Sources of Unwanted Nutrients at Findley Lake, NY

Findley Lake Watershed, view looking south

by

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Sources of Unwanted Nutrients at Findley Lake, NY

March 14, 2007

Summary

Three types of chemical information are available from water well samples from the Findley Lake watershed: nitrates (as NO_3-N), total phosphorus, and chlorides. As per the State of the Lake report, most quantities of these well-water chemicals (N, P, Cl) are above background values and in ranges associated with human-caused contamination. The three chemicals are neither randomly nor uniformly distributed through the watershed. Each has its own unique distribution. Nitrates in wells are especially prevalent at the northeast end of the lake (north central watershed). Phosphorus in wells occurs predominantly around the lakeshore. Chlorides in wells occur predominantly along roads around the lake, but especially in the urban area at the north end of the lake.

In addition to the distinctive map patterns mentioned above, we plotted bivariate graphs and calculated statistical correlations among the three well-water chemicals (N, P, Cl). The three chemical parameters are not statistically correlated with each other, which is evidence that each well-water chemical is primarily controlled by a different source.

A statistical investigation of the chemical well data revealed that there are no significant correlations between well depths and chemical quantities, other than to say that the very highest couple of values for each chemical type are for shallow wells. Thus we conclude that the dot patterns in the maps reflect real lateral variations and not vertical influences. The sand and gravel below and adjacent to the lake circulates water freely and has done so long enough that contaminants are vertically dispersed.

In summary, in groundwater adjacent to Findley Lake NO_3-N (nitrate) concentrations above 4 mg/L are almost entirely from agriculture, and at least partly from agriculture when between 1 and 4 mg/L. Total phosphorus concentrations above 0.05 mg/L are usually from septic systems. Chlorides above 15 mg/L are from road deicing. We estimate that 42% of wells are impacted by farm nitrates, 65% of wells are impacted by septic systems, and 70% of wells are impacted by road salt. Each contaminate type (N, P, Cl) requires its own BMPs. We reiterate the recommendation in the State of the Lake Report that there needs to be long term monitoring of ground water quality at several depths and sites; this will aid in demonstrating BMP success.

Sources of Unwanted Nutrients in Findley Lake, NY

Purpose and Scope

The citizens of the Findley Lake, NY watershed, especially the Town of Mina and the Findley Lake Watershed Foundation, are committed to improving the lake quality both in the near future and the long run. Citizen stewardship of the watershed and lake were demonstrated by participation in and completion of a State of the Lake Report (2002) and Management Plan (2002). Because of such lake investigation and planning, citizens were and are in a position to implement watershed and lake improvements. The various investigations led to proposals of site-specific best management actions such as addressing nutrient contributions from septic systems.

The community is involved in on-going benefit-cost analysis of BMPs (best management practices, i.e., actions). Benefit-cost analysis of BMPs not only involves economic analysis, but may also include detailed investigation of practical or logistical benefits of outcomes. Previous work such as the State of the Lake Report identified nutrients as causes of unwanted algae and invasive plants. The **purpose** of this report is to review evidence for sources of nutrients so that BMPs will have greatest practical benefits in reducing nutrients.

The scope of this project was to estimate the portion of groundwater contamination by source. Information was organized into computer databases for production of maps of land use, soil water infiltration, nutrient quantities, and indicator “water-quality” parameters (chlorides). This method is referred to as a Geographic Information System (GIS) and gives the scientist the ability to construct dozens or hundreds of maps of relationships between features, materials, processes or phenomena. Additionally, we also used traditional methods of analysis such as graphs of statistical correlations and geological cross-sections.

Background

Setting

Findley Lake was created by Alexander Findley in 1812 when damming the outlet of two ponds. A larger dam was built in the 1900s and today the lake covers 310 acres. The illustration on the cover of this report shows the view southward of the lake and surrounding watershed. The bathymetry under the lake is also shown including the two deep areas that were ponds formed from melting glacial ice about 16,000 or 17,000 years ago. The watershed around the lake comprises about 3,000 acres (4.7 mi^2). Busink's Creek is in the front left of this southerly view and is the largest of five creeks that together drain 62% of the lake watershed. Near the lake are 411 residences and 36 commercial establishments, all served by onsite wastewater treatment systems ("septic systems").

The water budget of Findley Lake is:

% Inputs		% Outputs	
groundwater	39	outlet	91
streams	28	evaporation	8
peripheral runoff	21	dam seepage	1
precipitation on lake	12		

Consequently both groundwater and surface runoff are very important to lake quality. This investigation focuses on groundwater (wells). The State of the Lake report concluded that 81% of chloride (Cl), 29% of total phosphorus (TP) and 49% of nitrate-nitrogen (NO_3-N) in the lake entered via groundwater. Cl and NO_3-N are typically able to pass through sediment (soil) and at least some TP also bypasses soil (especially through sand and gravel). Generally, groundwater chemical values are expected to be below 15 mg/L for Cl, 0.020 mg/L for TP, and 0.500 mg/L for NO_3-N. These threshold values may be compared to values cited on maps later in the report. In this study we are concerned both about groundwater quality impacting the lake and also about drinking water quality (well water).

Literature Review: Sources of Contaminants

It is now recognized that normally functioning septic systems with leach fields (seepage pits will be worse) can contribute substantial amounts of phosphorus to lakes or rivers (Green, 2002). Seventy percent of incoming TP may be passed through the system in sand and gravel soils such as those that surround Findley Lake. Systems older than 30 years may be worse. Once contaminated, phosphorus-bearing soils leach phosphorus for decades.

The NY City Department of Environmental Protection (NYC-DEP) reported at the NYC Watershed Conference (2006) that forested areas had Total Dissolved Phosphorus (TDP) of 0.005 to 0.015 mg/L while shallow monitor wells near septic systems contained 0.075 (May) to 0.175 (September) mg/L, deep monitor wells 0.025 to 0.085 mg/L, and manured fields 0.015 to 0.030 mg/L. In a study of a septic system plume in Lake Ontario shore sand, Ptacek (1998) found elevated phosphorus 60 meters (200 ft) toward the lake from the system and found PO_4-P up to 1.5 mg/L near drain tiles.

Nitrates (NO_3-N) were measured (Stites and Kraft, 2001) in ground water in sand near rotated potato, bean, pea and corn fields at 50 to 80 mg/L from fertilizer use at recommended levels. Also, KCl fertilizer use in the same study yielded similar concentrations of Cl. In an unpublished investigation of a Cl plume from deicing-salt storage on sand and gravel, the

Cattaraugus County Health Department measured over 2,000 mg/L Cl in home wells and a change in creek flow from 14 mg/L Cl upstream to 28 mg/L Cl downstream of the plume.

In summary, while there may be several sources of each contaminant, it is likely that septic systems will dominate TP, fertilizing vegetables will dominate NO_3-N, and road salt will dominate Cl. When all contaminants show up in the same place at once it will be difficult to determine sources. However, if the contaminants are geographically separated and adjacent to their likely sources, as in the later part of this report, then source identification is fairly simple.

GIS Maps Showing Land Use and Subsurface Relationships

Discussion in the following paragraphs guides the reader from land cover information through topography, soils, infiltration and into subsurface information. Then in the next section we present water quality data and move the discussion in the reverse sequence from subsurface conditions to soils and infiltration, to land cover.

More than half of the Findley Lake watershed is covered by forest and shrub lands (Boria and Wilson, ed., 2002), Figure 1. Farming occurs along Rte 430, Bailey Hill Rd. and Mann Rd at the north end of the watershed and farms also cover the tip of the south end of the watershed (Fig. 1). As with agriculture, residential development has almost no dispersion through the watershed; instead, residential land use dominates the lake shoreline (Fig. 1).

Detailed land use statistics are given in Table 1 from the Findley Lake State of the Lake Report (Boria and Wilson, ed., 2002). This will be convenient in the following paragraphs because it will give a sense of land use (land cover) as it applies to areas underlain by porous soils around the lake.

Another kind of land use that is important to understanding sources of nutrients is sewage waste disposal. Figure 2 shows parcel boundaries and types of septic systems. Exact geographic coordinates of septic systems are not known, however systems are known by parcel locations. The smaller the parcel the better for knowing the septic system location within the watershed, or as compared to soil boundaries, for example. Four types of septic systems are identified in the Findley Lake watershed and adjacent northerly area from CCDOH records. As of 2006, CCDOH issued 217 septic permits: 75 leach fields; 122 seepage pits; 18 sand filters; and 2 combined seepage pits with leach fields. This accounts for only 49% of the homes and commercial developments that exist in the watershed and adjacent northerly area. In essence, the other 51% do have some sort of septic system, but CCDOH does not have a record of them because they were either installed before 1968 or were put in without a permit. Figure 3 provides examples of different types of septic systems. Most systems in the Findley Lake watershed are near the lake.

Figure 4 presents the topographic contours and resulting watershed boundary. The uplands are composed of many small cigar-shaped hills (drumlins) with intervening shallow swales or sometimes deep ravines. These features were sculpted about 18,000 to 16,000 years ago by the great Laurentide glacier, along with the central valley now occupied by Findley Lake. As the glacier melted away it left deposits of mostly sand and gravel under and marginal to Findley Lake. Ravines were cut during the past 16,000 years and continue to be carved today. Streams in these ravines cut, rearrange, and deposit rock and soil. For example, Busink's Creek has a large gravel fan deposit that extends under the lake. The land uses and septic systems are on and in the surface of this glacial and post-glacial terrain.

The topography is immediately underlain by about fifty kinds of topsoils or subsoils as mapped by the U.S. Department of Agriculture (USDA). SUNY Fredonia, with input from USDA, reorganized these soil types into a dozen categories that indicate the kinds of near-surface sediments (Figure 5). These are the basic materials like clay or sand that occur within about three to five feet of the ground surface. USDA does not typically investigate soils below five feet. As can be seen in Figure 5, the uplands (purple on map) are underlain by clayey-gravelly soils while the central lake valley contains well-sorted layers of clay, silts, sand and gravel.

When the USDA makes modern soil maps (such as for Chautauqua County), each of the fifty or so topsoils and subsoils are tested for their ability to allow water percolation (infiltration). The soils are grouped into four basic categories known as hydrogroups A, B, C and D. The characteristics of these categories were summarized by the University of Rhode Island Cooperative Extension in a table we copied as Table 2. Our Figure 6 shows the hydrogroups for the Findley Lake area. Percolation (infiltration) is high in groups A and B, low in C and D. Rainstorm runoff has the opposite relationships.

Figure 7 presents land use ("land cover") compared to hydrogroups (percolation or infiltration). Several of the most extensive agricultural areas cover the most permeable soils in the northern part of the watershed. This relationship suggests the possibility of groundwater impacts in that region.

Recalling that most large parcels have a single septic system, we see that nearly all permitted septic systems (Figure 2) are grouped tightly around the lake. Consequently, nearly all permitted (and unpermitted) septic systems are within sands and gravels with high infiltration (hydrogroups A and B). These relationships immediately imply that septic systems may be sources of groundwater contamination.

Geologic cross-sections (Figures 8 and 9) allow us to perceive relationships deeper underground. Cross-sections are really theories as to what is below ground and the more evidence that is available, then the more inflexible the theory becomes. Several kinds of evidence can be brought to bear. First of all the very tops of the cross-sections are mostly known from USDA soils maps. USDA maps are not perfect, but USDA scientists did walk over much of the ground often probing with an auger or shovel, and relating their observations to air photos and topographic maps and understanding glacier history. Second, the soil geometry can be extended downward and sideward by use of well samples. The New York State Department of Environmental Conservation maintains files of well descriptions that were used to develop the cross-sections. Regrettably, such files are not numerous because NYS-DEC only recently mandated the collection of geologic drilling logs. Never the less, enough driller’s logs were available so that several good cross-sections could be constructed. Specific DEC well numbers used to identify the wells are shown in Figures 8 and 9. Third, knowledge of modern glacial geologic processes is used to help extrapolate information among wells when drawing cross-sections. Fourth, we use knowledge of regional context to constrain interpretations. For example, we know from detailed studies of numerous wells at the Ellery Landfill that drumlins are often cored with shale rock and overlying gray till while the whole region is draped with a cover of brown till on top. This scenario also occurs elsewhere across the county. Several wells in the cross-sections support this notion, as do several wells we studied in the Findley Lake region but slightly off the map (i.e., slightly beyond Fig. 8). There is thus far only one instance in Chautauqua County of drumlins composed of sand and gravel (Fig. 10); the authors are also aware of one instance near Geneseo, NY.

The visualization method used in constructing and presenting cross-sections in Figures 8 and 9 is referred to as serial sections. We completed a series of sections that were parallel to each other and perpendicular to some trend; in this case they are perpendicular to the lake and valley trend.

The cross-sections show that the uplands are commonly underlain by 40 to 100 feet of clayey gravelly glacial till that has low infiltration. The Findley Lake valley is underlain by about 40 to 150 feet of sand and gravel. The valley-filling portions of gravel, sand and clay change in a southerly direction; all gravel to the north but perhaps one-third of each to the south. Deposits that become finer vertically downward and finer laterally southward (Fig. 9) are commensurate with glacier advance from north to south. The irregularly shaped gravel hills forming the lakeshore (Fig. 8) mark a period of glacier melting (stagnation) ending the advance.

Unclear is the exact way that the upland glacial clayey-gravelly tills intersect or interfinger with the valley bottom gravel and sand. Several scenarios are drawn in Figure 9.

What the cross-sections make clear is that surface sources of contaminants such as septic systems, agriculture or road runoff can be connected to water wells in the sense of geometry of layers or hydraulics of porous gravels. In the next section of the report we will examine water chemistry evidence for these connections.

GIS Maps Showing Well Chemistry

Three types of chemical information are available from water well samples from the Findley Lake watershed: nitrates (as NO_3-N), total phosphorus, and chlorides. Usually in the United States, and elsewhere, all three are commonly enhanced by urbanization, agriculture, and sewage, as discussed at the beginning of this report. However, nitrates are especially related to dairy farms and silage production due to manure and other fertilizers; total phosphorus is enhanced by septic systems in addition to agriculture sources; and chlorides are especially added to natural waters by road deicing. As per the State of the Lake report, most quantities of these well-water chemicals (N, P, Cl) are above background values and in ranges associated with human-caused contamination. In the following paragraphs we will discuss the geographic distribution of these well-water chemicals and proceed to relate these distributions to subsurface and surface conditions in the Findley Lake watershed.

The three chemicals (nitrates, phosphorus and chlorides, N, P, and Cl) are neither randomly nor uniformly distributed through the watershed. Each has its own unique distribution. Nitrates in wells (Fig. 11) are especially prevalent at the northeast end of the lake (north central watershed). Phosphorus in wells (Fig. 12) occurs predominantly around the lakeshore. Chlorides in wells (Fig. 13) occur predominantly along roads around the lake, but especially in the urban area at the north end of the lake.

In addition to the distinctive map patterns mentioned above, we plotted bivariate graphs and calculated statistical correlations among the three well-water chemicals (N, P, Cl). Results are in Appendix A (Figures A-1 through A-9 and Table A-1). The three chemical parameters (N, P, Cl) are not statistically correlated with each other, which is evidence that each well-water chemical is primarily controlled by a different source.

A statistical investigation of the chemical well data (Appendix B, Figures B-1 through B-14) revealed that there are no significant correlations between well depths and chemical quantities, other than to say that the very highest couple of values for each chemical type are for shallow wells. Thus we conclude that the dot patterns in the maps (Figs. 11, 12, 13) reflect real lateral variations and not vertical influences. The sand and gravel below and adjacent to the lake (Fig. 8

and 9) circulates water freely and has done so long enough that contaminants are vertically dispersed.

Also notable is that all three contaminants (N, P, Cl) are free to be received from the ground surface adjacent to almost any well. Nearly all wells tested occur in the sand and gravel deposits and in the A and B (high percolation) soil groups, Figures 14 and 15.

Conclusions

Comparing nitrates to land use information in Figure 16 shows that farms on and uphill from the sand and gravel soils (hydrogroups A and B) adjacent to the northern third of Findley Lake are the main nitrate sources. Results shown in Figure 17 indicate residential land use as the primary source of phosphorus. Deicing is the primary cause of chlorides which have high values adjacent to roads, driveways, sidewalks and parking areas (roads and residential land use in Figure 18). Chlorides are highest near the north end of the lake where there is most urbanization. Salt storage may play or have played a role in enhancing Cl values at the north end of the lake. If KCl fertilizers were or are used in this region, then they too may contribute Cl.

In summary, in groundwater adjacent to Findley Lake NO_3-N (nitrate) concentrations above 4 mg/L are almost entirely from agriculture, and at least partly from agriculture when between 1 and 4 mg/L. Total phosphorus concentrations above 0.05 mg/L are usually from septic systems. Chlorides above 15 mg/L are from road deicing. We estimate that 42% of wells are impacted by farm nitrates, 65% of wells are impacted by septic systems, and 70% of wells are impacted by road salt. Each contaminate type (N, P, Cl) requires its own BMPs. We reiterate the recommendation in the State of the Lake Report that there needs to be long term monitoring of ground water quality at several depths and sites; this will aid in demonstrating BMP success.

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University of Rhode Island Cooperative Extension, Jamestown Source Water Assessment and Wastewater Analysis: Soil Hydrogroups
http://www.uri.edu/ce/wq/program/html/SWAP/Reports/Jamestown/James_Appendix.pdf

Table 1. Findley Lake Watershed and Land Use Summary

Entire Findley Lake Watershed

Land Use	Acres	Percent of Basin
Total Agriculture	***900.4***	***30.1***
Confined Feeding Area	0.0	0.0
Corn	159.0	5.3
Farmstead	12.1	0.4
Hayfield	367.8	12.3
Inactive Agriculture	97.6	3.3
Legume	109.2	3.7
Pasture	154.7	5.2
Total Forest	***1725.6***	***57.8***
Forest Brush	53.9	1.8
Forest Land	1671.7	56.0
Total Residential	***183.7***	***6.1***
High Density Residential	128.3	4.3
Rural Estate	0.0	0.0
Rural Residential	49.7	1.7
Rural Sted	5.7	0.2
Other	***177.2***	***5.9***
Barrow/ Fill	7.3	0.2
Commercial	52.0	1.7
Compost	10.5	0.4
Marsh	2.6	0.1
Open Area	58.4	2.0
Pond	0.3	0.0
Public Area	1.7	0.1
Roads	44.4	1.5
Total Watershed	***2986.8***	***100.0***

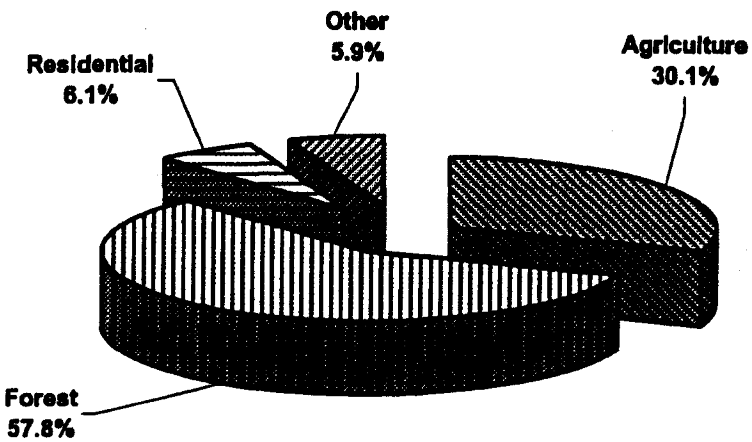


Table 2. Characteristics of Soil Hydrogroups

Soil Hydro-Group	Basic Description	Typical Depth to Seasonal High Water Table From ground surface	Water Quality Risks with Developed Land Use	Management implications
A	Sandy, deep water table, high infiltration, low runoff	Greater than 6 feet	• Highest pollutant movement to groundwater from septic systems and fertilizers, • Largest increase in runoff with impervious cover, • Greatest loss of groundwater recharge with impervious cover.	• Preserve as recharge areas. • Direct stormwater runoff to these areas to promote infiltration after pretreating to remove sediment and other pollutants. • Consider prohibiting deep wastewater seepage pits (galleys); evaluate need for advanced onsite treatment systems.
B	Most are well-drained, moderate runoff, moderate infiltration	Greater than 6 feet or 1½ to 3½ feet	• High potential for pollutant movement to groundwater from septic systems in sandy subsoils, • Moderate increase in runoff and loss of recharge with impervious cover. • May include prime farmland soils.	• Prime soils for building and agriculture. Consider best use to meet town goals and strategies to preserve prime farmland. • Consider prohibiting deep wastewater seepage pits (galleys); evaluate need for advanced onsite treatment systems.
C	Slowly permeable, collection areas for surface water, typically high water table, high runoff	1½ to 3½ feet or 0 to 1½ feet	• High pollutant movement to *surface waters* from septic systems, fertilizers, and land disturbance. • High potential for *hydraulic failure* of septic systems, with surfacing or lateral movement of effluent. • High potential for wet basements, temporary flooding.	• Septic systems may require use of filled leachfields to achieve minimum separation distance to groundwater; consider aesthetic impact of fill and need for advanced treatment. • Stormwater treatment ponds not suitable where water table is less than 2 feet from the ground surface. • Limit filling and regrading required to raise elevation of homes with full basements; consider prohibiting basements in wet soils. • Maintain undisturbed wetland buffers and drainageways. • Prohibit use of subdrains to lower water table; regulate location of subdrains adjacent to isds and their discharge, • Divert runoff from wells and septic systems.
D	Very high water table, often classified as wetlands based on wet (hydric) soils	0 to 1½ feet	• Highest pollutant movement to *surface waters*. • Loss of pollution treatment potential with disturbance of wetland buffers. • Wetland habitat encroachment.	• Avoid impacts to small streams, wetlands, and wetland buffers with development • Treat runoff before discharge to wetlands. • Identify wetland buffers for restoration. • Prohibit use of advanced treatment systems on shallow water tables (less than two feet) for new construction.

