Large Wood Technical Field School

Presentations from the Salmonid Restoration Federation Large Wood Technical Field School held on the Mendocino Coast October 30-31, 2018.
This two-day field school provided training for forestry and restoration professionals in both engineered and non-engineered large wood augmentation techniques that have been proven effective in restoring stream habitats on the Northern California coast. Participants learned how to effectively design and implement large wood restoration projects by learning how to identify geomorphic conditions of a treatment stream and select appropriate implementation methods to achieve desired results. Each day included classroom lectures, hands-on activities, field demonstrations, project site tours, and ample group discussion.

Hands-on group activities included buoyancy and other engineering computations and the construction of large wood site scenarios in the classroom. Field school contributors provided an on-site overview of heavy equipment implementation techniques. Additional discussion topics during the field school included project site identification, project layout, and design considerations.
(Slide 4) **Accelerated Recruitment: Cost-effective Restoration Techniques for Enhancing Instream Habitat in California Coho Streams**
Chris Blencowe – Blencowe Watershed Management, Inc.

(Slide 65) **Restoring Wood’s Essential Role in Controlling Channel Grade and Stability in Small Streams**
Mike Love – Michael Love and Associates, Inc.

(Slide 100) **How to Keep Your Wood from Floating Downstream: Interactive Computations for Stability of Large Wood Structures**

(Slide 132) **30 Years in the Making: California Conservation Corps Instream Large Wood Restoration Techniques**
California Conservation Corps

(Slide 152) **When is a Large Wood Project a Success?**
Margie Caisley, California Department of Fish and Wildlife
Accelerated Recruitment: Cost-Efficient Restoration Techniques for Enhancing Instream Habitat
Large Wood Technical Field School 10/30/18

Christopher Blencowe RPF, Blencowe Watershed Management in partnership with Ken Smith LTO, Pacific Inland
Phase 1: 1,000,000+ years of wood loading
Phase 2: Early Logging (1860s - 1920s)
Instream and streamside tree and wood clearing/splash dam logging
Phase 3: Post WW-II Logging
(1940s – 1970s) Excessive wood loading
Phase 4: Stream Clearing
(1970-80s)
Phase 5 (Present)
Waiting for riparian corridors to mature
Large Woody Debris (LWD) Function

• Create/maintain pool scour, backwater and side channel habitat
• Sort/store sediments including spawning gravel and increase floodplain connectivity
• Function as cover from predation, increase stream production and food availability
• Provide high velocity refugia during winter
Restoration Strategies

• Our strategy:
  • Increase pace and scale
  • Rapid, efficient accelerated recruitment of large wood as a stop-gap measure
  • ‘Nucleate’ the stream with functional large wood
  • Natural LWD recruitment is the goal
Techniques through Experience

• 11 years working together
• 49 number of unique projects
• 2600 structures
• 5700 pieces of LWD
• Not professionally trained in engineering or similar. Field based, evolution through ‘trial and error’
• This is just one tool in the restoration tool box
Design/Build Approach

• Structure designer is onsite for implementation everyday
• Oversees and modifies designs in real time as necessary ‘field fitting’
• Refined/revised through real world, on the ground situations and processes
• Critical to success of any one piece of wood, structure, project, etc
Implementation Methods

• Use rubber tired equipment to directly place (wedge) logs (onsite/offsite) through riparian roughness elements
• Use skidder to winch logs from onsite
• Direct falling near-stream conifers where appropriate
• Whole tree tipping
Structure Design Considerations

1. Evaluation of pre-existing in stream conditions including local channel morphology/thalweg location and quality of instream shelter. Prioritization of aggradated pools, flatwater, avoid tail outs/riffles

2. Orientation of riparian roughness elements for wedging/anchoring of LWD

3. Availability of favorable equipment access

4. Availability of suitable material trees for direct falling, or upslope tree falling and/or salvageable downed wood for potential placement.

5. Potential disturbance to riparian resources

6. Infrastructure/ aesthetic concerns
Characterizing the Impact of Geometric Simplification on Large Woody Debris Using CFD
Jeffrey B. Allen 1, David L. Smith
1Information Technology Laboratory, U.S. Army Engineer Research and Development Center, ATTN: CEERD-IE-C, 3909 Halls Ferry Road, Vicksburg, Mississippi, 39180, USA
Environmental Laboratory, U.S. Army Engineer Research and Development Center, ATTN: CEERD-IE-C, 3909 Halls Ferry Road, Vicksburg, Mississippi, 39180, USA
‘Throttle the Channel’

- Increase x-sectional surface area of project wood
SITE DESIGN 3

RECOMMENDATIONS
- 2-4 log structure with non-traditional anchoring designed to create debris accumulation and/or scour pool
- Instream ends of logs placed at unequal distances from the bank along a perpendicular plane configuration to downstream flow to create a 'debris fence'
- Logs placed at a 45° to 90° orientation to downstream flow
- SWD can be added immediately upstream of logs
- Target log length is 1.5 times or greater the bankfull width
‘Throttle the Channel’

• Increase x-sectional surface area of project wood
• Increase velocity/TKE around obstruction
‘Throttle the Channel’

