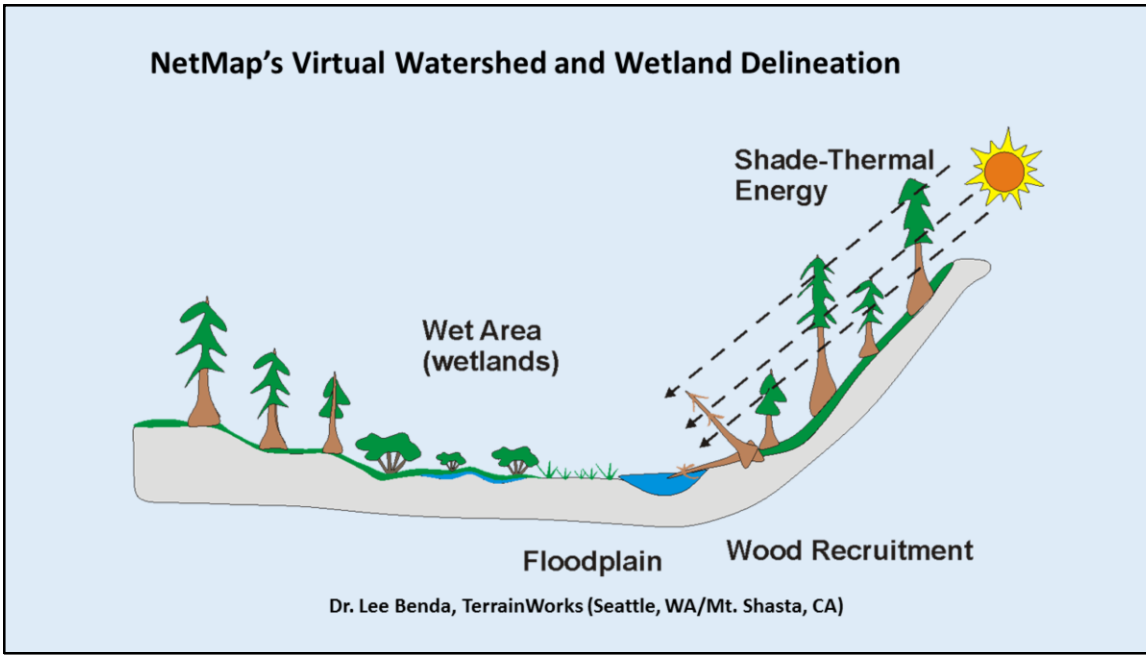


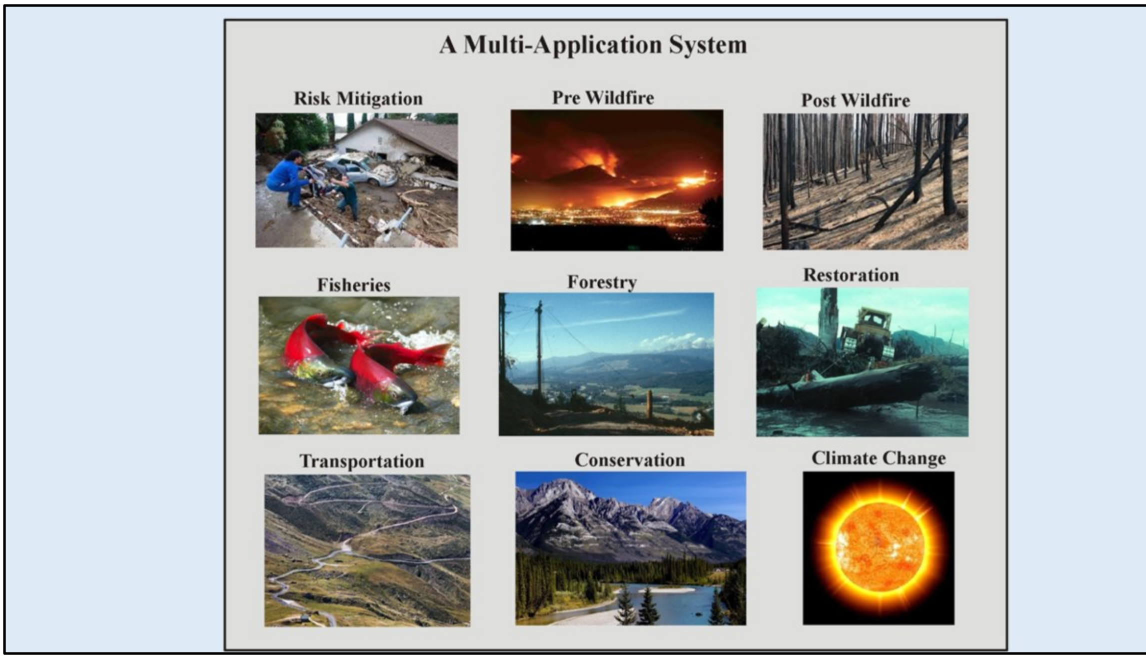
This powerpoint explains the potential for automated mapping of wetlands across Washington, as well as other states.

Table of contents:

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

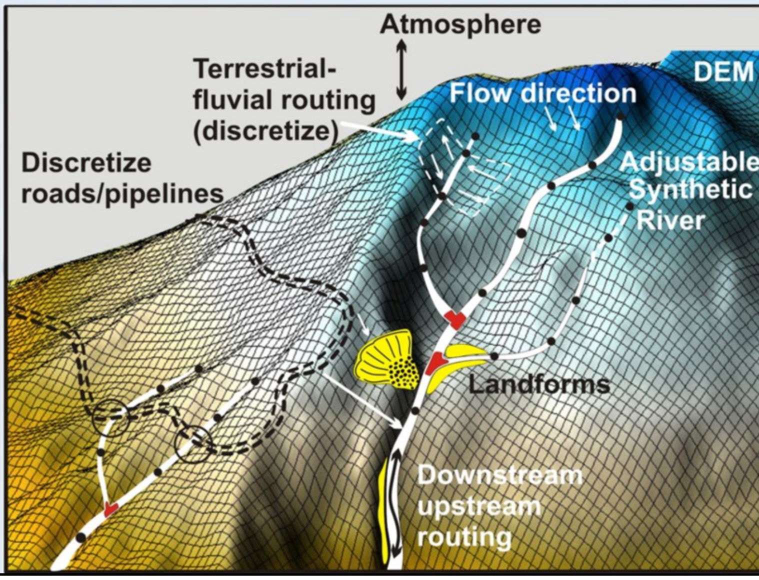
- National Forests (WA, OR, NCA, AK, ID, MT)
- Forest Service Research: PNW, PSW, RMRS
- US Fish & Wildlife Service
- NOAA
- BLM
- EPA
- Oregon Dept. Forestry
- WA Fish and Wildlife
- NGOs (TNC, Ecotrust, WSC, WCSSP)
- Watershed Councils
- Universities
- Private industry
- International (Canada, Spain,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

TerrainWorks (www.terrainworks.com)



NetMap is a multi-function application. Learn more at: www.terrainworks.com

Virtual Watersheds can be used to map wetlands



For additional information, refer to the end of this presentation or visit: www.terrainworks.com

TerrainWorks (www.terrainworks.com)

A virtual watershed numerical platform enables wetland mapping, as well as other inter-disciplinary analyses.

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)

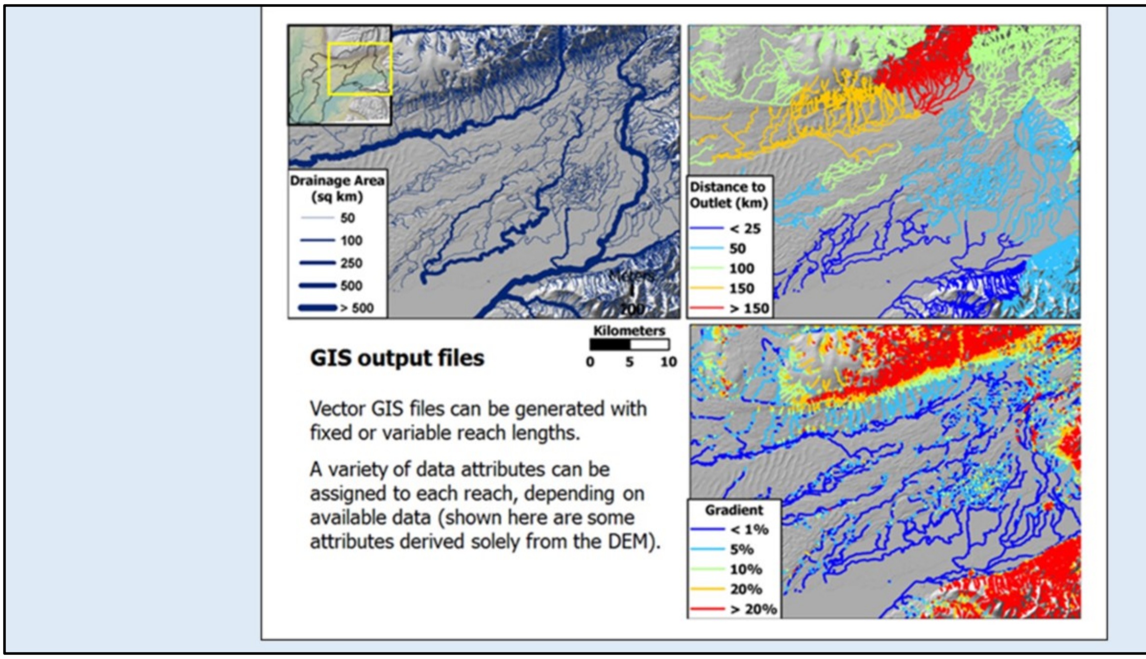
(2) Topographic wetness index (TWI), uses slope, curvature & contributing area (can add soils/transmissivity)

(3) Topographic depressions (DEM)

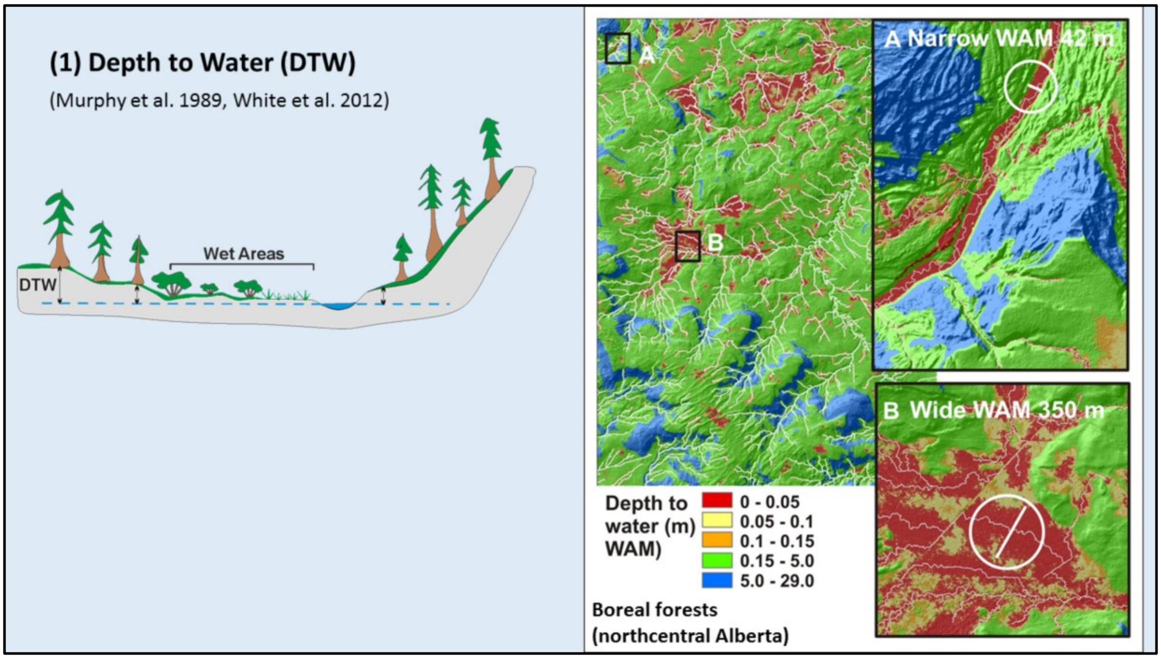
(4) Landform/material properties, add variable subsurface/surface flow network density – variable DTW

TerrainWorks (www.terrainworks.com)

There are several approaches to mapping floodplains. NetMap, at present (9/2015) does not contain wetland mapping capability, but it does contain the numerical architecture to do so (see below).

