T H E U N I V E R S I T Y O F M I C H I G A N

DEPARTMENT OF ENVIRONMENTAL AND INDUSTRIAL HEALTH
School of Public Health

Final Report

CRYSTAL LAKE WATER QUALITY INVESTIGATION

Covering Period May 1, 1969 - February 28, 1970

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Professor of Public Health Engineering

ORA Project 33304

supported by:

KEEP CRYSTAL CLEAR COMMITTEE
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I. INTRODUCTION

Residents of the Crystal Lake area have expressed concern in recent years over signs of lake water quality deterioration exhibited in terms of such things as increased algal growth on docks, stones, etc., and in reduced water calrity in several areas in the lake. In response to this concern, a group of interested citizens formed the Keep Crystal Clear Committee which has as its main objective the preservation of the excellent water quality which Crystal Lake has enjoyed over the years.

This committee approached the faculty and students of the Water Quality Program of the School of Public Health for help in the very important first step of evaluating the problem. A proposal was developed by the faculty and accepted by the committee with the committee then using this proposal as a basis for soliciting funds from concerned citizens to support the field and laboratory activities of the participants during the spring, summer, and fall of 1969. The necessary funds were raised and an agreement was entered into with The University of Michigan to support travel, supplies, housing, and report preparation expenses, with the faculty and students participating in the field program as part of their normal University responsibilities. Thus, the study developed as a truly shared responsibility between The University of Michigan and the citizens of the Crystal Lake area.

A number of specific study aims were agreed upon as follows:

1. To identify and measure major sources of pollution.

2. To define the physical, chemical, and biological characteristics of the waters of Crystal Lake under summertime conditions of maximum use.

3. To evaluate the influence of selected individual waste water disposal systems on ground water quality in the vicinity of the system, and on near shore lake water quality.

4. To evaluate the influence of selected nutrient sources on possible future lake biomass production.

The major field effort was conducted during the months of May, June, July, and August 1969, involving the establishment of a temporary Crystal Lake Field Station allowing the completion of many determinations on the site, but supported by the extensive chemical, biological, and bacteriological facilities of the School of Public Health in Ann Arbor. The excellent cooperation of a number of citizens involving donation of cottage and boat use together with the availability of the chemistry laboratory of the Benzie Central High School greatly facilitated this phase of the study.

The field studies involved the evaluation of a number of physical factors related to the lake such as: location and gaging of all major discharges into or out of the lake, checking the storm sewer system in Beulah, verifying the soundings on the Institute for Fisheries Research depth map, determining optical properties at different depths and lake locations, evaluation of vertical lake temperature profiles at various locations and for different times, determining lake current patterns using dye tracers, and the evaluation of the climatological data at the Frankfort weather station during the 1969 survey period, and relating this to the longer term weather data already available for this station.

In addition to the physical factors, a substantial number of water quality determinations, including chemical, bacteriological, and biological analyses, were made on samples of both lake water and tributaries. These included monthly samples collected at a number of stations on the lake at four regular lake transects, weekly samples on the various tributaries, monthly shore line samples collected in front of approximately 300 cottages close to the lake, a special well water testing clinic involving approximately 165 individual wells, testing at organized bathing beaches, and plankton and bottom samples at a number of lake stations.

Special studies were conducted to evaluate the influence of individual waste water disposal systems on near shore lake water quality involving the cooperation of several cottage owners allowing the use of dye tracers through their disposal facility. In addition, an extensive special study to evaluate the influence of selected nutrient sources on possible future lake biomass production was conducted at a test site in the lake near the Beulah end during the last two weeks in July 1969.

As the study progressed, it became apparent that information about the size, number of occupants, period of occupancy, etc., of the cottages around the lake would be useful, and this stimulated the organization of a household information survey under the general direction of The University of Michigan survey team, but with substantial help in the survey execution from the Crystalaire Girls Camp and the Woman's Association of the Congregational Summer Assembly.

A search was made for historical information on the physical, chemical, bacteriological, or biological characteristics of Crystal Lake and as a result of this effort, data was located and obtained from the Michigan Department of Natural Resources Institute for Fisheries Research, the Michigan Water Resources Commission, and the Grand Traverse-Leelanau-Benzie Counties Health Department. This information is included in the interests of a more complete evaluation of the problem.

II. PHYSICAL CHARACTERISTICS

Introduction

A number of important physical characteristics of Crystal Lake and the surrounding area were defined as part of the present survey. This section of the report includes: a basin description, important geological considerations of the area, the location and measurement of surface discharges, a description of each tributary stream above the point where it was measured, a presentation of dispersion patterns of discharge into Crystal Lake, a description of the storm sewer system of the Village of Beulah, a description of lake sampling and reference transects, a discussion of lake depths and volume, a diver's view of Crystal Lake, a discussion of light penetration in Crystal Lake, a consideration of the lake levels of Crystal Lake, and an evaluation of the climatological data at the Frankfort weather station during the 1969 survey period, and the relation of this to the longer term weather data already available for this station.

Basin Description

Crystal Lake is located in Benzie County, Michigan, in the northwestern part of the lower peninsula, west of Traverse City as shown in Figure II-1. The lake is adjacent to Lake Michigan but does not drain directly into it; rather, it discharges into the Betsie River which in turn discharges into Lake Michigan through Frankfort Harbor.

Crystal Lake is long and narrow with a maximum length of 8.2 miles, a maximum width of 2.3 miles, and a surface area of approximately 9,711 acres (15.18 sq mi) as shown in Figure II-2. Generally the lake lies in a northwest-southeast direction and has only one important tributary—Cold Creek—entering the lake at its southeastern end through the Village of Beulah.

The total drainage area at the outlet of the lake into the Betsie River as defined by the U. S. Geological Survey is approximately 32 square miles, while the Cold Creek drainage area as measured by the writer is approximately 10.35 square miles, and the surface area of Crystal Lake is approximately 15.18 square miles. Thus, the tributary drainage area is quite small and the lake surface itself makes up about 50% of the total outlet drainage area.

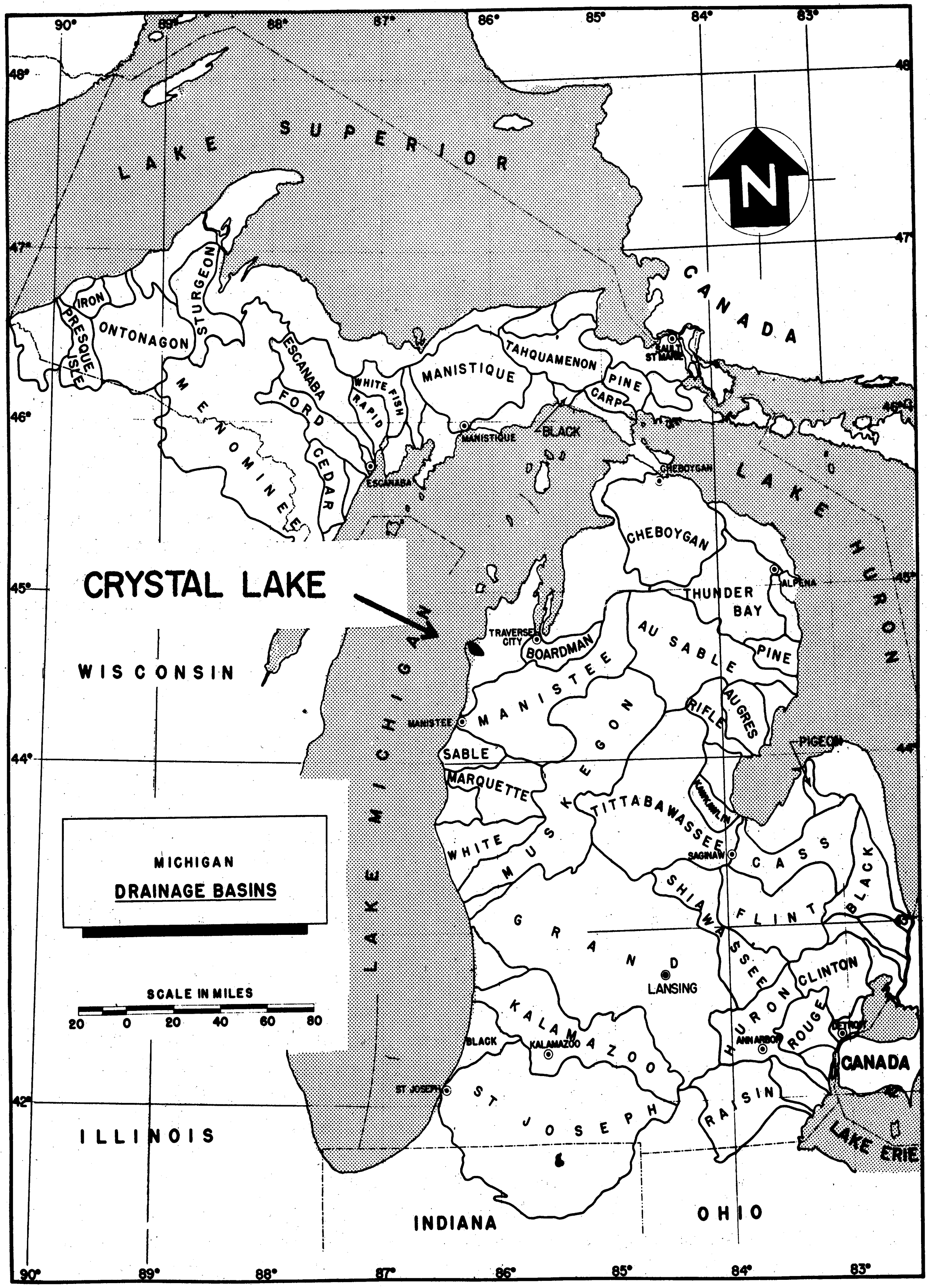
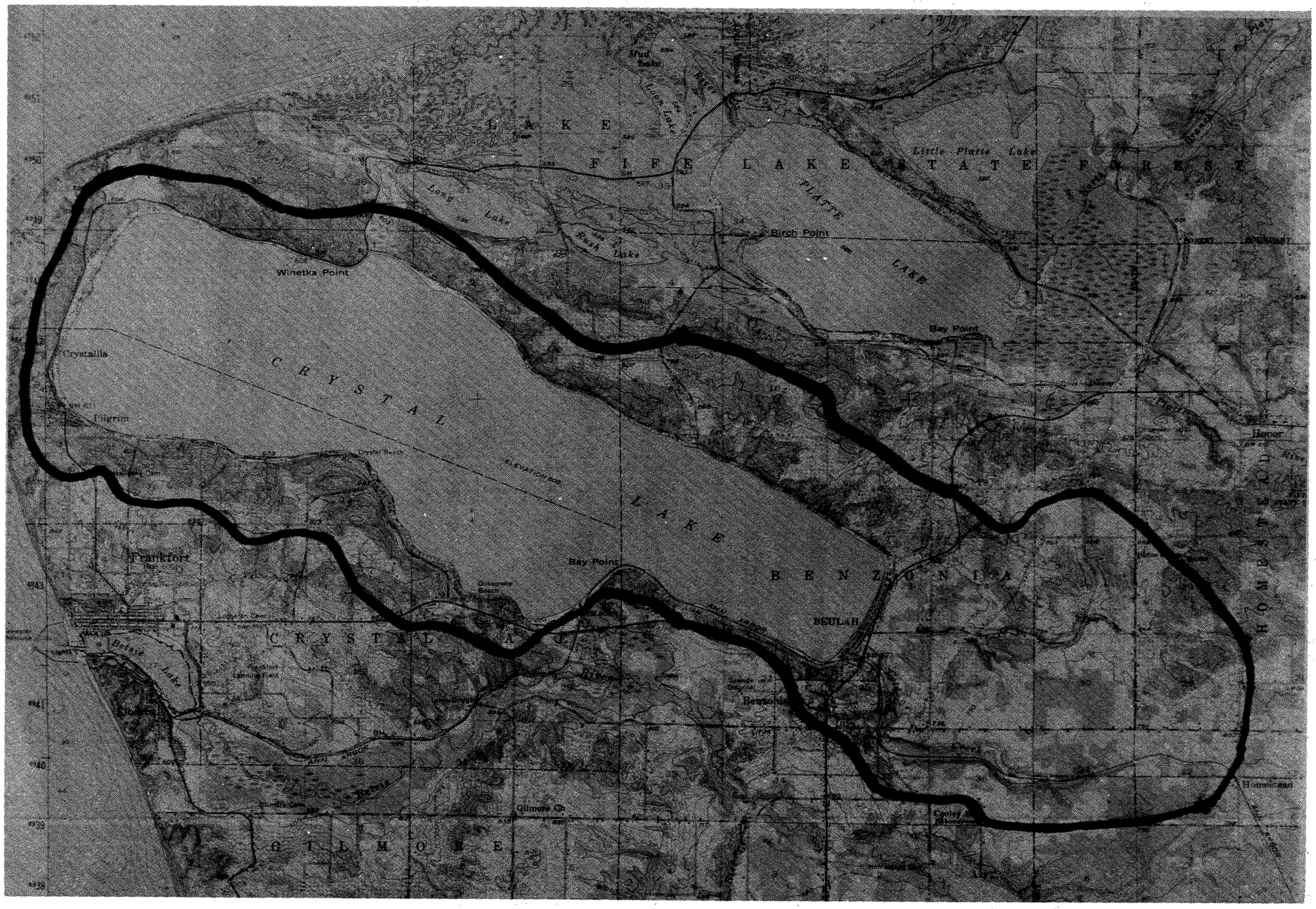

CRYSTAL LAKE
MICHIGAN
DRAINAGE BASINS
SCALE IN MILES
20 0 20 40 60 80
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
CANADA
WISCONSIN
ILLINOIS
INDIANA
OHIO
N
IRON
PRESQUE ISLE
ONTONAGON
STURGEON
MENOMINEE
ESCANABA
FORD
CEDAR
WHITE FISH
RAPID
MANISTIQUE
TAHQUAMENON
PINE
CARP
BLACK
CHEBOYGAN
THUNDER BAY
AU SABLE
PINE
AU GRES
RIFLE
BOARDMAN
MANISTEE
MUSKEGON
SABLE
MARQUETTE
WHITE
TITTABAWASSEE
KAWKAWLIN
PIGEON
CASS
BLACK
FLINT
SHIAWASSEE
GRAND
CLINTON
HURON
ROUGE
KALAMAZOO
BLACK
ST JOSEPH
RAISIN
TRAVERSE CITY
MANISTEE
MANISTIQUE
ESCANABA
CHEBOYGAN
ALPENA
SAULT ST MARIE
SAGINAW
LANSING
ANN ARBOR
DETROIT
KALAMAZOO
ST JOSEPH
90° 89° 88° 87° 86° 85° 84° 83°
48° 47° 46° 45° 44° 42°

Figure II-1



Crystal Lake drainage area.

Figure II-2

Geological Considerations

I. D. Scott[1] in his book, "Inland Lakes of Michigan," describes Crystal Lake as follows:

> "As regards the basin, it may be stated that it is relatively old. In fact, it is certain that it was in existence before the ice made its final advance, for it was filled with a small lobe, an offshoot from the Michigan lobe, which pushes through the opening at the west end, now closed with sand. This lobe deposited a strong morainic loop around this basin, which is continuous except at the outlet and a depression on the north side which runs northward into the Platte Lake depression, in the vicinity of Round Lake. At present the lake shores do not reach the morainic hills but are separated from them by a rather broad zone of sandy terrace. This widens greatly at the east end and extends nearly two miles before it is interrupted by the moraine.
>
> "The striking physiographic characters are the predominating high cliffs from whose base the sandy terrace mentioned above extends to the water's edge. The first surmise is that this lake has stood at a higher level and further observations prove this to be correct."

More detailed information on the geology of the Crystal Lake area is found in a doctoral thesis prepared at The University of Michigan by James L. Calver[2] on "The Glacial and Post-Glacial History of the Platte and Crystal Lake Depressions, Benzie County, Michigan," and published by the Michigan Department of Natural Resources in 1946.

Figure II-3 taken from the Calver study shows the geological formations in Northwestern Benzie County, Michigan; the moraine formations surrounding Crystal Lake are striking.

Particular attention is given by Calver to the Round Lake Basin on the north shore and the Crystal Lake Bar region on the west end of the lake. Figure II-4 summarizes the geological formations in the Round Lake Basin while Figure II-5 shows the formation of the Crystal Lake Bar through four different geological stages.

Surface Discharge Location and Measurement

One of the important aims of the study has been the identification and measurement of major sources of pollution. This involves not only an evaluation of the chemical, bacteriological, and biological constituents of a potential waste source, but also includes an evaluation of the corresponding flow.

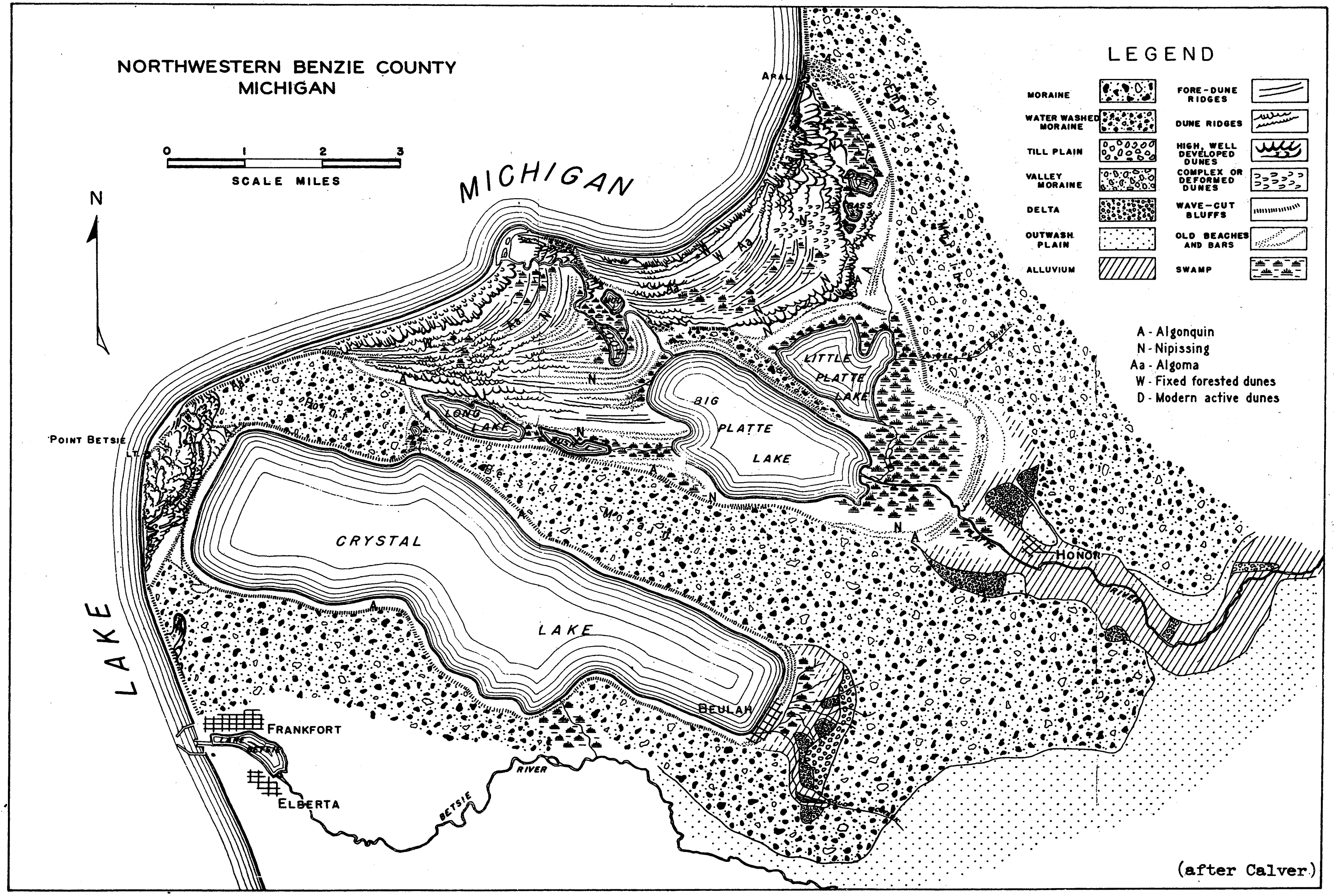
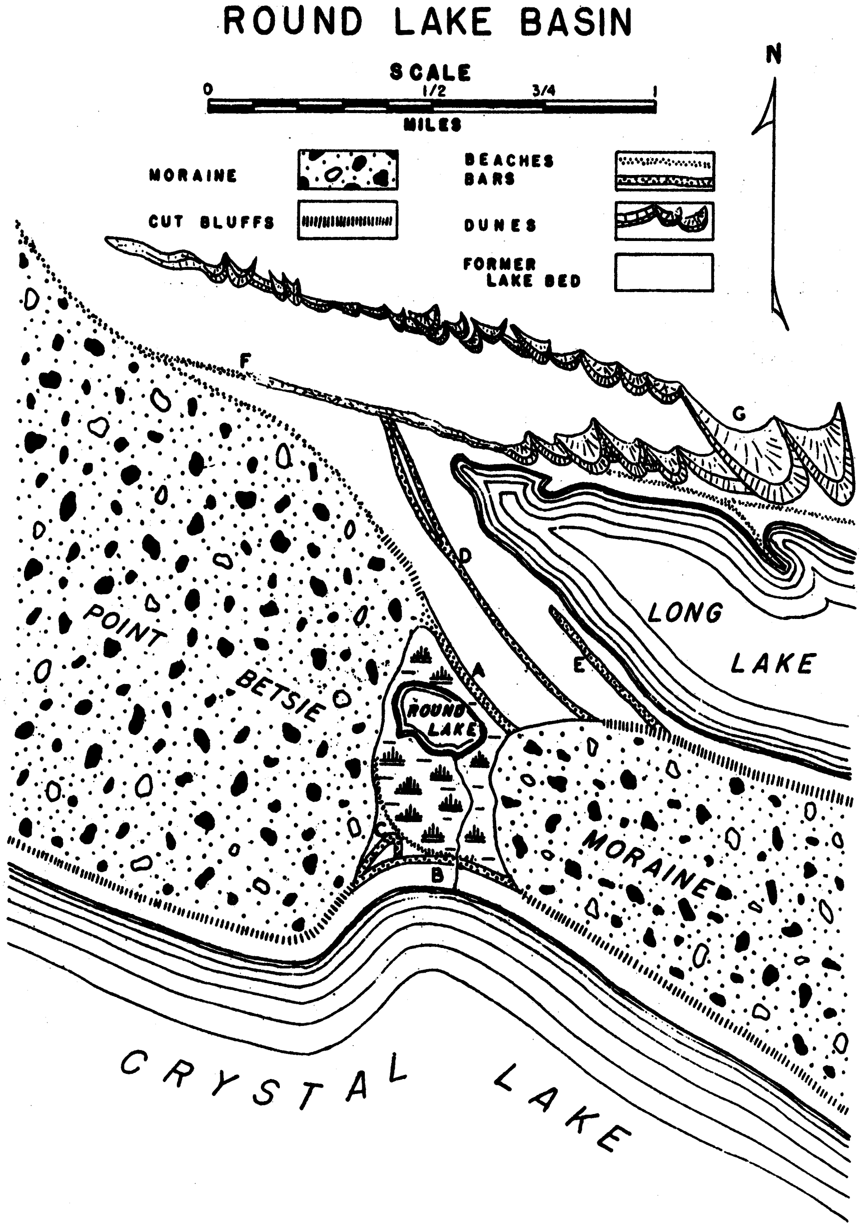
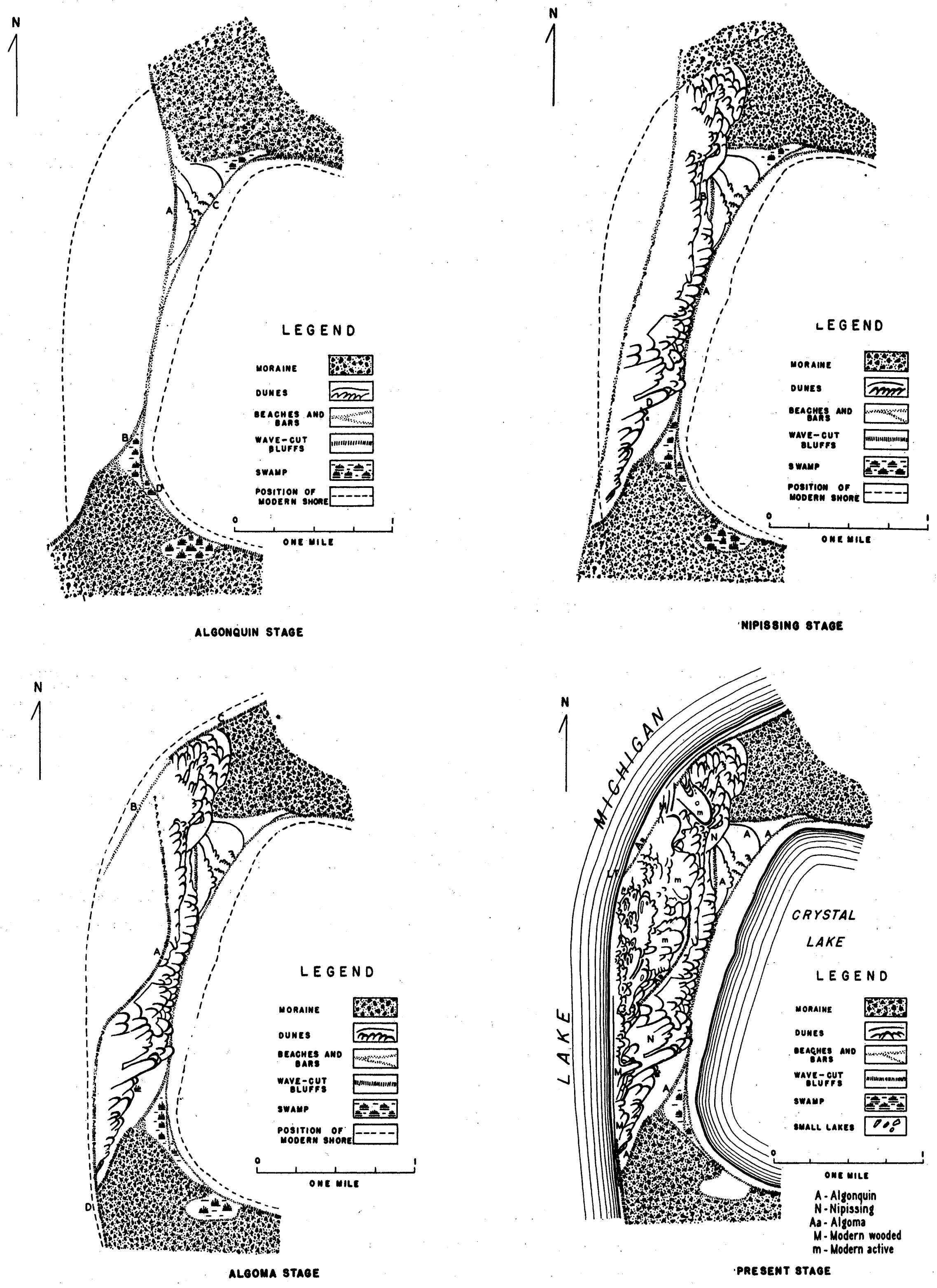

NORTHWESTERN BENZIE COUNTY
MICHIGAN
0 1 2 3
SCALE MILES
N
LAKE MICHIGAN
LEGEND
MORAINE
WATER WASHED MORAINE
TILL PLAIN
VALLEY MORAINE
DELTA
OUTWASH PLAIN
ALLUVIUM
FORE-DUNE RIDGES
DUNE RIDGES
HIGH, WELL DEVELOPED DUNES
COMPLEX OR DEFORMED DUNES
WAVE-CUT BLUFFS
OLD BEACHES AND BARS
SWAMP
A - Algonquin
N - Nipissing
Aa - Algoma
W - Fixed forested dunes
D - Modern active dunes
POINT BETSIE
LITTLE PLATTE LAKE
BIG PLATTE LAKE
LONG LAKE
CRYSTAL LAKE
HONOR
BEULAH
FRANKFORT
ELBERTA
BETSIE RIVER
(after Calver)

Figure II-3



(after Calver)

Figure II-4



(after Calver)

CRYSTAL LAKE BAR

Figure II-5

To this end, a serious effort was made to locate and measure all surface discharges both into and out of Crystal Lake during the summer of 1969.

As a first step of the field effort in May 1969, members of the survey team walked the complete shoreline of the lake looking for either existing surface discharges into the lake or for pipes that might discharge intermittently during periods of maximum use. Each surface discharge was carefully evaluated as to the best method of determining its pollution contribution, including measurement of the flow characteristics.

A number of established hydraulic methods are available for measuring open channel flow as presented in traditional hydraulic references such as Addison[3] and as adapted for waste surveys by the Ohio River Valley Water Sanitation Commission,[4] but generally they break down into two categories; one, involving the placing of some regular obstruction in the channel called a weir, where there is a definite relationship between the elevation of water above the weir crest and the discharge over the weir; and the other, involving an indirect approach where discharge is measured at a fixed location over a range of flows, using a current meter for velocity determination, so that a rating curve relating discharge and stage can be developed at that location.

In the Crystal Lake study, the survey team resorted to the weir approach most often because the discharges were generally small and involved drainage ditches where a temporary weir could be easily constructed. Once the weir was installed a discharge measurement was made merely by observing the water height above the weir crest by means of a Gurley point gage, and then calculating the discharge with the appropriate weir equation. The survey team constructed and installed thirteen temporary weir installations where discharge measurements were taken periodically throughout the summer, and especially when samples were collected for chemical and bacteriological evaluation. One weir station (W13) was developed from an existing structure.

Two major flow streams, Cold Creek and the Outlet, did not lend themselves to the weir approach because of their size and it became necessary to resort to the indirect approach involving current meter measurements as followed by the U. S. Geological Survey and as presented in detail by Corbett,[5] and Grover and Harrington.[6]

Two pipes on the north short (P1 and P2) did not readily lend themselves to either of these approaches because of surrounding obstructions and space limitation, and it became necessary to resort to another method involving the measurement of water depth in the pipe and then calculating the rate of flow from a knowledge of the pipe slope and characteristics using established hydraulic relationships as presented in standard reference works such as that of the Water Pollution Control Federation.[7]

All discharge measurements are reported in cubic feet per second (CFS) notwithstanding the specific method used in making the determination.

The location of shore sampling stations and discharge measurement points involved in the 1969 survey are shown in Figure II-6. Discharge measurements are available for 18 of the 20 stations and of the weir installations only two (W6 and W7) were removed by vandals before the end of the survey period. The Crystal Avenue and Broadway sampling stations were added after the weir construction and installation phase of the program had been completed, and it was not possible to construct weirs at these stations although the observed flow through the summer was quite small at both stations.

For purposes of documentation, the individual flow measurements at each station are presented including a photograph of most of the measuring stations, starting with weir 4 (W4) and proceeding clockwise around the lake to the outlet as shown in Figures II-7 to II-25.

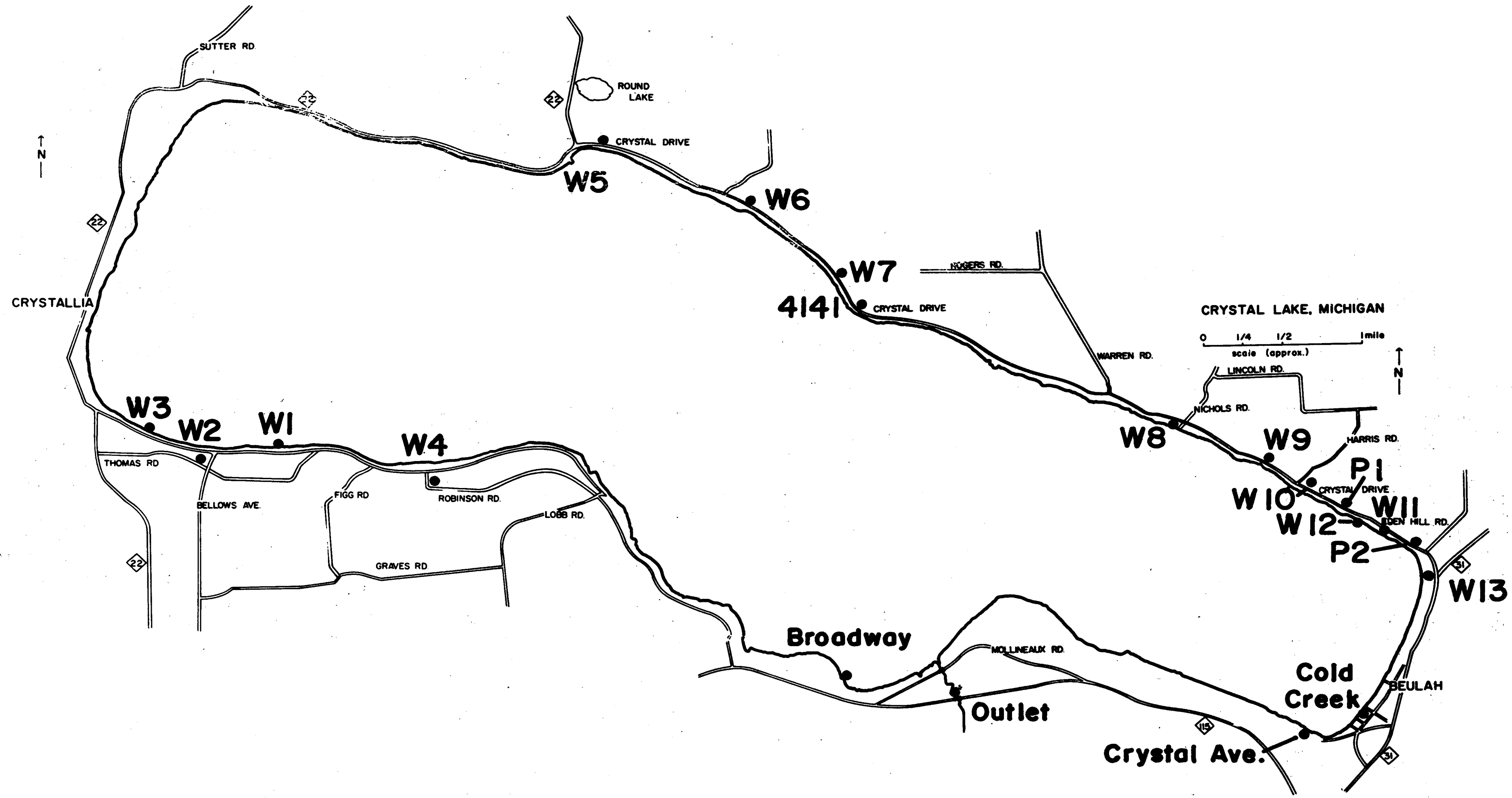
Description of Streams above Measuring Points

A field reconnaissance was made by members of the survey team up each stream that has a shore sampling station or discharge measurement point to gain some idea of the development or lack of development that might exist. Selections from the field observations made during these trips are presented for the information of the reader.

Most of the streams flow only a few hundred feet to one-half mile and emanate as a distinct flow from a hillside ravine. Generally there are few if any dwellings in the woods surrounding their sources. Several of the drains have or have had dams near their sources (W1, W4, and 4141) or impoundments elsewhere along their course (W1, W10). Pipe systems along the W4 and 4141 streams leading from the existing dams are used for irrigation of lawns. Also, it appears that several of the streams, W2, W4 and especially W7 lose significant water to ground seepage before getting to the weir or point of sampling.

Brief descriptions of each stream starting with broadway and proceeding clockwise around the lake to the outlet are presented as follows:

Broadway - 4132 Boyd Road.—This stream emanates from a pipe coming out of a wooded hillside on the south side of M115 opposite its western intersection with Mollineaux Road. From here it runs 100 yards in a wooded ravine on the south side of M115 before passing under the road. It them flows east along the north side of M115 for about 50 yards before passing under Mollineaux where a small box then impounds the water and an irrigation hose leads from the box. The stream continues another 400 feet to the lake through woods except for passing under Boyd Road and through the lawn of 4132.



Location of Shore Sampling Stations And Discharge Measurement Points Summer 1969

Figure II-6

Weir No. 4

Location: Crystal Lake
1600 South Shore
Junction - Robinson Road and South Shore Road
Frankfort, Michigan

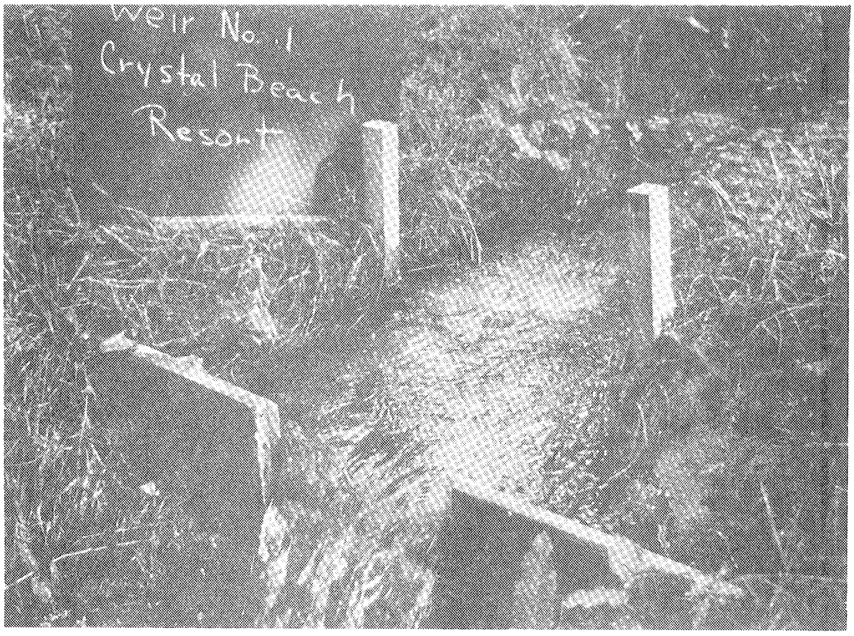
Weir Type: 1. V-Notch $Q = 2.50 H^{2.5}$

Date Installed: 5-16-69

Discharge Record

Date	cfs	Date	cfs
5-16-69	0.021	6-06-69	0.151
5-17-69	0.135	6-08-69	0.151
5-18-69	0.135	6-10-69	0.118
5-19-69	0.014	6-12-69	0.163
5-20-69	0.120	6-15-69	0.140
5-21-69	0.114	6-21-69	0.143
5-22-69	0.125	6-23-69	0.129
5-23-69	0.114	6-29-69	0.130
5-24-69	0.114	7-06-69	0.129
5-25-69	0.138	7-10-69	0.202
5-26-69	0.138	7-12-69	0.099
5-27-69	0.125	7-19-69	0.129
5-28-69	0.114	7-23-69	0.286
5-29-69	0.129	7-30-69	0.145
5-30-69	0.129	8-08-69	0.145
6-01-69	0.109	8-14-69	0.117
6-02-69	0.151	8-20-69	0.143
6-05-69	0.163		

Figure II-7



Weir No. 1

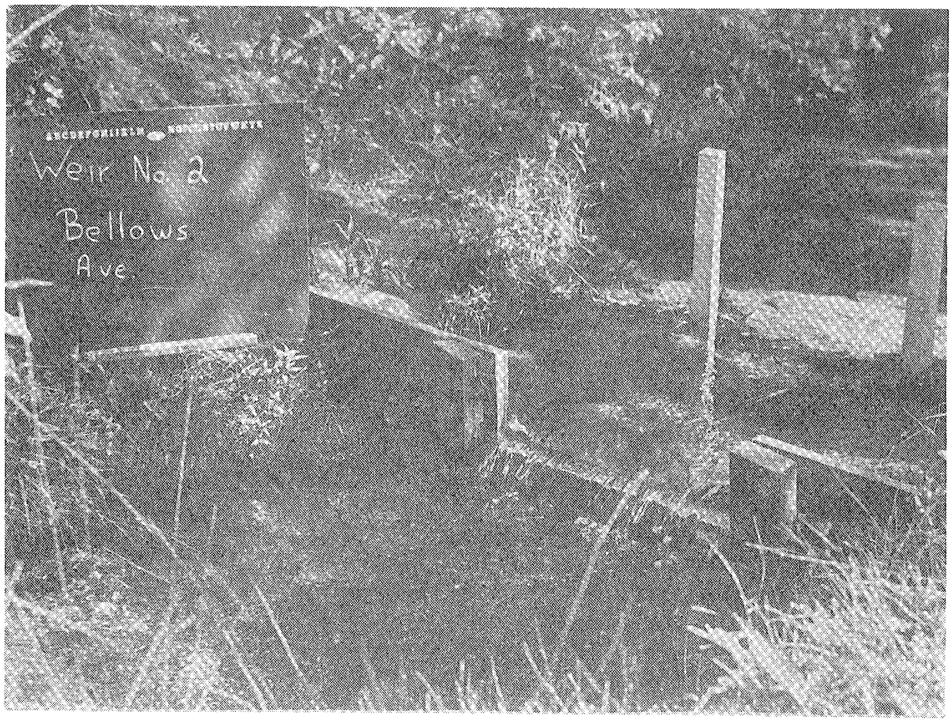
Location: Crystal Beach Resort
774 South Shore Road
Frankfort, Michigan

Weir Type	Date Installed	
1. V-Notch	5-15-69	$Q = 2.50\ H^{2.5}$
2. Rectangular	5-19-69	$Q = 3.33\ (L)\ (H)^{1.5}$
		$L = 0.823'$

Discharge Record

Date	cfs	Date	cfs
5-15-69	0.355	6-05-69	0.450
5-16-69	0.400	6-06-69	0.384
5-17-69	0.540	6-08-69	0.363
5-18-69	0.443	6-10-69	0.384
5-19-69	0.394	6-12-69	0.746
5-20-69	0.800	6-15-69	0.428
5-21-69	0.370	6-21-69	0.443
5-22-69	0.354	6-23-69	0.428
5-23-69	0.354	6-29-69	0.397
5-24-69	0.333	7-06-69	0.435
5-25-69	0.362	7-10-69	0.406
5-26-69	0.396	7-12-69	0.428
5-27-69	0.376	7-19-69	0.363
5-28-69	0.376	7-23-69	0.640
5-29-69	0.384	7-30-69	0.401
5-30-69	0.363	8-08-69	0.382
6-01-69	0.428	8-14-69	0.329
6-02-69	0.428	8-20-69	0.342

Figure II-8



Weir No. 2

Location: Crystal Lake
390 South Shore
Junction Bellows Avenue and South Shore Road
Frankfort, Michigan

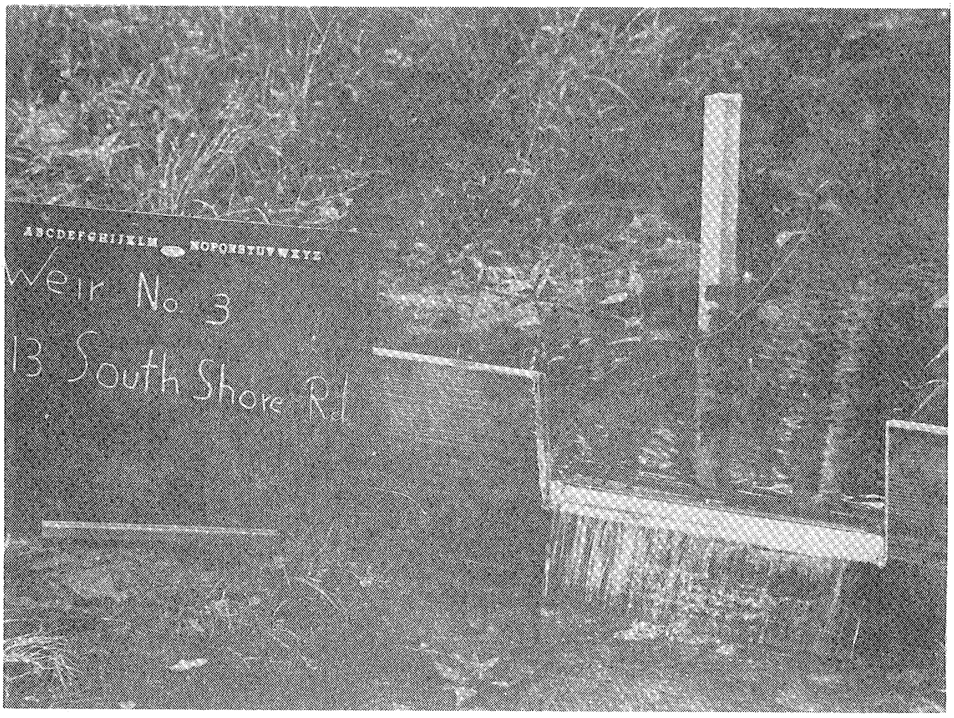
Weir Type: 1. Rectangular $Q = 3.33\ (L)\ (H)^{1.5}$

Date Installed: 5-16-69 L = 1.625'

Discharge Record

Date	cfs	Date	cfs
5-16-69	0.439	6-08-69	0.448
5-17-69	0.943	6-10-69	0.314
5-18-69	0.678	6-12-69	1.073
5-19-69	0.714	6-15-69	0.636
5-20-69	0.720	6-21-69	0.613
5-21-69	0.515	6-23-69	0.597
5-22-69	0.637	6-29-69	0.620
5-23-69	0.489	7-06-69	0.435
5-24-69	0.637	7-10-69	0.636
5-25-69	0.334	7-12-69	0.676
5-26-69	0.489	7-19-69	0.578
5-27-69	0.595	7-23-69	0.554
6-01-69	0.558	7-30-69	0.628
6-02-69	0.558	8-08-69	0.578
6-05-69	0.484	8-14-69	0.585
6-06-69	0.521	8-20-69	0.547

Figure II-9



Weir No. 3

Location: Crystal Lake
13 South Shore Road
Frankfort, Michigan

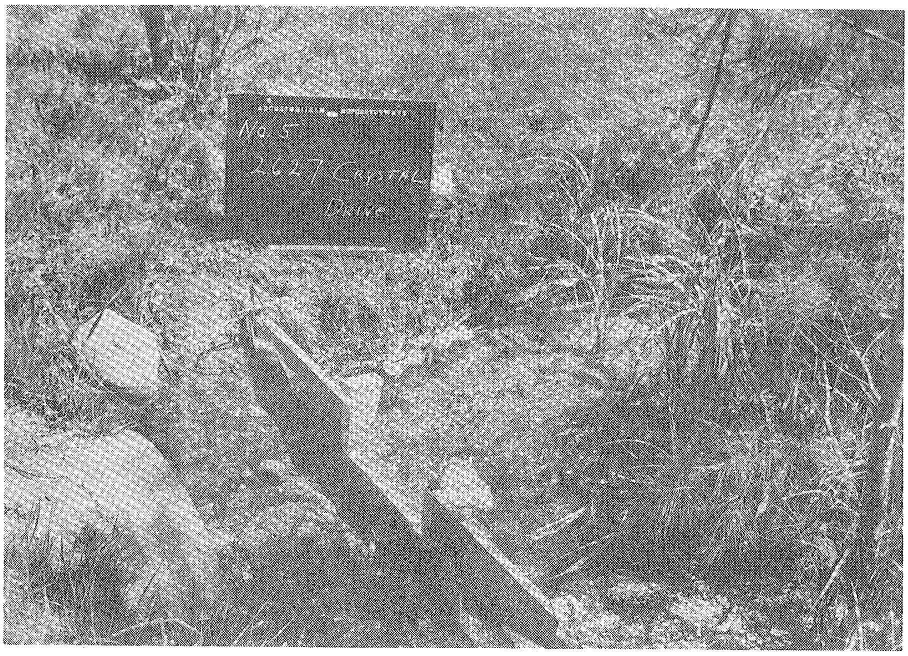
Weir Type: 1. Rectangular $Q = 3.33\ (L)\ (H)^{1.5}$

Date Installed: 5-16-69 $L = 1.48'$

Discharge Record

Date	cfs	Date	cfs
5-16-69	0.165	6-05-69	0.345
5-17-69	0.858	6-06-69	0.376
5-18-69	0.306	6-08-69	0.345
5-19-69	0.335	6-10-69	0.205
5-20-69	0.400	6-15-69	0.345
5-21-69	0.364	6-21-69	0.392
5-22-69	0.370	6-23-69	0.597
5-23-69	0.338	6-29-69	0.438
5-24-69	0.218	7-06-69	0.345
5-25-69	0.468	7-10-69	0.408
5-26-69	0.376	7-12-69	0.408
5-27-69	0.309	7-19-69	0.301
5-28-69	0.296	7-23-69	0.306
5-29-69	0.379	7-30-69	0.406
5-30-69	0.286	8-08-69	0.284
6-01-69	0.408	8-14-69	0.309
6-02-69	0.441	8-20-69	0.298

Figure II-10



Weir No. 5

Location: North Shore of Crystal Lake
2627 Crystal Drive
Beulah, Michigan
(Discharge from Round Lake to Crystal Lake)

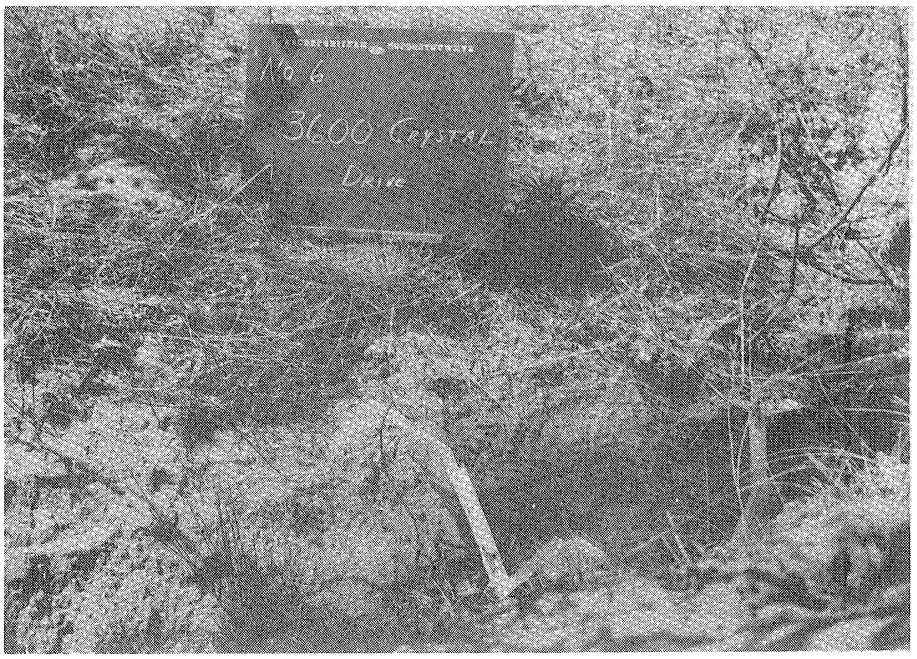
Weir Type: 1. Rectangular $Q = 3.33 (L) (H)^{1.5}$

Date Installed: 5-19-59 L = 1.00'

Discharge Record

Date	cfs	Date	cfs
5-19-69	0.355	6-08-69	0.156
5-20-69	0.270	6-10-69	0.090
5-21-69	0.206	6-12-69	0.972
5-22-69	0.183	6-15-69	0.416
5-23-69	0.130	6-21-69	0.197
5-25-69	0.148	6-23-69	0.254
5-26-69	0.148	6-29-69	0.397
5-27-69	0.096	7-07-69	0.441
5-28-69	0.079	7-10-69	0.254
5-29-69	0.075	7-12-69	0.233
5-30-69	0.075	7-19-69	0.233
6-01-69	0.233	7-23-69	0.033
6-02-69	0.276	7-29-69	0.546
6-05-69	0.254	8-07-69	0.121
6-06-69	0.276	8-13-69	0.019

Figure II-11



Weir No. 6

Location: North Shore of Crystal Lake
3600 Crystal Drive
Beulah, Michigan

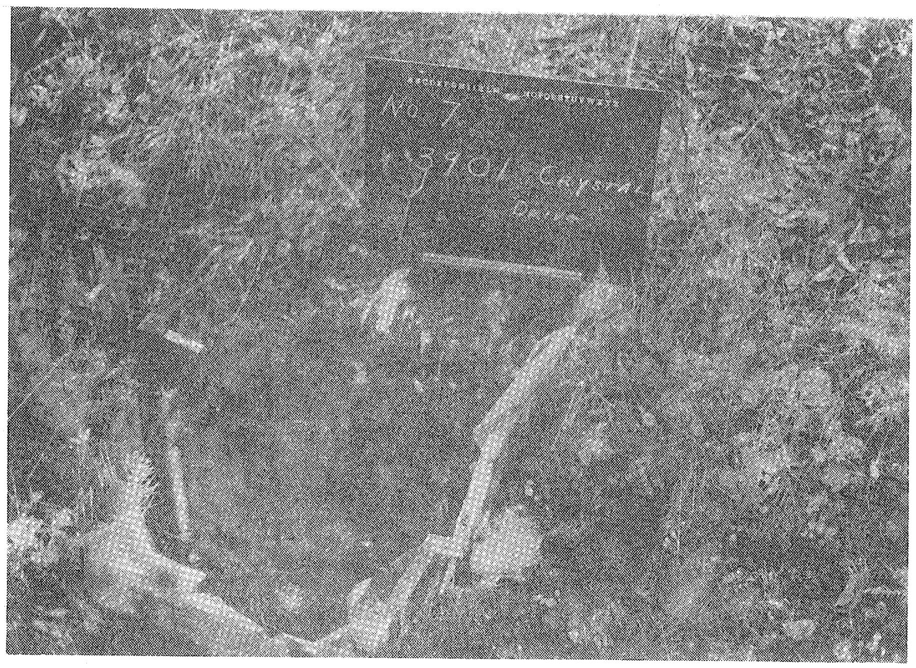
Weir Type: 1. V-Notch $Q = 2.50 (H)^{2.5}$

Date Installed: 5-19-69

Discharge Record

Date	cfs
5-19-69	0.009
5-20-69	0.013
5-21-69	0.008
5-22-69	0.007
5-23-69	0.005
5-24-69	0.005
5-25-59	0.007
5-26-69	0.005
5-27-69	0.005
5-28-69	0.005
5-29-69	0.005
5-30-69	0.004

Figure II-12



Weir No. 7

Location: North Shore of Crystal Lake
3901 Crystal Drive
Beulah, Michigan

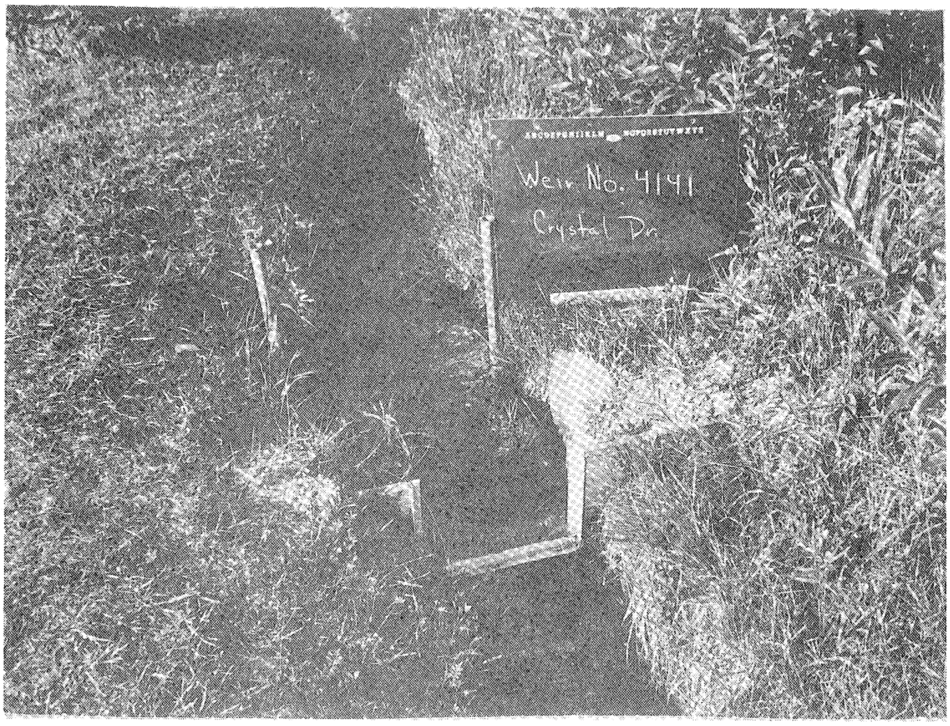
Weir Type: 1. V-Notch $Q = 2.50\ (H)^{2.5}$

Date Installed: 5-19-69

Discharge Record

Date	cfs
5-19-69	0.001
5-20-69	0.005
5-21-69	0.003
5-22-69	0.003
5-23-69	0.002
5-24-69	0.002
5-25-69	0.004
5-26-69	0.004
5-27-69	0.004
5-28-69	0.004
5-29-69	0.002
5-30-69	0.002
6-01-69	0.005
6-02-69	0.007
6-05-69	0.005
6-06-69	0.004
6-08-69	0.004
6-10-69	0.004
6-12-69	0.020
6-15-69	0.005
6-21-69	0.004
6-23-69	0.005
6-29-69	0.010

Figure II-13



Weir No. 4141

Location: North Shore of Crystal Lake
4141 Crystal Drive
Beulah, Michigan

Weir Type: 1. Rectangular $Q = 3.33 (L) (H)^{1.5}$

Date Installed: 6-24-69 $L = 1.00'$

Discharge Record

Date	cfs
6-24-69	0.216
6-29-69	0.213
7-07-69	0.213
7-10-69	0.213
7-13-69	0.193
7-19-69	0.160
7-23-69	0.160
7-29-69	0.172
8-07-69	0.205
8-13-69	0.203
8-20-69	0.169

Figure II-14

Weir No. 8

Location: North Shore of Crystal Lake
6200 Crystal Drive
Nichols Road and Crystal Drive
Beulah, Michigan

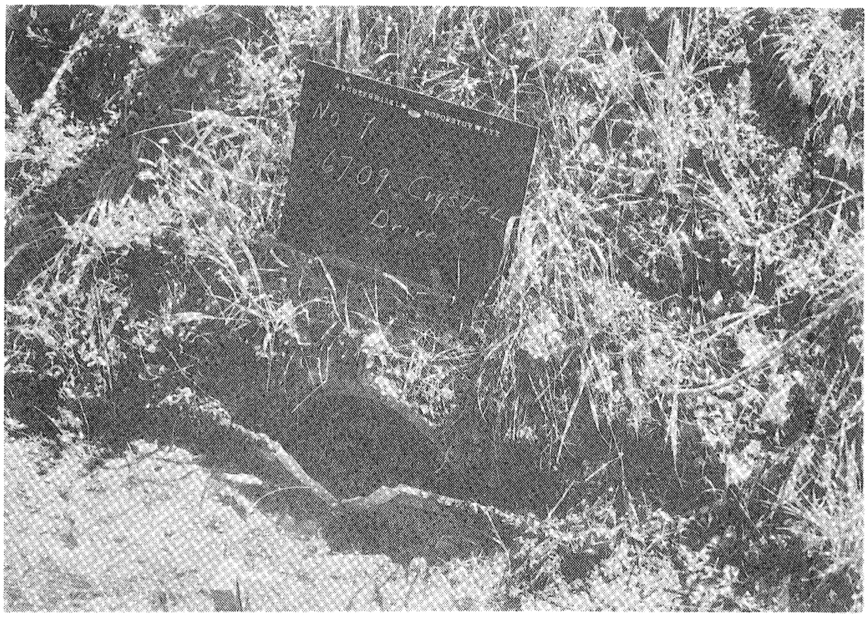
Weir Type: 1. Rectangular $Q = 3.33 (L) (H)^{1.5}$

Date Installed: 5-19-69 $L = 1.00'$

Discharge Record

Date	cfs	Date	cfs
5-19-69	0.130	6-10-69	0.105
5-20-69	0.186	6-12-69	1.039
5-22-69	0.130	6-15-69	0.193
5-23-69	0.112	6-21-69	0.110
5-24-69	0.065	6-24-69	0.105
5-25-69	0.148	6-29-69	0.169
5-27-69	0.065	7-07-69	0.193
5-28-69	0.096	7-12-69	0.213
5-29-69	0.075	7-19-69	0.090
5-30-69	0.075	7-23-69	0.086
6-01-69	0.213	7-29-69	0.324
6-02-69	0.213	8-07-69	0.113
6-05-69	0.121	8-13-69	0.065
6-06-69	0.174	8-20-69	0.039
6-08-69	0.156		

Figure II-15



Weir No. 9

Location: North Shore of Crystal Lake
6709 Crystal Drive
Beulah, Michigan
(Ditch on right hand side of road)

