APPENDIX 1: INDICATORS AND MONITORING METHODS

This appendix contains general information about watershed indicators and methods.

Descriptions of Indicators and Methods Options: Water Sampling and Analysis

This section describes the indicators and methods options for collecting and analyzing water samples. The table below covers basic information about sampling containers, sample sizes, preservation techniques, and holding times.

Sample Handling Requirements (from Standard Methods)

Indicator	Container Type	Minimum Size (mL)	Preservation	Max. Holding Time
Alkalinity	P, G	200	Ref.	24 h
Bacteria	P, G (S)	200	Ref.	6 h
BOD	P, G	1000	Ref.	6 h
Chlorophyll	P, G	500	Dark	30 d
Conductivity	P, G	500	Ref.	28 d
N-Ammonia	P, G	500	ASAP or acidify	7 d
N-Nitrate	P, G	100	ASAP of ref.	48 h
N-Kjeldahl	P, G	500	Ref., acidify	7d
Oxygen	G-BOD	300	Fix	8 h
	Electrode		Immed.	None
pH	P, G	-	ASAP	2h
Phosphate	G(A)	100	Ref.	48 h
Solids	P, G	-	Ref.	7 d
Temperature	P, G	-	Immed.	None
Turbidity	P, G	-	Ref., Dark	24 h

Abbreviations

P = Plastic, G = Glass — Ref. = refrigerate
G(A) = acid-rinsed glass — h = hours, d = days

(S) = sterile

General Information About Water Analysis Methods

This section describes the basic laboratory methods used to analyze water samples. These methods are referred to in the next section on methods for each indicator.

- **Titration:** Determining the concentration of an indicator in a sample by adding to it a standard reagent of known concentration in carefully measured amounts until a color change or electrical measurement is achieved, and then calculating the unknown concentration. Common indicators measured this way are dissolved oxygen and alkalinity.
- **Colorimetric:** Determining the concentration of an indicator in a sample by adding to it a reagent that causes a color change in direct proportion to the concentration of the indicator being measured. The intensity of the color (as measured by the extent to which it absorbs or transmits light) is measured using a meter and either read directly in appropriate reporting units or read in "% absorbance" or "% transmittance" units and converted to reporting units. Common indicators measured this way are nutrients.
- **Electrometric:** Determining the concentration of an indicator in a sample by using a meter with an attached electrode which measures the electric potential (millivolts) of the sample. This amount of electric potential is a function of the activity of ions or molecules in the sample and proportional to the concentration of the indicator being measured. The electrode is selected based on its response to specific ions (known as an "Ion Selective Electrode" (or ISE), general ionic activity (conductivity) or molecules (for example, a Membrane Electrode). The meters can either display results in either millivolts (mV) or in appropriate reporting units. Common indicators measured this way are dissolved oxygen, pH, conductivity, and nutrients.
- **Gravimetric:** Determining the concentration of an indicator in a sample by filtering a specified quantity of the sample and determining the weight of the material retained on the filter. Common indicators measured this way are total solids and total suspended solids.
- **Nephelometric:** Determining the clarity of a sample by measuring the intensity of light scattered by particles in the sample and comparing this with a known solution. The higher the intensity of the scattered light, the higher the turbidity, reported in nephelometric turbidity units (NTU's).
- **Membrane Filtration and Incubation:** Determining the bacteria concentration of a water sample by filtering a specified quantity through a specified gridded membrane filter, which retains the bacteria and other particles larger than 0.45 microns. After filtration, the membrane

containing the bacterial cells is placed on a specific nutrient medium and then incubated at a specified temperature for a specified length of time. Colonies growing on the filter are then counted.

WATER QUALITY INDICATORS AND METHODS

Fecal Coliform and *E. coli* Bacteria: Fecal coliforms and *E. coli* are bacteria that are common in the intestines and feces of warm-blooded animals. They are used both as an indicator of the presence of sewage or animal manure in the water and as an indicator of the health risk of swimming and other water contact recreation. Fecal coliforms are used in MA, *E. coli* are used in NH, per their water quality standards.