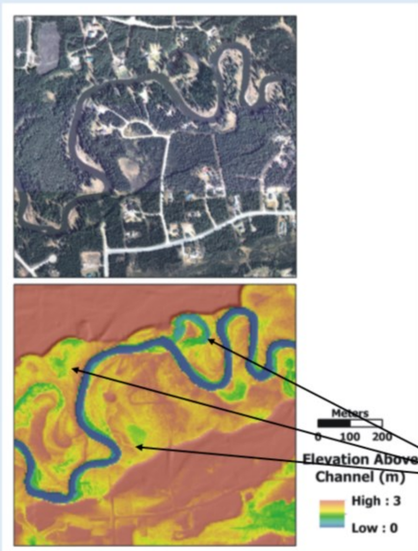


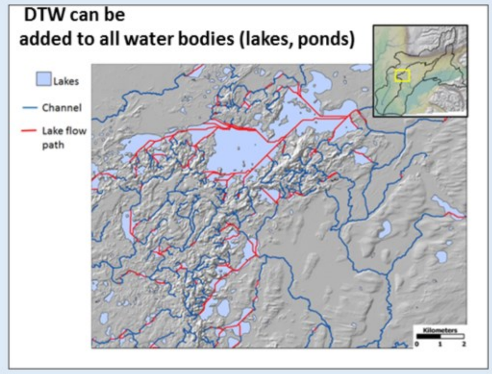
Need to start first with a synthetic river network derived from a DEM. See (http://www.terrainworks.com/virtual-watersheds-smart-river-networks) to learn more about NetMap's synthetic river networks.



First method: Depth to Water. Terrainworks is working with the Province of Alberta to incorporate their DTW analyses into NetMap.

NetMap's DTW along all streams and rivers





Provisional wet areas (wetlands)

(2) Topographic Wetness Index (TWI)
(Bevin and Kirkby 1979)
can add soils/transmissivity

- **land convergence**
- **contributing area**
- **slope**

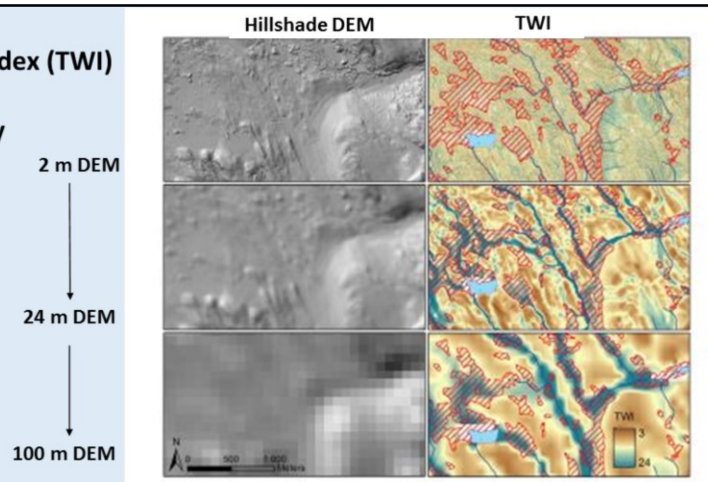
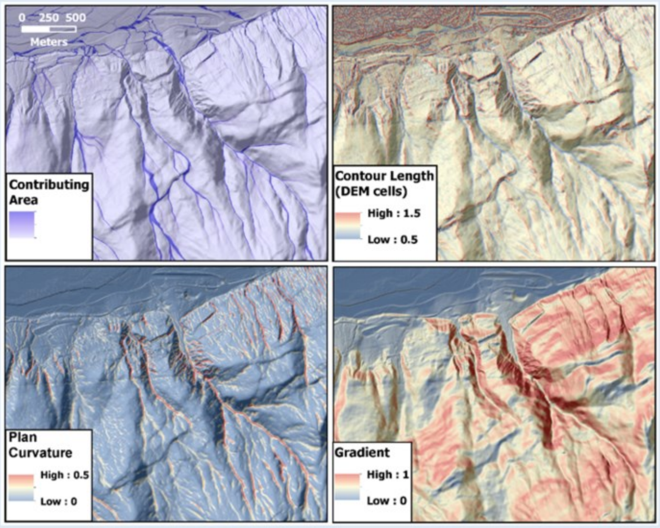


Figure 3. Topographic wetness index (T_{WI}, right) derived from the 2, 24, and 100 m DEMs (left, hill shaded), for a part of Area 1. Also shown on the right: lakes, streams, and wetlands (cross-hatched, red), previously mapped at 1 : 12 500.

TerrainWorks (www.terrainworks.com)

Second method: Topographic Wetness Index. NetMap contains all of the necessary components to implement the TWI index.

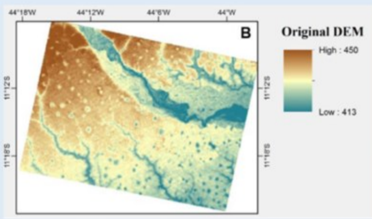


NetMap contains the data to create TWI

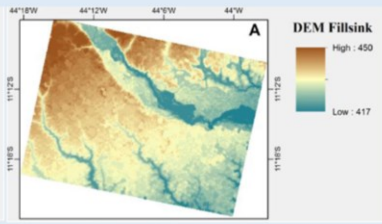
TerrainWorks (www.terrainworks.com)

(3) Topographic Depressions

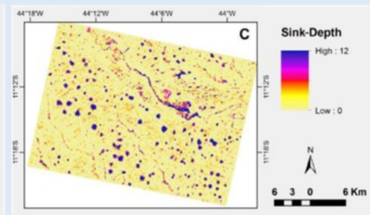
(1) Original DEM



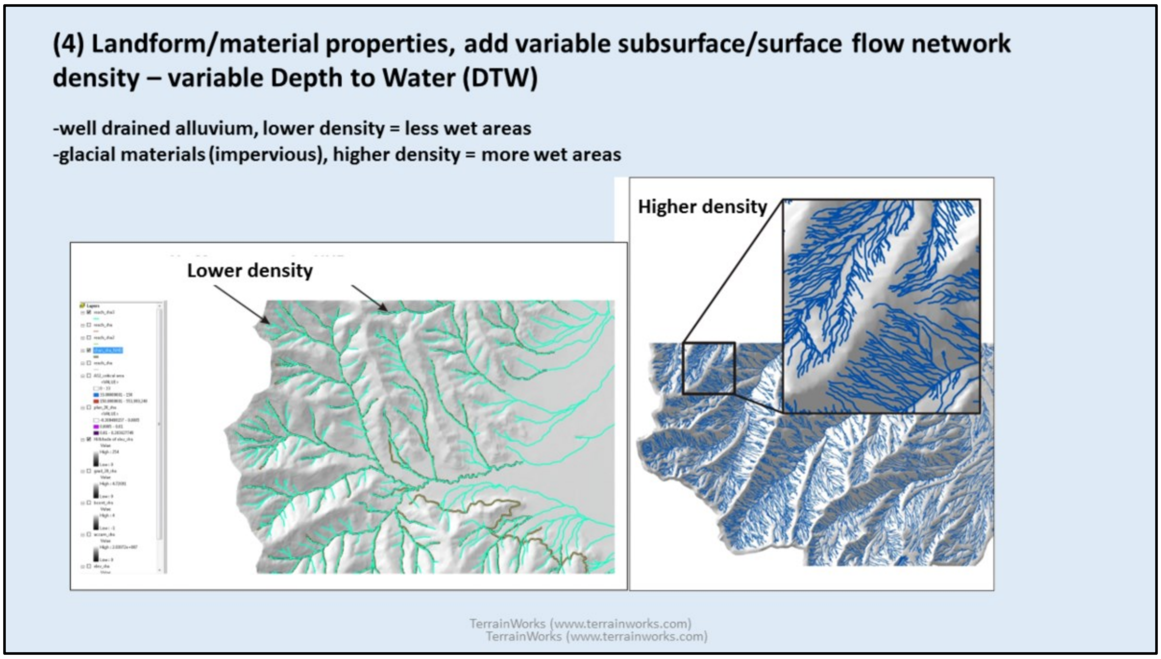
(2) Hydro-conditioned (filled)



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



Third ethod: Topographic depressions.



Depth to water predictions can be conditioned by other watershed attributes in NetMap.

