DIAGNOSTIC/FEASIBILITY STUDY REPORT
BURKE LAKE
GREGORY COUNTY, SOUTH DAKOTA

OFFICE OF WATER RESOURCES MANAGEMENT
SOUTH DAKOTA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

April 1991

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Prepared by

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SUMMARY

Burke Lake is a man-made lake that has been experiencing nuisance growth of blue-green algae and aquatic macrophytes, odor problems and fish kills. This study was initiated to provide a general assessment of the water quality of Burke Lake, identify sources of lake water quality degradation, and to propose restoration alternatives to improve the lake's water quality.

In March 1989, the South Dakota Department of Environment and Natural Resources began a Diagnostic/Feasibility Study on Burke Lake under a contracted agreement with the City of Burke and with the participation of the South Dakota Department of Game, Fish and Parks.

The study consisted of water quality monitoring of the lake and it's tributaries to evaluate watershed impacts on the lake. Limited groundwater monitoring was also conducted to evaluate potential impacts from an abandoned city landfill in the lake's watershed. In addition, sedimentation and algal surveys were conducted. Most field monitoring and surveys were completed by July, 1990. Groundwater monitoring was completed in October, 1990.

Results of the study indicated that tributaries to the lake repeatedly experienced contamination with high levels of fecal coliform bacteria and nutrients. Contaminants carried to the lake from the tributaries are the primary cause of the lake water quality degradation.

Watershed sources of the tributary loads of bacteria and nutrients included a dairy feedlot operation and animal pastures upgradient of the lake.

Data from this study and from an earlier groundwater study conducted by the South Dakota Geological Survey for the City of Burke (Hammond, 1990) indicate that nutrient contamination of the groundwater in the watershed is occurring. However, the nutrient levels found in groundwater were not substantial enough to account for the gross nutrient contamination of the tributaries.

The data suggest that a potential source of groundwater nutrient contamination exists within or close to the southeastern city limits. The abandoned city landfill did not appear to be the source of nutrients found in groundwater downgradient from the landfill. A more extensive groundwater investigation would be needed to thoroughly assess groundwater quality in the watershed, sources of contamination, and impacts on the lake.

Recommendations for lake restoration included 1) implementing appropriate engineering and conservation practices to control surface water pollution from dairy and pasture practices in the watershed, 2) conducting education activities directed toward all watershed land owners to reduce nutrient and sediment contributions to water resources, 3) undertaking a more extensive groundwater quality and lake impact study, 4) repairing the dam, 5) removing nutrient laden sediments from the lake, 6) removing nutrients from the lake water, 7) creating supplemental fisheries habitat and 8) designing and implementing an ongoing lake management/protection plan.

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BURKE LAKE DIAGNOSTIC/FEASIBILITY REPORT

INTRODUCTION

Burke Lake has been experiencing degraded conditions which impair the lake's designated beneficial uses which include sport fishing and swimming. The lake experiences dense algal blooms, nuisance growth of aquatic macrophytes, odor problems and fish kills. In addition, there have been reports of swimmers experiencing ear and eye infections, and itching.

In response to local inquiries for assistance, the State of South Dakota Department of Environment and Natural Resources (DENR) working in cooperation with the the local community, designed a Diagnostic/Feasibility (D/F) study for the lake. The study was implemented to identify and assess the current condition of the lake, determine water quality problems and pollution sources, and develop lake restoration alternatives.

Comprehensive water quality monitoring of tributary and in-lake waters was conducted during the period from March 28, 1989 through June 26, 1990. A sedimentation survey was conducted in February, 1989 and algal quantifications were conducted from March, 1989 through March, 1990. In addition, a groundwater investigation was conducted during October, 1990 to evaluate potential impacts from an abandoned landfill located within the watershed.

Data summaries, discussions, and management recommendations are presented in this report.

Study Area Description

Burke Lake is located within Gregory County in the extreme south central area of South Dakota. The lake has a surface area of approximately 36 acres and a watershed which encompasses 1568 acres (Figure 1).

The Burke Lake watershed consists primarily of shortgrass prairie and rangeland with a small portion being cultivated. A dairy operation is located along the southwest shore of the lake. The soils of the entire watershed are of the Anselmo-Holt-Tassel association which identifies them as well-drained loamy soils on the uplands underlain by sand or sand and gravel.

Average annual precipitation within the watershed is nearly 22 inches. Burke Lake is the principle receiving water body in the watershed and it discharges into Coon Creek which flows east to the Missouri River.

Burke Lake provides angling, boating, picnicking, camping and swimming opportunities. Following the lake construction in 1936, black bullheads and largemouth bass were the dominant fisheries. A later attempt to establish trout in the lake was unsuccessful. Currently, bullheads, perch, northern pike, crappie, bluegill and largemouth bass inhabit the lake.

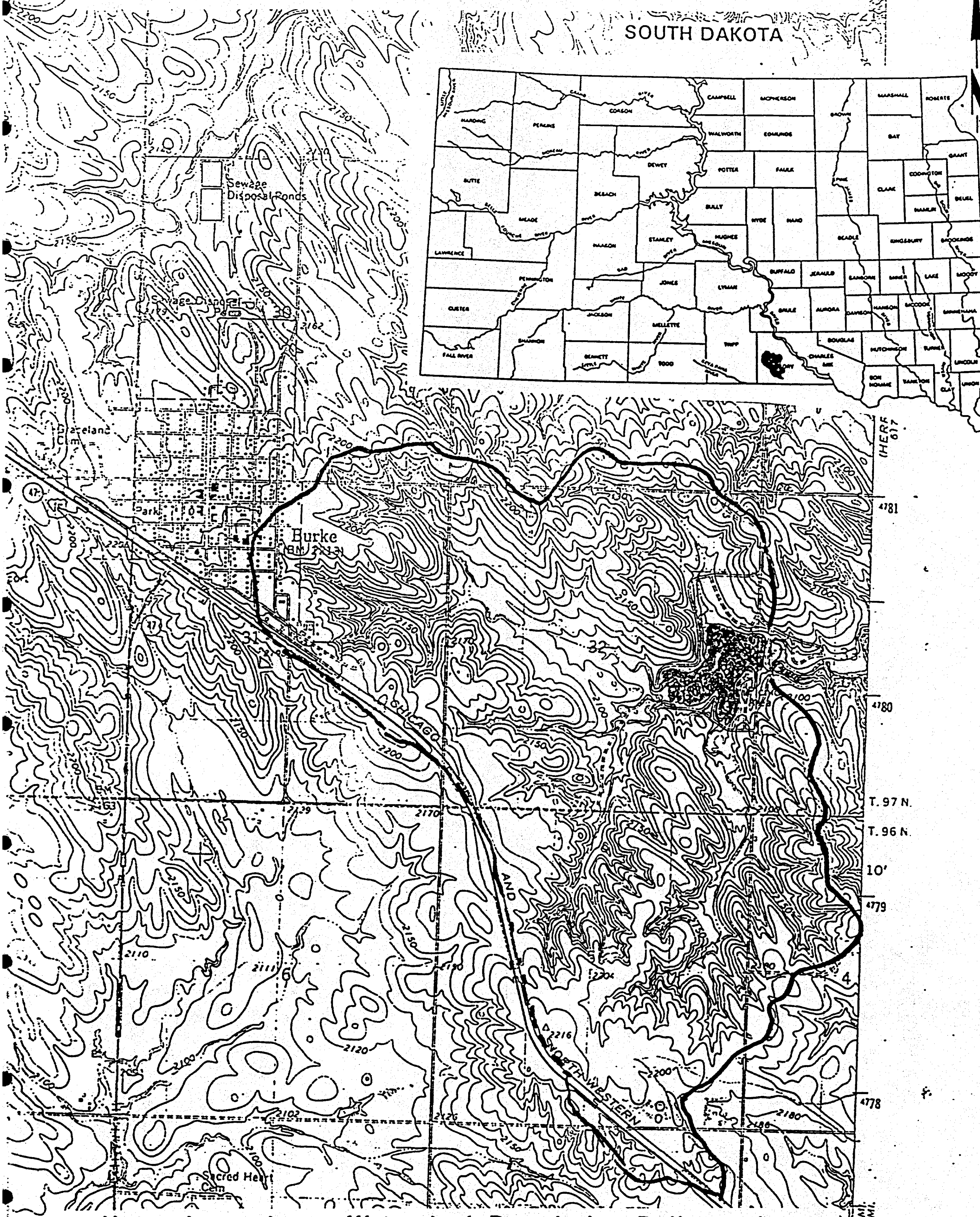
Burke Lake has experienced several partial and two complete winterkills (SD GFP, 1985).

Background/Historical Information

Burke Lake was constructed in 1936 as a Work Projects Administration (WPA) project with trees being planted around the lake in 1949. In 1967, the City of Burke deeded the lake to the State of South Dakota under the understanding that the state would develop the lake as a recreation area.

The City of Burke records indicate that the lake has experienced algae and aquatic vegetation problems since the late 1950's. After receiving complaints expressing concern that the dairy farm located adjacent to the lake was polluting Burke Lake, the DENR inspected the operation in 1986. In March 1986, the DENR requested that a plan for controlling runoff from the dairy feedlot be developed and implemented by the feedlot owner. No action was taken by the owner.

Figure 1. Burke Lake Study Site Location Map.



Note: Approximate Watershed Boundaries Delineated.

Water Quality Standards

The water quality standards for Burke Lake are based upon the beneficial uses assigned to the lake by the State of South Dakota. Each beneficial use category has a set of water quality criteria established for it. Burke Lake has the assigned beneficial uses of warmwater semipermanent fish life propagation, immersion recreation, limited contact recreation and wildlife propagation and stock watering. The water quality criteria for Burke Lake are a summary of the criteria defined for all the use categories using the most stringent values for individual parameters. The water quality criteria for Burke Lake are listed in Table 1.

Table 1. Burke Lake Water Quality Standards

Parameter	Criterion
Total Chlorine Residual	< 0.02 mg/l
Un-Ionized Ammonia Nitrogen	≤0.04 mg/l
Total Cyanide	≤ 0.02 mg/l
Free Cyanide	≤ 0.005 mg/l
Dissolved Oxygen	>5.0 mg/l
Undissassociated Hydrogen Sulfide	≤0.002 mg/l
pH	>6.5 units and
	<8.3 units
Total Alkalinity	≤750 mg/l
Total Dissolved Solids	≤2500 mg/l
Conductivity	≤4000 micromhos/cm
Nitrates	≤50 mg/l (as N)
Suspended Solids	≤90 mg/l
Temperature	≤90° F
Polychlorinated Biphenyls	≤0.000001 mg/l
Fecal Coliform Organisms	≤200 per 100 ml*

*Based on the mean of a minimum of 5 samples obtained during separate 24-hour periods for any 30-day period, and this value may not be exceeded in more than 20 percent of the samples examined in the 30-day period. A sample may not exceed 400 per 100 ml in any one sample from May 1 to September 30.

METHODS AND MATERIALS

Lake and Tributary Sampling

Water samples were collected from six sampling sites in the Burke Lake study area (Figure 2). Sites 1-3 were located on tributaries to Burke Lake upstream of the inlets to the lake. Site 4 was located at the outlet of the lake where the lake flows into Coon Creek. Sites 5 and 6 were in-lake sites. The description of sampling site locations is as follows:

Site 1 - Located approximately 50 yards upstream of the confluence of the northern tributary to Burke Lake. Latitude: 43^{o} 10' 04"N. Longitude: 99^{o} 15' 34". Site 1 samples are representative of the water quality of the northern tributary inflow to Burke Lake.

Site 2 - Located approximately 50 yards upstream of the confluence of the west tributary to Burke Lake. This site is downstream from a farmyard/feedlot which borders the lake. Latitude: 43^{o} 10' 26"N. Longitude: 99^{o} 15' 44". Site 2 samples are representative of water quality of the west tributary.

Site 3 - Located approximately 50 yards upstream of the confluence of the southern tributary to Burke Lake. Latitude 43^{o} 10' 50"N. Longitude 99^{o} 15' 32". Site 3 samples are representative of the water quality of the southern tributary.

Site 4 - Located on the east side of Burke Lake at the outlet. Latitude 43^{o} 10 '32"N. Longitude 99^{o} 15' 22". Site 4 samples are representative of the outflow of Burke Lake.

Site 5 - Located approximately 100 yards northeast of sampling site 2 and centrally located in the southwest bay of Burke Lake. Latitude 43^{o} 10' 28"N. Longitude 99^{o} 15' 38". This site provided in-lake data for the southern half of the lake basin.

Site 6 - Located approximately 100 yards west of sampling site 4 in the eastern part of the lake basin. Latitude 43^{o} 10' 34"N. Longitude 99^{o} 15' 28". This site provided in-lake data for the northern half of Burke Lake.

The sampling period for tributary and in-lake sampling extended from March 28, 1988 through June 26, 1990. During that period, a total of 155 samples were collected from the six sites (Table 2).

TABLE 2.-Sampling Period and Number of Samples

SITE #	SAMPLE TIME PERIOD FROM:		TO:	# OF SAMPLES
1	5/17/89	-	5/17/89	1
2	3/28/89	-	6/26/90	27
3	3/28/89	-	6/26/90	22
4	3/28/89	-	6/5/90	17
5	3/28/89	-	6/26/90	44
6	3/28/89	-	6/26/90	44
			Total Samples:	155

Figure 2. Burke Lake Sampling Site Locations.

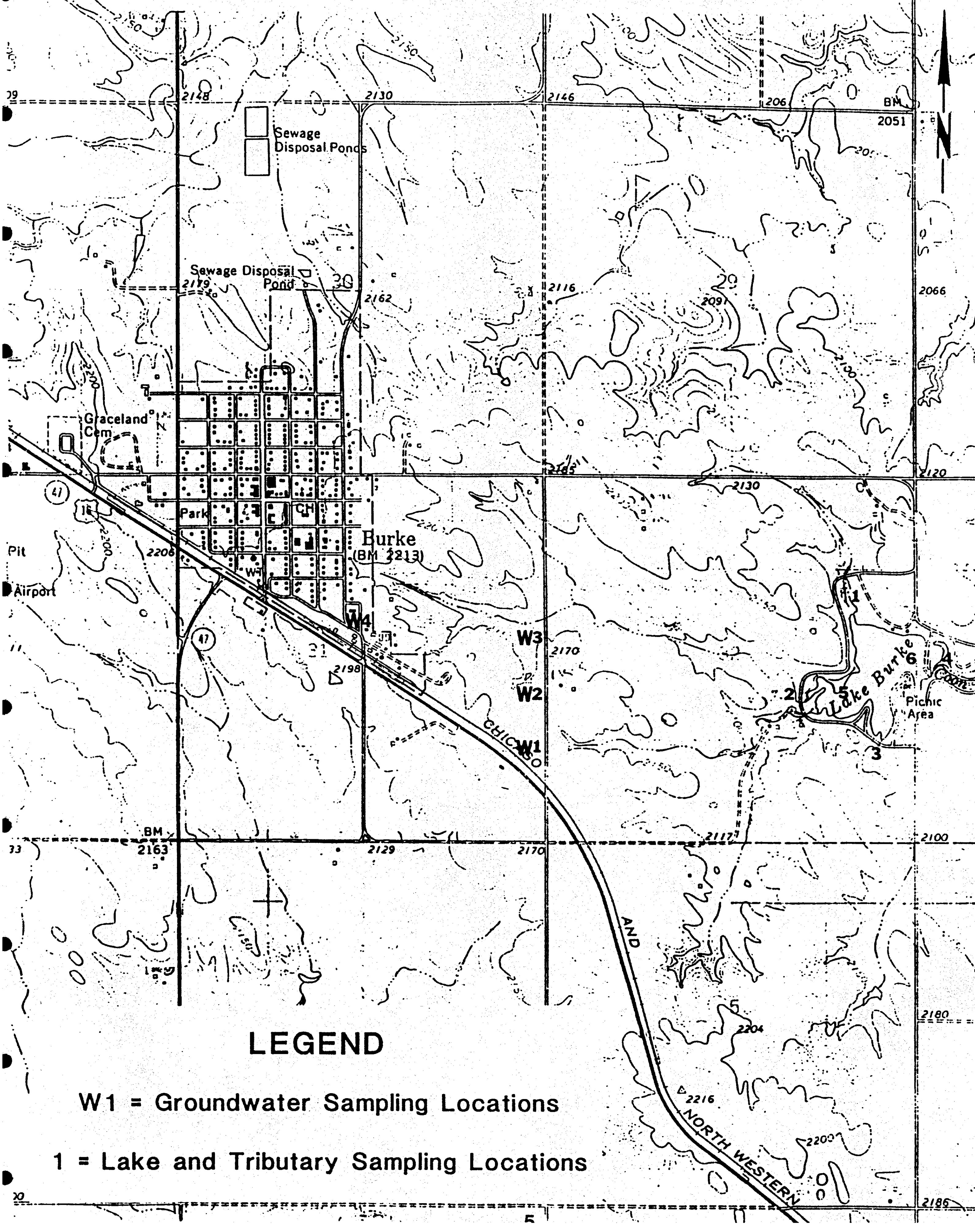


Table 3.-Water Quality Parameters

Water Temperature	Total Solids
Air Temperature	Total Dissolved Solids
Secchi Disk	Total Suspended Solids
Dissolved Oxygen	Ammonia
Field pH	Nitrates + Nitrites
Fecal Coliform Bacteria	Total Kjeldahl Nitrogen
Specific Conductance	Total Phosphorus
Laboratory pH	Orthophosphate
Total Alkalinity	Un-ionized Ammonia

In-lake sites were sampled twice a month at both the surface and bottom. Tributaries and the outflow were also sampled twice a month if flow was present. In addition, tributaries were sampled during rainfall events. Samples were analyzed for the parameters listed in Table 3.

Groundwater Sampling

An abandoned city landfill is located east of Highway 18 outside the extreme southeast limits of the City of Burke. Due to the location of the landfill and geology of the area, groundwater contamination to the lake was suspected. Therefore, a landfill monitoring investigation was initiated.

In early October, 1990, the South Dakota Geological Survey installed three monitoring wells downgradient of the landfill with a hollow auger drilling rig. A City of Burke municipal well was used as an upgradient well (Figure 2). Observation wells were constructed using 2 inch diameter schedule 80 PVC casing and screen. On October 9, 1990, two downgradient wells (W2 and W3) and the upgradient well (W4) were sampled following a snowfall and melt on October 8, 1990. Also, a sample from the tributary downgradient of the landfill, was collected on the same date for comparison.

Samples were analyzed for a variety of parameters which would indicate groundwater contamination. The following parameters were analyzed: fecal coliform bacteria, conductivity, pH, total dissolved solids, ammonia-N, nitrate + nitrite-N, total Kjeldahl-N, total phosphorus, ortho-phosphorus, and chemical oxygen demand (COD).

