Monitoring to Support and Improve H/WQ Modeling

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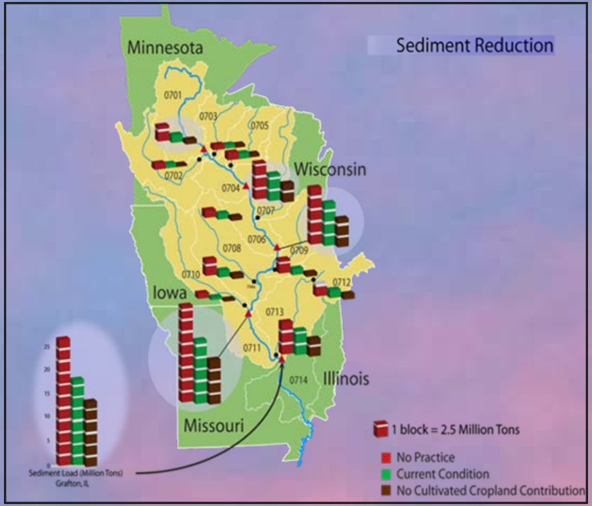
Monitoring, modeling, and decision-making

“I don’t trust models!”



“We have to use sound science!!”

“How can we get the biggest bang for our ‘cleanup’ buck??”

Monitoring, modeling, and decision-making

- Measured data…
  - stakeholders place more trust in
  - never have enough because it’s expensive, time-consuming, wrong scale, different conditions, etc.

Monitoring, modeling, and decision-making

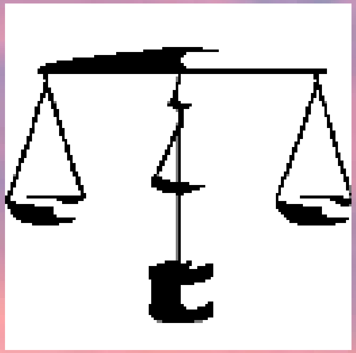
- Models…
  - need measured data to give stakeholders confidence in predictions
  - extremely valuable for simulating alternative practices, spatial relationships, various conditions, and future scenarios

- Both are necessary, since neither provides all the information needed for H/WQ decision-making.

Monitoring, modeling, and decision-making

- So… should we rely on modeling or monitoring in water quality decision-making?? WRONG QUESTION!!

- Right question is…How do we appropriately use modeling and monitoring in water quality decision-making??



Monitoring, modeling, and decision-making

- Typical decision is…
  - What is the best way to solve this water quality problem?
- This requires answering…
  - What are the important contributors to this problem?
  - What are the best practices to implement?
  - Where are the best locations to install these practices?
  - How can practice effectiveness be evaluated (post-implementation)?

Monitoring, modeling, and decision-making

- **Science-based options to answer these questions…**

Science-based options	cost	stakeholder trust	reliability
monitor	high	high	moderate
model	moderate	low	moderate
professional judgement	low	low	low

Monitoring, modeling, and decision-making

- Most decisions can be made with a similar approach to adaptive management:
  - One, determine sources - measured data, model, BPJ, and/or stakeholder input
  - Two, estimate contributions by various sources - model

Monitoring, modeling, and decision-making

- Three, make conservative reductions for significant (and willing) sources - use models to optimize practice type and location.
- Four, determine if reductions produce desired effect

  - measured data
- If necessary…
  - conduct research to better understand processes
  - improve model to better represent processes
  - make further reductions based on monitoring data, improved science

Any Questions??

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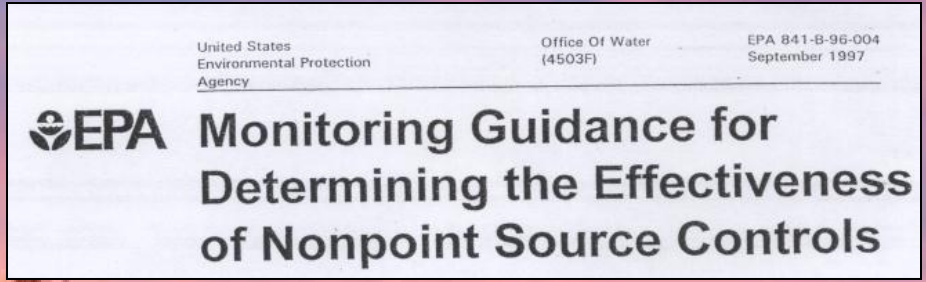
Outline

- **Monitoring, modeling, decision-making**

- **“How to” sample small watersheds ➡ data w/ less uncertainty**
- **H/WQ data uncertainty ➡ data with known uncertainty**
- **Challenging to understand and model ➡ *E. coli* example data**
- **MANAGE database ➡ more data**

Small watershed sampling guidance

- 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.



