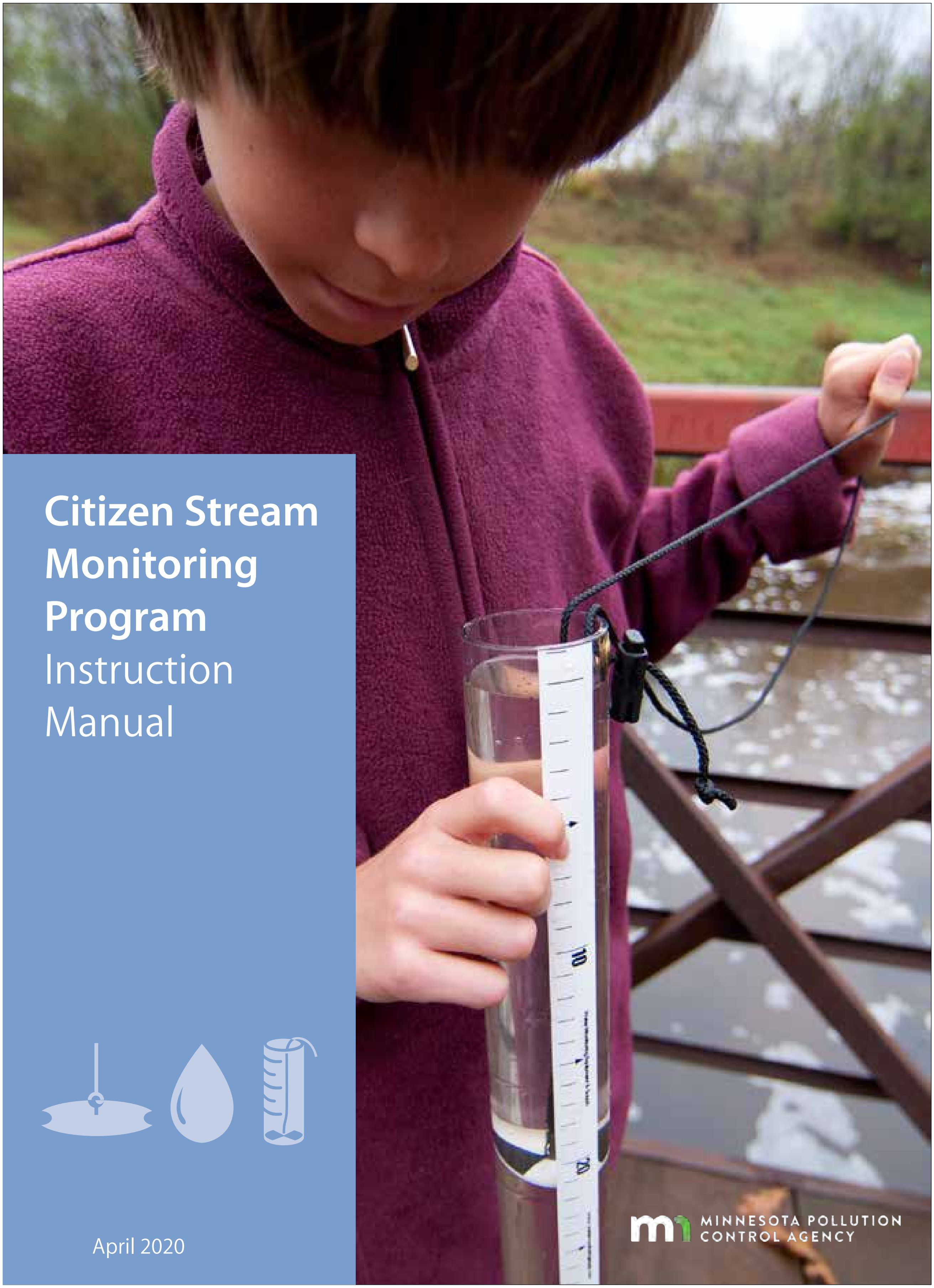

Citizen Stream Monitoring Program
Instruction Manual

April 2020

MINNESOTA POLLUTION CONTROL AGENCY

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This report is available in alternative formats upon request, and online at www.pca.state.mn.us.

Document number: wq-csm1-05

Contents

Photograph courtesy of Steven Howey
CSMP volunteer on the Yellow Medicine River
Lyon County

"Whether by snowshoe in winter or a hike in the spring, with canoe paddle, fly rod, or shotgun in the fall -- to those who would listen, the river valley is a magic music box. To those who would observe, the pattern of color and movement paint a picture that is a masterwork resulting from millions of years of nature's efforts, yet dynamic and ephemeral. Minnesota is rich with stream and river resources, that beyond economic utility make up our living environment, delight our senses, and indeed, form and mold our culture."

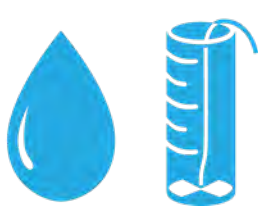
Tom Waters,
The Streams and Rivers of Minnesota

Introduction

Volunteer water monitoring has played an important role in the Minnesota landscape since the 1970's. In many cases volunteer monitors provide the only source of information available on the health of our state's streams and rivers. The Minnesota Pollution Control Agency's (MPCA) Citizen Stream Monitoring Program (CSMP) began in 1998 with the goal of giving individuals across Minnesota an opportunity for involvement in a simple, yet meaningful stream monitoring program. This manual describes how CSMP fits into the MPCA's monitoring strategy, and gives detailed instructions for selecting a monitoring site location, conducting CSMP sampling, and submitting data to the agency. The last section, entitled "How Rivers Run", consists of excerpts from the Department of Natural Resource's *"Healthy Rivers: A Water Course"*, which provide valuable information on river ecology.

For further instruction on the CSMP, please refer to the Citizen Water Monitoring training videos at: https://www.pca.state.mn.us/cmp/training-videos. For Information on designing and implementing a monitoring program in your community, please request a hard copy of the *"Volunteer Surface Water Monitoring Guide" by contacting* the MPCA at 651-296-3600 (Twin Cities Metro Area) or 1-800-657-3864 (Greater Minnesota).

CSMP staff hope that you, the volunteer, find this manual helpful as you monitor and protect your local river.



CSMP background

The CSMP uses a collaborative approach to stream monitoring by partnering with citizen volunteers who live on or near a stream, and are interested in water quality. Any person or group willing to devote a small amount of time and energy to conduct simple stream visits on a regular basis can participate in the CSMP. Volunteers receive a Secchi tube, data sheets, and instructions for taking measurements.

Once enrolled, participants visit an established spot once per week from April to September on a nearby stream to measure stream transparency, water level (stage), appearance, and recreational suitability.

Volunteers are also encouraged to monitor immediately after large rainfall events when possible to track the effects of rainfall runoff on their stream.

What is a Secchi tube?

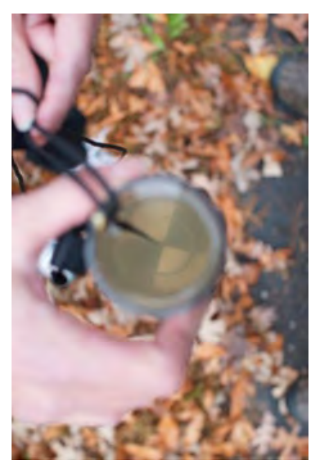
Figure 1. Secchi tube

The original transparency tube, developed in Australia for measuring stream water clarity, is a clear plastic tube that is 1 meter long x 1-3/4-inch wide. The Secchi tube is a modified transparency tube that is designed to function like the traditional Secchi disk used in lake monitoring. To measure water clarity, the tube is filled with water collected from a stream or river. Looking down into the tube, a weighted Secchi disk is lowered into the tube by a line, allowing the user to raise and lower the disk within the same water sample numerous times. To obtain a Secchi tube reading, the depth of the water at the midpoint between disappearance and reappearance of the disk is recorded in centimeters, which are marked on the side of the tube. If the symbol is visible when the tube is full, the transparency reading is “>100 centimeters.” A greater transparency reading reflects higher water clarity.

What does the Secchi tube measure?

Stream transparency is an indirect measure of the amount of *dissolved* and *suspended* materials present in water. For most bodies of water, the amount of solids suspended in the water is the most important factor: the more suspended materials, the lower the water transparency. In lakes, the majority of suspended solids are algae. In streams and rivers, soil particles (predominantly silts and clays) have a stronger influence on transparency as water flows downstream, carrying and depositing this sediment. A good example of dissolved material affecting transparency is the tea color caused by organic material of some northern, bog-influenced lakes and streams.

Tracking water transparency is like monitoring your blood pressure because it tells us about the health of a stream. Changes in transparency tell us when key water pollutants are present. In general, a low transparency reading reflects a large amount of sediment (excessive soil material) or other suspended material like algae in the water. Too much sediment in the water is a significant pollutant itself, whether it is suspended in the water column or deposited on stream bottoms (Figure 2).



Suspended sediment reduces light penetration needed for the growth of beneficial aquatic plants. It also interferes with the ability of fish to see and capture their prey.

A stream bottom is described as ”embedded” when smaller rocks such as gravel and cobble are surrounded or buried in clay, fine silt or sand. When a stream bottom is embedded, fewer fish and aquatic insects are able to survive. Less diverse assemblages of fish and insect species are also found in embedded streams. When a stream bottom is embedded from deposited sediment that has washed downstream, fish eggs become smothered, keeping them from getting the oxygen needed to survive. Deposited sediment also clogs spaces between rocks where insects like to live

(Waters 1995). Reduced insect habitat from excess sediment leads to fewer species of fish that depend on insects for food.

Finally, sediment may have pollutants attached to it, such as phosphorus and petroleum products. These pollutants degrade the quality of flowing water, as well as downstream lakes or reservoirs.