Obtained from the University of Rhode Island Cooperative Extension, Jamestown Source Water Assessment and Wastewater Analysis

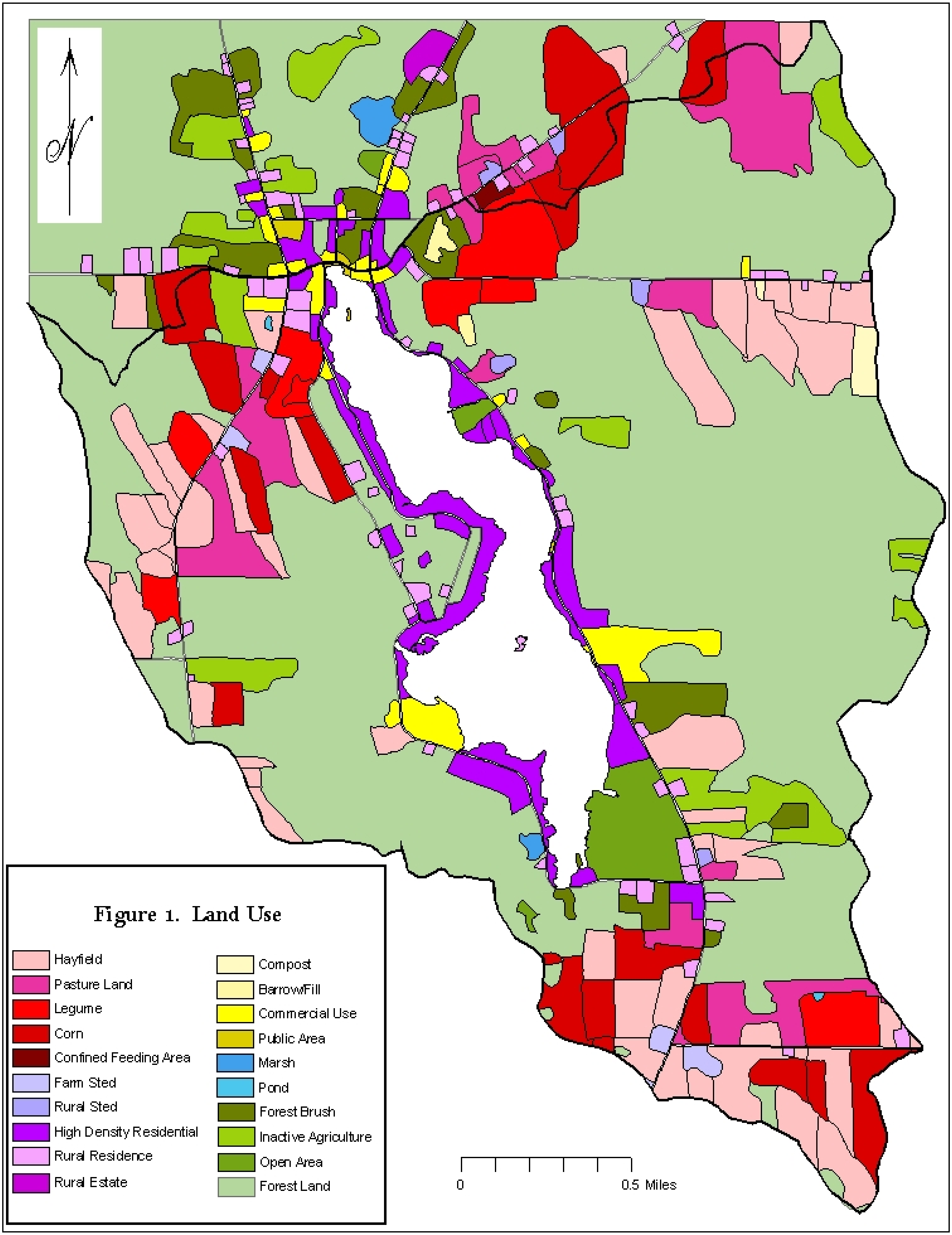


Figure 1. Land Use

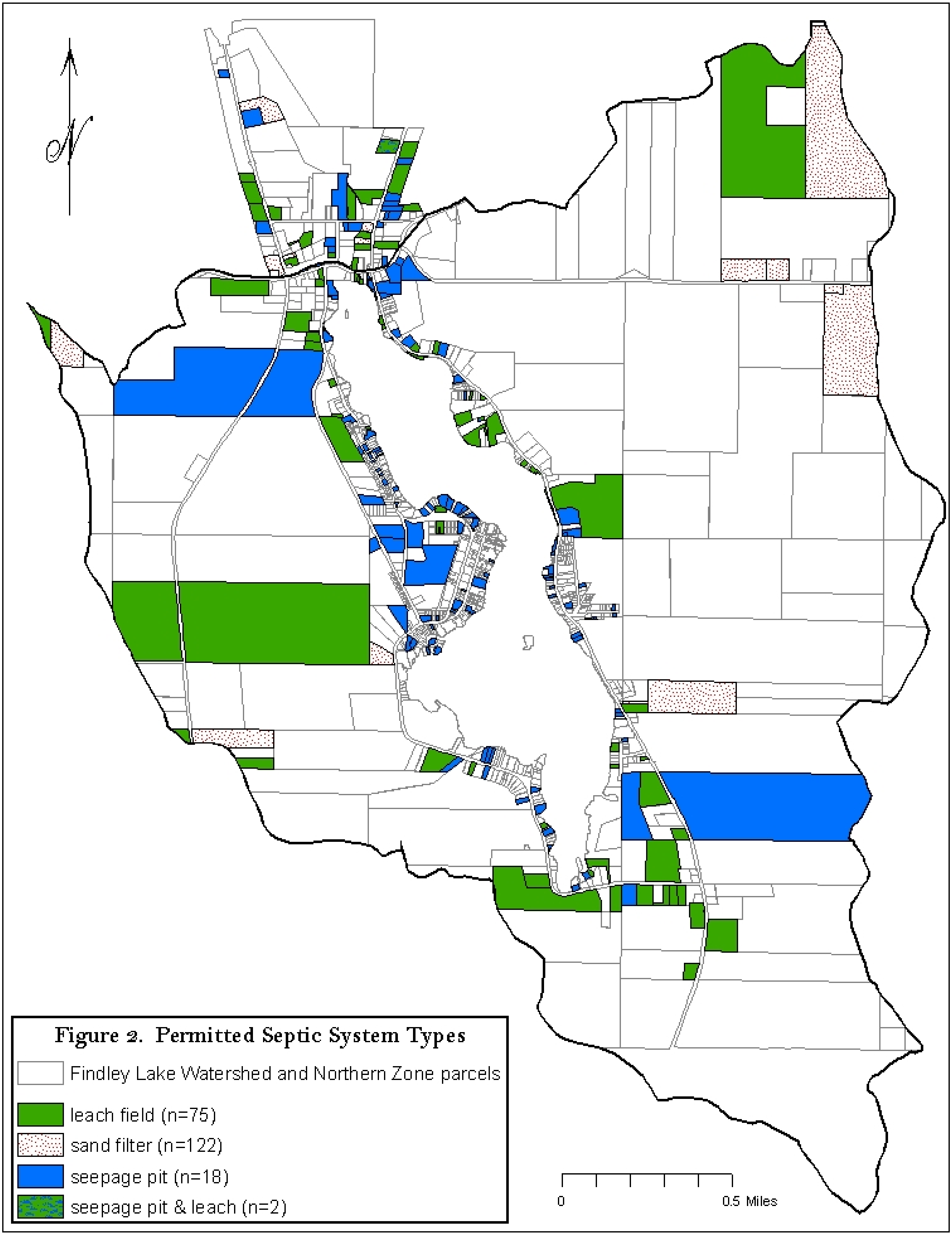
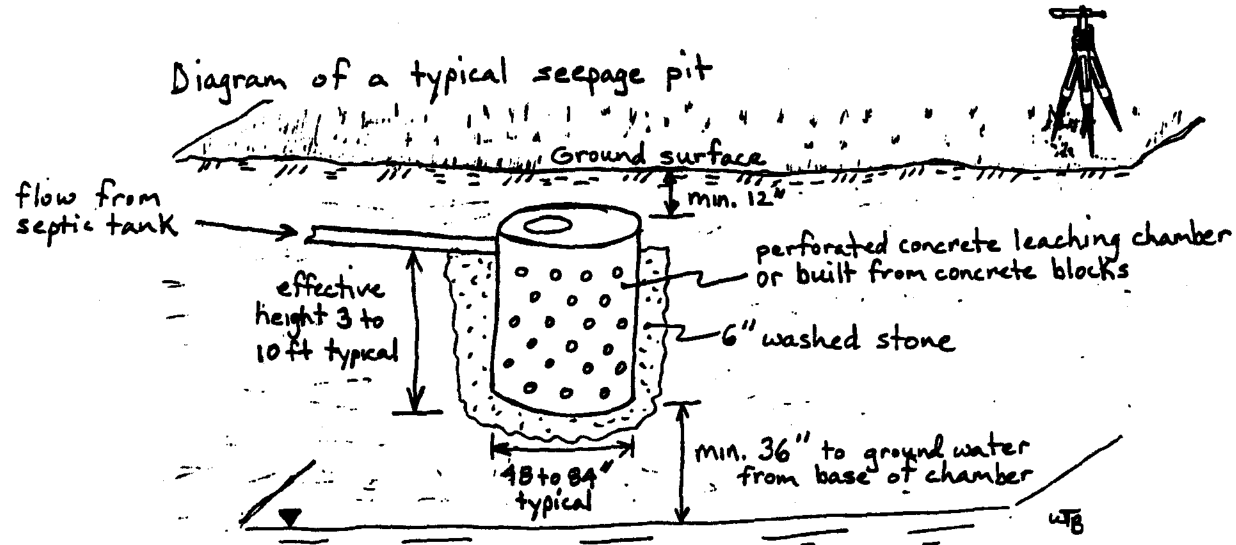
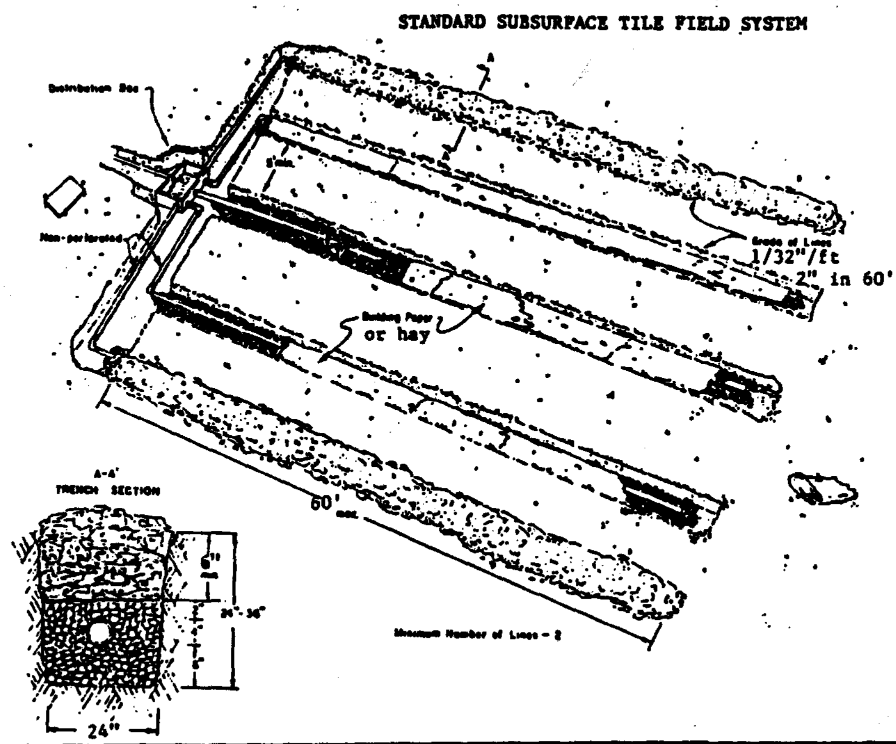
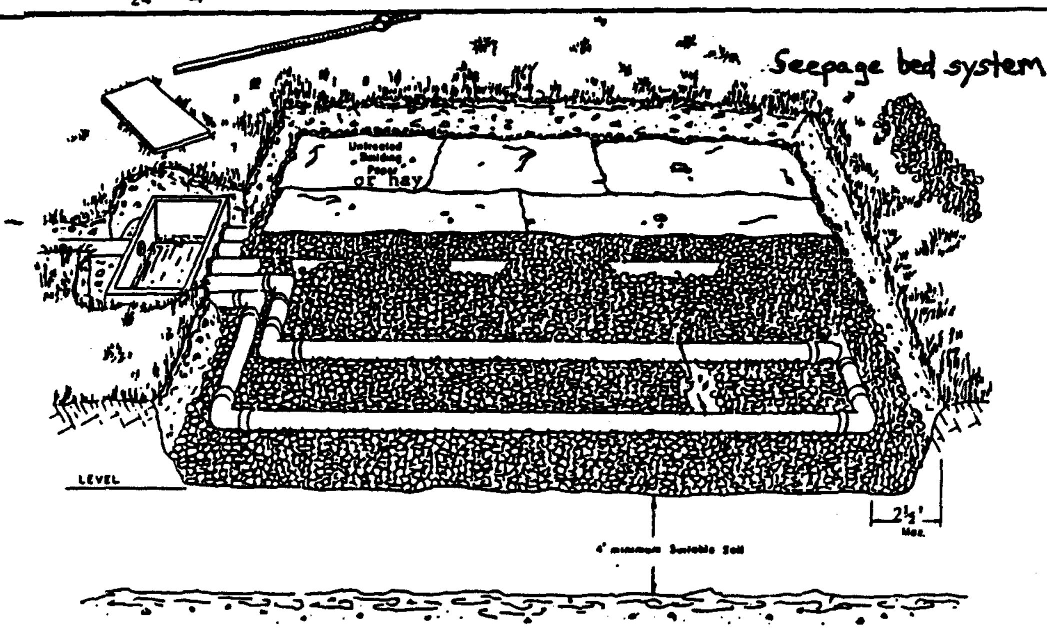


Figure 2. Permitted Septic System Types
Findley Lake Watershed and Northern Zone parcels
leach field (n=75)
sand filter (n=122)
seepage pit (n=18)
seepage pit & leach (n=2)
0
0.5 Miles

Figure 3. Types of Septic Systems







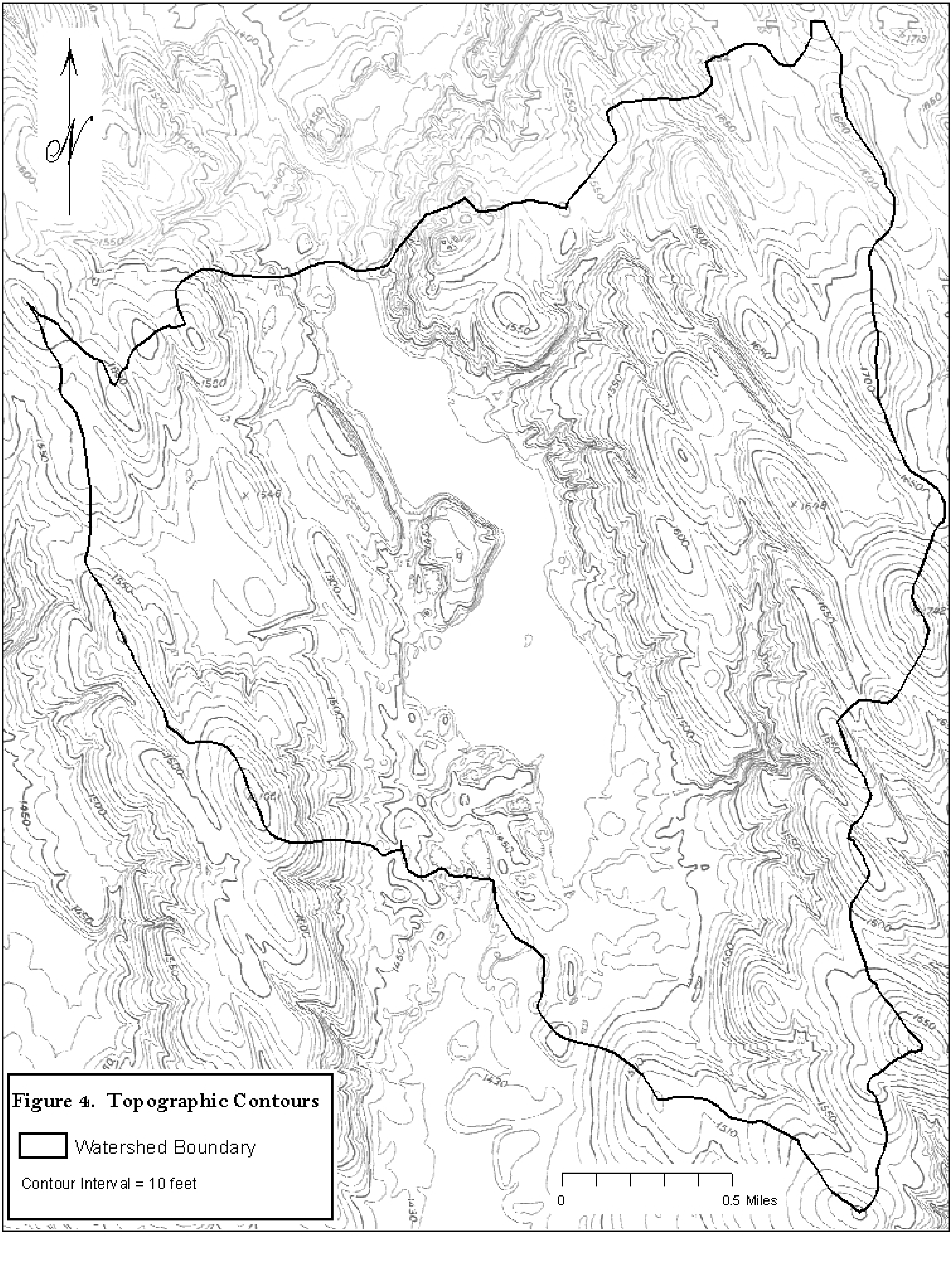


Figure 4. Topographic Contours
Watershed Boundary
Contour Interval = 10 feet
0
0.5 Miles

