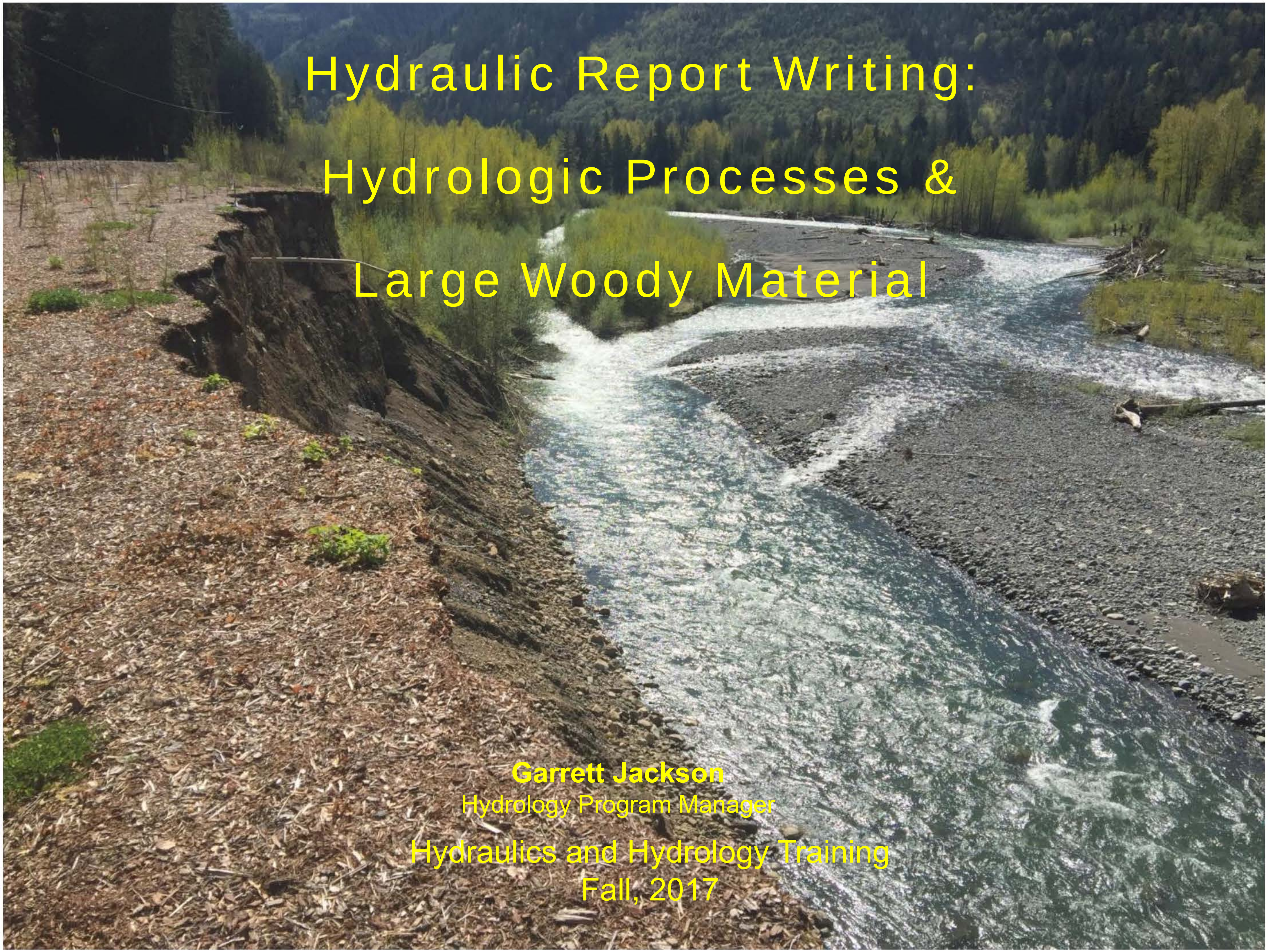


Hydraulic Report Writing:

Hydrologic Processes &

Large Woody Material

Garrett Jackson
Hydrology Program Manager

Hydraulics and Hydrology Training
Fall, 2017

Outline

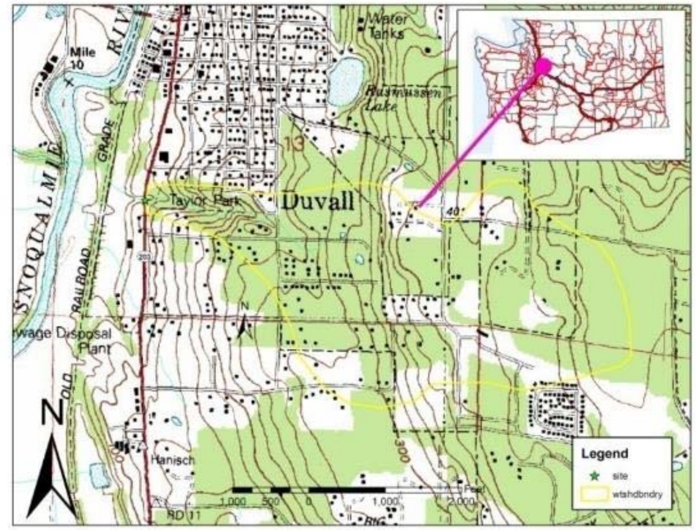
- Site & Reach Assessments
- Fluvial Geomorphic Processes
- Hydrologic Processes
- Large Woody Material (LWM)
- Streambank stabilization

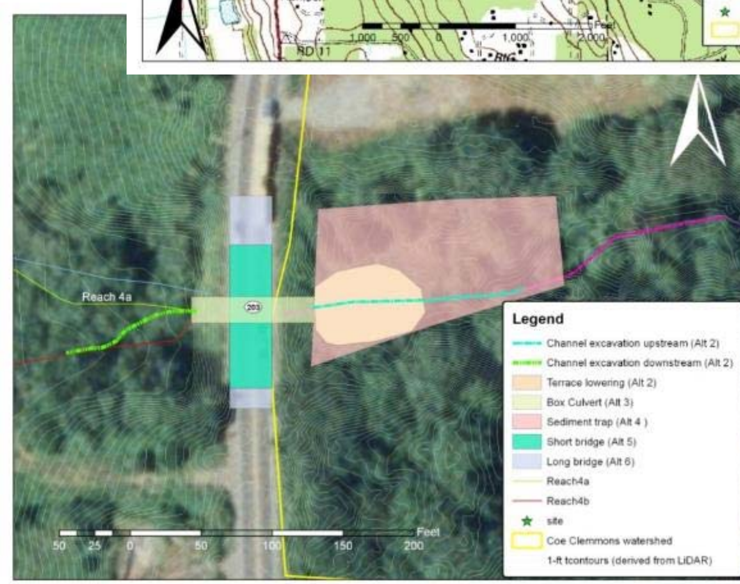
Site and Reach Assessments

- Provide background information for
  - Alternative selection
  - Permitting support
  - Conceptual Design
- Part of Preliminary Hydraulic Design (PHD)
- Foundational document for Chronic Environmental Deficiencies Program

Site and Reach Assessments

- Site vs. Reach
  - Site = highly local (e.g., bridge scour)
  - Contiguous stream segment with distinct characteristics = reach
    - Also refers to watershed contributing to reach
- Watershed based
  - Examine external drivers
  - Compounding factors
- Assessment = existing data
- Analysis = original work





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When to do a Site and Reach Assessment?

- When state infrastructure has been damaged or is threatened
- When problem site is in highly sensitive or contentious area
- To inform fish passage projects of watershed and site conditions
- Serves as common starting point for both design and permitting

Site/Reach Assessment Content

- Background – problem introduction
- Discussion of methods
- Site assessment
- Reach assessment
  - Land use/land cover
  - Geology & soils
  - Hydrology
  - Geomorphology
  - Riparian & large woody debris conditions
  - Fish and aquatic habitat

Site/Reach Assessment Content (cont'd)

- Causal mechanisms
- Alternative Considered
  - Comparison of treatments
  - Effectiveness – pros/cons
  - Habitat effects
  - Complexity
- Recommended Alternative

How are they done?

- Conducted by Hydrology Program & ESO biology staff
- Combined methods from
  - Federal Highways Administration (Hydraulic Engineering Circulars 18,20,& 23, (Level 1)
  - Interagency Streambank Protection Guidelines (ISPG)
  - WDFW's Stream Habitat Restoration Guidelines
  - WDNR's watershed analysis manual
- Duration -depending on the project, and field work, 3 weeks to 6 months

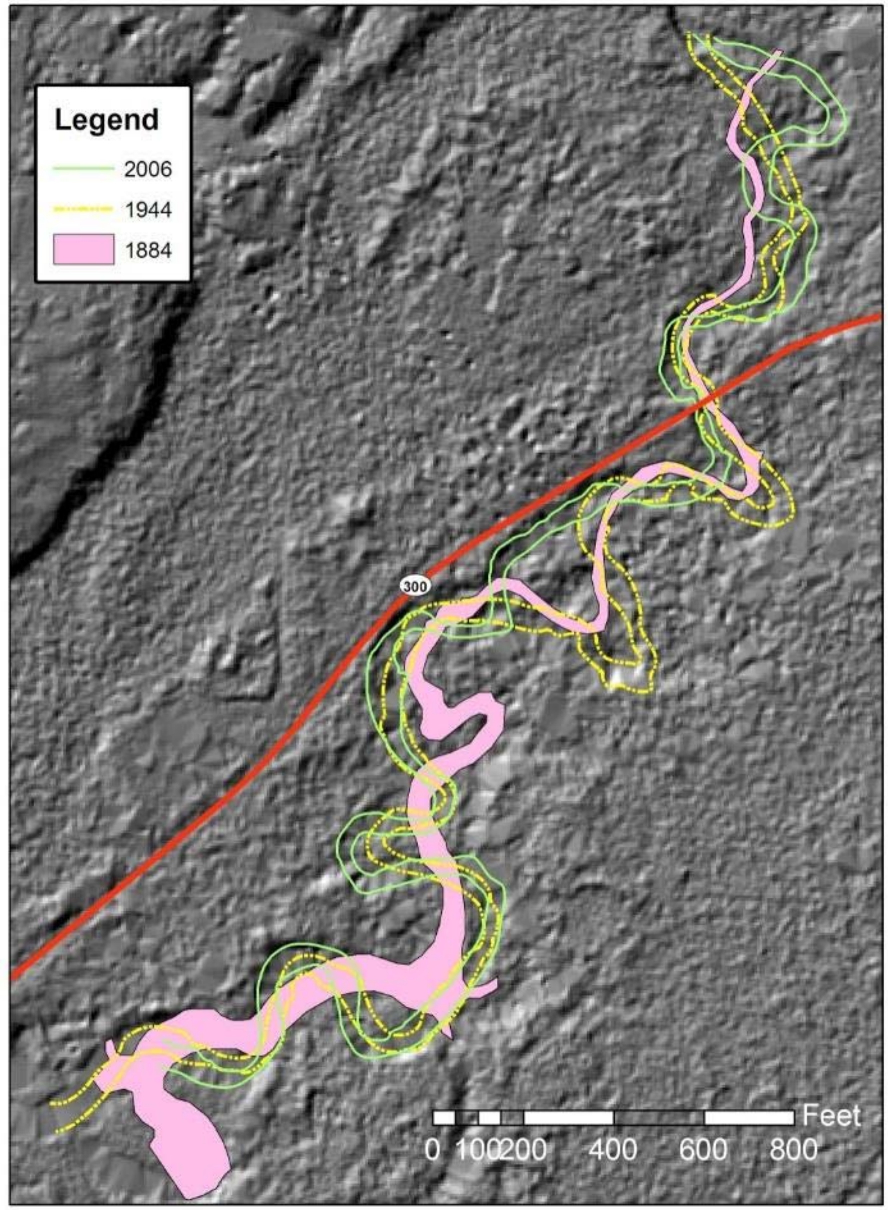
Existing literature review & data collection

