Fate of Nitrogen in a Ponded Recharge Basin

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Introduction

In developed areas on Long Island it is estimated that 13.5% of precipitation that enters the water table is from runoff (Ku and Simmons, 1983). Of particular interest in this study is the fate of nitrogen in runoff from impervious surfaces that enters a recharge basin. Studies of dry recharge basins show little or no removal of nitrate or nitrite in the soil or unsaturated zone before they reach the ground water (Ku and Simmons, 1986). However, little is known about what happens to nitrogen in a recharge basin with standing water. This study focused on a recharge basin with standing water to evaluate whether a wet basin is effective at reducing nitrogen in the water before it reaches the water table. The concentrations in nitrogen in runoff water are 1 to 2 ppm total N (Ku and Simmons, 1983) and similar to those in rain which has concentrations of 1.6 ppm in northeastern United States (Berner & Berner, 1996). While these values are much lower than the drinking water standard of 10 ppm N as nitrate, this type of study may be useful for better understanding the behavior of nitrogen in the Long Island groundwater system.

During a rain or snowstorm nitrogen oxides and ammonia (NH_3) in the atmosphere are converted to nitrate (NO_3^-) and ammonium (NH_4^+) and are carried by the rain or snow. A large fraction of the rain that lands on impervious enters storm sewers and is discharged into recharge basins. Snowmelt is often contaminated by fertilizer and animal wastes, which are high in nitrogen. If the ground is frozen, snowmelt on otherwise permeable surfaces will not infiltrate but may enter the storm sewer system.

Recharge basins on Long Island are usually constructed in moderately to highly permeable sand and gravel. They can be as shallow as 10 feet, or reach depths of 40 feet below land surface. The area of basins range from 0.1 to 30 acres, but average between one and two acres (Aronson & Seaburn, 1974). Older recharge basins may have a significant cover of plant growth or may have standing water. Standing water may be the result of soil clogging caused by the accumulation of fine inorganic solids (i.e. silts, clays, fine sands) and organic solids (i.e. algae, plant debris) on the basin floor (National Research Council, 1994). In these cases the standing water in recharge basins is perched well above the water table and any water that reaches the water table must first go through the unsaturated zone (Fetter, C. W., 1994) (Figure 1). Standing water may also be due to a sufficiently high inflow of water into the recharge basin which so that the recharge mound intersects the bottom of the basin.

Clogging layers in recharge basins may act as a bio-filter, removing nitrate before it leaches to the water table (National Research Council, 1994). In the clogged layer organic nitrogen may be broken down to ammonium. Nitrogen in the ammonium (NH_4^+) form is susceptible to volatilization immediately upon exposure to the air-water interface only at a pH greater than 8 (National Research Council, 1994). Volatilization is greater at a water-surface interface than it is at a soil-surface interface. Under anaerobic conditions bacteria near the sediment-water interface may denitrify nitrate forming nitrogen gas, which is returned to the atmosphere. Ammonium that is not volatilized or converted to nitrate may be sorbed on sediment surfaces by cation exchange. The ammonium that enters the unsaturated zone beneath a basin may also be converted to nitrate if it is in an oxidizing environment. This nitrate will be transferred to the groundwater. Water retention in a recharge basin may

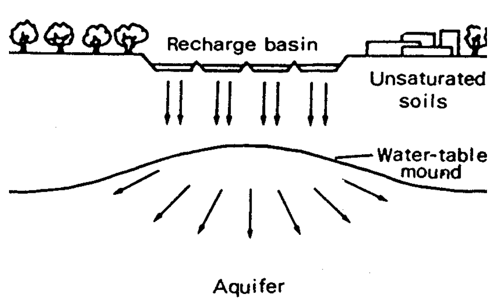

Fig. 1 Flow of water from a recharge basin through the unsaturated zone to the water table where the recharge water forms a water table mound.

