Channel incision and the loss of water storage in drainage networks

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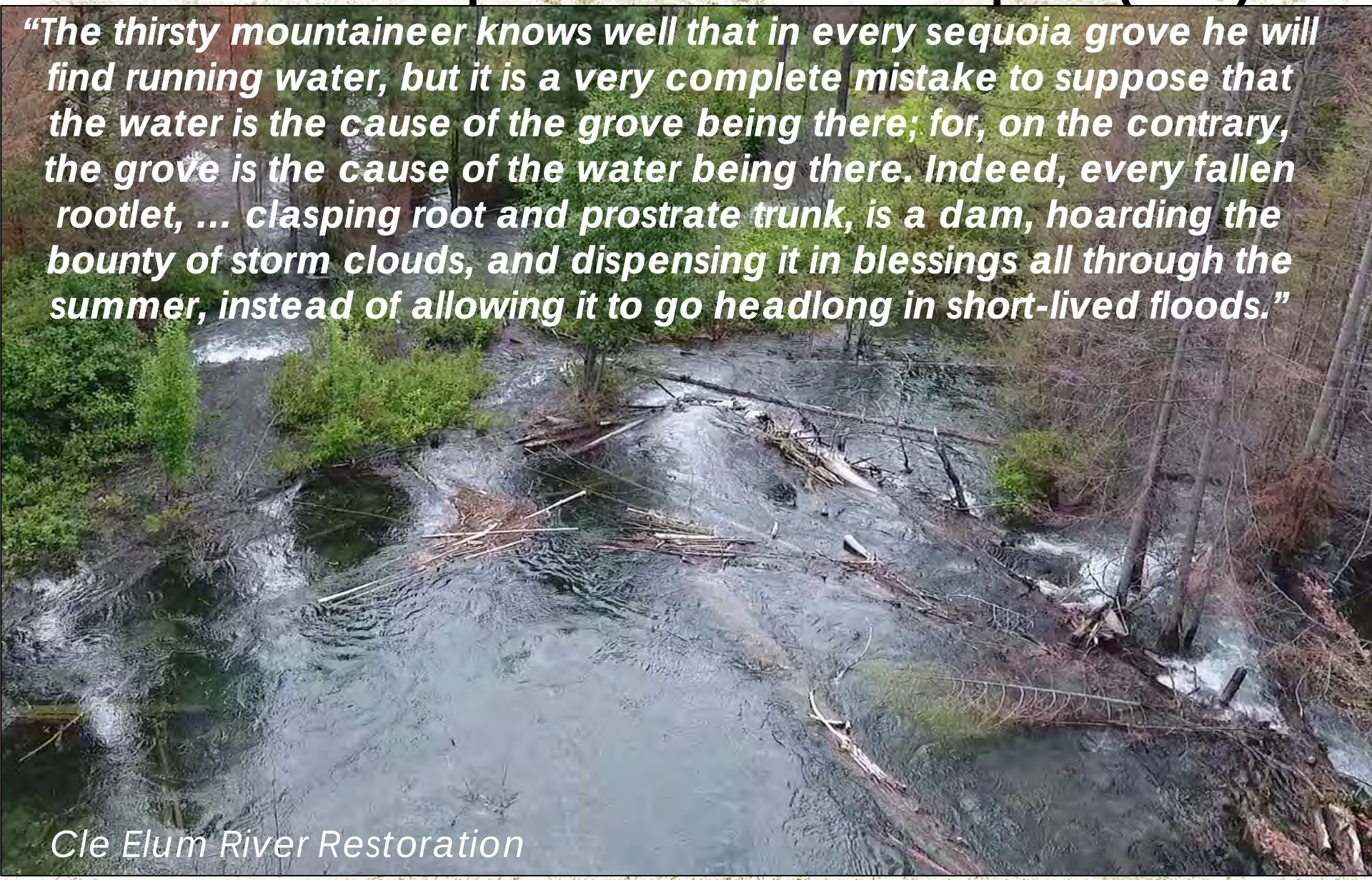
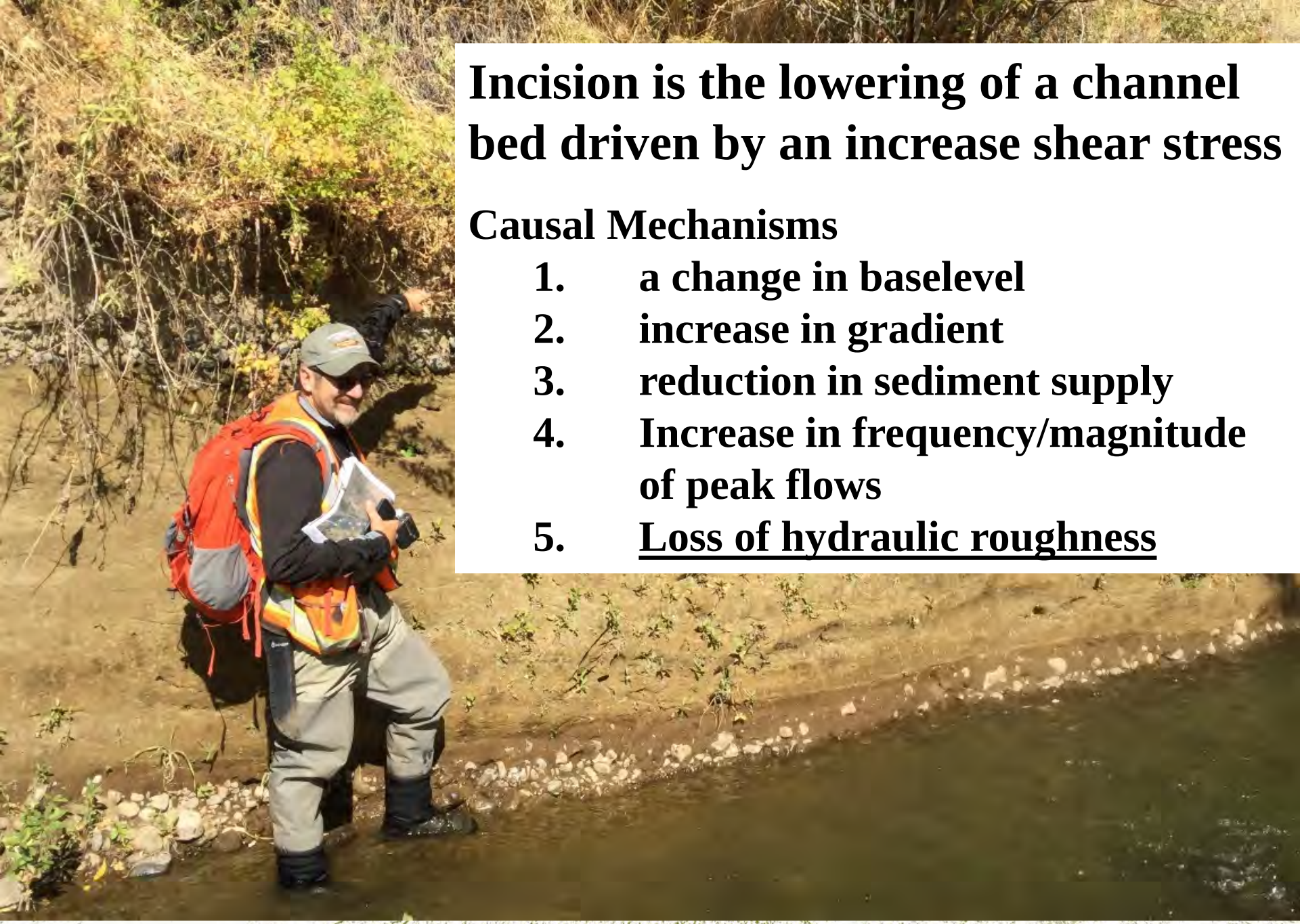
Natural Systems Design

Brender Creek, Chelan County 2017

John Muir on the persistence of Giant Sequoia (1878)



"The thirsty mountaineer knows well that in every sequoia grove he will find running water, but it is a very complete mistake to suppose that the water is the cause of the grove being there; for, on the contrary, the grove is the cause of the water being there. Indeed, every fallen rootlet, … clasping root and prostrate trunk, is a dam, hoarding the bounty of storm clouds, and dispensing it in blessings all through the summer, instead of allowing it to go headlong in short-lived floods."



