United States
Environmental Protection
Agency

Technical Memorandum #5

Presenting Results

This Technical Memorandum is one of 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.

December 2016

Steven A. Dressing, Donald W. Meals, James B. Stribling, and Jon B. Harcum. 2016. Technical Memorandum #5: Presenting Results, December 2016. Developed for U.S. Environmental Protection Agency by Tetra Tech, Inc., Fairfax, VA, 26 pp
Available online at *https://www.epa.gov/nps/watershed-approach-technical-resources*.

Introduction

Projects report data and present results at multiple levels in many forms to address a wide range of audiences and purposes. Communication with stakeholders is often best done through progress reports on a frequent, informal basis, whereas communication with outside audiences is more commonly accomplished via presentations at professional meetings or publication of comprehensive project findings. Funding agencies generally include reporting requirements in their grants or contracts. Within the overall scope of a watershed project, it is essential to budget both time and resources to support effective reporting, especially reporting of final project results.

Reports are essential means to document and communicate project results to participants, sponsors, and others who have an interest or need to learn from your experience. Project goals and objectives must be stated clearly and provide the focal point for presentation. Reporting must be accurate, objective, and complete to ensure that the audience fully understands the project and interprets the results appropriately. This technical memorandum is designed to provide guidance on effective reporting of final results for those involved in or directing current and future watershed projects, and should also be helpful for future revisions to Nonpoint Source Management Programs.

Overview of Reporting Options

While the emphasis of this technical memorandum is on final watershed project reports, it begins with a discussion of the organization and content typically expected of professional papers and peer-reviewed journal articles to provide some context for the scope of information, data, and discussion that should be included in full project reports. Then, we present an outline of the organization and content that has been recommended for annual and final reports from watershed projects in the past. This overview provides initial guidance in thinking about what to include in a final project report and how to organize the material.

Elements of a Professional Paper or Project Report

Watershed project reports are used to communicate information about project purpose, watershed conditions, design, implementation, and results. It is generally advisable to use a conventional report framework that is similar to that used effectively in other successful projects. Novel or innovative approaches are possible, but should be considered only when common frameworks will not be adequate for your report. Reports should be clearly structured and written to present complete information in a logical and efficient manner to the intended audience. Because most readers will use the report as their primary source of information about the project, the quality of the project is often judged by the content and quality of the written report. When a report will exist electronically or on a web site, consider using hyperlinks in the text to connect to useful supplementary documents in support of your narrative.

Report contents vary somewhat depending on the specific type of report. State and federal agencies have their own guidelines and reporting requirements. Professional publications and journals specify reporting requirements at their websites. Here we provide an overview of the typical contents of journal articles, annual project reports, and final project reports.

Professional Journal Article

Professional papers are generally directed to an audience with knowledge of the subject area. Well-established standards for paper length, writing style, a commonly used set of technical terms, detailed rules regarding tables and graphics, and short-hand reference to accepted methods and procedures frame the approach to writing these documents.

The elements of a journal article typically include:

- Abstract
- Introduction
- Project design
- Results
- Discussion
- Conclusions
- References

A summary of report contents is provided in the abstract, focusing on key results and conclusions. The introduction typically includes a problem statement, brief literature review (especially for a journal publication), and a statement of goals and objectives. Project design is covered in a section often referred to as "Materials and Methods" in journals and includes such information as a description of the project site, the study design, experimental procedures, analytical procedures, and data analysis methods. Project results include a presentation of all relevant data in narrative, tabular, and graphical form(s). The discussion provides interpretation of data and observations. Conclusions related to the project goals and objectives are presented next, followed by a list of references.

Annual or Quarterly Project Report

Annual or quarterly project reports are recommended (and often required) for a number of purposes, including to:

- Force timely analysis of data as a check on methods and procedures before it is too late to fix problems
- Show how project resources are being used appropriately to achieve project goals
  - Show that the project is on schedule or communicate the need to adjust the schedule if progress is delayed

  - Justify the need for additional resources if warranted
- Foster feedback to ensure that problems are being identified and addressed accurately
  - Highlight major successes or failures experienced during the year
  - Obtain input from stakeholders to increase the chances of project success
  - Demonstrate need for and seek approval for adjustments
- Sustain or generate additional interest and cooperation among stakeholders
- Build a detailed record of project activities that might get overlooked when the time comes to develop the comprehensive final report

Communicating with groups of individuals with varied levels of understanding and different learning styles requires a diverse approach that includes written materials, audio-visual presentations, and face-to-face communication. Simple annual or quarterly reports in a consistent format with easily interpreted graphs, summary tables, and maps will enhance the communication. Quarterly reports might follow a standardized repeatable format to make their preparation easier on project staff. Jargon is usually kept to a minimum in annual and quarterly project reports because they are written for both the expert and public communities and typically touch upon a broad range of project issues, including financial, technical, administrative, and social aspects of the project. Reports should highlight observed patterns and both raw data and metadata should be attached for those in the audience with more advanced understanding of project data.

Annual reports for watershed projects generally include the following elements:

- Project description
- Summary of work accomplished during the reporting period
- Summary of findings, including comparison with previous years' findings
- Summary of contacts with stakeholders
- Summary of problems that occurred and how they were addressed
- Changes in work plan or key project personnel
- Projected work for the next reporting period

Note that for long-term watershed projects, it may be advisable to produce a more comprehensive or analytical interim report at a particular project milestone such as the completion of land treatment implementation or the end of the calibration period in a paired-watershed project.

Final Project Report

Final project reports are generally expected to be comprehensive in their treatment of project activities and findings, covering water quality, land treatment, cost, and other important aspects of the project. The audience is broad as for annual project reports, but the various sections of the report are directed to subject area experts. For example, the discussion of data analysis and water quality results will be at a level similar to what is found in water resources journals. A socioeconomic assessment will be reported in a manner suitable for experts in that field.

An executive summary captures the essence of the report in a manner suitable for the general public. According to USC Libraries (2016), *an executive summary is a thorough overview of a research* *report or other type of document that synthesizes key points for its readers, saving them time and preparing them to understand the study's overall content. It is a separate, stand-alone document of sufficient detail and clarity to ensure that the reader can completely understand the contents of the main research study.*

Typical contents for a final report may include the following (inspired by Boslaugh 2007 and USEPA 2009):

- Executive summary
- Introduction
  - Background information
  - Project purpose and scope
  - Project goals and objectives
- Project design
  - Monitoring program background and objectives
    - Clear statement of purpose of data collection
    - Relationship between project and monitoring objectives
  - Monitoring design, station descriptions, and analytical parameters
  - Sample collection methods, including precipitation and flow measurement
  - Analytical methods, and method reporting limits (and discussion of whether/how they were adequate to meet project objectives)
  - Land use and land treatment data description and data collection methods
  - Data processing and/or recording procedures
  - Quality assurance/quality control (QA/QC) procedures
  - Statistical methods
- Results
  - QA/QC findings
  - Flow, precipitation, and water quality results and data validation information
  - Land use and land treatment data results and data validation information
  - Qualitative and statistical data evaluations/hypothesis testing as required
  - Photo-documentation of major project activities
- Discussion and conclusions, including any caveats or qualifying statements that will help the reader understand and use the reported information in the appropriate context
- Lessons learned and recommendations, e.g., changes in monitoring program, implementation of BMPs
- Glossary
- Appendices, e.g., raw data, engineering drawings

Project reports may also include or refer to supplemental materials such as a quality assurance project plan (QAPP) required when U.S. Environmental Protection Agency (EPA) funds are involved.

The remainder of this technical memorandum is focused on reporting results as part of final project reports for watershed projects.

Principles of Reporting Results

Project results are typically of greatest interest to the reader and of greatest consequence for those involved in the project. Project participants and sponsors will usually expect a project to achieve its objectives, with failures potentially resulting in discontinued support for or required modifications to similar projects in the future. This is not to say that all projects must prove that land treatment was successful in restoring water quality; even negative results (e.g., no water quality improvements were documented) provide important information that must be communicated and added to the body of knowledge. Clear, complete, and accurate reporting of project results, therefore, is paramount to ensure that success or failure is assessed correctly.

According to USC Libraries (2016), *the results section is where you report the findings of your study based upon the methodology you applied to gather information. The results section should simply state the findings of the research arranged in a logical sequence without bias or interpretation*.

The following points are suggested to facilitate the reporting of project results in an objective, clear, and accurate manner. While many of the suggestions will apply to both journal articles and annual reports, the emphasis here is on final watershed project reports.

Principles of Reporting Results

- Know your audience
- Simplify
- Present in a logical progression
- Emphasize key data
- Summarize and describe data clearly
- Illustrate key data relationships
- Logically represent data and analyses
- Use clearly explained graphs and tables efficiently

Know Your Audience

As discussed above under *Elements of a Professional Paper or Project Report*, the audience can range from subject matter experts to people with no familiarity with the type of information you will present in your report. While the executive summary is intended for the entire range of your audience, it may still be important to consider the non-expert element of your audience when presenting results in the body of your report.

