4-1982

Ground-Water Flow Along the Total Shoreline of Austin Lake and Its Environmental Contribution to Pollution of the Lake

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GROUND-WATER FLOW ALONG THE TOTAL SHORELINE OF AUSTIN LAKE AND ITS ENVIRONMENTAL CONTRIBUTION TO POLLUTION OF THE LAKE

by

William Thomas Williams

A Dissertation
Submitted to the
Faculty of The Graduate College
in partial fulfillment of the
requirements for the
Degree of Doctor of Philosophy
Science Education

Western Michigan University
Kalamazoo, Michigan
April 1982

GROUND-WATER FLOW ALONG THE TOTAL SHORELINE OF AUSTIN LAKE AND ITS ENVIRONMENTAL CONTRIBUTION TO POLLUTION OF THE LAKE

William Thomas Williams, Ph.D.

Western Michigan University, 1982

The vertical direction of ground-water flow in Austin Lake was determined by placing minipiezometers along the entire shoreline at fifty randomly selected sites. Ground-water samples were taken at each site and the specific conductivity of the water samples was determined along with the chloride and phosphate content. The data were analyzed to determine if there were any relationships among water movement, chemical content, and the presence or absence of an onshore septic tank. The minipiezometer data show that the primary direction of water movement through the sediment-water interface is downward but may become reversed at localized regions as conditions vary. The negative hydraulic differential is greater at the north and south ends of the lake than on the east and west sides. This observation makes a stronger case for reports by other researchers that Austin Lake is on the ground-water divide and that ground water flows to the north and to the south from the lake. Computer analyses of all data show relationships among specific conductivity, chloride content, and the presence of a septic tank. Offshore from septic tanks, the specific conductivity and chloride content

vary more and have higher average concentrations than offshore from areas without a septic tank, although visual inspection of the data shows pollution to be minimal. Phosphate content failed to show relationships with septic tanks, but tended to be higher on the west side of the lake--an area bounded by outwash and containing older functional and non-functional septic tanks.

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ACKNOWLEDGEMENTS

I am grateful to many people whose guidance, advice, and information were indispensable in completion of this project.

My appreciation goes to my committee members, Dr. W. Thomas Straw, Chairman, Dr. George G. Mallinson, Dr. Richard Passero, and Dr. Joseph G. Engemann for their guidance and suggestions for the design and completion of the project and editing the manuscript. An extra thank you goes to Drs. Straw and Mallinson for their direction throughout my student years at WMU.

I also want to thank Dr. Perry D. Haaland of the Upjohn Corporation for his advice in analyzing the data and the interpretation of the results, Dr. Lloyd Schmaltz and the total Geology Department of WMU for the use of their laboratory and for the basis of much of my financial support, to Dr. Robert H. Poel for the direction and guidance that he gave me, and to the many residents around Austin Lake who provided me with interesting information of the lake's past and present condition.

Lastly, I want to thank my wife, Eva, for her patience and support she has given me throughout it all.

William Thomas Williams

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CHAPTER 1

INTRODUCTION

Geographical Location

Austin Lake is located in the southeastern corner of Portage Township, Kalamazoo County, Michigan (Figure 1). The lake encompasses parts of sections 23, 24, 25, 26, 35, and 36, T. 3 S., R. 11 W.

Geology

Austin Lake lies in a region glaciated by a succession of at least four major continental ice sheets. The main topographical features of the area were formed during the recession of the last ice sheet. Austin Lake is a "kettle" lake, occupying a depression formed from the melting of an isolated block, or blocks, of ice left during the retreats and readvances of the Lake Michigan lobe of the glacier during the last Ice Age--Wisconsinan time (Deutsch, Vanlier, & Giroux, 1960). The three-dimensional shape of the basins suggests that the lake was formed by the melting of three blocks of ice that were partly connected (Straw, 1978). Organic sediments have filled the lake basins until at the present time the maximal surface water depth is less than 10 feet (3.0 m). The

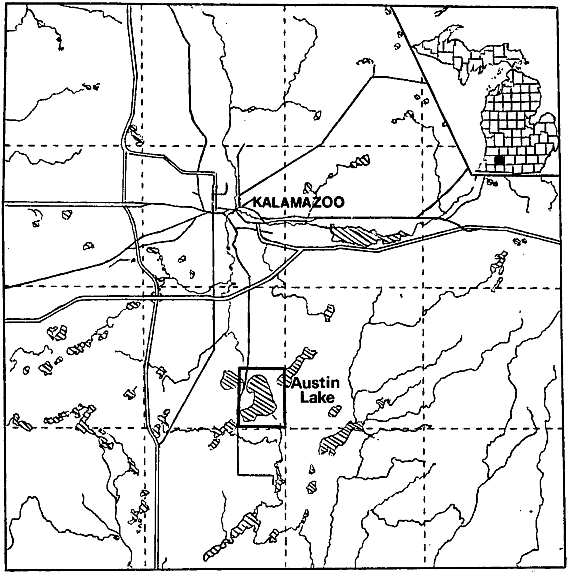

Figure 1. Location of study site in Kalamazoo County, Michigan.

basins formed by the three blocks of ice range in depth from 25 feet (7.6 m) to 50 feet (15.2 m) with the deepest being in the southwestern portion of the lake (Figure 2). Below the organic material in the basins, the sediment varies from coarse gravel to clay (Figure 3). Along most of the shoreline, the sediments have been modified by waves so that sand and gravel predominate.

Surface glacial deposits surrounding Austin Lake are of three types--morainal, outwash, and channel deposits. Adjacent to the lake on the northeast side are morainal deposits that trend northeastward. These morainal deposits were deposited directly from glacial ice with running water playing a minimal role in deposition. The west and south sides consist of outwash--material that was deposited from meltwater streams issuing from glacial ice. On the east side of the lake, trending southeastward, and from the north part of the lake northwestward are channel deposits. These are similar in origin to the outwash deposits, but have been reworked and covered with finer materials (Deutsch et al., 1960).

Sources of Water Entering and Leaving Austin Lake

Austin Lake covers an area of 1050 acres (2593.5 ha), but drains a land area that encompasses only 340

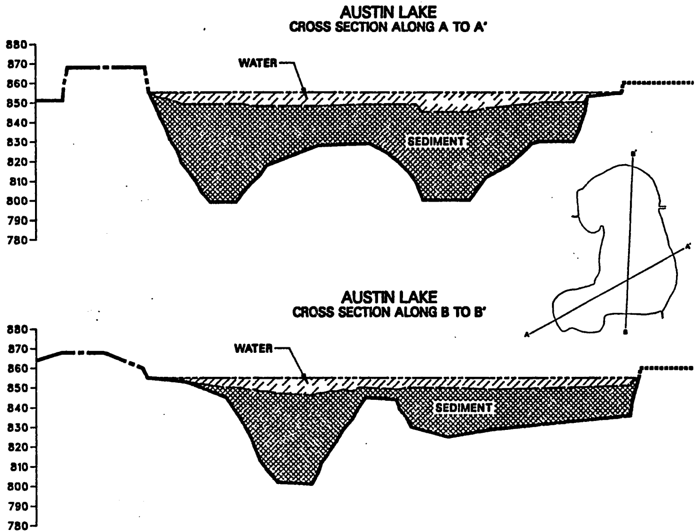

Figure 2. Cross sections of Austin Lake.

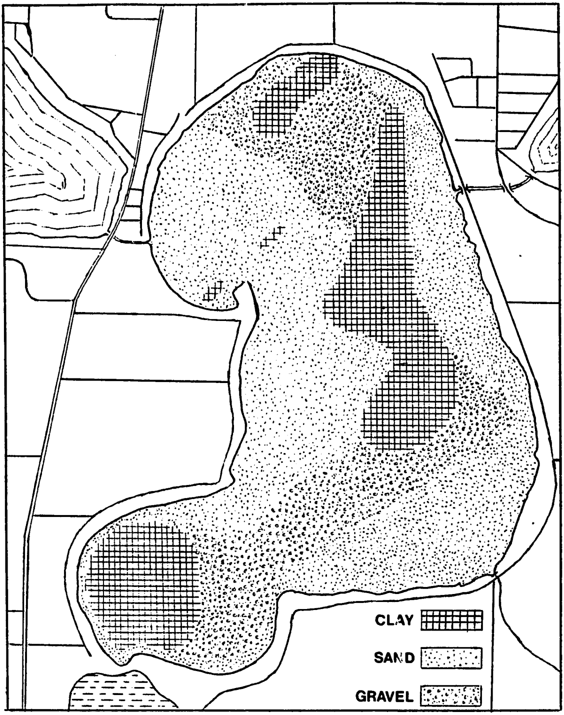

Figure 3. Basal sediment in Austin Lake (Straw, 1978).

acres (839.8 ha) (Straw, 1978). The effective drainage basin is considerably smaller because the permeability of the surrounding soil is high (Figure 4). Some surface water enters the lake from storm sewers, but otherwise surface water from the immediate drainage basin contributes little to the water budget. Some small ephemeral streams are present in areas of moderate to steep slopes, but most such drains do not contribute water unless rainfall is heavy. Other sources of water include canals from Long Lake and West Lake, direct precipitation, the Upjohn recharge pond, surface condensation, and ground-water discharge.

An outlet at the southeastern end of the lake leads to Gourdneck Creek. Water also seeps through the bottom to become part of the ground-water flow. Some water is lost through evaporation from the free water surface and through irrigation (Figure 5).

Austin Lake, with the other lakes in the complex, are all considered to be part of the St. Joseph River basin (Figure 6). Yet, Allen, Miller, and Wood (1972) placed the ground-water divide (major deep ground-water flow) on an east-west line through the center of Austin Lake with ground-water movement to the north and south of the lake (Figure 11).

Figure 4. Drainage basin of Austin Lake (Straw, 1978).

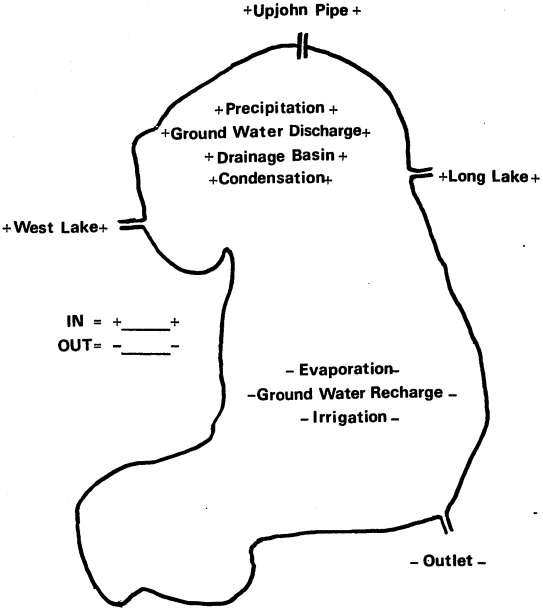

Figure 5. Water sources and losses of Austin Lake.

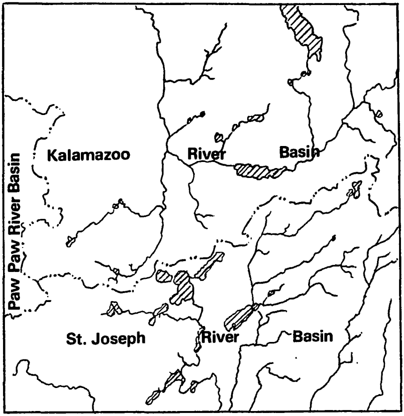

Figure 6. The primary drainage basins of Kalamazoo County, Michigan (Allen et al., 1972).

Location of Sewer Lines

The dwellings around Austin Lake are served by sewer lines with the exception of those in the southwestern corner. Because sewer lines surrounding the lake are of recent origin many residents still use septic tanks.

History

Natural accumulations of organic sediments have partly filled the lake since the retreat of the last glacier. Radiocarbon dating of the organic sediments in certain parts of the lake indicate that the rate of accumulation of these materials was about 1 inch (2.54 cm) every 20 years for the period 8000 B. P. (before present) to 3000 B. P., 1 inch (2.54 cm) every 12 years for the period 3000 B. P. to 1700 B. P., and 1 inch (2.54 cm) every 7 years since 1700 B. P. It is likely that sedimentation may now be taking place at the rate of 1 inch (2.54 cm) every 2 years (Straw, 1978).

In 1962 an attempt was made to pump out the organic sediment near the north end of the lake. The objectives of the project were to determine (1) how much solid material could be pumped out in one hour using a four inch pipe, (2) if the hole formed by the pumping of muck would be filled in by the surrounding material, and (3) at what rate the hole would fill (Zeno, Kalamazoo

Gazette, September 26, 1962). A holding area was constructed and filled with the pumped muck. The holding area was permeable so the water could drain out leaving the solids behind. After being filled, the weather turned cold, freezing and damaging the equipment. No further action was taken (Ryskamp, Note 1).

Also in 1962, concern over the lake level led to a plan for a ponding project to hold water tȯ be released when the level of the lakes dropped (Kalamazoo Gazette, December 4, 1962). In 1963 attention was directed towards pumping well water into the lakes to maintain their levels (Kalamazoo Gazette, Swptember 21, 1963). In 1964 a proposal was presented to divert water from the Upjohn pond to Austin Lake (Kalamazoo Gazette, February 23, 1964). This became known as the Tri-Lakes Upjohn Project and, after a series of legal battles, construction finally began in December of 1966 (Kalamazoo Gazette, December 23, 1966). On July 20, 1967, (Kalamazoo Gazette) the pipeline construction was completed and five million gallons of water a day began flowing into Austin Lake.

The pipeline was instrumental in solving the low water-level problem, but because the lake is shallow, sunlight is able to penetrate to the bottom stimulating the growth of rooted aquatic plants. Changes in the use of the lake from predominantly fishing to fishing, boating, and water skiing caused residents to view the growth of weeds with concern. Various methods have been proposed to alleviate this problem. These methods include dredging, aeration, chemical treatment, and harvesting, but costs and uncertainity of the results have prevented any action. More basic research to reduce the degree of uncertainity needs to be done before major steps can be taken to improve the lake basin.

Assessment of Lake Environments

This paper is a result of an investigation into the movement and quality of ground water as it relates to Austin Lake. The purpose of the investigation was to locate areas of inflow and outflow near the shoreline of Austin Lake and to determine if the lake is being polluted from ground-water sources.

The main hydrogeologic factors that are prerequisites for assessing lake environments are: (1) regime dominance (the relative magnitude of ground water in the water budget of a lake); (2) system efficiency (a term describing the rate aspects of surface- and ground-water movement through a lake system); and (3) position within a ground-water flow system (Born, Smith, & Stephenson, 1974). This paper is concerned with this last factor along with the water quality of the ground water that enters the lake.

The best information for determining the position of a lake in a ground-water flow system is the ground-water potential distribution beneath the lake bottom, and the vertical hydraulic gradient is the ideal criterion. If the vertical gradient is positive (potential increasing downward) the lake is in a ground-water discharge region. If the vertical gradient is negative (potential decreasing downward) the lake is in a ground-water recharge region. If the vertical gradient is zero or negative at one end and positive at the other, the lake is in a region of lateral flow. Measurement of this factor must be done onsite with piezometers (Born et al., 1974).

Significance of Study

This study is significant for three reasons: (1) little research has been done on the ground-water flow beneath lakes in Michigan and none on Austin Lake with the exception of generalized deep ground-water flow patterns. The ground-water flow into and out of the lake has not been determined in detail by use of piezometers; (2) the lakeshore is highly urbanized and there is the possibility of substantial pollution; and (3) a detailed knowledge of the hydrology of Austin Lake must be gained before an adequate plan can be developed for the restoration of the lake.