- Library & historical research
- Engineering records
  - As-built drawings
  - Plans (sometimes include old topo)
- Bridge information system (BEIST)
- GIS layers
- Aerial photographs & historic surveys
- Drones

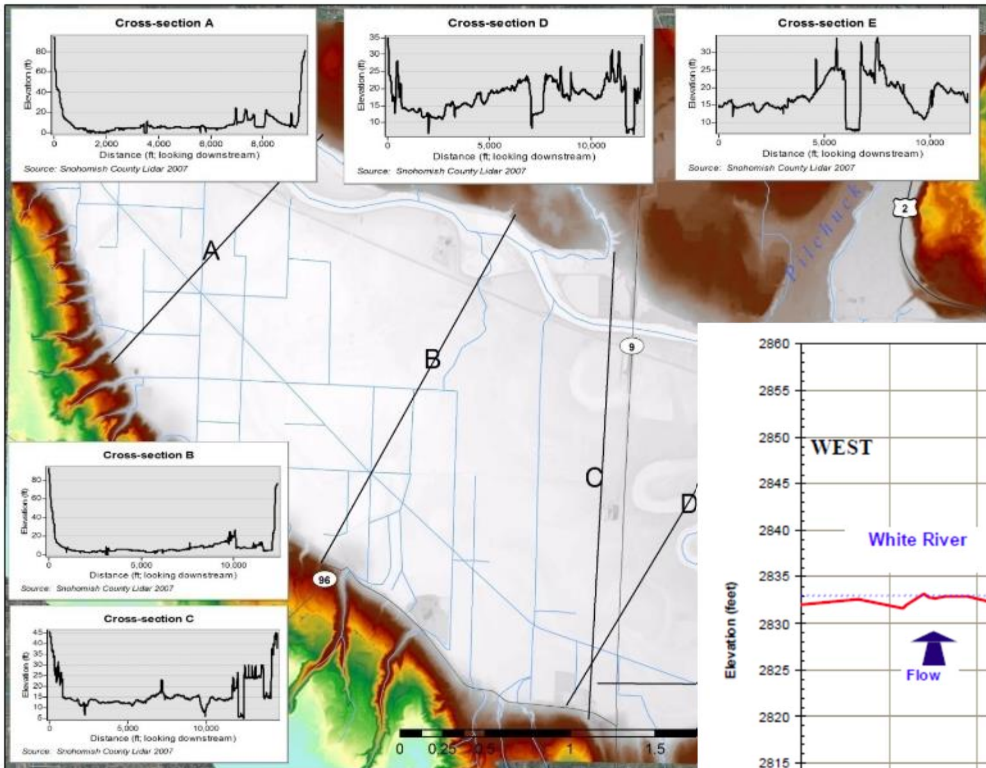
Types of Reach Assessment

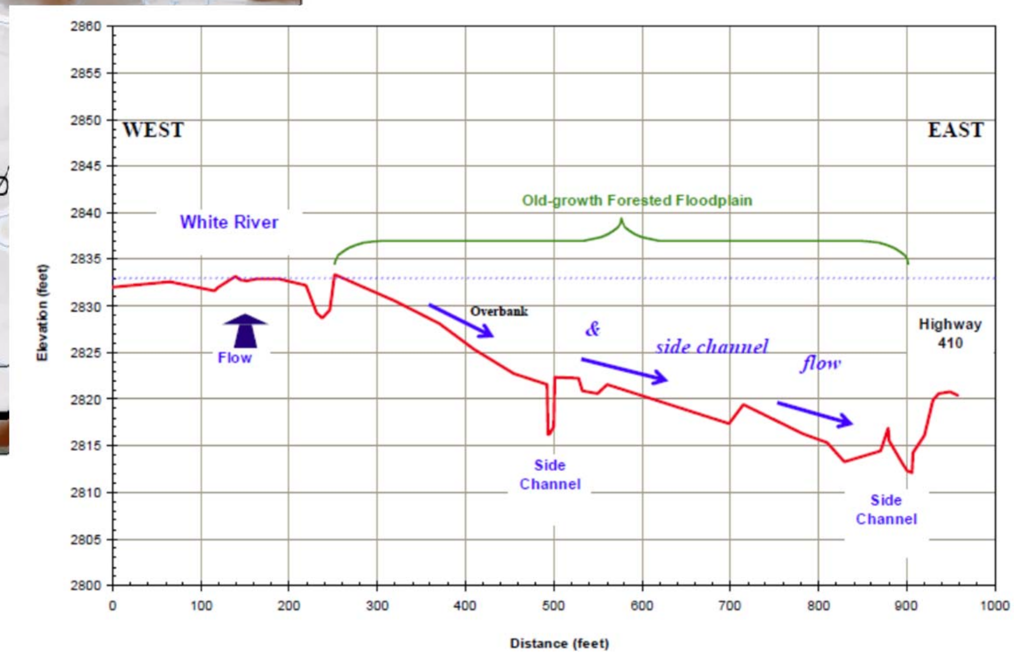
- Land use – change in pervious surfaces, canopy cover
- Geologic – landslide types and locations
- Geomorphic – channel form and type, channel migration, sediment transport, reconstruction of recent stream trends
- Hydrologic – peak flow analysis; trend in peak flows;
- Hydraulic – determining velocities, water surface elevation, shear stress
- Sediment transport (aggradation, degradation)

