# Watersheds and Nonpoint Source Pollution

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## Lower Grand River Watershed Lessons

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## Unit Three: Managing Pathogens

Groundswell

Communities for Clean Water

# Groundswell

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To learn more about Groundswell, environmental stewardship education, and to view the companion videos, please visit **groundswellmi.org**.

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OVERVIEW & LESSON

STUDENT ACTIVITY

ANSWER KEY

TEACHER RESOURCE

STUDENT READING

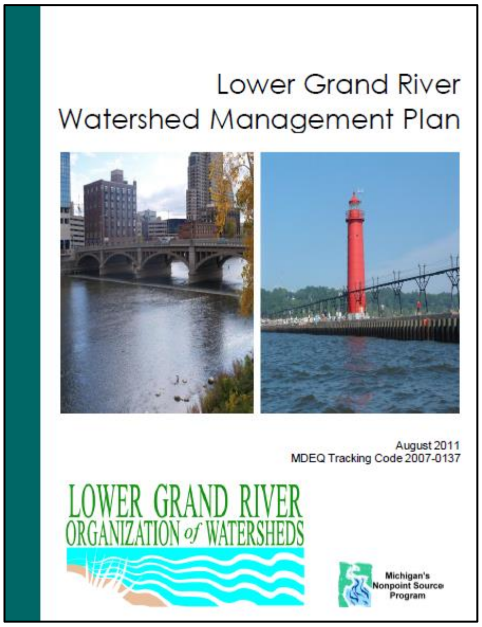
EPA

GRAND VALLEY STATE UNIVERSITY
COLLEGE OF EDUCATION

DEQ

## About the Lessons

The Michigan Department of Environmental Quality's Nonpoint Source Program assists numerous non-profit entities and other local, state, and federal partners to reduce nonpoint source (NPS) pollution statewide. NPS pollution comes from all over the watershed – anywhere rain falls. There is no specific source like a pipe or smoke stack. As such, the basis for this program is watershed management.




The *Lower Grand River Watershed Management Plan* (LGRWMP) is a document developed to provide a description of the watershed, identification of impairments, and goals and objectives for management and improvement of the watershed. The WMP's *Information and Education* (I&E) *Strategy* calls for educating stakeholders about the watershed and the impacts that stakeholders have on the watershed. The strategy has three steps: (1) awareness, (2) education, and (3) action.

With funding from the Michigan Department of Environmental Quality (MDEQ) Nonpoint Source Program, four lessons that draw upon information from the Lower Grand River Watershed Management Plan (WMP) have been developed for teachers. The purpose of these lessons is to further the I&E objectives that reach students as outlined in the WMP.

The three main nonpoint source pollutants of concern in the *Lower Grand River Watershed Management Plan* include sediment, pathogens, and nutrients. The lesson titles, which reflect this, are:

- Watersheds and Nonpoint Source Pollution
- Nonpoint Source Pollution: Managing Excess Sediment
- Nonpoint Source Pollution: Managing Pathogens
- Nonpoint Source Pollution: Managing Excess Nutrients

Videos have been developed to accompany each of the lessons. Lessons and videos are posted at http://groundswellmi.org/resources/educator-resources/. Educators can select the activities about the Lower Grand River Watershed that best fit their classrooms.

## About the Lower Grand River Watershed Management Plan

The current Lower Grand River Watershed Management Plan (LGRWMP) was approved by the Michigan Department of Environmental Quality (MDEQ) in 2011. The LGRWMP provides a detailed implementation plan and assigns responsibility to stakeholders to ensure the plan's actions are put into practice. The Lower Grand River Organization of Watersheds (LGROW) was formed in 2009 to provide basin-wide oversight, implement watershed-wide initiatives, and prioritize water quality concerns.

For more information: lgrow.org

The nine key elements of the Lower Grand River Watershed Management Plan include:

1. Understanding watershed characteristics
2. Identifying and involving local agencies and citizens in the watershed planning process
3. Identifying designated and desired uses
4. Defining critical areas which are contributing a majority of the pollutants
5. Identifying and prioritizing pollutants, sources, and causes
6. Determining objectives and tasks for meeting watershed goals
7. Identifying and analyzing existing local projects, programs, and ordinances that impact water quality within the watershed
8. Informing and involving the public
9. Developing an evaluation process

The chapters in the LGRWMP reflect these nine elements.

The LGRWMP also outlines a strategy to identify and restore the state's designated uses of the surface waters in the watershed, which are:

- Agricultural use
- Industrial water supply at the point of intake
- Public water supply at the point of intake
- Navigation
- Warmwater and/or coldwater fishery
- Other indigenous aquatic life and wildlife
- Partial body contact recreation
- Total body contact recreation between May 1 and October 31

Sediment, nutrients, pathogens, temperature, unstable hydrology, chemicals, and habitat fragmentation have an impact on the designated uses of the watershed. Designated uses are considered impaired if the water does not meet Michigan's water quality standards. Total Maximum Daily Loads (TMDLs), which establish the maximum amount of a pollutant allowed in a water body and serves as the starting point or planning tool for restoring water, have been developed for parts of the watershed.

Subjects/Target Grades

Science and Social Studies

Grades: 7-12

Duration

Five 50-minute class periods

Classroom and water body setting

Materials

*Per class*

- Videos: *Communities for Clean Water: Managing Pathogens*
- Teacher Resource masters
- Answer keys

*Per small group*

- Septic system model materials (container for the model, straws, milk cartons, clay, sand, room temperature coffee-prepared with grounds)
- *E. coli* monitoring kits

*Per student*

- Student activity sheets
- Student reading

MI Science Standards:

- Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment. MS-ESS3-3

# Lesson Three: Nonpoint Source Pollution: Managing Pathogens

## Lesson Overview

This lesson explores pathogens, a major type of nonpoint source pollution affecting the Lower Grand River Watershed. Fecal coliform and *Escherichia coli* (abbreviated as *E. coli*) bacteria data from sampling sites in the Lower Grand River Watershed are analyzed, and a task force is simulated to address pathogen issues.

## Focus Questions

Students answer these essential questions in the context of the Lower Grand River Watershed: What are waterborne pathogens? What are the sources and effects of pathogens? What are some methods of monitoring pathogens? How can the pathogen load in a stream or river be reduced?

## Objectives

Students will be able to: Identify pathogens as a major nonpoint source pollutant. Determine how pathogens enter into a lake, river, or stream system. Indicate the relative impact of pathogens in various parts of the Lower Grand River Watershed. Explore ways to reduce pathogens in our local water bodies.

## Background Information

A **pathogen** is any disease-producing agent, especially a virus, bacterium, or other microorganism. Examples of pathogens that are associated with waterborne disease outbreaks are: bacteria (*Legionella, Shigella, Vibrio cholerae, Salmonella, Yersimia, E. coli* 0157:H7, *Campylobacter*), protozoans (*Cryptosporidium, Giardia, Toxoplasma*), and viruses (hepatitis, coxsackie, Norwalk). Pathogenic organisms are generally present in surface waters in very low numbers, but typically pose relatively little risk to human health at such small amounts. Major sources of pathogens that pose a higher risk to human health are human waste (feces), agriculture practices (livestock operations and using manure as fertilizer), and animals (wildlife and pets).

Analytical tests to determine the presence, quantity, and type of pathogens in our water bodies are both expensive and difficult to conduct. Consequentially, levels of

**fecal coliform bacteria** and ***Escherichia coli*** **(*E. coli*)** bacteria are often used as **indicators** of the presence of pathogens instead of monitoring for each individual disease-causing organism. The presence of fecal coliform bacteria and *E. coli* bacteria in water samples indicates human waste might be present in the water. This means human waste potentially has contaminated the water with a variety of pathogens that could make people sick.

Fecal coliform bacteria and *E. coli* are naturally present in the intestines and feces of warm-blooded animals. Many strains of these bacteria pose no threat to human health. In fact, it has been estimated that 0.1% of the total bacteria within an adult's intestine is represented by *E. coli.*[1] There is evidence that these indicator bacteria are found in soils at the groundwater-surface water interface, sand pore water, drains, and sediments. With every rainfall, these naturally occurring bacteria can reach surface waters, creating a link between rainfall, flow, and bacterial counts. As such, indicator bacteria are not always associated with specific human activity and their presence doesn't necessarily mean pathogenic organisms are present.

The U.S. Environmental Protection Agency (EPA) "develops criteria to protect people from microbial organisms such as bacteria and viruses in water bodies (e.g., lakes, rivers, beaches). State and tribal governments can use the criteria as guidance when setting their own water quality standards to protect human health."[2] Water quality standards for pathogens are based on indicator bacteria since it is not feasible to test for each individual pathogenic organism. Rule 62 of the Michigan Water Quality Standards (Part 4 of Act 451) limits the concentration of microorganisms in surface waters of the state and surface water discharges, such as treated wastewater.[3]

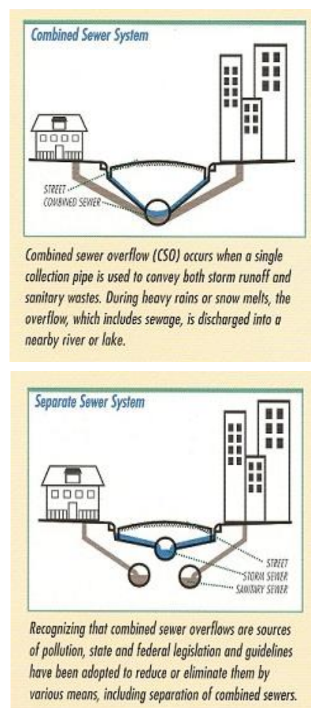
The allowable concentrations of *E. coli* depend on the designated use of the specific water body. During the typical swimming season (May through October), the total body contact standards apply to all waters of the state. Waters of the state that are protected for total body contact recreation must not exceed limits of 130 *Escherichia coli* (*E. coli*) per 100 milliliters (mL) water as a 30-day average and 300 *E. coli* per 100 mL water at any time. Some waters are designated partial body contact outside of the swimming season. The limit for waters of the state that are protected for partial body contact recreation is 1,000 *E. coli* per 100 mL water. Discharges containing treated or untreated human sewage shall not contain more than 200 fecal coliform bacteria per 100 mL water as a monthly average and 400 fecal coliform bacteria per 100 mL water as a 7-day average. These standards designate levels that are generally protective of human health. Waters that don't meet the standard are impaired (closed beaches). For infectious organisms, which are not addressed by Rule 62, the Michigan Department of Environmental Quality (MDEQ) has the authority to set limits on a case-by-case basis to assure that designated uses are protected.[3]

Since *E. coli* is used as an indicator of fecal contamination, water quality standards are designed to protect human health during recreation. When the water quality standard is exceeded (based on a 30-day geometric mean of five or more sampling events), the federal Clean Water Act requires Michigan to develop a Total Maximum Daily Load (TMDL) to provide a framework for restoring the water quality and reducing the level of *E. coli* to at or below the standard. Sources of *E. coli* are ubiquitous to human development and include livestock and improper or incomplete sewage treatment.[4] "Given the extent of this problem, and the multitude of potential sources, a statewide approach is likely to be more effective and more efficient at addressing this issue."[4]

MDEQ estimates that about half of Michigan's river miles are impaired by *E. coli*, and about 22% of beaches had closures due to *E. coli* contamination in 2014.[5] MDEQ's BeachGuard site can be consulted to view current beach closings and supporting monitoring data ([http://www.deq.state.mi.us/beach/](http://www.deq.state.mi.us/beach/)). Elevated *E. coli* levels are a reason to close beaches and limit recreational activities. However, depending on the method of testing, it sometimes takes 24 hours to determine whether or not a health-risk warning needs to be posted. Therefore, by the time the presence of *E. coli* is confirmed the risk might have passed or people might have already been exposed to pathogens. Alternative methods of detecting pathogens in a more timely manner are being developed. These include nucleic acid-based, immunology-based, and biosensor-based detection methods.