Sediment is measured directly through concentrations of Total Suspended Solids (TSS) or estimated from Secchi tube measurements. Because of these effects of excess sediment on streams, the MPCA sets limits on the discharge of suspended solids to waters. As part of the MPCA's requirement to report to the U.S. Environmental Protection Agency on the condition of Minnesota's lakes and streams, measurements of TSS in milligrams per liter (mg/L) are compared to Minnesota's water quality limits, or standards, for TSS. If a certain number of TSS measurements exceed the water quality standard, then the stream is listed as impaired.

By establishing a scientifically based link between transparency and TSS, more streams can be assessed for TSS standard compliance using citizen help. Transparency values, as measured by Secchi tubes (S-tube), reliably predict TSS and can serve as surrogates. While TSS measurements themselves are generally preferred, datasets for S-tube are often more robust, and their relative strength are considered in assessments.

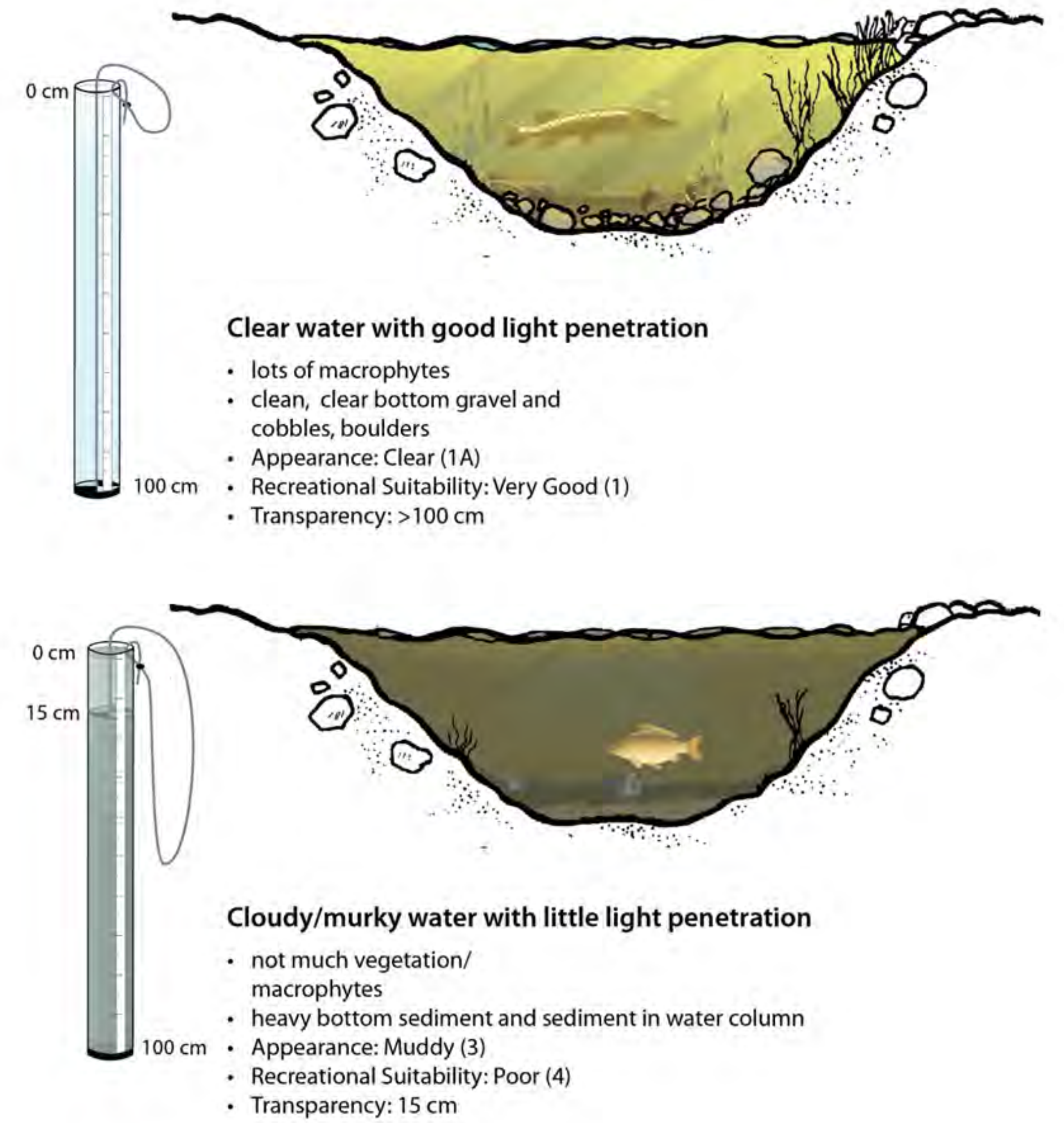
Because S-tube measurements are not perfect surrogates, however, their use involves a margin of safety. Therefore, the S-tube surrogate thresholds for determining if a stream exceeds the TSS standard are different than for determining if a stream meets the standard.

Minnesota's TSS (mg/L), S-tube (cm) and site-specific standards for specifically named river reaches.

Region or River	TSS	S-tube Exceeds	S-tube Meets
All Class 2A Waters	10	55	95
Northern River Nutrient Region as Modified for TSS	15	40	55
Central River Nutrient Region as Modified for TSS	30	25	35
Southern River Nutrient Region as Modified for TSS	65	10	15
Red River Mainstem – Headwaters to Border	100	5	10
(Assessment season for above waters is April through September)			
Lower Mississippi River Mainstem – Pools 2 through 4	32		
Lower Mississippi River Mainstem below Lake Pepin	30		
(Assessment season for Lower Mississippi is June through September)			

Details regarding RNR boundaries and assignments as adapted for application of the Minnesota TSS water quality standards can be found in Heiskary and Parson (2013) at https://www.pca.state.mn.us/sites/default/files/wq-s6-18.pdf

Figure 2. Measuring stream clarity with a Secchi tube



A stream is considered to exceed the standard for TSS/S-tube if 1) the standard is exceeded more than 10% of the days of the assessment season (April through September) as determined from a data set that gives an unbiased representation of conditions over the assessment season, and 2) there are at least three such measurements exceeding the standard. The Lower Mississippi River is considered to exceed the standard for TSS if summer (June through September) average concentrations exceed the standard in more than half of the summers.

S-tube measurements that fall between the two relevant surrogate values are considered to be indeterminate in exceeding or meeting the TSS standard. If a stream satisfies neither the criterion for exceeding the standard nor the criterion for meeting the standard, the stream is considered to have insufficient information regarding TSS levels.

CSMP's role in MPCA monitoring strategy

Minnesota has an abundance of water resources – more surface waters than any other of the 48 contiguous states. Minnesota's $10 billion-a-year tourism industry is based on its water resources, and water is important to a healthy agricultural and business economy. At the same time, the sheer abundance of waters results in greater challenges in monitoring, preventing degradation and restoring polluted waters. The MPCA and its partner organizations currently conduct a variety of water monitoring activities to provide information to assess – and ultimately to restore or protect – the integrity of Minnesota's waters.

The MPCA categorizes its environmental monitoring efforts by the purpose for the monitoring and how the information is assessed and used. In general, water monitoring efforts can be grouped into three "use" categories as follows:

- *Condition monitoring:* This type of monitoring is used to identify overall environmental status and trends by examining the condition of individual waterbodies in terms of their ability to meet established standards and criteria. Condition monitoring may include chemical, physical or biological measures. The focus of condition monitoring is on understanding the status of the resource, identifying changes over time, and identifying and defining problems at the overall system level. Examples include routine surface water monitoring, basin monitoring, Total Maximum Daily Load (TMDL) listing activities, and the ambient ground water network.
- *Problem Investigation Monitoring:* This monitoring involves investigating specific problems or protection concerns to allow for the development of a management approach to protect or improve the resource. Problem investigation monitoring is used to determine the specific causes of impairments to water or ground water and to quantify inputs/loads from various sources. It is also used to determine the actions needed to return a resource to a condition that meets standards or goals. Examples include Clean Water Partnership and Section 319 projects, TMDL development, site assessment, and investigation of specific ground water issues, such as pesticides.
- *Effectiveness Monitoring:* This is used to determine the effectiveness of specific regulatory or voluntary management actions taken to remediate contaminated water. Effectiveness monitoring allows for the evaluation and refinement of the management approach to ensure it is ultimately successful. Examples include implementation monitoring for TMDLs, CWPs and 319 projects, and monitoring associated with a particular best management practice. Another example of effectiveness monitoring is effluent monitoring done to assess the compliance of a facility with a permit, rule or statute (i.e. compliance tracking) and to provide information on the effect of regulatory actions on inputs to water bodies (not the effects on the waterbody itself).

The MPCA's guiding water monitoring strategy is organized around these three monitoring types. CSMP monitoring is a main component of the MPCA's Stream Condition Monitoring strategy, which consists of the following four data collection components:

1. MPCA stream and lake monitoring.
2. Stream and lake data collected by other organizations.
3. Remote sensing (aerial photos and satellite imagery).
4. Citizen monitoring – Citizen Stream and Citizen Lake Monitoring Programs.

Each of these components contributes important data to the system that results in both geographic coverage and data confidence. Citizen monitoring is a cost effective way to gather data on a large number of water bodies annually. The easy to use and low cost Secchi tubes, used as the core tool of the CSMP, have a high correlation with total suspended sediment and turbidity in streams. The four components of the monitoring strategy rely on each other mutually to provide the "complete monitoring picture." Detailed data collection by the MPCA and other organizations will provide the scientific rigor to ensure confidence in the data collected. Citizen monitoring and remote sensing will provide the geographic coverage and monitoring frequency needed to ensure appropriate targeting and priority-setting. CSMP monitoring is an important part of a larger process employed by the MPCA and its partners for restoring and protecting water quality across Minnesota. More information on this MPCA "Watershed approach to restoring and protecting water quality" is available at: https://www.pca.state.mn.us/water/watershed-approach-restoring-and-protecting-water-quality

Water quality status and CSMP monitoring

The following was excerpted from the Minnesota Department of Natural Resources' (DNR) **Healthy Rivers** compact disk (CD). Copyright (2004) DNR reprinted with permission. The framework for controlling the discharge of pollutants into streams and other waterways was set by the federal Clean Water Act (CWA), passed in 1972 as amendments to the federal Water Pollution Control Act.

