SNAMP:
Water IT Meeting

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What is the Sierra Nevada Adaptive Management Project?

SNAMP is a joint effort by the University of California, state and federal agencies, and the public to study management of forest lands in the Sierra Nevada.
1. Hydrology research program within SNAMP
2. Field measurement program – to inform modeling
3. Water-quality findings
4. Headwater synthesis and modeling
5. Scaling to the fireshed
6. Open questions and next steps after SNAMP
Hydrology Research Program

1. Hydrology (water quantity) research within SNAMP
   - Assessing SPLATS influence on water yield & timing
   - Expecting small hydrologic response from light treatments
   - Detailed water-balance measurements informing modeling
   - SNAMP goes well beyond a classical paired-watershed study and a modeling-only exercise
   - Drought is confounding some of the post-treatment hydrologic response

2. Water-quality research focusing on sediment source and movement

3. SNAMP addressing SPLATS; but knowledge gaps around “restoration” treatments & fire remain – i.e. effects of further vegetation removal
SNAMP Water Team Approach

1. Measure water balance, water quality components response to forest treatments

2. Model headwater processes control, treatment, and projected forest density

3. Transfer to large watersheds

*forest management implications*
Study Sites

Last Chance, Tahoe National Forest

Sugar Pine, Sierra National Forest
<table>
<thead>
<tr>
<th></th>
<th>Last Chance</th>
<th>Sugar Pine</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Headwater Basins</strong></td>
<td>1.6 – 1.8 km²</td>
<td>1.4 – 2.4 km²</td>
</tr>
<tr>
<td><strong>Headwater Elevation</strong></td>
<td>1550 – 2100 m</td>
<td>1750 - 2200 m</td>
</tr>
<tr>
<td><strong>Firesheds</strong></td>
<td>12 – 24 km²</td>
<td>18 – 22 km²</td>
</tr>
<tr>
<td><strong>Fireshed Elevation</strong></td>
<td>650 - 2100 m</td>
<td>600 - 2200 m</td>
</tr>
</tbody>
</table>
1. Hydrology research program within SNAMP
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Field Measurements – Water Quantity

Research Question:
Will forest treatments (SPLATs) increase water yield in response to reduced water demand by vegetation?

Hypothesis:
SPLATs will contribute to a small increase in water yield, most likely observed during summer baseflow.
Methods – Field Data Collection

- Upper, lower elevation met stations (4)
- North, south facing sensor nodes
  - snow depth (62), soil moisture (164)
- Stream stations (4)
  - discharge, sediment
Forest Treatments (Last Chance)

Strategically Placed Landscape Treatments (SPLATs)

<table>
<thead>
<tr>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underburn</td>
</tr>
<tr>
<td>Tractor Thin</td>
</tr>
<tr>
<td>Cable Thin</td>
</tr>
<tr>
<td>Mastication</td>
</tr>
</tbody>
</table>
Treatment

- Underburn
- Commercial Thin
- Hand Thin
- Mastication

Forest Treatments (Sugar Pine)
Water Yield Results

Last Chance Treatments

Sugar Pine Treatments

ET
Q

Control Watershed

Treatment Watershed
Field Observations

Last Chance

Average Wet Dry Treatments Dry

Days

Snow

Soil Moisture

Stream Discharge

WY 2010 WY 2011 WY 2012 WY 2013
Water Yield Results

- **Last Chance**:
  - 2010: Precipitation 150 cm, Control 50 cm, Treatment 50 cm
  - 2011: Precipitation 200 cm, Control 150 cm, Treatment 50 cm
  - 2012: Precipitation 200 cm, Control 50 cm, Treatment 50 cm
  - 2013: Precipitation 200 cm, Control 50 cm, Treatment 50 cm

- **Treatments**:
  - 2010: Precipitation 150 cm, Control 50 cm, Treatment 50 cm
  - 2011: Precipitation 200 cm, Control 150 cm, Treatment 50 cm
  - 2012: Precipitation 200 cm, Control 50 cm, Treatment 50 cm
  - 2013: Precipitation 200 cm, Control 50 cm, Treatment 50 cm

- **Sugar Pine**:
  - 2010: Precipitation 150 cm, Control 50 cm, Treatment 50 cm
  - 2011: Precipitation 200 cm, Control 150 cm, Treatment 50 cm
  - 2012: Precipitation 200 cm, Control 50 cm, Treatment 50 cm
  - 2013: Precipitation 200 cm, Control 50 cm, Treatment 50 cm
Last Chance Streamflow Results

Log Transformed Daily Streamflow

all years significantly different
Sugar Pine Streamflow Results

Log Transformed Daily Streamflow

all years significantly different
Field Measurements – Water Quantity

Research Question:
Will forest treatments (SPLATs) increase water yield in response to reduced water demand by vegetation?