Within the Lower Grand River Watershed, the presence and quantity of indicator bacteria varies by season, source, and weather. For example, fecal coliform levels in Plaster Creek were 6-8 times higher during wet weather conditions (during and immediately after a storm) than prior to a storm event.[6] (This means students should avoid sampling a creek right after a rain event to prevent potential exposure to pathogens.) However, lack of rain tends to concentrate bacteria from constant sources such as illicit connections and leaky septic systems.

Monitoring for indicator bacteria in the Lower Grand River Watershed has been conducted for decades by the Grand Rapids Water Resource Recovery Facility. The Facility's long-term datasets are valuable for assessing the variations in bacterial load from tributaries of the Grand River, as well as monitoring the efficacy of the operations of the Facility. The city has implemented several improvements to reduce the bacterial load coming from the Facility, such as construction of a retention basin, separating the sanitary sewer system from the storm sewer system, limiting discharges, evaluating and repairing sewer systems, and passing local ordinances. These improvements have largely eliminated combined sewer overflow events in Grand Rapids.[7] [Note: A combined sewer overflow event happens in cities with combined sewer systems where stormwater and sewage flow through the same system of pipes. During a large rain storm, the system can become overwhelmed due to the large volume of stormwater and the city is forced to release some of the water, untreated, into the river. Because the sewage and stormwater are combined in the same pipes, this means raw sewage is released into the river as well as the stormwater.]




Types of Sewer Systems
http://grcity.us/enterprise-services/Environment-Services/Pages/Combined-Sewer-Overflow.aspx

The Lower Grand River Watershed Management Plan (LGRWMP) identifies subwatersheds affected by pathogen pollution. Nonpoint sources of pathogen contamination appear to be more prevalent than point sources of contamination in the watershed. The main sources are cropland, livestock, septic tanks, ducks and geese, and the sanitary sewer.[8] Microbial source tracking tools are helpful in determining whether the source of the pathogens is from humans or animals (geese, cows, dogs, etc.). Conventional techniques for bacteria source tracking include targeted in-stream monitoring, sanitary or watershed surveys, and dye testing of septic systems. “Molecular and biochemical techniques assume there are characteristics unique to the fecal bacteria from a particular host and that these characteristics allow scientists to identify the source of the contamination. Most of these techniques target key genes that can be tied to a specific host.”[9]

A single result showing a high level of fecal coliform bacteria or *E. coli* might not mean anything for human health risk in the long run since it could be from excrement left by a single animal. However, a series of elevated samples could be a reason for concern. Extensive knowledge of the contributing watershed is the key to interpreting monitoring results. Health risk surveys, bacterial source investigations, rainy weather sampling, epidemiological studies, septic system inspections, and regular monitoring can contribute much information to clarify pathogen problems and help guide appropriate solutions.[10]

Source:

[1] Patton, B.S. (2007). *Applications and mechanisms of colicin E1*. Retrieved from http://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=16846&context=rtd
[2] U. S. Environmental Protection Agency. Microbial (Pathogen)/ Recreational Water Quality Criteria. Retrieved from https://www.epa.gov/wqc/microbial-pathogenrecreational-water-quality-criteria
[3] Michigan Department of Environmental Quality. Department of Environmental Quality Water Bureau Water Resources Protection. Retrieved from http://www.michigan.gov/documents/deq/wrd-rules-part4_521508_7.pdf
[4] Michigan Department of Environmental Quality. Michigan’s Statewide E.coli Total Maximum Daily Load. http://www.michigan.gov/deq/0,4561,7-135-3313_3681_3686_3728-376271--,00.html
[5] Michigan Department of Environmental Quality. E. coli in Surface Waters. http://www.michigan.gov/deq/0,4561,7-135-3313_3681_3686_3728-383659--,00.html
[6] LGROW. Plaster Creek Stewards. Retrieved from http://www.calvin.edu/admin/provost/pcw/learn/Plaster%20Creek%20WMP.pdf
[7] Grand Rapids Wastewater Treatment Plant. Retrieved from http://grcity.us/enterprise-services/Environment-Services/Pages/Combined-Sewer-Overflow.aspx
[8] LGROW. Lower Grand River Watershed Management Plan. Retrieved from http://www.lgrow.org/lgrwmp
[9] Department of Ecology – State of Washington. Microbial Source Tracking. Retrieved from https://fortress.wa.gov/ecy/publications/documents/1203010.pdf
[10] Vail, J.H. (1998). *An Analysis of Fecal Coliform Bacteria as a Water Quality Indicator*, PhD Thesis

## Lesson Procedure:

### 1. What are waterborne pathogens?

Ask students if they have ever gotten sick after swimming in a body of water or if they drank water that was contaminated. Mention some of the symptoms that can result from contact with contaminated water. Do they know what type of organism in the water might have caused their health issues? Point out that the main types of waterborne pathogens are bacteria, protozoa, and viruses. Also, note that around the world, millions of people die or get sick as a result of water-related diseases each year.

**Assign** the student reading: ***Waterborne Pathogens in the News*.**

Reference the *teacher background* on Maplewood Park and Plaster Creek to explain real-world examples of waterborne pathogens. Engage students in a discussion of these two examples. Follow up with the information about what is happening now by having the students research news stories related to Maplewood Park and Plaster Creek.

**Assign** a writing project, story board, or digital story telling for students to compare and contrast Maplewood Lake and Plaster Creek *E. coli* problems.

Use questions such as:

- What organism caused the problem?
- How do the two situations compare?
- What was the role of the state and local government in addressing these issues?
- What are the lessons learned from these situations?
- What should happen next for Plaster Creek and Maplewood Lake?

### 2. Explore the source of pathogens.

Using a pair-share format, have students brainstorm about sources of pathogens in water. Examples of sources include contamination from livestock, septic tanks, ducks and geese, cropland, pets, illicit connections, human waste, leaking sewer lines, urban stormwater runoff, boat discharges, and nuisance levels of wildlife. Show and discuss the *Compare and Contrast* teacher resource noting how water quality and sanitation in third world countries differs from your school's location. Follow up with the *Potential Sources of Pathogens* teacher resource to reinforce the understanding that pathogens come from multiple sources. Then have the teams create diagrams that show how they think water in the Lower Grand River Watershed could become contaminated with pathogens.

**View** the video: ***Communities for Clean Water: Managing Pathogens*** available at http://groundswellmi.org/resources/communities-for-clean-water/

Since it is important to know whether human pathogens are present in the water, focus on **septic systems** as an example of contamination from a human source. Ask students whether their household sewage waste goes to a wastewater treatment plant or to a septic system. Show the diagram of a septic system and explain how a septic system works. "Specifically, this is how a typical septic system works:

1. All water runs out of your house from one main drainage pipe into a septic tank.
2. The septic tank is a buried, water-tight container usually made of concrete, fiberglass, or polyethylene. Its job is to hold the wastewater long enough to allow solids to settle down to the bottom forming sludge, while the oil and grease floats to the top as scum.
   Compartments and a T-shaped outlet prevent the sludge and scum from leaving the tank and traveling into the drainfield area.
3. The liquid wastewater (effluent) then exits the tank into the drainfield.
4. The drain field is a shallow, covered, excavation made in unsaturated soil. Pretreated wastewater is discharged through piping onto porous surfaces that allow wastewater to filter though the soil. The soil accepts, treats, and disperses... wastewater as it percolates through the soil, ultimately discharging to groundwater.
   If the drainfield is overloaded with too much liquid, it will flood, causing sewage to flow to the ground surface or create backups in toilets and sinks.
5. Finally, the wastewater percolates into the soil, naturally removing harmful coliform bacteria, viruses and nutrients. Coliform bacteria is a group of bacteria predominantly inhabiting the intestines of humans or other warm-blooded animals. It is an indicator of human fecal contamination." (EPA, How Your Septic System Works, https://www.epa.gov/septic/how-your-septic-system-works)

To help students understand the design of a basic septic system, use the *Septic Systems* teacher resource as a guide to demonstrate or have students create a model of a septic system in an aluminum pan or plastic container using milk cartons (house and settling tank), straws (pipes), straws with holes (drainage field), clay (connectors), and sand for the soil. Have students run their system by adding various amounts of wastewater (Colored water with used coffee grounds). The solid portion of the wastewater will settle to the bottom of the tank, while the liquid (effluent) will exit the tank into the drainfield. (Scum can be represented by cooking oil.) Students should note that the system has a limited capacity. There is a chance that the groundwater and surface water could be contaminated with pathogens from households. The model could be further enhanced by placing dry coffee on the land or in the water to illustrate contamination by pets and wildlife.

Teacher Note: This activity is intended to show students the general design of a septic system. The above design will not will not completely filter out the colored water. Remind students that their model is missing the important component of microbes in the septic system.

Follow up this section with reflective reading of the *Bacteria and Water Quality* student reading.

**Michigan K-12 Science Standards Engineering Design Extension for MS-ETS1-1:** Septic system failure can happen in old systems, poorly maintained systems, or an improper location. Using the septic system models that were created as a guide, have students define the criteria and constraints of septic systems with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

**3. Evaluate indicator bacteria in streams and rivers.**

Pose the question: *How can we tell if there are pathogens in the water?* Direct counting and identification of all the different types of pathogens is expensive and time consuming. Introduce the idea of monitoring for pathogens through use of **indicator bacteria** such as fecal coliform bacteria and *Escherichia coli* (*E. coli*). The *Indicator Bacteria* teacher resource diagram illustrates that fecal coliform bacteria are a subset of coliform bacteria and *E. coli* bacteria are a subset of fecal coliform bacteria.

**Engage** students in **water quality monitoring** for bacteria.

Take appropriate precautions to protect student health. This is especially important if there is a chance that the stream, pond, or river being studied for other water quality parameters has bacterial contamination. It would not be wise to sample a stream with heavy contamination without precautions such as wearing gloves and avoiding direct contact with water. An example of a relatively inexpensive way to screen for bacteria is Petrifilm™. This method is described in *Monitoring for E. coli in Water Using Petrifilm™* teacher resource. Another method is described in the *Interpreting Coliscan Pour Plates™* teacher resource. However, other methods are certainly available as described in *Citizens Monitoring Bacteria: A training manual for monitoring E. coli* and *Safe Waters and Healthy Waters: A guide for citizen groups on bacterial monitoring in local waterways* as annotated in the additional resources section of this lesson.

**4. Research the indicator bacteria patterns in the Lower Grand River Watershed.**

**Extension:** Work with a math teacher to incorporate simple statistics and creation of box plots into this analysis. See the *Example of a Box Plot* teacher resource.

Pose the question: *How can monitoring data be translated into a usable format for understanding and decision-making?* Answers might include making graphs and charts, generating statistics, illustrating trends, incorporating maps, and other means of telling a story in an understandable way.