Analytical Methods

The laboratory analyses were conducted by the South Dakota State Health Laboratory in Pierre, South Dakota. Lake and tributary sampling was conducted by the South Dakota Game, Fish and Parks Department. Groundwater sampling was conducted by the DENR. Methods used for chemical analyses are listed in Table 4.

Table 4. Analytical Methods for Physical and Chemical Parameters.

Parameter	Method	Reference
Temperature	Thermometric	APHA (1985)
Secchi disc*	Shaded side of boat	Lind (1974)
Dissolved oxygen	Azide/Winkler	APHA (1985)
pH	pH probe	APHA (1985)
Total alkalinity	Potentiometric	APHA (1985)
Ammonia-N	Phenate	EPA (1983)
Nitrate + Nitrite-N	Cadmium reduction	EPA (1983)
Kjeldahl-N	Colorimetric	APHA (1985)
Ortho-phosphorus	Ascorbic acid	EPA (1983)
Total phosphorus	Persulfate digestion	EPA (1983)
Total solids	Gravimetric (103-105°C)	EPA (1983)
Total suspended solids	Gravimetric (103-105°C)	EPA (1983)
Total dissolved solids	Gravimetric (180°C)	EPA (1983)
Fecal coliforms	Membraned filter (1989)	APHA (1985)
Conductivity	Conductivity probe	EPA (1983)
Chemical oxygen demand	Colorimetric	EPA (1983)

* In-lake samples only

Sediment Sampling and Survey

A sediment and water depth survey was conducted on Burke Lake on February 2, 1989. Cross-section transect lines were established on the lake and water and sediment depths were measured with calibrated rebar and recorded at intervals along the transects.

At the same time as the survey, one sediment sample was collected from the center of the lake and submitted to the U.S. Army Corps of Engineers Laboratory in Omaha, Nebraska, for analysis of metals, pesticides and other potentially toxic chemicals.

Biological Sampling

From March, 1989 through March, 1990, water samples were collected on a bi-weekly basis and submitted to Mr. Keith E. Camburn for algal quantifications and identifications.

Watershed Inspection

A watershed inspection was conducted by DENR and U.S. Soil Conservation Service (SCS) personnel in July, 1990. Photographs of potential pollution sources in the watershed were taken in October 1990 by DENR personnel.

RESULTS AND DISCUSSION

In-Lake Water Quality

In-lake water quality mean data are summarized in Table 5 and the complete data set is presented in Appendix A. Discussions of the results have been divided into the components of trophic condition, algae, nutrients, fecal coliform bacteria, and fisheries impacts.

Trophic Condition

Lakes are commonly classified according to trophic condition. Three categories are used: 1) oligotrophic lakes are low in nutrients, are generally clear and support low numbers of animals and plants, 2) mesotrophic lakes are intermediate in nutrient load, and 3) eutrophic lakes are high in nutrients and support large numbers of plants and animals. These lakes often experience excessive algal and weed growth.

Lakes naturally age from oligotrophic to eutrophic conditions over thousands of years. Human activities, however, accelerate the process as a result of increased nutrient and sediment additions.

The Carlson Trophic State Index (TSI) is a method of ranking the trophic condition of the lake based on total phosphorus, Secchi depth and chlorophyll a measurements. The

Table 5. In-Lake Sampling Data Mean Values (n = 88).

Parameter	Combined mean values for sites 5 & 6
Secchi Depth	1.6 ft.
D.O.	11.6 mg/l
Field pH	8.7
Fecal Coliform	11.5 per/100 ml
Conductivity	341
Alkalinity	162 mg/l
Total Solids	274 mg/l
Total Dissolved Solids	238 mg/l
Total Suspended Solids	36 mg/l
Ammonia	0.2 mg/l
Nitrate + Nitrite	0.1 mg/l
TKN	2.6 mg/l
Total PO4-P	0.34 mg/l
Ortho PO4-P	0.07 mg/l

scale runs from 0 to 100 and lakes with values over 50 are considered to be eutrophic. Each division of 10 (10, 20 , 30 etc.) indicates a doubling of algal biomass.

TSI's for Burke Lake are based on mean total phosphorus and mean Secchi depth for both sampling sites in the lake over the entire study period. Based upon these values, the TSI value for Burke Lake is 90.8. This value is near the top of Carlson's scale classifying the lake as highly eutrophic.

Algae

Blue-green algae dominated Burke Lake during most of the sampling period. Diatoms were dominant during the cooler periods of spring (Figure 3). This relationship biologically indicates that the lake is highly eutrophic. Of the blue-green algae identified in the lake, the genera Aphanizomenon were the dominant forms present during the study period. Aphanizomenon are commonly identified as problem algae related with eutrophication, taste and odor problems, toxicity and aesthetic nuisance (Taylor, 1974).

Blue-green algae are similar in structure to bacteria but unlike bacteria, are able to photosynthesize like other green plants. Blue-greens often become abundant in nutrient rich lakes because they have several adaptations which allow them to outcompete other algae under enriched conditions. Upon death, blue-green algae cells decompose causing odor and scum formation. Several blue-green algae genera produce toxins which can be poisonous to animals and people (Haynes, 1988).

Other algal groups identified in the study included green algae, cryptomonads, and diatoms. Green algae are a diverse group and are also commonly found in eutrophic lakes. Green algae are generally not reported to produce toxins.

Cryptomonads are a group of motile algae which develop dense populations during cold periods of the year. They seem to do well under low light conditions and are commonly found in lakes during ice cover conditions.

Diatoms are algae which have silicified cell walls and typically exhibit an early spring population explosion when conditions are too cold for green and blue-green forms. Diatoms can be dominant forms throughout much of the year in eutrophic lakes in cooler regions.

Phosphorus

Phosphorus is an essential nutrient for plant growth and is typically the cause of excessive growth of algae and aquatic plants. Total phosphorus concentrations in excess of 0.03 mg/l have been shown to contribute nuisance growth (NIPC, 1989).

During the entire study period, total phosphorus concentrations exceeded 0.03 mg/l at both in-lake sites (range 0.14 - 1.76 mg/l). Surface and bottom samples exhibited similar phosphorus concentrations indicating the lake remains mixed throughout the year.

These data indicate that the lake has a large phosphorus surplus and therefore is susceptible to algal blooms and nuisance weed growth.

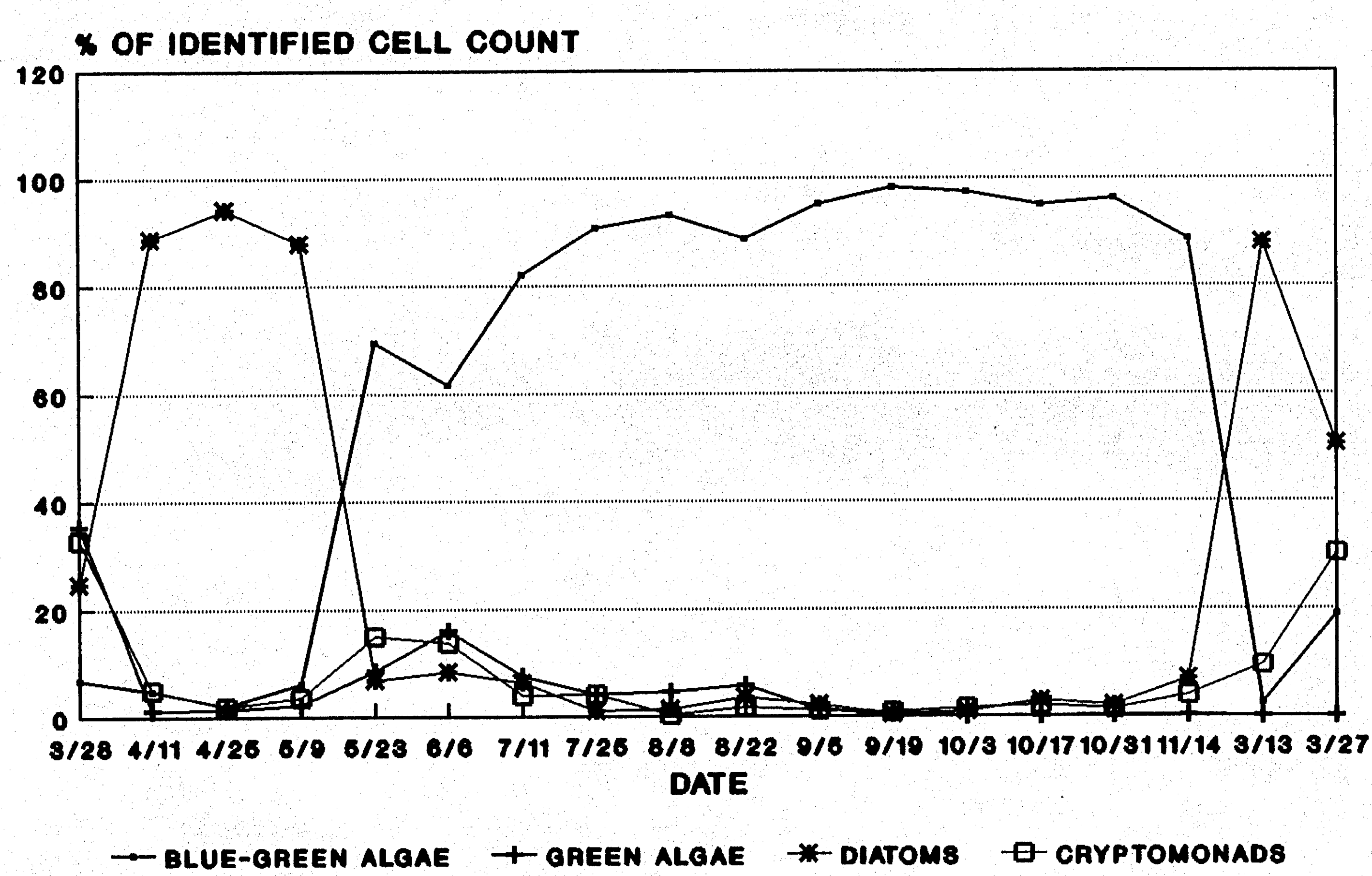
In general, sources of phosphorus to lakes include detergents, human and animal wastes, fertilizers and dead plant materials.

Nitrogen

Nitrogen is often the second most important nutrient to aquatic weed and algal growth in lakes. Inorganic nitrogen concentrations ($NO_3 + NO_2 + NH_4$) in excess of 0.3 mg/l are sufficient to stimulate algal growth (Sawyer, 1952).

Inorganic nitrogen concentrations in Burke Lake exceeded 0.3 mg/l throughout much of the 1988 sampling period and occasionally in 1990 (Appendix A). Nitrate + Nitrite ($NO_3 + NO_2$) values ranged from - 0.40 mg/l and ammonia (NH_4) values ranged from < 0.02 - 1.48 mg/l throughout the study period.

Figure 3.
Algal Cell Counts for Burke Lake



SAMPLING PERIOD FROM 3/28/89 - 3/27/90

Nitrogen is believed to be the limiting nutrient to algal growth if the ratio of total nitrogen (N) to total phosphorus (P) is less than 10:1 (Shaw, 1989). Blue-green algae are often dominant in lakes with a low N:P ratio since they are able to utilize atmospheric nitrogen which is dissolved in the water. Other algae cannot utilize atmospheric nitrogen and rely on inorganic forms. The N:P ratio in Burke Lake is less than 10:1 thus indicating it is nitrogen limited.

These data suggest that nitrogen concentrations in Burke Lake often exceed that needed to stimulate excessive algal growth, particularly blue-greens.

Major sources of nitrogen to lakes are fertilizers, animal and septic wastes.

Fecal Coliform Bacteria

Fecal coliform bacteria cell counts are used as indicators of human pathogens in water. Although the fecal coliforms are not usually pathogens themselves, they exhibit a close relationship with the human pathogens Salmonella and Shigella.

Recommended microbiological criteria for South Dakota public swimming beaches are that any single sample exceeding 200 fecal coliform/100ml of water is considered as "possibly unsafe" and and two consecutive samples exceeding 300 fecal coliform/100ml is considered unsafe for swimming.

Fecal coliform bacteria concentrations in Burke Lake did not exceed the swimming criteria during the study period. Fecal coliform concentrations ranged from < 10 to 120 per 100ml (Appendix A).

Fisheries Impacts

The beneficial uses assigned to Burke Lake include that of warmwater semipermanent fish life propagation. During the study period, most water quality parameters were sufficient to support a healthy warmwater fishery. However, the warmwater fishery criteria of 0.04 mg/l of un-ionized ammonia was exceeded on numerous sampling dates in 1989 and on one sampling date in 1990. Un-ionized ammonia concentrations over the study period ranged from 0.00 to 0.15 mg/l (Appendix A).

This data indicates that ammonia concentrations in the lake have reached sufficient concentrations to stress or kill warmwater game fish species. Several fish kills were reported prior to implementing this study. However, no fish kills were reported during the study period.

Tributary Water Quality

During the sampling period, only one sample was collected from tributary site #1 due to the lack of runoff from this tributary. The data collected, however, did not suggest that water quality degradation was occurring in this tributary.

Tributary sites #2 and #3 were sampled a total of 27 and 22 times respectively (Table 2). Water quality data indicated that these tributaries experience high levels of contamination and in return deliver high concentrations of contamination to Burke Lake.

Water quality parameters which are most closely associated with degrading the recreational potential of the lake and are also most indicative of pollution sources include fecal coliform bacteria and nutrients.

As previously discussed, fecal coliform concentrations exceeding 200/100ml of water in lakes is considered potentially unsafe. Although this standard does not apply directly to streams, it does help display the high level of contamination occurring in the tributaries. During the study period, fecal coliform concentrations in tributary sites #2 and #3 frequently exceeded 200/100ml. The range of fecal concentrations for sites #2 and #3 ranged from < 10 to 4,000,000 and from < 10 to 6,300, respectively (Appendix A).

Also, as previously discussed, excessive nutrient concentrations are the primary cause of excessive blue-green algae and aquatic plant growth in lakes. Tributaries #2 and #3 both contributed high concentrations of phosphorus and nitrogen to Burke Lake consistently throughout the study period. Total phosphorus concentrations for the tributaries ranged from 0.21 - 18.90 mg/l at site #2 and from 0.08 - 2.56 mg/l at site #3. Inorganic nitrogen concentrations ranged from 0.02 - 2.80 mg/l at site #2 and from 0.02 to 15.24 mg/l at site #3 (Appendix A).

Other water quality problems found in the tributaries also potentially have negative impacts on the fish resources in Burke Lake. Some of the problems include low dissolved oxygen concentrations, high un-ionized ammonia, and high concentrations of suspended solids.

Groundwater Investigation

The landfill property consists of 6.66 acres of which 4.09 acres were purchased in 1928 and the balance was purchased in 1967. The landfill was used for municipal wastes until sometime in late 1974 or early 1975.

The surficial geology in the area of the landfill includes deposits of the Herrick, Ash Hollow and Valentine Formations. These formations consist of coarse, fine and very fine sands. The Ogallala aquifer lies within the Valentine formation which is composed of very fine to fine sand with some silt and clay lenses (Hammond, 1990).

The landfill is located approximately 5000 feet upgradient of the lake and approximately 1000 feet upgradient of a lake tributary. The direction of groundwater flow from the landfill is to the east and northeast moving towards the lake (Hammond, 1990).

The results of the October, 1990 groundwater and tributary sampling are summarized in Table 6. The data indicate that groundwater in the watershed has elevated concentrations of nitrogen and phosphorus. A previous study (Hammond, 1990) reports that all city wells located within city limits display high concentrations of nitrate-nitrogen. This study confirmed the elevated nitrate in a city well but also indicated elevated nitrate and phosphorus in the monitoring well downgradient of the city and landfill.

Table 6. Results of October, 1990 Groundwater and Tributary Sampling.

Parameter	Background Well	MW #2	MW #3	Trib.
Fecal Coliform	14	<2	2	3800
pH	7.57	7.22	7.91	7.52
Cond.	400	588	382	515
TDS	288	395	288	363
Ammonia	<0.02	0.03	0.03	0.39
NO3+NO2	6.1	2.5	7.9	<0.1
TKN	0.14	0.58	0.88	1.56
Total PO4-P	0.047	0.082	0.359	0.966
Ortho PO4-P	0.030	0.073	0.350	0.367
COD	22	30	30	40

It is not clear what the exact source or sources of the contamination are from this investigation, however, data from this study and from the Hammond investigation indicate that the source(s) of the groundwater contamination is likely located within or near the southeastern city limits.

Although nutrient levels in the groundwater contribute to problems in the lake, the nutrient levels found in groundwater were not substantial enough to account for the gross nutrient contamination of the tributaries. In addition, fecal coliform and ammonia contamination in the tributaries is not attributable to groundwater. Therefore, other watershed sources are the primary sources of pollution to the tributary and to the lake.

Sediment Survey

The DENR conducted a sediment and water depth survey of Burke Lake on February 16, 1989. Cross-section locations used for the survey and the respective cross-section graphs are presented in Appendix B.

The maximum water depth found during the survey was 14.2 feet in the northcentral part of the lake (Figure 4). Most nearshore areas (50 feet from shore) have water depths less than 4 feet deep.

The mean sediment depth in the lake is 2.76 feet with a maximum sediment depth of 7.2 feet occurring in the central portion of the lake (Figure 5). Most nearshore areas have sediment depths of less than 2 feet deep. The lake has as an approximate sediment volume of 125,000 cubic yards.

High concentrations of total suspended solids were recorded entering the lake from tributary sampling site #2 (Appendix A) and typically corresponded with elevated organic nitrogen values (TKN - Ammonia) indicating that the solids are at least partially organic. It is unclear to what extent the load is made up of inorganic sediment (i.e. soil particles). Due to the ease at which sediments likely become redistributed in such a small shallow lake, it is unclear which tributary is the major source of sediment loading to the lake.

Elutriate Analysis

A sediment sample collected from the center of the lake was analyzed for a variety of metals, pesticides and other potentially toxic chemicals. Results indicated no toxic levels of chemicals in the elutriate (Appendix C). Therefore, the analysis indicated that disturbance of sediments via dredge activities should not present a toxicity problem to the lake.

Watershed Inspection

On July 31, 1990, DENR and SCS representatives conducted a watershed survey to identify potential sources of pollution to Burke Lake. Several potential sources were identified including a dairy operation, a horse pasture, a mule pasture, a fertilizer storage facility, and an abandoned landfill.

Photographs documenting watershed pollutant sources were taken on October 3, 1990 and are included in Appendix D.

Dam Inspection

The dam was inspected on May 8, 1990 by the DENR Division of Water Rights. The DENR recommended that the following repair and maintenance activities be performed:

1. Trees, brush and the root systems of the larger trees should be removed from both slopes of the dam and the holes backfilled with impervious material.
2. Erosion of the upstream slope should be repaired and sufficient riprap should be placed along the slope to prevent further erosion.
3. Trees and brush should be removed from the spillway discharge channel and the channel should be leveled to provide uniform flow.
4. Major spalls, cracks, and deteriorated joints should be repaired.