Simplify

While details are necessary to convey the validity of the information presented, it is important to keep the discussion as streamlined and direct as possible. If a standard statistical procedure is used, simply name the procedure and describe how assumptions and requirements to apply the procedure were met. Additional details on the procedure can be included in the project design section of the report. Technical audiences should not require a detailed discussion of the procedure, but non-technical readers may need a simple explanation of what the procedure is designed to test. For example, a report might explain briefly that a t-Test compares the means of two groups of data (e.g., weekly phosphorus concentrations at two monitoring stations) to determine if an apparent difference between the two stations is meaningful or likely due to chance.

Present Results in a Logical Progression

The presentation of project results needs to be framed in a manner that makes sense to the reader. For example, while a "story" about the project might be presented best in chronological order, project results may be presented best by project objective, sub-watershed, variable type (e.g., chemical or biological), or other scheme. For example, if there are multiple levels of monitoring designed to address both watershed-wide conditions and the performance of specific best management practices (BMPs), it may be logical to present the BMP-specific results first, thereby setting the stage for relating BMP performance to subsequent observations about watershed-wide results. Take the time to consider how the flow of information should be presented to enhance the reader's understanding of project results you present.

Emphasize Key Data

Data of greatest importance to the project and to the reader are generally those data that are directly tied to the project and monitoring objectives. For example, if a project was designed to reduce phosphorus loads from cropland to address a eutrophication problem, results should focus on phosphorus data, land treatment data for cropland, and eutrophication indicators (e.g., chlorophyll a). Meals et al. (2014) contains illustrative examples of appropriate land treatment data to track based on water quality problems addressed. This does not mean that other data should not be presented, but the report should emphasize these and associated parameters (e.g., sediment loss if a large portion of phosphorus is transported via sediment). Raw and non-essential data should be presented in appendices.

Summarize and Describe the Data Clearly

Present a clear summary and description of the key data and their characteristics. Such a presentation could include one or more tables of basic univariate statistics such as range, mean, median, standard deviation, and number of observations for each monitored characteristic. A summary can provide context for the project (e.g., was the weather during the project normal? does the watershed show unusually high or low sediment or nutrient concentrations?) and serves as a simple basis for comparison of results from year to year.

Illustrate Key Data Relationships

As noted above for phosphorus and sediment, important relationships between variables of interest should be documented. Associations among BMPs, pollutants, and transport mechanisms should also be illustrated if possible. For example, it has been shown that soluble phosphorus losses can increase when reduced tillage is implemented on cropland (Baker 2010, Joosse and Baker 2011). Projects implementing reduced tillage as a primary BMP to address nutrient problems should test for relationships between soluble P loss and reduced tillage acreage.

The principal goal of biological monitoring and assessment is to produce reliable indicators of degradation, but the biological data often do not provide direct information on the cause of the impairment. More detailed analysis of stressor conditions and biological responses can help identify the most likely cause(s) impacting the biota. Those analyses are part of a process called stressor identification (SI) (*https://www3.epa.gov/caddis/si_home.html*). Application of the SI process can be helpful to better understand what is causing the benthic impacts (stressors) and the sources of the stressors.

Ensure Narrative Logically Represents Data and Analyses

Narrative description of results should not stray beyond what is factual. As noted above, there should be no bias or interpretation of data in the results section. Interpretation belongs in the discussion section of the report.

Use Clearly Explained Graphics and Tables Efficiently

Figures and tables should be used to present results more effectively where possible (USC Libraries 2016). Specific recommendations for figures and tables are presented below, under *Figures and Tables*.

Presentation of Results

In addition to the principles described above, there are specific considerations regarding the actual mechanics of presenting project results. Key elements of the results section typically include:

- Flow, precipitation, and water quality results and data validation information
- Land use and land treatment data results and data validation information
- Qualitative and statistical data evaluations/hypothesis testing as required

Accurate data analysis requires a clean, or validated, data set that has passed through rigorous QA/QC procedures, beginning with sample collection. Specific QA/QC procedures should be described in the project design or methods section of the report and fully documented in the QAPP, with additional information provided in an appendix as appropriate. A short narrative on data quality is all that is generally required in the results section. This narrative should confirm that QA/QC procedures were followed and state whether data were found to meet project needs (e.g., data quality objectives). The fate of any data that fell short of project needs should also be stated. This short narrative on data quality can either be presented up front for all data presented in the results section or parsed out in accordance with how results are presented (e.g., biological data then chemical data). In this section, it may be useful to summarize field operations and data collection issues that may have occurred to influence data quality. This information will help later interpretation of results. For example, if ice buildup or freezing problems frequently interfered with winter data collection, subsequent discussion should address if and how results are fully representative of seasonal variations.

Organization

Data summaries should be presented in a logical progression that builds toward a clear understanding of the degree to which project goals were achieved. While suggestions are provided here, the best approach to use is project specific.

Presentation by Objective

Watershed projects often have multiple objectives or objectives and sub-objectives, such as determining the effectiveness of specific BMP(s), reducing pollutant loads from a watershed, and reversing impairment of a receiving waterbody. The order of reporting results by objective could be chosen to move up from BMP performance to receiving water if BMP efficiency was the main thrust of the project or to move down from the waterbody impairment if the primary focus of the project was restoration of a beneficial use.

Logical Progressions of Results

- Presentation by objective
- Presentation by variable type
- Presentation by monitored area, design, or scale
- Combination

Presentation by Variable Type

Another approach is to present results variable by variable. Present data on only key variables when using this method to avoid losing the reader in excessive detail. This approach can often be tedious unless the variables are ordered in a manner consistent with project objectives or in some other order that creates interest for the reader. For example, constituents for which key relationships are examined (e.g., sediment and total P) could be presented back to back, followed by the results from examining their relationship. Overall, however, this ordering of results is not recommended for project reports, although it is not unusual for technical journal articles.

Presentation by Monitored Area, Design, or Scale

Many projects have more than one monitoring activity designed to meet diverse project goals. For example, multiple subwatersheds of different characteristics or treatments may be monitored, or plot studies may be combined with sub-watershed, watershed, and waterbody studies. In addition, different monitoring designs may be employed in the same project, including synoptic surveys, single-station, above-below, and paired-watershed designs. Results can be reported by monitoring area or scale, often consistent with a progression of monitoring objectives (as described above). For example, results from plot or field studies of individual BMPs might be presented first, followed by reporting of nutrient concentrations and loads from each monitored subwatershed over time, then finally water quality results (e.g., water quality standard compliance, nuisance algae growth) from in-lake monitoring of the receiving waterbody. Alternatively, results may be presented by monitoring design, with results of synoptic surveys, subwatershed trend monitoring, above-below, and paired-watershed efforts reported separately.

Combinations

The most thoughtful and effective approach to presenting results is often a combination of objective-, monitoring area-, and variable-based ordering. A logical progression could be to begin with objectives, organized within each objective by monitoring area or design, with the variables most relevant to that combination of objective and monitoring design presented by logical groupings.

Analyses to Present

After the basic framework for presentation of results has been selected, decisions need to be made about the specific analyses and summaries to present for each sub-part of the results section. Within the overall project scope, the basic analytical approach should have been selected early, driven by project objectives and monitoring design. Readers should consult other resources on the selection of appropriate analytical procedures, e.g., *Helsel and Hirsch (2002)* and *Dressing et al. (2016).*

Summaries and analyses presented should all tie in directly to the objectives and sub-objectives for the project. Statistical methods used should be appropriate for both the data and the questions or objectives to be addressed. The report should include statements addressing the degree to which assumptions for any statistical test (e.g., normal distribution) were met, as well as the confidence levels applied. In addition, statistical analyses should be performed in a consistent fashion throughout the project with any deviations documented in the report, preferably in the project design section. The name and version of any software used for analyses should also be documented in the project design section; any original code (e.g., for *R*) should be saved and archived with a copy of the report.

The general approach for presenting analyses is to begin with descriptive statistics and follow with more advanced analyses such as regression, analysis of variance, etc. The presentation should focus on the results, not the analytical approach (which should be described earlier in the project design section of the report). Opportunities for analyzing data are nearly limitless and it is very important to ensure than any statistics and graphics provided in the report are derived from appropriate procedures and are representative of the data. It is also critically important that statistics and graphs serve a clear purpose and are not done simply because they can be. It may be easy, for example, to produce scatterplots illustrating the relationship (or lack of relationship) between all possible variable combinations, but not all such comparisons are useful or informative, especially when no correlation is apparent. See EPA's nonpoint source monitoring guidance for recommendations on appropriate statistical methods (*Dressing et al. (2016)*).

Figures and Tables

Judicious use of figures and tables will improve both the efficiency and impact of the results presentation. A good rule of thumb is that if results can be presented clearly in one or two sentences, a table or figure is not required; otherwise, figures or tables should be used to present more extensive or complex data (UNC 2014). In addition to the efficiency offered by tables and figures, they should serve as quick references for your reader and can reveal trends, patterns, or relationships that might otherwise be difficult to grasp. In general, figures and tables should include captions (title and description) that can stand alone to explain what is presented (including the timeframe represented by the data), be numbered in the order they appear in the text (figures and tables are usually numbered separately), and be located as close as possible to their first mention in the text.

