2022 Fish Passage and Stream Restoration Design Training

Module 11: Large Woody Material and other Habitat Features

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Current duties: Oversees hydrology program support of Chronic Environmental Deficiencies and Fish Passage Programs. Develops Large Wood policy and reviews implementation. Provides technical support to emergency actions. Designs nature-based shoreline stabilization in marine and freshwater. NCHRP panel support.

Background & Experience: Garrett's experience includes 30 years of theoretical and applied hydrology and geomorphology throughout the western United States and overseas. His work includes stream restoration, geomorphic reach assessments, streambank stabilization, wetland mitigation, geologic hazard evaluation, sediment transport studies, erosion control, hydrologic and hydraulic modeling. He has designed numerous streambank stabilization and stream restoration projects. Garrett worked in consulting for 16 years before joining WSDOT. During the last 12 years, Garrett has been conducting reach assessments, designing emergency streambank stabilization, designing large wood structures, hydraulic modeling, fluvial geomorphic studies, channel migration analysis, and project management.

Education: B.S., University of Arizona, 1986, Geosciences; M.S., 1990, University of Arizona, Geomorphology; Certificate in Stream Restoration, Portland State University, 2007.

Personal interests: Garrett is married and has a large cat, lives in Seattle, and loves backcountry skiing, mountaineering, kayaking, and sport climbing, playing Brazilian music, and singing sea shanties.

Learning Objectives

- Understand the basic design process of habitat complexity features
- Become familiar with use of large woody material, including constraints
- Become aware of other types of complexity features

Large Woody Material

What is it?

- 6 feet length
- 4 inches diameter

Why are we discussing it?

- Bank protection
- Channel resilience
- Aquatic habitat benefits
- Required by partnering entities

LWM habitat benefits

- Creates scour pools
- Provides hydraulic diversity
- Cover from predators
- Contributes to hyporheic flow
- Attenuates stream power
- Cooler water
- Macroinvertebrate habitat
- Gravel retention

LWM in fish passage program

- LWM concept developed in PHD
  - Determine LWM targets
  - Plan view depiction of concept
  - Description of each structure type & function
  - Any constraints discussed with HQ Hydraulics
- Stability, final sizing and layout in FHD
  - Develop anchor concepts
  - Log orientation and elevation finalized based on stability calculations.
- May need "as directed" notes in design drawings

Steps in the LWM design process

1. Determine project objectives
2. Conduct a Site and Reach Assessment (PHD)
3. Conduct a Water Safety Assessment (if needed)
4. Determine LWM targets
5. Determine LWM structure designs and locations
6. Address any constraints
7. Incorporate LWM structures in hydraulic model
8. FHD – conduct stability analysis and finalize design

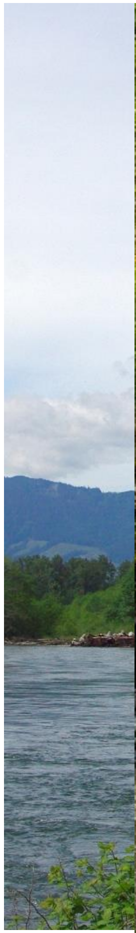
Determine Project Objectives

- Habitat functions (cover, shade, refuge - **typical**)
- Bank stabilization (less common)
- Flow Re-direction
- All of the above

Use a Site and Reach Assessment Approach

- Is it an alluvial or bedrock channel? Till?
- Evaluate riparian conditions
  - Contribution of LWM to stream function, stability
  - Is the stream lacking wood? If so, why?
- How confined is the stream?
- What is the channel gradient?
    - Generally, we place wood in channels up to 4%
    - Up to 12% if part of step-pool design
- What tendency for degradation? Aggradation?

Water Safety Assessment



- Is the stream considered
  ptable or
  lic?
  y from
  uation
  on
  or other
  -by-case
  tion may be
  needed

Determine LWM Targets

- Use LWM metrics calculator
- Enter project-specific information:
  - Length of regraded channel section
    - Includes length of crossing structure (even if we can't place wood)
  - Bankfull Width
  - Habitat zone
- Use lookup tables to determine target values
- Enter log dimensions and number
  - Meet key piece volume and number first
- Iteratively add and adjust log numbers and volumes
- Until targets are met

What is a key piece?

- Fox and Bolton (2007)/WFPB:
  - A log and/or rootwad that is (1) independently stable in the stream bank-full width (not functionally held…by another log, buried, trapped against a rock or bed form) and (2) retaining or having the potential to retain other pieces of organic debris.

- In fish passage/stream restoration projects:
  - A log with rootwad that meets the 75th percentile of the key piece volume for the appropriate bankfull width and habitat zone

LWM metrics calculator

State Route# & MP		if applicable
Stream name		
length of regrade[a]	360	ft
Bankfull width	26	ft
Habitat zone[b]	Western WA	
Key piece/ft	0.034	per ft stream
Key piece volume	3.28	yd3
Total LWM[c] pieces/ft stream	0.1921	per ft stream
Total wood vol./ft	0.3948	yd3/ft stream

Key Piece density lookup table

Habitat zone	BFW class (feet)	75th percentile (yd3/ft stream)
Western WA	0-33	0.0335
	34-328	0.0122
Alpine	0-49	0.0122
	50-164	0.0030
Douglas Fir/Pond. Pine (much of eastern WA)	0-98	0.0061

adapted from Fox and Bolton (2007), Table 4

Key piece volume lookup table

BFW class (ft)	volume (yd3)
0-16	1.31
17-33	3.28
34-49	7.86
50-66	11.79
67-98	12.77
99-164	13.76
165-328	14.08

adapted from Fox and Bolton (2007), Table 5

Total Wood Volume lookup table

Habitat zone	BFW class (feet)	75th percentile (yd3/ft stream)
Western WA	0-98	0.3948
	99-328	1.2641
Alpine	0-10	0.0399
	11-164	0.1196
Douglas Fir/Pond. Pine	0-98	0.0598

adapted from Fox and Bolton (2007), Table 4

Log type	Diam	Length[d]	Volume/log[d]	rootwad?	Key piece?	No. LWM pieces	Total wood volume[e]
	ft	ft	yd3				yd3
A	2.6	40	7.87	yes	yes	2	21.05
B	2	30	3.49	yes	yes	10	47.01
C	1.5	25	1.64	yes	no	20	42.94
D	1.2	20	0.84	yes	no	21	23.08
E	1.2	15	0.63	yes	no	16	14.24
F	1.5	20	1.31	no	no	1	1.31
G	1.5	20	1.31	yes	no	1	1.82
H			0.00		no		0.00
I			0.00		no		0.00
J			0.00		no		0.00
			Design	12	71	151.4	
			Targets	12	69	142.1	

Number of LWM pieces lookup table

Habitat zone	BFW class (feet)	75th percentile (per/ft stream)
Western WA	0-20	0.1159
	21-98	0.1921
	99-328	0.6341
Alpine	0-10	0.0854
	11-98	0.1707
	99-164	0.1921
Douglas Fir/Pond. Pine	0-20	0.0884
	21-98	0.1067

adapted from Fox and Bolton (2007), Table 4

key pieces

Total # pieces

Total volume

Determine LWM structure designs and locations

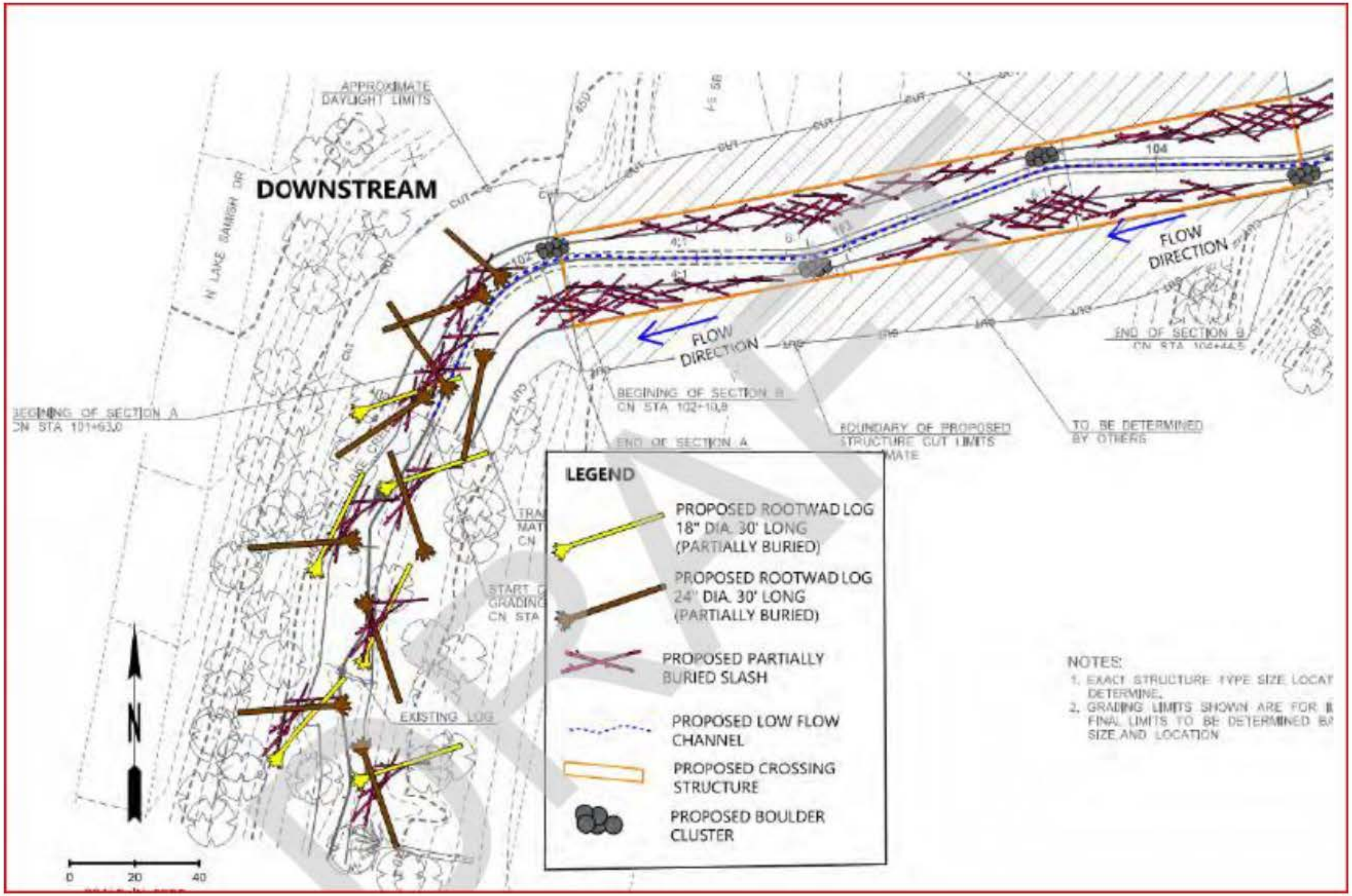
Determine LWM structure designs and locations

