Helicopter LWD

An Evolution in Cost-Effective Process-Based Restoration Approaches

for

Large Wood Applications in River Restoration

13 February 2025

Derek Marks

Tulalip Tribes—Timber Fish & Wildlife Manager

Deer Creek Enhancement Project

Helicopter Large Woody Debris Installation in Deer Creek on Weyerhaeuser Lands

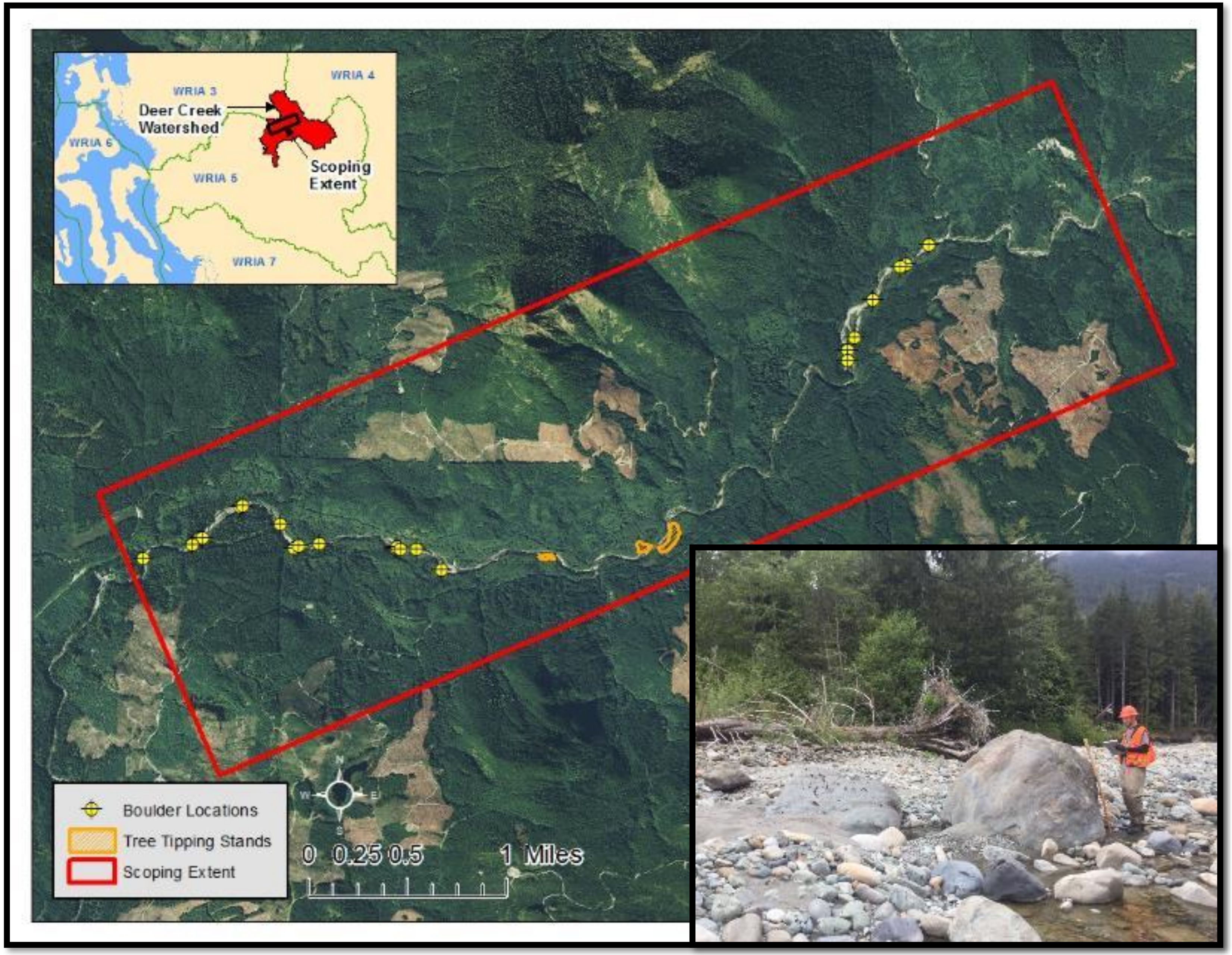
The Tulalip Tribes TFW Program

Neil Shea, Brett Shattuck, Derek Marks

2016

LWD Installation

- Current lack of LWD
- Installation to form jams by racking smaller wood
- Provide pools with thermal refugia
- Help form forested islands/channel narrowing (shade)
- Activation of side channels
- Sediment storage
- Lack of infrastructure in Deer Creek allows installation flexibility



Force Analysis

- Buoyancy force (F_b) = weight of displaced water:

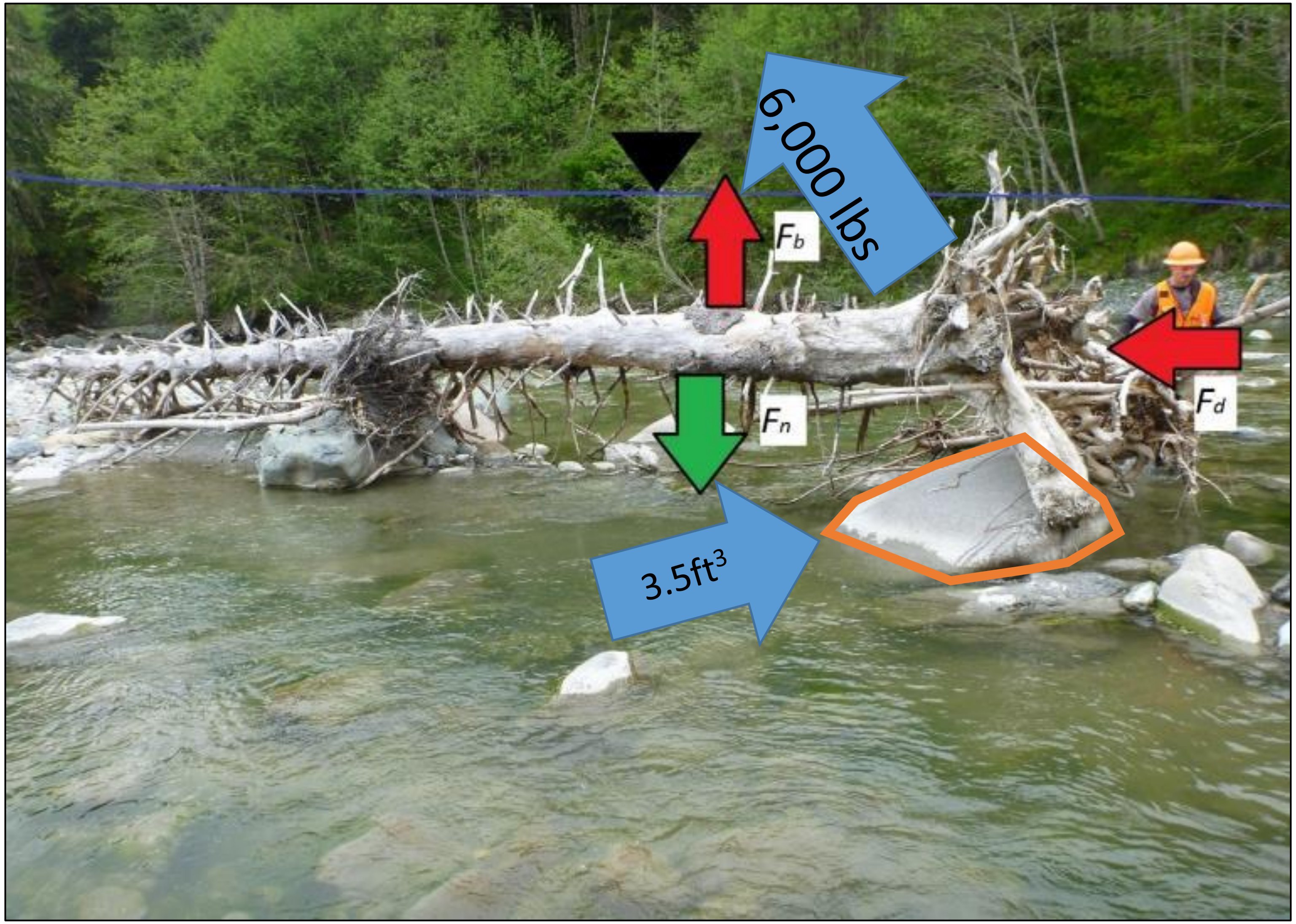
$$F_b = V_{ts}\Upsilon_w$$

- Counteracting force (F_n) = weight of log:

$$F_n = V_{ts}\Upsilon_t$$

- Drag force (F_d) = combination of the head and slope of the stream manifesting as a velocity acting upon the root wad of the log:

