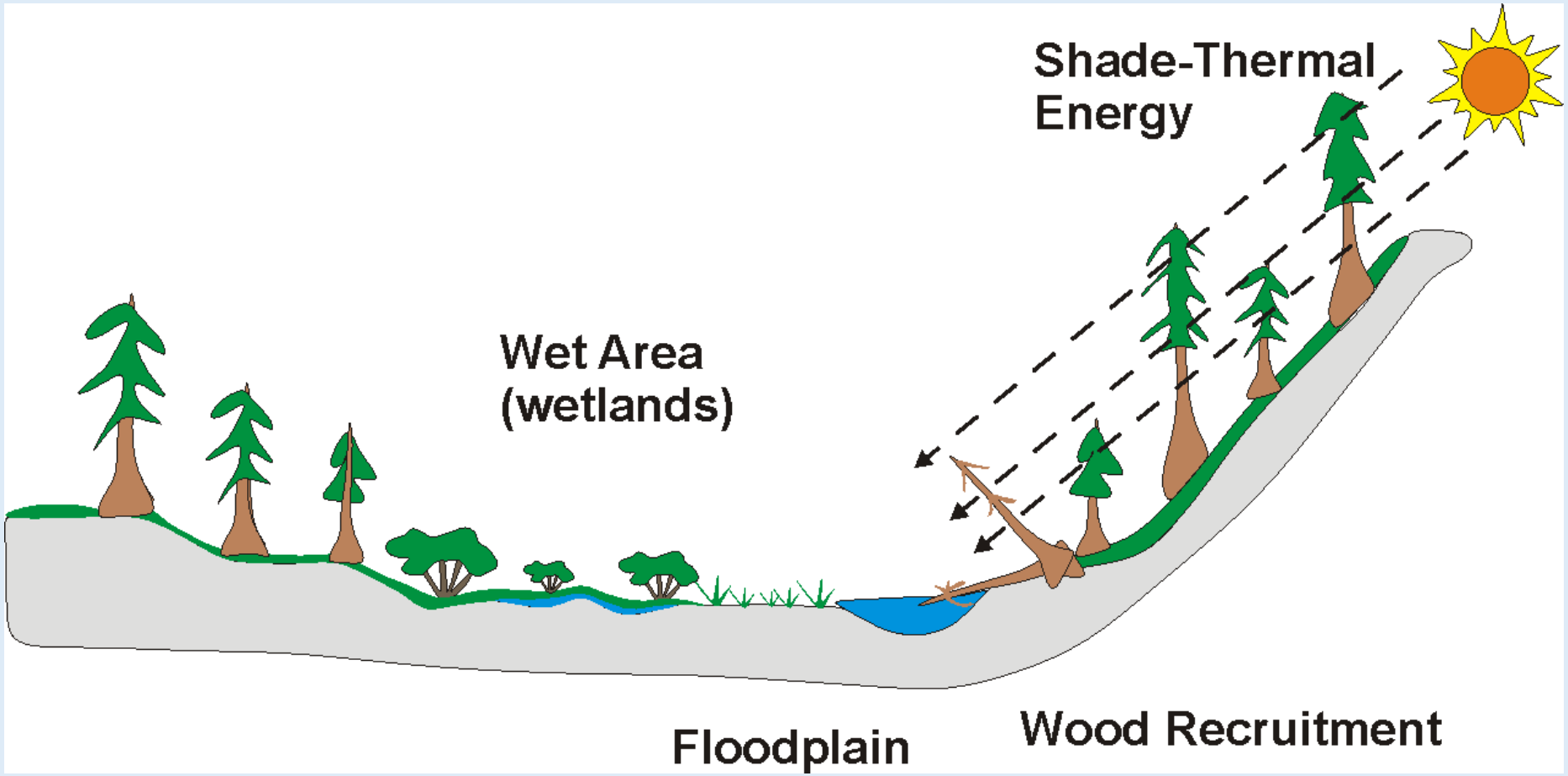
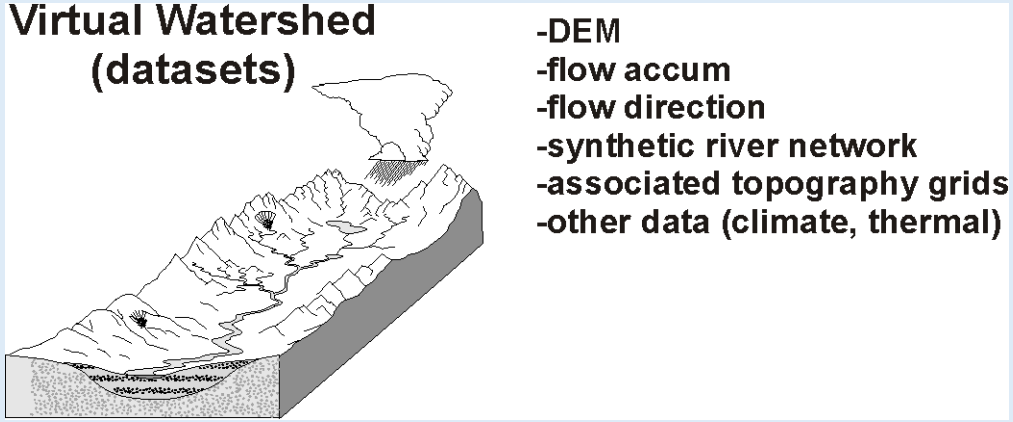
NetMap's Virtual Watershed and Decision Support Tools

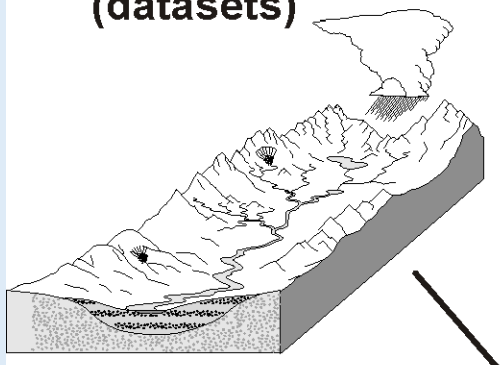


Dr. Lee Benda, TerrainWorks (Seattle, WA/Mt. Shasta, CA)

Consists of four parts:

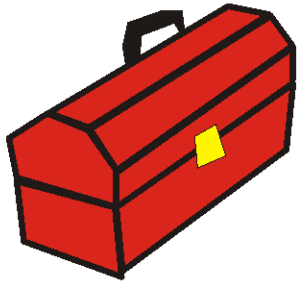


Virtual Watershed (datasets)



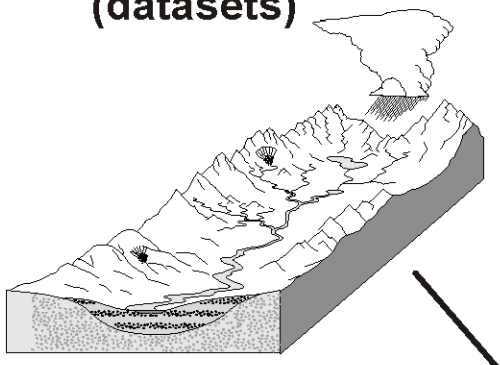
- -DEM
- -flow accum
- -flow direction
- -synthetic river network
- -associated topography grids
- -other data (climate, thermal)

Analysis/Decision Support Tools (ArcMap 10.x)



- -fluvial
- -aquatic habitats
- -riparian
- -erosion
- -roads
- -fire
- -climate

Virtual Watershed (datasets)



-DEM
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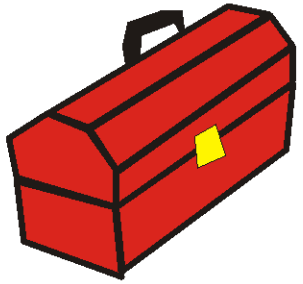
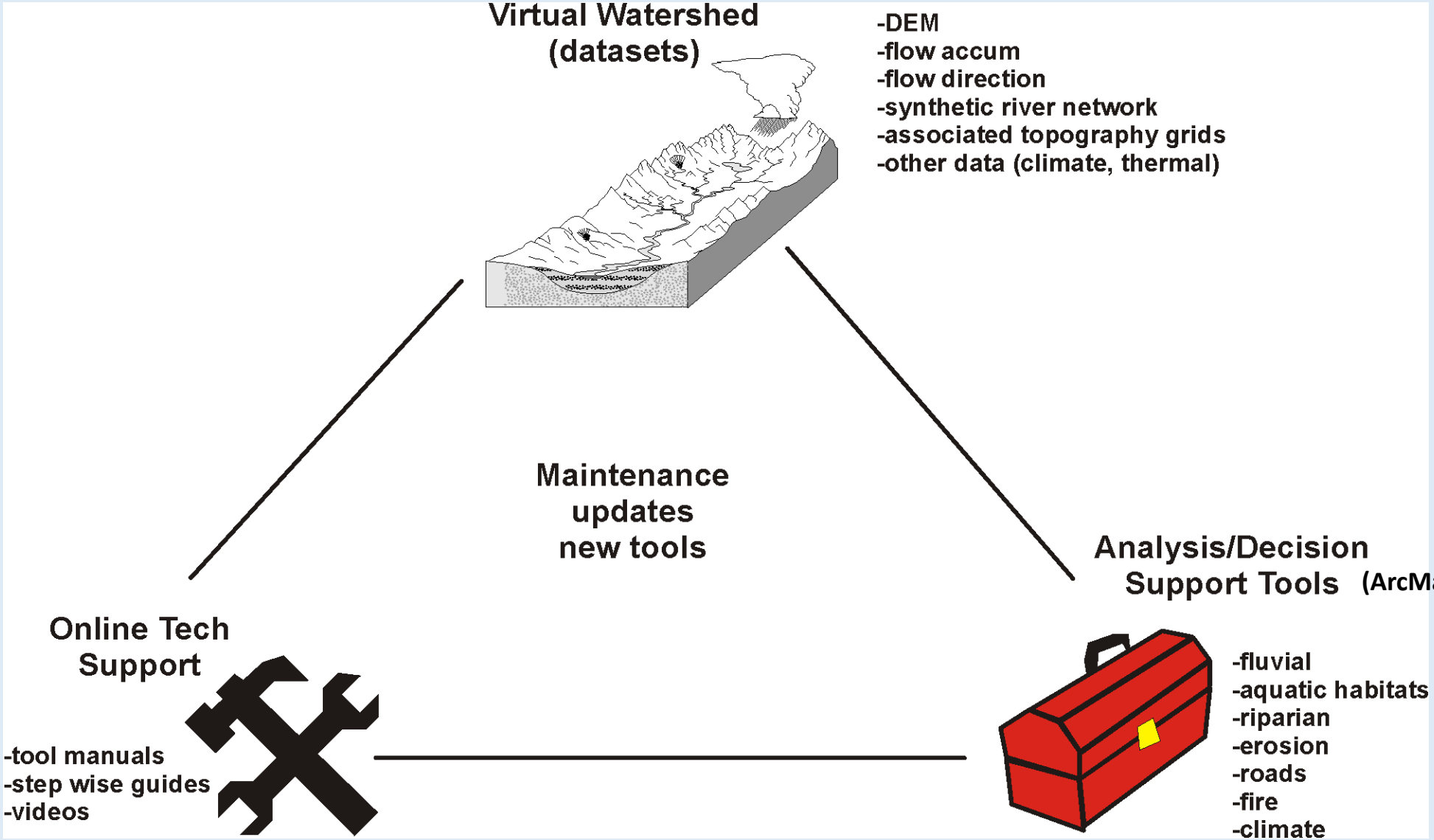
Analysis/Decision Support Tools (ArcMap 10.x)



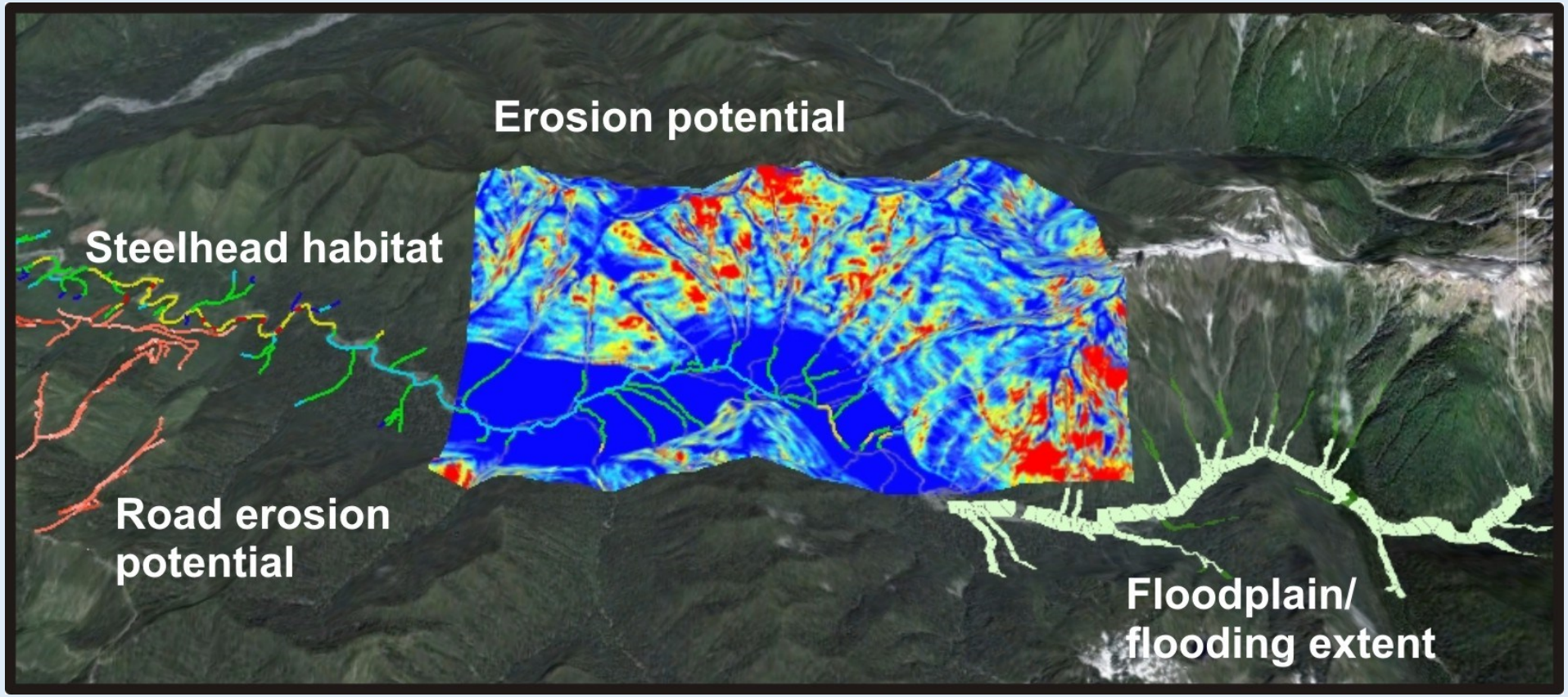
-fluvial
-aquatic habitats
-riparian
-erosion
-roads
-fire
-climate

Online Tech Support

-tool manuals
-step wise guides
-videos


Virtual Watershed
(datasets)
-DEM
-flow accum
-flow direction
-synthetic river network
-associated topography grids
-other data (climate, thermal)
Maintenance
updates
new tools
Analysis/Decision
Support Tools (ArcMap 10.x)
Online Tech
Support
-tool manuals
-step wise guides
-videos
-fluvial
-aquatic habitats
-riparian
-erosion
-roads
-fire
-climate

An integrated system to address resource use, risk management, restoration, and conservation



NetMap: A collaborative enterprise since 2007, with funding and participation from

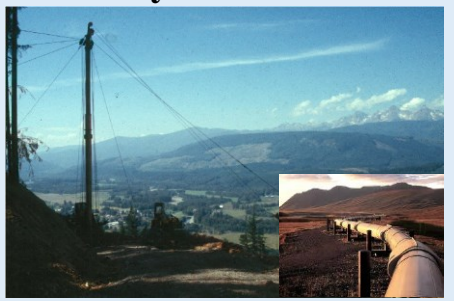
- National Forests (WA, OR, NCA, AK, ID, MT)
- Forest Service Research: PNW, PSW, RMRS
- US Fish & Wildlife Service
- NOAA
- BLM
- EPA
- Oregon Dept. Forestry
- WA Fish and Wildlife
- NGOs (TNC, Ecotrust, WSC, WCSSP)
- Watershed Councils
- Universities
- Private industry
- International (Canada, Spain, China, Russia)

Multi-application

Fisheries

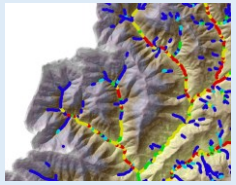
Risk Management

Forestry



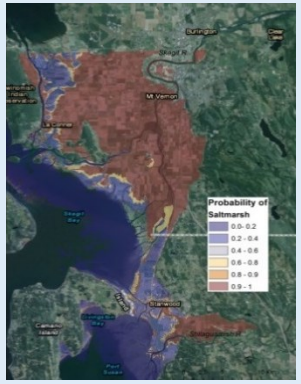
Conservation

Aquatic Habitats



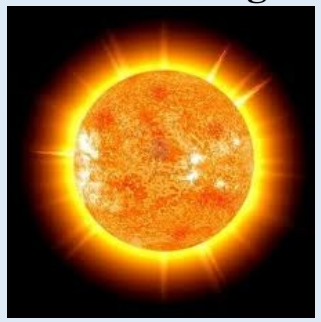
Transportation/Energy

Urban planning

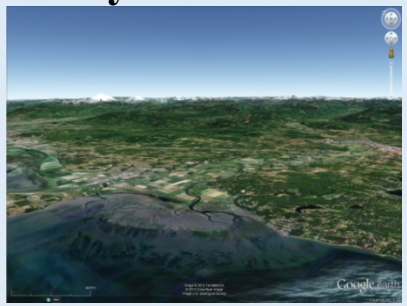


Restoration

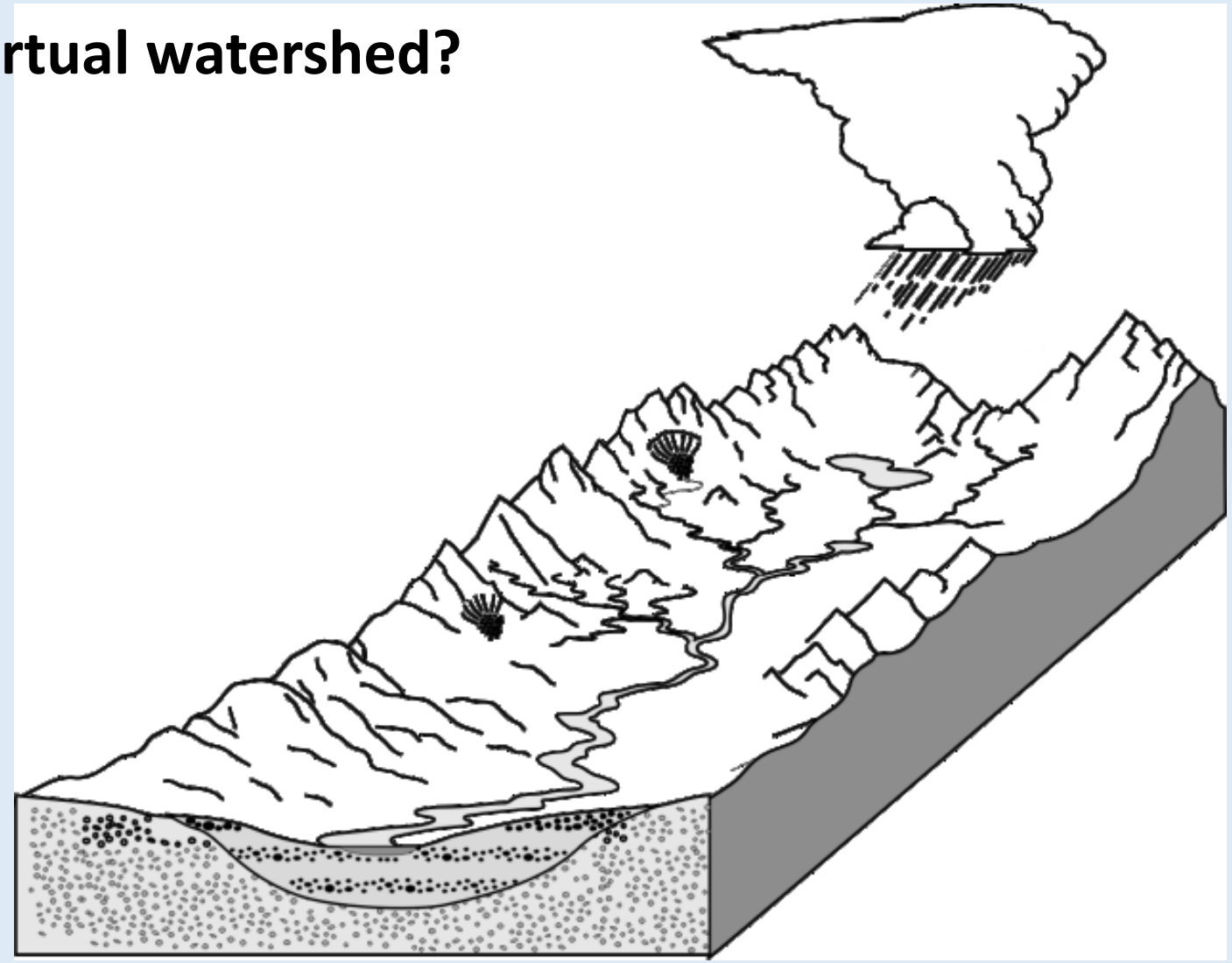
Climate change



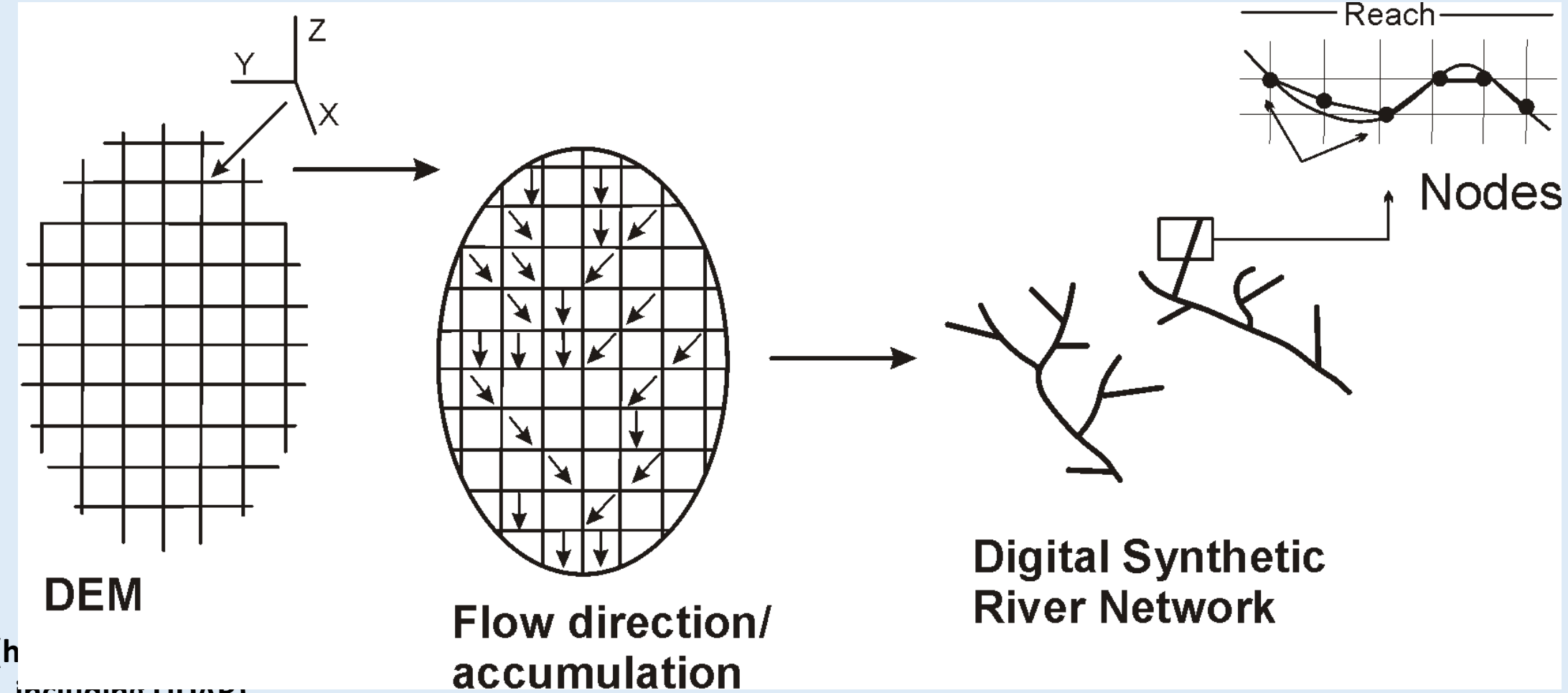
Ecosystem Services



What's a virtual watershed?



Virtual Watershed Components



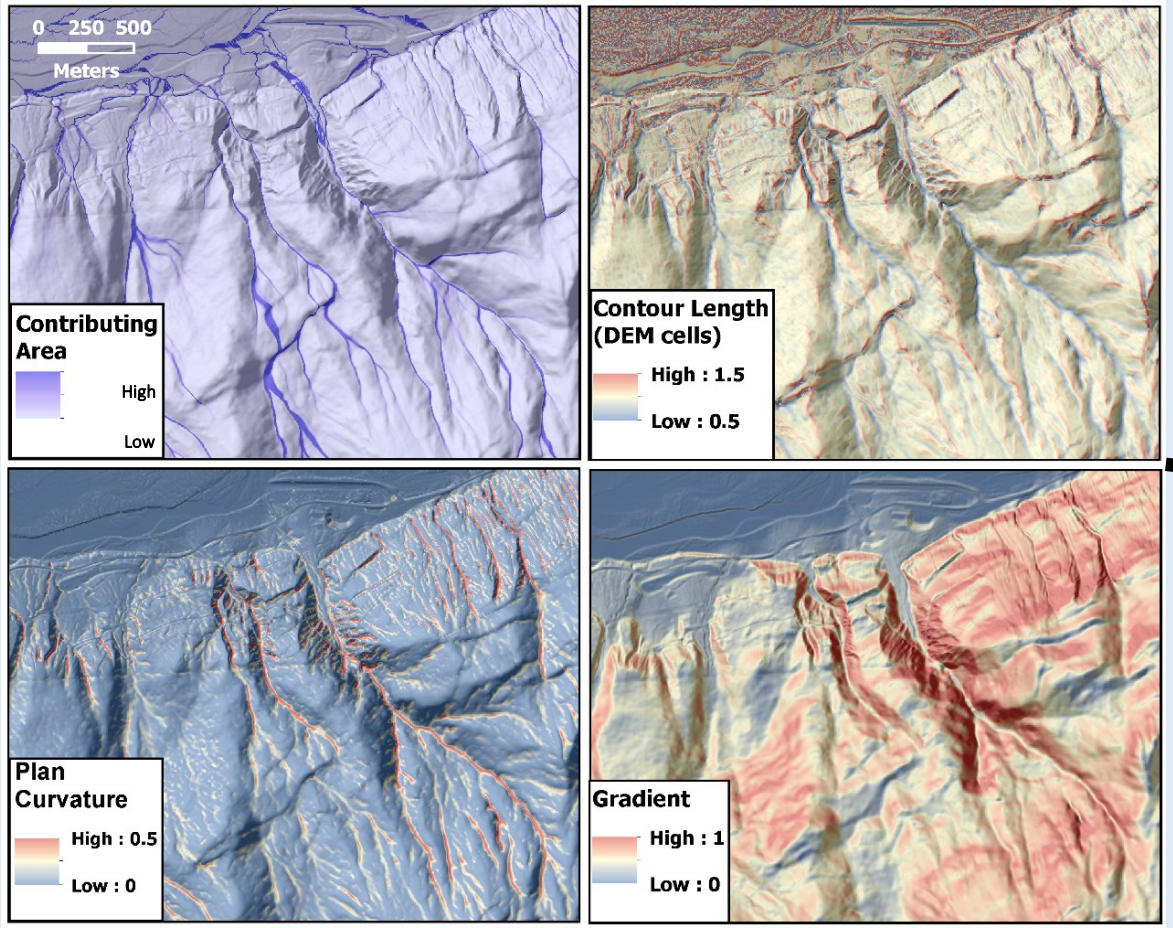
(h
including LiDAR)

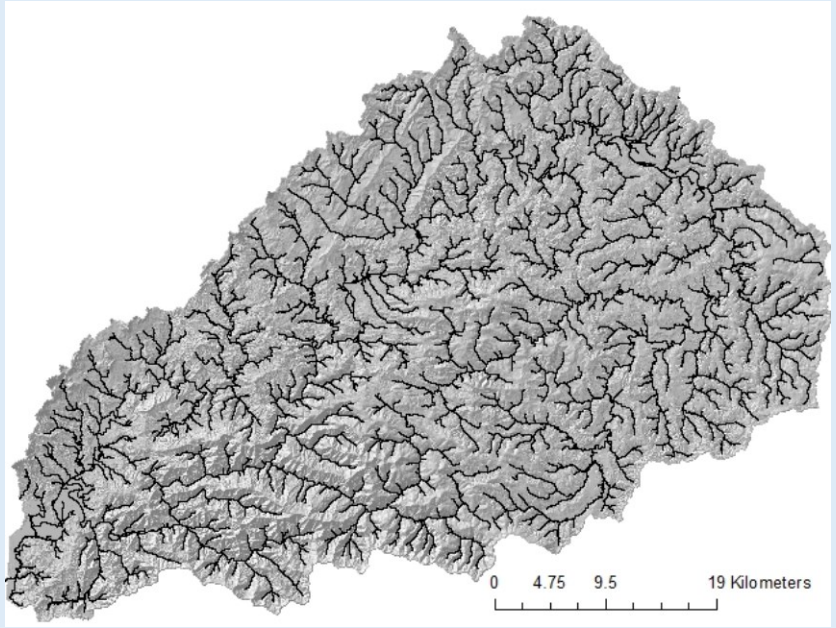
Synthetic river network

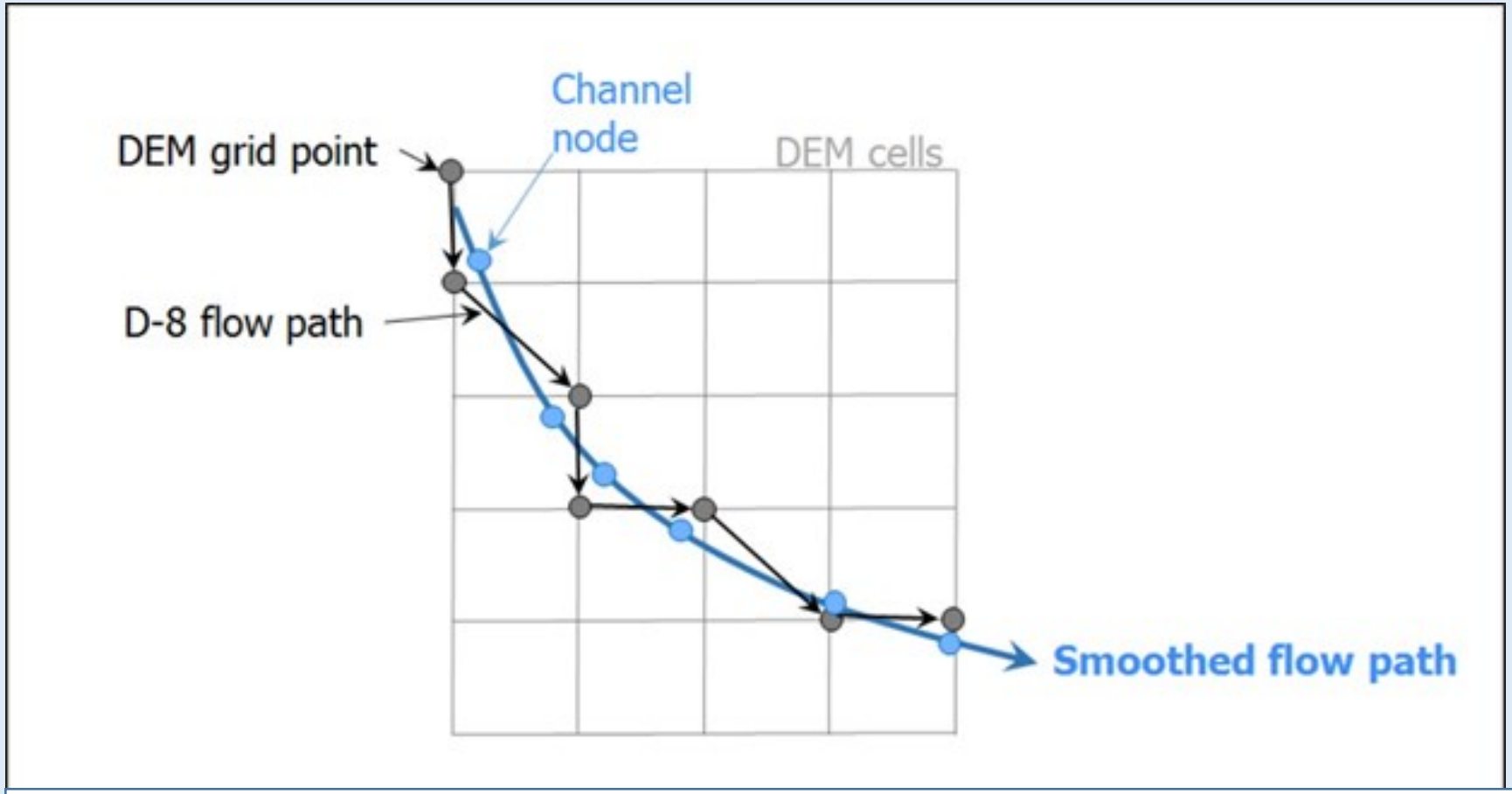
Channel-initiation threshold calibrated to DEM.

Four criteria:

1) Specific contributing area * slope squared (AS^2); measure of erosive potential.
2) Plan curvature; measure of topographic (flow) convergence.
3) Minimum flow length over which above two threshold musts be met.
4) Gradient.