- Design for the identified objectives (usually habitat)
- Incorporate diversity of structure

LWM diversity

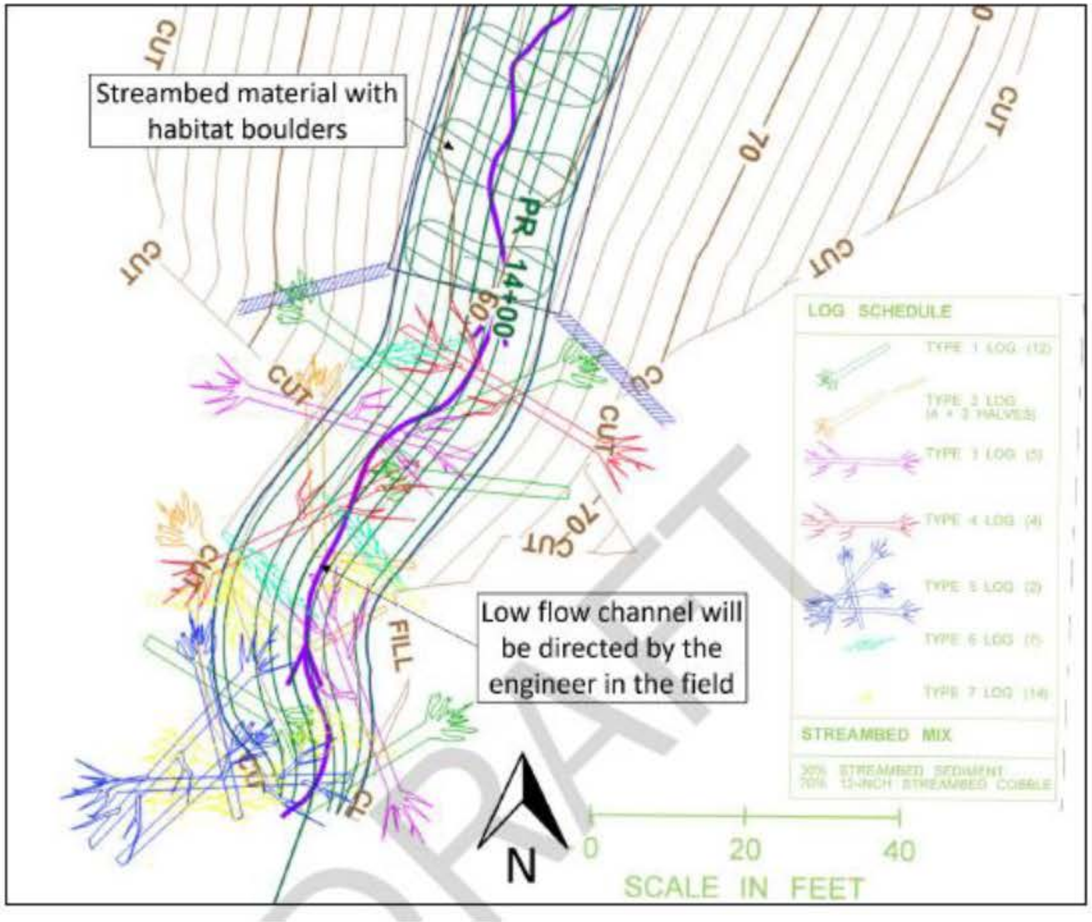
- LWM sizes (don’t rely on key pieces only)
- Orientation
- Elevation
- Angle (0-360 degrees)
- With/without rootwads (non-key pieces)
- Groupings of logs
- Degree of flow deflection
  - **OK to be farther out than centerline!**

Examples



DOWNSTREAM
APPROXIMATE DAYLIGHT LIMITS
N LAKE SAMISH DR
FLOW DIRECTION
FLOW DIRECTION
BEGINING OF SECTION A
CN STA 101+63.0
BEGINING OF SECTION B
CN STA 102+10.8
END OF SECTION A
BOUNDARY OF PROPOSED STRUCTURE CUT LIMITS
TO BE DETERMINED BY OTHERS
END OF SECTION B
EXISTING LOG
LEGEND
PROPOSED ROOTWAD LOG 18" DIA. 30' LONG (PARTIALLY BURIED)
PROPOSED ROOTWAD LOG 24" DIA. 30' LONG (PARTIALLY BURIED)
PROPOSED PARTIALLY BURIED SLASH
PROPOSED LOW FLOW CHANNEL
PROPOSED CROSSING STRUCTURE
PROPOSED BOULDER CLUSTER
NOTES:
N
0
20
40

Examples



Streambed material with habitat boulders
Low flow channel will be directed by the engineer in the field
PR 14+00
CUT
FILL
70
60
LOG SCHEDULE
STREAMBED MIX
N
0
20
40
SCALE IN FEET
DRAFT

Determine LWM structure designs and locations

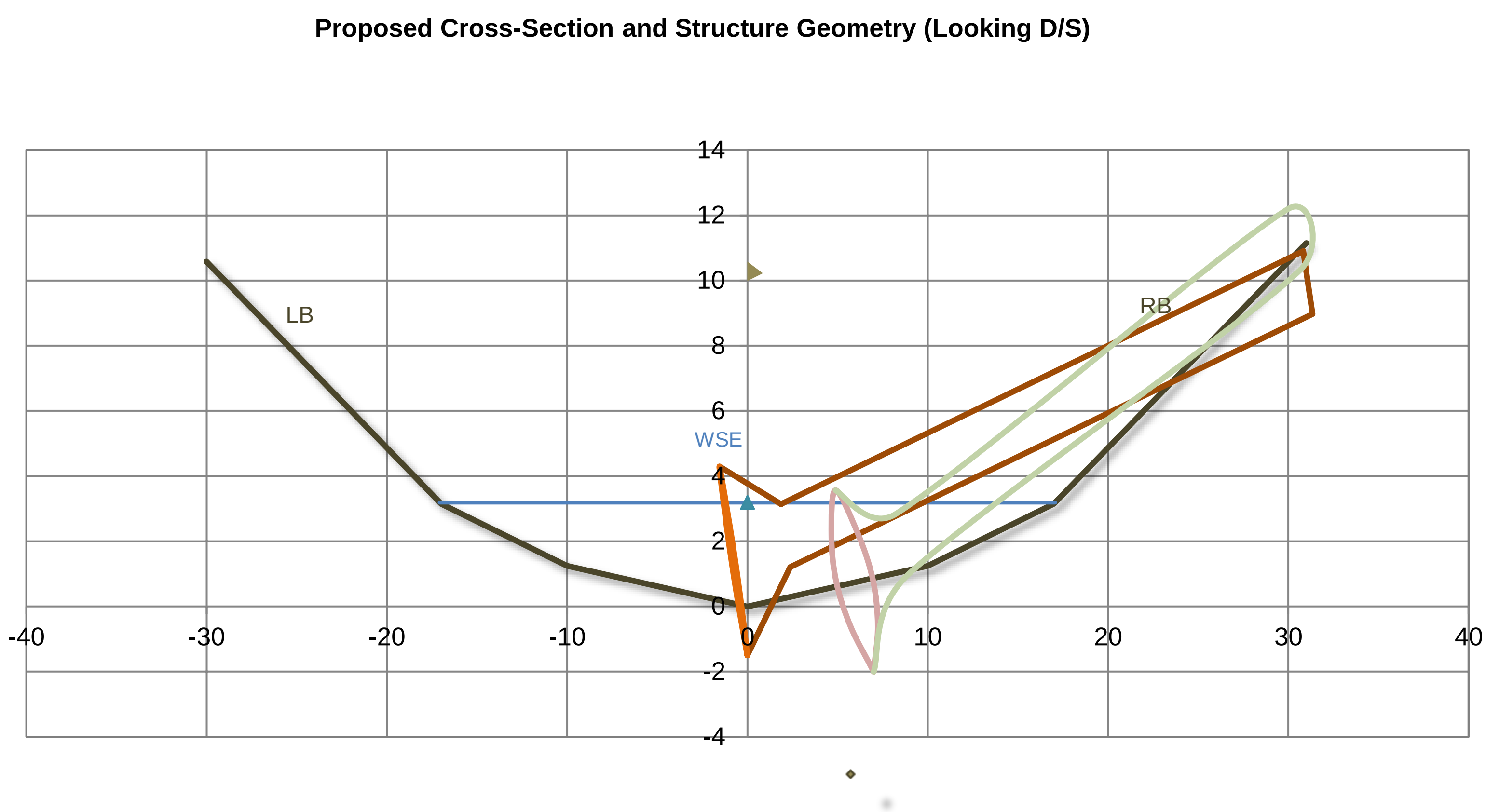
- Design for the identified objectives (usually habitat)
- Incorporate diversity of structure
- **Minimize anchors**