• Increase x-sectional surface area of project wood
• Increase velocity/TKE around obstruction
• Scour pool, create slow water refugia, sort store gravels
• Ability to rack and retain existing instream SWD/MWD/LWD
• Must design and size wood/anchoring appropriate for channel
Dynamic Anchoring

• Generally all wood is designed to be retained at structure location
• Wood is ‘wedged’ amongst riparian roughness elements providing the structural anchoring mechanisms
• Dynamic Anchoring can be with or without hardware
• Onsite logistics dictate feasibility
SITE DESIGN 1

RECOMMENDATIONS

- 1-2 log structure with at least one anchor point utilizing traditional 1” threaded rebar and washer/nut anchoring designed to create/enhance pool habitat
- Instream ends of logs placed adjacent the thalweg
- Logs placed at a 30° to 90° orientation to downstream flow
- Logs with rootwads attached may be substituted
- SWD may be added immediately upstream of logs
- Target log length is 1.5 times or greater the bankfull width
SITE DESIGN 6

RECOMMENDATIONS

- 2 log structure with at least one anchor point utilizing traditional 1" threaded rebar and washer/nut anchoring designed to create mid-channel debris accumulation and/or scour pool
- Instream end of logs cross up at or near bankfull height
- Log to be placed at a 30° to 90° orientation to downstream flow
- Some logs with small rootwads may be substituted
- Target log length is 1.5 times or greater the bankfull width

BLENCOWE WATERSHED MANAGEMENT
Small Woody Debris (SWD)

- SWD is may be manually added where appropriate
- Direct falling indirectly contributes SWD
- Stobbing of limbs
- High quality material that can be activated during winter flows. May be staggered up bank/channel
- SWD may be removed from wetted channel and even active channel
- SWD not always desirable
Some Design Concerns

• Locations without appropriate upslope anchors and lack of suitable onsite material

• Large deep pools with little cover
  - Real concern for slowing velocities and contributing to aggradation
  - Promote overhead cover and less LWD surface area into thalweg
  - Difficult to design for, less aggressive, passive structure
SITE DESIGN 7

RECOMMENDATIONS
- One log structure with non-traditional anchoring designed to enhance floodplain inundation, provide high water refugia, and create debris accumulation
- Instream end of log to be at or near bankfull height
- Log length should be as close to bankfull height as possible
- Log to be placed at a 50° to 90° orientation to downstream flow
- LWD and/or SWD can be added upstream of log
Lessons Learned

• Successfully falling trees into channel zone is much more difficult then expected
• Need to design for highest flow events, including buoyancy and racking capabilities, “Throttle the channel”
• All LWD is not created equal, design important
• Onsite wood is often the best
• SWD/MWD often difference between good/great structure
• 50ft max width for traditional Acc Recruc.
• Realistic structure designs for local conditions
• Size wood/anchors appropriately
• Good operators is critical to success
Costs of Engineered vs. Unanchored LWD

Cost Comparison of Engineered vs. Unanchored on SF Ten Mile River

Anchored Project on SF Ten Mile River (2005) (FRGP, CTM):
• 3 mile reach treated
• 40 logs
• 11 sites
• Total cost: $41,000
• $1000 per log
• 13 logs/mi

• 9.4 mile reach treated
• 309 logs
• 133 sites
• Total cost: $73,000
• $236 per log
• 32 logs/mi
Performance Metrics

• Pre- and post-treatment surveys
  -DFW Stream Habitat Typing Level II w/LWD survey
  -Longitudinal profile
• Tagging/GPS project wood
• Photo points
Survey results by CDFW’s Coastal Restoration Monitoring and Evaluation Program on SF Ten Mile, July 2012

• 82% of original pieces of tagged LWD pieces were located.
• 93% tagged LWD are currently considered to be positively functioning.
• 92% sites had minimal movement and/or maintained their original position.
• A significant increase (393%) in large (L>20ft) LWD.
• No significant percent change in maximum pool depth and residual pool depth was seen between 2007 and 2012.