CHAPTER 2

REVIEW OF PERTINENT LITERATURE

Ground-water flow and its association with lakes has only recently become the object of detailed research studies. Because of this, information on the subject is limited. Research on the quality of ground water that enters lakes is virtually non-existent. This chapter reviews research and writings of ground-water flow as it relates to lakes.

Ground-water Flow

Freeze and Cherry (1979) described ground-water movement in homogenous and isotropic materials as a flow from highlands towards valleys. In this situation the water table forms a subdued replica of the topography. The symmetry of the system creates vertical boundaries beneath the valleys and ridges across which there is no flow. These "ground-water divides" usually coincide exactly with surface-water divides, and their orientation is, for all practical purposes, vertical (Figure 7). Freeze and Weatherspoon (1966) showed that in more complex topographic and hydrogeologic environments ground-water movement becomes more complicated.

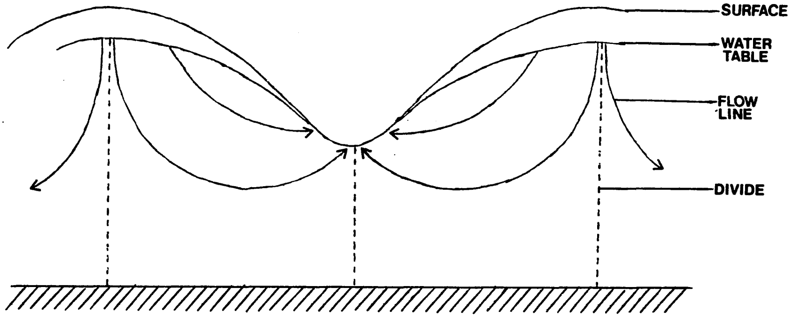

Figure 7. Simplified flow pattern of ground water showing ground-water divides (Freeze and Cherry, 1979).

Toth (1963) and Born et al. (1974) described ground-water flow as ground-water movement in response to gravity from regions of high to low potential along flow lines that describe the path of an individual water particle as it moves through the soil. A set of flow lines oriented so that any two flow lines adjacent at one point in the system remain adjacent throughout the system make up a ground-water flow system. All the flow lines in a ground-water flow system can be intersected by an uninterrupted surface across which flow takes place in one direction only. Freeze and Cherry (1979) stated that flow lines deliver ground water from recharge regions to discharge regions (Figure 8).

Freeze and Cherry (1979) described ground-water flow beneath a hilly topography. In this situation there are numerous subsystems within a major flow system. Water that enters the flow system in a given recharge region may be discharged in the nearest topographic low (local ground-water flow) or it may be transmitted to the regional discharge region in the bottom of the major valley. Toth (1963) showed that as the depth to lateral extent of the entire system becomes smaller and as the amplitude of the hummocks become larger, the local systems are more likely to reach the basal boundary, creating a series of small independent cells (Figure 9).

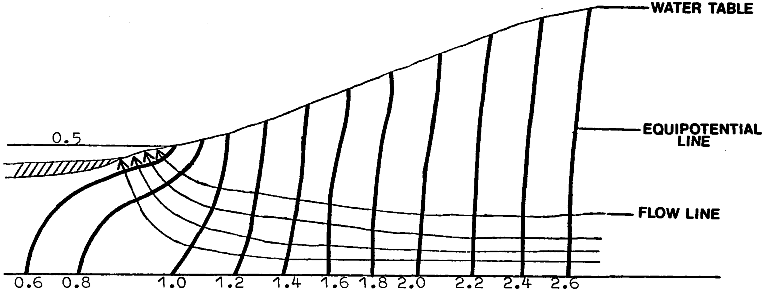

Figure 8. Flow lines and equipotential lines (McBride et al., 1975).

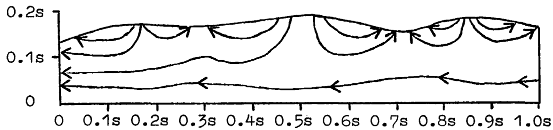

Figure 9. Effect of topography on regional ground-water flow patterns (Freeze and Cherry, 1979).

Freeze and Cherry (1979) listed the effects geological heterogeneity can have on regional ground-water flow. Heterogeneity can affect the interrelationship among local and regional ground-water flow, the surficial pattern of recharge and discharge regions, and the quantities of flow that are discharged through the systems.

Born et al (1974) discussed lakes and their association with ground water. Lakes situated in ground-water recharge regions (recharge lakes) contribute to the ground water throughout the entire lake bottom. Lakes in ground-water discharge regions (discharge lakes) gain ground water throughout the entire lake bottom. In regions of lateral ground-water flow, lakes lose to the ground water on one side and gain ground water on the other side. Such lakes are known as flow-through lakes (Figure 10). Lakes may be associated with the regional ground-water flow, local ground-water flow, or both. It is possible for lakes to intersect both a shallow and a deep flow system with the result that ground-water movement near the lake margins may be opposite to the directions of movement near the lake center.

Manson, Schwartz, and Allred (1968) indicated that "muck" is highly impermeable and therefore, where it exists, prevents water from moving in and out of a lake. They stressed the importance of bottom materials in preventing or permitting ground water to enter or to leave

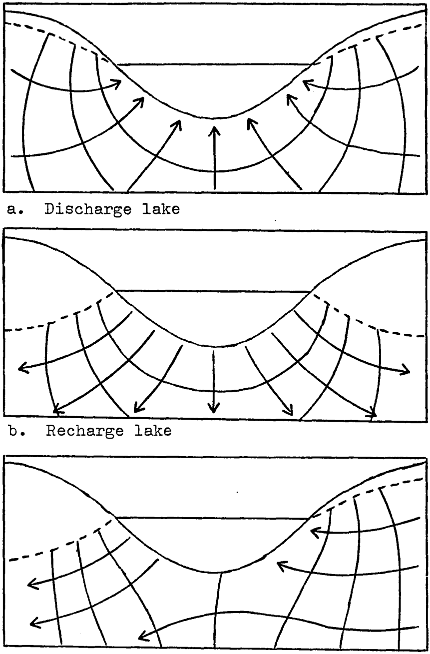

Figure 10. Configuration of ground-water flow systems around lakes (Born et al., 1974)

lakes. They also speculated that glacial lakes--not intersecting the water table--upon initial formation did not hold water. Finer materials carried in by sheet and gully erosion sealed the bottom of the kettles, thereby permitting the lakes to hold water. They presented data to support the view that the permeability of the soil and drift adjacent to the pond or lake are usually much greater than that of the bottom. Thus, when the water level rises to flood the normal basin, infiltration is rapid and the level tends to decline rather promptly to the usual level. Their investigation of ponds and small lakes in relatively deep depressions showed that inflow underground was largely limited to wet periods--and even then was not prevalent at all sites.

McBride and Pfannkuch (1975) and Lee (1972) showed that seepage into or out of lakes tends to be concentrated near the shore and decreases with increasing distance from the shore. In many places the rate of decrease is exponential. Their model indicated that little of the ground-water flow passes beneath the lake. Instead, most of it is diverted upward as it approaches the lake, passes through the lake, moves downward, and eventually comes back to the horizontal. McBride and Pfannkuch (1975) showed that this holds true only where the diameter of the lake is at least roughly comparable to the thickness of the underlying permeable materials.

Where ponds have diameters much less than the thickness of the sections, seepage occurs almost uniformly across the bottoms of the depressions.

McBride and Pfannkuch (1975) in citing Lee's (1972) study of Lake Sallie, Minnesota, noted that in the 2 km wide lake, one-half of the discharge occurs within 17 m of shore, 90 percent within 60 m and 99 percent within 120 m. The edge of the fine-grained sediments in the center of Lake Sallie is 300 m from shore. This and similar research done by Hackbarth (1968) in the Little St. Germain Lake Basin in Wisconsin show the importance of the geometry of the ground-water system and the relatively small role that lake sediments have in controlling the distribution of seepage in lakes.

Deutsch et al. (1960) and Allen et al. (1972), using water level data from observation wells, lakes, and streams, determined the direction of the regional ground-water flow in the Austin Lake complex. This complex includes Austin, West, Long, Sugarloaf, and Gourdneck lakes. These data indicated that the ground-water movement was both north and south of an east-west line crossing the approximate center of Austin Lake (Figure 11).

Allen et al. (1972) devised a water budget for the complex from October 1, 1965 to March 30, 1966 and again from April 1, 1966 to September 30, 1966. For their first budget, they cited a subsurface inflow of 73 acre-feet

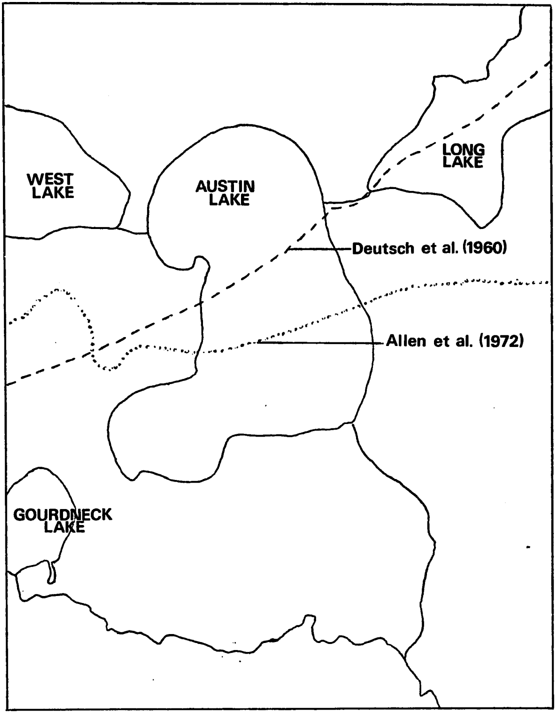

Figure 11. Ground-water divides as shown by Deutsch et al. (1960) and Allen et al. (1972).

and a subsurface outflow of 1,070 acre-feet. For the second budget, the subsurface inflow is 146 acre-feet and the subsurface outflow is 1,010 acre-feet. They said the subsurface outflow returns to the surface at Gourdneck Creek, a short distance to the south of Austin Lake and flowing east. These figures indicate that little ground water enters Austin Lake as compared with the total flow.

Ground-water Quality

Legrand (1965) described contaminant movement from waste sites into the subsurface water circulation. This movement results in contaminated zones, or enclaves, in the zone of saturation. The contaminants tend to be entrained in ground-water flow and also tend to attenuate to varying degrees by dilution in water, decay with time, or some other 'die away' mechanism, and adsorption on earth materials. Once a contaminated zone is approximately stable, an increase in concentration may cause it to remain about the same size under some conditions and enlarge in others according to combined attenuation effects. Where attenuation occurs only by dilution the contaminated zone will become enlarged with increased concentration, and even if attenuated only slightly by dilution may become greatly elongated in the direction of ground-water flow. Where attenuation occurs through decay or adsorption or through both mechanisms, the contaminated zone may not change appreciably, even if the concentration of contaminants increases. Where the contaminants sink into the ground, the vertical direction predominates in the zone of aeration that lies above the water table. When they reach the zone of saturation contaminants tend to spread laterally (Figure 12).

Lee (1972), in his study of lakes in a glacial terrain, found that septic tank effluent from lakeside houses entered the lake within 9 meters of the shoreline in a fan-shaped pattern. His study showed that 40 percent of the nitrogen entered the lake although the phosphorus was fixed in the soil.

Previous studies of the water quality of Austin Lake indicate low concentrations of dissolved nutrients. Jones and Henry Engineers, Limited (1972) showed that chloride concentrations on the western edge of the lake averaged 36 mg/l and 20 mg/l at other sampling points. Orthophosphates ranged from 0 to 0.45 mg/l.

Allen et al. (1972) listed chloride concentrations between 1 and 6 mg/l.

Chemical analyses by the author during a period from September to December, 1977, show low levels of phosphorus.

Information on the quality of ground water discharged into Austin Lake is not available.

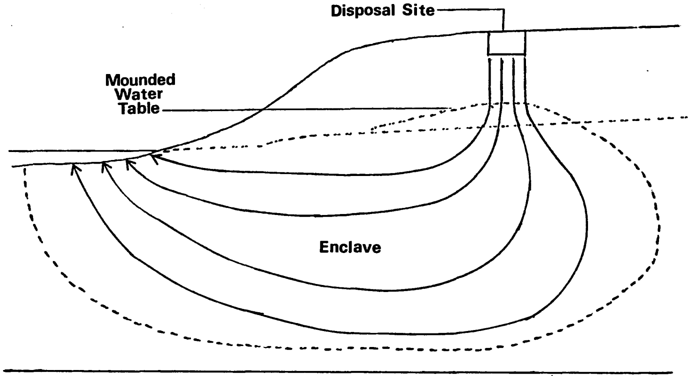

Figure 12. Lateral spread of pollutants in the zone of saturation (Legrand, 1965).

CHAPTER 3

PROCEDURE FOR COLLECTING DATA

The purpose of this investigation was twofold. The first objective was to determine the direction of water flow through the sediment-water interface along the total shoreline of Austin Lake. The second objective was to determine if this water was contributing to the degradation of the lake.

Determination of Hydraulic Head

The total shoreline of Austin Lake was divided into segments. Most lots represented one segment. Large lots were divided into two or more segments. Areas not designated as lots were divided into segments that were approximately 50 feet in width. Each of the 678 segments was assigned a number. Fifty segments were selected at random for the study (Figure 13).

In order to determine the direction of ground-water flow, minipiezometers were placed at the approximate center point of each segment at distances of 10 feet (3.0 m) and 20 feet (6.1 m) from shore.

The minipiezometer, modified from one used by Lee and Cherry (1978), consists of a 3/4 inch (1.9 cm) iron

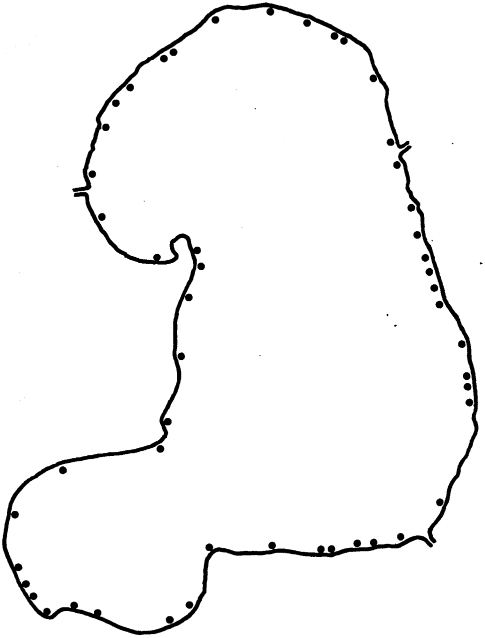

Figure 13. Approximate locations of sample sites on Austin Lake.

pipe. A 1/2 inch (1.3 cm) iron pipe 8 inches (20.3 cm) long was welded to one end. A 7/16 inch (1.1 cm) polyethylene tube 8 inches (20.3 cm) long was placed inside the 1/2 inch (1.3 cm) iron pipe and the two were drilled simitaneously and perforated with a 1/4 inch (0.6 cm) bit. The polyethylene tube was then removed, wrapped with a fine mesh nylon net and replaced. Care was taken to be sure the holes on the pipe and the tube lined up. They were then fixed in place with a small bolt through the pipe and tube. The 1/2 inch (1.3 cm) pipe was capped with a reducer and plugged. The reducer and plug served as a driving point.

The pipe was capped and driven to the desired depth. The cap was then removed and water allowed to rise up into the pipe. To facilitate the process, water was added until the water level in the pipe was at the level of the water in the lake. Subsequent water-level movement within the pipe was measured and recorded along with water depth and pipe depth into the sediment. Water-level movement was checked by varying the level of water in the pipe to determine if the results could be replicated. The difference between the water levels of the lake and pipe is the hydraulic head. To facilitate the measurement of the hydraulic head, a device (manometer) was inserted into the minipiezometer. Readings could then be made above the surface of the lake (Figure 14).

