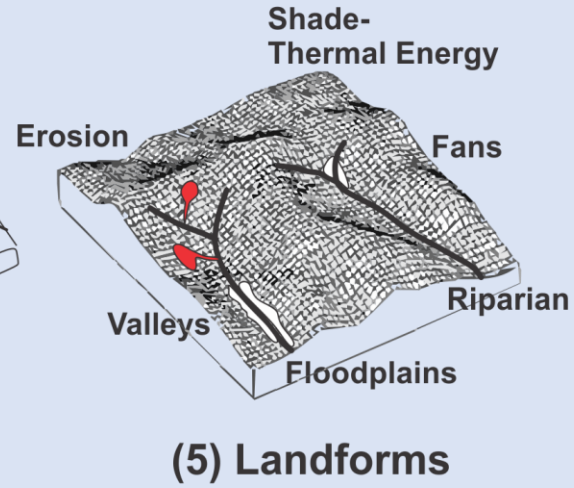
(Benda et al. 2007; Benda and Miller 2009; Benda et al. 2011; Miller et al. 2014; Barquin et al. 2015; Benda et al. 2015; Benda et al. submitted)

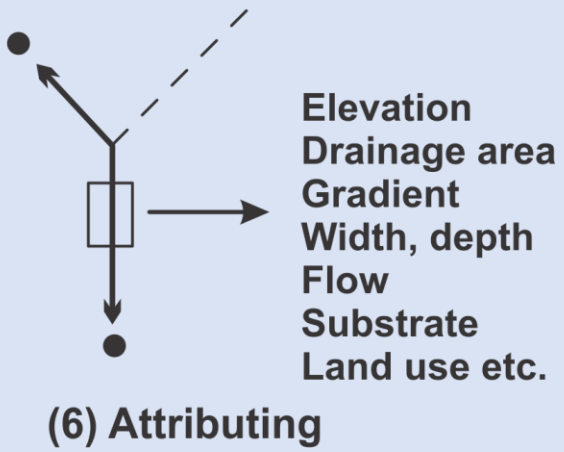




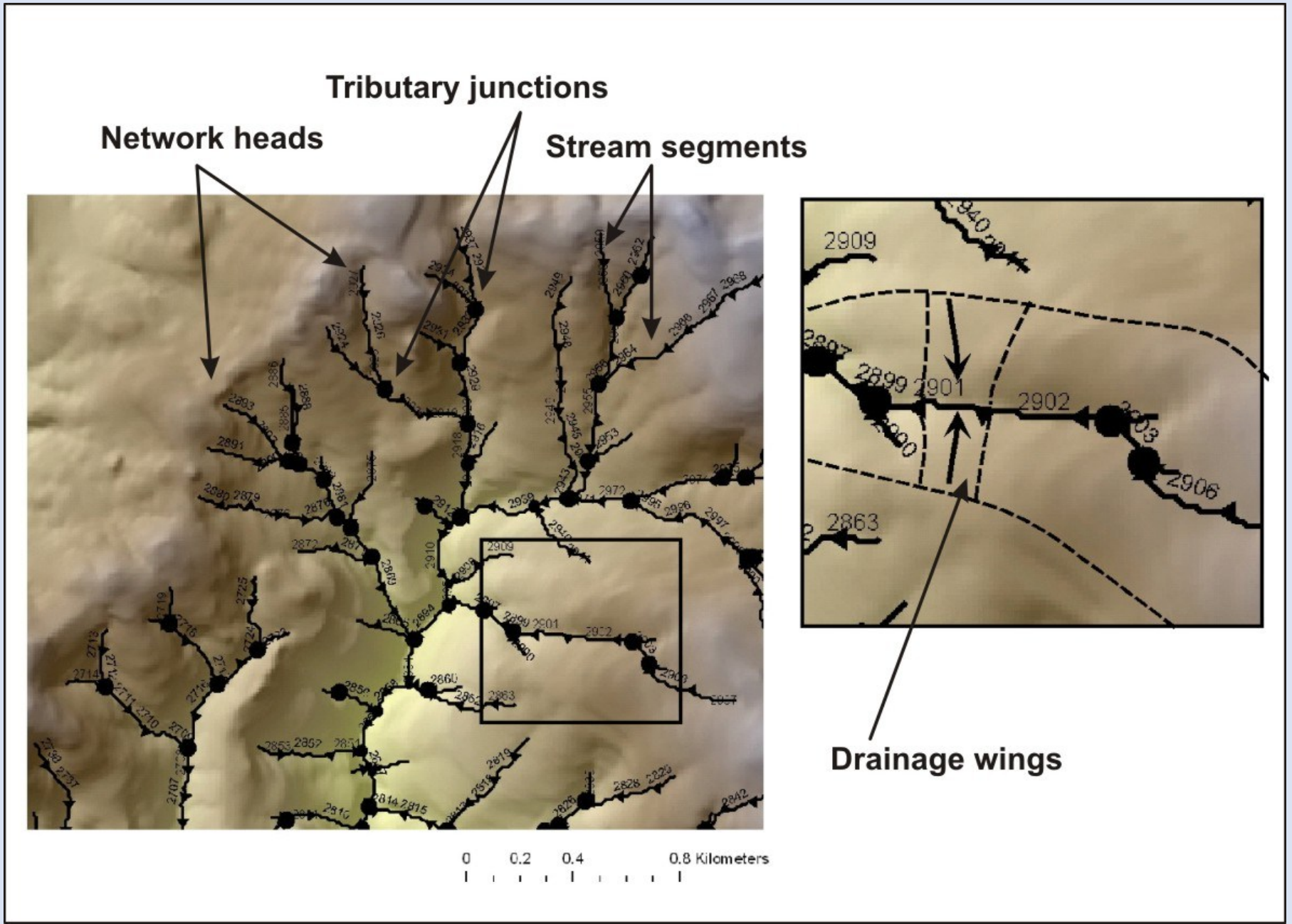








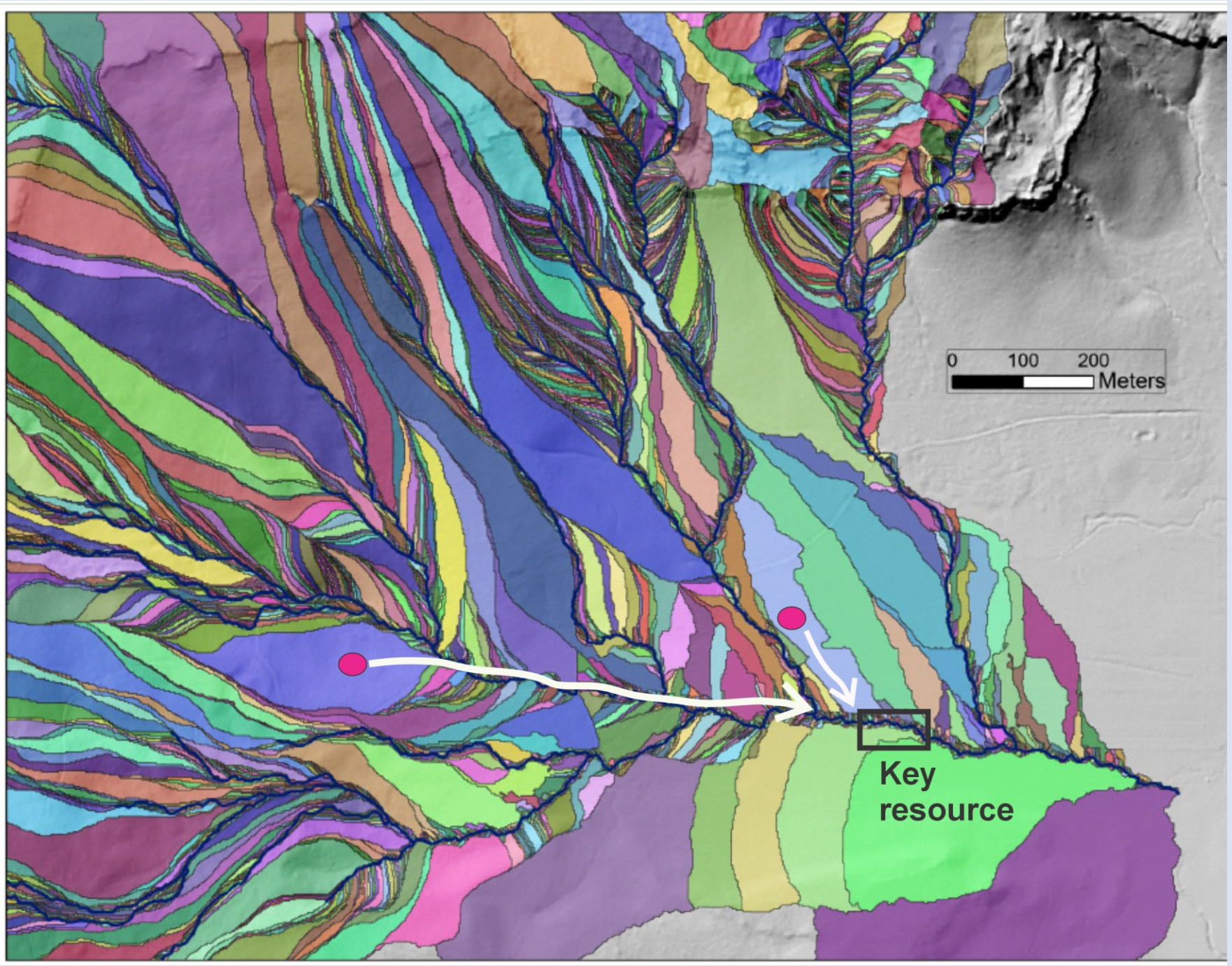
Virtual Watershed: terrestrial - channel connections



Linking hillslopes and floodplains to channels.