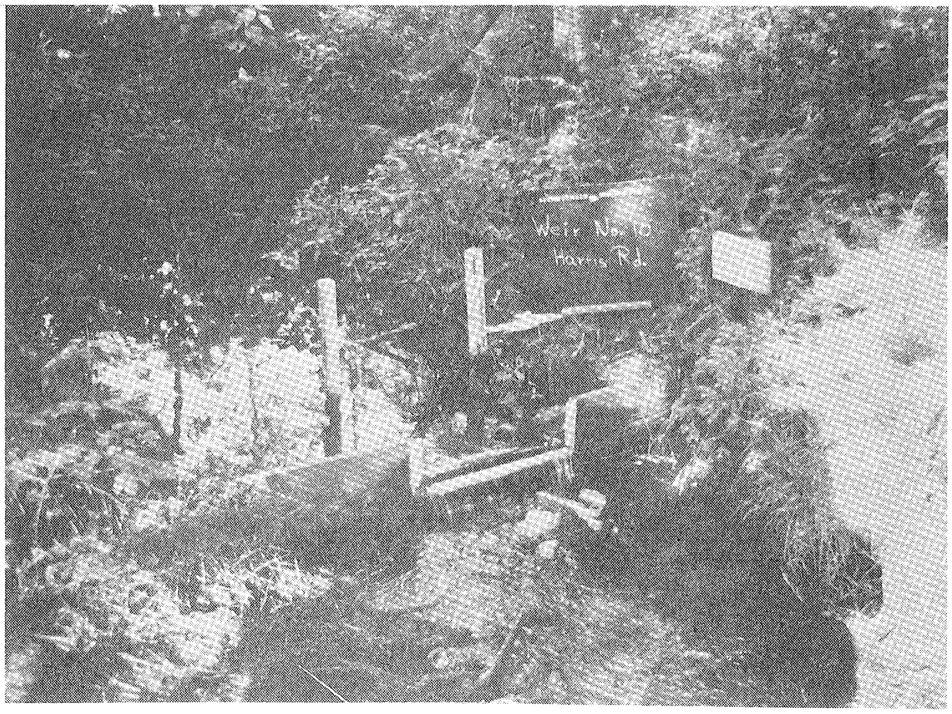
Weir Type: 1. V-Notch $Q = 2.50\ (H)^{2.5}$

Date Installed: 5-19-69

Discharge Record

Date	cfs	Date	cfs
5-19-69	0.078	6-08-69	0.096
5-20-69	0.078	6-10-69	0.090
5-21-69	0.082	6-12-69	0.099
5-22-69	0.087	6-15-69	0.090
5-23-69	0.087	6-21-69	0.134
5-24-69	0.087	6-24-69	0.129
5-25-69	0.096	6-29-69	0.134
5-26-69	0.087	7-07-69	0.129
5-27-69	0.087	7-10-69	0.129
5-28-69	0.087	7-12-69	0.129
5-29-69	0.090	7-19-69	0.129
5-30-69	0.090	7-23-69	0.126
6-01-69	0.118	7-29-69	0.144
6-02-69	0.099	8-07-69	0.138
6-05-69	0.090	8-13-69	0.135
6-06-69	0.047	8-20-69	0.133

Figure II-16



Weir No. 10

Location: North Shore of Crystal Lake
6863 Crystal Drive
Beulah, Michigan
(Harris Road, on property of Wilbur Johnson)

Weir Type: 1. Rectangular $Q = 3.33 (L) (H)^{1.5}$

Date Installed: 5-19-69 $L = 1.50'$

Discharge Record

Date	cfs	Date	cfs
5-19-69	0.122	6-08-69	0.135
5-20-69	0.144	6-10-69	0.135
5-21-69	0.120	6-12-69	0.414
5-22-69	0.144	6-15-69	0.158
5-23-69	0.144	6-21-69	0.208
5-24-69	0.144	6-24-69	0.208
5-25-69	0.144	6-29-69	0.314
5-26-69	0.144	7-07-69	0.290
5-27-69	0.169	7-10-69	0.290
5-28-69	0.144	7-12-69	0.262
5-29-69	0.135	7-19-69	0.146
5-30-69	0.158	7-23-69	0.198
6-01-69	0.158	7-29-69	0.229
6-02-69	0.158	8-07-69	0.177
6-05-69	0.158	8-13-69	0.135
6-06-69	0.135	8-20-69	0.125

Figure II-17

(No photograph available)

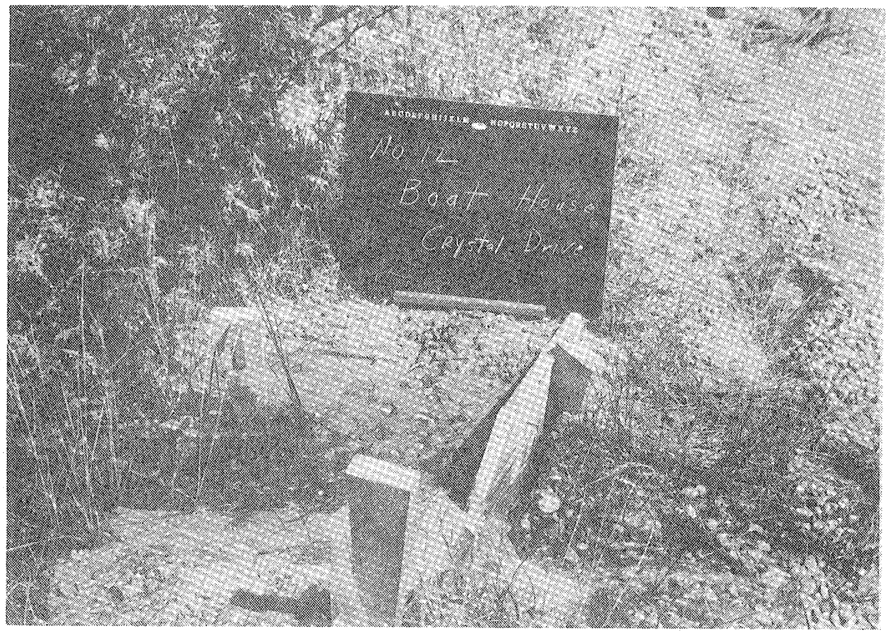
Pipe No. 1

Location: Crystal Lake
7271 Crystal Drive
Beulah, Michigan
(200 feet west side of Marina
Beulah Boat Shop)

Discharge Record

Date	cfs
6-01-69	0.166
6-02-69	0.166
6-05-69	0.195
6-08-69	0.222
6-10-69	0.166
6-12-69	0.395
6-15-69	0.222
6-21-69	0.222
6-24-69	0.275
6-29-69	0.246
7-07-69	0.222
7-10-69	0.246
7-13-69	0.086
7-19-69	0.166
7-24-69	0.115
7-30-69	0.222
8-07-69	0.222
8-13-69	0.166
8-21-69	0.086

Figure II-18



Weir No. 12

Location: North Shore of Crystal Lake
7281 Crystal Drive
Beulah, Michigan
(East Side of Beulah Boat Shop)

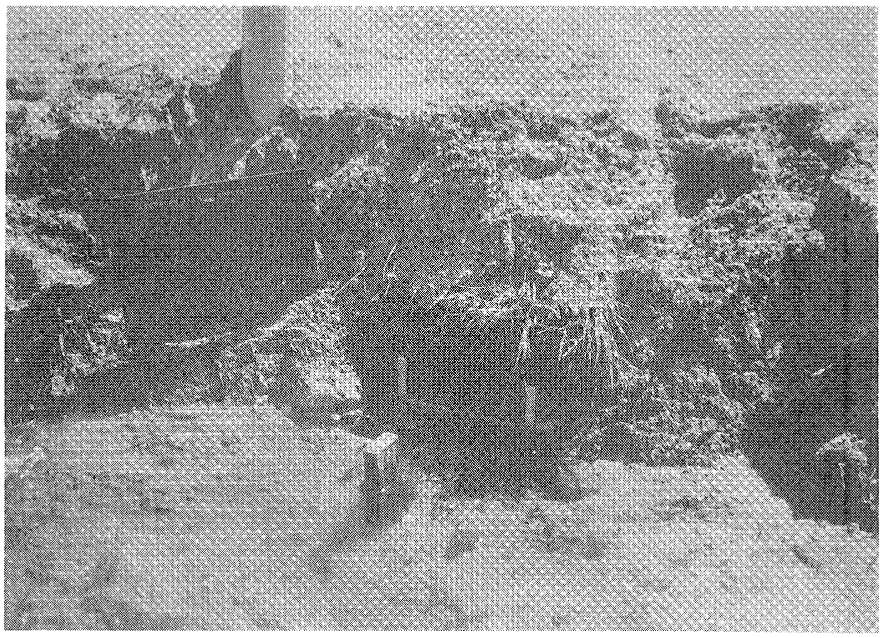
Weir Type: 1. V-Notch $Q = 2.50 \, (H)^{2.5}$

Date Installed: 5-20-69

Discharge Record

Date	cfs	Date	cfs
5-21-69	0.0285	6-10-69	0.0360
5-22-69	0.0285	6-12-69	0.0230
5-23-69	0.0285	6-15-69	0.0320
5-24-69	0.0285	6-21-69	0.0340
5-25-69	0.0285	6-24-69	0.0360
5-26-69	0.0381	7-05-69	0.0820
5-27-69	0.0329	7-10-69	0.0420
5-28-69	0.0329	7-13-69	0.0420
5-29-69	0.0420	7-19-69	0.0350
5-30-69	0.0360	7-24-69	0.0300
6-01-69	0.0470	7-29-69	0.0420
6-02-69	0.0320	8-07-69	0.0660
6-05-69	0.0360	8-13-69	0.0420
6-06-69	0.0360	8-20-69	0.042
6-08-69	0.0420		

Figure II-19



Weir No. 11

Location: North Shore of Crystal Lake
7468 Crystal Drive
Beulah, Michigan
(Large discharge pipe to lake)

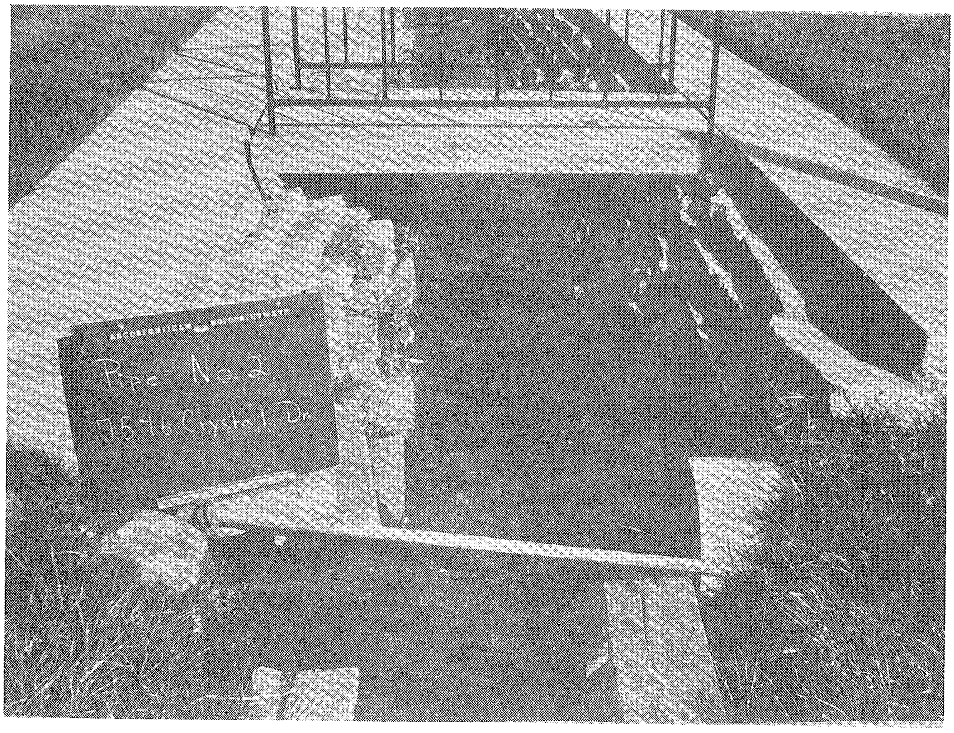
Weir Type: 1. Rectangular $Q = 3.33\ (L)\ (H)^{1.5}$

Date Installed: 5-19-69 L = 1.1146'

Discharge Record

Date	cfs	Date	cfs
5-20-69	0.253	6-10-69	0.241
5-21-69	0.253	6-12-69	0.312
5-22-69	0.277	6-15-69	0.312
5-23-69	0.253	6-21-69	0.199
5-24-69	0.253	6-24-69	0.197
5-25-69	0.253	6-29-69	0.246
5-26-69	0.277	7-05-69	0.223
5-27-69	0.253	7-10-69	0.241
5-28-69	0.277	7-13-69	0.220
5-29-69	0.253	7-19-69	0.220
5-30-69	0.253	7-24-69	0.230
6-01-69	0.310	7-29-69	0.206
6-02-69	0.277	8-07-69	0.215
6-05-69	0.287	8-13-69	0.223
6-06-69	0.287	8-20-69	0.189
6-08-69	0.264		

Figure II-20



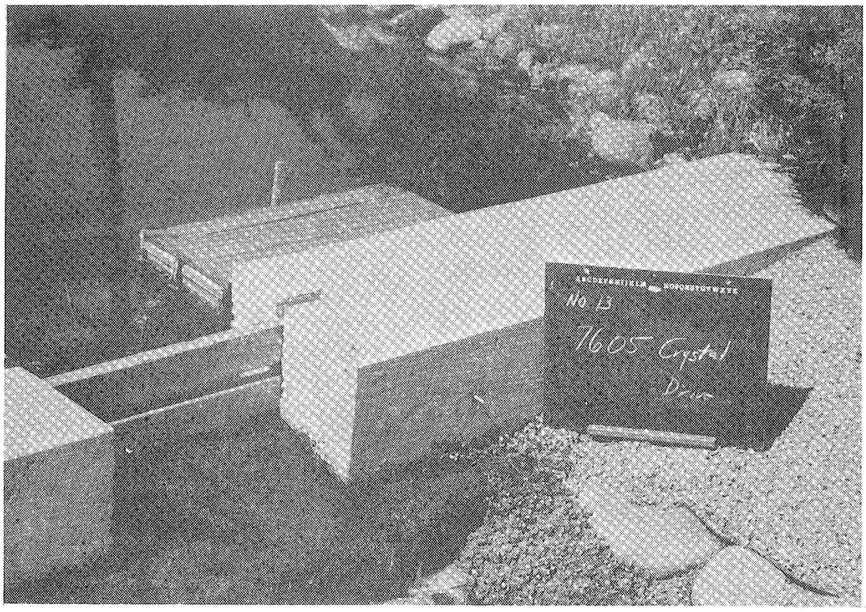
Pipe No. 2

Location: North Shore of Crystal Lake
7546 Crystal Drive
Beulah, Michigan

Discharge Record

Date	cfs
6-01-69	2.18
6-02-69	2.25
6-05-69	1.62
6-08-69	1.91
6-10-69	1.78
6-12-69	1.78
6-15-69	1.78
6-21-69	1.69
6-24-69	1.69
6-29-69	1.97
7-05-69	1.78
7-10-69	1.97
7-13-69	2.02
7-19-69	1.91
7-24-69	1.78
7-30-69	2.02
8-08-69	1.78
8-14-69	2.02
8-20-69	1.78

Figure II-21



Weir No. 13

Location: North Shore of Crystal Lake
7605 Crystal Drive

Mitchell Pond
752 Windemere
Beulah, Michigan

Weir Type: Broad Crested Rectangular

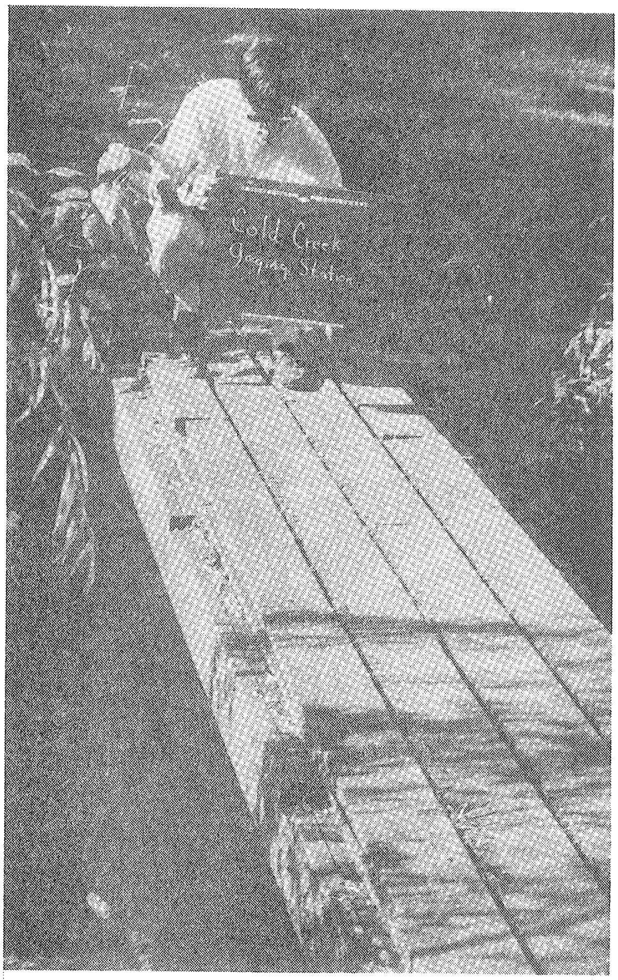
$Q = 3.09\ (L)\ (H)^{1.5}$

$L = 1.9375'$

Discharge Record

Date	cfs
6-01-69	0.144
6-02-69	0.144
6-05-69	0.094
6-08-69	0.117
6-10-69	0.094
6-12-69	0.117
6-15-69	0.144
6-21-69	0.117
6-24-69	0.094
6-29-69	0.117
7-05-69	0.117
7-10-69	0.117
7-13-69	0.144
7-19-69	0.117
7-24-69	0.117
7-30-69	0.144
8-08-69	0.173
8-14-69	0.066
8-20-69	0.144

Figure II-22



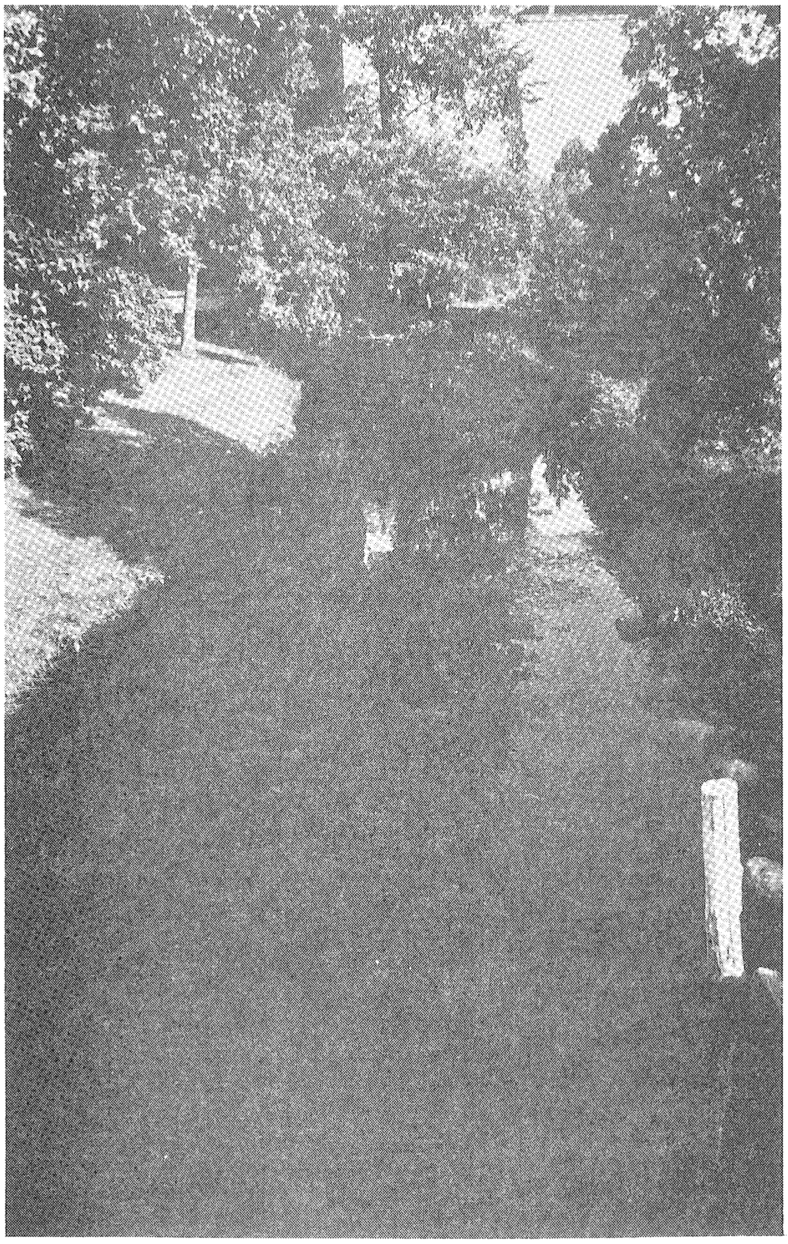
Cold Creek

Location: Benzie Boulevard (West side)
Beulah, Michigan
(Gaging station established on Second foot bridge)

Discharge Record

Date	cfs	Date	cfs
5-14-69	7.117	6-03-69	8.503
5-15-69	7.368	6-05-69	7.850
5-16-69	7.046	6-06-69	8.904
5-17-69	10.072	6-07-69	7.283
5-18-69	7.921	6-08-69	7.176
5-19-69	7.715	6-10-69	6.691
5-20-69	7.665	6-11-69	7.273
5-21-69	6.332	6-12-69	24.990
5-22-69	6.728	6-14-69	10.440
5-23-69	6.346	6-18-69	8.150
5-24-69	6.745	6-23-69	7.962
5-25-69	8.187	7-10-69	7.252
5-26-69	7.517	7-11-69	6.760
5-27-69	7.562	7-13-69	6.331
5-28-69	7.012	7-19-69	7.082
5-29-69	6.937	7-24-69	7.800
5-30-69	6.990	8-03-69	6.302
6-01-69	8.448	8-09-69	6.049
6-02-69	9.141		

Figure II-23

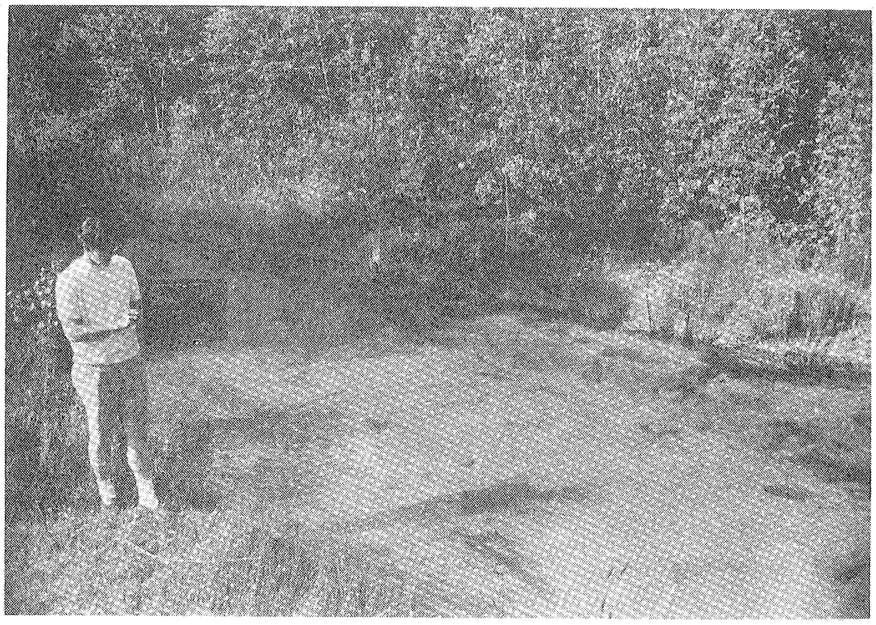


Cold Creek from Lake Street Bridge

Beulah

July 1969

Figure II-24



Outlet

Location: Outlet Channel of Crystal Lake
Right side of road, at M-115 crossing

Discharge Record

Date	cfs	Date		cfs
5-15-69	43.002	6-03-69		55.230
5-16-69	44.198	6-05-69		53.935
5-17-69	50.700	6-06-69		56.983
5-18-69	47.860	6-07-69		55.050
5-19-69	50.610	6-08-69		53.900
5-20-69	59.030	6-10-69		46.930
5-21-69	42.824	6-11-69		46.540
5-22-69	51.830	6-13-69	10 AM	91.340
5-23-69	47.580	6-13-69	4 PM	92.410
5-24-69	42.481	6-14-69		80.320
5-25-69	52.209	6-18-69		33.200
5-26-69	47.369	6-23-69		66.510
5-27-69	48.495	7-10-69		96.680
5-28-69	46.760	7-11-69		89.705
5-29-69	47.299	7-19-69		63.880
5-30-69	46.793	7-24-69		61.330
5-31-69	46.537	8-03-69		52.987
6-01-69	49.610	8-09-69		45.626
6-02-69	52.063	8-12-69		36.90

Figure II-25

W4 - 1600 S. Shore Drive.—The stream emanates from a marshy wooded hillside gully with a cherry orchard on one side of the gully about 200 yeards away. It is dammed at the base of the gully for lawn irrigation. The stream then travels through a large wooded ravine, crossing under Robinson Road and continuing to the outlet. A few cottages are above the east side of the ravine below Robinson Road and a cottage is at least 100 feet from the stream at the weir.

W1 - 774 S. Shore Drive at Crystal Beach Resort.—The main stream and its two tributaries emanates from the uninhabited wooded hillside 150 yards above Thomas Road. It has an approximately 250-yard course below that road to its outlet, flowing between 10-15 cottages in two rows, each at least 100 feet on either side of the stream. It also travels through several impoundments, the lower ones being used as a recreation site.

W2 - 390 S. Shore Drive.—The main stream and tributaries flow out of sparsely developed hillsides on either side of Bellows Avenue. The main flow comes out of pasture land on hills west of Bellows Avenue, then travels through uninhabited, rather boggy woods by the road. It crosses Thomas Road 100 feet west of Bellows Avenue and travels to the outlet on the west edge of the Frankfort public beach. The weir is on the south side of S. Shore Drive near an unoccupied cottage. At least two significant tributaries flow from the hillsides on the east side of Bellows Avenue. (A few cottages are in this area.) The tributaries cross the road about 100 and 300 feet, respectively, south of the intersection with Thomas Road. They join the main stream in the boggy woods but all remain fast flowing, distinct stream throughout their courses.

W3 - 13 S. Shore Drive.—The main stream emanates from uninhabited wooded hills about 100 yards above Thomas Road. It flows west to the road and then follows the road to the pipe where it is joined by a small drainage flowing east. After crossing the road, it flows 300 yards through the woods of the John Burrows property (the weir location) until it crosses S. Shore Drive to the outlet.

W5 - 2627 Crystal Drive.—This stream is the surface outlet of Round Lake and after seeping out of the swampy south side of this lake it flows about 100 yards through the woods to the point of discharge into Crystal Lake. Only one house at 2627 Crystal Drive - "Cloud 9" is within 100 feet of the stream. Toward the end of August, the stream was dry due to the lowering of the lake level of Round Lake, which is half marsh (south end) and half open water (north end), with the open water about 400 feet in diameter and about as clear as Crystal Lake. Generally Round Lake has a shallow shelf which drops off to at least 20 feet in depth.

W6 - 3600 Crystal Drive.—The stream at the weir receives drainage from a ditch which runs east to west 250 yards (on the north side of Crystal Drive), and 70 yards west to east with no one distinct source. A few tiny streams flow out of the hill which is 50-150 feet from the road. The stream weakly flows the 100 feet from the road to the lake and seeps into the sand just short of the water's edge. Unfortunately the weir was removed by vandals late in June and was not replaced. There are at least three cottages on the hill terrace above the ditch, with none on the lake.

W7 - 3901 Crystal Drive.—The stream emanates from a wooded, uninhabited hillside ravine flowing down to a roadside ditch 200 feet east of the under road pipe. Water appears to be lost here for the above ditch stream flow is steady while in the ditch the flow lessens considerably and after crossing the road is weed-choked, mosquito infested and sometimes dry. Its total length is about 300 yards. Abandoned orchards are on the hills above the stream and at the top of one ravine there is a large water tank. Only one cottage, within 50 feet on the lake side of Crystal Drive, is near the stream. The weir was removed by vandals early in July and was not replaced.

4141 Crystal Drive - "Glen Rhoda."—The stream flows from a hillside ravine similar to that of the W7 stream. There are only abandoned orchards on the south sloping hillsides. The stream is dammed 50 yards below its origin; lawn irrigation pipes lead from here to serve seven lawns. From the dam the stream tumbles down a deep wooded ravine to the road, and then flows within 50 feet of the house at 4141 Crystal Drive to the weir and then into Crystal Lake.

W8 - 6200 Crystal Drive.—The main stream flows out of wooded hills just below an orchard, and then flows through a wooded ravine approximately 300 yards before coming out behind the cottages on the east side of Nichols Road. There is evidence of periodic damming and there are several tributary impoundments at the head of the ravine near the stream's source and 150 yards downstream. At times the survey team have observed no flow at W8 due to temporary upstream storage. The stream runs behind and at least 100 feet from the first two cottages on Nichols Road but then turns to run within 15-30 feet of the last three on the east side. It crosses the road 75 feet above the intersection with Crystal Drive, coming within 50 feet of the last cottage on the west side of Nichols. It crosses the main road and comes within 50 feet of a cottage just before it outlets to Crystal Lake. W8 is 50 feet above the outlet. The lakeside stretch of Nichols Road is used as a boat launching and public recreation area.

W9 - 6709 Crystal Drive.—The stream emanates from the hillside on Crystal Drive and flows 100 feet east to the weir which is at the pipe draining under the road. It travels 150 feet on the lakeside of Crystal Drive, all but the last 10 feet underground. Cottages on either side at this point are within 50 feet of the stream. The buildings of an orchard are on the hill above the stream origin and the orchards are at least 300 yards up the hill. An ungaged stream was observed west of the W9 stream, outletting at 6681 Crystal Drive, and its water quality was observed to be similar to W9 based on sampling in June.

W10 - 6863 Crystal Drive.—The main stream originates in a wooded area bordering pasture land at least 1/2 mile from the lake. Two other tributaries join the main stream as it runs parallel to Harris Road until it reaches the weir gaging station just above Crystal Drive on the private property of Wilber S. Johnston. This area has been developed for recreational purposes and has some small impoundments.

P1 - 7230 Crystal Drive.—The main stream originates in the wooded hillside above mostly fallow farmland (some horses). It runs at least 200 yards through this land to an impoundment and then flows 100 feet to the road and west 200 feet to P1. From here it goes under Crystal Drive and outlets to Crystal Lake at a public boat launching area.

W12 - 7281 Crystal Drive.—The main source is from hillside seepage above the marina parking lot on the north side of Crystal Drive and below the house at 7270. It flows 150 feet east to a pipe crossing the road. Here it receives some ground water seepage and flows west 50 feet before turning and flowing 100 feet to the weir and the lake.

W11 - 7468 Crystal Drive.—The weir receives drainage from the north of road ditch, west to east for about 200 yards. The sources on this side of the weir seem to be all from ground water seepage directly into the ditch.

P2 - 7546 Crystal Drive.—The pipe receives drainage on the north of road side from many hillside springs as far as 100 feet west and 100 yards east. Five cottages front the ditch with 50-100 foot frontage and all have at least one drain pipe actively feeding water to the ditch. The major flow comes from the east and seems to originate from seepage of ground water from a gravel pit.

W13 - Mitchell Pond - 752 Windemere Road.—This pond is a trout filled impoundment on the large, well tended lawn and garden property of Don Mitchell. Its source is unknown, but if it is gravity fed then by the slope of the terrain, the water must come from the general area of the gravel pit at 7600 Crystal Drive, which is just across the road to the north of the pond. The pond itself is 30 feet south of Crystal Drive and is approximately 10 to 15 feet wide and 50 feet long. The routine discharge measurements were taken at the broad crested weir at the east end of the pond. The outlet stream below the pond winds through the property and then goes below ground into a pipe 150 feet from the lake.

Cold Creek.—Details on the drainage from Cold Creek are presented elsewhere in this report.

Crystal Avenue - 6875 Crystal Avenue at Benzie Street.—This stream flows from a storm sewer line coming down Benzie Street to Crystal Avenue. Benzie Street runs about 1/4 mile down a steep hill to the lake and has about 10 cottages along the street. The stream itself flows 120 feet above ground from its pipe under the road to the lake through undeveloped lake front.

Outlet.—The only surface discharge from Crystal Lake is through an outlet channel which discharges into the Betsie River. The lake level is maintained by means of a concrete dam and discharge is over this dam into the outlet channel. After careful review of the area together with a consideration of the various alternatives for measuring the Crystal Lake discharge, it was decided to establish a temporary gaging station on the outlet channel near the M115 highway bridge. The channel is stable, uniform, and accessible at this location. Generally the procedures for measuring discharge as used by the USGS[5] were employed.

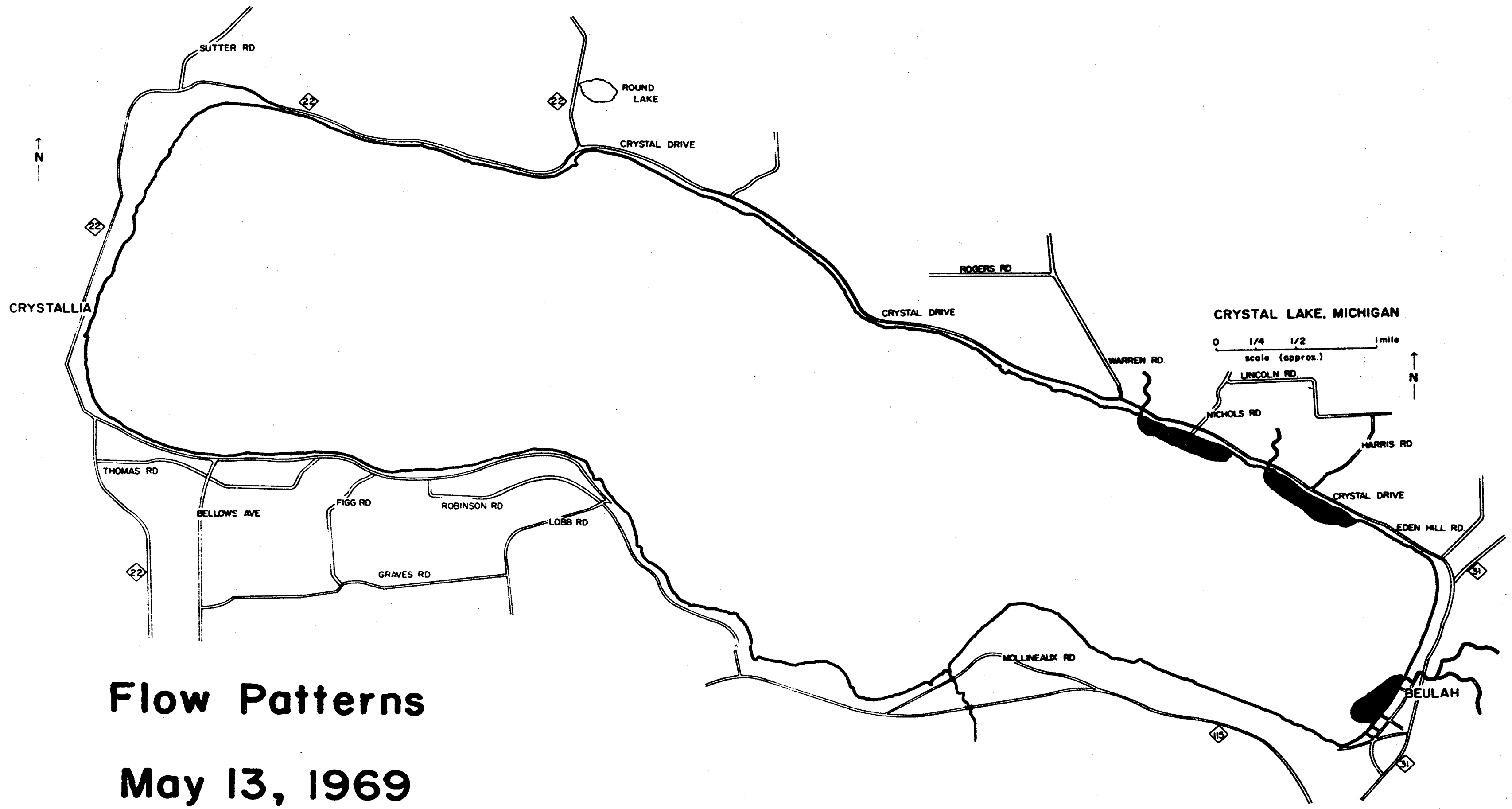
Dispersion Patterns of Discharges into Crystal Lake

One concern was the question of dispersion of waste sources after discharge into Crystal Lake. In order to evaluate the problem, limited dye dispersion studies were conducted at the very beginning of the field phase in May 1969. Generally Rhodamine WT dye was added to selected waste streams on the north shore and Cold Creek, and then monitored in the lake by boat, using a Turner Model III Fluorometer, following accepted procedures as explained in detail by Wilson[8] of the U. S. Geological Survey.

Dye was first added on May 13, 1969, to two streams discharging from the north shore near the east end of the lake as shown in Figure II-26. It is seen that the dye moved east toward Beulah staying close to the shore, and generally dispersed until the concentration became so low that it was less than the lower limit of sensitivity of the fluorometer. At the same time, dye was added to Cold Creek in Beulah on May 13, 1969, and May 17, 1969, showing the same clockwise pattern exhibited along the north shore. It is seen in Figure II-26 and especially in Figure II-27 that the flow from Cold Creek moves south in front of the Beulah Bathing beach before passing out into the lake and then toward the outlet. Certainly this has definite implication in terms of the influence of the Cold Creek discharge on the bathing beach water quality.

It must be appreciated that the discharge of any of the streams entering Crystal Lake is much too small to cause a direct current in the lake from the stream discharge itself. Rather, the predominating influence on the lake circulation is the prevailing wind direction and intensity. Thus, while the pattern shown in Figures II-26 and II-27 is a common one during the summer period as observed during other times in 1969 by following sediment dispersion, especially after heavy rainfall, it is recognized that under certain wind conditions the pattern may reverse itself and follow a counterclockwise direction. Close inspection by a member of the survey team on August 13 of the area in the vicinity of the Village of Beulah dock and new boat launching ramp showed evidence of counterclockwise movement of the Cold Creek discharge, in terms of black sediment deposit in the dock and boat launching area.

Unfortunately, it was beyond the scope of this study to explore more intensively Crystal Lake water circulation patterns.



Flow Patterns

May 13, 1969

Figure II-26

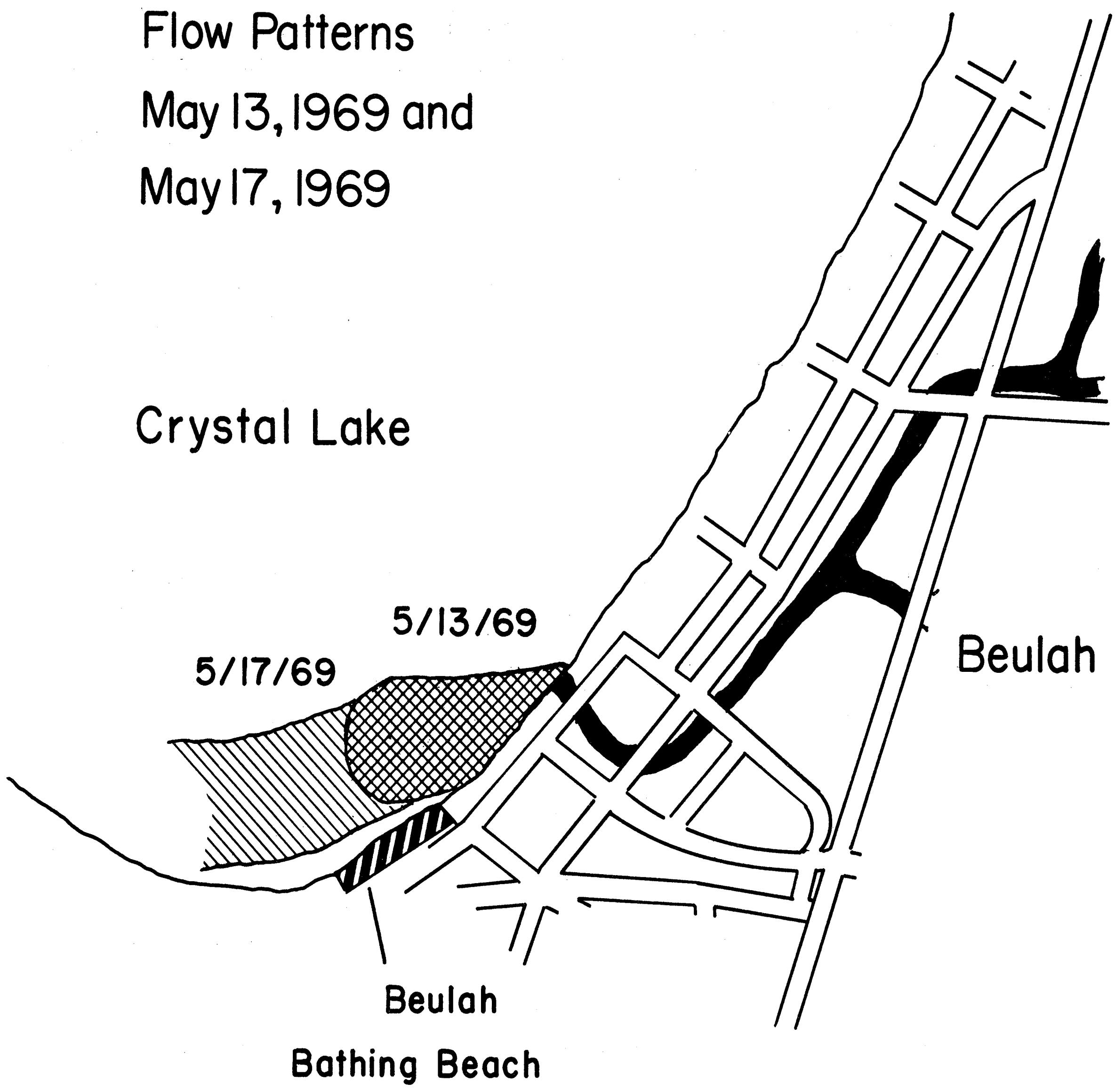

Flow Patterns
May 13, 1969 and
May 17, 1969
Crystal Lake
5/13/69
5/17/69
Beulah
Beulah
Bathing Beach

Figure II-27

Storm Sewer System of the Village of Beulah

The Village of Beulah has separate sanitary and storm sewer systems. Sanitary sewage is collected in several lines which lead to a pumping station on Crystal Avenue, and is then pumped out of the Crystal Lake drainage basin to a treatment facility which discharges to the Betsie River. Thus, only the storm water from the village drains either to Cold Creek or directly to Crystal Lake.

Existing storm sewer inlets and lines as related to the survey team by Walter Lentz, superintendent of the Village of Beulah, are located on Figure II-28, and presented as follows:

Line 1 starts at the junction of U. S. 31 and Spring Valley Street and runs north along Spring Valley Street to Prospect Avenue and then along Prospect Avenue to Crystal Lake.

Line 2 picks up surface runoff in the area of Commerical and Lake Shore Drive (near parking area) and discharges into Crystal Lake.

Line 3 picks up surface runoff in the business district between Commerical and Clark Streets and discharges to Cold Creek at the point where Benzie Boulevard crosses it.

Lines 4, 5, and 6 collect surface runoff on Clark Street and discharge directly to Cold Creek.

Line 7 collects surface runoff on Benzie Boulevard near Pleasant Street and discharges to Cold Creek.

Line 8 collects surface runoff on Benzie Boulevard near First Street and the point of discharge is unknown.

Line 9 collects surface runoff at Benzie Boulevard and U. S. 31 with the point of discharge unknown.

Lake Sampling and Reference Transects

After careful consideration, four lake transects were established as shown in Figure II-29 for the purpose of having regular lake sampling stations and as reference positions for other lake studies. In selecting the location two things were kept in mind, one, to locate the transects so as to be representative of as much of the lake as possible, and two, to locate them between land marks which could be seen and recognized from one side of the lake to the other and also recognized for future studies. The transects are further described as follows:

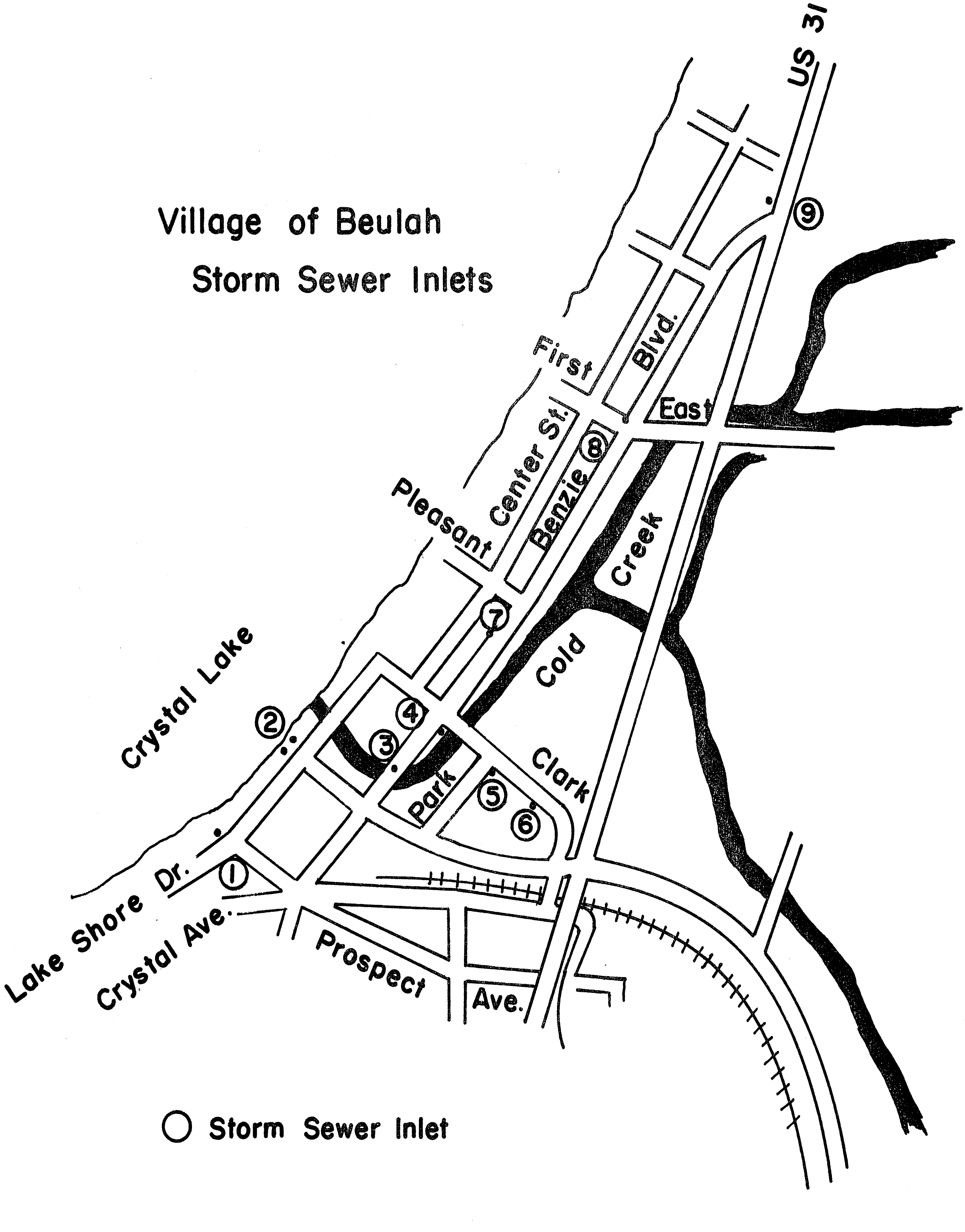
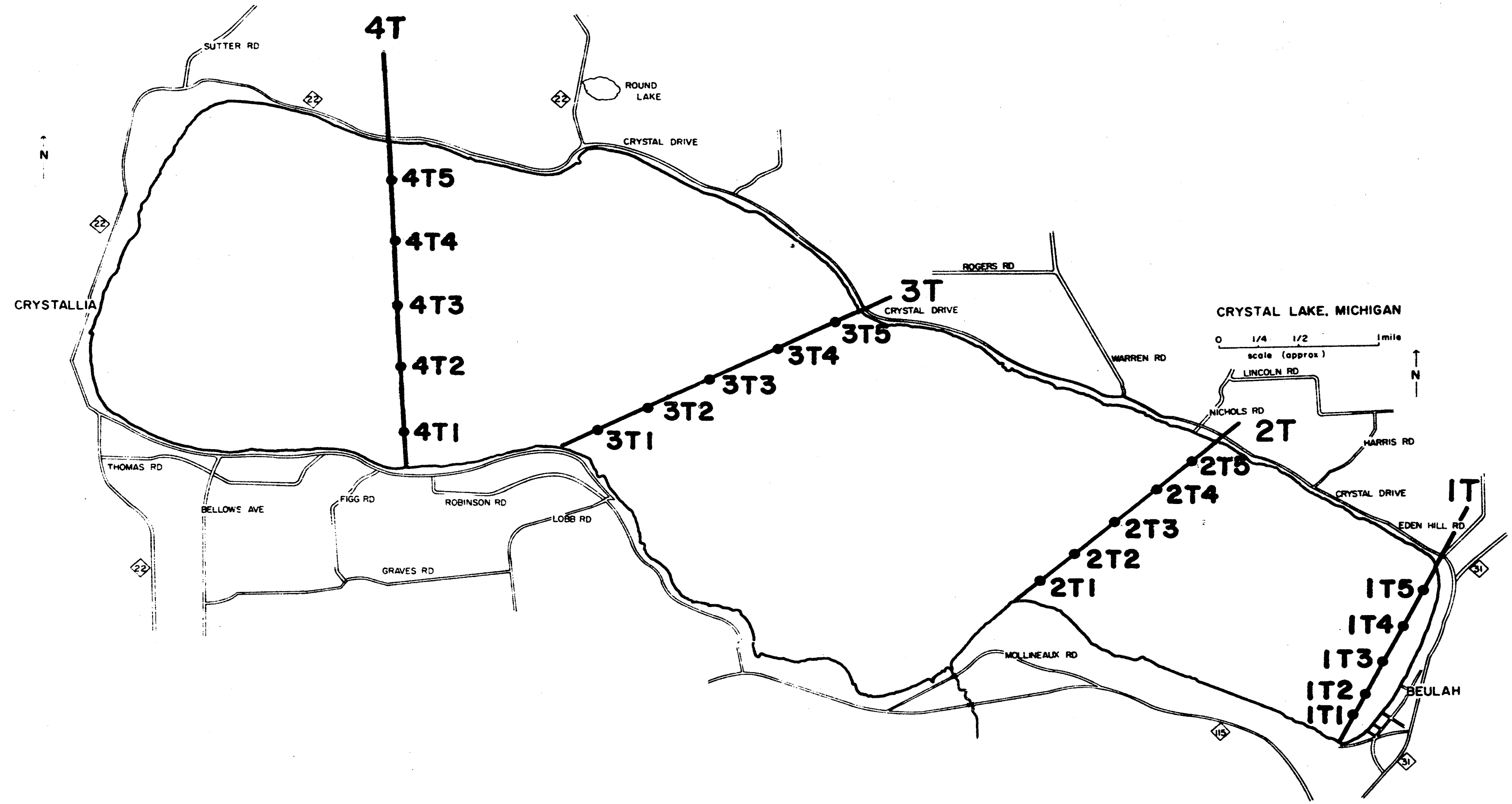

Village of Beulah
Storm Sewer Inlets
US 31
9
First
Blvd.
East
Center St.
8
Benzie
Pleasant
7
Creek
Cold
Crystal Lake
2
4
3
Park
5
6
Clark
1
Lake Shore Dr.
Crystal Ave.
Prospect
Ave.
Storm Sewer Inlet

Figure II-28



Crystal Lake Sampling Stations

Summer 1969

Figure II-29

1T - Transect number one was across the east end of the lake opposite the Village of Beulah staying approximately 150 to 200 yards from the shore line.

2T - Transect number two was from the cottage on railroad point (address 5014) to the clay bluff which was visible from the lake on the north shore at 6415 Crystal Drive.

3T - Transect number three was from the boat house at the Christian Assembly across to the 200-foot hill on the north shore, which clearly stands out from the others.

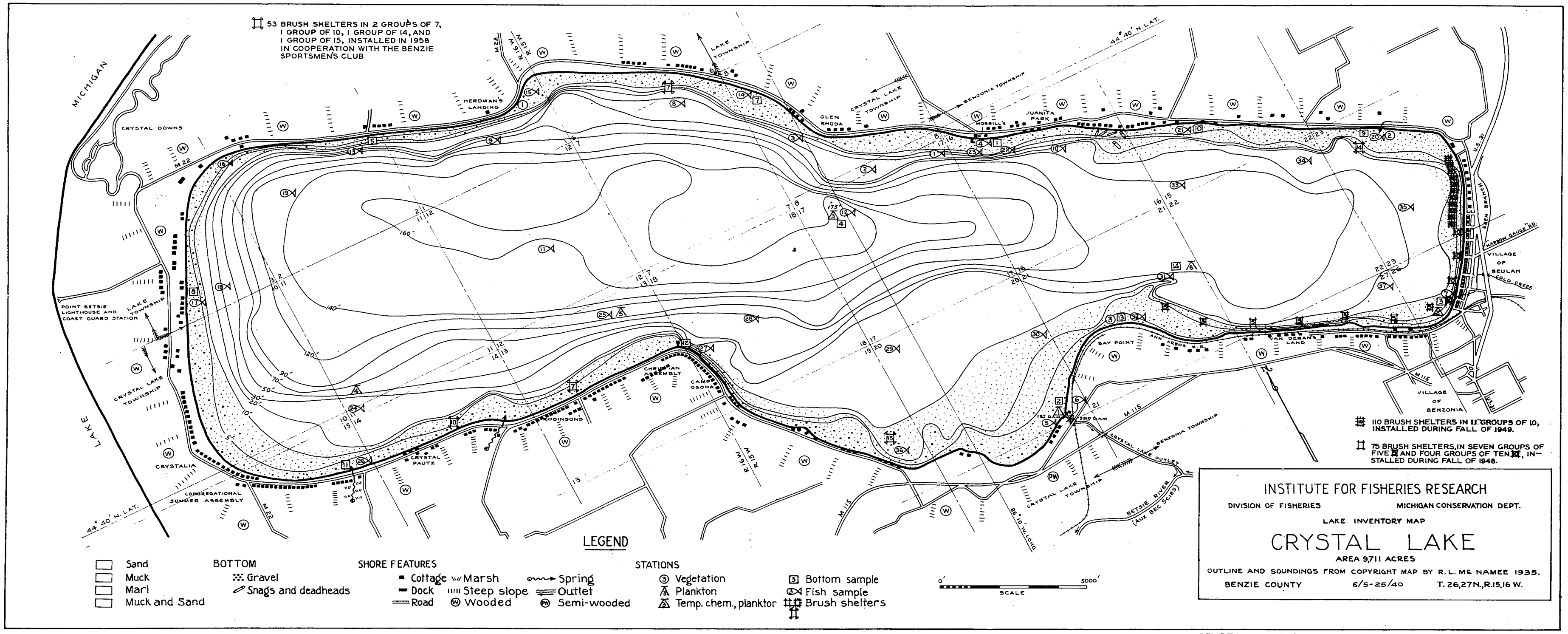
4T - Transect number four runs from the cottage at 1483 South Shore Drive across to the Chimney Corners resort on the north shore. The Chimney Corners ski slope was used as the visible point from the south shore.

All the stations on a given transect were numbered from 1 to 5 proceeding from south to north.

Lake Depths and Volume

One of the important physical considerations in a lake survey is the accurate definition of the lake bottom profile. Fortunately, in the case of Crystal Lake, a map showing the lake bottom contours (Figure II-30) is available as prepared by the Institute for Fisheries Research, Michigan Department of Natural Resources from soundings taken by R. L. McNamee. Because of the availability of this work, no extensive lake sounding program was undertaken by The University of Michigan survey team; however, it was felt that checks on the current accuracy of the map should be made. To do this, a portable recording fathometer—Raytheon Model DE 119—was mounted on the survey craft and bottom profiles were measured at the 1969 lake reference transects. Figure II-31 shows a comparison of the 1969 depths with those taken from the Fisheries Institute map where it is seen that agreement is good. As a result, no further sounding work was done and the Fisheries Institute map was used whenever needed.

The volume of Crystal Lake was determined from the Fisheries Institute map by planimetering areas between bottom contour lines and assuming the average depth between adjacent contours applied to the area. Using this technique, and by summing the individual volumes, the total volume of Crystal Lake was calculated as: 619,415.50 acre feet or 26,981,739,180 cubic feet.



CRYSTAL LAKE Benzie Co. T. 26,27 N., R. 15, 16 W.

Figure II-30

Comparison of Crystal Lake
Bottom Profiles at
1969 Sampling Transects

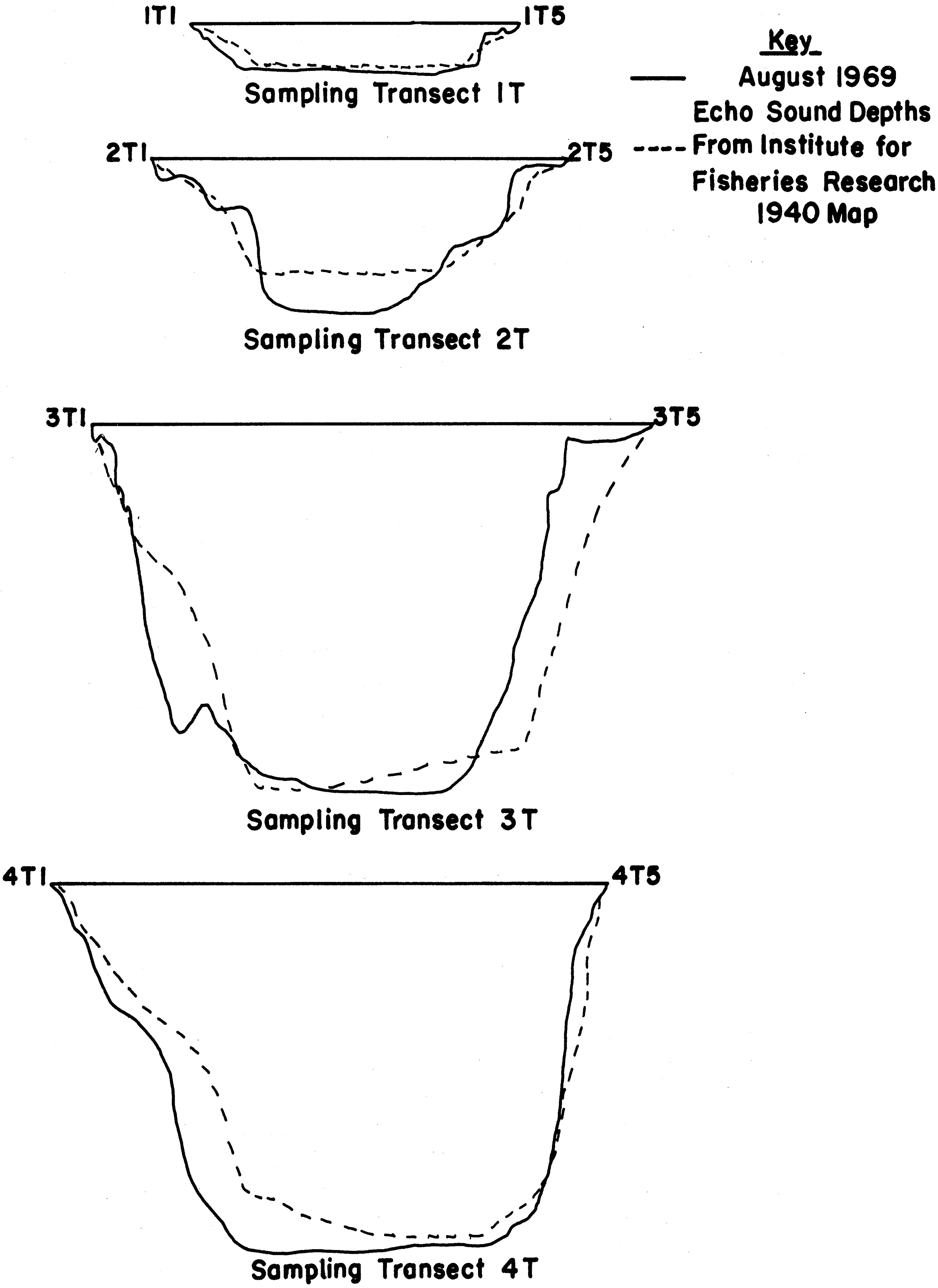


Figure II-31

A Diver's View of Crystal Lake

During the period July 21-27, 1969, Mr. Victor Graf, a researcher and diver from The University of Michigan, participated in the nutrient enrichment studies presented elsewhere in this report and at the same time had the opportunity to dive in several locations in Crystal Lake. His observation areas are shown in Figure II-32, and he made the following comments:

X - depths of 15 to 30 feet on slope, large clam beds, sand and silt bottom.