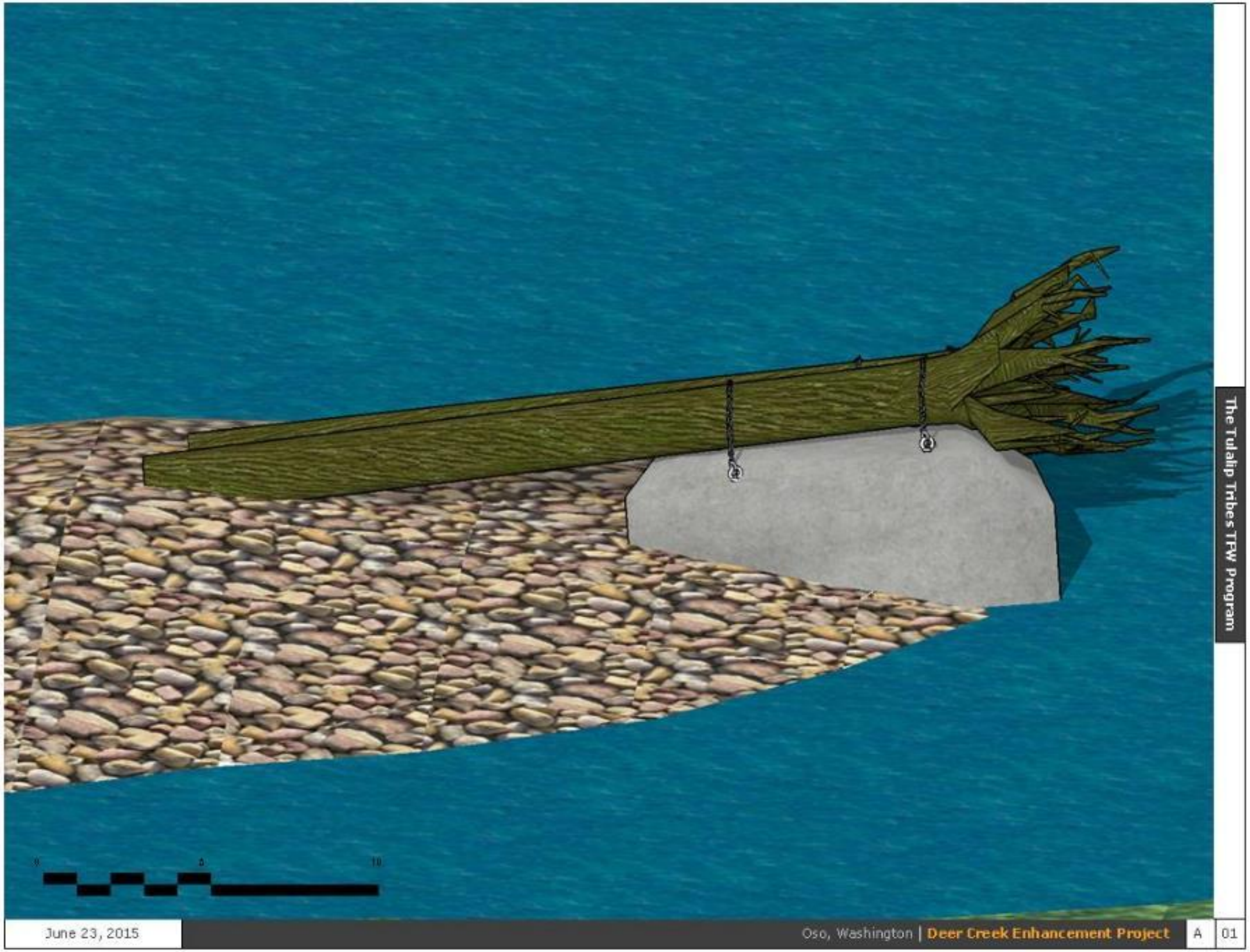
$$F_d = \frac{\frac{1}{2}\,\Upsilon_w C_d U^2 A_{sw}}{g}$$



Pilot Project Installation and Analysis

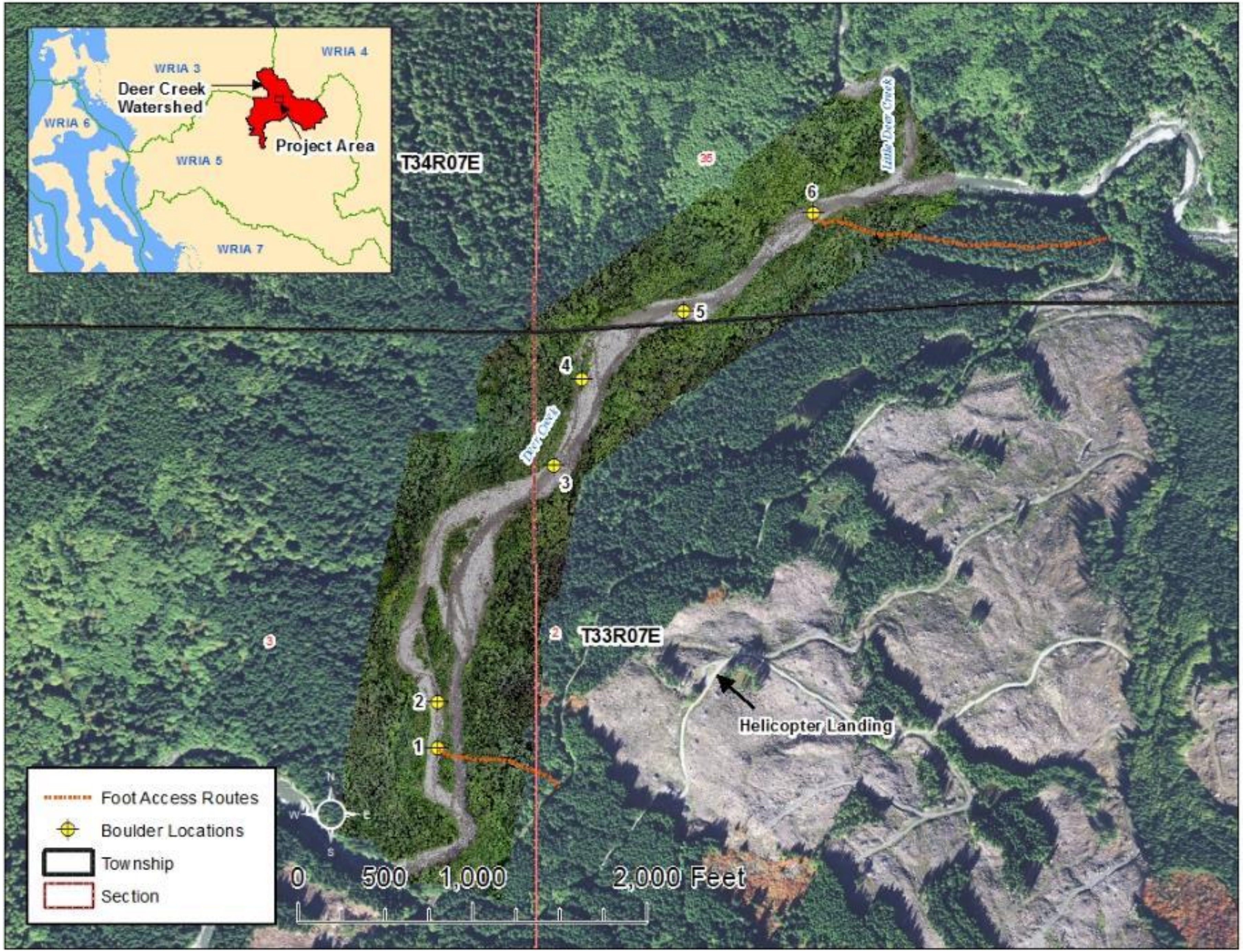
Pilot Project Installation and Analysis

Typicals



0
5
10
June 23, 2015
Oso, Washington | Deer Creek Enhancement Project
A
01
The Tulalip Tribes TFW Program

LWD Placement



LWD Placement

LWD Placement

LWD Placement

LWD Anchoring

Structure 6

BEFORE


Structure 6
AFTER


Deer Creek
Imagery Date: 7/25/2019


Structure 6
AFTER

Lessons Learned

- LWD weight is difficult to estimate remotely
- Anchoring method is vital to structure strength
- A larger single rotor helicopter (K-MAX or Blackhawk/Sikorsky) would provide larger wood capacity while retaining precise placement
- Chain anchors are effective as long as “porpoising” can be reduced through minimizing any slack in the system
- Pilot suggests that structures are effective at catching smaller LWD
- Deer Creek is an energetic system

