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Wall Lake, South Dakota : A Case Study in Geographic Planning

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WALL LAKE, SOUTH DAKOTA: A CASE STUDY IN GEOGRAPHIC PLANNING

BY

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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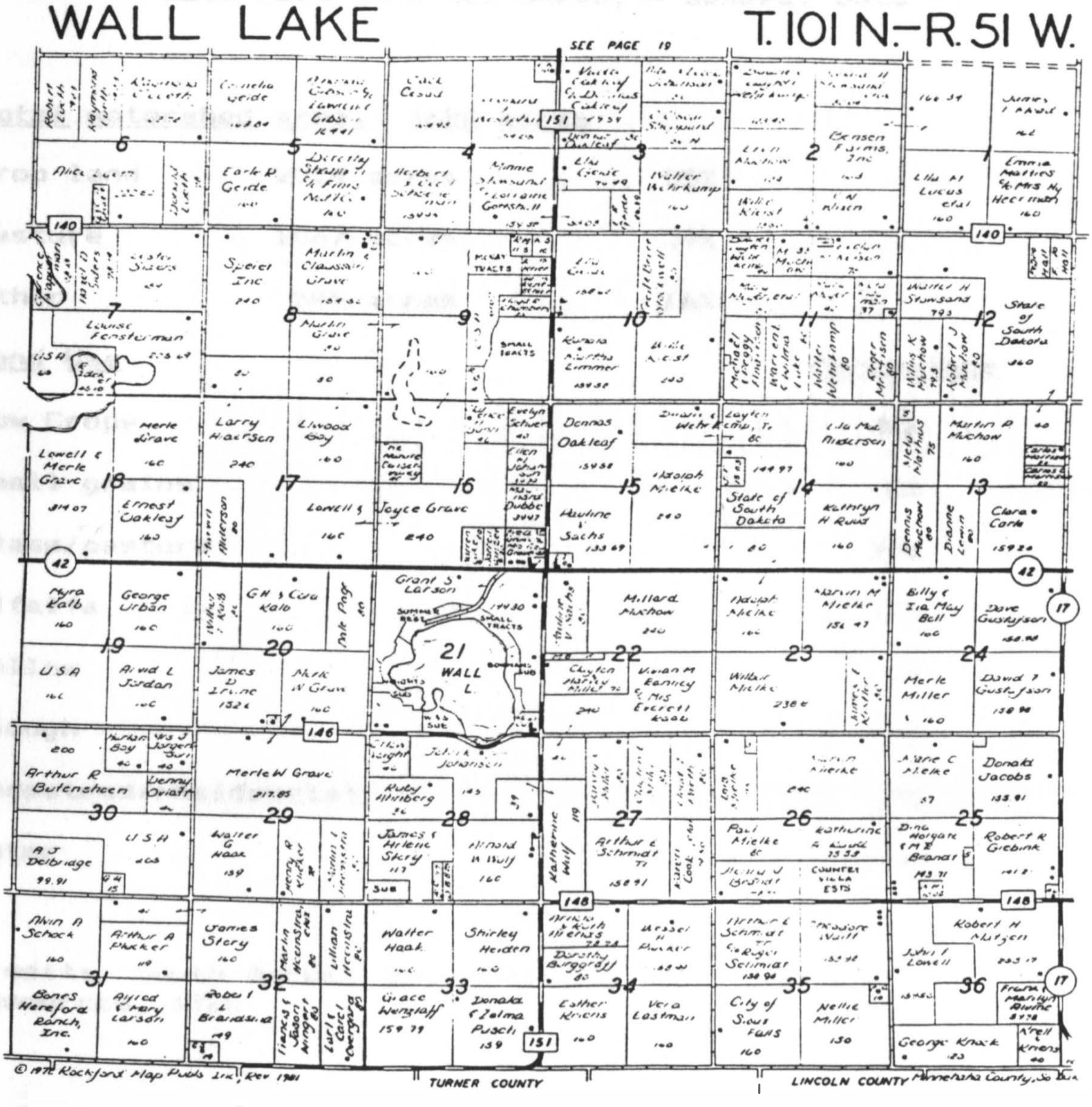
INTRODUCTION

Wall Lake is located in Minnehaha County, South Dakota, Section 21 and 28 of Wall Lake Township, T101N, R51W, latitude 43° 32′, longitude 96° 58′ (see Map 1). This body of water is south of State Highway #42, approximately nine miles west of the state's largest city, Sioux Falls. It is one in a series of glacial lakes in the Coteau des Prairie section of the Central Lowland Province. The surface area of the lake is 215-225 acres (Carter, 1981.) It has an average depth of nine feet (U.S. Army Corps of Engineers, 1980). Elevation is 1,449.5 feet above mean sea level (MSL). It is surrounded by rolling hills to flat terrain consisting of approximately 60 feet in relief. Shore line length is 13,200 feet (4,023 m) (DWNR, 1979). On the northeast shore line is a high wave cut terrace that forms a lake wall. Hence the name, Wall Lake (DWNR, 1985).

The watershed encompasses 3,680 acres (1,243 hectares) of mostly agricultural land to the west, northwest and north from which the three primary tributaries flow. The outlet discharges into Skunk Creek which joins the Big Sioux River by an unnamed stream (Map 2.) It consists of 55% crop land, 29% pasture and 16% water, farmsteads and residential areas (DWNR, 1988). A more precise breakdown of land use appears in Table 1.

Map 1: Plat



Credit: Minnehaha County Plat Book

Table 1

Wall Lake Land Use Survey - General Data

Total watershed area:	3680 acres	
Crop land	2024 acres	55%
Pasture	1067 acres	29%
Other	589 acres	16%

Land Use	Percentage
Row Crops	38%
Small grains	6%
Grass/pasture	29%
Alfalfa	7%
Fallow	4%
Slough	3%
Farmstead/residential	7%
Water	6%

Credit: South Dakota Department of Water and Natural Resources, 1988.

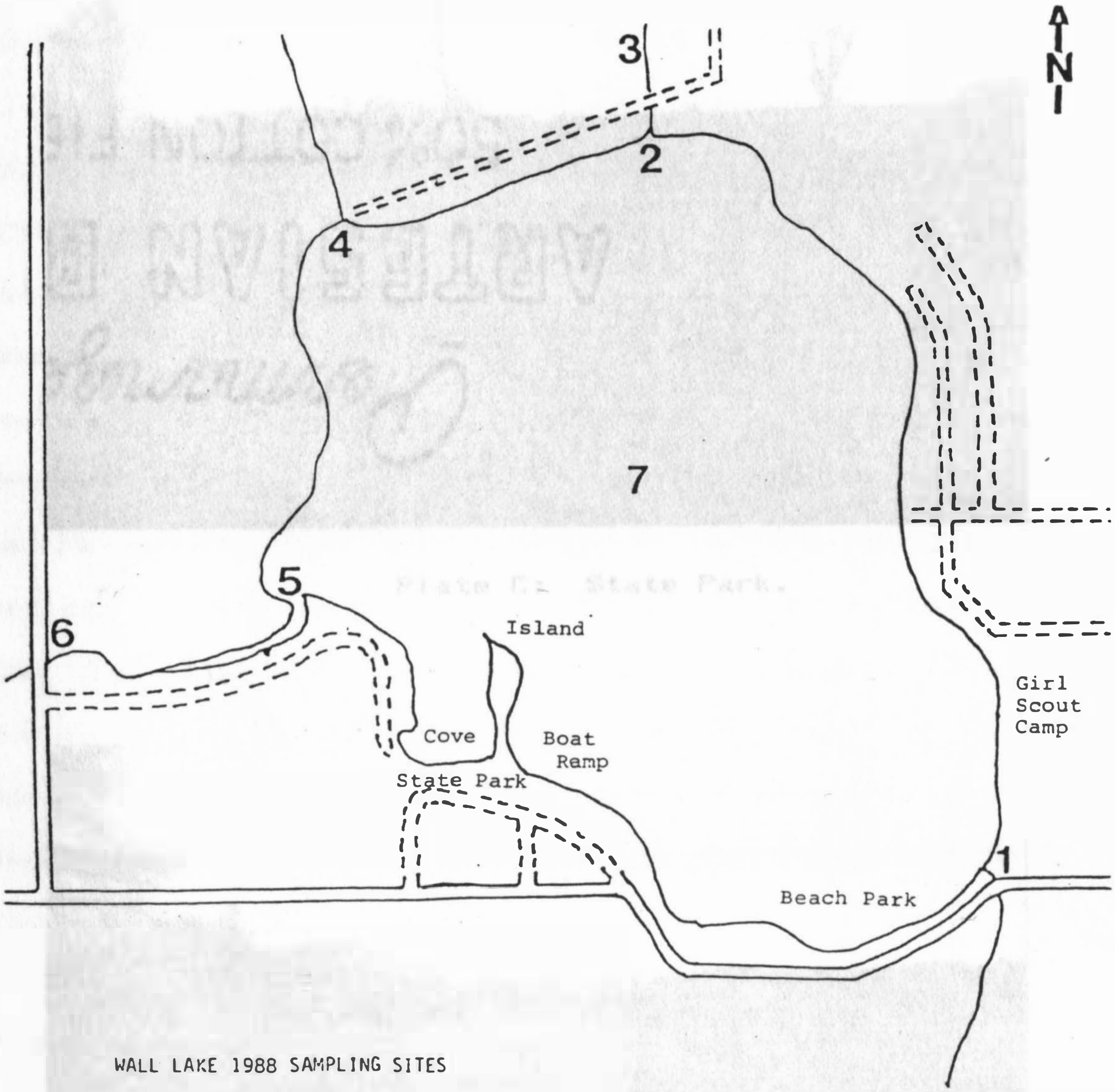
There are approximately 80 permanent and seasonal homes around the lake, 68 of which actually front the lake. A beach park exists on the south side, which recently has been improved by Minnehaha County to include a parking lot, picnic area, bathhouse and a foot bridge over the lake outlet (Plate A). A camp is located on the southeast lake shore which is owned by the County and leased, free of charge, to the Girl Scouts of America (Plate B). The State has a small park and picnic ground south of the cove (Map 3) and the Department of Game, Fish and Parks maintains the boat ramp on the east side of the island adjacent to the public dock (Plates C and D).

Summer uses of the lake include immersion recreation, fishing, boating, and water skiing. Winter activities include ice fishing, ice skating, snowmobiling, and cross-country skiing. Wildlife sustained by the lake provides hunters with game and sport. Numerous events are held at Wall Lake throughout the year including an annual fishing derby, a triathalon and many private parties (Horner, 1988.)

Plate A: Wall Lake Beach Park.

Plate B: Girl Scout Camp.

Map 3: Sampling Sites



WALL LAKE 1988 SAMPLING SITES

Site Number	Site Location
1.	Outlet
2.	North Tributary-mouth
3.	North Tributary-between pond by road and feedlot
4.	Northwest Tributary-mouth
5.	West Tributary-mouth
6.	West Tributary-at culvert on north-south road
7.	Inlake-centrally located

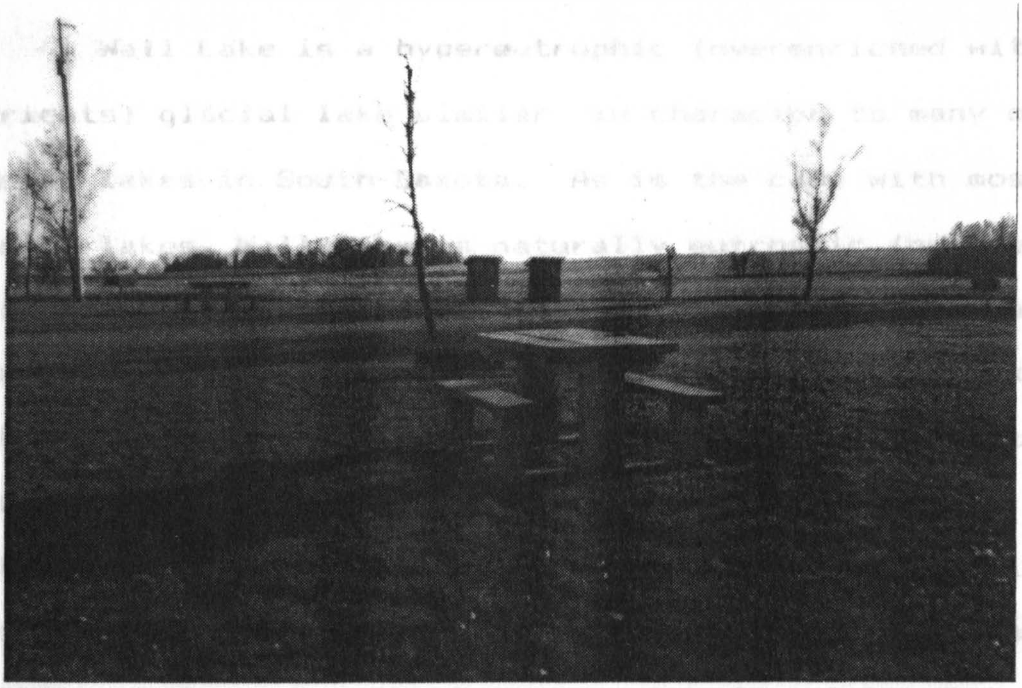


Plate C: State Park.

Plate D: Boat Ramp.

Wall Lake is a hypereutrophic (overenriched with nutrients) glacial lake similar in character to many other glacial lakes in South Dakota. As is the case with most glacial lakes, Wall Lake is naturally eutrophic (nutrient enriched) because of the nutrient rich loess which usually occurs in close proximity to glacial kettles and is mixed with nutrient rich glacial till. A hypereutrophic state occurs when additional nutrients are added to the lake by such sources as agricultural runoff, mixing of water with enriched sediments, and by wastewater systems. The result is the accelerated natural progression from lake, to wetland, to dry land. Overenrichment and contamination of the lake cause the overabundant growth of algae, fish kill due to oxygen (O_2) depletion, unsafe bacterial conditions for water immersion recreation, and the aesthetically displeasing odor of hydrogen sulfide which smells like rotten eggs.

PROBLEM STATEMENT:

Wall Lake is experiencing hypereutrophication which limits the recreational use by residents of Minnehaha County. Agricultural practices and wastewater systems influx has accelerated the natural processes of the lake so that it is feared that it may become a swamp prematurely.

PURPOSE:

The purpose of this study is to determine the feasibility of restoring the lake for Minnehaha County residents. Initially, current, consistent data analysis of runoff from the watershed area of Wall Lake was to be included. Drought prevented watershed runoff from being sampled for the majority of the testing period. Water samples disclosed that bacterial contamination and high nutrient levels continued to occur. This paper suggests that the most probable source of bacterial contamination during this period of testing was wastewater systems.

HYPOTHESIS:

There are three possible sources of nutrient and bacterial contamination that prevent recreational use of Wall Lake. They are: 1. Runoff from the watershed, 2. Faulty wastewater systems, 3. Existing sediments in the lake basin.

The most probable source of bacterial contamination during the testing period is faulty wastewater systems adjacent to the lake. This conclusion is reached by the process of elimination.

Runoff from agricultural sources did not exist except for the first part of the test period and is therefore not considered to be a contributor for the majority of the test period. Lake sediments cannot generate nutrients into the water column over long periods of time without the convection which exists in deep water (20+ feet) where thermal stratification occurs. Furthermore, the indicator bacteria lives approximately three months in soil or water. Hence, sediment from previous years could not contribute to high bacterial test results.

There is an interrelatedness of the various factors that impact contamination in Wall Lake. Nutrient and bacterial contamination can be derived from any or all of the sources under favorable circumstances.

LITERATURE REVIEW:

Based on an exhaustive review of journals and reports, no geographic literature was found that dealt with hypereutrophication in glacial lakes. Primary sources of information came from reports by the South Dakota Department of Water and Natural Resources, South Dakota Geologic Survey, interviews and personal observations. Due to the fact that some of the terms and abbreviations may be unfamiliar to geographers, a list of definitions is included at the end of the first chapter. Other terms not defined herein may be found in most physical geography texts or geologic dicitionaries.

DEFINITIONS

ABBREVIATIONS:

1. BMP's - Best Management Practices including but not restricted to those agricultural practices that reduce erosion and groundwater pollution by terracing, contour plowing, strip cropping, planting shelter belts, using fertilizer management, and animal waste management, enhanced wetlands or low overhead wiers.

2. SRF - State Revolving Fund. A new program whereby the federal government will phase out grants for water restoration projects and will designate seed money to the states for low interest loans. The interest rate for 1989 was set at 3%.

CHEMICAL FORMULAS:

1. N, NO_2, NO_3 - Nitrogen, nitrite, and nitrate respectively. Transported through soil by leaching.

2. NH_4 - Ammonia.

3. O_2 - Oxygen.

4. P, PO_4, P_2O_5 - Phosphorus and phosphorus with oxygen in the indicated proportions. Adheres to soil particles and therefore transported by runoff and erosion.

TERMS:

1. Continental glaciers - A thick ice sheet over a land mass that moves outward in all directions as a result of a center zone of accumulation. Glaciation in this context refers to Pleistocene Age lobes.

2. Convection - Circular movement of a fluid as a result of density differences caused by heating and cooling. Cold dense fluids sink while warm, less dense fluids rise causing a convection cell.

3. Enhanced wetlands - A practice often implemented to prevent nutrients and sediment from entering a body of water. A process whereby an existing swamp is seeded with plants known for their nutrient uptake. Existing channels may be deepened and structures may be erected to serve as traps or filters.

4. Eutrophic - Enriched. Usually pertains to a water body with prolific algal growth.

5. Glacial drift - Deposition on lacustrine, riparian or land regions by a glacier.

6. Glacial till - Unsorted, unstratified glacial deposit.

7. Grab Samples - Samples taken by hand.

8. Hypereutrophic - Overenriched. Usually pertains to a water body suffering from overabundant algal growth that depletes the oxygen supply in the water by creating a thick algal mat that restricts photosynthesis.

9. Immersion recreation - A beneficial use assigned to waters which are suitable for uses where the human body may come in direct contact with the water to the point of complete submersion and where water may be ingested accidentally or where certain sensitive organs such as the eyes, ears and nose may be exposed to water (SDCL Chapter 74:03:02:01 section 18.)

10. Loess - Eolian deposits of Pleistocene age. In South Dakota deposits are rich in nutrients and of a yellowish, maize color. Loess is often found in lacustrine or riparian environments.

11. Mammal - Class of warm blooded vertebrates that breathe air, nurse their young and have skin covered with hair. In this text, both livestock and humans harbor fecal coliform bacteria in their intestines and are considered.

12. Pristine - Crystal clear.

13. Sanitary District - An elected governmental body designed to address the wastewater needs of a specific region. Board members have the authority to levy taxes and assessment for services.

14. Thermal stratification - The layers that occur in a fluid body as a result of density differences induced by varying temperature.

15. Titration - A chemical analysis to separate and determine the quantity of a substance. In this text, the quantity of oxygen is the datum that is required.

UNITS:

1. /100 L - Parts per liter. Units for fecal coliform bacteria in this text.

2. mg/L - Milligrams per Liter. Units for the nutrients phosphorus and nitrogen in this text.

Chapter Two

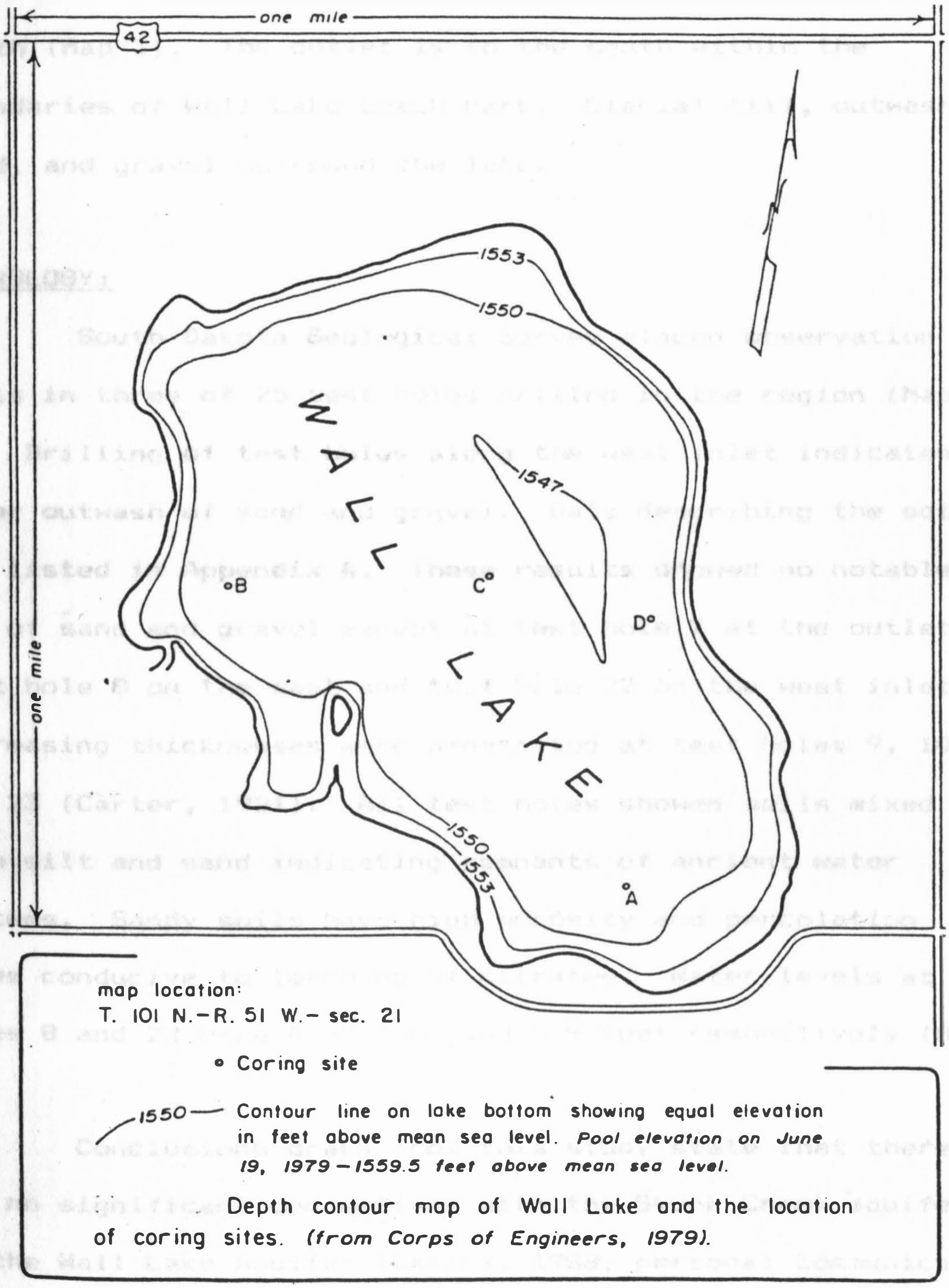
GEOGRAPHIC FACTORS

Geography consists of the study of spatial, locational, perceptual and conceptual relationships as they exist on the surface of the earth, be they organic or inorganic. As many geographic factors as possible should be considered in a planning region to render the best decisions for the public good.

GEOMORPHIC ORIGINS:

During the Pleistocene epoch, Minnehaha County was subjected to the Nebraskan, Kansan, Illinoian and Wisconsin glaciers which deposited till over Precambrian quartzite and Cretaceous chalks and shales. Approximately 90% of the County is covered by 200 feet of deposits from the two most recent glaciers. The Wall Lake watershed exemplifies ground moraines, kames, outwash plains and terraces from these glacial events (Flint, 1955). Wall Lake is the result of the late Wisconsin glaciation. This kettle lake is approximately 13,000 years of age, as indicated by Carbon-14 dating (DWNR, 1985). Because it is of recent geologic age, complex stream systems have not yet developed. The lake's maximum depth of 14 feet and average depth are nearly equal due to the extreme flatness of the lake bottom (U.S. Army Corps of Engineers, 1980). Map 4 shows the contour of the

Map 4: Wall Lake Basin



Credit: South Dakota Geologic Survey, Carter and Barari, 1981.

