Designing Monitoring Programs to Evaluate BMP Effectiveness

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Overview

• Lessons learned
  – USDA/CSREES Conservation Effects Assessment Project

The Guidance Document
  Water Quality Monitoring Training Resources
  – Components and key links…
  – Next steps
Objective 1. Determine if programs to promote adoption of best management practices have reduced P loads at a watershed scale.

Objective 2. Critically examine strengths and weaknesses of different water quality monitoring techniques.

Objective 3. Develop recommendations on the most effective and socioeconomically viable agricultural bmgs.
Little Bear River Hydrologic Unit Project
Pre-treatment problems:
Bank erosion, manure management, flood irrigation problems
WQ efforts in Little Bear

- Hydrologic Unit Area Project
- TMDL Project, 319 funds
- Additional cost share programs
- Other planning (e.g., Phase II, Source Water Protection)
Treatments:

- bank stabilization,
- river reach restoration,
- off-stream watering,
- improved manure and water management
Lessons Learned: Common problems in BMP monitoring programs

- Failure to design monitoring plan around BMP objectives
- Failure to identify and quantify sources of variability in these dynamic systems.
- Failure to understand pollutant pathways and transformations → choosing inappropriate monitoring approaches
• Failure to design monitoring plan around BMP objectives

• Failure to identify and quantify sources of variability in these dynamic system.

• A failure to understand pollutant pathways and transformations choosing inappropriate monitoring approaches
## Total Observations at Watershed Outlet site

<table>
<thead>
<tr>
<th>Year Range</th>
<th>Discharge</th>
<th>Total phosphorus</th>
</tr>
</thead>
<tbody>
<tr>
<td>1976 - 2004:</td>
<td>162</td>
<td>241</td>
</tr>
<tr>
<td>1994</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td>1995</td>
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<td>2003</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>2004</td>
<td>1</td>
<td>8</td>
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</table>

Number of observations each year
Was the original UDWQ monitoring program a failure?

No….Program was intended to detect exceedences of water quality criteria.

The failure was ours…. In attempting to use these monitoring data for detecting change in loads.
• Failure to design monitoring plan around BMP objectives

• Failure to identify and quantify sources of variability in these dynamic system.

• A failure to understand pollutant pathways and transformations → choosing inappropriate monitoring approaches
Since 2005, measure flow and turbidity at 30 minute intervals

Stage recording devices to estimate discharge
http://www.campbellsci.com

Turbidity sensors
http://www.ftsinc.com/

Dataloggers and telemetry equipment
http://www.campbellsci.com
Additional monitoring:

- Automated sampling of storm events at two sites
- Ongoing monitoring program by Utah Division of Water Quality
- Periodic grab samples to establish Flow / TSS and TSS/TP relationship
“upper watershed site”

“lower watershed site”
Understanding natural variability: Sources of error in sampling

- Relationship of surrogate to target pollutant
- Sampling frequency
- Timing of sampling
- Rare events
Seasonal and annual variation
January – December 2006

Upper Site
Flow (cfs)

• Seasonal and annual variation

• Variation between sites

Lower Site
Flow (cfs)

January – December 2006
Upper watershed site

Lower watershed site

Discharge (cfs)

October 2005 – October 2007
Upper Site
Flow (cfs)
and turbidity (NTU)

Lower Site
Flow (cfs)
and turbidity (NTU)

- Seasonal and annual variation
- Variation between sites
- Different pathways of pollutants

January – December 2006
• Variability in correlations between turbidity and water quality parameters (TSS and TP)
• Variability associated with frequency of sampling
2006 Upper Watershed Suspended Sediment Load Estimate

TSS Yearly Load Estimate (kg)

- minimum
- 25th percentile
- median
- 75th percentile
- maximum
- continuous
- deq

Time intervals:
- 30 min.
- twice daily
- daily
- weekly
- monthly
- DEQ 2006
The relative importance of two sources of variability in estimates of annual phosphorus load

Sampling frequency

Regressions of TP and turbidity

The relative importance of two sources of variability in estimates of annual phosphorus load.