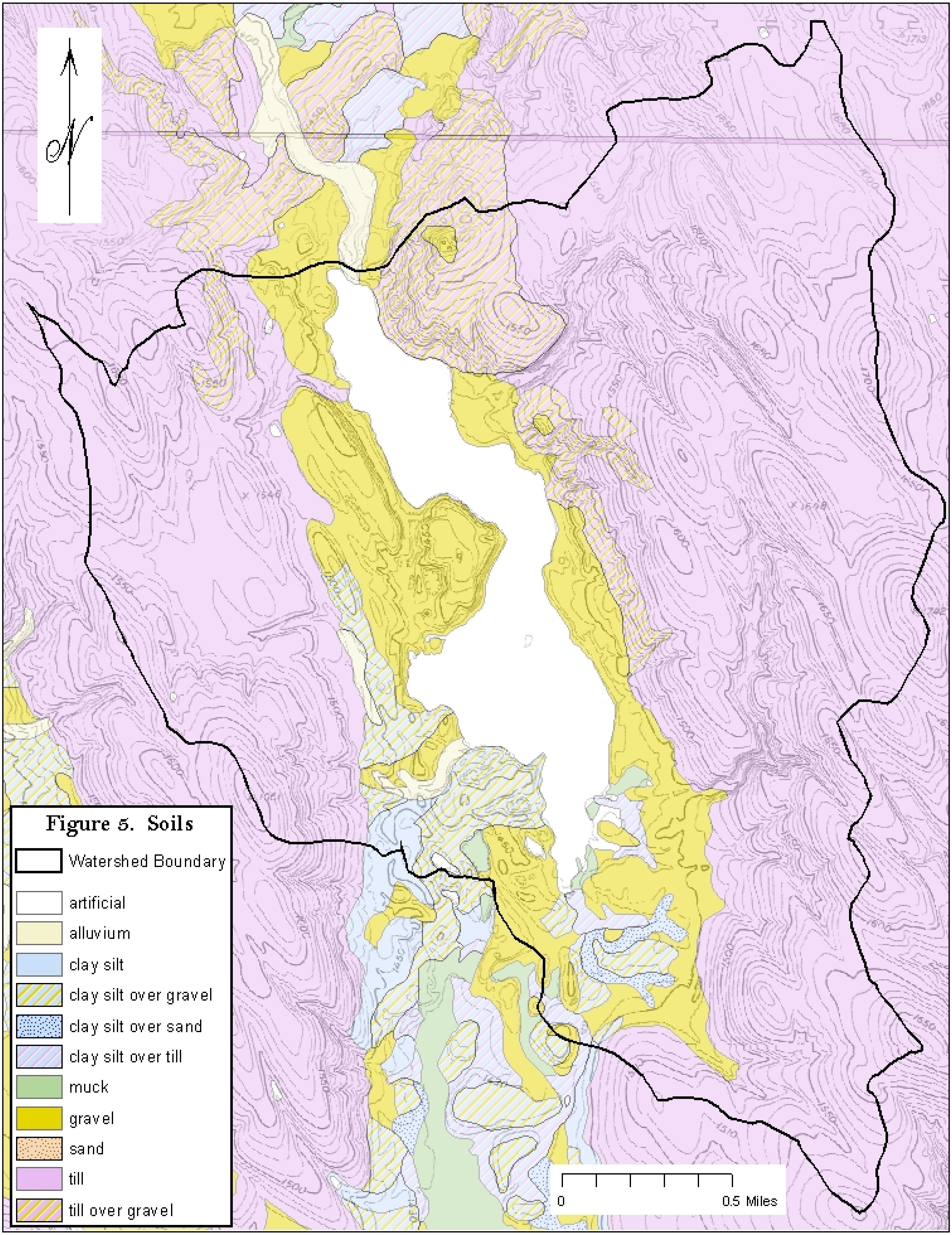


Figure 5. Soils

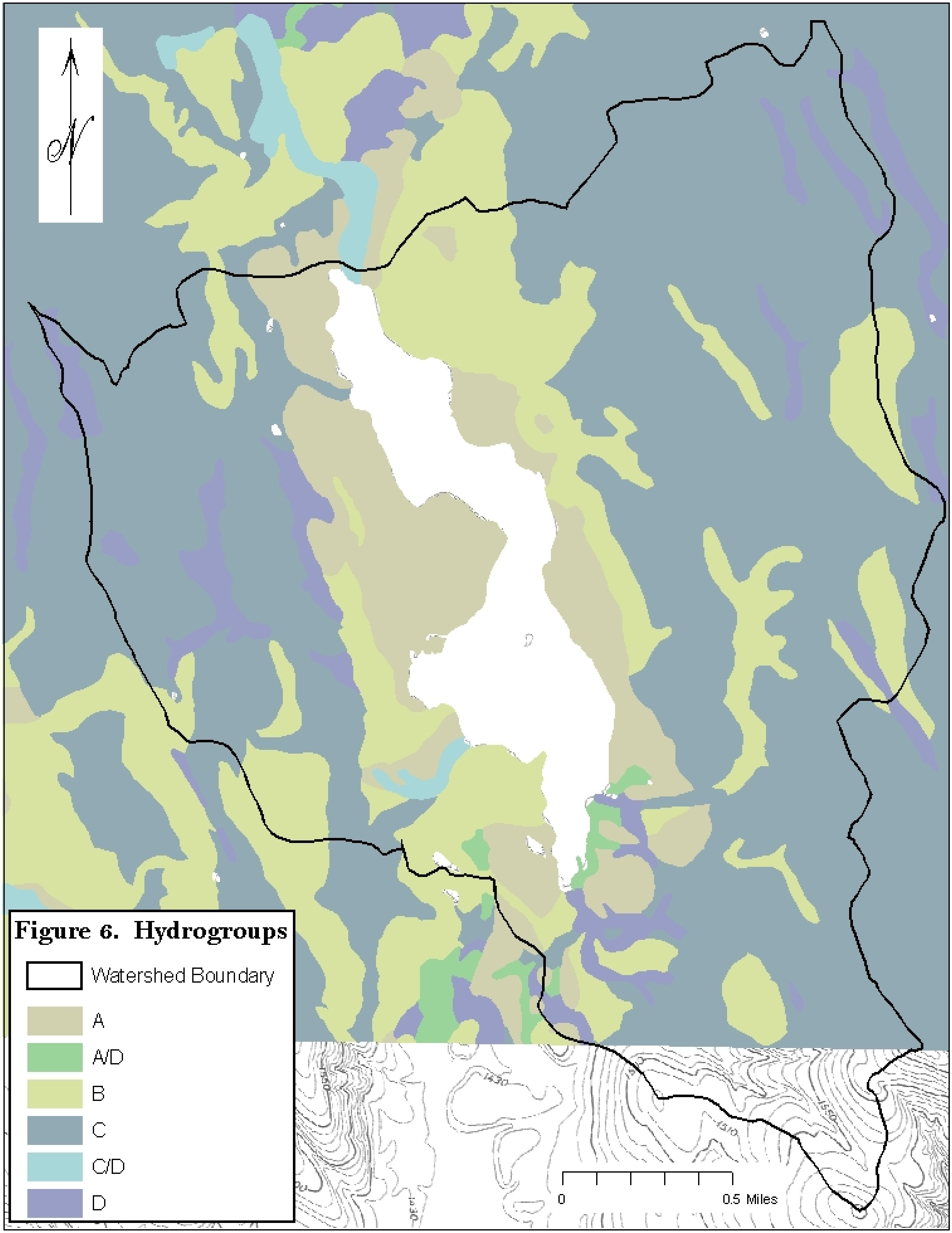


Figure 6. Hydrogroups

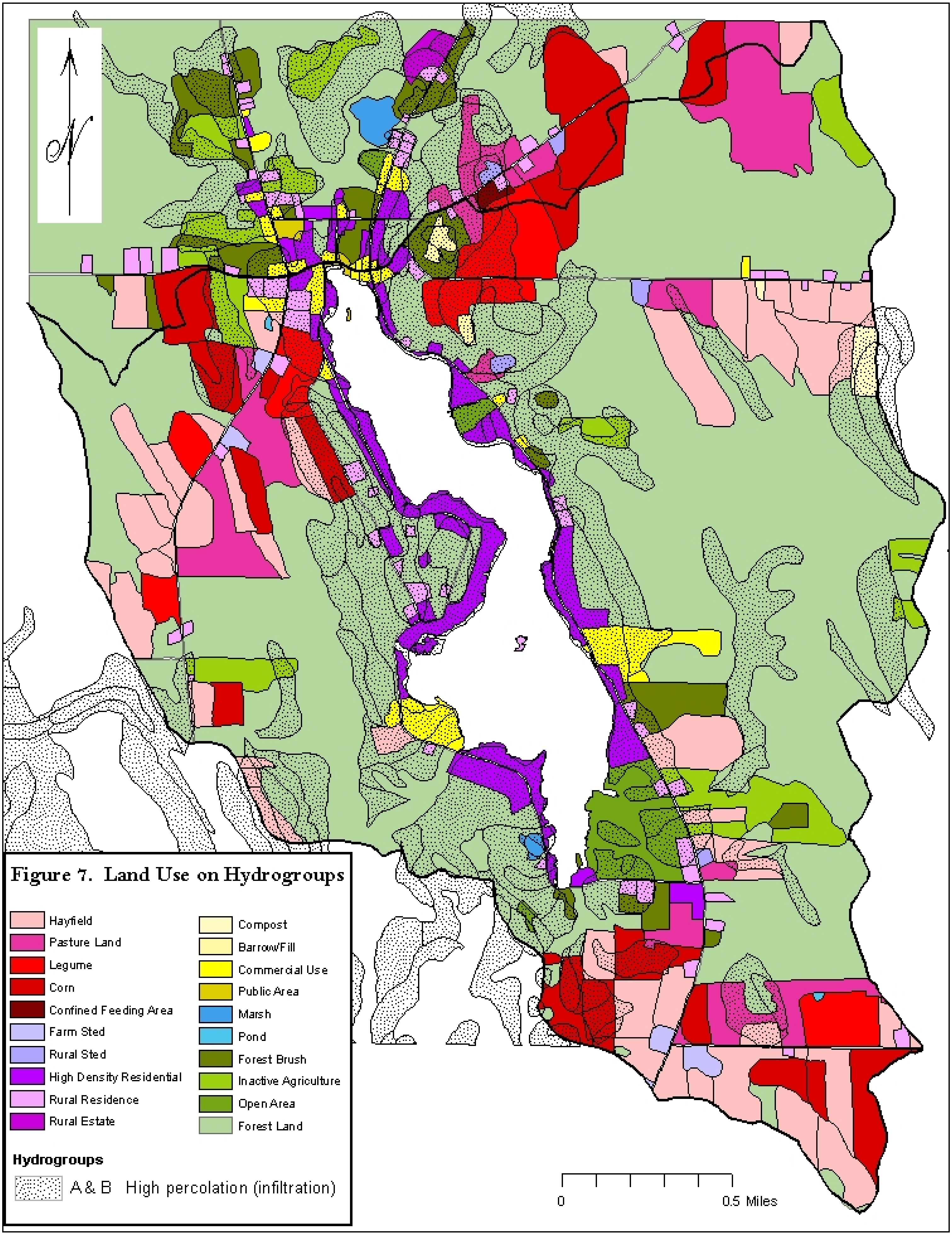
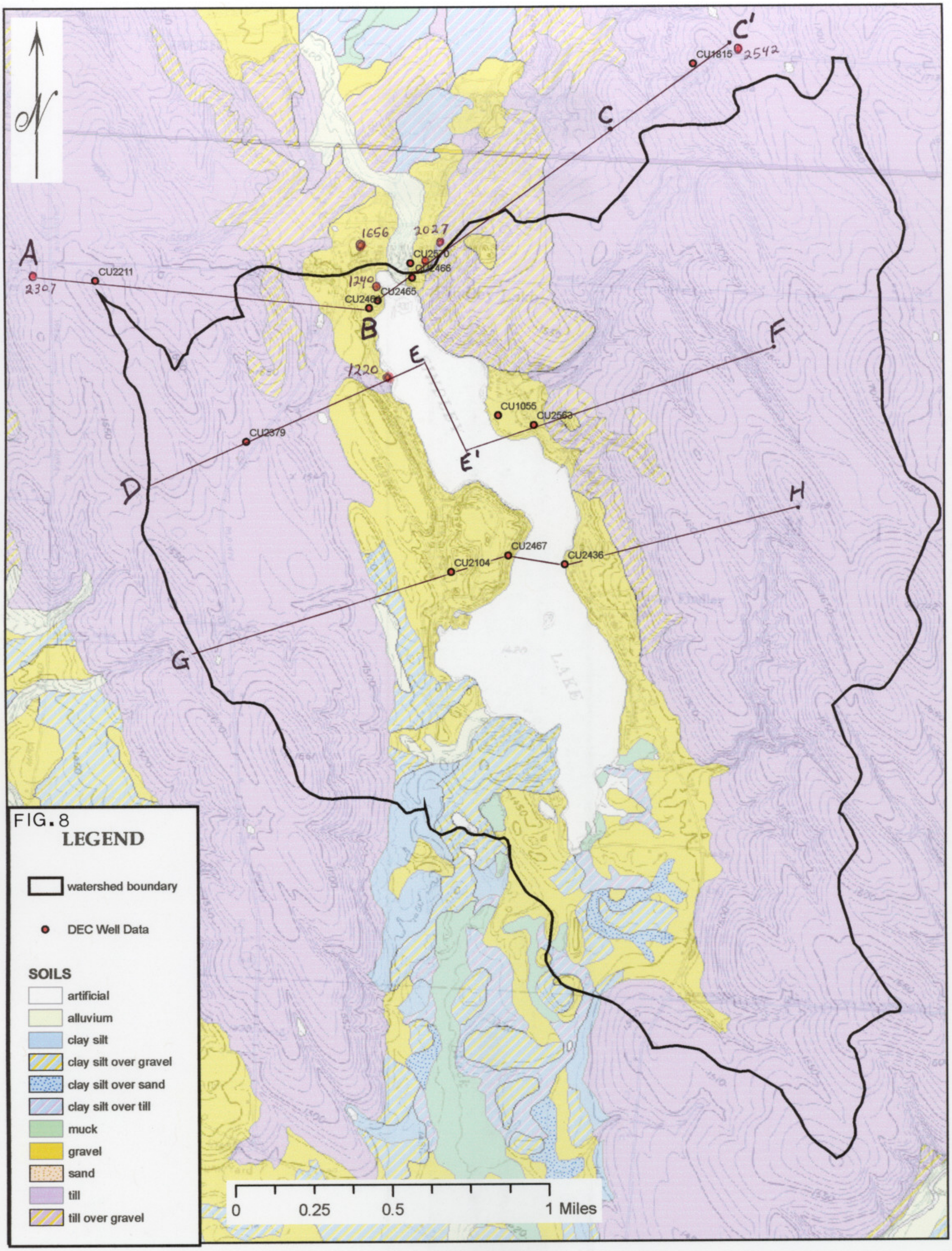


Figure 7. Land Use on Hydrogroups



N
A
2307
CU2211
B
1656
2027
CU2570
CU2466
1240
CU2465
CU2466
C
C'
CU1815
2542
E
E'
1220
F
CU1055
CU2563
CU2379
D
H
CU2467
CU2436
CU2104
G
LAKE
0
0.25
0.5
1 Miles
FIG. 8
LEGEND
watershed boundary
DEC Well Data
SOILS
artificial
alluvium
clay silt
clay silt over gravel
clay silt over sand
clay silt over till
muck
gravel
sand
till
till over gravel

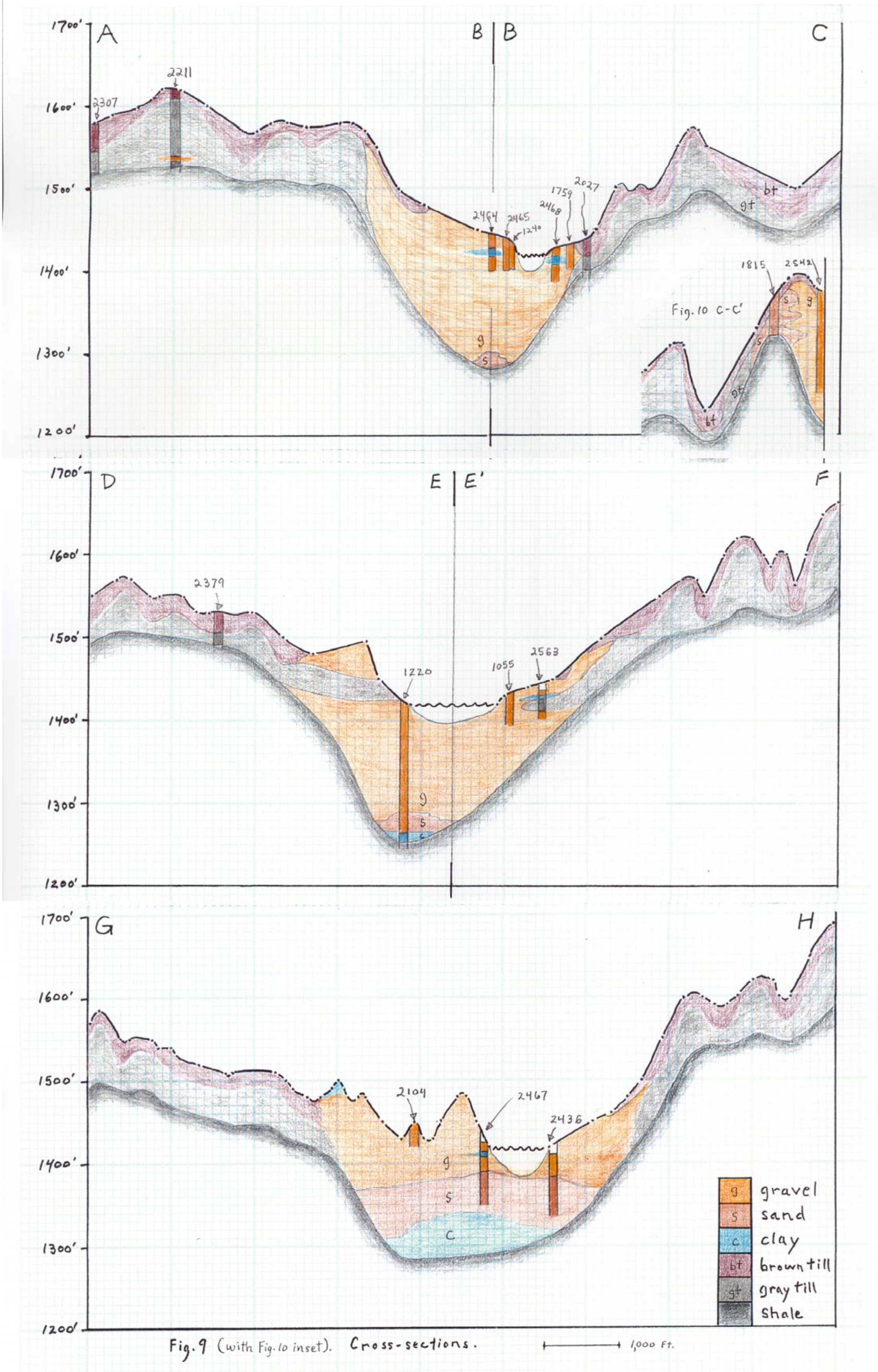


Fig. 9 (with Fig. 10 inset). Cross-sections.

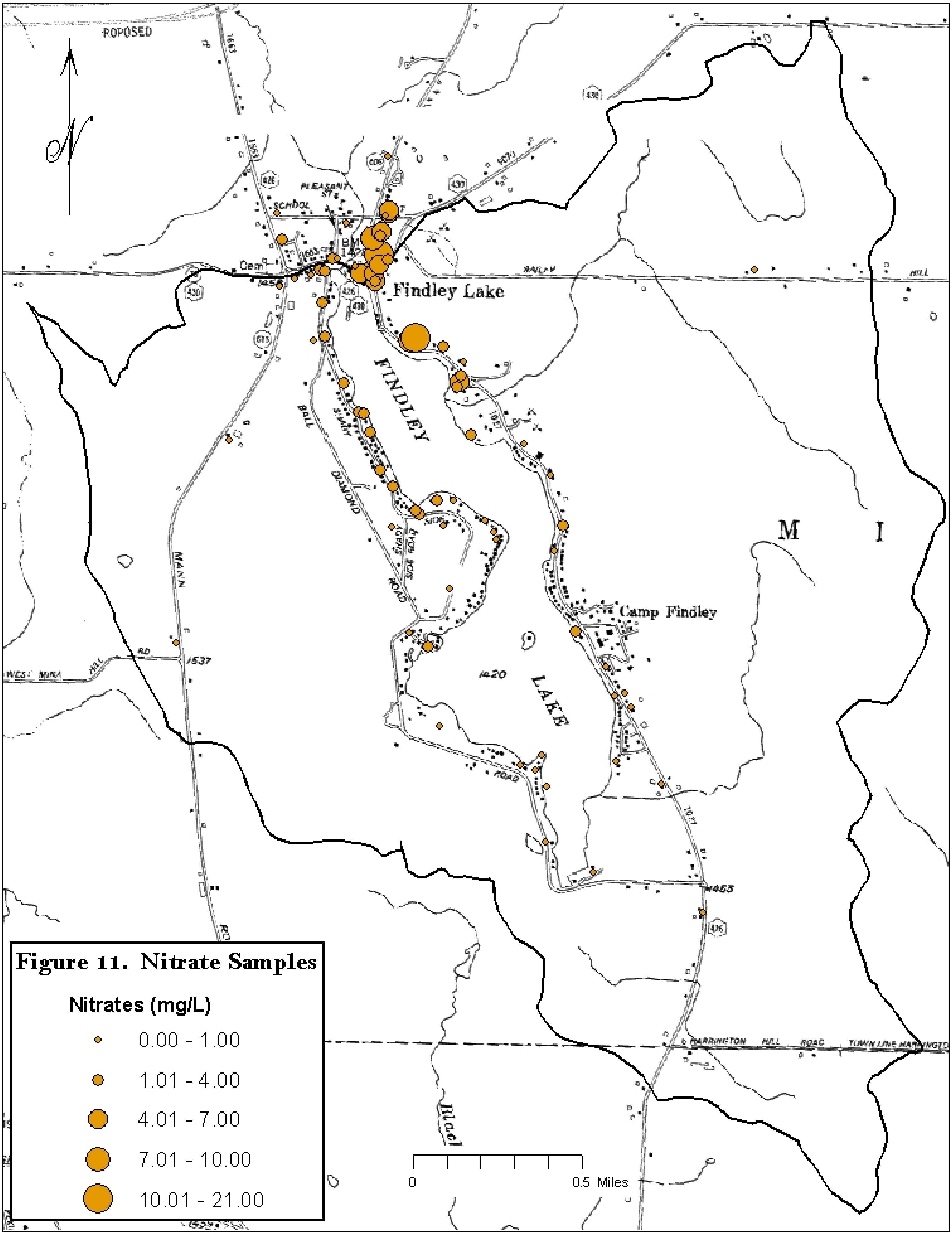


Figure 11. Nitrate Samples

Nitrates (mg/L)

