

REPORTS:

Phosphorus migration from a near-lake septic system in the Otsego Lake watershed, summer 2003

Holly Meehan¹

INTRODUCTION

Otsego Lake, located in Otsego County, New York, is a phosphorus-limited system whose nutrient sources have been documented in some level of detail (Harman et al. 1997). Research conducted since the 1970s on various trophic state indicators suggests a shift toward eutrophy, presumably due, in part, to increased available phosphorus (Harman et al. 2002). Past efforts to reduce nutrient loading to the lake were concerned primarily with loads from agricultural runoff in the watershed using Federal money provided through the Environmental Quality Incentives Program, with matching funding provided by the Otsego County Conservation Association (i.e. Meehan 2003). More recently, loading from septic systems has also come to be suspected as a major nutrient contributor. While estimated to account for only 3.5-7.3% of Otsego's total phosphorus budget (Albright 1996), the impact from this source may be substantial. Unlike most of that derived from fluvial sources, phosphorus originating from septic systems is largely in a soluble form which is readily available for algal uptake. Also, most coming from agricultural streams is associated with particulates during winter/spring runoff events. Much of that settles to the lake bottom prior to the onset of the first algae blooms. Conversely, septic-derived phosphorus is likely reaching the lake during summer months when algae can immediately use it. In order to provide a preliminary assessment of the severity of loading from the approximately 500 lake-side septic systems, a study of a system seemingly representative of many of those lake-side was developed and carried out in the spring and summer of 2003. The protocols used followed those of Ptacek (1998).

The site chosen for study was one of six sites offered for evaluation and was the only one suitable for monitoring because it was the only one at which ground water could be retrieved. The study site was located on the western shore of Otsego Lake, with the septic system's leach field believed to be 4.6 m from the lake's edge. The site itself has little slope and relatively coarse soils, however, areas above the system have a very steep gradient where runoff flows down from upland systems and the highway. Nothing is known about the septic system regarding the design of the tank, the placement and age of it, point of effluent release, etc. It receives waste from two individuals seasonally (June-August) on weekends only. It is one of an estimated 154 systems, most being on the northern part of the western shore, within 100 feet (30 m) of the shore (McIntyre 2003); while this is no longer acceptable for the installation of new systems, they are "grandfathered" in that they were acceptable when installed and will be allowable unless they fail some future inspection. This study will contribute to the understanding of the system, and determine approximate concentrations of nutrients that are coming through the

¹ Rufus J. Thayer Otsego Lake Research Assistant, summer 2003. Present affiliation: SUNY College of Environmental Science and Forestry, Syracuse, NY.

system toward the lake. The results of this study are intended to aid the Village of Cooperstown with the septic inspections that are slated to start in 2004. Residents having systems that pass conventional inspections but likely contribute phosphorus will be encouraged to pursue phosphorus removal technologies currently available (Baker et al. 1997; 1998).

METHODS

The site of study was chosen from a number of sites that were offered for study due to the fact that ground water could be accessed by piezometers. Initially, six drive-point piezometers with Teflon linings were installed down grade from the septic system in pairs at depths of 1 and 2 m spaced in a pattern that would be useful in determining the migration patterns of effluent and some basic characteristics of the system. This primary installation occurred in September of 2002. On 16 June, four additional piezometers were installed at the site, three at 1 m depth further below the leach field, and one above the site to the west (Figure 1). The later site, upgrade from the system, was intended to provide background concentrations of the analytes. This piezometer was initially placed at 1 m depth, but halfway through the study was extended to 2 m because it was not intercepting ground water. Bentonite was placed around each piezometer in order to seal the well from surface water contamination.

Water was retrieved from piezometers using an aspirator pump and lab tubing. Samples were taken twice weekly, on Mondays and Thursdays, from 19 May to 24 July. Monday and Thursday were chosen for collection times in order to assess the system immediately after a weekend use period and then after 4 days of no use to gauge the residence time of the leach field. Water samples were analyzed for soluble phosphorous, nitrate+nitrite nitrogen, ammonia and chlorides. These analytes all indicate the presence of septic effluent in the ground water. Fecal coliform analysis was also performed on water samples taken 23 June in order to gain insight into the retention of the system (elevated concentrations would be expected to indicate low retention and, in effect, a system close to failure). Fecal coliforms were, at the same time, evaluated just off the shore immediately adjacent to the site for comparative purposes. The methods used for each analysis are provided in Table 1. Because the volume of water was frequently limited, not all parameters were analyzed on all samples. Phosphorus, the focus of this research, was always measured. Piezometers were completely bailed following sampling so that subsequent pumping collected “new” water.