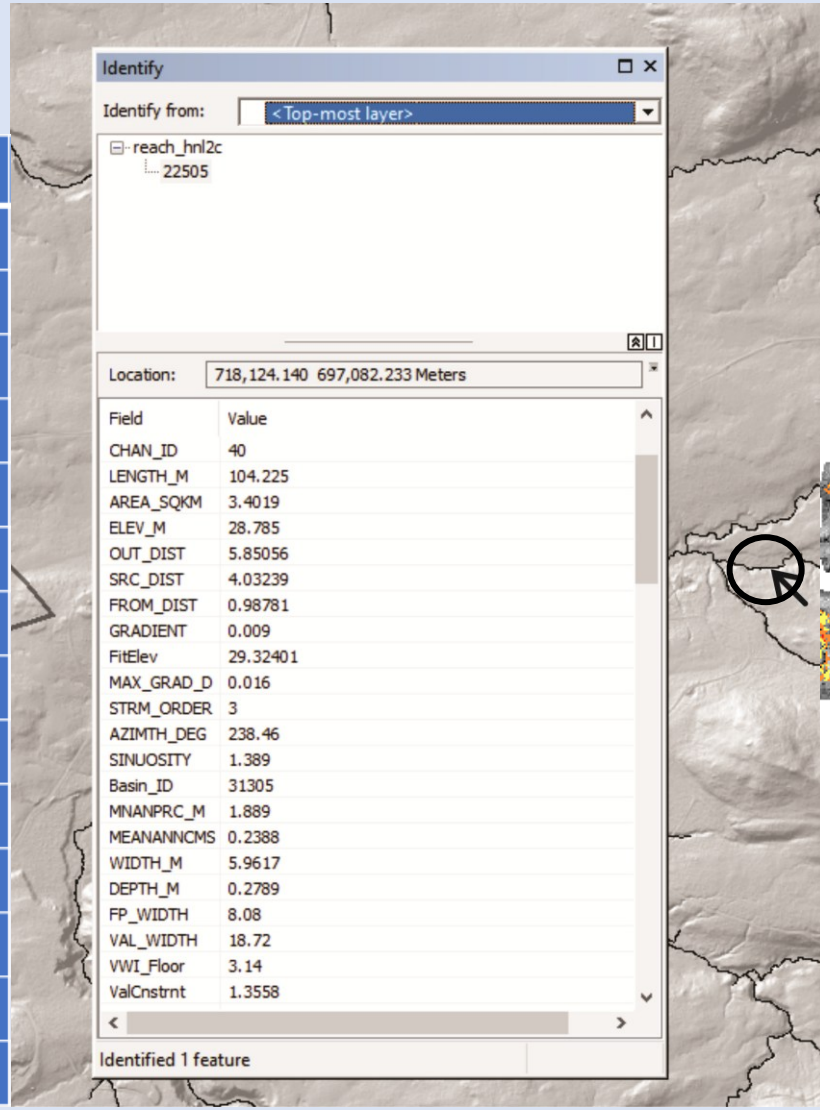
Drainage Wings

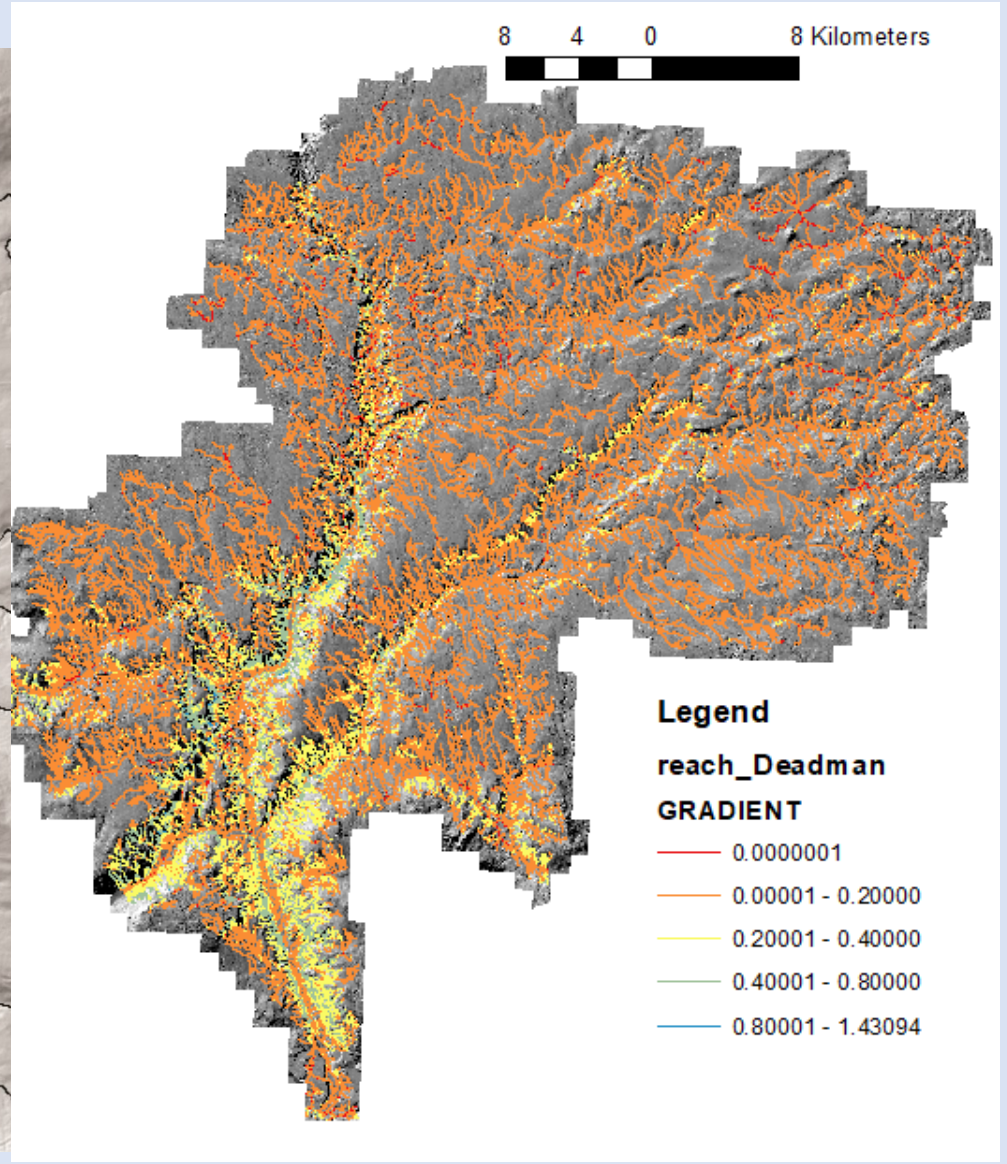
Each “wing” delineates the area draining to a single channel node.

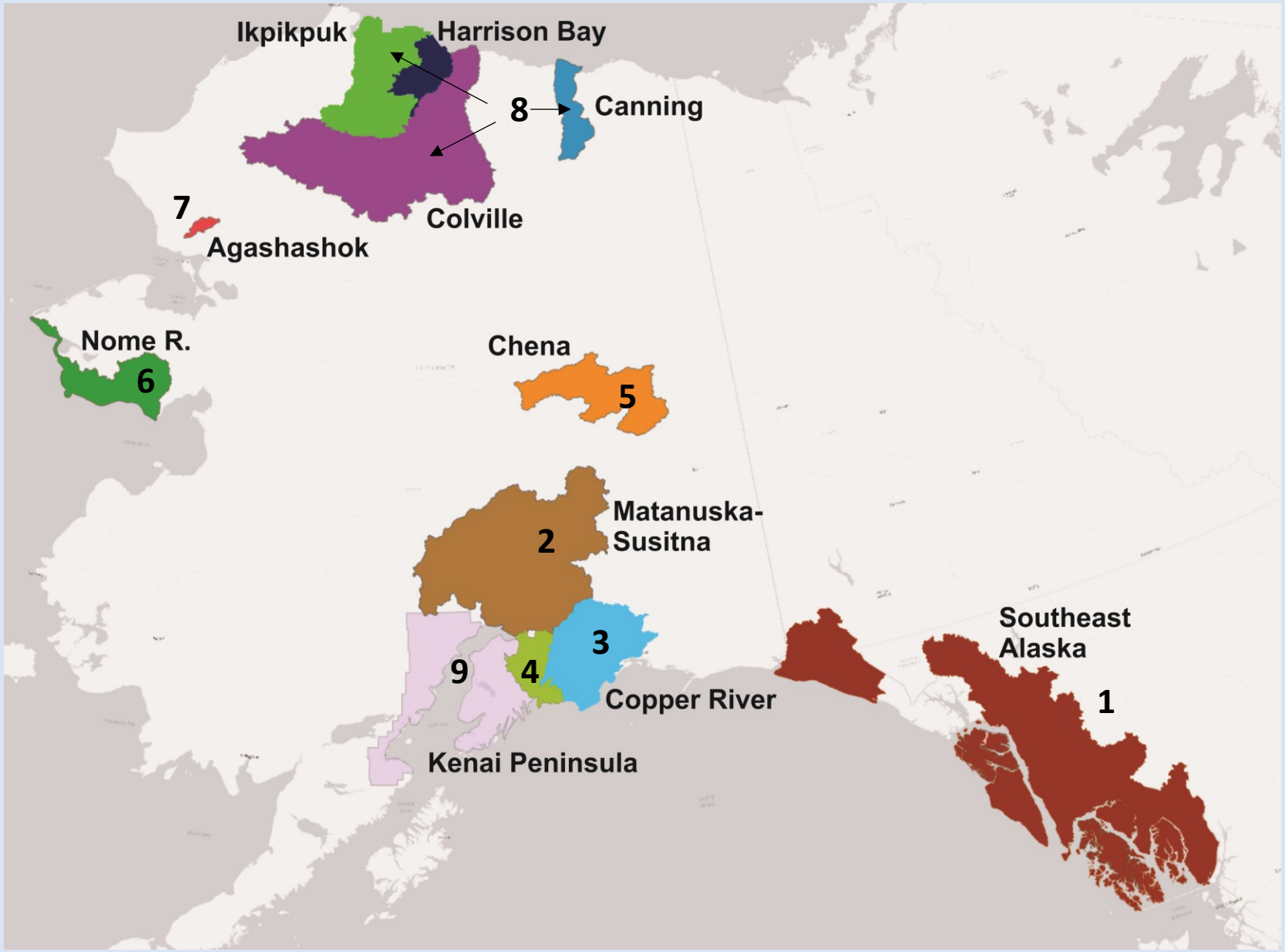


Each node or 100-m stream segment contains numerous channel and upstream watershed information

- Channel Attributes
- Gradient
- Elevation
- Distance to outlet
- Drainage area
- Mean flow
- Stream order
- Channel width and depth
- Bed substrate
- Channel sinuosity
- Channel classification
- Fish habitats
- Radiation loading
- Mean annual precipitation
- Gradient





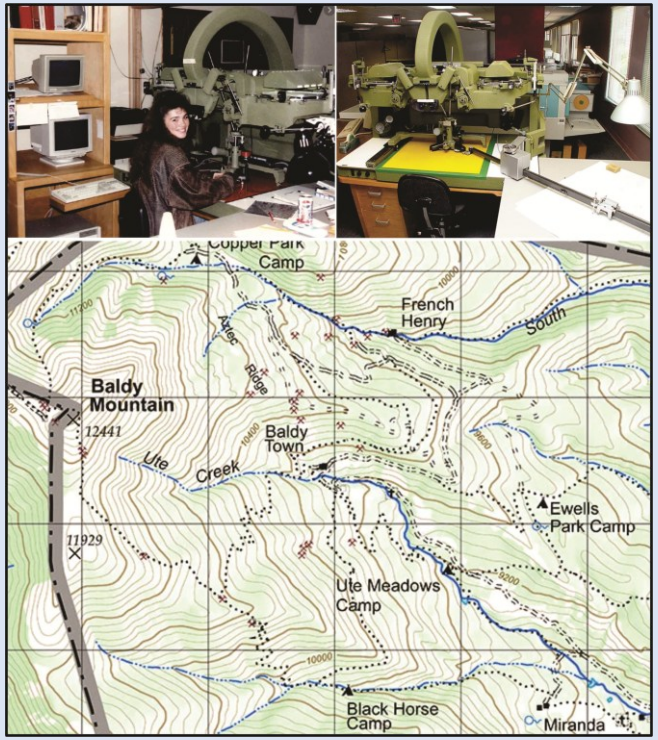


Existing IfSAR and LiDAR based virtual watersheds

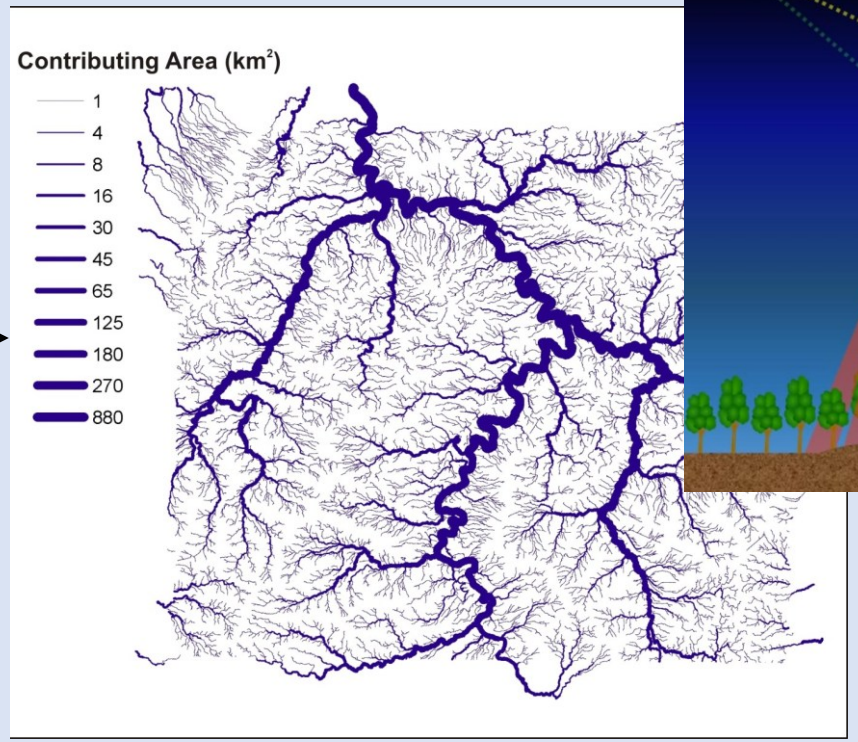
1) US Forest Service-Tongass/NRCS/Sealaska
2) The Nature Conservancy (+ partners)
3) Ecotrust/USFS
4) Chugach National Forest
5) Univ. of Alaska/US Fish & Wildlife
6) Arctic-Yukon Sustainable Salmon Initiative
7) USGS Fisheries
8) The Wilderness Society
9) Kenai Watershed Council

Example Applications

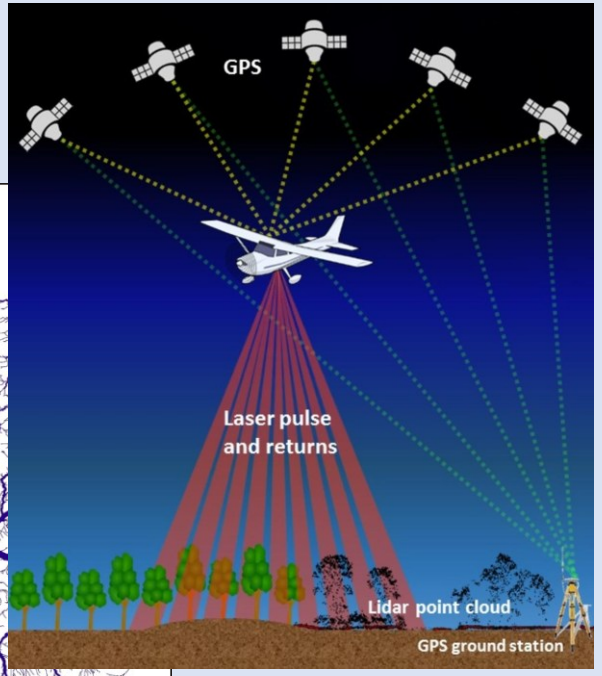
- More comprehensive & accurate networks – Matanuska-Susitna
- Salmon habitat mapping (finding missing habitats)—Chichigof Island, SE AK
- Floodplain and riparian mapping - Prince of Wales Island
- Landslides and debris flows - Sitka, Wrangell, Petersburg
- Forest roads and salmon (fish blockages) - Kupreanof Island