The CWA authorized the U.S. Environmental Protection Agency to set up pollution control programs. These programs established and enforced quality standards for contaminants in surface waters, regulated discharges according to those standards, and required comprehensive water quality monitoring.

The CWA banned the discharge of pollutants into navigable waters from a point source without a permit. The Act also funded the construction of sewage treatment plants. The overall goal: restoring and maintaining the chemical, physical, and biological integrity of the nation's waters.

Early on, federal, state, and tribal governments emphasized the control of point sources, such as industrial discharges and municipal sewage treatment effluent. As those sources of pollution were controlled, regulators turned to the more difficult task of controlling nonpoint sources, such as street and farmland runoff. Likewise, regulators at first concentrated on the chemical aspects of clean water. Recently, attention has shifted to physical and biological measures of water quality.

Reduction in pollutant loads were achieved through use of the following key tools that originated from the CWA:

- Section 319 to address nonpoint sources, such as farmland and forestry runoff, through planning, assessment and grants.
- Section 404 to regulate dredging or filling of wetlands and other waterways.

- Section 401 to require federal agencies to obtain certification from the state, territory, or Indian tribes before issuing permits that would result in increased pollutant loads to a water body.
- State revolving funds for loans to control municipal point and nonpoint pollution sources.
- The development of a TMDL for impaired waters. TMDLs determine what level of pollutant load would be consistent with meeting water quality standards.
- Section 402, National Pollutant Discharge Elimination System (NPDES) permit program to control point sources. Discharge of stormwater from municipalities and construction sites is included in this program.

The MPCA is required to provide a report to Congress every two years on the status of Minnesota lake and river water quality. CSMP transparency data is used for this report, to assess the quality of rivers in terms of sediment. Although the CWA has been a major success in addressing point source pollution in aquatic systems, nonpoint sources remain our biggest challenge. Because of their diffuse nature, financial disincentives, and lack of regulatory authority, solving nonpoint source pollution will require the combined efforts of each of our individual choices and actions.

Citizen Stream-Monitoring Program instructions

Safety

The first priority of stream monitoring is your safety. Always adhere to the following safety points when monitoring:

- Before monitoring, let someone know your itinerary, where you are going and when you'll be back. Then if you have trouble, another person knows where to start looking for you.
- Whenever possible, take along someone else when you monitor.
- If the weather is dangerous, don't go out to do stream monitoring.
- If you wade in a stream to take measurements, never enter fast-moving water or areas of unknown depth. If there is any question about your safety, record visual observations only from a secure location (Appearance, Recreational Suitability, and Estimated Stream stage). As a general rule, if stream depth (in feet) multiplied by its velocity (feet/second) is greater than your height (in feet), then DO NOT WADE:

  (Stream Depth) [ft.] x Stream Velocity [ft./sec.] > your height [ft.] = Do Not Wade!
- Always wear a personal flotation device whenever you enter a stream.
- If you are sampling from a bridge in traffic, wear a traffic safety vest.

Potential hazardous plants and infectious agents

It is important to protect yourself from potentially hazardous plants and ticks that carry diseases that you may encounter while monitoring your stream or river. The following plants are commonly encountered in Minnesota. Learn to recognize them and avoid them:

Poison ivy

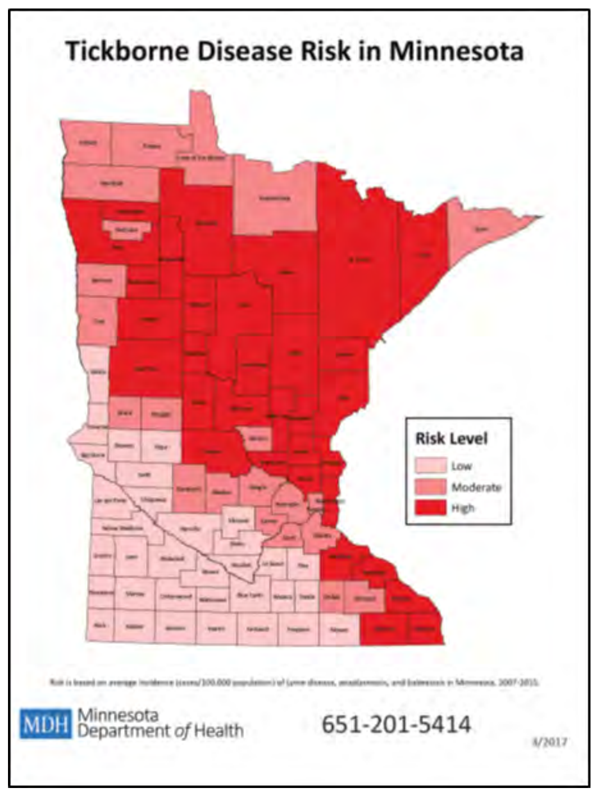
Wild parsnip

These plants produce an oily chemical on the leaves and stems that the human body reacts to as an irritant. Most people are sensitive to the oils produced in these plants. Wild parsnip produces a chemical that causes the skin to blister when exposed to sun light. If you think you have come into contact with these plants while outdoors, protect yourself from reacting to them by immediately washing the affected area with a soapy solution to cut the oils.

In Minnesota, there are about a dozen different types of ticks. Not all of them spread disease. Three types that people may come across in Minnesota are the blacklegged tick (aka deer tick), the American dog tick (aka wood tick), and the lone star tick. The blacklegged tick causes by far the most tick-borne disease in Minnesota.

To prevent tick-borne disease:

- Be aware of where ticks occur and when they are most active. The map at right shows tick-borne disease risk levels across the state.
- Use tick repellent.
- Check for ticks after spending time outdoors in areas where they are common.



For more information, please visit the Minnesota Department of Health website at: https://www.health.state.mn.us/diseases/tickborne/ticks.html.

Selecting a stream sampling point

It is important to select a stream sampling point that is representative of the entire stream. Select a point where the water is well mixed. Typically, this point will be at or near the stream center where the rate of flow is at or near its maximum. Collect the sample at a middle depth in the water column without disturbing stream bed sediments or collecting floating materials from the surface. Avoid points where the stream is swirling (eddies) or has pooled. Also, avoid points near the stream banks whenever possible, because this water may be atypically high in sediment.

It is essential to always access your monitoring station from public land or from private property that you own. When you first enroll in the program, Citizen Monitoring Program (CMP) staff will help ensure that the location where you plan to monitor has public access to it. If there is ever any question about the ownership of the access point to your monitoring station, please refrain from monitoring and contact CMP staff at csmp.pca@state.mn.us, 651-296-3600, or 1-800-657-3864. We will work with you to find a public access point to the monitoring location you select, or to find an alternate monitoring location that has public access.

When to monitor your stream or river

Try to visit your stream at the **same time** of day every time you monitor. There are two times when you should monitor your stream: once a week during the stream-monitoring season, and as needed, in response to significant rainfall events.

1. **Weekly stream readings:**

   The first priority and focus of your CSMP monitoring is to take measurements once a week during the months of April through September. A minimum of one measurement a month is needed for participation in the program and to make the data meaningful. Additional measurements taken earlier or later in the year are welcome, and all measurements will be entered into the state of Minnesota's water quality database known as EQuIS. Data are also shared with the U.S. Environmental Protection Agency's water quality database, where anyone can access it.

2. **Rainfall event stream readings:**

   Secondarily, and in addition to your weekly stream monitoring, measurements should be taken daily for 2-3 days (or longer) after a significant rain event, ***if possible***. We refer to these additional measurements as "Rainfall Event Stream Readings." Monitoring after a rain event allows you to detect potential changes in stream condition related to precipitation and runoff. However, taking a large number of readings after rainfall events has the potential to skew your transparency data to the lower end, so the majority of your readings should be taken on a weekly basis to obtain the most representative data for your stream.

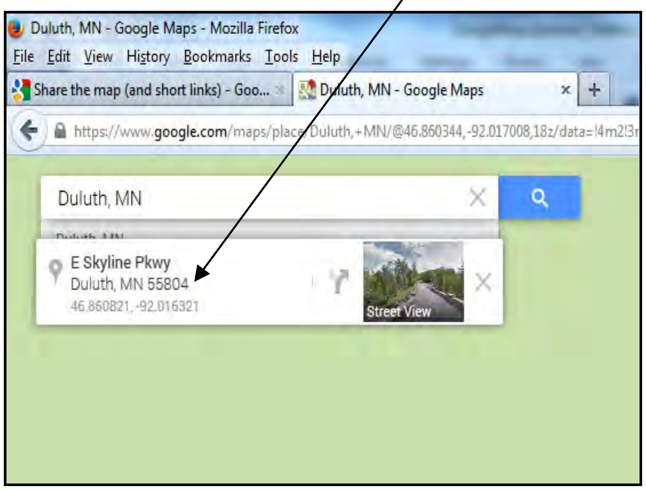
How do you know when a rainfall is significant? If the soil is saturated to the touch (i.e. during spring when there is a lot of water in the ground), a small amount of rain can produce a "significant" event. If the soil is very dry to touch, a larger amount of rain will have to fall to initiate runoff and potential changes in streams.

You may want to adjust the length of your daily measurement period (e.g. 4-5 days), depending on how quickly rainwater travels from the land to the stream channel and past your sampling location. Once you have monitored a few rainfalls, use your best judgment to determine when a rainfall is significant and how long stream conditions change in response to a rain event. Then take enough daily measurements to capture that change. You may find that daily measurements are not frequent enough to capture rapid changes, and decide to take readings more frequently. As a *general* rule of thumb, a rainfall of approximately 1/2-inch in a relatively short period of time can result in a significant runoff event.