Incision is the lowering of a channel bed driven by an increase shear stress

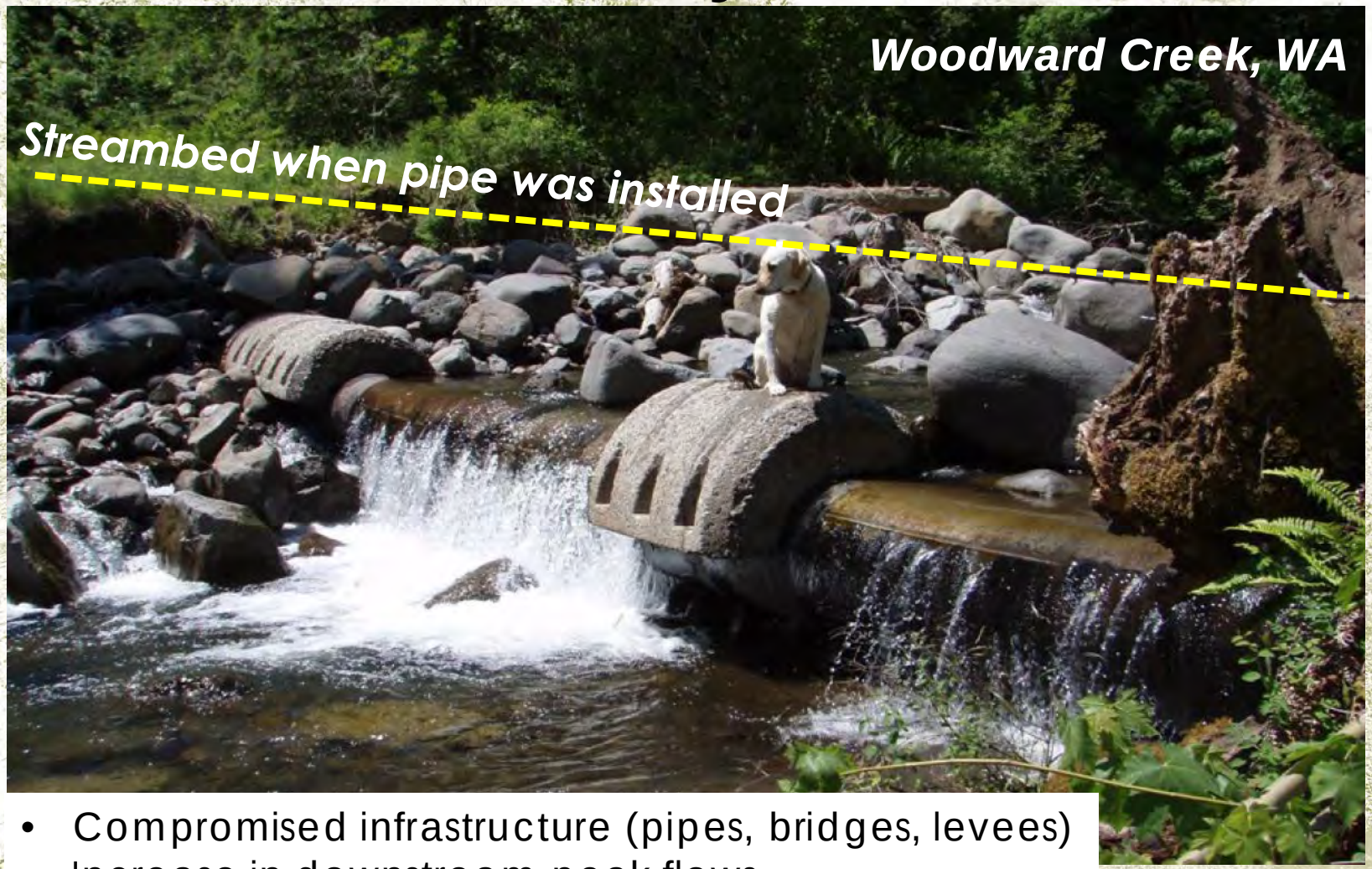
Causal Mechanisms

1. **a change in baselevel**
2. **increase in gradient**
3. **reduction in sediment supply**
4. **Increase in frequency/magnitude of peak flows**
5. **<u>Loss of hydraulic roughness</u>**

Why should we care about channel incision?

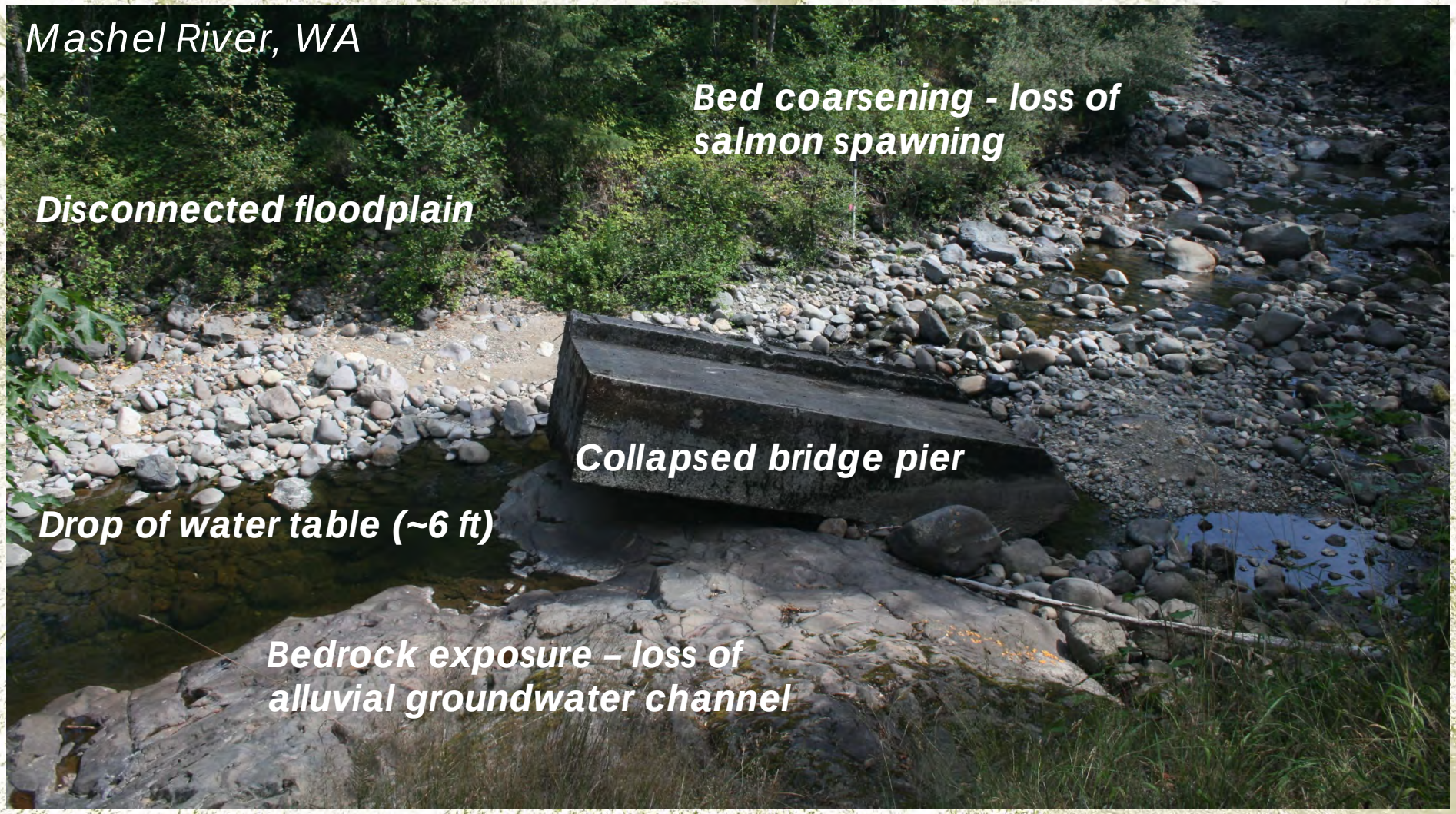
- Decrease in residence time of water in a channel network
- Decreased floodplain frequency inundation
- Loss of spawning gravels
- Increased probability of egg mortality
- Increase in wood mobility
- Simplification of in-stream habitat (e.g., loss of hydraulic refugia)

Additional reasons why we should care…



- Compromised infrastructure (pipes, bridges, levees)
- Increase in downstream peak flows
- **Lowering of water table and loss of water storage**