Seattle City Light

TULALIP TRIBES

THE SOUTH FORK TOLT LARGE WOODY DEBRIS PROJECT—AN INNOVATIVE PROCESS-BASED RESTORATION APPROACH

Elizabeth Ablow
Strategic Advisor
Seattle City Light

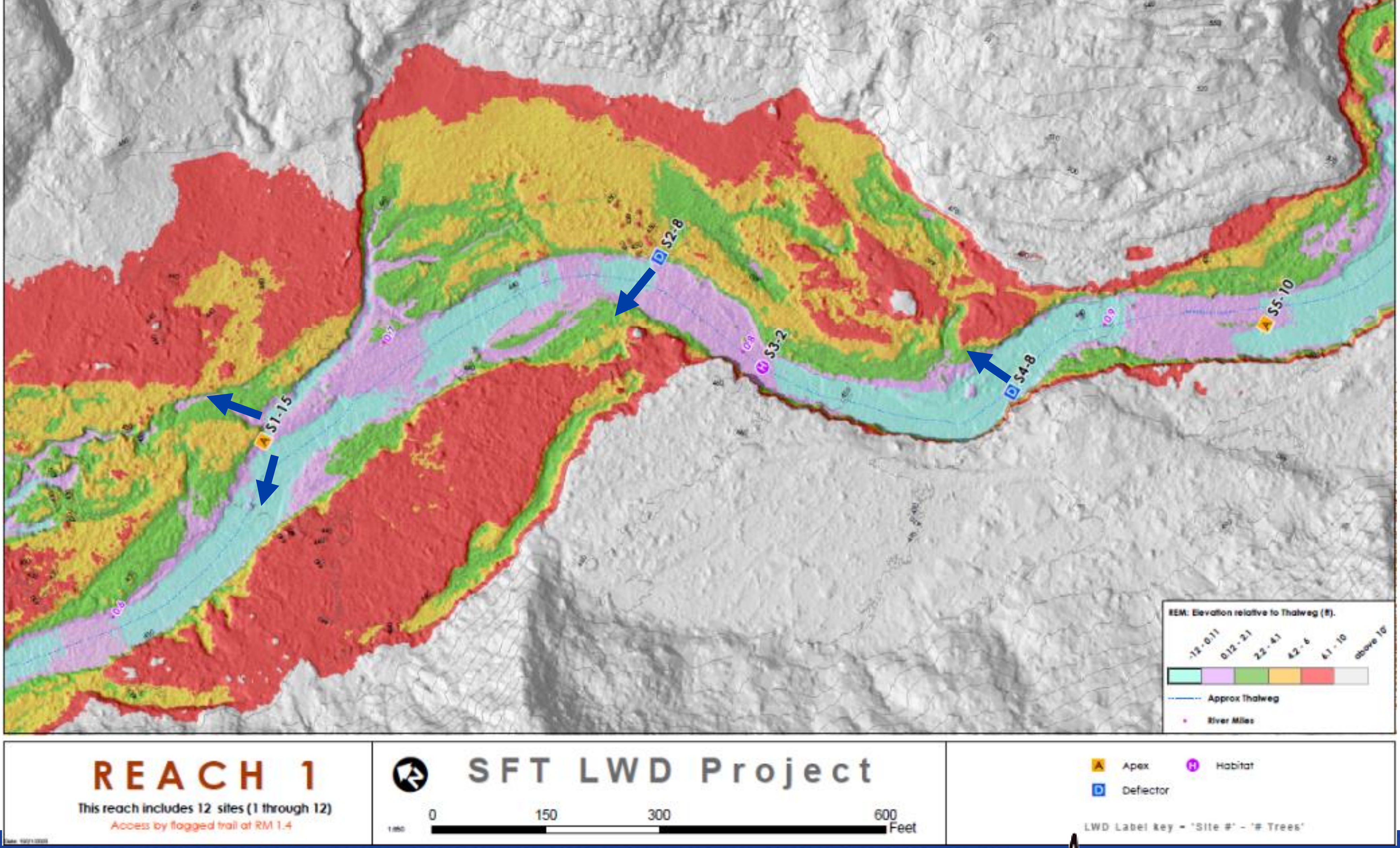
Derek Marks
Timber Fish & Wildlife Manager
Tulalip Tribes

David Beedle
Fish and Watershed Process Advisor
and
Ciarán McGee
Senior MSA
Seattle City Light

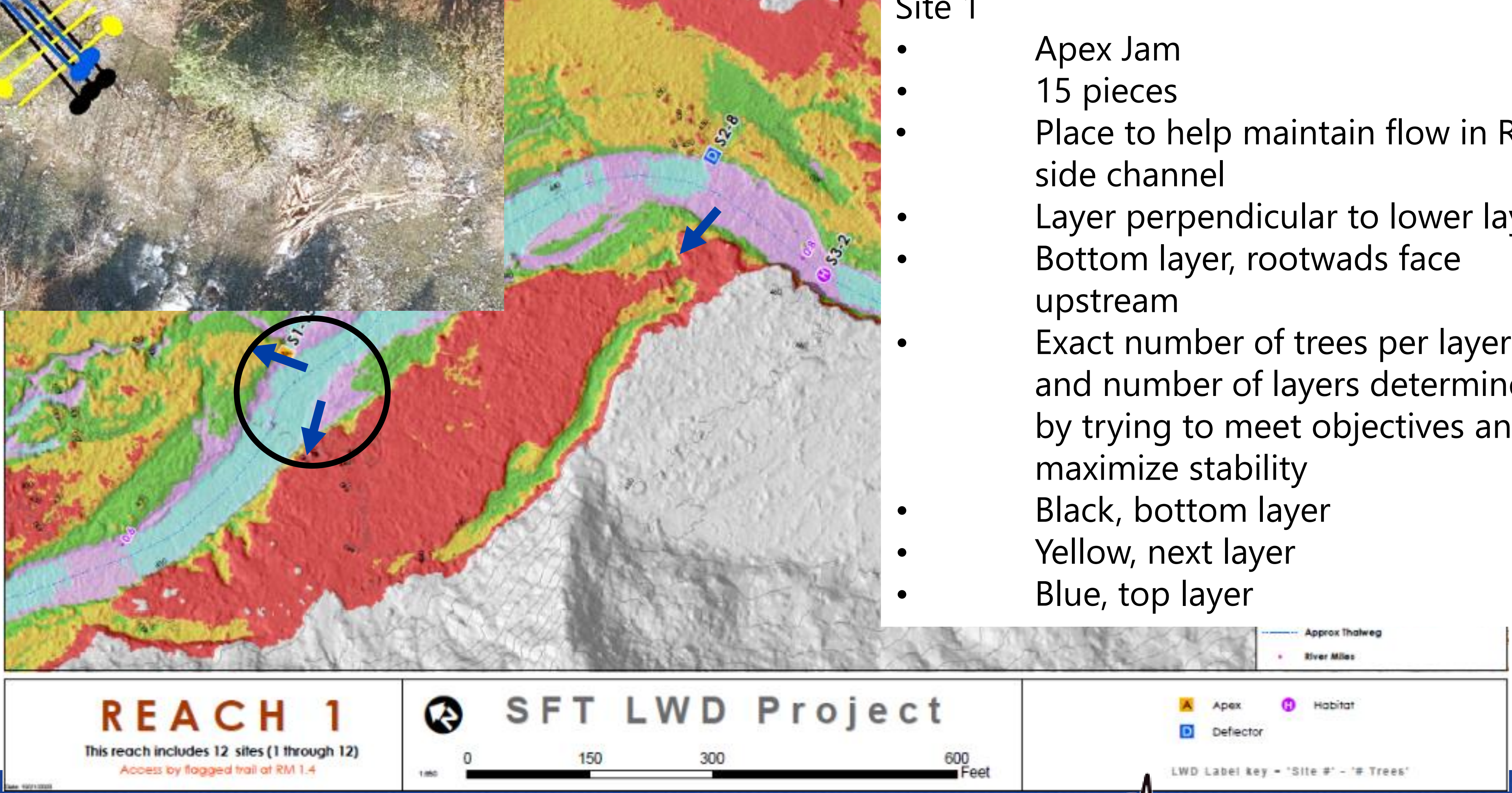
KEY TAKE AWAYS FROM PILOT (2006)

- Design flow for wood placements was Q10.
  - Q20 in 2007 over 80% of the LWD stayed at its original location
  - Q90 in 2009 ~ 50% of the LWD was still at their 2008 locations.
  - Of the wood that moved, ~ 60% was captured by d/s logjams.
- Confirmed bulk and scale of persisting jams
- Verified hydraulic information including depth associated with flood recurrence intervals.
- Assessed location of persisting jams and wood complexes.