Analysis	Method
Phosphorus	Ascorbic Acid Method following Persulfate Digestion (APHA 1992)
Chlorides	Mercuric Nitrate Method (APHA 1992)
Nitrate + Nitrite Nitrogen	Cadmium Reduction method (APHA, 1992)
Ammonia	Phenate Method (APHA 1992)
Fecal Coliform	Membrane Filter Technique (APHA 1992)

Table 1. Methods used for the analysis of soluble phosphorus, chlorides, nitrate+nitrate, ammonia and fecal coliform bacteria.

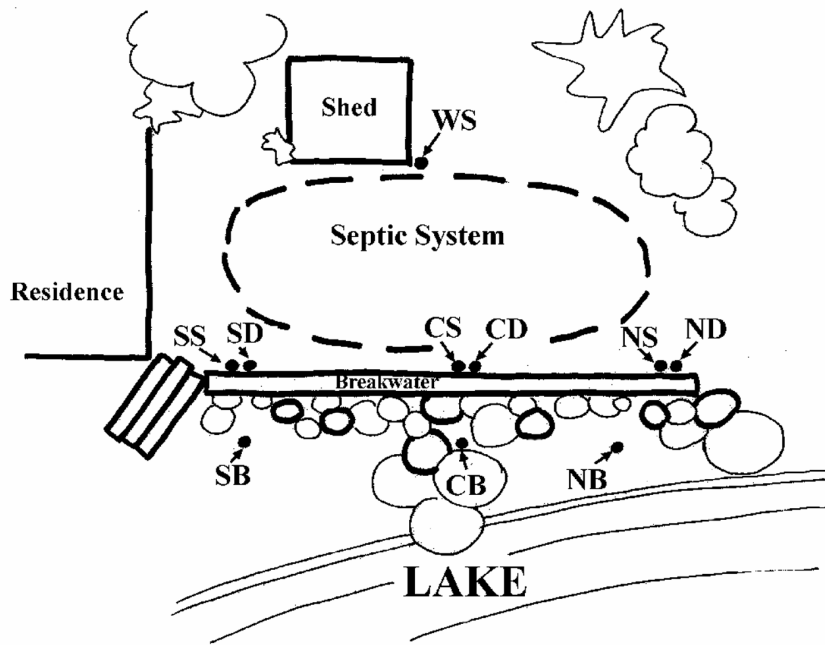


Figure 1. Schematic diagram of the study site showing piezometer placement. WS= West shed (2 m), SS= South Shallow (1 m), SD= South Deep (2 m), CS= Center Shallow (1 m), CD= Center Deep (2 m), NS= North Shallow (1 m), ND= North Deep (2 m), SB= South Beach (1 m), CB Center Beach (1 m) and NB= North Beach (1 m).

RESULTS AND DISCUSSION

Elevated levels of all chemical parameters tested, relative to background concentrations in the adjacent lake water, were found in the groundwater retrieved from each piezometer (Table 2). Fecal coliform levels were all less than 90 colonies/100 ml, and were, on average, less than ambient lake levels. This indicates that the effluent has a retention of a duration longer than that which these organisms can survive (i.e., the system is not failing in the conventional sense).

While chlorides are not considered a pollutant of concern in Otsego Lake, it was expected that its movement would provide insight into the migration of leachate, as effluent tends to have elevated chloride concentrations. Average chloride concentrations ranged from 158 mg/l at Center Shallow to 482 mg/l at South Deep, while average lake levels are approximately 15 mg/l. These high levels indicate septic water movement through the field and inevitably to the lake (due to the close proximity of the system to the shoreline). It should be noted that elevated chloride levels (>50 mg/l) have been documented in the groundwater throughout Otsego's watershed, presumably resultant of road salting (Albright in prep.). Average chloride concentrations were higher in the deeper wells (~2m), showing the high solubility and mobility of chloride compounds (Figure 2).

Phosphorus data for each sampling date is displayed in Table 2, which also provides site averages and standard errors. Contrary to the distribution of chlorides, phosphorus levels were highest in shallow wells (~1m), indicating the lower mobility of the phosphorus containing compounds (Figure 3). Phosphorus concentrations were consistently highest at the South Shallow site with the average being 2416 $\mu\text{g/l}$; comparatively, lake levels average around 12 $\mu\text{g/l}$ (Albright 2003). The lowest average concentration was 28 $\mu\text{g/l}$, occurring at the West Shed site. This site, situated above grade of the system, was intended to provide background conditions.