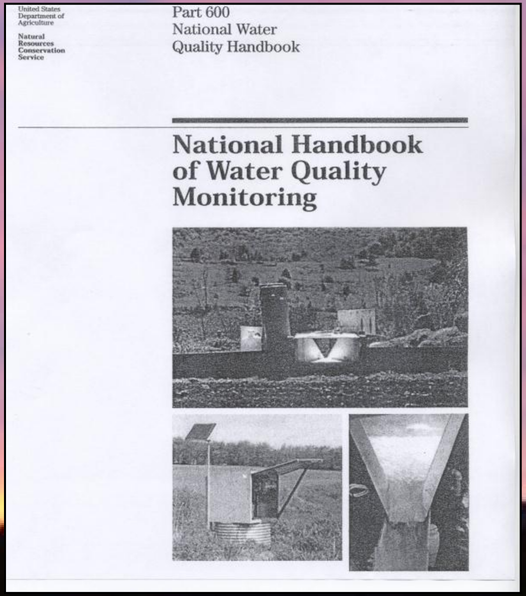
United States Environmental Protection Agency

Office Of Water (4503F)

EPA 841-B-96-004 September 1997

EPA

Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls



United States Department of Agriculture

Natural Resources Conservation Service

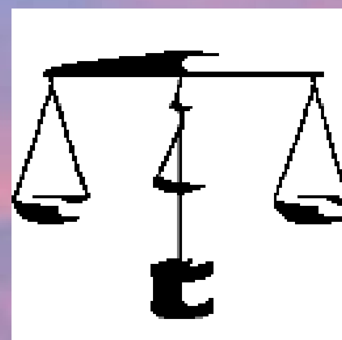
Part 600 National Water Quality Handbook

National Handbook of Water Quality Monitoring

Small watershed sampling guidance

- Practical “how to” guidance
  - Small watershed, “edge-of-field”
  - Automated storm sampling

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



<u>Products:</u>

1) Water quality data

2) Measurement uncertainty

www.ars.usda.gov/spa/hydro-collection

Small watershed sampling guidance

- 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

Successful projects balance project goals, data quality, sampling components.

Collection of high quality data requires a great deal of time, $$, commitment.

H/WQ data uncertainty

- The fact that all data are uncertain is typically ignored.
- Why?? 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.

"Should it not be required that every… (field and modeling study)… attempt to evaluate the uncertainty in the results?" Beven (2006)

H/WQ data 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**

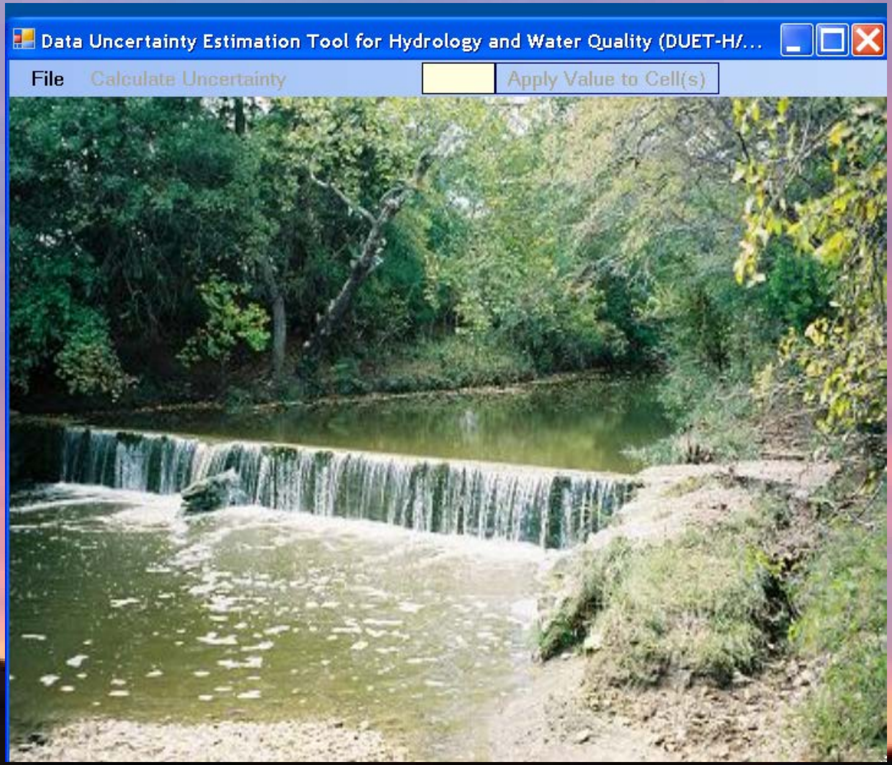
"The use of uncertainty estimation… (should be)… routine in hydrological and hydraulic science."
Pappenberger, Beven (2006)

H/WQ data uncertainty

- 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

H/WQ data uncertainty

- **Enhanced uncertainty estimation framework to make more user-friendly (2009)**
  - **added "data processing and management" procedural category**