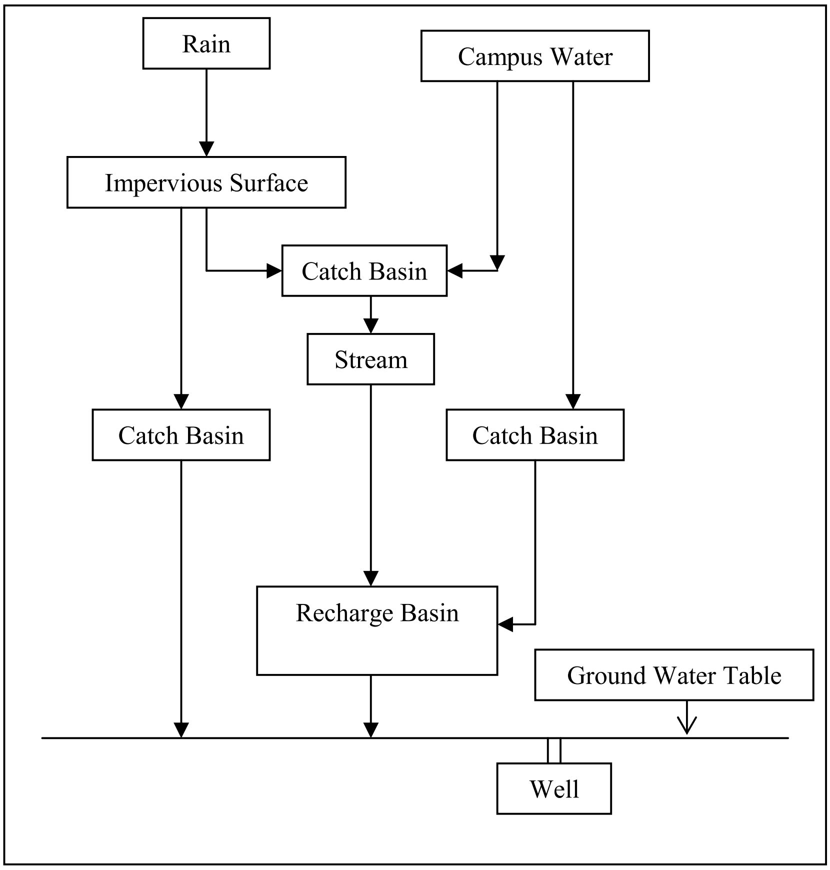

Figure 3. Flow chart of the sources and paths of water on campus. Campus water includes untreated cooling water and leaking chilled and hot water.

enhance removal of nitrogen by a variety of processes (National Research Council, 1994).

Setting

The recharge basin chosen for this study is located on the northwest corner of the SUNY Stony Brook campus, to the north of North Loop Road, and south of Route 25A. This recharge basin receives about one-half of all the storm drainage for Main Campus. To the west of this basin are two recharge basins used as overflow basins. All three recharge basins retain water throughout the year. Figure 2 shows the area on west Main Campus from which direct runoff enters the recharge basins through storm sewers. A significant fraction of the runoff water is directed from the storm sewers into an abandoned stream valley before entering another storm sewer system and the recharge basin.

Water Sources

There are several sources of water that enter the recharge basin:

- runoff from precipitation,
- cooling water,
- leaking chilled water, and
- leaking hot water.

A flow chart (Figure 3) shows the sources of water and the path that they take. Rainwater falls to an impervious surface, and enters a catch basin. If the catch basin is open bottomed, the water may directly infiltrate the ground. If the catch basin is clogged or close bottomed, the water will either enter the storm sewer system and travel directly to the recharge basin, or enter the storm sewer system, travel through a stream, again through the storm water system, and finally to the recharge basin.

Cooling water is from the Van de Graaff Accelerator, which uses Suffolk Count Water Authority water to cool the helium compressor. It is not chemically treated. This water enters directly into a catch basin, travels through the storm sewers, into the recharge basin.

The leaking water from the heating and cooling systems on Main Campus is chemically treated. This water is directed into the storm sewer system (Joel Newton, Director of Campus Facilities, oral communication, 1998). Some of this water travels through the storm water system that travels through the abandoned stream valley.

Flux into Recharge Basin

According to Rich Lefferets (oral communication, 1998), the discharge of cooling water from Van de Graaff Accelerator is approximately 70,000 gallons per day. Approximately 30,000 gal/day of campus leaking hot and chilled water enters the storm sewer system and the recharge basins. These two sources contribute a minimum of 100,000 gallons of water per day, or approximately 40 million gallons per year to the recharge basin.

Impervious surfaces account for 24% of the west campus or approximately 6.2 million square feet. The average rainfall is 44 inches per year. Thus a volume of 170 million gallons of rain lands on these impervious surfaces. If 85% of the precipitation reaches the storm sewer system, then approximately 145 million gallons of water enter the recharge basin as runoff per year. This added to the 40 million gallons added from the campus water yields a total of 185 million gallons of water that enters the recharge basin in one year. Approximately 20% of the water that enters the recharge basin is leaking and cooling water.

