Monitoring Water in Indiana:

Choices for Nonpoint Source and Other Watershed Projects




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Photo Credits

The manual benefited from photos that are used courtesy of the following organizations, agencies, and individuals.

Wabash River Enhancement Corporation: Photos on pages 11, 16, 32, 40, 61, 100

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All other photos were taken by the authors.

Data used in providing Indiana values for monitoring parameters

Data for Figures 1.1, 5.1, 10.1, 13.1, 14.1, and 16.1: Wabash River Enhancement Corporation and Purdue University monitoring of Wabash River tributaries (Little Wea Creek). Streamflow monitored by U.S. Geological Survey.

Lake data and summaries were all provided by Bill Jones and colleagues through the Indiana Clean Lakes Program, which added greatly to the thoroughness of the manual.

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(Note: Section titles have live links. Click on any title to go to that section.)

Introduction

The purpose of this manual is to provide information to help watershed groups develop a monitoring strategy to obtain useful information with limited resources. The manual was developed at Purdue University in collaboration with the Indiana Department of Environmental Management (IDEM) Watershed Assessment and Planning Branch, with contributions from monitoring experts from around the State as described below. The emphasis is on developing a monitoring strategy, rather than providing details on conducting the monitoring. It is not an operations manual, but rather provides links to monitoring protocols and Indiana-specific information to help make choices.

Water monitoring is expensive and complex, and doing it successfully requires a commitment to training, quality assurance, data management, and obtaining funding to monitor sufficiently to make it worthwhile. Monitoring that does not result in representative data of known quality is rarely useful. Monitoring too infrequently to represent the water quality is a poor use of the limited funds available for watershed management.

Before starting, determine whether you have the resources and need for monitoring

Watershed management does not necessarily require water monitoring. Alternatives may include using existing data, partnering with another agency that is monitoring, or documenting success with indicators that are not obtained through monitoring. These may be more efficient uses of resources to meet your watershed goals. Before developing a monitoring strategy, consider whether you are willing to dedicate the time and resources needed to monitor effectively, or whether it might be possible to develop an effective watershed management plan without monitoring. Poorly implemented monitoring does not just provide less information than doing it right; it can provide no information or even cause harm if incorrect information is used in decision-making. If adequate resources to monitor well are not available, it is best to identify another method to evaluate your project.

Explore existing data

Whether or not you conduct monitoring, it is useful to start by obtaining and examining data from any previous water monitoring that has taken place in your watershed. State, federal, local, and non-governmental agencies may have conducted water monitoring. Start with the following data sources.

- Watersheds that receive funding from the Section 319 Nonpoint Source Program have been found to be impaired, which means that monitoring by the IDEM has identified the impairment(s). Obtain IDEM data used to in assessing your watershed: Work with your watershed specialist to obtain available data. IDEM assesses water quality through several programs, including Fixed Station, Probabilistic or TMDL sampling, so data may be available in addition to the specific data used to assess whether water meets water quality standards.

- Search the Indiana Water Monitoring Inventory (http://engineering.purdue.edu/~inwater) for additional monitoring that has taken place in or near your watershed (Figure Intro 1). Important agencies that monitor water in Indiana include the following:
    - US Geological Survey: USGS operates flow gages throughout Indiana (Figure Intro.2), and also has some water quality monitoring programs.
    - Local sources: Local stormwater programs (MS4s), city, water utility, or other agencies may have data, and you should acquire any of these. Some are available at the Indiana Water Monitoring Inventory, but others may be available elsewhere. (If you locate additional data, please submit information to the Inventory).
    - Other sources: Universities, other state and federal agencies, and local watershed groups may also have monitoring information that you should obtain.

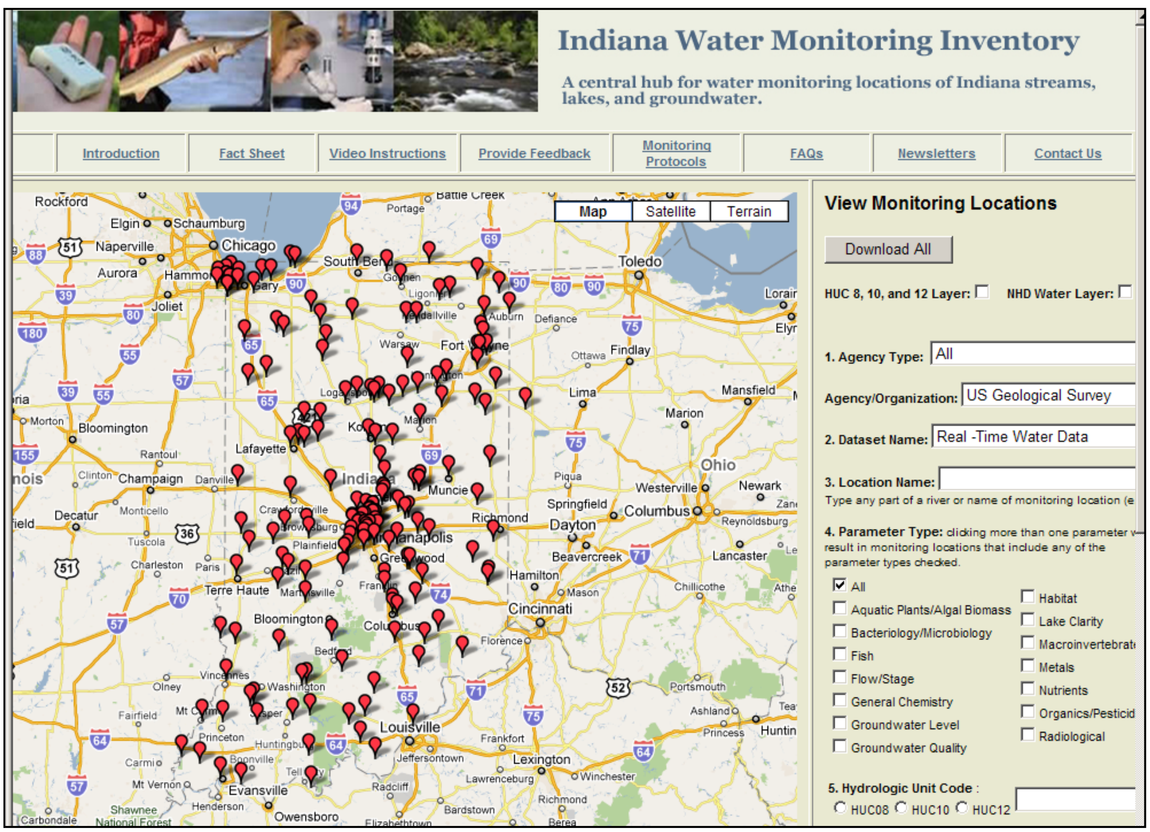


Figure I.1: USGS Real –Time Gaging Stations in Indiana, as displayed on the Indiana Water Monitoring Inventory (https://engineering.purdue.edu/~inwater/)

- Search for volunteer monitoring data in the Hoosier Riverwatch database (http://www.hoosierriverwatch.com/)

- Identify any nearby past watershed projects, especially those with similar land uses. Most watersheds are mostly agricultural, and data have been collected (http://www.in.gov/idem/nps/3180.htm).

Existing data may not provide all the information you would like, but will perhaps allow you to make a more informed decision on whether developing and implementing a monitoring strategy is right for you. Do existing data allow you to identify problems, estimate loads and improvements required, and select appropriate management measures to address the water quality impairments? If not, what are the specific data gaps?

Identify clear monitoring goals and means to achieve them

Setting goals seems like an obvious place to start but it is quite difficult to clearly define your monitoring objectives. Collecting data with vague goals and without a clear idea how the monitoring data will be able to achieve the goals, will rarely result in a good use of resources. Some past projects have collected data for one or more years, then realized that they cannot achieve the objectives with the monitoring frequency or parameters they have been using.

There are many possible goals of water monitoring, as listed in Table I.1, and in most cases it is not possible to achieve more than one. In fact, even achieving one of these goals would be a major achievement. In the list of monitoring objectives in Table I.1, only goals 1 to 4 are usually appropriate for watershed projects, and focusing on collecting data adequate for that goal is usually the best use of resources.

Table I.1: Possible Goals of Monitoring (Those in bold may be appropriate for nonpoint source projects)

1. **Characterize water quality problems**
2. **Estimate loads and load reductions needed**
3. **Identify locations where water quality is better or worse, for example to determine critical areas**
4. **Determine whether BMPs have improved water quality**
5. Assess water quality to determine whether designated uses are being attained. (This is the role of IDEM.)
6. Track water quality changes or trends
7. Determine fate and transport of pollutants

Once your objectives are clarified, it is equally important to design a monitoring strategy that can achieve your monitoring objectives. One critical decision is what parameters to monitor. In this manual, Part 1 provides monitoring parameters that IDEM has determined are most suitable to monitor such as the significance, typical levels, method overview, and resources required, as well as links to protocols used by statewide programs. Part 2 discusses monitoring frequency, site selection, and data collection methods needed to provide representative data. If available resources (money, staff time, volunteers, etc.) are not adequate to implement an adequate monitoring strategy, your choices are to either redefine the goals, or seek additional resources so that you can achieve the monitoring objectives.

How the manual was developed

Because there is no one right way to monitor or universally-agreed upon parameters to include, a collaborative process was undertaken to identify core indicators that should be assessed in Indiana watersheds. Experts in monitoring, together with experienced watershed coordinators, were invited to participate in an Expert Panel to determine core and supplemental indicators. They provided insights at a series of meetings and surveys, and the results of this process provided the list of parameters that should be considered as core indicators. Many other insights and ideas were shared at these meetings, which has strengthened this manual.

Core and supplemental indicators

A list of 27 potential parameters, that can be used as indicators, were selected through the Expert Panel process. Indiana Department of Environmental Management's Watershed Assessment and Planning Branch staff made the final selection of nine ***core parameters*** (Table I.2). For watershed projects that receive 319 funding for monitoring, the nine core parameters are required for watershed projects that monitor water.

Table I.2: Core and Supplemental Parameters for the IDEM Nonpoint Source Program

Core parameters for monitoring in the IDEM Nonpoint Source Program	**Supplemental parameters, also included in the manual**
1. Nitrate	1. Total Nitrogen
2. Total phosphorus	2. Ammonia
	3. Total Kjeldahl Nitrogen
A sediment measure:	4. Orthophosphate
3. Total Suspended Solids, or	5. Biochemical Oxygen Demand
4. Turbidity/Transparency	6. Conductivity
	7. Suspended Sediment Concentration
A habitat measure:	8. Bank Erosion Hazard Index
5. Qualitative Habitat Evaluation Index	9. Buffer Zone Width
6. Citizens Qualitative Habitat Evaluation Index	10. Richards-Baker Flashiness Index
	11. Indiana Index of Biotic Integrity for Fish Communities
7. Dissolved oxygen	12. Macroinvertebrate Indices of Biotic Integrity
8. pH	13. Chlorophyll A
9. Stream flow	14. Carlson's Trophic State Index
10. Water Temperature	15. Indiana Trophic State Index
11. *E. coli*	16. Hoosier Riverwatch Water Quality Index

The nine core parameters were selected for a number of reasons. First, they are useful information to know about every watershed, regardless of land use. Second, they are feasible for watershed project staff to monitor, even without extensive training or resources beyond what a watershed group can obtain. Finally, there is potential for these parameters to be measured by volunteers beyond the funded project.

In addition to the nine core parameters, nonpoint source projects are encouraged to monitor other parameters that can provide information that may be helpful in watershed management. Therefore, information is provided in this manual for the entire list of potential parameters, which many watershed groups monitor in Indiana. They were selected because they are the most likely to show management impacts, are sensitive to changes in management, and feasible for groups to monitor.

Monitoring protocols

State and federal agencies, as well as the statewide volunteer monitoring programs (Hoosier Riverwatch and Indiana Volunteer Lake Monitoring Program) all have protocols for monitoring. Watershed groups may select among these protocols in their monitoring program. They have been brought together in the ***Catalog of Monitoring Protocols Used by Indiana Agencies;*** a public web space designed to compile existing protocols used by statewide monitoring programs (Figure Intro.2), and is located at http://monitoringprotocols.pbworks.com/. Each statewide monitoring program has its own page at this site, which lists parameters that are collected by that program and any corresponding protocols (field and/or laboratory). If the protocols are available electronically, there is a direct link to either the document itself or a web site that houses the protocol information.

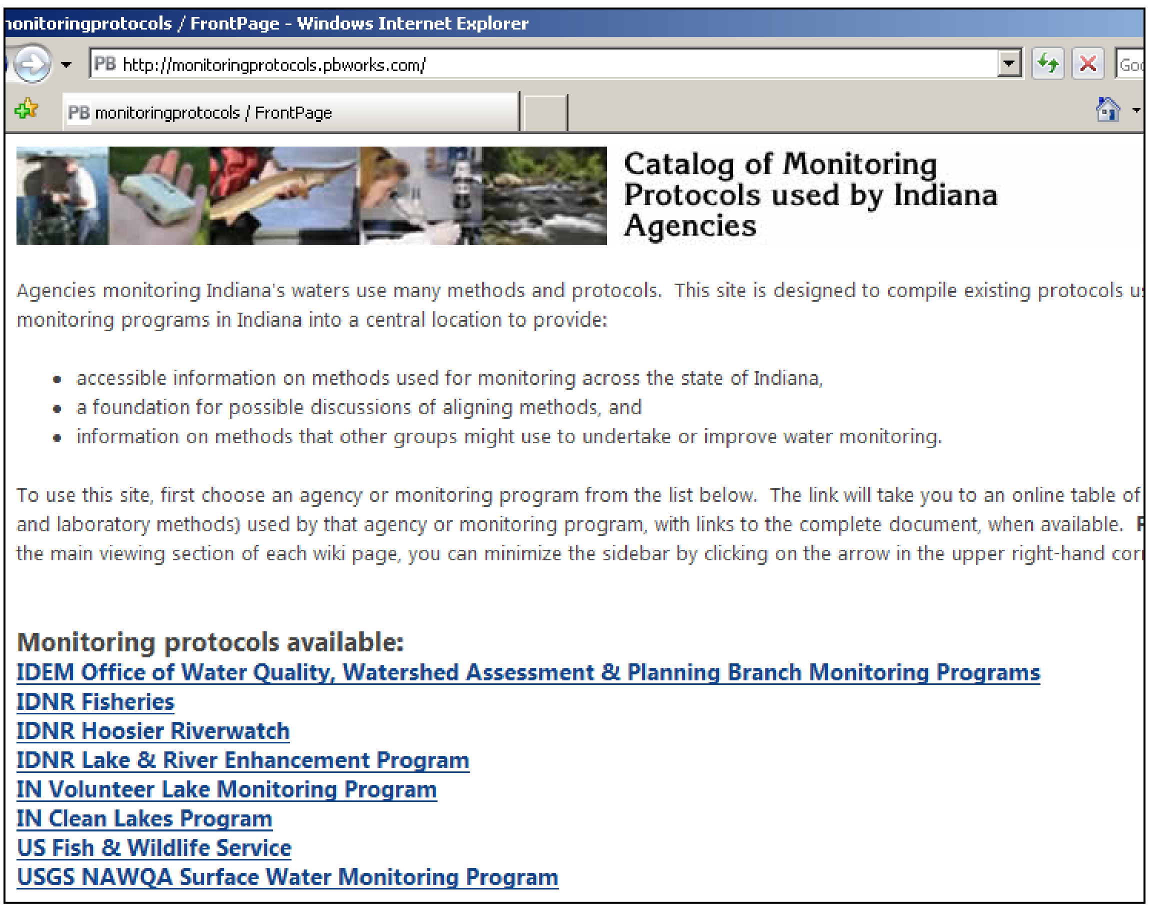


Figure I.2: Front Page of the Catalog of Monitoring Protocols Used by Indiana Agencies

Keeping the site current: Each monitoring program has identified a protocol steward, who will be responsible for ensuring the information provided on their protocols is complete and current, updating any links to documents or manuals, and providing the contact information for the program. Compiling this catalog was based on ideas developed by the Expert Panel. The compiled information relied on cooperation from many individuals, and forms the core of this manual.

Contributing to Coordination in Monitoring

Although not the original goal of this manual development, the process of developing it, together with the compilation of the Catalog of Monitoring Protocols, is linking monitoring programs in Indiana. This manual also benefited from the formation of the Indiana Water Monitoring Council in 2008. Many Expert Panel members were core organizers of the Indiana Water Monitoring Council, and we hope that these resources will continue to contribute to the Council's goals of "*enhancing the communication, collaboration, and coordination of professionals, organizations, and individuals involved in water monitoring within Indiana".* We welcome input to help this process expand and become even more valuable.

Specific uses for this manual in watershed planning

Writing a Nonpoint Source proposal for IDEM – This manual can help:

- identify your monitoring goals and define your monitoring strategy, including where you will monitor (how many sites) and what parameters you will monitor (core parameters are required; supplemental are optional);
- identify how samples will be collected and analyzed to estimate costs for your monitoring program;

Writing a Quality Assurance Project Plan – This manual can help you:

- identify where you will monitor (how many sites),
- determine what parameters you will monitor (core parameters are required; supplemental are optional),
- select methods appropriate for sample collection and analysis; and determine your monitoring goals.

Writing a Watershed Management Plan – This manual can help you:

- determine information that will help you calculate loads, identify critical areas, and accomplish your monitoring objectives.
- consider how your baseline characterization monitoring will influence how you can show change in your watershed

How this Manual is Organized

Most monitoring programs include chemical, physical and biological parameters, which all contribute to the ecological health of a water body as illustrated in Figure Intro.3 at right. This

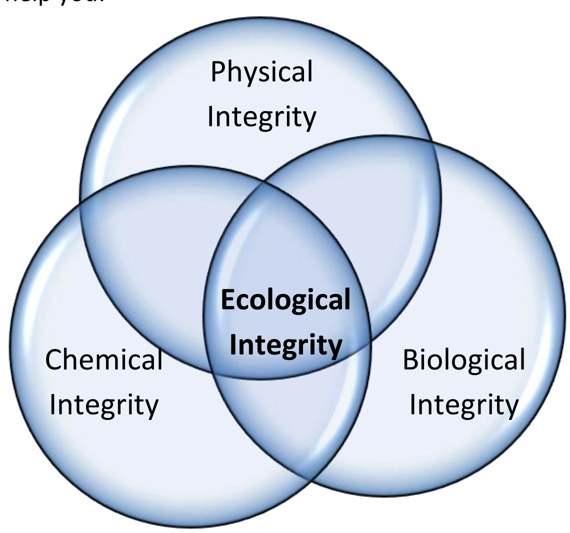


Figure I.3: Ecological integrity is attainable when chemical, physical, and biological integrity occur simultaneously. (Adopted from EPA, 1990) manual has been organized around these three basic types of monitoring activities. The 27 parameters are broadly divided in categories of Chemical Monitoring, Physical Monitoring, Biological Monitoring, and a few Indices that combine aspects of these different categories. Overviews of some groups of parameters are included, to help readers understand the various forms of nitrogen and phosphorus and how they are measured, the strengths and weakness of the different sediment measurement options, or the differences among macroinvertebrate indices.

For each parameter, the following information is provided:

- The **indicator**, which includes the units, an index where appropriate, and how the measurements are evaluated
- An overview of what the parameter is, and **who is monitoring that parameter in Indiana**. This resource includes hyperlinks to the monitoring protocols, where details on both field and laboratory analysis procedures can be found.
- **What the parameter indicates**. This section clarifies the importance of the parameter in assessing water condition, and why the parameter might be useful to monitor.
- **Method overview**. This section provides an idea of what is involved in conducting monitoring of this parameter, to help in planning. Instructions can be found in the hyperlinked information.
- **Typical levels in Indiana**. Data from existing monitoring sites in Indiana have been compiled to provide a range and median levels in Indiana. The statistics are often compiled by ecoregions, and a map is included for those who are not familiar with Indiana's ecoregions. These ranges, and in many cases a graph showing variation over time, are provided to help people have a better idea of what is typically found in Indiana streams and lakes. For people monitoring, it might help check that values are within the expected range, and for others it should be a useful overview of expected values. This section relies heavily on IDEM Fixed Station data, compiled by IDEM staff or at Purdue University, and Indiana Lakes data, compiled in two reports by Bill Jones and others.
- **Targets or protective levels**. This section provides any water quality standards in Indiana related to the parameter if they exist, or any criteria proposed in the state or nationally.
- **Resources needed**. This includes a rough estimate of equipment, time, expertise, and costs of monitoring the parameter, at the publication date of this manual.
- **References.** Sources of information are included, with direct hyperlinks if available.

Part 1: Parameters and Protocols

Chemical Monitoring

Chemical parameters include the following:

Nitrogen Overview

Nitrogen is a critical nutrient for plant growth, but too much nitrogen in the water can lead to eutrophication of streams and lakes. Nitrogen has also been identified as a major cause of hypoxia, or low oxygen, in the Gulf of Mexico. Sources of nitrogen include runoff from fertilized lawns, cropped fields, animal manure application and storage areas, wastewater treatment plants, failing septic systems, and industrial discharges. Nitrogen may be present in water in any of four forms: nitrate, nitrite, ammonia, or organic nitrogen. The sum of these four forms is known as "**total nitrogen**" (TN).

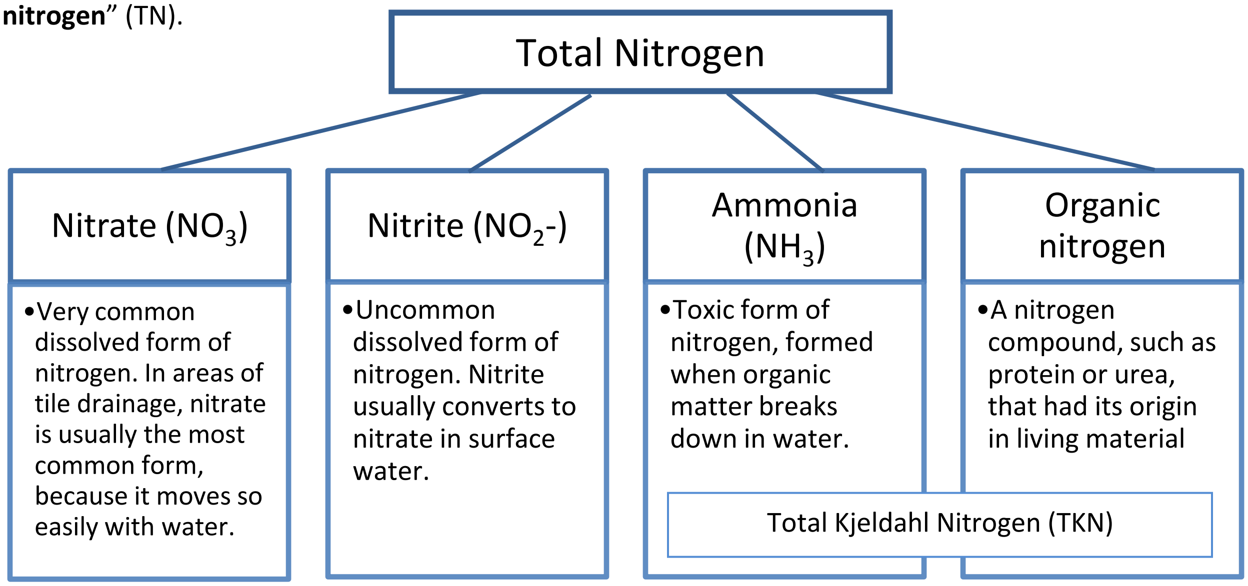


Figure N.1: Chemical forms of nitrogen in water.

Choices for Monitoring

Nitrate and nitrite are usually analyzed together, because the most common analysis involves converting nitrate to nitrite, then measuring both together. A separate test can give nitrite alone, which can be subtracted to give nitrate, but this is rarely done because there is usually very little nitrite in ambient water samples. Similarly, organic nitrogen and ammonia are usually analyzed together, in a process that starts with a digestion step to convert organic nitrogen to ammonia. The organic nitrogen and ammonia together are called Total Kjeldahl (pronounced kel-däl) Nitrogen or TKN, after the inventor of the test, Johan Kjeldahl. A separate test can be done for ammonia alone, without the digestion, to obtain values for ammonia or through subtraction for organic nitrogen. Total nitrogen can be analyzed in one step (which is done routinely only by the U.S. Geological Survey in Indiana) or calculated from the sum of nitrate+nitrite-N and TKN. Monitoring methods for four forms of nitrogen are therefore described in further detail in the following sections.

1. Nitrate+Nitrite (as N): Combination of nitrate + nitrite, expressed as the amount of nitrogen (N).
2. Ammonia: Ammonia can be analyzed separately, also expressed as N.
3. Total Kjeldahl Nitrogen (TKN): Combination of organic nitrogen + ammonia.
4. Total Nitrogen

1. Nitrate or Nitrate+Nitrite

Indicator: Average concentration (mg/L as N)

Nitrate is the major inorganic form of nitrogen, common in Indiana waters. Nitrate and nitrite are often combined, because analytic methods usually do not distinguish between these two forms of nitrogen. Because the *nitrite* portion is quickly converted to *nitrate* by bacteria, it is very uncommon in streams and lakes, so the total (nitrate plus nitrite) can be assumed to be close to the level of nitrate alone.

A potential source of confusion is that nitrate can either be reported as mg/L of nitrogen in the form of nitrate (often called nitrate-N) or in terms of mg/L of the nitrate molecule itself, which is 4.4 times greater. It is very important to distinguish these two. The concentrations in this manual are always for nitrate-N.

Table 1.1: Who's monitoring nitrate & nitrite in Indiana?

Agency	Field Collection Methods Used	Analysis Methods Used
IDEM Watershed Assessment & Planning Branch	IDEM Survey Section Field Procedure Manual	EPA 353.1, EPA 353.2, EPA 353.3
IDNR Lake & River Enhancement Program	IDEM Survey Section Field Procedure Manual (streams) IN Clean Lakes Program Procedure (lakes)	EPA 353.1, EPA 353.2, EPA 353.3 IN Clean Lakes Program Procedure
USGS National Water-Quality Assessment Program	National Field Manual Chapters 1-5	Open File Report 93-125 (USGS methods I-2545-90)
IN Clean Lakes Program	IN Clean Lakes Program Procedure	IN Clean Lakes Program Procedure
IDNR Hoosier Riverwatch	Volunteer Stream Monitoring Training Manual	WaterWorks™ Nitrate/Nitrite Test Strips (#480009)

What it indicates

Nitrate-N concentrations above about 1 mg/L indicate the influence of human activity (Smith et al. 2003). Elevated concentrations of nitrate can contribute to eutrophication. The limiting nutrient in freshwater lakes and streams is usually phosphorus, so elevated nitrate concentrations may not directly cause eutrophication in fresh water. However nitrate is a key cause of hypoxia in salt water, for example

Volunteer stream monitoring

in the Gulf of Mexico. Very high levels of nitrate (> 10 mg/L as N) also indicate a possible concern for drinking water.

Nitrate is not always introduced into the environment directly. The original nitrogen source causing high nitrate levels may have been fertilizer, organic nitrogen in soil or manure, treated wastewater, or other sources, which were converted into nitrate in the environment. Watersheds with a high percentage of tile-drained agricultural land often have particularly high levels of nitrate-N.

Method overview

Most nitrate monitoring consists of taking grab samples and sending them to a laboratory for analysis. Laboratory analysis usually consists of converting all forms of nitrogen to nitrite by using cadmium, then determining nitrite through measuring the color (colorimetry). This test can be done visually, comparing the treated sample to a set of reference colors. However, it is more accurate to use an electronic colorimeter. Volunteers also use simple methods like test strips or portable colorimeters to analyze nitrate in the field. Continuous nitrate samplers, which automate the cadmium reduction analysis method in the field have been developed but are very expensive (>$15,000). Electronic probes using ion-specific electrodes are available, but generally do not provide high-quality results at typical stream concentrations. New ultra-violet probes are a promising way to measure nitrate continuously, but cost approximately $25,000.

Nitrate values should be reported as milligrams per liter (mg/L) or parts per million (ppm) of nitrogen (or nitrate-N). If a sampling method measures the concentration of the nitrate molecule itself, divide by 4.4 to obtain the nitrate-N value in mg/L (or ppm). NOTE: mg/L is equivalent to ppm for substances dissolved in water, because the mass of one liter of water is 1 kg at standard temperature and pressure. 1 mg/kg equals 1 part per million.

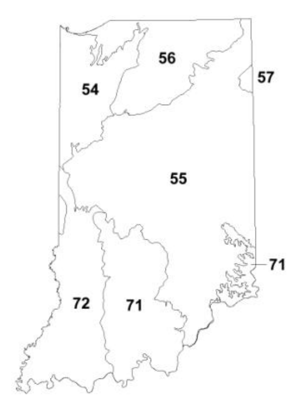
Typical levels in Indiana

As part of the development of this manual, nitrate concentrations from the 176 Fixed Stations monitored by IDEM since 1990 were analyzed to provide an overview of nitrate-N levels in Indiana (Table 1.2).

Table 1.2: Statistics for Nitrate+Nitrite Concentrations (mg/L) in Indiana waters by Level 3 Ecoregions (IDEM Fixed Station Data, 1990-2010)

No.	Ecoregion Name	No. of Samples	Min mg/L	25% mg/L	Median mg/L	75% mg/L	Max mg/L
54	Central Corn Belt Plains	5011	0.04	0.5	1.6	3.1	24
55	Eastern Corn Belt Plains	14056	0.04	1.6	2.9	4.6	960
57	Huron/Erie Lake Plain	222	0.4	1.9	2.8	4.1	16
56	S Michigan/N Indiana Drift Plains	4381	0.1	0.8	1.4	2.2	73
71	Interior Plateau	2914	0.05	1.2	2.1	2.9	11
72	Interior River Lowland	3803	0.1	1.2	2.2	3.6	14

Ecoregions of Indiana



Nitrate is generally higher in streams that drain agricultural watersheds, particularly when a large area is drained by subsurface tile drains. The concentration of nitrate-N in tile drains themselves is often above 10 mg/L (Brouder et al., 2005), and tile drains usually lead to higher concentrations in the receiving stream.

Seasonal variability in streams: Nitrate concentrations in streams are highly dependent on season, with values much higher in spring than in summer or fall. This is mainly the result of tile drains, which flow primarily in spring. Figure 1.1 below shows nitrate measurements for two years in a typical central Indiana stream. From December to June or July, the values are usually around 5 mg/L or greater, while in August to November, values are consistently less than 2 mg/L.

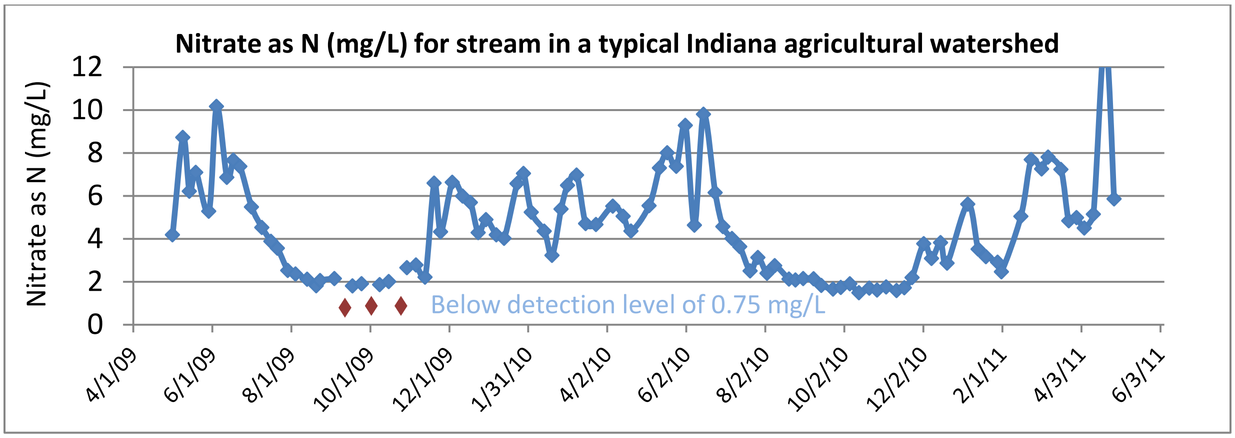


Figure 1.1: Nitrate variation in a typical Indiana stream

Lakes: Indiana lakes monitored by the Indiana Clean Lakes Program during 2010-2011 were found to have a median concentration of nitrate-N of 0.013 mg/L with a minimum concentration of 0.013 mg/L (detection limit) and a maximum concentration of 6.7 mg/L (Jones et al., 2012).

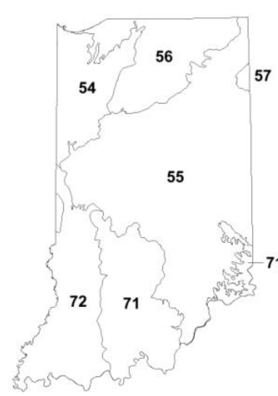
Targets or Protective levels

Indiana's Water Quality Standards do not currently include numeric criteria for nitrate-N or nitrate+nitrite. The U.S. EPA's proposed nutrient criteria for rivers and streams may be considered or used as benchmarks (USEPA, 2001). Criteria are proposed for each Indiana ecoregion below.

Table 1.3: EPA's Proposed Criteria for Nitrate+Nitrite Concentrations in Indiana waters by Level 3 Ecoregions

No.	Ecoregion Name	Nitrate (mg/L as N)
54	Central Corn Belt Plains	1.8
55	Eastern Corn Belt Plains	1.6
56	S Michigan/N Indiana Drift Plains	0.4
57	Huron/Erie Lake Plain	0.9
71	Interior Plateau	0.3
72	Interior River Lowland	0.2

Ecoregions of Indiana



Indiana's Consolidated Assessment Listing Methodology, which is based on both numeric and narrative criteria, is used to determine if stream reaches, lakes and reservoirs support the designated use of that waterbody or if the waterbody is impaired. (Box 1)

Box 1: Method for determining if stream reaches, lakes and reservoirs are impaired based on nutrients.

Based on IDEM's use of the narrative criteria in Indiana's WQS for nutrients, two or more of the following conditions for nutrient benchmarks must be met on the same date in order to classify a waterbody as impaired, assuming a minimum of three sampling events:

- Total Phosphorus: one or more measurements > 0.3 mg/L
- Nitrogen (measured as nitrate+nitrite): one or more measurements > 10.0 mg/L
- Dissolved Oxygen: measurements below or consistently at/close to the water quality standard or values greater than 12.0 mg/L (water quality standards are provided on page 45 under Targets or Protective Levels)
- pH: measurements above the water quality standard of 9.0 or are consistently at/close to the standard, in the range of 8.7-9.0
- Algal Conditions: algae are described as "excessive" based on field observations by trained staff

Nitrate-N levels above 10 mg/L exceed Indiana's drinking water standards (on an annual average basis) if the water is used for public water supply.