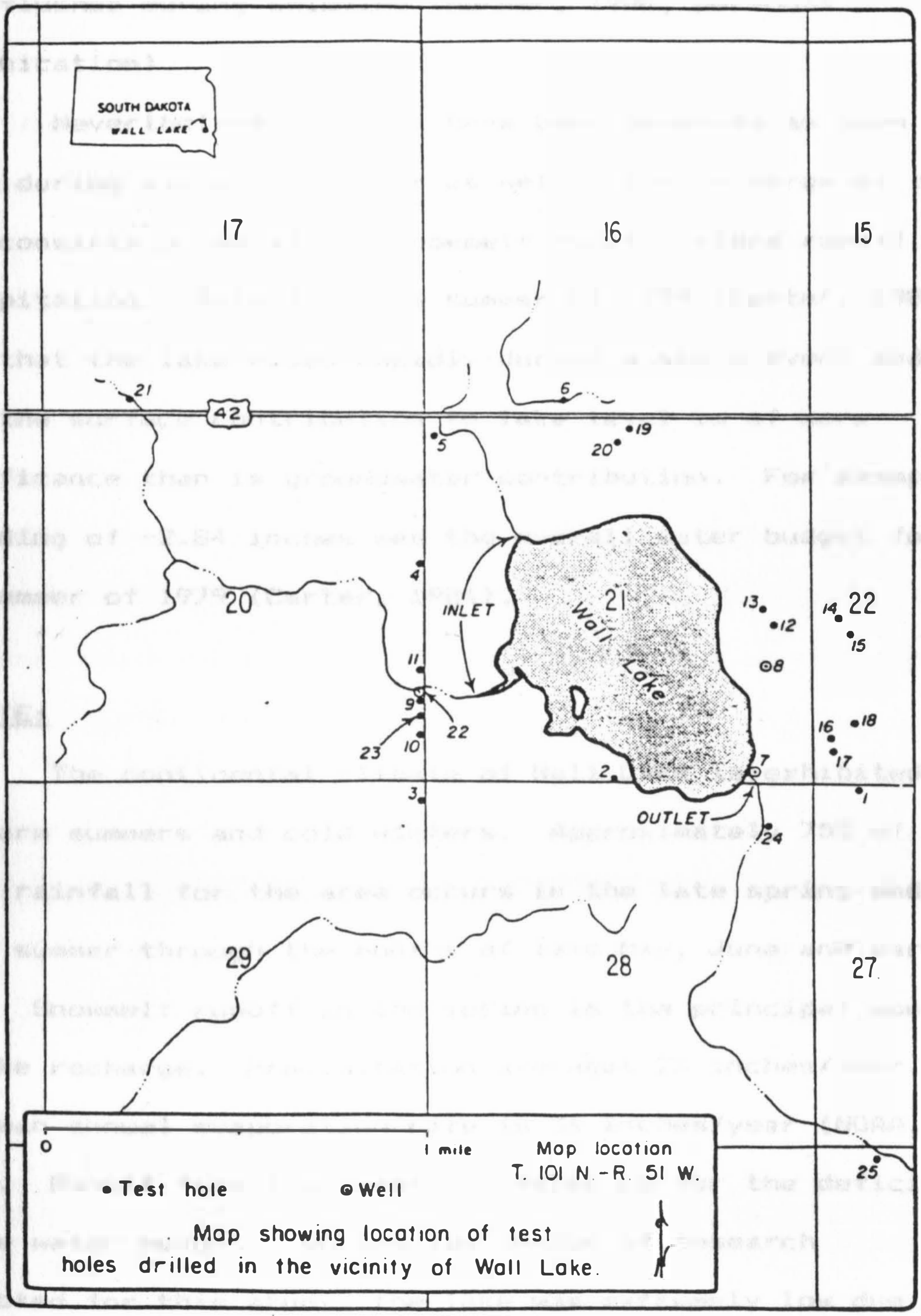
lake basin. Major inlets are to the west, northwest and north (Map 3). The outlet is to the south within the boundaries of Wall Lake Beach Park. Glacial till, outwash sand, and gravel surround the lake.

HYDROLOGY:

South Dakota Geological Survey placed observation wells in three of 25 test holes drilled in the region (Map 5). Drilling of test holes along the west inlet indicates minor outwash of sand and gravel. Data describing the soils are listed in Appendix A. These results showed no notable bed of sand and gravel except at test hole 7 at the outlet, test hole 8 on the east and test hole 22 on the west inlet. Decreasing thicknesses were penetrated at test holes 9, 10 and 23 (Carter, 1981). All test holes showed soils mixed with silt and sand indicating remnants of ancient water systems. Sandy soils have high porosity and percolation rates conducive to leaching of nitrates. Water levels at sites 8 and 22 were 8.32 feet and 5.9 feet respectively (Map 5).

Conclusions drawn from this study state that there are no significant connections with the Skunk Creek aquifer or the Wall Lake Aquifer (Barari, 1988, personal communication). Local residents indicate that there are minor springs in the lake, features experienced and identified as

Map 5: Hydrologic Test Holes



Credit: South Dakota Geologic Survey, Carter and Barari, 1981.

cold flushes during swimming (Horner, 1988, personal communication).

Nevertheless, springs have been observed as open water during winter ice cover as well. The recharge of the lake consists primarily of snowmelt runoff, storm runoff and precipitation. Data from the summer of 1979 (Carter, 1981) show that the lake rises rapidly during a storm event and that the surface contribution to lake level is of more significance than is groundwater contribution. For example, a reading of -2.84 inches was the overall water budget for the summer of 1979 (Carter, 1981).

CLIMATE:

The continental climate of Wall Lake is exhibited in the warm summers and cold winters. Approximately 75% of the total rainfall for the area occurs in the late spring and early summer through the months of late May, June and early July. Snowmelt runoff in the spring is the principal source of lake recharge. Precipitation averages 23 inches/year. The mean annual evaporation rate is 36 inches/year (NOAA, 1986). Runoff from the watershed makes up for the deficit in the water budget. During the period of research conducted for this study, the lake was extremely low due to the 1988 drought when normal runoff and recharge did not occur.

Temperature extremes range from approximately -20°F to 96°F. The average maximum and minimum temperatures range from about 57°F and 46° respectively (Soil Survey, Minnehaha County, 1964.)

FLORA AND FAUNA:

Wall Lake is lined with an assortment of trees and shrubs that stabilize the shore line and provide habitats for birds, squirrels, muskrats and other small animals. Ash, Cottonwood, and Chinese Elm dominate the shore line. In some areas rip rap has been added to stop erosion by wave action. Photos E and F depict a tributary south of Site 2 and the island, respectively.

Since at least 1961, higher order aquatic plants have been uncommon in Wall Lake (Dorband, 1983). The blue-green algae blooms increase in volume as the summer months progress. The most frequently occurring algae is *Aphanizomenon flos-aquae*. *Microcystis aeruginosa* is the second most abundant algae (Camburn, 1988). Both are typical of hypereutrophic lakes and are not toxic in reported quantities. Spring runoff from the watershed can be high in phosphorus and nitrates. These nutrients can come from fertilizers and livestock waste concentrated in small areas such as feedlots, if not properly drained. While chemicals increase the productivity of crops, they

Plate E:
Rip Rap
in Tributary.

Plate F: Rip Rap at the island.

also increase the production of algae. In addition to this, one animal unit contributes nutrient bearing, excretory waste equivalent to 16 humans (Little, 1988). As these plants increase, a mat of algae covers the water surface which excludes sunlight from the lower water levels. Photosynthesis in the water column, which produces oxygen (O_2), decreases and anaerobic (de-oxygenated) conditions under the algal mat are created. The algae at lower levels then dies, releasing a blue-green dye which looks like a slime on the surface. It is not necessarily dangerous to swimmers but is aesthetically undesirable. The unappealing odor of hydrogen sulfide, similar to rotten eggs, is often associated with this denitrification process of the algal mat (Houtcooper, 1988, personal communication; Dorband, 1988, personal communication).

The anaerobic conditions created by the excessive amount of algae does have an effect on the quality of fish in the lake. Only those fish that can adapt to lower oxygen levels survive. The result is that carp and bullhead constitute the majority of fish inhabiting the lake. According to South Dakota Game, Fish and Parks, 86.2% of the fish are black bullhead, (*Ictalurus melas*), 10.8% are yellow perch (*Perca flavescens*) and 2.9% are walleye (*Stizostedion vitreum*). These findings were based on the result of 12 net traps. Seining produced one northern pike (*Esox lucius*) and 28 fathead minnows (*Pimephales promelas*).

SOILS:

Soils surrounding Wall Lake are well drained due to underlying sand and gravel. Kranzeburg and Buse series dominate. These silty clay loams were formed when wind driven loess lodged on glacial till. They are medium textured soils, normally found in steep or rolling terrain. Parent material is glacial till with low organic content. It is usually calcareous and exhibits stones and pebbles. The Kranzeburg is slightly acid to slightly alkaline. These soils are normally associated with each other (Soil Survey Minnehaha County, South Dakota, 1964.)

In depressions, Hidewood, Parnell and La Prairie soils are found. The texture of Hidewood and Parnell soils is fine due to action of water in the depositional process from uplands. They are found in drainageways and in depressions. These soils show occasional deposits of calcium carbonate ($CaCO_3$) and contain considerable organic matter. Although they are located in agricultural land, they are often too wet to cultivate. The Parnell series can often be easily detected as moisture frequently collects in those areas.

La Prairie soils differ in that drainage is moderate. Though often inundated with water, they can be productive agricultural lands through proper management (Soil Survey Minnehaha County, South Dakota, 1964.)

Sediment load deposited by the tributaries was thought to be high in years gone by. Present indications are that tributaries are released of potential load by the natural lowlands surrounding the lakes that act as a natural sediment trap (Siegel, 1983). This also attests to the implementation of conservation practices by landowners in the watershed area (Top, 1988). However, there are some cells of land in the watershed that could be considered highly erodible (Map 6.) Best Management Practices (BMP's) would minimize nutrient laden particles from being deposited in Wall Lake by erosional processes.

POPULATION:

In 1988, Minnehaha County was the largest county in South Dakota with a population of approximately 124,000 people. Sioux Falls was rated one of the ten best cities in which to raise a family by "Money" magazine (Eisenberg, 1987). The rate of growth and influx of industry and commerce show a growing need for water-based recreation for this growing population. Table 2 shows population projections for Minnehaha County. In addition, Wall Lake is used by residents of adjacent Lincoln, McCook and Turner

Map 6: Problem Cells in the Watershed

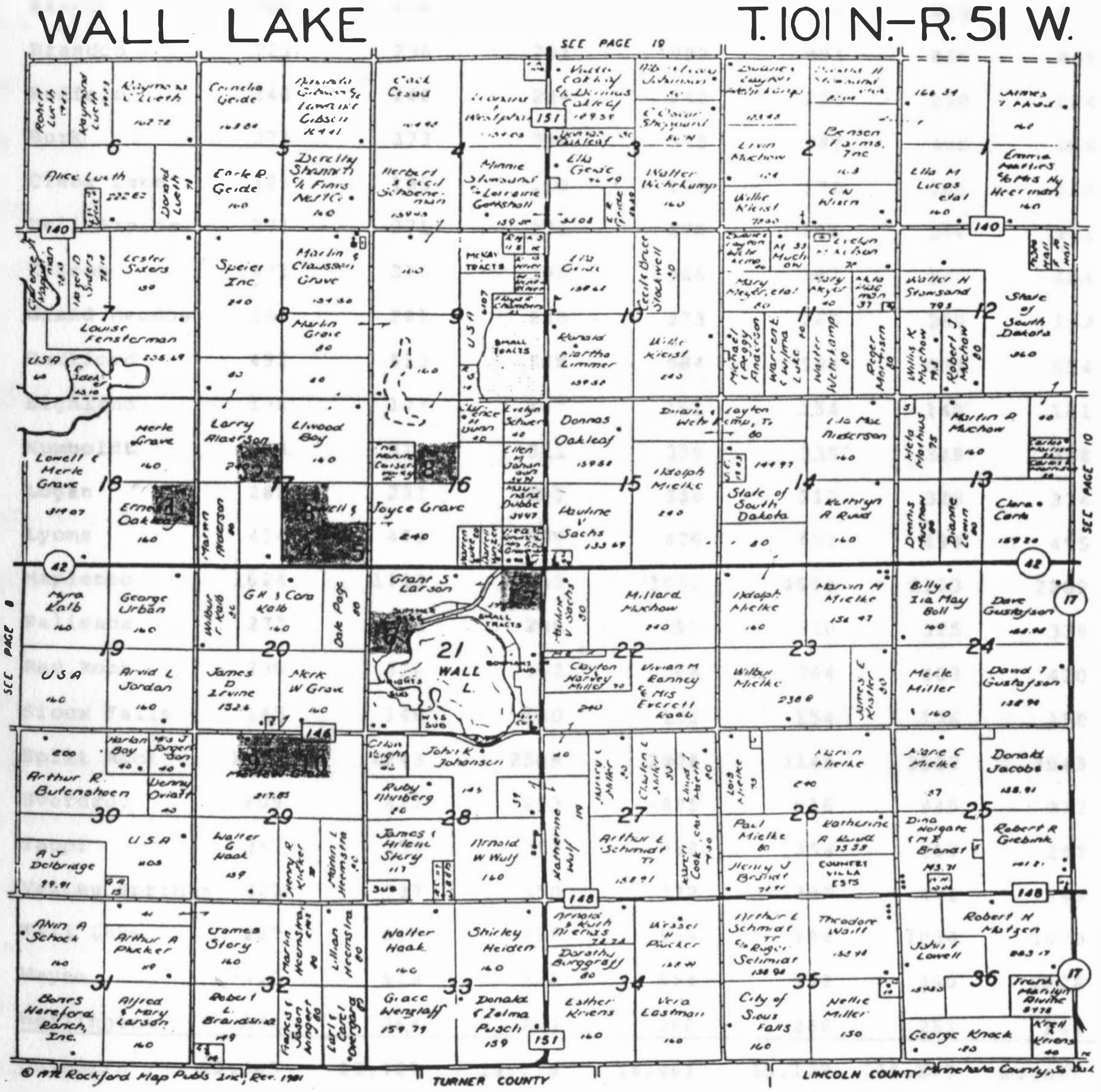


Table 2: Minnehaha County Population Projections

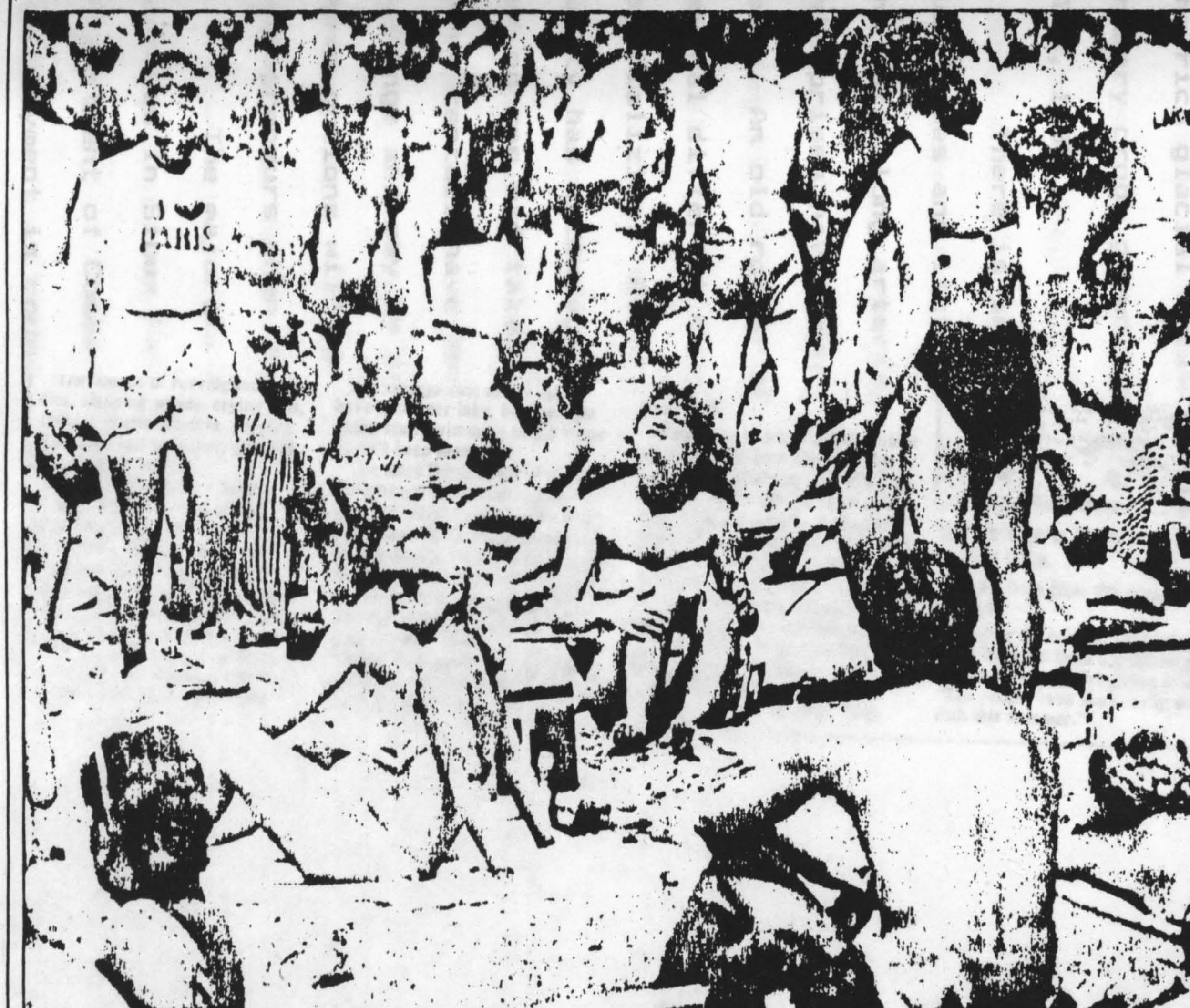
TOWNSHIP	1988	1990	1995	2000	2005	2010	2015
Benton	586	626	670	716	766	819	875
Brandon	721	736	751	787	803	826	846
Buffalo	246	246	244	242	236	230	224
Burk	371	373	380	385	387	392	396
Clear Lake	185	185	180	175	170	165	160
Dell Rapids	271	271	271	276	276	276	281
Edison	372	375	380	386	392	398	404
Grand Meadow	288	287	280	273	266	259	252
Hartford	492	513	548	584	584	622	654
Highland	176	173	167	161	154	148	141
Humboldt	309	312	321	330	339	349	358
Logan	288	291	299	308	317	325	334
Lyons	454	459	468	476	482	490	495
Mapleton	1624	1733	1842	1951	2064	2173	2282
Palisade	273	274	286	295	310	325	338
Red Rock	330	336	352	368	384	403	420
Sioux Falls	147	148	150	152	154	156	158
Split Rock	2063	2243	2509	2808	3145	3522	3943
Sverdrup	809	822	853	885	916	945	973
Taopi	357	357	357	358	358	357	357
Valley Springs	322	337	350	372	397	422	449
Wall Lake	887	890	922	959	994	1034	1073
Wayne	910	918	936	954	972	990	1008
Wellington	264	264	262	260	256	251	248
Unincorp	12,745	13,169	13,778	14,461	15,122	15,877	16,669
Incorp	11,600	12,000	12,900	13,600	14,200	14,700	14,900
Sioux Falls	100,000	105,000	110,000	112,000	115,000	119,000	121,000
Total Co	124,345	130,169	136,678	140,061	144,322	149,577	152,569

counties. As many as 3,000 people have been estimated to be crowded on the beach on hot days (Albrecht, 1987). The newspaper article on the following page relates the heavy use the public beach receives. According to Game Fish and Parks, the (1980) user day requirements for the population of 109,435 were 556,169. Because only 15,557 user days are provided for fishing by Wall Lake in Minnehaha County, there was a deficit of 540,612 user days.

HISTORY AND ECONOMICS:

Prior to settlement by Europeans, this area was inhabited by the Dakota Sioux Indians. It was first penetrated by the French explorer and fur trader, LeSeur in 1683. In 1857, the area to the east of Wall Lake was described by explorer and geographer, Dr. Joseph Nicollet in his publication, Travels in the Northwest. His description of the beautiful rivers and wooded land encouraged subsequent settlement of the area by the Western Town Company of Dubuque, Iowa and the Dakota Land Company. This settlement was vacated due to a threat of an Indian uprising and was subsequently burned to the ground by the Indians. The same site was re-established as present day Sioux Falls (Smith, 1949).

Lands around Wall Lake were homesteaded following the resettlement, resulting in the agricultural economy that



Argus Leader photos by DEAN CURTIS

Crowds throng to Wall Lake to escape the summer heat. The crowd was estimated at 3,000 people.

Having a

BALL

Summer sizzles at Wall Lake

By MARSHA ALBRECHT
Argus Leader Staff

WALL LAKE — Hot cars and hot bodies sizzle at Minnehaha County's sandbox supreme.

A little boy tosses a leach between his palms. Twenty scantilly-clad young adults toss a volleyball over a lake-anchored net. Hundreds of boys and girls toss come-hither looks. Countless beer cans are tossed in overflowing wastebaskets.

The scene is Sunday at the beach — Wall Lake style. Oh, the three thousand or so sunbathers crowding the two-block-long beach know it's not a great lake. But it's the only one we've got. We loyally return every year, forgetting the cut feet and green swimsuits from the summer before.

The sounds of revving motorcycles, slapping waves, crying kids, rocking ghetto blasters, popping beer tops and squealing girls fill the air on a hot day.

The sights of giant plastic sharks, bright-colored bikinis, gleaming aluminum cans, bikers sunbathing on their motorcycles, deaf swimmers signing, boys squirting girls, kids building sand castles and paunches peaking out over swim trunks fill the eye.

It's the ambiance of summer. It's being where your friends are, where people in pursuit of the same tanned skin and easy camaraderie of vacation gather.

Cathy Garry, 30, comes to Wall Lake from Sioux Falls often on days off with her husband and three daughters. "You'll find everybody here on a day like today."

The Garrys prefer lakes to the public pools. "I like this better, you bet, because it's free," Cathy Garry said.

Freedom lures the Garry children. They don't like to stop swimming for the mandatory 10-minute breaks at the public pools, and they like being able to take inflatable toys in the water.

The Garrys said they'd rather have a cleaner lake, but the light green stuff swimming in the water doesn't keep them out.

The state Department of Water and Natural Resources regularly tests the water at Wall Lake, and it has been declared relatively safe for swimming, County Administrator Dale Froehlich said. The green tint comes from algae blooming with the help of nitrogen runoff from lakeside farms.

Brian Bargmann, 20, of Madison, said he and his friends had thought about going to Lewis and Clark Lake at Yankton. It's brown. "We had a choice between brown and green and we chose green."

He likes the big beach, 40 feet wide and ½ mile long, better than the one at Lake Madison. "It's a nice beach," Bargmann said.

Bargmann didn't swim. He and his friends came to waterski, but they didn't. "When you go here, you can watch other people have fun. It keeps you entertained, anyway," he said.

Angie Vacanti, 17, and Angie Sherwood, 16, both of Lennox, come to the lake on weekends. Their reasons? "The guys," Vacanti said. "Just to lay out," Sherwood said.

Wall Lake is drawing big crowds seeking relief from the heat this summer. Minnehaha Sheriff's Deputy Phil Niedringhaus estimates at least 3,000 swimmers, sunbathers and fishermen throng to the public beach on Sundays. It's causing some parking problems as people fill the two parking lots and the south side of the road that parallels the beach. In desperation, people are parking illegally on the north side of the road when the parking runs out, he said. They face $40 fines from the county for doing it.

Despite the crowds, violence and noise have not been a problem yet this summer, Niedringhaus said. "The people have been really decent this summer."

County to discuss water tests

Minnehaha County commissioners Tuesday will discuss findings from water quality testing at Wall Lake by the state Department of Water and Natural Resources.

The state has been testing water at the lake for about a year. Studies also have been done by the Army Corps of Engineers. The commission has avoided dredging the lake because recommendations have been conflicting, County Administrator Dale Froehlich said.

Depending on the results of the state's recent findings, commissioners may again discuss options for cleaning up the lake. The meeting is at 9 a.m. Tuesday in the Minnehaha County Courthouse.

Volleyball is a favorite pastime at Wall Lake.

dominates the watershed and surrounding area of the lake. The rich glacial soils are used for pasture and crops. Primary crops grown include corn, barley, oats and soybeans (Top, 1988).

There is some diversification of employment in small businesses and light industries located to the northeast of the lake along arterial intersections. No commercial enterprises have been pursued in recent years around the lake. An old roller skating rink has been transferred to several different owners with the prospect of a restaurant materializing. Renovations have never been completed. The County has encouraged concessions at the County Park but so far no one has taken advantage of the opportunity. Boat and canoe rentals have been discussed at County Park Board meetings and may be in the future of Wall Lake. Perhaps these options will be more seriously pursued by entrepreneurs when the lake experiences remedial action.

The majority of the lake front homeowners are employed in Sioux Falls and commute to work on a daily basis (Department of Commerce, Transportation Area Zones, 1984). Unemployment is consistent with that of the County at about 3-4% (South Dakota Labor Bulletin, 1988). Low taxes, pastoral scenery and low population density, make Wall Lake a pleasant area in which to reside.

CULTURAL ENVIRONMENT:

Wall Lake is located in a state where residents are known for being traditional, fairly well educated and economically dependent on agriculture. Almost everyone has friends and relatives involved in farming activities. It follows therefore, that sympathies are often in favor of the farmers and indeed the State laws reflect this attitude by exempting farmers from environmental controls and protecting them legally by such things as density zoning. Legislators know that if the farmer suffers, everyone suffers. Hence steps are taken to ensure their well-being.

Minnehaha County is the most urban county in the state with Sioux Falls, the state's largest city. Many urbanites move out of the city onto an acreage without realizing that they are giving up a multitude of services at the same time. They expect protection from agricultural uses such as feedlots, manure and odors. They often don't understand that they many have to maintain their own road or that a private wastewater system requires private maintenance.

The result of these two situations coexisting is that non-compatible land uses are often side by side. The homes around Wall Lake are zoned Rural Residential (RR) but the land immediately adjacent is zoned Agricultural (A-1.) There are ways to make this coexistence more harmonious.

Natural barriers such as trees and shrubs are a good option. Cooperation with township boards regarding road maintenance and hiring licensed septage pumpers would help rural non-farm residents make the transition from an urban setting.

Using Best Management Practices, erosion control techniques, animal waste management structures, and fertilizer management would help the farmer to be a better neighbor. Some of these options are being implemented. However, it appears that traditional farming methods change slowly and are often a nuisance to rural nonfarm landowners.

POLITICAL ENVIRONMENT:

The Wall Lake Homeowner's Association is a close knit group of neighbors that have worked hard in coordinating efforts to restore the lake. Unfortunately, some homeowners have alienated surrounding watershed landowners by publicly denouncing their agricultural practices and their names to the media via television and newspapers.

The watershed landowners have stated that their agricultural practices are within state guidelines and the Soil Conservation Service recommendations. Some have stated they are good stewards of the land and believe in Best Management Practices.

The newly elected Wall Lake Sanitary District members are concerned businessmen and residents from the lake. They are in the process of pursuing engineering proposals for a central wastewater collection system. Township supervisors have indicated that if the homeowners address wastewater systems, the watershed people might consider cooperating.

The Minnehaha County Commissioners support the project but are reluctant to endorse any entity that cannot work cooperatively with another. Nevertheless, the State Department of Water and Natural Resources, Minnehaha County and East Dakota Water District have entered into an agreement to complete this study at which time a determination will be made as to the best course of action.

