Whole Watershed Restoration Planning Tools for Estimating Tradeoffs among Multiple Objectives

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Society For Ecological Restoration Northwest Chapter
Portland, Oregon
April 7, 2016

Outline

- Describe a set of integrated decision support tools for whole watershed restoration planning
- Case study demo: Salmon recovery planning in the Mashel River Watershed, WA
- Tools:
  - Climate & land use change data (model drivers)
  - Ecohydrological model
  - Stream shade model
  - Fish population model
  - Visualization/communication tools
- How are these tools being used to assist tribes, land managers & communities in balancing multiple objectives?

Why use a whole-watershed approach for salmon recovery planning?

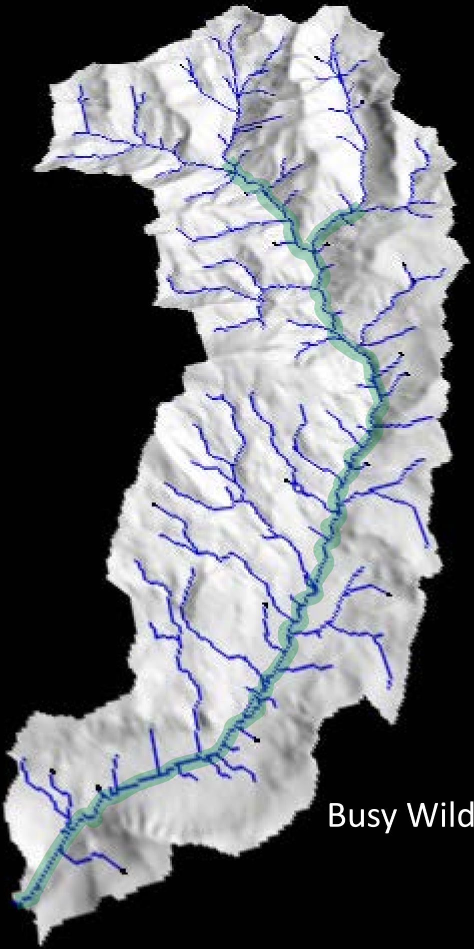
Fish bearing streams

Busy Wild River Watershed, WA

USEPA Office of Research and Development
National Health and Environmental Effects Research Laboratory

Why use a whole-watershed approach for salmon recovery planning?

…plus contributing streams & flow paths



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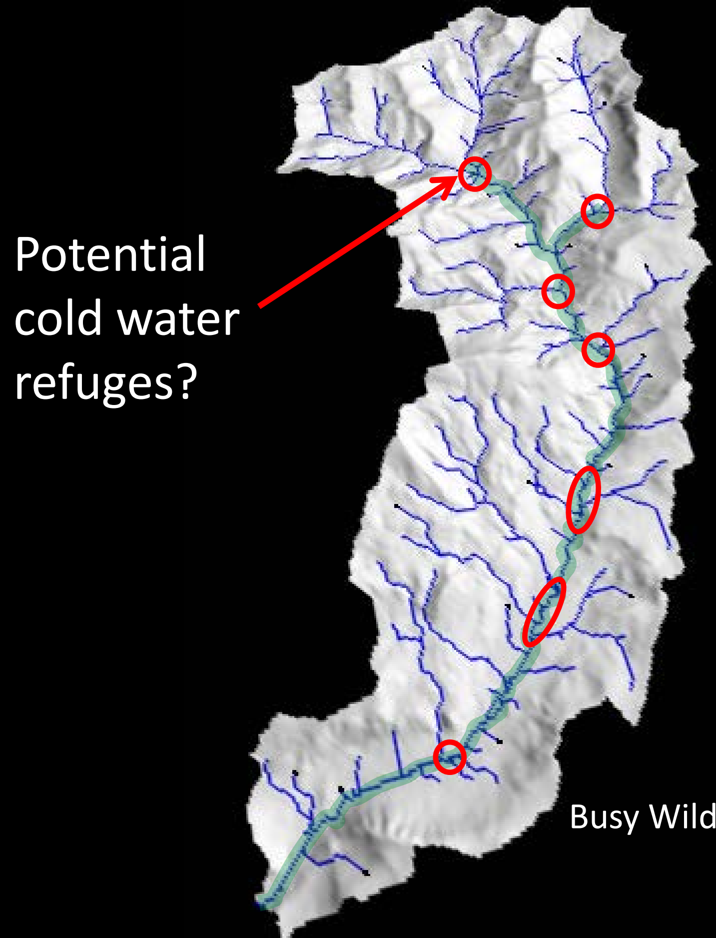


Busy Wild River Watershed, WA

Why use a whole-watershed approach for salmon recovery planning?

Premise: key salmon habitat factors are tightly linked to processes that extend from ridge to stream

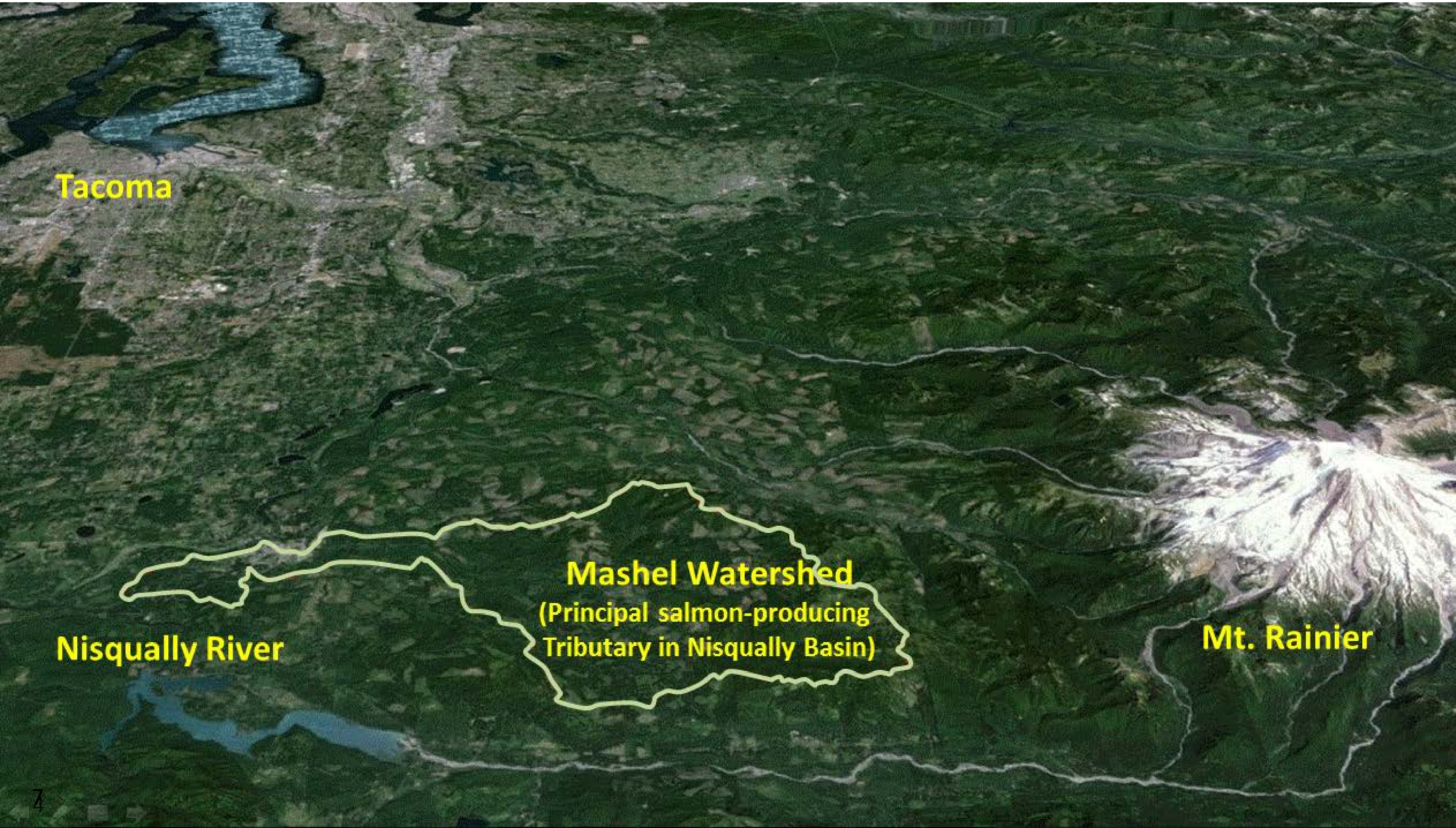
Peak & low flows

Stream temperature & sediments

Large woody debris (LWD)

Mashel Streamflow Modeling Project

Can long-rotation forestry improve summer low flow conditions that limit salmon migration & spawning in the Nisqually Basin?



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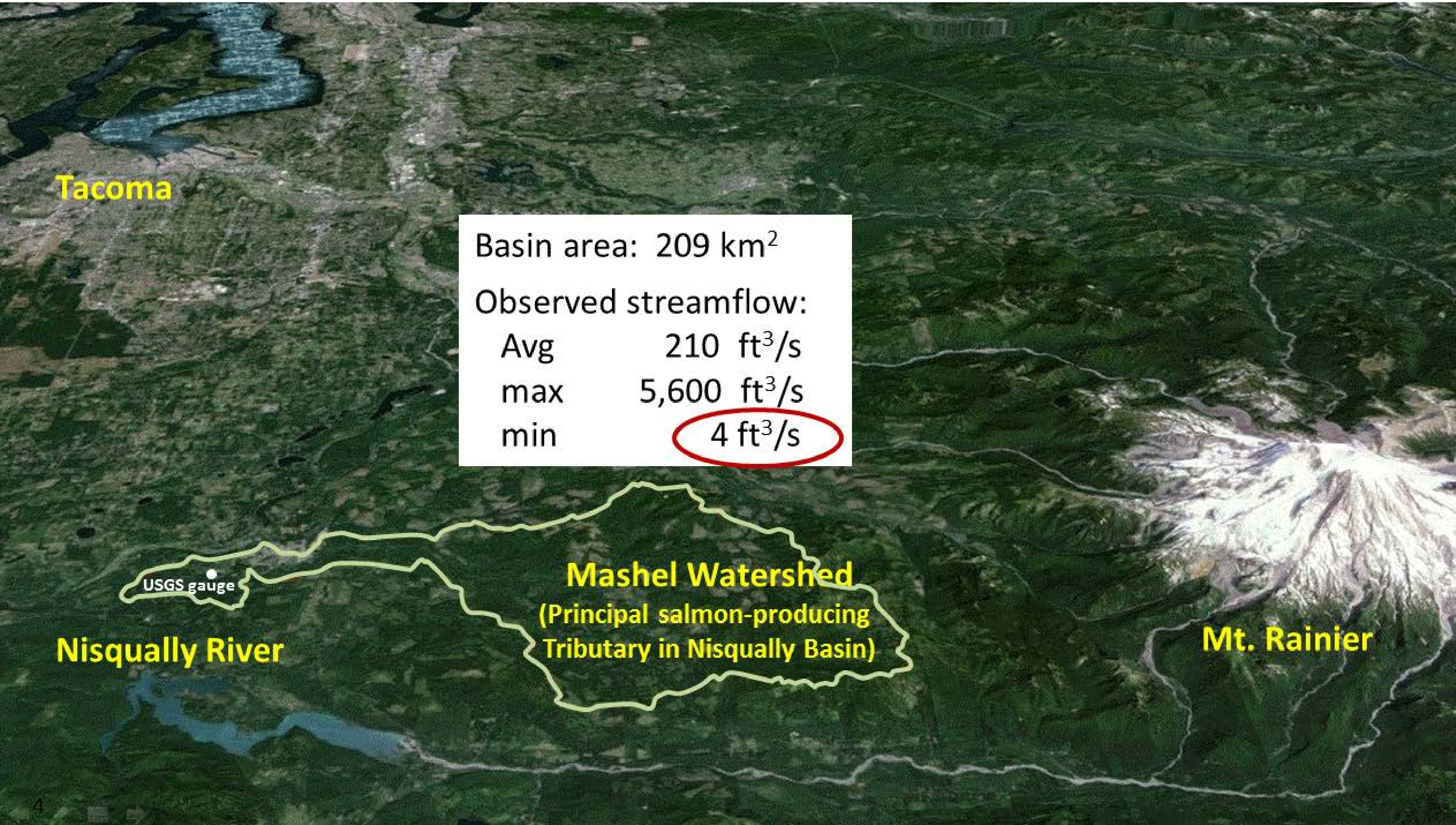

Mashel Streamflow Modeling Project

Can long-rotation forestry improve summer low flow conditions that limit salmon migration & spawning in the Nisqually Basin?

Mashel Stakeholders

Landowners	Interests
• Private Forest Industry	Forest products, profit, conservation easements
• State of Washington	Forest products, clean water, salmon recovery, recreation, stewardship
• Town of Eatonville, WA	Clean water, flood control
• Nisqually Land Trust	Community Forest → salmon, sustainable local forest jobs, stewardship, carbon markets…

”Downstream” Stakeholders

• Nisqually Tribe	Salmon recovery, cultural traditions, subsistence
• Nisqually WS Council	Salmon recovery, Community Forest goals
• Fishers, hunters, hikers…	Recreation, subsistence, sense of place…
• Puget Sound communities	Salmon recovery, stewardship, recreation…
• National / International	Climate change mitigation/adaptation

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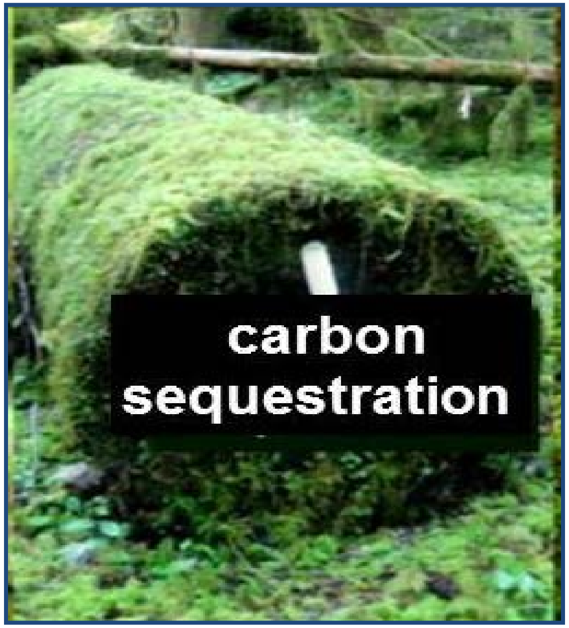
Can whole watershed restoration planning tools can help identify strategies for balancing tradeoffs among diverse objectives?



Tradeoffs?

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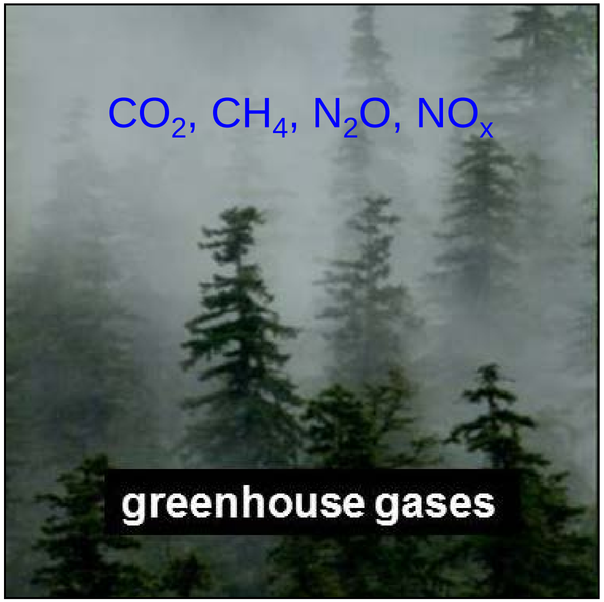
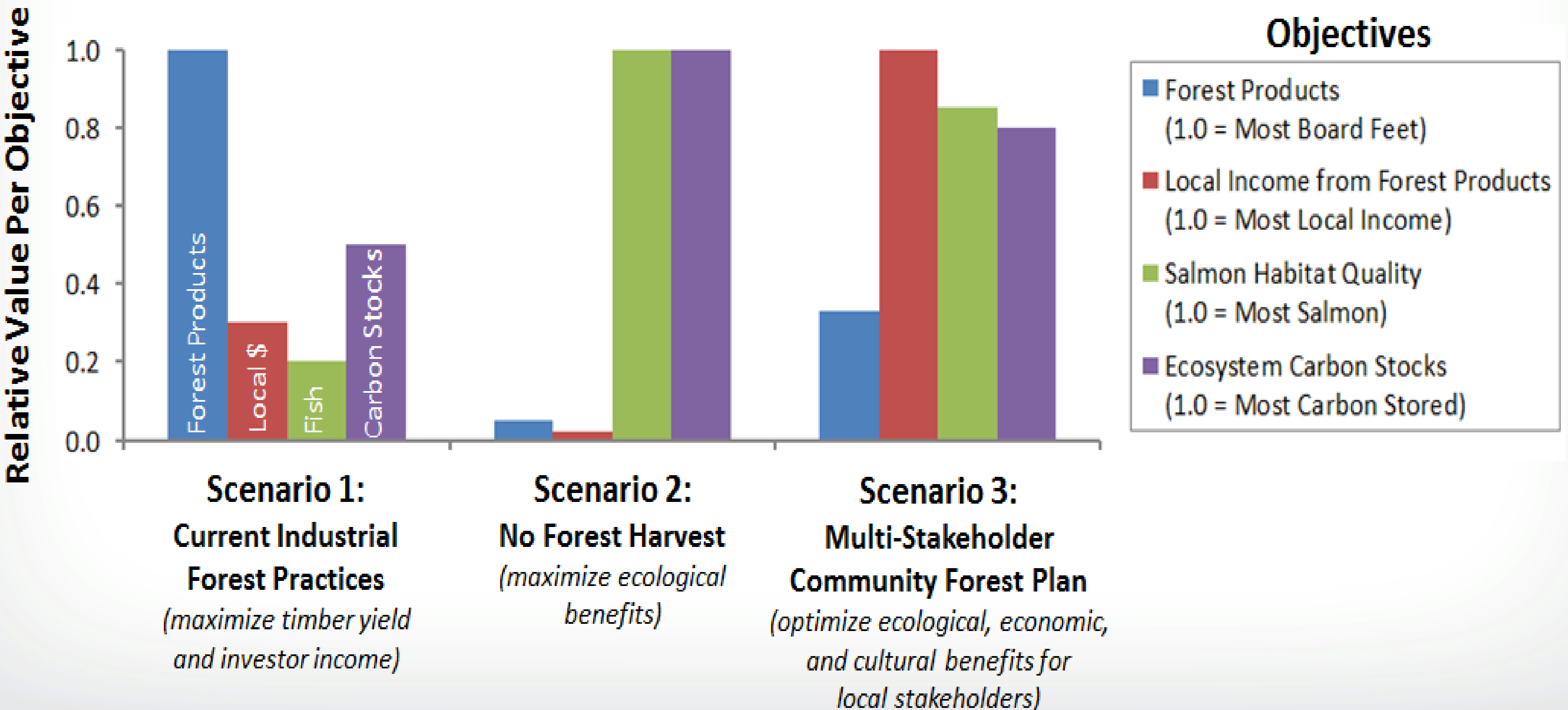