Y - area of nutrient enrichment study, depths of 45 to 60 feet. Sparse growths of nitella in patches, also algae patches, clay bottom.

A - sand bottom, thick weed growths, depths of 5 to 15 feet with drop off to 30 to 40 feet, silt bottom, much growth.

Z - depths to 160 feet, layer of 40°F water 3 to 4 feet off bottom at 156 feet.

T - silt bottom, depths to 40 feet, sparse growths, some algae.

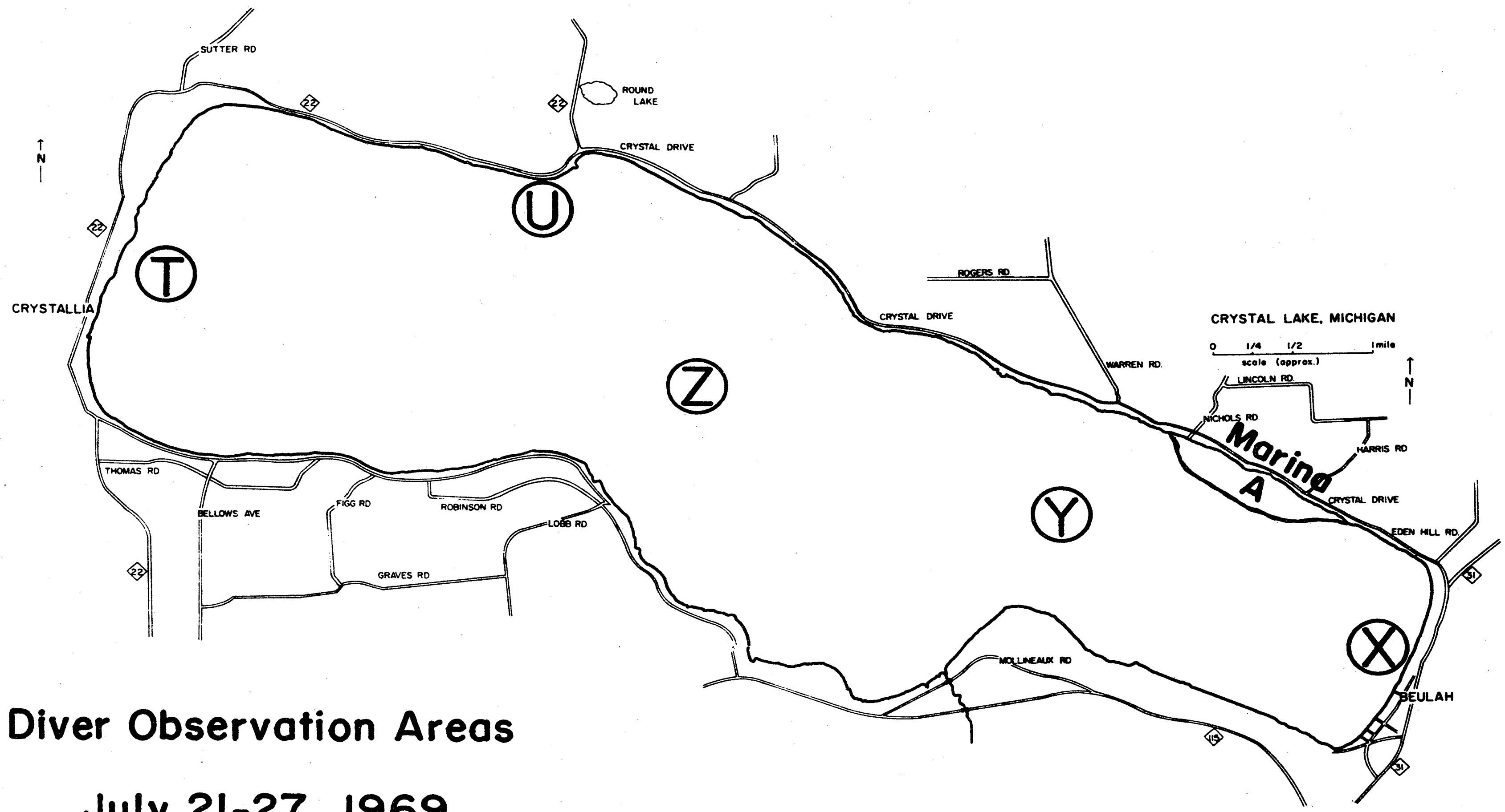
U - same as T except sandier.

Entire northeast part of Crystal Lake has various weed growth, algae growths, spirogyra in clusters, many crustaceans (crayfish) which disperse from Beulah docks. Also, several underwater springs were noted in this part of lake which supplement the several surface discharges into the lake.

Light Penetration in Crystal Lake

Light penetration readings were made as part of every lake transect run for dissolved oxygen and temperature profile determinations. These readings were made with a standard black and white Secchi disk on a light chain marked in feet. Readings were always made on the shaded side of the boat so the procedure was consistant, and the readings were made by the same member of the survey team. The disk was lowered in the water until its distinct outline disappeared; it was then slowly raised until its distinct image reappeared. This second depth is the reading which appears in Section III of this report. Precaution was made to see that the boat was still in the water so that the disk was suspended vertically.

The biggest factor in variance of readings was the roughness of the water surface. Crystal Lake does not often have a calm surface and with the limited



Diver Observation Areas

July 21-27, 1969

Figure II-32

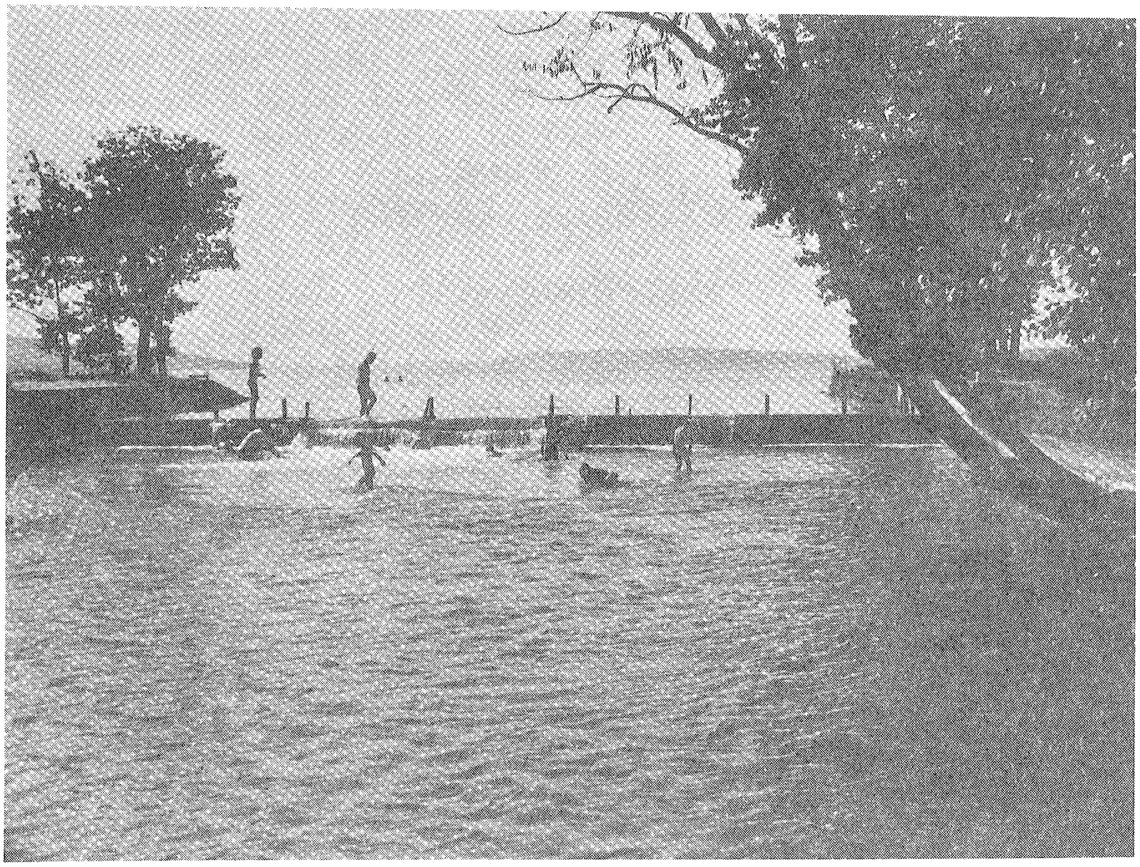
availability of an adequate boat, equipment, personnel, etc., perfect conditions could not be chosen for each run. Comparison of the readings of July 25 and August 19 show how important lake surface roughness can be, especially when the transparency ideally permits readings over 15 feet. July 25 was a relatively calm sunny day with smooth lake surface, while August 19 was windy and partly cloudy with a rough surface in all but the 5th station of each transect. On July 25 Secchi disc readings at transects two and three ranged between 22 and 26 feet, while on August 19 at these same two transects the readings ranged between 12 and 14 feet. Thus, rough lake surface definitely lowered the efficiency of the Secchi disk procedure. Notwithstanding these problems of measuring light penetration, Crystal Lake today has greater transparency than most inland lakes of Lower Michigan.

Lake Levels of Crystal Lake

The level of Crystal Lake is maintained by a dam at the outlet as shown in Figure II-33, with the legal lake level established at 600.48 feet above mean sea level, by resolution of the Board of Supervisors in October 1909.

James Lewis Calver[2] in his thesis, "The Glacial and Post-Glacial History of the Platte and Crystal Lake Depressions, Benzie County, Michigan," describes the history of the level of Crystal Lake as follows:

> "Wave and current activity during Algonquin times constructed bars across the opening of all these connecting channels and isolated Crystal Lake from the main body of water in the Michigan basin. The natural level of Crystal Lake used to be, therefore, the level of Lake Algonquin, and many shore features formed within the depression cannot be distinguished with certainty from the Algonquin features. Apparently the water stood at the Algonquin level until historic times. In the fall of 1873, the Betsie River Improvement Company, organized by Mr. Archibald Jones, supervised the digging of a channel through the Algonquin bar at the present outlet of Crystal Lake. This was part of an ambitious plan that would have permitted the passage of small sized lake steamers from Frankfort harbor to Crystal Lake, by way of the Betsie River and the outlet channel (Case[9]). No attempt was made to control the out rush of water when the channel was cut through the bar, and within a very short time the lake level dropped nearly 20 feet. Within a year, the Betsie River Improvement Company was declared bankrupt and the plan was never completed. Several years later a dam was constructed across the outlet and the water of Crystal Lake was raised to somewhere near its former level. However, the early dams were of wooden construction and the level of the lake fluctuated with the whim and fancy of the residents in the area. The concrete dam now in use was constructed about 1915, and since then



Swimming Around Outlet Dam

Crystal Lake

July 1969

Figure II-33

the water level has been controlled at an elevation of approximately 602 feet, or eight feet below its natural (Algonquin) level."

In addition to the elevation of the outlet structure, a number of other factors are involved with the lake water budget and therefore influence the resulting lake level. Certainly precipitation on and evaporation from the lake surface itself assumes importance, since the lake surface constitutes approximately 50% of the total drainage area. Other important concerns, of course include inflow into the lake from both surface and underwater sources and outflow from surface and possibly underwater sources. On a given day the wind direction and intensity could influence the level especially if a level measurement is made only at one point on the lake. Attempts were made to calculate water budgets for the 1969 summer period by members of the survey team, but certain of the important elements were not adequately defined to allow meaningful calculations.

Accurate information on the variation of the level of Crystal Lake has not been available since 1950 when the U. S. Geological Survey discontinued regular measurement of lake level. From June 1942 to September 1950 a staff gage was read daily, except that prior to 1946 this was done only during the summer and fall months. Results of these measurements are shown in Figure II-34, where it is seen that the lake level of Crystal Lake dropped below the legal lake level almost every summer during this time. Additional information as made available by the U. S. Geological Survey is presented in Appendix A.

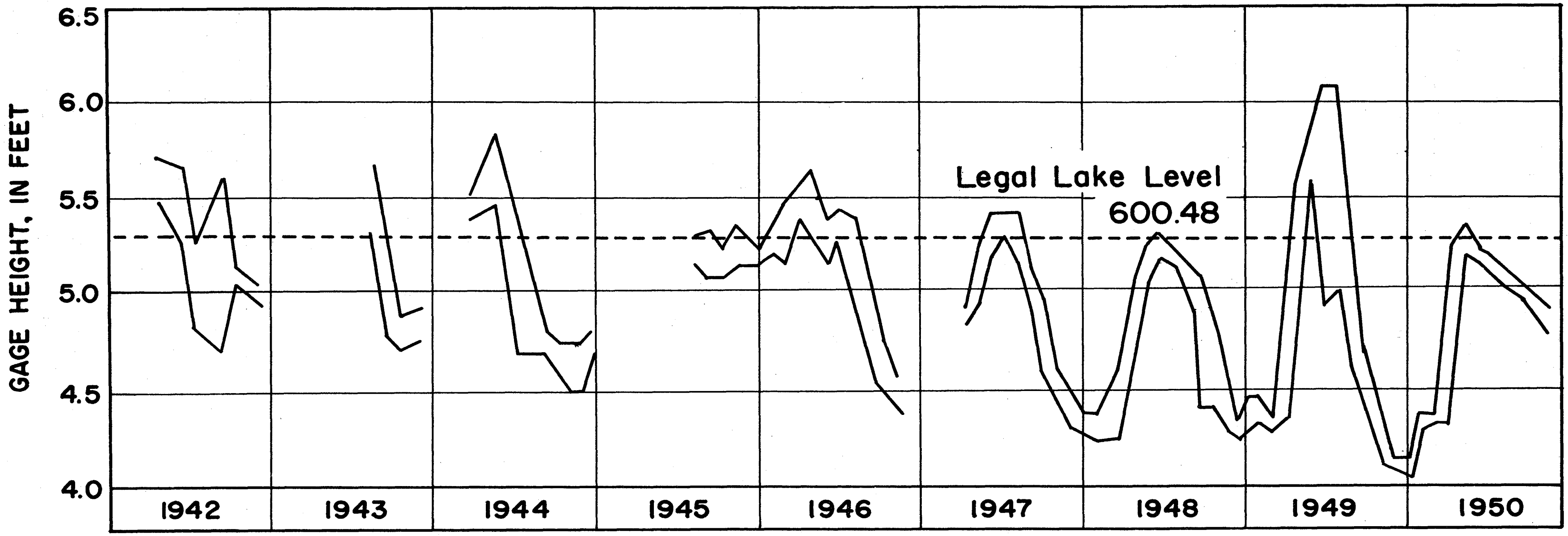
Members of the survey team had the opportunity to determine the following elevations at the outlet structure on August 18, 1969, working from a permanent bench mark located on an abutment on the nearby Ann Arbor Railroad bridge using established surveying procedures.

<u>August 18, 1969</u>

Bench Mark G-89	599.85
Top of Dam	600.38
Bottom of Notch	599.52
Water Level	600.17

Also, on October 25, 1969, a second water level elevation of 600.06 was determined. It must be appreciated that the elevation of the top of the dam and the bottom of the notch may vary slightly from the above elevation, depending on the exact spot the elevation is taken because of deterioration of the structure in places.

While no official measurement of Crystal Lake has been made in recent years, certain interested citizens have kept a record of the level for their information. The Rev. E. W. Willcox of Benzonia has made available his observations of the Crystal Lake level made at a staff gage at the outlet dam at intervals of from two to five days, during the period August 1968-August 1969, except during the December-March period when there was no flow due to freezing conditions.



Crystal Lake Level Fluctuations
1942 - 1950

(After U.S.G.S.)

Figure II-34

As a result of the survey work during the summer of 1969, the need for regular and reliable reports of Crystal Lake level became apparent. Logically this should be the responsibility of a governmental agency such as the U. S. Geological Survey or the Michigan Department of Natural Resources. If this is not possible, then a county office such as the Drain Commissioner should be assigned the responsibility. Because of considerable citizen interest in the level of Crystal Lake, some mechanism should be developed for the regular and public reporting of this information as it is collected, particularly during the summer period.

It is beyond the scope of this report to explore further the matter of the level of Crystal Lake. However, the reader should know that an engineering lake-level control study was completed in 1946 by the Michigan Department of Natural Resources.

Climatological Information

A cooperative station for the collection of Climatological data is maintained in the Frankfort, Michigan, area under the sponsorship of the Environmental Science Services Administration, U. S. Department of Commerce by Warren Putney on his property at 1510 Lobb Road. Regular reporting is made of the maximum and minimum temperature for each day, and the precipitation that occurs each 24 hour period. Because this information has significance in terms of interpretation of water quality data presented in Section III of this report, the complete information for the period May 1-August 31, 1969, is presented in Table II-1.

An important question that might be raised is: How does the 1969 precipitation compare to other years, and particularly how does the precipitation in the months of May, June, July, and August compare to these same months of other years? Long term precipitation information was provided by the National Weather Records Center at Asheville, North Carolina and included information not only for Frankfort, but a number of other long term stations such as Traverse City and Manistee.

Several years were incomplete for the Frankfort station for the period 1901-1968, and it became necessary to estimate the annual precipitation for these years by establishing a relationship using the least squares method between the Traverse City precipitation and the Frankfort precipitation (correlation coefficient = 0.882). By means of this approach, the incomplete years were estimated and a continuous record was available for analysis.

Gannon[10] and Velz[11] have successfully used probability paper for defining variation and this technique was employed in analyzing the Frankfort precipitation data. Figure II-35 shows a straight line fit of this information on a log

TABLE II-1

TEMPERATURE AND PRECIPITATION DATA

Frankfort, Michigan
May-August, 1969

Day	May Temp, °F Max	May Temp, °F Min	May Precip. in 24 hr	June Temp, °F Max	June Temp, °F Min	June Precip. in 24 hr	July Temp, °F Max	July Temp, °F Min	July Precip. in 24 hr	August Temp, °F Max	August Temp, °F Min	August Precip. in 24 hr
1	56	38	0	73	49	1.02	64	46	0	71	59	0
2	60	46	.07	55	43	.05	70	52	.65	75	58	0
3	61	44	0	52	40	.19	69	54	0	77	57	0
4	71	49	0	54	37	.28	78	58	.97	80	60	0
5	73	52	0	55	42	0	67	54	0	76	60	T
6	64	50	.32	60	42	.37	70	49	0	80	65	0
7	71	48	.03	63	45	0	70	47	0	77	66	.27
8	66	44	.80	60	44	0	74	54	0	76	64	0
9	50	39	.10	50	37	0	75	58	0	71	57	0
10	42	37	T	66	42	0	74	64	0	72	58	0
11	48	33	.01	71	58	1.80	80	61	0	78	56	0
12	49	34	.02	80	46	.86	80	59	.15	79	59	0
13	59	39	.02	57	43	.04	79	58	0	79	69	0
14	62	41	0	60	42	0	80	60	0	81	60	0
15	70	49	0	60	47	.04	82	63	0	82	62	0
16	75		0	67	43	0	78	68	T	81	66	0
17		37	.70	63	43	0	78	66	0	81	68	0
18	46	39	.08	64	45	T	77	63	0	77	66	0
19	53	39	.06	62	48	.76	81	60	0	71	58	0
20	52	36	.16	56	45	0	80	64	0	72	52	0
21	45	31	0	61	42	.16	72	59	0	72	52	0
22	53	40	0	62	43	T	78	59	0	80	50	0
23	64	37	0	64	47	.20	77	58	.37	82	52	0
24	61	42	1.17	66	47	0	75	61	0	84	64	0
25	59	35	0	78	53	0	72	60	T	83	65	0
26	58	29	0	79	62	2.17	79	56	0	79	58	0
27	73	42	.04	82	62	.20	73	65	.37	81	60	0
28	78	58	0	66	58	T	67	60	1.07	81	68	0
29	74	57	0	74	47	.20	73	71	.04	84	70	0
30	74	49	0	68	54	.95	75	56	0	85	59	0
31	80	54	T				70	56	.20	80	59	.60

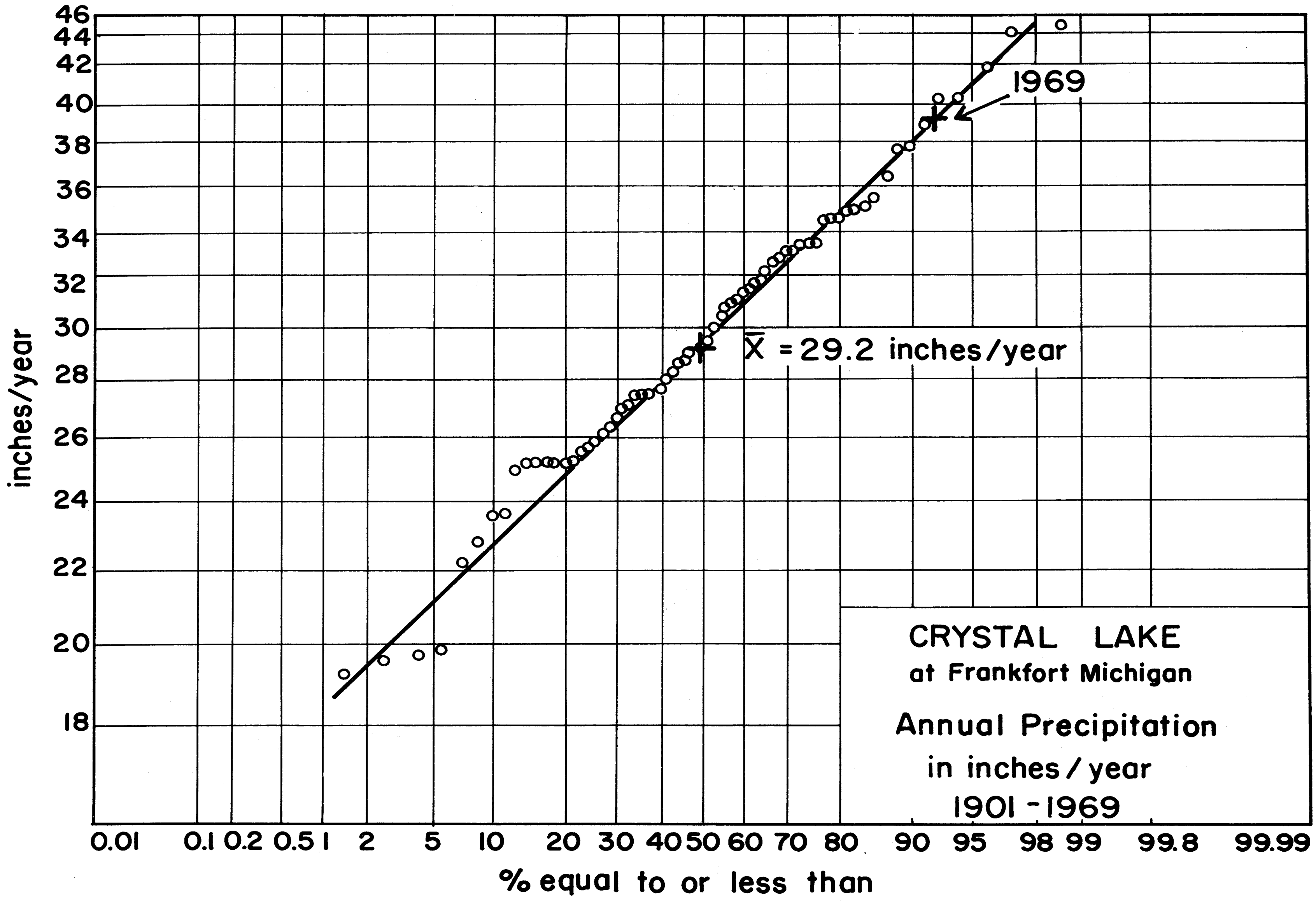

CRYSTAL LAKE
at Frankfort Michigan
Annual Precipitation
in inches / year
1901 - 1969
$\bar{X}$ = 29.2 inches/year
1969
inches/year
46
44
42
40
38
36
34
32
30
28
26
24
22
20
18
0.01
0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.99
% equal to or less than

Figure II-35

normal probability grid, thus making it possible to determine a probability of occurrence for a given level of rainfall.

The 1969 precipitation is shown on Figure II-35, where it is seen that this year was one of the highest precipitation years of record. Ninety two percent of the years were less than 1969, and only four years of the period 1901-1969 were wetter than 1969.

Similar analyses were made for each of the months of May, Juje, July, and August, for the same period 1901-1969, and these months for the year 1969 related to the long term period as follows:

May 1969 - 76% equal to or less than or 24% greater than
June 1969 - 98.5% equal to or less than or 1.5% greater than
July 1969 - 85.5% equal to or less than or 14.5% greater than
August 1969 - 11% equal to or less than or 89% greater than

Thus it is apparent that May, June, and July, 1969 were extremely wet months and August was relatively dry.

Wind velocity and direction is observed every four hours by personnel of the U. S. Coast Guard Station at Frankfort and this information was made available to the survey team. Because of its voluminous nature, the data is not included in this report. Unfortunately, no evaporation measurements are regularly made in the vicinity of Crystal Lake and the nearest reported evaporation information is at Lake City Experimental Farm.

Summary

A number of important physical characteristics of Crystal Lake and the surrounding area have been presented. These included: a basin description, important geological considerations, the location and measurement of surface discharges, a description of each tributary stream above the point where it was measured, a presentation of dispersion patterns of discharge into the lake, a description of the storm sewer system of the Village of Beulah, a description of lake sampling and reference transects, a discussion of lake depths and volume, a diver's view of Crystal Lake, a discussion of light penetration, a consideration of lake level, and an evaluation of the climatological data at the Frankfort Weather Station.

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10. Gannon, John. "Statistical Basis for Interpretation of Data." Proceedings of the Michigan Sewage and Industrial Wastes Association 1959 Annual Meeting, 34 pp (1959).

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III. WATER QUALITY CHARACTERISTICS

Introduction

A number of important water quality characteristics of Crystal Lake and its tributaries were defined as part of the present survey. This section of the report includes: a discussion of Michigan water quality standards and Crystal Lake use designation, a discussion of chemical and bacteriological observations including sampling and laboratory considerations, results of weekly tributary sampling including the many drains and ditches, results of a special Cold Creek study, results of shore line evaluation and water quality sampling involving monthly evaluation in front of approximately 300 cottages close to the lake, results of monthly samples collected at a number of stations on the lake at four regular lake transects, results of a special sampling of organized bathing beach areas on July 31, 1969, results of special sampling of the Crystal Beach resort area on June 27 and August 1, 1969, discussion of a special well water testing clinic conducted early in July involving approximately 165 individual wells in the Crystal Lake area, results of a special well water nitrate study of north shore wells, and a presentation of biological observations including a description of aquatic plant growth in Crystal Lake, results of lake bottom and plankton sample analysis, and results of a survey of macroscopic algal growth.

Water Quality Standards and Lake Use Designation

Responsibility for protection of the waters of the State of Michigan rests with the Water Resources Commission, Michigan Department of Natural Resources. One of the important elements in accomplishing this protection is through the development and adoption of water quality standards for intrastate waters for various uses, and then a designation of a specific use for the various waters of the state. The following summary of this authority as presented by the Water Resources Commission[1] is included for the information of the reader:

> "Act 245, Public Acts of 1929, as amended, sets forth the Michigan Water Resources Commission's authority to establish Intrastate Water Quality Standards and use designation areas. This act reads in part: 'An act to create a water resources commission to protect and conserve the water resources of the state, to have control over the pollution of any waters of the state and the Great Lakes, with power to make rules and regulations governing the same...'

Section 5 and Section 6(a) of this act again merit repeating as they apply equally to the Commission's authority to adopt regulations to control the pollution of the inland waters of the State as they do to the interstate waters.

> Sec. 5. 'The commission shall establish such pollution standards for lakes, rivers, streams and other waters of the state in relation to the public use to which they are or may be put, as it shall deem necessary.'
>
> Sec. 6(a). 'It shall be unlawful for any person directly or indirectly to discharge into the waters of the state any substance which is or may become injurious to the public health, safety or welfare; or which is or may become injurious to domestic, commercial, industrial, agricultural, recreational or other uses which are being or may be made of such waters; or which is or may become injurious to the value or utility of riparian lands; or which is or may become injurious to livestock, wild animals, birds, fish, aquatic life or plants or the growth or propagation thereof be prevented or injuriously affected; or whereby the value of fish or game is or may be destroyed or impaired.'

Michigan's Intrastate Water Quality Standards were adopted by the Water Resources Commission on January 4, 1968."

Several broad water use categories were followed in the development of the intrastate water quality standards as follows:

1. Water supply
    a. Domestic
    b. Industrial
2. Recreation
    a. Total body contact
    b. Partial body contact
3. Fish, wildlife, and other aquatic life
4. Agricultural use
5. Commercial and other uses

For each use, 11 water quality parameters were designated including coliform group of bacteria; dissolved oxygen; suspended, colloidal, and settleable materials; residues; toxic and deleterious substances; total dissolved solids; nutrients; taste and odor producing substances; temperature; hydrogen ion concentration; and radioactive materials.

It is the understanding of the writer that the waters of Crystal Lake have been designated for Recreation-Total Body Contact which has been described[1] as follows:

"Recreation

1. <u>Total Body Contact</u>

> This is the water source which is intended for uses where the human body may come in direct contact with water to the point of complete submergence. The water may be accidentally ingested and also certain body organs, such as the eyes, ears, etc., will be exposed to the water. Although water may be accidentally ingested it is not intended that this source be used as a potable supply unless treatment is applied. Some examples of total body contact recreation are: 1) swimming, 2) water skiing, and 3) skin diving."

Of the 11 water quality parameters used by the Water Resources Commission, the two having greatest relevance in Crystal Lake for total body contact include coliform group of bacteria and nutrients. In relation to the coliform group, "the geometric average of any series of 10 consecutive samples shall not exceed 1000 nor shall 20% of the samples examined exceed 5000. The fecal coliform geometric average for the same 10 consecutive samples shall not exceed 100." In relation to nutrients (phosphorus, ammonia, nitrates, and sugars), the requirements say "nutrients originating from industrial, municipal, or domestic animal sources shall be limited to the extent necessary to prevent the stimulation of growths of algae, weeds and slimes which are or may become injurious to the designated use."

Also, it is understood that Crystal Lake in addition has been designated for fish, wildlife, and other aquatic life-intolerant fish, cold water species (trout, whitefish, cisco) which has the following significant requirement: "In lakes capable of sustaining high oxygen values throughout the hypolimnion during periods of stagnation: maintain dissolved oxygen values greater than 6 mg/l throughout the entire lake."

In developing and applying water quality standards in Michigan, an important non-degradation objective was incorporated as follows[1]:

> "Waters in which the existing quality is better than the established standards on the date when such standards become effective <u>will not be lowered in quality</u> by action of the Water Resources Commission unless and until it has been affirmatively demonstrated to the Michigan Water Resources Commission that the change in quality will not become injurious to the public health, safety, or welfare; or become injurious to domestic, commercial, industrial, agricultural, recreational or other uses which are being made of such waters; or become injurious to livestock, wild animals, birds, fish, aquatic

life or plants, or the growth or propagation thereof be prevented or injuriously affected; or whereby the value of fish and game be destroyed or impaired, and that such lowering in quality will not be unreasonable and against public interest in view of the existing conditions in any intrastate waters of Michigan.

Water which does not meet the standards will be improved to meet the standards."

Crystal Lake was not observed to be a source of drinking water by members of the survey team, and major reliance for this purpose is on individual, or in a few instances, communal wells. Acceptable water quality for drinking purposes has been defined by the U. S. Public Health Service in the form of Drinking Water Standards,[2] which are revised periodically with the latest revision in 1962. Of greatest relevance to well water in the Crystal Lake area is the section dealing with coliform organisms which says: "When the membrane filter technique is used, the arithmetic mean coliform density of all standard samples examined per month shall not exceed one per 100 ml."

One of the chemical constituents of well water that is of concern in this area is nitrate nitrogen. Serious and occasionally fatal poisonings in infants have occurred following ingestion of well waters shown to contain nitrate. Nitrate poisoning appears to be confined to infants during their first few months of life; adults drinking the same water are not affected but breast-fed infants of mothers drinking such water may be poisoned.[3] The U. S. Public Health Service Drinking Water Standards[2] suggests an allowable upper limit of 10 mg/l NO_3 as N, or 45 mg/l as NO_3. Nitrate levels of well water in the Crystal Lake area reported later in this section should be viewed in relation to this standard.

Chemical and Bacteriological Observations

The evaluation of the water quality of Crystal Lake involved a number of chemical and bacteriological analyses of water collected from the following locations: the tributaries including drains and ditches, Cold Creek, the lake itself at various locations and depths, the lake shore area in front of cottages, organized bathing areas, and selected specialized areas. In addition, an extensive well water study was conducted on a voluntary basis during July and August 1969.

SAMPLING AND LABORATORY CONSIDERATIONS

Wherever possible accepted sampling and analytical procedures as outlined in Standard Methods for the Analysis of Water and Waste Water[4] or Limnological

Methods[5] were employed, but in some instances modifications or improved procedures were necessary. A temporary field laboratory was established in the chemistry room of the Benzie Central High School making it possible to initiate laboratory analyses within a period of one to two hours after sample collection. With the exception of the lake phosphate analysis, all other tests were performed at the temporary field laboratory including the bacteriological tests.

Lake water samples for chemical analyses were collected using a Kemmerer standard water sampler which was lowered and raised by means of the Fusilier gasoline-driven hoist illustrated photographically elsewhere in this report. Bacteriological samples of the lake shore line or tributary drains and ditches were collected using sterilized glass sampling bottles either 300 ml or 8 ounces in size.

The following analyses were selectively performed on the collected samples as indicated subsequently:

Temperature in °C
pH
Dissolved oxygen (D.O.) in mg/l
Ammonia (NH_4) as N in mg/l
Nitrite (NO_2) as N in mg/l
Nitrate (NO_3) as N in mg/l
Ortho phosphate (PO_4) in mg/l
Total phosphate (PO_4) in mg/l
Biochemical oxygen demand (BOD_5) in mg/l
Total coliform index as coliform/100 ml
Fecal coliform index as fecal coliform/100 ml

The specific procedures are presented and referenced in further detail in Appendix B.

Major reliance has been placed on the membrane filter procedure for both total and fecal coliform determinations and because of the limitations of equipment and sterilization facilities modifications were necessary as presented in Appendix B. Controls were run regularly throughout the summer and at no time were positive results obtained, thereby supporting the effectiveness of the procedures which were followed.

Historical coliform information has generally been obtained using the fermentation tube procedure as presented on page 594 of Standard Methods.[4] For comparison purposes, selected tributary samples were run in parallel employing both the membrane filter and fermentation tube procedures, with the results presented in Table III-1 as follows:

TABLE III-1

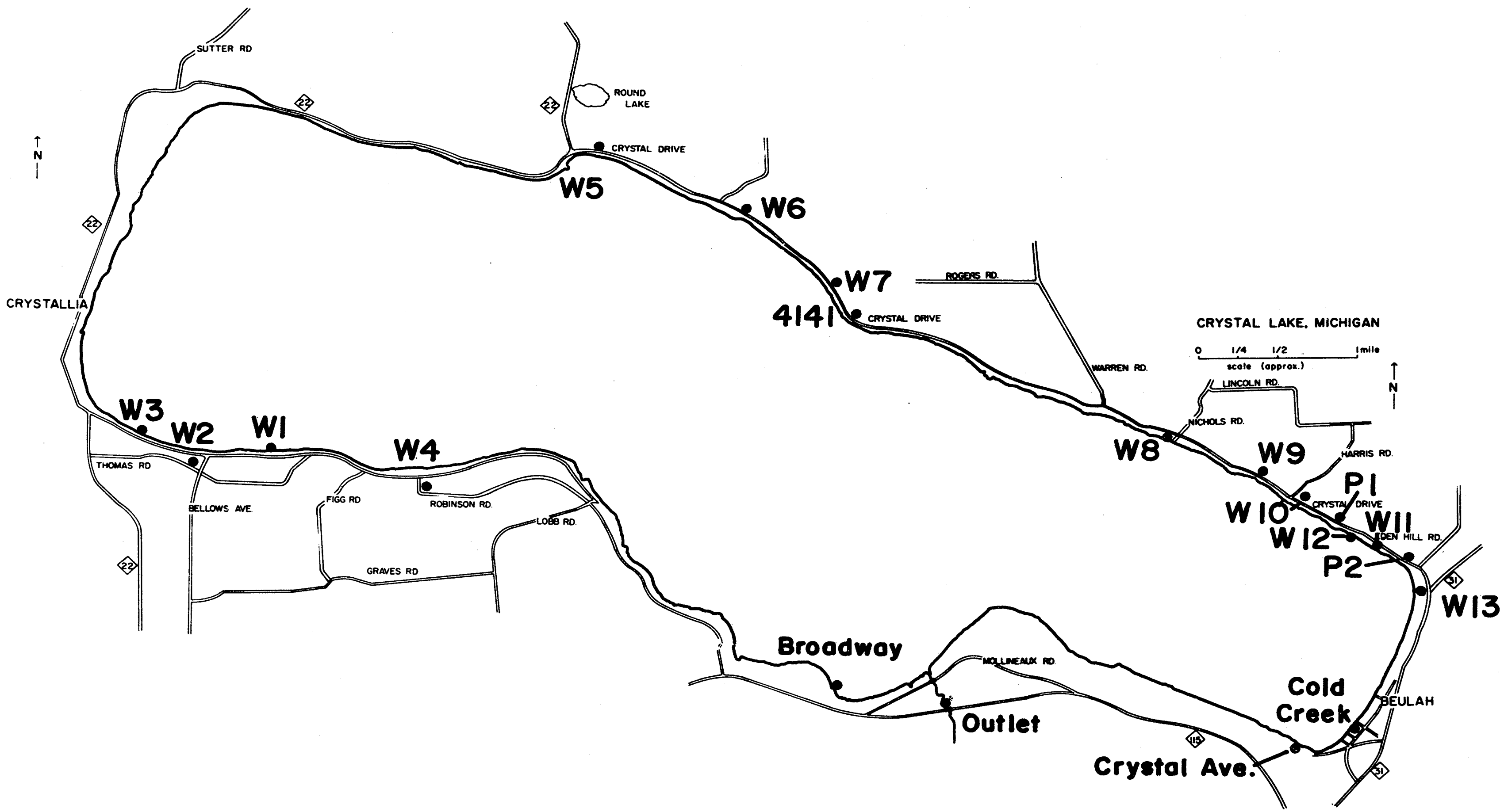
COMPARISON OF MEMBRANE FILTER AND FERMENTATION TUBE TECHNIQUES

Station	Date	Membrane Filter Coliform/100 ml	Fermentation MPN/100 ml
W-6	7-29-69	2,500	1,609
4141	7-29-69	170	918
P-2	7-30-69	800	9,180
CA (Crystal Ave.)	7-30-69	2,300	16,090
W-6	8-07-69	3,200	4,900
4141	8-07-69	350	5,420
Cold Creek	8-10-69	9,000	7.900
W-8	8-10-69	2,300	2,780
W-5	8-10-69	1,800	7,900
W-11	8-10-69	450	490
BW (Broadway)	8-10-69	1,000	1,300
W-1	8-10-69	2,100	4.900
P-2	8-08-69	2,200	330
CA (Crystal Ave.)	8-08-69	65,000	54,200

An inspection of these results shows general agreement in terms of order of magnitude, although not in terms of specific numbers. Because of the differences in the testing procedures, complete agreement is not to be expected.

Tributary Sampling Including Drains and Ditches

In addition to the discharge measurements of the various tributary drains and ditches presented in Section II of this report, knowledge of the chemical and bacteriological composition of these tributaries assumes considerable importance in terms of evaluating and quantifying pollution contribution to Crystal Lake. To evaluate these contributions, a weekly chemical and bacteriological sampling program was started on June 11 and extended to August 20, with the sampling stations indicated on Figure III-1 and the results presented in Tables III-2 through III-26 as follows:



Location of Shore Sampling Stations And Discharge Measurement Points Summer 1969

Figure III-1

TABLE III-2

CRYSTAL LAKE WATER QUALITY INVESTIGATION

STATION Broadway 4132 Boyd Rd. (Sampling point: 10 ft. from mouth of stream)

DATE 1969	6/18	6/25	7/6	7/13	7/24	7/30	8/8	8/14	8/20
TIME OF COLLECTION	AM 8:45	AM 8:15	AM 9:05	AM 7:25	AM 8:05	AM 8:35	AM 8:40	AM 8:25	AM 10:30
DISCHARGE HEAD (feet) CFS	-	-	-	-	-	-	-	-	-
TEMPERATURE (AIR) °C	-	18°	18°	20°	22°	21°	23.5°	22°	22.2°
WEATHER CONDITIONS	cloudy/ showers	over- cast	sunny	sunny	sunny	sunny	sunny	sunny	sunny

CHEMICAL ANALYSIS

TEMPERATURE (Sample) °C	10.5°	11.2°	12.0°	11.0°	12.0°	12.0°	13.0°	13.0°	12.0°
pH	8.40	8.32	8.30	8.10	8.20	8.32	8.40	8.35	8.20
DO mg/1	11.10	13.48	10.50	10.40	10.30	10.30	10.15	10.15	10.35
NH_4-N mg/1	00.02	0	0.02	0.14	0.19	0.09	0.11	0.26	0.30
NO_2-N mg/1	0.001	0.001	0.001	0.001	0.001	0	0	0	-
NO_3-N mg/1	0.69	0.48	0.60	0.60	0.64	0.76	0.48	-	-
Ortho PO_4 mg/1	0.03	0	0.02	0.01	0.02	0.03	0.03	0.03	-
Total PO_4 mg/1	0.03	-	-	0.06	0.03	0.03	-	-	-
BOD_5	1.60	-	0.90	1.83	1.90	1.85	1.28		
Initial	9.40	-	8.60	8.60	8.60	8.60	9.04		
Final	7.80	-	7.70	6.77	6.70	6.75	7.76		

BACTERIOLOGICAL RESULTS

Total Coliform									
Vol Filtered	10	10	10	1.0	1.0	1.0	1.0	10	10
Count Vol Filtered	24	20	45	11	47	5	5	50	4
Index	240	200	450	1100	4,700	500	500	500	40
Fecal Coliform									
Vol Filtered	50	100	100	100	100	100	100	100	100
Count Vol Filtered	0	16	3	1	21	15	1	6	2
Index	0	16	3	1	21	15	1	6	2

REMARKS

TABLE III-3

CRYSTAL LAKE WATER QUALITY INVESTIGATION

STATION Weir # 4 1600 S. Shore (East side of Robinson Rd., south of S. Shore Drive)

DATE 1969	6/16	6/23	7/6	7/12	7/23	7/30	8/8	8/14	8/20
TIME OF COLLECTION	AM 9:00	AM 8:22	AM 8:50	AM 6:50	AM 9:00	AM 8:25	AM 8:25	AM 8:10	AM 10:45
DISCHARGE									
HEAD (feet)	---	0.301		0.274	0.414	0.314	0.314	0.289	0.313
CFS		0.129	0.192	0.099	0.286	0.145	0.144	0.117	0.143
TEMPERATURE (AIR) °C	16°	14.8°	16°	19.5°	25°	21°	21.5°	22°	22°
WEATHER CONDITIONS	clear & sunny	overcast/ intermit. sun	partly cloudy	sunny	cloudy	sunny	sunny	overcast	sunny

CHEMICAL ANALYSIS

TEMPERATURE (Sample) °C	9°	9.5°	10.0°	11.0°	12°	11.0°	12.0°	12.0°	11.5°
pH	8.30	8.30	8.20	8.30	8.30	8.30	8.32	8.35	8.21
DO mg/1	11.30	11.05	10.80	10.30	10.20	10.50	10.25	9.85	10.30
NH_4-N mg/1	0	0.04	0.01	0.11	0.23	0.10	0.09	0.25	0.40
NO_2-N mg/1	0.003	0.002	0.001	0.001	0	-	0	0	-
NO_3-N mg/1	1.30	1.49	1.32	1.30	1.21	1.26	1.18	1.25	
Ortho PO_4 mg/1	0	0	0	0	0	0	0	0	
Total PO_4 mg/1	-	-	-	-	-	-	0.04	-	
BOD_5	0.40	0.00	-	0.21	0.50	0.57	0.51		
Initial	9.30	9.25	-	8.90	8.20	9.10	9.14		
Final	8.90	9.25	-	8.69	7.70	8.53	8.63		

BACTERIOLOGICAL RESULTS

Total Coliform	-								
Vol Filtered		5	10	1.0	10	1.0	10	10	10
Count Vol Filtered		12	15	8	49	4	36	37	32
Index		240	150	800	490	400	360	370	320
Fecal Coliform									
Vol Filtered		100	100	100	100	10	100	100	100
Count Vol Filtered		5	5	6	>100	2	8	8	13
Index		5	5	6	>100	20	8	8	13

REMARKS

TABLE III-4

CRYSTAL LAKE WATER QUALITY INVESTIGATION

STATION Weir # 1 Crystal Beach Resort, 774 S. Shore

DATE 1969	6/16	6/23	7/6	7/12	7/23	7/30	8/8	8/14	8/20
TIME OF COLLECTION	AM 9:15	AM 8:32	AM 8:40	AM 7:00	AM 9:00	AM 8:20	AM 8:20	AM 7:55	AM 10:55
DISCHARGE									
HEAD (feet)	-	0.286		0.288	0.379	0.278	0.269	0.246	0.259
CFS		0.428	0.435	0.428	0.640	0.401	0.382	0.329	0.342
TEMPERATURE (AIR) °C	17.0°	avg. 14.8°	16.0°	19.5°	24.0°	20.5°	21.5°	21.2°	22.8°
WEATHER CONDITIONS	clear/ sunny	overcast/ intermit. sun	partly cloudy	sunny	cloudy	sunny	sunny	over- cast	sunny

CHEMICAL ANALYSIS

TEMPERATURE (Sample) °C	9.0°	10.0°	11.0°	12.5°	13.0°	12.5°	13.5°	14.0°	12.2°
pH	8.10	8.05	8.10	8.19	8.20	8.10	8.05	8.18	8.00
DO mg/1	11.00	10.55	10.40	9.90	10.00	10.00	9.34	9.25	10.00
NH_4-N mg/1	0.03	0.08	0.09	0.17	0.24	0.23	0.17	0.31	0.40
NO_2-N mg/1	0.003	0.002	0.002	0.003	0.002	0	0.002	0.003	-
NO_3-N mg/1	0.42	0.73	0.52	0.48	0.52	0.52	0.50	-	-
Ortho PO_4 mg/1	0.04	0.03	0.04	0.04	0.03	0.06	0.03	0.03	-
Total PO_4 mg/1	-	-	-	-	-	0.06	-	0.03	-
BOD_5	0.08	0.00	-	0.72	0.70	0.68	1.18		
Initial	9.10	9.25	-	8.70	8.10	8.80	8.80		
Final	8.30	9.25	-	7.98	7.40	8.12	7.62		

BACTERIOLOGICAL RESULTS

Total Coliform									
Vol Filtered		5	10	1.0	1.0	0.1	1.0	1.0	1.0
Count Vol Filtered		14	21	> 100	36	5	23	10	16
Index		280	210	>10,000	3,600	5,000	2,300	1,000	1,600
Fecal Coliform									
Vol Filtered		100	10	100	100	10	100	100	100
Count Vol Filtered		>1,000	15	10	120	22	57	28	50
Index		>1,000	150	10	120	220	57	28	50

REMARKS

TABLE III-5

CRYSTAL LAKE WATER QUALITY INVESTIGATION

STATION Weir # 2 390 S. Shore Bellows Ave. and S. Shore (south side of road)

DATE 1969	6/16	6/23	7/6	7/12	7/23	7/30	8/8	8/14	8/20
TIME OF COLLECTION	AM 9:30	AM 8:40	AM 8:40	AM 7:10	AM 9:00	AM 8:10	AM 8:10	AM 7:45	AM 11:05
DISCHARGE HEAD (feet)	-	0.230	0.242	0.245	0.219	0.238	0.225	0.227	0.217
CFS		0.597	0.644	0.676	0.554	0.628	0.578	0.585	0.547
TEMPERATURE (AIR) °C	18°	14.8°	16°	19.0°	24°	20.0°	22.0°	21.0°	21.5°
WEATHER CONDITIONS	clear & sunny	overcast/ intermit sun	partly cloudy	sunny	cloudy	sunny	sunny	over-cast	sunny

CHEMICAL ANALYSIS

TEMPERATURE (Sample) °C	9°	10.0°	11.0°	13.0°	13.0°	12.5°	14.0°	14.5°	12.8°
pH	8.1	8.09	8.00	8.10	8.3	8.10	8.10	8.10	7.99
DO mg/1	10.9	10.55	10.1	9.60	9.7	9.70	9.44	9.15	9.75
NH_4-N mg/1	0	0.02	0.01	0.17	0.26	0.11	0.12	0.27	0.37
NO_2-N mg/1	0.001	0.002	0.001	0.001	0	0	0	0	-
NO_3-N mg/1	0.44	0.66	0.48	0.56	0.55	0.52	0.55	-	-
Ortho PO_4 mg/1	0.03	0	0	0.01	0	0	0.02	0.02	-
Total PO_4 mg/1	-	-	-	-	0.002	-		-	-
BOD_5	0.5	0.0	-	0.16	0.8	0.48	0.36		
Initial	9.1	9.16	-	8.70	8.40	8.70	8.84		
Final	8.6	9.16	-	8.54	7.6	8.22	8.48		

BACTERIOLOGICAL RESULTS

Total Coliform	-								
Vol Filtered		100	10	10	10	1.0	10	10	10
Count Vol Filtered		38	15	31	36	2	31	31	39
Index		38	150	310	300	200	310	310	390
Fecal Coliform									
Vol Filtered		100	100	100	100	100	100	100	100
Count Vol Filtered		1	3	1	12	31	1	2	19
Index		1	3	1	12	31	1	2	19

REMARKS

TABLE III-6

CRYSTAL LAKE WATER QUALITY INVESTIGATION

STATION Weir # 3 13 S. Shore

DATE 1969	6/16	6/23	7/7	7/12	7/23	7/30	8/8	8/14	8/20
TIME OF COLLECTION	9:45	8:48	8:30	7:20	9:30	8:00	8:05	7:40	11:10
DISCHARGE HEAD (feet)	---	0.205		0.193	0.157	0.189	0.149	0.158	0.154
CFS		0.474		0.408	0.306	0.406	0.284	0.309	0.298
TEMPERATURE (AIR) °C	19°	14.8°	16°	22.5°	25°	20.0°	21.5°	21.5°	21.5°
WEATHER CONDITIONS	clear sunny	overcst/ intermit. sun	sunny	sunny	cloudy	sunny	sunny	overcast	sunny

CHEMICAL ANALYSIS

TEMPERATURE (Sample) °C	10°	11.0°	11.5°	14.5°	15°	14.5°	16.0°	17.0°	14.0°
pH	8.20	8.15	8.20	8.11	8.25	8.20	8.30	8.30	8.21
DO mg/1	10.8	10.44	10.5	9.35	9.4	9.50	9.24	8.85	9.65
NH_4-N mg/1	0.06	0.12	0.04	0.16	0.27	0.11	0.16	0.26	0.39
NO_2-N mg/1	0.003	0.002	0.000	0.001	0	-	0	0	-
NO_3-N mg/1	0.48	0.68	0.59	0.52	0.66	0.57	0.64	-	-
Ortho PO_4 mg/1	0.03	0	0.02	0.03	0.03	0.05	0.07	0.05	-
Total PO_4 mg/1	-	-	-	-	-	0.08	0.8	0.04	-
BOD_5	0.06	0.0	0.65	0.69	0.9	1.80	0.56		
Initial	9.0	9.20	9.00	8.60	8.2	8.60	8.68		
Final	8.4	9.20	8.35	7.91	7.3	6.80	8.12		

BACTERIOLOGICAL RESULTS

Total Coliform									
Vol Filtered		5	10	10	10	10	10	1.0	10
Count Vol Filtered		3	8	18	39	57	56	8	31
Index		60	80	180	390	570	560	800	310
Fecal Coliform									
Vol Filtered		100	100	100	100	10	100	100	100
Count Vol Filtered		41	14	19	34	3	73	116	18
Index		41	14	19	34	30	23	116	18

REMARKS

TABLE III-7

CRYSTAL LAKE WATER QUALITY INVESTIGATION

STATION Weir # 5 2627 Crystal Drive 8/20

DATE ~~1969~~	6/11	6/16	6/23	7/7	7/12	7/23	7/29	8/7	8/13
TIME OF COLLECTION	AM 8:10	AM 10:00	AM 9:05	AM 8:50	AM 7:45	AM 9:30	AM 8:45	AM 9:45	AM 8:20
DISCHARGE or HEAD (feet) inches	1 1/8"		0.182'		0.171'	0.046'	0.299'	0.110'	0.032'
CFS	0.090		0.254		0.233	0.333	0.546	0.121	0.019
TEMPERATURE (AIR) °C	avg.day 22°	20°	14.8°	16°	20°	24°	24°	24°	25.8°
WEATHER CONDITIONS	hazy	clear & sunny	overcast /inter. sun	sunny	sunny	stormy	sunny	overcast /strong wst.wind	

CHEMICAL ANALYSIS

TEMPERATURE (Sample) °C	17°	15°	14°	15.5°	22°	21.5°	19.2°	23.5°	22.5°
pH	7.6	7.6	7.6	7.55	7.45	7.7	7.50	7.49	7.55
DO mg/1	5.4	6.6	6.46	4.90	3.40	6.0	4.10	4.18	3.55
NH_4-N mg/1	0	0.10	0.12	0.12	0.28	0.38	0.32	0.22	0.67
NO_2-N mg/1	0	0.002	0	0.000	0.000	0	0	0	0.003
NO_3-N mg/1	0	0	0.38	0.23	0.08	0.13	0.13	0.12	0.16
Ortho PO_4 mg/1	0.01	0	0	0.00	0.00	0	0.03	0	0
Total PO_4 mg/1	-	-	-	-	-	-	-	-	-
BOD_5	0.8	1.1	0.0	0.90	0.54	1.3	1.34	1.11	
Initial	8.2	8.1	8.35	7.40	5.65	7.5	5.90	5.88	
Final	7.4	7.0	8.35	6.50	5.11	6.2	4.56	4.77	

no flow (dry)

BACTERIOLOGICAL RESULTS

Total Coliform	-	-							
Vol Filtered			5	10	1.0	10	1.0	1.0	1.0
Count Vol Filtered			10	66	4	48	14	23	20
Index			200	660	400	480	1400	2300	2000
Fecal Coliform									
Vol Filtered			100	100	100	100	10	100	100
Count Vol Filtered			6	4	2	10	3	7	12
Index			6	4	2	10	30	7	12

REMARKS

TABLE III-8

CRYSTAL LAKE WATER QUALITY INVESTIGATION

STATION Weir # 6 3600 Crystal Drive (Sampling point: stream mouth on beach directly below this address)

DATE 1969	6/17	6/23	7/7	7/12	7/23	7/29	8/7	8/13	8/20
TIME OF COLLECTION	AM 8:45	AM 9:13	AM 8:55	AM 7:52	AM 10:00	AM 9:10	AM 9:50	AM 8:45	AM 11:25
DISCHARGE HEAD (feet) CFS	-	-	-	-	-	-	-	-	-
TEMPERATURE (AIR) °C	-	14.8°	16.5°	23.8°	24°	21.2°	24°	25.5°	22.8°
WEATHER CONDITIONS	cloudy	overcst/ intermit sun	sunny	sunny	stormy	sunny	overcst/ strong wst.wind		sunny

CHEMICAL ANALYSIS

TEMPERATURE (Sample) °C	15°	14.1°	13°	17°	20°	19°	22.5°	21°	19°
pH	8.1	8.1	8.00	7.88	8.2	8.00	8.05	7.99	8.18
DO mg/1	10.8	12.31	10.4	7.70	12.7	8.90	8.94	8.53	12.20
NH_4-N mg/1	.05	.08	.06	.21	.36	.17	.19	.96	.53
NO_2-N mg/1	.003	.003	.001	.003	.003	0	.002	0	-
NO_3-N mg/1	.69	1.30	1.49	1.44	2.20	1.21	1.20	1.85	-
Ortho PO_4 mg/1	.03	0	0	0	0	0	0	.03	-
Total PO_4 mg/1	-	-	-	-	-	.02	-	-	-
BOD_5	1.1	.61	.50	.47	3.7	.55	.71		
Initial	9.1	9.11	9	8.30	7.9	8.60	8.43		
Final	8.0	8.50	8.50	7.83	4.2	8.05	7.72		

BACTERIOLOGICAL RESULTS

Total Coliform									
Vol Filtered	10	5	1	1.0	1.0	1.0	1.0	1.0	1.0
Count Vol Filtered	64	75	38	46	21	25	32	11	8
Index	640	1,500	3,800	4,600	2,100	2,500	3,200	1,100	800
Fecal Coliform									
Vol Filtered	50	100	100	100	100	100	100	100	100
Count Vol Filtered	1	14	6	13	20	62	5	17	3
Index	2	14	6	13	20	62	5	17	3

REMARKS

TABLE III-9

CRYSTAL LAKE WATER QUALITY INVESTIGATION

STATION Weir # 7 3901 Crystal Drive

DATE 1969	6/16	6/23	7/7	7/12	7/23	7/29	8/7	8/13	8/20
TIME OF COLLECTION	AM 10:15	AM 9:25	AM 9:05	AM 8:00	-	9:20	AM 10:00	AM 8:55	AM 11:30
DISCHARGE HEAD (feet & inches) CFS	-	1" 0.0833 0.005	weir removed	-	-	-	-	-	-
TEMPERATURE (AIR) °C	20°	14.8°	16.5°	21.0°	-	22.8°	24.0°	24.0°	21.5°
WEATHER CONDITIONS	clear & sunny	overcast/ intermit. sun	sunny		-	sunny	overcast/ strong wind		sunny

CHEMICAL ANALYSIS

TEMPERATURE (Sample) °C	13°	12.5°	13°	16.5°	-	15.5°	20.0°	18.0°	16.0°
pH	8.0	8.18	8.0	7.90	-	8.20	8.22	8.22	8.15
DO mg/l	9.2	10.33	8.8	6.70	-	8.40	7.51	8.22	8.75
NH_4-N mg/l	.10	.04	.08	.17	-	.15	.13	.60	.53
NO_2-N mg/l	.003	.001	.001	.004	-	0	.003	0	-
NO_3-N mg/l	.13	.20	.48	.29	-	.52	.57	.65	-
Ortho PO_4 mg/l	0	0	.01	.03	-	.06	.02	.04	-
Total PO_4 mg/l	-	-	-	-	-	-	0	-	-
BOD_5	2.8	0	2.9	1.38	-	.78	.91		
Initial	8.6	9.25	8.8	8.2	-	8.4	7.92		
Final	5.8	9.25	5.9	6.82	-	7.62	7.01		

BACTERIOLOGICAL RESULTS

Total Coliform	-								
Vol Filtered		5	10	10		1.0	1.0	1.0	1.0
Count Vol Filtered		6	14	101		49	9	13	22
Index		120	140	1,010		4,900	900	1,300	2,200
Fecal Coliform									
Vol Filtered		100	100	100		10	100	100	100
Count Vol Filtered		16	1	2		10	31	32	9
Index		16	1	2		100	31	32	9
REMARKS	discharge very low				no flow	heavy rain day previous			

TABLE III-10

CRYSTAL LAKE WATER QUALITY INVESTIGATION

STATION # 4141 "Glen Rhoda" 4141 N. Crystal

DATE 1969	6/17	6/24	7/7	7/13	7/23	7/29	8/7	8/13	8/20
TIME OF COLLECTION	AM 8:50	AM 8:15	AM 9:10	AM 8:35	AM 10:00	AM 9:30	AM 10:05	AM 9:10	AM 11:35
DISCHARGE									
HEAD (feet)	-	0.159	0.156	0.151	0.132	0.139	0.156	0.155	0.137
CFS		0.216	0.213	0.193	0.160	0.172	0.205	0.203	0.169
TEMPERATURE (AIR) °C	-	16.5°	16.0°	27°	24°	20.2°	23.5°	21.5°	22°
WEATHER CONDITIONS	cloudy	sunny	sunny	sunny	stormy	sunny	overcast/ strong wst.wind	sunny	sunny

CHEMICAL ANALYSIS

TEMPERATURE (Sample) °C	10.5°	9.5°	9.5°	10.5°	12°	11°	15°	13°	10.5°
pH	8.50	8.20	8.38	8.38	8.40	8.40	8.40	8.40	7.83
DO mg/1	11.2	11.15	11.0	10.60	10.2	10.5	9.64	10.25	10.60
NH_4-N mg/1	0	.06	.03	.12	.24	.15	.10	.74	.71
NO_2-N mg/1	.001	0	0	.001	0	0	0	0	
NO_3-N mg/1	1.60	2.56	2.46	2.54	2.47	2.47	2.40	2.3	
Ortho PO_4 mg/1	0	.01	.01	.01	0	0	0	.02	
Total PO_4 mg/1	-	-	-	-	-	0	-	-	
BOD_5	1.40	-	.50	.40	1.0	.23	.67		
Initial	9.30	-	9.20	9.20	8.1	8.90	8.53		
Final	7.90	-	8.70	8.80	7.10	8.67	7.86		

BACTERIOLOGICAL RESULTS

Total Coliform									
Vol Filtered	50	5	10	10	10	10	10.0	10.0	10
Count Vol Filtered	6	2	2	16	55	17	35	14	19
Index	12	40	20	160	550	170	350	140	190
Fecal Coliform									
Vol Filtered	50	100	100	100	100	100	100	100	100
Count Vol Filtered	0	33	10	16	15	39	40	16	12
Index	0	33	10	16	15	39	40	16	12

REMARKS

TABLE III-11

CRYSTAL LAKE WATER QUALITY INVESTIGATION

STATION Weir # 8 6200 Crystal (west side of Nichols Rd. below Crystal Dr.)