Older “Cartographic”

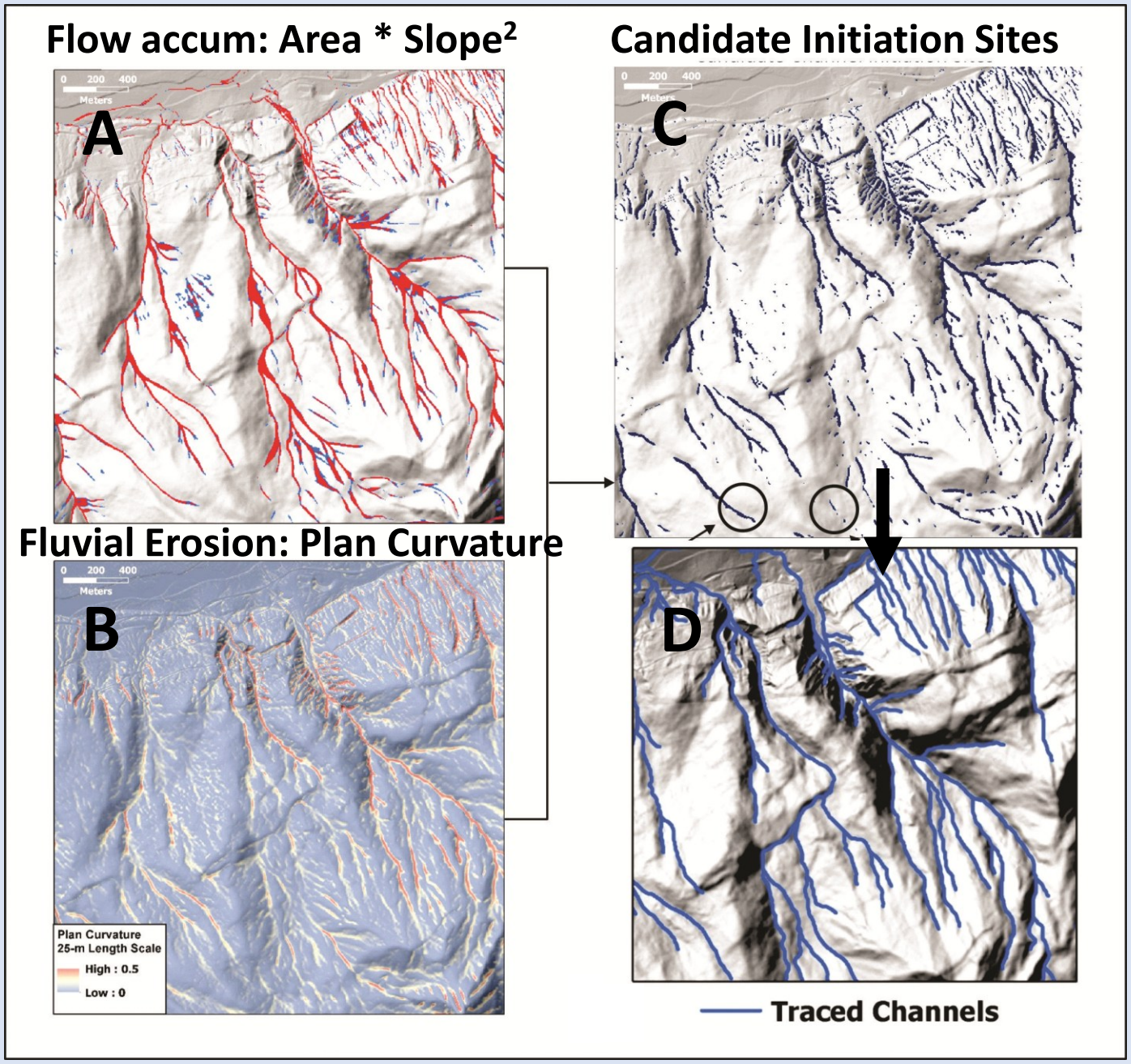


DEM derived “synthetic”



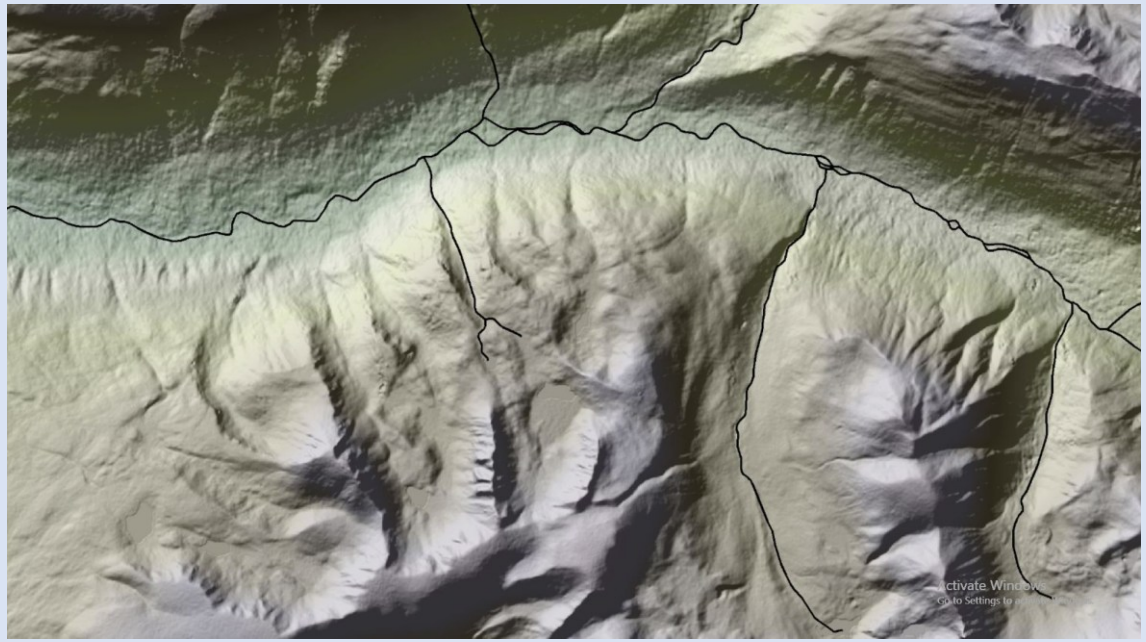
- **More comprehensive & accurate networks – Matanuska-Susitna**

Synthetic channel extraction from IfSAR or LiDAR DEM



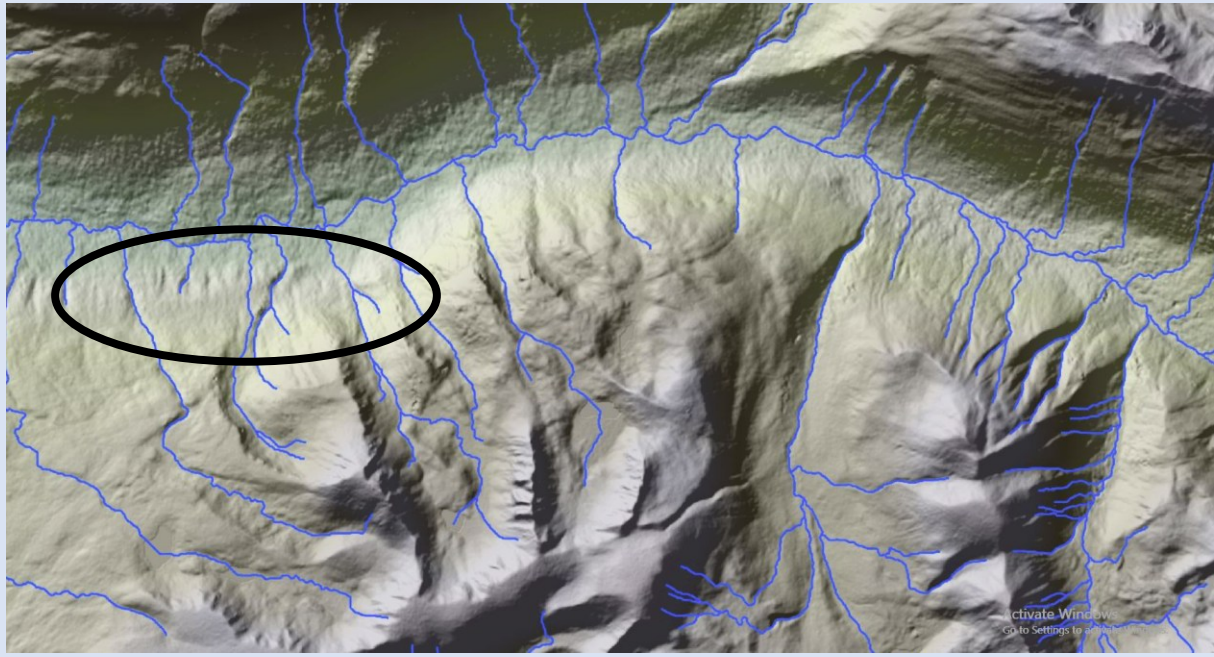
- **More comprehensive & accurate networks – Matanuska-Susitna**

Old Cartographic (NHD) Stream Network

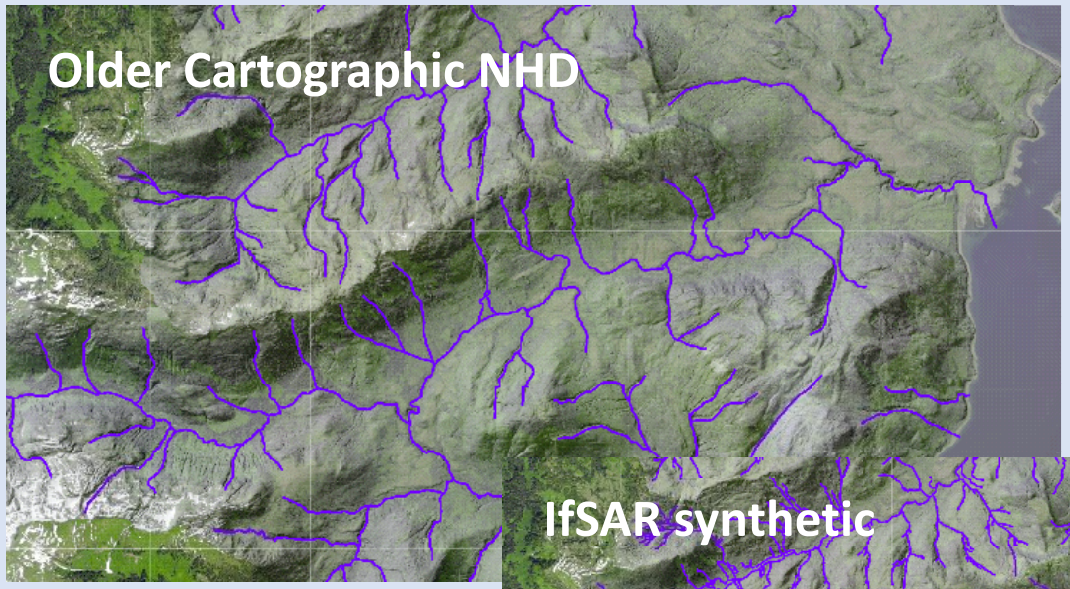


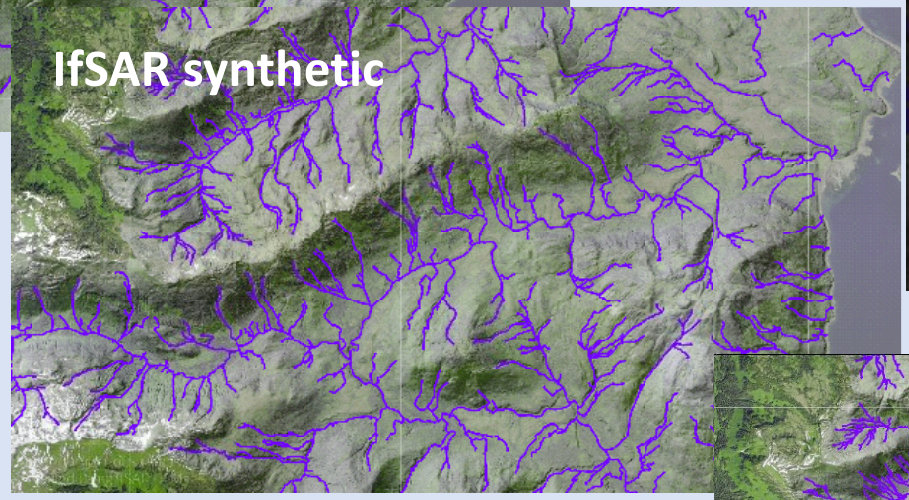
An additional 25,000 miles of new stream channels were identified on new maps in the Mat-Su basin.