Analytical Method for E. coli and Fecal Coliforms: Membrane Filtration Using mTEC: EPA method #1103.1
A water sample is collected in a sterile container and analyzed within 6 hours. Several subsamples are filtered through 0.45 micron filters, dry incubated on mTEC nutrient medium in petri plates at 35°C for 2 hours, then incubated at 44.5°C in a water bath for 22 hours. Fecal coliforms can be counted after incubation. *E. coli* can be counted after a 20 minute incubation at room temperature on a urea solution (this is known as a "confirmation" step).[1] The most reliable counts are produced on plates with between 20 and 80 colonies. Counts below 20 may be statistically unreliable. Counts over 80 are subject to overcrowding and are also statistically unreliable. Subsample sizes for filtration are selected to produce these counts. This method is acceptable for federal and state agency assessment.

Analytical Method for Fecal Coliforms: Membrane Filtration Using mFC: Standard Methods #9222 D
Another commonly used method for fecal coliform analysis involves a one-step incubation in a water bath for 24 hours on "mFC" nutrient medium.[2] This is acceptable in MA, but not in NH. We recommend the "mTEC" method per EPA and other guidance[3] noting this method's superior precision and accuracy and because it enables enumeration of both fecal coliforms and -*E. coli* by the same procedure. Plates are counted the same way as the mTEC method described above. This method is acceptable for federal and state agency assessment in Massachusetts only.

Method Variations

There are many variations of membrane filtration that use home-made incubators, one step paddles, different nutrient media, etc. They are too numerous to describe here. All methods but the two listed above are not acceptable for federal and state agency assessment, but are fine for education and awareness and some community assessments. In selecting one of these variations, keep two things in mind:

---

[1] For rivers that lie wholly within MA, this step can be omitted.

[2] Standard Method #9222D. This method is used by MA DEP to enumerate fecal coliforms.

[3] EPA document 600/4-85-076 and Pagel

- Does the method produce reliable counts, at the densities produced on the plate or paddle?
- Is the method EPA approved?

Notes on Methods

- Samples must be collected in sterile containers -- either pre-sterilized disposable containers or autoclaved re-usable containers.
- For rivers that flow in both states, use the "mTEC" lab analysis procedure to enumerate both fecal coliforms and *E coli*.
- For rivers that flow only in NH, use the "mTEC" lab analysis procedure to enumerate *E. coli*.
- For rivers that flow only in MA, use the "mTEC" lab analysis procedure to enumerate fecal coliforms. If necessary, you can use the "mFC" procedure, but realize that this is less accurate and precise than the "mTEC" protocol.

Dissolved Oxygen (DO): DO is the presence of oxygen gas molecules in the water. Since it is critical to many biological and chemical processes in the water and essential for aquatic life, dissolved oxygen is an indicator of the capability of the aquatic ecosystem to support life.

Hach or Lamotte Adaptation of Winkler Titration Method: Standard Method #4500-OG (or equivalent)

Samples are collected in 300 mL "BOD" bottles with glass stoppers so that no air bubbles are trapped. In lakes, an integrated sample is collected using a length of garden hose. Samples must be analyzed immediately or fixed and analyzed within 8 hours. The level of oxygen in the sample is "fixed" by adding reagents which produce a chemical reaction producing iodine in direct proportion to the amount of oxygen in the water. Sodium thiosulfate is then added incrementally using a digital titrator (Hach) or syringe (Lamotte). The amount of sodium thiosulfate it takes to turn the solution clear is proportional to the amount of iodine (which has taken the place of the oxygen) in the sample. This method is acceptable for federal and state agency assessment.

Meter (Membrane Electrode) Method: Standard Methods #4500-OG (or equivalent)

The meter directly measures dissolved oxygen from the water. A membrane-covered electrode probe is lowered into the water. The meter electronically measures the diffusion of oxygen from the water across a membrane-covered electrode, which is directly proportional to the DO concentration. This method is acceptable for federal and state agency assessment.

Modified Winkler Titration w/ a syringe or eyedropper (Hach via Mitchell & Stapp)

This is essentially the Modified Winkler Titration described above, with some changes. The titrant is phenylarsine oxide solution and the titrator is an eyedropper. The eyedropper gives less accuracy and sensitivity than other titrators because it dispenses larger drops -- each drop equals 0.5 mg/l. This method is not acceptable for federal and state agency assessment, but is fine for education and awareness and some community assessments.

Notes On Methods

- Water samples for dissolved oxygen will be collected in glass-stoppered BOD bottles so that no air is trapped in the sample.
- If you have more sites than can be monitored within a 2-hour window or you have a limited budget for this indicator (<$300), we recommend that you use the Hach or Lamotte Adaptation of Winkler Titration. The Hach digital titrator dispenses smaller increments of the sodium thiosulfate than the Lamotte syringe and therefore increases the sensitivity. But, it's more expensive.
- If you have the budget (_$600-800) to purchase a meter, and you have few sites that you can monitor within a 2-hour window, OR you need frequent (or continuous) measurements from a few sites, a meter will work best.