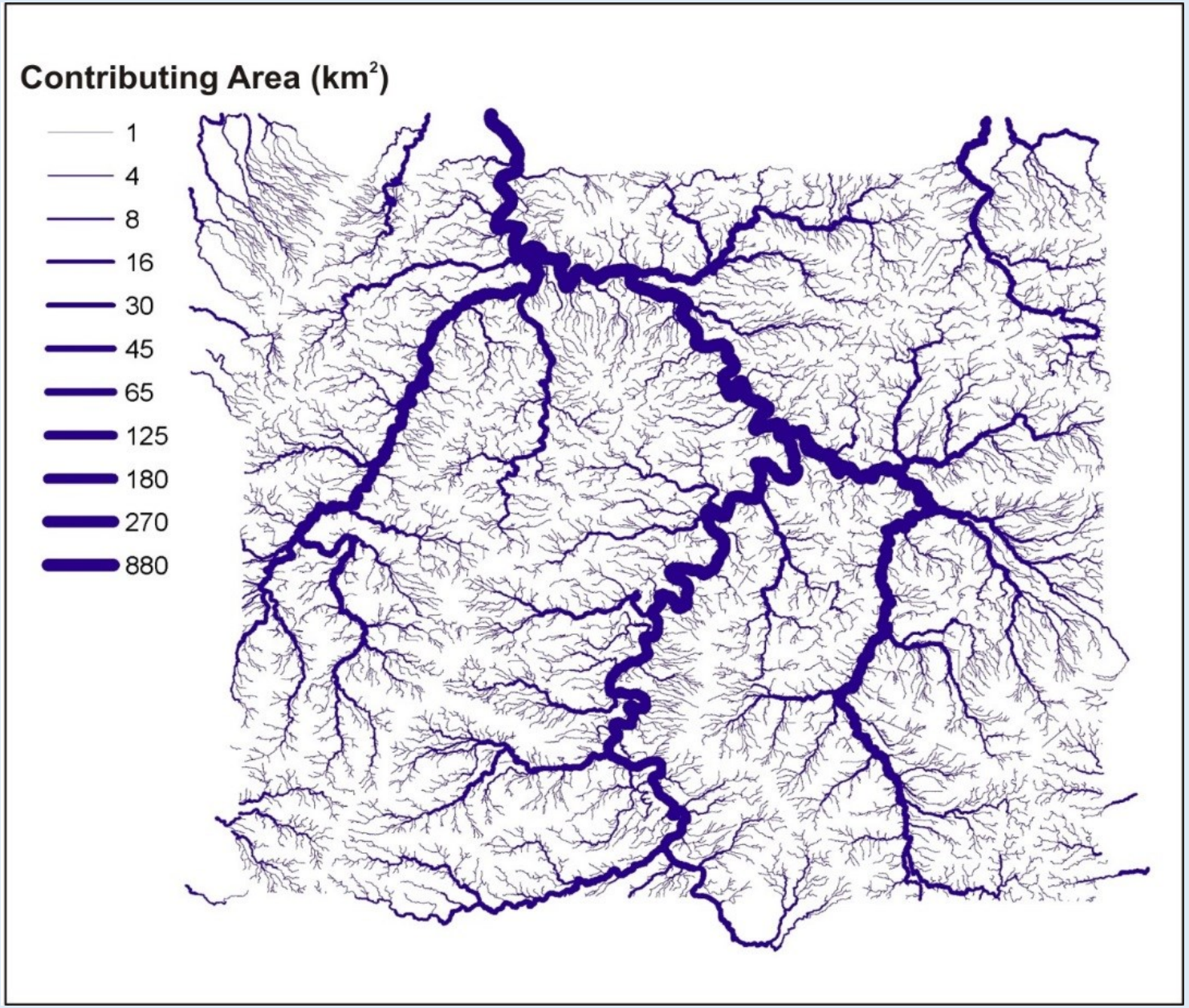




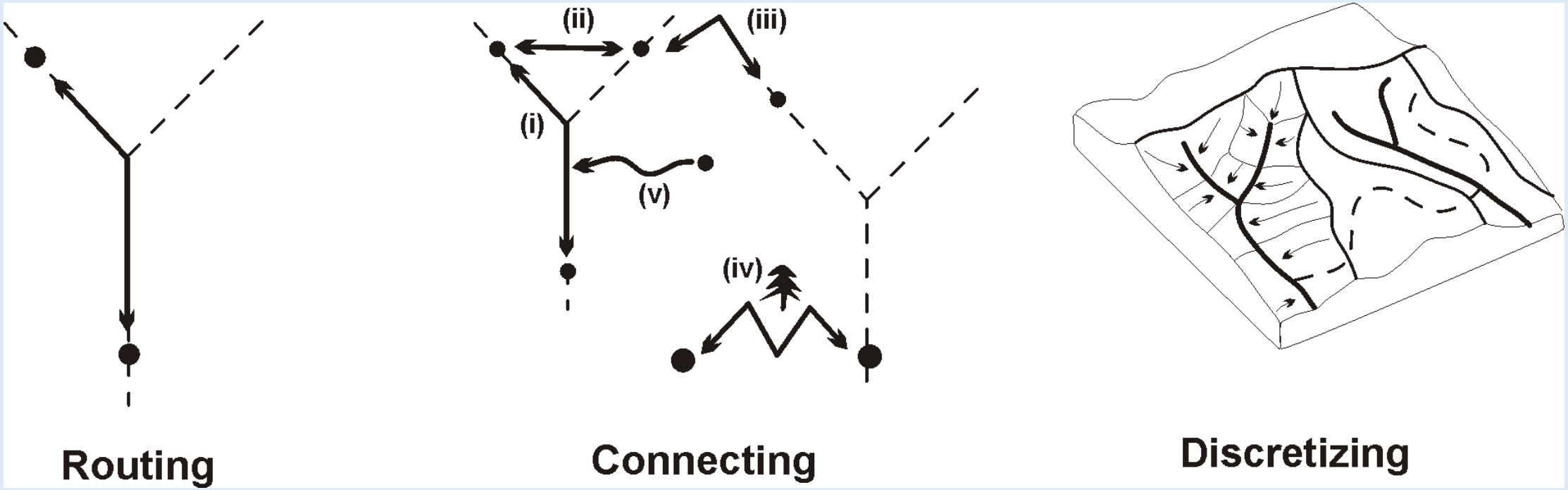
- **data stored at the spatial grain of the DEM**
- **each node is associated with a single DEM cell (supporting channel initiation anywhere)**
- **couples the channel network to the terrestrial for hydrologic, erosion, riparian, land use modeling**
- **each cell is associated with single (or multiple) channel nodes, so valley floors and hillslopes are associated with specific locations along flow paths**
- **node information summarized at any larger spatial scale to generate GIS vector lines**

Synthetic River Network

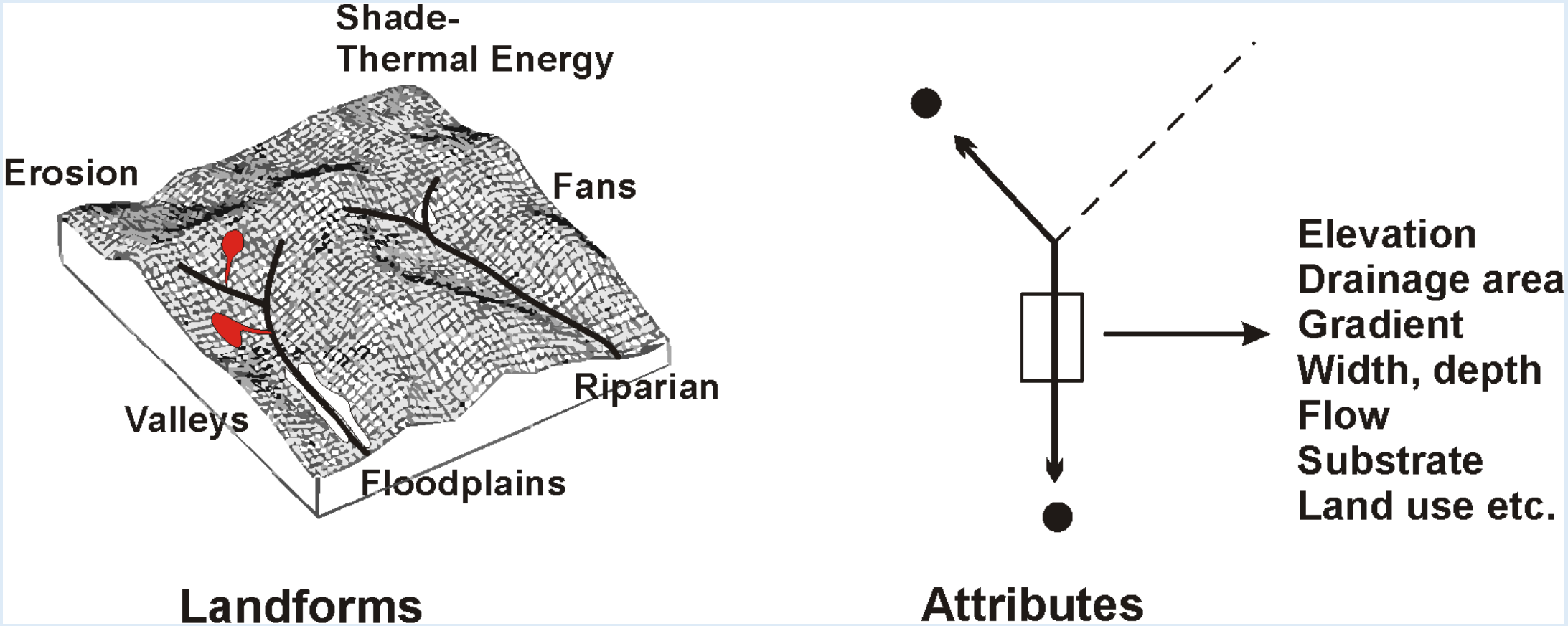
-includes headwaters & ephemerals
-can be trimmed to adjust network to field conditions



Other Virtual Watershed Components



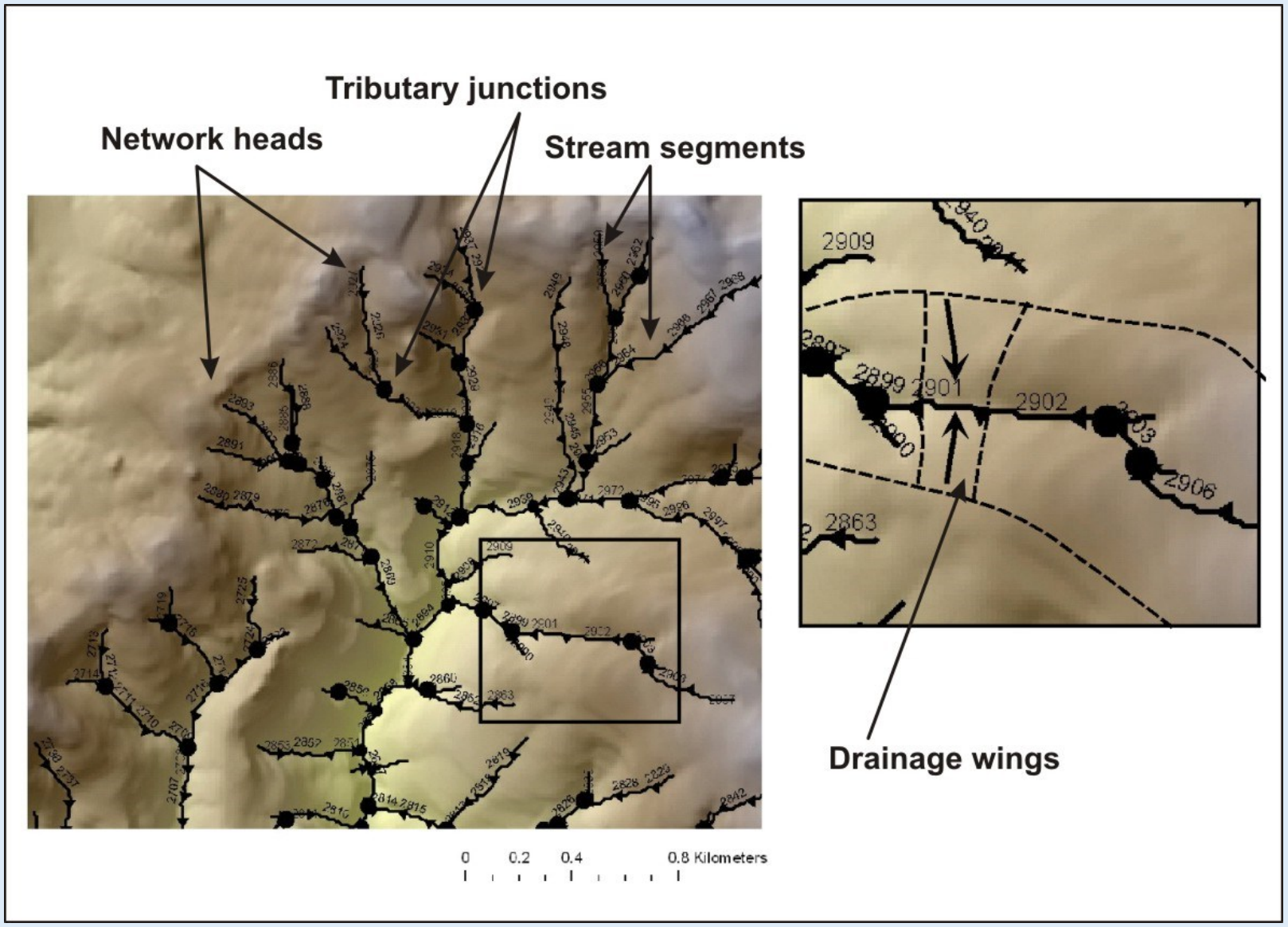
Other Virtual Watershed Components

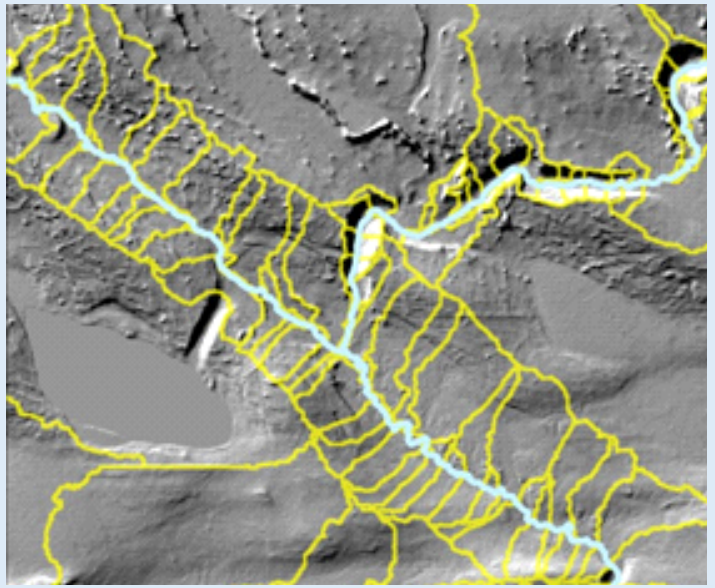


Stream and watershed attribution

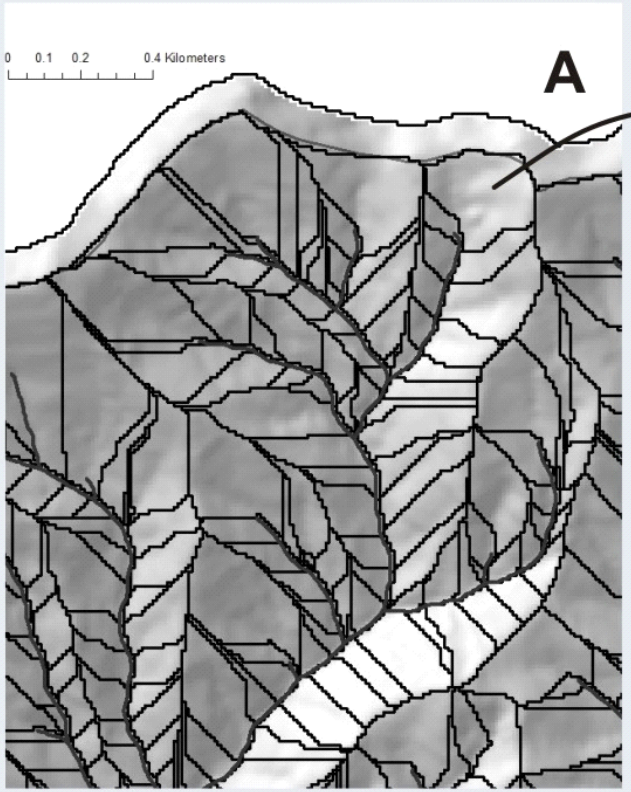
Channel Attributes	Landforms and Process Characterizations
• **Gradient** • **Elevation** • **Distance to outlet** • **Drainage area** • **Mean annual flow** • **Stream order** • **Channel width and depth** • **Bed substrate** • **Channel sinuosity** • **Channel classification** • **Fish habitats** • **Radiation loading** • **Mean annual precipitation**	• Floodplains • Terraces • Alluvial fans • Hillslope-gradient and convergence (mass wasting) • Tributary confluences • Erosion potential • Hillslope–slope profile (surface erosion) • Valley width and transitions • Debris flows • Earthflows

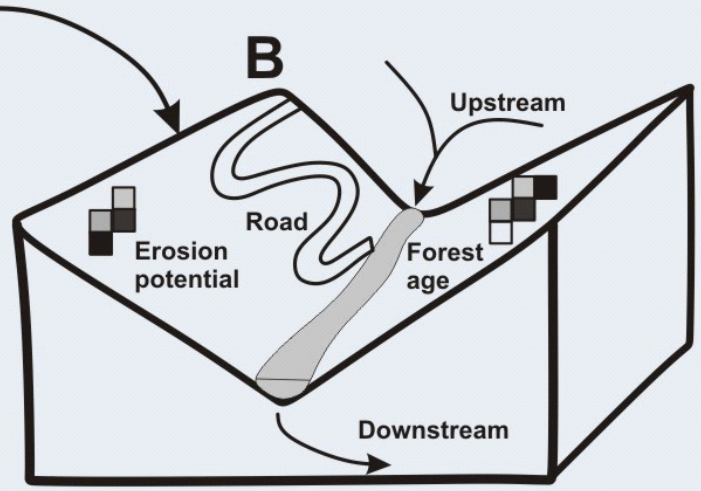
Connecting & discretizing – channels to terrestrial



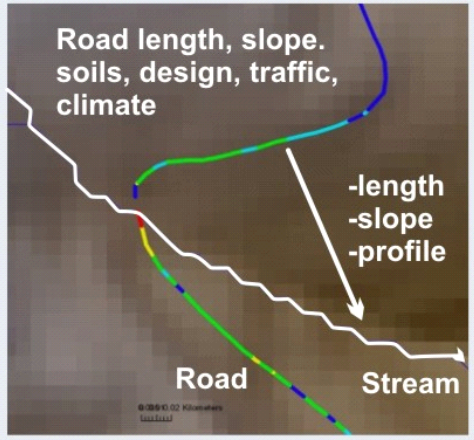


Drainage wings (discretize landscapes and land uses)

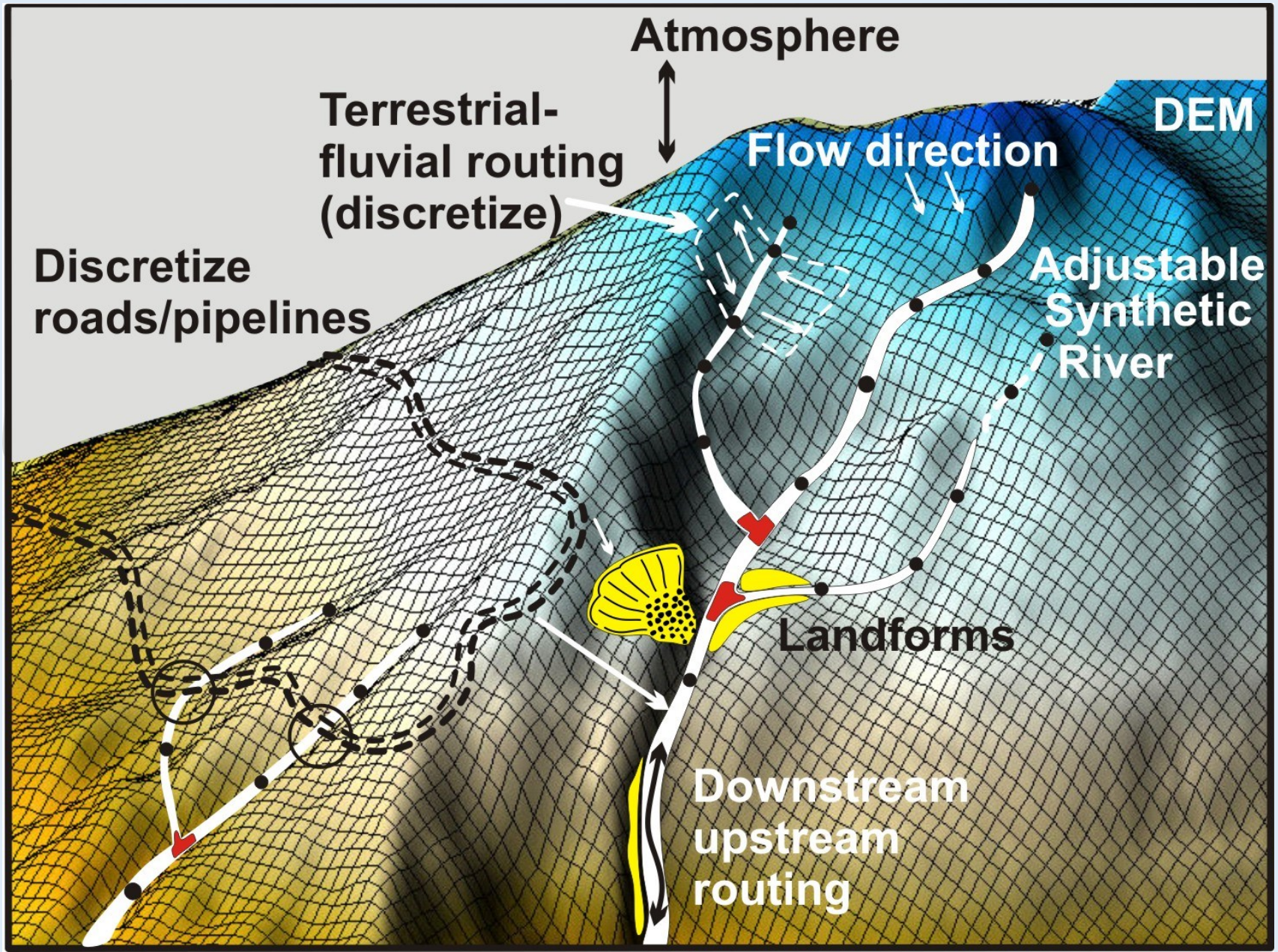




C



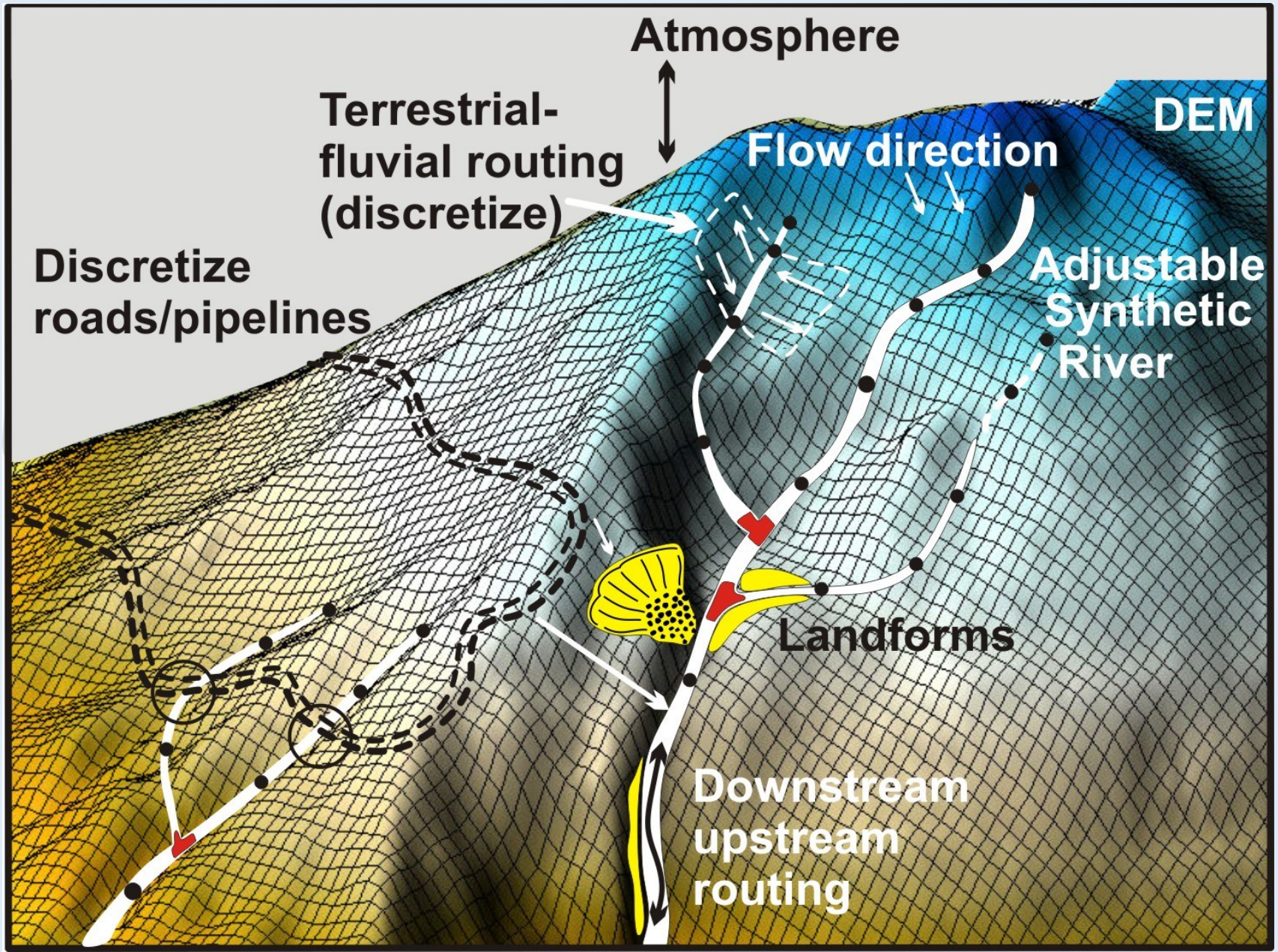
Virtual Watershed



A virtual watershed supports:

- **resource planning**
- **restoration**
- **conservation**
- **risk mitigation**
- **regulation**

Virtual Watershed

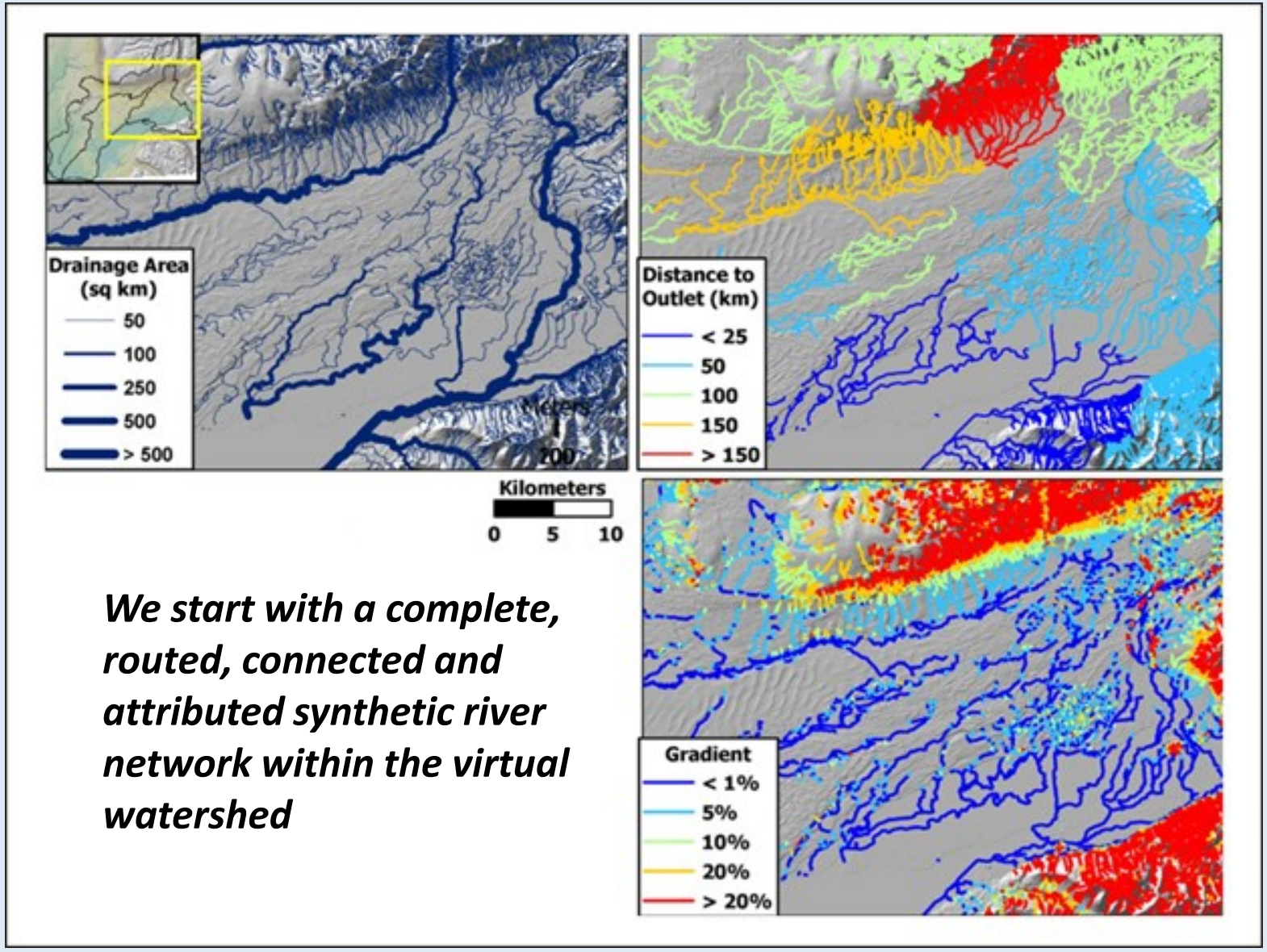


What else is out there?

NHD/NHDPlus is similar but not equivalent to NetMap's virtual watershed (w/tools).

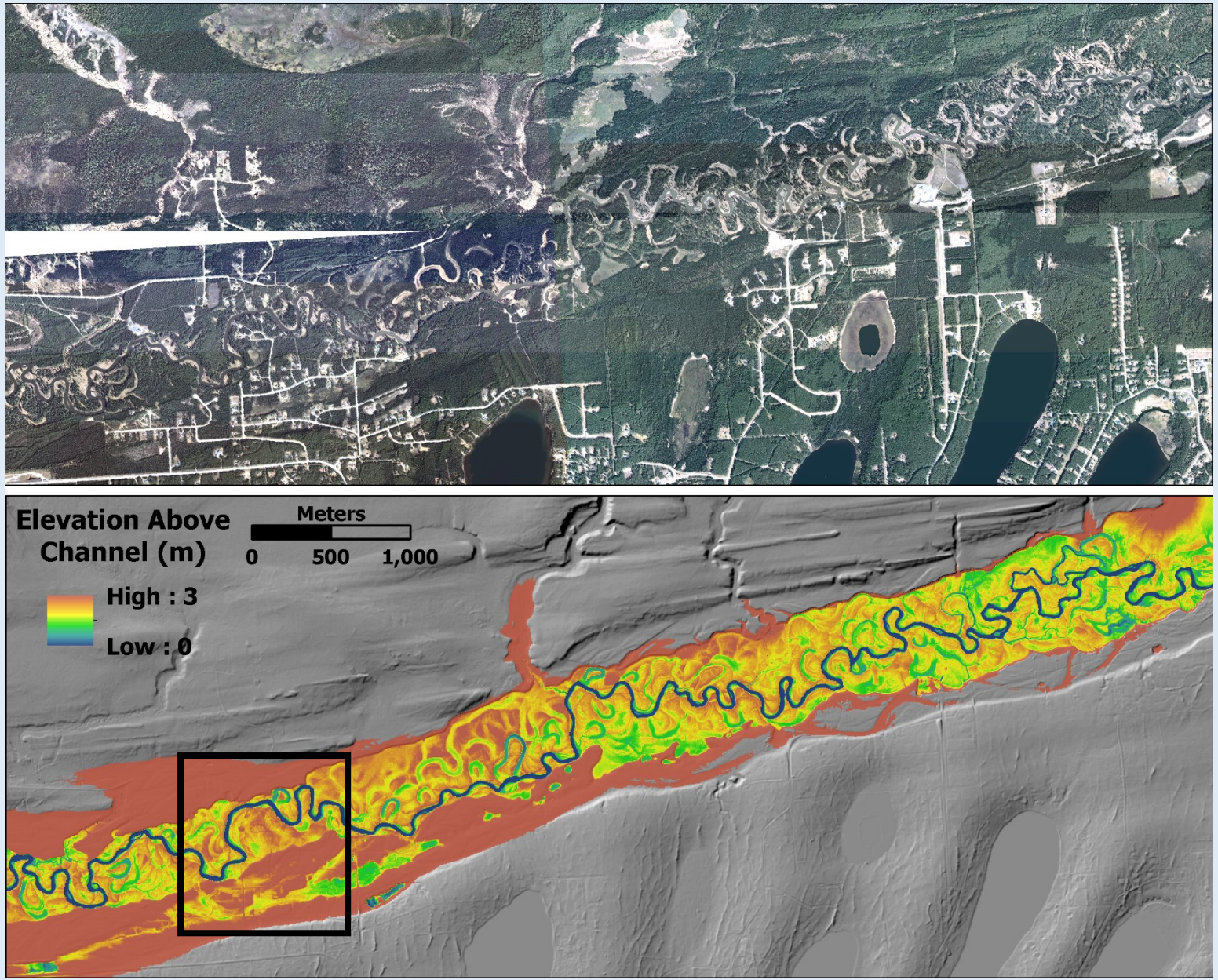
Other stream layers (including ArcHydro) are not a virtual watershed (includes TAU_DEM and others).