Following are additional guidelines for the use and design of figures and tables.

Figures

Figures, including graphs, charts, drawings, photos, and maps, are typically used to display trends and patterns of relationship (UNC 2014). Maps, for example, can be used to display spatial data that are often collected to assess patterns for watershed projects. Photo-point monitoring is often used to document BMP implementation; see *Dressing et al. (2016)* for details on photo-point monitoring for nonpoint source watershed projects.

Graphs, however, are the subset of figures that are most commonly used by watershed projects to display quantitative data patterns over time or relationships between variables. Graphs are a good means of summarizing numerical data because the visual image can simplify complex information and help to highlight patterns and trends in the data (U of L 2016). A summary of common types of graphs and their applications is provided in Table 1.

Table 1. Common Graphs and Their Uses (adapted from UNC 2014)

Type of Graph	Primary Use
Bar chart	Show the frequency or magnitude of values for dependent variables, where the independent variables are discrete (often nominal) categories.
Pie chart	Show relative proportions of values for categorical data.
Frequency histogram	Show the relationship between independent and dependent variables, where the independent variable is continuous, rather than discrete.
Scatter plot	Illustrate the relationship between two continuous variables. In this case, data are displayed as points in an x,y coordinate system, where each point represents one observation along two axes of variation. Often, scatter plots are used to illustrate correlation between two variables.
Regression plot	Similar to a scatter plot, but designed to show a mathematical relationship between two variables (independent and dependent) over the observed range.
Line graph	Depict a change in one variable as a function of another. Individual data points are joined by a line, drawing the viewer's attention to local change between adjacent points, as well as to larger trends in the data. Commonly used to represent a series of observations over time (time-series plot).
Cumulative frequency plot	Show the number, percentage, or proportion of observations that are less than or equal to particular values.
Box and whisker plot	Simultaneously show the central tendency, middle 50% of the observations, range, and extent of outliers; facilitate the rapid simultaneous comparison of several data groups.

Tufte (1983) discussed important characteristics of a good graph:

- Has a clear purpose
- Has a simple design
- Does not distort the data – graphical representations are proportional to actual data
- Invites the viewer to think about the substance, not the presentation

- Allows and encourages comparison of different pieces of information
- Uses a consistent type and style
- Avoids extraneous decoration, i.e., "chart junk"

Good graphs share a set of essential elements (Tufte 1983, UNC 2014):

- Label below the figure with figure number and descriptive title
- Axes labeled, including units
- Scale in appropriate range
- Legend, if plotting more than one data set
- Consistent style and type
- Consistent symbols and patterns among similar graphs
- Consider color vs. black & white (e.g., will a graph be readable in B&W if original is in color)
- Set figures apart from the text

Specific types of graphs are generally applicable to particular project objectives, data types and data analyses. For example:

- Time trend: time-series plot, scatterplot of concentration vs. time
- Synoptic survey: box and whisker plot, also shaded map
- Effectiveness monitoring: box and whisker plot, regression plot
- Surveillance monitoring: time-series plot, cumulative frequency plot
- Pollutant load estimation: histogram, time-series plot

Tables

Tables are an effective way of presenting data in the following situations (U of L 2016):

- When showing how a single variable (e.g., total P) varies when measured at different points in time or space
- When the dataset contains or can be summarized in relatively few numbers
- When the precise value is crucial and a graph would not convey the same level of precision
- When you do not want a few very high or low numbers to detract from the message contained in the rest of the dataset
- When other researchers may want to use your published data for another purpose and need to know exact values (rather than graphed values)

The following are general guidelines for creating tables (UNC 2014, U of L 2016):

- Plan row and column categories to ensure that the patterns to be highlighted are evident
- Structure the table around the most important variable in the table
- Provide column and/or row labels that describe the data, including units of measurement

- If the variables in two columns or rows are equally important and cannot be effectively highlighted in the same table, consider creating two tables to highlight the important patterns for each variable
- Present numbers in their simplest format (e.g., 2 kilograms rather than 2,000 grams) and do not report excessive significant figures (e.g., 143 grams rather than 142.942 grams)
- Labels should be located above the table and include a number and descriptive title
- The data source should be identified in the table
- Design the table (e.g., lines, shading) to facilitate interpretation by the reader and use consistent table formats throughout the document
- Set tables apart from the text

Examples of Data Presentation

This section contains examples of tables and figures to illustrate options for presenting project results. These examples do not cover all options, but they do represent successful attempts to convey project results for various scenarios in actual watershed final reports.

Figures 1 and 2 are examples of using tables to summarize data and facilitate comparisons. In Figure 1, weather data from a monitoring project can be compared to long-term averages to infer how representative the weather was during the study. Figure 2 summarizes event runoff data from four monitored fields over three years and allows comparison of the hydrologic performance of the study fields.

Table 6.12. Comparison of long-term mean air temperature and normal precipitation to temperature and precipitation recorded at study sites, 2007 – 2009.

Month	Mean/Normal[1]		2007		2008		2009	
	Mean air temp. (°C)	Normal precip. (mm)	Mean air temp. (°C)	Total precip. (mm)	Mean air temp. (°C)	Total precip. (mm)	Mean air temp. (°C)	Total precip. (mm)
May	12.4	84	--	--	10.3	21	12.1	125
June	17.0	88	17.5	57	17.8	118	15.8	101
July	19.6	83	18.1	148	19.8	183	17.9	182
August	18.4	102	18.2	32	17.4	248	19.2	101
September	13.7	84	15.2	89	14.9	33	13.4	42
October	7.6	79	10.6	106	7.0	153	6.0	104
November	1.3	77	0.5	92	--	--	--	--

[1] Source: NOAA 2002; 1970 – 2000 data for Montpelier Airport NWS station (WBAN ID 94705)

Figure 1. Table Summarizing Weather Data for Three Years at a Field Monitoring Site in Vermont and Comparing Observed Temperature and Precipitation with Long-Term Means/Normal (Meals et al. 2011).

Table 6.15. Summary of hydrologic parameters of monitored events, May, 2007 – November, 2009.
Qt is total event discharge in m3, ro is total event runoff in mm, and C is event runoff coefficient (runoff/precipitation).

	Corn-1			Corn-2		
	Qt (m^3)	Ro (mm)	C	Qt (m^3)	Ro (mm)	C
Range	1.7 – 439.4	0.1 – 19.5	0.01 – 0.55	2.8 – 1,596	0.06 – 34.5	0.004 – 0.80
Mean[1]	59.3	2.6	0.12	249.1	5.4	0.34
Median	75.1	3.3	0.14	376.9	8.1	0.26
Std. Dev.[2]	0.54	0.54	0.44	0.59	0.59	0.48
C.V.[2]	0.31	1.30	0.48	0.24	0.80	0.81
n	33	33	33	32	32	32
	Hay-1			**Hay-2**		
	Qt (m^3)	Ro (mm)	C	Qt (m^3)	Ro (mm)	C
Range	0.8 – 794.9	0.02 – 21.9	0.002 – 0.49	0.0 – 212.6	0.0 – 15.8	0.0001 – 0.38
Mean[1]	56.0	1.5	0.07	8.9	0.7	0.03
Median	85.4	2.4	0.09	8.1	0.6	0.03
Std. Dev.[2]	0.79	0.79	0.66	0.78	0.76	0.69
C.V.[2]	0.45	4.18	0.46	0.82	4.42	0.45
n	33	33	33	29	29	29

[1] anti-log of log mean [2] Std. Dev. And C.V. from log_{10}-transformed data

Figure 2. Table Summarizing Hydrologic Parameters of Monitored Runoff Events at a Field Monitoring Site in Vermont Over Three Years (Meals et al. 2011).

Figures 3 and 4 are examples of using line graphs to summarize project data. In Figure 3, a time-series plot of macroinvertebrate biotic index (MBI) values is shown, along with a vertical line denoting riffle construction and color-coded circles indicating season (White et al. 2003). In Figure 4, the authors combined hydrographs and water quality data in line graphs to show the relationship between streamflow and water chemistry variables, demonstrating that levels of pH, specific conductance (SC), and sulfates (SO_4-S) were higher during base flows in comparison to iron (Fe) concentrations that were elevated during high flows. The authors used these observations to contrast with other streams where different patterns existed and to argue that the observations in Swatara Creek might result from mixing weakly acidic storm runoff with poorly buffered streams.

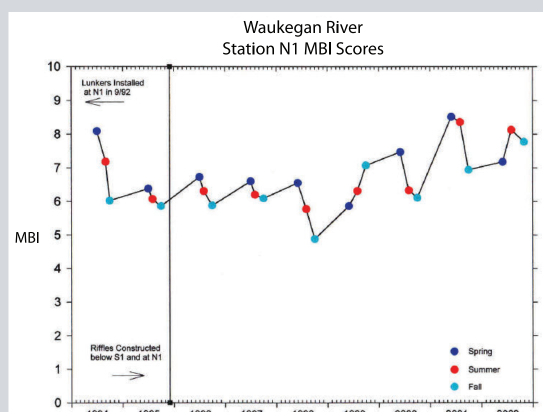

Figure 3. Line Graph of MBI Scores for 1994-2002 at Waukegan River Station 1 (White et al. 2003).

