Nonpoint Source Watershed Project Resources

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Steve Dressing, Tetra Tech, Inc.
Discussion Topics

• NEW Nonpoint Source Monitoring Guidance
• Tech Notes
• Technical Memorandums
• BMP Tracking Guides
Monitoring and Evaluating Nonpoint Source Watershed Projects

May 2016

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Order # EP-G135-00168

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2Heidelberg University, Tiffin, OH.

United States Environmental Protection Agency
Office of Water
Nonpoint Source Control Branch
Washington, DC 20460
EPA 841-R-16-010
May 2016

This document is available at: https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/monitoring-and-evaluating-nonpoint-source-watershed
Our nation's waters are monitored by state, federal, and local agencies, tribes, universities and volunteers. Water quality data are used to characterize waters, identify trends over time, identify emerging problems, determine whether pollution control programs are working, help direct pollution control efforts to where they are most needed and respond to emergencies such as floods and spills.

Nonpoint sources of water pollution are both diffuse in nature and difficult to define. Water quality monitoring for nonpoint sources of pollution includes the important element of relating the physical, chemical and biological characteristics of receiving waters to land use characteristics. Without current information, water quality and the effects of land-based activities on water quality cannot be assessed, effective management and remediation programs cannot be implemented, and program success cannot be evaluated.
Monitoring: Additional Resources

- **Monitoring and Evaluating Nonpoint Source Watershed Projects**: An update to the 1997 guidance, this guidance is written primarily for those who develop and implement monitoring plans for watershed projects management projects, or to evaluate the technical merits of monitoring proposals. EPA-841-R-16-010

- **Monitoring Guidance for Determining Effectiveness of Nonpoint Source Controls, Final**: (1997) This guidance addresses design of monitoring programs to assess water quality to determine impacts of nonpoint sources and effectiveness of best management practices (BMPs) used as controls. EPA-841-B-96-004


[https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/monitoring-additional-resources](https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/monitoring-additional-resources)
Monitoring and Evaluating Nonpoint Source Watershed Projects

This guide is written primarily for those who develop and implement monitoring plans for watershed management projects, but it can also be used by those who wish to evaluate the technical merits of monitoring proposals they might sponsor. It is an update to the 1997 Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls (EPA 841-B-96-004) and includes many references to that document.

Practice Data Set
There are exercises in the manual, here is a set of sample data to work with Sample Data (3 pp, 171 K)

Monitoring Cost Worksheets
These work sheets supplement Chapter 9 Monitoring costs

- monitoring cost estimation - master (5 pp, 1 MB)
- monitoring cost estimation - simple.xlsx (24 pp, 827 K)

Monitoring Guide
You will need Adobe Reader to view some of the files on this page. See EPA’s About PDF page to learn more.


Whole Document

Individual Chapters
Example Problems

- **Grabbow, 1999 (PDF)** (5 pp, 3 MB)
- **Suppnick 1999 (PDF)** (41 pp, 21 MB)
Monitoring and Evaluating Nonpoint Source Watershed Projects

Addresses the following gaps in the 1997 Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls (EPA 841-B-96-004)

• Details on monitoring designs
• Details on monitoring equipment
• Biological monitoring applications
• Pollutant load estimation methods
• Photopoint monitoring
• Cost analysis
• Real-world data analysis examples
Co-Author

• Don Meals, Tetra Tech
  – 30+ years of NPS monitoring experience
• Jon Harcum, Tetra Tech
  – Statistics and data analysis
• Jean Spooner, North Carolina State University
  – NCSU Water Quality Group
  – Statistics and data analysis
• Sam Stribling, Tetra Tech
  – Rapid Bioassessment Protocols
• Pete Richards, Heidelberg University
  – Pollutant load estimation techniques

Plus the wisdom, guidance, expertise, and documented findings of hundreds of NPS monitoring experts over the past 35 years.
Chapter 1. Overview of NPS Problem

• Nonpoint source problems
  – Source categories
  – Pollutants
  – Use impairments

• Brief overview of programs to address NPS
Chapter 2. Monitoring Objectives and Basic Designs

• Basic design steps
• Fundamentals of good monitoring
  – Understanding the system
  – Monitoring source activities
  – Logistics
  – QA/QC
  – Data management
  – Feedback
  – Limitations of monitoring
Chapter 2. Monitoring Objectives and Basic Designs