In order to further evaluate the retention of the system, phosphorus concentrations for Monday (immediately following a weekend of use) samplings were compared to Thursday (after several days of non-use) samplings. If the former were higher than the latter, it could be surmised that retention was low. However, there was no difference in concentration based on day of sampling (paired t-test; $p>0.05$).

Nitrate levels were found to be low and variable, with no distinct pattern (Table 2). Based on these findings during the study, nitrogen was hypothesized to have been in the form of ammonia due to the anaerobic conditions of the leach field. To verify this, ammonia was analyzed on the 21 July samples. Concentrations, which are generally below detection in the lake itself, ranged from 667 $\mu\text{g/l}$ at the South Deep site to 22,070 $\mu\text{g/l}$ at the Center Shallow site (Table 2). The next highest concentration of ammonia was found at the Center Beach site at 4140 $\mu\text{g/l}$, implying migration toward the lake.

Site	Chlorides mean (SE) [n]	Phosphorus mean (SE) [n]	Nitrates+Nitrites mean (SE) [n]	Ammonia mean (SE) [n]	Fecal Coliform mean (SE) [n]
North Deep	445 (20.2) [11]	43.6 (8.8) [16]	0.11 (.02) [10]	3320.6 [1]	0 [1]
North Shallow	232 (35.9) [11]	59.26 (15.4) [15]	0.16 (.04) [9]	983.2 [1]	70 [1]
Center Deep	457 (29.6) [11]	30.60 (6.1) [16]	0.71 (.63) [10]	1864.3 [1]	0 [1]
Center Shallow	158 (11.8) [11]	188.69 (59.4) [16]	0.4 (.01) [10]	22070.5 [1]	80 [1]
South Deep	482 (20.2) [11]	67.62 (11.1) [16]	0.08 (.01) [10]	667.1 [1]	0 [1]
South Shallow	193 (30.5) [11]	2416.88 (187.4) [16]	0.18 (.05) [10]	3450.2 [1]	90[1]
North Beach	253 (26.0) [3]	96.24 (29.1) [7]	0.08 [1]	2797.1 [1]	NA
Center Beach	218 (45.2) [5]	33.32 (9.8) [10]	0.08 (.03) [4]	4139.5 [1]	0 [1]
South Beach	340 [1]	123.81 (24.6) [9]	NA [0]	822.6 [1]	NA
West Shed	230 [1]	28.02 (4.5) [4]	0.47 [1]	1947.2 [1]	NA

Table 2. Average mean summer concentrations, (standard errors) and [sample size] for chlorides (mg/l), soluble phosphorus ($\mu\text{g/l}$), nitrates+nitrites (mg/l), ammonia ($\mu\text{g/l}$) and fecal coliform bacteria (colonies/100 ml).

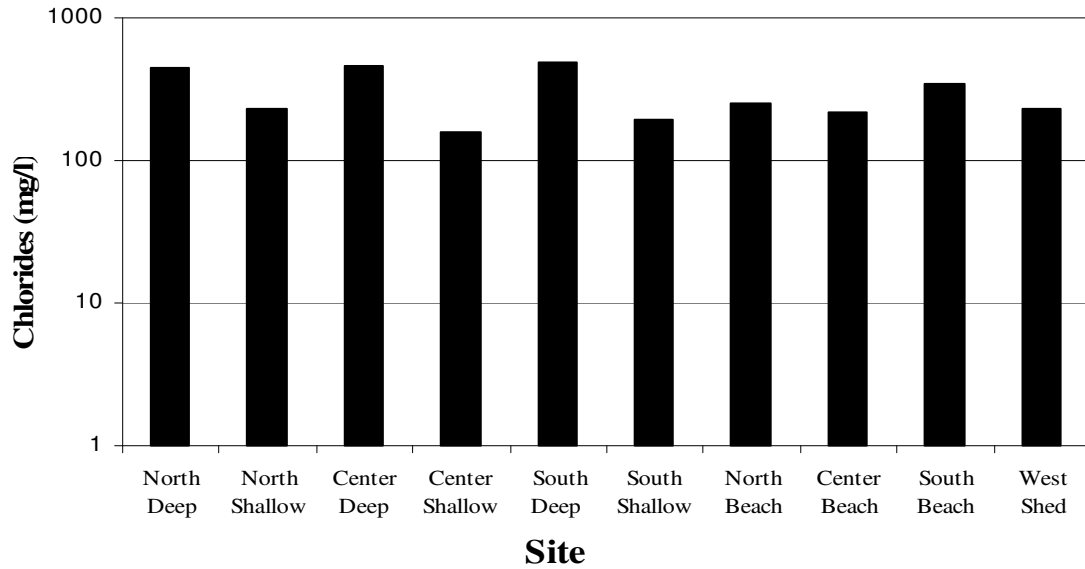


Figure 2. Average chloride concentrations (mg/l) for all sites, summer 2003. See Figure 1 for site locations. Note logarithmic scale.