Avoiding anchors

- Use topography to our advantage
  - Steep slopes easier to use for self-ballasting
- Use existing features (trees, mostly) and lashings
- Factor of Safety flexibility?
  - Downstream of crossing
  - What is downstream of the reach?
  - Possible to design for less than 100-year flow
  - ‘Mobile wood’

Self-ballasting LWM

Example – Pussyfoot Creek

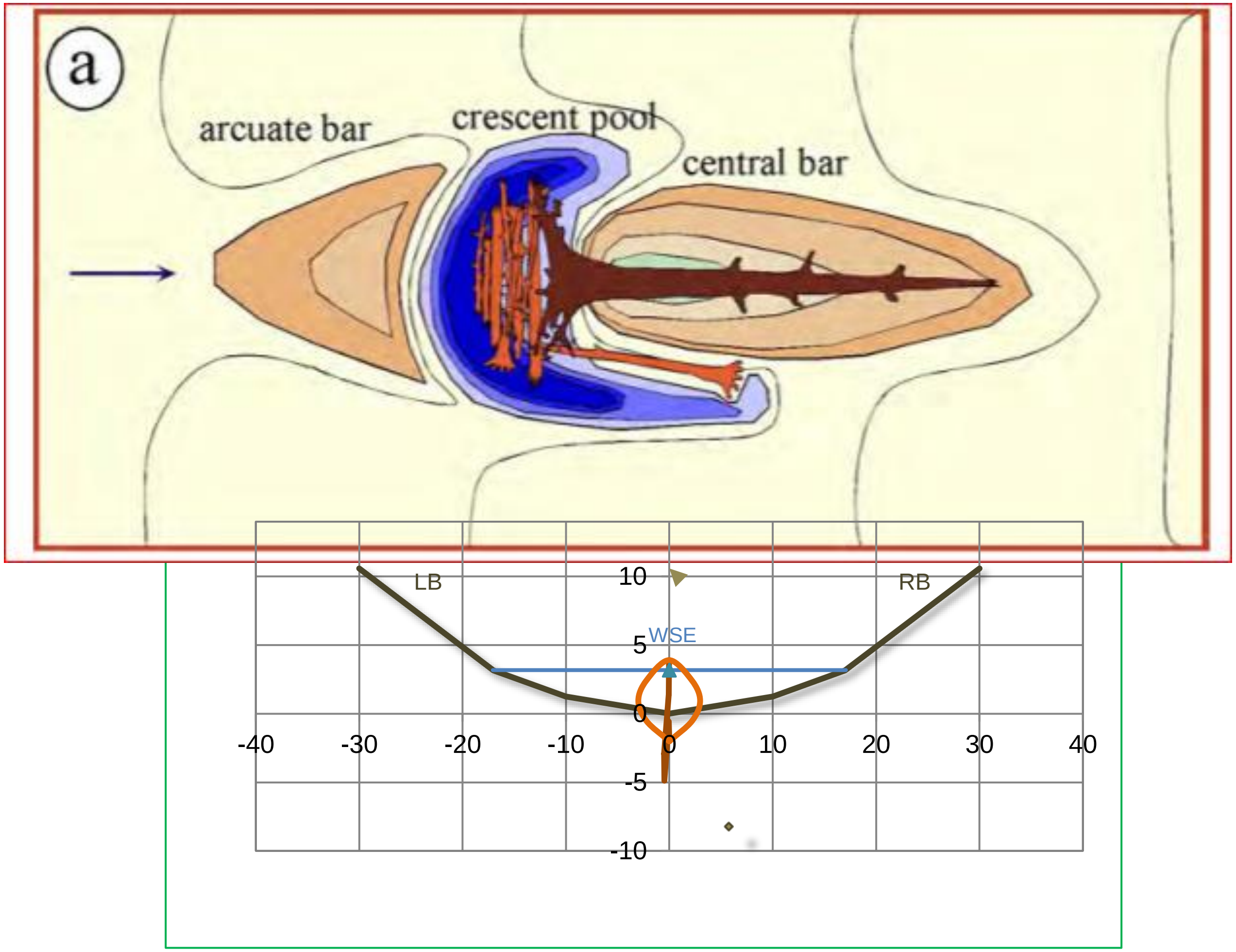


Existing Features as Anchors

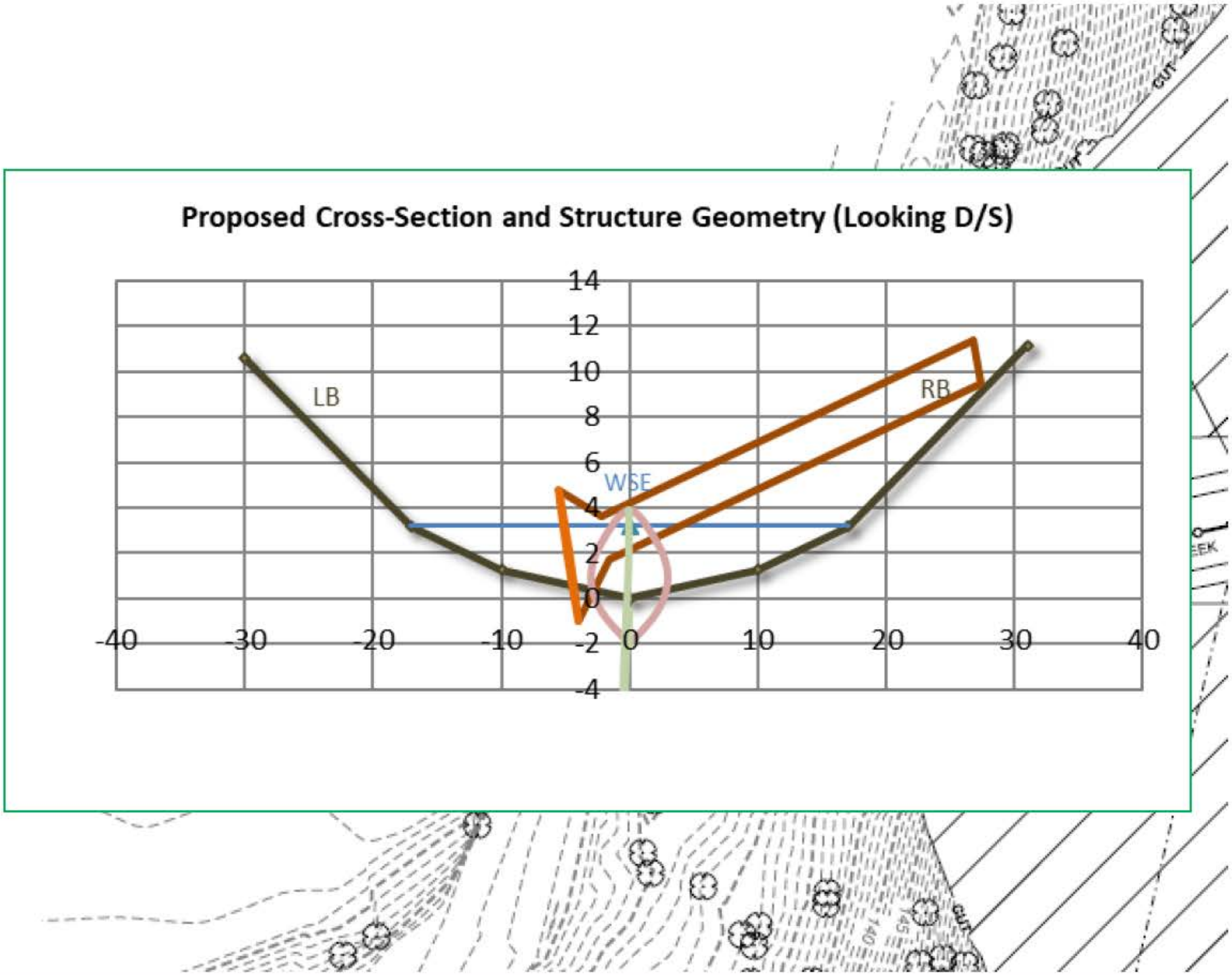
Determine LWM structure designs and locations

- Design for the identified objectives (usually habitat)
- Incorporate diversity of structure
- Minimize anchors
- **Key pieces engaged with all flows**
- **Non-key pieces engaged with flow as much as possible**
- **Create sinuous flow pathways**

Center of stream



Projecting



Proposed Cross-Section and Structure Geometry (Looking D/S)
14
12
10
8
6
4
2
0
-2
-4
-40
-30
-20
-10
0
10
20
30
40
LB
RB
WSE
CUT

