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Contributions of groundwater seepage to the water and nutrient budget of Mendums Pond Barrington, New Hampshire

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CONTRIBUTIONS OF GROUNDWATER SEEPAGE TO THE WATER AND NUTRIENT BUDGET OF MENDUMS POND BARRINGTON, NEW HAMPSHIRE

By

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Date

Dedication

Studying, learning, investigating and writing about Mendums Pond has been a tremendous blessing and challenge. I am thankful for all the assistance provided to make this project possible. In Particular, I would like to thank Jim and Diane Philbrick for their continual encouragement. Thank-you for your persistence, thoughtfulness, editing, and love through this whole experience.

Above all, this thesis project is dedicated to the One who formed and caused there to be such order in the Universe. Gaining further understanding about the Created world has been a very humbling experience.

"For by him all things were created, things in heaven and on earth, visible and invisible... all things were created by him and for him. His is before all things, and in him all things hold together" Colossians 1:16a,17a

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Samples were analyzed for nutrient data in the UNH Lakes Lay Monitoring lab managed by Robert Craycraft. Cation and Anion data were analyzed in the UNH Water Resource Research Center Lab under the leadership of Jeff Merriam.

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Table of Contents

Figures

Tables

ABSTRACT

CONTRIBUTIONS OF GROUNDWATER SEEPAGE TO THE WATER AND NUTRIENT BUDGET OF MENDUMS POND BARRINGTON, NEW HAMPSHIRE

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An understanding of the rates of groundwater seepage into and out of a pond or lake is important in assessing the flux of contaminants in a given system. Many studies have assessed the contribution of overland runoff and precipitation to freshwater pollution, but few have focused on direct measurement of groundwater inputs of nutrients and water to lakes. Spatial variation and natural heterogeneity of groundwater seepage around a large pond or lake can vary and make it an ambiguous and challenging parameter to quantify. The amount of groundwater seepage is thought to be related to the physical characteristics of a particular location. These include underlying soil type, slope, water-table characteristics. The aim of this study was to determine if land-use and upland topography impact groundwater seepage rates and nutrient contributions to Mendums Pond.

CHAPTER I

CONTRIBUTIONS OF GROUNDWATER SEEPAGE TO THE WATER AND NUTRIENT BUDGET OF MENDUMS POND, BARRINGTON, NEW HAMPSHIRE

Introduction

Watershed management and the enactment of effective land-use are critical for the protection of water quality. The quality of surface water is dependent on the quality of the contributing water sources which include groundwater, stream water, surface runoff and precipitation (Holdren et al. 2001). These contributing water sources are impacted by changes in land-use within the watershed. As a watershed becomes more developed, the potential for surface runoff, increased sedimentation, and groundwater contamination are increased. Protection of surface water requires the management of the contributing sources. Effective management benefits both ecological functioning and anthropogenic interests (NHDES, WD-07-31).

Contributing water sources to Mendums Pond in Barrington, New Hampshire were documented in 1992 (Connor et al. 1992). The present study was undertaken to evaluate and compare the current status of water quality entering and within the Pond. The primary focus of this thesis was to determine the contribution of water and nutrients entering the pond through littoral (< 15 feet) groundwater seepage. This was compared to the contribution of streams, unchannelized surface runoff, and precipitation. Littoral groundwater seepage measurements were gathered from June 2007 through November 2007. From October of 2006 through April 2008, water flow and nutrient concentration data were collected for the purpose of estimating the water and nutrient budgets for Mendums Pond (Schloss et al. 2009).

Sources of Nutrients

Groundwater contributions to surface water have the potential to impact water quality through the input of nutrients, especially phosphorus and nitrogen. The contribution of littoral groundwater (shallow groundwater) to the water budget of a lake is difficult to quantify. Over the last half-century, several methods have been applied to determine the flux of groundwater into lake surface water systems, by means of measurement, mass balance, energy budget, and kinds of vegetation respectively (Lee, 1977; Mitchell et al. 1988; Winter et al. 1988; Winter et al. 2003; Rosenberry 2005). Because the groundwater contribution is often estimated as less than 10% (Connor et al. 1992, Downing and Peterka, 1978, Connor and O'Loan 1992) it is sometimes determined indirectly from the data collected for the water budget of a Pond or Lake (Smagula and

Connor. 2002) and is assumed to be the difference between the net hydrologic inputs and the outputs, as illustrated in Craycraft (2008) water nutrient budget for Newfound Lake.

Nutrients present in lakes and ponds come from external and internal sources (Patrick 1974; Lake et al. 2006). External sources of nutrients are transported through streams, surface runoff, groundwater seepage, and directly through precipitation. Elevated levels of phosphorus and nitrogen species in the water can be attributed to increased human population and land-use (Vitousek et al. 1997). The main internal source of phosphorus and nitrogen loading occurs because of changing oxygen levels and rodox potential within the hypolimnion (Lake et al. 2006; Christophoridis and Fytianos, 2006). During stratification if the bottom water becomes anoxic, phosphorus and nitrogen which have been bound during oxic conditions can be released from the sediments into the water column, making them available for aquatic plants assimilation (Holdren et al. 2001; Christophoridis and Fytianos, 2006).

Seepage

Groundwater seepage rates to ponds and lakes have been shown to vary spatially, temporally, and seasonally (Schneider, 2005; Hagerthey and Kerfoot, 2005). Variation can be affected by geologic characteristics such as upland soil composition, substrate composition (silt/clay, sand, coarse material, boulders), slope steepness towards the water body, and depth to groundwater. Spatial variation in groundwater seepage has been found to impact species diversity within lake systems. Hagerthey and Kerfoot (1998 and 2005) have observed differences in benthic species in areas having variation in groundwater seepage. Seasonal variation in groundwater seepage has been observed as in the case of Mitchell (1988) who documented that groundwater inflow was about two times greater in the fall than the spring in several small Massachusetts lakes. He also observed significant differences in inflow based on topography of the landscape (Mitchell, 1988). This same phenomenon was documented by the New Hampshire Department of Environmental Services Study of Mendums Pond in 1992. The increased seepage to the pond corresponded with increased precipitation that is usually observed in New England during the autumn (Connor et al. 1992). Coastal New England might experience higher average monthly precipitation in the fall due to tropical storms, but these are rather isolated events (Keim and Rock, 2001). Similarly, Downing and Peterka (1978) observed a linear relationship ($r = 0.771$ $P < 0.001$) between increased precipitation (cm/day) and groundwater seepage rate (ml m^{-2} hr^{-1}), suggesting that precipitation causes a rise in the water table pushing water up and out through the sediment and into the pond/lake, resulting in an increase in groundwater seepage rates. Downing and Peterka (1978) did not observe a difference in nutrient concentrations during times with increased groundwater seepage rates. In both cases, groundwater seepage increased when the shallow groundwater table was elevated in response to precipitation.

The classic seepage meter Lee (1977) employed to understand the contribution of groundwater to lake and estuarine systems and the potential of this input to deliver nutrients. The original design was constructed using half of a steel drum with an apparatus attached to capture inflowing water for quantitative measurement. The physical design of seepage meters limits the types of sediment in which they can be placed. Because of the rigid walls of the barrels, sandy, mucky, or fine gravel areas are potential deployment sites. It is very difficult to place them in areas where there are large rocks and boulders (Lee, 1977).

Phosphorus and Productivity

Primary productivity of a lake is the net fixation of carbon by autotrophs, and is related to the amount of plant biomass supported during the growing season (Holdren et al. 2001). The primary productivity of lakes is generally limited by the amount of available phosphorus within the water column (Schindler, 1977). Phosphorus enters aquatic systems through surface runoff, precipitation, stream input, and groundwater seepage (Eaton, 2005; Carpenter et al. 1998). When present, the breakdown of apatite provides a natural geologic source of phosphorus to freshwater systems. Phosphorus is held and recycled by the vegetation efficiently with little being lost to aquatic systems (Wood et al. 1984). However, in Mendums, the sediments are acting as a major sink for phosphorus and could become a large source of internal nutrients (Schloss et al. 2009) if oxygen conditions degrade. Though phosphorus is necessary for plant growth, high levels of phosphorus may lead to the eutrophication of freshwater systems (Schindler et al. 1971).

Eutrophication of a lake can occur naturally over time as the system accumulates greater amounts of phosphorus and nitrogen, resulting in more primary productivity. Under these circumstances the aquatic system begins to have an increase in algal biomass (measured as chlorophyll *a*). Two observable outcomes of a water body becoming more productive are: a decrease in water clarity (secchi disk depth) and an increase in the chance of algal blooms. When algae die, the decomposing bacteria use available oxygen within the water column lowering the dissolved oxygen. In extreme cases, this process can lead to extensive fish kills and an overall degradation of water quality in response to lowering levels of dissolved oxygen (Carpenter et al. 1998).

The feces of waterfowl and other animals that reside near or in the water can degrade water quality through the addition of fecal phosphorus, other nutrients and coliform bacteria (Craycraft and Schloss, 2001). With increasing human population and land-cover changes within the watersheds of the feeder streams to Mendums Pond, there is increased potential for anthropogenic inputs of phosphorus and other anions and cations to the pond (sodium, chloride, nitrate, potassium, sulfate, magnesium). All septic systems (whether old or new), over use of fertilizers, removal of shoreline vegetation and gasoline from boat engines (especially 2-stroke engines) all contribute to the overall phosphorus levels in a lake (Fields, 2003). Over time, macrophytes and other vegetation in the water can take up phosphorus. As aquatic vascular plants and algae die, phosphorus containing organic matter eventually falls to the bottom of the lake and accumulates in the sediments (Thibodeaux, 1996). Under anoxic (less than 1mg/L of dissolved oxygen) conditions, the sediments can act as a source of phosphorus to the lake.

Research has indicated that as land within a watershed becomes developed, chloride concentrations in the streams and adjacent water bodies also begin to rise, likely caused by the increased use of road salt (Jackson and Jobbagy 2005). In developed areas road salt, water softener systems, and septic systems are the major contributors of chloride, sodium, forms of nitrogen and phosphorus to water (Kaushal et al. 2005). All of these can increase in groundwater due to the presence of septic systems, especially chloride as systems are not designed to remove chloride ions and over time nitrogen and phosphorus leach out of the systems and their treatment fields. As chloride is a very mobile species that is not removed by plants, its elevated presence in streams is a reliable indicator of land development. The main concern is the salinization of fresh water streams and the impact that may have on aquatic life. Kaushal et al. (2005), found that if the increase in chloride levels seen in streams since 1960 continues, over the next century streams in the northeast will have greater than 250mg/L of chloride, which would impact aquatic biota survival (Jackson and Jabbagy 2005).

Groundwater Seepage and Pore-water Nutrients

Studies have shown that pore-water chemistry is often different from surface water chemistry (Hagerthey and Kerfoot, 1998) and may be impacted by the rate at which groundwater seeps into a lake (Sebestyen and Schneider 2001; Sebestyen and Schneider, 2004). Hagerthey and Kerfoot (1998) observed that in areas of low groundwater discharge (-0.003 and -0.025 $ml/m^2/s$) the pore water samples had high ammonia concentrations (>100 μg/L) and low soluble reactive phosphorus (< 30μg/L). While in areas with high discharge the concentration of ammonia was below 100 μg/L and the soluble reactive phosphorus was above 30 μg/L. Sebestyen and Schneider (2004) suggest, from data collected from several lakes in the Adirondack Mountains of New York, that the residence time of water seeping through the sediments may be a contributing factor to causing differences in pore-water chemistry at different sites with similar substrates. However, they suggest that more research should be done to investigate the biogeochemical processes occurring in the sediment under different rates of seepage.

In particular, nitrogen retention and loss along hydrologic flow paths are strongly affected by groundwater residence time and the amount of organic material in the soil (Hill et al. 2004). Less contact time the water has with microbes in the soil decreases the chance for denitrification to occur. Thus, it is likely that amounts of nitrate may enter aquatic systems where water movement through the soil occurs at a faster rate. Rysgaard et al. (1994) observed that concentrations of nitrate and oxygen in water above lake sediments may impact the chance of denitrification from bottom sediments. They found that denitrification was more likely to occur in water where there was low nitrate and high oxygen in the water.

Objectives and Hypothesis

The main objective of this project was to determine the contribution of shallow groundwater (littoral <15 feet deep) nutrient flux to the overall nutrient budget of Mendums Pond. Shallow littoral groundwater seepage rates were monitored as well as concentrations of total phosphorus, nitrogen, and selected cations and anions.

Objective 1: Determine hydrologic and nutrient contribution of groundwater to Mendums Pond during field season of June 2007 –November 2007.

Objective 2: To observe if rates of groundwater seepage vary with the slope of the upland.

HP1: Groundwater seepage rates will increase as the slope of the upland increases.

Objective 3: To observe if monthly precipitation amounts are reflected in groundwater seepage rates with either increased seepage rates for wet months or decreased seepage for dry months.

HP2: Months with more precipitation will correspond with higher groundwater seepage rates.

Objective 4: To investigate the relationship between groundwater nutrient concentration with shore-land development.

HP3: Groundwater pore-water samples will have elevated concentrations of total Phosphorus, Nitrogen, and chloride in areas where there is development compared with non-developed areas.

CHAPTER II

SITE DESCRIPTION

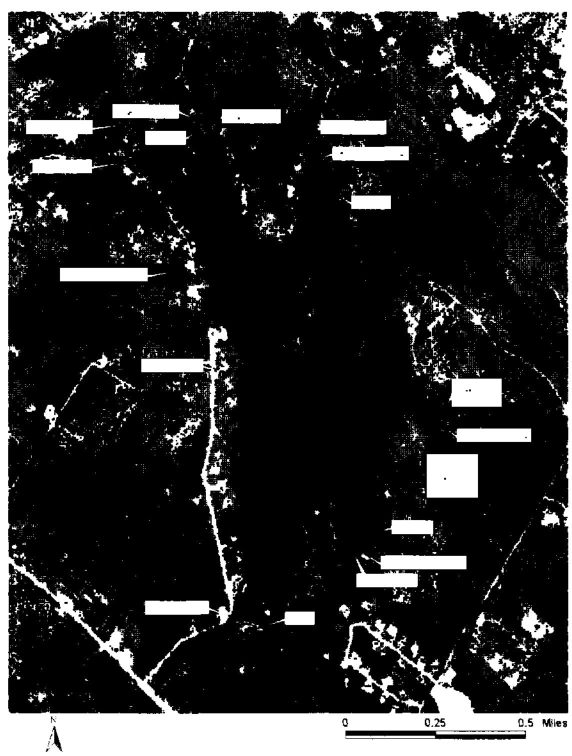


Figure 1: Map of Mendums Pond Streams

Mendums Pond is a 107 hectare (265-acre) pond located in Southeastern New Hampshire in the towns of Barrington and Nottingham within the Lamprey River watershed. The pond has three primary stream inlets, Perkins Brook, McDaniel Brook, and Wood Rd Brook along with several smaller seasonal feeding streams (Figure 1). The two outlets, the dam outlet and spillway are located at the south end of the pond. An earthen embankment 140 meters long and 10 meters high impounds the Little River creating the current size of Mendums Pond. The current earthen dam was constructed with dirt placed between vertical dry masonry walls (USEACOE, 1978). The original dam was constructed between 1839 and 1842 and has had improvements by New Hampshire Water Resource Division (Connor et al 1992). The Little River drains into the Lamprey River downstream in Lee after flowing through Nottingham. Ultimately water leaving Mendums Pond makes its way to the Great Bay Estuary of Coastal New Hampshire.

Table 1: Watershed Land-Cover Summary

Land-Cover	Area Hectares	Acres	% Coverage
Developed	22.7	56.0	1.40
Roads	42.6	105.2	2.50
Agriculture	5.2	13.0	0.33
Deciduous	300.9	743.6	18.59
Coniferous	1034.2	2555.6	63.88
Water*	191.6	473.5	5.24
Wetland	65.3	161.4	4.03
Disturbed	1.4	3.4	0.08
Cleared	39.9	98.6	2.47
Total	1703.8	4210.3	

Mendums Pond has a watershed area of approximately 1700 hectares (approximately 4200 acres). The land-cover of the watershed is predominantly coniferous and deciduous forest (Table 1, Figure 2).

Table 2: Impervious Surfaces of Watershed

Land-Cover	Area acres	Coefficient*	Impervious
Residential Development	56.0	0.106	5.9
Transportation	105.2	0.722	76.0
Disturbed	3.4	0.143	0.5
Cleared	98.6	0.212	20.9
Impervious Coverage (Acres)			103.3
Percent Impervious			2.45%

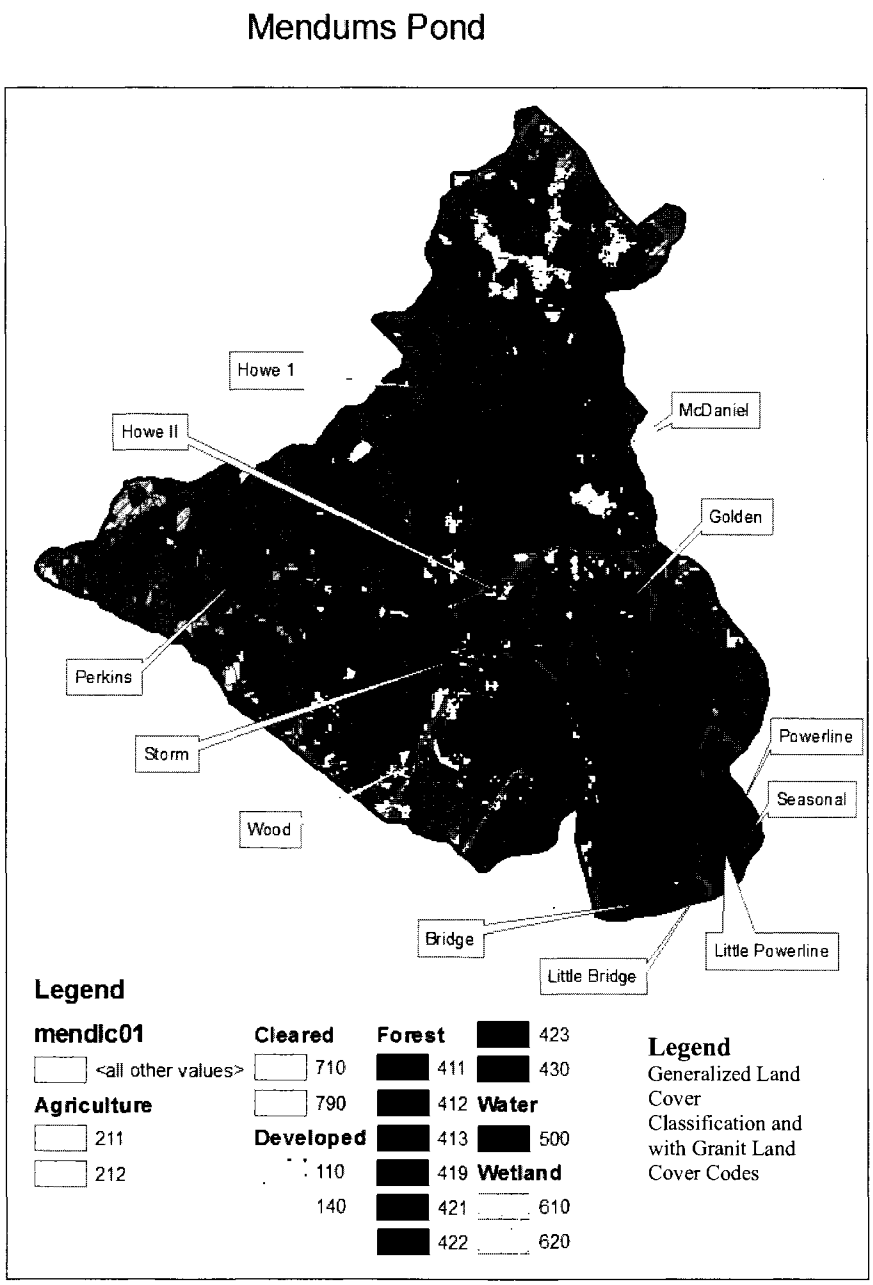
Under five percent of the watershed has been developed (developed plus roads), leaving the majority of the land as being coniferous and deciduous forest. Currently the entire Mendums Pond Watershed has about 2.5% impervious surfaces (Table 2), and the area within 76.2 m (250 foot) buffer of the pond has about 15.5 % impervious surface (Table 3)

Table 3: Impervious Surfaces of 76.2m buffer

Land-Cover	Area acres	Coefficient*	Impervious
Residential Development	6.014	0.106	0.637
Transportation	19.174	0.722	13.844
Disturbed	0.000	0.143	0.000
Cleared	2.603	0.212	0.552
Impervious Coverage (Acres)			15.033
Percent Impervious			15.544

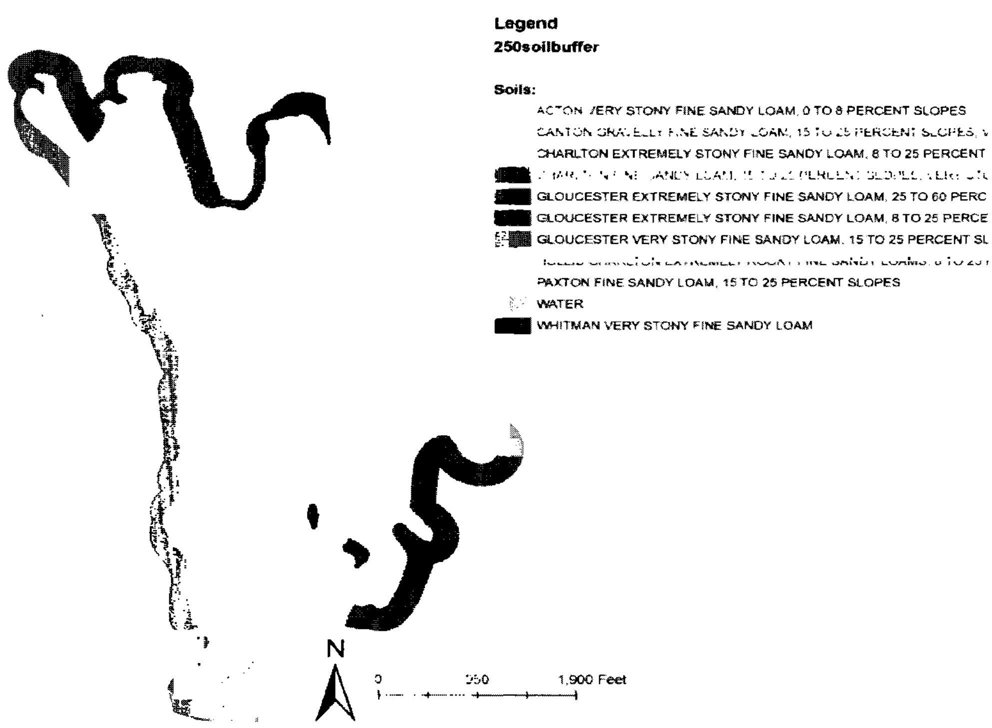
*Coefficients from DES Comprehensive Lake Inventory guidelines

Figure 2: Mendums Pond Watershed Land-Cover, with sub-watersheds delineated for each entering stream.



The soils in the Mendums Pond sub-watershed include several ranges of Acton, Canton, Charlton, Chatfield-Hollis-Canton complex Gloucester, Greenwood, Hollis-Charlton, Leicester, Montauk, Paxton, Ridgebury, Scituate-Newfield, Walpole Whitman, Windsor and Woodbridge (Vieira, 1973). The immediate shore of the Pond the soils are composed of Gloucester, Paxton, and Charlton (Figure 3). In the areas where the seepage meters were deployed the slope ranged from three to approximately twenty-five percent. Within the area of the shoreline, there are areas with slopes greater than 25% especially along with southeastern shore (Figure 4).

Figure 3: Soils in the 76.2 meter (250 foot) buffer around Mendums Pond



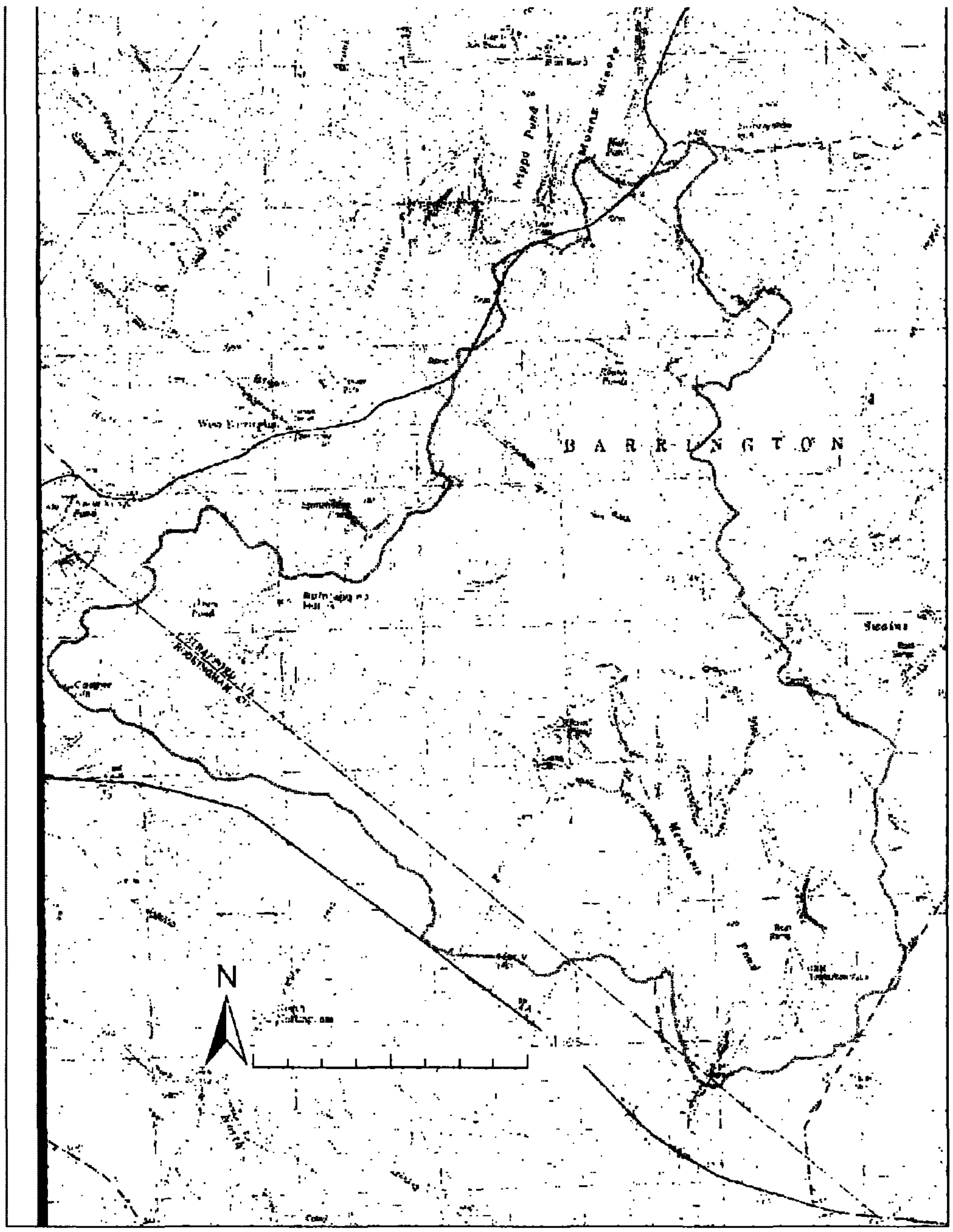
Along the immediate shoreline soils from the following series are found (Figure 3): Gloucester, Whitman, Acton, and Paxton. The characteristic soils are Gloucester extremely stony fine sandy loam, Whitman very stony fine sandy loam, Paxton fine sandy loam (15-25 % slope), Gloucester extremely stony fine sandy loam (25-60% slope) & Paxton very stony fine sandy loam (8-15% slope) (figure 4).

