Detecting Failing Septic Systems on Your Lake:

A COST EFFECTIVE METHODOLOGY

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Acknowledgements

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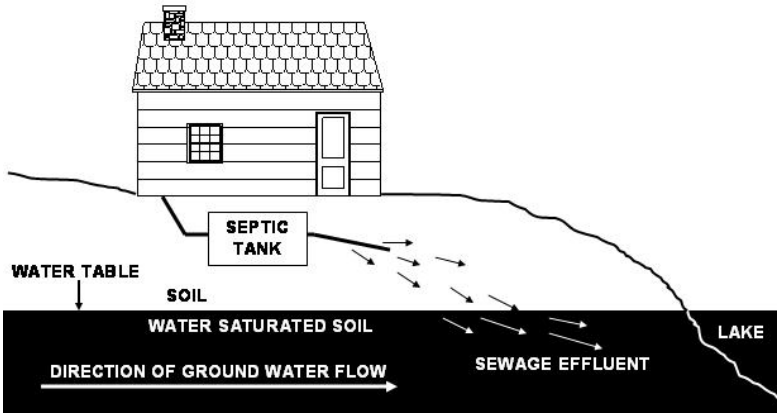
The Issue:

In the absence of municipal sewer service, septic systems are required in order to protect human health. Except in extreme cases, whether new or old, every rural and many suburban houses have septic systems. Septic systems are designed to treat liquid wastes from your house in order to prevent contamination of your well and nearby waterbodies. The problem is that all septic systems will eventually fail. Adding to that problem, due primarily to the fact that these systems are underground, many homeowners don't regularly think about their septic system and don't perform the necessary maintenance required to ensure that their septic system operates properly. As a result, the homeowner often doesn't realize there is a problem with their septic system until contamination has occurred and manifests itself at the surface. This usually takes the form of a soggy lawn, a backup of water or smell in the house or organic matter surfacing over the leach field; but these symptoms don't emerge until major contamination has occurred.

"…homeowners often don't realize there is a problem with their septic system until contamination has occurred…"

Before these signs of failure are evident, smaller amounts of contamination either leak from the septic tank, remain untreated in the soils of the leach field or pass untreated into the local groundwater supply. Once the groundwater has been contaminated, that contamination may spread to nearby wells and waterbodies connected to the groundwater system. Leakage from a septic tank or contamination due to an ineffective leach field can result in the release of a complex mixture of materials including bacteria, nitrates, metals, trace quantities of toxic materials, and salts. If a drinking water well or waterbody used for recreational purposes becomes contaminated it can lead to ailments caused by the ingestion of microorganisms such as *E coli*, *Giardia*, Cryptosporidium, Hepatitis A, and helminths (Craun, 1986).

The likelihood of contamination is increased when a septic system is sited near a lake. Not only is the tank and absorption field most often sited close to the water table, but due to the close proximity of the system to the lake, contamination can reach the lake very quickly. Also, since most lakes are used for some sort of recreation, the odds of someone coming in contact with the released material is also increased.



Given the increased risk associated with possible inputs from a failing septic system near the shoreline, it is that much more important that failing systems near waterbodies be identified quickly so that remedial action can be taken. However, failing septic systems near lakes can be even more difficult to spot than their upland counterparts. One accepted method used to identify whether or not there are failing septic systems on a given waterbody is to perform Bacterial

Source Tracking (BST). Using genetic analyses, researchers can determine if fecal bacteria found in the water are from local wildlife or from the lake's human population. Although this system works effectively, the price tag for such a procedure can be as much as several tens of thousands of dollars; a fee that most lake associations cannot afford.

"…Bacterial Source Tracking can cost as much as several tens of thousands of dollars…"

Even if BST is used to verify the presence of failing septic systems, further testing is still needed in order to determine exactly which septic system is the source of the contamination. Common practice is to flush a fluorescent dye such as rhodamine through the septic system. A colorimeter is then used to determine if the rhodamine passed from the system and into the nearby waterbody. This method is complicated by many factors, including the percolation rate of the property, the effect of rainfall on the colorimeter's ability to isolate the rhodamine, the availability of a colorimeter and the natural occurrence of organic compounds and organisms that can produce false positive readings for rhodamine.

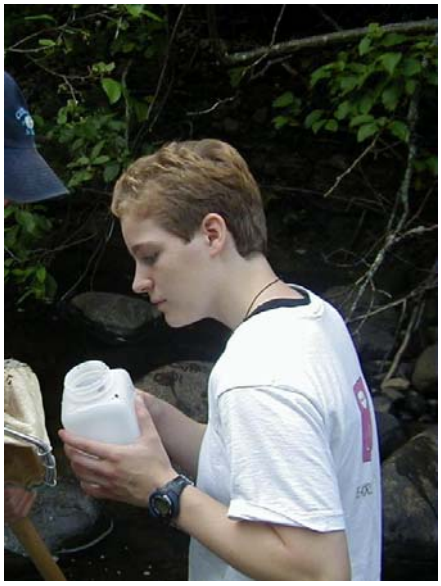
"In the material that follows, you will find a report documenting …the ability of local lakefront communities to cost-effectively monitor for failing septics systems."

In the material that follows, you will find a report documenting the findings of a joint study conducted by the Warren County Soil and Water Conservation District and Adirondack Community College demonstrating the ability of local lakefront communities to cost-effectively monitor for failing septics systems. Rather than using cost-prohibitive technology to determine whether bacteria in the water are from humans (releases from a septic system) or from local wildlife, the team was able to localize the areas where failing septics appeared to be contaminating the water by measuring the concentrations of fecal bacteria and chlorine in the lake. Chlorine was used for analysis since, present only due to human input, it does not exist naturally in the environment. Although not a step that was taken, identification of the failing septics within the isolated areas could then be determined through a small number of "flush" tests, where a substance such as chlorine is flushed down into the septic system and the system is deemed to be failing if that substance is later detected in the lake. This protocol enables local lakefront communities to achieve similar results at a fraction of the cost of larger studies which use genetically based bacteria identification.