<u>SUMMARY</u>:

Essentially, Wall Lake is naturally eutrophic due to the rich loess, but not hypereutrophic. It will have some algae growth because of its continental glacial origins, but in normal amounts. There are no major connections with aquifers that are a source of freshwater to the lake. Recharge is dependent on rainfall and runoff which have both been in short supply due to the 1988 drought. Trees and shrubs line the banks of the lake and crops are produced in the watershed area. Algae in the lake increases as the summer progresses. The flora surrounding the lake provide habitats for small game. Depth of the lake and oxygen levels cause survival of mostly carp and bullheads which can tolerate lower oxygen levels. The area has expanded in conjunction with Sioux Falls and serves several counties as an area for water recreation. The area is currently commercially unexploited. Lake homeowners and watershed landowners have been in conflict. Nevertheless, the various government entities have united with the Wall Lake Homeowner's Association to research the feasibility of lake restoration.

The improvements that need to take place in order to increase the water quality, and thus the usefulness of the lake, need to be addressed by studying the sources of contamination to the lake. Contamination sources have been studied and analyzed by experts over a period of ten years. Yet consistent, reliable data on the physical/chemical aspects of the lake were unavailable. This research was designed to provide that information.

Chapter Three

DATA COLLECTION

METHODS

Objective: Measure inflow and outflow.

A stage recorder was to be set at Sites 1 and 6 to monitor the volume of flow into and out of the lake.

Objective: Determine nutrient level in soils.

Soil samples were to be taken of each cell in the critical area of the watershed and tested for high level of phosphorus (P, P_2O_5, PO_4) and nitrogen (N, NO_2, NO_3, NH_4) applications.

Objective: Determine nutrient and bacteria loading.

Water samples were to be taken from seven sites (Map 3) on a bi-weekly basis for a period of eight weeks. In addition to this, water samples were taken from the beach and submitted for analysis on a weekly basis through the summer by County Planning and Zoning personnel. Tests for fecal coliform bacteria were conducted in accordance with South Dakota regulations for a public beach and according to EPA criteria.

Objective: Determine effects of algae on oxygen levels.

Oxygen titrations were conducted on the inlake samples once a month. Analysis of algae for the surface and bottom of the inlake sample was conducted.

Objective: Determine the ability of existing wastewater systems to function properly.

A door to door septic survey was conducted of all lake shore homes and homes in close proximity to the lake.

LIMITATIONS:

This study was affected by the following limiting factors:

1. The 1988 drought prohibited watershed runoff, thus disallowing it as a contributing factor during the test period. As a result, no outflow was recorded at Site 1.

2. Fecal coliform as an indicator bacteria does not indicate the specific origins of the bacteria.

3. EPA approved labs for E. Coli as an indicator bacteria, which would specify human or animal origins, are too far away to get water samples to the lab within the recommended EPA holding time.

4. Oxygen titrations were not performed for each sample which limits the ability of an analyst to determine the progressive effects of algal growth on oxygen levels

throughout the summer.

5. Ability to finance infrared photography which could relate considerable information with regard to lake influx would have been helpful.

6. Historically, in lake restoration projects addressing watershed issues has been voluntary and compliance has been light. Disagreements between lake homeowners and landowners in the watershed accentuate this problem.

7. Distrust between members of the various cooperating entities caused internal strife and lost time.

8. Financing the remedial operations will be a challenge. The governor's 1989 tax freeze cuts many otherwise potential funding mechanisms.

PROCEDURES:

The monitoring process began on April 13, 1988 and ended September 27, 1988. Drought made it impossible to sample at certain sites. Inflow to the lake was indicated from May 2 to June 2, 1988 as is verified in data from the stage recorder at Site 6 (Map 3) in Appendix B. Because the lake water level was so low, and there was no runoff for the remainder of the testing period only the stage recorder at the largest tributary was maintained at Site 6. Lack of precipitation to produce runoff is corroborated by NOAA meteorological data for the test period which also appear in Appendix B.

Soils

The soil survey was conducted on the parcels of land that contained what were considered to be the 10 most critical cells of nonpoint agricultural source problems in the watershed (Map 6). Samples were taken of soils that were the most representative of the area at a depth of two feet. The survey was conducted by a representative from the County Extension Service and a representative from Minnehaha County Conservation District.

Water Sampling

Water samples were taken from Sites 1-6 when there was runoff and when water existed at the sites. When no runoff existed, additional tests were taken in critical areas in the west inlet and cove. Grab samples (taken by hand) were taken at each site, packed in ice and sent for analysis to the Water Resources Institute at South Dakota State University. These samples were taken directly to the Sioux Falls Health Department lab for bacterial analysis. The results of these test are listed in Appendix C.

Earlier testing of the beach park was done through the summer months of 1986-1987. Grab samples were taken at mid-beach in approximately one foot of water. During 1986-1987, samples were put directly into bottles provided by the lab and set by express mail to the State Water Quality Lab at Pierre. The same procedures were followed in 1988, except that samples were taken directly to the Sioux Falls City Health Department lab. The reason for this change was that some samples set to Pierre took two days to arrive and were rejected because they were too old. However, several two day old samples had been accepted and analyzed previously. This cast doubt on the reliability of test results. The Sioux Falls lab was asked to analyze the samples in 1988 because of its closer proximity and thereby ensure more valid results by staying within the six hour holding time recommended by EPA.

Inlake samples (Site 7), algae samples and oxygen levels were collected one to three times per month when weather permitted. Oxygen titrations were performed by members of the Wall Lake Association as instructed by a DWNR staff person.

Septic Survey

The Department of Water and Natural Resources (DWNR), Office of Water Quality, set surveyors to conduct a door to door septic survey of wastewater systems for the lake shore homeowners. They were assisted by members of the Wall Lake Homeowner's Association, Wall Lake Sanitary District board members and County Planning and Zoning staff.

<u>RESULTS</u>:

Stage Recorder

The stage recorder was discontinued from the outlet because the lake was very low and there was no water running out of it. Plates G and H show how very dry the outlet was. The stage recorder at the west inlet showed no runoff from June 2, 1988 to the end of the testing period September 2, 1988, as can be seen from the meteorologic data sheets in Appendix B.

Soils

The soils survey results indicate that most watershed landowners are beneath the recommended amounts of fertilizer application. Additional fertilizer application was recommended by the surveyors in some instances. Terracing and contour plowing, as well as maintaining a minimum 100 foot strip of grass along water ways, were practices observed by the surveyors (Munk and Kappen, 1988, personal communication). Surveyors state that even if high

Plate G: Outlet.

Plate H: Culverts from Outlet.

nutrient content is found in the soil, that does not mean the nutrients will find their way into Wall Lake unless those lands are highly erodible since the nutrients adhere to soil particles. Livestock were being kept well away from the lake and contributing tributaries. The feed lot to the north of sites 2 and 3 has an extensive lagoon system which complies with South Dakota Administrative Regulations for a feedlot. Homeowners often complain of the smell and quality of runoff coming from the direction of this feedlot.

Water Quality

Results of the water samples showed a high concentration of phosphorus (P, PO_4, P_2O_5), ammonia (NH_4), and nitrates (NO_3, NO_2, N) in runoff from the tributaries. The west inlet was the most severely contaminated at Sites 5 and 6. By June, no runoff existed to be sampled. The only samples taken were from stationary water and the inlake site. Sites sampled are shown on Map 3. Data from the test results are shown in Appendix C. South Dakota does not have a standard for phosphorus but one might compare the rates with Minnesota's standard of .5mg/L. Most readings are well in excess of this standard.

Sites 2, 3, and 4 showed alarmingly high rates of fecal coliform bacteria. It could not be determined from the indicator bacteria (fecal coliform) if the source was from livestock or human waste. This initiated the taking of more samples from the troubled area in the west inlet and cove. Appendix C shows the results of the bacteria tests. A reading of 200/100L is the maximum standard for a public beach.

Bacteria analysis of the beach park water remained within the requirements of the state for water quality in immersion recreation. There are three criteria, any one of which would require the beach to be closed. They are:

1. Three successive fecal coliform bacteria counts of 200/100 ml, or more.

2. Two successive fecal coliform bacteria counts of 300/100 ml, or more.

3. One count of 1000/100 ml, or more.

Note should be made that these criteria apply only to public beaches, not all lake shore properties.

Algae Analyses

Algae analyses were found to be consistent with previous studies. Data in Appendix D show the most common forms of algae to be *Aphanazomenon flos-aquae* and *Microcystis aeruginosa, both* of which are typical of cultural eutrophication (Camburn, 1988). Cultural eutrophication is derived from anthropogenic activities. Concentrations increased as the summer progressed.

Septic Survey

The door to door septic survey showed that 88% of the lake shore homes were not within state standard (Houtcooper and Baer, 1988). Criteria used to determine this included:

1. Absorption area is too close to the lake.
2. Absorption area is too close to a building.
3. Septic tank is too close to a building.

Table 3 delineates the State's findings. The most frequently found violation was that the absorption areas were too close to the lake. South Dakota Code Law requires 100 feet between an absorption field and a waterway. Most lots are too small to meet this criterion. Many of the homes were built before 1979, which means that they were not required to meet the 1984 Administrative Regulations for On-Site Wastewater Disposal systems, Chapter 74. These homes are exempt from compliance unless they are polluting a State waterway which Wall Lake is, or unless the septage is surfacing.

Table 3: Septic System Survey

WALL LAKE SEPTIC SYSTEM SURVEY - JULY, 1988

- 52 of 67 lakeshore systems surveyed
- 6 systems surveyed were in compliance with DWNR regulations

COMMON PROBLEMS WERE:

- Absorption area too close to the lake (35 systems/67%)
- Absorption area too close to buildings (17 systems/33%)
- Septic tank too close to the lake (14 systems/27%)
- Septic tank too close to well/cistern (10 systems/19%)
- Septic tank too close to buildings (8 systems/15%)

Regional Results:

Lake Regional Location	North	West	South	East
No. systems surveyed	13	17	6	16
Absorp area too close to lake	10(77%)	10(59%)	4(67%)	11(69%)
Absorp area too close to bldg	3(23%)	6(35%)	3(50%)	5(31%)
Septic tank too close to lake	4(30%)	2(12%)	3(50%)	5(31%)
Septic tank too close to well	7(54%)	1(6%)	0(0%)	2(13%)
Septic tank too close to bldg	4(31%)	2(12%)	0(0%)	2(13%)

Credit: Department of Water and Natural Resources, 1988.

Other Problems:

- Absorption area has only 1 drain field (7 systems/13%)
- Absorption area too close to well/cistern (6 systems/12%)
- System uses seepage pit only (5 systems/10%)
- Septic tank too close to a waterline (4 systems/8%)
- Absorption area too close to a waterline (4 systems/8%)
- Septic tank too small (3 systems/6%)
- Absorp area or sep tank too close to property line (2 sys/4%)
- Absorption area on slant (2 systems/4%)
- Old system not abandoned properly (1 system/2%)

continued

Credit: Department of Water and Natural Resources, 1988.

Nutrients from the Watershed

Evaluation of nutrient contamination by DWNR is attributed to the watershed. The lack of a standard for phosphorus and nitrates makes legal determinations difficult should that become necessary. Nevertheless, in comparison to other glacial lakes, the numbers are high according to DWNR officials. The area of most concern is the west inlet where Sites 5 and 6 are located (Houtcooper, 1988.)

Nutrients from Wastewater Systems

The nutrient evaluation from DWNR made no mention of possible contamination from faulty wastewater systems. This was surprising especially in light of the high NH_4 (ammonia) which can be from liquid fertilizer but is also in urea. It is not possible to discriminate between sources. No mention was made of wastewater system as a possible source of phosphorus or nitrates and both are known to exist in human excrement (Little, 1989.)

DISCUSSION:

Bacteria from the Watershed

Because of the lack of precipitation, it is doubtful that the water samples can be considered representative of runoff from the watershed. This does not discount the watershed as a nonpoint source of contamination. It does eliminate the watershed as a contributing source during the test period from June 2-September 2, 1988. This means that it is unlikely that livestock in the watershed could be contributing bacterial contamination to the lake during this time. Neither is it likely that any applications of manure onto the soils of the watershed area during the test period would be a contributing source because there was no fluid medium (water) with which to mobilize the bacteria and cause it to migrate into the lake. However, tests do show high counts of nutrients that are normally associated with agricultural runoff. Therein lies the paradox our technology has yet to decipher. Some landowners in the watershed maintain that they are not responsible for contamination to the lake but that lake homeowners are responsible because of faulty septic systems. Others say they are already using BMP's and are being good stewards of the land (Wall Lake Watershed meeting, October, 1988.)

Bacteria from Wastewater Systems

Despite the lack of runoff, bacterial contamination continued to exist. When taking samples from Sites 1-4 became impossible due to drought, extra samples were taken at Sites 5 and 6 and from the cove area. Data show that the west inlet and cove areas had high levels of fecal coliform bacteria at unpredictable intervals. This region is characterized by an unsavory odor as well. The area has septic absorption systems that are too close to the lake and could be draining into the lake. The question homeowners raise is whether the high level of fecal coliform bacteria which prevents them from enjoying the lake is from human or livestock waste. Since the indicator bacteria is found in the intestines of all mammals, an absolute determination cannot be made as to the source of waste. The drought which prevented any watershed runoff does give a strong indication that it is human waste, presumably from faulty septic systems, since livestock waste bearing runoff did not enter the lake in close proximity of time to the test period which showed high fecal count.

Exceptions to this are at Sites 2, 3, and 4 where high fecal coliform counts were found in April and May when there was a small amount of runoff. The numbers listed in Appendix C indicate that this area is suspect and should be closely monitored with regard to spring runoff in 1989.

SUMMARY AND OUTLOOK:

The soil survey indicates that Best Management

Practices for the watershed area are already in place with the exception of six cells, and that conservation practices for erodible lands have been implemented for some time. The weekly monitoring of water quality at the public beach has also been considered. Agricultural lands surround the area to the south which also is the direction of outflowing drainage. The bathhouse at the park has a sealed holding tank from which waste is professionally pumped. It can be seen from the graph on the Wall Lake Beach Park in Appendix C that in July, 1988, the beach came close to being unfit for immersion recreation with a bacterial reading over 200/100 L. Compare this with the west inlet and cove which would have been closed if it had been a public beach rather than a private beach due to bacterial readings over 1000/100 L. The State posted warning signs against swimming because of the high bacteria count during the test period (see page 7 of Appendix C). The State has no authority to legally close private beaches. Persons swimming in this contaminated water could contract eye and ear infections and, if ingested, giardia could result (Bonrud, 1988).

Continued measures of O_2 by titrations during the winter will indicate the effects of ice and the winter turnover if depth is sufficient. If the lake is too shallow for O_2 to be sustained during the winter, high order fish which require higher O_2 levels, will die. Algal blooms will be detected in early stages by continued algae samples from Site 7.

The results of the door to door septic survey were not in agreement with previous studies. Wall Lake homeowners had been subject to a septic leachate survey by Swanson Environmental, Inc., in 1986. Data from this survey were interpreted to show that the biggest contributor of nutrient contamination was the watershed area (Swanson, 1986). An agricultural non-point source model also addressed water contaminants from the watershed area (Onstad, 1987.) The study herein contextualized is more site specific than either of these studies and takes into account the most recent data available with regard to soils in the critical cells.

The fact remains that almost all the lake homes are on lots that are too small and too close to the lake to treat wastewater for the duration of a home. Table 4 shows the distance bacteria and viruses can travel before being filtered or diluted to the point that they are no longer harmful. The data show that distance and time of travel through soils have a direct bearing on potential contamination. Most lots do not have the amount of land that is required to cleanse effluent from a septic system that is functioning properly. If the absorption system is sited in sand or gravel, as many probably are according to

Table 4: Distance Contaminants Travel

Distances Contaminants Travel in Soil

System	Contaminant	Day	Distance from Well	Research
septic	virus		220-1,310 ft.........	Keswick & Gerbe,1980
sand....	*Giardia* (99.3-99.9% removal rate)........			Logsdon et al.,1984
	(few outbreaks)..................			Craun, 1986
	(minor problems)................			Fitzgerald, 1983
septic...	polio.........	12....	175 ft..............	Westwood & Satter,
			(14.6 ft/day)........	1976
septic...	polio..........	8....	40.5-67.5 ft.........	Stramer, 1984
			94.5 ft.............	Stramer, 1984
		43....	151.5 ft............	Stramer, 1984
		71....	....	Stramer, 1984
		109....	into the lake sed.	
			(flow rate of GW)....	Stramer, 1984
mound...	polio........	105....	3.65 ft.............	Stramer, 1984
	coliform			
	100,000/			
	100 ml........	56....	....	Stramer, 1984

Data compiled in unpublished paper by the author entitled Septic/ Absorption Systems and Modifications for Single Family Rural Dwellings in Minnehaha County.

Table 3: Septic System Survey continued

less than 0.1	70-147	Stramer, 1984
septic in flood plain...polio	7-20 drainfield	Stramer, 1984
septic in sand..virus	82 ft	Wang et al., 1981
	213 ft	Vaugn et al., 1983
septic in loam..bacteria	91.8 ft	Reneau & Pettrey, 1975
septic...coliform	150 ft	Craun, 1981
septic *Salmonella typhi*	210 ft	McGinnis & DeWalle, 1983
septic...bacteria	50 ft	Craun, 1984
septic solid waste field...hepatitis A	100 ft	Craun, 1979

the hydrology reports, less filtration of contaminants takes place and groundwater may become polluted.

Only flow into the lake was recorded and that occurred prior to June at which point no runoff or precipitation was added to the lake. Since no runoff from agricultural sources in the watershed existed except in the earliest stages of testing, it can be assumed that sources of fecal bacteria and possibly nutrients during this test period are from wastewater systems in close proximity to the lake. This likelihood is supported by the results of the septic survey and the preliminary engineering report sponsored by the sanitary district.

Another probable source of contamination to Wall Lake is in the watershed. High phosphorus has been shown in the upper tributaries and in pre-June runoff. Contribution of nutrients into the water column from existing sediments is another possibility if mixing of sediments into the water column can be shown. However, the thermal stratification required for the convection that would inject nutrients into the water column does not exist in such shallow water. Furthermore, the indicator bacteria does not live long enough (3 months) to be injected from the year before if it was part of the sediment load (Table 5.) Since bacteria counts increased as the summer progressed, sediments appear to be a very unlikely source of bacteria.

Table 5: Survival Time of Pathogens

Reported Survival Times of Pathogens in the Free Environment

Organism	Survival Times In Water	Survival Times In Soil
Salmonella typhosa	Tap 4-7 days; raw river 1-4 days; drainage canal 2 days	Min. 1 day Max. 2 yrs. Gen. 100 days
Vibrio cholera	Tap 1-2 days; raw river 2-3 days	Moist tropical 7 days
Entamoeba histolyrica	3-153 days, 12-37°C	6-8 days Moist soil, 24-34°C
Shigella, spp.	Max. 10 days; does not grow in natural waters	
Hookworm		6-12 weeks, 15-35°C
Roundworm		3 weeks
Coliform bacteria		3 days 3 mos.
E. Coli.		2 yrs.
Enteric viruses	Sea water 2-130 days; river 2-188 days; tap 5-168 days; oysters 6-90 days	Soil 25-175 days; landfill leachates 7-90 days; marine and freshwater sediments

Source: Broward County (Fla.) Public Works Dept., Water Resources Management Division. *The Potable Water Wellfield Protection Program for Broward County, Florida* (December, 1983).

(Credit: Jaffe, 1987)

Chapter Four

After considering the forgoing information, it is suggested that the best interests of the residents of the County and the lake itself, would be served by pursuing the following courses of action.

RECOMMENDATIONS

1. The stage recorder should be set to record normal inflow and outflow during spring rains and runoff in 1989 or when normal precipitation resumes.

2. Spring runoff should be sampled and analyzed. Using E. coli as the indicator bacteria instead of fecal coliform will disclose whether the source of bacteria is from livestock or human waste (Dufour, 1984.) Analysis of these samples also will give representative data of the nutrient load from the watershed. There is a danger in this determination in that "finger pointing" may result and nothing productive be accomplished. All entities should cooperate to bear the financial burden of remedial action.

3. Restoration or enhancement of wetlands at the inlets should be encouraged to achieve a high percentage of nutrient filtration. Wetlands may be seeded with flora such as cattails, that use high concentrations of nutrients, thus filtering the water before it enters the lake. It is estimated that up to 60% of the nutrients may be dissem-

inated by this method (Siegel, 1988, personal communication.) Low overhead weirs (2-3 feet) should be constructed to slow down the flow, thus allowing nutrient laden sediments to settle out before the water enters the lake.

4. It has been suggested that nearby feedlots are responsible for the high levels of fecal coliform bacteria as well as the nutrient influx. The existing feedlots have been found to be in compliance with South Dakota's regulations for a cattle confinement operation with lagoons. A more likely possibility is that former grazing areas for livestock are leaching nitrates and allowing phosphorus runoff into the tributaries. When livestock are removed from an area, the hard pan created by hooves breaks up by natural processes of erosion and further leaching occurs. This can go on for 20 years or more (Top, 1988, and Kappen, 1988, personal communication.) There is a site to the southwest of the lake that used to be a hog operation. An intermittent stream drains from the area during high rainfall and heavy snowmelt. It drains into the cove which is full of nutrient rich sediment. A recent probe through the ice showed water in the cove ranged from 4-9 feet deep and known sediments ranged from two inches to 4 feet (personal observation, March 16, 1989.) Dredging of this area is therefore recommended.

5. Landowners not using Best Management Practices (BMP's) to curtail erosion should be encouraged to do so and should be made aware of the various help programs available to them through Soil Conservation Survey. This is critical because some nutrients adhere to soil particles, which when they are transported by erosion into the lake, also transport the nutrients. This causes overenrichment of nutrients which produces advanced algae growth. Lack of cooperation could be interpreted by the State as deliberate contamination of a state waterway which is a violation of South Dakota Code Law, Chapter 74.

6. It has been suggested by members of the Wall Lake ad hoc task force that nutrient rich sediments are churned up by wave action into the water column and could be responsible for the high levels of bacteria and/or nutrients in some test areas. However, this type of upwelling is usually generated by thermal stratification, or the different temperatures in a water body. The top layer of water becomes cold and sinks as the warm layer underneath rises to the surface, thus causing a convection cycle. Wall Lake is too shallow to have thermal stratification which would cause this convection induced churning, and thus advance nutrients into the water column. It is therefore recommended that this source be discounted for the time

being until more apparent contamination sources are addressed.

7. The revived Wall Lake Sanitary District has engaged an engineering firm to make recommendations regarding upgrading the present wastewater systems or implementing a collection system. During the interim, conscientious maintenance of existing systems is recommended. This may include using only low phosphate detergents.

8. Homeowners may want to be cautious about the amount of lawn fertilizer used in close proximity to the lake, as it contains the same chemicals used to fertilize crops in the watershed. In fact some homeowners water their lawns with lake water in order to benefit from the nutrients in the water and to save on their water bill.

9. Dredging would prolong the life of the lake by deepening it and slowing the natural process to wetland and dry land. At this time, the critical area for dredging is the west inlet and the cove which in the past has been subject to a heavy sedimentation. To dredge the entire lake would be a costly process but it would have positive effects on wildlife habits and fishing. Any dredging would be counter-productive if problems in the watershed and with wastewater systems are not addressed before dredging begins.

SUMMARY:

It therefore is recommended that a collection wastewater system be installed with proper lagoon treatment correctly sited servient to the drainage of the lake. The enhanced wetlands should be installed along with BMP's and deterrents to erosion in those cells which are critical. Feedlots should be required to have lagoon systems and those that exist should be spot checked for compliance with the State code. Dredging should occur at the cove and west inlet at a minimum. If the costs can be justified, dredging the entire lake could be a positive step but no dredging should occur without addressing the other problem areas.

COMPARISONS:

Lake Campbell is an example of a lake restoration project where dredging is preceding BMP's and installation of a homeowner's wastewater collection system. The benefits probably will be short term and the process is very expensive (unpublished paper by Van Hunnik, et al, 1987). Dredging costs about $40,000 per month. This is not to say that dredging is not valuable. Dredging Lake Campbell deepened the lake and, if it is done properly, creates habitats for a higher order of fish than presently occupy the lake in large numbers.

Lake Madison is another glacial lake where the lake association addressed a hypereutrophic situation by installing a central wastewater collection system. The results have been gradual but positive. Higher order fish have returned in greater numbers, less algae is apparent and water clarity has improved (Luther, 1988, personal communication.) The possibility of doing some dredging at this stage of the Lake Madison restoration is being addressed by the lake association. This approach makes more sense in that sources are being addressed first, in order to realize long term benefits.

IMPLEMENTATION

The Wall Lake restoration project is occurring during a unique time. The federal government has ceased to fund EPA grants for water projects, but has promised seed money to a State Revolving Fund (SRF) for loans toward water projects at very low interest. The idea is to replace grants with low interest loans that will become a renewable resource for funding. This would be especially advantageous in light of the fact that such a small number of people would be involved in bearing the load of a very expensive project. This use of tax dollars can be justified by the fact that heavy use comes from Sioux Falls and surrounding communities.

Whatever system is determined by the Sanitary District to be the most feasible option for the Wall Lake homeowners, it is hoped that matching funds will come from the state and federal government. Their engineering firm has submitted preliminary proposals along with costs to the Sanitary District for their consideration (Umland, et al, 1988, personal communication.) Costs range from $600,000 to $1.1 million.

<u>CONCLUSION</u>:

Implementation of these recommendations will increase the ability of Wall Lake to serve recreational needs of Minnehaha County and surrounding communities. Lake restoration will have positive long term ramifications. As the aesthetic value of the lake improves due to increased water quality, lake shore property will increase in value. Along the northwest shore, there are many platted lots which would not be served by installation of a wastewater collection system. If the owner decides to vacate those plats, the possibilities for development of another park and public recreation area becomes more feasible. If they are sold as lots requiring septic systems, more problems could result because the lots are too small to accommodate such systems over the life of a lake home.