0.00 - 1.00
1.01 - 4.00
4.01 - 7.00
7.01 - 10.00
10.01 - 21.00

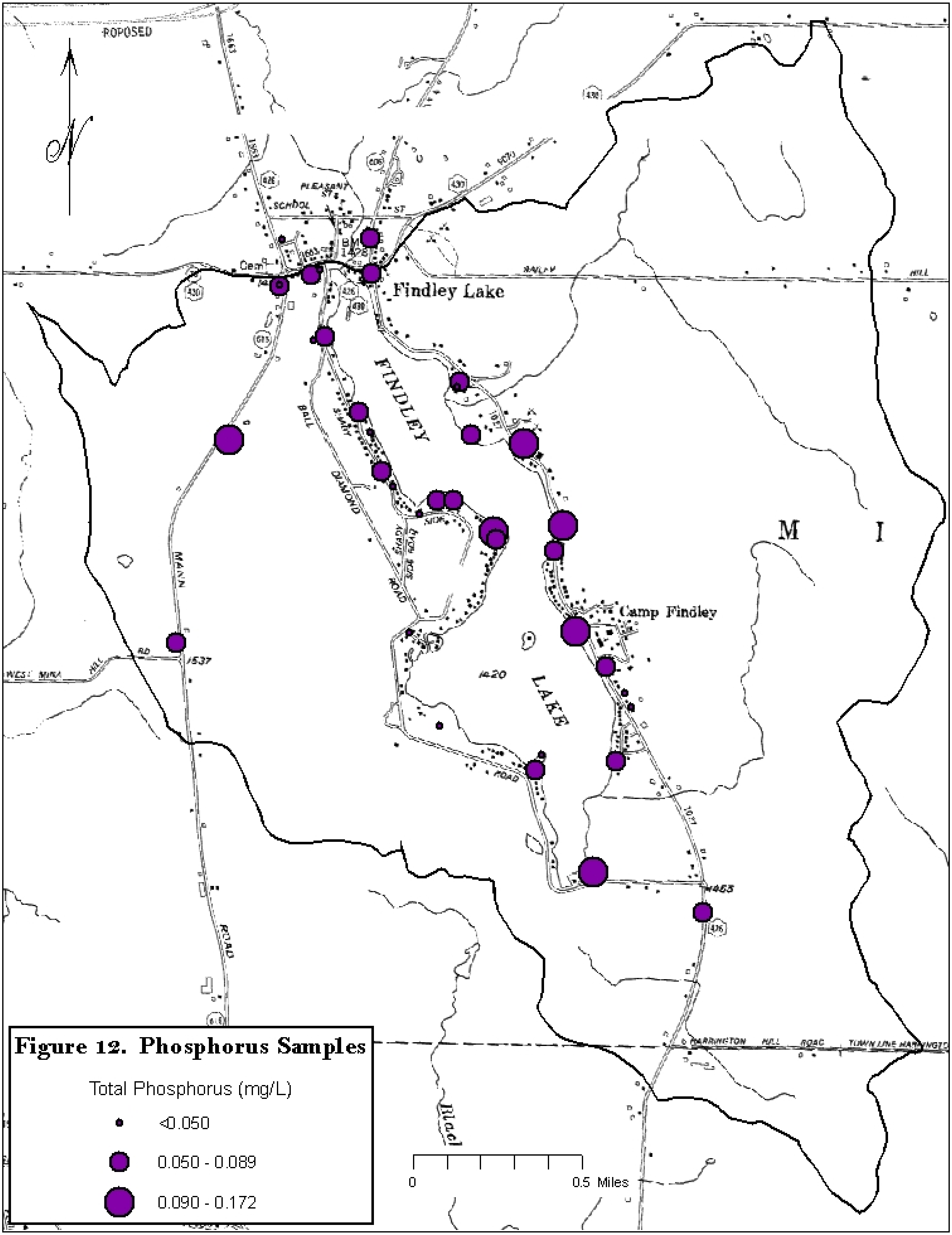


Figure 12. Phosphorus Samples

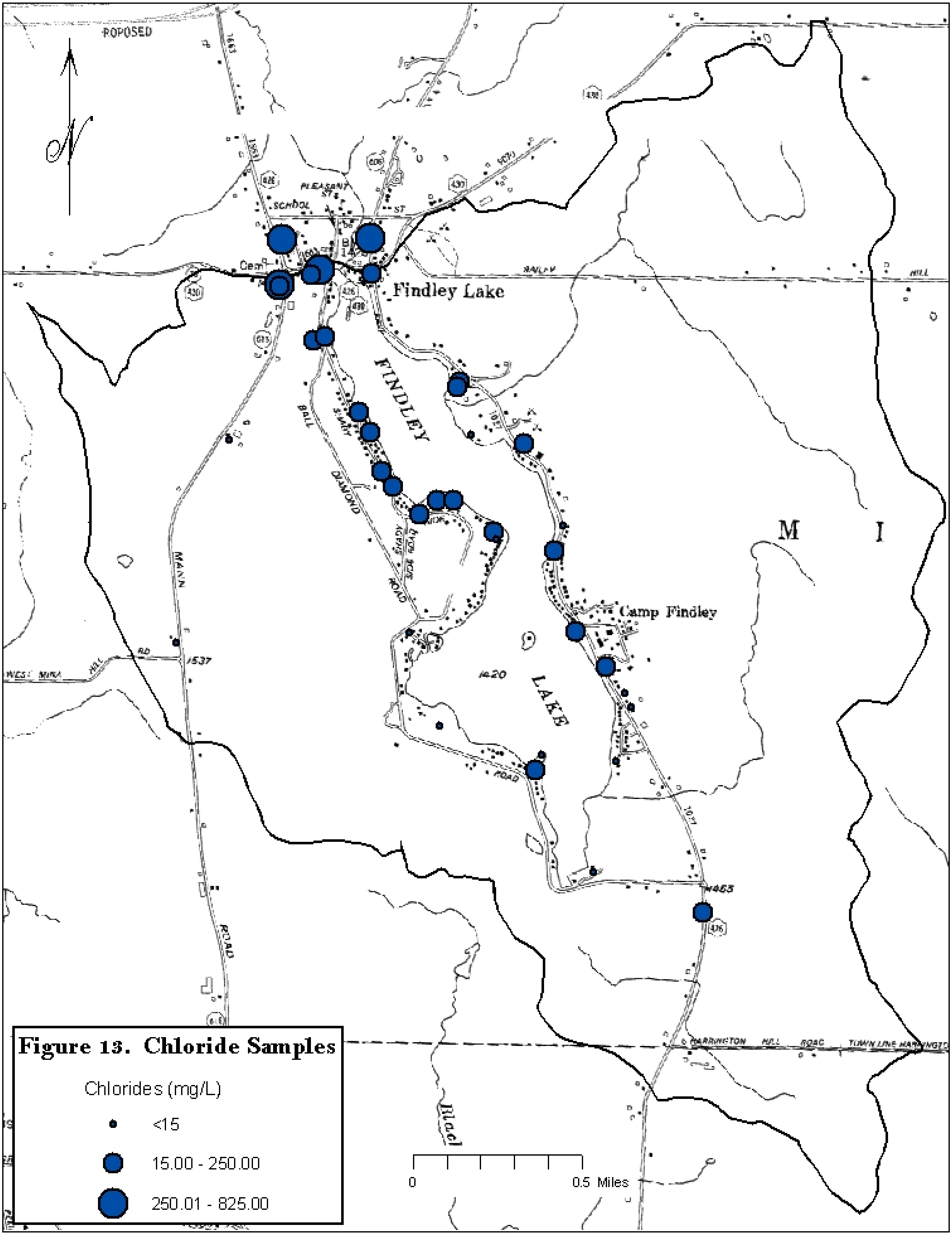
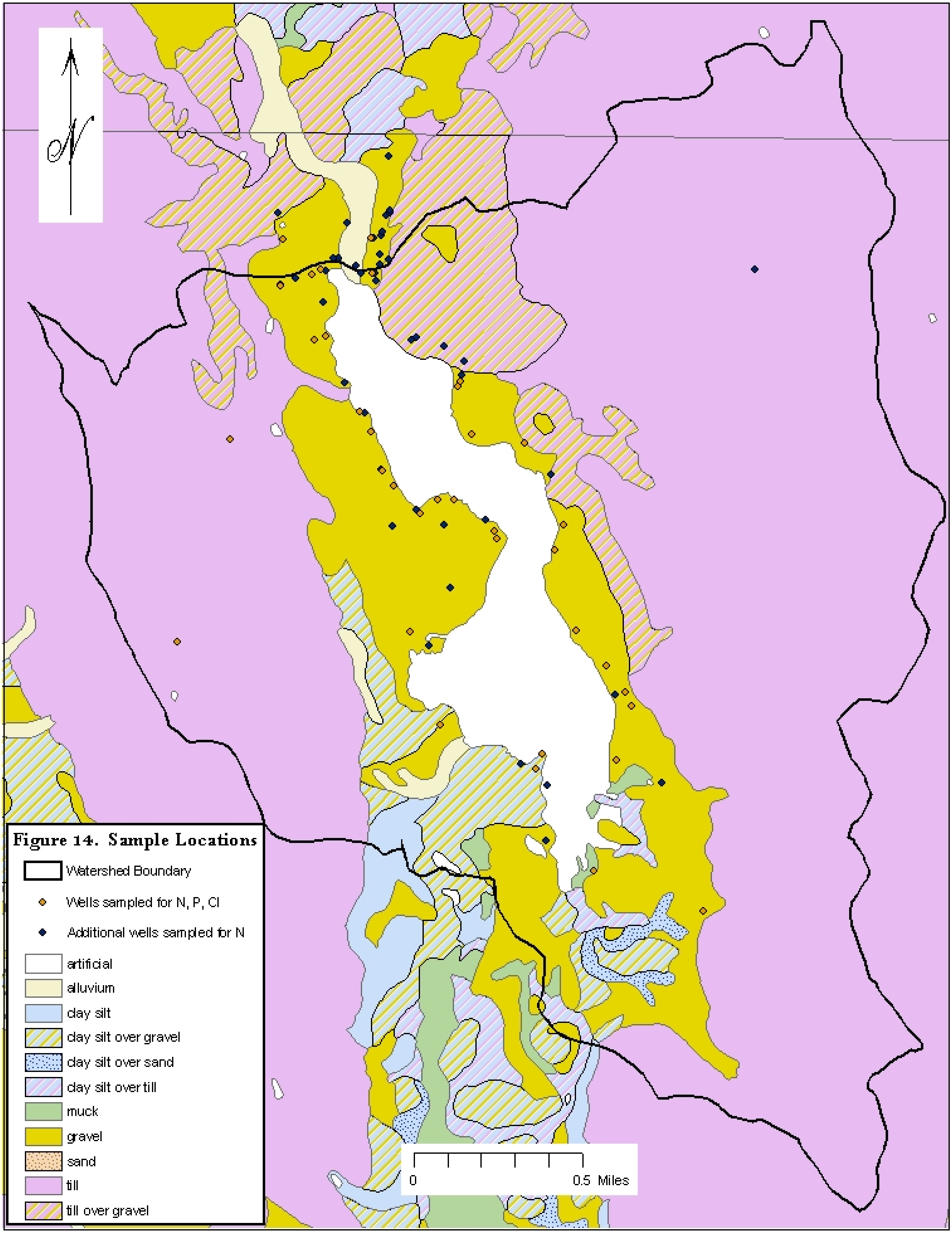


Figure 13. Chloride Samples


N
Figure 14. Sample Locations
Watershed Boundary
Wells sampled for N, P, Cl
Additional wells sampled for N
artificial
alluvium
clay silt
clay silt over gravel
clay silt over sand
clay silt over till
muck
gravel
sand
till
till over gravel
0
0.5 Miles

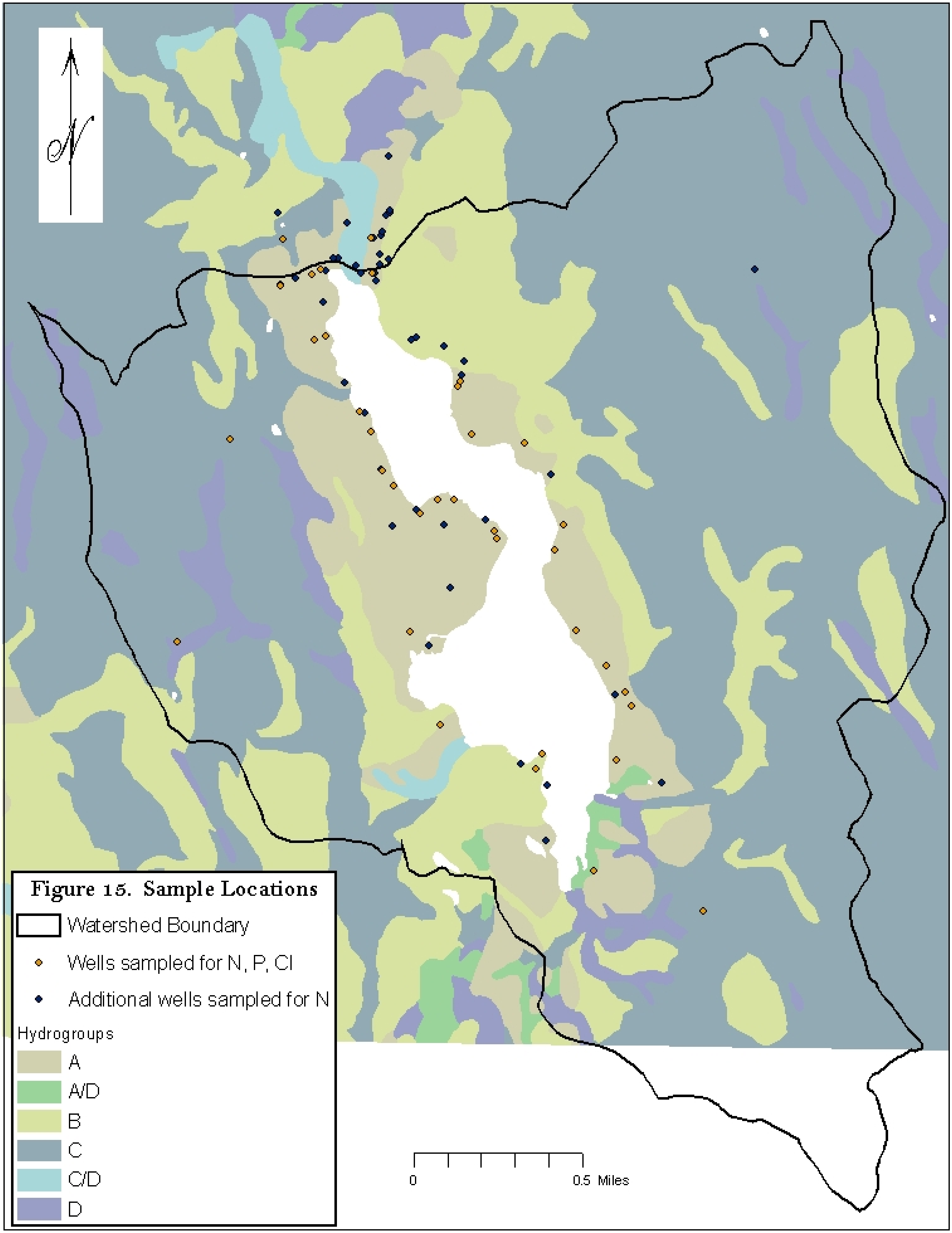


Figure 15. Sample Locations

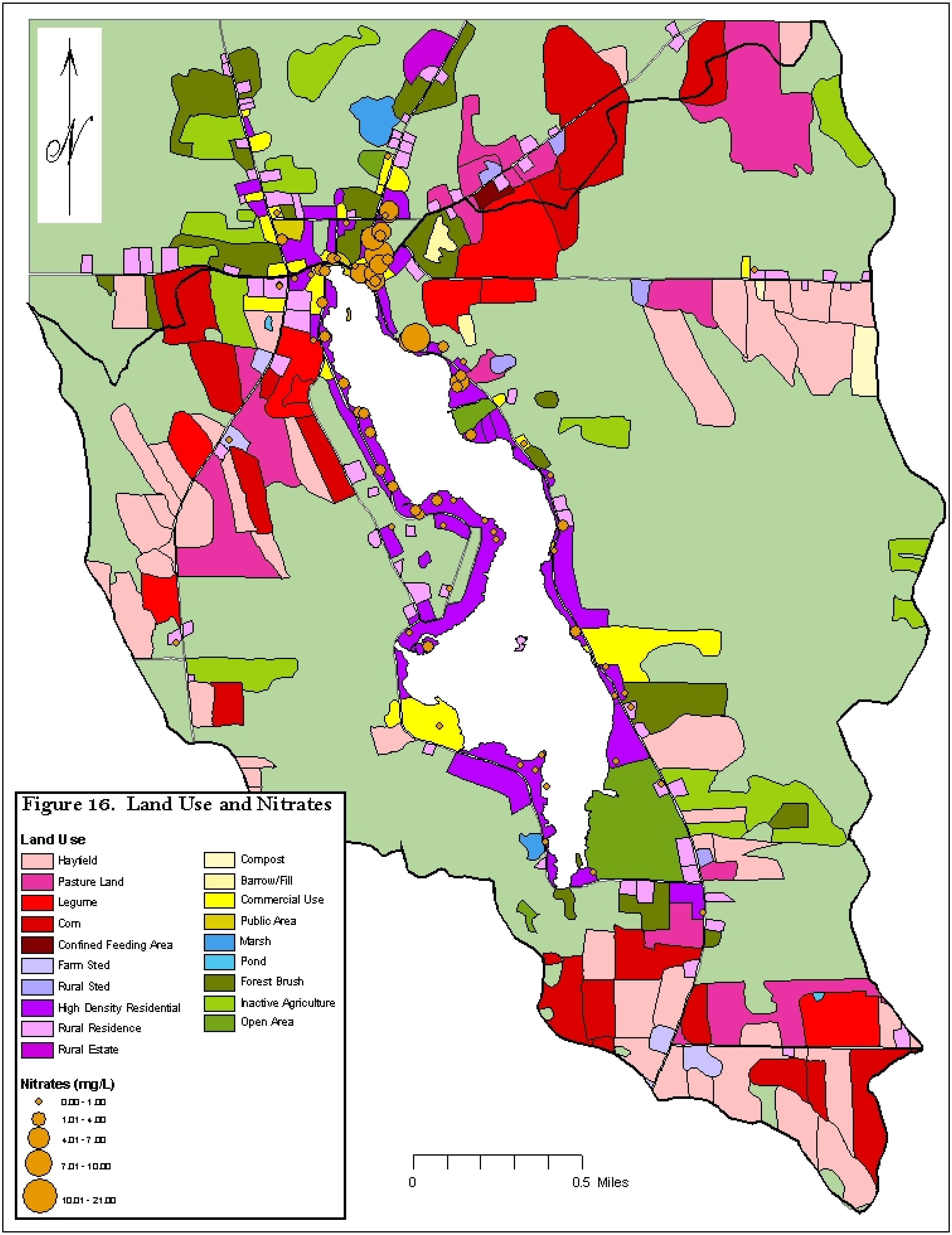
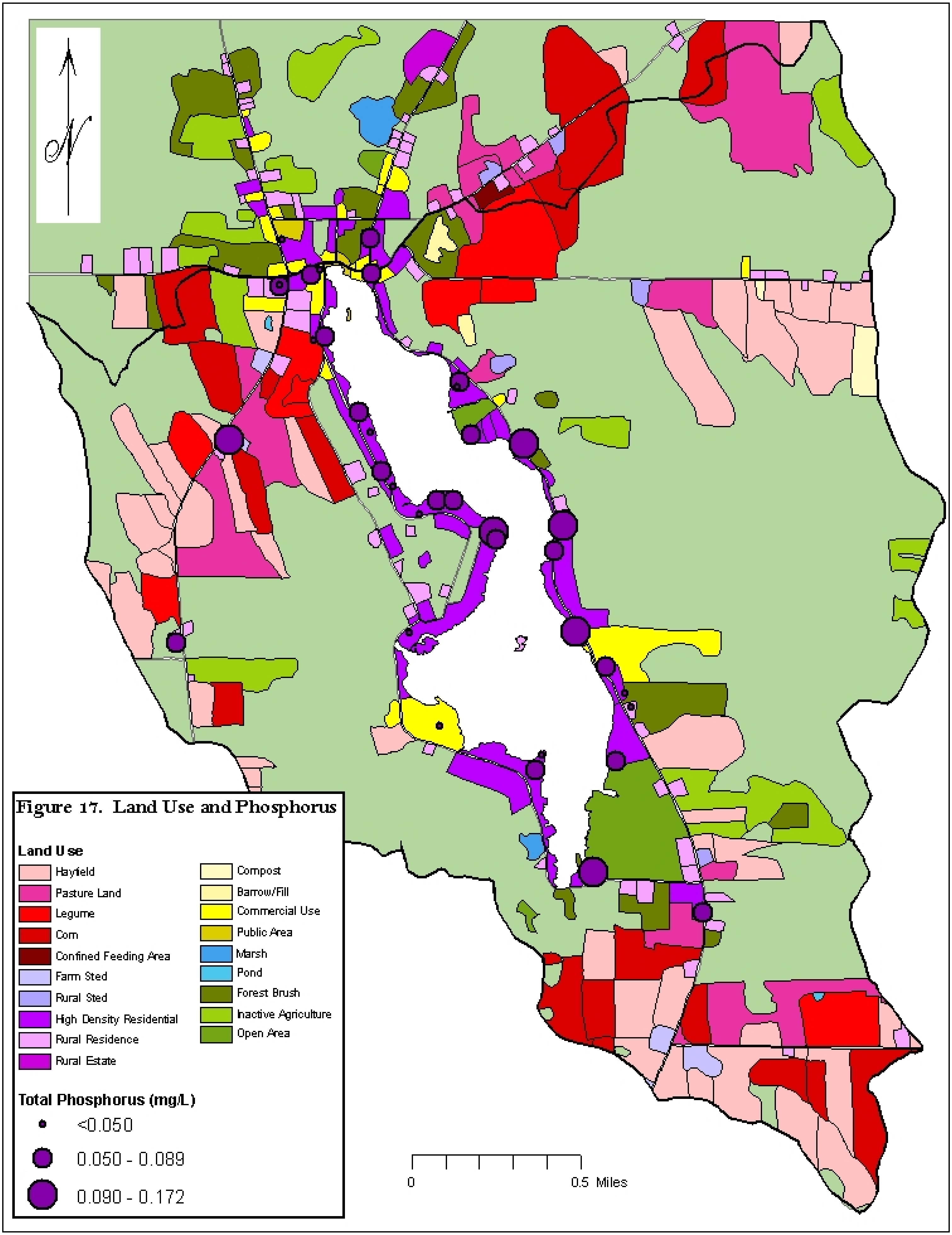


Figure 16. Land Use and Nitrates


N
Figure 17. Land Use and Phosphorus
Land Use
Hayfield
Pasture Land
Legume
Corn
Confined Feeding Area
Farm Sted
Rural Sted
High Density Residential
Rural Residence
Rural Estate
Compost
Barrow/Fill
Commercial Use
Public Area
Marsh
Pond
Forest Brush
Inactive Agriculture
Open Area
Total Phosphorus (mg/L)
<0.050
0.050 - 0.089
0.090 - 0.172
0
0.5 Miles

