Upper Truckee River Restoration
Lake Tahoe, California
Presented by Brendan Belby – Sacramento, California
Mike Rudd (Project Manager), Charley Miller & Chad Krofta
Declines in Tahoe’s Water Clarity

Source: UC Davis Tahoe Environmental Research Center (2008)
The Upper Truckee River watershed viewed from its headwaters near Carson Pass north towards Lake Tahoe

Source: Tahoe Resource Conservation District, 2003
Historic Land Uses

- Comstock Era Logging & Mining
- Grazing
- Urbanization
- Channelization
- Floodplain Encroachment
Historic Large-Scale Logging

- 60% of Tahoe Basin was clear-cut
- 95% is second growth forest

Figure 2-9b—Logging the Tahoe basin in 1895; note the large diameter logs (photograph courtesy of Nevada Historical Society).

Figure 2-12—Squaw Summit 1876, looking northwest from a point now located on the north side of Highway 50; Glenbrook Railroad is unloading milled lumber for transport to Carson City via V-frame, note cut-over slopes (photograph courtesy of Nevada Historical Society).

Upper Truckee Marsh in 1930

Source: Photo by Dr. Robert Orr, property of California Tahoe Conservancy
Tahoe Keys
Upper Truckee River
Trout Creek

# homes increased 500-19,000 from 1960-1980
Sediment Accretion Rates

- Logging: +600%
- Urbanization: +350%

Table 2. Lake bottom sediment accretion rates (Heyvaert 1998)

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Sediment Accretion Rate (g cm² yr⁻¹)</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>before 1850</td>
<td>0.006 (+/- 0.003)</td>
<td>Pre-disturbance condition</td>
</tr>
<tr>
<td>1860-1890</td>
<td>0.043 (+/- 0.011)</td>
<td>Increased sediment load due to forest harvesting</td>
</tr>
<tr>
<td>1900 - 1970</td>
<td>0.009 (+/- 0.004)</td>
<td>Forest re-growth, Low population densities</td>
</tr>
<tr>
<td>1970 - 1990</td>
<td>0.027 (+/- 0.006)</td>
<td>Modern land use patterns, High population densities</td>
</tr>
</tbody>
</table>

Planform Adjustments to Sediment Supply

Sedimentation in response to logging?

Minimal planform change reflection of low energy & cohesive meadow soils
Profile Adjustments to Sediment Supply

Bed elevation changes in response to urbanization?

Date of Measurement

Mean Daily Flow (cfs)

Elevation (ft above fixed datum)
Channel Response

Downcutting

• Doubling of channel capacity
• Lacustrine layer exposure
Channel Response

Bank Erosion

- Sod blocks
- Fine-grained sediment input
Channel Response

Aggradation/Widening
Incipient Floodplain

•New depositional landforms
•Lower base level
•Slow development

Existing Condition:
•Slope: 0.001
•D$_{50}$: 4 mm
•Width: 65 ft
•Depth: 5-6 ft
•Capacity: 700 cfs (2-yr RI) to 1,300 cfs (5-yr RI)

Taken 5/5/04 at ~350 cfs, RS 16000
Reaches 3 & 4 – Airport Reach

Clients: City of South Lake Tahoe and California Tahoe Conservancy
Planform Change 1940 vs. 2003

Construction of airport in 1960s eliminated ~75% of historic floodplain
Upper Truckee River – Reaches 3 & 4

Major Project Goals

• Reduce channel capacity to increase overbanking
• Increase deposition & storage of fine suspended sediment
• Decrease bank erosion
• Raise groundwater levels
• Improve habitat

Reaches 3 & 4
New Channel Construction
Started in Summer 2008

May 17, 2005 Flood

Source: City of South Lake Tahoe
Alternative 1 – Existing Channel with Habitat Improvements