The wide variety of sand, stones, boulders, and cobbles that litter the bottom of the pond and shoreline conform to the soil characteristics of the land surrounding the Pond. Water erosion over the years has removed the smaller sand and stone particles exposing all sizes of rocks and boulders left by the retreating glacier 13,000 years ago (Wessels, 1997).

The northeastern shore, south of where McDaniel Brook enters the pond, is characterized by Paxton fine sandy loam (15-25% slope). This soil series is usually found along the sides of drumlins. This soil series transitions to Gloucester (Gtd) via Acton very stony fine sandy loam (0-8% slope). Within this area of the watershed there are two seasonal brooks, Little Powerline and Seasonal Brook, which are in a small valley sandwiched between two areas of moderate to steep terrain. The Little Powerline Brook stream channel flows between and

around large boulders near the pond. The boulders and rocks create little waterfall like areas. The seasonality of stream flow is influenced by precipitation and spring snowmelt. During a flood in April 2007, the Seasonal Brook stream channel changed from being a single incised channel to having a braided composition.

Figure 4: Topographical Map of the Surrounding Area of Mendums Pond. Watershed boundary is shown in red.



The Gloucester series (GtD) continues down to just beyond where little Bridge Brook flows into Mendums. This soil is characterized as having 8-25% slopes and is extremely stony fine sandy loam. From this point south to the dam and county line, the soil are Charleston extremely stony fine sandy loams, which are well-drained soils. This soil series continues up the west side of the pond up to where Perkins Brook area where the soil shifts to Gloucester extremely stony fine sandy loam 25-60% slope. Perkins Brook drains from Round Pond down to Mendums. The Gloucester (GtE) series found there is characterized as having stones in the surface less that 5' apart and is often located in hilly areas (Vieira, 1973).

The Gloucester (GtD) series is located from the east side of Perkins Brook to the area near McDaniel Brook where a strip of Whitman series creates a boundary. This soil series follows McDaniel Brook up into the watershed. The Whitman very stony fine sandy loam is a nearly level poorly drained soil found in low laying areas and in upland drainage-ways. The poorly drained soil probably helps provide a consistent water input source to Mendums Pond via runoff of water unable to infiltrate through the soil (NCSS, 2006).

Historically, Mendums Pond has been classified as an oligotrophic water body based on a range of water quality observations. Oligotrophic water bodies characteristically have low levels of phosphorus (<15 ppb) and chlorophyll *a* (<3 ppb) and subsequently have water transparency greater than 4 meters (Craycraft, and Schloss 2004). High levels of dissolved organic carbon in the water result in the pond having a tea color to the human eye. Protecting the watershed of the major streams and area around the pond will be important for preventing anthropogenic eutrophication in the future

CHAPTER III

METHODS AND MATERIALS

Field Procedures

Construction and Installation of Seepage Meters

Figure 5: Top view of Seepage Meter with Coupler

Seventeen seepage meters were constructed following Lee's (1977) design as a prototype. Thirty and fifty gallon plastic barrels were cut in half and trimmed so that the height of the seepage meter prior to being installed in the sediment was approximately 0.5 meters. A hole was drilled in the top of the barrel so that a size #13.5-neoprene rubber stopper would tightly fit in the hole. A silicon seal was used to prevent water loss or gain in the area where the stopper met the barrel. The stoppers had a 0.95 cm hole drilled in the middle for a coupler to be inserted (figure 5). The coupler allowed for water to move from inside the barrel into the tubing. Nylon 0.95 cm (ID) tubing was cut and connected to the coupler. For accessibility, the tubing length from the barrel to connector area varied based on the depth each meter was deployed. Marker buoys were attached to the tubing and secured with electrical tape. The seepage meters located in areas with high recreational use or in areas with substantial water flow from tides or incoming stream water can be impacted by wave action impacting the velocity head of the seepage bag collector; however the lower boat recreational use on Mendums, helped to protect the meter apparatus from harsh wave conditions, so wave shields were not made for each meter (Murdoch et al. 2003).

Collection bags were made by cutting a piece of 0.95 cm (ID) nylon tubing 0.3 meters long and zip tying a polyethylene heavy-duty bag to the tubing to prevent water loss from where the tubing and bag were connected. When collecting seepage data, the collection bag tubing was connected to the meter tubing using quick disconnect valves. The disconnect valves would only allow water to flow from the tubing to the bags when both the male and female connectors were attached. This feature of the quick disconnect helped to prevent water loss during attaching and detaching the seepage bag.

Preliminary fieldwork was conducted on March 1, 2007 to find potential groundwater seepage locations. Walking on the ice with a Garmin 76S GPS unit allowed me to take coordinates at locations where ice conditions had a glazed look compared to the snow covered "harder" ice, suggesting thawing from incoming groundwater. In some areas water was pooled on the surface of the ice, also suggesting that there could be groundwater seepage. Pooling was observed most often along the easterly shore, in the area where the slope was between 20 and 25% (Figure 8). All potential groundwater seepage locations observed were close to the shore and within the littoral zone of the pond. There were other areas where the presence of large rocks may have caused the ice to have a glazed appearance, as the rocks were able to absorb heat and cause melting of the ice near them. This preliminary work aided in providing information used in conjunction with the prior DES study seepage meter locations (Connor et al., 1992; Figure 6). The field observation day explored the whole southern perimeter of the pond, both east and west shores up to the area where McDaniel Brook enters the pond.

The meters were positioned where they could be pushed down into the sediment (Table 4 and Figure 6). Some meters, were installed from the side of the boat by slowly lowering the meters to the bottom of the pond and pushing them into the sediment at least 0.2 meters. Each meter was located approximately 5 meters from the shore and in 1.5 to 2.5 m of water. Large rocks and boulders along the bottom of the pond limited the potential locations for placing some seepage meters. To prevent dislodgement, two bricks or large rocks were attached to the top of the seepage meter using silicon cement.

During the months of May and early June of 2007, seventeen meters were deployed at geographic locations similar to those used by the NH Department of Environmental Services during their diagnostic study in 1992 (Figure 5 and 6). The seepage meters were placed within the littoral zone of the pond in varying locations with varying topographical steepness.

Table 4: Seepage Meter Locations Garmen76S

Seepage Meter ID	Location	
	Latitude	Longitude
4	43.150	-71.050
5	43.167	-71.050
6	43.150	-71.050
7	43.150	-71.050
8	43.167	-71.067
9	43.167	-71.067
10	43.167	-71.067
11	43.167	-71.050
12	43.167	-71.050
13	43.167	-71.067
14	43.167	-71.050
15	43.167	-71.067
16	43.167	-71.050
17	43.167	-71.067
17a	43.167	-71.050
18	43.167	-71.067

Figure 6: Department of Environmental Services (Connor et al., 1992. Figure VII-I)
Seepage Meter Site Locations, Mean Annual Seepage Rates (L/m2/day)

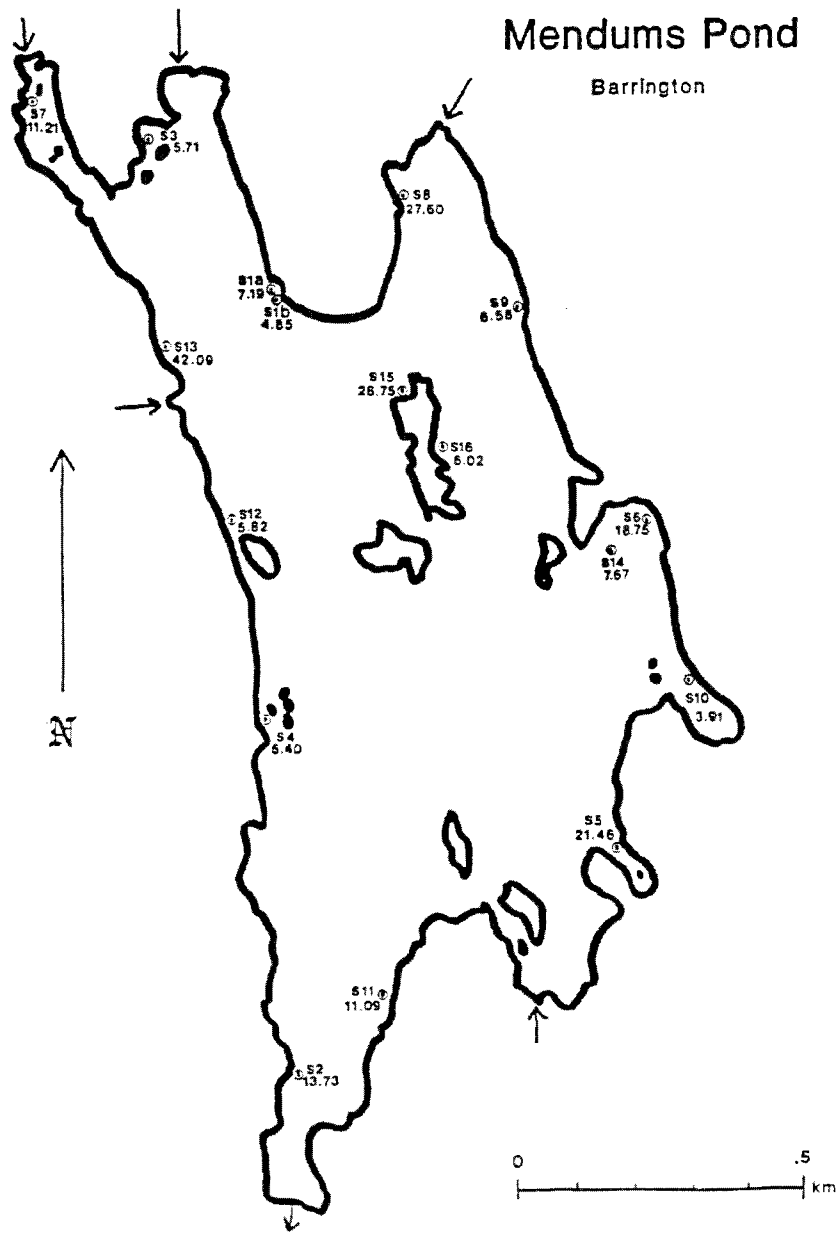
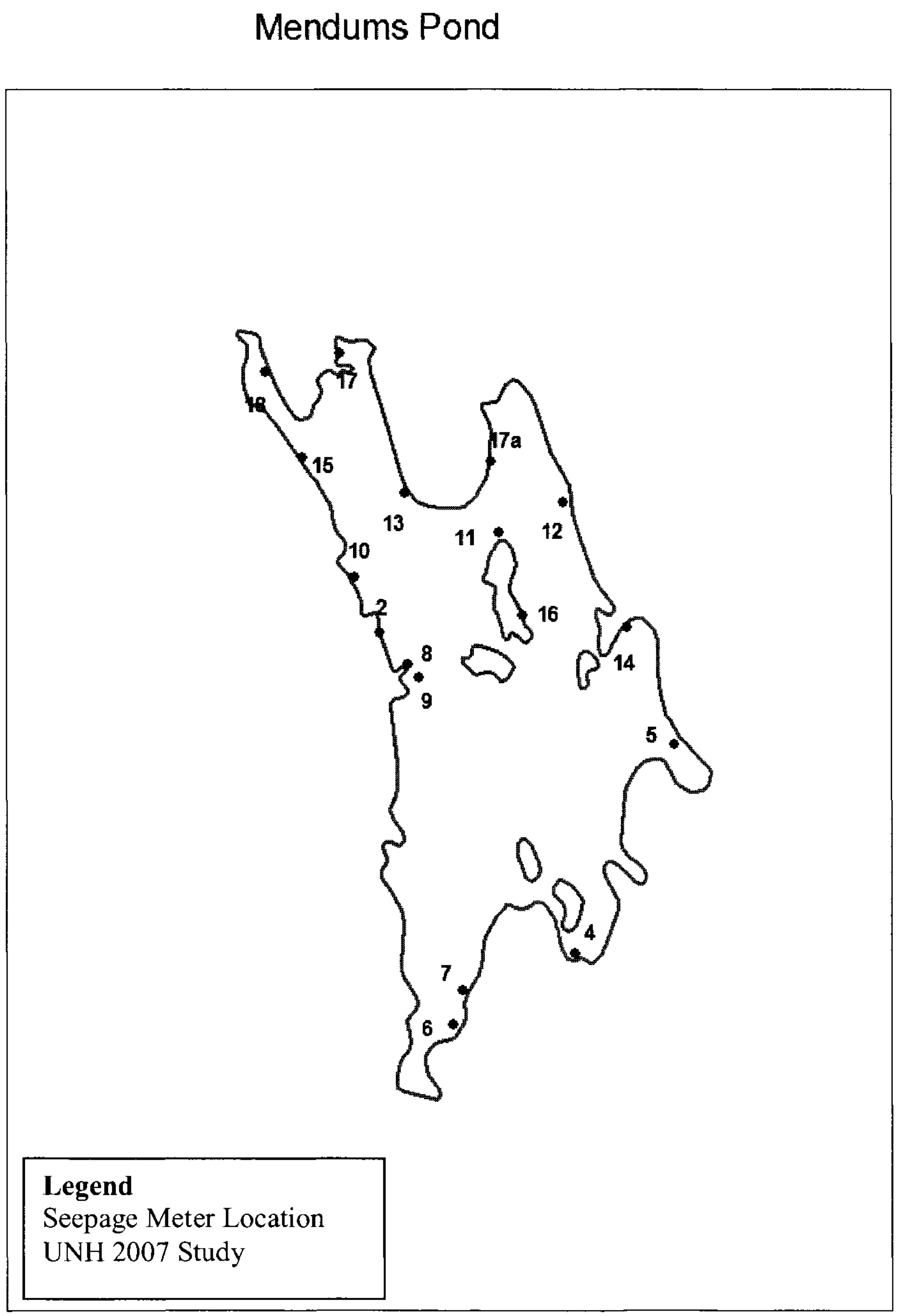


Figure 7: Seepage Meter Locations: June 2007 – November 2007



To estimate seepage rate, collection bags were filled with an initial volume of water (500 m) using a 1 Liter graduated cylinder (± 5 ml). Air was removed from the bags prior to attachment to the seepage meter to prevent a difference in pressure that could potentially skew the final volume. To prevent loss of water during connection, a quick disconnect male fitting was attached to the tubing from the seepage meter. The female fitting attached to the collection bag was then attached to the male connector. The time of connection was recorded as the initial time for measuring seepage data. After a few hours (usually 3-6 hours) the bags were disconnected using the quick disconnects to prevent loss of water during the disconnecting event. The bags were then emptied into the same 1 liter graduated cylinder and the final volume of water and corresponding time were recorded.

Groundwater seepage data was collected on a weekly basis during the months of June, July, August and biweekly during September, October, and early November. During the second week of November, the New Hampshire Department of Environmental Services began to draw down the lake for the winter months. By November 27th 2007, fifteen of the seventeen meters were no longer submerged. A shovel was needed to break the seal of the seepage meters in the sediment when the time came for removal, suggesting that the initial installation was effective. The meters that were still partially submerged had water within the meter when removed. The meters were removed from the pond to prevent damage during the winter months.

Calculating Groundwater Contribution

The rate of groundwater seepage at each meter was determined by calculating the change in volume (L) of the seepage bag. This change in volume was divided by the area the meter covered (m^2) on the bottom of the pond and then by the time (day) the bag was on the meter.

$$R = (V_f - V_i)/A * T$$

R= Rate (L/m^2day)
A = Area beneath meter (m^2)
T = time bag connected to meter (day)
V_i = Initial Volume in collection bag (L)
V_f = Final Volume in collection bag (L)

Positive R values represent groundwater seepage into the pond. If the R value is negative, it represents a loss of pond water into the ground (Appendix A).

Individual measurements taken from each meter were used in determining the overall seepage to the littoral zone of Mendums Pond. Monthly averages from each meter were averaged to achieve a monthly average seepage rate. These values were used in calculating the contribution of littoral groundwater to Mendums Pond. Total littoral seepage was determined on a monthly basis, by multiplying the monthly average seepage rate by the number of days in month and the total area of the littoral zone.

In order to consider the non-littoral groundwater seepage to the Pond, an estimate, (based on the results of Boyle 1994 study) was applied: that approximately 2.34 percent of what seeped in the littoral zone would seep into the Pond via the non-littoral seepage. In the Boyle 1994 study of non-littoral groundwater seepage it was observed that groundwater seepage decreased with distance from shoreline and water depth. The value estimated for the littoral zone groundwater seepage was based on data collected from June through October of 2007. The monthly littoral groundwater seepage rate per area was multiplied by 2.34 percent and the area of the non-littoral zone to estimate the volume of non-littoral groundwater seepage. The non-littoral groundwater seepage in glaciated areas is likely caused by regional groundwater flow through the stratified drift, as the water makes its way through the soil and fractured bedrock (Boyle, 1994).

Pore-water samples

Interstitial pore-water samples were collected monthly using a Solinist Model 615 Drive Point Piezometer and peristaltic pump during the summer and fall of 2007 (June-October). The piezometer was pushed down into the sediment near each seepage meter and the peristaltic pump was turned on in reverse to push out any water that may have entered the tubing while inserting the device. Once air bubbles were seen coming up through the sediment, the pump was turned on and suction began. At least 100 ml was collected at each site with 250 ml being the maximum sampling size. The mesh on the sampler was 0.297mm. The collected pore-water samples were then filtered through glass fiber filters (47 mm Whatman GF/C with effective filterability of 1.2 microns) and acidified using 1ml of concentrated sulfuric acid per 250 ml of sample. Pore-water and stream samples were analyzed for total phosphorus using the ascorbic acid reduction method (Eaton, 2005) in the University of New Hampshire (UNH) Center for Freshwater Biology Analytical Laboratory (Appendix B). The anion/cation samples were filtered in the field and frozen until analysis in the Water Resources Analytical Laboratory at UNH. Analysis for ammonium and nitrate were done using a Smartchem (Model 200 made by

Westco scientific instruments) Automated Discrete Analyzer. An Ion Chromatograph (Dionex Model ICS1000 with an AS40 auto-sampler) was used to measure the concentrations of sodium, potassium, magnesium and calcium in the samples. The IC works optimally with fresh water systems having low conductivity compared to specific ion analysis with electrodes (Appendix C).

Test of Variability of Seepage Meters

Variability of groundwater seepage rates at each meter was tested on October 26, 2007. Seepage rates were collected once in the morning and afternoon. The difference and standard deviation between morning and afternoon seepage rates were used to provide insight into the reliability of the seepage rates found during the study.

Water Input Calculations and Data Collection

Tributaries

Twelve feeder tributaries were monitored over the course of the nineteen month study, of which the best sampled months were used in estimating the water budget (Schloss et al. 2009 and Table 5). Volunteers and CFB staff collected tributary gauge heights at each of the feeder streams. Samples were collected biweekly over the course of the study. Staff from the Center for Freshwater Biology made stream discharge measurements using a flow meter (SonTekFlowTraker) and recorded the associated gauge heights. From the stream discharge measurements and gauge heights, rating curves were created for each stream (Appendix D).

The equations for each of the curves were then applied to each of the respective streams using the gauge height data to calculate a stream discharge value for measurements that only had gauge height readings. These values were then utilized in determining the quantity of water coming from each of the tributaries.

Table 5: Mendums Pond Stream Sampling Information

Study Streams	Site ID	Location: Latitude Longitude	Sampling Site Description	Stream Sampled in DES Study
Wood Road Brook	Men01T	43° 10' 34.3272" 71° 4' 12.8136"	Located above Conklin driveway; receives drainage from new development (Gerrior Drive subdivision)	Yes
Perkins Brook	Men02T	43° 10' 57.8388" 71° 4' 25.7700"	Major inflow previously	Yes
McDaniel Brook	Men03T	43° 10' 52.8744" 71° 3' 49.6980"	2nd major inflow previously; Need to sample above Men04T inflow	Yes
Golden Brook	Men04T	43° 10' 55.9416" 71° 3' 51.5880"	From culvert below road	Yes
Howe I Brook	Men05T	43° 10' 57.6660" 71° 4' 10.2648"	Site above McDaniel Shore Road	Yes
Howe II Brook	Men06T	43° 10' 58.0764" 71° 4' 13.9656"	Runs into Men05T below road	Yes
Powerline Brook	Men07T	43° 10' 15.3768" 71° 3' 25.9236"	Very close to Men17T sampled Near large boulder beneath area Where water pooled and began To flow.	Yes
Little Powerline Brook	Men08T	43° 10' 12.6480" 71° 3' 29.3652"	Wetland drainage	Yes
Bridge Brook	Men09T	43° 9' 57.3732" 71° 3' 43.5636"	At UNH property	Yes
Little Bridge Brook	Men10T	43° 9' 56.9736" 71° 3' 42.8868"	At UNH property: steep Gradient	Yes
Storm Brook	Men16T	43° 10' 52.5000"" 71° 4' 25.6476"	At driveway culvert	Yes
Seasonal Brook	Men17T	43° 10' 15.3300" 71° 3' 25.8264"		Yes
Outlet	Men011T		Below dam at stream channel	Yes
Spillway	Men 012T		Above where the water Merges with outlet. At base of the steep gradient	Yes

For each month the number of days that experienced no (0.0 mm <0.1 mm), light (0.1 mm – 19,9 mm), or heavy (> 19.9 mm) precipitation for each month was determined. Using this information and observing the actual and estimated discharge values, the quantity of water and nutrients entering the pond was determined. In some cases, values were based upon an average discharge spanning two months that showed similar flow or even flow that had been observed early in the study. Each monthly value was summed together to find the annual contribution of each tributary. For the purpose of this thesis, data from June through November was used to determine the percent contribution of groundwater to Mendums Pond.

Precipitation

Precipitation data was collected from the National Oceanic and Atmospheric Administration Climatological Station located at Thompson Farm in Durham, 2 miles south of the University of New Hampshire. The Water Resources Research lab at the University of New Hampshire analyzes rainfall collected at this site for a range of anion and cations. The Thompson Farm is located approximately twelve miles from Mendums Pond and provided the closest precipitation data for this study.

Table 6: Monthly Precipitation at Thompson Farm Climatological Center Durham NH

(Precipitation reported in mm)

	Thompson Farm
Latitude	**43 ° 11'**
Longitude	**70 ° 95'**
Elevation (feet)	**131**
Time of Observation	**0700 hour**
Jun-07	83.2
Jul-07	107.1
Aug-07	48.6
Sep-07	75.9
Oct-07	115.7
Nov-07	90.8
Total June 07 - Nov-07	521.3

July and October experienced the greatest amount of rain fall respectively during the course of the field season (Table 6). During July, two larger rain events contributed to the high precipitation for the month. The storms occurred on July 10^{th} and the 20^{th}, dropping about 28 mm of rain during both storm events. As the fall progressed there was an increase in precipitation during September and October (Table 6).

In addition to having access to precipitation amounts, precipitation chemistry data was available through NOAA dry fall/ wet fall data. This information was used in determining the atmospheric input of nutrients, in particular phosphorus.

<u>Runoff Contributions</u>

Runoff from ungauged watersheds was determined assuming a runoff coefficient of 0.52 for forested watersheds (Knox and Nordenson, 1955). Monthly rainfall data from the Thompson Farm Climatalogical Station was multiplied by the runoff coefficient and the area of the ungauged subwatersheds of Mendums Pond to estimate monthly water volume contribution from those areas.

Phosphorus contribution from ungauged subwatershed runoff was derived by considering the generalized land-cover characteristics of each subwatershed. Land-use classifications were done based on the NH Geographically Referenced Analysis and Information Transfer System land-cover data layer from 2000 (NH GRANIT; UNH Complex Systems Research Center). Land-cover classifications were broken down into six generalized categories: forest, cleared, water, wetland, agricultural, and developed. The area of the generalized land-cover within each subwatershed was multiplied by an appropriate annual phosphorus loading coefficient (Schloss and Connor, 2001). Monthly loading contributions were then distributed using relative percentage of the annual rainfall for that month.

Watershed Delineation and Analysis

Spatial analysis and digital watershed delineations of the Mendums Pond watershed were conducted using Arc Map 9.2. The data utilized for GIS analysis was obtained from the New Hampshire Geographically Referenced Analysis and Information Transfer System (NH GRANIT; UNH Complex Systems Research Center) data repository base. Sub-watersheds were delineated using the GRANIT 1:25,000 Digital Elevation Model and the ArcGIS "Flowfill" hydrology tool output to guide hand delineation on a 7.5 minute USGS topographical map. Land-cover summary data was generated for the whole Mendums watershed, gauged subwatersheds and ungauged subwatersheds and summarized to investigate connections between pore-water chemistry values and whether the upland area near the shoreline of the pond had been developed or left undeveloped.

CHAPTER IV

STATISTICAL ANALYSIS

Groundwater

A nonparametric approach was used in the statistical analysis of the data because the range of values was not evenly distributed, as a parametric assumption requires. A Wilcoxon/Kruskal-Wallis test was run on all the seepage rate data in the fit y by x platform of JMP 7.0 (SAS Institute Inc.) to determine if there was a statistical difference between site seepage rates based on the slope of the immediate shoreline. Seepage meters were grouped based upon the degree of the upland slope: 0-5% (A), greater than 5-15% (B), and greater than 15% (C). The Wilcoxon/Kruskal-Wallis test revealed a statistical difference with a p value <0.001.

Table 7: Summary Statistics: a Three Way ANOVA: Anion/Cation Response to Land-use and Slope

Anion/Cation	Land-use	Slope
Na^{+}	0.0212*	0.6386
K^{+}	0.1081	0.3628
Mg	0.1273	0.9900
Ca^{+2}	0.1291	0.9614
NPOC	0.6664	0.1881
SO_4^{2+}	0.0168*	0.4885
TDN	0.9033	0.7765
NO_3^{-}	0.2548	0.0033*
Cl^{-}	0.0207*	0.6128

*Significant Response $p \leq 0.05$

In order to determine which groups were statistically different, a comparison of all pairs using a

Tukey test was performed. There was a statistical difference between group A (0-5%) and C (>15%), but not with group B in either case. When the data was analyzed on a weekly basis there was only a statistical difference between slope classifications on August 3 and August 25, during the rest of the weeks the three classifications were not statistically different from one another.

Additionally, a three way ANOVA test conducted in the platform option of JMP 7.0 was done to analyze if the anion/cation concentration of the porewater samples were related to land-use and slope classification. Regarding land-use, seepage meters were classified as having a developed or non-developed upland area. Chloride ($p = 0.0207$), Sodium ($p = 0.0212$), and Sulfate ($p = 0.0168$) all had a statistically significant relationship with land-use, but not with slope classification ($p < 0.05$ was considered significant). Nitrate had a significant relationship with slope classification ($p = 0.0033$) (appendix D). The remaining anions and cations did not respond to either land-use or slope classification (Table 7 and Appendix E).

CHAPTER V

RESULTS

Groundwater Seepage Analysis of Monthly Data

Littoral Groundwater Seepage contributed 160.8 10^3 m^3 from June through October 2007 to Mendums Pond (Table 12). The greatest contribution from groundwater occurred during the month of October followed by July, which respectively had greater rainfall amounts than the other months observed (Table 6).

Seepage variation was observed between seepage meters on sampling days and it also varied over the course of the field season at each meter. Seepage meter 6, had the greatest seepage rate value (18.4 L/m^2 day) on June 22, 2007, while meter 17a had the greatest recharge rate value (-12.3 L/m^2 day) on June 29, 2007. For the most part, groundwater seepage rates into Mendums Pond were between 0 L/m^2/day and 5 L/m^2/day (Table 8, Appendix A). The meters that stayed most consistent were found in areas with upland slope ranging from 0-20%, except for meter 17a and meter 12 that showed some variation during the course of the field season (Figure 8, 9 and Table 9).