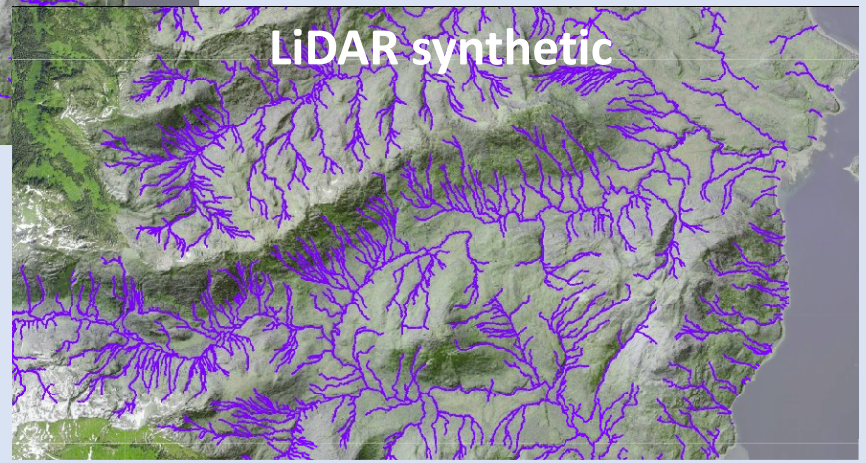
New LiDAR Synthetic Network

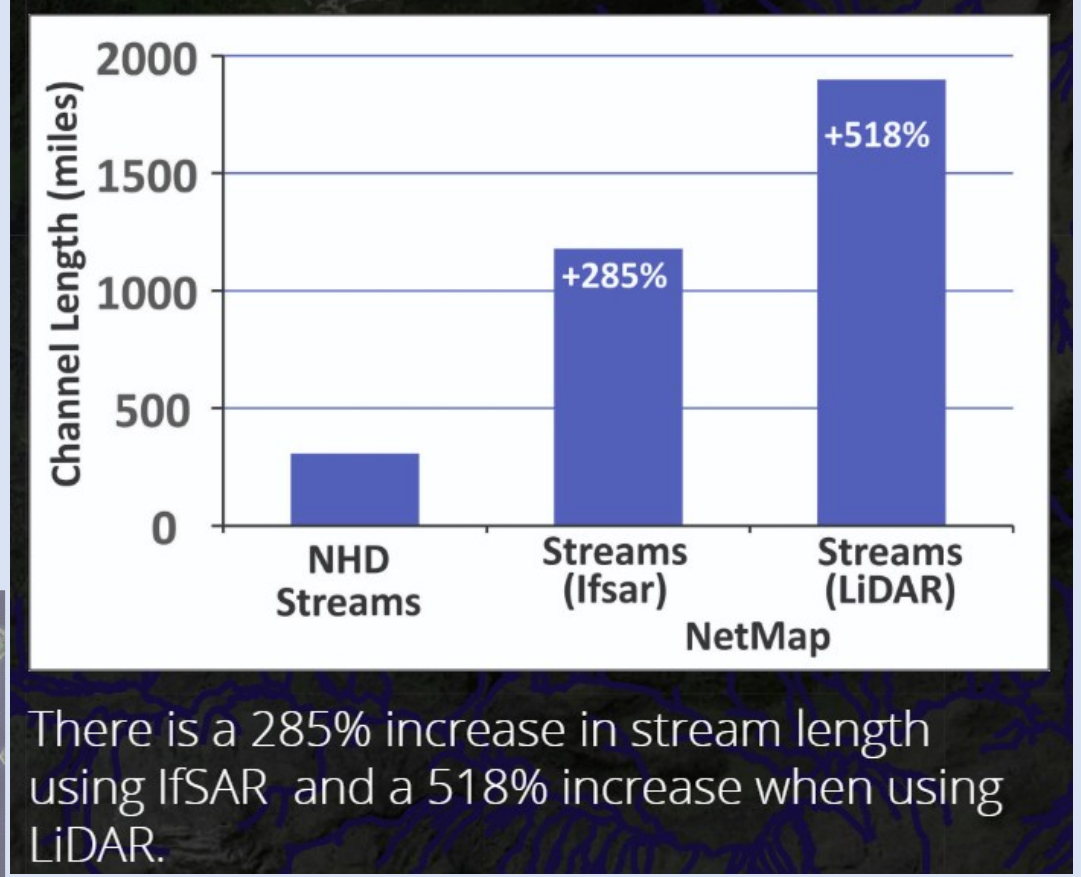


Chichigof Island, Southeast Alaska







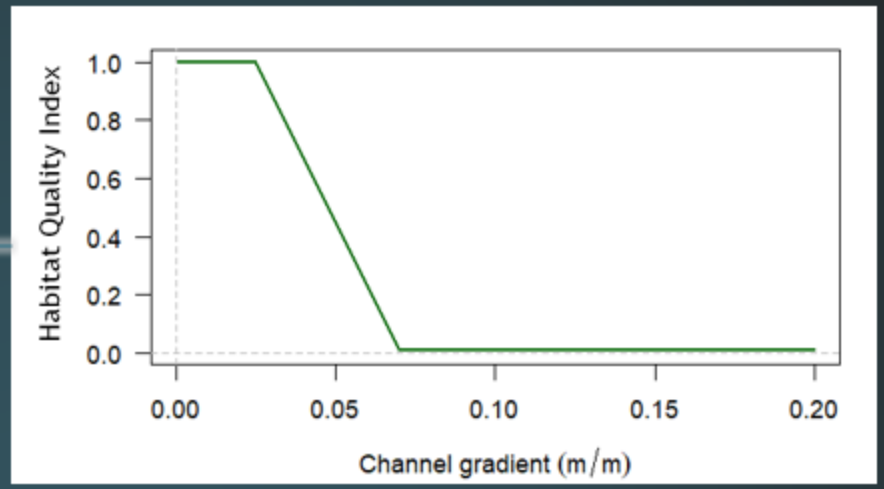


There is a 285% increase in stream length using IfSAR and a 518% increase when using LiDAR.

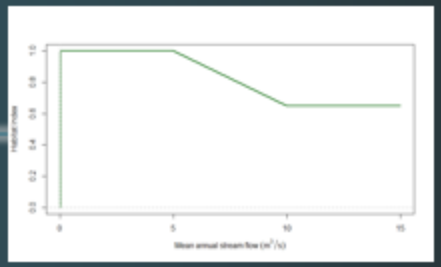
- **Salmon habitat mapping (finding missing habitats)—Chichigof Island, SE AK**

HIP Modeling Process

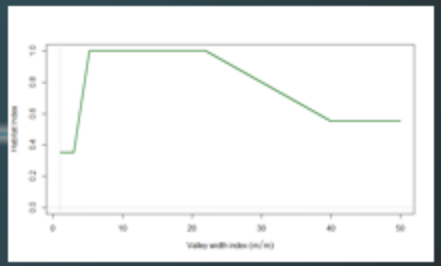
1. Develop synthetic LiDAR stream network and habitat attributes (NetMap)
2. Fish density range converted to habitat Index (0-1) for each attribute (Random Forest Partial Dependency)
3. Geometric mean of habitat index for stream reach
4. HIP (habitat quality) then predicted/mapped for entire landscape



Mean Annual Flow



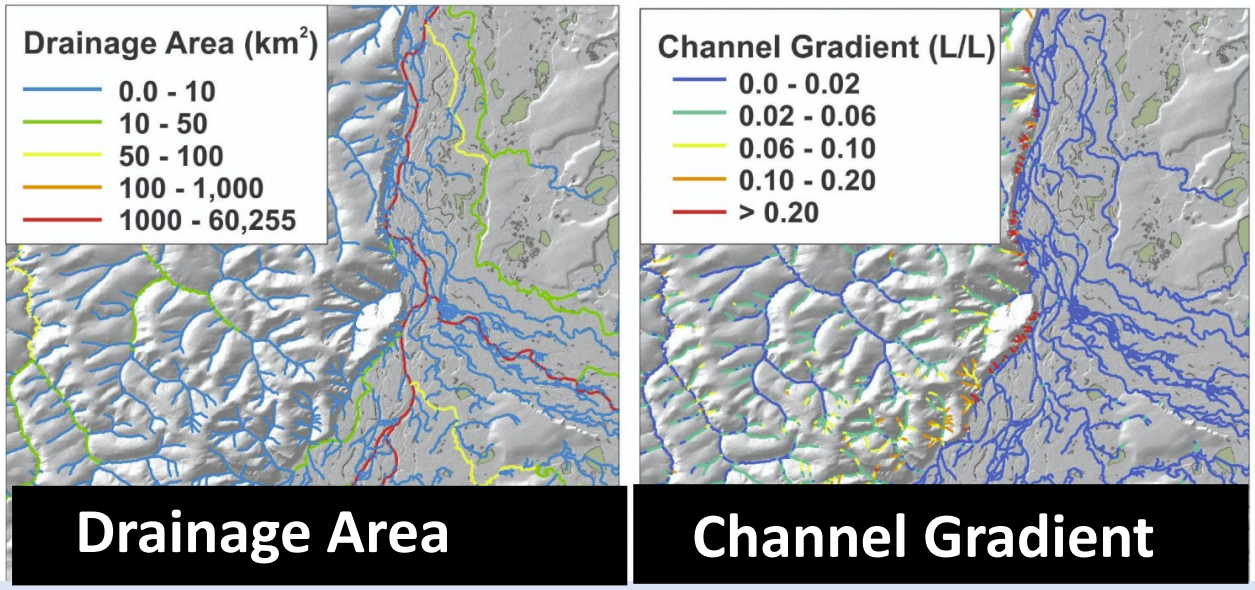
Valley Width Index



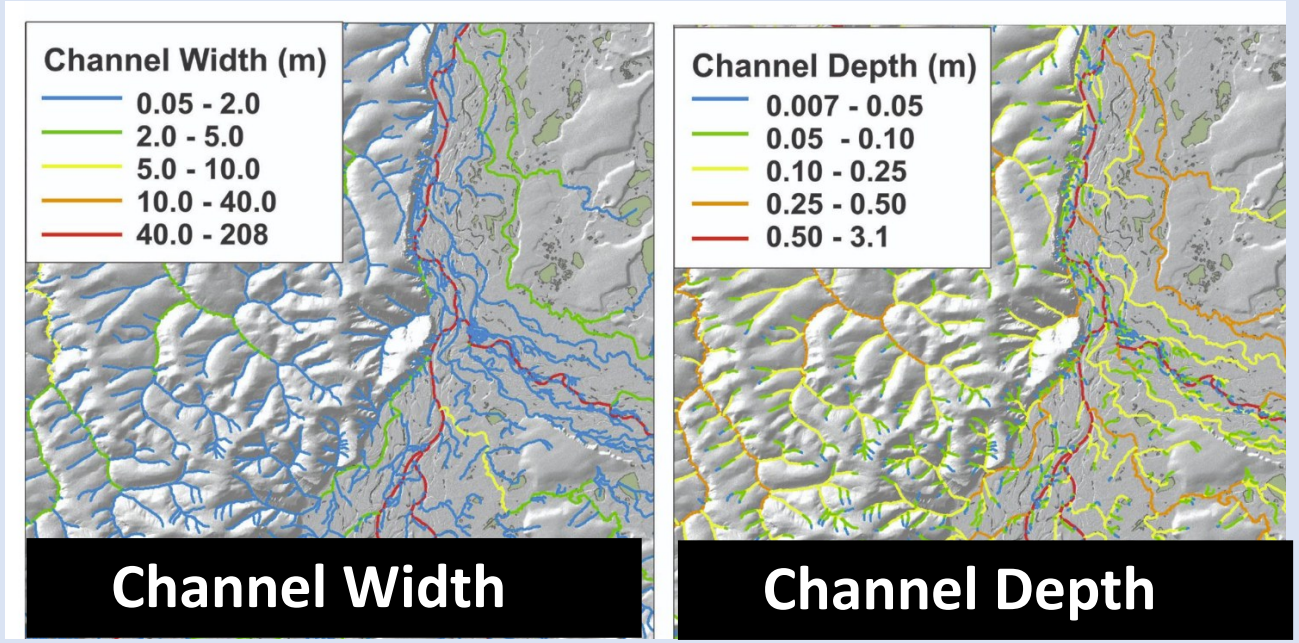
Potential to provide high-quality habitat

$$Reach\ HIP = \sqrt[3]{IP_{grad} IP_{flow} IP_{VWI}}$$

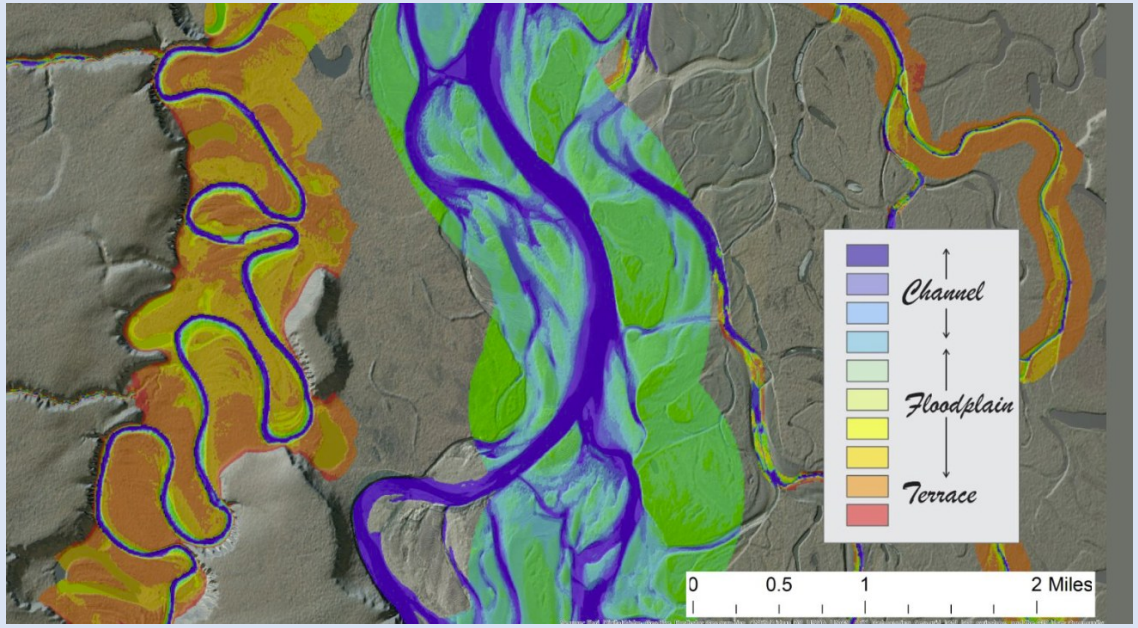
- **Salmon habitat mapping (finding missing habitats)—Chichigof Island, SE AK**