1. Construct in-channel habitat structures and bank stabilization features

2. Locally narrow channel at locations with large wood, vegetated bars, or ledges to create a more sinuous flow path

3. Construct an inset floodplain to enhance overbanking
Alternative 2 – Construct New Channel with Airport In-Place

1. Construct ~4,000 ft of new meandering channel
2. Re-grade airport terrace fill to create a new floodplain
3. Build large woody debris features for habitat improvement
4. Work within the constraints of the airport and existing utility lines
Alternative 3 – Construct New Channel with Partial Airport Removal

1. Remove ~1,500 ft of airport runway for the new channel

2. Relocate sections of existing gravity and forced main pipelines

3. Construct ~4,800 ft of new meandering channel
## Alternatives Ranking Criteria

<table>
<thead>
<tr>
<th>Objective</th>
<th>Desired Outcomes</th>
</tr>
</thead>
</table>
| Restore a more naturally functioning river and floodplain                 | ▪ Restore channel form in balance with hydrology and sediment supply  
▪ Increase frequency of overbanking  
▪ Increase deposition of riverborne fine sediment and nutrients onto the floodplain. |
| Improve water quality by restoring natural stream and floodplain processes. | ▪ Reduce nutrient and fine sediment loads generated within the Project area or transported through the Project area.                                |
| Restore, enhance and protect aquatic and terrestrial habitat diversity and quality | ▪ Enhance the habitat values of the river and floodplain for supporting native aquatic and terrestrial animals and plants.                      |
| Develop a cost-effective, timely and implementable design                 | ▪ Provide a cost-effective project  
▪ Provide a permittable project  
▪ Minimize time to project maturity and benefit                                      |
Floodplain Inundation Modeling

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>760 cfs (2-yr Event)</td>
<td></td>
</tr>
<tr>
<td>Existing Condition</td>
<td>0 acres</td>
</tr>
<tr>
<td>Future Constructed Condition</td>
<td>19 acres</td>
</tr>
</tbody>
</table>
## Alternatives Ranking Criteria Example

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Evaluation Criteria</th>
<th>Definition</th>
<th>Units</th>
<th>Existing</th>
<th>Alternative 1</th>
<th>Alternative 2</th>
<th>Alternative 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Restore natural channel planform and dynamics to the extent that existing constraints allow.</td>
<td>1.1.1 Longer and more sinuous channel through study reach.</td>
<td>Main channel length</td>
<td>ft</td>
<td>7.45N</td>
<td>7.15N</td>
<td>7.08N</td>
<td>6.93N</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sinuosity = channel length/valley length</td>
<td>ft/ft</td>
<td>1.11</td>
<td>1.11</td>
<td>1.24</td>
<td>1.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Criterion met?</td>
<td>Yes or No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rank score</td>
<td>1 to 4</td>
<td>2</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>1.1.2 Longer aeomorphically-sized channel.</td>
<td></td>
<td>Length of aeomorphically sized channel</td>
<td>ft</td>
<td>10</td>
<td>10</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ratio of all length to existing</td>
<td>ft/ft</td>
<td>0.00</td>
<td>0.00</td>
<td>0.36</td>
<td>0.43</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Length as a percent of channel length</td>
<td>%</td>
<td>10</td>
<td>10</td>
<td>45</td>
<td>57</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Criterion met?</td>
<td>Yes or No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rank score</td>
<td>1 to 4</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>1.2 Increased frequency of overbank flow and floodplain deposition of suspended sediment during small magnitude events.</td>
<td>1.2.1 Increase length of channel receiving overbank flow from 2-year (760 cfs) streamflow events.</td>
<td>Length of bank overtopped</td>
<td>ft</td>
<td>0</td>
<td>3.100</td>
<td>3.816</td>
<td>4.560</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Percent ‘out of bank’</td>
<td>%</td>
<td>30</td>
<td>40</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td></td>
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<td>Criterion met?</td>
<td>Yes or No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
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<td>1 to 4</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>1.2.2 Increase area of floodplain receiving overbank flow from 2-year (760 cfs) streamflow events.</td>
<td>Area of inundation</td>
<td>Acres</td>
<td>0</td>
<td>18.4</td>
<td>17.3</td>
<td>31.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Criterion met?</td>
<td>Yes or No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td></td>
<td></td>
<td>Rank score</td>
<td>1 to 4</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>1.3 Increase floodplain retention time during 2-year event.</td>
<td>1.3.1 No substantial increase in floodplain velocities and shear stress for the 1600 cfs event.</td>
<td>Average floodplain velocity for the 1600 cfs event</td>
<td>ft/sec</td>
<td>1.17</td>
<td>1.80</td>
<td>1.19</td>
<td>0.92</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Average out-of-bank shear stress for the 1600 cfs event</td>
<td>lbs/sq ft</td>
<td>0.10</td>
<td>0.08</td>
<td>0.04</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Criterion met?</td>
<td>Yes or No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Rank score</td>
<td>1 to 4</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