• Monitoring scale
• Monitoring design
  – Reconnaissance/synoptic
  – Plot
  – Paired
  – Single station
  – Above/below
  – Multiple station
  – Input/output
Chapter 3. Monitoring Plan Details

• Variable selection
  – General considerations
  – Selection factors (objectives, pollutant sources, impairments, cost, logistics, etc.)
  – Physical and chemical water quality constituents
    • Flow measurement
  – Biological data
  – Weather data
  – Watershed characteristics
Chapter 3. Monitoring Plan Details

• Sample type selection (grab, composite, integrated, continuous)
• Station location
• Sampling frequency and duration (minimum detectable change analysis)
Chapter 3. Monitoring Plan Details

• Monitoring station construction and operation
• Sample collection and analysis methods
• Land use and land treatment monitoring
• Pollutant load estimation considerations
• Data management
• Data reporting and presentation
Chapter 4. Biological Monitoring

• Types of biological monitoring
  – Benthic macroinvertebrates
  – Fish
  – Periphyton

• Linkages to habitat

• Limitations of biological monitoring

• Reference sites and conditions

• 4 case studies
Chapter 4. Biological Monitoring

- Biomonitoring program design
- Biological assessment protocols
  - Field sampling
  - Sample processing/laboratory analysis
  - Data reduction/indicator calculation
  - Index scoring and site assessment
  - Reporting assessment results at multiple spatial scales
Chapter 5. Photo-Point Monitoring

• Procedure (Frederick Hall, USDA-FS)
• Objectives
• Methods
• Areas to monitor
• Photo points and camera points
• Identifying sites and recording data
• Data analysis plans
Chapter 5. Photo-Point Monitoring

- Equipment needs
- Applications of photo-point monitoring
- Advantages, limitations, and opportunities
Chapter 6. Monitoring Challenges and Opportunities

- Monitoring pitfalls
  - Design flaws
  - Procedural problems
- Lag time issues
- Integrating monitoring and modeling
- Supporting BMP and other databases

![Diagram showing project management components, system components, and effects measurement components with equations for lag time.]

implified text: Chapter 6. Monitoring Challenges and Opportunities

- Monitoring pitfalls
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- Integrating monitoring and modeling
- Supporting BMP and other databases

![Diagram showing project management components, system components, and effects measurement components with equations for lag time.]

21
Chapter 7. Data Analysis

• Overview of statistical methods
  – Exploratory data analysis and data transformations
  – Dealing with censored data
  – Data analysis for water quality problem assessment
  – Project planning data analysis
  – BMP and project effectiveness data analysis
## Chapter 7. Data Analysis

<table>
<thead>
<tr>
<th>Analytical Objective</th>
<th>Monitoring Design Used</th>
<th>Recommended Method</th>
<th>Method Type*</th>
<th>Data Requirements</th>
<th>Major Cautions and Concerns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watershed project effectiveness</td>
<td>Above/below-before/after</td>
<td>t-Test of input vs. output EMCs or loads, ANCOVA, Wilcoxon Rank Sum, Mann-Whitney</td>
<td>P, N</td>
<td>Data must meet assumptions for parametric statistics to apply; otherwise use nonparametric test</td>
<td>Change in pollutant concentration or load measured at the below station may be difficult to detect if concentrations or loads at the above station are high.</td>
</tr>
</tbody>
</table>
Chapter 7. Exploratory Data Analysis and Data Transformations

- Steps in data exploration
- Key variable characteristics (e.g., variability)
- Transformations for non-normal data
- Examination for:
  - Extreme, outlier, missing, or anomalous values
  - Frequencies
  - Seasonality or other cycles
  - Autocorrelation
  - Relationships between two or more time periods or locations
  - Relationships between two variables
Chapter 7. Dealing with Censored Data

• Types of censoring
  – Left censored (e.g., less than detection limit)
  – Right censored (e.g., too numerous to count)

• Methods for handling censored data
  – Maximum likelihood estimation (MLE)
  – Regression on order statistics (ROS)
Chapter 7. Data Analysis for Water Quality Problem Assessment

• Summarize existing conditions
• Assess compliance with water quality standards

- Identify major pollutant sources
- Define critical areas
Chapter 7. Data Analysis for Project Planning