RELATIVE ELEVATION MODEL



STEPS TO SUCCESS



Site 1

- Apex Jam
- 15 pieces
- Place to help maintain flow in RB side channel
- Layer perpendicular to lower layer
- Bottom layer, rootwads face upstream
- Exact number of trees per layer and number of layers determined by trying to meet objectives and maximize stability
- Black, bottom layer
- Yellow, next layer
- Blue, top layer

STEPS TO SUCCESS

STEPS TO SUCCESS

Rootwads are Key:

- Unique geometry provides stability
- Rootwad mass combined with full length trees reduces buoyancy
- Increases likelihood of future LWD recruitment

STEPS TO SUCCESS

Using full length trees contributes to stability.

Tree length wider than average channel width ensures riparian entanglement.

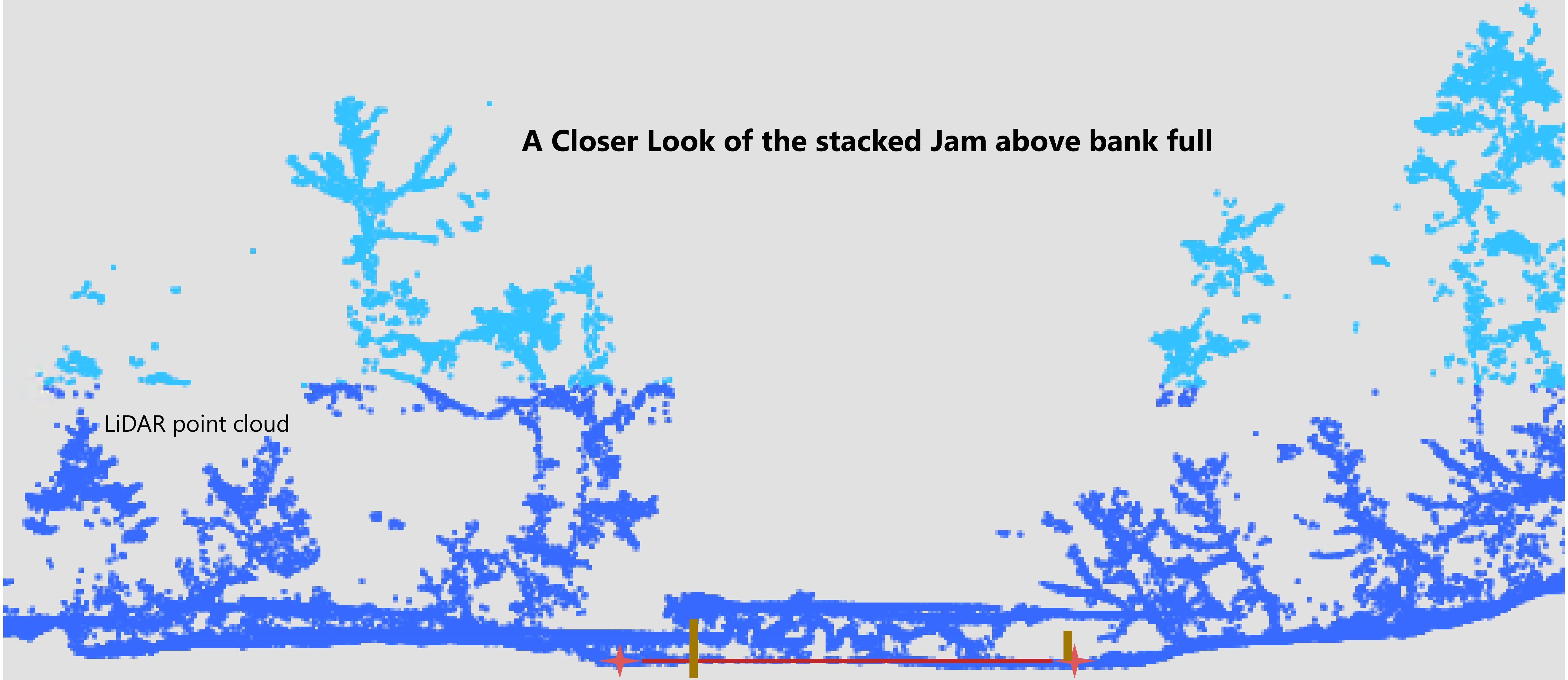
Longer length reduces transport capacity

STEPS TO SUCCESS

Jams were stacked at least 1 or 2 layers above bank full elevation

This reduces buoyancy by creating forces that push down on the Jam.