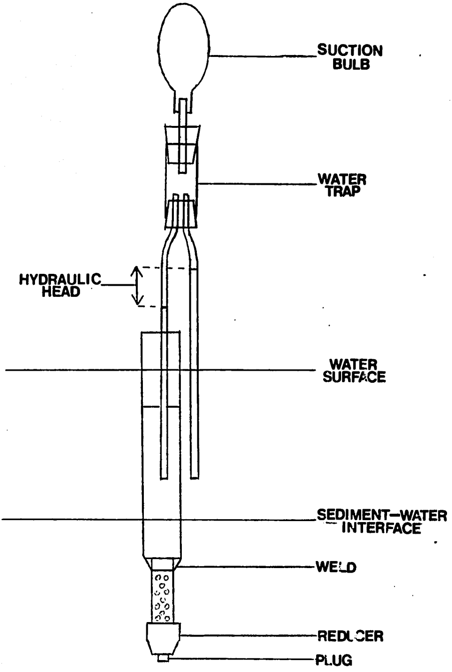

Figure 14. Sampling equipment.

Water Sampling

The minipiezometer was pumped dry (not always possible in permeable sediments) and ground-water samples taken from water that refilled the pipe from below.

Chemical Analysis

Each sample was frozen at the end of each sampling day. When enough samples accumulated, they were thawed. The specific conductivity was determined and the sample analyzed for its chloride and phosphate content.

Conductivity was measured using model EP-10 specific conductivity meter manufactured by the Myron L. Company of Encinitas, California. Results are given in micromhos/centimeter.

Chloride concentration was determined using the Hach mercuric nitrate method. In this procedure, diphenylcarbazone is the indicator and mercuric nitrate the titrant. Once all the chloride present in the sample is complexed by the mercuric ions, the excess mercuric ions combine with diphenylcarbazone to form a purple complex indicating the end point of the titration.

Phosphate concentration was determined using the Hach ascorbic acid method. In this phosphate analysis, orthophosphate reacts with molybdate in an acidic medium to produce phosphomolybdic acid that is then reduced to a heteropoly blue compound. The phosphate concentration of the water sample is then determined by measuring the intensity of the blue color.

Importance of Water Quality Parameters Measured

Conductivity is a measure of the ability of water to conduct an electrical current. It is expressed in micromhos per centimeter at 25°C. Pure water has a low conductivity. Conductivity increases with increasing concentrations of dissolved minerals in the water. Normally the amount of dissolved solids in milligrams per liter (mg/l) is approximately 65 percent of the conductivity. Dissolved solids are often contributed to ground water by industrial and domestic wastes.

Soluble Orthophosphate--Phosphorus is the dissolved form of phosphate that is directly available for plant growth. Phosphate is reported rather than phosphorus because the element, phosphorus, does not occur free in nature. Instead, it is found in combined forms, the most common being phosphates. Phosphorus, like nitrogen, is an element essential to plant growth and both elements can be derived from sources such as soils and decomposition of organic matter. Phosphorus has become increasingly evident in the environment because of its past extensive use in detergents and its present use in agriculture. In streams, phosphorus is an extremely limiting element for plant growth and thus an increased supply from outside sources such as sewage effluents may provide the stimulus for excessive production.

Phosphate movement in ground water is limited and therefore was not expected to be detected in large concentrations. Comparisons of phosphate concentrations with chloride concentrations may yield additional information regarding these species.

The chloride ion, in combination with one of several cations such as sodium, magnesium, and potassium, is a common impurity in most natural waters. Chloride compounds are readily dissolved from rocks by surface and subsurface waters. A concentration of several hundred milligrams per liter is necessary before a salty taste is imparted to the water or aquatic organisms are harmed.

Chlorides are essential in the diet and passes through the digestive system to become one of the major components of sewage. The wide use of salt in water softeners also contributes a large amount of chloride to sewage. In water, chloride concentrations are attenuated primarily by dilution and therefore high concentrations are good indicators of pollution.

CHAPTER 4

ANALYSIS OF DATA

The data were analyzed on an IBM 3033 computer operating from an IBM 3270 terminal under Time Sharing Option (TSO). The language used throughout the analysis was Statistical Analysis System (SAS).

Table Descriptions

The data analyzed are listed in Tables 1, 2, and 3.

Table 1, on pages 36, 37, 38, and 39, contains physical data from each sampling point. The data in Table 1 include the depth of the water at the sampling point (DW), the depth the piezometer was driven into the sediment (DP), the hydraulic head (HH), and whether or not a functioning septic tank was present on the lot onshore from the sampling site.

Table 2, on pages 40, 41, 42, and 43, contains the results of the ground-water sample analyses for each sampling point. The data in Table 2 include specific conductivity (COND), chloride content (CHL), and phosphate content (P).

Table 3, on pages 44, 45, and 46, contains data on other physical factors that may have an effect on ground-water movement and/or chemical properties of the ground

Table 1

Physical Data for Each Study Site

Location Number	Depth of Water (cm)		Depth of Pipe in Sediment (cm)		Hydraulic Head (mm)		Septic Tank (yes, no)
	3 m	6 m	3 m	6 m	3 m	6 m	
7	-	35	-	56	-	-5	no
18	-	-	61	61	-35	-10	yes
32	25	61	61	46	0	-10	yes
49	-	20	-	61	-	-65	yes
68	76	-	61	-	+7	-	yes
75	17	35	57	47	+3	+5	yes
120	34	96	55	59	-155	-189	yes
144	79	152	87	61	+2	-9	yes
168	62	122	65	55	-190	-280	yes
170	28	51	51	87	0	0	no
176	23	44	47	121	0	0	no
185	51	98	52	123	-3	-5	no

Table 1 (Continued)

Location Number	Depth of Water (cm)		Depth of Pipe in Sediment (cm)		Hydraulic Head (mm)		Septic Tank (yes, no)
	3 m	6m	3 m	6 m	3 m	6 m	
192	31	53	55	59	-1	-5	no
213	20	36	100	90	-10	-10	no
218	33	48	52	95	-10	-10	yes
244	28	40	52	95	-23	-120	no
260	25	31	95	95	0	-50	no
274	20	25	95	105	-5	-45	yes
275	20	25	70	104	-20	-125	yes
281	30	38	45	94	-30	-110	no
287	35	50	45	100	0	-215	no
305	49	54	113	96	-100	-100	yes
320	50	58	60	92	-15	-	no
361	12	20	68	100	-7	-43	yes
365	28	38	67	102	-15	-45	yes

Table 1 (Continued)

Location Number	Depth of Water (cm)		Depth of Pipe in Sediment (cm)		Hydraulic Head (mm)		Septic Tank (yes, no)
	3 m	6 m	3 m	6 m	3 m	6 m	
366	12	28	70	97	-42	-40	yes
373	28	52	67	98	-10	-25	yes
383	30	38	98	95	0	+5	no
401	30	38	68	92	0	0	no
403	30	33	68	95	0	0	no
416	51	51	81	101	0	-5	no
419	38	43	53	109	-25	-15	no
420	38	46	50	56	0	0	no
451	41	64	86	88	-75	-110	no
457	51	104	76	64	0	0	no
473	43	97	45	55	-5	-7	no
496	38	51	51	86	-150	-180	yes
497	38	51	89	71	-170	-200	yes

Table 1 (Continued)

Location Number	Depth of Water (cm)		Depth of Pipe in Sediment (cm)		Hydraulic Head (mm)		Septic Tank (Yes, no)
	3 m	6 m	3 m	6 m	3 m	6 m	
508	41	74	71	81	-255	-240	yes
519	51	74	119	73	-3	-5	no
548	58	99	74	53	-5	-10	no
560	41	69	88	83	-230	-360	no
563	-	-	75	81	-	-220	no
579	-	61	83	91	-	-310	no
585	41	-	63	96	-5	-	no
596	35	53	35	116	-5	-	no
614	66	74	56	48	+2	0	no
650	24	39	76	93	+70	+10	no
663	45	71	59	96	+28	-30	no

Table 2

Water Analysis Results for Each Study Site

Location Number	Specific Conductivity (μmhos/cm)		Chlorides (mg/l)		Phosphates (mg/l)	
	3 m	6 m	3 m	6 m	3 m	6 m
7	-	320	-	30	-	0.08
18	335	340	30	30	0.03	0.03
32	320	350	32	32	0.09	0.1
49	-	380	-	40	-	0.09
68	620	-	20	-	0.1	-
75	305	325	35	35	0.09	0.06
120	340	360	35	32	1.0	0.55
144	320	320	27	30	0.08	0.1
168	320	360	35	30	0.5	0.5
170	280	-	30	-	0.15	-
176	320	420	30	32	0.25	0.25
185	310	440	30	30	1.4	1.15

Table 2 (Continued)

Location Number	Specific Conductivity (μmhos/cm)		Chlorides (mg/l)		Phosphates (mg/l)	
	3 m	6 m	3 m	6 m	3 m	6 m
192	270	270	30	30	0.15	0
213	360	280	35	30	-	2.5
218	-	280	35	40	-	0.2
244	320	360	35	30	0.6	0.25
260	320	310	30	30	0.4	0.7
274	-	-	-	-	-	-
275	380	400	30	30	0.3	0.35
281	320	280	30	30	0.25	0.25
287	310	340	30	30	0.25	0.3
305	260	260	30	30	0.15	0.2
320	280	320	30	30	0.15	0.15
361	440	280	30	30	0.2	0.25
365	360	400	25	45	0.25	0.25

Table 2 (Continued)

Location Number	Specific Conductivity (μmhos/cm)		Chlorides (mg/l)		Phosphates (mg/l)	
	3 m	6 m	3 m	6 m	3 m	6 m
366	320	280	30	35	0.4	0.2
373	400	260	40	30	0.2	0.25
383	320	260	30	30	0.15	0.15
401	360	320	30	30	0.15	0.13
403	360	360	30	25	0.15	0.4
416	320	320	30	30	0.05	0.3
419	320	310	35	30	0.05	0.1
420	320	290	25	25	0.1	0.1
451	300	300	30	25	0.1	0.3
457	330	300	25	30	0.1	0.1
473	300	320	30	25	0.1	0.1
496	300	340	25	25	0.1	0.1
497	320	360	25	30	0	0.15

Table 2 (Continued)

Location Number	Specific Conductivity (μmhos/cm)		Chlorides (mg/l)		Phosphates (mg/l)	
	3 m	6 m	3 m	6 m	3 m	6 m
508	300	300	30	30	0.1	0.1
519	320	360	35	30	0.25	0.25
548	360	400	30	30	0.8	0.5
560	270	270	30	30	0.1	0.15
563	280	260	25	30	-	0.3
579	260	250	25	30	0.1	0.15
585	300	-	25	-	0.05	-
596	300	280	25	30	0.1	0.2
614	340	330	25	30	0.2	0.3
650	380	360	30	35	0.25	0.2
663	410	540	40	40	0.1	0.15

Table 3

Factors Considered in the Statistical Analysis of Austin Lake's Ground-water Characteristics

Location Number	Drainage Basin Altitude (ft)	Soil[a]	Glacial Material[b]	Permeability[c] 3 m	6 m
7	859	02	0	-	3
18	861	02	0	2	2
32	864	02	0	1	1
49	868	03	0	2	2
68	868	03	0	2	-
75	868	03	0	1	1
120	876	01	0	3	1
144	868	01	0	2	3
168	872	03	0	3	3
170	870	03	0	2	2
176	860	03	0	2	3
185	861	03	0	2	2
192	870	03	0	2	2
213	868	04	0	3	3
218	868	03	0	3	3
244	869	04	0	3	3
260	868	04	0	3	3
274	864	04	0	3	3
275	864	04	0	2	3
281	863	04	0	3	3

Table 3 (Continued)

Location Number	Drainage Basin Altitude (ft)	Soil[a]	Glacial Material[b]	Permeability[c]	
				3 m	6 m
287	862	04	O	3	3
305	858	A	C	2	2
320	861	B	C	2	2
361	861	04	C	3	3
365	861	04	C	3	3
366	861	04	C	3	3
373	861	04	C	3	3
383	861	04	C	2	2
401	861	04	C	3	3
403	861	04	C	3	2
416	861	04	C	3	3
419	861	04	C	3	3
420	861	04	C	3	3
451	859	04	C	3	3
457	859	04	C	3	3
473	859	04	M	3	3
496	861	04	M	2	2
497	861	04	M	2	2
508	861	04	M	2	2
519	861	04	M	3	2
548	858	04	O	2	2

Table 3 (Continued)

Location Number	Drainage Basin Altitude (ft)	Soil[a]	Glacial Material[b]	Permeability[c] 3 m	6 m
560	861	04	O	1	1
563	862	04	O	-	2
579	865	04	O	1	1
585	870	04	O	3	3
596	868	04	O	3	3
614	859	A	O	3	3
650	868	02	O	3	3
663	861	A	O	3	2

[a]01, 02, 03, 04 = varieties of Ostemo
A = Adrian
B = Brady

[b]O = outwash
M = morainal material
C = channel deposits

[c]1 = excellent
2 = good
3 = poor

water. These factors are the altitude of the drainage basin (DBA), the type of soil adjacent to and surrounding the lake, the surface glacial material adjacent to and surrounding the lake, and a subjective judgment of the permeability of the sediment at each sampling point.

The altitude of the drainage basin is the maximal altitude in the drainage basin perpendicular to the shoreline at the sampling site. The types of soil adjacent to and surrounding the lake include four varieties of Oshtemo (O1, O2, O3, O4), Brady (B), and Adrian (A). The types of surface material adjacent to and surrounding the lake are channel deposits (C), outwash (O), and morainal material (M). Permeability is classified as excellent (1), good (2), and poor (3).

Variable Descriptions

Variables are classified according to whether they are measurement or classification variables and whether they are dependent or independent variables.

Measurement variables have measured values. Classification variables do not have measured values, or if they do, they can be simply grouped and given a group name. Hydraulic head, depth of the water, depth of the piezometer in the sediment, altitude of the drainage basin, specific conductivity, chloride content, and phosphate content are all measurement variables. The classification variables are glacial material, soil, permeability of sediment, distance from shore, and presence or absence of a septic tank.

Dependent variables are subject to change if conditions change. Independent variables are fixed. They do not change. Hydraulic head, specific conductivity, chloride content, and phosphate content are dependent variables. Independent variables include all the classification variables.

Analytical Procedure

The first step in the analyses was to examine interdependencies among the variables DP, COND, HH, CHL, and P using pairwise Pearson Product Moment correlations (PROC CORR). In this procedure correlations were calculated considering breakdowns involving the independent variables--septic tank and distance from shore in the following manner: (1) all observations combined (Appendix A); (2) observations classified according to values on both independent variables (Appendix B); and (3) observations classified according to the presence or absence of a septic tank only (Appendix C).

The second step in the analyses used two-way analysis of variance procedures to determine the relationship between septic tank and distance from shore on the dependent variables HH, COND, CHL, and P. Because of unequal sample sizes a general linear models program (GLM) was used for this analysis. This analysis was performed in the following manner: (1) observations classified according to values on both independent variables (Appendix D) and (2) observations classified according to the presence or absence of a septic tank only (Appendix E).

Schematic plots were drawn for each dependent variable to determine if visual inspection could identify any differences in the effects of a septic tank and/or distance from shore (Appendix F). Examination of the plots indicated that other factors might be related to the results. Factors considered were the altitude of the drainage basin, depth of water at each sampling point, the soil surrounding the lake, and the surface glacial material surrounding the lake. Those parameters were added to the data base along with a subjective determination of the permeability of the sediment at each sampling site (Table 3).

