Collecting Small Watershed Runoff and Water Quality Data

Daren Harmel
Objectives

- Small watershed data collection
- Provide “How To” overview for managers
- Present “How To” details for technical staff
- Discuss balance between project resources, monitoring goals, and data uncertainty
Small Watershed Data Collection

• Prior to this research, little published guidance was available to support design and operation of small watershed data collection.
  • Costs and difficulties often under-estimated
  • Projects characterized by inconsistent methods, missing data values, short-term data sets.
• Developed and published practical “how to” guidance
  • Small watersheds (including “edge-of-field”)
  • Automated storm sampling
  • Q measurement - USGS, ARS

For example:


• Manual grab sampling - USGS
Difficulties in Storm Sampling

- Requires substantial resource commitment
  - equipment purchase and maintenance
    - automated samplers needed
  - personnel (travel, work hours)
  - lab analysis
- Constrained by QA/QC
- “Storm sampling”
  - safety, timing
- Problems will occur
Difficulties in Storm Sampling
Difficulties in Storm Sampling

8 in of rain following seeding/mulching

lightning
Designing Sampling Projects

Project Objective:
Achieve sampling goal(s) within financial, personnel, time, and watershed constraints

Products:
1) Water quality data
2) Measurement uncertainty

Sampling Components:
1) Automated vs Manual sampling
2) Q measurement
3) Enable level
4) Sampling interval
5) Discrete vs Composite samples
Sampling Components: Manual vs. Automated

- Automated sampling necessary in most projects
  - Most samplers have:
    - stage recorder/flow meter
    - sample collection pump & bottle(s)
    - programmable operation/memory
  - Must commit to regular maintenance
    - limit malfunctions
    - prevent data loss
Sampling Components: Q Measurement

- For continuous discharge measurement:
  - Option #1 -
    - establish stage-discharge relationship (rating curve)
    - measure stage - preferably in stilling well
    - determine Q with stage-discharge relationship
  - Option #2 –
    - use in-stream area-velocity sensor
Sampling Components: Q Measurement

Stage-discharge relationship

water level (ft)

flow (cfs)
Sampling Components: Q Measurement

- Developing a stage-discharge relationship in a natural channel requires
  - substantial time and effort
  - periodic adjustment
Sampling Components: Q Measurement

- Flow control (hydraulic) structure highly recommended
- Precalibrated flow control structure eliminates need to develop stage-discharge relationship
- Provides consistent, accurate Q measurement for load and EMC determination
Sampling Components: Enable Level

- High Minimum Flow Threshold “Enable Level”
- increases error, even if consider Q and estimate concentration outside sampling period
Sampling Components: Enable Level

- Low Minimum Flow Threshold “Enable Level”
- reduces error, especially if consider Q and estimate concentration outside sampling period
Sampling Components: Sampling Interval

- **Time-Interval Sampling**
  - **Advantages**
    - simple, reliable
  - **Disadvantages**
    - difficult to choose interval
    - Q needed to calculate load
  - “Low” interval recommended

<table>
<thead>
<tr>
<th>time interval (min)</th>
<th>composite samples per bottle</th>
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<tr>
<td>180</td>
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</table>
Sampling Components: Sampling Interval

- **Flow-Interval Sampling**
  - **Advantages**
    - produces EMC
    - easy to choose interval
    - uniform sampling for various watershed sizes
  - **Disadvantages**
    - must accurately measure Q
  - 1.5-5 mm interval recommended
Sampling Components: Discrete vs Composite

- **Discrete Sampling**
  - collection of 1 sample per bottle
  - difficult to sample complete storms of various duration
  - complete information on within-storm concentrations (if can sample complete event)
Sampling Components: Discrete vs Composite

- Composite Sampling
  - collection of 2+ samples per bottle
  - little or no increase in error
  - reduced information on within-storm concentrations
Designing Sampling Projects

Project Objective:
Achieve sampling goal(s) within financial, personnel, time, and watershed constraints

Sampling Components:
1) Automated vs Manual sampling
2) Q measurement
3) Enable level
4) Sampling interval
5) Discrete vs Composite samples

Products:
1) Water quality data
2) Measurement uncertainty
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<th>Alternative</th>
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<th>Recommend</th>
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<td>Decrease # storms</td>
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Flow-interval, composite sampling with single bottle
Conclusions

- In small watershed runoff and water quality data collection, it is important to understand that...
  - successful projects achieve a difficult balance between project goal(s), data quality, sampling components
  - collection of high quality data requires a great deal of time, $$, commitment
  - all measured data are uncertain
  - uncertainty increases dramatically without dedicated QA/QC
  - QA/QC should include uncertainty estimation and reporting to increase “value” of data.
Understanding and Reducing Uncertainty in Hydrology and Water Quality Data

Daren Harmel
Objectives

• Present background information on uncertainty in flow and water quality data
• Briefly describe the Data Uncertainty Estimation Tool for Hydrology and Water Quality (DUET-H/WQ)
• Discuss DUET results and personal experience related to uncertainty in small watershed sampling

“Should it not be required that every… (field and modeling study)… attempt to evaluate the uncertainty in the results?” Beven (2006)
Uncertainty in H/WQ Data