Channel migration zone analysis

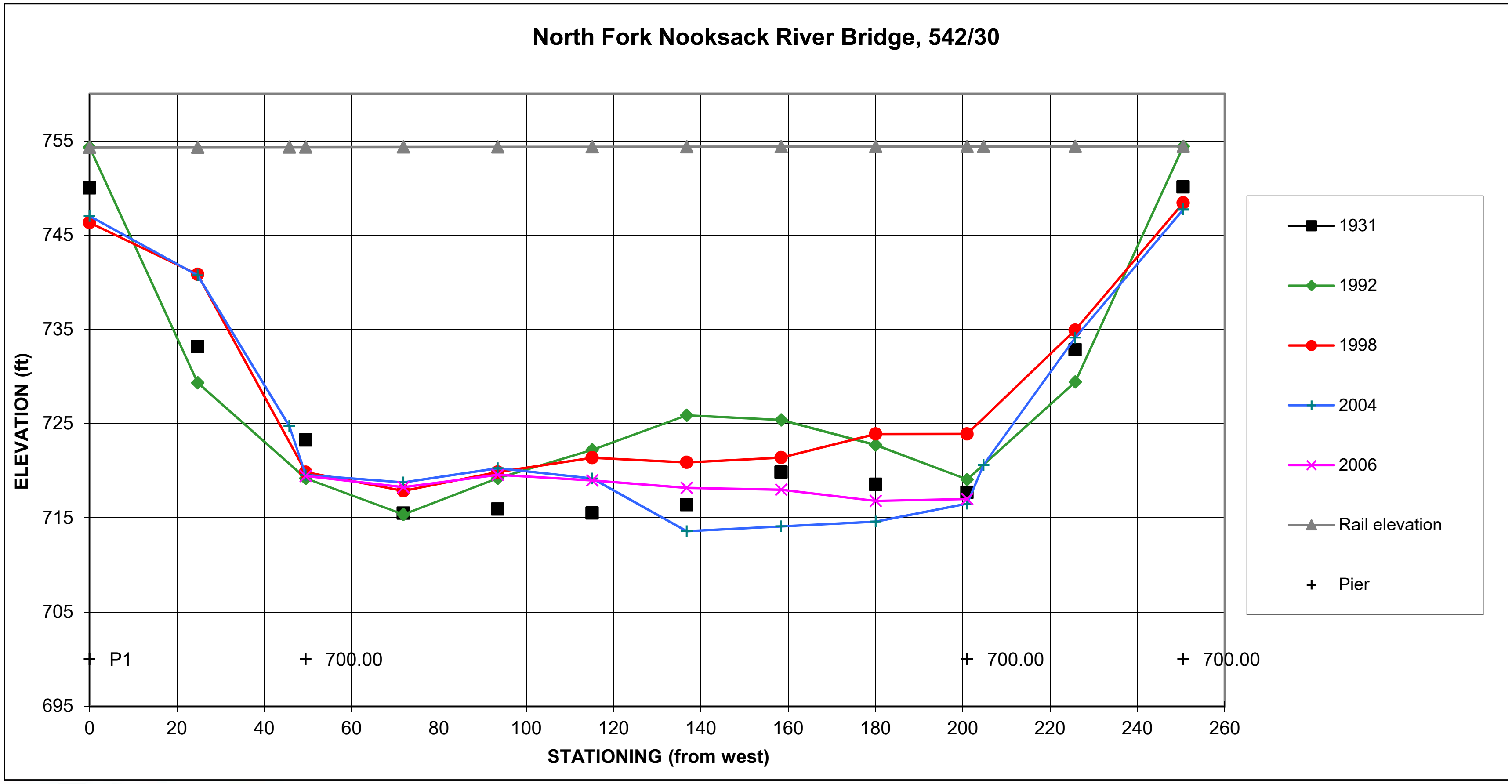


Topographic/geomorphic analysis

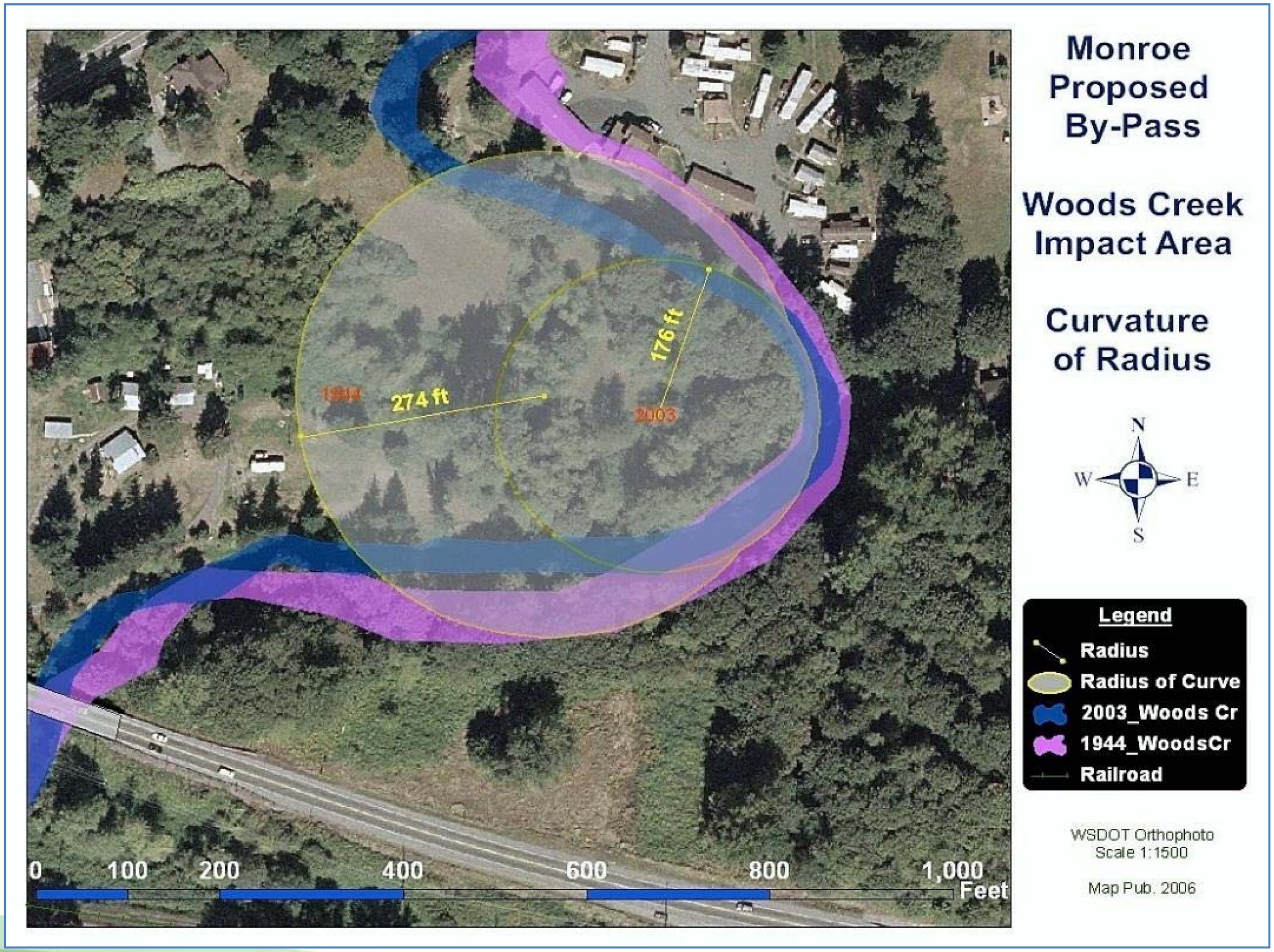




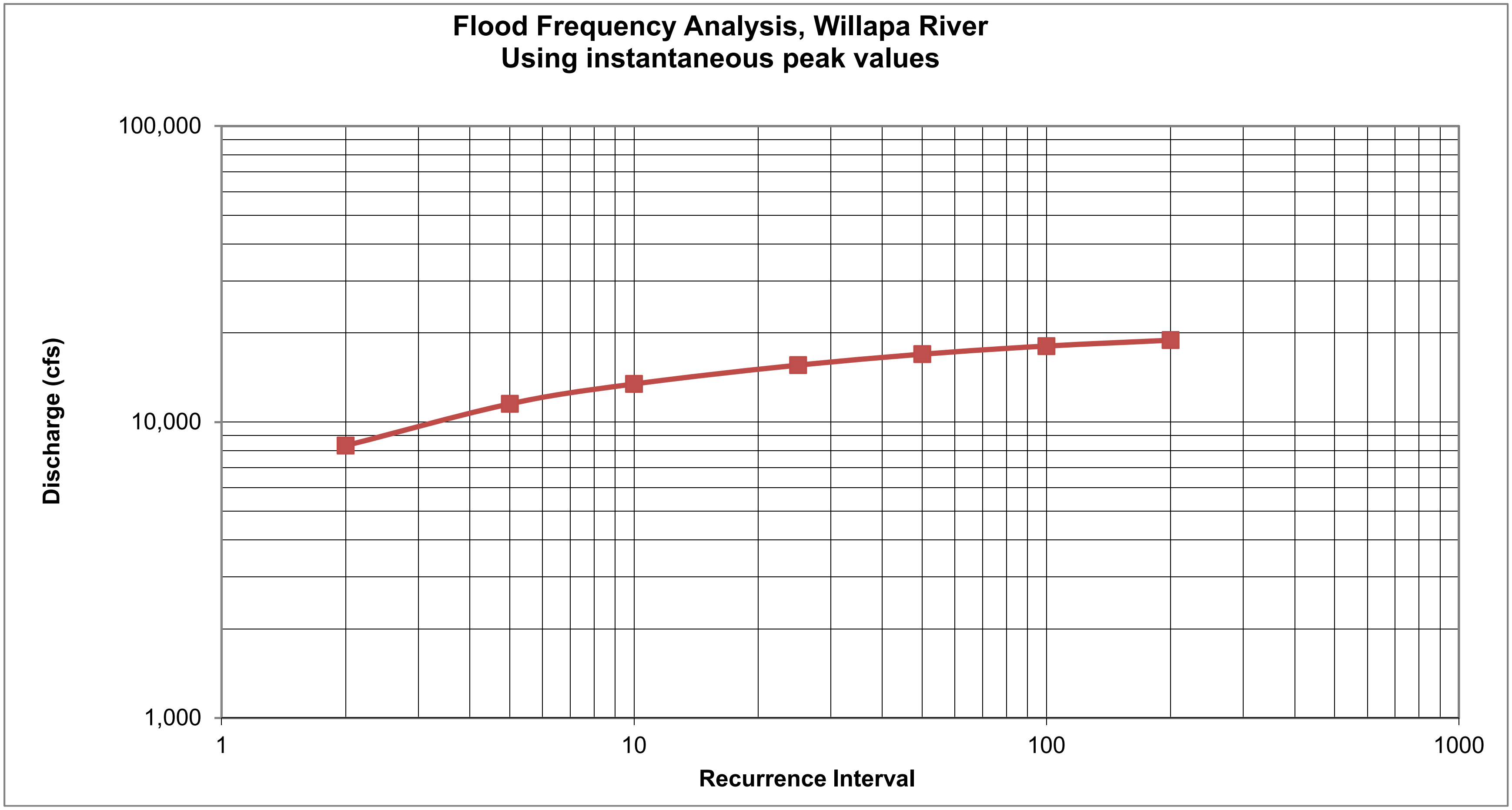
Historic cross-sections



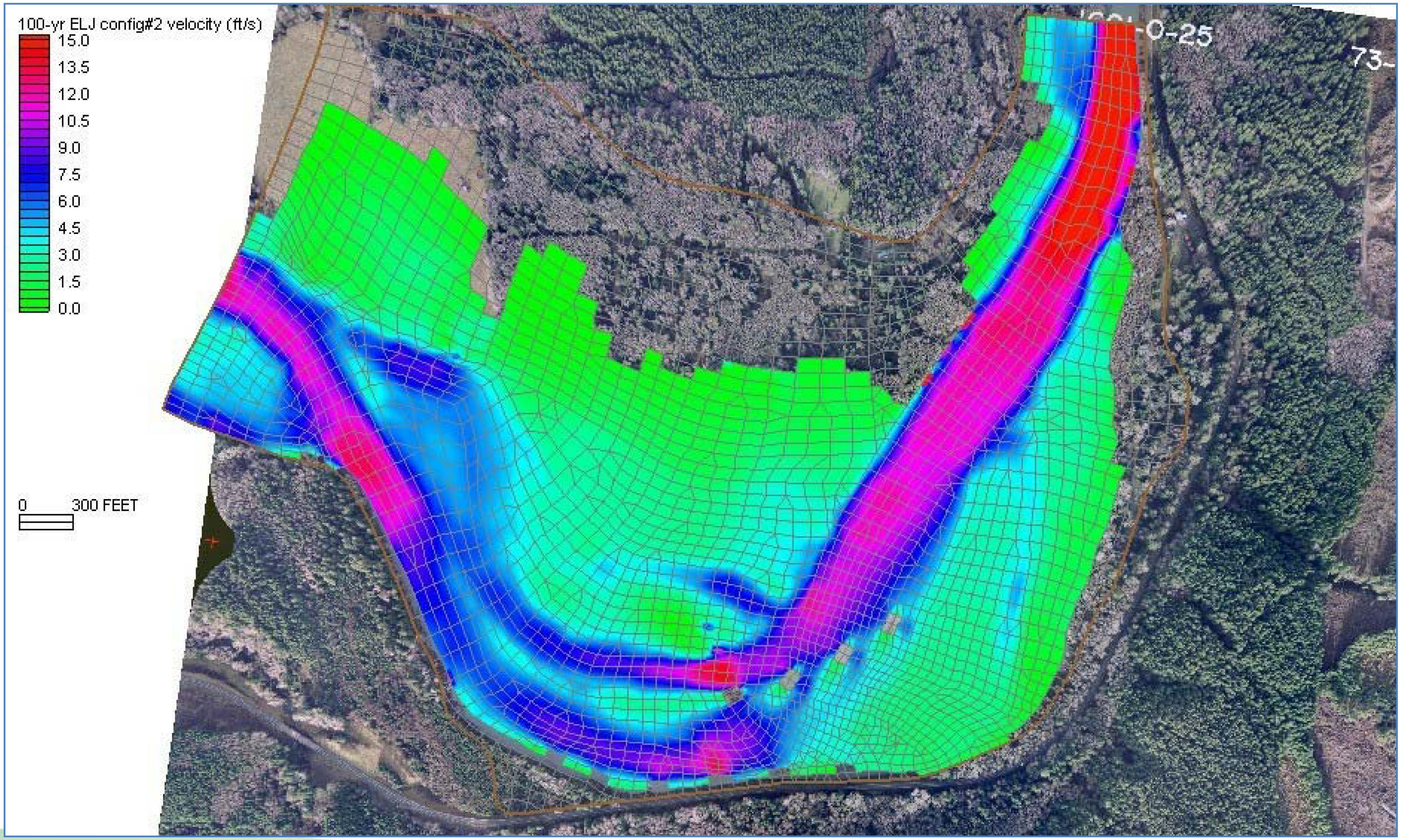
Forecasting change



Hydrologic analyses



Modeling velocity and erosion potential



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Developing sustainable solutions

- Determine causal mechanisms
  - Use evidence, judgment
  - Interdisciplinary effort
- Review potential solutions
  - Derived from WSDOT experience
  - Set of methods from ISPG & other manuals
  - Sometimes requires unique solution or adaption
  - Or no action..

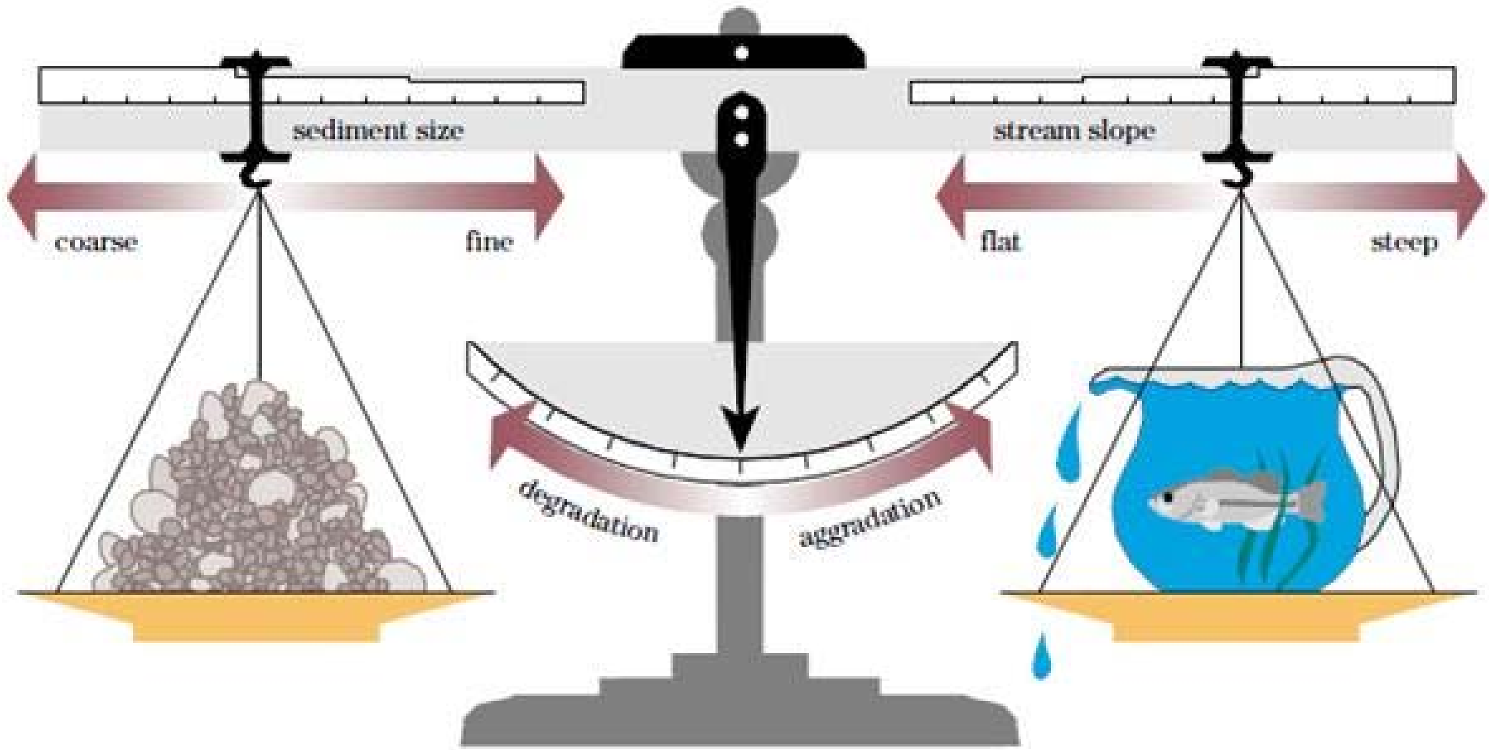
Fluvial Geomorphology

- Equilibrium
- Channel form
- Stream classification
- Erosion and deposition
- Sediment/water discharge balance
- Channel evolution and adjustment