Use of the County Beach Park and the Girl Scout Camp probably will increase. The old roller skating rink, which has been partially renovated, will be in an ideal location for business. Interest in developing the south shore has been shown by several firms. The State Park may experience greater use, as should the boat ramp area maintained by Game Fish and Parks. It may become necessary to monitor the number of boats or restrict motor size on the lake in the interest of safety.

The positive effects on wildlife, plants and the health of lake users will take time to evolve. The positive results of restoration of glacial lakes can be seen in the gradual improvement of Lake Madison and Lake Campbell. The improvement is most noticeable in Lake Madison where fish quality has increased, algal blooms have decreased, and water clarity has improved (Siegel and Luther 1988, personal communication.)

Wall Lake will never be pristine. That is not the character of a glacial lake. To return it to a healthy eutrophic state is an expensive and controversial undertaking. No one wants to claim responsibility for the contamination that exists. Studies of Wall Lake over the last ten years can substantiate or negate the responsibility of all three sources considered. It is not necessary however, to place blame in order to remediate the water quality at Wall Lake. Even if blame could be definitively placed, the same remedial measures would probably take place. If all entities involved will set aside their differences of opinion and cooperate with one another, the best interests of the public will be served.

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APPENDICES

APPENDIX A

SOIL TYPES

Logs of test holes drilled in the Wall Lake area
(for map location, see fig. 1)

The locations are given as quarter sections, section number, township, and range.

All elevations have been estimated using a 7 1/2 minute topographic base and are presented in feet above mean sea level.

Test Hole 1
Location: NE NW NW NW sec. 27, T. 101 N., R. 51 W.
Elevation: 1580
Date Drilled: July 5, 1979

0- 1	Topsoil
1- 13	Clay, brown, silty, sandy, pebbly (oxidized till)
13- 70	Clay, gray, silty, sandy, pebbly (unoxidized till)

* * * *

Test Hole 2
Location: SW SW SW SE sec. 21, T. 101 N., R. 51 W.
Elevation: 1560
Date Drilled: July 5, 1979

0- 1	Topsoil
1- 18	Clay, yellow-brown, sandy, pebbly (oxidized till)
18- 31	Clay, brown, silty, sandy, pebbly
31- 60	Clay, dark gray, silty, sandy, pebbly

* * * *

Test Hole 3
Location: SE NE NE NE sec. 29, T. 101 N., R. 51 W.
Elevation: 1602
Date Drilled: July 5, 1979

0- 1	Topsoil
1- 23	Clay, yellow, silty, sandy, pebbly
23- 60	Clay, dark gray with rust spots, sandy, silty, pebbly

* * * *

Test Hole 4
Location: NE SE SE NE sec. 20, T. 101 N., R. 51 W.
Elevation: 1576
Date Drilled: July 6, 1979

Test Hole 4 -- continued.

0- 10	Sand, brown to orange, fine, gravel, well-rounded
10- 27	Clay, yellow, sandy, silty, pebbly (weathered till)
27- 57	Clay, gray, sandy, silty, pebbly (till)

* * * *

Test Hole 5
Location: NW NW NW NW sec. 21, T. 101 N., R. 51 W.
Elevation: 1570
Date Drilled: July 9, 1979

0- 1	Topsoil, black, sandy
1- 5	Sand, fine to medium, with clay
5- 21	Clay, yellow-brown, silty, sandy, pebbly (weathered till)
21- 66	Clay, gray, silty, sandy, pebbly (till)

* * * *

Test Hole 6
Location: SE SW SE SW sec. 16, T. 101 N., R. 51 W.
Elevation: 1573
Date Drilled: July 9, 1979

0- 3	Topsoil, black, sandy
3- 16	Clay, brown, sandy, silty, pebbly (weathered till)
16- 67	Clay, brownish-gray, sandy, silty, pebbly (till)

* * * *

Test Hole 7
Location: SE SW SE SE sec. 21, T. 101 N., R. 51 W.
Elevation: 1560
Date Drilled: July 9, 1979

0- 1	Topsoil, black, sandy
1- 9	Sand, fine to medium, with clay, buff colored
9- 22	Clay, yellow-brown, silty, sandy, pebbly (weathered till)
22- 76	Clay, gray, silty, sandy, pebbly (till)

Observation well placed in the shallow sand

* * * *

Test Hole 8
Location: SE SW NE SE sec. 21, T. 101 N., R. 51 W.
Elevation: 1572
Date Drilled: July 10, 1979

0- 3	Topsoil, black, clayey, sandy
3- 6	Clay, yellow, sandy

Test Hole 8 -- continued.

6- 17	Sand, fine, gravel, well-rounded
17- 65	Clay, brown to gray, silty, very sandy and pebbly
65	Very hard rock, possibly quartzite or granite

Observation well 1: 15 feet of plastic casing and 3-foot sandpoint

* * * *

Test Hole 9
Location: NE NE SE SE sec. 20, T. 101 N., R. 51 W.
Elevation: 1562
Date Drilled: July 10, 1979

0- 1	Clay, yellow, silty, sandy, pebbly (weathered till)
1- 7	Sand, fine with silt
7- 13	Gravel, fine to medium, with sand, fine to coarse
13- 15	Clay, yellow, silty, sandy, pebbly
15- 31	Gravel, fine to medium, with sand and silt
31- 86	Clay, gray, silty, sandy, and very pebbly (till)

* * * *

Test Hole 10
Location: NE SE SE SE sec. 20, T. 101 N., R. 51 W.
Elevation: 1571
Date Drilled: July 10, 1979

0- 20	Clay, brown, sandy, pebbly (weathered till)
20- 57	Clay, gray, sandy, pebbly (till)

* * * *

Test Hole 11
Location: SE SE NE SE sec. 20, T. 101 N., R. 51 W.
Elevation: 1570
Date Drilled: July 10, 1979

0- 1	Topsoil
1- 11	Clay, yellow-brown, silty, sandy, pebbly (weathered till)
11- 66	Clay, gray, silty, sandy, pebbly (till)

* * * *

Test Hole 12
Location: SW NE NE SW sec. 21, T. 101 N., R. 51 W.
Elevation: 1582
Date Drilled: July 11, 1979

0- 3	Topsoil, black, clayey
3- 11	Clay, brown, sandy, pebbly

Test Hole 12 -- continued.

11- 18	Sand, fine to gravel, well-rounded
18- 67	Clay, gray, sandy, silty, pebbly (till)

* * * *

Test Hole 13
Location: SW SE SE NE sec. 21, T. 101 N., R. 51 W.
Elevation: 1579
Date Drilled: July 11, 1979

0- 1	Topsoil, black, sandy, silty
1- 5	Sand, rust, fine to gravel
5- 20	Clay, yellow, silty, sandy, very pebbly (weathered till)
20- 50	Clay, gray, silty, sandy, pebbly (till)
50- 66	Clay, gray, silty, very sandy, pebbly

* * * *

Test Hole 14
Location: SW NW NW SW sec. 22, T. 101 N., R. 51 W.
Elevation: 1580
Date Drilled: July 11, 1979

0- 3	Topsoil, black, sandy
3- 6	Sand, rusty, fine, gravel, well-rounded
6- 15	Clay, brown, sandy, silty, pebbly (weathered till)
15- 67	Clay, gray, sandy, silty, pebbly (till)

* * * *

Test Hole 15
Location: SE NW NW SW sec. 22, T. 101 N., R. 51 W.
Elevation: 1567
Date Drilled: July 11, 1979

0- 1	Topsoil, black, clayey, sandy
1- 15	Clay, yellow-brown, silty, sandy, pebbly (weathered till)
15- 76	Clay, gray, silty, sandy, somewhat pebbly (till)

* * * *

Test Hole 16
Location: NW SW SW SW sec. 22, T. 101 N., R. 51 W.
Elevation: 1580
Date Drilled: July 11, 1979

0- 2	Topsoil, black, clayey, sandy
2- 6	Clay, yellow, silty
6- 19	Sand, fine to gravel, silty, well-rounded

Test Hole 16 -- continued.

19- 24	Clay, brown, sandy, silty, pebbly (weathered till)
24- 57	Clay, gray, sandy, silty, pebbly (till)

* * * *

Test Hole 17
Location: NW SW SW SW sec. 22, T. 101 N., R. 51 W.
Elevation: 1580
Date Drilled: July 12, 1979

0- 1	Topsoil, black, sandy
1- 9	Clay, yellow, silty, sandy, pebbly (weathered till)
9- 24	Clay, yellow, silty, sandy, very pebbly
24- 33	Clay, gray, silty, sandy, very pebbly (till)
33- 56	Sand, silt to medium, subrounded with much gray clay (sandy till)

* * * *

Test Hole 18
Location: SE NW SW SW sec. 22, T. 101 N., R. 51 W.
Elevation: 1570
Date Drilled: July 12, 1979

0- 4	Topsoil, black, clayey
4- 7	Clay, yellow, silty
7- 21	Clay, brown, sandy, silty, pebbly (weathered till)
21- 67	Clay, gray, sandy, silty, very pebbly after 25 feet (till)

* * * *

Test Hole 19
Location: SE NE NE NW sec. 21, T. 101 N., R. 51 W.
Elevation: 1560
Date Drilled: July 12, 1979

0- 1	Topsoil, black, sandy, clayey
1- 15	Clay, buff, silty, sandy, pebbly (weathered till)
15- 55	Clay, gray, silty, sandy, pebbly (till)
55- 76	Sand, gray, very clayey, silty (very sandy till)

* * * *

Test Hole 20
Location: NW SE NE NW sec. 21, T. 101 N., R. 51 W.
Elevation: 1560
Date Drilled: July 12, 1979

0- 4	Topsoil, black, sandy
4- 7	Clay, dark brown, sandy, silty
7- 13	Clay, brown, sandy, silty, pebbly

Test Hole 20 -- continued.

13- 17	Sand, gray, fine, silty
17- 25	Clay, brown, sandy, silty, pebbly
25- 27	Clay, black, very little sand or silt
27- 60	Clay, gray, sandy, pebbly, very silty (till)

* * * *

Test Hole 21
Location: SE SE SW SW sec. 17, T. 101 N., R. 51 W.
Elevation: 1575
Date Drilled: July 12, 1979

0- 3	Topsoil, black, silty, sandy
3- 25	Clay, yellow-brown, silty, sandy, pebbly (weathered till)
25- 46	Clay, gray, silty, sandy, pebbly (till)

* * * *

Test Hole 22
Location: NE NE SE SE sec. 20, T. 101 N., R. 51 W.
Elevation: 1561
Date Drilled: July 13, 1979

0- 1	Topsoil, black, sandy
1- 15	Sand, rusty, fine, gravel
15- 22	Sand, medium, silt
22- 45	Silty sand and gravel, somewhat sorted in layers, 3 to 5 feet thick
45- 66	Clay, gray, silty, sandy, pebbly (till)

Observation well 2: 38 feet of plastic casing and 3-foot sandpoint

* * * *

Test Hole 23
Location: SE NE SE SE sec. 20, T. 101 N., R. 51 W.
Elevation: 1570
Date Drilled: July 13, 1979

0- 5	Sand, rusty, fine to coarse, silty
5- 24	Clay, brown, sandy, pebbly
24- 33	Sand, fine, gravel, silty, well-rounded
33- 35	Sand, gray, fine, very silty
35- 57	Clay, gray, sandy, silty, pebbly (till)

* * * *

Test Hole 24
Location: SE NW NE NE sec. 28, T. 101 N., R. 51 W.
Elevation: 1560
Date Drilled: July 13, 1979

0- 1	Topsoil, black, clayey, sandy
1- 21	Clay, yellow, silty, sandy, pebbly (weathered till)
21- 56	Clay, gray, silty, sandy, pebbly (till)

* * * *

Test Hole 25
Location: NW NE NW NW sec. 34, T. 101 N., R. 51 W.
Elevation: 1550
Date Drilled: July 16, 1979

0- 3	Clay, brown, sandy
3- 6	Sand, fine, gravel, well-rounded
6- 30	Clay, grayish-brown, sandy, silty, pebbly
30- 45	Clay, gray, sandy, silty, pebbly (till)
45- 52	Silt, sandy, some clay samples
52- 67	Clay, gray, sandy, silty, gravelly (till)

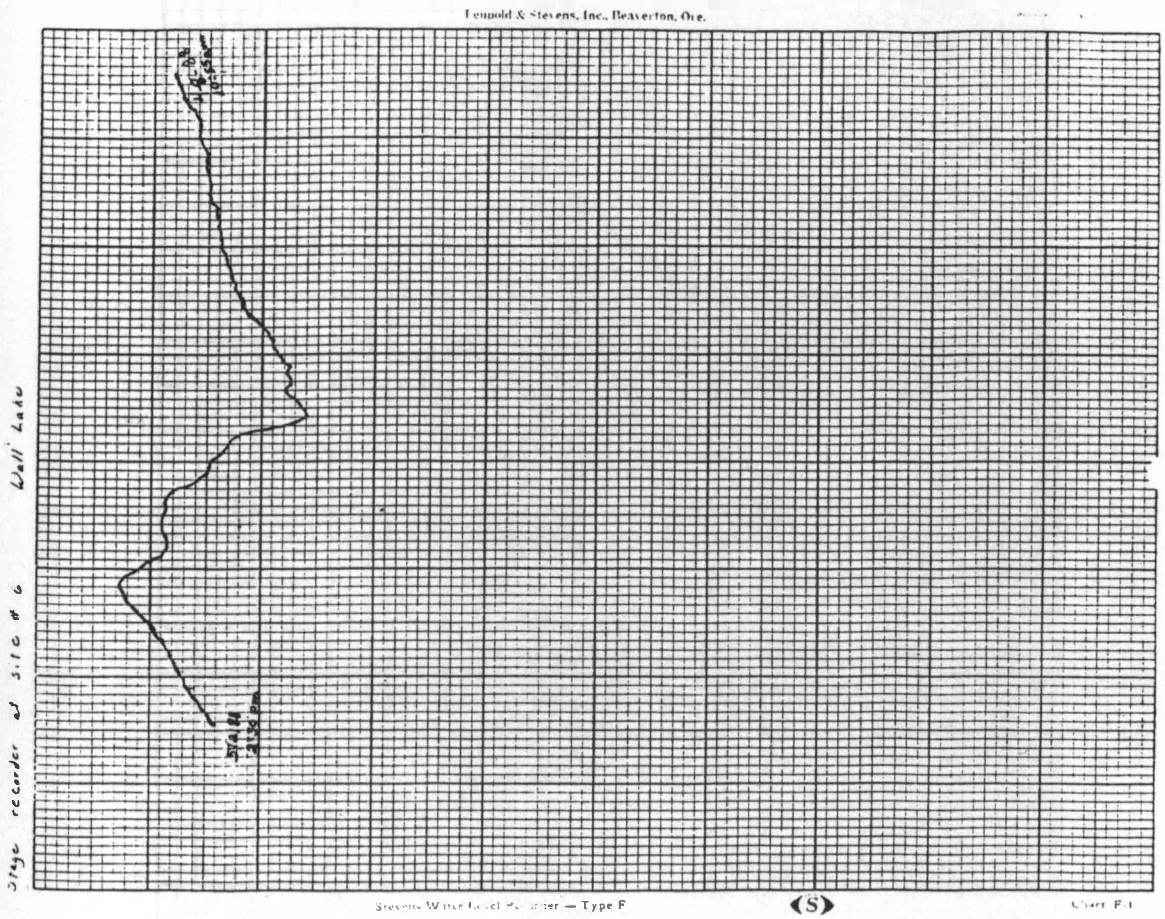
* * * *

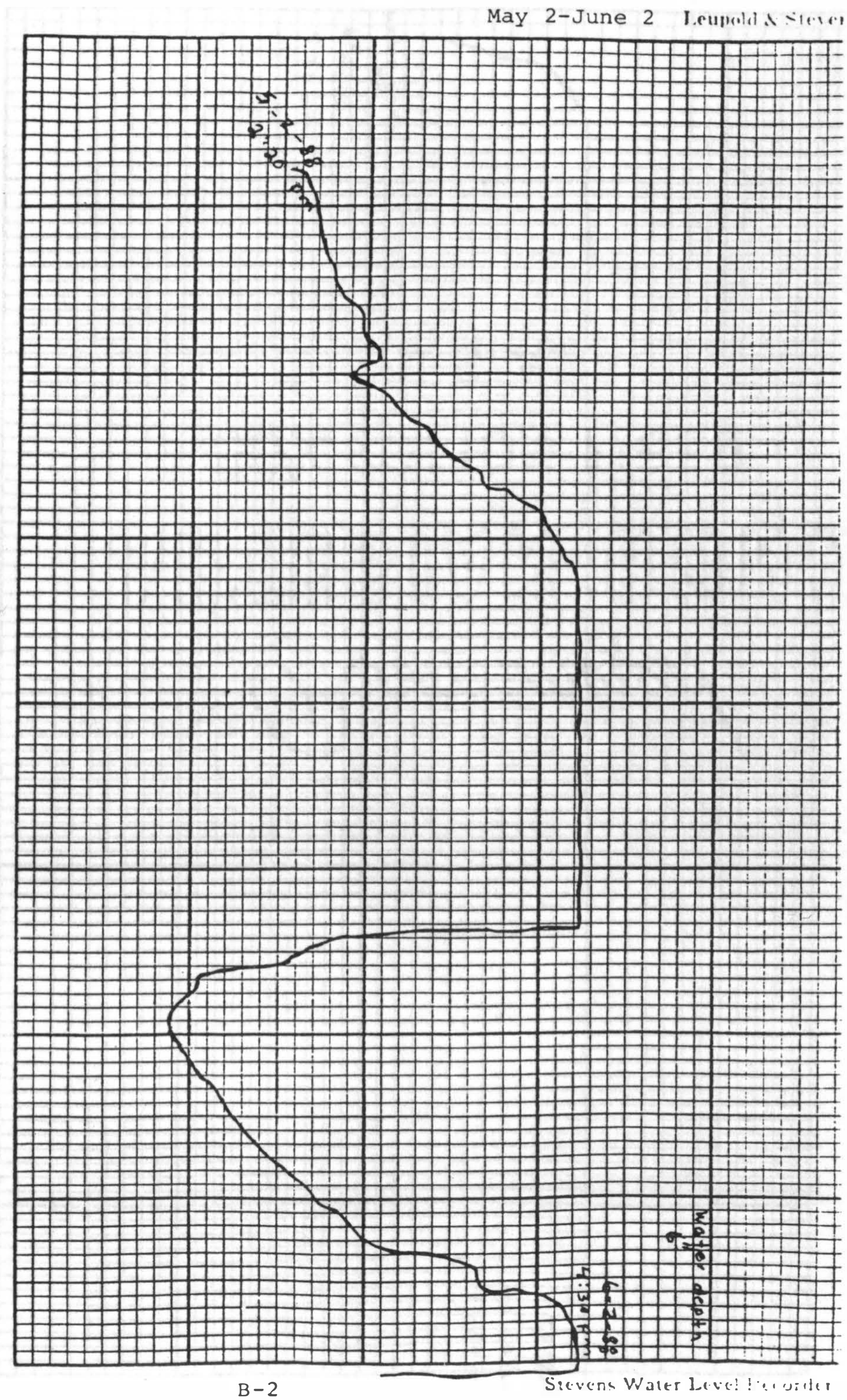
Credit: SDGS

APPENDIX B

RECORD OF LAKE INFLUX

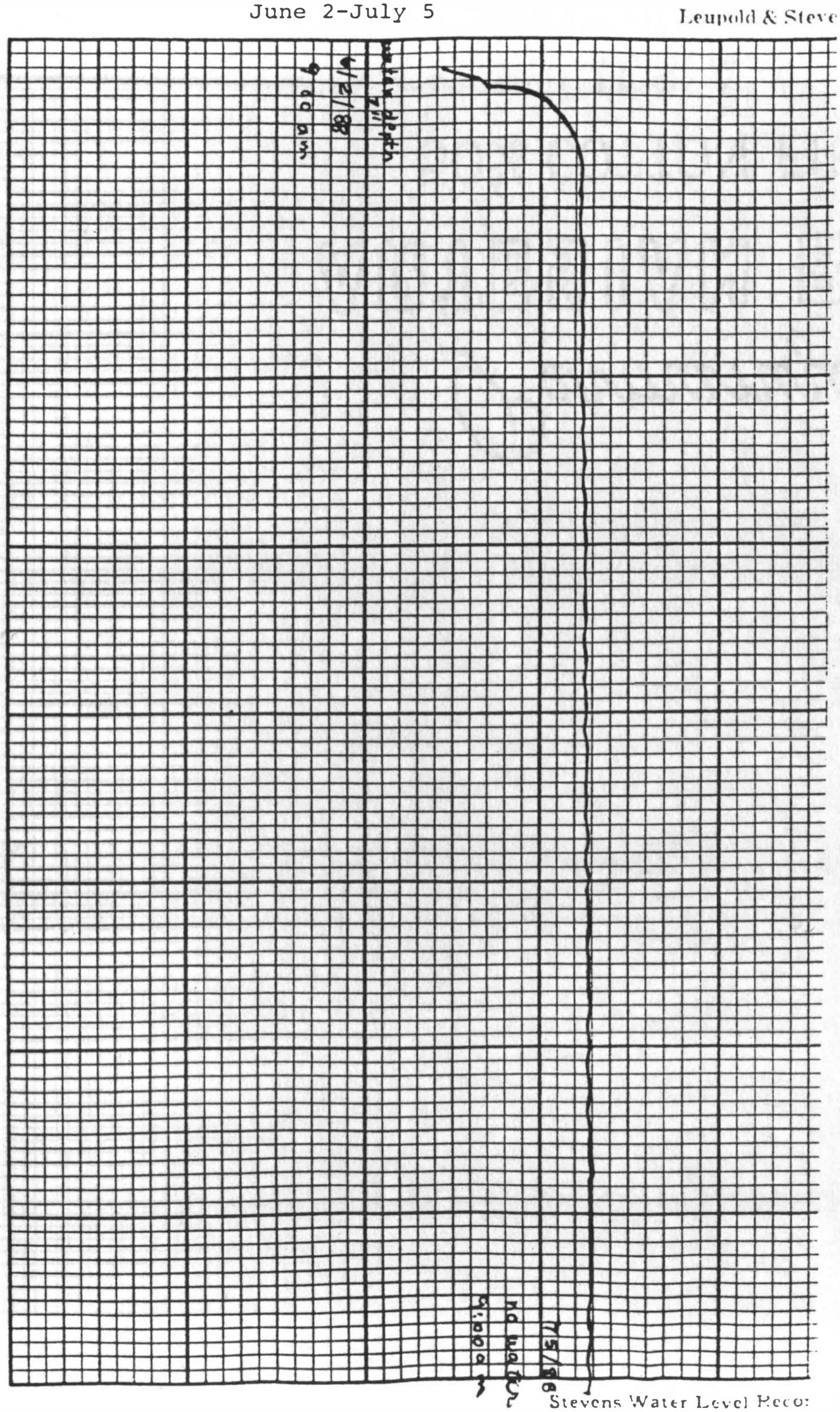
April 8-May 2


Leupold & Stevens, Inc., Beaverton, Ore.
Stage recorder at site # 6 Wall Lake
Stevens Water Level Recorder — Type F

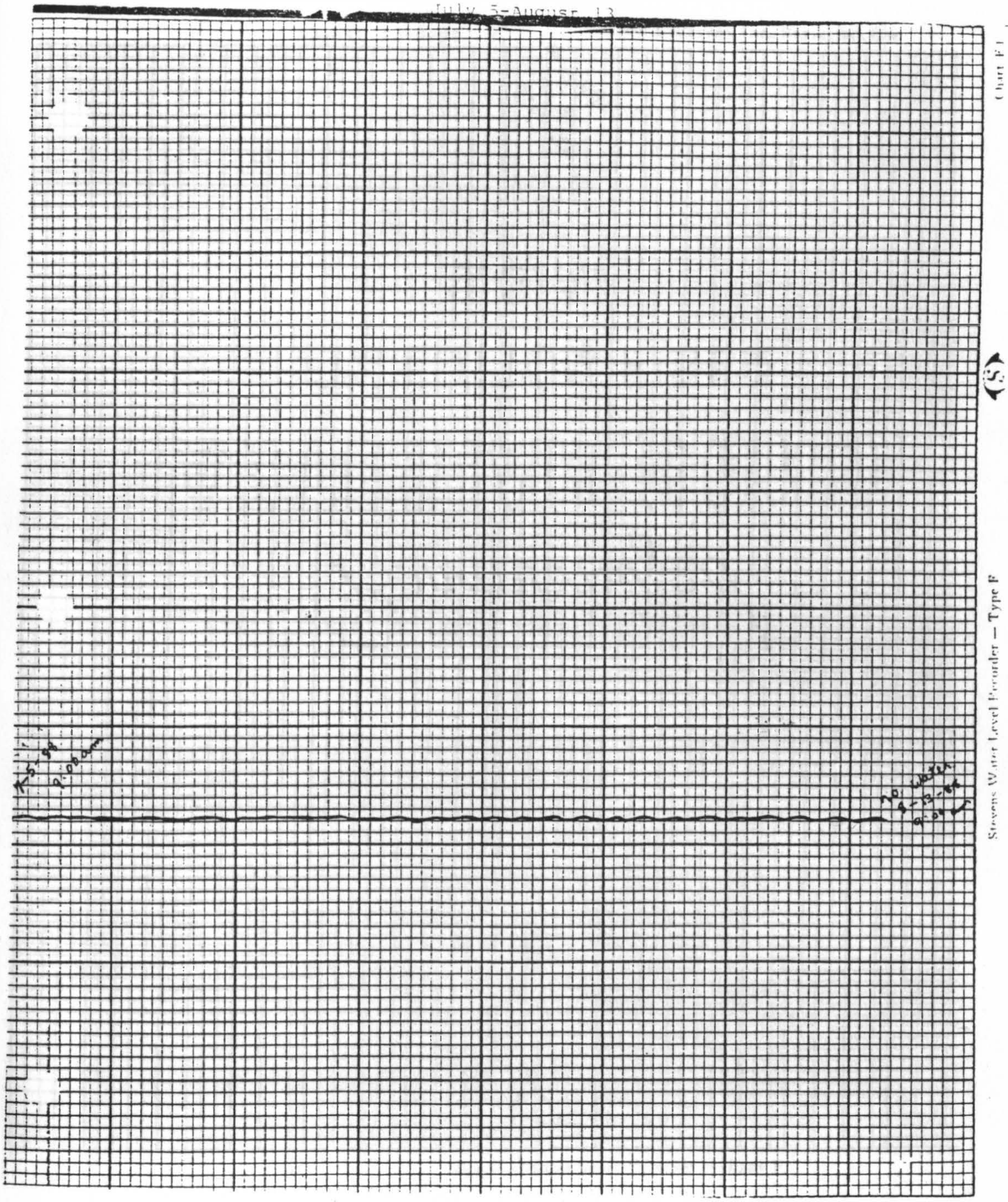

May 2-June 2
Leupold & Stever
5-2-88
2:30 pm
6-2-88
4:30 pm
Water depth
6"
Stevens Water Level Recorder