***Other Criteria, used elsewhere*:**

- Max: 1.0 mg/L - Ohio EPA recommended criteria for Warm Water Habitat (WWH) headwater streams and Modified Warm Water Habitat (MWH) headwater streams
- 1.5 mg/L - Dividing line between mesotrophic and eutrophic streams (Dodds et al. 1998)
- 10.0 mg/L IDEM draft TMDL target (IDEM, 2008)

Resources Needed

Table 1.4: Resources Needed for Monitoring Nitrate or Nitrate+Nitrite		
	Field Sampling	**Laboratory Analysis**
Equipment	Sample bottles; Hoosier Riverwatch method: Test strips; Kemmerer sampler (for lake samples only)	EPA Methods: Laboratory equipment such as a spectrophotometer or autoanalyzer;
Time	Test strips: 2 minutes/sample; 3-5 minutes per sample (for lakes)	Laboratory Analysis: Depends on equipment. Time must include making reagents and calibrations in addition to analysis.
Expertise	Low	Laboratory Analysis: High to very high, especially if using the data for publication or regulatory purposes.
Costs	Test strips: approximately $20 for a bottle of 50; Kemmerer samplers are generally $250-500	Laboratories generally charge $15 to $40 per sample for nitrate+nitrite.

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2. Ammonia Nitrogen

Indicator: Percent of days when ammonia concentration exceeds water quality standards

Table 2.1: Who's monitoring Ammonia Nitrogen in Indiana?		
Agency	**Field Collection Methods Used**	**Analysis Methods Used**
IDEM Watershed Assessment & Planning Branch	IDEM Surveys Section Field Procedure Manual	Standard Methods 4500-NH3(D), 4500-NH3(F) EPA 300.0, EPA 350.1, EPA 350.3
IDNR Lake & River Enhancement Program	IDEM Surveys Section Field Procedure Manual (streams) IN Clean Lakes Program Procedure (lakes)	Standard Methods 4500-NH3(D), 4500-NH3(F) EPA 300.0, EPA 350.1, EPA 350.3 IN Clean Lakes Program Procedure
USGS National Water-Quality Assessment Program	National Field Manual Chapters 1-5	Open File Report 93-125 (USGS methods I-2522-90)
IN Clean Lakes Program	IN Clean Lakes Program Procedure	IN Clean Lakes Program Procedure

Ammonia is a colorless gas with a strong pungent odor that is very soluble in water. NH_3 is the principal form of toxic ammonia.

What it indicates

Ammonia concentration is one indicator of whether the water can support aquatic life. Toxic levels depend on both pH and temperature; the higher the pH and the warmer the temperature, the more toxic the ammonia. Ammonia-N levels greater than approximately 0.1 mg/L usually indicate polluted waters.

Plants are more tolerant of ammonia than animals, and invertebrates are more tolerant than fish. When ammonia-N levels reach 0.06 mg/L, fish can suffer gill damage. When levels reach 0.2 mg/L, sensitive fish like trout and salmon begin to die. As levels near 2.0 mg/L, even ammonia-tolerant fish like carp begin to die. Such levels are uncommon in Indiana waterways and usually only last for a short time, and are unlikely to be captured by infrequent monitoring. Ammonia is therefore usually not a good parameter for assessing nonpoint source impacts.

Taking a water sample

Method overview

Most ammonia monitoring consists of taking grab samples and sending them to a laboratory for analysis. Monitoring and water quality models usually report total ammonia, and the un-ionized fraction must be estimated. Because ammonia is influenced by pH and temperature, it is critical to measure both pH and temperature at the same time as measuring ammonia.

Typical levels in Indiana

As part of the development of this manual, ammonia nitrogen concentrations from the 176 Fixed Stations monitored by IDEM since 1990 were analyzed to provide an overview of ammonia nitrogen levels in Indiana (Table 2.2).

Table 2.2: Statistics for Ammonia Nitrogen Concentrations (mg/L) in Indiana waters (IDEM Fixed Station Data, 1990-2010)

No. of Samples	Min (mg/L)	25% (mg/L)	Median (mg/L)	75% (mg/L)	Max (mg/L)
7578	0.01	0.1	0.2	0.3	162

Indiana lakes monitored by the Indiana Clean Lakes Program during 2010-2011 were found to have a median concentration of ammonia-N of 0.43 mg/L with a minimum concentration of 0.018 mg/L and a maximum concentration of 19.2 mg/L (Jones et al., 2012).

Targets or Protective levels

Indiana Water Quality Standards for regulating ammonia depend on temperature, pH, and maximum or 24-hour average ammonia concentrations.

- The **maximum ammonia concentration** (unionized ammonia as N) allowed in water quality standards ranges from 0.0075 mg/L (at 0 degrees C, pH=6.5) to 0.2137 mg/L (at 30 degrees C, pH=9.0).
- The **average ammonia concentration** (unionized ammonia as N) allowed in water quality standards ranges from 0.0005 mg/L as N (at 0 degrees C, pH=6.5) to 0.0294 mg/L (at 30 degrees C, pH=9.0).

The method for calculating total ammonia is located in the Indiana Administrative Code (IAC) 327 IAC 2-1-6.

Resources Needed

Table 2.3: Resources Needed for Monitoring Ammonia Nitrogen

	Field Sampling	Laboratory Analysis
Equipment	Sample bottles; Kemmerer sampler (for lake samples only)	EPA and standard methods: Autoanalyzer, ion chromatograph, or spectrophotometer
Time	3-5 minutes per sample	2-3 hours including making reagents
Expertise	Low	High, especially if using data for publication or regulatory purposes
Costs	Kemmerer samplers are generally $250-500	Laboratories generally charge $30 to $50 per sample.

References

Kentucky Department of Environmental Protection. [web page] Ammonia and Water Quality. http://www.kywater.org/ww/ramp/rmnh4.htm [Accessed 27 July 2011]

Hach Company. [web page] Important Water Quality Factors. http://www.h2ou.com/h2wtrqual.htm [Accessed 27 July 2011]

3. Total Kjeldahl Nitrogen

Indicator: Average concentration (mg/L)

Total Kjeldahl Nitrogen (TKN) is the sum of organic nitrogen and ammonia in a water body.

Table 3.1: Who's monitoring Total Kjeldahl nitrogen in Indiana?		
Agency	**Field Collection Methods Used**	**Analysis Methods Used**
IDEM Watershed Assessment & Planning Branch	IDEM Survey Section Field Procedure Manual	EPA 351.2, EPA 351.4, ASTM D3590-89 Standard Methods 4500 (Org)
IDNR Lake & River Enhancement Program	IDEM Survey Section Field Procedure Manual (streams) IN Clean Lakes Program Procedure (lakes)	EPA 351.2, EPA 351.4 Standard Methods 4500 (Org) IN Clean Lakes Program Procedure
IN Clean Lakes Program	IN Clean Lakes Procedure	EPA 351.2

What it indicates

High concentrations of TKN typically result from sewage and manure discharges to surface waters. Sources of TKN include decay of organic material (plants, animal waste, urban and industrial disposal of sewage and organic waste).

Method overview

Most TKN monitoring consists of taking grab samples, acidifying them, and sending them to a laboratory for analysis.

Typical levels in Indiana

As part of the development of this manual, TKN concentrations from the 176 Fixed Stations monitored by IDEM since 1990 were analyzed to provide an overview of TKN levels in Indiana (Table 3.2).

Table 3.2: Statistics for TKN Concentrations (mg/L) in Indiana waters (IDEM Fixed Station Data, 1990-2010)					
No. of Samples	**Min (mg/L)**	**25% (mg/L)**	**Median (mg/L)**	**75% (mg/L)**	**Max (mg/L)**
26064	0.1	0.5	0.7	1.1	28

Ammonia was usually about 10% of TKN, meaning that organic nitrogen is about 90% of the TKN.

Indiana lakes monitored by the Indiana Clean Lakes Program during 2010-2011 were found to have a median TKN concentration of 1.4 mg/L with a minimum concentration of 0.28 mg/L and a maximum concentration of 19.2 mg/L (Jones et al., 2012).

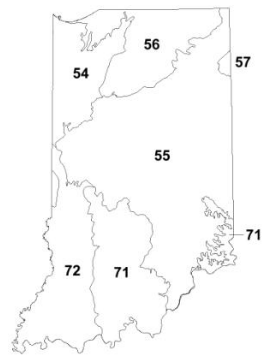
Targets or Protective levels

Indiana is currently developing nutrient criteria. Until these criteria are approved, the U.S. EPA's proposed nutrient criteria for rivers and streams may be used as benchmarks. Criteria are proposed for each Indiana ecoregion below.

Table 3.3: EPA's Proposed Criteria for TKN Concentrations in Indiana waters by Level 3 Ecoregions

No.	Ecoregion Name	TKN (mg/L)
54	Central Corn Belt Plains	0.66
55	Eastern Corn Belt Plains	0.4
56	S Michigan/N Indiana Drift Plains	0.58
57	Huron/Erie Lake Plain	0.65
71	Interior Plateau	0.28
72	Interior River Lowland	0.54

Ecoregions of Indiana



Resources Needed

Table 3.4: Resources Needed for Monitoring Total Kjeldahl Nitrogen

	Field Sampling	Laboratory Analysis
Equipment	Sample bottles; Kemmerer sampler (for lake samples only)	EPA and standard methods: Analytical laboratory equipment costs approximately $70,000 to $200,000
Time	3-5 minutes per sample	Approximately 8 hours if also making reagents
Expertise	Low	High, especially if using the data for publication or regulatory purposes
Costs	Kemmerer samplers are generally $250-500	Laboratories generally charge $25 to $60 per sample

References

Jones, W.W. 2004. Interpreting Lake Data – Indiana Clean Lakes Program. School of Public and Environmental Affairs, Indiana University, Bloomington, Indiana. Online at: http://www.indiana.edu/~clp/documents/Interpreting%20Lake%20Data.pdf [Accessed 27 July 2010].

Jones, W.W., M. Clark, J. Bond and S. Powers. 2012. Indiana Lake Water Quality Assessment Report for 2009 – 2011. School of Public and Environmental Affairs, Indiana University, Bloomington.

USEPA. 2001. Ecoregional Criteria Documents. Online at http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/criteria.cfm [Accessed 28 September 2011].

4. Total Nitrogen

Indicator: Average concentration (mg/L)

Total nitrogen is the sum of all forms of nitrogen including inorganic forms (nitrite, nitrate and ammonia) and organic nitrogen. Nitrogen can change forms, and total nitrogen is the analysis that provides information on all forms together.

Table 4.1: Who's monitoring total nitrogen in Indiana?

Agency	Field Collection Methods Used	Analysis Methods Used
USGS National Water-Quality Assessment Program	National Field Manual Chapters 1-5	WRIR 03-4174 (USGS methods I-4650-03)

What it indicates

Too much nitrogen in the water can lead to eutrophication of streams and lakes. Natural levels of total nitrogen in Midwestern streams are generally less than 1 mg/L, and levels above that usually indicate anthropogenic sources (Smith et al., 2003). Sources of nitrogen include runoff from fertilized lawns, agricultural lands, animal manure and storage areas, wastewater treatment plants, failing septic systems, and industrial discharges. These sources may supply organic nitrogen, nitrate, or other forms, but the nitrogen from any of these sources can change into other forms in water.

Method overview

Most total nitrogen monitoring consists of taking samples and sending them to a laboratory for analysis. Total nitrogen is often analyzed by adding chemicals to convert all of the nitrogen forms in a sample to nitrate, and then measuring nitrate using a colorimetric procedure. Because the method is more complex than simply measuring the nitrate form, total nitrogen is rarely monitored by volunteers.

Typical levels in Indiana

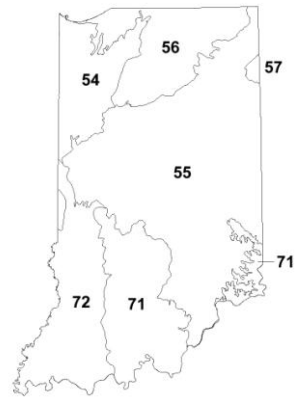
Although few agencies monitor total nitrogen as a single parameter, adding nitrate+nitrite with TKN results gives total nitrogen values. On average, 70% of the total nitrogen is in the form of nitrate, although the percentage varies widely depending on land use and tile drainage in the watershed.

Targets or Protective levels

There are no Indiana state water quality standards for total nitrogen. Indiana is currently developing nutrient criteria. Until these criteria are approved, the U.S. EPA's proposed nutrient criteria for rivers and streams may be used as benchmarks. Criteria are proposed for each Indiana ecoregion below.

Table 4.2: EPA's Proposed Criteria for Total Nitrogen Concentrations in Indiana waters by Level 3 Ecoregions		
No.	**Ecoregion Name**	**TN (mg/L)**
54	Central Corn Belt Plains	2.5-3.0
55	Eastern Corn Belt Plains	2.0-3.6
56	S Michigan/N Indiana Drift Plains	1.0-1.1
57	Huron/Erie Lake Plain	1.6-1.9
71	Interior Plateau	0.6-0.8
72	Interior River Lowland	0.8-1.7

Ecoregions of Indiana



Resources Needed

Table 4.3: Resources Needed for Monitoring Total Nitrogen		
	Field Sampling	**Laboratory Analysis**
Equipment	Sample bottles	USGS method: Continuous flow analyzer and other equipment needed for alkaline persulfate digestion.
Time	3-5 minutes per sample	Approximately 8 hours if also making reagents
Expertise	Low	High, especially if using data for publication or regulatory purposes
Costs	Staff time	Laboratories generally charge $40 to $100 per sample

References

Smith, R.A., R.B. Alexander, and G.E. Schwarz, 2003. Natural Background Concentrations of Nutrients in Streams and Rivers of the Conterminous United States. Environmental Science & Technology. 37(14): 3039-3047.

USEPA. 2001. Ecoregional Criteria Documents. Online at http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/criteria.cfm [Accessed 28 September 2011].

Phosphorus Overview

Phosphorus is a nutrient required for the basic processes of life, and is often the nutrient that limits the growth and biomass of algae in freshwater lakes and reservoirs. Nonpoint-source phosphorus comes from runoff from urban areas, construction sites, agricultural lands, manure transported in runoff from feedlots and agricultural fields, and human waste from failing septic systems. Point sources are wastewater treatment plants, industrial wastewater, and confined animal feeding operations.

Phosphorus terminology can be confusing because a particular form may be described either by its chemistry (i.e., orthophosphate or PO_4), or by what is measured by a particular test (i.e., soluble reactive phosphorus, which is the result of an analysis that includes filtration but not digestion).

Chemical forms of phosphorus

Phosphorus is found in three major chemical forms in water, with the sum of the three known as **total phosphorus**.

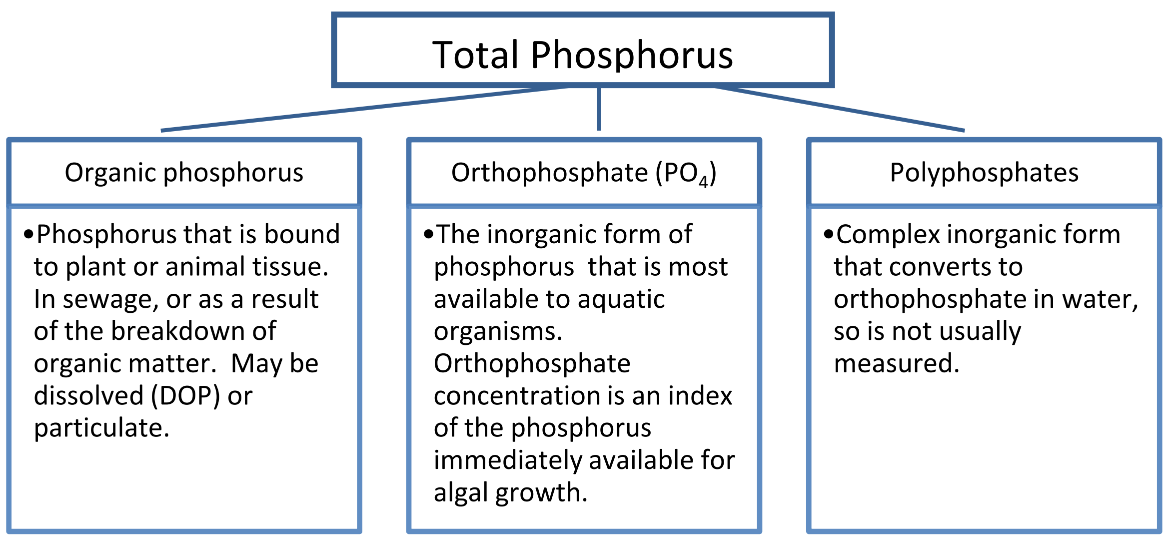


Figure P.1: Chemical forms of phosphorus in water

Methods for phosphorus analysis

The forms determined in analytical procedures are not the same as the chemical forms shown in Figure P.1, which can be confusing.

Phosphorus analysis is based on measuring the concentration of orthophosphate by letting it react with reagents that will change color, allowing the concentration to be measured based on color. The forms of phosphorus in addition to orthophosphate included in any analysis depend on which of the following processes are included:

- **Filtration**, which separates dissolved (soluble) from particulate (insoluble) by passing through a membrane filter with 0.45-micron pore size. Both inorganic and organic phosphorus can be soluble (dissolved) or particulate.
- **Digestion,** which converts organic phosphorus into the inorganic reactive form, orthophosphate. If digestion is included in the analysis, the result is either total phosphorus, or total soluble (or dissolved) phosphorus if filtration is included.
- **Hydrolysis,** which converts polyphosphates (hydrolysable phosphorus) to reactive orthophosphate. This analysis is uncommon in water monitoring.

For example, testing for *soluble reactive phosphorus* includes filtration but not digestion. The result of the test for soluble reactive phosphorus is generally assumed to be equal to orthophosphate, but because the test is not perfect, it may include a small fraction of some other forms. Therefore most scientific papers usually use the method-based term "soluble reactive phosphorus" for what is commonly referred to as orthophosphate. Similarly, more complex inorganic phosphate compounds are referred to as "condensed phosphates" or "polyphosphates", while the method-based term for these forms is "acid hydrolyzable." Various combinations of these steps are used in common analysis protocols to test for the following major forms:

- **Total phosphorus** (TP): The total of all forms of phosphorus, dissolved or particulate and reactive or non-reactive. Total phosphorus analysis includes digestion, but not filtration.
- **Soluble reactive phosphorus** (SRP): Usually equivalent to orthophosphate. The filterable (soluble) fraction of phosphorus that is reactive. SRP analysis includes filtration but not digestion.

Other forms can be obtained through various tests such as particulate phosphorus, which includes all forms captured on the filter including bacteria, algae, detritus, zooplankton, inorganic particulates such as clays; or total dissolved phosphorus, which is all of the phosphorus that passes through a 0.45 micron filter and may include orthophosphate, dissolved organic phosphorus, plus polyphosphates. This manual focuses on the **total phosphorus**, which is used for proposed nutrient criteria, and **orthophosphate**, which is the form of phosphorus most readily taken up by plants and also the easiest to measure.

Total phosphorus analysis requires digestion before analysis, a step that is not necessary for orthophosphate.

More information is at http://dipin.kent.edu/Phosphorus.htm, which includes an excellent discussion of forms, preservation, sampling techniques, etc.

5. Total Phosphorus

Indicator: Average concentration (mg/L)

Total phosphorus is the measure of all forms of phosphorus, dissolved or particulate, found in a water sample.

What it indicates

Phosphorus is usually the limiting nutrient in lakes and rivers, because it occurs in the least amount relative to the needs of plants. Eutrophication occurs when additional phosphorus is added to the water and excessive algae and aquatic plants are produced which use up oxygen when they die. Although only the dissolved inorganic form of phosphorus (orthophosphate) is readily available to algae or aquatic plants, other forms of phosphorus can be converted to orthophosphate. Therefore, *total phosphorus* is the most complete indicator of eutrophication potential, and is used in proposed nutrient criteria.

Table 5.1: Who's monitoring Total Phosphorus in Indiana?

Agency	Field Collection Methods Used	Analysis Methods Used
IDEM Watershed Assessment & Planning Branch	IDEM Surveys Section Field Procedure Manual	EPA 365.1 Standard Methods 4500P-E
IDNR Lake & River Enhancement Program	IDEM Survey Section Field Procedure Manual (streams) IN Clean Lakes Program (lakes)	EPA 365.1 Standard Methods 4500-F, 4500P-B, 4500P-E IN Clean Lakes Program Procedure
USGS National Water-Quality Assessment Program	National Field Manual Chapters 1-5	EPA 365.1 EPA 600/R-63/100
IN Clean Lakes Program	IN Clean Lakes Program Procedure	Standard Methods 4500P-B, 4500P-E
IN Volunteer Lake Monitoring Program	Expanded Volunteer Lake Monitoring Manual	Standard Methods 4500P-B, 4500P-E

Method overview

Most total phosphorus monitoring consists of taking grab samples, acidifying them, and sending them to a laboratory for analysis.

Typical levels in Indiana

As part of the development of this manual, total phosphorus concentrations from the 176 Fixed Stations monitored by IDEM since 1990 were analyzed to provide an overview of total phosphorus levels in Indiana (Table 5.2).

Table 5.2: Statistics for Total Phosphorus Concentrations (mg/L) in Indiana waters (IDEM Fixed Station Data, 1990-2010)

No. of Samples	Min (mg/L)	25% (mg/L)	Median (mg/L)	75% (mg/L)	Max (mg/L)
27516	0.02	0.07	0.12	0.22	4.58

Total phosphorus can be expressed as milligrams per liter (mg/L) or micrograms per liter (µg/L) which is 1000 times smaller.

Temporal variation: Total phosphorus varies considerably over time and is particularly sensitive to flow. Figure 5.1 shows Total Phosphorus for a typical stream in an agricultural area of Indiana. Most values are less than 0.02 mg/L, except during high flow events.

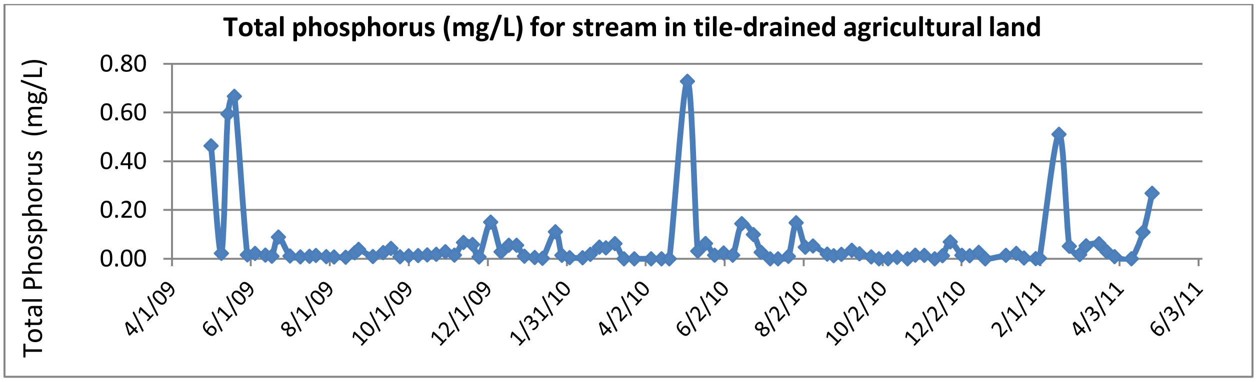


Figure 5.1: Typical variation in total phosphorus

Lakes: A compilation of data for 160 Indiana lakes collected during 2010-2011 by the Indiana Clean Lakes Program found a median concentration of total phosphorus of 0.071 mg/L with a minimum concentration of 0.010 mg/L and a maximum concentration of 0.82 mg/L (Jones et al., 2012).

A 2004-2008 compilation of data for 50 Indiana lakes (Jones and Powers, 2009) found the median total phosphorus concentration for each Indiana Ecoregion as:

0.05 mg/L in the Central Corn Belt Plains Ecoregion (54)
0.033 mg/L in the Eastern Corn Belt Plains Ecoregion (55)
0.034 mg/L in the Southern Michigan/Northern Indiana Drift Plains Ecoregion (56)
0.019 mg/L in the Interior Plateau Ecoregion (71)

Targets or Protective levels

Indiana’s Water Quality Standards do not include numeric criteria for total phosphorus. Indiana’s Consolidated Assessment Listing Methodology, which is based on both numeric and narrative criteria, is used to determine if stream reaches, lakes and reservoirs support the designated use of that waterbody or if the waterbody is impaired. Based on IDEM’s use of the narrative criteria in Indiana’s WQS for nutrients, two or more of the following conditions for nutrient benchmarks must be met on the same date in order to classify a waterbody as impaired, assuming a minimum of three sampling events:

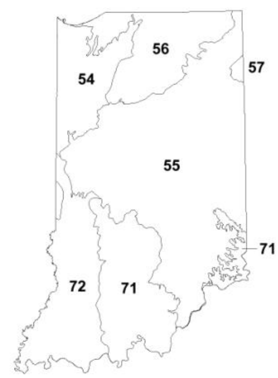
- Total Phosphorus: one or more measurements > 0.3 mg/L
- Nitrogen (measured as nitrate+nitrite): one or more measurements > 10.0 mg/L

- Dissolved Oxygen: measurements below or consistently at/close to the water quality standard or values greater than 12.0 mg/L (water quality standards are provided on page 45 under Targets or Protective Levels)
- pH: measurements above the water quality standard of 9.0 or are consistently at/close to the standard, in the range of 8.7-9.0
- Algal Conditions: algae are described as "excessive" based on field observations by trained staff

Indiana is currently developing nutrient criteria. Until these criteria are approved, the U.S. EPA's proposed nutrient criteria for rivers and streams may be used as benchmarks. Criteria are proposed for each Indiana ecoregion below.

Table 5.3: EPA's Proposed Criteria for Total Phosphorus Concentrations in Indiana waters by Level 3 Ecoregions		**Proposed Total Phosphorus (TP) criteria**	
No.	**Ecoregion Name**	**(mg/L)**	**(µg/L)**
54	Central Corn Belt Plains	0.07	70
55	Eastern Corn Belt Plains	0.062	62
56	S Michigan/N Indiana Drift Plains	0.031	31
57	Huron/Erie Lake Plain	0.07	70
71	Interior Plateau	0.03	30
72	Interior River Lowland	0.083	83

Ecoregions of Indiana



Other targets identified:

- 0.07 mg/L - Dividing line between mesotrophic and eutrophic streams (Dodds et al. 1998)
- Max: 0.08 mg/L - Ohio EPA recommendation to protect aquatic biotic integrity in warm water habitats
- Max: 0.3 mg/L - IDEM draft TMDL target (IDEM, 2008)
- Total phosphorus concentrations above 0.03 mg/L can promote nuisance algae blooms in lakes (Lillie and Mason 1983)

Resources Needed

Table 5.4: Resources Needed for Monitoring Total Phosphorus		
	Field Sampling	**Laboratory Analysis**
Equipment	Sample bottles; Kemmerer sampler (for lake samples only)	EPA and standard methods: Autoanalyzer or spectrophotometer
Time	3-5 minutes per sample	Approximately 8 hours if also making reagents
Expertise	Low	High, especially if using the data for publication or regulatory purposes.
Costs	Kemmerer samplers are generally $250-500	Laboratories generally charge $25 to $60 per sample

References

Correll, David L. 1998. The role of phosphorus in the eutrophication of receiving waters: a review. *J. Environ. Qual*., 27(2):261-266.

Dodds, W.K., Jones, J.R. and Welch E.B. 1998. Suggested Classification of Stream Trophic State: Distributions of Temperate Stream Types by Chlorophyll, Total Nitrogen, and Phosphorus. *Water Research* 32(5):1455-1462.

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Indiana Department of Natural Resources. Spring 2008. Volunteer Stream Monitoring Training Manual: Hoosier Riverwatch. Indianapolis, IN: Indiana Department of Natural Resources.

Jones, W.W. 2004. Interpreting Lake Data – Indiana Clean Lakes Program. School of Public and Environmental Affairs, Indiana University, Bloomington, Indiana. Online at: http://www.indiana.edu/~clp/documents/Interpreting%20Lake%20Data.pdf [Accessed 27 July 2010]

Jones, W.W. and Powers, S. 2009. Indiana Volunteer Lake Monitoring Report: 2004-2008. School of Public and Environmental Affairs, Indiana University, Bloomington, Indiana. Online at: http://www.indiana.edu/~clp/documents/2004_08%20Vol%20FINAL.pdf [Accessed 28 July 2010]

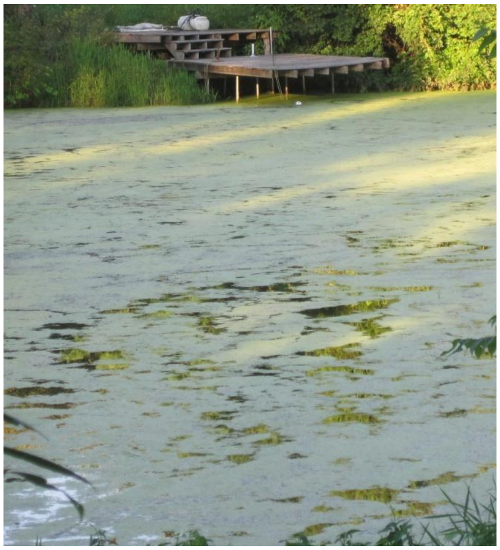
Jones, W.W., M. Clark, J. Bond and S. Powers. 2012. Indiana Lake Water Quality Assessment Report for 2009 – 2011. School of Public and Environmental Affairs, Indiana University, Bloomington.

Kent State University's Secchi Dip-In Web Site. [web page] Phosphorus. http://dipin.kent.edu/Phosphorus.htm [Accessed 28 July 2010]

Lillie, R.A. and Mason, J.W. 1983. Limnological characteristics of Wisconsin lakes. Technical Bulletin No. 138, Wisconsin Department of Natural Resources, 116 pgs. Online at: http://digital.library.wisc.edu/1711.dl/EcoNatRes.DNRBull138 [Accessed 15 February 2011]

Minnesota River Basin Data Center Web Site. 2004. Water Quality Overview-Phosphorus. http://mrbdc.wrc.mnsu.edu/mnbasin/wq/phosphorus.html [Accessed 28 July 2010]

USEPA. 2001. Ecoregional Criteria Documents. Online at http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/criteria.cfm [Accessed 28 September 2011].



Phosphorus is responsible for eutrophication in many Indiana ponds like this one.

6. Orthophosphate (also known as Soluble (or Dissolved) Reactive Phosphorus)

Indicator: Concentration (mg/L)

Orthophosphate is an inorganic form of phosphorus, a nutrient required for the basic processes of life but which also causes eutrophication in lakes and streams. The concentration of orthophosphate constitutes an index of the amount of phosphorus immediately available for algal growth.

Orthophosphate is easier to analyze than total phosphorus, which also includes organic forms of phosphorus, and is often used as the indicator of phosphorus concentration in a water body.

***Understanding the terms:* Is orthophosphate different from soluble reactive phosphorus?**

Most people use these terms interchangeably, but they are not technically the same.

Orthophosphate (ortho-P) is a chemical form of phosphorus, while soluble (or dissolved) reactive phosphorus is based on a specific analysis method. (See Phosphorus Overview for more information)

Table 6.1: Who's monitoring Orthophosphate in Indiana?

Agency	Field Collection Methods Used	Analysis Methods Used
IDEM Watershed Assessment & Planning Branch (SRP)	IDEM Surveys Section Field Procedure Manual	EPA 300.0, EPA 365.1, EPA 365.2
IDNR Lake & River Enhancement Program (SRP)	IDEM Surveys Section Field Procedure Manual (streams) IN Clean Lakes Program Procedure (lakes)	EPA 300.0, EPA 365.1, EPA 365.2 Standard Methods 4500-P E IN Clean Lakes Program Procedure
USGS National Water-Quality Assessment Program	National Field Manual Chapters 1-5	Open File Report 93-125 (USGS methods I-2601-90)
IN Clean Lakes Program (SRP)	IN Clean Lakes Program Procedure	Standard Methods 4500-P E
IDNR Hoosier Riverwatch (ortho-P)	Volunteer Stream Monitoring Training Manual	CHEMetrics Phosphate Test Kit K-8510

What it indicates

Orthophosphate is a good indicator of eutrophication potential because it is the form of phosphorus that is readily available to algae. It is typically found in very low concentrations in unpolluted waters. Eutrophication occurs when additional phosphorus is added to the water and excessive algae and aquatic plants are produced which use up oxygen when they die. The orthophosphate concentration indicates the amount readily available to algae or aquatic plants.

Method overview

Most orthophosphate monitoring consists of taking grab samples and either sending them to a laboratory for analysis or using a test kit for field analysis.

Typical levels in Indiana

Orthophosphate is often reported in milligrams per liter (mg/L) or in units 1000 times smaller, micrograms per liter (µg/L).

Indiana lakes monitored by the Indiana Clean Lakes Program during 2010-2011 were found to have a median concentration of SRP of 0.020 mg/L with a minimum concentration of 0.01 mg/L and a maximum concentration of 0.59 mg/L (Jones et al., 2012).

Orthophosphate is not measured by Indiana's Fixed Station program.

Targets or Protective levels

- SRP concentrations of 0.005 mg/L cause eutrophic or highly productive conditions in lake systems
- See total phosphorus targets

Resources Needed

Table 6.2: Resources Needed for Monitoring Orthophosphate (or Soluble Reactive Phosphorus)

	Field Sampling	Laboratory Analysis
Equipment	Sample bottles; Test kit; Kemmerer sampler (for lake samples only)	EPA and standard methods: Ion chromatograph, spectrophotometer, or colorimeter
Time	Test kit: less than 5 minutes/sample; 3-5 minutes per sample (for lakes)	Laboratory Analysis: 2-3 hours including making reagents
Expertise	Low	Medium
Costs	Test kit: approximately $60 for 30 samples; Kemmerer samplers are generally $250-500	Laboratories generally charge $20 to $50 per sample

References

Correll, David L. 1998. The role of phosphorus in the eutrophication of receiving waters: a review. *J. Environ. Qual.* 27(2):261-266.

Jones, W.W. 2004. Interpreting Lake Data – Indiana Clean Lakes Program. School of Public and Environmental Affairs, Indiana University, Bloomington, Indiana. Online at: http://www.indiana.edu/~clp/documents/Interpreting%20Lake%20Data.pdf [Accessed 27 July 2010]

Jones, W.W., M. Clark, J. Bond and S. Powers. 2012. Indiana Lake Water Quality Assessment Report for 2009 – 2011. School of Public and Environmental Affairs, Indiana University, Bloomington.