Preliminary Conclusion:
The climate variability and low precipitation following treatments masked observed changes in water yield directly related to SPLATs.
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SNAMP Water Quality
Research Question:
Will forest treatments (SPLATs) decrease water quality in response to increased flow?

System Concepts:
• Sediment poses biggest risk to water quality.
• Treatments are too distant for hillslope sediments to reach stream.
• Treatments too light to cause significant increase in discharge and thus subsequent increase in sediment transport.
• Groundwater storage helps to maintain some baseflow in dry years.
Sediment sources are localized: from channel bed and banks

Sediment connectivity between hillslopes and stream channel is very limited under “normal” conditions. (Stafford, 2011)
Turbidity response to discharge

Clockwise hysteresis loops indicate localized easy to mobilize sources of sediment (Wood, 1977; Williams, 1989)

<table>
<thead>
<tr>
<th></th>
<th>Fall</th>
<th>Early/Mid Winter</th>
<th>Snow Melt</th>
<th>Base Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clockwise</td>
<td>18</td>
<td>19</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>Counterclockwise</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Linear</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Figure Eight</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Complex</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

* Data from WY 2010-2012 (Martin et al., 2014)
Sediment production at bed and banks is not continuous

<table>
<thead>
<tr>
<th>Flow events with turbidity</th>
<th>High flow events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall</td>
<td>84%</td>
</tr>
<tr>
<td>Early/Mid Winter</td>
<td>56%</td>
</tr>
<tr>
<td>Snow Melt</td>
<td>49%</td>
</tr>
<tr>
<td>Base Flow</td>
<td>44%</td>
</tr>
</tbody>
</table>

- Fine sediment accumulates during low baseflow periods
- Sediment then depletes in winter and spring high flows
Bedload: Channel bed acts as temporary storage not a long-term source or sink

Bed stability:
Channel bed elevation changes during large events but gradually returns to equilibrium levels

Stable background conditions = banks supplying sediment and bed temporarily storing it
Baseflow season stream water conductivity

Day of Year

Blue/Cyan = wet years
Red/Pink = dry years
Stream Ca$^{2+}$ concentration during baseflow

**Big Sandy**

**Speckerman**

**Bear Trap**

**Frazier**

*Blue/Cyan = wet years*

*Red/Pink = dry years*
Stable isotope results: little evidence for evaporation

* June – Sept stream samples

Blue/Cyan = wet years
Red/Pink = dry years

?? (Last Chance)
Water Quality

Research Question:
Will forest treatments (SPLATs) decrease water quality in response to increased flow?

Preliminary Conclusions:
Stream **channels are main sediment source area.**
Channel **bed acts as temporary storage and banks are the dominant sediment source area** under background conditions.
The climate variability and low precipitation following treatments **masked potential changes** in water quality directly related to SPLATs.
Groundwater storage helps to **maintain some baseflow** during dry years.
1. Hydrology research program within SNAMP
2. Field measurement program – to inform modeling
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6. Open questions and next steps after SNAMP
Headwater synthesis & modeling

Research Question:

1) What will be the modeled response in water yield to vegetation reduction from SPLATs and even more severe forest treatments?

2) How will the response in water yield change due to wildfire removal of vegetation as opposed to forest treatments?

Hypothesis:

1) The model will show an increase in water yield in response to forest treatments, the response will not be linear.