Driving home the point



Catastrophic is an understatement

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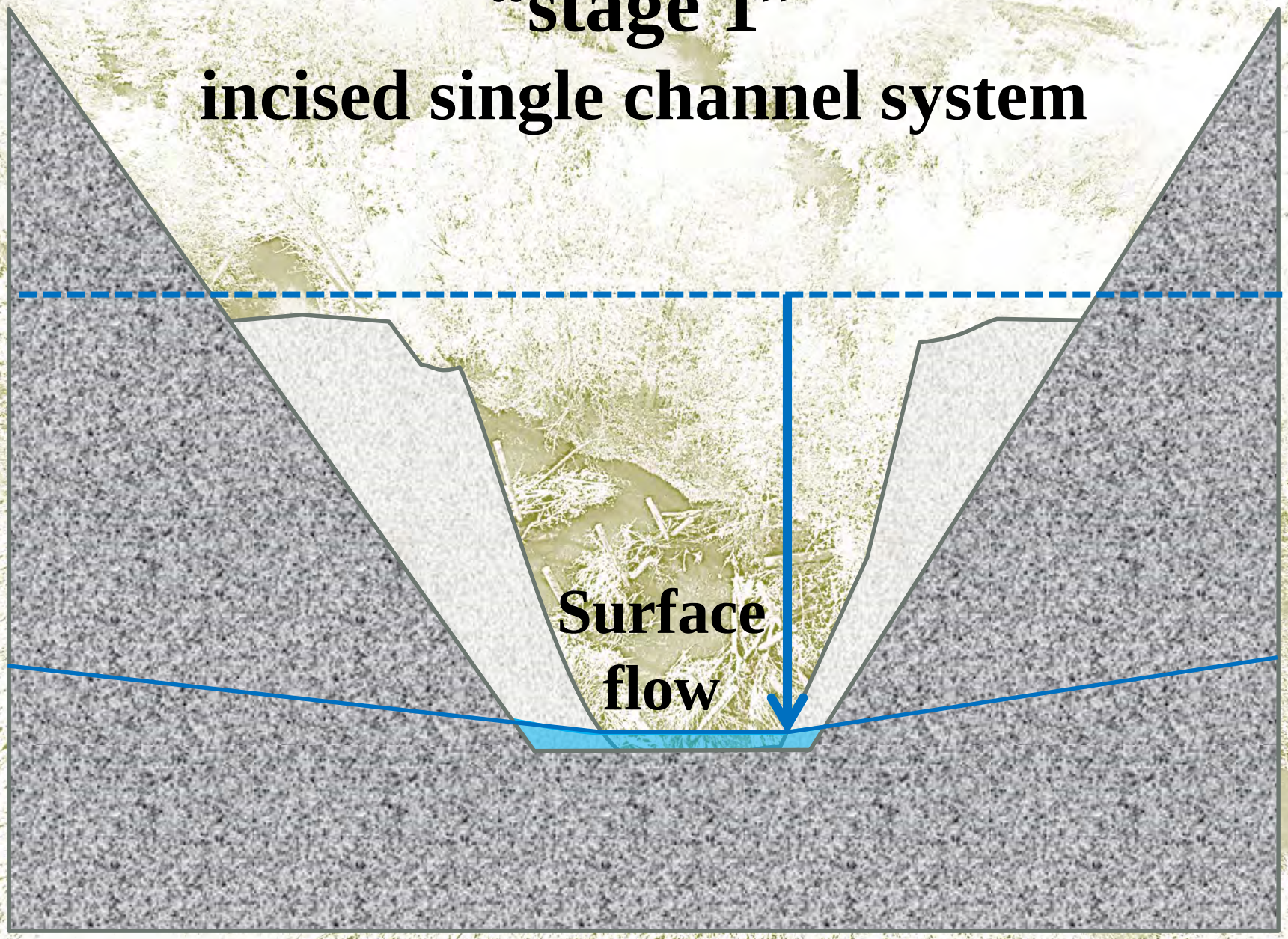
“stage 0”

“stage 1”
incised single channel system



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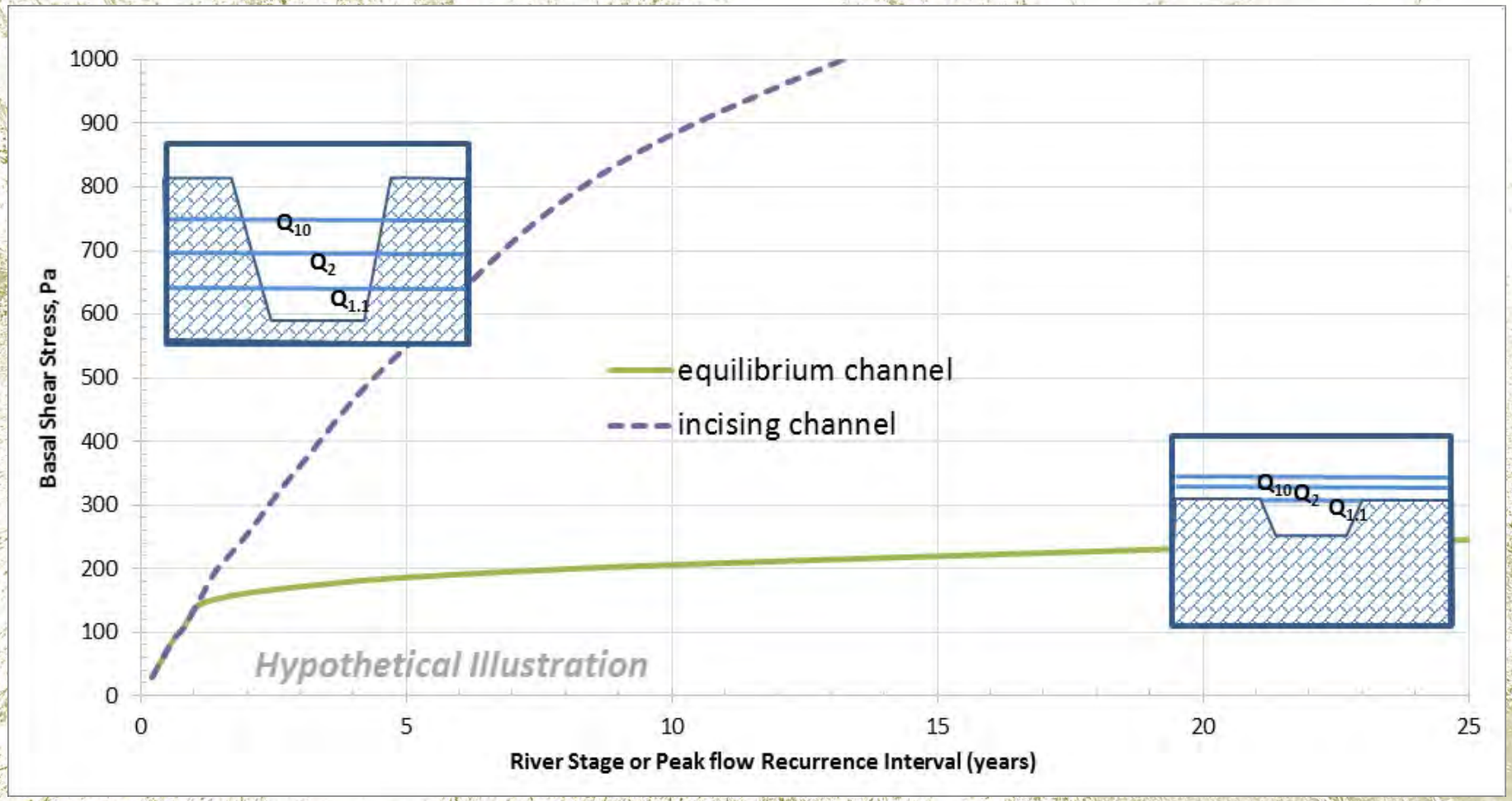
Incision sets up negative cascading effects