DATE 1969	6/16	6/24	7/7	7/12	7/23	7/29	8/7	8/13	8/20
TIME OF COLLECTION	AM 10:30	AM 8:30	AM 9:25	AM 8:07	AM 10:00	AM 9:50	AM 10:15	AM 9:25	AM 11:45
DISCHARGE HEAD (feet)	-	0.099	0.145	0.155	0.088	0.212	0.105	0.072	0.052
CFS		0.105	0.193	0.213	0.086	0.324	0.113	0.065	0.039
TEMPERATURE (AIR) °C	21°	16.5°	17°	22°	24°	23.5°	25.0°	25.2°	22.2°
WEATHER CONDITIONS	clear & sunny	sunny	sunny	sunny	stormy	sunny	overcast/ strong wst.wind	sunny	sunny

CHEMICAL ANALYSIS

TEMPERATURE (Sample) °C	13.5°	13.5°	14.5°	20.0°	21°	19.0°	18.0°	21.0°	17.8°
pH	8.30	8.40	8.38	8.25	8.40	8.38	8.38	8.40	8.30
DO mg/1	9.70	9.72	9.60	8.30	8.10	8.50	7.81	8.22	8.65
NH_4-N mg/1	0.16	0.12	0.14	0.21	0.32	0.22	0.16	0.71	0.74
NO_2-N mg/1	0.039	0.022	0.045	0.050	0.032	0.043	0.037	0.033	0.029
NO_3-N mg/1	2.32	3.53	2.26	3.74	4.70	3.24	4.70	4.65	5.40
Ortho PO_4 mg/1	0.03	0	0.04	0.01	0.03	0.14	0	0.02	0.04
Total PO_4 mg/1	-	-	-	0.10	0.04	0.21	0.03	0.06	0.03
BOD_5	2.80	-	2.20	2.67	2.10	2.10	1.89		
Initial	8.80	-	9.20	8.10	8.00	8.40	7.87		
Final	6.00	-	7.00	5.43	5.90	6.30	5.98		

BACTERIOLOGICAL RESULTS

Total Coliform	-								
Vol Filtered		5	10	1.0	1.0	1.0	1.0	1.0	1.0
Count Vol Filtered		15	51	15	31	33	56	48	58
Index		300	510	1500	3100	3300	5600	4800	5800
Fecal Coliform									
Vol Filtered		100	100	100	100	10	100	100	100
Count Vol Filtered		42	24	24	32	25	25	150	5
Index		42	24	24	32	250	25	150	5

REMARKS

TABLE III-12

CRYSTAL LAKE WATER QUALITY INVESTIGATION

STATION Weir # 9 6709 Crystal Dr. (Weir on north of road directly opposite address.)

DATE 1969	6/16	6/24	7/7	7/12	7/23	7/29	8/7	8/13	8/20
TIME OF COLLECTION	AM 10:45	AM 8:43	AM 9:32	AM 8:12	AM 10:00	AM 10:00	AM 10:20	AM 9:45	AM 11:50
DISCHARGE HEAD (feet) CFS	- 	0.297 0.129	0.303 0.129	0.299 0.129	0.297 0.126	0.313 0.144	0.308 0.138	0.306 0.135	0.304 0.133
TEMPERATURE (AIR) °C	22°	16.5°	17°	23.5°	25°	21.8°	24.5°	26.5°	23°
WEATHER CONDITIONS	clear & sunny	sunny			stormy	sunny	overcst/ strong wst.wind	sunny	sunny

CHEMICAL ANALYSIS

TEMPERATURE (Sample) °C	10°	10°	9.5°	10°	11°	11.8°	14°	25°	12°
pH	7.7	7.89	7.70	7.68	7.8	7.95	7.75	7.82	7.63
DO mg/1	7.2	9.00	7.90	7.30	8.7	8.40	7.05	8.42	8.00
NH_4-N mg/1	.06	0	.03	.12	.24	.10	.09	.69	.61
NO_2-N mg/1	.001	.002	.002	.002	.002	.002	.002	.002	-
NO_3-N mg/1	3.44	3.80	3.44	4.48	3.44	3.84	3.45	3.40	-
Ortho PO_4 mg/1	.03	.03	.00	.00	0	.03	.1	.02	-
Total PO_4 mg/1	-	-	-	-	-	.05	-	.03	-
BOD_5	.8	-	.25	.63	.8	.47	.76		
Initial	8.7	-	8.20	8.85	8.5	8.7	8.22		
Final	7.9	-	7.95	8.22	7.7	8.23	7.46		

BACTERIOLOGICAL RESULTS

Total Coliform	-								
Vol Filtered		5	10	10	10	10	10	10	10
Count Vol Filtered		16	106	12	43	40	20	21	6
Index		320	1060	120	430	400	200	210	60
Fecal Coliform									
Vol Filtered		100	100	100	100	100	100	100	100
Count Vol Filtered		9	3	0	14	36	1	6	0
Index		9	3	0	14	36	1	6	0

REMARKS

heavy rain yesterday (7/29)

TABLE III-13

CRYSTAL LAKE WATER QUALITY INVESTIGATION

STATION Weir # 10 6863 Crystal Drive.

DATE 1969	6/16	6/24	7/7	7/12	7/23	7/29	8/7	8/13	8/20
TIME OF COLLECTION	AM 11:00	AM 8:54	AM 9:37	AM 8:20	AM 10:30	AM 10:15	AM 10:30	AM 9:50	AM 11:55
DISCHARGE									
HEAD (feet)	-	0.119	0.150	0.139	0.116	0.128	0.107	0.096	0.084
CFS		0.208	0.290	0.262	0.198	0.229	0.177	0.135	0.125
TEMPERATURE (AIR) °C	22°	16.5°	18°	25°	23°	19°	24.5°	24°	21
WEATHER CONDITIONS	clear & sunny	sunny	sunny	sunny	stormy		overcast/ strong wst.wind	sunny	sunny

CHEMICAL ANALYSIS

TEMPERATURE (Sample) °C	10.5°	10.5°	11.0°	15.5°	14.5°	15°	18°	15.5°	13.2°
pH	8.10	8.13	8.15	8.05	8.10	8.15	8.15	8.11	7.95
DO mg/1	9.70	9.54	9.40	8.60	8.50	8.40	8.02	8.37	8.65
NH_4-N mg/1	0.11	0	0.05	0.16	0.26	0.18	0.16	0.72	0.70
NO_2-N mg/1	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.004	-
NO_3-N mg/1	1.44	1.96	1.96	1.80	1.92	1.64	1.68	1.70	1.85
Ortho PO_4 mg/1	0.11	0.13	0.11	0.16	0.14	0.16	0.16	0.15	0.14
Total PO_4 mg/1	-	0.14	-	0.16	0.14	0.13	0.20	0.14	0.17
BOD_5	1.00	-	0.85	0.62	0.70	-	0.52		
Initial	9.10	-	9.25	8.70	8.60	8.50	8.13		
Final	8.10	-	8.40	8.08	7.90	-	7.61		

BACTERIOLOGICAL RESULTS

Total Coliform	-								
Vol Filtered		100	10	10	10	10	10	1.0	1.0
Count Vol Filtered		21	5	14	46	48	36	19	9
Index		21	50	140	460	480	360	1900	900
Fecal Coliform									
Vol Filtered		100	100	100	100	100	100	100	100
Count Vol Filtered		7	10	1	21	98	43	71	>100
Index		7	10	1	21	98	43	71	>100

REMARKS

heavy rain yesterday

TABLE III-14

CRYSTAL LAKE WATER QUALITY INVESTIGATION

STATION Pipe # 1 7230 Crystal Drive (200 feet west of marina (7271) north of road)

DATE 1969	6/16	6/24	7/7	7/13	7/24	7/30	8/7	8/13	8/20
TIME OF COLLECTION	AM 11:15	AM 9:05	AM 9:45	AM 8:23	AM 8:45	AM 9:25	AM 10:35	AM 10:00	AM 12:00
DISCHARGE HEAD (feet/inches) CFS	-	H. .17' 0.275	1.75" 0.222	1.25" 0.086	1.375" 0.115	1.75" 0.222	1.75" 0.222	1.50" 0.166	1.25" 0.086
TEMPERATURE (AIR) °C	23°	16.5°	18.5°	27.5°	23.5°	23°	24.5°	27.5°	22.2°
WEATHER CONDITIONS	clear & sunny	sunny	clear & sunny	sunny	sunny	sunny	overcast strong wst.wind	sunny	sunny

CHEMICAL ANALYSIS

TEMPERATURE (Sample) °C	17.5°	14.5°	15°	18°	18°	18.5°	22°	21°	20.1°
pH	8.0	8.13	7.95	7.98	8.00	8.00	8.02	7.98	7.79
DO mg/1	8.6	8.70	7.70	6.70	6.70	7.70	7.11	7.41	7.95
NH_4-N mg/1	.07	.04	.03	.15	.20	.11	.23	.71	.65
NO_2-N mg/1	.15	.007	.005	.009	.017	.007	.006	.005	.006
NO_3-N mg/1	1.49	2.45	2.08	2.40	2.42	2.13	2.34	2.2	-
Ortho PO_4 mg/1	.01	0	0	0	0	0	0	0	-
Total PO_4 mg/1	-	-	-	-	-	0	-	-	-
BOD_5	.8	-	1.15	1.60	1.10	.69	.66		
Initial	8.5	-	8.35	8.40	8.20	8.00	7.46		
Final	7.7	-	7.20	6.80	7.10	7.31	6.80		

BACTERIOLOGICAL RESULTS

Total Coliform	-								
Vol Filtered		5	10	10	1.0	1.0	1.0	1.0	1.0
Count Vol Filtered		14	20	30	29	26	11	30	24
Index		280	200	300	2900	2600	1100	3000	2400
Fecal Coliform									
Vol Filtered		100	100	100	100	100	100	100	100
Count Vol Filtered		1	4	0	>100	3	3	28	1
Index		1	4	0	>100	3	3	28	1

REMARKS

TABLE III-15

CRYSTAL LAKE WATER QUALITY INVESTIGATION

STATION Weir # 12 7281 Crystal Drive (200 feet east of marina (7271)

DATE	6/17	6/24	7/5	7/13	7/24	7/29	8/7	8/13	8/20
TIME OF COLLECTION	9:25	9:12	AM 11:30	AM 8:15	AM 8:50	AM 11:10	AM 10:40	AM 10:10	AM 12:05
DISCHARGE HEAD (feet)	-	0.177		0.185	0.1667	0.1875	0.229	0.188	0.188
CFS		0.036	0.082	0.042	0.030	0.042	0.066	0.042	0.042
TEMPERATURE (AIR) °C	-	16.5°	20°	21°	22°	24.5°	24.0°	25.5°	22.8°
WEATHER CONDITIONS	cloudy	sunny	sunny	sunny	sunny	sunny	overcst/ strong wst.wind	sunny	sunny

CHEMICAL ANALYSIS

TEMPERATURE (Sample) °C	13°	12.0°	15°	13°	14°	16.8°	18°	17.2°	16.0°
pH	7.90	7.83	7.80	7.80	7.85	7.95	6.50	7.80	7.55
DO mg/1	7.30	6.62	8.30	5.70	5.50	7.80	7.80	6.44	6.20
NH_4-N mg/1	0.00	0.02	0.06	0.12	0.16	0.23	0.10	0.67	0.66
NO_2-N mg/1	.014	.013	.011	.017	.017	.017	.019	.017	.021
NO_3-N mg/1	1.48	2.08	2.60	2.14	1.96	2.14	2.08	2.10	-
Ortho PO_4 mg/1	.00	.00	.01	.01	.00	0	.03	0	-
Total PO_4 mg/1	-	-	-	-	-	.02	-	-	-
BOD_5	0.50	-	-	0.28	0.50	0.27	0.52		
Initial	9.00	-	-	8.60	8.70	8.40	7.32		
Final	8.50	-	-	8.32	8.20	8.13	6.80		

BACTERIOLOGICAL RESULTS

Total Coliform									
Vol Filtered	50	100	100	100	10	10	10	10	10
Count Vol Filtered	6	20	16	25	73	24	43	32	17
Index	12	20	16	25	730	240	430	320	170
Fecal Coliform									
Vol Filtered	50	100	100	100	100	10	100	100	100
Count Vol Filtered	0	0	0	0	5	5	1	3	0
Index	0	0	0	0	5	50	1	3	0

REMARKS

heavy rain yesterday

TABLE III-16

CRYSTAL LAKE WATER QUALITY INVESTIGATION

STATION Weir # 11 7300 Crystal Drive (just east of 7290)

DATE 1969	6/13	8/9							
TIME OF COLLECTION	AM 9:30	PM 7:30							
DISCHARGE HEAD (feet) CFS	-	-							
TEMPERATURE (AIR) °C	-	19°							
WEATHER CONDITIONS	-	clear calm							

CHEMICAL ANALYSIS

TEMPERATURE (Sample) °C	12°	13°							
pH	-	7.5							
DO mg/1	10.7	4.7							
NH_4-N mg/1	0.1	0.05							
NO_2-N mg/1	0.01	0.023							
NO_3-N mg/1	2.66	4.2							
Ortho PO_4 mg/1	0.04	0.02							
Total PO_4 mg/1	-	0.03							
BOD_5	0.0	-							
Initial	8.4	-							
Final	8.4	-							

BACTERIOLOGICAL RESULTS

Total Coliform	-	-							
Vol Filtered									
Count Vol Filtered									
Index									
Fecal Coliform									
Vol Filtered									
Count Vol Filtered									
Index									

REMARKS

TABLE III-17

CRYSTAL LAKE WATER QUALITY INVESTIGATION

STATION Weir # 11 7390 Crystal Drive

DATE 1969	6/13	8/9							
TIME OF COLLECTION	AM 9:35	PM 7:35							
DISCHARGE HEAD (feet) CFS	-	-							
TEMPERATURE (AIR) °C	-	19°							
WEATHER CONDITIONS	-	clear calm							

CHEMICAL ANALYSIS

TEMPERATURE (Sample) °C	11.5°	12°							
pH	-	7.7							
DO mg/l	9.5	7.1							
NH_4-N mg/l	0.05	0.03							
NO_2-N mg/l	0.01	0.010							
NO_3-N mg/l	2.50	3.16							
Ortho PO_4 mg/l	0.03	0							
Total PO_4 mg/l	-	0							
BOD_5	1.1	-							
Initial	9.2	-							
Final	8.1	-							

BACTERIOLOGICAL RESULTS

Total Coliform	-	-							
Vol Filtered									
Count Vol Filtered									
Index									
Fecal Coliform									
Vol Filtered									
Count Vol Filtered									
Index									

REMARKS

TABLE III-18

CRYSTAL LAKE WATER QUALITY INVESTIGATION

STATION Weir # 11 7468 Crystal Drive (at pipe)

DATE 1969	6/11	6/13	6/17	6/24	7/5	7/13	7/24	7/29	8/7
TIME OF COLLECTION	AM 8:30	AM 9:25	AM 9:30	AM 9:20	AM 11:35	AM 8:10	AM 8:55	AM 10:25	AM 10:45
DISCHARGE									
HEAD (feet/inches)	2.0"	-	-	0.137'		0.146'	9.156'	0.144'	0.148'
CFS	0.337			0.197	0.223	0.220	0.230	0.206	0.215
TEMPERATURE (AIR) °C	avg.day 22°	-	-	16.5°	20°	21°	22.5°	25°	24°
WEATHER CONDITIONS	hazy	-	cloudy	sunny	sunny	sunny	sunny	sunny	overcast strong wst.wind

CHEMICAL ANALYSIS

TEMPERATURE (Sample) °C	12°	12.5°	12°	11°	15°	11°	13°	14°	17°
pH	7.9	-	8.3	8.13	8.4	7.92	8.10	8.40	8.38
DO mg/1	11.0	9.2	13.0	11.81	13.5	8.20	9.90	12.40	13.10
NH_4-N mg/1	0	.08	0	.06	.04	.15	.17	.15	.08
NO_2-N mg/1	.005	.009	.011	.011	.015	.011	.012	.012	.016
NO_3-N mg/1	2.46	2.40	1.90	2.53	2.04	2.83	2.88	3.07	3.13
Ortho PO_4 mg/1	.01	.03	0	.01	.03	.01	.01	.03	0
Total PO_4 mg/1	-	-	-	-	-	.03	-	-	.02
BOD_5	.5	.2	.7	-	-	1.36	4.10	1.48	1.62
Initial	8.8	8.8	9.3	-	-	8.80	9.20	9.20	8.32
Final	8.3	8.6	8.6	-	-	7.44	5.10	7.72	6.70

BACTERIOLOGICAL RESULTS

Total Coliform	-	-							
Vol Filtered			50	5	10	10	1.0	1.0	1.0
Count Vol Filtered			50	7	7	34	40	25	16
Index			100	140	70	340	4,000	2500	1600
Fecal Coliform									
Vol Filtered			50	100	100	100	100	100	100
Count Vol Filtered			7	4	0	0	>100	>100	22
Index			14	4	0	0	>100	>100	22

REMARKS

TABLE III-19

CRYSTAL LAKE WATER QUALITY INVESTIGATION

STATION Weir # 11 (Continued) 7468 Crystal Drive

DATE	8/9	8/13	8/20						
TIME OF COLLECTION	PM 7:40	AM 10:20	AM 12:10						
DISCHARGE HEAD (feet) CFS	-	0.142 0.223	0.186 0.189						
TEMPERATURE (AIR) °C	19°	25.5°	22.5°						
WEATHER CONDITIONS	clear calm	sunny	sunny						

CHEMICAL ANALYSIS

TEMPERATURE (Sample) °C	15°	15°	14.8°						
pH	7.90	8.18	7.65						
DO mg/l	9.5	11.32	13.65						
NH_4-N mg/l	.02	.76	.71						
NO_2-N mg/l	.015	.011	.012						
NO_3-N mg/l	2.90	2.90	-						
Ortho PO_4 mg/l	.02	.02	-						
Total PO_4 mg/l	.15	.03	-						
BOD_5	-								
Initial	-								
Final	-								

BACTERIOLOGICAL RESULTS

Total Coliform	-								
Vol Filtered	-	10	10						
Count Vol Filtered		59	56						
Index		590	560						
Fecal Coliform									
Vol Filtered		100	100						
Count Vol Filtered		33	33						
Index		33	33						

REMARKS

TABLE III-20

CRYSTAL LAKE WATER QUALITY INVESTIGATION

STATION Weir # 11 E 7468 Crystal Drive (Just east of Weir # 11)

DATE 1969	6/13	8/9							
TIME OF COLLECTION	AM 9:20	PM 7:45							
DISCHARGE HEAD (inches) CFS	-	-							
TEMPERATURE (AIR) °C	-	19°							
WEATHER CONDITIONS	-	clear calm							

CHEMICAL ANALYSIS

TEMPERATURE (Sample) °C	12.5°	14°							
pH	-	7.95							
DO mg/1	9.2	8.3							
NH_4-N mg/1	0.17	0.03							
NO_2-N mg/1	0	0.003							
NO_3-N mg/1	2.26	2.32							
Ortho PO_4 mg/1	0.04	0							
Total PO_4 mg/1	-	0							
BOD_5	0.5	-							
Initial	8.6	-							
Final	8.1	-							

BACTERIOLOGICAL RESULTS

Total Coliform	-	-							
Vol Filtered									
Count Vol Filtered									
Index									
Fecal Coliform									
Vol Filtered									
Count Vol Filtered									
Index									

REMARKS

TABLE III-21

CRYSTAL LAKE WATER QUALITY INVESTIGATION

STATION Weir # 11 7510 Crystal Drive (east at drainpipe)

DATE	8/9								
TIME OF COLLECTION	PM 7:50								
DISCHARGE HEAD (feet) CFS	-								
TEMPERATURE (AIR) °C	19°								
WEATHER CONDITIONS	clear calm								

CHEMICAL ANALYSIS

TEMPERATURE (Sample) °C	12°								
pH	7.85								
DO mg/1	8.9								
NH_4-N mg/1	.04								
NO_2-N mg/1	.002								
NO_3-N mg/1	2.20								
Ortho PO_4 mg/1	0								
Total PO_4 mg/1	0								
BOD_5	-								
Initial	-								
Final	-								

BACTERIOLOGICAL RESULTS

Total Coliform	-								
Vol Filtered									
Count Vol Filtered									
Index									
Fecal Coliform									
Vol Filtered									
Count Vol Filtered									
Index									

REMARKS

TABLE III-22

CRYSTAL LAKE WATER QUALITY INVESTIGATION

STATION Pipe # 2 7546 Crystal Drive

DATE 1969	6/11	6/17	6/24	7/5	7/13	7/24	7/30	8/8	8/14
TIME OF COLLECTION	8:40	9:35	9:26	11:40	8:05	8:40	9:15	9:15	9:05
DISCHARGE HEAD (feet/inches) CFS	5.5" 1.78	-	.45' 1.69	5.5" 1.78	6" 2.02	5.5" 1.78	6" 2.02	5.5" 1.78	6" 2.02
TEMPERATURE (AIR) °C	22°	-	16.5°	20°	20.5°	23°	23°	24°	22°
WEATHER CONDITIONS	hazy	cloudy	sunny	sunny	sunny	sunny	sunny	sunny	sunny

CHEMICAL ANALYSIS

TEMPERATURE (Sample) °C	10.5°	11.5°	10°	12°	10.5°	11°	11°	7°	11°
pH	7.8	8	7.9	7.9	7.9	7.95	7.9	7.92	7.9
DO mg/1	8.8	8.7	8.7	8.3	8.2	8.1	8.6	8.22	8.35
NH_4-N mg/1	0	0	.04	.08	.12	.20	.09	.16	.29
NO_2-N mg/1	.001	.001	0	.002	.001	.002	-	.002	.002
NO_3-N mg/1	1.3	.70	1.12	1.22	1.4	1.22	1.4	1.3	1.4
Ortho PO_4 mg/1	.04	.03	.03	.02	.03	.02	.04	.06	.02
Total PO_4 mg/1	-	-	-	-	.03	-	-	.04	.06
BOD_5	.7	.5	-	-	1.23	.40	1.09	1.13	
Initial	9.3	9.2	-	-	8.9	9	8.9	8.64	
Final	8.6	8.7	-	-	7.67	8.6	7.81	7.51	

BACTERIOLOGICAL RESULTS

Total Coliform	-								
Vol Filtered		50	100	10	10	1.0	1.0	1.0	0.1
Count Vol Filtered		39	17	300	18	105	5	22	12
Index		78	17	3000	180	10,500	500	2200	12,000
Fecal Coliform									
Vol Filtered		50	100	100	100	100	100	100	100
Count Vol Filtered		15	1	4	0	>100	0	24	3
Index		30	1	4	0	>100	0	24	3

REMARKS

TABLE III-22 (Concluded)

CRYSTAL LAKE WATER QUALITY INVESTIGATION

STATION Pipe # 2 (Continued) 7546 Crystal Drive

DATE 1969	8/20								
TIME OF COLLECTION	PM 12:15								
DISCHARGE HEAD (feet/inches) CFS	 5.5" 1.78								
TEMPERATURE (AIR) °C	22°								
WEATHER CONDITIONS	sunny								

CHEMICAL ANALYSIS

TEMPERATURE (Sample) °C	11°								
pH	8.25								
DO mg/l	8.30								
NH_4-N mg/l	.63								
NO_2-N mg/l									
NO_3-N mg/l									
Ortho PO_4 mg/l	.04								
Total PO_4 mg/l	.04								
BOD_5									
Initial									
Final									

BACTERIOLOGICAL RESULTS

Total Coliform									
Vol Filtered	1.0								
Count Vol Filtered	14								
Index	1400								
Fecal Coliform									
Vol Filtered	100								
Count Vol Filtered	2								
Index	2								

REMARKS

TABLE III-23

CRYSTAL LAKE WATER QUALITY INVESTIGATION

Weir # 13

STATION MP (Mitchell Pond) 752 Windermere Road

DATE 1969	6/17	6/24	7/5	7/13	7/24	7/30	8/8	8/14	8/20
TIME OF COLLECTION	AM 9:50	AM 9:30	AM 11:45	AM 8:00	AM 8:35	AM 9:10	AM 9:10	AM 9:00	AM 12:20
DISCHARGE HEAD (feet/inches) CFS	-	H = .06'	.875" 0.117	1.0" 0.144	.875" 0.117	1.0" 0.144	1.125" 0.173	.625"	1.0" 0.144
TEMPERATURE (AIR) °C	-	16.5°	20°	21.5°	22°	22°	26°	23°	22.2°
WEATHER CONDITIONS	cloudy	sunny	sunny	sunny	sunny	sunny	sunny	sunny	sunny

CHEMICAL ANALYSIS

TEMPERATURE (Sample) °C	14°	12.5°	15°	14°	14°	14°	16°	17°	15.2°
pH	7.8	7.79	7.7	7.68	7.8	7.7	7.85	7.8	8.6
DO mg/1	6.2	5.55	6.1	5.3	5.0	4.8	5.68	4.75	5.4
NH_4-N mg/1	.11	.04	.14	.18	.23	.14	.15	.33	.28
NO_2-N mg/1	.006	.007	.008	.007	.008	.01	.009	.010	.007
NO_3-N mg/1	.00	1.16	.62	.56	.58	.60	.56	-	.55
Ortho PO_4 mg/1	.01	.04	.01	.03	.01	.03	.03	.02	.03
Total PO_4 mg/1	-	-	-	.03	-	-	-	-	-
BOD_5	1.0	-	0.9	0.95	1.4	1.02	1.02		
Initial	8.6	-	8.4	8.3	8.6	6.7	7.21		
Final	7.6	-	7.5	7.35	7.2	5.68	6.19		

BACTERIOLOGICAL RESULTS

Total Coliform									
Vol Filtered	50	100	100	10	10	10	10	10	10
Count Vol Filtered	0	0	0	7	57	29	18	8	4
Index	0	0	0	70	570	290	180	80	40
Fecal Coliform									
Vol Filtered	50	100	100	100	100	100	100	100	100
Count Vol Filtered	2	1	11	1	65	0	3	2	4
Index	4	1	11	1	65	0	3	2	4

REMARKS

TABLE III-24

CRYSTAL LAKE WATER QUALITY INVESTIGATION

STATION Cold Creek Station at second footbridge west side of Benzie Blvd.

DATE 1969	6/11	6/13	6/18	6/24	7/5	7/13	7/24	7/30	8/8
TIME OF COLLECTION	AM 8:45	AM 9:45	AM 9:10	AM 9:45	AM 11:55	AM 7:50	AM 8:25	AM 9:05	AM 9:05
DISCHARGE HEAD"(gage ht.) CFS	26.125"	-	25.250"	25.375"	-	23.375"	25.500" 7.800	-	
TEMPERATURE (AIR) °C	avg.day 22°	-	-	16.5°	20°	23°	21°	21.5°	22°
WEATHER CONDITIONS	hazy	-	cloudy/ showers	sunny	sunny	sunny	sunny	sunny	sunny

CHEMICAL ANALYSIS

TEMPERATURE (Sample) °C	15°	14°	12°	14.5°	17.5°	16°	16°	17°	18°
pH	8	-	8	8.09	7.8	7.99	8.05	7.98	8.1
DO mg/1	9.6	8.7	9.6	9.72	8.2	8.3	8.4	8.7	8.22
NH_4-N mg/1	0	.23	.28	.07	.14	.22	.28	.21	.16
NO_2-N mg/1	.008	-	.012	.008	.007	.011	.008	.005	.012
NO_3-N mg/1	1.13	1.84	1.32	.92	1.36	1.01	1.01	1.08	1.08
Ortho PO_4 mg/1	.07	.42	.10	.16	.45	.08	.08	.19	.05
Total PO_4 mg/1	-	.48	.24	.16	.49	.10	.09	.16	.06
BOD_5	1.9	1.4	3.1	-	1.4	1.54	1.3	.74	1.43
Initial	9.3	8.3	9.3	-	8.1	8.5	8.3	8.6	8.54
Final	7.4	6.9	6.2	-	6.7	6.96	7.0	7.86	7.11

BACTERIOLOGICAL RESULTS

Total Coliform	-	-							
Vol Filtered			1	1.0	1.0	1.0	1.0	0.1	1.0
Count Vol Filtered			17	14	50	13	58	7	39
Index			1,700	1,400	5,000	1,300	5,800	7,000	3,900
Fecal Coliform									
Vol Filtered			10	10	100	10	100	10	100
Count Vol Filtered			10	4	10	2	>100	10	3
Index			100	40	10	20	>100	100	3

REMARKS

TABLE III-24 (Concluded)

CRYSTAL LAKE WATER QUALITY INVESTIGATION

STATION Cold Creek Station at second footbridge west side of Benzie Blvd. (con't)

DATE 1969	8/14	8/20							
TIME OF COLLECTION	AM 8:50	PM 12:25							
DISCHARGE HEAD (feet) CFS	-	-							
TEMPERATURE (AIR) °C	22.0°	22.5°							
WEATHER CONDITIONS	sunny	sunny							

CHEMICAL ANALYSIS

TEMPERATURE (Sample) °C	18.5°	17.8°							
pH	8.15	8.07							
DO mg/l	7.60	9.85							
NH_4-N mg/l	.33	.37							
NO_2-N mg/l	.014	.010							
NO_3-N mg/l	1.25	1.30							
Ortho PO_4 mg/l	.08	.06							
Total PO_4 mg/l	.03	.09							
BOD_5									
Initial									
Final									

BACTERIOLOGICAL RESULTS

Total Coliform									
Vol Filtered	0.1	1.0							
Count Vol Filtered	5	19							
Index	5,000	1,900							
Fecal Coliform									
Vol Filtered	100	100							
Count Vol Filtered	78	42							
Index	78	42							

REMARKS

TABLE III-25

CRYSTAL LAKE WATER QUALITY INVESTIGATION

STATION Crystal Ave. 6875 Crystal Ave. (at Benzie St.) (Sampling point: pipe outlet in north side of road)

DATE 1969	6/18	6/25	7/6	7/13	7/24	7/30	8/8	8/14	8/20
TIME OF COLLECTION	AM 9:00	AM 8:40	AM 9:15	AM 7:40	AM 8:15	AM 8:50	AM 8:55	AM 8:40	AM 10:10
DISCHARGE HEAD (feet) CFS	-	-	-	-	-	-	-	-	-
TEMPERATURE (AIR) °C	-	18°	18.5°	31°	21°	21°	23.5°	22.5°	22°
WEATHER CONDITIONS	cloudy/ showers	over- cast	sunny	sunny	sunny	sunny	sunny	sunny	sunny

CHEMICAL ANALYSIS

TEMPERATURE (Sample) °C	11.0°	11.5°	12.0°	14.0°	14.5°	15.0°	16.2°	16.0°	15.5°
pH	8.40	8.29	8.20	8.10	8.20	8.20	8.30	8.22	9.30
DO mg/1	10.60	12.91	10.00	9.80	9.40	9.50	9.34	9.05	10.35
NH_4-N mg/1	0.32	0.28	0.48	0.56	0.40	0.33	1.20	0.95	0.38
NO_2-N mg/1	0.007	0.003	0.020	0.031	0.013	0.008	0.068	0.085	0.054
NO_3-N mg/1	0.14	0.11	0.17	0.23	0.28	0.15	0.60	0.90	0.70
Ortho PO_4 mg/1	0.07	0.08	0.15	0.12	0.12	0.20	0.58	0.50	0.23
Total PO_4 mg/1	0.12	-	0.30	0.34	0.15	0.36	0.45	1.15	0.46
BOD_5	2.20	-	0.40	1.46	1.30	1.49	3.87		
Initial	9.30	-	8.50	8.50	8.70	9.20	8.94		
Final	7.10	-	8.10	7.04	7.40	7.71	5.07		

BACTERIOLOGICAL RESULTS

Total Coliform									
Vol Filtered	50	100	10	1.0	1.0	1.0	0.1	0.1	1.0
Count Vol Filtered	0	0	20	5	46	23	65	8	36
Index	0	0	200	500	4,600	2,300	65,000	8,000	3,600
Fecal Coliform									
Vol Filtered	50	100	10	100	100	100	100	100	100
Count Vol Filtered	1	15	3	24	> 100	0	65	82	0
Index	2	15	30	24	> 100	0	65	82	0

REMARKS

TABLE III-26

CRYSTAL LAKE WATER QUALITY INVESTIGATION

#1 Located at dam & Crystal Lake
#2 300 yards south of railroad bridge
#3 Outlet Gaging Station

STATION Outlet

DATE 1969	6/25	8/8	8/8	8/8					
TIME OF COLLECTION	8:25	#1 6:10	#2 6:20	#3 6:25					
DISCHARGE ~~HEAD~~ (inches) CFS	g.h. 15.5"	g.h. 18.75" 45.626							
TEMPERATURE (AIR) °C	18°	14°	14°	14.5°					
WEATHER CONDITIONS	over-cast	hazy	hazy	hazy					

CHEMICAL ANALYSIS

TEMPERATURE (Sample) °C	16.1°	22°	22°	22°					
pH	8.31	8.45	8.48	8.42					
DO mg/1	12.37	8.47	8.17	8.12					
NH_4-N mg/1	100% 0	93% .08	96% .04	92% .09					
NO_2-N mg/1	99% 0	99% 0	99% 0	98% 0.001					
NO_3-N mg/1	99% 0	96% 0.16	100% 0	98% 0.06					
Ortho PO_4 mg/1	100% 0	100% 0	100% 0	100% 0					
Total PO_4 mg/1	-	100% 0	100% 0	100% 0					
BOD_5	-	-	-	-					
Initial	-	-	-	-					
Final	-	-	-	-					

BACTERIOLOGICAL RESULTS

Total Coliform									
Vol Filtered	100								
Count Vol Filtered	0								
Index	0								
Fecal Coliform									
Vol Filtered	100								
Count Vol Filtered	0								
Index	0								

REMARKS

In addition to the preceding data tabulations, the following observations and comments are presented for the information of the reader:

Broadway - Moderate but significant growth of Cladophera algae was observed on the rocks and logs around the mouth of the stream as it discharges into the lake. Best overall water quality of the several drains.

W4 - Quite moderate algal growth scattered on rocks and logs at outlet was observed.

W1 - Special bacteriological observations on 6/27/69 and 8/1/69 will be presented later as a special study. Heavy algal growth observed at mouth and along adjoining pier which was cleaned after August 12. High coliform counts noted in July during period of maximum occupancy.

W2 - Very little algal growth observed near mouth of stream at the sandy beach outlet.

W3 - Very little algal growth observed above mouth of stream or on sandy beach outlet or on nearby dock.

W5 - This stream is the surface outlet of Round Lake. On August 7, conditions of the north shore of Round Lake at one foot depth and at the weir were observed as follows:

	North Shore of Round Lake	W-5 Weir
Air Temp.	23°C	24°C
Water Temp.	22°C	23.5°C
pH	8.6	7.5
D. O. in mg/l	8.5	4.2

From these comparisons and the tan tinged color of the water at the weir, organic materials, some with low pH (tannic acid) must be leached out of the vegetation in the marshy south side of Round Lake. The low nitrogen and phosphorus content of the weir water reflect the good Round Lake water quality. There is luxurient algal growth (mostly Spirogyra) below the weir in the stream, about the mouth, and on the adjacent concrete bulkhead (mostly Cladophera on the bulkhead). Owners clean this periodically.

W-6 - There is a heavy Chara growth dominating the rich algal growth in the stream on the lake side of the road, but there is no algal growth on the sandy beach or on the few rocks in the shallow water near the mouth.

W-7 - On August 6 and 7, conditions 100 feet above the road and at the weir sampling point were observed as follows:

	100 Feet Above Road August 6 at 1PM	W-7 Sampling Point August 7 at 10 AM
Air Temp. °C	25.5°	24.0°
Water Temp. °C	14.5°	20.0°
pH	8.4	8.2
D. O. mg/l	9.9	7.5
NH_4-N mg/l	0.09	0.13
NO_2-N mg/l	0	0.003
NO_3-N mg/l	0.7	0.57

No lawns were observed in the area and very little algae were observed on the lake side of the stream, just weeds. Also, no algae were observed on the sandy beach and very little on the few rocks in the shallow water.

4141 Crystal Drive - "Glen Rhoda" - Moderate algal growth was observed around the outlet, while almost none was observed along the lake shore east of the mouth.

W-8 - Modest algal growth was observed in the stream near the outlet and moderate growth was observed on the surrounding rocks at the mouth. This stream has the highest nitrate (NO_3) content of all the tributaries. On August 6 and 7, conditions upstream from the weir and at the weir sampling point were observed as follows:

	August 6 - 1:00 PM			August 7 - 10 AM
	Just Above All Houses	Above Lower/ Pond	At Source	W-8 Sampling Point
Air Temp. °C	27°	26°	26°	25°
Water Temp. °C	23°	13.5°	9.5°	18°
pH	8.4	8.35	--	8.4
D. O. mg/l	7.5	9.7	--	7.8
NH_4-N mg/l	0.15	0.09	--	0.16
NO_2-N mg/l	0.045	0.003	--	0.037
NO_3-N mg/l	4.8	>10.0	>10.0	4.7
Ortho PO_4 mg/l	0.07	0.07	--	0

W-9 - There is very little algal growth in the stream and quite moderate growth on the beach at the outlet even though several cottages are close to the lake.

W-10 - Heavy algal growth was observed on the rocks, logs, and pier surrounding the outlet. The pier was cleaned on August 20. On August 6 and 7, conditions upstream from the weir and at the weir sampling point were observed as follows:

	August 6 - 1:00 PM		August 7 - 10:30 AM
	Lowest Tributary at Outlet Pipe	Major Stream Above Both Tributaries	W-10 Sampling Point
Air Temp. °C	27°	27°	24.5°
Water Temp. °C	20°	15.5°	18°
pH	8.35	8.2	8.15
D. O. mg/l	8.0	8.8	8.0
NH_4-N mg/l	0.09	0.08	0.16
NO_2-N mg/l	0.013	0.004	0.003
NO_3-N mg/l	3.05	1.92	0.68
Ortho PO_4 mg/l	0.09	0.10	0.16
Total PO_4 mg/l	--	--	0.20

P-1 - There are many weeds but almost no algal growth in the stream including the pebbly beach at its outlet which is a public boat launching area. There are no houses within 100 feet of its course and no fertilized area except the small pond lawn and the west end of an orchard 100 yards up the east hillside. On August 11 at 10 AM, conditions at the pipe P-1 and upstream were observed as follows:

	P-1 Sampling Station	Above Farmland 150 Yards from Source
Air Temp. °C	24°	23°
Water Temp. °C	20°	12°
pH	8.1	8.05
D. O. mg/l	9.8	< 8.0
NH_4-N mg/l	0.1	0.04
NO_2-N mg/l	0	0.005
NO_3-N mg/l	3.4	2.25
Total PO_4 mg/l	0	0

W-12 - There is almost no algal growth on the beach at the outlet either in the sand or on the rock pier projections surrounding it (undeveloped beach area). There is moderate growth in the grassy stream above the mouth.

W-11 - There is no algal growth in the sandy area on the beach just at the outlet pipe and quite modest growth on rocks and logs nearby.

P-2 - In the few feet the ditch water flows east of the entrance road of the gravel pit there is heavy algal growth. West of (below) the entrance road there is almost no algal growth though the stream bed, etc., appear the same. A sampling run was made to compare the water quality near the eastern origin (just below the entrance to the gravel pit) and at the drain pipe (P-2) with the following results:

	P-2 Sampling Station August 11 - 11 AM	200 Feet East August 14 - 9 AM
Air Temp. °C	22°	25°
Water Temp. °C	11°	16°
pH	7.9	8.0
D. O. mg/l	8.35	8.2
NH_4-N mg/l	0.29	0.03
NO_2-N mg/l	0.002	0
NO_3-N mg/l	1.40	0.7
Total PO_4 mg/l	0.06	0.06

There is no apparent algal growth on the sandy beach where the drain P-2 empties into the lake, but there is significant algal growth on the rocks and pier nearby.

W-13 - The Mitchell Pond is free from floating algae and most of the growth in the bottom appears to be Chara. Also, the stream itself is free from algae as a result of regular cleaning. Of the several water quality measurements taken, the dissolved oxygen levels were most influenced through the summer.

Cold Creek - Details on the water quality of Cold Creek are presented elsewhere in this report.

Crystal Ave. - 6875 Crystal Ave. at Benzie Street - There is modest algal growth on the rocks, logs, or docks around the mouth of the stream. The water quality of this stream has high nutrient content, high BOD_5, and high coliform concentrations. These high concentrations occur during July and early August corresponding to the time of peak human occupancy.

Outlet - Evaluation of the water quality of the outlet stream in June indicated excellent water quality involving high dissolved oxygen, no coliform organisms, and extremely low nutrient levels below the limits of detection of the instrumentation available at the field laboratory. As a result, no routine sampling of the outlet water was done through the summer with the exception of some special evaluations on August 8, 1969, when again the nutrient levels were extremely low. These results confirm the assumption that Crystal Lake is acting as a nutrient trap, allowing the build-up in Crystal Lake of nutrient contributions from the several waste sources.

Cold Creek Study

Special consideration was given to Cold Creek draining an area of approximately 10.35 square miles east of Beulah, and discharging into Crystal Lake at Beulah. The main stream (south branch) is about two miles long originating in the boggy woods above the Atlantic Lumber mill. There is a large impoundment for logs at the mill below which the stream crosses Homestead Road near its intersection with Case Road (an extension of Commercial Road in Beulah). It then winds down a small valley with several houses and gardens along its course beginning about 100 yards below Homestead Road. Eventually it crosses U. S. 31 to enter a marshy area just east of the business district of Beulah, where it is joined by a tributary from the north draining part of the hill plain on the east end of Crystal Lake. The mainstream of this tributary flows about one mile along Narrow Gauge Road.

Figure III-2 shows the various branches of Cold Creek in and around the Village of Beulah together with the 1969 water quality sampling stations. The only two sampling stations not indicated are station 6 below the dam of the Atlantic Lumber Company on the main or south branch, and station 7 at the end of the Atlantic Lumber Company swamp above the impoundment on this same branch.

Results of special sampling runs along Cold Creek on June 28, July 16, July 31, and August 4 are presented in Table III-27 through Table III-30, while the results of the routine weekly sampling program are presented in Table III-24. It is apparent that significant contributions of nutrients and coliform organisms are made by Cold Creek discharges to Crystal Lake. Also, it is apparent that phosphates are being contributed by several business establishments and houses along the north branch in the vicinity of sampling stations 3, 8, 9, and 10.

An artificial settling basin was observed in the main stream of Cold Creek above sampling station 2 and below the junction of the north and south branches. Apparently it is necessary to remove the sediment from this basin by external manual or mechanical means on a regular basis.

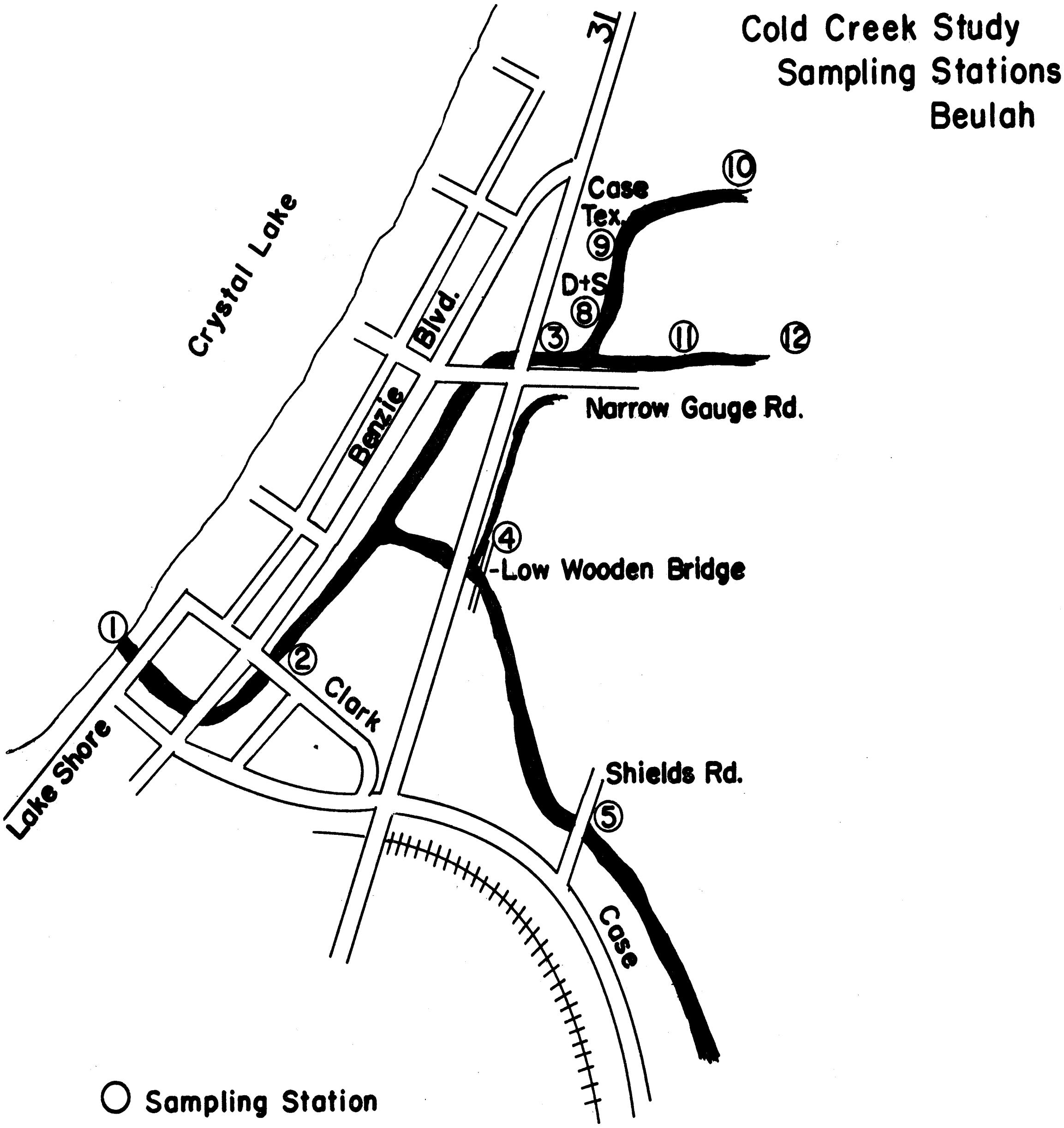

Cold Creek Study
Sampling Stations
Beulah
31
Crystal Lake
Benzie Blvd.
Case Tex.
D+S
Narrow Gauge Rd.
-Low Wooden Bridge
Clark
Lake Shore
Shields Rd.
Case
Sampling Station

Figure III-2

TABLE III-27

CRYSTAL LAKE WATER QUALITY INVESTIGATION

STATION Cold Creek Survey

DATE 6/28/69	1	2	3	3a	4	5	6		
TIME OF COLLECTION	AM 9:10	AM 9:00	AM 9:30	AM 9:40	AM 9:50	AM 10:15	AM 10:10		
DISCHARGE HEAD (feet) CFS									
TEMPERATURE (AIR) °C		20°							
WEATHER CONDITIONS		sunny							

CHEMICAL ANALYSIS

TEMPERATURE (Sample) °C	16.0°	15.7°	15.2°	15.0°	16.8°	17.0°	18.9°		
pH	7.8	7.9	7.7	8.0	8.0	8.0	7.9		
DO mg/1	9.65	9.6	9.35	10.55	9.65	9.25	8.85		
NH_4-N mg/1	0.18	0.15	0.28	0.00	0.09	0.04	0.10		
NO_2-N mg/1	0.004	0.004	0.001	0.001	0.013	0.018	0.036		
NO_3-N mg/1	1.25	1.30	1.84	0.98	1.08	1.12	0.85		
Ortho PO_4 mg/1	0.32	0.33	0.85	0.04	0.07	0.02	0.02		
Total PO_4 mg/1	-	-	-	-	-				
BOD_5	-	-	-	-	-				
Initial	-	-	-	-	-				
Final	-	-	-	-	-				

BACTERIOLOGICAL RESULTS

Total Coliform									
Vol Filtered	1.0	1.0	1.0	1.0	1.0	1.0	1.0		
Count Vol Filtered	9	74	53	17	53	11	23		
Index	900	7400	5300	1700	5300	1100	2300		
Fecal Coliform									
Vol Filtered	10	10	10	10	10	-	10		
Count Vol Filtered	20	7	31	3	4	-	6		
Index	200	70	310	30	40	-	60		

REMARKS

TABLE III-28

CRYSTAL LAKE WATER QUALITY INVESTIGATION

STATION Cold Creek Survey

DATE 7/16/69	1	2	3	4	5	6	7		
TIME OF COLLECTION	11:35	11:25	11:15	11:05	10:55	10:45	10:30		
DISCHARGE HEAD (feet) CFS									
TEMPERATURE (AIR) °C	25°	25°	25°	25°	25°	25°	25°		
WEATHER CONDITIONS	cloudy/ humid								

CHEMICAL ANALYSIS

TEMPERATURE (Sample) °C	20°	20°	18.5°	20°	20°	22°	19°		
pH	8.2		8.2				7.9		
DO mg/1	8.18	8.18	8.68	7.68	7.30	7.58	3.80		
NH_4-N mg/1	0.36	0.28	0.28	0.27	0.23	0.27	0.27		
NO_2-N mg/1	0.012	0.012	0.005	0.014	0.017	0.05	0.02		
NO_3-N mg/1	0.84	0.78	0.64	0.80	0.84	0.60	0.84		
Ortho PO_4 mg/1	0.09	0.055	0.09	0.03	0.03	0.01	0.03		
Total PO_4 mg/1									
BOD_5									
Initial									
Final									

BACTERIOLOGICAL RESULTS

Total Coliform									
Vol Filtered	1.0	1.0	1.0	10	1.0	10	10		
Count Vol Filtered	35	40	60	30	8	35	17		
Index	3,500	4,000	6,000	300	800	350	170		
Fecal Coliform									
Vol Filtered	100	100	10	100	100	10	100		
Count Vol Filtered	50	35	3	40	35	1	9		
Index	50	35	30	40	35	10	9		

REMARKS

TABLE III-29

CRYSTAL LAKE WATER QUALITY INVESTIGATION

STATION Cold Creek Survey Stations same as survey of 7/16 except *

DATE 7/31/69	1	2*	3*	4	5	6	7		
TIME OF COLLECTION	9:25	9:10	8:50	8:40	8:30	8:25	8:10		
DISCHARGE HEAD (feet) CFS	-	-	-	-	-	-	-		
TEMPERATURE (AIR) °C	21.5°	24.0°	21.0°	20.5°	22.0°	20.5°	21.0°		
WEATHER CONDITIONS	overcas	t and hum	id. Sto	rm broke	at appro	ximately	10:00		

CHEMICAL ANALYSIS

TEMPERATURE (Sample) °C	17.0°	17.0°	17.0°	17.5°	18.0°	19.5°	14.5°		
pH	7.80	7.80	7.75	7.80	7.90	7.80	7.85		
DO mg/1	5.70	8.00	7.80	8.10	8.70	8.70	8.85		
NH_4-N mg/1	0.14	0.15	0.22	0.12	0.15	0.21	0.15		
NO_2-N mg/1	0.012	0.012	0.004	0.013	0.015	0.021	0.015		
NO_3-N mg/1	1.04	0.99	0.73	1.04	1.12	1.01	1.26		
Ortho PO_4 mg/1	0.16	0.13	0.47	0.13	0.02	0	0.05		
Total PO_4 mg/1	0.24	0.22	0.43	0.21	0.03	0.13	0		
BOD_5	-	-	-	-	-	-	-	-	
Initial									
Final									

BACTERIOLOGICAL RESULTS

Total Coliform									
Vol Filtered	0.1	1	1	1	1	10	10		
Count Vol Filtered	11	91	>100 TNC	19	8	52	27		
Index	11,000	9100	TNC	1900	800	520	270		
Fecal Coliform									
Vol Filtered	10	10	10	100	100	100	100		
Count Vol Filtered	1	1	3	10	25	35	9		
Index	100	100	300	10	25	35	9		

REMARKS

* Station 2 - Sample taken 100 ft. upstream from usual point.
Station 3 - Sample taken 100 ft. downstream from usual point.

TABLE III-30

CRYSTAL LAKE WATER QUALITY INVESTIGATION

STATION Cold Creek Survey

DATE 8/4/69	3	8	9	10	11	12			
TIME OF COLLECTION	10:20					10:40			
DISCHARGE HEAD (feet) CFS									
TEMPERATURE (AIR) °C									
WEATHER CONDITIONS	Sunny	and warm							

CHEMICAL ANALYSIS

TEMPERATURE (Sample) °C									
pH	8.18	8.12	8.10	8.12	8.20	8.20			
DO mg/1									
NH_4-N mg/1									
NO_2-N mg/1									
NO_3-N mg/1									
Ortho PO_4 mg/1	0.25	0.40	0.42	0.33	0.00	0.00			
Total PO_4 mg/1	0.475	0.580	0.685	0.565	0.170	0.135			
BOD_5									
Initial									
Final									

BACTERIOLOGICAL RESULTS

Total Coliform									
Vol Filtered									
Count Vol Filtered									
Index									
Fecal Coliform									
Vol Filtered									
Count Vol Filtered									
Index									

REMARKS

Shore Line Evaluation and Water Quality Sampling

One important aim of this study has been the evaluation of the influence of shore line development on near shore lake water quality, including bacteriological levels and the extent of algal growth in these areas. The lake shore line was sampled and evaluated three separate times during the summer period, once in June, once in July, and once in August. The factors which were evaluated included: discharge pipes, total and fecal coliform concentrations, algae growth, lawn presence, and the number and kinds of pets.

CHOICE OF SAMPLING LOCATIONS

Since man and his activities were a major concern, only the dwellings which would most directly affect water quality were sampled. The choice involved the proximity of the house to the lake, i.e., within 100 feet of the lake and on the lake side of the road. The sample itself was taken from the lake directly off the left corner of the house as it faced the lake at a depth of 8 to 12 inches. If an algal growth was present, the sample would be taken from the center of growth again in 8 to 12 inches of water.

By using houses, the following design criteria could be met:

1. The sampling point was relatively permanent and easily available.

2. The sampling point would directly relate to man's influence on water quality.

3. The house number gave a definite location to the sampling point.

The house numbers were located by: (1) driving or walking and noting consecutive house numbers, (2) using a power company map where numbers were not available, and (3) asking occupants or owners of individual houses if methods 1 and 2 were inadequate.

Since the lake was relatively large, transportation became a problem. Travel by automobile was used when the lake was close to the road, and a pontoon boat was used when it was not feasible to drive to the sampling point because of the distance involved or road uncertainty. In any case, the actual sample was collected by wading.

PARAMETERS OF THE STUDY AND METHODS OF COLLECTION AND OBSERVATION

Discharge Pipes - Discharge pipes were located by visual inspection during a walking pipe search and during sampling periods. Only four inches or larger pipes of clay, cement, iron, plastic, or fiber were noted as possible discharge pipes. Sprinkler intake lines were ignored.

Coliform Index - The bacteriological study was started during the low occupancy period of June to establish a base line for comparison with the higher occupancy periods of July and August. Coliform contributions are made mostly by man through individual waste water system discharges; and other warm blooded animals.

Bacteriological samples were taken by inverting a 300 ml glass-stoppered bottle under the surface, top down, in 8 to 12 inches of water out from the left-hand corner of the house as it faced the lake, and then allowed to fill as previously stated. If an algal growth was present, the sample was collected from the center of the growth. A single member of the survey team collected 24 samples per day throughout the summer, and then processed the samples in the laboratory within three hours of collection. The membrane filter method was used in the laboratory as explained in detail in Appendix B. The following notation was used in the subsequent tabulations:

1. Coliform index - coliform organisms/100 ml.

2. >100 = greater than 100 coliform organisms/100 ml. A greater dilution should have been used.

3. TNC = too numerous to count. This notation was used where bacteria other than coliform organisms have overgrown the test plate.

Algae - Algae was chosen as a parameter because it is of concern to the residents of Crystal Lake, it is obvious, non-motile, can be easily observed requiring no elaborate laboratory procedure, and is sensitive to increased nutrient levels from human sewage, lawn fertilizers, natural runoff, or other sources. The algae grows more luxuriantly where the nutrient concentration is high, while it starves and diminishes where nutrient concentrations are low.

A single member of the survey team visually rated the algal growth on a 0 to 4 scale as follows:

0 - no algae visible

1 - rocks or dock have green tinge but no visible growth

2 - growth visible but still scanty; generally up to 1/8 inch thick

3 - growth heavy but not in excess; generally up to about one inch thick as it floats in water

4 - any growth thicker than one inch as it floats in water

The concentration rating was based on the algal growth thickness in the heaviest part of the bloom. The area covered by algae was not taken into consideration because at some points dock ledges were the only attachment site where the growth could be observed.

Lawns and Fertilizer - The number of lawns and fertilizer application sites are potential nutrient input points. A lawn was considered to be any part of the landscape which had been mowed. The use of fertilizers was determined by the condition of the lawn, the observance of fertilizers being applied, or by talking to the occupant during the household information survey.

Pets - The number and kinds of pets at each sampling point can indicate potential nutrient contributions, particularly if of a bacteriological nature. It may also indicate potential dog-bite locations to future investigators. Number and kinds of pets were determined by visual inspection of the premises for dog houses, chains, dishes, kennels, rooms, etc. Dogs barking in the house, cats sleeping in the windows, foot prints in the sand, or observation of the animal itself all were used to evaluate the number and kinds of pets. In addition, the household information survey provided further data.

SPECIAL BACTERIOLOGICAL STUDIES

Two special bacteriological studies were conducted as part of the shore line sampling, one involved replication of a sample collected in front of 5709 North Crystal Drive on July 30, and the other involved samples collected along both the south and north shores of Crystal Lake in areas somewhat removed from cottages to serve as background information.

Results of the special bacteriological replication and correlation study are presented in Table III-31, where it is seen that the total coliform levels using the membrane filter technique ranged from 26 to 42 with a mean of 34, while the fecal coliform levels of this same sample ranged from 0 to 6 with a mean of 2.0.

Results of the special background study are presented in Table III-32, where it is apparent that coliform organisms existed in Crystal Lake water on both August 6 and August 10 in areas somewhat removed from nearby cottages. This suggests that water circulation patterns in Crystal Lake do move water masses within the lake, and the fact that a high coliform level was observed in front of a given cottage does not necessarily mean that it was contributed by that cottage. However, where substantially higher coliform organisms were observed in the lake, it is reasonable to conclude that significant contributions are coming from some nearby area.

The results of the shore line evaluation and water quality sampling program are presented in Table III-33, involving some 288 individual sampling points.