B-2

June 2-July 5

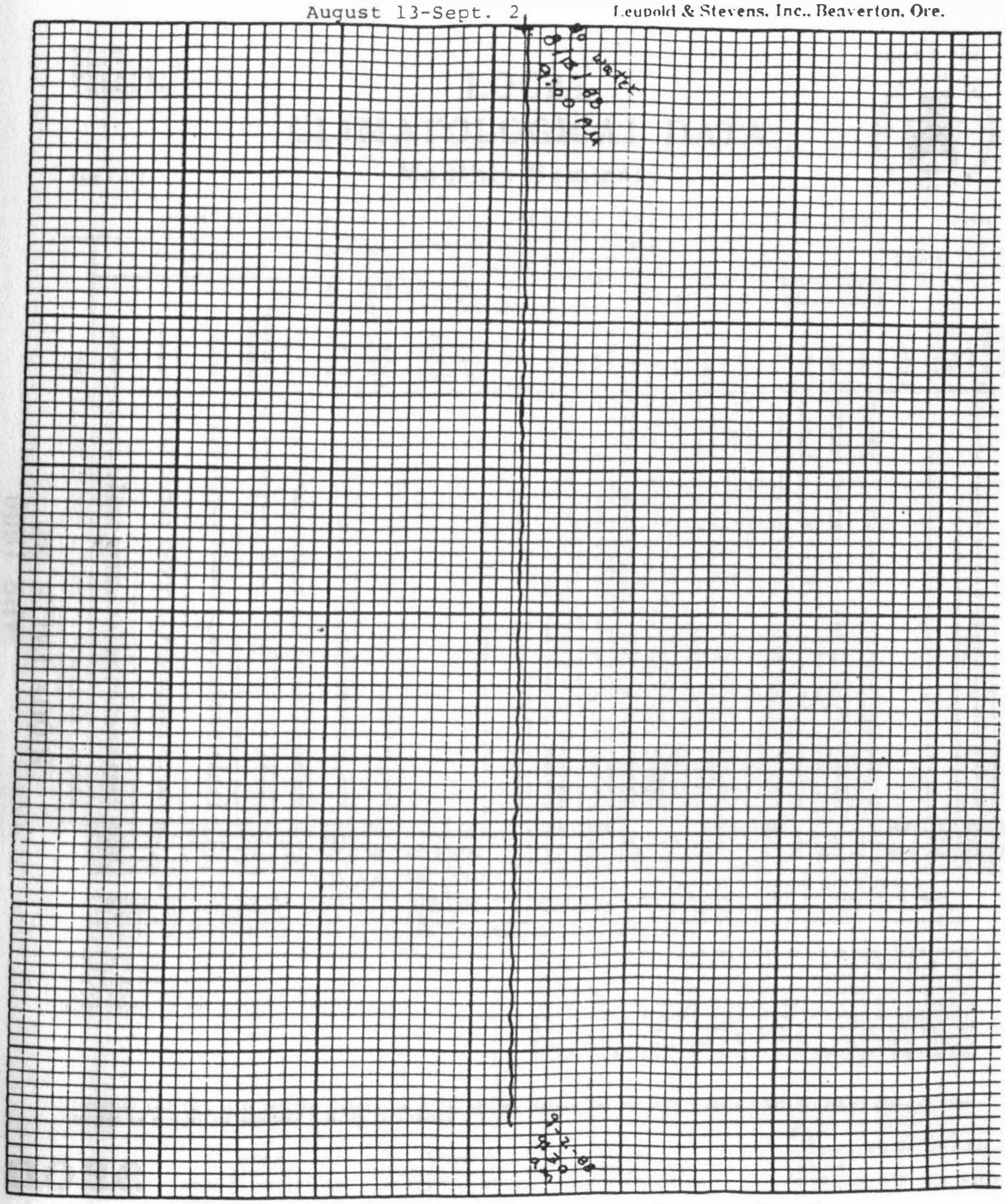

Leupold & Steve
9:00 am
6/2/88
water depth 2"
5:00 am
no water
7/5/88
Stevens Water Level Reco

July 5-August 13



August 13-Sept. 2

Leupold & Stevens, Inc., Beaverton, Ore.



Stevens Water Level Recorder — Type F

APR 1988
SIOUX FALLS, SD
NAT'L WEA SER FCST OFC
1 WEATHER LANE

ISSN 0198-4756

LOCAL CLIMATOLOGICAL DATA

Monthly Summary

FOSS FIELD

LATITUDE 43° 34' N LONGITUDE 96° 44' W ELEVATION (GROUND) 1418 FEET TIME ZONE CENTRAL 14944

APR 1988
SIOUX FALLS, SD

DATE 1	TEMPERATURE °F: MAXIMUM 2	MINIMUM 3	AVERAGE 4	DEPARTURE FROM NORMAL 5	AVERAGE DEW POINT 6	DEGREE DAYS BASE 65°F: HEATING (SEASON BEGINS WITH JUL) 7A	COOLING (SEASON BEGINS WITH JAN) 7B	WEATHER TYPES (1 FOG, 2 HEAVY FOG, 3 THUNDERSTORM, 4 ICE PELLETS, 5 HAIL, 6 GLAZE, 7 DUSTSTORM, 8 SMOKE, HAZE, 9 BLOWING SNOW) 8	SNOW ICE PELLETS OR ICE ON GROUND AT 0600 INCHES 9	PRECIPITATION: WATER EQUIVALENT (INCHES) 10	SNOW, ICE PELLETS (INCHES) 11	AVERAGE STATION PRESSURE IN INCHES ELEV 1427 FEET ABOVE M.S.L. 12	WIND (M.P.H.): RESULTANT DIR 13	RESULTANT SPEED 14	AVERAGE SPEED 15	PEAK GUST: SPEED 16	DIRECTION 17	FASTEST 1-MIN: SPEED 18	DIRECTION 19	SUNSHINE: MINUTES 20	PERCENT OF TOTAL POSSIBLE 21	SKY COVER (TENTHS): SUNRISE TO SUNSET 22	MIDNIGHT TO MIDNIGHT 23
01	54	27	41	2	25	24	0		0	0.00	0.0	28.620	07	8.1	9.5	20	E	15	09			10	[illegible]
02	47	40	44	5	39	21	0		0	0.00	0.0	28.230	05	11.6	12.3	26	NE	17	04			[illegible]	[illegible]
03	52	34	46	6	42	19	0		0	0.00	0.0	29.130	26	3.2	6.5	15	SW	12	24			[illegible]	[illegible]
04	71	39	55	14	43	10	0		0	0.00	0.0	29.090	28	4.0	10.6	33	W	23	29			9	[illegible]
05	57	39	46	7	39	17	0		0	0.32	0.0	28.390	33	8.8	9.7	33	NW	21	35			8	[illegible]
06	67	33	50	6	29	15	0		0	0.00	0.0	28.520	27	5.1	10.7	23	W	18	27			3	[illegible]
07	86*	40	63	21	35	2	0		0	0.00	0.0	28.270	17	9.5	10.3	33	S	18	17			2	[illegible]
08	85	44	65	22	41	0	0	8	0	T	0.0	28.230	22	6.8	20.1	38	W	30	29			9	5
09	55	31	43	0	27	22	0		0	0.06	0.0	28.740	34	17.2	17.5	36	N	29	35			6	7
10	57	24	41	-3	21	24	0		0	T	0.0	28.755	32	5.4	7.4	30	NW	16	36			4	2
11	62	23	43	-1	21	22	0		0	0.00	0.0	28.640	17	1.2	2.8	12	SW	7	15			0	0
12	74	36	55	10	25	10	0		0	0.00	0.0	28.460	20	6.8	7.4	20	SW	12	24			3	2
13	59	32	46	1	24	19	0		0	T	0.0	28.500	36	10.8	12.0	31	N	21	02			8	6
14	53	22	38	-8	17	27	0		0	0.00	0.0	28.620	34	9.4	10.3	32	NW	17	33			1	1
15	57	21	39	-7	17	26	0		0	0.00	0.0	28.690	36	3.2	4.6	16	NE	10	04			0	0
16	72	27	50	3	25	15	0		0	0.00	0.0	28.445	21	11.5	11.7	33	SW	20	21			3	2
17	57	31	44	-3	21	21	0		0	0.00	0.0	28.330	36	14.7	19.7	41	N	29	01			4	2
18	51	18*	35	-13	7	30	0		0	0.00	0.0	28.410	35	8.1	8.6	26	N	17	02			0	0
19	62	20	41	-7	14	24	0		0	T	0.0	28.330	21	4.1	7.4	22	SW	16	26			0	1
20	59	41	50	1	25	15	0		0	0.04	0.0	28.265	02	9.3	10.9	29	N	18	02			1	4
21	42	31	37	-12	27	28	0	1 4	T	0.36	3.6	28.320	05	11.7	12.1	28	N	18	06			10	10
22	37	33	35*	-15	31	30	0	1 34	1	0.57	4.7	28.230	05	12.7	13.7	29	NE	21	05			10	10
23	53	33	43	-7	32	22	0	2	3	0.02	0.1	28.355	31	9.3	11.0	22	NW	15	31			4	4
24	68	30	49	-1	36	16	0	3	0	0.15	0.0	28.320	21	5.0	8.3	48	N	18	06			2	3
25	52	34	43	-8	30	22	0		0	0.00	0.0	28.420	01	11.1	11.4	26	N	21	35			9	7
26	39	33	36	-15	33	29	0		T	0.46	2.9	28.420	35	13.0	14.3	33	N	22	33			10	9
27	56	31	44	-6	29	21	0		0	0.00	0.0	28.540	30	10.4	11.6	29	W	18	31			3	2
28	68	34	51	-1	30	14	0		0	0.00	0.0	28.580	22	3.3	4.3	18	SW	9	21			0	0
29	75	37	56	4	37	9	0		0	0.00	0.0	28.480	16	9.1	10.5	26	S	16	17			3	3
30	77	54	66*	13	49	0	1		0	0.02	0.0	28.400	17	16.6	17.0	39	S	23	18			7	7

	MAXIMUM	MINIMUM	AVERAGE	DEPARTURE	DEW POINT	HEATING	COOLING
	SUM	SUM				TOTAL	TOTAL
	1804	977				554	1
	AVG	AVG	AVG	DEP	AVG	DEP	DEP
	60.1	32.6	46.4	0.1	23.1	-7	1
						SEASON TO DATE	
						TOTAL	TOTAL
						7466	1
						DEP	DEP
						-127	1

NUMBER OF DAYS			
MAXIMUM TEMP		MINIMUM TEMP	
≥ 90°	≤ 32°	≤ 32°	≤ 0°
0	0	14	0

NUMBER OF DAYS	
PRECIPITATION ≥ .01 INCH	10
SNOW, ICE PELLETS ≥ 1.0 INCH	3
THUNDERSTORMS	2
HEAVY FOG	1
CLEAR 14 PARTLY CLOUDY 4 CLOUDY 12	

	PRECIPITATION TOTAL	SNOW, ICE PELLETS TOTAL	PRESSURE	RESULTANT DIR	RESULTANT SPEED	AVERAGE SPEED	PEAK GUST SPEED	PEAK GUST DIRECTION	FASTEST 1-MIN SPEED	FASTEST 1-MIN DIRECTION	SUNSHINE TOTAL	% FOR MONTH	SKY COVER SUM	SKY COVER SUM
FOR THE MONTH:	3.00	11.3	28.420	34	2.6	10.8	48	N	30	29			150	137
	DEP						DATE: 24		DATE: 8		POSSIBLE		AVG	AVG
	0.64												5.0	4.6

GREATEST IN 24 HOURS AND DATES				GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE	
PRECIPITATION		SNOW, ICE PELLETS			
1.00	02	4.7	22-23+	4	22

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE
T TRACE AMOUNT
\+ ALSO ON EARLIER DATE(S)
HEAVY FOG: VISIBILITY 1/4 MILE OR LESS
BLANK ENTRIES DENOTE MISSING OR UNREPORTED DATA

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Kenneth D Hadeen
DIRECTOR
NATIONAL CLIMATIC DATA CENTER

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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL ENVIRONMENTAL SATELLITE, DATA AND INFORMATION SERVICE
NATIONAL CLIMATIC DATA CENTER ASHEVILLE NORTH CAROLINA

MAY 1988
SIOUX FALLS, SD
NAT'L WEA SER FCST OFC
1 WEATHER LANE

ISSN 0198-4756

LOCAL CLIMATOLOGICAL DATA

Monthly Summary

FOSS FIELD

MAY 1988
SIOUX FALLS, SD

LATITUDE 43° 34' N LONGITUDE 96° 44' W ELEVATION (GROUND) 1418 FEET TIME ZONE CENTRAL 14944

DATE	TEMPERATURE °F: MAXIMUM (2)	MINIMUM (3)	AVERAGE (4)	DEPARTURE FROM NORMAL (5)	AVERAGE DEW POINT (6)	DEGREE DAYS BASE 65°F: HEATING (SEASON BEGINS WITH JUL) (7)	COOLING (SEASON BEGINS WITH JAN) (7B)	WEATHER TYPES (8)	SNOW, ICE PELLETS OR ICE ON GROUND AT 0600 INCHES (9)	PRECIPITATION: WATER EQUIVALENT (INCHES) (10)	SNOW, ICE PELLETS (INCHES) (11)	AVERAGE STATION PRESSURE IN INCHES ELEV. FEET ABOVE M.S.L. (12)	WIND M.P.H.: RESULTANT DIR (13)	RESULTANT SPEED (14)	AVERAGE SPEED (15)	PEAK GUST: SPEED (16)	DIRECTION (17)	FASTEST MILE: SPEED (18)	DIRECTION (19)	SUNSHINE: MINUTES (20)	PERCENT OF TOTAL POSSIBLE (21)	SKY COVER (TENTHS): SUNRISE TO SUNSET (22)	MIDNIGHT TO MIDNIGHT (23)
01	78	55	67	14	41	[illegible]	[illegible]		0	0.00	0.0	28.[illegible]	[illegible]	[illegible]	[illegible]	51	[illegible]	[illegible]	16			4	8
02	[illegible]	55	[illegible]	12	42	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	47	SE	[illegible]	15			9	9
03	65	46	57	[illegible]	47	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	W	[illegible]	27			9	4
04	[illegible]	39	[illegible]	[illegible]	43	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	28.[illegible]	[illegible]	[illegible]	6	24	W	[illegible]	29			[illegible]	2
05	76	41	59	5	42	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	28.[illegible]	[illegible]	5	[illegible]	23	SW	14	19			5	3
06	69	[illegible]	60	[illegible]	48	[illegible]	0		[illegible]	[illegible]	0.0	28.34[illegible]	[illegible]	[illegible]	8.4	43	SE	28	14			9	7
07	74	[illegible]	65	[illegible]	44	[illegible]	[illegible]	1 3	[illegible]	[illegible]	[illegible]	27.[illegible]	[illegible]	[illegible]	[illegible]	45	SW	[illegible]	18			4	[illegible]
08	65	44	55	[illegible]	44	[illegible]	[illegible]	3	[illegible]	[illegible]	[illegible]	27.848	[illegible]	[illegible]	12.9	32	NW	[illegible]	21			6	[illegible]
09	77	47	59	[illegible]	38	[illegible]	0	3	[illegible]	0.02	0.0	28.[illegible]	[illegible]	19.5	20.3	46	NW	[illegible]	33			3	4
10	80	43		6	41	3	0		[illegible]	0.00	0.0	28.50[illegible]	34	6.1	8.2	30	NW	2[illegible]	02			4	3
11	80	41		5	42	4	[illegible]		0	0.02	0.0	28.5[illegible]	29	4.3	7.2	25	W	[illegible]	26			6	5
12	87	46		13	44	[illegible]	2		0	0.00	0.0	28.426	30	9.2	15.1	37	NE	28	32			5	5
13	70	41	56	-1	25	9	0		0	0.00	0.0	28.562	08	8.2	12.4	31	NE	21	02			1	2
14	81	51	66	9	42	0	1		0	0.01	0.0	28.2[illegible]	23	5.1	13.9	39	SW	23	30			7	5
15	77	47	62	4	36	3	0		0	T	0.0	28.35[illegible]	31	18.9	20.0	47	NW	32	31			0	2
16	70	38*	54*	-4	35	11	0		0	0.00	0.0	28.54[illegible]	01	8.2	10.3	25	N	18	35			0	0
17	81	43	62	3	41	3	0		0	0.00	0.0	28.420	15	15.1	15.5	30	SE	22	15			1	1
18	78	61	70	11	54	0	5	3	0	0.11	0.0	28.3[illegible]	15	11.8	14.0	38	W	22	18			10	8
19	87	55	71	12	60	0	6	3	0	0.20	0.0	28.320	34	1.5	5.4	21	SE	14	02			5	7
20	77	60	69	9	60	0	4	1 3	0	0.53	0.0	28.370	04	5.8	9.1	35	W	21	28			10	10
21	69	57	63	3	58	2	0	1 3	0	0.27	0.0	28.[illegible]	03	12.8	13.3	28	NE	18	01			10	10
22	65	58	62	2	58	3	0	1	0	0.04	0.0	29.4[illegible]	24	12.5	13.1	23	N	16	01			10	10
23	76	54	65	4	49	0	0		0	0.00	0.0	29.[illegible]	03	10.3	10.7	28	NE	18	04			4	4
24	79	50	65	4	45	0	0		0	0.00	0.0	28.5[illegible]	08	6.[illegible]	6.8	24	E	14	07			3	2
25	82	49	66	5	48	0	1	3	0	0.00	0.0	28.5[illegible]	18	11.6	13.[illegible]	29	S	21	19			3	3
26	86	63	75	13	58	0	10	3	0	0.02	0.0	28.38[illegible]	19	13.1	14.3	28	SW	22	20			5	7
27	90*	63	77	15	57	0	12	3	0	T	0.0	28.2[illegible]	16	6.9	8.8	26	S	[illegible]	18			6	6
28	89	67	78	16	58	0	13		0	0.00	0.0	28.2[illegible]	18	13.2	13.[illegible]	30	S	22	20			6	4
29	87	66	78*	15	60	0	13	3	0	0.04	0.0	28.22[illegible]	17	16.4	17.0	36	S	25	18			9	9
30	86	66	76	13	60	0	11	3	0	0.06	0.0	28.3[illegible]	17	17.5	18.1	38	S	23	19			5	5
31	88	66	77	13	61	0	12	3	0	0.15	0.0	28.4[illegible]	16	14.7	15.2	37	S	22	16			7	6
	SUM	SUM				TOTAL	TOTAL	NUMBER OF DAYS		TOTAL	TOTAL	FOR THE MONTH								TOTAL	% FOR MONTH	SUM	SUM
	2415	1617				63	94			1.54	0.0	28.3[illegible]	19	3.1	13.2	51	S	32	31			172	168
	AVG	AVG	AVG	DEP	AVG	DEP	DEP	PRECIPITATION		DEP						DATE	*	DATE	15+		POSSIBLE	AVG	AVG
	77.9	52.2	65.1	6.3	47.9	-157	65	≥ .01 INCH 13		-1.67												5.5	5.4

NUMBER OF DAYS				SEASON TO DATE				GREATEST IN 24 HOURS AND DATES		GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE
				TOTAL	TOTAL	SNOW, ICE PELLETS ≥ 1.0 INCH	0			
MAXIMUM TEMP		MINIMUM TEMP		7549	95	THUNDERSTORMS	13	PRECIPITATION	SNOW, ICE PELLETS	
≥ 90°	≤ 32°	≤ 32°	≤ 0°	DEP	DEP	HEAVY FOG	0	0.[illegible] 20-21	[illegible]	0
1	0	0	0	-264	66	CLEAR 8	PARTLY CLOUDY 14	CLOUDY [illegible]		

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SIOUX FALLS, SD
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FOSS FIELD

LOCAL CLIMATOLOGICAL DATA
Monthly Summary

ISSN 0198-4756

JUN 1988
SIOUX FALLS, SD

LATITUDE 43° 34' N   LONGITUDE 96° 44' W   ELEVATION (GROUND) 1418 FEET   TIME ZONE CENTRAL   14944

DATE 1	TEMPERATURE °F: MAXIMUM 2	MINIMUM 3	AVERAGE 4	DEPARTURE FROM NORMAL 5	AVERAGE DEW POINT 6	DEGREE DAYS BASE 65°F: HEATING (SEASON BEGINS WITH JUL) 7A	COOLING (SEASON BEGINS WITH JAN) 7B	WEATHER TYPES (1 FOG, 2 HEAVY FOG, 3 THUNDERSTORM, 4 ICE PELLETS, 5 HAIL, 6 GLAZE, 7 DUSTSTORM, 8 SMOKE, HAZE, 9 BLOWING SNOW) 8	SNOW, ICE PELLETS OR ICE ON GROUND AT 0600 (INCHES) 9	PRECIPITATION: WATER EQUIVALENT (INCHES) 10	SNOW, ICE PELLETS (INCHES) 11	AVERAGE STATION PRESSURE IN INCHES ELEV 1427 FEET ABOVE M.S.L. 12	WIND (M.P.H.): RESULTANT DIR 13	RESULTANT SPEED 14	AVERAGE SPEED 15	PEAK GUST SPEED 16	PEAK GUST DIRECTION 17	FASTEST 1-MIN SPEED 18	FASTEST 1-MIN DIRECTION 19	SUNSHINE: MINUTES 20	PERCENT OF TOTAL POSSIBLE 21	SKY COVER (TENTHS): SUNRISE TO SUNSET 22	MIDNIGHT TO MIDNIGHT 23
01	82	62	72	6	62	0	7	3	[illegible]	[illegible]	0.0	28.400	[illegible]	5.2	[illegible]	29	SE	16	24			10	8
02	85	61	73	7	60	0	9	1	[illegible]	[illegible]	0.0	28.460	04	3.7	5.5	15	N	10	11			[illegible]	[illegible]
03	91	64	78	[illegible]	63	0	13	3	[illegible]	[illegible]	0.0	28.560	02	3.5	4.7	31	N	13	33			6	6
04	89	62	76	[illegible]	63	0	11		[illegible]	[illegible]	0.0	28.540	14	[illegible]	6.1	23	SE	16	15			6	1
05	88	65	76	[illegible]	57	0	12		[illegible]	[illegible]	0.0	28.530	[illegible]	[illegible]	[illegible]	25	SE	16	16			0	0
06	88	63	76	[illegible]	46	0	11		[illegible]	[illegible]	0.0	28.470	18	[illegible]	[illegible]	25	S	18	17			[illegible]	[illegible]
07	86	62	74	8	56	0	9	1 8	[illegible]	[illegible]	0.0	28.290	15	7.0	8.8	23	S	16	17			5	5
08	94	61	76	[illegible]	57	0	13	1 8	[illegible]	[illegible]	0.0	28.325	06	11.0	11.5	30	E	23	07			3	[illegible]
09	79	52	65	[illegible]	36	0	1		0	0.00	0.0	28.680	12	10.[illegible]	11.5	26	SE	17	14			6	4
10	86	41*	64*	-13	37	1	0		0	0.00	0.0	28.690	17	9.6	10.7	26	S	17	18			6	4
11	89	62	76	3	45	0	11		0	0.00	0.0	28.460	17	16.0	16.4	32	S	21	16			9	8
12	95	68	82	14	52	0	17		0	0.00	0.0	29.320	18	14.6	15.3	30	S	18	19			7	6
13	89	67	78	10	54	0	13	3	0	0.14	0.0	28.390	21	7.3	9.2	25	SW	16	18			6	5
14	83	63	73	5	56	0	8		0	T	0.0	28.540	27	11.0	13.3	28	W	21	27			6	5
15	82	53	68	0	49	0	3		0	0.00	0.0	28.720	32	5.3	6.7	18	NW	14	32			2	1
16	87	53	70	1	49	0	5		0	0.00	0.0	28.590	17	6.5	8.5	24	S	15	14			6	5
17	98	62	75	6	62	0	10	3	0	0.04	0.0	28.395	16	7.6	9.8	23	S	15	18			6	7
18	100	65	83	14	63	0	18		0	0.00	0.0	28.290	19	13.3	14.2	35	S	23	19			7	7
19	105	72	89	19	61	0	24		0	0.00	0.0	28.330	23	2.0	6.3	23	S	15	19			1	1
20	103	66	85	15	59	0	20		0	0.00	0.0	28.460	12	8.4	9.8	24	SE	16	13			0	0
21	110*	78	94*	24	64	0	29		0	0.00	0.0	28.230	20	9.3	11.6	26	SW	18	18			2	2
22	94	71	83	13	56	0	18	8	0	0.00	0.0	28.425	05	11.1	12.1	24	NE	18	06			3	2
23	82	63	73	2	55	0	8	3 8	0	0.06	0.0	28.450	12	12.9	15.0	38	SE	24	14			8	7
24	107	75	91	20	59	0	26		0	0.00	0.0	28.290	19	13.3	13.8	31	S	20	19			6	6
25	88	62	75	4	53	0	10		0	0.00	0.0	28.530	02	9.7	12.0	30	NE	18	02			1	3
26	86	56	71	0	52	0	6		0	0.00	0.0	28.630	09	7.1	8.7	24	NE	16	10			2	1
27	92	55	74	3	53	0	9		0	0.00	0.0	28.500	17	10.8	11.6	29	S	16	17			2	2
28	105	72	89	17	60	0	24	3	0	[illegible]	0.0	28.300	21	7.0	12.3	41	NE	17	35			8	7
29	72	61	67	-5	53	0	2	1 3	0	0.35	0.0	28.410	09	13.7	14.3	30	E	20	11			10	10
30	75	61	69	-4	49	0	3		0	T	0.0	29.480	10	14.3	14.7	29	SE	21	12			10	10
	SUM 2700	SUM 1678				TOTAL 1	TOTAL 349	NUMBER OF DAYS		TOTAL 0.9[illegible]	TOTAL 0.0	FOR THE MONTH: 28.460	15	5.4	11.0	41	NE	24	14	TOTAL	% FOR MONTH	SUM 147	SUM 134
	AVG 90.0	AVG 62.6	AVG 76.3	DEP 7.9	AVG 55.3	DEP -51	DEP 195	PRECIPITATION ≥ .01 INCH 7		DEP -2.73						DATE: 28		DATE: 23		POSSIBLE		AVG 4.9	AVG 4.5