- Estimation and formulating hypotheses for testing
- Estimating pollutant reductions needed (e.g., mass balance, load duration curve)
- Estimating land treatment needs
- Estimating minimum detectable change
- Locating monitoring stations
Chapter 7. Data Analysis for BMP Effectiveness

- Analysis of plot study data
- Analysis of BMP input/output data
- Analysis of BMP above/below data
- Analysis of BMP paired-watershed data
Chapter 7. Data Analysis for Project Effectiveness

- Paired-watershed data analysis
- Above/below-before/after data analysis
- Nested watershed data analysis
- Single watershed trend station data analysis
- Multiple watershed data analysis
- Linking water quality trends to land treatment
Chapter 7. Load Estimation

- Pete Richards, Heidelberg University
- General considerations
- Approaches to load estimation
  - Numeric integration
  - Regression
  - Ratio estimators
- Load duration curves
Example Datasets

Monitoring and Evaluating Nonpoint Source Watershed Projects

This guide is written primarily for those who develop and implement monitoring plans for watershed management projects, but it can also be used by those who wish to evaluate the technical merits of monitoring proposals they might sponsor. It is an update to the 1997 Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls (EPA 841-B-96-004) and includes many references to that document.

Practice Data Set
There are exercises in the manual, here is a set of sample data to work with Sample Data (3 pp. 171 K)

Three datasets in a simple spreadsheet file

Used in ten problems to test your understanding of concepts and analytical approaches

- Chapter 3 Problem 1: Sample Size for the Estimation of Mean of Sampled Population (PDF) (1 pg. 196 K)
- Chapter 3 Problem 2: Sample size for trend estimation (PDF) (1 pg. 195 K)
- Chapter 7 Problem 1: Test for normal distribution and
Example Datasets

<table>
<thead>
<tr>
<th>Problem Number</th>
<th>Objective</th>
<th>Test</th>
<th>Dataset</th>
<th>Problem and Answer File</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Test for conformance to normal distribution</td>
<td>Graphical, skewness, kurtosis, Shapiro-Wilk, Kolmogorov</td>
<td>1</td>
<td>normality.pdf</td>
</tr>
<tr>
<td>3</td>
<td>Compare two groups</td>
<td>t-Test</td>
<td>1</td>
<td>2groups.pdf</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wilcoxon/Kruskal-Wallace</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Compare input/output for a BMP</td>
<td>Paired t-Test</td>
<td>2</td>
<td>pairedtests.pdf</td>
</tr>
<tr>
<td>7</td>
<td>Assess change due to treatment in paired-watershed design</td>
<td>ANCOVA</td>
<td>1</td>
<td>pairedancova.pdf</td>
</tr>
</tbody>
</table>
Chapter 8. Quality Assurance and Quality Control

• Background and EPA policies
• Data quality objectives
• Elements of a Quality Assurance Project Plan
• Field operations
• Laboratory operations
• Data and reports
• Geospatial data
Chapter 9. Monitoring Costs

- Overview of cost items
- Cost estimation examples
- Using MDC to guide monitoring decisions
  - MDC and cost vs. number of sites, frequency, duration, variables
Monitoring Cost Spreadsheets

• Two cost estimation sheets (master & simple)
• Simple Version
  – 3 Designs: Above/Below, Paired-Watershed, Trend
  – 4 Sample Types: Biological/Habitat, Grab Samples, Sondes, Loads
  – 2 Variable Sets: Nutrients & Turbidity or Nutrients, Turbidity & Metals
  – Enter 18 bits of info and get total and annual costs
  – Users can change many default values
Monitoring Cost Spreadsheets

<table>
<thead>
<tr>
<th>Cost Category</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor</td>
<td>$66,947</td>
</tr>
<tr>
<td>Equipment and Supplies</td>
<td>$13,891</td>
</tr>
<tr>
<td>Sampling Analysis</td>
<td>$6,864</td>
</tr>
<tr>
<td>Vehicles</td>
<td>$557</td>
</tr>
<tr>
<td>Per Diem</td>
<td>$0</td>
</tr>
<tr>
<td><strong>TOTAL COST</strong></td>
<td><strong>$88,259</strong></td>
</tr>
<tr>
<td>Average Annual Cost</td>
<td>$17,652</td>
</tr>
<tr>
<td>Total Cost with Inflation</td>
<td>$88,894</td>
</tr>
<tr>
<td>Average Annual Cost with Inflation</td>
<td>$17,779</td>
</tr>
</tbody>
</table>

**TOTAL COST:** $88,259

Above/Below, 5 years, 26x/yr, Sondes, Nutrients & Turbidity
Tech Notes
2005-2014

Monitoring Data
Exploring Your Data, The First Step

Now that your monitoring program is up and running, it is time to evaluate the data. If you designed your monitoring program carefully (Tech Note #2), you will have the right kinds of data collected at appropriate times and locations to achieve your objectives. At the start, you should check your data for conformity with original plans and quality assurance/quality control (QA/QC) procedures. Use the Quality Assurance Project Plan (QAPP) as a guide.

