

▶ SECTION 4: STUDENT WORKBOOK

STUDENT NAME

GROUP

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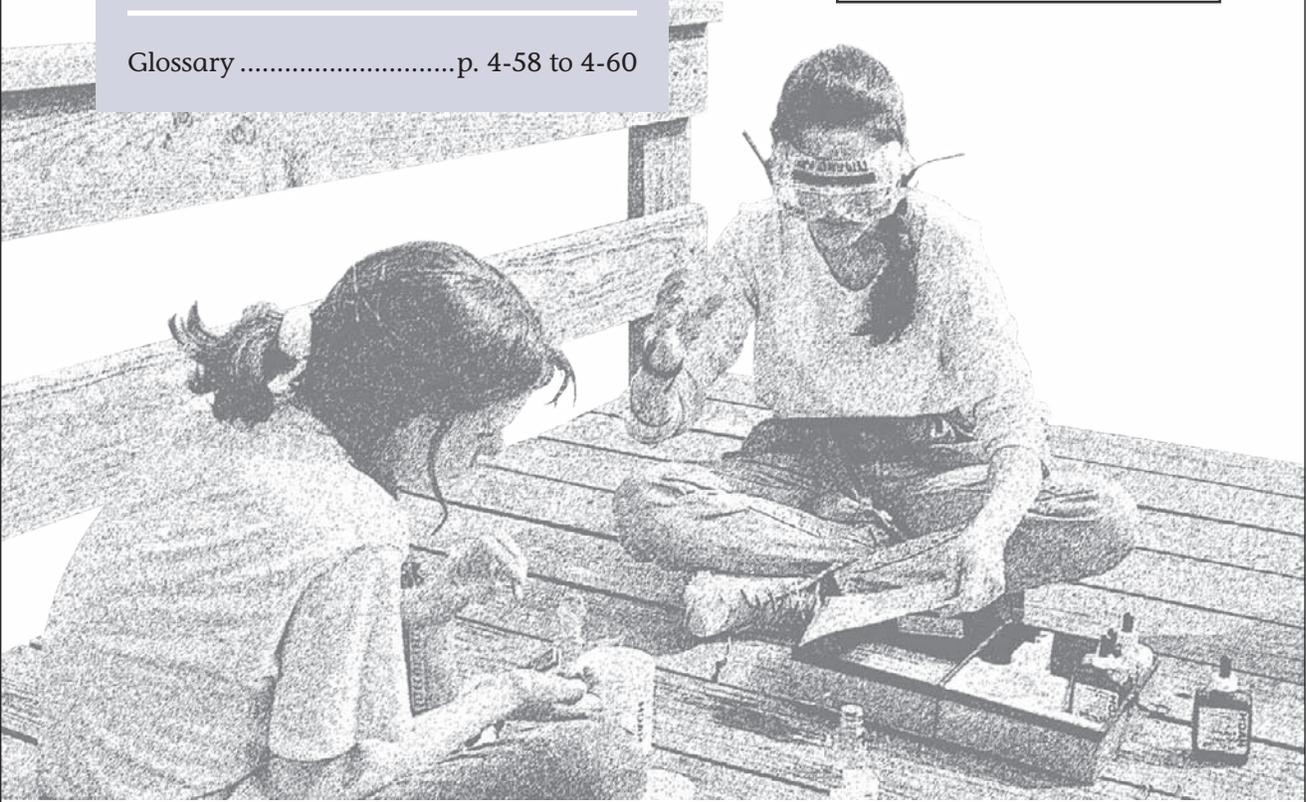
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Section 4 of six curriculum sections  
Developed by Kris Stepenuck, University of Wisconsin-Extension and Wisconsin Dept. of Natural Resources; and Katie Murphy, Middle School Science Teacher

For more information about volunteer stream monitoring opportunities in Wisconsin, and for printable pdfs of this curriculum visit:  
**[watermonitoring.uwex.edu/wav](http://watermonitoring.uwex.edu/wav)**

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HANDS-ON LEARNING ABOUT STREAMS WITHIN & OUTSIDE THE CLASSROOM – FOR MIDDLE & HIGH SCHOOL TEACHERS & STUDENTS

## TRANSPARENCY

- *Water clarity is one of the most obvious measures of water quality.*
- *Water clarity can be a useful indicator of runoff from construction sites, fields, logging activity, industrial discharges and other sources.*
- *Monitoring transparency before, during and immediately after rain can provide a useful picture of potential runoff problems.*

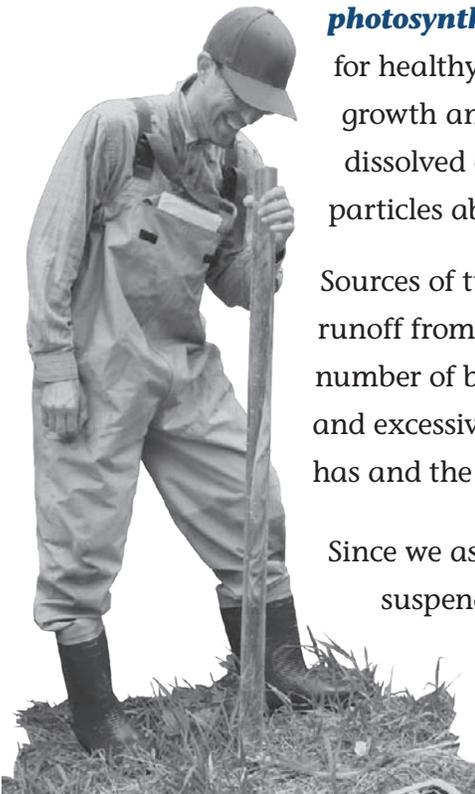
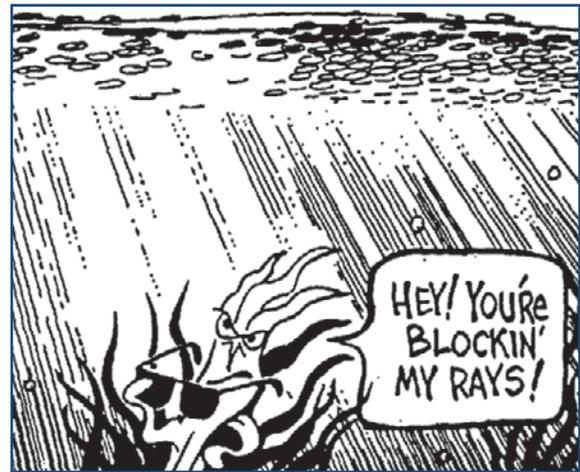
**M**urky water is easily seen as unhealthy. However, natural substances which are not harmful to the water can sometimes make water appear brown and murky. How do we know if the murky water is a cause for concern? Scientists have found a way to quantify the cloudiness of water by measuring its **turbidity**,

which relates to the amount of suspended particles in the water. These small particles of soil, algae or other materials generally range in size from the microscopic level to about one millimeter, (about as thick as a pencil lead). More free-floating particles cause greater turbidity, resulting in less light penetration through the water. This hinders

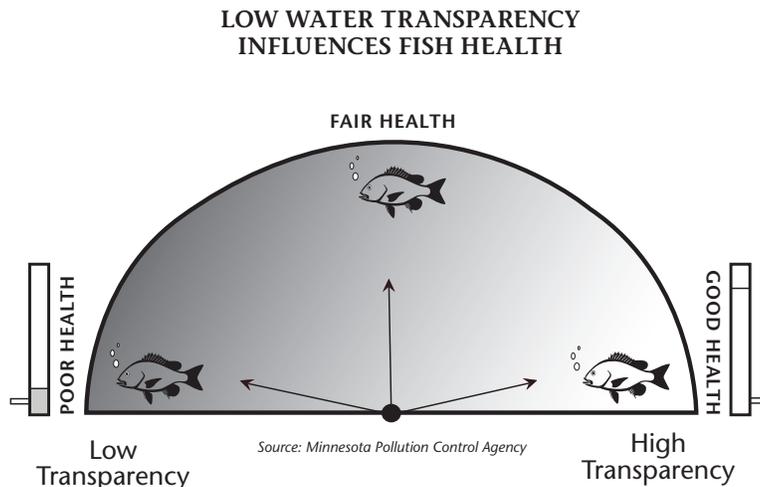
**photosynthesis**, necessary for healthy aquatic plant growth and production of dissolved oxygen. The water also becomes warmer because the suspended particles absorb heat.

Sources of turbidity include: erosion from fields, construction sites, urban runoff from rainstorms and melting snow, eroding streambanks, large number of bottom feeders (such as carp) which stir up bottom sediments and excessive algal growth. The faster a stream flows, the more energy it has and the more sediment it can carry.

Since we assess water clarity visually, we don't directly measure how many suspended particles are in the water. Instead we measure the transparency of the water, which takes into account both color and suspended particles. You will measure water clarity in centimeters (cm) using a transparency tube that is approximately 120 cm long. There is a black and white disc



in the bottom of the tube that you will look down – through the water sample – to attempt to see. If you cannot see the disc in the bottom of the tube, your monitoring partner will open a release valve to allow water to flow out of the tube. Your job is to alert your partner to close the valve when you can just see the contrast between black and white on the disc. However, if you can see the disc in the bottom of the tube when the tube is full, you will report a transparency value of 120 cm. It's important to note that you cannot determine the exact transparency if you can see the disc with the tube full, you only know that transparency is greater than 120 cm. This high transparency indicates good water quality (shown above).



All streams have background turbidity/transparency, or a baseline standard for a natural amount of turbidity/transparency. Fish and aquatic life that are native to streams have evolved over time to adapt to varying levels of background water clarity. For example, some native fish and aquatic life in the Mississippi River are very happy with their murky environment. What causes problems in any stream or river are unusual concentrations of suspended particles and how long the water clarity stays at a deviated level.

When you collect transparency samples, it is important to note any fluctuations in values, which can help detect trends in water quality. Time is probably the most influential factor in determining how turbidity affects the aquatic environment. The longer the water remains at unusually high values, the greater effect it has on fish and other aquatic life. Fish can become very stressed in waters that remain highly turbid for a long time. Signs of stress include increased **respiration** rate, reduced growth and feeding rates, delayed hatching and in severe cases, death. Fish eggs are ten times more sensitive to turbidity than adult fish.

Turbidity is measured in Nephelometric Turbidity Units (**NTU**) when scientists use a special meter, called a nephelometer, to assess this parameter. This type of meter shines light through a water sample and measures how much light is scattered by **suspended material** in the sample. We have a conversion chart for transparency measurements (which assess both particles in the water and water color) to NTU which can allow scientists to roughly compare transparency results obtained

with a tube to those obtained with a nephelometer (*See conversion chart at right*). This conversion also allows you to assess potential impacts of water clarity on organisms in the stream you sampled.

To further understand how time and turbidity impact fish, look at the graph below. The graph shows that the longer time turbidity levels are elevated, the greater the impact on aquatic life. High turbidity levels affect humans too. An acceptable turbidity level for recreation is 5 NTU and an acceptable level for human consumption ranges from 1-5 NTU.