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

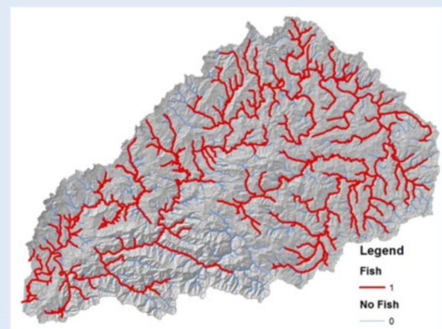
- Depth to water (DTW), all streams, rivers and mapped water bodies (option, add variable subsurface/surface network density based on variable landforms, subsurface materials, soils),
- Topographic wetness index (TWI), with option to add soils and transmissivity, and
- Topographic depressions

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)

TerrainWorks (www.terrainworks.com)



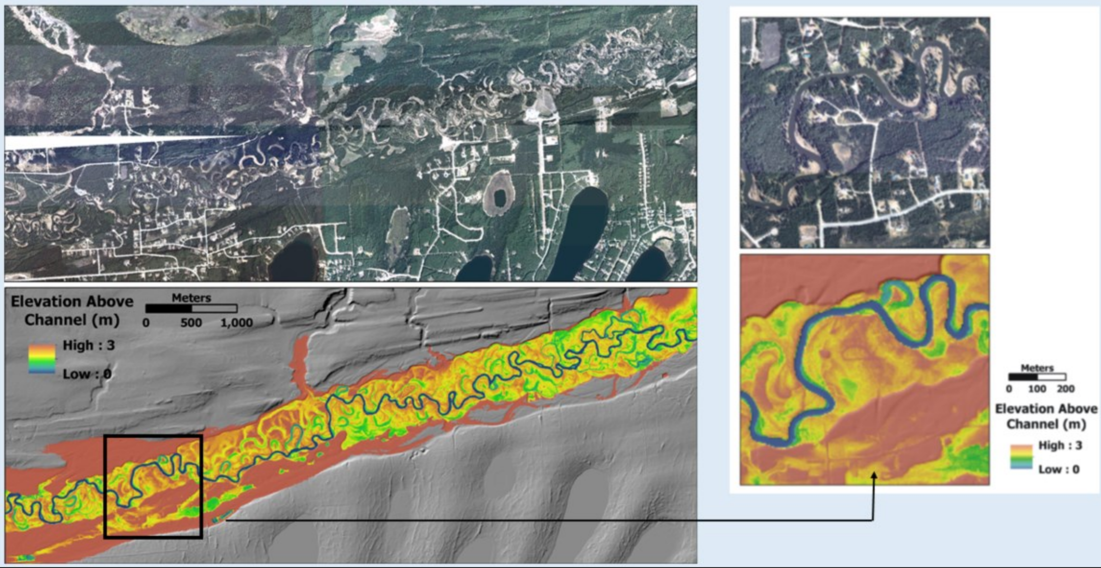
Here is one proposal for moving forward with a state wide wetland mapping system, to be incorporated into field based programs for validation and refinement.

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

TerrainWorks (www.terrainworks.com)

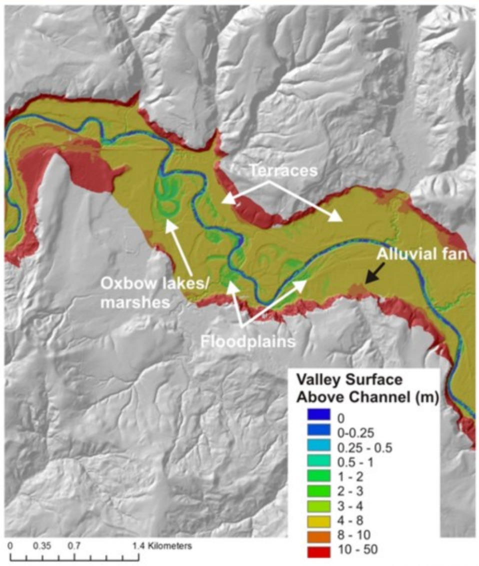
NetMap's 10 m DEM-based virtual watershed datasets already exist across all of Washington.

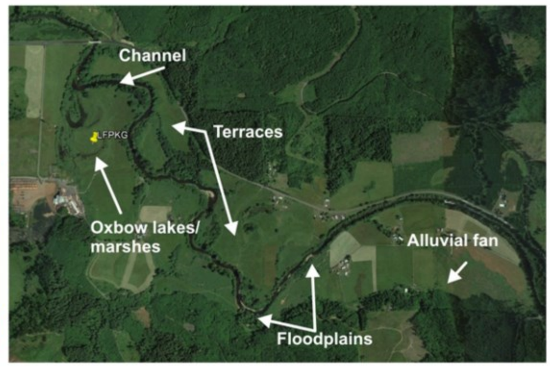
As additional background and capabilities related to wetland mapping, let's review NetMap's other riparian mapping tools.



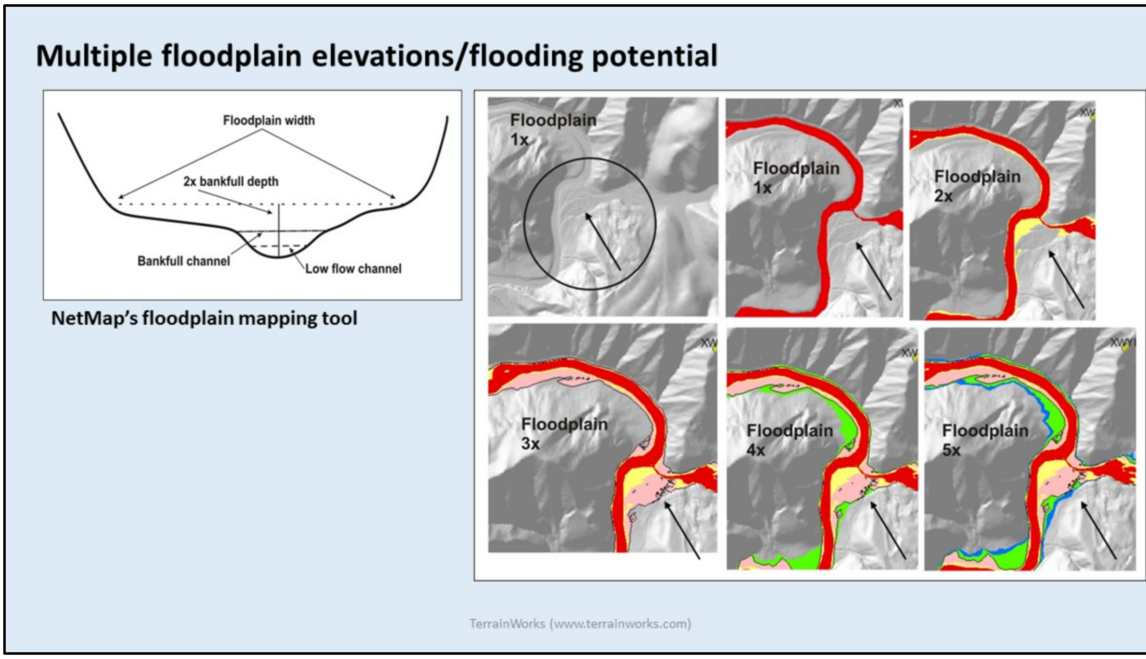
Elevation above channels is used to identify floodplains and related fluvial features.

Identify floodplains, terraces, alluvial fans, oxbows and marshes

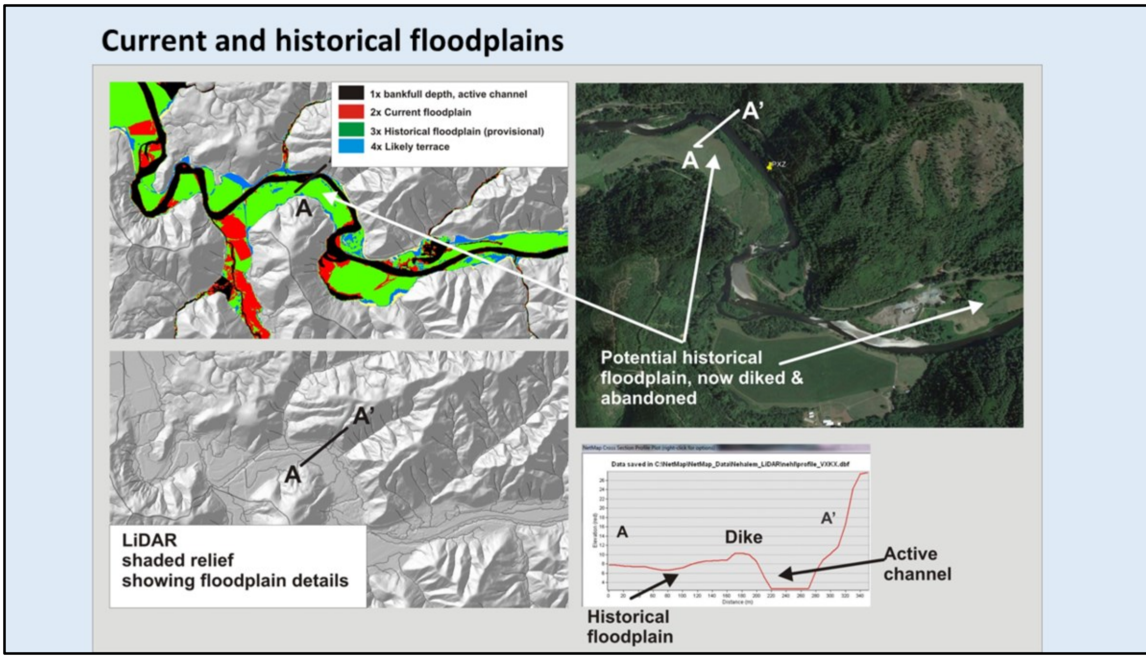




TerrainWorks (www.terrainworks.com)

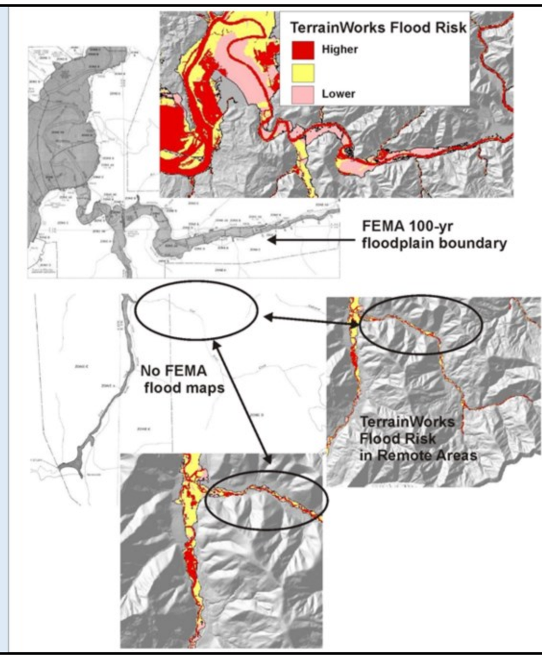


NetMap's advanced floodplain mapping tool calculates floodplains based on multiples of bankfull depths above the channel. This graphic (right panel) illustrates this using a 2.5 m LiDAR DEM in the Nehalem. Floodplains at 1x bankfull depth defines the active channels; floodplain at 2x defines the current active floodplain; floodplain at 3x defines the higher current floodplain and or the historically active floodplain in channels that have incised; floodplains above 3x are likely terraces that do not get inundated.