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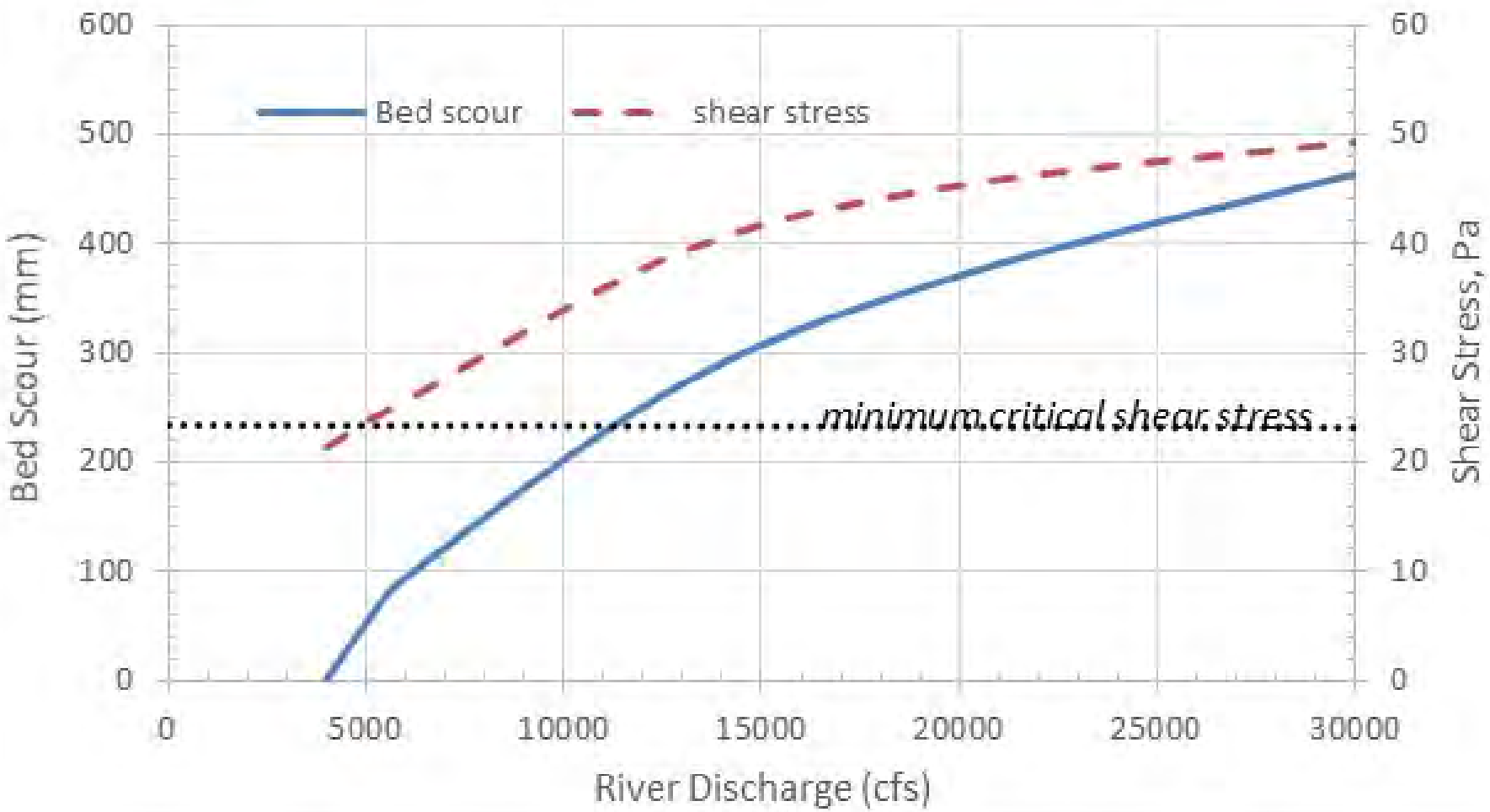
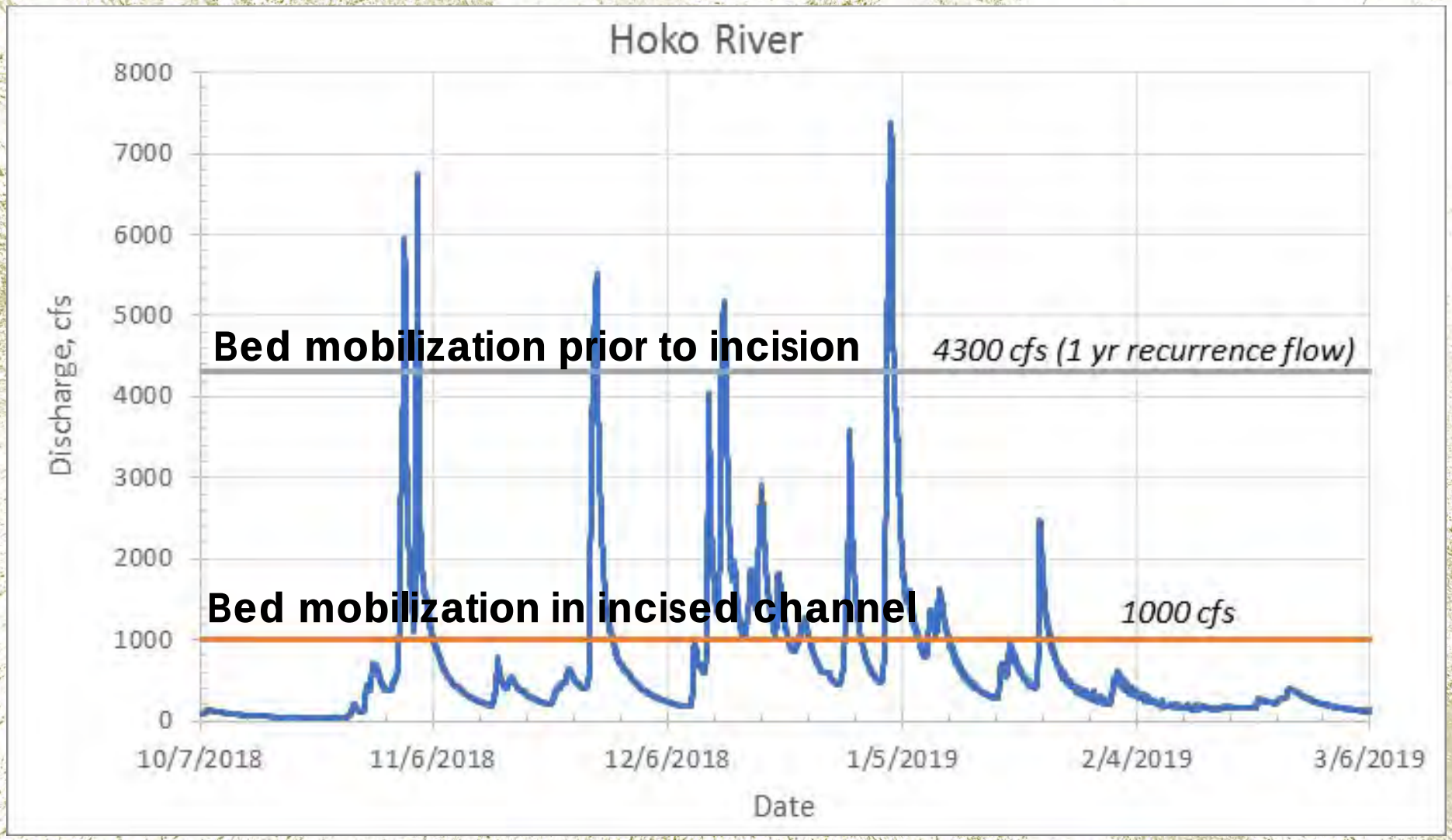
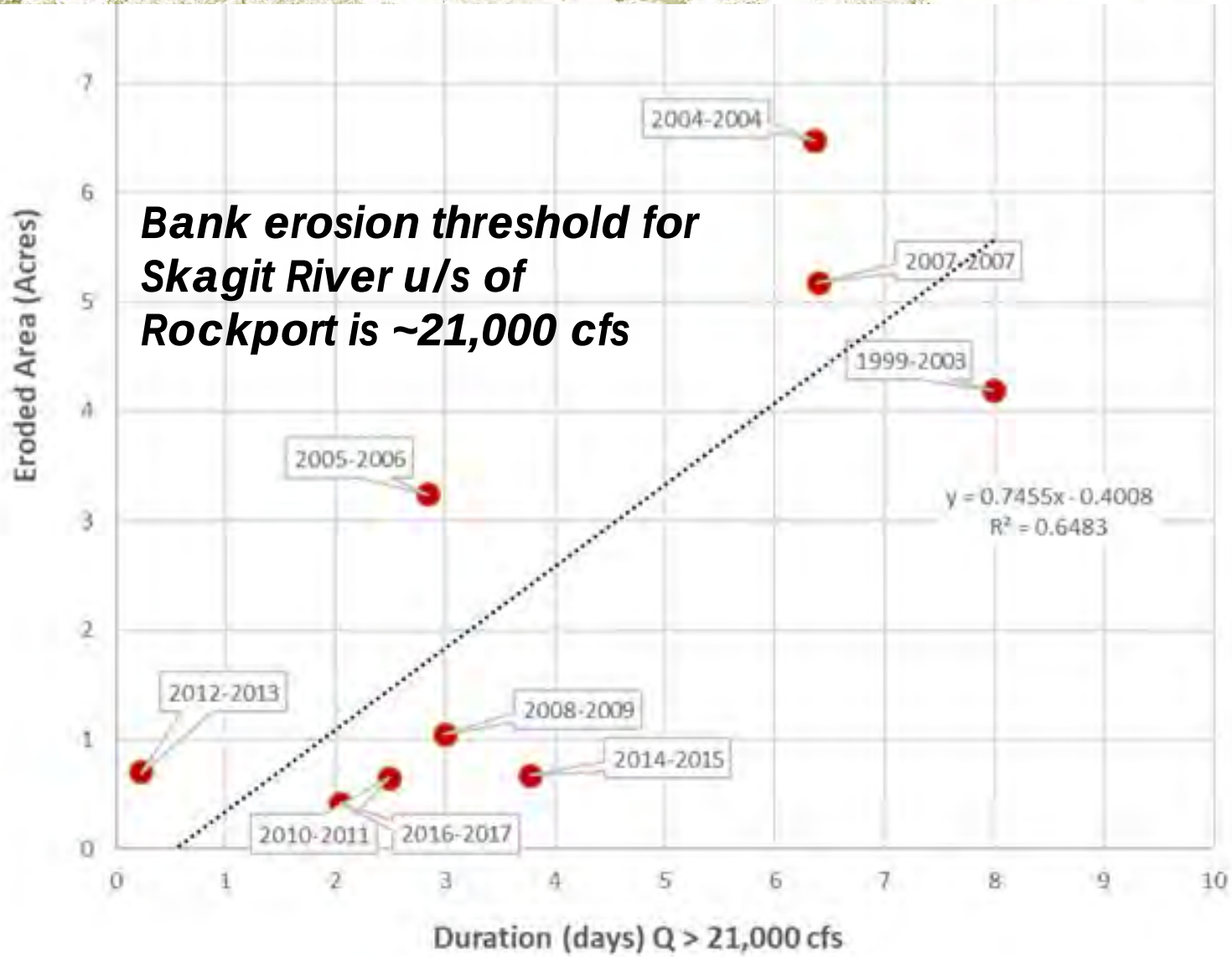
General scour follows same pattern as shear stress



Bed mobilization gone from 64 hrs to 717 hrs



Duration of sediment mobilizing events is important, take this example of bank erosion along the Skagit River



The Role of Wood

"A close study of conditions shows that in every instance <u>the current was first deflected by an accumulation of drift</u>, the huge timber of this section serving readily in its formation. … Gravel, sand, and silt collect in the dead water, behind the drift piles, strengthening them and preventing the river from returning to its original bed.