Provide students with datasets showing fecal coliform bacteria monitoring results from the Lower Grand River sites monitored by the Grand Rapids Water Resource Recovery Facility. See the *Fecal Coliform Levels (colonies/mL) at Sites in the Grand River Watershed* resource. Explain that the Facility has been monitoring the Grand River and its tributaries for many years. Show students the map of the sites that have been monitored (*River Monitoring Sampling Locations* teacher resource). Using the *Exploratory Data Analysis* student activity, have them analyze one of the sites found in the dataset. Their results can be presented to the class followed by a discussion. Pose the question: *So what do the data indicate?* Prior to 1994, the water quality standard in Michigan required that levels not exceed 200 fecal coliform colonies per 100 mL. Compliance with the fecal coliform standard was determined based on the geometric mean of any series of five or more consecutive samples taken over a 30-day period. For their site, have students determine the percent exceedance based on how many times a sample exceeds 200 fecal coliform colonies per mL. (*Teacher Note:* Geometric and arithmetic means are calculated differently. In this activity students are calculating arithmetic means.) Have them compare the values for the various sites in the Lower Grand River Watershed.

Share with the students the current water quality standards for *E. coli* (Table 1) and note that the standards vary based on the designated use of the water body.

Table 1. *E. coli* Water Quality Standards

| **Designated Use** | **Water Quality Standard** |
|---|---|
| *Total Body Contact (May 1 - October 31)* | • *Daily Maximum Geometric Mean: 300 E. coli per 100 milliliters (mL)*<br>• *30-Day Geometric Mean: 130 E. coli per 100 mL* |
| **Partial Body Contact (all year):** | *Daily Maximum Geometric Mean: 1,000 E. coli per 100 mL* |

Source: MDEQ, http://www.michigan.gov/documents/deq/wrd-swas-statewide-ecoli-tmdl_550369_7.pdf

**5. Formulate a plan to reduce pathogen loads.**

Ask students how they think the pathogen load in the Lower Grand River Watershed could be decreased. Present how the Lower Grand River Watershed Management Plan's *Information & Education Strategy to Address Pathogens and Bacteria* addresses this issue (see the teacher resource). It would be helpful to review of the concept of best management practices (BMPs) and green infrastructure as a way to manage erosion and runoff. In general, **best management practices** are physical or cultural methods to reduce pollutant loads. **Green infrastructure** includes a range of soil-water-plant systems that intercept, infiltrate a portion of water into the ground, evaporate a portion of it into the air, and in some cases release a portion of it slowly into a lake, stream, or sewer system.

Given the results of locations where high levels of fecal coliform have been identified in the Lower Grand River Watershed, have groups of students create a presentation or poster on the subwatersheds with identified fecal coliform bacteria impairments (Bass River; Buck Creek; Direct Drainage to Lower Grand River; Plaster Creek; Coldwater River; Coopers, Clear, and Black Creeks; Crockery Creek, Deer Creek; Threatened Uses: Upper/Lower Rogue River; Spring Lake/Norris Creek; Sand Creek).

Students should use the **Lower Grand River Watershed Management Plan** and the **Lower Grand River Organization of Watersheds** website* to research the land use and population characteristics in their chosen subwatershed. [* See: **Link 3A** and **Link 3B** on the Groundswell website at groundswellmi.org/lessonlinks]

Include information about the levels of fecal coliform bacteria from the Grand Rapids Water Resource Recovery Facility monitoring if available.

Have students present an outreach plan that supports the priorities of the *Information & Education Strategy to Address Pathogens and Bacteria* in the Lower Grand River Watershed Management Plan.

As a class, prioritize which watersheds might be of the most concern and what kind of project could best reach specific stakeholder groups, such as agricultural producers, local units of government, rural residents, urban residents, and/or outdoor enthusiasts. Note that the source of the bacteria is related to risk – human sources (high risk), non-human/animal feces (moderate risk), and environmental sources such as sediments, plants, soil (lower risk).

**Assessment**

1. Present students with two datasets from fecal coliform bacteria monitoring in two locations and have them use simple statistics and graphs to compare and contrast the two locations.

2. Have students write a persuasive essay about the importance of addressing pathogens in the Lower Grand River Watershed.

**Additional Resources**

Website links can be found at:
groundswellmi.org/lessonlinks

**Adopt a Beach Lessons**
This series of lessons could be used to develop the connection of the Lower Grand River Watershed to the beaches of Lake Michigan. In Lesson 4 – Beach Mysteries, students learn about bacteria as an indicator of beach water quality for swimming. In groups they solve hypothetical problems associated with beaches. **Link 3C**

**BeachGuard**

BeachGuard is an online system originally developed by the State of Michigan to collect beach sampling data from local health agencies and make the data available via a public website. Since launched in 2001, BeachGuard has been implemented by three other Great Lakes States: Illinois, Indiana, and Ohio. **Link 3D**

**Can the poop detectives solve a pollution mystery?**

A short article on which animals—from chickens and cows to deer and people—produce the fecal matter that is washing into and polluting a waterway based on source tracking. **Link 3E**

**Centers for Disease Control – Waterborne Disease**

Information and statistics about waterborne disease incidences in the United States can be found at this site. **Link 3F**

**Citizens Monitoring Bacteria: A training manual for monitoring *E. coli***

This manual is a result of a joint project to enhance citizen *E. coli* monitoring in streams of the upper Midwest. Detailed methods and helpful information is presented. **Link 3G**

**Go with the Flow**

*Go with the Flow* is an interactive wastewater treatment map that takes you on a visual journey through the wastewater treatment process. Beginning in our homes and businesses and ending when clean water is returned to oceans, lakes, and other bodies of water, each icon represents a different step in the wastewater treatment process and provides viewers with a simple, non-technical narrative description. The Water Environment Federation has additional teacher resources as well. **Link 3H**

**Homeowners Guide to Septic Systems**

Created by U.S. EPA, the *Homeowners Guide to Septic Systems* provides guidance to those who have septic tanks. **Link 3I**

**Lower Grand River Organization of Watersheds (LGROW)**

Useful maps and summaries of subwatersheds of the Grand River Watershed are found at this site. **Link 3J**

**Michigan Department of Environmental Quality**

Information, maps, and reports about how Michigan is addressing bacterial loads in water bodies can be found under the Total Maximum Daily Load (TMDL) section of the MDEQ website. **Link 3K**

**Michigan *E. coli* Pollution and Solution Mapper**
A new statewide, interactive mapping tool is available to assist in identifying impacted areas as well as provide resources for getting

involved in efforts to reduce the *E. coli* levels. **Link 3L**

### Microbial (Pathogen)/Recreational Water Quality Criteria

This U.S. EPA site has many links to information about recreational water quality criteria and drinking water as well. **Link 3M**

### Michigan Nonpoint Source Best Management Practices Manual

This document provides guidance on dealing with nonpoint source pollution to restore impaired waters and protect high-quality waters in Michigan. **Link 3N**

### Michigan Water Stewardship Program

The Michigan Water Stewardship Program (MWSP) is a partnership of organizations that provide educational assistance to Michigan's residents to identify and reduce contamination risks to water and other natural resources. The program encourages individuals to take voluntary proactive steps to protect Michigan's water quality – our drinking water – as well as protect our other valuable natural resources while caring for our family's health. **Link 3O**

### MIWATERS

The MIWATERS Site Explorer provides public access to many documents associated with MiWaters, which is a web-based permitting and compliance database for MDEQ's Water Resources Division (WRD). The site explorer has useful filters with a searchable format. **Link 3P**

### Nonpoint Source Pollution Environmental Resources Guides

The Air & Waste Management Association published several *Nonpoint Source Pollution Environmental Resources Guides*. The guides have a variety of lessons on nonpoint source pollution. **Link 3Q**

### Safe Waters, Healthy Waters: A guide for citizen groups on bacterial monitoring in local waterways

Published in April 2016, this document provides guidance for citizen groups on how to identify, narrow down sources, and communicate about bacterial contamination, with a specific focus on human sewage sources and monitoring techniques that are simple, reliable, and low-cost. **Link 3R**

### Project WET

The Project WET Curriculum and Activity Guide has activities tracing the source of a waterborne disease, transport of bacterial contamination in groundwater, and strategies to remove contaminants from water. **Link 3S**

# Waterborne Pathogens
in the news

## Sewage Leaking into Georgetown Twp. Lake

http://woodtv.com/2016/08/26/sewage-leaking-into-georgetown-twp-lake/

GEORGETOWN TOWNSHIP, Mich. (WOOD) — From fishermen to families, Maplewood Park in Georgetown Township is a summer hot spot. But high E. coli levels at the lake there have forced swimmers to avoid the water for years.

Township officials even removed the beach seven years ago and added a splash pad to keep people out of the water.

Now, a new study has revealed part of the problem: human waste leaking into the lake. And some homeowners may have to pay up to help fix the problem. "Noticed that some of the slime and what have you in the lake. This past spring it was really, really dirty. They did spray it and clean it up," Jim Kenyon told 24 Hour News 8.

Kenyon lives along the water is all too familiar with the recent E. coli issues. The new discovery comes as no surprise. Just a yard over from his home is one of the entry points where dogs sniffed out human wastewater in the study commissioned by the township.

It's a problem believed to be caused by faulty septic systems in nearby homes.

The main issue? "We're not going to be able to know for sure how many or which homes," Georgetown Township Superintendent Dan Carlton told 24 Hour News 8 Friday.

Now, it's up to the township board to find a solution. Two options are to enact a mandatory hookup to the township's sewer system for homeowners who do have access and add an additional sewer line for those who don't.

The township's connection fee is $2800. "The hardest part would be maybe those who fixed it (septic systems) more recently — and what they have to face," Carlton said.

But even if the human waste is cleaned out, it's unclear if swimmers will be able to return to the lake. E. coli levels may remain too high due to additional animal waste in the water. But more testing would be needed later to determine that.

Carlton is optimistic that people will eventually be allowed full access to the water once again. "That's the goal long-term," Carlton said. "That's why we started down this road."

Kenyon's home is already hooked up to a sewer line, so he won't be affected. But he hopes the lake is cleaned up as well. "It would be great. You would start seeing people use it more often," Kenyon said.

As for fishing in lakes with high E. coli level — according to DNR officials, as long as people wash their hands well and cook the fish properly, they should be okay.

Maplewood Park (photo credit: http://www.gtwp.com/)

## Superbugs in Our Watershed?

http://www.therapidian.org/placematters-superbugs-watershed

When Plaster Creek was known as Ken-O-Sha ("Water of the Walleye") it followed a meandering course marked by huge sycamore, tulip poplar, silver maple and bur oak trees with roots that held the stream's banks and canopies that cooled the singing waters. The creek supported many types of fish including brook trout, as well its namesake, the walleye. Ken-O-Sha helped to sustain local Ottawa Indians physically and spiritually, and later was a childhood playground for many Grand Rapidians. Today the creek is so full of sediment and bacteria that it has been designated as impaired, meaning it is unsafe for children to play in and even to touch.

How the creek became transformed from a life-giving community asset into a public health hazard is a story that Plaster Creek Stewards is trying to understand and eventually reverse. A main part of that story involves bacteria. One of these bacteria, E. coli, is normally found in the intestines of animals. Since it doesn't live very long on its own in the environment, E. coli's presence is used as an indicator of fecal contamination. As far as human health and recreation is concerned, there are three stages of E. coli contamination in water bodies. At the lowest concentrations (zero to 130 E. coli colonies per 100 ml of water) the creek is safe for swimming. At moderate E. coli concentrations (130 – 1000 colonies) the stream is unsafe for swimming, but considered safe for "partial body contact" (ex: fishing from shore). At high concentrations (>1000 colonies), the stream is unsafe for any human contact.