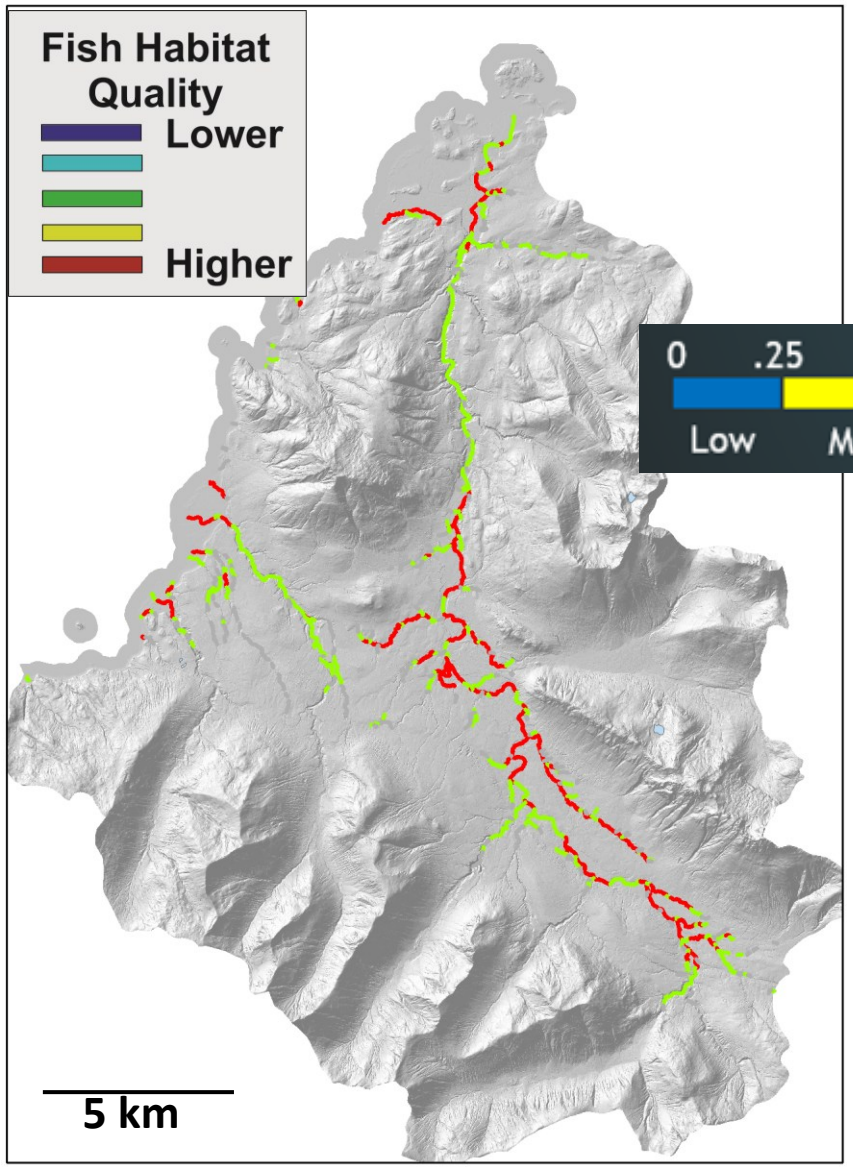
Requires watershed & channel attributes



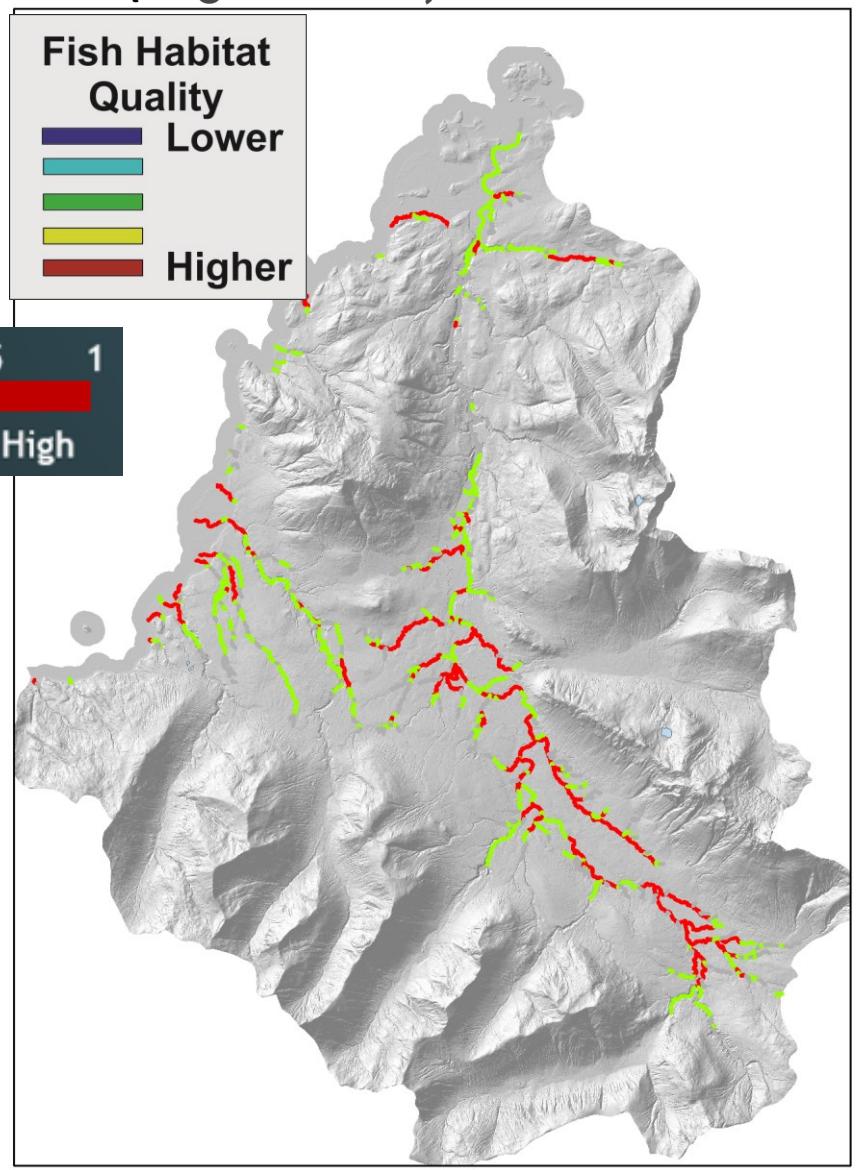
Floodplains/channel confinement



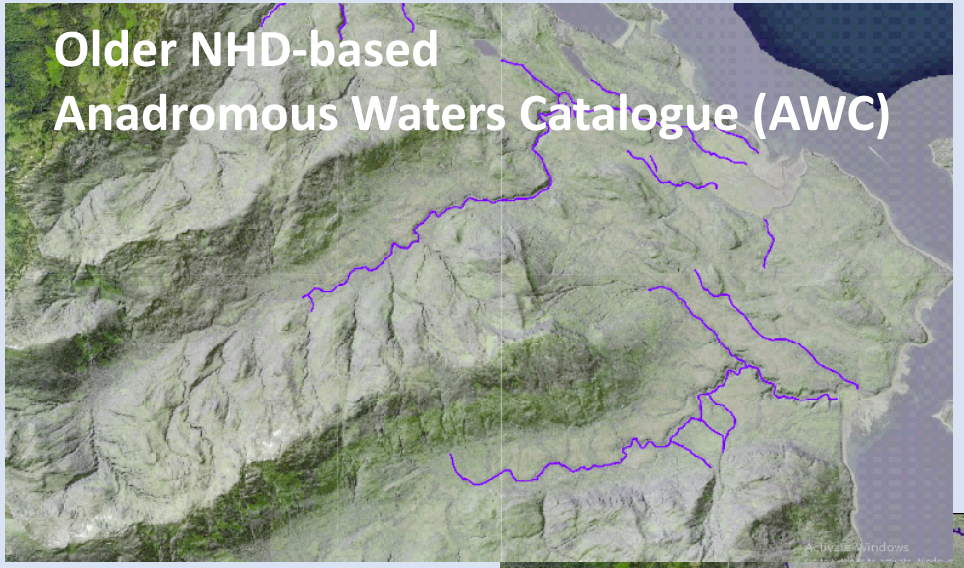
Chum (Oncorhynchus keta)

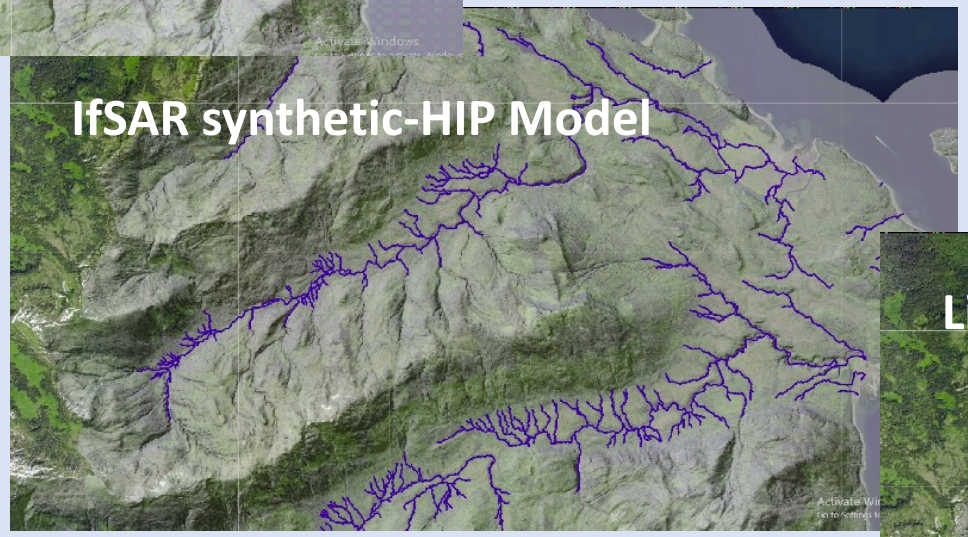


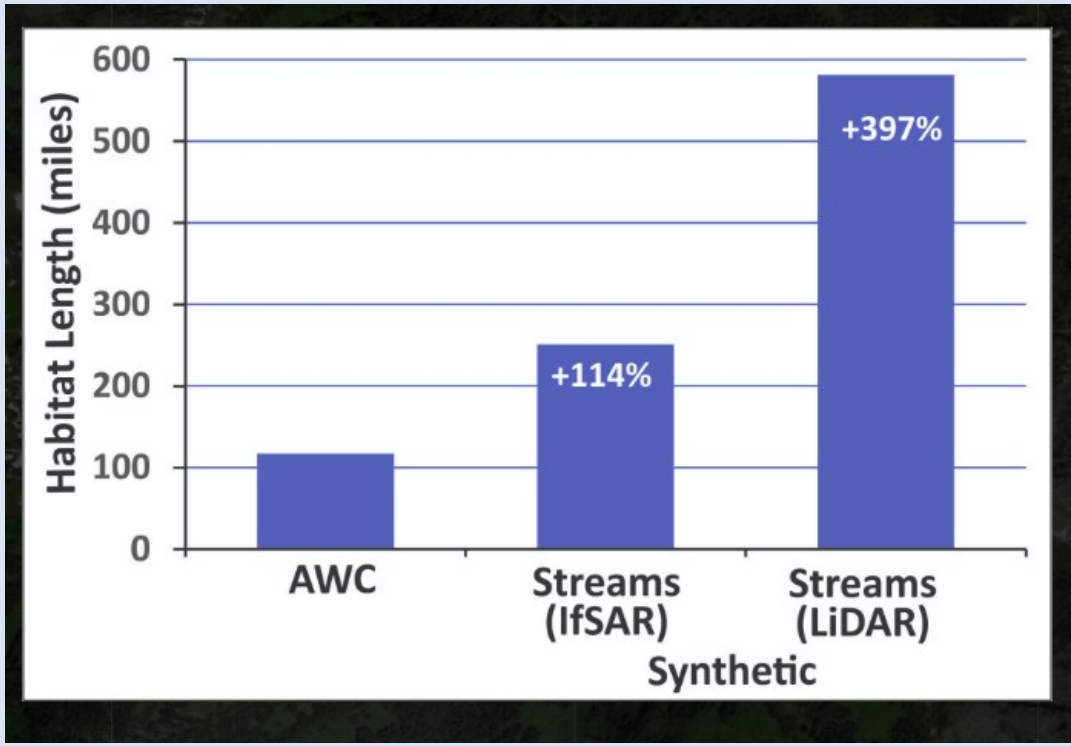
Pink (O. gorbuscha)