NUMBER OF DAYS				SEASON TO DATE			
MAXIMUM TEMP		MINIMUM TEMP		TOTAL	TOTAL	SNOW, ICE PELLETS ≥ 1.0 INCH	0
≥ 90°	≤ 32°	≤ 32°	≤ 0°	[illegible]553	444	THUNDERSTORMS	[illegible]
11	0	0	0	DEP	DEP	HEAVY FOG	0
				-235	261	CLEAR 12	PARTLY CLOUDY 12 CLOUDY 6

GREATEST IN 24 HOURS AND DATES: PRECIPITATION		SNOW, ICE PELLETS	GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE
0.59	28-29	0.0	0

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE
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JUL 1988
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1 WEATHER LANE

ISSN 0198-4756

LOCAL CLIMATOLOGICAL DATA

Monthly Summary

FOSS FIELD

LATITUDE 43° 34' N LONGITUDE 96° 44' W ELEVATION (GROUND) 1418 FEET TIME ZONE CENTRAL 14944

Date 1	Temp. Maximum 2	Temp. Minimum 3	Temp. Average 4	Departure from Normal 5	Average Dew Point 6	Heating (Season begins with Jul) 7A	Cooling (Season begins with Jan) 7B	Weather Types 8	Snow, Ice Pellets or Ice on Ground at 0600 (inches) 9	Precip. Water Equivalent (inches) 10	Precip. Snow, Ice Pellets (inches) 11	Avg. Station Pressure (inches, elev. 1427 feet above m.s.l.) 12	Resultant Dir 13	Resultant Speed 14	Average Speed 15	Peak Gust Speed 16	Peak Gust Direction 17	Fastest 1 Min Speed 18	Fastest 1 Min Direction 19	Sunshine Minutes 20	Percent of Total Possible 21	Sky Cover Sunrise to Sunset 22	Sky Cover Midnight to Midnight 23
01	79	[illegible]	70	[illegible]	[illegible]	0	5		0	[illegible]	[illegible]	28.540	[illegible]	7.3	9.9	26	E	14	11			[illegible]	[illegible]
02	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]		0	[illegible]	[illegible]	28.485	[illegible]	4.4	[illegible]	35	S	12	16			[illegible]	[illegible]
03	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]		0	[illegible]	[illegible]	28.360	[illegible]	[illegible]	[illegible]	30	S	21	17			[illegible]	[illegible]
04	99	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]		0	[illegible]	[illegible]	28.360	[illegible]	[illegible]	[illegible]	[illegible]	S	21	19			[illegible]	[illegible]
05	100	74	87	14	69	0	22		0	0.00	[illegible]	28.450	[illegible]	[illegible]	16.4	36	S	21	17			[illegible]	[illegible]
06	[illegible]	[illegible]	90	17	68	0	25	3	0	[illegible]	[illegible]	28.440	[illegible]	[illegible]	18.9	38	S	25	18			[illegible]	[illegible]
07	100	69	85	12	[illegible]	0	20	3	0	[illegible]	[illegible]	28.500	[illegible]	[illegible]	13.7	37	NW	26	31			5	5
08	[illegible]	66	75	2	67	0	10		0	[illegible]	[illegible]	28.570	10	3.3	5.9	15	S	9	17			9	10
09	[illegible]	63	74	0	56	0	9		0	[illegible]	[illegible]	28.440	[illegible]	4.2	5.7	23	NE	18	06			9	[illegible]
10	90	60	75	1	57	0	10		0	0.00	[illegible]	28.430	03	4.8	7.0	20	NE	12	06			2	4
11	76	[illegible]	68	-6	58	0	3		0	0.01	0.0	28.505	[illegible]	[illegible]	9.5	18	SE	13	13			9	8
12	90	61	76	2	64	0	11	3	0	T	0.0	28.360	15	14.5	15.6	36	SE	21	19			5	5
13	100	68	84	10	64	0	19	3	0	T	0.0	28.290	04	0.3	8.0	28	S	18	19			2	3
14	98	62	80	6	58	0	15		0	0.00	0.0	28.330	14	9.9	12.4	31	SE	21	14			6	5
15	96	73	85	11	66	0	20		0	0.00	0.0	28.320	23	8.6	12.4	38	SW	24	23			10	9
16	93	61	77	3	[illegible]	0	12		0	0.00	0.0	28.500	05	4.2	7.8	17	NE	13	01			2	2
17	89	68	79	5	65	0	14	3	0	0.02	0.0	28.500	09	4.5	9.7	24	S	16	13			6	6
18	89	62	76	2	54	0	11		0	0.00	0.0	28.530	04	6.3	7.7	20	N	13	04			5	5
19	76	60	68	-6	57	0	3		0	[illegible]	0.0	28.620	29	3.3	7.1	30	NW	21	34			8	7
20	81	54	68*	-6	50	0	3		0	0.00	0.0	28.660	33	9.6	11.2	31	N	23	35			2	2
21	88	52*	70	-4	51	0	5		0	0.00	0.0	28.650	33	2.9	5.4	21	N	10	31			2	1
22	90	54	72	-3	53	0	7		0	0.00	0.0	28.570	17	5.0	6.8	20	S	13	16			2	3
23	92	65	79	4	58	0	14	3	0	0.06	0.0	28.460	[illegible]	10.4	12.3	39	NW	20	33			4	5
24	89	60	75	0	56	0	10		0	0.00	0.0	28.540	02	6.2	6.7	20	N	14	02			8	7
25	89	54	72	-3	51	0	7		0	0.00	0.0	28.620	02	3.3	4.9	18	NW	12	34			4	3
26	95	55	75	0	55	0	10		0	0.00	0.0	28.560	21	6.2	7.9	21	S	13	20			6	6
27	96	64	80	5	59	0	15		0	0.00	0.0	28.505	20	[illegible]	12.4	28	S	18	17			0	2
28	96	71	84	9	63	0	19	3	0	0.00	0.0	28.465	19	14.9	15.4	33	S	21	17			4	4
29	93	70	82	7	64	0	17	3	0	0.08	0.0	28.455	19	8.9	10.1	32	S	24	19			7	7
30	96	66	81	6	65	0	16		0	0.00	0.0	28.520	13	8.3	10.4	25	SE	16	12			0	0
31	107*	76	92*	17	63	0	27		0	0.00	0.0	28.345	20	13.5	14.2	32	SW	22	23			0	0
	SUM	SUM				TOTAL	TOTAL	NUMBER OF DAYS		TOTAL	TOTAL	FOR THE MONTH:								TOTAL	% FOR MONTH	SUM	SUM
	2824	1975				0	393			0.43	0.0	28.480	17	4.9	10.3	39	NW	26	31			138	138
	AVG	AVG	AVG	DEP	AVG	DEP	DEP	PRECIPITATION ≥ .01 INCH	8	DEP						DATE: 23		DATE: 7		POSSIBLE		AVG	AVG
	91.1	63.7	77.4	3.4	[illegible]	-14	100			-2.22												4.5	4.5

NUMBER OF DAYS				SEASON TO DATE				GREATEST IN 24 HOURS AND DATES		GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE
MAXIMUM TEMP		MINIMUM TEMP		TOTAL	TOTAL	SNOW, ICE PELLETS ≥ 1.0 INCH	0			
≥ 90°	≤ 32°	≤ 32°	≤ 0°	0	837	THUNDERSTORMS	9	PRECIPITATION	SNOW, ICE PELLETS	
18	0	0	0	DEP	DEP	HEAVY FOG	0	[illegible] 19	0.0	0
				-14	361	CLEAR 12 PARTLY CLOUDY [illegible] CLOUDY 7				

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE
T TRACE AMOUNT
\+ ALSO ON EARLIER DATE(S)
HEAVY FOG: VISIBILITY 1/4 MILE OR LESS
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AUG 1988
SIOUX FALLS, SD
NAT'L WEA SER FCST OFC
1 WEATHER LANE

ISSN 0198-4756

LOCAL CLIMATOLOGICAL DATA

Monthly Summary

FOSS FIELD

AUG 1988
SIOUX FALLS, SD

LATITUDE 43° 34' N LONGITUDE 96° 44' W ELEVATION (GROUND) 1418 FEET TIME ZONE CENTRAL 14944

Weather types: 1 FOG; 2 HEAVY FOG; 3 THUNDERSTORM; 4 ICE PELLETS; 5 HAIL; 6 GLAZE; 7 DUSTSTORM; 8 SMOKE, HAZE; 9 BLOWING SNOW

DATE 1	TEMPERATURE °F: MAXIMUM 2	MINIMUM 3	AVERAGE 4	DEPARTURE FROM NORMAL 5	AVERAGE DEW POINT 6	DEGREE DAYS BASE 65°F: HEATING (SEASON BEGINS WITH JUL) 7A	COOLING (SEASON BEGINS WITH JAN) 7B	WEATHER TYPES 8	SNOW ICE PELLETS OR ICE ON GROUND AT 0600 INCHES 9	PRECIPITATION: WATER EQUIVALENT (INCHES) 10	SNOW, ICE PELLETS (INCHES) 11	AVERAGE STATION PRESSURE IN INCHES ELEV 1427 FEET ABOVE M S L 12	WIND M P H: RESULTANT DIR 13	RESULTANT SPEED 14	AVERAGE SPEED 15	PEAK GUST SPEED 16	PEAK GUST DIRECTION 17	FASTEST MILE SPEED 18	FASTEST MILE DIRECTION 19	SUNSHINE: MINUTES 20	PERCENT OF TOTAL POSSIBLE 21	SKY COVER (TENTHS): SUNRISE TO SUNSET 22	MIDNIGHT TO MIDNIGHT 23
01	100	76	89	14	63	0	24		0	0.00	0.0	28.290	18	15.3	15.7	35	S	[illegible]	18			4	4
02	99	74	87	13	61	0	22	3	0	0.33	0.0	28.335	19	5.8	12.0	28	S	[illegible]	18			8	[illegible]
03	80	67	74	[illegible]	65	0	9	3	0	0.74	0.0	28.450	19	1.3	9.1	31	NW	[illegible]	31			9	5
04	81	61	[illegible]	-3	59	0	6		0	T	0.0	28.530	34	9.1	6.9	24	NW	14	34			9	3
05	85	54	70	-4	55	0	5		0	0.00	0.0	28.475	22	[illegible]	9.3	24	SW	[illegible]	[illegible]			0	[illegible]
06	94	68	81	7	59	0	16		0	0.00	0.0	28.395	19	15.3	16.1	32	S	[illegible]	17			4	[illegible]
07	99	69	84	10	66	0	19	3	0	0.06	0.0	28.310	19	7.6	15.5	33	SW	[illegible]	[illegible]			5	6
08	84	62	73	-1	[illegible]	0	8	3	0	0.03	0.0	28.480	03	8.3	9.2	21	NE	16	[illegible]			2	4
09	88	56	72	-2	57	0	7		0	0.00	0.0	28.500	18	5.0	6.8	21	S	14	16			1	3
10	93	67	80	6	67	0	15		0	0.00	0.0	28.410	17	13.2	13.4	30	S	18	17			4	4
11	97	75	86	13	69	0	21		0	0.00	0.0	28.380	18	14.6	15.0	28	S	[illegible]	[illegible]			6	3
12	95	75	85	12	69	0	20		0	0.00	0.0	28.380	17	14.9	15.2	28	S	[illegible]	17			4	5
13	87	69	78	5	69	0	13	1	0	1.03	0.0	28.320	24	3.2	9.4	23	W	18	26			5	5
14	94	65	80	7	70	0	15	1	0	0.00	0.0	28.390	08	7.2	7.5	15	E	10	09			4	2
15	105*	70	88	15	69	0	23		0	0.00	0.0	28.370	17	9.6	10.7	25	S	[illegible]	17			2	2
16	101	80	9*	19	67	0	26		0	0.00	0.0	28.340	19	15.4	15.9	39	SW	30	21			0	1
17	98	75	87	15	67	0	22	3	0	0.00	0.0	28.410	32	3.0	9.4	23	N	[illegible]	35			4	3
18	83	61	72	0	65	0	7		0	T	0.0	28.490	04	7.8	8.6	22	N	15	[illegible]			9	7
19	80	62	71	-1	62	0	6	1	0	T	0.0	28.460	06	5.5	7.1	15	NE	12	[illegible]			9	8
20	85	55	70	-1	61	0	5	2	0	0.00	0.0	28.350	16	9.0	9.7	25	S	16	16			6	6
21	90	66	78	7	66	0	13	3 8	0	1.60	0.0	28.300	14	11.5	15.0	35	SE	25	36			10	10
22	83	65	74	3	64	0	9	1 3	0	0.23	0.0	28.360	01	2.1	6.7	23	E	19	11			5	5
23	82	55	69	-1	53	0	4		0	0.00	0.0	28.490	30	8.9	9.4	29	NW	18	31			0	0
24	84	54	69	-1	52	0	4		0	0.00	0.0	28.500	29	7.3	9.0	30	NW	[illegible]	33			0	0
25	76	54	65	-5	48	0	0		0	0.00	0.0	28.440	33	8.6	10.3	31	N	22	33			0	0
26	77	47	62	-7	50	3	0	3	0	0.05	0.0	28.350	17	5.5	7.6	26	SE	20	14			6	5
27	69	49	59	-10	48	6	0	3	0	0.05	0.0	28.450	34	10.3	12.2	30	NW	[illegible]	34			2	3
28	72	44	58*	-10	41	7	0		0	0.00	0.0	28.620	31	4.9	7.1	24	NW	18	32			1	1
29	78	42*	60	-8	46	5	0		0	0.00	0.0	28.580	04	6.2	7.0	18	NE	12	01			1	1
30	83	44	64	-4	49	1	0		0	0.00	0.0	28.410	16	6.8	8.7	23	S	15	17			2	3
31	89	62	76	9	56	0	11		0	0.00	0.0	28.280	17	15.7	16.1	35	S	22	19			9	7

SUM	SUM				TOTAL	TOTAL	NUMBER OF DAYS		TOTAL	TOTAL	FOR THE MONTH:								TOTAL	% FOR MONTH	SUM	SUM
2711	1924				22	330			4.02	0.0	28.410	18	3.5	10.8	39	SW	30	21			131	126
AVG	AVG	AVG	DEP	AVG	DEP	DEP	PRECIPITATION		DEP						DATE: 16		DATE: 16		POSSIBLE		AVG	AVG
87.5	62.1	74.8	3.0	60.2	7	104	≥ .01 INCH	9	0.89												4.2	4.1

NUMBER OF DAYS				SEASON TO DATE				GREATEST IN 24 HOURS AND DATES			GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE
MAXIMUM TEMP		MINIMUM TEMP		TOTAL	TOTAL	SNOW, ICE PELLETS ≥ 1.0 INCH	0	PRECIPITATION		SNOW, ICE PELLETS	
≥ 90°	≤ 32°	≤ 32°	≤ 0°	22	1167	THUNDERSTORMS	9	1.83	21-22	0.0	0
12	0	0	0	DEP -7	DEP 465	HEAVY FOG	[illegible]				
						CLEAR 12 PARTLY CLOUDY 12 CLOUDY 7					

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE
T TRACE AMOUNT
+ ALSO ON EARLIER DATE(S)
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'RELIMINARY ' 'CAL CLIMATOLOGICAL DATA

STATION: SIOUX FP' 'S SD
MONTH: SEPT YEAR: 1988

ATITUDE 43 Degrees 35 Minutes North LONGITUDE 95 Degrees 44 Minutes West ELEVATION 1418 Feet TIME ZONE: CENTRAL

	TEMPERATURE DEGREES F						PRECIPITATION			WIND				SUNSHINE					
				DEPAR-TURE FROM	DEGREE DAYS (BASE 65)				SNOW, ICE PELLETS OR ICE ON		* FASTEST MILE					SKY COVER			
AY	MAXI-MUM	MINI-MUM	AVER-AGE	NOR-MAL	HEAT-ING	COOL-ING	TOTAL WATER EQUIV	SNOW-FALL, ICE PELLETS	GROUND AT 6 AM CST	AVG SPEED (MPH)	SPEED (MPH)	DIREC-TION	TOTAL (MIN)	% POS SIBLE	SUNRISE -SUNSET	WEATHER OCCURRENCES	PEAK WIND (MPH)		
1	89	62	76	9	0	11	T	0.0	0	10.5	22	20			10		S 32		
2	83	50	69	3	0	4	0.03	0.0	0	10.2	20	35			4		NW 29		
3	71	52	62	-4	3	0	T	0.0	0	16.0	30	34			6		N 37		
4	78	47	63	-2	2	0	0.00	0.0	0	14.2	25	35			2		N 32		
5	72	40	56	-9	9	0	0.00	0.0	0	4.5	9	01			1		NW 23		
6	78	40	59	-6	6	0	0.00	0.0	0	8.8	16	17			0		S 25		
7	80	57	69	5	0	4	0.00	0.0	0	15.3	24	18			6		S 33		
8	74	44	59	-5	6	0	0.00	0.0	0	8.7	20	34			10		N 29		
9	82	41	62	-1	3	0	0.00	0.0	0	7.4	14	22			7		SW 21		
10	91	58	75	12	0	10	0.00	0.0	0	15.1	24	15			5		S 37		
11	89	60	75	12	0	10	0.01	0.0	0	16.7	22	16			2	3	S 35		
12	62	47	55	-7	10	0	0.21	0.0	0	12.8	20	34			9	3	N 25		
13	73	46	60	-2	5	0	0.00	0.0	0	6.2	12	26			3		W 18		
14	[illegible]	47	61	0	4	0	0.07	0.0	0	5.2	9	09			0		S 13		
15	64	57	61	0	4	0	1.50	0.0	0	9.0	17	11			10	13	E 23		
16	78	58	68	7	0	3	0.05	0.0	0	8.0	14	22			2	1	W 22		
17	88	56	72	12	0	7	0.00	0.0	0	8.1	14	17			0		S 20		
18	83	63	73	13	0	8	0.30	0.0	0	16.1	30	24			4	3	W 40		
19	63	47	55	-5	10	0	0.20	0.0	0	22.0	31	31			10	1	NW 46		
20	66	45	56	-3	9	0	0.00	0.0	0	9.4	21	31			2		NW 28		
21	78	47	63	4	2	0	0.00	0.0	0	9.6	14	13			0		S 21		
22	69	45	57	-1	8	0	0.00	0.0	0	11.0	22	33			0	28	N 31		
23	70	39	55	-3	10	0	0.00	0.0	0	6.6	13	17			0		S 18		
24	75	53	64	6	1	0	0.00	0.0	0	14.5	24	19			1		S 38		
25	79	42	61	4	4	0	T	0.0	0	11.7	21	12			6	3	SE 31		
26	83	55	69	12	0	4	0.60	0.0	0	9.2	14	18			0		S 24		
27	67	49	58	1	7	0	[illegible]	0.0	0	12.0	17	22			0	3	E 25		
28	62	52	57	0	8	0	1.51	0.0	0	9.7	17	10			10	13	E 25		
29	61	53	57	1	8	0	0.31	0.0	0	13.1	18	03			10	13	NE 24		
30	67	48	58	2	7	0	T	0.0	0	8.6	16	10			8	2	S 24		
SM	2254	1500			126	61	4.33	0.0		330.2			0		160				
AVG	75.1	50.0								11.0									
										MISC.	31	31	0	0	5.3				

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TEMPERATURE DATA

AVERAGE MONTHLY	62.6
DEPARTURE FROM NORMAL	1.6
HIGHEST 91 ON 10	
LOWEST 39 ON 23	
NUMBER OF DAYS WITH	
MAX 32 OR BELOW	0
MAX 90 OR ABOVE	1
MIN 32 OR BELOW	0
MIN 0 OR BELOW	0
HEATING DEGREE DAYS (BASE 65)	
TOTAL THIS MONTH	126
DEPARTURE FROM NORMAL	-35
SEASONAL TOTAL	148
DEPARTURE FROM NORMAL	-42
COOLING DEGREE DAYS (BASE 65)	
TOTAL THIS MONTH	61
DEPARTURE FROM NORMAL	20
SEASONAL TOTAL	1228
DEPARTURE FROM NORMAL	485

PRECIPITATION DATA

TOTAL FOR THE MONTH 4.39
DEPARTURE FROM NORMAL 1.60
GREATEST IN 24 HOURS 1.73 ON 27-28

SNOWFALL, ICE PELLETS

TOTAL FOR THE MONTH 0.0 IN.
GREATEST IN 24 HOURS 0.0 ON
GREATEST DEPTH ON
GROUND 0 ON

BAROMETRIC PRESSURE
(CLIMATOLOGIC STATION
ELEVATION)

HIGHEST SEA-LEVEL 30.27 IN. ON 13
LOWEST SEA-LEVEL 29.46 IN. ON 18

WEATHER

NUMBER OF DAYS-

CLEAR (SCALE 0-3)	11
PARTLY CLOUDY (SCALE 4-7)	7
CLOUDY (SCALE 8-10)	12
WITH 0.01 INCH OR MORE PRECIP	10
WITH 0.10 INCH OR MORE PRECIP	7
WITH 0.50 INCH OR MORE PRECIP	2
WITH 1.00 INCH OR MORE PRECIP	2

WEATHER SYMBOLS

1-FOG
2-FOG W/VISIBILITY
1/4 MILE OR LESS
3-THUNDER
4-ICE PELLETS
5-HAIL
6-GLAZE OR RIME
7-DUSTSTORM OR
SANDSTORM
8-SMOKE OR HAZE
9-BLOWING SNOW
X-TORNADO