Stream Stability and "Dynamic Equilibrium"

- Streams naturally move and change their shape
- Dynamic equilibrium -a stream can be “stable” even though its geometry may change over short spans of time
- Variation about an average = stability
- Unless the overall trend of a parameter such as gradient, begin to change

Lane's balance



$Q_s \bullet D_{50} \propto Q_w \bullet S$

From Rosgen (1996), from Lane, Proceedings, 1955.
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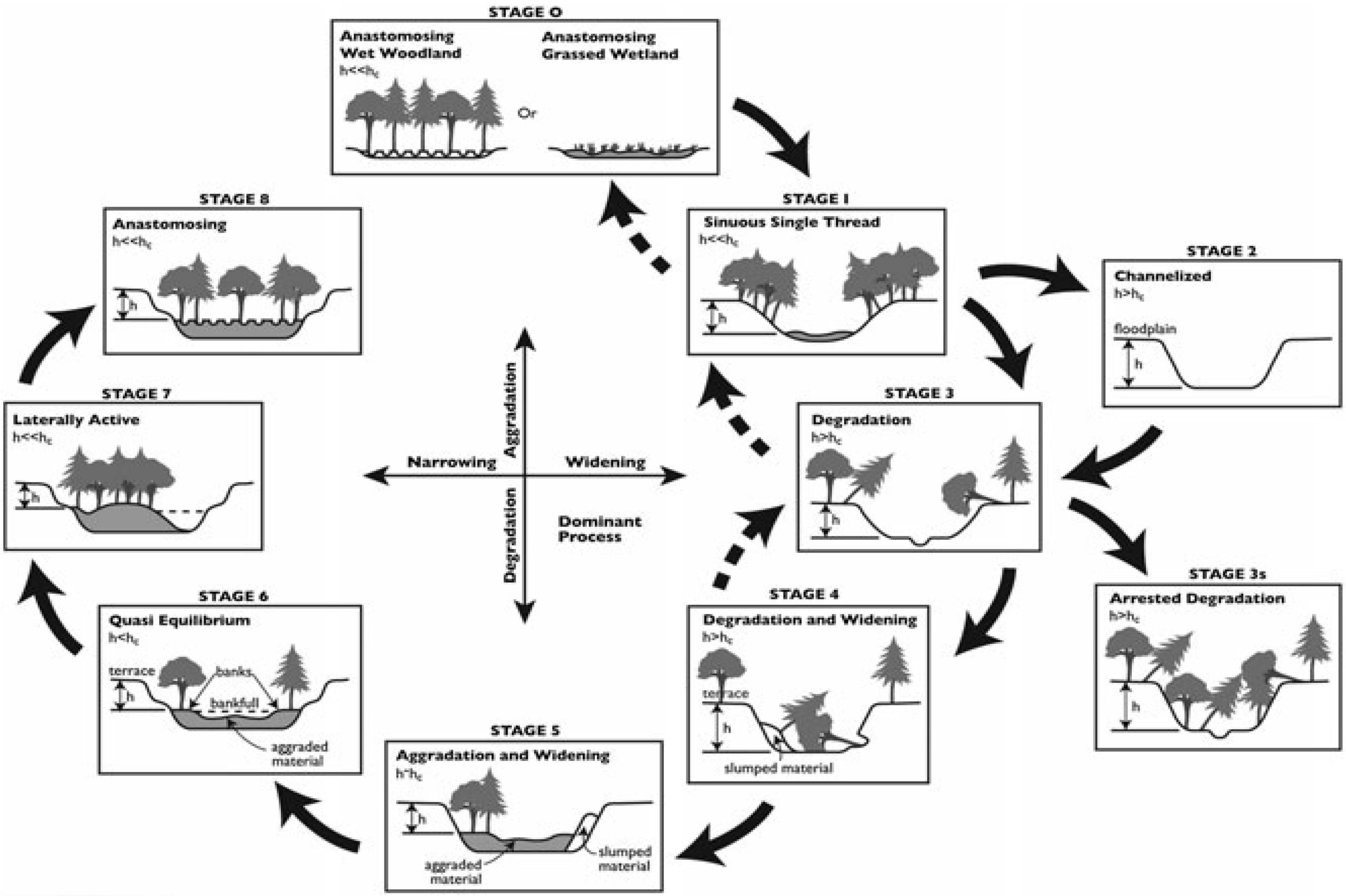
Channel adjustment

Aggradation and Degradation

- Used to describe contrasting processes that can occur when a stream becomes unstable.
- Stream gradients become steeper (aggradation) or less steep (degradation) due to excess deposition or erosion of sediment, respectively.
- often symptoms of a problem within the watershed,
- a stream may also aggrade or degrade very quickly if the problem is caused by a very large storm event or a localized disturbance

Channel evolution



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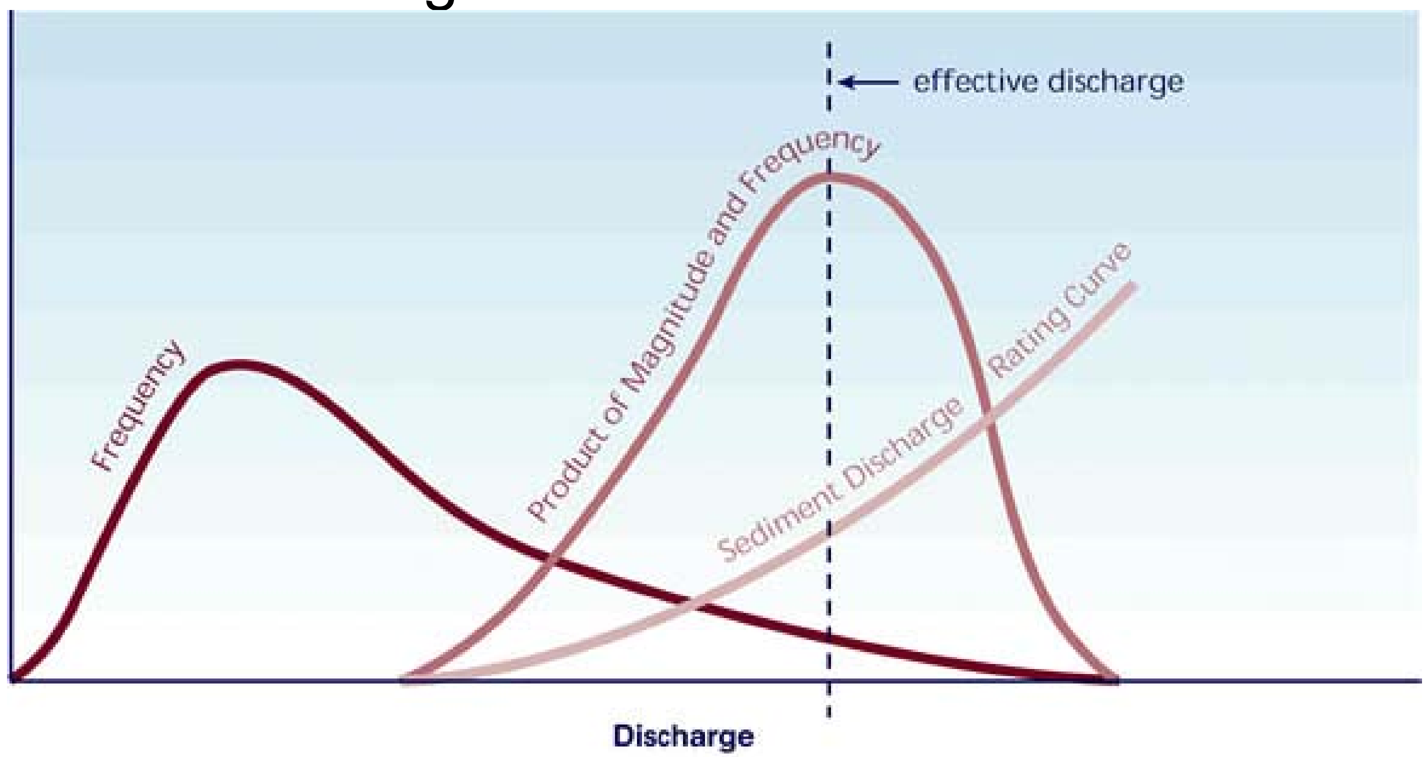
Bankfull Discharge

Bankfull (or "effective") discharge is the most efficient at doing work within the stream channel.