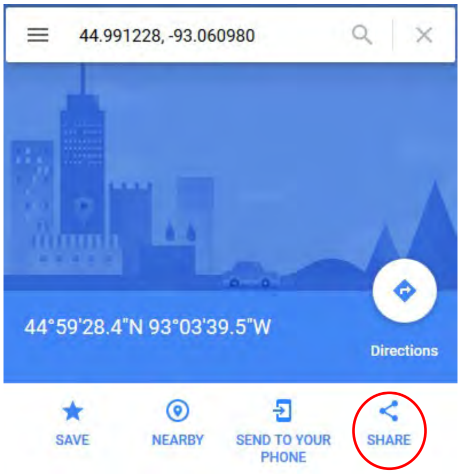
Documenting your CSMP monitoring location using Google Maps

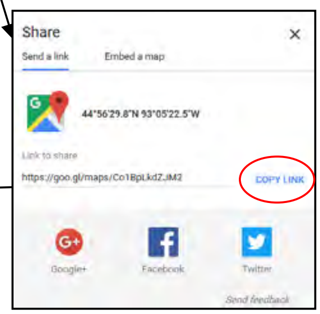
In order to use the stream data you collect, we need to document your monitoring location. Please follow these steps in "Google Maps" to email site information to MPCA Staff:

1. Go to Google Maps: http://maps.google.com/.
2. Find your stream location. Search for it by name (if common), nearby street intersection, city, or county including "Minnesota".
3. Zoom in to your exact location on the stream.
4. Right-click on your exact sampling site. In the dropdown menu, click on "What's here?" A *small window* will display in the lower portion of your screen that contains the address and coordinates (latitude and longitude) for the location that you selected.
5. Left click the numbers (coordinates) in this small window. A marker will display on the location that you selected, along with the coordinates.



6. Next, click Share SHARE in the box on the left:

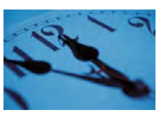




7. Click the Copy link to the right of the URL listed.
8. Paste this link into the body of an email message by and send the email to the CSMP Inbox at: csmp.pca@state.mn.us

TO OBTAIN A HARD COPY MAP OF YOUR AREA FOR SITE DOCUMENTATION PURPOSES, Please contact CSMP Staff at csmp.pca@state.mn.us or call 1-800-657-3864

Date and time



Record the date and time, in hours and minutes (e.g. 10:20), at which you conduct stream monitoring at your site. Check “am” or “pm” in the ”Time” column.

User perception assessments (Appearance and Recreational Suitability)

Your personal assessment of the stream water helps characterize what is happening in and around your stream. The ”Appearance” of stream water may provide information about material in it. The ”Recreational Suitability” assessment reflects how the water’s appearance affects the benefits that you receive from the stream such as swimming, fishing, and aesthetic enjoyment. Even if the stream is small and cannot be used to swim, fish, or boat, consider its aesthetic value when making this assessment. Do not factor weather conditions into your assessments. Consider water quality conditions, only. **Fill in the “Appearance” and “Recreational Suitability” columns *before* you take your transparency reading so your perception assessment is not biased.**

Appearance:

Each time you monitor your stream, please record the **one** number that best describes the appearance of stream water within one meter of your site.

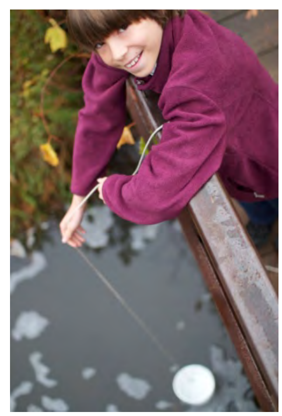
1A	**Clear**	Crystal clear, transparent water
1B	**Tea-colored**	Transparent water, which has been colored by dissolved organic matter from upstream bogs or wetlands
2	**Cloudy**	Not quite crystal clear; cloudy white, gray or light brown
3	**Muddy**	Cloudy brown due to high sediment levels
4	**Green**	Due to algae growth; indicative of excess nutrients released into the stream
5	**Muddy and Green**	A combination of cloudy brown from high sediment levels and green from algae growth

Recreational Suitability:

Please use the **one** number each day you sample that best describes your opinion of how suitable the stream water is for recreation and aesthetic enjoyment. Even if your stream is too small for swimming, fishing or boating, assess the stream for its aesthetic enjoyment.

1	**Very Good**	Beautiful; could not be better
2	**Good**	Very minor aesthetic problems; excellent for body-contact recreation (swimming, wading, etc.)
3	**Fair**	Body-contact recreation and aesthetic enjoyment slightly impaired
4	**Poor**	Recreation potential & level of enjoyment of the stream substantially reduced (would not swim but boating/canoeing okay)
5	**Very Poor**	Swimming and aesthetic enjoyment of stream nearly impossible

How to take stream transparency readings with a Secchi tube



Do **not** wear sunglasses while taking a measurement, as this affects the accuracy of your reading. If you wear photo gradient prescription sunglasses, please prevent them from darkening by wearing a hat or visor with a wide rim.

1. Collect your water sample in a clean bucket or bottle at mid-stream and depth. A clean paint bucket from your local hardware store works well. Here are the two most common methods for water collection.

   a. **Wading or from streambank:** Always sample safely - do not wade into fast-moving water or areas of unknown depth. If you cannot sample safely, record visual observations only (*Appearance, Recreational suitability, Estimated Stream stage*). If a sample from mid-stream and depth is not possible, avoid stagnant water and sample as far from the shoreline as is safe.

- Try not to stir up the bottom.
- Face upstream as you fill your bucket.
- Avoid collecting sediment from the stream bottom and materials floating on the water surface.

   b. **From atop a bridge or culvert:**

- With a rope tied to its handle, lower a bucket to the stream to collect water. A locking carabiner works well to securely attach the rope to the bucket handle. Tie a knot in the rope around the carabiner and lock the carabiner to the bucket handle.
- Pull the bucket back up, taking care not to bounce the rope or bucket on the side of the bridge / culvert to avoid knocking debris into the bucket.

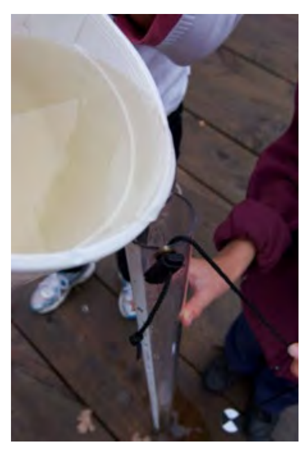
2. Take your tube readings in open conditions (not shady). Avoid direct sunlight by turning your back to the sun if necessary. Do **not** wear sunglasses.
3. Pull up the inside string to remove the black and white Secchi disk from the tube.
4. Fill the tube with water from your bucket. Let the water level drain to the zero mark on the tape measure.
5. While looking down into your tube from the top, slowly lower the Secchi disk down into it until the disk disappears from sight. When it does, stop lowering.
6. While continuing to look down the top of the tube, slowly pull the string to raise the disk until it reappears. Lower and raise the disk until you have found the midpoint between disappearance and reappearance of the disk.
7. Pinch the string against the side of the tube to hold the disk at the midpoint depth. Look at the side of the tube, across the top of the disk, to see the closest centimeter mark on the tape.
8. Write down this depth, to the nearest centimeter, on your stream data sheet under "Secchi tube depth." If the disk does not disappear, and you see it clearly sitting on the bottom of the tube, record "greater than 100" (>100).

Filling in the "rainfall event" column

We want your stream monitoring data to be representative of the overall condition of your monitoring location throughout the monitoring season. To this end, we recommend that you monitor once a week, on a regular basis throughout the season. In addition to this weekly "baseline" reading, we suggest that you also track how your stream responds to significant rainfall by monitoring a few so-called "rain events."

Check the appropriate box in the "rain event" column each time that you take a stream measurement. If you are taking your weekly, background transparency reading, check "no." If you are conducting your regular, weekly reading and it happens to be raining - either as you monitor or just prior to monitoring – check "no." You are NOT conducting a "rainfall event" sampling. Rather, you are conducting your regular, weekly sampling and it just happens to be raining. If you are taking an ***extra*** reading in addition to your weekly sampling, and in response to a rainfall event, check "yes." You may need to take stream measurements for a number of days after a large rain event to fully document changes in stream condition that occur. Remember to mark every measurement taken in response to a rain event as "yes" in this column. It is also important to note that we do not want you to monitor in response to rainfall too many times, to avoid your dataset being skewed toward high rainfall (and potentially runoff) situations.

Stream stage estimate



Stage refers to stream water level, or height, and measures the amount of water present in the stream channel. It is important to record stage information to determine how changes in water level are affected by rainfall, and how they affect transparency.

Please estimate the water level each time you sample. This refers to the relative amount of water flowing in the stream channel as shown by a rough visual estimate of the water level. "Low", "Normal", "High", "No flow", and "Dry" are broad categories, so do not agonize too much over which category to choose. The following guidance and graphics should help you decide:

L=Low	Water covers 1/3 or less of the distance from the stream bottom to the top of the bank.
N=Normal	Water covers 1/3 to 2/3 of the distance from the stream bottom to the top of the bank.
H=High	Water covers 2/3 or more of the distance from the stream bottom to the top of the bank. Water may be over the stream bank – flooding - at some point.
Z=No flow	Disconnected stagnant pools/puddles without observable flow.
D=Dry	The stream channel is dry.

Figure 3a. "Low" stream stage estimate

L=Low, water covers 1/3 or less of the distance from the stream bottom to the top of the bank.