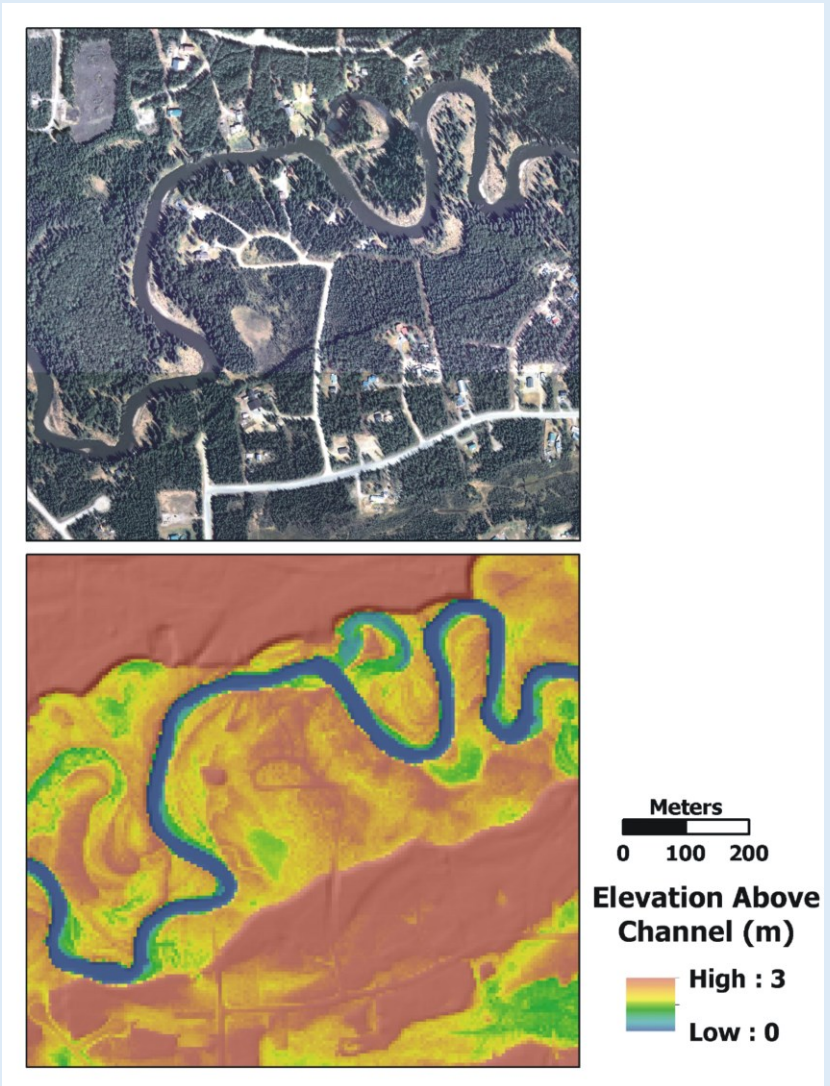
We'll get to wetlands, but first let's look at floodplains and riparian areas as background



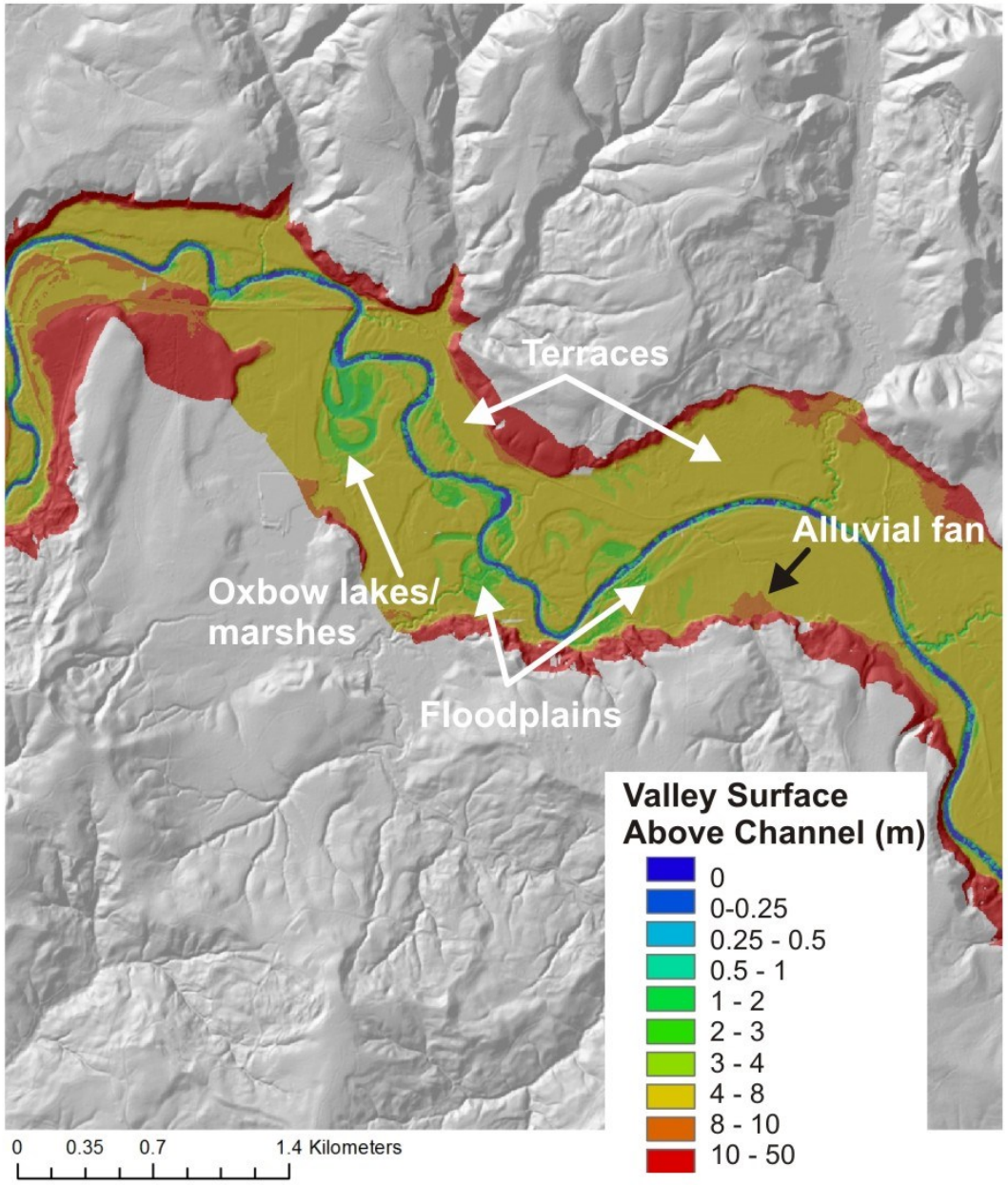
We start with a complete, routed, connected and attributed synthetic river network within the virtual watershed

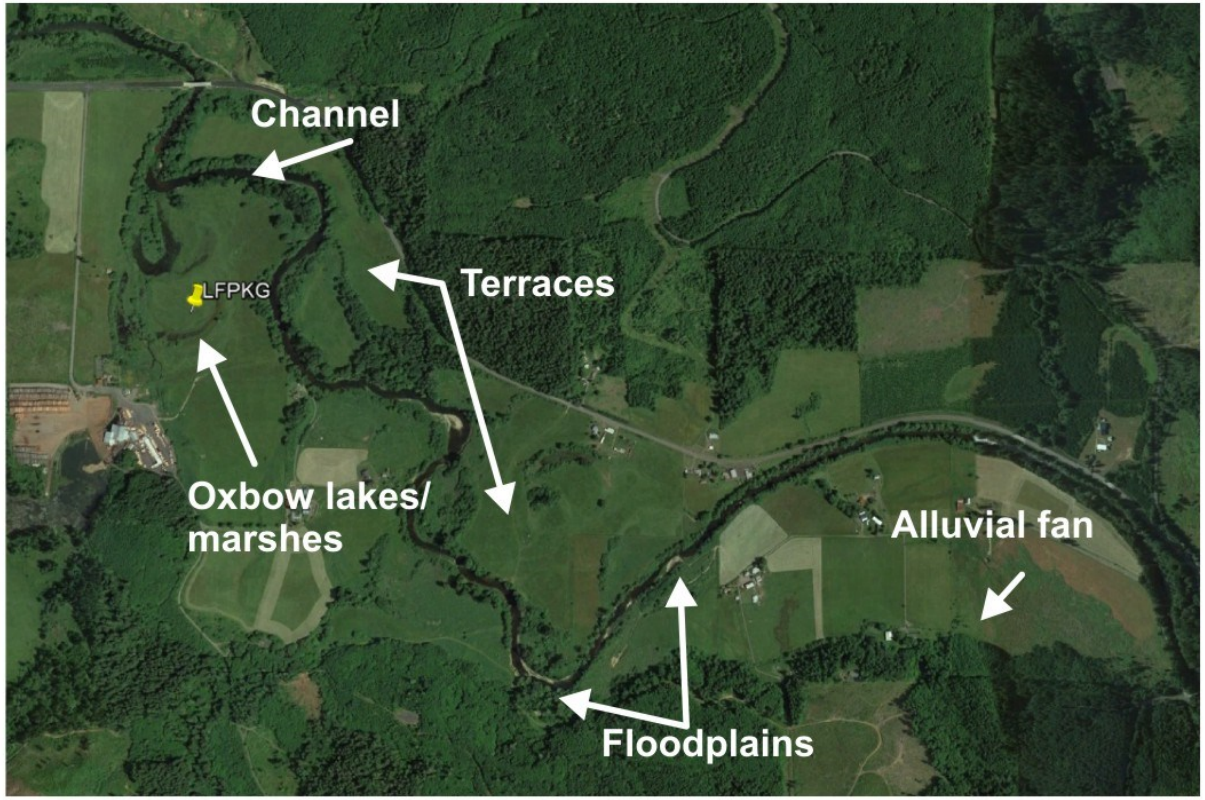
Map valley floor surfaces and floodplains



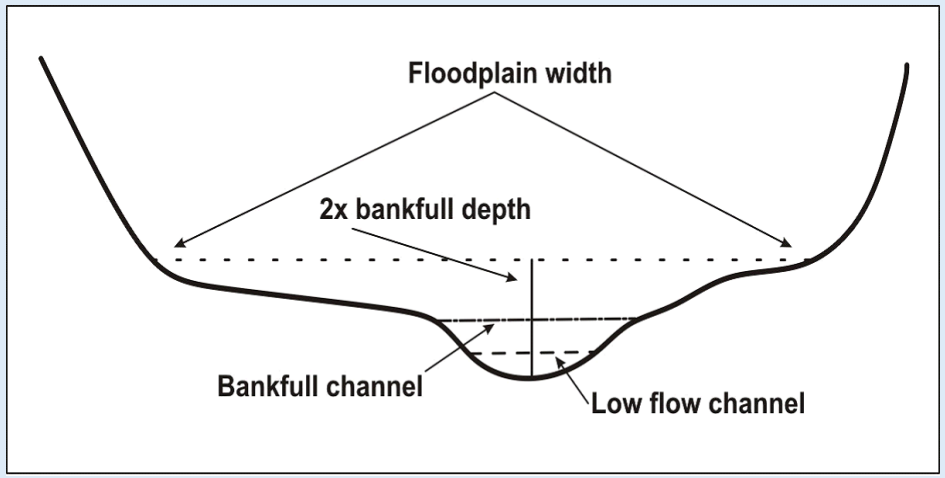


Identify floodplains, terraces, alluvial fans, oxbows and marshes

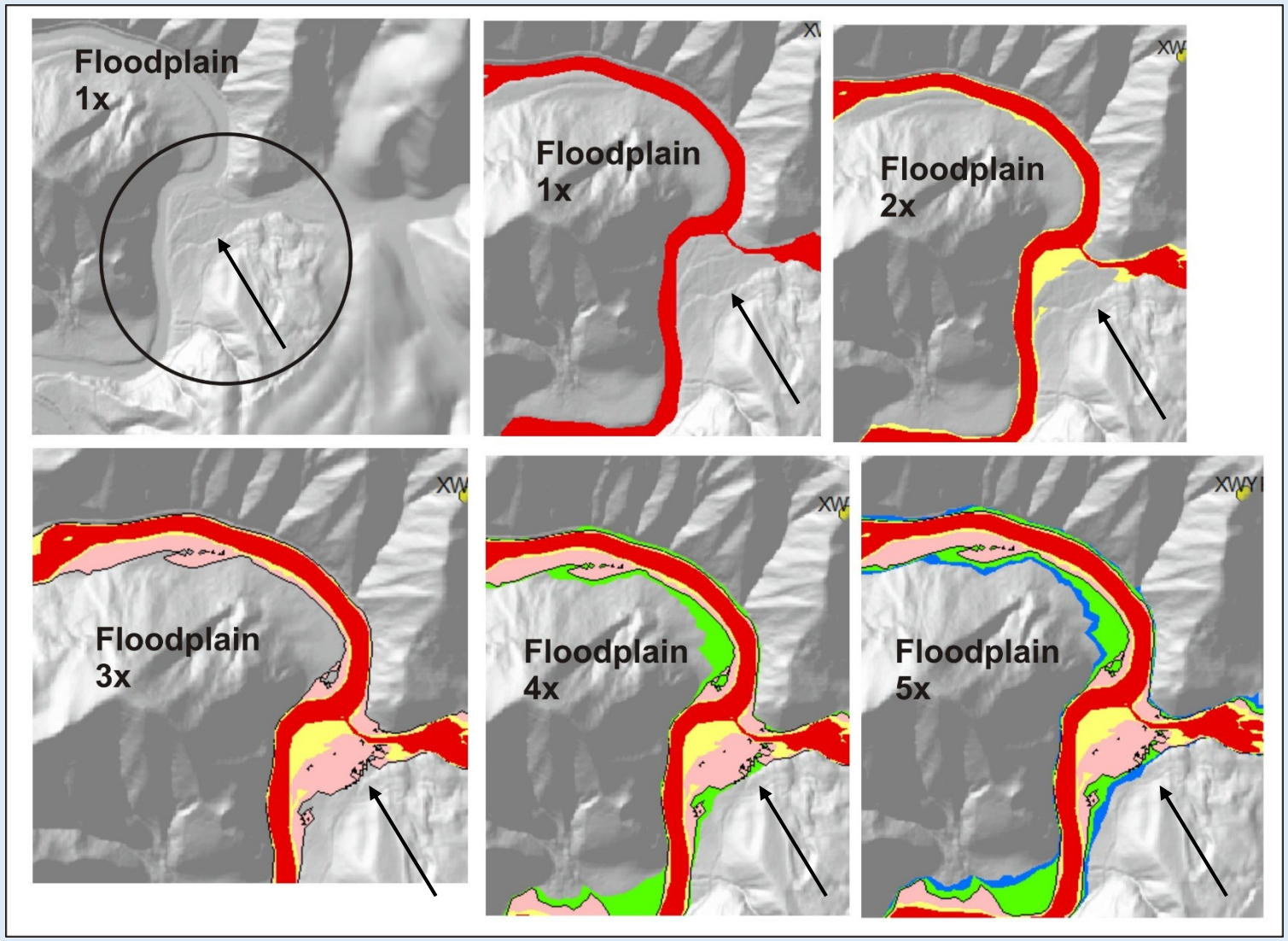




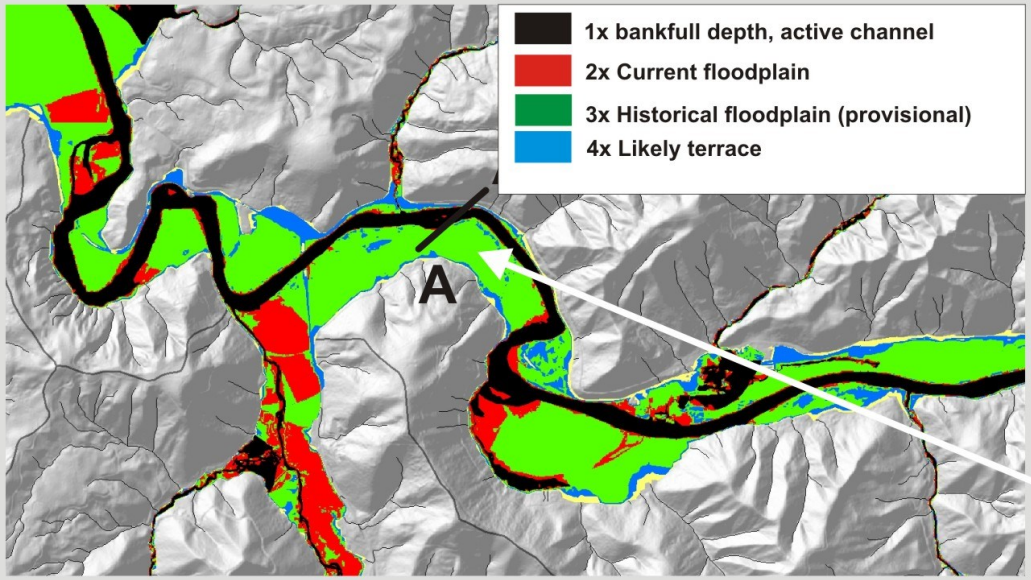
Multiple floodplain elevations

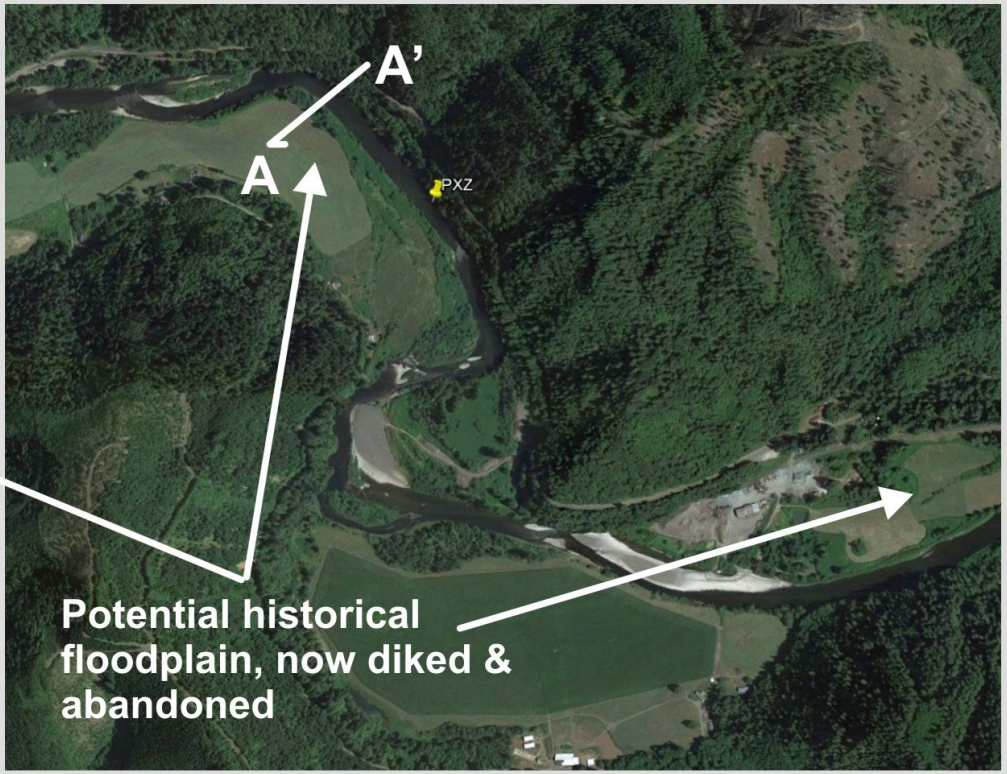


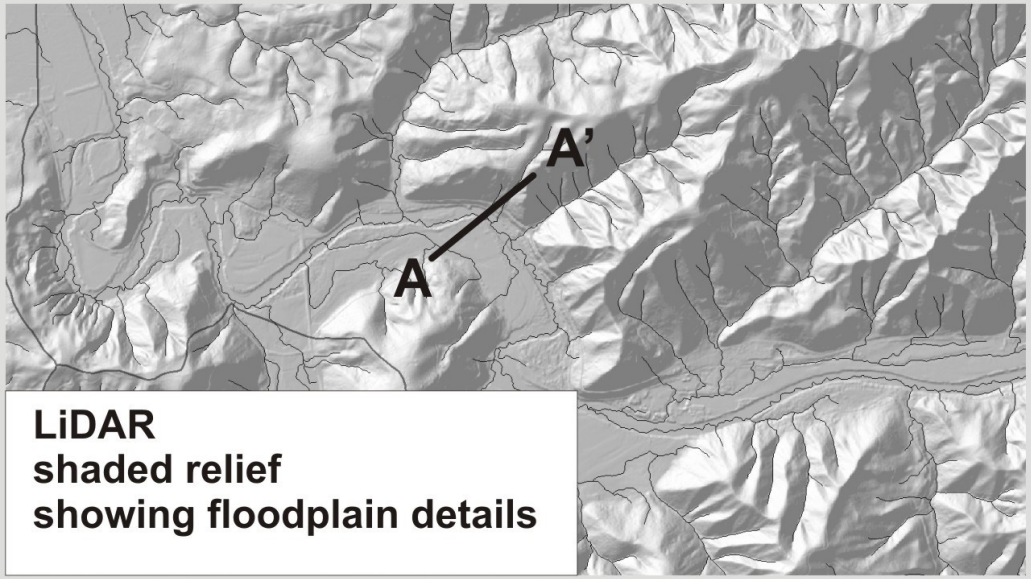
NetMap's floodplain mapping tool

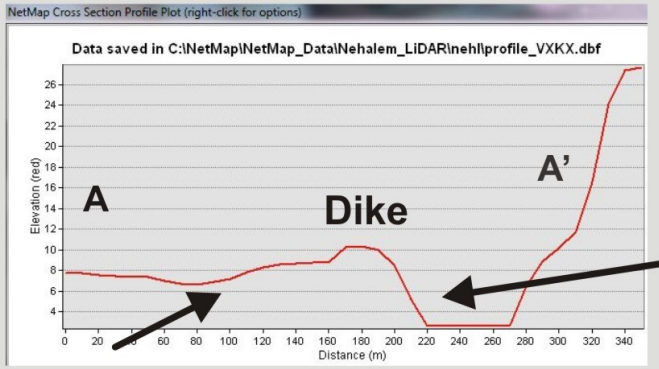


Current and historical floodplains

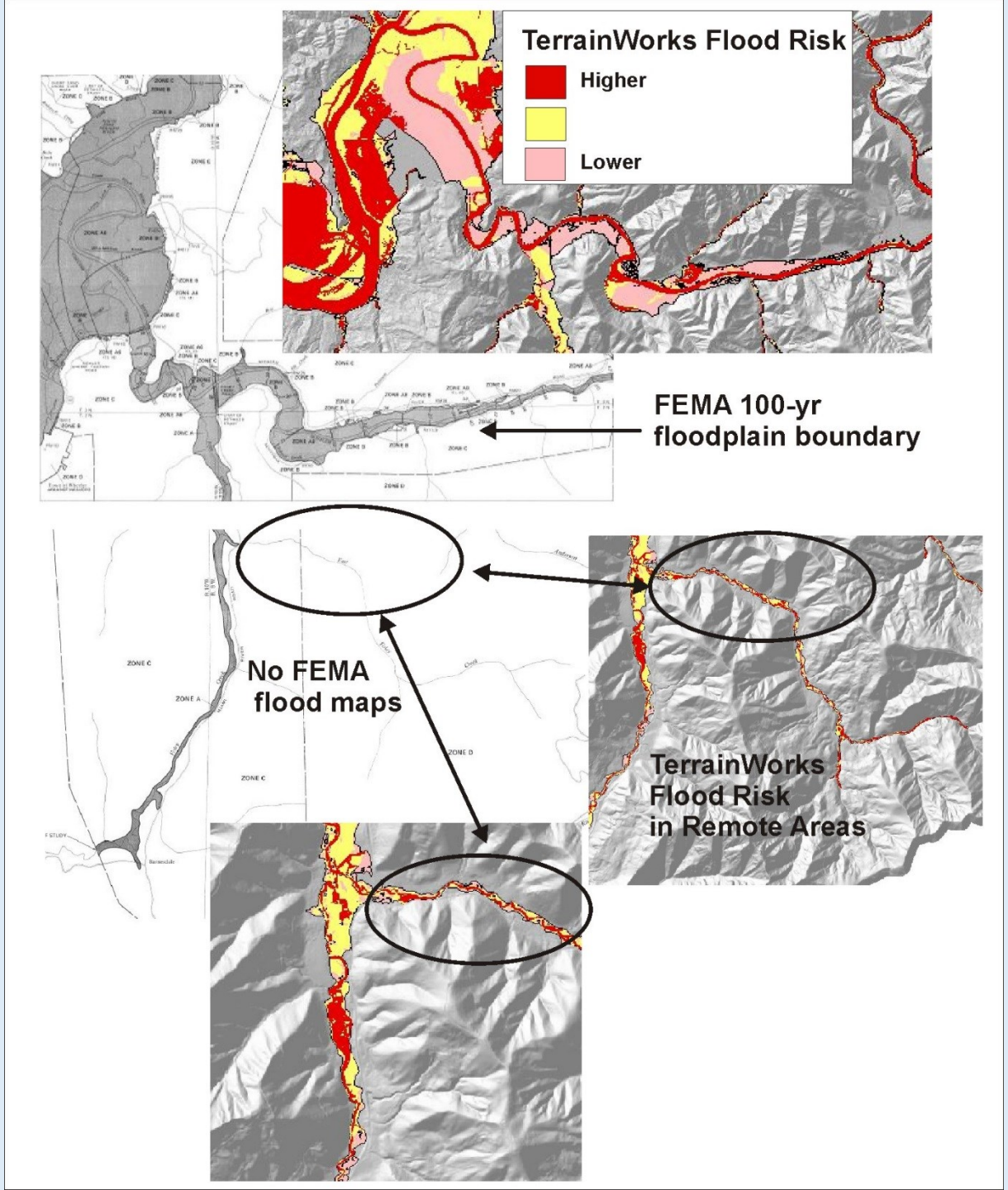




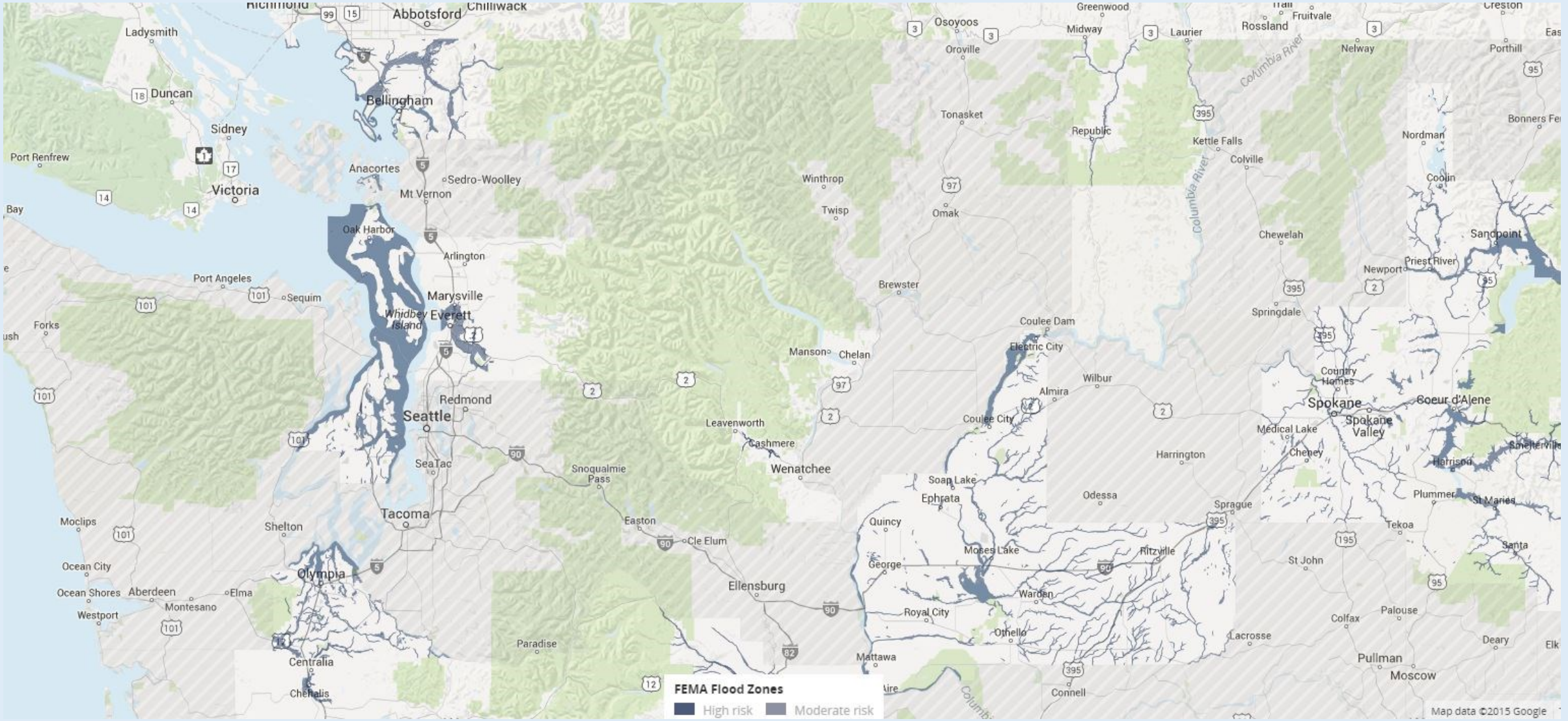




Compare with FEMA



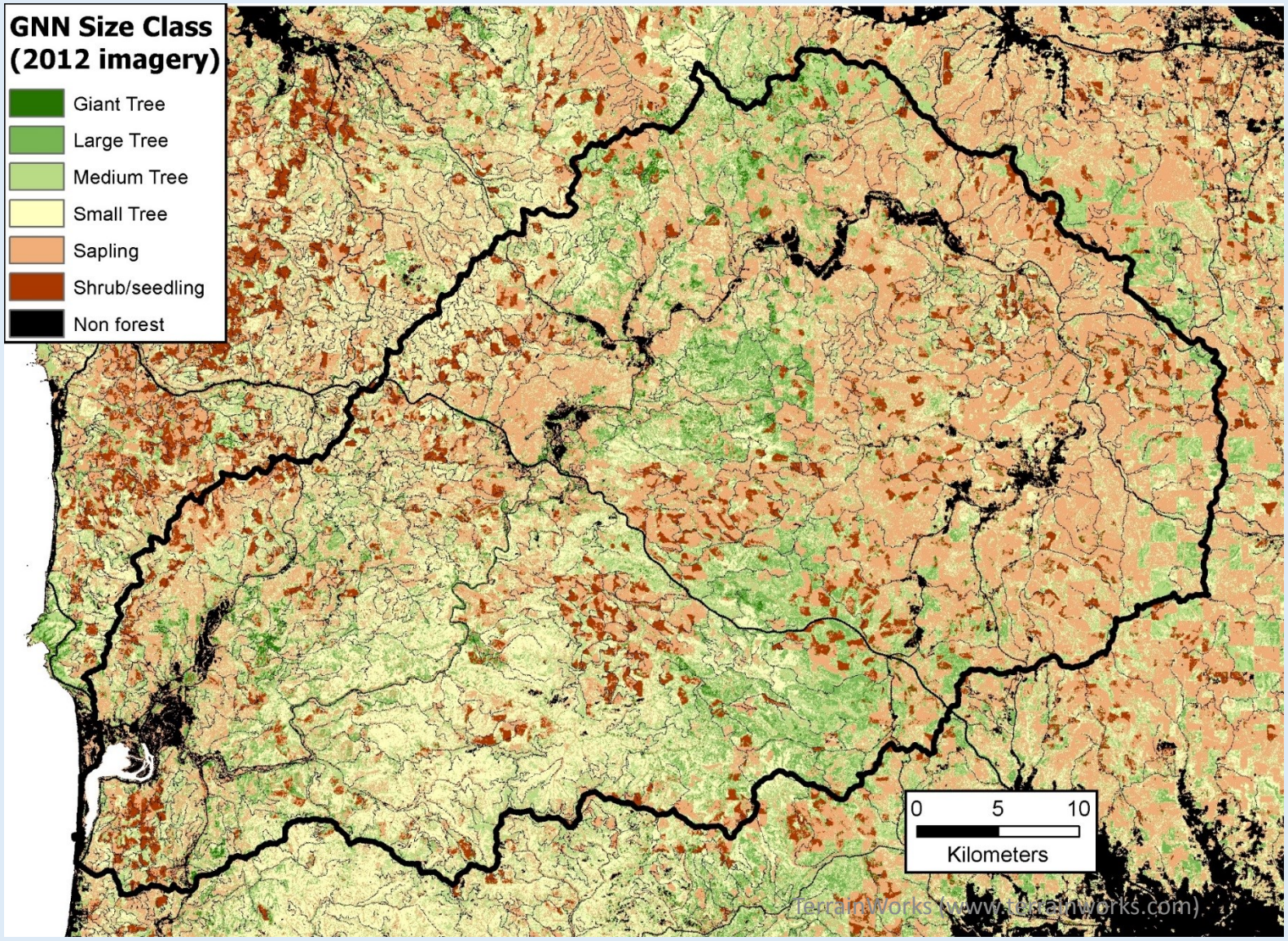
Compare with FEMA

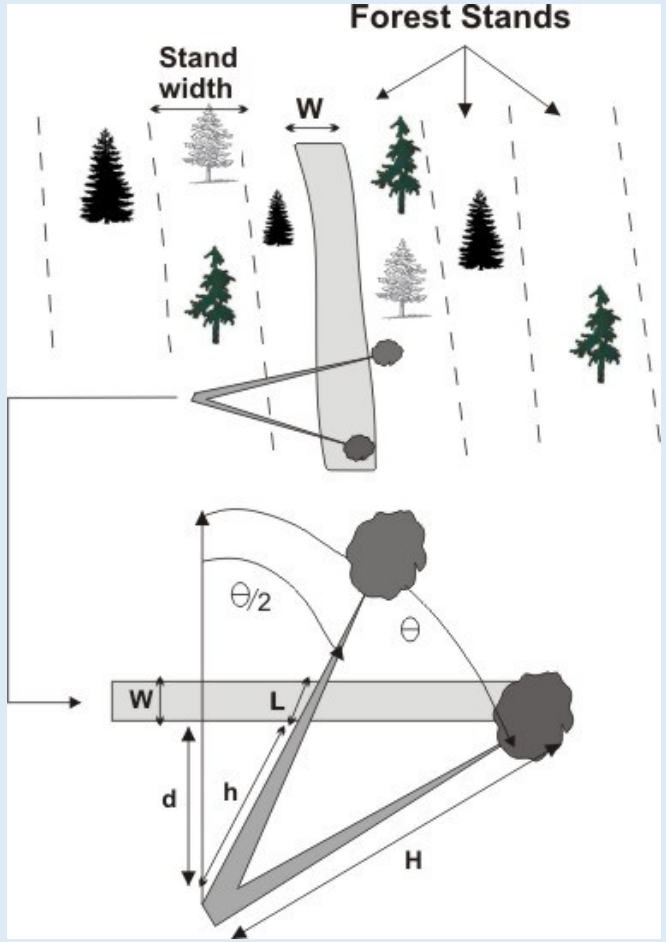


Riparian Processes/Zones

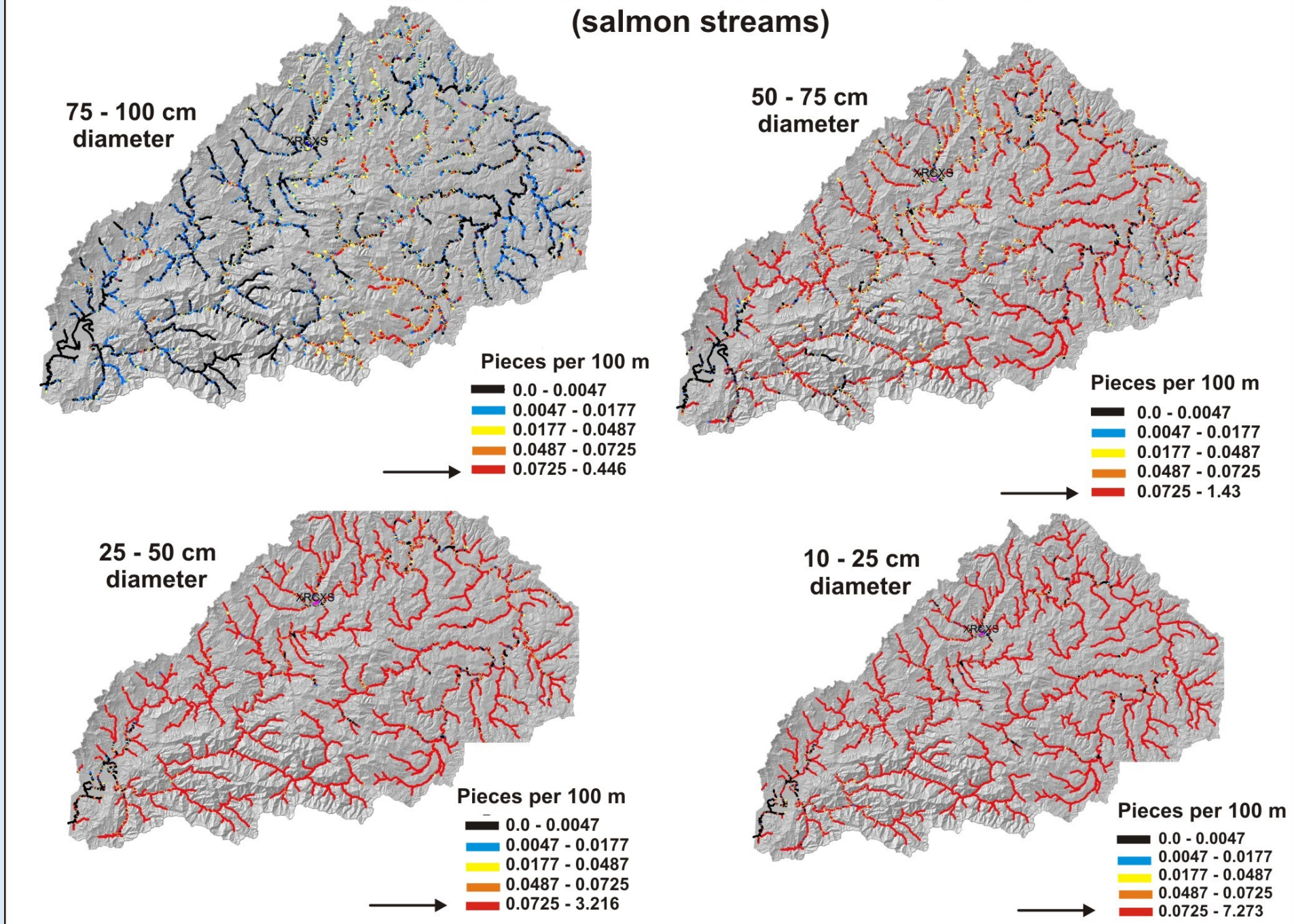
- shade-thermal energy
- instream wood recruitment
- thermal refugia
- wet areas
- spatially variable riparian delineation

