Water Quality Monitoring for National Water Quality Initiative Watershed Projects

Technical Background Information to Support Project Design Efforts

Fundamentals of Good Monitoring

- ► Understand the system.
- ► Design to meet objectives.
- ► Monitor source activities.
- ► Details – data management, QA/QC, logistics, record-keeping
- ► Feedback

Monitoring Design Steps (USDA, 2003)

1. Identify problem
2. Form objectives
3. Design experiment
4. Select scale
5. Select variables
6. Choose sample type
7. Locate stations
8. Determine frequency
9. Design stations
10. Define collection/ analysis methods
11. Define land use monitoring
12. Design data management

USDA. 2003. National Water Quality Handbook
http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044775.pdf

Also see Tech Notes #2 “Designing Water Quality Monitoring Programs for Watershed Projects”

http://www.bae.ncsu.edu/programs/extension/wqg/319monitoring/TechNotes/technote2_wq_monitoring.pdf

1. Identify the Problem

- Before design of monitoring project (or the land treatment!) *(should be done already for NWQI projects)*
- Elements of a problem statement
  - Use impairment (e.g., recreation)
  - Waterbody (e.g., lake)
  - Symptoms (e.g., algal blooms, anoxia)
  - Causes (e.g., excessive P load)
  - Sources (e.g., agricultural runoff)

2. Form Objectives

- Management and monitoring objectives must be complementary.
- Management objectives
  - Reduce annual P loading to lake by at least 15% in 5 years with nutrient management.
  - Reduce *E. coli* load to stream to meet water quality standards in 3 years.
- Monitoring objectives
  - Measure changes in annual P loading to lake and link to management actions.
  - Measure changes in compliance with water quality standard for *E. coli.*

NWQI: Monitoring Objectives

- To determine if NWQI practices are reducing nutrient, sediment, and pathogen pollution
  - Concentrations
  - Loads
  - Biological
- To determine if water quality has improved and can be associated with implementation of NWQI conservation systems

- Alternatively, for either objective above, **lump NWQI and all other conservation practices** (e.g., EQIP, state cost-share). Need to decide up front because it affects monitoring design, data collection, and data analysis. Subsequent slides assume focus on NWQI practices.

Approaches to Meeting Objectives

1. Demonstrate Cause-Effect
2. Demonstrate Association with Statistical Analysis
3. Infer Association in Qualitative Manner
4. Claim Success with Minimal Documentation

- #1 is not feasible
- #4 is not adequate
- Leaves #2 and #3 as viable options for NWQI

Demonstrate Association Statistically

- Before/After Step Trend or Change
- Monotonic Trend (a gradual change over time that is consistent in direction)
- Explanatory Variables to Improve Relationships
- Requires Tight Experimental Control
  - Examples
    - X% reduction of flow-adjusted median annual TP concentration in post- vs. pre-BMP period (t-test, 95% confidence)
    - X% reduction in flow-adjusted median annual TP concentration with time and nutrient management acreage as independent variables (linear regression, 95% confidence)

Infer Association Qualitatively

- ► Document Change in Condition or WQ Variable(s)
- ► Document Implementation of NWQI Practices
- ► Tell the Story (with Explanatory Variables)
- ► Less Experimental Control

  - ► Examples
    - Beneficial use support status changed from partial to full support. Qualitative interpretation based on documentation of NWQI practice implementation and weather patterns.
    - Average annual TN load generally lower in last 4 years versus first 4 years. Qualitative interpretation based on documentation of NWQI practice implementation and weather patterns.

Monitoring NWQI Projects: Ideal

2 years	2 years	3+ years
→	→	→
Pre	**Implementation**	**Post**

- NWQI practice implementation begins 2 years after project monitoring begins (i.e., 2 years pre-BMP).
- Practices in place at beginning of pre-BMP period remain in place and are operated and maintained consistently throughout project lifetime.
- New practice implementation is all from NWQI and completed within a 2-year time period.
- Monitoring occurs for 7-9 years (with possible break during 2-year NWQI practice implementation phase).

Monitoring NWQI Projects: Ideal

2 years	2 years	3+ years
→	→	→
Pre	**Implementation**	**Post**

- Supports pre-BMP vs. post-BMP analysis.
- Could support monotonic trend analysis if BMP implementation takes longer than expected.

Monitoring NWQI Projects: Likely

2-4 years →	3+ years →
Implementation	**Post**

- NWQI practice implementation began before monitoring begins (i.e., no pre-NWQI baseline).
- Practices in place at beginning of pre-BMP period remain in place and are operated and maintained consistently throughout project lifetime.
- NWQI practices are largely implemented within 4 years.
- Monitoring occurs for 7-9 years (with no break during NWQI practice implementation phase).

Monitoring NWQI Projects: Likely

2-4 years → **Implementation**

3+ years → **Post**

- If collect water quality, land use/treatment, and precipitation/flow data project should be able to perform statistical analysis and interpret water quality results.
- Project outcomes will vary due to differences in watersheds, precipitation/flow patterns, problem type, and BMP types and implementation patterns.
- Examine data and may find opportunities for:
  - Pre- vs. post-BMP step analysis
    - Little early BMP implementation followed by rapid completion within 5 years
    - Lag in BMP effects
  - Monotonic trend analysis
    - Steady implementation over first 5 years
    - Lag in BMP effects

Challenges to Meeting Objectives

- Will NWQI BMP implementation cause measurable change?
- Timeframe for measuring impact (lag time).
- Separating NWQI from other influences in the watershed.
  - Baseline = Pre-Implementation only if collected before NWQI
- Will variability in the weather affect agriculture (e.g., yields in drought/wet vs. good years), BMP performance (e.g., riparian growth), and hydrology (e.g., runoff in wet vs. dry years) in ways that affect achievement of objectives or complicate data interpretation?
- Cost and logistical constraints (e.g., will budget cuts jeopardize NWQI implementation?).