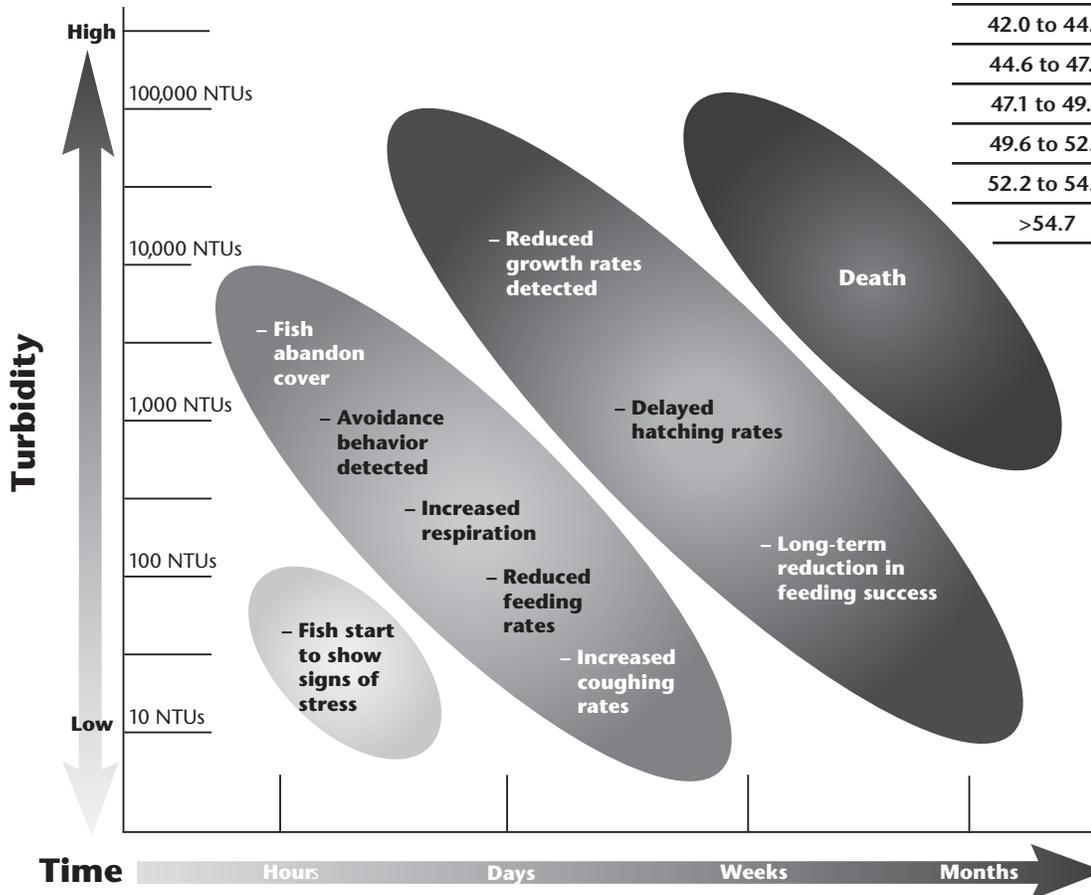
For additional information about monitoring transparency visit this website:

<http://watermonitoring.uwex.edu/wav/monitoring/transparency.html>

TRANSPARENCY VALUE CONVERSION CHART

Centimeters	Turbidity (NTUs)
6.4 to 7.0	240
7.1 to 8.2	185
8.3 to 9.5	150
9.6 to 10.8	120
10.9 to 12.0	100
12.1 to 14.0	90
14.1 to 16.5	65
16.6 to 19.1	50
19.2 to 21.6	40
21.7 to 24.1	35
24.2 to 26.7	30
26.8 to 29.2	27
29.3 to 31.8	24
31.9 to 34.3	21
34.4 to 36.8	19
36.9 to 39.4	17
39.5 to 41.9	15
42.0 to 44.5	14
44.6 to 47.0	13
47.1 to 49.5	12
49.6 to 52.1	11
52.2 to 54.6	10
>54.7	<10

RELATIONAL TRENDS OF FRESH WATER FISH ACTIVITY TO TURBIDITY VALUES AND TIME



1. High turbidity hinders plant \_\_\_\_\_ and the production of which gas? \_\_\_\_\_

2. List four factors that can make water more turbid:

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3. Turbid waters often have a higher temperature because the suspended particles absorb \_\_\_\_\_.

4. Turbidity is measured in what units? \_\_\_\_\_

5. Would you more likely find more smallmouth bass or trout in waters that are very turbid? Give at least three reasons to support your hunch.

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6. How might a large change in the turbidity of stream water over a long period of time affect aquatic organisms?

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7. What might increased turbidity or lower transparency tell us about human activities within the watershed?

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8. When assessing transparency, you will take two measurements with the transparency tube and then calculate the average transparency (cm). Then you will convert the average transparency (cm) to turbidity (NTU). If your transparency tube readings were 106 cm and 98 cm, what is the average transparency? What turbidity does that convert to?

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9. You will soon be assessing the transparency of a stream near your school. Do you think that your stream will be very transparent or not? Why? Note your hypothesis for your stream site and your plan of how to research that hypothesis here:

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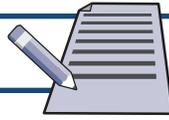
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STOP HERE  Go on field trip!!

Back in the



Classroom

## Calculating Transparency Statistics

### PROCEDURE:

1. Record all groups and their average transparency measurements (cm) in your student workbook (Table A).
2. For each average transparency measurement (cm), use the transparency value conversion chart (page 4-4) to determine the turbidity value in Nephelometric Turbidity Units (NTU). Record the turbidity values in your student workbook (Table A).
3. Then rewrite both lists in order from lowest to highest (Table B). Using a spreadsheet such as Excel may be helpful.
4. Determine the **average, median and mode** (optional) for transparency (cm) and turbidity (NTU), and record those in your student workbook (Table C). Use 9 to represent <10 NTU.
5. Determine the ranges of your transparency (cm) and turbidity measurements (NTU) by noting the lowest and the highest measurements recorded during the field trip. Indicate these ranges in your student workbook (Table C).
6. Answer the questions on the following page and write a conclusion paragraph or two about this **parameter**. You should state whether or not your hypotheses were correct and why or why not. You should also state the final results of the test (including average, median, range and mode) and what those results tell us about the stream quality. Also address any sources of error that may have influenced your results.



TRANSPARENCY TABLE C

	Transparency (cm)	Turbidity (NTU)
Average		
Median		
Low		
High		
Mode		

Does this stream meet the NTU requirements for human recreation? Consumption?

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Conclusions:

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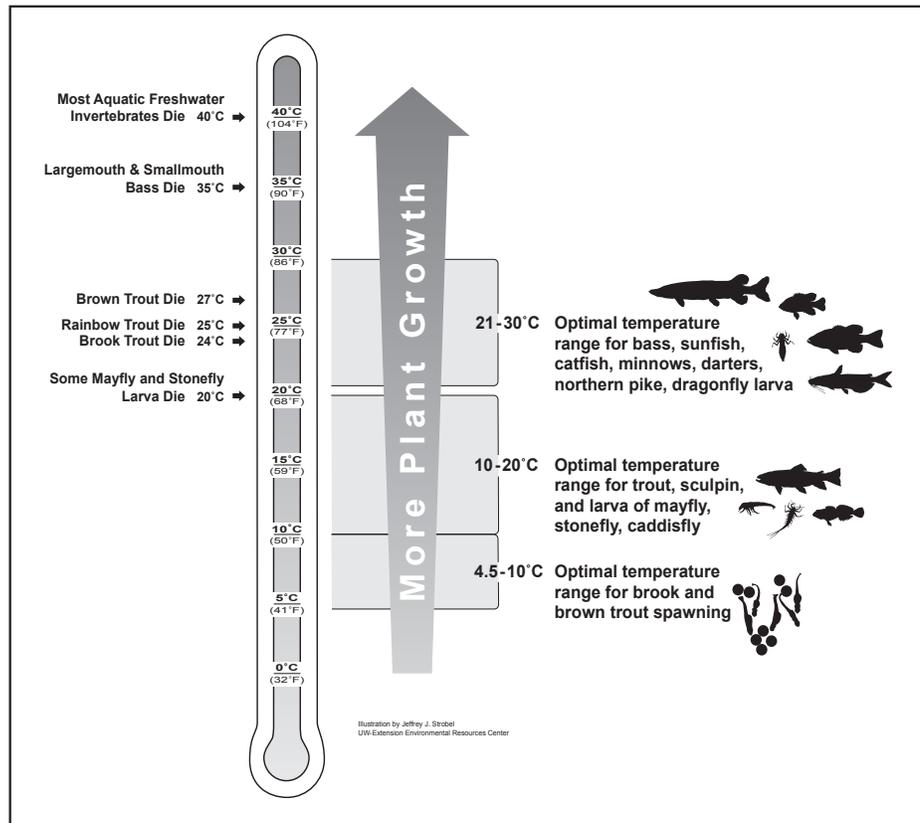
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# TEMPERATURE

- Although most aquatic life has adapted to survive within a range of water temperatures, some fish species (e.g., trout) require cooler waters. The metabolic rate of organisms, or the rate at which they convert food into energy, also increases with higher water temperatures, resulting in even greater demands on oxygen.
- Research also shows that extreme temperature fluctuations can make fish and insects more susceptible to disease, parasites and the harmful effects of toxic waste.

Stable water temperature is a critical factor in maintaining the health of a stream and its inhabitants. Temperatures over 75° F (24° C) for example, are usually fatal to brook trout, which need waters in the range of 55°-65° F (12.8°-18.3° C) in order to thrive. Other fish such as the smallmouth bass can survive to 90° F (35° C) and carp can live in even warmer waters. So as temperature increases, cold water species will gradually be replaced by warm water ones.



**THERMAL CRITERIA FOR COLD, COOL AND WARM WATER STREAMS IN WISCONSIN**

Thermal regime	Maximum instantaneous temperature	Maximum daily mean temperature
Cold water stream	<25°C (77°F)	<22°C (72°F)
Cool water stream	25-28°C	22-24°C
Warm water stream	>28°C (82°F)	>24°C (75°F)

The table to the left shows temperature ranges for cold, cool and warm streams.

One of the most drastic ways that stream temperature is increased is by thermal pollution. Thermal pollution occurs when warm water is added to the stream. Industries such as power plants, paper mills and cheese

factories may discharge heated water used in the manufacturing process into streams. Runoff, in a more indirect way, can also add warm water to streams. Rainwater running off warmed surfaces, especially parking lots, roof tops and roads, increases stream temperatures.

Mill ponds and impoundments also increase water temperature because they contain a large surface area of slow-moving water which is warmed by the sun, affecting water temperature downstream.

Removing all overhanging trees that shade and cool the stream can also negatively impact stream temperatures. Another factor contributing to higher stream temperatures is eroding soil. Turbid water that results from eroded soil heats up quickly because the suspended sediments absorb the sun's radiant heat. Sediment also makes stream channels shallow. A shallow stream warms up faster than deep waters.

Temperature changes can affect all aquatic life. For example, warm water holds less dissolved oxygen than cold water and triggers higher plant growth and respiration rates. The lowered oxygen levels of warmer waters are further reduced when plants and animals die and decay.

For additional information about water temperature, visit this website:

<http://watermonitoring.uwex.edu/wav/monitoring/temp.html>

1. Warm water holds less \_\_\_\_\_ than cold water.
2. Increased temperatures trigger \_\_\_\_\_ plant growth and \_\_\_\_\_ rates.
3. \_\_\_\_\_ decisions and stream \_\_\_\_\_ are often closely tied to water temperatures.
4. The water temperature of Stream X measured 27° C. What type of fish might you expect to find living here? What factors may be impacting the temperature of this stream? Explain.

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5. If you were a developer in a local community, what are some things you might do to minimize changes in stream water temperature?

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6. What impacts would drastic fluctuations in water temperature have on life in the stream?