Watershed scale wood recruitment potential



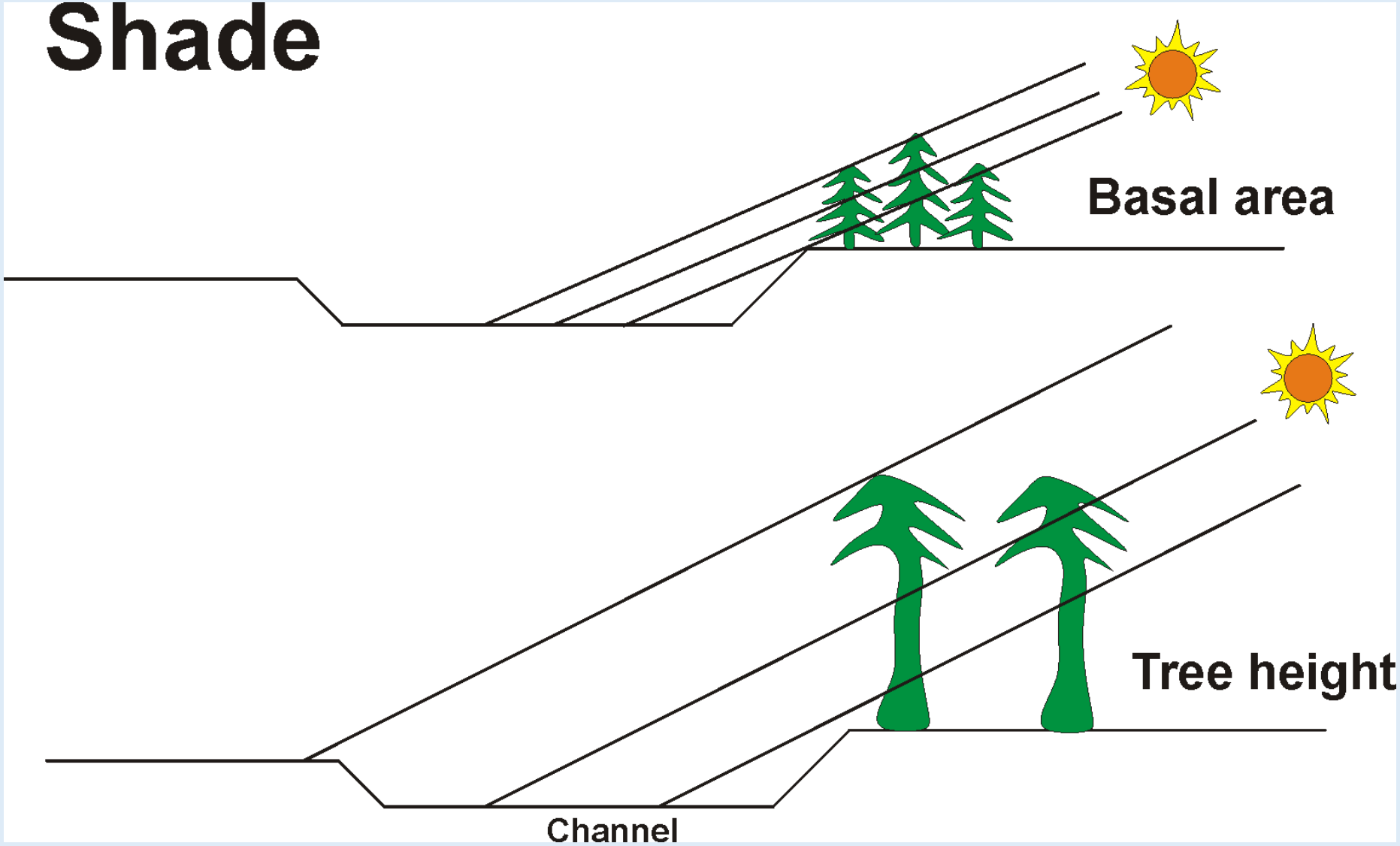


Current Annual In-Stream Wood Recruitment (salmon streams)

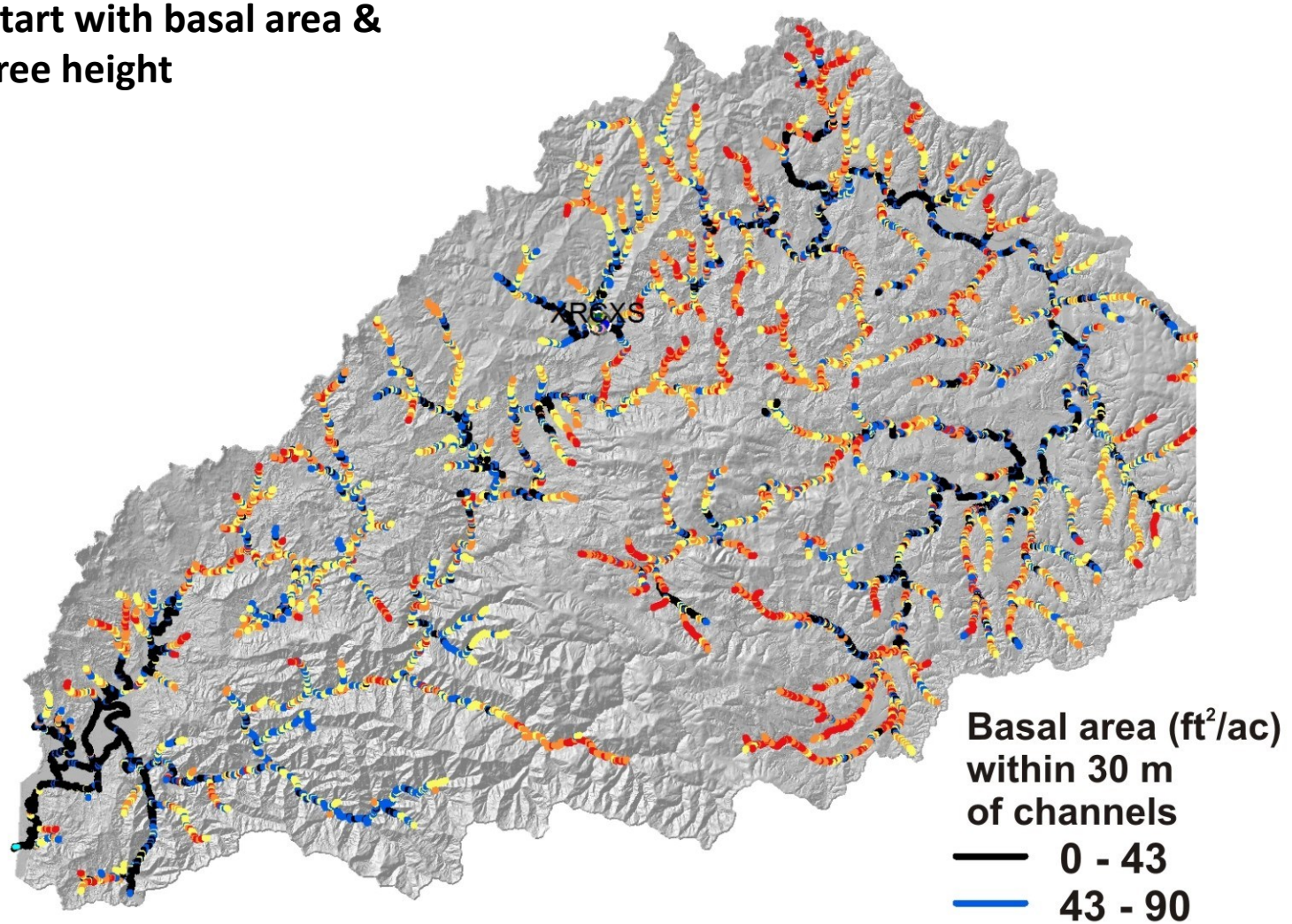


Shade/Thermal Loading

Shade

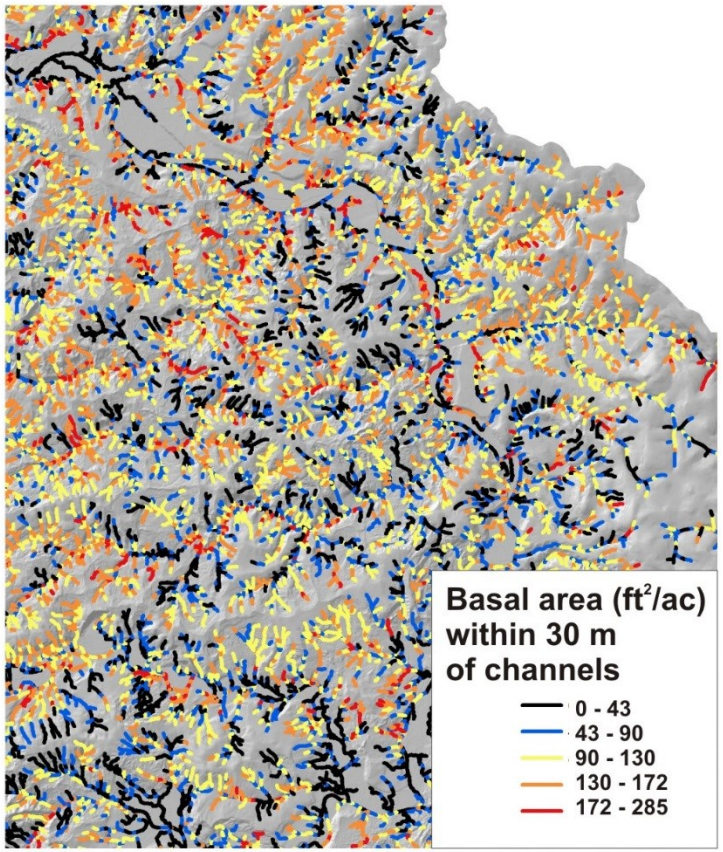


Start with basal area & tree height

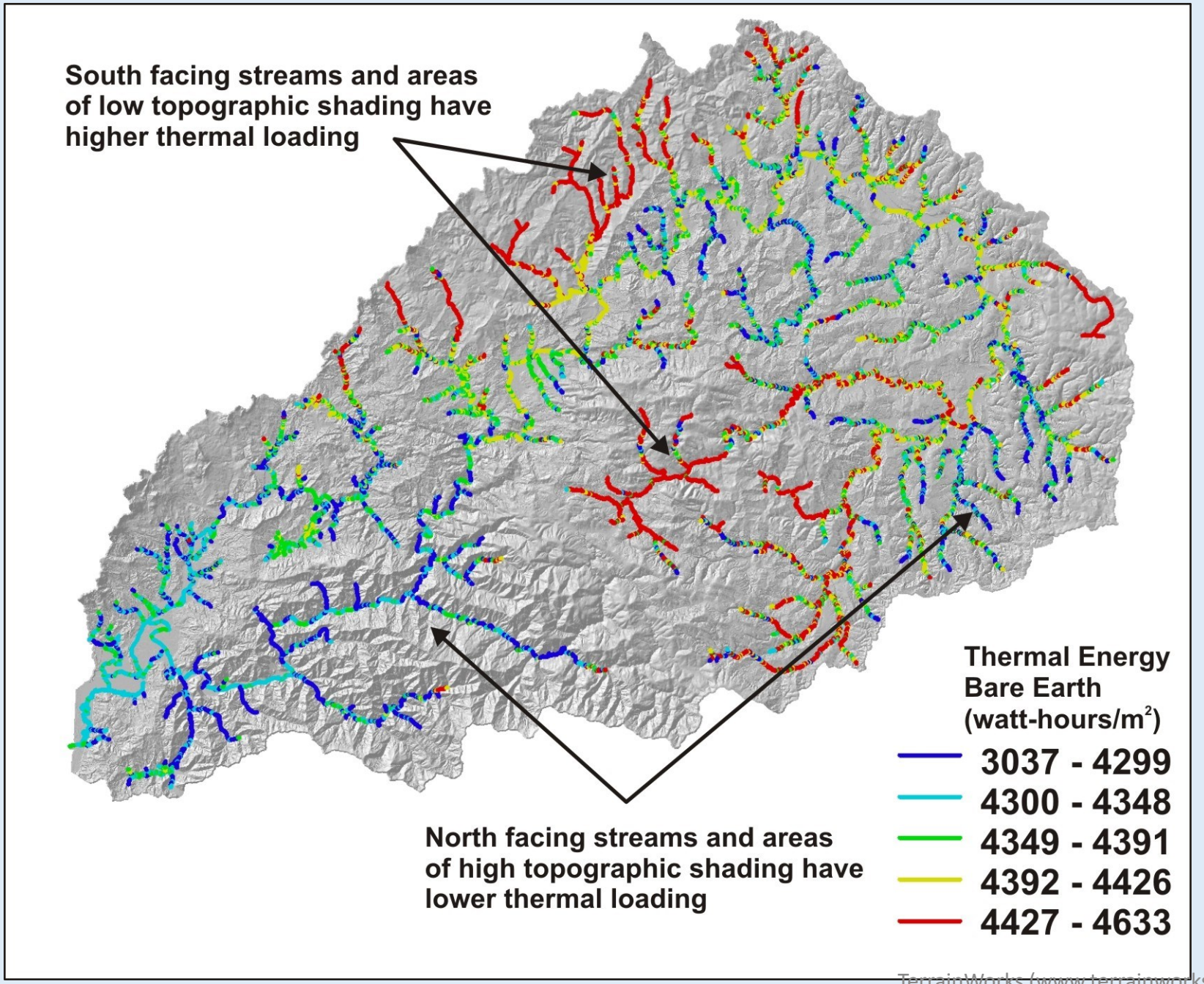


Fish – bearing streams

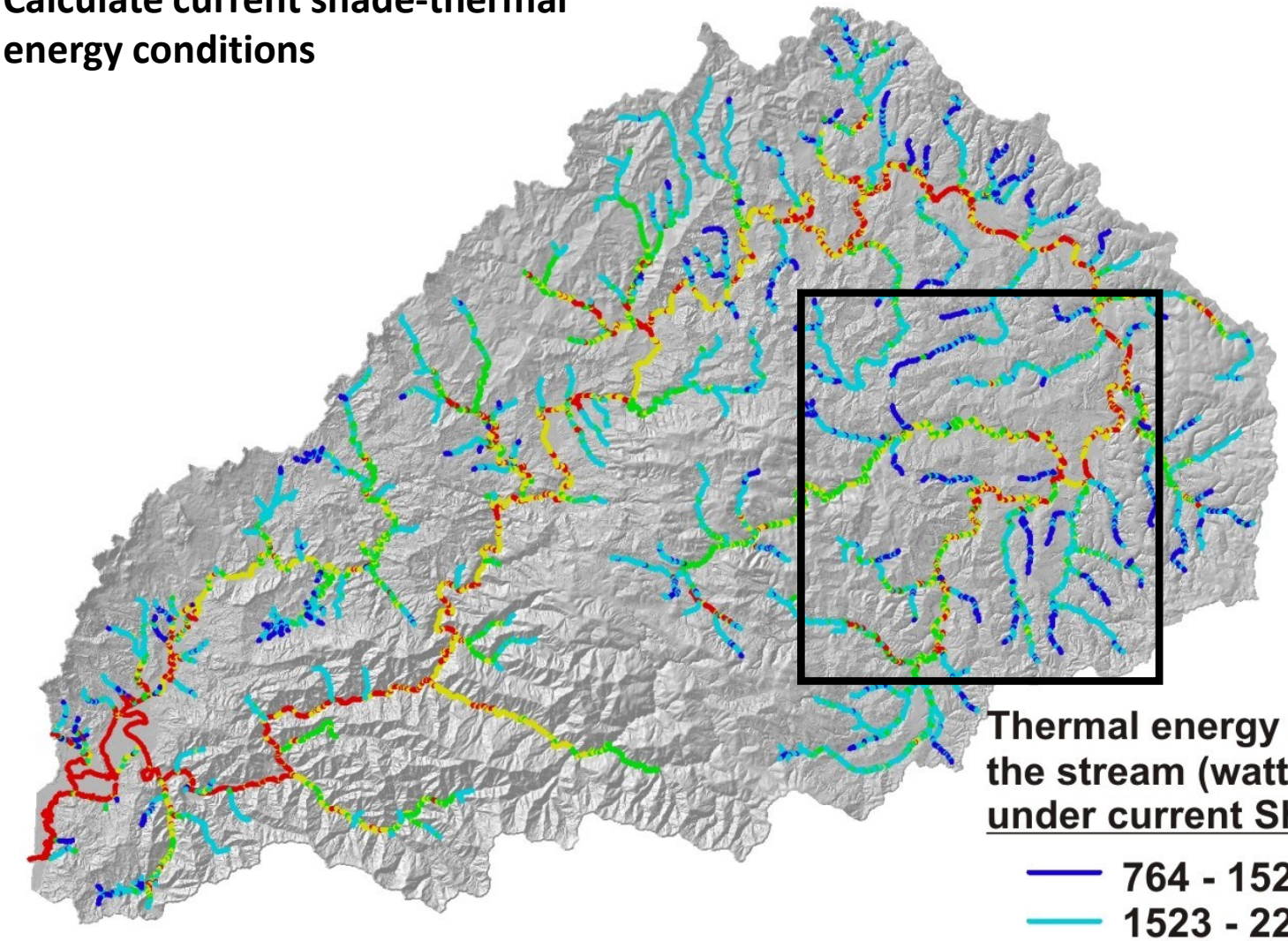
Include headwaters

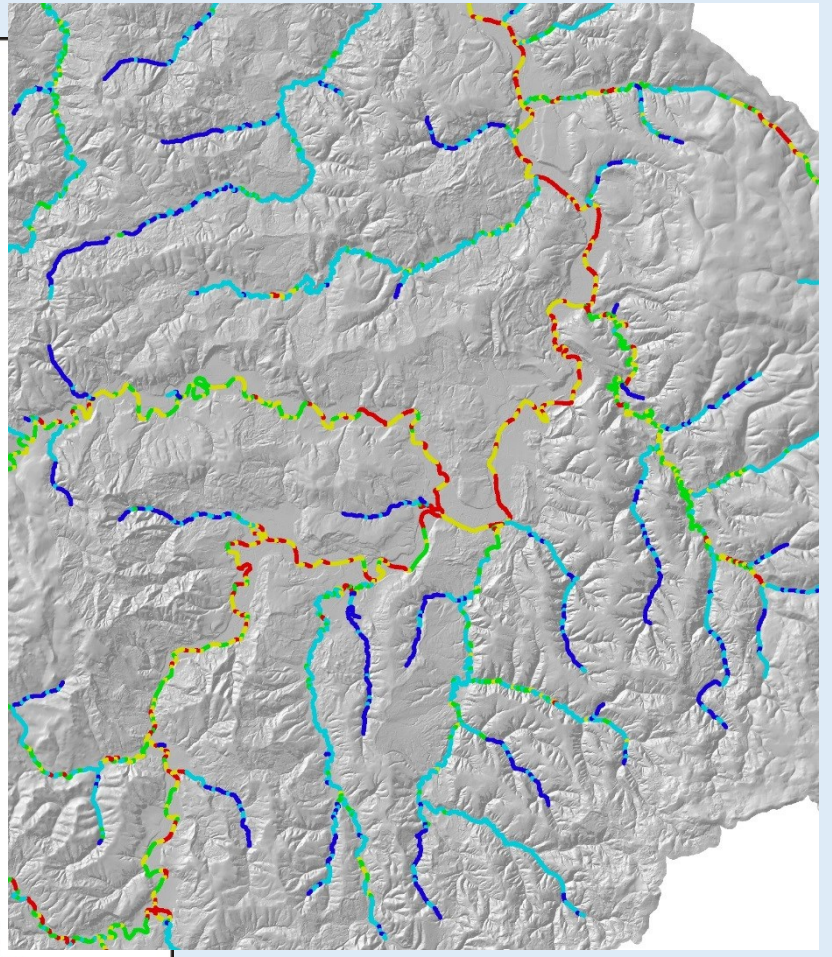


Add bare Earth radiation



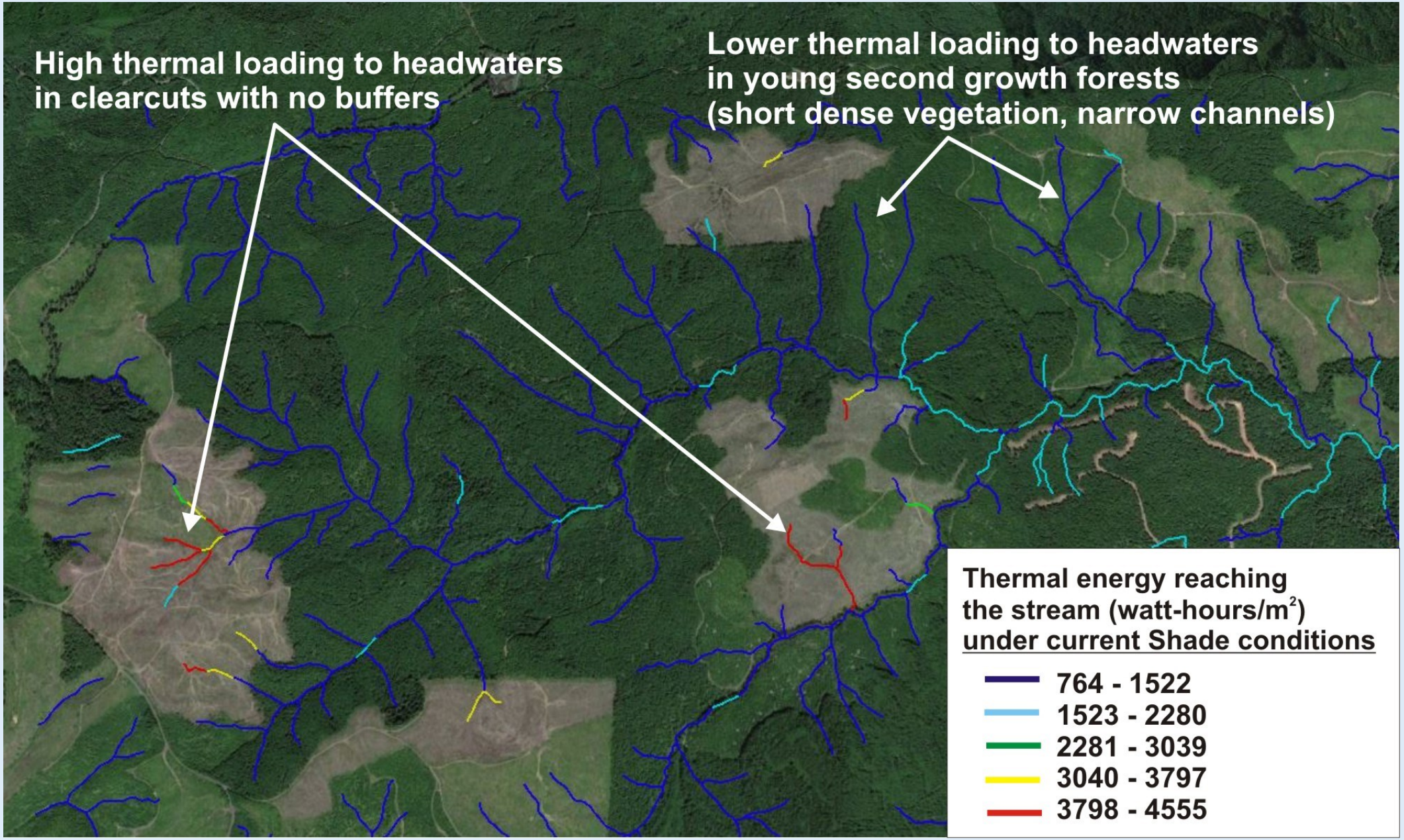
Calculate current shade-thermal energy conditions



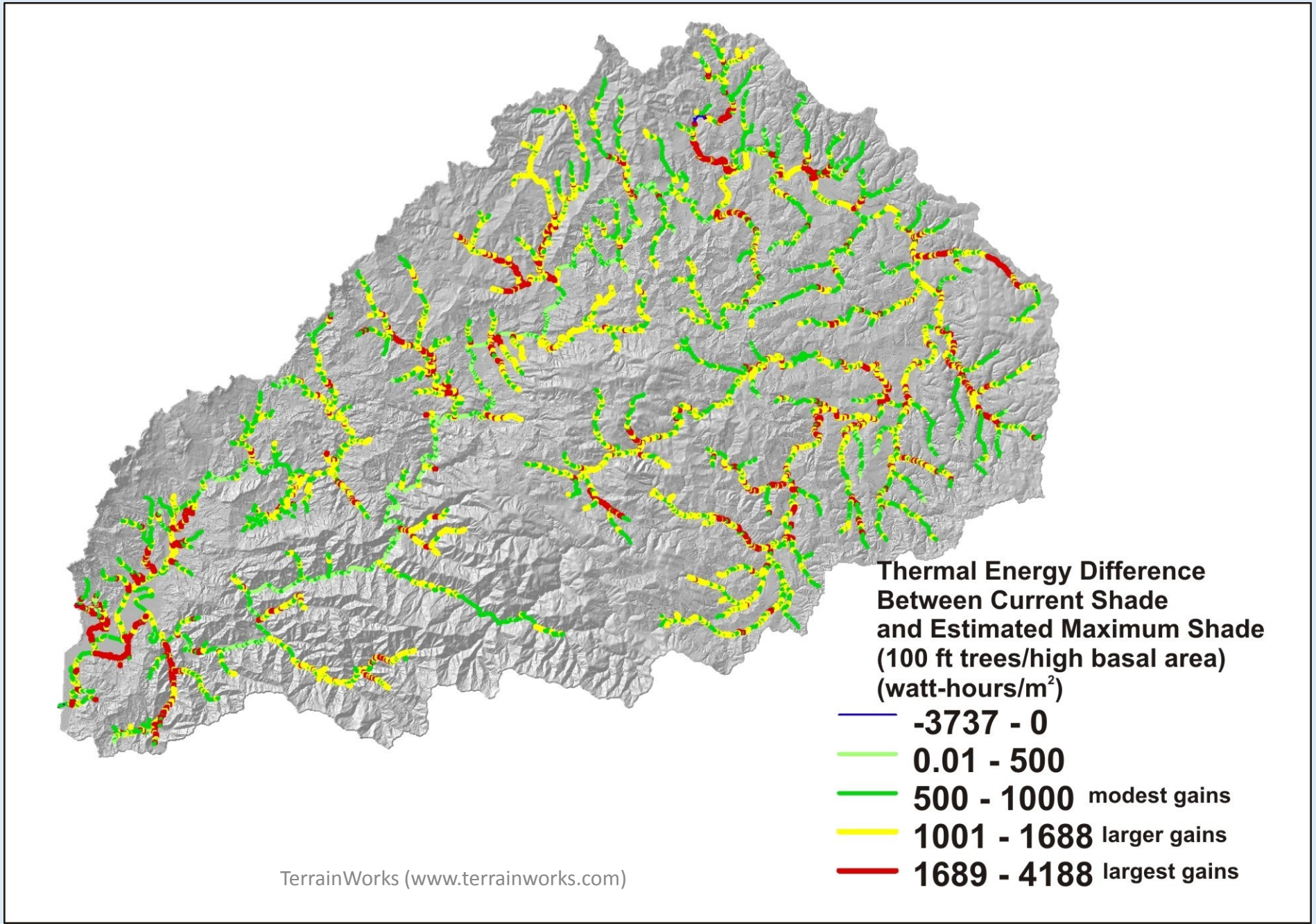


Thermal energy reaching the stream (watt-hours/m^2) under current Shade conditions

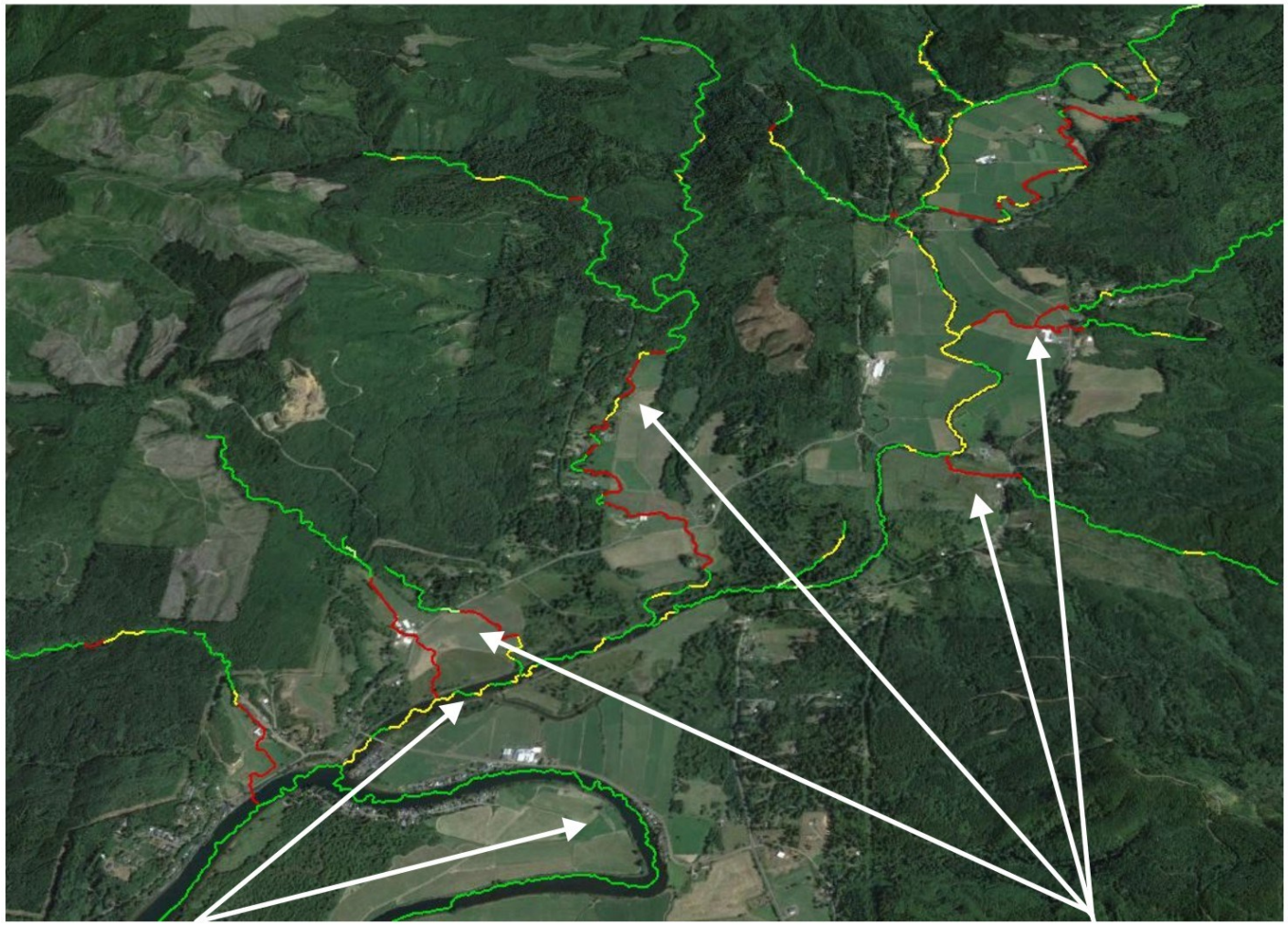
- 764 - 1522
- 1523 - 2280
- 2281 - 3039
- 3040 - 3797
- 3798 - 4555


High thermal loading to headwaters
in clearcuts with no buffers
Lower thermal loading to headwaters
in young second growth forests
(short dense vegetation, narrow channels)
Thermal energy reaching
the stream (watt-hours/m²)
under current Shade conditions
764 - 1522
1523 - 2280
2281 - 3039
3040 - 3797
3798 - 4555

Where is increased shade needed most?