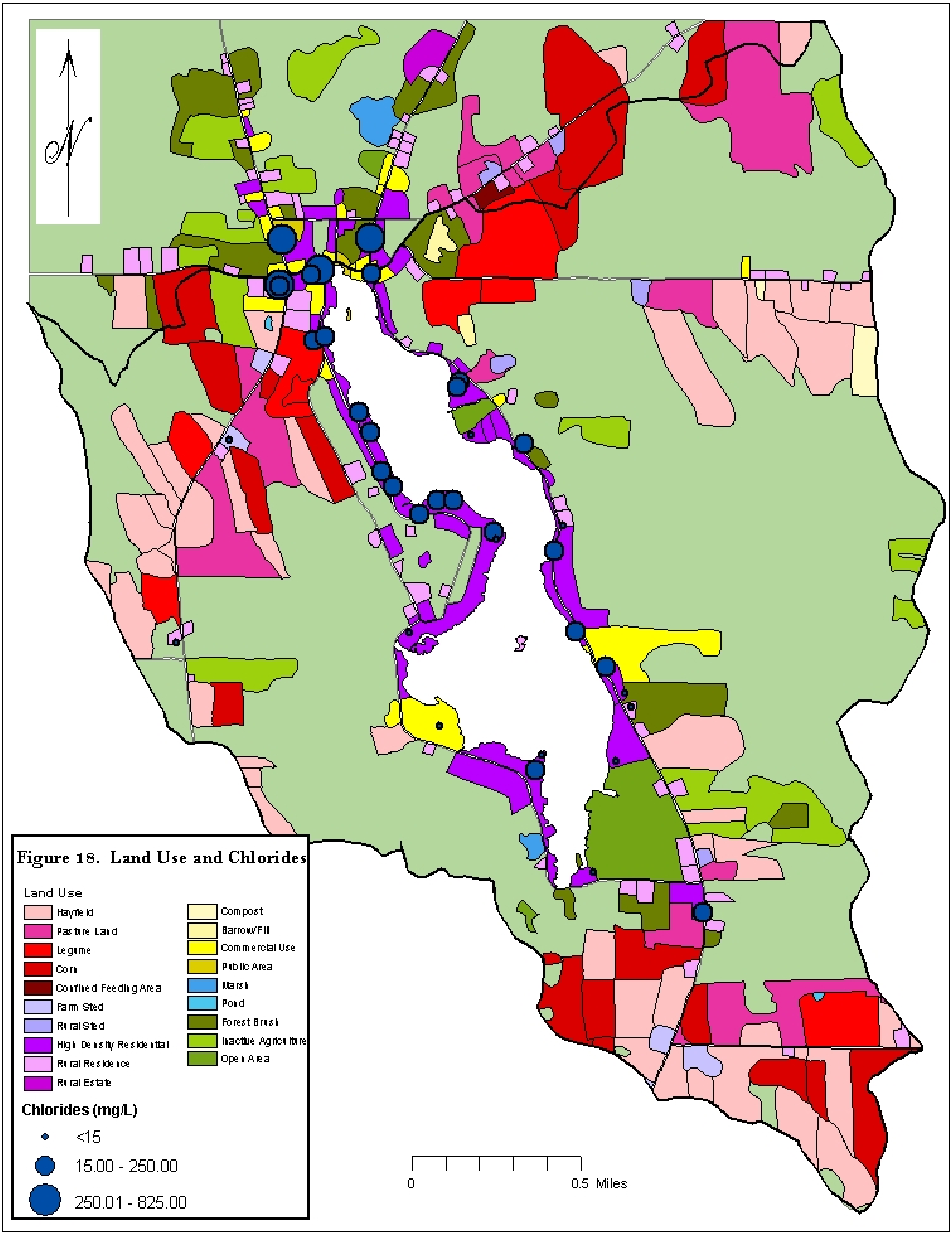


Figure 18. Land Use and Chlorides

Appendix A

Bivariate Scatter Plots and Correlation of Well-Water Chemicals

In the following graphs we demonstrate extremely poor correlations between Total Phosphorus (TP) and nitrates (NO_3-N) (Figs. A-1, A-2), then TP and chlorides (Cl) (Figs. A-3, A-4), and then nitrates and Cl (Figs. A-5, A-6). For each set of graphs (A-1, A-3, A-5) we removed several outlying values and regraphed the data (A-2, A-4, A-6). Regraphing without outliers did not help.

We noticed in Figure A-6 the presence of two subgroups and plotted these separately in Figures A-7 and A-8. Correlations were good for these subgroups. Data for these subgroups are tabulated in Table A-1 and the two groups are mapped as different size dots in Figure A-9. Their patterns are random and no conclusions can be made.