7. Biochemical Oxygen Demand

Indicator: Concentration (mg/L)

Table 7.1: Who's monitoring Biochemical Oxygen Demand in Indiana?		
Agency	**Field Collection Methods Used**	**Analysis Methods Used**
IDEM Watershed Assessment & Planning Branch	IDEM Assessment Branch Summary of Protocols: Probability Based Site Assessment	Standard Methods 5210B
IDNR Hoosier Riverwatch	Volunteer Stream Monitoring Training Manual	CHEMetrics Dissolved Oxygen Test Kit K-7512

Biochemical oxygen demand (BOD) is the measure of the amount of oxygen used by aerobic (oxygen-consuming) bacteria as they break down organic wastes over a specific time period.

What it indicates

Biochemical oxygen demand indicates the amount of organic pollution of water, which can include manure, sewage, and other organic matter that may use up oxygen in the stream. The greater the BOD, the more rapidly oxygen is depleted in the stream, which means less oxygen is available to higher forms of aquatic life. The consequences of high BOD are the same as those for low dissolved oxygen: aquatic organisms become stressed, suffocate, and die.

The rate of oxygen consumption in a stream is affected by a number of variables: temperature, pH, the presence of certain kinds of microorganisms, and the type of organic and inorganic material in the water.

Method overview

Most BOD monitoring consists of taking grab samples using black (light-free) sample bottles and sending them to a laboratory for analysis after a 5-day incubation period to obtain the BOD_5. Some volunteer monitoring programs analyze their own samples by measuring dissolved oxygen at the sampling site, then placing the light-free sample bottles in a light-free location at room temperature for 5 days. Then the dissolved oxygen of each sample is measured and the dissolved oxygen measured in the original sample taken 5 days prior is subtracted to obtain the BOD_5. It is critical to measure dissolved oxygen at the sampling site at the time the grab sample for BOD is collected to be able to calculate BOD_5.

Typical levels in Indiana

As part of the development of this manual, BOD concentrations from the 176 Fixed Stations monitored by IDEM since 1990 were analyzed to provide an overview of BOD levels in Indiana (Table 7.2).

Table 7.2: Statistics for Biochemical Oxygen Demand Concentrations (mg/L) in Indiana waters (IDEM Fixed Station Data, 1990-2010)					
No. of Samples	**Min (mg/L)**	**25% (mg/L)**	**Median (mg/L)**	**75% (mg/L)**	**Max (mg/L)**
7413	0.4	1.4	2	3.2	33

According to Hoosier Riverwatch's Volunteer Stream Monitoring Training Manual, biochemical oxygen demand typically ranges from 0.0 to 6.3 mg/L and the Indiana average is 1.5 mg/L.

Targets or Protective levels

Hoosier Riverwatch's guidance for Biochemical Oxygen Demand levels:

1-2 mg/L Clean water with little organic waste
3-5 mg/L Fairly clean with some organic waste
6-9 mg/L Lots of organic material and bacteria
10+ mg/L Very poor water quality; Very large amounts of organic material in water

Resources Needed

Table 7.3: Resources Needed for Monitoring Biochemical Oxygen Demand		
	Field Sampling	**Laboratory Analysis**
Equipment	Black (light-free) sample bottles; Test kit	EPA and standard methods: Incubator; Spectrophotometer and titration equipment
Time	2-3 minutes per measurement.	5 days
Expertise	Low	Low
Costs	Test kit: approximately $90 for 30 samples; Probe: several hundred dollars for meter with single functions, several thousand dollars for multi-parameter probes	Laboratories generally charge $20 to $100 per sample

References

Indiana Department of Natural Resources. Spring 2008. Volunteer Stream Monitoring Training Manual: Hoosier Riverwatch. Indianapolis, IN: Indiana Department of Natural Resources.

United States Environmental Protection Agency, Office of Water. 1997. Volunteer Stream Monitoring: A Methods Manual. EPA 841-B-97-003. Online at: http://www.epa.gov/volunteer/stream/vms52.html [Accessed 27 July 2010]

Physical Monitoring

Physical parameters include the following:

Sediment Overview

Why sediment is a core indicator

Measuring the amount of suspended particulate matter in water is important when assessing impacts to aquatic life diversity and habitat. As suspended sediment concentration increases, a water body begins to lose its ability to support a diversity of aquatic life. Suspended solids absorb heat from sunlight, which increases water temperature and subsequently decreases levels of dissolved oxygen (warmer water holds less oxygen than cooler water). Photosynthesis also decreases, since less light penetrates the water.

Suspended solids can also destroy fish habitat because they settle to the bottom and can eventually blanket the riverbed, smothering the eggs of fish and aquatic insects, and suffocating newly-hatched insect larvae. Suspended materials can also harm fish directly by clogging gills, reducing growth rates, and lowering resistance to disease. Changes to the aquatic environment may result in diminished food sources, and increased difficulties in finding food. Natural movements and migrations of aquatic populations may also be disrupted.

Sediment-laden runoff from a field can increase sediment concentration in the stream.

Three sediment measures

This section of the manual describes three ways to monitor water quality for sediment; suspended sediment concentration (SSC), total suspended solids (TSS), and turbidity. Although these three sediment measures are related and indicate the same problems found within the environment, the analytical methods used to measure them and their results differ significantly. Therefore, results are not comparable.

As stated in the introduction of this manual, IDEM has determined sediment as a core indicator, measured using either TSS or turbidity. Therefore, those projects that receive 319 funding for monitoring should collect TSS or turbidity.

Table S.1 provides advantages and disadvantages to the different sediment indicators is provided to assist in choosing one that is appropriate for your project needs.

Calculating sediment load

Turbidity is a good indicator of stresses to the aquatic system from sediment, but it cannot directly be used to calculate sediment loads. Projects that are developing watershed plans to meet 319 requirements must estimate annual sediment load, which can be done either by measuring TSS from time to time (for example monthly) or by using a model to estimate sediment load.

Table S.1: Advantages and Disadvantages of Three Sediment Measures		
	Advantages	**Disadvantages**
Suspended Sediment Concentrations (SSC)	The most scientifically-sound measure of sediment concentration.	Laboratory analysis costs are similar to TSS but fewer labs analyze SSC. Therefore, it may be difficult to locate a lab convenient for your project.
Total Suspended Solids (TSS)	Required for wastewater analysis, so widely available including at any wastewater treatment plant.	Does not only measure sediment, but might also include phytoplankton and other organic matter. Also, analysis is performed only on a subsample, so if sediment is not perfectly mixed may be less accurate.
Turbidity	A direct indicator of visibility in the water, which can be important to aquatic organisms. Least expensive and can be done by volunteers (secchi disk; transparency tube). Can also be measured continuously by a probe. If calibrated with regular SSC measurements, a turbidity probe can be the most accurate way to estimate sediment load.	Does not directly give sediment concentrations, so cannot be used for estimation of sediment load without a calibration curve for sediment.

8. Suspended Sediment Concentration

Indicator: Average concentration (mg/L)

Table 8.1: Who's monitoring Suspended Sediment Concentration in Indiana?		
Agency	**Field Collection Methods Used**	**Analysis Methods Used**
USGS National Water-Quality Assessment Program	National Field Manual Chapters 1-5	ASTM D-3977
Note: Other agencies usually measure TSS, so are not included here.		

Suspended sediment concentration (SSC) is a measure of the solid-phase material suspended in a water-sediment mixture and is usually expressed in mg/L. SSC and total suspended solids (TSS) are often used interchangeably, but the analytical procedures differ and can produce considerably different results. SSC data are produced by measuring the dry weight of all the sediment from a known volume of a water-sediment mixture, compared to TSS methods that generally measure the dry weight of solids from a known volume of a subsample of the original.


US DH-81 depth-integrating sampler used by the U.S. Geological Survey.

What it indicates

Regular monitoring of suspended sediments can help detect trends that might indicate increasing erosion in developing watersheds. However, suspended sediment concentration is closely related to stream flow and velocity, so the concentration of suspended sediment should also be correlated with these factors. Comparisons of the change in SSC over time, therefore, should be made at the same sampling point under the same flow conditions.


U.S. Geological Survey staff sampling the water column of a stream using a depth-integrating sampler.

Method overview

The U.S. Geological Survey (USGS) uses an equal width increment sampling method across rivers and streams so sampling points are equal distance from each other. They also use an isokinetic sampler to evenly sample the entire water column at each sampling point. Once the water samples are collected, they are shipped to a laboratory for analysis.

Typical levels in Indiana

Most monitoring programs collect TSS rather than SSC so few measurements are available.

Targets or Protective levels

Target concentrations of suspended sediment:

Max: 25.0 mg/L   U.S. EPA recommendation for excellent fisheries

25.0-80.0 mg/L   U.S. EPA recommendation for good to moderate fisheries

Resources Needed

Table 8.2: Resources Needed for Monitoring Suspended Sediment Concentration		
	Field Sampling	**Laboratory Analysis**
Equipment	Sample bottles; (optional) Isokinetic sampler	EPA and standard methods: Drying oven, desiccators, and analytical balance.
Time	3-5 minutes per sample	Approximately 4 hours over 2 days
Expertise	Low	High, especially if using the data for publication or regulatory purposes.
Costs	Isokinetic samplers are generally $1500-$7000	Laboratories generally charge $20 to $35 per sample*

*If you are interested in monitoring SSC and cannot locate a laboratory to analyze samples, the US Geological Survey's Kentucky Water Science Center will analyze samples for non-USGS customers. Their requirements include:

- USGS requires an agreement with an entity that has a DUNS number (Data Universal Numbering System). NOTE: If you have received a federal grant, you likely have a DUNS number.
- Completed forms with their Administrative Officer
- Minimum order of $3,000 (can extend across fiscal years)

For information on the laboratory, forms, and a price list, visit: http://ky.water.usgs.gov/technical_info/dist_sedlab_files/sed_lab.htm

References

Gray, J.R., Glysson, G.D, Turcios, L.M. and Schwarz, G.E. 2000. Comparability of Suspended-Sediment Concentration and Total Suspended Solids Data. U.S. Geological Survey, Water Resources Investigations Report 00-4191, Reston, VA. Online at: http://www.comm-tec.com/Library/technical_papers/Various/b/WRIR00-4191.pdf [Accessed 12 August 2010]

9. Total Suspended Solids

Indicator: Concentration (mg/L)

A total suspended solids (TSS) measurement quantifies all particles suspended and dissolved in water. Suspended materials include soil particles (clay, silt, and sand), algae, plankton, microbes, and other substances, which are typically in the size range of 0.004 mm (clay) to 1.0 mm (sand). Suspended solids are regulated in sanitary wastewater and many types of industrial wastewater. Nonpoint sources of suspended solids include soil erosion from agricultural and construction sites.

Table 9.1: Who's monitoring Total Suspended Solids in Indiana?

Agency	Field Collection Methods Used	Analysis Methods Used
IDEM Watershed Assessment & Planning Branch	IDEM Surveys Section Field Procedure Manual	EPA 160.2 Standard Methods 2540-D
IDNR Lake & River Enhancement Program	IDEM Surveys Section Field Procedure Manual	EPA 160.2 Standard Methods 2540-D
IN Clean Lakes Program	IN Clean Lakes Program Procedure	Standard Methods 2540-D

What it indicates

Total suspended solids (TSS) indicates the same problems occurring within the environment as other sediment measures. See the description provided under Sediment Overview. TSS and SSC differ by the analytical methods used to measure them and the results can differ significantly. Therefore, they are not comparable.

Method overview

Most total suspended solids monitoring consists of taking grab samples and sending them to a laboratory for analysis.

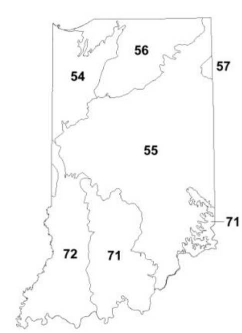
Typical levels in Indiana

In developing this manual, TSS concentrations from the 176 Fixed Stations monitored by IDEM since 1990 were analyzed to provide an overview of TSS levels in Indiana (Table 9.2).

Table 9.2: Statistics for Total Suspended Solids Concentrations in Indiana waters by Level 3 Ecoregions (IDEM Fixed Station Data, 1990-2010)

No.	Ecoregion Name	No. of Samples	Min mg/L	25% mg/L	Median mg/L	75% mg/L	Max mg/L
54	Central Corn Belt Plains	4134	1	7	12	23	656
55	Eastern Corn Belt Plains	12842	1	9	19	42	2740
57	Huron/Erie Lake Plain	219	4	24	43	77	372
56	S Mich./N Ind. Drift Plains	3609	2	6	10	18	376
71	Interior Plateau	2534	2	8	17	35	1480
72	Interior River Lowland	3836	4	25	48	81	2100

Ecoregions of Indiana



Targets or Protective levels

IDEM draft TMDL target from NPDES rule for lake dischargers (327 IAC 5-10-4) is a maximum of 30 mg/L (monthly average concentration for winter limits for small sanitary treatment plants).

According to the Michigan Department of Environmental Quality, general perceptions of water and TSS concentrations include (composition of the suspended solids may cause numbers to vary):

- Less than 20 mg/L, water is clear
- 40-80 mg/L, water is cloudy
- Greater than 150 mg/L, water is dirty

Target concentrations of Total Suspended Solids:

Max: 25 mg/L Concentrations above this value reduce fish concentrations (Waters 1995)
Max: 40 mg/L New Jersey criteria for warm water streams
Max: 46 mg/L Minnesota TMDL criteria for the protection of fish/macroinvertebrate health

Resources Needed

Table 9.3: Resources Needed for Monitoring Total Suspended Solids

	Field Sampling	Laboratory Analysis
Equipment	Sample bottles; Kemmerer sampler (for lake samples only)	EPA and standard methods: Drying oven, desiccators, and analytical balance.
Time	3-5 minutes per sample	Approximately 2 hours over 2 days
Expertise	Low	High, especially if using the data for publication or regulatory purposes.
Costs	Kemmerer samplers are generally $250-500	Laboratories generally charge $15 to $60 per sample

References

Michigan Department of Environmental Quality. [web page] Total Suspended Solids. http://www.michigan.gov/documents/deq/wb-npdes-TotalSuspendedSolids_247238_7.pdf [Accessed 12 August 2010]

Waters, T.F. 1995. Sediments in streams—Sources, biological effects, and control. American Fisheries Society Monograph 7, Bethesda, Maryland.

10. Turbidity or Transparency

Indicator: Nephelometric Turbidity Units (NTUs) and Secchi Depth (feet)

Turbidity and transparency are both measures of water clarity. Turbidity and transparency are not measures of the concentration of suspended materials in water, but rather their scattering and shadowing effect on light shining through the water. Suspended materials include soil particles (clay, silt, and sand), algae, plankton, microbes, and other substances, which are typically in the size range of 0.004 mm (clay) to 1.0 mm (sand).

Turbidity is a measure of how much the material suspended in water decreases the passage of light through the water, and is generally measured using a turbidity meter. Transparency measures how far light can penetrate a body of water and can be measured using a secchi disk or transparency tube.

Table 10.1: Who's monitoring Turbidity in Indiana?

Agency	Field Collection Methods Used	Analysis Methods Used
IDEM Watershed Assessment & Planning Branch	IDEM Surveys Section Field Procedure Manual	Datasonde: Standard Method 2130-B Hach™ turbidity kit: EPA 180.1
IDNR Lake & River Enhancement Program	IN Clean Lakes Program Procedure (lakes)	Secchi disk
IDNR Fisheries	Manual of Fishery Survey Methods	Secchi disk
IDNR Hoosier Riverwatch	Volunteer Stream Monitoring Training Manual	Transparency tube
USGS National Water-Quality Assessment Program	National Field Manual Chapter 6.7.3	Standard Methods 2130
IN Clean Lakes Program	IN Clean Lakes Program Procedure	Secchi disk
IN Volunteer Lake Monitoring Program	Volunteer Lake Monitoring Manual	Secchi disk

What they indicate

Turbidity and transparency indicate the visibility distance in water, which directly affects aquatic organisms. Turbidity can provide food and shelter for pathogens, and therefore has been used as a proxy or surrogate for bacterial pollution. The same conditions that cause stormwater runoff that carries *E. coli* will also cause high turbidity. It also affects the difficulty of treating water for drinking. Turbidity can be used for screening a watershed to determine likely sources, understanding how water quality changes seasonally and in response to precipitation, upstream and downstream of a site of interest, or monitoring inputs to the stream, or understanding long term water quality.

Turbidity and transparency are dependent upon the amount of suspended materials (algae and sediments) that are present in the water. Excessive amounts of these materials can be an indication of eutrophication.

Secchi Disk to measure transparency

Method overview

Turbidity is measured in rivers most often using a turbidity meter or transparency tube, but some stream monitoring programs also use a secchi disk. To use a transparency tube, sample water is collected into a bucket or other container, thoroughly mixed, and then poured into a calibrated transparency tube until the symbol on the bottom of the tube is no longer visible. The depth of water in the tube is then recorded in centimeters, which are marked on the side of the tube. Another way is to fill the tube, then while looking vertically down into the tube, release water until the symbol on the bottom of the tube is barely visible. Transparency is most often measured in lakes using a secchi disk. The secchi disk is suspended over the shady side of a boat and the depth at which the secchi disk disappears is noted. The disk is then lowered further and raised until it reappears. The mean depth between where the disk disappears and reappears is the transparency measurement.

Volunteer using a transparency tube to measure turbidity

Typical levels in Indiana

As part of the development of this manual, turbidity concentrations from the 176 Fixed Stations monitored by IDEM since 1990 were analyzed to provide an overview of turbidity levels in Indiana (Table 10.2).

Table 10.2: Statistics for Turbidity Concentrations (NTU) in Indiana waters (IDEM Fixed Station Data, 1990-2010)

No. of Samples	**Min** (mg/L)	**25%** (mg/L)	**Median** (mg/L)	**75%** (mg/L)	**Max** (mg/L)
24400	0.0	7.9	15	35.6	2150

Temporal variability in streams: Turbidity varies strongly over a short time scale, usually increasing sharply when stream flow increases. Figure 10.1 shows 15-minute turbidity data with USGS streamflow for a 40-day period in summer. Turbidity was usually less than 10 NTU, except during storm events when it rose as high as 400 NTU.

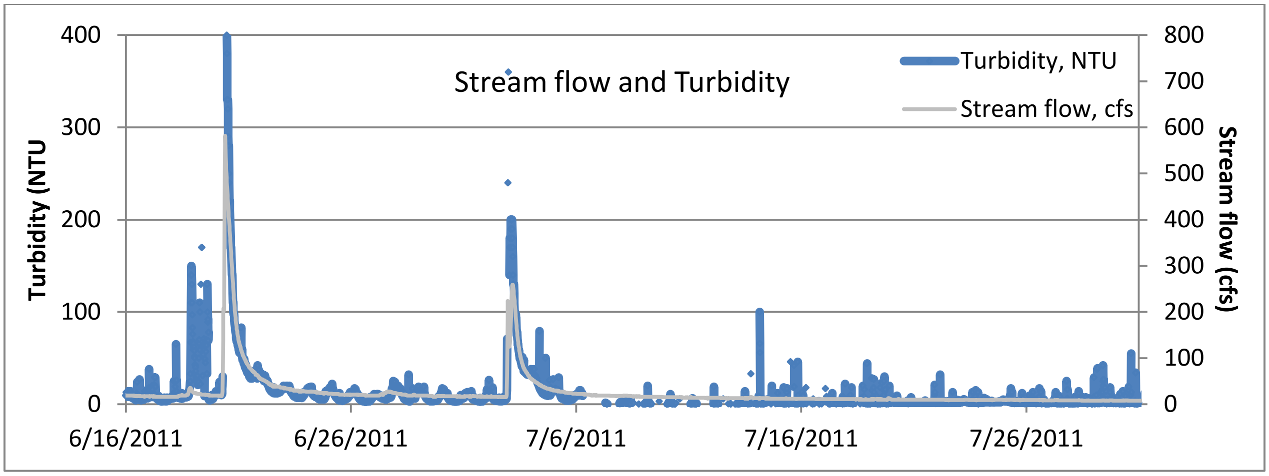


Figure 10.1: Stream flow and turbidity for an Indiana agricultural stream.

Transparency: A compilation of data for 160 Indiana lakes collected during 2010-2011by the Indiana Clean Lakes Program found a median secchi depth of 5.2 feet with a minimum depth of 0.7 feet and a maximum depth of 20.3 feet (Jones et al., 2012).

A 2004-2008 compilation of data for 120 Indiana lakes found the median secchi disk depth for each Indiana Ecoregion as:

6 feet in the Central Corn Belt Plains Ecoregion (54)
4 feet in the Eastern Corn Belt Plains Ecoregion (55)
5.8 feet in the Southern Michigan/Northern Indiana Drift Plains Ecoregion (56)
3.1 feet in the Interior Plateau Ecoregion (71)

Targets or Protective levels

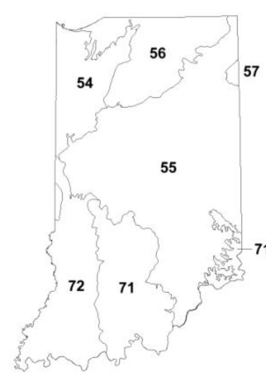
Turbidity:
The U.S. EPA's proposed nutrient criteria for rivers and streams include turbidity, which are shown for each Indiana ecoregion below (Table 10.3).

Table 10.3: EPA's Proposed Criteria for Turbidity in Indiana waters by Level 3 Ecoregions

No.	Ecoregion Name	Turbidity (NTU)
54	Central Corn Belt Plains	14
55	Eastern Corn Belt Plains	10.4
56	S Michigan/N Indiana Drift Plains	14.5
57	Huron/Erie Lake Plain	*
71	Interior Plateau	7.0
72	Interior River Lowland	15

*data inadequate or inconclusive

Ecoregions of Indiana



- Max: 10.0 NTU Minnesota Water Quality Standards for Class 2A waters (cold water fishery, all recreation)
- Max: 25.0 NTU Minnesota Water Quality Standards for Class 2B waters (cool and warm water fishery, all recreation) and Class 2C waters (indigenous fish, most recreation)
- Max: 10.4 NTU U.S. EPA recommendation

Transparency:

- Lakes with secchi depths less than 5 feet possess poor water quality

Resources Needed

Table 10.4: Resources Needed for Monitoring Turbidity or Transparency

	Field Sampling		**Laboratory Analysis**
	Turbidity	**Transparency**	
Equipment	Turbidity meter	Secchi disk (lake); Transparency tube (streams)	No laboratory analysis needed
Time	3-5 minutes per sample	Approximately 5 minutes per sample	
Expertise	Low; Training required.	Low; Training required.	
Costs	$700-$1300	Secchi disk $25 to $75; Transparency tube $40 to $60.	

References

Carlson, R.E. 1977. A trophic state index for lakes. Limnology and Oceanography, 22(2):361-369

Indiana Department of Natural Resources. Spring 2008. Volunteer Stream Monitoring Training Manual: Hoosier Riverwatch. Indianapolis, IN: Indiana Department of Natural Resources.

Jones, W.W. and Powers, S. 2009. Indiana Volunteer Lake Monitoring Report: 2004-2008. School of Public and Environmental Affairs, Indiana University, Bloomington, Indiana. Online at: http://www.indiana.edu/~clp/documents/2004_08%20Vol%20FINAL.pdf [Accessed 28 July 2010]

Jones, W.W., M. Clark, J. Bond and S. Powers. 2012. Indiana Lake Water Quality Assessment Report for 2009 – 2011. School of Public and Environmental Affairs, Indiana University, Bloomington.

Minnesota Pollution Control Agency. [web page] Administrative Rules Chapter 7050.0222, https://www.revisor.mn.gov/rules/?id=7050.0222 [Accessed 27 September 2011]

United States Environmental Protection Agency, Office of Water. 1997. Volunteer Stream Monitoring: A Methods Manual. EPA 841-B-97-003. Online at: http://www.epa.gov/volunteer/stream/vms55.html [Accessed 29 July 2010]

USEPA. 2001. Ecoregional Criteria Documents. Online at http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/criteria.cfm [Accessed 28 September 2011].

Habitat Overview

Why habitat is a core indicator

According to Karr et al. 1986, one of the major stressors to an aquatic system is altered habitat structure. As land use changes due to development pressures outside of traditional urban areas, rivers and streams are subject to physical changes (erosion, channelization, etc.) and the effects of non-point source stressors, such as runoff from impervious surfaces and agriculture carrying additional sediment. Therefore, assessing instream and nearshore habitat using habitat measures is important to document the physical condition of streams to determine where restoration is needed and to show improvement over time.

Two habitat measures

This section of the manual describes two ways to assess habitat; Qualitative Habitat Evaluation Index (QHEI) and Citizens Qualitative Habitat Evaluation Index (CQHEI). As stated in the introduction of this manual, IDEM has determined habitat as a core indicator, measured using either QHEI or CQHEI. Therefore, those projects that receive 319 funding for monitoring should collect QHEI or CQHEI, using IDEM and Hoosier Riverwatch methods, respectively.

In Indiana, QHEI has traditionally been collected at the same time as biological sampling (fish and/or macroinvertebrates) to provide an accurate assessment of the ecological integrity of a stream site, and for official purposes such as 303(d) listing, IDEM requires collection of habitat and biology together. Biological sampling requires expensive equipment and extensive training for taxonomic identification which are often beyond the capacity of a watershed group's abilities. However, for the purposes of the Non-Point Source program, it is important to assess stream habitat and restoration opportunities and not necessarily the biological condition. This can be accomplished by assessing QHEI alone or by collecting CQHEI.

References

Karr, J.R., K.D. Fausch, P.L. Angermeier, P.R. Yant, and l.J. Schlosser. 1986. *Assessing biological integrity in running waters: A method and its rationale.* Special publication 5. Illinois Natural History Survey.

Habitat influences the integrity of many Indiana streams.

11. Qualitative Habitat Evaluation Index (QHEI)

Indicator: QHEI index values, ranging from 0 to 100

The Qualitative Habitat Evaluation Index (QHEI) is a physical habitat index that was developed by the Ohio Environmental Protection Agency in 1989 to evaluate major stream and river habitat characteristics important to biological communities. The QHEI is composed of six metrics (Table 11.2), each designed to evaluate a different portion of the stream, and when added together, a total QHEI score is produced ranging from 0-100. A higher score is indicative of better stream habitat for aquatic biological communities.

Table 11.2: Metrics, Components and Maximum Scores per Metric for QHEI

Metric	Metric Component	Max Score
Substrate	• Type • Origin • Quality	20
Instream Cover	• Type/Presence • Amount	20
Channel Morphology	• Sinuosity • Development • Channelization • Stability	20
Bank Erosion and Riparian Zone	• Bank Erosion • Riparian Width • Flood Plain Quality	10
Pool/Glide Quality and Riffle/Run Quality	• Max Depth • Channel Width • Current Velocity • Riffle/Run Depth • Substrate Stability and Embeddedness	20
Map Gradient	• Uses Gradient and Drainage Area	10

Table 11.1: Who's monitoring QHEI in Indiana?

Agency	Field Methods Used
IDEM Watershed Assessment & Planning Branch	IDEM 2010 Probabilistic Monitoring Work Plan (p. 22) Ohio EPA QHEI Methods IDEM QHEI datasheet
IDNR Fisheries	Manual of Fishery Survey Methods
IDNR Lake & River Enhancement Program	IDEM 2010 Probabilistic Monitoring Work Plan (p. 22) Ohio EPA QHEI Methods IDEM QHEI datasheet
US Fish & Wildlife Service	Chapter 3: Methods for the Assessment of Habitat using the Qualitative Habitat Evaluation Index (QHEI) (Simon 2000)

What it indicates

The QHEI was initially written to provide information on a stream's ability to support fish communities by evaluating instream habitat and the land that surrounds it; however the QHEI has been modified to evaluate lake habitats (Thoma, 2006) and macroinvertebrate community habitat.

Method overview

Completing a QHEI consists of filling out a data sheet after walking through the stream bed for a specified distance. The data sheet clearly explains each metric and how to score it. The well illustrated and clearly described Ohio EPA QHEI method is online.

The Indiana Department of Environmental Managment (IDEM) completes the QHEI for both wadeable and non-wadeable streams. For official purposes such as 303(d) listing, the QHEI is always assessed together with biology (fish and/or macroinvertebrates). Watershed groups may complete the QHEI, either with or without biological monitoring, for ascertaining the quality of the habitat, as well as other physical characteristics such as streambank erosion.

Training is required in order to have the skills needed to conduct a QHEI. Currently, training is available through Ohio EPA (http://www.epa.ohio.gov/Default.aspx?tabid=4584, descriptions of different training levels provided). In addition, IDEM's Assessment and Planning Branch offers technical assistance on QHEI sampling questions and may offer the opportunity for training in the future. The Non Point Source program will keep 319 projects informed of any future training opportunities offered by the Assessment and Planning Branch. The level of training and/or professional experience should be identified in the Quality Assurance Project Plan.

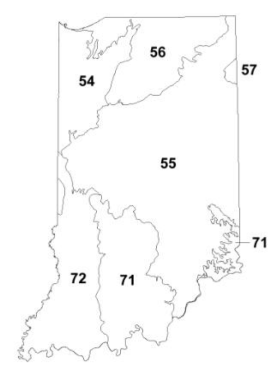
Typical levels in Indiana

Table 11.3 shows IDEM data (1990-2008) from the Assessment Information Management System (AIMS) database for total QHEI values by Ecoregion.

Table 11.3: Statistics for QHEI Scores for Indiana waters by Level 3 Ecoregions

No.	Ecoregion Name	No. of Samples	25%	Mean	Median	75%
	Entire State	2602	46	57	58	69
54	Central Corn Belt Plains	299	36	47	47	56
55	Eastern Corn Belt Plains	1298	50	60	62	71
57	Huron/Erie Lake Plain	11	46	53	51	60
56	S Mich./N Ind. Drift Plains	338	42	54	55	67
71	Interior Plateau	382	55	64	65	74
72	Interior River Lowland	274	39	50	50	60

Ecoregions of Indiana



Targets or Protective levels

Table 11.4: IDEM's scoring interpretation method for QHEI (as determined by IDEM 2008)

QHEI Score	Narrative Rating
>64	Habitat is capable of supporting a balanced warmwater community
51-64	Habitat is only partially supportive of a stream's aquatic life designation
<51	Poor habitat

Table 11.5: General narrative ranges assigned to QHEI scores by OH EPA.

Narrative Rating	QHEI Range	
	Headwaters	Larger Streams
Excellent	≥70	≥75
Good	55 to 69	60 to 74
Fair	43 to 54	45 to 59
Poor	30 to 42	30 to 44
Very Poor	<30	<30

Unlike the other agencies monitoring QHEI in Indiana, it is not apparent that IDNR has a standard method for interpreting QHEI scores, but instead this is left to the discretion of the biologist conducting the sampling. Reports indicate that both IDEM's interpretation (Table 11.4) and Ohio EPA's interpretation (Table 11.5) are used. Note that ranges vary slightly in headwater (watershed area ≤20 sq mi) vs. larger waters (from OH EPA, 2006).

Resources Needed

Table 11.5: Resources Needed for Monitoring Qualitative Habitat Evaluation Index

	Field Sampling	**Laboratory Analysis**
Equipment	Waders or boat; QHEI datasheets *(optional)* Spherical crown densiometer (used to measure canopy cover (% open) which is not required to calculate QHEI, but is included as a miscellaneous measurement used to make biological assessments). Approximately $100.	No laboratory analysis needed
Time	30-60 minutes per site per sampling event. Recommendation to do once per year unless there are substantial changes between sampling events.	
Expertise	Training is needed.	
Costs	Staff time; Consultants may charge $200-500 per site. Waders ($50 to $300/pair), boat (ranges from several hundred to several thousand dollars, QHEI datasheets (printing costs only).	

References

Indiana Department of Environmental Management (IDEM). 2008. Indiana Integrated Water Monitoring and Assessment Report. Indianapolis, IN: Indiana Department of Environmental Management.

Indiana Department of Natural Resources. Spring 2008. Volunteer Stream Monitoring Training Manual: Hoosier Riverwatch. Indianapolis, IN: Indiana Department of Natural Resources.

Methods for Assessing Habitat in Flowing Waters: Using the Qualitative Habitat Evaluation Index (QHEI). 2006. OHIO EPA Technical Bulletin EAS/2006-06-1. Online at: http://epa.ohio.gov/portals/35/documents/QHEIManualJune2006.pdf [Accessed 12 August 2010]

Simon, T.P. 2000. *Standard Operating Procedures for Development of Watershed Indicators in REMAP: Great Lakes Coastal wetlands*. U.S. Department of the Interior, Fish and Wildlife Service, Bloomington, Indiana.

Thoma, R.F. 2006. Development and assessment of a Qualitative Habitat Evaluation Index for application in coastal wetlands of the Great Lakes. pp. 171-194. In T.P. Simon & P.M. Stewart (Eds). Coastal Wetlands of the Laurentian Great Lakes: Health, Habitat, and Indicators. Authorhouse Press, Bloomington, IN. ISBN: 978-1-4259-2848-3.

12. Hoosier Riverwatch Citizens Qualitative Habitat Evaluation Index (CQHEI)

Indicator: CQHEI index value, ranging from 0 to 114
*streams only

Table 12.1: Who's monitoring CQHEI in Indiana?	
Agency	**Field Methods Used**
IDNR Hoosier Riverwatch	Volunteer Stream Monitoring Training Manual

The Citizens Qualitative Habitat Evaluation Index (CQHEI) is a modified version of the Qualitative Habitat Evaluation Index (QHEI) to allow volunteer stream monitors to easily assess stream habitat and riparian health in wadeable streams. The index consists of six metrics (Table 12.2) to evaluate different habitat attributes of a stream. The individual scores are summed to produce an overall CQHEI score, ranging from 0 to 114. A higher score is indicative of a higher quality stream.

Table 12.2: Metrics, Components and Maximum Scores per Metric for CQHEI		
Metric	**Metric Component**	**Max Score**
Substrate	• Size • Smothering • Silting	24
Fish Cover	• Cover Types	20
Stream Shape and Human Alterations	• Curviness or Sinuosity • How Natural is the Site?	20
Stream Forests and Wetlands & Erosion	• Width of Riparian Forest & Wetland • Land Use • Bank Erosion • How Much of Stream is Shaded	20
Depth & Velocity	• Deepest Pool • Flow Types	15
Riffles/Runs	• Riffles/Runs depth • Substrates	15

What it indicates

The CQHEI evaluates the physical factors of a stream that affect fish and other aquatic life and translates these factors into a single measure of stream habitat and riparian health. The CQHEI score can be used to compare changes at a particular site over time or to compare two different stream sites.

Method overview

Completing the CQHEI consists of evaluating a 200 ft. stream section for the predominant features of the six metrics. The CQHEI data sheet clearly explains each metric and how to score it. The score for each metric is summed to provide an overall score

Typical levels in Indiana

The Hoosier Riverwatch volunteer monitoring program has been using this index in Indiana since 2000. A compilation of 2521 samples of CQHEI taken throughout

Indiana from 2000 through 2011 show that 90% of the CQHEI scores were between 32 and 91, with a median of 70. Scores ranged from 5 to 109 (IDNR, 2011).