Red and yellow areas are those that could benefit from increased shade (reduced thermal energy to channels)

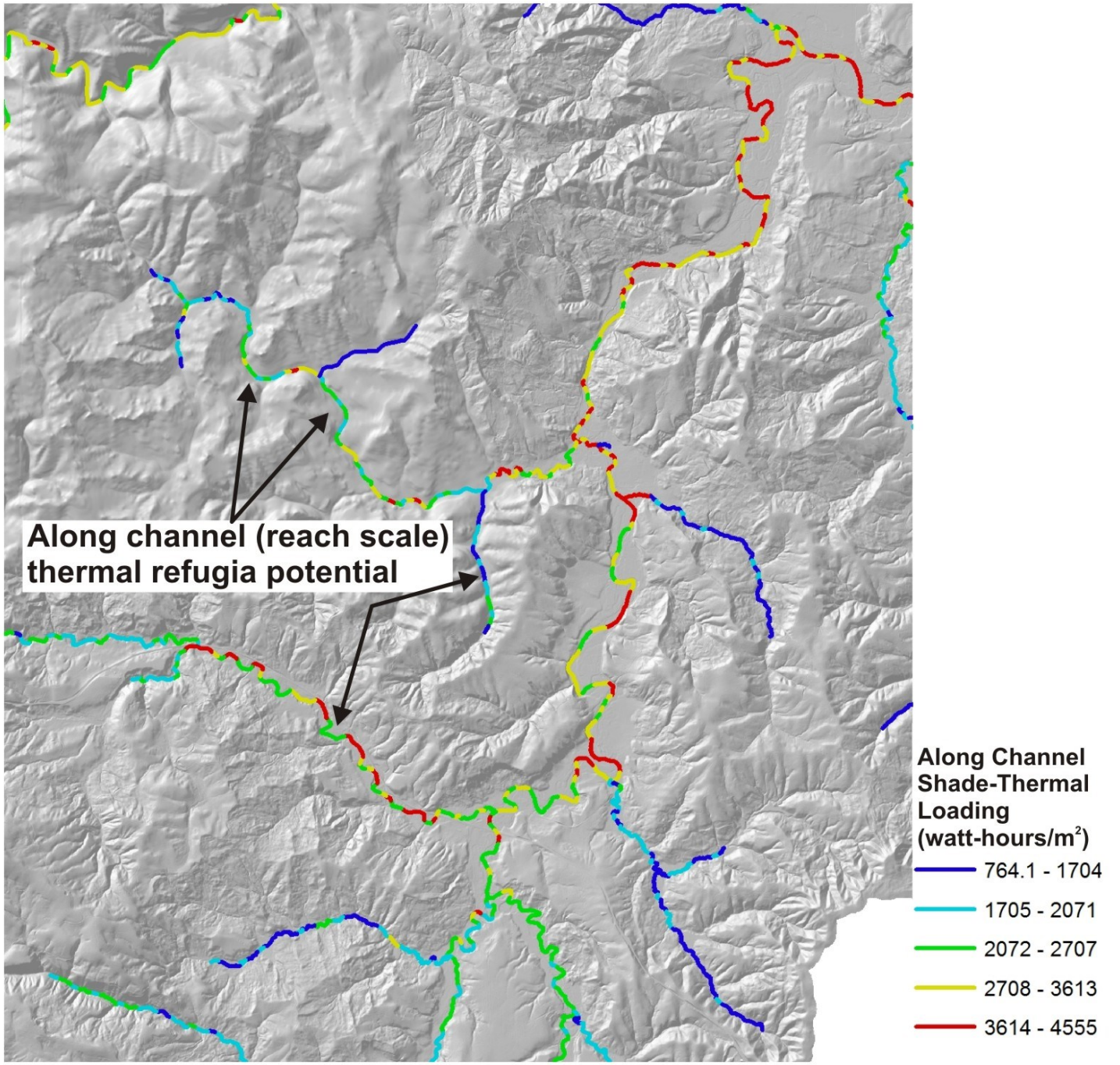


Shading and thus thermal energy in larger rivers cannot be significantly impacted by increasing shade, except very locally

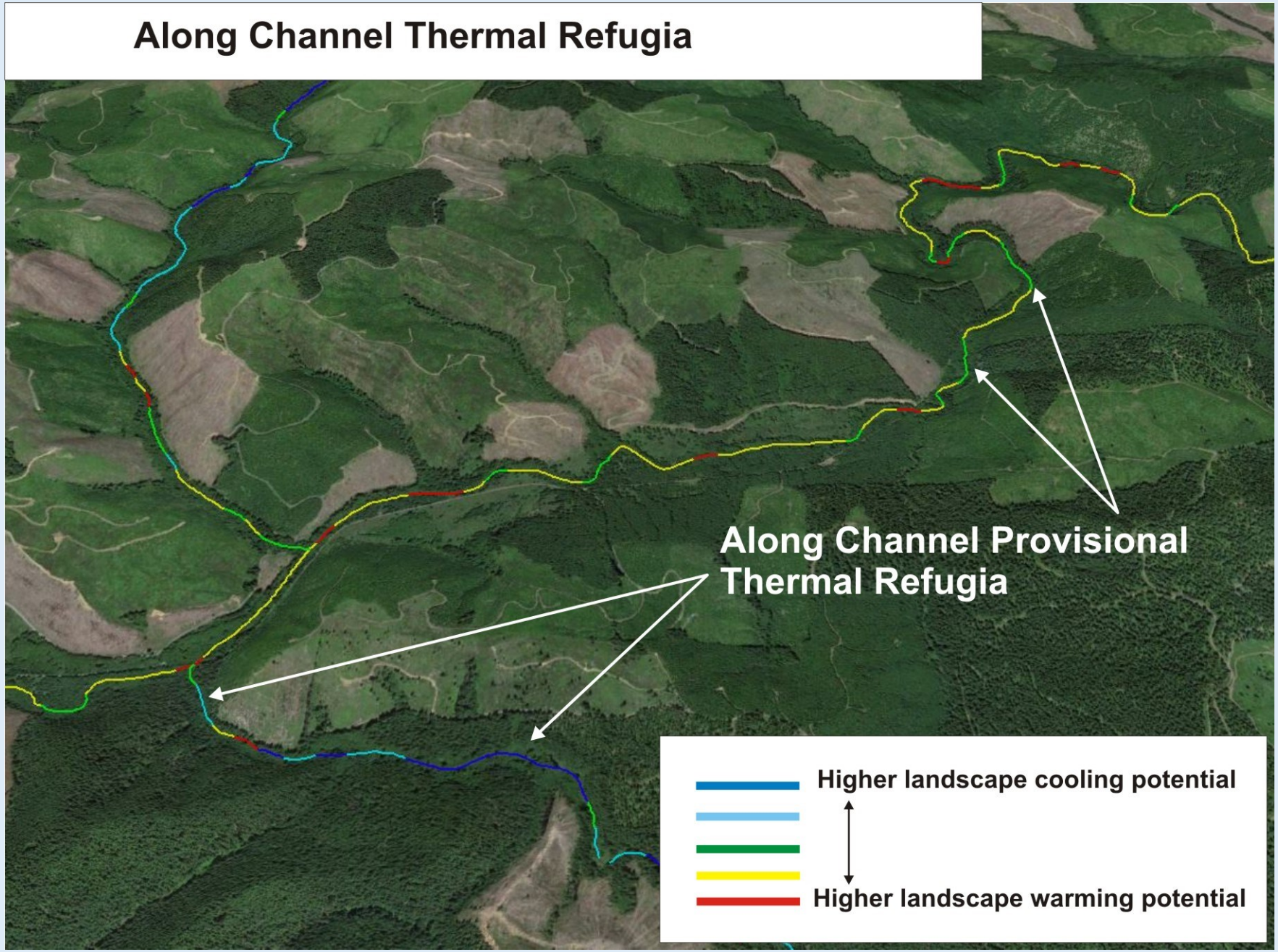
Smaller channels in areas of no shade would have the greatest benefit and most of these overlap with high quality coho habitat potential (e.g., high IP scores)

Along channel thermal refugia

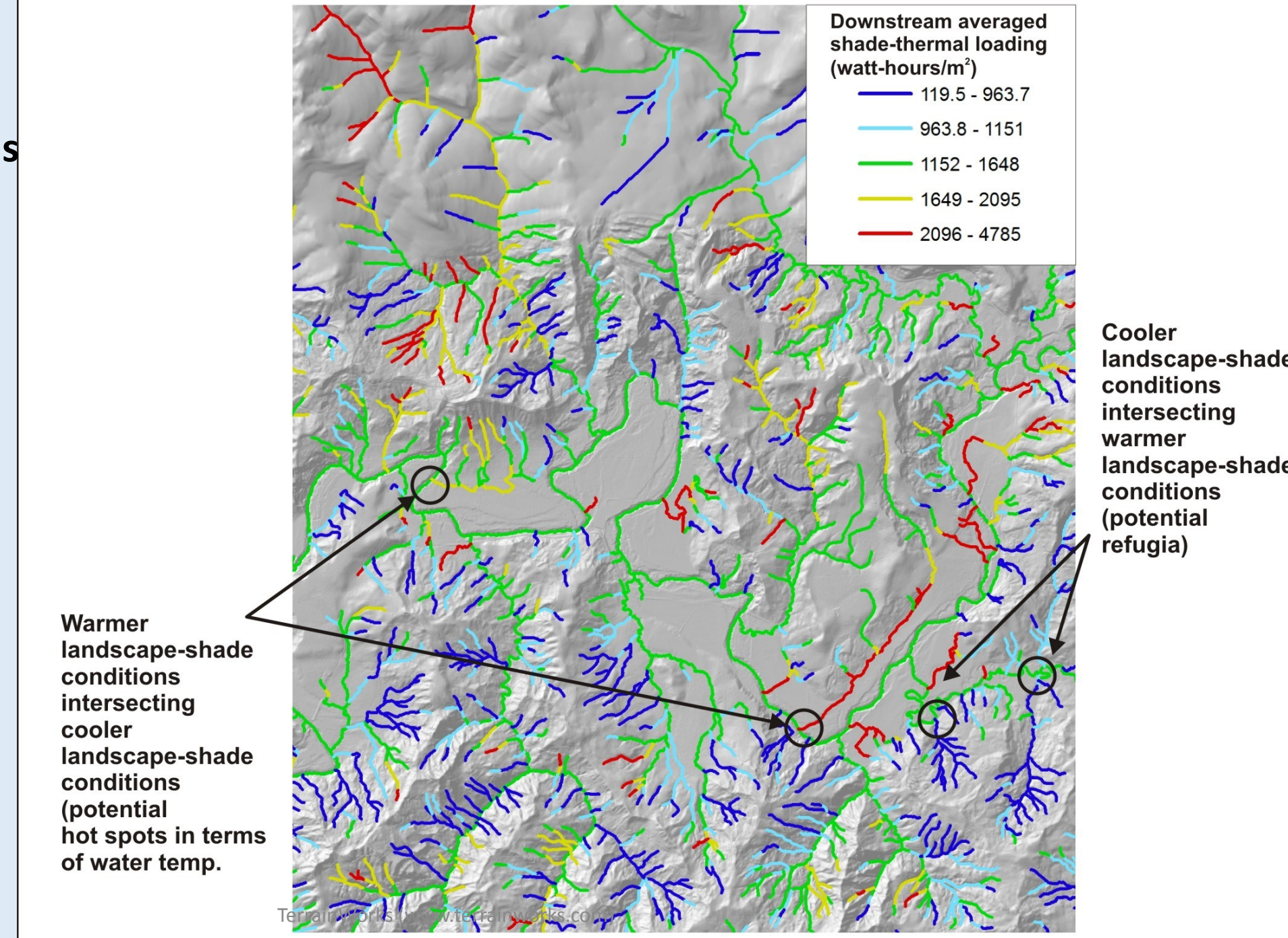
-latitude
-topographic shading
-stream azimuth
-stream width
-current vegetation



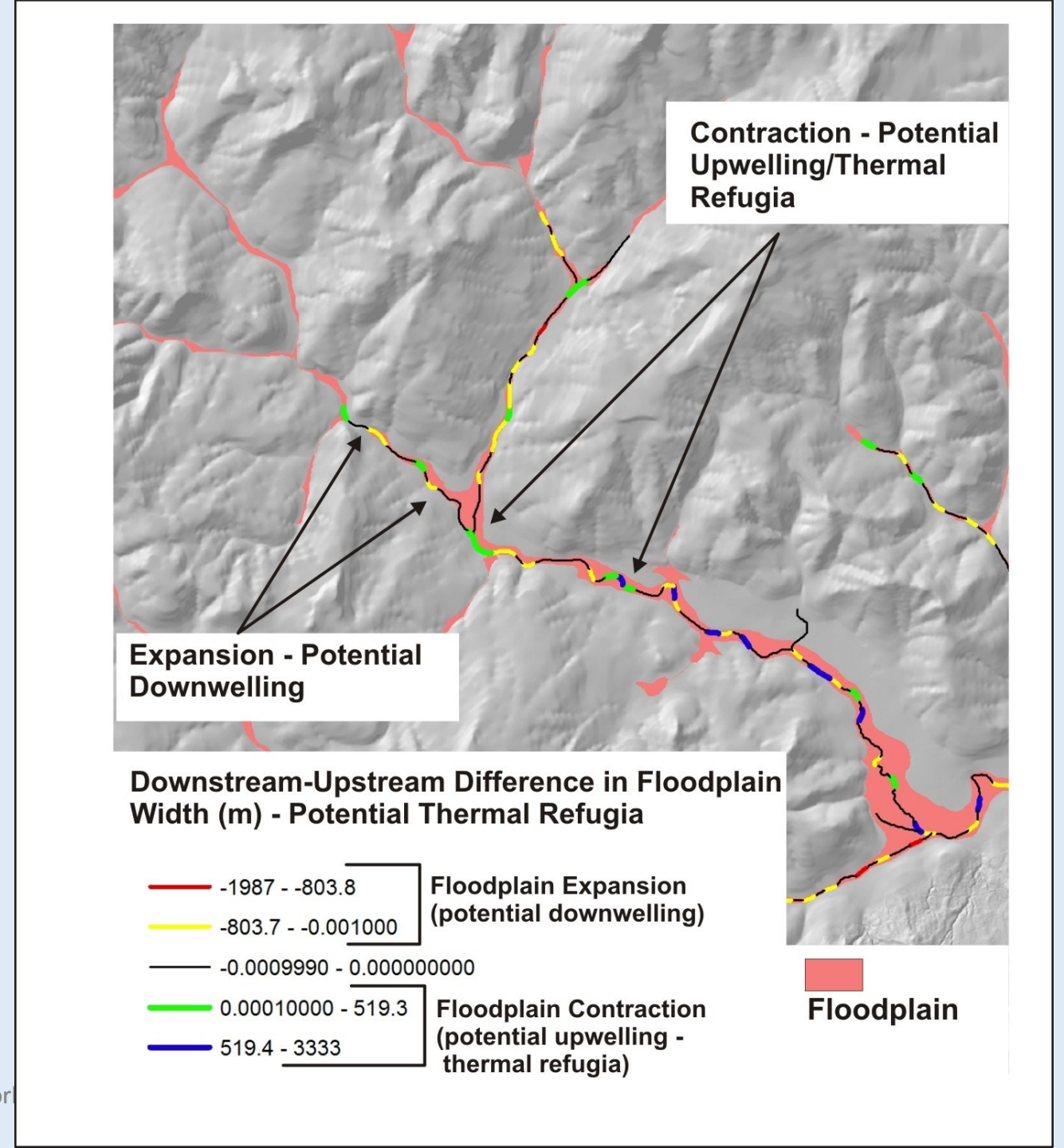
Along Channel Thermal Refugia

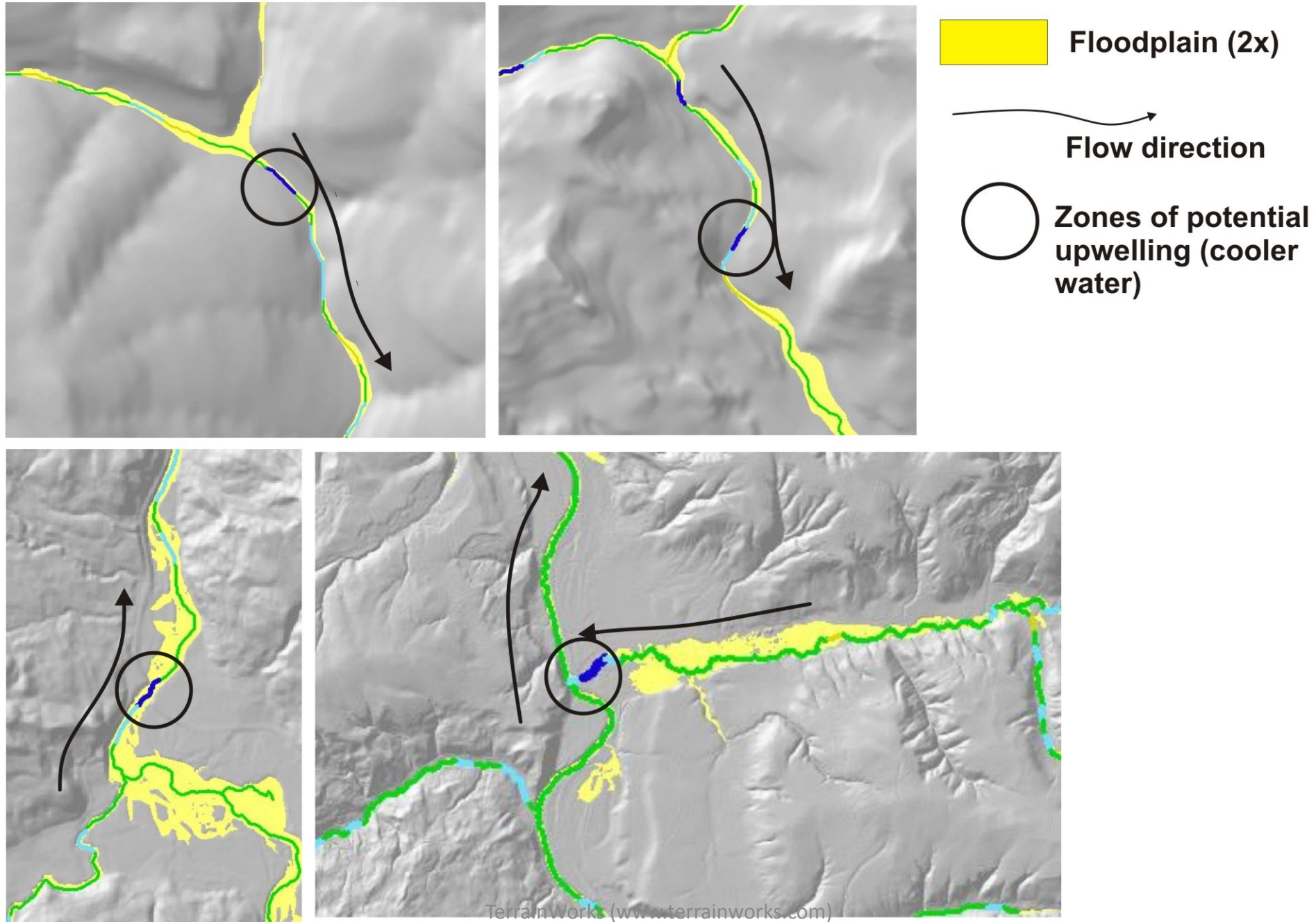


Thermal relationship between tributaries and mainstem channels



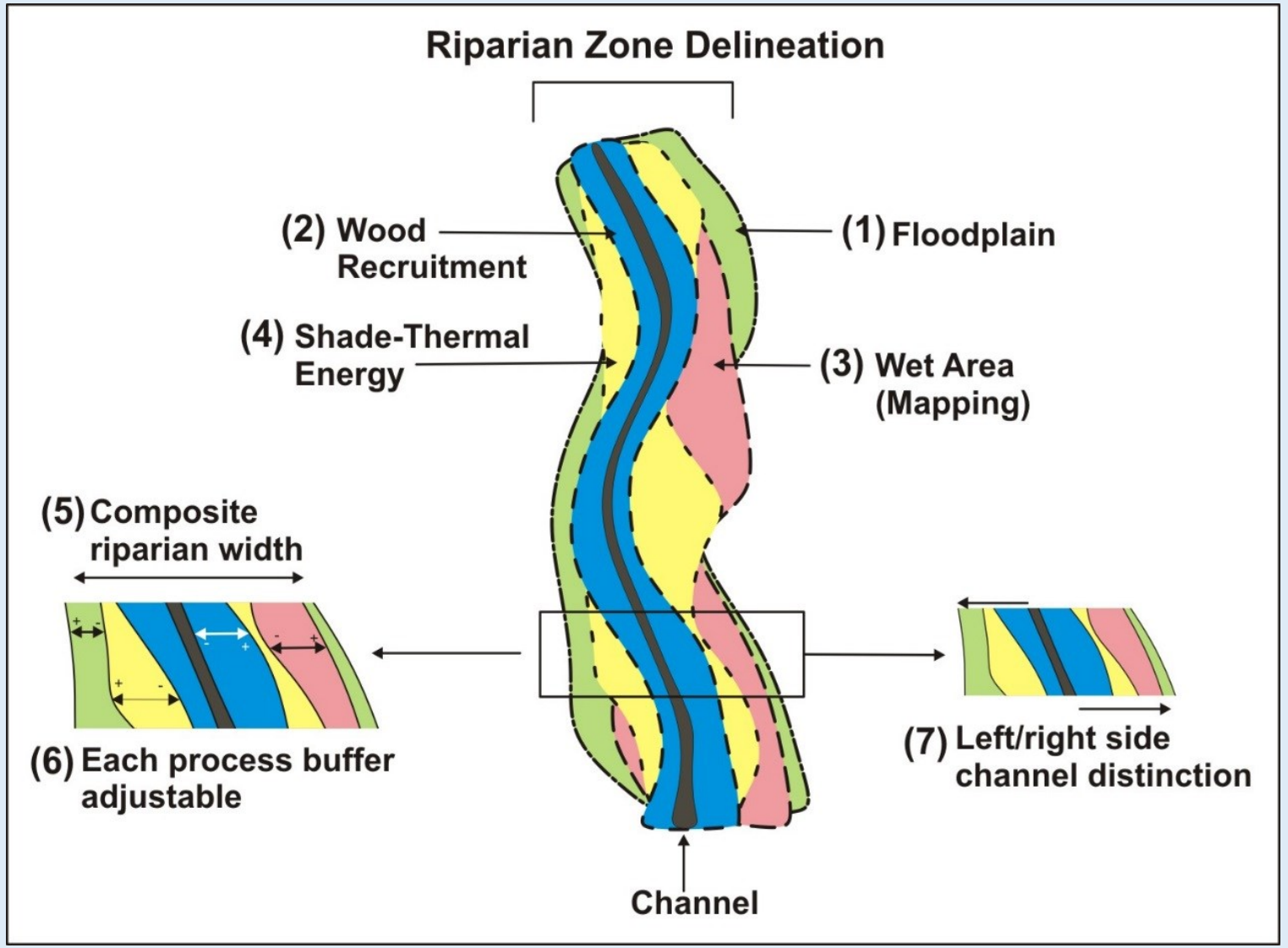
Valley contraction/expansion and potential upwelling and downwelling of hyporheic flow



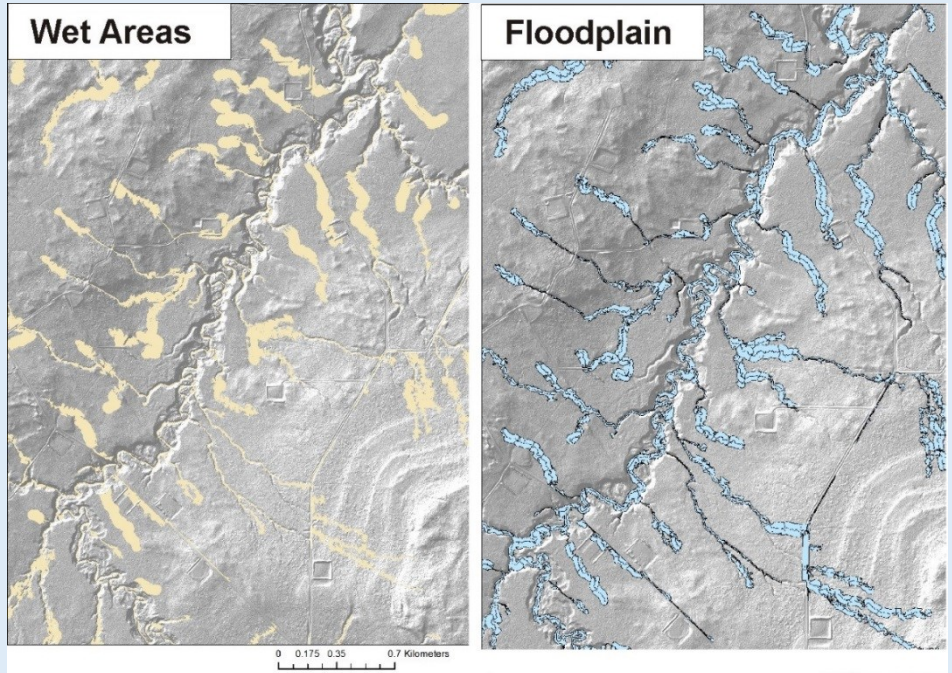

Floodplain (2x)
Flow direction
Zones of potential upwelling (cooler water)
TerrainWorks (www.terrainworks.com)

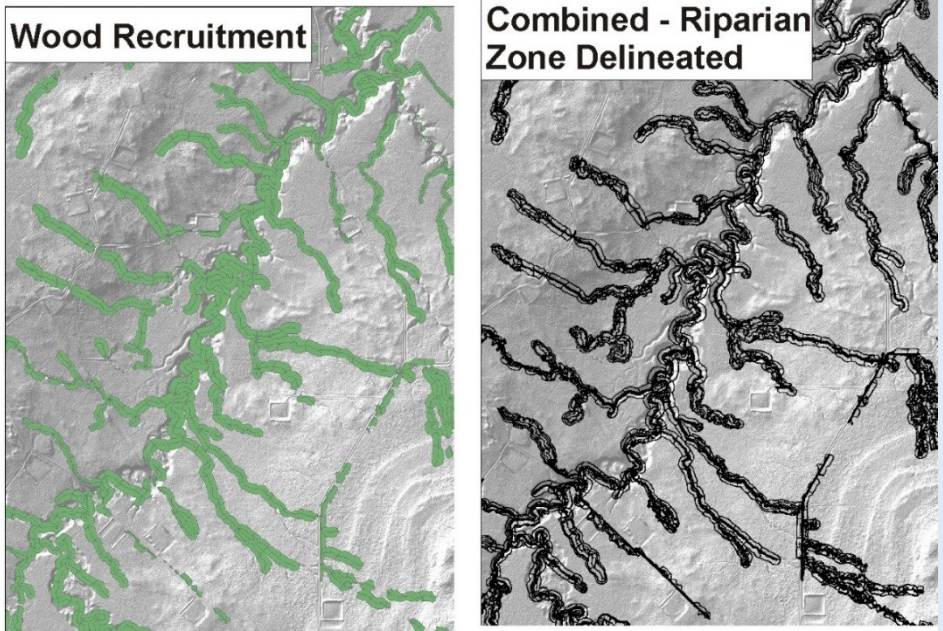
Delineating Riparian Zones

- floodplains
- wood recruitment
- shade thermal loading
- wet areas

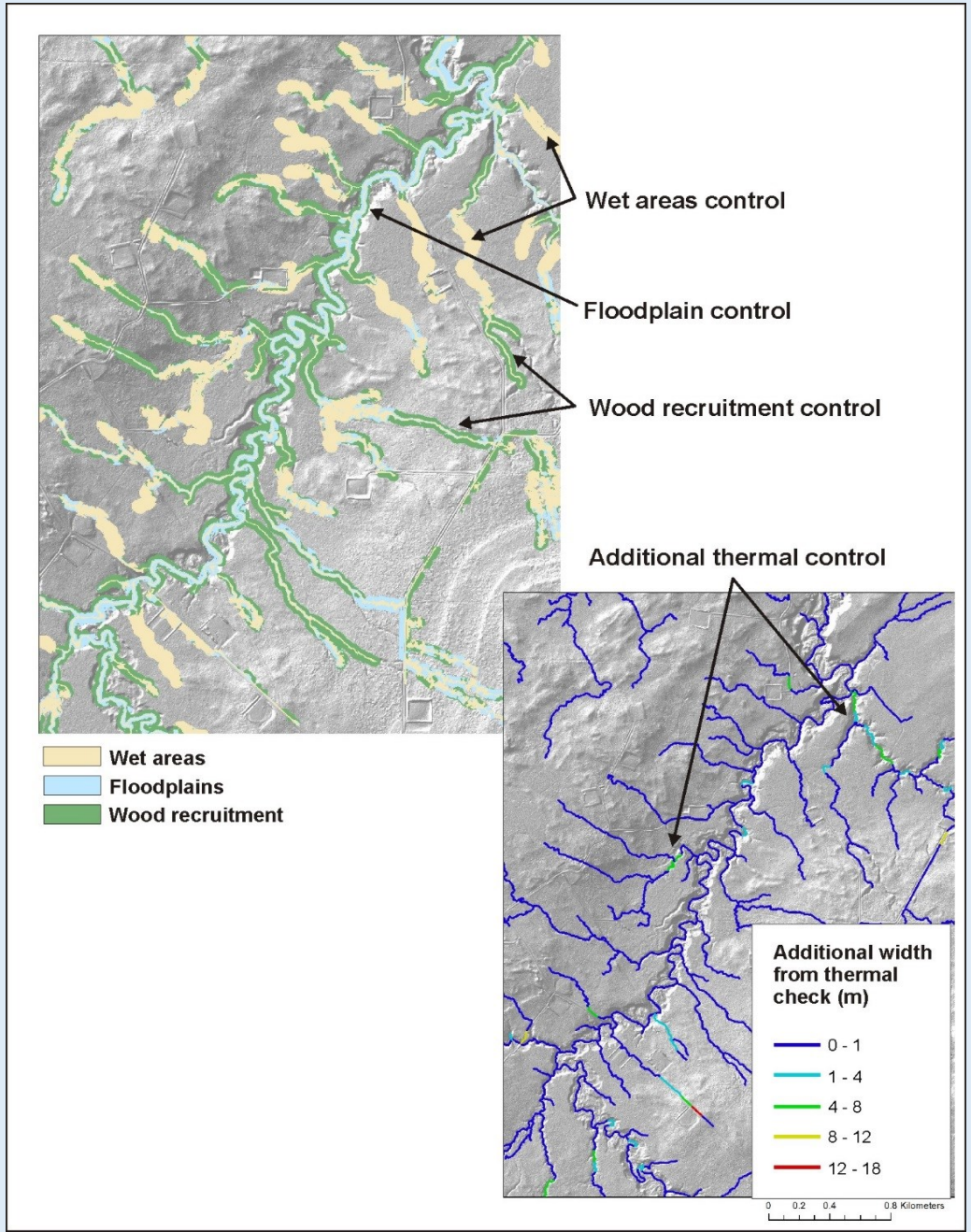


Riparian Zone Components

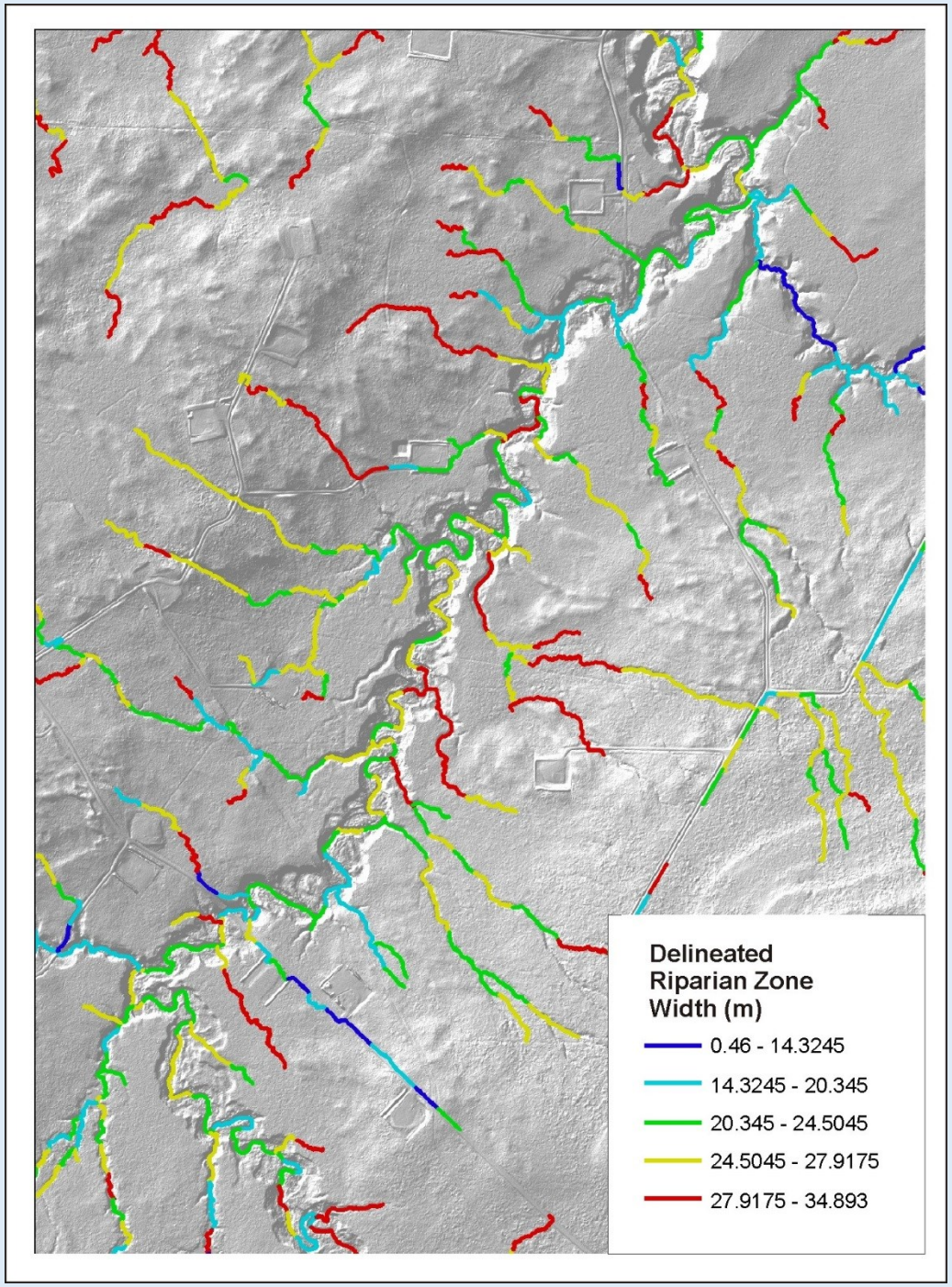


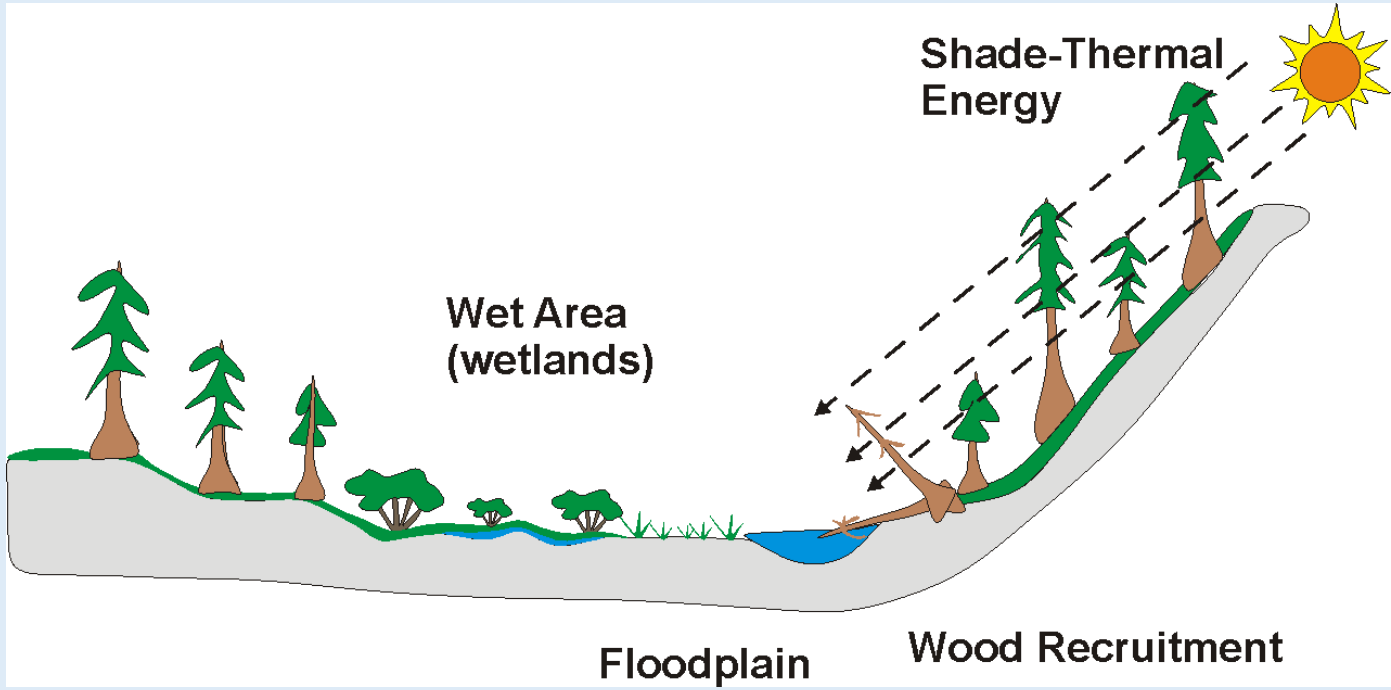


Variable Controls



Variable width riparian zones





Wetlands

- Field approaches
- Remote sensing (optical imagery)
- Modeling

  (1) Depth to water (DTW), NetMap already has for streams and rivers (can be extended to other water bodies)

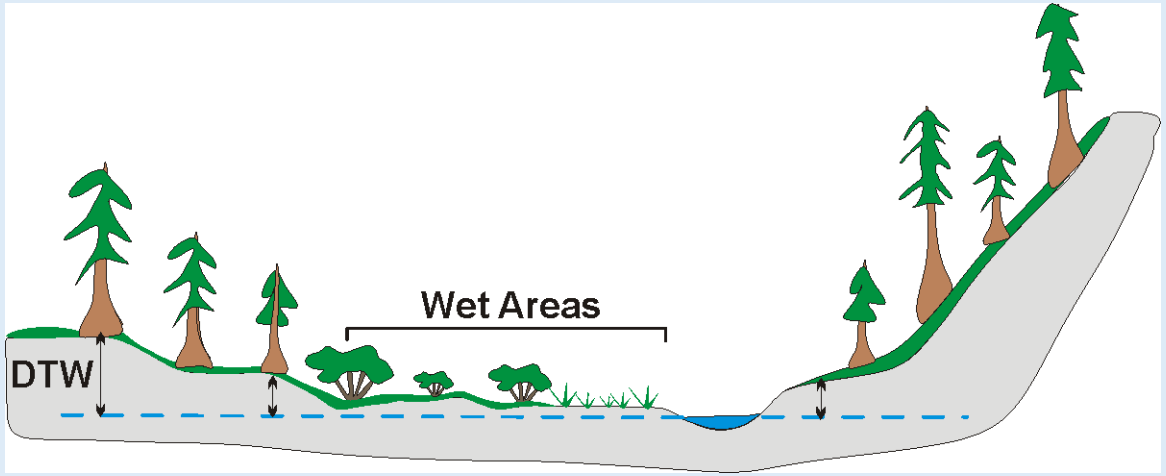
  (2) Topographic wetness index (TWI), uses slope, curvature & contributing area (can add soils/transmissivity)