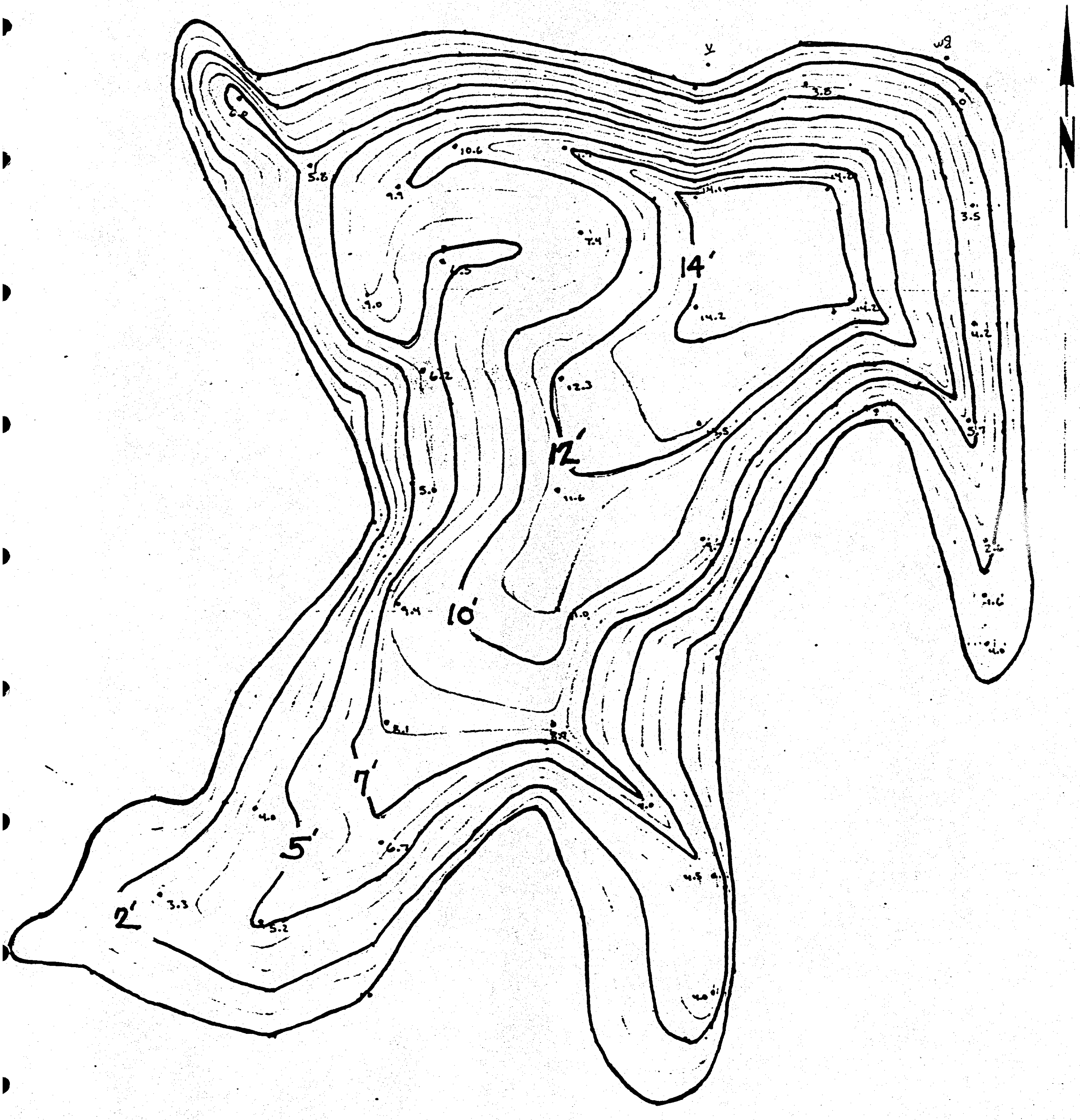


Figure 4. Burke Lake Bathymetric Map.

Note: Survey Data Collected 2/16/89.
Scale: 1 INCH = 180 FEET

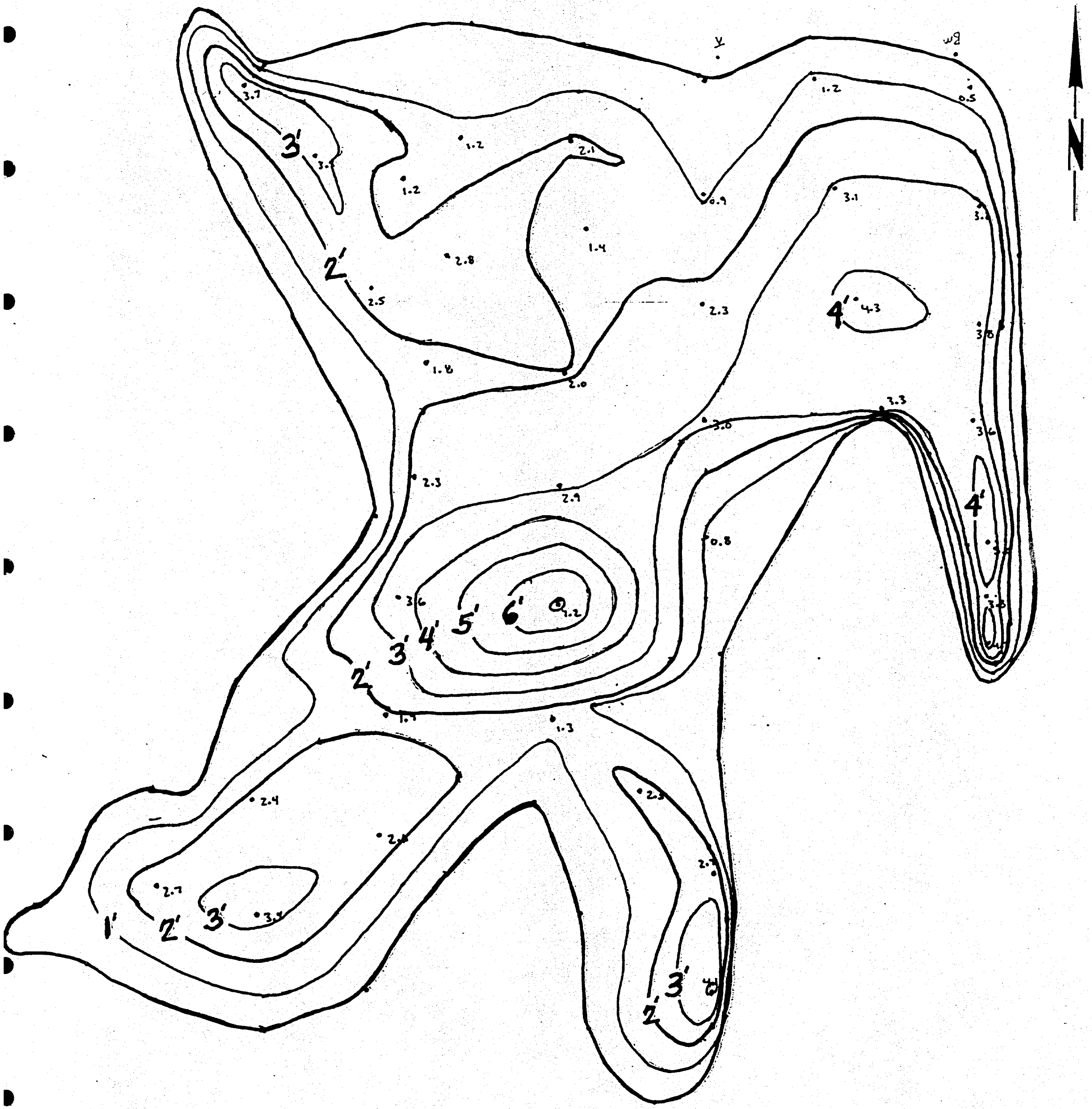


Figure 5. Burke Lake Sediment Thickness Contour Map.

Note: Survey Data Collected 2/16/89.
Scale: 1 INCH = 180 FEET

CONCLUSIONS

Burke Lake is highly eutrophic due to excessive nutrients entering the lake. Nutrients are entering the lake primarily from the west and south tributaries. Nutrients carried within the general groundwater flow to the lake are also likely contributing to the nutrient enrichment of the lake. However, the nutrient contribution from groundwater is likely much less than that from the west and south tributaries.

Potential sources of nutrients to all the tributaries included a dairy operation, a horse pasture, a mule pasture, and cropland. Fecal coliform data suggests that animals are the primary source of contamination in the west and south tributaries. These data in conjunction with the findings of the watershed inspection indicate that the dairy operation, located adjacent to the west and south tributaries, is the primary source of nutrient and fecal contamination entering the west and south tributaries. A horse pasture, located adjacent to the west tributary, is an additional source of nutrient and fecal contamination in the west tributary.

Due to the limited flow of the north tributary during the study period, it is not clear if this tributary could contribute significant contamination to the lake in times of heavy precipitation. However, the watershed inspection suggests that a mule pasture located along the north tributary could potentially contribute significant contamination to the tributary due to the improper storage of manure piles on tributary slopes.

The source or sources of groundwater nutrient contamination in the western portion of the watershed appear to be located within or near the southeast city limits. Potential sources of the contamination included a fertilizer storage facility and the abandoned landfill. A more comprehensive groundwater monitoring study would be needed to thoroughly evaluate the sources of groundwater contamination and the impacts of groundwater quality on the lake.

Based upon the evidence from this study, the most threatening source of pollution to the lake is the dairy operation.

Data from the sediment survey and from water quality sampling suggest that sediment loading is not a major problem in Burke Lake. However, due to the small and shallow character of the lake, the nutrient rich sediments likely have a large impact on algal and aquatic weed growth in the lake and also likely contribute to winter fish kills due to lack of sufficient depth.

RESTORATION ALTERNATIVES

Watershed Restoration

All restoration alternatives should begin with addressing contamination sources within the watershed. Reducing pollutant loading from the watershed will accelerate the control of aquatic vegetation in the lake, improve the fishery through the reduction of winterkill, and will improve swimmability. Watershed restoration activities should include those discussed below.

Foremost, an adequate system to control pollution coming from the dairy operation needs to be developed and implemented. In addition, pasture and cropping activities within the watershed need to be addressed via information to land owners on how to minimize manure, fertilizer and sediment contributions to water resources. Finally, sources of nutrient contributions to groundwater in the watershed need to be identified and controlled. A more comprehensive groundwater study may be needed to identify sources.

Although sediment loading to the lake does not appear to be as accelerated as in many South Dakota lakes, it is a problem which threatens the fishery and contributes to the eutrophic condition of Burke Lake. Addressing watershed activities to control sedimentation via education of land owners is the first step. Should this prove ineffective, a sediment/nutrient control system may have to be considered. An example of such a system would be the installation of one or more sediment detention basins or constructed wetlands within the watershed to act as sediment and nutrient traps and filters.

Prior to the implementation of any in-lake restoration activities, the lake's dam should be renovated and approved by the DENR Division of Water Rights. Renovation recommendations were outlined previously.

In addition to the Water Rights recommendations, cattails, sediment and debris should be removed from the area just in front of the upstream dam lip.

In-Lake Restoration

In-lake restoration can be approached either actively or passively. The passive approach is to take no action in the lake. If watershed contributions of nutrients to the lake are controlled, the lake may slowly improve in water quality over a period of several years. How much the lake would improve and to what extent it would improve are unknown. However, it is likely the lake would continue to experience algal and aquatic vegetation problems for many years.

Active in-lake restoration alternatives will be discussed in regards to the desired goals. The goals discussed are algae/weed control, fishery improvement and swimmability improvement.

Algae/Weed Control

Algae/aquatic weed control is accomplished by reducing the amount of nutrients available for plant growth or by direct removal of plants.

Sediment Nutrient Reduction

Nutrient availability from lake sediments can be reduced by a variety of methods including sediment consolidation, bottom sealing, sediment oxidation and full or partial lake dredging.

Sediment consolidation involves draining a lake and allowing the bottom sediments to dry out and become hardened. As a result, nutrients become bound in the hard sediment and sediment volume decreases due to drying. Sediments may take from several months to more than a year to dry sufficiently. Hardening the sediments may decrease or completely eliminate groundwater recharge to a lake. Since groundwater is an important source of water to Burke Lake, this method is not recommended.

Bottom sealing involves placing plastic or other sealing materials over the sediment surface to stop the exchange of nutrients between the sediments and water. Oxidation involves treating the upper sediment layer chemically to enhance the removal of nutrients. Of the methods described, only dredging has been demonstrated to be an effective long term method of sediment nutrient control.

Dredging involves the physical removal of nutrient rich sediments from the lake bottom. Full lake dredging involves the removal of sediments from most or all of the lake. Selective dredging involves the removal of sediments from only specific areas of the lake. For example, sediments could be removed from specific shorelines in order to create improved depth for swimming and to control aquatic vegetation growth.

Selective dredging will aid in the control of growth of aquatic weeds and algae, increase lake accessibility to boaters and increase swimmability. This approach will likely be less costly than full lake dredging but will also likely not result in as significant a reduction of algae and weeds. As with full lake dredging, care must be taken to maintain adequate shallow water habitats for fish production.

Dredging can be accomplished by hydraulic dredging, drag-line dredging, or mechanical dredging with a backhoe following a partial or complete drawdown of the lake. In general, drag-line and mechanical dredging are most economical if the volume of sediment to be removed is small. These methods of dredging are more labor intensive than hydraulic dredging and involve trucking the removed sediments away to a disposal area. In addition, these methods are more time intensive than hydraulic dredging.

Average costs to conduct mechanical dredging on two lake projects in South Dakota were $2.63 per cubic yard of sediment. Average costs for hydraulic dredging by the State of South Dakota are $1.46 per cubic yard with a 10 inch dredge.

Hydraulic dredging is most economical when large volumes of sediment are to be removed because of the initial costs involved in transporting the dredge, setting up the dredge, and constructing sediment holding ponds. Sediments mixed with water are pumped through a pipe to a sediment disposal pond.

The State of South Dakota currently owns and operates four dredges. By doing so, the state has been able to substantially reduce the cost of hydraulic dredging in comparison to contracting with a private dredging company. The cost for the state to operate a 8 inch dredge for one year is approximately $220,000. This cost includes all labor and disposal pond construction costs. Private contracting costs per cubic yard of sediment are approximately two to three times higher than the state cost.

<u>Water Nutrient Reduction</u>

Nutrient availability from the lake water itself can also be reduced. The best demonstrated method for accomplishing this is alum (AlSO4) treatment. Alum can be added to the water under controlled chemical conditions. The alum reacts with phosphorus in the water and forms an insoluble precipitate that settles into the sediments. This method works best in hard water lakes that are thermally stratified but it has been demonstrated to be effective for shorter durations in shallow mixed lakes. The alum must be applied in highly controlled conditions in order to prevent formation of substances that are harmful to aquatic life. Also, application of enough alum to coat the lake bottom with a thick layer of alum is desirable for sediment nutrient inactivation and longer duration water nutrient inactivation.

Alum treatment is small shallow lakes can result in the presence of the precipitate or floc on shores and on the lake bottom. This may be undesirable to lake users. In addition, alum treatment can result in a increase in water clarity which in turn can encourage an initial increase in aquatic weed growth.

The major cost involved in alum treatment is generally labor. A 40 acre lake in Ohio was treated with 100 tons of alum at a cost of $14,000 for the alum alone. The treatment costs will decrease if lower doses of alum are used as would be the case if the objective is to remove phosphorus from the water column only.

Aquatic Plant Removal

Aquatic plants can be removed from the lake through harvesting or chemical treatments. Chemical treatments typically result in short term aesthetic results and do not aid in the removal of nutrients from the system. In addition, toxic chemicals used in the treatments can accumulate in the lake sediments.

Harvesting removes weeds from the lake and as a result removes nutrients from the system. Harvesting costs range from approximately $140 to $310 per acre.

Harvesting can be used alone or in addition to dredging. However, if a dredge program is properly planned, the dredge activity can remove nuisance vegetation and create sufficient water depth to limit further aquatic weed growth from selected areas.

Fishery Improvement

Fishery improvement can be accomplished through preservation and enhancement of critical habitats (i.e. nursery, food production and winter habitats) and through the attainment of a balanced fishery (predator/prey balance). Nursery and food production habitats can be identified, preserved and enhanced and a balanced fishery can be attained via cooperation with and recommendations from the South Dakota Game Fish and Parks Department.

Critical habitat can be enhanced to reduce the risk of winterkills by creating sufficient deep water areas in the lake and by removing excessive aquatic vegetation and organic sediment materials. This can be accomplished via dredging.

Swimmability Improvement

Swimmability of the lake can be improved through control of nuisance vegetation. Methods for the control of vegetation were discussed previously.

RECOMMENDATIONS

Recommendations for the restoration of Burke Lake will be listed in order of priority, where the highest priority recommendations are listed first and should be implemented prior to, or in conjunction with, the implementation of lower priority recommendations.

1. An adequate system to control pollution coming from the dairy operation needs to be developed and implemented. The land owner working in cooperation with the Soil Conservation Service, should be responsible for the installation of adequate pollution control structures. The operation must achieve compliance with ARSD 74:03:18 regulations pertaining to animal feeding operations.

   The design and installation of two animal waste control ponds was estimated by SCS to cost approximately $150,000.

2. Pasture and cropping activities within the watershed need to be addressed via provision of information to land owners on how to minimize manure, fertilizer, and sediment contributions to water resources.

3. Sources of nutrient contributions to groundwater in the watershed should be identified and controlled. As a start, the South Dakota Department of Agriculture should be notified to conduct a compliance inspection at the grain elevator/fertilizer storage facility located near the southeast city limits. In addition, a more comprehensive groundwater study is needed to identify sources.

   Minimally, it is recommended that the wells sampled in the D\F study be resampled in the spring after at least one moderate spring rainfall event. In addition, two additional wells should be installed and sampled at the same time as the others. One well should be installed upgradient of the landfill and downgradient of the grain elevator/fertilizer storage facility in order to distinguish potential nutrient impacts from the elevator facility. A second well should be installed downgradient of the landfill and upgradient of the adjacent pasture. This well will serve to distinguish between impacts from the landfill and those from the pasture. Another upgradient well which can be sampled alike to the other downgradient wells, should also be sampled.

   Installation of two new wells by SDGS and one time sampling of four wells by the DENR would cost approximately $2,000.

4. Prior to the implementation of any in-lake restoration activities, the lake's dam must be renovated by undergoing the following repairs and maintenance:

   - Trees, brush and the root systems of the larger trees should be removed from both slopes of the dam and the holes backfilled with impervious material.
   - Erosion of the upstream slope should be repaired and sufficient riprap should be placed along the slope to prevent further erosion.
   - Trees and brush should be removed from the spillway discharge channel and the channel should be leveled to provide uniform flow.
   - Major spalls, cracks and deteriorated joints should be repaired.
   - Cattails, sediment and debris should be removed from the area just in front of the upstream dam lip.