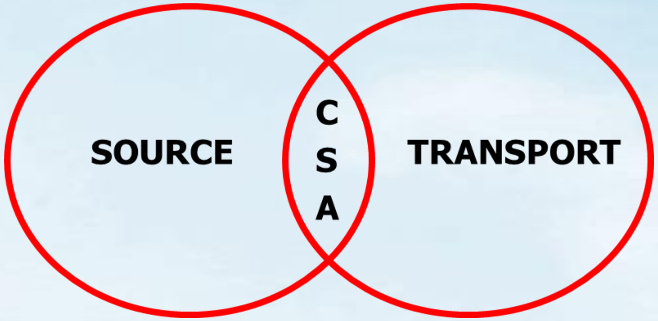
Will NWQI BMP implementation cause measurable change?

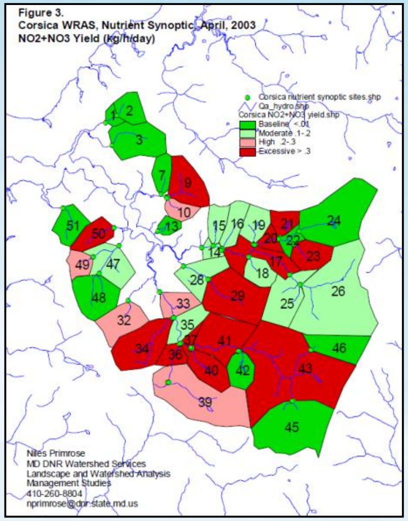
- ► BMPs selected for problem pollutants and sources?
- ► Targeted appropriately to achieve timely improvement?
  - ▪ WQ agencies have limited influence on NWQI implementation
  - ▪ Compare vs. existing TMDL or WBP
- ► Implemented to a level that is sufficient to cause measurable change?

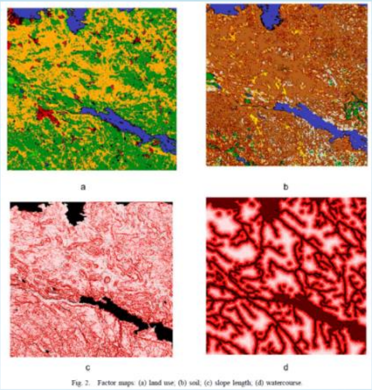
Use planning models appropriately.

- Model to reflect the range of possible outcomes rather than simply the "average" or "best case" scenarios.
- Temporal resolution of model must be considered.
  - e.g., STEPL is not designed to estimate actual annual loads for specific years. Rather, it is designed to estimate an *average annual load over 20 years*.

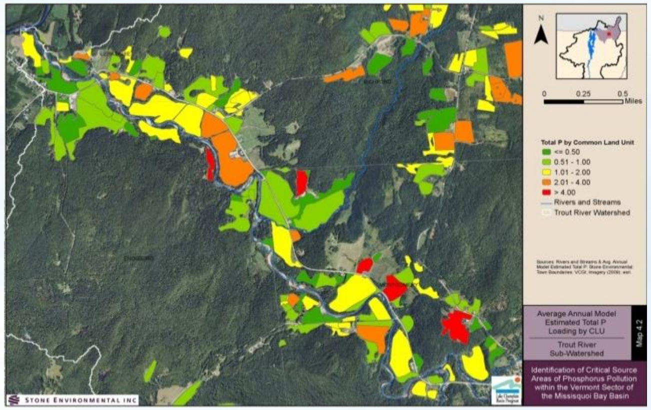
Critical Source Areas & Targeting







- Export coefficients
- Synoptic survey data
- GIS overlays
- Modeling



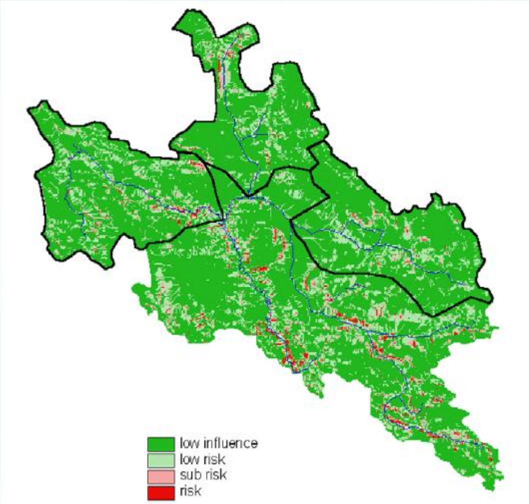


Fig. 7. Risk map for the Gisselö watershed.

Critical Source Areas & Targeting

Use biophysical measures to identify vulnerable locations within problem area.

↓

Assess salient behaviors in these locations to determine where disproportionality* may be occurring.

↓

Gain understanding why inappropriate behaviors are occurring in these locations.

↓

Design intervention effort based on this understanding.

*The degree of asymmetry emerging between a specific agricultural behavior, or a set of behaviors, and the resiliency or buffering capacity of the biophysical setting (i.e., space and time) where these actions occur.

Lag Time is Here to Stay

- Some watershed land treatment projects have reported little or no improvement in water quality after extensive implementation of best management practices (BMPs) in the watershed:
  - Insufficient landowner participation
  - Uncooperative weather
  - Improper selection of BMPs
  - Mistakes in understanding of pollution sources
  - Poor monitoring design
  - Inadequate level of treatment

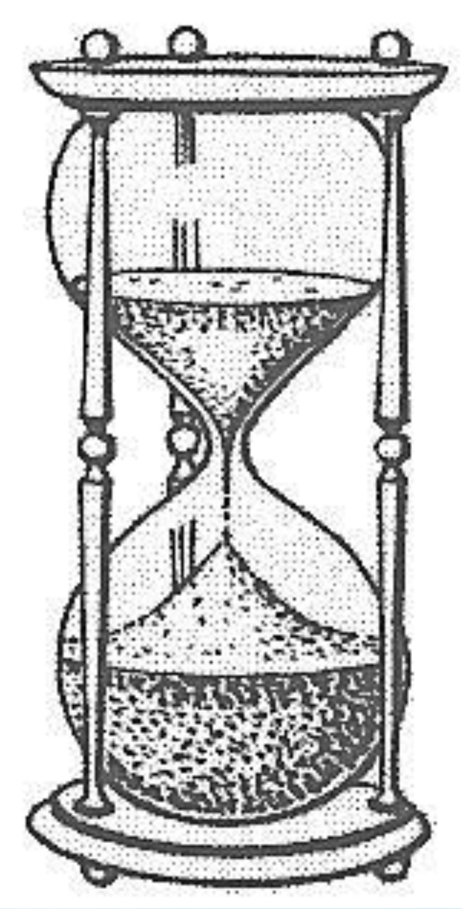
See Tech Notes #4 “Lag Time in Water Quality Response to Land Treatment”

http://www.bae.ncsu.edu/programs/extension/wqg/319monitoring/TechNotes/technote4_lag_time.pdf

Lag Time

An inherent characteristic of natural systems generally defined as the amount of time between an action and the response to that action

Lag time is the time elapsed between installation or adoption of land treatment and measurable improvement of water quality.

