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About This Red River Basin Water Quality Monitoring Volunteer Manual

"Whether we recognize it or not, each of us, regardless of position or perception, has a role in the decision-making process about how the river is ultimately treated, for our land uses and activities around the river contribute to what goes into the water."

Mark Mitchell and William Stapp

The goals of this manual are:

- To provide background information that educators can use to design their own curriculum and community volunteers can use to gain a better understanding of why, how and what to monitor.
- To provide clear information and technical procedures for implementing a sound water quality monitoring program including sampling, data management and analysis.
- To provide information for taking action to protect and improve a river and its watershed.

The manual includes general instructions on developing a monitoring program appropriate for any of the following goals:

- Educating the public and building awareness about a river and its ecology
- Establishing a baseline of ambient or background water quality
- Investigating specific water quality problems in a community

This Water Quality Monitoring Volunteer Manual includes information about the Red River Basin. Currently, most of the monitoring activities in the Basin are directly associated with the physical and chemical properties of rivers and water resources in North Dakota and Minnesota. As more information becomes available on biological monitoring, both methods and available data will be included in future editions. More information on Manitoba will also be added as it becomes available.

Material in this manual is drawn from several sources:

- *Volunteer Stream Monitoring: A Methods Manual*, U.S. Environmental Protection Agency, 1997.
- *Clean Water Initiative: Volunteer Stream Monitoring Methods Manual*, field test draft, Tennessee Valley Authority, December 1995.
- *River Monitors' Manual*, Mississippi Headwaters Board and Rivers Council of Minnesota, November 1997.
- *A River Runs North*, Red River Water Resources Council, 1993.
- *Utah Stream Team*, Utah State College of Natural Resources, USU Water Quality Extension.
- *Testing the Waters*, River Watch Network, 1997.

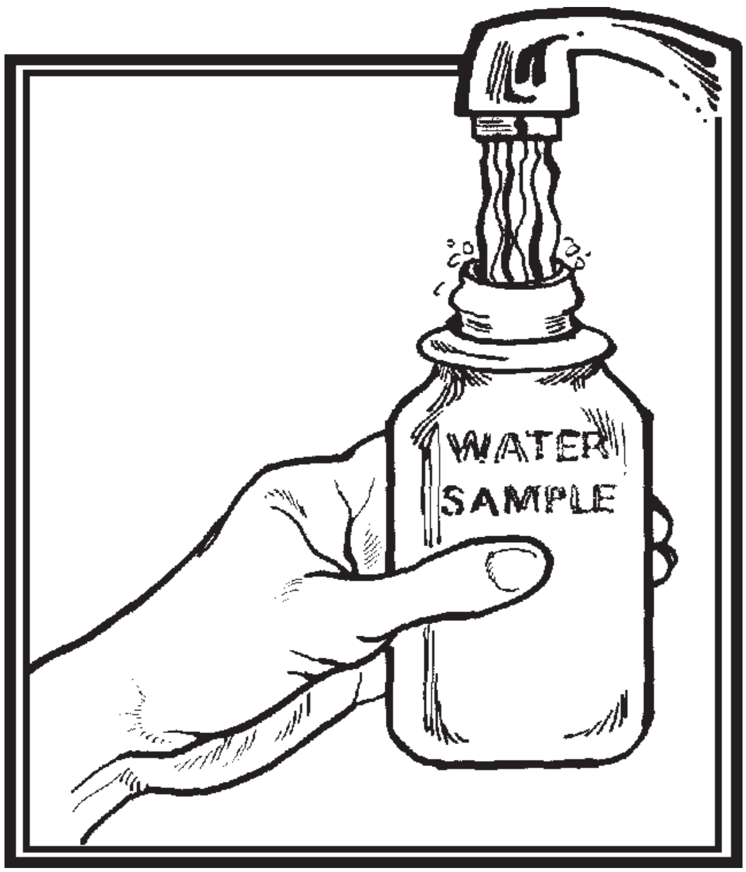
- *Watershed Information Network: A Watershed Report And Suggested Framework For Integrating Water Quality Monitoring Efforts*, Charles Fritz, July 2001.
- *Framework for Strategic Watershed Protection: Creating a Watershed Information System*, Barb Horn, 2002.

Through water quality monitoring, participants will:

- Understand the relevancy of their studies
- Gain confidence in their ability to positively influence their local environment
- Learn the importance and rewards of serving their community
- Develop skills to become better decision makers
- Realize that learning can be fun!

Key Concepts of Water Quality Monitoring

Water Quality Monitoring Goal:
Water quality monitoring helps communities establish sound scientific practices to measure the health of local streams so stakeholders can take actions to protect and improve desired conditions and uses of the river and its watershed for the future.



Community-Based Partnerships
+ Support
+ Sound Science
= Useful Data and Informed Decisions

Volunteer water quality monitoring is a partnership of local organizations: an educational partner, such as a school, nature center, or citizen group conducts the monitoring and analyzes the results along with organizational partners such as local government, soil and water conservation districts, watershed districts, state agencies, federal agencies and others who also assist with training and technical assistance. Actions are taken as needed by a coalition of these partners based on the analysis and problems identified. Communities implement water quality monitoring according to local resources and circumstances.

What is Volunteer Water Quality Monitoring?

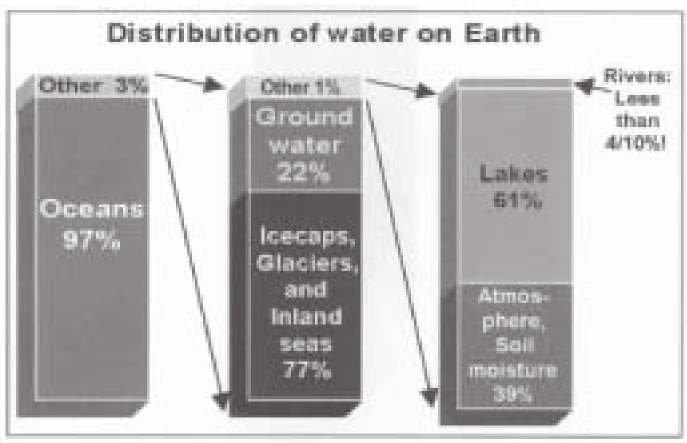
About Monitoring

The Introduction to *Testing the Waters*, defines monitoring as "a way of gathering information about the health of a river by observing, collecting and analyzing information about its parts." Monitoring is an activity that occurs over time. A teacher who said about his monitoring program, "We begin today, and we go on forever!" had it right—a good monitoring program is continuous—it is always producing valuable information.

Monitoring provides the following information:
- Current health of the river or waterbody
- Whether the river or waterbody meets its designated use
- How the river or waterbody has changed over time

Information gathered through monitoring can be used to:
- Inform citizens about the health and value of the river or waterbody
- Suggest that a river or waterbody requires improvement to meet its designated use
- Lead to actions to protect or restore the river or waterbody

Why do we care about water quality monitoring?



Water is one of the most abundant and important substances on Earth. Water comprises over 70 percent of the Earth's surface and 50 to 80 percent of every living organism's weight—it truly connects all living things. Each of us – student, bird, farmer and plant – depends on the same global, water-centered system. Within this system, our lives depend on the small volume of fresh water. Fresh, clean, drinkable water constitutes only one half of one percent of all the Earth's water. We depend on our streams and rivers to deliver much of this drinking water, as well as provide for irrigation for agriculture, recreation and other uses. Many animals and plants could not live without clean river water. Humans are the only species with the ability to manage water resources. With this ability comes an important responsibility to understand and protect streams and rivers. A vital tool for such action is water quality monitoring.

The information that we collect helps us:
- Determine the overall health of our streams
- Understand our streams and their role in the watershed
- Make good watershed management decisions
- Identify specific water quality problems
- Most importantly, take wise action to improve or protect the water quality of our streams

Who Monitors Rivers?

Water quality monitoring is performed by a variety of organizations, agencies and individuals. For example, industry or municipalities that discharge effluent from industrial or municipal treatment processes into public waters are required to monitor that effluent. The Minnesota Pollution Control Agency and the North Dakota Department of Health have lists of permitted dischargers.

Following is a partial list of agencies and groups that monitor rivers in the Red River Basin. For more details see the section “Summary of Water Management Function and Regulatory Authority”.

- Minnesota Pollution Control Agency
- North Dakota Department of Health
- United States Geological Society
- Minnesota Department of Natural Resources
- North Dakota Game and Fish
- Lake Associations
- Red River Basin River Watch
- River Keepers
- Center for Watershed Education
- Red River Riparian Project

History of Water Quality Monitoring in the Basin

Volunteer or citizen monitoring programs exist all over the United States. In fact, the U.S. Environmental Protection Agency has a program specifically intended to support these programs. Volunteer monitoring has a long history. The National Audubon Society has sponsored an annual bird count, conducted by thousands of volunteers, each December. The Izaak Walton League teamed with the states of Virginia and Ohio to develop a “Save Our Streams” volunteer monitoring program to inventory macroinvertebrate communities, both to educate the public and to provide data to the state agency.

Minnesota has a Clean Lakes and Stream Monitoring Program that uses hundreds of volunteers to monitor water quality each open-water season with data being used to better understand long-term water quality trends. As of Fall 2002, in the Red River Basin alone over 30 Minnesota schools were involved in the River Watch program, monitoring the health of rivers and streams at over 100 locations throughout all nine major watersheds in the Minnesota portion of the Basin. In May 2002, the Minnesota Legislature (both the House and Senate) passed a bill that encourages volunteer citizen monitoring.

Why Volunteer Monitoring?

In monitoring rivers and streams, citizens contribute to the body of information available to state and local decision makers. At the same time, the citizens learn for themselves how human uses affect the river or waterbody in his or her community. According to *Minnesota Watermarks*, a report by the Minnesota Environmental Quality Board, only 5 percent of Minnesota's streams and 12 percent of Minnesota's lakes have been fully assessed for meeting water quality standards. This means that decisions are often made without enough information.

State agencies simply don't have the staff and resources to monitor all of Minnesota's waterbodies. Citizen monitoring (that includes communities, volunteers, schools) is an important, cost-effective contribution to the State's base of information. These monitors are crucial not only because they can start to fill gaps, but more importantly, they are front-line participants who monitor the streams and lakes they care about and take ownership in and contribute to water and related land-use decisions.

Louise Hotka, a water quality specialist for the Minnesota Pollution Control Agency, described it this way,

> The primary value gained by citizen involvement in water monitoring is the potential to expand the number of rivers and lakes for which we have some information about their condition. We have found through experience that this is something that state and regional entities just cannot accomplish in any practical way. Citizens, by their relative nearness to their waters, have the potential to make observations at critical times of day or within the flow regime that could not be done around the state by an agency.
>
> Even some simple, low cost observations that are made extensively around the state will allow better informed priority setting for targeting limited monitoring resources.
>
> A second value is that for citizens to be informed about the waters they are personally interested in makes it more likely that they and their neighbors and local authorities will be more effective in protecting it. It is hard to put a dollar value on restoring or protecting a river system, but the folks who swim, fish and enjoy the habitat know the value.

Why are Students, Teachers and Community Volunteers Getting Involved?

Through the hands-on experience of water quality monitoring, participants further their understanding of water resources in the Basin. Just as important, they grow and learn from the experience. Water quality monitoring is also a powerful educational tool. This program can meet Core Curriculum Objectives, be taught in an interdisciplinary manner, provide meaningful content and activities, expose students to new learning environments and much more. It is a community organizing tool – a stepping stone to helping volunteers become active in addressing the broader issues facing their community.

Summary Of Water Quality Indicators

A variety of parameters may be monitored to assess the condition of streams and watersheds. Most volunteer monitoring programs will not monitor all of the parameters reviewed below but access to data from other local, state and federal monitoring partners may include these parameters thus a review will be provided here regarding how each specific water quality indicator relates to river health. Although the Red River Basin is part of several ecoregions, the Red River Valley ecoregion values are shown which represent conditions of the Red River mainstem and tributary reaches within the Glacial Lake Agassiz floodplain.