Figure A-1

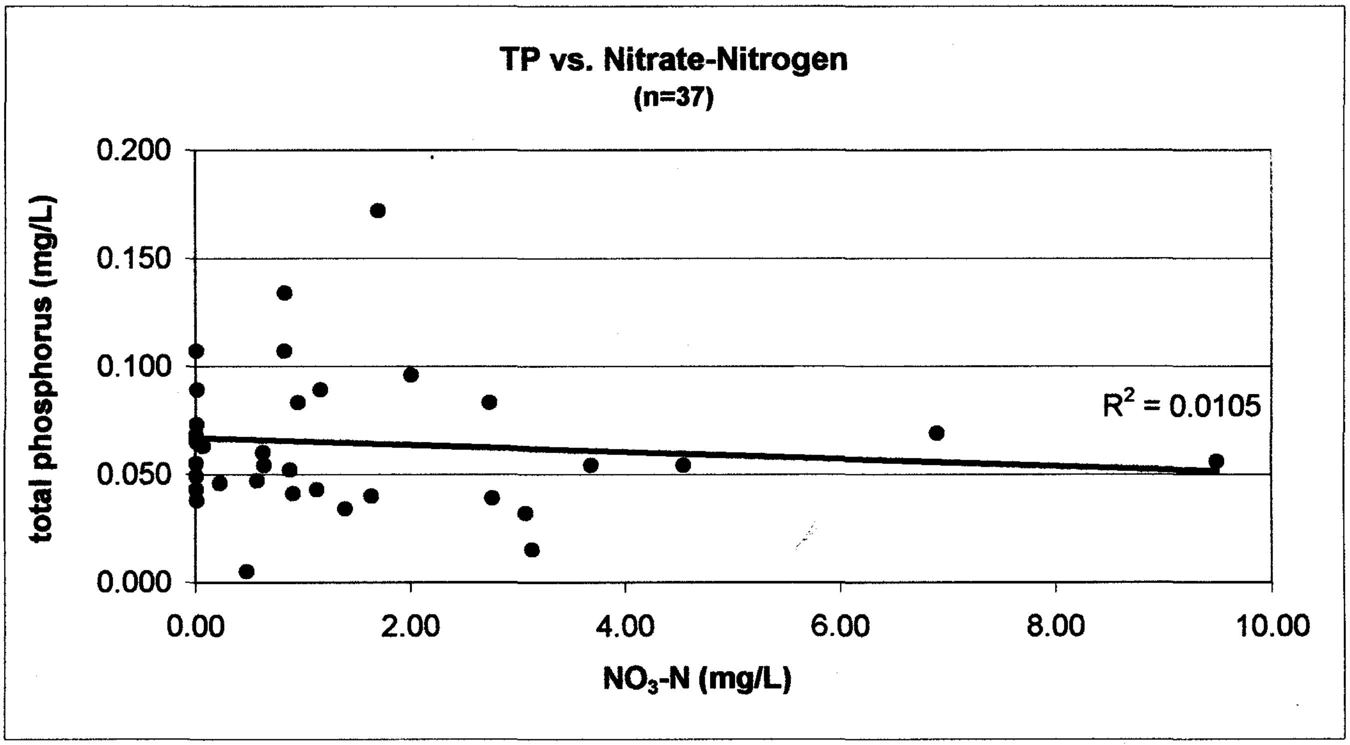


Figure A-2

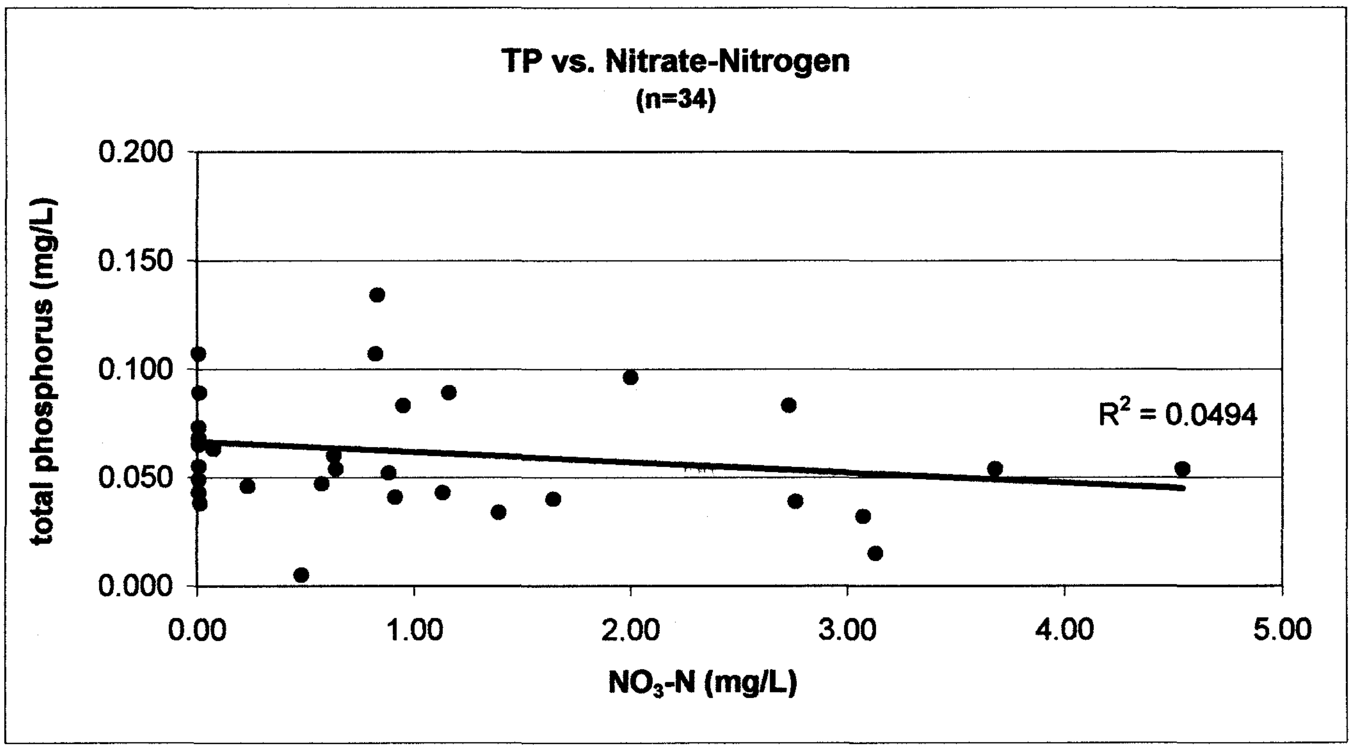


Figure A-3

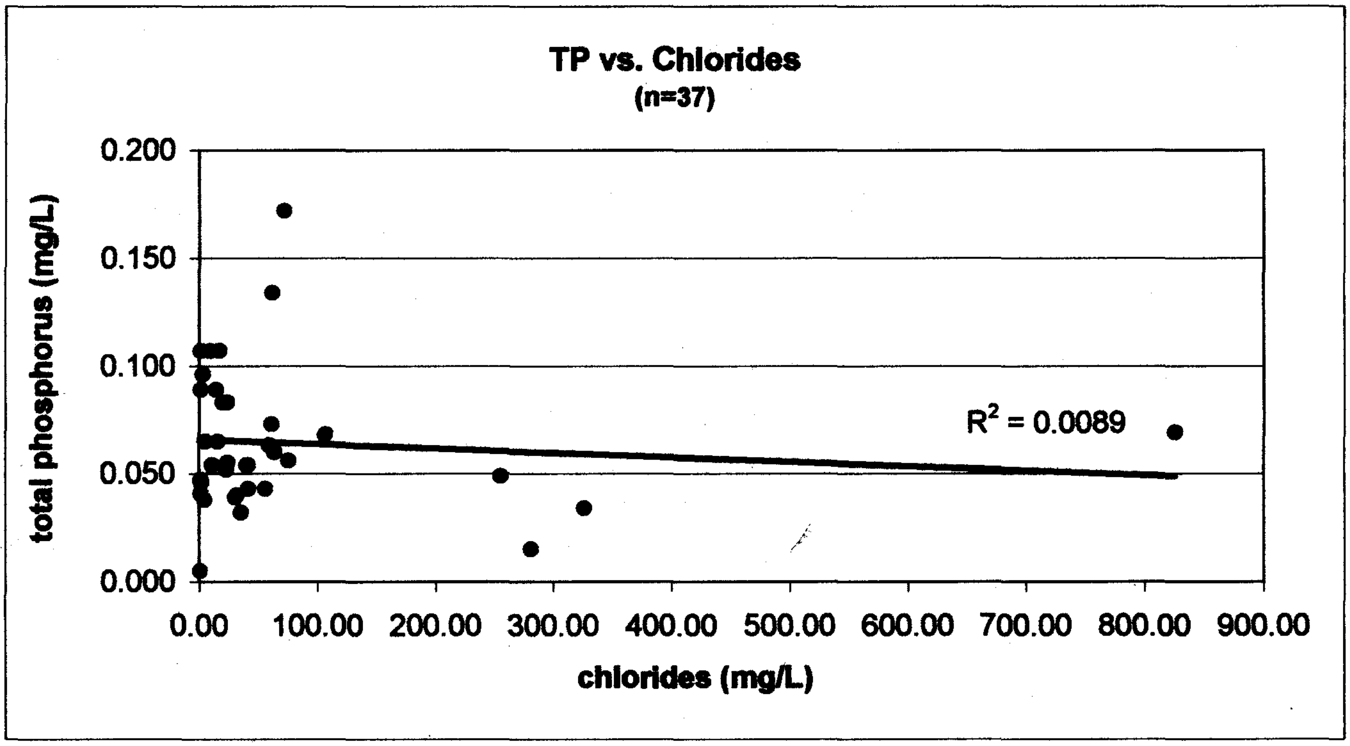


Figure A-4

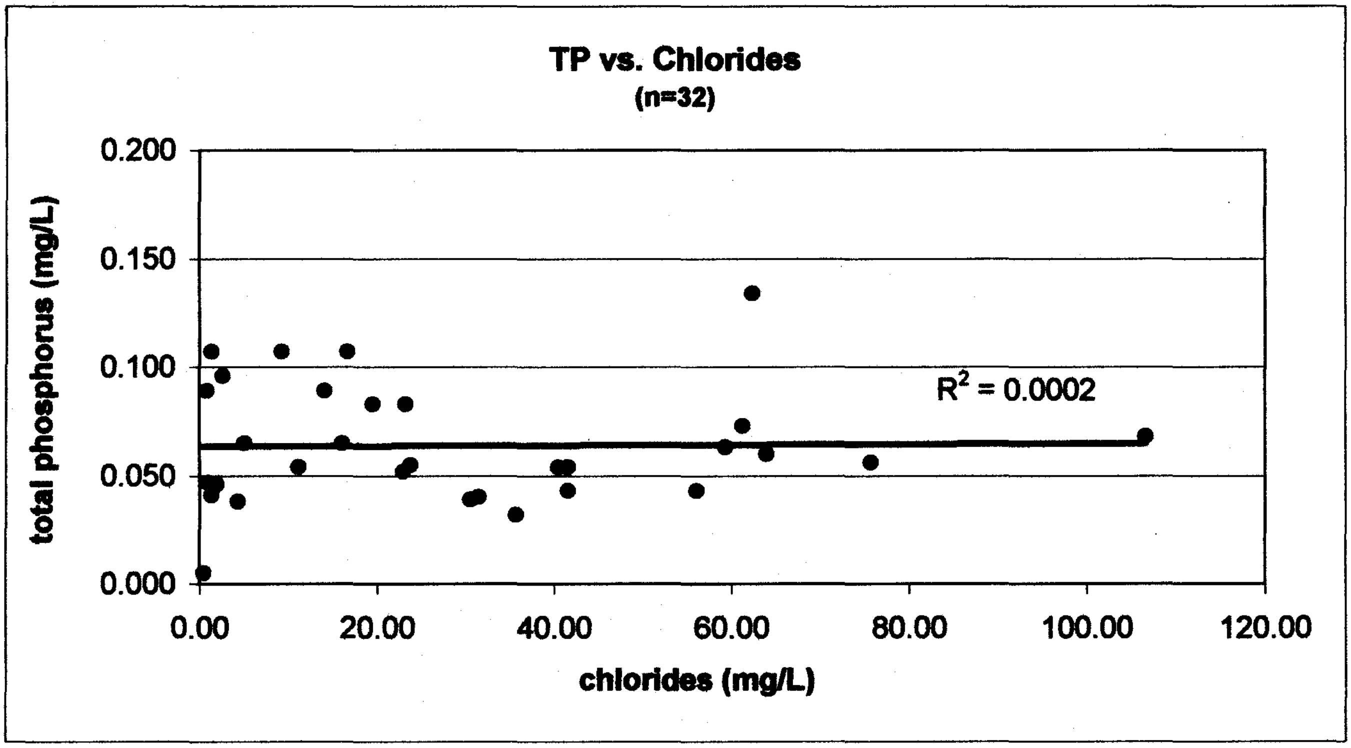


Figure A-5

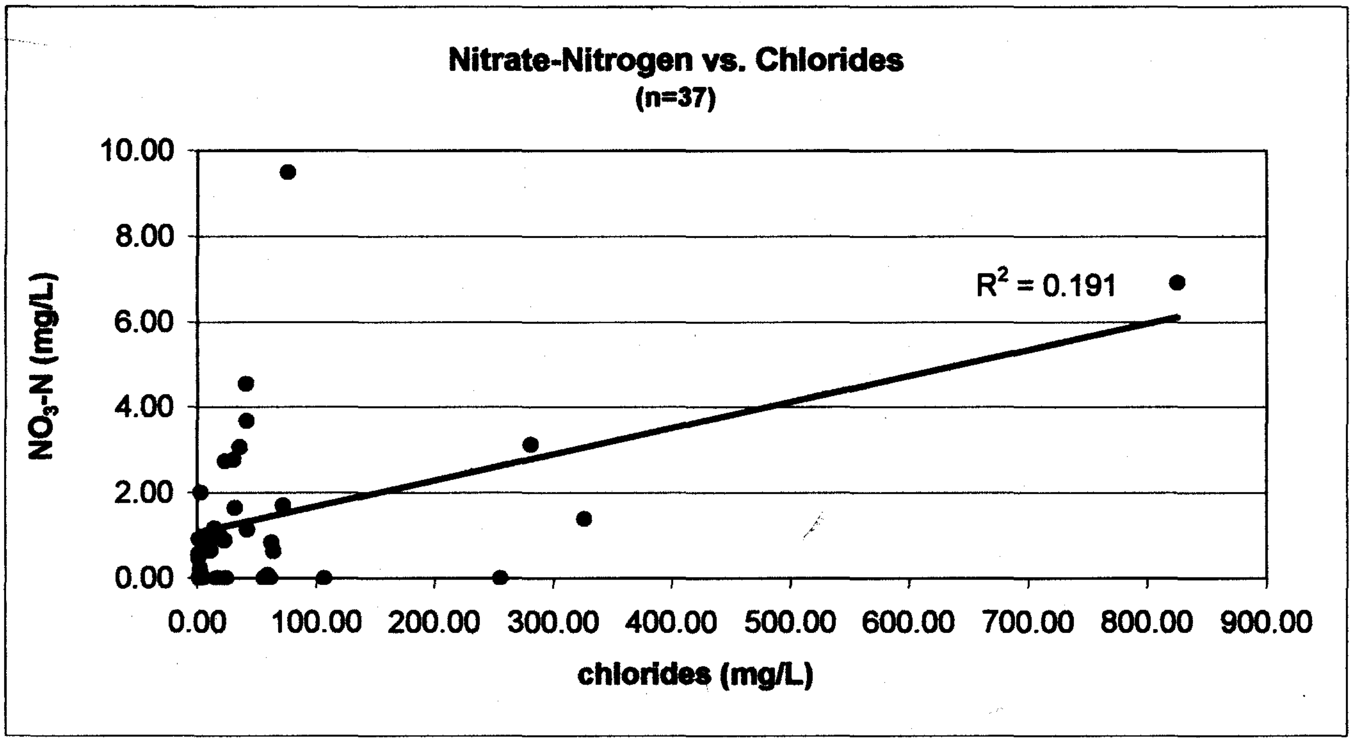


Figure A-6

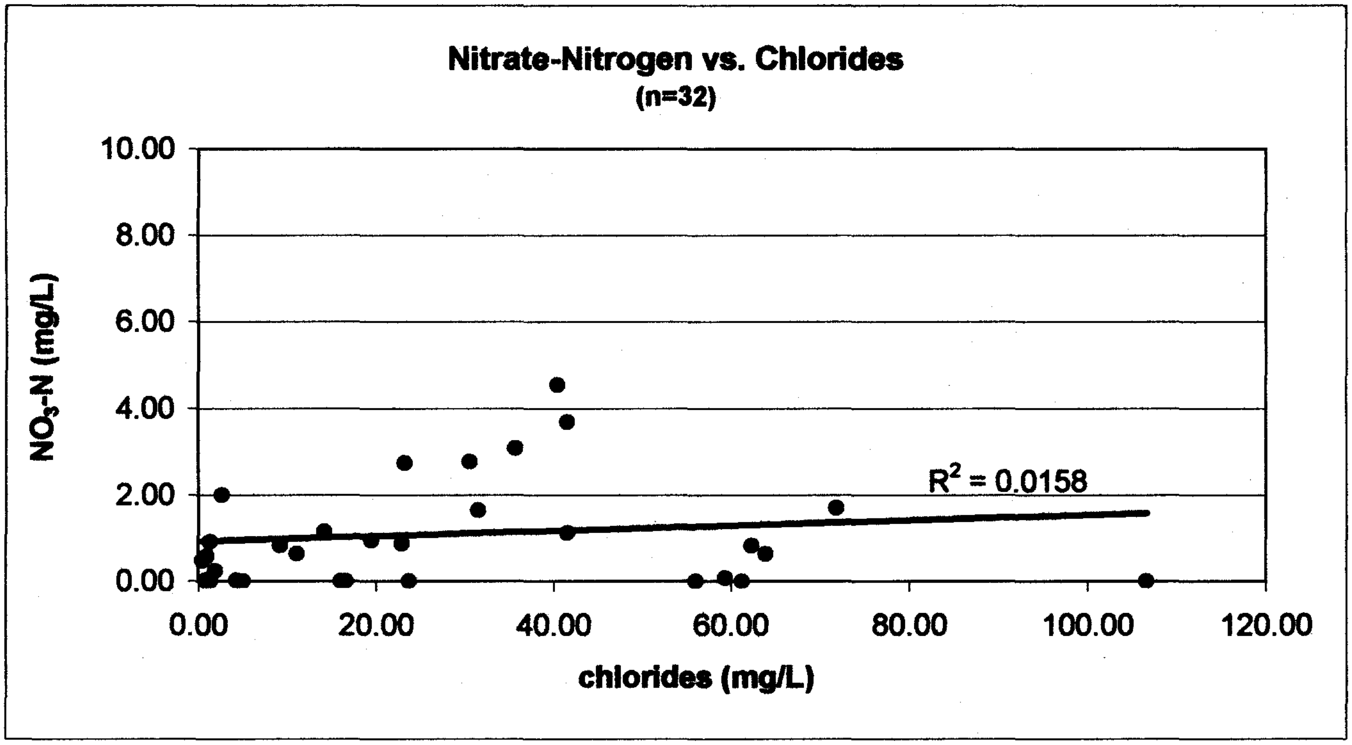


Figure A-7

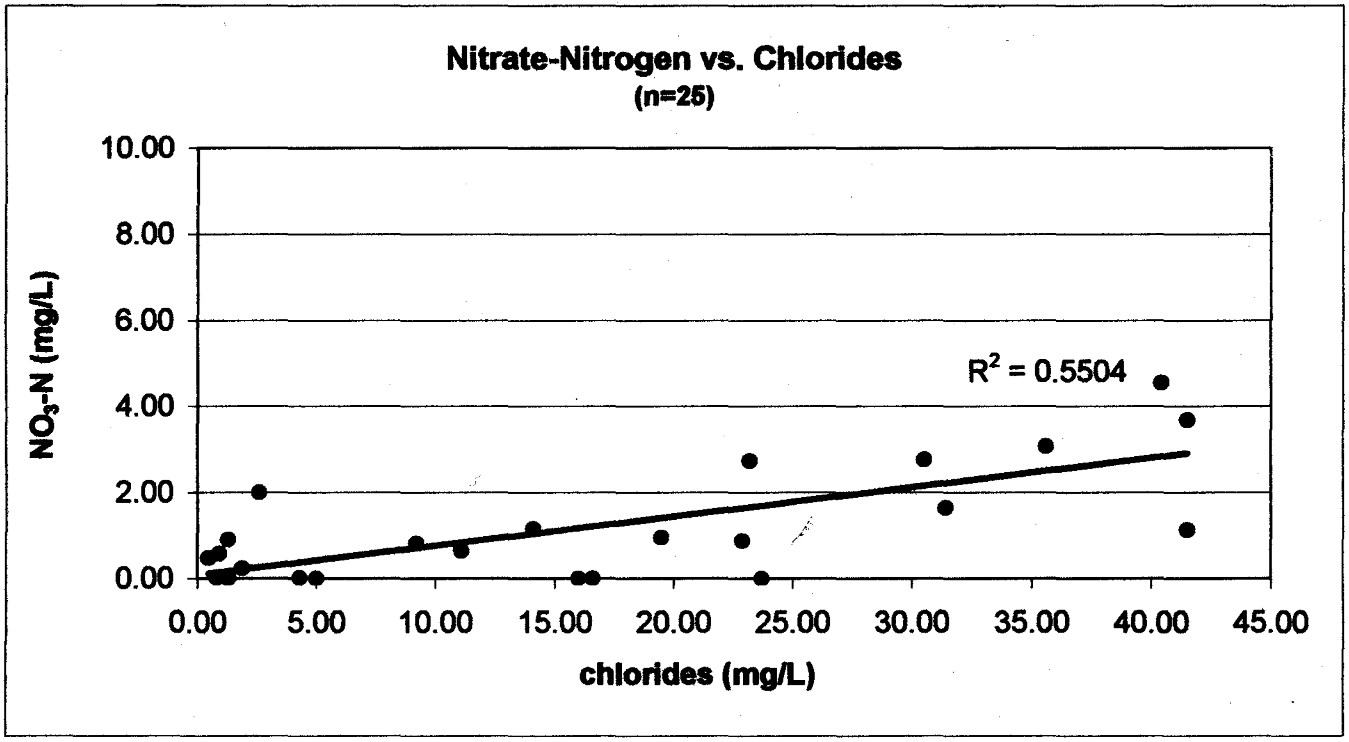


Figure A-8

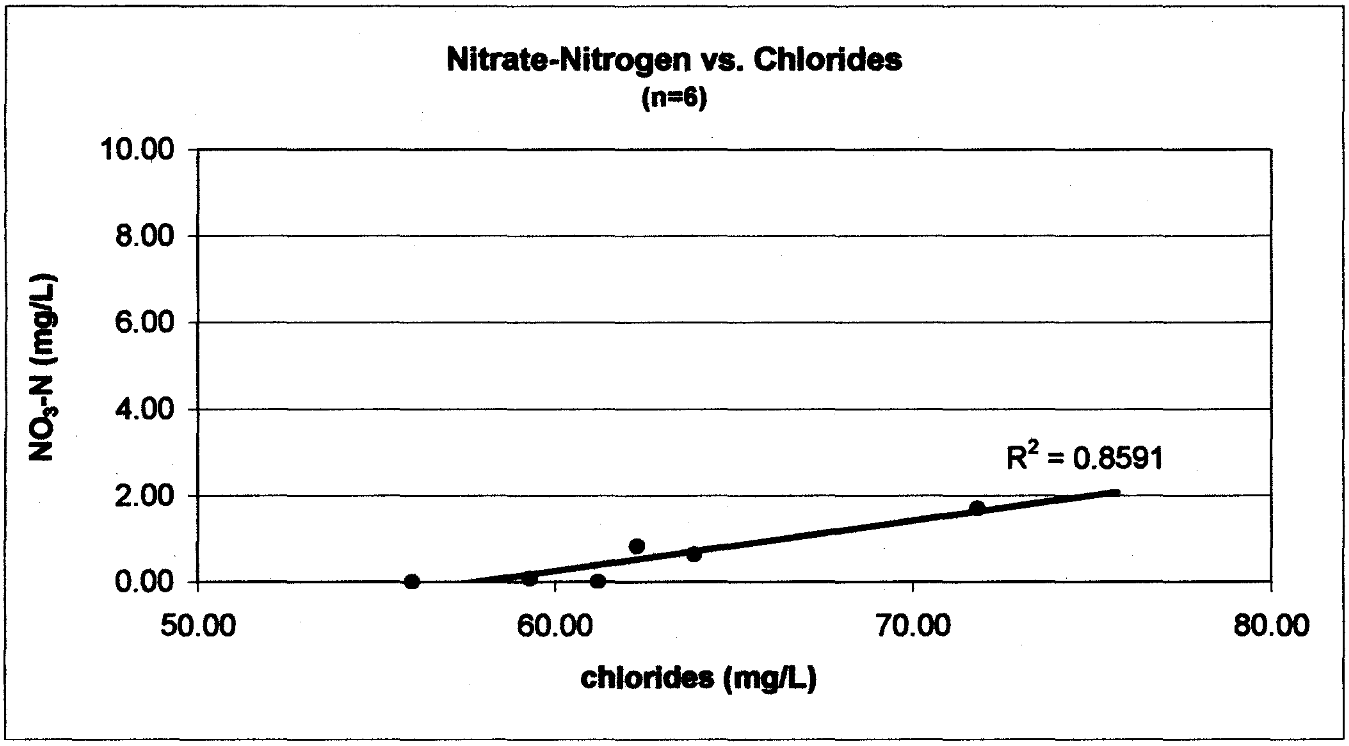


Table A-1.

WELL DEPTH	WATER LEVEL	AQUIFER	*chloride (-) outliers*	*nitrates (-) outliers*
15			*0.450*	*0.48000*
112			*0.820*	*0.01000*
			0.920	*0.57400*
112			*1.300*	*0.00500*
30			*1.300*	*0.91000*
			1.900	*0.23000*
			2.600	*2.00000*
			4.300	*0.01300*
180			*5.000*	*0.00500*
			9.200	*0.82200*
75			*11.100*	*0.63800*
			14.100	*1.16000*
60	30		*16.000*	*0.00500*
			16.600	*0.00500*
37	3		*19.500*	*0.95000*
			22.900	*0.88000*
70			*23.200*	*2.73000*
25			*23.700*	*0.00500*
23			*30.500*	*2.76000*
			31.400	*1.64000*
			35.600	*3.07000*
			40.400	*4.54000*
			41.500	*1.13000*
130			*41.500*	*3.68000*
130			*41.500*	*3.68000*
142	120	BEDROCK	*56.000*	*0.00500*
			59.300	*0.07400*
80			*61.200*	*0.00500*
			62.300	*0.83000*
37			*63.900*	*0.63000*
18			*71.800*	*1.70000*
			75.700	

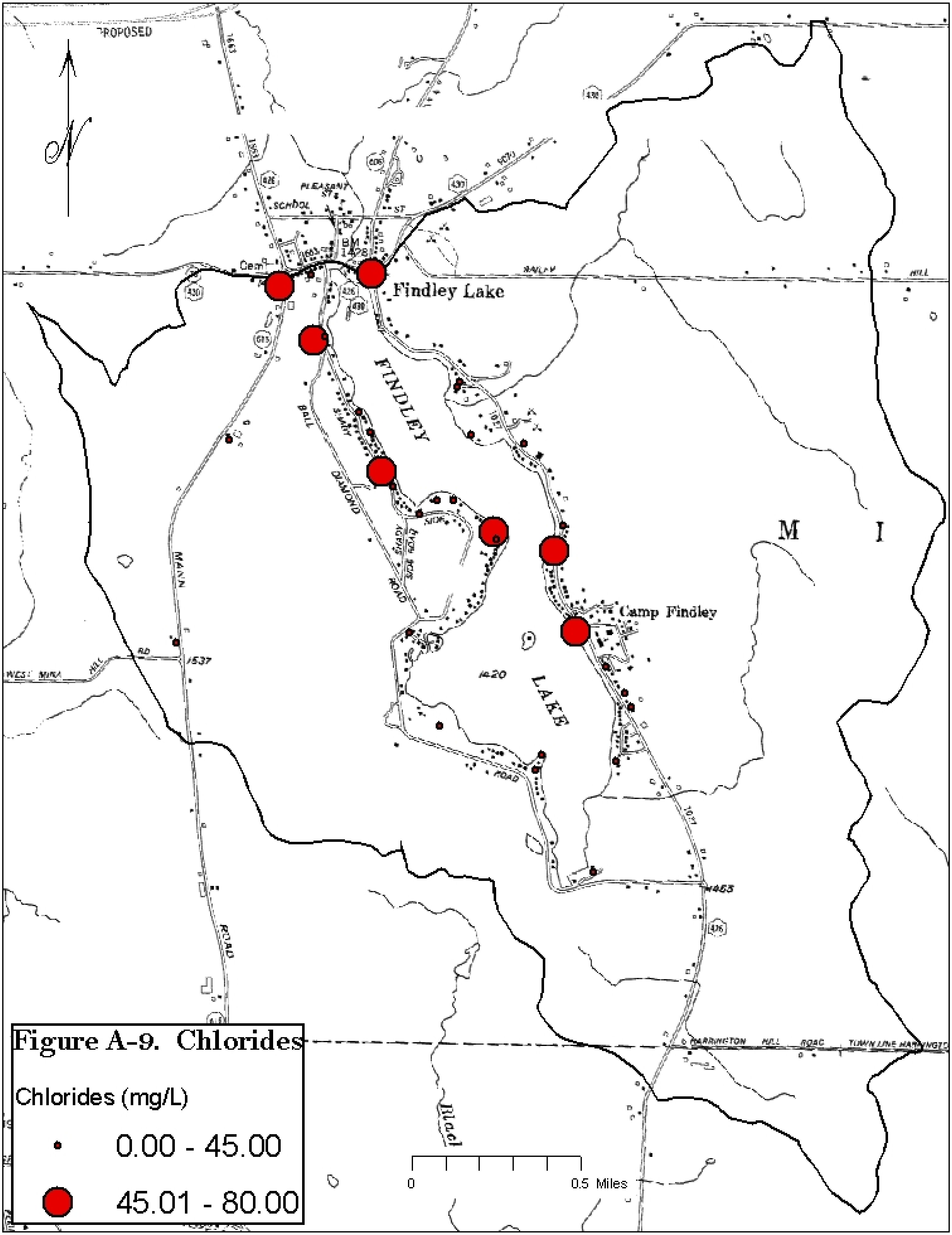


Figure A-9. Chlorides

Appendix B

Correlations of Well-Water Chemicals with Well Depths

Figures B-1 through B-14 follow. Figures B-1 through B-5 present nitrate vs. depth with and without outliers, and with linear, log and exponent best-fit lines (correlations). B-6 through B-9 are similar graphs for total phosphorus (TP) vs. depth; and B-10 through B-14 are similar graphs for chlorides vs. depth. There is one less graph for TP vs. depth than for the nitrates or chlorides because no important outliers were identified on the TP graphs. The "outliers" are high chemical values found in shallow wells. Otherwise, no significant correlations between well depths and chemical quantities were determined.