TABLE III-31

SPECIAL BACTERIOLOGICAL REPLICATION AND CORRELATION STUDY
(Date of Sample Collection—7-30-69; Address—5709 North Crystal Drive)

Sample Number	Coliform Index Total	Coliform Index Fecal
1	38	1
2	33	4
3	31	0
4	34	5
5	26	1
6	36	2
7	36	3
8	40	2
9	42	0
10	37	3
11	36	0
12	35	6
13	35	0
14	33	3
15	34	0
16	28	2
17	27	0
18	34	1
19	39	0
20	29	6
21	31	1
22	36	3
23	40	0

TABLE III-32

SPECIAL BACTERIOLOGICAL BACKGROUND STUDY

Address	Date of Sample Collection			
	8-6-69		8-10-69	
	Coliform Index/100 ml			
	Total	Fecal	Total	Fecal
South Shore				
1/4 mile west of Hill and Dale Beach	31	0	>100	0
1000 feet west of 5014, A.A.R.R. right of way	27	0	16	0
800 feet east of 4720, A.A.R.R. fight of way	5	0	12	1
300 feet east of outlet	38	8	6	0
West ~~of~~ Crystal Beach	17	3	>100	11
North Shore				
300 feet east of 1817	11	0	4	1
200 feet west of 2185	13	0	2	0
1/4 mile west of Cr. Drive	10	0	1	0
800 feet west of Cr. Drive	10	0	5	0
800 feet east of M-22	8	0	6	0
1/2 mile east of 4141	22	0	9	1
Boat launch Dr. Drive	11	0	1	0
300 feet east of boat launch	41	0	21	0
Boat shop	TNC	0	TNC	0

TABLE III-33

ADDRESS	DISCHARGE PIPES	COLIFORM INDEX Total June	Total July	Total Aug	Fecal June	Fecal July	Fecal Aug	ALGAE June	ALGAE July	ALGAE Aug	ALGAE Sep	LAWN PRESENT	FERTI-LIZER	PETS Number	PETS Kind
2235 M 22		2	>100	20	0	0	0				0				
2817 "		1	90	<10	0	1	0				0	Yes		1	Dog
3143 "		17	4	<10	0	1	0				0				
3333 "		3	0	10	0	0	0				0				
3401 "		8	4	0	0	6	0				0				
3419 "		200+	15	40	0	0	0				0				
3435 "		15	12	10	0	1	0				0				
3455 "		5	13	0	0	3	0				0				
3471 "		0	96	0	0	45	0				0				
3473 "		50	32	30	1	12	0				0			1	Dog
3491 "		0	5	0	0	0	0				0				
3701 "		1	0	10	0	0	0				0				
3789 "		14	7	10	0	0	0				0			1	Dog
3945 "		4	4	0	0	0	0				0	Yes	Yes	1	Dog
257 "		6	5	0	0	0	0				0				
539 "		1	1	0	0	0	0				0			1	Dog
565 "		2	10	20	0	0	0				0			1	Dog
613 "		1	3	0	1	0	0				0			1	Dog
781 "		6	12	5	0	5	0				0				
965 "		0	3	45	0	0	0				0				
1035 "		3	9	39	0	0	0				0	Yes	Yes	1	Dog
1037 "		3	5	10	0	0	0				1				
1047 "		10	30	27	0	1	0				1				

TABLE III-33 (Continued)

ADDRESS	DISCHARGE PIPES	COLIFORM INDEX Total June	Total July	Total Aug	Fecal June	Fecal July	Fecal Aug	ALGAE June	ALGAE July	ALGAE Aug	ALGAE Sep	LAWN PRESENT	FERTI-LIZER	PETS Number	PETS Kind
1071 M-22		3	5	12	1	0	0				0			1	Dog
1091 "		5	6	53	0	0	0				1				
1111 "		5	9	25	0	0	0				0	Yes	Yes		
1137 "	1	5	3	38	0	0	0				0	Yes			
1153 "		7	4	73	4	0	1				0				
1197 "		8	18	25	0	1	0				0	Yes	Yes		
1211 "		9	1	27	2	0	0				0	Yes	Yes	1	Dog
1273 "		3	0	33	0	1	0				0				
1299 "		0	1	15	0	0	0				0				
1327 "		0	1	15	0	0	0				0				
1359 "		5	6	53	0	0	0				1	Yes			
1369 "		9	19	TNC	0	0	0				1	Yes			
1413 "		0	18	25	0	0	0				1	Yes			
1423 "		2	1	18	0	0	0				1				
1433 "		2	3	30	0	0	1				0	Yes			
1455 "		1	TNC	87	0	0	0				1	Yes	Yes		
1471 "		7	3	18	0	0	0				2			2	Dog
1535 "		3	2	41	0	0	0				0			1	Dog
1545 "		4	4	28	4	0	0				0	Yes			
1563 "		16	22	37	21	0	0				0				
1575 "		6	18	62	3	0	0				0	Yes	Yes	1	Dog
1669 "		59	0	>100	0	0	8				0				
1679 "		4	>100	36	1	0	1				0				

TABLE III-33 (Continued)

ADDRESS	DISCHARGE PIPES	COLIFORM INDEX						ALGAE				LAWN PRESENT	FERTI-LIZER	PETS	
		Total June	Total July	Total Aug	Fecal June	Fecal July	Fecal Aug	June	July	Aug	Sep			Number	Kind
1705 M-22		4	3	26	2	0	0				0				
1817 "	2	4	36	> 100	5	0	4			2	2			1	Dog
1937 "		3	9	> 100	5	0	0		4	4	4	Yes		1	Dog
1957 "		2	10	63	2	0	0			4	4			1	Dog
1987 "	1-12" discharge	3	3	> 100	1	0	0			4	1	Yes	Yes		
2019 "		1	21	37	0	0	2			4	4				
2029 "		3	1	> 100	1	0	0		2	3	3				
2061 "	1	0	0	> 100	-	0	0		2	3	3	Yes	Yes		
2185 "		0	9	30	0	0	2				0	Yes			
2251 "		5	1	29	0	0	1				0				
2469 "		-	56	28	-	0	3				0			1	Dog
2627 N. Crystal Drive		3	17	> 100	9	0	0				1	Yes	Yes		
3169 "		1	2	69	0	0	1				0	Yes	Yes		
3171 "		1	1	53	0	0	0			1	1	Yes	Yes		
3179 "		0	1	63	0	0	0				3	Yes		1	Dog
3187 "		1	0	54	0	0	0				3	Yes	Yes		
3203 "		5	1	62	0	0	0		1	2	2	Yes	Yes	1	Dog
3293 "		> 100	> 100	53	5	0	0		2	4	4	Yes	Yes	1	Dog
3297 "		4	> 100	65	5	2	0				4	Yes	Yes	1	Dog
3673 "		0	0	25	0	0	0				0	Yes			
3709 "		2	22	9	5	0	1				1	Yes	Yes	1	Dog
3767 "		1	30	11	7	0	2				0	Yes	Yes	1	Dog
3831 "		12	6	6	7	0	0				0			2	Dog&Cat

TABLE III-33 (Continued)

ADDRESS	DISCHARGE PIPES	COLIFORM INDEX Total			COLIFORM INDEX Fecal			ALGAE				LAWN PRESENT	FERTI-LIZER	PETS	
		June	July	Aug	June	July	Aug	June	July	Aug	Sep			Number	Kind
3871 N. Crystal Dr.		11	32	1	0	0	0				0			1	Dog
3895 "		6	10	35	17	0	0				0				
3901 "		3	19	0	18	0	1				0	Yes			
3905 "		4	10	4	4	0	0				0	Yes			
3917 "		2	12	4	5	1	0				0			1	Dog
3925 "		2	25	4	9	8	0				0	Yes		1	Dog
3941 "		2	32	10	10	0	1				0			1	Dog
3951 "		1	30	8	0	3	1				0	Yes			
3961 "		9	18	8	6	2	1				0	Yes	Yes	1	Dog
3987 "		1	17	11	2	0	0				0	Yes			
4009 "		3	4	18	2	0	1				0			1	Dog
4025 "		5	1	13	5	0	0				0				
4035 "		2	0	8	7	0	2				0				
4053 "		4	5	16	8	0	2				0				
4065 "		0	1	9	1	0	0				0				
4073 "		3	1	21	5	0	1				0				
4077 "		7	4	13	5	0	0			3	3	Yes	Yes		
4081 "		12	4	10	23	0	1				0	Yes			
4141 "		17	7	4	6	0	1			3	3	Yes			
4271 "		0	1	8	0	0	1				0			1	Dog
5035 "		2	>100	23	0	1	1				2	Yes		1	Dog
5089 "		4	34	>100	3	0	4				1				
5107 "		6	2	81	2	0	0				2				

TABLE III-33 (Continued)

ADDRESS	DISCHARGE PIPES	COLIFORM INDEX						ALGAE				LAWN PRESENT	FERTI-LIZER	PETS	
		Total			Fecal										
		June	July	Aug	June	July	Aug	June	July	Aug	Sep			Number	Kind
5125 N. Crystal Dr.		3	10	73	7	0	0				3			1	Cat
5147 "		0	12	22	0	0	0				0				
5233 "		1	TNC	20	0	2	0				2				
5313 "		0	>100	30	0	4	0			2	2	Yes		3	Dog
5391 "		15	66	30	0	2	0				1	Yes		1	Dog
5481 "		4	11	9	2	0	0				3	Yes	Yes		
5485 "		0	6	7	0	0	0				4	Yes	Yes		
5575 "		2	9	4	0	1	0				3	Yes		1	Dog
5585 "		2	> 100	20	2	0	0			3	3	Yes		2	Dog
5627 "		0	> 100	50	0	8	0			3	3	Yes	Yes		
5651 "		0	26	10	0	5	5			2	2	Yes	Yes		
5671 "		1	36	19	0	4	2			2	2	Yes	Yes		
5691 "		0	30	11	0	4	3			2	2	Yes	Yes		
5709 "	1	0	31	1	0	2	11				1	Yes	Yes	1	Cat
5731 "		5	TNC	10	2	5	8			1	1	Yes	Yes	2	Cat&Dog
5751 "		0	>100	220	1	12	0			3	3	Yes			
5795 "		0	TNC	60	2	13	4			3	3				
5867 "		0	>100	20	1	1	3				3	Yes	Yes		
5893 "		0	59	26	0	2	0				1			1	Dog
5929 "	1	2	TNC	0	2	0	0			4	4				
5941 "		35	>100	10	1	7	0			4	4	Yes			
5975 "		15	71	10	1	2	6				2	Yes			
5977 "		0	100	30	0	0	0				4	Yes			

TABLE III-33 (Continued)

ADDRESS	DISCHARGE PIPES	COLIFORM INDEX Total June	Total July	Total Aug	Fecal June	Fecal July	Fecal Aug	ALGAE June	July	Aug	Sep	LAWN PRESENT	FERTI-LIZER	PETS Number	Kind
5997 N. Crystal Dr.		6	79	10	3	0	0			3	3	Yes			
6015 "		18	>100	190	4	0	0			4	4	Yes		1	Dog
6023 "		9	>100	30	0	0	0				3	Yes		1	Dog
6037 "	1	>100	>100	50	>100	0	1		4	4	4	Yes			
6045 "		10	104	40	5	0	1			4	4	Yes			
6051 "		9	47	20	22	0	1			4	4	Yes			
6053 "		24	27	35	0	0	0				3	Yes			
6055 "		11	29	27	0	0	2			4	4				
6057 "		13	46	23	1	1	1				3				
6063 "		14	40	>100	0	1	0				3	Yes			
6075 "		11	22	10	0	1	0				4	Yes			
6081 "		22	24	0	0	0	0				4	Yes			
6087 "		14	36	31	0	0	0				1	Yes			
6091 "	2 drain tile	9	5	7	0	1	0				2	Yes	Yes	1	Dog
6137 "		7	23	9	2	1	0			2	2	Yes		1	Dog
6149 "	12" tile	0	TNC	80	0	3	0		4	4	4	Yes		1	Dog
6167 "	12" tile	19	15	32	1	0	0				2	Yes			
6177 "		19	82	4	0	0	0				2	Yes	Yes		
6197 "		14	41	5	0	2	0				2	Yes		1	Dog
6225 "		>100	TNC	50	15	0	3			4	4				
6231 "		13	116	140	0	11	3			4	4	Yes	Yes	1	Dog
6243 "		3	67	>1000	0	0	4			1	1	Yes	Yes	1	Dog
6263 "		6	>100	60	0	2	0			2	2	Yes	Yes		

TABLE III-33 (Continued)

ADDRESS	DISCHARGE PIPES	COLIFORM INDEX						ALGAE				LAWN PRESENT	FERTI-LIZER	PETS	
		Total			Fecal										
		June	July	Aug	June	July	Aug	June	July	Aug	Sep			Number	Kind
6273 N. Crystal Dr.		0	>100	150	0	1	0				3	Yes	Yes		
6283 "		5	80	150	0	0	0				1	Yes			
6301 "		1	99	220	0	0	0		4	4	4	Yes	Yes	1	Dog
6319 "		3	82	480	0	0	2			4	4	Yes	Yes	1	Dog
6343 "		7	61	410	1	0	0			3	3			1	Dog
6363 "		0	95	160	0	1	0			4	4	Yes			
6381 "		0	93	380	0	4	1			4	4	Yes			
6393 "		0	79	150	0	3	0			4	4	Yes		1	Dog
6413 "	2 drains	3	48	200	2	0	0			4	4	Yes	Yes		
6415 "	12" drain	0	80	300	1	1	1			3	3	Yes	Yes		
6453 "	3	1	48	280	0	5	0				3	Yes		1	Dog
6463 "		0	57	580	0	0	11			4	4	Yes			
6465 "		3	50	580	0	0	10			4	4	Yes			
6473 "		5	71	>10000	6	0	6			4	4	Yes		1	Dog
6493 "		4	TNC	840	2	0	2		2	2	2	Yes			
6503 "		4	TNC	150	0	3	3			4	4	Yes		1	Dog
6523 "		0	TNC	300	2	7	4			4	4	Yes			
6537 "		4	>100	>10000	1	1	>100			4	4	Yes			
6585 "		8	TNC	460	0	0	0				2	Yes			
6597 "		5	94	300	0	0	1				2	Yes		1	Dog
6617 "		3	53	40	1	0	4		4	4	4				
6631 "		23	>100	510	0	0	5				3	Yes			
6649 "		12	49	1040	0	0	5				4	Yes		1	Dog

TABLE III-33 (Continued)

ADDRESS	DISCHARGE PIPES	COLIFORM INDEX Total June	Total July	Total Aug	Fecal June	Fecal July	Fecal Aug	ALGAE June	July	Aug	Sep	LAWN PRESENT	FERTI-LIZER	PETS Number	Kind
6681 N. Crystal Dr.		17	>100	>100	1	0	4		4	4	4	Yes		1	Dog
6701 "		>100	>100	310	1	1	1			4	4	Yes			
6709 "		21	>100	210	1	0	0				2	Yes			
6713 "		35	106	390	0	1	9			4	4	Yes			
6727 "		16	TNC	520	2	0	4				2	Yes			
6767 "		9	42	250	0	0	1				2	Yes			
6781 "		19	90	270	2	0	24		3	4	4	Yes			
6783 "		11	44	320	1	0	5				2				
6809 "		17	38	80	0	0	0				4	Yes	Yes		
6855 "		19	54	220	0	0	4				2	Yes	Yes		
6863 "		10	43	270	0	0	6			4	4	Yes	Yes	1	Dog
6893 "	1	>100	TNC	80	0	1	7			3	3	Yes	Yes		
6909 "		>100	45	40		1	0			4	4	Yes	Yes		
6925 "		12	TNC	20	3	1	3		3	4	4	Yes	Yes		
6939 "		>100	61	130	2	2	1			4	4	Yes	Yes	1	Dog
6987 "	4	14	39	30	0	1	0			4	4	Yes	Yes	1	Dog
7019 "	1	2	93	240	1	0	3				0			1	Dog
7155 "		2	20	90	0	1	0				1			1	Dog
7161 "		4	56	30	2	0	0				1	Yes			
7189 "		7	>100	TNC	0	3	2				1	Yes			
7195 "		7	TNC	90	0	1	0			2	2	Yes			
7205 "	1	9	>100	>100	0	0	7			2	2	Yes		1	Dog
7217 "		4	TNC	170	3	0	1				2			1	Dog

TABLE III-33 (Continued)

ADDRESS	DISCHARGE PIPES	COLIFORM INDEX Total June	Total July	Total Aug	Fecal June	Fecal July	Fecal Aug	ALGAE June	July	Aug	Sep	LAWN PRESENT	FERTI-LIZER	PETS Number	Kind
7227 N. Crystal Dr.		3	TNC	20	1	0	0				2	Yes			
7271 "		4	>100	70	0	0	0				1				
7591 "	6" drain	>100	TNC	100	9	0	0			4	4	Yes	Yes		
752 Windemere	3" pipe 12" pipe	3	30	130	0	0	0			4	4	Yes	Yes		
684 "	10" drain 6" drain	2	19	20	0	4	9				4	Yes	Yes		
666 "		7	TNC	<10	0	1	0				4	Yes	Yes		
658 "		16	TNC	40	0	0	0				4	Yes	Yes		
644 "		6	TNC	10	1	1	1				4	Yes		1	Dog
614 "		1	TNC	50	0	1	0				0	Yes			
600 "		1	TNC	180	0	6	-				2	Yes			
586 "		2	TNC	90	0	1	0				0	Yes			
576 "		6	38	20	0	3	1				0	Yes			
570 "		7	TNC	10	0	5	1				3			1	Dog
544 "		12	>100	<10	2	3	0				3	Yes			
526 "		2	TNC	10	0	4	0				0				
514 "		2	TNC	<10	0	7	0				0			1	Dog
508 "		7	TNC	<10	0	7	0				0			1	Dog
Elmwood - Beulah		7	21	10	1	0	0				4				
Birchwood		1	TNC	10	4	2	0				0				
Fourth		4	TNC	20	0	1	0				0				
Third		27	TNC	10	2	15	0				0				
Second		3	TNC	30	0	11	0				0				
First		11	>100	50	0	21	-				0				

TABLE III-33 (Continued)

ADDRESS	DISCHARGE PIPES	COLIFORM INDEX Total June	Total July	Total Aug	Fecal June	Fecal July	Fecal Aug	ALGAE June	July	Aug	Sep	LAWN PRESENT	FERTI-LIZER	PETS Number	Kind
Pleasant - Beulah		20	>100	330	0	82	10				0				
Clark		47	TNC	>1000	1	>100	>100				2				
Commercial		23	TNC	<10	0	31	0				0				
Prospect	24" storm drain	12	23	70	0	9	1				2				
350 Crystal Ave.		14	TNC	20	2	>100	2				0				
364 Crystal Ave.		20	-	30	0	-	11				0				
Steinhauer Log Cabin		>100	TNC	110	0	>100	4				1				
6740 Crystal Ave.		47	TNC	60	0	18	2				0			1	Dog
5014 AA RR Right of Way		3	27	100	0	6	3				1				
4634 Mollineaux		1	4	3	0	0	1				0				
4624 "		0	17	8	0	4	3				0				
4612 "		1	3	11	0	2	6				0	Yes			
4296 "		3	10	9	0	0	0				0				
4292 "		0	13	2	0	0	0				0	Yes		1	Dog
4190 Linden		-	12	3	-	1	0				0			1	Dog
4112 Broadway		8	84	70	0	4	0			2	2	Yes			
4098 Broadway		4	37	50	1	3	0			2	2	Yes			
4088 Boyd		7	5	>100	0	0	2				2	Yes		1	Dog
4076 "		7	43	10	3	4	0				2	Yes		1	Dog
4064 "		0	26	60	4	0	0				2	Yes			
4034 "		12	28	460	0	0	3		2	2	2	Yes			
4030 "		13	3	65	0	0	0				2	Yes			
4022 "	1	25	14	65	0	0	0			3	3	Yes			

TABLE III-33 (Continued)

ADDRESS	DISCHARGE PIPES	COLIFORM INDEX						ALGAE				LAWN PRESENT	FERTI-LIZER	PETS	
		Total			Fecal										
		June	July	Aug	June	July	Aug	June	July	Aug	Sep			Number	Kind
4000 Boyd		7	TNC	70	0	0	0	1	1	1	1	Yes			
3986 "		19	21	26	1	0	1				1				
3970 "		5	0	25	0	0	0				0	Yes			
3958 "		7	56	30	1	0	3				1	Yes			
3948 "		8	70	<10	1	0	1				0				
3938 "		4	64	140	0	0	13				0			1	Dog
3884 "		1	9	13	0	0	0				0				
3880		19	33	560	0	0	1				0				
3874 Jones		13	>100	470	0	0	0				0				
3868 "		4	10	7	0	0	0				0			1	Dog
3830 "		4	TNC	250	1	0	3			4	4	Yes	Yes		
3824 "		5	18	59	0	0	8				1	Yes	Yes		
3816 "		1	14	104	0	0	2			3	3			1	Dog
3749 "		2	15	12	0	0	0				0				
3607 "		2	53	30	0	0	0				1				
3592 "		0	>100	70	0	0	1				0				
3574 "		2	15	27	0	0	3				0				
3558 "		0	15	17	0	0	3				1			1	Dog
3518 "		17	>100	<10	2	1	0				1			1	Dog
391 Onkeonwe		59	38	250	0	0	1				0	Yes		1	Dog
405 "		18	29	<10	1	0	0				0	Yes			
461 "		0	TNC	60	0	1	3				0	Yes		2	Dog
477 "		3	2	76	0	0	3				0				

TABLE III-33 (Continued)

ADDRESS	DISCHARGE PIPES	COLIFORM INDEX						ALGAE				LAWN PRESENT	FERTI-LIZER	PETS	
		Total			Fecal										
		June	July	Aug	June	July	Aug	June	July	Aug	Sep			Number	Kind
593 S. Shore		4	6	62	0	0	17				0				
637 "		2	9	TNC	0	0	3				1	Yes		1	Dog
659 "		1	3	19	0	0	0				1	Yes			
707 "		0	>100	250	0	0	1				2	Yes	Yes	1	Dog
727 "		19	78	280	0	0	0			2	2	Yes	Yes	1	Dog
747 "	1	-	>100	20	-	0	9			3	3			3	Dog
767 "		1	48	240	0	1	1				3	Yes	Yes		
791 "		5	9	11	0	0	2				2	Yes			
961 "		18	4	39	0	0	0				2			1	Dog
973 "		10	0	14	0	0	0				0			1	Dog
995 "		10	1	17	0	0	0				0				
1015 "		0	13	19	0	0	0				3				
1033 "		15	3	16	0	0	0				3	Yes		1	Dog
1053 "		10	20	70	0	0	0				1				
1105 "		11	13	35	0	0	0				0				
1135 "		2	3	9	0	0	0				3	Yes			
1235 "		22	20	<10	0	0	0				4				
1255 "		82	24	<10	0	0	0			1	1				
1325 "		16	13	19	5	0	0			4	4			?	Dogs/Cats
2744 "		2	>100	20	0	0	0				1	Yes			
2732 "		15	49	70	0	10	0				1	Yes		1	Dog
2714 "		13	31	80	0	0	0				3	Yes			
2678 "		0	18	TNC	0	0	0				1	Yes			

TABLE III-33 (Concluded)

ADDRESS	DISCHARGE PIPES	COLIFORM INDEX						ALGAE				LAWN PRESENT	FERTI-LIZER	PETS	
		Total			Fecal										
		June	July	Aug	June	July	Aug	June	July	Aug	Sep			Number	Kind
2658 S. Shore		7	32	190	0	2	1				1	Yes		1	Dog
2648 "		2	47	100	0	0	0				1				
2636 "		17	4	3	0	0	0				0	Yes			
2628 "		4	TNC	20	0	1	0				0	Yes			
2608 "		6	34	30	0	0	0				1	Yes		1	Dog
1765 "		5	TNC	30	0	32	0				4	Yes	Yes		
774 "		200	>100	290	0	30	3			3	3	Yes			
774 - 11 "		200	TNC	100	0	45	4				2	Yes			
724 "		200	>100	40	0	70	0				1	Yes			
584 "		4	>100	50	0	17	0			1	1	Yes		1	Dog
570 "		9	>100	60	0	11	1			3	3	Yes		1	Dog
552 "	12" drain	12	>100	330	0	21	0			3	3	Yes			

Lake Water Quality Evaluation

Lake water samples were collected at the four lake transects at various depths and stations a number of times during the summer high-use period starting on June 26, 1969, and ending on August 19, 1969. During the June 26 - July 2 period, samples were collected at five stations at both transects 1T and 2T and evaluated for temperature, pH, dissolved oxygen (D. O.), ammonia (NH_4 as N), nitrite (NO_2 as N), nitrate (NO_3 as N), ortho phosphate (OPO_4), total phosphate (TPO_4), total coliform, and fecal coliform. It became apparent from inspection of the results of this sampling run that the levels of NH_4, NO_2, NO_3, ortho PO_4, total PO_4, total coliform, and fecal coliform in Crystal Lake itself, away from the shore line, was below the levels of detection of the instrumentation available at the field station. As a result, these analyses were dropped in subsequent runs from the lake sampling program and reliance was placed on temperature, dissolved oxygen, and Secchi disk measurements for light penetration.

Detailed results of the several lake runs are presented in Tables III-34 through III-38 as follows. Sample dissolved oxygen and temperature variations with depth for three separate summer sampling runs are presented in Figure III-3 for station 2T3 and in Figure III-4 for station 3T3.

Station 3T3 represents the deeper section of Crystal Lake and it is apparent that thermal stratification has taken place by August 19, where the surface water temperature is 24.1°C and the deeper water temperature is 8.8°C, with most rapid temperature change with depth occurring around 50 to 60 feet below the surface. Notwithstanding this thermal stratification, the dissolved oxygen levels in the lower part of the lake did not drop below 7.2 mg/l lending further support to the classification of Crystal Lake as an oligotrophic rather than a eutrophic lake. In a eutrophic lake, the dissolved oxygen level is generally very low or nonexistent in the hypolimnion or lower part of the lake during the period of thermal stratification.

A special lake survey was conducted on August 14, 1969, for evaluation of the phosphate level in the lake water away from the shore line. These samples were transported to Ann Arbor immediately after collection for analysis using more sensitive analytical procedures than available at the field station.

The samples were all clear in appearance, therefore, no filtering was necessary before analysis. The phosphate samples were analyzed by the "Modified Single Solution Method for the Determination of Phosphate in Natural Waters" by J. Murphy and J. P. Riley.[6] This method is similar to the method presented in "Standard Methods of Analysis for Water and Waste Water"[4] except ascorbic acid instead of stannous chloride is used for reducing the phosphomolybdic complex. The spectrophotometric measurements were determined at 882 mμ wavelength instead of 690 mμ and 10 cm cylindrical cells were used.

The results of this special survey are presented in Table III-39.

TABLE III-34

CRYSTAL LAKE WATER QUALITY INVESTIGATION
LAKE SAMPLING SUMMARY SHEET

DATE: 6/26/69 AIR TEMPERATURE: 22°C

WEATHER CONDITIONS: Overcast - Heavy rain in the afternoon

SAMPLING STATIONS

	1T1	1T2	1T3	1T4	1T5
Time	12:30	12:20	12:00	11:25	11:00
Depth ft.	(a) 0 (b) 8	(a) 0 (b) 16	(a) 0 (b) 18	(a) 0 (b) 18	(a) 0 (b) 4
Temp °C	(a) 14.8° (b) 13.9°	(a) 14.7° (b) 13.9°	(a) 14.8° (b) 13.0°	(a) 14.2° (b) 12.8°	(a) 16.5° (b) 15.5°
pH	(a) 8.49 (b) 8.30	(a) 8.43 (b) 8.25	(a) 8.38 (b) 8.38	(a) 8.41 (b) 8.40	(a) 8.45 (b) 8.41
DO mg/l	(a) 12.81 (b) —	(a) 12.88 (b) 13.38	(a) 12.80 (b) 13.34	(a) 12.89 (b) 13.01	(a) 12.11 (b) 12.02
NH_4-N mg/l	(a) 0.10 (b) 0.02	(a) 0.06 (b) 0.05	(a) 0.06 (b) 0.00	(a) 0.02 (b) 0.05	(a) 0.00 (b) 0.00
NO_2-N mg/l	(a) 0.00 (b) 0.00	(a) 0.00 (b) 0.00	(a) 0.00 (b) 0.00	(a) 0.00 (b) 0.00	(a) 0.00 (b) 0.00
NO_3-N mg/l	(a) 0.00 (b) 0.05	(a) 0.00 (b) 0.00	(a) 0.07 (b) 0.05	(a) 0.45 (b) 0.36	(a) 0.28 (b) 0.85
ORTHO PO_4 mg/l	(a) 0.02 (b) 0.00	(a) 0.00 (b) 0.00	(a) 0.02 (b) 0.00	(a) 0.00 (b) 0.00	(a) 0.00 (b) 0.00
TOTAL PO_4 mg/l	(a) 0.00 (b) 0.00	(a) 0.00 (b) 0.00	(a) 0.00 (b) 0.00	(a) 0.00 (b) 0.00	(a) 0.00 (b) 0.00
BACTERIOLOGICAL RESULTS (Surface Only)					
TOTAL COLIFORM	3	0	65	2	0
FECAL COLIFORM	1	0	52	0	0

TABLE III-34 (Concluded)

CRYSTAL LAKE WATER QUALITY INVESTIGATION
LAKE SAMPLING SUMMARY SHEET

DATE: 7/2/69 AIR TEMPERATURE: 20°C

WEATHER CONDITIONS: Partly cloudy to Sunny.

SAMPLING STATIONS

	2T1	2T2	2T3	2T4	2T5
Time	10:30	10:40	11:50	12:20	12:35
Depth ft.	(a) 0 (b) 12	(a) 0 (b) 21	(a) 0 (c) 50 (b) 25 (d) 68	(a) 0 (c) 53 (b) 26	(a) 0 (b) 28
Temp °C	(a) 17.0° (b) 16.5°	(a) 17.0° (b) 16.5°	(a) 17.0° (c) 13.0° (b) 16.5° (d) 10.0°	(a) 17.0° (c) 14.0° (b) 16.5°	(a) 17.5° (b) 16.5°
pH	(a) 8.40 (b) 8.45	(a) 8.45 (b) 8.45	(a) 8.45 (c) 8.40 (b) 8.45 (d) 8.40	(a) 8.45 (c) 8.40 (b) 8.50	(a) 8.50 (b) 8.40
DO mg/l	(a) 11.6 (b) 11.6	(a) 11.7 (b) 11.9	(a) 11.8 (c) 12.6 (b) 11.8 (d) 13.5	(a) 11.7 (c) 12.5 (b) 11.8	(a) 11.7 (b) 11.8
NH_4-N mg/l	(a) 0.00 (b) 0.00	(a) 0.00 (b) 0.00	(a) 0.00 (c) 0.00 (b) 0.00 (d) 0.00	(a) 0.00 (c) 0.00 (b) 0.00	(a) 0.00 (b) 0.00
NO_2-N mg/l	(a) 0.00	(a) 0.00	(a) 0.00	(a) 0.00	(a) 0.00
NO_3-N mg/l	(a) 0.00 (b) 0.00	(a) 0.07 (b) 0.00	(a) 0.07 (c) 0.14 (b) 0.07 (d) 0.14	(a) 0.14 (c) 0.14 (b) 0.14	(a) - (b) -
ORTHO PO_4 mg/l	(a) 0.00 (b) 0.00	(a) 0.00 (b) 0.00	(a) 0.00 (c) 0.00 (b) 0.00 (d) 0.01	(a) 0.00 (c) 0.00 (b) 0.00	(a) 0.00 (b) 0.00
BACTERIOLOGICAL RESULTS (Surface Only)					
TOTAL COLIFORM	7	0	0	0	0
FECAL COLIFORM	0	0	0	0	0

TABLE III-35

CRYSTAL LAKE WATER QUALITY INVESTIGATION

LAKE SAMPLING SUMMARY SHEET

DATE: 7/3/69		TIME: 11:45 - 12:30		
WEATHER CONDITIONS: Sunny to partly cloudy with light wind.				
AIR TEMPERATURE: 19.5° to 21.0°				
SAMPLING STATIONS				
1T1	1T2	1T3	1T4	1T5
Temp °C (a) 18.0° (d) (b) 18.0° (e) (c) (f)	(a) 18.2° (d) (b) 17.3° (e) (c) (f)	(a) 18.3° (d) (b) 17.0° (e) (c) (f)	(a) 19.0° (d) (b) 16.8° (e) (c) (f)	(a) 18.0° (d) (b) 17.5° (e) (c) 16.0° (f)
Depth ft. (a) 0 (d) (b) 5 (e) (c) (f)	(a) 0 (d) (b) 18 (e) (c) (f)	(a) 0 (d) (b) 23 (e) (c) (f)	(a) 0 (d) (b) 27 (e) (c) (f)	(a) 0 (d) (b) 15 (e) (c) 30 (f)
DO mg/1 (a) 9.3 (d) (b) (e) (c) (f)	(a) 9.3 (d) (b) 9.2 (e) (c) (f)	(a) 9.2 (d) (b) 9.4 (e) (c) (f)	(a) 9.3 (d) (b) 9.5 (e) (c) (f)	(a) 9.2 (d) (b) 9.3 (e) (c) 8.9 (f)
Secchi: Shallow	14 feet	14 feet	18 feet	16 feet

Transect (T1) taken approximately 200 yards from shore.

TABLE III-35 (Continued)

CRYSTAL LAKE WATER QUALITY INVESTIGATION

LAKE SAMPLING SUMMARY SHEET

DATE: 7/3/69 TIME: 12:45 - 2:00

WEATHER CONDITIONS: Sunny to partly cloudy with light wind.

AIR TEMPERATURE: 19.5° to 21.0°

SAMPLING STATIONS

	2T1	2T2	2T3	2T4	2T5
Temp °C	(a) 18.0° (d) (b) 17.0° (e) (c) (f)	(a) 19.0° (d) (b) 16.0° (e) (c) (f)	(a) 19.5° (d) 10.0° (b) 17.0° (e) (c) 15.0° (f)	(a) 19.5° (d) (b) 17.5° (e) (c) 13.2° (f)	(a) 20.0° (d) (b) 17.0° (e) (c) (f)
Depth ft.	(a) 0 (d) (b) 10 (e) (c) (f)	(a) 0 (d) (b) 22 (e) (c) (f)	(a) 0 (d) 70 (b) 25 (e) (c) 50 (f)	(a) 0 (d) (b) 25 (e) (c) 58 (f)	(a) 0 (d) (b) 28 (e) (c) (f)
DO mg/1	(a) 9.7 (d) (b) 9.6 (e) (c) (f)	(a) 9.4 (d) (b) 9.7 (e) (c) (f)	(a) 9.3 (d) 9.4 (b) 9.5 (e) (c) 9.3 (f)	(a) 9.3 (d) (b) 9.4 (e) (c) 9.5 (f)	(a) 9.3 (d) (b) 9.4 (e) (c) (f)
Secchi:	Shallow	17 feet	20 feet	18 feet	16 feet

TABLE III-35 (Continued)

CRYSTAL LAKE WATER QUALITY INVESTIGATION

LAKE SAMPLING SUMMARY SHEET

DATE: 7/3/69 TIME: 2:15 - 3:30

WEATHER CONDITIONS: Sunny to partly cloudy with light wind.

AIR TEMPERATURE: 19.5° to 21.0°

SAMPLING STATIONS

	3T1	3T2	3T3	3T4	3T5
Temp °C	(a) 17.5° (d) (b) 17.3° (e) (c) (f)	(a) 17.0° (d) 6.5° (b) 15.2° (e) (c) 9.6° (f)	(a) 17.0° (d) 6.2° (b) 15.2° (e) 5.8° (c) 8.5° (f)	(a) 17.9° (d) 8.7° (b) 16.2° (e) 7.0° (c) 14.7° (f)	(a) 19.0° (d) (b) 18.7° (e) (c) (f)
Depth ft.	(a) 0 (d) (b) 7 (e) (c) (f)	(a) 0 (d) 118 (b) 40 (e) (c) 80 (f)	(a) 0 (d) 120 (b) 40 (e) 165 (c) 80 (f)	(a) 0 (d) 80 (b) 40 (e) 115 (c) 50 (f)	(a) 0 (d) (b) 8 (e) (c) (f)
DO mg/l	(a) 9.8 (d) (b) (e) (c) (f)	(a) 9.6 (d) 11.0 (b) 9.6 (e) (c) 11.0 (f)	(a) 9.5 (d) 12.7 (b) 9.7 (e) 9.7 (c) 11.5 (f)	(a) 9.5 (d) 11.3 (b) 9.6 (e) 10.3 (c) - (f)	(a) 9.4 (d) (b) 9.5 (e) (c) (f)
Secchi:	Shallow	19 feet	20 feet	20 feet	Shallow

TABLE III-35 (Concluded)

CRYSTAL LAKE WATER QUALITY INVESTIGATION

LAKE SAMPLING SUMMARY SHEET

DATE: 7/3/69 TIME: 4:00 - 5:30

WEATHER CONDITIONS: Sunny to partly cloudy with light wind.

AIR TEMPERATURE: 19.5° to 21.0°

SAMPLING STATIONS

	4T1	4T2	4T3	4T4	4T5
Temp °C	(a)18.3° (d) (b)18.3° (e) (c) (f)	(a)17.0° (d) (b)16.0° (e) (c)15.5° (f)	(a)17.2° (d) 6.9° (b)15.8° (e) 5.5° (c)18.9° (f)	(a)17.0° (d) 6.3° (b)15.6° (e) 5.2° (c) 9.5° (f)	(a) 16.3°(d) (b) 15.8°(e) (c) (f)
Depth ft.	(a) 0 (d) (b) 5 (e) (c) (f)	(a) 0 (d) (b) 25 (e) (c) 52 (f)	(a) 0 (d) 120 (b) 40 (e) 168 (c) 80 (f)	(a) 0 (d) 120 (b) 40 (e) 160 (c) 80 (f)	(a) 0 (d) (b) 25 (e) (c) (f)
DO mg/1	(a) 9.8 (d) (b) (e) (c) (f)	(a) 9.5 (d) (b) 9.7 (e) (c) 9.9 (f)	(a) 9.6 (d) 9.8 (b) 9.7 (e) 9.1 (c) 11.6 (f)	(a) 9.5 (d) 11.6 (b) 9.8 (e) 10.2 (c) 11.5 (f)	(a) 9.6 (d) (b) 9.7 (e) (c) (f)
Secchi:	Shallow	24 feet	23 feet	22 feet	17 feet

TABLE III-36

CRYSTAL LAKE WATER QUALITY INVESTIGATION

LAKE SAMPLING SUMMARY SHEET

DATE: 7/25/69			TIME: 9:05 - 9:40		
WEATHER CONDITIONS: Sunny and mild with light wind in morning/strong in afternoon					
AIR TEMPERATURE: 22.0° - 22.5°					
SAMPLING STATIONS					
	1T1	1T2	1T3	1T4	1T5
Temp °C	(a) 22.3° (d) (b) (e) (c) (f)	(a) 22.3° (d) (b) 22.2° (e) (c) (f)	(a) 22.2° (d) (b) 21.5° (e) (c) (f)	(a) 22.5° (d) (b) 22.1° (e) (c) (f)	(a) 22.5° (d) (b) 22.0° (e) (c) (f)
Depth ft.	(a) 7 (d) (b) (e) (c) (f)	(a) 0 (d) (b) 18 (e) (c) (f)	(a) 0 (d) (b) 22 (e) (c) (f)	(a) 0 (d) (b) 24 (e) (c) (f)	(a) 0 (d) (b) 23 (e) (c) (f)
DO mg/1	(a) (d) (b) (e) (c) (f)	(a) (d) (b) (e) (c) (f)	(a) (d) (b) (e) (c) (f)	(a) (d) (b) (e) (c) (f)	(a) (d) (b) (e) (c) (f)
Secchi:	Shallow (7 ft.)	18 feet	21 feet	20 feet	16 feet

TABLE III-36 (Continued)

CRYSTAL LAKE WATER QUALITY INVESTIGATION

LAKE SAMPLING SUMMARY SHEET

DATE: 7/25/69		TIME: 10:00 - 11:20		
WEATHER CONDITIONS: Sunny and mild with light wind in morning/strong in afternoon				
AIR TEMPERATURE: 20.5° - 22.0°				
SAMPLING STATIONS				
2T1	2T2	2T3	2T4	2T5
Temp °C (a) 22.2° (d) (b) (e) (c) (f)	(a) 22.1° (d) (b) 20.0° (e) (c) 13.2° (f)	(a) 22.0° (d) (b) 20.2° (e) (c) 9.9° (f)	(a) 22.0° (d) (b) 19.9° (e) (c) 14.9° (f)	(a) 22.1° (d) (b) 19.9° (e) (c) (f)
Depth ft. (a) 9 (d) (b) (e) (c) (f)	(a) 0 (d) (b) 30 (e) (c) 62 (f)	(a) 0 (d) (b) 30 (e) (c) 68 (f)	(a) 0 (d) (b) 30 (e) (c) 54 (f)	(a) 0 (d) (b) 33 (e) (c) (f)
DO mg/1 (a) (d) (b) (e) (c) (f)	(a) (d) (b) (e) (c) (f)	(a) (d) (b) (e) (c) (f)	(a) (d) (b) (e) (c) (f)	(a) (d) (b) (e) (c) (f)
Secchi: Shallow (9 ft.)	26 feet	25 feet	23 feet	22 feet

TABLE III-36 (Continued)

CRYSTAL LAKE WATER QUALITY INVESTIGATION

LAKE SAMPLING SUMMARY SHEET

Supplementary Temperature Information
at Selected Stations

DATE: 7/25/69 TIME: 10:00 - 11:20

AIR TEMPERATURE: 20.5° - 22.0°

SAMPLING STATIONS					
2T2		2T3		2T4	
Depth ft.	Temp °C	Depth ft.	Temp °C	Depth ft.	Temp °C
0'	21.1°	0'	22.0°	0'	22.0°
20'	21.8°	20'	21.7°	20'	21.7°
30'	20.0°	30'	20.2°	30'	19.9°
40'	17.8°	40'	18.0°	40'	18.3°
50'	15.5°	50'	15.7°	50'	17.1°
62'	13.2°	60'	11.8°	54'	14.9°
		68'	9.9°		

TABLE III-36 (Concluded)

CRYSTAL LAKE WATER QUALITY INVESTIGATION

LAKE SAMPLING SUMMARY SHEET

DATE: 7/25/69			TIME: 11:35 - 12:30		
WEATHER CONDITIONS: Sunny and mild with light wind in morning/strong in afternoon					
AIR TEMPERATURE: 21.1° - 23.0°					
SAMPLING STATIONS					
	3T1	3T2	3T3	3T4	3T5
Temp °C	(a) (d) (b) 21.9° (e) (c) (f)	(a) 22.2° (d) 7.5° (b) 17.6° (e) 6.1° (c) 10.1° (f)	(a) 21.7° (d) 6.2° (b) 17.0° (e) 5.2° (c) 19.2° (f)	(a) 21.9° (d) 9.0° (b) 17.5° (e) (c) 9.3° (f)	(a) 22.3° (d) (b) (e) (c) (f)
Depth ft.	(a) 0 (d) (b) 26 (e) (c) (f)	(a) 0 (d) 120 (b) 40 (e) 150 (c) 80 (f)	(a) 0 (d) 120 (b) 40 (e) 164 (c) 80 (f)	(a) 0 (d) 95 (b) 40 (e) (c) 80 (f)	(a) 5 (d) (b) (e) (c) (f)
DO mg/1	(a) (d) (b) (e) (c) (f)	(a) (d) (b) (e) (c) (f)	(a) (d) (b) (e) (c) (f)	(a) (d) (b) (e) (c) (f)	(a) (d) (b) (e) (c) (f)
Secchi:	23 feet	26 feet	24 feet	26 feet	shallow (5 ft.)

TABLE III-37

CRYSTAL LAKE WATER QUALITY INVESTIGATION

LAKE SAMPLING SUMMARY SHEET

DATE: 8/1/69			TIME: 3:50 - 4:20		
WEATHER CONDITIONS: Sunny to partly cloudy with strong wind from the west.					
AIR TEMPERATURE: Probe broken					
SAMPLING STATIONS					
	1T1	1T2	1T3	1T4	1T5
Probe broken — Temp °C	(a) (d) (b) (e) (c) (f)	(a) (d) (b) (e) (c) (f)	(a) (d) (b) (e) (c) (f)	(a) (d) (b) (e) (c) (f)	(a) (d) (b) (e) (c) (f)
Depth ft.	(a) - (d) (b) 6 (e) (c) (f)	(a) 0 (d) (b) 16 (e) (c) (f)	(a) 0 (d) (b) 20 (e) (c) (f)	(a) 0 (d) (b) 21 (e) (c) (f)	(a) 0 (d) (b) 15 (e) (c) (f)
DO mg/1	(a) - (d) (b) 8.48 (e) (c) (f)	(a) 8.48 (d) (b) 8.32 (e) (c) (f)	(a) 8.22 (d) (b) 8.43 (e) (c) (f)	(a) 8.22 (d) (b) 8.42 (e) (c) (f)	(a) 8.32 (d) (b) 8.64 (e) (c) (f)
Secchi:	Shallow (6 ft.)	16 feet	16 feet	13 feet	Shallow (15 feet)

TABLE III-37 (Continued)

CRYSTAL LAKE WATER QUALITY INVESTIGATION

LAKE SAMPLING SUMMARY SHEET

	DATE: 8/1/69			TIME: 2:40 - 3:35		
	WEATHER CONDITIONS: Partly cloudy to sunny.					
	AIR TEMPERATURE: 20.3°					
	SAMPLING STATIONS					
		2T1	2T2	2T3	2 T4	2T5
Probe Broken	Temp °C	(a) 21.7° (d) (b) 21.5° (e) (c) (f)	(a) (d) (b) (e) (c) (f)	(a) (d) (b) (e) (c) (f)	(a) (d) (b) (e) (c) (f)	(a) (d) (b) (e) (c) (f)
	Depth ft.	(a) 0 (d) (b) 9 (e) (c) (f)	(a) 0 (d) (b) 22 (e) (c) (f)	(a) 0 (d) (b) 40 (e) (c) 65 (f)	(a) 0 (d) (b) 25 (e) (c) 35 (f)	(a) (d) (b) 3 (e) (c) (f)
	DO mg/1	(a) - (d) (b) 8.44 (e) (c) (f)	(a) 8.22 (d) (b) 8.33 (e) (c) (f)	(a) 8.28 (d) (b) 8.64 (e) (c) 10.26 (f)	(a) 8.44 (d) (b) 8.33 (e) (c) 8.52 (f)	(a) - (d) (b) 8.42 (e) (c) (f)
	Secchi:	Shallow (9 ft.)	20 feet	19 feet	19 feet	Shallow (3 feet)

TABLE III-37 (Continued)

CRYSTAL LAKE WATER QUALITY INVESTIGATION

LAKE SAMPLING SUMMARY SHEET

DATE: 8/1/69 TIME: 12:20 - 2:25

WEATHER CONDITIONS: Partly cloudy

AIR TEMPERATURE: 18.7° - 20.1°

SAMPLING STATIONS

	3T1	3T2	3T3	3T4	3T5
Temp °C	(a) 21.3° (d) (b) 21.0° (e) (c) (f)	(a) 21.0° (d) 6.0° (b) 19.8° (e) 5.1° (c) 9.5° (f)	(a) 20.7° (d) 6.0° (b) 19.9° (e) 5.3° (c) 9.0° (f)	(a) 20.9° (d) 7.7° (b) 19.8° (e) (c) 8.3° (f)	(a) - (d) (b) 21.4° (e) (c) (f)
Depth ft.	(a) 0 (d) (b) 19 (e) (c) (f)	(a) 0 (d) 120 (b) 40 (e) 159 (c) 80 (f)	(a) 0 (d) 120 (b) 40 (e) 165 (c) 80 (f)	(a) 0 (d) 100 (b) 40 (e) (c) 80 (f)	(a) 0 (d) (b) 3 (e) (c) (f)
DO mg/l	(a) 8.68 (d) (b) 8.64 (e) (c) (f)	(a) 8.43 (d) 10.25 (b) 8.47 (e) 11.18 (c) 11.17 (f)	(a) 8.53 (d) 10.45 (b) 8.74 (e) 10.76 (c) 10.96 (f)	(a) 8.53 (d) 10.36 (b) 8.74 (e) (c) 10.86 (f)	(a) - (d) (b) 8.80 (e) (c) (f)
Secchi:	Shallow (19 ft.)	22 feet	23 feet	23 feet	Shallow (3 feet)

TABLE III-37 (Continued)

CRYSTAL LAKE WATER QUALITY INVESTIGATION

LAKE SAMPLING SUMMARY SHEET

Supplementary Temperature Information
at Selected Stations

DATE: 8/1/69 TIME: 12:20 - 2:25

AIR TEMPERATURE:

19.7°		20.2°		18.7°	
SAMPLING STATIONS					
3T2		3T3		3T4	
Depth ft.	Temp °C	Depth ft.	Temp °C	Depth ft.	Temp °C
0'	21.0°	0'	20.7°	0'	20.9°
20'	20.8°	20'	20.7°	20'	20.8°
30'	20.6°	30'	20.5°	30'	20.6°
40'	19.8°	40'	19.9°	40'	19.8°
50'	14.3°	50'	13.9°	50'	16.2°
60'	11.8°	60'	12.8°	60'	12.1°
70'	10.2°	70'	10.9°	70'	10.1°
80'	9.5°	80'	9.0°	80'	8.3°
90'	7.9°	90'	7.9°	90'	7.9°
100'	6.9°	100'	6.9°	100'	7.7°
120'	6.0°	120'	6.0°		
159'	5.1°	165'	5.3°		

Air Temp: 3T1 - 20.1°
3T5 - 19.3°

TABLE III-37 (Continued)

CRYSTAL LAKE WATER QUALITY INVESTIGATION

LAKE SAMPLING SUMMARY SHEET

DATE: 8/1/69			TIME: 9:25 - 11:55		
WEATHER CONDITIONS: Partly cloudy to sunny - strong wind from west.					
AIR TEMPERATURE: 17.7° - 20.2°					
SAMPLING STATIONS					
	4T1	4T2	4T3	4T4	4T5
Temp °C	(a) 20.4° (d) (b) 20.1° (e) (c) (f)	(a) 20.6° (d) 9.6° (b) (e) (c) 14.1° (f)	(a) 20.3° (d) 6.0° (b) 17.9° (e) 5.0° (c) 9.0° (f)	(a) 20.2° (d) 6.0° (b) 18.3° (e) 5.1° (c) 8.2° (f)	(a) 20.4° (d) (b) 20.3° (e) (c) (f)
Depth ft.	(a) 0 (d) (b) 4 (e) (c) (f)	(a) 0 (d) 92 (b) 25 (e) (c) 50 (f)	(a) 0 (d) 120 (b) 40 (e) 163 (c) 80 (f)	(a) 0 (d) 120 (b) 40 (e) 155 (c) 80 (f)	(a) 0 (d) (b) 14 (e) (c) (f)
DO mg/l	(a) - (d) (b) 8.83 (e) (c) (f)	(a) 8.83 (d) 10.76 (b) 8.83 (e) (c) 10.88 (f)	(a) 8.48 (d) 10.58 (b) 9.75 (e) 11.17 (c) 11.06 (f)	(a) 8.54 (d) 10.38 (b) 8.64 (e) 10.35 (c) 11.08 (f)	(a) 8.13 (d) (b) 8.73 (e) (c) (f)
Secchi:	Shallow (4 ft.)	24 feet	24 feet	23 feet	Shallow (14 ft.)

TABLE III-37 (Concluded)

CRYSTAL LAKE WATER QUALITY INVESTIGATION

LAKE SAMPLING SUMMARY SHEET

Supplementary Temperature Information
at Selected Stations

DATE: 8/1/69 TIME: 9:25 - 11:55

AIR TEMPERATURE:

19.0° 19.0° 17.7°

SAMPLING STATIONS					
4T2		4T3		4T4	
Depth ft.	Temp °C	Depth ft.	Temp °C	Depth ft.	Temp °C
0'	20.6°	0'	20.3°	0'	20.2°
20'	20.5°	20'	20.2°	20'	20.1°
30'	20.1°	30'	20.1°	30'	19.9°
40'	16.2°	40'	17.9°	40'	18.3°
50'	14.1°	50'	14.2°	50'	15.8°
60'	11.6°	60'	12.4°	60'	12.4°
70'	10.9°	70'	10.7°	70'	9.8°
80'	10.1°	80'	9.0°	80'	8.2°
92'	9.6°	90'	8.0°	90'	7.2°
		100'	7.0°	100'	6.9°
		120'	6.0°	120'	6.0°
		163'	5.0°	155'	5.1°

Air Temp: 4T1 - 20.2°
4T5 - 18.0°

TABLE III-38

CRYSTAL LAKE WATER QUALITY INVESTIGATION

LAKE SAMPLING SUMMARY SHEET

DATE: 8/19/69 TIME: 3:15 - 3:55

WEATHER CONDITIONS: Partly cloudy, strong wind from N.E., lake rough, secchi readings difficult to make.

AIR TEMPERATURE: 21.0° 21.2° 21.3° 21.4° 21.2°

SAMPLING STATIONS

	1T1	1T2	1T3	1T4	1T5
Temp °C	(a)21.0° (d) (b) (e) (c) (f)	(a)25.0° (d) (b)24.9° (e) (c) (f)	(a)24.5° (d) (b)24.7° (e) (c) (f)	(a)24.5° (d) (b)24.7° (e) (c) (f)	(a)24.7° (d) (b) (e) (c) (f)
Depth ft.	(a) 4 (d) (b) (e) (c) (f)	(a) 0 (d) (b) 15 (e) (c) (f)	(a) 0 (d) (b) 19 (e) (c) (f)	(a) 0 (d) (b) 21 (e) (c) (f)	(a) 3 (d) (b) (e) (c) (f)
DO mg/1	(a) 8.65 (d) (b) (e) (c) (f)	(a) 8.55 (d) (b) 8.35 (e) (c) (f)	(a)8.30 (d) (b)8.55 (e) (c) (f)	(a) 8.25 (d) (b) 8.30 (e) (c) (f)	(a) 8.25 (d) (b) (e) (c) (f)
Secchi:	Shallow	10 feet	13 feet	12 feet	Shallow

TABLE III-38 (Continued)

CRYSTAL LAKE WATER QUALITY INVESTIGATION

LAKE SAMPLING SUMMARY SHEET

DATE: 8/19/69 TIME: 2:15 - 2:55

WEATHER CONDITIONS: Partly cloudy, strong wind from N.E., lake rough, secchi readings difficult to make.

AIR TEMPERATURE: 20.5° 20.5° 20.0° 20.3° 20.0°

SAMPLING STATIONS

	2T1	2T2	2T3	2T4	2T5
Temp °C	(a) 24.8° (d) (b) (e) (c) (f)	(a) 24.8° (d) (b) 24.7° (e) (c) (f)	(a) 24.3° (d) (b) 22.8° (e) (c) 13.0° (f)	(a) 24.2° (d) (b) 23.1° (e) (c) (f)	(a) 24.7° (d) (b) (e) (c) (f)
Depth ft.	(a) 10 (d) (b) (e) (c) (f)	(a) 0 (d) (b) 22 (e) (c) (f)	(a) 0 (d) (b) 40 (e) (c) 67 (f)	(a) 0 (d) (b) 38 (e) (c) (f)	(a) 3 (d) (b) (e) (c) (f)
DO mg/1	(a) 8.35 (d) (b) (e) (c) (f)	(a) 8.25 (d) (b) 8.15 (e) (c) (f)	(a) 8.15 (d) (b) 8.40 (e) (c) 9.50 (f)	(a) 8.15 (d) (b) 8.65 (e) (c) (f)	(a) 8.25 (d) (b) (e) (c) (f)
Secchi:	Shallow	12 feet	14 feet	13 feet	Shallow

TABLE III-38 (Continued)

CRYSTAL LAKE WATER QUALITY INVESTIGATION

LAKE SAMPLING SUMMARY SHEET

Supplementary Temperature Information
at Selected Stations

DATE: 8/19/69 TIME: 2:15 - 2:55

AIR TEMPERATURE: 20.0°

SAMPLING STATION	
2T3	
Depth ft.	Temp °C
0'	24.3°
20'	24.3°
30'	23.9°
40'	22.8°
50'	19.2°
55'	17.1°
60'	15.4°
67'	13.0°

TABLE III-38 (Continued)

CRYSTAL LAKE WATER QUALITY INVESTIGATION

LAKE SAMPLING SUMMARY SHEET

DATE: 8/19/69	TIME: 12:15 - 2:00			
WEATHER CONDITIONS: Partly cloudy, strong wind from N.E., lake rough, secchi readings difficult to make.				
AIR TEMPERATURE: 21.2°	19.9°	21.8°	20.3°	20.7°
SAMPLING STATIONS				
3T1	3T2	3T3	3T4	3T5
Temp °C (a) 24.2° (d) (b) (e) (c) (f)	(a) 24.0° (d) 9.3° (b) 23.4° (e) 9.0° (c) 12.3° (f)	(a) 24.1° (d) 9.3° (b) 23.5° (e) 8.8° (c) 12.0° (f)	(a) 24.3° (d) 10.1° (b) 23.4° (e) 9.2° (c) 12.8° (f)	(a) 23.9° (d) (b) (e) (c) (f)
Depth ft. (a) 7 (d) (b) (e) (c) (f)	(a) 0 (d) 110 (b) 40 (e) 139 (c) 80 (f)	(a) 0 (d) 120 (b) 40 (e) 159 (c) 80 (f)	(a) 0 (d) 100 (b) 40 (e) 135 (c) 80 (f)	(a) 5 (d) (b) (e) (c) (f)
DO mg/1 (a) 8.40 (d) (b) (e) (c) (f)	(a) 8.15 (d) 10.00 (b) 8.15 (e) 9.35 (c) 10.55 (f)	(a) 8.25 (d) 10.15 (b) 8.35 (e) 7.15 (c) 10.65 (f)	(a) 8.15 (d) 10.25 (b) 8.40 (e) 8.65 (c) 10.45 (f)	(a) 8.40 (d) (b) (e) (c) (f)
Secchi: Shallow	14 feet	13 feet	13 feet	Shallow

TABLE III-38 (Continued)

CRYSTAL LAKE WATER QUALITY INVESTIGATION

LAKE SAMPLING SUMMARY SHEET

Supplementary Temperature Information
at Selected Stations

DATE: 8/19/69 TIME: 12:15 - 2:00

AIR TEMPERATURE:
19.9° 21.8° 20.3°

SAMPLING STATIONS					
3T2		3T3		3T4	
Depth ft.	Temp °C	Depth ft.	Temp °C	Depth ft.	Temp °C
0'	24.0°	0'	24.1°	0'	24.3°
20'	24.0°	20'	24.0°	20'	24.1°
30'	23.5°	30'	23.9°	30'	23.9°
40'	23.4°	40'	23.5°	40'	23.4°
50'	19.5°	50'	20.3°	50'	19.9°
55'	16.4°	55'	16.9°	60'	15.2°
60'	15.2°	60'	15.3°	70'	13.8°
70'	13.5°	70'	13.7°	80'	12.8°
80'	12.3°	80'	12.0°	90'	11.0°
90'	11.2°	90'	10.9°	100'	10.1°
110'	9.3°	100'	10.3°	135'	9.2°
139'	9.0°	120'	9.3°		
		140'	8.9°		
		159'	8.8°		

TABLE III-38 (Continued)

CRYSTAL LAKE WATER QUALITY INVESTIGATION

LAKE SAMPLING SUMMARY SHEET

DATE: 8/19/69		TIME: 10:20 - 12:00			
WEATHER CONDITIONS:	Partly cloudy, strong wind from N.E., lake rough, secchi readings difficult to make.				
AIR TEMPERATURE:	21.3°	21.3°	21.8°	21.0°	23.0°
SAMPLING STATIONS					
	4T1	4T2	4T3	4T4	4T5
Temp °C	(a) 23.6° (d) (b) (e) (c) (f)	(a) 24.3° (d) (b) 24.1° (e) (c) 16.5° (f)	(a) 24.3° (d) 9.1° (b) 24.1° (e) 8.1° (c) 12.2° (f)	(a) 23.9° (d) 9.0° (b) 23.8° (e) 8.0° (c) 11.9° (f)	(a) 22.7° (d) (b) 22.8° (e) (c) (f)
Depth ft.	(a) 4 (d) (b) (e) (c) (f)	(a) 0 (d) (b) 30 (e) (c) 63 (f)	(a) 0 (d) 120 (b) 40 (e) 164 (c) 80 (f)	(a) 0 (d) 120 (b) 40 (e) 160 (c) 80 (f)	(a) 0 (d) (b) 24 (e) (c) (f)
DO mg/1	(a) 8.25 (d) (b) (e) (c) (f)	(a) 8.25 (d) (b) 8.40 (e) (c) 11.15 (f)	(a) 8.25 (d) 9.25 (b) 8.25 (e) 6.10 (c) 10.55 (f)	(a) 8.25 (d) 10.05 (b) 8.30 (e) 10.35 (c) - (f)	(a) 8.25 (d) (b) 8.65 (e) (c) (f)
Secchi:	Shallow	15 feet	15 feet	17 feet	16 feet

TABLE III-38 (Concluded)

CRYSTAL LAKE WATER QUALITY INVESTIGATION

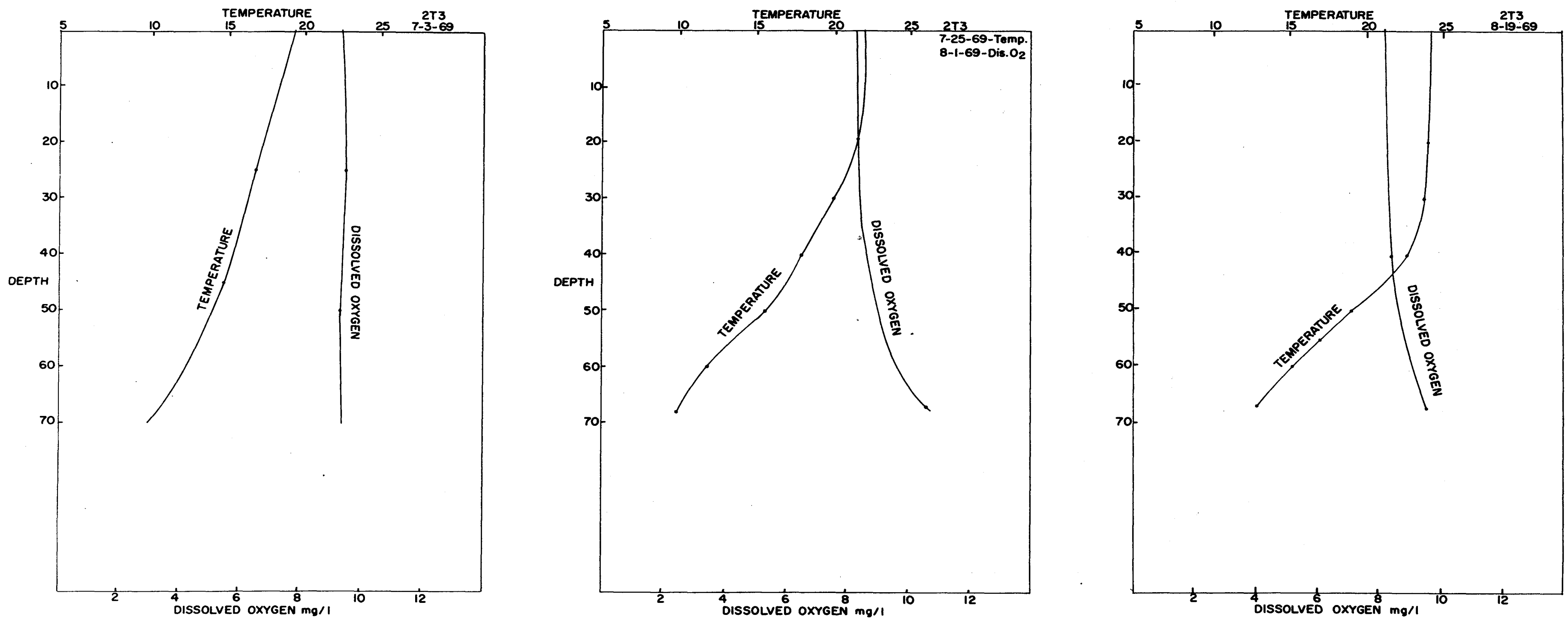
LAKE SAMPLING SUMMARY SHEET

Supplementary Temperature Information
at Selected Stations

DATE: 8/19/69 TIME: 10:20 - 12:00

AIR TEMPERATURE:
21.3° 21.8° 21.0°

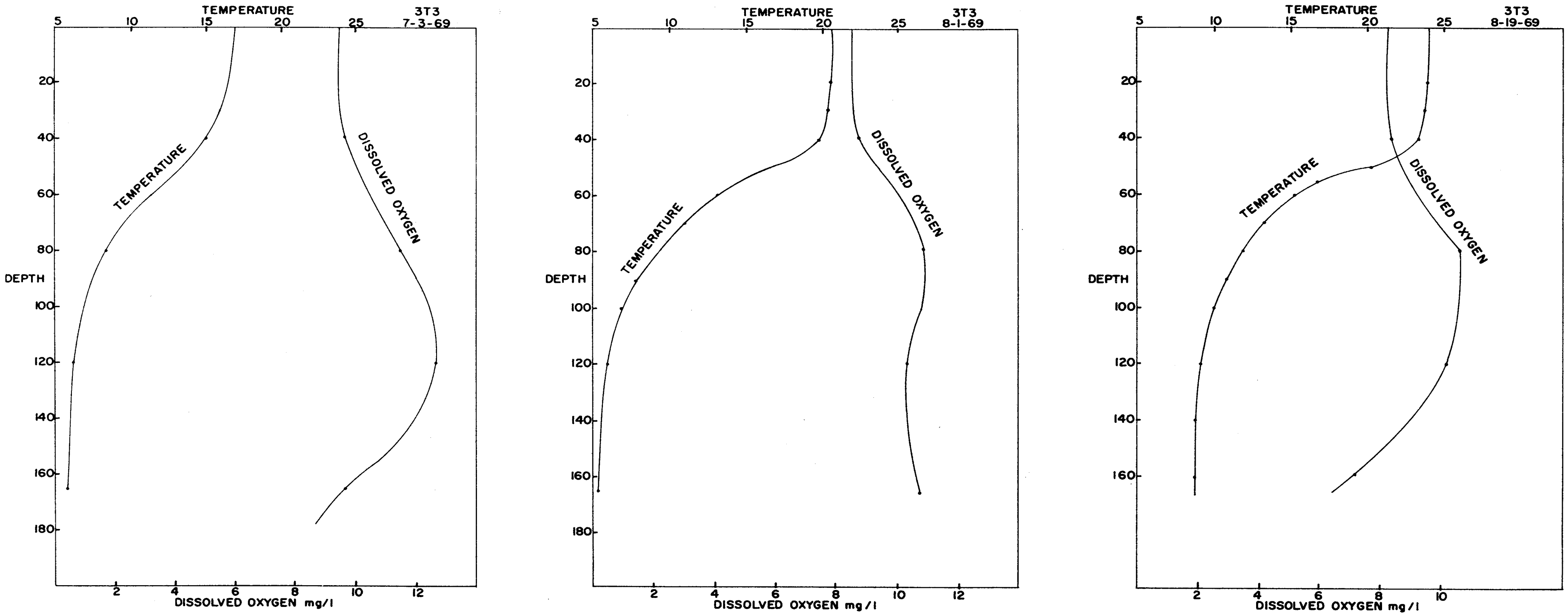
SAMPLING STATIONS					
4T2		4T3		4T4	
Depth ft.	Temp °C	Depth ft.	Temp °C	Depth ft.	Temp °C
0'	24.3°	0'	24.3°	0'	23.9°
20'	24.3°	20'	24.4°	20'	23.9°
30'	24.1°	30'	24.3°	30'	23.9°
40'	23.5°	40'	24.1°	40'	23.8°
50'	20.1°	50'	21.6°	50'	21.9°
63'	16.5°	55'	17.8°	55'	18.1°
		60'	16.1°	60'	15.3°
		70'	13.7°	70'	13.5°
		80'	12.2°	80'	11.9°
		90'	11.2°	90'	10.8°
		100'	10.3°	100'	9.9°
		120'	9.1°	120'	9.0°
		140'	8.5°	140'	8.2°
		164'	8.1°	160'	8.0°



VERTICAL TEMPERATURE AND DISSOLVED OXYGEN PROFILES AT STATION 2T3

CRYSTAL LAKE, MICHIGAN

Figure III-3



VERTICAL TEMPERATURE AND DISSOLVED OXYGEN PROFILES AT STATION 3T3

CRYSTAL LAKE, MICHIGAN

Figure III-4

TABLE III-39

AUGUST 14, 1969 LAKE SAMPLING SUMMARY

Sampling Station	Time of Collection	Water Temp °C	Air Temp °C	Phosphate (Unfiltered) µg/l of P as PO_4^-	
				Ortho	Total Dissolved
1T2	9:32 AM	24.5	27	8.8	15.0
1T3	9:35 AM	24.5		8.3	11.3
1T4	9:40 AM	24.5		5.3	17.5
2T2	10:10 AM	24.0		5.0	11.3
2T4	10:03 AM	24.0		5.3	16.3
3T2	10:38 AM	23.2	25.2	9.5	11.3
3T4	10:25 AM	23.2		7.5	11.3
4T3 (Shallow)	10:50 AM	23.0		6.7	12.5
4T3 (Deep)	10:55 AM	16.8		7.5	11.3
Cold Creek	11:50 AM			33.8	60.0

Organized Bathing Beach Areas

A special water quality sampling effort was directed toward the organized bathing beach areas of Crystal Lake on July 31, 1969. Generally four samples were collected at each location, from left to right along the beach facing the lake, at a depth of 8 inches to 10 inches below the water surface. The results of this survey are presented in Table III-40. While elevated coliform levels were observed at some locations, none were above the upper allowable coliform level for total body contact.