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7. You will soon be measuring water temperature at a stream near your school. What water temperature do you expect to find? Why? Note your hypothesis for your stream site and your plan for how to research that hypothesis here:

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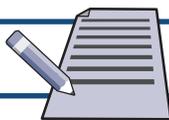
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Back in the



Classroom

## Calculating Temperature Statistics

### PROCEDURE:

1. Record all groups and their measured air and water temperatures ( $^{\circ}\text{C}$ ) in your student workbook (Table A).
2. Then rewrite the lists in order from lowest to highest (Table B). Using a spreadsheet such as Excel may be helpful.
3. Determine the average, median and mode (optional) for water and air temperatures and record those in your student workbook (Table C).
4. Determine the range of water and air temperatures by noting the lowest and the highest water and air temperatures recorded during the field trip. Indicate these ranges in your student workbook (Table C).
5. Use the conversion chart on page 4-15 to convert the average, median, mode (if determined) and low and high water and air temperatures to  $^{\circ}\text{F}$ . Record this information in your student workbook (Table C).
6. Write a conclusion paragraph or two about this parameter. You should state whether or not your hypotheses were correct and why or why not. You should also state the final results of the test (including average, median, range and mode) and what those results tell us about the stream quality. Also address any sources of error that may have influenced your results.



TEMPERATURE  
CONVERSION  
CHART

°F	°C
33	.6
34	1.1
35	1.7
36	2.2
37	2.8
38	3.3
39	3.9
40	4.4
41	5
42	5.6
43	6.1
44	6.7
45	7.2
46	7.8
47	8.3
48	8.9
49	9.4
50	10
51	10.6
52	11.1
53	11.7
54	12.2
55	12.8
56	13.3
57	13.9
58	14.4
59	15
60	15.6
61	16.1
62	16.7
63	17.2
64	17.8
65	18.3
66	18.9
67	19.4
68	20
69	20.6
70	21.2
71	21.7
72	22.2
73	22.8
74	23.3
75	23.9
76	24.4
77	25
78	25.6
79	26.1
80	26.7
81	27.2
82	27.8
83	28.3
84	28.9
85	29.4
86	30
87	30.6
88	31.1

TEMPERATURE TABLE C

	Water Temperature (°C)	Water Temperature (°F)	Air Temperature (°C)	Air Temperature (°F)
Average				
Median				
Low				
High				
Mode				

Conclusions:

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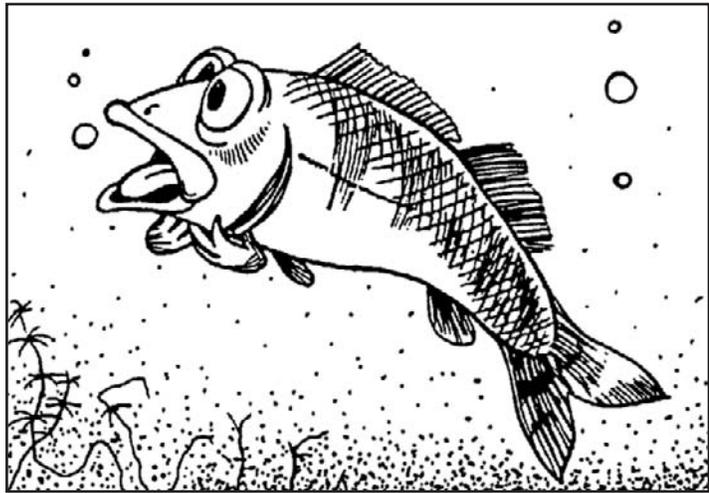
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## DISSOLVED OXYGEN

- *All plants and animals require oxygen for survival.*
- *Dissolved oxygen levels in streams fluctuate over the course of 24 hours.*
- *Cold water can hold more dissolved oxygen than warmer water.*

Oxygen is a clear, colorless, odorless and tasteless gas that dissolves in water. Small but important amounts of it are dissolved in water. It is supplied by **diffusion** of atmospheric (air) oxygen into the water and by production of oxygen from photosynthesis by aquatic plants. Wind, waves and tumbling water in fast-moving streams increase the rate of diffusion.

Both plants and animals depend on dissolved oxygen for survival. Lack of dissolved oxygen can cause aquatic animals (e.g., fish, macroinvertebrates) to quickly leave the area or face death. Under low oxygen conditions, the aquatic animal community changes quickly. Under extreme conditions, lack of oxygen can kill aquatic plants and animals. Measuring dissolved oxygen is probably the most significant water quality test to determine the suitability of a stream for fish and many other aquatic organisms. However, these measures only provide a snapshot of the oxygen levels at that particular time. Levels can fluctuate widely throughout the day and year. Fish and other organisms have to live and breathe in that water all year long. A short time without oxygen can be fatal.



Dissolved oxygen (D.O.) is reported as milligrams of oxygen per liter of water (mg/L) which can also be called parts per million (ppm) by weight. Different aquatic organisms have different oxygen needs. Trout and stoneflies, for example, require high dissolved oxygen levels. Trout need water with at least 6 mg/L D.O. Warm water fish like bass and bluegills survive nicely at 5 mg/L D.O. and some organisms such as carp and bloodworms can survive in streams with less than 1 mg/L of D.O. Based on this, there are stream classifications in Wisconsin that define the minimum amount of oxygen that must be maintained in a stream with a given classification (see charts on the next page).

The oxygen demand of aquatic plants and **cold-blooded** animals also varies with water temperature. A trout uses five times more oxygen while resting at 80° F (26.7° C) than at 40° F (4.4° C).

There are many factors that affect the amount of dissolved oxygen in the water (see chart below). A major one is photosynthesis. Aquatic plants produce oxygen by photosynthesis during daylight hours, but they also use oxygen for respiration. High day-time levels of D.O. are often countered with low night-time levels

(see a sample diel cycle for dissolved oxygen on the next page). This is due to respiration of living organisms, including fish, bacteria, fungi and protozoans, as well as the cessation of photosynthesis. Wide daily fluctuations of D.O. stress fish and other aquatic animals. Oxygen depletion can occur because of heavy plant growth. Complete depletion of D.O. can sometimes be detected with your nose. Anaerobic decay results in a rotten egg smell (hydrogen sulfide gas).

**MINIMUM DISSOLVED OXYGEN LEVELS ALLOWED FOR WATERS WITH VARIED CLASSIFICATIONS IN WISCONSIN**

Stream Classification	Minimum Dissolved Oxygen Allowed
Trout waters	6 mg/l (out of spawning season) and 7 mg/L (during spring/fall spawning season)
Fish or aquatic life-designated waters	5 mg/L
Limited forage fish waters	3 mg/L
Limited aquatic life waters	1 mg/L

**DISSOLVED OXYGEN REQUIREMENTS OF AQUATIC PLANTS AND ANIMALS**

Very High D.O.	Moderately High D.O.	Low D.O.
A N I M A L S		
Brook or rainbow trout	Brown trout	Carp
Mottled sculpin	Redbelly dace	Green sunfish
	Bass	Fathead minnow
P L A N T S		
Much plant variety	Moderate plant variety	Little plant variety

Source: Dane County Water Watchers

Factors That Could <b>Increase</b> The Amount of Dissolved Oxygen in Water	Factors That Could <b>Decrease</b> The Amount of Dissolved Oxygen in Water
<ul style="list-style-type: none"> <li>• High atmospheric pressure</li> <li>• Clear water</li> <li>• Photosynthesis</li> <li>• Much turbulence/wave action</li> <li>• Cold water</li> <li>• Presence of excessive amounts of plants (during daytime)</li> </ul>	<ul style="list-style-type: none"> <li>• Respiration of animals and plants living in the water</li> <li>• Chemical reactions of the decaying process</li> <li>• Low atmospheric pressure</li> <li>• High levels of turbidity (such as from erosion)</li> <li>• Warm water</li> <li>• Presence of excessive amounts of plants (during nighttime)</li> <li>• Excessive organic materials (such as sewage, manure or fertilizers)</li> </ul>

However, oxygen levels can be improved with good management practices such as planting or maintaining vegetation that filters rainwater runoff and shades the water, and protecting the stream channel in other ways to maintain or increase turbulence.

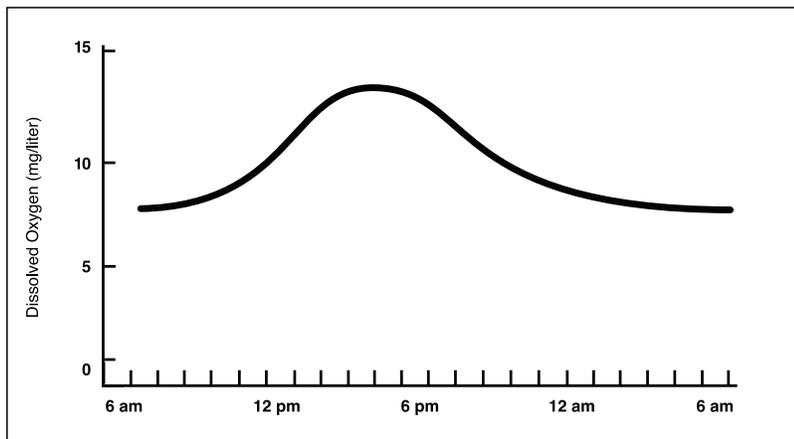
Recording dissolved oxygen differs from other tests in that it requires two distinct calculations. We are interested in both the absolute amount of D.O. and how close the value is to the equilibrium value for that temperature and air pressure (known as the percentage of saturation). Values between 91% and 110% of saturation are excellent. **Supersaturated** (over 100%) values may sound good but they can also indicate problems, such as excessive plant growth.

You can assess the range of dissolved oxygen levels that aquatic plants and animals at your stream site must withstand by monitoring twice in one day – early in the morning just before sunrise, and later in the afternoon when plants have been exposed to the most direct sunlight for an extended period.

For additional information about monitoring dissolved oxygen visit this website:

<http://watermonitoring.uwex.edu/wav/monitoring/oxygen.html>

SAMPLE DIEL FLUCTUATION OF DISSOLVED OXYGEN IN A STREAM



Dissolved Oxygen Levels (% Saturation)
Excellent: 91-110
Good: 71-90
Fair: 51-70

SOURCE: Field Manual for Water Quality Monitoring (13th Edition)

1. How does oxygen get into the water?

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2. What factors affect the levels of dissolved oxygen in the water?

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3. When is oxygen consumed in streams?

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4. What is the problem with wide fluctuations in dissolved oxygen?

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5. The dissolved oxygen level of the water in Stream Z was recently tested. It was found to have a dissolved oxygen level of 4 ppm. Is this considered low or high?

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6. Which organisms might you expect to find thriving in Stream Z?

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7. Based on this dissolved oxygen level (of 4 ppm), what might you expect to be true about the transparency and temperature of the stream?

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8. Explain why dissolved oxygen levels may be higher in the day and lower at night. What other variables can cause changes in the dissolved oxygen levels?