Targets or Protective levels

According to Riverwatch's Volunteer Stream Monitoring Training Manual, a set of ranges to interpret CQHEI scores as excellent, medium, poor, or very poor have not been developed, but they provide the following guidance:

- If the score is greater than 100, the stream has exceptional high quality
- QEHI scores greater than 60 have been found to be generally conducive to the existence of warmwater fauna

Resources Needed

Table 12.4: Resources Needed for Monitoring the Citizens QHEI

	Field Sampling	Laboratory Analysis
Equipment	Waders or hip boots; CQHEI datasheets	No laboratory analysis needed
Time	30-60 minutes per site per sampling event. Recommendation to do once per year unless there are substantial changes between sampling events.	
Expertise	Low; Training required; Typically analyzed by volunteers	
Costs	Staff time; Waders ($50 to $300/pair), CQHEI datasheets (printing costs only).	

References

Indiana Department of Natural Resources. 2008. Volunteer Stream Monitoring Training Manual: Hoosier Riverwatch. Indianapolis, IN: Indiana Department of Natural Resources.

Indiana Department of Natural Resources. 2011. [web page] Hoosier Riverwatch Datawatch. http://www.hoosierriverwatch.com/DataWatch.html [Accessed 22 November 2011]

13. Dissolved Oxygen

Indicator: Number of days when dissolved oxygen drops below 4 mg/L or ppm

Dissolved oxygen (DO) concentration represents the amount of oxygen that is dissolved in a waterbody. The solubility of oxygen varies with temperature, and DO levels fluctuate regularly, particularly between day and night. Percent saturation is the level of DO in the water compared to the total amount of DO that the water has the ability to hold at a given temperature and pressure.

Table 13.1: Who's monitoring Dissolved Oxygen in Indiana?

Agency	Field Collection Methods Used	Analysis Methods Used
IDEM Watershed Assessment & Planning Branch	IDEM Surveys Section Field Procedure Manual EPA 360.1	Hydrolab or YSI Datasonde Method: Standard Methods 4500-OG Hach Test Kit: OX-2P Winkler Titration: Standard Methods 4500-OC
IDNR Lake & River Enhancement Program	IDEM Surveys Section Field Procedure Manual (streams) EPA 360.1 IN Clean Lakes Program Procedure (lakes)	Hydrolab or YSI Datasonde Method: Standard Methods 4500-OG Hach Test Kit: OX-2P Standard Methods 4500-OC
IDNR Fisheries	Manual of Fishery Survey Methods	Not applicable
IDNR Hoosier Riverwatch	Volunteer Stream Monitoring Training Manual	CHEMetrics Dissolved Oxygen Test Kit K-7512
USGS National Water-Quality Assessment Program	National Field Manual Chapter 6	National Field Manual Chapter 6.2
IN Clean Lakes Program	IN Clean Lakes Program Procedure	Not applicable
IN Volunteer Lake Monitoring Program	Volunteer Lake Monitoring Manual	Not applicable
US Fish & Wildlife Service	ASTM D888	ASTM D888

What it indicates

Dissolved oxygen levels indicate whether the water can support aquatic life.

Causes of insufficient DO include:

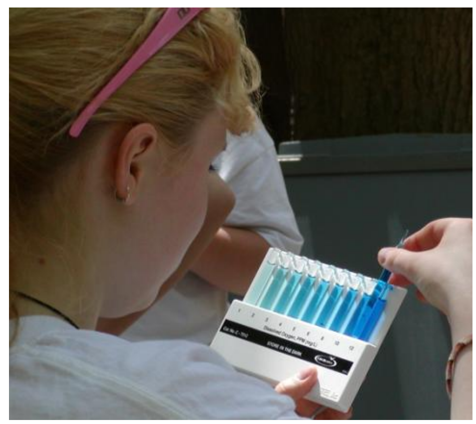
- Rapid decomposition of organic materials, including dead algae, shoreline vegetation, manure or wastewater.
- High ammonia concentrations in the stream that use up oxygen in the process of oxidizing ammonia (NH_4^+) to nitrate (NO_3^-).
- Higher temperatures, which allow less oxygen to dissolve in water.
- Lack of turbulence or mixing to expose water to atmospheric oxygen.
- Low flow or water level

While an aquatic system cannot have “too much” oxygen, high levels of dissolved oxygen (12-18 ppm), known as “super-saturation,” often occur in stagnant waters when nutrient pollution has stimulated an algal bloom. Plants or algae produce large amounts of oxygen during the day through the process of photosynthesis, resulting in a high dissolved oxygen level. When photosynthesis stops for the evening, those same plants and algae will consume oxygen from the water for respiration, causing a dip in dissolved oxygen levels.

Dissolved oxygen is often measured with a digital probe.

Method overview

Dissolved oxygen is usually measured in the field, either with a digital meter (often a multi-parameter meter that also measures temperature and pH, for example), a digital probe that may be linked to a data logger for continuous data, or through a test kit that includes a reactive chemical with colors for comparison. The meters or probes use either membrane electrodes or more recently a luminescence method.



IDNR Hoosier Riverwatch volunteer analyzing DO using a test kit.

Dissolved oxygen is influenced by photosynthetic activity, and therefore fluctuates within a 24-hour period depending on the incidence of sunlight on the water. It is best to measure DO throughout a 24 hour period and construct a diurnal curve. At a minimum, t DO should be measured pre-sunrise (approximately 4:00 am) and pre-sunset (approximately 4:00 pm) to capture the diurnal fluctuation and dip in dissolved oxygen level likely to occur before dawn.

Typical levels in Indiana

As part of the development of this manual, dissolved oxygen concentrations from the 176 Fixed Stations monitored by IDEM since 1990 were analyzed to provide an overview of oxygen levels in Indiana (Table 13.2).

Table 13.2: Statistics for Dissolved Oxygen Concentrations (mg/L) in Indiana waters (IDEM Fixed Station Data, 1990-2010)

No. of Samples	Min (mg/L)	25% (mg/L)	Median (mg/L)	75% (mg/L)	Max (mg/L)
29232	1.2	8.0	9.6	11.4	22.3

According to Hoosier Riverwatch’s Volunteer Stream Monitoring Training Manual, dissolved oxygen typically ranges from 5.4 to 14.2 mg/L and the Indiana average is 9.8 mg/L.

Temporal variability: Dissolved oxygen varies greatly within one day, a phenomenon known as diurnal variation. Therefore, measurements taken at different times should not be compared. In the stream shown in Figure 13.1, the diurnal variation is the most obvious source of variability. Dissolved oxygen also decreased when the streamflow increased on June 21 and July 5, and the diurnal variation also decreased before the normal pattern returned a few days later.

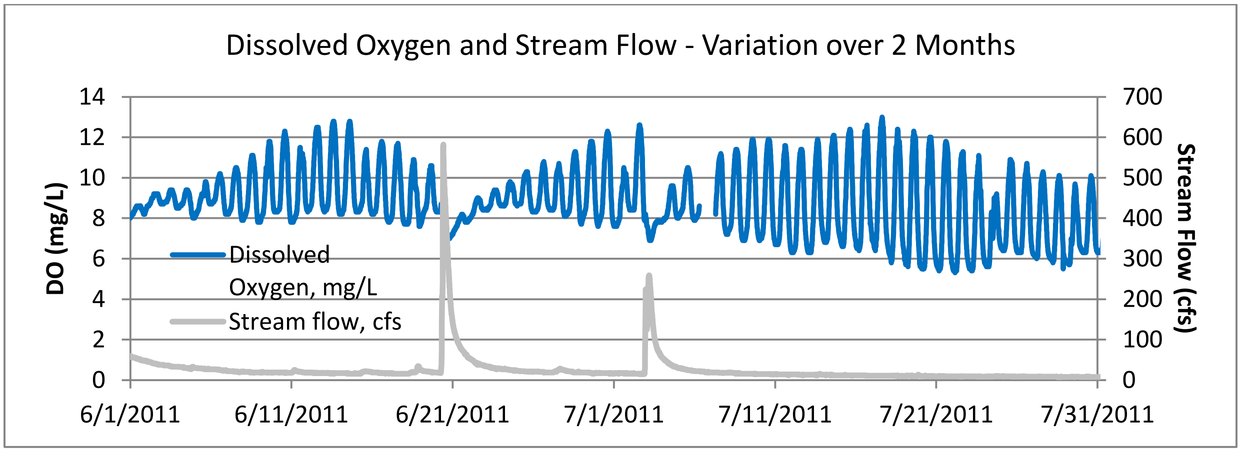


Figure 13.1: Dissolved oxygen and stream flow in an agricultural stream. The daily (diurnal) fluctuations are difficult to represent with only a few measurements.

Targets or Protective levels

DO levels below 4 mg/L are stressful to most aquatic life. DO levels below 2 mg/L will not support fish. Levels of at least 5 to 6 mg/L are usually required for healthy growth and activity of aquatic life.

Indiana Water Quality Standards for DO: Indiana Administrative Code (IAC) 327 IAC 2-1-6 [Non-Great Lakes] and 327 IAC 2-1.5-8 [Great Lakes]

Concentrations of dissolved oxygen in warm waters shall:

- average at least 5.0 mg/L per calendar day; and
- not be less than 4.0 mg/L at any time

For coldwater fishery streams*, dissolved oxygen concentrations shall not be less than:

- 6.0 mg/L at any time; and
- 7.0 mg/L in spawning areas

*Waters protected for coldwater fish include those waters designated by the Indiana Department of Natural Resources for put-and-take trout fishing as well as salmonid waters listed in 327 IAC 2-1.5-5.

Resources Needed

Table 13.3: Resources Needed for Monitoring Dissolved Oxygen		
	Field Sampling	**Laboratory Analysis**
Equipment	Sample bottles; Test kit Digital meter or probe linked to a data logger	EPA and standard methods: Spectrophotometer and titration equipment
Time	30 seconds-3 minutes per measurement. Probes require calibration. Frequency of calibration is generally determined by the manufacturer but general practice is to calibrate before each field trip. Calibration takes approximately 20-30 minutes.	5-10 minutes per measurement
Expertise	Low	Low
Costs	Test kit: approximately $90 for 30 samples Probe: several hundred dollars for meter with single functions, several thousand dollars for multi-parameter probes	Laboratories generally charge $10 to $40 per sample

References

Indiana Department of Natural Resources. Spring 2008. Volunteer Stream Monitoring Training Manual: Hoosier Riverwatch. Indianapolis, IN: Indiana Department of Natural Resources.

Water On the Web. [web page] Understanding Water Quality: Dissolved Oxygen. http://www.waterontheweb.org/under/waterquality/oxygen.html [Accessed 18 November 2011]

Adobe Creek Streamkeeper measuring dissolved oxygen

14. pH

Indicator: Number of days when pH drops below 6 or is above 9

pH is the concentration of hydrogen ions in a solution on a scale of 0 to 14 (<7 is acidic, 7=neutral, >7 is basic). A change of 1 unit on a pH scale represents a 10 fold change in the pH, for example, water with a pH of 6 is 10 times more acidic than water with a pH of 7.

Table 14.1: Who's monitoring pH in Indiana?

Agency	Field Collection Methods Used	Analysis Methods Used
IDEM Watershed Assessment & Planning Branch	IDEM Surveys Section Field Procedure Manual	EPA 150.1
IDNR Lake & River Enhancement Program	IDEM Surveys Section Field Procedure Manual (streams) IN Clean Lakes Program Procedure (lakes)	EPA 150.1 IN Clean Lakes Program Procedure
IDNR Fisheries	Manual of Fishery Survey Methods	Hach kit
IDNR Hoosier Riverwatch	Volunteer Stream Monitoring Training Manual	WaterWorks™ pH Test Strips (#481104)
USGS National Water-Quality Assessment Program	National Field Manual Chapter 6.4	Not applicable
IN Clean Lakes Program	IN Clean Lakes Program Procedure	IN Clean Lakes Program Procedure
US Fish & Wildlife Service		ASTM D1293-99(2005): Standard Test Methods for pH of Water

What it indicates

pH levels indicate whether the water can support aquatic life. Most aquatic animals and plants have adapted to life in water with a specific pH and even slight changes can reduce hatching success of fish eggs, irritate fish and aquatic insect gills and damage membranes, and affect amphibian populations.

The most significant environmental impact of pH involves its effect on the form or toxicity of other substances. For example, the pH of the water will determine the toxic effects of pollutants like iron, aluminum, ammonia or mercury. For example, 4 mg/L of iron would not present a toxic effect at a pH of 4.8, while as little as 0.9 mg/L of iron at a pH of 5.5 can cause fish to die.

The pH of a body of water is affected by several factors:

A simple pH meter

- the bedrock and soil composition through which the water moves, both in its bed and as groundwater. Some rock types such as limestone can, to an extent, neutralize the acid while others, such as granite, have virtually no effect on pH
- the amount of plant growth and organic material within a body of water
- discharge or dumping of chemicals into the water by individuals, industries, and communities
- acid precipitation that falls in the watershed. Acid rain is caused by nitrogen oxides (NO_x) and sulfur dioxide (SO_2) in the air combining with water vapor. These pollutants are primarily from automobile and coal-fired power plant emissions
- coal mine drainage (also known as acid mine drainage). Iron sulfide, a mineral found in and around coal seams, combines with water to form sulfuric acid

Method overview

pH is relatively easy to measure. pH should be measured directly in the stream or lake, either with a digital meter (often a multi-parameter meter that also measures temperature and DO, for example), a digital probe that may be linked to a data logger for continuous data, or through simple test strips. If samples are intended for laboratory analysis, the analysis should be completed within one day of sample collection.

Volunteers match the color on the test strip to determine the pH level.

pH is influenced by photosynthetic activity and therefore, fluctuates within a 24 hour period depending on the incidence of sunlight on the water. It is best to measure pH throughout a 24-hour period and construct a diurnal curve, but at a minimum, it is recommended that pH be measured pre-sunrise (approximately 4:00 am) and pre-sunset (approximately 4:00 pm).

Typical levels in Indiana

Due to the state's limestone geology, Indiana surface waters will typically have a pH that is relatively basic (>7). According to Hoosier Riverwatch's Volunteer Stream Monitoring Training Manual, pH typically ranges from 7.2 to 8.8 and the Indiana average is 8.0.

Temporal variability: pH does not vary as much as many other parameters, although it rises and falls each day, and approaches a more neutral value when surface runoff is higher after a rain event.

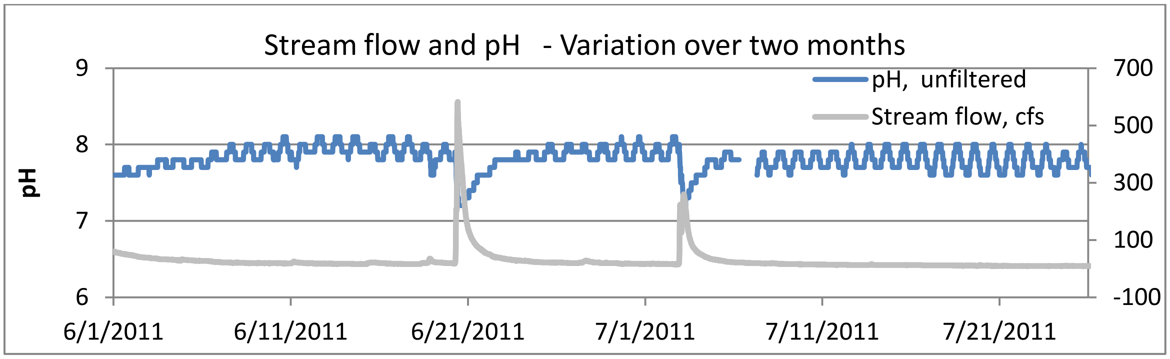


Figure 14.1: Streamflow and pH in an agricultural stream.

Targets or Protective levels

- A pH range of 6.5 to 8.2 appears to provide protection for most aquatic organisms (IDNR, 2008)
- Indiana Water Quality Standards for pH: Must be above 6 and below 9. Indiana Administrative Code (IAC) 327 IAC 2-1-6 [Non-Great Lakes] and 327 IAC 2-1.5-8 [Great Lakes].

Resources Needed

Table 14.2: Resources Needed for Monitoring pH		
	Field Sampling	**Laboratory Analysis**
Equipment	Test strips; Probe; Sample bottles; Kemmerer sampler (for lake samples only)	EPA and standard methods: pH meter
Time	30 seconds per measurement. Probes require calibration.	Laboratory Analysis: 1-2 min. per measurement
Expertise	Low	Low
Costs	Test strips: approximately $20 for a bottle of 50 Probe: several hundred dollars for meter with single functions, several thousand dollars for multi-parameter probes; Kemmerer samplers are generally $250-500	Laboratories generally charge $10 to $20 per sample

References

Indiana Administrative Code. Article 2. Water Quality Standards. Online at http://www.in.gov/legislative/iac/T03270/A00020.PDF

Indiana Department of Natural Resources. Spring 2008. Volunteer Stream Monitoring Training Manual: Hoosier Riverwatch. Indianapolis, IN: Indiana Department of Natural Resources.

Kentucky Water Watch. [web page] pH and Water Quality. http://www.kywater.org/ww/ramp/rmph.htm [Accessed 29 July 2010]

Oram, B. pH in the Environment. Water Research Center, B.F. Environmental Consultants Inc., Dallas, PA. Online at: http://www.water-research.net/Watershed/pH.htm [Accessed 29 July 2010]

15. Stream Flow

Stream flow is a core monitoring parameter. A record of the **variation of stream flow over time,** known as a *hydrograph*, is particularly important, because water quality may be quite different and high and low flow, or when streamflow is increasing or decreasing. It is generally more useful to obtain even rough estimates of **continuous flow records** than to take great care in measuring the flow at one instant. A continuous record of stream flow is needed to:

- understand whether monitoring samples were taken at high flow or low flow, or while flow was increasing or decreasing.
- develop indicators of stream flashiness, such as the Richards-Baker index, and
- calculate annual load from a series of concentration measurements.

Table 15.1: Who's monitoring stream flow in Indiana?

Agency	Field Collection Methods Used
US Geological Survey	Discharge measurements at gaging stations
IDEM Watershed Assessment & Planning Branch	IDEM Survey Section Field Procedure Manual
IDNR Lake & River Enhancement Program	IDEM Survey Section Field Procedure Manual
IDNR Hoosier Riverwatch	Volunteer Stream Monitoring Training Manual
US Fish & Wildlife Service	ASTM D5389

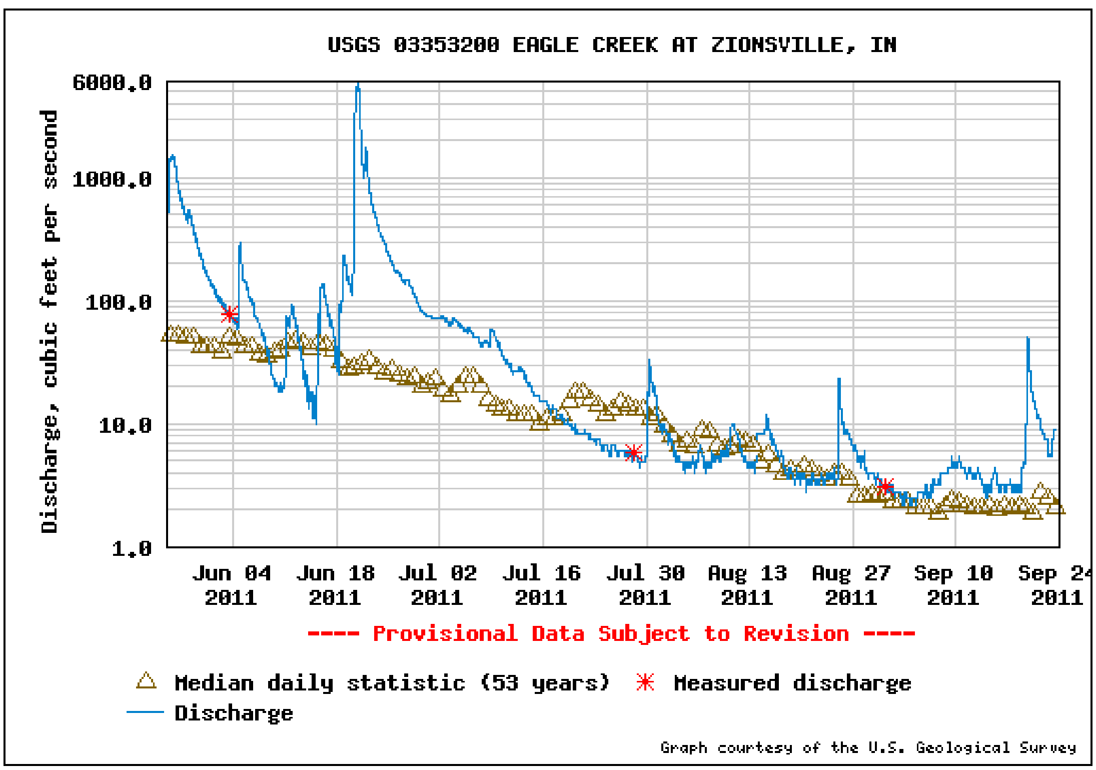


Figure 15.1: A typical stream flow record from USGS. This record shows that stream flow varied from more than 6000 cubic feet per second to less than 2 cubic feet per second in just a few months.

What it indicates

Streamflow is particularly important as a supporting measurement, to give context to other measurements and to allow the calculation of pollutant loads. Concentrations of many parameters such as sediment and phosphorus are much higher at high flow, and therefore measurements that do not have the flow context provide much less information. Concentrations of other parameters such as nitrate have less relation to flow, except in watersheds with tile drainage, where nitrate increases when the tiles are flowing.

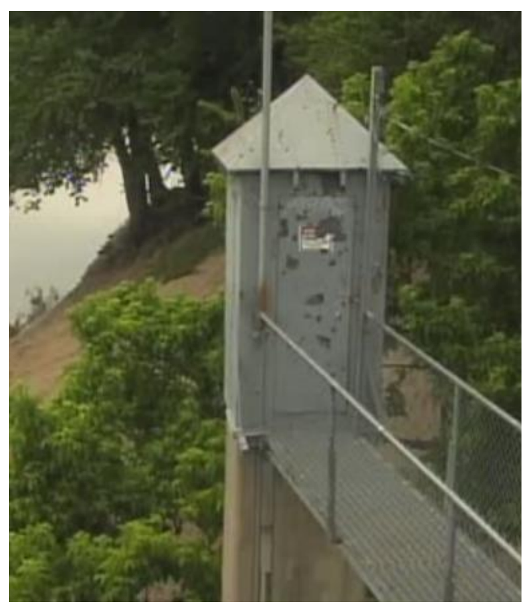
Continuous, high-quality streamflow records can be used to calculate stream flashiness (the rapid change in water level due to a rain event), which is an indicator of impervious area in the watershed or hydrologic modification. Hydrologic modifications such as pipes or other direct conveyances into the stream cause increased stream flashiness, while modifications such as dams or debris in the channel can decrease stream flashiness.

Method Overview

Instantaneous flow measurements can be made fairly easily with flow monitoring equipment or simple float techniques, but isolated measurements are of little value in understanding water quality since they only represent one moment of a continuously changing value. They cannot be used for providing context on the measurement or to calculate flashiness, and they can be very misleading if used to calculate load. Instantaneous flow measurements might be used for reconnaissance purposes to determine the general magnitude of flow at a location, and particularly are used to develop a rating curve linking stream height (stage) to stream flow.

Continuous flow measurements are of much more value since stream flow changes so quickly. , Watershed groups can obtain continuous streamflow through one of the following methods, which are described in more detail below.

Method 1: Select monitoring sites at an existing USGS gaging station (highly recommended if one exists in our watershed)
Method 2: Use data from the nearest USGS gaging station, correcting for the difference in watershed area
Method 3: Install and develop a rating curve for a continuous gaging station yourself
Method 4: Contract with USGS to set up a station at a site in your watershed


USGS stream gages provide real-time, continuous data.

Method 1: Monitor at an existing USGS gage.
The U.S. Geological Survey (USGS) maintains a network of about 200 stream gaging stations throughout Indiana (Figure 15.1). Unfortunately, the number of USGS gaging stations is decreasing, but those that remain provide valuable data, not only at the specific locations measured, but also as generalized information for other nearby streams. Streamflow locations are available at http://waterwatch.usgs.gov/ or in the Indiana Water Monitoring Inventory.

Method 2: Nearest USGS station with watershed area ratio
The method consists of six steps:

1. Find the nearest stream gage
2. Obtain the drainage area for that stream gage
3. Obtain the drainage area for your site
4. Calculate the drainage area ratio, which is the area for your monitoring site divided by the area for the USGS stream gage.
5. Obtain daily stream flow records for the USGS stream gage
6. Multiply the flow each day by the drainage area ratio

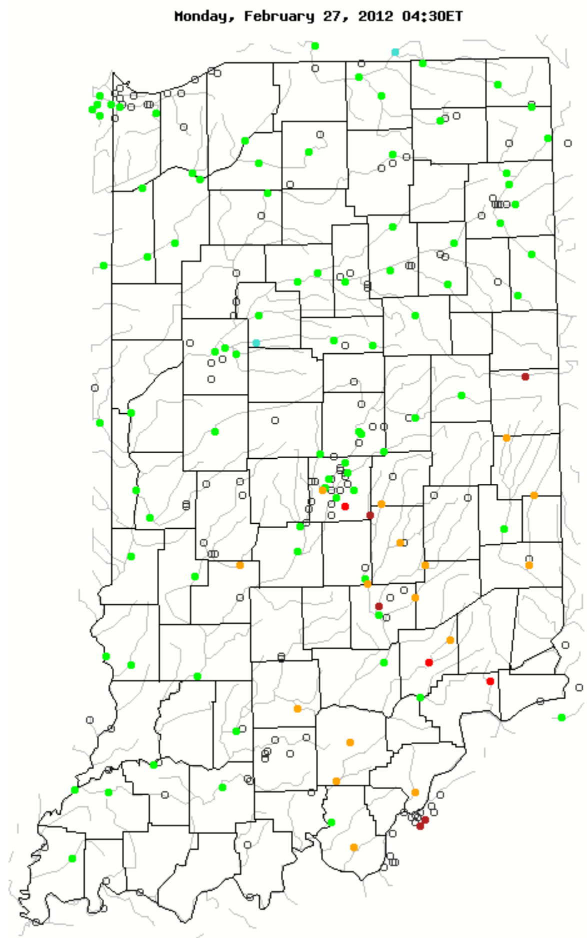


Figure 15.1: USGS real-time stream gages in Indiana provide continuous flow data. (Image from USGS Water Watch web site)

Instantaneous measurements at your site on a number of days can be compared to the drainage area ratio adjusted flow measurement at the USGS stream gage. Instructions on all these steps are in the publication “Estimating Continuous Stream Flow at Ungaged Sites from USGS Records”, available at http://engineering.purdue.edu/watersheds/resources.

Method 3. Install a continuous stream gage
Installing a stream gage is a complex task, well beyond this manual. It involves

- Installing a measurement method for water height. This includes a pressure transducer or other sensor for measuring precise height, connected to a data logger to record, or other continuous measure to give precise stage measurements and record them.

- Taking regular measurements of streamflow to develop a rating curve of stage height and flow. The USGS usually does this at least every 6 weeks, sometimes for several years. The standard method is to measure depth and flow at regular intervals across the stream. Velocity can be estimated with an orange or similar floating object, counting the amount of time it takes to travel a measured distance, but it is more accurate to use meters such as acoustic Doppler or electromagnetic sensors. Weir or flumes provide flow estimates without measuring, but are seldom practical in natural streams. Measurements to establish a rating curve must be taken during different flow conditions (high flow, low flow, winter, spring, summer, and fall, rain and shine). The rating curve also needs to be checked or redeveloped after any catastrophic sediment movement event in the channel. Therefore, if it is important to have reliable stream flow measurements, it is probably best to contract with USGS to set up a gage where you need it.

Method 4: Contract with USGS to install a stream gage at your site

USGS can install a new stream gage through a contract with watershed projects, and in some cases USGS matching funds may be available. Gage installation cost is typically $12,000 to $15,000, and gage operation and maintenance is $13,000 per year for a full streamflow gage. A stage-only gage (no streamflow) costs $4,500 per year. Contracting with USGS ensures a rugged, vandal-resistant infrastructure, reliable monitoring, and provision of data through the Internet at http://waterdata.usgs.gov/in/nwis/rt. USGS provides more information on setting up a new gage at http://in.water.usgs.gov/projects/USGS_Indiana_Streamgage_Information.pdf

Remember, taking the time and spending the resources to conduct water monitoring is of limited value without reliable, **continuous** streamflow.

USGS stream gage provides reliable, real-time flow measurements.

16. Water Temperature

Indicator: degrees Celsius or Fahrenheit

Water temperature is a critical water quality and environmental parameter because it governs the kinds and types of aquatic life, regulates the maximum dissolved oxygen concentration of the water, and influences the rate of chemical and biological reactions. The organisms within the ecosystem have preferred temperature regimes that change as a function of season, organism age or life stage, and other environmental factors.

Table 16.1: Who's monitoring water temperature in Indiana?

Agency	Field Collection Methods Used	Analysis Methods Used
IDEM Watershed Assessment & Planning Branch	IDEM Surveys Section Field Procedure Manual	HACH or YSI Datasonde Method: Standard Methods 2550B(1), 2550B(2)
IDNR Lake & River Enhancement Program	IDEM Surveys Section Field Procedure Manual (streams) IN Clean Lakes Program Procedure (lakes)	HACH or YSI Datasonde Method: Standard Methods 2550B(1), 2550B(2) YSI temperature probe
IDNR Fisheries	Manual of Fishery Survey Methods	
IDNR Hoosier Riverwatch	Volunteer Stream Monitoring Training Manual	Thermometer
IN Volunteer Lake Monitoring Program	Volunteer Lake Monitoring Manual	YSI temperature probe
USGS National Water-Quality Assessment Program	National Field Manual Chapter 6.1.3	Standard Methods 2130
IN Clean Lakes Program	IN Clean Lakes Program Procedure	YSI temperature probe

What it indicates

Most aquatic organisms are poikilothermic ("cold-blooded"), which means they are unable to internally regulate their core body temperature. Therefore, temperature exerts a major influence on the biological activity and growth of aquatic organisms; the higher the water temperature, the higher the rate of metabolic reactions. The rate of photosynthesis is also affected by temperature resulting in increased plant and algal growth with increased temperatures.

Temperature is also an important influence on water chemistry. The rate of chemical reactions generally increases at higher temperature, which in turn affects biological activity. Warmer temperatures increase the solubility of salts in water but decrease the solubility of gasses in water. Another important example of the effects of temperature on water chemistry is its impact on oxygen. Warm water holds less oxygen than cool water, so it may be saturated with oxygen but still not contain enough for survival of aquatic life.

Stream temperature is determined by many factors, including:

- Air temperature - the only parameter in this list that does not directly change with urban development in the watershed (although big cities are, in fact, warmer than the suburbs)
- The amount of light hitting the water - clearing stream side (riparian) vegetation allows more sunlight to reach the stream, warming the water
- Water depth - more volume leads to cooler habitats at greater depths
- How dirty the water is - dirty or turbid water absorbs more heat from the sun. Erosion causes the water to become turbid with suspended sediment
- How much groundwater is coming into the stream and the presence/absence of cold springs
- The types of land surfaces in the watershed, such as impervious surfaces, that get hot from sunlight

Lake temperature is affected by all of the above, plus:

- depth (water in shallow lake can warm up faster and to a higher temperature)
- size and temperature of inflows (e.g., a stream during snowmelt, or springs or a lowland creek)
- how quickly water flushes through the lake (a shallow lake may remain cool if fed by a comparatively large, cold stream)

Method overview

The simplest field method is to use a thermometer. Aquatic scientists usually measure temperature with temperature probes, often as one component of a multi-parameter probe. Water temperature fluctuates within a 24-hour period depending on the incidence of sunlight. Therefore, it is best to monitor water temperature through a 24-hour period to construct a diurnal curve, but at a minimum it is recommended that water temperature be measured pre-sunrise (approximately 4:00 am) and pre-sunset (approximately 4:00 pm). Most existing monitoring programs measure water temperature in streams once per sample site (noting the time of day when sampled). Lake water temperature is generally measured at the surface and at pre-determined intervals to the lake bottom. Although air temperatures reported in the news media in the U.S. are given in degrees Fahrenheit (°F), scientists and the rest of the world usually record temperatures in Celsius (°C), because this is the unit designated by the International System of Units.

Volunteers measuring water temperature.

Typical values in Indiana

Because water temperature is highly influenced by time of day, season, and any thermal inputs, typical values do not exist. Figure 16.1 shows typical variation that must be considered in monitoring.

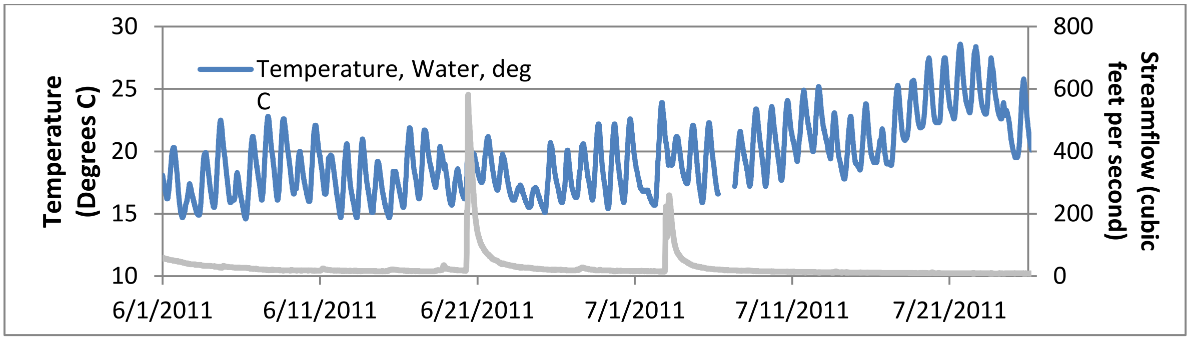


Figure 16.1: Water temperature and streamflow for an agricultural stream

Targets or Protective levels

Indiana Water Quality Standards for temperature are used to maintain a well-balanced aquatic community, Indiana Administrative Code (IAC) 327 IAC 2-1-6 [Non-Great Lakes] and 327 IAC 2-1.5-8 [Great Lakes]:

- Abnormal temperature changes cannot adversely affect aquatic life unless caused by natural conditions
- Normal daily and seasonal temperature fluctuations that existed before the addition of heat due to other than natural causes shall be maintained. Maximum temperature rise above natural temperatures shall not exceed 5 °F (2.8 °C) in streams, or 3 °F (1.7 °C) in lakes and reservoirs
- Specific maximum water limits are given for the Ohio River Main Stem, St. Joseph River (Lake Michigan), and other Indiana streams in the Indiana Water Quality Standards.

