Engineering Techniques for Condit Dam Removal

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Dam Features

- Completed in 1913
- Concrete Dam
- 125 Feet High
- 250 Feet Wide at Top
- 40 Feet Wide at Bottom
- 110 Feet Thick at Bottom
Why Remove the Dam

- Requires FERC Relicensing
- No Fish Passage
- Only One Dam Downstream – Bonneville
- Miles of Excellent Fish Habitat Upstream
- Over $25 Million for Ladders
- $17 Million to Remove
Settlement Agreement

- PacifiCorp Requested FERC to Allow Removal
- PacifiCorp to Operate Dam for 7 Years
- Local Support and Resistance to Removal
- Environmental Community Supported Removal
- Tribes Support Removal
Major Issues

- Dam Removal Technique
- Sediment Removal Technique
- Impacts of Sediment Removal
- Project Cost
Structure Removal Approaches

- Incrementally Remove Notches from Top Reservoir Removal Time – **6 Months**
- Construct Low Level Outlet - Reservoir Drains in **6 Hours**
- Long Hole Slot Construction from Top - Reservoir Removal Time – **4 Months**
Dam Removal Approach

- Construct New Low-Level Outlet
- Blast Opening and Allow Reservoir to Drain in 6 Hours
- Rapidly Erode Sediment
- Remove Dam Concrete by Blasting after Reservoir Lowered
Northwestern Lake - Reservoir

- 92 Acres
- 350 to 400 Feet Wide
- 2 Miles Long
Pre-dam Topography
Pre-Dam Geometry

- Deeply Incised River Canyon
- Vertical Canyon Walls
- Flatter Vegetated Overbanks
- Steep Longitudinal Profile
- Narrow River Channel
Looking Upstream from Station 5+00

Pre-dam Photograph

Water Surface

Sediment Surface
Approaches Investigated

More Costly Approaches
- Mechanical Removal
- Slurry
- Stabilize in Place
- Upland Disposal

Least Costly
- Natural Erosion
Sediment Removal and Stabilization Approach

- Natural Erosion
- Remove Impediments to Channel Formation
- Allow Formation of Natural Stable River and Embankment Geometry
Features Favoring Natural Erosion Approach

- Well Defined Pre-dam Channel
- Reliable Hydrology
- Short Distance to Columbia River
- No Downstream Water Users
- Most Rapid Method
- Fewest Impacts
Sediment Conditions

- 2.4 Million Cubic Yards of Trapped Sediment as of 1998
- 75% to 85% of Sediment is Suspendsable
River Flow Conditions

- Average Daily Flow – 1125 cfs
- Average Daily Flow October – 629 cfs
- 100 Year Flood – 13,600 cfs
- 5 Year Flood – 7,000 cfs
- 2 Year Flood – 4,700 cfs
Sediment Locations

- Predominantly Sand Mixed with Silt
- Predominantly Sand
- Sand Gravel Mix
- Silty
- Diversion Dam
- Condit Dam
- Diversion Flume
- Northwestern Lake Bridge
Sediment Response to Dam Breach

- Rapid Reservoir Drawdown – 6 Hours
- Erodes Most Fine Sediment in 1st Week
- Coarse Sediment Erodes by Head Cutting during 1st Month
- High Flows Continue to Erode Bed Load and Embankments after 1st Month
Fine Sediment Behavior

- Semi-liquid until Dry
- Wet Angle of Repose Approx. 10 H to 1 V
- Dry Angle of Repose of 1.7 H to 1 V
- Stays in Suspension in River Flow
- Contributes to Total Suspended Sediment - TSS
Coarse Sediment Behavior

- Wet and Dry Angle of Repose is Approximately 1.7 H to 1 V
- Moves as Bed Load
- Erodes More Slowly by Head Cutting in Channel
Permitting Agency Concerns

- Intensity and Timing of Suspended Sediment Concentrations
- Effects of Water Users
- Intensity in White Salmon 200 x Intensity in Columbia
- No water users on White Salmon
3 Phases of Erosion Processes

- Initial Erosion - River Channel Development - Up to 1 Year
- Mid Term Upland Erosion - 3 to 5 Years
- Long Term Erosion - Flood Plain Development - After 5 Years
Initial Erosion

- Numerical Modeling – HEC6 - for Bed Load Erosion Poor Results
- Analysis Using Regime Equations to Determine Width
- Suspended Sediment Concentrations – Estimated Based on Sediment and Water Volumes
- Initial Concentrations ~ 150,000 ppm In White Salmon
- Concentrations Decrease with Time
Sediment Concentrations White Salmon River

Maximum Early Removal

Suspended Sediment Concentration (ppm)

Volume of Eroded Material (Cubic Yard)

Time (Days)
Mid Term Erosion

- Surface Erosion and Upland Contour Formation Based on USLE
- Initial Sediment Concentrations < 100 ppm
- Intensity of Erosion Declines as Vegetation Develops
1st Year White Salmon

TSS in White Salmon River
1st Year from Surface Erosion

- Flow
- TSS related to Surface Erosion
- Channel Erosion Period

Date

Flow cfs

TSS mg/l

Long Term Assumptions

- Stream Widens with Larger Flow – HEC-RAS Determines Width Based on Predam Topography
- Wider Stream Causes Bank Failure
- Sediment from Bank Failure Causes TSS
- All Sediment is Eroded with High Flow Event
Long Term Erosion Analysis Approach

- Conservatively Assumes Initial Steep Side Slopes
- Conservatively Assumed All Future Embankment Failures become TSS
- Assumes All Streambed Erosion Complete after 1st Year
Eroded Volume Calculation

- Eroded Volume vs. Flow Calculated
- Regression Analysis From Flow vs. Volume
- Incremental Volume Based on River Width
- Banks Start at Water Surface
Example Cross Section

- Flood Elevation
- Stable Embankment Material
- Stable Slope Angle
- Silt and Sand to Remain in Place
- Pre-Dam Surface
- 2 Year Flood

1.73
Flow Combinations

- Simulate Post Dam Flow Conditions
- Combined Sequences of Low, Medium, and High Flow Years
- Low Flow after Dam Removal Most Critical
Typical Eroded Cross Section

- Slopes – 1.7 H to 1 V

Station 35+00

- Pre-dam Elevation
- High Flow Crosssection
- Current Sediment Elevation
- Low Flow Eroded Section
TSS Charts

- Flow
- TSS
Thirty Year Simulation

Flow
TSS

Date
TSS in ppm
Flow cfs
TSS
Results of Post Dam TSS Analysis

- Most High TSS Events Occur in 1st Year
- Frequency and Magnitude Decrease with Time
- No More Than 3 High TSS from Bank Erosion after 3rd Year
Conclusions

■ Rapid Drawdown Removes Largest Volume of Sediment
■ Also Least Expensive Structure Removal
■ Initial TSS Concentrations Very High
■ Most Fine Material Eroded
■ Rapid Decrease in Magnitude and Frequency
■ Sediment Stable until High Flow Event
■ Few High TSS Events after 3rd Year
■ No Downstream Mitigation Required
Better Tools Needed

- Better Numerical Modeling Techniques for Sediment Erosion
  - Models for Erosion of Silt and Clay
    - No Method Erosion and TSS
  - Coarse Models
    - Moveable Boundaries
    - Head cutting