This was a survey of a lower 3.5 mile reach of the 2007 project area by Trevor Lucas et al (2012)
<table>
<thead>
<tr>
<th></th>
<th>% Pools by Total Length</th>
<th>Total LWD (6'-19')</th>
<th>Total LWD (≥20&quot;)</th>
<th>Residual Pool Depths</th>
<th># of Pools 3.0' - 3.9'</th>
<th># of Pools ≥ 4.0'</th>
<th>Pool Shelter Rating</th>
<th>% shelter is LW</th>
<th>% shelter is SW</th>
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<tbody>
<tr>
<td><strong>Signal Creek</strong></td>
<td>38.0%</td>
<td>46.0%</td>
<td>113.0%</td>
<td>-4.0%</td>
<td>11.0%</td>
<td>33.0%</td>
<td>5.0%</td>
<td>81.0%</td>
<td>47.0%</td>
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<tr>
<td><strong>SF Big River (Wegner Reach)</strong></td>
<td>25.0%</td>
<td>22.0%</td>
<td>9800.0%</td>
<td>-11.0%</td>
<td>-30.0%</td>
<td>-33.0%</td>
<td>60.0%</td>
<td>1300.0%</td>
<td>2100.0%</td>
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<td><strong>LNF Big River</strong></td>
<td>6.0%</td>
<td>10.0%</td>
<td>97.0%</td>
<td>4.0%</td>
<td>14.0%</td>
<td>50.0%</td>
<td>37.0%</td>
<td>12.0%</td>
<td>18.0%</td>
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<tr>
<td><strong>Kass Creek (lower 1400 ft)</strong></td>
<td>24.0%</td>
<td>13.0%</td>
<td>62.0%</td>
<td>0.0%</td>
<td>-100.0%</td>
<td>0.0%</td>
<td>24.0%</td>
<td>49.0%</td>
<td>24.0%</td>
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<tr>
<td><strong>Lower Inman Creek</strong></td>
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<td>123.0%</td>
<td>327.0%</td>
<td>3.0%</td>
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<tr>
<td><strong>NF Garcia</strong></td>
<td>10.0%</td>
<td>-7.0%</td>
<td>152.0%</td>
<td>-9.0%</td>
<td>233.0%</td>
<td>0.0%</td>
<td>36.0%</td>
<td>78.0%</td>
<td>76.0%</td>
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<tr>
<td><strong>Mean</strong></td>
<td><strong>21.2%</strong></td>
<td><strong>34.5%</strong></td>
<td><strong>1758.5%</strong></td>
<td><strong>-2.8%</strong></td>
<td><strong>21.3%</strong></td>
<td><strong>25.0%</strong></td>
<td><strong>41.3%</strong></td>
<td><strong>299.5%</strong></td>
<td><strong>475.3%</strong></td>
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<tr>
<td><strong>SD</strong></td>
<td>11.6%</td>
<td>46.7%</td>
<td>3940.6%</td>
<td>6.2%</td>
<td>112.0%</td>
<td>46.8%</td>
<td>28.3%</td>
<td>498.7%</td>
<td>825.6%</td>
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Longitudinal Profile of Lower 1400’ Project Reach in Kass Creek (Noyo River) (2010-2012) (FRGP, NOAA/TU, SRA)
Longitudinal Profile of Lower 1400’ Project Reach in Kass Creek (Noyo River) (2010-2012)
(FRGP, NOAA/TU, SRA)
Longitudinal Profile of Lower 1400’ Project Reach in Kass Creek (Noyo River)
2010 and 2013 and 2017
(FRGP, NOAA/TU, SRA)

Kass Creek Thalweg Profile - 11/2/2010 to 11/13/17
J. Hvozda, D. Kyle, C. Blencowe,
Big Questions:

• How much wood is good?
• How much wood can we reasonably add to these watersheds without causing problems to the channels and without depleting the still young riparian corridor?
Big Questions:

• How much wood is good?
• How much wood can we reasonably add to these watersheds without causing problems to the channels and without depleting the still young riparian corridor?
• Does wood actually make more fish? The biological component is missing.
The Pudding Creek Project: a BACI Study

- A partnership between Lyme Timber, CDFW, TNC, TU
- Six years of baseline data on coho life history metrics
- Approximately 80% of the fish bearing habitat will be treated using accelerated recruitment
- Caspar Creek, a similar watershed with a similar monitoring history, will be the control stream
- Changes in biological (e.g., spawner to smolt) and physical indices will be closely monitored for six years after treatment
Limitations/Applicability

- Landowners with large holdings, lots of trees and little risk to infrastructure
- The 18 largest landowners own 81% of the properties in Mendocino County’s CCC ESU Coho Core Areas
Limitations/Applicability

- Bankfull widths up to 50 feet
- Direct falling best in 20’-30’ bankfull
- Low gradient alluvial streams
- Willing, supportive landowners

- Avoid deeply entrenched, flashy high volume channels
Low-Cost Restoration Techniques for Rapidly Increasing Wood Cover in Coastal Coho Salmon Streams

Jennifer K. Carah, Christopher C. Blencowe, David W. Wright, and Lisa A. Bolton

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Published online: 09 Sep 2014.

Abstract
Like many rivers and streams in forests of the Pacific Northwest, California north coast rivers and streams have been depleted of downed wood through timber harvest and direct wood removal. Due to the important role of wood in creating and maintaining salmonid habitat, wood augmentation has become a common element of stream restoration. Restoration efforts in the Northwest often focus on building anchored, engineered wood structures at the site scale; however, these projects can fail to meet restoration goals at the watershed scale, do not closely mimic natural wood leading processes or dynamics, and can be expensive to implement. For critically imperiled populations of Coho Salmon Oncorhynchus kisutch in California, there is a strong impetus to achieve habitat restoration as quickly as possible in priority watersheds to avoid the short term and mid-term consequences of extirpated populations and ecosystem inefficiency. In this multi-site project, we investigated unanchored techniques for wood leading to evaluate cost and contribution to salmonid habitat in Mendocino County, California. Over a period of 6 years, 72.4 km of streams were treated with 1,873 pieces of strategically placed wood. We found that unanchored wood leading techniques were much less costly than commonly used anchored techniques, reliably improved habitat, and retained wood at high water levels (mean = 92%) in small- to moderate-sized streams, at least over the short term (~6 years). The average cost of design and construction for the unanchored projects was US$229 per log, equivalent to 22% of the cost associated with the anchored wood augmentation methods examined here. Our results suggest that this unanchored wood leading approach has the potential to increase the pace and scale at which wood augmentation projects are implemented in the Pacific Northwest and beyond.