Channel spanning

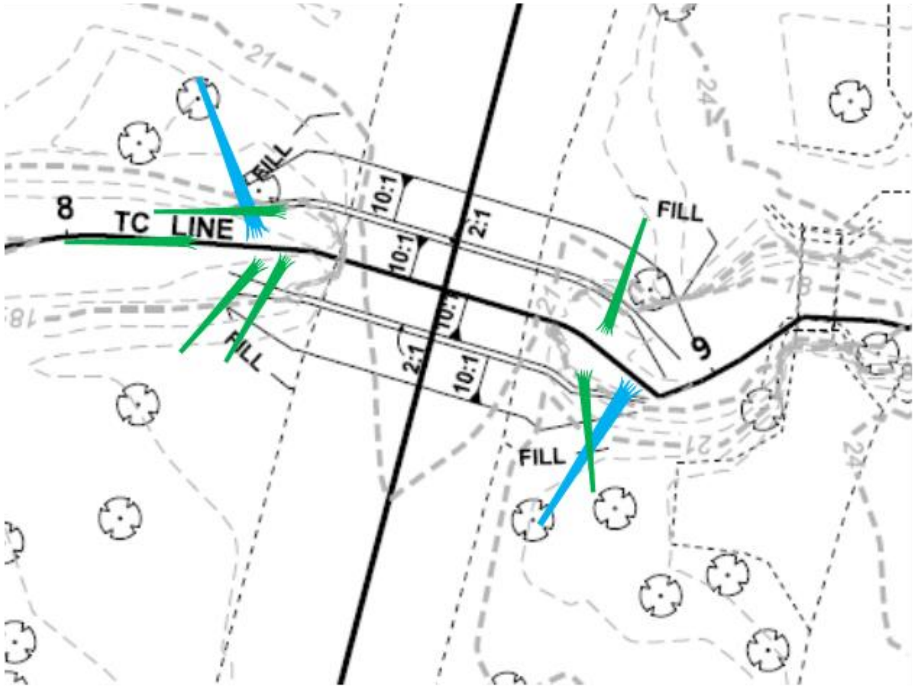
- Higher risk to structures, property
- Potential barriers
- Can span above the design flow

Determine LWM structure designs and locations

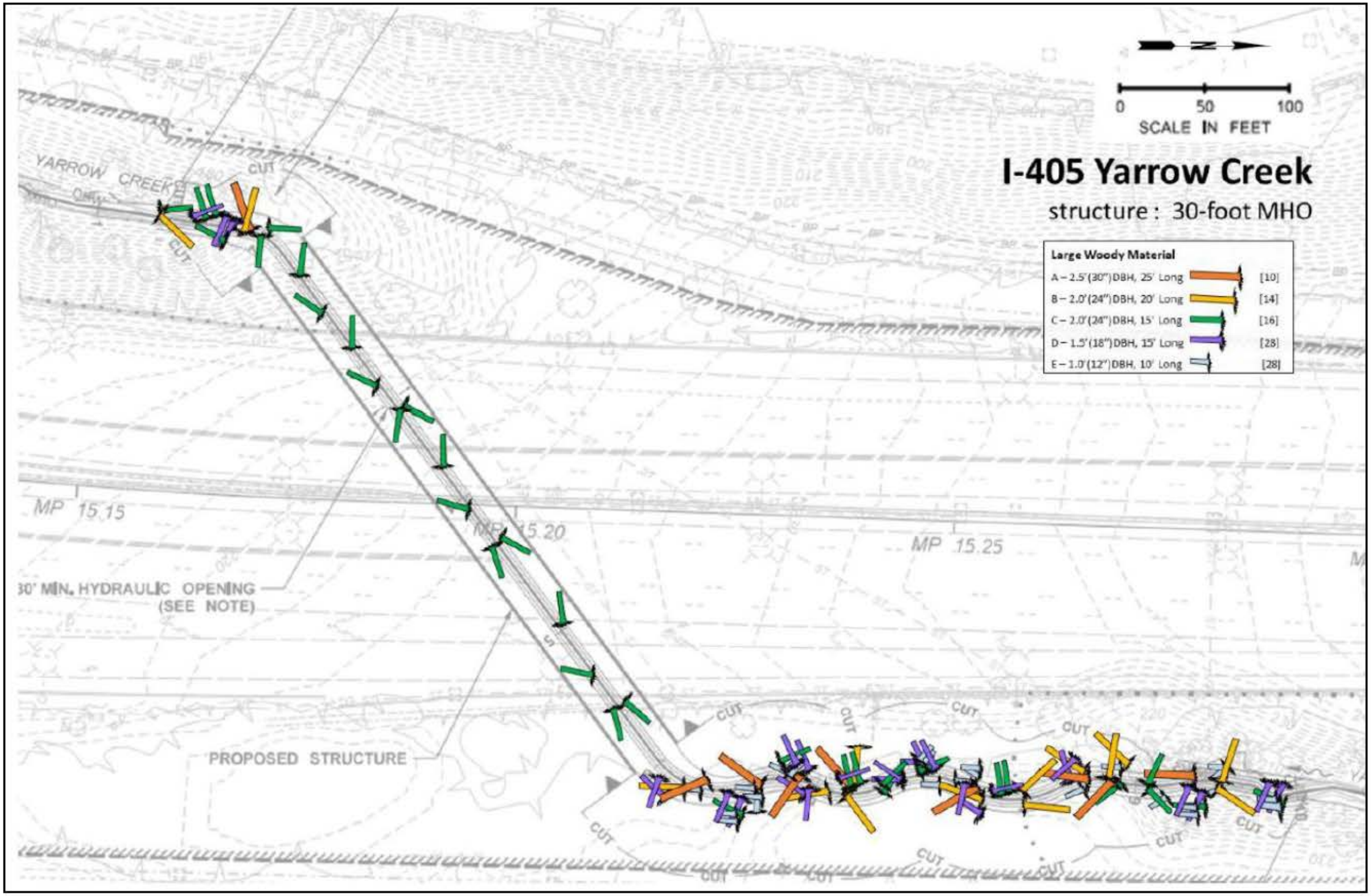
- Design for the identified objectives (usually habitat)
- Incorporate diversity of structure
- Minimize anchors
- Key pieces engaged with all flows
- Non-key pieces engaged with flow as much as possible
- Key pieces engaged with all flows
- Non-key pieces engaged with flow as much as possible
- Create engagement at all flow levels
- Create sinuous flow pathways
- **Working with Constraints**

Working with constraints

Conceptual LWM layout
Type A – 2.2’ DBH, 25’ Long (2)
Type B - 2.0’ DBH, 20’ Long (6)



Working with constraints



LWM in or near crossing structures

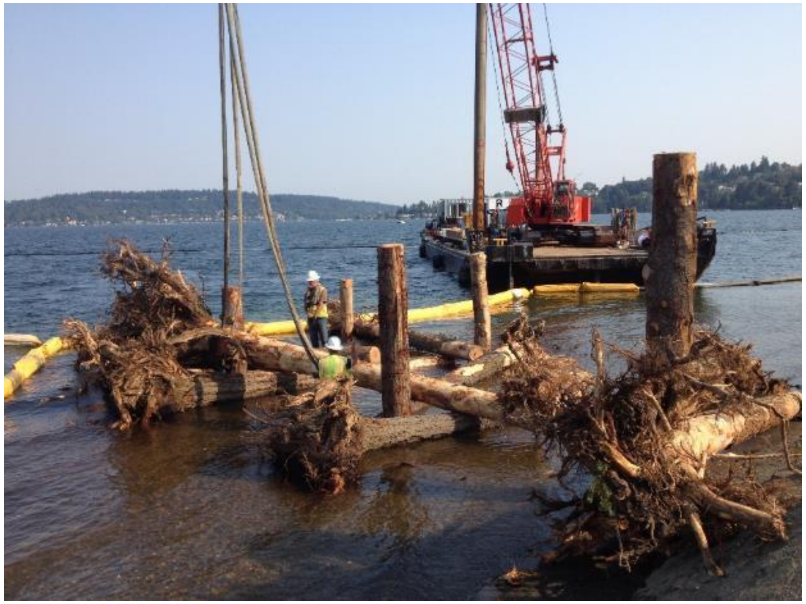
Must consider:

1) Is there wracking potential? If so, consider design that would limit it (no rootwads, orientation parallel to flow, limited protrusion)
2) Potential for undermining abutments (including wracking)
3) Backwater effects on highway, other property if present
4) Maintain freeboard – 6 feet for equipment, up to 10 feet (HM section 7-4.5.2)
5) Bed scour – would wracking create excess scour that would affect bridge?

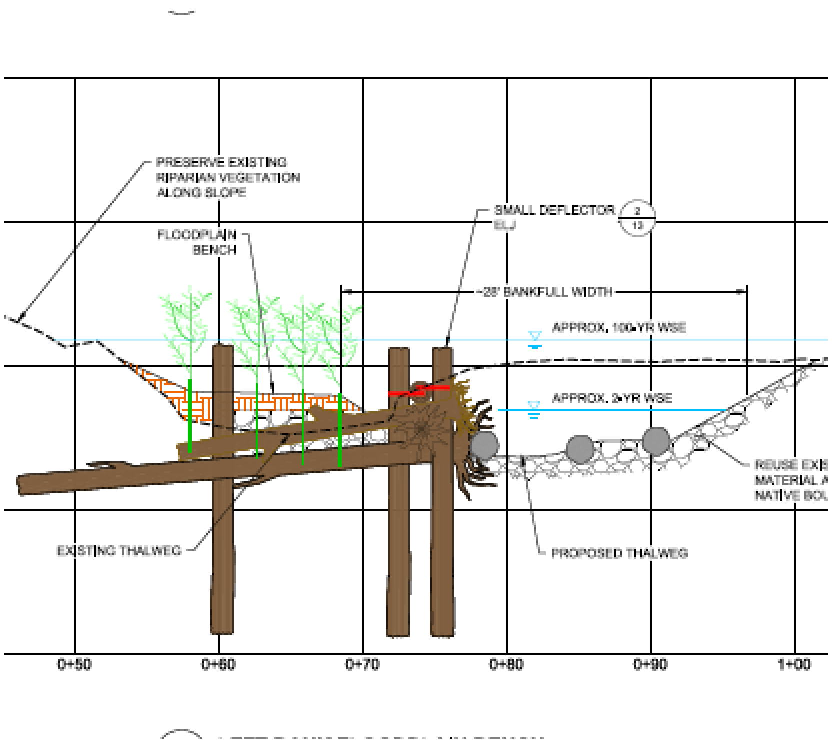
If placing LWM near or under bridges, Factor of safety of 2 for buoyant and drag forces. (or consider mobile wood)