Pacific Northwest Ecosystem Services Case Study

Trade-offs for Alternative Forest Management Scenarios

Hypothetical Example



Linking Multiple Models for Salmon Recovery Planning

VELMA: Streamflow & Sediment*

VELMA: Large Woody Debris

Penumbra: Stream Temperature

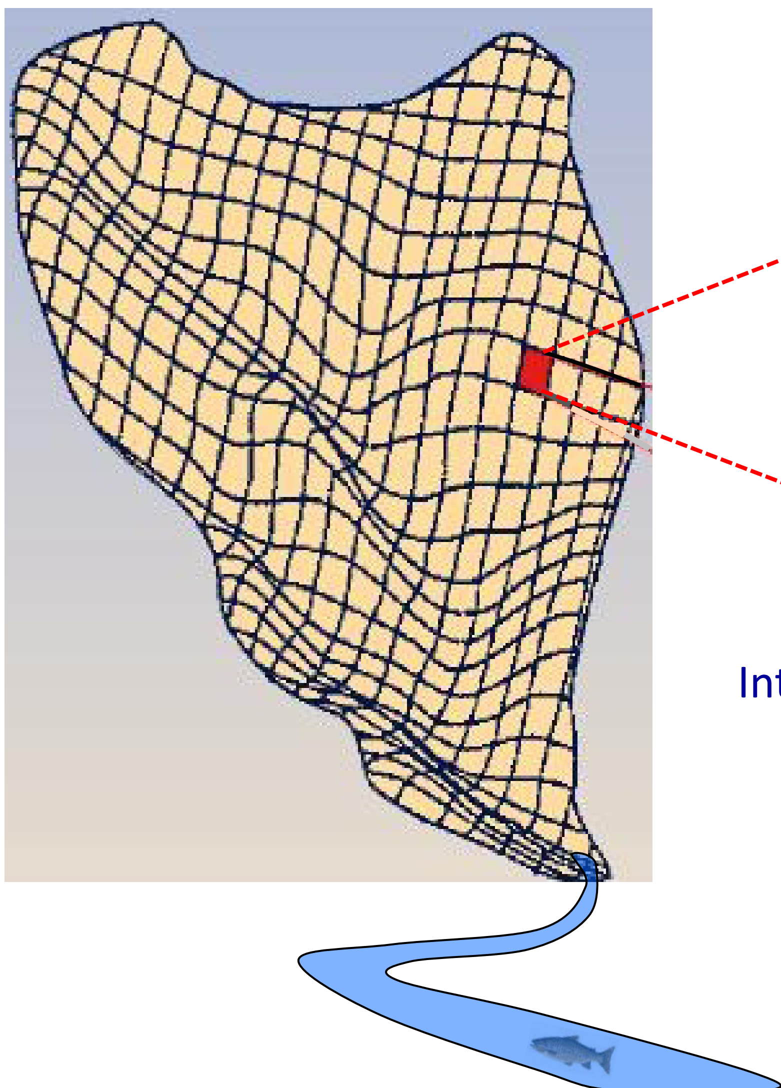
EDT: Fish Habitat

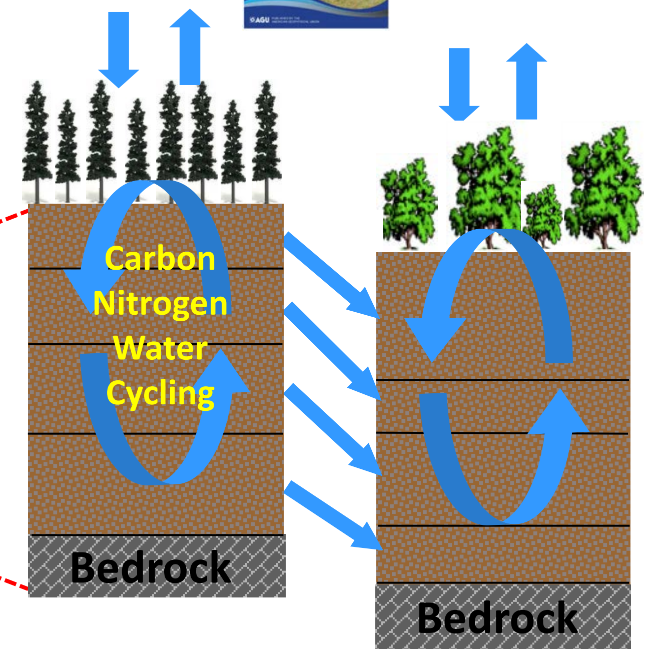
*Sediment model in development

VELMA Ecohydrological Model

Abdelnour, Stieglitz, Pan & McKane, 2011

Abdelnour, McKane, Stieglitz & Pan, 2013





Interaction of hydrological & biogeochemical processes:

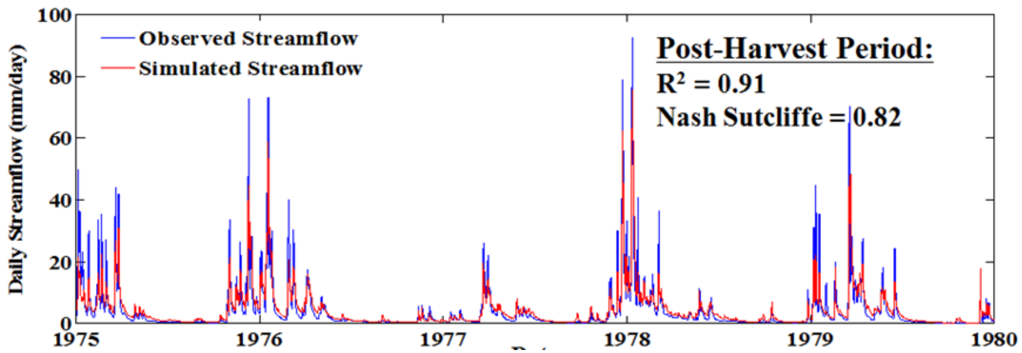
- ***Hydrological:*** *streamflow, vertical & lateral flow, ET…*
- ***Biogeochemical:*** *plant-soil carbon & nutrient dynamics, transport of dissolved nitrogen, carbon, mercury and other contaminants*
- ***Drivers of change:*** *climate (temperature, rain, snow), fire, harvest, fertilization, development… <u>forest age</u>*

VELMA Validation

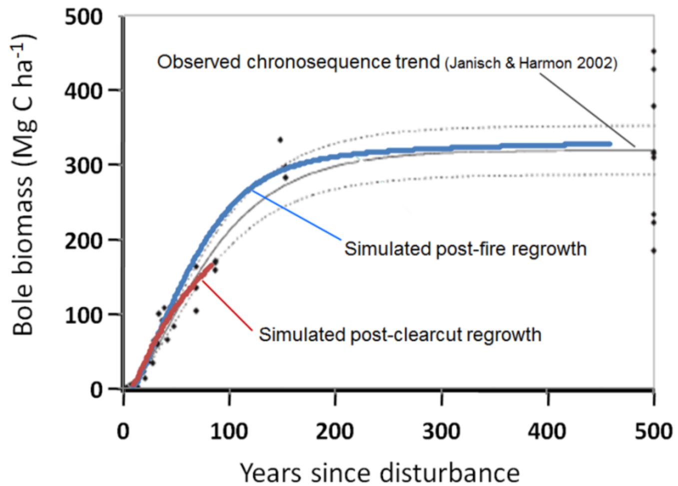
HJ Andrews Experimental Forest, Oregon Cascades

Abdelnour et al. 2011 and 2013, *Water Resources Research*

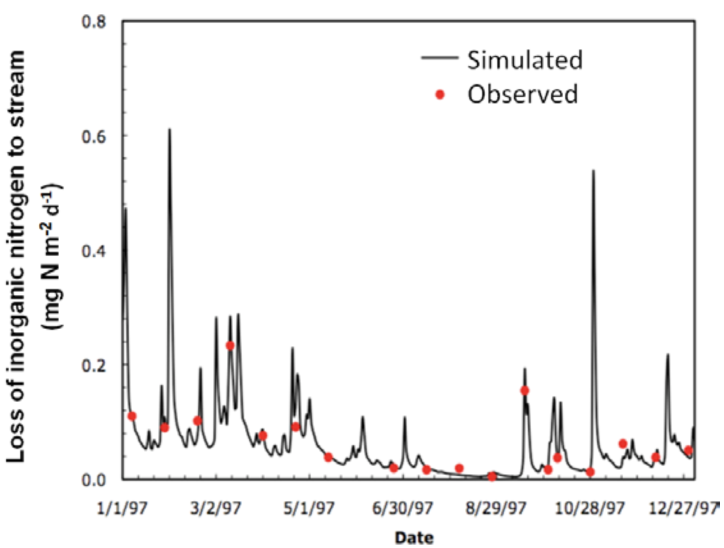
Streamflow Validation



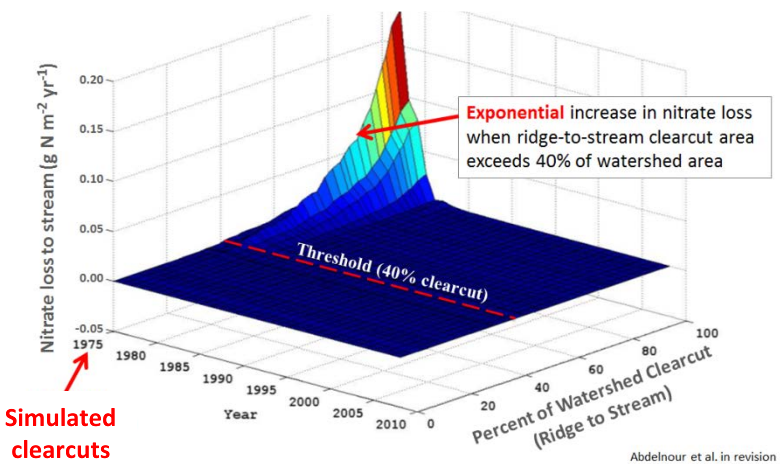
Forest Growth Validation



Stream Chemistry Validation



Simulated stream nitrogen loads vs. riparian buffer cover & time since harvest

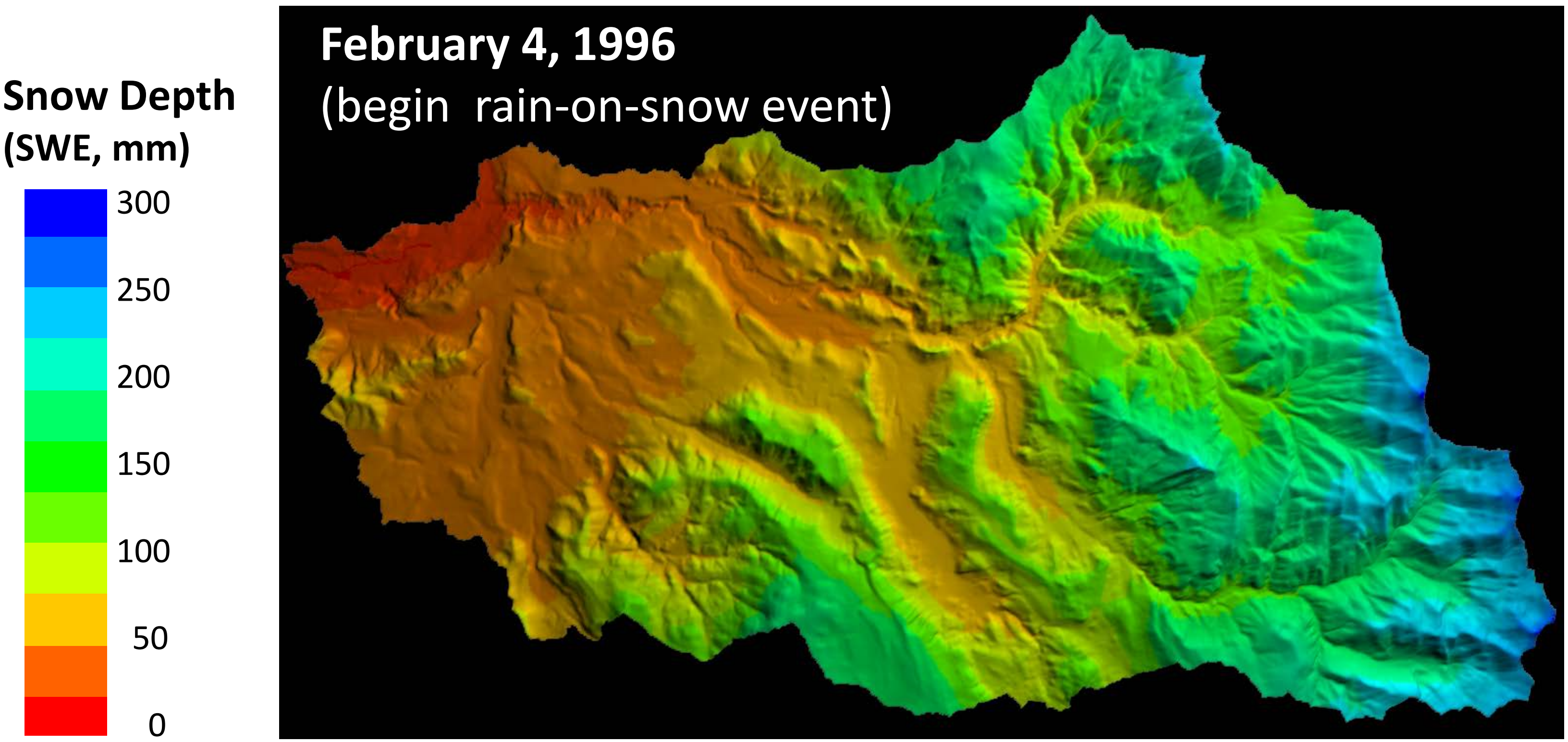


Climate Data

Daily climate grids:
- ✓ **mean temperature**
- ✓ **total precipitation**

(30-m grid → ¼ million grid cells in 209 km^2 Mashel watershed)

VELMA models daily snow dynamics from temp. & precip. inputs



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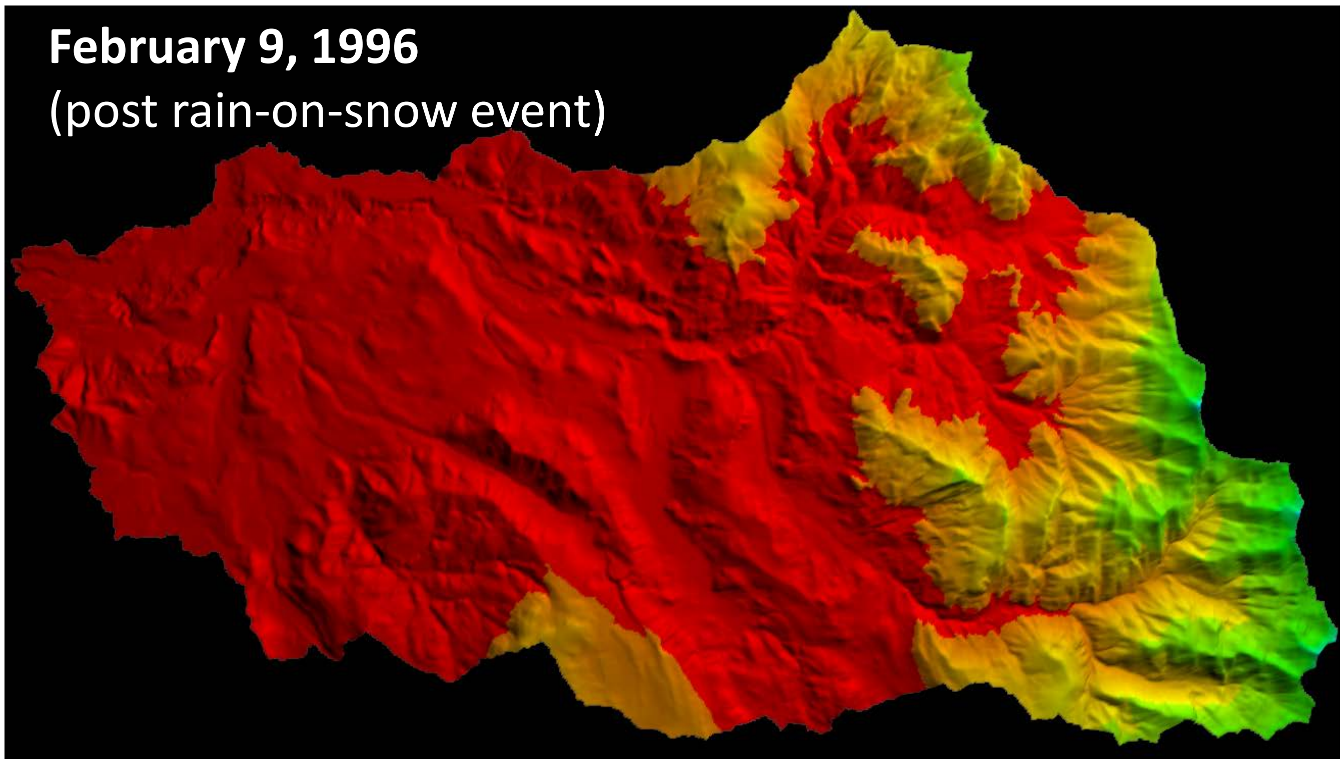
PRISM CLIMATE GROUP http://www.prism.oregonstate.edu