Resources Needed

Table 16.3: Resources Needed for Monitoring Water Temperature

	Field Sampling	Laboratory Analysis
Equipment	Probe or thermometer	None needed
Time	30 seconds-3 minutes per measurement. Probes also require calibration.	
Expertise	Low expertise	
Costs	Probe: several hundred dollars for meter with single functions. Thermometer: approximately $15 each	

References

Lake Superior Streams.org. [web page] Temperature. http://www.lakesuperiorstreams.org/understanding/param_temp.html [Accessed 27 July 2010]

Water On the Web. [web page] Understanding Water Quality: Temperature. http://www.waterontheweb.org/under/waterquality/temperature.html [Accessed 27 July 2010]

17. Conductivity

Indicator: microSiemens per centimeter (µS/cm) or micromhos per centimeter (µmhos/cm)

Conductivity is a measure of the ability of water to pass an electrical current. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Organic compounds do not conduct electrical current very well and therefore have a low conductivity when in water. Conductivity is also affected by temperature: the warmer the water, the higher the conductivity. For this reason, conductivity is reported as conductivity at 25 degrees Celsius (25° C), also referred to as specific conductance.

Table 17.1: Who's monitoring Conductivity in Indiana?

Agency	Field Collection Methods Used	Analysis Methods Used
IDEM Watershed Assessment & Planning Branch	IDEM Surveys Section Field Procedure Manual	Standard Methods 2510B
IDNR Lake & River Enhancement Program	IDEM Surveys Section Field Procedure Manual	Not applicable
IDNR Fisheries	Manual of Fishery Survey Methods	Not applicable
USGS National Water-Quality Assessment Program	National Field Manual Chapter 6.3.3	Not applicable
IN Clean Lakes Program	IN Clean Lakes Program Procedure	Not applicable

What it indicates

Over most ranges, the conductivity is directly proportional to the amount of salts dissolved in the water, called total dissolved solids or TDS.

Waterbodies tend to have a relatively constant range of conductivity that, once established, can be used as a baseline for comparison with regular measurements. Significant changes in conductivity could indicate a discharge or other source of pollution has entered the waterbody.

Conductivity in streams and rivers is affected primarily by the geology of the area through which the water flows. Streams that run through areas with granite bedrock tend to have lower conductivity because granite is composed of more inert materials that do not ionize (dissolve into ionic components) when washed into the water. On the other hand, streams that run through areas with clay soils tend to have higher conductivity because of the presence of materials that ionize when washed into the water.

Method overview

Conductivity is usually measured in the field, either with a digital meter (often a multi-parameter meter that also measures temperature and pH, for example), or a digital probe that may be linked to a data logger for continuous data. If samples will be collected in the field for later measurement, the sample container should be glass or polyethylene, and pre-washed using a phosphate-free detergent and rinsed thoroughly with both tap and distilled water.

Conductivity (specific conductance) can be measured as part of a multi-parameter probe.

Typical levels in Indiana

As part of the development of this manual, conductivity concentrations from the 176 Fixed Stations monitored by IDEM since 1990 were analyzed to provide an overview of conductivity levels in Indiana (Table 17.2).

Table 17.2: Statistics for Conductivity (µmho/cm) in Indiana waters by Level 3 Ecoregions (IDEM Fixed Station Data, 1990-2010)

No.	Ecoregion Name	No. of Samples	Min *(µmho /cm)*	25% *(µmho /cm)*	Median *(µmho /cm)*	75% *(µmho /cm)*	Max *(µmho /cm)*
54	Central Corn Belt Plains	4138	5.06	514	630	786	2290
55	Eastern Corn Belt Plains	14047	2.14	519	618	722	2530
57	Huron/Erie Lake Plain	216	168	481	600	738	1379
56	S Michigan/N Indiana Drift Plains	3977	3.44	535	604	665	1224
71	Interior Plateau	2957	132	373	475	580	1640
72	Interior River Lowland	3801	109	462	558	642	3510

Targets or Protective levels

Indiana does not have ambient water quality standards for conductivity, but the Indiana Administrative Code (IAC) 327 IAC 2-1-6 [Non-Great Lakes] and 327 IAC 2-1.5-8 [Great Lakes] sets a standard for dissolved solids in public or industrial water supplies to not exceed 750 mg/L. 327 IAC 2-1-6 states that "a specific conductance of one thousand two hundred **(1,200) micromhos per centimeter** (at twenty-five (25) degrees Celsius) may be considered equivalent to a dissolved solids concentration of seven hundred fifty (750) milligrams per liter."

Resources Needed

Table 17.3: Resources Needed for Monitoring Conductivity		
	Field Sampling	**Laboratory Analysis**
Equipment	Probe	
Time	5-10 seconds per measurement. Probes also require calibration	
Expertise	Low	
Costs	Probe: several hundred dollars for meter with single functions, several thousand dollars for multi-parameter probes	Laboratories generally charge $15 to $20 per sample

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18. Bank Erosion Hazard Index (BEHI)

Indicator: BEHI index values, ranging from 0 to 50

Table 18.1: Who's monitoring Bank Erosion Hazard Index in Indiana?
No statewide assessment programs were identified.

The Bank Erosion Hazard Index (BEHI), created by David Rosgen of Wildland Hydrology, Inc. (Rosgen 2001; Rosgen 2008), is one of several procedures for assessing stream bank erosion condition and potential. It assigns point values to several aspects of bank condition (Table 18.2) and provides an overall score that can be used to inventory stream bank condition over large areas and prioritize eroding banks for remedial actions. Due to the difficulty of accurately measuring bankfull height, the BEHI method is often limited to professional assessments rather than volunteer groups.The BEHI is not currently used in Indiana, but a modified version (that eliminates the need to measure bankfull height) has been used frequently to assess Michigan streams, and a new program to Indiana, the Fluvial Erosion Hazard Mitigation Program, is using a bank assessment tool similar to Michigan's modified BEHI method.

What it indicates

The BEHI methodology evaluates a stream bank's susceptibility to erosion as a function of seven factors (table below), including ratio of bank height to bankfull height, ratio of root depth to bank height, root density, surface protection, bank angle, bank materials, and stratification of bank material. Eroding stream banks can be a major source of sediment to a stream (up to 80% of the annual load; Simon and Thorne 1996), and human activities such as urbanization or dam construction can accelerate bank erosion rates by more than an order of magnitude. It is often difficult, however, to distinguish between stream banks that are eroding at a natural rate from those that are or have the potential to erode at unnaturally high rates due to altered watershed hydrology or sediment loads.

Table 18.2: Bank Erosion Hazard Index (BEHI) metrics

Metric	Metric Description
Ratio of root depth to bank height (%)	Ratio of the average plant root depth to the bank height
Root density (%)	Percentage of the stream bank surface covered (and protected) by plant roots
Surface protection (%)	Percentage of stream bank covered (and therefore protected) by plant roots, downed logs and branches, rocks, etc.
Bank angle (degrees)	Angle of the "lower bank" – the bank from the waterline at base flow to the top of the bank
Ratio of bank height to bankfull height	The most challenging metric, because of the difficulty of accurately identifying bankfull indicators (Williams 1978). Michigan's modified procedure eliminates this.
Bank materials	Composition of the stream bank (boulders, clay, sand, etc.)
Stratification of bank material	Presence or absence of layers within the stream bank; assessment of single or multiple layers

Method overview

The BEHI procedure consists of seven metrics; six observational and one that requires quantitative measurement. Stream segments of at least 100 feet in length (with 2-3 meander lengths) are preferable. After assessing the seven metrics, point values are assigned to the first five metrics according to Table 18.4 and the BEHI score is calculated by summing these five scores. Then, the score is adjusted for bank materials and stratification according to Table 18.5. Conditions on both banks should be assessed, and if they are consistently different, scored separately. The overall BEHI score is compared to its corresponding hazard category (Table 18.4).

The Michigan Department of Environmental Quality uses a modified BEHI procedure, which does not require identification of bankfull width. The modified BEHI procedure is intended for use by workers who lack experience in identifying bankfull indicators, including volunteer monitors (Rathbun 2011).

In 2011, the Indiana Silver Jackets initiated a Fluvial Erosion Hazard (FEH) Mitigation Program (http://www.indianafeh.polis.iupui.edu/). As part of this effort, a research team from the Center for Earth and Environmental Science (IUPUI), POLIS (IUPUI), and the U.S. Geological Survey's Indiana Water Science Center is developing a set of tools to help better understand the physical character of Indiana streams. One of these tools is a bank assessment tool similar to Michigan's modified BEHI procedure. The assessment tool, developed by Bhowmik et al. (1997), includes 5 metrics; bank angle, bank height, bank material, vegetation conditions, and signs of bank erosion or sediment deposition. Assessment is conducted by qualitative observation of these metrics in each stream segment, comparing results to general channel-bank characteristics to determine a bank-condition category (Table 18.3). Areas determined as having the potential for severe erosion can then be targeted for restoration efforts.

Table 18.3: Bank Assessment Results for the Kankakee River (Bhowmik et al. 2001)and White River between Anderson and Indianapolis (Robinson 2003),

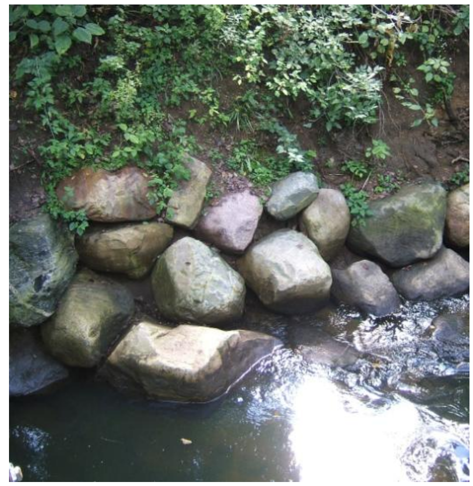
Bank-Condition Category	**Description**	Kankakee River		White River	
		River Miles	%	River Miles	%
Stable	Well-vegetated banks, bank angles less than 40 degrees, no field evidence of active erosion	5.6	5	50.4	40
Slight Erosion	Vegetated banks with some root exposure, cohesive bank materials, bank angles less than 40 degrees	46.9	46	53.6	43
Moderate Erosion	Partially denuded scarp less than 4 feet high, bank angles greater than 30 degrees, erosional impacts to vegetation, cohesive bank materials	27.7	27	9.3	7
Severe Erosion	Denuded scarp 4 or more feet in height, non-cohesive bank materials, mass-wasting conditions, bank angles greater than 40 degrees	7.4	7	2.8	2
Depositional	Recently deposited bar materials lacking vegetative cover, commonly point bars			4.2	3
Hardened	Bank protected by riprap, gabions, sheet pile, or sea walls	13.4	13	4.6	4

Typical values in Indiana

It appears that the BEHI is not currently used in Indiana to assess stream banks, but a modified version of BEHI (Rathbun 2011) is used frequently in Michigan. Modified BEHI scores vary from low to extreme in many Michigan watersheds. Therefore, there are not typical values statewide. Instead, here are some illustrated examples of the various modified BEHI scores from southern Michigan streams (taken from Rathbun 2011).

Tributary, Kalamazoo River watershed.
Modified BEHI Score = 6 (Low)

Battle Creek River .
Modified BEHI Score = 27 (High)



Rouge River
Modified BEHI Score = 23.5 (High)

Hagar Creek, Ottawa County
Modified BEHI Score = 37 (Extreme)

The bank assessment tool developed by Bhowmik et al. 1997 has been used to assess the main stem of the Kankakee River in Illinois and Indiana (Bhowmik et al., 2001) and the White River between Anderson and Indianapolis, Indiana (Robinson 2002). Results of these evaluations are shown in Table 18.3.

Targets or Protective levels

Risk is rated based on the five characteristics in Table 18.4, then adjusted as shown in Table 18.5.

Table 18.4: Point values for the Bank Erosion Hazard Index (Rosgen 2001)

Risk rating categories	Bank Height/ Bankfull Ht	Root Depth/ Bank Height	Root Density (%)	Bank Angle (Degrees)	Surface Protection (%)
Very low	1.0-1.1	1.0-0.9	100-80	0-20	100-80
Low	1.11-1.19	0.89-0.5	79-55	21-60	79-55
Moderate	1.2-1.5	0.49-0.3	54-30	61-80	54-30
High	1.6-2.0	0.29-0.15	29-15	81-90	29-15
Very high	2.1-2.8	0.14-0.05	14-5.0	91-119	14-10
Extreme	<2.8	< 0.05	< 5	>119	< 10

Table 18.5: Adjustment Factors for the Bank Erosion Hazard Index (Rosgen 2008)

Bank Materials (if banks =)	**Score Adjustment**
bedrock	Always classify as "Very Low"
Boulders	Always classify as "Low"
Cobble	Subtract 10 points from the BEHI score
Gravel or gravel/sand mix that is mostly gravel	Add 5 points
Gravel/sand mix that is mostly sand	Add 10 points
Sand	Add 10 points
Silt or clay	No adjustment
Stratification	**Score Adjustment**
No layers	No adjustment
Single layer of erodible material (usually sand)	Add 5 points
Multiple layers of erodible materials	Add 10 points

Resources Needed

Table 18.7: Resources needed for monitoring Band Erosion Hazard Index

	Field Sampling	**Laboratory Analysis**
Equipment	BEHI datasheets (printing costs only) *(optional)* Inclinometer. Approximately $60-$150	No laboratory analysis needed
Time	Less than 1 minute to assess a single eroded bank; 5 to 10 minutes to assess longer reaches of a stream	
Expertise	Training is needed. Michigan's modified procedure can be conducted by volunteers.	
Costs	Staff time	

References

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19. Buffer Zone Width

Indicator: Width (feet)

Table 19.1: Who's monitoring Buffer Zone Width in Indiana?
No statewide assessment programs were identified.

Riparian buffers are areas of natural perennial vegetation such as grass, shrubs, or trees along a stream or river. Because of the many benefits for stream condition and water quality, buffer width or condition have been suggested as a monitored parameter.

What it indicates

Well-functioning riparian buffers help stabilize a stream, reduce runoff into streams, and reduce water temperature. They also slow water runoff, trap sediment, and enhance infiltration to reduce fertilizer, pesticide, and pathogen transport into streams. There is not a fixed buffer width adequate to protect water quality in all cases. Monitoring width provides information on whether the buffer is wide enough to protect the stream. Wider buffers are generally more protective.

Method overview

Buffers are often monitored through field observations, either from a vehicle at bridge crossings, or from a boat, in conjunction with GPS measurements and potentially photos, although the full width may not be visible from a boat, Aerial photos, which are available in online programs like IndianaMap or even Google maps, can also be used.

Typical values in Indiana

Buffer widths vary widely, from none (crops planted to the top of the bank or even further) to hundreds of feet.

Targets or Protective levels

Adequate buffer widths vary, depending upon location, erosion potential, soil, and slope. Natural Resources Conservation Service's Planning & Design Manual provides some guidance on width needed for various buffer functions.

- *Filter sediment and sediment-attached contaminants from runoff* - For slopes less than 15%, most sediment settling occurs within a 25-30 ft wide buffer of grass. Greater width may be required for shrub and tree vegetation, on steeper slopes, or where sediment loads are particularly high.
- *Filter soluble nutrients and pesticides from runoff* - Width up to 100 ft (30 m) or more may be necessary on steeper slopes and less-permeable soils to obtain sufficient capacity for infiltration of runoff, and vegetation and microbial uptake of nutrients and pesticides.
- *Provide shade, shelter, and food for aquatic organisms* - Warm water fisheries may require only very narrow buffers, except where shade and temperature control is needed to

discourage algae blooms. Width up to 100 ft (30 m) in trees may be needed for adequate shade and water temperature control for cold water fisheries in warmer climates.

- *Provide wildlife habitat* - Width required is highly dependent upon desired species. For example, Indiana NRCS Conservation Practice Standard states a minimum width of 950 ft (290 m) of woody plants to promote amphibians and aquatic reptiles, and a minimum width of 330 ft (100 m) to promote general wildlife.
- *Stabilize eroding banks* - On smaller streams and lakes, good erosion control may require only the width of the bank to be covered with shrubs and trees. Extending buffer vegetation beyond the bank is necessary where more active bank erosion is occurring.

Resources Needed

Table 19.2: Resources Needed for Monitoring Buffer Zone Width

	Field Sampling	Laboratory Analysis
Equipment	None	None needed
Time	The aerial photo method is fairly quick, perhaps 15 minutes per mile of stream. Driving or visiting in a boat would necessitate travel time in addition to actual measurements.	
Expertise	Low	
Costs	Low	

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20. Richards-Baker Flashiness Index

Indicator: Annual Index Value, ranging from 0 to 2

Table 20.1: Who's monitoring Richards-Baker Flashiness Index in Indiana?
No statewide assessment programs were identified.

Stream flashiness is the stream flow response to storms. Streams that rise and fall quickly are considered flashier than those that maintain a steadier flow. The Richards-Baker Flashiness (R-B Index) is used to quantify the frequency and rapidity of short-term changes in stream flow (Baker, et. al. 2004). This index has low inter-annual variability relative to most flow regime indicators and thus greater power to detect trends. An increase in flashiness, often due to changing land use, is a common cause of stream channel instability.

What it indicates

Flashiness is an important characteristic of a stream's hydrologic regime. A variety of land and water management changes may lead to increased or decreased flashiness. This flashiness index is based on mean daily flows. An increase in flashiness, due to higher peak flows or more frequent bankfull flows, may result in measurable changes to the channel shape – width, depth, sinuosity, and slope. These changes occur by erosion. Reducing excessive erosion is a common Nonpoint Source project objective. A frequent dilemma in selecting and siting best management practices is assessing the scale of the stream channel stability problem versus the scale of the problem's cause. The R-B Index is one tool for diagnosing the scale of a particular stream channel problem. Over time, the goal should be to reduce the R-B Index calculated for a stream channel.

Method overview

The index is calculated by dividing the sum of the absolute values of day-to-day changes in mean daily flow by total discharge during that time interval. In equation form, the index is

$$R - B\ Index = \frac{\sum_{i=1}^{n} |q_i - q_{i-1}|}{\sum_{i=1}^{n} q_i}$$

where q_i is the mean daily flow at day i ($m^3\ s^{-1}$) and q_{i-1} is the mean daily flow at day i-1 ($m^3\ s^{-1}$). The index can easily be calculated from USGS stream gage records using a spreadsheet provided by Richards and Baker (Figure 20.1). Because daily flow data are required as input, the index can only be calculated for sites and time periods where continuous data exist.

The R-B index alone indicates the degree of variability in daily flows. To understand how stream flashiness is affected by another parameter, the correlation needs to be tested. For example, if a watershed group wants to determine how converting urban area to pasture might impact the stream flashiness, they will need to evaluate the correlation between R-B index for a given time period and compare it to the change in land cover.

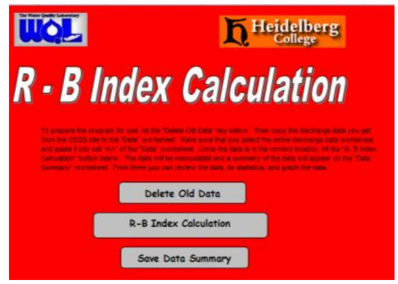

Figure 20.1: Spreadsheet developed by Richards and Baker for calculating the R-B index. (Available at https://engineering.purdue.edu/watersheds/tools.html)

Typical values in Indiana

Michigan's Nonpoint Source Program has integrated the R-B Index into their stream stability assessments and watershed management plans, and is beginning to collect data for streams throughout the state where daily flow data are available. The Michigan Department of Environmental Quality applied the R-B Index to gauged Michigan rivers and streams and found that the yearly-averaged R-B Index values for Michigan watersheds ranged from 0.006 to 1.009 (Fongers, et al. 2007).

The R-B Index in Indiana was calculated in 16 small watersheds within the White River basin for two 12-year periods; 1980-1991 and 1992-2003 (Yang, et al. 2009). In most cases, the index increased slightly, likely the result of increases in impervious surface. (Table 20.2)

Table 20.2: Drainage Area, Impervious Surface Area and R-B Index Values for 16 Indiana Watersheds within the White River Basin, ranked by R-B Index for 1992-2003 (from Yang, et al. 2009).

Site Name	Drainage Area (km2)	Impervious Surface 1983 (%)	R-B Index (1980-1991)	Impervious Surface 2001 (%)	R-B Index (1992-2003)
Sugar Creek At New PalestIne, IN	243.1	0.7	0.31	1	0.34
Buck Creek Near Muncie, IN	91.9	0.03	0.32	0.5	0.37
Stony Creek Near Noblesville, IN	131.5	1.0	0.34	1.1	0.40
Pipe Creek At Frankton, IN	292.5	1.0	0.39	1.3	0.45
Harberts Creek Near Madison, IN	277.0	3.8	0.51	7.2	0.51
Buck Creek At Acton, IN	204.0	4.5	0.54	6.7	0.54
Eagle Creek At Zionsville, IN	274.4	0.8	0.56	1.4	0.55
Clifty Creek At Hartsville, IN	236.6	0.2	0.58	0.2	0.61
West Fork White Lick Creek At Danville, IN	74.5	0.6	0.54	0.9	0.70
Patoka River Near Hardinsburg, IN	33.1	0.1	0.72	0.1	0.75
Crooked Creek At Indianapolis, IN	46.3	20.7	0.71	25.7	0.77
Back Creek At Leesville, IN	62.3	0.2	0.66	0.2	0.82
Little Eagle Creek At Speedway, IN	62.9	24.9	0.78	38	0.85
Lick Creek At Indianapolis, IN	40.3	24.3	0.79	28.5	0.87
Brush Creek Near Nebraska, IN	29.5	0.3	1.03	0.9	1.09
Pleasant Run At Arlington Av At Ind, IN	19.6	41.7	1.02	43.1	1.13

Targets or Protective levels

Because the R-B Index is influenced by the size of the watershed, the percent of impervious surface area, and likely (at least in Indiana) the amount of tile drainage, it is difficult to offer target levels for this parameter. Instead, annual index values can be calculated and analyzed over time for any trends.

Resources Needed

Table 20.3: Resources Needed for Monitoring Richards-Baker Flashiness Index

	Field Sampling	**Laboratory Analysis**
Equipment	Computer; Spreadsheet provided by Richards and Baker (Provided at https://engineering.purdue.edu/watersheds/tools.html; see Figure 19.1)	No laboratory analysis needed
Time	20-30 minutes per stream gage/flow dataset	
Expertise	Training may be needed; Instructions are clear.	
Costs	Staff time	

References

Baker, D. B., Richards, R. P., Loftus, T. T., and Kramer, J. W. 2004. A New Flashiness Index: Characteristics and Applications to Midwestern Rivers and Streams. *Journal of the American Water Resources Association* Vol. 40(2):503-522.

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Biological Monitoring

Biological parameters include the following:

21. Indiana Index of Biotic Integrity (IBI) for Fish Communities

Indicator: Fish IBI values, ranging from 6 to 60

The original multi-metric Index of Biotic Integrity (IBI) was developed by Dr. James Karr (1981) to assess fish community health in small warm water streams in central Illinois and Indiana.

The IBI is composed of 12 metrics, which look at characteristics of the fish community including the number of fish species and/or individuals as well as their feeding and reproductive behavior and sensitivity to pollution. These 12 metrics vary depending on ecoregion, watershed, type of waterbody (i.e., lake or stream/river), and size of waterbody (i.e., headwater, wadeable, great river, etc.).

Table 21.1: Who's monitoring Fish IBI in Indiana?

Agency	Field Collection Methods Used	Analysis Methods Used
IDEM Watershed Assessment & Planning Branch	IDEM Assessment Branch Summary of Protocols: Probability Based Site Assessment	See Simon and Dufour 2006 for Ecoregion , Large and Great Rivers, Inland Lakes and Great Lakes Nearshore
IDNR Fisheries	Manual of Fishery Survey Methods	See Simon and Dufour 2006 for Ecoregion , Large and Great Rivers, Inland Lakes and Great Lakes Nearshore
US Fish & Wildlife Service		See Simon and Dufour 2006 for Ecoregion , Large and Great Rivers, Inland Lakes and Great Lakes Nearshore

As the Karr IBI gained popularity, the original index was modified for various regions, ecosystems, and organisms. Most Indiana researchers calculating IBI scores use a series of publications by U.S. EPA Region 5 and other professional journal articles that measure fish community integrity for the 5 ecoregions of Indiana, large and great rivers, inland lakes, and Great Lakes nearshore. Many of these publications were written by Dr. Thomas P. Simon with assistance from other federal, state, and local government agencies. Several of these documents are available at: http://monitoringprotocols.pbworks.com/US-Fish-and-Wildlife-Service

More information about the IBI is at http://www.epa.gov/bioiweb1/html/ibi_history.html.

What it indicates

The fish IBI provides information on the health of a stream based on attributes of the resident fish population. There are many advantages of using fish for looking at stream health. Most fish have a life span of greater than three years, which allows detection of degradation that has occurred over an extended period of time. There is also extensive life history information for fish species, so the feeding and reproductive behavior of many species is well documented. Also, the identification of many species of fish can be made in the field without extensive laboratory processing.


Stream sampling using backpack electrofishing equipment.

If IDEM's assessment found impaired biological communities in your watershed, it is important to determine if the impairment is based on fish or macroinvertebrates. You might consider continued monitoring based on the impairment.

Method overview

Conducting sampling in order to calculate a fish IBI requires expensive electrofishing equipment, a Scientific Purposes License from the Indiana Department of Natural Resources, training on how to use the equipment safely and properly in sampling different aquatic habitats, and knowledge about fish taxonomy for the local region. The area sampled and proper equipment used to collect a representative fish community sample depends on the size of the waterbody. Most methods require electrofishing equipment and seines to collect all observed fish that are then sorted by species. For each species, total number of individuals is recorded along

Table 21.2: Metrics and Components of the Indiana Fish IBI

Metric	Metric Components Used in Indiana
Species Richness and Composition Metrics	• Total Number of Fish Species (total taxa) • Number of Round Body Sucker Species • Number of Darter Species • Number of Sunfish Species
Indicator Species Metrics	• Number of Intolerant or Sensitive Species • Percent of Tolerant Individuals • Percent of Pioneer Individuals (first to colonize after disturbance)
Trophic Function Metrics	• Percent of Omnivore Individuals • Percent of Insectivore Individuals • Percent of Carnivore Individuals • Percent of Detritivore Individuals
Reproductive Function Metrics	• Percent of Simple Lithophilic Individuals (require clean substrates to effectively reproduce)
Abundance and Condition Metrics	• Number of Total Fish • Percent of Individuals with Anomalies, like Deformities, Eroded Fins, Lesions, or Tumors (DELTs)

with minimum and maximum length, total weight, and numbers of diseased fish including those with deformities, eroded fins, lesions, and tumors. It is also highly recommended that one or two individuals of each species be preserved in 3.7% formaldehyde solution to verify identifications (voucher specimens). Fish collections for the IBI should be conducted between June and October during low flow conditions with little to no turbidity. For detecting trends, conducting one sampling event every year around the same date with similar stream conditions is preferred.

If your monitoring strategy includes collecting fish IBI and your watershed project received 319 funding for monitoring, please note that IDEM requires their methods be used to collect and analyze fish IBI.

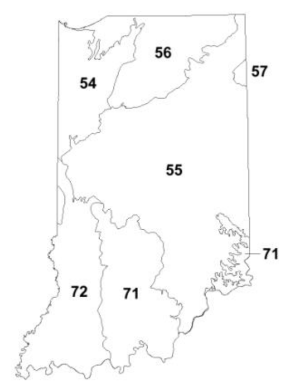
Typical levels in Indiana

Table 21.3 shows IDEM data (1996-2010) from the IDEM Assessment Information Management System (AIMS) database for fish IBI values by Ecoregion (includes only streams and large rivers).

Table 21.3: Fish IBI Scores in Indiana waters by Level 3 Ecoregions

No.	Ecoregion Name	No. of Samples	25%	Mean	Median	75%
	Entire State	1537	30	36	38	44
54	Central Corn Belt Plains	260	24	31	34	40
55	Eastern Corn Belt Plains	746	32	38	40	48
57	Huron/Erie Lake Plain	7	16	28	22	42
56	S Michigan/N Indiana Drift Plains	198	28	33	34	42
71	Interior Plateau	173	36	42	44	50
72	Interior River Lowland	153	24	34	36	40

Ecoregions of Indiana



Target levels

Indiana narrative biological criteria 327 IAC 2-1-3 states that “all waters, except those designated as limited use, will be capable of supporting a well-balanced, warm water aquatic community.” The water quality standard definition of a “well-balanced aquatic community” is “an aquatic community which is diverse in species composition, contains several different trophic levels, and is not composed mainly of strictly pollution tolerant species” 327 IAC 2-1-9. A stream segment is non-supporting for Aquatic Life Use when the monitored fish community receives an IBI score of less than 35 which is considered “Poor” or “Very Poor.”

Table 21.4: Target IBI values for streams and rivers (Sobat et al. 2006)		
Total IBI Score	**Integrity Class**	**Attributes**
53-60	Excellent	Comparable to "least impacted" conditions, exceptional assemblage of species.
45-52	Good	Decreased species richness (intolerant species in particular), sensitive species present.
35-44	Fair	Intolerant and sensitive species absent, skewed trophic structure.
23-34	Poor	Top carnivores and many expected species absent or rare, omnivores and tolerant species dominant.
12-22	Very Poor	Few species and individuals present, tolerant species dominant, diseased fish frequent.
<12	No fish	No fish captured during sampling.

Resources Needed

Table 21.5: Resources Needed for Monitoring Indiana Fish IBI		
	Field Sampling	**Laboratory Analysis**
Equipment	Electrofishing equipment, buckets and baskets to sort fish, personal protective equipment (i.e. life jacket, waders, electrofishing gloves), measuring board, scale to weigh fish, 3.7% formaldehyde solution in jar to preserve unknown and a few known individuals for each fish species, camera to take photos of larger fish species that cannot be preserved, and data sheets.	Ventilation System, gloves, carboy for waste disposal, sampling pan, forceps, taxonomic identification keys, dissecting microscope, and 70% Denatured Alcohol with jars to permanently store fish specimens.
Time	1 to 6 hours depending on stream size and number of fish captured. This includes electrofishing, sorting fish by species, and number of individuals per species.	30 minutes to two hours, depending on taxonomic expertise and number of fish per sample.
Expertise	Indiana Scientific Purposes License is required with the signature of two scientists in a relevant field to serve as references (312 IAC 9-10-6). Fish taxonomic identification skills to species. Training is needed for electrofishing and effective sampling. QA/QC includes 10% field revisits and maintaining voucher specimens to be verified by a professional taxonomist.	Professional level taxonomic skills are necessary to identify fish to the species level.
Costs	Consultants may charge $200-500/site Electrofishing equipment costs between $6,000 and $70,000. Many consultants have this equipment.	Ichthyologist may charge from $20-$60/hour, plus a fee for waste disposal of formaldehyde (around $15/gallon) and staff time to maintain permanently housed fish specimens.

References

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22. Macroinvertebrate Indices of Biotic Integrity

Aquatic macroinvertebrates are often used as indicators of the habitat and water quality of aquatic ecosystems because they are sensitive to local conditions due to their limited mobility and tend to respond rapidly to changes within the environment. In addition, sampling methods for aquatic macroinvertebrates are generally simple and do not require a lot of expensive equipment.

Different metrics have been developed to use macroinvertabrates to quantify changes in aquatic ecosystems. Most common are indices of biotic integrity or IBIs which are scoring systems generally specific to geographic areas or ecoregions. Macroinvertebrates collected for IBIs are generally identified in the laboratory allowing flexibility to when the sample is processed and by whom (e.g., it may be possible to hire a consultant to identify the macroinvertebrate sample collected by a watershed group).

If IDEM's assessment found impaired biological communities in your watershed, it is important to determine if the impairment is based on fish or macroinvertebrates. You might consider continued monitoring based on the impairment.

Macroinvertebrate sampling and identification. .

In Indiana, the main macroinvertebrate IBIs used are modified versions of the *EPA Rapid Bioassessment Protocols* (EPA RPB) (Plafkin et al. 1989; Barbour et al. 1999) and the *Multi-habitat Macroinvertebrate Index of Biotic Integrity* (MHAB mIBI) developed by the Indiana Department of Environmental Management (IDEM) (IDEM 2010). The Hilsenhoff Biotic Index (HBI) is an additional index not currently used independently by state or federal agencies in Indiana, but was identified by the expert panel as a potential indicator for assessing low dissolved oxygen caused by organic loading in streams. The HBI is used by the IDNR Lake & River Enhancement (LARE) Program and was previously used by IDEM to calculate mIBI using a modified EPA bioassessment protocol. The Hoosier Riverwatch volunteer monitoring program uses an index called the Macroinvertebrate Diversity Index, which relies on distinguishing benthic organisms by color, size and shape, but because it focuses on pollution tolerance categories rather than precise macroinvertebrate identification, this index is not included.

The IDNR LARE Program uses the single habitat collection methods and eight metrics suggested by Plafkin et al. 1989. This method requires conducting kick sample collections at two riffles within a designated stream reach. Organisms are sorted and identified to the lowest practical taxon (generally genus or species). This method includes eight metrics, each are scored as 6 (nonimpaired), 4 (slightly impaired), 2 (moderately impaired), or 0 (severely impaired) when using the RBP III genus/species level approach (recommended for measuring long-term trends) based on scoring criteria (scoring criteria differs if using the RBP II family level approach – recommended for diagnostic studies). The total score is then calculated against a reference site to achieve a percent comparison to reference score.

Prior to 2005 (1990-2003), IDEM used a modification of the EPA RBP single habitat approach that differs from LARE's modified version. This method required compositing 2 kick samples (2 square meters) using a kick net in riffle/run habitats within a designated stream reach. The sample was taken back to the lab and placed in a gridded tray where a randomly selected sub-sample of at least 100 organisms are sorted and identified to the family level in the laboratory. This sampling method included 10 metrics, each scored as 0, 2, 4, 6, or 8. The metric scores were then averaged for a total score of 0 to 8, where 0-2 (severely-impaired), 2-4 (moderately-impaired), 4-6 (slightly-impaired), 6-8 (non-impaired).

In 2005, IDEM began using a multi-habitat (MHAB) mIBI method which composites a riffle/run kick and a sweep of 50 meters of all available shoreline habitats using a d-frame net. The sample is then picked for 15 minutes in the field with an emphasis on diversity and relative abundance. All organisms in the subsample are identified to the lowest practical taxon, usually to the genus or species level. The MHAB mIBI includes 12 metrics that describe the structural, functional and compositional integrity of the macroinvertebrate community which helps characterize the quality of the stream or river. The scores for each individual metric (1, 3 or 5) are totaled and range from 12 to 60. As with the fish community IBI, MHAB mIBI scores less than 36 are considered non-supporting of aquatic life use while those equal to or greater than 36 are supporting of aquatic life use.