Biochemical Oxygen Demand (BOD): BOD is a measurement of the amount of oxygen consumed by organic matter and associated microorganisms and through chemical oxidation in the water over a period of time, usually 5 days. Measuring the bio-chemical oxygen demand (BOD) of the water tells us whether oxygen demanding wastes might cause low DO levels at times.

Modified BOD-5 Day Method (Hach via Mitchell & Stapp)

Two samples are collected in glass-stoppered BOD bottles (one clear and one black) as in the DO method. The DO is determined for the clear bottle, using Modified Winkler Titration with a syringe or eyedropper. The black bottle in placed in the dark and incubated for 5 days at 68°F. The DO for this sample is then determined the same way. BOD is determined by subtracting the DO level of the black bottle from the clear bottle. This method is not acceptable for federal and state agency assessment, but is fine for education and awareness and some community assessments.

pH: pH is a measure of the acidity of the water. Since pH affects many biological and chemical reactions in the water and most organisms have a preferred range, it is a good indicator of capability of the aquatic ecosystem to support life.

Electrometric Method

pH is either measured on a collected sample or directly in the water body, using a laboratory-quality meter with an electrode in either case. The Massachusetts Water Watch Partnership adaptation of EPA Method 150.1 involves collecting a sample by completely filling with water a plastic sample bottle (with a screw cap) and refrigerating for no more than 24 hours and measuring with a pH meter immediately after opening. pH can also be measured directly by immersing the probe in the water body. The meter must be equipped with a probe suitable for low ionic strength waters. This method is acceptable for federal and state agency assessment.

Other Electrometric Methods

There are less expensive pH pens or "pocket pals" on the market. These should be checked against a reliable, laboratory-quality meter to establish accuracy and precision. This method is not acceptable for federal and state agency assessment, but is fine for education and awareness and some community assessments.

Colorimetric Method (Hach via Mitchell & Stapp)

This method involves the addition of pH indicator solution to a water sample which changes color according to the pH. The sample color is matched to colors labeled in pH units in a color comparator. The analyst determines the closest color match and records the pH. This should be considered an approximation only. This method is not acceptable for federal and state agency assessment, but is fine for education and awareness and some community assessments.

pH Paper

This is similar to the colorimetric method, except that a specially coated paper is dipped in the sample and turns color according to the pH. This should be considered an approximation only. This method is not acceptable for federal and state agency assessment, but is fine for education and awareness and some community assessments.

Notes on Methods

- Most waters in the Merrimack River watershed are low in ionic strength. Accurate pH measurements require a probe that will respond in these types of waters.
- pH samples should be collected so that no air is trapped in the sample.
- The colorimetric method is subject to variation in the light source and the judgments of the analyst. It is inherently imprecise.

Total Alkalinity: This is a measure of the water's ability to neutralize acids -- the higher the alkalinity levels, the more acid-neutralizing capacity the water has. This is important for aquatic ecosystems because it protects against changes in pH, which can harm aquatic life.

Double End-point Titration Method (MassWWP)

Total alkalinity if measured by titrating a sample with a known concentration of sulfuric acid using a method used by the Massachusetts Water Watch Partnership.[4] In this method, the sample is collected and measured as for pH. It is then titrated with measured amounts of sulfuric acid (using a digital titrator) to a pH of 4.5, then 4.2. The amount of acid added to reach these two

[4] This method was originally developed by the University of MA Acid Rain Monitoring Project

points is converted to total alkalinity. This method is acceptable for federal and state agency assessment.

Conductivity: This is a measure of the water's ability to pass an electrical current. This ability depends on the presence of inorganic dissolved solids made up of ions (particles that carry a positive or negative electrical charge). Since it measures a wide range of materials, its primary importance is as an indicator of general pollution, rather than a specific pollutant.

Electrometric Method (EPA Adaptation of Standard Methods 2510 B)

Conductivity is measured directly using a conductivity meter per the US EPA Volunteer Stream Monitoring Methods Manual. This meter contains a probe with two electrodes. The probe is lowered into the water, voltage applied, and the drop in voltage caused by the resistance of the water is measured and converted to conductivity. This method is acceptable for federal and state agency assessment.