STEPS TO SUCCESS



RESTORATION RESPONSE
ANECDOTAL EVIDENCE

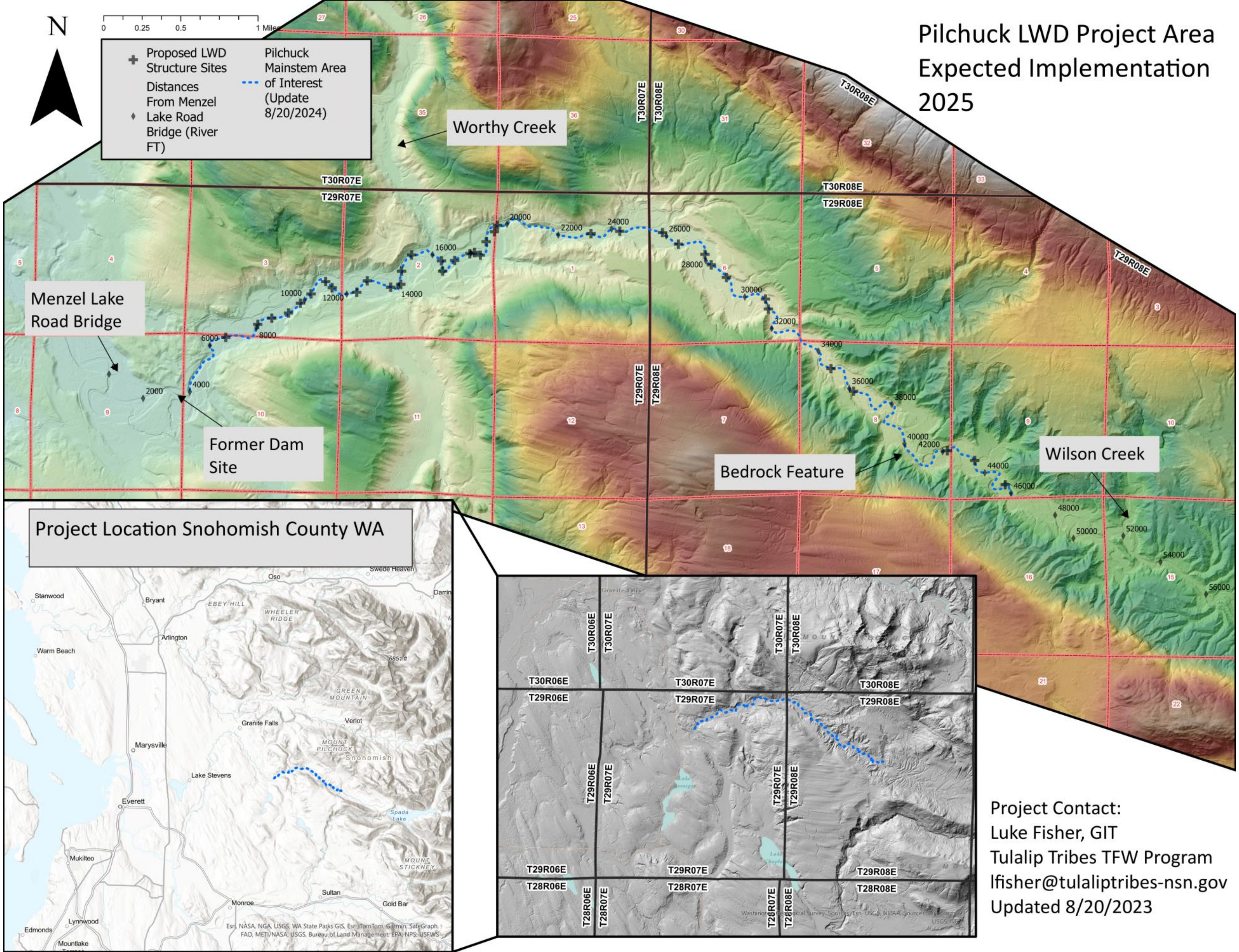
RESTORATION RESPONSE
ANECDOTAL EVIDENCE

Aerial IMAGERY 2023

SUMMER STEELHEAD REDDS 2021-2023, RM 4.5-4.9

Pilchuck River Heli-LWD Project coming 2025

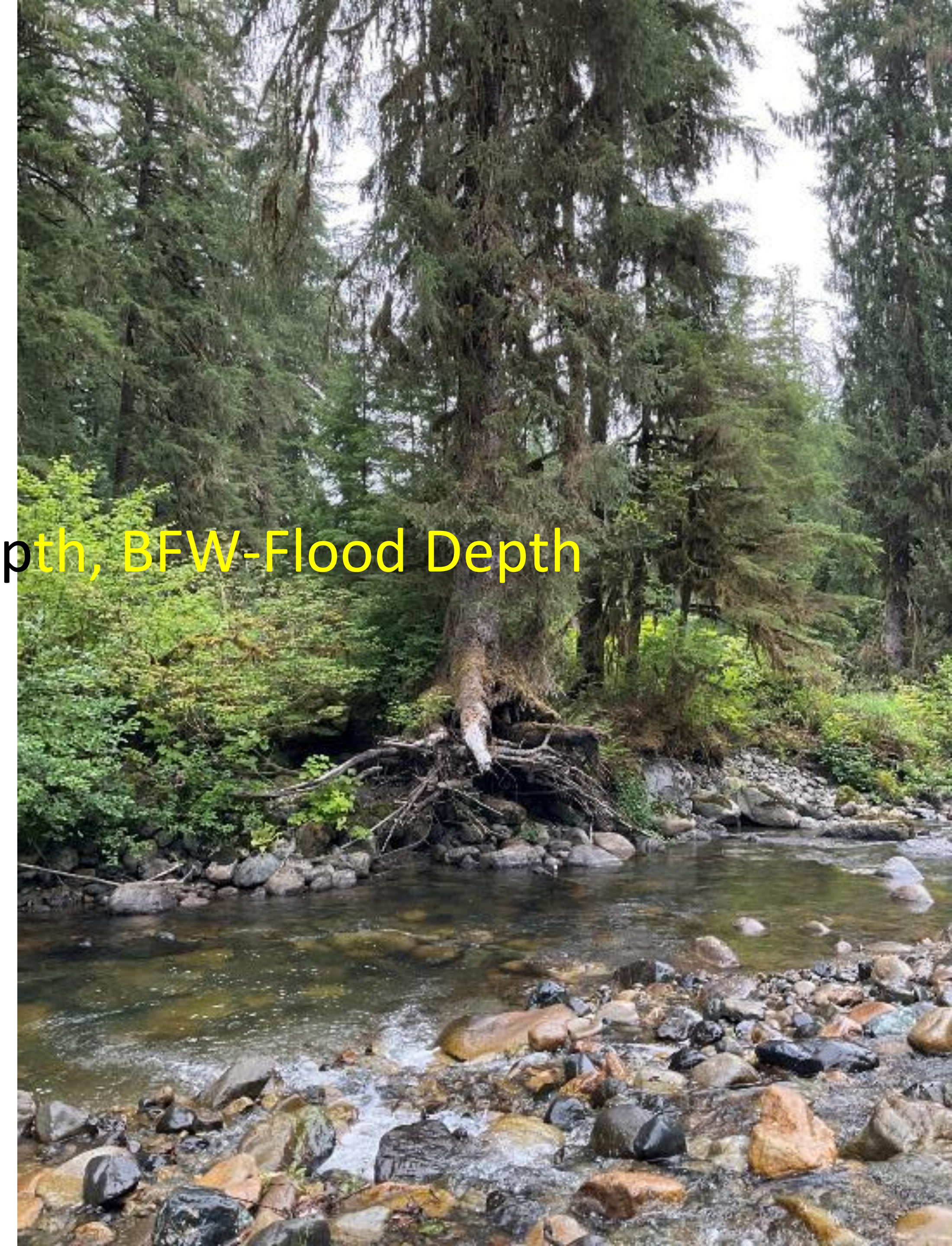
Pilchuck LWD Project Area Expected Implementation 2025



Project Contact:
Luke Fisher, GIT
Tulalip Tribes TFW Program
lfisher@tulaliptribes-nsn.gov
Updated 8/20/2023

Implementation Strategy

- Locations where wood makes sense
- # of logs
- Stability – Anchoring, 100-year Flood Depth, BFW-Flood Depth
- Model Results
- Field Verification
- Permitting Typicals
- Site Specific Prescriptions
- AND…Flipping conventional wisdom?



LWD Natural Analog—IDEAL!!

Conceptual: Natural Anchoring

Boulders

Stacking

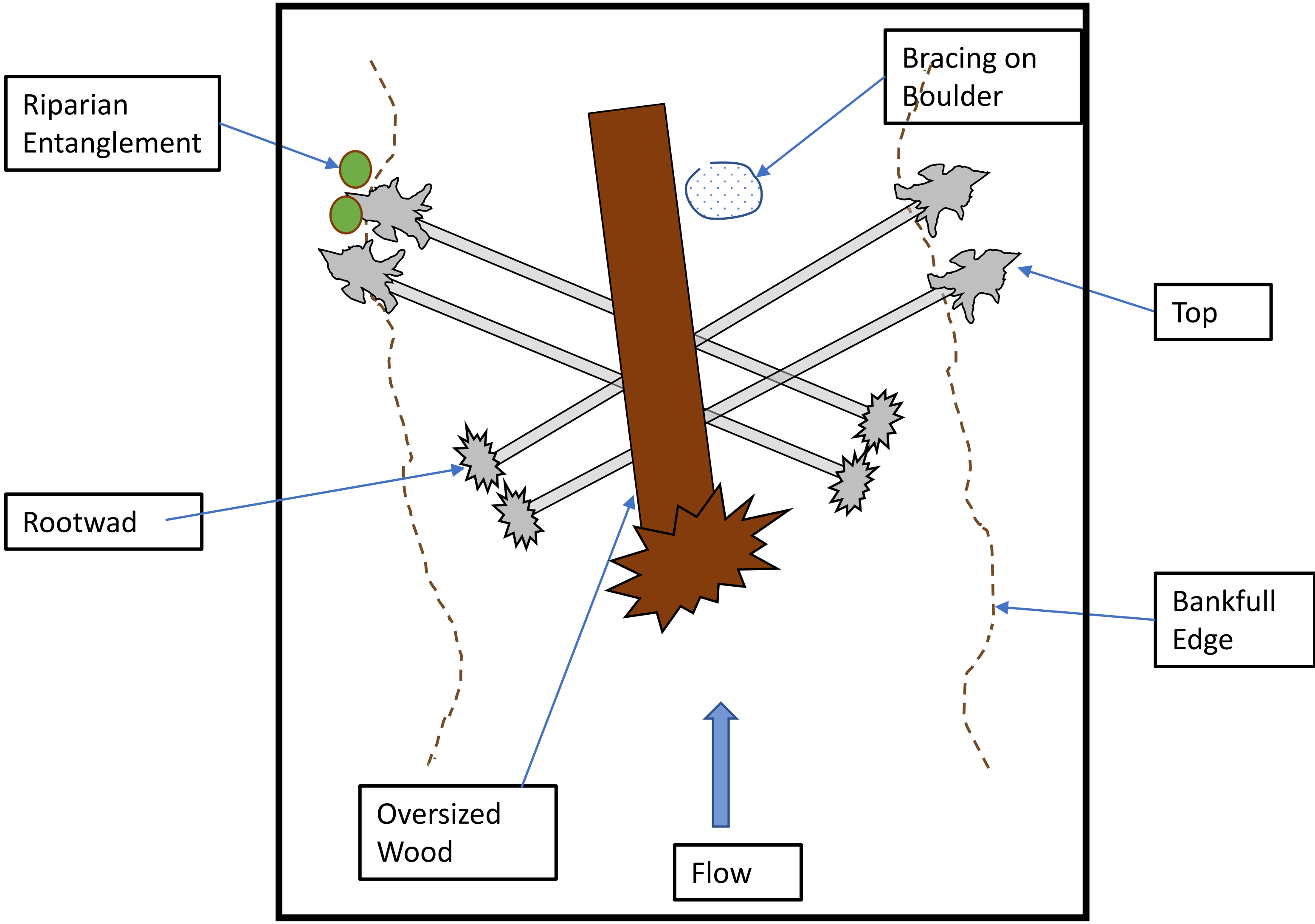
Riparian/Bank Anchor

Iterative Design Process

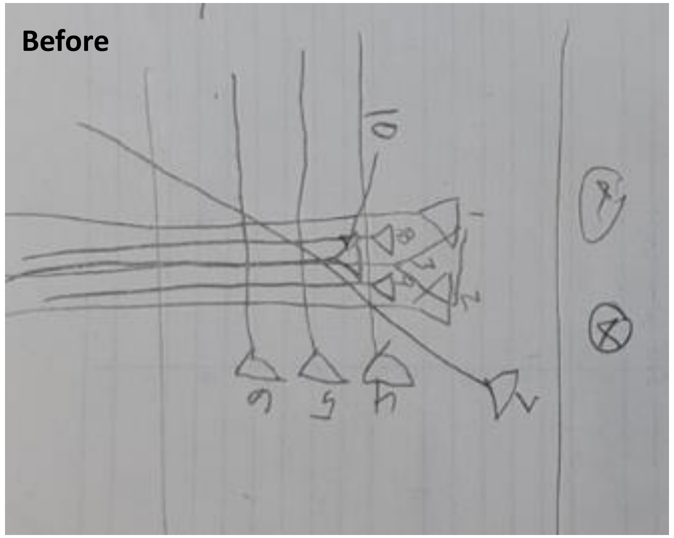
- Crayon Sketches
- 2D HEC-RAS Model Results (Flow-Depth, Wetted Width, Velocity Etc.)
- LiDAR XS for Channel Geometry
- Layout in Arc-GIS for Structure Geometry
- Individual Piece Stability (Free Body Diagram) → Overall Jam Stability (Through Interaction Forces)
- Guess-And-Check