DUET-H/WQ - LookUp Table for calculation of uncertainty in discharge measurement

Select the published value for each step or source of uncertainty

Individual discharge measurement

Individual discharge measurement	Uncertainty	Reference
Direct - area-velocity method - poor conditions	±20%	Sauer and Meyer (1992)
Direct - area-velocity method - average conditions	±6%	Sauer and Meyer (1992)
Direct - area-velocity method - ideal conditions	±2%	Sauer and Meyer (1992)
Direct - area-velocity method - ideal conditions	±2%	Boning (1992)
Direct - area-velocity method - ideal conditions (0.2,0.8d velocity)	±6.1%	Pelletier (1988)
Direct - area-velocity method - ideal conditions (0.6d velocity)	±8.5%	Pelletier (1988)
Manning's equation - Stable, uniform channel; surveyed reach and cross-section; accurate "n" estimate	±15%	Slade (2004)
Manning's equation - Unstable, irregular channel; surveyed reach and cross-section; poor "n" estimate	±35%	Slade (2004)
Direct - area-velocity method	±5% to ±15% (average ±9.3%)	Tillary et al. (2006)

± [ ] %
(Click to change)

Continuous discharge measurement

Pre-calibrated flow control structure (properly designed and installed) with periodic meter checks	±5% to ±8%	Slade (2004)
Pre-calibrated flow control structure (properly designed and installed)	±5% to ±10%	Slade (2004)
Stable channel with stable control, 8-12 stage-discharge measurements per year	±10%	Slade (2004)
Shifting channel, 8-12 stage-discharge measurements per year	±20%	Slade (2004)
Natural channel, ideal conditions	±6%	Boning (1992)
Instream velocity meter	----	N/A
OTHER -	---	N/A

± [ ] %
(Click to change)

Continuous stage measurement

Float recorder	±2%	Cooper (2005), unpublished data
Float recorder	±3 mm	Hershey (1975)
KPSI series 173 pressure transducer	±0.1%, ±0.022% thermal error	KPSI (2005)
ISCO 730 bubbler flow module	±0.035 ft ±0.0003 * ft * temp. change from 72 deg. F	Teledyne ISCO (2005)
Campbell Scientific SR50-L ultrasonic distance sensor	Larger of ±1 cm or 0.4% of distance to water surface	Campbell Scientific (2003)
OTHER -	---	N/A

± [ ] %
(Click to change)

Effect of streambed condition

Stable, firm bed	±0%	Sauer and Meyer (1992)
Mobile, unstable bed	±10%	Sauer and Meyer (1992)
OTHER -	---	N/A

± [ ] %
(Click to change)

Cancel

Data Uncertainty Estimation Tool for Hydrology and Water Quality (DUET-H/WQ)

File | Calculate Uncertainty | Apply Value to Cell(s) | Help

	Site_ID	Date_Time	discharge_(ft3/s)	Uncertainty(±%)	conc_NO3N_mg/l	Uncertainty(±%)
00001	Wild Cr...	3/12/2007 11:30	0.0	50	1	42
00002	Wild Cr...	3/12/2007 11:45	0.9	10	1	42
00003	Wild Cr...	3/12/2007 12:00	14.9	23	1	42
00004	Wild Cr...	3/12/2007 12:15	15.3	23	1	42
00005	Wild Cr...	3/12/2007 12:30	15.8	23	1	42
00006	Wild Cr...	3/12/2007 12:45	15.5	23	1	42
00007	Wild Cr...	3/12/2007 13:00	15.3	23	1	42
00008	Wild Cr...	3/12/2007 13:15	14.3	23	1	42
00009	Wild Cr...	3/12/2007 13:30	13.9	23	1	42
00010	Wild Cr...	3/12/2007 13:45	13.3	23	1	42
00011	Wild Cr...	3/12/2007 14:00	12.6	23	1	42
00012	Wild Cr...	3/12/2007 14:15	12.2	23	1	42
00013	Wild Cr...	3/12/2007 14:30	11.6	23	1	42
00014	Wild Cr...	3/12/2007 14:45	11.1	23	1	42
00015	Wild Cr...	3/12/2007 15:00	10.4	23	1	42
00016	Wild Cr...	3/12/2007 15:15	10.2	23	1	42
00017	Wild Cr...	3/12/2007 15:30	9.7	10	1	42
00018	Wild Cr...	3/12/2007 15:45	9.5	10	1	42
00019	Wild Cr...	3/12/2007 16:00	9.0	10	1	42
00020	Wild Cr...	3/12/2007 16:15	8.9	10	1	42
00021	Wild Cr...	3/12/2007 16:30	8.5	10	1	42
00022	Wild Cr...	3/12/2007 16:45	8.2	10	1	42