Table 1. Data are in ppm nitrogen as $N0_3$, NH_3, $N0_2$ and Organic N. Basin data are given for depth in basin.

	pH	**T (^{0}C)**	**0_2 (ppm)**	**NO_3 (ppm)**	**NH_3 (ppm)**	**NO_2 (ppm)**	**Org-Nitrogen (ppm)**	**Tot.-N (ppm)**
22 Jun 98								
Basin (1ft)				0.40	0.01	0.15		
Basin (10ft)				0.80	0.02	0.15		
Basin (16ft)				1.00	0.11	0.20		
Basin (26ft)				4.50	1.09	0.33		
7-Jul-98								
Basin (1ft)				0.40	0.02	0.03	0.04	0.49
****23-Ju1-98**								
Rainwater	4.44		8					
Stream	6.38	24	5.5	1.50	0.17	0.01	0.86	2.54
Basin (1ft)	9.45	27	12	0.00	0.01	0.01	0.65	0.67
MonitoringWell	6.31	18	8	0.70	0.00	0.01	0.38	1.09
30-Jul-98								
Stream (no storm)	6.74	29	7	0.80	0.00	0.01	0.38	1.19
****31 -Jul-98**								
Rainwater	4.77	19	7	2.90	0.70	0.02	0.05	3.67
Stream	6.29	28	6	2.10	0.92	0.05	0.77	3.84
Catch Basin	6.56	24	7	0.60	0.93	0.03	0.48	2.04
Basin (1ff)	9.05	24	8	0.20	0.01	0.01	0.46	0.68
Monitoring Well	6.26	19	7	0.40	0.00	0.00	0.28	0.68
3-Sep-98								
Culvert (no storm)	8.6	21	9	0.90	0.01	0.03	0.74	1 .68
Basin (1ff)	6.92	29	8	1.30	0.00	0.00	0.28	1.58
30-Sep-98								
Basin (1ft)	8.38	21		0.70	0.00	0.01	0.75	1.46
Basin (7ft)	8.3	20		0.70	0.00	0.02	0.38	1.10
Basin (13ft)	7.28	19		0.80	0.00	0.01	0.28	1.09
Basin (19ft)	7.13	19		0.80	0.01	0.01	0.46	1.28
Basin (25ft)	6.88	19		0.70	0.04	0.01	1.37	2.12
12-Nov-98								
Basin (1ft)	6.6	12		1.30	0.04	0.01	0.24	1.59
Basin (7ft)	6.75	12		1.30	0.03	0.01	0.06	1.40
Basin (13ft)	6.84	11		1.20	0.01	0.01	0.08	1.30
Basin (19ft)	6.99	11		1.30	0.01	0.01	0.08	1.40
Basin (25ft)	7.01	11		1.40	0.01	0.02	0.08	1.51
MonitoringWell	6.24	10.5		1.20	0.00	0.00	0.09	1.29

* Data for sample taken at 25 feet may be unreliable due to disturbance of the bottom of the recharge basin .

* * Storm events

Residence Time in Basin

The volume of water in the recharge basin is approximately 2 million gallons with an influx of 185 million gallons per year. The average residence time in the basin is 4 days. During periods of no rain the residence time for cooling and leaking water is 20 days.

Recharge Mound

Typically groundwater mounds below recharge basins are one to six feet after a rain event (Haskell & Bianchi, 1965), and the mound usually disappears within five days of a heavy rainfall (Ku and Simmons, 1983). The recharge basin used in this study differs in that it maintains a constant inflow of water from campus facilities, so a recharge mound is always present. The height of the regional water table is about 35 feet above mean sea level based on Water Resources Investigations Report 98-4019 and on measurements in monitoring wells on campus. At the monitoring well 45 feet from the northwest corner of the basin the water table level ranged from 55 to 51 feet above mean sea level. The bottom of the basin is 60 feet above sea level. Thus the mound may intersect the bottom of the recharge basin.

Analytical Results

Data were collected over the period from late June to mid November 1998. This was a period of light rainfall. There was no rainfall from the start of the study until July 23, 1998. It was intended to sample water both during a storm and during dry periods. The locations were the same for all samplings. At the beginning of a storm a rain collector was placed on the roof of the Earth and Space Sciences building, where there is little disturbance. One-liter samples were then collected from the stream, a catch basin just before the recharge basin, recharge basin and the monitoring well (Figure 2).

The stream sample was collected near the end of the stream, where the stream enters a culvert and is incorporated into the storm sewer system. The catch basin was sampled because it is representative of the characteristics of the water between entry of the stream into the storm sewers and the recharge basin.

During storm events, the recharge basin water was sampled at a depth of 1 foot below surface. During periods of dry weather, the recharge basin was sampled at various depths.

Immediately after the collection of the water samples temperature, dissolved oxygen content (DO) and the pH were measured. The samples were then placed in a cooler with ice. In the lab the samples were filtered to remove sediment particles, which could interfere with chemical analysis. The samples were analyzed for organic nitrogen, ammonium, nitrite, and nitrate using a Hach spectrophotometer. The data are presented in Table 1.