- Wolff, H.H. (1916) (describing the White River draining Mt Rainier, WA)

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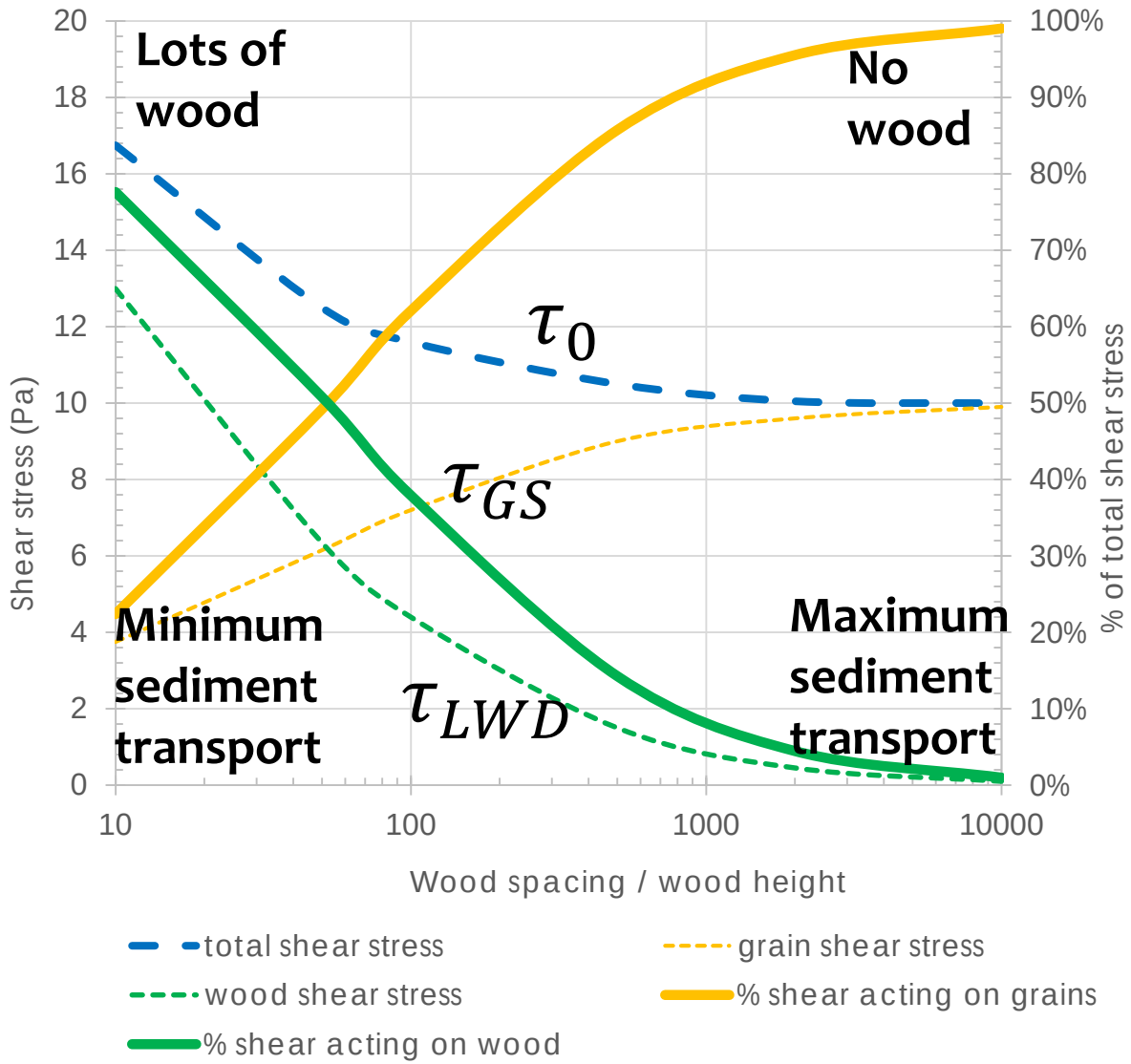
The Role of Wood: Stress Partitioning

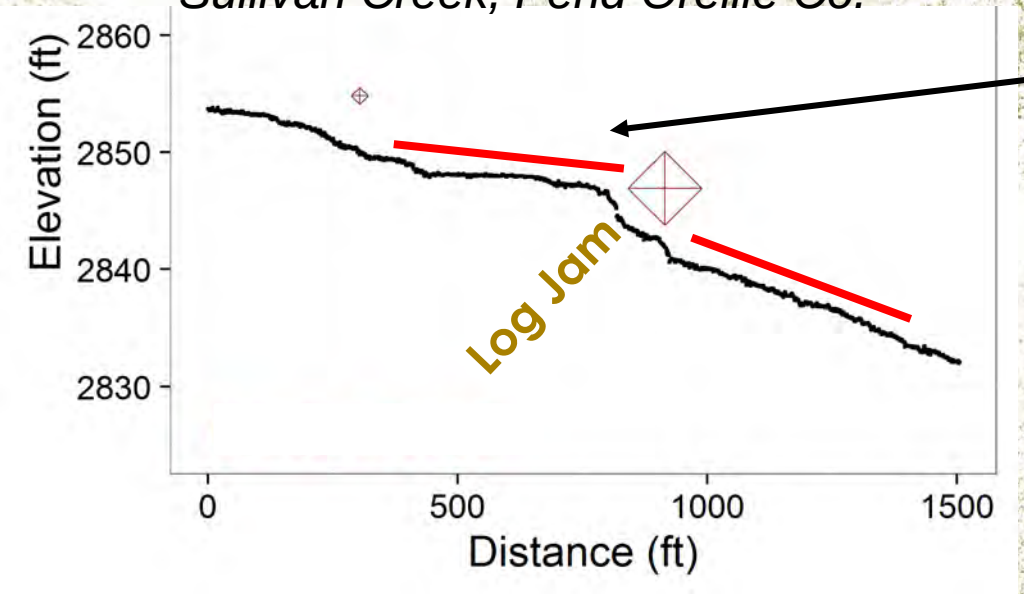


Adapted from Manga and Kirchner 2000

Sediment transport capacity is an inverse function of in-stream wood

$$\tau_0 = \tau_{GS} + \tau_{LWD}$$

Sullivan Creek, Pend Oreille Co.



reduce channel slope, reduce basal shear stress

$$\tau_0 = \rho_w \, g \, R \, \underline{S}$$

$$\tau_{LWD} = \rho \, C_{DA} \, (H/2L) \, U^2$$

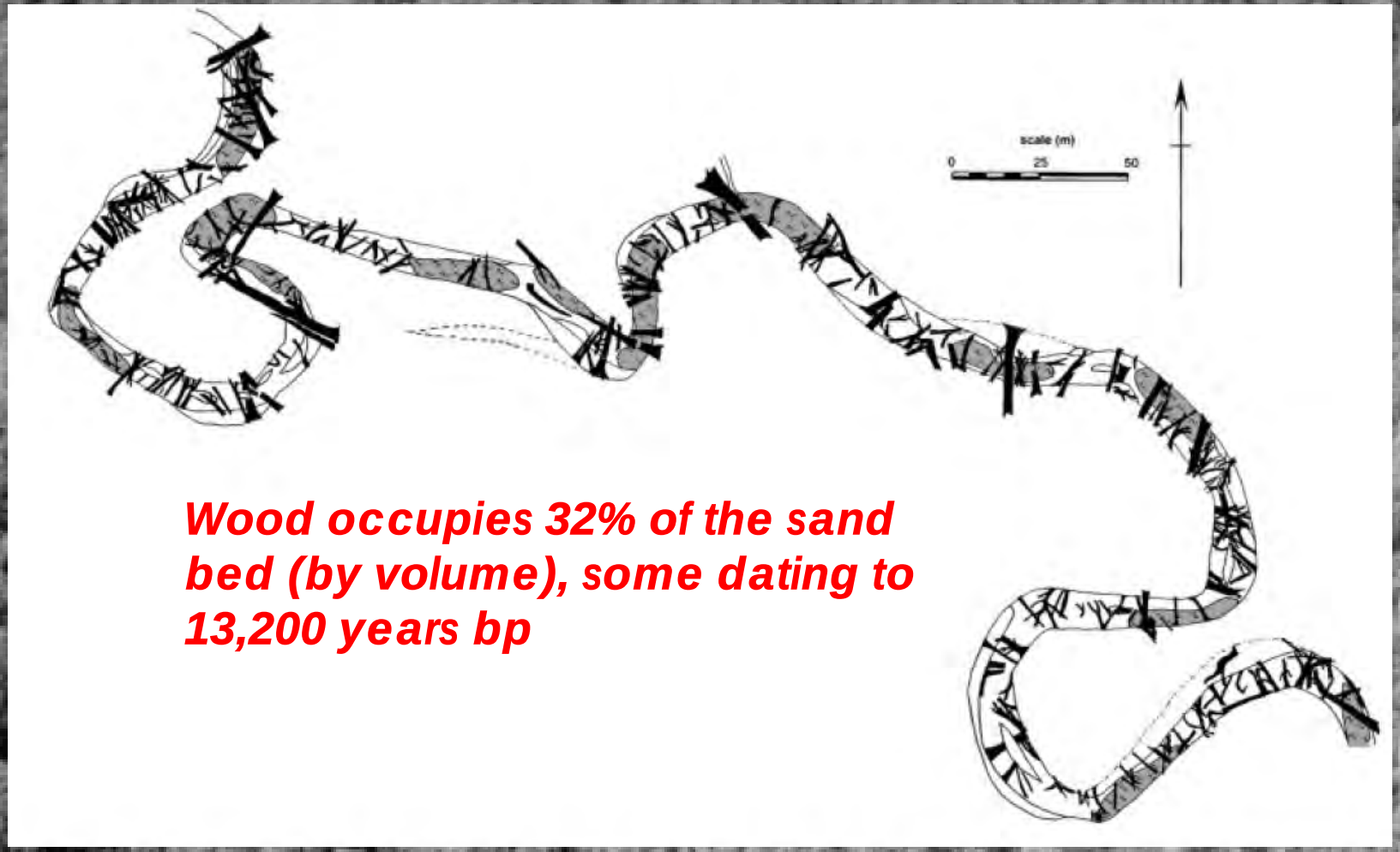
C_{DA} = drag coefficient = $C_D/(1\text{-}B)^2$
B = blockage coefficient = H/h
H = diameter of LWD
L = spacing of LWD

Increase wood:
C_{DA} & H increase, L decreases

Eagle Creek, Chelan Co.