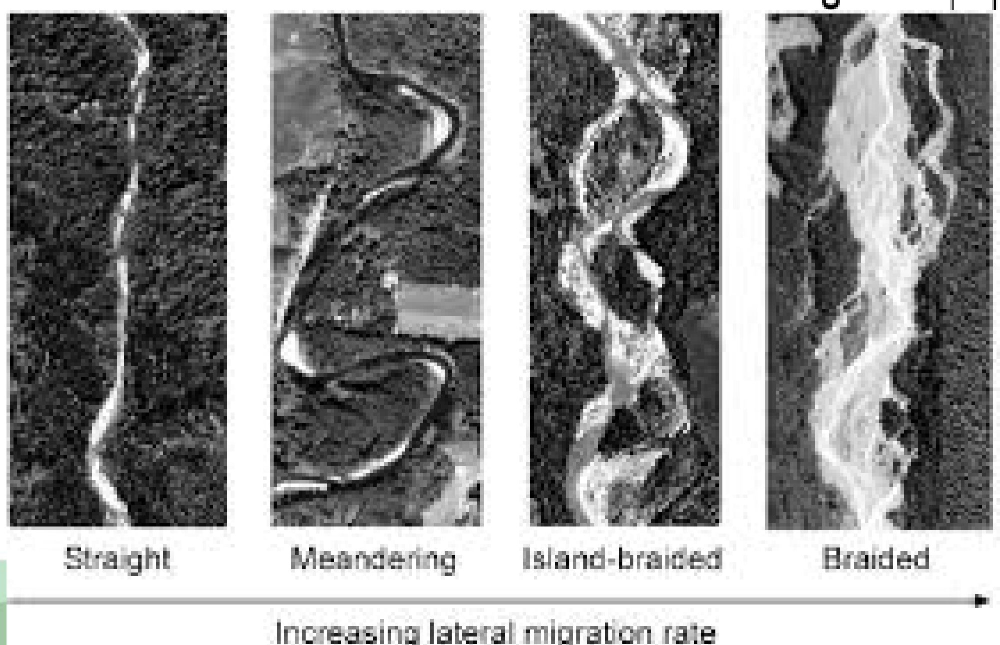


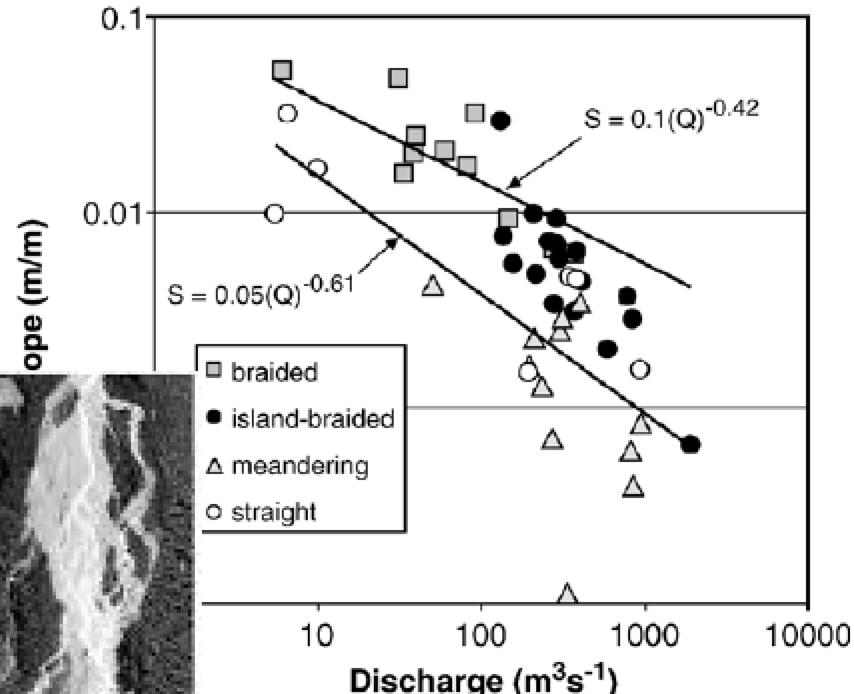
From Wolman and Miller, 1960.

Fig. 7.5 – Effective discharge determination from sediment rating and flow duration curves.
In Stream Corridor Restoration: Principles, Processes, and Practices, 10/98.
Interagency Stream Restoration Working Group (FISRWG)(15 Federal agencies of the US).

Channel forms

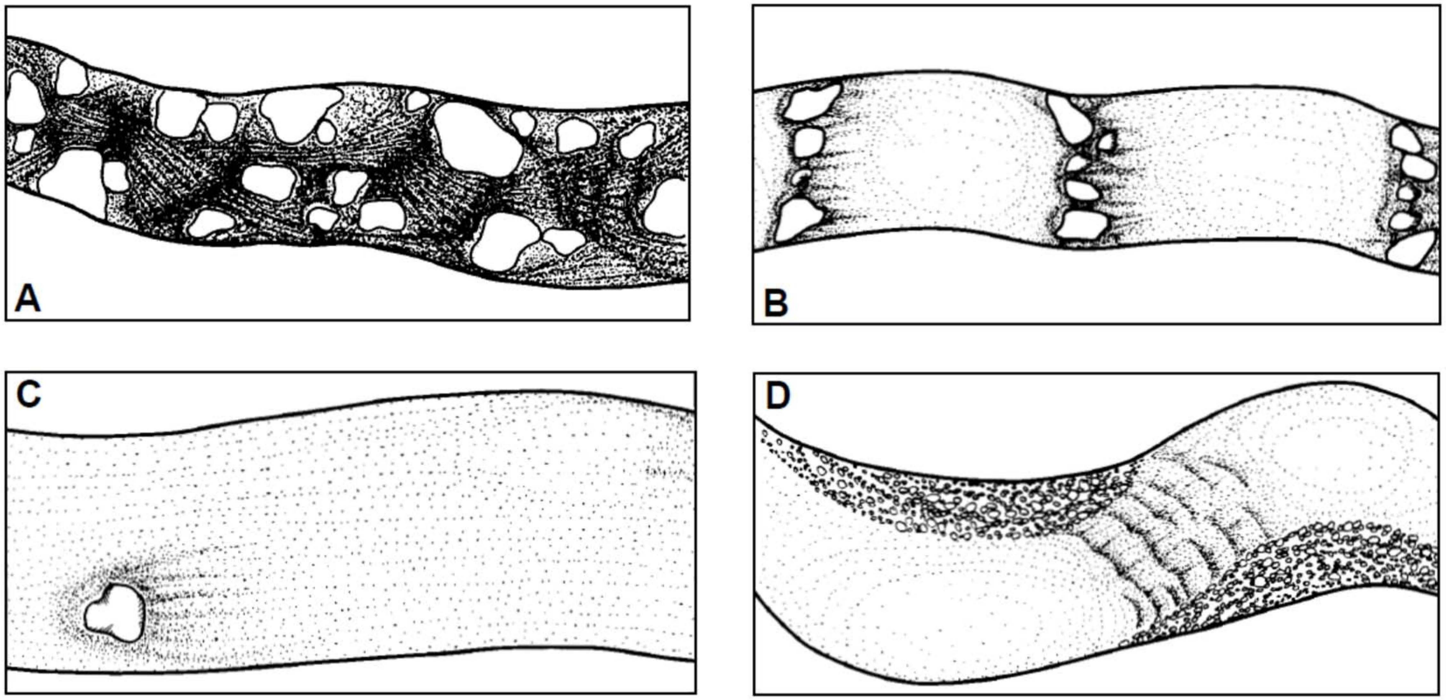
- Braided
- Anastomosing (island-braided))
- Meandering





Stream Classification

- Useful for having a common understanding of stream "character" – single thread streams
- Several different classification schemes (Rosgen most common)
- Northwest – Montgomery & Buffington



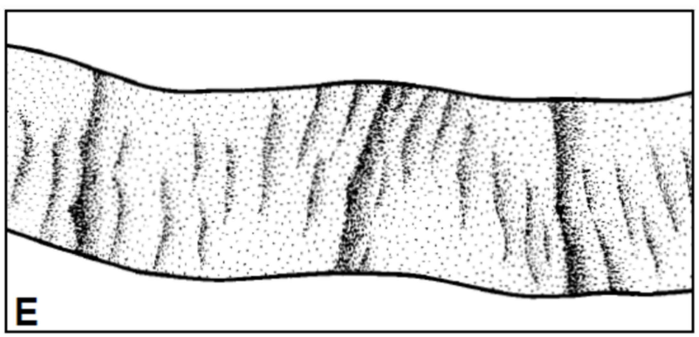


Figure 2. Schematic planform illustration of alluvial channel morphologies at low flow: (A) cascade channel showing nearly continuous, highly turbulent flow around large grains; (B) step-pool channel showing sequential highly turbulent flow over steps and more tranquil flow through intervening pools; (C) plane-bed channel showing single boulder protruding through otherwise uniform flow; (D) pool-riffle channel showing exposed bars, highly turbulent flow through riffles, and more tranquil flow through pools; and (E) dune-ripple channel showing dune and ripple forms as viewed through the flow.

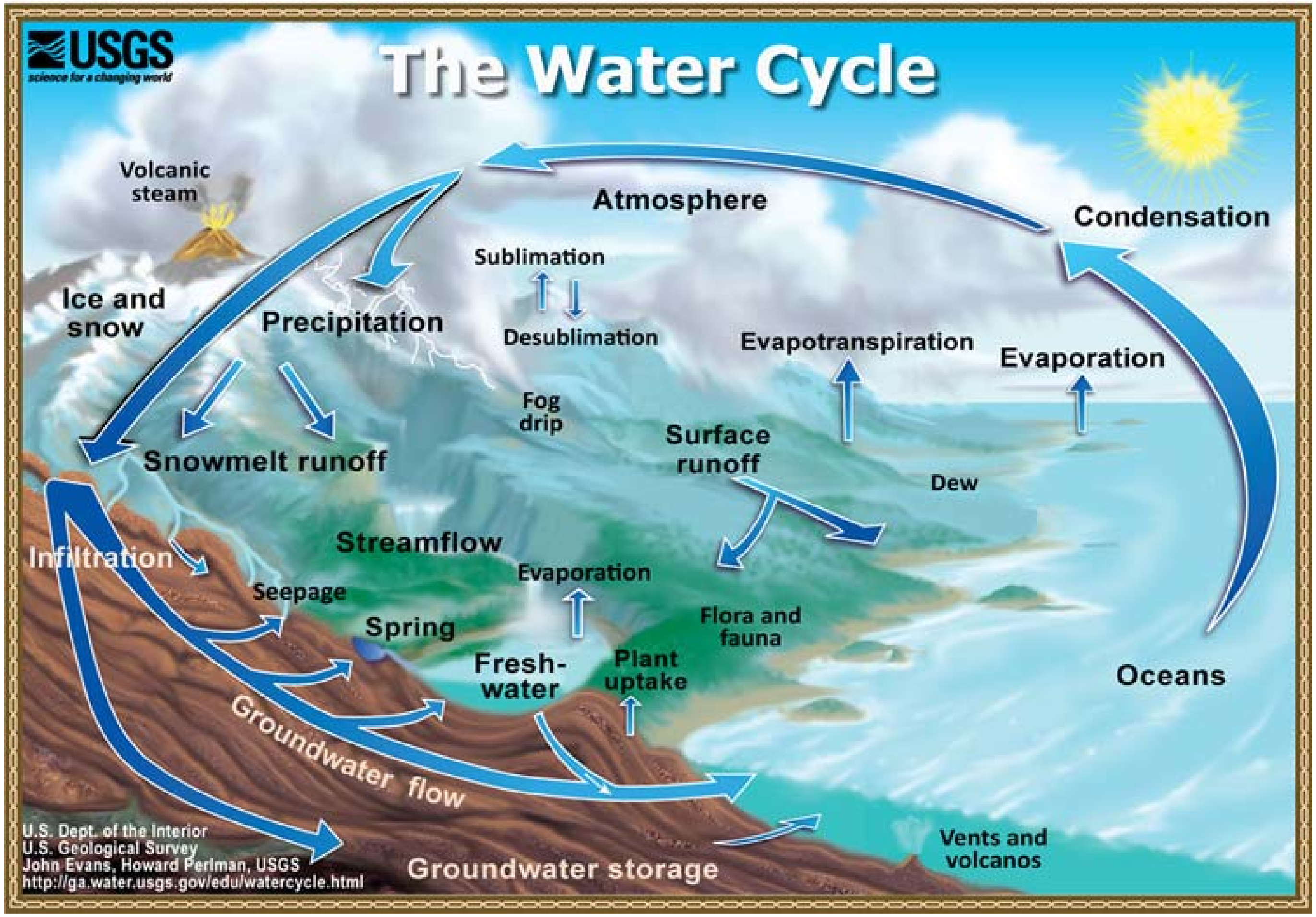
TABLE 1. DIAGNOSTIC FEATURES OF EACH CHANNEL TYPE

	Dune ripple	Pool riffle	Plane bed	Step pool	Cascade	Bedrock	Colluvial
Typical bed material	Sand	Gravel	Gravel-cobble	Cobble-boulder	Boulder	Rock	Variable
Bedform pattern	Multilayered	Laterally oscillatory	Featureless	Vertically oscillatory	Random	Irregular	Variable
Dominant roughness elements	Sinuosity, bedforms (dunes, ripples, bars) grains, banks	Bedforms (bars, pools), grains, sinuosity, banks	Grains, banks	Bedforms (steps, pools), grains, banks	Grains, banks	Boundaries (bed and banks)	Grains
Dominant sediment sources	Fluvial, bank failure	Fluvial, bank failure	Fluvial, bank failure, debris flows	Fluvial, hillslope, debris flows	Fluvial, hillslope, debris flows	Fluvial, hillslope, debris flows	Hillslope, debris flows
Sediment storage elements	Overbank, bedforms	Overbank, bedforms	Overbank	Bedforms	Lee and stoss sides of flow obstructions	Pockets	Bed
Typical confinement	Unconfined	Unconfined	Variable	Confined	Confined	Confined	Confined
Typical pool spacing (channel widths)	5 to 7	5 to 7	None	1 to 4	<1	Variable	Unknown

Hydrologic Processes

- The hydrologic cycle
- Types of runoff
- Hydrologic prediction

The hydrologic cycle



Hydrologic prediction

- Usually we are most concerned with runoff
  - Design flood (typically Q100)
    - Water surface elevation
    - Shear stress
  - Low flow
  - Channel-forming flow

Methods used to predict runoff

- Stream gage records
  - USGS, Ecology, County, other local groups
  - At least 10 years' worth of data necessary
  - Mindful of stationarity
    - Most long term gages in Washington have shown increases in peak flow in last 30 yr.
- Modeling
  - Equation
  - Computer

Methods used to predict runoff - models

- Drainage area ratios – use with caution

$$Q_{ungaged} = Q_{gaged}*(A_{ungaged}/A_{gaged})$$

Must be nearby, similar geology, elevation, etc.