Step-by-Step Protocol

Getting Started

1. Secure the necessary assistance and supplies
    a. **Coordinate the help of a local community college** or establish a contract with professional lab.
        i. These partners should have well stocked laboratories and trained staff, which will be necessary in order to:
            1. **Perform bacterial culturing**
                a. Grow enough bacteria to determine the type and concentration present in the samples
            2. **Determine the results**
                a. Counting the number of colony forming units (CFU) of:
                    i. Fecal Coliform
                    ii. Fecal Enterococci
            3. **Dispose of bacterial testing material**
                a. A standard lab will have equipment to safely dispose of the bacteria material
    b. **Arrange for the use of a boat**
        i. A shallow draft boat, preferably with an electric or trolling motor.
    c. **Purchase or borrow a colorimeter**
        i. Colorimeter must be complete with all necessary reagents and accessories.
        ii. Several varieties of colorimeters can be purchased from water testing supply companies through catalog purchases at an initial cost of about $800.
            1. Once purchased, the device can be used repeatedly for only the cost of the required testing supplies (reagents).
    d. **Arrange for volunteers to aid in sample collection**
        i. Collecting samples could be done, in most cases, over a couple of days by a team of two people. The length of time required will depend on the size of the lake, the number of zones chosen for testing and the number of volunteers (see Set up the Sampling Protocol).



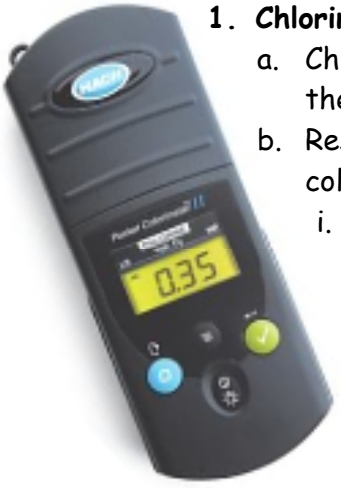
Set up the Sampling Protocol

2. Divide the lake shore into zones to be tested
    a. Near the shoreline in the center of each zone, water samples will be taken.
    b. The number of zones to be tested should be balanced based on several factors:
        i. **Lake Size**
            1. A larger number of samples would make determining which septics are failing easier, but would be more costly and take more time, especially on larger lakes (e.g. in the attached study, 40, 350 ft. zones were sampled.)
        ii. **Density of development**
            1. The denser the development, the more individual septics would be in each zone which would require more septic tests if positive results are detected within a given zone.
                a. A balance must be set between dividing the lake into more zones or performing more individual septic tests.

*** Concentration Gradient Test** (Step 3.a.i.2) - The results of this test should reduce the number of zones and the number of "flush" tests needed.

Sampling

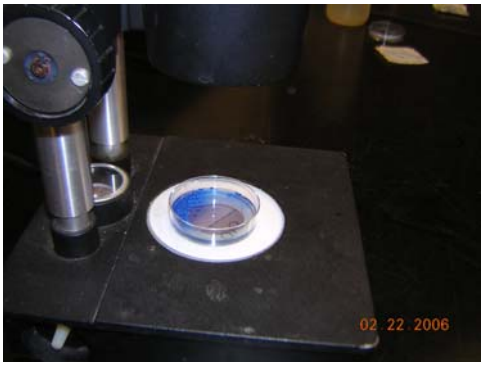
3. Collect the Samples
    a. **Collect samples**, by boat, for chlorine and bacteria analysis at all sampling locations (step 2).
        i. Samples should be taken at a time of the year when most homes are occupied and thus, most septics systems are in use.



1. Chlorine Sampling
    a. Chlorine testing should be performed using a colorimeter while at the sampling location, according to manufacture's directions.
    b. Results of the chlorine analysis will be shown immediately on the colorimeter. **Hach Pocket Colorimeter II pictured at left**
        i. **Concentration Gradient Testing** - If a positive test for chlorine is discovered, perform additional sampling for chlorine in both directions from the original site until chlorine levels drop off.
            1. If chlorine levels increase in a given direction, the source of the chlorine is most likely in that direction.
            2. This test may help to narrow down the likely source of input within a given zone.

Sampling Cont…

2. **Bacteria Sampling**
    a. Bacteria samples, taken and stored in clean containers, must be kept cool (i.e. on ice in a cooler) and sent to a cooperating laboratory that day for culturing, analysis and disposal.
    b. Results from these analyses should take about a week to produce.



Analysis

4. Compare zones around the lake based on chlorine and bacteria levels.
    a. Areas that potentially have failing septic systems will:
        i. have high fecal bacteria levels (30 CFU/100mL vs. 5 CFU/100mL) compared to other samples taken around the lake and
        ii. have colorimeter readings indicating the presence of chlorine at concentrations greater than 0.1 mg/L.

Identifying a Specific Septic

5. "Flush Testing"
    a. "Flush" testing should be performed on septic systems within sampling zones where bacteria counts are high and chlorine is found.
        i. A "flush" test entails pouring a detectable fluid (dye) into the septic system (down a drain or toilet) and determining if it quickly makes its way out of the system. Visit The Home Inspection and Construction Website (www.inspect-ny.com) for more information.
            1. The number of septics to be tested may be limited based on the results of the Concentration Gradient Testing done in Step 3.a.i.2
            2. Contacting homeowners and arranging for such testing should be the responsibility of the lake association representative or town involved, and performed by a certified laboratory.

Remedies

6. Appropriate action should be taken, based on the results of the "flush" test(s), in order to repair or replace the failing septic system(s).
    a. **Determine the appropriate remedy**
        i. In consultation with the local municipal planning or zoning office
            1. The appropriate remedy will depend on several factors:
                a. **The nature of the septic system's malfunction**
                    i. The Tank vs. Absorption Field
                b. **The severity of the septic system's malfunction**
                    i. Repair vs. Replacement
                c. **The location of the septic system**
                    i. Will local laws allow for the placement or repair of a septic system in the current location?
                    ii. Does the homeowner have any other possible locations where a septic system could be sited?
                        1. Newer technologies can allow for placement of a septic system where it would have been impossible in the past.

Costs

* All of the necessary equipment and supplies, with the exception of the cooler and boat, were purchased from the HACH Company.