Explanatory Variables: Improving the Ability to Detect Changes in Water Quality in Nonpoint Source Watershed Studies

Introduction
An important objective of many nonpoint source (NPS) watershed projects is to document water quality changes and associate them with changes in land management. Accounting for major sources of variability in water quality and land treatment/land use data increases the likelihood of isolating water quality trends resulting from best management practices.
Through the National Nonpoint Source Monitoring Program (NNPSMP), states monitor and evaluate a subset of watershed projects funded by the Clean Water Act Section 319 Nonpoint Source Control.
1. Monitoring Data - Exploring Your Data, The First Step

• Steps in exploratory data analysis (EDA)
• Quantitative techniques
• Graphical approaches
• Single variables
• Multiple variables
2. Designing Water Quality Monitoring Programs for Watershed Projects

• Goals
• Review of existing data and monitoring efforts
• Statistical designs (e.g., above/below)
• Scale, variables, sample type, number of samples, etc.
• Land treatment
• QA/QC

- Basic principles of discharge measurement
- Stage measurements
- Stage-discharge curves
- Flow measurement methods
- Applications of flow data
4. Lag Time in Water Quality Response to Land Treatment

- Components of lag time
- Dealing with lag time
5. Using Biological and Habitat Monitoring Data to Plan Watershed Projects

• Overview of biological and habitat monitoring

• Opportunities to use biological and habitat data in watershed project planning
  – Examples

- Presents and demonstrates the basic analysis of long-term water quality data for trends
- Data exploration, data reduction, flow adjustment
- Tests with and without covariates
- Seasonality
7. Minimum Detectable Change Analysis

• Factors affecting magnitude of MDC
• Steps to calculate MDC
• Examples

\[
\text{MDC} = \left( N \right) \times t_{(n^*N-2)\text{df}} \times 365 \times s_b \]

\[
\text{MDC} = t_{(n_{\text{pre}} + n_{\text{post}} - 2)} \sqrt{\frac{\text{MSE}_{\text{pre}}}{n_{\text{pre}}} + \frac{\text{MSE}_{\text{post}}}{n_{\text{post}}}}
\]
8. Pollutant Load Estimation for Water Quality Monitoring Projects

• General considerations
• Issues of variability
• Planning monitoring for load estimation
• Approaches to load estimation
  – Numeric integration
  – Regression
  – Ratio estimators
• Load duration curves
9. Monitoring for Microbial Pathogens and Indicators

- Bacteria
- Fecal indicator bacteria
- Protozoa
- Viruses
- Sources, fate, and transport
- Monitoring issues
- Microbial source tracking
- Case studies
10. Baseline Assessment of Left-Censored Environmental Data Using R

• Basic information on R
  – Installation of R and Rstudio
  – Starting up and using R
  – Importing data

• Censored data
  – Methods for estimating summary statistics (e.g., robust ROS)

• Detailed example-Little Calumet East Branch

• Data set and R script provided
11. Land Use and BMP Tracking for NPS Watershed Projects

- Variable selection
- Geographic coverage
- Frequency, duration, timing
- Data collection methods
- Data management, QA/QC
- Challenges (e.g., confidentiality)
- Relating land use/land treatment data to water quality data
12. Explanatory Variables: Improving the Ability to Detect Changes in Water Quality in Nonpoint Source Watershed Studies

• Discussion of explanatory variables, importance, and their use
• How to determine most important explanatory variables to measure and use in trend analysis
• Incorporating explanatory variables in trend analyses
• Examples
Technical Memorandum #4
Applying Benthic Macroinvertebrate Multimetric Indexes to Stream Condition Assessments

Introduction
The primary objective of the Federal Water Pollution Control Amendments of 1972—commonly known as the Clean Water Act (CWA)—“is to restore and maintain the chemical, physical, and biolog-
We all live in a watershed — the area that drains to a common waterway, such as a stream, lake, estuary, wetland, aquifer or even the ocean — and our individual actions can directly affect it. Working together using a watershed approach will help protect our nation’s water resources.
Watershed Approach: Technical Resources

- Watershed Central Wiki - The Watershed Central Wiki is where you can share tools, case studies, datasets and any other watershed related resource you have found invaluable. You can also add information for your watershed group and projects and read what others are doing around the country.