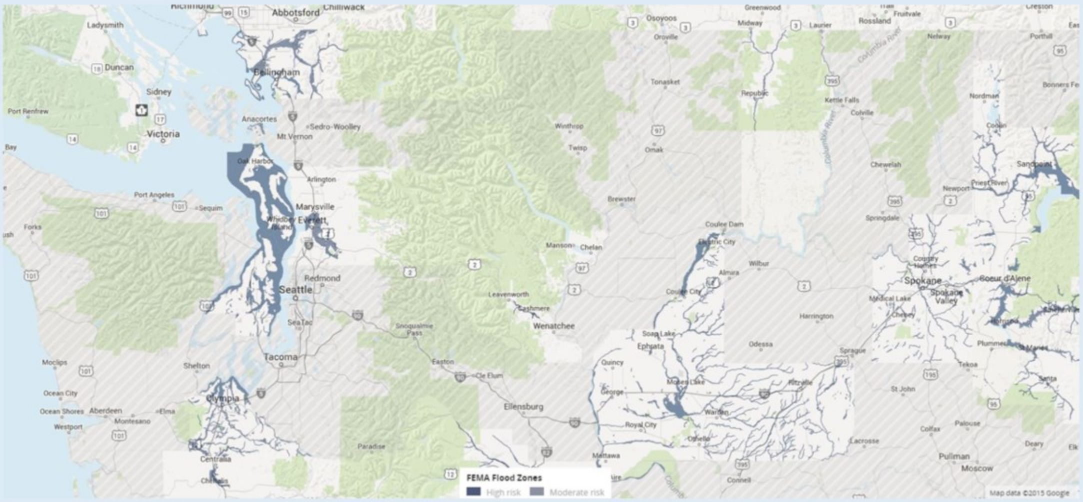
Using LiDAR DEMs, the floodplain mapping tool can be used to detect the effects of dikes in isolating floodplains from their river systems, as illustrated above.

Compare with FEMA



FEMA floodplains are limited in spatial extent, including in Washington. Most forest streams have no FEMA floodplain maps.

Compare with FEMA



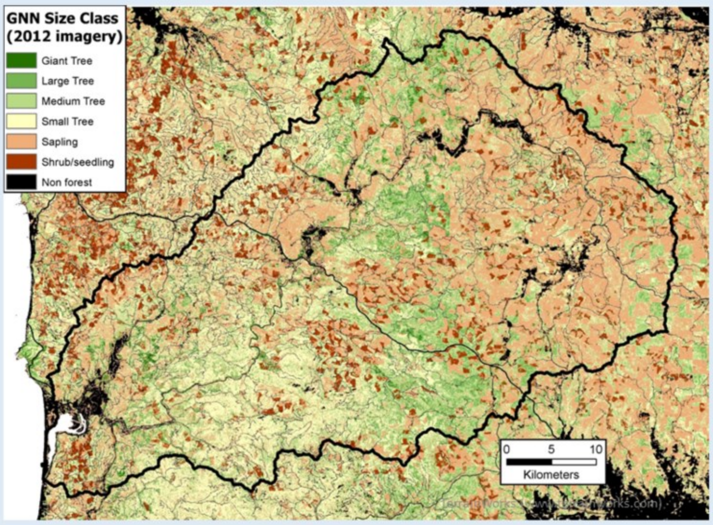
Minimal FEMA floodplain mapping in Washington State.

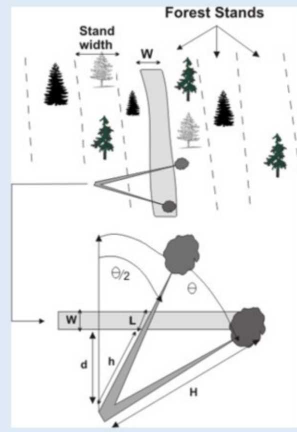
Riparian Processes/Zones

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

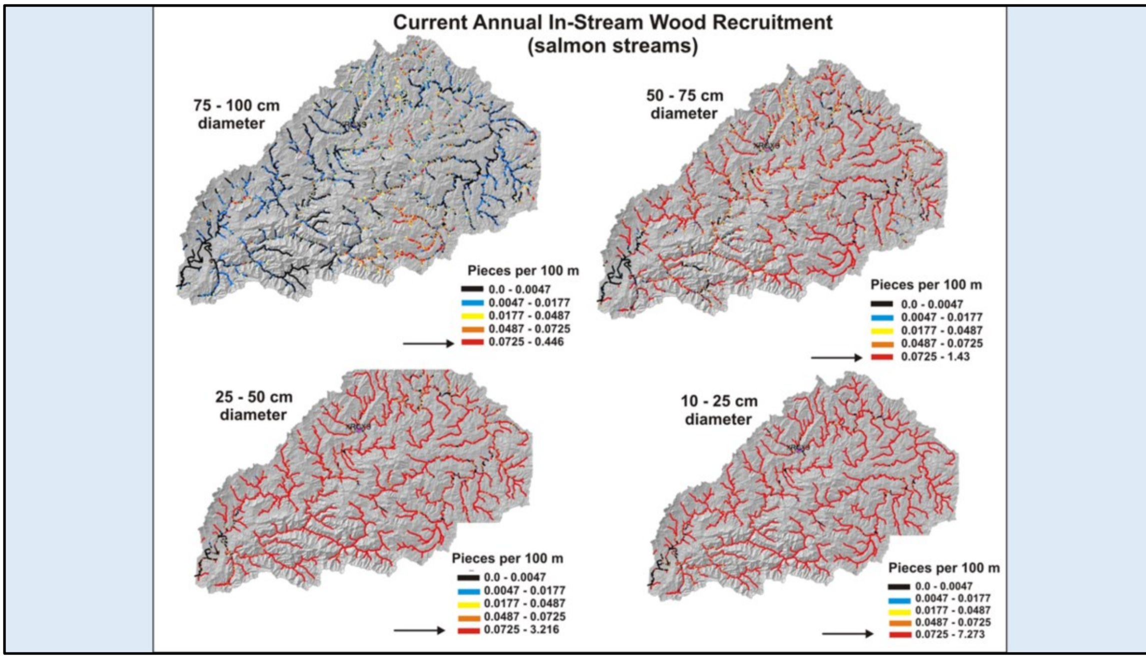
Mapping riparian zones can encompass near stream wetlands, as well as other processes, as illustrated in the next set of slides.

NetMap's Watershed scale wood recruitment potential

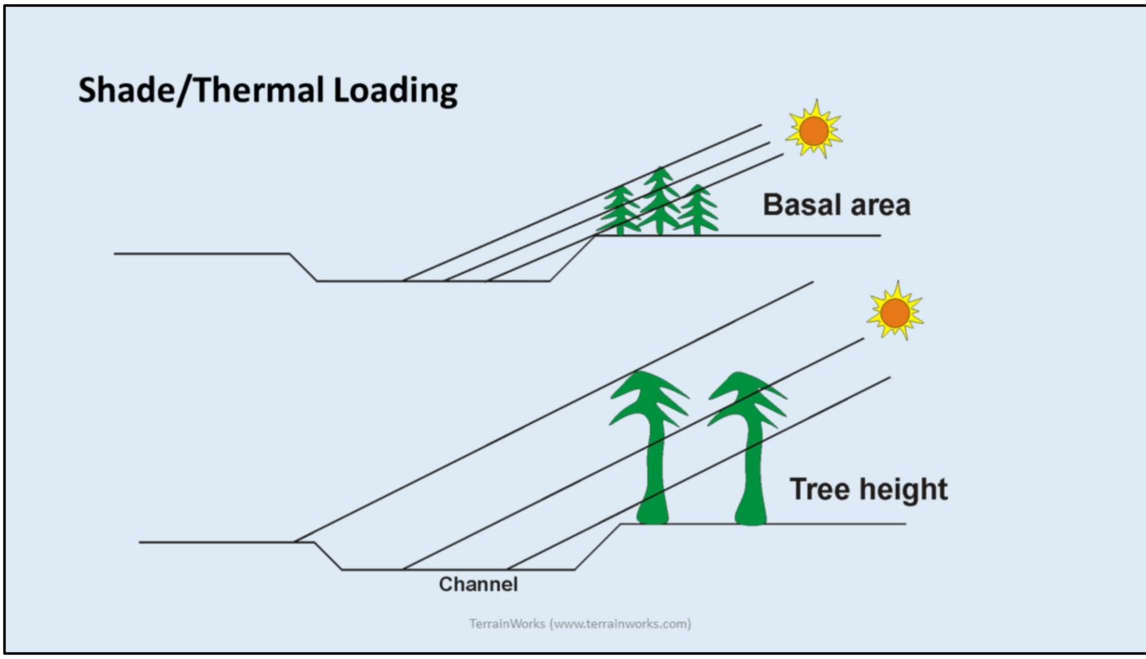




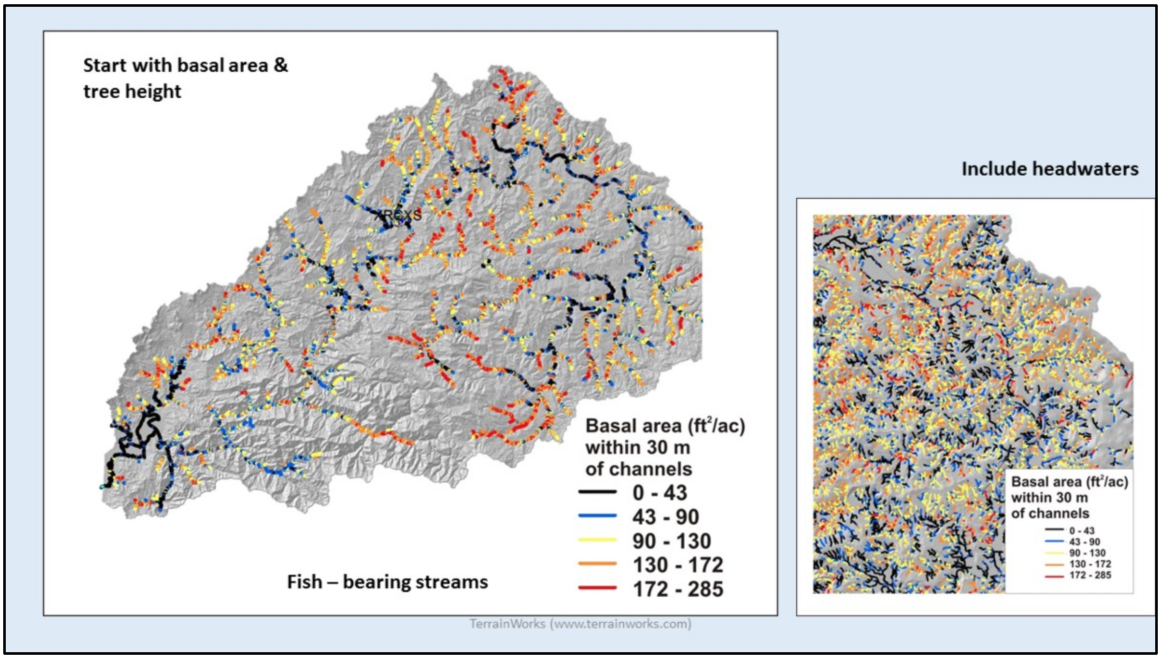
Remote sensing data from LEMMA is used in NetMap's watershed scale wood recruitment tool. Here we can see the distribution of vegetation/tree sizes across the Nehalem watershed. The ownership map in the top right corner that shows the distribution of private and public (state) lands corresponds in large part to the distribution of tree sizes. The dominance of small trees and saplings is concentrated in the private lands. However, many streams, particularly fish bearing, do have vegetation buffers that include larger trees (not easily seen in the watershed scale map).