Figure 8: Seepage Rate vs. Date for All Seepage Meters

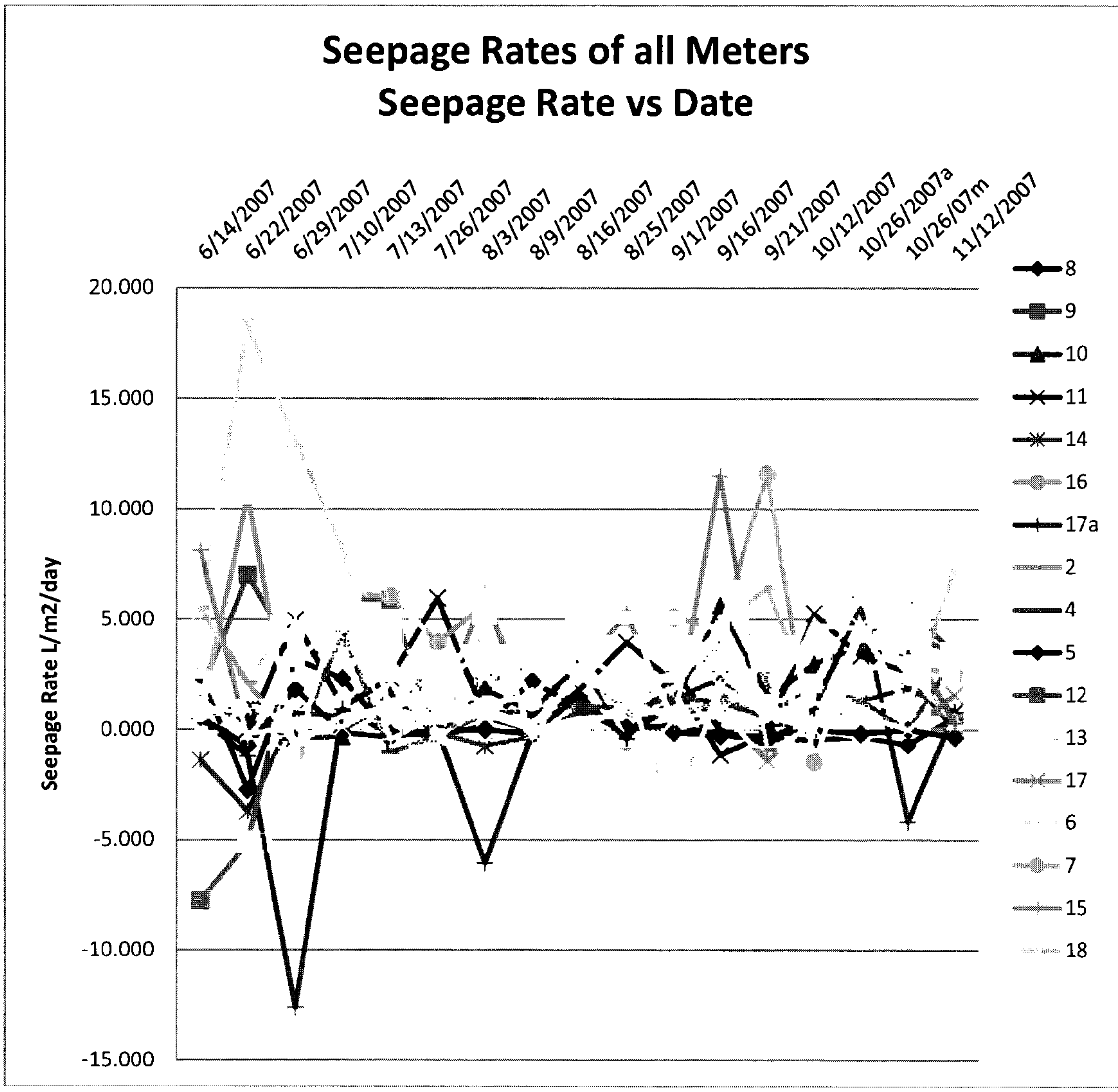


Figure 9: Seepage Rates Slope A Classification

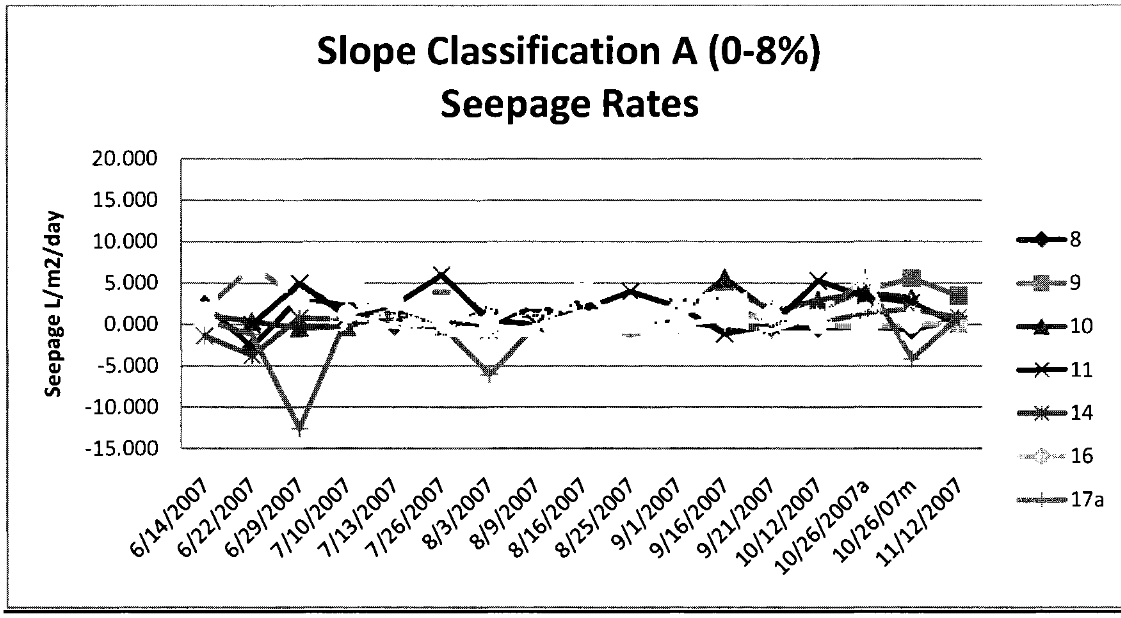


Figure 10: Seepage Rate Slope B Classification

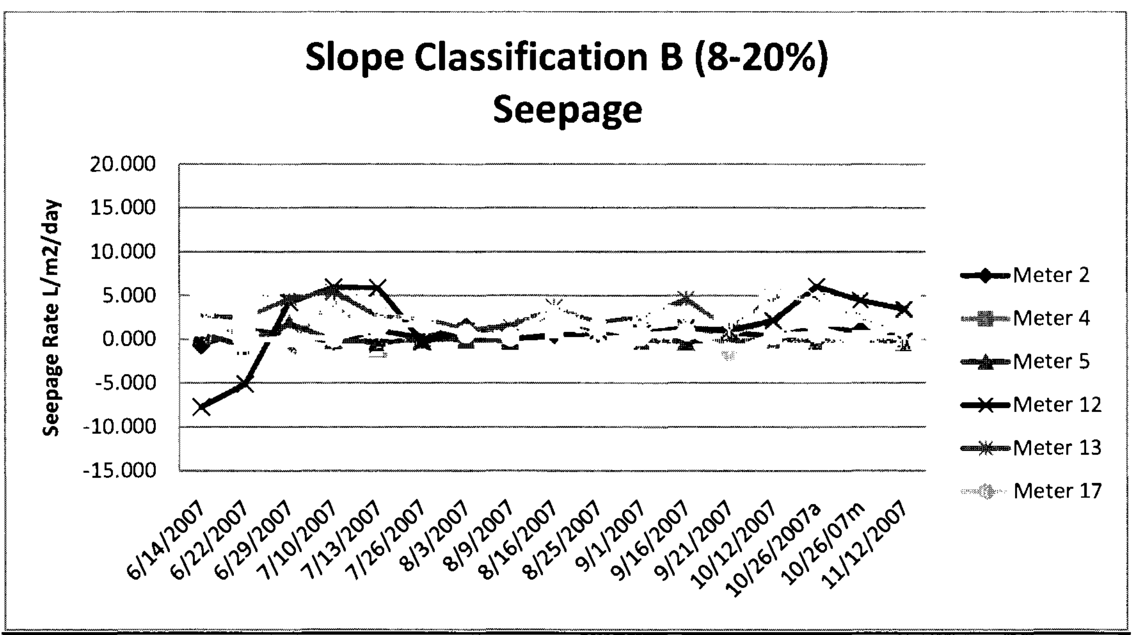
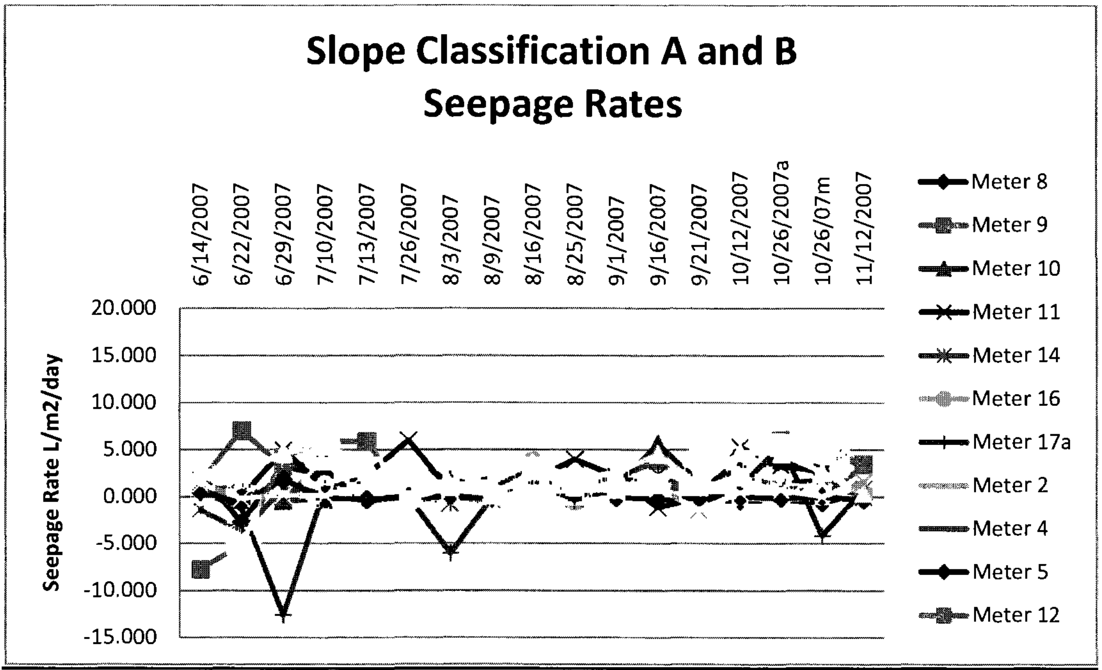
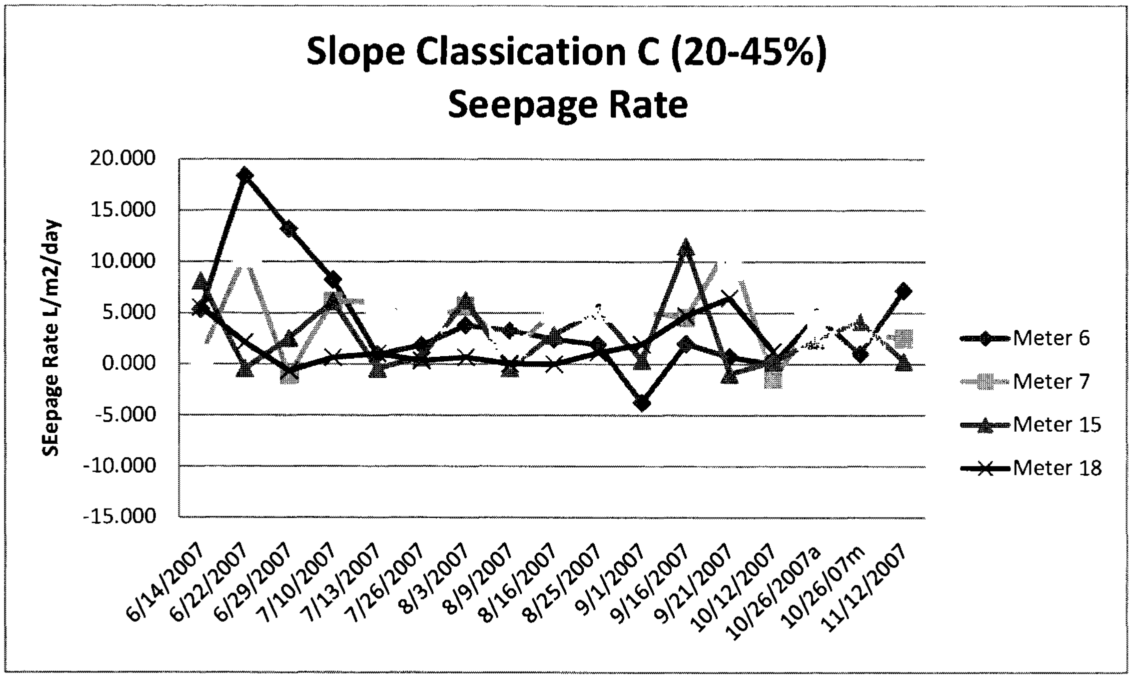


Figure 11: Seepage Rates Slope A and B Classification



Seepage meters classified as A and B had for the most part had similar seepage over the course of the field season (Figure 11). Meter 17a had the greatest recharge to the sediments occurring on June 29th 2007. Meter 9 had inflow at or above 5 L/m2/day during late June through July 13th and then again in October, while the inflow at that meter was decreased during August and September. There was no statistical difference between A and B seepage meters ($p > 0.05$).

Figure 12: Seepage Rate Slope C Classification



Meter 6 and 7 had a higher seepage rate on June 22, 2007 than the other meters. Meter 15 peaked on September 16, and meter 7 peaked on September 21st. Meter 6 and 15 had a decrease in seepage on September 1st compared with seepage on August 25th. For these meters the seepage did rebound on September 16th. Comparing Figures 10 and 11with Figure 12 illustrates that seepage meters located in areas with slope greater than 20 % (meters classified as C) had greater variation in seepage. Unlike this differs from the more consistent seepage rates observed by meters found in areas of the pond with less upland slope (0-20%) (Figure 9).

Figure 13: Seepage Rate Slope A and C Classification

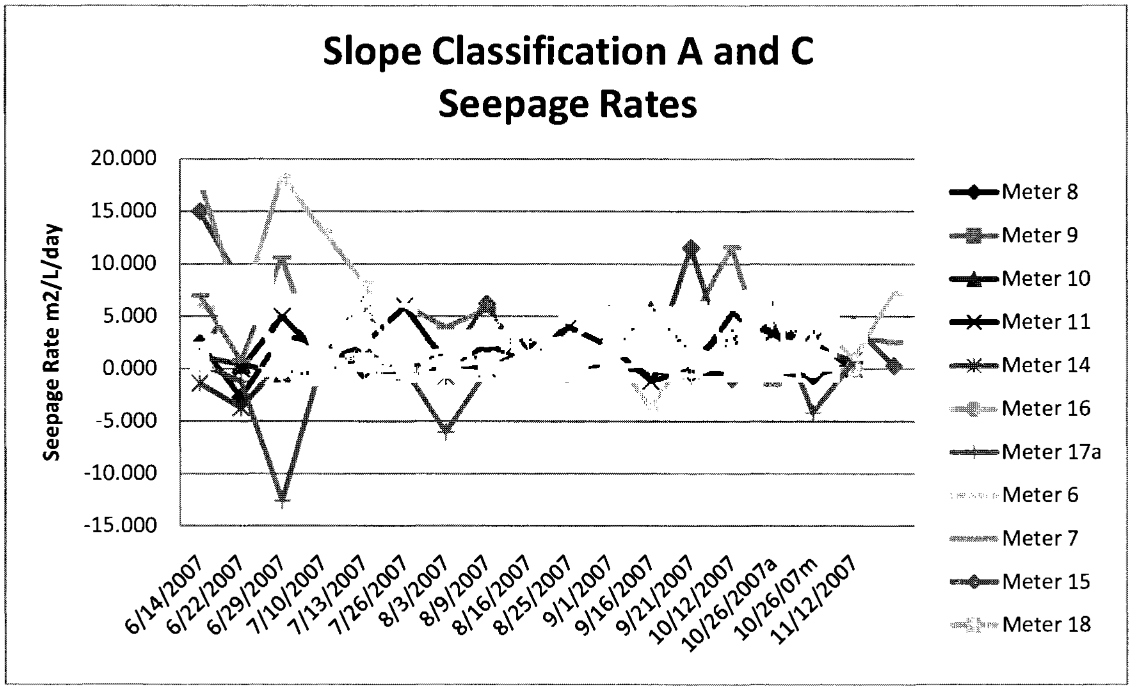


Table 8: Seepage Rate Average, Minimum, Maximum and Rage for Each Meter

Seepage Meter ID	Slope Classification	Location Latitude	Longitude	Seepage Rate Data (L/m^2/day) Average	Min	Max	Range
8	A	43.167	-71.067	0.182	-2.741	3.183	5.925
9	A	43.167	-71.067	3.776	0.574	7.003	6.429
10	A	43.167	-71.067	2.768	-0.414	5.627	6.041
11	A	43.167	-71.050	2.968	-1.142	5.969	7.111
14	A	43.167	-71.050	0.982	-3.718	2.338	6.056
16	A	43.167	-71.050	1.312	-0.522	3.820	4.342
17a	A	43.167	-71.050	-0.012	-12.606	5.645	18.251
2	B			1.103	-0.705	1.415	2.120
4	B	43.150	-71.050	1.373	-1.013	4.406	5.419
5	B	43.167	-71.050	-0.194	-0.744	1.826	2.570
12	B	43.167	-71.050	3.250	-7.753	6.042	13.796
13	B	43.167	-71.067	3.770	0.401	5.415	5.014
17	B	43.167	-71.067	1.147	-1.399	2.369	3.768
6	C	43.150	-71.050	2.879	-3.761	18.376	22.137
7	C	43.150	-71.050	6.305	-1.455	11.600	13.055
15	C	43.167	-71.067	3.568	-0.948	11.514	12.462
18	C	43.167	-71.067	1.937	-0.671	6.448	7.119

Over the course of the field season, a few of the meters had consistent seepage with a range of variation of less than 5 L/m^2/day (Table 8 and Appendix A). Other meters, particularly meter 6, 7, 12, 15, 16, and 17a had a range of seepage measurements greater than 10 L/m^2/day. Meter 6 had the greatest variation in seepage with a minimum seepage rate of -3.761L/m^2day and a maximum rate of 18.376 L/m^2day (Table 8). Meter 17a also had high variation, mainly caused by a low seepage value recorded on June 29th 2007 with a minimum value of -12.606 L/m^2/day and a max of 5.646 L/m^2/day (Table 8, Appendix A). Meters 5 and 17a had negative seepage average values for the field season. Meter 7 had the highest average seepage rate of 6.305 L/m^2/day.

Variability of Seepage Meters

One main potential error associated with gathering seepage data was in measuring and pouring the initial amount of water into the seepage bag. The graduated 1 liter cylinder had measuring graduations of 10 milliliters. The initial or final volume had the potential error of ± 5 milliliters. Therefore, the change in volume used in calculating the seepage meter rate, could have been as much as 10 milliliters away from the actual value. When dealing with small changes in volume there is greater potential for error, which could have lead to a high difference in morning and afternoon seepage rates. However, the variation in groundwater seepage over the course of the day may have been a natural result of changing groundwater flow into or out of the Pond.

The impact of time on the error was very small. Time used to calculate the seepage rate with within ±1 minute and overall seepage bags were attached for three to six hours of time each sampling day, making it a very small contribution to measuring error. Meters with difference greater than ±1 (L/m^2/day) may be revealing a concern about the reliability of the seepage rates

Table 9: Absolute Difference for Seepage Meters Data collected 10/26/07

Seepage Meter Identification #	Morning L/m^2day	Afternoon L/m^2day	Difference	Standard Deviation
10	3.25	3.77	0.52	0.37
2	0.97	1.27	0.3	0.21
8	-0.68	-0.32	0.36	0.25
9	5.55	4.06	-1.49	1.05
7	2.99	4.39	1.4	0.99
6	1	4.68	3.68	2.60
4	0	1.33	1.33	0.94
5	0	-0.17	-0.17	0.12
14	1.88	1.33	-0.55	0.39
16	0	-0.34	-0.34	0.24
11	2.62	3.36	0.74	0.52
12	4.45	6.04	1.59	1.12
17a	-4.18	5.65	9.83	6.95
13	2.61	4.62	2.01	1.42
17	0	0.68	0.68	0.48
15	4.14	2.36	1.78	1.26

recorded at these particular sites because of human or equipment error. Meter 17a had the greatest difference (Table 9), and this meter also had variable seepage over the course of the field season (Figure 8). The meters with high (greater than 1) differences were located in all three slope classifications (Table 10). Three of the four seepagemeters found in areas with a slope greater than 20% (classification C) had a difference greater than 1 ($L/m^2/day$). No distinct pattern of meter location is evident regarding the high variability in seepage from the morning to afternoon sampling. Four of the meters (Table 8) had decreased seepage rates in the afternoon ranging in difference of -0.17 $L/m^2/day$ to -1.49 $L/m^2/day$. The four meters that had a decrease in seepage in the afternoon were in areas with slope less than 20 % (Classification A and B). Of the four meters, three of them (5, 14, and 16) are located on the eastern shore, with meter 14 and 5 being in similar geographic locations. Meter 16 was located on the eastern side of the main island, while, meter 9 was located off the shore near Mendums Landing (Figure 6 and 7).

Table 10: Slope classification Meters with difference greater than ±1 and standard deviation greater than 1

Slope Classification	Meters
A	9, 17a
B	4*, 12, 13
C	6, 7*, 15

*Standard deviation < 1

Groundwater seepage contribution to water budget

Groundwater seepage contribution to the total water inputs during the months of June through November was approximately 5 percent (Table 11). Gauged tributary contributed the most incoming water, followed by ungauged subwatershed runoff, and precipitation respectively (Figure 14).

Table 11: Mendums Pond Hydrologic Inputs June 2007 - November 2007

Mendums Hydroligic Inputs
June 2007 - November 2007
Units are water volume in 1000 cubic meters (10^3 m^3)

	June	July	August	September	October	November
Gauged Watersheds						
men01T Wood Road Brook	51.2	74.6	28.7	87.9	1.1	37.3
men02T Perkins Brook	113.3	248.3	110.9	112.1	140.3	180.1
men03T McDaniel Brook	78	88.3	44.7	55.4	44.2	20.7
men04T Golden Brook	10.9	0	0	2.3	8.1	10.3
men05T Howe I Brook	3.8	4.9	3.4	5.2	77	129.4
men06T Howe II Brook	3	1.6	0.9	0.1	1.4	2.4
men07T Powerline Brook	6.9	0.9	0	0	1.3	4.1
men08T Little Powerline Brook	5.7	1.3	0	0	1.1	1.6
men09T Bridge Brook	9	2.1	1	1	1.1	9.7
men10T Little Bridge Brook	4.8	1.5	0	0	0	7.8
men16T Storm Brook	12.4	2.3	0.2	0	0.1	13.5
men17T Seasonal Brook	13.3	6	0	0	0	6.1
Total Streams	312.3	431.8	189.8	264	275.7	423
Ungauged (Direct Runoff)	79	101.6	46.1	72	219.6	172.3
Mendums	89.1	114.7	52	81.3	123.6	97
Littoral Zone Estimate	24.6	28.6	20.9	26.7	29.9	26.2
Non-littoral Estimate	0.6	0.7	0.5	0.7	0.7	0.6
Total Groundwater	25.2	29.3	21.4	27.4	30.6	26.8
Total Inputs	505.6	677.4	309.3	444.7	649.5	719.1

Figure 14: Water Inputs to Mendums Pond

June 2007 – November 2007

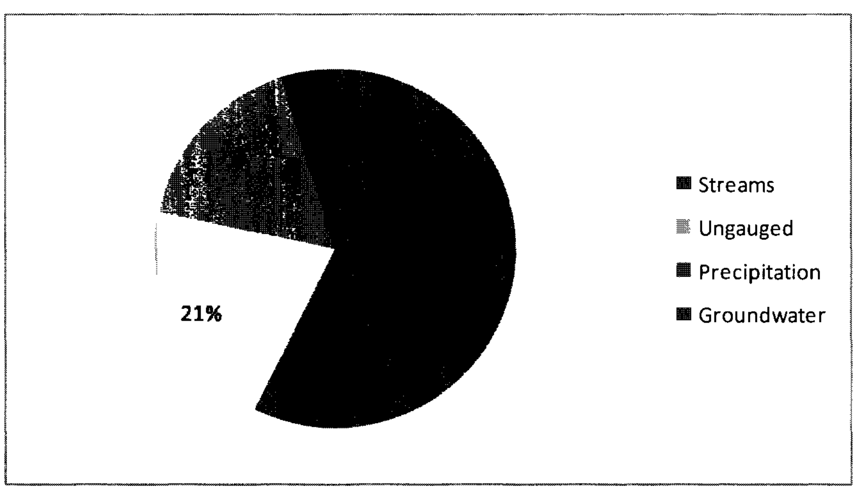


Table 12: Water Inputs to Mendums Pond June 2007 - November 2007

Sources	Vol (10^3 m^3)
Streams	1896.7
Ungauged	690.7
Precipitation	557.7
Groundwater	160.8
Total	3305.9

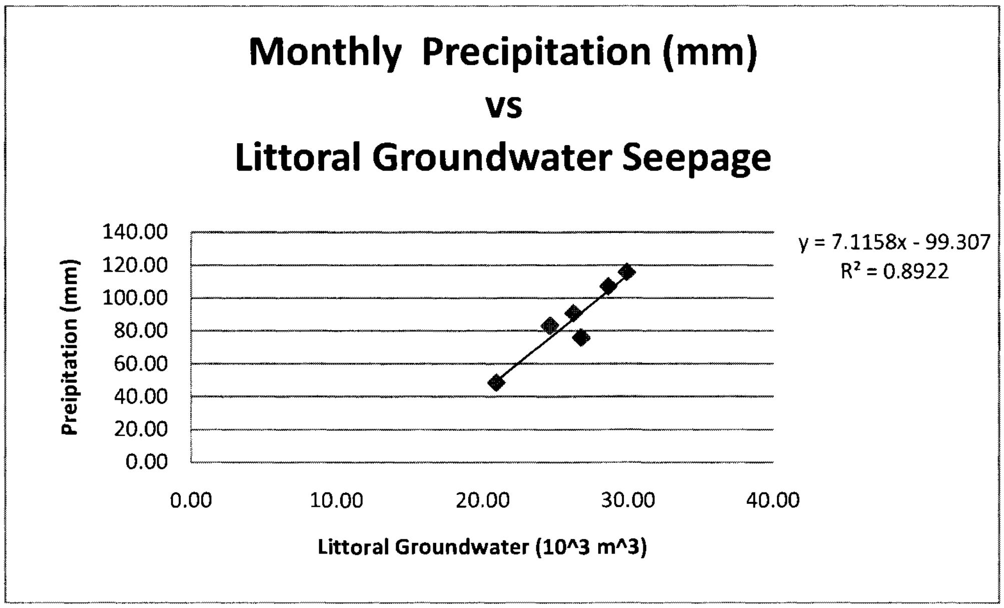
Overall, the littoral groundwater seepage was greatest during the months of July and October, with the smallest contribution occurring in August. October and July respectively had the greatest rain fall during the field season (Table 12).