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9. You will soon be testing the dissolved oxygen content of a stream near your school. Make a hypothesis. Do you think that your stream will have high or low levels of dissolved oxygen? Why? Note your hypothesis for your stream site and your plan for how to research that hypothesis here:

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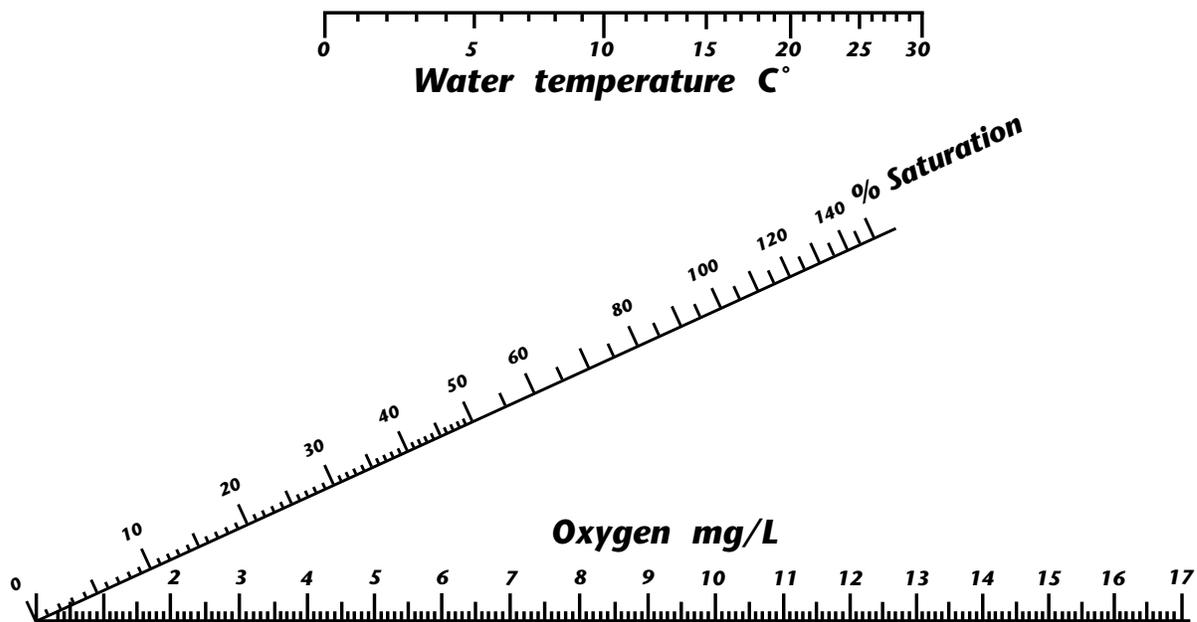


Back in the  Classroom

### Calculating Dissolved Oxygen Statistics

1. Record all groups and their dissolved oxygen measurements (mg/L) and water temperature (°C) measurements in your student workbook (Table A).
2. Determine dissolved oxygen percent saturation for each pair of dissolved oxygen and water temperature measurements using the Level of Oxygen Saturation Chart and following directions in step 3.

LEVEL OF OXYGEN SATURATION CHART



3. Using a straight edge, find the water temperature and align that with the oxygen mg/L scale for the oxygen measurement for that water temperature. The percentage of saturation is found on the line inbetween the temperature and oxygen lines. For example, 5°C with 10 mg/L of oxygen aligns with 75% saturation.
4. Record each dissolved oxygen percent saturation measurement in your student workbook (Table A).
5. Then rewrite the lists of dissolved oxygen in mg/L and percent saturation in order from lowest to highest (Table B). Using a spreadsheet such as Excel may be helpful.

(CONTINUED ON NEXT PAGE)

6. Determine the average, median and mode (optional) for dissolved oxygen in mg/L and in % saturation and record these in your student workbook (Table C).
7. Determine the range of dissolved oxygen measurements in mg/L and in % saturation by noting the lowest and the highest measurements recorded during the field trip. Indicate these ranges in your student workbook (Table C).
8. Write a conclusion paragraph or two about this parameter. You should state whether or not your hypotheses were correct and why or why not. You should also state the final results of the test (including average, median, range and mode) and what those results tell us about the stream quality. Describe results in terms of both mg/L and percent saturation. Also address any sources of error that may have influenced your results.



DISSOLVED OXYGEN TABLE C

	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% saturation)
Average		
Median		
Low		
High		
Mode		

**Conclusions:**

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## STREAM FLOW

- *Stream flow is a measure of the volume of water moving past a point during a span of time.*
- *Stream flow is affected by runoff of rain or snowmelt to the stream from the surrounding **watershed**, and also by groundwater inputs.*

Stream flow, or **discharge**, is the volume of water moving past a cross-section of a stream over a set period of time. It is usually measured in cubic feet per second (cfs). Stream flow is affected by the amount of water within a watershed – increasing with rainstorms or snowmelt, and decreasing during dry periods. Flow is also important because it defines the shape, size and course of the stream. It is integral not only to water quality, but also to habitat. Food sources, spawning areas and migration paths of fish and other wildlife are all affected and defined by stream flow and velocity. Velocity and flow together determine the kinds of organisms that can live in a stream (some need fast-flowing areas; others need quiet, low-velocity pools). Different kinds of vegetation require different flows and velocities as well.

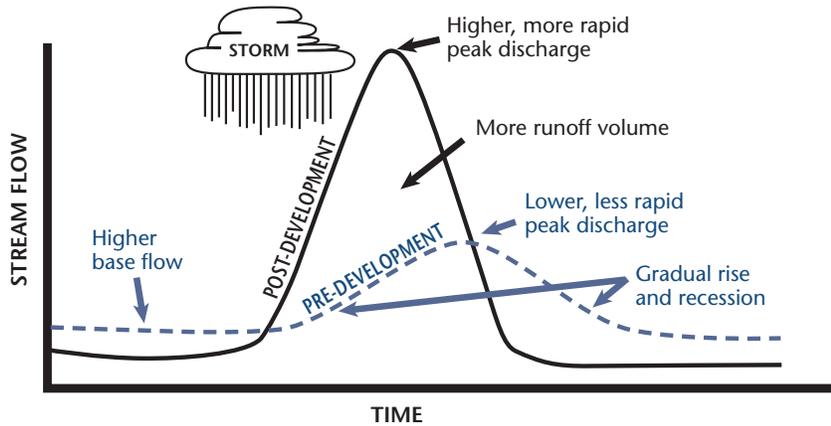


Stream flow is affected by both forces of nature and by humans. In undeveloped watersheds, soil type, vegetation and slope all play a role in how fast and how much water reaches a stream. In watersheds with high human impacts, water flow might be depleted by withdrawals for irrigation, domestic or industrial purposes. Dams used for electric power generation may affect flow, particularly during periods of peak need when stream flow is held back and later released in a surge. Drastically altering landscapes in a watershed, such as with development, can also change **flow regimes**. For instance, increasing areas of **impervious surface** causes faster runoff during storm events and higher peak flows. These altered flows can negatively affect an entire ecosystem by upsetting habitats and organisms dependent on natural flow rates.

Tracking stream flow measurements over a period of time can give us baseline information about the stream’s natural flow rate.

For more information about stream flow, visit this website:

<http://watermonitoring.uwex.edu/wav/monitoring/flow.html>



A hydrograph is a graph that shows stream flow over time. This hydrograph shows how stream flow changes as a watershed goes from a natural land cover (pre-development) to an urbanized land cover (post-development).

1. What is stream flow?

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2. What units are used to measure stream flow? \_\_\_\_\_

3. Name at least three ways that humans can alter stream flow:

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4. Name at least four ways that changes in stream flow can affect fish:

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5. Why would a stream in the forest have lower peak flows following a rain storm than a stream of the same size in a city?

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6. You will soon be measuring stream flow at a stream near your school. What flow do you expect to find? Why? Note your hypothesis for your stream site here:

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STOP HERE
Go on field trip!!

# Back in the Classroom

## Calculating Stream Flow Statistics

**PROCEDURE:**

1. Obtain your original stream flow data sheet from your teacher.
2. Transfer your data onto the data sheet below.
3. Determine stream flow in cubic feet per second using the data you collected by following instructions in the data sheet below, or steps 4 to 9.

(CONTINUED ON NEXT PAGE)

Inches	Tenths of ft.
3/8-7/8	0.05
1-1 1/2	0.1
1 3/8-2	0.15
2 1/8-2 3/8	0.2
2 3/4-3 1/4	0.25
3 3/8-3 7/8	0.3
4-4 3/8	0.35
4 1/2-5	0.4
5 1/8-5 5/8	0.45
5 3/4-6 1/4	0.5
6 3/8-6 7/8	0.55
7-7 3/8	0.6
7 1/2-8	0.65
8 1/8-8 3/8	0.7
8 3/4-9 1/4	0.75
9 3/8-9 7/8	0.8
10-10 3/8	0.85
10 1/2-11	0.9
11 1/8-11 3/8	0.95
11 3/4-12	1.0

**1. SITE LOCATION**

Length Assessed:  ft.

**2. STREAM WIDTH & DEPTH**

If stream ≤ 20 ft. wide, measure depth every foot across the width. If stream is > 20 ft. wide, measure depth at 20 equal intervals across the entire width.

Stream Width:  ft.

Interval	Depth (ft./in.)	Depth (10 <sup>ths</sup> ft.)	Interval	Depth (ft./in.)	Depth (10 <sup>ths</sup> ft.)
1	0	0	11		
2			12		
3			13		
4			14		
5			15		
6			16		
7			17		
8			18		
9			19		
10			20		

ft. ←Add together→  ft.

$$\frac{\text{sum of depths}}{\text{\# of intervals}} = \text{Average Depth}$$

Compute Average Cross-Sectional Area:

$$\text{average depth} \times \text{width} = \text{Cross-Sectional Area}$$

**3. VELOCITY MEASUREMENT**

Float Trials	Time (seconds)
1	
2	
3	
4	

$$\frac{\text{sum}}{\text{\# of trials}} = \text{Average Float Time}$$

$$\frac{\text{length assessed}}{\text{average float time}} = \text{Average Surface Velocity}$$

**4. CALCULATING STREAM FLOW**

Correction value for rough, loose, coarse, weedy bottom..... 0.8  
 Correction value for smooth bottom..... 0.9

$$\text{correction value} \times \text{average surface velocity} = \text{Corrected Surface Velocity}$$

**STREAM FLOW:**

$$\text{cross-sectional area} \times \text{corrected surface velocity} = \text{cubic feet per sec. (round to nearest tenth)}$$

4. If you measured depth in inches, use the conversion chart to determine each depth in tenths of feet, or simply divide each depth by 12 to convert to tenths of feet.
5. Determine the average depth at your monitoring site and record this in the appropriate location on your data sheet.
6. Next, multiply your average depth by the stream width. This is the cross-sectional area (ft<sup>2</sup>) of the stream. Record this in the appropriate box on your data sheet.
7. Determine the average float time (seconds) and record it on your data sheet.
8. Divide the length of your stream segment (i.e., 20 feet) by the average float time (seconds) to determine the average surface velocity at the site. Record the average surface velocity (ft/sec) on your data sheet.
9. Determine the correction factor below that best describes the bottom of your stream and multiply it by the average surface velocity measurement to account for the effects of friction with the stream bottom on water velocity. Record your corrected average surface velocity on your data sheet.
  - a) Correction factor for rough, loose rocks, coarse gravel or weeds: 0.8
  - b) Correction factor for smooth mud, sand or bedrock: 0.9
10. Multiply the average cross-sectional area (ft.<sup>2</sup>) by the corrected average surface velocity (ft/sec) to determine stream flow. Record stream flow (ft.<sup>3</sup>/sec or cfs) in the space provided on your data sheet.
11. Report this result to your teacher so other students in the class can obtain this information.
12. Once you have a complete list of stream flow measurements in cfs from everyone in your class, record these measurements in your student workbook (Table A). Then rewrite them in order from lowest to highest in Table B. Using a spreadsheet such as Excel may be helpful.
13. Determine the average, median and mode (optional) for stream flow for all samples collected and record these in your student workbook.
14. Determine the range of stream flow measurements by noting the lowest and the highest measurements recorded during the field trip and indicate this information in your student workbook.
15. Write a conclusion paragraph or two about this parameter. You should state whether or not your hypotheses were correct and why or why not. You should also state the final results of the test (including average, median, range and mode) and what those results tell us about the stream quality. Also address any sources of error that may have influenced your results.