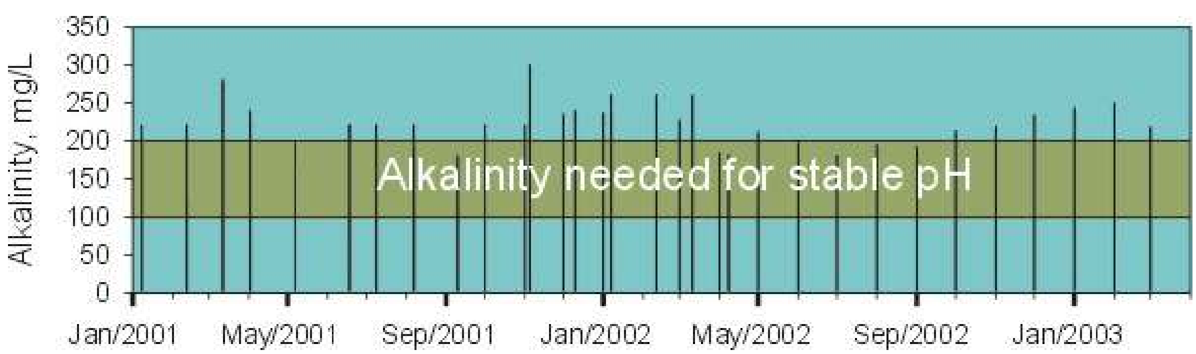
Alkalinity

Alkalinity is a measure of all the substances in water that can resist a change in pH when acid is added to the water. In other words, alkalinity describes how well water recovers from an "acidic" punch.

Alkalinity is typically expressed in mg/L of calcium carbonate ($CaCO_3$) because calcium carbonate is a good acid neutralizer. Water with low alkalinity has a low capacity to neutralize or "buffer" incoming acids and is, therefore, very susceptible to acidic pollution. In contrast, water with greater alkalinity, or buffering capacity, will have the ability to neutralize more of the incoming acidity and therefore resist rapid changes in pH. Sufficient alkalinity in water protects aquatic life against rapid changes in pH and makes water less vulnerable to acid rain.

Alkalinity in the Red River

Alkalinity of 100-200 mg/L will sufficiently stabilize the pH in a stream. As shown on the graph below, the waters of the Red River in the Fargo-Moorhead (F-M) area average 216 mg/L, a rather high alkalinity. This alkalinity is maintained because the Red River is surrounded by alkaline soils and geologic deposits (soils and geologic deposits rich in dolomite and limestone that contain carbonate). Although high alkalinity is often associated with hard water and high dissolved solids, characteristics that may adversely affect the water's use and taste, there are no negative health effects from alkalinity.



Graph of alkalinity (mg/L) for the Red River in the F-M metro area for the period January 2001 to January 2003 in relation to the level of alkalinity (100 to 200 mg/L shown in dark band) needed to stabilize pH.

Ammonia (NH_3)

Ammonia is a source of nitrogen (N), an important nutrient for plants and algae. Ammonia is excreted by animals and is produced during the decomposition of plants and animals. Ammonia is an ingredient in many fertilizers and is also present in sewage, stormwater runoff, certain industrial wastewaters and runoff from animal feedlots.

Ammonia in Water

At the temperature and pH range typical of most rivers and lakes, ammonia exists predominantly in the ionized form (NH_4+). As pH and temperature increase, the ionized ammonia changes to un-ionized ammonia gas (NH_3). Ammonia gas can be toxic to fish and other aquatic organisms. If dissolved oxygen is present, ammonia can easily be broken down by nitrifying bacteria to form nitrite and nitrate.

Ammonia in the Red River

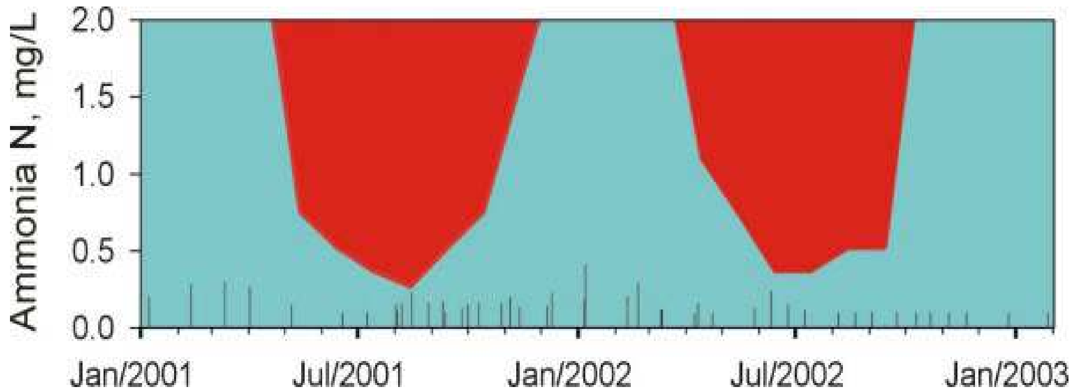
The water quality standards for ammonia in both Minnesota and North Dakota are intended to protect aquatic life against the impacts of gaseous ammonia (un-ionized ammonia). The Minnesota Pollution Control Agency standard, based on chronic (long-term) exposure to un-ionized ammonia, is set at 0.016 mg/L of nitrogen from un-ionized ammonia. The North Dakota Department of Health has two ammonia-related standards for the Red River:

1. A chronic standard, and
2. A site-specific chronic standard for a 32-mile stretch of the Red River in the Fargo-Moorhead area extending from Fargo’s 12th Avenue North bridge downstream to the mouth of the Buffalo River.

The proportion of ammonia gas to the total ammonia concentration increases with temperature and pH. The pH of the Red River is slightly alkaline year ’round but the temperature of the water varies from just above freezing (0°C) to over 25°C (over 80°F). The changes in water temperature mean that only a small portion of the total ammonia in the water occurs as a gas in the winter but a greater proportion of ammonia occurs as a gas in the summer. Both North Dakota Department of Health chronic standards are calculated using mathematical equations that account for both temperature and pH.

Trends

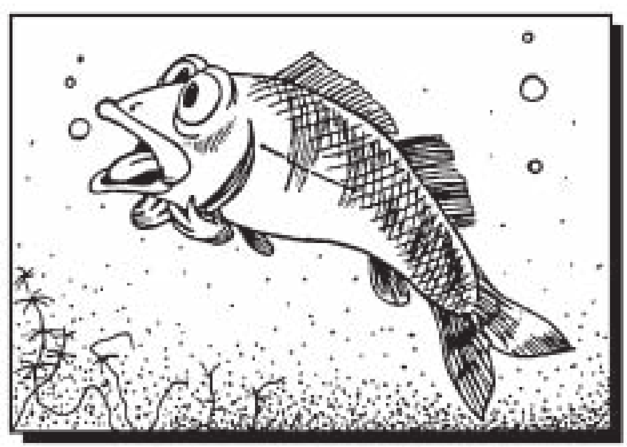
The graph shows the monthly average concentration of total ammonia in the Red River. If the concentration of total ammonia enters the black zones on the graph, fish and other aquatic organisms can be harmed by ammonia gas. As you can see, the concentration of total ammonia in the river is generally too low to pose a danger to river organisms, even in the warmer water of the summer months when more ammonia occurs as a gas.



Graph of total ammonia (mg/L) for the Red River in the F-M metro area for the period January 2001 to January 2003. The black areas on the graph, defined by the pH and temperature of the water, indicate the levels of total ammonia that would produce levels of ammonia gas that would be harmful to aquatic life. Because more of the total ammonia converts to ammonia gas increases as the temperature and pH of the water increase, the danger to aquatic life from high levels of ammonia gas is greatest in the summer.

Dissolved Oxygen (DO)

Dissolved oxygen refers to the amount of oxygen (O) dissolved in water. Because fish and other aquatic organisms cannot survive without oxygen, dissolved oxygen is one of the most important water quality parameters. Dissolved oxygen is usually expressed as a concentration of oxygen in a volume of water (milligrams of oxygen per liter of water, or mg/L).



In nature, oxygen gets into water in two ways. Oxygen from the atmosphere is mixed into (diffuses into) the water from the atmosphere. Where water is rough (for example, where water is tumbling over rocks or where there are waves), the oxygen and the water mix more easily, resulting in more oxygen from the atmosphere being dissolved in the water. Oxygen is also introduced into water by green aquatic plants and algae during photosynthesis.

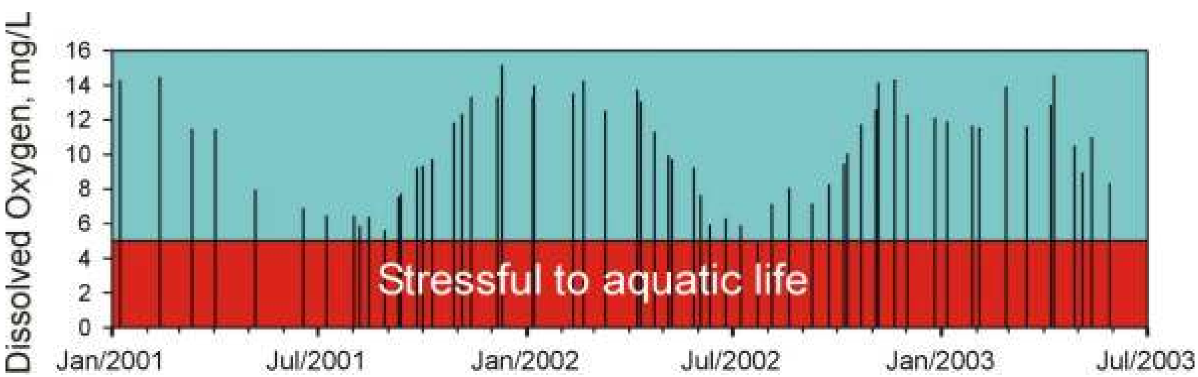
Cold water holds more oxygen than warm water. For example, pure water at 4°C (just above freezing) can hold about 13.2 mg/L dissolved oxygen at 100 percent saturation, while pure water at 250°C can hold only 8.4 mg/L at 100 percent saturation. Water with a high concentration of dissolved minerals cannot hold as much dissolved oxygen as pure water.

Dissolved Oxygen in the Red River

Dissolved oxygen is an essential element for the maintenance of healthy lakes and rivers. Most aquatic plants and animals need a certain amount of oxygen dissolved in water for survival. The atmosphere, algae and vascular aquatic plants are the sources of dissolved oxygen in lakes and rivers. The accumulation of organic wastes depletes dissolved oxygen.

Aquatic life is put under stress when the dissolved oxygen concentration falls below 5 mg/L (dark band on graph). If the dissolved oxygen concentration falls under 2 mg/L for just a few hours, large fish kills can result. Good fishing waters have a dissolved oxygen concentration around 9 mg/L.

As shown on the graph, dissolved oxygen concentrations in the Red River vary from highs of 15 mg/L in the winter (water temperature from 0.2° to 10°C) to summer lows of 7 mg/L (water temperature from 20° to 26°C). Human activity can also affect dissolved oxygen levels in the Red River. Summer increases in the amount of nutrients (phosphorus, nitrogen as ammonia, yard waste, nitrite and nitrate) from lawn and farm fertilizers in runoff, runoff from feedlots, stormwater and other discharges can result in the increased growth of plants and algae. Bacteria take up oxygen and reduce dissolved oxygen as they decompose this excess organic matter.



Graph of dissolved oxygen (mg/L) for the Red River in the F-M metro area for the period January 2001 to July 2003 in relation to the level of dissolved oxygen (less than 5 mg/L; dark band) stressful to aquatic life.