*- INDICATES FASTEST ONE-MINUTE WIND
SPEED AND ITS DIRECTION

B12

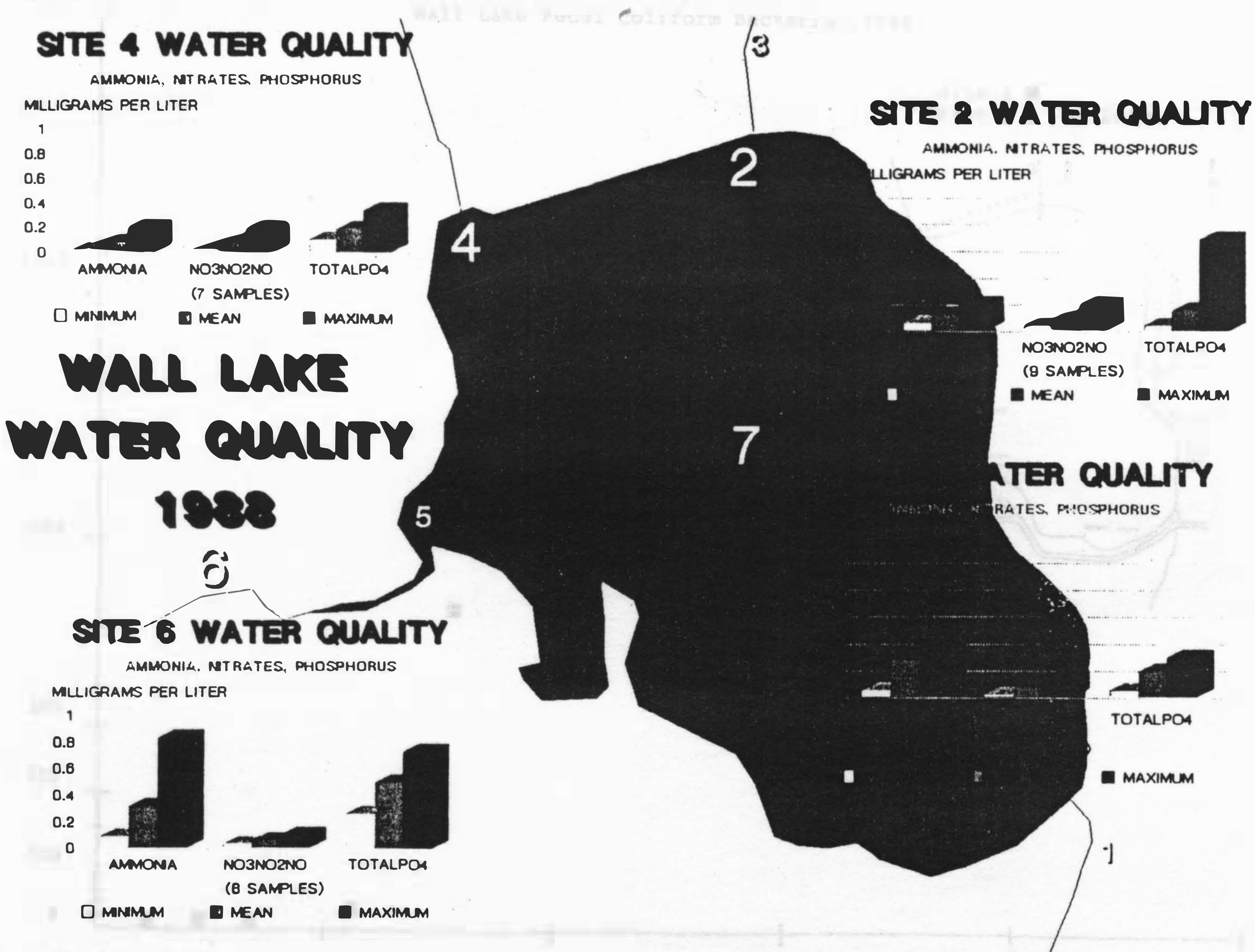
APPENDIX C

WATER QUALITY ANALYSES

1988 Wall Lake Water Sample Analysis

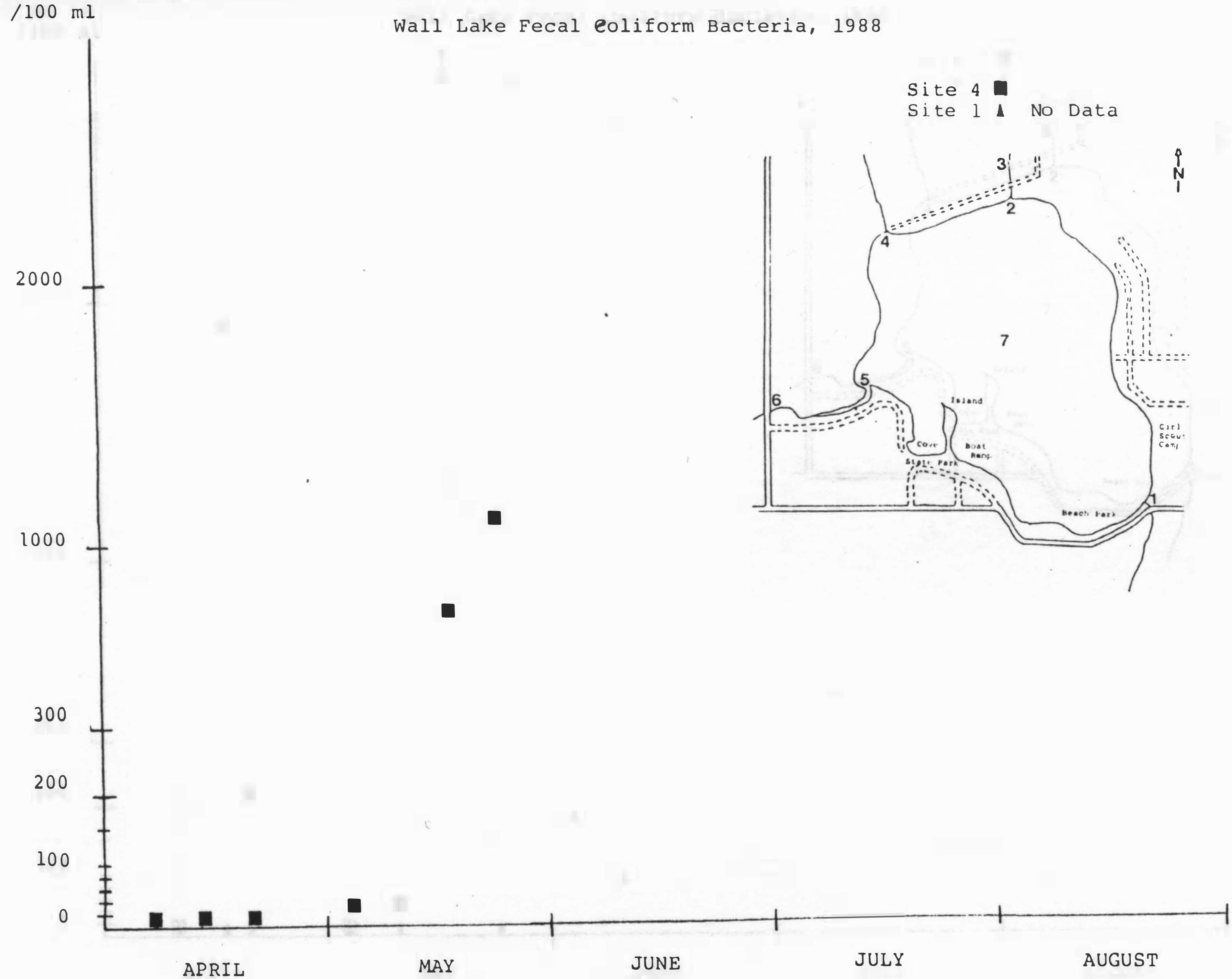
Date	Site	Conduct. / °C.	pH	Alk. mg/L	Total Solids mg/L	Susp. Solids mg/L	Ortho-PO_4 mg/L	Total PO_4 mg/L	NH_4 mg/L	Nitrogen NO_3-NO_2 mg/L	TKN-N mg/L	Dis. Oxygen mg/L	Fecal Colif. /100ml
4-13	2	2226	8.21	344	2308	5	.030	.090	.13	1.68	1.59		10
	4	2329	7.94	336	2540	114	.120	.280	.07	1.513	1.42		3
	5	1440	8.64	158	1292	28	.02	.130	.09	1.521	1.48		1
	6	2299	7.66	280	2392	10	.390	.450	.12	1.22	1.16		6
4-27	2	2237	8.05	236	2440	9	.03	.030	.12	1.65	1.54		1
	3	2472	7.81	268	2452	72	.230	.330	.17	3.77	1.53		1900
	4	2296	7.77	260	2136	5	.100	.140	.07	.963	.77		6
	5	1577	8.28	160	1328	15	.060	.090	.07	1.30	1.27		1
	6	2351	8.31	219	2380	10	.360	.460	.10	1.34	1.28		14
4-28	7S	1530	8.41	160	1264	22	.020	.050	.01	1.77	1.75		est2
	7B	1530	8.15	158	1256	14	.010	.260	.002	2.282	2.14		1
4-29	2	2531	7.97	260	2536	4	.020	.050	.11	1.541	1.50		1
	3	2484	7.80	328	2824	12	.190	.330	.22	3.144	1.63		230
	4	2325	7.71	252	2276	5	.080	.110	.08	1.071	1.05		1
	5	1577	8.41	172	1332	1	.020	.060	.08	1.101	1.09		4
	6	2443	7.83	244	2402	2	.320	.380	.12	1.371	1.33		1
5-2	2	2472	8.51	276	2788	2	.020	.120	.10	1.381	1.33		1
	4	2266	8.22	336	2264	4	.090	.120	.06	.721	.69		29
	5	1554	8.42	168	1260	14	.030	.130	.08	1.711	1.69		10
	6	2472	8.20	284	2576	4	.360	.430	.10	1.562	1.52		4
5-22	2	1849	8.26	184	1812	6	.04	.11	.16	.10	1.16		
	3	3629	8.31	304	3856	38	.48	.64	.40	4.434	3.65		47
	4	2288	8.21	332	2492	14	.18	.26	.06	.06	.97		
	5	1502	8.32	188	1380	54	.03	.27	.33	.165	2.45		
	6	2300	8.20	208	2328	27	.57	.70	.09	.06	1.66		
5-23	2	3582	8.36	352	3868	37	.48	.64	.36	3.26	3.01		17000
	3	1976	8.28	240	2068	18	.04	.15	.18	.104	1.47		17000
	4	2369	8.08	340	2408	14	.14	.21	.09	.052	.92		740
	5	2369	8.33	220	2184	10	.56	.70	.11	.095	.70		320
	6	1629	8.27	180	1472	42	.09	.27	.43	.106	1.97		1300
	7S	1467	8.37	172	1336	7	.07	.12	.46	.09	1.34	6.8	7
	7B	1545	7.77	176	1388	13	.07	.11	.47	.101	1.51	4.5	13
5-24	2	2017	7.20	244	2132	5	.04	.08	.09	.103	1.37		13
	4	3446	8.37	352	2512	12	.11	.16	.03	.021	.55		1100
	5	1668	8.07	188	1672	50	.09	.29	.62	.157	2.20		350
	6	2390	8.35	24[illegible]	2340	13	.55	.74	.11	.104	2.30		1000

6-1	6												
6-2	2	3005	8.24	348	2932	8	.04	.10	.20	.07	1.74		180
	5	1479	8.68	172	1390	69	.02	.32	.18	.101	3.79		700
	6	2225	8.08	348	2496	106	.52	.63	.84	.085	2.37		4900
6-3	2	2936	8.10	364	3480	12	.05	.10	.12	.08	1.89		57
	5	1063	8.55	168	1664	92	0	.39	.09	.18	4.34		330
	6	2253	8.01	384	2716	94	.54	.70	.77	.062	2.23		1300
6-20	7S	1550	8.67	166	1332	7		.21	.52	.049	2.93		3
	7B	1465	8.67	162	1340	13		.18	.34	.047	2.67		1
6-21	5												76
	6												920
6-28	7S	1250	9.00	223	1540	27	.08	.23	.05	.03	1.99	2.2	22
	7B	1288	8.76	198	1486	30	.08	.20	.08	.03	1.98	3.5	7
7-19	7S	1723	8.52	185.8	1492	24	.13	.26	.29	.065	2.24	6.4	22
	7B	1738	8.51	183.7	1520	30	.12	.30	.35	.087	2.60	7.0	22
7-26	7S	1630		182	1604	13	.18	.33	.57	.112	2.54		22
	7B	1570	8.39	191	1612	78	.18	.45	.61	.143	3.06		22
8-4	7S	1752	8.23	186	1496	16	.14	.28	.31	.065	2.21		22
	7B	1934	8.11	182	1532	35	.15	.33	.27	.054	2.57		22
8-9	7S	1760	8.54	203	1530		.12	.25	.13	.063	2.22		20
	7B	1702	8.56	207	1536		.13	.26	.24	.083	1.69		20
8-18	7S	1600	8.76	189	1560		.04	.16	.18	.08	2.00		20
	7B	1590	8.82	198	1526		.04	.15	.15	.061	2.12		20
8-30	7S												20
	7B												20
8-31	7S	1690	8.64	176	1530	39	.01	.17	.06	.09	2.63		
	7B	1700	8.67	204	1560	39	.01	.18	.03	.081	2.35		
9-27	7S	1719	8.34	131	1484	16	.01	.10	.45	.08	5.53	8.2	170
	7B	1755	8.26	170	1420	17	.01	.09	.37	.069	5.26	8.8	170


SITE 4 WATER QUALITY
AMMONIA, NITRATES, PHOSPHORUS
MILLIGRAMS PER LITER
1
0.8
0.6
0.4
0.2
0
AMMONIA
NO3NO2NO
(7 SAMPLES)
TOTALPO4
MINIMUM
MEAN
MAXIMUM
WALL LAKE
WATER QUALITY
1988
SITE 2 WATER QUALITY
AMMONIA, NITRATES, PHOSPHORUS
LLIGRAMS PER LITER
NO3NO2NO
(9 SAMPLES)
TOTALPO4
MEAN
MAXIMUM
TER QUALITY
RATES, PHOSPHORUS
TOTALPO4
MAXIMUM
SITE 6 WATER QUALITY
AMMONIA, NITRATES, PHOSPHORUS
MILLIGRAMS PER LITER
1
0.8
0.6
0.4
0.2
0
AMMONIA
NO3NO2NO
(8 SAMPLES)
TOTALPO4
MINIMUM
MEAN
MAXIMUM
2
3
4
5
6
7

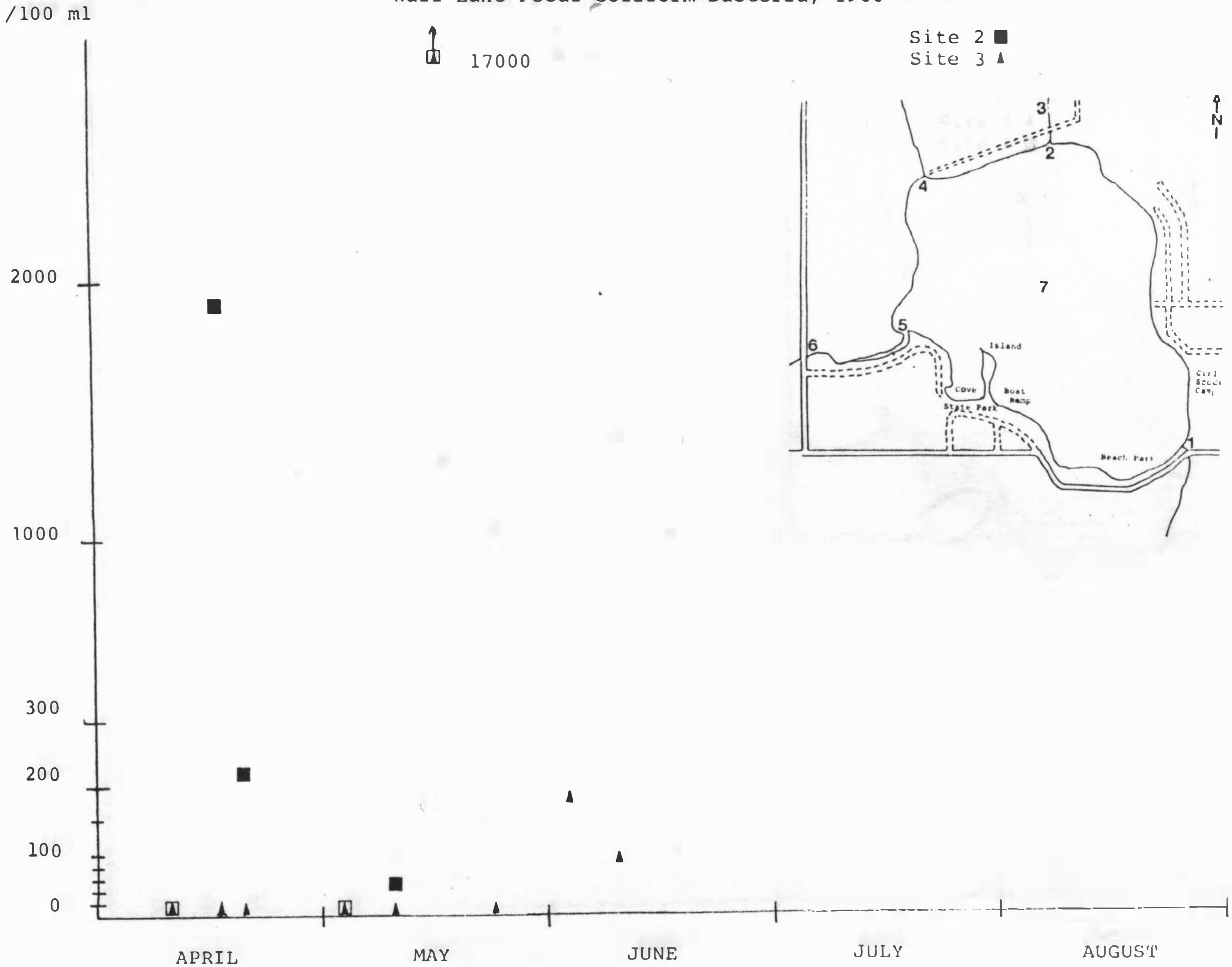
Credit: DWNR

Wall Lake Fecal Coliform Bacteria, 1988

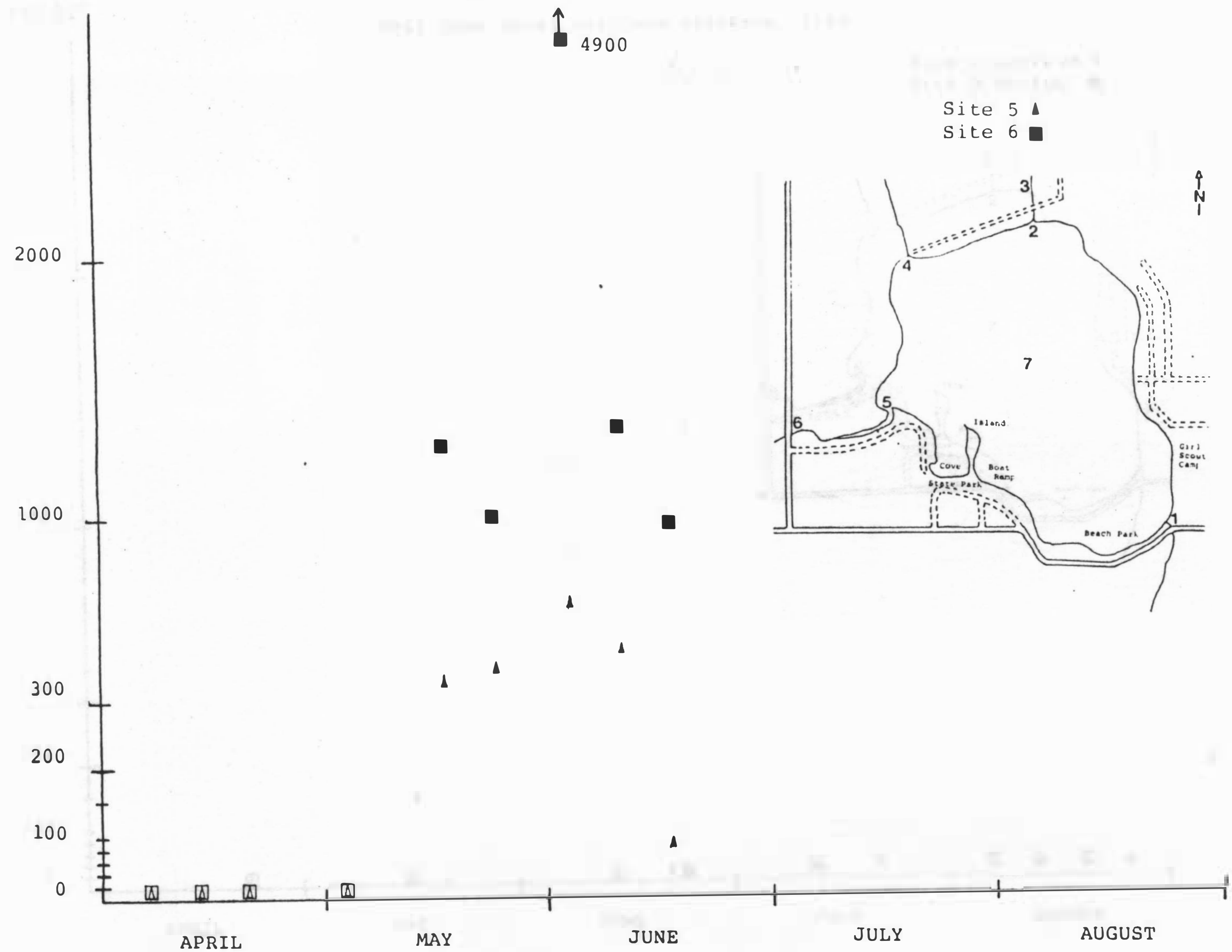


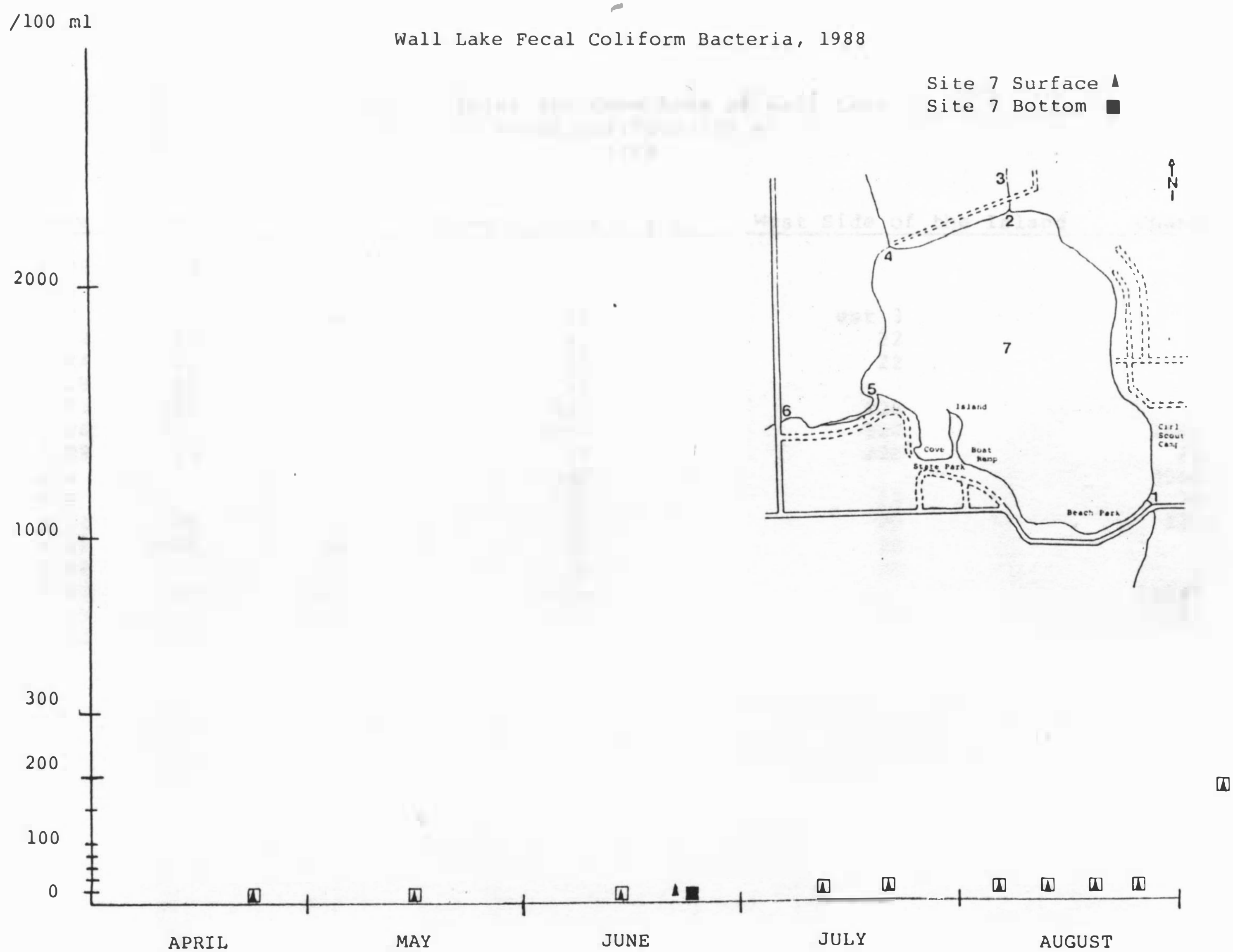
C3

Wall Lake Fecal Coliform Bacteria, 1988



Wall Lake Fecal Coliform Bacteria, 1988




/100 ml
Wall Lake Fecal Coliform Bacteria, 1988
Site 7 Surface
Site 7 Bottom
2000
1000
300
200
100
0
APRIL
MAY
JUNE
JULY
AUGUST
N
1
2
3
4
5
6
7
Island
Cove
Boat Ramp
State Park
Beach Park
Girl Scout Camp

Inlet and Cove Area of Wall Lake
Fecal Coliform/100 ml
1988

Date	Cove	Site 5	Between Sites 5 & 6	West Side of the Island	Channel
6-28	3				
7-5	15				
7-7		16	16	est 3	
7-12	22		91	22	
7-14	22	92	92	22	
7-19	22	22	92		
7-21	220	920	220	220	
7-26	220		1600	920	1600
7-28	22		22	220	22
8-4			330		3500
8-9			110	22	22
8-11	20		20	20	130
8-16	2400	20	20	20	
8-18		20	20	20	
8-23	330	5400	16000		16000
8-25		1300	110	20	1300
8-30	20				

CAUTION!