Total Phosphorus: Phosphorus is an essential nutrient for plant growth and metabolic reactions in plants ad animals. Together with nitrogen, it is the primary source of food energy in the aquatic ecosystem. Too much phosphorus can cause too much biological activity and cause undesirable effects. Phosphorus occurs in various forms in the water, some of which are more available for plant growth than others. Total phosphorus includes all the forms. It is a good indicator of enrichment from various sources, such as sewage, manure, or fertilizer.

Persulfate Digestion Followed by Ascorbic Acid Method (EPA Method #365.2 or equivalent)

A sample is collected in a phosphorus-free container. A 25 mL sub-sample is boiled, acidified, and oxidized to convert all forms of phosphorus to orthophosphate (persulfate digestion). Orthophosphate is then analyzed by adding ascorbic acid reagent which turns the sample blue (ascorbic acid method). The intensity of the blue color is proportional to the amount of phosphorus in the sample. This blue color is measured using a spectrophotometer or colorimeter and compared with results for a set of standard concentrations. This method is acceptable for federal and state agency assessment.

Temperature: Since temperature affects many biological and chemical reactions in the water and most organisms have a preferred range, it is a good indicator of capability of the aquatic ecosystem to support life.

Direct Measurement (Standard Methods 2550)

Temperature is measured directly in the river with a thermometer, thermometer, thermocouple, or thermistor or a multi-use meter. It is measured in degrees Fahrenheit (°F) or degrees Celsius (°C). This method is acceptable for federal and state agency assessment.

Turbidity (for rivers only): Turbidity describes how the particles suspended in the water affect its clarity by scattering light. It is an indicator of the presence of suspended sediment from erosion, which can decrease biological activity, raise water temperatures, and clog fish gills and gravel spawning areas. Turbidity results are usually reported as nephelometric turbidity units (NTUs).

Nephelometric Method (Standard Methods #2130 or equivalent)

Turbidity is measured by collecting and analyzing a water sample using a nephelometer. A nephelometer consists of a light source that projects a beam of light through the water sample and a photo-electric cell that measures the intensity of light scattered by particles at a 90° angle from its original path. The results are reported as nephelometric turbidity units (NTUs). This method is acceptable for federal and state agency assessment.

Turbidity Tubes (Lamotte)

Two graduated cylinders with black dots on the bottom are filled to a specific volume -- one with sample water the other with turbidity-free water. A reagent is added to the turbidity-free water cylinder, until the visibility of the dot on the bottom is equivalent to that of the cylinder with the sample. The results are reported in unspecified units. This method actually measures absorbance plus scattering, so the results are not actually NTUs. This method is not acceptable for federal and state agency assessment, but is fine for education and awareness and some community assessments.

Turbidity Tubes (Tennessee Valley Authority)

These tubes are marked in increments of NTUs on the side and a wave pattern on the bottom. The sample is poured into the tube until the wave pattern disappears. The NTU increment level of the sample is reported. This method actually measures absorbance plus scattering, so the results are not actually NTUs. In fact, they should be reported in centimeters or inches. This method is not acceptable for federal and state agency assessment, but is fine for education and awareness and some community assessments.

Notes on Methods

- Measure turbidity in rivers.
- Make sure that the meter you purchase is a nephelometer that measures light scattered at a 90° angle.
- Turbidity tubes are not acceptable substitutes for a nephelometer, since they actually measure transparency (light scattering and absorption), rather than just light scattering. Because of this, they are highly unreliable in colored waters, which absorb light, though may not be turbid at all. They are really more analogous to secchi disks, in that your eye responds

to absorption. If you use these tubes, report your results as a depth (in centimeters or inches) rather than NTUs.

Nitrogen: Nitrogen is a gas in the atmosphere. It combines with oxygen or hydrogen to produce various compounds -- ammonia, nitrates, and nitrates. Is an essential nutrient for plant growth and metabolic reactions in plants ad animals. Together with nitrogen, it is the primary source of food energy in the aquatic ecosystem. Too much of certain forms of nitrogen can cause too much biological activity and cause undesirable effects. It is also toxic to babies in high concentrations. Nitrogen occurs in various forms, both organic and inorganic in the water, some of which are more available for plant growth than others. In some waters, nitrogen is the nutrient in short supply, so that relatively small amounts can cause impacts. Three forms of nitrogen are recommended as indicators in this guide: ammonia, nitrates, and total.