Table 13: Littoral Groundwater Contribution and Monthly Precipitation for June 2007 - November 2007

Month	Littoral Groundwater (10^3 m^3)	Monthly Precipitation (mm)
June	24.6	83.2
July	28.6	107.1
August	20.9	48.6
September	26.7	75.9
October	29.9	115.7
November	26.2	90.8

There was a strong positive correlation ($r^2 = 0.892$) between littoral groundwater seepage and monthly precipitation (Figure 15).

Figure 15: Monthly Precipitation (mm) vs. Littoral Groundwater Seepage June 2007- November 2007



Pore-water Chemistry Data

Pore-water samples were collected four times during the field season. There were differences in pore-water chemistry between the sites. In particular, Chloride, Sulfate and Sodium were statistically different in areas that had development in the upland ($p \leq 0.05$). The highest chloride concentration (33 mg/L) was found at site 2 along Mendums Landing (Table 14). The lowest chloride concentration (4.14 mg/L) was found at site 5 along the Eastern Shore, just beyond where the UNH Recreational area ends and where there is minimal shoreline development. Sulfate concentrations were also elevated in areas with development as the values ranged from 0.9 mg/L to 2.55 mg/L, whereas the levels in non-developed areas ranged from 0.56 mg/L to 1.15 mg/L (Table 8). The other anions and cations analyzed for did not have any noticeable patterns of difference.

Table 14: Average Pore-water Chemistry Data

Average Pore-water chemistry

Site	Classification	Cl*	NO3**	SO4*	Na*	K	Mg	Ca	NPOC	TDN	PO4	NH4
		(mg Cl/L)	(mg N/L)	(mg S/L	(mg Na/L)	(mg K/L)	(mg Mg/L)	(mg Ca/L)	(mg C/L)	(mg N/L)	(ug P/L)	(ug N/L)
2	d	33.04	0.03	1.83	5.78	0.51	0.25	2.28	3.74	0.27	2.5	49.69
8	d	7.08	0.04	2.55	6.54	1.07	0.35	2.66	2.9	0.24	2.5	53.21
9	d	6.27	0.1	2.74	6.49	1.01	0.3	2.7	2.88	0.35	2.5	123.56
10	d	8.26	0.04	1.43	7.47	0.71	0.21	2.41	10.38	0.71	0	245.33
13	d	5.1	0.01	1.58	5.54	0.47	0.13	1.84	3.33	0.17	2.5	26.4
15	d	8.61	0	1.71	9.25	0.92	0.5	3.79	4.72	0.28	6.28	140.75
16	d	5.27	0.06	0.9	4.65	0.5	0.23	2.35	2.95	0.21	2.5	60.37
17a	d	5.25	0.03	1.65	4.90	0.49	0.32	2.58	3.28	0.18	2.50	27.26
17	d	5.27	0.06	0.9	4.65	0.5	0.23	2.35	2.95	0.21	2.5	60.37
4	n	5.34	0.03	1.02	4.64	0.47	0.19	1.98	3.23	0.21	2.5	31.49
5	n	4.14	0	0.56	4.02	0.47	0.24	2.3	6.35	0.39	7.97	135.27
6	n	4.65	0.01	0.94	3.88	0.41	0.2	1.88	3.35	0.19	2.5	50.93
7	n	6	0.05	0.96	5.4	0.5	0.17	1.91	3.19	0.21	7.77	82.19
11	n	4.33	0.13	1	3.89	0.49	0.16	2.06	2.44	0.31	2.5	66.79
12	n	4.68	0.02	1.09	3.93	0.44	0.17	1.96	3.45	0.18	2.5	18.38
14	n	5.35	0.01	1.15	4.82	0.52	0.2	2.03	3.72	0.19	3.53	38.15
18	n	4.82	0	1.07	4.01	0.52	0.19	2.29	3.63	0.21	2.5	59.66

* Significant difference between developed and non-developed sites

** Significant difference with slope classification not with development

In addition to anion and cation sampling, total phosphorus analysis was also done on pore-water and grab samples from near each seepage meter. Except for meter 6, 11, and 13, pore-water total phosphorus values were higher than the surface grab water sample. In developed areas the Total Phosphorus pore-water values ranged from 5.79 ppb to 11.40 ppb. Non-developed had a range of total Phosphorus values of 4.85 ppb to 17.25 (meter 14) (Table 14). Grab samples from developed areas ranged from 6.10 ppb to 8.90 ppb, and non-developed areas ranged from 5.74 to 7.88 ppb.

Table 15: Summary Table of Average TP Pore-water (PW) and Average Grab Samples (GS).

Site	Classification	Average PW TP	Average GS TP
2	d	6.38	6.10
8	d	11.34	8.90
9	d	9.95	6.94
10	d	18.73	6.10
13	d	5.79	7.32
15	d	11.40	8.50
16	d	10.70	6.61
17	d	7.91	6.59
17a	d	10.09	7.56
4	n	9.88	7.18
5	n	10.70	7.17
6	n	5.36	6.03
7	n	6.01	5.74
11	n	4.85	7.49
12	n	9.16	7.39
14	n	17.25	6.59
18	n	10.38	7.88

Groundwater seepage contribution to nutrient budget

Phosphorus contribution from septic systems was estimated incorporating data collected by Jen Drociak in 2005 regarding the age and kinds of septic system in homes around Mendums Pond. The data was collected for the purpose of compiling information to complete the Comprehensive Lake Inventory for Mendums Pond as part of her class project for the UNH course Interdisciplinary Lake Management. She sent out surveys to all home owners around Mendums Pond, 41 of 56 families responded. Loading from septic systems was calculated as:

$$\text{Phosphorus Loading} = \sum (Kp_i * (1 - Sr_i) * y_i * n_i)$$

$\mathbf{Kp_i}$ = Phosphorus Loading per person for house *i* (set to 1.2, 1.3, 1.4 kg/person/year depending on no, either or both dishwasher and washing machine respectively

$\mathbf{Sr_i}$ = Soil Retention capacity of leach field and soils for house *i* (Set to 0.80, 0.65, or 0.50 if house was<10 years old, 10-25 years old, or >25 years old respectively)

$\mathbf{Y_i}$ = Fraction of year family is in house *i* resides

$\mathbf{N_i}$ = number of family members in house *i*

It was estimated that 24.42 kg of total phosphorus was contributed to Mendums pond from septic systems during the study period June through November 2007. The septic contribution was distributed monthly based on when the home owners were using their cabin (Table 16).

Table 16: Septic Load Distribution of Total Phosphorus Loading (modified from Schloss et al. (2009))

Mendums Pond Septic P Loading June 2007 - November 2007							
	June	**July**	**August**	**September**	**October**	**November**	
Year Round	1.62	1.62	1.62	1.62	1.62	1.62	
7 months	0.22	0.22	0.22	0.22	0.22	0.22	
6 months	0.38	0.38	0.38	0.38	0.36	0.36	
4 months	0.08	0.08	0.08	0.08	0.00	0.00	
3 months	0.55	0.55	0.55	0.00	0.00	0.00	
2 months	0.00	0.41	0.41	0.00	0.00	0.00	
1 month	0.00	0.16	0.07	0.00	0.00	0.00	**Grand**
no survey	1.36	1.36	1.36	1.36	1.36	1.36	**Total**
Total	4.20	4.77	4.68	3.65	3.56	3.56	24.42

Assimilation values used 1-10 year old system 0.80
>10 year old system 0.65
> 25 year old system 0.50

However, from actual pore-water samples analyzed from near the seepage meters in the vicinity of homes or cabins there was usually only a small amount of total phosphorus detected as entering the pond. The pore-water samples had total phosphorus values ranging from below detectable limits (2ppb) to 59 ppb (Appendix B). The orthophosphate values ranged from below detectable limit (2ppb) to 18.9 µg/L (Appendix C). In June, a few pore-water samples were acidified prior to being filtered, those samples had very high Total Phosphorus values ranging from 74 ppb to 572.2 (Appendix B).

The groundwater contribution to the overall total phosphorus input to the pond was approximately 20 % if including the septic and littoral pore-water total phosphorus data (Table 17 & 18, Figure15). The pore-water data collected contributed about 2 % to the Total Phosphorus input (Table 17).

Table 17: Mendums Pond Phosphorus Inputs June 2007 - November 2007

Mendums Pond Total Phosphours Input June 2007 - November 2007 (Kg Tp)						
Site	June	July	August	September	October	November
INPUTS						
men01T Wood Road Brook	0.47	0.69	2.02	3.72	1.28	1.40
men02T Perkins Brook	2.29	5.21	2.77	3.88	3.43	5.74
men03T McDaniel Brook	4.03	5.82	3.17	2.81	6.50	5.72
men04T Golden Brook	0.15	0.00	0.00	0.03	0.21	0.50
men05T Howe I Brook	0.05	0.15	0.18	0.08	0.77	1.11
men06T Howe II Brook	0.04	0.04	0.02	0.00	0.07	0.05
men07T Powerline Brook	0.17	0.03	0.00	0.00	0.18	0.19
men08T Little Powerline Brook	0.09	0.01	0.00	0.00	0.38	0.43
men09T Bridge Brook	0.32	0.05	0.02	0.02	1.54	1.64
men10T Little Bridge Brook	0.12	0.03	0.00	0.00	0.51	0.41
men16T Storm Brook	0.10	0.02	0.00	0.00	0.06	0.07
men17T Seasonal Brook	0.06	0.03	0.00	0.00	0.11	0.13
Total	7.89	12.08	8.18	10.54	15.04	17.39
UG1 - UG 8	2.83	3.64	1.65	2.58	6.66	5.76
Groundwater (porewater)	0.29	0.67	0.39	0.13	0.23	0.67
Septic Systems	4.2	4.77	4.68	3.65	3.56	3.57
Total Groundwater	4.49	5.44	5.07	3.78	3.79	4.24
From Precipitation/Dryfall	4.76	0.9	1.18	1.19	4.12	3.12
Total Input Phosphorus	19.97	22.06	16.08	18.09	29.61	30.51

October and November 2007 data based on 2006 TP budget Schloss et al. (2009)

Figure 16: Total Phosphorus (Kg) Inputs to Mendums Pond June 2007 - November 2007

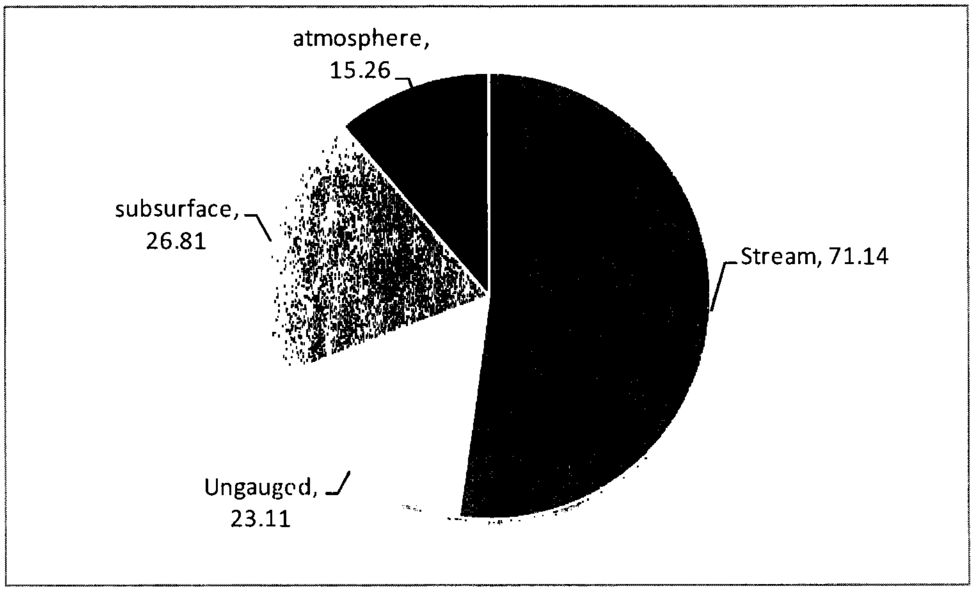


Table 18: Total Phosphorus Input (kg)

Sources	Kg TP	%
Stream	71.14	52.19
Subsurface	26.81	19.67
Ungauged	23.11	16.95
Atmosphere	15.26	11.19
Total	136.31	100.00

CHAPTER VI

DISCUSSION

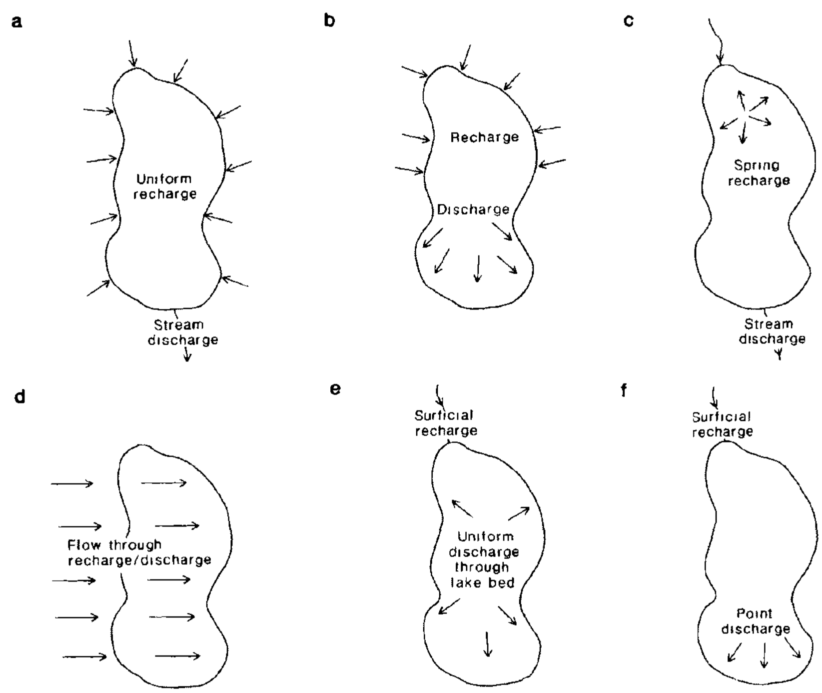
Groundwater Seepage and Precipitation

Groundwater seepage rates around the pond varied in space and time (Appendix A). Lag time between precipitation events and increased seepage rates was not specifically documented. Between one and three days after a rain event, there was no noticeable increase in seepage. It was however, often observed in areas with steep slopes within a week of the event. The average seepage over the course of a month was positively correlated with rainfall ($r^2 = 0.892$), as shown in Figure 14. This suggests that increased precipitation results in increased groundwater seepage contributions to Mendums Pond. The increased seepage in relation to precipitation may be the result of changing the level of the groundwater table as the precipitation infiltrates through the soil. Peterka (1978), observed a similar result in a study of groundwater seepage at Lake Metigoshe in North Dakota and Mantoba. Similar to Mendums, groundwater contribution to Lake Metigoshe was found to be 2% of the total inputs for the water budget. They observed high groundwater seepage rates in June which was attributed to a higher water table caused by the melting snow from the winter. During the rest of their study, seepage rates increased when precipitation occurred.

The variation in seepage rates measured at a particular seepage meter throughout a single day could have been caused by natural variation or a combination of human error. There were five potential opportunities for error when setting up each seepage meter to detect seepage. The bag attached to the seepage meter was initially filled using a graduated cylinder and a small funnel with 450 or 500ml of water. Once the water was in the bag the excess air in the bag was expelled by carefully compressing the bag until there were no air bubbles left. Leaving air in the bag potentially changes the hydraulic head of the bag and prevents accurate measurement of seepage rates. If during the expulsion of air, water was lost through the quick disconnect this would add to measurement error. Connecting the bag to the meter required placing the male connector into the tubing from the meter and then connecting the female connector. During this process no water should have been lost, however there were a few cases, where there was air trapped in the lower tube, such that when the bag was connected a few air bubbles filled the bag. Bags were left connected as long as they did not float on the surface. The final opportunity for measurement error occurred when disconnecting and measuring the final volume in the bag. The bag was empted into a graduated cylinder and recorded. Considering the small changes (0-50ml) in volume observed at sites that bordered flat to moderate sloped shorelands, it cannot be said with certainty that water seeped in or out at these sites. There is the potential that these meters were located in areas where groundwater was not seeping in or out of the lake. The larger changes in volume (> ±100ml) measured during the sampling interval are more likely reflecting groundwater seepage (+) or recharge (-). However, given the littoral groundwater estimate of this study is comparable to other lakes within and outside New Hampshire the results seem reasonable.

Groundwater seepage to Mendums Pond based on observations of the gathered seepage data showed statistically that seepage is related to upland slope. Approximately 3 percent of the water entering the pond occurs through direct groundwater seepage to the pond. Understanding where the water is likely to seep into the pond, should be of concern for protecting the quality of the water in Mendums and further down within the watershed. Boyle (1994) examined patterns of groundwater movement into and out of a lake body (Figure 17).

Figure17: Figure 1. Classification of lake environments into six main classes based on types and relative influences of surface and groundwater movement. Recharge and discharge are used here to denote surface and groundwater movement into and out of the lake body from Boyle 1994



Groundwater movement through Mendums Pond is likely a mix of classifications above of b, c and f. Where groundwater is mainly seeping in along the majority of the perimeter of the pond and water is recharging in the southern area of Mendums Pond most likely occurring near the dam outlet and providing water to the wetland complex below the dam.

The major streams entering Mendums in the Northern section: Perkins, McDaniel, and Golden all had measured water contributions greater than would have been estimated using Knox and Nordsons runoff and their respective sub-watershed areas. The exceeding amount of water in these streams is likely the influence of groundwater base flows into the streams. Perkins, McDaniel, and Golden brook also have wetland complexes in their sub-watershed areas which are likely to aid in groundwater base flow and post storm additions to these streams.

Groundwater Nutrient Concentration and Land-use

Chloride

The nutrient summary data of groundwater (pore-water) from the different monitored seepage sites revealed differences between developed and non-developed areas. Chloride and sodium had higher concentrations in areas where there was development. Since the average concentration of chloride and sodium are almost a 1:1 relationship, this is likely caused from contamination from road salt, septic tanks, and or water softener system discharge.

When snow melts in the spring, road runoff carries with it dissolved chloride and sodium ions to the stream, which are transported downstream. The chloride ions that do not reach the stream and are able to infiltrate into the ground are not used by biological processes and are transported via shallow groundwater to the pond. Storm Brook had the highest surface water concentration of chloride at 55.55mg Cl^-/L. The pore-water having the highest concentration occurred on

Alwood Drive at site 15, with a value of 11.89 mg Cl^-/L. Sites 10, 8 and 9, along Mendums landing also had high concentrations, with the greatest ranging from 9.31 mg Cl^-/L to 8.14 mg Cl^-/L. Sites where the upland is not inhabited by people or roads have lower values ranging from 2.72 to 4.00 mg Cl^-/L (Appendix B).

Within a 250 foot buffer of Mendums Pond, 15.5 percent of the area is considered impervious (Table 3; using the equation and coefficients from the Comprehensive Lake Inventory published by New Hampshire Department of Environmental Services). The main contributor of imperviousness is caused by the roads within the 76.2 m buffer (250 foot) of Mendums Pond (Table 3). Compared with other impervious contributing surfaces, roads are ranked as the highest contributors to imperviousness. Impervious surfaces prevent water from being able to infiltrate the soil and direct it towards other drainage areas. Limiting development within the 250 foot buffer of the Pond will help prevent a further increase in percent imperviousness. The percent impervious impacts shallow groundwater and stream water chemistry. With increased storm frequencies and precipitation quantities volumes chloride and other anion/cations in the soils could be transported to the pond.

Sulfate

Pore-water samples from areas with developed upland also had higher levels of sulfate compared with non-developed sites. This may be related to impervious surfaces in developed areas, as the water has less opportunity to infiltrate into the ground. Instead the water flows over the surface and in some locations is directed near to the pond. Infiltrating of runoff into the groundwater closer to the pond facilitates the movement of sulfate to the pond faster than if the precipitation had been able to infiltrate into the ground further up in the watershed. The major natural source of sulfate comes from precipitation. Unlike nitrate, sulfate is less reactive and is more likely to travel through the soil and into the pond.

Nitrate

The nitrate response to slope steepness may be caused by reduced retention time in the soils located in those areas. Reducing the amount of time the water spends in the soils reduces the chance for the nitrate to experience assimilation by plants or denitrification. In order for nitrate to be reduced it needs to be in contact with heterotrophic bacteria and or anaerobic soils. Saturated soil conditions provide anaerobic conditions for the reduction of nitrate necessary for denitrification. Unsaturated soils have oxygen trapped between the particles of soil. With the available oxygen in these soils, it is unlikely the nitrate will be reduced to nitrogen or nitrous oxide (Naimen et al, 2005). The quality and quantity of organic matter and soil microbes in the soil also plays a role in nitrogen retention and denitrification (Bohlen et al. 2001). Thus, the steeply sloped areas around Mendums Pond may not provide the advantageous soil characteristics necessary for denitrification. This may be part of the reason why the nitrate concentration increased as upland slope increased.

The lack of response of pore-water nitrate concentrations with development suggests that there is good land stewardship occurring near where the seepage meters were located. Nitrates occurring in groundwater can be elevated by anthropogenic means via over use of fertilizers and failed/failing septic systems. With the pore water nitrate levels not correlating to development during this study, it may be that the septic systems set backs are sufficient to prevent elevated nitrate to the groundwater. Or it may also be locations of the seepage meters were not located near enough to those septic system leach fields. Another reality is that the soils and plants may be sequestering nitrate before it makes it to the pond, however, this ability to prevent nitrate from migrating to the pond will not last forever. Once the soil becomes saturated, it will no longer be able to hold back the nitrate and potentially other nutrients. The areas where development is present around the Pond is in areas with less steepness, as compared with the meters where elevated nitrate levels were found, so the observation of nitrate not responding to development may actually be showing that there are lower levels of nitrate in areas with less slope, as most development can only occur in areas not characterized as having steep slopes.

Phosphorus

Groundwater contributed approximately five percent of the inflowing water to Mendums Pond. The phosphorus concentration in the pore-water samples ranged from: 2.5 μg/L to 18.9 μg/L (detection limit 2.5 μg/L). The overall average of phosphate in the pore-water samples was 3.6 μg/L. This value was applied to the monthly seepage rates to determine an estimate of groundwater contribution of phosphorus to Mendums Pond. Subsurface groundwater (septic and pore-water data) contributed twenty percent of the phosphorus entering the pond (Figure 15). It appears that the soil and vegetation surrounding Mendums Pond are assimilating a large amount of the phosphorus that is being given off from septic systems, as the phosphorus concentration of pore-water samples near areas with development were not statistically different from areas with no development. Another possible reason why the pore-water samples may not have revealed higher concentrations of phosphorus was the sediment had been filtered prior to analysis, so any phosphorus bound to the sediment would not have been observed in the samples.

A few of the pore-water samples that were collected were acidified prior to being filtered. The highest total phosphorus value of these samples was 555 μg/L. Acidification releases sediment bound phosphorus. Considering the groundwater contribution to the water and phosphorus budget it appears the sediments are acting more as a sink than a source of phosphorus. There was no statistically significant relationship found between phosphorus concentration with land-cover or slope. Even in areas where the upland was developed the phosphorus values in the pore-water samples were not elevated (Appendix B). The meters may have been too far from the septic leach fields to notice their actual phosphorus contribution to the Pond. However, the soils will not be an infinite sink for phosphorus. Once the soil becomes saturated with phosphorus, the groundwater will start to be a greater contributor of phosphorus to Mendums Pond. Such has been observed on Swains Lake, just a few miles north of Mendums Pond. The watershed of Swains Lake has much more development than Mendums in part this has impacted the water quality of Swains Lake. Over the last several years, Swains Lake has had issues with cyano bacteria and excess algal growth. It would appear that this water body may be reflecting the impact of higher phosphorus levels.

Sediments are able to act as a sink for phosphorus under certain conditions. Patrick et.al (1974) explored the impact aerobic and anaerobic conditions had on soils ability to sequester phosphorus. There appears from the literature, that iron is in part responsible for whether phosphorus is released or absorbed. Under anaerobic conditions, Fe (II) is the predominate iron species which is soluble in water, in aerobic conditions Fe (III) is predominate and less soluble. Iron (III) is able to absorb phosphate, and since this form is less soluble, the phosphorus becomes bound up in the sediments of the lake (Stumm and Morgan, 1996).

Interactions of nutrient transfer at the interface between the sediment and lake water changes throughout the year. Seasonal circulation and stratification of lake water creates changing chemistry status. During the summer and late winter it is possible for bottom waters to become oxygen deprived, leading to anaerobic conditions and the release of nutrients from the sediments. Spring turn-over cycles the bottom water and replaces it with more oxygenated waters, allowing for nutrient sequestration in the sediments. The nutrients released from the sediments are able to be used by aquatic vegetation. At the end of the vegetations life, the material that settles back down to the lake bottom and can undergo decomposition (Thibodeaux, 1996).

Schloss et al. (2009) estimated the sediments of Mendums Pond are acting as a major sink for phosphorus. If Mendums Pond water quality deteriorated to a point that would chemically facilitate the release of phosphorus from the sediments, the pond would be in danger of experiencing eutrophication. A change in oxygen levels within the pond causing it to experience anoxic conditions would cause a release of phosphorus into the Pond and likely cause greater export of phosphorus through the Lamprey River watershed.

CHAPTER VII

CONCLUSION

From a management perspective, applying the precautionary principle would help protect the biological integrity of Mendums Pond. Fortunately, Mendums Pond has remained less developed than other lakes and ponds in Southern New Hampshire which has helped to protect its water quality (Howarth et al. 2000, Barrios 2000). Schloss et al. (2009) compared 2007 data with that of the 1992 DES diagnostic study (Connor et al. 1992), to see if there had been a change in areal phosphorus loading based upon changes to the land-use surrounding incoming streams. In particular the following streams experienced an increase in their areal phosphorus loading to Mendums: Wood Rd Brook, Golden, McDaniel, Seasonal, Storm, Howe I and Little Bridge Brook. Other streams where Connor et al. (1992) had mentioned concerns about runoff have had a decrease in phosphorus areal loading, such as in at Bridge and Little Bridge Brook (Schloss et al. 2009). Action taken on the UNH Recreational area has helped reduce the areal phosphorus loading and has thereby protected the water quality of Mendums Pond. Barrington should continue to consider how to best plan development, such that the streams and groundwater entering Mendums Pond do not become compromised and lead to cultural eutrophication. In particular, areas characterized by steep slopes should be protected from development, as these areas are already a natural source of increased nitrate to the Pond.

Increased development especially within the 76.2 meter buffer area of Mendums would equate to increased surface and subsurface nutrient loading.

It will be important for people living near the Pond and within the watershed to consider how they can help prevent further negative impact to Mendums Pond water quality. Groundwater may be contributing a small percentage of the total water entering the pond, however, it is estimated to be contributing 20% of the Total Phosphorus input. The major source of groundwater total phosphorus is estimated to be coming from septic systems. Residents who live within the 76.2 meter buffer should especially see that their septic systems are kept in good condition and consider how they can help reduce their nutrient input to the pond through stewardship of their properties in a way that prevents runoff and leaching to the pond or groundwater respectively.

