Transport of Mercury Past a Recreational Dam on Deer Creek in Nevada County, CA

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River Scientist
Who are we?

• Started in 1996 by a group of concerned local citizens, when Nevada City was replacing the historic Pine Street Bridge.

• Working closely with the city, Friends of Deer Creek successfully protected and monitored the creek during construction.

• Focus on scientific investigation and methods, to find solutions to Deer Creek's problems.
Sierra Streams Institute Programs

**Restoration**
- Restoration of salmon habitat
- Remediation of abandoned mine lands

**Research**
- Transport of mercury over dams
- Health impacts of mining contaminants

**Training**
- State protocols for watershed groups

**Education**
- Activity-based science

**Laboratory**
- Chemical and biological analysis

**Friends of Deer Creek**
- Water quality monitoring, habitat assessments
- Trail Construction
Mercury in the Deer Creek Watershed

• Historic gold mines in the Deer Creek watershed
  • Hg used to extract gold
  • Estimated Hg loss in Sierra Nevada of 11-12 million pounds of mercury (Churchill, 2000; Alpers et al. 2005).

• Bioaccumulation of Hg

• Downstream transport of Hg to Bay/Delta
  • Storm Events
  • Reservoir Releases

• Does Hg travel downstream past dams? Local problem? Downstream problem?
Transport of Sediment and Mercury in the Deer Creek Watershed

- Lake Wildwood Drawdown Releases
  - October 2008, 2011

- Storm Events
  - October 2009, January 2010
Lake Wildwood Drawdown Releases
Lake Wildwood Drawdown Releases

- Lake Wildwood built from 1969-1970
- Drawdown releases began in 1979
- Releases occur in mid-October
- Reservoir located downstream from historic gold mines on Deer Creek
  - 54.5 mi$^2$ upstream watershed area
- 4 miles upstream from salmon habitat
Collaboration with Lake Wildwood

• Began in 2004

• Lake Wildwood Lake Committee
  • Monthly Lake Committee Meetings

• Monitoring and Data Analysis
  • Lake Sampling
  • Drawdown Releases and Storm Sampling
Lake Wildwood Drawdown Release Monitoring

- 2001 – 2004
  - Grab Samples (water quality)
- 2007
  - Autosamplers
    - Water Quality
    - Total Suspended Solids (TSS)
- 2008, 2011
  - Autosamplers
    - Water Quality
    - TSS, Mercury
    - Aquatic Biology
2008 Lake Wildwood Drawdown Release

• Collaboration With Lake Wildwood
  • Monthly Meetings
    • Plan for Release

• October 8-26, 2008
  • 18 day release. Peak flow 136 cfs.

• Autosamplers
  • Weir, Site 10
2008 Release - Results

2008 Lake Wildwood Release Sampling: 10/8-10/25
Weir Autosampler

Weir Sediment Load: 16,880.1 kg
Weir Mercury Load: 9.1 g
2008 Lake Wildwood Release Sampling: 10/8-10/25
Site 10 Autosampler
Site 10 Sediment Load: 24,101.2 kg
Site 10 Mercury Load: 13.5 g
2008 Release - Results

2008 Lake Wildwood Release Sampling: 10/8-10/25
Weir Autosampler
Sediment Load vs. Mercury Load
$R^2 = 0.70$

2008 Lake Wildwood Release Sampling: 10/8-10/25
Site 10 Autosampler
Sediment Load vs. Mercury Load
$R^2 = 0.87$
2008 Release - Problems

- Duration
- Equipment Stuck
2011 Lake Wildwood Drawdown Release

- Collaboration With Lake Wildwood
  - Monthly Meetings
    - Hydrologic Data Analysis
    - Plan for Release
  - Lake Sampling Pre-release

- October 16-25, 2011
  - 9 day release. Peak flow 386 cfs.
    - Half the duration of the 2008 release

- Autosamplers
  - Weir, Site 10
Collaboration With Lake Wildwood

2011 LWW Release Model D
Gate Open - Natural Flow Decrease Due to Loss of Head; Adjust if Needed for Desired Release Volume

Projected Flow
Release Volume = 118,000,000 cubic feet
2011 Release - Results

2011 Lake Wildwood Release Sampling: 10/16-10/25
Weir Autosampler

Weir Sediment Load: 18,614.0 kg
Weir Mercury Load: 6.1 g
2011 Release - Results

2011 Lake Wildwood Release Sampling: 10/16-10/25
Site 10 Autosampler
Site 10 Sediment Load: 29,601.8 kg
Site 10 Mercury Load: 13.2 g
2011 Release - Results

2011 Lake Wildwood Release Sampling: 10/16-10/25
Weir Autosampler Data
Sediment Load vs. Mercury Load
$R^2 = 0.50$

2011 Lake Wildwood Release Sampling: 10/16-10/25
Site 10 Autosampler
Sediment Load vs Mercury Load
$R^2 = 0.95$
Lake Wildwood Drawdown Release Summary