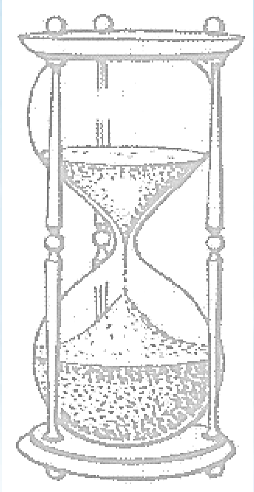


If lag time > monitoring period…..

may not show definitive water quality results

Project Management

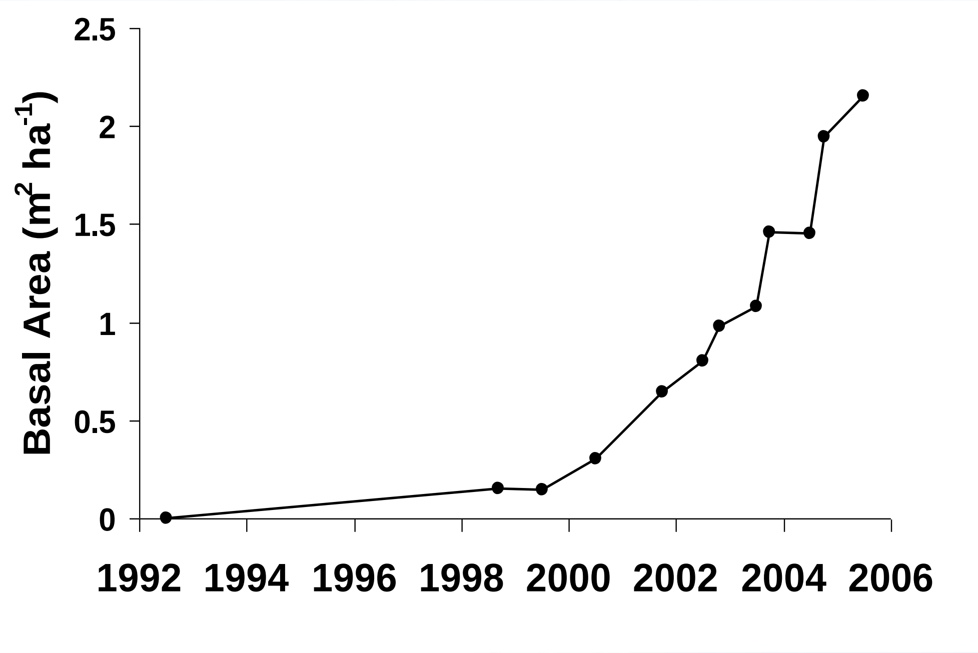
Time required for practice(s) to produce desired effect + Time required for effect to be delivered to water resource + Time required for water body to respond to effect =