What does wood loading look like in a system that hasn't been disturbed in 16000 years?

Thurra River, SE Australia



Wood occupies 32% of the sand bed (by volume), some dating to 13,200 years bp

Brooks and Brierley 2001

Brooks et al (2003) explain how the Cann River in Australia experienced <u>little change for 27,000 yrs</u>. After European settlement things changed:

- **360% increase in depth**
- **240% increase in slope**
- **700% increase in capacity**
- **150-fold increase in rate of channel migration**

changes entirely attributed to removal of wood and riparian vegetation

Assani and Petit 1995 study of wood influence on bed mobility

	with logjams	no logjams	units	logjams/ no logjams	no logjams/ logjams
Q_{im}	35	25	l/s		
Frequency of Q_{im}	**1.7**	**4.7**	**times/yr**	**36%**	**3**
Duration of Q_{im}	2	10	hours/event	20%	5
Duration of Q_{im}	**3.4**	**47**	**hours/yr**	**7%**	**14**
D50 mobilized	9.7	12.5	mm	78%	29%
D90 mobilized	32	66	mm	48%	106%

Q_{im} = Q at initiation of bed load motion
(~50% of marked pebbles in motion)

Tributary to Middle Nemah River, Willapa Hills

Pacific Northwest streams often have only a thin layer of alluvium. In many situations, wood is all that retains the alluvium.

Surface water flow (Manning's equation):

$$U = \frac{(R^{2/3}\ S^{1/2})}{\boldsymbol{n}}$$

U = flow velocity, m/s
R = hydraulic radius, m
S = hydraulic gradient
n = Manning's coefficient (smooth~0.035, rough~0.09)

Sub-Surface Flow (Darcy's equation):

$$U = \frac{\boldsymbol{K}}{p}\ \frac{\Delta h}{\Delta L}$$

K = hydraulic conductivity, m/s
p = porosity of the material
$\Delta h/\Delta L$ = hydraulic gradient (S)
Δh = hydraulic head, m
ΔL = horizontal distance of flow path

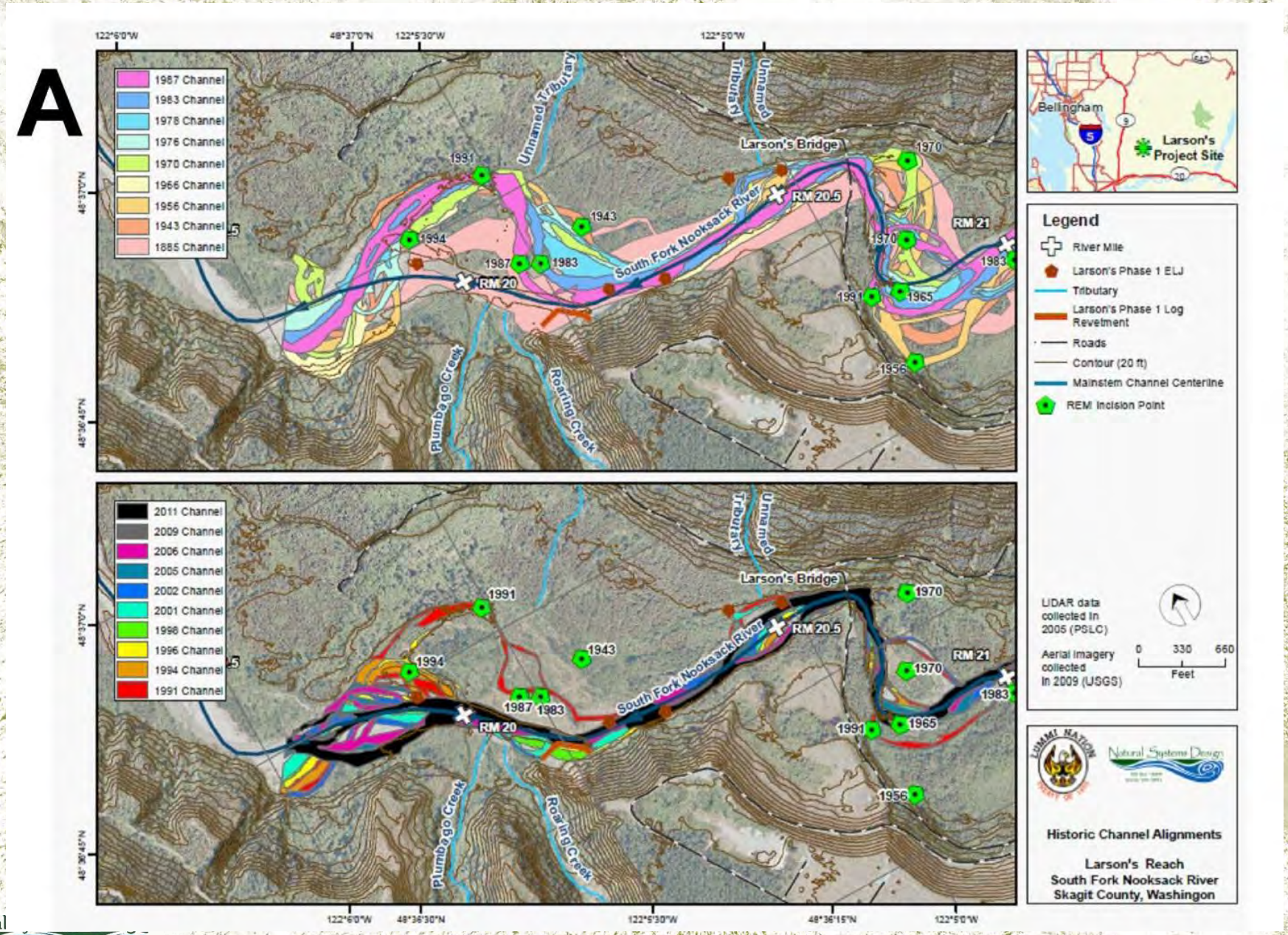
Water residence time (storage) in a channel depends on what it flows through

Routing times vary by orders of magnitude

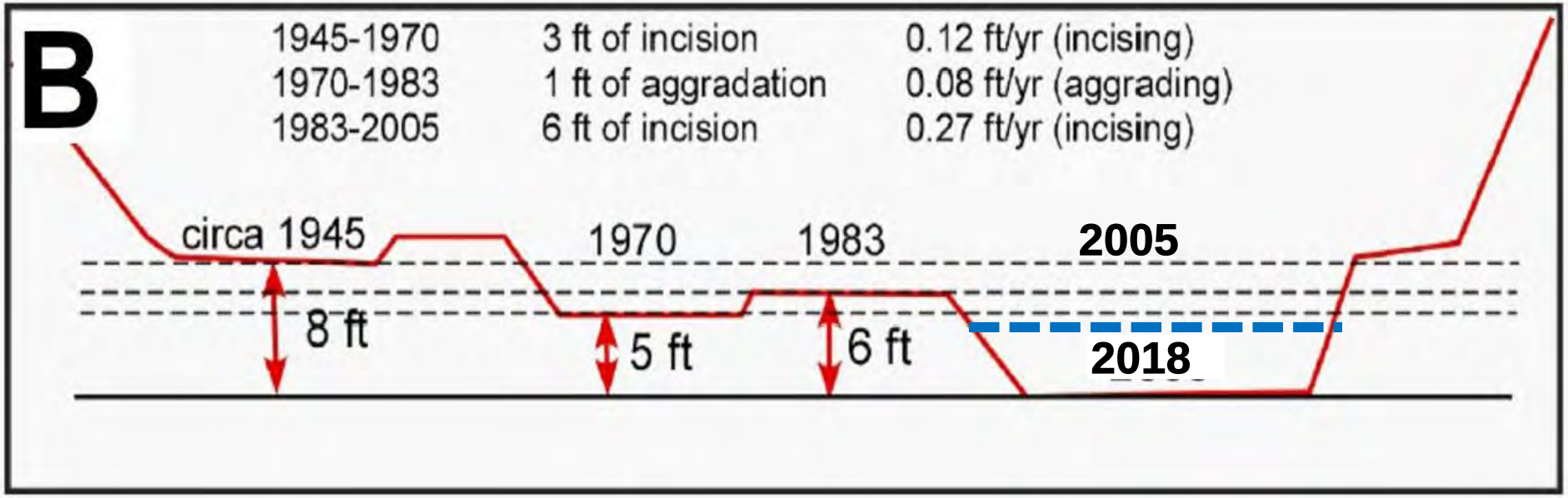
(example: 10 km alluvial stream with a 3% gradient)