STREAM FLOW TABLE C

	Stream Flow (cfs)
Average	
Median	
Low	
High	
Mode	

Consider factors that would influence stream flow. Were there any notable events that would make you believe that this stream flow measurement is higher or lower than the average for this stream? (For example: recent rain or drought, recent snow melt, dam release, etc.):

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**Conclusions:**

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## HABITAT ASSESSMENT

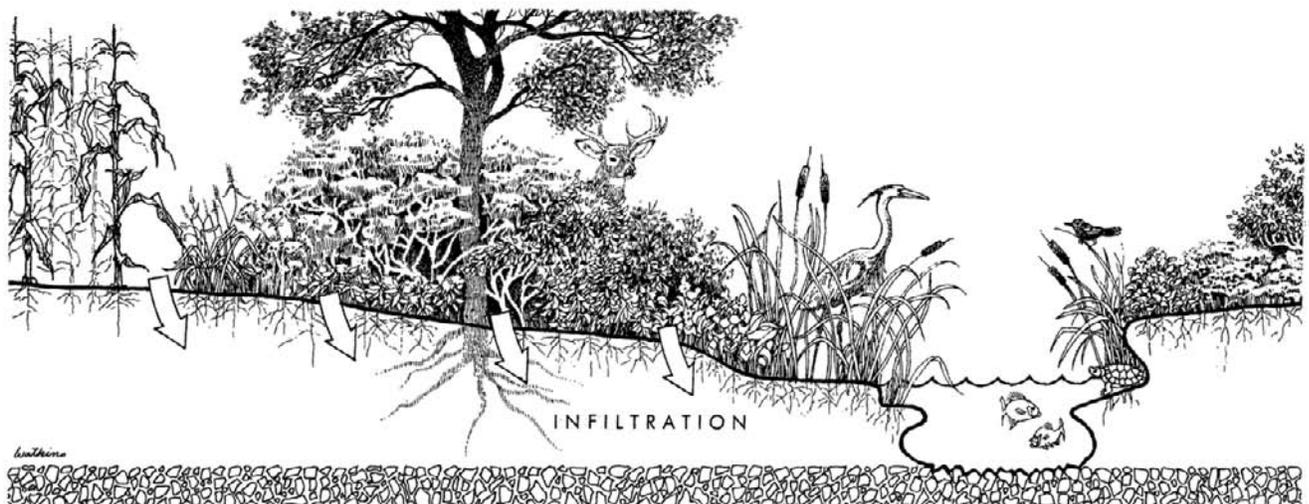
- *The habitat functions holistically, so any changes to a part may affect the entire habitat.*
- *Certain land uses affect habitat quality and stream health.*
- *The Habitat Checklist uses visual measurements of land and water conditions to help pinpoint land uses affecting water quality.*

A healthy stream is a busy place. Wildlife find shelter and food near and in its waters. Vegetation grows along its banks, shading the stream and filtering pollutants before they enter the stream. Within the stream are fish, insects and other tiny creatures with specific needs: dissolved oxygen to breathe; rocks, overhanging tree limbs, logs and roots for shelter; vegetation and other tiny animals to eat; and special places to breed and hatch their young. For any of these activities, organisms might also need water of specific velocity, depth and temperature. Many land-use activities can alter these characteristics, causing problems within the entire habitat. The Habitat Assessment is an easy-to-use approach for identifying and assessing the elements of a stream's habitat. This assessment is useful as: 1) a screening tool to identify habitat stressors and 2) a method for learning about stream ecosystems and environmental stewardship.



A stream with a healthy riparian zone.

Taking stock of the habitat's characteristics may begin at the **riparian zone** where land is making a transition into water. Within healthy stream corridors, this area generally has certain



This healthy vegetated buffer in the riparian zone allows runoff water to infiltrate into the ground instead of rushing into the stream unfiltered. Note the vegetated undercut bank on the right, which provides animal habitat and is resistant to erosion.

kinds of vegetation that act as a buffer between land and water, soaking up many pollutants carried in runoff. Moving on, the stream assessment will then focus on the condition of the upper and lower banks and finally the stream channel and stream itself. In order to help prepare you to fill out the Habitat Checklist, certain stream and river characteristics and concepts are defined in the following text.

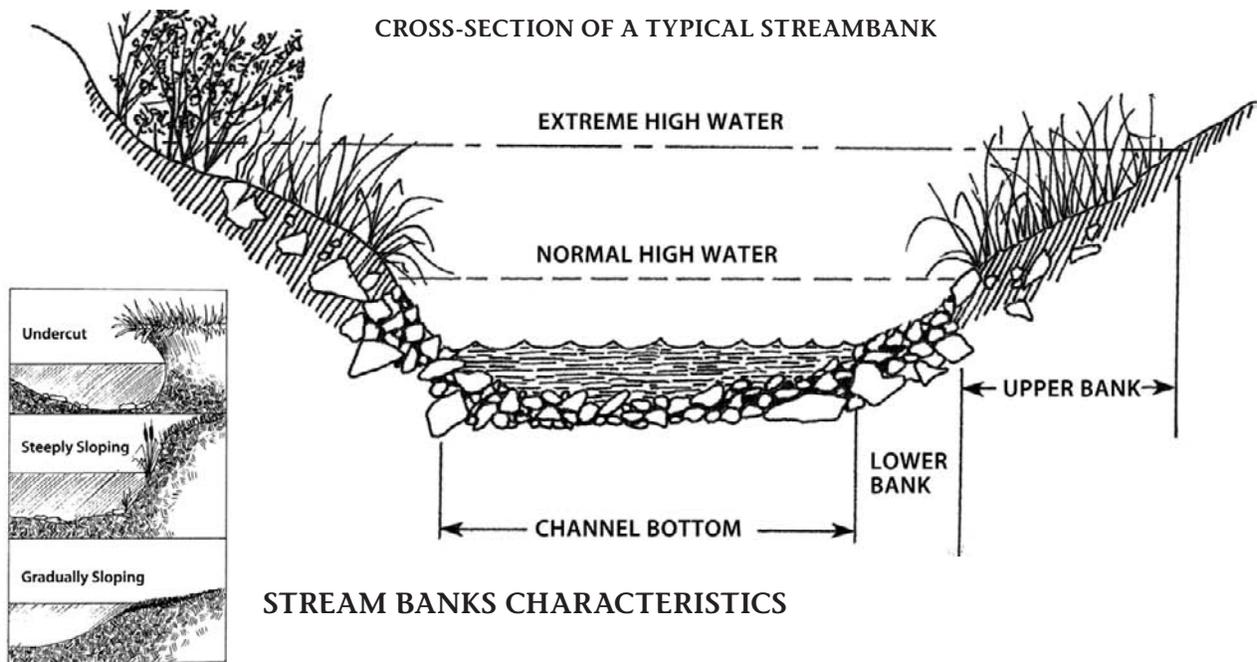
## RIPARIAN ZONE

The healthy riparian zone is characterized by trees, bushes, shrubs and tall grasses that help to buffer the stream from polluted runoff and create habitat for fish and wildlife. These plants also provide stream shading (or overhead canopy) and serve several important functions in the stream habitat. The canopy helps keep water temperatures cool by shading the water from the sun, while offering protection and refuge for animals.

Certain conditions in the riparian zone can negatively affect the stream's habitat. Lawns maintained to the water's edge are abrupt transitions from land to water, offering very little or no buffering protection for the stream. In these cases, lawn care products and grass clippings could be entering the stream. Short-grassed streambanks also provide poor habitat for animals. Bare soil and pavement provide no buffering action from runoff.

Features to note in riparian zones:

- Evergreen trees (conifers) – cone-bearing trees that do not lose their leaves in winter.
- Hardwood trees (deciduous) – in general, trees that shed their leaves at the end of the growing season.
- Bushes – short conifers or deciduous shrubs less than 15 feet high.
- Tall grass, ferns, etc. – includes tall, natural grasses, ferns, vines and mosses.
- Lawn – cultivated and maintained short grass.
- Boulders – rocks larger than 10 inches.
- Gravel/cobbles/sand – rocks smaller than 10 inches in diameter; sand.
- Bare soil
- Pavement or structures – any structures or paved areas, including paths, roads, bridges, houses, etc.
- Garbage or junk adjacent to the stream – note the presence of litter, tires, appliances, car bodies or other large objects.



### STREAM BANKS CHARACTERISTICS

The streambank consists of the **upper bank** and **lower bank**. The shape and condition of the streambank can give many clues to the types of land uses in the adjacent watershed. For example, sometimes the channel may be altered by too much water flooding the stream in a short time. This may indicate a nearby urban area with many impervious surfaces, so the rain or melting snow cannot naturally soak into the ground. Large volumes of runoff then flood the nearest stream with too much water, which erodes and distorts the stream channel. Sometimes it is obvious that the banks have been eroded by excessive water because the normal flow does not reach the new shoreline which has been pushed back.

A **vertical** or **undercut bank** rises vertically (at an approximate 90-degree angle) or overhangs the stream. This type of bank generally provides good cover for aquatic invertebrates (small animals without backbones) and fish, and is resistant to erosion. This bank usually has a good vegetative cover that helps to stabilize the bank. If seriously undercut, however, the bank could collapse.



A stream with a gradually sloping bank.

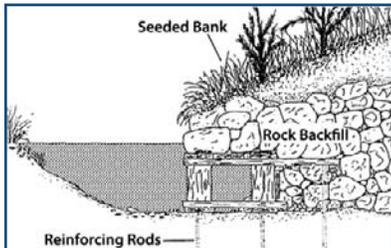
A **steeply sloping bank** (right) slopes at more than a 45-degree angle. This type of bank is very vulnerable to erosion.

A **gradually sloping bank** (left) has a slope of about 30 degrees or less. Although this type of streambank is highly resistant to erosion, it does not provide much streamside cover.



A steeply sloping bank with severe erosion.

**Artificial bank modifications** include ditching and other changes such as concrete embankments and gabions to stem further erosion due to the action of the water. Also included are LUNKER structures which are



LUNKER structure.

wooden underwater habitats set into the bank and designed for trout and other game fish. Rock rip rap placed at bends and other areas subject to erosion serve to improve

fish habitat and stabilize stream meanders.

Poor streambank conditions can include the loss of natural plant cover. Erosion can occur when streamside vegetation is trampled or missing or has been replaced by poorly designed landscaping or pavement. More severe cases of streambank erosion include washed away banks or banks that have collapsed. Excessive mud or silt entering the stream from erosion can distort the stream channel, and interfere with beneficial plant growth, dissolved oxygen levels and the ability of fish to sight prey. It can also irritate fish gills and smother fish eggs in spawning areas. Often it is the result of eroding streambanks, poor construction site practices, urban area runoff, silviculture (forestry practices) or ditches that drain the surrounding landscape.



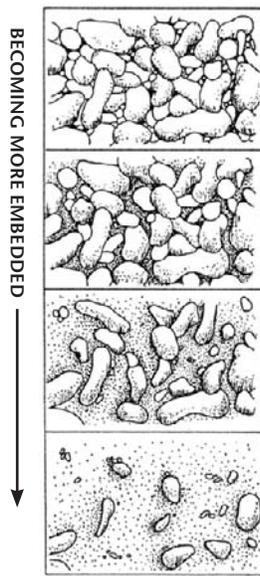
A stream with a fortified concrete embankment.