Table 22.1: Macroinvertebrate indices of biotic integrity, with associated protocols

Indiana Agency	**Protocol name**	**Name of index**
LARE	Modified EPA Rapid Bioassessment *Protocol for Use in Streams and Rivers: Macroinvertebrates and Fish*	Percent compared to a reference score
IDEM	Prior to 2005: 10 metric/single habitat/family level analysis Multi-habitat Macroinvertebrate Index of Biotic Integrity	mIBI MHAB mIBI
None	HIlsenhoff	HBI or H-FBI

The Hoosier Riverwatch Program Macroinvertebrate Diversity Index for its volunteer stream monitoring is described at: http://www.in.gov/dnr/nrec/files/nc-Riverwatch_Manual.pdf (page 98).

22a. IDNR LARE EPA Rapid Bioassessment Protocol

Indicator: index value

Benthic communities in streams can be evaluated using a macroinvertebrate Index of Biotic Integrity (mIBI), one of several multi-metric indices that measure the structural, compositional, and functional integrity of the benthic community. A modified EPA Rapid Bioassessment Protocol (EPA RBP), currently used by the IDNR LARE Program is one of two mIBI methods used in Indiana.

22a.1: Who's monitoring EPA RBP mIBI in Indiana?		
Agency	**Field Collection Methods Used**	**Analysis Methods Used**
IDNR Lake & River Enhancement Program	EPA Rapid Bioassessment Protocol II Single Habitat, Family Level or III Genus/Species	EPA Rapid Bioassessment Protocol II Single Habitat, Family Level or III Genus/Species

What it indicates

The mIBI is designed to provide an assessment of the biological integrity of a wadeable stream.

Method overview

Macroinvertebrate sampling generally does not require expensive equipment. However, the modified EPA RBP subsampling methods require that those collecting samples have the expertise necessary to readily distinguish between different taxa among very small organisms. Also, because some metrics can vary depending upon the collection and subsampling methodologies used to survey a stream, it is important to adhere to the specific method being used in order to ensure the comparability of your macroinvertebrate data to that collected by the agencies.

Sampling in a stream

This method involves taking kick samples in the stream using a D-frame dipnet or kick screen. After collection, the samples are rinsed of debris at least five times through a sieve (size may vary). The contents of the sieve are then identified to the lowest practical taxon. The lowest practical taxon for a given organism is based on the level of detail available in the taxonomic keys most commonly used for macroinvertebrate identification.

Once the sample organisms have been identified, each metric is determined (see Table 22a.2). For the modified EPA RBP, scoring criteria is compared to a reference site to assign biological condition categories.

It is critical to conduct sampling for the mIBI at the same time of the year in order to compare results. It is best to conduct macroinvertebrate sampling in the fall because the organisms' development is more advanced making identification easier.

Table 22a.2 Metrics used to calculate EPA RBP indices (IDNR 2011)

EPA Rapid Bioassessment Protocol Metrics	• Number of Taxa • EPT Index • Percent Dominant Taxa • Ratio of EPT/Chironomidae • Modified Hilsenhoff Biotic Index (also known as family-level Hilsenhoff Biotic Index) • Ratio of Scraper/Filtering Collectors • Ratio of Shredder/Nonshredder • Community Loss Index

Typical values in Indiana

The LARE Program has not summarized statewide data using this index.

Targets or Protective levels

EPA's Rapid Bioassessment Protocol:

Table 22a.3: Biological Condition Categories for the EPA RBP III Genus/Species Approach *(Plafkin et al. 1989)*

Percent Compared to Reference Score	Biological Condition Category	Attributes
>83%	Non-impaired	Comparable to the best situation to be expected within an ecoregion. Balanced trophic structure. Optimum community structure (composition and dominance) for stream size and habitat quality.
54-79%	Slightly impaired	Community structure less than expected. Composition (species richness) lower than expected due to loss of some intolerant forms. Percent contribution of tolerant forms increases
21-50%	Moderately impaired	Fewer species due to loss of most intolerant forms. Reduction in EPT index.
<17%	Severely impaired	Few species present. If high densities of organisms, then dominated by one or two taxa.

Resources Needed

Table 22a.4: Resources Needed for Monitoring EPA RBP Indices		
	Field Sampling	**Laboratory Analysis**
Equipment	Sampling bottles; D-frame sampling net ($65-$170); Waders ($50-$300/pair); Forceps; Ethanol	Shallow sampling pans, forceps, taxonomic identification keys, compound and/or dissecting microscope
Time	Approximately 1 hour	If identification to genus, 1-5 hours per sample, depending on experience; identification to species could take up to 10 hours per sample
Expertise	Training needed to distinguish between different instream habitats and to readily distinguish between different taxa among very small organisms.	Professional level taxonomic skills are necessary to identify organisms to the genus/species level. QA/QC includes 10% field duplicates and maintaining voucher specimens to be verified by a professional taxonomist.
Costs	Staff time; Consultants may charge $200-500 per site	

References

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22b. Multi-habitat Macroinvertebrate Index of Biotic Integrity (MHAB mIBI)

Indicator: index value

Benthic communities in streams can be evaluated using a macroinvertebrate Index of Biotic Integrity (mIBI), one of several multi-metric indices that measure the structural, compositional, and functional integrity of the benthic community. The multi-habitat mIBI (MHAB mIBI) is one of two mIBI methods used in Indiana.

22b.1: Who's monitoring MHAB mIBI in Indiana?		
Agency	**Field Collection Methods Used**	**Analysis Methods Used**
IDEM Watershed Assessment & Planning Branch	IDEM Multi-habitat (mHAB) Macroinvertebrate Collection Procedure	IDEM mIBI Calculation Instructions (contact IDEM)

What it indicates

The MHAB mIBI is designed to provide an assessment of the biological integrity of a wadeable stream.

Method overview

Macroinvertebrate sampling generally does not require expensive equipment. However, the MHAB mIBI subsampling methods require that those collecting samples have the taxonomic expertise necessary to readily distinguish between different macroinvertebrate taxa in the field. Each collection and subsampling methodology used to survey a stream features its own set of metrics; it is important to adhere to the specific field and laboratory methods being used by the agency to which you plan to submit your macroinvertebrate data.

Table 22b.2 Metrics used to calculate IDEM's MHAB mIBI	
IDEM MHAB mIBI Metrics	• Total Number of Taxa (collected from a 50-meter reach) • Total Abundance of Individuals (15 minute subsampling) • Number of EPT Taxa (score based on drainage area of stream reach sampled) • Percent Orthocladinae + Tanytarsinii of Chironomidae • Percent Non-insects (not including crayfish) • Number of Diptera Taxa • Percent Intolerant Taxa (Tolerance Value 0-3) • Percent Tolerant Taxa (Tolerance Value 8-10) • Percent Predators • Percent Shredders + Scrapers • Percent Collector-Filterers • Percent Sprawlers

The MHAB mIBI sampling methods consist of using a D-frame dipnet to collect a one-minute kick sample within a riffle/run habitat and a "sweep" of all available habitats in a 50 meter section of the stream. After collection, the kick and sweep samples are combined in a bucket of water, agitated by hand and poured through a No. 35 (500 µm) sieve a minimum of five times. After each pour, the contents of the sieve are emptied into a white tray. The contents of the tray are then picked in the field for 15 minutes, with an emphasis on obtaining the greatest diversity and relative abundance of macroinvertebrates possible. The picked macroinvertebrates are then preserved in the field and taken back to the laboratory for processing and identification to the lowest practical taxonomic level. The lowest practical taxon for a given specimen is usually based on the availability and quality of macroinvertebrate taxonomic keys and the age and physical condition of the specimen.

Once the sample organisms have been identified, each metric is determined (see Table 21a.2.). The MHAB mIBI includes 12 metrics that describe the structural, functional and compositional integrity of the macroinvertebrate community which helps characterize the quality of the stream or river. The scores for each individual metric (1, 3 or 5) are totaled and range from 12 to 60. For the MHAB mIBI, metric scores are summed to determine the mIBI score for that particular site. As with the fish community IBI, MHAB mIBI scores less than 36 are considered non-supporting of aquatic life use while those equal to or greater than 36 are supporting of aquatic life use. The index period for the mHAB mIBI is July 15 – November 15. Samples collected outside of this index period may not score correctly and could result in an inaccurate measurement of the macroinvertebrate community of the sampling site.

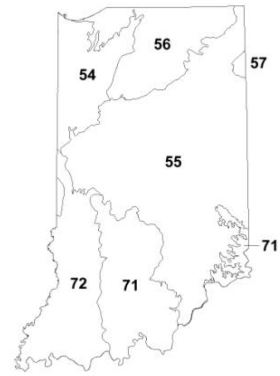
Macroinvertebrate identification in the laboratory.

Typical values in Indiana

Table 22b.3 shows IDEM data (2004-2010) from the IDEM Assessment Information Management System (AIMS) database for MHAB mIBI values by Ecoregion.

Table 22b.3: Statistics of MHAB mIBI Scores for Indiana waters by Level 3 Ecoregions (from IDEM)						
No.	**Ecoregion Name**	**No. of Samples**	**25%**	**Mean**	**Median**	**75%**
	Entire State	511	32	35.4	36	40
54	Central Corn Belt Plains	49	30	34.5	34	38
55	Eastern Corn Belt Plains	193	32	36.3	36	40
57	Huron/Erie Lake Plain	3	30	36.7	38	42
56	S Michigan/N Indiana Drift Plains	74	26	31.6	31	36
71	Interior Plateau	112	32	36.6	36	42
72	Interior River Lowland	80	32	35.1	34	38

Ecoregions of Indiana



Targets or Protective levels

Narrative description of IDEM's MHAB mIBI:

Indiana narrative biological criteria 327 IAC 2-1-3 states that "all waters, except those designated as limited use, will be capable of supporting a well-balanced, warm water aquatic community." The water quality standard definition of a "well-balanced aquatic community" is "an aquatic community which is diverse in species composition, contains several different trophic levels, and is not composed mainly of strictly pollution tolerant species" 327 IAC 2-1-9. A stream segment is non-supporting for Aquatic Life Use when the monitored macroinvertebrate community receives an IBI score of less than 35 which is considered "Poor" or "Very Poor."

Table 22b.3: Target IBI values for streams and rivers (Sobat et al. 2006)		
Total IBI Score	**Integrity Class**	**Attributes**
53-60	Excellent	Comparable to "least impacted" conditions, exceptional assemblage of species.
45-52	Good	Decreased species richness (intolerant species in particular), sensitive species present.
35-44	Fair	Intolerant and sensitive species absent, skewed trophic structure.
23-34	Poor	Many expected species absent or rare, tolerant species dominant.
12-22	Very Poor	Few species and individuals present, tolerant species dominant.

Resources Needed

Table 22b.4: Resources Needed for Monitoring MHAB mIBI		
	Field Sampling	**Laboratory Analysis**
Equipment	Sampling bottles; D-frame sampling net ($65-$170); Waders ($50-$300/pair); Forceps; Ethanol; No. 35 Sieve; Buckets; White Sampling Trays	Forceps, Taxonomic identification keys, Compound and/or dissecting microscope
Time	Approximately 1 hour	1-10 hours per sample, depending on experience, and number and diversity of organisms in sample
Expertise	Training needed to distinguish between different instream habitats and to readily distinguish between different macroinvertebrate taxa.	Professional level taxonomic skills are necessary to identify organisms to the genus/species level. QA/QC includes 10% field duplicates and maintaining voucher specimens to be verified by a professional taxonomist.
Costs	Staff time; Consultants may charge $200-500 per site	

References

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22c. Hilsenhoff Biotic Index

Indicator: Index values, ranging from 0 to 10

Table 22c.1: Who's monitoring Hilsenhoff Biotic Index in Indiana?
No statewide assessment programs were identified.

The Hilsenhoff Biotic Index (HBI) was originally developed in 1977 by Dr. William Hilsenhoff of the University of Wisconsin - Madison, to assess low dissolved oxygen caused by organic loading in streams. The Wisconsin Department of Natural Resources (WIDNR) began using the HBI (Hilsenhoff 1977, 1982, 1987) in 1979 to assess water quality in streams and rivers as part of several non-point source pollution monitoring programs and now statewide efforts collect about 450 HBI samples/year. Pollution tolerance scores for the HBI were improved with additional stream analyses and are published by Hilsenhoff (1977, 1982, 1987, and 1988a). The procedures for sampling and laboratory processing were standardized in 1983 and statistical analysis procedures for applying the HBI were developed by Narf et al. (1984).

Although no Indiana agencies currently use it as an independent index, the HBI was identified during the expert panel process as a potentially advantageous indicator because it can assess low dissolved oxygen caused by organic loading in streams. The HBI is currently used by LARE as one of eight metrics used to calculate their mIBI and was used by IDEM prior to 2005 in the same way. A compilation of pollution tolerance scores from Wisconsin, Ohio, New York, and North Carolina are used for sampling conducted in Indiana because tolerance scores for Indiana are not available.

In 1988, Hilsenhoff proposed a family-level biotic index (H-FBI). The purpose of the H-FBI is to provide a rapid, but less critical, evaluation of streams and is not intended as a substitute for the HBI when detailed taxonomic information is available. The H-FBI uses the same formula as the HBI but substitutes average pollution tolerance scores (a_i) for a family instead of differences in species. Pollution tolerance scores for the H-FBI are published by Hilsenhoff (1988b.)

Using a D-net to sample macroinvertebrates.

What it indicates

Although originally developed to assess low dissolved oxygen caused by organic loading, a purpose for which it works best (Hilsenhoff 1977, 1982, 1987), the HBI may also be sensitive to the effects of impoundment, thermal pollution, and some types of chemical pollution (Hilsenhoff 1998, Hooper 1993).

The Hilsenhoff 1977 formula is $HBI = \frac{\sum n_i a_i}{N}$

where n_i is the number of specimens in each taxonomic group, a_i

is the pollution tolerance score for that taxonomic group, and N is the total number of organisms in sample.

Comparison of the HBI and H-FBI using Wisconsin stream samples indicated that the H-FBI is not as accurate as the HBI and that the H-FBI usually indicates greater pollution than the HBI in unpolluted/slightly polluted streams and less pollution in polluted streams. The purpose of the H-FBI is to provide a rapid, less critical assessment procedure, but is not intended to replace the HBI.

Method overview

Macroinvertebrate collection methods include sampling a riffle area or shallow run using a D-net. The net should be placed against the stream bottom while disturbing the substrate immediately upstream of the net until an excess of 100 arthropods are collected (>200 arthropods may bias the sample). The macroinvertebrate sample is emptied into a collection pan and 100 arthropods are removed and identified to genus/species to calculate HBI and family to calculate H-FBI. The number of arthropods in each genus/species or family is recorded, depending on which biotic index is used.

The calculations for HBI and H-FBI are the same; multiply the number of individuals in each genus/species or family by the tolerance value for that genus/species or family. These results are then summed and divided by the number of individuals in the sample, or 100. The tolerance values vary depending on which biotic index is used.

Typical values in Indiana

The only HBI values identified in Indiana were from three sites sampled at the U.S. Army Atterbury Reserve Forces Training Area during 2002. Two sites scored 5.6 and 5.7 (fair) and one site scored 7.9 (poor) (Robinson 2004).

Targets or Protective levels

Table 22c.2: Water Quality Classifications for the Hilsenhoff Biotic Index (HBI) (Hilsenhoff 1987) and H-FBI (Hilsenhoff 1988b)

Water Quality Interpretation	Degree of Organic Pollution	HBI Index Scores	H-FBI Index Scores
Excellent	No apparent organic pollution	0.00-3.50	0.00-3.75
Very Good	Slight organic pollution	3.51-4.50	3.76-4.25
Good	some organic pollution	4.51-5.50	4.26-5.00
Fair	fairly significant organic pollution	5.51-6.50	5.01-5.75
Fairly Poor	Significant organic pollution	6.51-7.50	5.76-6.50
Poor	very significant pollution	7.51-8.50	6.51-7.25
Very Poor	severe organic pollution	8.51-10.00	7.26-10.00

Resources Needed

Table 22c.3: Resources Needed for Monitoring Hilsenhoff Biotic Index		
	Field Sampling	**Laboratory Analysis**
Equipment	Sampling bottles, D-frame sampling net, Waders, Forceps, and Ethanol	Shallow sampling pans, forceps, taxonomic identification keys, compound and/or dissecting microscope
Time	2-3 hours per sample site to calculate HBI; 30 minutes to 1 hour per sample site to calculate H-FBI	If identification to genus, 1-5 hours per sample, depending on experience; identification to species could take up to 10 hours per sample
Expertise	Training needed; Low	Taxonomic identification skills to family, genus or species needed
Costs	Staff time; Consultants may charge $200-500 per site D-frame sampling net ($65-$170) and Waders ($50-$300/pair)	

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23. Chlorophyll a

Indicator: Average concentration (µg/L)

Chlorophyll a is the photosynthetic pigment that causes the green color in algae and plants. Chlorophyll a is the most dominant chlorophyll pigment found in algae.

What it indicates

Scientists use chlorophyll a as an indirect estimate of algal biomass in surface waters. The right amount of algae is needed to maintain a balanced food web while too much algae can cause large scale algae blooms. Studies have tried to find relationships between nutrient (N and P) concentrations and chlorophyll a, but in the nutrient-rich water of Indiana this has been difficult. It may be that habitat factors are more important in controlling algae and chlorophyll a levels.

Method overview

Chlorophyll a can be monitored by collecting periphyton (a mixture of algae, cyanobacteria, microbes, and detritus that are attached to submerged surfaces) or phytoplankton (suspended or free-floating) samples. Sampling periphyton is more representative in small streams (drainage area < 500 square miles; see graph on page 34 in Lowe et al., 2008). Phytoplankton chlorophyll a monitoring (preferred for larger streams; > 500 square miles drainage area) usually consists of taking grab samples at regularly spaced intervals and sending them to a laboratory for

Table 23.1: Who's monitoring chlorophyll a in Indiana?

Agency	Field Collection Methods Used	Analysis Methods Used
IDEM Watershed Assessment & Planning Branch	IDEM Assessment Branch Summary of Protocols: Probability Based Site Assessment Open File Report 02-150 (using a modification of these methods)	EPA 445.0 Standard Methods 10200H
IDNR Lake & River Enhancement Program	IN Clean Lakes Program Procedure (lakes)	Standard Methods 10200H
USGS National Water-Quality Assessment Program	National Field Manual Chapter 7.4.3 Open File Report 02-150	National Field Manual Chapter 7.4
IN Clean Lakes Program	IN Clean Lakes Program Procedure	Standard Methods 10200H
IN Volunteer Lake Monitoring Program	Expanded Volunteer Lake Monitoring Manual	Standard Methods 10200H

Algae growing in a storm water retention pond, Marion County, Indiana.

analysis. Periphyton collection procedures are habitat dependent and require extensive training to conduct properly. Therefore, methods are not described here. Analysis in the laboratory includes filtering a known volume of sample to collect all the algae onto filter paper, extracting the chlorophyll pigments using a solvent and tissue grinder, and quantifying the chlorophyll a concentration using a spectrophotometer or fluorometer. If analysis is delayed, filtered samples should be stored frozen in the dark for no more than 3 ½ weeks before extraction. Longer storage can result in a significant loss of chlorophyll a.

Chlorophyll can also be estimated through optical methods, either using a chlorophyll probe, or through remote sensing, using a hyperspectral sensor flown on special aircraft. These methods are less accurate but can provide measurements much more often and/or at many more locations than sampling.

Typical levels in Indiana

The U.S. Geological Survey collected seston chlorophyll a concentrations (the chlorophyll a concentration found in free-floating algae) within eight river basins in Indiana from 2001 through 2005. The results for by river basin are in Table 23.2 (Lowe, et al. 2008).

Table 23.2: Seston chlorophyll a concentrations in eight Indiana river basins (Lowe, et al. 2008)

River	Year	Minimum chl a concentration (μg/L)	Median chl a concentration (μg/L)	Maximum chl a concentration (μg/L)
West Fork White	2001	0.22	2.7	56.1
Whitewater	2002	0.09	2.73	24.4
East Fork White	2002	0.16	4.01	66.1
Upper Wabash	2003	0.13	2.02	69.8
Kankakee	2004	0.33	2.59	251
Lower Wabash	2004	0.03	2.71	166
Tributaries to Great Lakes	2005	0.41	2.31	161
Tributaries to Ohio River	2005	0.05	1.5	41.2

Algal biomass concentrations by individual basin in Indiana, 2006-2009 (provided by IDEM)

Table 23.3: Algal biomass chlorophyll a concentrations by individual basin

River	Year	Number	Minimum chl a concentration (μg/L)	Median chl a concentration (μg/L)	Maximum chl a concentration (μg/L)
West Fork White	2006	75	0.19	1.36	310.98
Patoka	2006	69	0.10	1.29	21.37
Whitewater	2007	116	0.26	2.61	170.22
East Fork White	2007	112	0.16	2.86	273.09
Upper Wabash	2008	121	0.33	3.42	97.04
Kankakee	2009	130	0.32	3.19	65.90
Lower Wabash	2009	127	0.28	3.51	195.96
All Data	2006-09	750	0.10	2.69	310.98

Lakes: A compilation of data for 160 Indiana lakes collected during 2010-2011 by the Indiana Clean Lakes Program (Jones et al., 2012).

Table 23.4 Statistics for 2010-2011 Clean Lakes Program sampling (Jones, 2012)		
Minimum chl a concentration (µg/L)	**Median chl a concentration (µg/L)**	**Maximum chl a concentration (µg/L)**
0.3	6.2	156.8

A 2004-2008 compilation of data for 50 Indiana lakes found the median chlorophyll a concentration for each Indiana Ecoregion as:

11.45 µg/L in the Central Corn Belt Plains Ecoregion (54)
3.18 µg/L in the Eastern Corn Belt Plains Ecoregion (55)
2.10 µg/L in the Southern Michigan/Northern Indiana Drift Plains Ecoregion (56)
1.27 µg/L in the Interior Plateau Ecoregion (71)

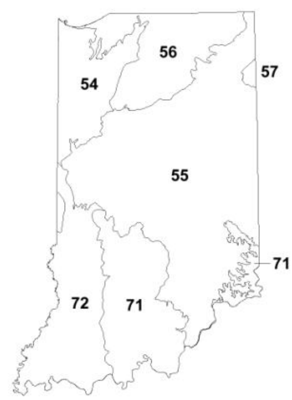
Targets or Protective levels

U.S. EPA's proposed nutrient criteria for rivers and streams, by Ecoregion in Indiana

Table 23.5: EPA's Proposed Criteria for Chlorophyll a Concentrations in Indiana waters by Level 3 Ecoregions		
No.	**Ecoregion Name**	**Chlorophyll a* (µg/L)**
54	Central Corn Belt Plains	2
55	Eastern Corn Belt Plains	**
56	S Michigan/N Indiana Drift Plains	3.5
57	Huron/Erie Lake Plain	3.2
71	Interior Plateau	3.9
72	Interior River Lowland	1.5

*measured by fluorometric method with acid correction
**data inadequate or inconclusive

Ecoregions of Indiana



In lake assessments, chlorophyll a concentrations below 2 µg/L are considered low, and those exceeding 10 µg/L are considered high and indicative of poor water quality (Peel, 2005).

Resources Needed

Table 23.6: Resources Needed for Monitoring Chlorophyll a		
	Field Sampling	**Laboratory Analysis**
Equipment	Sample bottles; Kemmerer sampler (for lake samples only)	EPA and standard methods: Fluorometer, Centrifuge, and Tissue Grinder
Time	3-5 minutes per sample	Approximately 2 hours over 2 days
Expertise	Low	Very high; requires training.
Costs	Kemmerer samplers are generally $250-500	Laboratories generally charge $150-250 per sample

References

Jones, W.W. 2004. Interpreting Lake Data – Indiana Clean Lakes Program. School of Public and Environmental Affairs, Indiana University, Bloomington, Indiana. Online at: http://www.indiana.edu/~clp/documents/Interpreting%20Lake%20Data.pdf

Jones, W.W. and Powers, S. 2009. Indiana Volunteer Lake Monitoring Report: 2004-2008. School of Public and Environmental Affairs, Indiana University, Bloomington, Indiana. Online at: http://www.indiana.edu/~clp/documents/2004_08%20Vol%20FINAL.pdf

Jones, W.W., M. Clark, J. Bond and S. Powers. 2012. Indiana Lake Water Quality Assessment Report for 2009 – 2011. School of Public and Environmental Affairs, Indiana University, Bloomington.

Lowe, B.S., Leer, D.R., Frey, J.W., and Caskey, B.J. 2008. Occurrence and Distribution of Algal Biomass and Its Relation to Nutrients and Selected Basin Characteristics in Indiana Streams, 2001-2005. U.S. Geological Survey Scientific Investigations Report 2008-5203. Online at: http://pubs.usgs.gov/sir/2008/5203/pdf/sir20085203.pdf.

Peel, S. 2005. Four Lakes Watershed Diagnostic Study, Marshall County, Indiana. Online at: http://www.in.gov/dnr/fishwild/files/fw_Four_Lakes_Watershed_Diagnostic_Study_Marshall_County_July_2005.pdf

USEPA. 2001. Ecoregional Criteria Documents. Online at http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/criteria.cfm [Accessed 28 September 2011].

Farm pond with algae, Tippecanoe County

24. *E. coli*

Indicator: CFU/100 mL

Table 24.1: Who's monitoring E. Coli in Indiana?		
Agency	**Field Collection Methods Used**	**Analysis Methods Used**
IDEM Watershed Assessment & Planning Branch	IDEM Survey Section Field Procedure Manual	IDEM Survey Section Field Procedure Manual Standard Methods 9213D, 9223B
IDNR Lake & River Enhancement Program	IDEM Survey Section Field Procedure Manual	IDEM Survey Section Field Procedure Manual Standard Methods 9213D, 9223B
IDNR Hoosier Riverwatch	Volunteer Stream Monitoring Training Manual	Coliscan Easygel Method and 3M Petrifilm Method
USGS National Water-Quality Assessment Program	National Field Manual Chapter 7.1.2	National Field Manual Chapter 7.1

Fecal coliform bacteria are found in the feces of warm-blooded animals, including humans, livestock, and waterfowl. *E. coli* is a specific species of fecal coliform bacteria used in many state's water quality standards, including Indiana.

What it indicates

High levels of *E. coli* indicate fecal contamination and the potential presence of pathogens that could cause human illness. Elevated *E. coli* levels can occur throughout the year; however Indiana's water quality standards for *E. coli* only apply in the recreation season (April to October) and therefore the water body is only considered "impaired" by *E. coli* if the high levels occur then. Sources of *E. coli* include:

- Human waste, which may reach water through poorly functioning septic systems, wastewater treatment plants during the winter or that are non-compliant, or combined sewer overflows
- Animal waste including waste from pets, wildlife/waterfowl, and livestock. Livestock waste most commonly reaches water bodies after having been applied to fields.

Many attempts have been made to differentiate *E. coli* from humans and animals, but it remains uncertain and requires resources far beyond most nonpoint source projects.

Results of *E. coli* monitoring using a test plate

Lakes and streams usually contain a variety of microorganisms including bacteria, viruses, protozoa, fungi, and algae. Most of these occur naturally and have little impact on human health. If fecal pollution is present, there is greater potential for microorganisms that can cause illness and disease in humans.

Monitoring *E. coli* in winter is not generally done by state agencies because the water quality standard only applies to the recreation season, but some dischargers, such as those discharging to the Ohio River, conduct year-round monitoring. Watershed groups may gain insight into sources of *E. coli* by also monitoring throughout the year. They should be aware that point sources (NPDES dischargers) do not chlorinate during the winter, which will impact *E. coli* levels.

Method overview

Most *E. coli* monitoring consists of taking grab samples using sterile sampling equipment and sending them to a laboratory for analysis. Some volunteer monitoring programs analyze their own samples. First, they inoculate test medium with the stream sample, then incubate the test plates for 24-hours, and finally, count colonies.

Water quality standards are based on the geometric mean of five samples.

What is a Geometric Mean?

A geometric mean of 5 concentrations means the 5th root of the product of the concentrations $(C1*C2*C3*C4*C5)^{1/5}$ which can easily be calculated in an Excel spreadsheet with the function GEOMEAN(C1..C5).

More examples and methods for calculating the geometric mean are at http://www.buzzardsbay.org/geomean.htm

Typical levels in Indiana

As part of the development of this manual, dissolved oxygen concentrations from the 176 Fixed Stations monitored by IDEM since 1990 were analyzed to provide an overview of oxygen levels in Indiana (Table 24.2).

Table 24.2: Statistics for E. coli Concentrations (CFU/100mL) in Indiana waters (IDEM Fixed Station Data, 1990-2010)

No. of Samples	Min (CFU/100mL)	25% (CFU/100mL)	Median (CFU/100mL)	75% (CFU/100mL)	Max (CFU/100mL)
7167	2	70	210	670	1,204,000

Temporal variability in streams: *E. coli* is highly variable. Figure 24.1, from a typical Indiana agricultural stream, shows the level varying from approximately 10 CFU/100 ml to approximately 10,000 CFU/100 mL. It is very difficult to get enough *E.coli* samples to ensure representativeness.

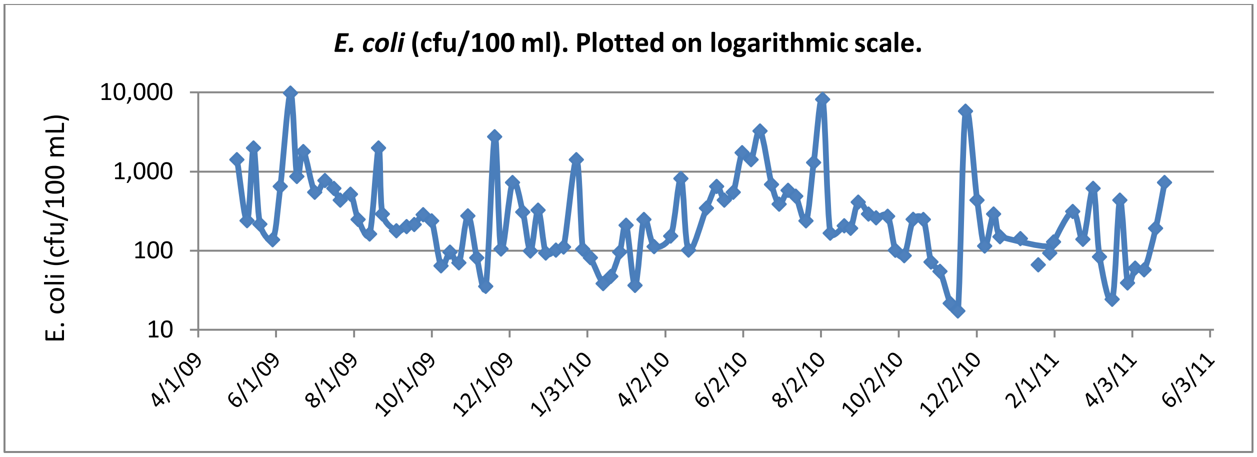


Figure 24.1: *E. coli* in an Indiana stream. Note the logarithmic scale because of high variability. (The range is from about 20 CFU/100mL to 10,000 CFU/100 mL)

Targets or Protective levels

All Indiana streams and lakes are designated to meet the use of “full body contact recreation”, or swimming. Indiana Water Quality Standards for *E. coli* are that during the recreation season (April through October):

- The geometric mean of 5 equally spaced samples over a 30-day period must be less than 125 CFU/100 mL.
- All samples must be less than 235 CFU/100 mL.

Resources Needed

Table 24.3: Resources Needed for Monitoring E. coli		
	Field Sampling	**Laboratory Analysis**
Equipment	Sample bottles	EPA and standard methods: Microscope, ultraviolet unit for sanitization, vacuum pump/aspirator, incubator, and sterile petri dishes Testing plates
Time	3-5 minutes per sample	Approximately 25 hours
Expertise	Low to medium; training on using sterile techniques is important	Low to medium
Costs	Staff time	Laboratories generally charge$40 to $50 per sample; Testing plates: Approximately $25/10 plates

References

Indiana Department of Natural Resources. Spring 2008. Volunteer Stream Monitoring Training Manual: Hoosier Riverwatch. Indianapolis, IN: Indiana Department of Natural Resources

Multi-Parameter Indices

Multi-Parameter indices include the following:

25. Carlson's Trophic State Index

Indicator: CTSI index values, ranging from 0 to 100
*lakes only

Table 25.1: Who's monitoring Carlson's Trophic State Index in Indiana?		
Agency	**Field Collection Methods Used**	**Analysis Methods Used**
IN Volunteer Lake Monitoring Program	Expanded Volunteer Lake Monitoring Manual	Carlson, R.E. 1977

The most widely used and accepted Trophic State Index in the U.S. is one developed by Bob Carlson called the Carlson's TSI (CTSI). Carlson analyzed summertime total phosphorus, chlorophyll *a*, and Secchi disk transparency data for numerous lakes and found statistically significant relationships among the three parameters. He developed mathematical equations for these relationships and used these for the basis for the CTSI.

What it indicates

The Carlson's Trophic State Index is a simple and quick way to demonstrate the associations between water clarity, nutrients, and overall algal biomass.

Method overview

Using the relationship developed by Carlson, a CTSI value can be generated by one of three measurements: Secchi disk transparency, chlorophyll *a* or total phosphorus. Data for one parameter can also be used to predict a value for another. The CTSI values range from 0 to 100. Each major CTSI division (10, 20, 30, etc.) represents a doubling in algal biomass. All three measurements can also be used to calculate three separate CTSI scores for some sampling point. If the lake sampled is similar to those lakes used to develop the CTSI, the three scores should be similar. If there is a distinct difference in the three scores, the difference may indicate the limiting factor within the lake sampled.

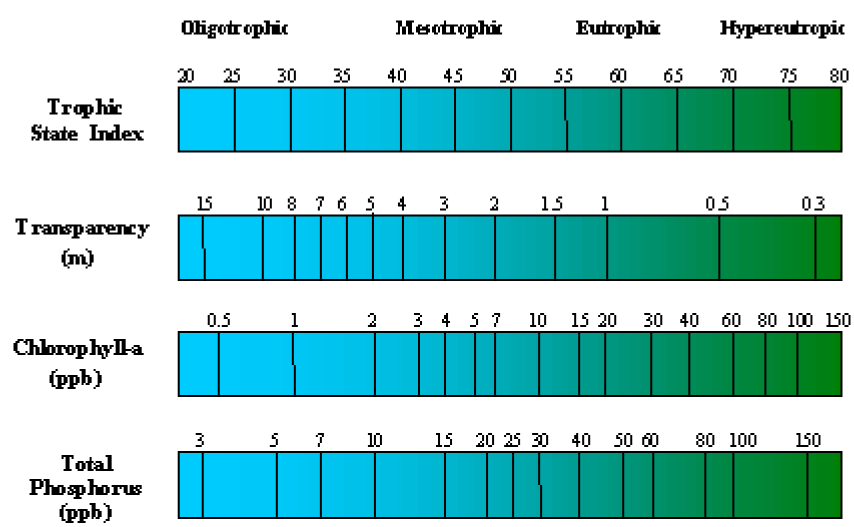


Figure 25.1: Graphical representation of Carlson's Trophic State Index from http://www.lakeaccess.org/lakedata/datainfotsi.html.