Sampling frequency

Regressions of TP and turbidity

Coefficient of variation of estimates

Grab samples -- sampling frequency (d)

Continuous monitoring -- $R^2$ between TP and turbidity
Effect of sample timing

Average TSS Loads
Upper Watershed Site - Little Bear River

Lower Watershed Site Diel TSS Loads
Importance of monitoring rare events

Upper watershed site

Flow cfs

Date

12/14/05 3/4/06 5/23/06 8/1/06 10/30/06 1/18/07

Storms
Lower watershed site

Flow cfs

Date

12/14/05
3/4/06
5/23/06
8/11/06
10/30/06
1/18/07

Stroms
<table>
<thead>
<tr>
<th>TSS Load</th>
<th>Upper Site</th>
<th>Lower Site</th>
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</thead>
<tbody>
<tr>
<td>Annual (kg)</td>
<td>8.9 x 10^6</td>
<td>1.4 x 10^7</td>
</tr>
<tr>
<td>Runoff (% of total)</td>
<td>89%</td>
<td>54%</td>
</tr>
<tr>
<td>Baseflow (% of total)</td>
<td>11%</td>
<td>46%</td>
</tr>
<tr>
<td>Storms (% of baseflow)</td>
<td>&lt;1%</td>
<td>16%</td>
</tr>
</tbody>
</table>
• Failure to design monitoring plan around BMP objectives

• Failure to identify and quantify sources of variability in these dynamic system.

• A failure to understand pollutant pathways and transformations → choosing inappropriate monitoring approaches
Problems with “one-size-fits-all” monitoring design

Rees Creek TSS load

<table>
<thead>
<tr>
<th>Weeks</th>
<th>kg/day</th>
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<tbody>
<tr>
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<tr>
<td>2</td>
<td>2000</td>
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<td>7</td>
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</tr>
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<td>8</td>
<td>35000</td>
</tr>
<tr>
<td>9</td>
<td>45000</td>
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</table>

Above

Below
Problem: excess phosphorus

Average flow = 1000 cfs

BMP = fence cattle OUT of riparian area and revegetate

Bear River phosphorus load

<table>
<thead>
<tr>
<th>load (kg/day)</th>
</tr>
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<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>50</td>
</tr>
<tr>
<td>100</td>
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<td>250</td>
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<td>300</td>
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<td>350</td>
</tr>
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<td>400</td>
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</table>

<table>
<thead>
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<th>weeks</th>
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</thead>
<tbody>
<tr>
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<tr>
<td>3</td>
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<td>7</td>
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<td>9</td>
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</table>

For Stream Systems

Developed by:
Nancy Messner and Andrea Walker, Utah State University
Ginger Page, University of Wyoming
July 24, 2007

Funded by USDA-CSREES Water Quality Grant

Focuses on the considerations and decisions necessary as a project is first being considered.

NOT a “how-to” manual of protocols

Document in review
Training workshops underway
Target Audience

- State Environmental Agencies
- Conservation Groups
- Land Management Agencies
- Citizen Monitoring Groups
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- **APPENDIX A** Specific Models to Consider
What is your objective?

- Long term trends?
- UPDES compliance?
- Educational?
- Assessment for impairment?
- Track response from an implementation?
How do pollutants “behave” within your watershed?

✓ How does the pollutant move from the source to the waterbody?

✓ How is the pollutant processed or transformed within a waterbody?

✓ What is the natural variability of the pollutant? Will concentrations change throughout a season? Throughout a day?

✓ What long term changes within your watershed may also affect this pollutant?

✓ What else must be monitored to help interpret your data?
What to monitor?

- Monitor the pollutant(s) of concern?
- Monitor a “surrogate” variable?
- Monitor a response variables?
- Monitor the impacted beneficial use?
- Monitor the BMP itself?
- Monitor human behavior?
- Model the response to a BMP implementation.
- Collect other data necessary to interpret monitoring results OR calibrate and validate the model?
Where and when to monitor?