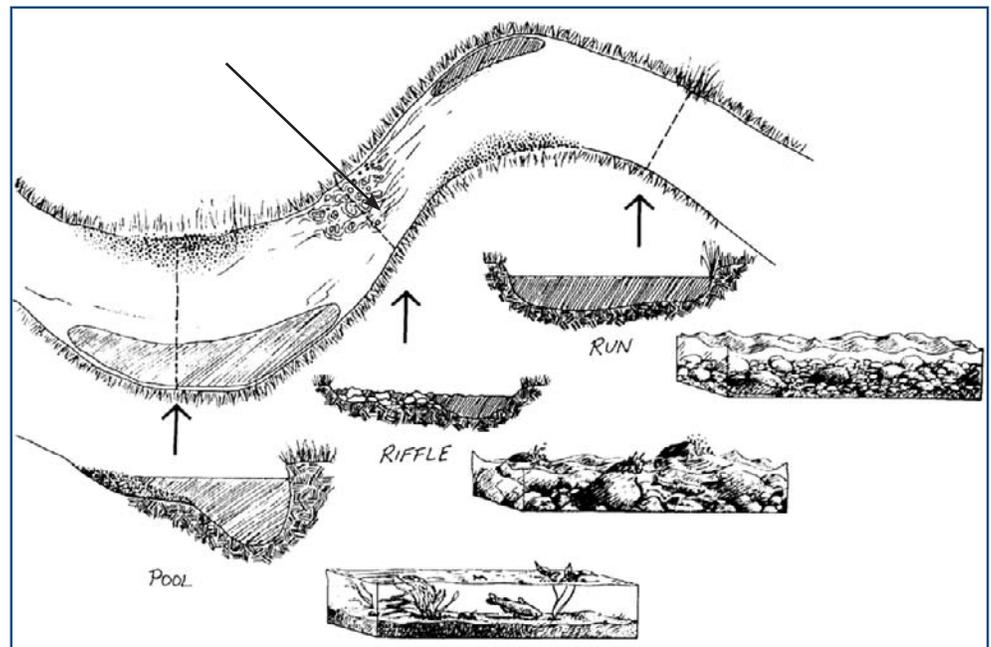
A rocky-bottom stream with lots of riffles and fast, turbulent shallow water.

## IN-STREAM CHARACTERISTICS

Stream bottoms (substrate) are classified according to the material that they are made of. Rocky-bottom streams are defined as those made up of gravel, cobbles and boulders in any combination. They usually have definite **riffle** areas. Soft-bottom streams have naturally muddy, silty or sandy bottoms that lack riffles. Usually, these are slow-moving, low-gradient streams (i.e., streams that flow along flat terrain). A different questionnaire for each type of stream bottom has been designed for you to use.



A rocky-bottom stream becomes embedded with sand. As sand settles on the streambed, spaces between the rocks fill up.



A stream with a mixture of pools, riffles and runs. Varying flows and depths create a variety of habitats for macroinvertebrates.

Substrate types include:

*Silt/clay/mud* – This substrate has a sticky feeling. The particles are fine. The spaces between the particles hold a lot of water, making the sediments feel like ooze.

*Sand* (up to 0.1 inch) – A sandy bottom is made up of tiny, gritty particles of rock that are smaller than gravel but coarser than silt (gritty, particles are smaller than a grain of rice).

*Gravel* (0.1-2 inches) – A gravel bottom is made up of stones ranging from tiny quarter-inch pebbles to rocks of about 2 inches (fine gravel is rice size to marble size; coarse gravel is marble to ping pong ball size).

*Cobbles* (2-10 inches) – Most rocks on this type of stream bottom are between 2 and 10 inches (between a ping pong ball and a basketball in size).

*Boulders* (greater than 10 inches) – Most of the rocks on the bottom are greater than 10 inches (between a basketball and a car in size).

*Bedrock* – This kind of stream bottom is solid rock (or rocks bigger than a car).

*Embeddedness* is the extent to which rocks (i.e., gravel, cobbles and boulders) are buried by silt, sand or mud on the stream bottom. Generally, the more embedded the rocks, the less rock

surface or space between rocks there is available for **aquatic macroinvertebrate** habitat and for fish spawning. Excessive silty runoff from erosion can increase a stream's embeddedness. To calculate embeddedness, estimate the amount of silt or finer sediments overlying, inbetween, and surrounding the rocks (see diagram on previous page).

Presence of logs or woody debris in streams can provide important fish habitat. Be sure to differentiate between logs or woody debris and naturally occurring or moderate amounts of organic material in streams, which includes leaves and twigs.

## WATER CHARACTERISTICS

Streams are made up of **pools, riffles and runs**. A mixture of flows and depths creates a variety of habitats to support fish and invertebrate life.

- Riffles are shallow with fast turbulent water running over rocks.
- Runs are deeper with fast-moving water with little or no turbulence.
- Pools are deep with slow water.

Stream velocity influences the health, variety and abundance of aquatic animals. If water flows too quickly, some organisms might be unable to maintain their hold on rocks and vegetation, and they may be flushed downstream. If water flows too slowly, oxygen **diffusion** might be insufficient for species needing high levels of dissolved oxygen. Dams, channelization or straightening out the stream's natural bends (sinuosity), certain kinds of terrain, runoff and other factors can also affect stream velocity.

Rooted aquatic plants provide food and cover for aquatic organisms. They can also indicate water quality problems. Sometimes, excess nutrients may flush into the stream and stimulate unnatural aquatic plant growth. To decide if there are too many plants, compare the amount of plants in your stream to other streams in the area with varied land uses in their watersheds.

Algae are simple plants that do not grow true roots, stems or leaves, and that mainly live in water, providing food for animals low on the food chain. Algae may be green or brown, grow on rocks, twigs or other submerged materials, or float in the water. Excessive algal growth may indicate excessive nutrients (e.g., organic matter or a pollutant such as fertilizer) in the stream.

**What do Habitat Assessments Mean?** Each stream will have a unique habitat assessment value ranging between 13 (worst) and 52 (best). This value is an important baseline measure for future comparisons. By comparing specific habitat parameter scores (between years at one site or

between sites in small watersheds) the connection between land use and aquatic habitat may be better understood.

For more information about habitat, visit this website:

<http://watermonitoring.uwex.edu/wav/monitoring/habitat.html>

1. Why do you think it is important to include a quantitative habitat assessment when evaluating the health of a stream?

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2. Why is it important for a stream to have a healthy riparian zone?

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3. What types of habitat would support a more diverse fish and aquatic insect population?

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4. You will soon be assessing habitat at a stream near your school. What habitat score do you expect to find? Why? (A total score of between 13 and 52 is possible, the higher the score, the healthier the stream.) Note your hypothesis for your stream site and your plan for how to research that hypothesis here:

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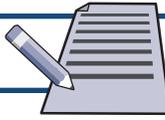
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STOP HERE



Go on field trip!!

Back in the



Classroom

## Calculating Habitat Statistics

### PROCEDURE:

1. Record all groups and their total habitat scores in your student workbook (Table A).
2. Then rewrite the list in order from lowest to highest (Table B). Using a spreadsheet such as Excel may be helpful.
3. Determine the average, median and mode (optional) for the habitat scores and record these in your student workbook (Table C).
4. Determine the range of habitat scores by noting the lowest and the highest measurements recorded during the field trip and indicate this in your student workbook (Table C).
5. Write a conclusion paragraph or two about this parameter. You should state whether or not your hypotheses were correct and why or why not. You should also state the final results of the test (including average, median, range and mode, and type of bottom substrate (i.e., rocky or soft)) and what those results tell us about the stream quality. Also address any sources of error that may have influenced your results. Tip: You can use the individual questions' scores on the Station Leader data sheet to assist with your assessment of habitat at the site.



HABITAT TABLE C

	Habitat Score
Average	
Median	
Low	
High	
Mode	

What evidence of human impact on this environment did you observe?

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Conclusions:

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## BIOTIC INDEX

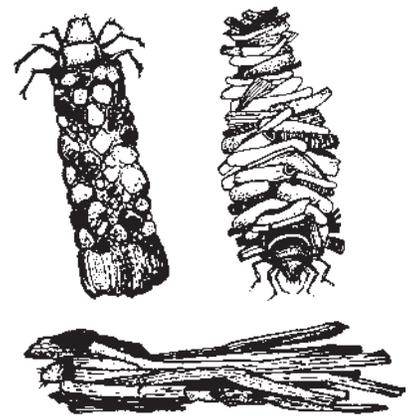
- *Aquatic macroinvertebrates are small animals without backbones. Their presence or absence can reflect a stream's general condition.*
- *Certain macroinvertebrates respond differently to the physical, chemical and biological conditions within a stream.*
- *Aquatic macroinvertebrates are relatively immobile, so they can't escape either short-term or long-term pollution exposure. This is important when assessing long-term pollution events within the stream.*

From the crayfish burrowing in the streambed to the tiny aquatic insects skirting the water's surface, streams and rivers swarm with life. The inhabitants of this living place are affected by poor water quality just like humans are affected by an unhealthy environment. However, scientists have found that not all aquatic organisms react the same to poor water quality. Some species are pollutant-tolerant while some are very pollutant-sensitive. From this knowledge, a scale was developed to determine water quality based on the types of life found in the water.

For example, streams with primarily pollutant-tolerant organisms generally have poorer water quality than those streams with many pollutant-sensitive animals. This is because streams that become more polluted gradually lose pollutant-sensitive animals until only the pollutant-tolerant species are left. A healthy stream will have many different organisms, both pollutant-tolerant and those sensitive to pollution.

Although relatively accurate in assessing stream conditions, the **Citizen Monitoring Biotic Index** does have its limitations. The biotic index can indicate a problem, but it cannot specify what that problem might be. For example, manure, sewage, fertilizers, sediment and organic materials all negatively impact water quality. In order to pinpoint these possible pollutant sources, other monitoring such as the habitat assessment, dissolved oxygen and temperature needs to be conducted. The biotic index is useful for identifying long-term pollution problems, since these organisms carry out a portion or all of their life cycle in streams. Most of the other parameters you will monitor (except habitat) only indicate the water quality conditions at the time of testing.

To determine a biotic index score, you will collect organisms, identify them, and rate them based



Caddisfly larva inside cases they make from pebbles, sticks and other stream materials.

on their tolerance to pollution, using a chart like the one below. The most tolerant organisms will get a score of 1; the least tolerant get a score of 4. Review the example below to see how a biotic index score is determined:

## Macroinvertebrate Tally

Name of Collector \_\_\_\_\_  
Location \_\_\_\_\_ Date of Collection \_\_\_\_\_

**GROUP 1 – Sensitive to pollutants**  
Circle each animal that is found.

Number of GROUP 1 animals circled: 1

**GROUP 2 – Semi-Sensitive to pollutants**  
Circle each animal that is found.

Number of GROUP 2 animals circled: 3

**GROUP 3 – Semi-Tolerant of pollutants**  
Circle each animal that is found.

Number of GROUP 3 animals circled: 2

**GROUP 4 – Tolerant of pollutants**  
Circle each animal that is found.

Number of GROUP 4 animals circled: 1

**Tally animals circled in each category. Then multiply by number given.**

Group 1	Sensitive	<u>1</u> x 4 =	<u>4</u>
Group 2	Semi-Sensitive	<u>3</u> x 3 =	<u>9</u>
Group 3	Semi-Tolerant	<u>2</u> x 2 =	<u>4</u>
Group 4	Tolerant	<u>1</u> x 1 =	<u>1</u>
Total		<u>7</u> (E)	<u>18</u> (F)
Divide (F) by (E):		<u>18</u> ÷ <u>7</u>	
Index Score (F ÷ E)		<span style="border: 1px solid black; padding: 2px 5px;">2.6</span>	

**How healthy is the stream?**

3.6 and up	Excellent
2.6 - 3.5	Good
2.1 - 2.5	Fair
1.0 - 2.0	Poor

Water Action Volunteers is a cooperative program between the University of Wisconsin–Extension and the Wisconsin Department of Natural Resources. For more information, contact the Water Action Volunteers Coordinator at 608-264-8946. WAV materials revised Summer, ©2005

For additional information about macroinvertebrates, visit these websites:

<http://watermonitoring.uwex.edu/wav/monitoring/biotic.html>

<http://watermonitoring.uwex.edu/wav/monitoring/coordinator/ecology/macro.html>

3. What are aquatic macroinvertebrates?

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3. Give some examples of aquatic macroinvertebrates.