FHD – finalize LWM design

- Conduct stability calculations
- Factor of Safety
  - >1.5 generally, for buoyant force, shear force, moment
- Adjust elevation, orientation, angles to minimize anchors while meeting factor of safety
- Determine anchor style based on site conditions

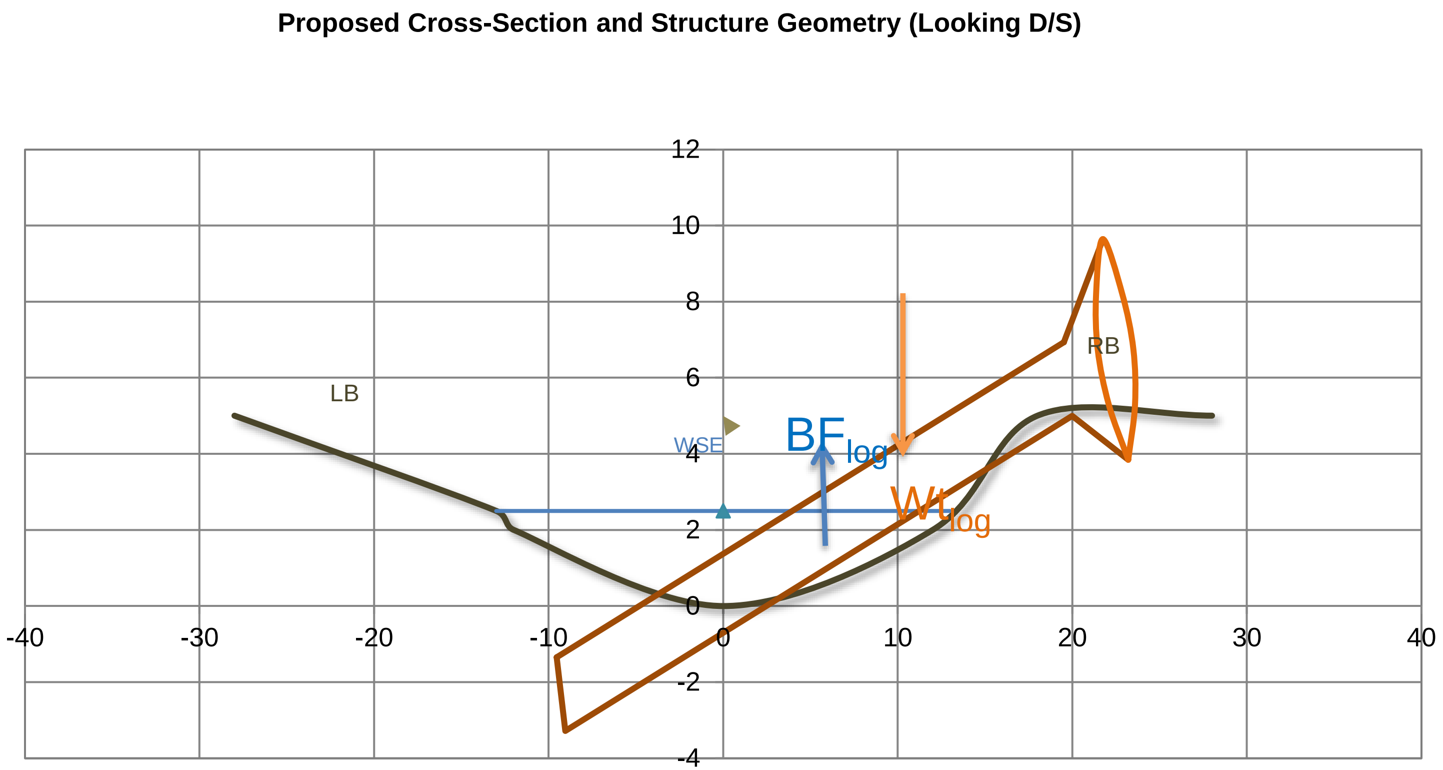


Anchoring preferences



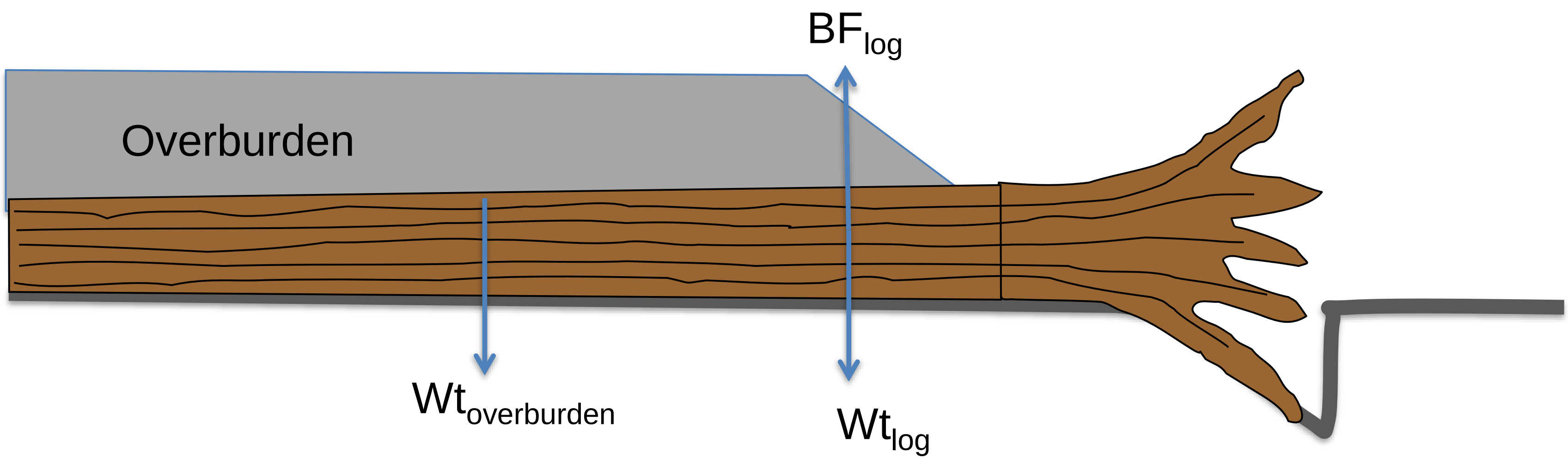
- Natural existing vegetation
- Self-ballasted
- Soil ballasted
- Wood ballasted
- Wood piles/racking
- Boulder anchors
- Earth anchors
- Dollosse
- Deadman anchors

Self-ballasting



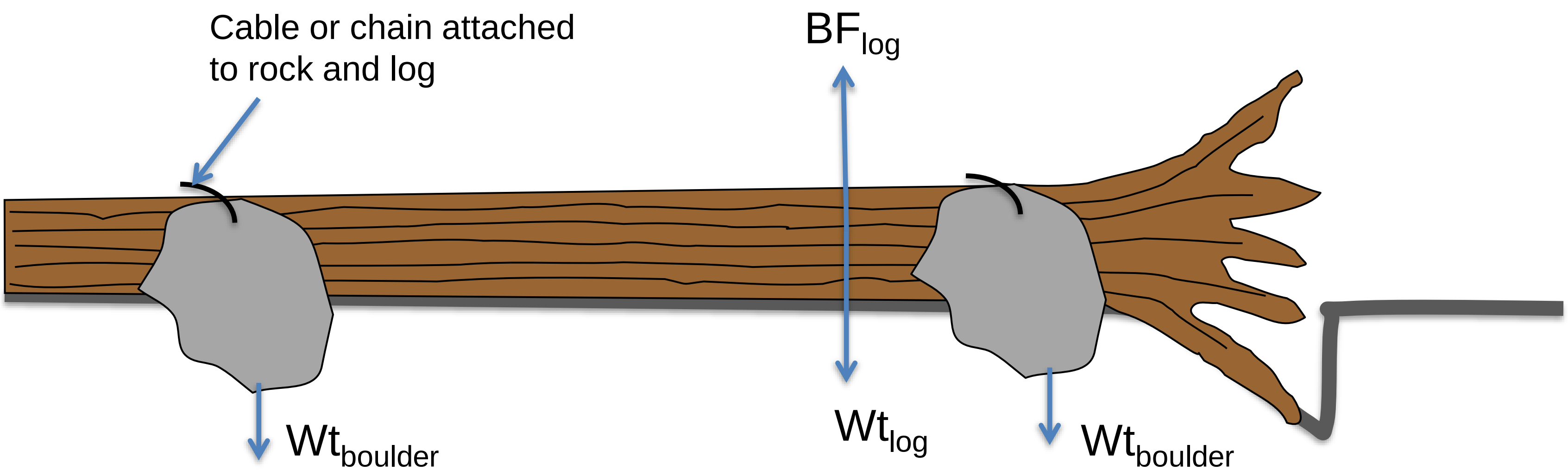
Anchoring by Burial

- Buoyant forces resisted by weight of overburden (rocks, soil, slash)
- Risks: insufficient overburden, flanking by bank erosion.