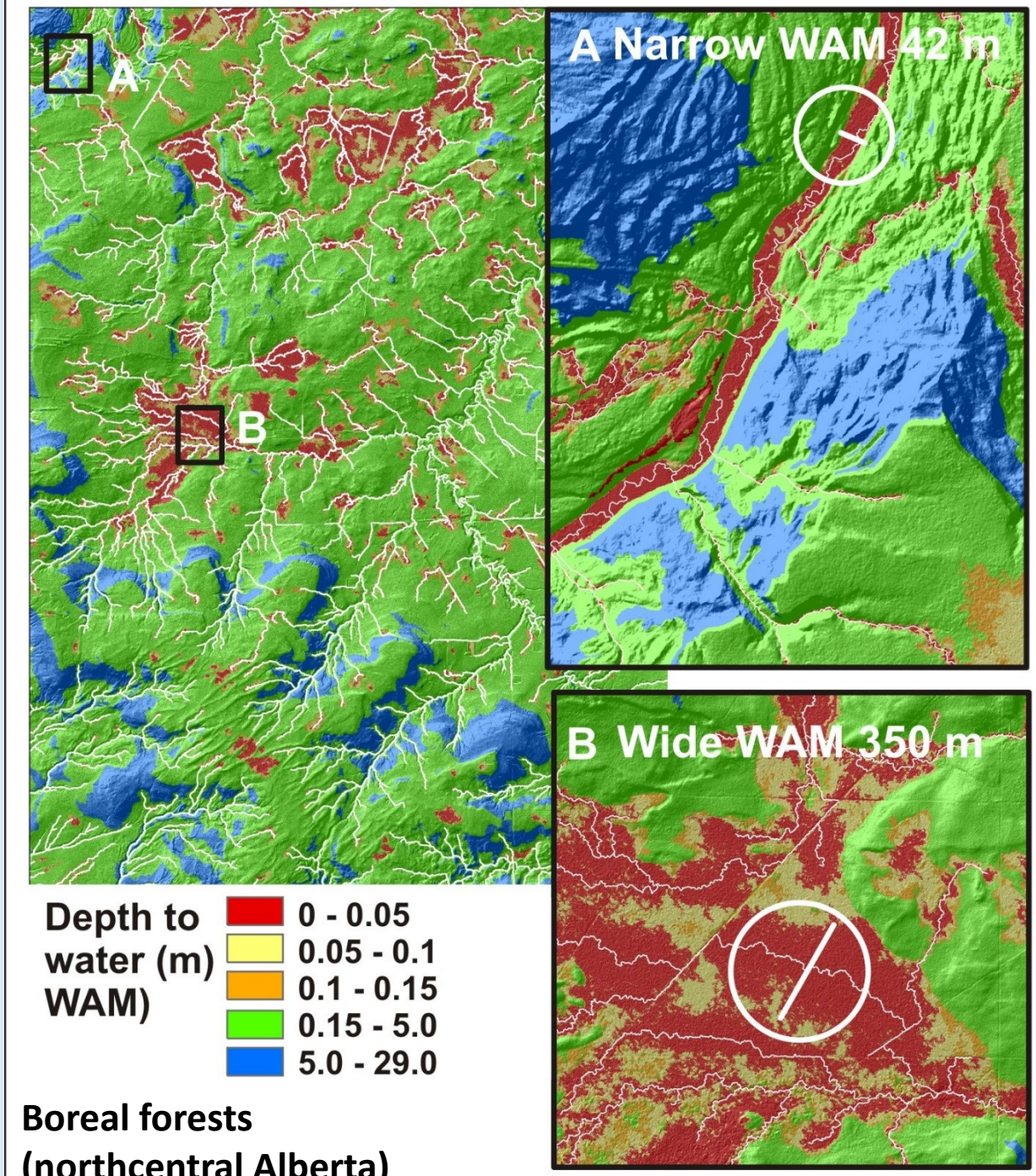
  (3) Topographic depressions (DEM)

  (4) Landform/material properties, add variable subsurface/surface flow network density – variable DTW

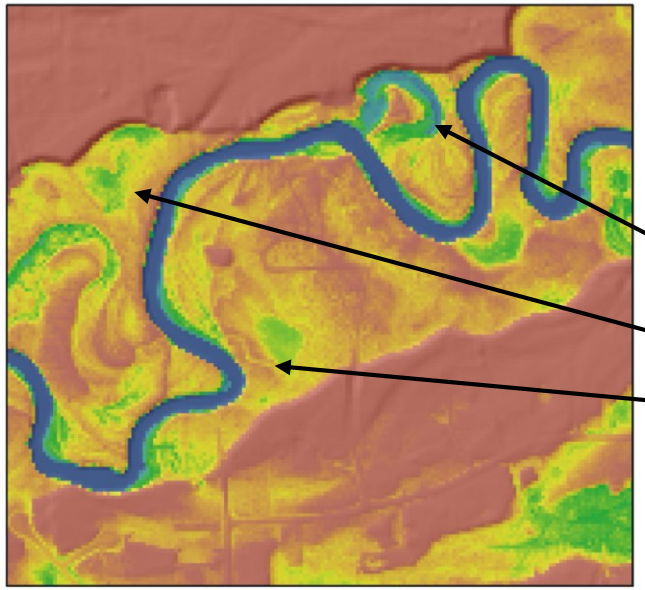
(1) Depth to Water (DTW)

(Murphy et al. 1989, White et al. 2012)

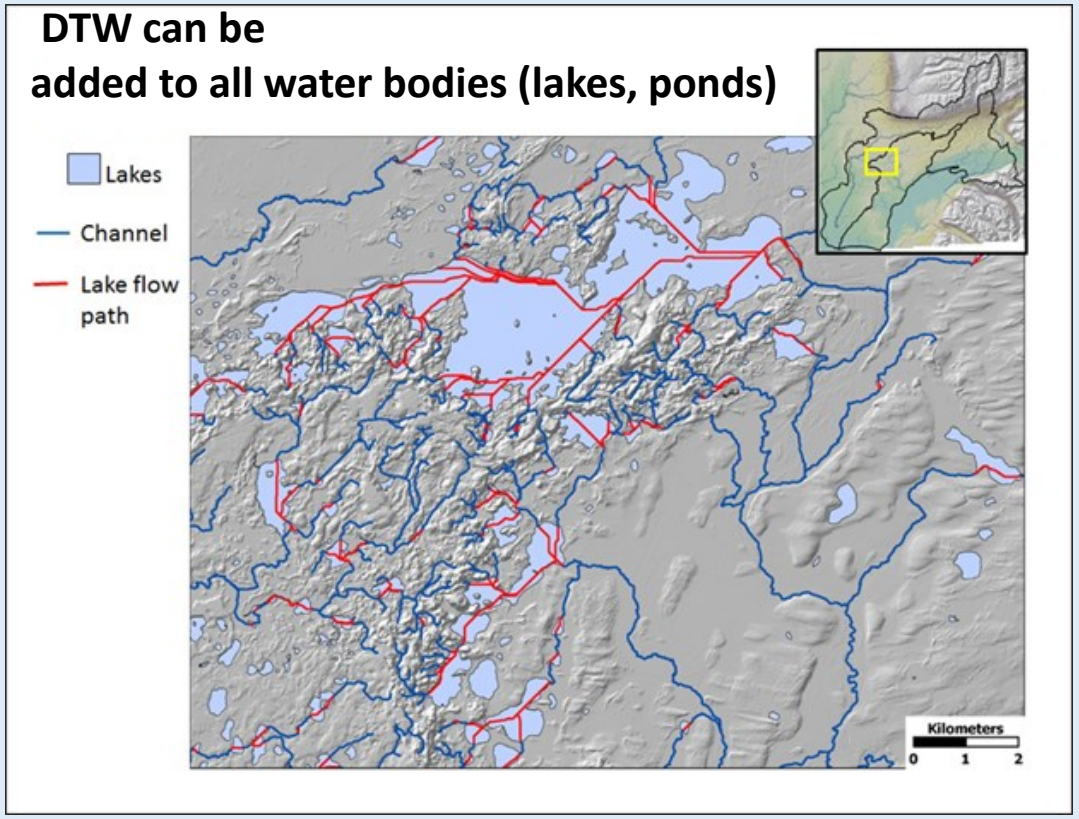




NetMap's DTW along all streams and rivers



DTW can be added to all water bodies (lakes, ponds)



Provisional wet areas (wetlands)

(2) Topographic Wetness Index (TWI) (Bevin and Kirkby 1979)

can add soils/transmissivity

- land convergence
- contributing area
- slope

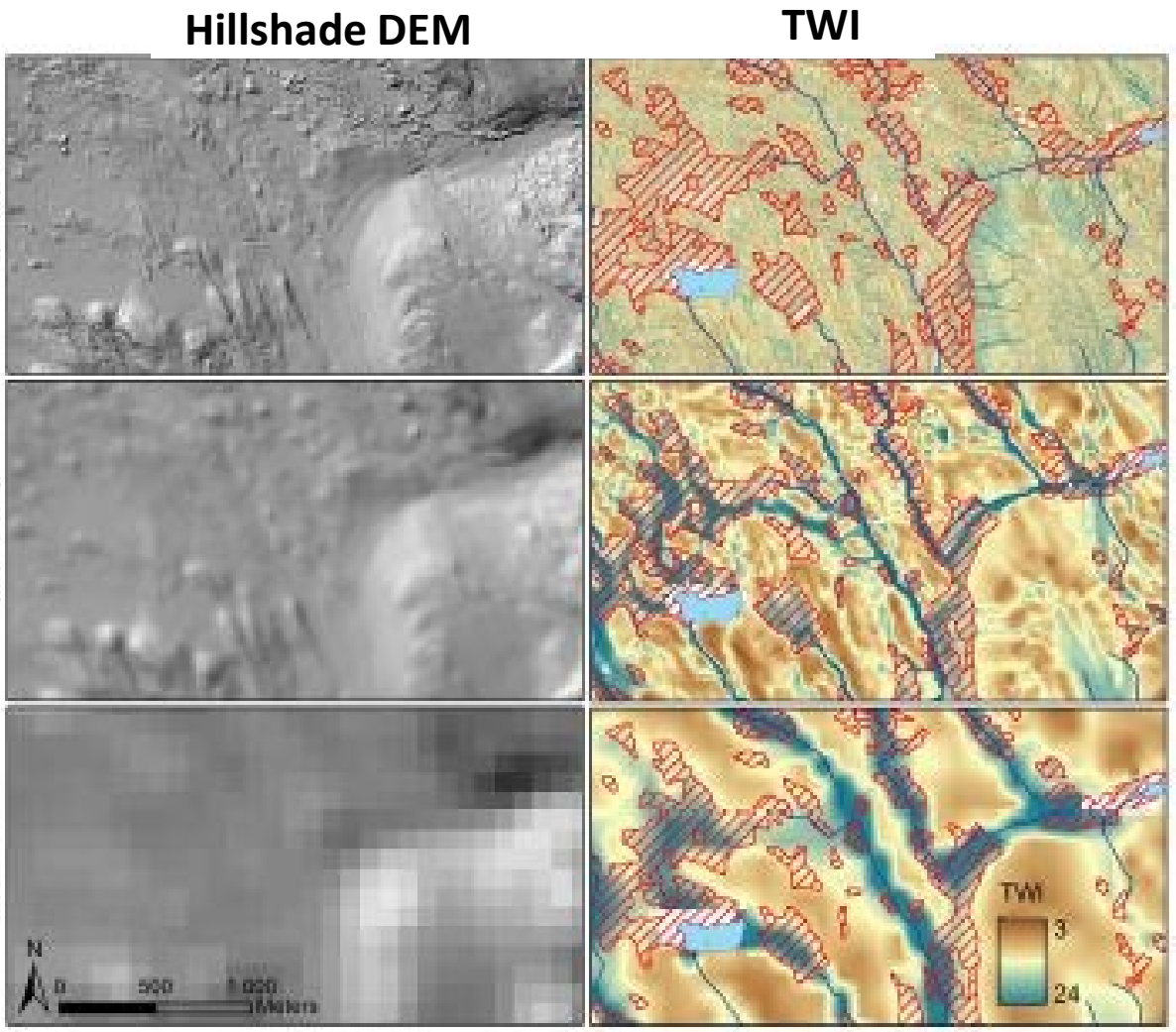
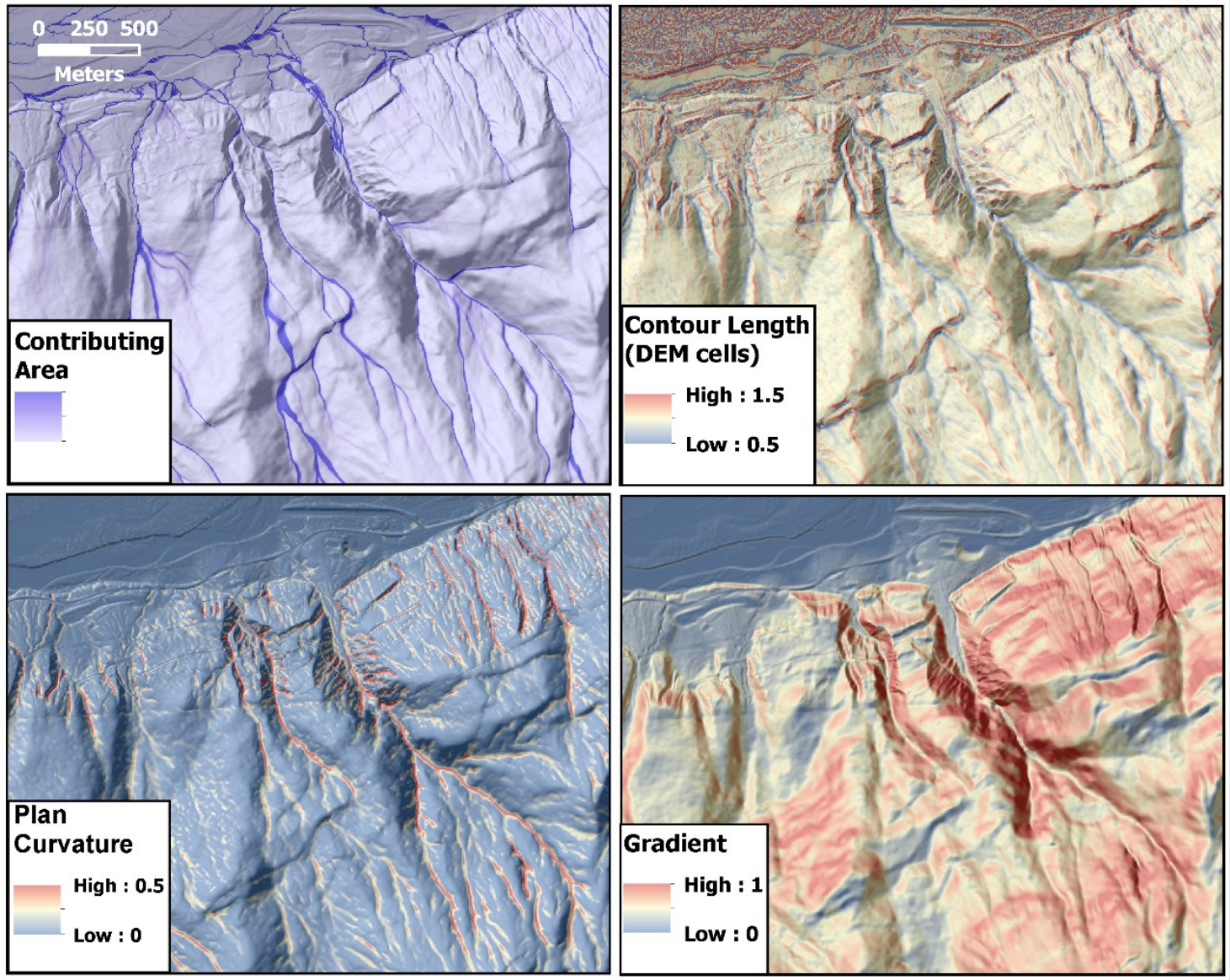


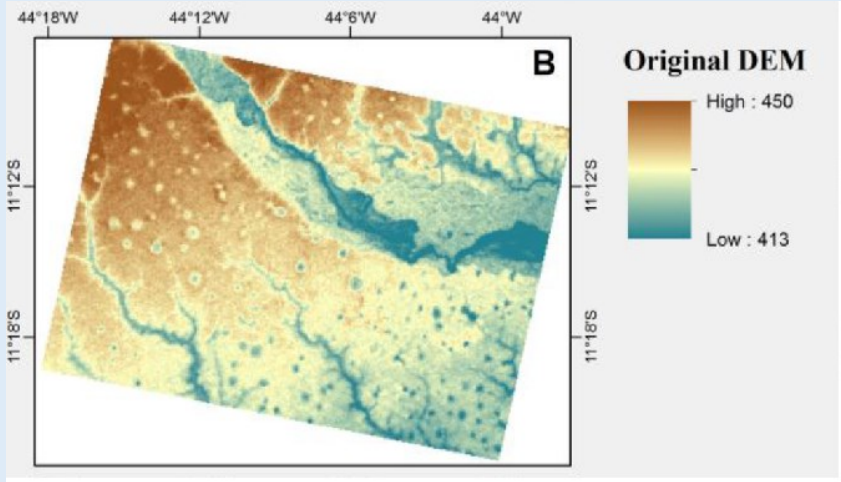
Figure 3. Topographic wetness index (*TWI*, right) derived from the 2, 24, and 100 m DEMs (left, hill shaded), for a part of Area 1. Also shown on the right: lakes, streams, and wetlands (cross-hatched, red), previously mapped at 1 : 12 500.



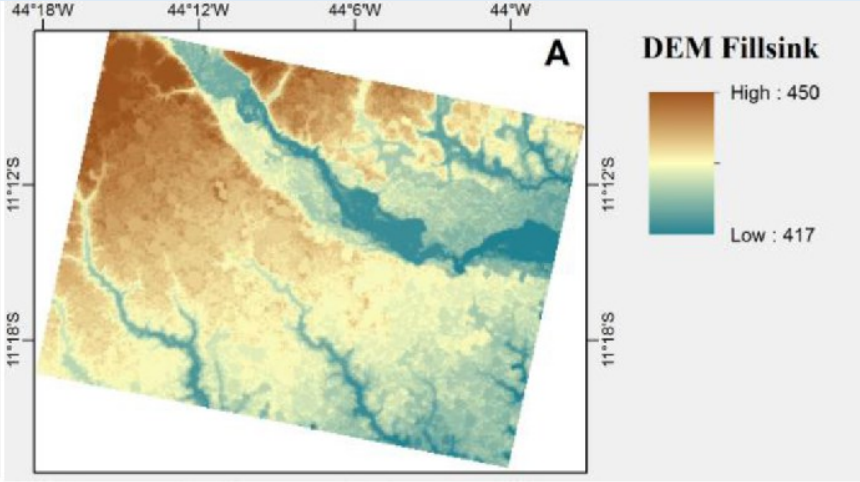
NetMap contains the data to create TWI

(3) Topographic Depressions

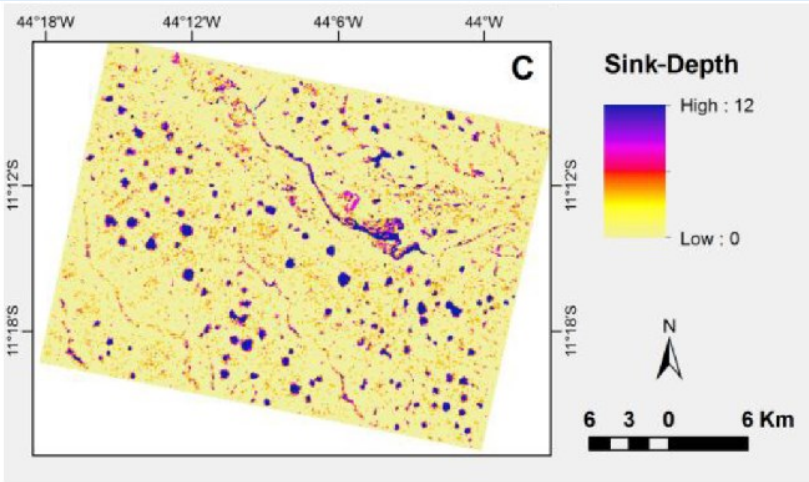
(1) Original DEM



(2) Hydro-conditioned (filled)

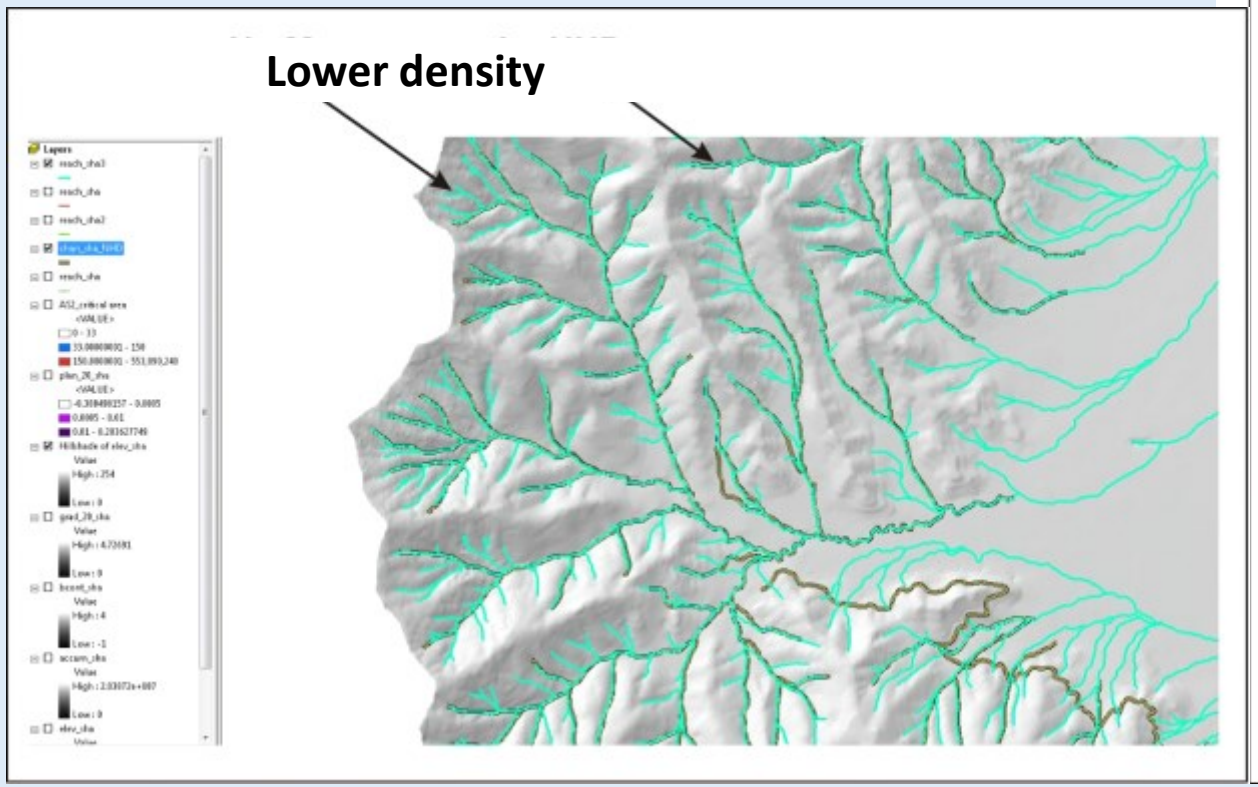


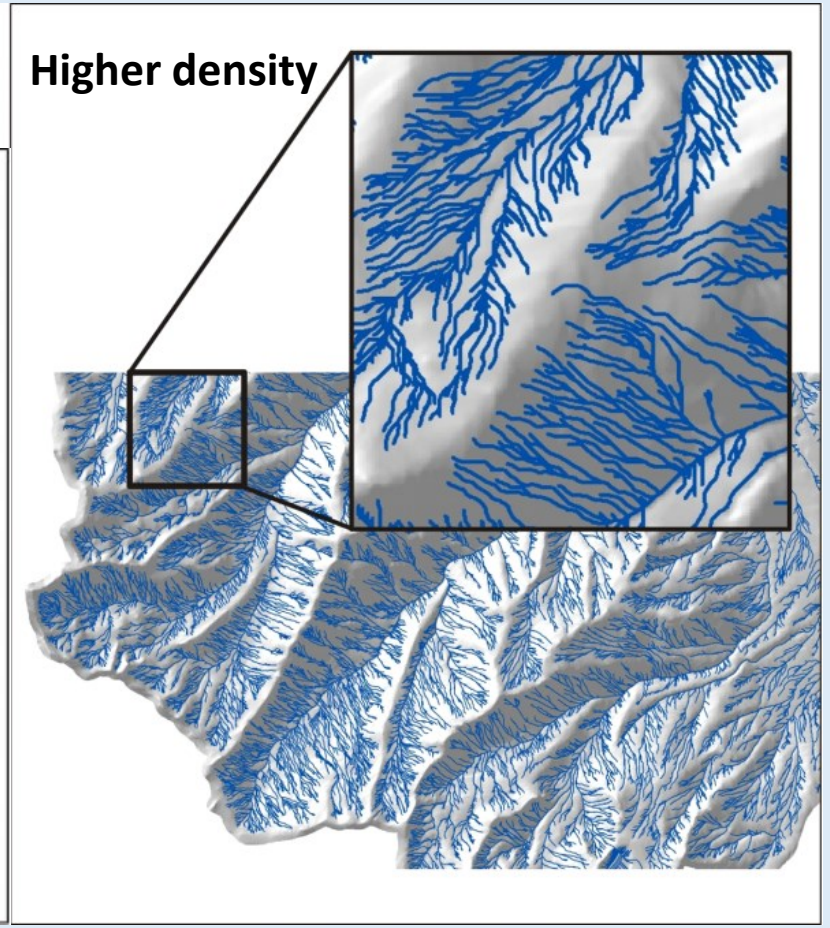
(2) – (1) = depressions (provisional wet areas)



(4) Landform/material properties, add variable subsurface/surface flow network density – variable Depth to Water (DTW)

-well drained alluvium, lower density = less wet areas
-glacial materials (impervious), higher density = more wet areas





TerrainWorks (www.terrainworks.com)

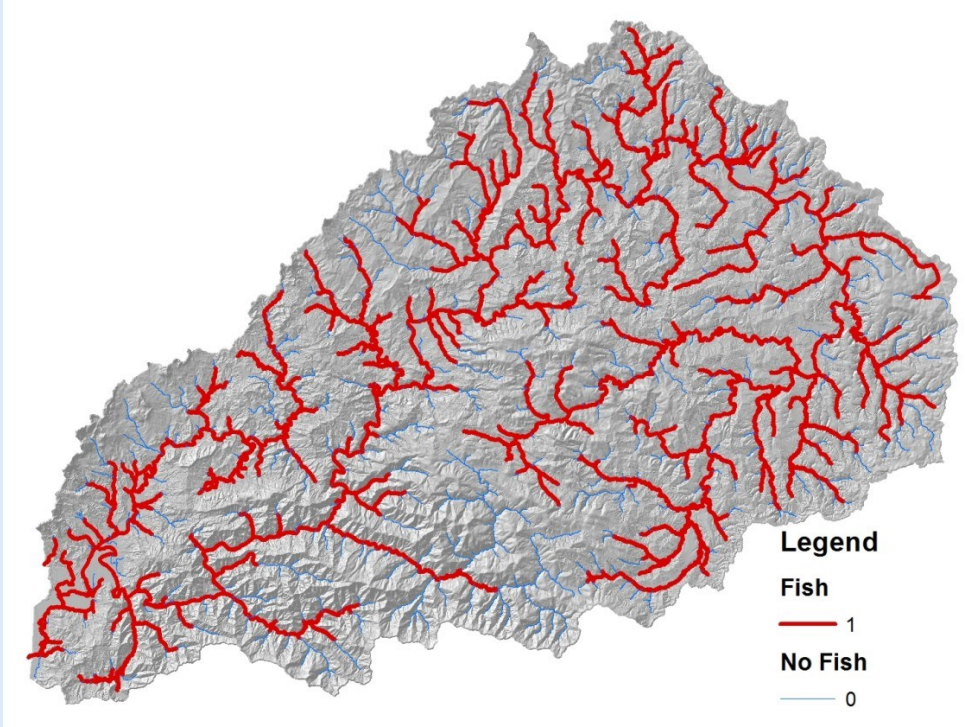
A statewide, automated wet areas/wetland mapping tool could consist of:

- Depth to water (DTW), all streams, rivers and mapped water bodies (option, add variable subsurface/surface network density based on variable landforms, subsurface materials, soils),
- Topographic wetness index (TWI), with option to add soils and transmissivity, and
- Topographic depressions

Create an index with higher to lower likelihood of encountering wet areas (wetlands) based on overlapping zones of the three indexes

Combine with field and remote sensing (optical) mapping of wetlands to test/validate/calibrate predictions

Other options
Combine with riparian delineation, riparian process diversity index
Combine with fish habitat quality (anadromous, resident)
Combine with climate change indices (NorWest Climate Shield)



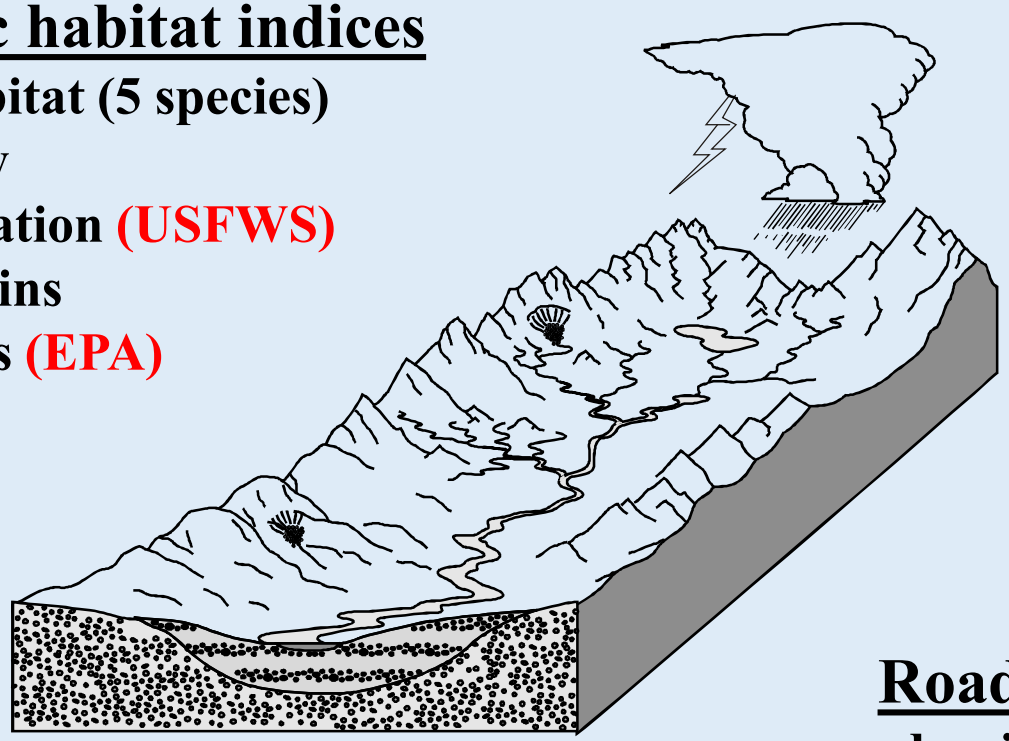
NetMap's Virtual Watersheds exist for the entire State of Washington (10 m DEM)

Community NetMap Tools

(ArcMap 10.x)

Aquatic habitat indices

-Fish habitat (5 species)
-diversity
-classification (USFWS)
-floodplains
-estuaries (EPA)



Erosion

-Shallow slide/debris flow (USFS)
-Surface erosion
-Sediment yield

Vegetation

-riparian
-fuels/fire risk (WWETAC)
-post fire

Roads

-density (multi-scale)
-upstream hab. length/quality
-surface erosion (CFLRP)
-stability
-drainage diversion

Riparian Management

-floodplains
-valley surfaces (TNC)
-wood recruitment (USFS)
-shade-thermal (NOAA)
-delineation (Prov. Alberta)

Google Earth Interface/online tech help

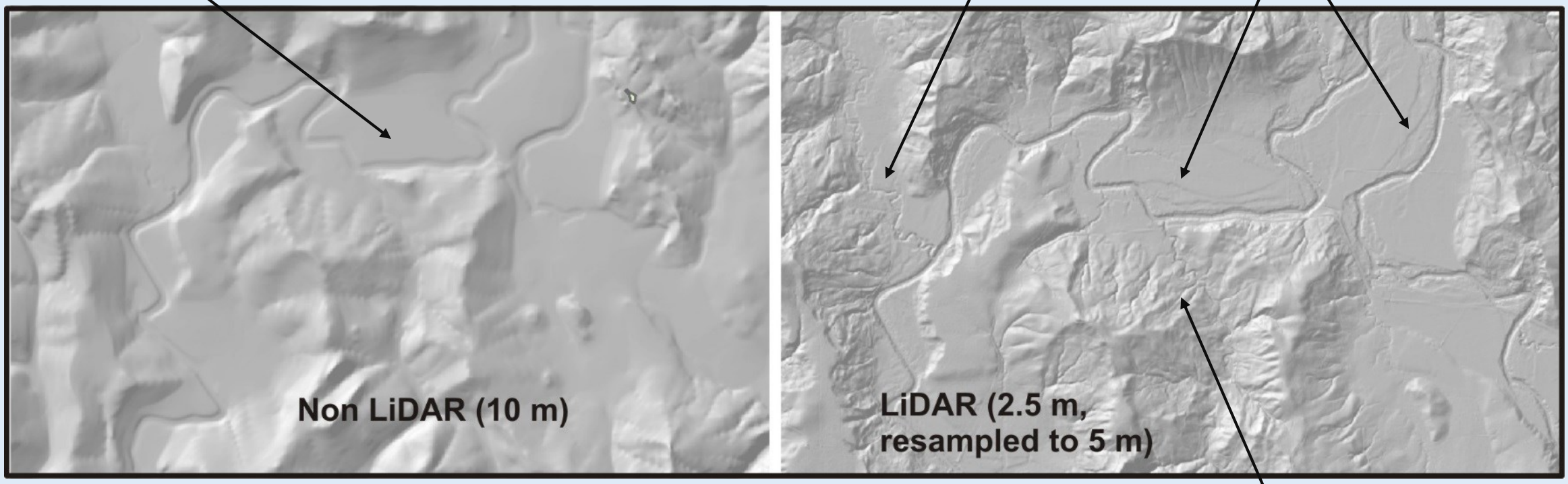
Some NetMap Projects

- WDFW, entire WA state, habitat modeling
- USFS, Region 6 (WA/OR)
- EPA, Puget Sound, including estuaries
- WCSSP, fish habitat modeling, western Olympics
- NOAA/Watershed Councils/Tribes – Coho, Oregon Coast Range (restoration, delisting)
- TNC, Matanuska-Susitna Watershed, AK (salmon habitat mapping, floodplains)
- USFWS, Kansas channel-biota classification
- USFWS/SRLCC, Southern WY oil/gas development
- Alberta Prov. Gov/UA, riparian delineation, cumulative watershed effects-oil/gas/logging
- Tongass National Forest
- SWCC, Blackfoot & Swan Rivers Forest Restoration (MT)