   GFP working in conjunction with the local sponsor should be responsible for dam repairs.

5. In-lake restoration is recommended to include the following:

   - Full lake dredging to remove sediment nutrients and nuisance stands of aquatic vegetation, and to create deep water areas which will limit regrowth of aquatic vegetation and create deep fish habitat holes to prevent winterkills. Since lake sediments contain and often recycle nutrients to the lake, they represent a pollution source to the lake. Sediment removal via dredging is often utilized as a way of improving the lake quality through removal of nutrients and enhancement of lake usability by increasing depth. Lake deepening can increase storage capacity, prevent winterkills, expand recreational areas, decrease area available for plant growth and may aid in the reduction of resuspended sediments (Sefton, 1983). A fish management plan should be developed with the GFP department prior to any dredging activities.

Full lake dredging by DENR is estimated to take approximately 1.5 years to complete with an 8 inch dredge. Dredging costs are estimated to be approximately $330,000.

- Following dredging activities, a one time alum treatment would aid in reducing nutrient availability from the lake water itself. This method works best in hard water lakes that are thermally stratified. After the completion of dredging and the creation of deep holes, the lake will likely stratify to some extent and will therefore likely benefit from alum. The alum must be applied in highly controlled conditions in order to prevent formation of substances that are harmful to aquatic life. Also, application of enough alum to coat the lake bottom with a thick layer of alum is desirable for sediment nutrient inactivation and longer duration water nutrient inactivation.

The cost of alum and application by a private contractor is estimated to be approximately $12,000. Additionally, the cost of contractor travel is estimated to be up to $10,000 based upon an applicator located in Pennsylvania. Travel costs per lake can be substantially reduced if more than one lake is treated during the trip.

6. Upon completion of the outlined lake restoration techniques, an ongoing lake management/protection plan for the lake should be developed and implemented. A system of long term water quality monitoring should be developed as part of that strategy to detect problems early. This plan should be developed as a cooperative effort between GFP, DENR, and the City of Burke.

7. If aquatic vegetation continues to persist at nuisance levels after dredging is completed, selective weed harvesting may be used as an option in the long term lake management strategy. A small scale harvester such as a Hockney could be purchased through cooperative funding and operated by a local or state entity. The purchase price of a Hockney is approximately $10,000 without shipping.

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APPENDIX A
Water Quality Data

BURKE LAKE 1989 SAMPLING DATA

DATE	TIME	SITE	SAMPLE	DEPTH	WTEMP	ATEMP	SDISK	DISOX	FPH	FECAL	COND	LABPH	ALK(T)	TSOL	TDSOL	TSSOL	AMMON	NO3+2	TKN-N	TPO4-P	OPO4-P	UNIAM
05/17/89	1135	1	SURFACE	0.5	66	64		9.4	8.15	10		8.37	115	405	401	4	0.06	0.10	0.82	0.10	0.02	0.003
03/28/89	1500	2	SURFACE	0.5	54	60		8.5	7.70	<10		7.77	236	331	315	16	0.47	1.20	1.38	0.25	0.17	0.005
03/30/89	1030	2	SURFACE	0.5	36	40		9.0	6.60	10		7.70	230	346	317	29	0.42	0.20	1.78	0.41	0.15	0.000
04/11/89	1100	2	SURFACE	0.5	37	46		9.6	7.10	40		7.82	219	349	314	35	0.14	0.20	0.81	0.21	0.18	0.000
04/25/89	935	2	SURFACE	0.5	58	60		5.5	7.40	2100		8.09	158	251	210	41	0.77	<0.10	3.94	1.58	0.03	0.005
05/09/89	1120	2	SURFACE	0.5	59	62		13.5	7.60	1600		8.03	232	371	319	52	0.04	<0.10	1.68	0.76	0.42	0.000
05/23/89	1030	2	SURFACE	0.5	66	73		4.3	7.30	50		7.31	240	503	334	169	0.15	<0.10	1.78	2.16	0.37	0.001
06/06/89	1300	2	SURFACE	0.5	76	82		2.5	6.70	20		7.42	225	1048	355	693	0.06	0.10	2.14	0.85	0.20	0.000
06/20/89	1030	2	SURFACE	0.5	78	82		6.3	8.50	180		7.89	293	423	391	32	<0.02	<0.10	1.08	0.39	0.29	0.000
06/26/89	945	2	SURFACE	0.5	60	67		2.0	7.60	720000		7.50	197	425	407	18	0.21	<0.10	3.46	1.17	0.64	0.002
07/11/89	1050	2	SURFACE	0.5	84	90			8.60	4000		7.15	351	5799	417	5382	1.80	<0.10	6.76	6.68	0.19	0.412
07/25/89	915	2	SURFACE	0.5	68	80			7.40	1000		7.36	255	674	398	276	0.63	<0.10	1.99	1.54	0.75	0.006
08/08/89	915	2	SURFACE	0.5	60	64			8.10	5000		6.67	491	1863	510	1353	2.80	<0.10	27.20	18.90	0.13	0.097
08/22/89	915	2	SURFACE	0.5	64	76			7.10	4000		7.29	294	464	398	66	0.89	<0.10	2.10	1.63	1.02	0.004
09/05/89	900	2	SURFACE	0.5	64	72		2.8	7.40	7100		7.38	286	526	430	96	1.11	<0.10	3.03	1.83	1.17	0.009
09/19/89	1320	2	SURFACE	0.5	65	80		4.5	8.10	4000000		7.22	306	2187	535	1652	0.98	0.90	9.59	5.32	1.95	0.042
10/03/89	1025	2	SURFACE	0.5	46	44			7.90			7.52	257	392	390	2	0.41	<0.10	1.22	1.07	0.87	0.005
10/17/89	925	2	SURFACE	0.5	38	40		7.0	8.40	490		7.85	242	397	387	10	0.22	0.10	1.00	0.85	0.71	0.006
10/31/89	925	2	SURFACE	0.5	36	50		7.0	7.90	1300		7.67	240	401	388	13	0.21	0.10	1.11	0.88	0.71	0.002
11/14/89	1135	2	SURFACE	0.5	33	34		8.5	7.80	15000		7.82	234	395	340	55	0.27	0.20	1.20	0.61	0.45	0.001
03/28/89	1530	3	SURFACE	0.5	52	60		12.0	7.80	<10		7.96	185	256	241	15	<0.02	<0.10	0.58	0.13	0.06	0.000
03/30/89	915	3	SURFACE	0.5	36	38		7.6	6.60	<10		7.66	194	268	263	5	<0.02	<0.10	0.63	0.10	0.05	0.000
04/11/89	1125	3	SURFACE	0.5	36	42		14.0	7.40	<10		7.98	191	283	249	34	<0.02	<0.10	0.35	0.08	0.07	0.000
04/25/89	1005	3	SURFACE	0.5	58	52		5.3	6.90	40		7.77	241	336	307	29	<0.02	0.20	0.64	0.19	0.14	0.000
05/09/89	1200	3	SURFACE	0.5	59	63		10.5	7.30	30		7.78	231	311	307	4	<0.02	<0.10	0.52	0.17	0.12	0.000
05/23/89	1100	3	SURFACE	0.5	63	65		3.5	7.10	1700		7.56	259	408	357	51	0.02	<0.10	1.18	0.32	0.18	0.000
06/06/89	1110	3	SURFACE	0.5	68	72		6.0	9.80	1200		7.78	271	359	358	1	0.03	<0.10	1.77	0.24	0.14	0.021
06/20/89	915	3	SURFACE	0.5	68	82		4.3	7.30	30		7.47	220	634	321	313	0.11	<0.10	2.19	2.04	0.21	0.001
06/26/89	1010	3	SURFACE	0.5	62	64		5.0	8.70	1600		7.70	171	283	261	22	0.04	<0.10	1.27	0.33	0.19	0.005
07/11/89	1130	3	NO WATER TO SAMPLE																			
07/25/89	1000	3	SURFACE	0.5	64	74		4.5	7.80	100		8.00	281	466	437	29	0.09	<0.10	1.49	0.34	0.17	0.002
08/08/89	930	3	NO WATER TO SAMPLE																			
08/22/89	945	3	NO WATER TO SAMPLE																			
09/05/89	930	3	NO WATER TO SAMPLE																			
09/19/89	1345	3	NO WATER TO SAMPLE																			
10/03/89	945	3	SURFACE	0.5	43	42			8.00	6300		7.63	277	509	488	21	0.19	<0.10	2.81	0.91	0.54	0.003
10/17/89	1000	3	SURFACE	0.5	36	40		7.5	8.10	600		7.73	232	363	357	6	<0.02	<0.10	0.60	0.28	0.28	0.000
10/31/89	1000	3	SURFACE	0.5	36	46		8.0	8.00	<10		7.61	238	383	371	12	<0.02	<0.10	0.69	0.25	0.22	0.000
11/14/89	1105	3	SURFACE	0.5	33	38		10.0	8.20	20		7.84	245	365	319	46	<0.02	<0.10	0.52	0.31	0.17	0.000

DATE	TIME	SITE	SAMPLE	DEPTH	WTEMP	ATEMP	SDISK	DISOX	FPH	FECAL	COND	LABPH	ALK(T)	TSOL	TDSOL	TSSOL	AMMON	NO3+2	TKN-N	TPO4-P	OPO4-P	UNIAM
03/28/89	1545	4	SURFACE	0.5	54	68		17.5	8.00	<10		8.11	169	321	236	85	0.04	<0.10	1.76	0.30	0.06	0.001
03/30/89	940	4	SURFACE	0.5	44	38		11.3	7.30	<10		8.19	186	269	249	20	0.03	0.10	2.12	0.31	0.03	0.000
04/11/89	1145	4	SURFACE	0.5	43	42		14.2	8.70	<10		8.86	171	298	234	64	0.04	<0.10	2.54	0.53	0.01	0.003
04/25/89	1035	4	SURFACE	0.5	60	60		6.8	7.90	20		7.75	242	438	323	115	0.05	<0.10	1.83	1.14	0.70	0.001
05/09/89	1215	4	SURFACE	0.5	62	62		11.5	8.10	<10		8.40	166	290	220	70	0.03	<0.10	1.28	0.21	0.02	0.001
05/23/89	1130	4	SURFACE	0.5	68	70		5.5	8.10	300		7.37	132	1512	207	1305	0.15	<0.10	5.05	1.38	0.02	0.007
06/06/89	1130	4	SURFACE	0.5	65	72		2.0	11.80	200		7.51	151	1771	227	1544	0.71	<0.10	5.24	2.46	0.21	0.707
06/20/89	945	4	SURFACE	0.5						260		7.32	148	777	201	576	1.25	<0.10	5.56	2.34	0.19	
06/26/89	1030	4	SURFACE	0.5	65	64		2.5	9.20	10		8.06	123	208	186	22	0.04	<0.10	2.00	0.29	0.05	0.014
07/11/89	1130	4	SURFACE	0.5	78	80	1.3	8.0	10.30	<2	270	9.21	132	229	208		0.03	<0.10	2.74	0.36	0.03	0.028
07/25/89	1015	4	NO WATER TO SAMPLE																			
08/08/89	945	4	NO WATER TO SAMPLE																			
08/22/89	945	4	NO WATER TO SAMPLE																			
09/05/89	930	4	NO WATER TO SAMPLE																			
09/19/89	1350	4	NO WATER TO SAMPLE																			
10/03/89	1000	4	NO WATER TO SAMPLE																			
10/17/89	1015	4	NO WATER TO SAMPLE																			
10/31/89	1000	4	NO WATER TO SAMPLE																			
11/14/89	1115	4	NO WATER TO SAMPLE																			
03/28/89	1345	5	SURFACE	0.5	45	58	2.3	14.0	7.70	<10	363	8.21	171	255	237	18	0.04	<0.10	2.02	0.34	0.06	0.000
03/28/89	1345	5	BOTTOM	4.5	45	58	2.3	17.0	7.70	<10	363	8.13	178	258	244	14	0.02	0.10	1.72	0.25	0.05	0.000
04/11/89	1300	5	BOTTOM	3.0	44	44	2.3	15.6	8.90	<10	355	8.87	175	291	240	51	<0.02	<0.10	1.48	0.17	<0.01	0.000
04/11/89	1300	5	SURFACE	0.5	42	44	2.3		8.80	<10	355	8.88	177	288	237	51	<0.02	<0.10	1.43	0.16	0.01	0.000
04/25/89	1235	5	SURFACE	0.5	64	60	2.0	9.3	8.70	10	330	8.66	164	243	207	36	<0.02	<0.10	1.66	0.17	0.01	0.000
04/25/89	1235	5	BOTTOM	4.0	62	60		9.0	8.70	20	330	8.72	166	264	205	59	<0.02	<0.10	1.45	0.19	0.01	0.000
05/09/89	1000	5	SURFACE	0.5	60	52	2.0	10.5	8.20	<10	354	8.48	172	243	227	16	<0.02	<0.10	1.52	0.16	0.01	0.000
05/09/89	930	5	BOTTOM	4.0	58	52	2.0	9.5	8.20	<10	356	8.37	171	256	224	32	0.02	<0.10	1.55	0.18	<0.01	0.001
05/23/89	915	5	SURFACE	0.5	63	64	2.0	14.8	8.60	10	330	8.29	156	267	226	41	0.02	<0.10	1.77	0.24	0.06	0.002
05/23/89	930	5	BOTTOM	4.0	63	64	2.0	10.5	8.60	<10	331	8.57	154	252	221	31	0.02	<0.10	1.46	0.24	0.05	0.002
06/06/89	950	5	SURFACE	0.5	70	72	2.0	12.5	8.70	<10	259	9.11	125	194	190	4	0.10	<0.10	2.09	0.16	0.01	0.018
06/06/89	1000	5	BOTTOM	4.0	70	72	2.0	12.0	8.80	<10	259	9.07	126	191	179	12	0.14	<0.10	2.52	0.16	0.01	0.030
07/11/89	930	5	BOTTOM	4.0	79	87	1.3	7.5	8.90	20	281	8.84	130	218	206	12	0.46	<0.10	2.32	0.31	0.05	0.151
07/11/89	930	5	SURFACE	0.5	79	87	1.3	4.5	9.10	30	270	8.72	131	234	209	25	0.06	<0.10	2.58	0.36	0.06	0.026
07/25/89	1045	5	BOTTOM	4.0	76	80	1.0	5.0	9.40	80	289	8.67	133	229	218	11	0.08	<0.10	2.96	0.50	0.10	0.046
07/25/89	1030	5	SURFACE	0.5	74	80	1.0	6.0	8.90	60	294	8.69	134	289	215	74	0.10	<0.10	2.74	0.48	0.10	0.029
08/08/89	1015	5	BOTTOM	3.0	72	70	0.8	8.0	8.50	20	306	7.95	140	253	206	47	0.49	<0.10	3.95	0.48	0.11	0.063
08/08/89	1000	5	SURFACE	0.5	65	70	0.8	7.0	8.70	50	306	8.56	139	251	206	45	0.28	0.10	4.24	0.48	0.12	0.042
08/22/89	1000	5	BOTTOM	3.0	72	72	0.5		8.90	2	303	9.11	143	277	206	71	0.05	0.30	4.89	0.52	0.10	0.014
08/22/89	1000	5	SURFACE	0.5	71	72	0.5		9.00	<10	303	9.14	143	280	205	75	0.06	<0.10	4.56	0.51	0.08	0.019
09/05/89	1000	5	BOTTOM	3.0	71	72	0.5	8.0	8.70	50	308	8.85	146	285	222	63	0.07	<0.10	4.76	0.55	0.15	0.013
09/05/89	1000	5	SURFACE	0.5	70	72	0.5	6.0	8.50	40	339	8.68	148	278	225	53	0.11	<0.10	4.94	0.55	0.13	0.013
09/19/89	1400	5	SURFACE	0.5	70	76	6.0	15.0	9.30	70	307	9.25	152	297	245	52	0.03	<0.10	5.34	0.52	0.11	0.014
09/19/89	1405	5	BOTTOM	2.0	69	76	6.0	14.0	9.40	30	307	9.23	155	329	242	87	0.03	<0.10	4.67	0.56	0.13	0.015