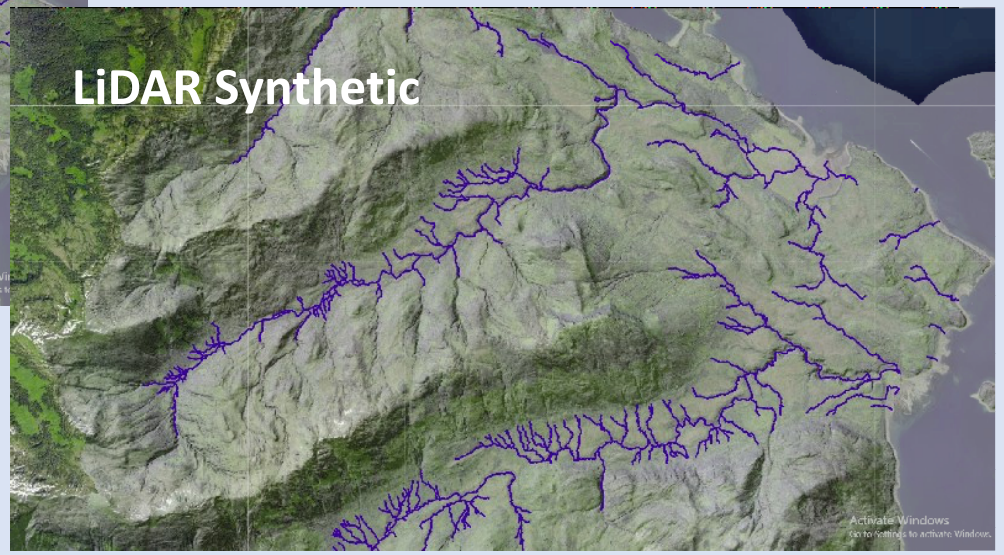


- **Coho salmon habitat mapping—Chichigof Island, SE AK**

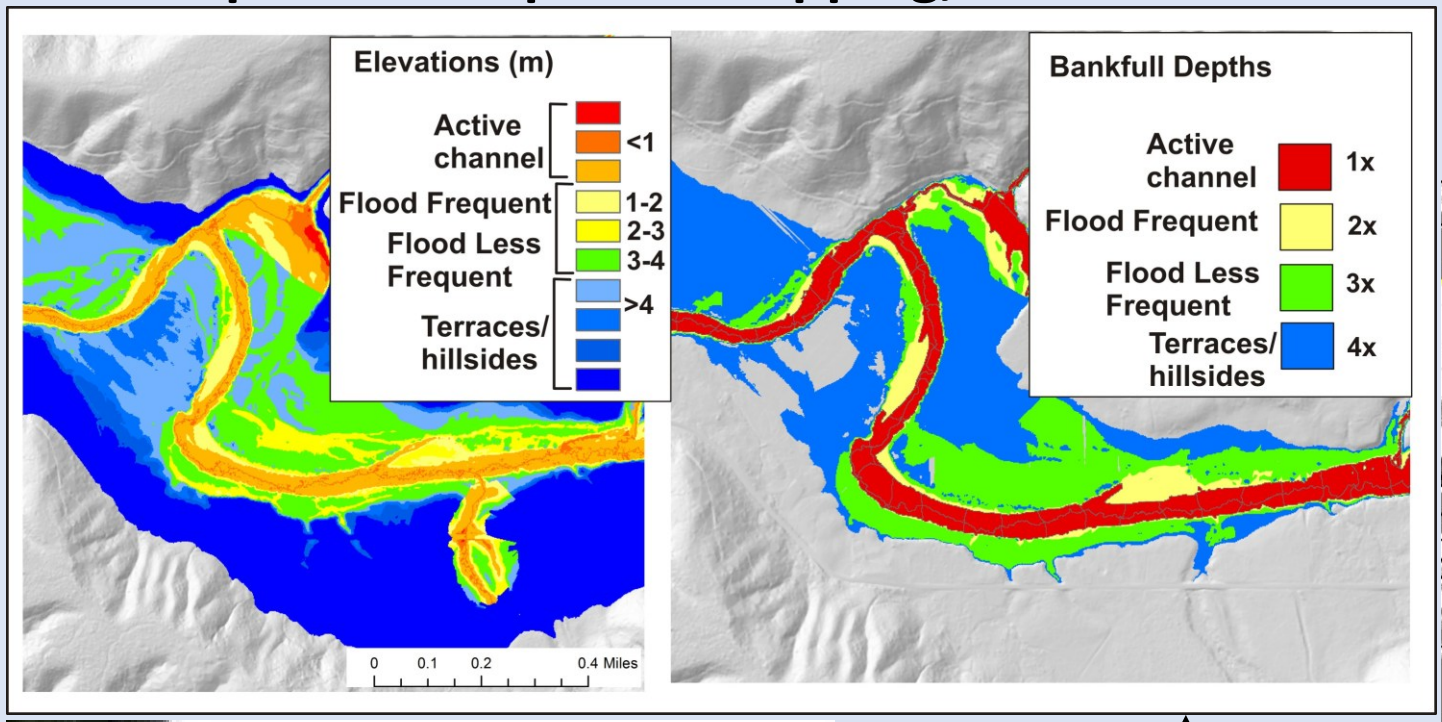






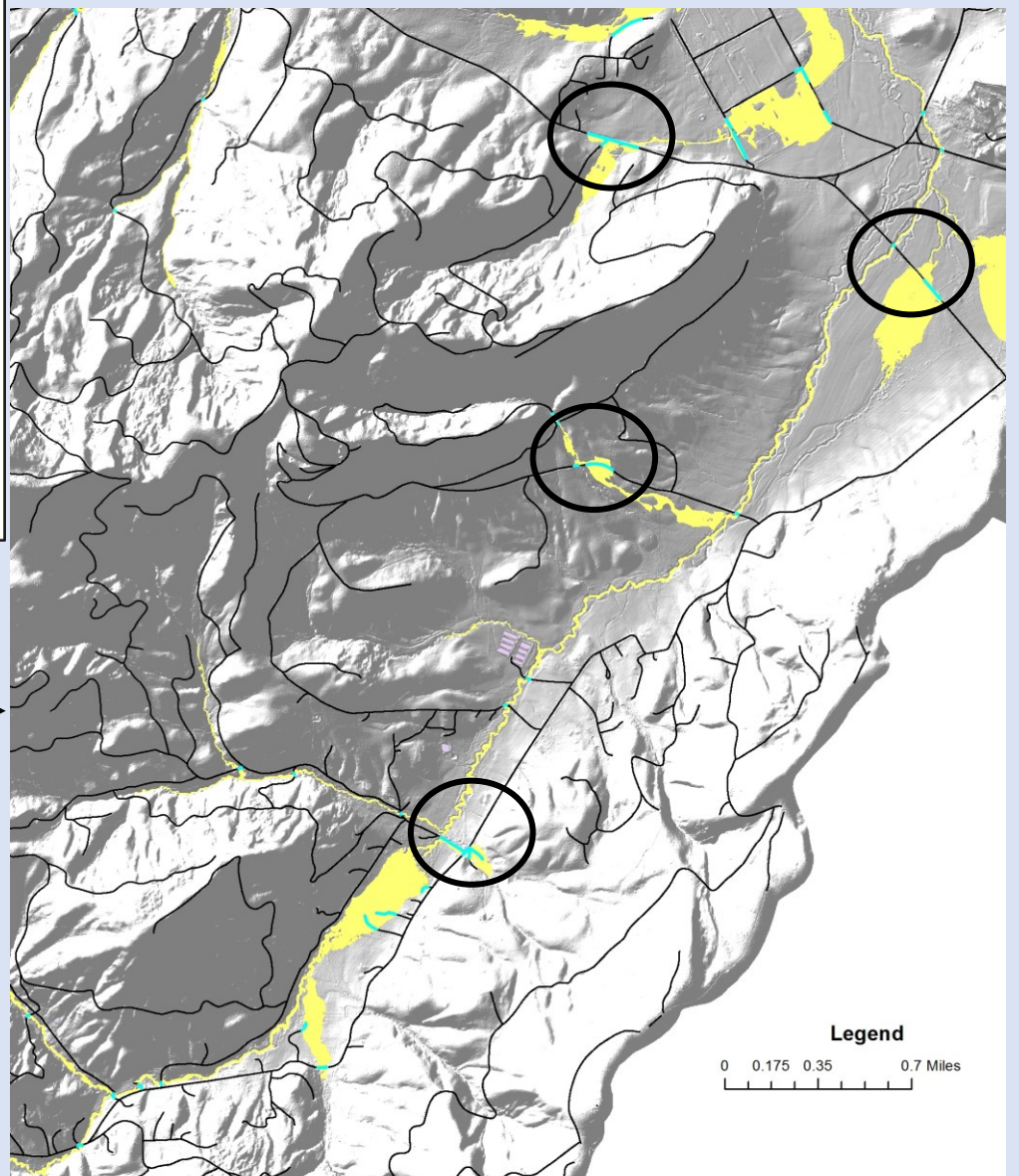


- **Floodplain and riparian mapping, Prince of Wales Island**



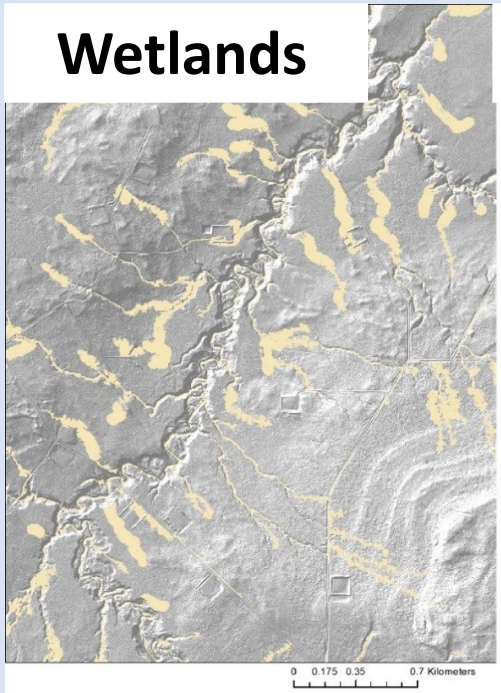
Floodplain

Network of rivers, network of floodplains, network of roads – where are overlaps?