Anchoring with Boulders

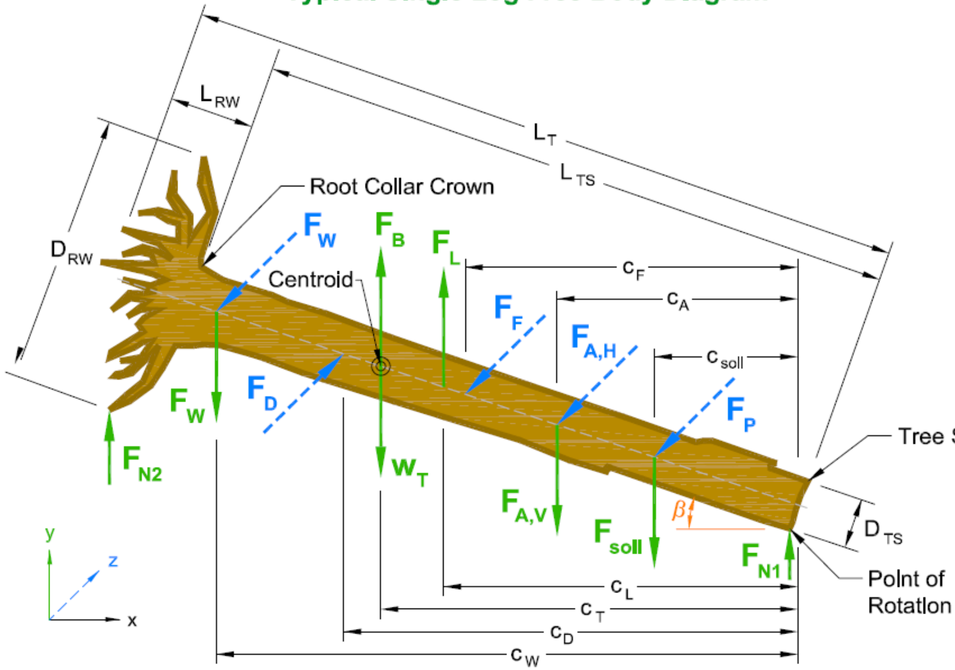
- Buoyancy and drag resisted by weight of boulders
- Attach boulders with chains or cable
- Risks: failure of cable attachments (slack in cable)
- Benefits: as scour happens, structure can settle as a unit



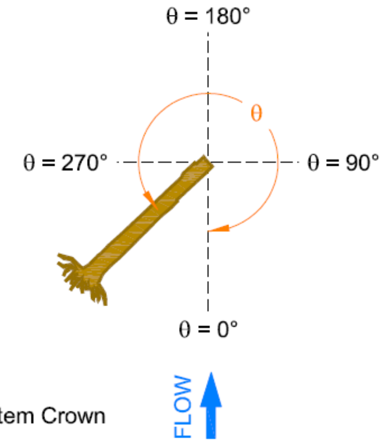
Stability Calculations

- FHD stage (typically)
- Use tool such as Rafferty (2016)
  - Gather inputs
- If cannot be stable to a reasonable Fs, using weight of LWM and/or soil
  - Turn to artificial anchors

Typical Single Log Free Body Diagram

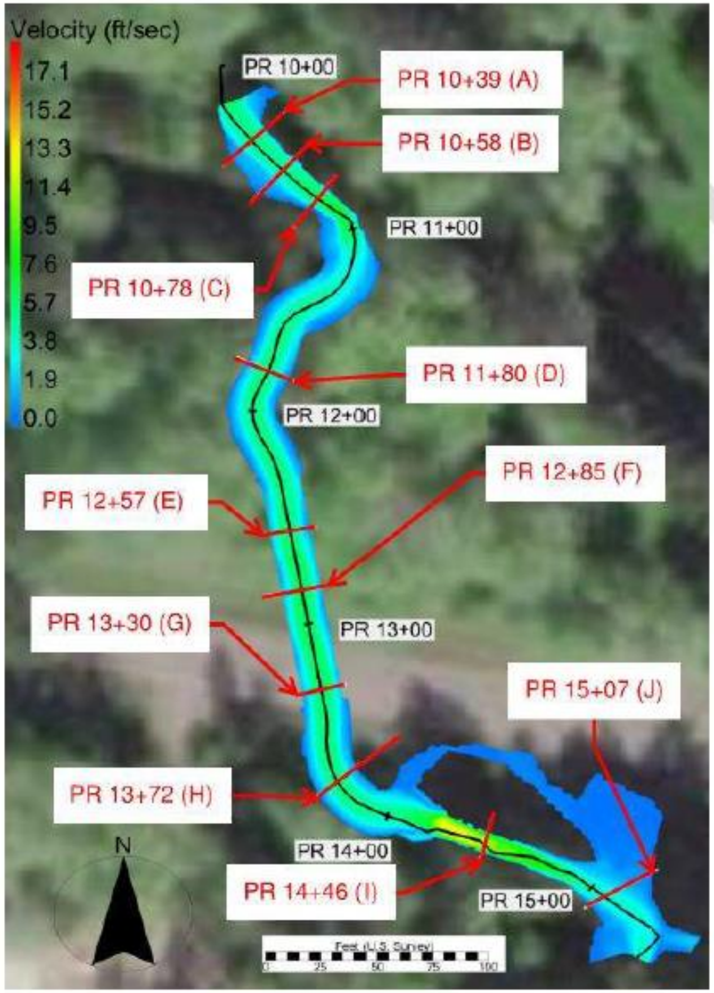


Log Orientation (Plan View)



Incorporate LWM structures in hydraulic model

- Obstruction?
- Porous?
- Roughness?
- Sensitivity analysis



When is LWM not appropriate?

- Under a low bridge
- Where debris flows might be expected
- Backwatering
- Excessive scour as other LWM racks (think fire)