Contact information: Hach Company
PO Box 608
Loveland, CO 80539
1-800-227-4224
www.hach.com

General:

- Boat to collect samples (shallow draft; electric or trolling motor)
- Cooler (large enough to keep samples cool while on the boat and being shipped to lab)
- Ice for preserving bacterial samples in the cooler

Tests for Chlorine:

- Colorimeter
  - Pocket Colorimeter II (single parameter – chlorine) $335
  - DR820 Colorimeter (multiple parameters) $579
  - Chlorine test reagent (DPD powder pillows) $16.30/100 tests

Microbiological Tests:

- Sampling bottles, polycarbonate, square or round, 500 mL
  - ~ $10/bottle
- Filtration units (recommend at least 2)
  - Vacuum flask, sidearm #8 stopper $40
  - #8 rubber stopper, one hole $5
  - rubber tubing (if necessary) $10
  - Filter holder unit (magnetic; polyphenylsulfone) $152
- Membrane filters (Millipore HA; 0.45 µm; sterile) $87.20/200
- Culture medium:
  - mTEC modified culture medium (prepared) $60/15 plates
  - mEI culture medium (prepared) $60/15 plates

Necessary Standard Lab Equipment:

- 100 mL graduated cylinders (recommend at least 2) $18 ea.
- Laboratory incubators (2) $1,000 (portable)
  $2,000 (bench top)
- Vacuum pump, water aspiration unit, or hand pump $500 max.

*An autoclave is recommended to sterilize sampling bottles and filtration units but not absolutely required.

Purchasing/Cost information:

Lab Equipment:

* A college or high school laboratory may be equipped with the following standard lab equipment, and therefore purchase of the following may not be necessary

• 2 Incubators	$4,000
• Vacuum pump	$500
• Glassware and other laboratory equipment	$500
Total:	$5,000

Reusable equipment/supplies:

• Hach Colorimeter	$335 - $579
• 2 filtration "units" (flask, stopper, tubing, filter holder)	$400
• Sampling bottles (50)	$500
Total:	$1,235 - $1,479

Consumables (cost based on 200 tests)

• Culture media – prepared plates	$1600
• DPD powder pillows (for chlorine assay)	$32.60
• Membrane filters	$87.20
Total:	$1,720

Overall Costs (200 tests)

• Lab Equipment	$0 - $5,000
• Reusable equipment/supplies	$1,235 - $1,479
• Consumables	$1,720
Approximate Total:	$3,000 - $9,000

This brochure is intended for informational use only. Although it is the hope of the authors that local lake associations review and utilize the methods set out in this report, this methodology was not developed to be regulatory in any way.

For information regarding methodology please contact:

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Abstract

Detection of failing shoreline septic systems is an important component of maintaining water quality on lakes with development along their shorelines. However, the current method for detecting failing shoreline septic systems, Bacteria Source Tracking, requires a series of genetic tests and often carries a price tag too large to make the test affordable for a typical lake association. In an effort to develop a cost-effective, relatively inexpensive approach to test for failing shoreline septic systems, staff from Adirondack Community College and staff from Warren County Soil and Water Conservation District developed such a method, based on sampling for relatively simple water quality metrics.

As a pilot study used to develop an inexpensive detection protocol, the shoreline of an Adirondack lake was divided into approximately 350 ft. zones in which samples for fecal bacteria, chlorine and phosphorus were collected, once a month from May to August. Fecal bacteria levels were found to correlate positively with chlorine levels but not phosphorus levels. Although the fecal bacteria could not be positively identified as being from a human source (i.e. a failing septic system), when combined with positive readings for chlorine, a man-made substance not naturally found in nature, researchers were able to use the results of the sampling to isolate areas of probable septic system failure. Phosphorus levels were not found to be a good predictor of septic system failure.

By using this method to focus in on a limited span of the shoreline in which septic system failure is most likely occurring, traditional “flush” testing can be performed on a limited number of houses in order to determine which septic system is the source of the input. This protocol greatly reduces the cost of finding failing shoreline septic systems and makes it economically feasible for the average lake association.

A Case Study: Small Lake Model Sampling Program to Test For Failing Septic Systems

Holly Ahern[1] and Casey Holzwrth[2]

Introduction

Over the past several decades, lakes in New York State have seen a tremendous increase in development along their shorelines. By the 1950's and 60's, summer camps and small retreats began to dot the shorelines of most lakes across the state. More recently, lakes that were once characterized by low to moderate levels of seasonal development are now seeing much more pressure in terms of density of development and a transformation from seasonal use to year round habitation. With increased development pressure comes increased concern over human-based impacts to these lakes.

Pollution of surface water impacts the heath and safety of people who use the water, whether for drinking or recreation. Chemical or biological contamination may come from a single (point) source, or the source may be diffuse (a nonpoint source). Nonpoint source (NPS) pollution of lakes, ponds, rivers and streams typically comes from surface run-off from areas in the surrounding watershed. Run-off from land used for agriculture, for example, may carry phosphate, nitrate, and other inorganic nutrients from fertilizers, as well as biological agents found in manure or other animal excrement. Surface run-off is often visible to landowners and lake managers, and steps can be taken to correct such problems.

Another possible source of NPS pollution is onsite wastewater treatment (septic) systems, a common fixture in rural communities. Unlike typical NPS pollution, inputs from failing on-site wastewater treatment (septic) systems don't normally manifest themselves at the surface unless the failure is severe. The material they release filters through the ground and into the groundwater. This makes failing onsite wastewater treatment (septic) systems difficult to detect and thus difficult to remedy. Septic systems, if properly designed, sited, installed and maintained, have been shown to effectively treat wastewater. Faulty systems, however, may be a major problem for some lakes where non-ideal site conditions, poor design, improper installation, inadequate maintenance and, in particular, the system's proximity to water can make the pollution from failing septics a primary cause of poor water quality.

There are several ways to simply detect the presence of pollutants that impact water quality in lakes. These include tests for substances such as phosphate and nitrate as indicators of NPS pollution, and bacteria such as *Escherichia coli* and *Enterococcus* spp. as indicators of fecal contamination. However, the actual source of this type of pollution has historically been difficult to determine. Nutrients such as phosphate and nitrate may be associated with surface run-off or faulty septic systems, but they are also found naturally in many aquatic environments. Similarly, the fecal bacteria typically used as indicator organisms may be septic system related, but are common to all warm-blooded animals, including indigenous wildlife; particularly waterfowl. Thus there exists a need to discriminate among the various sources of these pollutants to better assess the impact of septic systems on any given lake.