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Appendix A: Raw Seepage Data

Summary Raw Seepage Data Field Season 2007
(F-NM --- Field not measured)

Date	Seepage Meter ID	Initial Vol (ml)	Final Vol (ml)	Fraction of day	Seepage rate L/M2/day
6/14/2007	10	500	550	0.18	1.152
6/14/2007	2	500	470	0.17	-0.705
6/14/2007	8	400	500	0.17	2.418
6/14/2007	9	400	470	0.17	1.692
6/14/2007	7	500	520	0.16	0.741
6/14/2007	6	500	640	0.16	5.342
6/14/2007	4	500	520	0.16	0.511
6/14/2007	5	500	520	0.15	0.544
6/14/2007	14	500	450	0.15	-1.386
6/14/2007	16	500	530	0.15	0.839
6/14/2007	12	500	240	0.14	-7.753
6/14/2007	17a	500	510	0.13	0.452
6/14/2007	13	500	560	0.13	2.714
6/14/2007	17	500	545	0.13	1.370
6/14/2007	18	500	680	0.13	5.507
6/14/2007	15	500	760	0.13	8.124
6/22/2007	10	500	510	0.10	0.392
6/22/2007	2	500	530	0.10	1.175
6/22/2007	8	500	430	0.10	-2.741
6/22/2007	9	500	680	0.10	7.003
6/22/2007	7	500	680	0.10	10.601
6/22/2007	6	500	812	0.10	18.376
6/22/2007	4	500	530	0.11	1.152
6/22/2007	5	500	480	0.11	-0.744
6/22/2007	14	500	400	0.11	-3.718
6/22/2007	16	500	F-NM	F-NM	F-NM
6/22/2007	11	500	500	0.11	0.000
6/22/2007	12	500	370	0.10	-5.126
6/22/2007	17a	500	480	0.10	-1.202
6/22/2007	13	500	540	0.10	2.455
6/22/2007	17	500	495	0.10	-0.208
6/22/2007	18	500	550	0.10	2.113
6/22/2007	15	500	490	0.10	-0.426
6/29/2007	10	500	485	0.15	-0.414
6/29/2007	2	500	515	0.15	0.420
6/29/2007	8	500	610	0.14	3.183
6/29/2007	9	500	615	0.15	3.202
6/29/2007	7	500	475	0.14	-1.075
6/29/2007	6	500	800	0.14	13.164
6/29/2007	4	500	475	0.14	-0.749
6/29/2007	5	500	560	0.13	1.826
6/29/2007	14	500	525	0.13	0.761

Date	Seepage Meter ID	Initial Vol (ml)	Final Vol (ml)	Fraction Of Day	Seepage Rate L/M2/day
6/29/2007	16	500	F-NM	F-NM	F-NM
6/29/2007	11	500	655	0.13	4.976
6/29/2007	12	500	630	0.13	4.196
6/29/2007	17a	500	240	0.13	-12.606
6/29/2007	13	500	595	0.12	4.657
6/29/2007	17	500	505	0.12	0.167
6/29/2007	18	500	480	0.12	-0.671
6/29/2007	15	500	575	0.12	2.532
7/10/2007	10	500	490	0.13	-0.314
7/10/2007	2	500	490	0.14	-0.282
7/10/2007	8	500	580	0.14	2.315
7/10/2007	9	500	630	0.14	3.781
7/10/2007	7	500	650	0.15	6.151
7/10/2007	6	500	695	0.14	8.227
7/10/2007	4	500	665	0.15	4.406
7/10/2007	5	500	495	0.16	-0.131
7/10/2007	14	500	525	0.17	0.607
7/10/2007	16	500	555	0.17	1.330
7/10/2007	11	500	540	0.16	1.004
7/10/2007	12	500	738	0.16	5.924
7/10/2007	17a	500	525	0.16	0.934
7/10/2007	13	500	645	0.16	5.415
7/10/2007	17	500	505	0.16	0.126
7/10/2007	18	500	525	0.16	0.636
7/10/2007	15	500	745	0.16	6.125
7/13/2007	10	500	595	0.25	1.577
7/13/2007	2	500	555	0.23	0.994
7/13/2007	8	500	490	0.22	-0.188
7/13/2007	9	500	530	0.21	0.574
7/13/2007	7	500	705	0.21	6.057
7/13/2007	6	500	530	0.20	0.924
7/13/2007	4	500	455	0.18	-1.013
7/13/2007	5	500	485	0.17	-0.355
7/13/2007	14	500	545	0.16	1.130
7/13/2007	16	500	585	0.13	2.670
7/13/2007	11	500	580	0.14	2.327
7/13/2007	12	500	705	0.14	5.875
7/13/2007	17a	500	495	0.14	-0.215
7/13/2007	13	500	560	0.14	2.607
7/13/2007	17	500	530	0.10	1.232
7/13/2007	18	500	530	0.12	1.001
7/13/2007	15	500	490	0.09	-0.438
7/26/2007	10	500	490	0.15	-0.265
7/26/2007	2	500	505	0.15	0.137
7/26/2007	8	490	480	0.15	-0.280
7/26/2007	9	500	610	0.15	3.092

Date	Seepage Meter ID	Initial Vol (ml)	Final Vol (ml)	Fraction Of Day	Seepage Rate L/m2/day
7/26/2007	7	510	600	0.14	3.969
7/26/2007	6	500	540	0.13	1.819
7/26/2007	4	500	490	0.13	-0.304
7/26/2007	5	500	500	0.13	0.000
7/26/2007	14	510	505	0.13	-0.155
7/26/2007	16	500	535	0.13	1.077
7/26/2007	11	500	690	0.13	5.969
7/26/2007	12	500	490	0.13	-0.321
7/26/2007	17a	500	500	0.13	0.000
7/26/2007	13	510	560	0.13	2.398
7/26/2007	17	500	555	0.12	1.805
7/26/2007	18	500	510	0.12	0.340
7/26/2007	15	510	525	0.09	0.668
8/3/2007	10	495	610	0.26	1.821
8/3/2007	2	500	585	0.25	1.415
8/3/2007	8	480	490	0.23	0.174
8/3/2007	9	505	625	0.23	2.123
8/3/2007	7	495	700	0.22	5.675
8/3/2007	6	495	625	0.21	3.790
8/3/2007	4	490	525	0.20	0.719
8/3/2007	5	475	475	0.17	0.000
8/3/2007	14	490	460	0.17	-0.740
8/3/2007	16	500	510	0.16	0.255
8/3/2007	11	495	515	0.15	0.532
8/3/2007	12	490	525	0.15	0.961
8/3/2007	17a	485	345	0.14	-6.052
8/3/2007	13	495	520	0.13	1.143
8/3/2007	17	480	500	0.13	0.646
8/3/2007	18	480	500	0.12	0.671
8/3/2007	15	490	670	0.12	6.220
8/9/2007	10	500	545	0.22	0.834
8/9/2007	2	500	500	0.22	0.000
8/9/2007	8	500	610	0.20	2.205
8/9/2007	9	500	650	0.20	2.987
8/9/2007	7	500	540	0.19	1.263
8/9/2007	6	500	600	0.19	3.250
8/9/2007	4	500	540	0.18	0.887
8/9/2007	5	500	490	0.18	-0.224
8/9/2007	14	500	485	0.18	-0.342
8/9/2007	16	500	630	0.18	3.007
8/9/2007	11	500	500	0.17	0.000
8/9/2007	12	500	505	0.17	0.123
8/9/2007	17a	500	495	0.16	-0.187
8/9/2007	13	500	540	0.16	1.540
8/9/2007	17	500	510	0.15	0.266
8/9/2007	18	500	500	0.15	0.000
8/9/2007	15	500	485	0.15	-0.397

Date	Seepage Meter ID	Initial Vol (ml)	Final Vol (ml)	Fraction Of Day	Seepage Rate L/m2/day
8/16/2007	10	490	640	0.21	2.977
8/16/2007	2	500	525	0.20	0.508
8/16/2007	8	500	545	0.19	0.968
8/16/2007	9	500	540	0.19	0.877
8/16/2007	7	500	650	0.18	5.024
8/16/2007	6	500	570	0.18	2.438
8/16/2007	4	490	535	0.17	1.083
8/16/2007	5	500	F-NM	F-NM	F-NM
8/16/2007	14	500	535	0.16	0.871
8/16/2007	16	500	645	0.15	3.820
8/16/2007	11	500	565	0.15	1.810
8/16/2007	12	500	590	0.14	2.617
8/16/2007	17a	500	535	0.14	1.543
8/16/2007	13	500	580	0.13	3.657
8/16/2007	17	500	575	0.13	2.369
8/16/2007	18	500	500	0.12	0.000
8/16/2007	15	500	585	0.12	2.853
8/25/2007	10	500	490	0.20	-0.205
8/25/2007	2	500	530	0.20	0.627
8/25/2007	8	500	505	0.19	0.110
8/25/2007	9	500	565	0.19	1.430
8/25/2007	7	500	650	0.18	5.063
8/25/2007	6	500	555	0.18	1.900
8/25/2007	4	500	540	0.17	0.971
8/25/2007	5	500	F-nm	0.00	F-NM
8/25/2007	14	500	495	0.16	-0.126
8/25/2007	16	500	480	0.16	-0.522
8/25/2007	11	500	650	0.15	3.969
8/25/2007	12	500	535	0.15	0.961
8/25/2007	17a	500	490	0.15	-0.420
8/25/2007	13	500	545	0.14	1.945
8/25/2007	17	500	545	0.14	1.328
8/25/2007	18	500	535	0.13	1.124
8/25/2007	15	500	670	0.13	5.229
9/1/2007	10	490	550	0.22	1.091
9/1/2007	2	490	540	0.22	0.938
9/1/2007	8	490	500	0.21	0.196
9/1/2007	9	500	595	0.21	1.879
9/1/2007	7	520	690	0.20	5.092
9/1/2007	6	500	380	0.19	-3.761
9/1/2007	4	490	555	0.18	1.469
9/1/2007	5	500	495	0.17	-0.121
9/1/2007	14	500	555	0.16	1.381
9/1/2007	16	490	490	0.16	0.000
9/1/2007	11	500	580	0.15	2.146
9/1/2007	12	500	525	0.14	0.720

Date	Seepage Meter ID	Initial Vol (ml)	Final Vol. (ml)	Fraction Of Day	Seepage Rate L/m2/day
9/1/2007	17a	500	560	0.14	2.659
9/1/2007	13	490	545	0.13	2.567
9/1/2007	17	505	520	0.12	0.495
9/1/2007	18	500	555	0.12	1.923
9/1/2007	15	485	495	0.11	0.372
9/16/2007	10	490	740	0.18	5.627
9/16/2007	2	500	555	0.18	1.282
9/16/2007	8	500	490	0.17	-0.246
9/16/2007	9	490	645	0.16	3.858
9/16/2007	7	500	600	0.13	4.547
9/16/2007	6	490	540	0.15	1.985
9/16/2007	4	500	545	0.15	1.253
9/16/2007	5	490	480	0.15	-0.280
9/16/2007	14	500	580	0.14	2.338
9/16/2007	16	490	510	0.13	0.612
9/16/2007	11	510	475	0.13	-1.142
9/16/2007	12	500	535	0.11	1.261
9/16/2007	17a	500	500	0.11	0.000
9/16/2007	13	500	585	0.11	4.521
9/16/2007	17	490	510	0.10	0.858
9/16/2007	18	500	605	0.09	4.709
9/16/2007	15	500	745	0.09	11.514
9/21/2007	10	490	565	0.21	1.449
9/21/2007	2	495	530	0.20	0.707
9/21/2007	8	500	480	0.19	-0.421
9/21/2007	9	490	595	0.19	2.235
9/21/2007	7	495	840	0.18	11.600
9/21/2007	6	500	520	0.17	0.699
9/21/2007	4	500	525	0.17	0.595
9/21/2007	5	495	485	0.16	-0.254
9/21/2007	14	500	510	0.15	0.263
9/21/2007	16	490	535	0.15	1.230
9/21/2007	11	500	495	0.14	-0.142
9/21/2007	12	495	530	0.14	1.033
9/21/2007	17a	490	475	0.13	-0.689
9/21/2007	13	490	515	0.13	1.192
9/21/2007	17	500	460	0.12	-1.399
9/21/2007	18	500	680	0.11	6.448
9/21/2007	15	490	465	0.11	-0.948
10/12/2007	10	490	600	0.15	2.992
10/12/2007	2	510	525	0.14	0.434
10/12/2007	8	490	475	0.14	-0.450
10/12/2007	9	500	560	0.13	1.865
10/12/2007	7	480	450	0.13	-1.455
10/12/2007	6	470	470	0.12	0.000
10/12/2007	4	470	530	0.12	2.098

Date	Seepage Meter ID	Initial Vol. (ml)	Final Vol. (ml)	Fraction Of Day	Seepage Rate L/m2/day
10/12/2007	5	500	500	0.11	0.000
10/12/2007	14	500	505	0.11	0.188
10/12/2007	16	450	450	0.10	0.000
10/12/2007	11	470	600	0.10	5.267
10/12/2007	12	470	520	0.10	2.098
10/12/2007	17a	480	495	0.09	0.975
10/12/2007	13	480	550	0.09	4.725
10/12/2007	17	460	470	0.09	0.463
10/12/2007	18	500	525	0.08	1.214
10/12/2007	15	500	505	0.08	0.251
10/26/07a	10	500	620	0.13	3.770
10/26/07a	2	500	540	0.13	1.270
10/26/07a	8	500	490	0.13	-0.319
10/26/07a	9	500	625	0.13	4.057
10/26/07a	7	500	590	0.13	4.388
10/26/07a	6	500	595	0.12	4.684
10/26/07a	4	500	540	0.12	1.328
10/26/07a	5	500	495	0.12	-0.166
10/26/07a	14	500	540	0.12	1.328
10/26/07a	16	500	490	0.12	-0.340
10/26/07a	11	500	600	0.12	3.357
10/26/07a	12	500	680	0.12	6.042
10/26/07a	17a	500	610	0.12	5.645
10/26/07a	13	500	590	0.12	4.619
10/26/07a	17	500	520	0.12	0.683
10/26/07a	18	F-NM	F-NM	F-NM	F-NM
10/26/07a	15	500	580	0.14	2.362
10/26/07m	10	500	600	0.13	3.246
10/26/07m	2	500	530	0.13	0.968
10/26/07m	8	500	480	0.12	-0.679
10/26/07m	9	500	670	0.13	5.548
10/26/07m	7	500	560	0.12	2.992
10/26/07m	6	500	520	0.12	1.003
10/26/07m	4	500	500	0.12	0.000
10/26/07m	5	500	500	0.12	0.000
10/26/07m	14	500	555	0.12	1.879
10/26/07m	16	500	500	0.12	0.000
10/26/07m	11	500	575	0.12	2.623
10/26/07m	12	500	625	0.11	4.450
10/26/07m	17a	500	420	0.12	-4.179
10/26/07m	13	500	550	0.12	2.612
10/26/07m	17	500	500	0.12	0.000
10/26/07m	18	F-NM	F-NM	F-NM	F-NM
10/26/07m	15	500	615	0.11	4.145
11/12/2007	10	F-NM	F-NM	F-NM	F-NM
11/12/2007	2	480	515	0.22	0.649

Date	Seepage Meter ID	Initial Vol. (ml)	Final Vol. (ml)	Fraction Of Day	Seepage Rate L/m2/day
11/12/2007	8	490	520	0.22	0.567
11/12/2007	9	510	690	0.21	3.456
11/12/2007	7	510	585	0.18	2.531
11/12/2007	6	490	720	0.20	7.183
11/12/2007	4	485	630	0.18	3.276
11/12/2007	5	510	495	0.18	-0.342
11/12/2007	14	505	540	0.17	0.822
11/12/2007	16	490	490	0.17	0.000
11/12/2007	11	500	500	0.13	0.000
11/12/2007	12	500	630	0.15	3.425
11/12/2007	17a	500	520	0.15	0.809
11/12/2007	13	500	510	0.15	0.401
11/12/2007	17	520	575	0.14	1.576
11/12/2007	18	F-NM	F-NM	F-NM	F-NM
11/12/2007	15	500	510	0.14	0.285

Appendix B: Raw Seepage Data, Grab Sample and Pore-water sample Data

Mendums Pond Seepage, Pore-Water and Lake Chemistry					
			Phosphorus		
		Seepage Rate	grab sample	pore water	
Site #	Date	L/m2/day	(ppb)	(ppb)	
2	6/14/2007	-0.705	N/A	N/A	
2	6/22/2007	1.175	N/A	N/A	
2	6/29/2007	0.420	N/A	N/A	
2	7/10/2007	-0.282	N/A	4	
2	7/13/2007	0.994	N/A	572.5	unfiltered
2	7/26/2007	0.137	N/A	N/A	
2	8/3/2007	1.415	5.8	55	
2	8/9/2007	0.000	6.4	5.9	
2	8/16/2007	0.508	N/A	N/A	
2	8/25/2007	0.627	5.4	13.4	
2	9/1/2007	0.938	6.6	2.7	
2	9/16/2007	1.282	8.1	2.3	
2	9/21/2007	0.707	5.0	5.4	
2	10/12/2007	0.434	5.5	7.7	
2	10/26/2007	1.270	N/A	N/A	
2	10/26/2007	0.968	N/A	N/A	
2	11/12/2007	0.649	6.0	9.6	
4	6/14/2007	0.511	N/A	N/A	
4	6/22/2007	1.152	N/A	N/A	
4	6/29/2007	-0.749	N/A	N/A	
4	7/10/2007	4.406	N/A	129.5	
4	7/13/2007	-1.013	N/A	213	
4	7/26/2007	-0.304	N/A	N/A	
4	8/3/2007	0.719	6.2	8.7	
4	8/9/2007	0.887	12.9	24.6	
4	8/16/2007	1.083	N/A	N/A	
4	8/25/2007	0.971	7.4	18.9	
4	9/1/2007	1.469	6.0	6	
4	9/16/2007	1.253	5.5	1.8	
4	9/21/2007	0.595	6.0	3.2	
4	10/12\2007	2.098	4.0	2.8	
4	10/26/2007	1.328	N/A	N/A	
4	10/26/2007	0.000	N/A	N/A	
4	11/12/2007	3.276	9.4	13	
5	6/14/2007	0.544	N/A	N/A	
5	6/22/2007	-0.744	N/A	N/A	
5	6/29/2007	1.826	N/A	N/A	
5	7/10/2007	-0.131	N/A	77.4	
5	7/13/2007	-0.355	N/A	76.2	
5	7/26/2007	0.000	N/A	N/A	
5	8/3/2007	0.000	7.8	18.2	
5	8/9/2007	-0.224	-----	----	

Meter	Date	Seepage	Grab Sample	Pore-Water	
5	8/16/2007	-0.121	N/A	N/A	
5	8/25/2007	-----	6.3	10.3	
5	9/1/2007	-----	7.2	9.9	
5	9/16/2007	-0.280	7.5	9.2	
5	9/21/2007	-0.254	7.0	9.1	
5	10/12\2007	0.000	6.1	12.1	
5	10/26/2007	-0.166	N/A	N/A	
5	10/26/2007	0.000	N/A	N/A	
5	11/12/2007	-0.342	8.3	6.1	
6	6/14/2007	5.342	N/A	N/A	
6	6/22/2007	18.376	N/A	N/A	
6	6/29/2007	13.164	N/A	N/A	
6	7/10/2007	8.227	N/A	148.9	unfiltered
6	7/13/2007	0.924	N/A	216.9	unfiltered
6	7/26/2007	1.819	N/A	N/A	
6	8/3/2007	3.790	6.2	59	
6	8/9/2007	3.250	5.0	3.6	
6	8/16/2007	2.438	N/A	N/A	
6	8/25/2007	1.900	7.3	13.6	
6	9/1/2007	-3.761	4.5	3.3	
6	9/16/2007	1.985	8.2	1.5	
6	9/21/2007	0.699	6.8	6.2	
6	10/12\2007	0.000	4.2	1.7	
6	10/26/2007	4.684	N/A	N/A	
6	10/26/2007	1.003	N/A	N/A	
6	11/12/2007	7.183	6.0	7.6	
7	6/14/2007	0.741	N/A	N/A	
7	6/22/2007	10.601	N/A	N/A	
7	6/29/2007	-1.075	N/A	N/A	
7	7/10/2007	6.151	N/A	76.8	
7	7/13/2007	6.057	N/A	115.3	unfiltered
7	7/26/2007	3.969	N/A	N/A	
7	8/3/2007	5.675		5	
7	8/9/2007	1.263	4.9	4.1	
7	8/16/2007	5.024	N/A	N/A	
7	8/25/2007	5.063	7.3	14.9	
7	9/1/2007	5.092	4.4	4.5	
7	9/16/2007	4.547	5.3	1.6	
7	9/21/2007	11.600	6.5	3.1	
7	10/12\2007	-1.455	5.4	3.1	
7	10/26/2007	4.388	N/A	N/A	
7	10/26/2007	2.992	N/A	N/A	
7	11/12/2007	2.531	6.4	11.8	
8	6/14/2007	2.418	N/A	N/A	
8	6/22/2007	-2.741	N/A	N/A	
8	6/29/2007	3.183	N/A	N/A	
8	7/10/2007	2.315	N/A	116.8	unfiltered

Meter	Date	Seepage	Grab Sample	Pore-Water	
8	7/13/2007	-0.188	N/A	128.2	unfiltered
8	7/26/2007	-0.280	N/A	N/A	
8	8/3/2007	0.174	5.2	23.2	
8	8/9/2007	2.205	7.8	19.2	
8	8/16/2007	0.968	N/A	N/A	
8	8/25/2007	0.110	10.4	13.9	
8	9/1/2007	0.196	5.5	4.5	
8	9/16/2007	-0.246	15.4	2.8	
8	9/21/2007	-0.421	11.9	17.6	
8	10/12\2007	-0.450	4.4	4.2	
8	10/26/2007	-0.319	N/A	N/A	
8	10/26/2007	-0.679	N/A	N/A	
8	11/12/2007	0.567	10.6	5.3	
9	6/14/2007	1.692	N/A	N/A	
9	6/22/2007	7.003	N/A	N/A	
9	6/29/2007	3.202	N/A	N/A	
9	7/10/2007	3.781	N/A	-----	
9	7/13/2007	0.574	N/A	112.3	unfiltered
9	7/26/2007	3.092	N/A	N/A	
9	8/3/2007	2.123	5.2	11	
9	8/9/2007	2.987	7.0	19.7	
9	8/16/2007	0.877	N/A	N/A	
9	8/25/2007	1.430	5.6	22.4	
9	9/1/2007	1.879	5.1	3.9	
9	9/16/2007	3.858	9.2	2.8	
9	9/21/2007	2.235	9.5	6.6	
9	10/12\2007	1.865	4.2	5	
9	10/26/2007	4.057	N/A	N/A	
9	10/26/2007	5.548	N/A	N/A	
9	11/12/2007	3.456	9.7	8.2	
10	6/14/2007	1.152	N/A	N/A	
10	6/22/2007	0.392	N/A	N/A	
10	6/29/2007	-0.414	N/A	N/A	
10	7/10/2007	-0.314	N/A	203.2	unfiltered
10	7/13/2007	1.577	N/A	87.2	unfiltered
10	7/26/2007	-0.265	N/A	N/A	
10	8/3/2007	1.821	7.7	142.1	unfiltered
10	8/9/2007	0.834	6.0	36.6	
10	8/16/2007	2.977	N/A	N/A	
10	8/25/2007	-0.205	8.5	45.6	
10	9/1/2007	1.091	5.6	13	
10	9/16/2007	5.627	5.2	5.8	
10	9/21/2007	1.449	5.2	7.6	
10	10/12\2007	2.992	4.5	3.8	
10	10/26/2007	3.770	N/A	N/A	
10	10/26/2007	3.246	N/A	N/A	
10	11/12/2007	----			

Meter	Date	Seepage	Grab Sample	Pore-Water	
11	6/14/2007	---	N/A	N/A	
11	6/22/2007	0.000	N/A	N/A	
11	6/29/2007	4.976	N/A	N/A	
11	7/10/2007	1.004	N/A	---	
11	7/13/2007	2.327	N/A	116.1	unfiltered
11	7/26/2007	5.969	N/A	N/A	
11	8/3/2007	0.532	9.0	5.4	
11	8/9/2007	0.000	5.6	10.1	
11	8/16/2007	1.810	N/A	N/A	
11	8/25/2007	3.969	7.4	9.5	
11	9/1/2007	2.146	6.4	3.1	
11	9/16/2007	-1.142	13.2	1.8	
11	9/21/2007	-0.142	6.5	1.4	
11	10/12\2007	5.267	4.7	4.6	
11	10/26/2007	3.357	N/A	N/A	
11	10/26/2007	2.623	N/A	N/A	
11	11/12/2007	0.000	7.1	2.9	
12	6/14/2007	-7.753	N/A	N/A	
12	6/22/2007	-5.126	N/A	N/A	
12	6/29/2007	4.196	N/A	N/A	
12	7/10/2007	5.924	N/A	----	
12	7/13/2007	5.875	N/A	133.1	unfiltered
12	7/26/2007	-0.321	N/A	N/A	
12	8/3/2007	0.961	5.6	149.5	unfiltered
12	8/9/2007	0.123	7.6	11.3	
12	8/16/2007	2.617	N/A	N/A	
12	8/25/2007	0.961	6.9	7	
12	9/1/2007	0.720	5.3	5	
12	9/16/2007	1.261	9.1	5	
12	9/21/2007	1.033	6.7	5	
12	10/12\2007	2.098	10.5	3.3	
12	10/26/2007	6.042	N/A	N/A	
12	10/26/2007	4.450	N/A	N/A	
12	11/12/2007	3.425		27.5	
13	6/14/2007	2.714	N/A	N/A	
13	6/22/2007	2.455	N/A	N/A	
13	6/29/2007	4.657	N/A	N/A	
13	7/10/2007	5.415	N/A	----	
13	7/13/2007	2.607	N/A	396.3	unfiltered
13	7/26/2007	2.398	N/A	N/A	
13	8/3/2007	1.143		30.5	
13	8/9/2007	1.540	8.8	3.7	
13	8/16/2007	3.657	N/A	N/A	
13	8/25/2007	1.945	6.5	14.1	
13	9/1/2007	2.567	6.8	3.2	
13	9/16/2007	4.521	7.5	3.1	
13	9/21/2007	1.192		3.5	

Meter	Date	Seepage	Grab Sample	Pore-Water	
13	10/12\2007	4.725	7.5	4.8	
13	10/26/2007	4.619	N/A	N/A	
13	10/26/2007	2.612	N/A	N/A	
13	11/12/2007	0.401	6.8	8.1	
14	6/14/2007	-1.386	N/A	N/A	
14	6/22/2007	-3.718	N/A	N/A	
14	6/29/2007	0.761	N/A	N/A	
14	7/10/2007	0.607	N/A	442	unfiltered
14	7/13/2007	1.130	N/A	104.6	unfiltered
14	7/26/2007	-0.155	N/A	N/A	
14	8/3/2007	-0.740	6.0	25.2	
14	8/9/2007	-0.342	5.9	-----	no sample
14	8/16/2007	0.871	N/A	N/A	
14	8/25/2007	-0.126	5.4	38	
14	9/1/2007	1.381	6.0	3.5	
14	9/16/2007	2.338	7.8	3.7	
14	9/21/2007	0.263	9.7	N/A	
14	10/12\2007	0.188	5.8	19.2	
14	10/26/2007	1.328	N/A	N/A	
14	10/26/2007	1.879	N/A	N/A	
14	11/12/2007	0.822	6.1	13.9	
15	6/14/2007	8.124	N/A	N/A	
15	6/22/2007	-0.426	N/A	N/A	
15	6/29/2007	2.532	N/A	N/A	
15	7/10/2007	6.125	N/A	---	
15	7/13/2007	-0.438	N/A	523.5	unfiltered
15	7/26/2007	0.668	N/A	N/A	
15	8/3/2007	6.220	5.4	7	
15	8/9/2007	-0.397	6.7	7.5	
15	8/16/2007	2.853	N/A	N/A	
15	8/25/2007	5.229	7.9	29.4	
15	9/1/2007	0.372	6.3	9.6	
15	9/16/2007	11.514	16.3	6.4	
15	9/21/2007	-0.948	6.4	8.5	
15	10/12\2007	0.251	6.8	N/A	
15	10/26/2007	2.362	N/A	N/A	
15	10/26/2007	4.145	N/A	N/A	
15	11/12/2007	0.285	12.2	94	
16	6/14/2007	0.839	N/A	N/A	
16	6/22/2007	---	N/A	N/A	
16	6/29/2007	---	N/A	N/A	
16	7/10/2007	1.330	N/A	----	
16	7/13/2007	2.670	N/A	110.9	unfiltered
16	7/26/2007	1.077	N/A	N/A	
16	8/3/2007	0.255		19.7	
16	8/9/2007	3.007	6.6	9.7	
16	8/16/2007	3.820	N/A	N/A	