Flow Condition	Routing time (over 10 km)
	hours
Surface water through incised channel (no wood)	0.4
Surface water through natural channel (w/ wood)	3.2
Subsurface water through alluvium*	14,854

Incision of a large river: South Fork Nooksack River



Incision of a large river: South Fork Nooksack



Incision Driver	Occurrence
Upstream Dams	No
Channel straightening	No
Increase in peak flows	
Urbanization	No
Forest clearing	Yes
Wood removal	Yes

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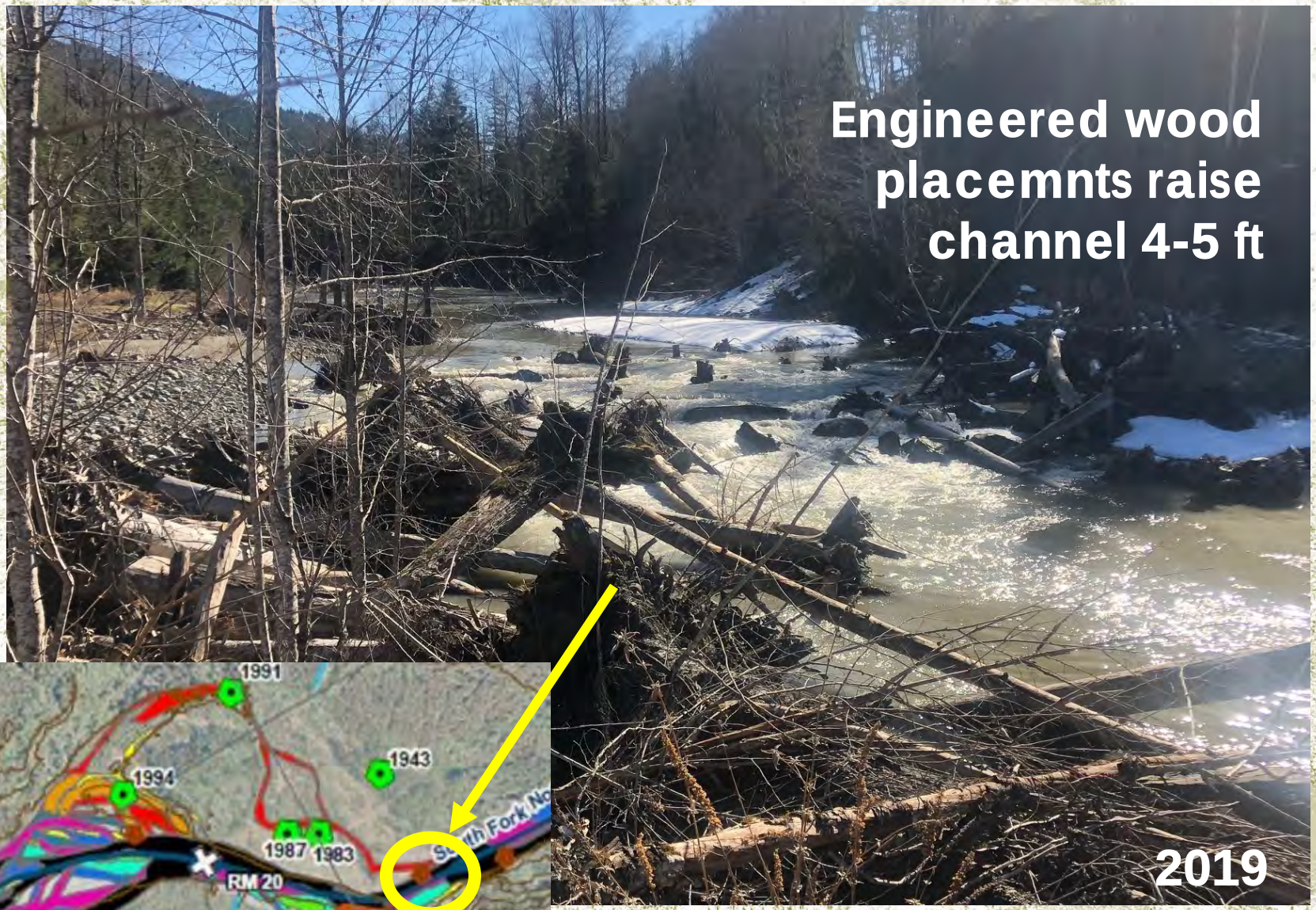
Restoration of an incised river: South Fork Nooksack



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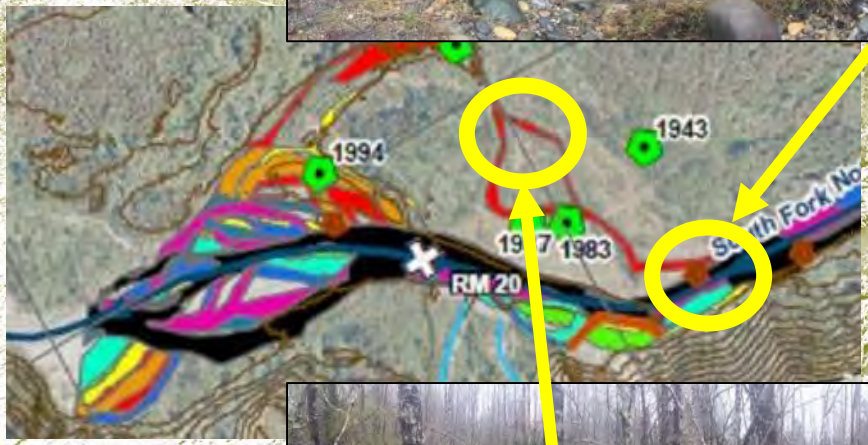

Estimated increase in water storage = 30 ac-ft (102 ac-ft/mile)

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Restoration of an incised river: Toppenish Creek