DAYMET DAILY SURFACE WEATHER AND CLIMATOLOGICAL SUMMARIES ORNL DAAC NASA https://daymet.ornl.gov

VELMA models daily snow dynamics from temp. & precip. inputs

Snow Depth (SWE, mm)

300
250
200
150
100
50
0



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Land Use Data

Robert Kennedy, Ph.D.
College of Earth, Ocean and Atmospheric Sciences
Oregon State University

Forest harvest in Washington's Cascades Mountains

Forests in the Pacific Northwest are harvested for timber production. In this false color composite, dark green colors correspond to older forest, pink to recent clearcuts. As areas recovery vegetation (thought not always forests), red and pink transitions to light green and eventually to darker green.

http://landtrendr.forestry.oregonstate.edu/content/how-landtrendr-works

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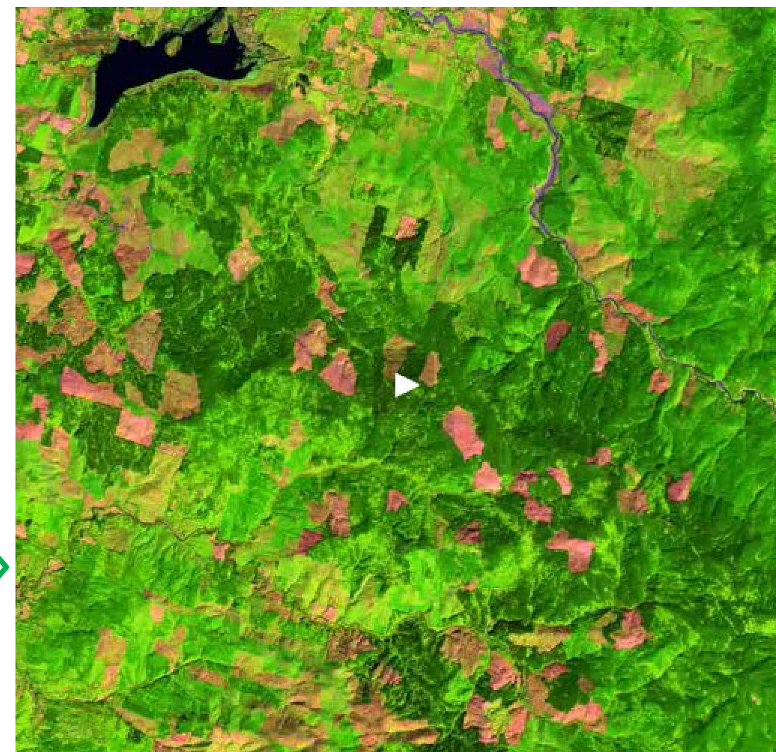

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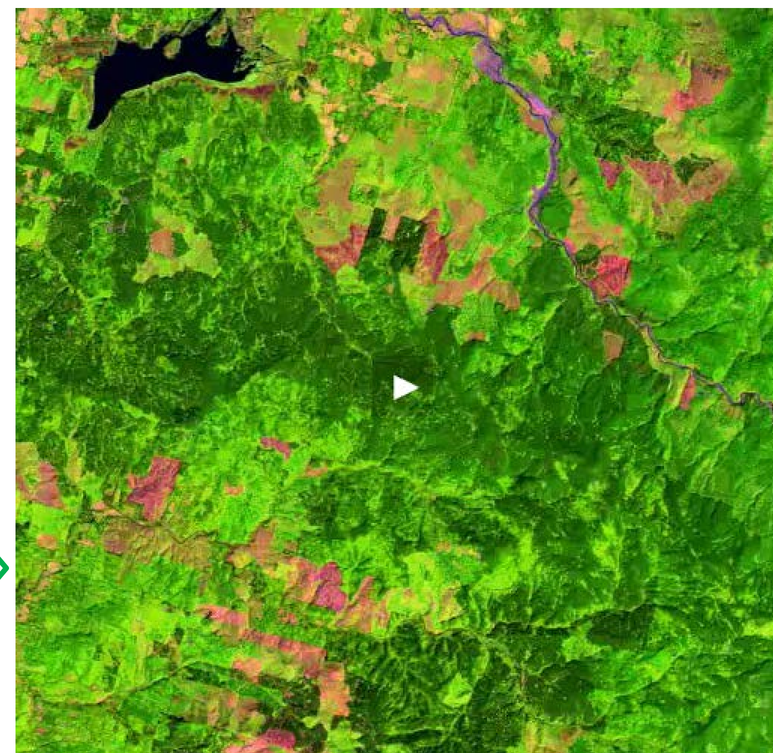

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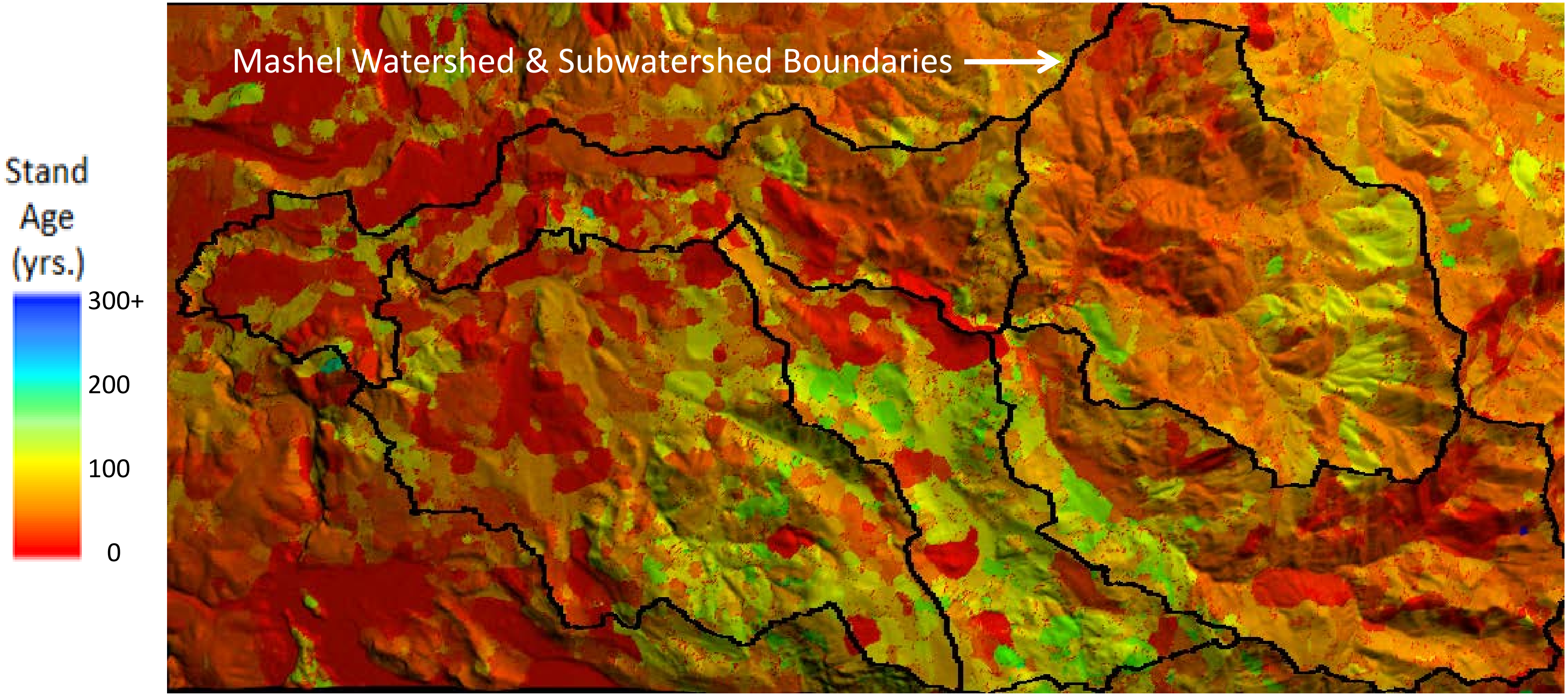
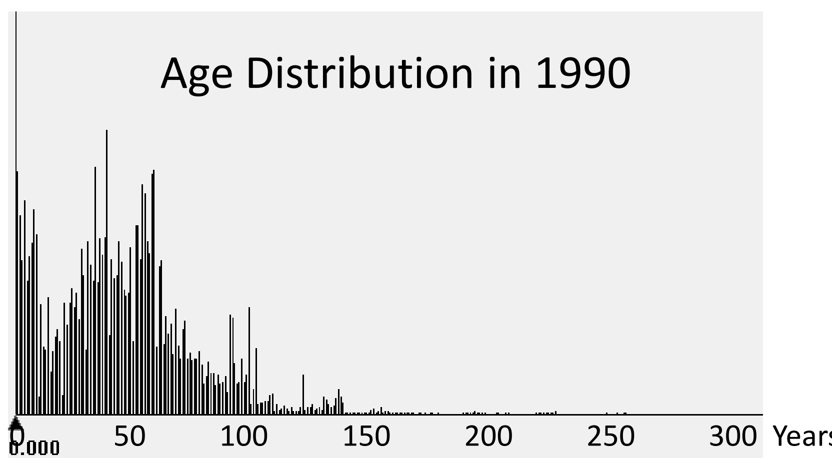
Mashel Forest Age Map in 1990

LandTrendr data, Kennedy et al.



VISTAS visualization



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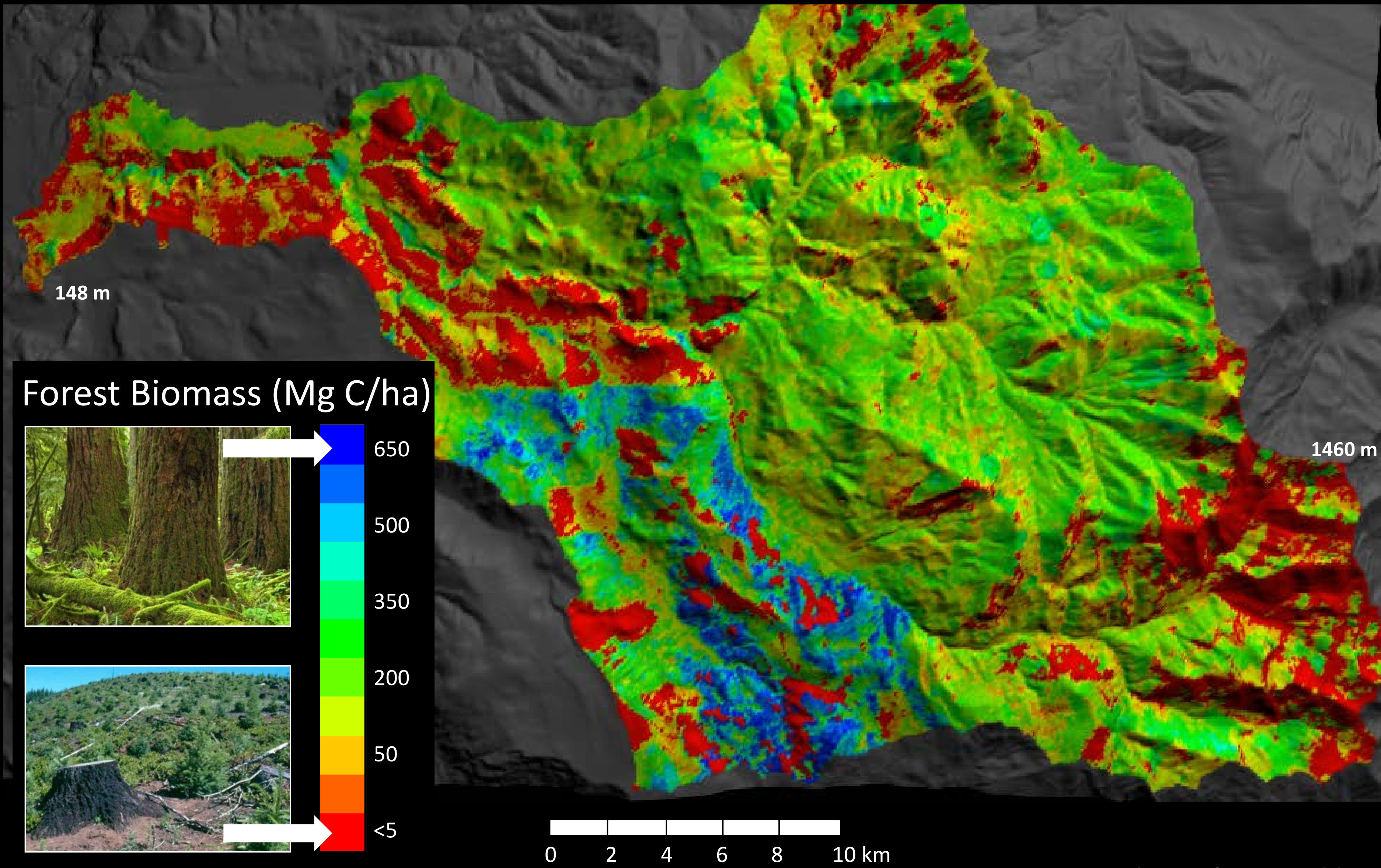
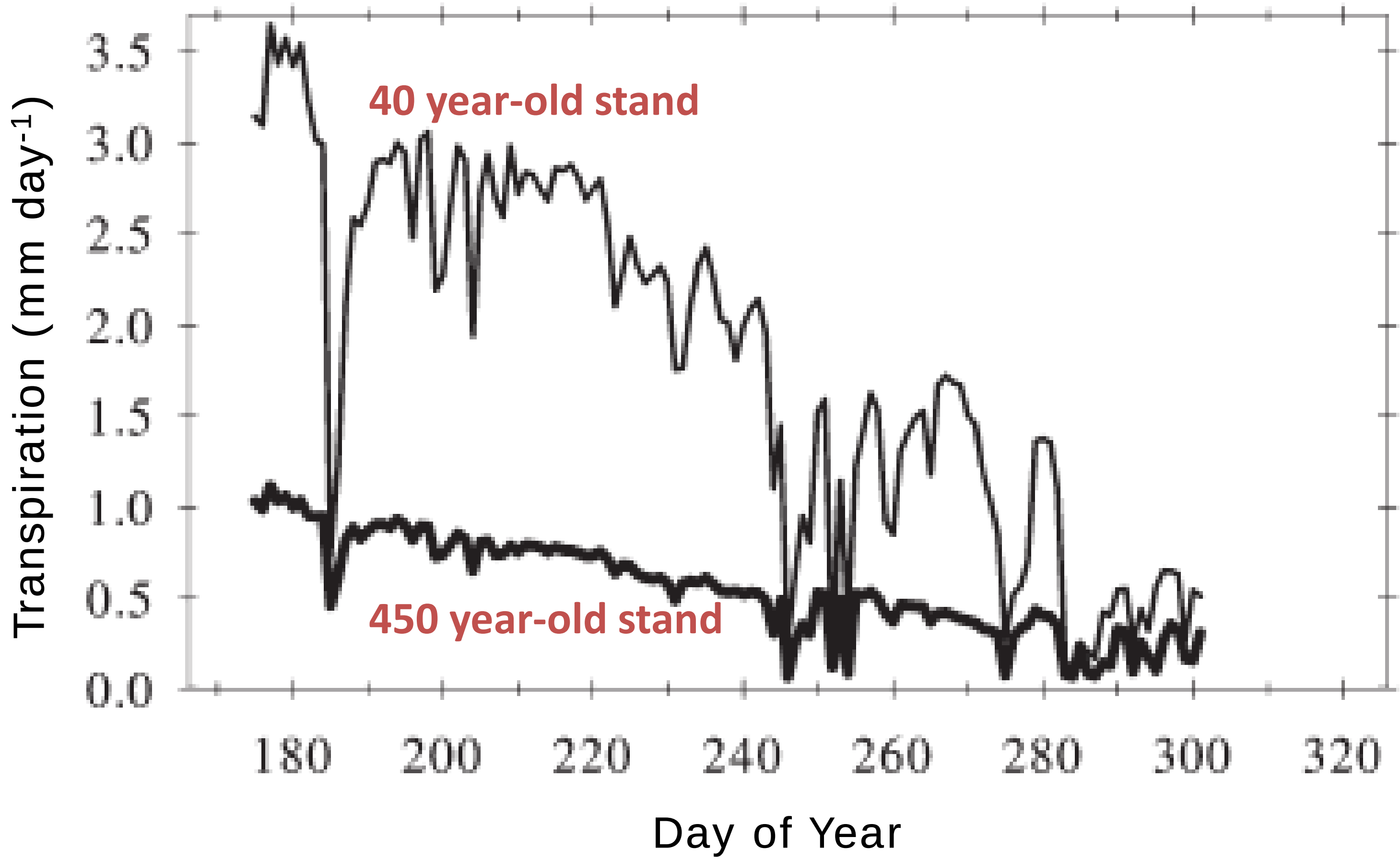
Forest Biomass
Mashel Basin – Year 2000