The dependent variable data were examined for skewness using the univariate procedure. Log transformations were made on the data to reduce the skewness for all dependent variables except hydraulic head (Appendix G).

In the final analyses the GLM procedure was used because both classification and measurement variables were among the independent variables. These analyses included the added factors and the log transformations.

In the final analysis of HH, the classification variables were types of glacial material, types of soil, and permeability of the sediment. The measurement variables were the altitude of the drainage basin, depth of the piezometer, and the depth of the water (Appendix H).

In the final analysis of the other dependent variables (COND, CHL, P) the classification variables were septic tank, distance from shore, glacial material, soil, and permeability. The measurement variables were hydraulic head, altitude of the drainage basin, depth of the piezometer, and depth of the water (Appendix I).

In all analyses using the GLM procedure, the results referred to are from using the Type IV sum of squares. The Type IV sum of squares is the most appropriate for this study because it is adjusted for differences in sample size.

Computer Results

Hydraulic Head

In the initial correlational procedure observations were not grouped according to the independent variables septic tank and distance from shore. Here hydraulic head was seen to have a significant relationship to conductivity, $\underline{r}$ (84) = 0.21843, $p \leq 0.0433$. At locations without a septic tank, there was a highly significant relationship between hydraulic head and conductivity at a distance of 3 meters, r (25) = 0.49835, $p \leq 0.0082$. At 6 meters, the relationship of hydraulic head to conductivity was marginally significant, r (24) = 0.36871, $p \leq 0.0638$. At locations with a septic tank the relationship of hydraulic head to conductivity was marginally significant at 3 meters, r (14) = 0.43058, $p \leq 0.0959$. At 6 meters from shore, the relationship of hydraulic head to conductivity was not found to be significant, but the relationship of hydraulic head to phosphates was significant, r (15) = -0.48480, $p \leq 0.0486$. Because the relationship of hydraulic head to phosphates was shown to be significant in only one correlation set, it is likely that this statistic is the result of chance alone.

In the second series of correlations in which distance from shore was not a factor, the relationship of hydraulic head to conductivity was significant to localities where a septic tank was not present, r (51) = 0.34441, $p \leq 0.0116$. When a septic tank was present, the relationship of hydraulic head to phosphates was marginally significant, r (31) = -0.32440, $p \leq 0.0655$.

The GLM procedure showed an overall significant relationship to hydraulic head, F (3, 86) = 3.54, $p \leq 0.0179$. Individually there was a significant relationship of hydraulic head to the presence of a septic tank, F (1, 86)

= 5.14, $p \leq 0.0259$, and a significant relationship of hydraulic head to distance from shore, $F_{(1, 86)} = 4.31$, $p \leq 0.0408$. The interaction between septic tank and distance from shore for hydraulic head was not found to be significant, $F_{(1, 86)} = 0.41$, $p \leq 0.5228$.

The schematic plot showed that the hydraulic head decreased with distance from shcre and decreased in the presence of a septic tank.

In the final analysis of hydraulic head, the independent variables were the class variables (glacial material, soil, and permeability) and the measurement variables (altitude of the drainage basin, water depth, and the depth of the piezometer). This model was highly significant, $F_{(12, 74)} = 4.0$, $p \leq 0.0001$, and explained about 39 percent of the variability.

Overall, the relationship of hydraulic head to the type of glacial material was significant, $F_{(2, 74)} = 3.87$, $p \leq 0.0251$. The least squares means for channel deposits and outwash were -52.8 and 49.5 respectively and the least squares mean for morainal material was -130.6. This indicates a greater outflow in the area of the lake that is bounded by morainal material.

The relationship of hydraulic head to soil type was marginally significant, $F_{(5, 74)} = 2.10$, $p \leq 0.0738$. Because of this overall marginal significance little emphasis is placed on it.

The relationship of hydraulic head to the permeability of the sediment was highly significant, F (2, 74) = 9.62, $p \leq 0.0002$. From the least squares means, poor permeability, with a least squares mean of -30.19, was associated with the highest hydraulic head (most positive number and lowest outward flow) as compared to excellent permeability with a least squares mean of -159.0.

The relationship of hydraulic head to the altitude of the drainage basin was significant, F (1, 74) = 5.33, $p \leq 0.0237$. The estimate of the linear coefficient on the effect of the drainage basin altitude is -22.66. This is the slope of the linear regression line and being negative gives a result of a more negative head with an increase in the altitude of the basin.

The relationship of hydraulic head to the depth of the piezometer in the sediment was significant, F (1, 74) = 4.32, $p \leq 0.0411$. The estimate of the linear coefficient on the depth is -0.80. This means that the deeper the piezometer is placed in the sediment, the greater the negative hydraulic potential differential.

The relationship of hydraulic head to water depth was significant, F (1, 74) = 4.29, $p \leq 0.0419$. The estimate of the linear coefficient on the water depth is -0.77. This is negative, therefore the greater the depth, the greater the negative hydraulic potential differential.

Conductivity

In the initial correlational procedure that did not group observations according to the independent variables septic tank and distance from shore, the correlation of conductivity with hydraulic head was significant as reported in the previous section. In addition, when no septic tank was present, conductivity had a significant relationship to chlorides at 3 meters, r (27) = 0.38365, $p \leq 0.0399$, and a highly significant relationship to chlorides at 6 meters, r (26) = 0.53692, $p \leq 0.0032$.

In the second series of correlations when distance from shore was not considered in the analysis, again conductivity had a significant relationship to hydraulic head as reported previously. Conductivity had a very high significant relationship to chlorides, r (55) = 0.43355, $p \leq 0.0008$, when no septic tank was present. With the presence of a septic tank, conductivity had a marginally significant relationship to the depth of the piezometer, r (31) = -0.30350, $p \leq 0.0860$.

The schematic plots for conductivity showed a marginal increase in the presence of a septic tank. There was a marginal increase with distance when the septic tank was absent and a decrease with the presence of a septic tank.

In the final analysis, the independent class variables are glacial material, soil type, permeability, distance from shore, and septic tank. The independent measurement variables are hydraulic head, altitude of the drainage basin, depth of the piezometer in the sediment, and depth of the water.

The full model for the log of conductivity was not found to be significant, $\underline{F}$ (15, 67) = 1.17, p ≤ 0.3151. In this model conductivity had a marginally significant relationship to hydraulic head, $\underline{F}$ (1, 67) = 3.19, p ≤ 0.0788. The estimate of the linear coefficient for the effect of the hydraulic head was 0.0004. This is positive and means that the greater the hydraulic head the greater the conductivity. In other works, the faster the water is flowing out of the lake, the lower the conductivity.

None of the other variables was found to be significant and these variables are not considered further.

A reduced model was designed for the log of conductivity. This model contained only the factors that showed significant values in the full model. These factors were hydraulic head and septic tank. This model was significant, $\underline{F}$ (3, 82) = 3.29, p ≤ 0.0246, and explained almost 11 percent of the variability. In this model conductivity had a significant relationship to hydraulic head, $\underline{F}$ (1, 82) = 6.01, p ≤ 0.0164. The presence of a septic tank no longer showed a particularly strong relationship, but when considered separately from hydraulic head, the relationship became marginally significant. This implies that the conductivity is greater in the presence of a septic tank.

Chlorides

In the correlational procedures, significant relationships were not found other than that of conductivity previously mentioned.

The GLM procedure showed a marginal significant relationship between chloride content and septic tank presence, $\underline{F}$ (1, 87) = 3.22, $p \leq 0.0761$.

The schematic plot for chlorides showed a fairly strong relationship with the presence of septic tanks. Chloride content was greater and varied more in the presence of a septic tank.

In the final analysis, the independent variables were the same as in the analysis of the log of conductivity. The full model for the log of chlorides was not found to be significant, $\underline{F}$ (15, 68) = 1.53, $p \leq 0.1198$. Chlorides had a marginally significant relationship to permeability, $\underline{F}$ (2, 68) = 2.38, $p = 0.1001$, and a significant relationship to the depth of the water, $\underline{F}$ (1, 68) = 4.13, $p \leq 0.0459$. The estimate of the linear coefficient for water depth was negative (-0.0016), therefore the deeper the water, the lower the level of chlorides.

None of the other relationships was strong enough to consider.

Phosphates

The initial correlations did not reveal any significant relationships between phosphate content and the several variables.

In the full model for the log of phosphates, the independent variables were the same as in the analyses of the other full models. The overall model was not found to be significant, $\underline{F}$ (15, 66) = 1.27, $p \leq 0.2450$. Glacial material had the only significant relationship to phosphate content, $\underline{F}$ (2, 66) = 3.75, $p \leq 0.0288$. The least squares mean for outwash is 0.242 as compared to channel deposits at 0.074 and morainal deposits at 0.004. This means that outwash has a greater level of phosphates, but overall, phosphate content was not found to be significant.

CHAPTER 5

DISCUSSION AND CONCLUSIONS

Ground-water Flow

The first objective of this investigation was to determine the direction of ground-water flow through the sediment-water interface along the total shoreline of Austin Lake. This was done by placing minipiezometers in the sediment beneath the water surface and measuring the hydraulic head. The data obtained show that at most sites the water movement has a downward component. The greatest downward flow appears to be at the northern, southern, and southwestern portions of the lake (Figure 15). Few measurements show ground water moving into the lake. The compass direction of flow cannot be determined from the data, but can be inferred from previous data as presented by Deutsch et al. (1960) and Allen et al. (1972). Their models suggest that ground water moves to the north and to the south from Austin Lake. Austin Lake is situated on the ground-water divide.

During the collection of hydraulic head data, three conditions were found to exist: (1) a negative hydraulic head for both samples at the sampling site; (2) a positive hydraulic head for both samples at the sampling site; and

AUSTIN LAKE

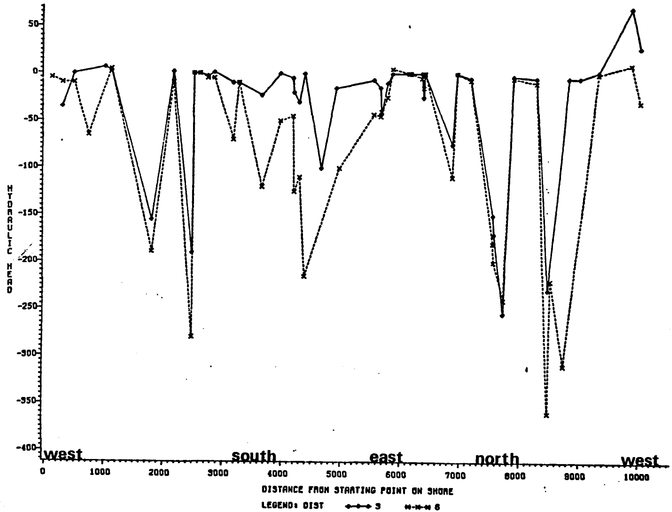

Figure 15. Hydraulic head at each sampling site around Austin Lake.

(3) a zero or a positive hydraulic head at 3 meters and a negative hydraulic head at 6 meters.

In the first situation, water is seeping through the lake seal and becoming part of the ground-water flow (recharge point). In the second situation, the ground-water movement is upward and into the lake (discharge point). The third situation suggests a combination of the first two. Ground water is moving into the lake at 3 meters and moving out of the lake at 6 meters (Figure 16). This last situation could occur if there is a slight local elevation of the water table near shore and would be enhanced by the presence of a channel for ground-water movement into the lake. These channels may be present. During sampling it was noticed that the sediment was layered at many points around the lake. These layers were narrow--from one to several centimeters in thickness. They were made of sand interbedded with finer material with organic material scattered throughout. At some of these sites the piezometer was driven deeper. The hydraulic head then became negative.

Computer analysis shows several factors affecting the hydraulic head. One factor is the depth of the piezometer in the sediment. This was expected. The deeper the piezometer is in the sediment, the more equipotential lines intersected, the greater the hydraulic head (Figure 8).

Another factor affecting the hydraulic head is the

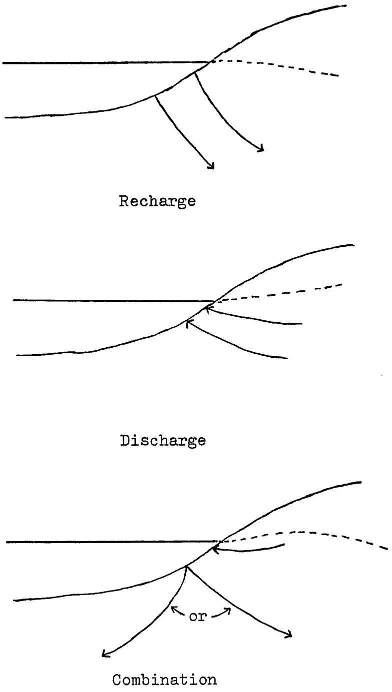

Figure 16. Possible ground-water flow patterns at Austin Lake.

depth of the water. As the depth of the water increases, the hydraulic head becomes more negative. This statistic is probably the result of the greatest outward flow being at the areas of the lake that were the deepest, namely the northern, southern, and southwestern portions.

The permeability of the sediment affects the hydraulic head. The largest hydraulic head differential occurs where the permeability is the greatest. At one sampling site that exhibited excellent permeability, a siphoning hose was placed from the lake into the minipiezometer. Water ran into the piezometer (out of the lake) for some time until the hose was removed. This indicates a thin seal in the lake. Once through the seal, the sediments are permeable.

The statistical analysis of the relationship of drainage basin altitude to hydraulic head is significant but not in the way expected. The higher the altitude of the drainage basin, the more negative the hydraulic head. Examination of the sampling results show high negative hydraulic head (outward) readings in the southwestern region of the lake. This region contains some of the highest points in the drainage basin. The southwestern region is illustrated on the cross-section of Austin Lake (Figure 2). The left side of A-A' is the surface of Gourdneck Lake. This surface of Gourdneck Lake is below the surface of Austin Lake. It is reasonable to assume that this lower surface has a major effect on ground-water flow from Austin Lake towards Gourdneck Lake and that the topographic high between the two lakes is overshadowed by this effect.

The northern shore of Austin Lake also shows a large negative head. The surface-water divide is to the north (Figure 6). This neans that surface water flows to the south and ground water flows to the north in this region. Therefore altitude of the drainage basin has a minimal effect on the total ground-water flow at Austin Lake.

In glacial sediment, morainal material shows the greatest outward flow (Figure 17). It is unclear whether this is a true picture of what is happening because of the small extent of morainal material adjoining the lake. These glacial materials are surface deposits and may have only a minimal effect on regional ground-water flow.

Pollution

The second objective was to determine if the lake is being polluted by ground water by examining the specific conductivity, chloride content, and phosphate content of ground-water samples from beneath the lake.

Three factors, hydraulic head, depth of the piezometer in the sediment, and presence or absence of a septic tank, affect the specific conductivity. The more positive the hydraulic head, the greater the conductivity (Figure 18).

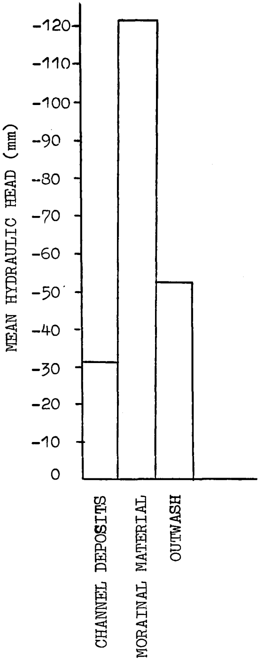

Figure 17. Average hydraulic head readings for the different types of glacial material.