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3. What are some advantages to using macroinvertebrates to identify water quality as compared to studying other physical or chemical aspects of water quality?

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4. After sampling the macroinvertebrate population at Stream X in Central Wisconsin that had low gradient and a muddy bottom, you noticed that there were not very many different types of organisms present. Before filling out the biotic index sheet, what would you speculate about the water quality of Stream X? Why?

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5. If you were standing on the edge of a stream planning where to go within it to collect aquatic macroinvertebrates, where would you try looking for them?

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6. If you collected caddisflies, mayflies, riffle beetles, amphipods and both non-red midges and bloodworms, what would your biotic index score be?

<u>Group Number</u>	<u>Number of Animals</u>	<u>Group Value</u>	<u>Scoring</u>
Group 1	_____	x4	= _____
Group 2	_____	x3	= _____
Group 3	_____	x2	= _____
Group 4	_____	x1	= _____
Total Number =	<input type="text"/>	Total Score =	<input type="text"/>
Total Score	<input type="text"/>	/ Total Number	<input type="text"/> = <input type="text"/>
(3.6+=Excellent, 2.6-3.5=Good, 2.1-2.5=Fair, 1.0-2.0=Poor)			Biotic Index Score

7. You will soon be determining a biotic index score at a stream near your school. What water quality do you expect to find? Why? Note your hypothesis for your stream site and your plan for how to research that hypothesis here:

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STOP HERE  Go on field trip!!



### Calculating a Biotic Index Score and Statistics

**PROCEDURE:**

1. Obtain your biotic index data sheet from your teacher.
2. Calculate your biotic index score for your site by following the directions below:
  - a. Count the number of animals circled in each group and write those in the work area below.
  - b. Multiply the entered number from each group – by the group value.
  - c. Do this for all groups.
  - d. Total the number of animals circled for all groups.
  - e. Total the calculated scores for all groups.
  - f. Divide the total score by the total number of types of animals found.
  - g. Record this number. This is you Biotic Index Score.

SHOW ALL MATH (Use space below to do your math computations)

Group Number	Number of Animals	Group Value	Scoring
Group 1	_____	x4	= _____
Group 2	_____	x3	= _____
Group 3	_____	x2	= _____
Group 4	_____	x1	= _____
Total Number = <input style="width: 100px; height: 20px;" type="text"/>		Total Score = <input style="width: 150px; height: 20px;" type="text"/>	
Total Score <input style="width: 60px; height: 20px;" type="text"/> / Total Number <input style="width: 60px; height: 20px;" type="text"/>		= <input style="width: 60px; height: 20px;" type="text"/>	
(3.6+=Excellent, 2.6-3.5=Good, 2.1-2.5=Fair, 1.0-2.0=Poor)			Biotic Index Score

3. Report this result to your teacher so other students in the class can obtain this information.
4. Once you have a complete list of biotic index scores, record these measurements in your student workbook (Table A).
5. Then rewrite the list in order from lowest to highest (Table B). Using a spreadsheet such as Excel maybe be helpful.
6. Determine the average, median and mode (optional) for the biotic index scores and record these in your student workbook (Table C).
7. Determine the range of biotic index scores by noting the lowest and the highest measurements recorded during the field trip and indicate this in your student workbook (Table C).
8. Write a conclusion paragraph or two about this parameter. You should state whether or not your hypotheses were correct and why or why not. You should also state the final results of the test (including average, median, range and mode) and what those results tell us about the stream quality. Also address any sources of error that may have influenced your results.



BIOTIC INDEX TABLE C

	Biotic Index Score
Average	
Median	
Low	
High	
Mode	

What was the average score for your stream? \_\_\_\_\_

What does that mean? (circle one) Excellent 3.6+, Good 2.6-3.5, Fair 2.1-2.5, Poor 1.0-2.0

What reasons can you think of to support why this stream scored the way that it did?

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What suggestions do you have for the future health of this stream?

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Conclusions:

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## E. COLI BACTERIA MONITORING

- Most bacteria do not cause human health problems; some, including *E. coli*, can be used as indicators of possible pollution in surface waters.
- Runoff from land is the leading cause of surface water pollution in the United States.
- Sources of fecal coliform bacteria in surface waters include manure spread on land that has run off into surface waters, failed septic systems, pet wastes, and wildlife and bird feces.

**B**acteria are microscopic, single-celled organisms that are the most numerous organisms on Earth. They are so small that over five million could be placed on the head of a pin. Bacteria can live in numerous environments and perform many complex actions, some of which are beneficial and some harmful. Most bacteria, however, are not harmful and do not cause human health problems. Those that are disease producing are referred to as pathogenic. Viruses and some protozoans can also be pathogenic.

Coliform bacteria are part of the Enterobacteriaceae family and individual cells cannot be seen with the naked eye due to their small size (but colonies can be seen.) While some coliform bacteria can be naturally found in soil, the type of coliform bacteria that live in the intestinal tract of warm-blooded animals and originate from animal and human waste are called fecal coliform bacteria.



Angie Tilton (both photos)

*Escherichia coli* (*E. coli*) is one subgroup of fecal coliform bacteria. Even within this species, there are numerous different strains, some of which can be harmful. However, the release of these naturally-occurring organisms into the environment is generally not a cause for alarm. However, other disease causing bacteria, which can include some pathogenic strains of *E. coli*, or viruses may also be present in these wastes and pose a health threat.



## **E. COLI AS INDICATOR BACTERIA**

Trying to detect disease-causing bacteria and other pathogens in water is expensive and may pose potential health hazards. Further, testing for pathogens requires large volumes of water, and the pathogens can often be difficult to grow in the laboratory and isolate. *E. coli* bacteria are good indicator organisms of fecal contamination because they generally live longer than pathogens, are found in greater numbers, and are less risky to collect or culture in a laboratory than pathogens. However, their presence does not necessarily mean that pathogens are present, but rather indicate a potential health hazard may exist.

The Environmental Protection Agency (EPA) has determined that *E. coli* are one of the best indicators for the presence of potentially pathogenic bacteria (US EPA, 2002). Because *E. coli* monitoring does not measure the actual pathogens, the assessment is not foolproof, however, it is a good approach for assessing the likelihood of risks to human health. Monitoring for these indicator organisms is an easy and economical method for citizens or professionals to assess health risks due to bacterial contamination of surface waters.

## **COMMON SOURCES OF E. COLI**

Bacteria in water can originate from the intestinal tracts of both humans and other warm-blooded animals. Human sources include failing septic tanks, leaking sewer lines, wastewater treatment plants, sewer overflows, boat discharges, swimming “accidents” and urban storm water runoff. In urban watersheds, fecal indicator bacteria are significantly correlated with human density (Frenzel and Couvillion, 2002). Animal sources of fecal coliform bacteria in surface waters include manure that has been spread on the land, livestock defecating in streams, pet wastes (e.g., dogs, cats), wildlife (e.g., deer, elk, raccoons) and birds (e.g., geese, pigeons, ducks, gulls).

If you are sampling in a watershed area without significant human impact and are finding *E. coli*, the source may be birds or wildlife. In a study comparing *E. coli* concentrations in waters from agricultural and “pristine” sites, contamination was found in both settings. The researchers deduced that the levels of *E. coli* at the pristine site likely came from wildlife, such as deer and elk, living the area (Niemi and Niemi, 1991).

Another source of bacterial pollution to stream waters comes from Combined Sewer Overflows (CSOs). Some sewer and storm water pipes are not separated. When a large storm event occurs, the wastewater treatment plants cannot handle the excess volume of water being pumped to them. As a result, untreated sewage along with storm water is dumped directly into rivers and streams.

Remember, the presence and levels of *E. coli* in a stream do not give an indication of the source of the contamination. However, monitoring them can be a good first step in investigating a watershed for potential sources.

### COMMON ROUTES OF BACTERIA TO STREAMS

Polluted water runoff from the land is the leading cause of water quality problems nationwide (US EPA, 2002). Fecal material as well as other pollutants can be transported to waterways through runoff. How quickly they are transported partially depends on the type of land use. Non-developed lands including grasses and other vegetation tend to soak up rainfall, thereby increasing infiltration into the ground and reducing runoff to waterways. Developed lands such as streets, rooftops, sidewalks, parking lots, driveways and other hard surfaces that are impervious to infiltration cause runoff to increase. Lands that support domesticated animals, such as cattle, hogs or horses, can also be a source of bacteria, particularly if animals enter the water for drinking or if heavy rains wash manure from the land into receiving waters.

### RISKS TO HUMAN HEALTH

Most people are concerned about the risk that bacteria may pose to human health. When bacterial counts are above health standards, people exposed to water that contains bacteria may exhibit fever, diarrhea, abdominal cramps, chest pain or hepatitis. While *E. coli* by itself is not generally a cause for alarm, other pathogens of fecal origin that are health threats include *Salmonella*, *Shigella* and *Pseudomonas aeruginosa*. Non-bacterial pathogens that may be present with fecal material include protozoans, such as *Cryptosporidium* and *Giardia*, and viruses.

There are some strains of *E. coli* that are pathogenic themselves. One that has received much attention is the *E. coli* strain named O157:H7 that lives in the intestinal tract of cattle. This strain is primarily spread to people who eat contaminated, undercooked beef or drink unpasteurized milk and is not generally found in surface waters.

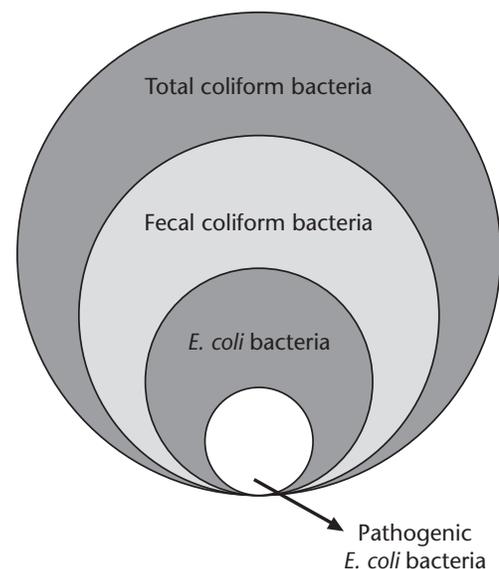
## EXAMPLES OF AT-RISK CONCENTRATION LEVELS

Criteria for acceptable concentrations of indicator bacteria in recreational waters have been developed by the US EPA (1986). Initially, total coliform bacteria were used as the benchmark. However, because it was shown that *E. coli* were more closely correlated with swimming-related illnesses, the US EPA later recommended that *E. coli* be used as the indicator in freshwater recreational areas (US EPA, 2002).

Many states have since adopted this recommendation; however, some such as Wisconsin, still use total fecal coliform bacteria when determining acceptable concentrations for recreating in surface waters. For *E. coli* the EPA mandates that the acceptable risk level for total body contact recreation, which involves activities such as swimming or water skiing, is 126 colonies of organisms (referred to as colony forming units or cfu) per 100 milliliters (ml) of water or less, based on a **geometric mean** (calculated over 30 days with at least 5 samples) or a one-time concentration of 235 cfu/100 ml. The risk of getting sick increases as total numbers of colonies are exceeded.