- Mid-Atlantic Nonpoint Source Watershed Implementation Tracking - This map displays state Nonpoint Source Management plans, the annual reports of the state nonpoint source work as well as the watershed implementation plans and NPS progress reports for the mid-Atlantic states.

- Technical Memorandum - These Technical Memoranda are a series of publications designed to assist watershed projects, particularly those addressing nonpoint sources of pollution. Many of the lessons learned from the Clean Water Act Section 319 National Nonpoint Source Monitoring Program are incorporated in these publications.

You will need Adobe Reader to view some of the files on this page. See EPA’s About PDF page to learn more.

- Technical Memorandum #1 Adjusting for Depreciation of Land Treatment When Planning Watershed Projects (PDF) (16 pp, 1 MB, October 2015)

https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/watershed-approach-technical-resources
1. Adjusting for Depreciation of Land Treatment When Planning Watershed Projects

• Causes of depreciation
• Assessment of depreciation
  – BMP verification
  – Depreciation indicators
• Adjusting for depreciation
  – Assessing baseline conditions
  – Adaptive management
  – Etc.
• Recommendations
2. Relative Applicability of Particle Distribution Measures and Bank Slope Stability in Evaluating NPS Watershed Projects

- Measurements of bedded sediments and bank stability (e.g., surface particle size distribution)
- Application of bank and sediment measures (e.g., setting treatment priorities)
3. Minimum Detectable Change and Power Analysis

• Builds from Tech Notes #7 on MDC

• Tech Notes #7
  – Power = (1-β) = 0.5
  – β = Type II error rate (Accept $H_0$ when $H_0$ is False)

• This memorandum provides for MDC calculations at other power levels (e.g., 0.8)
  – Step-trend analysis
  – No explanatory variables
4. Applying Benthic Macroinvertebrate Multimetric Indexes to Stream Condition Assessments

• Application of index of biological integrity to assessment of and reporting on aquatic ecological condition of a water body
  – Field sampling
  – Laboratory processing
  – IBI calculation
  – Site assessment
5. Data Reporting and Presentation

• Under Development – December 2016
• Water quality and land treatment data
• Accurate and complete reporting
• Statistical confidence and power
Monitoring: Additional Resources

Monitoring and Evaluating Nonpoint Source Watershed Projects: An update to the 1997 guidance, this

Techniques for Tracking, Evaluating, and Reporting the Implementation of Nonpoint Source Control Measures - Agriculture: (1997) Focusing specifically on monitoring agricultural BMPs, this manual covers site selection, sample size estimation, sampling and results evaluation and presentation. EPA 841-B-97-010

Techniques for Tracking, Evaluating, and Reporting The Implementation of Nonpoint Source Control Measures for Forestry: (1997) This guidance is intended to assist state, regional, and local environmental professionals in tracking the implementation of BMPs used to control nonpoint source...
BMP Tracking

• Techniques for Tracking, Evaluating, and Reporting the Implementation of Nonpoint Source Control Measures – Agriculture (1997)
• Techniques for Tracking, Evaluating, and Reporting the Implementation of Nonpoint Source Control Measures for Forestry (1997)
• Techniques for Tracking, Evaluating and Reporting the Implementation of Nonpoint Source Control Measures Urban (2001)
BMP Tracking

- Sampling design
- Methods for evaluating data
- Conducting the evaluation
- Presentation of evaluation results
- Methods being applied to Chesapeake Bay BMP verification efforts
Wrap-Up

• Much of what has been learned in NPS over the past 30+ years is documented and available at EPA’s website

• Constant need for training
  – NPS staff turnover: Use website materials for NPS 101 training ... and advanced classes
  – Review these materials BEFORE diving into a watershed project or monitoring effort

• More is out there:
  – USGS

• Re-learning old lessons is a waste of resources – READ!
Discussion