Downed wood plays an essential role in stream morphology and productivity, particularly in salmon-bearing streams of the Pacific Northwest (Horne and Rosebrough 1986; Bisson et al. 1995; National Research Council 1996; Abbe et al. 2004; and northern California (Keller et al. 1981; Lisle 1986; Lassen, and Harris 2003). Wood influences downstream erosion and deposition processes by locally altering water velocities and shear stress (Lisle 1986; Abbe and Montgomery 1996). These processes trap sediments, increase bed and other depositional features, provide gravel necessary for salmon spawning, and increase floodplain development and connectivity (Lisle 1986; Bisson et al. 1987; Fetherston et al. 1995). Wood can increase score in other areas, creating slow-water habitats like pools, backwaters, and side channels, thus providing both oversummer and overwinter...
Additional Thanks

- JJ Brunner
- Dave Wright, TNC
- Trout Unlimited (North Coast Coho Project)
- Scott Monday, DFW
- Jonathan Warmerdam, NCRWQCB
- Jen Carah, TNC
- All other project partners
Restoring Wood’s Essential Roll in Controlling Channel Grade and Stability in Small Streams

Cedar Creek, Jedediah Smith State Park, California

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1. Role of large wood in controlling profiles of streams
2. Causes and Process of channel incision in historically wood controlled streams
3. Impact of incision on geomorphic stability, water quality, and aquatic habitat
4. Identifying channel incision
5. Restoration of incised channels through reintroduction of wood
Large Wood in Small Streams

Photo: Zack Larson

Clarks Creek, Jedediah Smith State Park, California
Geomorphological Role of Large Wood in Small Mountain Streams

- Racks smaller wood & traps sediment
- Raises/maintains channel bed elevation
- Promotes connectivity to benches/floodplain
- Forces overall profile of the channel
- Scours pools and sorts bed material
- Slows the flow and raises groundwater
- Provides long-term structural controls
Wood Forced Morphologies in Mountain Streams

Montgomery & Buffington (1997):

- Wood obstructions force the channel morphology and slope
- Wood forced pool-riffle and step-pool channels most common
- Wood forced morphologies can maintain steeper gradients than their analogous free-formed morphologies

From Montgomery et al. (1995) >>
Wood-Forced Channel Morphology in Mountain Drainage Basins

Large Wood / Roots Controlling Grade

Forced Pool-Riffle

Forced Step-Pools

Floodplain Elevation

Wood Forced Channel Profile
Large Wood in Small Streams

Dunn Creek, coastal northern Mendocino County
Process of Incision Following Wood Removal

Headward Migration

Floodplain Elevation

Original Stream Grade

Channel Profile

Knickpoint

Hard Knickpoint, Stops Incision

Culvert, Bedrock, Debris Jam

Incised Stream Channel

Channel Head Cutting
Arrested Kickpoints
Loss of Wood Controls

Causes

- Old-growth wood removed as part of historical logging
- Tractor logging in channels
- “Stream cleaning” to remove debris jams, fish passage, flood conveyance
- Fire burns in-channel wood
- Lack of riparian wood recruitment
Historical Logging in Stream Beds

Logging using Corduroy and Steam Donkey in Tributary to Big River
Mendocino County, CA

From KRIS
Stream Cleaning

Gulch C, Tributary to Noyo River
Mendocino County, CA

Historical Streambed?
Sawcut Old-Growth Redwood Roots
Highly Incised Complete Lack of Wood Controls
Incising Channel 100-years Later

Logged circa 1916 by Rail
Manly Gulch, Trib. to Little North Fork Big River
Mendocino County, CA
Channel Evolution Model (CEM)

Stage III: Incised and Widening

from Schumm, Harvey, and Watson. 1984.
Stream Evolution Model (SEM)

from Cluer and Thorne, 2013
Stream Evolutionary Stage vs. Ecological Benefits

from Cluer and Thorne, 2013
“We conclude channel incision presents a syndrome that is characterized by perturbed hydrology, degraded physical habitat, elevated nonpoint source pollution, and depleted fish species richness and that is extremely deleterious to instream ecosystem services.”

No Incision Evident. Wood Controlling Channel Profile from 0+25 to Culvert
Combined Field and Thalweg Profile Interpretation
Neefus Gulch – Navarro River Watershed

Historic Channel Bed?
Other Channel Incision Indicators

- **Lack of Sediment Deposition**
  Erosion of channel bed down to bedrock or other resistant soil layers

- **Toe of Bank is Vertical**
  Exposed roots, lack of sediment layering at streambed-banks interface

- **Actively Widening**
  Active bank failures, low depositional bars

- **Lack of Pools**
  Long reaches of riffles/runs without pools

- **Cultural Features Exposed**
  Perched culverts or exposed bridge footings, aprons, and pipelines

List adapted from J. Castro, 2003
Restoring Stability – Choose a Stage

Move to another Stage

from Cluer and Thorne, 2013
Restoring Incised Channels and Connectivity
Placing Wood - Profile Restoration

Baker Creek
Sanctuary Forest

photos: Sam Flanagan, BLM
Profile Restoration
Outlet Creek
Washington State

Upstream of Culvert
No Incision Experienced >>

<< Downstream of Perched Culvert Crossing was Incised to “Hardpan”

Photos from Kozmo Bates
Profile Restoration
Outlet Creek

- Large Wood Placed to Trap Small Wood and Retain Bedload
- Raised Channel Bed to Pre-Incision Elevation
- Constructed 2000; Photos from 2005
Incising Channel 100-years Later

Logged circa 1916 by Rail
Manly Gulch, Trib. to Little North Fork Big River
Mendocino County, CA
Historical Logging in Stream Bed
Manly Gulch?