- Computer Models – HSPF, MGSflood, WWHM, etc

Large Woody Material

What is it?

-Generally greater than 6 feet in length, and greater than 6” diameter (DBH = diameter at breast height)

Why are we discussing it?

– Bank protection
– Aquatic habitat benefits
– Required by partnering entities

Basis of WSDOT policy

- Hydraulic Section oversight of regions & project offices
- Consistent application of principles of safety and design stability agency-wide

LWM objectives

- LWM should address the threat of erosion – often in newly formed topography
- LWM should provide habitat and habitat critical functions that address anticipated deficiencies in a project reach
- LWM projects should be in harmony with anticipated stream behavior
- Effects on safe recreation are minimized

Steps in the design process

1. Determine project objectives
2. Conduct a Site and Reach Assessment
3. Conduct a Water Safety Assessment
4. Determine LWM structure designs and placements
5. Incorporate LWM structures in hydraulic model (implicitly or explicitly)
6. Run stability calculations
7. Adjust anchor design (if needed)

Determine Project Objectives

- Habitat?
- Stability/counter-erosion?
- Both?

Conduct a Reach Assessment

- Evaluate riparian conditions
  - How is wood currently functioning in the channel?
  - Is the stream lacking wood? If so, why?
- Is it an alluvial or bedrock channel?
- Is the channel confined?
- What is the channel gradient?
  - generally we place wood in channels <2%
  - up to 5%(?)
- Contribution of LWM to stream function, stability

Water Safety Assessment

- Which streams are "recreational?"
  - Wild and Scenic rivers.
  - Navigable waters designated by the U. S. Coast Guard.
  - Rivers and streams within State Parks, and the National Park system.
  - All water bodies known to local law enforcement, fire departments, or river rescue organizations to receive recreational use.
  - Streams greater than 30 feet in bankfull width.

Water Safety Assessment (cont'd)

- Would LWM create unacceptable or unmitigatable risk to the public?
- Place where there is visibility from upstream
- Don't design or place in a situation that prevents circumnavigation
- Design to prevent "straining"
- Don't place near boat ramps or other access points
- Consider signage on a case-by-case basis
- Public involvement/notification may be needed

Determine LWM structure designs and placements

- Design for the identified objective(s)
- Incorporate diversity of structure, where possible
- For habitat, generally use key pieces as indicator – about 3.3 pieces/100’ of stream

For habitat - Target Wood Loading

Piece numbers and volumes (per 100m)

Region	BFW Class	75^{th} Percentile	Median	25^{th} Percentile
		Number of Pieces		
Western Washington	0-6 m	>38	29	<26
	>6–30 m	>63	52	<29
	>30–100 m	>208	106	<57
Alpine	0–3 m	>28	22	<15
	>3–30 m	>56	35	<25
	>30–50 m	>63	34	<22
[1]DF–PP forest zone	0–6 m	>29	15	<5
	>6–30 m	>35	17	<5
		Volume (m^3)		
Western Washington	0–30 m	>99	51	<28
	>30–100 m	>317	93	<44
Alpine	0–3 m	>10	8	<3
	>3–50 m	>30	18	<11
[1]DF–PP forest zone	0–30 m	>15	7	<2
		Number of key pieces		
Western Washington	0–10 m	>11	6	<4
	>10–100 m	>4	1.3	<1
Alpine	0–15 m	>4	2	<0.5
	>15–50 m	>1	0.3	<0.5
DF–PP forest zone	0–30 m	>2	0.4	<0.5

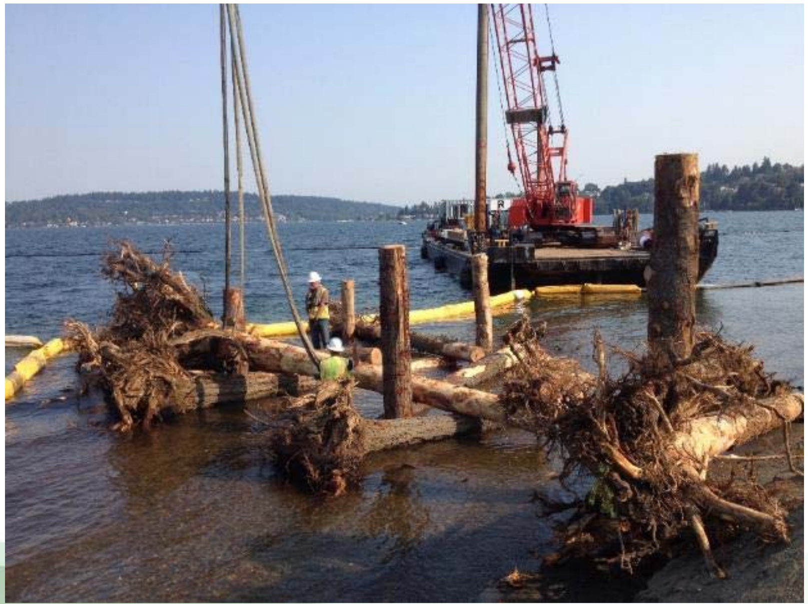
From Fox and Bolton (2007)

Incorporate LWM structures in hydraulic model (implicit or explicitly)

- Determine effects on:
  - Water surface elevation
  - Velocity near culvert
  - Shear stress on bed and opposite bank
- Determine adjustments in design or other design elements needed

Conduct stability calculations

- Determine minimum anchor strength for acceptable Factor of Safety
  - Avoid artificial anchors, if possible
- Determine anchor style based on site conditions



Factors of Safety to account for design risk and uncertainty

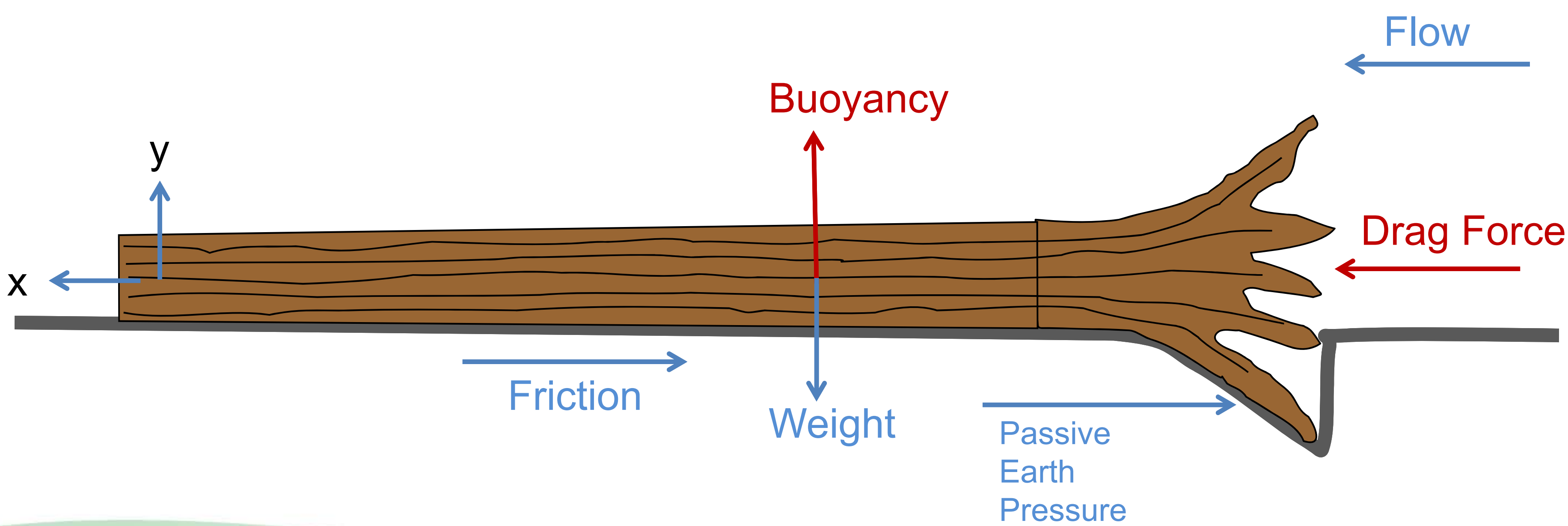
- Factor of Safety = Resisting Forces/Driving Forces
- Fs of 1.0 means marginal stability.
- Goal of Fs >1.5
- Fs of at least 2.0 near infrastructure to account for uncertainty and risk.

When is LWM not appropriate?

- Under a low bridge
- In a culvert
- Where debris flows might be expected
- Very steep streams
- Rapidly aggrading or degrading streams

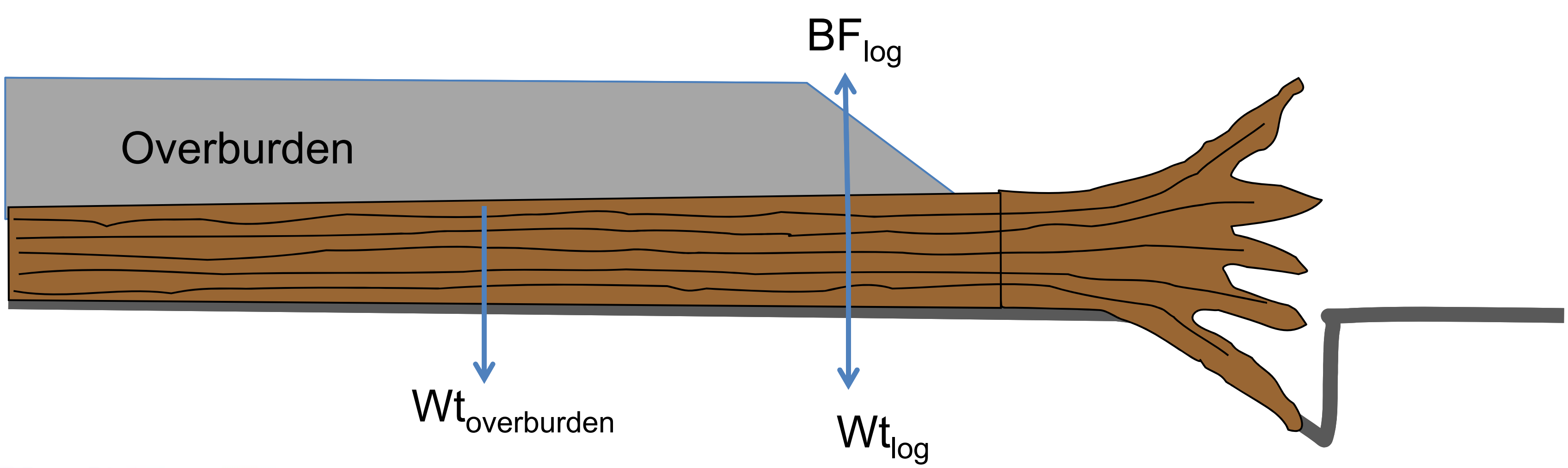
Force Balance on a Log on the Streambed

- Log is stable if resisting forces are greater than driving forces
- Analyze balance of forces in the vertical and horizontal directions
- Also look at where forces act to see if they could turn the log (Moments Balance)