Fecal Bacteria

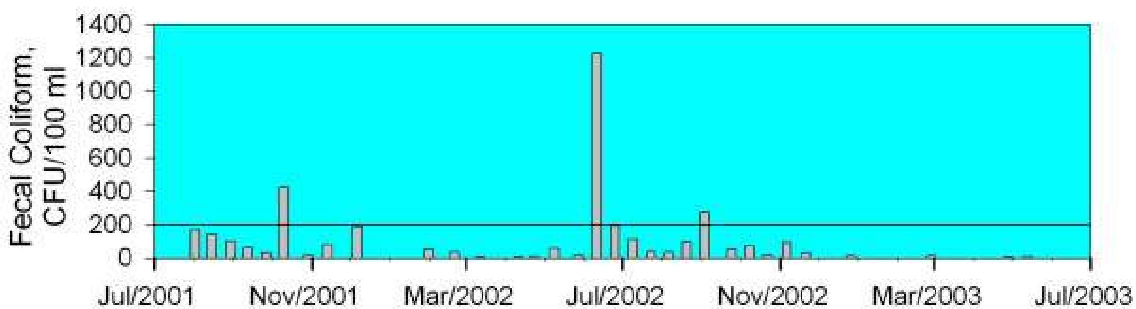
Members of two bacteria groups, coliforms and fecal streptococci, are used to test for contamination from sewage. These bacteria are called "fecal" indicators because they live in the intestinal track of humans and animals and are found in human and animal feces. The fecal indicators themselves are not harmful, but because they live in the same portion of the digestive system where disease-causing microorganisms occur, the presence of these fecal bacteria in a water sample indicates that water might contain microorganisms harmful to human health. Very high levels of fecal bacteria can give water a cloudy appearance, cause unpleasant odors and increase oxygen demand. Sources of fecal contamination to surface waters include wastewater treatment plants, on-site septic systems, domestic and wild animal manure, and storm runoff.

Measuring Fecal Bacteria

Fecal bacteria levels in water are determined by incubating a water sample for 24 hours and then counting the number of bacterial colonies that grew during that time. The unit for reporting fecal bacteria is "colony-producing units" per 100 milliliters of water (CPU/100 mL). CPUs/100 mL is used interchangeably with "organisms per 100 mL."

Fecal Bacteria in the Red River

The regulatory standard for fecal bacteria in the water varies by state and several fecal bacteria indicators can be used. In this region we use fecal coliform. The regulatory limit in North Dakota is 200 organisms/100 mL of water, which applies only during the recreational season, May 1 to September 30. The regulatory limit in Minnesota is also 200 organisms/100 mL of water. The level of fecal bacteria and other parameters in treated sewage that is discharged to the Red River is checked frequently. The monthly average for treated wastewater from the Fargo and Moorhead Wastewater Treatment Plants is usually less than 100 CPU/100 mL and in most winter months is less than 10 CPU/100 mL). Specific reaches of the Red River, including the F-M metropolitan area and some of its tributaries contain elevated levels of fecal coliform bacteria. State regulatory agencies are developing a water quality management plan to address and remedy these impairments. The target date for implementing this plan is 2004.



Graph of fecal bacteria levels (CPU/100 mL) for the Red River in the F-M metro area for the period July 2001 to July 2003 in relation to the regulatory limit for surface water of 200 CPU/100 mL (line) intended to protect human health.

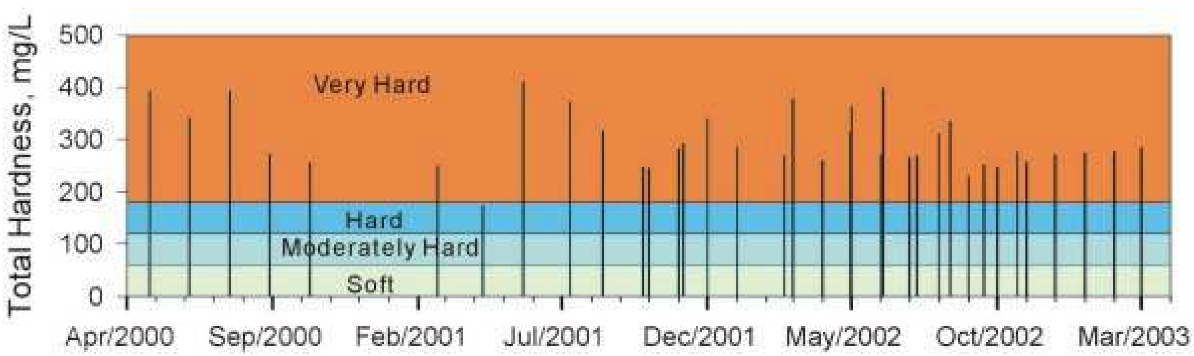
Hardness

Waters, that contain a significant concentration of dissolved minerals like calcium, magnesium, strontium, iron and manganese, are called "hard" because it takes a large amount of soap to produce a lather or foam with these waters. When hard waters are heated in water heaters, hot water pipes and boilers, for example, they leave a mineral deposit called "scale." Total hardness is expressed as mg/L of calcium carbonate because calcium and carbonate are the dominant ions in most hard waters. The following table gives the concentration of calcium carbonate dissolved in water by its degree of hardness.

Degree of Hardness	mg/l of $CaCO_3$
Soft	0-60
Moderately Nard	60-120
Hard	120-180
Very Hard	>180

Hardness in the Red River

Water in the Red River can be considered very hard. The graph shows the total hardness for the Red River in the F-M metropolitan area for the period of April 2000 to March 2003. Hardness over that period ranged from a low of 232 mg/L to a high of 411 mg/L. This would put the Red River water in the "very hard" category. Hardness does not present a health concern, but it is an important consideration for water treatment plant operators. At the local water treatment plants, the "very hard" water from the Red River is "softened" to the "moderately hard" level before it is made available to households, businesses and industries in the F-M area.



Graph of hardness (mg/L of calcium carbonate) for the Red River in the F-M metro areafor the period April 2000 to April 2003 in relation to the U.S. Geological Surveywater hardness categories.

Nitrite and Nitrate

Nitrite and nitrate are sources of nitrogen, an important nutrient for plants and algae. As ammonia is broken down by bacterial action, nitrite is formed and is then converted to the more stable, much less toxic, nitrate through a process called "nitrification." Nitrates are used in fertilizers and also occur in effluent discharges from wastewater treatment plants and runoff from animal feedlots.

Nitrates and Nitrites in Water

The typically low natural levels of nitrate in surface water can be supplemented with nitrate from human sources. Nitrate from the fertilizer not taken up by crops in fields and grass in lawns can enter waterbodies in runoff. Nitrate can also enter waterbodies from wastewater discharge or runoff from feedlots. Once in the water, nitrates can stimulate excessive plant and algae growth. Decomposition of the plant and algal material by bacteria can deplete dissolved oxygen, adversely impacting fish and other aquatic animals.

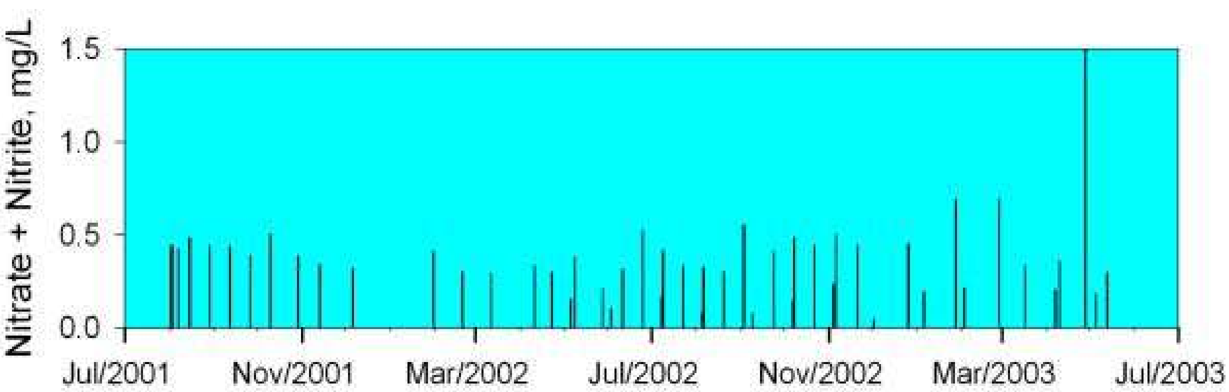
As early as 1940, it was recognized that consuming waters with high nitrate levels contributed to methemoglobinemia (“blue baby” syndrome). This condition, usually in infants, impairs the ability of blood to carry oxygen to the body. The U.S. Environmental Protection Agency National Primary Drinking Water Standards require that nitrate nitrogen not exceed 10 mg/L in public water supplies. Nitrite, much more toxic than nitrate, is regulated at a level not to exceed 1.0 mg/L in public water supplies.

Nitrites and Nitrates in the Red River

Nitrate is regulated to protect human health as well as aquatic environments. The Minnesota Pollution Control Agency uses the U.S. Environmental Protection Agency limits of 10 and 1.0 mg/L for nitrate and nitrite nitrogen, respectively, in drinking water supplies. The North Dakota Department of Health, on the other hand, has established what it intends as an interim guideline limit of 1.0 mg/L nitrate nitrogen. The North Dakota Department of Health is reserving the right to review this standard after additional study and to set specific limitations for constituents that cause excessive plant growth in surface water. The North Dakota Department of Health states that in no case shall the standard for nitrate nitrogen ever exceed 10 mg/L for any waters used as a municipal or domestic drinking water supply.

Trends

The graph below shows measured nitrite + nitrate concentrations expressed as nitrogen in the local stretch of the Red River from July 2001 through May 2003. Even with higher levels in the summer, attributed in part to runoff from fields and urban green spaces, the concentrations of nitrite and nitrate in the river water were below the federal regulatory limits set for public water supplies.



pH

The pH value of water, on a scale of 0 to 14, measures the concentration of hydrogen ions. The pH represents the balance between hydrogen ions and hydroxide ions in water. Solutions with more hydrogen than hydroxide ions have a pH value lower than 7 and are said to be acidic. Solutions with pH values higher than 7 have more hydroxide than hydrogen ions and are said to be basic, or alkaline. Pure distilled water is considered neutral, with a pH reading of 7. Water is basic if the pH is greater than 7; water with pH of less than 7 is considered acidic.

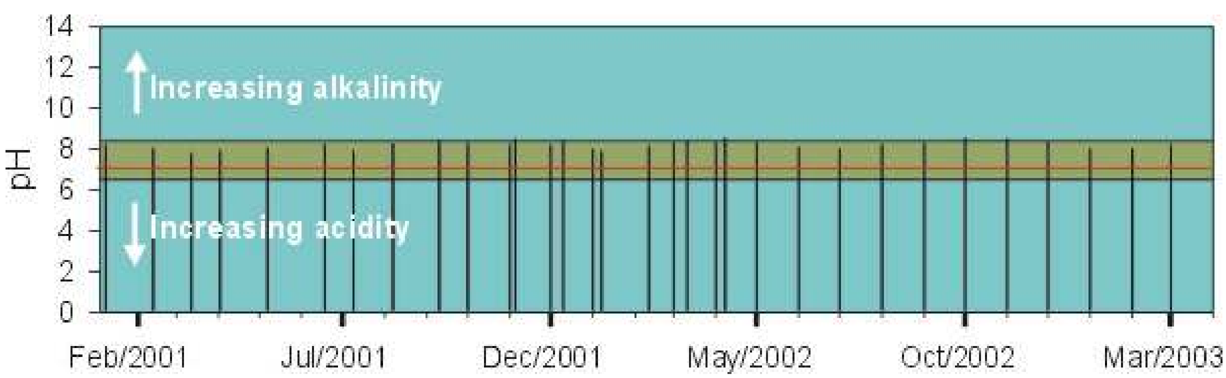
For every one unit change in pH there is approximately a ten-fold change in how acid or basic the sample is. This means that each step on the scale represents a ten-fold change in the hydrogen concentration. For example, water with a pH of 5 has ten times the number of hydrogen ions than water with a pH of 6 and is ten times more acidic.

pH and Water

Water with a pH of less than 4.8 or greater than 9.2 can be harmful to aquatic life. Most freshwater fish prefer water with a pH range between 6.5 and 8.4 (darker shaded band on the graph below). The pH is also a useful indicator of the chemical balance in water. A high or low pH will adversely affect the availability of certain chemicals or nutrients in the water for use by plants.

pH in the Red River

As seen in the graph below, the pH in the Red River at F-M is relatively constant year 'round within a narrow range between 7 and 9. The average pH of the Red River is around 8, or slightly basic. The slightly basic pH and the stability of the pH result from the alkalinity of the regional environment. The pH of municipal water in the F-M area is maintained at around 9.