Logging by Rail in Tributary to Little North Fork Big River
Mendocino County, CA

From KRIS
Manly Gulch Incising Channel Profile

Over 8-ft of Incision

Unconfined Channel on River Floodplain

Narrow Valley between Steep Hills

Estimated Historical Channel Profile

Multiple Kickpoints

Approximate Volume of Sediment Mobilized 2,150 Cubic Yards
Manly Gulch Channel Profile Restoration Design

- Camp 3 Footbridge
- Plank Footbridge
- Overall Top of Bank Slope 2.85%
- Historic Thalweg Slope 2.83%
- Permeable Jam
- Log Jam
- Existing Thalweg
- Roadway Bridge
- Trail Bridge

Elevation, feet (Assumed)

Station, feet
Summary

- Large wood in small streams controls the channel morphology and profile
- Loss of wood controls results in
  - Dramatic incision & channel instabilities,
  - Delivery of large volumes of sediment to downstream
  - Degradation of Habitat
- Determine depth & extent of incision and current SEM stage using annotated channel profile surveys & field interpretation
- Adding high densities of large wood to small streams may restore the channel profile, improve downstream water quality, and restore fisheries habitat
How to Keep Your Wood From Floating Downstream: Interactive Computations for Stability of Large Wood Structures

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Salmonid Restoration Federation 2018 Large Wood Technical Field School
Purpose of Presentation

1. Understand the basic forces on in-stream large wood
2. Give you basic computational tools
3. Understand some of the uncertainties
1. Driving and resisting factors on log structures
2. Sample calculations for stability against buoyancy
3. Hands-on computations for 4 different scenarios (groups)
4. Review of computations and discussion
5. TEST
6. References
Driving Forces on Logs

Vertical

1. Buoyancy
2. Lift

Horizontal

1. Drag
2. Overturning
Resisting Forces on Logs

Vertical
1. Weight of logs
2. Weight of soil
3. Ballast (Rocks, etc)

Vertical and Horizontal
1. Posts/Piles
2. Active/passive earth pressure
Is it Stable?

Resisting Forces vs Driving Force

- Stable when Resisting Forces are Greater than Driving Forces
- Factor of Safety

Not Stable
Factor of Safety

\[
FS = \frac{\text{Resisting Forces}}{\text{Driving Forces}}
\]

- Stable when \( FS > 1 \)
- Risk Analysis and Selection of FS....
Buoyancy
Buoyancy

Archimedes Principle:

The buoyant force on an object submerged in a fluid is equal to the weight of the fluid that is displaced by that object.
Resisting Buoyancy

Resisting Forces (Downwards)

Driving Forces (Upwards)
Buoyant Stability of a Buried Log: Testing the 2/3 Embedment Rule

- 2 foot diameter redwood log, 30 feet log, no root wad
- Buried 3 feet deep in silt, projecting 10 feet into stream channel
- Assume full submergence, dry wood
Buoyancy of a Buried Redwood Log: Forces Acting on Log

Driving Forces
- Buoyancy

Resisting Forces
- Weight of Log
- Weight of soil (submerged)
Buoyancy of a Buried Redwood Log: Log Volume

Buoyancy (B) is the Weight of water displaced by the volume of the log

\[ B_{\text{log}} = V_{\text{log}} \gamma_{\text{water}} \]

Volume of Log:

\[ V_{\text{log}} = \pi R^2 L_{\text{log}} \]

\[ V_{\text{log}} = \pi \times 1 \text{ft}^2 \times 30 \text{ft} \]

\[ V_{\text{log}} = 94.2 \text{ft}^3 \]

- \( D_{\text{log}} = 2 \text{ feet} \)
- \( L_{\text{log}} = 30 \text{ feet} \)
Buoyancy of a Buried Redwood Log: Buoyant Force of Log

- Buoyancy (B) is the Weight of water displaced by the volume of the log

\[ B_{\text{log}} = V_{\text{log}} \gamma_{\text{water}} \]

\[ \gamma_{\text{water}} = \text{Density Water (62.4 lbs/ft}^3) \]

\[ B_{\text{log}} = 94.2 \text{ ft}^3 \times 62.4 \text{ lbs/ft}^3 \]

\[ B_{\text{log}} = 5,878 \text{ lbs} \]
Buoyancy of a Buried Log: Resisting Force: Weight of Log

Weight of Log

\[ W_{\text{log}} = V_{\text{log}} \gamma_{\text{wood}} \]

\[ \gamma_{\text{wood}} = \text{Density Dry Redwood (24.5 lbs/ft}^3) \]

\[ W_{\text{log}} = 94.2 \text{ ft}^3 \times 24.5 \text{ lbs/ft}^3 \]

\[ W_{\text{log}} = 2,308 \text{ lbs} \]
Buoyancy of a Buried Log: Resisting Force: Weight of Soil Over Log