We have consistently found that the levels of E. coli in Plaster Creek are beyond what the State considers safe for both full and partial body contact. On its worst days, E. coli in the stream has reached levels that are 100 times higher than what is considered safe for swimming.

Besides E. coli, there are many other types of bacteria in waterways, much of which is naturally occurring and harmless to humans. But in urban streams like Plaster Creek, it's not well understood how much of the bacteria in streams is potentially harmful to public health. But high E. coli levels tend to indicate the likely presence of other disease-causing microbes. Another growing concern is whether or not bacteria in these public waterways are resistant to antibiotics.

# Waterborne Pathogens in the news (More Information)

**Georgetown Township Michigan, Maplewood Lake**

**Nonpoint Source Pollution problem: High levels of *E. Coli***

## Trained dogs sniff out human waste in Maplewood Lake (August 2016)

Source: http://www.mlive.com/jenison/index.ssf/2016/08/trained_dogs_sniff_out_maplewo.html

Over the years, locating the source of E. coli pollution in Maplewood Lake has been an ongoing mystery in Georgetown Township.

Now the township has brought in dogs to try to solve it.

Assistant Township Manager Rod Weersing reported to the board on Aug. 22 on a project conducted by Environmental Canine Services (ECS).

Weersing and ECS conducted tests around Maplewood Lake, located on 12th Avenue north of Baldwin Street. Specially trained dogs were used to detect human waste in water samples taken from various points along the borders.

According to Weersing's report, dogs reacted by barking or pointing to water samples from the northwest side of the lake, downhill from two houses at the end of Elmwood Drive; at the creek outfalling on the northwest side of the lake; on samples taken near the dock; manholes and catch basins on 12th Avenue, and varied responses to points along the south and southeast borders of the lake. The teams also explored the creek on the northwest side of the lake. Specific testing sites and results are listed in the report.

Jamestown also used ECS this summer in planning the Rush Creek Watershed Management Plan.

In the past, water quality in the lake was monitored regularly by the Ottawa County Health Department. From time to time the beach was closed due to high levels of E. coli in the water. Studies were conducted around area homes and farms to try to determine where pollution might be coming from, but tests did not show whether human or animal waste was at fault.

"We encouraged people not to feed the ducks, or walk their dogs along the shore, and encouraged people in the area to hook up to public sewer," said Township Manager Dan Carlton, but pollution levels were still high, especially after heavy rains.

In 2009 the lake was closed permanently to swimmers. A splash pad opened as part of the park upgrade in 2011. The problem of contamination continued to be studied.

The township has called on other interested individuals to help monitor water quality. Lee Westerveldt, principal at the Jenison Early Childhood Center, monitored water samples for about two summers sending results to the county, the Department of Environmental Quality, and Michigan State University. MSU is qualified to determine whether pollution is human or animal. Results also were given to the Township Board, Westerveldt said.

"They were trying to determine if (the contamination) was animal or human," Westerveldt said. "The water quality of the lake has improved over time. My guess is, they hooked up more area homes to the (public) sewer." Westerveldt discontinued testing in 2014. He advised the board the best solution might be to require hookups to public sewer, and offer low-interest or zero-interest loans to make it possible.

"All testing told us in the past was that there were E. coli issues," Weersing said. "Nothing was done to tell us if it was animal, human or both. We wanted to find that out."

Weersing said the report has been forwarded to the township utilities committee, which will make a recommendation, possibly in September, to the Township Board.

## Georgetown will require Maplewood Lake neighbors to connect to public sewer (October 2016)

Source: http://www.mlive.com/jenison/index.ssf/2016/10/georgetown_will_require_maplew.html

GEORGETOWN TOWNSHIP -- Seventy home sites in the Maplewood Lake area will be affected by enforcement of a Georgetown Township ordinance after a resolution was adopted by the Township Board on Oct. 10.

Citing the "health, safety and welfare" of the community, the board approved requiring owners of specified properties where public sewer is available to hook up to it within the next 18 months.

Some of the streets where there are homes not yet connected to public sewer include Broadview Drive, Chickadee Drive, Englehurst Drive, Ridgewood Drive, Maplewood Drive and Cypress Drive, mostly on the borders of Maplewood Lake. A full listing of addresses is available on the township website.

The township has spent several years studying the sources of pollution of the lake, testing for human, agricultural and animal sources.

"The area of the homes is the vicinity of Maplewood Lake," said Township Manager Dan Carlton, who presented a report on the area to the Township Board at the Sept. 12 meeting.

Carlton said the Maplewood Lake area is the largest neighborhood where sewer hookups have not been done, but similar resolutions have been done in the past. About 300 to 400 homes in other areas still are without sanitary sewer. "We need to address the systems that are failing," Carlton said.

The township's standard financing of sewer hookup costs is for 10 years at 6 percent. A special rate for this project is being considered by the utilities committee for 20 years at 3 percent, officials said. The committee will then make its recommendation to the Township Board.

Official publication of the resolution will be in the Advance, and homeowners will receive a letter in mid-November.

# Waterborne Pathogens in the news (More Information)

**West Michigan, Plaster Creek**

**Nonpoint Source Pollution problem: High levels of *E. Coli***

## Cleaning Up Plaster Creek will take 'watershed-wide effort'

Source: Grand Rapids Business Journal: http://www.grbj.com/articles/74530-cleaning-up-plaster-creek-will-take-watershed-wide-effort

Plaster Creek is considered the most polluted creek in West Michigan, according to Gail Heffner, a faculty member and director of community engagement at Calvin College. It covers 14 miles and traverses agricultural, suburban and urban landscapes in its journey from Caledonia/ Dutton to downtown Grand Rapids, where it empties into the Grand River near Market Avenue.

"It's a long urban creek that is in a highly degraded state," Heffner said. "It's in bad shape. It's considered the most polluted creek in West Michigan, for a variety of reasons."

Heffner said E. coli is present in the river at 50 times higher than what is considered safe for human contact. In addition, chemicals and toxins have made their way into the river. The pollutants come from agriculture, vehicles, lawn upkeep and many other sources.

Due to the high levels of contaminates, Plaster Creek poses a serious health risk to the community surrounding it. It also has the potential to devalue property and hurt businesses in the area due to flooding and its less-than-enviable state.

The Plaster Creek Stewards, which includes members of Calvin College, West Michigan Environmental Action Council, other environmental organizations and neighborhood churches, are hoping to change that through cleanup efforts and educating the community within the watershed area.

Late last month the group held a workshop, "Love Thy Downstream Neighbor: From Plaster Creek to the St. Lawrence River," that involved an education component and the planting of two rain gardens upstream as part of its ongoing cleanup efforts.

Much of the pollution in the creek arrives there from runoff following large rain events; rain gardens are one way of helping suburban and urban environments prevent runoff by keeping the water onsite and helping the ground absorb it.

"When you have the landscape covered in concrete, whether it's for roads or parking lots or strip malls — anything that is covered in concrete, water can't be absorbed into the ground," Heffner said. "It runs off. When you have a heavy rain event and you have a large amount of water running off (and) getting in storm drains, it causes a lot of flooding. So what is better to do is to try and manage water on site."

Suburban and urban areas are not the only areas where runoff can occur.

"Runoff can occur in agriculture areas as sheet or gully erosion," said Connie Redding, district administrator for the Kent Conservation District. "Sheet erosion moves water over the surface of soil, and gully erosion is runoff which wears a path through the soils. Both types of runoff result in erosion and can be caused by several factors, including soil type, slope, over-irrigation and plowing practices.

"Proper irrigation and equipment, along with conservation practices including cover crops, filter strips, grassed waterways and increasing crop residue, will slow the excess water and allow it to infiltrate the ground. It is in the best economic interest of the farmer to keep his water and his soils."

The cleanup event was made possible due to a $4,000 Fulbright Eco-Leadership Program grant that was awarded to former Calvin College professor and current Gordon College Provost Janel Curry.

The grant provides former Canadian Fulbright scholars with money to use in their local communities.

The Michigan Department of Environmental Quality also recently allocated $375,000 to the Plaster Creek Stewards for cleanup efforts and education, and the U.S. Environmental Protection agency has given the group $58,500.

But that is a minimal amount in comparison to what is needed for the substantial cleanup required. Heffner said that she expects it would take 20 to 30 years of concerted effort and was hesitant to put a dollar amount on what would be needed to achieve a clean Plaster Creek.

She was not hesitant, however, in suggesting ways in which a clean creek would impact the economy of the area. She pointed to property values as a key impact opportunity, noting the creek can be both an asset for homeowners and a problem if a house is located in one of the flood-prone areas.

She noted that businesses have the ability to aid cleanup efforts through the creation of their own rain gardens and landscaping choices. Known as green infrastructure, rain gardens, vegetation choices, green roofs, rain barrels and permeable pavements all are options with a positive environmental impact and good for a business's bottom line, directly or indirectly. They are also ideas that have been around for a while.

Heffner mentioned Catalyst Partners as a business that is doing it right in terms of reducing stormwater runoff. She also noted that both Pioneer Construction and Cascade Engineering have been involved in cleanup efforts.

**Continued on page 2.**

# Waterborne Pathogens in the news (More Information)

**West Michigan, Plaster Creek**

**Nonpoint Source Pollution problem: High levels of *E. Coli***

**Continued from page 1:**

"Plaster Creek is a long-neglected community asset," said Chris Beckering, Pioneer Construction's director of business development. "It is actually a quite beautiful, natural refuge in the heart of a largely industrialized area. Our team members volunteer twice a year to clean up the area from the U.S. 131 overpass to Buchanan. Since we began our effort four years ago, we've noticed a real improvement.

"When we first started, we pulled thousands of pounds of garbage out of the creek and its banks. We found everything from shopping carts to tires to car parts. It was essentially being used as a garbage dump. As the creek has been cleaned up, I think people are now treating the area with greater respect. We now see walkers and bikers including families and young children enjoying the creek.

"Our efforts to date have focused primarily around cleanup. We are in the process of evaluating measures we can take to reduce runoff from our properties and working with Calvin College to educate people who live and work in the watershed area about the impact of their activities. In 2009, we received the Associated Builders and Contractors' green contractor certification. The certification process evaluates environmental impacts of our headquarters operations and helps us establish benchmarks and plans for improvement. It's going to take a watershed-wide effort to restore Plaster Creek to health."

Plaster Creek has a long way to go before it will be clean enough for human contact, but its potentially hazardous health and economic impact means there are many people and businesses with a vested interest in seeing the cleanup efforts succeed.

## Excerpt from the Plaster Creek Watershed Management Plan

Source: Plaster Creek Watershed Management Plan: http://www.lgrow.org/watershed/plastercreek/about

### Watershed Description

The Plaster Creek Watershed (Watershed) has a drainage area of 58 square miles and is located entirely in Kent County on the south and east sides of the Grand Rapids Metropolitan Area. Plaster Creek's headwaters begin in Gaines Township and flow north and then west to its confluence with the Grand River.