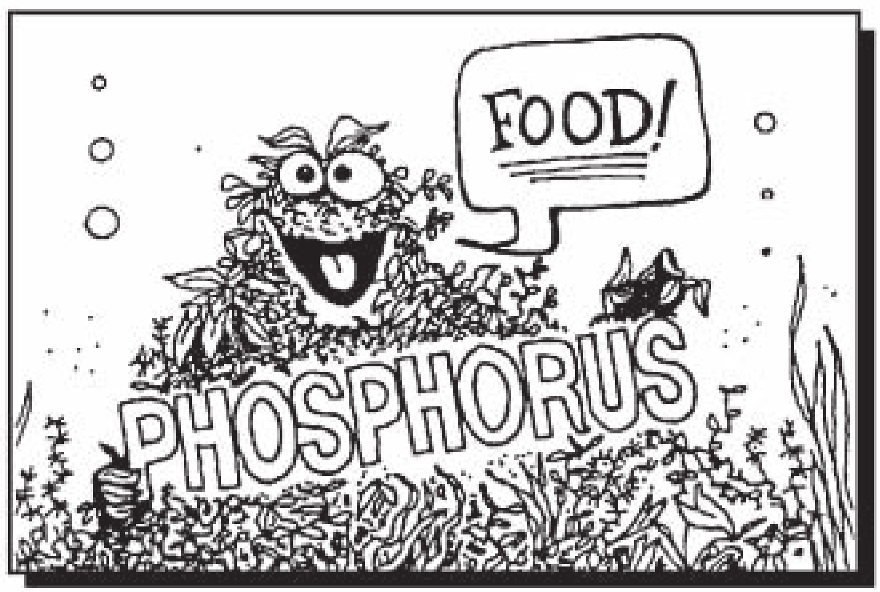


Graph of pH (relative acidity/alkalinity) for the Red River in the F-M metro area for the period January 2001 to April 2003 in relation to neutral pH (7) and the optimal pH conditions for fish (darker band).

Phosphorus

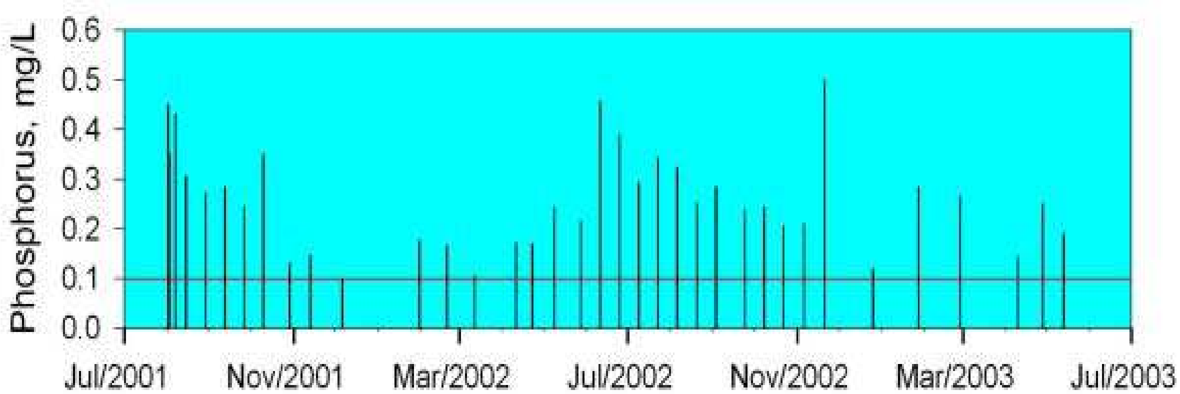
Phosphorus, like nitrogen (found in ammonia, nitrite, nitrate), is an important nutrient for plants and algae. Because phosphorus is in short supply in most fresh waters, even a modest increase in phosphorus can cause excessive growth of plants and algae that deplete dissolved oxygen during their growth and as they decompose. Algal blooms color the water a pea soup green and are a classic symptom of cultural eutrophication. Excessive growth can also reduce the transparency of the water. Much of the excess phosphorus available to plants in the environment comes from farm and lawn fertilizers, runoff containing soil-bound phosphate, yard waste, runoff from animal feedlots, stormwater and certain industrial wastewaters.

Total phosphorous includes organic phosphorous and inorganic phosphate. Organic phosphorous is a part of living plants and animals. It is attached to particulate organic matter composed of once-living plants and animals. Inorganic phosphates comprise the ions bonded to soil particles and phosphates present in laundry detergents.



Phosphorus in the Red River

The limits for phosphorus in water set by the North Dakota Department of Health and the Minnesota Pollution Control Agency are designed to prevent the excessive growth of aquatic plants and algae. The North Dakota Department of Health has established an interim guideline limit for phosphorus at 0.1 mg/L. The Minnesota Pollution Control Agency does not have a specific numeric limit for phosphorus, but addresses the issue as part of a comprehensive strategy for phosphorus control.



Graph of phosphorus (mg/L) for the Red River in the F-M metro area for the period July 2001 to December 2003 in relation to the North Dakota Department of Health standard of 1.0 mg/L (line) for surface waters intended to prevent excessive plant growth.

Trends

A graph illustrating phosphorus levels in the Red River in the F-M area is shown above. These levels are above the 0.1 mg/L interim guideline limit (line) set by the North Dakota Department of Health to protect the river environment. You can help reduce the phosphorus level in the Red River by properly applying fertilizer to lawns and gardens and proper disposal of yard waste.

Organic Matter

Living things, both plants and animals, are composed of organic substances that contain carbon. Organic carbon can occur in water in naturally-occurring organic matter including plant and animal detritus. Organic carbon can also occur as traces of lubricants, liquid fuels, fertilizers and pesticides. Biochemical oxygen demand and total organic carbon measure the level of organic carbon in wastewater and in natural waters.

Biochemical Oxygen Demand (BOD)

Biochemical oxygen demand is used to describe the potential of domestic and industry wastewaters to pollute surface waters. Biochemical oxygen demand measures the amount of oxygen consumed by living organisms (bacteria) in decomposing the organic portion of a waste. In the case of treated wastewater from the sewage treatment plants in the F-M area, the biochemical oxygen demand of the treated wastewater is used to determine the optimal rate of discharge that will ensure the health of the receiving body of water (Red River). The rate of discharge is particularly important to ensure adequate levels of dissolved oxygen.

Total Organic Carbon (TOC)

Total organic carbon is a measure of the organic matter in water in terms of the organic carbon content. Naturally-occurring organic material from decaying plants and animals contributes to the total organic carbon levels in rivers. Human sources of organic carbon can include petroleum products, pesticides and herbicides.

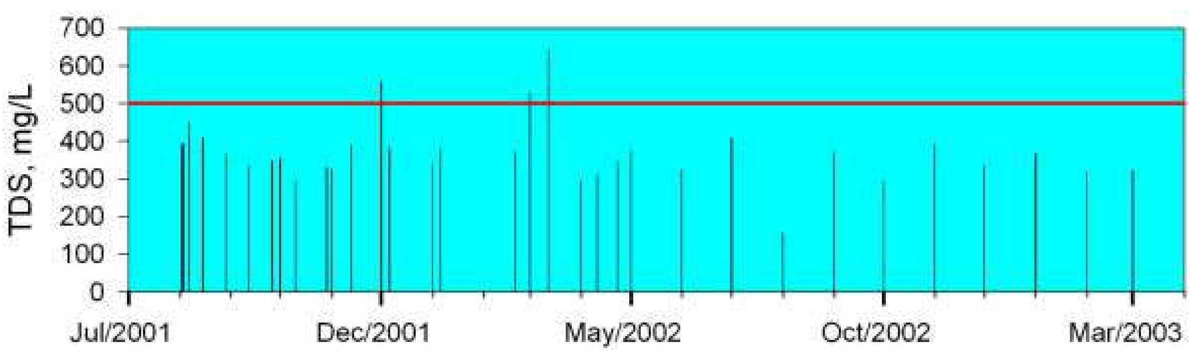
Total organic carbon itself is not regulated but is an important consideration for the operators of water treatment plants when they consider disinfection practices. When chlorine is used to disinfect water supplies, it reacts with total organic carbon to form chlorinated organic compounds that are collectively referred to as disinfection byproducts, which are cancer-causing compounds. The levels of these compounds in drinking water are regulated under the U.S. Environmental Protection Agency's National Primary Drinking Water Standards. These standards are presently under review and may become more stringent. As such, local water treatment plant operators continually evaluate alternative disinfection practices to ensure healthful drinking water for the F-M area.

Total Dissolved Solids (TDS)

Total dissolved solids is a measure of the total amount of all the materials that are dissolved in water. These materials, both natural and anthropogenic (made by humans) are mainly inorganic solids and a minor amount of organic material. Total dissolved solids can vary greatly from a few milligrams per liter to percent levels (tens of thousands of milligrams per liter), depending on the type of water. Seawater contains 3.5 percent (35,000 mg/L) total dissolved solids. The U.S. Environmental Protection Agency's Secondary Drinking Water Standards recommend that the total dissolved solids concentrations in drinking water not exceed 500 mg/L, based on taste and aesthetics.

Total Dissolved Solids in the Red River

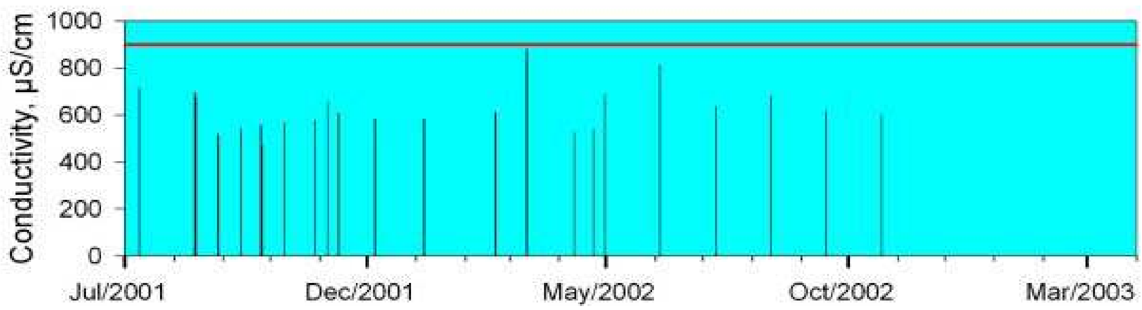
Total dissolved solids levels in the Red River in the F-M area are shown in the graph below. While the Red River tends to carry a high suspended-solids loading, as evidenced by turbidity and the water is considered relatively hard, the dissolved solids content is below the U.S. Environmental Protection Agency's 500 mg/L guideline (line on graph) even before entering the local water treatment plants.



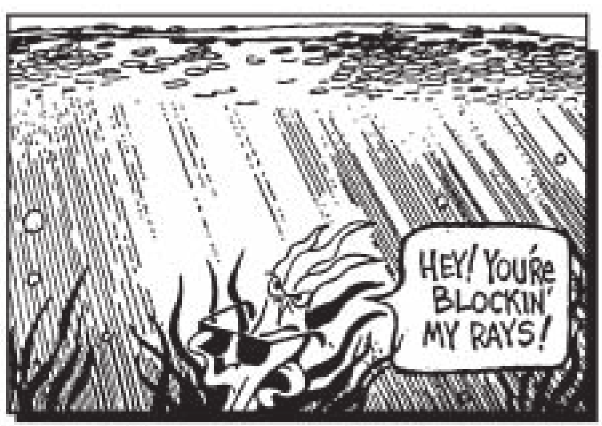
Graph of total dissolved solids (mg/L) for the Red River in the F-M metro area for the period July 2001 to March 2003 in relation to the U.S. Environmental Protection Agency guideline (500 mg/L; line) for drinking water.