Volume of Soil Over Log

\[ V_{soil} = L_{emb} D_{log} D_{emb} \]

\[ V_{soil} = 20 \text{ feet} \times 3 \text{ feet Deep} \times 2 \text{ feet Log Width} \]

\[ V_{soil} = 120 \text{ ft}^3 \]
Buoyancy of a Buried Redwood Log:
Resisting Force: Weight of Soil Over Log

Submerged Weight of Soil Over Log

\[ W_{soil} = V_{soil} \gamma_{soil} \]

\[ \gamma_{soil} = \text{Submerged Density Firm Silt (56.0 lbs/ft}^3) \]

\[ W_{soil} = 120 \text{ ft } 3 \times 56.0 \text{ lbs/ft}^3 \]

\[ W_{soil} = 6,720 \text{ lbs} \]
Buoyancy of a Buried Redwood Log: Summary of Forces

Driving Forces

- Buoyancy

\[ B_{\text{log}} = 5,878 \text{ lbs} \]

Resisting Forces

- Weight of Log

\[ W_{\text{log}} = 2,308 \text{ lbs} \]

- Weight of soil (submerged)

\[ W_{\text{soil}} = 6,720 \text{ lbs} \]
Buoyancy of a Buried Redwood Log: Factor of Safety (Force-Based)

\[ FS = \frac{W_{\text{log}} + W_{\text{soil}}}{B_{\text{log}}} \]

\[ FS = \frac{2,308 \text{ lbs} + 6,720 \text{ lbs}}{5,878 \text{ lbs}} \]

Resisting Forces

Driving Forces

\[ FS = 1.53 \]
Buoyancy of a Buried Redwood Log: Factor of Safety (Moment-Based)

Driving Moments Vs Resisting Moments
Buoyancy of a Buried Redwood Log: Factor of Safety (Moment-Based)

Driving Moments Vs Resisting Moments

Point of Rotation

Length of Lever Arm
Buoyancy of a Buried Redwood Log: Factor of Safety (Moment Based)

Driving Moment-Buoyancy

\[ M_{d-Buoy} = B_{log} \cdot C_{log} \]

\( C_{log} \) is length to center of mass of log = length to middle of log = 15 feet

\[ M_{d-Buoy} = 5,878 \text{ lbs} \times 15 \text{ feet} \]

\[ M_{d-Buoy} = 88,170 \text{ foot lbs} \]
Center of Mass?!

= Center of Balance

Diagram 1: Two individuals, one weighing 50 pounds and the other 50 pounds, are evenly balanced on a seesaw, with the center of balance marked at the midpoint.

Diagram 2: An individual weighing 40 pounds is balanced against one weighing 160 pounds, with the center of balance marked accordingly.
Buoyancy of a Buried Redwood Log: Factor of Safety (Moment Based)

Resisting Moments - Moment of Log Weight

Moment of Log Weight:

\[ M_{r-log} = W_{log} \cdot C_{log} \]

\( C_{log} \) is length to the center of mass of log = length to middle of log = 15 feet

\[ M_{r-log} = 2,308 \text{ lbs} \times 15 \text{ feet} \]

\[ M_{r-log} = 34,620 \text{ foot lbs} \]
Buoyancy of a Buried Redwood Log: Factor of Safety (Moment Based)

Resisting Moments - Moment of Soil Weight

Moment of Soil Weight:

\[ M_{r-soil} = W_{soil} C_{soil} \]

\( C_{log} \) is center of mass of soil over the log = 10 feet

Without Root Wad

\[ M_{r-soil} = 6,720 \text{ lbs} \times 10 \text{ feet} \]

\[ M_{r-soil} = 67,200 \text{ foot lbs} \]
Buoyancy of a Buried Redwood Log: Factor of Safety (Moment Based)

Summary of Forces

Driving Moments

- Buoyancy

\[ M_{d-Buoy} = 88,170 \text{ foot} - \text{ lbs} \]

Resisting Moments

- Moment of Log Weight

\[ M_{r-log} = 34,620 \text{ foot} - \text{ lbs} \]

- Moment of Soil Weight

\[ M_{r-soil} = 67,200 \text{ foot} - \text{ lbs} \]
Buoyancy of a Buried Redwood Log: Factor of Safety (Moments)

\[ FS = \frac{M_{r-log} + M_{r-soil}}{M_{d-Buoy}} \]

\[ FS = \frac{34,620 \text{ ft} \cdot \text{lbs} + 67,200 \text{ ft} \cdot \text{lbs}}{88,170 \text{ ft} \cdot \text{lbs}} \]

Resisting Moments
Driving Moments

\[ FS = 1.15 \]
### Your Turn

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Redwood Log in Silt</td>
<td>Example</td>
</tr>
<tr>
<td>Redwood Log in Gravel/Cobble</td>
<td>Group 1</td>
</tr>
<tr>
<td>Douglas Fir Log in Silt</td>
<td>Group 2</td>
</tr>
<tr>
<td>Douglas Fir Log in Gravel/Cobble</td>
<td>Group 3</td>
</tr>
<tr>
<td>Douglas Fir 4-foot dia. Root Wad in Gravel/Cobble</td>
<td>Group 4</td>
</tr>
</tbody>
</table>
## Answers