For further identification of fecal bacteria, bacteria source tracking (BST) methods are required. BST is a general term for a suite of procedures that can determine and distinguish between minute differences in bacteria, beyond the species level. BST methods are used to separate bacteria based on slight differences that result from unique adaptations that occur as a result of

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the environment in which they are most often found. These differences are then used to identify the most probable source.

Scott et.al. (2002) reviews various microbiological, genotypic, phenotypic and chemical methods currently used to determine the actual source of NPS contaminants. Although still in its infancy, bacterial source tracking, or BST, has been used successfully to pinpoint the source of fecal bacteria in several studies (Kuntz, 2003). The majority of these methods are costly and have only been shown to be effective in situations where the fecal contamination as evidenced by large numbers of fecal bacteria (>1,000 cfu/100 mL), which may not be applicable for barely discernable contamination caused by septic system failure.

The primary objective of this study was to develop a collaborative, cost-effective plan that would allow small lakes in communities with limited resources to (1) measure water quality by monitoring for chemical and biological contaminants, and (2) discriminate among potential sources of contaminants to better assess the actual impact of failing septic systems on lakes in New York State. Lake Luzerne in Warren County, New York was chosen as the site of this pilot study.

Methodology

Sampling

Prior to May, 2004, a cooperative relationship was forged among multiple community-based groups, including the Warren County Soil and Water Conservation District (SWCD), the Lake Association of Lake Luzerne, the Town of Lake Luzerne, and Adirondack Community College (ACC). Maps and land use information were obtained by the SWCD with input from the Town of Lake Luzerne and the Lake Association. A comprehensive map of Lake Luzerne and the surrounding area was generated by the SWCD using ArcView GIS, which is shown in Figure 1.

Patterns of lake usage were discussed with year-round lakefront residents in order to determine appropriate dates for sampling. It was reported that lake usage increased after Memorial Day and peaked in July, particularly around the July 4th weekend. Lake usage declined during August, and by early September, only year-round homeowners remained on the lake.

Based on the number of water sample tests that could be completed in a day, forty evenly spaced sampling locations were selected, encompassing the entire shoreline of Lake Luzerne. The decision to collect samples at sites evenly distributed around the lake allowed us to conduct an unbiased and comprehensive survey with regard to the contaminants that may be associated with septic systems. Each sampling location, located with the aid of a GPS Garmin 5™ GPS unit, was approximately 356 ft apart (Figure 1). During each sampling effort, student research assistants from ACC, with the assistance of Jim Lieberum of the Warren County SWCD, would use the GPS unit and pertinent visible shoreline markers to traverse by boat to each sampling location. Samples were taken as close to shore as possible, between 1 and 5ft from land.

Sampling was conducted at these sites over two consecutive days each month during the months of May, June, July and August of 2004. The dates were chosen at random, except in May, when sampling was performed prior to Memorial Day (to provide a baseline), and July when sampling was performed after the July 4th holiday weekend (to account for excepted high lake usage). Tests done during the month of May were performed on the 24th and 25th, before the majority of summer visitors had arrived at the lake. These values were used as a baseline to which all subsequent tests were compared.

Chemical/Biological Analysis of Water Samples

A colorimetric assay for free chlorine was performed on lake water immediately after collection at each site using a Hach DR/800 colorimeter and Hach reagents, according to manufacturer's recommendations. For the purpose of this study, a cutoff value of 0.1 mg/L was assigned, and concentrations above this point were considered significant. As is standard practice, this analytical detection value (0.1 mg/L) was five times the method detection limit of the assay, estimated by Hach to be 0.02 mg/L Cl_2. This value also happened to be the approximate value at which students were able to detect color with the naked eye (approximately 0.08 mg/L Cl_2). Since there are no natural sources of free chlorine (in the form of hypochlorous acid or hypochlorite ion) in lake water, this value could possibly be lowered to the detection limit of the assay for future studies.

In an attempt to narrow the possible locations at which the chlorine contamination was occurring, additional tests were performed at sites where the chlorine concentration exceeded 0.1 mg/L. This procedure involved taking additional samples at approximately 3 foot intervals in both directions along the shoreline, away from the site, until the concentration dropped below the cutoff value.

Also, at each site a grab sample was obtained approximately 10-20 cm under the surface of the water in sterile 500 mL Nalgene bottles. All samples were stored in a cooler and transported to the laboratory at ACC where they were processed within 6 hours of collection.

In the laboratory, each sample was tested by membrane filtration for two types of fecal bacteria; thermotolerant *Escherichia coli* (USEPA Method 1603: *Escherichia coli* (*E. coli*) in Water by Membrane Fitration Using Modified membrane-Thermotolerant *Escherichia coli* (Modified mTEC) Agar), and enterococci (USEPA Method 1600: Enterococci in Water by Membrane Filtration Using membrane-Enterococcus Indoxyl-β-D-Glucoside (mEI) Agar). These methods were obtained from the EPA website (www.epa.gov). The presence of either of these bacteria indicates that fecal contamination has occurred, without regard to its source. Although New York State does have contact recreation standards for fecal bacteria, for the purpose of this study, any sample that showed fecal bacteria was considered potentially significant. However, for illustrative purposes, these standards were used during the month of May, when several sites exceeded those standards.

Additionally, a colorimetric assay for phosphate (defined as compounds that produce the PO_4^{-3} radical in aqueous solution) was performed on each water sample (Eaton et al., 1998). Phosphates in this form may be derived from chemical fertilizers and detergents. Although small amounts of phosphates are necessary to support plant growth, an overabundance of this nutrient may result in excessive growth of algae and water plants, and thereby contribute to the eventual eutrophication of the lake. Since there are natural sources of phosphates in lake water, the concentration of phosphate at each site was examined for a positive correlation with other test results. For illustrative purposes, phosphorous concentrations capable of producing eutrophic conditions (0.05 mg/L) were documented (Walker, on-line).

Finally, to determine if it were possible to discriminate among animals based on the composition of their normal fecal flora, samples of dog, horse, goose, and cow fecal specimens were cultured on Bile Esculin Agar, a medium selective for enterococci. Additional colonies were selected from the mEI cultures of lake water. Colonies of Gram positive cocci that were esculin positive and catalase negative were considered as presumptive *Enterococcus* spp. Several hundred such colonies were identified phenotypically to genus and species using the MicroLog Microbial Identification System from Biolog, according to manufacturer's instructions.