VISTAS 3D visualization of VELMA model output

Young vigorously growing forests have been shown to transpire over three times more water than old forests

Figure 3 from Moore et al. 2004, Tree Physiology 24, 481-491
(Research conducted at HJ Andrews Experimental Forest, OR)



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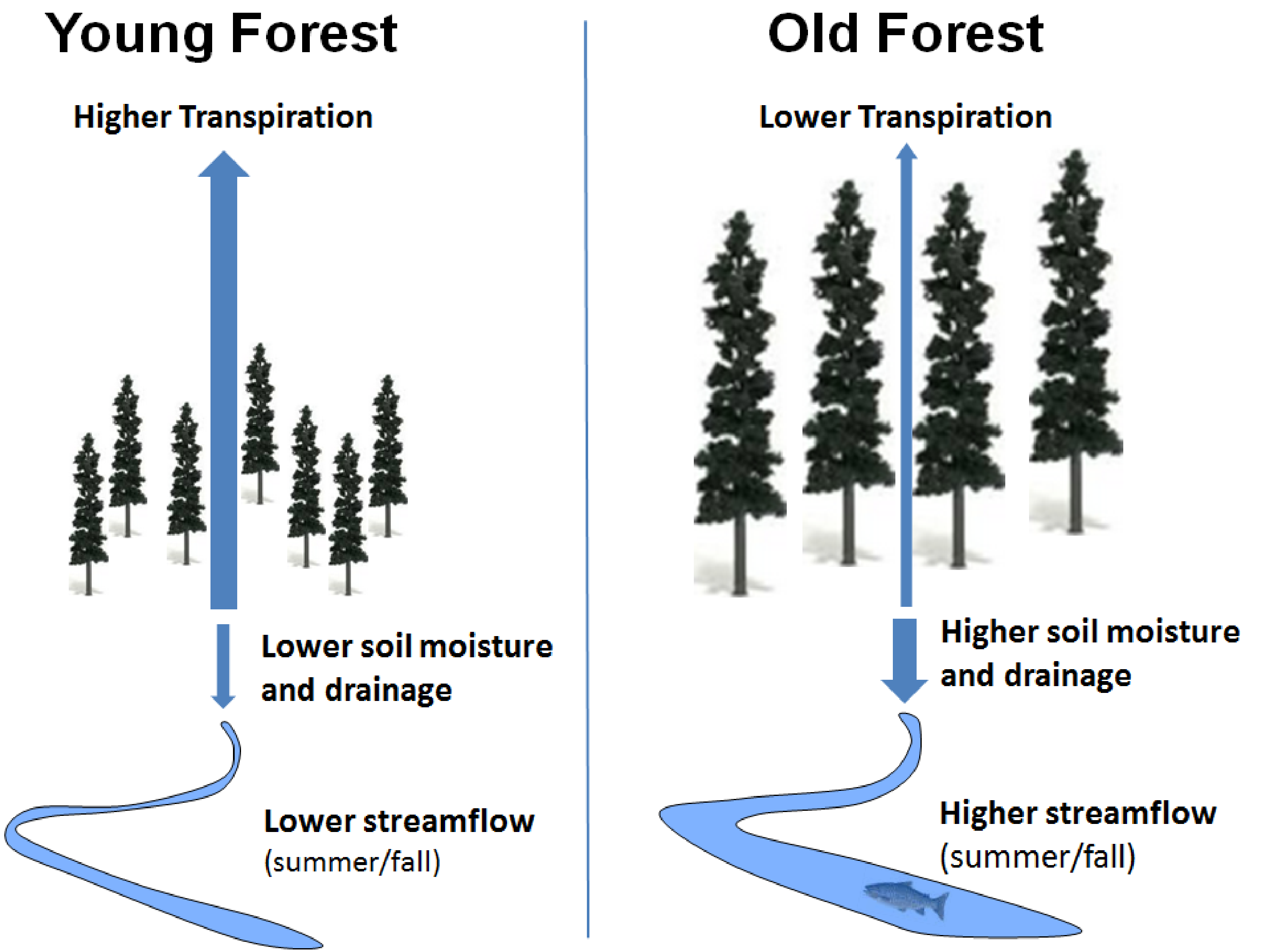
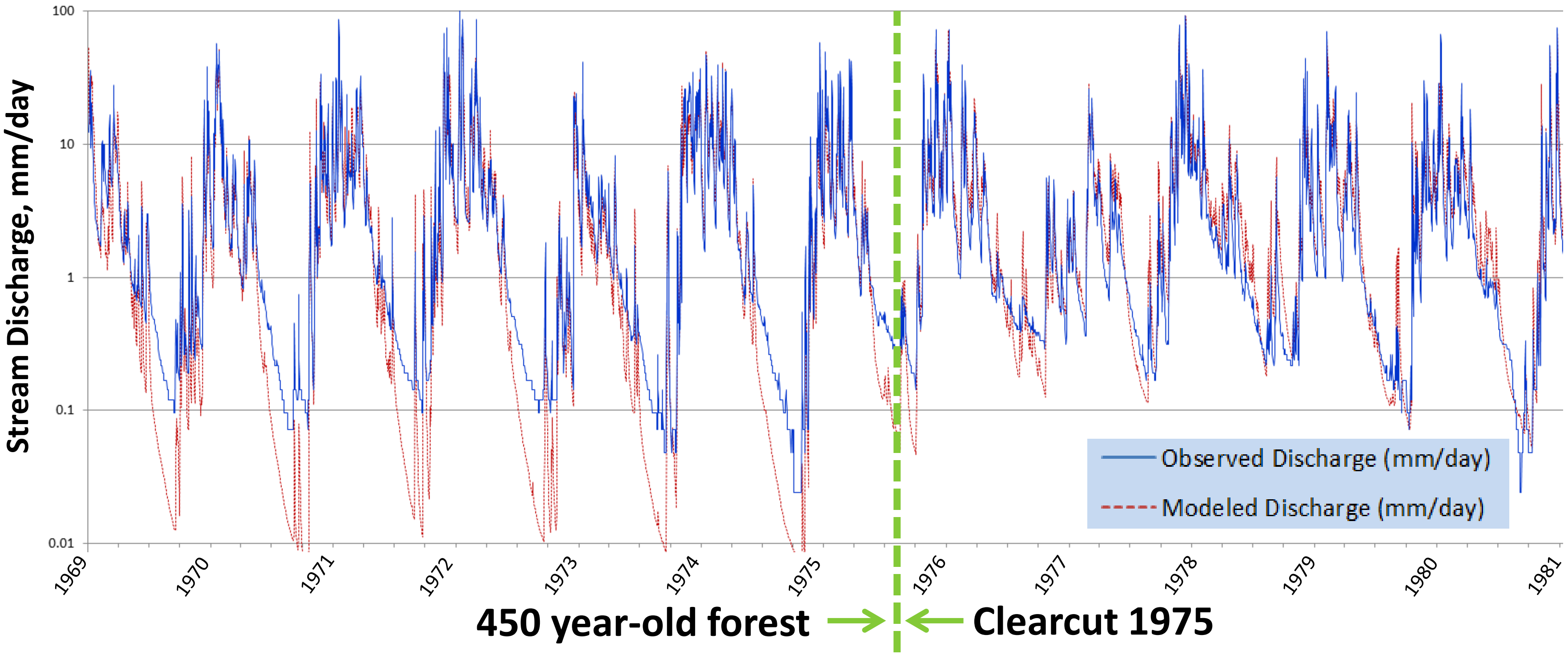


Jones & Post (2004 *Water Resources Research* 40) confirm these trends and also note exceptions

HJ Andrews Watershed 10, Oregon

- 0.1 km^2 catchment
- 450 year-old conifer forest
- Clearcut in 1975
- Stream discharge data 1969 – present

Forest age effect on stream discharge turned OFF



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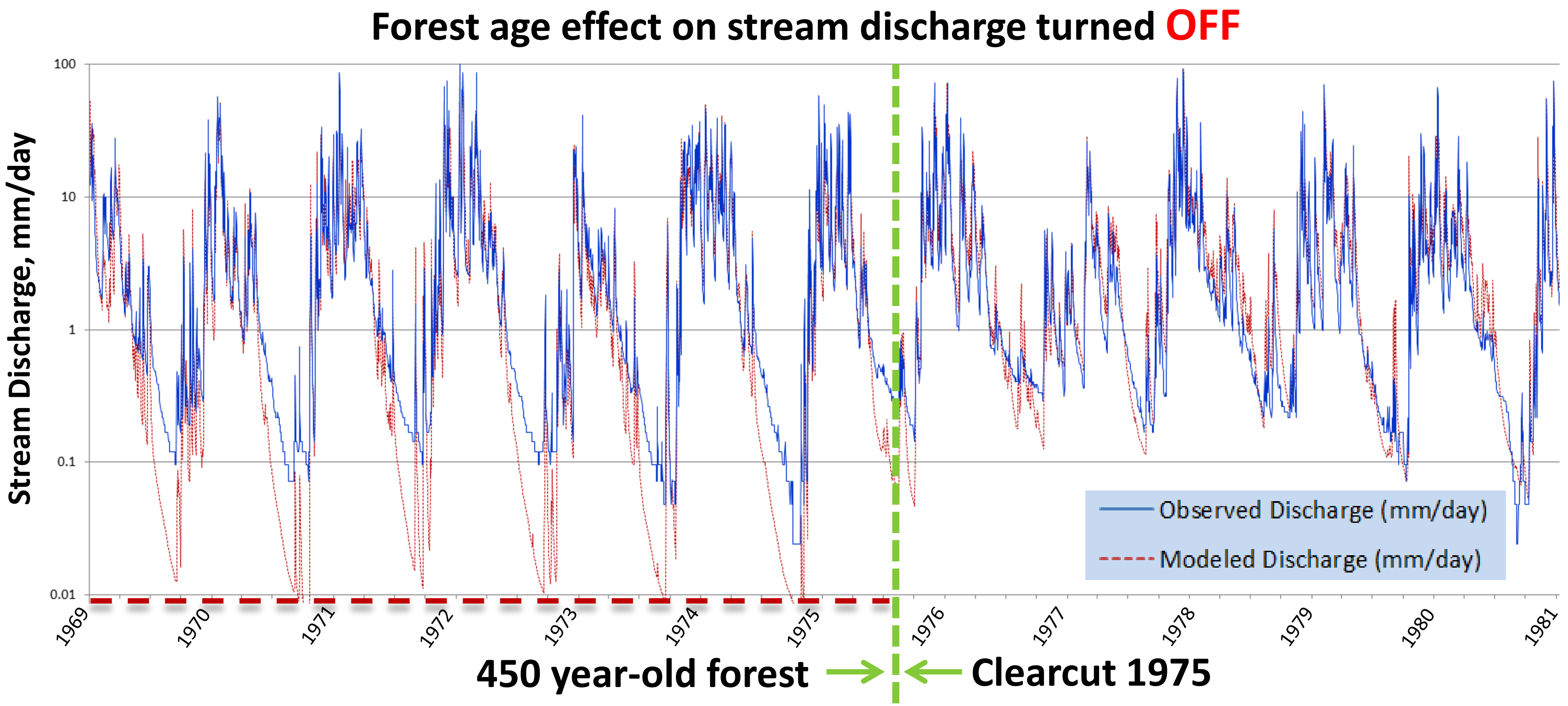

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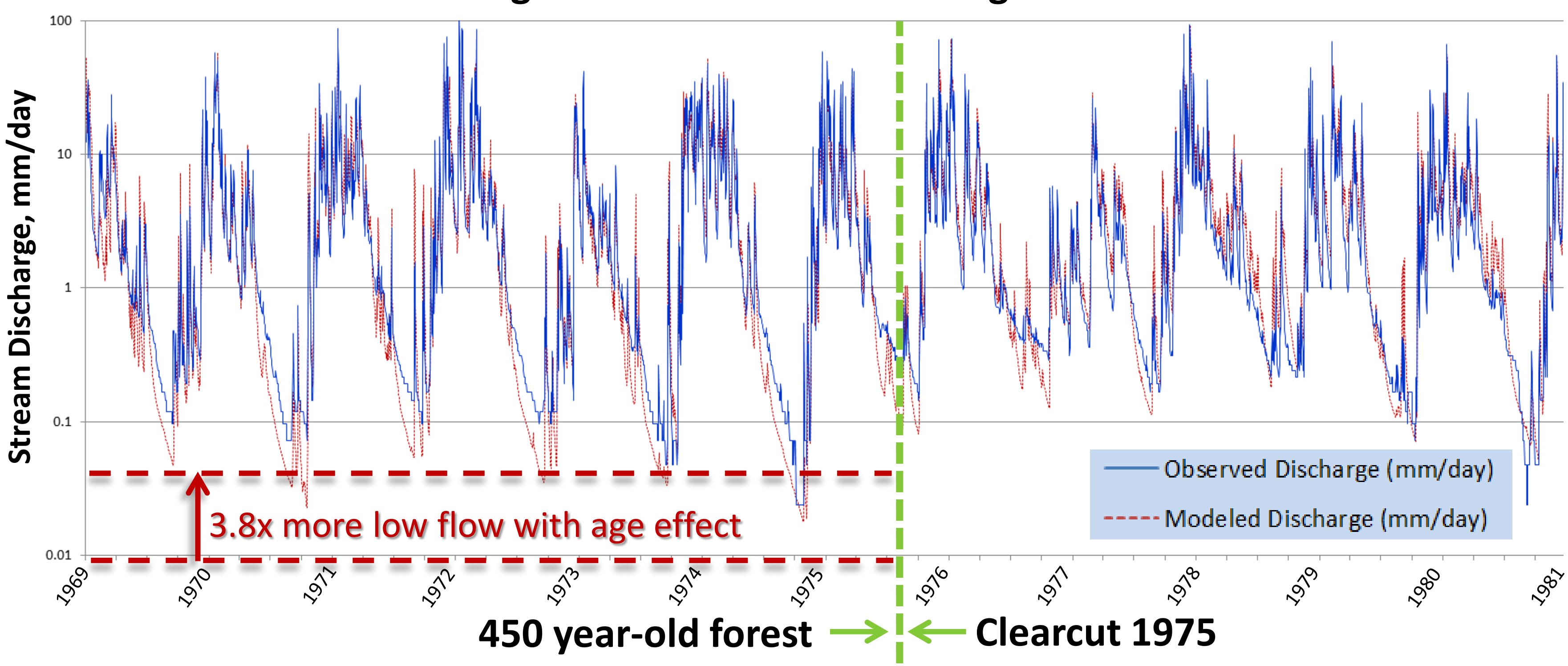
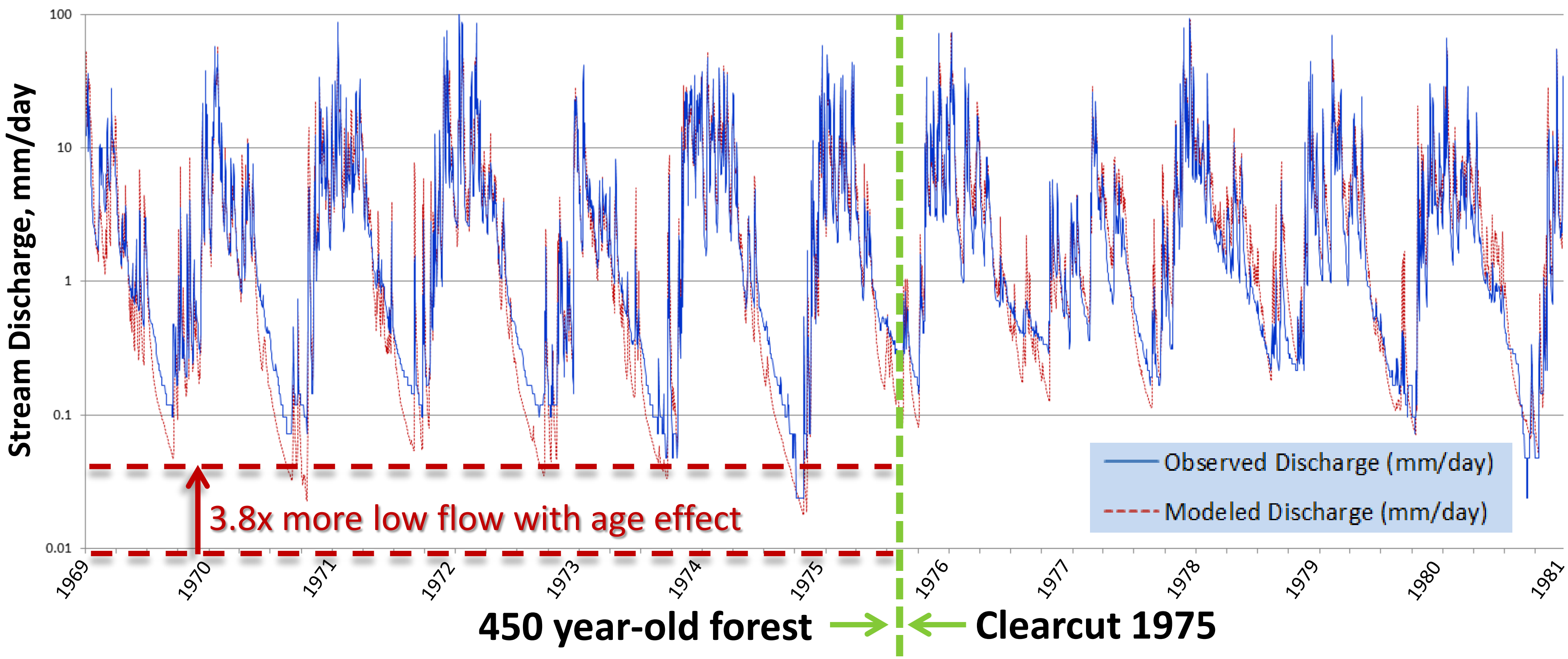