NetMap's watershed scale wood recruitment tool reveals patterns of potential in-stream wood loading for salmon streams. All legend classes are the same across all four diameter classes, with the exception of the highest values. Darker colors (black/blue) indicate low wood loading for size classes and the warmer colors (orange/red) indicate higher wood loading (pieces/100 m). There are patches of higher wood recruitment for the larger diameter classes (upper left). Many fish streams have higher levels of recruitment but of the smaller diameter classes. Areas of high to low recruitment of large to small wood could be matched up with higher intrinsic potential (IP) scores and used to help prioritize restoration site selection.

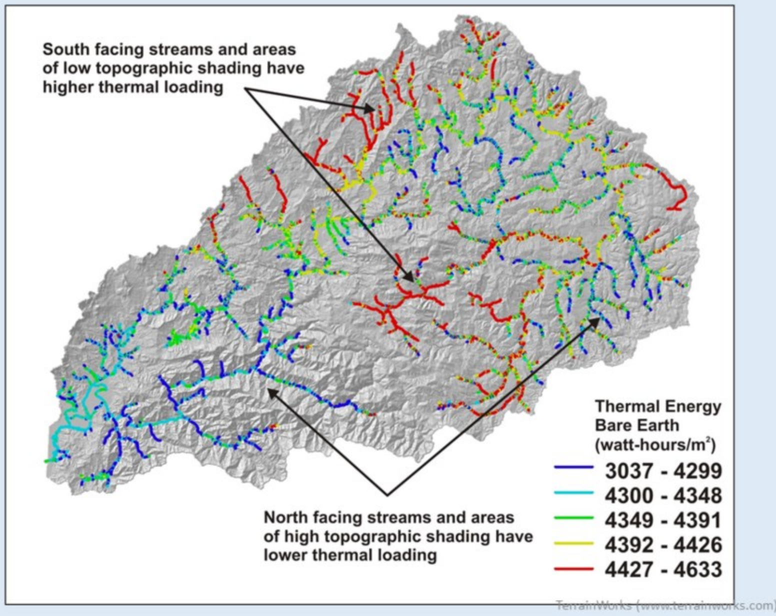


We combined NetMap's physically based thermal loading tool with a model to predict percent shade using basal area and tree height (shade model by Groom et al. 2014). The diagram above illustrates how the shade model works. Percent shade is positively correlated with basal area (think vegetation density) and negatively correlated with tree height (e.g., more light gets through taller trees that have less dense vegetation and more open canopies compared to shorter vegetation with dense vegetation). However, as trees get taller they shade an increasing proportion of the channel width, so taller vegetation equals greater shading also. Keep that in mind as we examine the predictions about how basal area and tree height, combined with natural thermal loading, affect streams in the Nehalem watershed in the next couple slides.

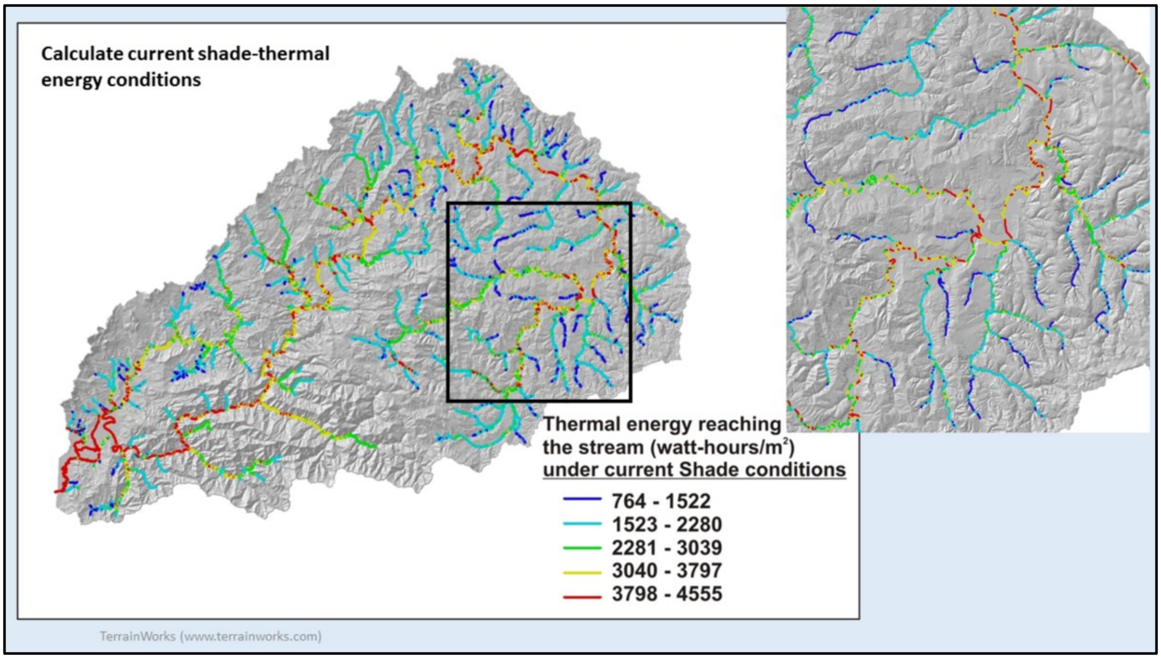


Here is a map of coho salmon bearing streams only revealing areas of high to low shade. Certain areas stand out as having low shade including the larger valley floors that are developed including for agriculture.

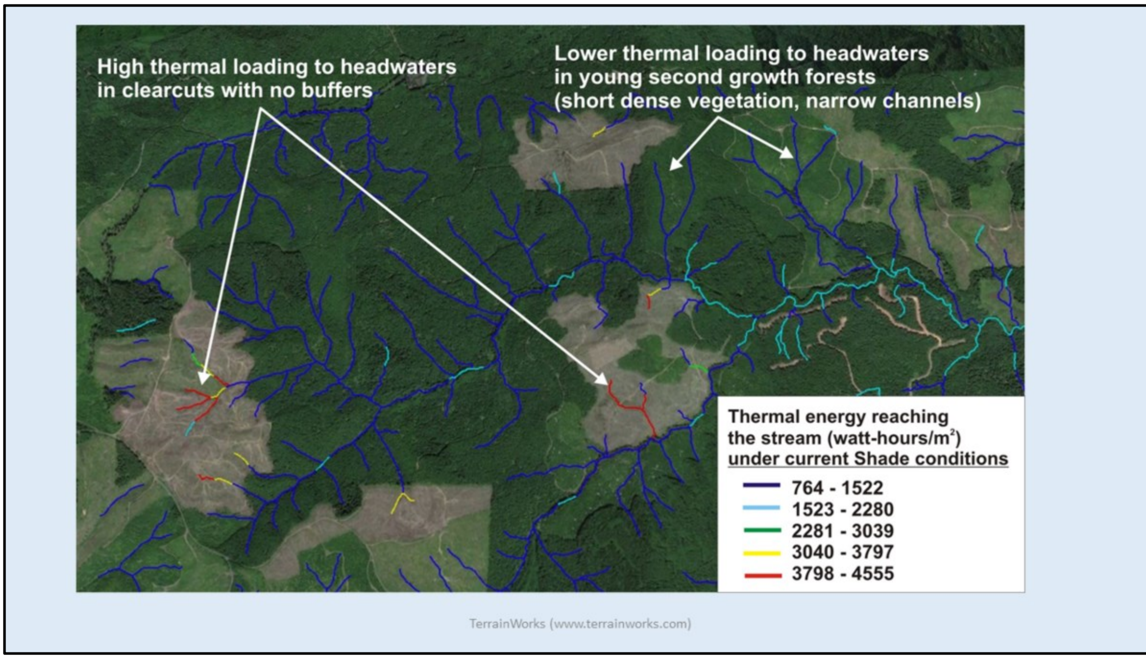
Add bare Earth radiation



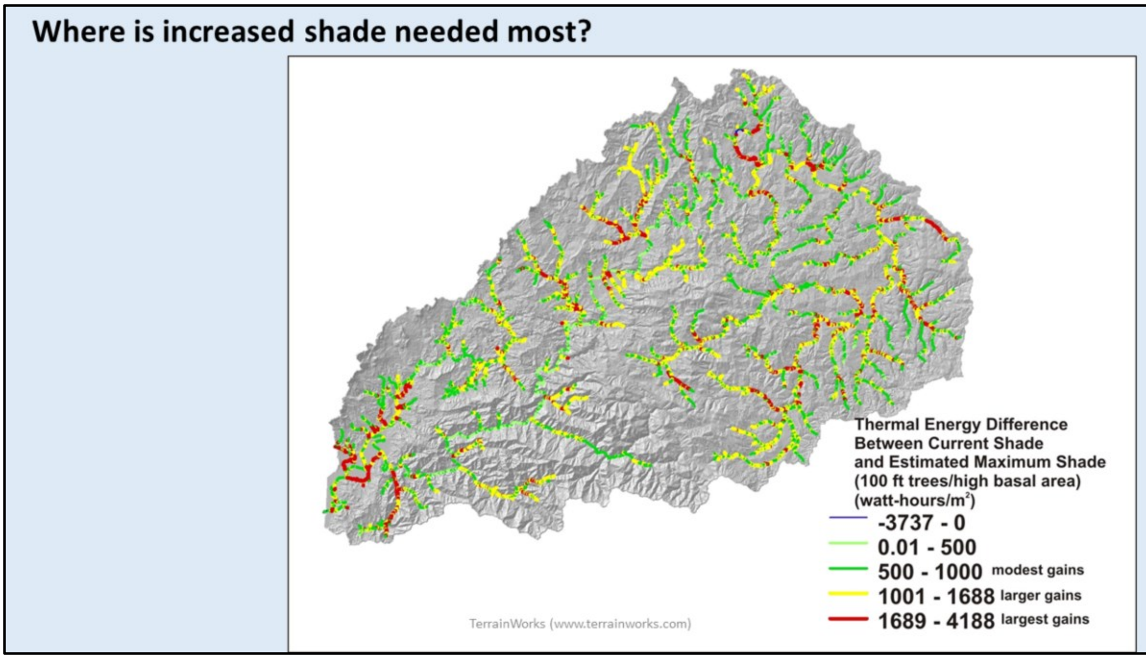
Bare earth thermal energy loading to coho salmon streams in the Nehalem watershed. Spatial patterns are evident: south facing streams and stream with low topographic shading have higher thermal energy. North facing streams and areas with high topographic shading have lower energy loading.



