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INVESTIGATION OF THE INFLUENCE OF THERMAL DISCHARGE FROM
A LARGE ELECTRIC POWER STATION ON THE TEMPERATURE AND
NEAR-SHORE CIRCULATION OF LAKE MICHIGAN

Quarterly Progress Report

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I. Introduction

In order to investigate the effect on Lake Michigan of the thermal effluent from the Oak Creek Power Plant located at Oak Creek, Wisconsin, the Center for Great Lakes Studies has been conducting a combined study of the ecology of natural populations and the physics of nearshore circulation. This preliminary report on the nearshore circulation studies consists of four sections; introduction, current meter program, data analysis, and plans for future work.

II. Current Meter Program

2.1 Installation

In order to obtain a detailed picture of the nearshore current structure in the lake near Oak Creek, a current meter array network was established in this vicinity (Fig.1). This network is more extensive and concentrated than the one originally proposed in the contract (Fig. 2). The stations established and the duration of installations are listed in Table 1. Four surveys have thus far been conducted. The first survey was conducted from November 1971 to March 1972; the second survey from April 1972 to June 1972, the third survey from June 1972 to August 1972, and the fourth survey will be conducted from August 1972 to October 1972.

Since delivery of the Braincon current meters, loaned by the Wisconsin Electric Power Company for this study was delayed until December 1971, one of the Center's current meters was used for the first

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Figure 1

Current Meter Station Locations

TABLE I
OAK CREEK CURRENT METER STUDY

<u>Survey</u>	<u>Station</u>	<u>No. of Meters</u>	<u>Date Set</u>	<u>Date Retrieved</u>	<u>Tape Cartridge</u>
I	T ₂	1	24 Nov. 1971	unrecovered	
II*	1	1	3 Apr. 1972	5 June 1972	O.K.
	2	1	3 Apr. 1972	5 June 1972	O.K.
	3	1	2 May 1972	5 June 1972	O.K.
	4	2	4 May 1972	6 June 1972	O.K.
III*	1	1	5 June 1972	Still at large	
	2	1	5 June 1972	Still at large	
	3	1	5 June 1972	29 July 1972 in Sheboygan Harbor	tape torn
	4	2	7 June 1972	17 August 1972 so. of Terry An- drae Park.	one tape cut one tape O.K.
	6	2	21 June 1972	3 September 1972 near Ludington	one tape O.K. one tape un- wound
	8	1	14 June 1972	4 August 1972 at Terry Andrae Park	tape unwound
	T ₁	1	14 June 1972	25 August 1972	O.K.
	T ₃	1	15 June 1972	25 August 1972	O.K.
IV	T ₁	1	25 August 1972	still operating	
	T ₃	1	25 August 1972	still operating	

* Data from Surveys II and III are in their final form.

installation. The current meter was installed at station T_2 on a current meter tower structure because mooring lines are not feasible in shallow nearshore regions. Plans to install three more current meters for Survey I in the early part of 1972 with anchor buoy systems using Sedar release mechanisms were cancelled due to adverse weather conditions.

Five current meters were installed for Survey II. The first two were installed in early April, 1972, but the installation of the other three meters was delayed until early May due to adverse weather conditions and lack of ship time during the latter part of April. All five current meters were successfully recovered on July 5, and June 6, 1972.

Ten current meters were installed during Survey III. In addition to the meters loaned by the Wisconsin Electric Power Company for this study, current meters from the Center were also used. Two current meters were installed on tower structures and the rest on 'taut line' systems with Sedar releases. Since good visibility and calm lake conditions needed for meter installations occurred rarely in June, the installation dates for the meters were spread out and also meters could not be installed at Stations 5 and 7 as planned.

A disaster, to be discussed later, occurred with the meters used for Survey III. A locally severe thunderstorm on 14 July 1972 released the Sedar mechanisms prematurely, and all the meters except those on the towers floated away from the Oak Creek area. Eighty percent of these meters were successfully recovered and will be replaced to commence Survey IV.

2.2 Current Meter Mooring Systems

2.2.1 "Taut Line" System

A schematic diagram of the mooring systems used in the installation of Braincon current meters is illustrated in Figure 3. The mooring system consisted of a float bag, a grapnel*, a current meter or current meters, a lifting eye, a pulley block for lowering, a Braincon Sedar release mechanism*, a concrete sinker, and a wire cable.

The float bag was designed to provide enough buoyancy to ensure that the meters remained vertical. Since there were only two tilt sensors available, one of the sensors was put in a current meter installed at Station 8. This current meter was supported in the taut line system with the lowest net buoyancy (50 lbs.) of the single current meter mooring systems. Preliminary studies of the tilt sensor readings indicate that the current meter remained within 5° of the vertical. The other single meter mooring systems had greater net buoyancy than the one in Station 8 indicating that the meters from the other stations remained within 5° also. The other tilt sensor was installed in the upper meter in the two-meter mooring system installed at Station 6. Unfortunately, the tape cartridge did not wind the magnetic tape properly and all of the data were lost. However, based on previous current meter work conducted by the Center, the fact that both of the double meter mooring systems had net buoyancies of 138 pounds each would indicate that sufficient net buoyancies had been provided to keep the current meters vertical.