### Water Quality Concerns

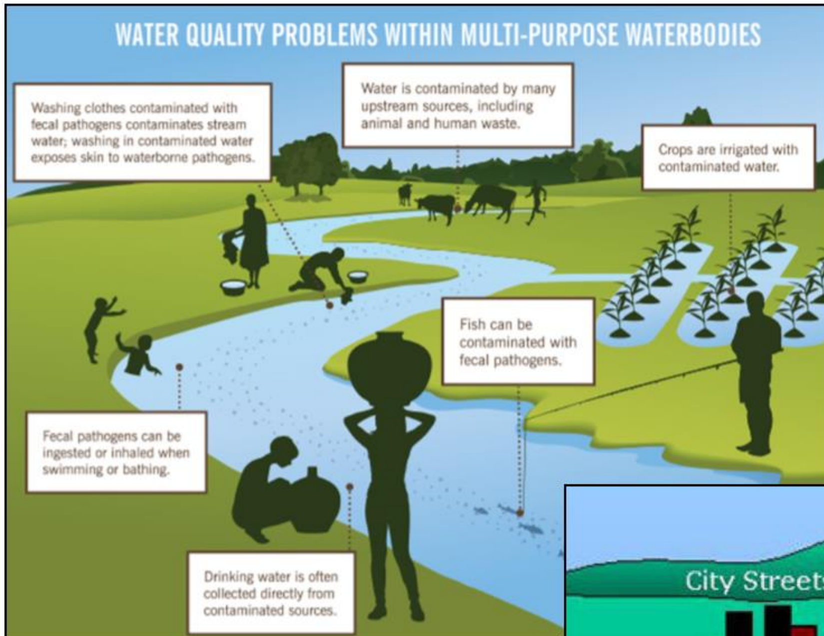
Previous hydrologic models conducted on Plaster Creek indicated that the watershed's hydrology changed drastically when it transitioned from a natural condition to an active agricultural area in the early 1900s. The watershed is transitioning again to a highly urbanized watershed, spurred recently by the addition of a freeway across the watershed's headwater tributaries. Increased urbanization has continued to increase storm water runoff volumes and peak flows, further challenging the drainage system and increasing channel erosion and flooding.

The Michigan Department of Environmental Quality (MDEQ) conducted a biological assessment of a 12-mile reach of Plaster Creek in 2001. This assessment rated the macroinvertebrate community as minimally acceptable to poor at the four survey stations, while physical habitat conditions were rated as good to fair (moderately impaired). In 2002, the MDEQ included a portion of Plaster Creek, a 12-mile stretch from the Grand River confluence upstream to Dutton Park, on the Section 303(d) non-attainment list due to elevated levels of Escherichia Coli (E. coli) and poor fish and macroinvertebrate communities (due to excessive sediment loading).

A stream inventory was conducted in 3 subwatersheds of Plaster Creek in 2007 as part of the Lower Grand River Watershed (LGRW) Implementation Project to investigate sites of nonpoint source (NPS) pollution. Sites with observable NPS pollution were classified according to eleven categories: debris/trash/obstructions, stream crossing, gully erosion, livestock access, non-point agricultural source, tile outlet, streambank erosion, construction, urban/residential, rill erosion, and other. There were 84 sites observed to be contributing NPS pollution to surface water. Based on the inventory information, it is estimated that Watershed carries a sediment load of 180.28 tons/year, a phosphorous load of 153.23 lbs/year, and the nitrogen load of 306.47 lbs/year. In addition, a monitoring program was conducted from September 2005 to October 2006 to sample E. coli at 13 sites in the Watershed as part of this project. Approximately 80% of the sampling sites sampled during dry weather did not meet the water 10/2008 quality standard (WQS) for total body contact recreation (300 E. coli per 100 milliliter [ml]). None of the sites sampled during wet weather events met the WQS for total body contact recreation or partial body contact recreation (1,000 E. coli per 100 ml as a 30-day geometric mean).

# Compare and Contrast

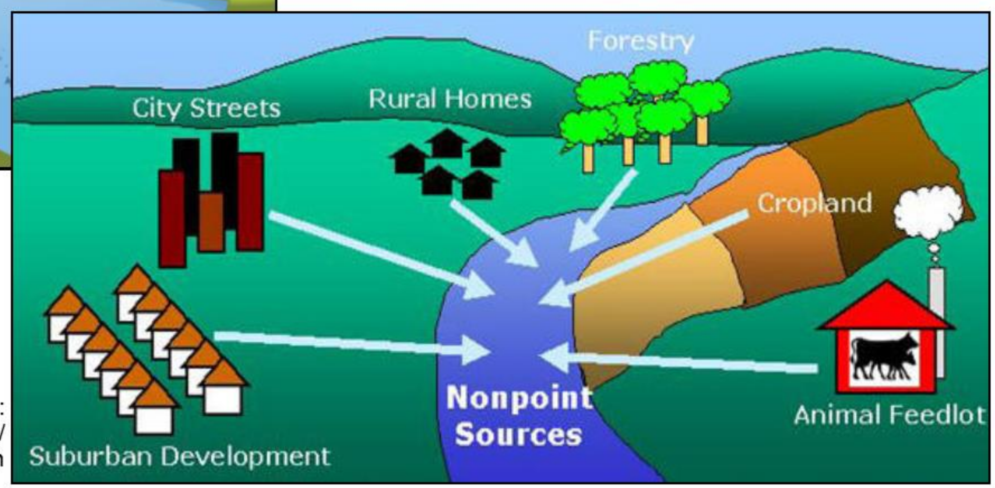
What are the similarities and differences in pathogen sources for an area similar to the Lower Grand River Watershed and a third world country?



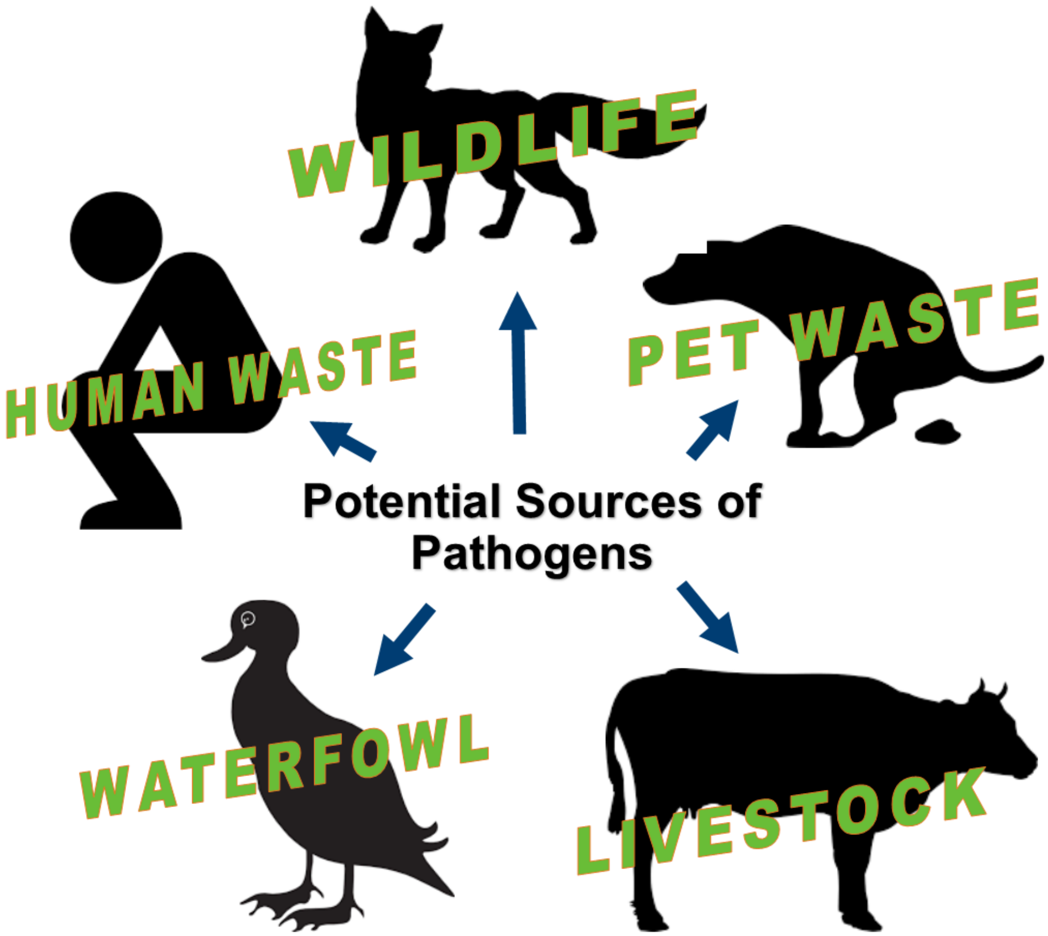

Source: Water Quality & Health Council: http://www.waterandhealth.org/global-water-pathogen-project-helping-meet-post-2015-sustainable-development-goals/

Think about the following:

Contamination from livestock, septic tanks, wildlife, cropland, pets, illicit connections, leaking sewer lines, human waste, urban stormwater runoff, and boat discharges

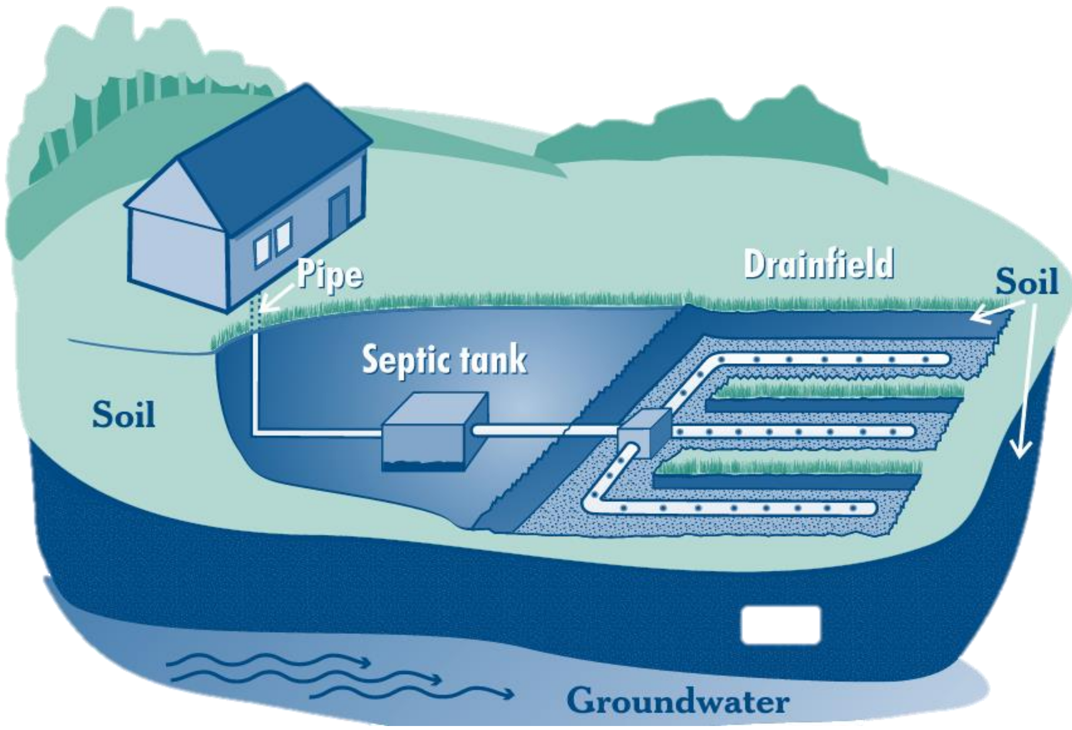



Source: Watershed Education: http://www.oldhamcounty.net/watershed-education

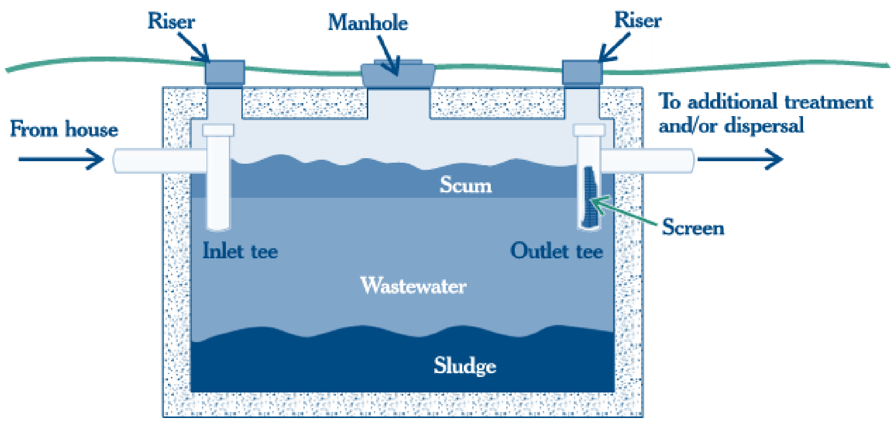



Pathogens come from multiple sources.