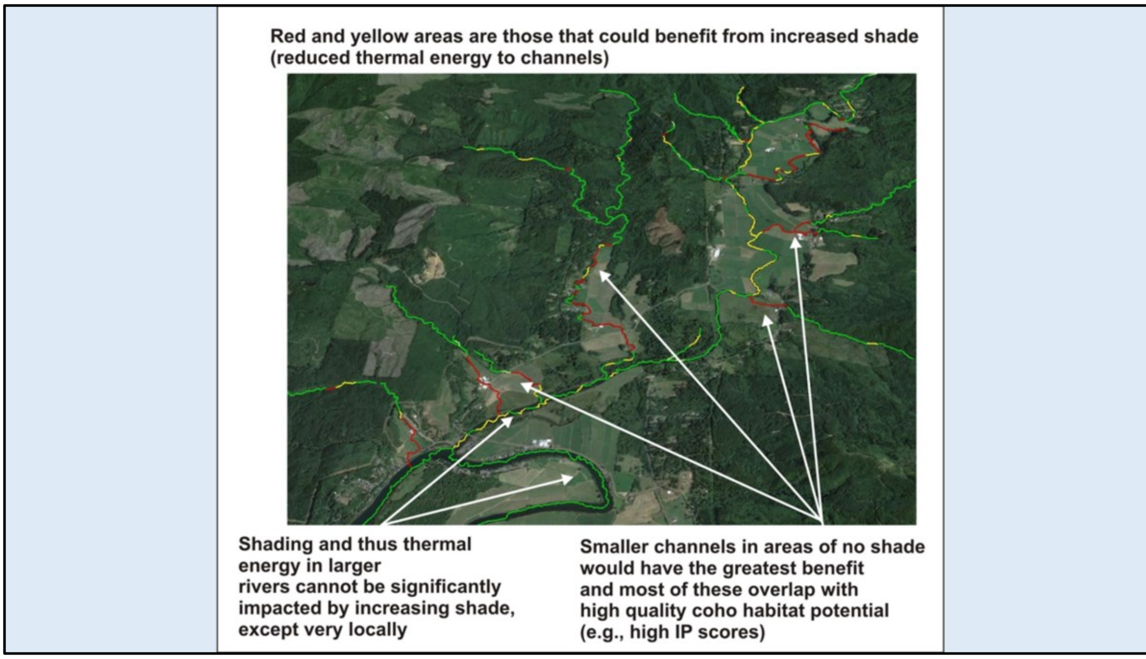
We now evaluate how current shade conditions (basal area combined with tree height) affects thermal loading along streams in the Nehalem watershed. The warmer colors in the map indicate channels that have higher thermal loading due to present day shade, combined with
natural patterns of thermal loading controlled by channel width, orientation, topography and solar angles.



NetMap's predicted current shade-thermal loading conditions including for small headwater channels. Recent clearcuts have the highest thermal loading potential because of the absence of stream side vegetation and buffers. However, younger second growth forests do provide significant shade and thus lower thermal loading, including because of narrow (1-2 m wide) channels. Recall that shading is positively associated with basal area but negatively correlated with tree height (see slide 52).

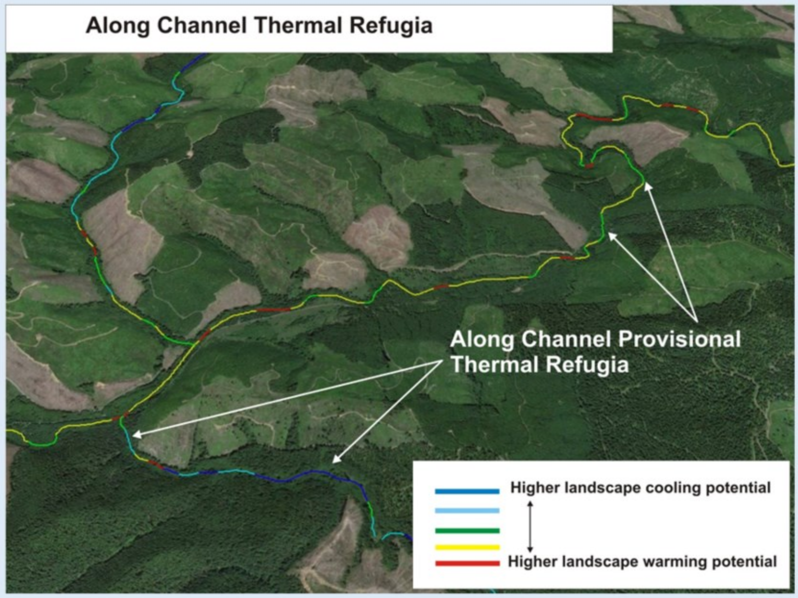


We can estimate, based on Nehalem specific vegetation conditions, a likely maximum shade condition, combining basal area and tree height. A maximum shade condition is calculated using a high basal area (122) and a 100 ft tree height. The current shade condition (previous) slide is subtracted from that. The result is a map that shows where increasing shade by vegetation manipulation would have the largest potential benefit on water temperatures. The yellow and red areas in particular may be areas where increasing shade would be an improvement. See also next slide.



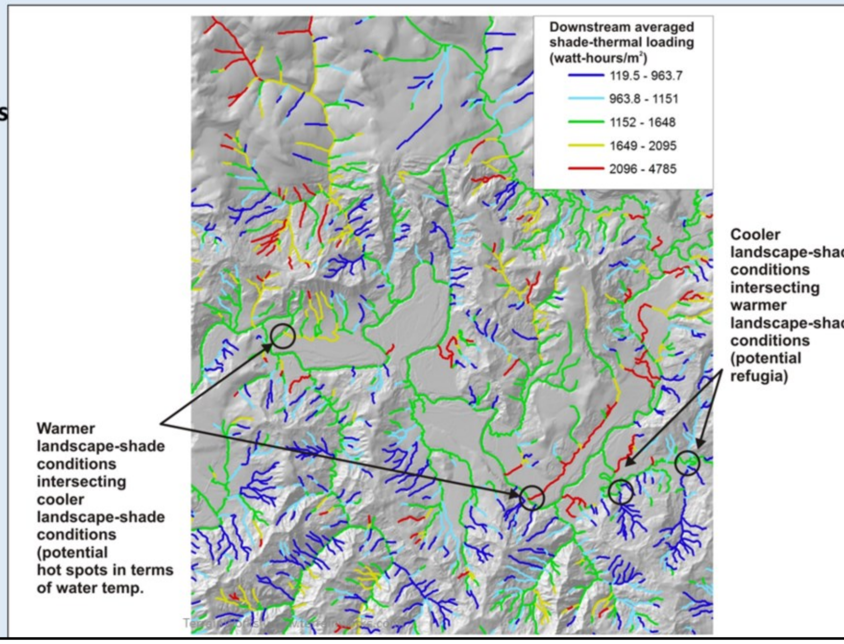
As would be expected, small high value coho streams located on floodplains and terraces, but under current agriculture, are most sensitive to current low shade levels compared to larger rivers where shade is proportionally less important in reducing thermal loading.

-latitude
-topographic shading
-stream azimuth
-stream width
-current vegetation (shade)

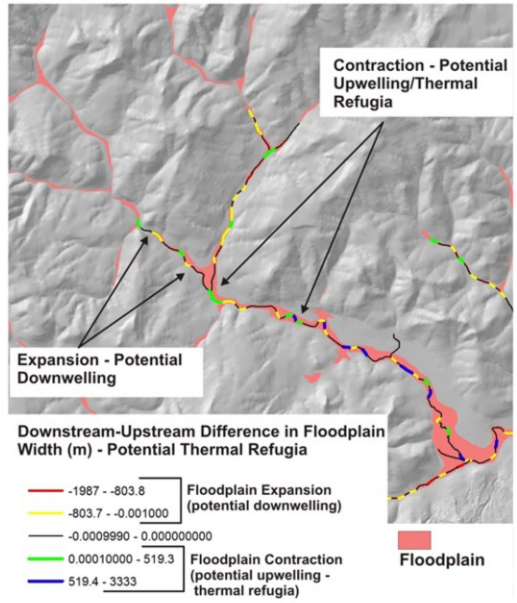


TerrainWorks (www.terrainworks.com)

Thermal relationship between tributaries and mainstem channels



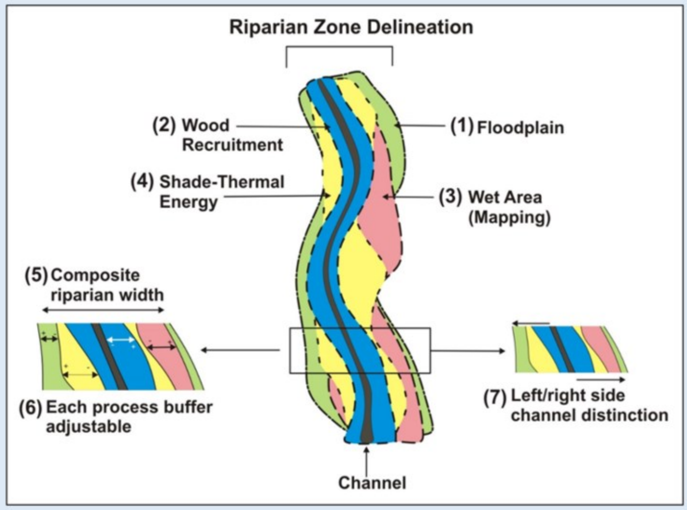
Valley contraction/expansion and potential upwelling and downwelling of hyporheic flow