More…www.terrainworks.com/about/projects

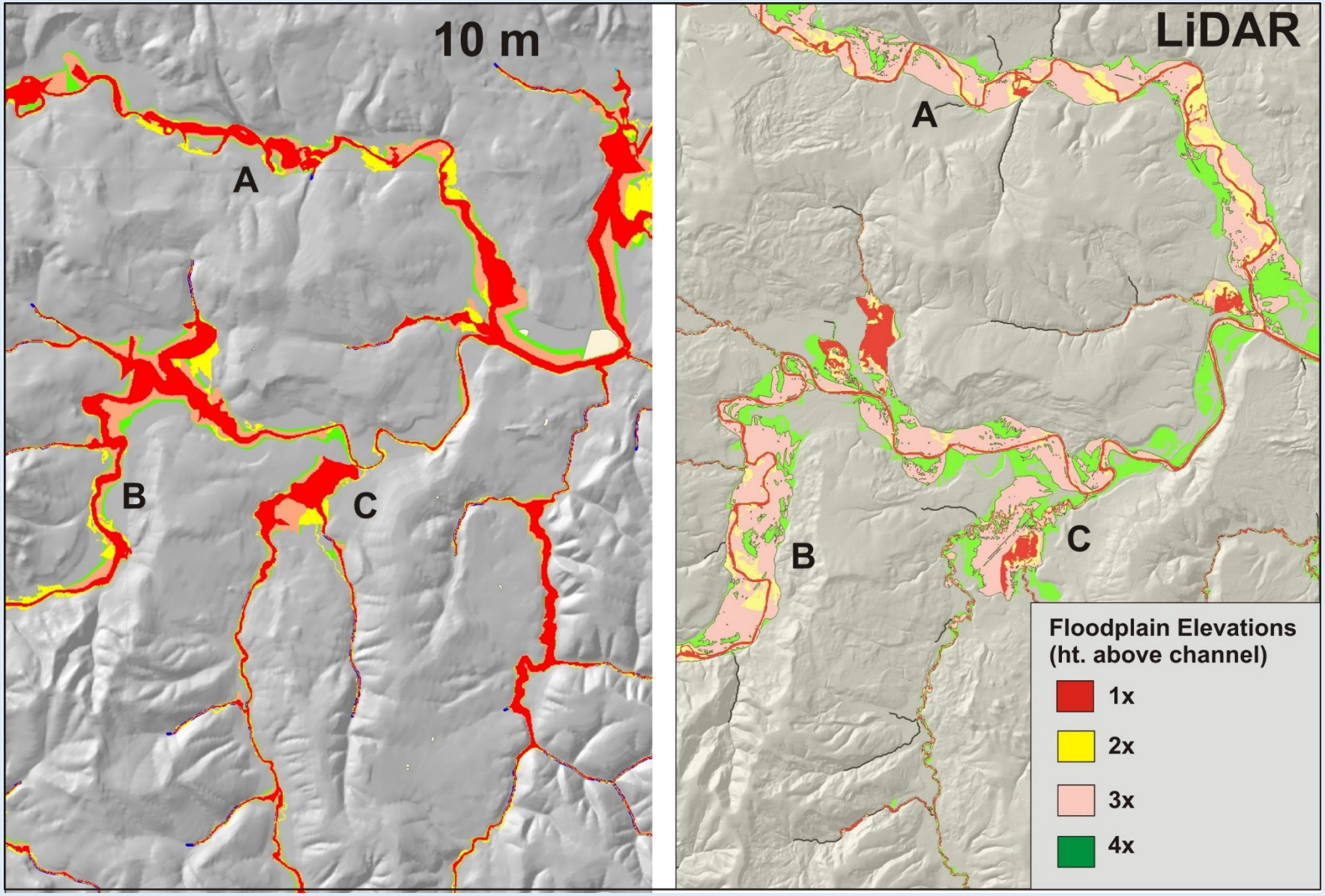
Questions/Discussion

The issue of DEM resolution

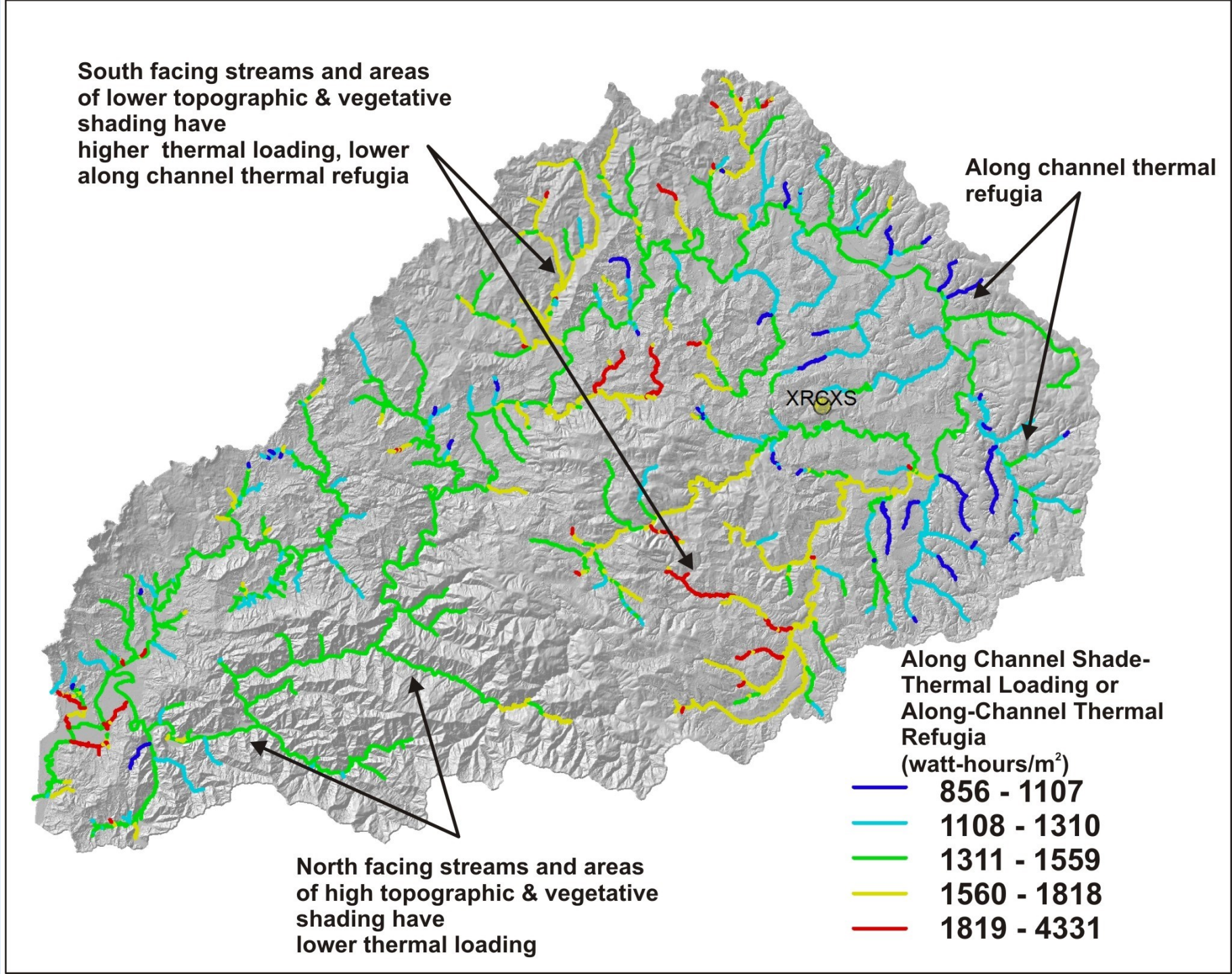


LiDAR = 4 x higher resolution
16 x more data!

The issue of DEM resolution

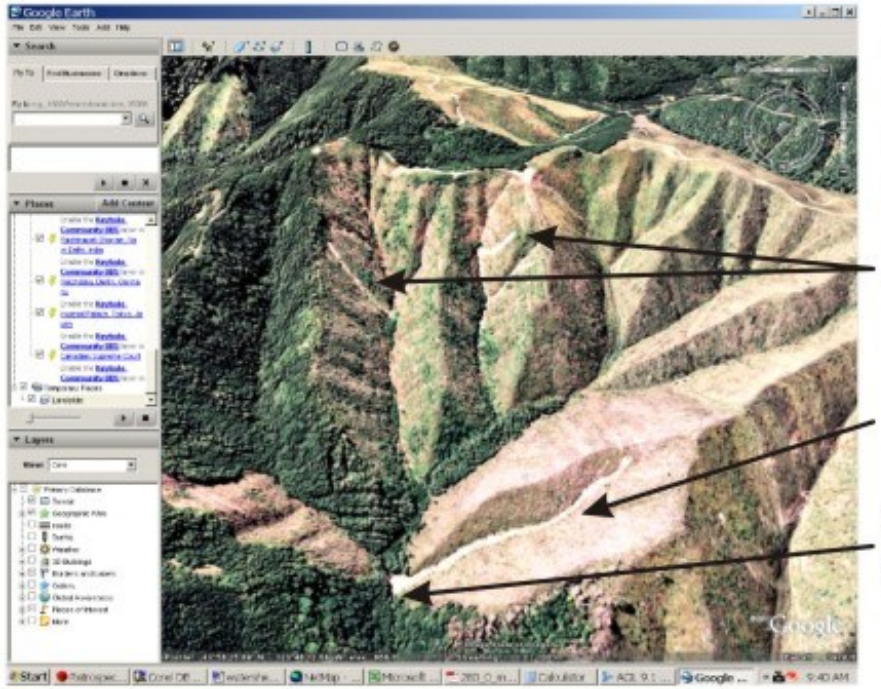


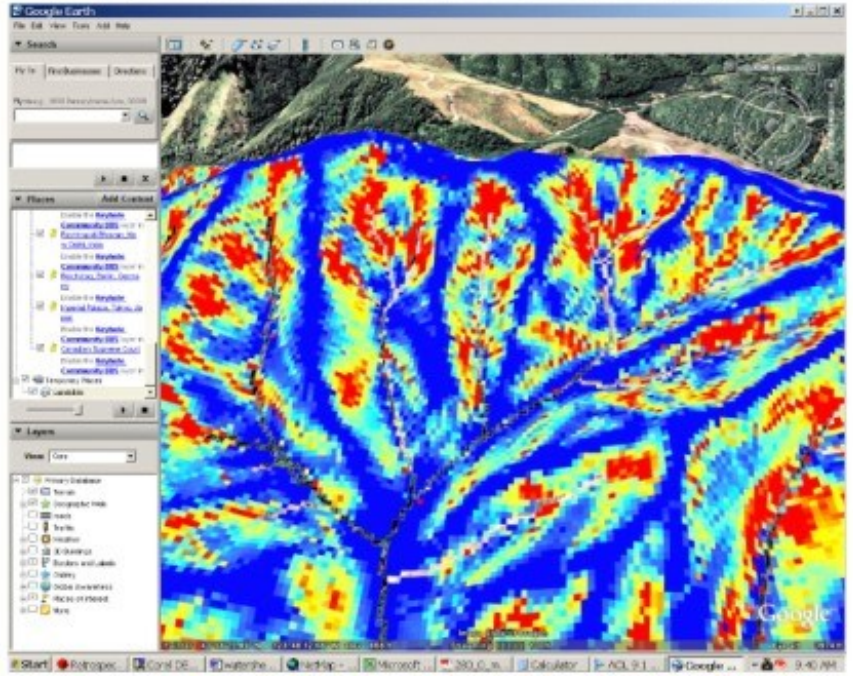
Tributary scale thermal refugia



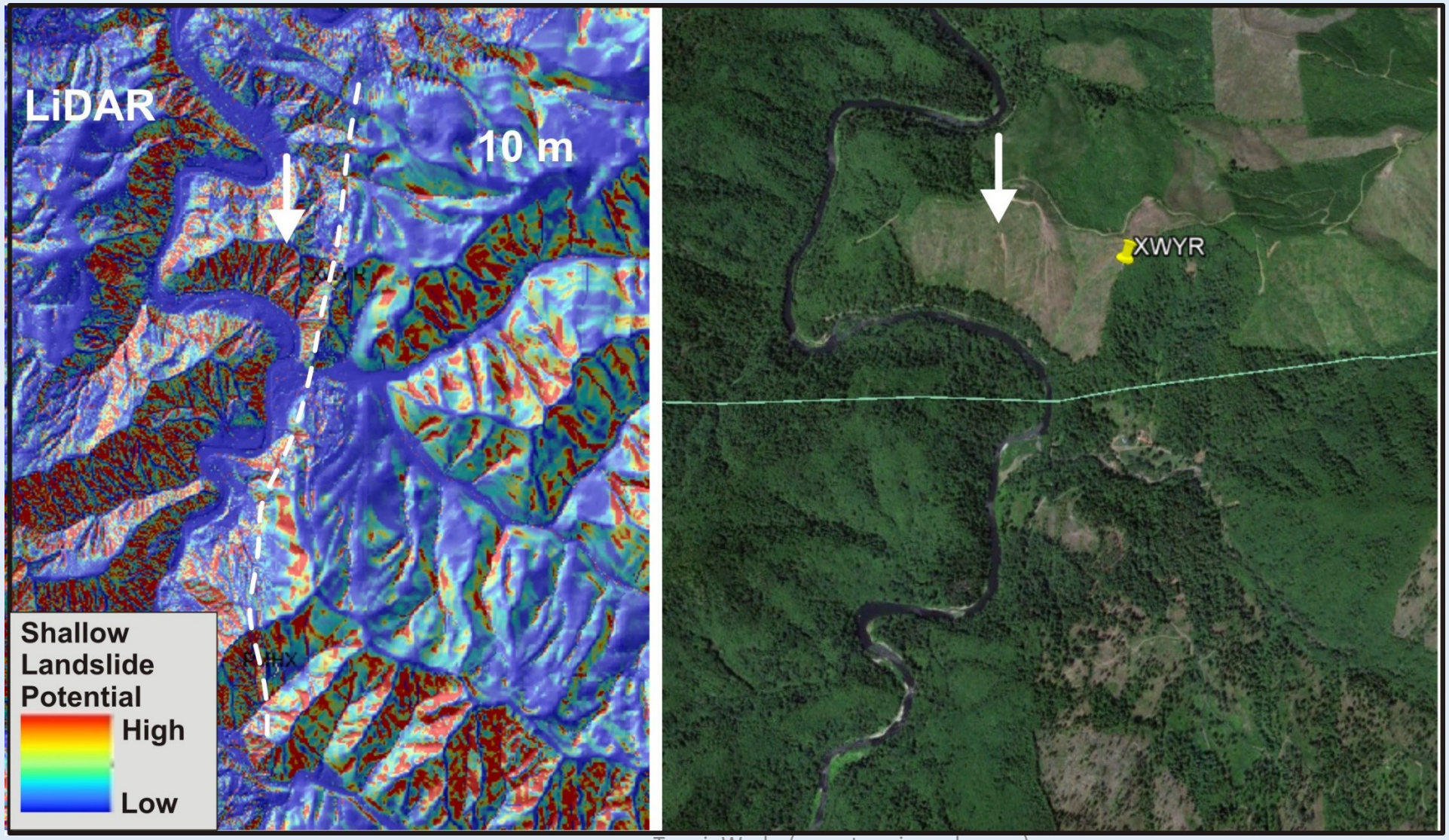
Other attributes to consider: landslide potential

highest resolution DEMs + latest models



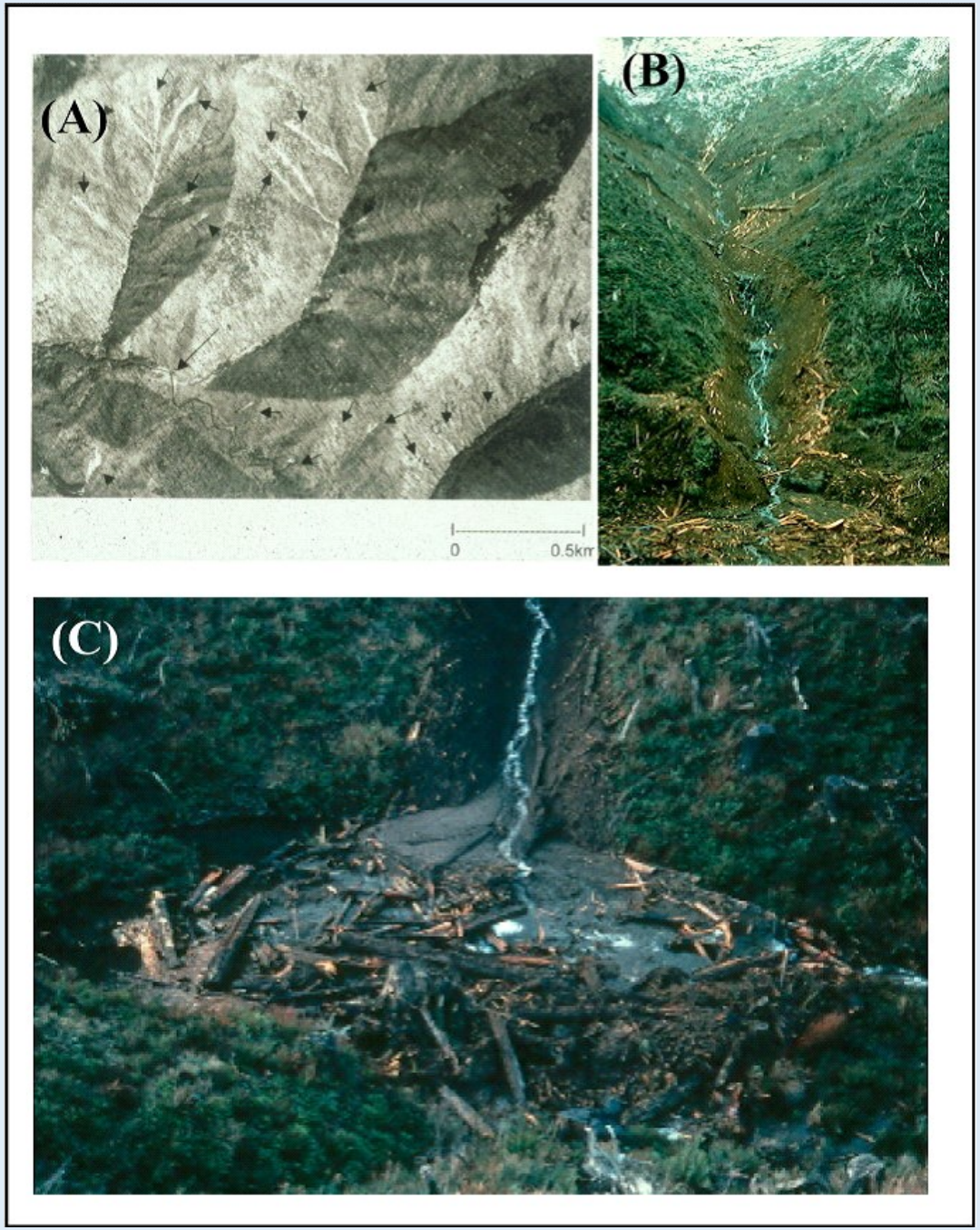


Nehalem shallow landslide Potential

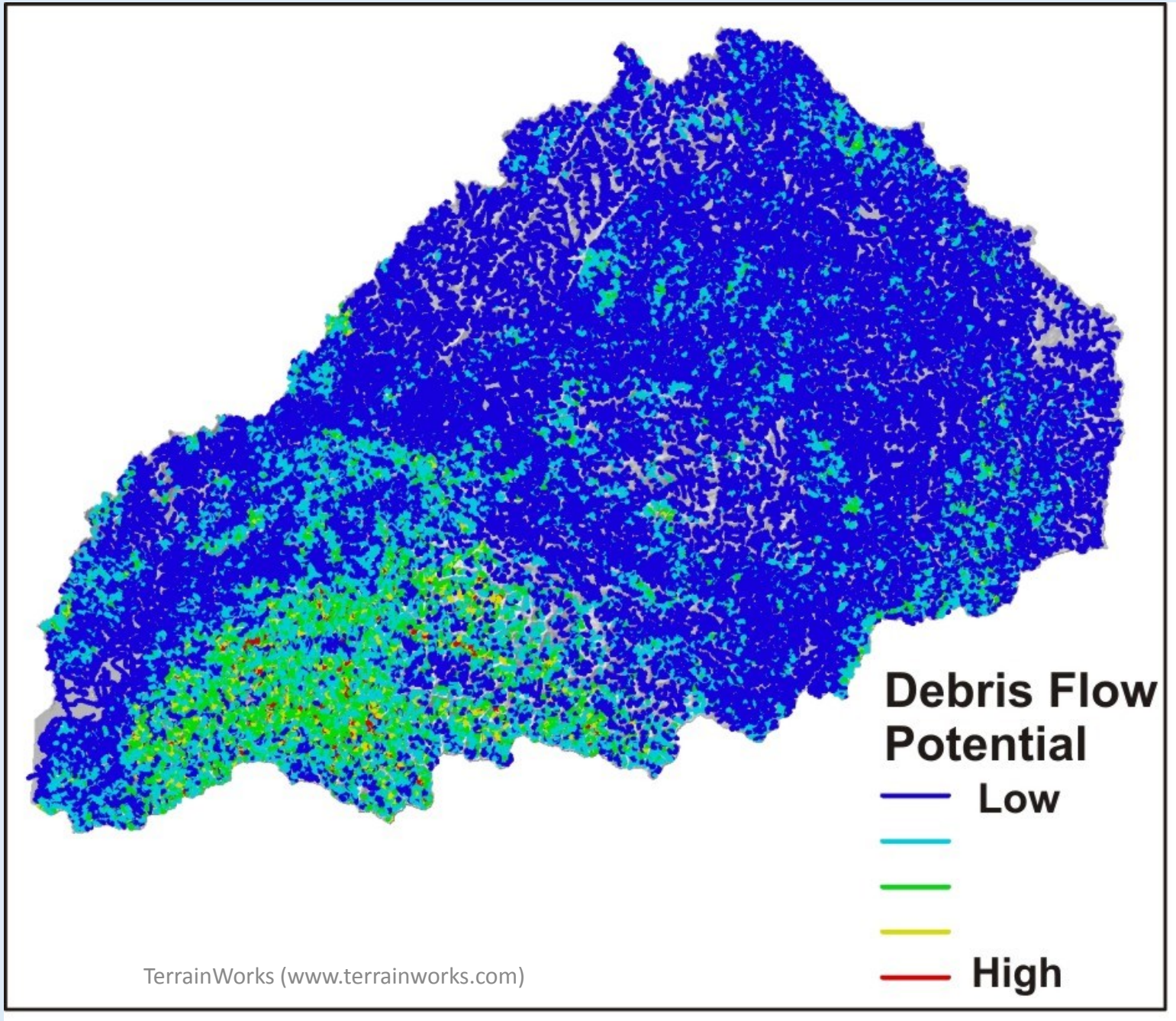


Debris flows –

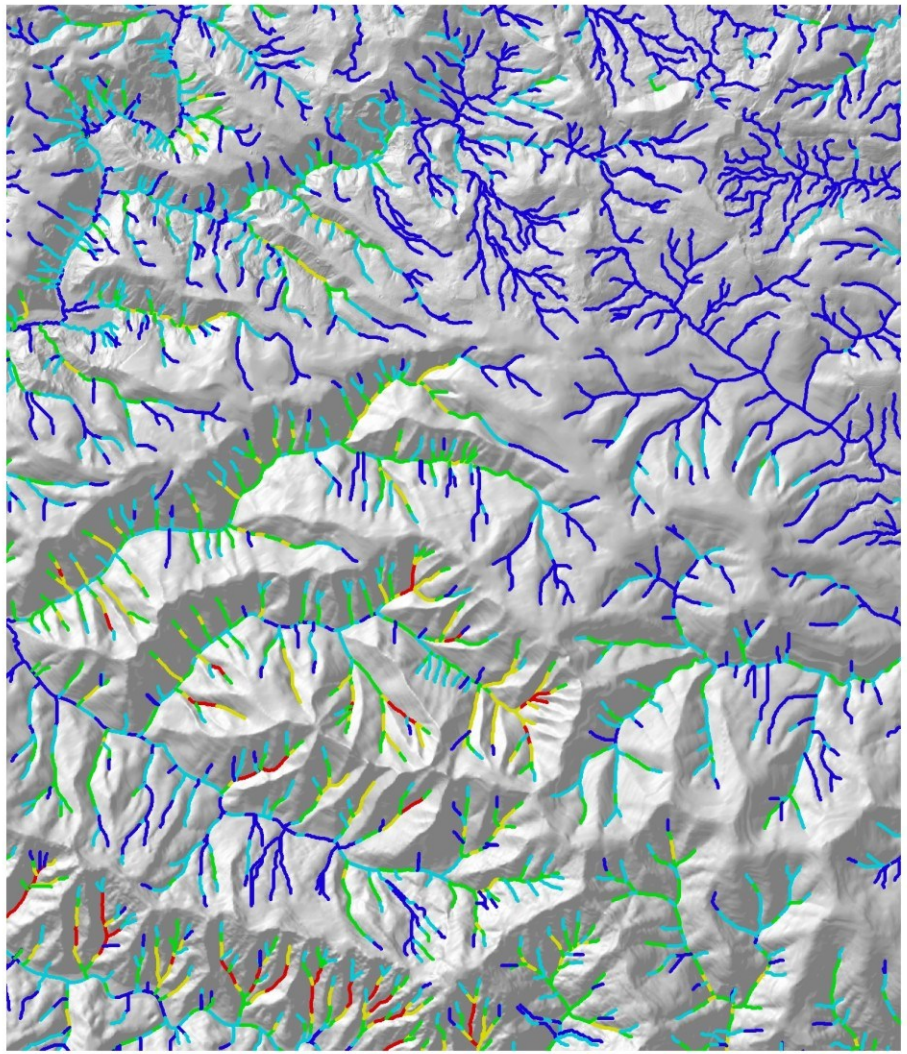
impact potential but also upslope sources of large wood to streams



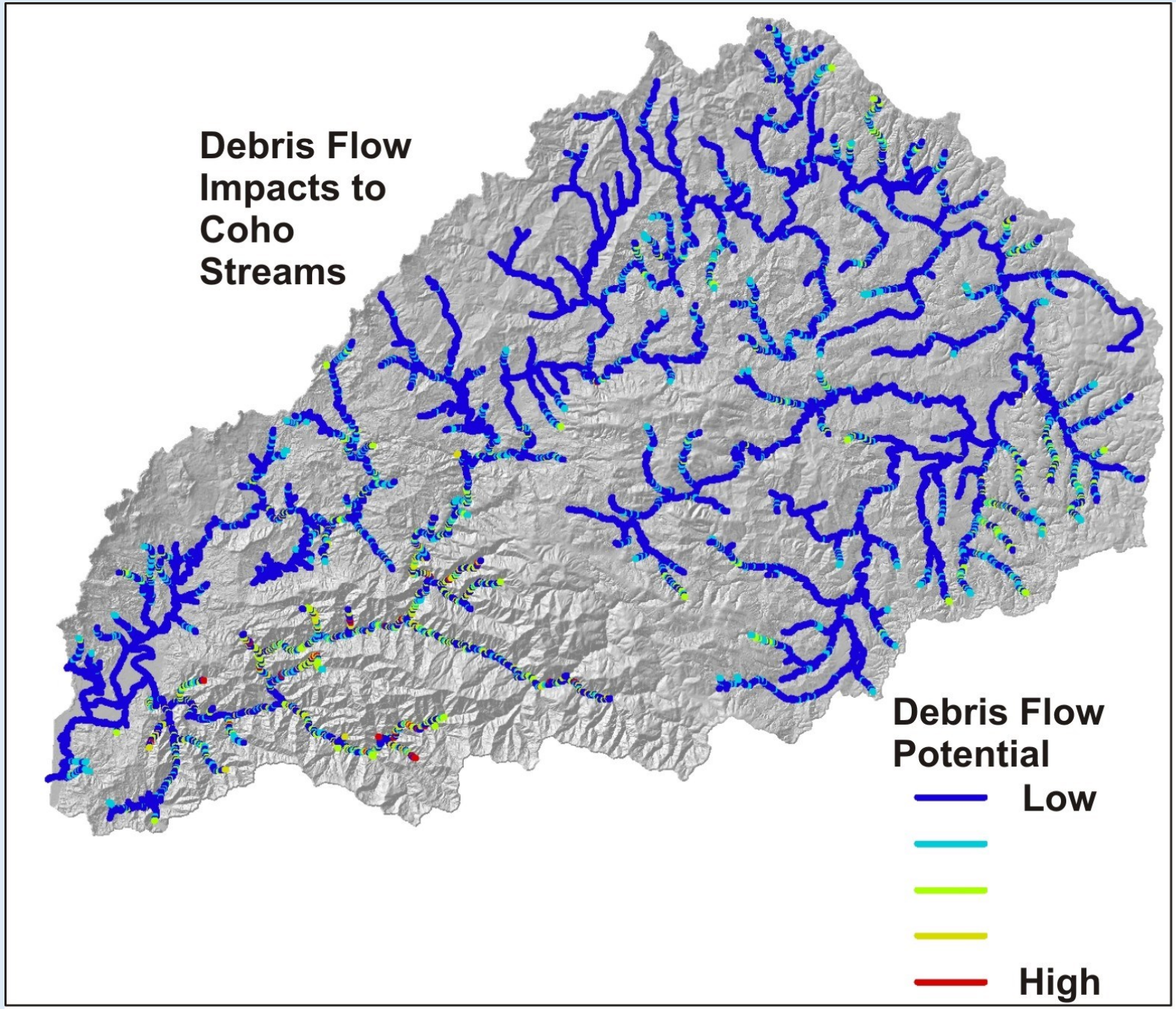
ADD debris flows



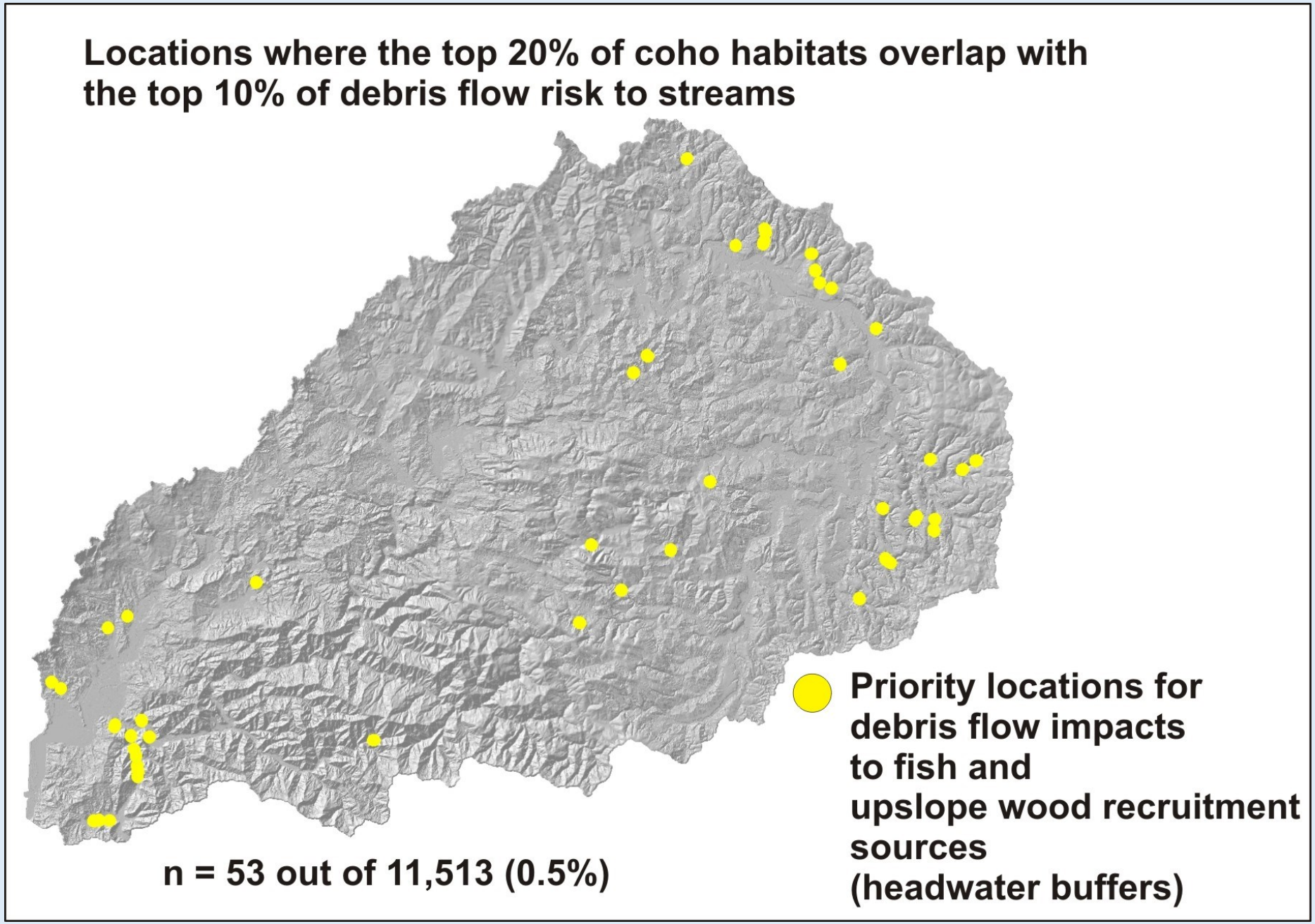
Debris flows –
close up



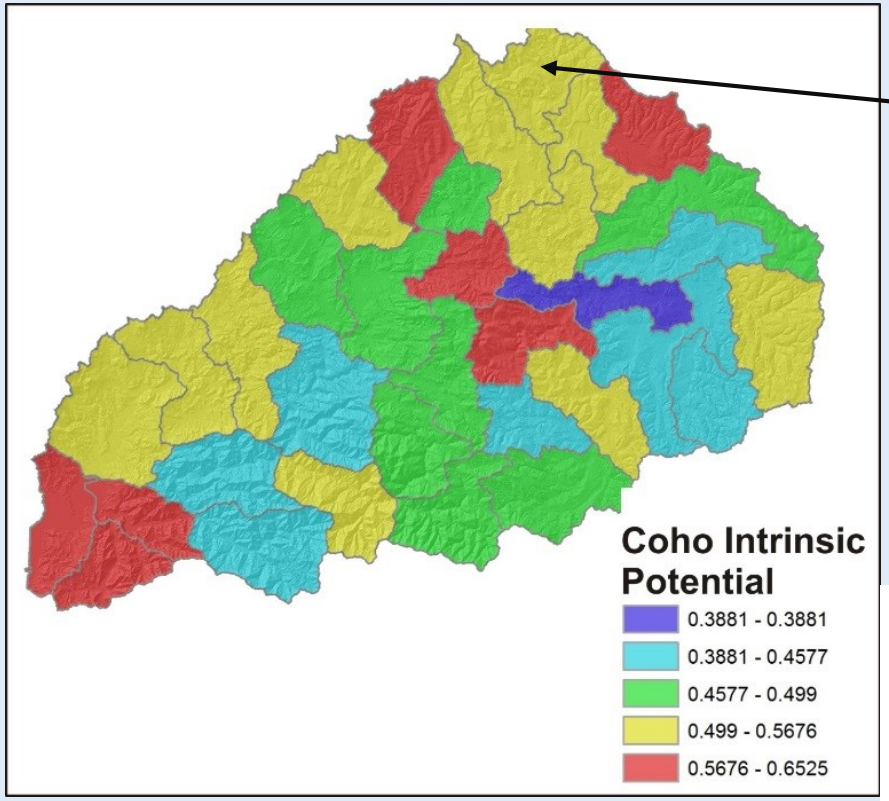
Debris flow risk to coho streams



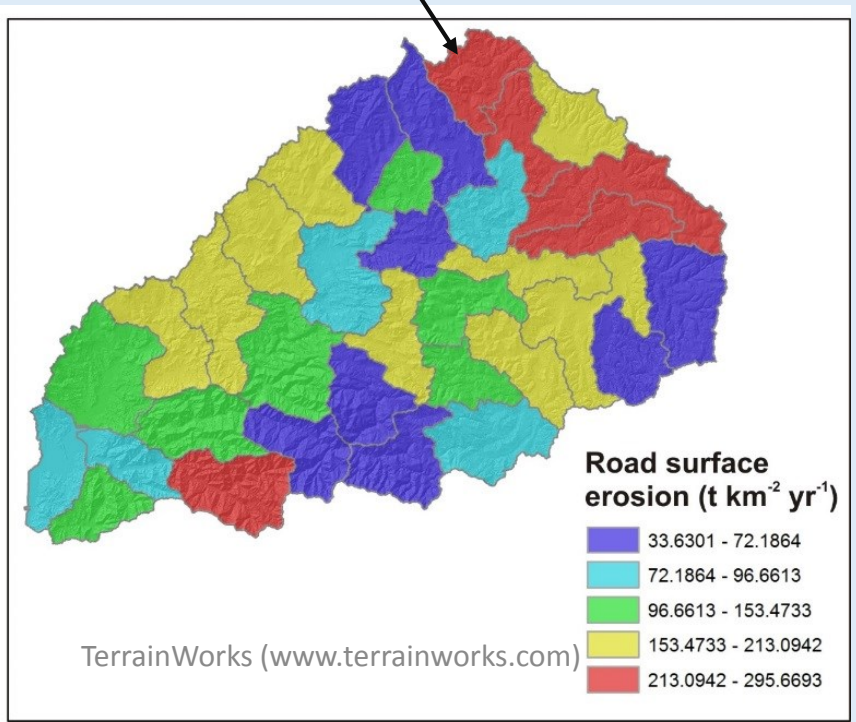
Application: Management of debris flow risk / upslope wood recruitment