The number of colony forming units of *E. coli* organisms per 100 ml of water and the method of determination may vary slightly by state, based on state public health codes and water quality Standards. The EPA recommends a set of standards for *E. coli* in freshwater bodies as a single maximum allowable count. These rates correspond to an acceptable risk level of 8 people out of 1,000 getting sick. In Wisconsin, these guidelines are used for swimming beaches, but a fecal coliform standard (of which *E. coli* is a subset) is used for other recreational waters. The fecal coliform standard is 400 cfu/100 mL for a single event.

Even with good watershed management measures, there will always be fecal material in the environment. If you find unusually high levels of *E. coli* on a long-term, regular basis in your stream samples, you should alert and work with your local health agency.



Fecal coliform bacteria which include *E. coli* are part of a larger group of coliform bacteria. (Figure not to scale.)

## WEATHER AND SEASONAL INFLUENCES

The number of bacteria colonies can be influenced by weather and seasonal effects. This variability makes the bacterial concentrations in natural water difficult to predict at any one time. Bacteria counts often increase following a heavy storm, snow melt or other excessive runoff. *E. coli* bacteria are often more prevalent in turbid waters because they live in soil and can attach to sediment particles. Bacteria can also remain in streambed sediments for long periods of time. If the streambed has been stirred up by increased flow or rainfall, your sample could have elevated bacteria levels. This is why you should avoid disturbing the streambed as you wade out into the stream to collect your sample. You should also collect the water sample upstream from you. If you are collecting at several sites within the stream, collect the furthest downstream sample first and proceed upstream.

A number of other weather influences may affect bacteria levels in the stream. Higher *E. coli* counts may be found in warmer waters because *E. coli* survive more easily in these waters. (*E. coli* typically live in the warm environment of the intestines of warm-blooded animals.) Ultraviolet rays of sunlight, however, can kill bacteria, so a warm sunny day may produce counts lower than expected.

For more information about *E. coli* bacteria monitoring visit this website:

<http://www.usawaterquality.org/volunteer/EColi/Manual.htm>

### References

- Frenzel, S.A. and C.S. Couvillion (2002) Fecal-indicator bacteria in streams along a gradient of residential development. *Journal of the American Water Resources Association*. 38:265-273.
- Niemi, R.M. and J.S. Niemi (1991) Bacterial pollution of waters in pristine and agricultural lands. *Journal of Environmental Quality*. 20:620-627.
- US EPA (1986). Ambient Water Quality Criteria for Bacteria. EPA 440/5-84-002. Office of Water.
- US EPA (2002). Implementation Guidance for Ambient Water Quality Criteria for Bacteria (Draft). May 2002 ([www.epa.gov/waterscience/standards/bacteria/bacteria.pdf](http://www.epa.gov/waterscience/standards/bacteria/bacteria.pdf)).

1. What are three sources of *E. coli* in surface waters?

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2. Disease-causing bacteria are called \_\_\_\_\_ bacteria.

3. Are the majority of bacteria disease-causing? \_\_\_\_\_

4. What are some advantages to using *E. coli* bacteria to monitor water quality?

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5. What symptoms might humans infected with water-borne pathogens display?

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6. In what units are *E. coli* measured? \_\_\_\_\_

7. What is the EPA-recommended one-time concentration limit for *E. coli* for total body contact activities such as swimming?

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8. What factors can influence the concentration of bacteria in surface waters?

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9. You will soon be monitoring the *E. coli* bacteria level in a stream near your school. What water quality do you expect to find? Why? Note your hypothesis for your stream site and your plan for how to research that hypothesis here:

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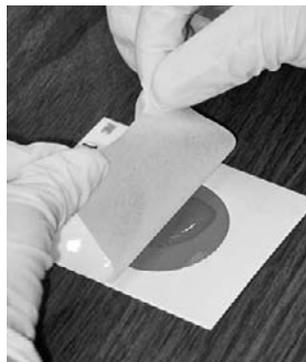
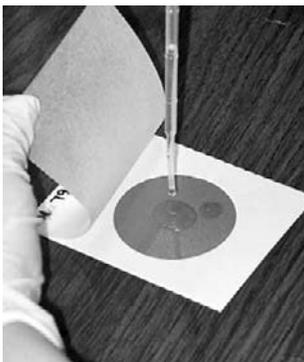
STOP HERE		Go on field trip!!
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## Back in the Classroom

### Classroom Procedure for *E. coli* Bacteria Monitoring:

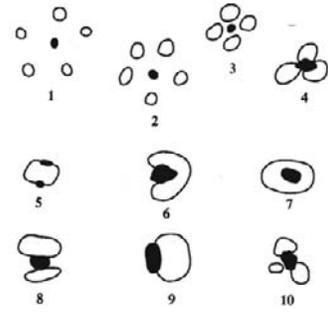
During your class field trip, you will collect your sample from a stream near your school using methods outlined in the Wisconsin State Lab of Hygiene video, and transport your sample on ice to your classroom. You will then use 3M™ Petrifilm™ to monitor *E. coli*. It is essential that you maintain sterile conditions while plating your sample, since this is the time with the greatest potential for external contamination of the samples. Follow these steps to process the sample:

1. Remove 3M™ Petrifilm™ from refrigerator and allow the package to come to room temperature before opening. This will take at least 10-15 minutes.
2. Sanitize your working surface by spraying or wiping it with a dilute bleach solution.
3. Wash your hands thoroughly with soap and water.
4. Label the back side of three 3M™ Petrifilm™ plates with the date, time, sampling site and replicate number (1 to 3).
5. Always shake your sample bottle before extracting a sample with a pipette.
6. Place a 3M™ Petrifilm™ plate on a level surface.
7. Lift the top film and dispense 1 mL of sample in the upper portion of the pink portion of the plate.



8. Slowly roll the top film down onto the sample to prevent trapping air bubbles.
9. If needed, with the smooth side down, place the plastic spreader over the closed plate and distribute the sample evenly across the pink area of the plate by *gently* tapping with one finger on the center of the plastic spreader.

10. If used, remove the spreader and leave the plate undisturbed for at least one minute to permit the gel to solidify.
11. Repeat this process for your other two replicate samples.
12. Incubate the plates in a horizontal position, with the clear side up in stacks of up to 20 plates.
13. Incubate for 24 hours at 35°C.
14. After 24 hours, wearing nitrile or other lab gloves, remove the plates from the incubator and count blue and blue-purple colonies that have associated gas bubbles and are within the pink circle. Holding the plates up to light can help distinguish colonies with gas bubbles.
15. On the data sheet below record the number of colonies you counted.
16. Since you used just 1 mL of sample, multiply the number of colonies counted by 100 to determine the number of colony-forming units per 100 mL of sample.
17. After you have counted colonies, place all of the Petrifilm plates in a Ziploc bag that has had about two tablespoons of bleach added to it. Seal the bag and throw it away in the regular rubbish. The bleach will disinfect the plates.



All 10 examples depict various bubble patterns associated with gas-producing colonies. Each numbered picture would be counted as one colony. (From 3M™ Petrifilm™ interpretation guide)

**Note:**

Petrifilm *E. coli* plates with colonies that are too numerous to count (TNTC) have one or more of the following characteristics: many small colonies, many gas bubbles, and deepening of the gel color. High concentrations of *E. coli* will cause the growth area to turn blue, while high concentrations of coliforms (non-*E. coli*) will cause the growth area to turn dark red. When any of these occur, you will not be able to count the sample – and should write TNTC on your data sheet.

Names: _____ Incubation temperature: _____°C		
Date: _____ Times samples place in incubator: _____		
	Number of <i>E. coli</i> colonies counted at 24 hours	Number of <i>E. coli</i> (calculated) cfu/100 mL at 24 hours
Replicate 1		
Replicate 2		
Replicate 3		

Average: \_\_\_\_\_cfu/100mL

## Calculating *E. coli* Statistics

### PROCEDURE:

1. Record all groups and their *E. coli* scores in your student workbook (Table A).
2. Then rewrite the list in order from lowest to highest (Table B). Using a spreadsheet such as Excel may be helpful.
3. Determine the average, median and mode (optional) for the *E. coli* scores and record these in your student workbook (Table C).
4. Determine the range of *E. coli* scores by noting the lowest and the highest measurements recorded during the field trip and indicate this in your student workbook (Table C).
5. Answer any remaining questions in your student workbook and then write a conclusion paragraph or two about this parameter. You should state whether or not your hypotheses were correct and why or why not. You should also state the final results of the test (including average, median, range and mode, and what those results tell us about the stream quality. Also address any sources of error that may have influenced your results.



*E. COLI* TABLE C

	<i>E. coli</i> Score (cfu/100mL)
Average	
Median	
Low	
High	
Mode	

Following the EPA recommended guidelines for beaches, did you find that your average *E. coli* results were above or below the 235 cfu/100 mL standard?

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What does that mean in regards to human safety and potential for illness if someone were to swim at your monitoring location on the day you sampled?

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What reasons can you think of to support why this stream scored the way that it did?

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What suggestions do you have for the future health of this stream?

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**Conclusions:**

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## GLOSSARY

*Aquatic Macroinvertebrates:* Small animals without backbones that live in water and are visible to the human eye.

*Average:* The arithmetic average is determined by adding together all the measurements and dividing by the total number of samples collected.

*Citizen Monitoring Biotic Index:* Water Quality Index for Wisconsin wadable streams using aquatic macroinvertebrates.

*Cold-blooded:* Animals whose body temperatures match that of their surroundings. Fish, invertebrates, snakes, frogs and toads are cold-blooded.

*Diffusion:* The movement of molecules, for example oxygen molecules, from an area of higher concentration (e.g., the air) to an area of lower concentration (e.g., the water).

*Flow Regime:* The pattern of stream flow over time, including increases with stormwater runoff inputs and decreases to a base-flow level during dry periods.

*Geometric Mean:* A type of mean (average) that helps reduce the effect of a few extreme values.

*Impervious Surface:* A surface that does not allow water (e.g., rain) to pass through (infiltrate).

*Lower Bank:* The intermittently submerged portion of the bank from the normal water line to the high water line, or beginning of the upper bank.

*Median:* This is the middle number in an ordered list of measurements. If there was an even number of measurements made, the average of the two middle numbers is the median.

*Mode:* The mode is the most commonly recorded value in the dataset. It is possible that more than one number may be the mode.

*NTU:* Nephelometric Turbidity Units, which is a measure of the amount of light scattered by suspended material in the sample.

*Parameter:* The stream characteristic to be measured.

*Photosynthesis:* The process in which green plants convert carbon dioxide and water, using the sun's energy, into simple sugars and oxygen.

*Respiration:* The cellular process in which plants and animals use oxygen and release carbon dioxide. Basically, it is the reverse of photosynthesis because carbon dioxide, water and energy are released in the process.

*Riffle:* Shallow area in stream where water flows swiftly over rocks.

*Riparian Zone:* The land between the water's edge and the upper edge of the flood plain; transition zone between water and land.

*Run:* An area of a stream that has swift water flow and is slightly deeper than a riffle (a run will be about knee/thigh deep).

*Sediment:* Soil or other bits of eroded material that run off land and settle in still water.

*Supersaturation:* An indication that more oxygen is dissolved in water than would be in a state of equilibrium. Supersaturation could indicate that some processes are affecting the water's natural balance found in the state of equilibrium.

*Suspended Material:* Small particles floating in the water.

*Turbidity:* The amount of suspended particles in the water.

*Upper Bank:* The portion of the bank from the beginning of the high water line to the extreme high water line.

*Watershed:* An area of land that drains to a main water body.