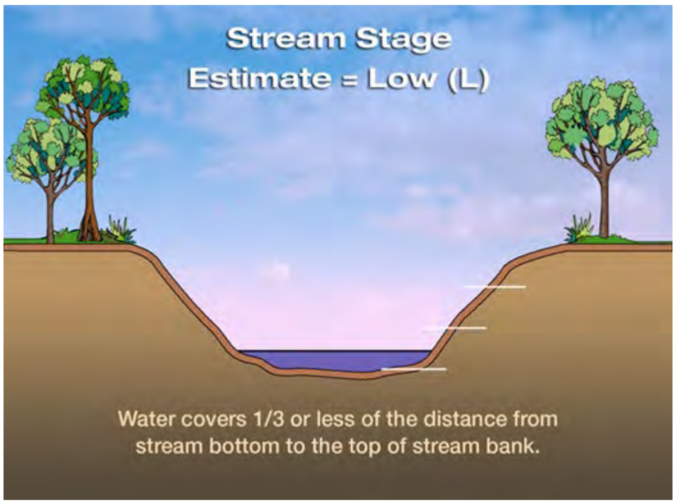


Figure 3b. "Normal" stream stage estimate

N=Normal, water covers 1/3 to 2/3 of the distance from the stream bottom to the top of the bank.

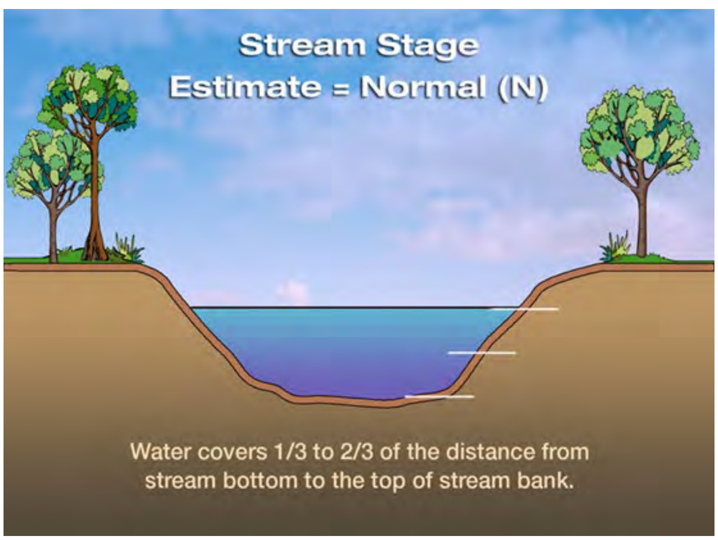
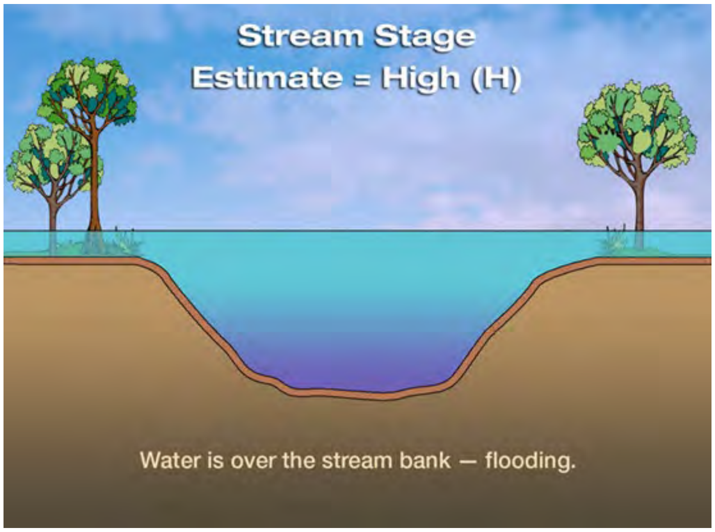


Figure 3c. "High" stream stage estimate

H=High, water covers 2/3 or more of the distance from the stream bottom to the top of the bank. Water may be over the stream bank – flooding - at some point.



Optional measures

Congratulations! You have completed the required portion of CSMP monitoring. The following procedures are optional.

Tracking daily rainfall

The CSMP partners with the Community Collaborative Rain, Hail and Snow Network (CoCoRaHS) to coordinate daily rainfall monitoring in conjunction with your stream monitoring. If you have agreed to monitor rainfall in addition to the CSMP stream monitoring, you will need to formally enroll in CoCoRaHS and enter your rain data to their website**.** Enrollment in CoCoRaHS requires that participants enter 24-hour rain amounts on a daily basis. Because data are entered on a daily basis, rain observations are immediately available to scientists and the public.

To join CoCoRaHS, visit their website at www.cocorahs.org. Once on the website, there are three important areas to access:

- Click the "Join CoCoRaHS" link to formally enroll in the program. **Under "How did you find out about CoCoRaHS" on the enrollment form, *be sure* to enter "CSMP" for program coordination purposes.**
- View a training slide show on the website.
- Access and print data sheets to record your daily rain observations.

Once enrolled in CoCoRaHS, you will receive an email that welcomes you to the program and provides an assigned station name, number, and complete instructions.

We strongly encourage you to join CoCoRaHS. This partnership with a national network of precipitation observers will allow you to collect high quality data and ensure that your data will be used to its fullest extent by a broad range of users.

Temperature

Water temperature influences what lives in your stream, particularly fish such as trout that cannot tolerate high temperatures. If you would like to monitor temperature, please use a non-mercury thermometer to avoid accidents. Whenever possible, hold the thermometer directly in the stream for two minutes, stirring it a bit. Record the temperature in degrees Fahrenheit. If you cannot place the thermometer directly in the stream or river, hold it in the water in your sample bucket for two minutes, stirring occasionally. Record the temperature to the nearest degree Fahrenheit on the stream datasheet.

Picture taken and comments

Pictures document changes at your site over time, and will be used in Clean Water Act water quality assessments as a tool to view conditions at monitoring sites at the time of individual sampling events. If possible, take photographs of your site under a variety of conditions. Check the box under "Photo" each time a picture is taken. Save electronic images in jpg format. Document each photograph by naming it using the station code (S-Code, e.g. Sxxx-xxx), then a space, followed by the two digit month, two digit date and four digit year. If multiple photos were taken on the same date, use an alphabetical identifier at the end of the file name to identify unique photos:

Example: S000-001 06012016A.jpg

Please email electronic photographs to csmp.pca@state.mn.us at the end of the monitoring season, along with your datasheets. You can also send images on a CD, or hard-copy photographs, along with your completed datasheets at the end of the monitoring season.

Use the “Comments” space to record anything unusual that you observe during a sampling visit; note things like recent severe weather, construction activities occurring upstream, changes in adjacent land use, or a dramatic change in the appearance of stream water.

Submitting data

Each spring, CSMP staff mails customized paper datasheets to all volunteers. CSMP volunteers should use this datasheet to record data collected throughout the monitoring season. Volunteers should submit data to CSMP staff once annually, at the end of each monitoring season. You can do this by:

- Mailing in your hard copy datasheet using the postage paid envelope included in the spring datasheet mailing. If you misplace the metered envelope, send forms to:

  Citizen Stream Monitoring Program Coordinator
  MPCA
  520 Lafayette Rd. N.
  St. Paul, MN 55155

- Emailing your data using the CSMP Electronic Datasheet, available for download on the CMP webpage (www.pca.state.mn.us/cmp). Instructions are contained within the file, but do not hesitate to contact CSMP staff with questions.

The off-season

The monitoring season is over and you’ve submitted your data. Now what? Each fall/winter CMP staff review, proof, and upload data collected by volunteers into the state water quality database. CSMP staff then create individual, online monitoring site reports summarizing Secchi transparency data submitted by each volunteer. These annual reports are usually available to volunteers by the following spring, and volunteers are notified by email when they are available. CMP staff also compile annual statewide results on program participation and Secchi transparency. This *Annual Statewide Summary Report* is available on the CMP website each spring: www.pca.state.mn.us/cmp.

Caring for your equipment

Cleaning your Secchi tube:

Your Secchi tube will last longer if it is kept clean and protected from scratches. We suggest a thorough cleaning once a year, at the end of the monitoring season. More frequent cleanings may be necessary, depending on the condition of the water you collect. Clean the inside of your tube by filling it ¾ full with tap water, add a couple drops of dish soap, and push a clean, soft rag or washcloth down the tube with the end of a broom handle or cleaning brush, scrubbing the sides. If you take the stopper out of the bottom, be sure to fit it back into the tube securely. There is a screw attaching the stopper to the wall of the tube that can be removed with a Phillips head screw driver.

Rain Gauge maintenance (optional monitoring):

During the monitoring season, clean the outer and inner cylinders regularly to get rid of any soil or uninvited bugs that might influence your reading. Before the first hard freeze each year, bring the inner cylinder and top funnel indoors to prevent cracking. If you want to track snowfall for your own records, leave the outer cylinder outside during the winter months. When it snows, melt the snow indoors and pour snowmelt through the funnel into the inner cylinder to take your reading.

How the MPCA uses CSMP data

Volunteer-collected water transparency data are extremely valuable to the MPCA. The MPCA uses CSMP data to:

- Convey information about the general condition of streams and rivers.
- Calculate trends to detect changes in stream transparency over time. For more information, visit: https://www.pca.state.mn.us/water/transparency-trends.
- Determine if a stream section is meeting state water quality standards for sediment as part of a formal assessment process (when used alongside TSS data) For more detailed information on this process visit: https://www.pca.state.mn.us/water/using-secchi-tube-readings-stream-water-quality-assessments.
- As part of watershed investigations and restoration and protection efforts. For more information on the MPCA's Watershed Approach, visit: https://www.pca.state.mn.us/water/watershed-approach-restoring-and-protecting-water-quality.