Figure 1. 2001 Orthoimagery map displaying the approximate locations where water samples were taken and tested for concentrations of Free Chlorine, Phosphorus and fecal bacteria. Sampling sites were located approximately 356 ft. apart and were located in the field with the aid of a GPS Garmin 5™ GPS unit. Water samples were taken 1-5 ft. from shore at a depth of 10-20 cm.

Results

May: Samples were collected and testing performed on May 24th and 25th, immediately prior to the Memorial Day weekend. Chlorine concentrations were not determined during sampling in May due to the lack of a necessary reagent. Phosphate concentrations were generally low, with only one site recording a concentration greater than 0.05mg/L (site 35). Fecally-derived bacteria (*E. coli* and enterococci) were detected at most locations, with counts of enterococci significantly elevated (>200 cfu/mL) at sites 30 and 31. A corresponding increase in phosphate concentration at these sites was not noted.

June: Testing was performed on June 7th and 8th. Free chlorine (hypochlorous acid or hypochlorite ion) concentrations were above threshold at was detected at 6 locations. At sites 30 and 31 there was a corresponding increase in the number of fecal bacteria (both *E. coli* and *enterococci* at site 30, and *E. coli* at site 31). Phosphate concentration exceeded 0.05 mg/L at 15 sites, none of which appeared to co-vary with increased bacteria or chlorine.

July: Sampling this month was performed immediately following the July 4th holiday, on July 6th and 7th. *E. coli* was found at concentrations near or greater than 50 cfu/100 mL at six sites, notably sites 19 and 31, which was consistent with the two previous months. Chlorine concentrations above threshold levels were detected at six sites, two of which (18 and 30) are in close proximity to sites at which fecal bacteria were found.

August: Sampling for the month of August was performed on the 9th and the 11th. Somewhat surprisingly, the numbers of fecal bacteria and the phosphate concentration were relatively low for all of the sites. This could be attributable to rainfall amounts for the month of August. Chlorine concentrations above threshold levels were found at 11 sites, including 19 and 31, although only sites 16, 31 and 37 also had elevated levels of fecal bacteria.

Table 1a. Sites where, during the month of May, phosphate, fecal coliform and fecal enterococci concentrations exceeded the documentation threshold.

Site	PO_4^{-3} (mg/L)	Coliform (CFU/100mL)	Enterococci (CFU/100mL)
30	0.037	16	268**
31	0.014	102	245**
35	0.079*	16	7
38	0.012	40	73**

Note: * indicates concentration above threshold for PO_4^{-3} or free chlorine (0.05 mg/L and 0.1mg/L respectively)
** indicates bacteria concentrations in excess of the NYS Contact Recreation Standards for fecal coliform or enterococci (1,000 cfu/100 mL and 61 cfu/100mL respectively).

Table 1b. Sites where, during the month of June, chlorine, phosphate, fecal coliform and fecal enterococci concentrations exceeded the documentation threshold.

Site	Cl (mg/L)	PO_4^{-3} (mg/L)	Coliform (CFU/100mL)	Enterococci (CFU/100mL)
6	0.02	0.073*	1	1
9	< 0.02	0.054*	0	1
11	0.23*	0.042	0	0
17	< 0.02	0.102*	0	9
18	0.41*	0.039	5	10
24	0.03	0.310*	3	0
27	0.21*	0.029	3	0
29	0.10*	0.029	15	0
30	0.21*	0.060*	75	28
31	0.26*	0.058*	64	8
32	< 0.02	0.058*	30	6
33	0.04	0.091*	64	2
34	0.06	0.070*	15	
35	0.03	0.058*	5	27
36	0.08	0.056*	1	0
37	0.04	0.054*	2	12
38	0.09	0.058*	7	11
39	0.02	0.074*	3	22
40	0.04	0.054*	2	2

Note: * indicates concentration above threshold for PO_4^{-3} or free chlorine (0.05 mg/L and 0.1mg/L respectively)

Table 1c. Sites where, during the month of July, chlorine, phosphate, fecal coliform and fecal enterococci concentrations exceeded the documentation threshold.

Site	Cl (mg/L)	PO_4^{-3} (mg/L)	Coliform (CFU/100mL)	Enterococci (CFU/100mL)
1	0.11*	0.004	5	18
2	< 0.02	0.061*	10	1
3	< 0.02	0.122*	14	5
4	< 0.02	0.222*	48	2
6	0.04	0.256*	45	1
12	0.22*	0.039	4	5
14	0.05	0.052*	36	2
17	0.06	0.043	6	36
18	0.17*	0.056*	1	3
20	< 0.02	0.056*	4	4
21	0.16*	0.030	2	0
27	< 0.02	0.052*	5	4
30	0.38*	0.143*	8	1
31	0.05	0.022	38	29
36	0.10*	0.030	3	1

Note: * indicates concentration above threshold for PO_4^{-3} or free chlorine (0.05 mg/L and 0.1mg/L respectively)

Table 1d. Sites where, during the month of August, chlorine, phosphate, fecal coliform and fecal enterococci concentrations exceeded the documentation threshold.

Site	Cl (mg/L)	PO_4^{-3} (mg/L)	Coliform (CFU/100mL)	Enterococci (CFU/100mL)
3	0.15*	0.040	0	0
16	0.10*	0.019	10	0
17	0.27*	0.019	0	0
19	0.16*	0.019	0	0
20	0.22*	0.017	0	0
26	0.12*	0.024	2	0
27	0.24*	0.018	3	0
29	< 0.02	0.055*	8	0
31	0.17*	0.032	19	1
36	0.28*	0.035	1	1
37	0.14*	0.031	18	3
38	0.35*	0.031	8	1

Note: * indicates concentration above threshold for PO_4^{-3} or free chlorine (0.05 mg/L and 0.1mg/L respectively)

Correlation Analyses:

Correlation analyses, using data from all four months, reveal a statistically significant positive correlation (r = 0.35, df = 138) only between fecal coliform levels and fecal enterococci levels. However, other measures were shown to be correlated when considered on a within month basis. In the month of May, only the two types of fecal bacteria were positively correlated. However, in the month of June, along with the bacteria correlation, there was also a positive correlation between chlorine levels and the levels of fecal coliform (r = 0.48 and 0.42 respectively, df = 138). In July, the bacterial correlation persisted and there was a statistically significant correlation between fecal coliform concentrations and phosphorus concentrations (r = 0.37 and 0.22 respectively, df = 138) and a negative correlation between fecal coliform concentrations and chlorine concentrations (r = -0.21, df = 138). Lastly, in samples taken in the month of August, fecal coliform counts were positively correlated with phosphorus concentrations (r = 0.22, df = 138) but not with fecal enterococci concentrations.