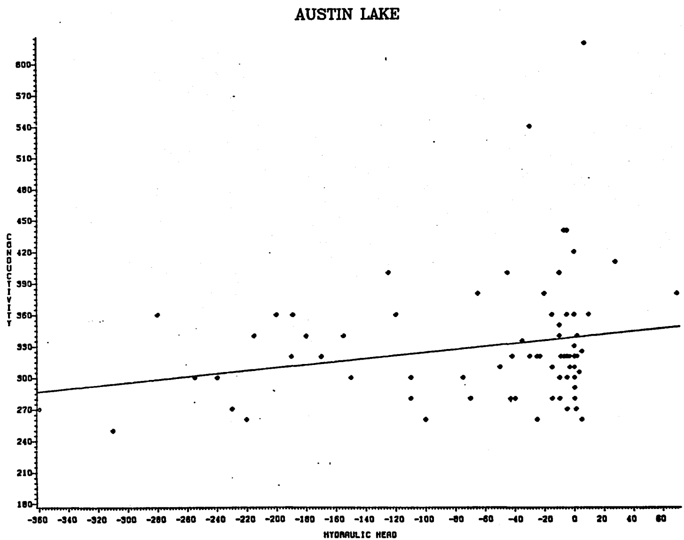

Figure 18. As the hydraulic head becomes more positive the conductivity increases.

In other words, the faster water is moving out of the lake, the lower the conductivity. The deeper the piezometer was placed in the sediment, the greater the conductivity. Conductivity is higher when a septic tank is present (Figure 19). Consequently, it appears that septic tank effluent is entering the lake. These results seem to indicate that at certain times during the year, at some points and under certain conditions, ground water moves into the lake bringing in dissolved compounds. Later when the ground-water direction is reversed, the compounds are carried downward and away from the lake, therefore the higher concentrations will be at the lower level. This idea is strengthened by the fact that a late summer check of the hydraulic head on the west side of Austin Lake indicated an outward flow even though some of the points had indicated an inward flow earlier in the spring and summer.

Chlorides exhibit some of the same relationships as conductivity. Offshore from septic tanks chloride content varies considerably. At locations without a septic tank chloride content varies little (Figure 20). This difference in variance indicates some inflow of effluent from septic tanks.

Significant relationships were not found between phosphates and any of the dependent variables. This is

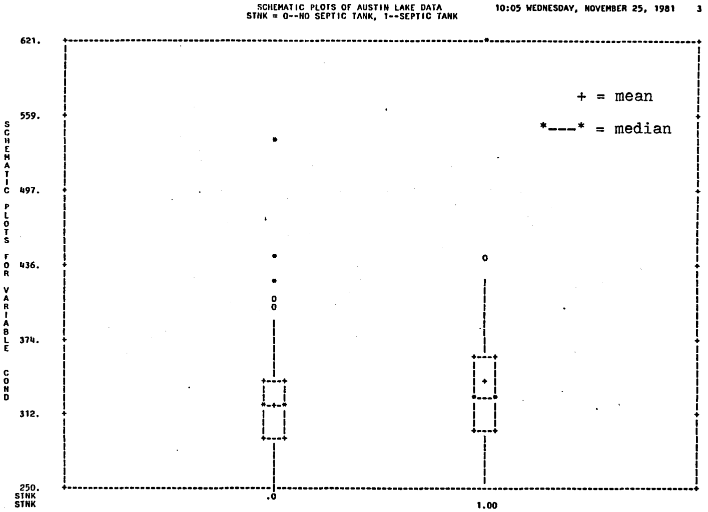

Figure 19. A comparison of the specific conductivity with the presence or absence of a septic tank.

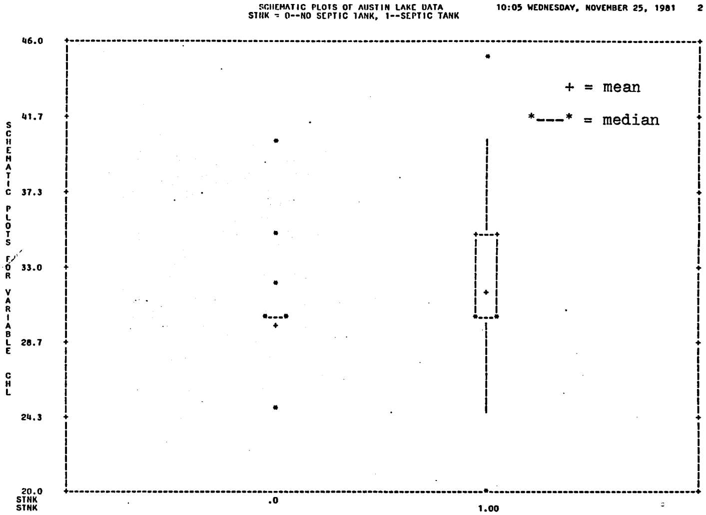

Figure 20. A comparison of the chloride concentrations with the presence or absence of a septic tank.

as expected as phosphates are rapidly attenuated in sediment. One interesting result is that a greater concentration of phosphates was present near glacial outwash. This area contains mostly older homes and the possibility exists that phosphates are entering the lake from older functional or non-functional septic systems (Figure 21).

Summary of Conclusions

The conclusions directly related to the objectives are:

1. The primary direction of water flow is downward through the sediment-water interface.
2. Under certain conditions ground water moves up through the sediment-water interface.
3. Upward movement of ground water brings in dissolved materials from onshore septic systems.
4. The amount of septic tank effluent entering the lake is minimal.
5. The lake-bottom sediment forms a thin seal that retards, but does not prevent, downward movement of water.

Conclusions not related to the objectives but that are consistent with those of other researchers are:

1. The deeper the piezometer is in the sediment, the greater the hydraulic differential.

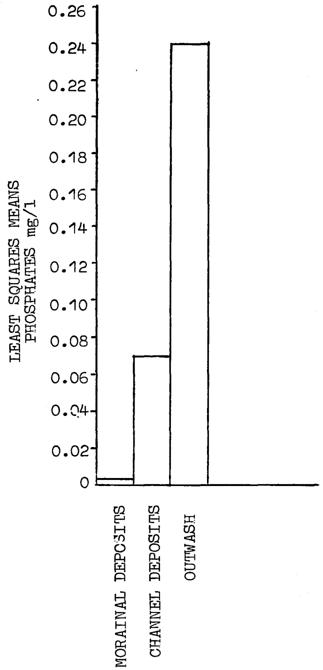

Figure 21. Phosphate concentration averages for the different types of glacial material.

2. Water movement is primarily north and south of Austin Lake, with little east or west flow. This suggests that the divide is along an east-west line that crosses Austin Lake and probably changes position during the year as the lake varies from recharging to discharging at particular points.

CHAPTER 6

RECOMMENDATIONS

Recommendations for future investigations include:

1. A study of the near shore hydrology. What are the effects of the layered sediments on local ground-water flow? Could these layers shed any light on historical development of the lake?
2. A study of conditions necessary for water movement into the lake. Does water move into the lake at all points or is it limited in extent--near topographic highs or near the ground-water divide on the east and west sides?
3. A study of the water movement through the organic sediment filled basins. Are the basins impermeable? Do they act as sinks for dissolved materials?

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APPENDIX A

PEARSON PRODUCT MOMENT CORRELATIONS OF ALL OBSERVATIONS COMBINED

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M   18:20 FRIDAY, OCTOBER 23, 1981   1

VARIABLE	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
DP	95	76.73684211	20.98743825	7290.00000000	35.00000000	123.00000000
HH	90	-52.58888889	86.02702664	-4733.00000000	-360.00000000	70.00000000
COND	90	328.72222222	57.30149473	29585.00000000	250.00000000	620.00000000
CHL	91	30.43956044	4.05848574	2770.00000000	20.00000000	45.00000000
P	88	0.26113636	0.33696561	22.98000000	0	2.50000000

CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS

	DP	HH	COND	CHL	P
DP	1.00000 0.0000 95	-0.12954 0.2236 90	-0.02632 0.8055 90	0.10645 0.3152 91	0.10254 0.3418 88
HH	-0.12954 0.2236 90	1.00000 0.0000 90	0.21842 0.0433 86	0.05521 0.6115 87	-0.04594 0.6763 85
COND	-0.02632 0.8055 90	0.21842 0.0433 86	1.00000 0.0000 90	0.12991 0.2223 90	0.02352 0.8278 88
CHL	0.10645 0.3152 91	0.05521 0.6115 87	0.12991 0.2223 90	1.00000 0.0000 91	0.05506 0.6104 88
P	0.10254 0.3418 88	-0.04594 0.6763 85	0.02352 0.8278 88	0.05506 0.6104 88	1.00000 0.0000 88

APPENDIX B

PEARSON PRODUCT MOMENT CORRELATIONS OF OBSERVATIONS CLASSIFIED ACCORDING TO VALUES ON INDEPENDENT VARIABLES--DISTANCE FROM SHORE AND PRESENCE OR ABSENCE OF A SEPTIC TANK

STATISTICAL ANALYSIS SYSTEM 18:20 FRIDAY, OCTOBER 23, 1981 2

STNK=0 DIST=10

VARIABLE	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
DP	29	69.13793103	20.61331771	2005.00000000	35.00000000	119.00000000
HH	27	-12.33333333	49.06980899	-333.00000000	-230.00000000	70.00000000
COND	29	316.55172414	33.94069008	9180.00000000	260.00000000	410.00000000
CHL	29	29.82758621	3.65541639	865.00000000	25.00000000	40.00000000
P	27	0.24074074	0.28623452	6.50000000	0.05000000	1.40000000

CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS

	DP	HH	COND	CHL	P
DP	1.00000 0.0000 29	-0.15327 0.4453 27	-0.00287 0.9882 29	0.17333 0.3686 29	-0.06973 0.7297 27
HH	-0.15327 0.4453 27	1.00000 0.0000 27	0.49835 0.0082 27	0.01702 0.9328 27	0.09592 0.6411 26
COND	-0.00287 0.9882 29	0.49835 0.0082 27	1.00000 0.0000 29	0.38365 0.0399 29	0.11225 0.5772 27
CHL	0.17333 0.3686 29	0.01702 0.9328 27	0.38365 0.0399 29	1.00000 0.0000 29	0.13145 0.5134 27
P	-0.06973 0.7297 27	0.09592 0.6411 26	0.11225 0.5772 27	0.13145 0.5134 27	1.00000 0.0000 27

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M   18:20 FRIDAY, OCTOBER 23, 1981   3

SINK=0   DIST=20

VARIABLE	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
DP	30	86.56666667	20.25643079	2597.00000000	48.00000000	123.00000000
HH	27	-60.62962963	101.64006938	-1637.00000000	-360.00000000	10.00000000
COND	28	327.50000000	63.34064285	9170.00000000	250.00000000	540.00000000
CHL	28	29.89285714	2.91025372	837.00000000	25.00000000	40.00000000
P	28	0.33607143	0.48096615	9.41000000	0	2.50000000

CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS

	DP	HH	COND	CHL	P
DP	1.00000	-0.12863	0.22496	0.27730	0.19485
	0.0000	0.5226	0.2498	0.1531	0.3204
	30	27	28	28	28
HH	-0.12863	1.00000	0.36871	0.01878	0.01881
	0.5226	0.0000	0.0638	0.9275	0.9273
	27	27	26	26	26
COND	0.22496	0.36871	1.00000	0.53696	0.01754
	0.2498	0.0638	0.0000	0.0032	0.9294
	28	26	28	28	28
CHL	0.27730	0.01878	0.53696	1.00000	-0.03947
	0.1531	0.9275	0.0032	0.0000	0.8419
	28	26	28	28	28
P	0.19485	0.01881	0.01754	-0.03947	1.00000
	0.3204	0.9273	0.9294	0.8419	0.0000
	28	26	28	28	28

STNK=1 DIST=10

VARIABLE	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
DP	18	70.16666667	16.21999492	1263.00000000	51.00000000	113.00000000
HH	18	-64.00000000	82.87907563	-1152.00000000	-255.00000000	7.00000000
COND	16	352.50000000	83.40663443	5640.00000000	260.00000000	620.00000000
CHL	17	30.23529412	4.91845265	514.00000000	20.00000000	40.00000000
P	16	0.22437500	0.24671086	3.59000000	0	1.00000000

CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS

	DP	HH	COND	CHL	P
DP	1.00000	-0.07207	-0.29363	-0.18819	-0.24672
	0.0000	0.7763	0.2697	0.4695	0.3570
	18	18	16	17	16
HH	-0.07207	1.00000	0.43058	0.00134	-0.25374
	0.7763	0.0000	0.0959	0.9959	0.3430
	18	18	16	17	16
COND	-0.29363	0.43058	1.00000	-0.36439	-0.04074
	0.2697	0.0959	0.0000	0.1653	0.8809
	16	16	16	16	16
CHL	-0.18819	0.00134	-0.36439	1.00000	0.40456
	0.4695	0.9959	0.1653	0.0000	0.1201
	17	17	16	17	16
P	-0.24672	-0.25374	-0.04074	0.40456	1.00000
	0.3570	0.3430	0.8809	0.1201	0.0000
	16	16	16	16	16

STATISTICAL ANALYSIS SYSTEM 18:20 FRIDAY, OCTOBER 23, 1981 5

STNK=1 DIST=20

VARIABLE	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
DP	18	79.16666667	21.25268149	1425.00000000	46.00000000	105.00000000
HH	18	-89.50000000	90.20124559	-1611.00000000	-280.00000000	5.00000000
COND	17	329.11764706	46.03786804	5595.00000000	260.00000000	400.00000000
CHL	17	32.58823529	4.96309913	554.00000000	25.00000000	45.00000000
P	17	0.20470588	0.14688931	3.48000000	0.03000000	0.55000000

CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS

	DP	HH	COND	CHL	P
DP	1.00000 0.0000 18	0.09275 0.7143 18	-0.31739 0.2145 17	0.10469 0.6893 17	0.14122 0.5888 17
HH	0.09275 0.7143 18	1.00000 0.0000 18	-0.26538 0.3033 17	0.40332 0.1084 17	-0.48480 0.0486 17
COND	-0.31739 0.2145 17	-0.26538 0.3033 17	1.00000 0.0000 17	0.23629 0.3612 17	0.19012 0.4649 17
CHL	0.10469 0.6893 17	0.40332 0.1084 17	0.23629 0.3612 17	1.00000 0.0000 17	-0.02204 0.9331 17
P	0.14122 0.5888 17	-0.48480 0.0486 17	0.19012 0.4649 17	-0.02204 0.9331 17	1.00000 0.0000 17

APPENDIX C

PEARSON PRODUCT MOMENT CORRELATIONS OF OBSERVATIONS CLASSIFIED ACCORDING TO THE PRESENCE OR ABSENCE OF A SEPTIC TANK ONLY

STATISTICAL ANALYSIS SYSTEM 17:09 FRIDAY, OCTOBER 30, 1981 1

STNK=0

VARIABLE	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
DP	59	78.00000000	22.07979260	4602.00000000	35.00000000	123.00000000
HH	54	-36.48148148	82.72385085	-1970.00000000	-360.00000000	70.00000000
COND	57	321.92982456	50.40686590	18350.00000000	250.00000000	540.00000000
CHL	57	29.85964912	3.28110715	1702.00000000	25.00000000	40.00000000
P	55	0.28927273	0.39676868	15.91000000	0	2.50000000

CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS

	DP	HH	COND	CHL	P
DP	1.00000 0.0000 59	-0.22424 0.1031 54	0.16919 0.2083 57	0.20429 0.1274 57	0.13787 0.3155 55
HH	-0.22424 0.1031 54	1.00000 0.0000 54	0.34441 0.0116 53	0.02999 0.8312 53	-0.00475 0.9734 52
COND	0.16919 0.2083 57	0.34441 0.0116 53	1.00000 0.0000 57	0.43355 0.0008 57	0.05026 0.7156 55
CHL	0.20429 0.1274 57	0.02999 0.8312 53	0.43355 0.0008 57	1.00000 0.0000 57	0.03011 0.8273 55
P	0.13787 0.3155 55	-0.00475 0.9734 52	0.05026 0.7156 55	0.03011 0.8273 55	1.00000 0.0000 55

STATISTICAL ANALYSIS SYSTEM 17:09 FRIDAY, OCTOBER 30, 1981 2

STNK=1

VARIABLE	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
DP	36	74.66666667	19.18332609	2688.00000000	46.00000000	113.00000000
HH	36	-76.75000000	86.34494774	-2763.00000000	-280.00000000	7.00000000
COND	33	340.45454545	66.79450338	11235.00000000	260.00000000	620.00000000
CHL	34	31.41176471	5.00979433	1068.00000000	20.00000000	45.00000000
P	33	0.21424242	0.19854203	7.07000000	0	1.00000000

CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS

	DP	HH	COND	CHL	P
DP	1.00000	-0.01190	-0.30350	0.04008	-0.07081
	0.0000	0.9451	0.0860	0.8220	0.6954
	36	36	33	34	33
HH	-0.01190	1.00000	0.16990	0.17022	-0.32440
	0.9451	0.0000	0.3445	0.3358	0.0655
	36	36	33	34	33
COND	-0.30350	0.16990	1.00000	-0.17517	0.02777
	0.0860	0.3445	0.0000	0.3295	0.8781
	33	33	33	33	33
CHL	0.04008	0.17022	-0.17517	1.00000	0.20827
	0.8220	0.3358	0.3295	0.0000	0.2448
	34	34	33	34	33
P	-0.07081	-0.32440	0.02777	0.20827	1.00000
	0.6954	0.0655	0.8781	0.2448	0.0000
	33	33	33	33	33

APPENDIX D

ANALYSIS OF OBSERVATIONS CLASSIFIED ACCORDING TO VALUES ON BOTH INDEPENDENT VARIABLES USING A GENERAL LINEAR MODELS PROGRAM

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
STNK	2	0 1
DIST	2	10 20

NUMBER OF OBSERVATIONS IN DATA SET = 95

GROUP	OBS	DEPENDENT VARIABLES
1	90	HH
2	90	COND
3	91	CHL
4	88	P

NOTE: VARIABLES IN EACH GROUP ARE CONSISTENT WITH RESPECT TO THE PRESENCE OR ABSENCE OF MISSING VALUES.

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M   18:20 FRIDAY, OCTOBER 23, 1981   7

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: HH

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	3	72366.99259259	24122.33086420	3.54	0.0179	0.109870	157.0049
ERROR	86	586290.79629630	6817.33484065		STD DEV		HH MEAN
CORRECTED TOTAL	89	658657.78888889			82.56715352		-52.58888889

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
SINK	1	35025.55740741	5.14	0.0259	1	35025.55740741	5.14	0.0259
DIST	1	34535.21111111	5.07	0.0270	1	29407.82407407	4.31	0.0408
STNK*DIST	1	2806.22407407	0.41	0.5228	1	2806.22407407	0.41	0.5228

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M   18:20 FRIDAY, OCTOBER 23, 1981   8

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: COND

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C V.
MODEL	3	13386.11843588	4462.03947863	1.38	0.2546	0.045807	17.3221
ERROR	86	278841.93711968	3242.34810604		STD DEV		COND MEAN
CORRECTED TOTAL	89	292228.05555556			56.94162016		328.72222222

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
STNK	1	7172.15443913	2.21	0.1406	1	7368.39148553	2.27	0.1353
DIST	1	60.09733392	0.02	0.8920	1	807.25673375	0.25	0.6191
STNK*DIST	1	6153.86666283	1.90	0.1719	1	6153.86666283	1.90	0.1719

STATISTICAL ANALYSIS SYSTEM 18:20 FRIDAY, OCTOBER 23, 1981 9

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: CHL

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	3	98.42460937	32.80820312	2.06	0.1095	0.066395	13.1029
ERROR	87	1383.99297305	15.90796521		STD DEV		CHL MEAN
CORRECTED TOTAL	90	1482.41758242			3.98847906		30.43956044

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
STNK	1	51.30509532	3.23	0.0760	1	51.26135421	3.22	0.0761
DIST	1	19.25899013	1.21	0.2742	1	31.13086715	1.96	0.1654
STNK*DIST	1	27.86052392	1.75	0.1892	1	27.86052392	1.75	0.1892

STATISTICAL ANALYSIS SYSTEM 18:20 FRIDAY, OCTOBER 23, 1981 10

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: P

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	3	0.24421604	0.08140535	0.71	0.5523	0.024722	129.6888
ERROR	84	9.63427032	0.11469369		STD DEV		P MEAN
CORRECTED TOTAL	87	9.87848636			0.33866457		0.26113636

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
STNK	1	0.11610939	1.01	0.3172	1	0.11245420	0.98	0.3249
DIST	1	0.05996307	0.52	0.4717	1	0.02949724	0.26	0.6134
STNK*DIST	1	0.06814358	0.59	0.4430	1	0.06814358	0.59	0.4430

APPENDIX E

ANALYSIS OF OBSERVATIONS CLASSIFIED ACCORDING TO THE PRESENCE OR ABSENCE OF A SEPTIC TANK ONLY USING A GENERAL LINEAR MODELS PROGRAM

STATISTICAL ANALYSIS SYSTEM 17:09 FRIDAY, OCTOBER 30, 1981 3

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
STNK	2	0 1

NUMBER OF OBSERVATIONS IN DATA SET = 95

GROUP	OBS	DEPENDENT VARIABLES
1	90	HH
2	90	COND
3	91	CHL
4	88	P

NOTE: VARIABLES IN EACH GROUP ARE CONSISTENT WITH RESPECT TO THE PRESENCE OR ABSENCE OF MISSING VALUES.

STATISTICAL ANALYSIS SYSTEM 17:09 FRIDAY, OCTOBER 30, 1981 4

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: HH

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	1	35025.55740741	35025.55740741	4.94	0.0288	0.053177	160.0776
ERROR	88	623632.23148148	7086.72990320		STD DEV		HH MEAN
CORRECTED TOTAL	89	658657.78888889			84.18271737		-52.58888889

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
STNK	1	35025.55740741	4.94	0.0288	1	35025.55740741	4.94	0.0288

STATISTICAL ANALYSIS SYSTEM 17:09 FRIDAY, OCTOBER 30, 1981 5

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: COND

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	1	7172.15443913	7172.15443913	2.21	0.1403	0.024543	17.3139
ERROR	88	285055.90111643	3239.27160360		STD DEV		COND MEAN
CORRECTED TOTAL	89	292228.05555556			56.91459921		328.72222222

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
STNK	1	7172.15443913	2.21	0.1403	1	7172.15443913	2.21	0.1403

STATISTICAL ANALYSIS SYSTEM 17:09 FRIDAY, OCTOBER 30, 1981 6

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: CHL

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	1	51.30509532	51.30509532	3.19	0.0775	0.034609	13.1736
ERROR	89	1431.11248710	16.07991559		STD DEV		CHL MEAN
CORRECTED TOTAL	90	1482.41758242			4.00997701		30.43956044

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
STNK	1	51.30509532	3.19	0.0775	1	51.30509532	3.19	0.0775

STATISTICAL ANALYSIS SYSTEM 17:09 FRIDAY, OCTOBER 30, 1981 7

GENERAL LINEAR MODELS PROCEDURE

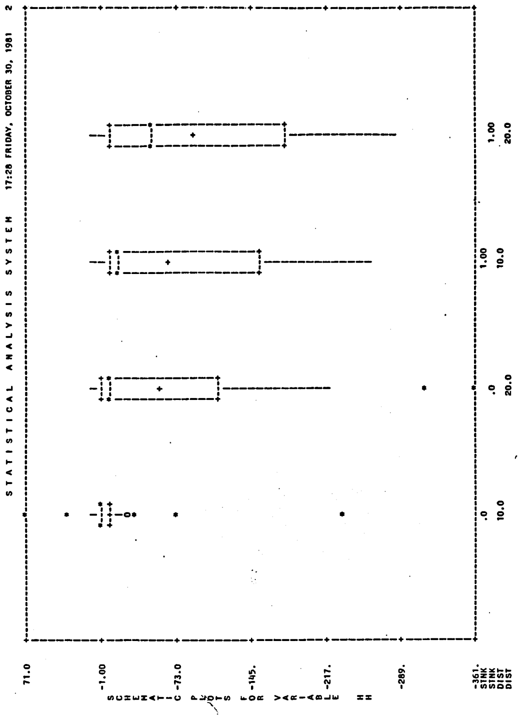
DEPENDENT VARIABLE: P

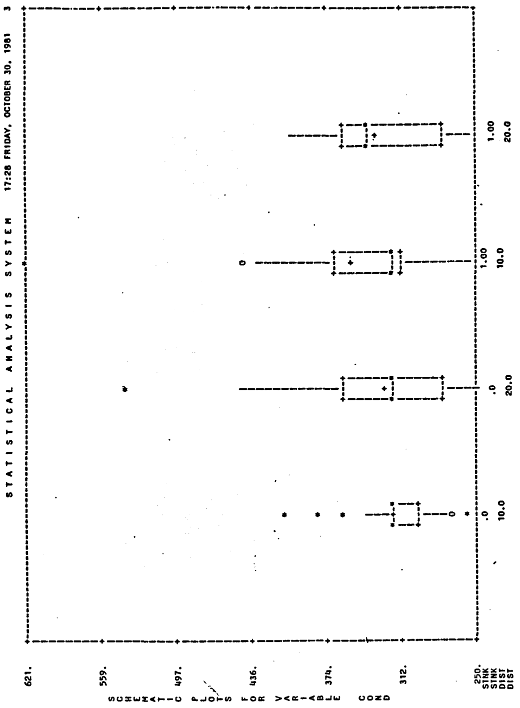
SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	1	0.11610939	0.11610939	1.02	0.3147	0.011754	129.0212
ERROR	86	9.76237697	0.11351601		STD DEV		P MEAN
CORRECTED TOTAL	87	9.87848636			0.33692137		0.26113636

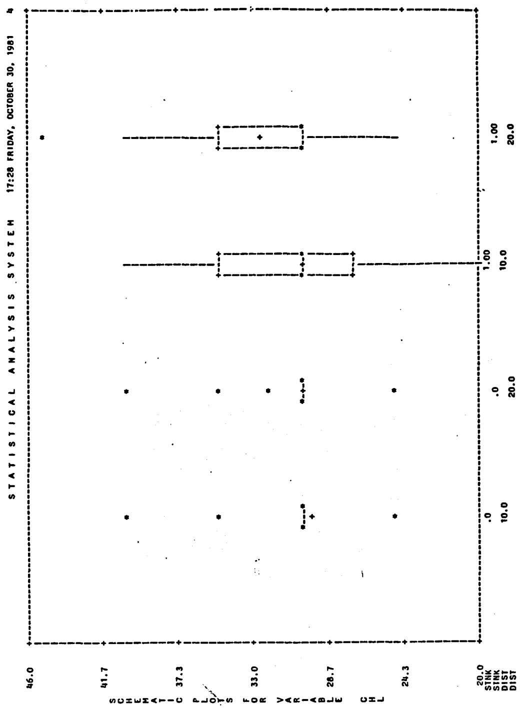
SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
STNK	1	0.11610939	1.02	0.3147	1	0.11610939	1.02	0.3147

APPENDIX F

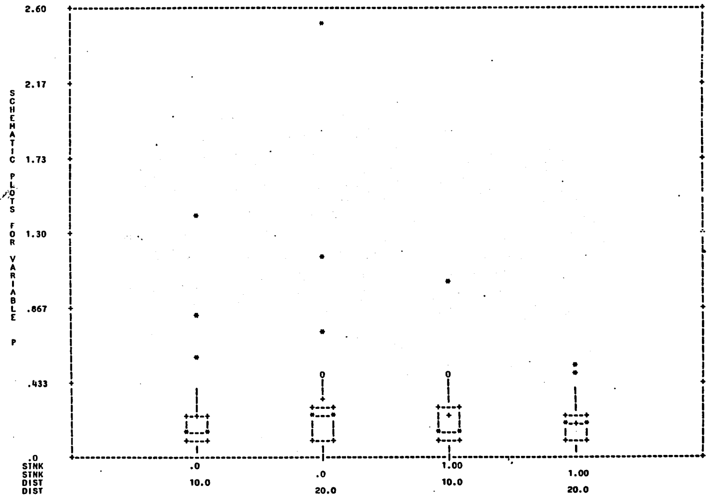
SCHEMATIC PLOTS FOR THE DEPENDENT VARIABLES


STATISTICAL ANALYSIS SYSTEM 17:28 FRIDAY, OCTOBER 30, 1981 2
SCHEMATIC PLOTS FOR VARIABLE HH
71.0
-1.00
-73.0
-145.
-217.
-289.
-361.
STNK
STNK
DIST
DIST
.0
10.0
.0
20.0
1.00
10.0
1.00
20.0


STATISTICAL ANALYSIS SYSTEM 17:28 FRIDAY, OCTOBER 30, 1981 3
SCHEMATIC PLOTS FOR VARIABLE COND
621.
559.
497.
436.
374.
312.
250.
.0
10.0
.0
20.0
1.00
10.0
1.00
20.0


STATISTICAL ANALYSIS SYSTEM 17:28 FRIDAY, OCTOBER 30, 1981
46.0
41.7
37.3
33.0
28.7
24.3
20.0
STNK
STNK
DIST
DIST
.0
10.0
.0
20.0
1.00
10.0
1.00
20.0
SCHEMATIC PLOTS FOR VARIABLE CHL

STATISTICAL ANALYSIS SYSTEM 17:28 FRIDAY, OCTOBER 30, 1981 5



APPENDIX G

EXAMINATION FOR SKEWNESS USING THE UNIVARIATE PROCEDURE

EXAMINATION OF DISTRIBUTIONS FOR SKEWNESS   11:54 SATURDAY, NOVEMBER 14, 1981   1

UNIVARIATE

VARIABLE=HH

MOMENTS

N	90	SUM WGTS	90
MEAN	-52.5889	SUM	-4733
STD DEV	86.027	VARIANCE	7400.65
SKEWNESS	-1.69155	KURTOSIS	2.13861
USS	907561	CSS	658658
CV	-163.584	STD MEAN	9.06804
T:MEAN=0	-5.79936	PROB>|T|	0.0001

QUANTILES(DEF=4)

100% MAX	70	99%	70
75% Q3	0	95%	5.89999
50% MED	-10	90%	1.89999
25% Q1	-71.25	10%	-199
0% MIN	-360	5%	-246.75
		1%	-360
RANGE	430		
Q3-Q1	71.25		
MODE	0		

MISSING VALUE	.
COUNT	5
% COUNT/NOBS	5.26

EXTREMES

LOWEST	HIGHEST
-360	5
-310	7
-280	10
-255	28
-240	70

EXAMINATION OF DISTRIBUTIONS FOR SKEWNESS 11:54 SATURDAY, NOVEMBER 14, 1981 2

UNIVARIATE

VARIABLE=COND

MOMENTS				QUANTILES(DEF=4)				EXTREMES	
N	90	SUM WGTS	90	100% MAX	620	99%	620	LOWEST	HIGHEST
MEAN	328.722	SUM	29585	75% Q3	360	95%	429	250	420
STD DEV	57.3015	VARIANCE	3283.46	50% MED	320	90%	400	260	440
SKEWNESS	2.18468	KURTOSIS	8.07382	25% Q1	300	10%	270	260	440
USS	10017475	CSS	292228	0% MIN	250	5%	260	260	540
CV	17.4316	STD MEAN	6.04011			1%	250	260	620
T:MEAN=0	54.4232	PROB>|T|	0.0001	RANGE	370				
				Q3-Q1	60				
				MODE	320				