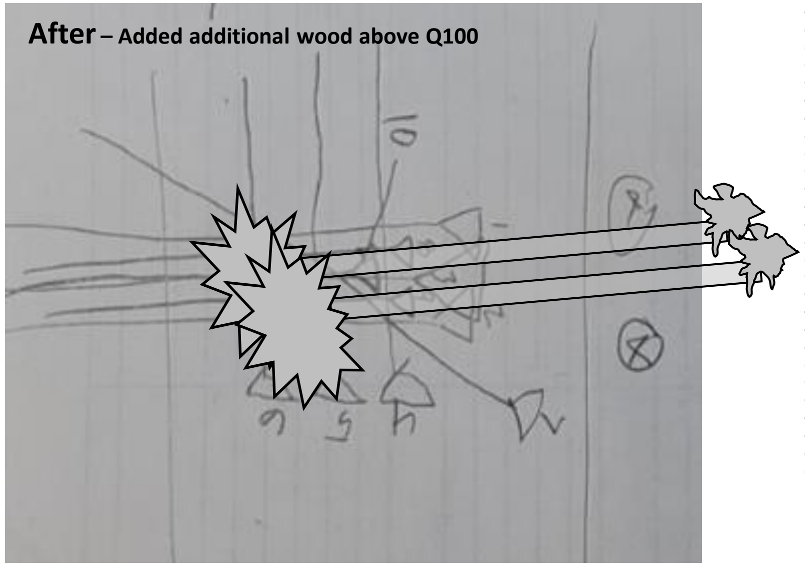
Pilchuck Specifics

- Wood Type
- Target FS ≈ 1+
- 100yr/25yr/10yr design discharges
- Riparian Anchoring
- Interactions for stacked wood pieces

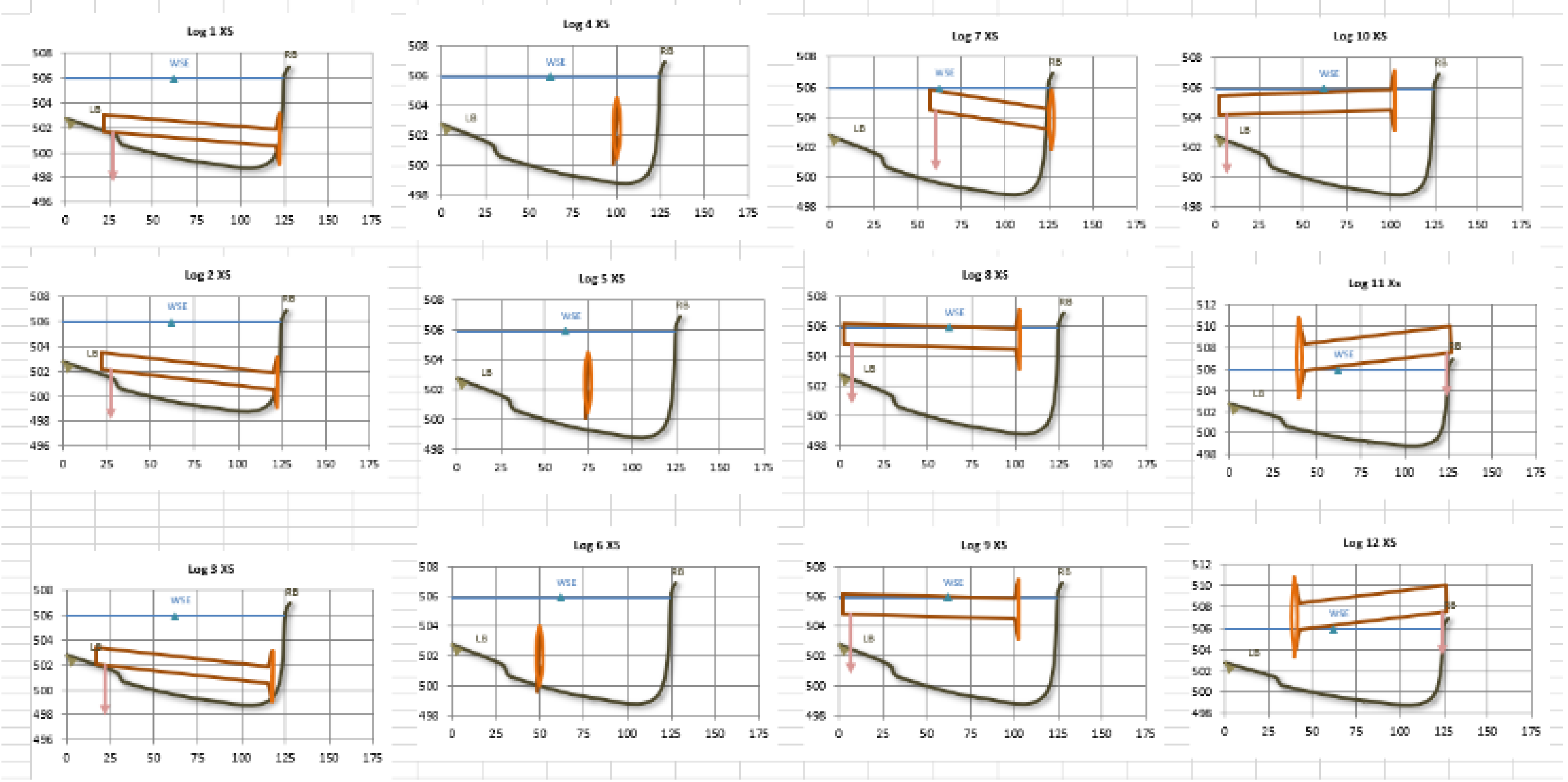


Example Jam Stability Calc - Partial Channel Spanner





Layout



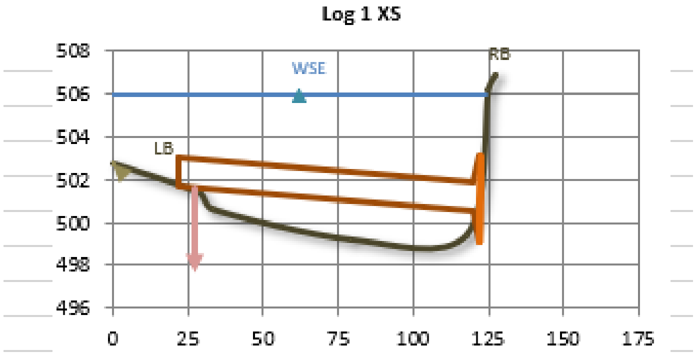
Hydro Inputs

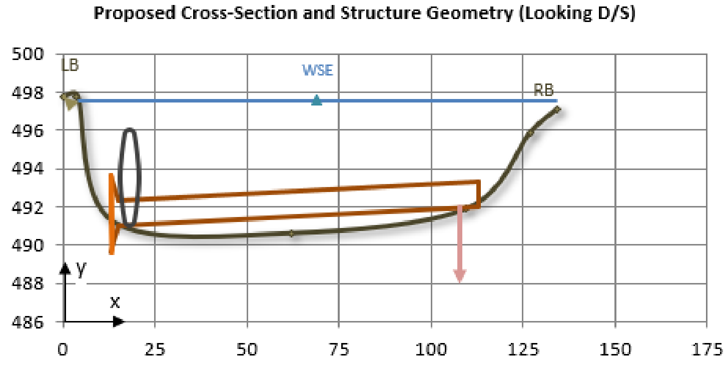
Design Discharge	Velocity (ft/s)	Depth (ft)	Discharge (CFS)
Q100	11.2	6.7	8000
Q25	9.2	5	4000
Q10	8.2	4.2	2800

Summary Output

Log	Length (ft)	Diameter (ft)	Log Weight (lb)	FS_V	FS_H	FS_M	V_F	H_F	Interactions
Log1	100.00	1.33	4,584.28	1.00	2.20	3.59	0.00	52,097.40	Log4, Log5, Log6
Log2	100.00	1.33	4,584.29	1.00	2.22	3.66	0.00	52,743.72	Log4, Log5, Log6
Log3	100.00	1.33	4,584.29	1.00	2.09	3.49	0.00	49,296.86	Log4, Log5, Log6
Log4	100.00	1.33	4,584.28	1.16	7.14	3.38	1,435.78	24,353.37	Log7
Log5	100.00	1.33	4,584.28	1.16	7.14	3.38	1,435.78	24,353.37	Log7
Log6	100.00	1.33	4,584.28	1.13	7.16	3.20	1,180.45	24,174.86	Log7
Log7	100.00	1.33	4,584.28	2.95	4.81	6.11	17,841.87	81,223.38	Log8, Log9, Log10
Log8	100.00	1.33	4,584.28	1.85	2.27	4.22	7,311.34	51,111.86	Log 11, Log 12
Log9	100.00	1.33	4,584.28	1.85	2.64	4.81	7,311.34	66,111.86	Log 11, Log 12
Log10	100.00	1.33	4,584.28	1.77	2.37	4.34	6,943.32	61,238.15	Log 11, Log 12
Log11	100.00	2.50	17,990.17	18.32	63.89	201.58	17,008.26	112,988.50	
Log12	100.00	2.50	17,990.17	18.32	63.89	201.58	17,008.26	112,988.50	

Cross Section Detail: WSE, Forces, Boulder, Riparian Etc.