Bacterial Identification:

Over the course of the summer, several hundred colonies of enterococci derived from lake water and fecal specimens from dog, horse, goose and human sources were cultured and identified by biochemical profiling. Although several different species of enterococci were identified, no one enterococcal species predominated from any of the sources. *Enterococcus mundtii* was the most common identified species from goose and also from the lake water specimens, but numerous other species, included *E. faecalis, E. faecium* and others, were found as well. The host range for *E. faecalis* was previously found to be limited to humans, dogs and chickens (Wheeler, 2002), however, specific host ranges for other enterococci have not been determined.

Concentration Gradient Tracking:

In an attempt to pinpoint the source of contamination during the July sampling sessions, a series of assays were performed at 3 foot increments in opposite directions away from three of the sites at which chlorine concentrations were found to be in excess of 0.1 mg/L. At two of

those sites (site 1 and site 18) chlorine concentrations increased as the researchers moved away from the original sampling site, indicating that the source of the chlorine was not at the original sampling site. At the third site, chlorine concentrations dropped on either side, indicating that the source was localized at that site. In all three instances, this testing helped to narrow the potential target area of the source of the chlorine. These results are shown in Figure 2.

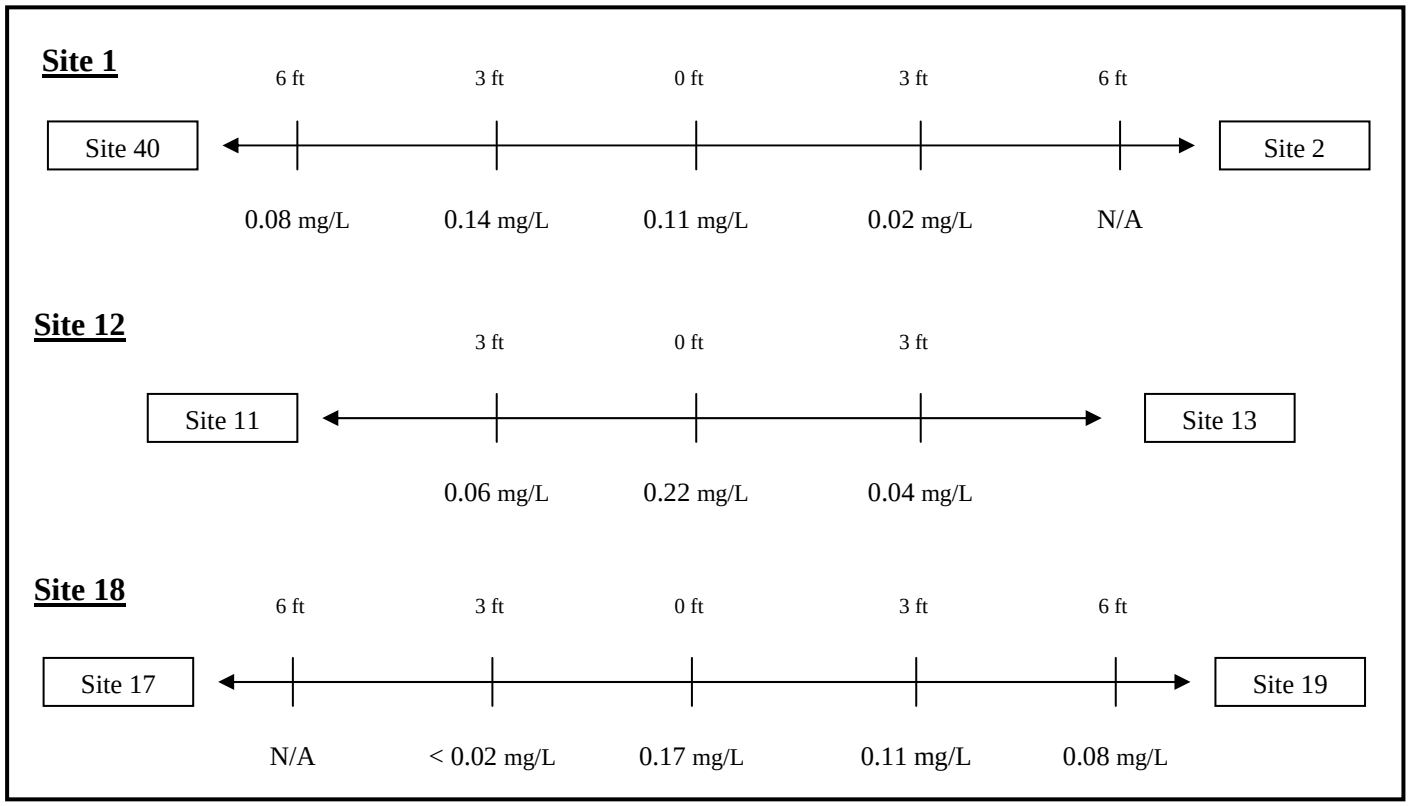

Figure 2. Diagram illustrating recorded Chlorine concentrations at sites 1, 12 and 18 along with corresponding chlorine concentration readings taken at 3ft intervals away from each original site.

Discussion

Fecal Bacteria

Both fecal coliform and enterococci were found in significant numbers at numerous locations over the first three months of testing. However, sampling in August yielded very few colonies of either fecal bacteria while the month of May had the most number of contaminated sites (3) and yielded the two highest bacteria colony counts of any month. This may have been due to heavy rains prior to the May sampling dates, which had raised the level of the lake by nearly one foot (Jim Lieberum, personal observation/communication). This result was still not expected since it was anticipated that, if there were any failing septic systems, the busiest time of the year in terms of the local residential population (June and particularly July) would have the highest number of sites showing fecal bacteria contamination.