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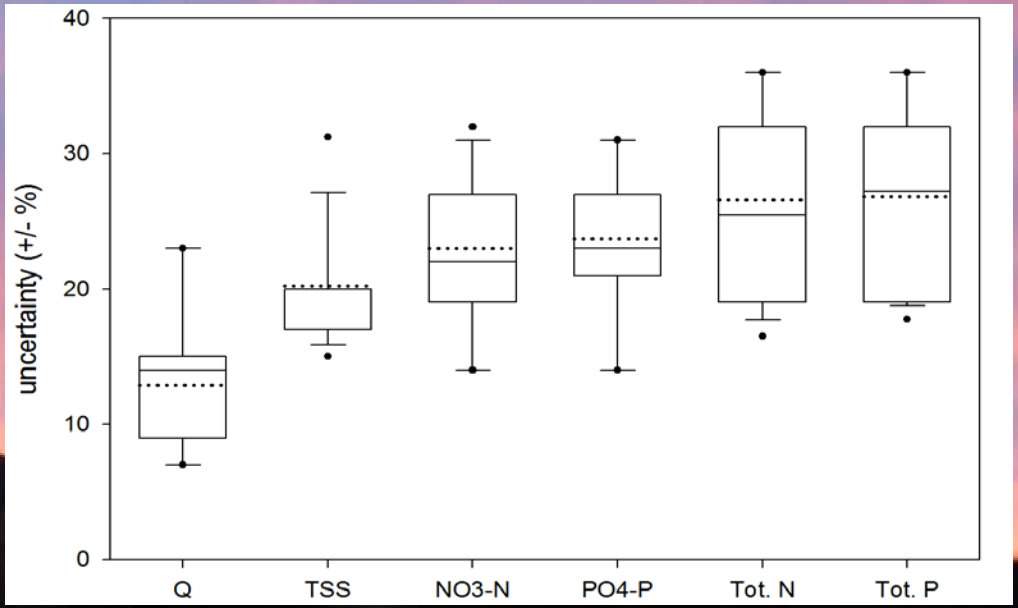
H/WQ data uncertainty

- **Developed 1st uncertainty estimation framework for HWQ**

$$EP = \sqrt{E_Q^{\,2} + E_C^{\,2} + E_{PS}^{\,2} + E_A^{\,2} + E_{DPM}^{\,2}}$$

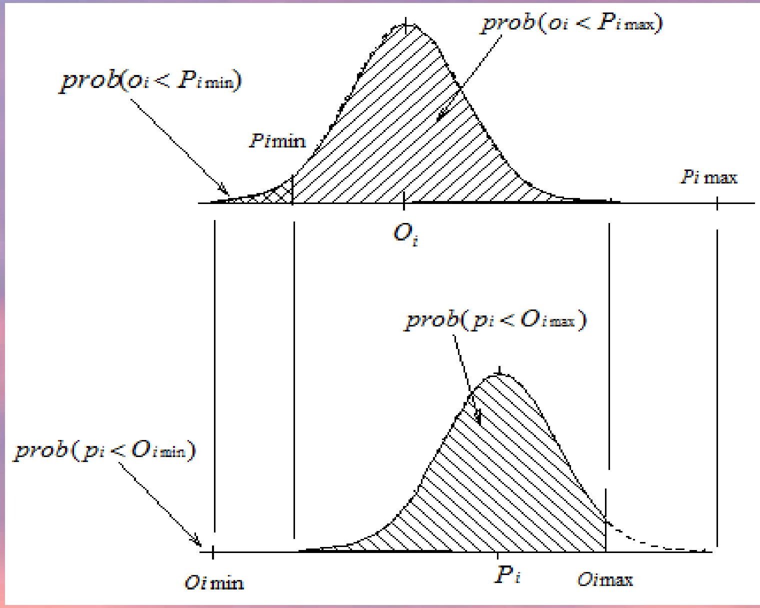
- **Produced 1st comprehensive uncertainty analysis for H/WQ**

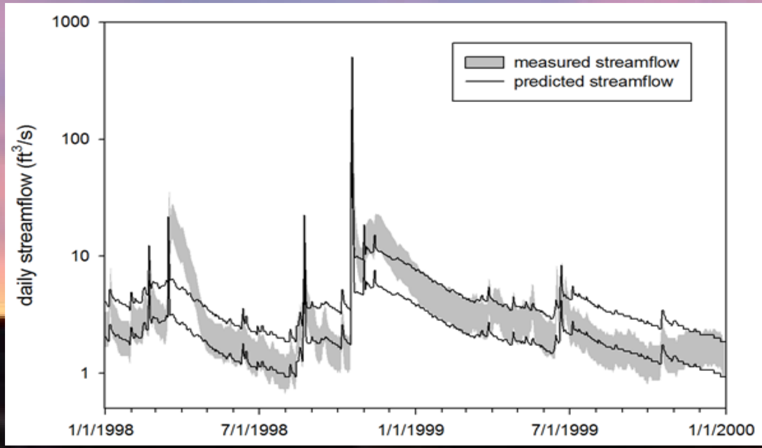


H/WQ data uncertainty

- Led effort to emphasize importance of considering uncertainty in…
  - Model evaluation
  - Monitoring
  - Data reporting
  - Policy/regulation