Timing of Response / Impact

- Watersheds
- Subwatersheds
- Reaches
- Points

- Construction BMPs
- Willow Planting
- Upland Grazing Management
- Manure Management

Months | Years | Decades
Choose appropriate monitoring or modeling

Control

Treatment “A”

Sampling points

BACI Design

Above and below treatment design

Above-treatment monitoring stations

Below-treatment monitoring stations
Guide to multiple approaches, including model resources
<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Direct Monitoring</th>
<th>Surrogate Monitoring</th>
<th>Other important variables *</th>
<th>Response variables</th>
<th>Models</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>Probes, launched monitors (e.g. hobo), and direct measurements</td>
<td>Light / shading, ground water signal (stable isotope variables)</td>
<td>Air temperature</td>
<td>Algae, macros, and fish</td>
<td>CEQual WASP(7) SNTEMP (USGS)</td>
</tr>
<tr>
<td>Dissolved Oxygen (DO)</td>
<td>Probes and direct measurements</td>
<td>Temperature, redox, and Flow/temperature/algal biomass</td>
<td>Temperature will affect percent saturation</td>
<td>Macros and fish</td>
<td>Streeter Phelps</td>
</tr>
<tr>
<td>Nutrients (phosphorus and nitrogen)</td>
<td>Grab samples and integrated samples In some cases use probes, or streamside auto-analyzers to collect surrogate samples</td>
<td>Turbidity or sediment</td>
<td>pH, temperature, and DO might affect the solubility of phosphorus</td>
<td>Algae, macros, and fish</td>
<td>UAFRI SWAT QUAL2K</td>
</tr>
<tr>
<td>Sediment</td>
<td>Grab samples and integrated samples</td>
<td>Turbidity</td>
<td>Physical characteristics, embeddedness, macros, and algae</td>
<td>Macros and fish</td>
<td>PSIAC AgNPS SWAT KINEROS2</td>
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<tr>
<td>Salts / TDS</td>
<td>Probes and grab samples</td>
<td>Riparian vegetation</td>
<td></td>
<td>Macros and fish</td>
<td>QUAL2K</td>
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<tr>
<td>Pathogens</td>
<td>Grab samples and integrated samples</td>
<td>Fecal Coliform Bacteria, <em>E.coli</em></td>
<td>Turbidity, nutrients</td>
<td></td>
<td></td>
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<tr>
<td>Metals</td>
<td>Grabs samples</td>
<td>Bioaccumulation in living organisms</td>
<td>DO might affect total hardness</td>
<td>Bacteria in the sediments</td>
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<tr>
<td>Organics</td>
<td>Grabs samples</td>
<td>Bioaccumulation in living organisms</td>
<td></td>
<td>Bacteria in the sediments</td>
<td></td>
</tr>
</tbody>
</table>
How to monitor?

✓ points in time versus continuous
✓ integrated versus grab samples
✓ consider:
  cost
  skill and training required
  accessibility of sites
Monitoring plans require careful thought before anything is implemented.

Consider how the data will be used to demonstrate change.

Use your understanding of your watershed and how the pollutants of concern behave to target monitoring most effectively

Use different approaches for different BMPs
In Conclusion:

Keep project goals and objectives in mind when monitoring BMPs

Monitor at an appropriate scale

Keep time lags in mind

Be selective, consider individual situations

Monitor surrogates when appropriate

Control or measure human behaviors / other watershed changes.
Next Steps

- Finalizing document & review process
- Available as a document & online as pdf
- Northern Plains and Mountains Website
  http://region8water.colostate.edu/

- Links to “key” information
  - models
  - websites
  - water quality standards
Thank You

Questions?
Before any monitoring program is initiated…
think carefully about goals and objectives.

- Why?
- What?
- Where?
- When?
- How?

“One size fits all” approach rarely fits anything very well