Interest existed as to the water quality along the stream passing through the Crystal Beach Resort area on the south shore of Crystal Lake, and designated as W-1 in the routine weekly sampling of all the tributary streams. Figure III-5 shows the location of the seven sampling stations occupied first on June 27, 1969, and then on August 1, 1969. The total and fecal coliform levels observed at these stations at these times are presented in Table III-41. It is apparent that high total coliform levels were observed on August 1 at stations 1 and 2.

TABLE III-40

SAMPLING OF CRYSTAL LAKE WATER IN ORGANIZED BATHING BEACH AREAS
(July 31, 1969)

Four samples were collected from left to right along the beach area facing the lake at a depth of 8 inches to 10 inches below water surface.

Sample Location	Total Coliform/100 ml	Fecal Coliform/100 ml
Beulah Beach		
#1	80	0
#2	33	0
#3	200	0
#4	63	0
Girl's Camp		
#1	67	0
#2	40	0
#3	28	0
#4	17	0
Christian Assembly		
#1	22	0
#2	11	0
#3	0	0
#4	3	0
Crystal Beach Resort		
#1	690	0
#2	620	0
#3	150	0
#4	710	0
7th Street		
#1	8	0
#2	11	0
#3	22	0
#4	6	0
Congregational Assembly		
#1	6	0
#2	3	0
#3	0	0
#4	3	0
Chimney Corners		
#1	61	0
#2	44	1
#3	30	2
#4	40	1

TABLE III-41

CRYSTAL BEACH RESORT AREA SPECIAL STUDY

Sampling Station Number	June 27, 1969		August 1, 1969	
	Total Coliform/100 ml	Fecal Coliform/100 ml	Total Coliform/100 ml	Fecal Coliform/100 ml
1	TNC	86	>1000	10
2	TNC	80	890	16
3	TNC	12	580	35
4	TNC	48	450	89
5	TNC	18	350	0
6			150	7
7			350	0

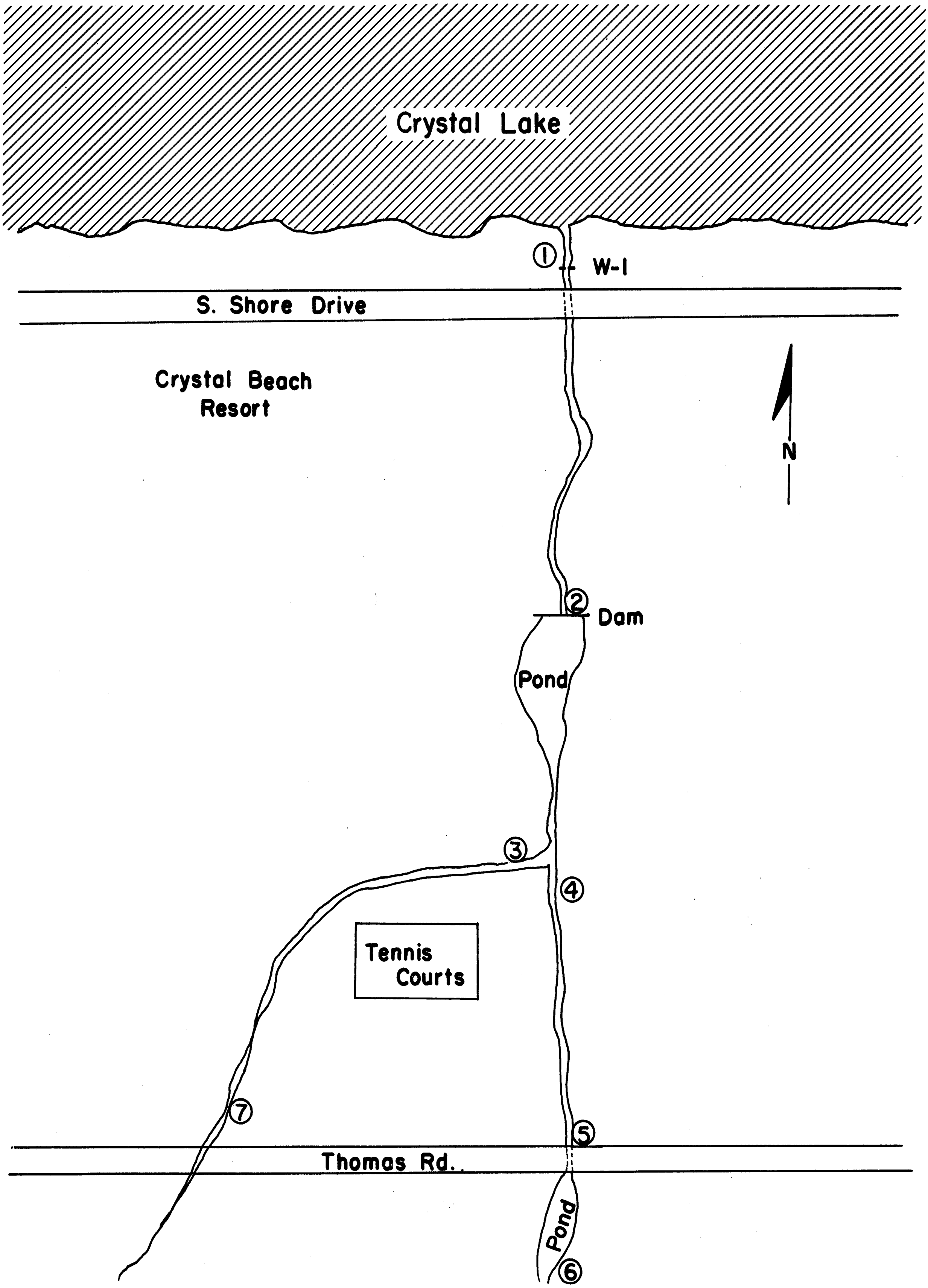

Crystal Lake
①
W-1
S. Shore Drive
Crystal Beach
Resort
N
②
Dam
Pond
③
④
Tennis
Courts
⑦
⑤
Thomas Rd.
Pond
⑥

Figure III-5

Well Water Quality Evaluation

A special effort was made during the week of July 13 to conduct a voluntary well water testing clinic by members of the survey team. Residents of the area were given the opportunity to pick up sterile containers on July 14 at stations located at both the east and west end of the lake, collect their own well water sample on the morning of July 15, and return these samples to the same collection stations for immediate processing at the field station laboratory. The laboratory tests included total and fecal coliform evaluation and determination of the nitrate level.

The response was enthusiastic with 165 separate well water samples tested in a two-day period. Of these samples, approximately 10% showed positive total coliform results during this first analysis. Members of the survey team personally visited each home having a positive result and collected a second sample, rather than relying on the homeowner to do the sampling. As a result of this followup and resampling, all of the samples previously positive showed negative, suggesting that contamination may have been introduced during the initial sample collection by the individual homeowner.

In addition to the examination of the well water for the presence of coliform bacteria, the same samples were tested for nitrogen in the form of nitrate compounds. A simple spot test was used to screen all samples for the presence of nitrates as referenced in Appendix B. The test is based on the fact that a few drops of nitrate bearing water will give a distinct blue color after addition of several drops of a sulfuric acid solution. Generally, the test is detectable to 0.5 mg/l NO_3 as N; the intensity and rate of color development is related to the concentration of nitrate in the sample. Samples found with high concentrations of nitrates were further tested by the chromotropic acid technique as described in Appendix B.

Of 165 well water samples tested, 43 were positive with the spot test. Twenty-two of the positive samples had concentrations greater than 2 mg/l and six samples had concentrations greater than 4 mg/l. One sample exceeded the U. S. Public Health Service drinking water standard of 10 mg/l. Nitrates were found in equal proportions in water samples taken from all sides of Crystal Lake, but a significantly higher percentage of the north shore samples had nitrate concentrations greater than 2 mg/l. All samples found with nitrate concentrations exceeding 4 mg/l were taken from wells on the north shore of Crystal Lake. Generally, the positive results were distributed between the north and south shore as follows:

26 positive out of 80 samples - south shore

18 positive out of 44 samples - north shore

11 greater than 2 mg/l out of 80 samples - south shore

11 greater than 2 mg/l out of 43 samples - north shore

WELL WATER NITRATE STUDY

Following the major well water survey of the week of July 13, one member of the survey team did additional evaluation of the nitrate content of well water through August 11. The north shore of Crystal Lake was selected for this followup since it did show a much higher percentage of significant nitrate content in well waters than did other areas. Generally, sampling was started at those addresses which had high (>1 mg/l) NO_3 content indicated by the spot test during the main well water survey, with sampling then proceeding in both directions from this starting point until the nitrate content decreased below 1 mg/l. In addition, wells were selected which were regularly spaced along the north shore and around streams showing a high nitrate content. The results of this effort are presented in Table III-42. Those areas having high well water nitrate levels are apparent from the tabulation.

Biological Observations

A series of biological observations were made as a complement to the numerous physical, chemical, and bacteriological observations presented elsewhere in this report. Generally, these observations consisted of a description of the aquatic plant growth observed along the shore line and in the outlet channel and Cold Creek; results of two separate bottom sampling efforts, one on August 15, 1969, and the other on September 1, 1969; results of a single plankton sampling effort on August 16, 1969; and results of the collection and identification of macroscopic algae at 11 near-shore sites on August 27, 1969.

AQUATIC PLANT GROWTH IN CRYSTAL LAKE

Crystal Lake is a typical oligotrophic lake in terms of aquatic plant growth with the lake observed to be very infertile with respect to aquatic plants. Bulrish (Scirpus) was found to be the dominant erect and emergent aquatic plant. Growths of this genus were found to exist along the southeast shore line and to a large extent between Railroad Point and the village of Beulah. Smaller growths of this genera were also observed along the southwestern and western shore lines. Occasionally, species belonging to the order Equisitales were observed among the bulrush, but not to any great abundance.

Among the plants submerged beneath the water surface, Chara, Water Star Grass (Heteranthera dubia), and curly-leafed pondweed (Potamogeton crispus) were the three most common. Chara and Water Star Grass were observed at different locations along the shore line. Large beds of Chara and some Potamogeton were found in the area where Cold Creek discharges into Crystal Lake at the village of Beulah.

TABLE III-42

WELL WATER NITRATE SURVEY DATA, NORTH SHORE
(All addresses are on North Crystal Drive unless otherwise indicated)

Address	mg/l NO_3-N
1602 M-22	< 1*
Weir 5 (2627 North Crystal Drive) 0 - .67 mg/l NH_4, 0 - .38 mg/l NO_3	
2684	0
2906	0
2940	< 1
2992	4.20**
3018	~ 1
3020	1.4
3050	6.75
3076	2.0
3118	4.75
3128	2.35
3138	3.45
3148	2.80
3169	0
3171	0
3187	0
3203	2.60
3244	< 1
3280	2.15
3293	4.70
3297	0
3300	0
3360	0
3598	0
Weir 6 (3600 North Crystal Drive) .05 - .96 NH_4, .69 - 2.2 NO_3	
3709	0
3895	0
Weir 7 (3901 North Crystal Drive) .04 - .60 NH_4, .13 - .65 NO_3	
3901	< 1
3905	0

*All values 0, < 1 , ~ 1 determined by negative spot test, no color until after one minute, some light color before 1 minute, respectively.

**All such values rounded to nearest .05 mg/l and determined by chromotropic acid test.

TABLE III-42 (Continued)

Address	mg/1 NO_3-N	
3917	< 1	
3925	0	
4035	1.85	
4053	2.40	
4060	~ 1	
4077	4.10	
4081	3.65	
4141	4.75	
Glen Rhoda (4141 North Crystal Drive)		0 - .74 NH_4, 1.6 - 2.56 NO_3
4174	2.25	
4248	< 1	
4271	~ 1	
4398	0	
4482	0	
5089	0	
5100	0	
5230	< 1	
5348	< 1	
5485	< 1	
5575	< 1	
5709	< 1	
2061 Warren Road	0	
5867	1.2	
6037	~ 1	
6084	0	
6087	0	
6088	0	
6091	2.4	
6112	< 1	
Weir 8 (6200 at Nichols Road)		.12 - .74 NH_4, 2.3 - 5.4 NO_3
1719 Nichols Road	3.0	
1722 Nichols Road	0	
1732 Nichols Road	0	
1742 Nichols Road	0	
1761 Nichols Road	3.85	
1801 Nichols Road	2.90	
1825 Nichols Road	1.70	
6231	1.80	
6243	4.10	
6263	< 1	
6681	2.0	

TABLE III-42 (Concluded)

Address	mg/l NO_3-N	
Weir 9 (6709 North Crystal Drive)		0 - .69 NH_4, 3.40 - 4.48 NO_3
Weir 10 (6863 North Crystal Drive) at Harris Road		0 - .72 NH_4, 1.44 - 1.96 NO_3
6863	1.65	
6893	0	
7219	0	
Pipe 1 (7230 North Crystal Drive)		.03 - .71 NH_4, 1.49 - 2.45 NO_3
7270	4.20	
7271	2.60	
Weir 12 (7281 North Crystal Drive)		0 - .67 NH_4, 1.48 - 2.6 NO_3
7290	6.0	
7390	< 1	
7402	2.55	
7430	6.25	
7448	3.45	
7454	3.80	
Weir 11 (7468 North Crystal Drive)		0 - .76 NH_4, 1.9 - 3.2 NO_3
7468	14.5	
7482	10.0	
7512	3.40	
7510	0	
7538	3.10	
7542	2.60	
7546	1.75	
Pipe 2 (7546 North Crystal Drive)		0 - .63 NH_4, .7 - 1.4 NO_3
7272	0	

Cold Creek itself was observed to be quite abundant in aquatic growth with Potamogeton being the most common type of growth. Duck Weed (lemna) was found to be floating on the water surface near the shore at the point where Cold Creek discharges into the lake.

It was noted that the outlet from Crystal Lake was relatively free from all types of growth in early May but had an abundant growth of Water Star Grass and the nuisance algae Cladophora by the first of August.

Cladophora was also found to be growing attached to rocks along the shore line in front of cottages very near the lake. This was not always the case for it was also found in areas in which no cottages were located, but for the most part, the majority of the growth was located near cottages. During an early sanitary survey in May, these growths were relatively absent but began to appear at different locations with differing degrees of intensity as the summer progressed.

BOTTOM AND PLANKTON SAMPLE ANALYSIS

Bottom and plankton samples were secured at nine sampling stations along three transects on August 15 and 16, 1969, to determine if a difference existed in the make-up of the bottom fauna and flora between the transects, and also to see if a noticeable change in the aquatic community structure occurred since earlier lake surveys.

A qualitative analysis of single Ponar dredge hauls at each station showed no significant difference in the number and types of organisms between each of the three transects (see Table III-43).

The absence of mayflies, Hexaginia, in this survey was due to seasonal variations, in that emergence of adults occurred prior to the sampling period. A large number of cast nymphal skins were still visible in the water near the shore during the sampling period.

Animals found by turning over stones along the shore were caddis fly larvae (Hydropsyche), very yound mayfly nymphs belonging to the family, Heptageniidae.

Additional bottom samples were collected on September 1, 1969, to determine the density and diversity of organisms utilizing the benthic substrate. Stations were sampled in accordance with previously established transect lines and sampling points along these lines.

Sampling was done using a Ponar dredge attached to the Fusilier gasoline-driven hoist as shown in Figures III-6 and III-7. The biotic bottom substrate separator screen as shown in Figure III-6 was used to remove most of the bottom sediment by washing.

Results of the September 1 sampling are presented in Table III-44.

TABLE III-43

BOTTOM SAMPLES
(August 15, 1969)

1T-1 — 12-Foot Depth

10 - AMPHIPODA
HAUSTORIIDAE
PONTOPOREIA

DIPTERA
TENDIPEDIDAE

3 - TENDIPES PLUMOSA

9 - PENTANEURA

1 - PELECYPODA
UNIONIDAE

2T-1 — 6-Foot Depth

3 - DIPTERA
TENDIPEDIDAE
PENTANEURA

3T-3 — 90-Foot Depth

12 - AMPHIPODA
HAUSTORIIDAE
PONTOPOREIA

DIDTERA
TENDIPEDIDAE

8 - PENTANEURA

15 - TENDIPEDIDAE

1T-3 — 25-Foot Depth

8 - DIPTERA
TENDIPEDIDAE

1 - AMPHIPODA
HAUSTORIIDAE
PONTOPOREIA

2T-3 — 62-Foot Depth

1 - AMPHIPODA
HAUSTORIIDAE
PONTOPOREIA

6 - DIPTERA
TENDIPEDIDAE

4 - PELECYPODA
SPHAERIIDAE
PISIDIUM

3T-4 — 20-Foot Depth

5 - DIPTERA
TENDIPEDIDAE

1 - PELECYPODA
SPHAERIIDAE
PISIDIUM

1 - LYMNAEIDAE
LYMNEA

1T-5 — 5-Foot Depth

2 - PELECYPODA
SPHAERIIDAE
PISIDIUM

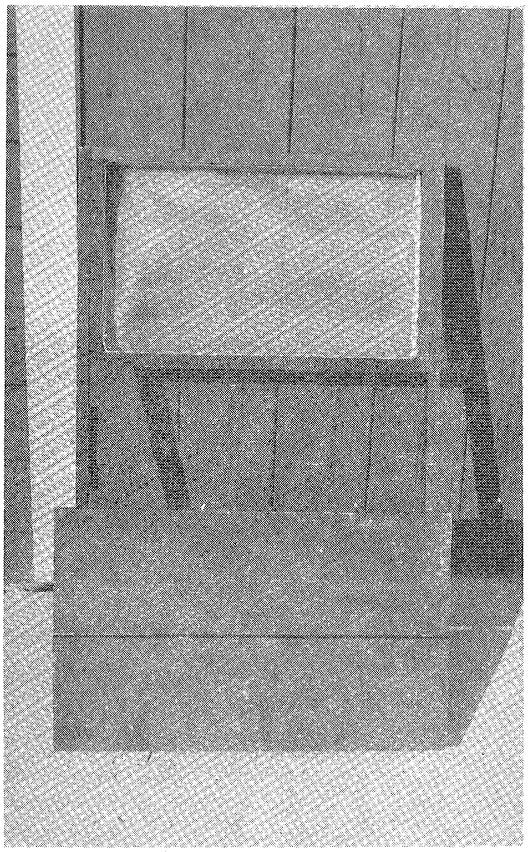
3 - DIPTERA
TENDIPEDIDAE
PENTANEURA

2T-5 — 5-Foot Depth

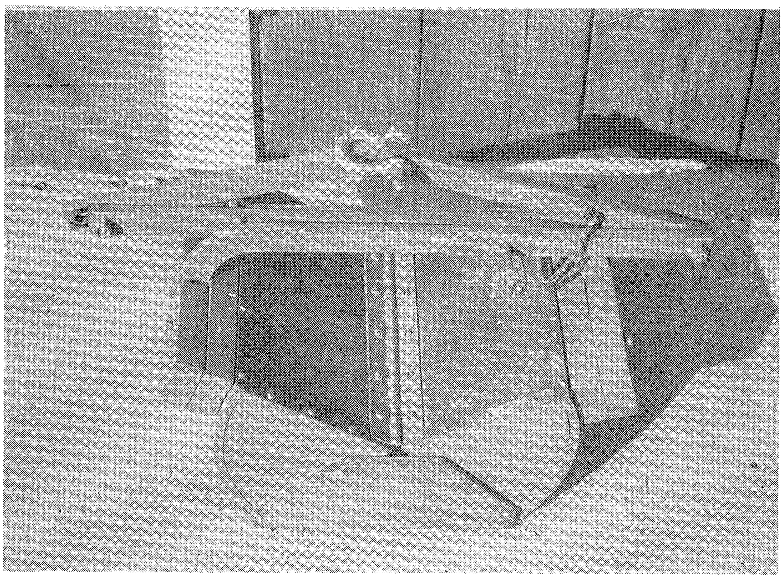
2 - PULMONATA
LYMNAEIDAE
LYMNAE

3T-5 — 5-Foot Depth

6 - DIPTERA
TENDIPEDIDAE

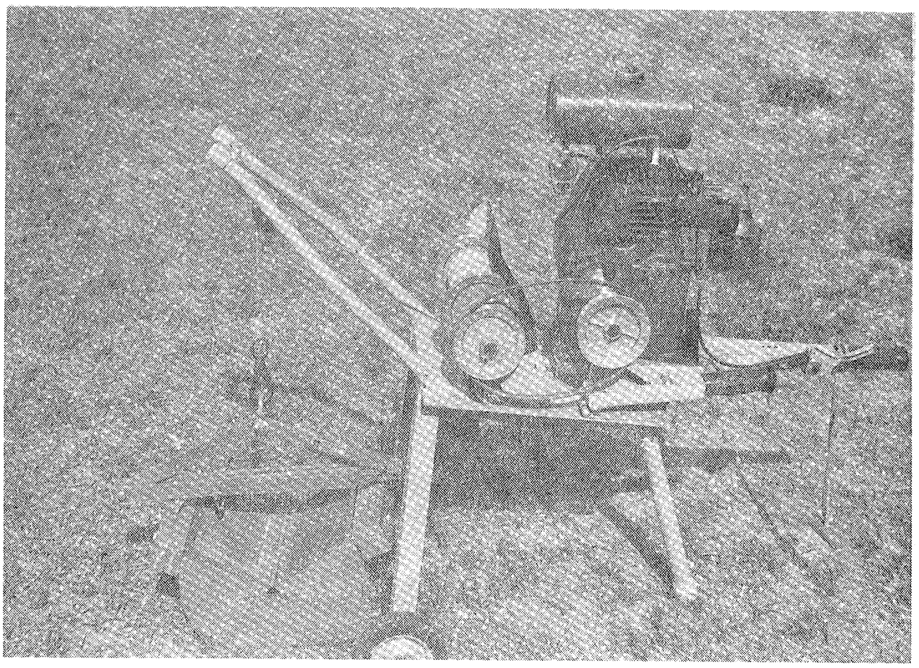


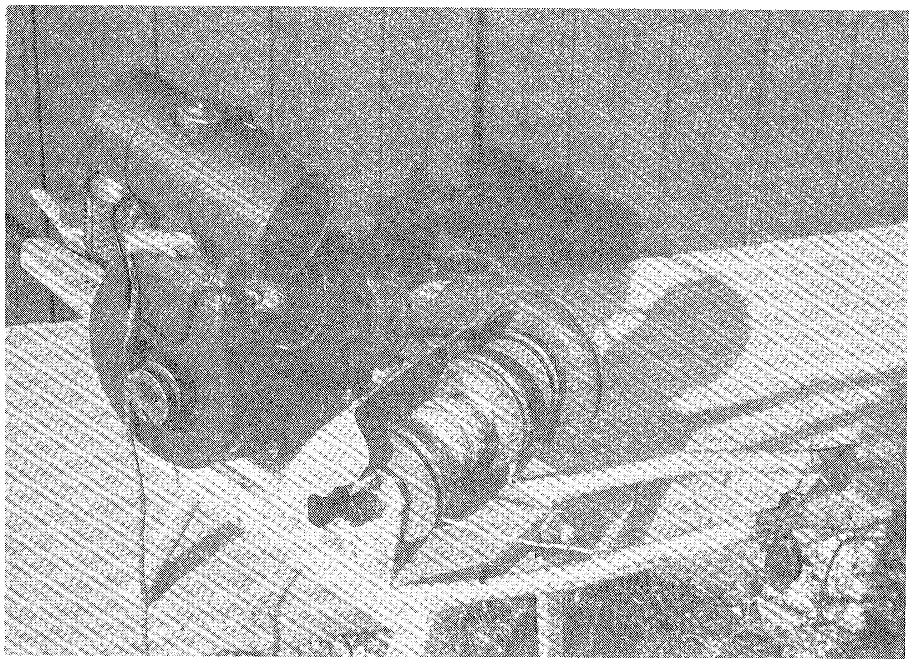
BIOTIC BOTTOM SUBSTRATE
SEPARATOR SCREEN



PONAR GRAB SAMPLER

Figure III-6





FUSILIER GASOLINE DRIVEN HOIST

Figure III-7

TABLE III-44

RESULTS OF ORGANISMS FOUND BY BOTTOM SAMPLING METHODS
(September 1, 1969)

Organism (Genus Only Given)	Transect - Station - Numbers Collected								
	1-T1	1-T2	1-T3	1-T4	1-T5	2T-2	2T-4	4T-2	4T-4
I. Nematoda (Roundworms)			14				2	6	7
II. Gastropoda (Snails)									
Pulmonata (*Physa*, *Lymnaea*, *Helisoina*)			universally abundant					0	0
Ctenobranchiata (*Pleurocera* and *Boniobasis*)			universally abundant					0	0
III. Pelecypoda (Clams)									
Sphaeridae (*Sphaerium* and *Pisidium*)			universally abundant					(few)	
Unionidae		abundant in shallow water						(few)	
IV. Decapoda (Crayfish)		1							
V. Amphipoda (Scuds)									
Gammaridae (*Gammarus*)	2		1				6		
Haustoriidae (*Pontoporeia*)							14	31	24
VI. Mysidacea (Oppossum Shrimp)									
Mysis								2	
VII. Insecta (Aquatic larvae)									
A. Collembola (Springtail-*Podura*)			1						
B. Diptera (flies)									
(1) Tepulidae-*Tepula* (Cranefly)								1	
(2) Tendipedidae-*Tendipes* (Midge)		2	12	1	6	8	13	5	
C. Ephemeroptera (Mayflies)									
(1) *Ephemera*	15	1			3				
(2) *Hexagenia*				2				2	
D. Tricoptera (Caddisflies) (Numerous cases found but no larvae)									

As indicated in Table III-44, there is a restricted number of species present (diversity) while some species (Amphipods and aquatic insects) seem to be present in fairly high numbers (density). A relationship of high density and low diversity has been utilized in the past to indicate a trend toward "pollution." Crystal Lake can hardly be placed in this category, however, based on other data collected during this survey. It therefore appears that exceptions to this density/diversity relationship do exist, especially in quite deep, cold, and fairly clear "oligotrophic-like" bodies of water. Such conditions could very well place restrictions upon the flora and fauna present and create adaptability by some species while an extinction potential would exist for others.

Amphipods and insect larvae seem to be the primary food source available to larger organisms in the food web. The occurrence of these organisms even at the extreme depths (up to 160 feet) would indicate a fairly deep euphotic zone at least partially contributing dissolved oxygen from photosynthesis for these organisms to exist.

The universal abundance of gastropods (snails) and Pelecypods (clams), in addition to a few leeches noted along portions of the shore line, tend to indicate an eutrophication process occurring in the shallower areas. Such a process, requiring an abundance of nutrients, will result in a gradual floral and faunal change within the aquatic environment in the not too distant future.

Thirteen water samples were taken with a Kemmerer sampler for plankton analysis. Although the concentration of the plankton is higher than that reported in an earlier survey, it is still below that found in Lake Michigan. It is also interesting to note the difference in the concentration of the plankton between transects 1 and the other transects (Table III-45). The samples were taken at 3 feet and, if the depth permitted, at 12 feet. There was no significant difference between the plankton concentration at 3 and 12 feet at each station.

The Palmer cell was utilized to count the plankton under 430 X magnitication. The most numerous plankton belonged to the genera Diatoma, Fragilaria, Cymbella, and Anabaena.

A visual survey along the shore showed mats of mostly Cladophora mixed with Spirogyra.

TABLE III-45

PLANKTON SAMPLES

Crystal Lake
Collected on August 16, 1969
Hazy Weather Conditions

Station	Depth	Number/ml
1T-1	3 feet	337
1T-3	3 feet	552
	12 feet	584
1T-5	3 feet	368
2T-1	3 feet	368
2T-3	3 feet	184
	12 feet	215
2T-5	3 feet	245
3T-1	3 feet	154
	12 feet	184
3T-3	3 feet	245
	12 feet	215
3T-5	3 feet	215

SURVEY OF MACROSCOPIC ALGAL GROWTH (Prepared by Charles Cubbage, Eastern Michigan University)

A small sample of obvious algal growth was taken from 11 sites located directly on the lake on August 27, 1969. The sampling was largely for the purpose of identifying the algal forms which residents have made note of, and subsequently prompted the study of Crystal Lake. While a detailed study of the flora of the lake would add much to the total survey, only the most common genera were identified.

The following is the tabulation of the genera located at each site.

Location	Genera
H. P. beachy-protected dock 327 (M-22)	Oscillatoria Mougotia Spirogyra Merismopedia Scenedesmus Spirulina Pediastrum

Location	Genera
1817 (M-22)	Cladophora Stigeoclonium
3187 North Crystal Drive	Cladophora Haplosyphon
4077 North Crystal Drive	Cladophora Tabellaria
5709 North Crystal Drive	Cladophora
6187 North Crystal Drive	Cladophora Oedogonium Spirogyra Tabellaria Stigeoclonium
6863 North Crystal Drive	Cladophora Spirogyra Merismopedia Ulothrix Vaucheria
752 Windemere	Cladophora Tabellaria Stigeoclonium
1325 South Shore (Crystalaire)	Spirogyra Oscillatoria
1765 South Shore Drive	Cladophora Spirogyra Tabellaria
552 South Shore Drive	Spirogyra Cladophora Lyngbya Tabellaria Cocconeus

In all selected sites, the major component of the macroscopic algal growth was Cladophora. The genus Tabellaria was found in frequent association with Cladophora (not great in biomass though). The next most abundant was Spirogyra, followed in greatly reduced quantity by the other genera.

Cladophora may be found the year around; producing a number of generations each year. The cell wall of Cladophora consists mainly of cellulose (up to as much as 41%), and thus is very likely to be subjected to epiphytism, providing a sanctuary for numerous other species. Food storage in Cladophora is largely fructose. The Great Lakes have supported substantial growths of Cladophora glomerata, and since 1960 this has become a major problem on beaches and in boating areas. Identification of the species just mentioned, as well as others of this genus, is very difficult since there are innumerable morphological variations. These variations are evidently in response to different factors in the environment.

Since the shore of Crystal Lake provides abundant anchoring sites for Cladophora, which is an epilithic form, and since it is quite unlikely that the population of the area will diminish, the prognosis is for continued appearance of macroscopic algal forms. The rate at which this occurs will in part depend on the amount of nutrients which the residents of the area contribute to the waters of the lake.

The sampling was done by Charles Cubbage, Director of Audio-Tutorial Biology, Eastern Michigan University. He wishes to acknowledge the assistance received of Mr. Dennis Jackson also of Eastern Michigan University (recipient of the G. W. Prescott Collection) in checking some of the identified forms. The information on the genus Cladophora was substantiated by The Algae: A Review by G. W. Prescott.

Summary

A number of important water quality characteristics of Crystal Lake and its tributaries have been presented. These included: a discussion of Michigan water quality standards and Crystal Lake use designation, a discussion of chemical and bacteriological observations including sampling and laboratory considerations, results of weekly tributary sampling including the many drains and ditches, results of a special Cold Creek study, results of shore line evaluation and water quality sampling involving monthly evaluation in front of approximately 300 cottages close to the lake, results of monthly samples collected at a number of stations on the lake at four regular lake transects, results of a special sampling of organized bathing beach areas on July 31, 1969, results of special sampling of the Crystal Beach resort area on June 27 and August 1, 1969, discussion of a special well water testing clinic conducted early in July involving approximately 165 individual wells in the Crystal Lake area, results of a special well water nitrate study of north shore wells, and a presentation of biological observations including a description of aquatic plant growth in Crystal Lake, results of lake bottom and plankton sample analysis, and results of a survey of macroscopic algal growth.

References

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3. Donahue, W. E., "Cyanosis in Infants with Nitrates in Drinking Water as Cause," Pediatrics 3, pp. 308-311 (1949).

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7. Penak, Robert W., Fresh-Water Invertebrates of the United States, The Ronald Press Company, New York, New York, 1953.

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IV. SPECIAL STUDIES

Introduction

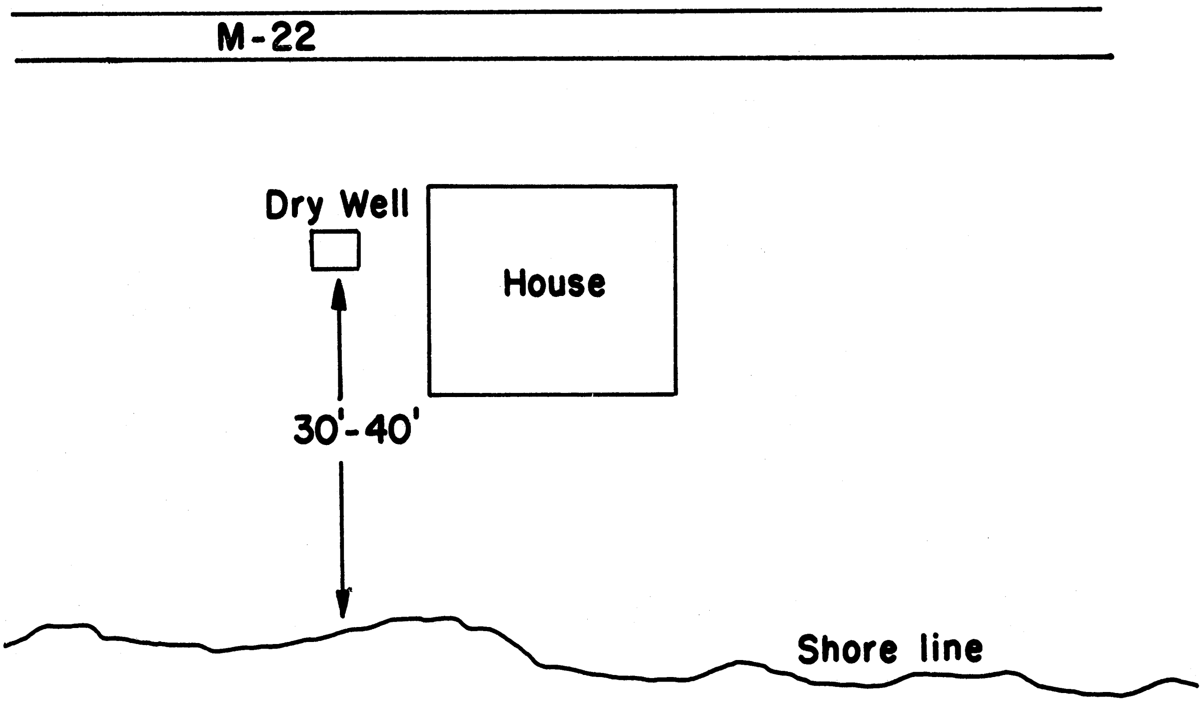
Studies were conducted to evaluate the influence of individual waste water disposal systems on near shore lake water quality involving the use of dye tracers through the disposal facilities of several cooperating cottage owners. In addition, an extensive special study to evaluate the influence of selected nutrient sources on possible future lake biomass production was conducted at a test site in the lake near the Beulah end during the last two weeks in July 1969. As the study progressed, it became apparent that information about the size, number of occupants, period of occupancy, etc., of the cottages around the lake would be useful, and this stimulated the organization of a household information survey under the general direction of The University of Michigan survey team, but with substantial help in the survey execution from the Crystalaire Girls Camp and the Woman's Association of the Congregational Summer Assembly. Limited efforts were directed to evaluate the extent of pesticide used in the Crystal Lake drainage area, and also the existing level of selected pesticides in Crystal Lake itself.

Individual Waste Water Systems

One phase of the study involved an effort to evaluate the influence of individual waste water disposal systems on near shore lake water quality, since this is the area generally used by the cottage occupant for swimming purposes. In addition to the extensive shore line sampling information reported in Section III of this report, four cottages were selected for dye tracer studies with the hope that it would be possible to add dye to a household drain and eventually observe the dye in the lake after passing through the household waste water system.

The cottages selected were 1035 M-22, 3203 North Crystal Drive, 4141 North Crystal Drive, and 6037 North Crystal Drive with the important features schematically presented in Figures IV-1, IV-2, IV-3, and IV-4. Generally, the cottages were selected on the basis of the cooperation of the occupant and because they were typical of the cottages in their respective areas of the lake; selection in no way implies waste water systems significantly different or inferior to other systems in the area. Obviously one of the difficulties in selecting and evaluating an individual system is the fact that it is buried and therefore not visible to the observer, and in many cases, the details of the installation are not known to either the occupant or the owner. It was beyond the scope of this study to physically uncover selected systems, or to investigate more than the four systems reported here.

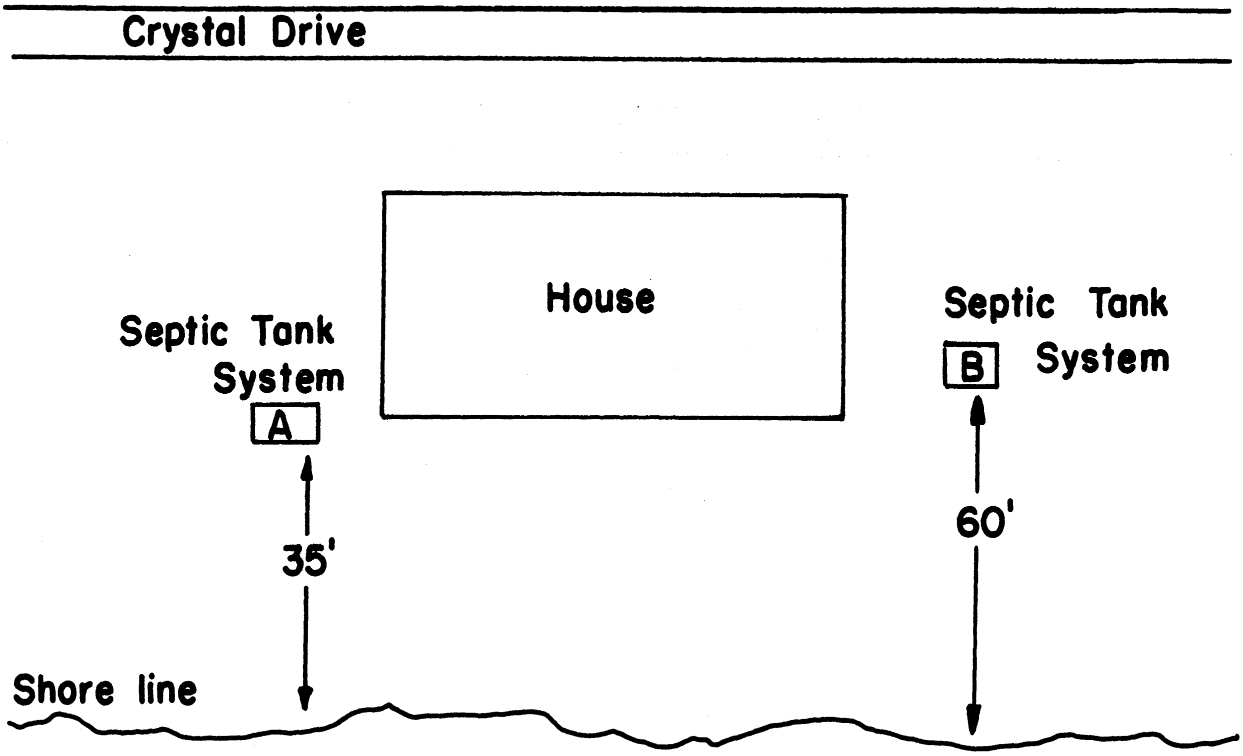
1035 M-22 (Dahman's cottage)



Septic tank with Dry well is located approximately 30 to 40 feet from lake and approximately 10 to 15 feet above the water level.

Figure IV-1

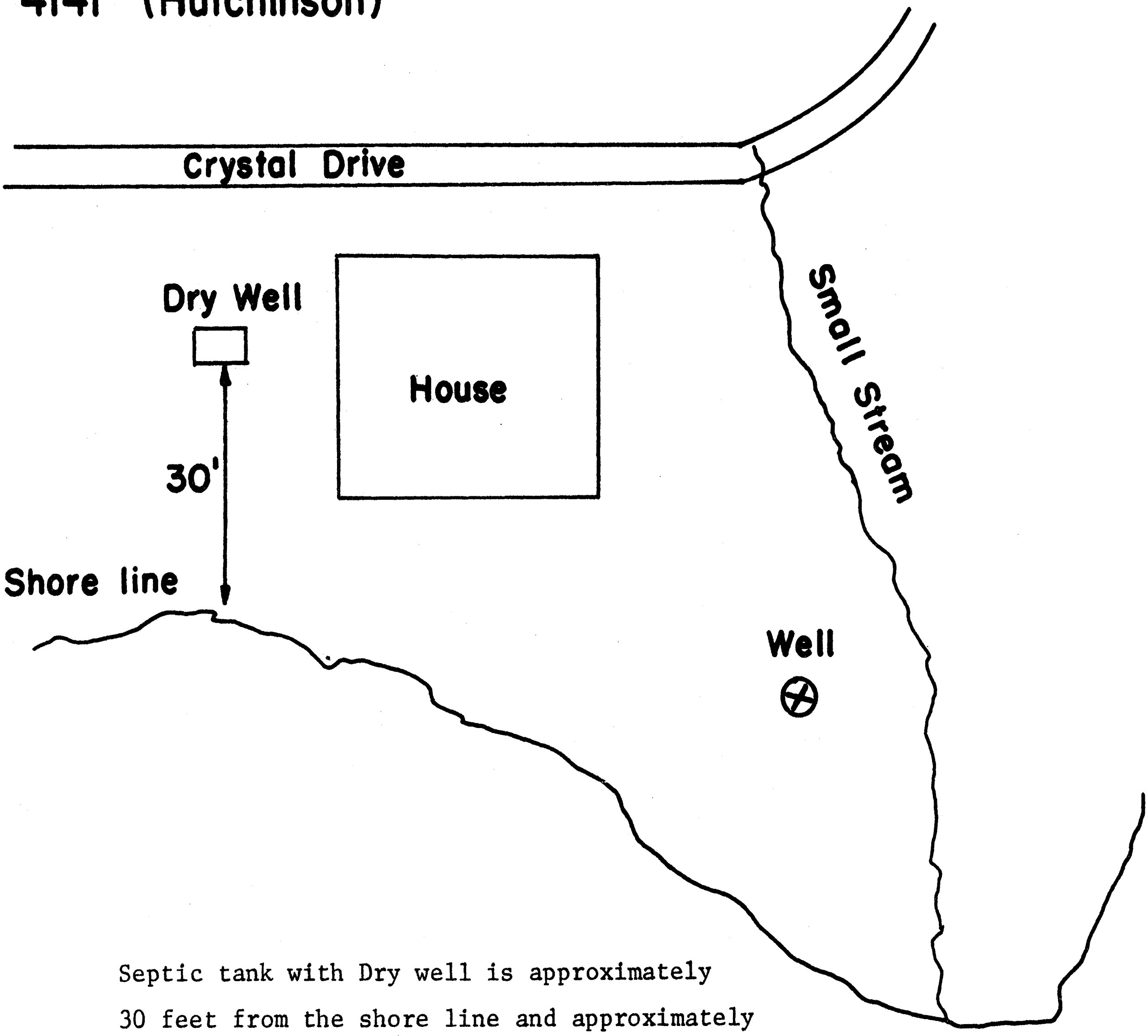
3203 Crystal Drive (Flegenheimer)



This house has two disposal systems, system A being the main system for the bathroom and system B being for the washing machine with a toilet also connected.

Figure IV-2

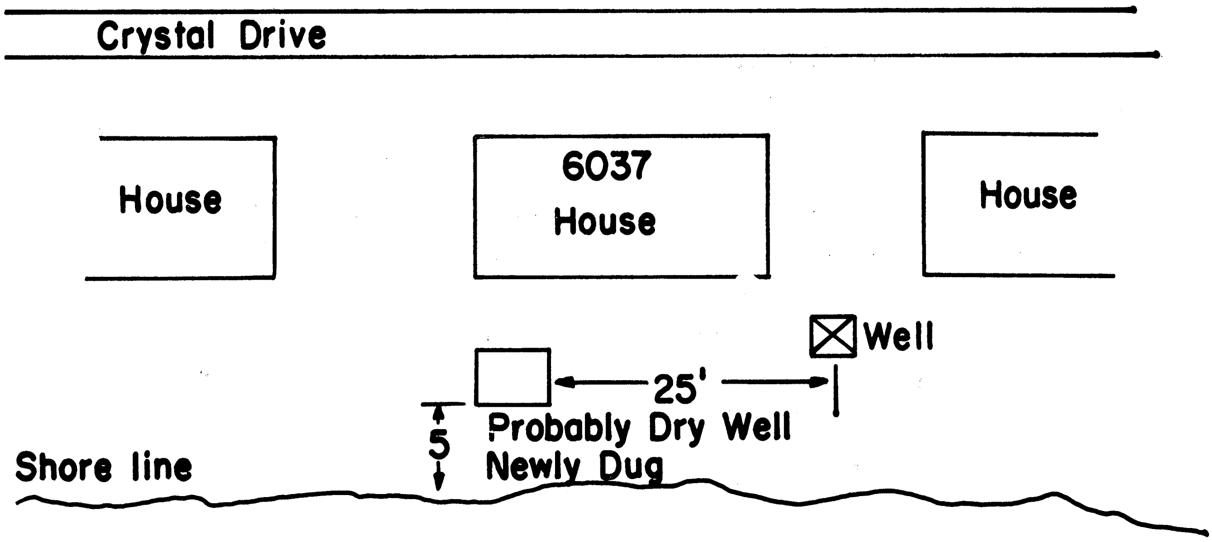
4141 (Hutchinson)



Septic tank with Dry well is approximately 30 feet from the shore line and approximately 8 feet above the water surface.

Figure IV-3

6037 Crystal Drive (Stevenson)



What appeared to be a newly constructed Dry Well was located approximately 5 feet from the shoreline of the lake and approximately 3 feet above the water level.

Figure IV-4

The test procedure involved the addition of a strong charge of Rhodamine WT dye to the household drain by a University of Michigan survey team member followed by an extensive flushing of the affected fixture. This was repeated daily for a period of three or four days and the occupant was asked to watch for the appearance of color in the lake. In no case was color observed during the test period, and the experiment was discontinued because of the pressure of other survey responsibilities. It is possible that the dye was absorbed by the solids in the septic tank or by the soil or that the occupant was not available when the dye appeared in the lake. Notwithstanding the results of this experiment, it is the feeling of the writer that the physical conditions are such in the selected test areas on the north shore of Crystal Lake that it should be possible to detect a dye tracer in the lake if dye is added to the system over a long enough period of time, and if a sensitive fluorometer is used to continuously monitor the lake water. Experiments of this nature should be continued in any future studies.

INDIVIDUAL SEWAGE DISPOSAL AND WATER SUPPLY REQUIREMENTS

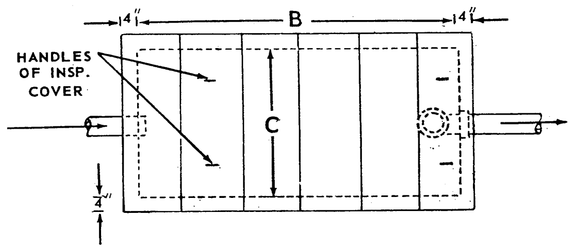
Since January 1, 1964, the Grand Traverse and Benzie Counties Health Department has had in effect a Sanitary Code of Minimum Standards Regulating Sewage Disposal, Water Supplies and Sanitation of Habitable Buildings, which applies to the Crystal Lake area. Selections from this code are presented as Appendix C for the benefit of the reader who may not have ready access to the information.

The usual method of disposal of waste water for individual dwellings where a publicly operated sewage system is not available is a septic tank and tile field. The septic tank is a watertight tank through which sewage flows very slowly allowing the solids to separate from the liquid and then decompose by bacterial action, while the tile field allows the liquid discharge from the septic tank to percolate into the ground.

A typical plan of a sewage disposal system for small installations as prepared by the Division of Engineering, Michigan Department of Health, and included in a pamphlet on Questions and Answers about Home Sewage Disposal[2] is presented as Figure IV-5. Additional background information on sewage systems is contained in the Manual of Septic Tank Practice[3] and on water systems in the Manual of Individual Water Supply Systems.[4]

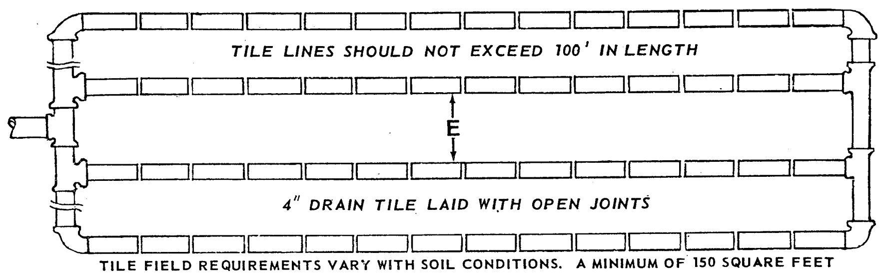
During May 1969, an opportunity presented itself to photograph the septic tank effluent liquid dispersal facility of a cottage under construction on the north shore of Crystal Lake before the unit was covered by earth. Two photographs of the facility are presented as Figure IV-6 where it is seen the unit consists of a concrete box with a series of slits around the sides to allow the liquid fraction to percolate into the surrounding soil, with the septic tank itself shown in the rear of the lower photograph. Apparently this unit replaced the tile field suggested in the minimum standards of the Grand Traverse and Benzie Counties Health Department.

SEPTIC TANK



PLAN VIEW OF TANK SHOWING SLAB TOP

TILE DISPOSAL FIELD

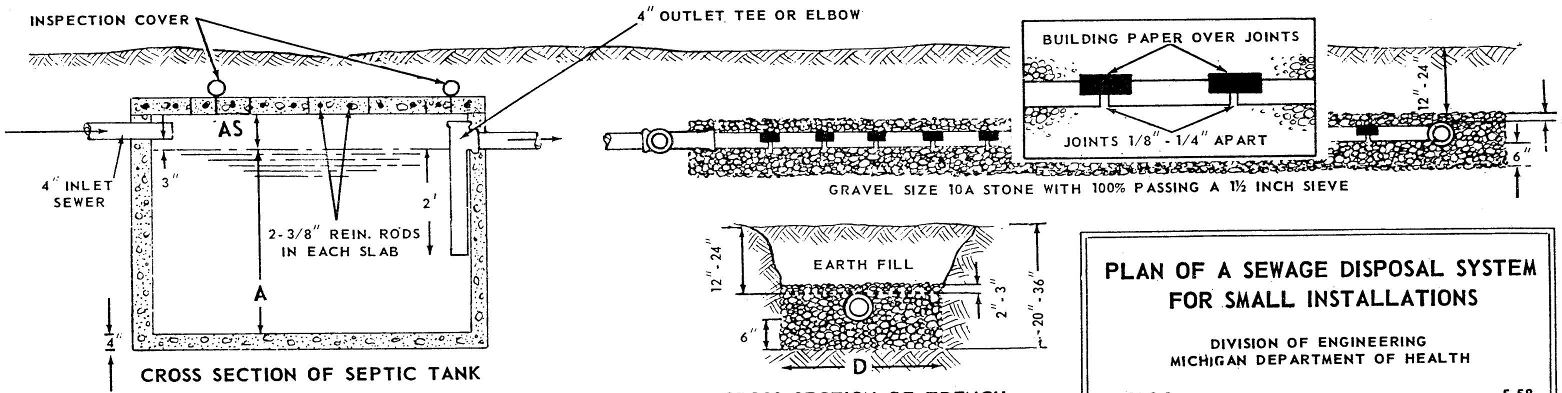


TILE FIELD REQUIREMENTS VARY WITH SOIL CONDITIONS. A MINIMUM OF 150 SQUARE FEET OF ABSORPTION AREA SHOULD BE PROVIDED IN SANDY OR GRAVELLY SOIL. TILE LINES SHOULD HAVE, APPROXIMATELY 1 INCH FALL IN 50 FEET

INSIDE DIMENSIONS FOR SEPTIC TANKS OF VARYING CAPACITIES*				
TANK	A	B	C	AS
GALLONS	WATER DEPTH	LENGTH	WIDTH	AIR SPACE
500	4'-0"	5'-10"	2'-10"	9.6"
600	4'-6"	5'-10"	3'- 1"	10.8"
750	4'-6"	6'- 8"	3'- 4"	10.8"
1000	5'-0"	9'- 0"	3'- 0"	12.0"

**Many local codes specify tank capacities be sure to check local requirements*

SIZE AND SPACING FOR DISPOSAL TRENCHES			
D			E
WIDTH OF TRENCH BOTTOM	DEPTH OF TRENCH	EFFECTIVE ABSORPTION AREA PER 100' OF TILE	SPACING OF TILE LINES
18"	20"-36"	150 sq. ft.	6.0'
24"	20"-36"	200 sq. ft.	6.5'
30"	20"-36"	250 sq. ft.	7.0'
36"	20"-36"	300 sq. ft.	7.5'



CROSS SECTION OF SEPTIC TANK

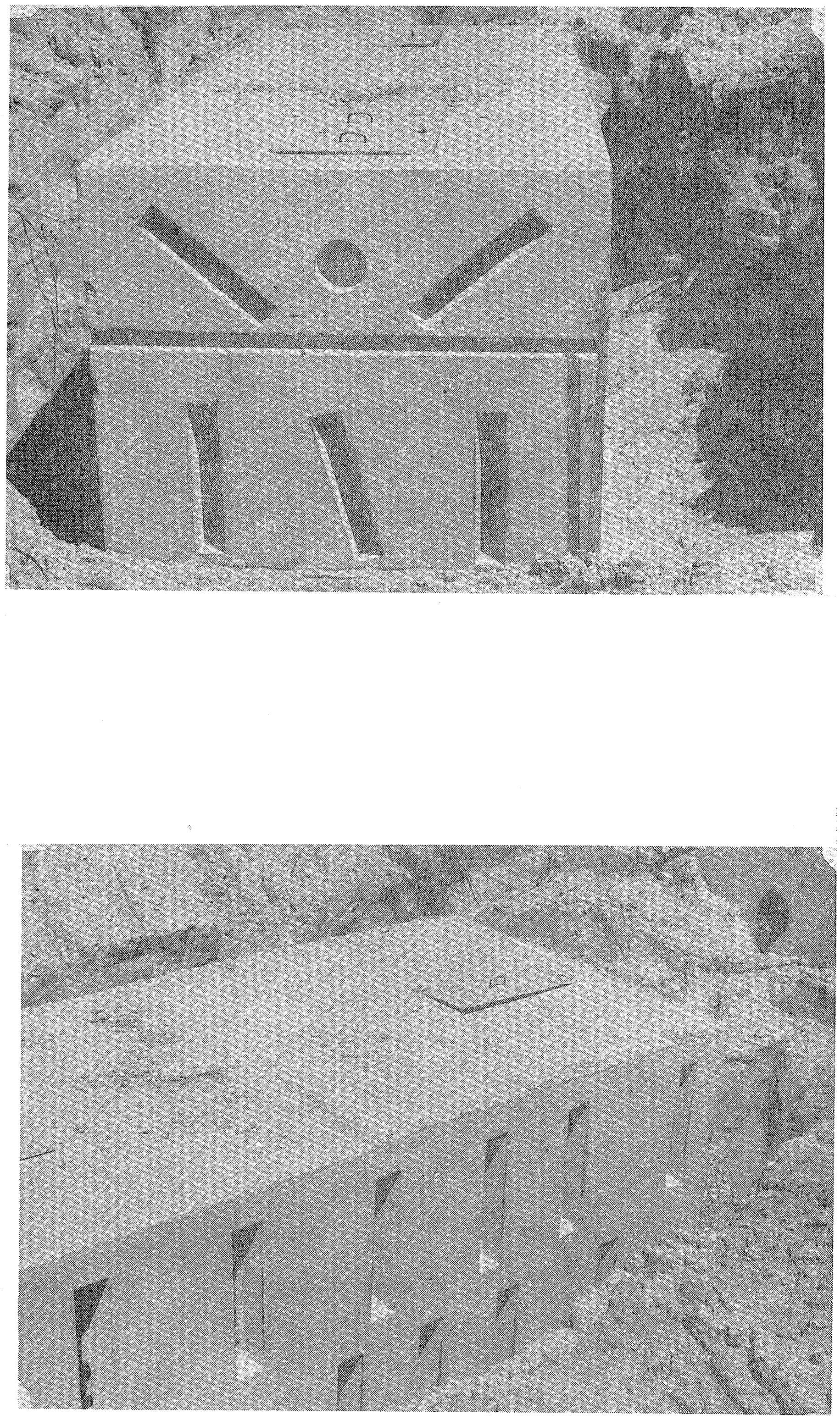
CROSS SECTION OF TRENCH

PLAN OF A SEWAGE DISPOSAL SYSTEM FOR SMALL INSTALLATIONS

DIVISION OF ENGINEERING
MICHIGAN DEPARTMENT OF HEALTH

D 13.1-1 5-58

Figure IV-5



SEPTIC TANK EFFLUENT LIQUID DISPERSAL FACILITY

Figure IV-6

Review of the distances between cottage, water system, sewage system, and Crystal Lake for many existing dwellings around the lake will show these distances less than the minimum distances required of new homes by the Grand Traverse and Benzie Counties Health Department. It is recognized that many existing cottages were constructed before the January 1, 1964 sanitary code became effective, nonetheless it should be appreciated that a number of the cottage sanitary facilities are inadequate and pose a potential health hazard to cottage users both in terms of contaminated well water and lake water. This has been particularly reflected during the summer of 1969 in terms of elevated coliform counts and increased algal growths along certain sections of the lake shore line.