### Ranking Scores

<table>
<thead>
<tr>
<th>Key Evaluation Criteria</th>
<th>Alternative 1</th>
<th>Alternative 2</th>
<th>Alternative 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subtotal Score</td>
<td>15</td>
<td>14</td>
<td>5</td>
</tr>
<tr>
<td>Total Score</td>
<td>61</td>
<td>75</td>
<td>79</td>
</tr>
<tr>
<td>Number of Criteria Met (24 Total Criteria)</td>
<td>19</td>
<td>22</td>
<td>19</td>
</tr>
</tbody>
</table>
Channel & Floodplain Design

Design a channel and floodplain with an appropriate morphology that is in balance with the prevailing hydrology and sediment regimes.
Bedload Supply

How much bedload should the channel be able to transport?

- Measure transport throughout spring runoff
- Calibrate transport modeling with measurements
Measured & Modeled Transport

ENTRIX Measured Bedload Transport (2006)
Modeled Bedload Transport - Ackers & White (1973) with Proffitt & Sutherland’s (1983) Hiding Function

\[ Q_s \] (tons/day)

\[ \tau_{rg}^* = 0.01 \]  
\[ \tau_{rs}^* = 0.03 \]

Are \( \tau_{c}^* \) values reasonable?

Source: Wilcock and Kenworthy 2002
Select Design Discharge

Effective Discharge Analysis

$Q_{\text{eff}} = 400$ cfs
How wide should the channel be?

Equation: Huang and Nanson 1998 – $f(Q_{bf}, S, n)$

<table>
<thead>
<tr>
<th>Bank Type</th>
<th>Channel Width (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderately cohesive sand</td>
<td>44.5</td>
</tr>
<tr>
<td>highly cohesive sand</td>
<td>31.4</td>
</tr>
<tr>
<td>moderately vegetated and moderately cohesive sand</td>
<td>36.6</td>
</tr>
<tr>
<td>heavily vegetated and highly cohesive sand</td>
<td>26.7</td>
</tr>
</tbody>
</table>

Selected Design Width = 38 ft
How steep and deep should the channel be?

Equilibrium Slope Analysis

- Equilibrium Slope
- Depth (ft)

Channel Width (ft)

40 ft

38 ft
Channel Morphology
River Architectural Models

Gravel-sand meandering

- CR: Crevasse channel
- CS: Crevasse splay
- LA: Lateral-accretion macroform
- FF: Overbank fines
- CH: Channel (abandoned)

Fine-grained meandering

Final Channel Design

Irregular bends
Steeply dipping point bars & low W/D
Fill existing channel

Micro-topography

[Diagram showing channel design with highlighted features]
Construction – Summer 2008
Acknowledgements

- The City of South Lake Tahoe
- The California Tahoe Conservancy
- Mike Rudd - ENTRIX Project Manager
- Charley Miller - ENTRIX
- Chad Krofta - ENTRIX