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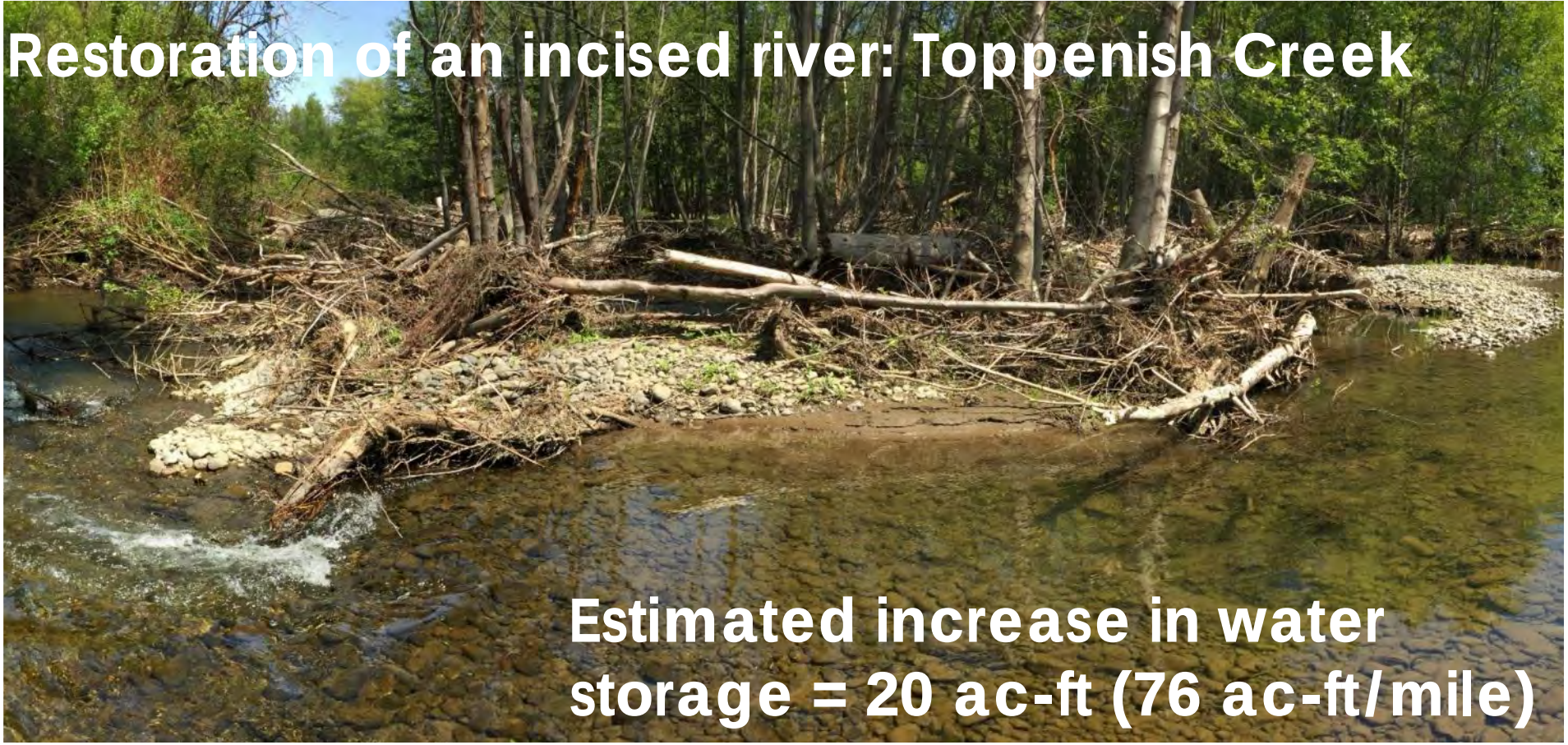
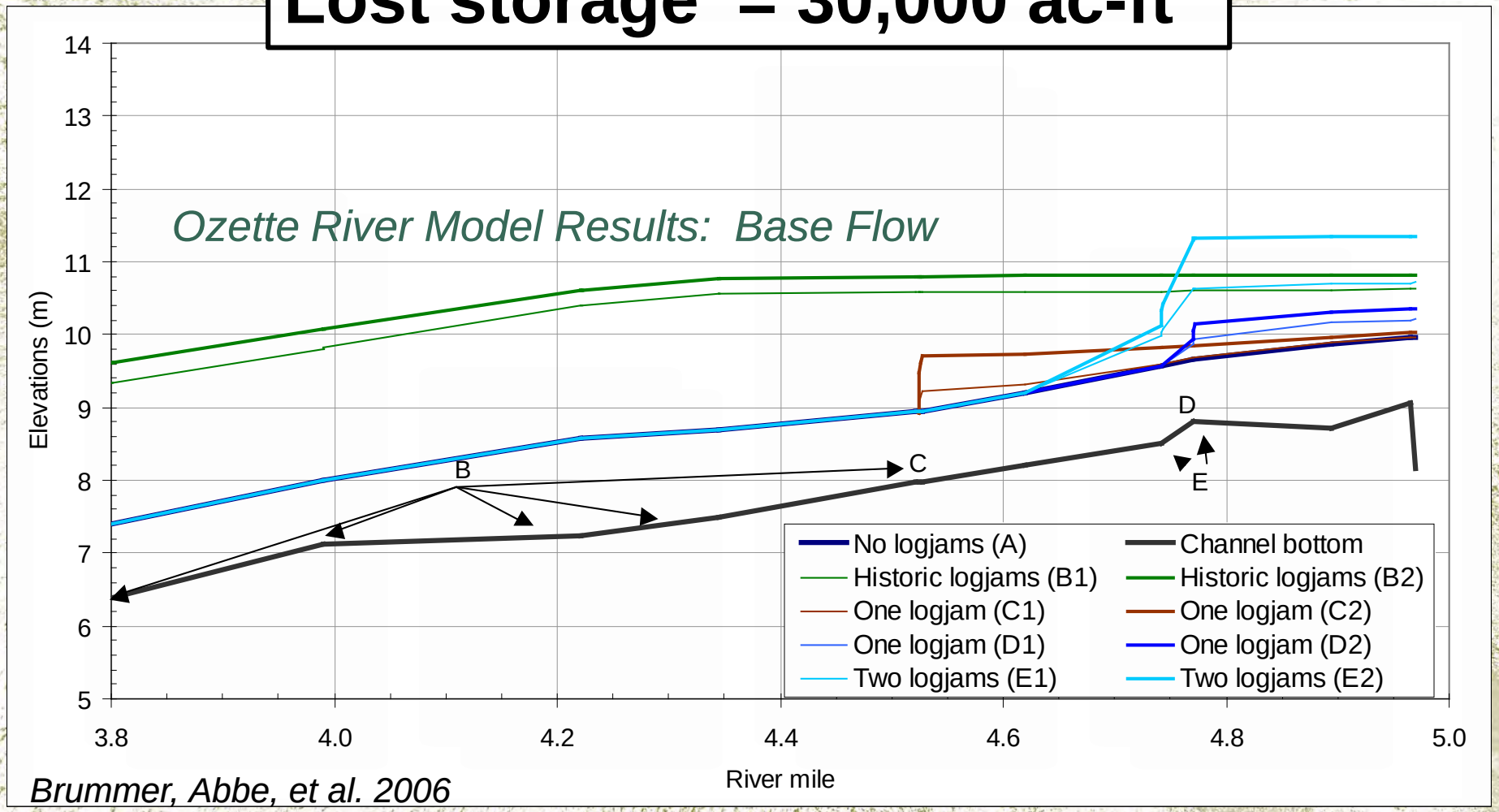


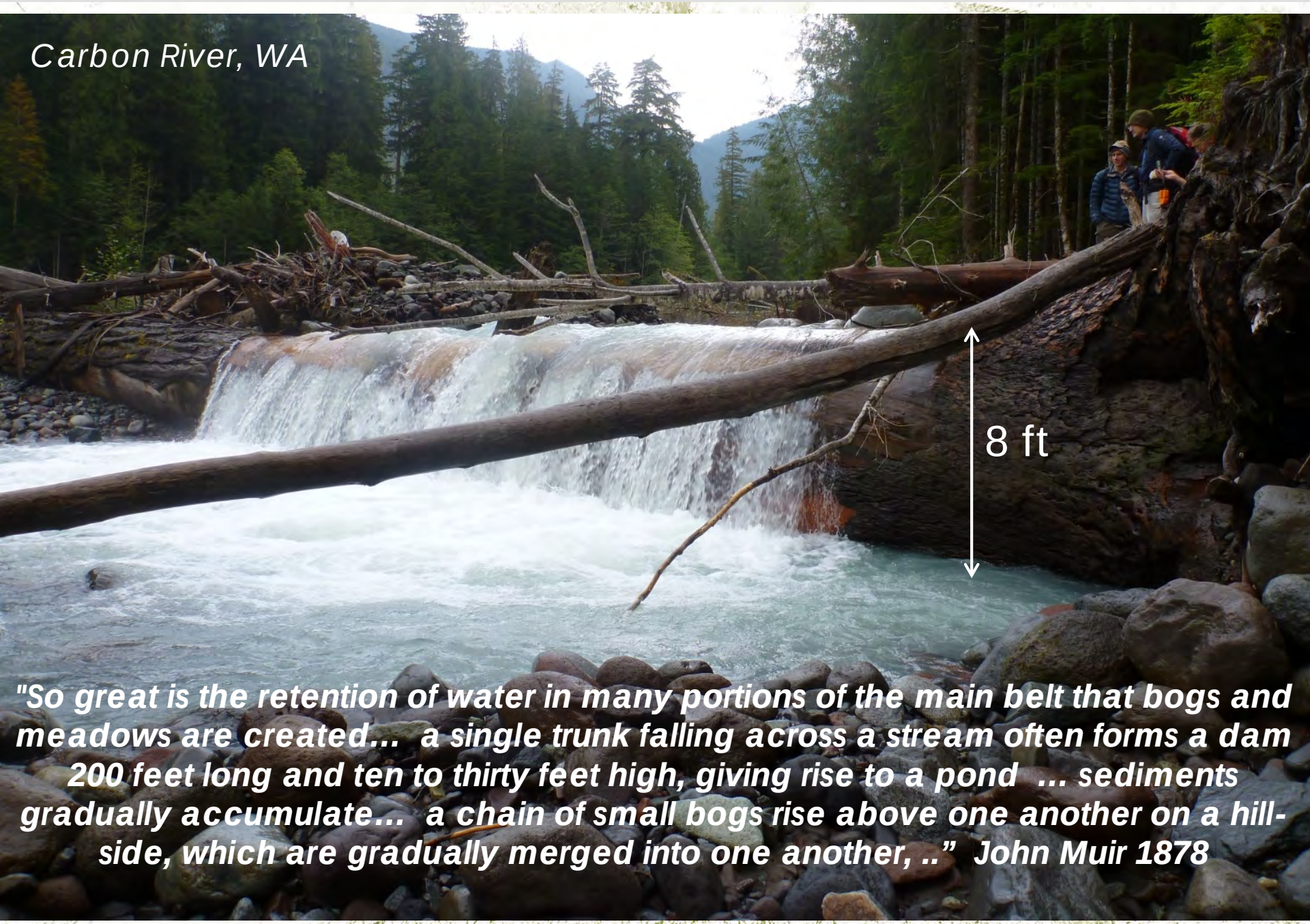
Estimated increase in water storage = 20 ac-ft (76 ac-ft/mile)

After logjam removal from the Ozette River, Lake Ozette dropped about 4 ft

Lost storage = 30,000 ac-ft



Brummer, Abbe, et al. 2006



"So great is the retention of water in many portions of the main belt that bogs and meadows are created… a single trunk falling across a stream often forms a dam 200 feet long and ten to thirty feet high, giving rise to a pond … sediments gradually accumulate… a chain of small bogs rise above one another on a hill-side, which are gradually merged into one another, .." John Muir 1878

Summary – *this is the beginning …*

Washington lost water storage = 1.5 to 18 <u>million</u> ac-ft

<u>Acknowledgements</u>

Trees
Chelan County Natural Resources Department
WA DNR
Kittitas Conservation Trust (Cle Elum restoration)
Lummi Indian Nation (SF Nooksack restoration)
Yakama Indian Nation (Toppenish restoration)