TerrainWor

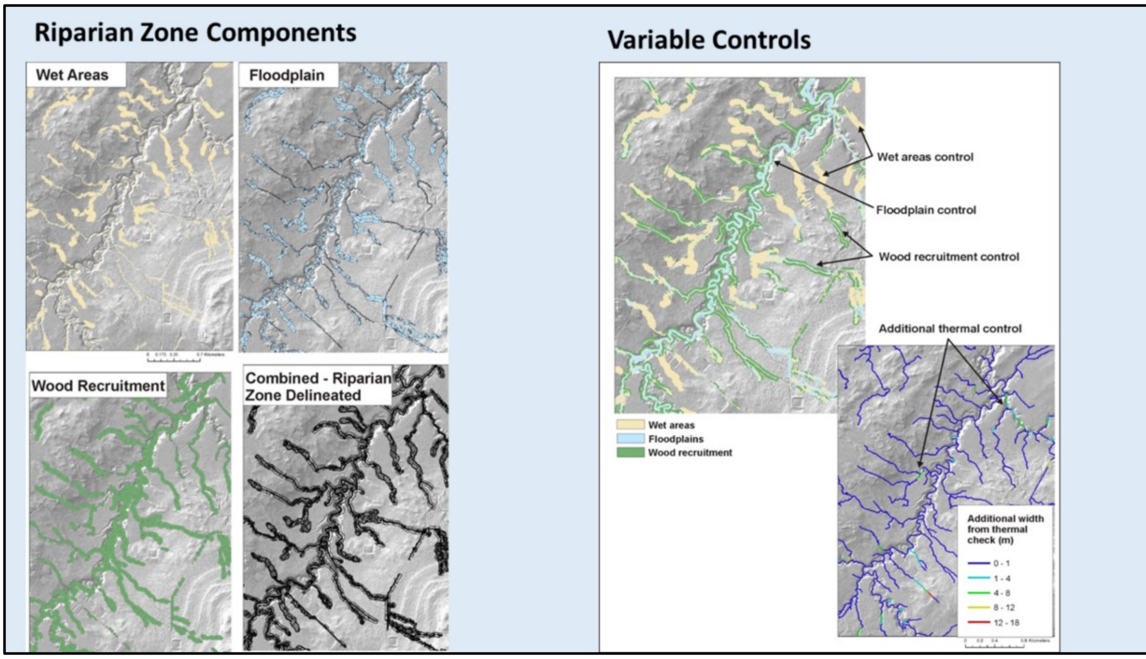
Delineating Riparian Zones

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

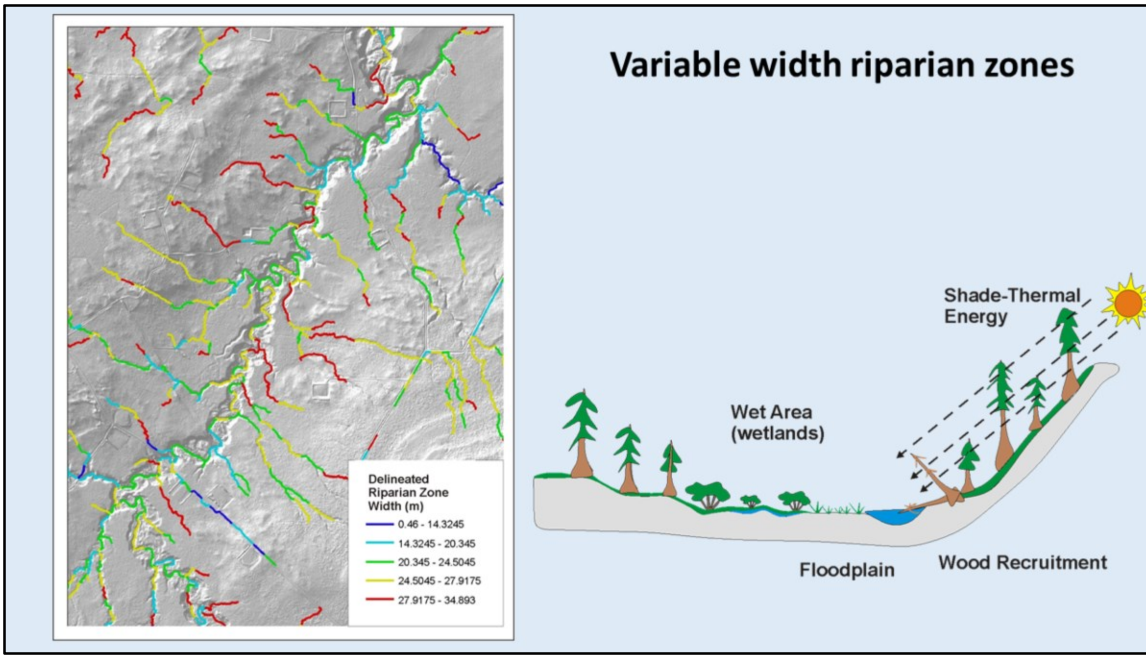


TerrainWorks (www.terrainworks.com)

NetMap contains a tool for delineating spatially variable riparian zones that encompass a range of processes.

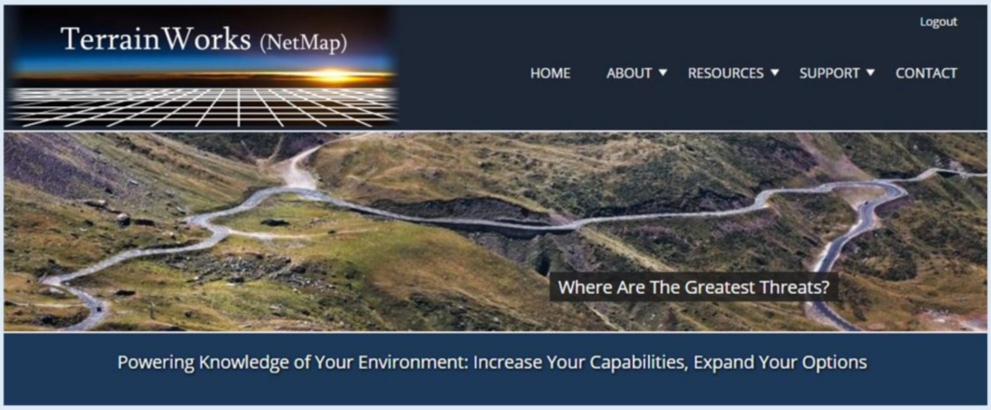


Here is an example from NW Alberta, Canada



Delineated riparian zones are spatially variable. This represents one of the most advanced methods for delineating riparian areas.

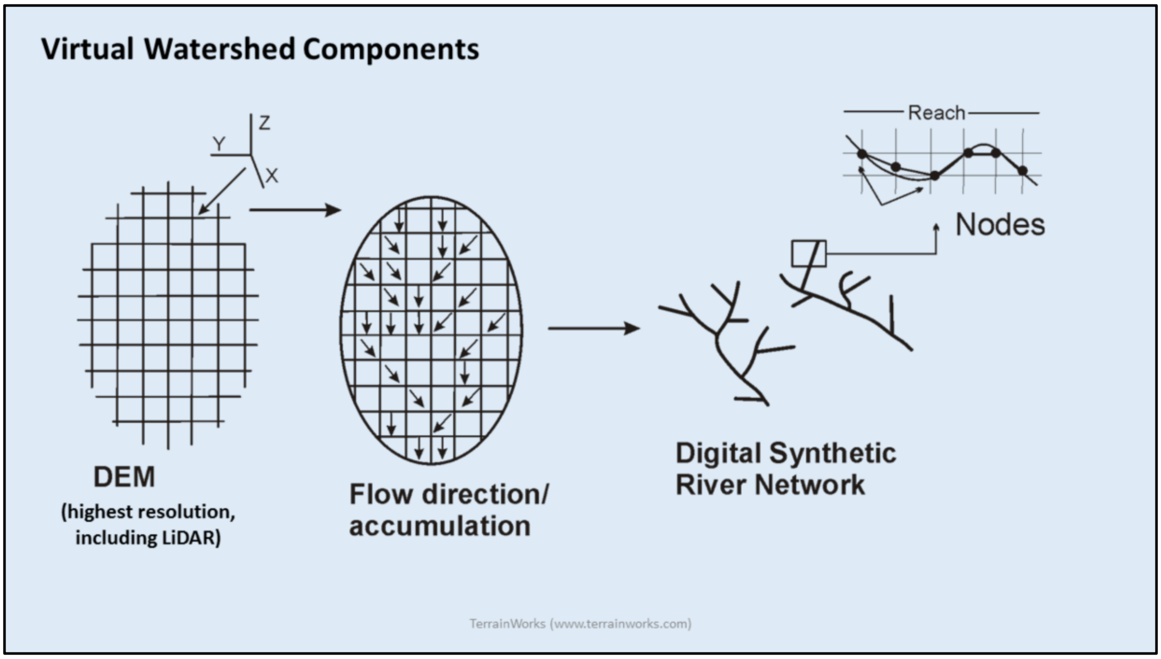
For additional information go to www.terrainworks.com



TerrainWorks (www.terrainworks.com)

The next set of slides provides additional background information on the numerical structure of NetMap's virtual watershed technology.

TerrainWorks (www.terrainworks.com)



First step in building a virtual watershed and a synthetic river network.

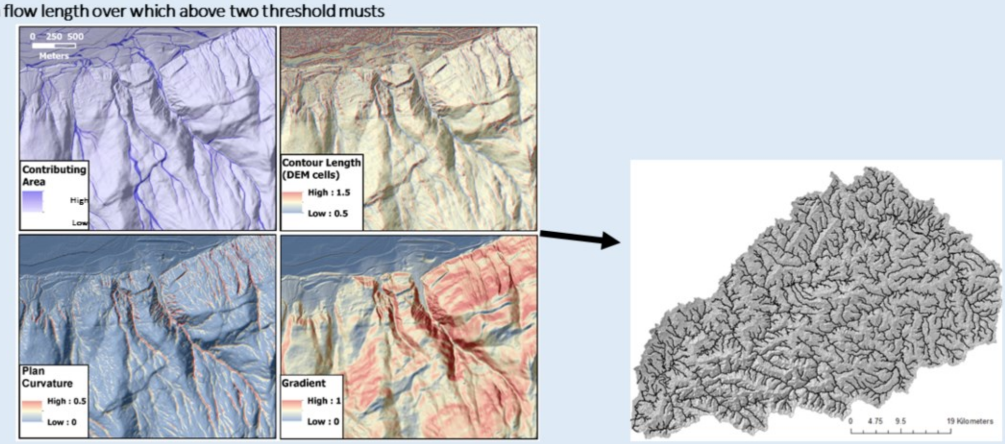
Synthetic river network

TerrainWorks (www.terrainworks.com)

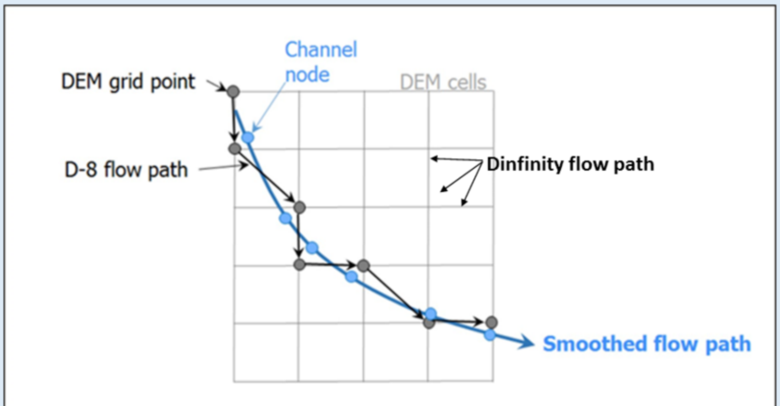
Channel-initiation threshold calibrated to DEM.

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.

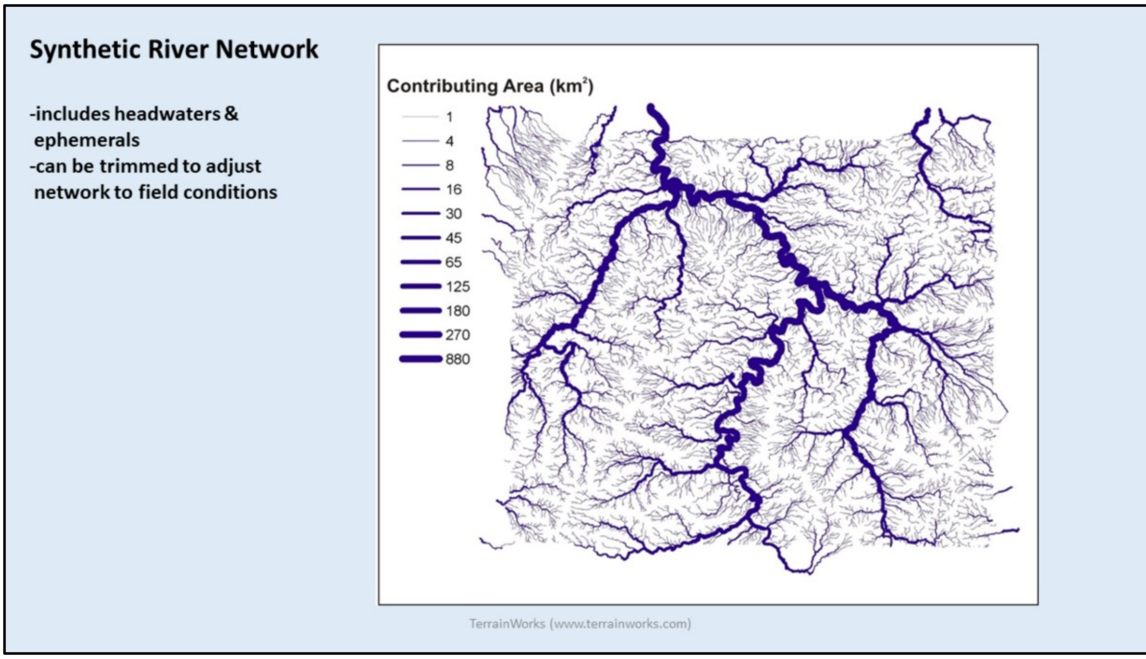


How to build a synthetic river network within a virtual watershed.