The total length of the mooring line was calculated to be such that the floats would remain at least thirty feet below the surface of the water. The reason for using submerged floats was twofold.

* A grapnel was installed for emergency recovery in the event that the Sedars might fail to release. We were not warned that they might release prematurely.

** The Sedar release instrument is an underwater release mechanism which can be remotely activated when a proper voltage gradient is received by the mechanism. It has previously been used in some fifteen successful operations elsewhere in the lake.

Schematic of a Single Current Meter Mooring System

First, the floats had to be below the thirty foot depth to ensure that they would not interfere with navigation of ships in the Oak Creek area. Second, if the floats were too close to the surface or at the water surface, they would be too easily affected by wave action which would result in erroneous data being recorded by the current meters.

The mooring system was installed by first connecting the Sedar to the sinker with a chain and then attaching the wire cable to the top of the Sedar. This whole bottom section was lifted by the lifting eye using the winch and placed in the water by the side of the vessel. A one inch nylon rope was put through the pulley block and used to support the bottom section of the mooring system. The top section of the mooring line was then connected to the bottom section. One end of the nylon rope was held in place while the other end was slacked slowly in order to allow the sinker to descend gently to the bottom of the lake. The secured end was then released and pulled through the pulley block and retrieved.

2.2.2 Current Meter Tower Structures

Two different current meter tower structures were designed and built. Schematics of the two tower types are given in Figures 4(a) and 4(b). The first type was constructed in November, 1971 and used at Station T₂ in fifty feet of water. This tower was built to be used in shallow water where "taut line" systems were not feasible. The base of the tower was built from angle irons, and the beam was made from iron pipes.

Two towers of the second type were built in April, 1972. These towers were designed so that they could be used in even more shallow water than the one used previously. Also, they were built using angle aluminum to avoid having large metallic objects around the current meters. These two towers were used to install current meters at Stations T₁ and T₃ in 42 and 38 feet of water, respectively.

Figure 4

Schematics of Current Meter Tower Structures

4(a)

4(b)

2.3 Premature Release of Sedar Mechanisms

The Sedar release system was used to release the 'taut line' system from the concrete sinker. Sedar is an acronym for Submerged Electrode Detection and Ranging. The system operates on the basis of generating and detecting an AC electric field in the water. Submerged transmitter electrodes are used to generate the electric field. The receiver electrodes on the Sedar can detect a low voltage gradient which is amplified by narrow band high-gain amplifiers to the desired threshold of the detector circuit. When a voltage gradient of the proper frequency and duration (range of 600 to 1600 Hz for at least 10 seconds) is detected, the release mechanism is triggered and the 'taut line' system becomes disengaged from the sinker.

As will appear from the following evidence, the Sedar release mechanisms were prematurely released on 14 July 1972. This was an unexpected event since we had had success in using these instruments previously and had not planned on resetting the current meters until the latter part of August. The premature release of the Sedar systems was probably caused by severe thunderstorm activity on Lake Michigan on the evening of 14 July 1972. When lightning hits the water, it can generate an electric field covering a wide spectrum of frequencies and duration. This electric field was detected by the receiver electrodes and the Sedars were released. Unfortunately, we were not warned of this possibility by the manufacturers.

Two of the meters recovered in Sheboygan indicate the release time of the Sedars as being July 14 at 6:30 and 7:30 P.M. C.S.T.

Computer printouts and graphs of temperature readings (Tables 2 and 3, and Figure 5, respectively) indicate sudden increases in temperature at these times caused by the upward motion of current meters from the cold lower layers to the warm upper layers of the lake. The spikes which appear in Figure 5 were caused by noise in the current meter and will be filtered out later. No conclusion could be drawn from the other meters recovered due to faulty tape cartridges which did not provide complete data for the period during which the current meters were in operation.

Thus far, six of the eight lost current meters and four of the six lost Sedars have been recovered. Active search is being continued for the remainder. A summary of the recovery dates are given in Figure 6. The first indication that the instruments were floating free occurred when the C&O Railroad car ferry reported seeing float bags 18 miles northeast of Milwaukee on 21 July 1972. Notices were sent out to the Coast Guard to report any sightings of the float bags. One current meter was recovered in Sheboygan Harbor by the Coast Guard on 29 July 1972. More notices were again sent to the Coast Guard and also the Sheboygan Press. As a result, a second current meter was recovered by the Terry Andrae State Park staff on 5 August, 1972. Two more current meters were recovered south of Terry Andrae State Park on 17 August 1972. Another two current meters were recovered by a charter boat near Ludington, Michigan on 30 August 1972.

Numerous current meter searches were made between Sheboygan and Milwaukee during the month of August. Cruises were conducted along the shoreline, contacts were made with residents in the Oostburg area, notices were also distributed in this area. An example of the notice is given in Figure 7. Reports of recovery of float balls by residents along the lake are being documented so that they may be used to provide a clue to the whereabouts of the other two meters.