DATE	TIME	SITE	SAMPLE	DEPTH	WTEMP	ATEMP	SDISK	DISOX	FPH	FECAL	COND	LABPH	ALK(T)	TSOL	TDSOL	TSSOL	AMMON	NO3+2	TKN-N	TPO4-P	OPO4-P	UNIAM
10/03/89	1100	5	SURFACE	0.5	52	52	0.5		8.80	<10	336	8.54	156	274	255	19	0.42	<0.10	3.70	0.49	0.13	0.048
10/03/89	1100	5	BOTTOM	2.0	54	52	0.5		8.80		336	8.46	160	371	256	115	0.47	<0.10	3.81	0.73	0.12	0.058
10/17/89	1050	5	BOTTOM	2.0	47	44	0.5	9.0	8.80	80	357	8.31	169	357	271	86	0.79	<0.10	3.75	0.56	0.18	0.074
10/17/89	1100	5	SURFACE	0.5	43	44	0.5	11.5	8.90	<10	347	8.54	161	316	274	42	0.73	<0.10	4.04	0.44	0.17	0.072
10/31/89	1045	5	SURFACE	0.5	42	44	0.5	11.0	8.80	10	385	8.39	171	290	274	16	0.95	<0.10	2.98	0.43	0.20	0.072
10/31/89	1045	5	BOTTOM	2.7	42	44	0.5	12.0	8.80	<10	385	8.39	173	296	278	18	0.98	<0.10	2.87	0.44	0.21	0.075
11/14/89	1000	5	SURFACE	0.5	38	30	2.0	12.0	7.80	30	396	8.28	183	307	262	45	1.48	<0.10	3.06	0.31	0.20	0.010
11/14/89	1015	5	BOTTOM	2.5	38	30	2.0	11.5	8.00	30	385	8.28	184	312	254	58	1.36	<0.10	2.93	0.32	0.20	0.015
03/28/89	1115	6	SURFACE	0.5	45	60	2.0	15.0	7.60	<10	363	8.09	175	258	245	13	0.12	0.10	1.80	0.28	0.06	0.001
03/28/89	1228	6	BOTTOM	10.5	44	60	2.0	17.5	7.70	<10	352	8.15	170	260	234	26	0.05	0.10	1.78	0.33	0.06	0.000
04/11/89	1345	6	SURFACE	0.5	42	45	2.5	14.8	8.60	<10	354	8.93	176	276	238	38	<0.02	<0.10	1.29	0.14	<0.01	0.000
04/11/89	1345	6	BOTTOM	10.0	45	45	2.5		8.60	<10	355	8.93	174	277	238	39	<0.02	<0.10	1.36	0.16	<0.01	0.000
04/25/89	1205	6	BOTTOM	16.0	61	62	2.0	11.0	8.70	10	330	8.91	164	253	214	39	<0.02	<0.10	1.64	0.16	<0.01	0.000
04/25/89	1205	6	SURFACE	0.5	63	62	2.0	11.5	8.70	10	330	8.95	297	242	205	37	<0.02	<0.10	1.34	0.13	<0.01	0.000
05/09/89	1030	6	BOTTOM	12.0	60	58	2.0	11.5	8.30	<10	352	8.60	168	245	224	21	<0.02	<0.10	1.18	0.14	<0.01	0.000
05/09/89	1020	6	SURFACE	0.5	58	60	2.0	11.5	8.30	<10	352	8.63	169	232	217	15	<0.02	<0.10	1.68	0.16	<0.01	0.000
05/23/89	950	6	SURFACE	0.5	68	70	2.0	16.0	8.80	<10	290	8.67	136	233	201	32	0.03	<0.10	1.53	0.22	0.01	0.006
05/23/89	1000	6	BOTTOM	12.0	65	70	2.0	12.8	8.70	<10	305	8.63	117	210	198	12	<0.02	<0.10	1.75	0.19	0.02	0.000
06/06/89	1030	6	SURFACE	0.5	70	74	2.0	12.5	9.30	<10	233	9.51	110	194	183	11	0.02	<0.10	2.97	0.29	0.01	0.009
06/06/89	1030	6	BOTTOM	12.0	70	74	2.0	14.0		<10	242	9.20	116	193	186	7	0.03	<0.10	2.25	0.25	<0.01	0.000
07/11/89	1000	6	BOTTOM	12.0	80	86	1.3	7.5	9.20	<2	270	9.19	133	229	205	24	0.04	<0.10	3.30	0.38	0.03	0.020
07/11/89	1000	6	SURFACE	0.5	78	80	1.3	8.0	10.30	<2	270	9.21	132	229	208	21	0.03	<0.10	2.74	0.36	0.03	0.028
07/25/89	1100	6	SURFACE	0.5	78	80	1.0	10.5	7.60	<10	276	9.39	132	293	218	75	1.41	<0.10	3.24	0.43	0.07	0.032
07/25/89	1100	6	BOTTOM	12.0	77	80	1.0	10.5	9.00	10	273	9.38	130	295	212	83	0.35	<0.10	3.45	0.45	0.06	0.127
08/08/89	1030	6	SURFACE	0.5	72	70	0.8	8.5	9.20	<10	306	7.95	141	243	203	40	0.08	<0.10	3.11	0.45	0.10	0.034
08/08/89	1040	6	BOTTOM	12.0	72	70	0.8	7.5	9.00	4	301	7.98	140	249	192	57	0.44	<0.10	3.81	0.45	0.20	0.140
08/22/89	1045	6	BOTTOM	10.0	74	73	0.5		8.70	<10	300	8.84	144	269	209	60	0.04	<0.10	4.23	0.55	0.11	0.008
08/22/89	1045	6	SURFACE	0.5	74	73	0.5		8.80	<10	303	8.98	144	266	193	73	0.05	<0.10	3.45	0.52	0.10	0.012
09/05/89	1030	6	SURFACE	0.5	72	72	0.5	8.5	8.20	<10	333	9.01	147	287	233	54	0.06	<0.10	5.83	0.58	0.12	0.004
09/05/89	1030	6	BOTTOM	10.0	72	72	0.5	7.5	8.90	<10	351	8.95	148	281	224	57	0.05	<0.10	4.09	0.58	0.13	0.014
09/19/89	1420	6	BOTTOM	10.0	65	76	6.0	13.0	9.00	10	318	8.96	153	309	246	63	0.02	0.20	4.90	0.53	0.11	0.005
09/19/89	1415	6	SURFACE	0.5	70	76	6.0	15.0	9.40	50	307	9.17	154	298	243	55	0.02	4.10	1.79	0.53	0.11	0.010
10/03/89	1130	6	BOTTOM	10.0	56	48	0.5		8.70	<10	341	8.48	158	285	259	26	0.38	<0.10	3.91	0.49	0.13	0.041
10/03/89	1130	6	SURFACE	0.5	52	48	0.5		8.50	<10	336	8.41	157	276	258	18	0.38	<0.10	3.60	0.49	0.12	0.023
10/17/89	1115	6	BOTTOM	10.0	50	44	0.5	10.0	8.70		357	8.58	162	301	268	33	0.68	<0.10	3.76	0.46	0.15	0.058
10/17/89	1115	6	SURFACE	0.5	48	44	0.5	10.0	8.60	<10	357	8.55	162	307	273	34	0.66	<0.10	3.62	0.44	0.15	0.042
10/31/89	1100	6	BOTTOM	10.0	47	44	0.5	10.5	8.70	<10	360	8.45	169	299	274	25	0.82	<0.10	2.82	0.43	0.17	0.062
10/31/89	1100	6	SURFACE	0.5	43	44	0.5	10.0	8.70	<10	364	8.39	167	296	275	21	0.82	<0.10	2.66	0.43	0.17	0.053
11/14/89	1030	6	BOTTOM	10.0	40	30	2.0	11.5	9.00	10	375	8.34	183	306	262	44	1.40	<0.10	3.46	0.35	0.18	0.149
11/14/89	1030	6	SURFACE	0.5	38	30	2.0	12.0	8.80	10	378	8.36	183	308	255	53	1.42	<0.10	3.23	0.34	0.19	0.091

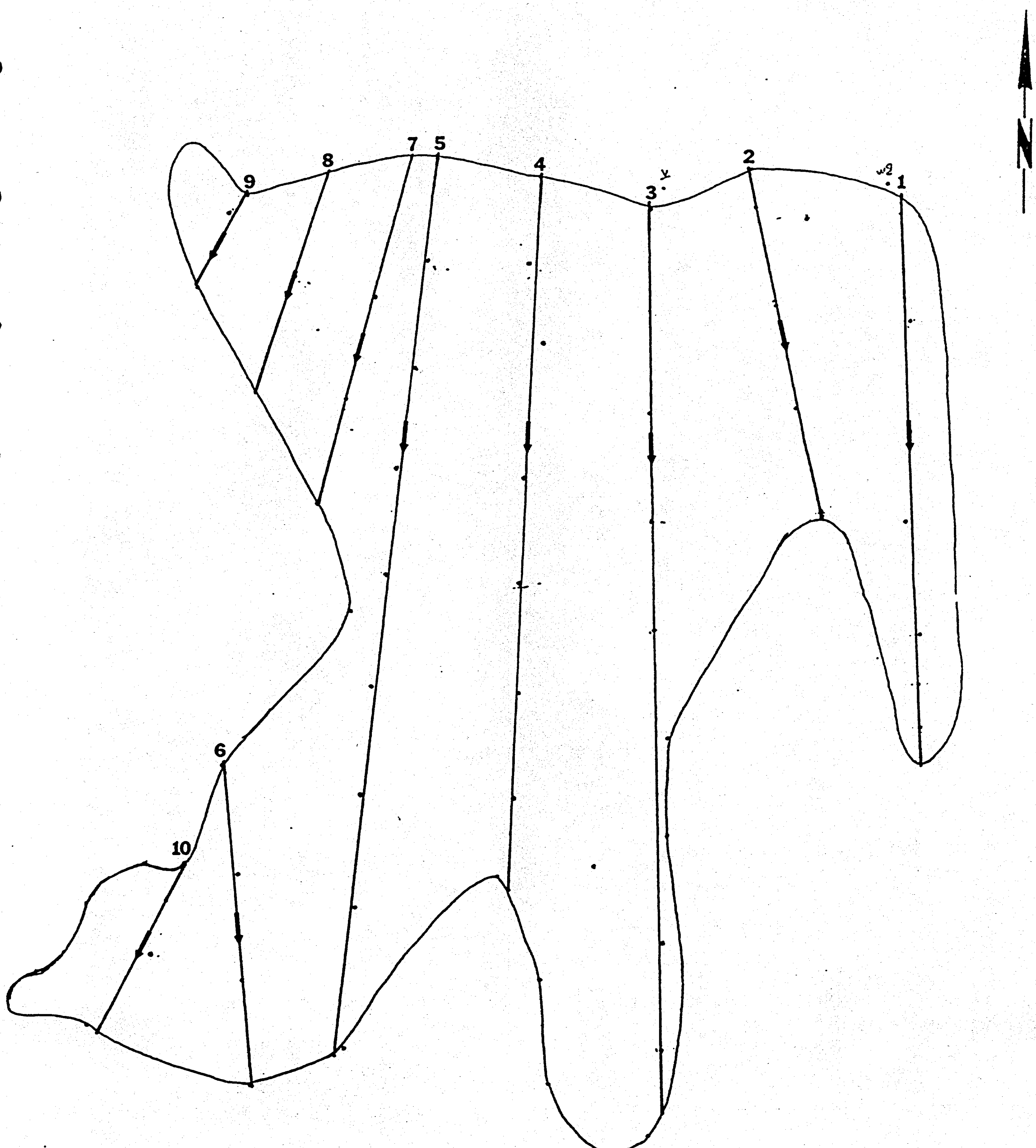
BURKE LAKE 1990 SAMPLING DATA

DATE	TIME	SITE	SAMPLE	DEPTH	WTEMP	ATEMP	SDISK	DISOX	FPH	FECAL	COND	LABPH	ALK(T)	TSOL	TDSOL	TSSOL	AMMON	NO3+2	TKN-N	TPO4-P	OPO4-P	UNIAM
03/13/90	1200	2	SURFACE	0.5	39	33		7.3	8.10	10		7.74	210	337	321	16	0.40	0.10	1.77	0.68	0.47	0.001
03/27/90	935	2	SURFACE	0.5	38	50		11.0	7.50	430		7.69	194	300	294	6	0.13	0.10	0.91	0.37	0.23	0.000
04/10/90	915	2	SURFACE	0.5	38	40		10.3	7.40	1300		7.69	199	315	291	24	0.02	<0.10	0.52	0.73	0.43	0.000
04/24/90	915	2	SURFACE	0.5	62	64		3.5	7.60	70		7.78	224	347	342	5	0.26	0.10	1.29	1.76	1.35	0.000
05/08/90	915	2	SURFACE	0.5	54	66		7.5	7.80	160000		7.68	229	378	358	20	0.30	<0.10	2.18	1.70	1.50	0.001
05/22/90	1030	2	SURFACE	0.5	63	68		8.0	7.70			7.52	230	392	366	26	0.08	0.10	1.17	0.78	0.63	0.000
06/05/90	915	2	SURFACE	0.5	62	71		4.3	7.50	630		7.56	228	490	351	138	0.38	0.10	1.94	1.39	0.94	0.001
06/26/90	1045	2	SURFACE	0.5	76	86		2.5	7.50	50		7.54	228	361	337	4	0.17	<0.10	1.19	0.97	0.64	0.000
03/13/90	1240	3	SURFACE	0.5	37	34		11.0	8.30			7.80	200	287	282	5	0.03	<0.10	0.46	0.14	0.12	0.000
03/27/90	1010	3	SURFACE	0.5	36	45		13.5	7.90	250		7.89	184	270	257	13	<0.02	<0.10	0.61	0.12	0.09	0.000
04/10/90	945	3	SURFACE	0.5	38	41		6.5	7.90	100		7.64	211	291	282	9	0.12	<0.10	1.49	0.91	0.11	0.000
04/24/90	940	3	SURFACE	0.5	58	64		5.1	7.60	70		7.76	246	356	354	2	<0.02	0.10	0.68	0.29	0.22	0.000
05/08/90	945	3	SURFACE	0.5	52	60		7.8	7.70	60		7.78	212	315	306	9	<0.02	<0.10	0.73	0.20	0.18	0.000
05/22/90	1100	3	SURFACE	0.5	60	64		5.5	7.60			7.51	215	345	313	32	0.02	0.10	0.86	0.29	0.14	0.000
06/05/90	945	3	SURFACE	0.5	58	61		3.5	7.50	390		7.45	220	336	311	14	0.03	<0.10	0.94	0.33	0.20	0.000
06/26/90	1015	3	SURFACE	0.5	70	80			7.70			7.56	436	814	639	64	15.24	<0.10	19.44	2.56	0.62	0.051
03/13/90	1250	4	SURFACE	0.5	41	32		15.5	9.10	>10		8.51	181	337	263	74	0.07	<0.10	2.89	0.53	0.02	0.002
03/27/90	1015	4	SURFACE	0.5	40	51		12.3	8.40	<10		8.48	177	284	264	20	0.02	<0.10	1.56	0.18	0.01	0.000
04/10/90	1010	4	SURFACE	0.5	38	40		7.5	7.90	<10		7.98	179	320	253	67	0.08	0.10	1.87	0.57	0.04	0.000
04/24/90	1000	4	SURFACE	0.5	58	64		5.3	7.80	<10		7.97	183	277	274	3	0.12	0.10	1.24	0.16	0.08	0.000
05/08/90	1000	4	SURFACE	0.5	48	62		9.5	7.30	80		8.17	180	290	264	26	0.08	<0.10	1.66	0.25	0.05	0.000
05/22/90	1110	4	SURFACE	0.5	64	68		12.5	8.70	1200		8.19	182	672	265	407	0.13	0.10	1.41	0.45	0.03	0.003
06/05/90	1030	4	SURFACE	0.5	62	70		11.5	8.60	60		8.26	165	279	256	6	0.02	<0.10	1.85	0.27	0.12	0.000
06/26/90		4	NO WATER TO SAMPLE																			
03/13/90	1010	5	BOTTOM	4.5	40	41	2.0	16.0	9.10	<10	407	8.60	181	292	268	24	0.02	<0.10	1.96	0.24	0.01	0.000
03/13/90	1005	5	SURFACE	0.5	40	41	2.0	16.0	9.20		391	8.58	184	295	273	22	0.03	<0.10	2.52	0.22	0.01	0.001
03/27/90	1100	5	SURFACE	0.5	40	51	2.0	13.5	8.50	<10	388	8.46	178	278	266	12	0.02	<0.10	1.77	0.18	<0.01	0.000
03/27/90	1105	5	BOTTOM	4.0	40	51	2.0	14.0	8.50	10	381	8.44	182	287	260	27	0.02	<0.10	1.71	0.28	0.01	0.000
04/10/90	1055	5	SURFACE	0.5	40	40	2.0	11.5	8.20	<10	386	8.44	182	270	255	15	0.02	<0.10	1.51	0.17	0.02	0.000
04/10/90	1100	5	BOTTOM	4.0	40	40	2.0	12.5	7.90	10	381	8.39	184	285	256	29	0.03	<0.10	1.53	0.31	0.02	0.000
05/08/90	1030	5	BOTTOM	4.0	60	62	1.5	12.0	8.30	120	420	8.37	183	281	261	20	<0.02	<0.10	1.54	0.37	0.06	0.000
05/08/90	1030	5	SURFACE	0.5	60	62	1.5	11.0	8.50		428	6.93	182	281	271	10	<0.02	<0.10	1.29	0.21	0.05	0.000
05/22/90	945	5	SURFACE	0.5	60	65	1.0	15.5	8.70	<10	395	8.73	183	303	272	31	<0.02	0.10	1.68	0.26	0.05	0.000
05/22/90	945	5	BOTTOM	2.5	60	65	1.0	15.5	8.50	10	394	8.73	183	304	285	19	0.03	<0.10	1.54	0.25	0.06	0.000
06/26/90	930	5	SURFACE	0.5	82	76	0.5	9.0	8.90	<10	331	8.89	157	281	248	33	0.02	<0.10	2.12	0.39	0.10	0.002
06/26/90	930	5	BOTTOM	3.0	76	82	0.5	9.0	8.90	<10	337	8.82	157	272	246	26	0.03	0.40	2.10	0.37	0.11	0.002

DATE	TIME	SITE	SAMPLE	DEPTH	WTEMP	ATEMP	SDISK	DISOX	FPH	FECAL	COND	LABPH	ALK(T)	TSOL	TDSOL	TSSOL	AMMON	NO3+2	TKN-N	TPO4-P	OPO4-P	UNIAM
03/13/90	1045	6	SURFACE	0.5	42	40	2.0	16.8	9.10	<10	391	8.70	178	295	269	26	0.04	<0.10	2.07	0.31	<0.01	0.001
03/13/90	1050	6	BOTTOM	13.0	40	40	2.0	17.0	9.00		376	8.69	178	296	270	26	0.02	<0.10	2.27	0.22	<0.01	0.000
03/27/90	1130	6	SURFACE	0.5	38	51	2.0	13.3	8.50	<10	376	8.56	181	278	262	16	0.02	<0.10	1.71	0.18	<0.01	0.000
03/27/90	1130	6	BOTTOM	12.0	41	51	2.0	13.5	8.50	<10	391	8.54	181	280	261	19	0.02	<0.10	1.60	0.23	<0.01	0.000
04/10/90	1130	6	BOTTOM	12.0	41	38	2.0	13.5	8.50	<10	381	8.34	181	277	252	25	0.02	<0.10	1.54	0.21	0.01	0.000
04/10/90	1120	6	SURFACE	0.5	42	38	2.0	13.5	8.50	<10	376	8.51	181	280	253	27	0.02	<0.10	1.48	0.16	0.02	0.000
05/08/90	1045	6	BOTTOM	12.0	59	62	1.5	11.8	8.60	20	418	8.46	181	286	258	28	<0.02	<0.10	1.40	0.21	0.04	0.000
05/08/90	1040	6	SURFACE	0.5	60	62	1.5	12.0	8.60	20	422	8.40	182	290	260	30	0.02	<0.10	1.40	0.17	0.05	0.000
05/22/90	1000	6	SURFACE	0.5	63	60	1.0	16.0	8.50	<10	365	8.80	181	294	267	27	0.02	<0.10	1.37	0.21	0.02	0.000
05/22/90	1000	6	BOTTOM	11.0	56	60	1.0	9.0	8.40		340	8.51	180	283	277	6	0.02	<0.10	1.32	0.20	0.03	0.000
06/26/90	945	6	BOTTOM	10.0	71	82	0.5	8.0	8.40	<10	370	8.35	163	269	253	16	0.22	<0.10	2.11	0.41	0.23	0.004
06/26/90	945	6	SURFACE	0.5	76	82	0.5	13.0	9.20	<10	337	9.21	159	286	249	37	<0.02	<0.10	1.99	0.37	0.13	0.000