Electrical Conductivity

The electrical conductivity of water is directly related to the concentration of dissolved solids in the water. Dissolved ions in water influence the ability of that water to conduct an electrical current, which can be measured using a handheld conductivity meter. When correlated with laboratory total dissolved solids measurements, electrical conductivity can provide an accurate estimate of the total dissolved solids concentration. As illustrated in the plot below, conductivity measurements for the Red River correlate very closely to the total dissolved solids determinations shown in the previous graph. Water in the Red River is usually below the 900 microsiemens/cm (line on graph) set by the National Secondary Water Standards of the U.S. Environmental Protection Agency even before entering the local water treatment plants.



Graph of electrical conductivity (S/cm) for the Red River in the F-M metro area for the period July 2001 to April 2003 in relation to the Environmental Protection Agency guideline (900 S/cm; red line) for drinking water.



Total Suspended Solids (TSS)

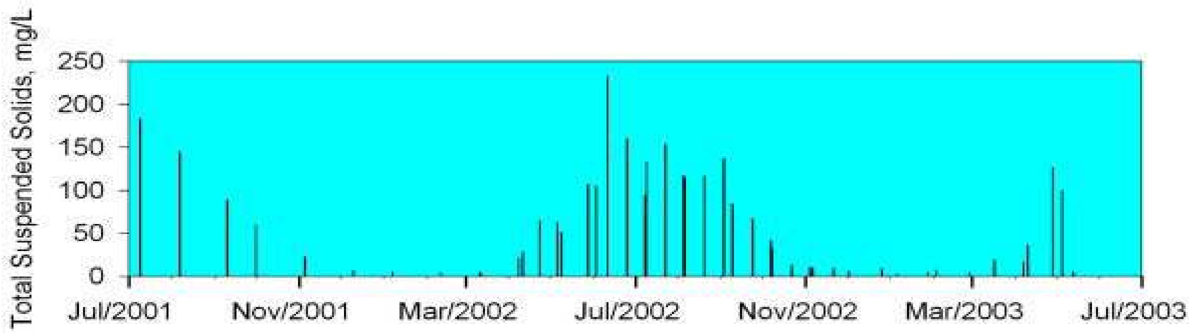
"The volume of particles that float in a sample of water is called total suspended solids. To remain permanently suspended in water (or suspended for a long period of time), particles have to be light in weight (they must have a relatively low density or specific gravity), be relatively small in size and/or have a surface area that is large in relation to their weight (have a shape like a sheet of paper). The greater the total suspended solids in the water, the higher its turbidity and the lower its transparency (clarity).

Measuring Total Suspended Solids

The volume of total suspended solids can be estimated from measurements of turbidity or transparency, but an accurate total suspended solids measurement involves carefully weighing the amount of suspended material from a water sample. To accomplish this, a sample of water is first run through a filter. The filter and the material trapped on the filter are dried in an oven. The dried material is then weighed and the weight of the total suspended solids is determined by subtracting the weight of the filter. Total suspended solids is reported in milligrams per liter (mg/L; weight of the suspended solids per volume of water).

Total Suspended Solids in the Red River

Total suspended solids is relatively high for the mainstream Red River and the lower reaches of its tributaries, reflecting the muddy soils in the central Red River Valley. In the F-M area, total suspended solids varies seasonally, with highs in summer (greater than 100 mg/L). This reflects the influx of sediment from runoff and bank erosion. In the winter, when the ground is frozen and precipitation is stored in snow, the total suspended solids level drops to nearly zero.



Graph of total suspended solids (mg/L) for the Red River in the F-M metro area for the period July 2001 to July 2003.

Transparency

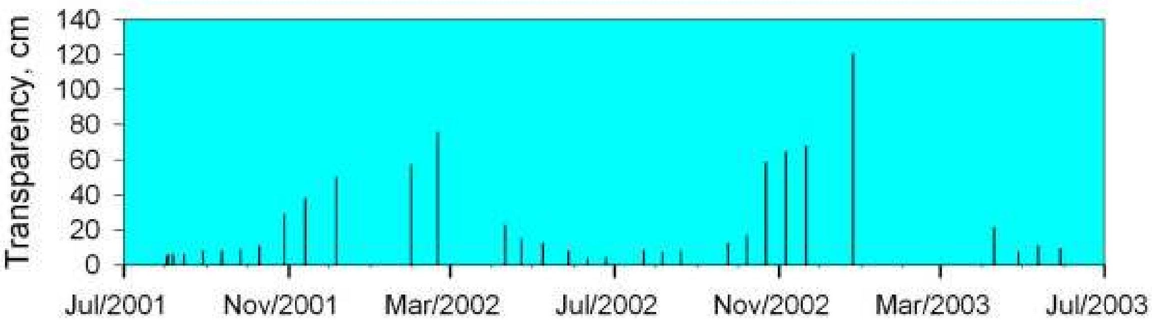
Transparency (sometimes called clarity), like turbidity, is a measure of how far light can travel in water. Although the suspended particles that influence the turbidity reading can include organic particles (microbes, algae and plant particles and animal detritus) as well as inorganic particles (silt and clay particles), the transparency of the Red River water is usually a measure of the relative concentration of the inorganic particles that account for most of the total suspended solids. The fewer particles that occur suspended in a sample of water, the easier it is for light to travel and the higher the water's transparency, or clarity.

Measuring Transparency

Transparency is measured using a Secchi disk or a transparency tube (a plastic tube with a Secchi disk pattern at its base). Transparency is the distance (in centimeters) through the water from which a person can clearly see the pattern on a Secchi disk. The transparency can be given as centimeters of depth (Secchi disk) or height (transparency tube). The lower the concentration of suspended particles (or dissolved materials like dark-colored humic acids, common in peat bog water), the greater the distance light can penetrate through the column of water and the greater the transparency.

Transparency in the Red River

Transparency varies seasonally in the Red River. In the winter, when the ground is frozen, precipitation is stored in the snowpack and runoff and erosion are very low, the transparency increases (from 20 to more than 80 centimeters, or from 8 to more than 32 inches). During the summer, however, the suspended particles carried into the river by runoff and bank erosion reduce transparency to less than 20 centimeters (about 8 inches) and as low as 5 centimeters (2 inches).



Graph of transparency (cm) for the Red River in the F-M metro area for the period July 2001 to April 2003.

Turbidity

Turbidity, like transparency, is a measure of water clarity (how far light can travel through water). The more particles suspended in a sample of water, the more difficult it is for light to travel through it and the higher the water's turbidity or murkiness. Although the suspended particles that reduce clarity can include organic particles (microbes, algae and plant particles and animal detritus) as well as inorganic particles (silt and clay particles), turbidity in the Red River is usually a measure of the inorganic particles that account for most of the total suspended solids.

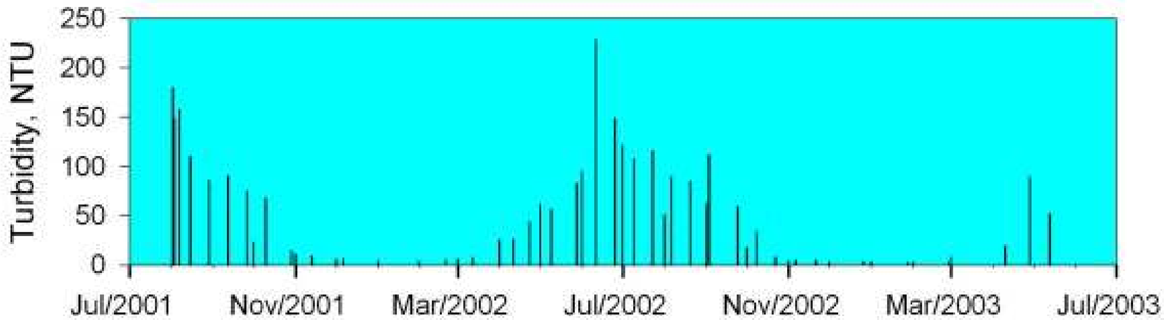
Oxygen levels decrease in turbid waters as they become warmer as the result of heat absorption from the sunlight by the suspended particles and with decreased light penetration resulting in decreased photosynthesis. Suspended solids can clog fish gills, reduce growth rates and disease resistance and prevent egg and larval development. Settled particles can accumulate and smother fish eggs and aquatic insects on the river bottom, suffocate newly-hatched insect larvae and make river bottom microhabitats unsuitable for mayfly nymphs, stonefly nymphs, caddisfly larvae and other aquatic insects.

Measuring Turbidity

Turbidity is measured by an instrument called a nephelometer and is reported in nephelometric units (NTUs). The nephelometer, also called a turbidimeter, has a photocell similar to the ones used in cameras to indicate when the "flash" is needed. The water sample is placed in a column in the instrument and the photocell reads the intensity of a beam of light showing through the water column. The lower the intensity of the light that reaches the photocell, the higher the NTUs and the cloudier, or more turbid, the water. High levels of total suspended solids or the presence of dark-colored humic acids from the decay of vegetation, common in the water of peat bogs, would result in a high turbidity reading.

Turbidity in the Red River

Turbidity varies seasonally for the Red River. In the winter, when the soil is frozen, precipitation is stored in the snowpack and runoff and erosion are very low, the turbidity is low (less than 10 NTUs). During the summer, the soil and plant particles entering the river from runoff and bank erosion result in high turbidity (above 60 NTUs), with the highest levels in July and August (over 100 NTUs). The local water treatment plants bring the turbidity level down to meet the U.S. Environmental Protection Agency National Primary Drinking Water Standards (turbidity in local municipal water is usually less than 1 NTU).



Graph of turbidity (NTU) for the Red River in the F-M metro area for the period July 2001 to April 2003.

Water Temperature

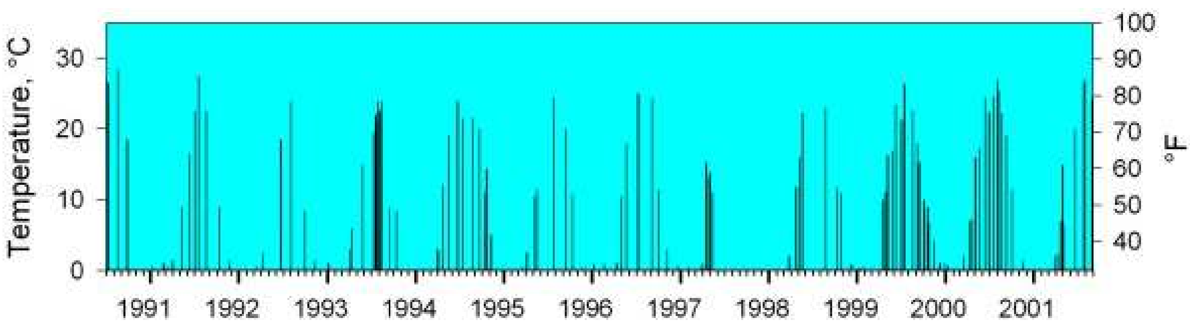
Many of the physical, biological and chemical characteristics of surface water are dependent on temperature. Temperature is measured in degrees Fahrenheit (180° between the freezing and boiling point of water) or degrees Celsius (100° between the freezing and boiling point of water).

The optimal health of aquatic organisms from microbes to fish depends on temperature. If temperatures are outside the optimal range for a prolonged period, organisms are stressed and can die. For fish, the reproductive stage (including spawning and embryo development) is the most temperature-sensitive period. Macroinvertebrates (for example, insects, crayfish, worms, clams and snails) will move in the stream bed to find their optimal temperature.

The temperature of the water also affects the volume of dissolved oxygen it can hold (water's ability to contain dissolved oxygen decreases as water temperature rises), the rate of photosynthesis by aquatic plants, metabolic rates of aquatic organisms and the sensitivity of organisms to pollution. Water temperature is affected by the seasons and can also be affected by weather, removal of shading stream bank vegetation, building dams on rivers, discharging cooling water, discharging stormwater and groundwater influx.