Figures 5 and 6 demonstrate the use of cumulative frequency plots to illustrate important data results. Figure 5 documents that the contact recreation water quality standard for *E. coli* bacteria was violated more than 60 percent of the time in a one-year period; only about 38 percent of the observations were below the standard. Figure 6 shows that the entire distribution of observed suspended solids (SS) concentrations was reduced with passage through a stormwater treatment device, an approach to assessing BMP effectiveness considered superior to simple percent reduction at a single input concentration.

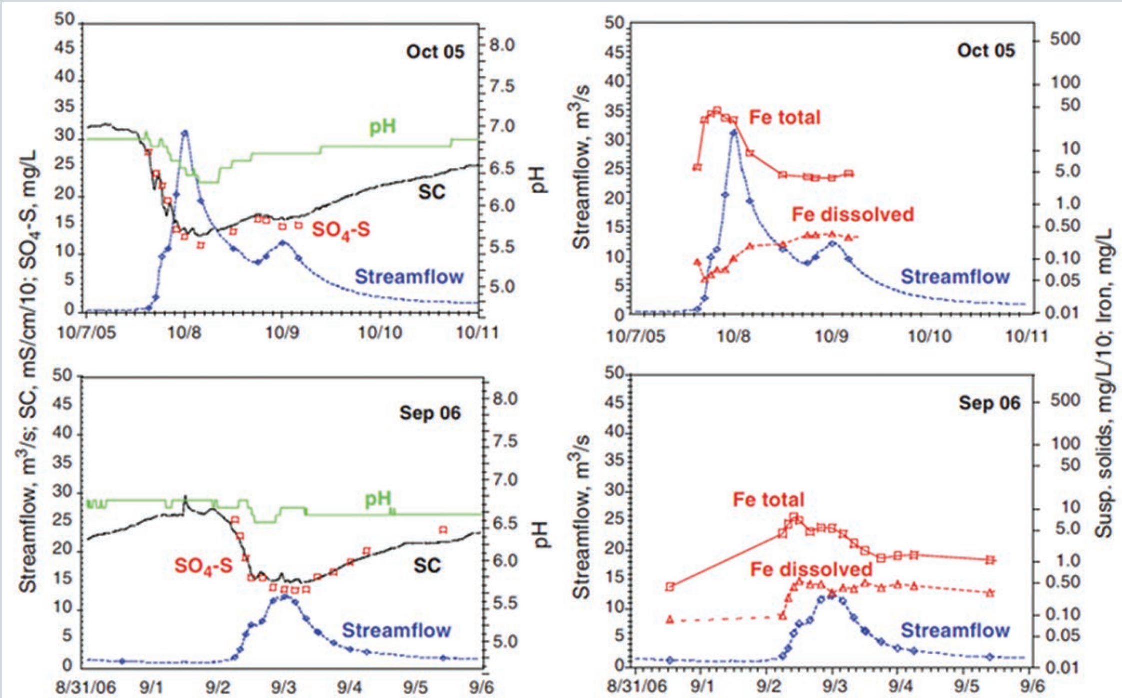

Figure 4. Hydrographs and Associated Water-Quality Data for Selected Stormflow Events, Swatara Creek at Ravine, PA. October 7-9, 2005 and September 2-4, 2006. (Values Shown for Specific Conductance (SC) and Concentration of SO4-S (Divided by 3) as Sulfur.) (Cravotta et al. 2010).

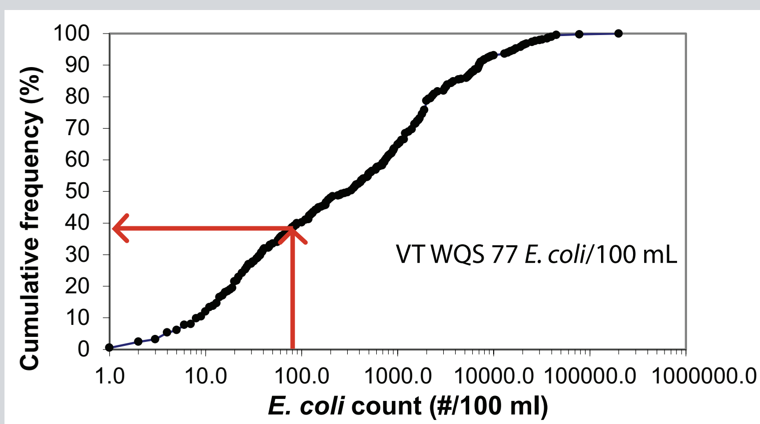

Figure 5. Cumulative Frequency Plot of *E. coli* Data Collected Twice Weekly in a Vermont Stream in 1996 (Meals 2001).

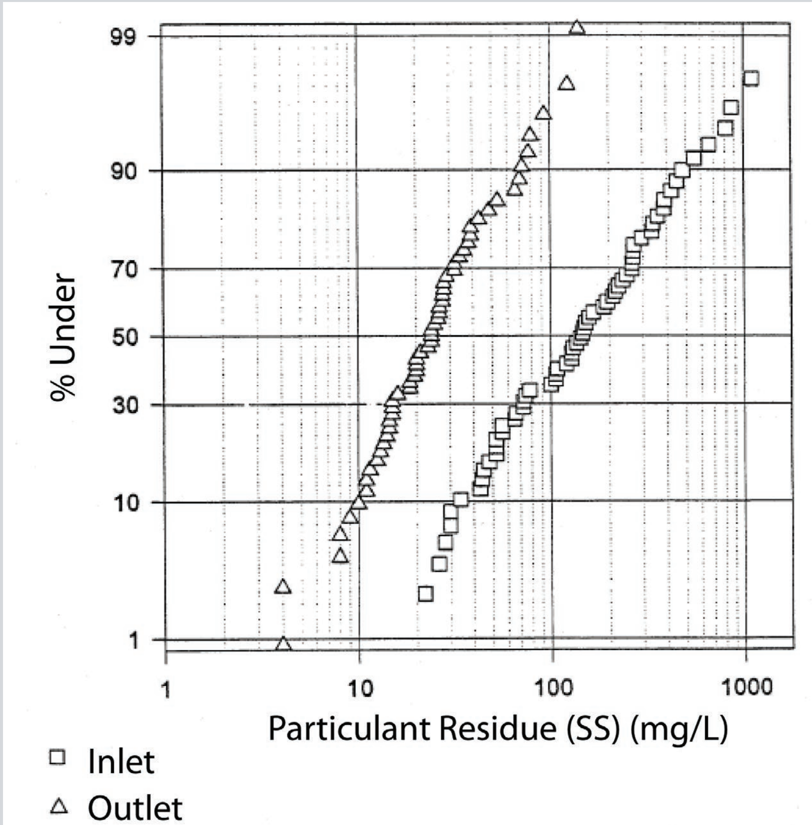

Figure 6. Cumulative Frequency Plots Comparing the Distribution of Input and Output SS Concentrations through a Stormwater Treatment Device (Geosyntec Consultants and Wright Water Engineers, Inc. 2009).

Figures 7-9 illustrate the use of box and whisker plots to summarize and interpret project data. In Figure 7, the authors used box and whisker plots to show that *E. coli* export from hay fields tended to be lower than that from corn fields, but considerably more variable during the monitoring period. The plots in Figure 8 were used to suggest that TSS concentrations declined in the treated watershed relative to the control watershed after implementation of livestock exclusion and riparian restoration BMPs. Figure 9 shows a visual comparison and numeric data comparing the performance of various stormwater treatment systems on TSS concentration.

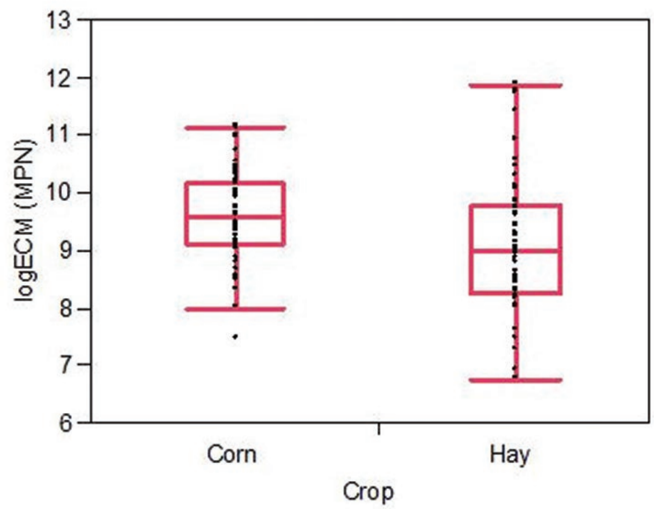

Figure 7. Box and Whisker Plots Comparing the Distribution of *E. coli* Export from Corn and Hay Fields in Vermont Over a Three-Year Study Period (Meals et al. 2011).