Effects Measurement Components

Magnitude of Lag Time

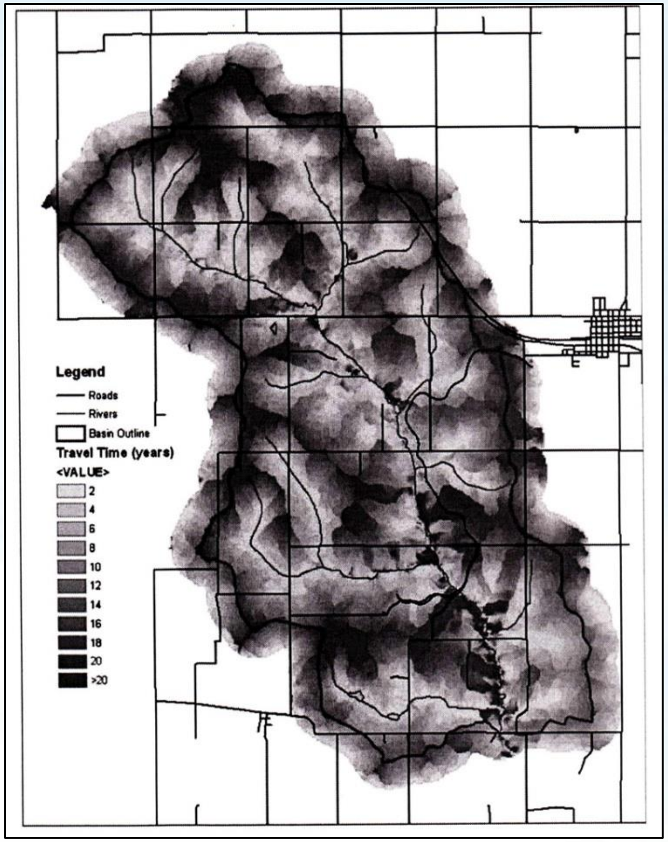
Riparian forest buffer, PA



8 to 12 years to grow riparian forest buffer

Magnitude of Lag Time

Prairie restoration, Iowa



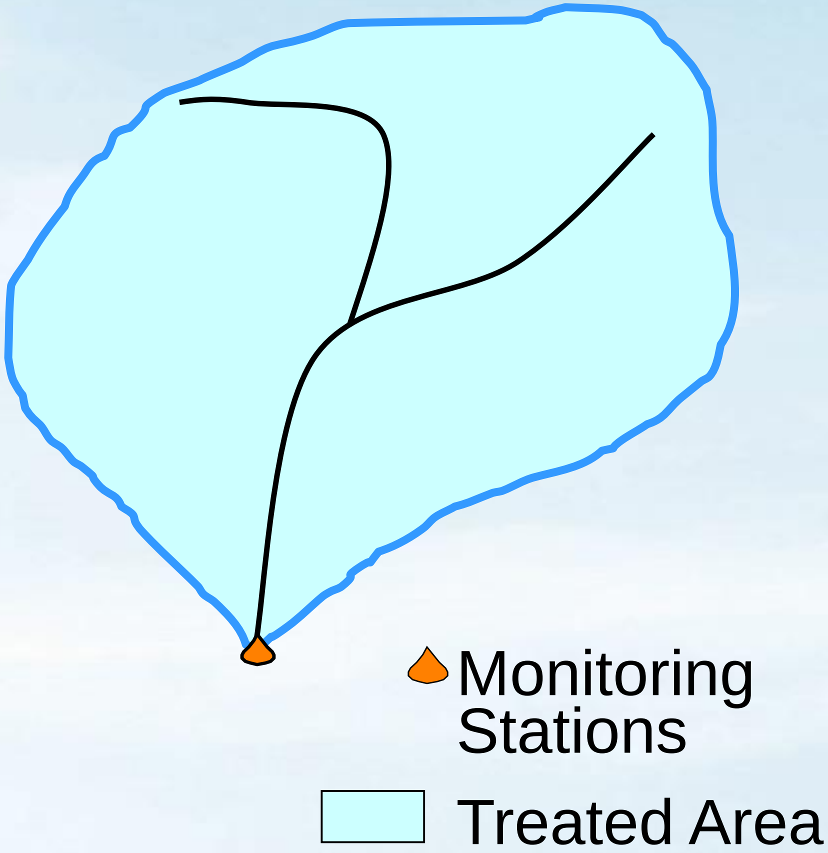
- An Iowa project estimated mean groundwater travel time in the 7.8 km^2 watershed to be10.1 yr, with a range from 2 d to 308 yr.
- Water from only ~20% of restored prairie areas reached the stream during the monitoring period.

3. Design Monitoring to Address Challenges

- Separate effects of NWQI from other influences in the watershed … (may choose to lump NWQI with all other practices).
- Account for weather variability and lag time.
- Keep costs down by focusing on objectives.
- Several experimental designs possible
  - Depends on study objective
  - Select before project begins
- We will limit discussion to above/below and single-station (before/after and trend) designs.

Single Watershed Before/After

- Purposes
  - To evaluate the effects of practice implementation in watershed
  - To assess changes in relationship between water quality and climate variables due to BMPs



Single Watershed Before/After

- Statistical designs
  - Difference between means
    - t-test
    - Paired t-test is not appropriate (no pairs)
  - Analysis of covariance
    - Difference between slopes and intercepts of regression relationships for pre- and post- periods
    - Multivariate regressions using flow or climate variables could help

Single Watershed Before/After

- Sampling
  - Single station
  - Grab, storm, or composites
  - Biological

Where loads are specified in TMDLs and other watershed plans, need to measure flow and cover storms.

Single Watershed Before/After

- Advantages
  - One monitoring station
  - Easy to apply
  - Can support trend analysis (step trend)
- Disadvantages (for watershed project evaluation)
  - Vulnerable to climate variability
  - Difficult to attribute causes (BMPs or climate?)
- Strengthen this design by:
  - Increasing pre- and post-BMP monitoring periods
  - Adding covariates (e.g., flow – needed for loads)
  - Ensuring that BMPs are implemented completely within the designated time period (i.e., a sharp divide between pre- and post-)
  - Collect detailed data on BMP implementation

Trend

- Purposes
  - To determine if BMPs improved water quality
  - To determine changes in water quality over time
    - e.g. – Change in E. *coli* levels
    - e.g. – Change in compliance over time
    - e.g. – Change in load under a TMDL

Trend monitoring is similar to single watershed before/after, but there is assumed to not be a distinct implementation period as in before/after studies, and trend monitoring is assumed to continue for a much longer period (10 or more years versus 2-6 years).

If BMP implementation does not occur within the designated timeframe, monotonic trend analysis should be considered.