Crystal Lake Productivity
by Michael E. Bender and Robert A. Jordan

INTRODUCTION

Several methods are available to assess the productive potential of lake waters. All involve the measurement of a substance or activity related to the quantity of plant material in the water. The basic aim of the measurements is to provide an estimate of the quantity of organic matter which is produced from inorganic substances within the lake. This organic material is produced by floating and attached aquatic plants from carbon dioxide, water, nitrogen, phosphorus, and other minor nutrients, using sunlight to power the reaction.

The process is called photosynthesis, and the rate at which CO_2 is converted to organic matter is defined as gross primary productivity. Within limits, the amount of plant material which can be supported in a given lake is dependent upon the nutrient materials in the water. However, this is true only as long as light does not limit the growth of the algae. Moreover, given the same concentration of nutrients in a cubic meter of water, as the depth increases, the amount of light available for plant growth decreases. In nutrient rich waters, the algae themselves will grow abundantly in the upper waters, consequently limiting the penetration of light and shortening the column of water in which photosynthesis may occur. In clear and relatively nutrient poor lakes, photo synthesis will occur to great depths, making it possible for the production of organic matter per unit area of lake surface in these lakes to equal that of nutrient rich lakes.

In this study, estimates of carbon fixation or productivity were made using C^{14} (radioactive carbon) as a tracer for normal C^{12} uptake. Profiles of production (measurements of carbon assimilation at various depths) were made on July 25th and 29th at two stations, one located 300 yards off Cold Creek, the other off railroad point in the center of the lake. The profiles were conducted to establish the present levels of primary production in the lake for background information and for comparisons with other lakes. These locations were selected to detect possible differences in production due to the influence of Cold Creek on the chemical composition of the water at the near shore station.

As mentioned earlier, the magnitude of production within a given water column is determined by the available light and the nutrient levels within the column. Down to a certain depth, before light becomes limiting, the nutrient environment controls the quantity of production. In order to ascertain which nutrient or nutrients could be responsible for increasing the primary production in the lake, a bioassay of three growth substances was conducted.

METHODS

Productivity Profile

Samples were collected at the two stations with a Van Dorn sampler. The samples were placed in 300-ml BOD bottles, 2 light and 2 dark, for each depth. Following the removal of 1 ml of lake water from each sample, 1 ml of a solution containing 0.9μC/ml of C-14 as sodium bicarbonate was added. The samples were then incubated at their respective depths for 8 hours. After incubation, the samples were filtered through 0.45μ membrane filters, air dried, glued to planchets, and their beta activity counted for 10 minutes in a gas flow proportioned counter (Beckman-Sharpe Laboratories Low Beta II). These counts were then converted to carbon uptake following the method of Saunders, et al., 1964.

Nutrient Bioasssays

Experiments to determine the effect of algal growth stimulating substances in lakes have been conducted using: (1) whole lake fertilization (Ball and Tanner[5]), (2) addition of nutrients to glass bottles or polyethylene tubes suspended in the lake (Wetzel[6] and Goldman[7]; and (3) batch and continuous laboratory bioassays of the lake water of interest (Oswald[8] and Pearson, et al.,[9]). In all of these methods, the goal is to extrapolate from the experimental results to what would occur in the lake if the same conditions were maintained. However, there is little agreement among workers in the field as to the best method of study. Goldman,[7] showed that in Castle Lake, algal production was limited by molybdenum, and recently has verified his results by actually adding molybdenum to the lake system and following the response of the algae.

The magnitude of response is, however, the most difficult factor to extrapolate to the whole lake. It must be remembered, therefore, that projections from nutrient addition experiments are only estimates of what could occur in the whole lake.

In this study, the response of the present algal population of Crystal Lake to addition of nitrogen, phosphorus, and a chelating agent was determined by measuring increases in production after addition of these substances to 5-gallon jugs of lake water. These substances were added to the lake water in all of their possible combinations according to the following format, in which the low level is the present or ambient level of the substance in the lake water.

Crystal Lake

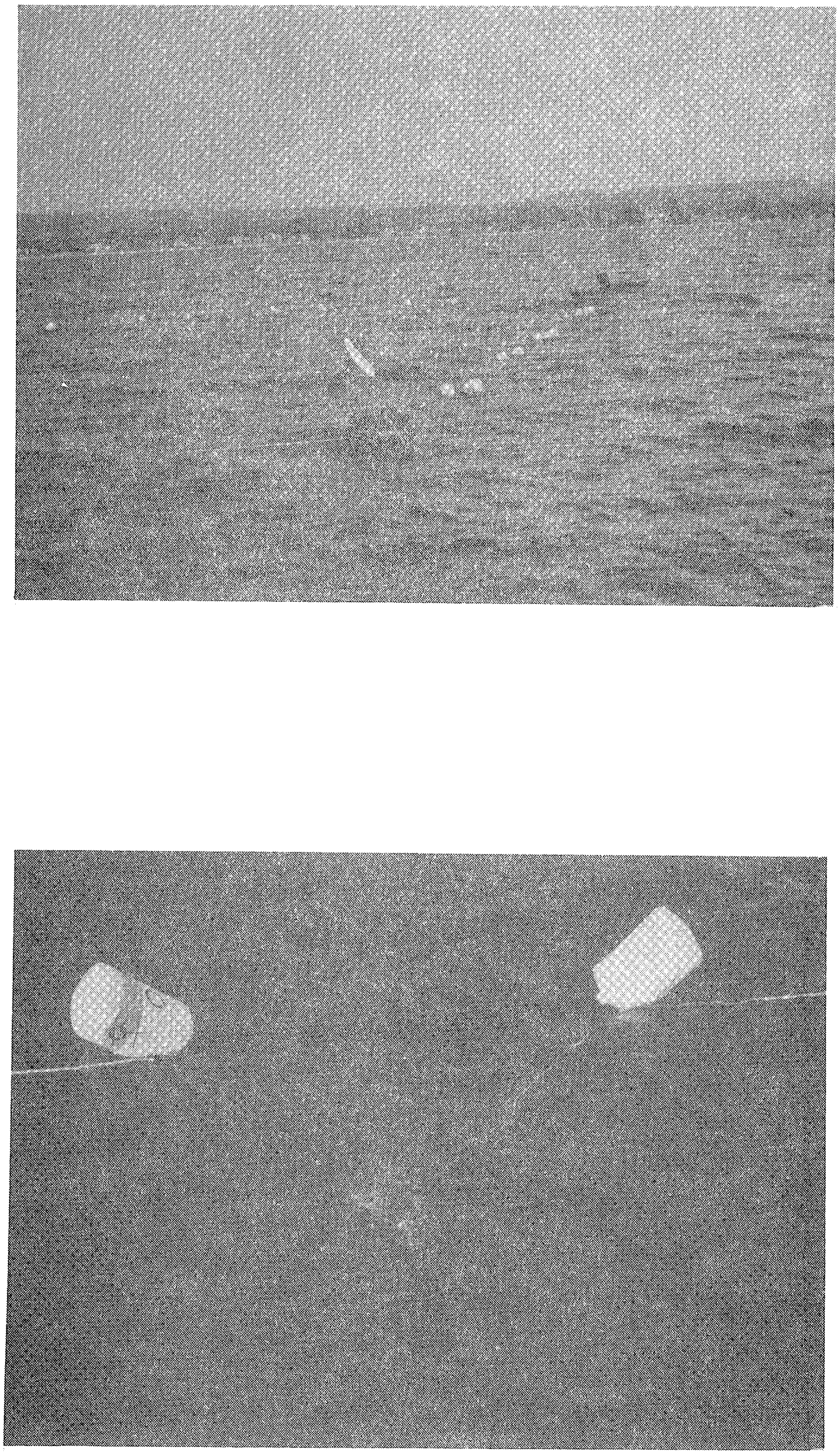
	Ambient or Low Level	Addition Level	High Level
NO_3-N	30 μg/l	50 μg/l	80 μg/l
PO_4-P	3.6 μg/l	5 μg/l	8.6 μg/l
EDTA	-	500 μg/l	500 μg/l

Concentration in Treatment in μg/l

Treatment	NO_3-N	PO_4-P	EDTA
npc	30	3.6	-
Npc	80	3.6	-
nPc	30	8.6	-
npC	30	3.6	500
NpC	80	3.6	500
NPc	80	8.6	-
nPC	30	8.6	500
NPC	80	8.6	500

Two 5-gallon jugs received each treatment. The jugs were filled in a random order from a 150-gallon reservoir tank which had been filled by pumping lake water from a depth of 1 meter at a station located off railroad point in the center of the lake. During the filling process, the reservoir tank was mixed continually with a large plunger. After the jugs had been filled, the nutrients were added and mixed. The jugs were then stoppered and suspended in the lake at a depth of 1 meter, from a specially constructed incubation rack as shown photographically in Figure IV-7.

Samples were removed from each of the jugs on July 24th, 27th, and 30th for productivity measurement. The samples were collected in 125-ml glass stoppered bottles, 2 light and 1 dark for each jug. After collection, a 1-ml portion of each sample was removed and 1 ml of a solution containing 0.9μC/ml of C-14 as bicarbonate was added. The samples were then placed in an exposure rack and returned to the lake for an incubation period of 8 hours. At the end of the incubation period, the samples were filtered and their activities determined as described previously.



CRYSTAL LAKE

BIOLOGICAL PRODUCTION EXPERIMENTAL APPARATUS

Figure IV-7

RESULTS

Productivity Profiles

The profiles of carbon fixation obtained on July 25th and 29th in the lake are tabulated in Table IV-1 and shown in Figure IV-8. On both dates the inshore station exhibited somewhat less productivity than the offshore. The difference on the 29th was very slight while on the 25th it was quite pronounced. A possible explanation is that light penetration was much greater on this date at the offshore station. There is some evidence for this in that the photosynthetic maximum was higher in the inshore station.

Estimates of productivity on an area basis were made by extending the present profiles to the vertical axis, which was necessary because the profiles were not conducted to great enough depths. Table IV-2 compares the primary productivity levels determined in various lakes with those found in Crystal Lake.

TABLE IV-1

CRYSTAL LAKE PRODUCTIVITY PROFILE
(Estimate of Photosynthesis in $mgC/m^3/day$)

Depth	7-25-69		7-29-69	
	Inshore	Offshore	Inshore	Offshore
Surface	10.0	14.5	12.3	16.5
1 meter	18.5	20.0	19.5	19.8
2 meters	15.7	23.5	23.5	22.5
3 meters	10.5	19.3	18.5	21.0
4 meters	14.0	19.3	----	----
5 meters	13.0	16.5	20.3	21.0
6 meters	14.0	18.0	19.5	23.0
9 meters	----	----	----	19.0

TABLE IV-2

Lake	Production in $g.-c/m^2/year$
Tahoe	36.65
Lunzer Untersee	30.00
Crystal	73.00
Traverse Bay, Lake Michigan	166.63
Douglas Lake	48.10

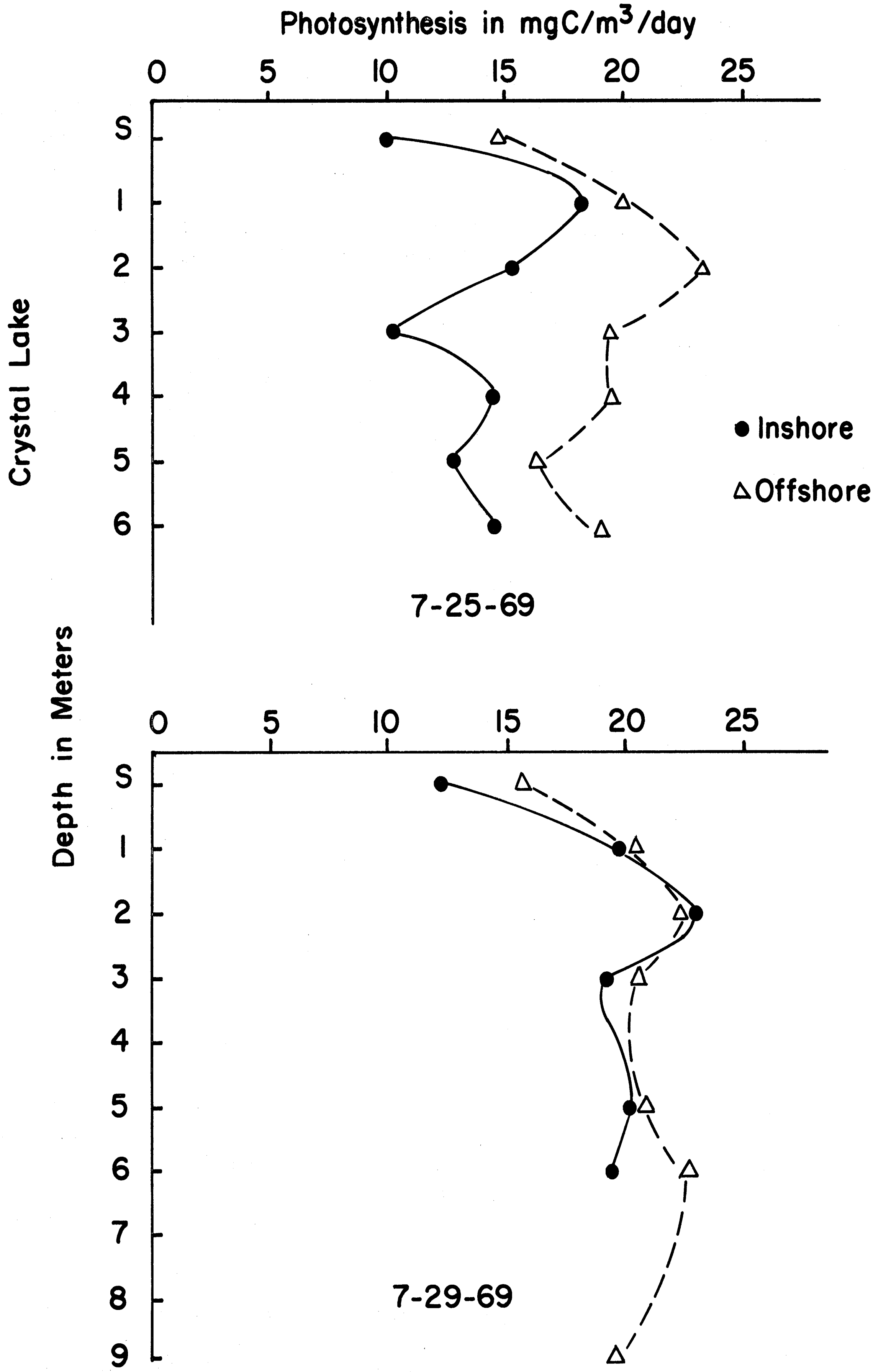

Photosynthesis in mgC/m3/day
0 5 10 15 20 25
S 1 2 3 4 5 6
Crystal Lake
Depth in Meters
• Inshore
△ Offshore
7-25-69
0 5 10 15 20 25
S 1 2 3 4 5 6 7 8 9
7-29-69

Figure IV-8

Nutrient Enrichment Studies

The nutrient bioassay study was based on a 2 x 2 x 2 factorial statistical design and consisted therefore of eight separate treatment combinations, with two replicate experimental vessels assigned to each treatment. The three variables used in the experiment were nitrate, orthophosphate, and EDTA.

Table IV-3 shows the rates of carbon assimilation resulting from the various treatment combinations. The treatments are indicated by upper and lower case letters, lower case indicating that the nutrient was at the ambient lake level, while upper case indicates that the nutrient was added to the experimental vessel at the level indicated in the design. Figure IV-9 graphically depicts the changes in production in each experimental vessel. In the experiment, the greatest increase in production was realized when all three factors were at the high level. The nitrogen-phosphorus combination produced the next most noticeable effect followed by a phosphorus effect.

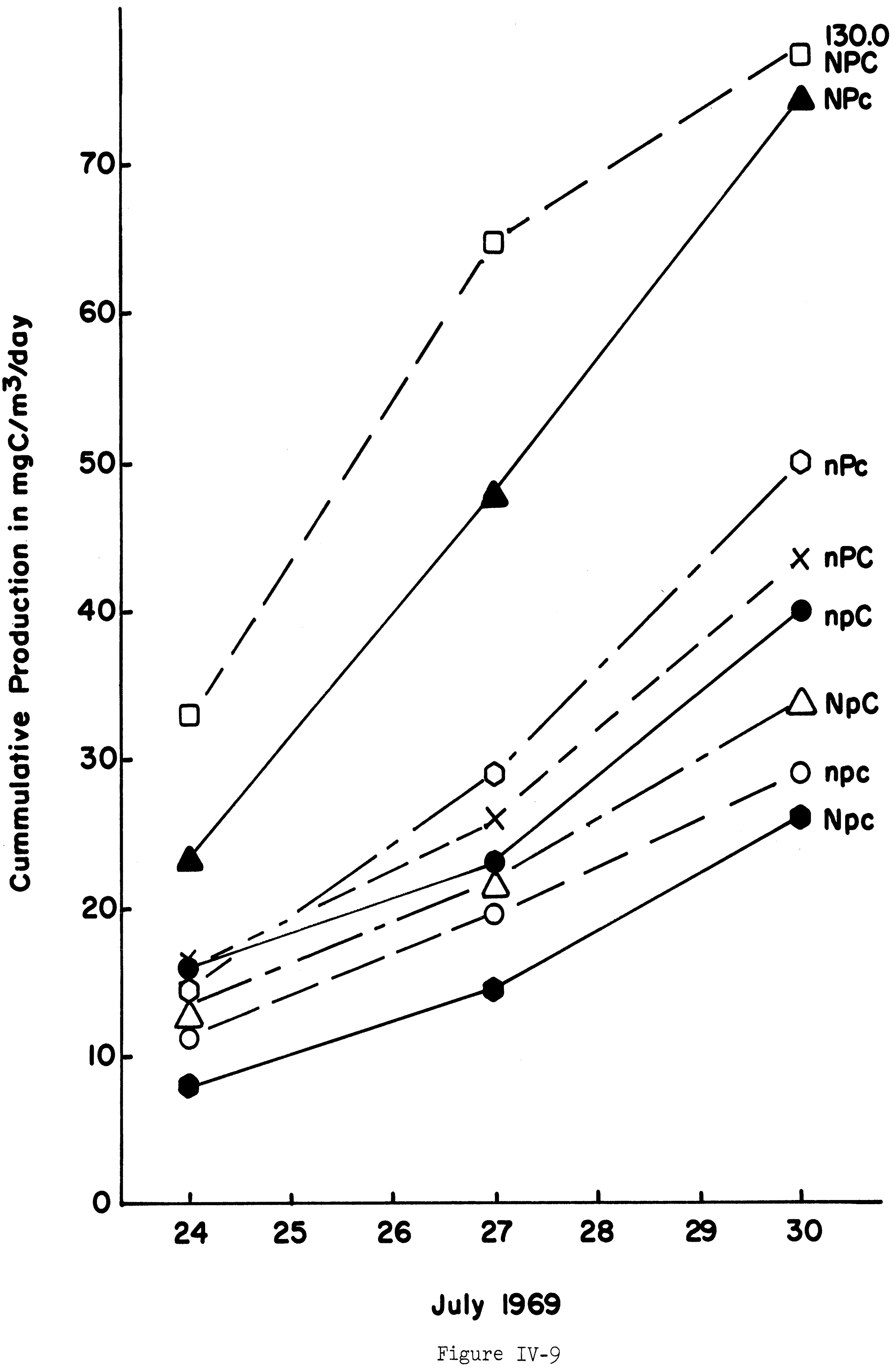
TABLE IV-3

Response in mg.C/m^3

Treatment	Date		
	7-24	7-27	7-30
npc	11.5	8.0	9.5
npC	15.75	7.75	16.00
nPc	13.25	14.75	21.50
Npc	8.00	6.25	14.25
nPC	15.75	10.00	17.50
NpC	13.25	9.25	11.50
NPc	23.25	24.00	27.25
NPC	33.75	31.00	65.00

Figures IV-10, IV-11, and IV-12 show graphically the possible two-way interactions between the various algal growth stimulating substances tested. An interaction between two factors means that the increased or decreased production caused by the addition of two nutrients is not equal to the summation of the production increases or decreases observed when the two factors are added singly.

In this case, significantly greater amounts of carbon were fixed when nitrogen was added together with phosphorus than could be accounted for by summing the individual effects. The algae responded to this treatment by producing three times as much organic matter, in the experimental period, as



130.0
NPC
NPc
nPc
nPC
npC
NpC
npc
Npc
Cummulative Production in mgC/m3/day
0
10
20
30
40
50
60
70
24
25
26
27
28
29
30
July 1969

Figure IV-9

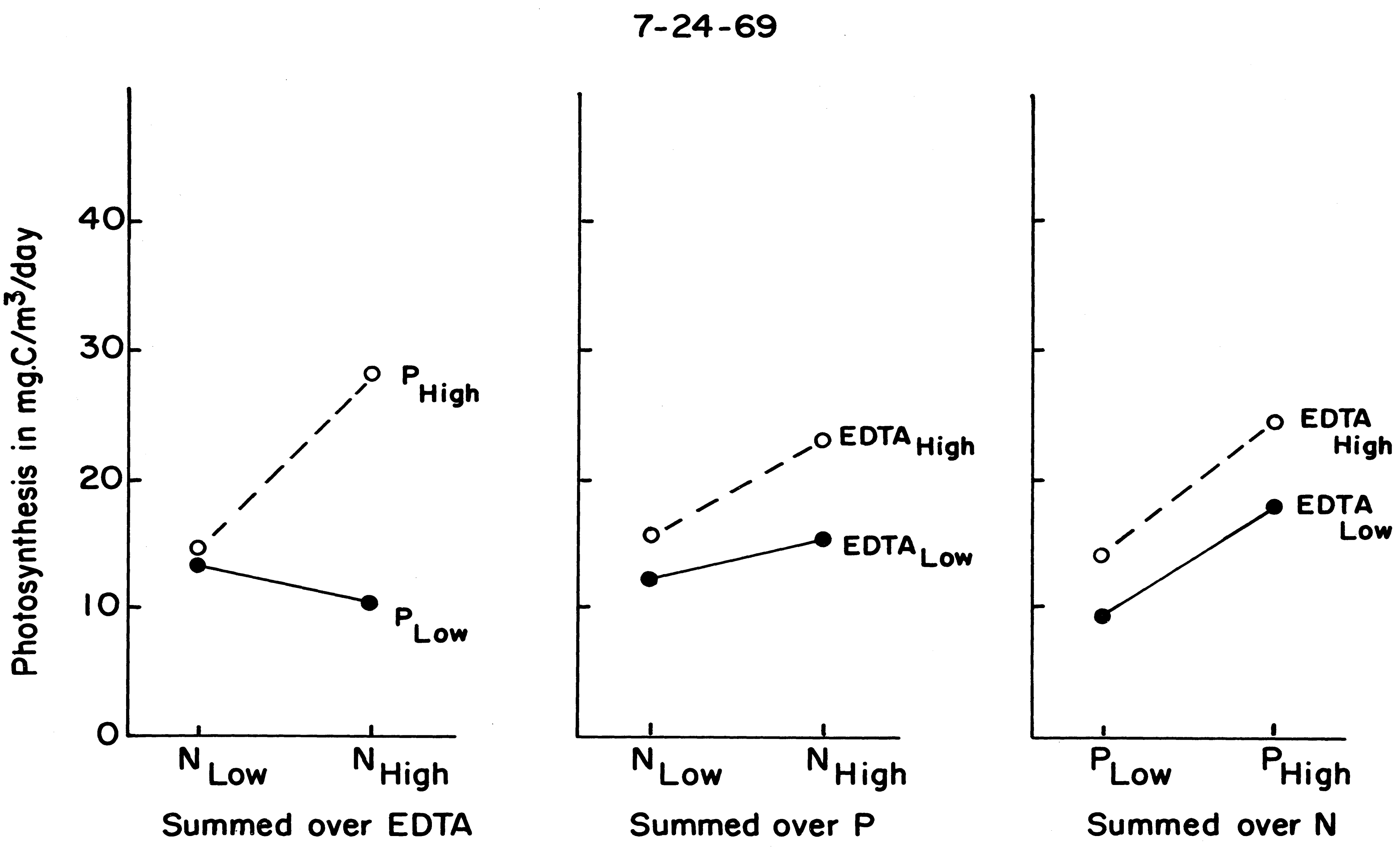

7-24-69
Photosynthesis in mg.C/m3/day
40
30
20
10
0
PHigh
PLow
NLow
NHigh
Summed over EDTA
EDTAHigh
EDTALow
NLow
NHigh
Summed over P
EDTA High
EDTA Low
PLow
PHigh
Summed over N

Figure IV-10

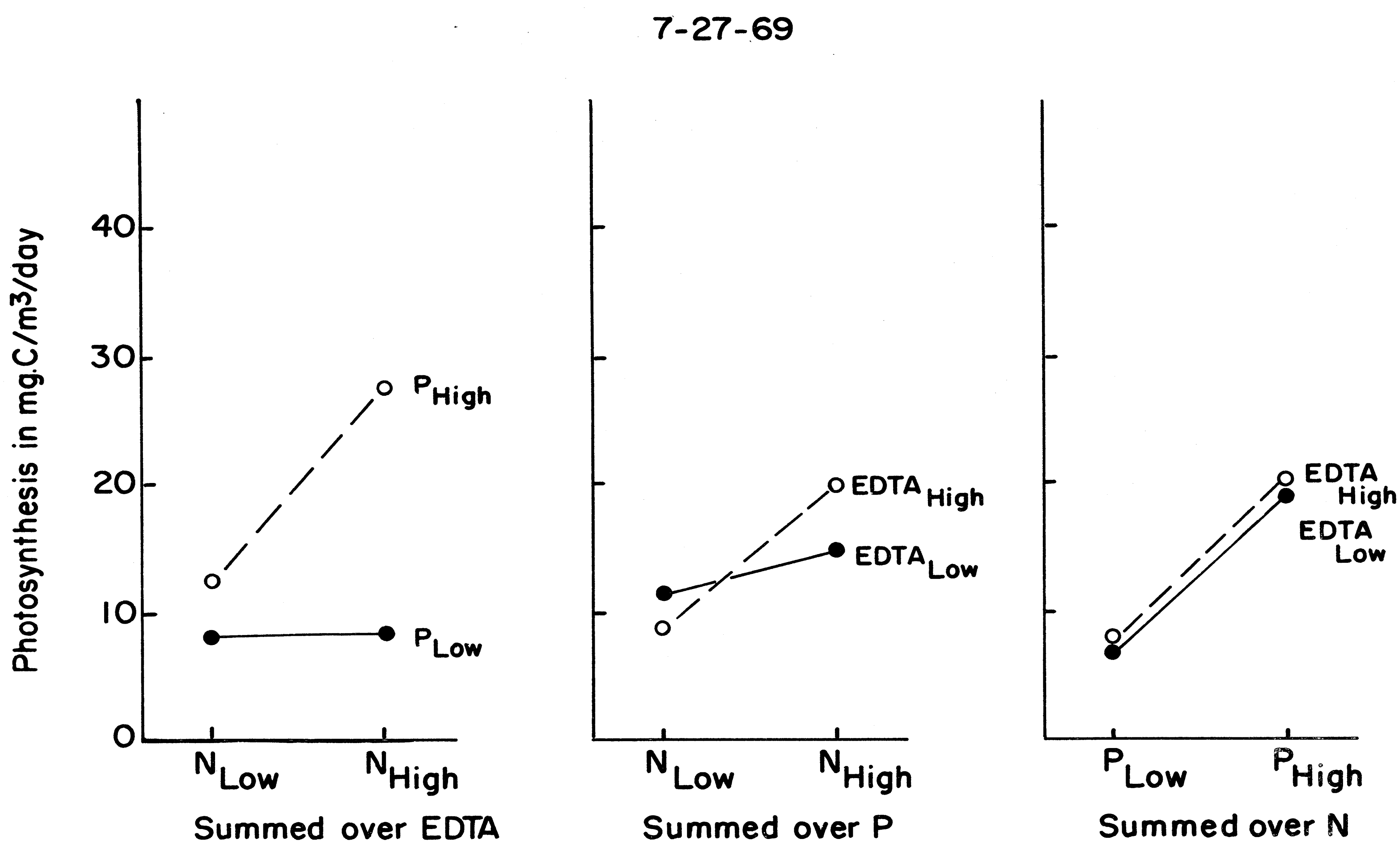

7-27-69
Photosynthesis in mg.C/m3/day
0
10
20
30
40
PHigh
PLow
NLow
NHigh
Summed over EDTA
EDTAHigh
EDTALow
NLow
NHigh
Summed over P
EDTA High
EDTA Low
PLow
PHigh
Summed over N

Figure IV-11

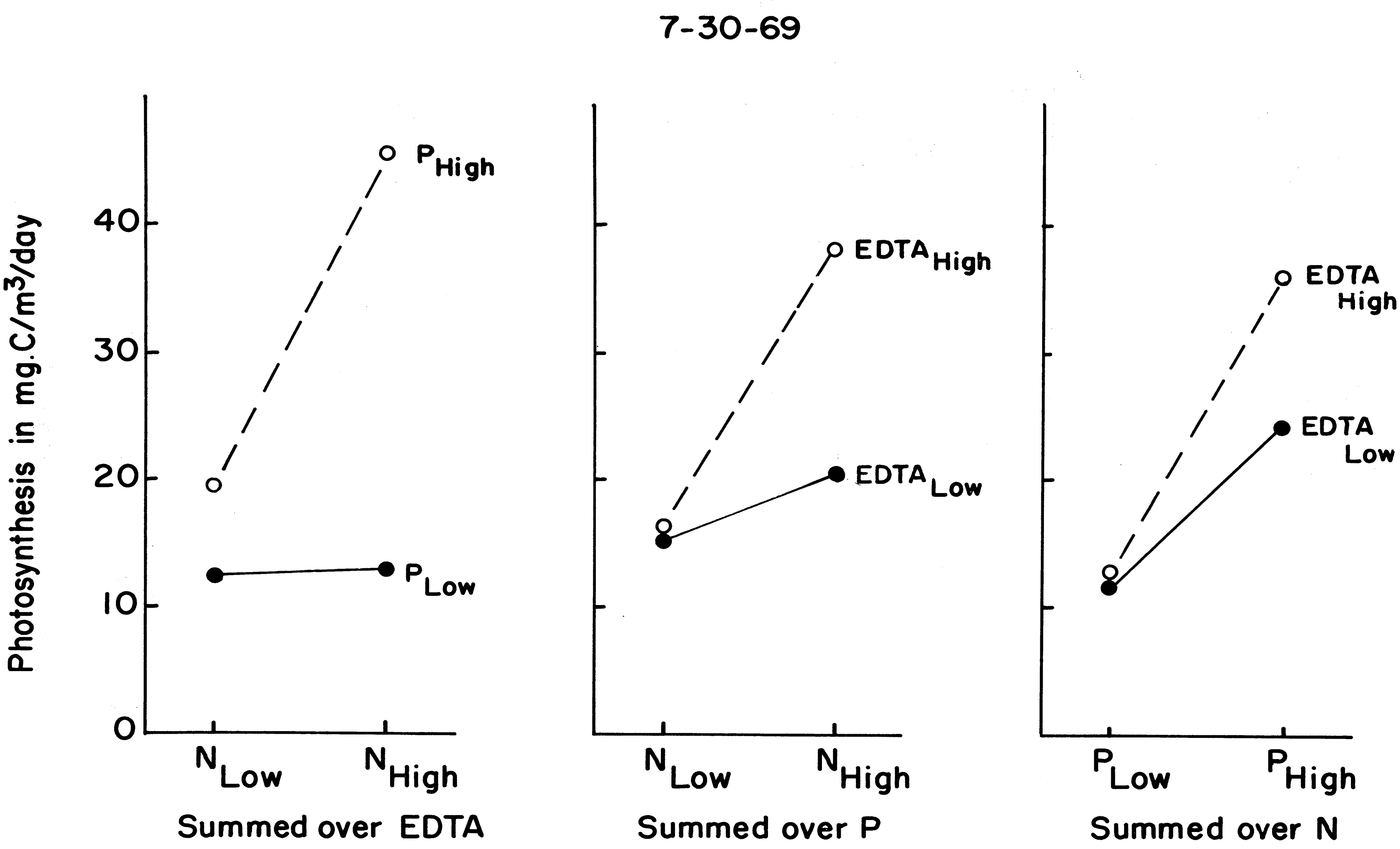

7-30-69
Photosynthesis in mg.C/m3/day
40
30
20
10
0
P High
P Low
N Low
N High
Summed over EDTA
EDTA High
EDTA Low
N Low
N High
Summed over P
EDTA High
EDTA Low
P Low
P High
Summed over N

Figure IV-12

did the controls. Figure IV-13 shows a microscopic comparison of plankton density before and after treatment (NPC). In addition, the response of major algal species to nutrient treatments is presented in Table IV-4.

In order to estimate how soon the lake could reach the nutrient levels used in this treatment, the calculations shown in Table IV-5 were made, based on the following assumptions:

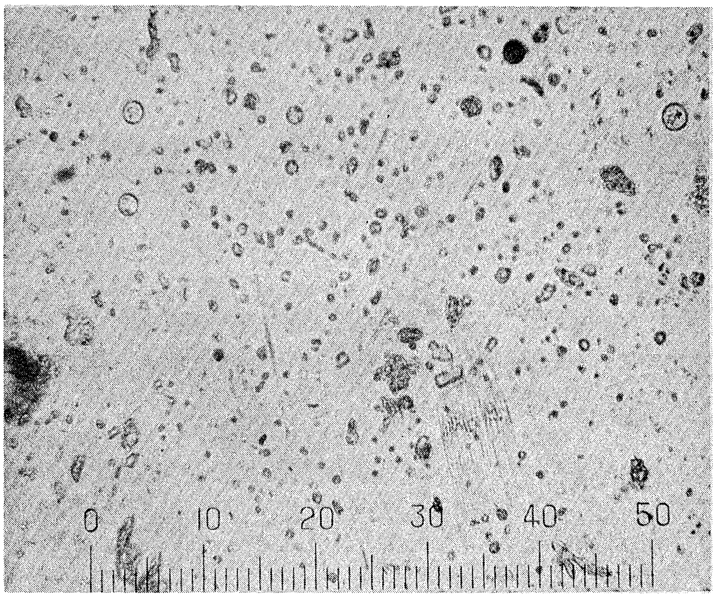
(1) Cold Creek is the major measurable source of nutrients.
(2) The lake is effectively acting as a nutrient trap.
(3) Once the nutrients are trapped in the lake, they are available for algal growth.

It is apparent from this analysis that the algal mass in Crystal Lake will increase three times in a period of 7 to 10 years on the basis of these assumptions.

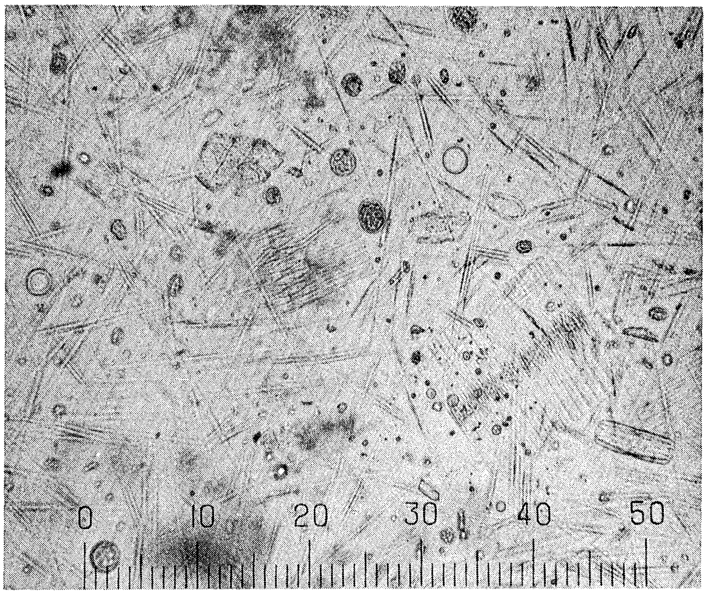
TABLE IV-4

RESPONSE OF MAJOR ALGAL SPECIES TO NUTRIENT TREATMENTS
EXPRESSED IN μg/300 ml SAMPLE

Species	Initial	npc	NPC
Synedra radians	7.86	40.5	262.6
Fragilaria crotonensis	1.77	2.46	17.9
Cyclotella sp (5μ diameter)	7.66	4.28	3.51
Anabaena spiroides	.39	.01	.50
Anabaena circinalis	.08	.01	.54
Microcystis aeruginosa	.72	.0	.92
Glenodinium borgei	2.63	1.70	2.79
Cryptomonas ovata	8.82	9.22	13.41
Pediastrum boryanum	.14	.22	.16



(a) Before Treatment (400X)



(b) After Treatment (400X)

COMPARISON OF PLANKTON DENSITY
BEFORE AND AFTER TREATMENT (NPC)

CRYSTAL LAKE

JULY 1969

Figure IV-13

TABLE IV-5

Flow of Cold Creek	=	7 cubic feet second
	=	16.34×10^{6} liters/day
Lake Volume	=	8.4×10^{11} liters
Phosphate as P in Cold Creek	=	70 μg/l
P-input	=	11.44×10^{8} μg/day
	=	2.5 pounds/day
P-necessary to raise whole lake to 8.6 μg/l	=	9200 pounds
Time necessary	=	10 years
Nitrate as N in Cold Creek	=	1000 μg/l
N-input	=	16.34×10^{9} μg/day
	=	36 pounds/day
N-necessary to raise whole lake to 80 μg/l	=	92000 pounds
Time necessary	=	7 years

Household Information Survey

As the study progressed, it became apparent that information about the size, number of occupants, period of occupancy, etc., of the cottages around the lake would be useful, and this stimulated the organization of a household information survey under the general direction of The University of Michigan survey team, but with substantial help in the survey execution from the Crystalaire Girls Camp and the Woman's Association of the Congregational Summer Assembly.

A single page questionnaire was developed as illustrated in Table IV-6 to serve as a basis for uniform question asking and response recording. Questions were kept short and direct so that relatively untrained interviewers could effectively participate in the survey. No major problems of interpretation of questions were brought to the attention of the survey team.

TABLE IV-6

THE UNIVERSITY OF MICHIGAN - SCHOOL OF PUBLIC HEALTH
HOUSEHOLD INFORMATION SURVEY

Crystal Lake Water Quality Investigation

ADDRESS: Number and Street ______________________________

Name of Owner or Occupant ______________________________

When do you normally live in this cottage? From ____________ to ____________

How many adults normally live in this cottage? ______________________________

How many children normally live in this cottage? ______________________________

How many bedrooms does this cottage have? ______________________________

Does the cottage have a clothes washing machine? ______________________________

Does the cottage have a dishwashing machine? ______________________________

Does the cottage have a garbage disposal? ______________________________

Is there a lawn? ______________________________

(If yes) how often is it fertilized? ______________________________

Do you use the lake for:

Swimming ____________________ How often? ____________

Boating ____________________ How often? ____________

Fishing ____________________ How often? ____________

Do you have any pets? ______________________________

(If yes) what kind? ____________________ How many? ____________

Do you feel that Crystal Lake is polluted? ______________________________

(If yes) what do you think can be done about this pollution?

The first group of questions was aimed at obtaining information about occupancy, size, water using appliances, lawn existence and fertilization, etc. The last group related to lake use and frequency, existence of pets and kind, and an expression of whether or not the respondent felt Crystal Lake is polluted, and what might be done about it.

A total of 687 individual cottages were visited by either girls from the Crystalaire Camp, members of the Woman's Association of the Congregational Summer Assembly, or members of The University of Michigan survey team. Cooperation of the cottage residents was enthusiastic and generally people were eager to supply information or give opinions. Some cottages were not occupied at the time of the first contact on August 11 and 12, 1969, and a second visit was made to these places by members of the survey team the following week. Notwithstanding these two visits, some cottages were not included because occupants were not at home.

Addresses were obtained either from the house number on the cottage, asking the occupant, or from a Consumers Power Company map. Generally this approach proved satisfactory.

Information on such things as lawn existence, frequency of fertilization, existence of pets including numbers and kinds have been presented in previous tabulations such as Figure III-33.

No attempt will be made to present all the information collected, particularly the questions on opinions, because of the difficulty in summarizing this data. Also, it is appreciated the other information is not complete in every respect. The detailed survey sheets are available for further use in the offices of the Water Quality Program, Department of Environmental and Industrial Health.

Pesticide Evaluation

Limited efforts were directed to evaluate the extent of pesticide use in the Crystal Lake drainage area, and also the existing level of selected pesticides in Crystal Lake itself.

A member of the survey team contacted the Benzie Co-operative Company in Beulah in terms of pesticide sales, and he also contacted the major orchard operators in the area in terms of pesticide use. Major interest centered around DDT, Dieldrin, and Aldrin, with very little if any of these compounds currently in use in the Crystal Lake area.

Two samples were collected on May 29, 1969, one at lake sampling station 4T3, and the other at the Nichols Road drain on the north shore designated W-8.

The samples were immediately transported to Ann Arbor for laboratory analysis using gas chromatography by Professor Rolf Hartung of the Toxicology Section, Department of Environmental and Industrial Health. The results of these analyses are as follows:

TABLE IV-7

PESTICIDE EVALUATION
(Sample Collected May 29, 1969)

	Station 4T3	W-8 North Shore
Time of collection	8:50 A.M.	8:13 A.M.
DDT	2.44 ppt	1.81 ppt
Dieldrin	0.35 ppt	1.29 ppt
Aldrin	----	0.82 ppt

In terms of DDT, it is apparent that higher levels existed in the lake than in the discharge from the W-8 drain which includes drainage from an orchard area, no doubt reflecting past use practices where DDT was more widely applied. The level of DDT in Crystal Lake on May 29, 1969, is below that of nearby bodies of water.

Because of limitations of time, no further effort was directed along these lines.

Summary

Studies were conducted to evaluate the influence of individual waste water disposal systems on near shore lake water quality involving the use of dye tracers through the disposal facilities of four cooperating cottage owners. The test procedure involved the addition of a strong charge of Rhodamine WT dye to the household drain by a University of Michigan survey team member followed by an extensive flushing of the affected fixture. This was repeated daily for a period of three or four days and the occupant was asked to watch for the appearance of color in the lake. In no case was color observed during the test period, and the experiment was discontinued because of the pressure of other survey responsibilities.

Review of distances between cottage, water system, sewage system, and Crystal Lake for many existing dwellings around the lake will hsow these distances less than the minimum distances required of new homes by the Grand

Traverse and Benzie Counties Health Department. It is recognized that many existing cottages were constructed before the January 1, 1964, sanitary code became effective; nonetheless, it should be appreciated that a number of the cottage sanitary facilities are inadequate and pose a potential health hazard to cottage users both in terms of contaminated well water and lake water. This has been particularly reflected during the summer of 1969 in terms of elevated coliform counts and increased algal growths along certain sections of the lake shore line.

An extensive special study to evaluate the influence of selected nutrient sources on possible future lake biomass production was conducted at a test site in the lake near the Beulah end during the last two weeks in July 1969. Results of the experiment have been presented in this section of the report. In the experiment, the greatest increase in production was realized when all three factors (nitrogen, phosphorus, and a chelating agent) were at the high level. The nitrogen-phosphorus combination produced the next most noticeable effect followed by a phosphorus effect. From an analysis that was made based on several assumptions of nutrient input, etc., it is estimated that the algal mass in Crystal Lake will increase three times in a period of 7 to 10 years.

As the study progressed, it became apparent that information about the size, number of occupants, period of occupancy, etc., of the cottages around the lake would be useful, and this stimulated the organization of a household information survey under the general direction of The University of Michigan survey team, but with substantial help in the survey execution from the Crystalaire Girls Camp and the Woman's Association of the Congregational Summer Assembly. Discussion of this survey has been presented.

Results of limited efforts directed to the evaluation of the extent of pesticide use in the Crystal Lake drainage area, and also the existing level of selected pesticides in Crystal Lake itself have been presented.

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V. HISTORICAL INFORMATION

A search was made for historical information on the physical, chemical, bacteriological, or biological characteristics of Crystal Lake; and as a result of this effort, data was located and obtained from a number of sources.

Bacteriological information in terms of total coliform concentration at bathing areas on Crystal Lake and also at locations in and around Cold Creek was obtained from the files of the Grand Traverse-Leelanau-Benzie Counties Health Department in Traverse City, through the courtesy of Ralph Wolf and Irv Menzel. This data is presented in Table V-1 covering the period from the summer of 1965 through the summer of 1969. It is apparent that in several instances the reported levels in Crystal Lake exceeded that of 1000 set by the Michigan Water Resources Commission as the average upper limit for total body contact water use. Also, it is apparent that significant contributions of coliform organisms are made to Crystal Lake by the discharge from Cold Creek.

Information on a sanitary and biological reconnaissance survey of Crystal Lake made by the Michigan Water Resources Commission on September 14, 1967, is presented in detail in Appendix D. They found that even though the lake was thermally stratified no indication of decomposition was found in the uncirculating lower stratum (hypolimnion). The dissolved oxygen content in the hypolimnion of Crystal Lake (10.0 mg/l) was higher than it was in the upper circulating water strata (epilimnion) at the end of the summer stagnation period. This agrees with the observations of the present survey. Generally, the Michigan Water Resources Commission Survey indicated there have been no major changes in the trophic nature of Crystal Lake in recent years.

Results of analyses of samples of Crystal Lake collected by the Michigan Water Resources Commission on July 24, 1968, are presented in detail in Appendix E. Three sampling stations were occupied, one at the east end of the lake, one at the center of the lake, and one at the west end of the lake. Generally, results agree with the 1969 survey and include a number of additional chemical analyses not run in 1969.

Excerpts from "Fisheries Survey of Crystal Lake" conducted in 1940 by C.V.D. Brown and John Funk of the Institute of Fisheries Research, Michigan Department of Natural Resources, are presented in Appendix F. Information on temperature and dissolved oxygen distribution agree remarkably well with the 1969 survey data, especially in August in the deep section of the lake. Additional information is presented on aquatic plants and bottom samples collected at a number of locations around the lake.

TABLE V-1

TRI-COUNTY HEALTH DEPARTMENT COLIFORM DATA

		Coliform Index
7/9/69	Swimming Area at Beulah	6,600
7/9/69	7th St. Public Swimming Area	400
7/9/69	Swimming Area at Crystalaire	26,000
3/12/69	Cold Creek - Timber Products	1,000
	Cold Creek - Below Narrow Gauge Rd.	15,000
	Cold Creek - Back of Cases Restaurant	2,000
	Cold Creek - Back of Mrs. Styles	5,000
	Cold Creek at Crystal Lake	13,000
	Cold Creek at Settling Basin	11,000
7/9/68	Swimming Area	<100
	Swimming Area at Camp Crystalaire	600
8/4/66	Mouth of Cold Creek	21,000
8/4/66	South of Beach Rd. - Cold Creek	24,000
7/11/66	Camp Crystalaire for Girls	<30
7/20/66	Christian Assembly Swimming Area	<30
8/4/66	Chimney Corners Swimming Area	<30
8/12/66	Chimney Corners	<30
8/4/66	Swimming Area - Beulah	<30
8/4/66	Frankfort South Side Swimming Area	<30
8/10/66	Cold Creek - 300 ft. up the Creek	3,900
8/4/66	Public Beach North Side Swimming Area, Beulah	230
8/10/66	Congregational Assembly Swimming Area	36
8/10/66	Mouth of Cold Creek	4,300
8/10/66	Beulah Swimming Area	<30
8/10/66	North Shore Swimming Area, Beulah	91
8/20/66	Pilgrim Sta. - C.A. Beach	230
8/4/65	Mouth of Cold Creek	24,000
8/4/65	East Side of Trailer Park-End of Dock, Beulah	430
8/4/65	Cold Creek South of Beach Road, Beulah	24,000
	East of Creek - End of Dock	150
7/26/65	Congregational Assembly Beach at 3' deep in Lake	91
8/4/65	West Side of Cold Creek - End of Dock	930
8/11/65	Cold Creek South of Beach Rd., Beulah	24,000
8/11/65	West Side of Cold Creek - End of Dock	390
8/11/65	East Side of Trailer Park - End of Dock - Swimming Area	91
8/11/65	East of Creek - End of Dock	4,300
8/11/65	Mouth of Cold Creek	46,000

VI. SUMMARY AND CONCLUSIONS

Summaries and conclusions are presented by report section for the convenience of the reader. Also, future study areas are suggested.

SECTION I - INTRODUCTION

A number of specific study aims were agreed upon with the Keep Crystal Clear Committee as follows:

1. To identify and measure major sources of pollution.

2. To define the physical, chemical, and biological characteristics of the waters of Crystal Lake under summertime conditions of maximum use.

3. To evaluate the influence of selected individual waste water disposal systems on ground water quality in the vicinity of the system, and on near shore lake water quality.

4. To evaluate the influence of selected nutrient sources on possible future lake biomass production.

The major field effort was conducted during the months of May, June, July, and August 1969, involving the establishment of a temporary Crystal Lake Field Station allowing the completion of many determinations on the site, but supported by the extensive chemical, biological, and bacteriological facilities of the School of Public Health in Ann Arbor. The excellent cooperation of a number of citizens involving donation of cottage and boat use, together with the availability of the chemistry laboratory of the Benzie Central High School greatly facilitated this phase of the study.

SECTION II - PHYSICAL CHARACTERISTICS

A number of important physical characteristics of Crystal Lake and the surrounding area were defined as part of the present survey.

Crystal Lake is long and narrow with a maximum length of 8.2 miles, and a maximum width of 2.3 miles. The total drainage area at the outlet of the lake into the Betsie River as defined by the U. S. Geological Survey is approximately 32 square miles, while the Cold Creek drainage area is approximately 10.35 square miles, and the surface area of Crystal Lake is approximately 15.18 square miles. Thus, the tributary drainage area is quite small and the lake surface itself makes up about 50% of the total outlet drainage area.

I. D. Scott, in his book "Inland Lakes of Michigan," described the geology of Crystal Lake, and further detailed geological information is presented by James C. Culver in his thesis, "The Glacial and Post-Glacial History of the Platte and Crystal Lake Depressions, Benzie County, Michigan." Excerpts from both references have been presented.

As a first step in the field effort in May 1969, members of the survey team walked the complete shore line of the lake looking for either existing surface discharges into the lake or for pipes that might discharge intermittently during periods of maximum use. Each surface discharge was carefully evaluated as to the best method of determining its pollution contribution, including measurement of the flow characteristics. Discharge measurements were made at 18 of 20 sampling stations, involving the construction of weir measuring devices at a number of these stations, and the establishment of gaging stations on Cold Creek and the outlet channel. For purposes of documentation, the individual flow measurements at each station have been presented including a photograph of most of the measuring stations.

A field reconnaissance was made by members of the survey team up each stream that has a shore sampling station or discharge measurement point located on it to gain some idea of the development or lack of development that might exist. Selections from the field observations made during these trips have been presented.

One concern has been the question of dispersion of waste sources after discharge into Crystal Lake. In order to evaluate the problem, limited dye dispersion studies were conducted at the very beginning of the field phase in May 1969. Generally, Rhodamine WT dye was added to selected streams on the north shore and Cold Creek, and then monitored in the lake by boat, using a Turner Fluorometer. Dye added to two streams on the north shore on May 13, 1969, moved east toward Beulah staying close to the shore, while dye added to Cold Creek in Beulah on May 13, 1969, and May 17, 1969, moved south in front of the Beulah Bathing Beach before passing out into the lake and then toward the outlet. It must be appreciated that the discharge of any of the streams entering Crystal Lake is much too small to cause a direct current in the lake from the stream discharge itself, rather, the predominating influence on the lake circulation is the prevailing wind direction and intensity. Thus, while the pattern during May was a clockwise one, it is recognized that under certain wind conditions the pattern may reverse itself and follow a counterclockwise direction.

The Village of Beulah has separate sanitary and storm sewer systems. Sanitary sewage is collected in several lines which lead to a pumping station on Crystal Avenue, and then is pumped out of the Crystal Lake drainage basin to a treatment facility which discharges to the Betsie River. Thus, only the storm water from the village drains either to Cold Creek or directly to Crystal Lake. The location of existing storm sewer inlets and lines as related to the survey team by Walter Lentz, Superintendent of the Village of Beulah, have been indicated.

After careful consideration, four lake transects were established for the purpose of having regular lake sampling stations and as reference positions for other lake studies. The location of these transects has been described.

One of the important physical considerations in a lake survey is the accurate definition of the lake bottom profile. Fortunately, in the case of Crystal Lake, a map showing the lake bottom contours is available as prepared by the Institute for Fisheries Research, Michigan Department of Natural Resources. Members of the survey team verified the accuracy of this map at the sampling transects.

During the period July 21-27, 1969, Mr. Victor Graf, a researcher and diver from The University of Michigan, had the opportunity to dive in several locations in Crystal Lake. His observations have been presented.

Light penetration readings in the lake using a Secchi disk have been observed as high as 22 to 26 feet in July.

The level of Crystal Lake is maintained by a dam at the outlet, with the legal lake level established at 600.48 feet above mean sea level, by resolution of the Board of Supervisors in October 1909. Attempts were made to calculate water budgets for the 1969 summer period by members of the survey team, but certain of the important elements were not adequately defined to allow meaningful calculations. As a result of the survey work during the summer of 1969, the need for regular and reliable reports of Crystal Lake level became apparent. Logically this should be the responsibility of a governmental agency such as the U. S. Geological Survey or the Michigan Department of Natural Resources. If this is not possible, then a county office such as the Drain Commissioner should be assigned the responsibility. Because of considerable citizen interest in the level of Crystal Lake, some mechanism should be developed for the regular and public reporting of this information as it is collected, particularly during the summer period.

A cooperative station for the collection of climatological data is maintained in the Frankfort, Michigan, area under the sponsorship of the Environmental Science Services Administration, U. S. Department of Commerce. Analysis of the long term precipitation information for this station showed that 1969 was one of the highest precipitation years on record. Ninety-two percent of the years were less than 1969, and only four years of the period 1901-1969 were wetter than 1969. In addition, the months of May and June were especially wet.

SECTION III - WATER QUALITY CHARACTERISTICS

A number of important water quality characteristics of Crystal Lake and its tributaries were defined as part of the present survey.

It is the understanding of the writer that the waters of Crystal Lake have been designated by the Michigan Water Resources Commission for Recreation-Total Body Contact. Of the 11 water quality parameters used by the Water Resources Commission, the two having greatest relevance in Crystal Lake for total body contact include coliform group of bacteria and nutrients. In relation to the coliform group "The geometric average of any series of 10 consecutive samples shall not exceed 1000 nor shall 20% of the samples examined exceed 5000. The fecal coliform geometric average for the same 10 consecutive samples shall not exceed 100." In relation to nutrients (phosphorus, ammonia, nitrate, and sugars), the requirements say "nutrients originating from industrial, municipal, or domestic animal sources shall be limited to the extent necessary to prevent the stimulation of growths of algae, weeds, and slimes which are or may become injurious to the designated use. Also, it is understood that Crystal Lake in addition has been designated for fish, wildlife, and other aquatic life-intolerant fish, cold water species (trout, whitefish, cisco) which has the following significant requirement: "In lakes capable of sustaining high oxygen values throughout the hypolimnion during periods of stagnation: maintain dissolved oxygen values greater than 6 mg/l throughout the entire lake."

Wherever possible, accepted sampling and analytical procedures as outlined in Standard Methods for the Analysis of Water and Waste Water or Limnological Methods were employed, but in some instances modifications or improved procedures were necessary. With the exception of the lake phosphate and pesticide analyses, all other tests were performed at the temporary field laboratory in the Benzie Central High School including bacteriological tests. The analyses included temperature in °C, pH, dissolved oxygen in mg/l, ammonia in mg/l, nitrite in mg/l, nitrate in mg/l, ortho phosphate in mg/l, total phosphate in mg/l, biochemical oxygen demand in mg/l, total coliform in coliform organisms/100 ml, and fecal coliform in fecal coliform organisms/100 ml.

To evaluate the contributions from the many drains and ditches, a weekly chemical and bacteriological sampling program was started on June 11, 1969, and extended to August 20, 1969. Results of this extensive sampling program have been presented in the body of the report and will serve as a basis for planning any lake water quality management program. On occasion, high coliform levels were observed at the P-2 drain, the Crystal Avenue drain, W-1 drain, and Cold Creek. In addition, observations and comments on each drain have been presented.

Special consideration was given to Cold Creek draining an area of approximately 10.35 square miles east of Beulah, and discharging into Crystal Lake at Beulah. Results of special sampling runs along Cold Creek on June 28, July 16, July 31, and August 4 have been presented. It is apparent that significant contributions of nutrients and coliform organisms are made by Cold Creek discharges to Crystal Lake. Also, it is apparent that phosphates are being contributed by several business establishments and houses along the north branch.

To evaluate the influence of shore line development on near shore lake water quality, the lake shore line was sampled and evaluated in front of 288 cottages close to the lake three separate times during the summer period, once in June, once in July, and once in August. The factors which were considered included: discharge pipes, total and fecal coliform concentrations, algae growth, lawn presence, and the number and kinds of pets. Results of this extensive evaluation have been presented in the report. It is apparent from the review of this information that the highest coliform levels and algal concentrations existed in the waters adjacent to the north shore toward the east end of the lake.