Not all lakes have the same relationship between transparency, chlorophyll and total phosphorus as Carlson's lakes do. Other factors such as high suspended sediments or heavy predation of algae by zooplankton may keep chlorophyll concentrations lower than might be otherwise expected from the total phosphorus or chlorophyll concentrations. High suspended sediments would also make transparency worse than otherwise predicted by Carlson's index.

It is also useful to compare the actual trophic state points for a particular lake from one year to the next to detect any trends in changing water quality. While climate and other natural events will cause some variation in water quality over time (possibly 5-10 trophic points), larger point changes may indicate important changes in lake quality. Because many states have their own more complex indices, the CTSI is also useful for comparing lakes throughout the nation.

Typical levels in Indiana

CTSI was calculated for each parameter; secchi depth, chlorophyll a and total phosphorus, for each lake participating in the Indiana Volunteer Lake Monitoring Program from 2004-2011. A summary of the minimum, maximum and averages for each year are at the right. Secchi depths were measured in approximately 80 lakes. Chlorophyll a and total phosphorus were measured in approximately 40 lakes.

Table 25.2: Carlson's TSI values for various lakes in Indiana from 2004 to 2011

		2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Secchi Disk Transparency	Minimum	32	33	34	32	36	34	32	33
	Maximum	87	95	76	74	76	77	78	69
	Average	52	50	51	50	51	51	51	51
Chlorophyll a	Minimum	24	34	20	34	31	21	0	1
	Maximum	66	66	57	70	73	64	56	99
	Average	49	47	39	47	51	37	9	13
Total Phosphorus	Minimum	49	37	41	44	1	8	54	55
	Maximum	77	75	76	75	76	77	79	77
	Average	59	54	57	55	55	59	61	61

Targets or Protective levels

Table 25.3: Carlson's Trophic State Index Ranges		
CTSI value	**Trophic State**	**Attributes**
<40	Oligotrophic	Clear water, oxygen throughout the year in the hypolimnion
40-50	Mesotrophic	Water moderately clear; increasing probability of hypolimnetic anoxia during summer
50-60	Eutrophic	Anoxic hypolimnion; macrophyte problems possible
>60	Hypereutrophic	Dense algae and macrophytes

Resources Needed

Table 25.4: Resources Needed for Monitoring Carlson's Trophic State Index		
	Field Sampling	**Laboratory Analysis**
Equipment	Secchi disk; sample bottles	EPA and standard methods: see equipment needed for individual parameters
Time	Approximately 5 minutes per sample	Approximately 10 hours over 2 days
Expertise	Low; Training required.	Ranges from low to very high depending on parameter analyzed
Costs	Staff time; Secchi disk $25 to $75	Laboratories generally charge $20 per sample for chlorophyll a and $10 to $60 per sample for total phosphorus

References

Carlson, R.E. 1977. A trophic state index for lakes. *Limnology and Oceanography* 2(2): 361-369.

Jones, W.W. and Powers, S. 2009. Indiana Volunteer Lake Monitoring Report: 2004-2008. School of Public and Environmental Affairs, Indiana University, Bloomington, Indiana. Online at: http://www.indiana.edu/~clp/documents/2004_08%20Vol%20FINAL.pdf

Jones, W.W., M. Clark, J. Bond and S. Powers. 2012. Indiana Lake Water Quality Assessment Report for 2009 – 2011. School of Public and Environmental Affairs, Indiana University, Bloomington.

26. Indiana Trophic State Index

Indicator: ITSI index values, ranging from 0 to 75
*lakes only

Physical, chemical, and biological data gathered on each lake are combined into a standardized multi-metric index known today as the Indiana Trophic State Index (ITSI); a modified version of the BonHomme Index developed for Indiana in 1972.

Table 26.1: Who's monitoring Indiana Trophic State Index in Indiana?

Agency	Field Collection Methods Used	Analysis Methods Used
IN Clean Lakes Program	IN Clean Lakes Program Procedure	IN Clean Lakes Program Procedure

What it indicates

The Indiana Trophic State Index is used to broadly classify lakes based on eutrophication, a lake's natural process of aging. These lake classifications are then used to determine general approaches to lake management, including fisheries and aquatic plant control.

Method Overview

Samples are taken at both the surface (epilimnion) and bottom of the lake (hypolimnion) to identify the effects of stratification on water chemistry. Eutrophy points are assigned to each parameter and totaled to create a final ITSI score ranging from 0 to 75. Lower scores indicate lower levels and effects of nutrients on factors related to lake management and use, including water clarity, nutrients available for plant growth and blue green algae dominance (IDNR 2007).

Table 26.2: Metrics and Point Ranges Used to Calculate Indiana's Trophic State Index

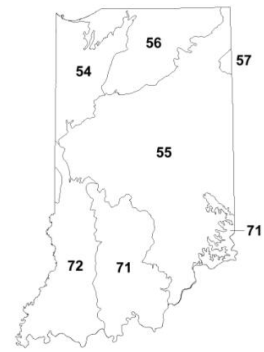
Metric	Eutrophy Points Range
Total Phosphorus (µg/L)	1 to 5
Soluble Phosphorus (µg/L)	1 to 5
Organic Nitrogen (mg/L)	1 to 4
Nitrate (mg/L)	1 to 4
Ammonia (mg/L)	1 to 4
Dissolved Oxygen – Percent Saturation at 5 ft from surface	0 to 4
Dissolved Oxygen – Percent of measured water column with at least 0.1 ppm DO	0 to 4
Light Penetration (secchi disk)	6
Light Transmission (photocell) – Percent of light transmission at a depth of 3 ft	0 to 4
Total Plankton per liter of water sampled from a single vertical tow between the 1% light level and the surface	0 to 25 (10 additional points for blue-green algae dominance)

Typical levels in Indiana

The Indiana Lake Quality Assessment Report for 2004-2008 (Montgrain and Jones, 2009) provides ITSI scores calculated for 5 sampling periods from the 1970's to 2008. (Table 26.3). The general trend of Indiana lakes is towards mesotrophy..

Table 26.3: Indiana Trophic State Index Scores for Indiana waters by Level 3 Ecoregions		
No.	**Ecoregion Name**	**Average ITSI score ranges from 1970 through 2008**
54	Central Corn Belt Plains	48 to 25
55	Eastern Corn Belt Plains	40 to 24
56	S Michigan/N Indiana Drift Plains	34 to 23
71	Interior Plateau	23 to 16
72	Interior River Lowland	35 to 15

Ecoregions of Indiana



Targets or Protective levels

A rising ITSI score for a particular lake from one year to the next indicates that water quality is degrading while a lower ITSI score indicates improving conditions. However, natural factors such as climate variation can cause changes in ITSI score that do not necessarily indicate a long-term change in lake condition. Thus, a long-term (5+years) approach should be used when evaluating lakes.

Table 26.4: Lake Quality Assessment Based on Indiana Trophic State Index Score	
ITSI Total	**Water Quality Classification**
0-15	Highest quality (oligotrophic)
16-31	Intermediate quality (mesotrophic)
32-46	Low quality (eutrophic)
>47	Lowest quality (hypereutrophic)

Resources Needed

Table 26.5: Resources Needed for Monitoring Indiana Trophic State Index		
	Field Sampling	**Laboratory Analysis**
Equipment	Sample bottles; Secchi disk; Light meter; Conical tow net; boat	EPA and standard methods: see equipment needed for individual parameters
Time	Approximately 30 minutes per sample	Approximately 24-28 hours for all parameters
Expertise	Low; Training required.	Taxonomic identification skills needed to identify plankton genera
Costs	Secchi disk $25 to $75; Light meter ranges from $250 to $1300; Tow nets are approximately $200; Boats can range from several hundred dollars to several thousand dollars	Laboratories generally charge $20 per sample for chlorophyll a and $10 to $60 per sample for total phosphorus

References

Indiana Department of Natural Resources. 2007. Use of the Indiana Trophic State Index (ITSI) to Guide Lake Management. Online at: http://www.in.gov/dnr/files/Use_of_Indiana_TSI_for_Lake_Classification_Dec_2007.pdf [Accessed 28 July 2010]

Jones, W.W. 2004. Interpreting Lake Data – Indiana Clean Lakes Program. School of Public and Environmental Affairs, Indiana University, Bloomington, Indiana. Online at: http://www.indiana.edu/~clp/documents/Interpreting%20Lake%20Data.pdf

Montgrain, L.A. and Jones, W.W. 2009. Indiana Lake Water Quality Assessment Report for 2004-2008. School of Public and Environmental Affairs, Indiana University, Bloomington, Indiana. Online at: http://www.indiana.edu/~clp/documents/LWQA08%20FINAL.pdf.

27. Hoosier Riverwatch Water Quality Index

Indicator: WQI index values, ranging from 0 to 100
*streams only

Table 27.1: Who's monitoring Water Quality Index in Indiana?		
Agency	**Field Collection Methods Used**	**Analysis Methods Used**
IDNR Hoosier Riverwatch	Volunteer Stream Monitoring Training Manual	Methods are listed separately for each component

The Water Quality Index (WQI) provides a single number that expresses overall water quality at a certain location and time based on several water quality parameters. Each test within the Water Quality Index is weighted according to its level of importance compared to the overall water quality. Dissolved oxygen has the highest weighting factor (0.18); therefore, the oxygen results are the most important value in determining the water quality rating using the index. According to the Volunteer Stream Monitoring Training Manual, the "weighting scheme allows analysts to condense complex test results into a common water quality measurement that can be readily communicated to the public and to other volunteers. The Water Quality Index score is like a final grade - weighting the results of multiple tests and exams."

Table 27.2: Chemical tests included in calculating the Water Quality Index
• Dissolved Oxygen • *E. coli* • pH • Biochemical Oxygen Demand (5 day) • Water Temperature Change • Total Phosphorus • Nitrate • Turbidity

What it indicates

The objective of the Water Quality Index is to turn complex water quality data into information that is understandable and useable by the public. The WQI can be used to track changes of a site over time, or compare the quality with other stream sites.

Method overview

The WQI provides an analysis of eight chemical tests (Table 27.2) conducted at a stream sampling site, allowing sites to be classified as excellent, good, medium, bad, or very bad for that particular monitoring session. Once each chemical test is complete, the results are used to derive the Q-values for each test. Each Q-value is then multiplied by a weighting factor. These results are then added together to determine the Water Quality Index (methods vary slightly if all tests were not completed).

Typical levels in Indiana

The Hoosier Riverwatch volunteer monitoring program has been using this index in Indiana since 1995. A compilation of 4070 samples of WQI throughout Indiana from 1995 through 2011 indicate monthly averages ranging from 43.9 in July to 61.9 in January (IDNR, 2011).

Targets or Protective levels

Table 27.3: Water Quality Index Rating Scale		
90-100	Excellent	Supports high diversity of aquatic life
70-90	Good	
50-70	Medium	Generally less diversity of aquatic organisms and frequently has increased algae growth
25-50	Bad	Supports low diversity of aquatic life and is likely experiencing problems with pollution
0-25	Very Bad	May only support a limited number of aquatic life forms, likely abundant water quality problems

Resources Needed

Table 27.4: Resources Needed for Monitoring the Water Quality Index		
	Field Sampling	**Laboratory Analysis**
Equipment	Black (light-free) sample bottles; Regular sample bottles; Test kits; Kemmerer sampler (for lake samples only)	EPA and standard methods: Incubator; Spectrophotometer and titration equipment
Time	10-15 minutes per measurement.	*E. coli* incubation and analysis takes 25 hours; measurement for biochemical oxygen demand takes 5 days
Expertise	Low; Training required; Typically analyzed by volunteers	Laboratory analysis: ranges from low to high depending on parameter
Costs	Test kits: approximately $245, which provides supplies for multiple samples; Transparency tube $40 to $60; (optional) Probe: several thousand dollars for multi-parameter probes; Kemmerer samplers are generally $250-500	Laboratories generally charge $80 to $250 per sample for all parameters

References

Boulder Area Sustainability Information Network. 2005. [web page] Water Quality Index. http://bcn.boulder.co.us/basin/watershed/wqi_info.html [Accessed 12 August 2010]

Indiana Department of Natural Resources. 2008. Volunteer Stream Monitoring Training Manual: Hoosier Riverwatch. Indianapolis, IN: Indiana Department of Natural Resources.

Indiana Department of Natural Resources. 2011. [web page] Hoosier Riverwatch Datawatch. http://www.hoosierriverwatch.com/DataWatch.html [Accessed 14 June 2011]

Additional Parameters

Several additional parameters have been recommended for inclusion in the manual by various stakeholders. They do not have a separate section either because they were not supported by at least 50% of Expert Panel members, or because they were not brought up in the discussion. Therefore they are included as supplements to the supplemental

Blue-Green Algae (Cyanobacteria)

Indicator: Cell counts (cells/mL) or toxin concentration (parts per billion or ppb)

Blue-green algae, also known as cyanobacteria, are photosynthetic bacteria that have been linked to human and animal illnesses. Under the right combinations of water temperature, low depth water conditions, and nutrients, blue-green algae grow very quickly causing algal "blooms" that may appear as a thick, paint-like scum on the surface of the water. In Indiana, blooms generally occur from May to October in lakes or slow-moving rivers and streams, but have been documented in December. There are many types of blue-green algae, but only some produce toxins that can result in illness.

Table BG.1: Who's monitoring blue-green algae in Indiana?

Agency	Cell count	Toxin concentration
IDEM Watershed Assessment & Planning Branch	Nageotte Counting Chamber method (originally developed to count blood cells)	Abraxis ELISA
Center for Earth and Environmental Science (CEES) at Indiana University-Purdue University Indianapolis	Nageotte Counting Chamber method (originally developed to count blood cells)	Abraxis ELISA
Kosciusko Lakes & Streams (Grace College) - *samples sent to IUPUI-CEES for analysis*	Not measured	Abraxis ELISA
Indiana Clean Lakes Program	Standard Methods 10200F	Abraxis ELISA

What it indicates

Some concerns associated with blue-green algae blooms include:

- Reduced light penetration at high algal densities
- Taste and odor problems in drinking water, even after treatment to remove the toxins
- Low oxygen concentration in water as algal blooms degrade, sometimes causing fish kills
- Toxin production

Because blue-green algae can cause illness, people should avoid swimming when there is a visible bloom in the water. Animals the drink water with blue-green algae blooms can become very ill and even die.

Blue-green algal bloom at Lake Shipshewana, IN.

Method overview

In Indiana, IDEM, the Center for Earth and Environmental Sciences at Indiana University-Purdue University at Indianapolis, Grace College, and the Indiana Clean Lakes Program monitor swimming beaches for blue-green algae and public health concerns during the recreational season (April through October). Two parameters are measured to assess blue-green algae: cyanobacterial cell counts and microcystin toxin concentration, which is the toxin produced by some types of blue-green algae. IDEM and the Clean Lakes Program assess both cell counts by counting under a microscope, and microcystin through an ELISA test. Results are posted on IDEM's blue-green algae web site, http://www.algae.in.gov.

Typical levels in Indiana

Harmful algal blooms are increasing throughout the U.S. and blue-green algae are occurring where they had not been observed previously, which suggests that levels may continue to rise in Indiana.

Blue-green algae have only been monitoring in Indiana for a few years. As part of the development of this manual, cyanobacterial cell counts from three monitoring programs were analyzed to provide an overview for Indiana lakes for the 2011 recreational season (Table BG.2).

Table BG.2. Overview of Cyanobacterial Cell Count Monitoring in Indiana Lakes during 2011.

Sampling Program	**Number of lakes**	**Cyanobacterial Cell Counts (cells/mL)**		
		Min	**Max**	**# occurrences >100,000 cells/mL**
IDEM	14	1800	798,140	25 out of 54
CEES-IUPUI	4	0	731,000	1
Indiana Clean Lakes Program	30	301	1,092,764	11

As part of the development of this manual, microcystin toxin concentrations from four monitoring programs were analyzed to provide an overview for Indiana lakes (Table BG.3).

Table BG.3. Overview of Microcystin Toxin Concentration Monitoring in Indiana Lakes during 2011.

Sampling Program	**Number of lakes**	**Microcystin Toxin Concentration (µg/L)**		
		Min	**Max**	**# occurrences >6 µg/L**
IDEM	11	>0.15 (below detection limit)	<1.0	0
CEES-IUPUI	4	>0.15 (below detection limit)	0.97	0
Kosciusko Lakes & Streams	44	>0.15 (below detection limit)	5.94	0
Indiana Clean Lakes Program	81	0.033	13.39	2

Targets or Protective levels

Research is on-going in the United States to determine safe levels of algal toxins found in recreational lakes and reservoirs. Currently, IDEM provides the following guidelines:

Cell Counts: For protection of human health, the World Health Organization defines a high risk health alert as a blue-green algae cell count greater than 100,000 cells per milliliter (cells/mL).

Toxin Production: In Indiana, IDEM uses a microcystin concentration of 6 ppb as a warning level.

Table BG.4. Guidelines for microcystin concentrations, provided by IDEM. (http://www.in.gov/idem/algae/2343.htm)

Toxin Concentration	**Risk**	**Action Recommendation**	**Corresponding World Heath Organization Guideline**
<4 ppb	Very low/no risk	Use common sense practices	Level 1 Recreational Water Guideline
4 to 20 ppb	Low to moderate risk	Reduce recreational contact with water	Level 2 Recreational Water Guideline
>20 ppb	High risk	Seriously consider avoiding contact with water until levels of toxins decrease	

References:

Indiana Department of Environmental Management. [web page]. Blue-Green Algae. http://www.in.gov/idem/algae/ [Accessed 20 December 2011]

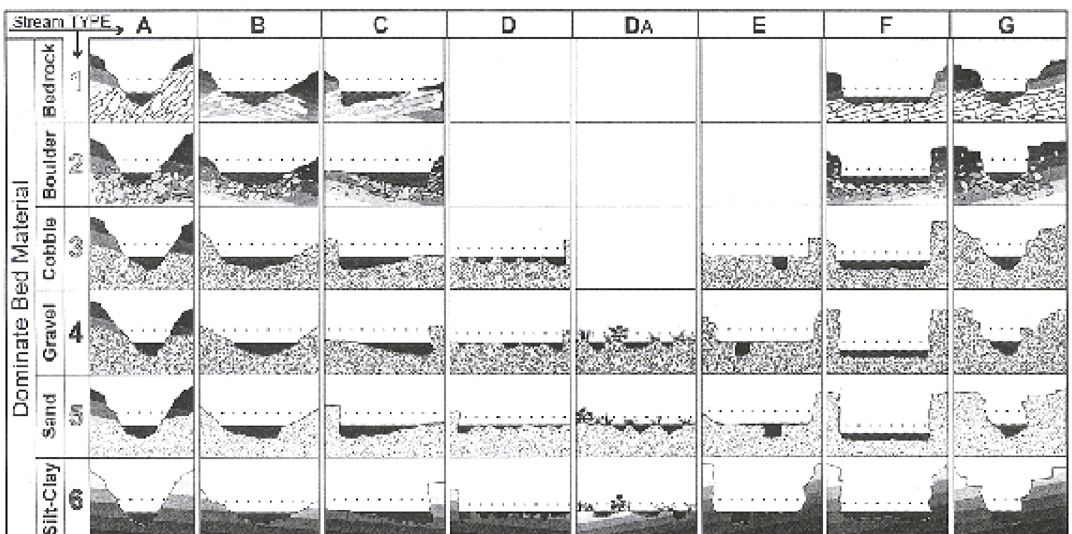
Indiana Department of Environmental Management. 2011. Blue-Green Algae Fact Sheet. Online at: http://www.in.gov/idem/files/factsheet_bluegreen_algae.pdf [Accessed 20 December 2011]

Wisconsin Department of Natural Resources. [web page]. Blue-Green Algae. http://dnr.wi.gov/lakes/bluegreenalgae/ [Accessed 20 December 2011]

Rosgen Stream Classification System

The Rosgen method is a widely-used method for classifying streams and rivers based on common patterns of channel morphology. The purpose of this system is to classify streams based on quantifiable field measurements to produce consistent, reproducible descriptions of stream types and conditions. Level I stream types (A through G) are distinguished on the basis of the valley landforms, and further characterized by channel substrate materials (bedrock, boulders, cobble, gravel, sand, or silt/clay). Level II stream types are determined using field measurements from specific channel reaches and fluvial features, using more finely resolved criteria to address questions of sediment supply, stream sensitivity to disturbance, potential for natural recovery, channel response to changes in flow regime, and fish habitat potential.

Rosgen's classification system is not a parameter that can used to assess water quality, but is becoming more commonly used in stream restoration studies in Indiana. It may be useful in many watershed monitoring programs, especially since it has established a common language for communication among associated stream disciplines. The Fluvial Erosion Hazard Mitigation Program uses the Rosgen Classification System in working with streams.



Stream TYPE	A	B	C	D	DA	E	F	G
Entrchmnt.	< 1.4	1.4 - 2.2	> 2.2	n/a	> 4.0	> 2.2	< 1.4	< 1.4
W/D Ratio	< 12	> 12	> 12	> 40	< 40	< 12	> 12	< 12
Sinuosity	1 - 1.2	> 1.2	> 1.4	n/a	variable	> 1.5	> 1.4	> 1.2
Slope	.04-.099	.02-.039	< .02	< .04	< .005	< .02	< .02	.02-.039

Figure R.1: Primary delineative criteria for the major stream types in the Rosgen Stream Classification Systems (from http://stream.fs.fed.us/news/streamnt/apr01/apr_01_01.htm)

References:

Rosgen, Dave, 1996. Applied River Morphology. Wildlife Hydology, Pagosa Springs, CO.

USDA-NRCS. 2007. National Engineering Handbook, Part 654 Stream Restoration Design. Chapter 3: Site Assessment and Investigation. Online at: http://policy.nrcs.usda.gov/OpenNonWebContent.aspx?content=17779.wba [Accessed 13 December 2011]

Photo Monitoring

Although not a separate parameter, photo monitoring is an immensely useful tool that should be part of every monitoring program to document changes in site condition over time. Some conditions where photo monitoring is beneficial include:

- Photo monitoring of a practice that was installed, to document that it was done.
- Photo monitoring of a visible change such as stream restoration or change in erosion resulting from the practice.
- Photos of conditions each time water is monitored, to complement numeric measurements.

Selecting locations

Photo monitoring locations should be selected based on the condition you are interested in monitoring. For instance, if you are monitoring changes in the stream site every time you monitor that stream, a photo from the bridge may be the most effective location. If you are monitoring the presence of a rain garden and the health of its vegetation, photo points that allow for height measurement or percent rain garden cover may be needed in addition to a photo documenting the presence of the rain garden.

Figure P.1: Photo monitoring can show the effect of a BMP such as a fence on riparian vegetation.
(Photos Oregon Water Enhancement Board, 2007.)

When to take photos

Photos should usually be taken before and after a practice is implemented. The season or the time of day may be important for some photos. If you are documenting the success of a rain garden, photographing it during the growing season on a sunny day at approximately noon will minimize photo shadows and allow for calculation of cover and plant height.

Documentation

All photo monitoring points should be documented with GPS location, and also marked with permanent fence posts or stakes if possible. Additionally, a map of the project site or area including the location of the photo monitoring point, the distance from the photo monitoring point to the object being recorded (e.g., stream erosion), and the angle of the camera (e.g., 30 degrees north). These efforts will help relocate your photo monitoring point upon subsequent return trips.You can document some characteristics in the photo itself, by including a large card with the site name, photo monitoring point, and date in the photo. After taking the photos, it is important to download and label digital photos with the site name, photo point, date, and time of day. Also, keep a file to document notes about the photo monitoring such as, observations when taking the photograph and how it is different from the previous photo monitoring at that site.

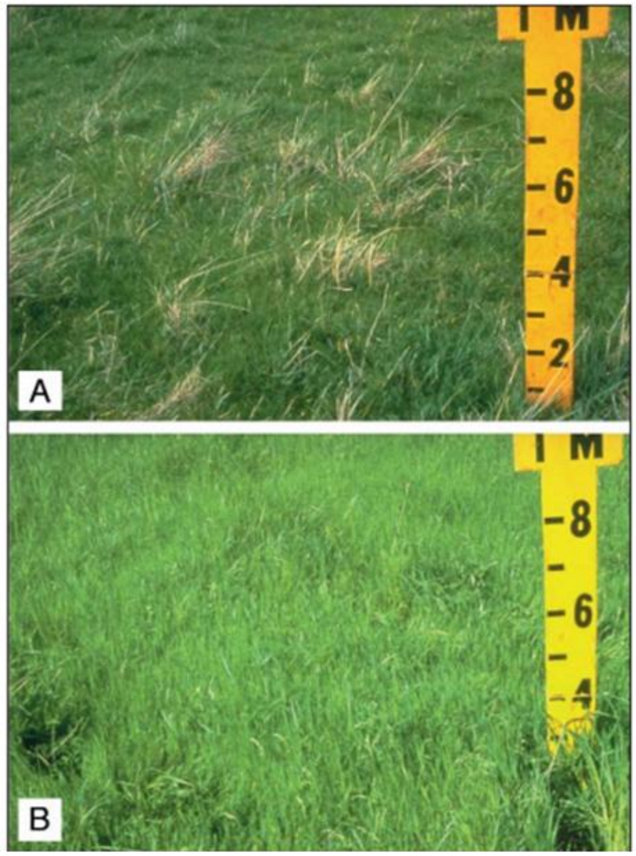


Figure P.2: Including a reference object such as a meter board is helpful to show quantitative changes such as depth of vegetation. (Photo from Hall, 2002)

"Picture Post", a structure for consistent, long-term photo monitoring

The "Picture Post" program (http://picturepost.unh.edu/) has developed a unique program for photo documentation of sites, where a permanent post is installed and photos can easily be uploaded to a web site and shared.

Figure P.3: A permanent picture post can be used to take nine consistent photos at each visit, which provides a way to see changes through time. (Photos of Little Long Pond, at http://picturepost.unh.edu)

References:

Hall, Frederick C. 2002. Photo Point Monitoring Handbook: Part A-Field Procedures. General Technical Report PNW-GTR-526 United States Department of Agriculture, **Forest Service,** Pacific Northwest Research Station, Portland, Oregon. Online at http://www.treesearch.fs.fed.us/pubs/3255.

Oregon Watershed Enhancement Board, 2007. OWEB Guide to Photo Point Mon itoring http://www.oregon.gov/OWEB/docs/pubs/PhotoPoint_Monitoring_Doc_July2007.pdf?ga=t

Part 2: Making Choices for Effective Monitoring

The importance of representative data

"If a sampling design results in the collection of nonrepresentative data, even the highest quality laboratory analysis cannot compensate for the lack of representative data." - *EPA Guidance on Choosing a Sampling Design for Environmental Data Collection for Use in Developing a Quality Assurance Project Plan*

In order to achieve monitoring goals, the data collected must be representative of the water quality that is being measured. Water quality varies in both space and time (chemical and physical parameters vary far more in time than in space). A monitoring project represents an effort to obtain an understanding of the physical, chemical, and biological characteristics of water by sampling a subset of water or the stream at a few times in a few places. Therefore, monitoring must be thought of as a sampling process – sampling only **some** of the water, to make inferences about **all** the water. Inferences about all the water can only be made correctly if the data collected are representative of the water as a whole.

Methods for designing a monitoring project that is representative of a water system have been described in many useful publications, so are not covered here. Useful references include:

- EPA's *Handbook for Developing Watershed Plans to Restore and Protect Our Waters* http://water.epa.gov/polwaste/nps/handbook_index.cfm (Chapter 5: Gather Existing Data & Create an Inventory, Chapter 6: Identify Data Gaps & Collect Additional Data if Needed, and Chapter 12, section 6: Develop a Monitoring Component, and section 7: Estimate costs).
- EPA's *Guidance on Choosing a Sampling Design for Environmental Data Collection for Use in Developing a Quality Assurance Project Plan at* http://www.epa.gov/quality/qs-docs/g5s-final.pdf.

Quality Assurance and Quality Control

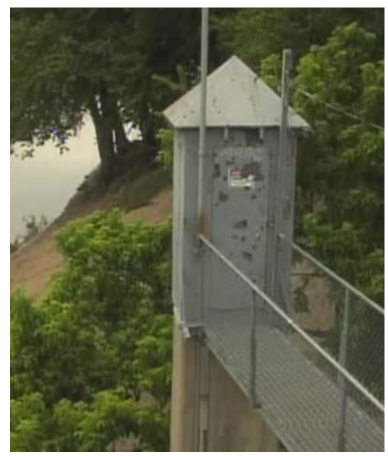
U.S. EPA-funded monitoring programs must have an EPA-approved Quality Assurance Project Plan (QAPP) before sample collection begins. IDEM has been delegated authority to review the QAPPs submitted for projects in Indiana. If your project is collecting environmental data, including physical, chemical or biological data, and Section 319 money is being used to pay for the monitoring and/or monitoring is being used as match for a 319 project, a QAPP must be submitted before monitoring begins. A template and guidance document for developing a QAPP are available at http://www.in.gov/idem/nps/3383.htm.

2.1 Selecting a Monitoring Site or Sites to Obtain Representative Data

There are no perfect sites for monitoring. The considerations listed below will help your monitoring project obtain data that can be used in decision-making. It is important to select sites carefully, as a good monitoring program will last many years.

Do not try to monitor too many sites. It is generally more useful to have adequate (representative) data from a single site than to have just a few measurements at many sites. Many water parameters do not vary significantly over a short distance, and often there is more variability over time than over short distances in a stream. Chemical parameters and *E. coli* need to be measured at least weekly to estimate loads with reasonable precision, so limiting the number of sites is usually necessary to be able to take an adequate number of samples at a site. It may be possible to monitor biological or habitat parameters at more sites, since they can be measured less frequently.

If there is a USGS flow gage, select that site. USGS gages provide free, accurate, continuous flow measurements, which makes all monitoring data much more valuable. Continuous flow data is needed to determine at what flow conditions your samples were taken, and to estimate annual load in order to estimate reductions needed. If there is no USGS gage in the watershed, locate the closest gage(s) and if possible select a site that is on the same waterbody, and that has a watershed area similar to the USGS gage watershed area.



If there is a USGS stream gages in your watershed, monitor there.

There are advantages to monitoring either large or small watersheds. Monitoring at the outlet of your watershed (i.e., a relatively large watershed) is the best way to characterize the entire watershed. It allows your stakeholders to understand how and why their actions over the entire watershed can make a difference. However, monitoring at the outlet of much smaller watersheds is more likely to show change due to your BMP implementation.

To show the effectiveness of your implementation, **select sites to allow such an analysis**. If you have an idea where management practices will be implemented, upstream and downstream of that site would be excellent monitoring locations. However, such locations are rarely known in advance. A powerful way to show change is to monitor two similar "paired" watersheds, then focus implementation in only one of them. This allows you to compare the paired watersheds both before and after BMPS implementation, minimizing the influence of different weather conditions that might occur during the two monitoring periods. A disadvantage is that you need to commit to not implementing BMPs in the control watershed.

Monitoring sites must be accessible. Access to the site should be both legal and safe. Although the stream itself is owned by the public, the land surrounding a stream is often privately owned. Landowners do not have to grant access for monitoring, even for sites adjacent to a bridge. A site that is surrounded by land accessible to the public (for example city or county property) is advantageous. Unfortunately, it can be difficult to find such sites in rural areas. Sampling from a bridge allows safer sampling at high flows when entering the stream can be dangerous, but there are often safety concerns if the bridge has a high amount of traffic.

The land surrounding a stream is often privately owned, so accessibility depends on the landowner.

The best sites may not be the same for chemical and biological monitoring. Chemical sampling only requires access to the water in a stream, so can be done from a bridge if the water body is not accessible. Biological sampling requires access to the aquatic life in the water, so sites appropriate site selection may be more restrictive.

Think about your watershed community. If there is a site of particular interest to your community, consider that site. Monitoring a well-known fishing spot or location that people like to go to may increase stakeholder buy-in and interest in the watershed project. If there is a previously monitored location, consider continuing previous monitoring efforts because of the possibility of seeing trends over time using previously collected data.

Monitoring a site that people in your community enjoy may increase interest in your results.

2.2 Taking samples

Specific methods vary for each parameter, and are included in the protocols provided by the agencies (see the Catalog of Monitoring Protocols). A brief overview is provided here for planning purposes. There are three general types of methods for collecting water samples:

Direct filling: In this method, the container that will be sent to the laboratory is used directly. If the stream is wadeable, wade to the middle or deepest part of the stream, and lower the container into the water following the protocol for each parameter. If the stream is not wadeable, an extended bottle holder such as a long pole can sometimes be used to sample from a bridge or a dock. Some programs place the containers in a perforated bucket to fill from a bridge. For sediment sampling, an isokinetic sampling device is recommended.

Figure T.1: Three methods for taking a sample. *Top:* Extended bottle holder. *Middle:* Simple dip and fill. *Bottom:* Automated sampler.

Capture and transfer: In this method, water is collected in one device, then transferred into a bottle for analysis. One example of this is the Kemmerer water trapping device.

Pumping: Water can also be drawn from the desired depth with a pump. This method is most often used by **automated samplers**. Automated samplers can be programmed to collect prescribed volumes of sample at prescribed times, either as a composite or up to 24 discrete samples, which can greatly increase the representativeness of samples.

The standard sampling depth for most measurements is about one foot or elbow deep. If the depth of the water is less than 1.5 feet, samples should be collected about one-third of the way from the surface to the bottom.

Streams and rivers are variable. A grab sample only captures a single moment in a single location. Inherent temporal and spatial variability in streams usually exceeds any limitation in precision due to the instruments. Parameter values are not necessarily the same at different locations in the stream, even close together. *Protocols that include taking samples from various stream positions and compositing will usually result in more representative.* Quality assurance procedures usually require taking field duplicates, as shown in locations 1 and 1a for the stream shown in Figure T.2.

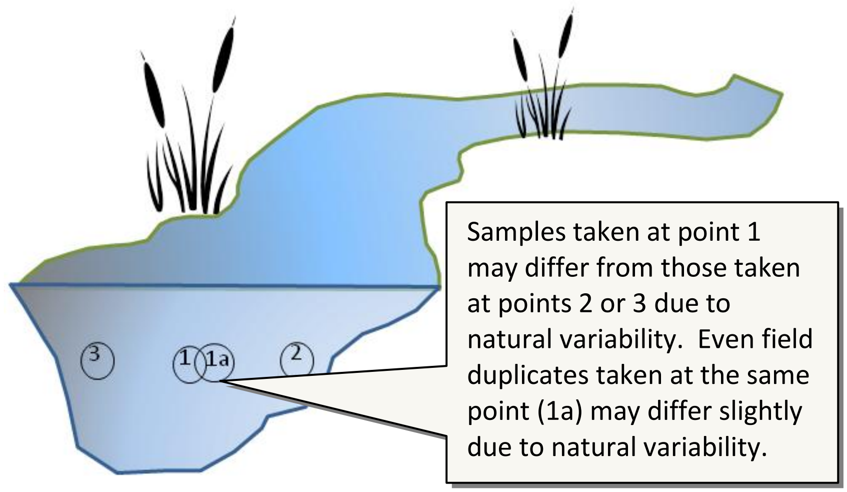


Figure T.2. Parameters can vary within a stream, even at the "same location" as defined by GPS coordinates.