MISSING VALUE .
COUNT 5
% COUNT/NOBS 5.26

EXAMINATION OF DISTRIBUTIONS FOR SKEWNESS 11:54 SATURDAY, NOVEMBER 14, 1981 3

UNIVARIATE

VARIABLE=LNCOND

MOMENTS				QUANTILES(DEF=4)				EXTREMES	
N	90	SUM WGTS	90	100% MAX	6.42972	99%	6.42972	LOWEST	HIGHEST
MEAN	5.78241	SUM	520.417	75% Q3	5.8861	95%	6.06119	5.52146	6.04025
STD DEV	0.155637	VARIANCE	0.0242228	50% MED	5.76832	90%	5.99146	5.56068	6.08677
SKEWNESS	1.24091	KURTOSIS	3.18002	25% Q1	5.70378	10%	5.59842	5.56068	6.08677
USS	3011.42	CSS	2.15583	0% MIN	5.52146	5%	5.56068	5.56068	6.29157
CV	2.69156	STD MEAN	0.0164056			1%	5.52146	5.56068	6.42972
T:MEAN=0	352.466	PROB>|T|	0.0001	RANGE	0.908258				
				Q3-Q1	0.182322				
				MODE	5.76832				

MISSING VALUE .
COUNT 5
% COUNT/NOBS 5.26

EXAMINATION OF DISTRIBUTIONS FOR SKEWNESS 11:54 SATURDAY, NOVEMBER 14, 1981 4

UNIVARIATE

VARIABLE=CHL

MOMENTS

N	91	SUM WGTS	91
MEAN	30.4396	SUM	2770
STD DEV	4.05849	VARIANCE	16.4713
SKEWNESS	0.83571	KURTOSIS	2.00416
USS	85800	CSS	1482.42
CV	13.3329	STD MEAN	0.425445
T:MEAN=0	71.5476	PROB>|T|	0.0001

QUANTILES(DEF=4)

100% MAX	45	99%	45
75% Q3	30	95%	40
50% MED	30	90%	35
25% Q1	30	10%	25
0% MIN	20	5%	25
		1%	20
RANGE	25		
Q3-Q1	0		
MODE	30		

MISSING VALUE .
COUNT 4
% COUNT/NOBS 4.21

EXTREMES

LOWEST	HIGHEST
20	40
25	40
25	40
25	40
25	45

EXAMINATION OF DISTRIBUTIONS FOR SKEWNESS 11:54 SATURDAY, NOVEMBER 14, 1981 5

UNIVARIATE

VARIABLE=LNCHL

MOMENTS

N	91	SUM WGTS	91
MEAN	3.40726	SUM	310.061
STD DEV	0.130257	VARIANCE	0.016967
SKEWNESS	0.208293	KURTOSIS	1.43409
USS	1057.99	CSS	1.52703
CV	3.82293	STD MEAN	0.0136547
T:MEAN=0	249.531	PROB>|T|	0.0001

QUANTILES(DEF=4)

100% MAX	3.80666	99%	3.80666
75% Q3	3.4012	95%	3.68888
50% MED	3.4012	90%	3.55535
25% Q1	3.4012	10%	3.21887
0% MIN	2.99573	5%	3.21887
		1%	2.99573
RANGE	0.81093		
Q3-Q1	0		
MODE	3.4012		

MISSING VALUE .
COUNT 4
% COUNT/NOBS 4.21

EXTREMES

LOWEST	HIGHEST
2.99573	3.68888
3.21887	3.68888
3.21887	3.68888
3.21887	3.68888
3.21887	3.80666

EXAMINATION OF DISTRIBUTIONS FOR SKEWNESS 11:54 SATURDAY, NOVEMBER 14, 1981 6

UNIVARIATE

VARIABLE=P

MOMENTS

N	88	SUM WGTS	88
MEAN	0.261136	SUM	22.98
STD DEV	0.336966	VARIANCE	0.113546
SKEWNESS	4.28089	KURTOSIS	23.5692
USS	15.8794	CSS	9.87849
CV	129.038	STD MEAN	0.0359207
T:MEAN=0	7.26981	PROB>|T|	0.0001

QUANTILES(DEF=4)

100% MAX	2.5	99%	2.5
75% Q3	0.25	95%	0.909998
50% MED	0.15	90%	0.505
25% Q1	0.1	10%	0.059
0% MIN	0	5%	0.039
		1%	0
RANGE	2.5		
Q3-Q1	0.15		
MODE	0.1		

MISSING VALUE .
COUNT 7
% COUNT/NOBS 7.37

EXTREMES

LOWEST	HIGHEST
0	0.8
0	1
0.03	1.15
0.03	1.4
0.05	2.5

EXAMINATION OF DISTRIBUTIONS FOR SKEWNESS 11:54 SATURDAY, NOVEMBER 14, 1981 7

UNIVARIATE

VARIABLE=LNP

MOMENTS

N	88	SUM WGTS	88
MEAN	0.209185	SUM	18.4083
STD DEV	0.195096	VARIANCE	0.0380623
SKEWNESS	2.80769	KURTOSIS	10.4232
USS	7.16217	CSS	3.31142
CV	93.2644	STD MEAN	0.0207973
T:MEAN=0	10.0583	PROB>|T|	0.0001

QUANTILES(DEF=4)

100% MAX	1.25276	99%	1.25276
75% Q3	0.223144	95%	0.645734
50% MED	0.139762	90%	0.408744
25% Q1	0.0953102	10%	0.057321
0% MIN	0	5%	0.0382129
		1%	0
RANGE	1.25276		
Q3-Q1	0.127833		
MODE	0.0953102		

MISSING VALUE .
COUNT 7
% COUNT/NOBS 7.37

EXTREMES

LOWEST	HIGHEST
0	0.587787
0	0.693147
0.0295588	0.765468
0.0295588	0.875469
0.0487902	1.25276

APPENDIX H

FINAL ANALYSIS OF HYDRAULIC HEAD USING THE GENERAL LINEAR MODELS PROCEDURE

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
CL	3	c m o
SOIL	6	a b o1 o2 o3 o4
PHBL	3	1 2 3

NUMBER OF OBSERVATIONS IN DATA SET = 95

NOTE: ALL DEPENDENT VARIABLES ARE CONSISTENT WITH RESPECT TO THE PRESENCE OR ABSENCE OF MISSING VALUES. HOWEVER, ONLY 87 OBSERVATIONS IN DATA SET CAN BE USED IN THIS ANALYSIS.

SECOND PRINT OUT--HAS DW AND DP--DOES NOT HAVE DIST
THIS SEEMS TO BE THE BEST MODEL FOR HH

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: HH

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	12	247203.00618733	20600.25051561	4.00	0.0001	0.393400	139.7498
ERROR	74	381172.94783566	5150.98578156		STD DEV		HH MEAN
CORRECTED TOTAL	86	628375.95402299			71.77036841		-51.35632184

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
GL	2	62104.94037356	6.03	0.0038	2	39901.07561094	3.87	0.0251
SOIL	5	39196.56208504	1.52	0.1924	5	54158.81373570	2.10	0.0738
PMBL	2	90188.22659953	8.75	0.0004	2	99144.44790641	9.62	0.0002
DBA	1	13615.26705871	2.64	0.1082	1	27479.59268100	5.33	0.0237
DP	1	20009.92429768	3.88	0.0525	1	22261.01277721	4.32	0.0411
DW	1	22088.08577280	4.29	0.0419	1	22088.08577280	4.29	0.0419

PARAMETER	ESTIMATE	T FOR HO: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
DBA LINEAR	-22.66445491	-2.31	0.0237	9.81262740
DW LINEAR	-0.77247085	-2.07	0.0419	0.37303384
DP LINEAR	-0.80187072	-2.08	0.0411	0.38572436

LEAST SQUARES MEANS

GL	HH LSMEAN	STD ERR LSMEAN	PROB > |T| HO:LSMEAN=0	PROB > |T| HO: LSMEAN(I)=LSMEAN(J) I/J	1	2	3
c	-52.810557	23.248604	0.0260	1	.	0.0110	0.8897
m	-130.571157	34.475071	0.0003	2	0.0110	.	0.0138
o	-49.478125	19.278604	0.0123	3	0.8897	0.0138	.

NOTE: TO ENSURE OVERALL PROTECTION LEVEL, ONLY PROBABILITIES ASSOCIATED WITH PRE-PLANNED COMPARISONS SHOULD BE USED.

SOIL	HH LSMEAN	STD ERR LSMEAN	PROB > |T| HO:LSMEAN=0	PROB > |T| HO: LSMEAN(I)=LSMEAN(J) I/J	1	2	3	4	5	6
a	-118.040351	36.601938	0.0019	1	.	0.8366	0.2235	0.0395	0.1725	0.9315
b	-101.264237	75.726155	0.1852	2	0.8366	.	0.5172	0.3297	0.6228	0.7955
o1	-43.757861	48.151513	0.3664	3	0.2235	0.5172	.	0.6748	0.6822	0.1367
o2	-18.741664	35.716058	0.6013	4	0.0395	0.3297	0.6748	.	0.2804	0.0069
o3	-62.893036	26.040672	0.0182	5	0.1725	0.6228	0.6822	0.2804	.	0.0401
o4	-121.022531	14.234734	0.0001	6	0.9315	0.7955	0.1367	0.0069	0.0401	.

NOTE: TO ENSURE OVERALL PROTECTION LEVEL, ONLY PROBABILITIES ASSOCIATED WITH PRE-PLANNED COMPARISONS SHOULD BE USED.

PMBL	HH LSMEAN	STD ERR LSMEAN	PROB > |T| HO:LSMEAN=0	PROB > |T| HO: LSMEAN(I)=LSMEAN(J) I/J	1	2	3
1	-159.003278	33.486766	0.0001	1	.	0.0007	0.0001
2	-43.665534	20.106438	0.0331	2	0.0007	.	0.5130
3	-30.191028	22.899093	0.1914	3	0.0001	0.5130	.

NOTE: TO ENSURE OVERALL PROTECTION LEVEL, ONLY PROBABILITIES ASSOCIATED WITH PRE-PLANNED COMPARISONS SHOULD BE USED.

APPENDIX I

FINAL ANALYSIS OF SPECIFIC CONDUCTIVITY, CHLORIDE CONTENT, AND PHOSPHATE CONTENT USING THE GENERAL LINEAR MODELS PROCEDURE

FULL MODEL FOR LOG OF CONDUCTIVITY 14:01 SATURDAY, NOVEMBER 14, 1981 1

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
GL	3	c m o
SOIL	6	a b o1 o2 o3 o4
PMBL	3	1 2 3
DIST	2	3 6
STNK	2	0 1

NUMBER OF OBSERVATIONS IN DATA SET = 95

NOTE: ALL DEPENDENT VARIABLES ARE CONSISTENT WITH RESPECT TO THE PRESENCE OR ABSENCE OF MISSING VALUES. HOWEVER, ONLY 83 OBSERVATIONS IN DATA SET CAN BE USED IN THIS ANALYSIS.

DEPENDENT VARIABLE: LNCOND

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	15	0.41659720	0.02777315	1.17	0.3151	0.207772	2.6591
ERROR	67	1.58847276	0.02370855		STD DEV		LNCOND MEAN
CORRECTED TOTAL	82	2.00506996			0.15397581		5.79053374

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
GL	2	0.05843242	1.23	0.2981	2	0.08529341	1.80	0.1734
SOIL	5	0.05131437	0.43	0.8255	5	0.03299559	0.28	0.9227
PMBL	2	0.10575010	2.23	0.1154	2	0.05417424	1.14	0.3252
DIST	1	0.00046802	0.02	0.8887	1	0.01004486	0.42	0.5173
STNK	1	0.04431046	1.87	0.1762	1	0.12010925	5.07	0.0277
HH	1	0.06685864	2.82	0.0978	1	0.07555854	3.19	0.0788
DBA	1	0.02841662	1.20	0.2775	1	0.00710891	0.30	0.5858
DP	1	0.00011494	0.00	0.9447	1	0.00571883	0.24	0.6249
DW	1	0.06093163	2.57	0.1136	1	0.06093163	2.57	0.1136

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
DBA LINEAR	-0.01228158	-0.55	0.5858	0.02242875
DW LINEAR	0.00156221	1.60	0.1136	0.00097448
DP LINEAR	0.00046345	0.49	0.6249	0.00094363
HH LINEAR	0.00046836	1.79	0.0788	0.00026235

FULL MODEL FOR LOG OF CONDUCTIVITY 14:01 SATURDAY, NOVEMBER 14, 1981 3

GENERAL LINEAR MODELS PROCEDURE

LEAST SQUARES MEANS

GL	LNCOND LSMEAN	STD ERR LSMEAN	PROB > |T| HO:LSMEAN=0	I/J	PROB > |T| HO: LSMEAN(I)=LSMEAN(J) 1	2	3
c	5.69286462	0.05167406	0.0001	1	.	0.9834	0.0717
m	5.69144839	0.07873586	0.0001	2	0.9834	.	0.1732
o	5.79706785	0.04303170	0.0001	3	0.0717	0.1732	.

NOTE: TO ENSURE OVERALL PROTECTION LEVEL, ONLY PROBABILITIES ASSOCIATED WITH PRE-PLANNED COMPARISONS SHOULD BE USED.

SOIL	LNCOND LSMEAN	STD ERR LSMEAN	PROB > |T| HO:LSMEAN=0	I/J	PROB > |T| HO: LSMEAN(I)=LSMEAN(J) 1	2	3	4	5	6
a	5.74443409	0.08056614	0.0001	1	.	0.5606	0.6015	0.6520	0.9818	0.7385
b	5.64046158	0.16520076	0.0001	2	0.5606	.	0.8708	0.4212	0.5562	0.4348
o1	5.67300035	0.11255300	0.0001	3	0.6015	0.8708	.	0.3818	0.5167	0.4329
o2	5.79242649	0.07957017	0.0001	4	0.6520	0.4212	0.3818	.	0.5811	0.7964
o3	5.74242230	0.05957824	0.0001	5	0.9818	0.5562	0.5167	0.5811	.	0.6815
o4	5.77001691	0.03547725	0.0001	6	0.7385	0.4348	0.4329	0.7964	0.6815	.

NOTE: TO ENSURE OVERALL PROTECTION LEVEL, ONLY PROBABILITIES ASSOCIATED WITH PRE-PLANNED COMPARISONS SHOULD BE USED.

PMBL	LNCOND LSMEAN	STD ERR LSMEAN	PROB > |T| HO:LSMEAN=0	I/J	PROB > |T| HO: LSMEAN(I)=LSMEAN(J) 1	2	3
1	5.65658257	0.07717500	0.0001	1	.	0.1455	0.1679
2	5.76831000	0.04440764	0.0001	2	0.1455	.	0.7959
3	5.75648829	0.05042015	0.0001	3	0.1679	0.7959	.

NOTE: TO ENSURE OVERALL PROTECTION LEVEL, ONLY PROBABILITIES ASSOCIATED WITH PRE-PLANNED COMPARISONS SHOULD BE USED.