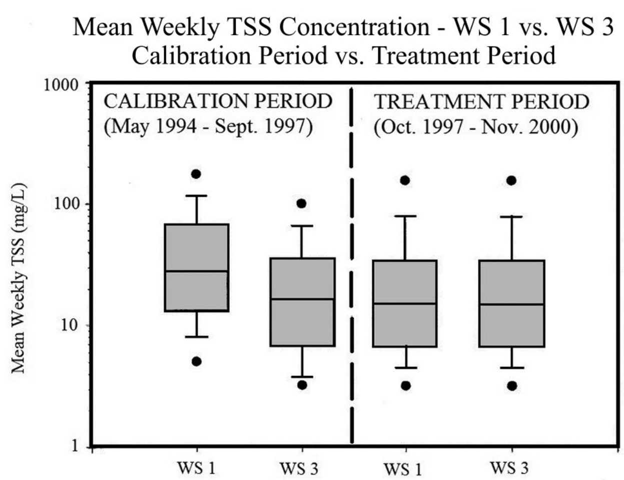

Figure 8. Box and Whisker Plots Showing the Distributions of Mean Weekly TSS Concentrations in Treated (WS1) and Control (WS3) Watersheds During the Calibration and Treatment Periods of a Paired-Watershed Study (Meals 2001).

Figure 2. Box Plots of Influent/Effluent TSS Concentrations

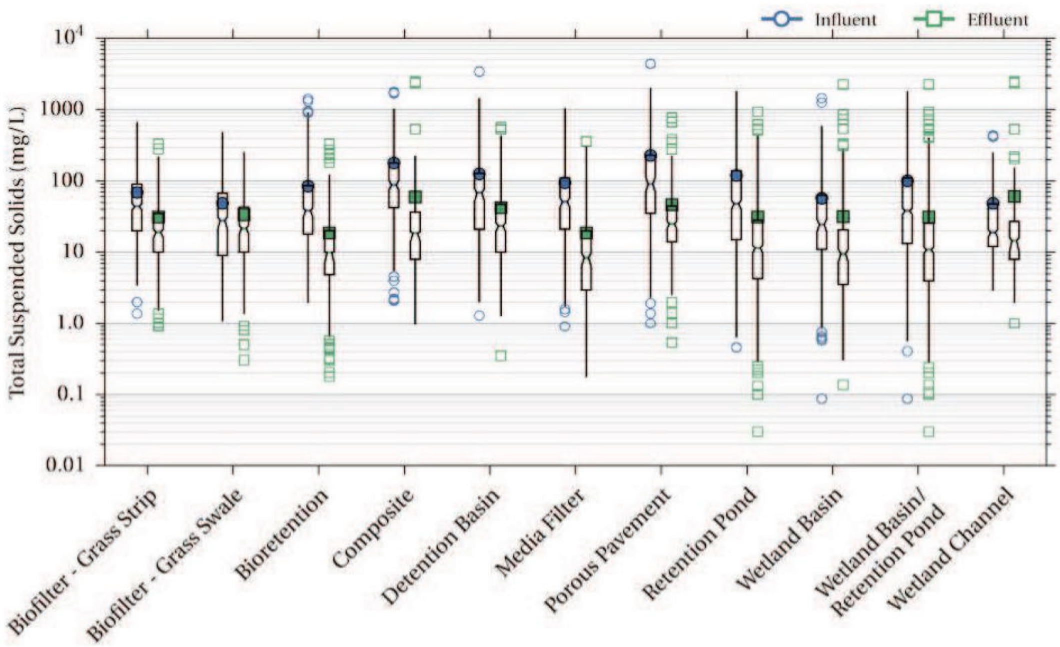

Table 2. Influent/Effluent Summary Statistics for TSS (mg/L)

BMP Type	Count of Studies and EMCs		25th Percentile		Median (95% Conf. Interval)*		75th Percentile	
	In	Out	In	Out	In	Out	In	Out
Biofilter - Grass Strip	19; 361	19; 282	20.0	10.0	44.1 (39, 48)	19 (15.9, 21)**	90.0	35.0
Biofilter - Grass Swale	23; 399	23; 346	9.0	10.0	27.7 (21, 31.6)	21.6 (17.8, 24)**	67.0	43.0
Bioretention	22; 461	22; 393	18.0	4.9	38.1 (31, 42)	9.9 (7, 10)**	86.0	20.0
Composite	10; 202	10; 174	42.4	8.0	87.6 (75.1, 101.5)	18.4 (14, 19.3)**	178.8	36.5
Detention Basin	22; 321	22; 336	21.0	10.0	68.2 (52.3, 77.3)	23.3 (19.5, 26)**	128.0	47.0
Media Filter	23; 381	23; 358	21.1	3.0	50.9 (42.8, 58)	8.4 (6.3, 9.8)**	110.5	19.9
Porous Pavement	8; 356	8; 220	35.0	14.0	90.3 (69, 115)	24.9 (21.5, 27)**	230.0	44.4
Retention Pond	56; 923	56; 933	15.0	4.3	47.7 (40, 54)	11.5 (10, 12.3)**	139.8	28.0
Wetland Basin	19; 395	19; 385	11.0	3.5	24.5 (19.1, 28.9)	9.4 (7.4, 11)**	63.3	20.6
Wetland Basin/Retention Pond	75; 1318	75; 1318	13.3	4.0	37.9 (34, 41.6)	10.9 (9.6, 11.7)**	110.0	25.4
Wetland Channel	8; 171	8; 151	12.0	8.0	18.9 (16, 21)	14.4 (10, 16)**	47.5	27.0

NA – not available or less than 3 studies for BMP/constituent.
*Computed using the BCa bootstrap method described by Efron and Tibishirani (1993).
**Hypothesis testing in Attachment 1 shows statistically significant decreases for this BMP category.

Figure 9. Box and Whisker Plots and Tabular Data Comparing Influent and Effluent TSS Concentrations from a Variety of Stormwater BMPs (Geosyntec Consultants and Wright Water Engineers, Inc. 2014).

Figure 10 illustrates two ways of presenting biological data. In Figure 10, researchers used a combination of bar and line graphs to portray results of 11 years of fish monitoring in three Pennsylvania streams and to relate those findings to streamflow and water temperature.