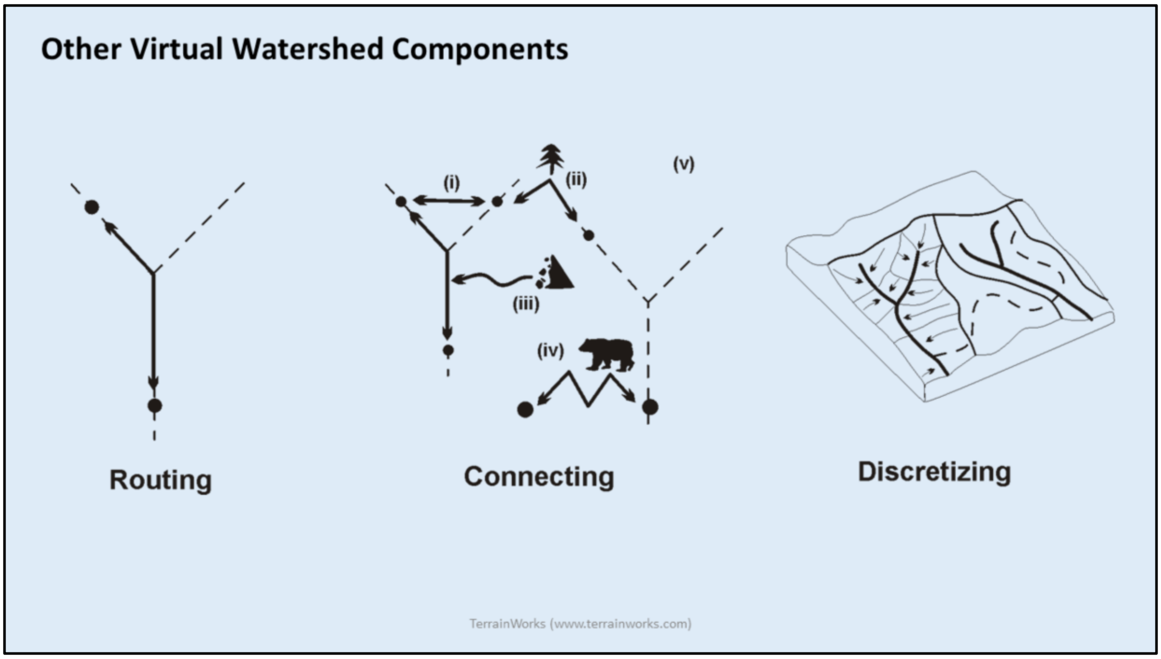


- data stored at the spatial grain of the DEM
- each node is associated with a single DEM cell (supporting channel initiation anywhere)
- couples the channel network to the terrestrial for hydrologic, erosion, riparian, land use modeling
- each cell is associated with single (or multiple) channel nodes, 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

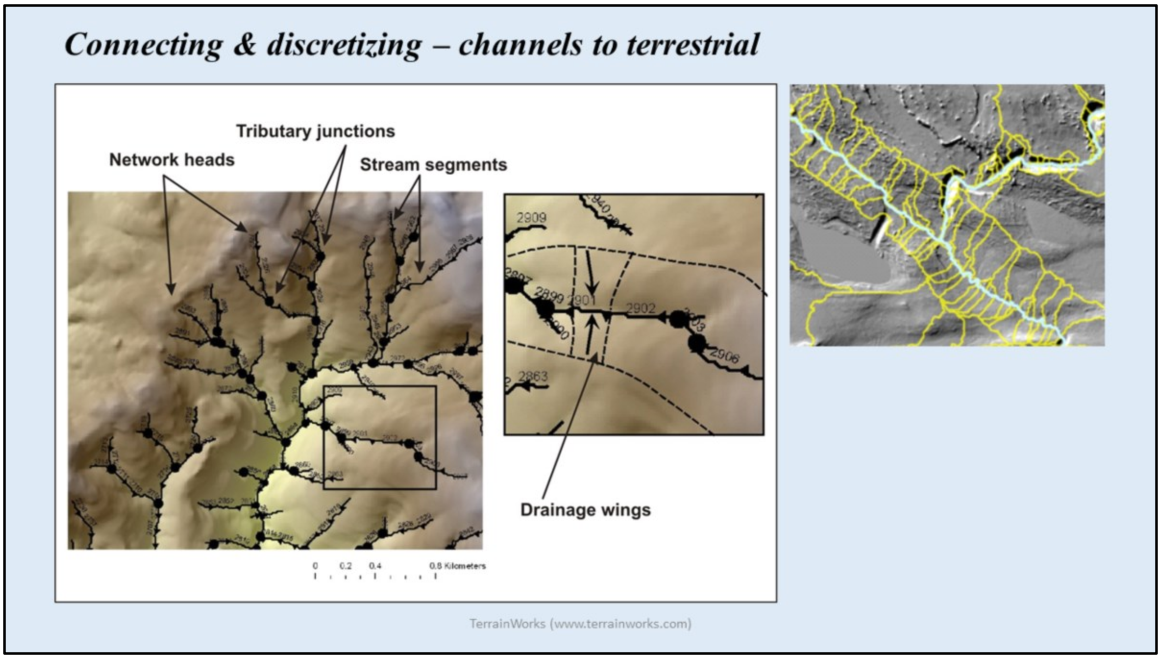
All spatial data is maintained at the finest spatial grain.



Building of synthetic networks is customized and flexible to match project needs; http://www.terrainworks.com/customized-and-flexible-river-networks-and-virtual-watersheds

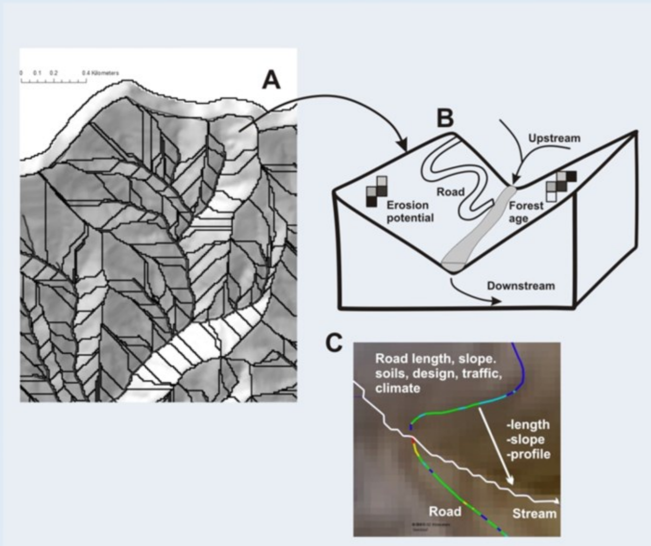


Other components are critical to building a virtual watershed.



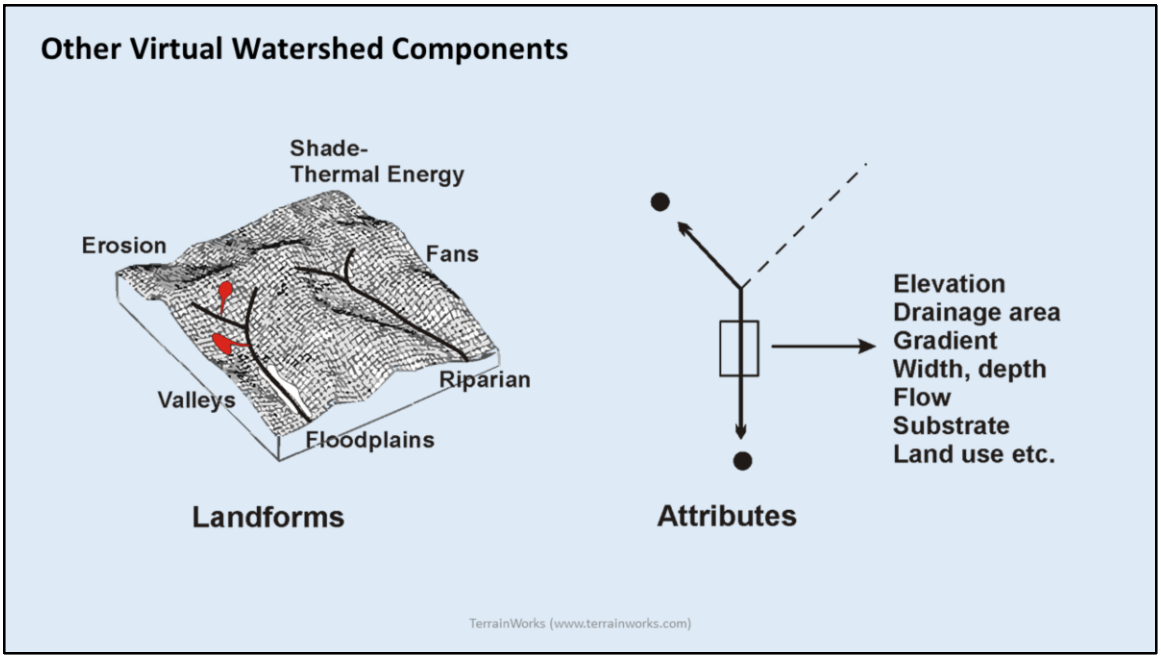
Linking terrestrial environments to the river network is key.

Drainage wings (discretize landscapes and land uses)



TerrainWorks (www.terrainworks.com)

Drainage wings provide the numerical basis for the terrestrial-river linkage.



Mapping of landforms and attribution are important features.

Stream and watershed attribution

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

TerrainWorks (www.terrainworks.com)

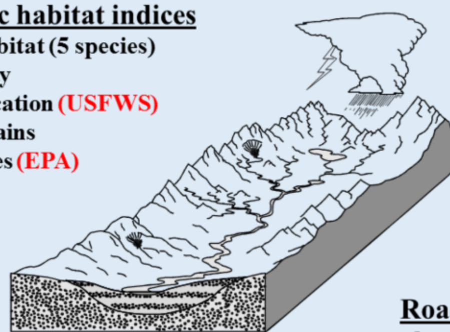
There are numerous attributes and process characterization.

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

NetMap has “community tools”, learn more at:
http://www.terrainworks.com/science-technology-network

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

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