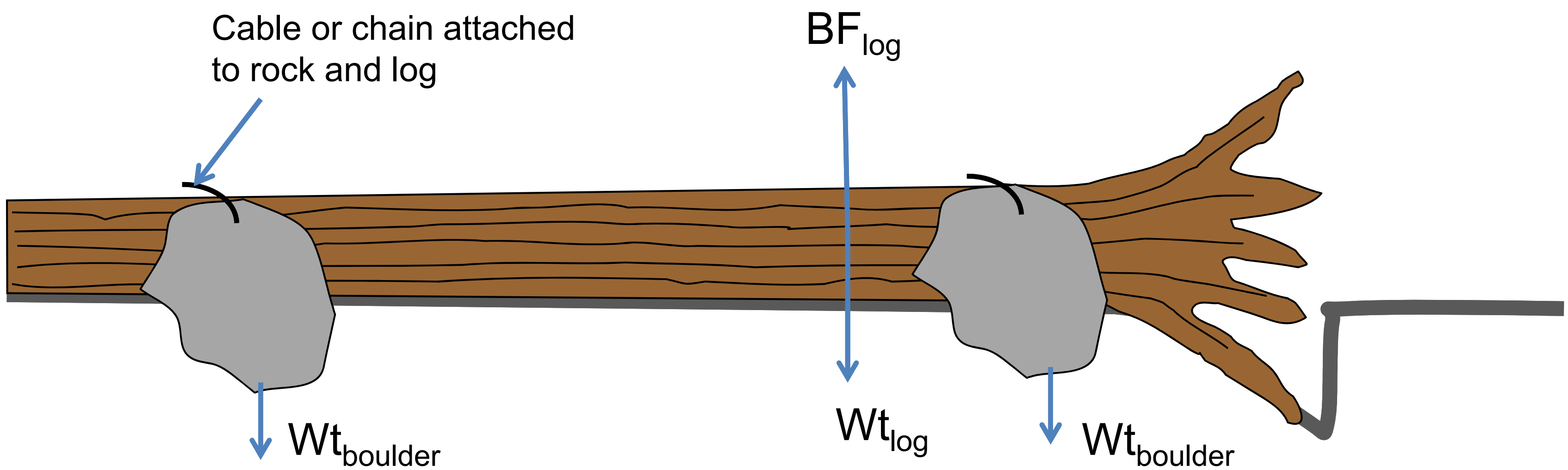
Anchoring by Burial

- Buoyant forces resisted by weight of overburden (rocks, soil, slash)
- Risks: insufficient overburden, flanking by bank erosion. General guideline is to bury at least 2/3 of the log length.



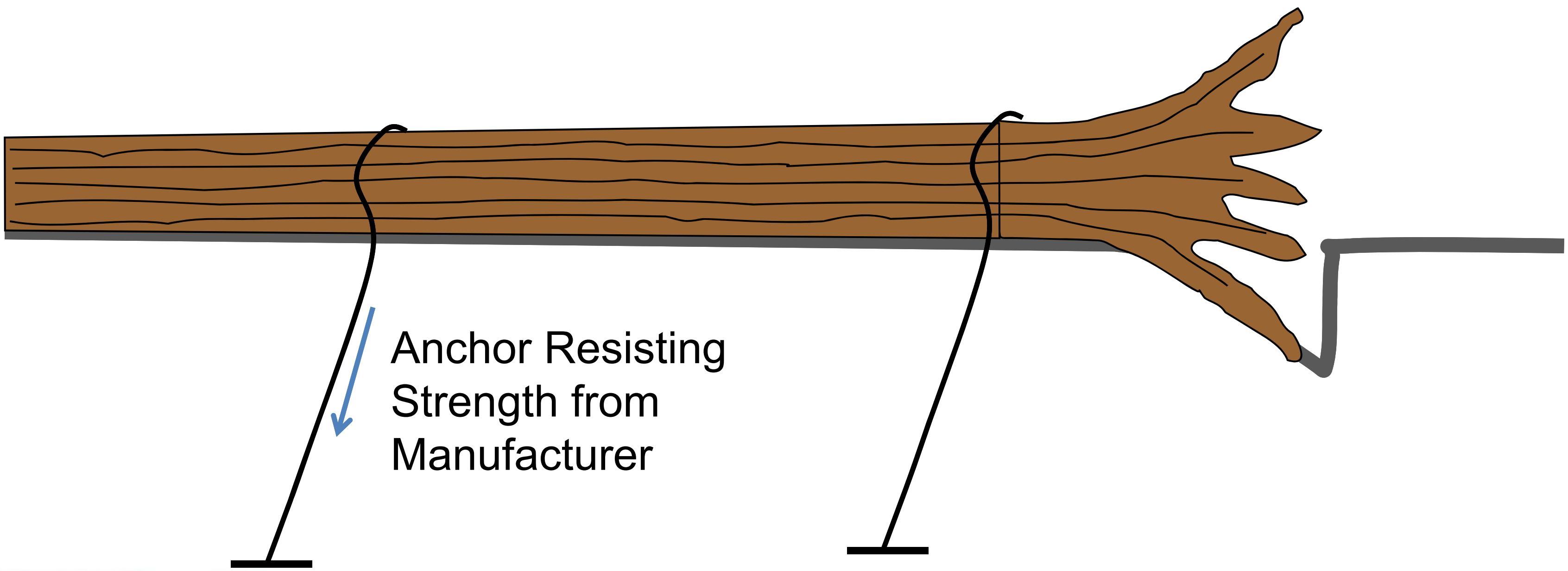
Anchoring with Boulders

- Buoyancy and drag resisted by weight of boulders
- Attach boulders with chains or cable
- Risks: failure of cable attachments (slack in cable)
- Benefits: as scour happens, structure can settle as a unit



Earth Anchors

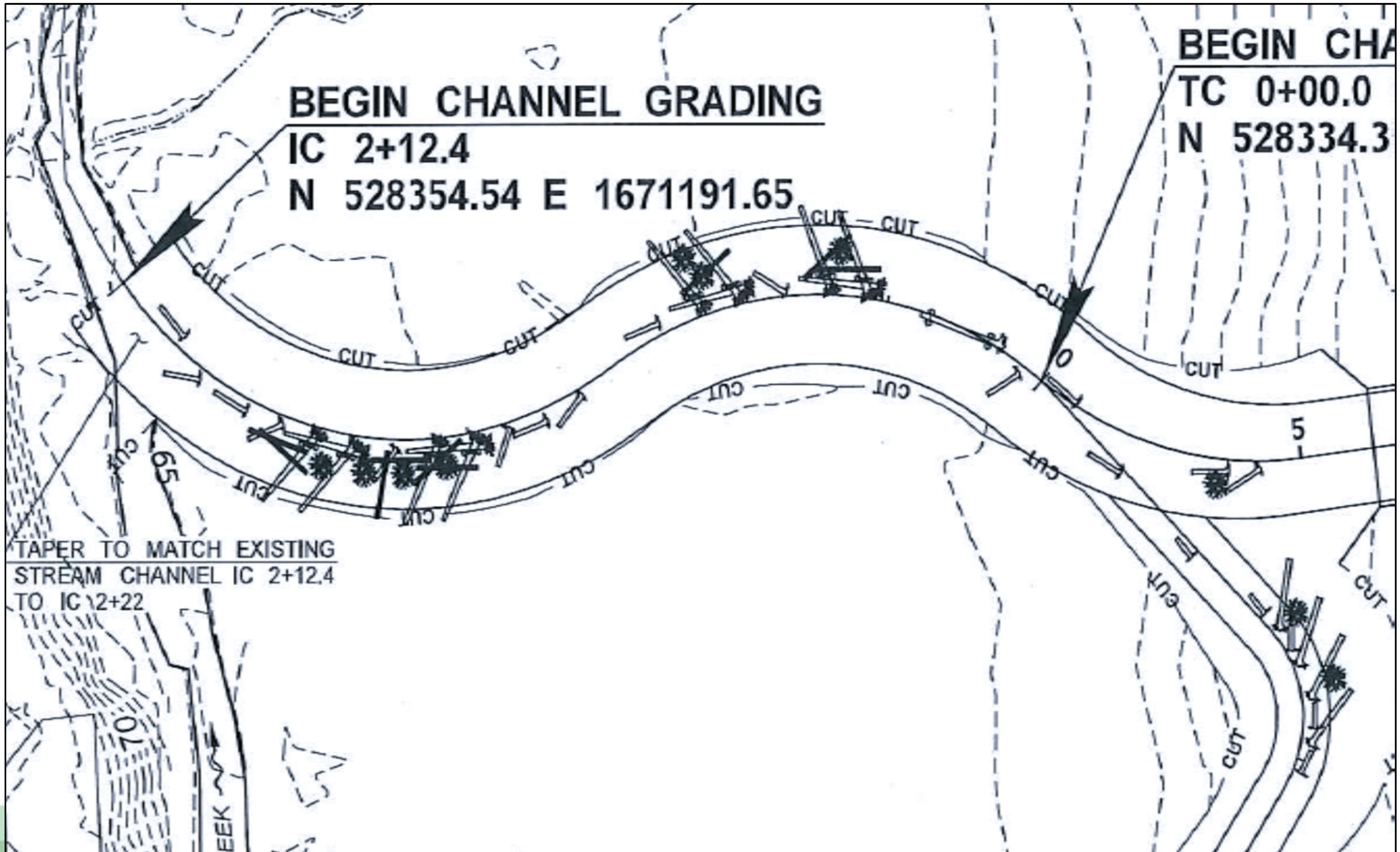
- Buried anchors sized based on sediment type and magnitude of forces
- Risks: dislodgement by flexing, poor performance in loose alluvium, difficult to install in boulder substrate, failed cables can be a safety hazard



LWM Examples - Habitat

LWM Examples – Multi-log

NF Issaquah Creek 2017



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LWM Examples – Engineered Log Jams