Figure B-1

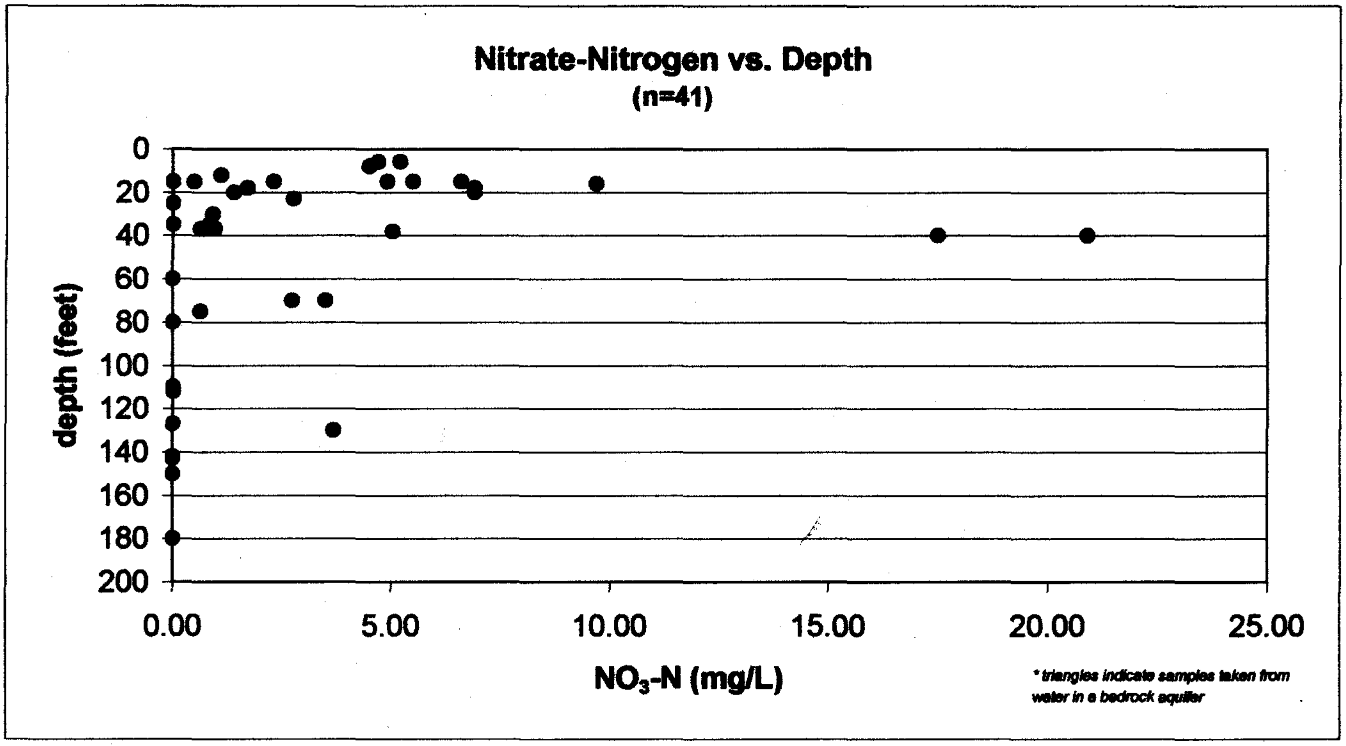


Figure B-2

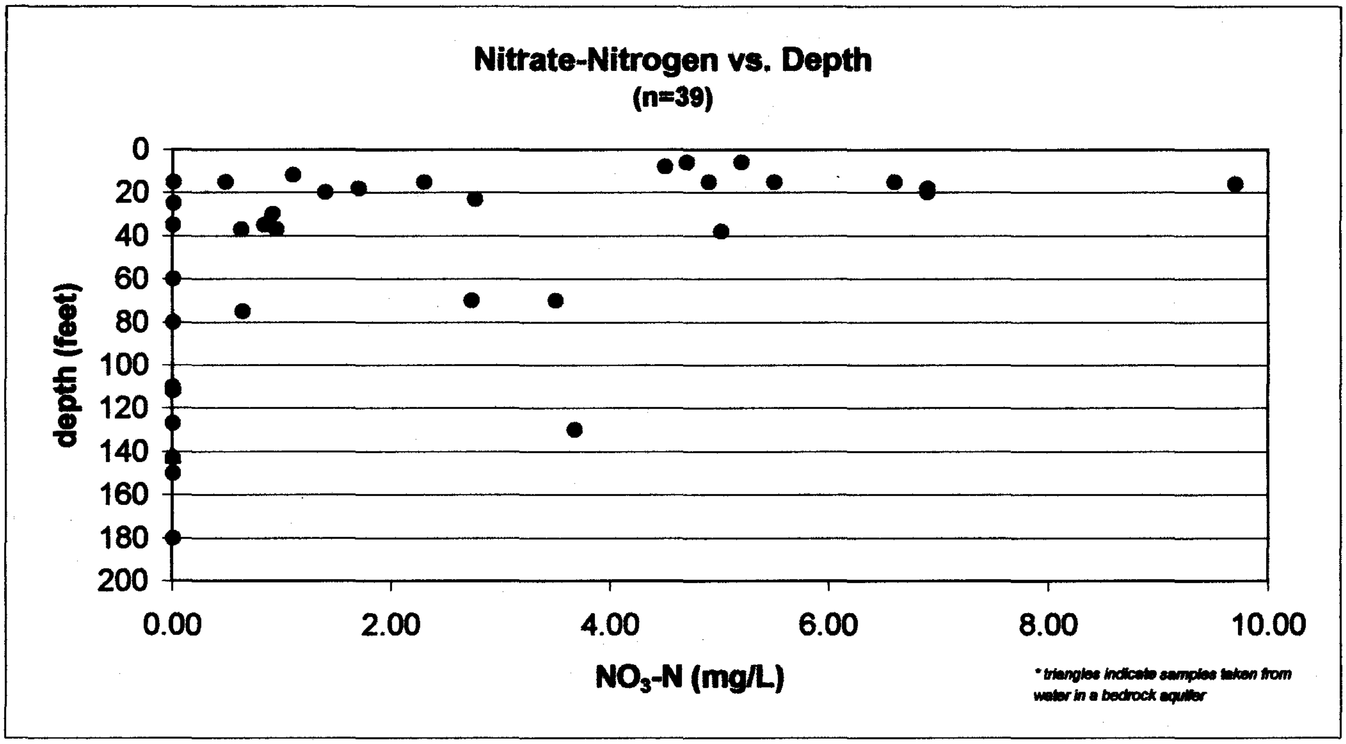


Figure B-3

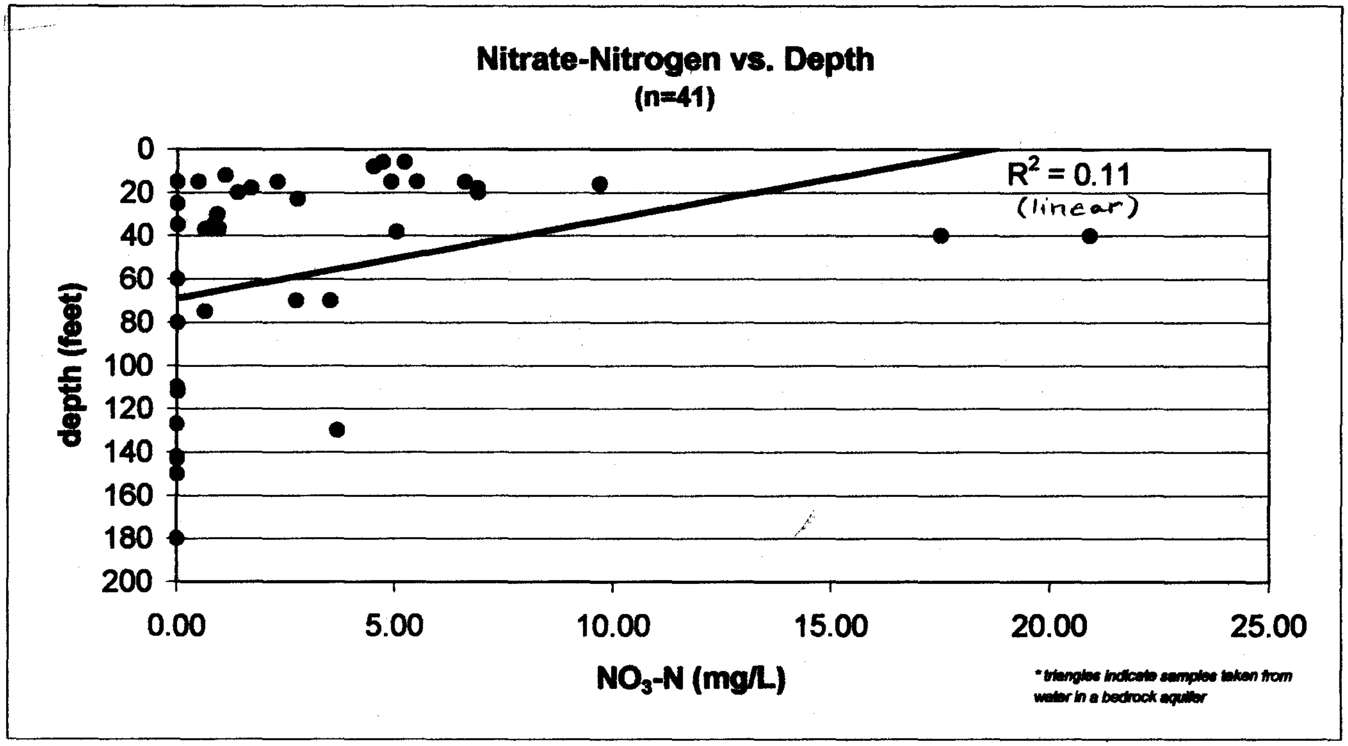


Figure B-4

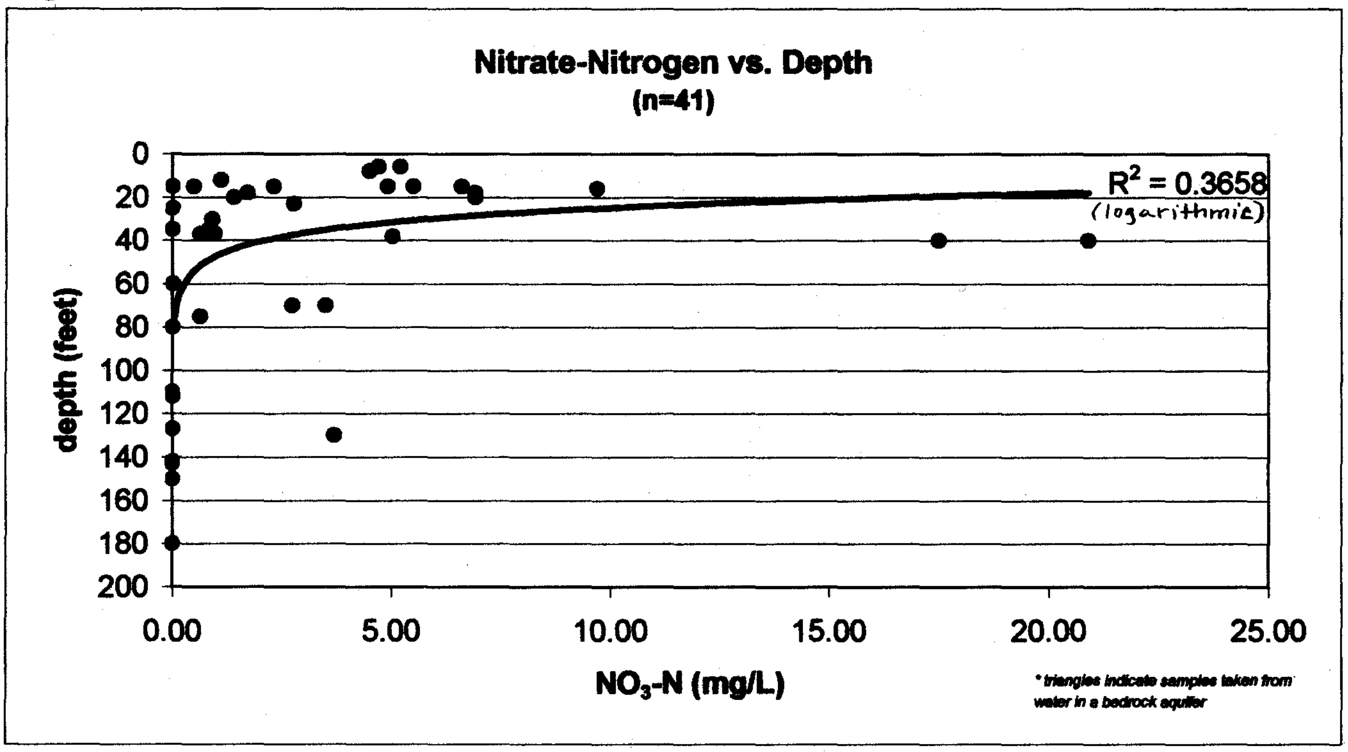


Figure B-5

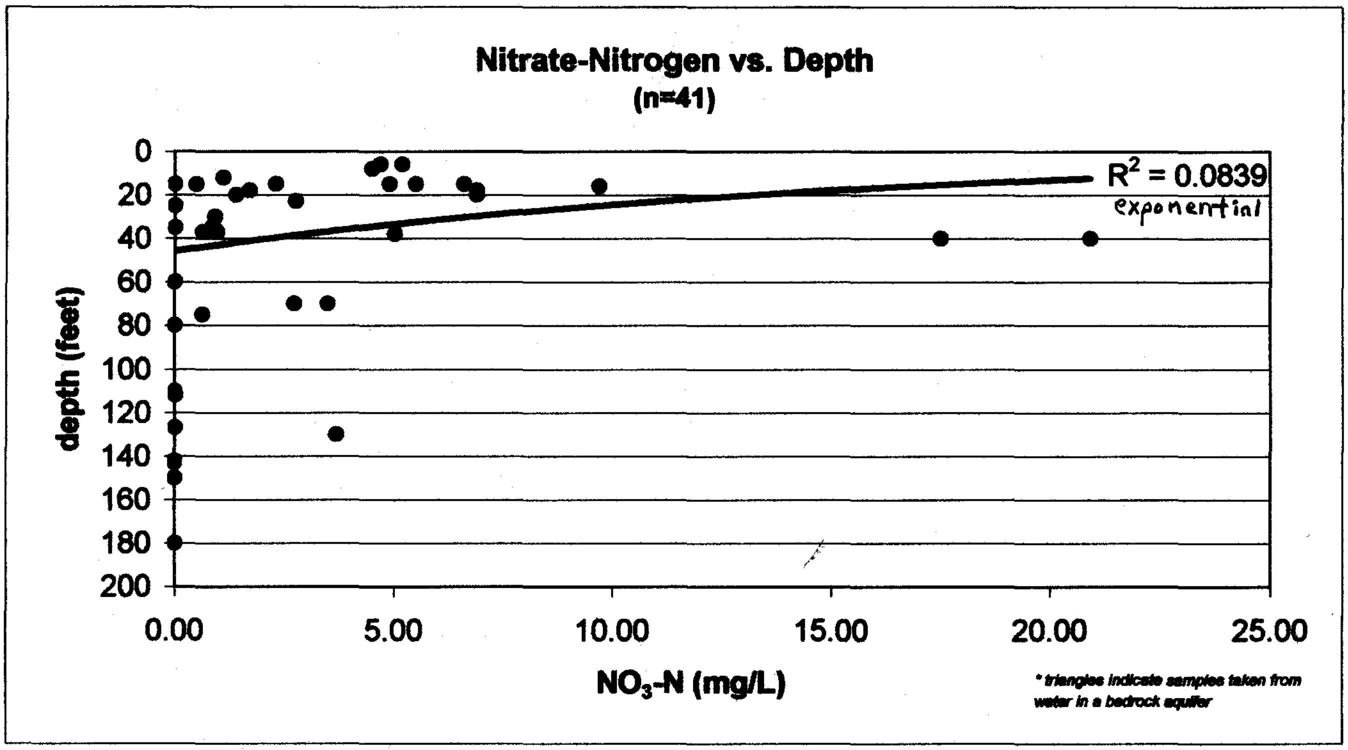

Nitrate-Nitrogen vs. Depth
(n=41)
$R^2 = 0.0839$
exponential
depth (feet)
0
20
40
60
80
100
120
140
160
180
200
0.00
5.00
10.00
15.00
20.00
25.00
NO_3-N (mg/L)
* triangles indicate samples taken from water in a bedrock aquifer