Ammonia Nitrogen: Ammonia (NH_3-) is produced when organic nitrogen and/or urea break down. It is a byproduct of sewage decomposition. It is naturally present in surface waters, and can be toxic to aquatic life at relatively low concentrations (<1.0 mg/l).

Distillation followed by Nesslerization (Standard Methods #4500-NH3 C or equivalent)

A water sample is first distilled, after buffering with a borate solution, using a distillation apparatus. Distillation involves boiling the sample and collecting the steam. This removes certain interferences. This is followed by a process known as Nesslerization. This involves pretreatment to remove turbidity-producing compounds and adding a nessler reagent. This produces a yellow to brown color that is measured with a spectrophotometer. The reading is compared with a set of standard concentrations and reported as mg/l NH_3-N. This method is acceptable for federal and state agency assessment.

Nitrate Nitrogen: Nitrate (NO_3-) is produced naturally by nitrogen-fixing plants and lightning acting on atmospheric nitrogen or ammonia. Nitrate is a form of nitrogen readily used by plants. In excess, it can cause excessive biological activity in surface waters and can be toxic to infants.

Cadmium Reduction followed by spectrophotometry (Standard Methods #4500-NO_3-E or equivalent)

A cadmium reduction reagent is added to a water sample. This causes a chemical reaction and turns the sample yellow-orange. This color is measured with a spectrophotometer. The reading is compared with a set of standard concentrations and reported as mg/l NO_3-N. This method is acceptable for federal and state agency assessment.

Cadmium Reduction followed by Color Comparator (Hach via Mitchell & Stapp)

This is essentially the same procedure as above, except the color is read using a visual color comparator. The sample color is matched to colors labeled in pH units in a color comparator. The analyst determines the closest color match and records the nitrate concentration. This should be considered an approximation only. This method is not acceptable for federal and state agency assessment, but is fine for education and awareness and some community assessments.

Total Kjeldahl Nitrogen (TKN): This refers to the total of organically bound nitrogen and ammonia. By analyzing samples for both ammonia and total Kjeldahl nitrogen, organic nitrogen can be calculated. This enables you to estimate how much nitrogen is in the system is in organic form, intermediate form (ammonia) and inorganic form (nitrate). It may tell you how much comes from sewage, versus fertilizer, for example.

Digestion followed by Nesslerization followed by spectrophotometry (Standard Methods #4500-Norg B or equivalent)

A water sample is first digested to convert organic and ammonia compounds to ammonia nitrogen. Ammonia is then measured using the Nesslerization Method. This involves pretreatment to remove turbidity-producing compounds and adding a nessler reagent. This produces a yellow to brown color that is measured with a spectrophotometer. The reading is compared with a set of standard concentrations and reported as mg/l TKN. This method is acceptable for federal and state agency assessment.

Chlorophyll *a*: Chlorophyll *a* is a green pigment found in all plants. It is used to quantify the abundance of algae in water. When chlorophyll *a* degrades, it converts to pheophytin. The ratio of chlorophyll *a* to pheophytin is used to determine the health of the algae sampled.

Pigment extraction followed by spectrophotometry (Adapted by Paul Godfrey from Standard Methods # 10200 H)

An integrated water sample is collected using a clean container (at least 1 qt). A subsample is filtered (quantity depends on a secchi reading) using a glass fiber filter and vacuum pump. Filters are either analyzed immediately, frozen, or dried. Pigment is extracted by grinding the filter, steeping the ground mass in 90% acetone, and centrifuging in tubes to de-suspend fibers from the solution. The color is then read with a spectrophotometer and the concentration calculated. Hydrochloric acid is then added to the sample to convert all chlorophyll to pheophytin. The color is then read again with a spectrophotometer and the concentration of pheophytin calculated. This method is acceptable for federal and state agency assessment.

Solids: Solids include materials that are dissolved, suspended, or settled in the water column. *Total solids* include all of these. They affect water clarity and can reduce photosynthesis and higher temperatures. Dissolved *solids* include various ions of calcium, chlorides, nitrate, phosphate, iron, sulfur and others that will pass though a 2 micron pore. These affect the water balance in the cells of aquatic organisms, making it difficult for them to maintain position in the water column.

Gravimetric method: Total Solids Dried at 103-105° C (Standard Methods #2540B)

Total solids are measured by weighing the amount of solids in a water sample. This is done by first weighing a ceramic dish, filling it with a known volume, evaporating the water in an oven at 103-105° C, and then weighing the beaker with the residue. Total solids are calculated by subtracting the weight of the dish from the weight of the dish with residue. Results are reported as mg/l. This method is acceptable for federal and state agency assessment.