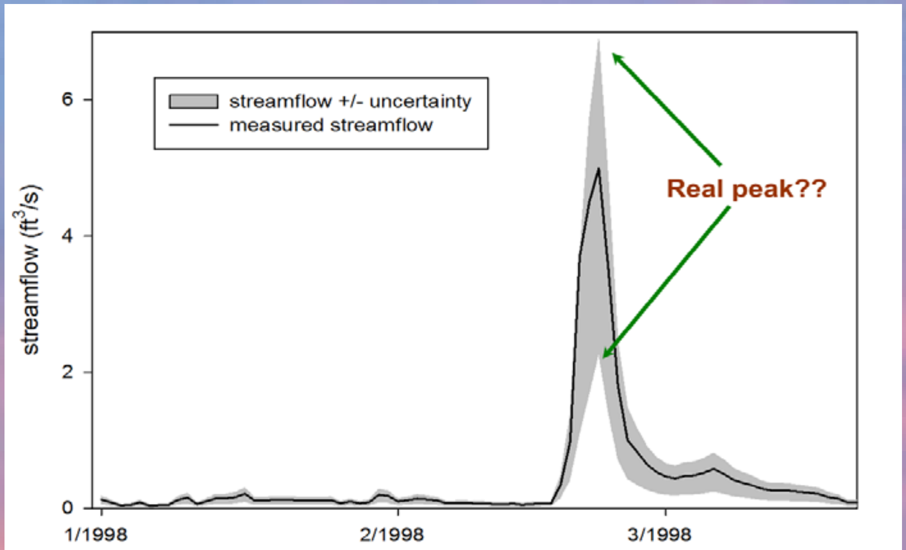
$$e(meas+pred)_i = CF(meas+pred)_i \times (O_i - P_i)$$

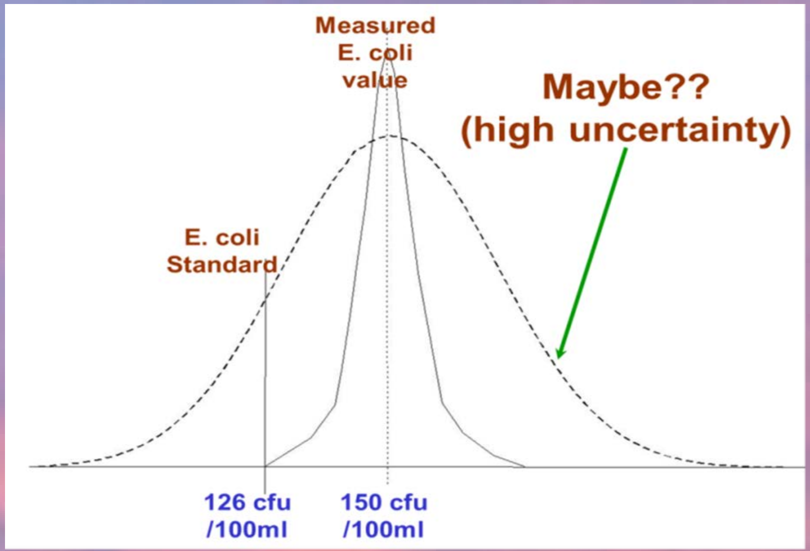




Conclusions

- **The ramifications of decisions based on these data are too great to continue to ignore uncertainty!!!**



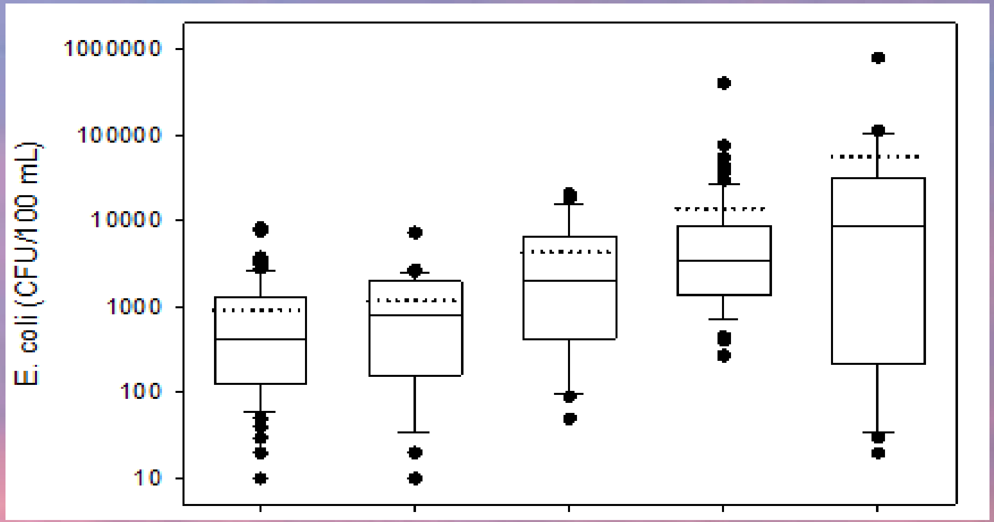


Uncertainty increases dramatically without QA/QC.