How Rivers Run

Excerpts from the Minnesota Department of Natural Resources' Healthy Rivers CD. Copyright (2004) DNR, Reprinted with Permission:

> *Healthy Rivers* was developed by an interdisciplinary group of natural resource professionals — ecologists, fisheries biologists, aquatic biologists, hydrologists, and water chemists — who have been working in the area of systems ecology and water management for many years. Their goal is to communicate current understanding of river systems in ways that might add to the intelligence and stewardship efforts of receptive citizens.
>
> What follows draws from the section of the CD titled "How Rivers Run." It is meant to build a deeper understanding of the structure and function of river systems based on a five component framework. We hope that CSMP volunteers find this background information on river ecology helpful and interesting throughout their stream monitoring and protection efforts.

Five components of healthy streams

The beauty of a stream lies in the illusion of movement, tumult, freedom, and chaos as it runs headlong to bigger water and ultimately to the sea. But there is a pattern to a stream's procession from mountaintop to sea. There is order to its chaos—to the way the water flows, to the shape of the channel, to the multitudes of insects, fish and other life that swim its waters.

In the last 25 years, scientists have gained new understanding of streams and the processes that form them and sustain them. In ways we didn't appreciate before, we realize that a stream is a product of activities throughout its entire watershed. According to author and stream scientist Thomas F. Waters, a stream is also an organism that has to be fed, it has to breathe, and to have its metabolic wastes processed.

While each stream is unique, it shares common aspects of structure and process with other streams around the world. Streams can be understood and characterized by five major components:

- Flow of a stream, or Hydrology
- Shape of a stream, or Geomorphology
- Connections of a stream, or Connectivity
- Quality of a stream, or Water quality
- Life of a stream, or Biology

These elements are not independent of each other, but rather continuously interact in a myriad of relationships. For that reason, altering a single component—manipulating flow through the construction of a dam, for example—can affect all other components in unpredictable and often deleterious ways.

Flow of a river – Hydrology

In the context of stream dynamics, hydrology is the distribution and movement of water through the stream and its floodplain and tributaries. Water is the most obvious feature of the river. It is vital to life in the stream and the nearby environment. Its movement provides the energy to shape the stream and its surrounding landscape. Its unique physical properties—it floats when it turns to ice and has an unusual ability to retain heat, for example—have important consequences to the stream environment.

The hydrology of a river system determines the appearance and behavior of the stream and its ability to support life and other processes and uses, including those that humans depend on. There are four variables or dimensions of hydrology:

- *Longitudinal*, the movement of water from headwaters downstream to the mouth.
- *Lateral*, the ebb and flow of water between the main channel and the floodplain.
- *Vertical*, the flux of water underground.
- *Chronological*, the flow over time.

The water cycle

Most rivers are like perpetually flowing fountains. Where does the water come from? While many ancients understood that precipitation fed streams, many thinkers during the Middle Ages believed that water from the ocean traveled through the ground and fed the headwaters of the world's streams.

Figure 4. The water cycle

Steve Adams / DNR

Now, we understand that precipitation through the *hydrologic cycle* feeds the world's streams. Water evaporates from the world's oceans (and to a lesser extent, lakes and streams) and via transpiration of plants. It falls from the atmosphere as rain or snow. Flowing over ground as runoff or underground as groundwater, water finds its way to a stream and then eventually to the sea.

Why do rivers continue to flow, even when little or no rain has fallen? Much of the water feeding a stream runs slowly underground through shallow aquifers.

These sediments are saturated like natural sponges and respond slowly to rainfall and drought. Several factors affect the timing, rate, and volume of flow through a stream system:

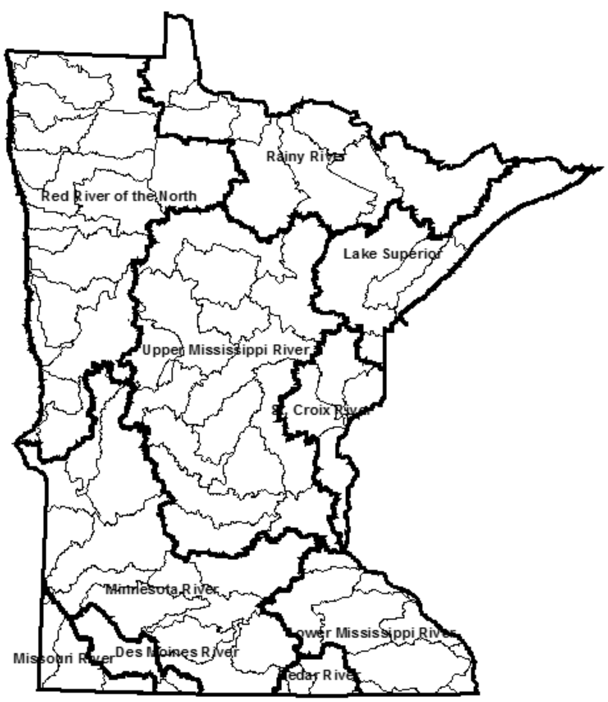
A. Climate
B. Precipitation
C. Evaporation
D. Transpiration
E. Vegetation: Amount and type of plant cover
F. Geology
G. Land use activities
H. Soil

Watersheds

A stream's *watershed* (also called its *basin* or *catchment*) is the land area that drains into that particular stream. As your point of reference moves downstream, the length of the stream and the watershed feeding it grows in size.

As one stream joins another, the watershed jumps in size as two watersheds are joined. Thus a watershed grows to great proportions. The watershed of the Mississippi River at its mouth stretches from the ridge of the Appalachians to the east slope of the Rockies. It drains all or parts of 31 states and 2 Canadian provinces—a total of 41% of the continental United States. Minnesota contains portions of 10 river basins, each of which can be broken down into major watersheds:

Figure 5. Boundaries of Minnesota's ten river basins and major watersheds



Shape of a river – Geomorphology

What distinguishes a mountain stream from a pasture brook of similar size? Why does one rush quickly while the other eases slowly though riffles and bends? Why do some streams crash over falls and steep rapids, while others flow swiftly over riffles of sorted cobble? Why are so few rivers straight and so many, large and small, settled into a pattern of alternating bends?

The answers to these questions lie in the realm of geomorphology, the study of the geologic forces that form the landscape, creating streams and continuing to shape them largely through the action and effects of moving water.

Large-scale geologic forces such as uplift, volcanic activity, and glacial erosion and deposition shape the land over which rivers eventually flow. As you would expect, a stream flowing down the steep slope of a mountain appears different from one running through a nearly flat plain of glacial till. A stream flowing over bedrock has different characteristics from one flowing over a bed of sand. Geology sets the stage for what is to come.

As draining water seeks out and establishes a river channel, geomorphological forces are at work. Over time, land may continue to move on a large scale. Much of the Canadian Shield, for example, continues to rebound from the weight of the glaciers; in places the land continues to rise several inches per century.

In arctic or alpine regions, glaciers may continue to advance or melt. In geologically active areas, earthquakes or volcanoes may alter streambeds.

Geologic forces aside, the most dramatic forces shaping rivers are hydrodynamic, that is, the result of interplay between the force of moving water and the materials forming the streambed. Hydrodynamic forces form islands and sandbars, grade rapids and riffles, create deltas, and form—and eliminate—meanders.

The form of a stream channel depends on the interaction of eight variables, which are determined by climate and the geology of the area:

- Discharge (the volume of water)
- Sediment supply
- Sediment size
- Channel width
- Channel depth
- Water velocity
- Slope (or gradient)
- Roughness of channel materials

Imagine the difference between a low gradient, highly meandering prairie stream and a steep, fairly straight stream flowing over highly resistant bedrock.

That prairie stream will be nearly as deep as it is wide, whereas the bedrock stream will be much wider than it is deep. The type and amount of sediment will be different as well, and so will the type and amount of fish and insects.

While these two examples present striking contrasts, they also illustrate the importance of all these factors in determining the shape of a river, and how these factors balance or reach equilibrium over time.

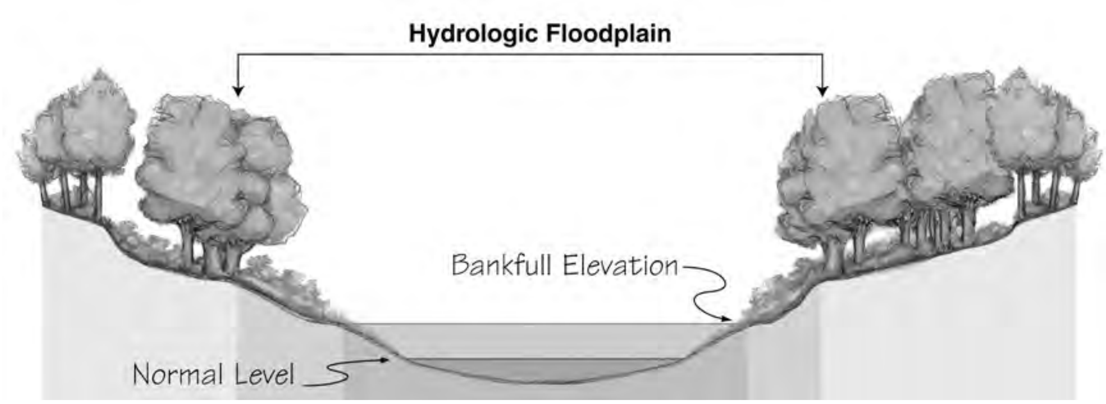
Bankfull flows

A river’s shape is determined over time through the continuous interaction between water and the landscape. Rivers and streams of all shapes and sizes have a tendency toward dynamic equilibrium, where the energy of the system is expressed in its pattern, dimension and profile.

While the largest floods move large amounts of sediment over short periods of time and shape the valleys and floodplain, they are relatively rare. Research over the past 50 to 60 years has increasingly demonstrated the importance of bankfull flows in defining a river’s shape.