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Buoyancy Wood (lbs)</th>
<th>Weight Log (lbs)</th>
<th>Weight Soil (lbs)</th>
<th>FS (Force)</th>
<th>FS (Moment)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Redwood Log in Silt (Example)</td>
<td>5,878 lbs</td>
<td>2,308 lbs</td>
<td>6,720 lbs</td>
<td>1.53</td>
<td>1.15</td>
</tr>
<tr>
<td>Redwood Log in Gravel/Cobble (Group 1)</td>
<td>5,878 lbs</td>
<td>2,308 lbs</td>
<td>10,236 lbs</td>
<td>2.13</td>
<td>1.55</td>
</tr>
<tr>
<td>Douglas Fir Log in Silt (Group 2)</td>
<td>5,878 lbs</td>
<td>3,156 lbs</td>
<td>6,720 lbs</td>
<td>1.68</td>
<td>1.29</td>
</tr>
<tr>
<td>Douglas Fir Log in Gravel/Cobble (Group 3)</td>
<td>5,878 lbs</td>
<td>3,156 lbs</td>
<td>10,236 lbs</td>
<td>2.27</td>
<td>1.69</td>
</tr>
<tr>
<td>Douglas Fir 4’ Root Wad in Gravel/Cobble (Group 4)</td>
<td>6,452 lbs</td>
<td>3,464 lbs</td>
<td>10,236 lbs</td>
<td>2.12</td>
<td>1.49</td>
</tr>
</tbody>
</table>
Differences in Centers of Mass

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


https://www.fs.fed.us/biology/nsaec/assets/lw_design_tool_v1-1.xlsm
TEST TIME
30 YEARS IN THE MAKING: CALIFORNIA CONSERVATION CORPS INSTREAM LARGE WOOD RESTORATION TECHNIQUES

Mission Statement:

The young women and men of the Corps work hard protecting and restoring California's environment and responding to disasters, becoming stronger workers, citizens and individuals through their service.

Hard Work, Low Pay, Miserable Conditions and More
• Project design and development, proposal submission, implementation and reporting

• Work as contractor/labor force for project partners
• Partnered with CDFG in 1980 to conduct salmon habitat restoration (stream cleaning). The goal was to flush sediment and remove barriers to fish migration (log jams).

• CCC was a major contractor for stream clearance efforts.
• Around 1986, it became more widely accepted that it was good to have wood in the channel
• Started leaving some wood in the channel and identifying places for structures
• The CCC has installed over 6500 habitat structures
• 1990’s - 2000’s
• 1-3 pieces coming off one or both banks of channel. Channel spanning logs were rare.
• Most structures were hard anchored
• More channel spanning logs, logs coming off both banks and crossing or meeting in the channel
• Collect more small woody material/slow the water down
HABITAT GOALS FOR LARGE WOOD STRUCTURES

- Create pools
- Enlarge existing pools
- Collect and sort spawning gravels
- Add complex cover to existing pools and flatwater habitats
- Increase channel roughness and complexity
- Stream characteristics
- Habitat needs and potential for enhancement
- Availability of material
- Ways to stabilize sites
- Risk to infrastructure
- Access
COMMON OPPORTUNITIES FOR ENHANCEMENT
WHERE IS THE WOOD?

- Do we have any material around on the ground? Can we cut trees?
WOOD LOADING/FELLING TREES

- Ability to fell trees adjacent to project sites
  - Allows for higher wood loading densities
  - More reliability, and longevity
  - Reduces need for hard anchors
STABILIZING THE STRUCTURE

Trees, stumps, boulders or any hard points that can be used to brace structure
UNANCHORED/WEDGING

- Utilize wedge-points or use full trees to avoid anchoring
- Reduces cost and amount of metal left in stream and riparian zone
- Allows structure to adjust over-time as pool develops
MAKING PLANS
BUILDING SITES

• LWD is moved into position utilizing grip-hoists and wire rope rigging techniques, and other hand tools

• To accomplish work, 12-15 person crews typically spike-camp near project reach for 8-day deployments
- Bolting LWD together and/or to live trees on the bank

- Retains LWD in-place to protect downstream infrastructure

- Allows for effective placement of shorter logs, making more cull logs on the forest floor viable for use in structures
• Varying levels of pinning and anchoring

- hard anchor logs to trees adjacent to channel with at least 2 pieces of rebar

- hinge pin (soft anchor), can allow structure to adjust or settle as scouring occurs while preventing the log from floating out (used in conjunction with wedging)

- pinning complex structures into a single unit, (no hard anchors, hinge pins)
• Collaborate on development and implementation of large wood projects
• Serve as Labor-Force for anchoring and/or moving/positioning of LWD
• Work together in conjunction with heavy equipment to treat a watershed
Background

• Role of instream wood – geomorphic → biologic
• Land use – forestry, agriculture, urbanization
• Previous wood clearing practices
• Accelerate natural recovery
What’s our setting?