2) Vegetation reductions from wildfire will show even higher increases in water yield than forest treatments.
RHESSys Hydro-Ecologic Modeling

Mountain hydrology – water fluxes

- precipitation
- evapotranspiration
- infiltration
- sublimation
- snowmelt
- runoff
- ground & surface water exchange

Input: Precipitation

Filter 1: Snow accumulation and melt
- seasonal snow zone
- transient snow zone

Filter 2: Drainage Efficiency
- rainfall
- snowmelt
- shallow subsurface flow
- deep groundwater flow

Response: Hydrograph
- fall
- winter
- spring
- summer
Regional Hydro-Ecological Simulation System

Met Inputs
- Precipitation
- Temperature
- Relative Humidity
- Vapor Pressure Deficit

Spatial Inputs
- LiDAR/Forest Plot Vegetation Map
- SoilsMap
- LiDAR Elevation

Outputs
- Snowpack
- Soil Storage
- Water Yield
Headwater Model - Calibration

Bear Trap Creek

Snow cm

Soil Storage cm

Discharge cm

Oct Dec Feb Apr Jun Aug

Water Year Day 2011

Observed
Model

Observed
Model

Observed
Model

30+ observations/site
80+ observations/site
2 observations/site

Work in progress
## Modeling considerations

<table>
<thead>
<tr>
<th></th>
<th>Fuel Treatments</th>
<th>Wildfire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetation Reduction</td>
<td>Strategic, scaled to fuel density</td>
<td>Variable, burn intensity &amp; pattern</td>
</tr>
<tr>
<td>Snow Albedo</td>
<td>comparable</td>
<td>decreased 2-5 years after</td>
</tr>
<tr>
<td>Soil Moisture</td>
<td>Potential compaction, reduced storage</td>
<td>Potential increase in surface hydrophobicity</td>
</tr>
<tr>
<td>Litter Cover</td>
<td>Low reduction from thinning operations</td>
<td>High reduction, replaced by ash layer</td>
</tr>
<tr>
<td>Vegetation Recovery</td>
<td>20 – 30 years (Collins/Stephens model results)</td>
<td>Similar, but longer in high intensity burn areas with shrubs dominating initially</td>
</tr>
</tbody>
</table>
Modeling considerations

- Bare
- Ponded areas
- Thin litter/ash layer
- Saturated
- Thick litter/ash layer
- Saturated

Infiltration flux
Evaporation flux
Model input

- 0% cover
- 50% cover
- 100% cover

modified from
Woods & Balfour, J. Hydro. 2010
Headwater Model Results
soil cover scenarios

Work in progress

Percent of Precipitation Converted to Runoff

- 90% Soil Cover
- 10% Soil Cover

- pre-treatment
- 33% vegetation removed
- 66% vegetation removed

Decrease in biomass from thinning or fire

191-cm precipitation (2010, avg yr)

Current 51% Runoff

pre-fire suppression veg density

Work in progress

Current 51% Runoff
Headwater synthesis & modeling

Research Question:

1) What will be the modeled response in water yield to vegetation reduction from SPLATs and even more severe forest treatments?
2) How will the response in water yield change due to wildfire removal of vegetation as opposed to forest treatments?

Preliminary results:

1) Model projections indicate a 50% decrease in vegetation could result in a 10% increase in water yield.
2) Model sensitivity to the forest litter layer shows wildfires may not increase water yield more than treatments.
1. Hydrology research program within SNAMP
2. Field measurement program – to inform modeling
3. Water-quality findings
4. Headwater synthesis and modeling
5. Scaling to the fireshed
6. Open questions and next steps after SNAMP
Fireshed-scale modeling

Research Question:
1) Can the setup for the headwater version of the hydrologic model be transferred to the larger firesheds?
2) How does the fireshed response to forest treatments and wildfires differ from the headwater response?

Hypothesis:
1) The calibrations for the headwater model will also be successful in setting up the fireshed model.
2) The water yield will increase in response to forest treatments and wildfires, but lower than in the headwaters.
groundwater infiltration from surface

rate of water flow into soil

flow rate slows with soil depth

groundwater exfiltration to Stream

Subsurface model processes

Factors controlling subsurface flow
- Soil type
- geology

Basin Similarities
- Hydrograph comparisons
- Geology comparisons
Shoo Fly Complex
Low potential storage and flow

Miocene – Pliocene (orange)
High potential storage and flow
<table>
<thead>
<tr>
<th>Basin</th>
<th>Shoo Fly Complex</th>
<th>Miocene-Pliocene</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrologic</td>
<td>low storage, flow (metasedimentary)</td>
<td>high storage, flow (volcanic)</td>
</tr>
<tr>
<td>characteristics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bear Trap</td>
<td>69%</td>
<td>31%</td>
</tr>
<tr>
<td>Frazier</td>
<td>21%</td>
<td>79%</td>
</tr>
<tr>
<td>Fireshed Avg</td>
<td>76%</td>
<td>24%</td>
</tr>
<tr>
<td>NFMF, Am. R.</td>
<td>78%</td>
<td>17%</td>
</tr>
</tbody>
</table>
Bass Lake Tonalite
High potential storage and flow