Meter	Date	Seepage	Grab Sample	Pore-water	
16	8/25/2007	-0.522	9.7	16.4	
16	9/1/2007	0.000	5.6	6.4	
16	9/16/2007	0.612	8.3	3.1	
16	9/21/2007	1.230	5.0	2.6	
16	10/12\2007	0.000	5.0	4.8	
16	10/26/2007	-0.340	N/A	N/A	
16	10/26/2007	0.000	N/A	N/A	
16	11/12/2007	0.000	6.1	22.9	
17	6/14/2007	1.370	N/A	N/A	
17	6/22/2007	-0.208	N/A	N/A	
17	6/29/2007	0.167	N/A	N/A	
17	7/10/2007	0.126	N/A	-----	
17	7/13/2007	1.232	N/A	555.9	unfiltered
17	7/26/2007	1.805	N/A	N/A	
17	8/3/2007	0.646	6.8	8.1	
17	8/9/2007	0.266	7.4	9	
17	8/16/2007	2.369	N/A	N/A	
17	8/25/2007	1.328	6.7	10.6	
17	9/1/2007	0.495	7.7	3.6	
17	9/16/2007	0.858	6.4	1.8	
17	9/21/2007	-1.399	5.6	4.2	
17	10/12\2007	0.463	6.2	2.4	
17	10/26/2007	0.683	N/A	N/A	
17	10/26/2007	0.000	N/A	N/A	
17	11/12/2007	1.576	5.9	23.6	
17a	6/14/2007	0.452	N/A	N/A	
17a	6/22/2007	-1.202	N/A	N/A	
17a	6/29/2007	-12.606	N/A	N/A	
17a	7/10/2007	0.934	N/A	-----	
17a	7/13/2007	-0.215	N/A	172.2	unfiltered
17a	7/26/2007	0.000	N/A	N/A	
17a	8/3/2007	-6.052	8.7	18.9	
17a	8/9/2007	-0.187	9.2	5.7	
17a	8/16/2007	1.543	N/A	N/A	
17a	8/25/2007	-0.420	8.4	27.8	
17a	9/1/2007	2.659	7.5	3.2	
17a	9/16/2007	0.000	6.5	3.9	
17a	9/21/2007	-0.689	7.5	2.7	
17a	10/12\2007	0.975	6.4	5.7	
17a	10/26/2007	5.645	N/A	N/A	
17a	10/26/2007	-4.179	N/A	N/A	
17a	11/12/2007	0.809	6.3	12.8	
18	6/14/2007	5.507	N/A	N/A	
18	6/22/2007	2.113	N/A	N/A	
18	6/29/2007	-0.671	N/A	N/A	
18	7/10/2007	0.636	N/A	217.9	unfiltered
18	7/13/2007	1.001	N/A	946.5	unfiltered

Meter	Date	Seepage	Grab Sample	Pore-Water
18	7/26/2007	0.340	N/A	N/A
18	8/3/2007	0.671		51.8
18	8/9/2007	0.000	9.1	16.8
18	8/16/2007	0.000	N/A	N/A
18	8/25/2007	1.124	13.0	25.5
18	9/1/2007	1.923	6.6	5
18	9/16/2007	4.709	8.3	4.9
18	9/21/2007	6.448	4.8	4.8
18	10/12\2007	1.214	5.5	5.3
18	10/26/2007	----	N/A	N/A*
18	10/26/2007	---	N/A	N/A*
18	11/12/2007	---	N/A	N/A*

*Unable to re-set seepage meter in sediment

Appendix C: Raw Pore-water Anion/Cation Data

Sample Name	Date	Cl (mg Cl/L)	NO3 (mg N/L)	SO4 (mg S/L	Na (mg Na/L)	K (mg K/L)	Mg (mg Mg/L)	Ca (mg Ca/L)	NPOC (mg C/L)	TDN (mg N/L)	PO4 (ug P/L)	NH4 (ug N/L)
Pore Water #2	8/14/2007	87	0	2.89	8.01	0.6	0.43	2.85	4.14	0.28	2.5	96.88
Pore Water #2	9/21/2007	5.11	0	0.95	3.84	0.45	0.26	2.35	4.96	0.22	2.5	2.5
Pore Water #2	10/12/2007	7.01	0.1	1.65	5.5	0.48	0.07	1.64	2.13	0.3	2.5	----
Median		*5.11*	*0*	*0.95*	*3.84*	*0.45*	*0.07*	*1.64*	*2.13*	*0.22*	2.5	2.5
high		*87*	*0.1*	*2.89*	*8.01*	*0.6*	*0.43*	*2.85*	*4.96*	*0.3*	2.5	96.88
average		*33.04*	*0.03*	*1.83*	*5.78*	*0.51*	*0.25*	*2.28*	*3.74*	*0.27*	2.5	49.69
Pore Water #4	8/3/2007	5.88	0.04	1.15	5.16	0.52	0.18	1.86	2.91	0.17	----	----
Pore Water #4	8/14/2007	5.4	0.01	0.73	4.88	0.45	0.1	1.59	3.42	0.2	2.5	----
Pore Water #4	9/21/2007	4.16	0.04	1.05	3.81	0.49	0.29	2.57	2.67	0.19	2.5	----
Pore Water #4	10/12/2007	5.9	0.01	1.13	4.7	0.41	0.2	1.9	3.91	0.26	2.5	31.49
Median		*4.16*	*0.01*	*0.73*	*3.81*	*0.41*	*0.1*	*1.59*	*2.67*	*0.17*	*2.5*	*31.49*
high		*5.9*	*0.04*	*1.15*	*5.16*	*0.52*	*0.29*	*2.57*	*3.91*	*0.26*	*2.5*	*31.49*
average		*5.34*	*0.03*	*1.02*	*4.64*	*0.47*	*0.19*	*1.98*	*3.23*	*0.21*	*2.5*	*31.49*
Pore Water #5	8/14/2007	5.55	0	0.96	4.57	0.48	0.15	1.63	4.42	0.19	2.5	11.29
Pore Water #5	9/21/2007	2.82	0	0.63	3.84	0.47	0.3	3.01	9.54	0.55	2.5	----
Pore Water #5	10/12/2007	4.03	0	0.08	3.64	0.47	0.26	2.27	5.1	0.42	18.92	259.25
Median		*2.82*	*0*	*0.08*	*3.64*	*0.47*	*0.15*	*1.63*	*4.42*	*0.19*	*2.5*	*11.29*
high		*5.55*	*0*	*0.96*	*4.57*	*0.48*	*0.3*	*3.01*	*9.54*	*0.55*	*18.92*	*259.25*
average		*4.14*	*0*	*0.56*	*4.02*	*0.47*	*0.24*	*2.3*	*6.35*	*0.39*	*7.97*	*135.27*
Pore Water #6	7/10/2007	4	0.03	1.2	3.56	0.42	0.28	2.04	2.4	0.16	2.5	34.78
Pore Water #6	8/3/2007	4.2	0	0.61	3.44	0.33	0.12	1.5	3.08	0.21	2.5	83.91
Pore Water #6	8/14/2007	3.49	0	0.9	3.96	0.46	0.25	2.42	3.58	0.24	2.5	85.22
Pore Water #6	9/21/2007	4.86	0.01	0.98	3.62	0.42	0.24	2.11	4.06	0.17	2.5	28.02
Pore Water #6	10/12/2007	6.7	0	0.98	4.84	0.42	0.12	1.33	3.62	0.17	2.5	22.75
Median		*3.49*	*0*	*0.61*	*3.44*	*0.33*	*0.12*	*1.33*	*2.4*	*0.16*	2.5	22.75
high		*6.7*	*0.03*	*1.2*	*4.84*	*0.46*	*0.28*	*2.42*	*4.06*	*0.24*	2.5	85.22
average		*4.65*	*0.01*	*0.94*	*3.88*	*0.41*	*0.2*	*1.88*	*3.35*	*0.19*	2.5	50.93
Pore Water #7	8/3/2007	6.33	0.09	0.93	5.54	0.48	0.14	1.79	2.9	0.19	----	----
Pore Water #7	8/14/2007	5.09	0.02	0.94	4.59	0.46	0.14	1.84	2.73	0.13	2.5	16.15
Pore Water #7	9/21/2007	6.76	0.01	0.87	6.19	0.52	0.19	2.26	3.58	0.2	2.5	74.95
Pore Water #7	10/12/2007	5.82	0.07	1.1	5.27	0.54	0.22	1.75	3.57	0.32	18.3	155.46
Median		*5.09*	*0.01*	*0.87*	*4.59*	*0.46*	*0.14*	*1.75*	*2.73*	*0.13*	*2.5*	*16.15*
high		*6.76*	*0.09*	*1.1*	*6.19*	*0.54*	*0.22*	*2.26*	*3.58*	*0.32*	*18.3*	*155.46*
average		*6*	*0.05*	*0.96*	*5.4*	*0.5*	*0.17*	*1.91*	*3.19*	*0.21*	*7.77*	*82.19*
Pore Water #8	8/3/2007	6.1	0.01	2.27	5.59	0.77	0.26	2.2	2.8	0.18	2.5	44.82
Pore Water #8	8/14/2007	8.28	0.02	1.93	7.06	0.87	0.4	2.4	3.73	0.28	2.5	----
Pore Water #8	9/21/2007	7.21	0.01	2.78	7.23	1.13	0.3	2.46	2.41	0.16	2.5	48.3
Pore Water #8	10/12/2007	6.71	0.14	3.21	6.27	1.52	0.44	3.6	2.66	0.35	2.5	66.5
Median		*6.1*	*0.01*	*1.93*	*5.59*	*0.77*	*0.26*	*2.2*	*2.41*	*0.16*	2.5	*44.82*
high		*8.28*	*0.14*	*3.21*	*7.23*	*1.52*	*0.44*	*3.6*	*3.73*	*0.35*	2.5	*66.5*
average		*7.08*	*0.04*	*2.55*	*6.54*	*1.07*	*0.35*	*2.66*	*2.9*	*0.24*	2.5	*53.21*
Pore Water #9	8/3/2007	4.5	0.02	2.14	6.11	0.94	0.37	3.09	2.13	0.16	2.5	35.98
Pore Water #9	8/14/2007	6.9	0.06	2.79	7.09	0.87	0.29	2.46	3.47	0.22	2.5	76.75
Pore Water #9	9/21/2007	8.14	0.06	2.72	7.27	1.16	0.34	2.93	2.91	0.25	2.5	65.12
Pore Water #9	10/12/2007	5.54	0.25	3.29	5.48	1.09	0.18	2.32	3.02	0.77	2.5	316.41
Median		*4.5*	*0.02*	*2.14*	*5.48*	*0.87*	*0.18*	*2.32*	*2.13*	*0.16*	*2.5*	*35.98*
high		*8.14*	*0.25*	*3.29*	*7.27*	*1.16*	*0.37*	*3.09*	*3.47*	*0.77*	*2.5*	*316.41*
average		*6.27*	*0.1*	*2.74*	6.49	*1.01*	0.3	2.7	2.88	0.35	2.5	*123.56*

Sample Name	Date	Cl (mg Cl/L)	NO3 (mg N/L)	SO4 (mg S/L	Na (mg Na/L)	K (mg K/L)	Mg (mg Mg/L)	Ca (mg Ca/L)	NPOC (mg C/L)	TDN (mg N/L)	PO4 (ug P/L)	NH4 (ug N/L)
Pore Water #10	8/14/2007	7.32	0.07	1.55	6.89	0.74	0.2	1.78	14.11	0.6	----	----
Pore Water #10	9/21/2007	9.31	0	1.97	9.22	0.83	0.22	2.31	11.4	0.68	----	2.5
Pore Water #10	10/12/2007	8.16	0.04	0.78	6.31	0.54	0.2	3.16	5.65	0.84	----	488.15
Median		*7.32*	*0*	*0.78*	*6.31*	*0.54*	*0.2*	*1.78*	*5.65*	*0.6*		*2.5*
high		*9.31*	*0.07*	*1.97*	*9.22*	*0.83*	*0.22*	*3.16*	*14.11*	*0.84*		*488.15*
average		*8.26*	*0.04*	*1.43*	*7.47*	*0.71*	*0.21*	*2.41*	*10.38*	*0.71*		*245.33*
Pore Water #11	8/3/2007	3.42	0.11	0.76	3.06	0.48	0.17	2.28	2.34	0.28	2.5	45.98
Pore Water #11	8/14/2007	4.55	0.01	1.11	3.8	0.47	0.21	2.05	3.14	0.33	2.5	172.36
Pore Water #11	9/21/2007	4.91	0.01	1.06	4.26	0.48	0.11	1.92	3.24	0.18	2.5	43.05
Pore Water #11	10/12/2007	4.43	0.4	1.05	4.44	0.52	0.13	2	1.03	0.45	2.5	5.75
Median		*3.42*	*0.01*	*0.76*	*3.06*	*0.47*	*0.11*	*1.92*	*1.03*	*0.18*	*2.5*	*5.75*
high		*4.91*	*0.4*	*1.11*	*4.44*	*0.52*	*0.21*	*2.28*	*3.24*	*0.45*	*2.5*	*172.36*
average		*4.33*	*0.13*	*1*	*3.89*	*0.49*	*0.16*	*2.06*	*2.44*	*0.31*	*2.5*	*66.79*
Pore Water #12	8/3/2007	4.55	0.03	1.21	3.77	0.46	0.21	2	2.96	0.18	2.5	23.01
Pore Water #12	8/14/2007	4.84	0	0.93	4.19	0.44	0.14	1.84	3.95	0.18	2.5	18.25
Pore Water #12	9/21/2007	4.46	0.05	1.16	3.8	0.43	0.15	1.89	3.04	0.2	2.5	26.21
Pore Water #12	10/12/2007	4.87	0.02	1.05	3.96	0.43	0.19	2.12	3.84	0.16	2.5	6.07
Median		*4.46*	*0*	*0.93*	*3.77*	*0.43*	*0.14*	*1.84*	*2.96*	*0.16*	*2.5*	*6.07*
high		*4.87*	*0.05*	*1.21*	*4.19*	*0.46*	*0.21*	*2.12*	*3.95*	*0.2*	*2.5*	*26.21*
average		*4.68*	*0.02*	*1.09*	*3.93*	*0.44*	*0.17*	*1.96*	*3.45*	*0.18*	*2.5*	*18.38*
Pore Water #13	8/3/2007	5.41	0.01	1.28	4.46	0.49	0.25	1.82	3.49	0.16	2.5	23.56
Pore Water #13	8/14/2007	4.9	0.01	1.44	4.64	0.47	0.08	1.63	3.41	0.19	2.5	23.93
Pore Water #13	9/21/2007	5.13	0.02	1.4	4.53	0.42	0.13	2.14	2.9	0.2	2.5	42.47
Pore Water #13	10/12/2007	4.95	0.01	2.21	8.55	0.49	0.08	1.75	3.53	0.13	2.5	15.65
Median		*4.9*	*0.01*	*1.28*	*4.46*	*0.42*	*0.08*	*1.63*	*2.9*	*0.13*	*2.5*	*15.65*
high		*5.41*	*0.02*	*2.21*	*8.55*	*0.49*	*0.25*	*2.14*	*3.53*	*0.2*	*2.5*	*42.47*
average		*5.1*	*0.01*	*1.58*	*5.54*	*0.47*	*0.13*	*1.84*	*3.33*	*0.17*	*2.5*	*26.4*
Pore Water #14	8/3/2007	5.58	0.01	1.39	4.89	0.52	0.2	1.92	2.68	0.14	2.5	29.76
Pore Water #14	8/14/2007	5.9	0	1.02	5.49	0.54	0.23	1.76	4.75	0.24	6.63	----
Pore Water #14	9/21/2007	4.26	0.01	1.21	4.27	0.58	0.24	2.71	3.46	0.2	2.5	65.84
Pore Water #14	10/12/2007	5.66	0	1	4.64	0.46	0.15	1.72	3.98	0.17	2.5	18.85
Median		*4.26*	*0*	*1*	*4.27*	*0.46*	*0.15*	*1.72*	*2.68*	*0.14*	*2.5*	*18.85*
high		*5.9*	*0.01*	*1.39*	*5.49*	*0.58*	*0.24*	*2.71*	*4.75*	*0.24*	*6.63*	*65.84*
average		*5.35*	*0.01*	*1.15*	*4.82*	*0.52*	*0.2*	*2.03*	*3.72*	*0.19*	*3.53*	*38.15*
Pore Water #15	8/14/2007	5.92	0	1.1	5.75	0.64	0.36	3.72	5.51	0.42	2.5	231.59
Pore Water #15	9/21/2007	11.89	0	2.03	12.82	1	0.65	4.07	4.47	0.14	7.11	22.17
Pore Water #15	10/12/2007	8.03	0	2.01	9.19	1.12	0.48	3.6	4.18	0.29	9.24	168.49
Median		*5.92*	*0*	*1.1*	*5.75*	*0.64*	*0.36*	*3.6*	*4.18*	*0.14*	*2.5*	*22.17*
high		*11.89*	*0*	*2.03*	*12.82*	*1.12*	*0.65*	*4.07*	*5.51*	*0.42*	*7.11*	*168.49*
average		*8.61*	*0*	*1.71*	*9.25*	*0.92*	*0.5*	*3.79*	*4.72*	*0.28*	*6.28*	*140.75*
Pore Water #16	8/14/2007	4.62	0	1.19	3.65	0.45	0.37	2.42	2.71	0.13	2.5	33.71
Pore Water #16	9/21/2007	4.67	0	0.76	3.89	0.5	0.15	2.29	3.82	0.23	2.5	116.28
Pore Water #16	10/12/2007	6.52	0.17	0.77	6.4	0.56	0.17	2.35	2.31	0.26	2.5	31.12
Median		4.62	0	0.76	3.65	0.45	0.15	2.29	2.31	0.13	2.5	31.12
high		6.52	0.17	1.19	6.4	0.56	0.37	2.42	3.82	0.26	2.5	116.28
average		5.27	0.06	0.9	4.65	0.5	0.23	2.35	2.95	0.21	2.5	60.37

Sample Name	Date	Cl (mg Cl/L)	NO3 (mg N/L)	SO4 (mg S/L	Na (mg Na/L)	K (mg K/L)	Mg (mg Mg/L)	Ca (mg Ca/L)	NPOC (mg C/L)	TDN (mg N/L)	PO4 (ug P/L)	NH4 (ug N/L)
Pore Water #17	8/14/2007	6.89	0.02	1.39	3.79	0.46	0.16	1.58	2.72	0.2	----	----
Pore Water #17	9/21/2007	4.47	0.01	1.64	4.65	0.59	0.22	2.98	2.97	0.14	2.5	26
Pore Water #17	10/12/2007	4.69	0.09	1.65	5.09	0.7	0.28	3.19	2.17	0.19	2.5	34.88
Median		*4.47*	*0.01*	*1.39*	*3.79*	*0.46*	*0.16*	*1.58*	*2.17*	*0.14*	*2.5*	*26*
high		*6.89*	*0.09*	*1.65*	*5.09*	*0.7*	*0.28*	*3.19*	*2.97*	*0.2*	*2.5*	*34.88*
average		*5.35*	*0.04*	*1.56*	*4.51*	*0.58*	*0.22*	*2.58*	*2.62*	*0.18*	*2.5*	*30.44*
Pore Water #18	8/3/2007	4.31	0	0.88	3.39	0.56	0.19	2.8	3.66	0.23	2.5	85.87
Pore Water #18	8/14/2007	4.48	0	1.18	3.57	0.48	0.24	2.3	2.97	0.22	2.5	80.89
Pore Water #18	9/21/2007	5.67	0	1.15	5.09	0.53	0.14	1.78	4.27	0.2	2.5	28.85
Pore Water #18	10/12/2007	2.72	0	1.22	3.67	0.59	0.17	2.9	2.77	0.15	2.5	43.05
Median		*4.31*	*0*	*0.88*	*3.39*	*0.48*	*0.14*	*1.78*	*2.97*	*0.2*	*2.5*	*28.85*
high		*5.67*	*0*	*1.18*	*5.09*	*0.56*	*0.24*	*2.8*	*4.27*	*0.23*	*2.5*	*85.87*
average		*4.82*	*0*	*1.07*	*4.01*	*0.52*	*0.19*	*2.29*	*3.63*	*0.21*	*2.5*	*59.66*
Pore Water 17a	7/10/2007	4.28	0.01	1.76	3.69	0.46	0.42	2.7	3.46	0.18	2.5	53.76
Pore Water 17a	8/3/2007	5.04	0.02	1.91	5.17	0.51	0.09	2.15	2.15	0.12	2.5	5.41
Pore Water 17a	8/14/2007	5.39	0.03	1.2	4.61	0.52	0.27	2.35	4.21	0.27	2.5	52.12
Pore Water 17a	9/21/2007	6.39	0	1.05	5.43	0.52	0.18	2.1	3.84	0.16	2.5	11.93
Pore Water 17a	10/12/2007	5.14	0.09	2.34	5.6	0.45	0.66	3.61	2.75	0.17	2.5	13.06
Median		*4.28*	*0*	*1.05*	*3.69*	*0.45*	*0.09*	*2.1*	*2.15*	*0.12*	*2.5*	*5.41*
high		*6.39*	*0.09*	*2.34*	*5.6*	*0.52*	*0.66*	*3.61*	*4.21*	*0.27*	*2.5*	*52.12*
average		*5.25*	*0.03*	*1.65*	*4.9*	*0.49*	*0.32*	*2.58*	*3.28*	*0.18*	*2.5*	*27.26*

Appendix D: Raw Stream Total Phosphorus and Discharge Data

Site ID	CFB or VOL	Date	Gauge	Gauge	Discharge Measured	Discharge Estimates	Total Phosphorus ppb
Men01T	CFB	10/27/2006	0.60	0.60	0.0083	------	8.0
Men01T	CFB	11/14/2006	1.20	1.22	F-NM	------	10.5
Men01T	CFB	12/21/2006	0.64	0.64	F-NM	------	6.8
Men01T	CFB	1/10/2007	0.86	0.86	0.0784	------	5.5
Men01T	CFB	3/15/2007	1.00	F-NM	F-NM	------	10.6
Men01T	CFB	3/23/2007	0.98	0.98	0.0904	------	7.3
Men01T	CFB	4/2/2007	0.86	0.86	0.0690	------	7.6
Men01T	CFB	4/16/2007	2.50	2.48	2.5668	------	31.0
Men01T	CFB	4/30/2007	0.60	0.60	F-NM	------	5.6
Men01T	VOL	5/3/2007	0.50				4.0
Men01T	CFB	5/21/2007	0.78	0.78	0.0777	------	4.9
Men01T	CFB	5/24/2007	0.50	0.50	F-NM	------	5.1
Men01T	CFB	6/4/2007	0.48	0.48	F-NM	------	13.3
Men01T	VOL	6/6/2007	1.08				8.5
Men01T	CFB	6/21/2007	0.14	0.15	F-NM	------	9.0
Men01T	CFB	6/21/2007	F-NM	F-NM	F-NM	------	9.3
Men01T	VOL	7/6/2007	0.02				10.0
Men01T	CFB	7/25/2007	0.16	0.16	F-BDL	0.0003	10.5
Men01T	CFB	7/25/2007	0.16	0.16	F-NM	0.0003	13.4
Men01T	VOL	8/9/2007	0.02				12.2
Men01T	CFB	8/29/2007	F-NM	F-NM	F-DRY	------	F-DRY
Men01T	VOL	9/20/2007	1.00				8.1
Men01T	CFB	9/30/2007	F-NM	F-NM	F-NM	------	F-TS
Men01T	VOL	10/13/2007	0.30				F-NM
Men01T	CFB	10/29/2007	0.40	0.40	F-BDL	0.0010	7.8
Men01T	CFB	10/29/2007	0.40	0.40	F-BDL	0.0010	F-NC
Men01T	CFB	11/16/2007	0.78	F-NM	F-NM	------	8.9
Men01T	CFB	11/30/2007	F-NM	F-NM	0.0099	------	4.8
Men01T	CFB	12/18/2007	0.56	0.56	F-ICE	------	2.9
Men01T	CFB	12/18/2007	F-NM	F-NM	F-NM	------	3.0
Men01T	CFB	1/7/2008	F-ICE	F-ICE	F-ICE	------	F-ICE
Men01T	CFB	1/23/2008	0.60	0.60	F-NM	------	4.2
Men01T	CFB	1/23/2008	F-NM	F-NM	F-NM	------	16.3
Men01T	CFB	1/30/2008	0.70	0.70	F-ICE	------	5.9
Men01T	CFB	2/6/2008	0.90	0.90	0.0619	------	4.5
Men01T	CFB	2/28/2008	F-ICE	F-ICE	0.0223	------	8.1
Men02T	CFB	10/27/2006	1.10	1.09	0.0550	------	24.2
Men02T	CFB	11/14/2006	0.96	0.96	F-NM	------	12.1
Men02T	CFB	12/21/2006	1.05	1.05	F-NM	------	11.6
Men02T	CFB	1/10/2007	1.56	1.56	0.3965	------	10.5
Men02T	CFB	3/15/2007	F-NM	F-NM	F-NM	------	16.8
Men02T	CFB	3/23/2007	1.37	1.37	0.2164	------	16.8
Men02T	CFB	4/2/2007	1.36	1.36	0.1857	------	16.7
Men02T	CFB	4/16/2007	F-UW	F-UW	F-NM	------	48.4
Men02T	CFB	4/17/2007	2.30	2.30	2.8870		15.9

Site ID	CFB Or Vol	Date	Gauge	Gauge	Discharge Measured	Discharge Estimate	Total Phosphorus ppb
Men02T	CFB	4/30/2007	1.28	1.26	F-NM	------	14.4
Men02T	VOL	5/3/2007	1.14				12.8
Men02T	CFB	5/21/2007	1.40	1.40	0.3670	------	13.6
Men02T	CFB	5/24/2007	1.14	1.14	F-NM	------	14.6
Men02T	CFB	6/4/2007	0.96	0.96	F-NM	------	22.7
Men02T	VOL	6/6/2007	1.68				19.5
Men02T	CFB	6/21/2007	0.79	0.78	0.0174	------	21.7
Men02T	VOL	7/6/2007	0.70				21.6
Men02T	CFB	7/25/2007	0.78	0.78	0.0134	------	24.2
Men02T	VOL	8/9/2007	0.64				34.9
Men02T	CFB	8/29/2007	0.48	0.48	F-BDL	0.0001	23.8
Men02T	VOL	9/20/2007	0.68				48.3
Men02T	CFB	9/30/2007	0.70	0.70	F-BDL	0.0005	14.9
Men02T	VOL	10/13/2007	0.92				
Men02T	CFB	10/29/2007	1.08	1.08	F-BDL	0.0005	31.0
Men02T	CFB	11/16/2007	1.50	F-NM	F-NM	------	21.3
Men02T	CFB	11/30/2007	1.10	1.10	0.0543	------	13.2
Men02T	CFB	12/18/2007	1.04	1.04	F-BDL	0.0200	12.0
Men02T	CFB	1/7/2008	1.10	1.10	F-ICE	------	11.2
Men02T	CFB	1/23/2008	F-ICE	F-ICE	F-ICE	------	8.2
Men02T	CFB	1/30/2008	F-ICE	F-ICE	F-ICE	------	10.9
Men02T	CFB	2/6/2008	1.29	1.29	0.2347	------	8.3
Men02T	CFB	2/6/2008	1.29	1.29	0.2168	------	7.6
Men02T	CFB	2/28/2008	1.15	1.15	0.1631	------	6.1
Men02T	CFB	2/28/2008	1.15	1.15	0.1557	------	14.6
Men03T	CFB	10/27/2006	1.80	1.80	0.0265	------	22.9
Men03T	CFB	11/14/2006	4.38	4.40	F-NM	------	14.2
Men03T	CFB	12/21/2006	0.60	F-NM	F-NM	------	13.4
Men03T	CFB	1/10/2007	1.20	1.40	0.1403	------	12.0
Men03T	CFB	3/15/2007	F-NM	F-NM	F-NM	------	22.8
Men03T	CFB	3/23/2007	1.05	1.05	0.0966	------	20.2
Men03T	CFB	4/2/2007	F-NM	F-NM	0.0862	------	22.5
Men03T	CFB	4/16/2007	2.90	2.90	F-NM	------	31.3
Men03T	CFB	4/17/2007	1.70	1.70	0.8880	------	17.5
Men03T	CFB	4/30/2007	0.82	0.82	F-NM	------	17.7
Men03T	VOL	5/3/2007					16.8
Men03T	CFB	5/21/2007	0.86	0.85	0.0694	------	21.0
Men03T	CFB	5/24/2007	0.64	0.64	F-NM	------	22.4
Men03T	CFB	6/4/2007	0.67	0.67	F-NM	------	45.0
Men03T	VOL	6/6/2007					21.0
Men03T	CFB	6/21/2007	0.19	0.18	0.0016	------	63.7
Men03T	VOL	7/6/2007	0.26				68.4
Men03T	CFB	7/25/2007	0.30	0.30	0.0101	------	60.8
Men03T	VOL	8/9/2007	0.22				70.6
Men03T	CFB	8/29/2007	0.14	0.14	F-BDL	0.0001	73.1
Men03T	VOL	9/20/2007	0.26				47.9
Men03T	CFB	9/30/2007	0.28	0.28	F-BDL	0.0100	60.7