Lake water samples were collected at the four lake transects at various depths and stations a number of times during the summer high-use period, starting on June 26, 1969, and ending on August 19, 1969. Detailed results of the several lake runs have been presented in the report. Station 3T3 represents the deeper section of Crystal Lake and it is apparent that thermal stratification has taken place by August 19, where the surface water temperature is 24.1°C and the deeper water temperature is 8.8°C, with the most rapid temperature change with depth occurring around 50 to 60 feet below the surface. Notwithstanding this thermal stratification, the dissolved oxygen levels in the lower part of the lake did not drop below 7.2 mg/l lending further support to the classification of Crystal Lake as an oligotrophic rather than a eutrophic lake.

A special water quality sampling effort was directed to the organized bathing beach areas of Crystal Lake on July 31, 1969. While elevated coliform levels were observed at some locations, none were above the upper allowable coliform level for total body contact.

Interest existed as to the water quality along the stream passing through the Crystal Beach Resort area on the south shore of Crystal Lake, and designated as W-1 in the routine weekly sampling of all the tributary streams. Seven sampling stations were occupied first on June 27, 1969, and then on August 1, 1969. It is apparent from the coliform data, that high coliform levels were observed on August 1 at stations 1 and 2 near the mouth of the drain.

A special effort was made during the week of July 13 to conduct a voluntary well water testing clinic by members of the survey team. Residents of the area were given the opportunity to pick up sterile containers on July 14 at stations at both the east and west end of the lake, collect their own well water sample on the morning of July 15 and return these samples to the same collection stations for immediate processing at the field station laboratory. The laboratory tests included total and fecal coliform evaluation and determination of the nitrate level. The response was enthusiastic with 165 separate well water samples tested in a two-day period. Of these samples, approximately 10% showed positive total coliform results during this first analysis. Members of the survey team personally visited each home having a positive result and collected a second sample, rather than relying on the homeowner to do the sampling. As a result of this followup and resampling, all of the samples previously positive showed negative, suggesting that contamination may have been introduced during the initial sample collection by the individual homeowner.

In addition to the examination of the well water for the presence of coliform bacteria, the same samples were tested for nitrogen in the form of nitrate compounds. Of 165 well water samples tested, 43 were positive. Twenty-two of the positive samples had concentrations greater than 2 mg/l and six samples had concentrations greater than 4 mg/l. One sample exceeded the U. S. Public Health Service drinking water standard of 10 mg/l. Nitrates were found in water samples taken from all sides of Crystal Lake, but a significantly higher percentage of the north shore samples had nitrate concentrations greater than 2 mg/l. All samples found with nitrate concentrations exceeding 4 mg/l were taken from wells on the north shore of Crystal Lake.

Following the major well water survey of the week of July 13, one member of the survey team did additional evaluation of the nitrate content of well water. The north shore of Crystal Lake was selected for this followup since it did show a much higher percentage of significant nitrate content in well waters than did the other areas. Generally, sampling was started at those addresses which had high (>1 mg/l) NO_3 content indicated during the main well water survey, with sampling then proceeding in both directions from the starting point until the nitrate content decreased below 1 mg/l. Detailed results of this effort have been presented in the report. A high concentration of 14.5 mg/l was observed in one sample.

A series of biological observations were made as a complement to the numerous physical, chemical, and bacteriological observations presented elsewhere in the report. Generally, these observations consisted of a description of the aquatic plant growth observed along the shore line and in the outlet channel and Cold Creek, results of two separate bottom sampling efforts, one on August 15, 1969, and the other on September 1, 1969, results of a single plankton sampling effort on August 16, 1969, and results of the collection and identification of macroscopic algae at 11 near shore sites on August 27, 1969.

SECTION IV - SPECIAL STUDIES

Studies were conducted to evaluate the influence of individual waste water disposal systems on near shore lake water quality involving the use of dye tracers through the disposal facilities of four cooperating cottage owners. The test procedure involved the addition of a strong charge of Rhodamine WT dye to the household drain by a University of Michigan survey team member followed by an extensive flushing of the affected fixture. This was repeated daily for a period of three or four days and the occupant was asked to watch for the appearance of color in the lake. In no case was color observed during the test period, and the experiment was discontinued because of the pressure of other survey responsibilities. Notwithstanding the results of this experiment, it is the feeling of the writer that the physical conditions are such in the selected test areas on the north shore of Crystal Lake that it should be possible to detect a dye tracer in the lake if dye is added to the system over a long enough period of time, and if a sensitive fluorometer is used to continuously monitor the lake water. Experiments of this nature should be continued in any future studies.

Review of distances between cottage, water system, sewage system, and Crystal Lake for many existing dwellings around the lake will show these distances less than the minimum distances required of new homes by the Grand Traverse and Benzie Counties Health Departments. It is recognized that many cottages were constructed before the January 1, 1964, sanitary code became effective; nonetheless, it should be appreciated that a number of the cottage sanitary facilities are inadequate and pose a potential health hazard to cottage users both in terms of contaminated well water and lake water. This has been particularly reflected during the summer of 1969 in terms of elevated coliform counts and increased algal growths along certain sections of the lake shore line.

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Results of limited efforts directed to the evaluation of the extent of pesticide use in the Crystal Lake drainage area, and also the existing level of selected pesticides in Crystal Lake itself have been presented.

SECTION V - HISTORICAL INFORMATION

A search was made for historical information on the physical, chemical, bacteriological, or biological characteristics of Crystal Lake, and as a result of this effort, data was located and obtained from the Grand Traverse-Leelanau-Benzie Counties Health Department, the Michigan Water Resources Commission, and the Institute for Fisheries Research, Michigan Department of Natural Resources. This information is included in the interests of a more complete evaluation of the problem.

FUTURE STUDIES

As a result of the 1969 survey and data analysis, the following future studies are indicated:

1. Additional dye tracer studies through selected cottage wastewater systems over a longer period of time than was possible in 1969.

2. Monitoring of chemical and bacteriological discharges from the several drains and ditches during July and August, including Cold Creek and the outlet channel.

3. Monitoring of coliform levels and algal growth along the shorelines during the month of August.

4. Evaluation of thermal stratification and dissolved oxygen levels at the four lake transects during July and August.

5. Repeat of the biological production experiment during late July or early August.

VII. ACKNOWLEDGMENTS

Financial support was provided by the Keep Crystal Clear Committee to The University of Michigan to support the field and laboratory activities of the participants during the spring, summer, and fall of 1969, and also for the preparation and duplication of the final report.

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Special thanks are due to the School Board for the use of the facilities of the Benzie Central High School and to Barry Burdo for his assistance, first as the Principal of the High School, and then later in the summer as the Superintendent of Schools.

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William H. Dahman donated the use of his cottage at 1483 S. Shore Drive for the survey team from May 12 through June 30 at no cost to the project.

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Consumers Power Company, Manistee, Michigan
Walter Lenz, Village of Beulah
Paula and Gus Leinbach and Crystalaire Camp for Girls
Warfside Restaurant, Frankfort, Michigan
Francis Wilson, Beulah
Woman's Association of the Congregational Summer Assembly

Finally, thanks are due to all the residents of the Crystal Lake area for their excellent cooperation and support.

APPENDIX A

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Water Resources Division

Benzie County

Crystal Lake at Beulah, Michigan

Location: Lat 44° 38' 11", long 86° 8' 50", in many sections, Tps.26 and 27 N., Rs. 15 and 16 W., 2.7 miles west of Beulah.

Surface Area: 9,710 acres.

Maximum Depth: 162 ft.

Drainage Area at Outlet: 32 sq.mi., approximately.

Records Available: June 1942 to September 1950. Prior to 1946, records obtained only during summer and fall months.

Gage: Staff gage read daily. Datum of gage is 595.18 ft. above mean sea level (levels by Michigan Department of Natural Resources).

Established legal level: 600.48 ft. above mean sea level, by resolution of Board of Supervisors in October, 1909.

Extremes: 1942-50: Maximum stage observed, 6.12 ft. June 24-28, July 1-4, 1949; minimum observed, 4.12 ft., Dec. 20-31, 1949.

Regulation or control: Lake level is maintained by dam at outlet.

Remarks: Cold Creek enters Crystal Lake at Beulah at the southeastern end of the lake. Crystal Lake outlet flows southward into Betsie River about 2-1/2 miles west of Beulah.

An engineering lake-level control study was completed in 1946 by the Michigan Department of Natural Resources.

No discharge measurements are available on the inlet. The following discharge measurements have been made at the outlet of the lake.

DATE	DISCHARGE (cfs)	WATER TEMP.°F	DATE	DISCHARGE (cfs)	WATER TEMP.°F
Oct 7, 1942	4.36		Oct 9, 1947	5.81	
May 10, 1944	36.8		Jan 15, 1948	.50	
Sep 19, 1944	6.05		Apr 2, 1948	18.9	
Nov 21, 1944	7.10		Aug 12, 1948	11.2	70
Aug 9, 1945	23.3		Oct 8, 1948	2.44	
Nov 5, 1945	23.3		Jan 4, 1949	1.45	
Jan 31, 1946	30.3		Apr 14, 1949	15.3	
Apr 23, 1946	31.7		Aug 11, 1949	15.4	
Jul 10, 1946	27.0	70	Oct 17, 1949	.06	59
Sep 27, 1946	4.91		Dec 22, 1949	0	
Jan 23, 1947	0		Mar 29, 1950	15.0	
May 16, 1947	35.6	49	Jul 25, 1950	19.6	71
Jul 28, 1947	28.0	75	Oct 2, 1950	7.20	

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Water Resources Division

Betsie River near Karlin

Sec.5, T.25 N., R.12 W., at highway
bridge, 1 mi. NW of Karlin, Michigan

DATE	DISCHARGE (cfs)	WATER TEMP.°F	DATE	DISCHARGE (cfs)	WATER TEMP.°F
Nov 21, 1944	43.4		Jan 7, 1957	55.8	34
Oct 17, 1945	84.8		Apr 30, 1957	63.6	47
Jan 30, 1946	109		Jul 25, 1957	40.3	75
Apr 23, 1946	83.4		Oct 15, 1957	27.9	55
Jul 10, 1946	45.6	75	Jan 29, 1958	62.3	34
Oct 28, 1946	33.7	55	Apr 4, 1958	55.4	38
Dec 30, 1946	43.4	32	Jul 29, 1958	29.2	73
May 16, 1947	133	46	Oct 23, 1958	39.4	55
Jul 28, 1947	44.3	72	Jan 20, 1959	51.6	33
Oct 7, 1947	44.8	60	Apr 15, 1959	102	42
Jan 15, 1948	47.7		Jul 8, 1959	32.9	72
May 17, 1948	76.8	48	Oct 27, 1959	50.9	49
Aug 12, 1948	30.4	70	Jan 25, 1960	75.2	33
Oct 8, 1948	25.5	59	Jan 30, 1961	64.8	33
Jan 4, 1949	50.8	34	Apr 18, 1961	89.2	39
Apr 14, 1949	75.0		Jul 14, 1961	34.4	72
Aug 11, 1949	25.0		Oct 11, 1961	80.1	61
Oct 17, 1949	24.9	58	Apr 17, 1962	97.7	38
Dec 22, 1949	46.5	35	Jul 12, 1962	31.2	75
Mar 29, 1950	67.3		Oct 10, 1962	42.2	58
Jul 25, 1950	38.4	71	Jan 10, 1963	53.4	33
Oct 18, 1950	39.1		Apr 16, 1963	101	39
Jan 31, 1951	54.5		Jul 10, 1963	27.8	69
Apr 23, 1951	128	39	Oct 9, 1963	24.3	58
Jul 26, 1951	47.4	74	Jan 21, 1964	53.8	34
Oct 8, 1951	46.3	56	Apr 14, 1964	83.7	38
Jan 21, 1952	95.0	33	Jul 14, 1964	29.7	71
Apr 23, 1952	149	42	Oct 8, 1964	34.6	52
Jul 29, 1952	66.2	70	Jan 14, 1965	62.9	32
Oct 14, 1952	23.4	47	Apr 8, 1965	62.5	37
Jan 9, 1953	60.5	33	Jul 9, 1965	27.6	68
Apr 23, 1953	84.2	43	Oct 11, 1965	79.2	54
Jul 27, 1953	50.4	78	Jan 5, 1966	85.8	36
Oct 20, 1953	31.1	58	Apr 6, 1966	105	37
Jan 28, 1954	51.0	34	Jul 14, 1966	25.1	77
Apr 19, 1954	80.0	41.5	Oct 20, 1966	39.0	53
Jul 14, 1954	110	73	Jan 12, 1967	94.3	34
Oct 5, 1954	60.0	60.5	Apr 5, 1967	105	38
Jan 20, 1955	57.5	34	Jul 18, 1967	57.1	69
Apr 6, 1955	78.0	37	Oct 3, 1967	37.5	60
Jul 26, 1955	29.8	76	Jan 3, 1968	71.0	34
Oct 20, 1955	23.1	51	Apr 12, 1968	85.4	45
Jan 13, 1956	47.1	34	Jul 22, 1968	43.4	73
Apr 12, 1956	80.9	37	Oct 8, 1968	48.2	58
Jul 30, 1956	48.1	67	Jan 21, 1969	81.7	32.5
Oct 2, 1956	39.6	58	Apr 14, 1969	86.6	39

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Water Resources Division

Betsie River near Benzonia

NW 1/4 sec.19, T.25 N., R.14 W., 50 ft. upstream from bridge on State Highway 115, and 4-3/4 mi. SE of Benzonia, Michigan.	DA 158 sq.mi.

DATE	DISCHARGE (cfs)	WATER TEMP.°F	DATE	DISCHARGE (cfs)	WATER TEMP.°F
Oct 15, 1957	101	46	Apr 10, 1964	301	42
Oct 28, 1959	209	42	Jul 7, 1964	115	65
Jan 13, 1960	265	36	Oct 7, 1964	146	42
Apr 16, 1960	348	50	Jan 13, 1965	166	32
Oct 12, 1960	135	44	Apr 7, 1965	264	41
Jan 13, 1961	199	36	Jul 8, 1965	120	66
Apr 12, 1961	231	45	Oct 6, 1965	228	47
Jul 14, 1961	128	63	Jan 5, 1966	227	34
Oct 11, 1961	207	59	Apr 6, 1966	311	40
Jan 22, 1962	214	32	Jul 8, 1966	106	63
Apr 12, 1962	312	41	Oct 5, 1966	119	49
Jul 11, 1962	129	68	Jan 12, 1967	216	32
Oct 11, 1962	135	52	Apr 4, 1967	455	41
Jan 10, 1963	169	34	Jul 18, 1967	187	62
Apr 12, 1963	273	42	Oct 5, 1967	138	57
Jul 10, 1963	113	52	Jan 16, 1967	151	32
Oct 9, 1963	109	49	Apr 8, 1968	249	45
Jan 8, 1964	157	35	Jul 8, 1968	162	63
			Oct 1, 1968	159	50
			Jan 21, 1969	230	33
			Apr 14, 1969	270	50

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Water Resources Division

LOW-FLOW INVESTIGATIONS

Betsie River basin near Thompsonville, Mich.

An investigation in the Betsie River basin was made on Oct. 15, 1957, for the purpose of determining the base-flow yields of various parts of the basin. The Michigan Department of Conservation, which sponsored the investigation, intends to use the data collected in planning watershed and channel improvement work in the basin, one of the main objectives being the improvement of habitat for trout. Results of base-flow investigations such as this are used to determine which portions of the basin are adapted to successful improvement work and to appraise the results of such work later on. Weather records at Thompsonville, which is located within the basin, show that there was no significant precipitation for two weeks preceding Oct. 15; the measurements therefore represent base flow.

The measurements on each stream are listed in order proceeding downstream and each tributary is inserted in the order in which it enters the main stream. Drainage areas shown were determined from U. S. Geological Survey topographic maps (contour interval, 20 ft.), dated 1956.

Discharge measurements of Betsie River and tributaries near Thompsonville, Mich. 10/15/57

Stream	Location	Drainage Area (sq mi)	Discharge (cfs)	Cfs per sq.mi.	Water Temp. °F
Ellis Lake Outlet.....	NW 1/4 sec.15, T.26 N.,R.12 W.,75 ft downstream from U.S. Hwy 31, 1/2 mi.downstream from Ellis Lake.1 mi NW of Interlochen & 2-1/2 mi.W of Grawn.	1.79	1.04	0.581	52
Cedar-Hedge Lake Outlet	SE 1/4 sec.8,T.26 N.,R.12 W. 30 ft upstream from U.S.Hwy 31, 1/3 mi.downstream from Cedar-Hedge Lake, & 1 mi.NW of Interlochen.	4.02	2.85	.709	51
Betsie River..........	NW 1/4 sec.5,T.25 N.,R.12 W. 600 ft downstream from Green Lake, 1-3/4 mi.NW of Karlin, 4-1/4 mi.SW of Interlochen.	59.6	27.9	.468	55
Do..............	SW 1/4 sec.2,T.25 N.,R.13 W. 250 ft.downstream from Mich. Conservation Dept.dam,3/4 mi. downstream from Grass Lake Creek, & 4-1/2 mi.NW of Karlin.	80.9	45.0	.556	51
Do..............	SW 1/4 sec.10,T.25 N.,R.13 W. 100 ft. upstream from Worlds Bridge, 3/4 mi.east of Wallin & 5 mi.NE of Thompsonville.	83.0	43.0	.518	51

Stream	Location	Drainage Area (sq mi)	Discharge (cfs)	Cfs per sq.mi.	Water Temp. °F
Do...............	On Line between secs.16 & 17 T.25 N., R.13 W., 1/2 mi.SW of Wallin & 4 mi.NE of Thompsonville.	86.9	44.1	.507	51
Do...............	NW 1/4 sec.20, T.25 N.,R.13 W. 1-3/4 mi.SW of Wallin, 2-1/2 mi.upstream from Little Betsie River, & 3 mi.NE of Thompsonville.	89.6	47.4	.529	50
Do...............	SW 1/4 sec.19,T.25 N.,R.13 W. on County Road 669, 1-1/4 mi. upstream from Little Betsie River & 1-3/4 mi.N of Thompsonville.	95.4	47.4	.497	50
Little Betsie River...	SW 1/4 sec.27,T.25 N.,R.13 W. 1 mi.N of Nessen City & 3-1/2 mi.NE of Thompsonville.	4.90	6.86	1.40	49
Do................	SW 1/4 sec.29,T.25 N.,R.13 W. 2 mi.NE of Thompsonville,2 mi. NW of Nessen City, & 2-1/2 mi. upstream from Betsie River	5.94	8.39	1.41	50
Do................	SW 1/4 sec.30, T.25 N.,R.13 W. on County Road 669, 1/2 mi. upstream from mouth & 1 mi. north of Thompsonville.	9.30	9.21	.990	50
Betsie River	SW 1/4 sec.25,T.25 N.,R.14 W. 200 ft downstream from Thompsonville Dam.	106	65.9	.622	48
Do................	SE 1/4 sec.35,T.25 N.,R.14 W. 10 ft downstream from Red Bridge & 3/4 mi.W of Thompsonville.	110	67.9	.617	48
Unnamed tributary.....	SW 1/4 sec.36,T.25 N.,R.14 W. 500 ft upstream from Betsie River & 3/4 mi. SW of Thompsonville	1.83	0	0	-
Betsie River..........	SW 1/4 sec.2, T.24 N.,R.14 W. 2 mi. SW of Thompsonville & 3-1/4 mi. NW of Copemish.	115	80.9	.703	48
Do................	NW 1/4 sec.8, T.24 N.,R.14 W. 4-1/2 mi. SW of Thompsonville & 5-1/2 mi. NW of Copemish.	121	82.1	.679	48
Do................	NE 1/4 sec.6, T.24 N.,R.14 W. 50 ft upstream from Manistee-Benzie County line, 5 mi.W of Thompsonville & 6-1/2 mi.NW of Copemish.	128	89.4	.698	48
Do..............	NE 1/4 sec.36,T.25 N.,R.15 W. 5-3/4 mi. W of Thompsonville & about 8 mi.upstream from Homestead Dam.	134	90.0	.672	46

Stream	Location	Drainage Area (sq mi)	Discharge (cfs)	Cfs per sq.mi.	Water Temp. °F
Deer Creek.........	NW1/4 sec.15,T.25 N.,R.14 W. 10 ft upstream from County Road 671, 4-1/4 mi.NW of Thompsonville & 6 mi.SE of Benzonia	10.2	3.04	.298	47
Do..............	SW 1/4 sec.16, T.25 N.,R.14 W. 4-1/2 mi.NW of Thompsonville & 6 mi.SE of Benzonia.	14.4	4.26	.296	47
Unnamed tributary..	NW 1/4 sec. 22, T.25 N.,R.14W on County Road 671, 1 mi.upstream from mouth & 3-1/2 mi. NW of Thompsonville	1.30	.30	.231	48
Deer Creek.........	NE 1/4 sec.19,T.25 N.,R.14 W. 25 ft.upstream from State Hwy 115, 5-1/4 mi.NW of Thompsonville, and 5-1/2 mi.SE of Benzonia.	17.6	7.38	.419	44
Betsie River.......	NW 1/4 sec.19, T.25 N.,R.14 W. 50 ft.upstream from State Hwy 115, 4-3/4 mi. SE of Benzonia and about 5 mi.upstream from Homestead Dam.	158	101	.639	46

From WSP 1557, 1958

APPENDIX B

TEST AND TEST PROCEDURES

Total Coliform - Membrane Filter Procedure

1. Use m-Endo Broth MF - 4.8 g/100 ml of distilled water
2. Add 2 ml of ethyl alcohol/100 ml
3. Heat to the first sign of bubbling - rotating flask while heating - allow to cool to room temperature
4. Place membrane filter pads in dishes using sterilized tongs
5. Pipette 2.5 ml of broth on each pad - allow time for the pads to become saturated and pour off excess
6. Place membrane filter grid on filtering dish using sterilized tongs
7. Clamp on top half of filter
8. Pour filter about 20 ml of phosphate buffer through filter
9. Filter desired sample size - remembering to shake sample about 25 times first
10. Wash with phosphate buffer twice
11. Remove grid from filter and roll onto pad
12. Incubate in an inverted position at 35±0.5°C for 24 hr

It was necessary to sterilize the filter funnels between each sample run. The method of sterilization used was to burn alcohol in the funnels between samples. This method was used since it would be impossible to have enough filter equipment to sterilize any other way. Controls were run throughout the summer to keep a check on this procedure of sterilizing and none of the controls were positive.

Fecal Coliform - Membrane Filter Procedure

1. Use m-FC Broth - 3.7 g/100 ml of distilled water
2. Add 1 ml of rosolic acid/100 ml of broth
3. Heat as in total coliform
4. Filter as in total coliform
5. Incubate in watertight plastic bags in water bath at 45±0.5°C for 24 hr

Notes

1. Same sterilization procedure used between samples on fecal coliform test as total coliform
2. Low dilution always run first on each sample run
3. Collection bottles sterilized by heating in autoclave for 30 min at 230°F (with caps on)
4. Pipettes sterilized in oven at 320°F for 30-45 min without container cover and then 1 hr with cover
5. PO_4 buffer prepared by adding 1.25 ml/l of distilled water then heating to first sign of bubbling
6. Rosolic acid prepared - standard methods (1 g of acid/100 ml of 0.20 NaOH

Chemical Analysis

Water samples were analyzed for nitrogen in the form of nitrates, nitrites and ammonia; phosphorus in the form of dissolved ortho phosphate and total phosphates. The dissolved oxygen concentration and pH of each sample was also determined.

A. Nitrates: The analysis for nitrate content of all water samples was performed using a modification of the "chromotropic acid" method as described by West and Ramachandran in Analytica Chimica Acta, 35 (1966) 317-324. Modifications included an increase in the volume of sample analyzed (6.5 ml instead of 2.5 ml), and a reduction in the amount of antimony sulfate solution used. All other reagent volumes were increased proportionally to provide for the increased volume of sample.

Reagents and Appartus: NO_3 Test

1. Chromotropic acid reagent. Dissolved 80 mg reagent grade chromotropic acid in 50 ml conc H_2SO_4. Reagent was prepared fresh at least once every two weeks.

2. Sulfite urea solution. Dissolved 5 g urea and 4 g reagent grade anhydrous sodium sulfite in 100 ml distilled water.

3. Antimony solution. Solution was prepared by heating 0.2 g antimony metal in 80 ml conc H_2SO_4 until all of the metal was dissolved. The solution was cooled and added to 20 ml of distilled water.

4. Reagent grade conc sulfuric acid.

5. Appartus. Per cent transmittance was measured at 410 mμ using a Bausch and Lomb "Spectronic 20" with 1" colorimeter tubes. Measurements were made against a distilled water blank with reagents added.

B. Nitrites: Samples were analyzed for NO_2 content following the method described in Standard Methods for the Examination of Water and Wastewater 12th edition pp. 205-208 (Sulfanilic acid, napthylamine hydrochloride method). Transmittance measurements were made at 520 mμ using the "Spectronic 20" with 1" colorimeter tubes.

C. Ammonia Nitrogen: The Direct Nesslerization Method was used following the procedure described in Standard Methods, 12th edition, pp. 193-194. Transmittance measurements were made at 412.5 mμ using 1" colorimeter tubes (Bausch and Lomb Spectronic 20).

D. Dissolved Oxygen: The dissolved oxygen content of all samples was determined by the Azide Modification of Iodometric Method ("Winkler test") as described in Standard Methods, 12th edition, pp. 406-410.

E. Phosphate: Analysis for orthophosphate was performed using the Stannous Chloride Method as described in Standard Methods, 12th edition, pp. 234-236. Measurements were made at 690 mμ using 1" colorimeter tubes (Spectronic 20). Total phosphate was determined by autoclaving the sample, as recommended in Standard Methods, followed by the determination of orthophosphate content.

F. Nitrate Screening Test: A quick spot test was used in the well water survey to screen samples for concentrations of nitrate above 1 mg/l NO_3-N. The method used was adopted from "Qualitative Analysis by Spot Tests" by Fritz Feigl, Elsevier Pub. Co., 1956.

APPENDIX C

SELECTIONS FROM

SANITARY CODE OF MINIMUM STANDARDS

REGULATING

SEWAGE DISPOSAL - WATER SUPPLIES

AND

SANITATION OF HABITABLE BUILDINGS

IN

GRAND TRAVERSE AND BENZIE COUNTIES, MICHIGAN

Article IV DISPOSAL OF WATER CARRIED SEWAGE ON PREMISES WHERE A PUBLICLY OPERATED SEWERAGE SYSTEM IS NOT AVAILABLE:

4.1 GENERAL REQUIREMENTS

All flush toilets, lavatories, bathtubs, showers, laundry drains, sinks, and any other similar fixtures or devices hereafter constructed to be used to conduct or receive water carried sewage shall be connected to a septic tank or some other device in compliance with these minimum standards and the Michigan Department of Health regulations, and finally disposed of in a manner in compliance with these minimum standards and the Michigan Department of Health regulations and any other applicable law, ordinance, or regulations.

Provided that such facilities existing at the time these standards are adopted which may become a nuisance or menace to the public health in the opinion of the health officer shall be connected to a septic tank or other approved device and finally disposed of in a manner in compliance with these standards and the Michigan Department of Health requirements. Footing drains, roof water, and any other similar waste water not defined as sewage shall not be connected to or discharged into the sewage disposal system.

4.2 SEWAGE DISCHARGED INTO A BODY OF WATER

No sewage or sewage disposal system shall discharge into any body of water or into or onto the ground surface closer than twenty-five feet (25) feet from a body of water, or its highest known level, or into a public drain.

4.21 TYPE AND LOCATION

No unexposed sewers or pipe used to conduct untreated sewage from a dwelling or habitable building shall be located closer than 10 feet from the nearest unprotected water suction line, well casing, spring structure or other potable water source. When such unexposed pipe or sewer is closer than 50 feet from any unprotected water suction line, well casing, spring structure, or other potable water source, such sewer line shall be constructed of extra heavy cast iron pipe with leaded and caulked joints, tested for water tightness or cast iron pipe with water-tight joints, or other pipe of equal quality approved by the health officer. Where any such pipe or sewer is located inside or beneath a habitable building or dwelling or within 5 feet outside the inner face of such building foundation wall such sewer pipe shall be constructed of such material as described above.

4.22 SIZE

Such pipes or sewers shall be four inches in diameter or larger.

4.23 GRADE

Sewers shall be laid at such a grade as to maintain a sewage flow velocity of not less than two feet per second when flowing full. Sewers four to six inches in diameter shall have a grade of not less than 12 inches per 100 feet or one inch per eight feet of sewer pipe.

4.3 SEPTIC TANKS

4.3.1 LOCATION

Septic tanks shall be located at least 50 feet from any potable water supply, well, spring, or unprotected water suction line, except in the case of schools, resorts, trailer parks, restaurants, taverns or other dwellings or habitable buildings which serve the public such distance shall be 75 feet, except where the Michigan Department of Health regulations require a greater distance, or upon the written approval of the health officer an exception is granted. No septic tank shall be located closer than 5 feet to any footing or foundation wall. No septic tank shall be placed within 10 feet of any lot lines, or within 25 feet of the highest known water mark of any lake, creek, river, pond or other body of water. No septic tank shall be located where it is inaccessible for cleaning or inspection, nor shall any structure be placed over any septic tank rendering it inaccessible for cleaning or inspection.

4.32 MATERIALS AND CONSTRUCTION

Septic tanks shall be of watertight construction and of a material not subject to decay or corrision when installed. Concrete blocks or bricks at least eight inches in thickness may be used in septic tank construction. Septic tanks shall be provided with one or more suitable openings with watertight covers to permit cleaning and inspection. The outlet from such tank shall be constructed so as to permit flow of liquid from the tank and to prevent the escape of floating or settled solids. The inlet shall be designed to permit gasses collected above the liquid level to pass through the inlet and out the vent pipe serving the sewers leading into the septic tank. Cinder blocks shall not be approved for septic tank construction.

4.33 CAPACITY

Every septic tank hereafter installed shall have a liquid capacity of at least the average volume of sewage flowing into it during any 24-hour period. However, in no case shall the liquid capacity of any septic tank be less than 500 gallons. If a compartment tank is installed, the first compartment shall have not less than one-half nor more than two-thirds the total capacity.

The following capacity for septic tanks shall be required except in the opinion of the health officer where increased capacities may be required.

Two-bedroom dwelling 500 gallons (with garbage grinder 750)
Three-bedroom 750 gallons (with garbage grinder 1000 gallon)
Four bedroom dwelling 1000 gallons (with garbage grinder 1250 gallon)

4.4 DOSING TANK

The health officer may require that dosing tanks be provided with automatic siphons or pumps of a type approved by the Michigan Department of Health be used on installations where the liquid capacity of the septic tank is 2,000 gallons or more.

4.51 LOCATION

Sub-surface disposal systems shall be located at least 50 feet from any potable water supply, well casing, spring structure, or unprotected water suction lines, except where the Michigan Department of Health requires a greater distance. Such drain fields shall be located at least 10 feet from a lot line, and 25 feet from any lake, pond, creek, or other surface water flooding, or its highest known level and at least 10 feet from any habitable building or dwelling.

4.52 SEPTIC TANK EFFLUENT

Under no condition may the overflow from any septic tank or any other sewage wastes from any existing or hereinafter constructed premise be discharged upon the surface of the ground within two hundred (200) yards of any habitable building other than the building from which it originates. No sewage shall be discharged into any roadside ditch.

4.53 SIZE AND QUALITY OF DRAIN LINES

4.53 SIZE

Sub-surface disposal system lines shall have a diameter of not less than four inches.

4.53.2 QUALITY

Sub-surface disposal system lines shall be constructed from extra quality drain tile, or such other materials as approved by the Michigan Department of Health and the health officer.

4.54 DEPTH AND POSITION OF TILE OR OTHER APPROVED DEVICE FOR DISTRIBUTION LINES

4.541 DEPTH, SLOPE, AND LENGTH OF LINES

The top of the sub-surface distribution lines shall be not less than 12 inches nor more than 30 inches below the finished grade.

Slope of the distribution lines shall be not more than 4 inches per 100 feet.

Length of any one lateral line shall not exceed 100 feet.

4.542 HEADERS

Watertight headers, or a distribution box or other method or device approved by the health officer shall be set true and level so as to afford an even distribution of all septic tank effluent throughout the sub-surface disposal area.

4.55 FILTER MATERIAL

Sub-surface disposal system lines for distributing septic tank effluent for direct soil absorption shall be laid over at least six inches of washed stone from one-half to one inch in size, or an equivalent aggregate approved by the health officer.

4.56 TRENCH CONSTRUCTION

Trenches shall be not less than 18 inches wide at the bottom. The same washed stone or such other aggregate as may be necessary to prevent the filtering of backfill material around the lateral distribution lines shall be spread over the distribution line to a depth of at least two inches.

4.57 FIELD AREA

Sub-surface disposal field area shall comply with the following minimum trench or stone bed areas, depending upon the average daily volume of septic tank effluent and the type soil in the drain area.

SOIL	Perc. test time for one inch drop	Minimum absorption area per single family residence 3 bedrooms or less
Coarse sand or gravel	Less than 5 min.	300 sq. feet
Sand	5 - 10 min.	450 sq. feet
Loam	11 - 20 min.	600 sq. feet
Sandy clay or clay loam	21 - 30 min.	750 sq. feet
Clay	31 - 45 min.	900 sq. feet
Heavy Clay	over 45 min.	not suitable
	Minimum filter bed (Area: 400 sq.ft.)	

In heavy soils (clay) where the drop in water level is over 45 minutes per inch by standard percolation test or where ground water or an impervious hard pan is found less than 4 feet from the ground surface, an alternate drainage device may be approved at the discretion of the health officer or the permit denied. Drainage for systems to serve other than single family residences of 3 bedrooms or less shall be prescribed by the health officer.

Sub-surface disposal systems shall contain at least one (1) lineal foot of tile for every three (3) feet of trench width. Trench excavations exceeding 36 inches in width at the bottom shall be considered tile beds and shall require 50% more trench bottom absorption area than required for single line trench.

Article V. PERMIT

On and after January 1, 1964, no person shall begin construction of any sewage disposal facility as defined in these minimum standards until such person or his duly authorized representative has made written application to the health officer and has received a duly signed construction permit from the health officer, provided, however, no such application or construction permit shall be required in those cases where a permit from the State Department of Health is a statutory prerequisite and has been obtained. Such construction permit shall be issued only when plans and specifications for the proposed installation of the average system are not less than the requirements set forth in these minimum standards.

Said permit shall be in duplicate and shall contain a sketch showing all pertinent plans and specifications of the proposed sewerage disposal installation. Said permit shall be signed by the applicant and the health officer. One copy of the permit shall be given to the applicant to be posted at the construction site. One copy of the application permit shall be retained by the health officer and remain on file in the health department.

The health officer shall make such inspection at the construction site as he deems necessary. Failure to construct according to the approved plans and specifications shall be deemed a violation of these minimum standards for which the person installing the system shall be held liable.

Article III. PRIVATE WATER SUPPLIES

3.1 Private water supplies hereafter installed shall comply with the following:

3.11 LOCATION

All well casing, spring structures, water suction lines, or other drinking water or potable water structure shall be located 50 feet or more from all sources of possible contamination such as seepage pits, cesspools, privies, barnyards, septic tanks, sub-surface disposal systems, surface water drains, waste water or other sources of possible contamination. Buried or unexposed sewers or pipes through which sewage may back up shall not be located closer than ten (10) feet from any potable water well casing or suction pipe. When such sewers or pipes are located within the ten to fifty (10 to 50 foot area),the sewer pipes shall be constructed of extra heavy cast iron with leaded and caulked joints tested for water tightness. All wells shall be located so that possibilities of flooding are reduced to a minimum. The area immediately adjacent to the well shall be such that the surface water is diverted away from the well casing.

3.13 MINIMUM DEPTH

No wells less than 25' in depth shall hereafter be installed or constructed without written approval of the health officer.

APPENDIX D

MICHIGAN WATER RESOURCES COMMISSION

Report of Sanitary and Biological Reconnaissance Survey
Village of Beulah
(Crystal Lake) - Benzie County

September 14, 1967

A sanitary survey of the Village of Beulah was conducted on the above date to determine if sewage was entering Cold Creek. Cold Creek, a tributary to Crystal Lake, was carefully observed and the banks were inspected from the Lake, upstream through the Village of Beulah. The outlet to Crystal Lake was also observed and bacteriological and chemical samples were collected from both locations. In addition, Secchi Disc readings, a temperature profile, plankton samples and bottom samples of single Ponar dredge hauls were obtained at a few locations in Crystal Lake. See Figure 1 showing locations of sampling stations or observations.

Table 1. Results of water quality measurements of Crystal Lake and Cold Creek, September 14, 1967.

Sampling Station		Parameter	Results	
Station 1 - Cold Creek at point where it empties into Crystal Lake		Total Coliforms	2100	counts/100 ml
		Fecal Coliforms	300	counts/100 ml
		pH	8.2	
		Total PO_4	.05	mg/1
		NO_3	1.3	mg/1
Station 2: Crystal Lake, 300' west of Cold Creek outlet		Total Coliform	100	counts/100 ml
		Fecal Coliform	10	counts/100 ml
		Secchi Disc transparency	11	feet
		Bottom samples	321	animals/sq.ft.
Station 3: Crystal Lake*		Phytoplankton	240	ml
		Secchi Disc transparency	11	feet
		Bottom Samples	25	animals/sq.ft.
Station 4: Crystal Lake		Secchi Disc transparency	11	feet
		Bottom Samples	100	animals/sq.ft.
Station 5: Crystal Lake				
	10' Deep	BOD	1.8	mg/1
		DO	9.4	mg/1
		pH	8.6	
		Total PO_4-PO_4	0.00	mg/1
		NO_3	0.00	mg/1
	75' Deep	BOD	1.4	mg/1
		DO	9.4	mg/1
		pH	8.6	mg/1
		Total PO_4-PO_4	0.00	mg/1
		NO_3	0.00	mg/1

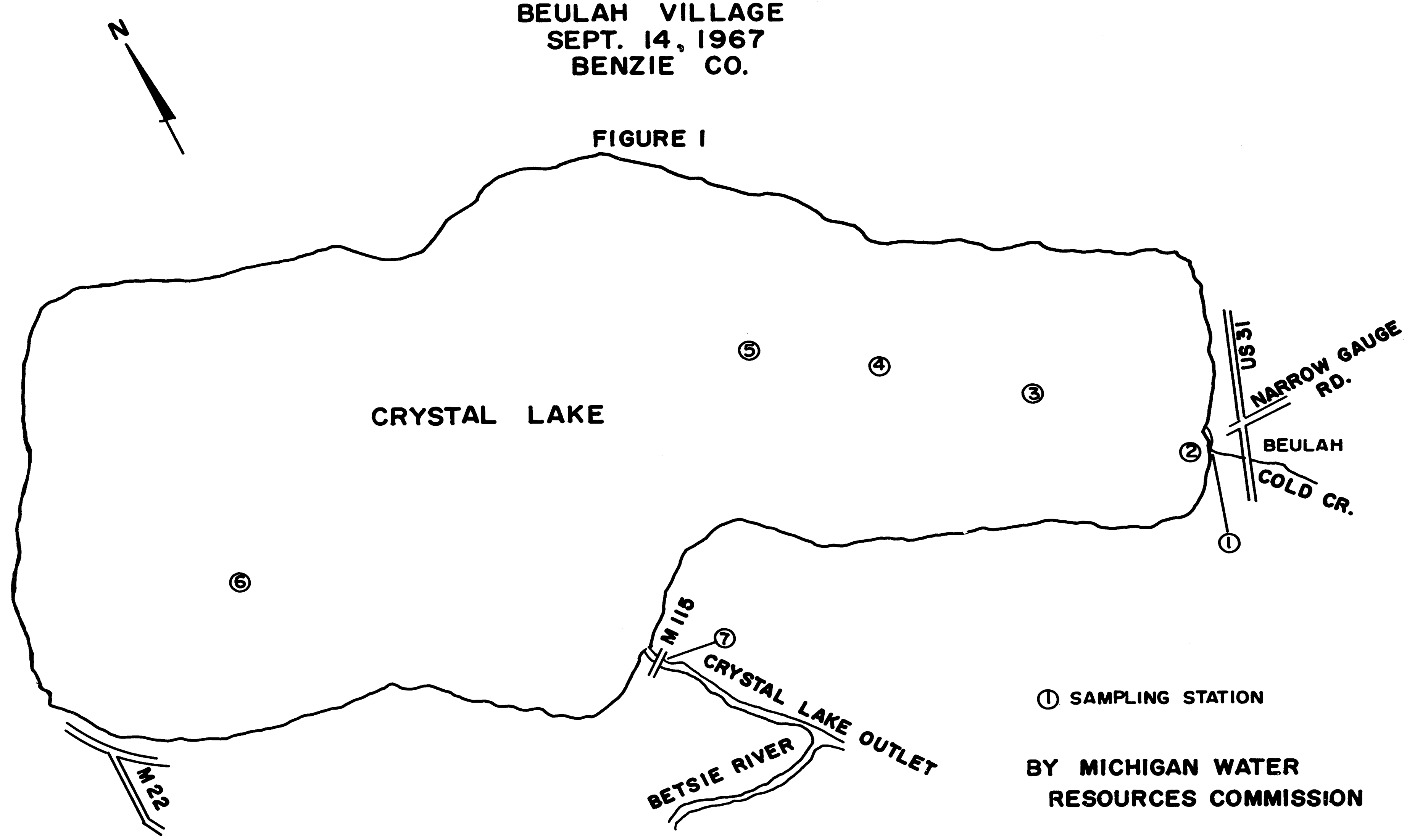
Table 1 Continued:

Sampling Station		Parameter	Results	
(Station 5 Con't)	95' Deep	BOD	2.4	mg/1
		DO	10.0	mg/1
		pH	8.2	mg/1
		Total PO_4-PO_4	0.00	mg/1
		NO_3	0.00	mg/1
		Phytoplankton	80	organisms/ml
		Bottom sample	64	animals/sq.ft.
		Temperatures:		
	20' Deep		66°F	
	30' Deep		65	
	40' Deep		64	
	50' Deep		61	
	60' Deep		54	
	70' Deep		52	
	80' Deep		50	
	90' Deep		49	
	95' Deep		49	
Station 6: (Crystal Lake)		Phytoplankton	120	organisms/ml
Station 7: outlet		Total Coliforms	500	counts/100 ml
		Fecal Coliforms	10	counts/100 ml
		pH	8.6	
		Total PO_4-PO_4	0.00	mg/1
		NO_3	0.00	mg/1

*See Figure 1 for location of sampling stations.

SANITARY SURVEY
BEULAH VILLAGE
SEPT. 14, 1967
BENZIE CO.

FIGURE I



The water quality data obtained from this investigation (Table 1) indicates that Crystal Lake is very infertile (oligotrophic). Even though the lake was thermally stratified no indication of decomposition was found in the uncirculating lower stratum (hypolimnion). In fertile lakes decomposition in these lower waters causes depression of dissolved oxygen after a long period of stagnation. Interestingly, the dissolved oxygen content in the hypolimnion of Crystal Lake (10.0 mg/l) was higher than it was in the upper circulating water strata (epilimnion) at the end of the summer stagnation period. Decomposition also causes an increase in nutrient concentrations in the hypolimnion. Neither phosphorous nor nitrates were detected in the epilmnion or the hypolimnion of Crystal Lake in September. A sample taken on April 12, 1967 at the time of the spring overturn, which probably represents the annual peak in fertility contained only small concentrations of nutrients (0.00 mg/l soluble orthophosphate, 0.02 mg/l total phosphate, 0.10 mg/l nitrates as N).

Four samples of bottom-dwelling macroinvertebrates were obtained with a ponar dredge at the locations shown on Figure 1. Samples were taken at 20, 32, 70, and 95 foot depths. A complete listing of the animals found at these locations is shown on Table 1. The sample taken 20 foot deep in the littoral zone, i.e. area inhabited by rooted aquatic plants, contained 14 different types of bottom animals. The upper sediments consisted of natural silt mostly of plant origin. The amphipod Hyalella azteca was the dominant animal found. Other occupants of this area were mayfly nymphs (Hexagenia limbata), and caddisfly larvae, (Neuroclipsis). A sample was taken at Station 3 from a depth of 32 feet where the bottom sediments consisted of clean marl. Tolerant midges were numerically dominant here but the larger mayflies (Hexagenia limbata) made up the bulk of the biomass. The number and variety of animals living on this marl substrate were the lowest found of the four locations sampled.

The benthic community found at 70 and 90 feet depths was dominated by a common inhabitant of Lake Michigan, the amphipod Pontoporeia affinis. A very interesting member of this profundal community was the crustacean Mysis oculata var. relicta. This shrimp-like animal is found only in cold, deep, oligotrophic lakes where it serves as an important food source for lake trout.

A comparison of communities found at the 20 and 70 foot depths in this survey with those found in a survey conducted in 1940[1] is shown in Table 2. The decrease in mayflies observed at the 20 foot depth between 1940 and 1967 is probably due to seasonal variation. The 1940 sample was taken in June prior to emergence of adult mayflies from the lake whereas the 1967 sample was taken in late summer long after this emergence period.

Table 2 Comparison of the benthic communities in Crystal Lake in 1940 and 1967 at 20 and 70 feet depths. Numbers indicate animals per square foot of substrate.

Depth	Date	Total number of organisms	Mayflies	Midges	Amphipods	Clams	Oligochaete
21	1940	346	58	156	112	2	
20	1967	321	4	44	174		4
70	1940	55	2	18	20	2	14
70	1967	100	1	33	58	6	1

[1] Brown, C.V.D., and John Funk. 1940. Fisheries survey of Crystal Lake, Benzie County. Institute of Fisheries Research Report No. 629 Michigan Department of Natural Resources.

The general impression from this rough comparison is that the components of the benthic community were essentially the same in 1967 as they were in 1940.

The average plankton count was 146 organisms per ml in the three samples obtained from Crystal Lake. This is very low compared to average counts from Lake Michigan which range from 800 to 1000. Average phytoplankton counts from Lake Superior range between 70 to 120.

Water transparency as measured by a Secchi disc was 11 feet at three stations during our September 1967 survey. Brown and Funk cited Secchi transparency as 19 feet in their June 1940 survey. Unfortunately these figures are not directly comparable since the observations were made at different times of the year. Transparency varies seasonally with changes in the density of planktonic communities.

Dictyosphaerium, a green alga, was the dominant phytoplankter and copepods were the dominant zooplankter. Copepods made up the bulk of the material trapped in our tow net. Some algae were of the nuisance blue-green type (*Anabaena* and *Aphanothece*). All of these species were present in only small numbers. The desmid *Staurastrum* and *Dinobryon*, both common inhabitants of oligotrophic lakes, were abundant.

The analyses of these samples substantiate the chemical and benthic analyses which indicate that this lake is oligotrophic.

Summary and Remarks

The findings of our limnological reconnaissance survey indicate that there have been no major changes in the trophic nature of Crystal Lake in recent years.

The sanitary reconnaissance survey of Cold Creek did not reveal the presence of any discharges to the watercourse.

Attached excerpts from the 1940 survey of Crystal Lake[1] contain an excellent description of the oligotrophic nature of this lake.

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[1] Ibid. pp 3, 4, 7, 8, 9 and 10

Field work by: John Robinson, Aquatic Biologist
Blanchard Mills Water Pollution Investigator

Report by: John Robinson
John Cosens, Sanitary Engineer
Water Quality Appraisal Unit
WATER RESOURCES COMMISSION
Department of Natural Resources

Table 1 Quantitative survey of bottom dwelling macroinvertebrates, Crystal Lake September 14, 1967

	6	10	21	29
Station	2	3	4	5
Depth	20	32	70	95
Scientific name		Number of animals		
Hexagenia limbata	4	6	1	
Hyalella azteca	174			
Orconectes rusticus rusticus	1			
Anatopynia Sp. R	1			
Glyptotendipeds senilis	1			
Tendipes riparius	22			
Tanytarsus jucundus	17			
Hydra carina	1			
Tubificidae	4		1	10
Anatopynia Sp. X	1			
Pentaneura sp.	1			
Procladius riparius	92			
Neureclipsis sp.	1			
Procladius adumbratus	1	3	6	1
Tendipes plumosus		12		
Tendipes tuxis		1		
Cryptochironomus digitatus		3		
Mysis oculata var. relicta			1	1
Pontoporeia affinis			58	43
Pisidium			6	
Harnischia tenuicaudata			3	
Tendipes modestus			10	
Cryptochironomus sp. R			1	
Calopsectra dives			1	
Calopectra deflecta			9	
Harnischia (near) nais			3	
Cricotopus sp.				1
Calopsectra sp. E.				7
Number of animals/sq. ft.	321	25	100	63
Total number of species	14	5	12	6

APPENDIX E

Analyses of Samples of Crystal Lake, Benzie County
Collected
July 24, 1968

Sampling Station	Depth (ft.)	Temp. (°C)	Dissolved Oxygen	5-day BOD	Total Solids	Total Dissolved Solids	Suspended Solids	NH_3-N	NO_3-N	Soluble ortho PO_4-P	Total PO_4-P
East end of Lake	T	21.5	9.0	1.0	215	204	11	0	0	0	0.01
	30	21.0	9.2	---	---	---	--	--	--	--	----
	40	19.5	9.6	0.7	---	---	--	--	--	--	----
	45-B	19.0	---	---	205	198	7	0	0	0	0.01
Center of Lake	T	21.0	9.3	---	---	---	--	--	--	--	----
	15	21.0	9.1	0.5	208	198	10	0	0	0	0.01
	30-B	21.0	9.4	0.8	202	198	4	0	0	0	0.01
West end of Lake	T	21.0	9.0	---	---	---	--	--	--	--	----
	45	19.5	9.2	---	---	---	--	--	--	--	----
	50	17.5	10.2	0.8	202	198	4	0	0	0	0.01
	60	16.0	10.2	---	---	---	--	--	--	--	----
	150-B	10.0	9.4	0.8	208	204	4	0	0	0	0.01

Note: All constituents except ph are expressed as mg/l unless otherwise noted.

Analyses of Samples of Crystal Lake, Benzie County
Collected
July 24, 1968

(continued)

Sampling Station	Cl	SO_4	Ca	Mg	Na	K	Fe	pH	Hardness	Alkalinity	CO_3	Total Coliforms (counts/100 ml)	Fecal Coliforms (counts/100 ml)
East end of Lake	3	40	40	15	4.9	0.6	0	8.1	160	120	0	600	<10
	--	--	--	--	---	---	--	---	---	---	-	---	--
	--	--	--	--	---	---	--	---	---	---	-	---	--
	3	40	--	--	5.0	0.6	0	8.1	155	120	0	---	--
Center of Lake	--	--	--	--	---	---	--	---	---	---	-	<100	<10
	2	40	40	13	5.0	0.7	0	8.1	155	120	0	---	--
	2	41	40	13	4.9	0.7	0	8.1	155	120	0	---	--
West end of Lake	--	--	--	--	---	---	--	---	---	---	-	800	<10
	--	--	--	--	---	---	--	---	---	---	-	---	--
	3	40	40	13	5.0	0.7	0	8.2	155	120	0	---	--
	--	--	--	--	---	---	--	---	---	---	-	---	--
	2	38	40	15	5.0	0.7	0	8.0	160	120	0	---	--

Note: All constituents except ph are expressed as mg/l unless otherwise noted.

APPENDIX F

Excerpts from "Fisheries survey of Crystal Lake,"Benzie County, Institute of Fisheries Research, Report No. 629

by

CVD Brown and John Funk, 1940
(pages 3, 4, 7, 8, 9, and 10)

Crystal Lake, formerly known as Cap Lake, is long and narrow with a maximum length of 8.2 miles, a maximum width of 2.3 miles, and a surface area of 9,711 acres. Its long axis approaches a northwest-southeast direction. The shoals are broad and sandy with an extremely abrupt drop-off. The basin is somewhat irregular in detail, although there is only one major depression. The center of this occurs 1 1/4 miles directly north of the Christian Assembly camp. The origin and age of the lake basin is described by I.D. Scott in his book, "Inland Lakes of Michigan," as follows:

> "As regards the basin, it may be stated that it is relatively old. In fact, it is certain that it was in existence before the ice made its final advance, for it was filled with a small lobe, an offshoot from the Michigan lobe, which pushed through the opening at the west end, now closed with sand. This lobe deposited a strong morainic loop around this basin, which is continuous except at the outlet and a depression on the north side which runs northward into the Platte Lake depression, in the vicinity of Round Lake. At present the lake shores do not reach the morainic hills but are separated from them by a rather broad zone of sandy terrace. This widens greatly at the east end and extends nearly two miles before it is interrupted by the moraine.
>
> "The striking physiographic characters are the predominating high cliffs from whose base the sandy terrace mentioned above extends to the water's edge. The first surmise is that this lake has stood at a higher level and further observations prove this to be correct."

The steep morainic slopes around the lake are covered with a mixed growth of conifers and hardwoods, and the surrounding country is of a similar nature. Some fine orchards exist on the slopes of these moraines.

Crystal Lake is reported to have a maximum depth of 175-200 feet. Such depths may occur, but only as very limited pockets. The survey party in its operations found no depth greater than 162 feet. More systematic soundings will probably settle this point. The shoal (0-20 ft. depths) makes up about 25 per cent of the surface area of the lake. The bottom here is barren sand dispersed with gravel and rubble. The bottom beyond the 20-foot contour is sand and marl on the slopes and muck in the bottom of the depression.

The water is colorless and very clear. On a dull cloudy day a secchi disc could be seen at a depth of 19 feet. This indicates a clearness considerably greater than the average for southern Michigan lakes.

Crystal Lake drainage is limited to the immediate surroundings and the small valley of Cold Creek at the east end. The immediate borders of the lake are quite sandy, having been part of the shoal at higher lake levels. In the flats east of Beulah the soil is predominantly muck, with celery and other vegetables being the principal crops.

The only important inlet to Crystal Lake, Cold Creek, is a stream 12 feet wide. At the time of the survey it was approximately 12 inches in depth and had a moderately swift rate of flow. According to local inhabitants, it has moderate fluctuations in level, but does not flood its banks. All other sources are small brooks (a yard or so in width and a few inches deep) draining springs. Springs are also reported in the lake proper. The level of the lake was set by court act a number of years ago after real estate title difficulties arose. During the logging days, the outlet of the stream was dredged to make it suitable for floating logs and the lake level was greatly lowered for a time. The present dam was later built and the present level has been maintained since that time. This is several feet lower than the original level, however, causing the extensive area of low ground which now surrounds the lake.

A summary of the temperature and chemical conditions in Crystal Lake is given in the following table.

Summary of Temperature and Chemical Conditions
Found in Crystal Lake

Location of Station	Station I near outlet	Station II near inlet	Station III over deepest point	
Date	6/8/40	6/8/40	6/10/40	8/11/40
Air temperature	66° F.	58° F.	64° F.	77° F.
Water temperature				
Surface	60° F.	61° F.	58° F.	74° F.
Bottom	...	...	43° F.*	43° F.*
Thermocline, middle of	none	none	none	51° F. (63 ft.)
Oxygen, p.p.m.				
Surface	10.3	9.4	10.2	8.1
Bottom	...	...	10.7*	7.2*
CO_2, p.p.m. range	0.0	0.0	0.0-3.0	0.0-6.0
Methyl orange alkalinity, p.p.m. range	112.0	117.0	106-120	106-119
pH range	8.0	8.0	7.9-8.0	7.6-8.2

The low surface temperatures existing in Crystal Lake are very probably the main cause for the delayed spawning of perch and bass living there, although the season of 1940 is not representative or average as to temperature conditions. Delayed spawning was noted in many other places in the state this year. Surface temperatures taken during August were near 74°F. This is probably the maximum for the year. Bottom temperatures remained almost constant throughout the season, at 43°F.

No thermocline (zone of rapid change in temperature) was present during the June survey, but in August a very definite zone was established which included the layer of water between 42 and 120 feet. From the top to the bottom of this layer, the temperature declined 24°F.

*Depth = 162 ft.

There was very little chemical stratification, however. Abundant oxygen was found from top to bottom at the time both analyses were made. Free carbon dioxide was so scarce that it has little significance to fish production. The water in Crystal Lake is only moderately hard (methyl orange alkalinity, 106-120 p.p.m.). Some sparse Chara beds have been developed and there is a thin layer of marl over a small area of the bottom. The water is distinctly alkaline with a pH range of 7.6-8.0.

The temperature conditions found in Crystal Lake are definitely more suited to cold water species of fish than to the warm water ones. There is no reason, from the point of view of the temperature and chemical conditions, why Crystal Lake cannot be utilized by trout, almost from top to bottom throughout the year. There is adequate oxygen from the surface to the bottom even in late summer and the other chemical conditions are favorable for trout.

As has already been pointed out, the physical conditions existing in Crystal Lake are very unfavorable for the growth of aquatic plants. There are only a few species represented here and these are nowhere abundant. A list of the plants present is given below.

Muskgrass, *Chara fragilis*
Horsetail, *Equisetum* sp.?
Pondweed, *Potamogeton natans*
" " *graminifolius* var. *myriophyllus*
" " *filiformis*
" " *pectinatus*
Spike rush, *Eleocharis compressa*
Bulrush, *Scirpus americanus*
Sedge, *Carex substricta*
Rush, *Juncus balticus* var. *littoralis*
Bladderwort, *Utricularia*

Muskgrass and pondweeds were found sparsely scattered over the rubble beds on the shoals near shore. Muskgrass was rather infrequently found in the deeper water. The other species listed above were confined almost entirely to one small beach pool on the north shore.

Fish food studies included a general sampling of the lake in order to determine what kinds of fish food organisms were present and how abundant they were. Plankton samples indicated that the population of these free-floating organisms was comparatively low during the period of the survey. Zooplankton (animal forms) was predominant, although a definite phytoplankton (plant organisms) was present. Considering the great fluctuations in plankton which exist from week to week, and place to place, it is not possible to accurately estimate the significance of a few samples. Continuous studies over a two or three year period would be necessary to determine the abundance and significance of plankton as food for fish in Crystal Lake.

Bottom samples taken on the shoal and in the deep water with a clamshell (Ekman) dredge are summarized in the following table.

Shoal Samples

Station	Depth	Area	Bottom	Vegetation	Volume, c.c.	No. of Organisms	Mayflies	Dragonflies	Damselflies	Midges	Other flies	Stone flies	Caddis flies	Freshwater Shrimp	Leeches	Snails	Clams	Crustacea	Aquatic Worms	Alder flies
1.	18-20"	Qualitative	Sand	None	...	13	5	1	.	6	1	.	.	.	.	.	.	.	.	.
2.	14"	1/2 sq.ft.	Sand & gravel	None	0.3	3	.	1	.	1	1	.	.	.	.	.	.	.	.	.
3.	21'	1/2 sq.ft.	Sand & detritus	<u>Chara</u>	1.0	173	29	.	.	78	.	.	.	56	3	6	1	.	.	.
5.	6"	Qualitative	Rubble	Algae	...	44	29	.	2	3	.	.	.	.	.	8	.	2	.	.
7.	6-12"	Qualitative	Rubble	None	...	24	14	1	.	.	.	.	9	.	.	.	.	.	.	.
8.	6-12"	Qualitative	Rubble	None	...	52	35	.	1	2	.	1	5	2	.	5	.	.	1	.
9.	14"	Qualitative	Rubble	None	...	21	13	.	.	4	1	.	2	.	1	.	.	.	.	.
10.	12"	1 sq.ft.	Rubble	<u>Chara</u>	0.5	38	15	.	.	6	.	.	1	15	1	.	.	.	.	.
11.	2'	1 sq.ft.	Rubble	<u>Chara</u> <u>Potamogeton</u>	0.8	19	12	.	.	1	.	.	4	.	1	1	.	.	.	.
12.	2'	1 sq.ft.	Rubble	None	...	6	2	.	.	3	.	.	.	1	.	.	.	.	.	.
13.	16"	1 sq.ft.	Rubble	None	0.4	31	20	.	.	10	.	.	.	.	.	.	.	.	.	.

Bottom (70 to 160 ft.) Samples

Station	Depth	Area	Bottom	Vegetation	Volume c.c.	No.	Aquatic worms	Fresh-water shrimp	May-flies	Clams	Midges
4.	160'	1/2 sq.ft.	Muck	None	0.7	37	10	26	1	.	.
6.	160'	1/2 sq.ft.	Muck	None	0.5	20	4	16	.	.	.
14.	70'	1/2 sq.ft.	Muck	None	0.3	27	7	4	1	2	13
		1&1/2 sq.ft.			1.15	84	21	46	2	2	13

Mayflies were found to be the most abundant food organism on the rubble shoals, with midge larvae, freshwater shrimp, caddis flies and snails following in that order. The rubble patches compensate, at least in part, for the sparse vegetation and offer cover for most of the organisms mentioned. Small crayfish were fairly abundant on the rubble shoals and large ones were taken in nets in 30 or more feet of water. Stomach examinations of perch and rock bass show the crayfish to be an important food item, at least for the time of the year when the survey was made. Amphipods ("shrimps"), oligochaetes (aquatic earthworms) and midge larvae dominated the bottom mud in deep water. On the whole, the fish food supply seems fairly good, considering the dearth of vegetation.

A study of the kinds and abundance of fish present in Crystal Lake was made during the survey. Fish were collected by means of gill nets, seines, and fyke nets.