Sugar Pine Basin Geology

Quartzite & Phyllite
Low potential storage and flow

Bear Trap
Frazier
<table>
<thead>
<tr>
<th>Basin</th>
<th>Quartzite &amp; Phyllite</th>
<th>Bass Lake Tonalite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrologic characteristics</td>
<td>low storage, flow (metasedimentary)</td>
<td>high storage, flow (plutonic)</td>
</tr>
<tr>
<td>Big Sandy</td>
<td>0%</td>
<td>100%</td>
</tr>
<tr>
<td>Speckerman</td>
<td>0%</td>
<td>100%</td>
</tr>
<tr>
<td>Lewis Fork</td>
<td>9%</td>
<td>91%</td>
</tr>
<tr>
<td>Nelder Creek</td>
<td>19%</td>
<td>81%</td>
</tr>
</tbody>
</table>
Last Chance Upscaling, Discharge Results

Work in progress

Bear Trap Headwater
Frazier Headwater
NFMF Am. River

Correlation
BTP x FRZ 0.98
BTP x NFMF 0.98
FRZ x NFMF 0.97
Last Chance Upscaling, Discharge Results

Work in progress

Similar Low Flow Recession slopes
Headwater: 0.0025 (400 days to drain)
Downstream: 0.0022 (430 days to drain)
Research Question:
1) Can the setup for the headwater version of the hydrologic model be transferred to the larger firesheds?
2) How does the fireshed response to forest treatments and wildfires differ from the headwater response?

Preliminary Results:
1) The calibrations for the headwater model can be used in the fireshed model due to geologic and hydrograph similarities.
2) Results anticipated soon!
1. Hydrology research program within SNAMP
2. Field measurement program – to inform modeling
3. Water-quality findings
4. Headwater synthesis and modeling
5. Scaling to the fireshed
6. Open questions and next steps after SNAMP
Additional recurring questions around water & forests

1. How will the post-fire water yield differ from before?

2. What will be the water yield w/ climate warming, vs. today?

3. What was the historical water yield prior to fire suppression?

Photos: J. Power & D. Buckley, USFS
Ongoing forest-watershed studies

SNAMP: 2 sets of paired catchments, Sierra Nevada Framework treatments

Stanislaus-Tuolumne EF: snow & soil moisture

KREW (USFS) watershed research site & CZO (NSF, UC): 8 headwater catchments; tree removal:
- 39% for <10 in
- 21% for 10-20 in
- 4% for 20-30 in
Further opportunities to build the knowledge base around water implications of forest management

Wildfire-affected areas
Restoration treatments
Fire opportunity 1 – American Fire

Extend SNAMP measurements for 5 years
Strategically placed sensors

Government Fire, 2008

American Fire

Star Fire, 2001

Snow, temperature, soil

Stream
Fire opportunity 2 – Illilouette basin

Multiple fires in recent decades
Regrowth at sustainable forest densities
Snow dominated
New JFSP/UCB project

Yosemite NP
Illilouette
Lower elevation, largely rain dominated – less potential
More sensors added post fire; 2014 upgrades planned – multi-objective research
UCM Ph.D. student, YNP, others
New studies – proposed to address knowledge gaps
<table>
<thead>
<tr>
<th>Name</th>
<th>acres</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice 3</td>
<td>480</td>
<td>Restore</td>
</tr>
<tr>
<td>Rice 2</td>
<td>720</td>
<td>Control</td>
</tr>
<tr>
<td>Rice</td>
<td>1040</td>
<td>Control</td>
</tr>
<tr>
<td>Dolly</td>
<td>2320</td>
<td>Light</td>
</tr>
</tbody>
</table>
Hemlock Project
Stanislaus NF

Discussions on hold

All on USFS land, more treatable area
Other potential project areas that have been discussed

1. Sierra Pacific Industries lands – Central Sierra area
2. Onion Creek, Tahoe NF – very dense, designated experimental area; see UC Phase I report
3. Sagehen area, including Truckee-Donner Land Trust lands – east side of Sierra
4. Scott River, Klamath NF – Phase I evaluation completed; multi-year planning required
5. El Dorado NF – no specific sites identified