This finding suggests that more than just human-based sources of fecal contamination are impacting the lake's water quality. In order to determine the source of these bacteria, isolates of enterococci from the mEI plates were identified to genus and species. Several different species

were found, *Enterococcus mundtii* being the most common. However, since various strains of *E. mundtii* have been isolated from humans, dogs, horses, Canada geese and domestic geese (Bahirathan, 1998), the source of the fecal bacteria could not be determined from this test.

Chlorine and Phosphorus

Chlorine and phosphorus levels measured in this study, unlike the isolated bacteria, are more easily attributable to human activity. Free chlorine does not occur naturally and thus could only be the result of human input. Phosphate, although it does occur naturally in water as a result of such processes as mineral weathering and the deposition of animal feces, usually exists in concentrations that are quite low (approximately 0.02mg/L) (Walker, on-line); well below the 0.05mg/L threshold set by the USEPA and utilized by this study.

During the sampling period, chlorine was detected at numerous sites. 23 of those sites had chlorine levels that met or exceeded the 0.1mg/L threshold set for this study. Since chlorine does not exist naturally, it can be assumed that the elevated levels were due to human-based contamination. In fact, the increased levels of chlorine in the August samples may represent increased use of bleach as a cleaning agent at the end of the vacation season. However, even if many more samples had been taken, it still may have been impossible to determine whether the chlorine present was due to failing septic systems or due to surface contamination from some other activity such as outdoor/lakeside cleaning.

Phosphorus concentrations exceeded the EPA standards on many occasions. As seen in Table 2, phosphorus concentrations started low, with only one of the May samples sites exceeding 0.05 mg/L but then increased dramatically in June. Levels stayed elevated for the July sampling period and then dropped substantially for the month of August. These elevated levels in June and July were concurrent with what was deemed to be the busiest lake vacation times based on anecdotal accounts. This would suggest that the elevated levels of phosphorus could be due to the increased number of human visitors, possibly utilizing some failing septic systems. Phosphorus levels declined in August, concurrent with decreased vacationer levels. This adds to the evidence that the increased phosphorus levels were caused by the temporary human inhabitants of the lake. However, even though tests showed a positive correlation between fecal coliform bacteria and phosphorous in the months of July and August, this correlation did not prove useful in isolating specific areas of possibly failing septic systems.

Table 2. Summary of number of sites showing significant pollutant concentrations and the average pollutant concentration of all sites for each sampling period.

	Chlorine		**Phosphorus**	
Month	**# Sites**	**Mean Mg/L**	**# Sites**	**Mean Mg/L**
May	N/A	N/A	1	0.032
June	6	0.062	15	0.054
July	6	0.049	9	0.048
August	11	0.064	1	0.030

Interactions

When considered separately, no one measure of water quality metric sampled in this study can be used to determine if septics surrounding Lake Luzerne are failing. This is due to a combination of factors including the difficulty in isolating human caused increases in fecal bacteria from natural, non-human caused outbreaks and the inability to determine if chlorine and phosphorus levels detected are due to increased usage of failed septic systems or as a result of other human and nonhuman-induced causes. However, when these metrics are used together to analyze for the possibility of failing septic systems, a more powerful predictive tool may be possible.

Correlation analyses revealed that the variations in concentration of fecal bacteria, chlorine and phosphorus levels in Lake Luzerne during the months of May through August were related to each other. This correlational relationship suggests that a common factor may be causing these related fluctuations. Although the bacteria found could not be isolated to a human source and the phosphorus and chlorine could not be proven to have come from failing septic systems, the correlations observed between these measurements suggest that failing septic systems may be to blame. A closer look at individual sites may better illustrate this point.

Certain sites along the lake shore consistently tested positive for elevated levels of fecal bacteria, chlorine and phosphorus. For example, the water near sites 30 and 31 showed elevated levels of fecal enterococci during the month of May. In June this area again tested positive for elevated levels of chlorine, phosphate and both forms of fecal bacteria, in one case not quite meeting the threshold. In July this area again tested positive for elevated levels of all four contaminants, this time site 30 showed increased chlorine and phosphorus levels while site 31 had increased levels of enterococci. However, in the month of August, although fecal coliform counts were somewhat elevated, only chlorine counts at site 31 were above threshold limits.

The combination of elevated fecal bacteria, chlorine and phosphorus concentrations, detected at these two locations, was considered the strongest indicator that the contamination was most likely related to a failing septic system. Although the specific septic system was not determined, the county, town, and/or homeowners may be able to request additional tests, performed by a public or private laboratory, to isolate the precise source of the contamination.

One possible method of further testing is comprehensive bacterial source tracking (BST), a method that could be used to compare samples from specific septic systems with the fecal bacteria found in the lake. In this process, highly technical genetic procedures are used to determine slight differences among members of the same species caused by adaptation to a specific host. Apart from being highly scientific and difficult to do, this process is expensive. Estimates for analysis range from $25 - $100 per isolate. The number of isolates recommended varies widely and the exact cost to determine which septic system might be leaching a particular bacterium would more than likely be out of the range of a typical lake community (USEPA 2002).

A more cost effective approach might be to detect a chemical agent in the lake following voluntary “flushing” of the substance in a toilet. Historically, a fluorescent dye such as rhodamine has been passed through the septic system, followed by fluorimetry of water samples from the lake in front of the property to detect the rhodamine. This method is complicated by many factors, including the percolation rate of the property, rainfall, availability of a fluorimeter, the natural occurrence of organic compounds and organisms that fluoresce at

approximately the same wavelength as rhodamine, and the willingness of local residents to volunteer to participate. Given the ease and sensitivity of the chlorine assay, and the lack of natural sources of chlorine, this method may be improved by substituting bleach for rhodamine as the flushable agent, and using the colorimetric assay for chlorine to determine the integrity of a specific septic system.

Conclusion

Although it was possible to rule out most sources of fecal bacteria, it was not possible to establish a direct link between the species of fecal bacteria in surface water and failing lakeside septic systems by phenotypic identification. However, it appears to be possible to identify locations with potential septic system issues by performing standard tests for fecal bacteria (*E. coli* and enterococci) in combination with an assay for free chlorine (hypochlorous acid or hypochlorite ion), a substance not naturally found in surface water and strongly associated with human activity.