Gravimetric method: Total Dissolved Solids Dried at 180°C (Standard Methods #2540C)

Total dissolved solids are measured filtering a sample through a glass fiber filter, weighing a ceramic dish, pouring the filtered sample into the dish, evaporating the water at 180°C, and weighing the dish plus residue. Total solids are calculated by subtracting the weight of the dish from the weight of the dish with residue. Results are reported as mg/l. This method is acceptable for federal and state agency assessment.

Secchi Depth Transparency (for lakes only): Transparency describes scattering and absorption of light by small particles and molecules in the water. This is most commonly expressed as the depth at which a black and white patterned device known as a *secchi disk* disappears from sight. The more transparent the water, the lower the depth at which the disk disappears. Reduced transparency has the same effects as elevated turbidity.

Secchi Disk (MassWWP or equivalent)

Transparency is measured using a secchi disk, a black and white patterned device. This disk is lowered into the water until it disappears from sight and then brought up until it appears again. The average of these two depths is the secchi depth transparency. This method is acceptable for federal and state agency assessment.

Descriptions of Indicators and Methods Options: Field Surveys of Physical Characteristics

Visual Field Surveys: Visual surveys involve observations, inventories, and estimates of river, riparian, lakeshore, and watershed characteristics, uses, values, and threats:

- *A pollution source inventory*
- *Water color, odor, and appearance*
- *Corridor land uses*
- *Evidence of pollution*
- *Habitat types*
- *Pipe Survey*
- *Channel and shoreline vegetation*
- *Bottom composition*
- *Condition of shorelines*
- *Water uses*
- *In-stream or in-lake plant growth*

The area surveyed should include the watershed zones of interest -- the water column, river banks, riparian areas, or upland areas. Typically, the presence or absence of these characteristics is noted, the quantity or extent visually estimated, and location mapped.

Methods Options

There are a variety of visual survey methods available. Sources of these methods include:

* *Massachusetts Department of Environmental Protection, Office of Watershed Management*
* *New Hampshire Department of Environmental Services, Volunteer Lakes Assessment Program*
* *Massachusetts Water Watch Partnership.*
* *Massachusetts Riverways Program*
* *River Watch Network*
* *Volunteer Environmental Monitoring Network*
* *UNH Cooperative Extension*

These agencies and organizations have method that have been field tested and found to produce useful information and can be taught to and carried out by volunteers and schools. Select a method that will provide information useful to your data users and meets your data quality goals.

River Flow: This is the volume of water passing a point expressed in cubic feet or meters per second. Flow affects the rivers physical characteristics, such as erosion and sedimentation, bottom composition, amount of the bottom that’s covered with water, etc.

Embody Float Method (EPA Volunteer Stream Monitoring Method Manual)

Flow is measured by first calculating cross-sectional areas (width times average depth) of two transects in a 20-foot section of stream. Then current velocity is measured by measuring how long it takes a float (typically an orange) to travel the length of the 20-foot segment. Flow is calculated by multiplying the average cross sectional area times a constant (or rocky or muddy stream bottoms) times the length (20 ft.) and dividing by how long it takes a float (typically an orange) to travel the length of the 20-foot segment. Flow is reported in cubic feet per second. This method is acceptable for federal and state agency assessment.

Lake Level: Lake level is the elevation of the water surface elevation relative to a fixed elevation. This is typically done by fixing a staff gage (a stick marked in inch or centimeter increments) to an object anchored to the lake bottom, such as a dock or pier support. Levels are read directly off the gage. Frequently, lake level gages are located at lake outlet dams.

Rainfall: Rainfall amounts can be measured using a rain gage, or gotten from the National Oceanic and Atmospheric Administration (NOAA). Rain gages are essentially collection devices marked in inches. The amount collected in the gage is read and recorded at the time interval of interest (daily, hourly, etc.). NOAA data is collected at various locations throughout the country. If one of these stations is in your watershed, this data may serve your needs. However, since rainfall patterns can vary over a region, you may need to set up your own gages that more accurately reflect conditions in your areas of interest.