Water Temperature in the Red River

As shown on the graph, the water temperature in the Red River varies seasonally from just above freezing (0°C or 32°F) in the winter to over 25°C (over 77°F) in the summer. Among other things, this seasonal change in river water temperature causes seasonal changes in the level of dissolved oxygen and in the level of ammonia gas in the Red River.



Graph of water temperature (°C) for the Red River in the F-M metro area for the period July 1990 to July 2001.

Developing and Implementing a Monitoring Project

Before beginning a monitoring project, a plan should be developed. Answering the questions below and writing down the answers will help assure that the data collected is useful.

The framework for creating an information system for monitoring is listed below. These steps are presented linear 1 through 15, but in reality, it does not function from beginning to end, in fact most groups "enter" the framework in the middle somewhere. A great place to start is with an evaluation of where you are at by reviewing each of the steps below and asking what has been accomplished in this area, is it documented and what needs to be worked on? Finally, prioritize and strategize on the "need to work on" list. Revisit previous steps several times to update and tweak them in order to move forward.

Step 1: Inventory

What do you know?

What do you know, what do you want to know and what do you need to know? Develop watershed vision and management goals. This step can be overwhelming at the end with lots of information, issues and concerns raised. It does not mean you will be dealing with everything you discover.

- Do you have a basic description of your watershed? For example geology, topography, physiographic regions, ecological zones, major urban areas, general hydrology, groundwater, precipitation and climate.
- What do you know about the waters you are interested in? How many rivers, tributaries, lakes, ponds, wetlands, etc. are there and where are they? Who owns them or operates them? Do you have maps that you can delineate each watershed (sub watersheds), municipalities, communities, and land uses? Do you know the land use types, land ownership, historic uses of water and land, cultural values and areas, and areas of special value? Which waterbodies are your interest or responsibility?
- What is the status of the waters you are interested in? Status can be defined by political boundaries, jurisdictions, legislation, regulation, communities, assessments, reports, your own experience and values.
- What do you know about your fishery (or riparian zone or water quality, replace this with what you are focused on)? Historic species list, life histories, community composition, fluctuations, eradication, stocking, native versus non-native, exotic or nuisance, economic value versus not valued, species threatened or endangered, physical habitat requirements, etc.

- Who are the potential decision makers and influential key targets in the watershed related to your waterbody and focus? Who should be involved with this and who might you need to collaborate with? What is your relationship with these individuals or groups? What data is available, who has it, where and what format is it in? What are the data gaps?

What do you want to know?

- What are the most pressing threats and issues facing your water of interest, local, regional and national? What do you want your watershed, fishery, etc. to look like? Vision and brainstorm here, be specific and write it down. What are the key areas to preserve, reclaim, focus on, etc? What might be the important ecological, political, social, economic functions that you are trying to preserve, may need to utilize, change or focus on in some manner? What might benchmarks be for the watershed vision (ecological, political, social and economic)?

- The big task now is to translate all the above into watershed management goals and objectives. If it helps make a huge list or broad vision, then narrow it down here to what you can do as an organization and/or what you can do in the next one to five years. Whatever you document it has to be real to you. If you have trouble following the next informational steps, it might mean you need to focus more specifically and/or strategically. Document the watershed management goals.

What do you need to know?

- Now you have watershed management goals and broad objectives. What do you need to know to achieve this? Who has the data or information, where is it, what format is it in, are there gaps in data, time, space, or quality? Who is actively acquiring data in the Basin, what is your relationship with them and how might you work with them? Who should be at the table that is not and how might you involve them?
- Who are the key decision makers, managers and other influential people related to your watershed goals? What type of decisions does each of them make, how and when? What type of information do they need and where does it come from? How do these information needs relate to your watershed goals? What is your relationship with them?

Organize, document and summarize all the information in this step. It will be useful later.

[redacted]

Step 2: Relevance

Identifying what piece of the watershed goals and vision your organization chooses to influence. At this point your organization needs to have a documented mission and goals. This step helps narrow the focus in a strategic manner for further design steps. Identifying what resources your organization currently has, will need and how you might plan for the future in this regard.

- Does your organization have a current supported mission, mandates, goals and objectives? If not, these need to be formulated, documented and if appropriate adopted. If these are developed explore the question of how does the watershed vision and goals relate to these organization mission and goals?
- What are some possible management objectives that might result from the common ground? Formulate and document.
- If these management objectives were to be achieved, what might be accomplished within a year, two, five and ten years?
- What resources are available to address this work today and in the future? If there is a deficit, strategize and document a plan to simultaneously obtain sufficient resources.
- Who do we need to include from an organizational perspective, internally and externally? What is our relationship with them? What might we do to collaborate and partner? Do we need to re-evaluate organizational goals?

Who will use the monitoring data?

Each user will have different data needs. It is important to have at least one user committed to receiving and using the data. Potential data users could include:

- Local, county, state or federal water quality analysts
- Fisheries and aquatic biologists
- Universities, school teachers, and students
- Environmental organizations
- Parks and recreation staff
- Planning and zoning agencies
- State and local health departments
- Watershed and soil and water conservation districts
- Volunteers

How will the data be used?

Knowing the ultimate uses of the collected data will help determine the right kind of data to collect and the level of effort required to collect, analyze, store and report the data. Potential uses could include the support of:

- Local zoning requirements
- A stream protection study
- State preparation of water quality assessments
- Residents educated about the importance of water resources

[redacted]

Step 3: Create and Document Information Blueprint

Step 3 is where you discover and document, in relation to your watershed vision and goals, management objectives and/or organizational goals, what decision or action do you want to happen as a result of your monitoring or campaigning, who makes those decisions, what are their information needs (what do they need, when and how). This is the power-mapping step. This step provides the inexplicable link of monitoring data to information to a decision and decision maker. We suggest producing and documenting an information blueprint that provides a road map from data to action. The steps to make an information blueprint were described in the power mapping section.

In a campaign effort, Step 3 involves identifying those who can bring about desired decisions, what information they will need to make them, which target audience to employ in campaigning, what the components of the message should be, and how the campaigning objectives will produce that information. This is what becomes the information blueprint. You build your monitoring or campaign components around decision makers' needs in addition to other organizational needs. For a campaign this would include identifying target audiences that may or may not be the ultimate decision maker.

Once this step has been completed, go back and recalibrate the products from Steps 1 and 2, if necessary, based upon information discovered in this step.

SAMPLE INFORMATIONAL BLUEPRINT

GOAL	ACTION
Management goal:	Monitor current water quality for trends
Monitoring objective:	Establish current quality
Definition of water quality:	Water quality variables of dissolved oxygen, zinc and pesticides (used as indicators by Health Department, my decision maker)
Analyses, statistics, criteria, assessment, etc.:	Water quality seasonal Kendall t-test hypothesize upward trend, all dissolved values within aquatic life requirements for all life stages. Dissolved zinc below brown trout toxicity values, pesticide A, Z and D not measured.
Monitoring system product:	Conclusions regarding statistical significance of water quality trends (hypothesized upward trend) at all sites for dissolved oxygen, zinc and pesticides A, Z and D not present.
Reporting to management:	Management goal is met when establish water quality trend slope to determine next steps.

[redacted]

Step 4: Why monitor?

In creating specific monitoring objectives, consider the specific questions related to water monitoring that you want answered. There might be more than one per management objective. In many cases, the management objective and monitoring objective are very similar, if you are very specific. This is the step that establishes the benchmarks and relevance for the informational blueprint. This step focuses on what data and information need to be produced in order to make the desired decision, which is driven by the informational needs of the decision makers.

Whether the result of a simple brainstorming session, or whether your monitoring objectives become very well-defined goals, consider the inclusion of such items as:

1. Key conditions
2. Key processes (natural/political)
3. Key locations
4. Key indicators
5. Benchmarks/reference locations
6. Criteria, metrics
7. Data inventory and gaps
8. Resources

Typical reasons for initiating a volunteer monitoring project include:

- Developing baseline data
- Documenting water quality changes over time
- Screening for potential water quality problems
- Providing information for watershed assessment
- Educating the local community about river ecology
- Building awareness about the Red River
- Providing a hands-on learning experience
- Developing stewardship in young people
- Describing status and trends
- Describing and ranking existing and emerging problems
- Designing management and regulatory programs
- Evaluating program effectiveness
- Responding to emergencies

You may not be able to conduct all the possible monitoring desired. You will need to go backward here, check in with the previous steps and calibrate accordingly. If you document what you decided not to do and why, as well as what you decide to do and why, it will assist with determining the next steps—evaluation and credibility. This can be useful for others who might consider using this information. You will want to document what specific data objectives you have and why will these objectives be able to answer the related question(s).

[redacted]

STEP 5: What Will Be Monitored?

In this step you select what variables and indicators you will monitor for in order to answer your monitoring data objectives. Some of questions you might consider include variables:

1. For stresses, exposure and/or response?
2. In chemistry, physical and biological?
3. In the water column, substrate, instream habitat, riparian zone, groundwater, etc.?

You will be choosing variables to monitor that will serve as the “indicators” for your data for the conclusion, interpretation, assessment and, ultimately, the information to be used to make the decision or take action. It is important the most sensitive, representative and accurate indicators possible are chosen.

Indicators are measurable features that provide evidence of the magnitude of stress, the degree of exposure to stress, or the degree of ecological response to the exposure or habitat quality. If you don’t choose the right indicator you will not answer your question and be able to make a very good decision.

What parameters to monitor will depend on the monitoring goals and, hence, needs of the data user, the intended use of the data and the resources of the volunteer program. Money for meters and lab facilities and the ability and desires of volunteers will also clearly have an impact on the choice of parameters to be monitored. See Summary of Water Quality Indicators that explains what they measure and what they mean for the river.

There are many ways to categorize potential indicators. Below is one example:

1. Biological (response and exposure)

- Macroinvertebrates
- Fish
- Wildlife (aquatic, riparian, terrestrial, avian)
- Pathogens and fecal indicator bacteria
- Plankton (phytoplankton and zooplankton)
- Periphyton
- Aquatic and semi-aquatic macrophytes
- Habitat characteristics

2. Chemical (response and exposure)

- Dissolved gases like oxygen and carbon dioxide
- Major ions, alkalinity, sulfate, calcium, magnesium
- Conductivity, pH, dissolved or total solids
- Nutrients, like nitrogen, phosphorus, chloride, fluoride
- Odor and taste, potentially hazardous chemicals (in the water, bottom or attached to sediment and algae)

3. Physical Habitat

4. Water Column and Channel

- Water quantity
- Water temperature
- Water clarity
- Suspended sediment
- Bed sediment and bottom characteristics
- Geomorphology (channel characteristics)
- Habitat (type and distribution)
- Riparian or shoreline characteristics
- Habitat (types, fragmentation, linkages)
- Groundwater (springs and seeps)
- Land (geology, soils, topography)
- Vegetation (type and diversity)

5. Watershed-Level Stress

- Land cover and vegetation

- Application of chemicals and wastes
- Airborne contaminants
- Assimilative capacity
- Channel or flow modifications
- Ecoregional characteristics

6. Ecosystem Integrity
- Habitat quality
- Aquatic life use support
- Indices of biotic integrity
- Species at risk
- Wetland acreage

7. Public Health
- Occurrence of disease
- Exposure to disease-causing agents
- Failing or at risk drinking water systems
- Protected water sources
- Fish consumption advisories
- Closed shellfish waters

8. Human Land and Water Use
- Drinking water uses supported
- Fish and shellfish consumption supported
- Recreation use supported
- Total water consumption
- Land use patterns

9. Economic (affected by ecological condition)
- Property values
- Fish and shellfish harvest levels
- Impacts of nuisance plant and animal species
- Reservoir capacity

Scientific considerations when considering indicators include:
- Will this indicator help you answer your data objectives?
- Can you measure or quantify it?
- Does it respond over a reasonable time period?
- Does it respond to the impacts you are evaluating? What is the sensitivity?
- Can you isolate the conditions that cause fluctuation in your indicator?
- Does it integrate over time and space?
- Does it respond to changes in other indicators?
- Is it a true measure of the condition you're assessing?
- Is there a reference condition?
- Does it provide early warning of changes?