Site ID	CFB Or Vol	Date	Gauge	Gauge	Discharge Measured	Discharge Estimate	Total Phosphorus ppb
Men03T	VOL	10/13/2007	0.44				
Men03T	CFB	10/29/2007	0.40	0.40	0.0048	------	35.8
Men03T	CFB	11/16/2007	0.68	F-NM	F-NM	------	18.3
Men03T	CFB	11/30/2007	0.58	0.58	0.0164	------	14.6
Men03T	CFB	11/30/2007	F-NM	F-NM	0.0295	------	F-NS
Men03T	CFB	12/18/2007	0.58	0.58	F-ICE	------	15.2
Men03T	CFB	1/7/2008	F-ICE	F-ICE	F-ICE	------	F-ICE
Men03T	CFB	1/23/2008	F-ICE	F-ICE	F-ICE	------	10.3
Men03T	CFB	1/30/2008	0.80	0.80	F-NM	------	10.4
Men03T	CFB	2/6/2008	1.00	1.00	0.1723	------	11.9
Men03T	CFB	2/28/2008	0.76	0.76	0.0607	------	7.6
Men04T	CFB	10/27/2006	0.08	0.08	0.0014	------	37.0
Men04T	CFB	11/14/2006	0.64	0.65	F-NM	------	11.5
Men04T	CFB	12/21/2006	0.01	F-NM	F-NM	------	20.8
Men04T	CFB	1/10/2007	0.20	0.20	0.0141	------	11.9
Men04T	CFB	3/15/2007	F-NM	F-NM	F-NM	------	10.7
Men04T	CFB	3/23/2007	F-NM	F-NM	F-NM	------	19.8
Men04T	CFB	4/2/2007	F-NM	F-NM	0.0136	------	12.5
Men04T	CFB	4/16/2007	1.36	1.36	0.5197	------	25.9
Men04T	CFB	4/17/2007	0.68	0.68	F-NM	------	12.7
Men04T	CFB	4/30/2007	0.15	0.16	F-NM	------	9.1
Men04T	VOL	5/3/2007	0.10				8.4
Men04T	CFB	5/21/2007	0.20	0.20	0.0148	------	6.9
Men04T	CFB	5/24/2007	0.10	0.10	F-NM	------	7.1
Men04T	CFB	6/4/2007	0.12	0.12	F-NM	------	16.4
Men04T	VOL	6/6/2007	0.32				8.2
Men04T	CFB	6/21/2007	F-NM	F-NM	F-BDL	------	12.9
Men04T	VOL	7/6/2007					37.6
Men04T	CFB	7/25/2007	0.00	0.00	F-BDL	------	13.3
Men04T	VOL	8/9/2007					17.9
Men04T	CFB	8/29/2007	F-DRY	F-DRY	F-DRY	------	F-DRY
Men04T	VOL	9/20/2007	X				10.8
Men04T	CFB	9/30/2007	F-NM	F-NM	F-BDL	0.0000	11.2
Men04T	VOL	10/13/2007	0.08				
Men04T	CFB	10/29/2007	0.12	0.12	F-BDL	0.0020	F-TS
Men04T	CFB	11/16/2007	0.17	F-NM	F-NM	------	10.7
Men04T	CFB	11/30/2007	0.06	0.06	0.0029	------	8.7
Men04T	CFB	12/18/2007	0.04	0.04	F-BDL	0.0003	76.5
Men04T	CFB	1/7/2008	0.08	0.08	F-NM	------	7.2
Men04T	CFB	1/23/2008	F-NM	F-NM	F-NM	------	8.3
Men04T	CFB	1/30/2008	0.10	0.10	F-NM	------	7.6
Men04T	CFB	1/30/2008	0.10	0.10	F-NM	------	9.4
Men04T	CFB	2/6/2008	0.26	0.26	0.0218	------	7.3
Men04T	CFB	2/28/2008	0.06	0.06	F-BDL	0.0030	6.8
Men05T	CFB	10/27/2006	0.20	0.20	0.0020	------	F-NC
Men05T	CFB	11/14/2006	0.36	0.36	F-NM	------	15.0
Men05T	CFB	12/21/2006	0.20	0.20	F-NM	------	16.1
Men05T	CFB	1/10/2007	0.32	0.32	0.0070	________	11.3

Site ID	CFB Or Vol	Date	Gauge	Gauge	Discharge Measured	Discharge Estimate	Total Phosphorus ppb
Men05T	CFB	3/15/2007	0.62	0.60	F-NM	------	16.7
Men05T	CFB	3/23/2007	0.22	0.22	0.0010	------	13.0
Men05T	CFB	4/2/2007	0.03	0.03	0.0044	------	10.1
Men05T	CFB	4/16/2007	1.00	1.02	0.1982	------	22.7
Men05T	CFB	4/30/2007	0.28	0.29	0.0044	------	7.9
Men05T	VOL	5/3/2007	0.18				7.4
Men05T	CFB	5/21/2007	0.36	0.36	0.0065	------	8.6
Men05T	CFB	5/24/2007	F-NM	F-NM	F-NM	------	8.8
Men05T	CFB	5/24/2007	F-NM	F-NM	F-NM	------	8.6
Men05T	CFB	6/4/2007	0.08	0.08	F-NM	------	13.0
Men05T	VOL	6/6/2007	0.52				13.1
Men05T	CFB	6/21/2007	0.18	0.18	F-BDL	0.0010	22.1
Men05T	VOL	7/6/2007	0.10				41.2
Men05T	CFB	7/25/2007	0.20	0.20	F-BDL	0.0001	29.2
Men05T	VOL	8/9/2007	0.12				52.4
Men05T	CFB	8/29/2007	0.08	0.08	F-BDL	------	F-TS
Men05T	VOL	9/20/2007	0.18				15.9
Men05T	CFB	9/30/2007	0.16	0.16	F-BDL	------	F-TS
Men05T	VOL	10/13/2007	0.58				
Men05T	CFB	10/29/2007	0.54	0.54	F-BDL	0.0003	F-TS
Men05T	CFB	11/16/2007	0.62	F-NM	F-NM	------	15.3
Men05T	CFB	11/30/2007	0.62	0.62	F-BDL	0.0015	12.9
Men05T	CFB	12/18/2007	F-NM	F-NM	F-BDL	0.0008	F-TS
Men05T	CFB	1/7/2008	F-ICE	F-ICE	F-ICE	------	F-ICE
Men05T	CFB	1/23/2008	0.74	0.74	F-ICE	------	13.9
Men05T	CFB	1/30/2008	0.58	0.58	F-ICE	------	14.7
Men05T	CFB	2/6/2008	F-NM	F-NM	F-NM	------	F-NC
Men05T	CFB	2/28/2008	0.68	0.68	0.0030	------	6.1
Men06T	CFB	10/27/2006	0.32	0.32	F-BDL	0.0005	20.4
Men06T	CFB	11/14/2006	0.40	0.42	F-NM	------	13.2
Men06T	CFB	12/21/2006	0.38	F-NM	F-NM	------	50.7
Men06T	CFB	1/10/2007	0.52	0.54	0.0084	------	10.2
Men06T	CFB	3/15/2007	F-NM	F-NM	F-NM	------	18.1
Men06T	CFB	3/23/2007	F-ICE	F-ICE	F-ICE	------	F-ICE
Men06T	CFB	4/2/2007	0.52	0.52	0.0015	------	11.1
Men06T	CFB	4/16/2007	2.62	2.64	0.2544	------	19.9
Men06T	CFB	4/30/2007	0.53	0.53	F-NM	------	7.2
Men06T	VOL	5/3/2007	0.46				6.6
Men06T	CFB	5/21/2007	0.60	0.59	F-BDL	0.0035	7.8
Men06T	CFB	5/24/2007	0.48	0.48	F-NM	------	7.2
Men06T	CFB	6/4/2007	0.43	0.43	F-NM	------	15.1
Men06T	CFB	6/4/2007	0.43	0.43	F-NM	------	15.1
Men06T	VOL	6/6/2007	0.80				11.9
Men06T	CFB	6/21/2007	0.38	0.38	F-NM	------	16.1
Men06T	VOL	7/6/2007	0.34				26.6
Men06T	CFB	7/25/2007	0.37	0.37	F-BDL	0.0001	22.2
Men06T	VOL	8/9/2007	0.30				29.7
Men06T	CFB	8/29/2007	F-DRY	F-DRY	F-DRY	________	F-DRY

Site ID	CFB Or Vol	Date	Gauge	Gauge	Discharge Measured	Discharge Estimate	Total Phosphorus ppb
Men06T	VOL	9/20/2007	0.30				8.0
Men06T	CFB	9/30/2007	F-DRY	F-DRY	F-DRY	------	F-DRY
Men06T	VOL	10/13/2007	0.40				
Men06T	CFB	10/29/2007	0.40	0.40	F-BDL	0.0002	F-TS
Men06T	CFB	11/16/2007	0.42	F-NM	F-NM	------	15.5
Men06T	CFB	11/30/2007	0.42	0.42	F-BDL	0.0008	13.1
Men06T	CFB	12/18/2007	0.38	0.38	F-ICE	------	F-ICE
Men06T	CFB	1/7/2008	F-ICE	F-ICE	F-ICE	------	F-ICE
Men06T	CFB	1/23/2008	0.46	0.46	F-NM	------	11.5
Men06T	CFB	1/30/2008	0.44	0.44	F-NM	------	10.4
Men06T	CFB	2/6/2008	F-NM	F-NM	F-NM	------	F-NC
Men06T	CFB	2/28/2008	0.59	0.59	F-BDL	0.0010	5.2
Men07T	CFB	10/27/2006	0.20	0.20	F-BDL	0.0008	9.1
Men07T	CFB	11/14/2006	0.49	0.50	F-NM	------	16.7
Men07T	CFB	12/21/2006	0.22	0.22	F-NM	------	10.9
Men07T	CFB	1/10/2007	0.31	0.31	F-NM	------	9.7
Men07T	CFB	3/15/2007	F-ICE	F-ICE	F-ICE	------	50.7
Men07T	CFB	3/23/2007	F-NM	F-NM	F-NM	0.0100	18.9
Men07T	CFB	4/2/2007	0.22	0.22	F-NM	0.0060	12.4
Men07T	CFB	4/16/2007	1.16	1.16	0.1809	------	24.0
Men07T	CFB	4/30/2007	0.69	0.70	F-NM	------	4.4
Men07T	VOL	5/21/2007	0.30				5.9
Men07T	CFB	5/21/2007	0.31	0.32	0.0094	------	12.9
Men07T	CFB	5/24/2007	0.22	0.22	F-NM	------	9.9
Men07T	CFB	6/4/2007	0.28	0.28	F-NM	------	30.1
Men07T	VOL	6/6/2007	0.40				34.6
Men07T	CFB	6/21/2007	0.20	0.20	F-BDL	------	15.4
Men07T	VOL	7/11/2007					21.8
Men07T	CFB	7/25/2007	0.21	0.21	F-BDL	0.0005	33.3
Men07T	VOL	8/15/2007					-----
Men07T	CFB	8/29/2007	0.20	0.20	F-DRY	------	F-DRY
Men07T	VOL	9/13/2007					-----
Men07T	CFB	9/30/2007	F-DRY	F-DRY	F-DRY	------	F-DRY
Men07T	CFB	10/29/2007	0.18	0.18	F-BDL	0.0001	F-TS
Men07T	CFB	11/16/2007	0.24	F-NM	F-NM	------	9.2
Men07T	CFB	11/30/2007	0.20	0.20	F-BDL	0.0010	5.5
Men07T	CFB	12/18/2007	0.26	0.26	F-BDL	0.0025	F-TS
Men07T	CFB	1/7/2008	F-ICE	F-ICE	F-ICE	------	F-ICE
Men07T	CFB	1/23/2008	0.70	0.70	F-ICE	------	3.5
Men07T	CFB	1/30/2008	0.49	0.49	F-NM	------	10.4
Men07T	CFB	2/16/2008	0.40	0.40	F-NM	------	3.6
Men07T	CFB	2/28/2008	F-NM	F-NM	F-BDL	0.0005	4.5
Men08T	CFB	10/27/2006	0.74	0.74	F-BDL	0.0005	7.2
Men08T	CFB	11/14/2006	1.90	1.10	F-NM	------	8.7
Men08T	CFB	12/21/2006	0.72	0.72	F-NM	------	6.8
Men08T	CFB	1/10/2007	0.82	0.82	0.0009	------	5.2
Men08T	CFB	3/15/2007	0.90	F-NM	F-NM	------	8.1
Men08T	CFB	3/23/2007	0.79	0.79	0.0060		13.0

Site ID	CFB Or Vol	Date	Gauge	Gauge	Discharge Measured	Discharge Estimate	Total Phosphorus ppb
Men08T	CFB	4/2/2007	0.79	0.79	0.0044	------	9.2
Men08T	CFB	4/16/2007	1.28	1.28	0.0777	------	10.4
Men08T	CFB	4/30/2007	0.32	0.32	F-NM	------	14.2
Men08T	VOL	5/21/2007	0.80				4.3
Men08T	CFB	5/21/2007	0.68	0.68	0.0075	------	4.3
Men08T	CFB	5/24/2007	0.60	0.60	F-NM	------	5.3
Men08T	CFB	6/4/2007	0.76	0.76	F-NM	------	40.3
Men08T	VOL	6/6/2007	0.74				10.5
Men08T	CFB	6/21/2007	0.44	0.44	F-BDL	0.0001	3.6
Men08T	VOL	7/11/2007	0.50				5.2
Men08T	CFB	7/25/2007	0.42	0.42	F-BDL	0.0000	6.7
Men08T	VOL	8/15/2007					-----
Men08T	CFB	8/29/2007	F-DRY	F-DRY	F-DRY	------	F-DRY
Men08T	VOL	9/13/2007					-----
Men08T	CFB	9/30/2007	F-DRY	F-DRY	F-DRY	------	F-DRY
Men08T	CFB	10/29/2007	0.52	0.52	F-BDL	0.0000	9.2
Men08T	CFB	11/16/2007	0.75	F-NM	F-NM	------	6.5
Men08T	CFB	11/30/2007	0.62	0.62	F-BDL	0.0005	2.4
Men08T	CFB	12/18/2007	F-ICE	F-ICE	F-ICE	------	F-ICE
Men08T	CFB	1/23/2008	0.40	0.40	F-ICE	------	6.7
Men08T	CFB	1/30/2008	0.69	0.69	F-NM	------	4.3
Men08T	CFB	2/16/2008	0.72	0.72	F-NM	------	2.5
Men08T	CFB	2/28/2008	0.70	0.70	F-BDL	0.0010	5.4
Men09T	CFB	10/27/2006	0.54	0.54	F-NM	------	24.5
Men09T	CFB	11/14/2006	0.90	1.00	F-NM	------	20.7
Men09T	CFB	12/21/2006	0.39	0.39	F-NM	------	17.9
Men09T	CFB	1/10/2007	0.54	0.54	0.0071	------	8.9
Men09T	CFB	3/15/2007	F-NM	F-NM	F-NM	------	15.6
Men09T	CFB	4/2/2007	F-NM	F-NM	F-NM	------	22.4
Men09T	CFB	4/16/2007	1.18	1.18	0.2555	------	21.0
Men09T	CFB	4/30/2007	0.40	0.40	F-NM	------	22.2
Men09T	VOL	5/21/2007	0.44				
Men09T	CFB	5/21/2007	0.44	0.44	F-NM	------	20.6
Men09T	CFB	5/24/2007	0.30	0.30	F-NM	------	12.0
Men09T	CFB	6/4/2007	0.39	0.39	F-NM	------	51.4
Men09T	VOL	6/6/2007	0.58				17.0
Men09T	CFB	6/21/2007	0.20	0.20	F-BDL	0.0001	105.2
Men09T	VOL	7/11/2007	0.24				22.3
Men09T	CFB	7/25/2007	0.20	0.20	F-BDL	0.0001	28.7
Men09T	VOL	8/15/2007					-----
Men09T	CFB	8/29/2007	F-DRY	F-DRY	F-DRY	------	F-DRY
Men09T	VOL	9/13/2007					-----
Men09T	CFB	9/30/2007	F-DRY	F-DRY	F-DRY	------	F-DRY
Men09T	CFB	10/29/2007	0.18	0.18	F-BDL	0.0000	20.3
Men09T	CFB	11/16/2007	0.32	F-NM	F-BDL	------	12.6
Men09T	CFB	11/30/2007	0.26	0.26	F-BDL	0.0025	42.1
Men09T	CFB	12/18/2007	F-NM	F-NM	F-NM	------	5.7
Men09T	CFB	1/23/2008	F-ICE	F-ICE	F-ICE	------	F-ICE

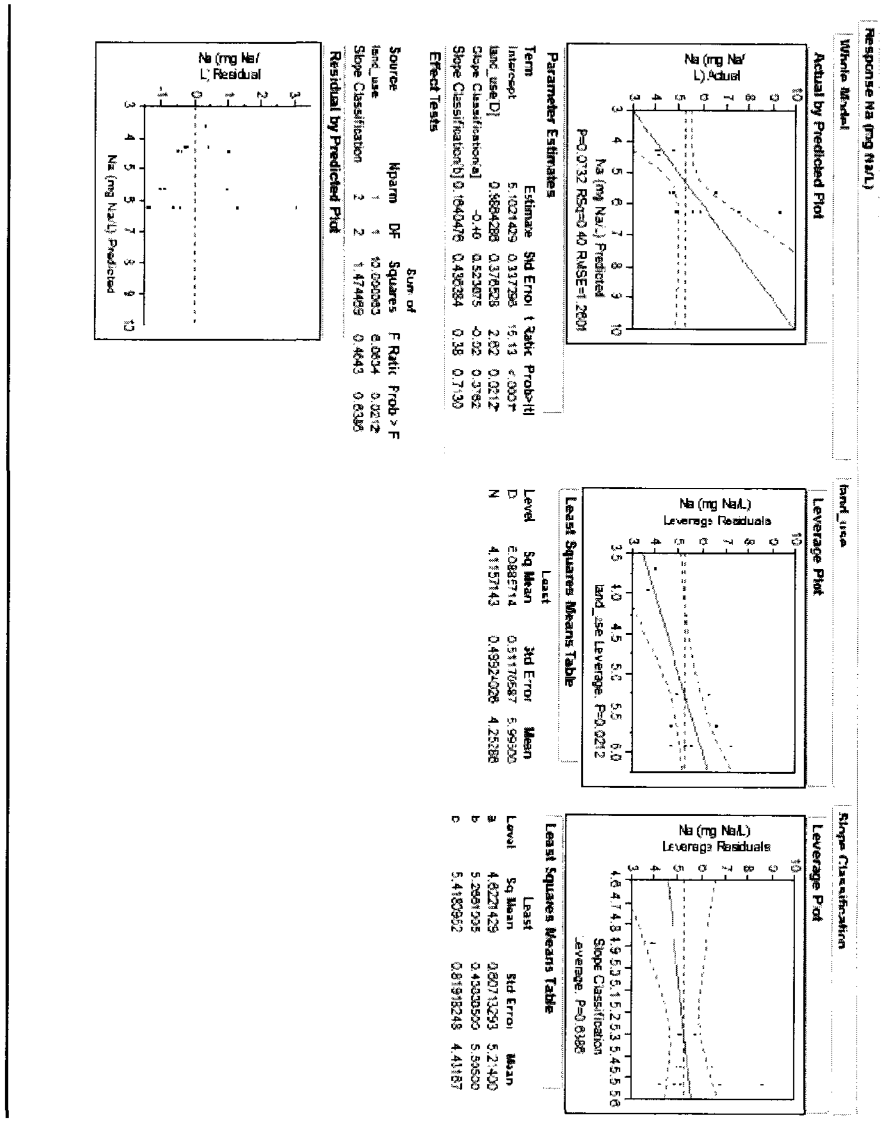
Site ID	CFB Or Vol	Date	Gauge	Gauge	Discharge Measured	Discharge Estimate	Total Phosphorus ppb
Men09T	CFB	1/30/2008	F-NM	F-NM	F-NM	------	45.5
Men09T	CFB	2/16/2008	0.46	0.46	F-NM	------	9.7
Men09T	CFB	2/28/2008	F-NM	F-NM	F-BDL	0.0005	4.5
Men10T	CFB	10/27/2006	0.50	0.50	0.0009	------	33.6
Men10T	CFB	11/14/2006	1.20	1.00	F-NM	------	20.6
Men10T	CFB	12/21/2006	0.42	0.42	F-NM	------	12.7
Men10T	CFB	1/10/2007	0.64	0.64	0.0092	------	10.2
Men10T	CFB	3/15/2007	F-ICE	F-ICE	F-ICE	------	19.8
Men10T	CFB	3/23/2007	F-ICE	F-ICE	F-ICE	------	16.1
Men10T	CFB	4/2/2007	F-ICE	F-ICE	F-ICE	------	12.7
Men10T	CFB	4/16/2007	1.26	1.26	0.2686	------	23.5
Men10T	CFB	4/30/2007	0.44	0.44	F-NM	------	16.9
Men10T	VOL	5/21/2007	0.54				15.8
Men10T	CFB	5/21/2007	0.56	0.54	0.0025	------	18.4
Men10T	CFB	5/24/2007	0.40	0.40	F-NM	------	10.8
Men10T	CFB	6/4/2007	0.45	0.45	F-NM	------	77.6
Men10T	VOL	6/6/2007	0.76				21.0
Men10T	CFB	6/21/2007	F-DRY	F-DRY	F-DRY	------	F-DRY
Men10T	VOL	7/11/2007					16.1
Men10T	CFB	7/25/2007	0.33	0.33	F-BDL	0.0000	22.3
Men10T	VOL	8/15/2007					-----
Men10T	CFB	8/29/2007	F-DRY	F-DRY	F-DRY	------	F-DRY
Men10T	VOL	9/13/2007					-----
Men10T	CFB	9/30/2007	F-DRY	F-DRY	F-DRY	------	F-DRY
Men10T	CFB	10/29/2007	F-DRY	F-DRY	F-DRY	------	F-DRY
Men10T	CFB	11/16/2007	0.48	F-NM	F-NM	------	11.9
Men10T	CFB	11/30/2007	0.44	0.44	F-BDL	0.0010	7.6
Men10T	CFB	12/18/2007	F-ICE	F-ICE	F-ICE	------	F-TS
Men10T	CFB	1/23/2008	F-ICE	F-ICE	F-ICE	------	F-ICE
Men10T	CFB	1/30/2008	F-ICE	F-ICE	F-ICE	------	F-ICE
Men10T	CFB	2/16/2008	F-ICE	F-ICE	F-ICE	------	6.6
Men10T	CFB	2/28/2008	0.50	0.50	F-BDL	0.0005	4.0
Men110T	CFB	10/27/2006	F-NM	F-NM	0.1157	------	8.3
Men110T	CFB	11/14/2006	F-NM	F-NM	F-NM	------	10.6
Men110T	CFB	12/21/2006	F-NM	F-NM	F-NM	------	8.8
Men110T	CFB	1/10/2007	F-NM	F-NM	0.3458	------	7.9
Men110T	CFB	1/10/2007	F-NM	F-NM	0.3458	------	7.9
Men110T	CFB	3/15/2007	F-NM	F-NM	F-NM	------	7.7
Men110T	CFB	3/23/2007	F-NM	F-NM	0.0124	------	10.3
Men110T	CFB	4/2/2007	F-NM	F-NM	0.0063	------	7.2
Men110T	CFB	4/21/2007	F-NM	F-NM	0.6570	------	12.3
Men110T	CFB	4/30/2007	F-NM	F-NM	F-NM	------	12.9
Men110T	CFB	5/21/2007	F-NM	F-NM	F-NM	------	7.0
Men110T	CFB	5/24/2007	F-NM	F-NM	F-NM	------	6.9
Men110T	CFB	6/4/2007	F-NM	F-NM	F-NM	------	7.1
Men110T	CFB	6/21/2007	F-NM	F-NM	0.0311	------	7.3
Men110T	CFB	7/25/2007	F-NM	F-NM	0.0197	------	7.1
Men110T	CFB	8/29/2007	F-NM	F-NM	0.0082	______	5.5