• Many California streams have already experienced bed degradation
• Bed material is cobble or coarser, sometimes bedrock
•Disconnected from benches, side channels, and floodplains
• Lower groundwater levels and reduced summer base flow
Project Goals for Fish

- Rearing habitat – Pools with cover
- Spawning habitat – Gravel pool tailouts
- Velocity refugia
- Food sources – invertebrate production
- Healthy temperatures and dissolved oxygen concentrations
Restore Physical Processes

Raising the bed to reconnect to floodplains and side channels will

• Reduce stream power

• Deposit finer sediment such as gravel

• Allow pools to form at lower flows and scour deeper

• Retain spawning gravels

• Have side channels and floodplains become habitat again

• Recover groundwater levels and increase summer base flows
What’s that look like?

- Located in a bend
- Used a vertical post

- Captured large and small woody debris
- Resulted in gravel deposition and sorting both upstream and downstream
- Increasing Sinuosity
What are the steps for success?

• Watershed Planning – who, what, where, when, why?
  • Identify opportunities
  • Assess risks
  • Site characterization

• Design

• Construction
Project Planning

Coastal Watershed Planning Assessment Program

Big River Basin Assessment
November 2006

Gold Ridge Resource Conservation District

Upper Green Valley Creek Watershed Plan
A Living Document to Facilitate the Restoration of Coho Salmon and Preservation of Sustainable Agriculture

June 30, 2010
Opportunities: Inset Benches and Floodplains

Albion River – Mendocino County

Fish Creek – Lawrence Creek Tributary
Risks

- Infrastructure
- Property
- Recreational Activities
- Erosion
- Environmental damage
Site Characterization – All projects

- Qualitative Geomorphic Assessment of planform, confinement, bed and bar forms, substrate
- Limited survey of longitudinal profile and cross-section to determine stream gradient, bankfull width and depth, and entrenchment ratio
- Sources of wood
- Areas for equipment access

Notes:
- gradients of 1-3% recommended
- ER<1.4 need more anchoring
Structure Categories

• Simple Low Risk – key piece size logs (1.5 x bankfull) or anchored to existing trees or bedrock

• Complex Low Risk – logs secured using piles, boulders or other material, or trenched into banks – require stability calcs

• High Risk – site has potential to harm public safety, private property, or infrastructure – stability calcs and PE required

• Use Watershed Plans, Opportunities, Risks, and Site Characterization to determine project goals and appropriate structure categories
Simple Structures = Small Goals?
Gravel Bar Connectivity

Fish Creek – trib to Lawrence

February 2016

March 2018
Improving Bed Material Composition

Fish Creek – trib to Lawrence

50’ d/s of LWD
5’ u/s of LWD
50’ u/s of LWD
100’ u/s of LWD
Why go complex when risk is low?

• Ideal geomorphic location for a structure may lack anchor points
  – No trees on the bank at a bend
  – Need a structure mid channel

• Stream is too wide to have opposing structures meet

• Entrenchment Ratio is less than 1.4 and stream power can rotate or break logs

• Control the water surface – make sure you meet your goal
Mid-Channel Features - Bar Apex Jams
Site Characterization – Part II

For low risk complex and high risk projects:

• Quantitative assessment of bed and bank material
• Subsurface exploration
• Assessment of reach stability
• Other site constraints – access, permitting...
• Detailed topographic survey
• Hydrologic and hydraulic analyses
Reach Stability – Channel Evolution Model
Channel Evolution Model – who cares?

- Particularly in Stage 1 – if you don’t address the drivers of incision your project won’t last. It’s not enough to just throw wood in the channel.

- You may not want to arrest Stage 4 as it is what will supply material for aggradation – beware of stabilizing banks!

- Stage 3s may result from lack of sediment supply – no supply means no aggradation.
What phase are you going through?

Green Valley Creek – Sonoma County - photo courtesy of SWRCB
Next Steps in Design - Iterative

• Project Layout – where to place structures to achieve goals
• Hydraulic Modeling
  – Determine size of structures
  – Check that goals are being met – go back to layout if necessary
  – Look for areas of concern – high velocities, etc.
  – Use model results for stability calculations
• Perform Stability Calculations
• Construction Details
Skipping some steps...

- Rachel is covering stability calculations
- Tom is covering working with contractors
- Chris, Ken, and the CCCs are covering construction
- Sadly, no one is covering hydraulic modeling
  - Manning’s equation, 1D, 2D, 3D, Physical models – it’s all been done
  - What do you want to know?
What is a successful LWD project?

- One that accomplishes the goals of the project
- Generic benefit to fish is not enough
When you take a river that looks like this and make it look like this

Significant gravel deposition on bedrock and cobble bed
Goal not achieved – Why???

• Structures failed - Logs relocated, shifted, rotated, shifted
  – Greater than design storm occurred?
  – Calculations incorrect, too low a safety factor for stability
  – Other design errors – ballast size
  – Not constructed according to plans

• Stream did not react as expected
  – Structure flanked
  – Inadequate design analyses
  – Hydrologic/watershed conditions
  – Site Selection
Where’d my ballast go?

– What was your safety factor when doing stability calcs?
– What is your safety factor now?
Flanked Structure
Conclusions

• Geomorphic restoration leads to improved conditions for fish
• Need to be specific about goals
• Planning is important – lots of steps need to happen before design or construction
• Channel Evolution Model is important
• It’s not always the contractor’s fault