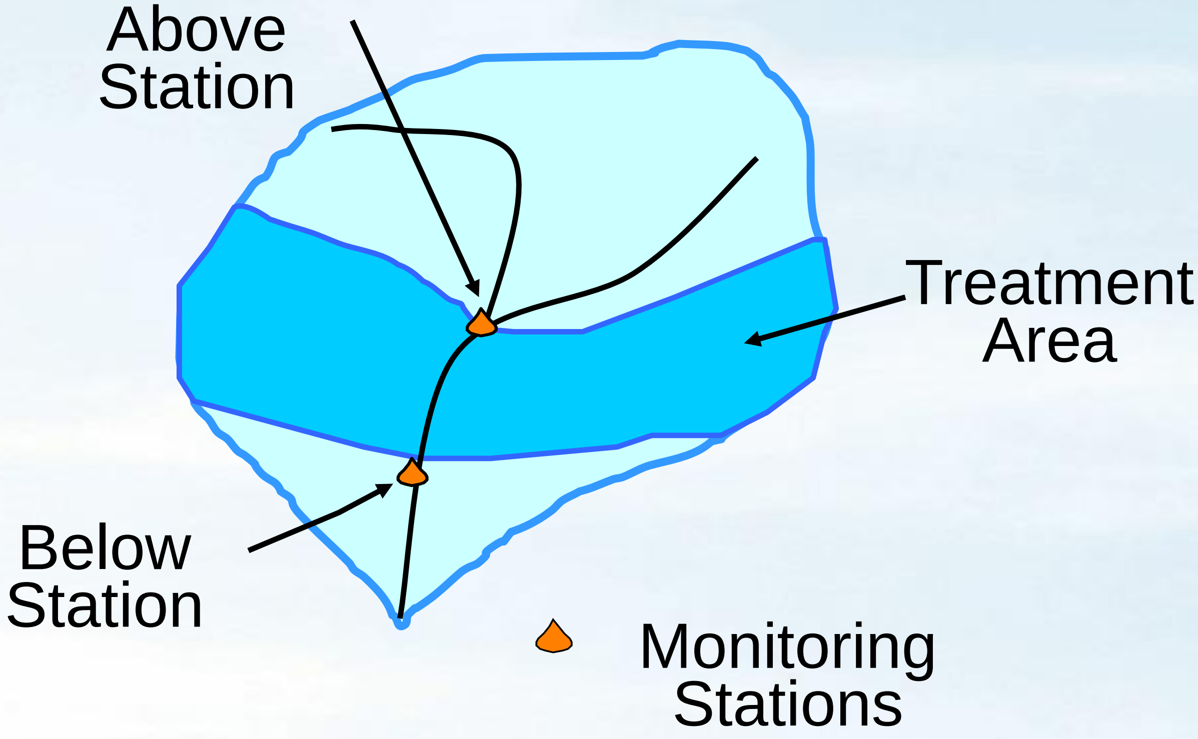
Trend

- Advantages
  - One monitoring station
  - Widely applicable
  - BMP implementation can be gradual over time
  - Accounts for lengthy lag times
  - Consistent with TMDL needs if loads measured

- Disadvantages (for watershed project evaluation)
  - Must track land use, land treatment, precipitation, and flow
  - Takes many years (often 10+)
  - Cannot have data gaps
  - Vulnerable to major land use changes
  - Cannot change sampling and analysis methods over entire study period

Above/Below

- Purposes
  - To assess the water quality impact of isolated sources
  - To determine the effectiveness of BMPs at isolated sources



Above/Below

- Statistical designs
  - Paired t-test (above and below)
  - Non-parametric t-tests
  - Compare regressions for above and below
    - e.g. – Concentration vs. flow
  - If sample before and after BMPs, use paired-watershed analytical approach
    - Develop regression relationships between control and study watersheds for both calibration and treatment periods.
      - Test significance with ANOVA for regression
      - Compare regression relationships for identical slopes and intercepts using ANCOVA

Above/Below

- Sampling
  - Paired samples at two stations (above/below = nested pairs)
  - Grab, storm, or composites
  - Biological

Where loads are specified in TMDLs and other watershed plans, need to measure flow and cover storms.

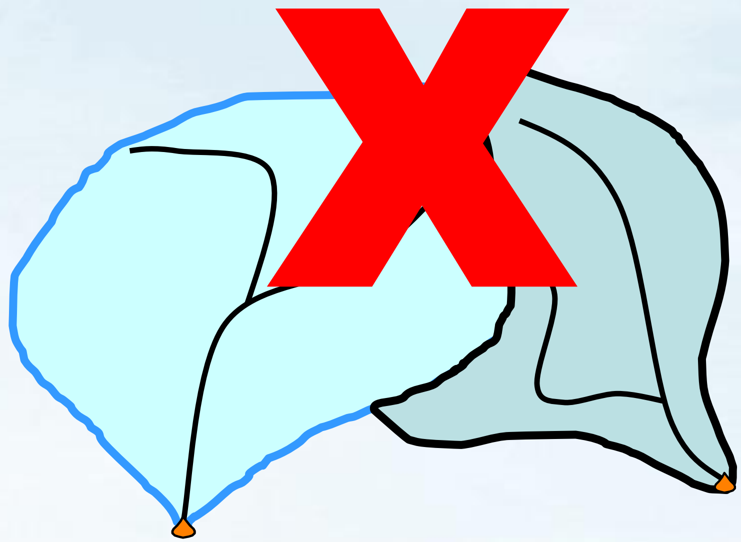
Above/Below

- Advantages (for watershed project evaluation)
  - Not as vulnerable to climate variability as single watershed
  - Widely applicable
  - Useful for isolating critical areas
  - Can treat as paired watersheds if sample before and after BMPs
- Disadvantages
  - Potential upstream impacts on downstream water quality
  - Differences between station data may be caused by*:
    - Geology
    - Interactions between BMPs and watershed
    - BMPs

*Pre- and post- BMP monitoring can address these issues.

Not So Useful Monitoring Designs

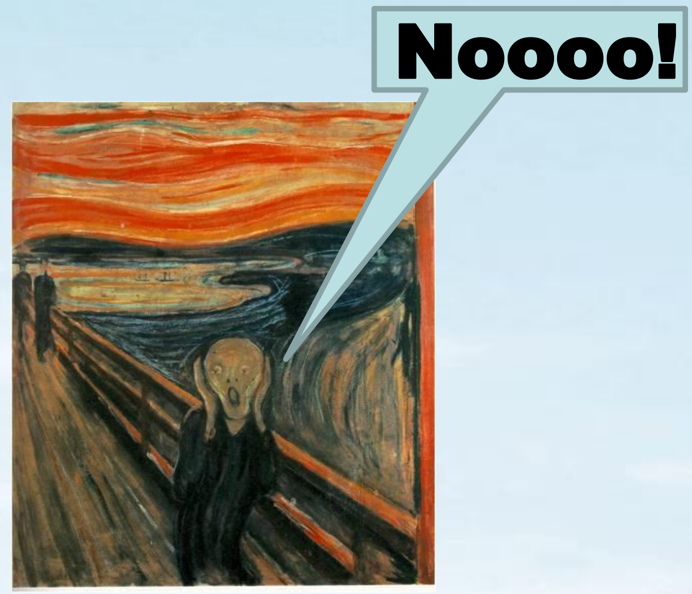
Side-by-side watersheds



Treatment Area A

Treatment Area B

Monitoring Stations



4. Determine Study Scale

- ► Watershed* is assumed in this case.
  - Smaller, more responsive (i.e., shorter lag times) watersheds (e.g., HUC 14) will be more likely to yield measurable water quality results during a 7-10 year monitoring project.
- ► Watershed scale is good for
  - Trend monitoring
  - Watershed project effectiveness
- ► Watershed scale is relatively moderate to high cost
  - Typically need to be >7 years to be successful
  - Sampling is typically bi-weekly or weekly using automatic samplers

*Watersheds or subwatersheds, preferably in the ballpark range of a few thousand to no more than 50,000 acres (e.g., HUC 12) for monitoring projects.