Programmatic considerations to include in indicator selection are:

- Do you have the resources to measure it?
- How difficult is it to measure?
- Does it help you understand a major part of the ecosystem?
- Is it explainable to your target audience?

Once you determine what indicators and variables you decide will answer your monitoring questions, check that these indicators and variables align with the information needs of the decision makers, the monitoring objectives, management goals, and watershed vision and goals.

Step 5 Product: *List of variables and indicators that will be employed for monitoring, including variables with multi-metrics and indexes.*

STEP 6: When Will Monitoring Occur?

To get as close to the truth or accurate understanding as possible, you want the chosen time when you sample to capture the most representative information. To achieve this, you should consider items like the frequency and duration of sampling, the time of year and or day, key weather or hydrologic events and other conditions or information needs. This determination will be a function of each indicator, geographic and temporal scale, proposed statistics and or other analyses, interpretation or assessment methods. There are four strategies to increase representativeness on when and where to sample. They include:

- Targeted: identify impaired waters, certain populations
- Probabilistic: representative "index sites"
- Stratified: homogenous classes
- Rotating Watersheds: intensive but infrequent

Refer to the goals of the project. Physical and visual site assessment should be conducted at least two to three times per year. In general, monthly chemical sampling and semi-annual visual surveys are adequate. Monitoring at the same time of day and at regular intervals will help ensure comparability of data over time. To help determine when to sample, consider how water quality changes in the following ways:

Daily changes: Samples taken at different times of the day may yield different results. Changes in stream flow, air temperature, shading and the photosynthetic activity of aquatic plants may affect chemical properties of water.

Seasonal changes

- Nutrient levels may vary seasonally with changes in the abundance of aquatic plants (plants use up nutrients in the water).
- Spring runoff may increase nutrient levels, stream flow and turbidity.
- Macroinvertebrate populations also vary in abundance and types across seasons. You'll find the greatest diversity in the spring and fall and easier collecting in the fall (when water levels are low).
- Sample once each season to see how water quality changes over the course of the year.

Special events

- High runoff events, such as spring snowmelt, may offer different results than other times of the year. Look for lower pH levels and higher turbidity.
- If you wish to monitor the effects of human actions on water quality, monitor before, during and after the action. For example, if your class is interested in the effects of a construction project on turbidity in a nearby stream, measure turbidity in the stream before, during and after the project.

[redacted]

STEP 7: How Will You Monitor?

This is the step where you determine how you will obtain data for the indicators. Will you obtain it by observational monitoring, field measurements, laboratory analyses or reviewing existing data sets? If conducting any collection and analysis, what methods, procedures, guidance, manuals and equipment should you employ? Will the method produce sensitive, comparable, reproducible and representative data? All of these decisions should be identical to or compatible with those the decision maker employs for collection and analyses (if the decision maker is not you). The choices will vary by indicator, variable, sample type, monitoring objective and information needs of decision maker. The easiest or cheapest method may not produce the data or information you desire.

Always ask the question: Will our chosen methods to collect and analyze the data align with the information needs of the decision maker, our data objectives and our organizational goals?

What methods should be used?

The methods adopted by a volunteer program depend primarily on how the data will be used and what kind of data quality is needed. While sophisticated methods usually yield more accurate and precise data, they are also more costly and time-consuming. Considerations include:

- How samples will be collected (grabbing samples or measuring with a meter)
- What sampling equipment will be used (disposable Whirl-pak bags, glass bottles)
- What equipment preparation methods are necessary (container sterilization or equipment calibration)
- What protocols will be followed
- Who will train the volunteers
- Who will analyze the samples
- How will samples be transported to the lab
- How much sample should be collected

[redacted]

STEP 8: Where Will You Monitor?

Where to monitor becomes a function of geographic and temporal scale, indicators, analyses, interpretation and assessment plans which all should be driven by the information needs of the decision makers. As with when to sample, some strategies include targeted, random or a combination of either.

There are several types of sites to consider, they include:

- Watershed reference
- Pollution source control, impact and recovery
- Aquatic life habitat (fish and benthic macroinvertebrates)
- Public health
- Political, historical, cultural, and economic water uses
- Tributary impacts: Consider reference, impact, recovery, integrator, dilutor and recruitment

Where are the monitoring sites?

Sites might be chosen for many reasons such as accessibility, proximity to volunteers' homes, value to potential users, or location in problem areas. To provide baseline data, monitor a number of sites representing a range of conditions in the stream. To compare quality of volunteer-generated data with professional data, monitor a professionally monitored site.

To help determine sites, ask the following questions:

- Where are other groups monitoring?
- Can you identify sites on a map and on the ground?
- Is it representative of a reach of the watershed?
- Does the site have water in it during the time of year that monitoring will take place?
- Is there safe, convenient access to the site?
- Is there access all year long?
- Can landowner permission be acquired?
- Have enough sites been selected for the study?
- How much time will it take to get to the site and back to the lab?

Step 8 Product: *Generate a list of sampling locations and why they are appropriate to answer monitoring objectives, management objectives, and informational needs of decision makers.*

STEP 9: What are Your Data Quality Assurances and Control Objectives?

In this step you are answering the question, "How good does my data need to be to be useful, to answer my questions, to make the decision or take the desired action?" It provides credibility to the data. Quality assurance and control objectives should be established for individual samples as well as the entire information system. It should be documented for both sample collection and analyses. It includes qualitative (numeric) and quantitative (narrative) descriptions of how good the data is in order to meet the data objectives.

Some examples of numeric and narrative descriptions include:

1. Representative
2. Completeness
3. Comparability
4. Reproducibility
5. Detection limits
6. Measurement range
7. Precision
8. Accuracy

Some components to consider in your quality assurance and control plan include documentation of the plan, laboratory facilities, equipment and supplies, data management of data and reporting of results. Data quality measures should include internal and external, evaluation of results, response actions, training, manuals and guidance documents used. The minimum description, components and measures should be those that are identical, compatible or comparable to those information needs of the decision maker(s).

How will the quality of data be assured?

The heart of a solid monitoring program is its quality assurance. All monitoring programs should have a quality assurance project plan. This plan will help the user of the data be confident that the collected data meets their needs and assures credibility and usefulness of the data. Data collected through River Watch's participating locations has been used by the State of Minnesota in preparing its biennial report to the U.S. Congress on the health of Minnesota's water resources.

In natural systems such as streams, lakes, estuaries and wetlands, variability is a fact of life. Changes in temperature, flow, sunlight and many other factors affect these systems and the animals that inhabit them. Variability also occurs when we attempt to monitor such systems. Each of us reads, measures and interprets differently. We may also apply different levels of efforts in how we monitor. The equipment we use may be contaminated, broken or incorrectly calibrated. These, and many other differences, can lead to variability in monitoring results. Measures of precision, accuracy, representativeness, completeness, comparability and sensitivity help us evaluate sources of variability and error and thereby increase confidence in our data.

A Quality Assurance Project Plan demonstrates that the data gathered through your program is:

- Consistent over time, within projects and group members;
- Collected and analyzed using standardized and acceptable techniques; and
- Comparable to data collected in other assessments using the same methods.

Establish a small team to serve as advisors in development of a Quality Assurance Project Plan by offering feedback and guidance throughout the project. The team could be made up of trained professionals with experience in analytical chemistry or field biology, such as the Minnesota Pollution Control Agency, Minnesota Department of Natural Resources, U.S. Fish and Wildlife Service, or the faculty of a local college or university.

Developing specific answers to the above questions is the first step to ensuring that the data are credible. Credible data meet specific needs and can be used with confidence for those needs. Other steps include:

- Train, test and retrain volunteers
- Evaluate the project's success and make any necessary adjustments
- Assign specific quality assurance tasks to qualified individuals
- Document, in a written plan, all the steps taken to sample, analyze, store, manage and present data

Step 9 Product: *A quality assurance and control plan for each sample type and variable, field and laboratory. Include guidance documents and manuals and link to informational needs of decision makers and monitoring objectives.*

STEP 10: Data Analyses Plans

When determining the information needs of the decision makers you must include how each decision maker will make his or her own decision. How will they summarize, analyze, interpret and make conclusions or assessments with the data in order to make a decision or recommendation? All of these needs of the decision maker should be researched and included. Chosen analyses plans should emulate or be compatible with those of the decision makers.

The type of data analysis will also be a function of:

- Each indicator
- Space versus time
- Indicators' correlation with other variables
- Chosen criteria, reference, history
- Statistics
- Modeling (predictive or representative)

In the design of a monitoring system, one should include who will be conducting the data analysis, interpretation and assessment. This not only provides credibility but opportunities for others to participate. This is the nucleus of how the data will be "translated" into information. For example, through interpretation the data might be compared to the quantified expected condition, such as a reference condition, a criteria or historic data. Through this comparison you will make some assessment about your waterbody, such as it is impaired and requires restoration, such as it is healthy and requires protection, or such as the reclamation processes were successful or failed. The product of data analysis, interpretation and assessment then is potentially observations, findings, conclusions and recommendations. This is all information to move forward toward the decision.

When you have completed designing the data analyses necessary for the decision maker you should check in and ask 1) will this analysis plan answer the monitoring objective questions, 2) if the data collected will be credible for the decision maker and decision? 3) do we need to recalibrate any of the previous steps due to discoveries here?

Where will samples be analyzed?

Use maximum sample storage times to decide whether to analyze all the indicators in the field or do a combination of some in the field and some in the lab. Options include:

- Professional at a local water treatment plant or certified private laboratory
- Volunteers analyze the samples in a lab
- Volunteers analyze in the field by using meters

[redacted]

STEP 11: Data Management Needs

Once the information needs of the decision maker have been defined and the associated data summary, analysis, interpretation and assessment needs you have the details to determine data management needs in order to analyze the data. When considering data management needs, include all the needs for all data types (water column, sediment, physical habitat, biological) and indicators. Consider at this point decision maker and organization reporting needs but also data accessibility and retrievability needs. If you can identify all these needs at this point, you can select the best set of tools to manage the data such as hard and software.

Within data management, considerations should include:

- How data entry will occur
- Validation of that data, and
- How will you manage missing data points, detection limits, zero values, meta-data (data that describes the data such as who collected it and site location), data generated through quality control and assurance and data that has values such as “too numerous to count”.

Documentation of data management steps and processes are essential for credibility, accountability, trouble shooting, evaluation and reproducibility.

[redacted]

STEP 12: Reporting and Utilizating Information

Think about how the information the monitoring data produces will be used by the decision maker and your organization. It probably won't be in a raw or summarized form alone. Most decision makers use a "report" or "form" format to gather all the information for a certain decision. How does the decision maker need or request the monitoring results that support the decision be reported? What information in the report might you need to include you have not? Are there any other organizational needs to include in reporting? With any report used, what is the type of report, format, frequency of production or review, target audience and evaluation of report? Have you considered the reporting needs in the data management design (will the data be in ready form for report needs)?

Are there other organizational needs to report the data independent of the decision maker, such as for a funder or for constituency-like members? If so, what might that reporting look like? Some examples might include fact sheets, alerts, flyers, posters, slide presentations, videos, web sites, public announcements, meetings or forums.

Some common missing element in the design process include an evaluation of reporting. It is important to consider whether the report presents the information in such a way as to assist in the decision-making process. Reporting requires adequate resources. Be sure to allocate resources for report creation, dissemination and evaluation.

Most formats for information utilization include data summaries such as tables and graphs. Tables and graphs should stand alone or be able to be understood without additional text. Make sure tables are readable and logical to follow. Include clear column and row headings with a title at the top and include parameter units. Graphs should tell a story about the data. Make sure graphs have clear titles, labeled axes, elements that illustrate a clear point or allow the reader to discover the point, a legend if appropriate, reporting units and minimal clutter.

How will the data be managed and presented?