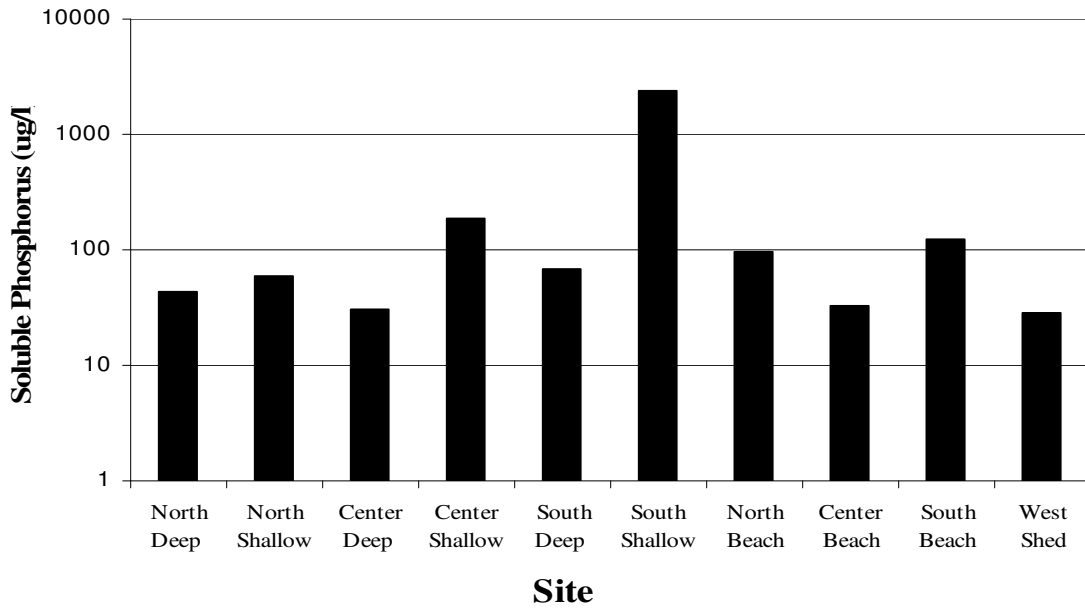


Figure 3. Average soluble phosphorus concentrations (ug/l) for all sites, summer 2003. See Figure 1 for site locations. Note logarithmic scale.

CONCLUSION

The results of this study clearly demonstrate a localized influence by a near lake septic system in down-grade, shallow groundwater, despite the fact that this system serves only two people, two days a week, three months a year. While this system would not be allowed for new installation, in that it is within 100 feet (30 m) of the shoreline, it would likely pass any conventional inspection. There was not surfacing of septage evident by the presence of odors or wet areas (despite higher than average rain during this study). Further, low concentrations of fecal coliform in the groundwater immediately below the leach field, as well as the lack of difference in phosphorus concentrations between days immediately following system usage and several days later, implies reasonable retention.

While the concentrations of phosphorus in the groundwater were substantially elevated, loading estimates cannot be made due to the lack of information on the extent of groundwater movement. Even with this particular system being in such close proximity to the shoreline, the amount of loading that is occurring at this particular site is likely small due to the low usage of the system. However, with many similar systems around the lake, the cumulative effects of small loading problems are likely to be a major source of nutrients to the lake. While accounting for a small fraction of the overall phosphorus input to Otsego Lake, the impacts may be substantial due to the high bioavailability of this fraction of phosphorus, and the fact that its introduction coincides with the algal growing season (Harman et al. 1997)

From this study it has been documented that even a functional conventional septic system, which would pass a standard inspection, is inadequate for nutrient immobilization from wastewater. While nutrient removal from leachate is not regulated, this may be a substantial source of this pollutant to sensitive waterbodies. Current technologies designed to intercept nutrients should be considered for any near lake system on less-than-ideal sites. These systems typically involve modular units containing “reactive mixtures” of metal oxide (often available as a by-product of steel manufacturing), crushed limestone (which provides suitable pH conditions and a constant calcium source, allowing for the formation of calcium/phosphorus minerals, as well as reactive surfaces necessary for phosphorus mineralization) and sand (which provides an inert media with a suitable porosity) (i.e., Green 2002; Baker et al. 1997; 1998).

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