QA/QC should include uncertainty estimation, reporting to increase data "value".

E. coli runoff example

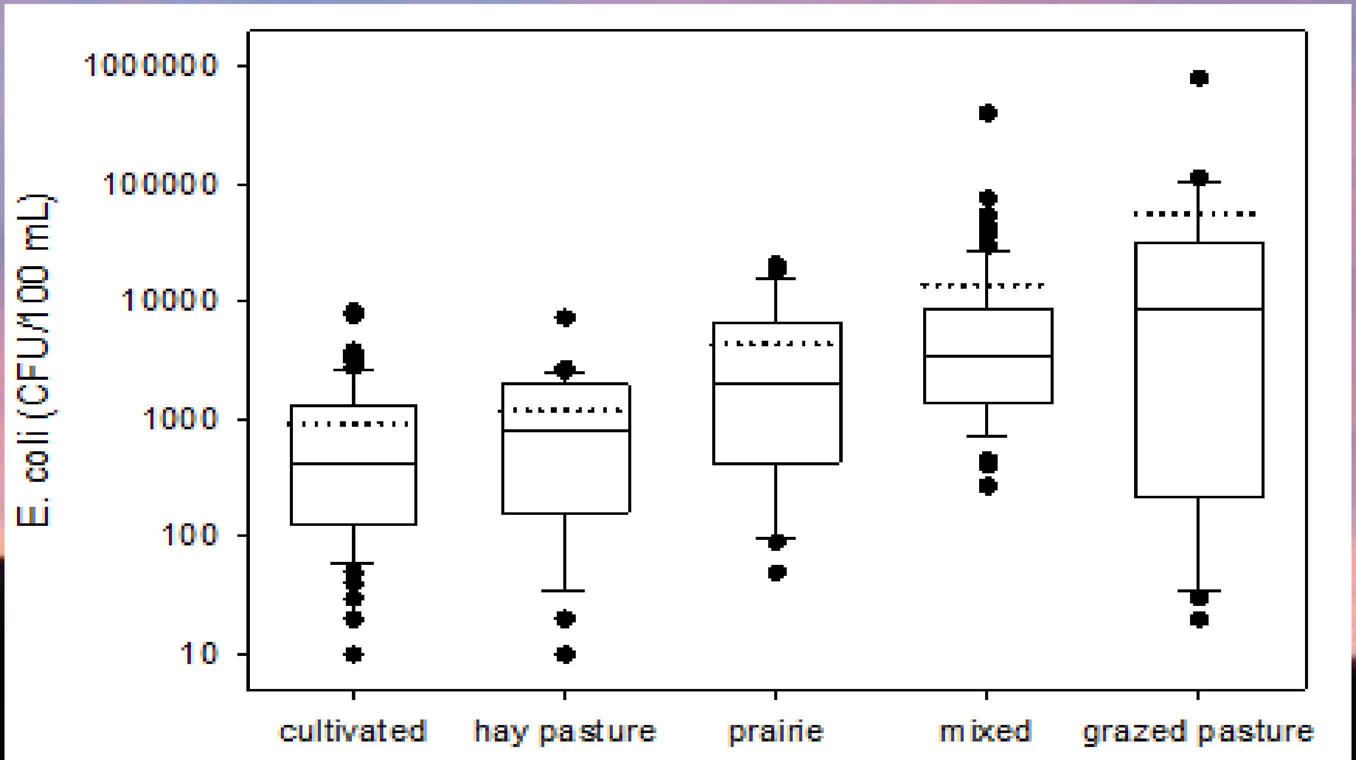
- Measure *E. coli* at edge-of-field and in small streams
  - understand management/land use impacts
  - evaluate potential sources
  - inform WQS process



Native prairie, Mixed, Cultivated, Hay pasture, Grazed pasture?????