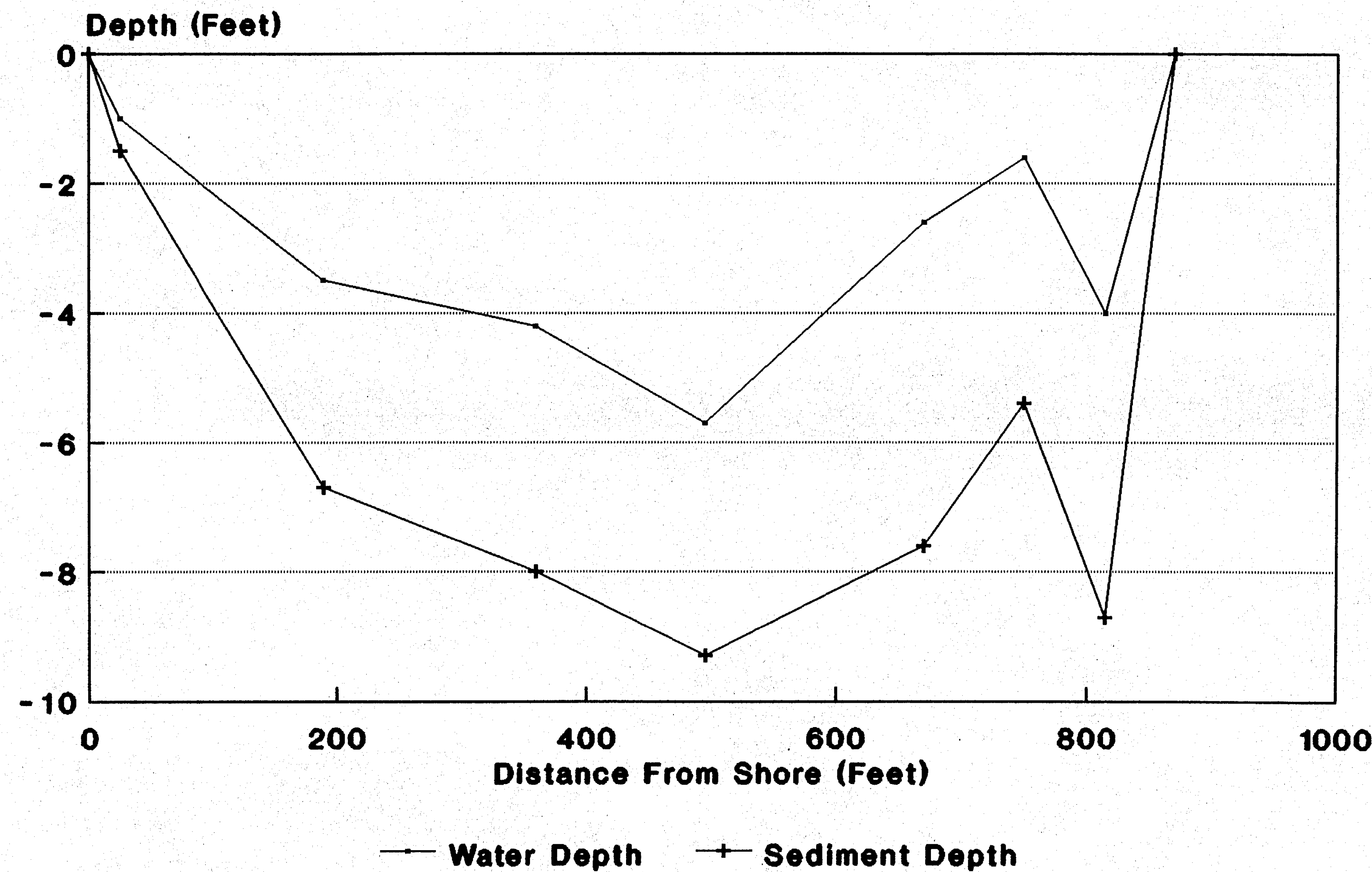
APPENDIX B
Lake Basin Cross Sections

Burke Lake Survey Cross-Section Locations.



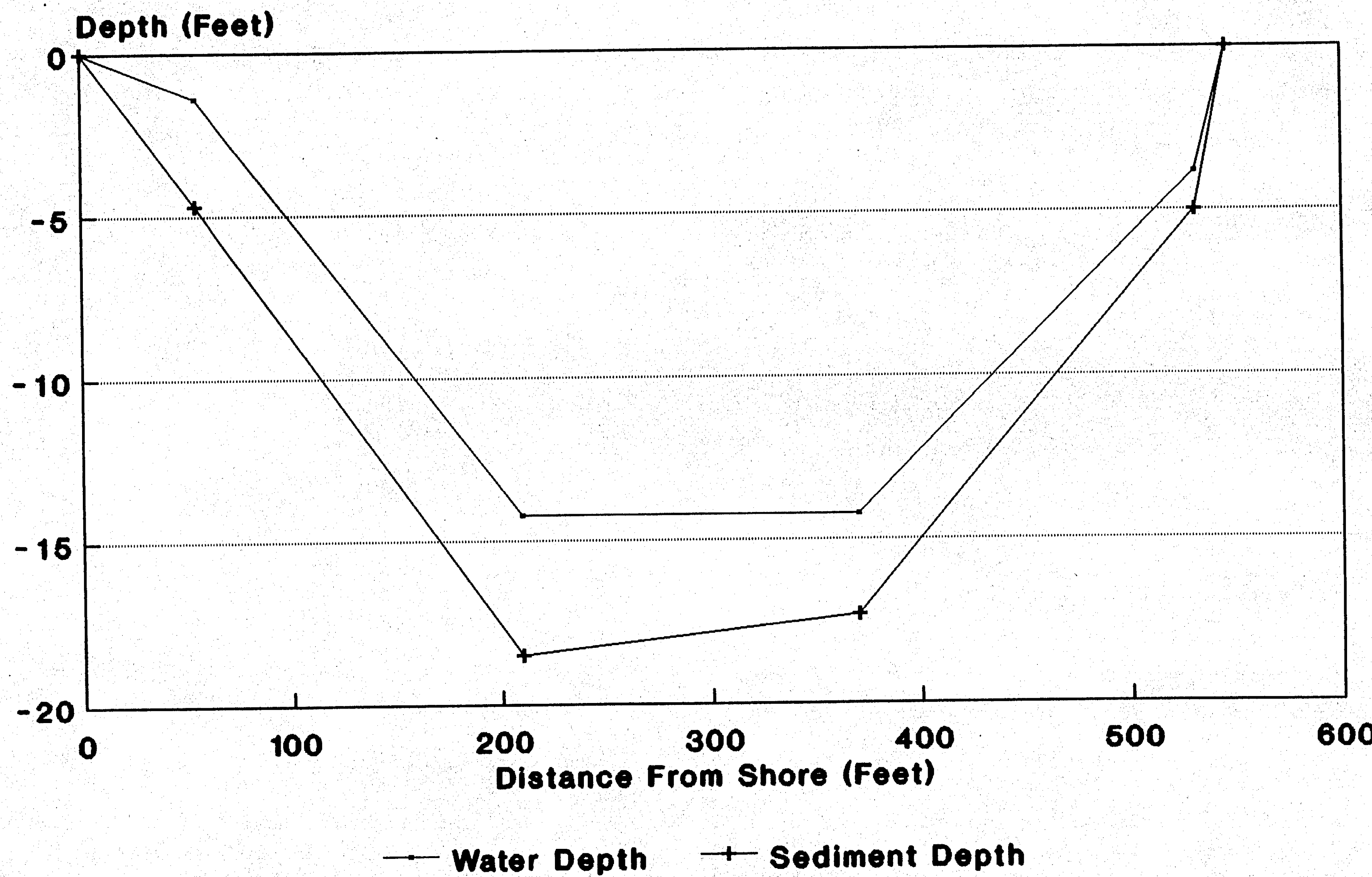
Note: Survey Data Collected 2/16/89.