DIST	LNCOND LSMEAN	STD ERR LSMEAN	PROB > |T| HO:LSMEAN=0	PROB > |T| HO: LSMEAN1=LSMEAN2
3	5.74088800	0.04797368	0.0001	0.5173
6	5.71336591	0.05187684	0.0001	

STNK	LNCOND LSMEAN	STD ERR LSMEAN	PROB > |T| HO:LSMEAN=0	PROB > |T| HO: LSMEAN1=LSMEAN2
0	5.67771814	0.05354731	0.0001	0.0277
1	5.77653577	0.04685309	0.0001	

REDUCED MODEL FOR LOG OF CONDUCTIVITY--HH AND STNK ONLY
MODEL INCLUDES TEST FOR INTERACTION BETWEEN HH AND STNK   14:01 SATURDAY, NOVEMBER 14, 1981   4

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
STNK	2	0 1

NUMBER OF OBSERVATIONS IN DATA SET = 95

NOTE: ALL DEPENDENT VARIABLES ARE CONSISTENT WITH RESPECT TO THE PRESENCE OR ABSENCE OF MISSING VALUES. HOWEVER, ONLY 86 OBSERVATIONS IN DATA SET CAN BE USED IN THIS ANALYSIS.

DEPENDENT VARIABLE: LNCOND

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	3	0.22103629	0.07367876	3.29	0.0246	0.107320	2.5868
ERROR	82	1.83857037	0.02242159		STD DEV		LNCOND MEAN
CORRECTED TOTAL	85	2.05960666			0.14973840		5.78858207

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
STNK	1	0.03663481	1.63	0.2048	1	0.02028803	0.90	0.3443
HH	1	0.16130638	7.19	0.0088	1	0.13468570	6.01	0.0164
HH*STNK	1	0.02309510	1.03	0.3131	1	0.02309510	1.03	0.3131

PARAMETER	ESTIMATE	T FOR HO: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
HH LINEAR	0.00047767	2.45	0.0164	0.00019489

LEAST SQUARES MEANS

STNK	LNCOND LSMEAN	STD ERR LSMEAN	PROB > |T| HO:LSMEAN=0	PROB > |T| HO: LSMEAN1=LSMEAN2
0	5.76069992	0.02100802	0.0001	0.0770
1	5.82245504	0.02734543	0.0001	

FULL MODEL FOR LOG OF CHLORIDE 14:01 SATURDAY, NOVEMBER 14, 1981 7

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
GL	3	c m o
SOIL	6	a b o1 o2 o3 o4
PMBL	3	1 2 3
DIST	2	3 6
STNK	2	0 1

NUMBER OF OBSERVATIONS IN DATA SET = 95

NOTE: ALL DEPENDENT VARIABLES ARE CONSISTENT WITH RESPECT TO THE PRESENCE OR ABSENCE OF MISSING VALUES. HOWEVER, ONLY 84 OBSERVATIONS IN DATA SET CAN BE USED IN THIS ANALYSIS.

DEPENDENT VARIABLE: LNCHL

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	15	0.36641465	0.02442764	1.53	0.1198	0.252024	3.7062
ERROR	68	1.08747393	0.01599226		STD DEV		LNCHL MEAN
CORRECTED TOTAL	83	1.45388858			0.12646052		3.41211025

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
GL	2	0.07914713	2.47	0.0918	2	0.00783736	0.25	0.7834
SOIL	5	0.03926353	0.49	0.7837	5	0.09177549	1.15	0.3440
PMBL	2	0.06580013	2.06	0.1357	2	0.07615292	2.38	0.1001
DIST	1	0.01346969	0.84	0.3620	1	0.03137513	1.96	0.1659
STNK	1	0.03520335	2.20	0.1425	1	0.01494383	0.93	0.3371
HH	1	0.00439116	0.27	0.6020	1	0.00347926	0.22	0.6424
DBA	1	0.00602627	0.38	0.5414	1	0.00046458	0.03	0.8652
DP	1	0.05699377	3.56	0.0633	1	0.02647777	1.66	0.2026
DW	1	0.06611962	4.13	0.0459	1	0.06611962	4.13	0.0459

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
DBA LINEAR	0.00313597	0.17	0.8652	0.01839911
DW LINEAR	-0.00162635	-2.03	0.0459	0.00079984
DP LINEAR	0.00099526	1.29	0.2026	0.00077348
HH LINEAR	0.00010050	0.47	0.6424	0.00021547

FULL MODEL FOR LOG OF CHLORIDE   14:01 SATURDAY, NOVEMBER 14, 1981   9

GENERAL LINEAR MODELS PROCEDURE

LEAST SQUARES MEANS

GL	LNCHL LSMEAN	STD ERR LSMEAN	PROB > |T| HO:LSMEAN=0	I/J	PROB > |T| HO: LSMEAN(I)=LSMEAN(J) 1	2	3
c	3.44599750	0.04249541	0.0001	1	.	0.6274	0.5450
m	3.47311118	0.06470447	0.0001	2	0.6274	.	0.9839
o	3.47438788	0.03516867	0.0001	3	0.5450	0.9839	.

NOTE: TO ENSURE OVERALL PROTECTION LEVEL, ONLY PROBABILITIES ASSOCIATED WITH PRE-PLANNED COMPARISONS SHOULD BE USED.

SOIL	LNCHL LSMEAN	STD ERR LSMEAN	PROB > |T| HO:LSMEAN=0	I/J	PROB > |T| HO: LSMEAN(I)=LSMEAN(J) 1	2	3	4	5	6
a	3.51135602	0.06629866	0.0001	1	.	0.8643	0.7319	0.2226	0.5775	0.0587
b	3.53637960	0.13560696	0.0001	2	0.8643	.	0.6991	0.3942	0.6468	0.2859
o1	3.47289426	0.09237738	0.0001	3	0.7319	0.6991	.	0.5400	0.9849	0.4194
o2	3.40427498	0.06528690	0.0001	4	0.2226	0.3942	0.5400	.	0.3637	0.8506
o3	3.47124613	0.04818223	0.0001	5	0.5775	0.6468	0.9849	0.3637	.	0.1421
o4	3.39084214	0.02921968	0.0001	6	0.0587	0.2859	0.4194	0.8506	0.1421	.

NOTE: TO ENSURE OVERALL PROTECTION LEVEL, ONLY PROBABILITIES ASSOCIATED WITH PRE-PLANNED COMPARISONS SHOULD BE USED.

PMBL	LNCHL LSMEAN	STD ERR LSMEAN	PROB > |T| HO:LSMEAN=0	I/J	PROB > |T| HO: LSMEAN(I)=LSMEAN(J) 1	2	3
1	3.50383082	0.06340807	0.0001	1	.	0.1268	0.7123
2	3.40751445	0.03650618	0.0001	2	0.1268	.	0.0467
3	3.48215129	0.04105315	0.0001	3	0.7123	0.0467	.

NOTE: TO ENSURE OVERALL PROTECTION LEVEL, ONLY PROBABILITIES ASSOCIATED WITH PRE-PLANNED COMPARISONS SHOULD BE USED.

DIST	LNCHL LSMEAN	STD ERR LSMEAN	PROB > |T| HO:LSMEAN=0	PROB > |T| HO: LSMEAN1=LSMEAN2
3	3.44020745	0.03932294	0.0001	0.1659
6	3.48879025	0.04267950	0.0001	

STNK	LNCHL LSMEAN	STD ERR LSMEAN	PROB > |T| HO:LSMEAN=0	PROB > |T| HO: LSMEAN1=LSMEAN2
0	3.44723775	0.04399166	0.0001	0.3371
1	3.48175996	0.03832405	0.0001	

REDUCED MODEL FOR LOG OF CHLORIDES--HH AND STNK ONLY 10
MODEL INCLUDES TEST FOR INTERACTION BETWEEN HH AND STNK 14:01 SATURDAY, NOVEMBER 14, 1981

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
STNK	2	0 1

NUMBER OF OBSERVATIONS IN DATA SET = 95

NOTE: ALL DEPENDENT VARIABLES ARE CONSISTENT WITH RESPECT TO THE PRESENCE OR ABSENCE OF MISSING VALUES. HOWEVER, ONLY 87 OBSERVATIONS IN DATA SET CAN BE USED IN THIS ANALYSIS.

DEPENDENT VARIABLE: LNCHL

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	3	0.04785133	0.01595044	0.94	0.4262	0.032905	3.8154
ERROR	83	1.40638221	0.01694436		STD DEV		LNCHL MEAN
CORRECTED TOTAL	86	1.45423354			0.13017052		3.41173395

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
STNK	1	0.03003043	1.77	0.1867	1	0.04443695	2.62	0.1092
HH	1	0.00864444	0.51	0.4771	1	0.01170479	0.69	0.4083
HH*STNK	1	0.00917645	0.54	0.4639	1	0.00917645	0.54	0.4639

PARAMETER	ESTIMATE	T FOR HO: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
HH LINEAR	0.00013999	0.83	0.4083	0.00016843

LEAST SQUARES MEANS

STNK	LNCHL LSMEAN	STD ERR LSMEAN	PROB > |T| HO:LSMEAN=0	PROB > |T| HO: LSMEAN1=LSMEAN2
0	3.39658611	0.01824054	0.0001	0.1305
1	3.44178400	0.02330795	0.0001	

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
GL	3	c m o
SOIL	6	a b o1 o2 o3 o4
PMBL	3	1 2 3
DIST	2	3 6
STNK	2	0 1

NUMBER OF OBSERVATIONS IN DATA SET = 95

NOTE: ALL DEPENDENT VARIABLES ARE CONSISTENT WITH RESPECT TO THE PRESENCE OR ABSENCE OF MISSING VALUES. HOWEVER, ONLY 82 OBSERVATIONS IN DATA SET CAN BE USED IN THIS ANALYSIS.

DEPENDENT VARIABLE: LNP

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	15	0.72250670	0.04816711	1.27	0.2450	0.224221	90.3173
ERROR	66	2.49979115	0.03787562		STD DEV		LNP MEAN
CORRECTED TOTAL	81	3.22229785			0.19461661		0.21548100

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
GL	2	0.28304683	3.74	0.0290	2	0.28374077	3.75	0.0288
SOIL	5	0.19696296	1.04	0.4022	5	0.11910154	0.63	0.6806
PMBL	2	0.14427385	1.90	0.1570	2	0.14537895	1.92	0.1548
DIST	1	0.03042560	0.80	0.3734	1	0.00327691	0.09	0.7696
STNK	1	0.00002094	0.00	0.9813	1	0.00187160	0.05	0.8246
HH	1	0.02941663	0.78	0.3814	1	0.01950469	0.51	0.4755
DBA	1	0.00180485	0.05	0.8279	1	0.00037834	0.01	0.9207
DP	1	0.03630822	0.96	0.3311	1	0.03231544	0.85	0.3590
DW	1	0.00024683	0.01	0.9359	1	0.00024683	0.01	0.9359

PARAMETER	ESTIMATE	T FOR HO: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
DBA LINEAR	-0.00286446	-0.10	0.9207	0.02866021
DW LINEAR	-9.9443545E-05	-0.08	0.9359	0.00123186
DP LINEAR	0.00112667	0.92	0.3590	0.00121976
HH LINEAR	-0.00023928	-0.72	0.4755	0.00033344

FULL MODEL FOR LOG OF PHOSPHATES 14:01 SATURDAY, NOVEMBER 14, 1981 15

GENERAL LINEAR MODELS PROCEDURE

LEAST SQUARES MEANS

GL	LNP LSMEAN	STD ERR LSMEAN	PROB > |T| HO:LSMEAN=0	PROB > |T| HO: LSMEAN(I)=LSMEAN(J) I/J	1	2	3
c	0.07415940	0.06545252	0.2613	1	.	0.4146	0.0240
m	0.00369804	0.09928908	0.9704	2	0.4146	.	0.0168
o	0.24165080	0.05451940	0.0001	3	0.0240	0.0168	.

NOTE: TO ENSURE OVERALL PROTECTION LEVEL, ONLY PROBABILITIES ASSOCIATED WITH PRE-PLANNED COMPARISONS SHOULD BE USED.

SOIL	LNP LSMEAN	STD ERR LSMEAN	PROB > |T| HO:LSMEAN=0	PROB > |T| HO: LSMEAN(I)=LSMEAN(J) I/J	1	2	3	4	5	6
a	0.01278890	0.10159980	0.9002	1	.	0.5619	0.2905	0.8923	0.4002	0.1685
b	0.14379792	0.20890103	0.4936	2	0.5619	.	0.8343	0.6368	0.8681	0.9872
o1	0.19686402	0.14281001	0.1727	3	0.2905	0.8343	.	0.3373	0.5087	0.7518
o2	0.03102889	0.10067651	0.7589	4	0.8923	0.6368	0.3373	.	0.5054	0.2946
o3	0.10737810	0.07563328	0.1604	5	0.4002	0.8681	0.5087	0.5054	.	0.6439
o4	0.14715864	0.04502133	0.0017	6	0.1685	0.9872	0.7518	0.2946	0.6439	.

NOTE: TO ENSURE OVERALL PROTECTION LEVEL, ONLY PROBABILITIES ASSOCIATED WITH PRE-PLANNED COMPARISONS SHOULD BE USED.

PMBL	LNP LSMEAN	STD ERR LSMEAN	PROB > |T| HO:LSMEAN=0	PROB > |T| HO: LSMEAN(I)=LSMEAN(J) I/J	1	2	3
1	-0.00826803	0.09734747	0.9326	1	.	0.0815	0.0583
2	0.16144727	0.05608889	0.0054	2	0.0815	.	0.9327
3	0.16632900	0.06370308	0.0112	3	0.0583	0.9327	.

NOTE: TO ENSURE OVERALL PROTECTION LEVEL, ONLY PROBABILITIES ASSOCIATED WITH PRE-PLANNED COMPARISONS SHOULD BE USED.

DIST	LNP LSMEAN	STD ERR LSMEAN	PROB > |T| HO:LSMEAN=0	PROB > |T| HO: LSMEAN1=LSMEAN2
3	0.09857828	0.06054154	0.1082	0.7696
6	0.11442722	0.06557783	0.0857	

STNK	LNP LSMEAN	STD ERR LSMEAN	PROB > |T| HO:LSMEAN=0	PROB > |T| HO: LSMEAN1=LSMEAN2
0	0.11267045	0.06752568	0.0999	0.8248
1	0.10033504	0.05911010	0.0943	

REDUCED MODEL FOR LOG OF PHOSPHATES--HH AND STNK ONLY 16
MODEL INCLUDES TEST FOR INTERACTION BETWEEN HH AND STNK 14:01 SATURDAY, NOVEMBER 14, 1981

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
STNK	2	0 1

NUMBER OF OBSERVATIONS IN DATA SET = 95

NOTE: ALL DEPENDENT VARIABLES ARE CONSISTENT WITH RESPECT TO THE PRESENCE OR ABSENCE OF MISSING VALUES. HOWEVER, ONLY 85 OBSERVATIONS IN DATA SET CAN BE USED IN THIS ANALYSIS.

DEPENDENT VARIABLE: LNP

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	3	0.11100808	0.03700269	0.94	0.4260	0.033717	93.6334
ERROR	81	3.18137960	0.03927629		STD DEV		LNP MEAN
CORRECTED TOTAL	84	3.29238767			0.19818247		0.21165793

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
STNK	1	0.04373832	1.11	0.2944	1	0.09822616	2.50	0.1177
HH	1	0.02843148	0.72	0.3974	1	0.04068153	1.04	0.3118
HH*STNK	1	0.03883828	0.99	0.3230	1	0.03883828	0.99	0.3230

PARAMETER	ESTIMATE	T FOR HO: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
HH LINEAR	-0.00026263	-1.02	0.3118	0.00025806

LEAST SQUARES MEANS

STNK	LNP LSMEAN	STD ERR LSMEAN	PROB > |T| HO:LSMEAN=0	PROB > |T| HO: LSMEAN1=LSMEAN2
0	0.22983203	0.02806086	0.0001	0.1883
1	0.16913695	0.03613032	0.0001	

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