The term *bankfull* refers to the water level stage that just begins to spill out of the channel into the floodplain. Bankfull flows tend to occur fairly frequently, on the average every two out of three years. Because bankfull floods occur frequently, they move the most sediment over time and shape the stream channel itself. The range of forces—from major floodplain-forming events to recurring bankfull flows—are necessary for healthy river systems.

Figure 6. Bankfull flows

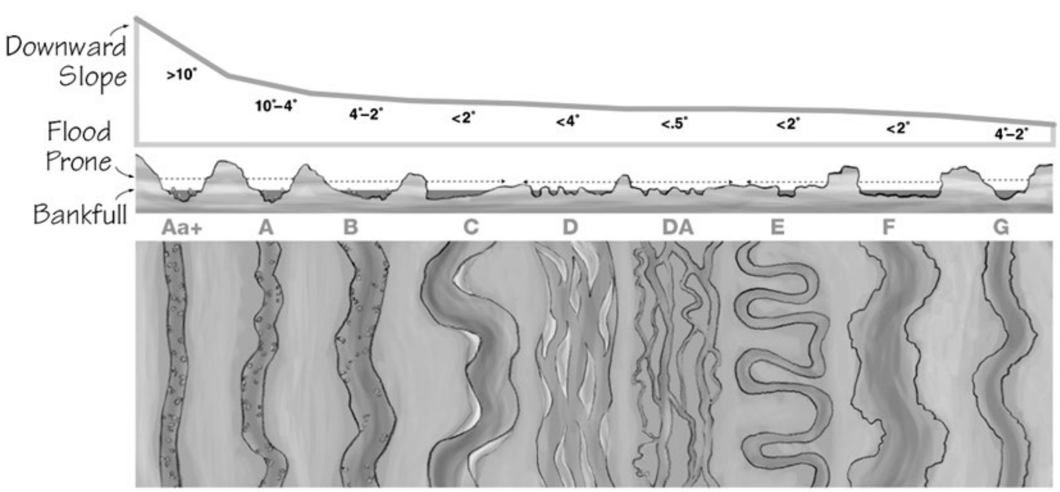


Stream classification

The eight variables important in shaping a stream interact in predictable and measurable ways. For example, the natural form of the low gradient streams characteristic of most of Minnesota is sinuous, narrow, and deep. Steeper rivers found on the North Shore of Lake Superior are less sinuous and have boulder and bedrock rapids more like mountain streams. Many variations on these forms can be found throughout the world.

One of the ways to better understand streams is a classification system developed by Dave Rosgen, (1994). This system helps us predict the form and shape of a stream when faced with changes in the hydrologic regime and the bankfull discharge, loss of stream length due to straightening, or increases in sediment supply.

Figure 7. Rosgen stream classification system



Graphic depicting the stream channel classification system developed by Dave Rosgen. Reprinted from Catena 22, Dave Rosgen, A classification of natural rivers, 169-199, Copyright (1994), with permission from Elsevier.

Patterns

Suppose we imagine a low gradient prairie stream and increase the amount of water that flows through the stream on a regular basis. Because we know that width and depth are related to discharge, we can predict that the stream will become either wider and shallower, or will become narrower and deeper, depending on the substrate and bank vegetation.

Meandering pattern is related to the bankfull width. With increased discharge we can predict an increase in meander radius and meander length. The result is a progressive increase in bank erosion that results in additional sediment, with potentially costly consequences.

Streams express their energy by the formation of *meanders* and by adjusting their slope. This fact is most obvious where streams flow over beds of unconsolidated sediment. Streambeds composed largely of bedrock prevent or inhibit the expression of these features.

Meanders develop according to fairly consistent patterns, regardless of stream size. Bends form, alternating right to left, with a radius about two to four times stream width. Vary the scale, and an aerial photograph of a small creek would resemble the pattern of a large river.

As streams continue to cut against the outside of the stream bank, they accentuate the bend. Many meanders eventually break through, allowing the flow to shortcut the meander. The abandoned meander is called an *oxbow*.

Connections of a river – connectivity

The most obvious example of connections of a river or *connectivity* is the free flow of water downstream and the passage of fish upstream. The construction of a high dam across a stream is the most vivid and obvious illustration of *fragmentation*, the loss of connectivity.

Connectivity takes many subtler forms. Broadly, the term refers to the flow, exchange, and pathways that move organisms, energy, and matter through a stream system. The hallmarks of connectivity are continuity, complexity, and interdependence. This continuum of hydrologic, biological, and chemical interactions extends along four dimensions (Nilsson and Berggren, 2000):

- Longitudinal (upstream and downstream)
- Lateral (midchannel to floodplain)
- Vertical (underground, in the sediment surrounding the channel)
- Temporal (continuity over time)

The River Continuum Concept--or “RCC” (Vannote et al., 1980)—illustrates longitudinal connectivity in greater complexity. Developed by a group of stream ecologists, RCC hypothesizes that streams exist in a continuous and fairly predictable pattern along their entire length. Streams have evolved in accordance with physical factors. The structure of the stream and its biological communities change along the length of the river. Organism functions change in response to food resources.

Quality of a river – water quality

Water is vital to all life on Earth. The water in a stream sustains aquatic organisms such as fish and insects as well as organisms that live throughout the entire watershed. That includes humans. Entire cities may depend on the water in a single medium-sized river. Water is used for drinking, washing, watering and irrigation, and many commercial and industrial processes. The same water transports the effluent of wastewater treatment.

Because water is vital to life, it is accurate to say that poor water quality equals a poorer quality of life. Even the human womb is an aquatic environment where the development and beginning of life is affected by water quality.

Because we satisfy our personal needs with water from a tap, we think of water as high in quality if it is clear and cold. Although that is a narrow measure of good water for human consumption, it is insufficient for measuring the overall quality of water in a stream.

Water quality in a stream can be assessed using biological indicators. Water quality is also determined by measuring a variety of physical and chemical properties, including:

- Temperature
- Dissolved oxygen
- Alkalinity and pH
- Nutrients
- Sediment and turbidity
- Contaminants

Each natural stream tends to exhibit and maintain a characteristic range of water quality measures, depending on such variables as hydrology and geomorphology (the availability of fine sediments and groundwater, for example). Water quality changes when human activities upset the basic conditions of the stream system. These changes are often harmful from the standpoint of stream life and system balance.

Each of these properties is important. We focus here on sediment and turbidity, as it is closely linked to the CSMP through use of transparency data. Turbidity is the property of water that causes light to be scattered or absorbed. Turbidity is caused by the presence of suspended particulate matter in the water column. These particles may be organic forms, such as algae and finely divided plant and animal material, or they may be inorganic forms, such as silts and clays. The visual result of high concentrations of these materials is that water appears muddy, or turbid. A consequence of increased turbidity is reduced water transparency. Transparency is an important measure of stream quality and is commonly assessed in the field.

Sediment takes two forms: suspended and deposited. Fine sediment stays more easily in suspension than coarse sand and gravel, which may be moved by bursts of currents, but soon falls to rest on the streambed.

For example, fine clay particles from the Blue Earth River in south-central Minnesota are transported all the way from the Minnesota River basin to the Mississippi River basin, where they are finally deposited in quiet backwaters or in Lake Pepin.

Both organic and inorganic particles can block sunlight from the streambed, preventing photosynthesis by aquatic plants. Suspended sediment injures gills of fish and other aquatic organisms, and can impair foraging by sight-feeding fish.

Of the pollutants in our streams, the most expensive to deal with and most damaging to stream life is sediment. It plugs spaces between gravel and rocks (interstices) in the streambed, preventing their use as living spaces for life forms that live on the stream bottom. Sediment can smother eggs of fish, especially trout and salmon, whose eggs rest in the interstices of well-oxygenated gravel beds. An excess of sediment in streams spells the end of natural reproduction in trout.

In most "natural" systems, the input of sediment from the surrounding basin is modest. What enters is shifted and moved throughout the river channel. It is the sudden influx, usually from human activities, that creates problems.

Erosion and sedimentation occur over broad areas and result from many activities. An excess of sediment often results from the following:

- Construction and use of logging roads and skid trails, especially in steep topography.
- Road construction, home and commercial construction.
- Off-road vehicle use.
- Plowing and other agricultural activities that remove plant cover and loosen topsoil.
- Overgrazing and continual trampling of streambanks.

Sediment can be intercepted and trapped before it reaches waterways. Eroded waterways can be restored by methods such as regrading, planting, and stabilizing slopes and banks. But it is generally cheapest and most effective to prevent erosion and sedimentation in the first place.

Conservation tillage on farmland can reduce erosion. Fencing riparian zones to keep cattle out or to carefully manage grazing along streams can keep streambanks in good health. Damage from logging can be reduced through more careful siting of logging roads, less damaging forms of skidding (such as cable skidding systems), or avoiding logging on steep stream valleys.

Even solving loss of erosion from land will not immediately remedy sedimentation of streams. After a century or more of erosion from farmland and other sources, some stream reaches will require decades or more to move and redeposit accumulated sediment.

Life of a river – biology

Rivers are indeed ribbons of life—complex, productive, valuable communities of terrestrial and aquatic plants and animals joined and sustained by the many forces, interactions, and pathways that make up a living stream. But river systems are much more than simply the narrow corridor of the waterway itself. The ribbon of water weaves through a rich landscape tapestry teeming with life—full of vibrant sounds, smells, sights, and the continual mystery of birth, death, and renewal.

While all of us benefit from clean, healthy streams, few are in a position to fully realize the extent of the great variety of life forms that live in a stream system. As canoeists, we may see the osprey and beaver. As anglers we may know the stream’s gamefish, but stream life is far more complex than that.

Terrestrial plants along the stream, in its floodplain, and in its valley are vital to the character of the stream. The pattern of vegetation along a stream corridor will depend on climate; disturbance such as flood, erosion, and fire; formation of floodplains; soil type; and soil moisture.