Site ID	CFB Or Vol	Date	Gauge	Gauge	Discharge Measured	Discharge Estimate	Total Phosphorus ppb
Men110T	CFB	8/29/2007	F-NM	F-NM	0.0059	------	5.5
Men110T	CFB	9/30/2007	F-NM	F-NM	0.0136	------	4.8
Men110T	CFB	9/30/2007	F-NM	F-NM	0.0171	------	5.0
Men110T	CFB	10/29/2007	F-NM	F-NM	0.0123	------	5.8
Men110T	CFB	11/16/2007	F-NM	F-NM	F-NM	------	6.9
Men110T	CFB	11/30/2007	F-NM	F-NM	0.6592	------	7.1
Men110T	CFB	11/30/2007	F-NM	F-NM	F-NM	------	8.1
Men110T	CFB	12/18/2007	F-NM	F-NM	0.3852	------	5.3
Men110T	CFB	1/7/2008	F-NM	F-NM	F-NM	------	9.0
Men110T	CFB	1/7/2008	F-NM	F-NM	F-NM	------	7.9
Men110T	CFB	1/23/2008	F-NM	F-NM	0.3787	------	6.1
Men110T	CFB	1/23/2008	F-NM	F-NM	0.3458	------	16.3
Men110T	CFB	1/30/2008	F-NM	F-NM	F-NM	------	7.4
Men110T	CFB	2/6/2008	F-NM	F-NM	0.2482	------	7.6
Men110T	CFB	2/28/2008	F-NM	F-NM	F-NM	0.2482	12.8
Men120T	CFB	12/21/2006	F-NM	F-NM	F-NM	------	F-NC
Men120T	CFB	4/21/2007	F-NM	F-NM	0.3330	------	12.5
Men120T	CFB	4/30/2007	F-NM	F-NM	F-NM	------	12.6
Men120T	CFB	5/21/2007	F-NM	F-NM	0.5078	------	8.1
Men120T	CFB	5/24/2007	F-NM	F-NM	F-NM	------	6.9
Men120T	CFB	6/4/2007	F-NM	F-NM	F-NM	------	6.7
Men120T	CFB	6/21/2007	F-NM	F-NM	0.0239	------	8.4
Men120T	CFB	7/25/2007	F-NM	F-NM	0.0633	------	5.9
Men120T	CFB	8/29/2007	F-NM	F-NM	F-DRY	------	F-DRY
Men120T	CFB	9/30/2007	F-NM	F-NM	F-DRY	------	F-DRY
Men120T	CFB	10/29/2007	F-NM	F-NM	F-DRY	------	F-DRY
Men120T	CFB	12/18/2007	F-NM	F-NM	F-DRY	------	F-DRY
Men120T	CFB	2/28/2008	F-NM	F-NM	F-NM	------	F-NC
Men16T	CFB	10/27/2006	F-NM	F-NM	0.0005	------	3.3
Men16T	CFB	11/14/2006	F-NM	F-NM	F-NM	------	13.6
Men16T	CFB	12/21/2006	F-NM	F-NM	F-NM	------	4.6
Men16T	CFB	1/10/2007	0.077	0.075	0.0043	------	5.6
Men16T	CFB	3/15/2007	F-NM	F-NM	F-NM	------	13.8
Men16T	CFB	3/23/2007	F-NM	F-NM	F-NM	------	8.0
Men16T	CFB	4/2/2007	F-NM	F-NM	0.0060	------	9.8
Men16T	CFB	4/16/2007	0.400	0.400	0.2437	------	83.6
Men16T	CFB	4/30/2007	F-NM	F-NM	F-NM	------	3.7
Men16T	VOL	5/3/2007					4.7
Men16T	CFB	5/21/2007	0.090	0.090	0.0043	------	6.1
Men16T	CFB	5/24/2007	0.090	0.090	F-NM	------	5.4
Men16T	CFB	6/4/2007	F-NM	F-NM	F-NM	------	16.6
Men16T	VOL	6/6/2007					13.5
Men16T	CFB	6/21/2007	F-NM	F-NM	F-NM	------	5.4
Men16T	VOL	7/6/2007					7.5
Men16T	CFB	7/25/2007	F-NM	F-NM	F-BDL	0.0001	5.3
Men16T	CFB	7/25/2007	F-NM	F-NM	F-NM	------	14.6
Men16T	VOL	8/9/2007					5.9
Men16T	CFB	8/29/2007	F-NM	F-NM	F-DRY	______	F-DRY

Site ID	CFB Or Vol	Date	Gauge	Gauge	Discharge Measured	Discharge Estimate	Total Phosphorus ppb
Men16T	VOL	9/20/2007					3.4
Men16T	CFB	9/30/2007	F-NM	F-NM	F-DRY	------	F-DRY
Men16T	VOL	10/13/2007					
Men16T	CFB	10/29/2007	F-NM	F-NM	F-BDL	0.0005	3.4
Men16T	CFB	11/16/2007	0.025	F-NM	F-NM	------	12.0
Men16T	CFB	11/30/2007	0.040	0.040	F-NM	------	3.6
Men16T	CFB	12/18/2007	F-NM	F-NM	F-ICE	------	F-ICE
Men16T	CFB	1/7/2008	F-NM	F-NM	F-ICE	------	F-ICE
Men16T	CFB	1/23/2008	F-NM	F-NM	F-ICE	------	3.7
Men16T	CFB	1/30/2008	F-NM	F-NM	F-NM	------	3.4
Men16T	CFB	2/6/2008	F-NM	F-NM	0.0049	------	34.4
Men16T	CFB	2/28/2008	F-NM	F-NM	F-BDL	0.0005	2.9
Men17T	CFB	10/27/2006	0.33	0.33	F-BDL	0.0005	2.2
Men17T	CFB	11/14/2006	0.90	0.89	F-NM	------	7.3
Men17T	CFB	12/21/2006	0.62	0.61	F-NM	------	3.1
Men17T	CFB	1/10/2007	0.72	0.72	0.0041	------	3.2
Men17T	CFB	3/15/2007	0.50	F-NM	F-NM	------	5.4
Men17T	CFB	3/23/2007	0.45	0.45	0.0017	------	28.6
Men17T	CFB	4/2/2007	0.49	0.49	0.0069	------	6.2
Men17T	CFB	4/16/2007	F-NM	F-NM	F-NM	------	13.5
Men17T	CFB	4/30/2007	0.58	0.58	F-NM	------	6.7
Men17T	VOL	5/21/2007	0.54				3.8
Men17T	CFB	5/21/2007	0.54	0.54	F-NM	------	4.3
Men17T	CFB	5/24/2007	0.40	0.40	F-NM	------	2.1
Men17T	CFB	6/4/2007	0.12	0.12	F-NM	------	10.5
Men17T	VOL	6/6/2007	0.70				11.1
Men17T	CFB	6/21/2007	0.46	0.46	F-BDL	0.0001	2.1
Men17T	VOL	7/11/2007	0.24				3.0
Men17T	CFB	7/25/2007	0.14	0.14	F-BDL	0.0000	12.7
Men17T	VOL	8/15/2007					-----
Men17T	CFB	8/29/2007	F-NM	F-NM	F-DRY	------	F-DRY
Men17T	VOL	9/13/2007					-----
Men17T	CFB	9/30/2007	F-NM	F-NM	F-DRY	------	F-DRY
Men17T	CFB	10/29/2007	F-NM	F-NM	F-DRY	------	F-DRY
Men17T	CFB	11/16/2007	F-NM	F-NM	F-NM	------	2.5
Men17T	CFB	11/30/2007	0.24	0.24	F-BDL	0.0003	1.0
Men17T	CFB	12/18/2007	0.36	0.36	F-BDL	0.0003	F-TS
Men17T	CFB	1/23/2008	0.60	0.60	F-NM	------	1.5
Men17T	CFB	1/30/2008	0.50	0.50	F-NM	------	2.3
Men17T	CFB	2/16/2008	0.68	0.68	F-NM	------	2.9
Men17T	CFB	2/28/2008	F-NM	F-NM	F-BDL	0.0010	1.3

Appendix E: Statistical Results for Response of Anion/Cations with Land-Use and Slope

Sodium responded with land-use but not with slope p 0.0212

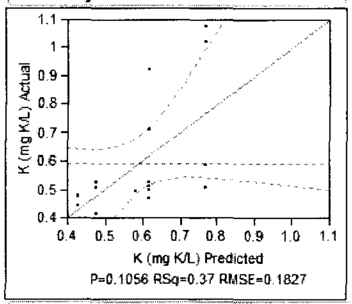


Potassium did not respond with either land-use or slope

Response K (mg K/L)

Whole Model

Actual by Predicted Plot



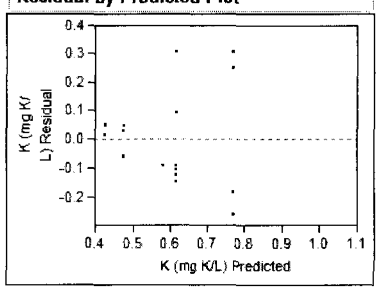
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.5902262	0.048891	12.07	<.0001*
land_use[D]	0.0941786	0.054578	1.73	0.1081
Slope Classification[a]	0.0856667	0.075936	1.13	0.2796
Slope Classification[b]	-0.066619	0.063254	-1.05	0.3114

Effect Tests

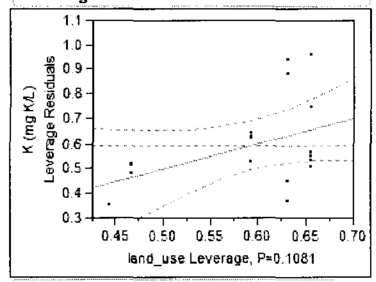
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
land_use	1	1	0.09933956	2.9776	0.1081
Slope Classification	2	2	0.07320617	1.0972	0.3628

Residual by Predicted Plot



land_use

Leverage Plot

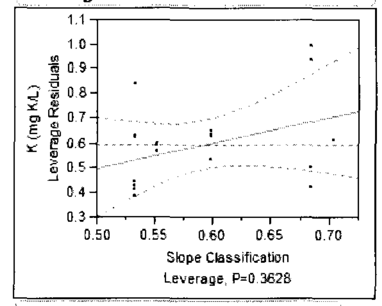


Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
D	0.68440476	0.07417185	0.678700
N	0.49604762	0.07236496	0.471571

Slope Classification

Leverage Plot



Least Squares Means Table

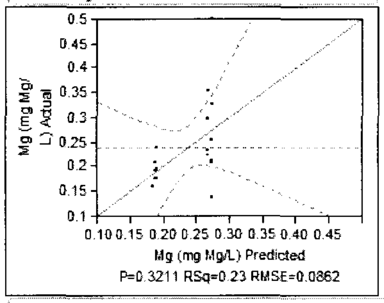
Level	Least Sq Mean	Std Error	Mean
a	0.67589286	0.08800402	0.732400
b	0.52360714	0.06354399	0.555000
c	0.57117857	0.11874064	0.477000

Magnesium did not respond to land-use slope

Response Mg (mg Mg/L)

Whole Model

Actual by Predicted Plot



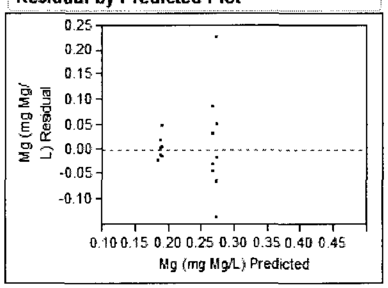
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.2295992	0.02308	9.95	<.0001*
land_use[D]	0.0419643	0.025764	1.63	0.1273
Slope Classification[a]	-0.003778	0.035846	-0.11	0.9177
Slope Classification[b]	0.0030794	0.02986	0.10	0.9194

Effect Tests

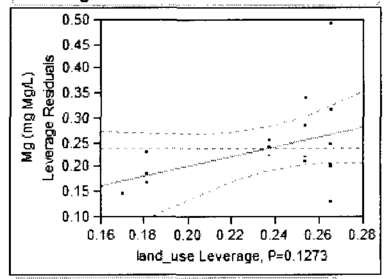
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
land_use	1	1	0.01972321	2.6530	0.1273
Slope Classification	2	2	0.00014888	0.0100	0.9900

Residual by Predicted Plot



land_use

Leverage Plot

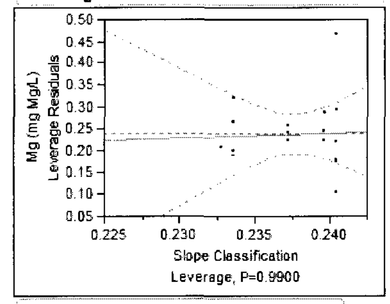


Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
D	0.27156349	0.03501368	0.271900
N	0.18763492	0.03416072	0.188714

Slope Classification

Leverage Plot



Least Squares Means Table

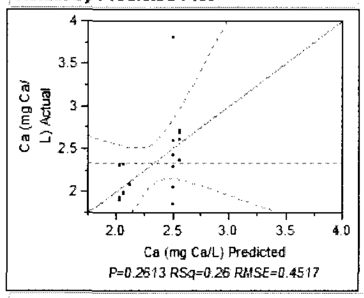
Level	Least Sq Mean	Std Error	Mean
a	0.22582143	0.04154332	0.251000
b	0.23267857	0.02999668	0.246667
c	0.23029762	0.05605290	0.188333

Calcium did not respond to land-use or slope.

Response Ca (mg Ca/L)

Whole Model

Actual by Predicted Plot



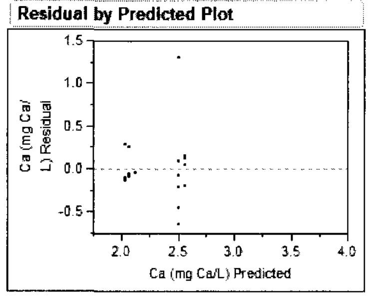
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	2.2891653	0.120921	18.93	<.0001*
land_use[D]	0.2187738	0.134985	1.62	0.1291
Slope Classification[a]	0.0523704	0.187809	0.28	0.7847
Slope Classification[b]	-0.009312	0.156444	-0.06	0.9534

Effect Tests

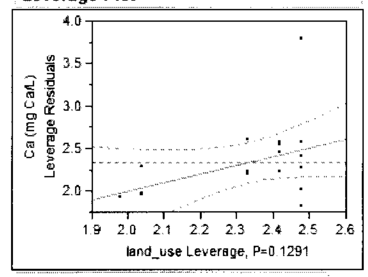
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
land_use	1	1	0.53605417	2.6267	0.1291
Slope Classification	2	2	0.01612897	0.0395	0.9614

Residual by Predicted Plot



land_use

Leverage Plot

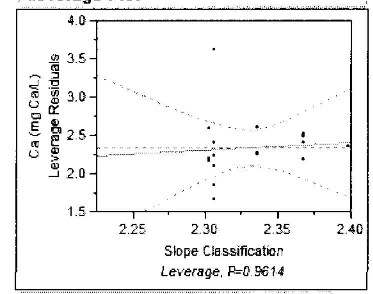


Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
D	2.5079392	0.18344660	2.52330
N	2.0703915	0.17897767	2.05543

Slope Classification

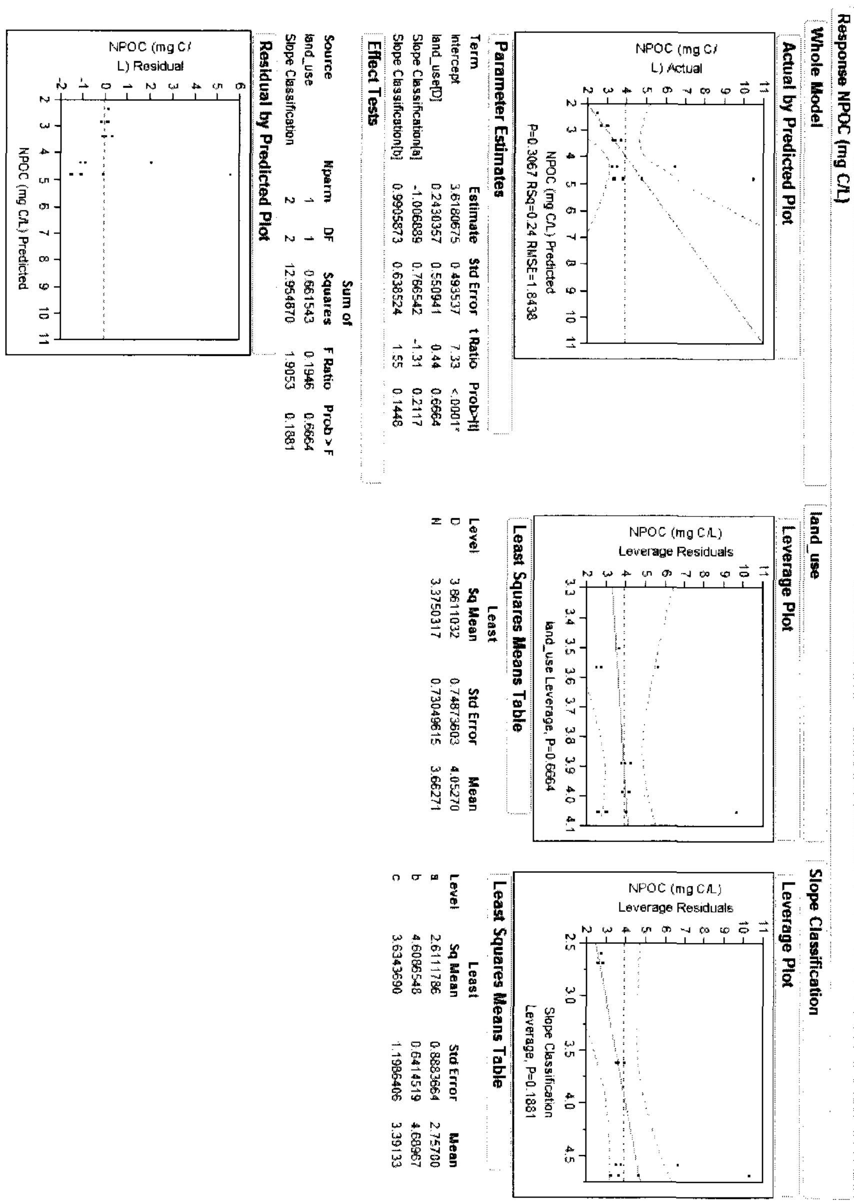
Leverage Plot



Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
a	2.3415357	0.21765720	2.47280
b	2.2798532	0.15716109	2.35278
c	2.2461071	0.29367699	2.02733

NPOC did not respond to land-use or slope

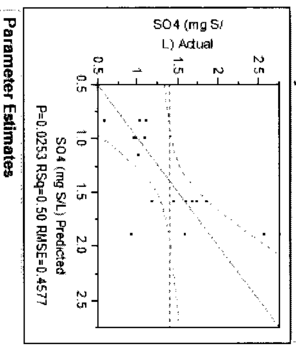


Sulfate responded with land-use but not with slope

Response SO4 (mg S/L)

Whole Model

Actual by Predicted Plot



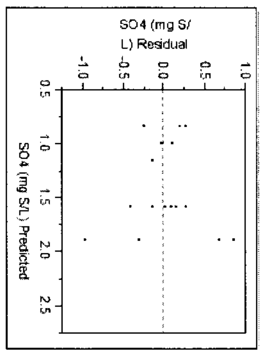
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1.366455	0.122525	11.15	<.0001*
land_use[D]	0.3748095	0.136776	2.74	0.0168*
Slope Classification[a]	0.1572593	0.1903	0.83	0.4235
Slope Classification[b]	-0.15528	0.158519	-0.98	0.3452

Effect Tests

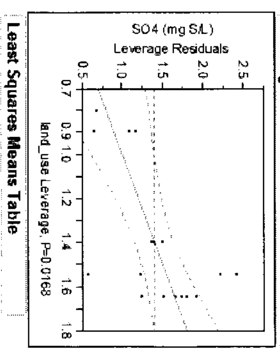
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
land_use	1	1	1.5734004	7.5094	0.0168*
Slope Classification	2	2	0.3173811	0.7574	0.4885

Residual by Predicted Plot



land_use

Leverage Plot

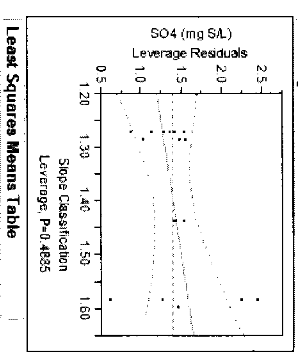


Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
D	1.7412646	0.18587985	1.71100
N	0.9916455	0.18135165	0.94671

Slope Classification

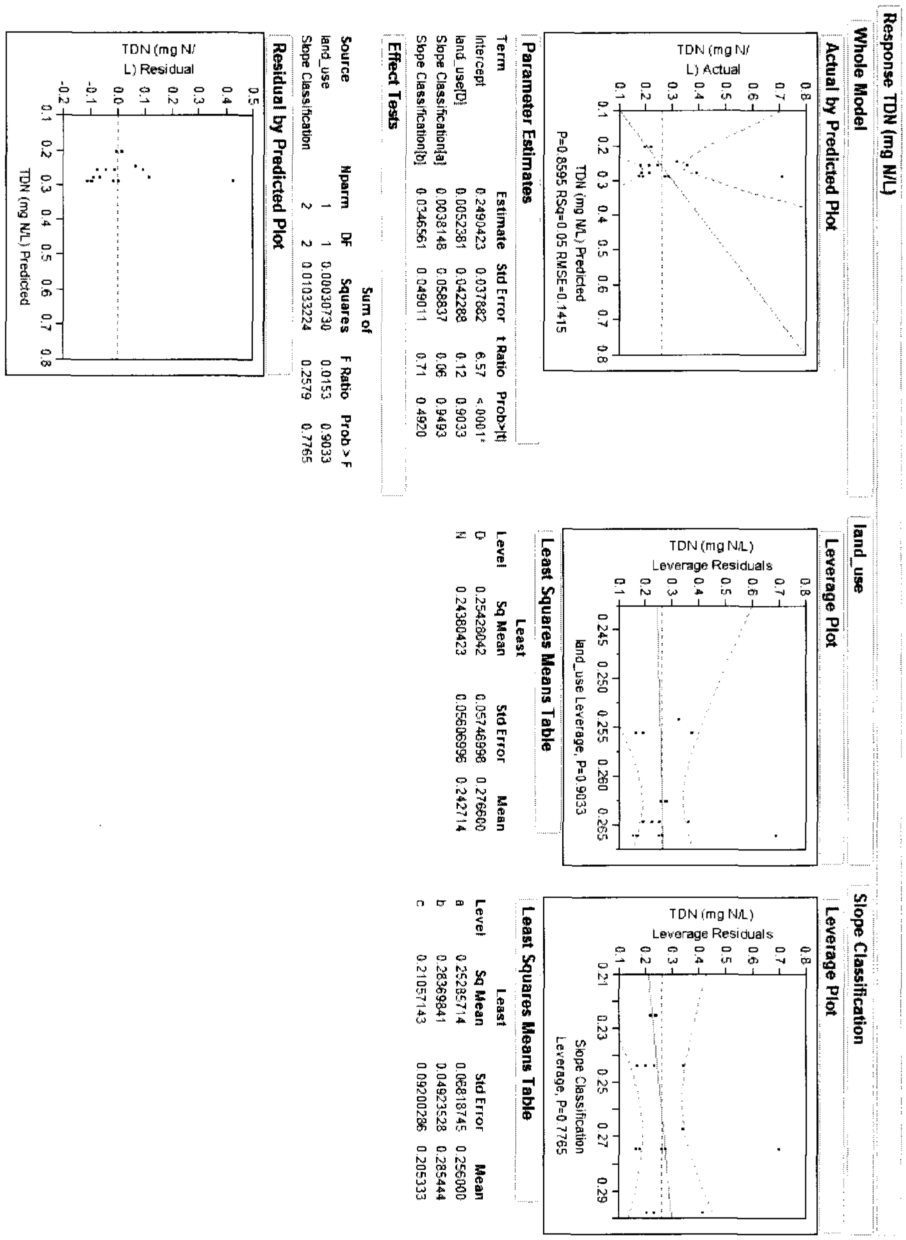
Leverage Plot



Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
a	1.5237143	0.22054423	1.74860
b	1.2111746	0.15924569	1.33611
c	1.3644762	0.29757234	0.96967

No response detected for TDN



Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.2490423	0.037882	6.57	<.0001*
land_use[D]	0.0052381	0.042288	0.12	0.9033
Slope Classification[a]	0.0038148	0.058837	0.06	0.9493
Slope Classification[b]	0.0346561	0.049011	0.71	0.4920

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
land_use	1	1	0.00030730	0.0153	0.9033
Slope Classification	2	2	0.01033224	0.2579	0.7765

Least Squares Means Table (land_use)

Level	Least Sq Mean	Std Error	Mean
D	0.25428042	0.05746998	0.276600
N	0.24380423	0.05606996	0.242714

Least Squares Means Table (Slope Classification)

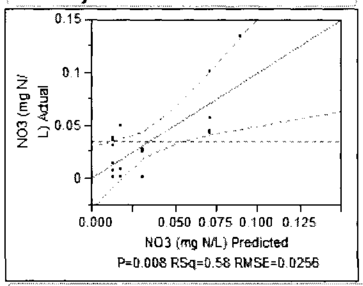
Level	Least Sq Mean	Std Error	Mean
a	0.25285714	0.06818745	0.256000
b	0.28369841	0.04923528	0.285444
c	0.21057143	0.09200286	0.205333

Nitrate increased with slope (p = 0.0033) but not with land-use

Response NO3 (mg N/L)

Whole Model

Actual by Predicted Plot



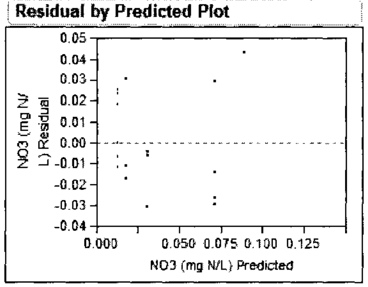
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.0369233	0.006856	5.39	0.0001*
land_use[D]	-0.009119	0.007654	-1.19	0.2548
Slope Classification[a]	0.0431481	0.010649	4.05	0.0014*
Slope Classification[b]	-0.015106	0.008871	-1.70	0.1124

Effect Tests

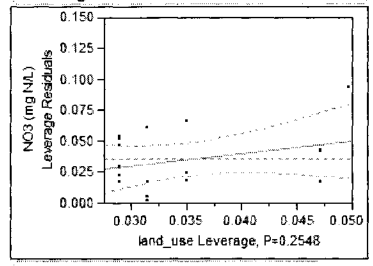
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
land_use	1	1	0.00093136	1.4195	0.2548
Slope Classification	2	2	0.01198603	9.1342	0.0033*

Residual by Predicted Plot



land_use

Leverage Plot

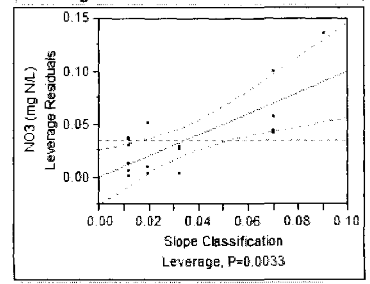


Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
D	0.02780423	0.01040164	0.036000
N	0.04604233	0.01014825	0.033714

Slope Classification

Leverage Plot



Least Squares Means Table

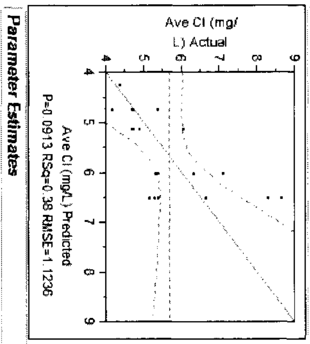
Level	Least Sq Mean	Std Error	Mean
a	0.08007143	0.01234142	0.074600
b	0.02181746	0.00891122	0.018778
c	0.00888095	0.01665183	0.018000

Chloride responded with land-use (p = 0.0207) but not slope classification

Response Ave Cl (mg/L)

Whole Model

Actual by Predicted Plot



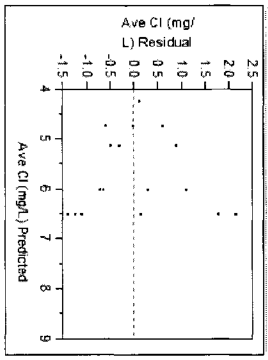
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	5.600754	0.300756	18.62	<.0001*
land_use[D]	0.8839286	0.335737	2.63	0.0207*
Slope Classification[a]	-0.471111	0.467122	-1.01	0.3316
Slope Classification[b]	0.0312698	0.389109	0.08	0.9372

Effect Tests

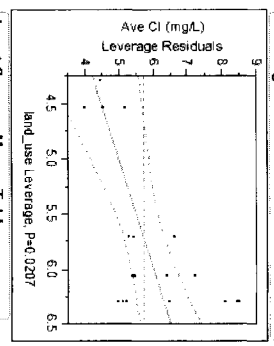
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
land_use	1	1	8.7508929	6.9316	0.0207*
Slope Classification	2	2	1.2841619	0.5086	0.6128

Residual by Predicted Plot



land_use

Leverage Plot

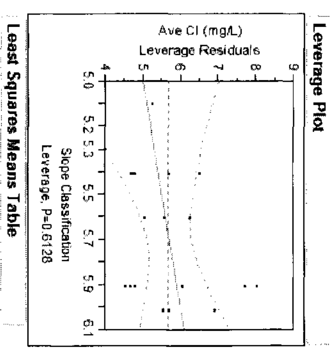


Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
D	6.4846825	0.45627115	6.31500
N	4.7168254	0.44515597	4.85143

Slope Classification

Leverage Plot



Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
a	5.1296429	0.54136029	5.66000
b	5.6320238	0.39089344	5.92667
c	6.0405952	0.73043784	5.15667