5. Select Variables

- Study objectives
  - Quantitative or qualitative
  - Condition or pollutants
- Type of water resource sampled (surface assumed)

- Waterbody use/problem
- Difficulty and cost of analysis
- Sample covariates for full story (e.g., stage or flow for grab samples)

- Prioritize selection of variables
- Simplify
  - Utility?
  - Surrogates?

Variables

- ► Agricultural sources
  - D.O./BOD, flow, TSS, SSC, nutrients, fecal indicator bacteria, macroinvertebrates
- ► Consider difficulty and cost of analysis
  - Temperature, pH, conductivity inexpensive
  - Benthic macroinvertebrates vs. chemistry
  - Sample holding times (TP vs. PO_4)
  - Analytic range and accuracy
    - WaterWorks nitrate test strips (0.5-50 mg/L in steps) vs. EPA Method 300.0 (0.004 mg/L D.L.; upper end of range determined by analyst)
    - Visit http://www.nemi.gov/ for information on methods

Variables

- ► Sample covariates for full story
  - Flow* for suspended sediment concentration and particulate P
  - Eutrophication
    - Algae + D.O. + temperature + nutrients + chlorophyll a
  - Fish
    - D.O., temperature, substrate, shade

*See Tech Notes #3 "Surface Water Flow Measurement for Water Quality Monitoring Projects"

http://www.bae.ncsu.edu/programs/extension/wqg/319monitoring/TechNotes/technote3_surface_flow.pdf

Which Form of P?

Variable	Details	Possible Application
Total P	All P forms converted to dissolved ortho-PO_4 and measured.	Situations where ortho-PO_4 isn't major P form.
Ortho-PO_4	Most stable PO_4. Filterable and particulate.	Most situations.
SRP	Orthophosphate; filterable (soluble, inorganic) fraction.	Most situations.
Acid-hydrolyzable P	Condensed PO_4 forms. Filterable & particulate.	Research?
Organic P	Phosphate fractions converted to orthophosphate by oxidation.	Manure-impacted areas with rapid delivery to waterbody.

TSS or SSC?

- ► SSC better for loads
  - TSS underestimates by 25-34%
  - Problem is sub-sampling not laboratory analysis
- ► TSS-SSC correlation improbable
- ► TSS good for other purposes
  - Use appropriately
  - Document clearly

Gray, J.R., et al. 2000. http://water.usgs.gov/osw/pubs/WRIR00-4191.pdf

Variables Selection Process

- Prioritize selection of variables
  - Consider all relevant factors
    - E.g., objectives, cost, logistics
    - E.g., preservation, collection, and analysis
    - E.g., sample type and location
    - E.g., monitoring station setup and costs
  - Rank, etc.
  - Written justification for each selected variable

8. Sampling Frequency Issues

Appropriate sample frequency/size varies with the objectives of the monitoring project:

- Estimation of the mean
- Detection of change
- Estimation of load

Applies to project design right from the start.

Autocorrelation

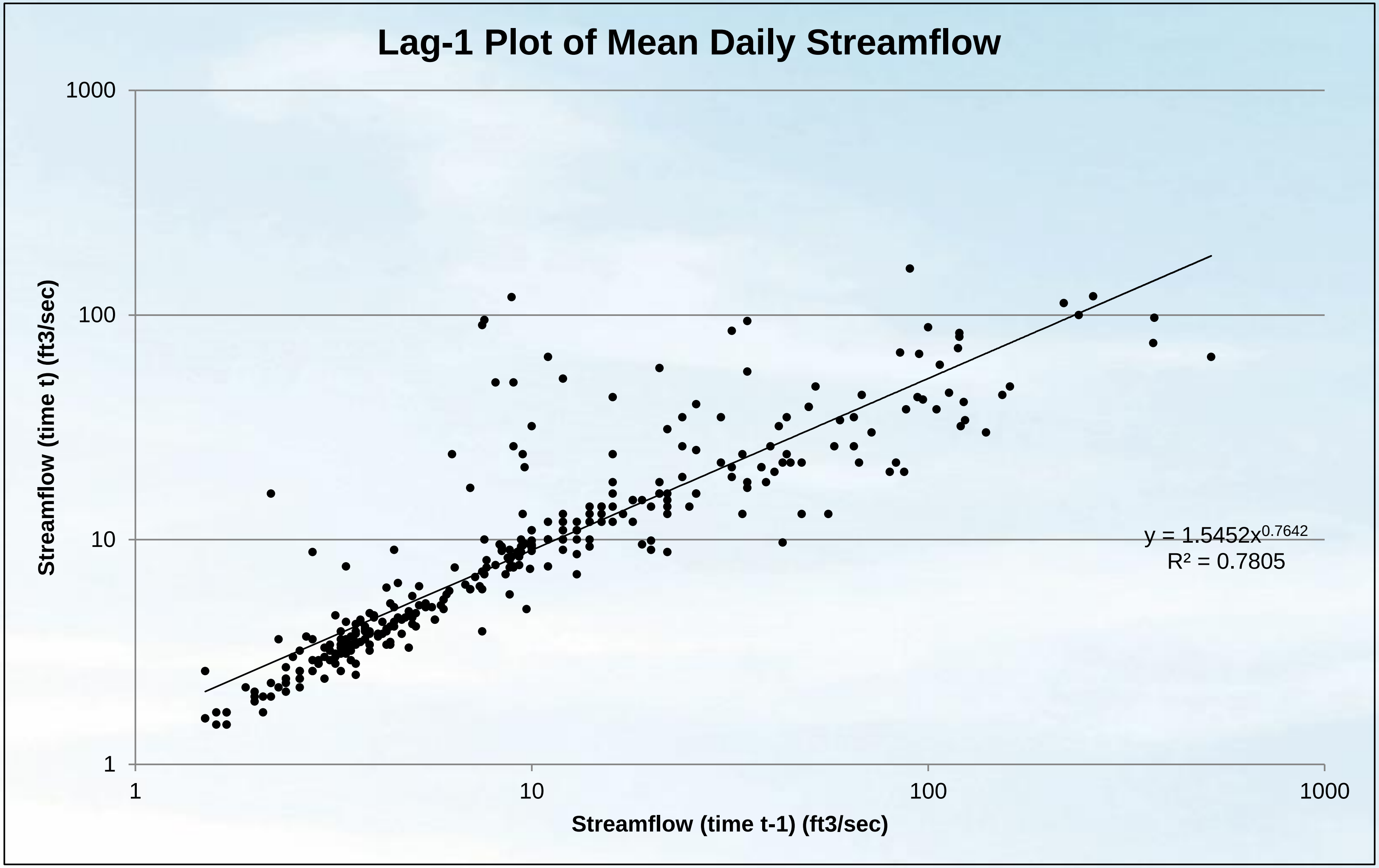
Essentially means that subsequent samples are influenced by previous samples. These subsequent samples contain less new information than would otherwise be obtained from a completely independent additional sample (i.e., there is information overlap). The result is that autocorrelation reduces the *effective* sample size compared to the situation with no autocorrelation.