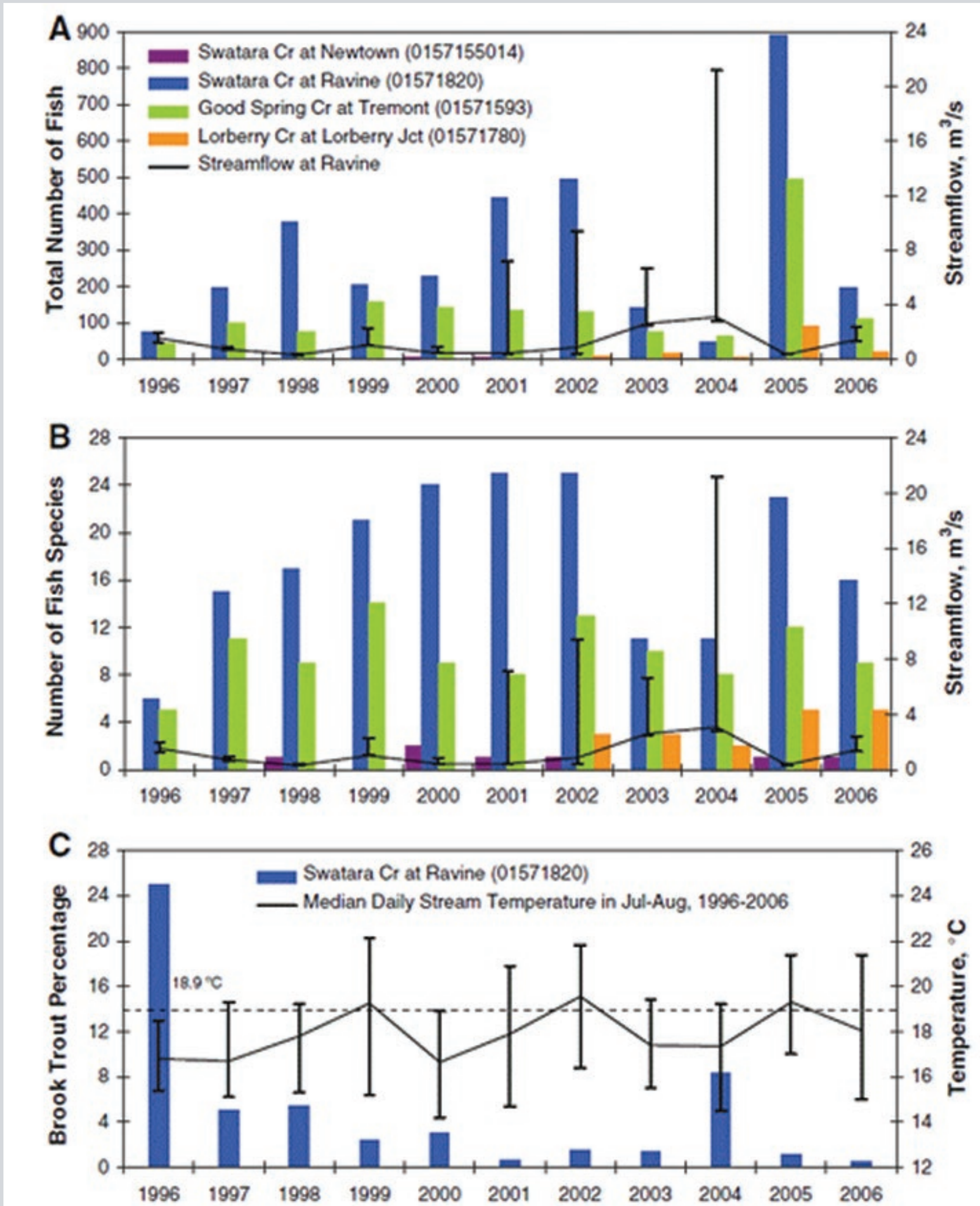

Figure 10. Combined Bar Charts and Line Graphs Showing Fish Numbers (A), Fish Species (B), and Percent Brook Trout (C) Combined with Streamflow and Water Temperature in a Pennsylvania Stream Over an 11-year Monitoring Period (Cravotta et al. 2010).

Figure 11 illustrates how a Vermont project displayed results from a paired-watershed analysis. The data table shows the regression equations for the paired-watershed regressions for storm event discharge, *E. coli* count, and *E. coli* export from the paired fields (corn and hay land uses). Analysis of Covariance (ANCOVA) models were applied where slopes differ between the calibration (CAL) and treatment (TRT) periods ("Full model") and where slopes do not differ between the two periods ("Reduced model"). The accompanying paired regression plot shows the ANCOVA model comparing the relationship between bacteria counts in runoff from control and treatment corn fields, indicating that *E. coli* counts in the treated field (C2) declined relative to those from the control field (C1) during the treatment period.

Table 6.25. Summary of paired watershed ANCOVA models.
"P Slopes" and "P Intercepts" refer to the P level indicating significant difference between calibration and treatment slopes and intercepts, respectively.

Period	Model	Equation	*P* Slopes	*P* Intercepts
CORN Event Discharge				
CAL	Full	logCorn-2Qt = 1.120(logCorn-1Qt) + 0.380	**0.009**	**0.004**
TRT		logCorn-2Qt = 0.671(logCorn-1Qt) + 1.303		
CORN *E. coli* count				
CAL	Reduced	logCorn 2EC = 0.971(logCorn-1EC) + 0.248	0.586	0.373
TRT		logCorn-2EC = 0.971(logCorn-1EC) + 0.121		
CORN *E. coli* export				
CAL	Reduced	logCorn-2ECM = 0.738(logCorn-1ECM) + 3.227	0.957	0.466
TRT		logCorn-2ECM = 0.738(logCorn-1ECM) + 3.111		
HAY Event Discharge				
CAL	Full	logHay-1Qt = 0.998(logHay-2Qt) + 0.592	**0.028**	**0.005**
TRT		logHay-1Qt = 0.455(logHay-2Qt) + 1.556		
HAY *E. coli* count				
CAL	Reduced	logHay-1EC = 0.697(logHay-2 EC) + 0.811	0.116	0.183
TRT		logHay-1 EC = 0.697(logHay-2EC) + 1.036		
HAY *E. coli* export				
CAL	Reduced	logHay-1ECM = 0.726(logHay-2 ECM) + 2.863	0.272	**0.024**
TRT		logHay-1 ECM = 0.726(logHay-2ECM) + 3.414		

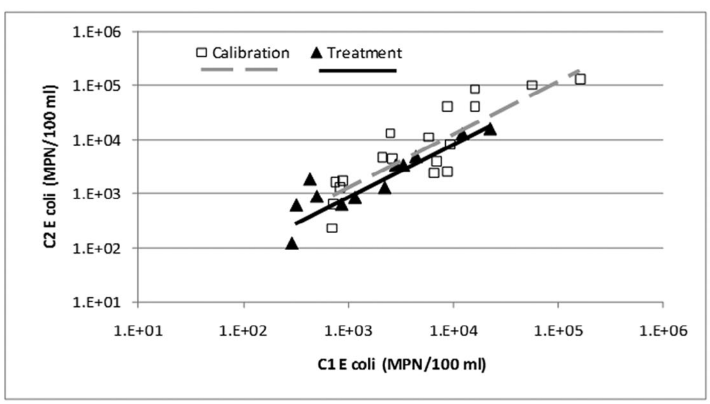

Figure 6.37. Paired regression plot of Calibration Period and Treatment Period event E. coli count from the corn fields. Regression lines do not differ significantly in either slope (P=0.586) and intercept (P=0.373).

Figure 11. Data Table Showing Paired-Watershed ANCOVA Model Equations and Regression Plots Showing the Effects Of Treatment on *E. coli* in Runoff from Vermont Corn Fields (Meals et al. 2011).

Figures 12 and 13 illustrate how simple graphs can be used to relate land treatment and water quality over two very different time scales. The authors used Figure 12 to illustrate the elevation of bacteria levels in storm event runoff closely following manure application within a single cropping season. Figure 13 illustrates the dramatic effect of the implementing numerous BMPs over a long time period on watershed sediment yield.

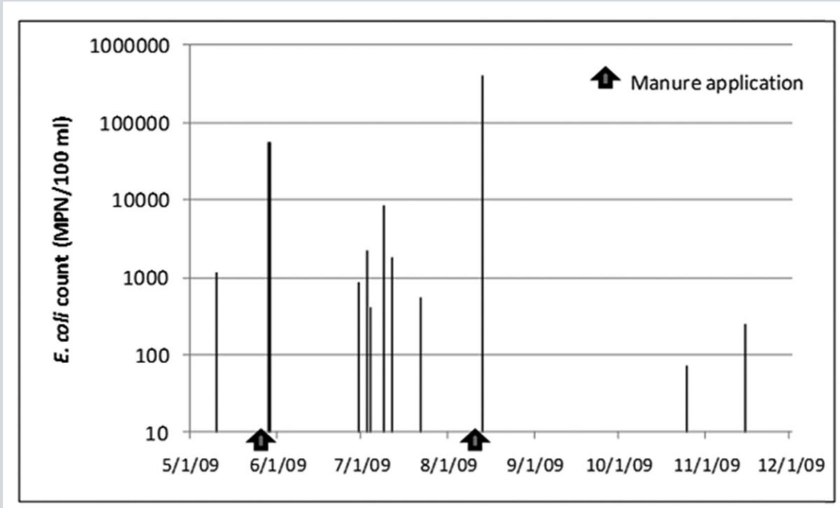

Figure 12. Bar Graph Showing *E. coli* Counts in Storm Event Runoff from a Vermont Hay Watershed in Relation to Manure Applications (Meals et al. 2011).

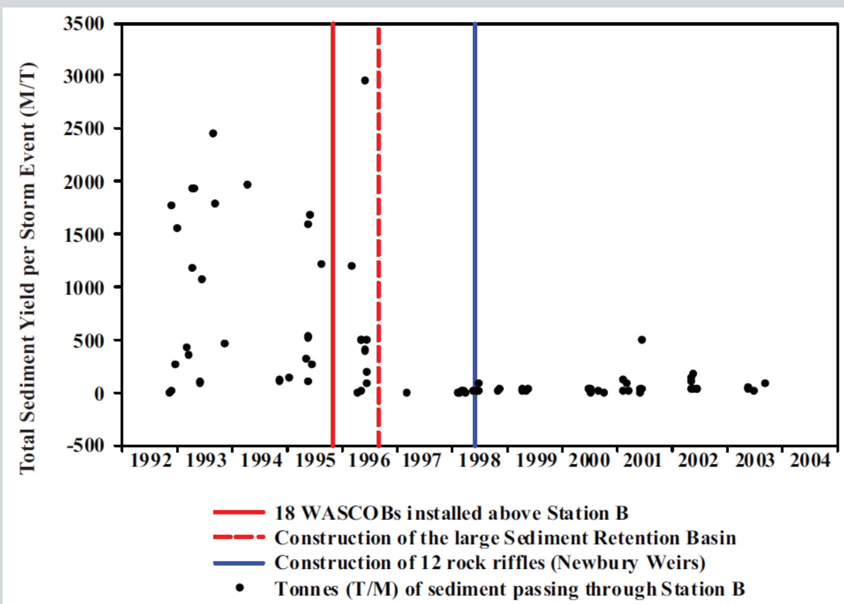

Figure 13. Scatterplot of Storm Event Sediment Yield Over 12 Years in an Illinois Watershed, with Implementation of a Series of BMPs Indicated (White et al. 2008).