Lake Wildwood Release Mercury Loads

- **Mercury Load (g)**
- **Site**
  - Weir
  - Site 10

- **Years**
  - 2008
  - 2011

The diagram shows a comparison of mercury loads at Weir and Site 10 for the years 2008 and 2011.
Storm Sampling

- Sierra Nevada Conservancy Grant (2007-2012)
  - Mercury Bioavailability and Transport in Deer Creek
- Collaboration With Lake Wildwood
- Autosamplers, Grab samples
  - Upstream and Downstream of Lake Wildwood
- October 2009 and January 2010 Storm Events
Storm Sampling - October 2009

- Collaboration With Lake Wildwood
  - Access Cards
  - Monthly Meetings
- October 12-15, 2009
  - 3 day storm event. Peak flow 143 cfs.
- Autosampler
  - Watershed Outlet (Site 10)
Storm Sampling - October 2009

2009 Storm Sampling 10/12-10/15
Site 10 Autosampler

Sediment Load: 8,072.7 kg
Mercury Load: 5.6g

Value (see legend for units)

Date

Discharge (cfs)
Sediment Load (kg/hr)
Mercury Load (mg/hr)
Storm Sampling - October 2009

2009 Storm Sampling: 10/12 - 10/15
Site 10 Autosampler
Sediment Load vs. Mercury Load

$R^2 = 0.97$
• January 17-21, 2010
  • 4 day storm event. Peak flow 1,740 cfs.
• Autosampler
  • Watershed Outlet (Site 10)
• Grab Samples
  • Upstream, Downstream of Lake Wildwood
Storm Sampling – January 2010

2010 Storm Sampling 1/17- 1/21
Site 10 Autosampler

Site 10 Sediment Load: 180,766.3 kg
Site 10 Mercury Load: 315.5 g
Storm Sampling – January 2010

2010 Storm Sampling: 1/17- 1/21
Site 10 Autosampler
Sediment Load vs. Mercury Load
$R^2 = 0.76$
Storm Sampling Summary

Storm Mercury Loads

Mercury Load (g)

Year

2009

2010

350
300
250
200
150
100
50
0
### FODC Storm Flow Mercury Data

#### Retention of Total Suspended Solids (TSS) in LWW during Storm Flows

<table>
<thead>
<tr>
<th>Date</th>
<th>Site 6 TSS</th>
<th>LWW Weir TSS</th>
<th>% TSS Retention in Lake</th>
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<td>1</td>
<td>18.9</td>
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<tr>
<td>12/12/09</td>
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<td>29.8</td>
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<td>2/27/10</td>
<td>1</td>
<td>51.5</td>
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<tr>
<td>3/3/10</td>
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<td>21.2</td>
<td>3</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td><strong>7</strong></td>
<td><strong>32.2</strong></td>
<td><strong>12</strong></td>
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</tbody>
</table>

#### Retention of Mercury (Hg) in LWW during Storm Flows

<table>
<thead>
<tr>
<th>Date</th>
<th>Site 6 Hg</th>
<th>LWW Weir Hg</th>
<th>% Hg Retention in Lake</th>
</tr>
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<tbody>
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<tr>
<td><strong>Mean</strong></td>
<td><strong>7</strong></td>
<td><strong>0.029</strong></td>
<td><strong>12</strong></td>
</tr>
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</table>
Releases vs. Storm Events

Comparison of Mercury Loads Between Storms and Release

- 2008 Lake Wildwood Release
- 2009 Storm
- 2010 Storm
- 2011 Lake Wildwood Release

Mercury Load (g) vs. Event
Conclusions

• Transport of mercury & sediment past Lake Wildwood reservoir
  • Sediment & mercury retained by reservoir
  • Downstream transport to Bay/Delta?

• Releases
  • Significant sediment and mercury loading between Weir & Site 10
    • 2008 Weir: 9.1g Hg, 2008 Site 10: 13.5g Hg - 4.4g Hg
    • 2011 Weir: 6.1g Hg, 2011 Site 10: 13.2g Hg - 7.1g Hg

• Storms
  • Significant sediment and mercury loading during storm events
    • Timing
    • Reservoir Dynamics

• Sediment Composition
  • Residual Data
    • 2009 storm/releases: 40% - 50% avg. inorganic material, 50% - 60% organic
    • 2010 storms: 60 - 70% avg. inorganic material, 30 - 40% organic

• Hg Partitioning?
  • Organic component? Inorganic component?
    • Material Separation
Future Projects and Ideas

• Summer Hg dynamics in Lake Wildwood
  • Colloidal material
  • Anaerobic sediments

• Mercury Transport/Deposition Studies
  • Lake Wildwood Mass Balance Hg
  • Scotts Flat Reservoir, Englebright Reservoir

• Bioaccumulation of Mercury

• Heavy Metal Contamination Clean-Up
  • EPA Brownfields, Phytoremediation

• Human Health and the Environment
Linking water, science, and people.