Are we there yet?

Rho (ρ)

- Rho is the **coefficient of autocorrelation**, and basically describes the relationship between the current value and its past values (e.g., Tuesday's TP concentration vs. Monday's or last Tuesday's TP concentration).
- Rho increases as the strength of the relationship between current and past samples increases.
- Larger rho means that each collected sample has less new information (i.e., effective sample size is reduced).
- So, the relative improvement in estimates of a mean or a minimum detectable change decreases as sample size increases.
  - This does NOT mean that less frequent sampling is better. It simply means that there is a point where increasing sampling frequency no longer provides meaningful or cost-effective improvements in the information obtained.

Lag Plot



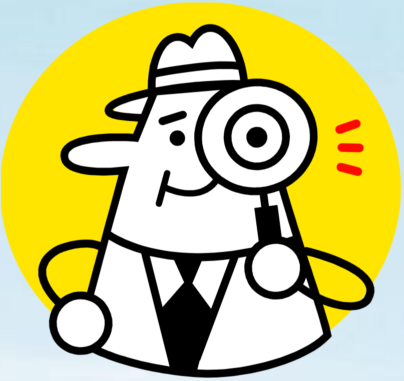
Lag-1 Plot of Mean Daily Streamflow
1000
100
10
1
1
10
100
1000
Streamflow (time t) (ft3/sec)
Streamflow (time t-1) (ft3/sec)
y = 1.5452x^0.7642
R² = 0.7805

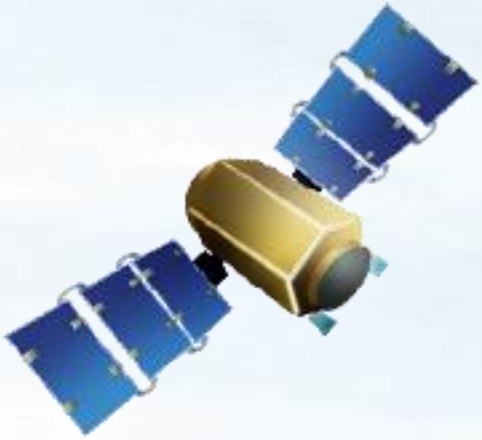
11. Define Land Use Monitoring

- Purposes
  - To measure progress of treatment
  - To assess pollutant generation
  - To help explain changes in water quality

Basic Land Use Monitoring Methods

- Direct observation
- Producer records/interviews
- Agency reporting
- Remote sensing





Scale

- **Characterizatio**n: an initial snapshot of land use/land cover, focusing on relatively static parameters (at least relative to the project period) such as water bodies, highways, impervious cover, and broad patterns of urban, agricultural, and forest land uses;
- **Annua**l: an annual survey for annually-varying features such as crop type;
- **Weekly**: weekly observations or log entries to identify specific dates/times of critical activities like manure or herbicide applications, tillage, construction, and street sweeping; and
- **Quantitative**: data collection on rates and quantities (e.g., nutrient or herbicide application rates, number of animals on pasture, logging truck traffic).

- ► Variables
  - Relevant to the WQ problem and WQ variables
  - Expected to change with BMP implementation
  - Be creative
    - – # head and time grazing/day in riparian zone <u>not</u> acres under grazing management
    - – Tons/gallons of animal waste managed properly <u>not</u> number of lagoons or pits.

- ► Look for the unexpected
  - Don’t simply track areas where BMPs are planned
  - Look for unplanned land use changes
  - Track control watersheds the same as study watersheds

BMP verification

- Design specifications of the practice.
- Degree (number and areal extent) to which the practice was ***implemented*** according to specifications.
- Degree (number and areal extent) to which the practice was ***maintained and operated*** according to specifications.
- Management activities conducted under the scope of the practice.
- Any situations where the BMP operated outside of design conditions.

Land use/land treatment monitoring

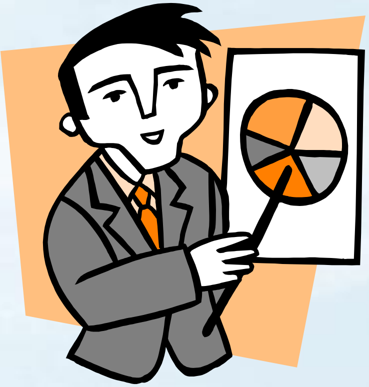
Water Quality Monitoring Variable	~Weekly Land Use/Treatment Monitoring Variables	~Annual Land Use/Treatment Monitoring Variables
Suspended Sediment (cropland erosion)	• Date of tillage operations; • Tillage equipment used; • Crop canopy development; • Cover crop density	• Acreage (and %) of land under reduced tillage; • Acreage (and %) served by terrace systems; • Acreage (and %) of land converted to permanent cover; • Linear feet (and % of linear feet) of watercourse protected with riparian buffers
Total Nitrogen (agricultural cropland)	• Manure, fertilizer application rates; • Manure and/or fertilizer forms; • Date of manure and/or fertilizer application; • Manure, fertilizer application methods	• Number (%) and acreage (%) of farms implementing comprehensive nutrient management plans; • Annual fertilizer and manure N applications per acre; • Legume acreage; • N fertilizer sales

Analytical Approaches

- Decide on temporal and spatial scales
- Match water quality and LU/LT data
  - Temporal: Annual, seasonal
  - Spatial: LU/LT data for area nearest monitoring station
- Written plan for relating land and water quality data

12. Design Data Management

- Data acquisition
- Data storage
- Examine data frequently
- Report quarterly
- Keep everyone informed
- Plan for major milestone reports



Possible NWQI Implementation Scenarios

- Occurs after or slowly during the first ~2 years of monitoring with accelerated “completion” within years 3-5 of monitoring startup
  - Step change possible (assumes rapid BMP response)

OR

- Is essentially completed during years 1-2 of monitoring.
  - Gradual change (monotonic trend) possible if BMP effects lag 1-2 years and increase over time.
  - Monitoring will probably need to go beyond 7 years to show improvements if implementation drags out over 3 to 5 years.