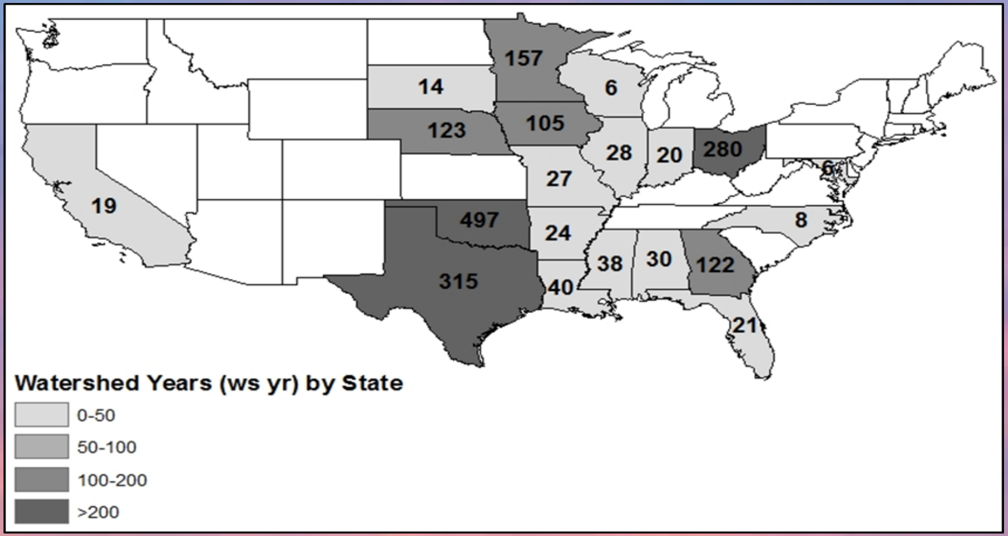
E. coli runoff example

- Still understand very little about *E. coli* fate and transport
  - large variability
  - counterintuitive results
  - very difficult to model



MANAGE database

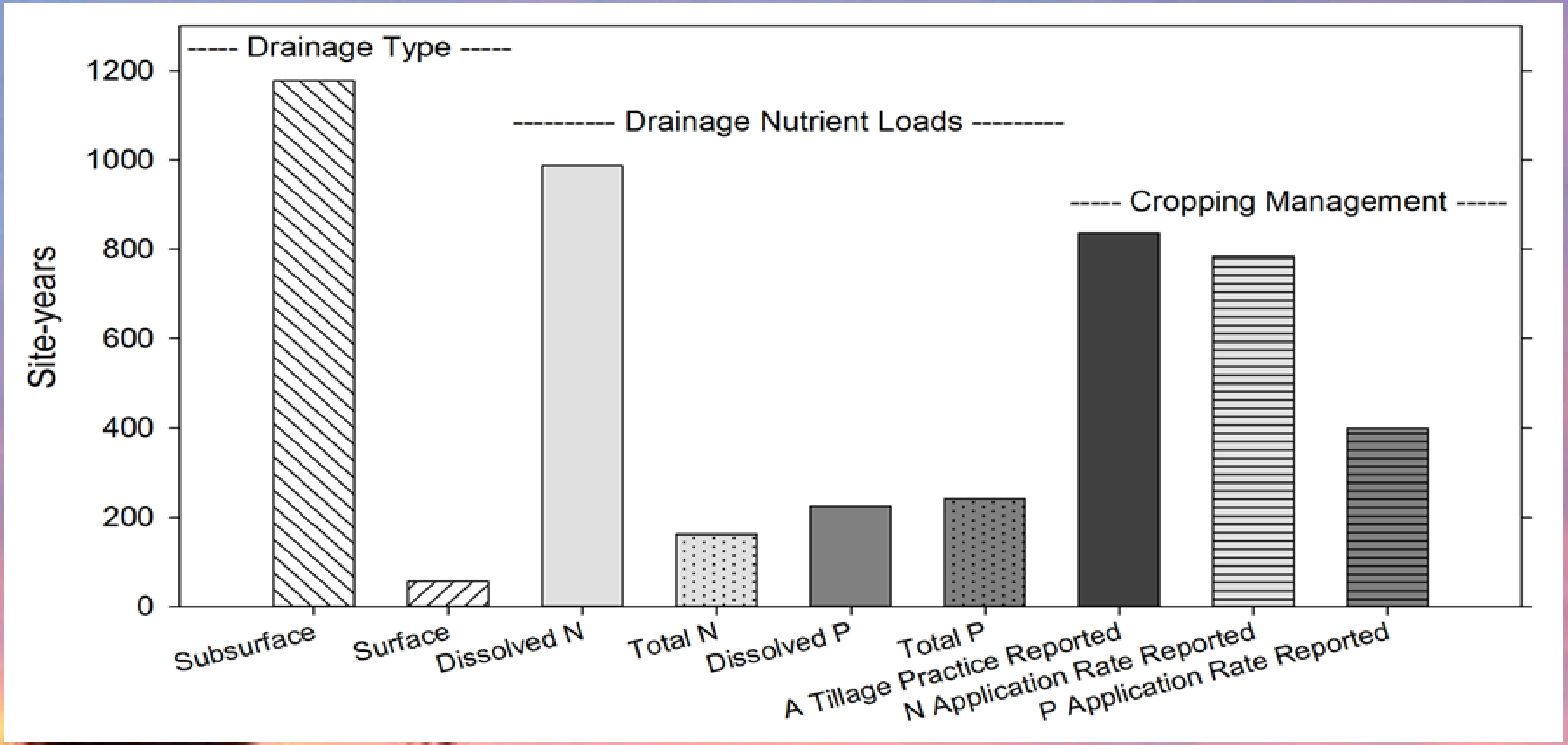
- Data from “all” studies with measured N, P runoff
  - Agricultural (67 studies)
  - Forest (30 studies)