# Septic Systems




Typical single-compartment septic tank with ground-level inspection risers and screen



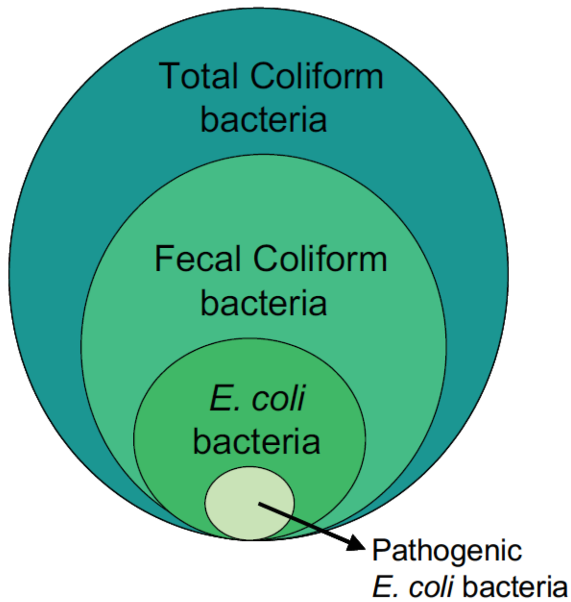

Homowner's Guide to Septic Systems
http://www.yorktownny.org/sites/default/files/fileattachments/engineering_amp_sewer/page/131/homeownersguidesepticsystem-yorktown.pdf

# Bacteria and Water Quality

## Introduction

**Bacteria** are among the simplest, smallest, and most abundant organisms on earth. Bacteria have a cellular structure lacking an organized nucleus and nuclear membrane. Instead of containing genetic information stored on several chromosomes, bacteria contain a single strand of DNA. These organisms reproduce by binary fission, which occurs when a single cell divides to form two new cells called daughter cells. Each daughter cell contains an exact copy of the genetic information contained in the parent cell. The generation time is the time required for a given population to double in size. This time can be as short as 20 minutes for some bacteria species (e.g., *Escherichia coli*).

While the vast majority of bacteria are not harmful, certain types of bacteria cause disease in humans and animals. Examples of **waterborne diseases** caused by bacteria are: cholera, dysentery, shigellosis, and typhoid fever. During the London cholera epidemics of 1853-1854, Dr. John Snow observed that nearly everyone who became ill obtained their drinking water from a specific well into which a cesspool was leaking. Those who became ill either drank water from the well or came into contact with fecally contaminated material while tending those already sick.




*Fecal coliform bacteria which include E. coli are part of a larger group of colifom bacteria.*

Citizens Monitoring Bacteria: A training manual for monitoring E. coli: http://blog.uvm.edu/kstepenu/files/2016/09/Final_ecoli_06c1.pdf

Concerns about bacterial contamination of surface waters led to the development of analytical methods to measure the presence of waterborne bacteria. Since 1880, **coliform bacteria** have been used to assess the quality of water and the likelihood of pathogens being present. Although several of the coliform bacteria are not usually pathogenic themselves, they serve as an indicator of potential bacterial pathogen contamination. It is generally much simpler, quicker, and safer to analyze for these organisms than for the individual pathogens that may be present. **Fecal coliforms** are the coliform bacteria that originate specifically from the intestinal tract of warm-blooded animals (e.g, humans deer, etc.). They are cultured in a special growth media and incubated at 44.5$^{\circ}$C. ***E. coli*** *bacteria* are a subset of coliform bacteria.

The first U.S. standards for drinking water, established by the Public Health Service in 1914, were based on coliform evaluations. It was reasoned that the greatest source of human pathogens in water was from human waste. Each day, the average human excretes billions of coliform bacteria. These bacteria are present whether people are ill or healthy. Monitoring for coliform bacteria was designed to prevent outbreaks of enteric diseases, rather than to detect the presence of specific pathogens. Today, coliform bacteria concentrations are determined using methods specified by the Environmental Protection Agency (EPA) and *Standard Methods for the Examination of Water and Wastewater*.

**Sources of Bacteria**

***Point Sources***

Human sources of bacteria can enter water via either point or nonpoint sources of contamination. Point sources are those that are readily identifiable and typically discharge water through a system of pipes. Communities with sewers may not have enough capacity to treat the extremely large volume of water sometimes experienced after heavy rainfalls. At such times, treatment facilities may need to bypass some of the wastewater. During bypass or other overflow events, bacteria-laden water is discharged directly into the surface water as either **sanitary sewer overflow (SSO)** or as **combined sewer overflow (CSO)**. Power outages and flooding can also contribute to the discharge of untreated wastewater.

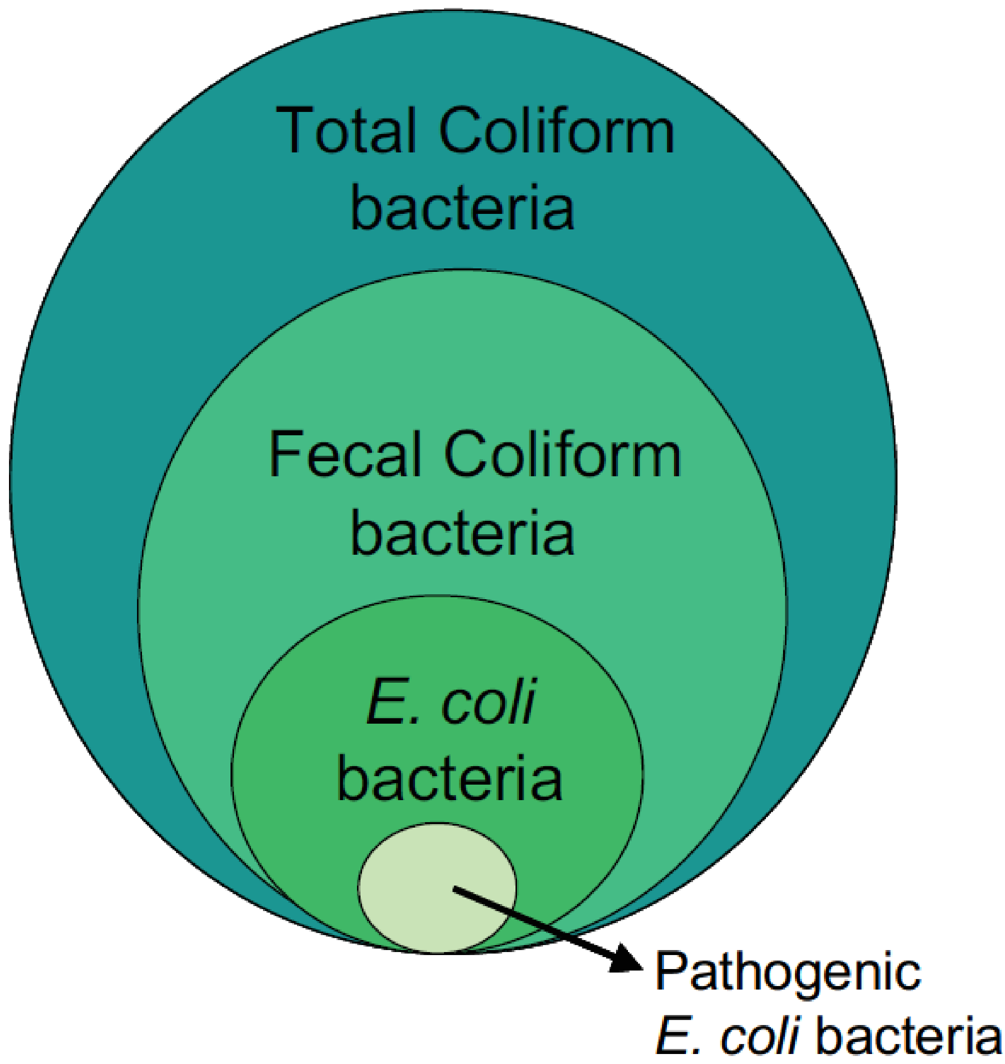
**Illicit connections** to storm sewers are a source of bacteria in surface waters, even during dry periods. A connection to a storm sewer is “illicit” when the wastewater requires treatment prior to discharge and should be routed to the sanitary sewer. Only stormwater and certain permitted discharges (e.g. clear noncontact cooling water) should be discharged to a storm sewer.

***Nonpoint Sources***

Nonpoint sources are those that originate over a more widespread area and can be more difficult to trace back to a definite starting point. Failed on-site wastewater disposal systems (**septic systems**) in residential or rural areas can contribute large numbers of coliforms and other bacteria to surface water and groundwater. Animal sources of bacteria are often from nonpoint sources of contamination. **Concentrated animal feeding operations**, however, are often point source dischargers. Agricultural sources of bacteria include livestock excrement from barnyards, pastures, rangelands, feedlots, and manure storage areas. **Stormwater runoff** from residential, rural, and urban areas can transport waste material from domestic pets and wildlife into surface waters. Land application of manure and sewage sludge can also result in water contamination, which is why states require permits, waste utilization plans, or other forms of regulatory compliance. Bacteria from both human and animal sources can cause disease in humans.

Bacteria-laden water can either leach into groundwater and seep, via subsurface flow, into surface waters or rise to the surface and be transported by overland flow. Bacteria in overland flow can be transported freely or within organic particles. Overland flow is the most direct route for bacteria transport to surface waters. Underground transport is less direct, because the movement of water and bacteria is impeded by soil porosity and permeability constraints.
Source: http://www.michigan.gov/documents/deq/wb-npdes-Bacteria_247230_7.pdf

# Indicator Bacteria




*Fecal coliform bacteria which include E. coli are part of a larger group of colifom bacteria.*

Source: Citizens Monitoring Bacteria: A training manual for monitoring *E. coli*: http://blog.uvm.edu/kstepenu/files/2016/09/Final_ecoli_06c1.pdf

**Monitoring for *E. coli* in Water Using Petrifilm™**


**General Methodology:**

The simple Petrifilm method can be used to screen lakes and streams for *Escherichia coli* bacteria. This is essentially a semi-quantitative presence/absence method successfully used in programs such as Florida Lakewatch and volunteer monitoring in Michigan. One milliliter of water is inoculated on a gel and incubated at 35°C for 24 hours. After 24 hours, colonies are counted. Blue colonies with gas are *E. coli* bacteria and red colonies are other coliform bacteria. For one mL of sample, each blue colony represents 100 *E. coli* colonies/100 mL. The U.S. Environmental Protection Agency recommends that the geometric mean of *E. coli* be no more than 126 *E. coli* colonies per 100 mL in 5 samples over a 30-day period.