River Channel Characteristics (wadeable waters only): River channel characteristics are the various physical features of the river channel that reflect geological and hydrological changes over time. The river channel is a dynamic land form that is constantly moving as water erodes the land surface. It also responds to human-caused changes in watershed land use and alterations of the river channel. These characteristics form the physical foundation of the river system and provide habitat for aquatic life. Monitoring these characteristics must be a long term, on-going, effort. Characteristics recommended in this guide are Bottom Composition, Embeddedness, Channel Cross Section, and Longitudinal Profile. These characteristics should be surveyed at both pool (low energy) and riffles (high energy) habitats. These measurements can be done only in wadeable waters.

Bottom Composition (Wolman Pebble Count, US Forest Service Stream Channel Reference Sites Guide)

Bottom composition the percent of the bottom in various size classes: sand, gravel, cobble, and boulder. It is measured using the pebble count procedure. This involves measuring the intermediate axis (neither the shortest nor the longest of the sides) of randomly selected particles on the stream bottom along transects where cross sections are measured. Each particle is placed in a size class, from sand (<2mm) to very large boulders (2048-4096 mm). This data can be plotted in various ways to represent bottom composition. The

USFS recommends plotting cumulative % (cumulatively adding the percent of the total count in each size class percent from smallest to largest) versus particle size. The changes in particle size over time will reflect the effects of erosion and deposition.

Embeddedness (US EPA Environmental Monitoring and Assessment Program)

Embeddedness is the extent to which larger particles (especially cobbles) are surrounded by sand and silt. It is measured by estimating the percentage of the particle surface (the same particle used in the pebble count) that is surrounded by sediment. The area that was buried is typically lighter in color than that which was exposed. Changes in embeddedness can indicate scouring and deposition.

Channel Cross Section (US Forest Service Stream Channel Reference Sites Guide)

A channel cross section is the shape of a "slice" of the channel -- its width and depth. It is also the location where flow and bottom composition are measured. A channel cross section is measured at locations that represent typical channel form, clear channel features, clear indicators of bankfull (top of the bank flow) and active floodplain, clear terraces and a straight reach. It is measured by locating and determining the elevations of endpoints on either side of the channel, measuring the depths (using a surveyors level and rod) from a line stretched across the endpoints to the channel bottom and water surface. The measurements are plotted as distance versus elevation to depict the cross-section. Changes in channel cross-section will reflect scouring, deposition, and channel movement.

Longitudinal Profile(US Forest Service Stream Channel Reference Sites Guide)

A longitudinal profile measures and plots the slope of a 300-500 foot reach of the river. It is measured by first locating and marking important channel and related features (such as terraces, riffles, pools, vegetation changes, etc.). Elevations at the marked features are measured using a surveyor's level and rod. Elevations of the channel bottom, water surface, terraces, and floodplains can all be gathered. The data are plotted as elevation versus distance. Changes in channel cross-section will reflect scouring and deposition.

Descriptions of Indicators and Methods Options: Field Surveys of Biological Characteristics

Benthic Macroinvertebrates: These are critters without backbones that live on the river bottom. They include aquatic insects such as mayflies, mollusks, crustaceans, and worms. They are good indicators of ecological conditions and human impacts, since they are integral to the river's food web and the community present reflects both water and habitat quality.

Four different levels of effort are recommended in this guide:

- Intensive Benthic Macroinvertebrate Assessment: Net Collection
- Intensive Benthic Macroinvertebrate Assessment: Rock Basket Collection
- Basic Benthic Macroinvertebrate Assessment
- Streamside Benthic Macroinvertebrate Assessment

Methods for each are described below.

Intensive Benthic Macroinvertebrate Assessment: Net Collection (River Watch Network)

This guide recommends a metal frame net with an opening of 18" wide by 8" high with 0.6 mm nylon mesh. This mesh size is the standard recommended by the U.S. EPA. This size catches the smaller critters (like midges) but does not quickly plug up with sediment. The collection method is carried out in the field and lab. It involves the collection with the specified net of three composite samples from 2 fast and 2 slow spots in riffle habitats. This sample is preserved in alcohol for later lab identification. Twenty-two habitat characteristics are estimated or measured in the field. Critters are identified to family and counted in the lab. This survey produces a fairly sensitive assessment of conditions based on a number of numerical analyses of community composition, functional feeding groups, pollution tolerance of families, and allows numerical site to site comparisons. It can detect shifts in families within major groups that might result from pollution or habitat alteration. This method is acceptable for federal and state agency assessment.