Finally, Figures 14 and 15 illustrate two ways of representing spatial data. Figure 14 portrays the spatial distribution of biological assessment results from a Maryland county, based on application of the Maryland Benthic Index of Biological Integrity (B-IBI) that uses community-level metrics to quantify characteristics of the benthic macroinvertebrate assemblage at specific sites. Figure 15 relates the site B-IBI ratings to more general levels of biological degradation at a county scale. These percentages and the shading patterns may help convey the overall scope of biological assessment data in a more broadly understandable way at the county level, whereas mapping of the raw data categories in Figure 14 shows biological conditions in a more spatially-explicit fashion.

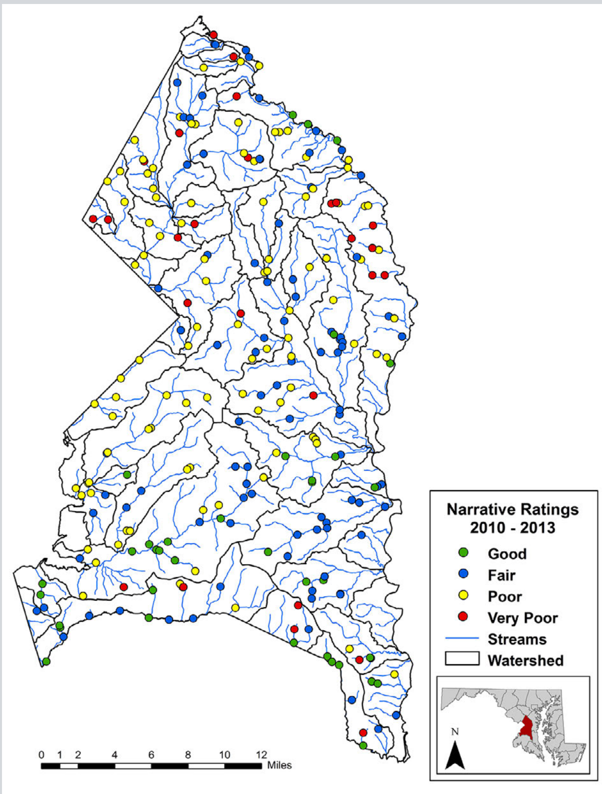

Figure 14. Map Showing Site-Specific Biological Assessment Results in Prince George's County, MD, 2010 – 2013 (Millard et al. 2013).

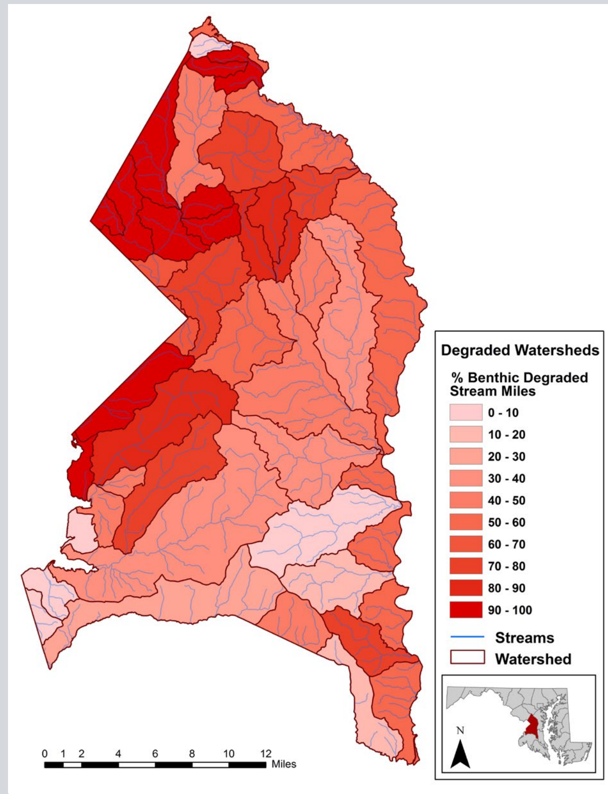

Figure 15. Map Showing Watershed-Scale Percent Biological Degradation Results for Prince George's County, MD 2010 – 2013 (Millard et al. 2013).

Overview of Helpful Resources

Good reporting begins with good study design and there are numerous resources available to help plan watershed projects, including:

- Monitoring design
  - USEPA (U.S. Environmental Protection Agency). *Guidance on Systematic Planning Using the Data Quality Objectives Process.* (QA-G4), EPA/240/B-06/001. U.S. Environmental Protection Agency, Washington, DC.
  - USEPA (U.S. Environmental Protection Agency). *Aquatic Resources Monitoring – Monitoring Design and Analysis*. U.S. Environmental Protection Agency, Washington, DC.

  - Dressing, S.A., D.W. Meals, J.B. Harcum, J. Spooner, J.B. Stribling, R.P. Richards, C.J. Millard, S.A. Lanberg, and J.G. O'Donnell. 2016. *Monitoring and Evaluating Nonpoint Source Watershed Projects*. EPA 841-R-16-010. U.S. Environmental Protection Agency, Washington, DC.
- Monitoring methods manuals
  - Flotemersch, J.E., J.B. Stribling, and M.J. Paul. 2006. *Concepts and Approaches for the Bioassessment of Non-Wadeable Streams and Rivers*. EPA/600/R-06/127. U. S. EPA, Office of Research and Development, National Exposure Research Laboratory, Cincinnati, OH.
  - Dressing, S.A., D.W. Meals, J.B. Harcum, J. Spooner, J.B. Stribling, R.P. Richards, C.J. Millard, S.A. Lanberg, and J.G. O'Donnell. 2016. *Monitoring and Evaluating Nonpoint Source Watershed Projects*. EPA 841-R-16-010. U.S. Environmental Protection Agency, Washington, DC.

Guidance on data analysis is also available from numerous sources, including these from EPA and other sources:

  - Meals, D.W. and S.A. Dressing. 2005. *Monitoring Data – Exploring Your Data, the First Step*, Tech Notes #1, July 2005. Prepared for U.S. Environmental Protection Agency, by Tetra Tech, Inc., Fairfax, VA.
  - Meals, D.W., J. Spooner, S.A. Dressing, and J.B. Harcum. 2011. *Statistical Analysis for Monotonic Trends*, Tech Notes #6, September 2011. Prepared for U.S. Environmental Protection Agency, by Tetra Tech, Inc., Fairfax, VA. Accessed December 20, 2016. *https://www.epa.gov/nps/nonpoint-source-monitoring-technical-notes*.
  - Dressing, S.A., D.W. Meals, J.B. Harcum, J. Spooner, J.B. Stribling, R.P. Richards, C.J. Millard, S.A. Lanberg, and J.G. O'Donnell. 2016. *Monitoring and Evaluating Nonpoint Source Watershed Projects*. EPA 841-R-16-010. U.S. Environmental Protection Agency, Washington, DC.
  - USEPA (U.S. Environmental Protection Agency). 2006. *Data Management, Interpretation, and Presentation. Chapter 8 in Volunteer Estuary Monitoring Manual, a Methods Manual*, 2nd ed. Prepared for U.S. Environmental Protection Agency, by The Ocean Conservancy, Washington, DC. Accessed December 20, 2016. *https://www.epa.gov/sites/production/files/2015-09/documents/2007_04_09_estuaries_monitoruments_manual.pdf*
  - Helsel, D.R., and R.M. Hirsch. 2002. Statistical Methods in Water Resources. Book 4, Chapter A3 in *Techniques of Water-Resources Investigations*. U.S. Geological Survey, Reston, VA. Accessed December 14, 2016. *http://pubs.usgs.gov/twri/twri4a3/*.
  - Gilbert, R.O. 1987. *Statistical Methods for Environmental Pollution Monitoring*. Van Nostrand Reinhold, New York.

Software tools for data analysis and presentation are also plentiful, including simple spreadsheet tools and more advanced statistical software packages. Table 2 identifies some options for study design, data analysis, and presentation.

Table 2. Software Tools for Study Design, Data Analysis, and Data Presentation

Package Name	Web Site URL
Analyse-It (add in for MS Excel)	http://www.analyse-it.com
ArcGIS	https://www.arcgis.com/features/index.html
DataDesk	http://www.datadesk.com
Generalized Random Tessellation Stratified (GRTS) Survey Designs	https://archive.epa.gov/nheerl/arm/web/html/design_intro.html
JMP	http://www.jmp.com/en_gb/software.html
Mathematica	http://www.wolfram.com/mathematica/
MATLAB	http://www.mathworks.com/products/matlab/
MINITAB	https://www.minitab.com/en-us/
Python	https://www.python.org/
R	https://www.r-project.org/
SAS/Stat, SAS/Insight	http://www.sas.com/technologies/analytics/statistics/index.html
Spatial Survey Design and Analysis Tools	https://archive.epa.gov/nheerl/arm/web/html/software.html
SPSS	http://www.spss.com/spss/
SYSTAT	http://www.systat.com/products/Systat/
WINKS	http://www.texasoft.com/

Guidance on data presentation and report writing is plentiful (UNC 2014, U of L 2016, Tufte 1983). The challenge is to adapt that information to your specific situation.