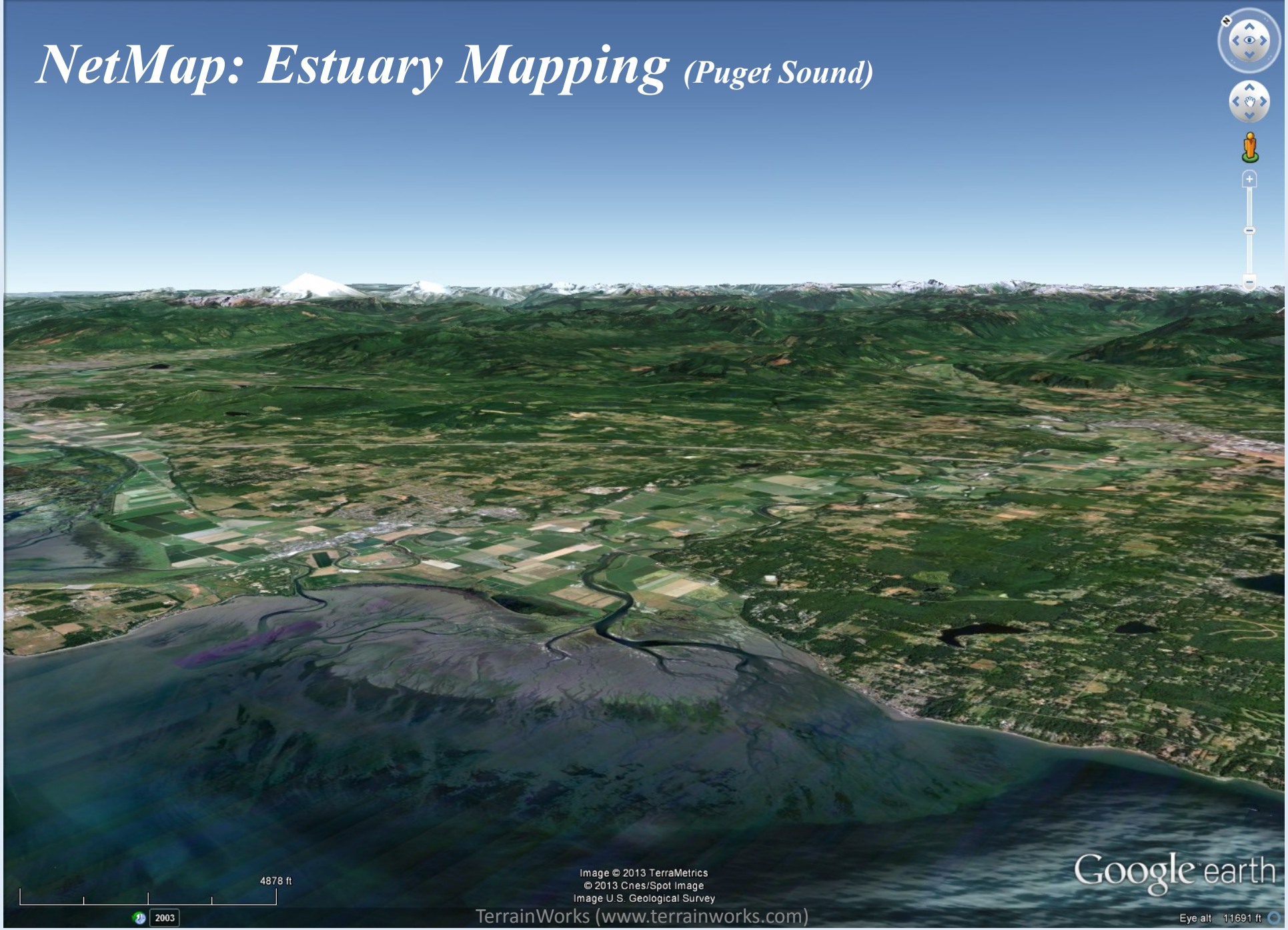
The entire 5 step analysis can be done at larger spatial scales, for example HUC 12 digit (6th fie



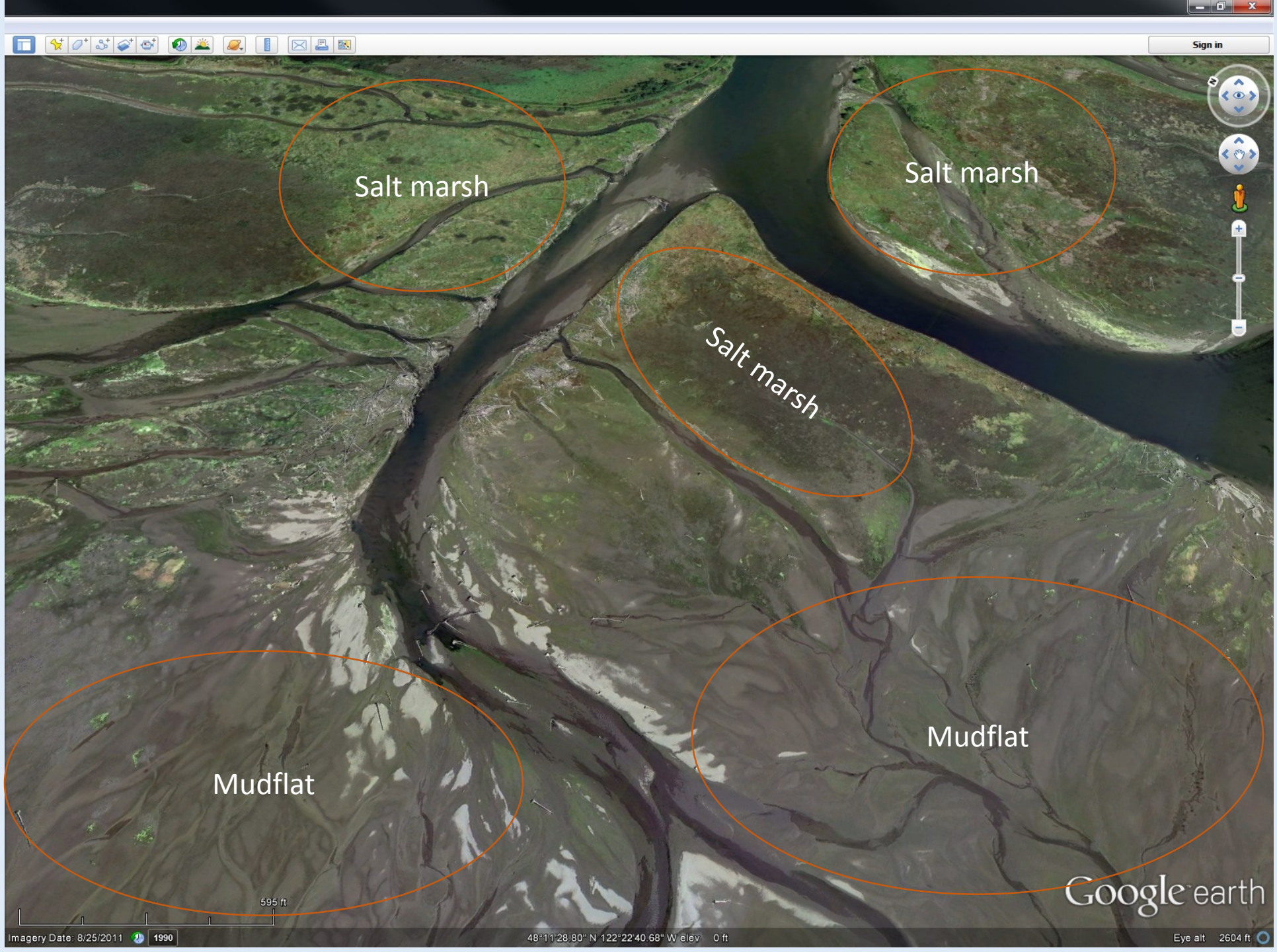
Search for overlaps



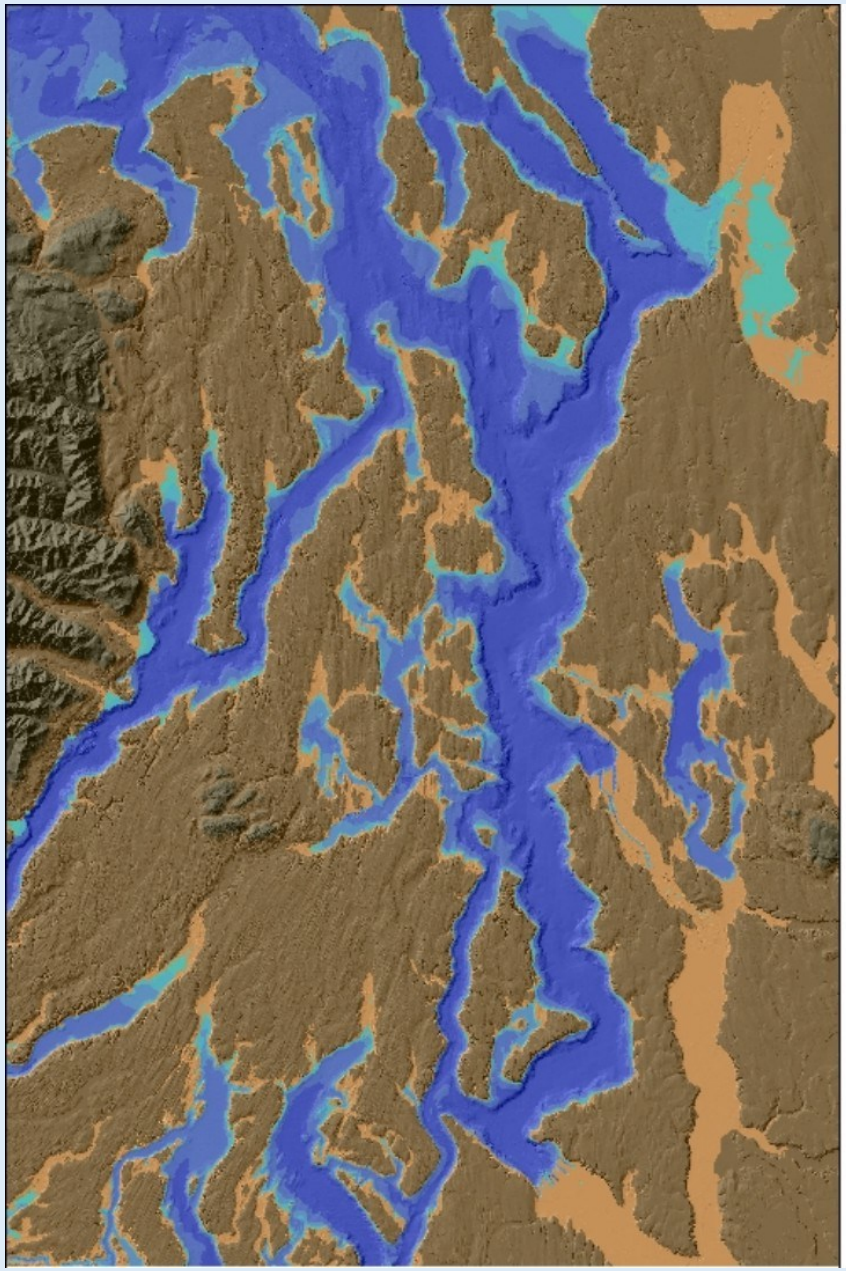
NetMap: Estuary Mapping (Puget Sound)



TerrainWorks (www.terrainworks.com)


Sign in
Salt marsh
Salt marsh
Salt marsh
Mudflat
Mudflat
595 ft
Google earth
Imagery Date: 8/25/2011
1990
48°11'28.80" N 122°22'40.68" W elev 0 ft
Eye alt 2604 ft

Model



-merged DEM (LiDAR)
-tidal gauge data
-proportion inundation (0 – 100%)
-logistic regression model (inundation vs estuary hab)

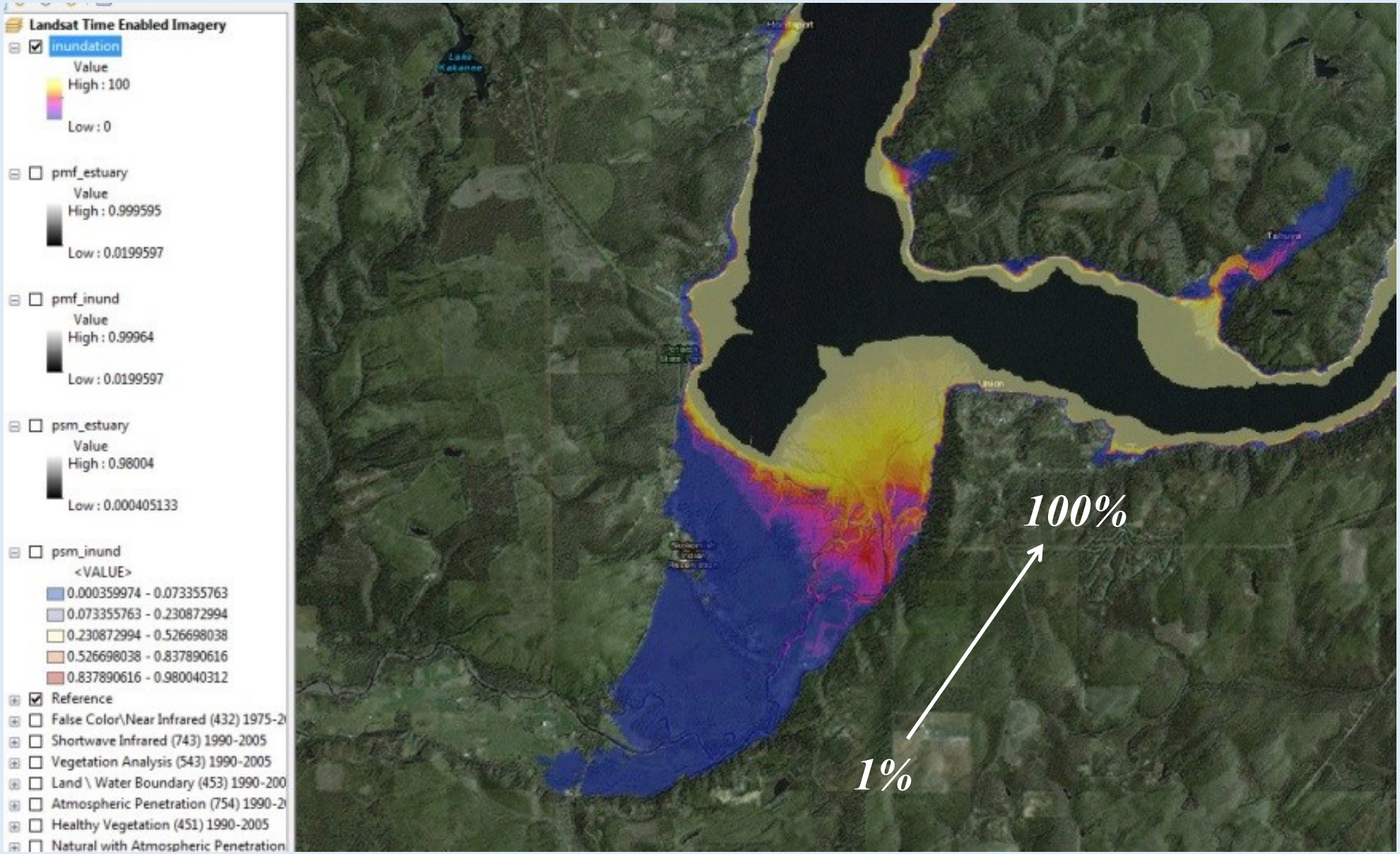
Merged LiDAR DEM and Bathymetry (ft)

- -1000 to -152
- -152 to -40
- -40 to -10
- -10 to 0
- 0 to 10
- 10 to 100
- 100 to 1000
- >1000

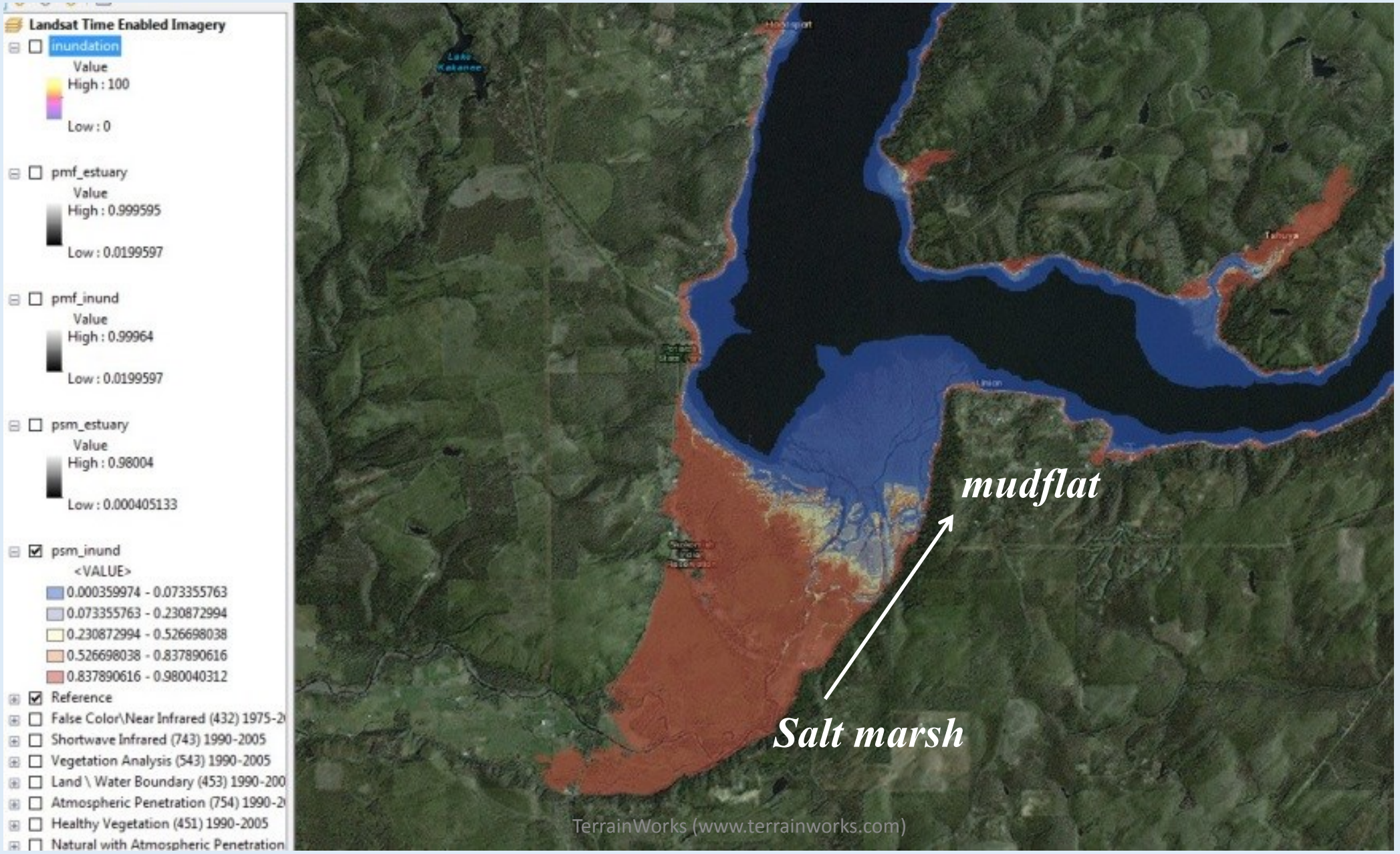
Results

Skokomish River estuary

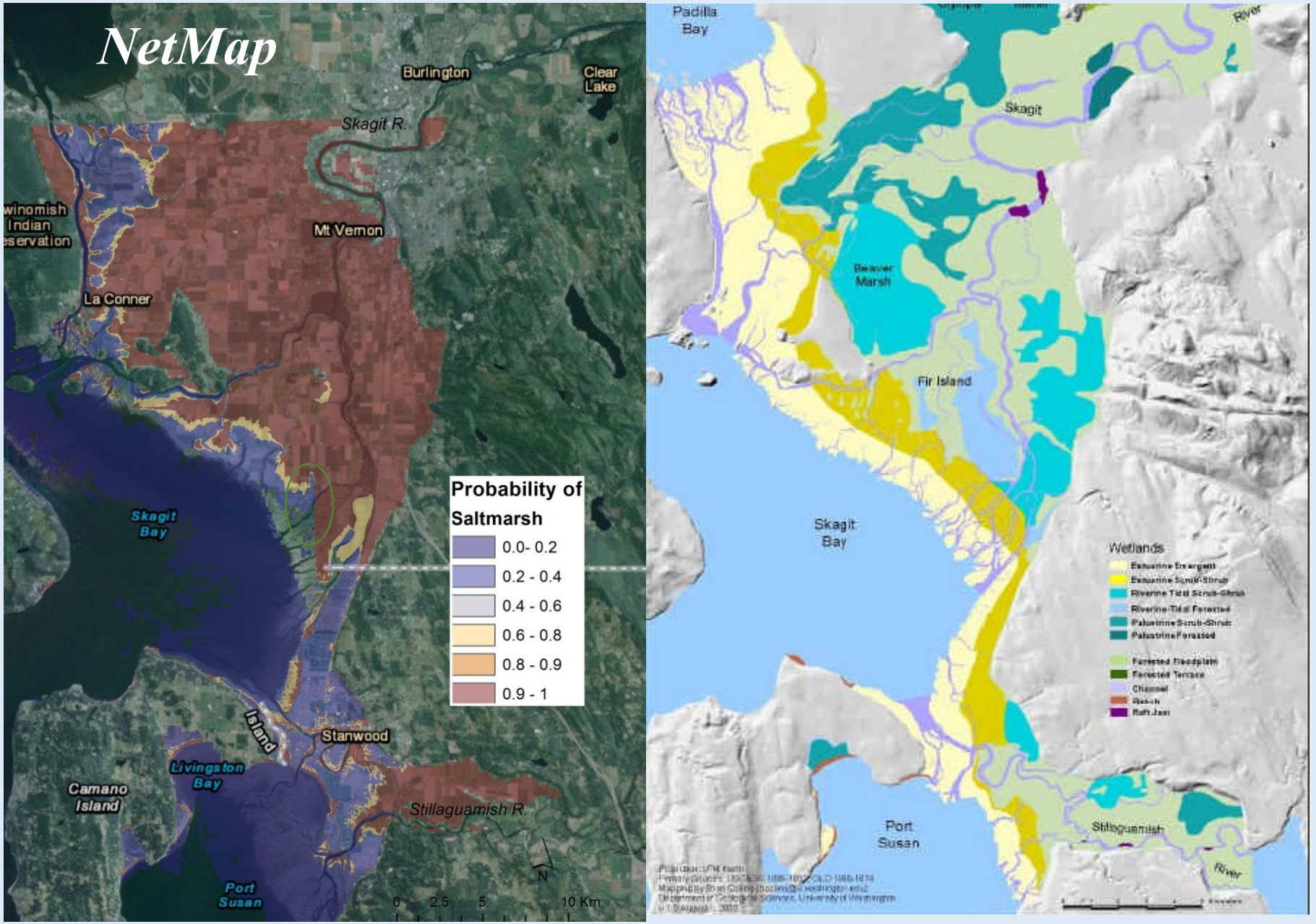
Percent Inundation



Probability salt marsh

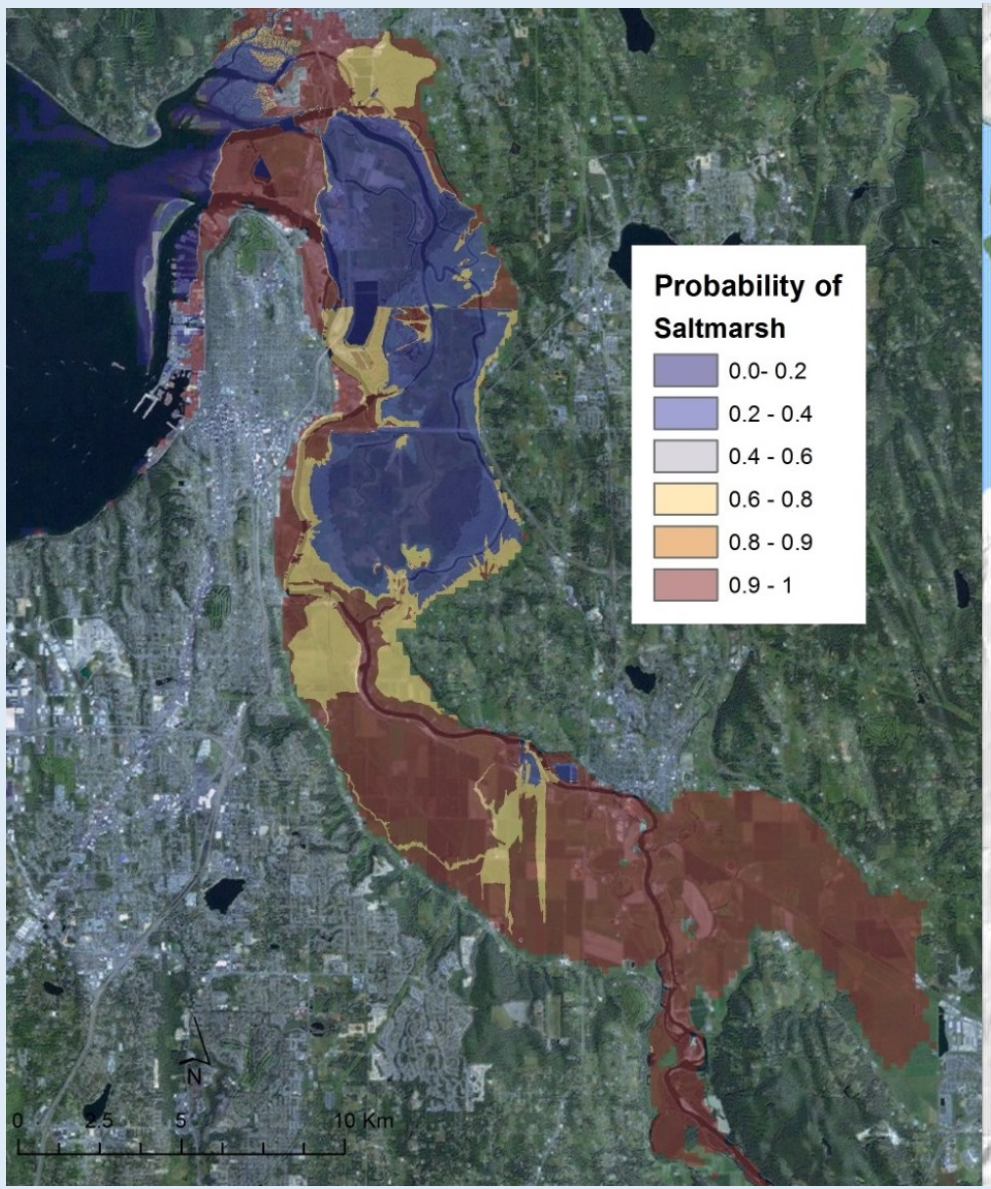


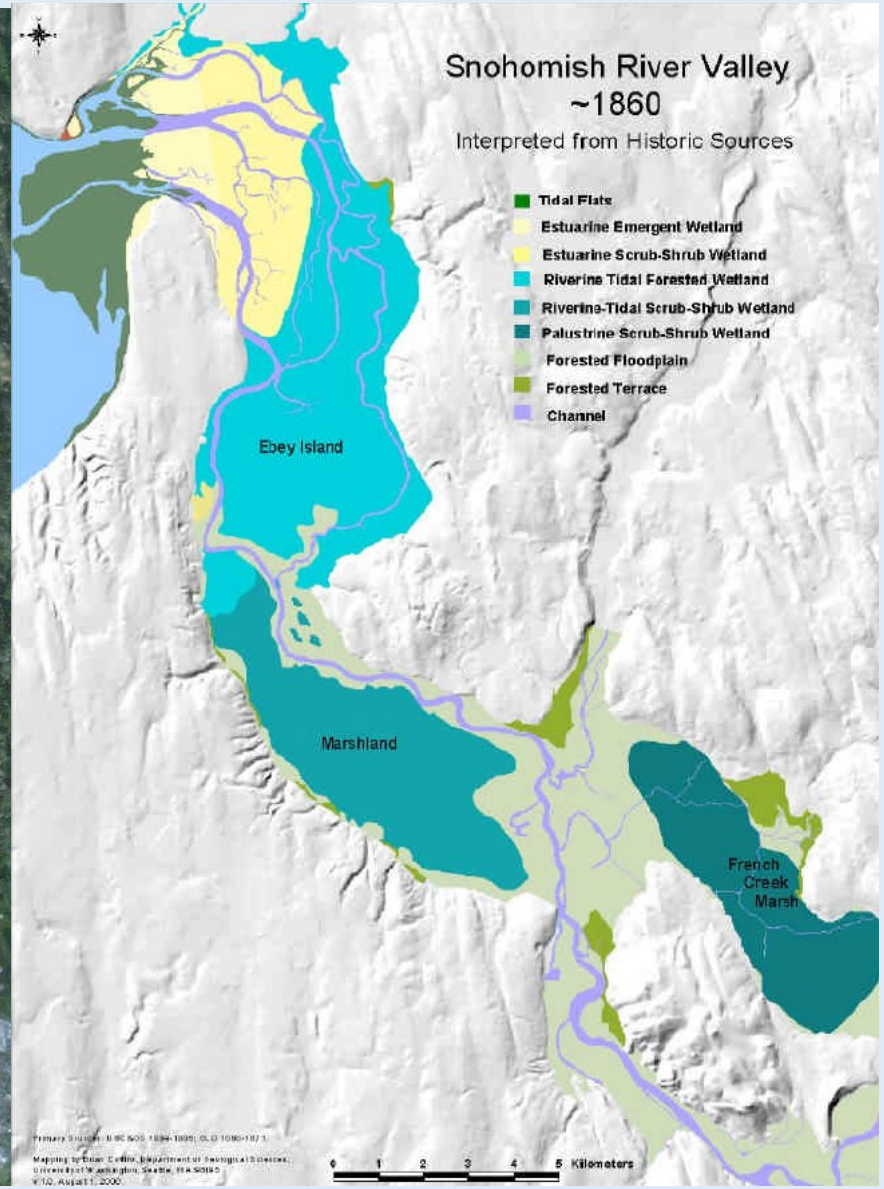
Skagit Delta



Collins 2008

Snohomish Delta



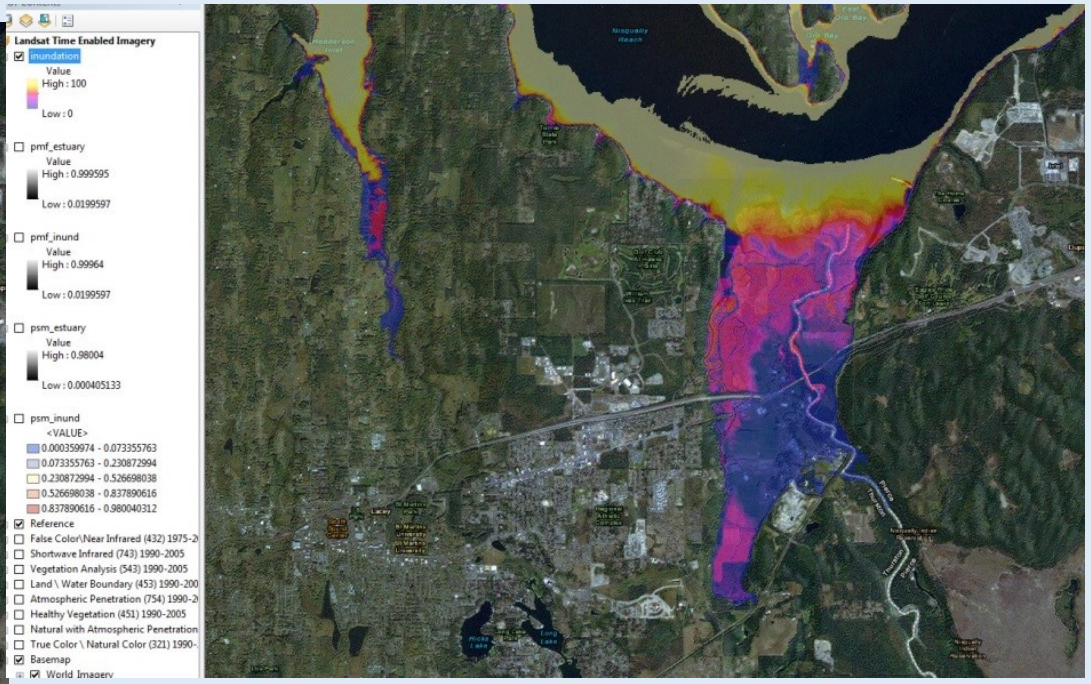


TerrainWorks (www.terrainworks.com)

Collins 2008

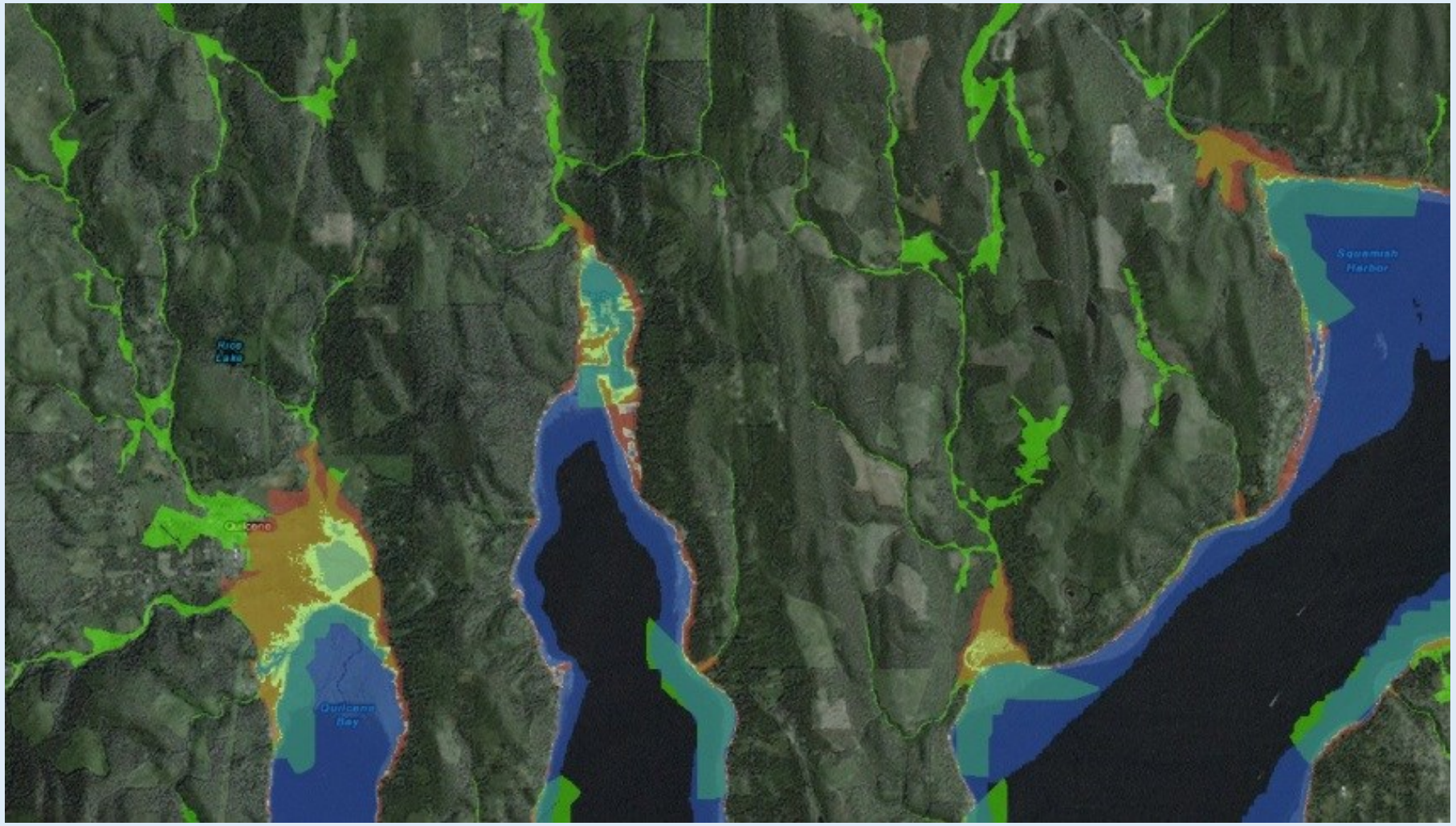
Nisqually Delta

Inundation



Probability of salt marsh

New classification schemes: estuary + floodplain



New classification schemes: estuary + floodplain + fish hab