Free Spreadsheet Tool Available From USFS – Based on Free-Body Diagram

Sample Multi-Log Structure

Spreadsheet developed by Michael Rafferty, P.E.

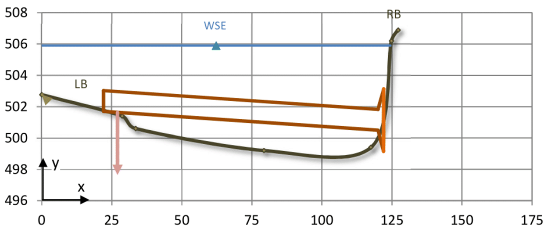
Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
e Channel Sp	Mid-Channel	Mid-channel	Outside	80+00	6.70	6.38	14.80

Multi-Log Structures	Layer	Log ID
	Key Log	Log1

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	0.00	502.77
Top LB	28.70	501.40
Toe LB	33.52	500.60
Thalweg	79.30	499.20
Toe RB	117.50	499.40
Top RB	124.80	506.20
Fldpln RB	127.20	506.90

Proposed Cross-Section and Structure Geometry (Looking D/S)

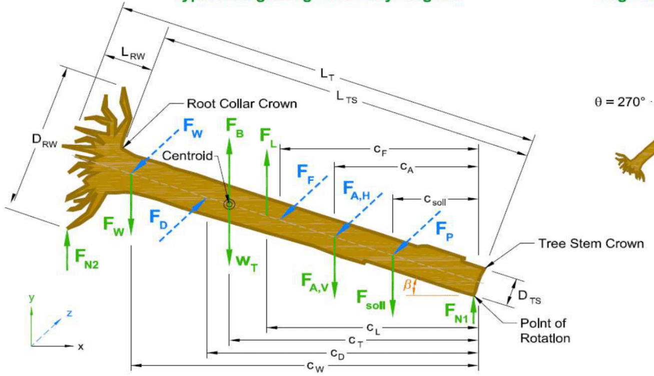


Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Hemlock, Western	Yes	100.0	1.33	2.00	3.99	31.4	41.0

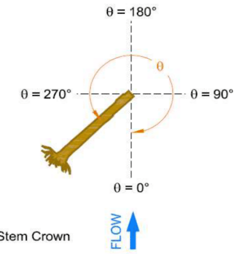
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	$y_{T,min}$ (ft)	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	89.0	0.7	Root collar: Bottom	120.00	500.50	499.15	503.14	129.37

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	φ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Small Cobble	136.4	84.9	41.0	4	0.00	0.00	0.00
Bank	Gravel/cobble	137.0	85.3	41.0	4	1.90	1.80	1.09

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft^3)	V_{RW} (ft^3)	V_T (ft^3)	W_T (lbf)	F_B (lbf)
↑WSE	0.0	0.0	0.0	0	0
↓WS↑Thw	136.2	9.6	145.8	4,584	9,096
↓Thalweg	0.0	0.0	0.0	0	0
Total	136.2	9.6	145.8	4,584	9,096

Lift Force

C_{LT}	0.03
F_L (lbf)	790

Vertical Force Balance

F_B (lbf)	9,096
F_L (lbf)	790
W_T (lbf)	4,584
F_{soil} (lbf)	196
$F_{W,V}$ (lbf)	0
$F_{A,V}$ (lbf)	5,106
Σ F_V (lbf)	0
FS_V	1.00

Soil Ballast Force

Soil	V_{dry} (ft^3)	V_{sat} (ft^3)	V_{soil} (ft^3)	F_{soil} (lbf)
Bed	0.0	0.0	0.0	0
Bank	0.0	2.3	2.3	196
Total	0.0	2.3	2.3	196

Horizontal Force Analysis

Drag Force

A_{Tp} / A_w	Fr_L	C_{Di}	C_w	C_D*	F_D (lbf)
0.21	2.26	0.98	0.00	1.57	43,269

Passive Soil Pressure / **Friction Force**

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	4.81	0	2.00	0.87	0
Bank	4.81	472	4.00	0.87	0
Total	-	472	6.00	-	0

Horizontal Force Balance

F_D (lbf)	43,269
F_P (lbf)	472
F_F (lbf)	0
$F_{W,H}$ (lbf)	0
$F_{A,H}$ (lbf)	94,894
Σ F_H (lbf)	52,097
FS_H	2.20

Moment Force Balance

Driving Moment Centroids			Resisting Moment Centroids			
$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
52.3	14.4	49.0	52.3	99.3	0.0	99.0

*Distances are from the stem tip

Point of Rotation: Rootwad

Moment Force Balance

M_d (lbf)	2,707,908
M_r (lbf)	9,718,479
FS_M	3.59

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft^3)	V_{Awet} (ft^3)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
Custom#1	5.00	Bank	100,000
			0

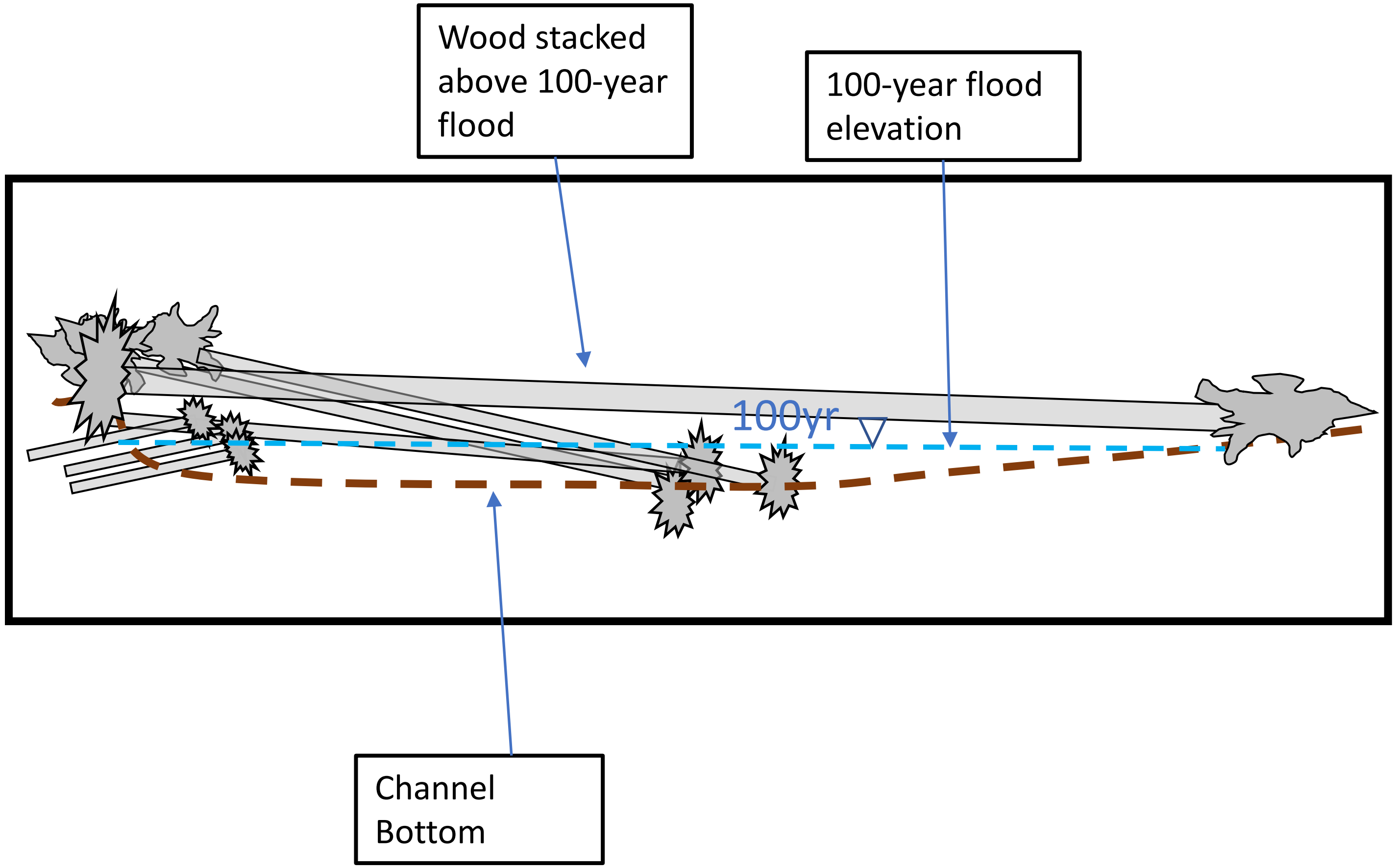
Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft^3)	$V_{r,wet}$ (ft^3)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
Behind								0	0
Above								0	0
Above								0	0