Things to avoid

Toe logs parallell to flow

LWM placed marginal to channel

Similar angles, uniformity

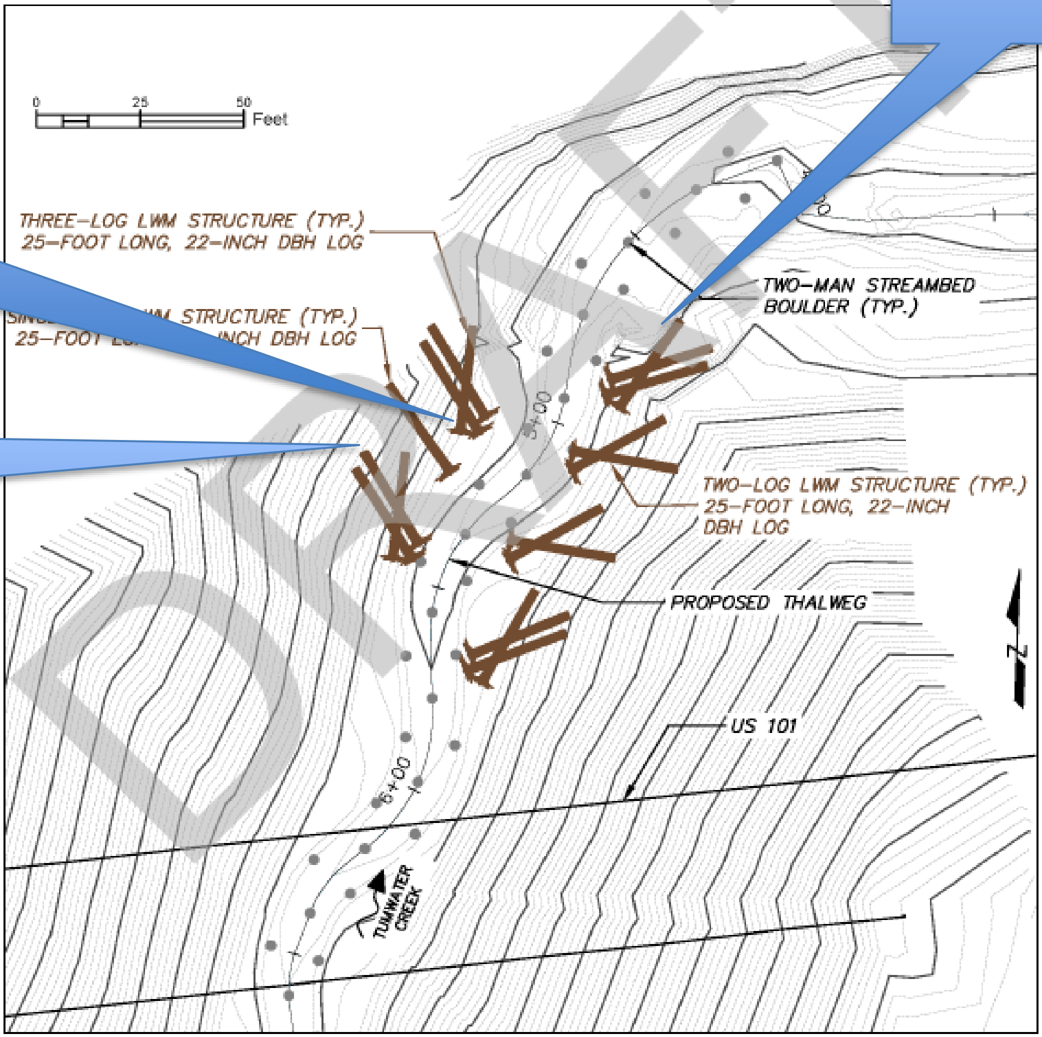


Figure 9.3 Conceptual Large Woody Material Layout

LWM for habitat example

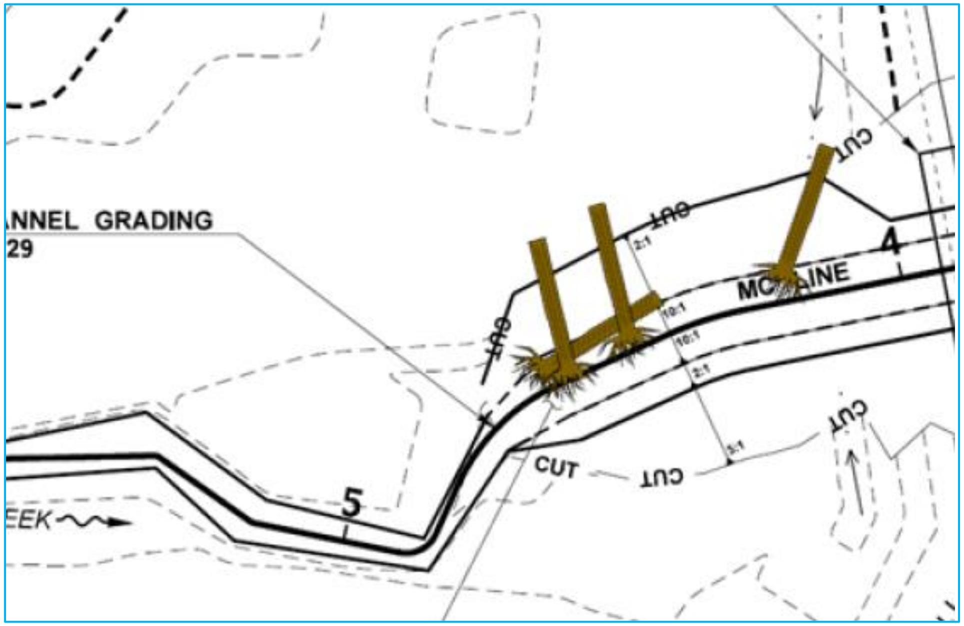
LWM for habitat example

LWM Examples – Flow re-direction

LWM Examples – Multi-log

LWM for bank protection

- Many *recent* designs reflect legacy of using this style
- This uses wood to provide flow re-direction, lateral support, without rock
- Not best for habitat



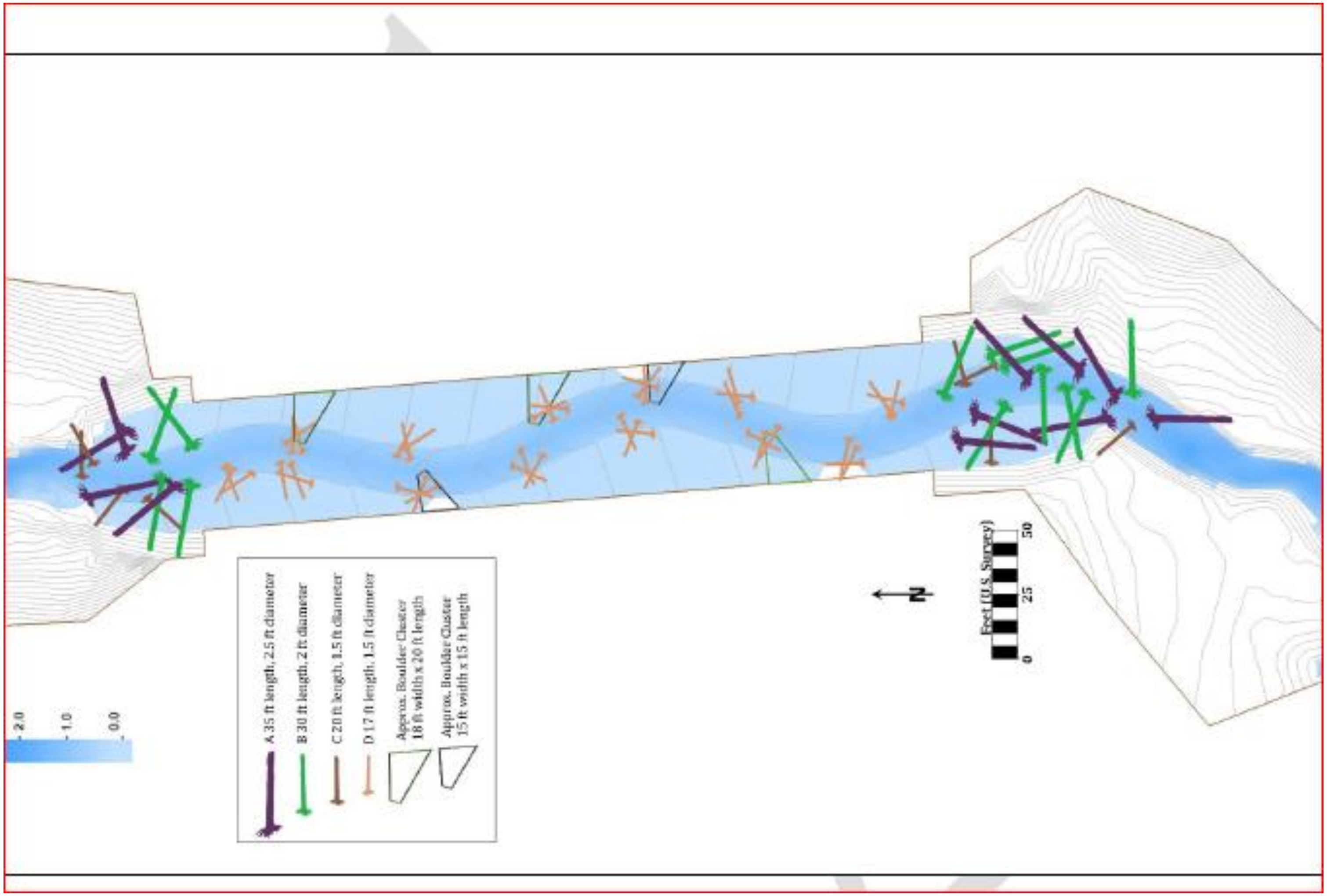
Other channel habitat features

- Mobile Wood
- Buried Wood
- Boulders
- Beaver Dam Analogs
- Step Pools
- Bioengineering banks

Mobile Wood

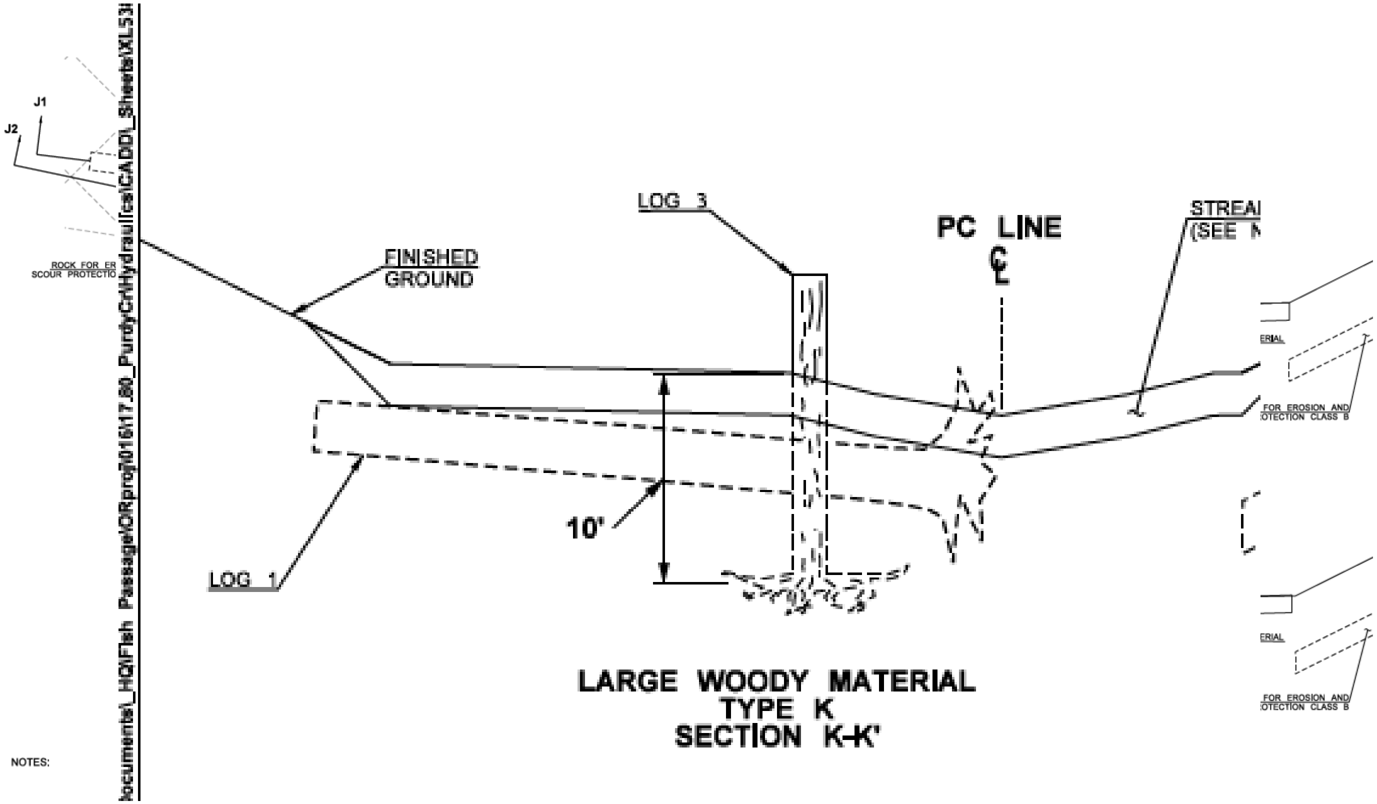
- Design flow less than 100 year
- Stability is project-specific
  - Mobile with as little as 2-year flow
- Consider downstream constraints carefully
- Can meet LWM volume targets
  - Not for key piece targets

Mobile wood example



Buried Wood

- Used as tool against degradation uncertainty
- Designed carefully – avoid barrier potential