- Why is data uncertainty typically ignored?? Until recently...
  - An adequate understanding of H/WQ measurement uncertainty had not been established.
  - No complete uncertainty (error propagation) analysis had been conducted on measured H/WQ data.
  - No easy-to-use tool was available to assist with uncertainty estimation in H/WQ.
Sources of Uncertainty

- discharge measurement - individual Q’s, stage-discharge relation, channel conditions
- sample collection - EWI vs. grab vs. automated, sampling frequency, location in x-section, discrete vs. composite
- sample preservation/storage - pre-processing, preservation, storage duration and conditions
- laboratory analysis - reagents, standards, method, instrument, best fit curve
- data processing and management - mistakes, missing data

“The use of uncertainty estimation… (should be)… routine in hydrological and hydraulic science.”
Pappenberger, Beven (2006)
Uncertainty in H/WQ Data

- Developed uncertainty estimation framework (2006)
- focused on Q, TSS, N, and P data for small watersheds
- listed published uncertainty estimates in 4 categories
  - discharge, sample collection, preservation/storage, analysis
- analyzed “data quality” scenarios (best, typical, worst)
  - compared uncertainty introduced by each procedural category
- calculated cumulative uncertainty in resulting data
Uncertainty in H/WQ Data

- Enhanced uncertainty estimation framework to make more user-friendly (2009)
- added “data processing and management” procedural category
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### DUET-H/WQ Default Discharge Uncertainty

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### DUET-H/WQ Default Concentration Uncertainty

#### Storm Concentration Uncertainty

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<th>TSS(%)</th>
<th>NO3-N(%)</th>
<th>NH4-N(%)</th>
<th>Total N(%)</th>
<th>Diss. P(%)</th>
<th>Total P(%)</th>
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#### Baseflow Concentration Uncertainty

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## DUET-HWQ - Lookup Table for calculation of uncertainty in discharge measurement

### Individual discharge measurement

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<tr>
<th>Measurement</th>
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<th>Reference</th>
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<tbody>
<tr>
<td>Direct - area-velocity method - poor conditions</td>
<td>±20%</td>
<td>Sauer and Meyer (1992)</td>
</tr>
<tr>
<td>Direct - area-velocity method - average conditions</td>
<td>±6%</td>
<td>Sauer and Meyer (1992)</td>
</tr>
<tr>
<td>Direct - area-velocity method - ideal conditions</td>
<td>±2%</td>
<td>Boning (1992)</td>
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<tr>
<td>Direct - area-velocity method - ideal conditions (0.60.8d velocity)</td>
<td>±6.1%</td>
<td>Pelletier (1988)</td>
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<tr>
<td>Direct - area-velocity method - ideal conditions (0.6d velocity)</td>
<td>±8.5%</td>
<td>Pelletier (1988)</td>
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<tr>
<td>Manning's equation - Stable, uniform channel; surveyed reach and cross-section; accurate &quot;n&quot; estimate</td>
<td>±15%</td>
<td>Slade (2004)</td>
</tr>
<tr>
<td>Manning's equation - Unstable, irregular channel; surveyed reach and cross-section; poor &quot;n&quot; estimate</td>
<td>±35%</td>
<td>Slade (2004)</td>
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<tr>
<td>Direct - area-velocity method</td>
<td>±5% to ±15% (average ±9.3%)</td>
<td>Tillary et al. (2006)</td>
</tr>
</tbody>
</table>

### Continuous discharge measurement

- Pre-calibrated flow control structure (properly designed and installed) with periodic meter checks: ±5% to ±8% (Slade, 2004)
- Stable channel with stable control, 8-12 stage discharge measurements per year: ±5% to ±10% (Slade, 2004)
- Natural channel, ideal conditions: ±20% (Slade, 2004)
- OTHER: --- (N/A)

### Continuous stage measurement

- Float recorder: ±2% (Cooper, 2005, unpublished data)
- Float recorder: ±3 mm (Horsley, 1975)
- KPSI series 173 pressure transducer: ±0.1%, ±0.022% thermal error (KPSI, 2005)
- ISCO 730 bubbler flow module: ±0.036 ft±0.0003 °F temp, change from 72 deg F (ISCO, 2005)
- Optical distance sensor: ±1 cm or 0.4% of distance to water surface (Campbell Scientific, 2003)
- OTHER: --- (N/A)

### Effect of streambed condition

- Stable, firm bed: ±0% (Sauer and Meyer, 1992)
- Mobile, unstable bed: ±10% (Sauer and Meyer, 1992)
- OTHER: --- (N/A)
Uncertainty in H/WQ Data
Uncertainty in H/WQ Data
Uncertainty in H/WQ Data
Uncertainty in H/WQ Data
Conclusions

• Uncertainty is almost always ignored in spite of:
  • numerous pleas for uncertainty analysis
  • fact that all measurements are inherently uncertain.
• Uncertainty is rarely estimated and included in:
  • Research and monitoring
  • Data reporting
  • Regulation and policy
  • Model evaluation

• However, the ramifications of decisions based on these data are too great to continue to ignore uncertainty!!!
Conclusions
Any Questions??

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Includes uncertainty-related pubs (7) and sampling methods-related pubs (10)