Terrestrial plants

Plant communities form a mosaic, depending on conditions along the stream and in the floodplain. The disturbance of periodic floods provides an opportunity for new plant growth. For example, plains cottonwood, black willow, and silver maple are adapted to taking root in recently deposited sediments. Because these species are able to withstand deposition of sediment and scouring that exposes their root systems, they can outcompete other tree species in a floodplain environment.

Streamside plants are important sources of shade and energy in narrow headwater reaches. Throughout a stream’s length, the vegetation along the riparian corridor intercepts flows of incoming runoff, nutrients and contaminants. Plants are critical components of nitrogen, carbon, and oxygen cycles —

serving as production sites and conversion centers for life-sustaining elements. A biologically diverse plant community is more resilient to disturbances and disease than simplified communities or monocultures. (Tilman et al., 1996); (Tilman et al., 1997)

Deep-rooted native plants anchor soil in place and stabilize streambanks (see illustration at left). Plants at the water's edge also serve as buffers from bank erosion, absorbing the energy of lapping waves and swift currents.

Terrestrial animals

A mosaic of terrestrial plant communities provides more diverse habitats that support more diverse animal communities than homogeneous plant communities, such as cornfields.

Fens, marshes, floodplain forests, outwash plains, oxbow lakes, side channels, mudflats, shrub swamps, sand prairies and wet meadows are examples of habitats in river systems that support a rich diversity of life. The physical structure of the habitat in large part determines habitat quality.

Many reptile and amphibian species rely on waterways and their surrounding habitat. Pickerel frogs are closely tied to the forested, cold-water streams in southeastern Minnesota. While bullfrogs have been relocated to a variety of areas throughout Minnesota, the Mississippi River backwaters of southeastern Minnesota are their only naturally occurring habitat in the state.

Birds are also attracted to the river corridor. The diversity of species depends on the plant diversity, age classes and width of the corridor. Research has shown that older, larger trees are important habitat for nesting herons, egrets, osprey, eagles, and a variety of declining songbirds. Bald eagles and osprey prefer large white pine and aspen trees near the water for roosting and nesting sites. Kingfishers swoop down from streamside perches to catch their lunch.

In the Minnesota River Valley State Recreation Area, the one remaining stand of intact floodplain forest with large cottonwood and silver maple trees is home to a wide variety of bird species that are not found in other parts of the valley where forests are being selectively logged. Species include red-shouldered hawk, Acadian flycatcher, and cerulean warbler.

The Vermillion River Bottoms along the upper Mississippi River is one of the last places to support Cerulean warblers. Crucial structural requirements for Cerulean warblers in floodplain forests include the presence of tall trees with large upper branches sturdy enough to support nests. Large cottonwood, swamp white oak, and elm trees are particularly good species.

Life cycles of terrestrial animals

Many animals rely on a combination of upland and stream habitats in order to complete their life cycles. Both wetlands and sandy uplands are necessary for the Blanding's turtle to complete its life cycle.

Fluvial outwash plains, such as those in Weaver Bottoms along the Mississippi River, provide nesting habitat for Blanding's turtles, bullsnakes (also called gopher snakes), hognose snakes, map turtles, tiger beetles, jumping spiders, grassland birds (such as meadowlarks), and more. Fox snakes live in forested riparian habitats.

The rare wood turtle hibernates in rivers, nests on exposed sandy banks, but spends much of its time in nearby upland forests eating berries, mushrooms, insects and earthworms.

An ancient resident, wood turtles can live up to 40 years under favorable habitat conditions. Threats to this protected species include illegal harvesting, predation, and vehicles.

Travel corridors

Because many animals require both upland and stream habitats for their life cycles, it is essential to keep these physical habitats connected. It is important to also protect habitats along lateral and longitudinal gradients to allow movement of migrating and traveling wildlife. Long wooded stream courses provide many species, especially mammals, important avenues of movement to other habitats. Larger river corridors are major continental flyways for migrating birds.

Remaining refuges

The existence of streams and rivers becomes especially important in altered and developed landscapes. In urban and agricultural areas, the floodplain of a river is sometimes the only stretch of remaining native habitat for birds, mammals, amphibians, reptiles and invertebrates. Under such circumstances, the wooded streamside may have the best or only available cover for large mammals, such as fox, raccoon, and deer.

According to Fred Harris, Plant Ecologist, the Minnesota River Valley is an important corridor of native plant communities that supports some of the state's rarest plant species and noteworthy concentrations of animals in a mostly agricultural or urban part of Minnesota.

In the southeastern corner of Minnesota, forested bluffs with steep stream drainages and rocky cliffs that escaped logging and cultivation provide habitats for many of the state's rarest reptiles and amphibians. Remnant populations of timber rattlesnakes survive on the bluffs of the Mississippi River, while the five-lined skink occurs among forested rock outcrops in the Mississippi and Minnesota River valleys.

Aquatic habitats

Several life forms spend most, if not all, of their lives in rivers and streams. These aquatic organisms include types of bacteria, algae, plants, zooplankton, crayfish, insects, mussels, fish, amphibians, reptiles, and mammals.

The diversity of aquatic organisms depends on the variety of stream habitats. A sinuous stream provides more habitats than a straight channel. A streambed composed of rocks and sediment of many sizes provides a greater assortment of habitats than a streambed of uniform sediment. Pristine streams can exhibit astounding diversity. An inventory of a small stream in Germany revealed more than 1,300 species in a 1.2-mile stretch.

Critical niches for amphibians and reptiles are provided by different stream and river habitats. River backwaters and sluggish reaches of streams are especially important to frogs and turtles for reproduction and overwintering. Sand and gravel bars provide crucial nesting and basking sites for many turtle species, such as map and softshell turtles.

Spiny softshell turtles spend their lives in rivers and streams, leaving only to lay their eggs (PARC, 2002). Mudpuppies, which are the only hosts for the salamander mussel, spend their entire lives within streams, foraging by night and hiding under rocks and ledges by day with the mussel colony they help perpetuate.

Woody material, such as fallen trees in the water and logs along the bank, provide beneficial structure. They become an integral part of the channel, deflecting current, forming scour holes, and providing substrate for attaching organisms, basking sites for reptiles and amphibians, and overhead cover for others.

Summary of five components of a river

In this section, **How Rivers Run**, we presented an overview of very complex river systems based on a five-component framework. Central themes that repeatedly emerge are the interconnectedness of land and water; that healthy systems have evolved natural regimes to maintain them and sustain us; that water cycles through systems such that we all live upstream and we all live downstream, in other words, "wastes" don't disappear; and that our clumsy if not careless interventions with complex ecosystems are not done without costly consequences.

In short, we provide a scientific foundation to explain why it makes sense to manage rivers and streams as systems, considering relationships among all five components. This management approach is based on a healthy respect, if not reverence, for how rivers run, versus a narrowly focused approach that attempts to run the rivers.

References

Dieter, C.D. 1990. Causes and effects of water turbidity: a selected annotated bibliography. South Dakota State University, South Dakota Cooperative Wildlife Research Unit, Technical Bulletin 5, Brookings.

DNR. 2004. Healthy Rivers: A Water Course. CD-ROM.

Nilsson, C. and K. Berggren. 2000. Alterations of riparian ecosystems caused by river regulation. BioScience 50:783-792.

Partners in Amphibian and Reptile Conservation (PARC). 2002. Habitat Management Guidelines for Amphibians and Reptiles of the Midwest.
U.S.A. website: http://www.parcplace.org

Rosgen, D.L. 1994. A classification of natural rivers. Catena 22:169-199.

Tilman, D., D. Wedin, and J. Knops. 1996. Productivity and sustainability influenced by biodiversity in grassland ecosystems. Nature 379:718-720.

Tilman, D., J. Knops, D. Wedin, P. Reich, M. Ritchie and E. Siemann. 1997. The influence of functional diversity and composition on ecosystem processes. *Science* 277:1300-1302.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell, and C.E. Cushing. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37:130-137.

Waters, T.F. 1995. Sediment in Streams: sources, biological effects and control. American Fisheries Society Monograph 7. American Fisheries Society. Bethesda, Maryland.

Waters, T.F. 2000. Wildstream, A Natural History of the Free Flowing River. Riparian Press. St. Paul, Minnesota.

Glossary of terms

Chlorophyll – the molecule found in algae that provides pigmentation (color).

Drainage Basin – the area of land drained by a number of rivers or streams.

Ecoregion – geographic areas distinguished by ecological characteristics such as climate, soils, geology, and vegetation.

Eutrophication – the natural and artificial addition of nutrients to a water body, which may lead to depleted oxygen concentrations. Eutrophication is a natural process that is frequently accelerated and intensified by human activities.

Geomorphology – the study of the evolution and configuration of landforms.

Hypolimnion – the cool, dense layer of water found at greater lake depths.

Macrophyte – rooted or free-floating large aquatic plants in wetlands, lakes, and streams.

Oligotrophy – term used to describe the condition of a lake that is characterized by clear blue water, low nutrient levels, and Secchi-disk transparencies of over 8 meters. Oligotrophic lakes are generally deep with relatively small drainage areas.

Photosynthesis – the process by which green plants synthesize carbohydrates from carbon dioxide and water using light as an energy source and releasing oxygen as a byproduct.

Stream Discharge – quantity of stream flow per unit of time. Stream discharge is calculated by multiplying stream velocity (V) by stream cross-sectional area (A) so that Q=VA, where Q = discharge (m^3/second); V = velocity (m/s); and A = cross section (m^2).

Total Maximum Daily Load (TMDL) - The maximum amount of a pollutant that a waterbody can receive and still meet water quality standards. TMDL also refers to the process of allocating pollutant loadings among point and nonpoint sources.

Trophic – refers to the nutrient production level of a water body.

Turbidity – murkiness or cloudiness of water, indicating suspended sediments, dissolved solids, natural or man-made chemicals, algae, etc.

Watershed – the area of land drained by a particular river of stream system, which when added together make up a drainage basin.