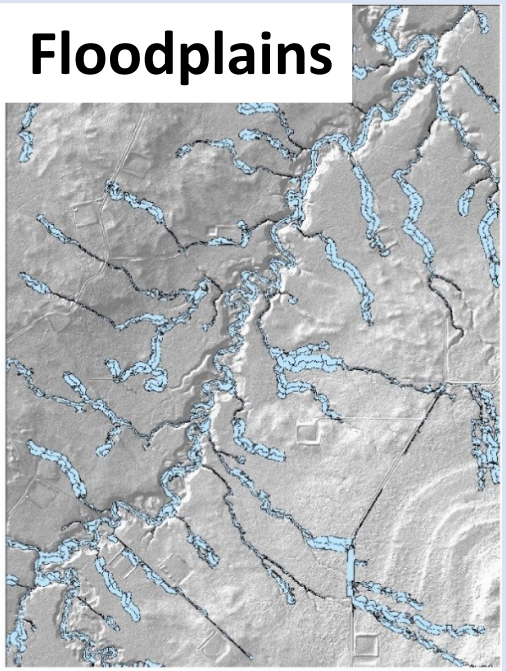


Riparian Zone Protection/Management

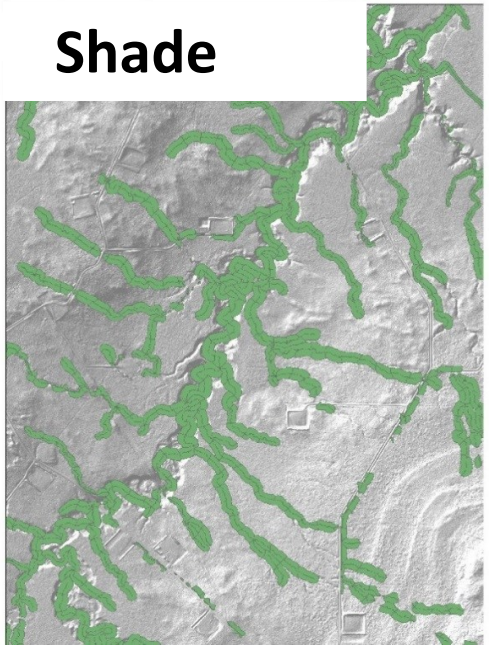
Wetlands



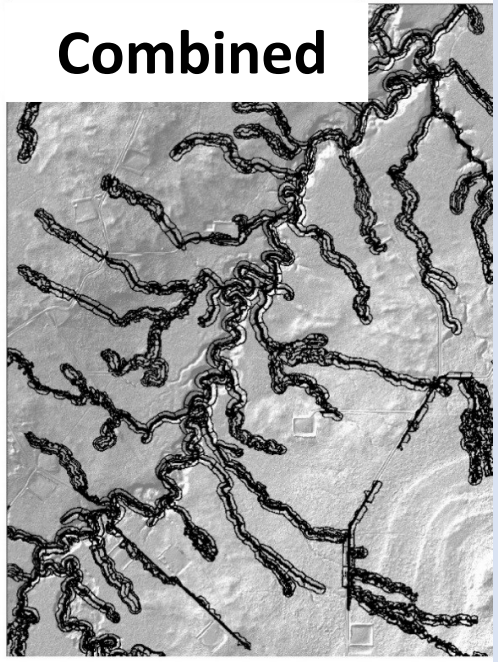
Floodplains



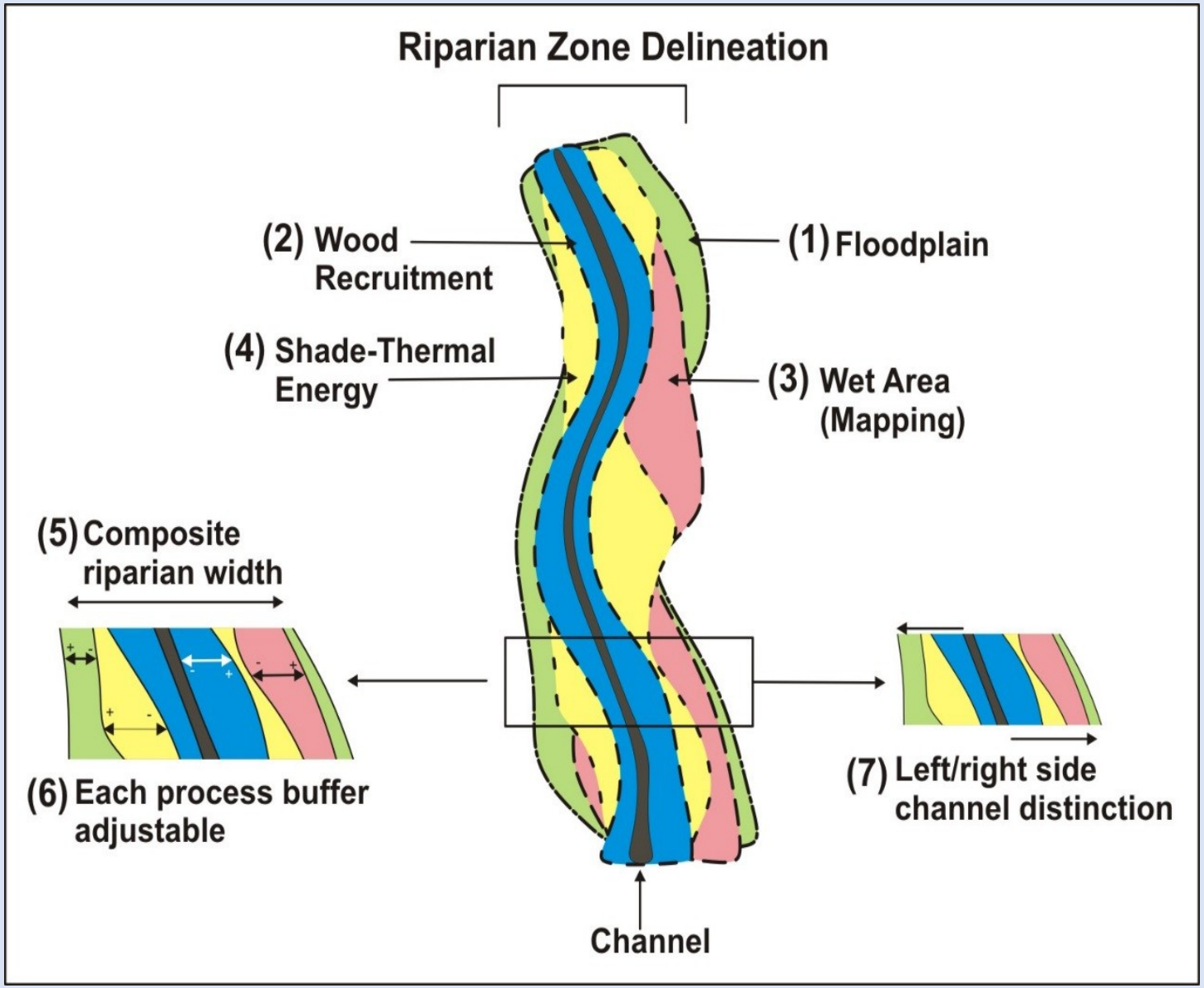
Shade



Combined



Riparian Zone Delineation

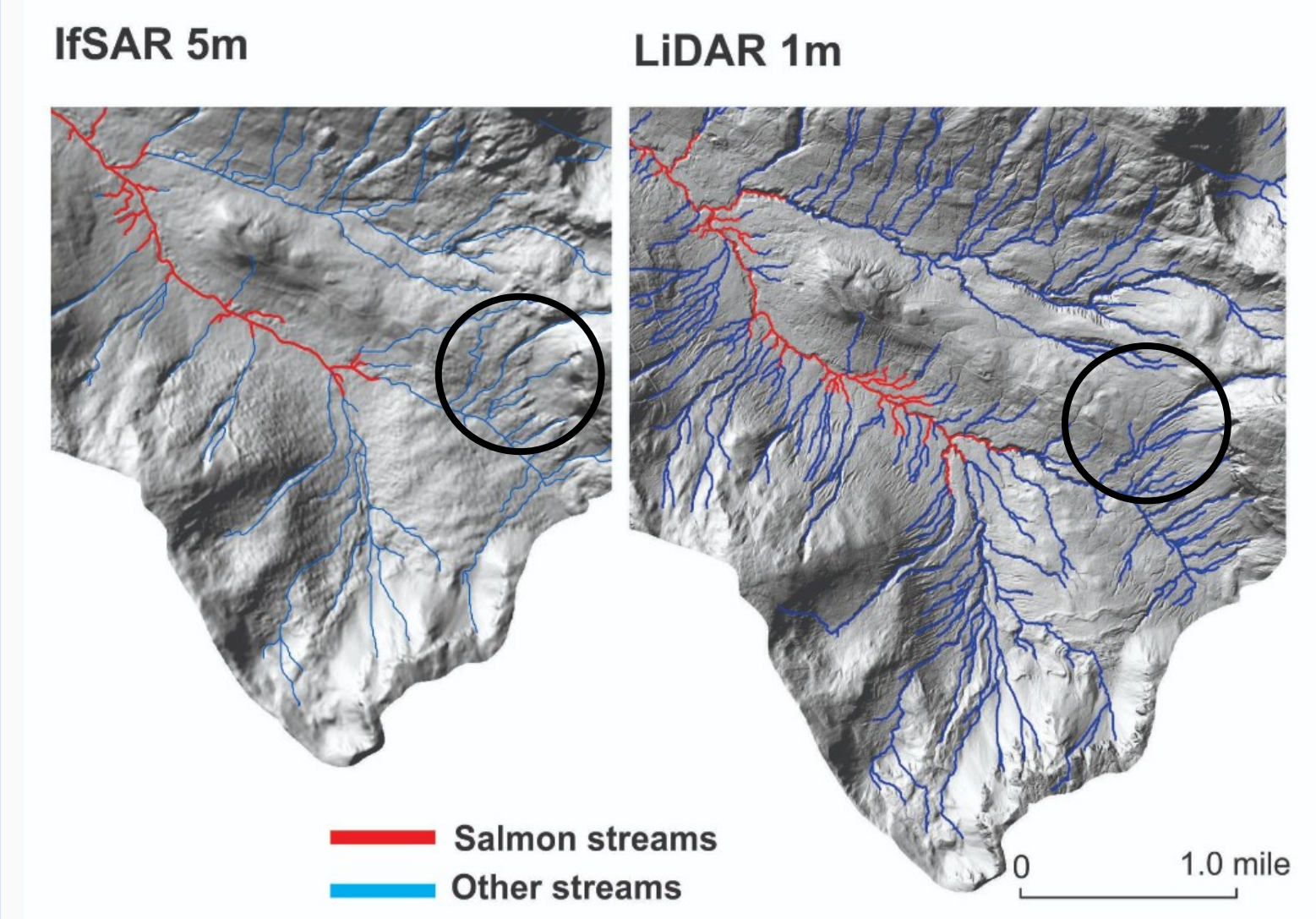


- **Landslides & Debris Flow Risk—Southeast Alaska**

Haines slide, 2020

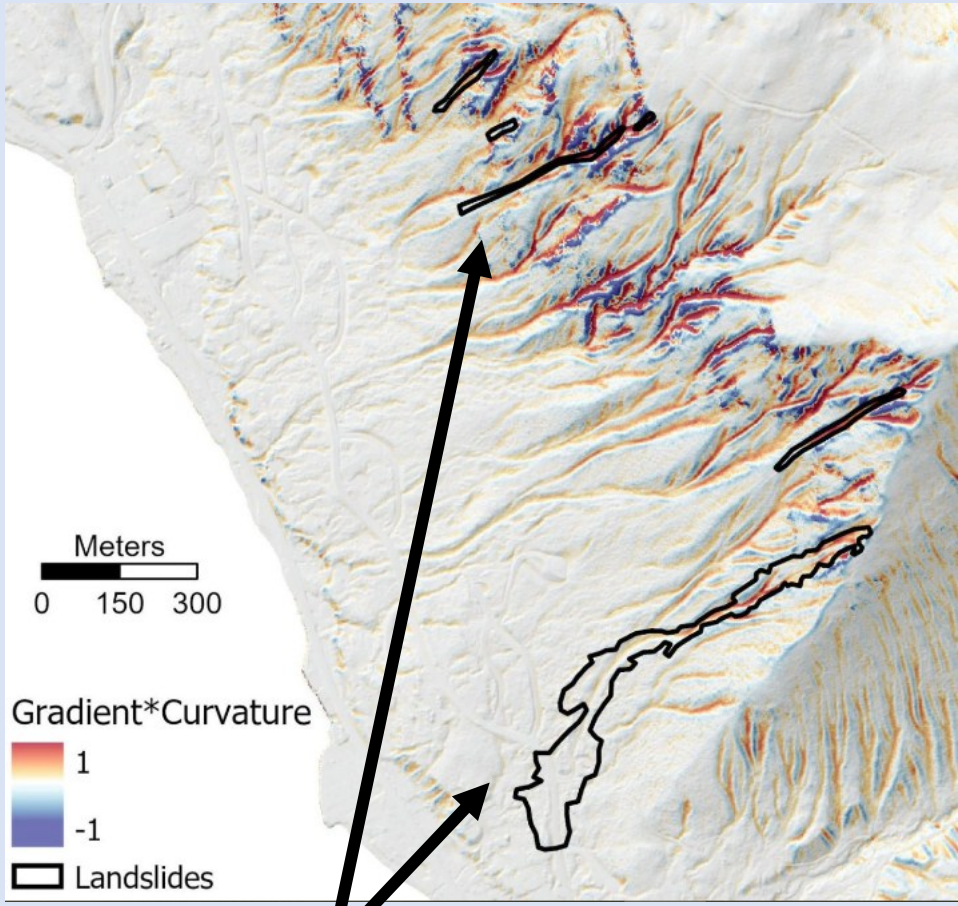
Wrangell slide 2024

- **Landslides & Debris Flow Risk—Southeast Alaska**



Delineating headwaters and ephemeral streams for predicting runout of debris flows and flash flood potential, and propagating downstream hazards

Empirical modeling, landslide inventory



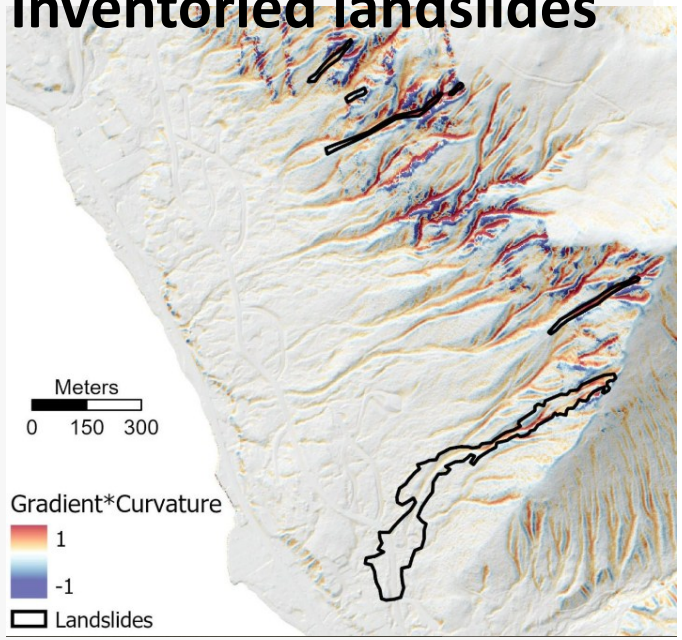
Mapped Landslides
(Tongass N.F. inventory = 12,000+ slides)

Application to Sitka, Alaska

Predicted Landslide initiation, runout, and inundation (combined)

Our model is able to rank increasing levels of landslide susceptibility. The highest 20% is shown in red.