Figure B-6

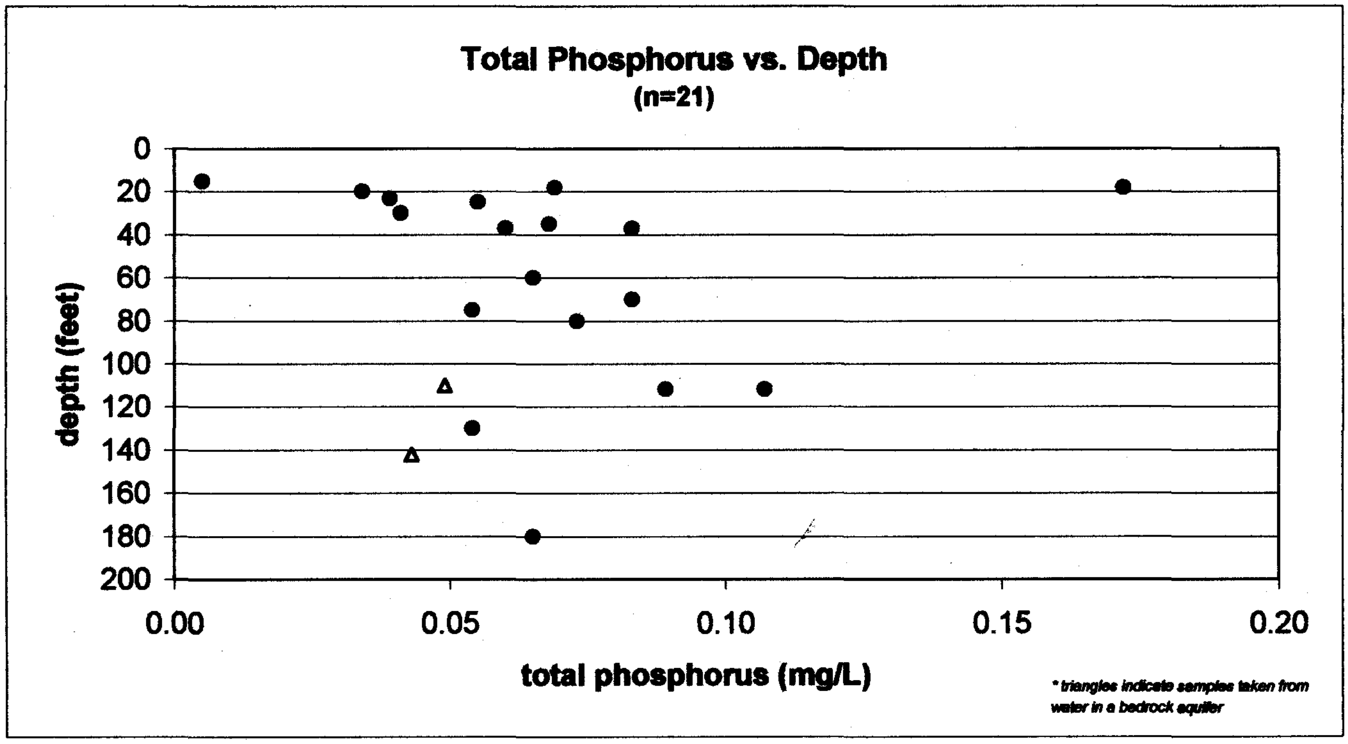


Figure B-7

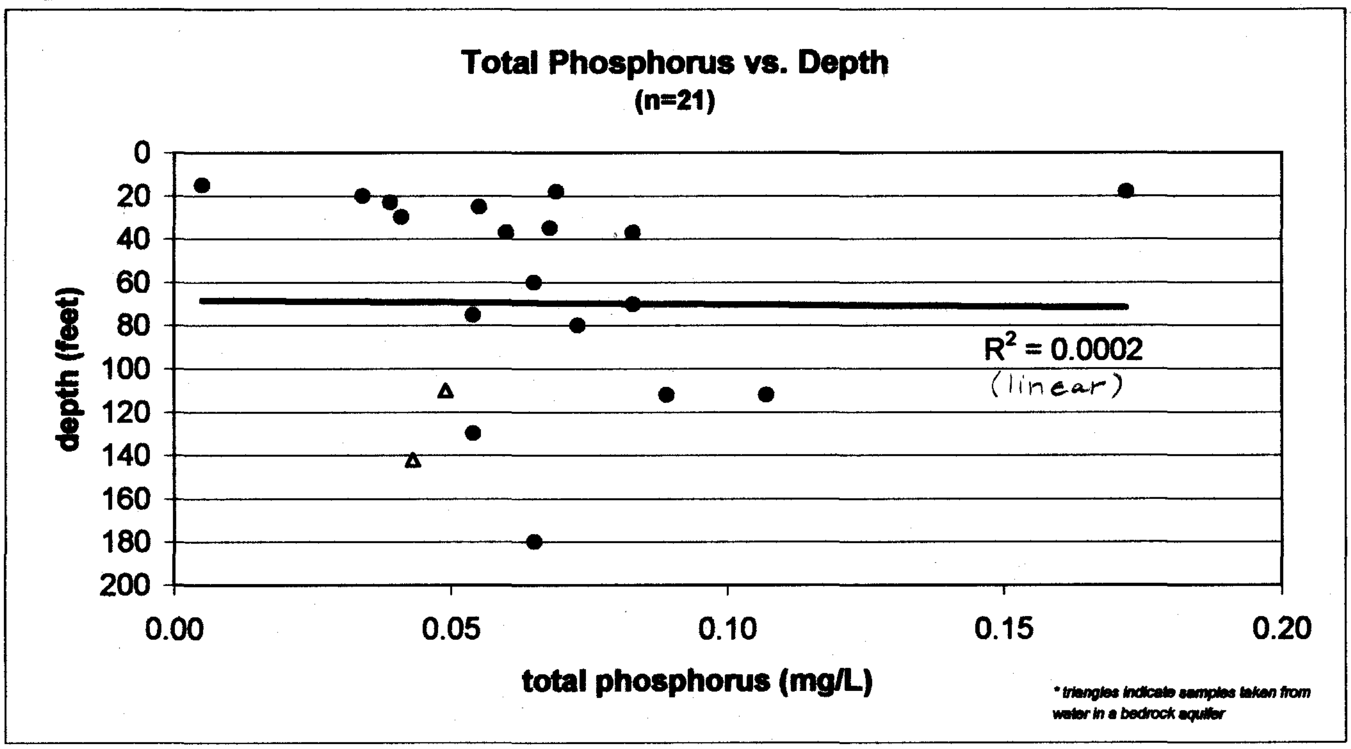


Figure B-8

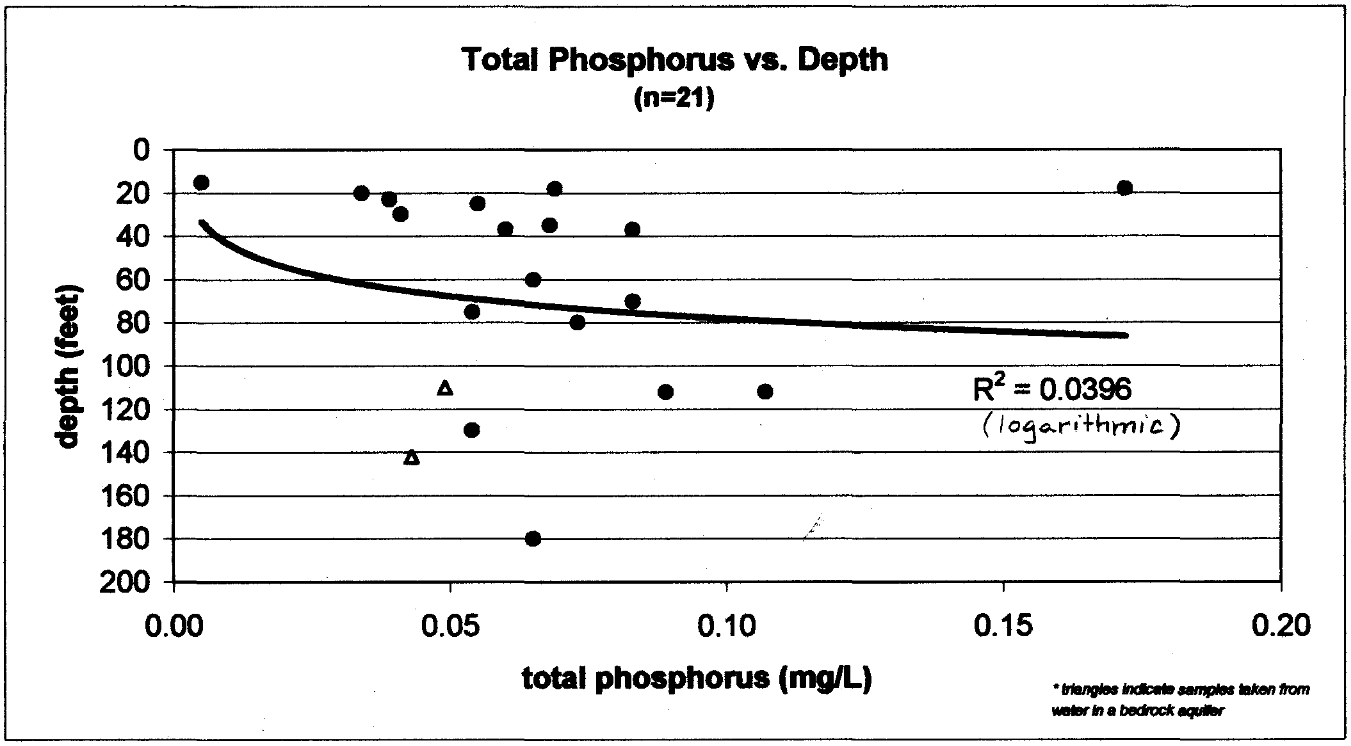


Figure B-9

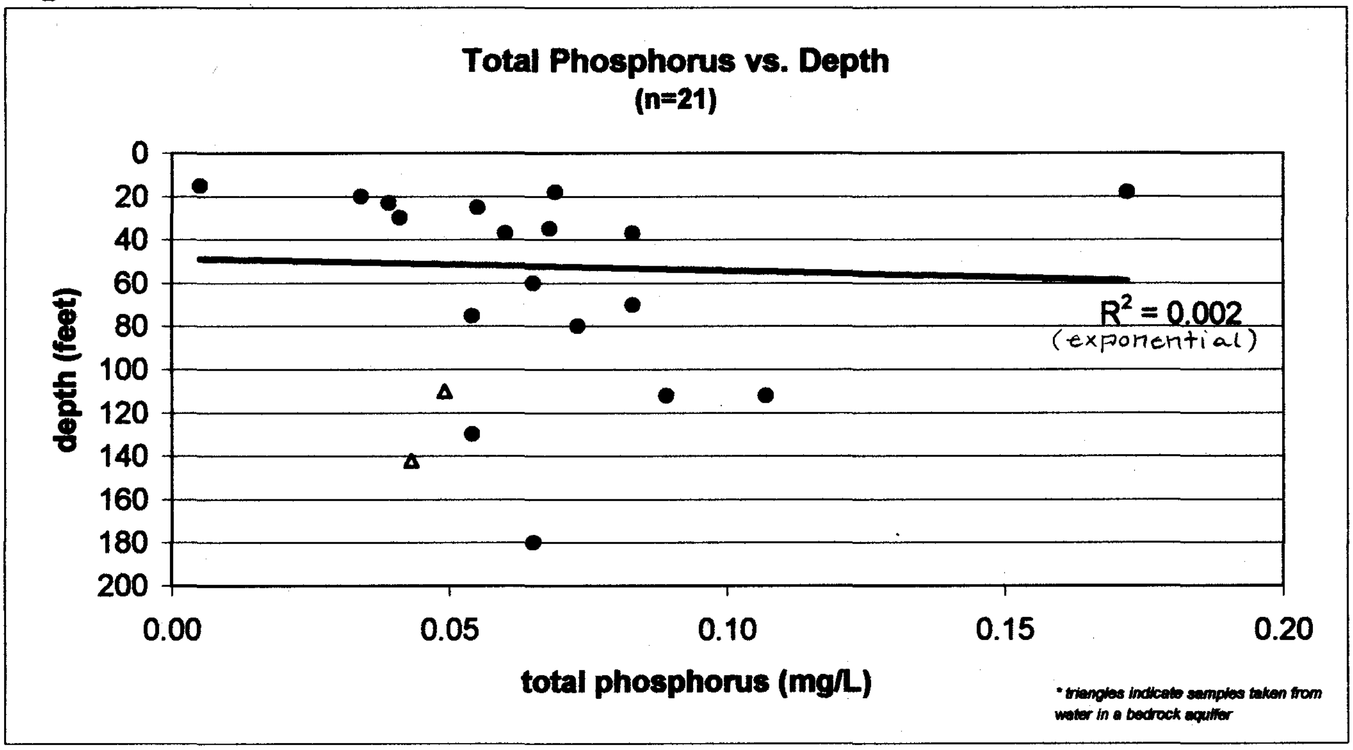


Figure B-10

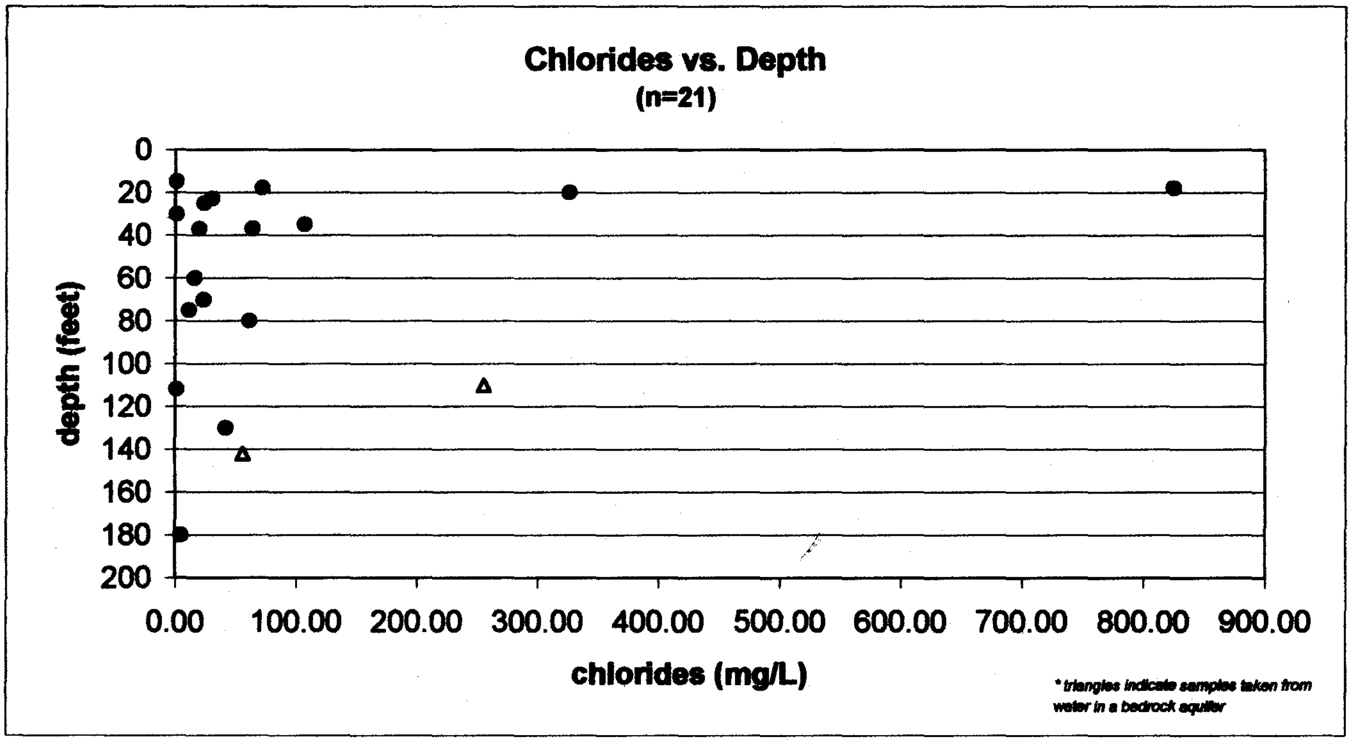


Figure B-11

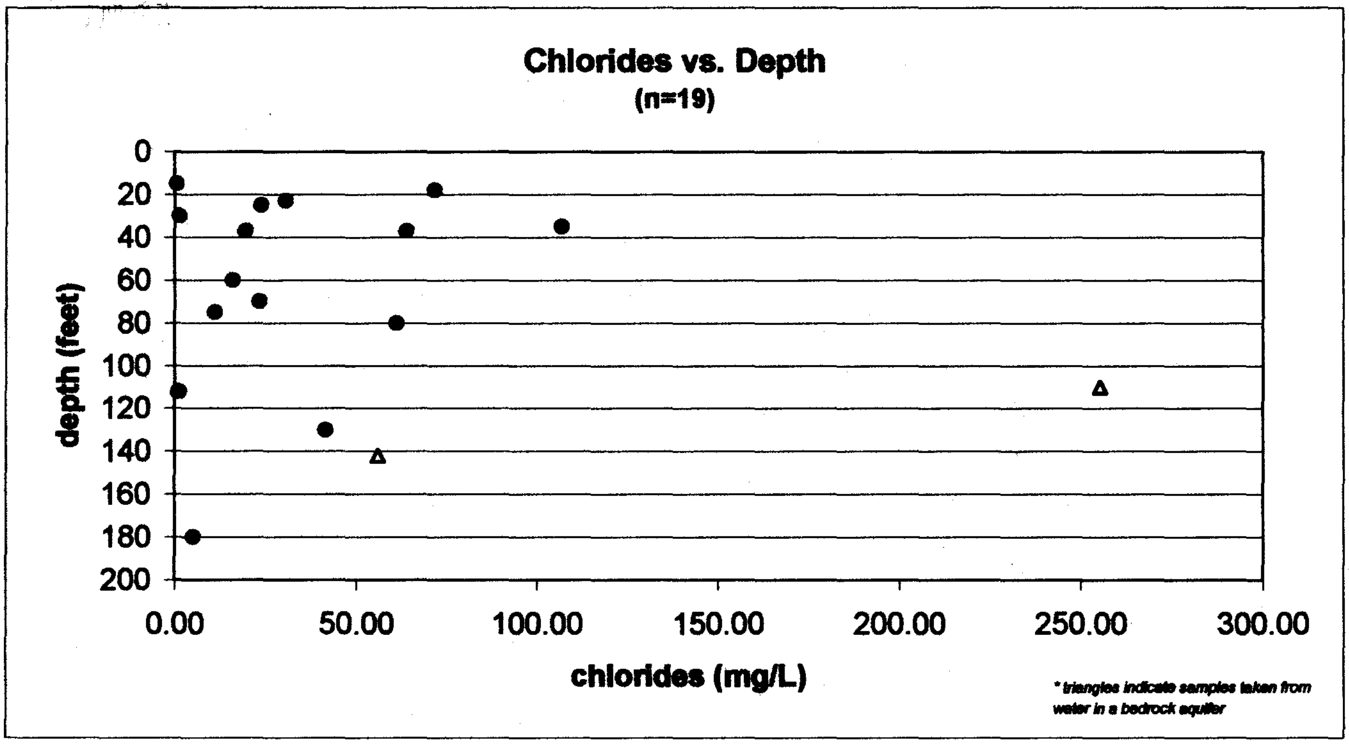


Figure B-12

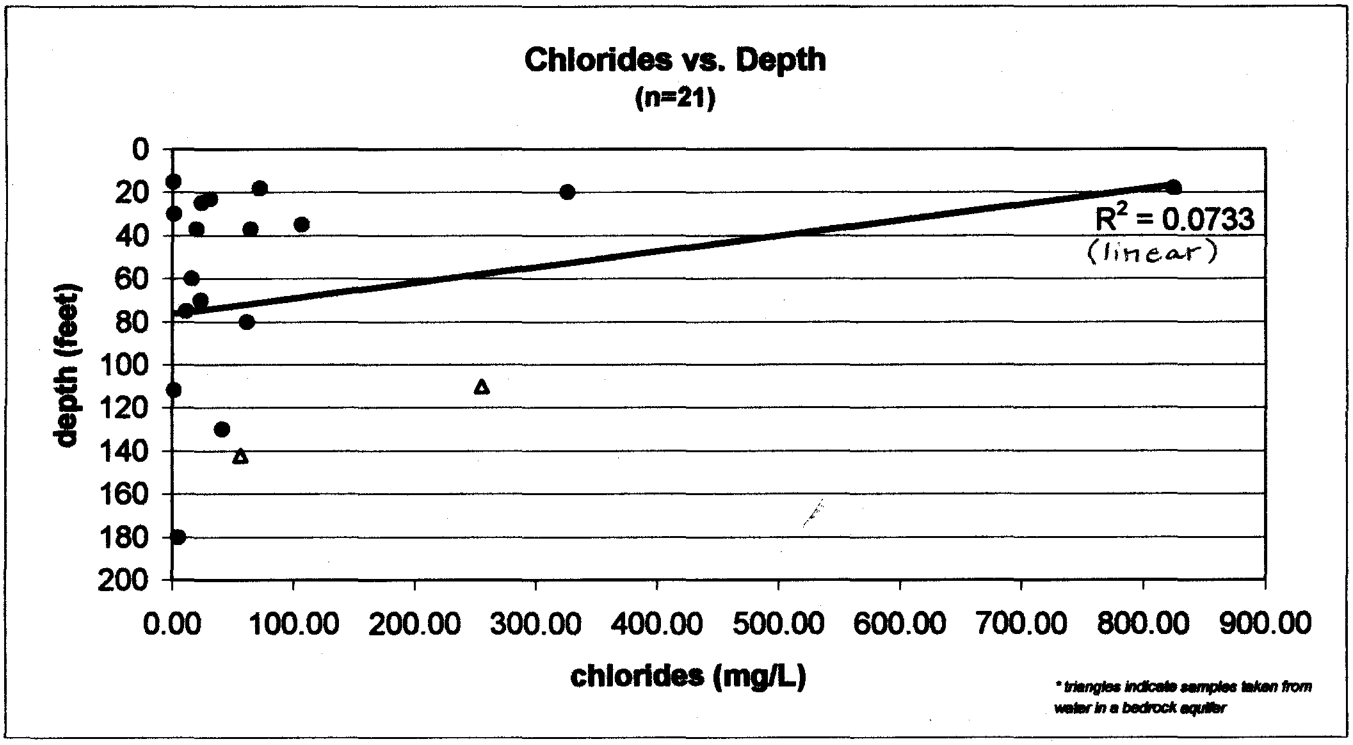


Figure B-13

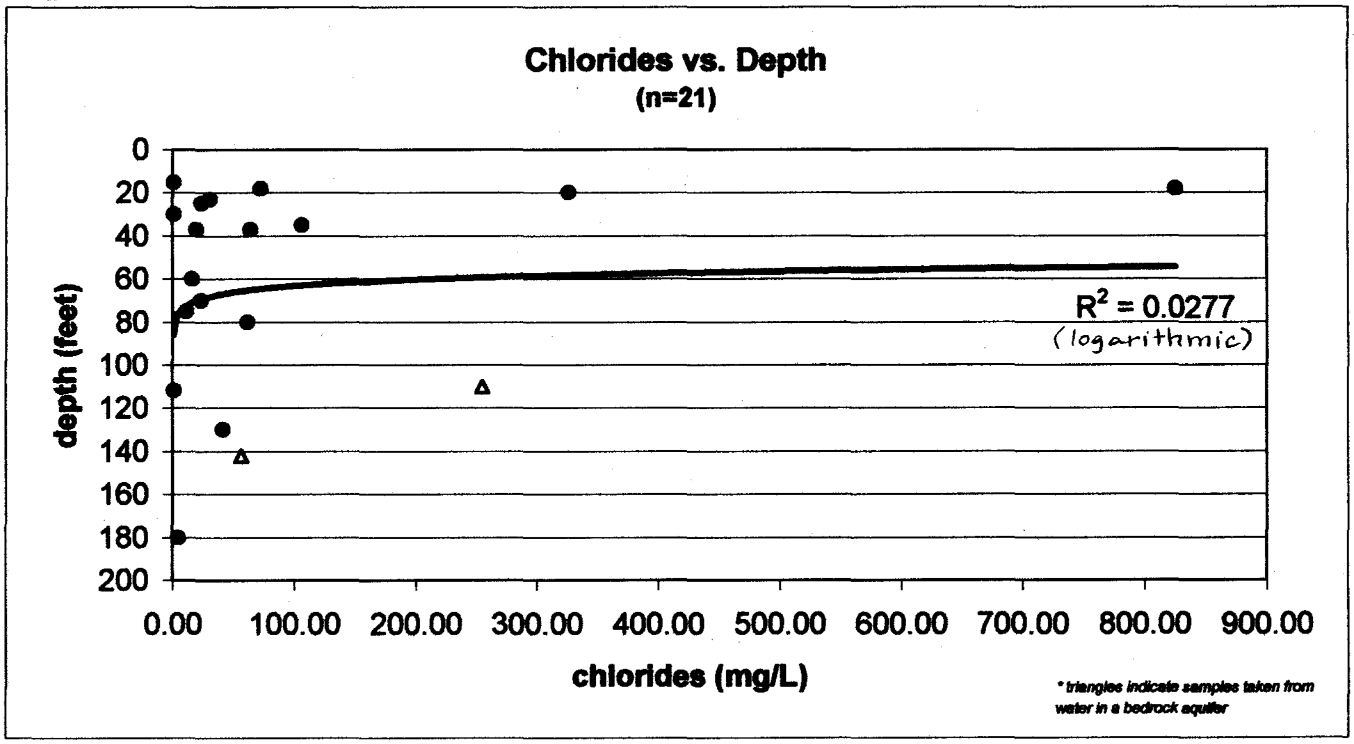
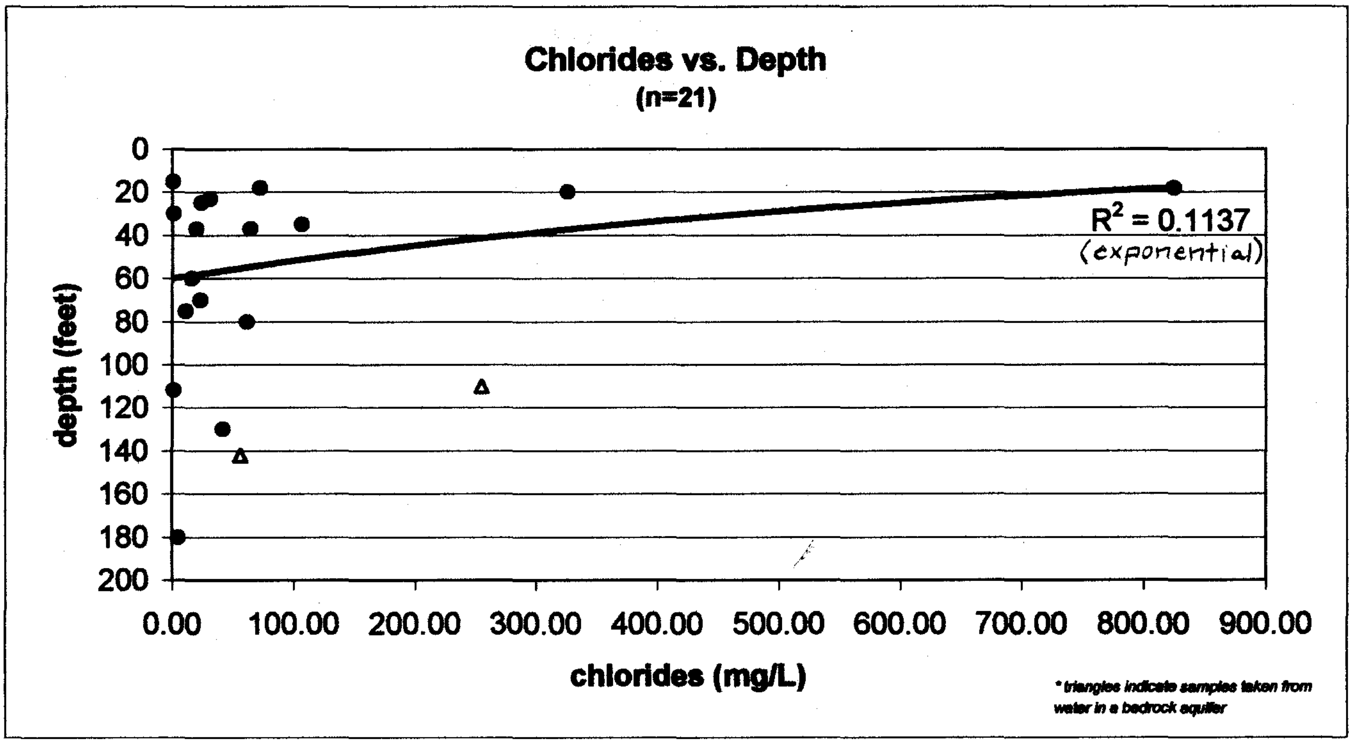


Figure B-14

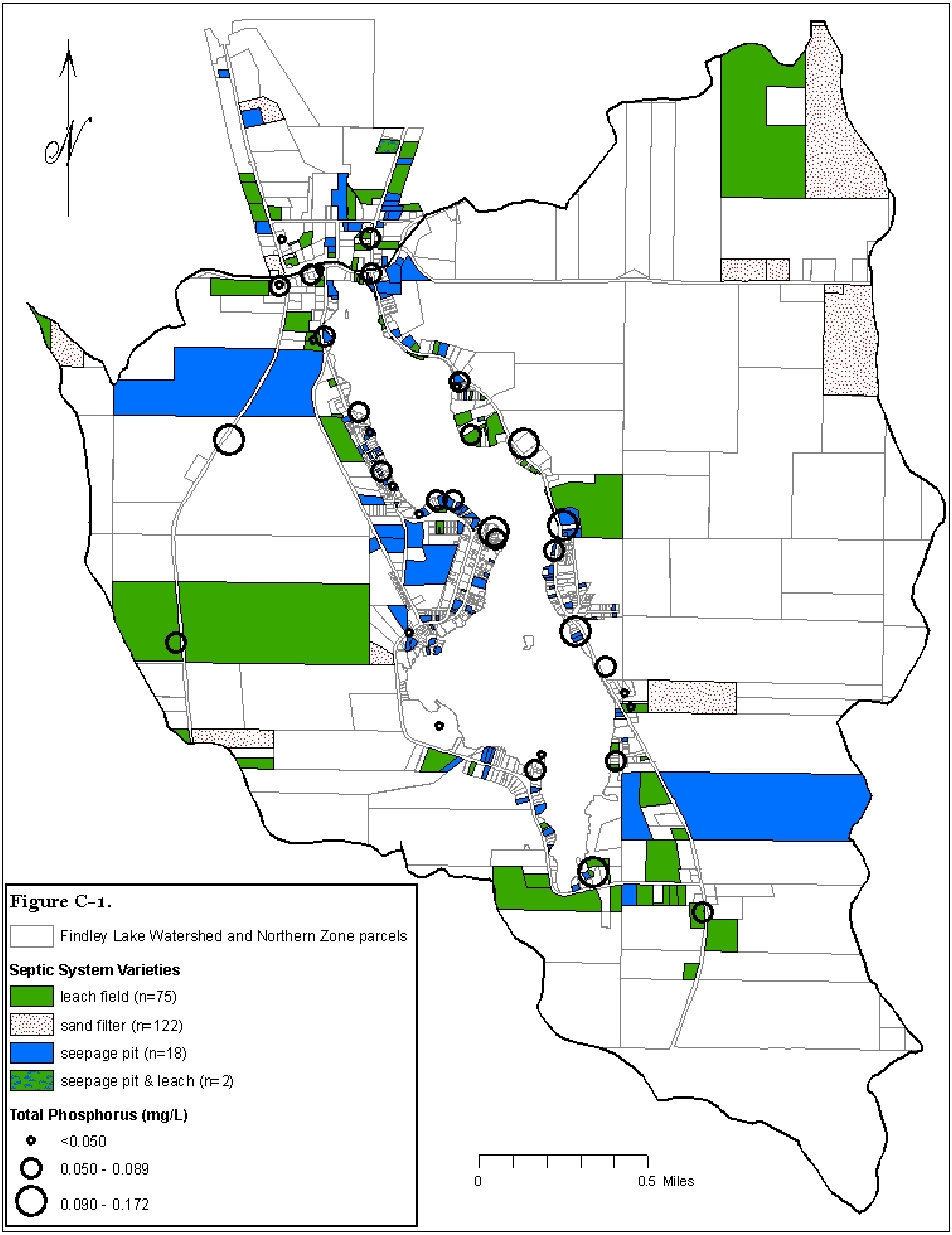

Chlorides vs. Depth
(n=21)
0
20
40
60
80
100
120
140
160
180
200
depth (feet)
0.00
100.00
200.00
300.00
400.00
500.00
600.00
700.00
800.00
900.00
chlorides (mg/L)
R2 = 0.1137
(exponential)
* triangles indicate samples taken from water in a bedrock aquifer

Appendix C

Studies of Septic-System Sources

Maps of nitrates, total phosphorus, and chlorides were constructed as open circles projected over parcels with permitted septic systems (Figure C-1 is phosphorus example), with parcels identified as to system types. For example, it was hoped that types of systems causing maximum phosphorus could be identified. All results were inconclusive.

Better results might be achieved in the future if exact geographic coordinates were available for all wells, and all septic systems (both permitted and not permitted), and their locations relative to groundwater flow directions (such as their distances to the lake).


N
0
0.5 Miles
Findley Lake Watershed and Northern Zone parcels
Septic System Varieties
leach field (n=75)
sand filter (n=122)
seepage pit (n=18)
seepage pit & leach (n=2)
Total Phosphorus (mg/L)
<0.050
0.050 - 0.089
0.090 - 0.172
Figure C-1.