2.3 Monitoring Sufficiently Over Time to Acquire Representative Data

The representativeness of monitoring data depends strongly on **frequency**, **seasonality**, **range of flow conditions** (monitoring at both high and low flow), and the **duration** of the monitoring program. Numerous monitoring projects have not been used in decision-making, in part because the monitoring was not conducted at a frequency high enough to do so. The Hoosier Riverwatch Manual states "To get an accurate picture of a stream's water quality, tests have to be performed on a regular basis (consistently), over a period of years (persistently)." They also have to be performed often and at a range of flow conditions to be truly representative.

Frequency

The **frequency** needed depends on the variability of the data. Variability depends on the parameter being measured and also on the type of water body.

- **Parameter effect on variability**: Chemical parameters need to be monitored more frequently than biological and habitat parameters (although *E. coli* is a biological parameter, its variability is more like the chemical parameters). In general, *E. coli*, total suspended solids, and phosphorus vary more day to day than nitrate. Biological monitoring is difficult each time it is done, but because organisms are able to aggregate water quality information over time it can be done less frequently with more accurate estimates of the average over time.
- **Water body effect on variability**: Moving water (streams and rivers) vary more, and small streams vary the most. Water in lakes and reservoirs are much more stable, and therefore monitoring that takes place only monthly or less can often be representative.

Figure R.1 suggests conceptually the relative variability of parameters, and the differences between types of water body, and the resulting number of samples needed per year for representativeness.

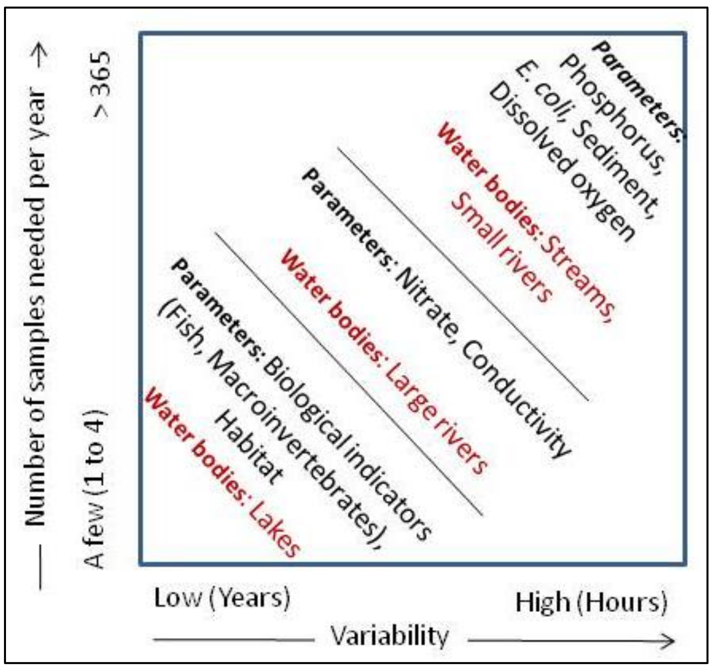


Figure R.1: The relative variability of parameters and water bodies. E. coli, sediment, and phosphorus are highly variable, and therefore require frequent samples (dozens to hundreds of samples over the course of a year), while habitat and biological indicators are more stable and can be monitored less often.

More frequent sampling is better, but how much better? The few examples where monitoring has been done very frequently can help answer that question. Heidelberg College monitored several parameters four times per day for several years, then took subsamples of the complete data set to determine the effect on estimated annual load of various sampling frequencies. Results are shown in Table R-1 for a stream draining a 172 square-mile watershed with 83% cropland. These results are likely to be similar for streams in Indiana, although no similar analysis has been published.

Table R.1: Range of 95% confidence half-intervals of annual load calculated from various sampling frequencies for a medium-sized agricultural stream (From Richards & Holloway, 1987).					
Sampling Frequency	**Conductivity (dissolved solids) %**	**Nitrate-N %**	**Sol. Reactive Phosphorus %**	**Total Phosphorus %**	**Suspended Sediment %**
Monthly	65	99	108	180	427
2 weeks	46	67	71	127	239
Weekly	26	41	47	96	160
Daily	4	4	6	12	28

In this study, loads calculated from subsamples of the data at various frequencies (daily, weekly, bi-weekly and monthly) had low precision (large confidence intervals), showing the problems of collecting infrequent samples. Starting at the top left, for conductivity measured with monthly samples, the 95% confidence half-interval of 65% means that if the load from this watershed was estimated to be 100 lbs, there would only a 95% chance that the true load is between 35 lbs and 165 lbs (alternatively, it could be stated that there is a 5% chance that the estimated load is off by more than 65%). The precision is even lower for the other parameters, with nitrate having a 5% chance of being off by 99%, soluble reactive phosphorus by 108%, total phosphorus by 180%, and suspended sediment by 427%. What does this tell us about estimating loads from monitoring data?

- If a monitoring program has a goal of estimating load **within 10% of the true load** (with 95% confidence), daily sampling is needed for conductivity, nitrate-N, and soluble reactive phosphorus, but even daily sampling would not be adequate obtain loads with 10% for total phosphorus or suspended sediment.
- If the goal is to estimate load **within 100% of the true load** (with a 95% probability), which of course would not be adequate for most uses, conductivity and nitrate-N could be sampled monthly, soluble reactive phosphorus could be sampled every two weeks, total phosphorus would need to be sampled weekly, and suspended sediment would need to be sampled more than weekly. Even at these high sampling rates, the calculated load is likely to be lower than the actual load.

This shows the great difficulty in collecting adequate data for reliable load estimates. It also suggests the value of collecting high-frequency data at a very limited number of sites, rather than monitoring at many sites, at least for chemical and physical parameters. Biological and habitat sampling can be done less often.

Seasonality

While some parameters vary evenly throughout the year depending on rainfall and flow conditions, some have consistent seasonal patterns. An important parameter in this category, at least for Indiana, is **nitrate**, as shown in Figure R.2. During the months of December to June, nitrate concentrations were generally between 4 mg/L and 10 mg/L. In July to about November, concentrations were generally 2 mg/L or less. This is a well-known pattern in Indiana, due mainly to the prevalence of nitrate from tile drains, which generally only flow December to June.

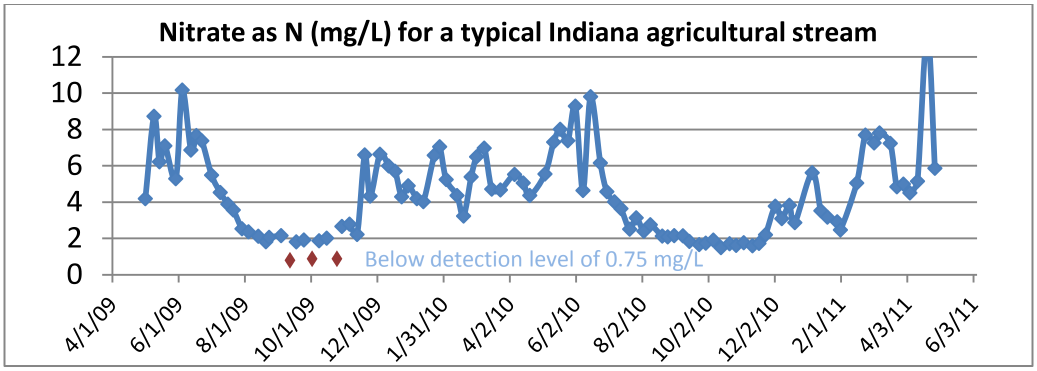


Figure R.2: Seasonal variability of nitrate-N in an Indiana stream, showing high values in winter/spring and low values in summer/fall. Sampling throughout the year is critical for obtaining representative samples and calculating loads.

Range of Flow Conditions

Many parameters vary significantly based on known factors other than season. Figure R.3 shows variability with flow and between day and night.

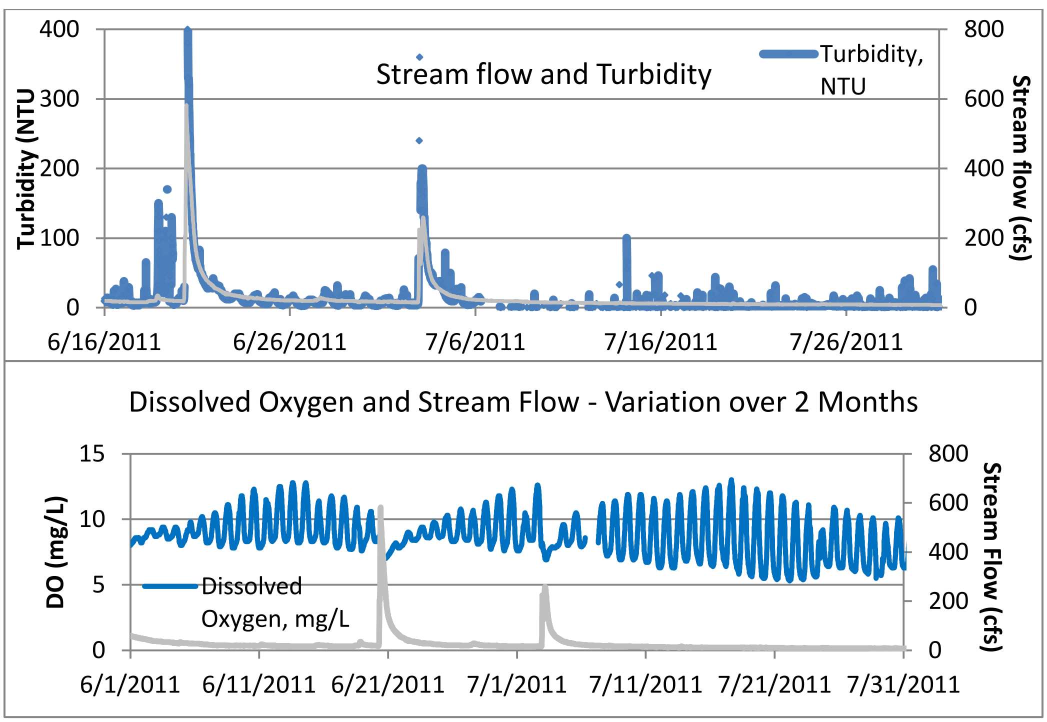


Figure R.3: Temporal variability of turbidity (or related sediment parameters not measured), top, and of dissolved oxygen, bottom. Both vary with stream flow. Dissolved oxygen also has a strong daily variability, not represented with isolated samples.

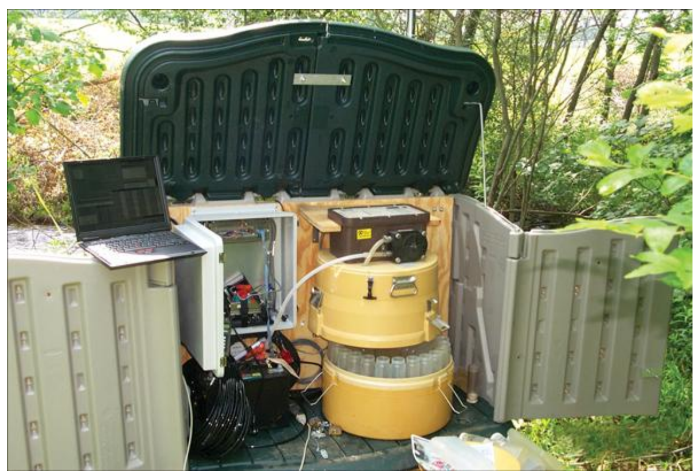
Sediment parameters including turbidity are usually thousands of times higher during high flow than low flow (Figure R.3). In fact, in five rivers in Ohio more than 37% of the annual suspended sediment load occurred during just the 1% highest flow events, and more than 85% occurred in the highest 10% of flow. Therefore to understand sediment it is critical to sample during high flows.

Monitoring during the winter is needed for understanding annual load.

Dissolved oxygen varies somewhat with streamflow, but more over the course of each day. To understand dissolved oxygen it is best to have a permanently installed probe, but if not it is important to measure during both day and night to understand variability.

Automated Samplers

Using automated samplers allows frequent samples to be collected without traveling to the site as frequently. More importantly, automated samplers can collect data that is proportional to flow, sampling less often at base flow, when conditions change slowly, and more often during storms. This greatly increases the representativeness of data. Automated samplers are expensive ($3000 to $8000) and require some expertise to program and maintain. Some consulting firms provide this service.

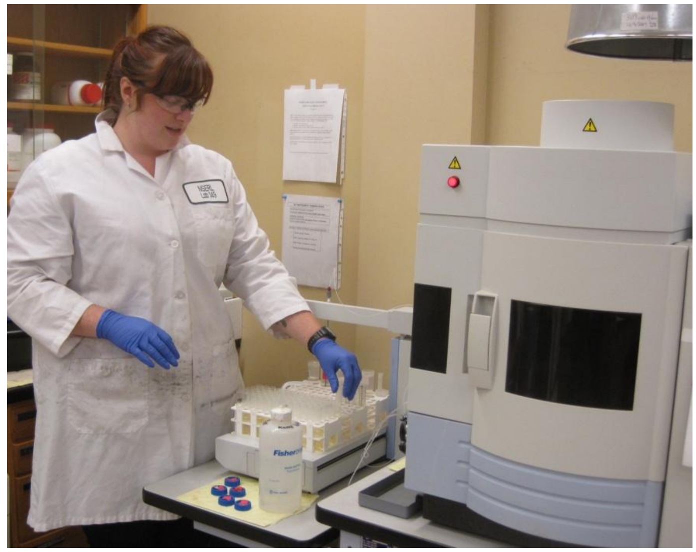


Automated sampling stations can collect samples at specific time intervals or proportional to flow over a specified period, greatly increasing the representativeness.

References:

Richards, R.P and J. Holloway, 1987. Monte Carlo studies of sampling strategies for estimating tributary loads. Water Resources Research 23:1939-1948.

2.4 Working with a Laboratory for Analysis



A number of analysis laboratories in or near Indiana provide water quality testing. They each follow specific laboratory analysis protocols such as those from EPA or Standard Methods noted in the protocols section. You can inquire which one is used for the parameters you wish to have analyzed.

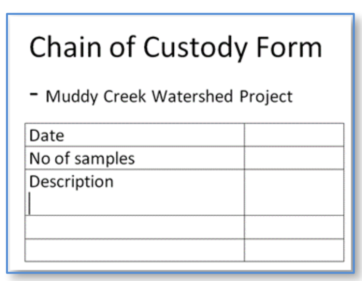
Selecting a laboratory

There is no master list of water analysis laboratories in Indiana. Many watershed monitoring programs work with a local water or wastewater treatment plant, who can do water analysis. The Indiana State Department of Health is responsible for certifying laboratories under the Safe Drinking Water Act, and their list (http://www.in.gov/isdh/24859.htm) provides numerous laboratories that you can contact. Few laboratories publish cost schedules on the web, so it is usually necessary to call to obtain specific information.

Processing samples and transporting/shipping to the laboratory

A laboratory that is within driving distance makes transportation easier, but samples can also be shipped to a laboratory. For most parameters, samples can be frozen, and then shipped in a cooler. Most laboratories send bottles for samples, and include preservatives if needed. A chain of custody form helps to maintain integrity and would be required if any legal procedures. Whether or not it is the form of a formal chain of custody, documentation sent with the samples should include the sample IDs, date, and number of containers.

Some samples may need to be preserved with acid. The laboratory will provide sample bottles and instructions.



Chain of Custody Form

- Muddy Creek Watershed Project

Date	
No of samples	
Description	

Include documentation with the samples, so that communication with the laboratory is clear.

Samples can be cooler and sometimes frozen, then shipped in coolers to a laboratory. Follow instructions to make sure the sample remains at required temperatures.

Examples of laboratories that can analyze core parameters

To provide cost estimates in this manual, we called many laboratories. The four listed below are well known, charge reasonable fees, and were willing to be listed in this manual to give readers a rough estimate of laboratory costs. It is not intended to be an exclusive list, or an endorsement.

Core parameters	Environmental Consultants, Inc	Heritage Environmental Services LLC	Sherry Labs	The Michigan Water Research Center *
Nitrate	$29 (SM 4500-3-D)	$30 (EPA 300.0)	$15 (EPA 300.0)	$27 (SM 4500NO3-F)
Total Phosphorus	$35 (SM 4500 P-E)	$35 (EPA 365.2)	$25 (SM 4500)	$9 (SM 4500-P E)
Suspended Sediment Concentration	Does not analyze	$35 (Not currently analyzed, but capable of doing it)	Does not analyze	Does not analyze
Total Suspended Solids	$25 (SM 2540D)	$25 (EPA 160.2)	$15 (SM 2540-D)	$11 (SM 2540-D)
Turbidity	$25 (EPA 180.1)	$10 (EPA 180.1)	$15 (SM 2130-B)	$3 (SM 2130B)
Dissolved Oxygen	Recommends in situ sampling	$10 (EPA 360.1)	$10 (SM 4500)	$7 (SM 4500-O C)
pH	Recommends in situ sampling	$10 (EPA 150.1)	$10 (SM 4500)	$3 (SM 4500)
E coli	$40 (SM 9223B)	$50 (SM 9223B)	$40 (Colilert)	$13.50 (SM 9213D)
Contact	Stephanie 812-282-8481 eci375@aol.com	Gary Klingler 317-390-3187 gary.klingler@heritage-enviro.com	John Rigdon 765-378-4141 John.Rigdon@sherrylabs.com	Dr. Scott McNaught 989-774-1335 mcnau1as@cmich.edu
Equipment Provided From Lab	Sample bottles, coolers, and preservatives are provided (if necessary), general sampling guidance provided	Price quote, sample kit (sample bottles, preservatives, chain of custody form), and general sampling guidance are provided	Sample bottles, coolers, and preservatives are provided (if necessary), general sampling guidance provided	Sample bottles, coolers, and preservatives are provided (if necessary), general sampling guidance provided
Sample Shipment to Lab	Samples should be placed on ice and returned to lab overnight.	Samples should be placed on ice and returned to lab overnight.	Samples should be placed on ice and returned to lab overnight.	Samples should be placed on ice and returned to lab overnight.
Minimum Order	None	None	$50	None

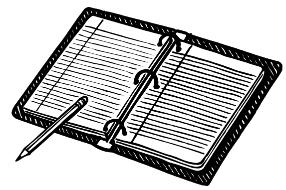
**The Michigan Water Resources Center will process water samples from Indiana entities. (Analytical prices are not included in the Resources Needed table for each parameter within this document.)*

The National Center for Water Quality Reseach at Heidelberg University offers a suite of nutrient and sediment analyses for surface water testing. The package includes TSS, total phosphorus, total Kjeldahl nitrogen, nitrate, nitrite, ammonia, dissolved reactive phosphorus, conductivity and others for $60. They do not offer *E. coli*, pH, or dissolved oxygen.

2.5 Managing Monitoring Data

All the hard work of developing and implementing a monitoring project is lost if the resulting data are not carefully managed.

Data management includes the following aspects.



- **Develop and document standard operating plans and procedures.** These include sampling routes, sample preservation and transportation or shipping to laboratories, measures taken for quality control such as field blanks, as well as recording the measurements clearly and completely.
- **Create field data sheets** that make it easy to follow the field procedure step by step and record measurements.

Enter data regularly and consistently into an electronic format. It is a good investment of time early in the project to develop data identifiers that will make retrieval easy. Monitoring projects often group samples by date, location, or parameter. If the project is funded by IDEM, data will need to be recorded in the AIMS template so studying required information early is critical. The data identifier system also needs to record blanks and other QA procedures, as well as calibration of multi-meters or any other equipment used.

- **Identify a method for long-term, securely backed up data storage**. All valuable data need to be backed up in an off-site location. Free or low-cost sites can back up your data “in the cloud”, so there is no excuse for lost data.
- **Conduct regular checks of the data** to make sure they are consistent and complete. Having an outside party review the monitoring project and data collected regularly can help ensure that the data will be useful and usable.
- **Create regular reports for your stakeholders.** This is helpful to stakeholders, and also helps to see what is being learned (if anything) from the monitoring.

Sharing Your Data with IDEM

Everyone monitoring water in Indiana is encouraged to share their water quality monitoring results, making data available to other organizations, institutions, and the public. Groups can share their data voluntarily through IDEM’s external data framework, a systematic process to submit data for possible use in various IDEM programs. Information on the external data framework and the various data submittal levels is available at http://www.in.gov/idem/nps/2916.htm.

For watershed groups that receive 319 funding for monitoring, IDEM requires submittal of monitoring data with the final report in specific formats in order to facilitate data sharing through their Assessment Information Management System (AIMS) database and the U.S. EPA's STORET (STOrage and RETrieval) database. STORET data are available to numerous entities including state and federal agencies, universities, private individuals, and potential partners and grantors.

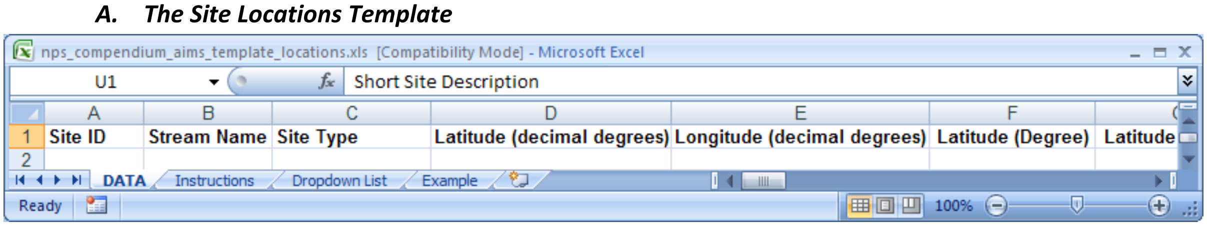
IDEM provides three template spreadsheets to format the data as required, available at http://www.in.gov/idem/nps/3383.htm.

A. ***AIMS Template for Site Locations*** (Used to provide site information, to obtain Site IDs)
B. ***AIMS Template for Stream Sampling*** and ***AIMS Template for Lake Sampling*** (Used to enter data values, using the Site IDs provided by IDEM)

When beginning a monitoring project, first complete the "AIMS Template for Site Location" spreadsheet (data worksheet) with the location information. Once completed, submit the Excel file electronically to your IDEM project manager who will enter your project into the AIMS database. Once your project has been entered into AIMS, individual site ID numbers will be generated and provided to you electronically in the "AIMS Template for Site Location" spreadsheet, column A, which you can transfer to the "AIMS Template for Sample Results" spreadsheet, column A, for use with data collection.

For each template spreadsheet, download, then save and rename the file for a format you can edit. Click on the column heading to obtain a short description of the field and whether the information is required, conditional, or optional. Instructions are provided with each spreadsheet, but we have provided additional clarification below for the required fields.

A. The Site Locations Template



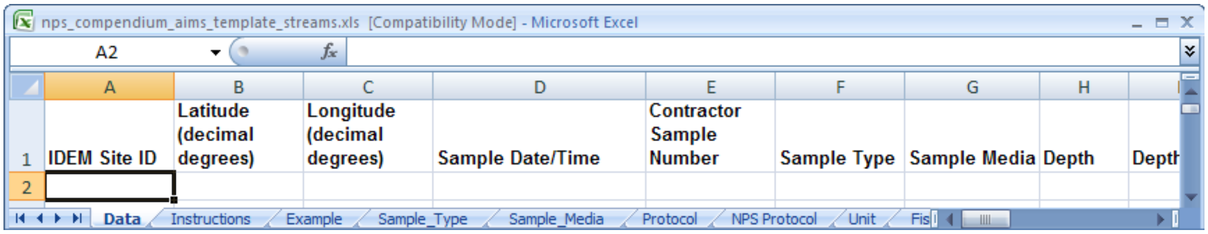
There are only three required fields.

1. Coordinates for your sampling sites in either decimal degrees, degrees-minutes-seconds, or UTM northing and easting. (Only one format is required – Column D through N.)
2. Your own unique side identifier that you use to track your data per sampling site (in the Comments column AV).
3. GPS metadata if you use a GPS to collect your data point for each site (columns AW through BE). If you are unable to locate the metadata from your GPS unit, at the minimum, provide GPS Unit type (column AZ)

All other fields are optional. Two recommended fields include Stream Name (column B) and Short Site Description (column U), used by IDEM to verify your locations.

Also include Project Name, Grant Agreement Number, and Contact Name, Telephone Number, and Email Address in the yellow box on the Instructions worksheet.

The Stream Sampling or Lake Sampling Template



IDEM Site ID – (required) This is the site ID number provided to you by IDEM as a result of submitting the "AIMS Template for Site Location" spreadsheet. If you are integrating additional sites into an existing project, provide the decimal degrees (conditional) for the new sites and IDEM will give them new site ID numbers.

Sample Date and Time – (required) The required format is MM/DD/YYYY HH:MI:SS AM. (If you have date in another format, Excel can change date/time data easily using Format Cells→Number→Date.)

Contractor Sample Number – (conditional) A unique number you generate to identify a sample result that does not already have an IDEM Site ID.

Sample Type – (required) For this and columns listed below, there is a dropdown list visible when you click inside the cell. For sample type, the choices are Normal (sample used to obtain results you use), Duplicate, Field blank, Equipment blank, or MS/MD

Sample Media – Choices are Fish_Community, Fish_Tissue, Lakes, Macro, Other, Sediment, Sludge, Water. Specific media chosen will require you to complete additional fields. For example, if your media is:

- Sediment - complete Sediment Particle Size and corresponding unit (columns U and V)
- Fish tissue – complete Fish Sample Type (column W).
- Fish Community – complete Fish/Macro Count (column Z)
- Macroinvertebrates (or Macro) – complete Fish/Macro Count (column Z) and Macro Square Count (column AA). To complete the Macro Square Count: use 15-Minute SSam if using mHAB mIBI sampling methods. Other options (100-Organism SSam and 100-Organism Lab) are only used for older IDEM macroinvertebrate sampling methods.

Lab/Field Indicator – (required) Indicate if the results were determined in the field or by a laboratory

Protocol or NPS Protocol – (conditional) If your project is funded by the Nonpoint Source (319) program, leave the Protocol column blank and choose the protocol used from the ***NPS Protocol*** list. Other projects should use the ***Protocol*** list. To find the protocol choices, first click on the NPS Protocol (or Protocol) worksheet tab, to at least know the number in the list to look for. The NPS Protocol and Protocol lists do not include all the protocols listed in this manual. Contact your Program Manager for guidance if this case occurs.

Concentration and corresponding unit – (required) Enter your sampling result, although depending on the parameters sampled, your results may not be a concentration value. Unit choices are in a dropdown list in column N. You can look up the list first in the "Units" worksheet tab. If the units you use are not available, you will need to convert your values to one of the units provided.

Detection Limit and corresponding unit – (required) Detection limit comes from your protocols and lab reports, and should be available in your QAPP.

Quantitation level – (conditional) This is only required if the parameter type is metal.

Assessment Level – (optional but recommended) Most NPS data are categorized as Assessment Level NPS 2 or 3 (See Assessment Level worksheet tab for descriptions)

2.6 Estimating Costs of a Monitoring Program

Note: This section is based in part on EPA's *Handbook for Developing Watershed Plans to Restore and Protect Our Water*, Ch 12.

Monitoring program costs depend on the number and locations of sampling stations, the types and number of samples collected, the parameters measured, staff and equipment required, and other factors. In general, personnel costs are the most expensive part, and are sometimes not budgeted because a watershed coordinator is paid by the project whether or not monitoring is done. But monitoring takes time that could be spent on other aspects of the plan like talking with stakeholders, so it is useful to make rough estimates at least of time involved.

Personnel costs: Even a fairly simple monitoring program requires a substantial investment of time. Staff time is needed for at least the following tasks:

- Reconnaissance and selecting sampling sites, contacting land owners to gain permission to use the sites, and mapping the locations.
- Driving to the site(s) for regular sample collection, conducting field measurements, collecting samples, keeping careful field records, and performing initial (field) processing if needed.
- Delivering or mailing the samples to the laboratory, following chain of custody procedures.
- Calibrating and maintaining equipment, especially if probes are used.
- Developing and implementing a data management system to record field measurements, receive and record sampling results, checking the data and performing basic analyses, and implementing a system for long-term data archiving.
- Writing reports and sharing data with local stakeholders, IDEM, and other partners.

Staff also need time and funding for training to continuously improve procedures, even if they are water professionals. If staff will conduct specialized monitoring techniques such as stream morphologic assessment or collection and identification of stream biota, they will need in-depth training. More training may be needed if there is staff turnover during the monitoring program.

Training of personnel is one of the costs of a monitoring program.

Equipment costs: Equipment needed for each parameter are listed in the first section, in the "Resources Needed" table. More sophisticated equipment like probes require time and investment in calibration and maintenance.

Supplies: Monitoring requires substantial numbers of sampling supplies like bottles, batteries, chemicals, labels, and ice packs, as well as supplies needed to tabulate and report data collected.

Travel costs: Operating and maintaining a sampling network requires logistical support. The cost of travel between the project base and remote sampling locations must be considered, and maintenance and field checks should also be included in mileage estimates. Additional costs may be needed to deal with difficult weather conditions like harsh winters or major storms.

Laboratory costs: Analytical costs are relatively straightforward to estimate using direct price quotes from one or more laboratories. Be sure to discuss sample numbers and schedules at the start so that the lab can give you its best price. Remember to include your own field quality control samples in your estimates of total sample numbers for the lab.

Data management costs: Adequate computer hardware and software are a good investment, so that the consistent, representative data you have collected have no risk of being lost due to computing limitations. Offsite backup of all data is a cost that is well worthwhile.

Example estimations of monitoring costs

To give an idea of the costs of monitoring, a rough estimate was made for two possible monitoring programs. Both measure IDEM's core parameters. The first is a bare-bones monitoring program to collect only minimum core parameters, with a frequency adequate to estimate annual nitrate loads within 41% (i.e., weekly). For both programs, the assumption was that the site is 10 miles away, requiring on average 20 minutes travel time, and is located at a USGS streamflow gage.

Option 1: Most economical

- Weekly sampling for nitrate, total phosphorus, and *E. coli* (sent to a local laboratory at $10 for nitrate, $30 for TP, and $40 for *E. coli*) and field measurements of turbidity (turbidity tube), dissolved oxygen, pH and temperature (probe). QHEI measured by a consultant two times per year.

Fixed costs (independent of number of parameters, location, frequency): $3600/year • Minimal training • Time for QAPP development • Low-cost probe for DO, temperature, pH: $500 • Time for analysis and communication of data – to IDEM, post on website, etc.	**Costs per sampling event**, independent of parameters: $85/event • Equipment Preparation • Travel Time & Mileage • Data management	C**osts per location per sampling event** $105 • Field procedures time • Analysis costs

Total cost for one site: $14,500/year
Total cost for three sites: $31,300/year

Option 2: Added samples for highly representative data

Automated sampler that takes daily samples, analyzed for the suite of nutrients and sediment at Heidelberg University. *E. coli* and field parameters sampled weekly. QHEI measured by a consultant two times per year. Consultant also measures macroinvertebrates to provide additional information.

Fixed costs (independent of number of parameters, location, frequency): $13,00/year	**Costs per sampling event**, independent of parameters: $85/event	C**osts per location per week:** $480
• Training and Time for QAPP development • Automated sampler and related equipment: $10,000 • Time for analysis and communication of data – to IDEM, post on website, etc.	• Equipment Preparation • Travel Time & Mileage • Data management	• Field procedures time • Analysis costs

Total estimated cost for one site: $46,000/year

2.7 Continuing to Learn: Accessing Training and Additional Information

This manual provides basic information to help you start to make choices about water monitoring. Monitoring is complex, and anyone monitoring needs to seek opportunities for continual learning. Some resources for learning more are listed below.

1. Join the Indiana Water Monitoring Council (InWMC) and participate in events and projects. The Indiana Water Monitoring Council serves as a broad-based, state-wide body to enhance the communication, collaboration and coordination of professionals, organizations, and individuals involved in water monitoring within Indiana.

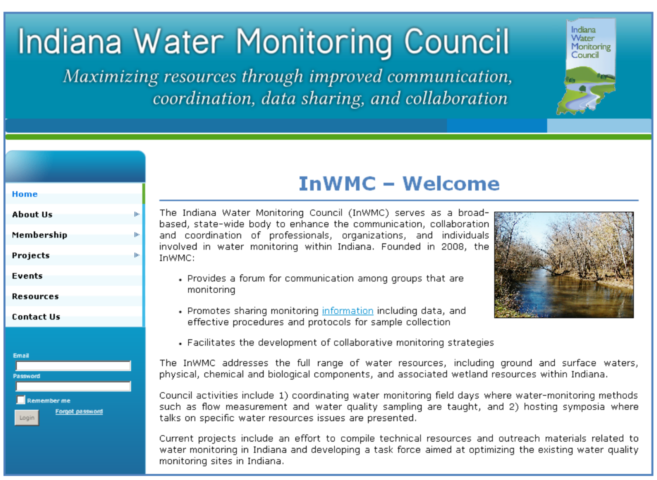


Figure 2.7.1: The Indiana Monitoring Council (http://www.inwmc.org) coordinates among organizations that monitor water in Indiana.

2. Hoosier Riverwatch provides workshops throughout the year around Indiana. Basic water quality monitoring training is a full day, and additional topics are sometimes offered. http://www.in.gov/dnr/nrec/3033.htm.
3. Watch the Monitoring Webinars presented by Barry Tonning, Tetra Tech, in 2010 and recorded by Purdue University. Powerpoint presentations and recorded video is provided.
4. The Indiana Watershed Webinar Series covers a variety of topics including monitoring. Register for any webinar and you will be on the mailing list to receive information about future webinars.
5. The California Water Boards, Surface Water Ambient Monitoring Program has information on methods, quality assurance, and many other aspects of monitoring, at An Online Field Methods Course is a narrated powerpoint covering many of the issues in monitoring.
6. The National Water Quality Monitoring Council provides a forum to improve understanding and stewardship of our water resources. It is not a membership organization, but provides resources to agencies and state monitoring councils. This includes the national monitoring conference every two years, and the National Environmental Methods Index (NEMI), which is a foundation for monitoring methods. The descriptions are complex for people without a background in analysis, but the methods provide a foundation for protocols used throughout the U.S.

Expert Panel Members

The following people contributed time to help select parameters and develop ideas used in this manual. Their positions or titles at the time of the Expert Panel meeting (2008) are included.

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