Burke Lake Cross-Section Data
Cross-Section 1



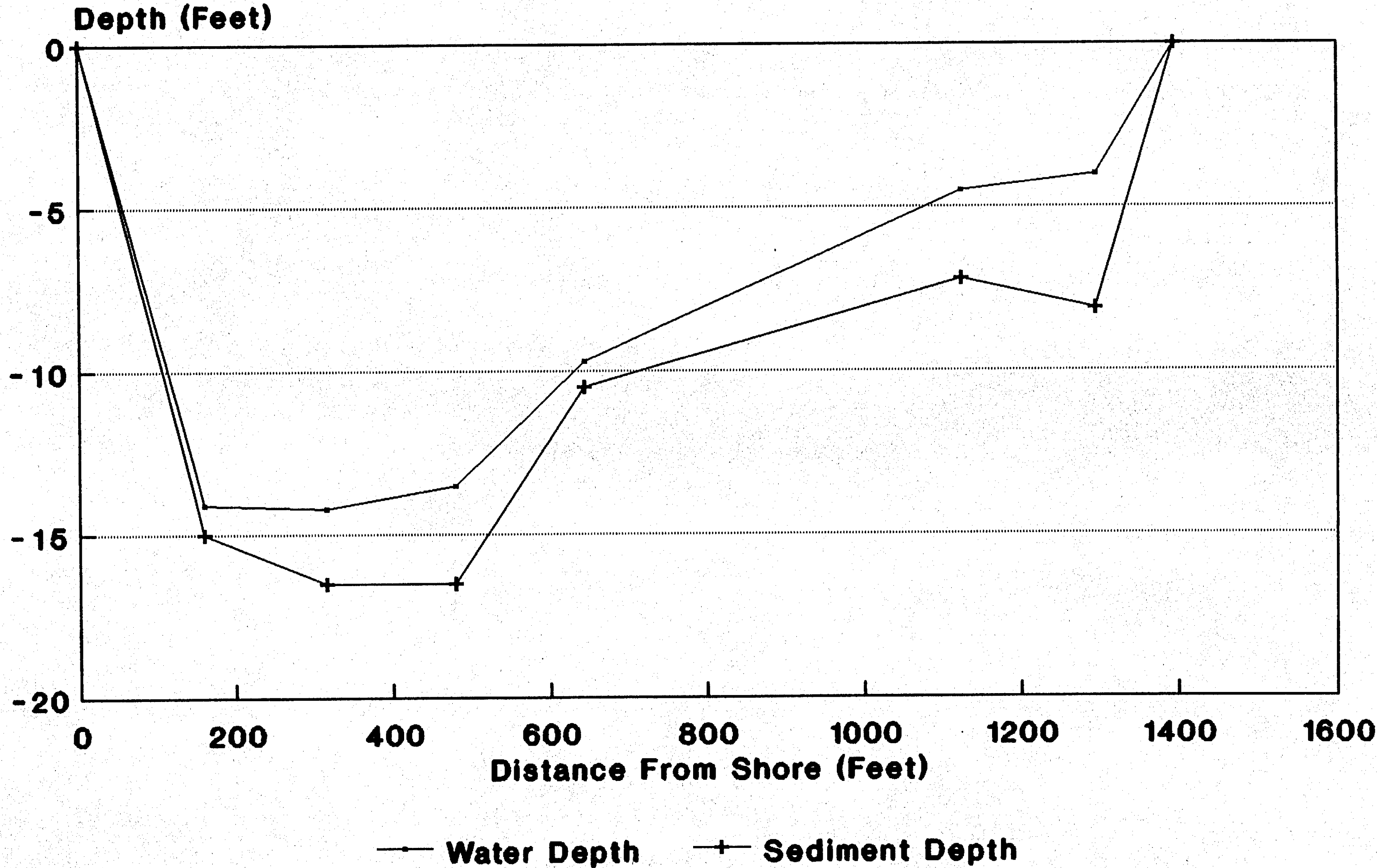
Data Collected 2/16/89

Burke Lake Cross-Section Data
Cross-Section 2



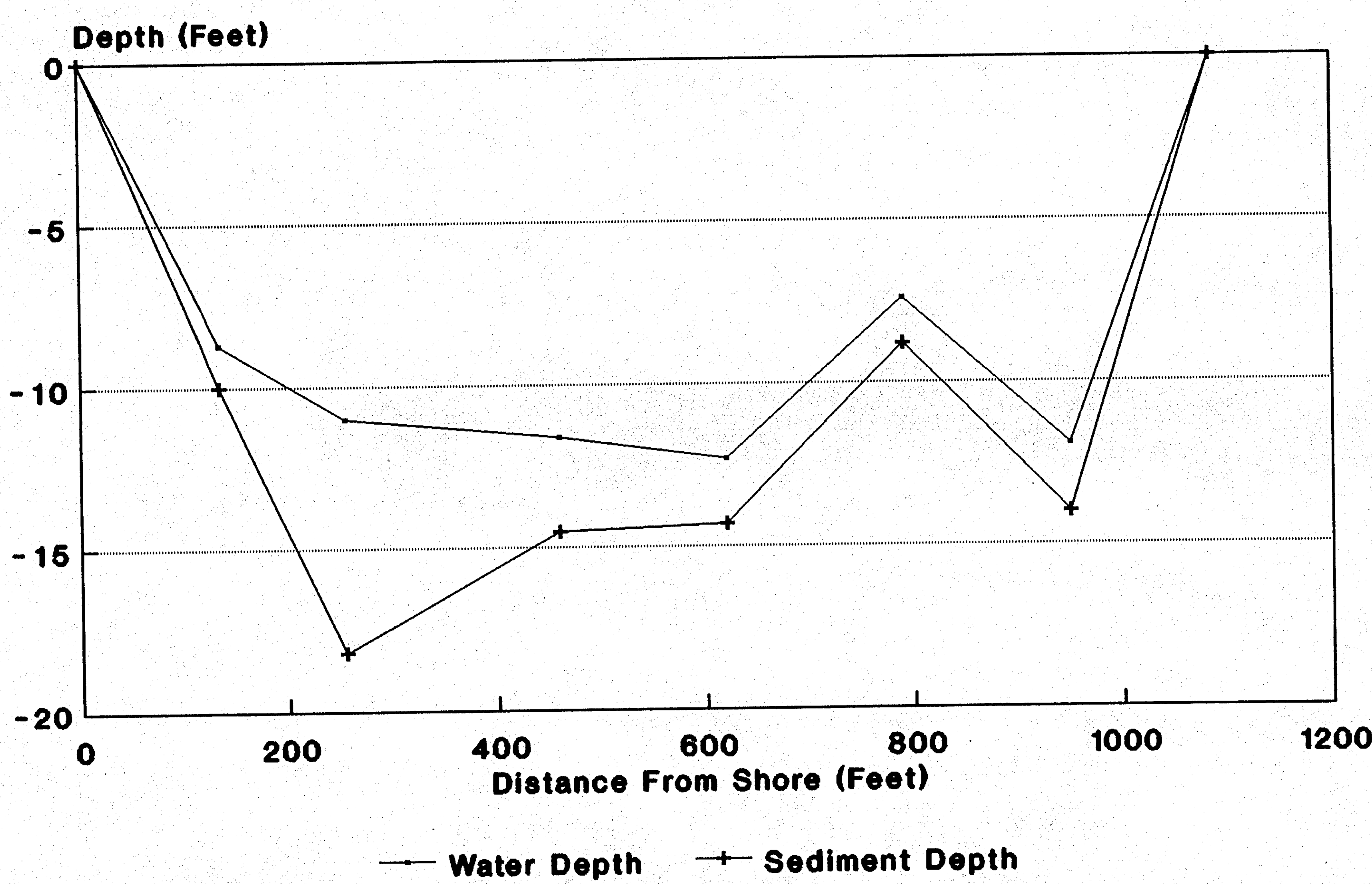
Data Collected 2/16/89

Burke Lake Cross-Section Data
Cross-Section 3



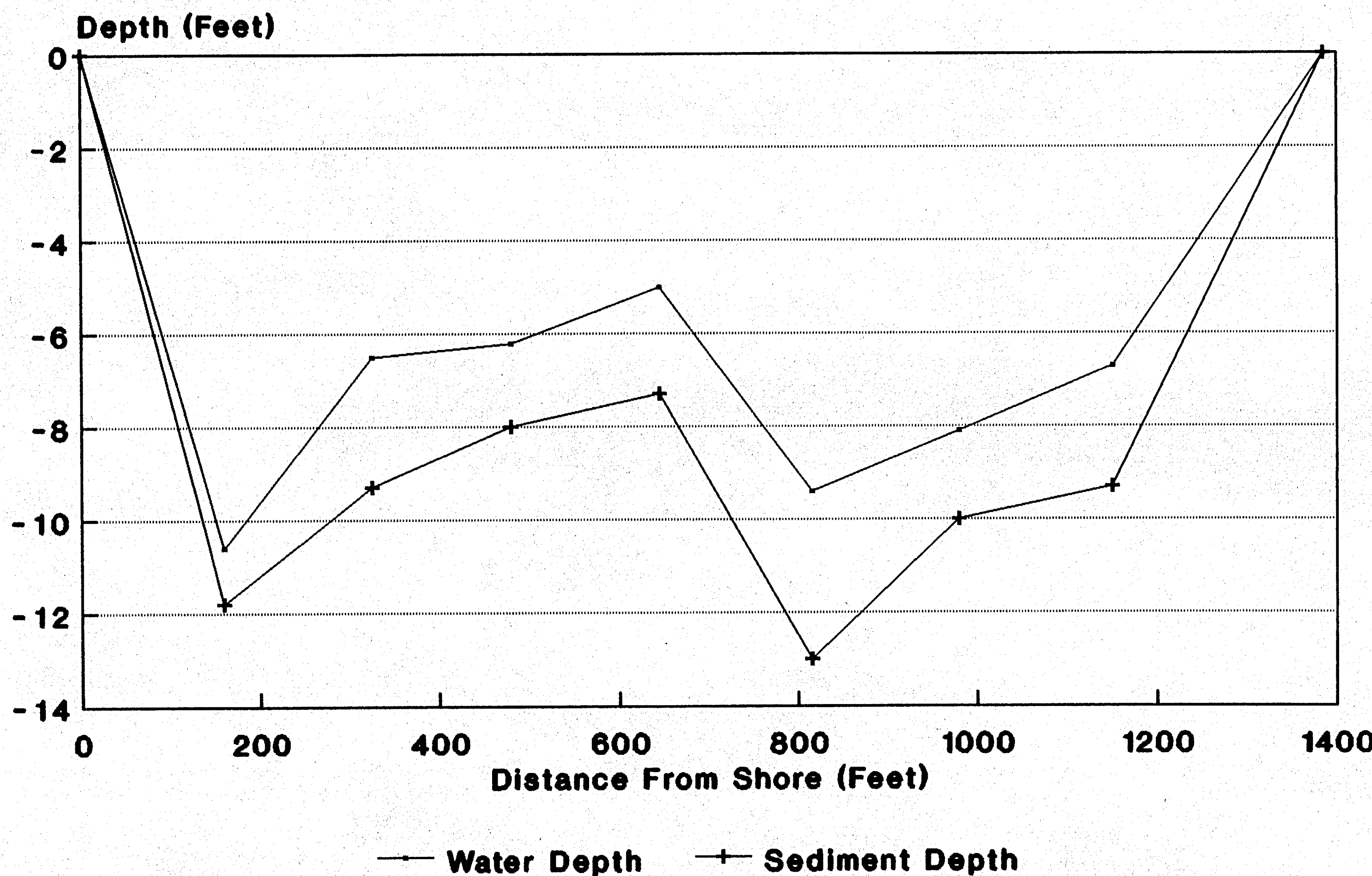
Data Collected 2/16/89

Burke Lake Cross-Section Data
Cross-Section 4



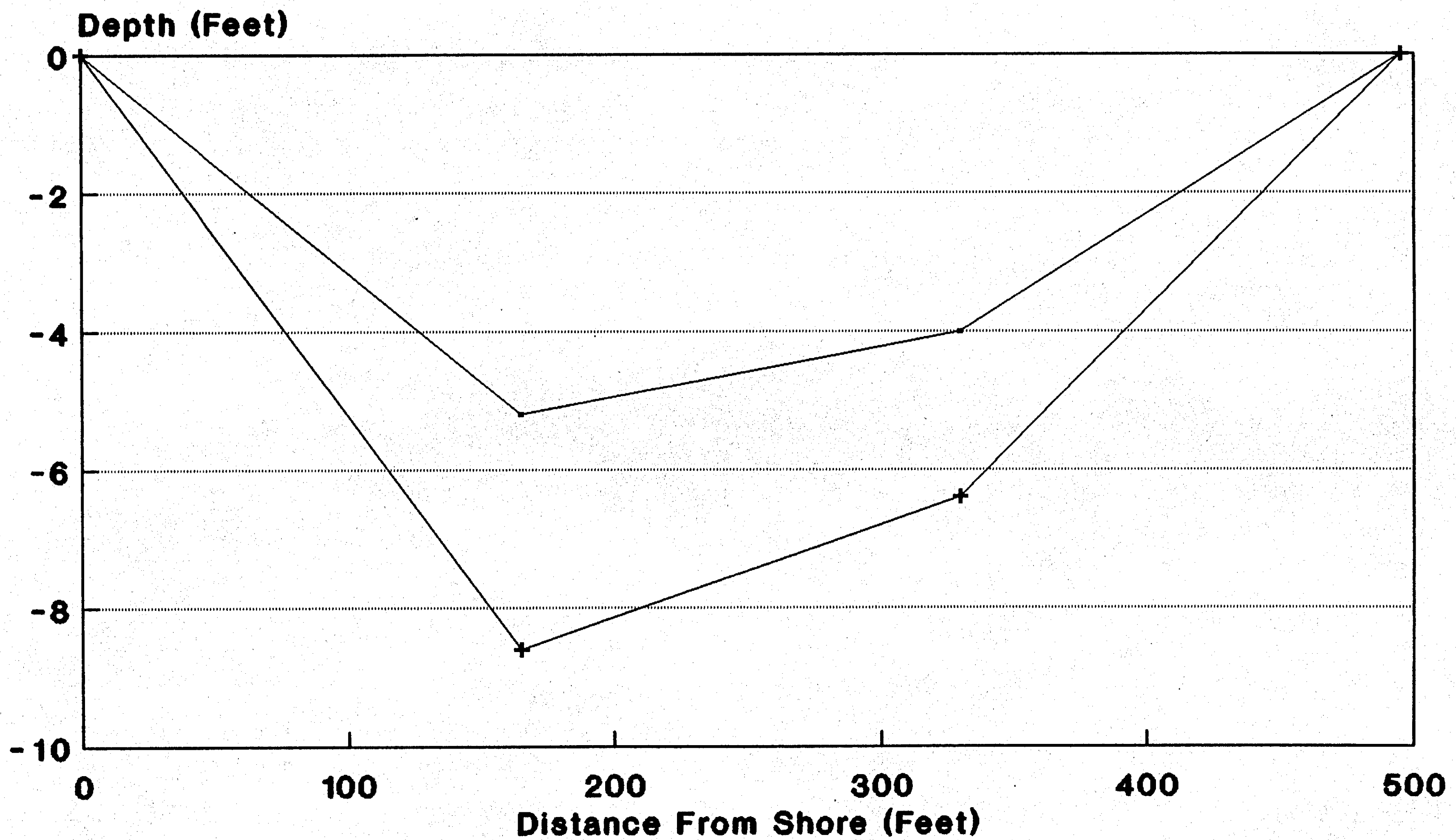
Data Collected 2/16/89

Burke Lake Cross-Section Data
Cross-Section 5



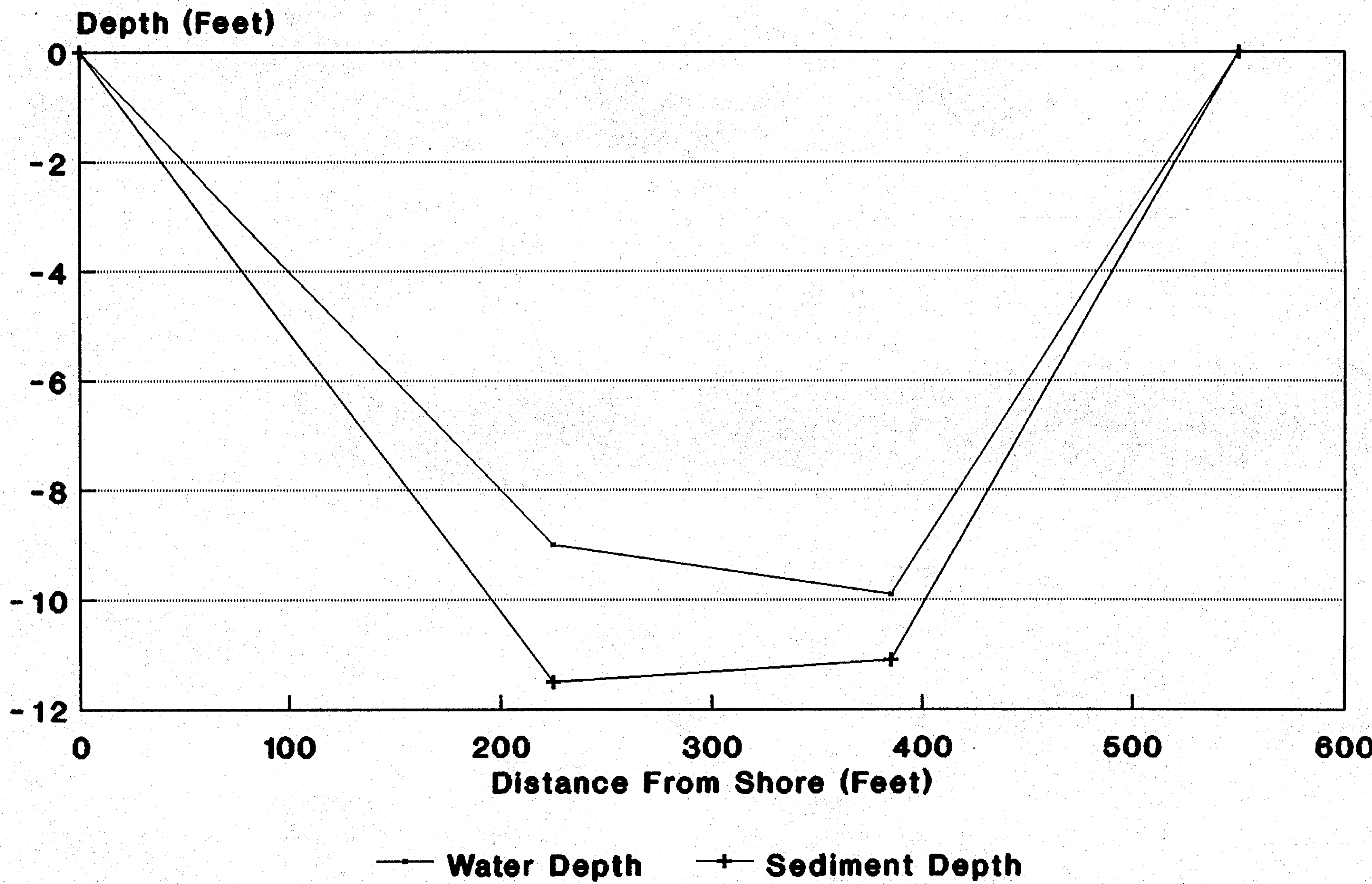
Data Collected 2/16/89

Burke Lake Cross-Section Data
Cross-Section 6



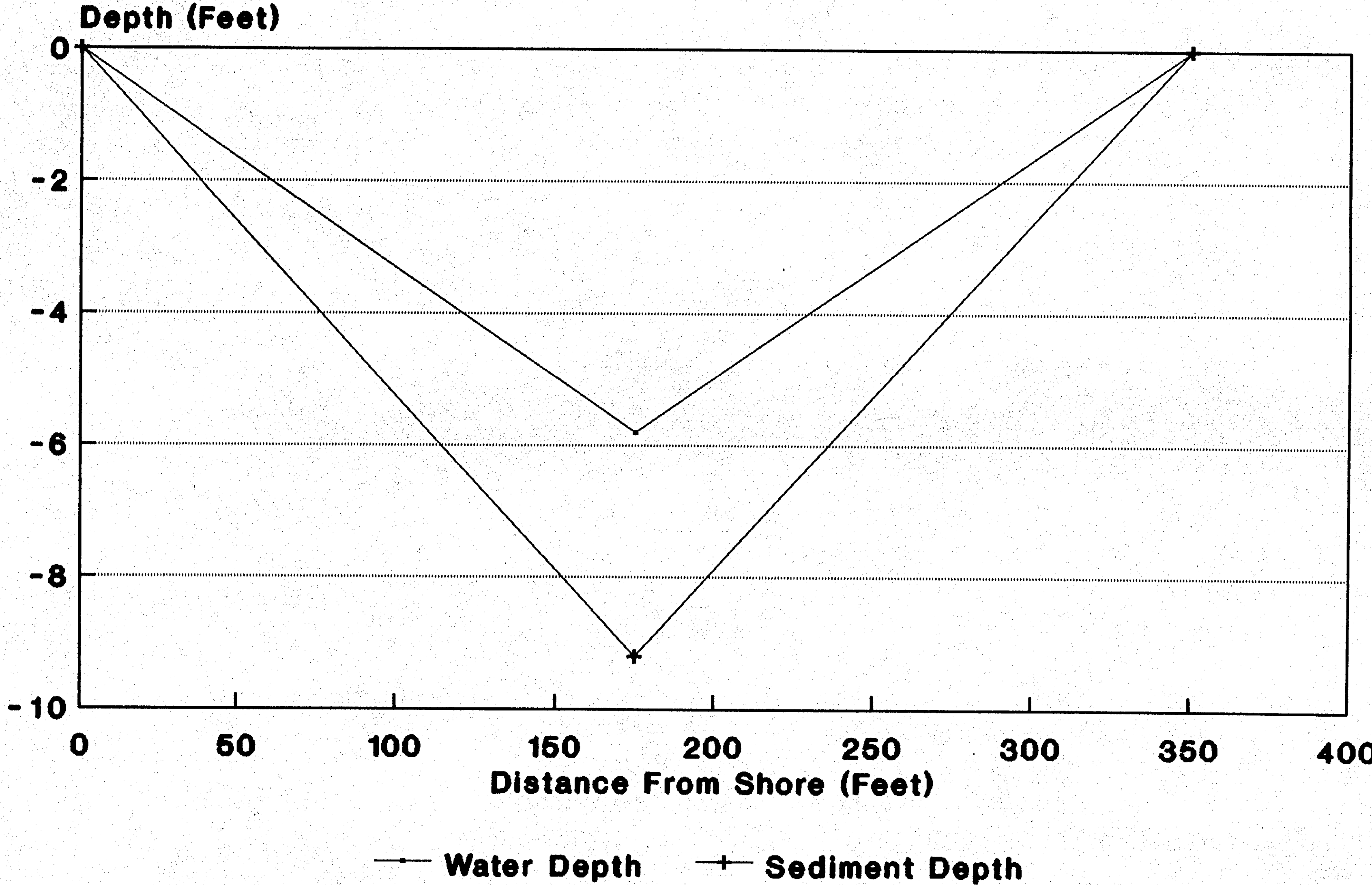
Data Collected 2/16/89

Burke Lake Cross-Section Data
Cross-Section 7



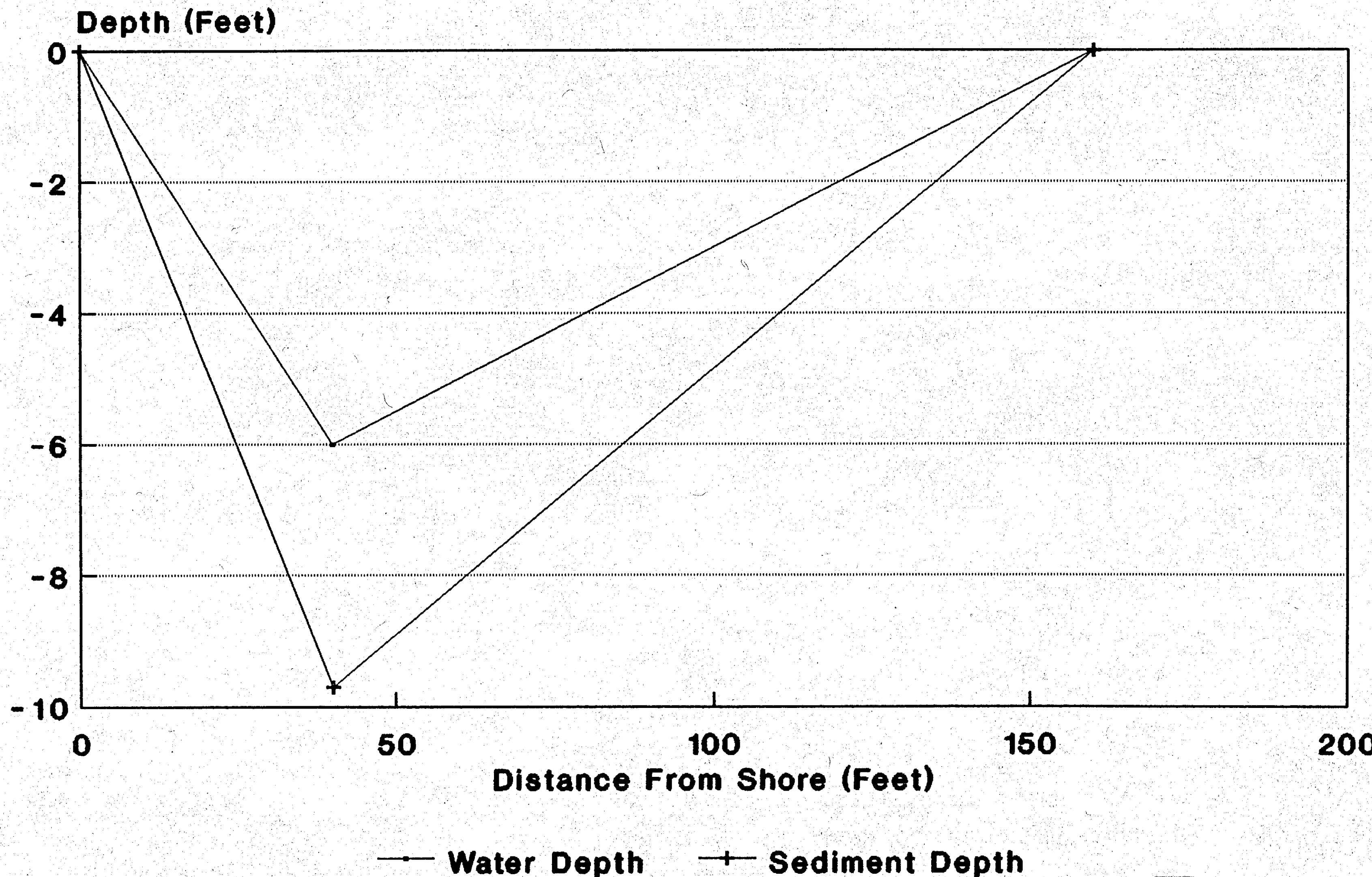
Data Collected 2/16/89

Burke Lake Cross-Section Data
Cross-Section 8



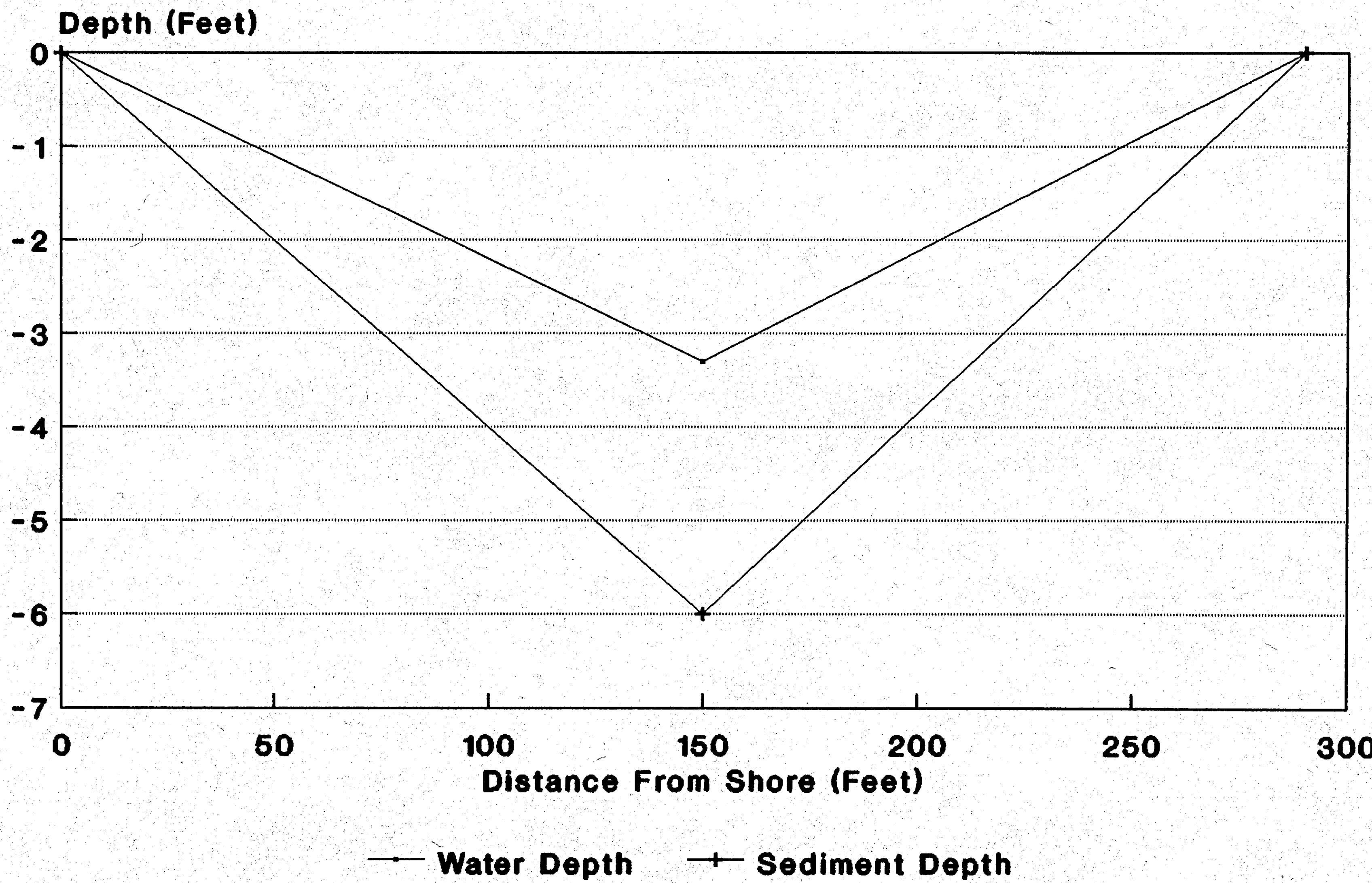
Data Collected 2/16/89

Burke Lake Cross-Section Data
Cross-Section 9



Data Collected 2/16/89

Burke Lake Cross-Section Data
Cross-Section 10



Data Collected 2/16/89

APPENDIX C
Elutriate Sample Data

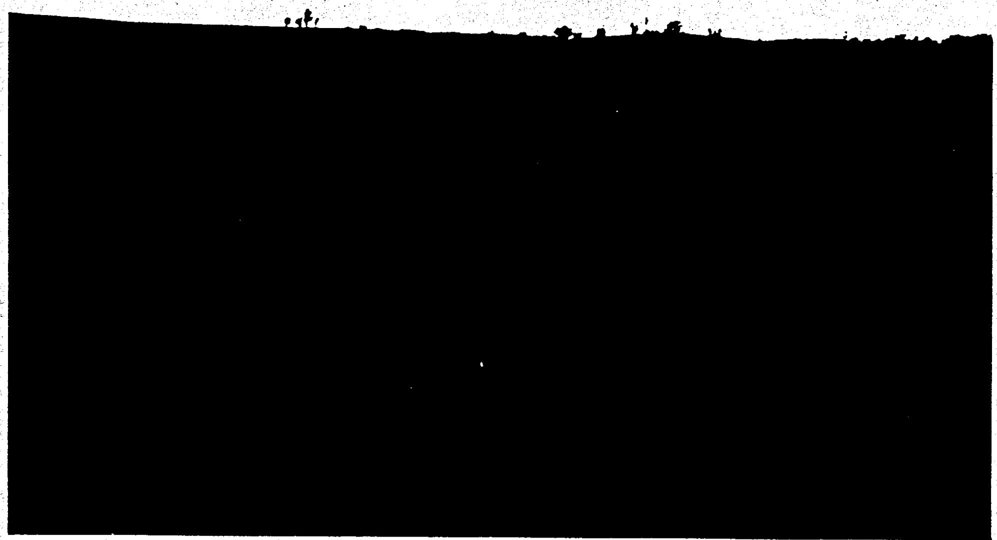
MRD LAB No. 89/672

DEPARTMENT OF THE ARMY
Missouri River Division, Corps of Engineers
Division Laboratory
Omaha, Nebraska