Sampling During Rain Storms

The first storm event sampled was on July 23, 1998 after a period of about one month without rain. Due to the small amount of rainfall only samples from the stream, recharge basin and monitoring well were collected. The rainwater had a pH of 4.44. The recharge basin had a pH of 9.45. The lack of rain for the previous month implies that the water in the recharge basin was dominantly from the leaking and cooling campus water. The cooling water is Suffolk County Water Authority water that has a pH of approximately 7. While the leaking water is chemically treated, information regarding the chemistry or pH of the leaking water is not available. We are suspicious that the leaking water occasionally has high pH and that leaking water is a major source of water in the recharge basin when there is no rain. This does not agree with the estimate by University personnel that cooling water makes up the larger source. Of the three locations sampled and analyzed for nitrogen, the stream had the highest total nitrogen, 2.45 ppm, and the recharge basin had the lowest concentration, 0.67 ppm.

The second storm was on July 31, 1998. The rain had a pH of 4.77. The recharge basin had a pH of 9.05. The concentration of nitrate in rainwater was 2.9 ppm. The highest total nitrogen concentration was found again in the stream, but the lowest concentration, 0.68 ppm, was found in both the recharge basin and in the monitoring well. These data suggest that the water in the recharge basin is similar to that of the well.

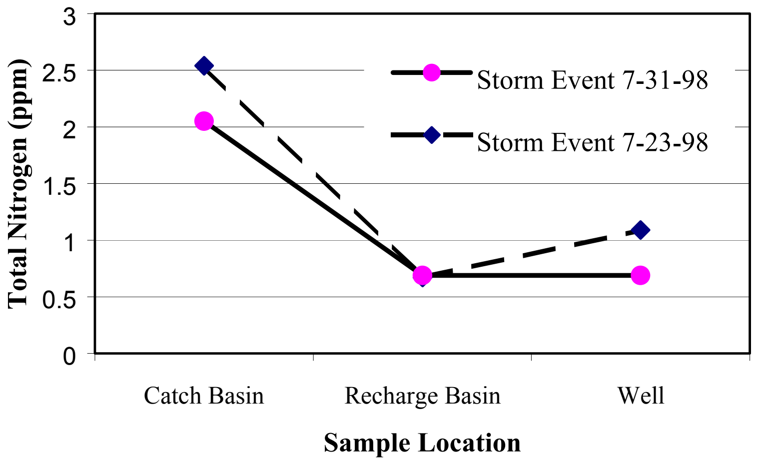

Fig. 4 Data from two storm events show that the groundwater from the monitoring well into the recharge mound below the recharge basin has lower total nitrogen than does the runoff in the catch basin just before the recharge basin.

Sampling During Dry Periods

Samples at various depths were again collected on June 22, 1998, September 30, 1998, and November 12, 1998. During each of these events, the recharge basin was sampled at depths of one, seven, thirteen, nineteen and twenty-five feet. The data for the bottom water (25ft) in the first set of samples may be invalid because the bottom of the recharge basin floor was disturbed before sampling. In September the pH was highest at the top, 8.38, and lowest at the bottom, 6.88, of the recharge basin. In November, the pH was similar at the top, 6.60, and bottom, 7.01. Possible explanations for the variation in pH from the summer to the fall could be that during July both leaking and chilled water are entering the recharge basin, but in mid fall the chilled water is shut off for the winter. The amount of rainfall may also affect the pH, although there was little rain during the fall.

The concentrations of the nitrogen species were relatively similar at all depths. The only notable difference was the organic nitrogen concentration of 1.37 ppm at a depth of 25 feet on September 30, 1998. This concentration was much higher than those taken at other depths on the same day. The organic nitrogen concentration of 0.08ppm at 25 feet depth on November 12, 1998 was similar to that at the shallower depths. The decay of organic matter in the recharge basin towards the end of the summer may have led to the higher value in September.

On July 30, 1998, during a dry period the stream, which should have had only leaking campus water, had a pH of 6.74, and a total nitrogen concentration of 1.19 ppm. This is inconsistent with leaking water having a high pH.

On September 3, 1998 during a dry spell water was collected from the culvert where leaking campus water enters the stream, and from the surface of the recharge basin. The culvert water had a pH of 8.6 and a total nitrogen content of 1.68ppm. The recharge basin water had a pH of 6.92 and a total nitrogen concentration of 1.58ppm.

Summary of Results

Based on the constant inflow of water and the water table measurements from area wells, the recharge mound below the basin may intersect the bottom or even sides of the recharge basin. This recharge basin differs from typical Long Island basins in that it receives a constant flow of water.

While the pH in the recharge basin during the summer was greater than 9, the source of the high pH is not known. What should be only leaking water had variable and lower pH's. It appears that bases are added to the system sporadically from unknown sources.

Nitrate is the dominant form of nitrogen in all water sampled. Ammonium is much lower, in proportion to nitrate, in the recharge basin than in rainwater. A decrease in ammonium concentration may be due to nitrification to nitrate or ammonia may be lost to the atmosphere in the recharge basin due to the high pH. The total nitrogen content of water in the monitoring well is generally lower than that of all of the sources of water. Thus it appears that nitrogen is lost from the system most likely due to processes within the recharge basin.

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