**Specific Methods:**

1. At least two hours before sampling, turn on and set the incubator to 35°C. Check the thermometer in the chamber to insure that the interior temperature is 35°C before placing any samples in the incubator.

2. Place the Petrifilm on a flat surface. Write the date and sample number in small print in the upper left hand corner.

3. Obtain a sterile sampling bag and tear off the top making sure to avoid handling the mouth of the bag.

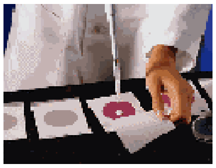
4. Open the mouth of the bag by pulling on the side tabs. Attach the bag to the sampling pole by attaching the metal side tabs to the alligator clamps.

5. Sample the surface water by filling the sampling bag at least half full of water. Use a new sterile bag at each new site.

6. Using a pipette with a sterile tip or a sterile dropper, withdraw one milliliter of water from the sample.

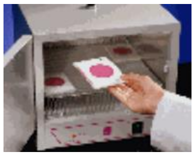
7. Lift the top film of the Petrifilm unit and dispense the one milliliter sample onto the center of the bottom film.

8. Slowly roll the top film down onto the sample to prevent air bubbles.



9. Distribute sample evenly within the circular area using a gentle downward pressure on the center of the plastic spreader (flat side down). Do not slide spreader across the film. Remove spreader and leave plate undisturbed for one minute to permit solidification of the gel.

10. Repeat the process with another one milliliter of the water sample on a new Petrifilm unit. You can use the
same pipette tip if it has not been contaminated.



11. Incubate plates in a horizontal position with the clear side up for 24 ± 2 hours at 35°C.

12. After 24 hours ± 2 hours, count the colonies. Blue colonies with gas will be *E. coli* and red colonies with gas bubbles will be other coliforms.

13. Report the number of *E. coli* and other coliforms (See Figures 1-4). Each colony is equivalent to 100 colonies per 100 mL.

14. After counting the bacteria, use a dropper to place 1 mL of bleach on the Petrifilm. Place in a biohazard bag or sealed plastic bag and dispose of properly.

15. Store unopened Petrifilm foil pouches in the refrigerator. After opening, return unused Petrifilm to foil pouches and seal with tape. However, do not refrigerate open packages, store at room temperature.

Figure 1.
**No colonies**

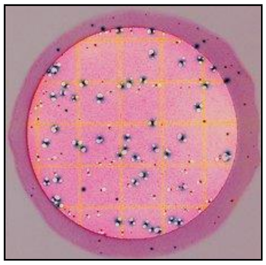


Figure 2.
***E. coli* = 49** (blue colonies with gas)
**Total coliform = 87** (red and blue colonies with gas)

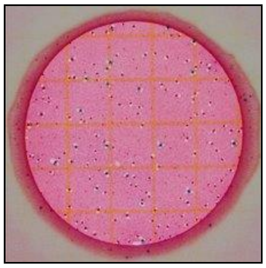


Figure 3.
***E. coli* count = 17**
**Estimated total coliform count = 150**

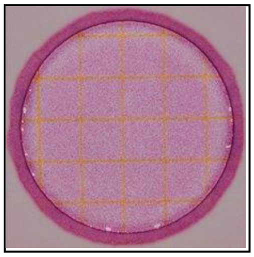


Figure 4.
**Actual Count = TNTC**
**(Too numerous to count)**

Adapted from: 3M Microbiology:
http://multimedia.3m.com/mws/media/236246O/petrifilm-ecoli-coliform-interpretation-guide.pdf

## INTERPRETING COLISCAN® POUR PLATES

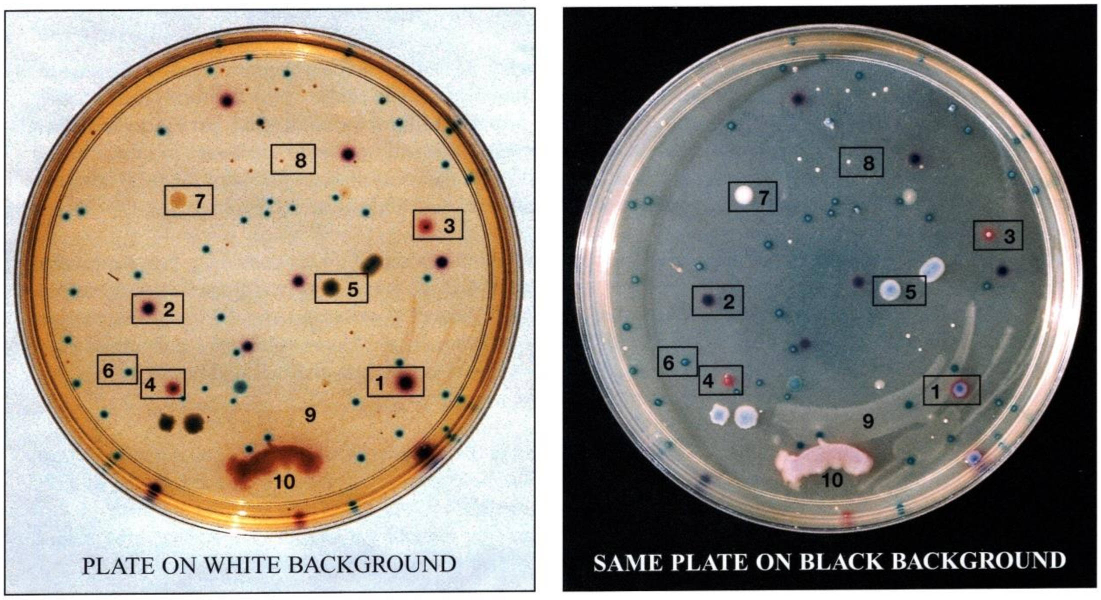


PLATE ON WHITE BACKGROUND    SAME PLATE ON BLACK BACKGROUND

**Explanation of colony types (24-48 hrs. incubation)**

1. purple surface colony (hazy halo)
2. purple submerged colony
3. pink surface colony
4. pink submerged
5. blue-green surface colony (white halo)
6. blue-green submerged colony
7. white surface colony
8. white submerged colony
9. white spreader on plate bottom
10. pink spreader on surface

Note that submerged colonies are smaller than the same type growing on the exposed surface and color and appearance are different when viewed over different backgrounds.
No's. 1 & 2 are typical *E. coli* (fecal coliform) colonies which produce both galactosidase and glucuronidase and are purple due to the combination of the pink and blue-green chromagens that indicate the presence of the respective enzymes.

No's. 3 & 4 are typical general coliforms (Genera *Citrobacter, Enterobacter, Klebsiella*) which produce galactosidase and are therefore a pink colony color.

No's. 5 & 6 are characteristic of less common bacteria that produce glucuronidase only and are therefore a blue-green colony color.

No's. 7 & 8 are characteristic of bacteria that produce neither galactosidase nor glucuronidase and therefore are a white or colorless colony.

No's. 9 & 10 are spreaders and can each be counted as only one colony.

Bacteria that appear like No's. 5, 6, 7, 8 & 9 are likely members of the family Enterobacteriaceae, but are not technically coliforms because they don't produce the characteristic enzyme pattern. However, these types include such important genera as *Proteus, Salmonella and Shigella* and should not be ignored as insignificant.

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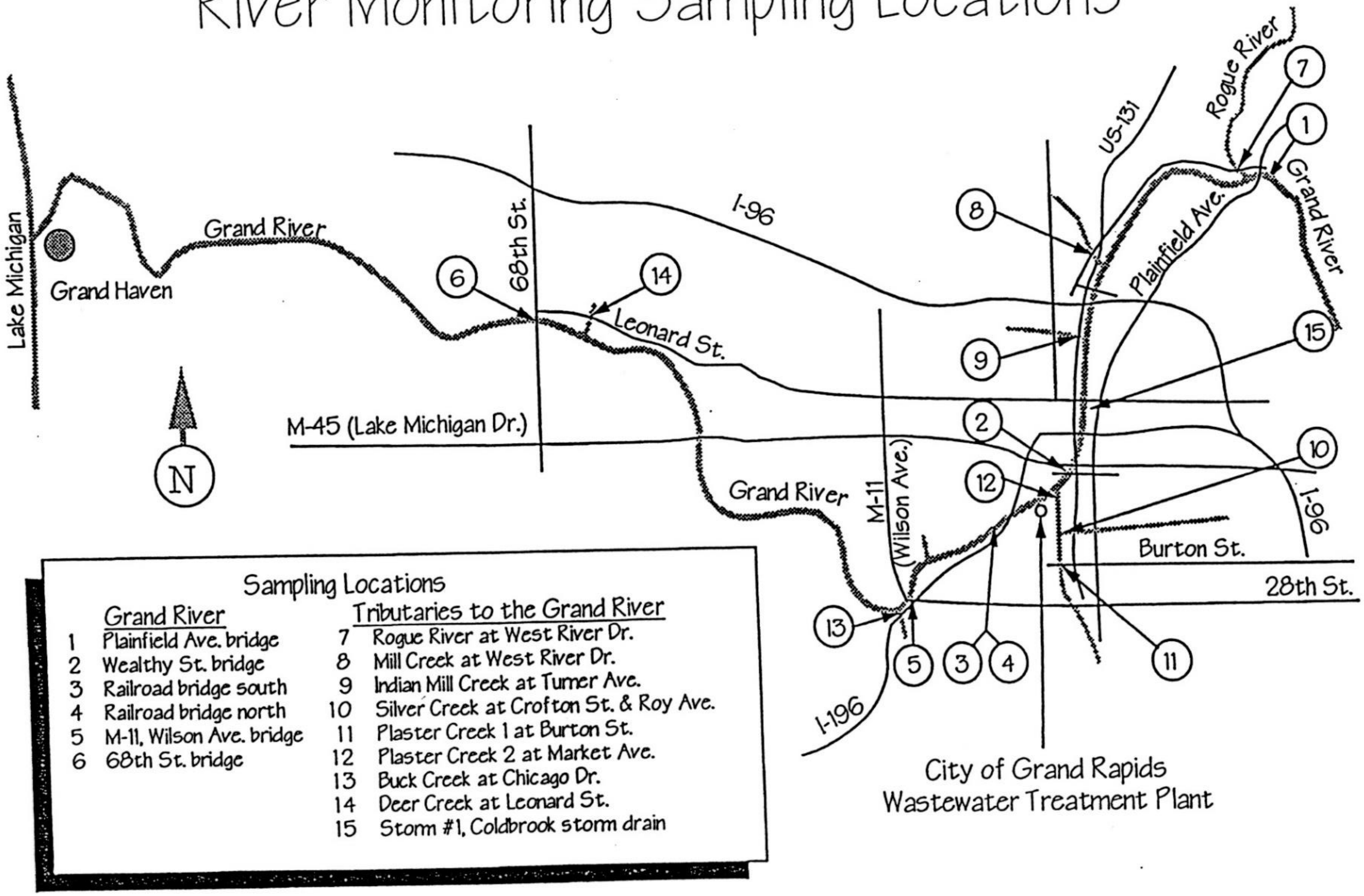
# River Monitoring Sampling Locations




Source: Grand River Monitoring, http://www.grand-rapids.mi.us/enterprise-services/Environment-Services/Pages/GR%20ESD%20Grand%20River%20Monitoring.pdf

## Exploratory Data Analysis

Site Location**:** ______________________________________________

1. Select a site in the Lower Grand River Watershed for analysis.

3. Examine data graphically. (line graphs, bar graphs, scatterplots, box plots)

4. Look for relationships and trends. (How many times were the fecal coliform levels above 200 mL per 100 mL? Were there seasonal trends?)