LWM Examples – Self-ballasted

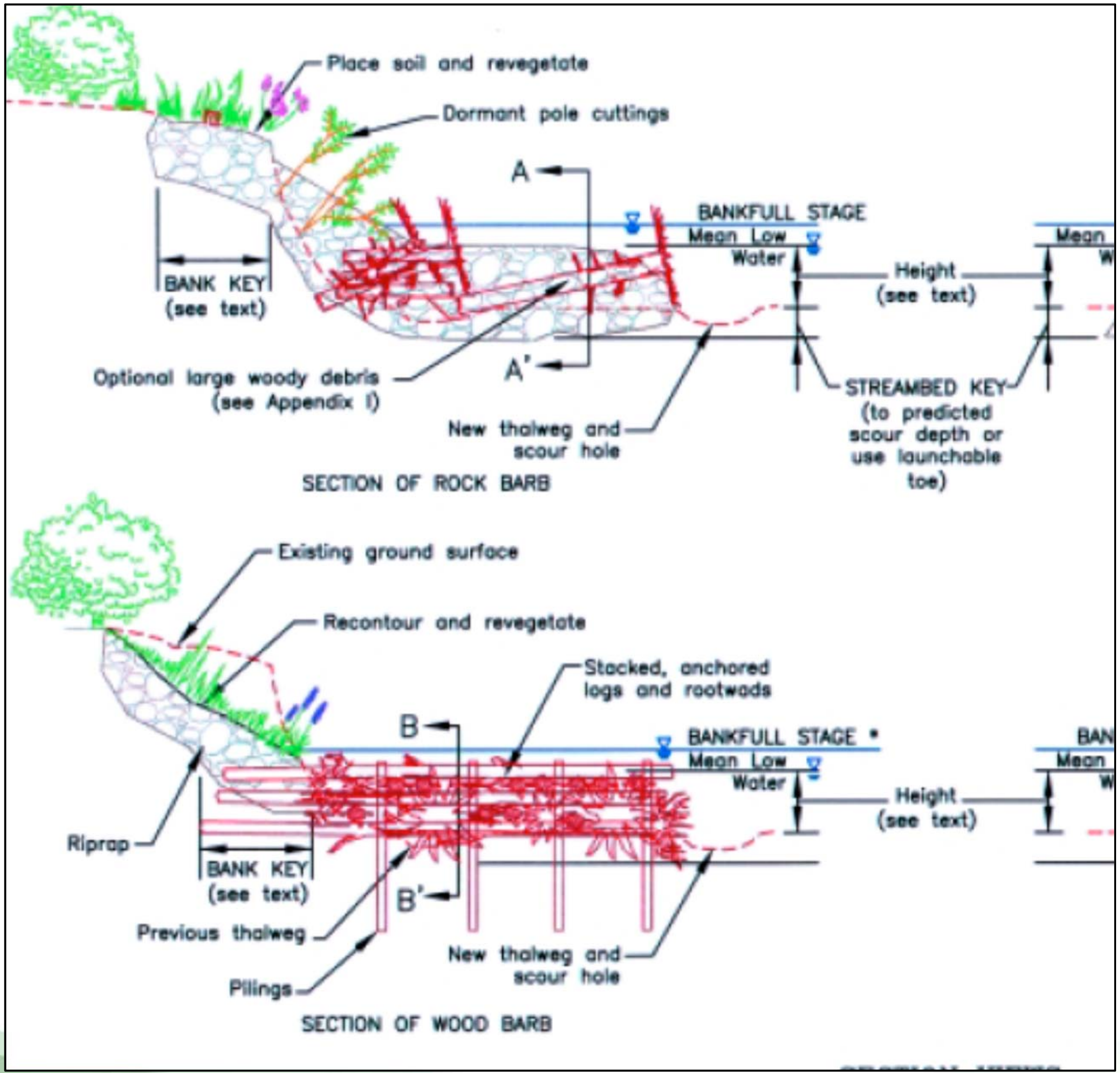
LWM Inspection/Maintenance

- After 1 year or first significant flood event, which ever is sooner
- After 5 years
- After 10 years
  - assess condition of wood
  - assess potential recruitment of wood
  - assess re-vegetation
  - assess need for repair, replacement, or additional monitoring

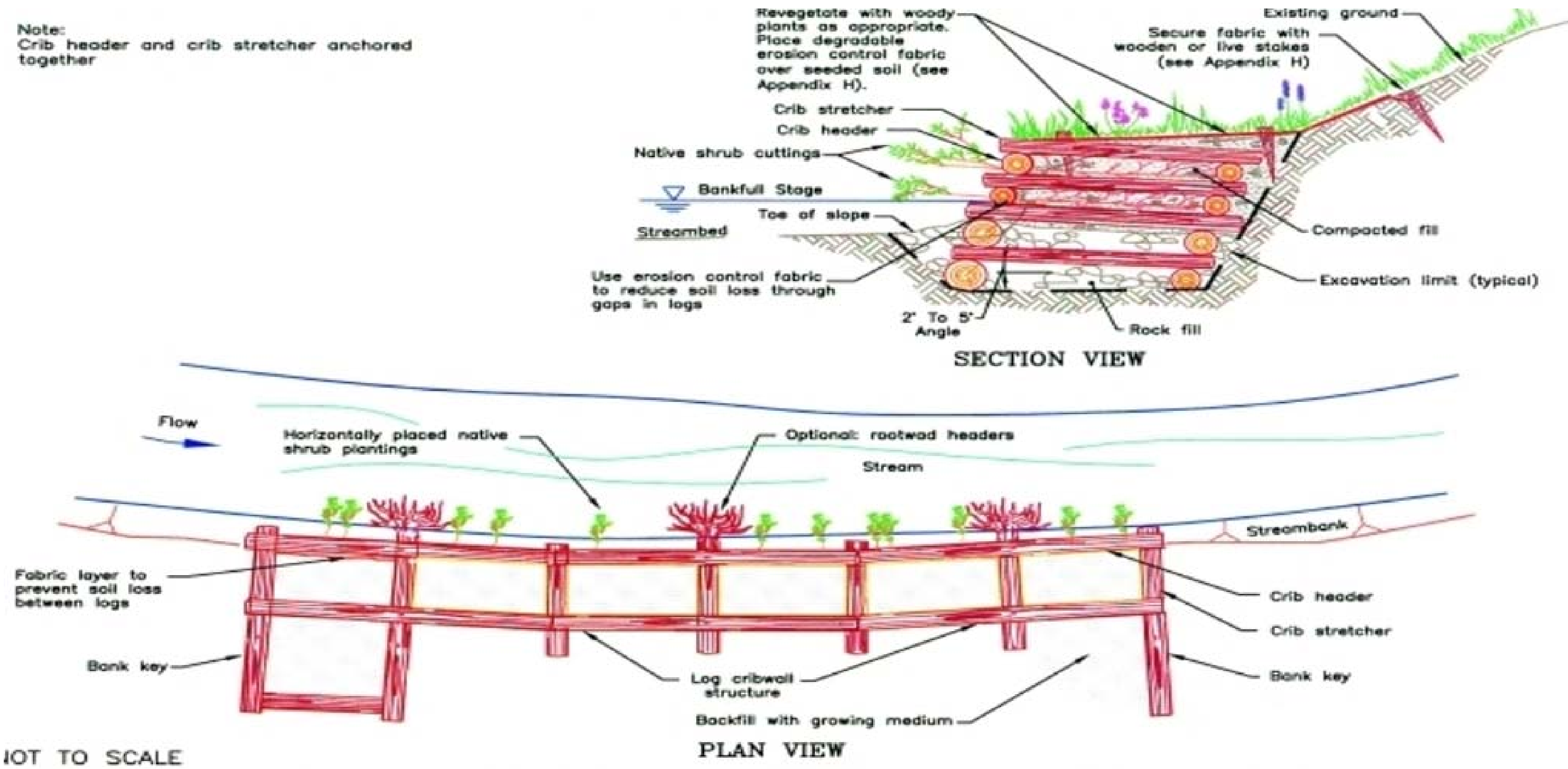
Streambank stabilization

- Wide range of options available for various situations
- Habitat requirements necessitate
- Complete reach assessment
- Gain understanding of causal mechanisms

Barbs with wood

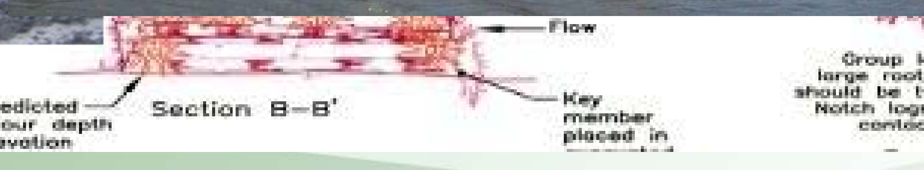


Log Crib Walls

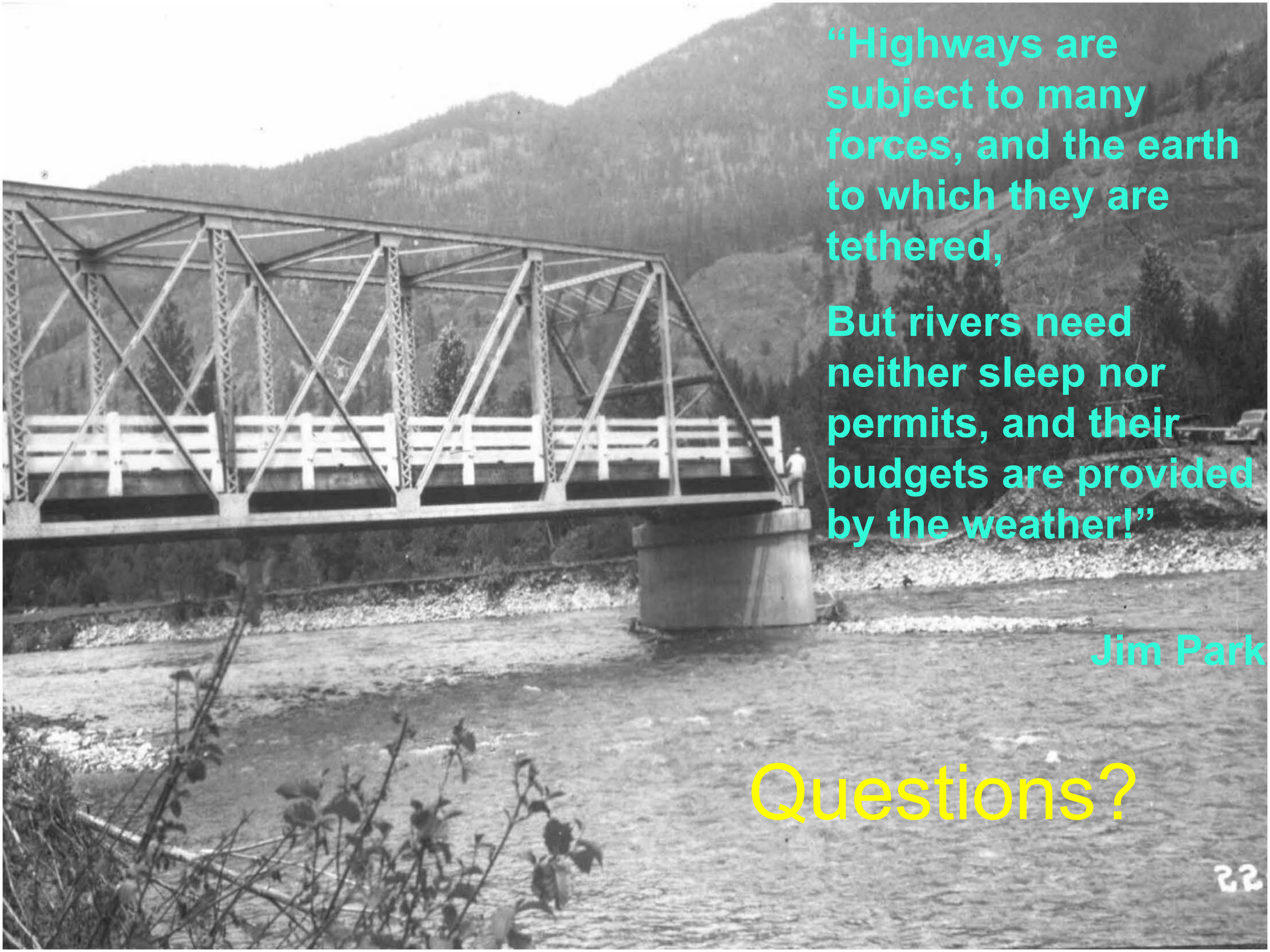


Rock revetment with Log Toes

Engineered Log Jams (ELJs)



Dolotimbers


"Highways are subject to many forces, and the earth to which they are tethered,
But rivers need neither sleep nor permits, and their budgets are provided by the weather!"
Jim Park
Questions?
22