THIS AREA IS UNSAFE FOR SWIMMING

UNTIL FURTHER NOTICE

PLEASE USE THE PUBLIC SWIMMING BEACH

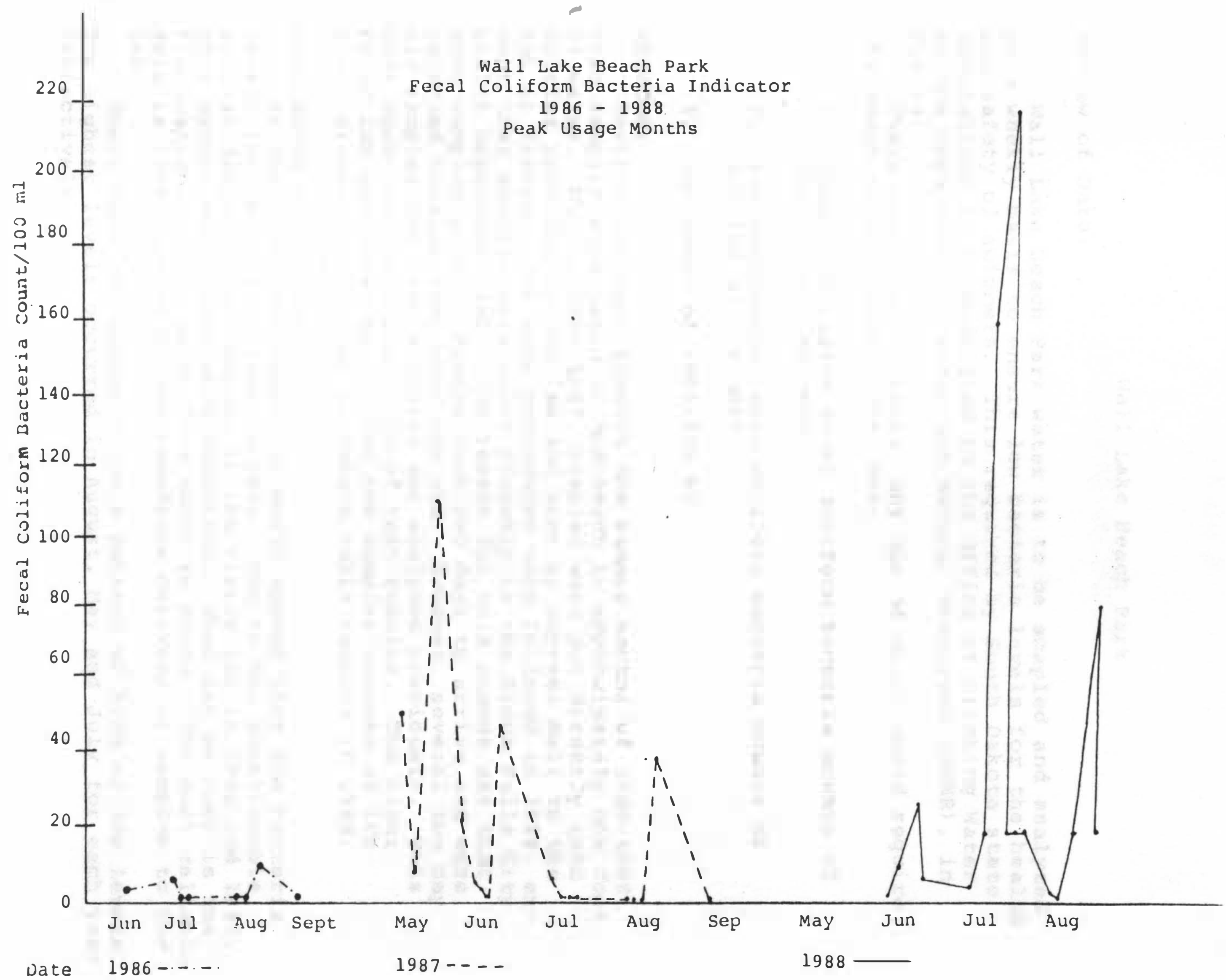
SOUTH DAKOTA CLEAN LAKES PROGRAM
DEPARTMENT OF WATER AND NATURAL RESOURCES

Wall Lake Beach Park
Fecal Coliform Bacteria Indicator
1986 - 1988
Peak Usage Months

Date	Time	Test Date	Lab #	Total Coliform	Fecal Colif.
8-30-88	10:30A	8-30	083013		20/100 ml
8-23	10:30	8-23	082315		80
8-16	10:30	8-16	081618		20
8-8	10:00	8-8	080802	110	2
8-3	9:30	8-3	080306	130	4
7-27-88	9:30	7-27	072701		22
7-26	10:30	7-26	072621		22
7-25	9:00	7-25	072501		22
7-21	9:15	7-24	072131		220
7-21	4:15P		072130		220
7-19	10:30	7-19	071917		160
7-12	9:00	7-12	071214		22
7-5	9:00	7-5	070504		est6
6-28-88	8:45	6-28	062807		est9
6-21	9:00	6-21	062106		32
6-14	9:00	6-14	061406		13
6-7	9:15	6-7	060704		est4
5-23-88	9:50	5-25	Rejected, too old.		
9-1-87	9:00	9-2	27		2
8-31	8:30	9-1	6		38
8-24	9:00	8-25	276		2
8-17	9:30	8-18	192		2
8-10	9:00	8-11	88		2
8-4	9:15	8-4	39		2
7-28	9:00	7-29	143		2
7-20	9:30	7-21	30		2
7-13	9:00	7-14	185		2
7-6	9:00	7-7	71		8
6-30-87	9:30	6-30	423		48
6-22	9:30	6-16	34		2
6-15	9:30	6-16	193		4
6-9	9:15	6-11	92		6
6-1	9:15	6-2	5		24
5-26	9:00	5-27	284		110

Wall Lake Beach Park
Fecal Coliform Bacteria Indicator
Continued.

Date	Time	Test Date	Lab#	Total Coliform	Fecal Colif.
5-19-87	9:30	5-20	196		8
5-11	9:00		97		50
9-2-86	9:00	9-3	13		2
8-25	9:00	8-26			10
8-18	10:20	8-20	Rejected, too old.		
8-11		8-12	120		2
8-4	9:15	8-5	37		2
7-28	9:15	7-29	466		2
7-21	9:00	7-22	346		2
7-14	9:45	7-15	185		6
6-7	9:30	7-8	82		4


Wall Lake Beach Park
Fecal Coliform Bacteria Indicator
1986 - 1988
Peak Usage Months
Fecal Coliform Bacteria Count/100 ml
220
200
180
160
140
120
100
80
60
40
20
0
Jun
Jul
Aug
Sept
May
Jun
Jul
Aug
Sep
May
Jun
Jul
Aug
Date
1986 -·-·-
1987 - - - -
1988 ——

Wall Lake Beach Park

Review of Data:

Wall Lake Beach Park water is to be smapled and analyzed on a weekly basis to ensure low bacteria levels for the health and safety of swimmers. This required by South Dakota state regulations to be sufmitted to the Office of Drinking Water at the Department of Water and Natural Resources (DWNR), in Pierre.

There are three criteria, any one of which would require the beach to be closed. They are:

1. Three successive fecal coliform bacteria counts of 200/100 ml, or more.

2. Two successive fecal coliform bacteria counts of 300/100 ml, or more.

3. One count of 1000/100 ml.

METHODS:

Testing was done through the summer months of 1986-1988. Grab samples were taken at mid-beach in approximately one foot of water. During 1986-1987, samples were put directly into bottles provided by the lab and sent by express mail to the lab at Pierre. The same procedures were followed in 1988, except that samples were taken directly to the Sioux Falls City Health Department lab. The reason for this change was that some samples sent to Pierre took two days to arrive and were rejected because they were too old. However, several two day old samples had been accepted and analyzed previously. This cast doubt on the reliability of test results. The Sioux Falls lab was asked to analyze the samples because of its close proximity and thus to ensure valid results in 1988.

DISCUSSION OF RESULTS:

As the graph indicates, it would appear that the bacteria levels increased from year to year. Due to the questionable arrival dates of the samples to the Pierre lab in 1986 and 1987, this cannot be a reasonable deduction. What can be seen is the fluctuations in the count from month to month. The most reliable data is 1988 because of the immediate delivery of samples to the lab.

There does not appear to be a pattern of high or low levels. The highest levels occurred in August, May and July for each year respectively

APPENDIX D

NUTRIENTS IN SOILS

SOILS DATA

Field No.	Soil text	pH	Sol. salt	Org. mat. %	N lb/A top	NO_3 total	P lb/A
1	fine	7.1	0.8	3.7	14	46	7
2	fine	7.2	0.7	2.8	16	34	29
3	fine	7.2	0.6	3.4	44	98	33
4	fine	6.9	0.6	3.5	10	24	20
5	fine	7.1	0.5	3.0	8	24	4
CR1	fine	6.7	0.4	4.2	4	12	6
RK1	fine	6.9	0.6	3.3	11	38	10
RK2	fine	7.0	0.6	3.5	34	79	11
RK3	fine	8.2	0.5	4.0	19	45	19
M61	fine	6.8	0.7	4.0	9	28	7
S-1	fine	7.0	0.6	4.7	15	35	34
8	fine	6.9	0.7	3.6	18	71	7
9	fine	7.6	0.5	3.1	20	54	10
10	fine	7.2	0.4	3.0	40	122	26

RECOMMENDATIONS

Add to Field No.	N lb/A	P_2O_5 lb/A
1	65	50
2	76	20
3	15	12
4	86	35
5	72	46
CR1	0	41
RK1	87	53
RK2	45	51
RK3	80	41
M61	0	43
S-1		
8	17	42
9		
10		

Original data sheets may obtained from the Minnehaha County Commission office or the Minnehaha County Extension Office, Sioux Falls, South Dakota.

APPENDIX E

ALGAE ANALYSES

Methods and Materials

Sampling stations were established at Wall Lake, South Dakota, during the spring of 1987. Water samples were procured from the surface of the lake and immediately off the bottom with a grab sampler. The samples were preserved with Lugol's solution.

A 0.1 ml aliquot of each sample was placed in a Palmer-Maloney Nannoplankton Cell and counted at 400X with an Olympus microscope equipped with bright-field optics. In all cases the whole water samples were concentrated to facilitate taxonomic enumeration. Except in a few samples which contained a sparse amount of phytoplankton, 300 units of phytoplankton were counted from each sample. The standard calculation utilized in determining the concentration of organisms with the Palmer-Maloney Nannoplankton Cell is as follows:

$$\text{Organisms per ml} = \frac{C \times 1000\ mm^3}{A \times D \times F}$$

C = number of organisms counted
A = area of a field, mm^2
D = depth of field, mm
F = number of fields counted

In this investigation the strip-count method was utilized where a strip (or multiple strips) was counted in a transect across the counting cell. The volume of sample examined was determined by multipling the area of the counting cell examined by the depth. Therefore, the total number of units/ml (or cells/ml) for a given taxon was determined by the following formula:

$$\text{Units/ml} = \frac{C \times 1000\ mm^3}{A\ (mm^2) \times D\ (mm)}$$

C = number of organisms counted
A = total area counted, mm^2
D = depth of Palmer-Maloney Nannoplankton Cell, 0.4 mm

Example:

1. 548 Actinastrum counted

2. A total length of 42 mm in strips is counted across the counting cell and the width of field at 400X is 0.5 mm for a total area of 21 mm^2. You multiply the 21 mm^2 by the depth of the counting cell which is 0.4 mm. Therefore, the total volume of sample counted is 8.4 mm^3.

3. The 1000 mm^3 represents the volume of a cubic ml. The volume of the Palmer-Maloney Nannoplankton Cell is 0.1 ml or 100 mm^3 so the 1000 mm^3 includes the multiplication factor of 10 to express the phytoplankton in units/ml rather than units/0.1 ml.

4. Concentration Factor. If the whole water sample is examined without concentration this value is 1. If you start with a 150 ml sample and concentrate that to 40 ml your concentration factor would be 3.75. You must divide your final units/ml by this factor to compensate for concentration.

Actinastrum

$$\frac{548 \times 1000\ mm^3}{21\ mm^2 \times 0.4\ mm} = 65238\ units/ml$$

$$\frac{65238}{3.75} = 17397\ units/ml$$

For the purposes of this investigation the following list illustrates what constituted a unit:

Cryptomonads = 1 cell/unit
Diatoms = 1 cell/unit
Colonial Green and Blue-Green Algae = 1 colony/unit
Filamentous Blue-Green Algae = greater than 100 um/unit

In the case of filamentous diatoms, such as Melosira granulata, each cell was counted as a single unit. With filamentous Blue-Green Algae, such as Aphanizomenon flos-aquae and Oscillatoria, extensive fragmentation may occur during the fall as well as during sample aging. Therefore, many trichomes composed of only a few cells are encountered. In these cases the fragments were "added together" to comprise filaments at least 100 um in length which were subsequently counted as a single unit.

Credit: Keith Camburn

June 20, 1988

Regarding: Methods and Materials for algae sampling

Samples are taken from inlake station number 7 as established for the Wall Lake restoration project. Landmarks on the West, North and East sides of the lake are lined up in order to be as consistent as possible in locating the sampling station.

Surface samples are procured by lowering 100ml plastic bottles horizontallly into the water. The samples are preserved with 1ml of Lugol's solution in brown bottles and shaken slightly. ~~Since the~~ bottles are clear, they are stored out of the ~~sunlight~~. Labels are then placed on each bottle to designate the date, location, and depth.

Bottom samples are taken by first measuring the water depth, then lowering the grab sampler until it is just above the bottom. Two brass messengers are then dropped to trigger the closing mechanism. The sampler is raised. About 25-50ml of water is flushed through the sampler drain tube. The water sample bottles are filled, preserved and labeled.

Hope this is what you needed for sampling procedures. Please call if there are any questions.

Don Ortman
528-6575

8255 Congdon Blvd.
Duluth, Minnesota 55804
June 5, 1988

Ms. Jane E. Van Hunnik
Office of Planning & Zoning
Minnehaha County Courthouse
415 North Dakota Avenue
Sioux Falls, South Dakota 57102

Dear Jane:

Please find enclosed my analyses of the two phytoplankton samples from Wall Lake. I honestly expected to find a more developed phytoplankton community by the 23rd of May. It is particularly surprising to find so few diatoms. Although I have no reason to compare Wall Lake with Big Stone Lake, the standing crops at Big Stone Lake on the 8th of April, 1987, ranged from 12222 to 22337 units/ml which is well above the values of 869 and 903 units/ml from the Wall Lake samples. As the summer progresses I would expect the phytoplankton community to change considerable from the May 23rd sampling.

For your information I have enclosed a "draft" of the Methods and Materials I utilized in analyzing your samples. As time permits I would appreciate it if the individuals who actually take the water samples could expand the first paragraph which covers the procurement of the samples.

sent note to Don Ortman 6-9-88 jvh

Sincerely,

Keith

Keith E. Camburn

Wall Lake, South Dakota

May 23, 1988

Sites (in lake #7)

	Top	Bottom
Blue-Green Algae		
Anabaena	17	-
Aphanizomenon flos-aquae	174	15
Chroococcus	-	-
Dactylococcopsis	12	3
Merismopedia	-	-
Microcystis	-	3
Oscillatoria	-	3
Green Algae		
Scenedesmus	-	-
Schroederia	75	87
Stichococcus	-	-
Flagellates	-	-
Green Algae (other)	-	12
Diatoms		
Asterionella formosa	-	-
Cyclotella meneghiniana	-	3
Fragilaria crotonensis	-	-
Melosira granulata	9	21
Nitzschia	3	12
Stephanodiscus niagarae	-	-
Diatoms (centric)	43	237
Diatoms (other)	9	21
Cryptomonads		
Cryptomonas ovata	-	-
Cryptomonas sp.	197	144
Cryptomonad #1	-	-
Cryptomonad #2	281	285
Cryptomonads (other)	9	15
Dinoflagellates		
Ceratium		
(other)	-	6
Algae (flagellates)	17	-
(other)	23	36
TOTAL	869	903

May 23, 1988

In Lake Site #7. The phytoplankton standing crop on this date ranged from 869 units/ml at the lake surface to 903 units/ml at the lake bottom. As expected for this early in the season the standing crop was relatively low. Of particular interest was the occurrence of Cryptomonad #2 in both samples with a nearly identical abundance. A similar situation occurred with Cryptomonas sp. The only obvious differences between these samples (surface and bottom) was the more abundant occurrence of Aphanizomenon flos-aquae at the surface and the more abundant occurrence of a small, centric diatom at the bottom.

Wall Lake, South Dakota

June 20, 1988

Sites (in lake #7)

	Top	Bottom
Blue-Green Algae		
Anabaena	-	-
Aphanizomenon flos-aquae	5018	292
Chroococcus	-	-
Dactylococcopsis	-	-
Merismopedia	-	-
Microcystis	-	-
Oscillatoria	-	4
Green Algae		
Scenedesmus	-	-
Schroederia	34	18
Stichococcus	-	-
Flagellates	-	-
Green Algae (other)	-	-
Diatoms		
Asterionella formosa	-	-
Cyclotella meneghiniana	-	-
Fragilaria crotonensis	-	-
Melosira granulata	-	-
Nitzschia	-	-
Stephanodiscus niagarae	-	-
Diatoms (centric)	-	7
Diatoms (other)	-	4
Cryptomonads		
Cryptomonas ovata	-	-
Cryptomonas sp.	-	-
Cryptomonad #1	-	-
Cryptomonad #2	34	39
Cryptomonads (other)	-	7
Dinoflagellates		
Ceratium	-	-
(other)	-	-
Algae (flagellates)	-	-
(other)	34	28
TOTAL	5120	399

June 20, 1988

In Lake Site #7. The phytoplankton standing crop on this date ranged from 5120 units/ml at the lake surface to 399 units/ml at the lake bottom. Unlike the samples taken on May 23, 1988, which exhibited little difference between the phytoplankton in the surface and bottom samples, the samples taken on June 20, 1988, are very different. As expected the Aphanizomenon flos-aquae is becoming very common in the warm surface water. Also of interest is the relative lack of cryptomonds which were rather common in the May samples, and the apparent lack of small, centric diatoms.

8255 Congdon Blvd.
Duluth, Minnesota 55804
June 24, 1988

Ms. Jane E. Van Hunnik
Office of Planning & Zoning
Minnehaha County Courthouse
415 North Dakota Avenue
Sioux Falls, South Dakota 57102

Dear Jane:

Please find enclosed my analyzes of the two phytoplankton samples from Wall Lake which were collected on June 20th. These samples arrived in the June 22nd mail which indicates that things are spending up with the mail. These samples were rather "typical" with the ever present <u>Aphanizomenon</u> becoming increasingly common which is a trend which should last into September.

Also enclosed in a billing invoice for these first four samples. Please let me know this type of invoice is unsatisfactory. As we discussed before I will be on vacation until July 16th so any samples collected between now and then should be kept in a refrigerator in Sioux Falls until I return. I trust that you are keeping warm (it's 47 today in Duluth).

Sincerely,

Keith E. Camburn

8255 Congdon Blvd.
Duluth, Minnesota 55804
July 27, 1988

Ms. Jane E. Van Hunnik
Office of Planning & Zoning
Minnehaha County Courthouse
415 North Dakota Avenue
Sioux Falls, South Dakota 57102

Dear Jane:

Please find enclosed my analyses of the five phytoplankton samples from Wall Lake which were collected on June 28th and July 19th. The samples from June 28th were not labeled "top" and "bottom". In the future the samples should include a label with site name/number, date of collection, and location within the water column. Once again these samples were "typical" with the ever present Aphanizomenon being the the most abundant alga present.

Also enclosed is a billing invoice for these five samples. I am returning your 9 bottles under separate cover.

Sincerely,

Keith E. Camburn

Wall Lake, South Dakota

July 19, 1988

Sites (in lake #7)

	Top	Bottom
Blue-Green Algae		
Anabaena	-	-
Aphanizomenon flos-aquae	2647	4060
Chroococcus	-	-
Dactylococcopsis	-	-
Merismopedia	-	-
Microcystis	-	-
Oscillatoria	-	-
Green Algae		
Scenedesmus	-	-
Schroederia	9	30
Stichococcus	-	-
Flagellates	9	-
Green Algae (other)	-	-
Diatoms		
Asterionella formosa	-	-
Cyclotella meneghiniana	-	-
Fragilaria crotonensis	-	-
Melosira granulata	-	133
Nitzschia	-	-
Stephanodiscus niagarae	-	-
Diatoms (centric)	-	-
Diatoms (other)	-	-
Cryptomonads		
Cryptomonas ovata	-	-
Cryptomonas sp.	-	-
Cryptomonad #1	-	-
Cryptomonad #2	54	192
Cryptomonads (other)	-	-
Dinoflagellates		
Ceratium	-	-
(other)	-	-
Algae (flagellates)	-	-
(other)	9	15
TOTAL	2728	4430

Wall Lake, South Dakota

June 28, 1988

Sites (in lake #7)

	# 1	# 2	Surface Skim
Blue-Green Algae			
Anabaena	-	-	
Aphanizomenon flos-aquae	3626	5224	7575757
Chroococcus	-	-	
Dactylococcopsis	-	-	
Merismopedia	-	-	
Microcystis	-	-	
Oscillatoria	-	-	
Green Algae			
Scenedesmus	-	-	
Schroederia	24	-	
Stichococcus	-	-	
Flagellates	12	-	
Green Algae (other)	-	-	
Diatoms			
Asterionella formosa	-	-	
Cyclotella meneghiniana	-	-	
Fragilaria crotonensis	-	-	
Melosira granulata	-	-	
Nitzschia	-	-	
Stephanodiscus niagarae	-	-	
Diatoms (centric)	-	-	
Diatoms (other)	-	-	
Cryptomonads			
Cryptomonas ovata	-	-	
Cryptomonas sp.	-	-	
Cryptomonad #1	-	-	
Cryptomonad #2	24	35	
Cryptomonads (other)	-	-	
Dinoflagellates			
Ceratium	-	-	
(other)	-	-	
Algae (flagellates)	-	-	
(other)	12	-	
TOTAL	3698	5259	7575757

June 28, 1988

In Lake Site #7. The phytoplankton standing crop on this date ranged from 3698 units/ml in Sample # 1 to 5259 units/ml in Sample # 2 (the samples received were not labeled "top" and "bottom"). As in previous samples the most abundant alga was the blue-green Aphanizomenon flos-aquae. A sample taken directly from a floating bloom of blue-green algae was also collected by skimming the surface of Wall Lake. In this "Pea Soup" Aphanizomenon was the only alga present and occurred with an abundance of 7,575,757 units/ml.

During sampling at Wall Lake in June the field crew noticed areas of intense blue-green color in the water. These areas of concentration are caused by lake currents which concentrate the Aphanizomenon. If these aggregations of algae represent unhealthy, old, or dying specimens the photosynthetic pigments, the phycobiliproteins and in particular the blue pigment phycocyanin, will be released directly into the water causing and intense blue color.

July 19, 1988

In Lake Site #7. The phytoplankton standing crop on this date ranged from 2728 units/ml at the lake surface to 4430 units/ml at the lake bottom. Of interest is the occurrence of Melosira granulata in the bottom sample as well as more specimens of Cryptomonad #2.

Wall Lake, South Dakota

July 26, 1988

Sites (in lake #7)

	Top	Bottom	Surface Skim NW Inlet
Blue-Green Algae			
Anabaena	-	-	
Aphanizomenon flos-aquae	4500	4590	disassociated into cell fragments
Chroococcus	-	-	
Dactylococcopsis	-	-	
Merismopedia	-	-	
Microcystis	-	-	
Oscillatoria	-	71	
Green Algae			
Scenedesmus	-	-	
Schroederia	20	-	
Stichococcus	-	-	
Flagellates	-	-	
Green Algae (other)	-	54	
Diatoms			
Asterionella formosa	-	-	
Cyclotella meneghiniana	-	-	
Fragilaria crotonensis	-	-	
Melosira granulata	-	214	
Nitzschia	-	250	
Stephanodiscus niagarae	-	-	
Diatoms (centric)	-	-	
Diatoms (other)	-	71	
Cryptomonads			
Cryptomonas ovata	-	-	
Cryptomonas sp.	20	-	
Cryptomonad #1	-	-	
Cryptomonad #2	1507	125	
Cryptomonads (other)	-	-	
Dinoflagellates			
Ceratium	-	-	
(other)	-	-	
Algae (flagellates)	-	-	
(other)	-	-	
TOTAL	6047	5375	

Wall Lake, South Dakota

August 4, 1988

	Sites (in lake #7)	
	Top	Bottom
Blue-Green Algae		
Anabaena	-	-
Aphanizomenon flos-aquae	4523	3560
Chroococcus	-	-
Dactylococcopsis	-	-
Merismopedia	-	-
Microcystis	-	-
Oscillatoria	-	14
Green Algae		
Scenedesmus	-	-
Schroederia	54	43
Stichococcus	-	-
Flagellates	-	-
Green Algae (other)	127	43
Diatoms		
Asterionella formosa	-	-
Cyclotella meneghiniana	-	-
Fragilaria crotonensis	-	-
Melosira granulata	-	-
Nitzschia	18	-
Stephanodiscus niagarae	-	-
Diatoms (centric)	72	29
Diatoms (other)	-	29
Cryptomonads		
Cryptomonas ovata	-	-
Cryptomonas sp.	-	101
Cryptomonad #1	-	-
Cryptomonad #2	36	188
Cryptomonads (other)	36	29
Dinoflagellates		
Ceratium	-	-
(other)	-	-
Algae (flagellates)	109	-
(other)	362	318
TOTAL	5337	4354

July 26, 1988

In Lake Site #7. The phytoplankton standing crop on this date was 6047 units/ml at the lake surface and 5375 units/ml at the lake bottom. As in the June 28th and July 19th samples, the most abundant alga present in both samples was Aphanizomenon flos-aquae. The most obvious difference from these previous samples was the abundance of Cryptomonad #2 in the surface sample (1507 units/ml). The lake bottom sample contained a large amount of detritus and based on that fact, along with the presence of benthic diatoms, suggest that in sampling the bottom substrate was disturbed. A "surface skim" composed of blue-green algae was taken from the NW Inlet and unlike the June 28th sample, this sample contained masses of Aphanizomenon flos-aquae which had disassociated into cell fragments which made the determination of units/ml impossible.

August 4, 1988

In Lake Site #7. The phytoplankton standing crop on this date was 5337 units/ml at the lake surface and 4354 units/ml at the lake bottom. As previously, Aphanizomenon flos-aquae was the most abundant alga present.

Wall Lake, South Dakota

August 18, 1988

Sites (in lake #7)

	Top	Bottom	Surface Skim near shore
Blue-Green Algae			
Anabaena	-	-	
Aphanizomenon flos-aquae	5168	3895	large masses of clumped Aphanizomenon
Chroococcus	-	-	
Dactylococcopsis	-	-	
Merismopedia	-	-	
Microcystis	-	20	
Oscillatoria	23	20	
Green Algae			
Scenedesmus	-	-	
Schroederia	-	-	
Stichococcus	-	-	
Flagellates	-	-	
Green Algae (other)	-	-	
Diatoms			
Asterionella formosa	-	-	
Cyclotella meneghiniana	1224	1866	
Fragilaria crotonensis	-	-	
Melosira granulata	113	61	
Nitzschia	45	61	
Stephanodiscus niagarae	-	-	
Diatoms (centric)	-	-	
Diatoms (other)	-	-	
Cryptomonads			
Cryptomonas ovata	-	-	
Cryptomonas sp.	-	-	
Cryptomonad #1	-	-	
Cryptomonad #2	-	-	
Cryptomonads (other)	-	-	
Dinoflagellates			
Ceratium	-	-	
(other)	-	-	
Algae (flagellates)	-	-	
(other)	159	223	
TOTAL	6732	6146	

August 18, 1988

In Lake Site #7. The phytoplankton standing crop on this date was 6732 units/ml at the lake surface and 6146 units/ml at the lake bottom. As in the June 28th, July 19th, and July 26th samples, the most abundant alga present in both samples was Aphanizomenon flos-aquae. It is interesting to note the appearance of the diatom, Cyclotella meneghiniana, which had not previously been noted in the Wall Lake samples. This is an extremely common centric diatom often associated with eutropic waters. A "surface skim" from a near shore area contained masses of Aphanizomenon flos-aquae. These masses appeared healthy and due to clumping the determination of units/ml was not possible.

Jane-for your information: Aphanizomenon = Ah-fan-ah-zom-in-on