5. Compare results with other geographic areas.

Optional: Calculate basic descriptive statistics. (arithmetic average, geometric mean, median, range)

**Questions:**

1. What trends did you see at your site?

2. In what percentage of sampling events were the fecal coliform levels above 200 colonies/100 mL?

3. Does the time of the year influence what was happening at your site?

4. How did your site compare with other sites?

5. Based on the monitoring data alone, should this be a priority area to address for bacterial contamination? Why or why not?

6. How would information on stream flow and land use help to answer Question 5?

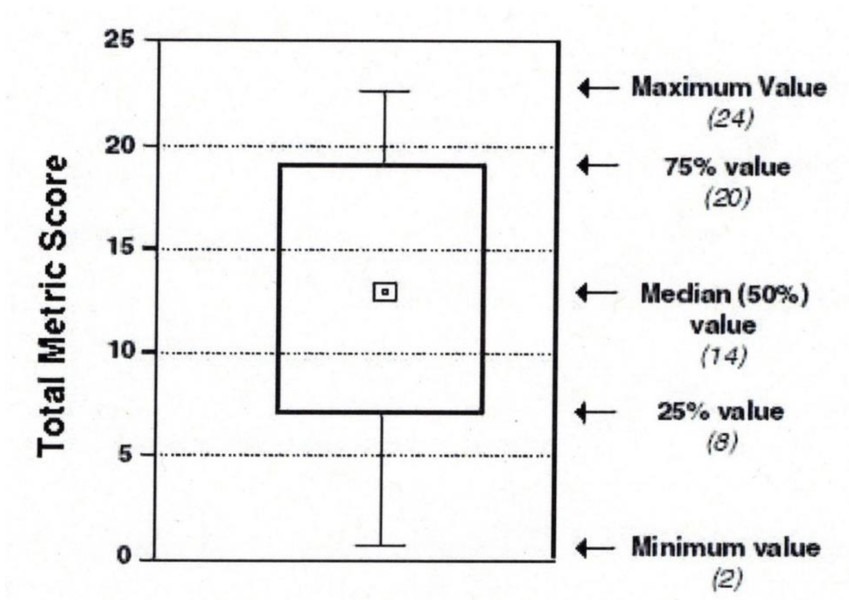
## Fecal Coliform Levels (colonies/100 mL) at Sites in the Grand River Watershed

Source: Grand Rapids Wastewater Treatment Plant

| Date | Buck Creek | Eastmanville | Indian Mill Creek At Turner | Mill Creek | Northland Drive (Plainfield) | Plaster Creek 1 – at Burton | Plaster Creek 2- at Market | Rogue River At West River |
|---|---|---|---|---|---|---|---|---|
| 2/15/12 | 155 | 20 | 109 | 36 | 10 | 380 | 260 | 36 |
| 5/16/12 | 770 | 77 | 970 | 230 | 62 | 950 | 2,400 | 340 |
| 8/15/12 | 360 | 120 | 900 | 230 | 22 | 780 | 920 | 82 |
| 11/14/12 | 230 | 80 | 260 | 136 | 3 | 320 | 260 | 64 |
| 3/13/13 | 82 | 290 | 2,300 | 164 | 250 | 191 | 200 | 127 |
| 4/29/13 | 73 | 152 | 36 | 91 | 49 | 270 | 36 | 82 |
| 6/12/13 | 460 | 80 | 710 | 490 | 97 | 290 | 630 | 127 |
| 9/18/13 | 270 | 147 | 670 | 280 | 25 | 400 | 1,320 | 73 |
| 12/11/13 | 45 | 50 | 440 | 9 | 32 | 2,700 | 145 | 45 |
| 1/15/14 | 182 | 145 | 100 | 127 | 70 | 680 | 820 | 91 |
| 4/16/14 | 109 | 68 | 164 | 182 | 43 | 1,180 | 640 | 173 |
| 6/18/14* | >15,000 | >1,500 | >15,000 | >15,000 | 97 | >15,000 | >15,000 | 7,000 |
| 7/16/14 | 833 | 143 | 700 | 500 | 123 | 1,200 | 600 | 100 |
| 8/13/14 | 6,500 | >1,500 | 5,300 | 2,300 | 690 | >15,000 | >15,000 | 480 |
| 9/17/14 | 370 | 210 | No data | 280 | 60 | 650 | 2,200 | 127 |
| 10/15/14 | 4,700 | >1,500 | 3,500 | 6,100 | >660 | 5,600 | 5,100 | 3,000 |
| 2/18/15 | 9 | No data | 590 | 9 | 20 | 36 | No data | 9 |
| 5/13/15 | 200 | 670 | 1,500 | 1,300 | 100 | 1,800 | 1,190 | 400 |
| 6/17/15 | 750 | 420 | 2,100 | 780 | 670 | 1,030 | 560 | 191 |
| 7/15/15 | 3,700 | 710 | 2,700 | 670 | >1,500 | 4,600 | 5,600 | 300 |
| 8/12/15 | 880 | 340 | 6,700 | 2,100 | >500 | 940 | 1,300 | 650 |
| 9/16/15 | 460 | 90 | 660 | 250 | 52 | 290 | 2,200 | 155 |
| 11/18/15 | 700 | 137 | 320 | >15,000 | 28 | 460 | 3,800 | 127 |
| 3/23/16 | 100 | 10 | 45 | 18 | 10 | 45 | 560 | 27 |
| 5/18/16 | 164 | 55 | 1,340 | 200 | 40 | 300 | 250 | 82 |
| 6/14/16 | 1,400 | 107 | 4,200 | 460 | 12 | 470 | 4,000 | 164 |
| 7/20/16 | 690 | 5 | 840 | 350 | 28 | 1,170 | 2,400 | 64 |

Note: There was 2.08 inches of rain on 6/18/14.

## Example of a Box Plot



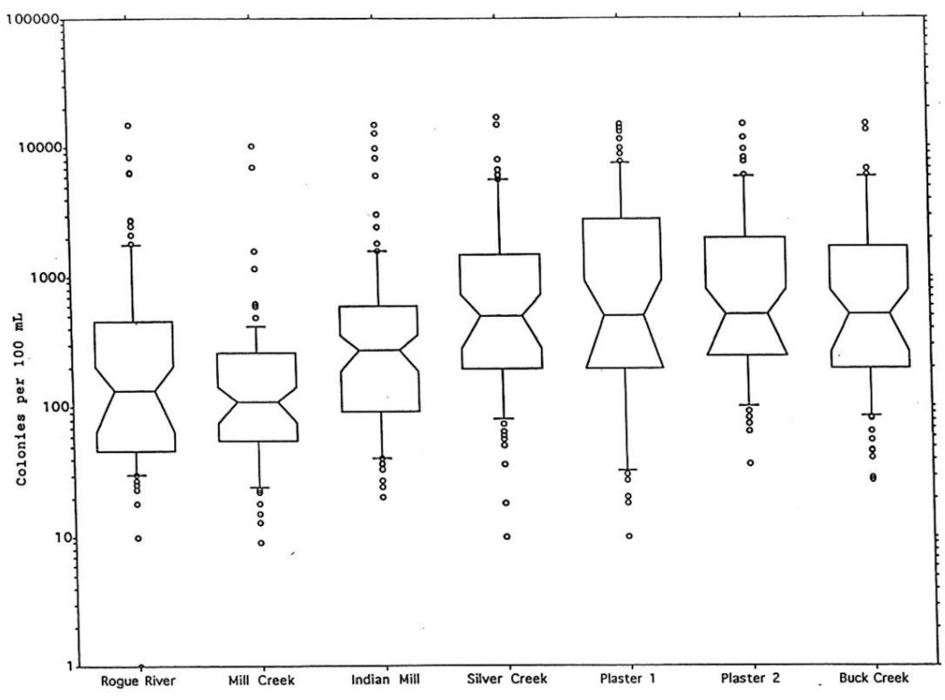




Figure 21. Notched Boxplots of GR WWTP Fecal Coliform Bacteria Tributary Monitoring Stations, 1987-96.

Source: Vail, J.H. 1998. *An Analysis of Fecal Coliform Bacteria as a Water Quality Indicator*, PhD Thesis

# Information & Education Strategy to Address Pathogens and Bacteria

**Source:** Lower Grand River Watershed Management Plan http://www.lgrow.org/lgrwmp

**Goal:** Restore and maintain waterbodies for partial body contact and full body contact use.

**Pollutant 1: Pathogens and Bacteria**

**Objectives:**

1) Implement manure management planning and implementation,

2) Implement livestock management practices at access sites,

3) Implement vegetative buffering practices,

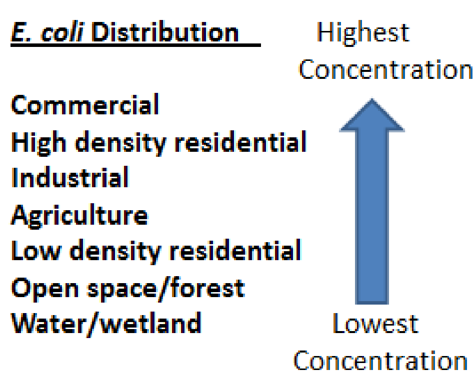
4) Encourage proper septic tank management,

5) Implement MDEQ population management practices, and

6) Implement sanitary sewer maintenance practices.

**Message:** Human actions increase the chances of pathogen and bacterial contamination in waterbodies. Bacterial contamination from cropland, livestock, septic tanks, ducks and geese, and the sanitary sewer create unsafe water for human contact.

**Critical Areas:** Impaired Uses: Bass River; Buck Creek; Direct Drainage to Lower Grand River; Plaster Creek; Coldwater River; Coopers, Clear, and Black Creeks; Crockery Creek, Deer Creek; Threatened Uses: Upper/Lower Rogue River; Spring Lake/Norris Creek; Sand Creek



## Practices for Eliminating or Treating Existing Bacterial Sources

| Low Density Watershed |
| --- |
| • Rehabilitate failing septic systems<br>• Connect failing septic systems to sewers<br>• Increase septic system clean outs<br>• Retrofit stormwater ponds<br>• Retrofit ditches as dry swales<br>• Waterfowl management<br>• Install recreational sewage pumpouts<br>• Enforce septic system regulations (design standards, setback from streams, receiving soil)<br>• Implement conservation plans at farms<br>• Reduce impervious cover |
| High Density Watershed |
| • Eliminate illicit connections to storm sewers<br>• Rehabilitate existing sewer systems to eliminate sanitary sewer overflows<br>• Abate or disinfect combined sewer overflows if present<br>• Relocate storm outfalls<br>• Disinfect at the end-of-pipe<br>• Retrofit stormwater ponds<br>• Retrofit ditches as dry swales<br>• Waterfowl management<br>• Enforce pet waste disposal<br>• Reduce impervious cover<br>• Encourage "urban housekeeping" of property |

Source: Total Maximum Daily Loads and National Pollutant Discharge Elimination System Stormwater Permits for Impaired Waterbodies: A Summary of State Practices, page 61. https://www.epa.gov/sites/production/files/2015-07/documents/state_practices_report_final_09_07.pdf