HJ Andrews Watershed 10, Oregon

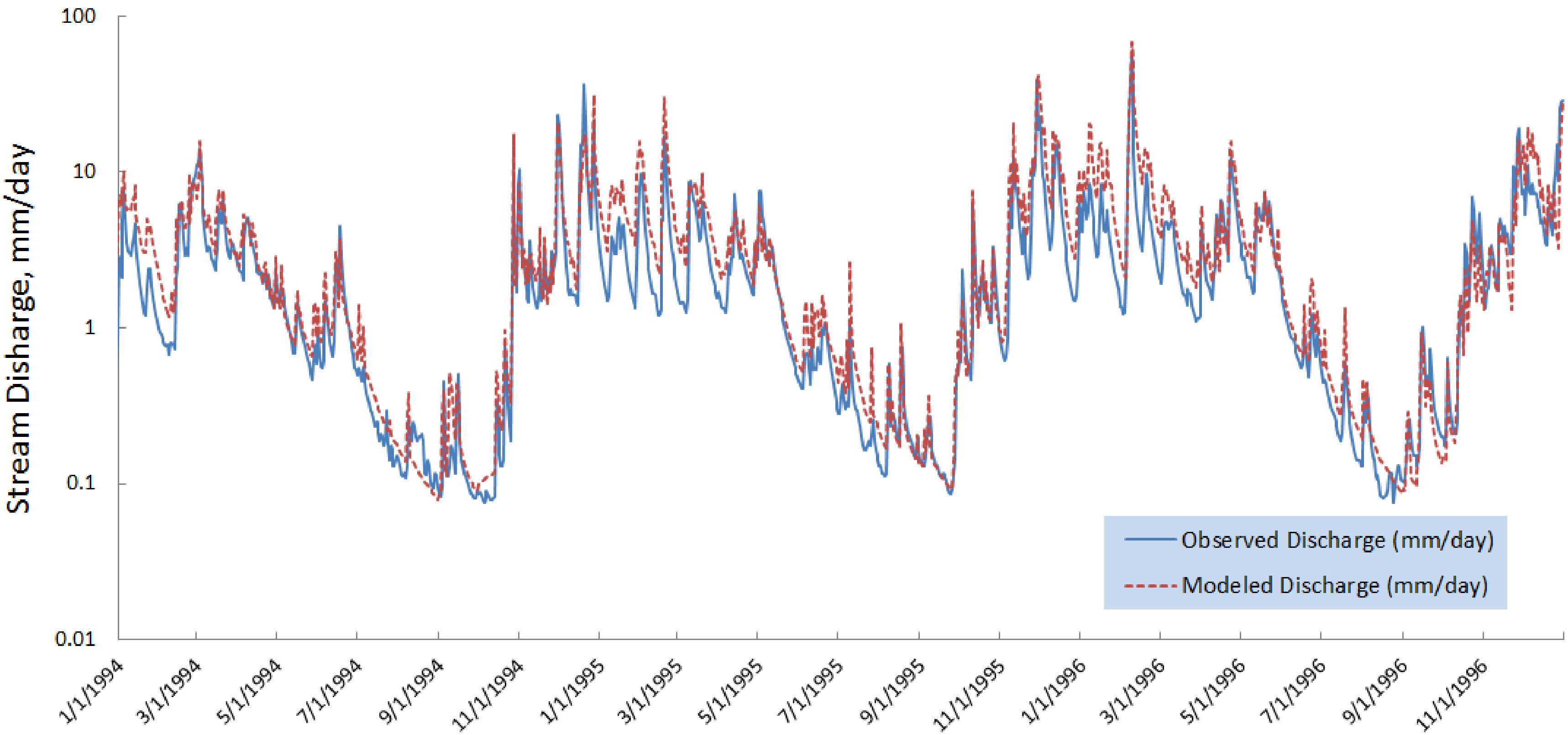
Preliminary conclusion:
Effect of forest age on summer low flow scales well from
tree → stand → catchment
(Moore et al. 2004) *(this study)*

Forest age effect on stream discharge turned ON



Mashel River Watershed, WA

- 209 km^2
- Mixture of forest stand ages, most < 60 yr
- Stream discharge data 1992 - present



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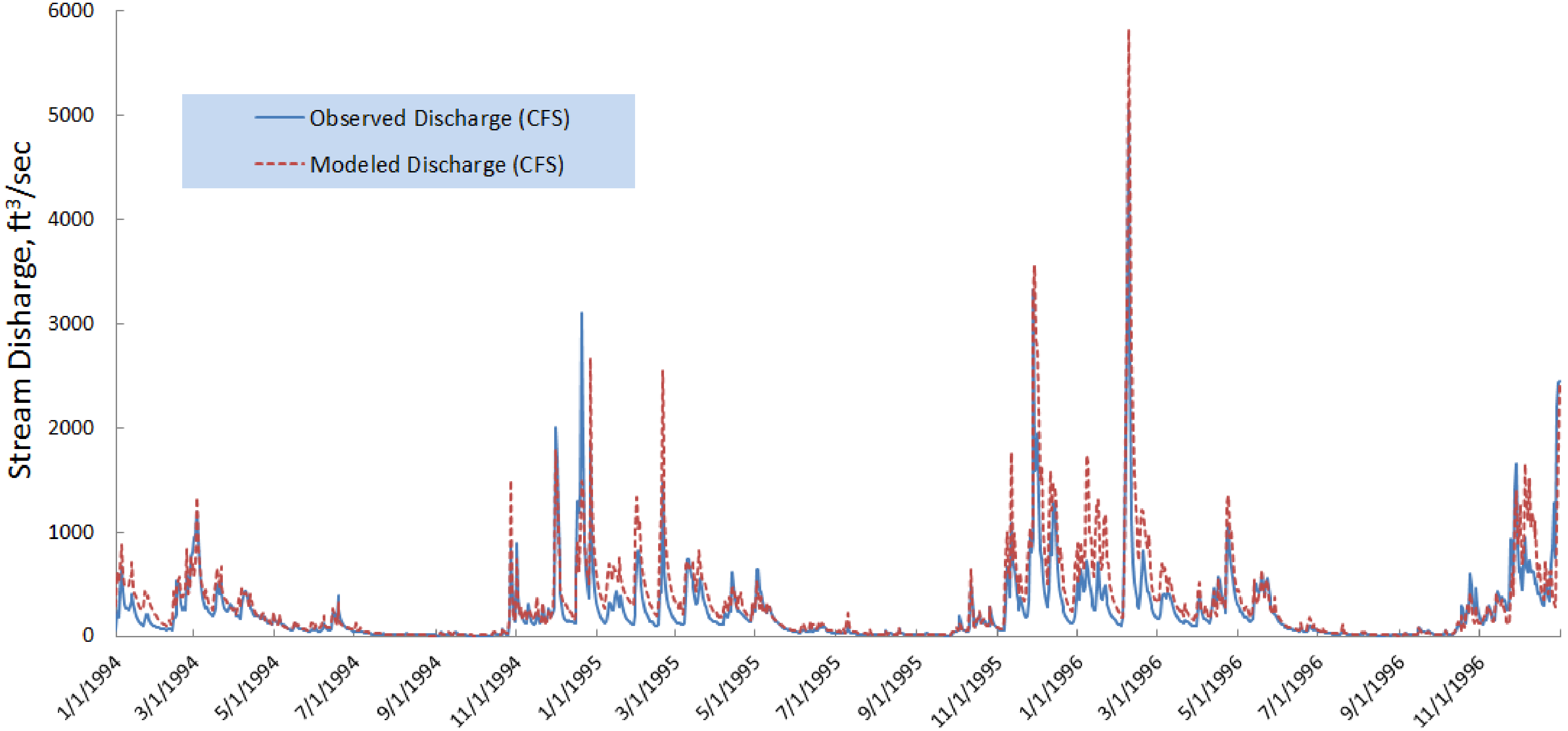

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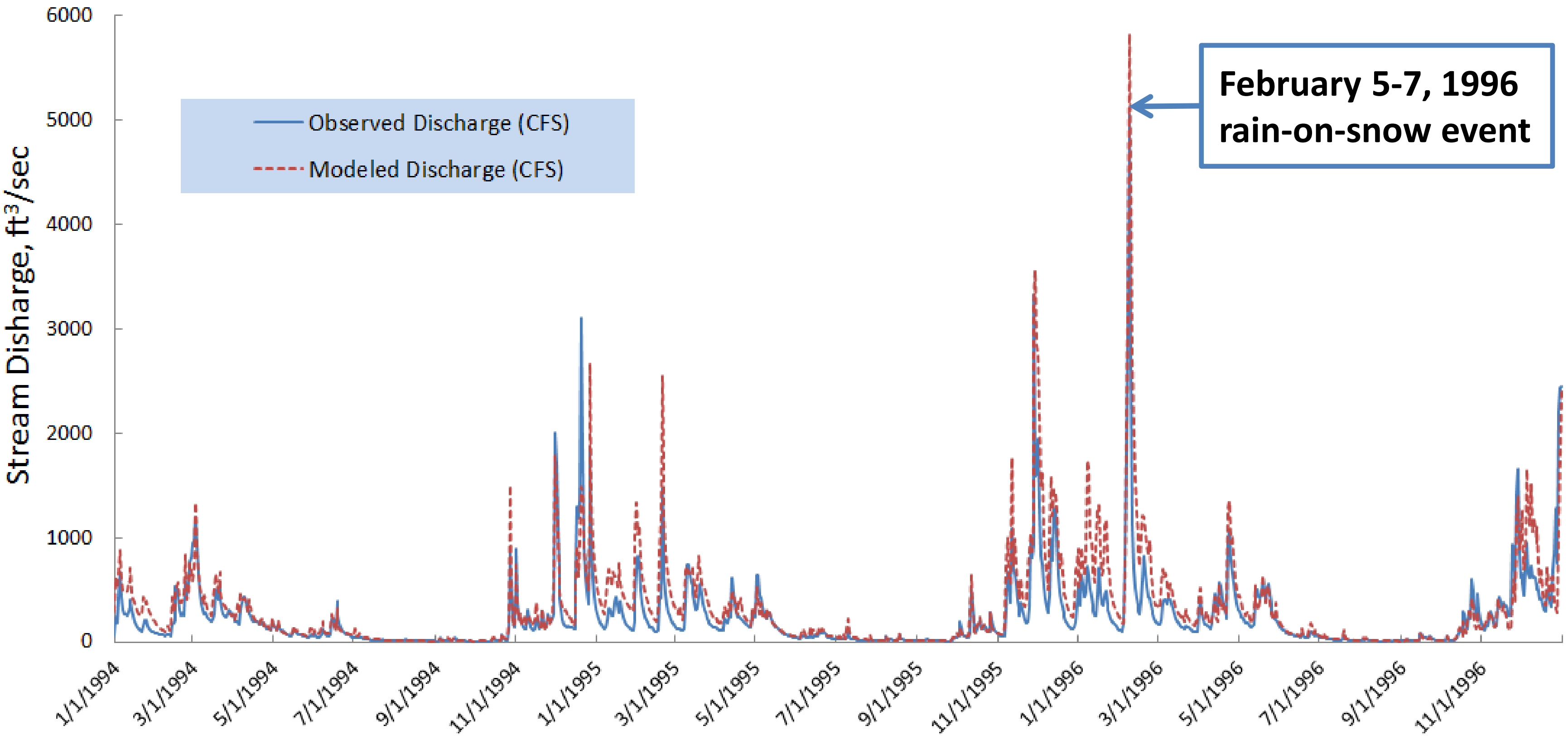

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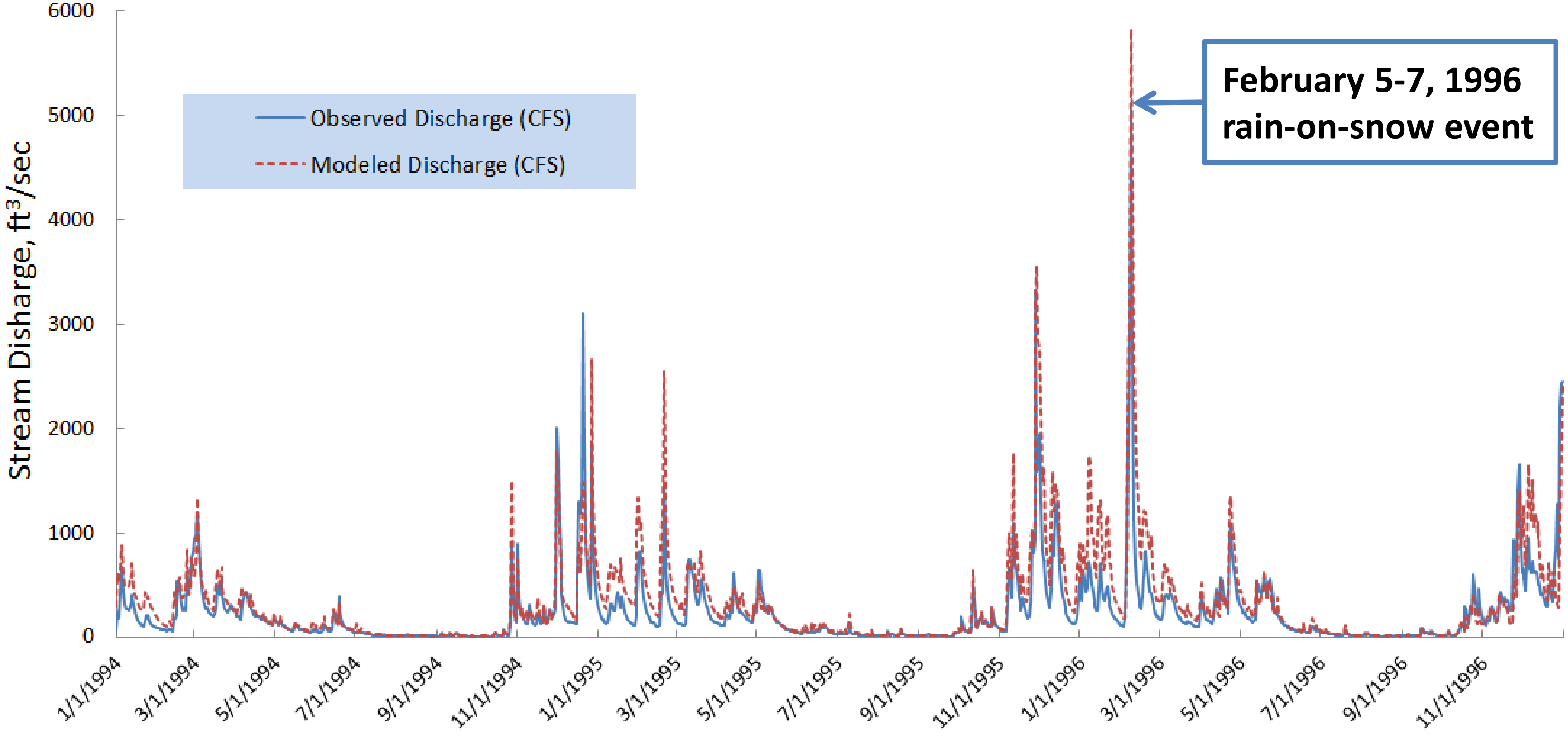
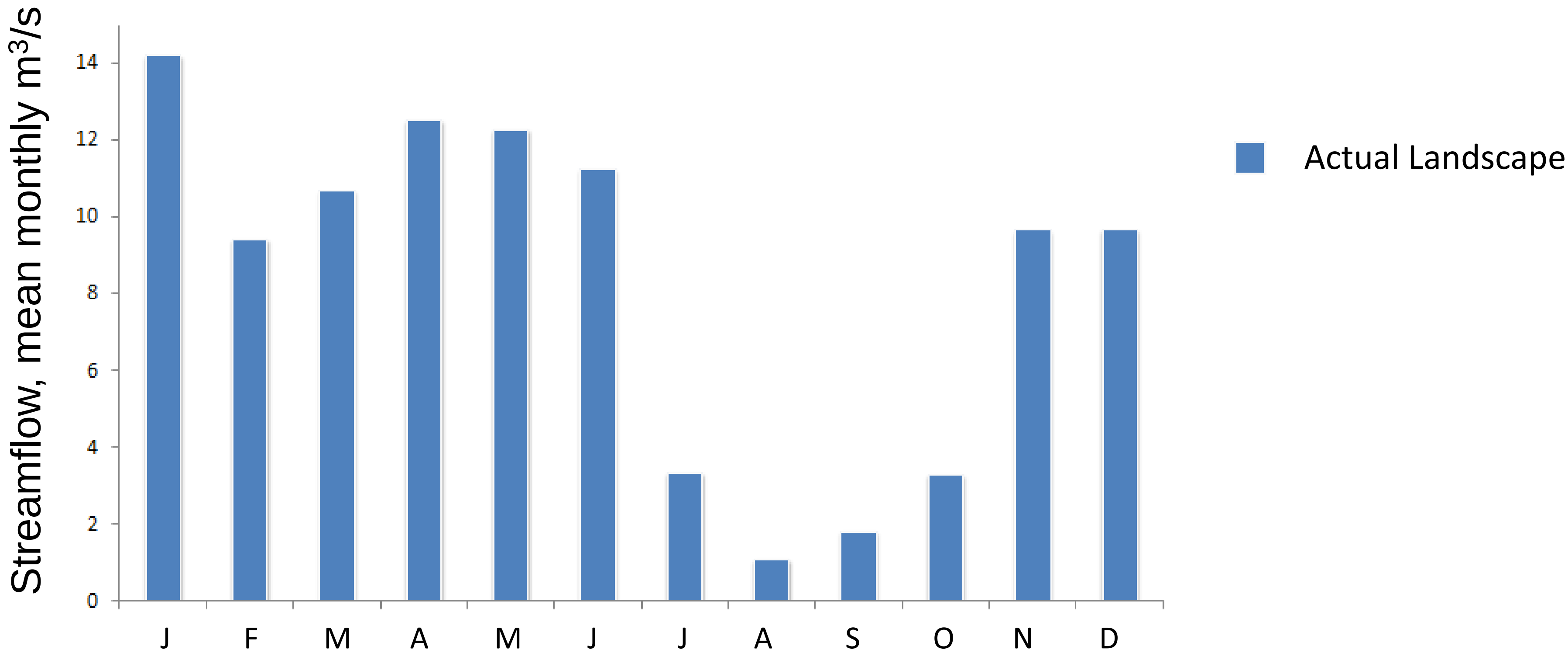
Mashel River Watershed, WA

VELMA parameters including age effect for HJ Andrews site scale well to the 20,000x larger, mixed-age Mashel Watershed



Can longer forest harvest intervals increase summer streamflow for salmon recovery?