OR

- Occurs throughout monitoring period with no clear pre-condition or clear “completion” date.
  - Skipping water quality monitoring years may be appropriate, but need to know what is happening in watershed during those years.
  - Longer-term monitoring effort likely needed.

Monitoring NWQI Projects: A Few Options

- Single station or above/below design
- Biological monitoring (2x/year) or nutrients/sediments (12x, 26x, or 52x/year or weekly flow-weighted composites for load)
- Monitoring timeframe:
  - 2-4 years during NWQI practice implementation
  - 3 or more years after NWQI practice implementation
- Land use/land treatment tracking 2x/yr every year

Cost spreadsheet

- Estimates the cost of monitoring programs from QAPP development to the production of final reports.
- Includes information on costs of equipment, services, and sample analysis drawn from vendors, various websites, and watershed projects.
- Various monitoring designs (above/below, paired-watershed, trend).
- Chemical, biological, habitat, discharge.
- Land use/treatment tracking.
- Tt can provide cost estimates under EPA contract.

NWQI Example: Broken Sword Creek, OH

- Assess and characterize baseline water quality conditions prior to full implementation of NWQI on-farm BMPs
  - Biological conditions
  - Relative concentrations of nutrients, etc.
  - Assess physical habitat influences on stream biotic integrity
  - Determine beneficial use attainment status
  - Confirm or revise causes and sources of beneficial use impairment determined in 2001

Final Thoughts on Meeting the Challenge

Using explanatory variables

Tracking practice implementation

Dealing with the weather

Dealing with lag time

Dealing with autocorrelation

Sycamore Creek, MI

Separating NWQI from Other Influences in the Watershed

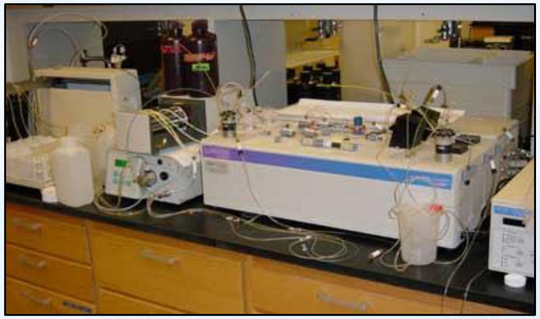
- Because there is less experimental control there is a far greater need to document explanatory variables (i.e., experimental design does not factor them out).
- Inventory NWQI vs. non-NWQI practices implemented at beginning of project. Separate and catalog to the degree possible.
  - Pollutants and source magnitude addressed
  - Location and delivery pathways
  - Anticipated timeframe for delivering desired effects (lag)
  - Plus, use same tracking variables identified above
- Greater likelihood of detecting effects of NWQI practices if there is more room for additional, effective BMPs that are implemented rapidly.

Accounting for Weather Variability

- Longer-term monitoring (e.g., 7 years or more) is necessary to collect data needed to account for this variability.
- Monitor precipitation and flow consistently over time.
- Baseline period (if possible) must be at least 2 years, but may need to be extended if unusual weather during baseline period.
- Affects sources (e.g., erosion), BMP performance, and water quality response.
- Expect it and be ready for it.

Dealing with Lag Time

- Recognize it and adjust expectations (even plan for it)
- Understand the watershed
- Consider lag time in BMP selection
- Consider lag time in siting of BMPs
- Monitor in small watersheds close to sources
- Select indicators carefully
- Be careful with models
- Design monitoring programs to detect change



Dealing with Autocorrelation

You can't really *prevent* it yet some attempt to do so by:

- Aggregating the data
  - Information is lost due to averaging.
- Taking samples less frequently
  - Information is lost due to missed events.

Best approach is to *recognize* that it exists, *adjust* for it in data analysis (i.e., adjust standard error), and *reduce* it through prudent planning (e.g., avoid exceedingly high sampling frequencies).

Sycamore Creek, MI (1990-1997)
Willow Creek Subwatershed (suspended solids)

Step 1: Change in Water Quality

- BMPs implemented gradually over time (t), so tested for monotonic trend rather than a step change (Grabow 1999).
- Explanatory variables considered: discharge (Q) and peak flow (Q_P).
- Log transformed discharge, peak flow, and total suspended solids concentration (TSS).
- TSS correlated with discharge and peak flow. Test for autocorrelation of discharge and peak flow was negative.
- Regression analysis indicated 60% reduction in SS (α=.05).

$$logTSS = \beta_0 + \beta_1 Q + \beta_2 Q_P + \beta_3 t$$

Sycamore Creek, MI (1990-1997)
Willow Creek Subwatershed (suspended sediment)

Step 2: Correlating Land Use and Water Quality Changes

- Tested % land in no-till and % land in continuous cover as factors in multiple linear regression along with Q and Q_P.
- Negative regression coefficient for % land in no-till was statistically significant.
- Project also cited an analysis of sediment sources to indicate that stream bank stabilization may also be responsible for reductions in TSS.
  - Illustrates why we collect all land treatment information rather just what is contracted under a specific program.

Working Together to Protect and Restore Our Water Resources

2013 National Nonpoint Source Monitoring Conference and Workshops

October 28-30, 2013

Wyndham Cleveland at Playhouse Square, Cleveland, Ohio

- Oral Presentations
- Field Trips
- Mini-Workshops

https://npsmonitoring.tetratech-ffx.com/index.htm

Questions?