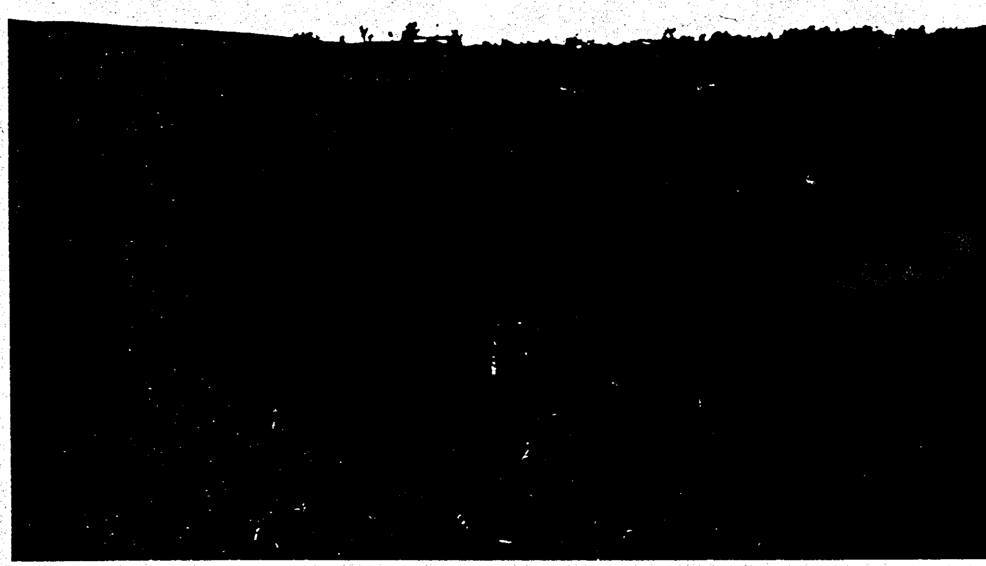
Project: South Dakota Department of Water and Natural Resource
Date Sample Taken: 16 Feb 89 Customer Sample Id: Burke Lake
Date Sample Received: 21 Feb 89 Lab Sample No: M-983
Sample Description: Water and Sediment Sample Container: 2-1gal glass (water) and 1-1gal glass (sediment)
Time Sample Taken: 3:45pm
Comments: Burke Lake (Center of Lake, PT 12) Gregory County, SD

Analysis	Sediment Result	Units	Receiving Water Result	Units	Elutriate Water Result	Units
Ammonia Nitrogen			0.82	mg/L	3.6	mg/L
Chemical Oxygen Demand			43	mg/L	57.0	mg/L
Total Cyanide			<0.02	mg/L	<0.02	mg/L
Nitrate-Nitrite Nitrogen			0.28	mg/L	<0.01	mg/L
Total Phosphorus			0.22	mg/L	0.14	mg/L
Total Kjeldahl Nitrogen			5.3	mg/L	1.6	mg/L
Oil and Grease			<5	mg/L	10	mg/L
Antimony	0.42	mg/Kg	<1	ug/L	<1	ug/L
Arsenic	1.5	mg/Kg	2	ug/L	4	ug/L
Barium	340	mg/Kg	420	ug/L	210	ug/L
Beryllium	1.0	mg/Kg	<1	ug/L	<1	ug/L
Cadmium	<0.5	mg/Kg	<0.1	ug/L	<0.1	ug/L
Chromium	20	mg/Kg	<1	ug/L	<1	ug/L
Copper	26	mg/Kg	<5	ug/L	<5	ug/L
Iron	27000	mg/Kg	70	ug/L	220	ug/L
Lead	<5	mg/Kg	<1	ug/L	<1	ug/L
Magnesium	7400	mg/Kg	13	mg/L	10	mg/L
Manganese	630	mg/Kg	13	ug/L	990	ug/L
Mercury	<0.1	mg/Kg	<0.2	ug/L	<0.2	ug/L
Selenium	1.2	mg/Kg	<1	ug/L	<1	ug/L
Zinc	77	mg/Kg	<2	ug/L	<2	ug/L
Nickel	12	mg/Kg	2	ug/L	<1	ug/L
Aluminum	33000	mg/Kg	<40	ug/L	<40	ug/L
Calcium	43000	mg/Kg	51	mg/L	42	mg/L
Sodium	240	mg/Kg	16	mg/L	16	mg/L
Potassium	4500	mg/Kg	24	mg/L	14	mg/L
Silver	<1	mg/Kg	<0.2	ug/L	<0.2	ug/L
Simazine (Princep)	<100	ug/Kg	<0.1	ug/L	<0.1	ug/L
Metribuzin (Lexone)	<100	ug/Kg	<0.1	ug/L	<0.1	ug/L
Atrazine (Aatrex)	<100	ug/Kg	<0.1	ug/L	<0.1	ug/L
Aldrin	<10	ug/Kg	<0.01	ug/L	<0.01	ug/L
alpha-BHC	<10	ug/Kg	<0.01	ug/L	<0.01	ug/L
beta-BHC	<10	ug/Kg	<0.01	ug/L	<0.01	ug/L
gamma-BHC (Lindane)	<10	ug/Kg	<0.01	ug/L	<0.01	ug/L
Mirex	<10	ug/Kg	<0.01	ug/L	<0.01	ug/L
Chlordane	<10	ug/Kg	<0.01	ug/L	<0.01	ug/L
P'P"DDD	<10	ug/Kg	<0.01	ug/L	<0.01	ug/L
P'P"DDE	<10	ug/Kg	<0.01	ug/L	<0.01	ug/L
P'P"DDT	<10	ug/Kg	<0.01	ug/L	<0.01	ug/L
Dieldrin	<10	ug/Kg	<0.01	ug/L	<0.01	ug/L
Endosulfan I	<10	ug/Kg	<0.01	ug/L	<0.01	ug/L
Propachlor (Ramrod)	<100	ug/Kg	<0.1	ug/L	<0.1	ug/L
Metolachlor (Dual)	<100	ug/Kg	<0.1	ug/L	<0.1	ug/L
Alachlor (Lasso)	<100	ug/Kg	<0.1	ug/L	<0.1	ug/L
Diazinon	<100	ug/Kg	<0.1	ug/L	<0.1	ug/L
Endrin	<10	ug/Kg	<0.01	ug/L	<0.01	ug/L
Heptachlor	<10	ug/Kg	<0.01	ug/L	<0.01	ug/L
Heptachlor epoxide	<10	ug/Kg	<0.01	ug/L	<0.01	ug/L
Methoxychlor	<10	ug/Kg	<0.01	ug/L	<0.01	ug/L
Toxaphene	<500	ug/Kg	<0.5	ug/L	<0.5	ug/L
PCB-1016	<100	ug/Kg	<0.1	ug/L	<0.1	ug/L
PCB-1221	<100	ug/Kg	<0.1	ug/L	<0.1	ug/L
PCB-1232	<100	ug/Kg	<0.1	ug/L	<0.1	ug/L
PCB-1242	<100	ug/Kg	<0.1	ug/L	<0.1	ug/L
PCB-1248	<100	ug/Kg	<0.1	ug/L	<0.1	ug/L
PCB-1254	<100	ug/Kg	<0.1	ug/L	<0.1	ug/L
PCB-1260	<100	ug/Kg	<0.1	ug/L	<0.1	ug/L

APPENDIX D
Watershed Photographs

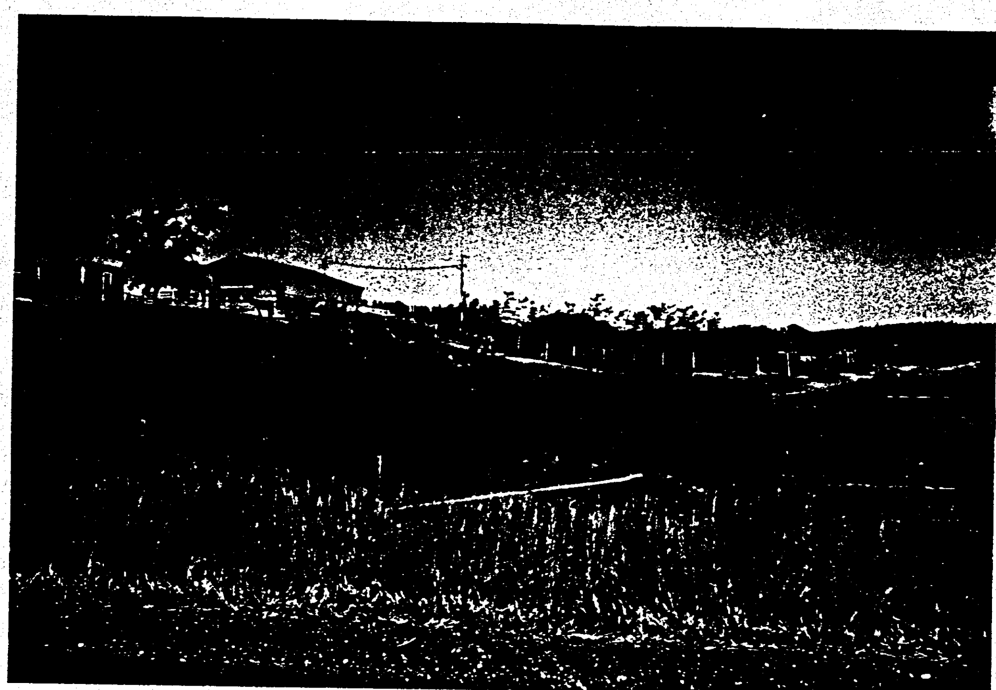


Photograph 1.
Date: 10-3-90
Photographer: P. Szewczykowski
Orientation: Looking west towards abandoned landfill.
Description: D/F study monitoring well #2. Well is located directly east and approximately 1500 feet downgradient of the abandoned city landfill.

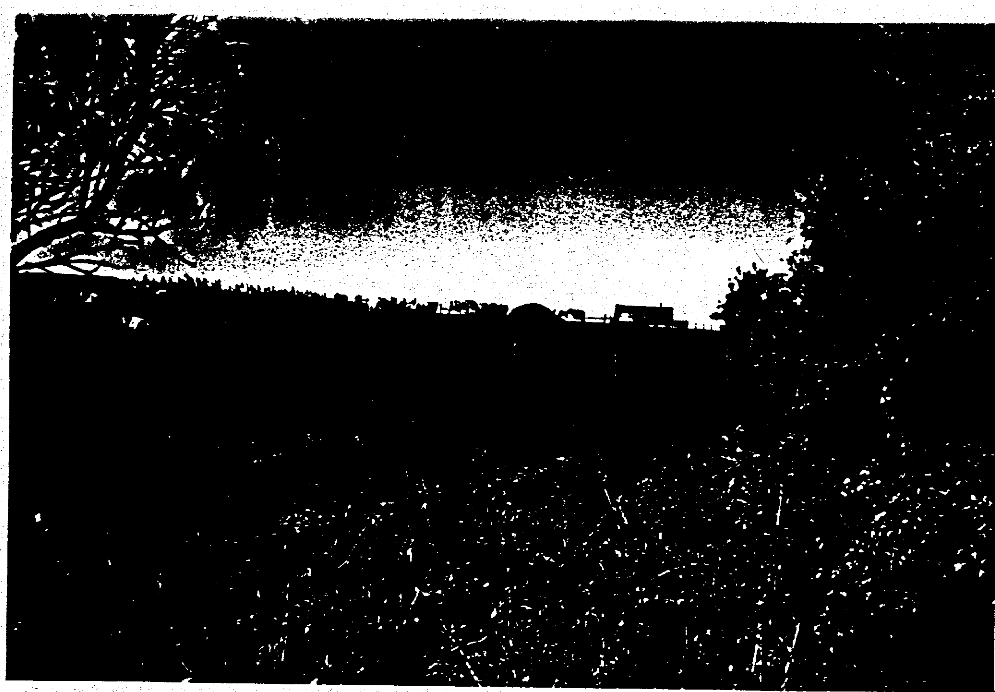


Photograph 2.
Date: 10-3-90
Photographer: P. Szewczykowski
Orientation: Looking southwest towards the abandoned landfill.
Description: D/F study monitoring well #3. Well is located northeast and approximately 1750 feet downgradient of the abandoned city landfill.

Photograph 3.
Date: 10-3-90
Photographer: P. Szewczykowski
Orientation: Looking northeast towards the western tributary to Burke Lake.
Description: The tributary bed was dry at this time of year and was being utilized for grazing horses.



Photograph 4.
Date: 10-3-90
Photographer: P. Szewczykowski
Orientation: Looking north from the east-west county road which leads to the lake access road.
Description: Manure piles in the watershed of Burke Lake. During precipitation events, this manure can wash into a tributary to Burke Lake and can impact groundwater.

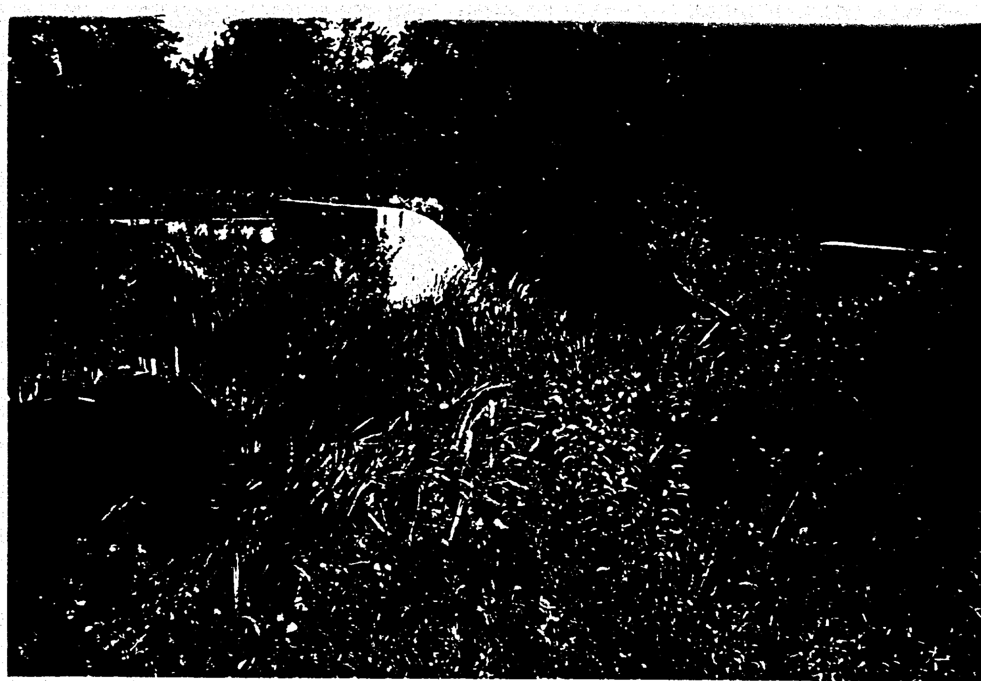


Photograph 5.
Date: 10-3-90
Photographer: P. Szewczykowski
Orientation: Looking west from the southwest shore of Burke Lake.
Description: Dairy operation located along the southwest and west borders of Burke Lake. Runoff from the feedlot can directly enter the lake.

Photograph 6.
Date: 10-3-90
Photographer: P. Szewczykowski
Orientation: Looking west from the southwest shore of Burke Lake.
Description: Dairy operation located along the southwest and west borders of Burke Lake.

Photograph 7.
Date: 10-3-90
Photographer: P. Szewczykowski
Orientation: Looking east from the dairy operation.
Description: Aquatic vegetation on Burke Lake.

Photograph 8.
Date: 10-3-90
Photographer: P. Szewczykowski
Orientation: Looking east at Burke Lake near tributary sampling site #3.
Description: Turbidity in Burke Lake.



Photograph 9.
Date: 10-3-90
Photographer: P. Szewczykowski
Orientation: Looking northeast.
Description: The outlet structure at Burke Lake. The structure is overgrown with vegetation.

Photograph 10.
Date: 10-3-90
Orientation: Looking east and downstream from the outlet.
Description: Debris and trees at the bottom of the outlet.

OFFICE OF WATER RESOURCES MANAGEMENT

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RICH HANSON - PROGRAM SCIENTIST
PHIL LIDEL - ENGINEER
KEN MADISON - SCIENTIST
ANDREW REPSYS - SCIENTIST
BILL STEWART - SCIENTIST
GENE STUEVEN - SCIENTIST
PAUL SZEWCZYKOWSKI - SCIENTIST