VELMA Results, 2006 – 2014:



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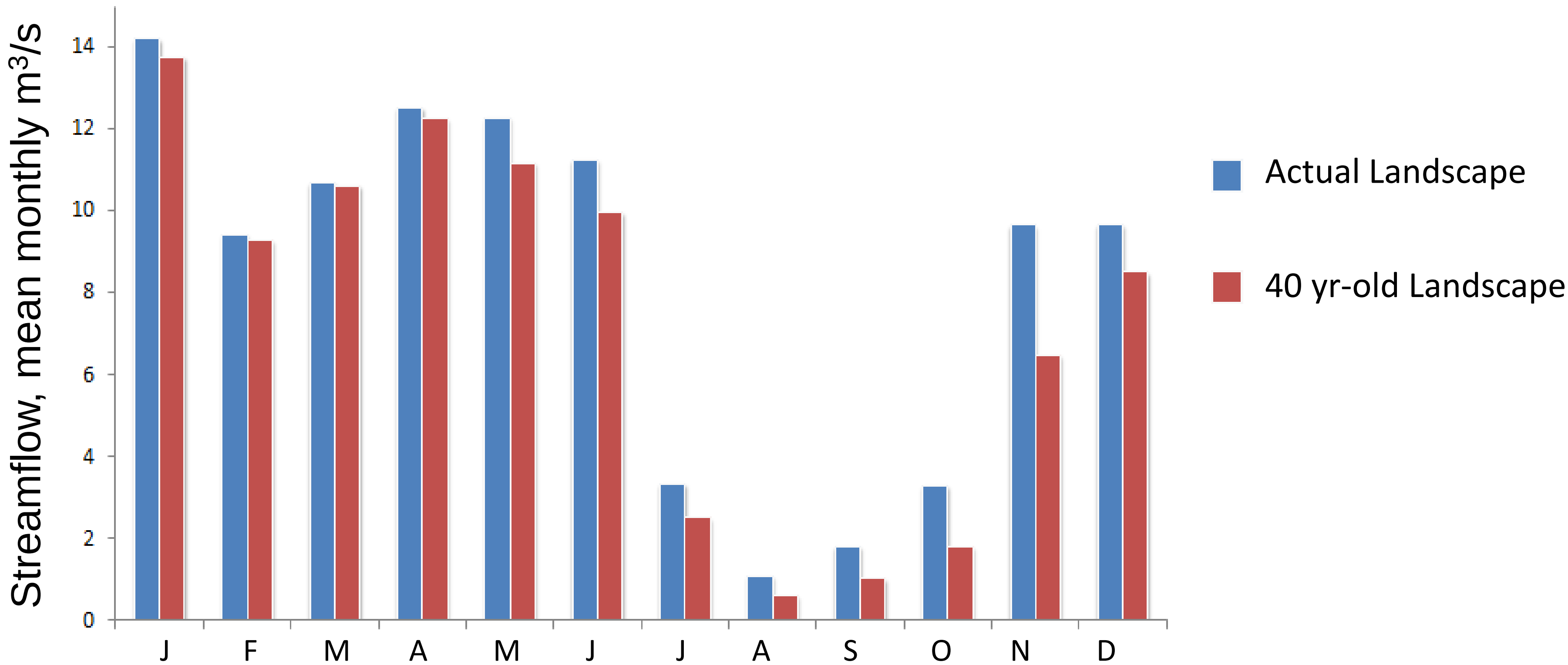

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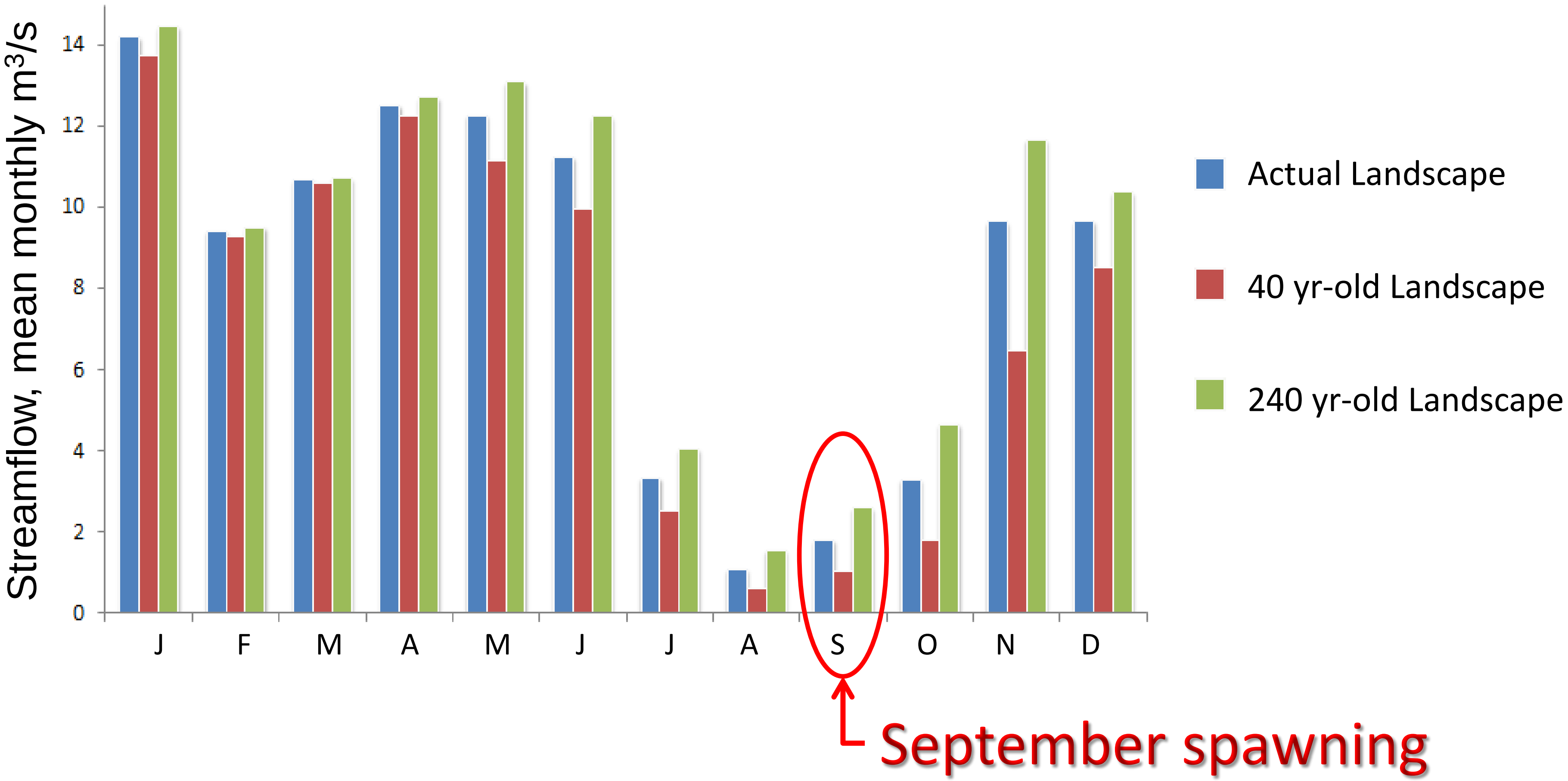
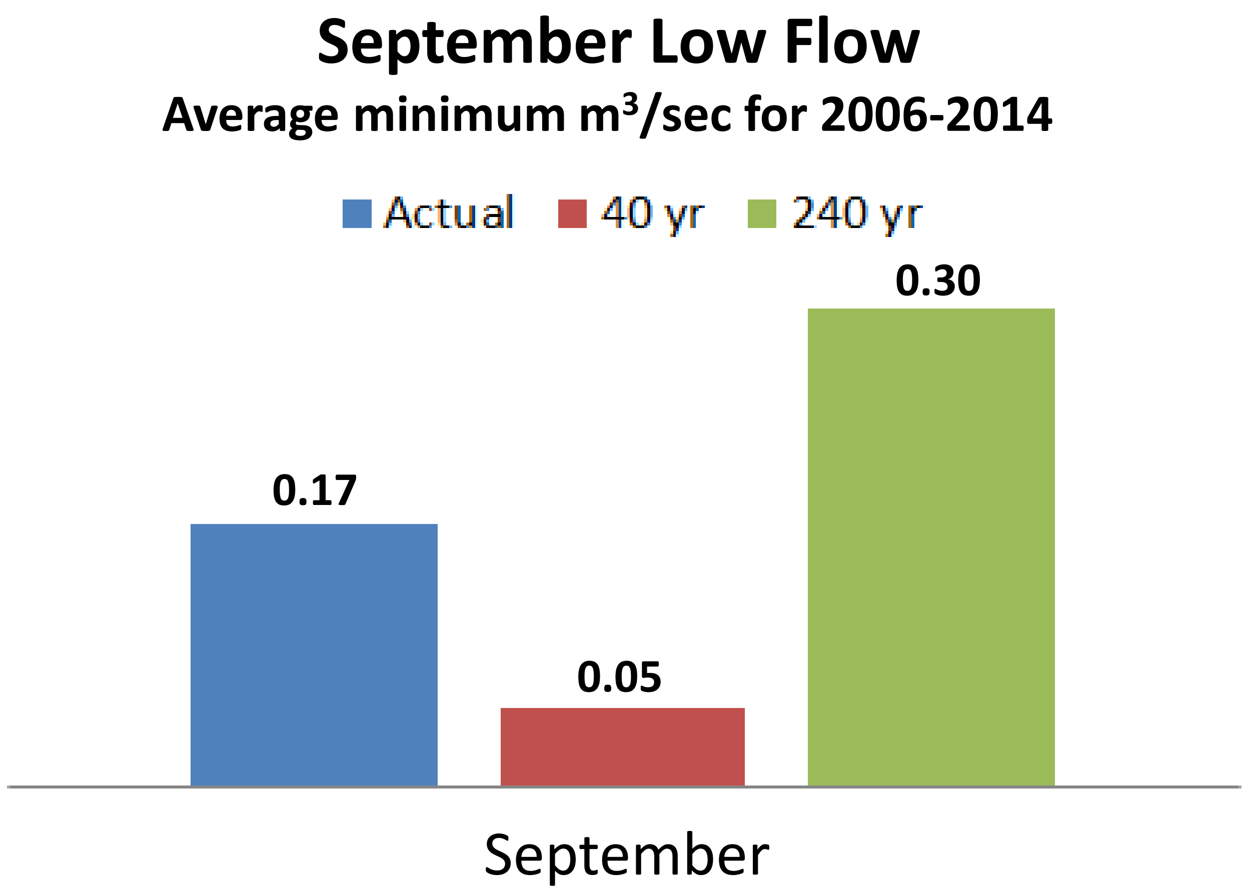


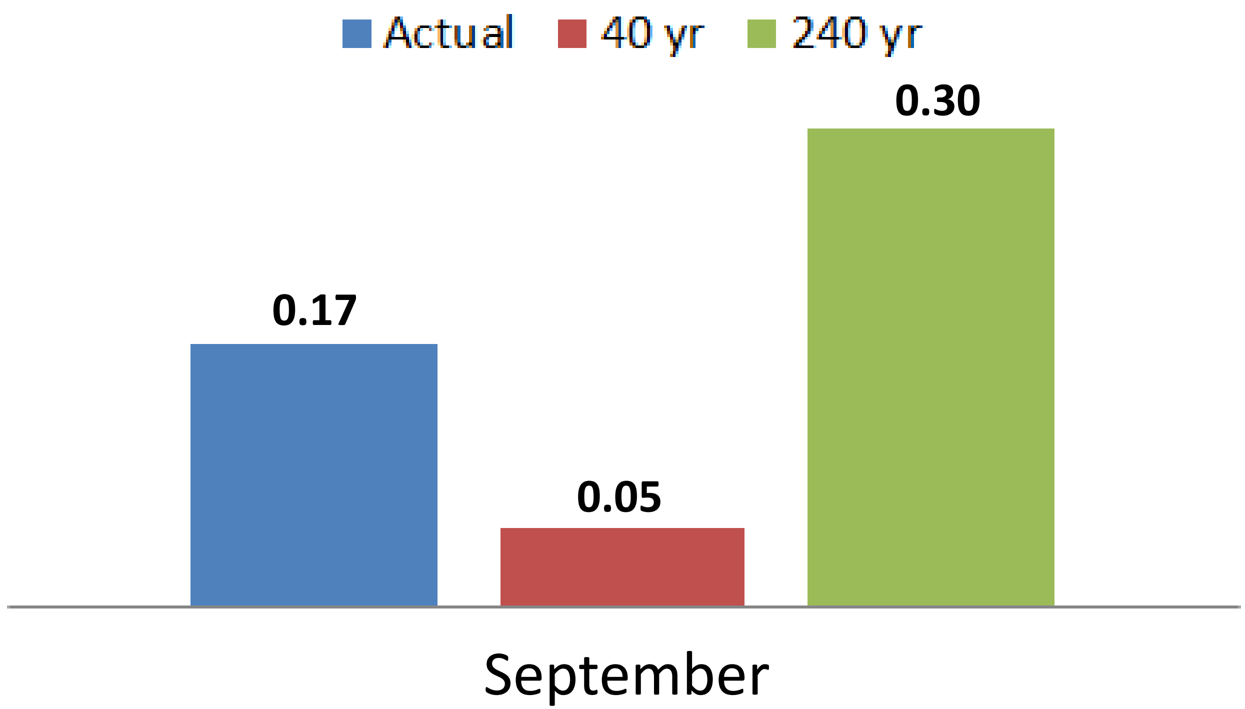
Can longer forest harvest intervals increase summer streamflow for salmon recovery?

Preliminary VELMA Results, 2006 – 2014:



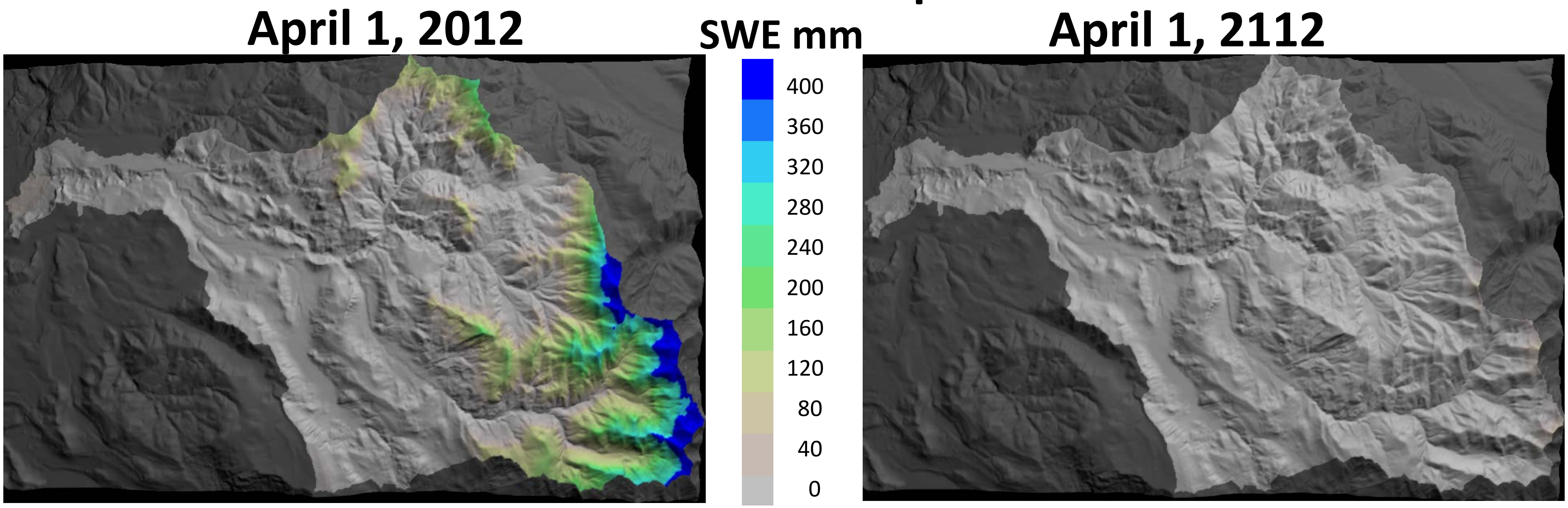
Can longer forest harvest intervals increase summer streamflow for salmon recovery?