In this study, there appeared to be a consistent correlation between free chlorine and fecal bacteria at two sites, which was taken as a good indicator of septic system contamination. Because of the distance between sites, an exact location (meaning, a single septic system associated with a specific home/camp) could not be precisely pinpointed. However, concentration gradient sampling appears to be a possibly effective way to further narrow the area of possible contamination. Gradient sampling performed in this study successfully narrowed the possible range of discharge down to approximately six feet in all three tests. Although these tests could more than likely not allow for positive identification of a single source, by limiting the number of possible sources the scope of further testing could be diminished.

The logical next step would be to run dye tests on the septic systems within the range outlined by the concentration gradient sampling. However, rather than using rhodamine, chlorine could be used as the flushable agent, allowing the samplers to avoid some of the standard pitfalls of using rhodamine while at the same time allowing for the use of the same colorimeter used to perform the original assays for free chlorine. Then by testing the lake water in front of their property for the presence of free chlorine over a 24 to 48 hour period, it could be determined whether or not a particular septic system was failing.

One of the main focuses of this study and the development of the outlined procedure was to develop a reliable, cost-effective protocol that could be used by lake associations across New York State. To that end, it is important to note the applicability of this method on a statewide scale. Max phosphorous levels may vary slightly across the state, however, this measure was not found to be of predictive value in this study anyway. Max fecal bacteria standards (i.e. NYS Contact Recreation Standards) differ only if salt waters, as opposed to freshwaters, are considered. Since this study focuses on lakefront water quality, this does not affect the value of this protocol. The most robust metric measured in this study is free chlorine, Cl_2. The fact that free chlorine only exists in nature for short periods of time shortly after being introduce by some sort of human-related source makes finding free chlorine in nature a definitive marker of human-related pollution input. Although finding chlorine may not implicate a nearby failing septic system with 100% certainty, combining its discovery along with the detection of increased fecal bacteria counts in the same sampling location provides at least probable cause to perform a test for failing septic systems in that area.

Bacterial Source Tracking companies price their services at approximately $25 to $100 per isolate. This price may not seem too costly; however, a typical study may require 1,000's of isolates which could inflate the cost of performing a standard BST to many thousands of dollars for a single round of sampling. In addition, even if fecal bacteria specific to humans are found, some form of dye testing would still be required in order to determine exactly which septic systems are failing. By combining the testing for free chlorine with tests for simply the presence of high fecal bacteria levels, this protocol allows the researchers to perform essentially the same test at a far reduced cost.

With the aid of a local community college or well-equipped High School science lab, the estimated start-up cost for the protocol outlined in this report would be in the range of $1200 to $1500. After the initial set up, it would only be necessary to buy additional media (approx. $280/1000 plates for each type of media) and DPD pillows for the chlorine assay ($50/100 tests) for each additional sampling effort.

Based on the ability to form a partnership with a local science lab, these costs do not include items such as: incubators (two are needed because of the two types of media/bacteria), glassware (specifically, 100 mL graduated cylinders), Bunsen burners and forceps. Also not included is this cost estimate is the price of a boat, however, it is assumed that a local lake association would have access to a boat at no charge. However, an additional cost would be required for the disposal of the bacteriological waste. This could be accomplished at minimum cost if the partnering science lab had an autoclave (a small one will do). If there is not access to an autoclave, than a contract with a waste hauler that can deal with biological waste (biohazard material) would be necessary. Contracting with a waste hauler would be considerably more expensive in the long run.

Failing septic systems located near open water have the potential to cause major impacts to water quality and human health. Identifying failing septic systems near shorelines, although very important, can be very difficult and costly. Having developed a cost-effective protocol for identifying failing shoreline septic systems, The Warren County Soil and Water Conservation District hopes you use the information in this report to conduct your own water sampling and determine if failing septic systems may be impacting your local lake. If your results reveal no increased levels of bacteria and chlorine; great! But if you do find increase levels of these two measures contact your local health department as soon as possible. If a problem is detected, work together to remedy the situation by either repairing the existing septic system or installing a new septic system that can effectively treat the household wastes in order to protect our natural resources.

References:

Bahirathan, M., Puente, L. and Seyfried, P. (1998). *Use of yellow-pigmented enterococci as a specific indicator of human and nonhuman sources of faecal pollution.* Can. J. Microbiol./Rev. Can. Microbiol. 44(11): 1066-1071.

Craun, G.F. 1986. Waterborne Disease in the United States. CRC Press, Inc. Boca Raton, FL.

Eaton, Andrew D., Clesceri, Lenore S., Greenberg, Arnold E., Franson, Mary Ann H. (1998). Standard methods for the examination of water and wastewater, 20th ed. Washington, DC: American Public Health Association.

Lieberum, James. Personal observation and communication. 11/9/05.

Scott, T.M., Rose, J.B., Jenkins, T.M., Farrah, S.R., and Lukasik, J. (2002). *Microbial Source Tracking: Current Methodology and Future Directions. Applied and Environmental Microbiology* 68:5796-5803.

United States Environmental Protection Agency. Method 1603: *Escherichia coli (E. coli) in Water by Membrane Filtration Using Modified Membrane-Thermotolerant Escherichia coli Agar(Modified mTEC).* http://www.epa.gov/nerlcwww/1603sp02.pdf. Accessed 1/23/06.

United States Environmental Protection Agency. *Method 1600: Enterococci in Water by Membrane Filtration Using Membrane-Enterococcus Indoxyl-β-D-Glucoside Agar (mEI)* http://www.epa.gov/nerlcwww/1600sp02.pdf. Accessed 1/23/06.

United States Environmental Protection Agency (2002). *Wastewater Technology Fact Sheet, Bacterial Source Tracking*. http://www.epa.gov/owm/mtb/bacsortk.pdf. Accessed 11/17/05.

Walker, F. *Best Management Practices for Phosphorous in the Environment.* http://www.utextension.utk.edu/publications/pbfiles/PB1645%20.pdf. Accessed 11/8/05.

Wheeler, Andrea L., Hartel, Peter G., Godfrey, Dominique G., Hill, Jennifer L., and Segars, William I., (2002) *Potential of Enterococcus faecalis as a human fecal indicator for microbial source tracking*. Journal of Environmental Quality. 31:1286-1293.