References

Baker, D.B. 2010. *Trends in Bioavailable Phosphorus Loading to Lake Erie, Final Report, LEPF Grant 315-07*. Prepared for Ohio Lake Erie Commission, by National Center for Water Quality Research, Heidelberg University, Tiffin, OH. Accessed December 20, 2016.http://lakeerie.ohio.gov/Portals/0/Closed%20Grants/small%20grants/SG%20315-07%20Final%20Report.pdf.

Boslaugh, S. 2007. *Secondary Data Sources for Public Health: A Practical Guide*. Cambridge University Press.

Cravotta, C.A., R.A. Brightbill, and M.J. Langland. 2010. Abandoned Mine Drainage in the Swatara Creek Basin, Southern Anthracite Coalfield, Pennsylvania, USA: 1. Stream Water Quality Trends Coinciding with the Return of Fish. *USGS Staff -- Published Research*. Paper 291. Accessed December 21, 2016. http://digitalcommons.unl.edu/usgsstaffpub/291/

Dressing, S.A., D.W. Meals, J.B. Harcum, J. Spooner, J.B. Stribling, R.P. Richards, C.J. Millard, S.A. Lanberg, and J.G. O'Donnell. 2016. *Monitoring and Evaluating Nonpoint Source Watershed Projects*. EPA 841-R-16-010. U.S. Environmental Protection Agency, Washington, DC. Accessed December 20, 2016.
https://www.epa.gov/nps/monitoring-and-evaluating-nonpoint-source-watershed-projects.

Flotemersch, J.E., J.B. Stribling, and M.J. Paul. 2006. Concepts and Approaches for the Bioassessment of Non-Wadeable Streams and Rivers. EPA/600/R-06/127. U. S. EPA, Office of Research and Development, National Exposure Research Laboratory, Cincinnati, OH. Accessed December 20, 2016. *https://www3.epa.gov/region1/npdes/merrimackstation/pdfs/ar/AR-1157.pdf*.

Geosyntec and WWE (Wright Water Engineers, Inc.). 2009. *Urban Stormwater BMP Performance Monitoring*. Prepared for U.S. Environmental Protection Agency, Water Environment Research Foundation, Federal Highway Administration, and Environmental and Water Resources Institute of the American Society of Civil Engineers, by Geosyntec Consultants and Wright Water Engineers, Inc., Washington, DC. Accessed December 21, 2016. *http://www.bmpdatabase.org/Docs/2009%20Stormwater%20BMP%20Monitoring%20Manual.pdf*.

Geosyntec and WWE (Wright Water Engineers, Inc.). 2014. *International Stormwater Best Management Practices (BMP) Database Pollutant Category Statistical Summary Report: Solids, Bacteria, Nutrients, and Metals*. Geosyntec Consultants, Inc. and Wright Water Engineers, Inc, Washington, DC. Accessed December 21, 2016. *http://www.bmpdatabase.org/Docs/2014%20Water%20Quality%20Analysis%20Addendum/BMP%20Database%20Categorical_StatisticalSummaryReport_December2014.pdf.*

Gilbert, R.O. 1987. *Statistical Methods for Environmental Pollution Monitoring*. Van Nostrand Reinhold, New York.

Helsel, D.R., and R.M. Hirsch. 2002. Statistical Methods in Water Resources. Book 4, Chapter A3 in *Techniques of Water-Resources Investigations*. U.S. Geological Survey, Reston, VA. Accessed December 21, 2016. *https://pubs.usgs.gov/twri/twri4a3/*.

Joosse, P. J. and Baker, D. B. 2011. Context for re-evaluating agricultural source phosphorus loadings to the Great Lakes. *Can. J. Soil Sci.* 91:317-327.

Meals, D.W. 2001. *Lake Champlain Basin Agricultural Watersheds Section 319 National Monitoring Program Project, Final Project Report: May, 1994-September, 2000*. Vermont Department of Environmental Conservation, Waterbury, VT.

Meals, D.W., D.C. Braun, and J.A. Hanzas. 2011a. *Assessment of Dairy Manure Management Practices to Reduce Pathogen Runoff Losses in Agricultural Watersheds*. Final Report. Prepared for U.S. Department of Agriculture, National Institute of Food and Agriculture, by Stone Environmental, Inc., Montpelier, VT.

Meals, D.W. and S.A. Dressing. 2005. *Monitoring Data – Exploring Your Data, the First Step*, Tech Notes #1, July 2005. Prepared for U.S. Environmental Protection Agency, by Tetra Tech, Inc., Fairfax. VA. Accessed December 20, 2016. *https://www.epa.gov/nps/nonpoint-source-monitoring-technical-notes*.

Meals, D.W., S.A. Dressing, J.Kosco, and S.A. Lanberg. 2014. *Land Use and BMP Tracking for NPS Watershed Projects*, Tech Notes #11, June 2014. Prepared for U.S. Environmental Protection Agency, by Tetra Tech, Inc., Fairfax, VA. Accessed December 20, 2016. *https://www.epa.gov/nps/nonpoint-source-monitoring-technical-notes*.

Meals, D.W., J. Spooner, S.A. Dressing, and J.B. Harcum. 2011. *Statistical Analysis for Monotonic Trends*, Tech Notes #6, September 2011. Prepared for U.S. Environmental Protection Agency, by Tetra Tech, Inc., Fairfax, VA. Accessed December 20, 2016. https://www.epa.gov/nps/nonpoint-source-monitoring-technical-notes.

Millard, C. J., C. L. Wharton and J.B. Stribling. 2013. *Biological Assessment and Monitoring of Streams and Watersheds in Prince George's County. Round 2, Year 3*. Prepared for Prince George's County, Department of Environmental Resources, Largo, Maryland, by Tetra Tech, Inc., Center for Ecological Sciences, Owings Mills, MD. For more information, contact James Stribling at james.stribling@tetratech.com.

Tufte, E. R. 1983. *The Visual Display of Quantitative Information*. Graphics Press, Cheshire, CT.

UNC. 2014. *Figures and Charts*. The Writing Center, University of North Carolina at Chapel Hill, Chapel Hill, NC. Accessed December 13, 2016. http://writingcenter.unc.edu/handouts/figures-and-charts/.

U of L. 2016. *Presenting Numerical Data*. Student Learning Development, University of Leicester, Leicester, UK. Accessed December 13, 2016. http://www2.le.ac.uk/offices/ld/resources/numerical-data/numerical-data.

USC Libraries. 2016. *Organizing Your Social Sciences Research Paper: Executive Summary*. Research Guides, University of Southern California. Accessed December 21, 2016. http://libguides.usc.edu/writingguide/executivesummary.

USEPA (U.S. Environmental Protection Agency). *Aquatic Resources Monitoring – Monitoring Design and Analysis*. U.S. Environmental Protection Agency, Washington, DC. Accessed December 14, 2016. https://archive.epa.gov/nheerl/arm/web/html/design_analysis.html.

USEPA (U.S. Environmental Protection Agency). 2006. Data Management, Interpretation, and Presentation. Chapter 8 in *Volunteer Estuary Monitoring Manual, a Methods Manual,* 2nd ed. Prepared for U.S. Environmental Protection Agency, by The Ocean Conservancy, Washington, DC. Accessed December 20, 2016. https://www.epa.gov/sites/production/files/2015-09/documents/2007_04_09_estuaries_monitoruments_manual.pdf

USEPA (U.S. Environmental Protection Agency). 2009. *EPA New England Quality Assurance Project Plan Guidance for Environmental Projects Using Only Existing (Secondary) Data.* EPA-820-S-10-001. U.S. Environmental Protection Agency New England, Quality Assurance Unit, Office of Environmental Measurement and Evaluation, Boston, MA. Accessed December 21, 2016. https://www.epa.gov/quality/epa-new-england-quality-assurance-project-plan-guidance-environmental-projects-using-only.

USEPA (U.S. Environmental Protection Agency). 2006. *Guidance on Systematic Planning Using the Data Quality Objectives Process*. (QA-G4), EPA/240/B-06/001. U.S. Environmental Protection Agency, Washington, DC. Accessed December 20, 2016. https://www.epa.gov/quality/guidance-systematic-planning-using-data-quality-objectives-process-epa-qag-4.

White, W.P., J. Beardsley, D. Devotta, and S. Tomkins. 2008. Lake Pittsfield Illinois national nonpoint source monitoring program project. *NWQEP Notes* 129:1-12. North Carolina State University Cooperative Extension, Raleigh, NC. Accessed December 21, 2016. https://319monitoring.wordpress.ncsu.edu/files/2016/05/notes129.pdf.

White, B., J. Beardsley, J. Rodsater, and L. Duong. 2003. *Biological and Physical Monitoring of Waukegan River Restoration Efforts in Biotechnical Bank Protection and Pool/Riffle Creation*. Prepared for Illinois Environmental Protection Agency, by Illinois Department of Natural Resources, State Water Survey, Champaign, IL.