Yes, preliminary results indicate that establishment of older (>80 yr?) forest landscapes could increase late summer & early fall streamflow by several times compared to the present-day Mashel watershed



How will climate change affect snowpack, ET & flow?

Simulated Snowpack

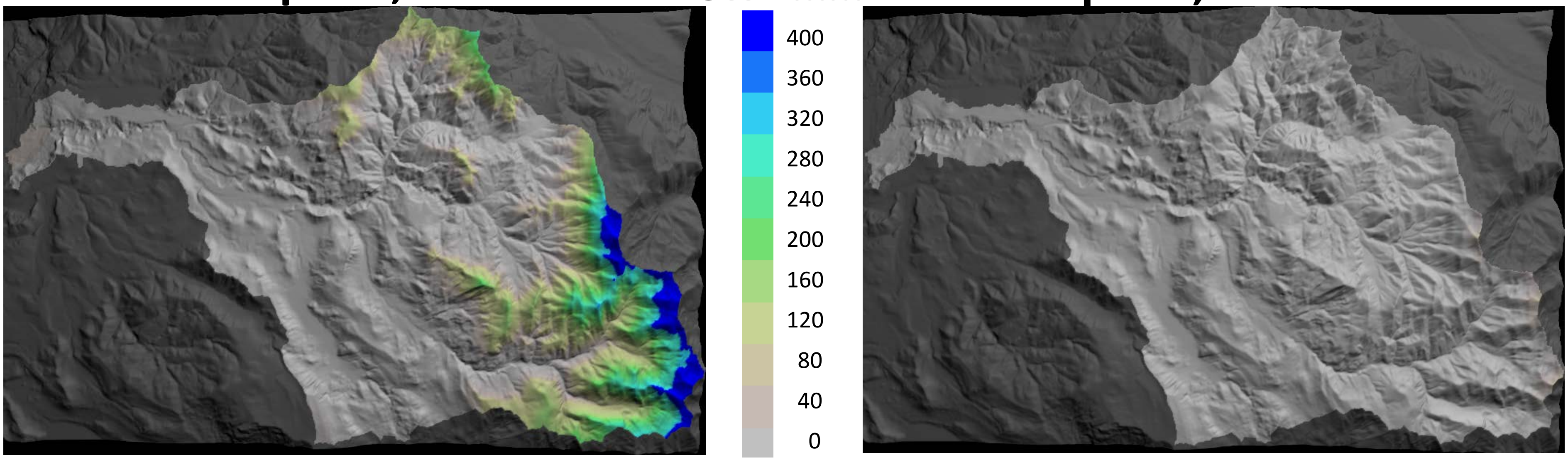


Simulation	ET/Precipitation (Annual Ratio)	Streamflow (Sept min m^3/sec)
Actual Forest, Present climate	**0.40**	**0.17**
Actual Forest, +3.5 °C	**0.51**	**0.09**

How will climate change affect snowpack, ET & flow?

Simulated Snowpack

April 1, 2012 | **SWE mm** | **April 1, 2112**



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Actual Forest, Present climate	**0.40**	**0.17**
Actual Forest, +3.5 °C	**0.51**	**0.09**
240 year-old Forest, +3.5 °C	**0.43**	**0.19**

How will climate change affect snowpack, ET & flow?

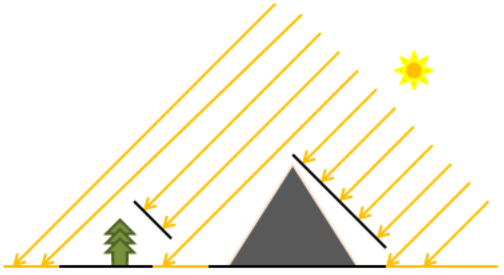
Older (>80 yr?) forest landscapes can help mitigate effects of climate change on late summer & early fall low flows.

Effects of climate change on loss of spring snowpack and summer stream temperature is under study.

Simulation	ET/Precipitation (Annual Ratio)	Streamflow (Sept min m^3/sec)
Actual Forest, Present climate	0.40	0.17
Actual Forest, +3.5 ^oC	0.51	0.09
240 year-old Forest, +3.5 ^oC	0.43	0.19

Penumbra: Stream Shade & Temperature Model

Developer: Jonathan Halama

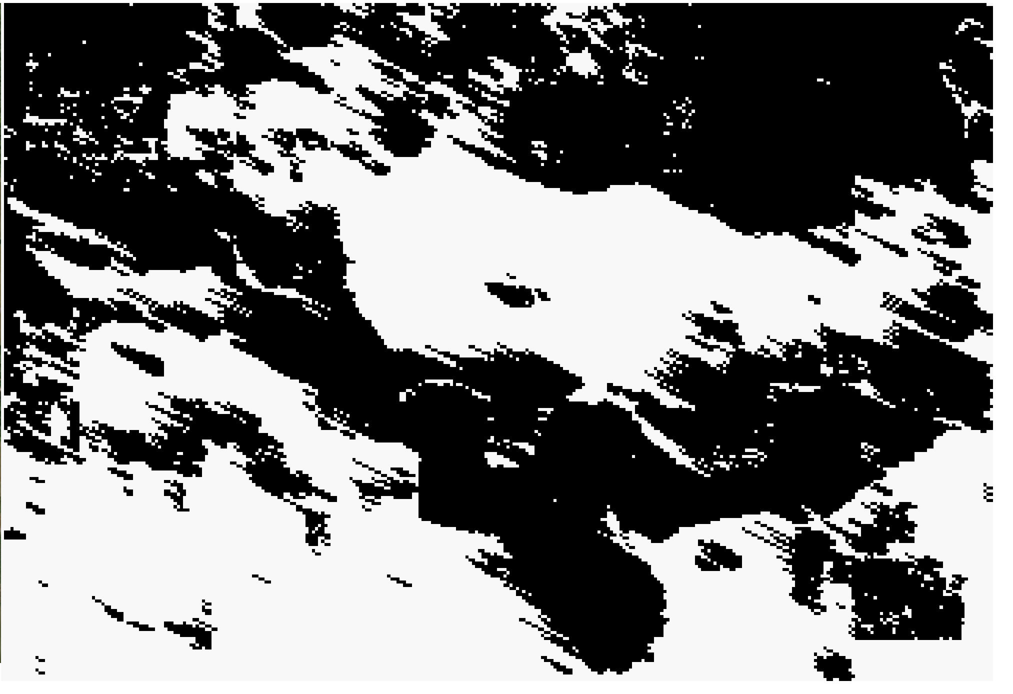


- Shade modeling component is operational now
- Integrate with VELMA → Long-term riparian vegetation and stream temperature dynamics

Calapooia River

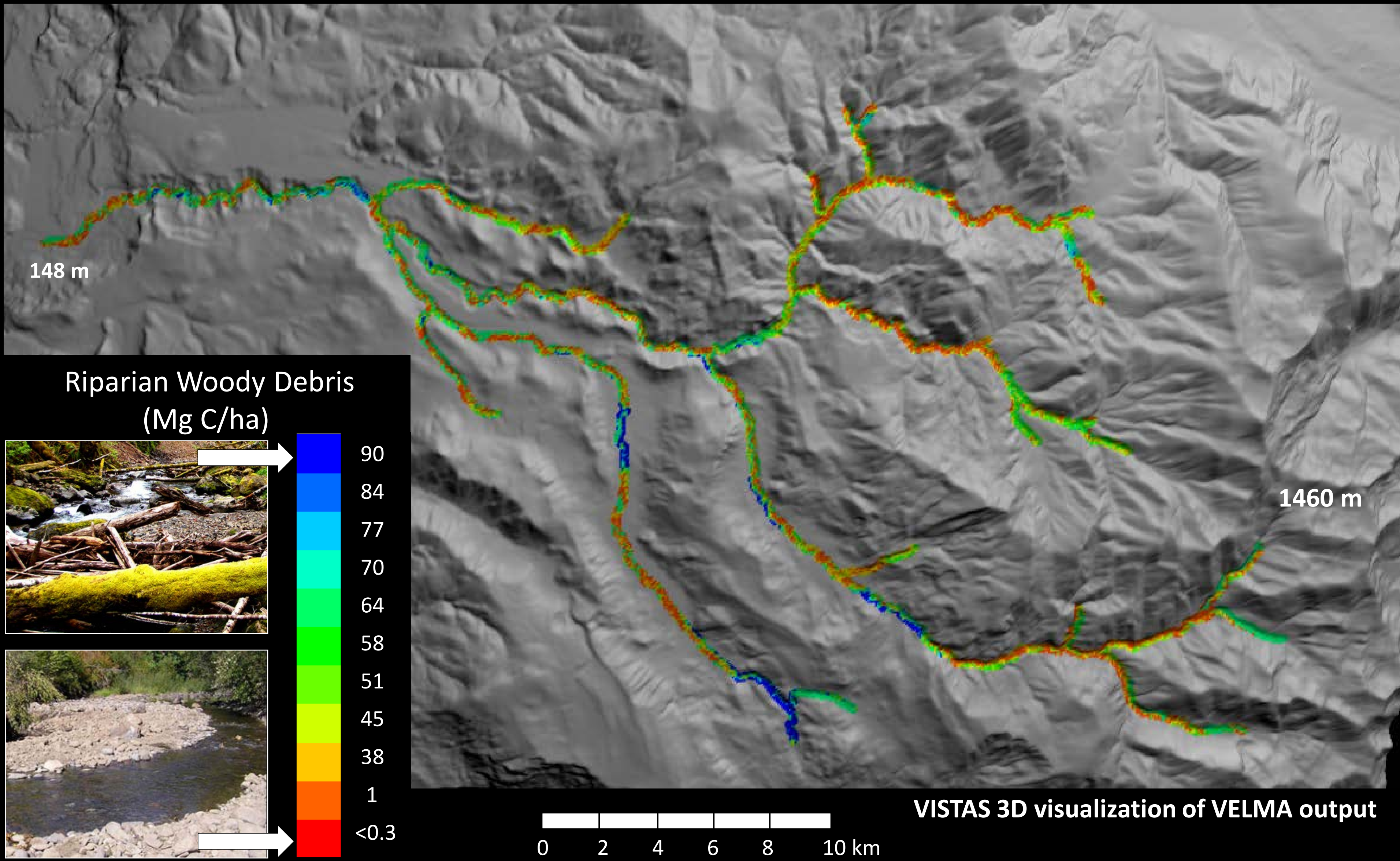
Stream shade movie for June 15, sunrise to sunset

Click on image to reveal movie play button



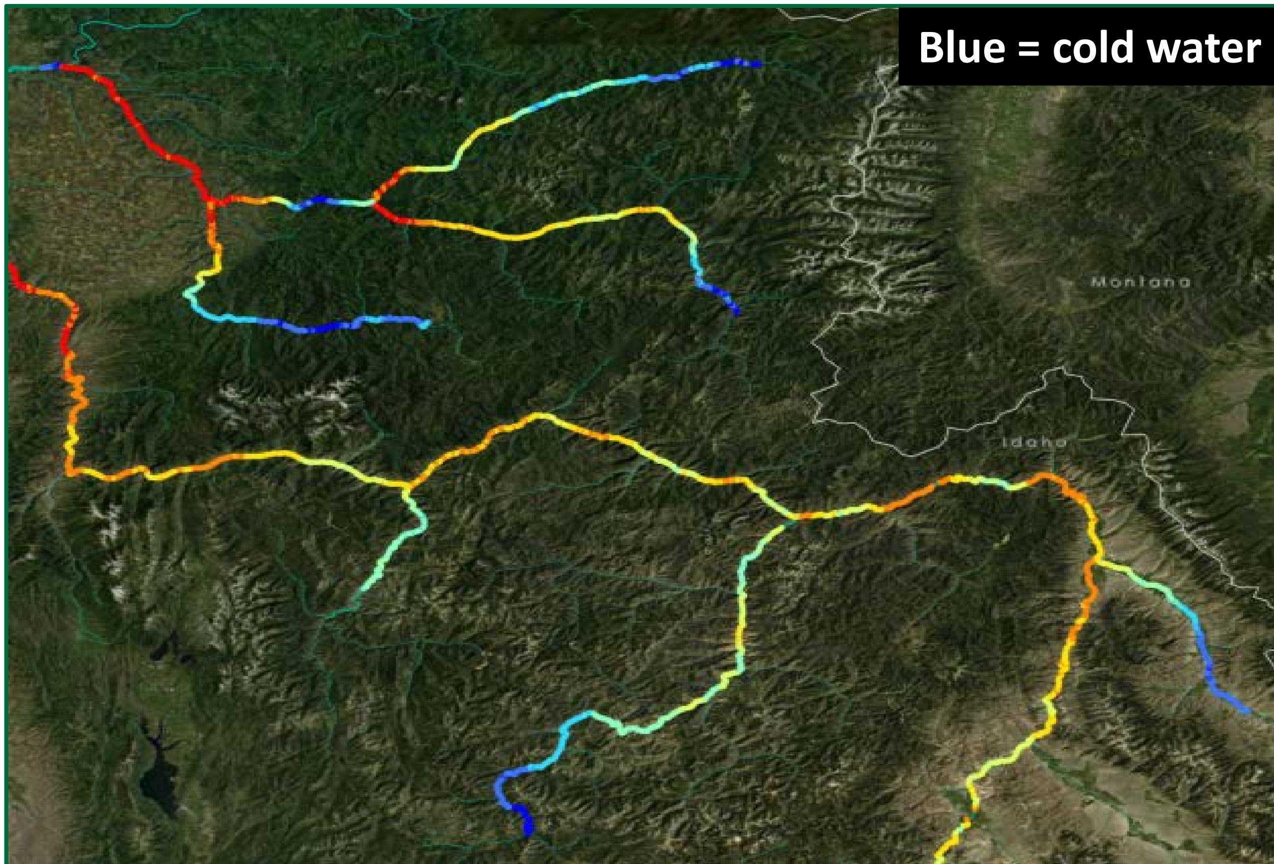
Riparian Large Woody Debris

Mashel Basin – VELMA Simulation, Year 2000



Climate Refuges

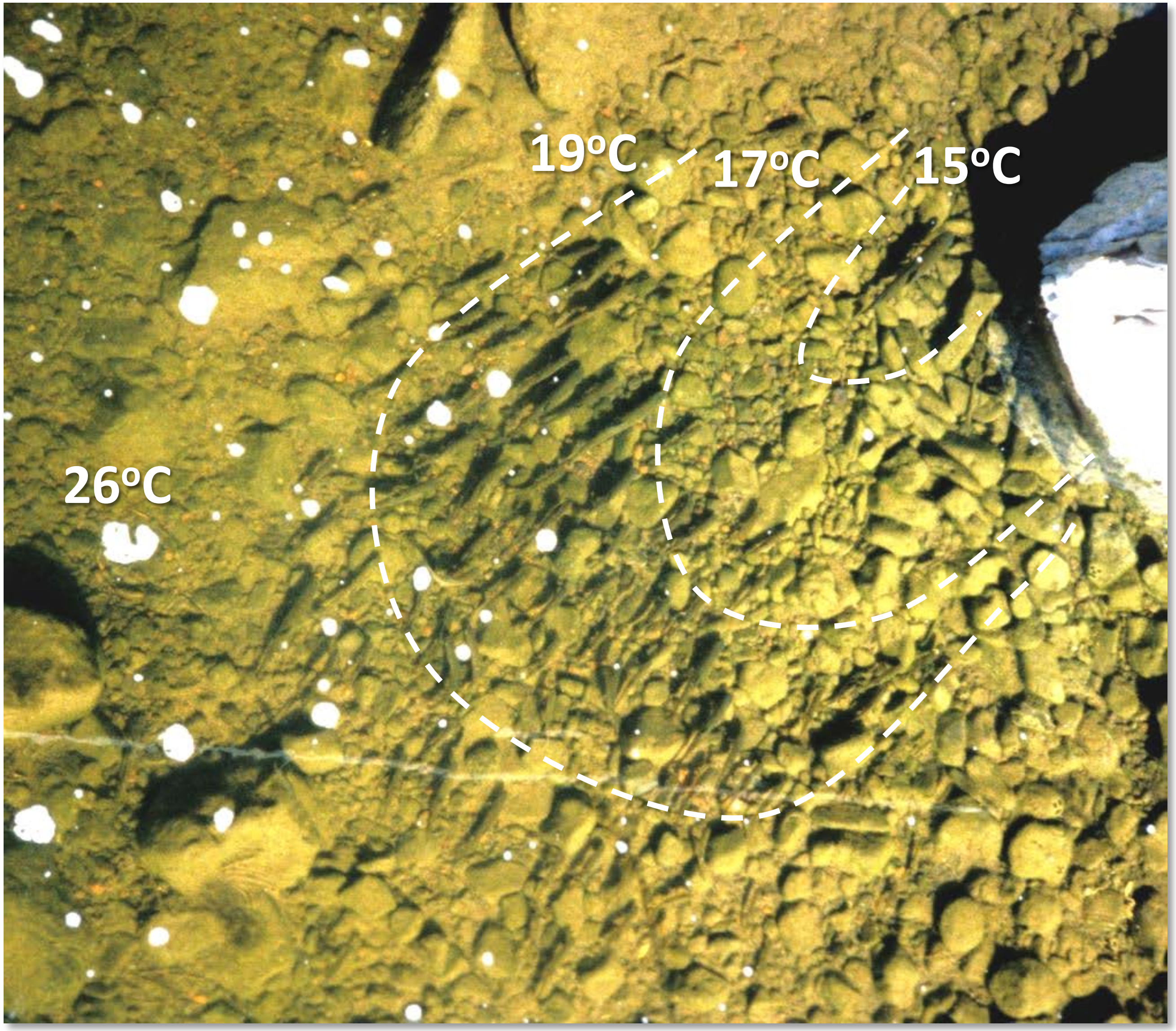
Where and what type of restoration practices can be used to establish and enhance cold water refuges for salmon?