Intensive Benthic Macroinvertebrate Assessment: Rock Basket Collection (River Watch Network)

Rock Baskets consist of a wire mesh basket filled with similar sized rocks (4 to 12 cm in diameter). This assessment is carried out in the field and lab. It involves a quantitative collection (organisms colonize the rock basket over a period of 5 weeks) of two or three samples from riffle and run habitats. This sample is preserved in alcohol for later lab identification. Twenty-two habitat characteristics are estimated or measured in the field. Critters are identified to family and counted in the lab. This survey produces a fairly sensitive and more quantitative assessment of conditions based on a number of numerical analyses of community composition, functional feeding groups, pollution tolerance of families, and allows more precise numerical site to site comparisons. It can detect shifts in families within major groups that might result from pollution or habitat alteration. This method is acceptable for federal and state agency assessment.

Basic Benthic Macroinvertebrate Assessment (River Watch Network)

This method is carried out in the field and lab. It involves the collection with a specified net (0.6 mm mesh) of one composite sample from 1 fast and 1 slow spot in riffle habitats. This sample is preserved in alcohol for later lab identification. Twenty-two habitat characteristics are estimated or measured in the field. Critters are identified to major group and counted in the lab. This survey produces a somewhat sensitive assessment of conditions based on a number of numerical analyses of community composition, gross pollution tolerance of major groups and allows site to site comparisons (if the communities are different enough to produce dramatically different results). This method is not acceptable for federal and state agency assessment, but is fine for education and awareness and some community assessments.

Streamside Benthic Macroinvertebrate Assessment (River Watch Network, Izaak Walton League, or equivalent)

This assessment is carried out entirely in the field. It involves the collection of one composite sample from 1 fast and 1 slow spot in riffle habitats. Critters are identified to major group and the relative abundance estimated in the field. Three primary habitat characteristics are estimated or measured. This survey produces a quick estimate of conditions, based on the presence and relative abundance of key indicator organisms. This method is not acceptable for federal and state agency assessment, but is fine for education and awareness and some community assessments.

Benthic Macroinvertebrate Habitat: Benthic macroinvertebrates exist in a wide range of locations in the river:

* Shallow, fast moving, rocky bottom areas known as *riffles.*
* Deeper, slower moving sandy and gravely bottom areas known as *runs.*
* And deep, slow moving muddy-bottom areas known as *pools.*

However, the number and diversity of organisms present is greatest in riffles. Habitat quality must be assessed in order to separate the influence of water column chemistry and biology from habitat on the community. While all of these are affect by human activities, natural variations in habitat might produce changes that might be mistaken for human-caused changes. So, a habitat assessment is a critical part of a benthic macroinvertebrate assessment.

Habitat Assessment (River Watch Network Adaptation of EPA Rapid Bioassessment Protocol II)

A habitat assessment is the estimate and measurement of certain physical characteristics of the river in order to determine the overall quality of the habitat for benthic macroinvertebrates. Examples of these characteristics include the velocity of the current, the composition of the river bottom, depth, the nature and extent of riffles. Together with water quality, these characteristics determine the kinds and numbers of macroinvertebrates that can live there. Both habitat quality and water quality are affected by human activities in the river or on lands in the watershed. This includes physical characteristics of the river that provide habitat for the invertebrates such as bottom composition, sedimentation, current velocity, shading, extent of riffle habitat, and others. Results for each site from the "Benthic Macroinvertebrate Habitat Assessment Field Sheet" are scored, totaled, and compared with the total score from the reference site (least impaired upstream conditions). This method is acceptable for federal and state agency assessment.

Aquatic Vegetation (lakes): Aquatic vegetation is an important part of a lake ecosystem, especially in near-shore areas. They provide habitat for aquatic animals and are an important source of oxygen. Some are nuisance plants, and cause dramatic habitat alterations and interfere with recreational uses. The types, density, diversity, and growth patterns are important characteristics to assess.

Aquatic Vegetation Mapping/ Identification (MassWWP or equivalent)

Aquatic vegetation mapping and identification involves visual observation and mapping and collection of specimens for identification. For mapping, monitors take a tour of the lake shoreline and observe areas of the lake where aquatic vegetation is at or near the surface. The location and extent of vegetation beds is drawn onto a map. For identification, vegetation samples are collected along a transect using a weighted rake. The samples are sorted, a qualitative estimate is made of the percentage and density of each type of plant, and specimens of each type bagged or shipment to a botanist for identification. This method is acceptable for federal and state agency assessment.