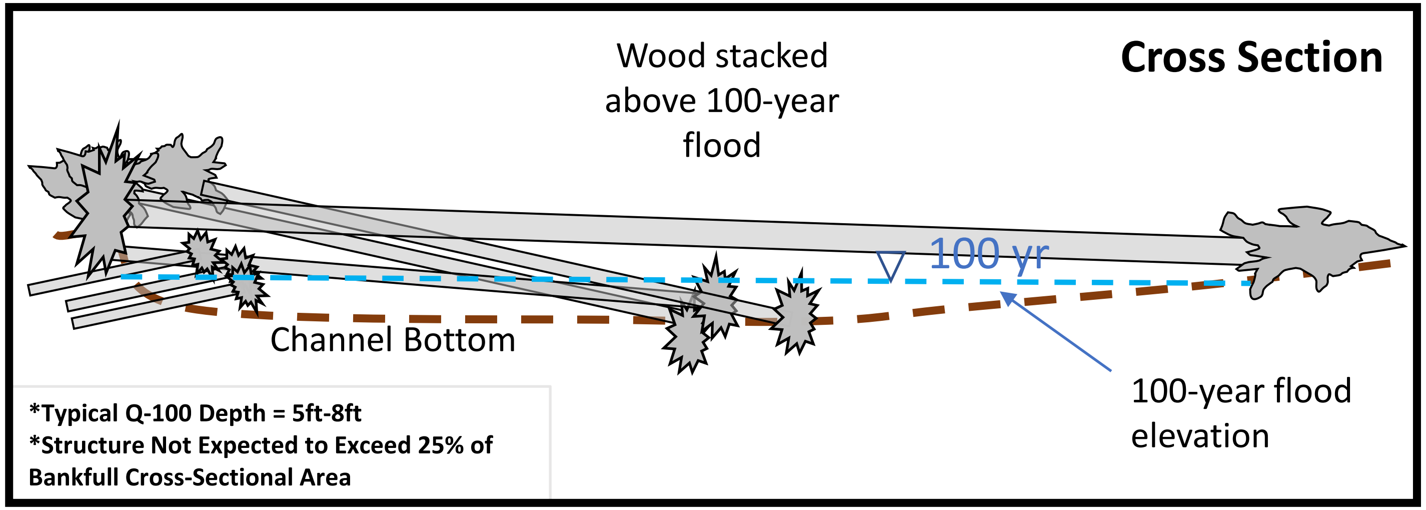
Interaction Forces with Adjacent Logs

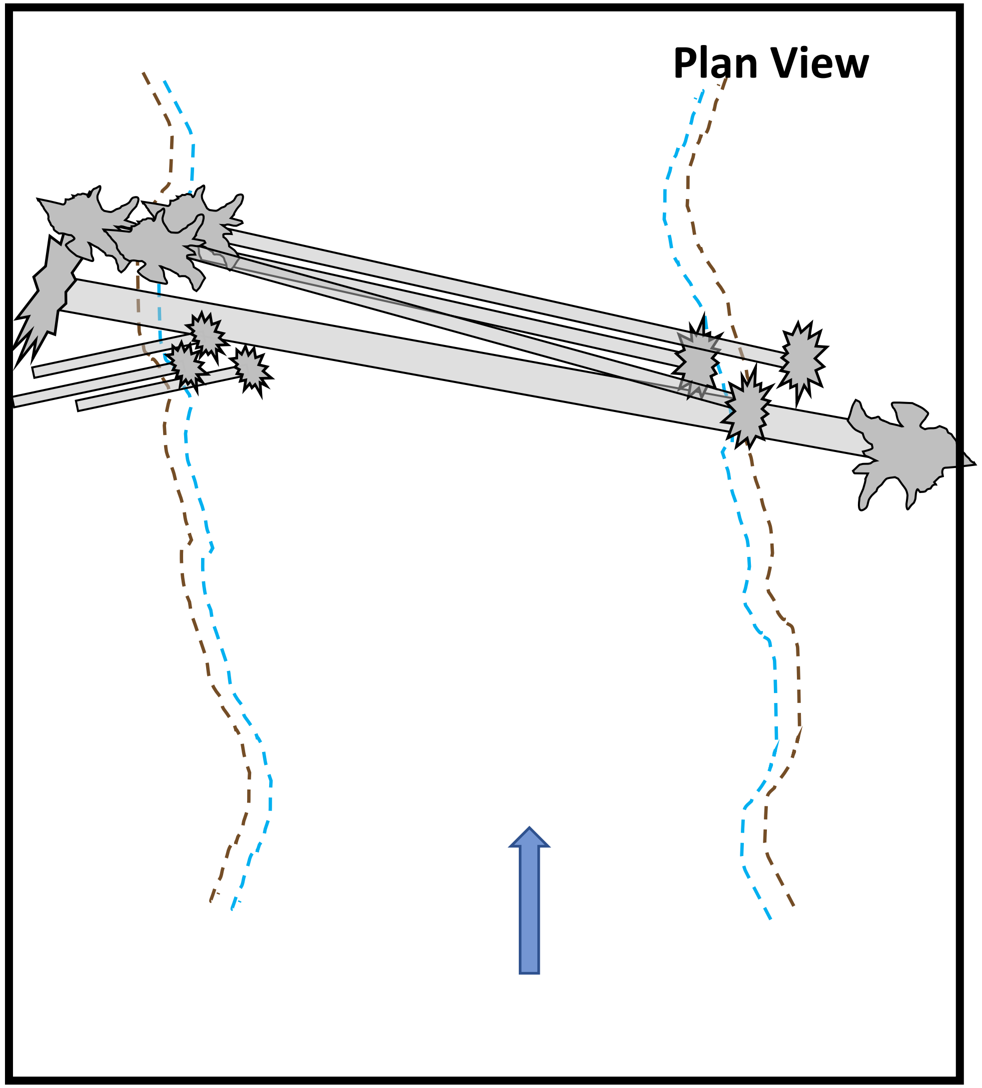
Log ID	Position	Link	c_{WI} (ft)	$F_{W,V}$ (lbf)	$F_{W,H}$ (lbf)	Applied Forces from other Logs: $F_{W,V}$ (lbf)	Applied Forces from other Logs: $F_{W,H}$ (lbf)
Log4	Above	Gravity	50.0	479	24,353	0	0
Log5	Above	Gravity	50.0	479	24,353	0	0
Log6	Above	Gravity	50.0	393	24,175	0	0
						0	0

LWD Jam Anatomy (Cross-Section View)



Channel Spanning Jam Anatomy – Conceptual Drawing (Site-Specific Typical)





Conceptual: Field Fit Channel Spanning Jam on Boulder Feature

Conceptual: Field Fit Channel Spanning Jam on Boulder Feature

Lessons Learned, thus far:

- Detailed engineering is not necessary where risks are appropriate
- Hydraulic modeling is a valuable tool for increasing stability
- A variety of methods/factors can result in jam stability
- Work with gravity and against buoyancy
- Natural analogs can inform conceptual designs at the site scale
- Mobile woody debris is a necessary ingredient for project success
- Regulated rivers may be slower to respond to treatments
- Helicopter LWD projects can be incredibly cost-effective

Thank you!

- David Bailey
- Luke Fisher
- Liz Ablow
- Ciaran McGee
- Dave Beedle
- Brett Shattuck
- Neil Shea
- Scott Rockwell
- Channing Syms
- Cygnia Rapp

- Tolt Fish Advisory Committee
- NW Helicopters
- Columbia Helicopters
- Seattle City Light
- SPU
- Weyerhaeuser Co
- WA Dept Natural Resources
- Campbell Global
- AND Many others!