Aimee Fullerton, NOAA/UW

- Shade
- Snowpack
- Groundwater
- Hyporheic flow
- Coarse woody debris

Juvenile O. mykiss thermoregulating in a refuge



Slide courtesy of Joe Ebersole, EPA

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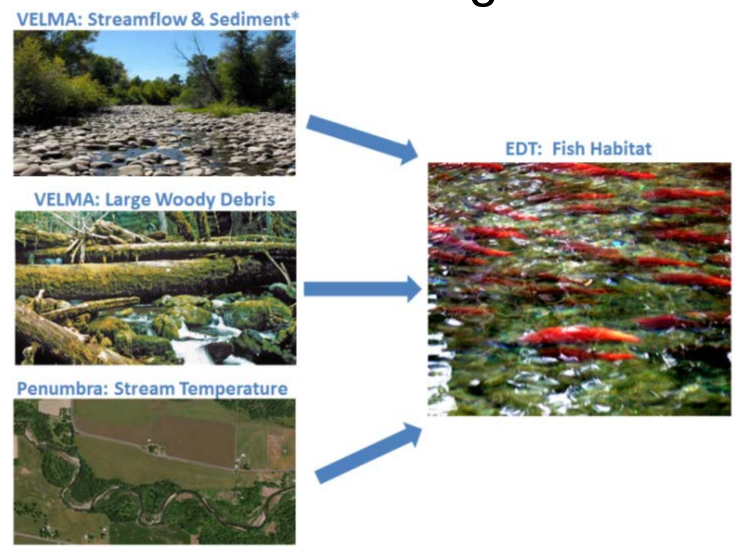
Fish Habitat Modeling:

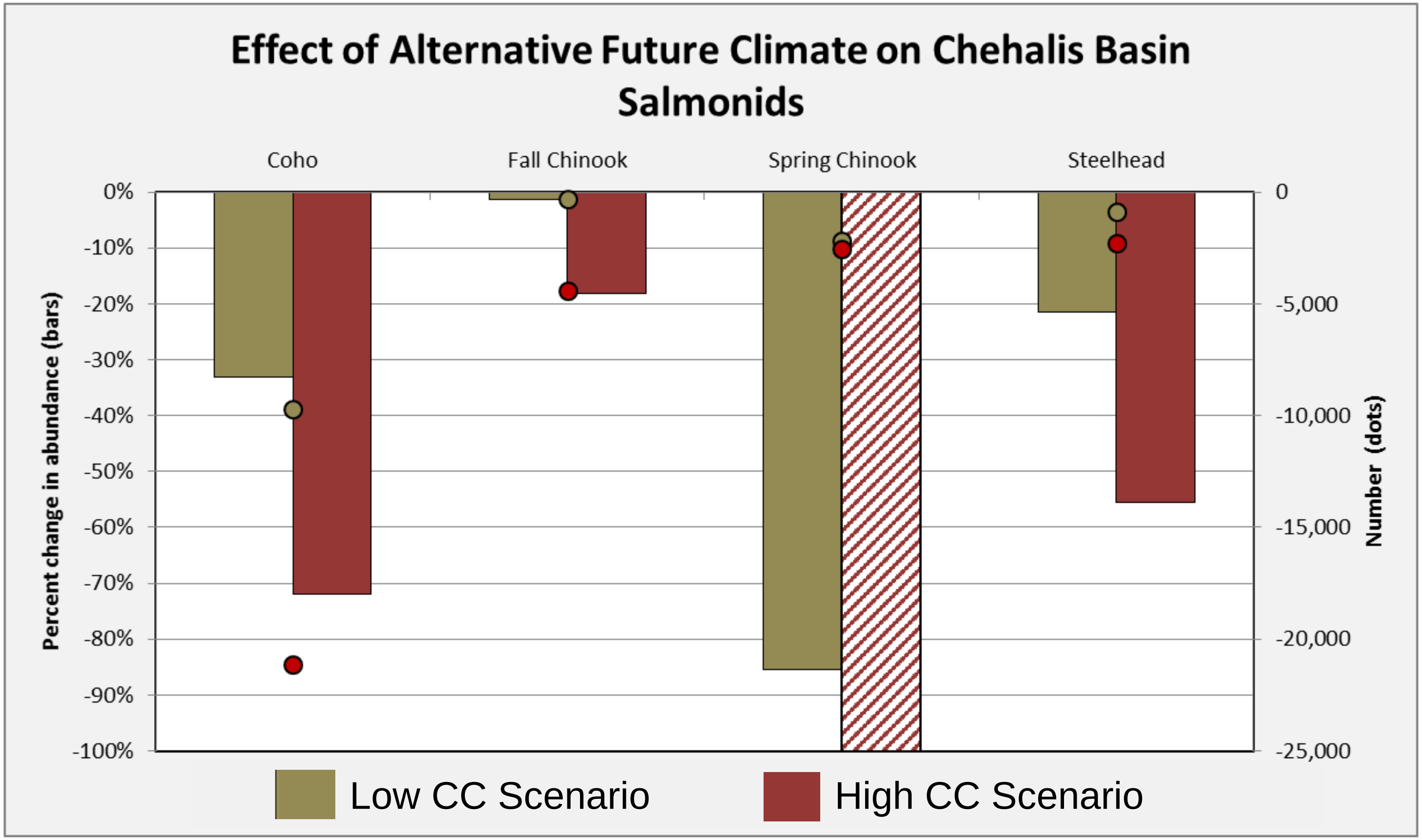
Ecosystem Diagnosis & Treatment (EDT) Model

- EDT is a fish life-cycle habitat model that assesses habitat using metrics relevant to managers and biologist
  - Synthesizes available data and information
  - Prioritizes habitat restoration needs
  - Identifies limiting factors
  - Evaluates alternative habitat solutions



- EDT is not a population dynamics model
  - Does not evaluate extinction risk
  - Does not set recovery targets
  - But it does help managers devise solutions to meet recovery and management targets

EDT:
Basin-level Effects of Alternative Climate Conditions (relative to current conditions)



EDT:

Pattern of Habitat Degradation by Subbasin, Nisqually River Watershed

Geographic area priority			Habitat class priority for restoration															
Geographic area	Protection benefit	Restoration benefit	*Channel stability*	*Chemicals*	*Competition (w/ hatch)*	*Competition (other sp)*	*Flow*	*Food*	*Habitat diversity*	*Harassment/poaching*	*Obstructions*	*Oxygen*	*Pathogens*	*Predation*	*Sediment load*	*Temperature*	*Withdrawals*	*Key habitat quantity*
Nisqually River Mainstem	High	Medium							Low		Medium							Low
McAllister Creek			Low						Medium			Low	Low		Low			Low
Muck Creek	Low	High	Low				Low	Low	Low	Low	High			Low	Medium	Medium		Medium
Prairie Tributaries	Medium	High					Low	Low	Medium		High			Low	Medium	Medium		Low
Toboton/Powell/Lackamas	Low	Low					Low	Low	Low		High	Low			Low	Low		Low
Ohop Creek	Low	Low	Low				Low		Medium						Low	Medium		Medium
Mashel River	Medium	High	Low				Low	Low	Low						Medium	Low		Medium

Restoration Priorities

High — Medium — Low — Indirect or General

EDT:

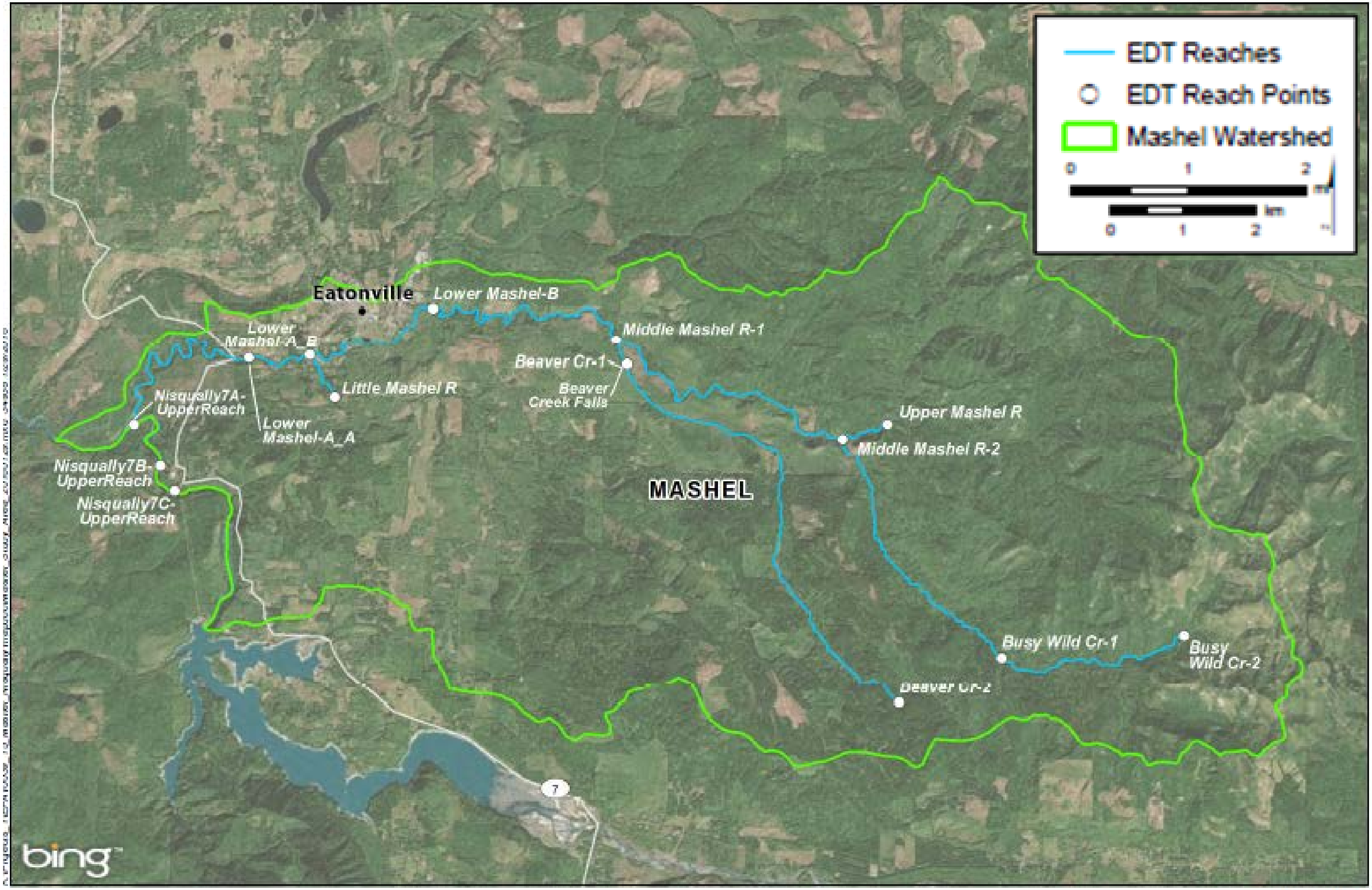
Pattern of Habitat Degradation by Subbasin, Nisqually River Watershed

Geographic area priority			Habitat class priority for restoration															
Geographic area	Protection benefit	Restoration benefit	Channel stability	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
Nisqually River Mainstem	High	Medium							Low		Medium							Low
McAllister Creek			Low						Medium			Low	Low		Low			Low
Muck Creek	Low	High	Low				Low	Low	Low	Low	High			Low	Medium	Medium		Medium
Prairie Tributaries	Medium	High					Low	Low	Medium		High			Low	Medium	Medium		Low
Toboton/Powell/Lackamas	Low	Low					Low	Low	Low		High	Low			Low	Low		Low
Ohop Creek	Low	Low	Low				Low		Medium						Low	Medium		Medium
Mashel River	Medium	High	Low				Low	Low	Low						Medium	Low		Medium

Restoration Priorities

High | Medium | Low | Indirect or General

Mashel EDT stream reaches



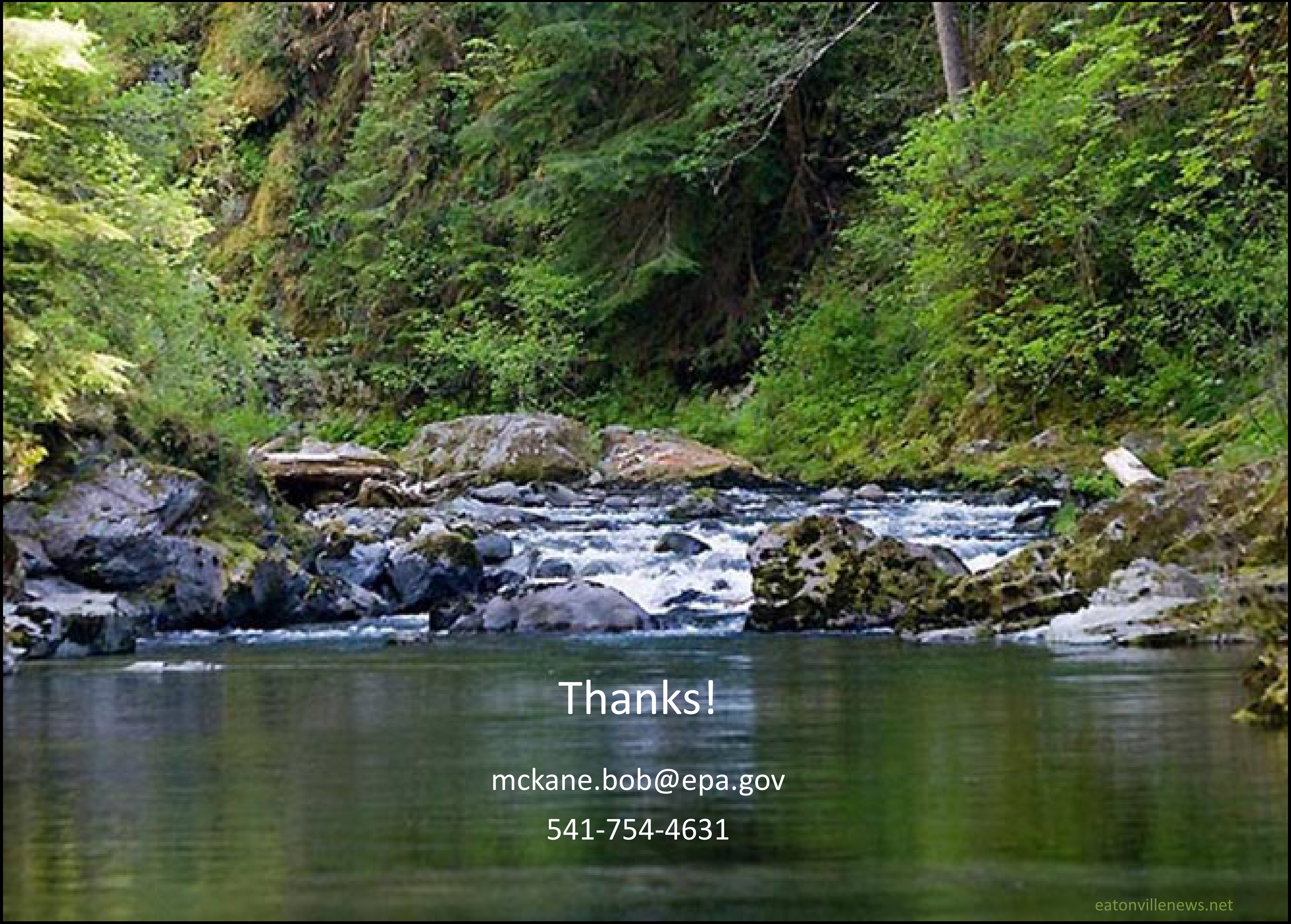
Study Area

Scenarios for Watershed Restoration?

- Which restoration practices are most important for salmon recovery? Riparian plantings, large woody debris, floodplain/side-channel reconnection, low flow enhancement?
- Where should restoration projects be located to be most cost effective?
- How long will it take for restoration to have an impact?
- To what extent will projected changes in climate limit future effectiveness of restoration?
- Scenarios for optimizing multiple ecosystem services: salmon, timber, water quality & quantity, carbon, GHGs…

Preliminary Conclusions

- Establishment of older (>80 yr?) forest landscapes can
  - Increase streamflow by several times during low-flow months crucial for salmonid spawning
  - Help mitigate effects of climate change on streamflow
  - Generate large woody debris for instream habitat
- Next: Integrate VELMA/Penumbra/EDT to
  - Assess salmonid habitat responses to present and projected changes in flow, woody debris and stream temperature
  - Help inform riparian & whole watershed restoration plans aimed at establishing cold water refuges for a warmer climate



Thanks!

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