Inventoried landslides



rs
0 200 400

2015 Sitka Landslide

0% - <= 20% **Highest**

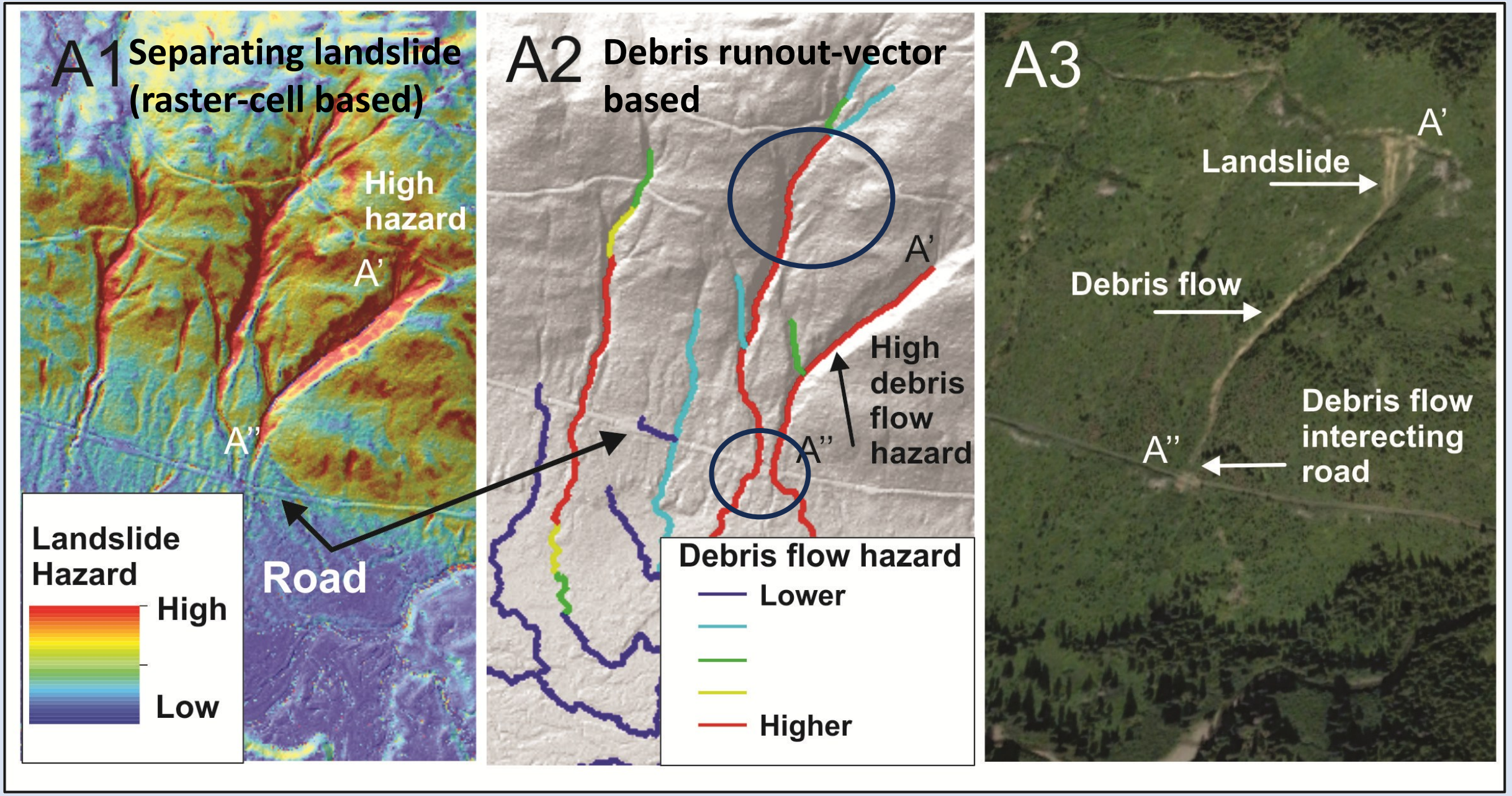
20% - <= 40%

40% - <= 60%

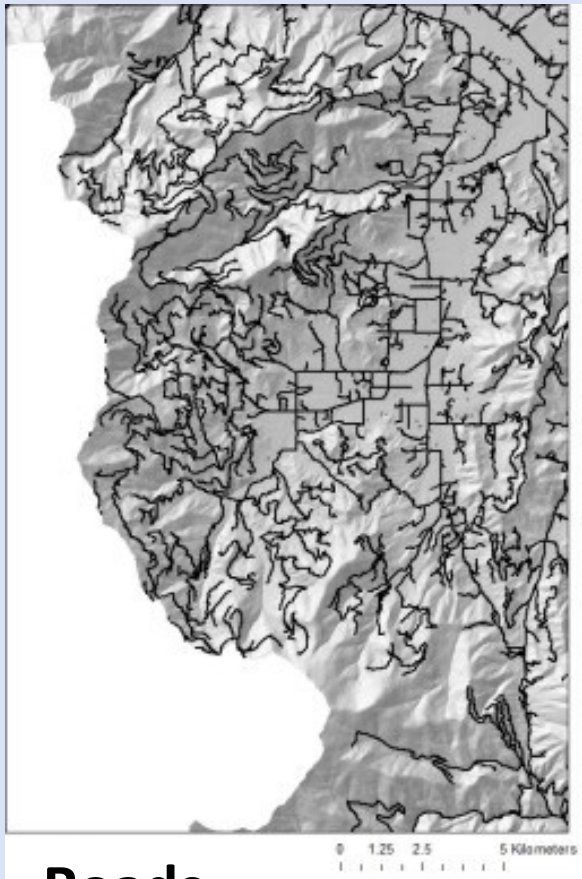
60% - <= 80%

80% - 95% **Lowest**

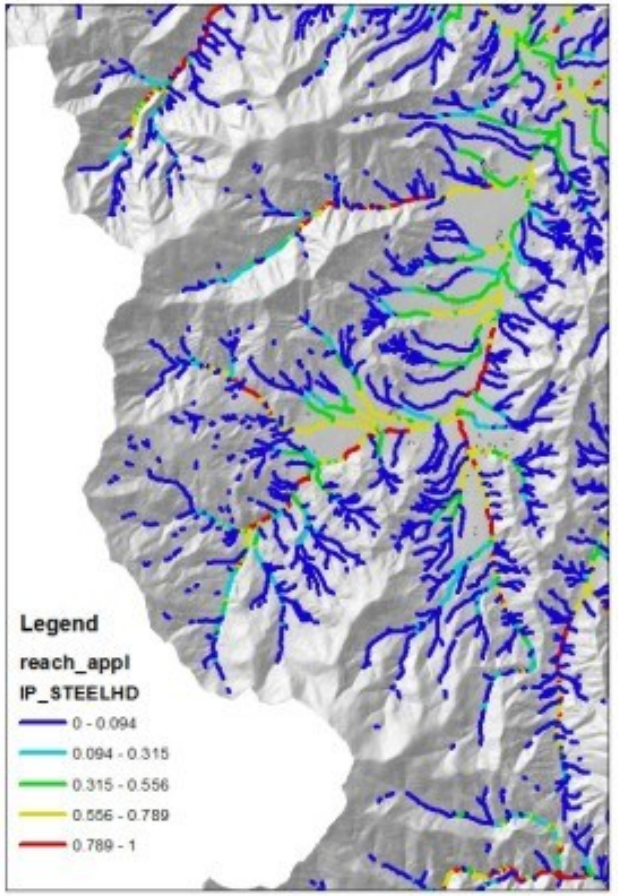
- **Landslides and debris flows, Sitka, Wrangell, Petersburg, Prince of Wales Island (fish)**



- **Forest roads and salmon (potential fish blockages), Kupreanof Island**

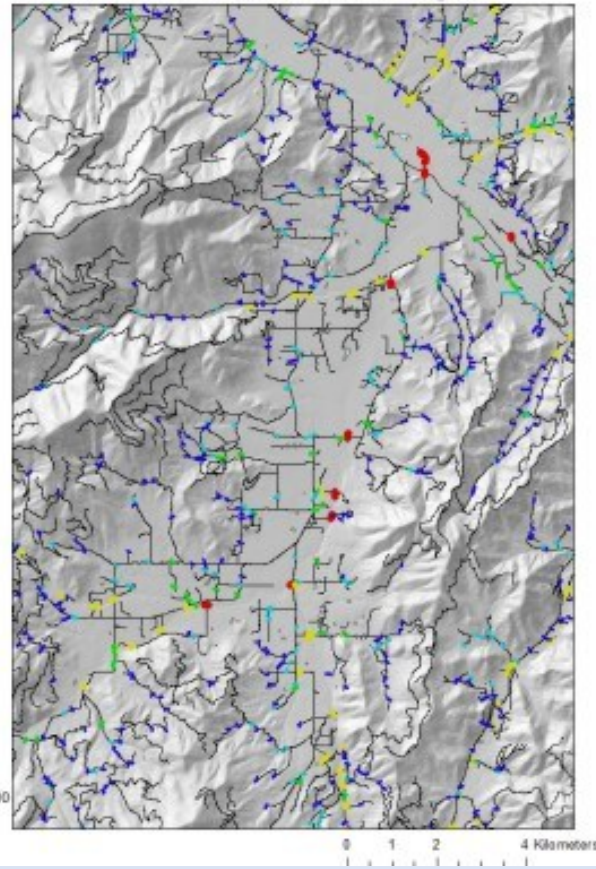


Roads



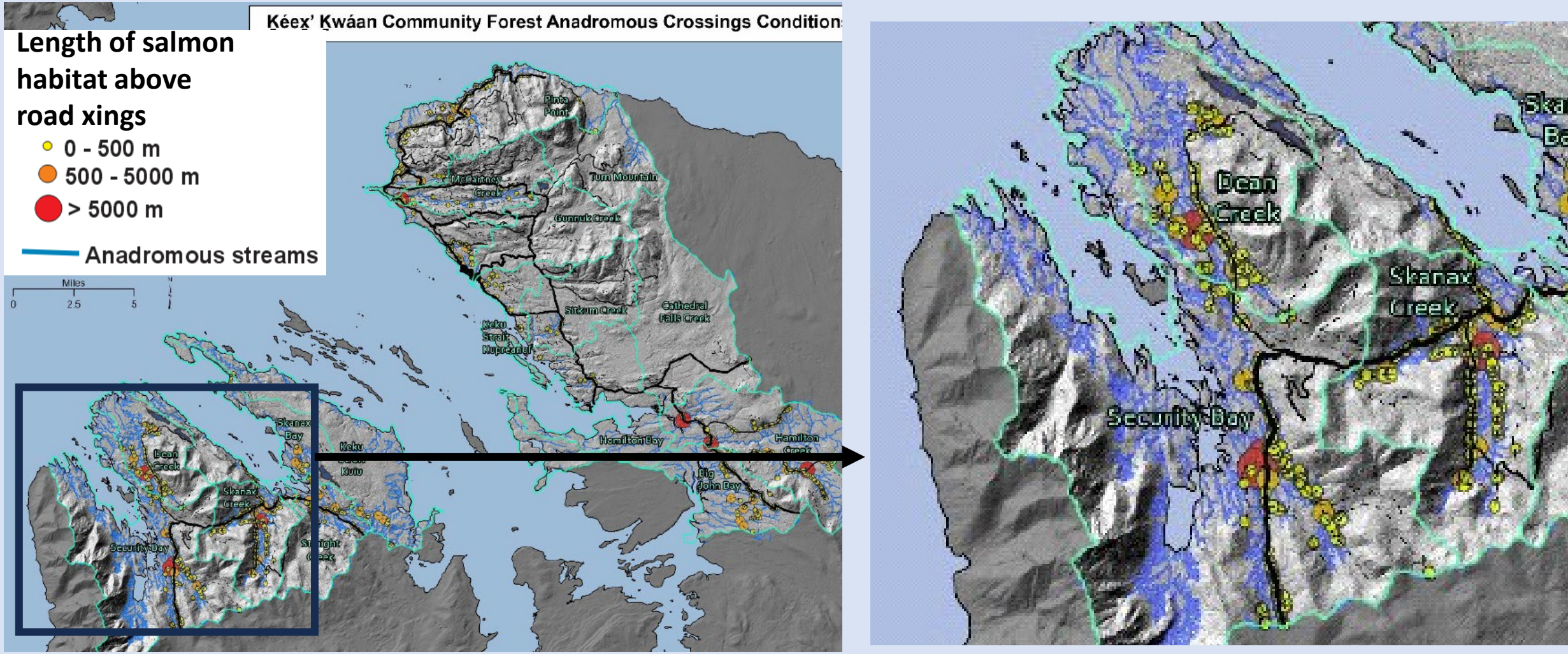
Fish habitat

Habitat length above road crossings



- **Forest roads and salmon (fish blockages), Kupreanof Island**

Keex' Kwáan Community Forest Partnership Landscape Assessment; Robert Christensen et al. 2024



Classify by subbasin for strategic planning