Treatment	Total N (kg/ha)	Diss. N (kg/ha)	Part. N (kg/ha)
Land use			
Corn	18.70	3.02	7.27
Cotton	7.88	2.47	9.13
Sorghum	3.02	0.30	-
Peanuts	-	-	-
Soybeans	-	2.70	21.9
Oats/Wheat	6.61	1.31	5.90
Fallow Cultivated	3.00	0.90	2.70
Pasture	0.97	0.32	0.62
Various Rotations	3.68	3.12	1.36

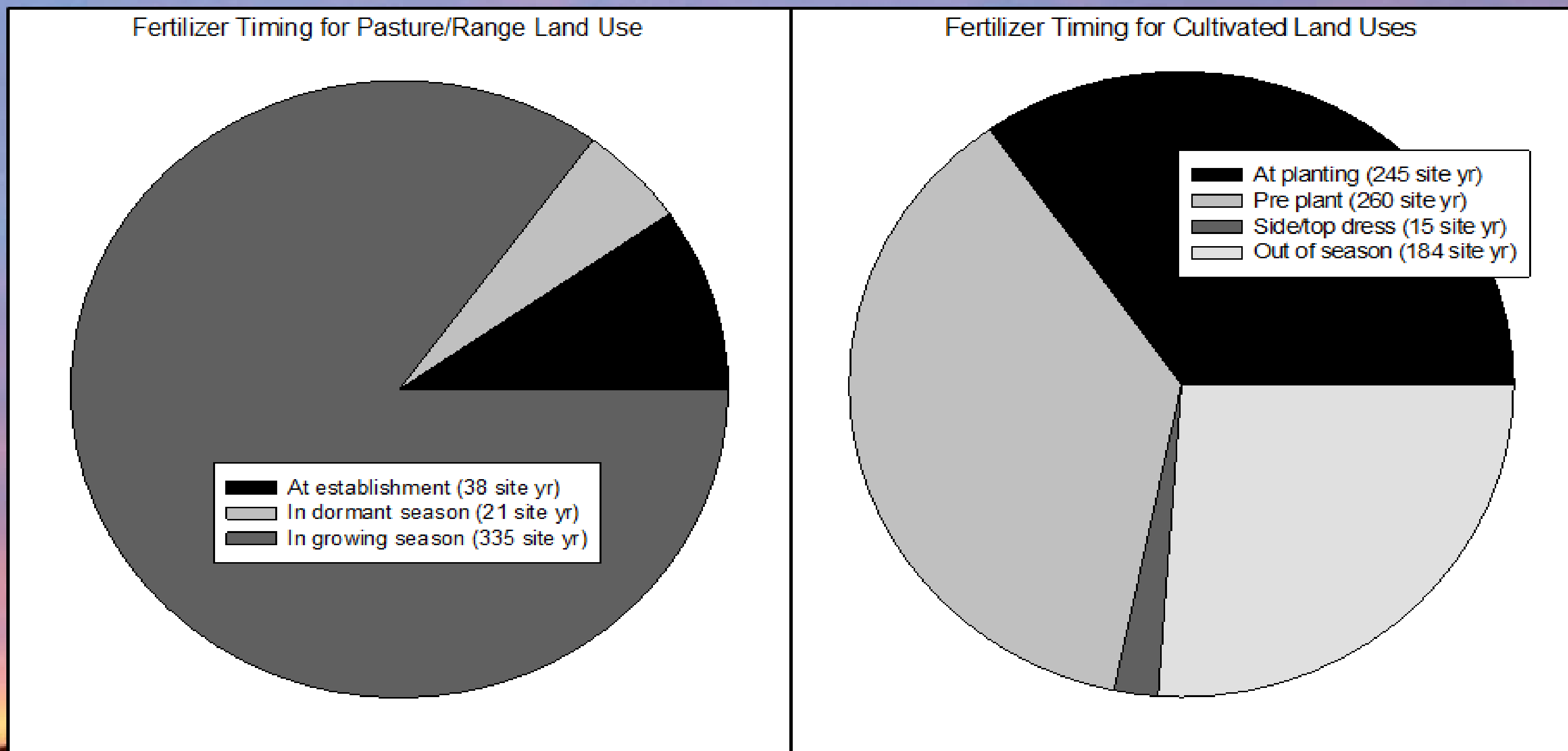
MANAGE database

- Recent additions include:
  - Drainage (91 studies)



MANAGE database

- **Recent additions include:**
  - **Additional management info**



Use all available "hard" &"soft" data to calibrate, constrain, evaluate HWQ models.