There should be a clear plan for how to deal with the data collected each year.

- Who will check datasheets for completeness?
- Who will enter the data into a database?
- Who will manipulate the data and generate reports to data users?
- How will the data be presented?

[redacted]

STEP 13: Who Will Do What?

This is an often overlooked or taken-for-granted step. In order for a monitoring design to operate as an information system, all tasks need to be assigned to someone and communicated to everyone who is doing what. A house would never be built if this did not occur. It is also important to document these roles and responsibilities to "formalize" the system structure and function.

You will want to designate coordinators or leaders. You may want to consider using committees for such things as technical support. Regardless, designate and document the assignment of tasks. For each person, communicate the level of responsibility, level of authority and communication structure (who reports what to whom)? Finally, share this with everyone within the monitoring system and as externally appropriate.

Some examples of monitoring design tasks:

1. Find laboratory(s)
2. Purchase equipment
3. Recruit/organize volunteers/staff
4. Train field and lab personnel
5. Monitoring (access, safety, travel, etc.)
6. Quality assurance
7. Data management
8. Analyses
9. Reporting
10. Presentation
11. Evaluation

Some examples of coordinator positions:

1. Program coordinator
2. Trainer
3. Lab coordinator
4. Quality assurance officer
5. Volunteer coordinator
6. Data management
7. Technical committee

Some examples of roles and responsibilities for a technical committee:

- Role: Advise project staff on technical aspects of monitoring design system
- Responsibilities:
- Decide on data use goals and data quality objectives to address monitoring objectives and information goals
- Develop monitoring questions
- Review comment on monitoring design system
- Recommend, review and comment on quality assurance and quality control
- Assist staff with technical problems
- Review training manuals and documentation
- Assist staff in data analysis
- Review comment on reports
- Commit “X” time and attend “Y” meetings

What is the role of the volunteer in the field?

Each person on the team has a unique role. Consider the following points:

- Volunteer should clearly understand their role before reaching the field.
- Volunteers should be held accountable for completing their tasks
- Give volunteers a choice in the role they assume. This is a great planning exercise and further increases motivation for the program.
- Have volunteers switch roles on subsequent visits

[redacted]

STEP 14: System Documentation

This is never an urgent priority but so essential for long-term success. Document the monitoring design system overall as well as all the individual components. Documentation is crucial for future studies regarding duplication, replication and review. By stating what you ARE doing, you are stating what you are NOT doing as well. If the design is documented, there is an opportunity for peer review, which opens the door for others to participate (e.g. the decision makers, stakeholders, etc.) and may help establish credibility. Be sure to update the plan with the occurrence of significant changes. This “documentation” provides the basis for accountability, credibility and evaluation. It also will serve to preserve the institutional knowledge of your organization or program.

[redacted]

STEP 15: Evaluation

Evaluate the monitoring design success in answering the questions asked or monitoring objectives and in achieving the desired decision or action, the management goal. Then evaluate this in context with moving forward on the watershed vision and goals.

If you don’t ask, how will you ever know if your monitoring work produced the information necessary to make the desired decision? What steps in the design need to be modified? Perhaps none do, but perhaps more data is necessary. The documentation completed and updated in Step 14 will be of great value in this step.

Plan and conduct formal and informal evaluation(s) at determined system points and frequencies to evaluate information product (produced by monitoring system or informational system).

[redacted]

How Does the Design Function in Reality?

In an ideal situation, if every step was defined and documented before any monitoring was conducted, we would have an information system that by design provides reproducibility, accountability, credibility and the basis for evaluation. Ultimately this design also produces the best possible information to make the desired decision. We want to strive to be information rich, not data rich and information poor. Start with an evaluation of your own monitoring efforts.

How might this work if I have several monitoring objectives and programs going on at once? You might have one large watershed goal that has many monitoring objectives or management objectives that may or may not include monitoring. Each monitoring objective will have its own 15-step design and documentation in order to explicably connect the monitoring results to a specific decision.

When monitoring your 15-step informational systems, strive for connectivity and document such instances. Picture an axle of a car. You want each wheel on that axle, pretend there can be many, to be connected via that axle. They all may have their own objectives but what do they have in common, how are they connected? If not connected by design, document that also. What you don't want is a graveyard of tires, each representing a monitoring effort that might produce information, but will only be so effective because it is not connected to a larger watershed goal or vision. It is easy to become fragmented but it reduces your effectiveness.

Summary of 15-Step Design and Intended Results

Step 1:
Inventory

Overall umbrella watershed vision and goals, lots of information about your watershed, an assessment of information gaps in different areas, a knowledge of who is doing what now and a general idea of who makes what kind of decisions.

Step 2:
Relevance

All management objectives for watershed vision and goals articulated in as "desired" decisions, potential priorities and time frames, resources outlay and list of potential partners and strategies for collaboration.

Step 3:
Power Mapping and Informational Blueprint

Decision making tree, information needs of decision maker and informational blueprint.

Step 4:
Why Monitor?

All monitoring objectives and which ones you decide to attempt and what you determine you cannot attempt and why.

Step 5:
What to Monitor?

List of variables and indicators that will be employed for monitoring, including variables with multi-metrics and indexes.

Step 6:
When to Monitor?

Documentation of when sampling for each variable that aligns with information needs of decision maker, monitoring and management objectives and watershed goals.

Step 7:
How to Monitor?

Description and list of how data monitoring objectives will be met and why appropriate for monitoring objectives.

Step 8:
Where to Monitor?

A list of sampling locations and why appropriate to answer monitoring objectives, management objectives and informational needs of the decision makers.

Step 9 :
Quality Assurance and Control

A quality assurance and control plan for each sample type and variable, field and laboratory. Include guidance documents and manuals and link to information needs of decision makers and monitoring objectives.

Step 10:
Data Analysis Plans

Data analysis plan, including all data summary, statistic, analysis, interpretation and assessment tools, methods, etc. and why these will answer the monitoring objectives.

Step 11 :
Data Management Plans

Data management plans, including hardware and software, validation, storage, and how this plan will provide the tool for data summary, analysis, interpretation, and assessment for the monitoring objectives, the decision makers and decision.

Step 12:
Data Utilization Reporting

How monitoring data results will be reported, to whom, when, in whatformat, how reported and by whom. The decision makers' needs are explicit here.

Step 13:
Who Will Do All This?

A description of who will be responsible for all monitoring design steps, including reporting, evaluation, corrective action and the communication structure.

Step 14:
Documentation

Develop the sample plan, the informational system, and the informational blueprint.

Step 15:
Evaluation

Written performance evaluation with observations, conclusions and recommendations regarding the effectiveness of the monitoring design to produce the intended information for an identified decision and decision makers.

Training

Training should be an essential component of any volunteer stream monitoring program.

Some of the key elements in training volunteers are:

- **Plan Ahead:** Consider who will do the training? When and where will the training be held? What equipment will be used? What handouts would be useful? What is the goal of the training?

- **Put it in Writing:** Note the training specifics in the Quality Assurance Project. Write a job description.

- **Be Prepared:** The elements of a successful training session include:
  - Enthusiastic, knowledgeable trainers
  - Short presentations with effective visual aids that encourage participation
  - Presentations that explain why monitoring is needed, what the program hopes to accomplish and what will be done with the data
  - Hands-on opportunities to practice sampling
  - Refreshments and opportunities to network and have fun
  - Time for questions and answers

- **Conduct Quality Control Checks:** Schedule opportunities to ensure that volunteers are monitoring and using proper and consistent protocols.

- **Evaluate Trainings:** Encourage volunteers to complete a training and a program evaluation form.

Water Quality Monitoring Procedures

Field Safety

- Have an adult supervisor accompany each separate group with six youth or less per adult.
- Keep a good line of communication between groups at all times (e.g., stay within hearing distance).
- Have a first aid kit available and know how to use the contents.
- Know any important medical conditions of team members, such as which students are allergic to bee stings.
- Know the causes and early warning signs of hypothermia and heat exhaustion.
- Listen to weather reports. Never sample if there is severe weather.
- Develop a safety plan. Find out the location and telephone number of the nearest telephone. Locate the nearest medical center and know how to get there.
- If you drive, park in a safe location. Be sure your car doesn't pose a hazard to other drivers and that you don't block traffic.
- Put your wallet and keys in a safe place.
- Be aware of your own physical limitations and the difficulty of collecting water at certain locations under certain conditions.
- Be aware of steep, slippery banks. Holes, vertical banks and other hazards can be especially difficult to see when the banks are very heavily vegetated.
- If sampling from a bridge, be wary of passing traffic and do not lean over bridge rails.
- Scout the area for dangerous trash such as broken glass, rusted wire or metal scraps. Flag areas to avoid, if necessary.
- Scout the area for poison ivy, poison oak and stinging nettles. Make sure everyone in the group can identify these plants.
- Moving water is deceptively dangerous. Don't let students enter water over their knees or water that is moving very fast (more than 1 foot per second).

- If you suspect your stream is seriously polluted, contact your local County Health Department or local Division of Water Quality office to determine if your stream is safe for student monitoring.

- Never sample during a lightning storm and beware of sudden storms higher in the watershed which could produce flash floods.

- Do not enter the stream without proper clothing (waders, or good wading shoes and a change of clothing).

- Never enter water if enough adult team members are not present.

Sampling Method Requirements

The way a sample is collected can have a tremendous influence on the data results. All samples should be collected in exactly the same way, so that results can be accurately compared. Sample in the main current by wading, from a boat, or standing on shore or a bridge. Avoid sampling surface water or stagnant water.

Wading:

- Approach the site from downstream, stand facing upstream.
- Do not disturb the bottom sediment.
- Remove cap from bottle just before sampling. Do not touch inside of the bottle or cap.
- Hold the bottle near its base and plunge it (with the opening downward) below the water surface. Hold it 8 to 12 inches beneath the surface or midway between the surface and bottom if the water is shallow.
- Fill the bottle by turning it into the current.
- Empty the bottle downstream and repeat three times. If acid preservative is in the bottle already, rinsing is not an option.
- Fill the bottle, leaving one inch of air space to allow for shaking or mixing before analysis – except for dissolved oxygen and biochemical oxygen demand samples

From bridge:

- Stand mid-stream and place weight on sampler.
- Lower samplers and rinse three times.
- Lower sampler to 60 percent depth of water column.

Water quality samples will be collected using a Kemmerer or Beta-bottle sampler. Depending on the analyte being monitored, clean glass or polyethylene containers of varying capacities will be used as sample containers for delivery to the analytical laboratory and will generally be rinsed three times with source water prior to the actual sampling (review laboratory's protocols for each parameter).

(**Note**: The following also applies to hand dipped samples from wading.) Sample bottles will be labeled with bottle number, site identification, date and time, and packed in ice at the sampling location. A chain-of-custody record including project name, sampler's signature, unique field station identification sample numbers, parameters for analysis, matrix, number and size of containers, date/time and appropriate signatures will accompany all samples.

One field quality control water sample set for laboratory analyses, including a field blank for each sample type (unpreserved and H_2SO_4 preserved) and a grab sample duplicate, will be collected for every set of sites sampled following the grab sample collection protocol. The field blanks will be used to determine whether sampling procedures introduce contaminants in the field. Field duplicates for laboratory analyses will also be collected to determine whether duplicate grab samples produce consistent results.

4. Insure that the conductivity probe is completely submerged in standard. The hole in the side of the probe must be under the surface of the solution and not have any trapped bubbles in the opening.

5. If the sonde should report **"Out Of Range"**, investigate the cause. Never override a calibration error message without fully understanding the cause. Typical causes for error messages are incorrect entries, for example, entering 1000 microsiemens instead of 1.0 millisiemens (note: the sonde requires the input in millisiemens). Low fluid level and/or air bubbles in the probe bore are other error causes.

6. When the calibration has been accepted check the conductivity cell constant which can be found in the sondes **"Advanced Menu"** under **"Cal Constants"**. The acceptable range is 5.0 +/- 0.45. Numbers outside of this range usually indicate a problem in the calibration process or a contaminated standard was used.