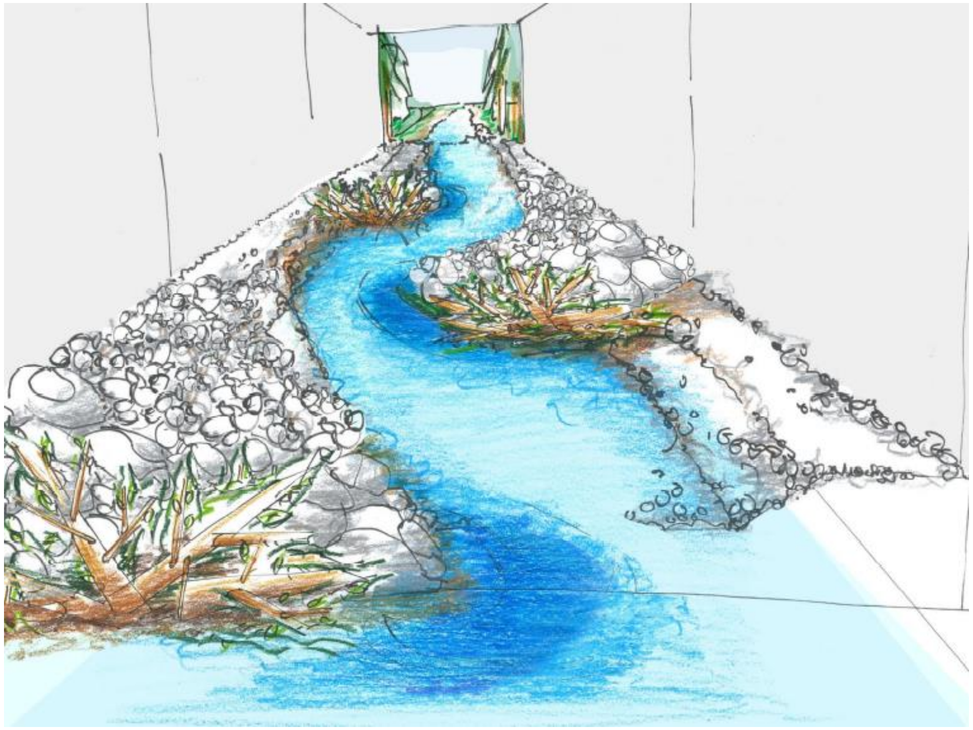


Boulders and other features

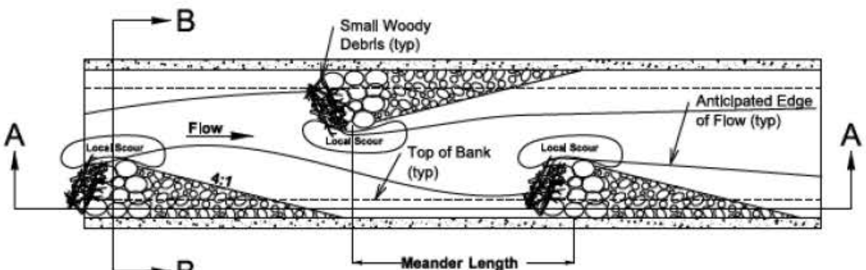
- Boulders
  - When present in reference reach
  - Added for hydraulic diversity
  - May consider for increasing roughness
- Meander bars
  - Meant to maintain low flow channel
  - Sinuosity
  - Scour

Meander Bars

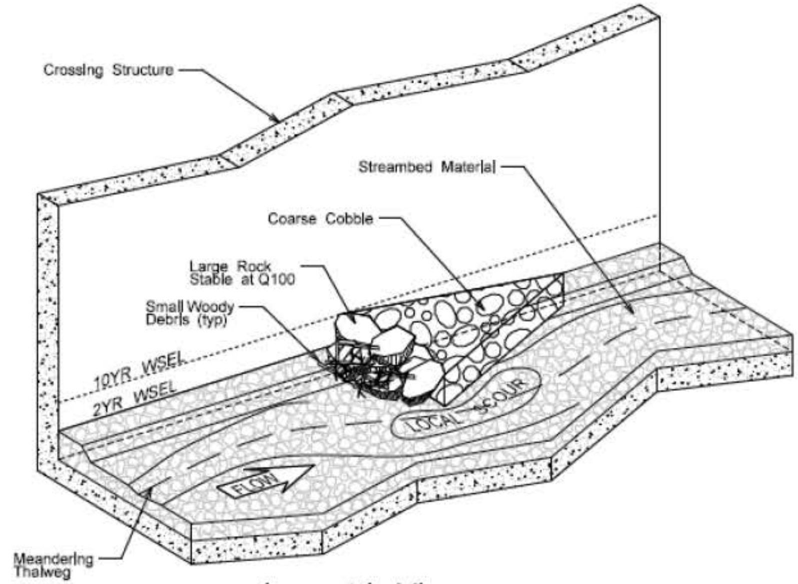
- A way of creating habitat diversity within a buried structure
- Can’t simulate root strength of riparian zone
- Want to maintain low flow channel
- Keep flow off structure walls



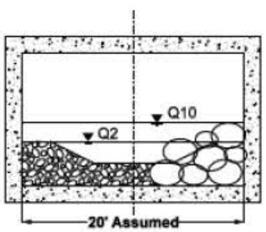
Meander Bars



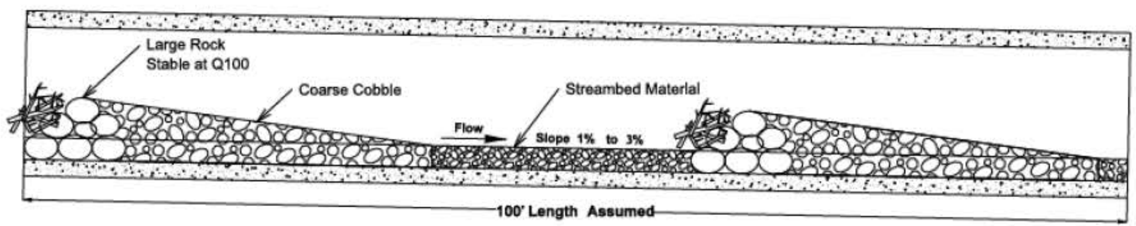
Plan View



Isometric View

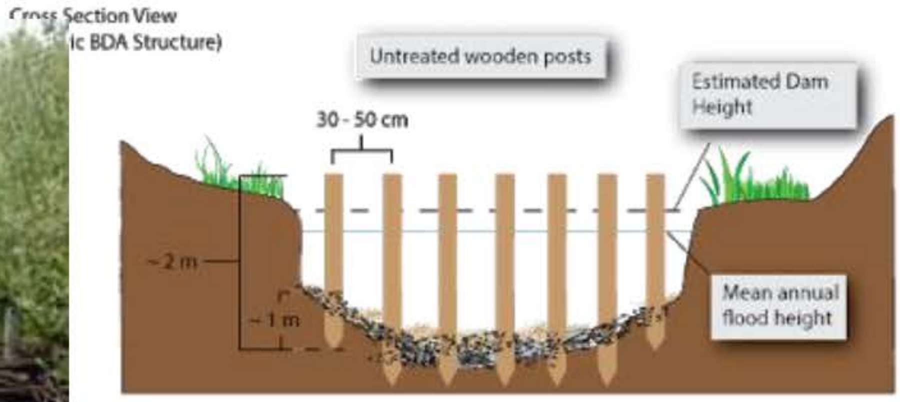


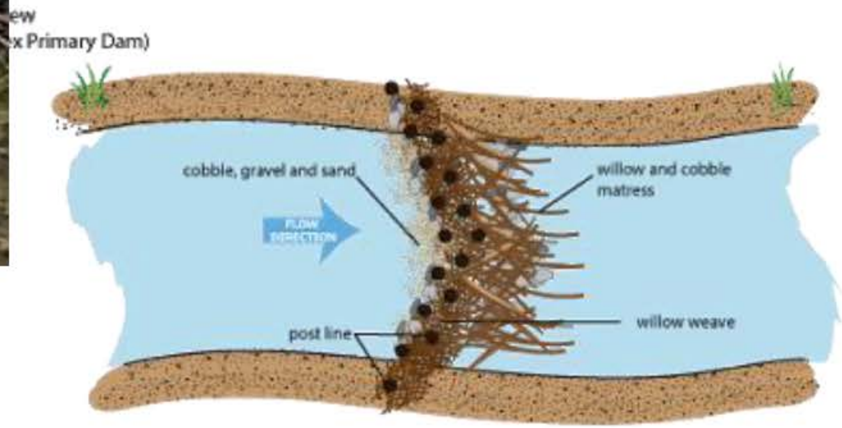
Section B-B



Section A-A

Beaver dam analogs





Step pools

Bioengineering streambanks

Resources

- National Academies of Sciences, Engineering, and Medicine. 2017. Guidance for Design Hydrology for Stream Restoration and Channel Stability. Washington, DC: The National Academies Press. https://doi.org/10.17226/24879.
- Curran, J., 2010, Mobility of large woody debris (LWD) jams in a low gradient channel; Geomorphology, v.116, 3–4, pp.320-329.
- Bandrowski, D., 2016, National Large Wood Manual: Assessment, Planning, Design, and Maintenance of Large Wood in Fluvial Ecosystems: Restoring Process, Function, and Structure Large Woody Material – Risk Based Design Guidelines, Bureau of Reclamation, Denver, CO.
- Rosgen, D., 1998, The Reference Reach: A Blueprint for Natural Channel Design, Proceedings, Wetlands Engineering and River Restoration Conference, Denver, CO
- WDFW, 2013, Stream Habitat Restoration Guidelines
- https://www.calsalmon.org/node/810 (Large Wood Technical Field School)

Summary

- Definition of LWM and why we use it
- Steps in the LWM design process
- Using the log metric calculator
- Adjusting log design to work with site constraints
- When and how log stability is calculated
- Alternative habitat complexity features
- Things to avoid in LWM placement and meander bar placement

Questions?