Table 2

CURRENT METER DATA

LOCATION: OAK CREEK POWER PLANT

SURVEY: 72-2

STATION NUMBER: 72-2-8

METER STARTING DATE: JUNE 14, 1972 8:00

METER IN WATER: JUNE 14, 1972 11:45

Date: July 14, 1972

Time	SPEED (cm/sec)	DIB (°)	IEMP (°C)	Time	SPEED (cm/sec)	DIB (°)	IEMP (°C)	Time	SPEED (cm/sec)	DIB (°)	IEMP (°C)
12:10 AM	2.880	209.520	8.7	12:20 AM	.720	203.760	8.8	12:30 AM	.000	204.840	8.8
12:40 AM	.000	219.240	8.7	12:50 AM	.000	212.040	8.7	1:00 AM	.000	207.720	8.8
	.000	212.760	8.7		.000	224.280	8.7		.000	234.000	8.8
	.000	228.600	8.6		.720	231.640	8.7		.000	232.560	8.7
	.720	268.560	8.8		.000	270.360	8.7		.000	257.400	8.7
	.000	261.720	8.6		.720	282.240	8.7		4.480	285.840	8.6
	2.080	265.120	8.6		.000	293.040	8.6		.000	294.120	8.5
	.000	298.440	8.6		2.880	299.160	8.6		.000	298.440	8.4
	.720	300.960	8.4		5.520	316.440	8.5		5.880	323.280	8.5
	6.240	326.880	8.5		5.880	335.160	8.5		6.240	323.640	8.5
	5.880	322.560	8.4		5.980	326.880	8.4		6.240	330.840	8.4
	6.500	330.840	8.4		6.240	331.560	8.4		5.880	331.200	8.4
6:10 AM	4.480	338.760	8.4	6:20 AM	5.880	327.680	8.4	6:30 AM	7.800	335.520	8.4
	4.480	334.080	8.4		3.600	331.200	8.4		.000	332.280	8.4
	.000	331.920	8.4		.000	329.120	8.4		.720	336.960	8.4
	.000	332.640	8.4		.000	342.720	8.5		.000	341.640	8.4
	.720	8.640	8.5		.720	358.200	8.5		.000	14.760	8.5
	.000	348.480	8.5		.000	350.280	8.6		.000	.360	8.6
	.720	15.480	8.7		.000	352.440	8.7		.000	15.480	8.6
	.720	3.240	8.7		.000	7.560	8.7		.000	13.320	8.7
	.000	.720	8.6		.000	352.800	8.6		.000	.720	8.6
	.720	358.920	8.6		.000	358.560	8.6		.000	.000	8.6
	.000	353.520	8.6		.000	346.320	8.6		.720	356.400	8.7
	.000	.720	8.6		.000	48.600	8.8		.000	52.920	8.7
12:10 PM	1.440	45.360	8.7	12:20 PM	.000	42.480	8.8	12:30 PM	.000	45.000	8.7
12:40 PM	.720	41.040	8.7	12:50 PM	.000	50.400	8.7	1:00 PM	.000	113.040	8.7
	.000	118.440	8.8		.000	111.960	8.7		.000	105.120	8.6
	.000	133.920	8.6		.720	133.920	8.6		.000	138.240	8.7
	.720	127.440	8.6		.000	129.240	8.6		.000	122.760	8.6
	.720	132.840	8.6		.720	176.760	8.6		1.440	180.720	8.6
	.000	217.060	8.6		.000	242.280	8.7		2.160	232.560	8.6
	4.480	231.480	8.6		.720	232.920	8.6		.000	236.520	8.6
	4.480	237.960	8.6		2.160	245.880	8.6		.720	241.200	8.6
	.720	240.040	8.5		2.160	247.320	8.5		3.600	249.120	8.6
	2.080	270.000	8.6		7.448	265.640	8.7		6.960	292.680	8.8
	6.000	295.200	8.8		4.480	298.080	8.7		2.160	297.720	8.7
6:10 PM	5.520	293.760	8.8	6:20 PM	7.800	290.520	8.7	6:30 PM	4.480	297.300	8.7
	5.880	297.360	8.5		7.800	299.020	8.6		7.440	310.600	8.7
	6.240	302.040	8.8		5.880	299.880	8.6		6.960	302.040	8.8
	10.840	195.480	14.5		7.552	124.560	13.3		17.552	50.400	12.7
	20.168	334.080	13.4	Temperature jump	22.340	.360	14.1		20.024	54.360	13.8
	19.604	52.560	14.0		18.040	51.840	13.9		20.024	59.400	14.2
	17.260	74.160	13.9		22.088	59.400	14.0		25.024	72.720	14.1
	22.595	154.040	14.6		21.720	141.040	14.4		21.720	103.440	14.0
	22.088	59.400	14.1		22.596	234.000	14.3		20.168	292.160	14.4
	19.096	207.360	14.2		17.476	111.240	13.4		17.552	76.680	13.5
11:10 PM	17.372	198.720	14.3	11:20 PM	19.820	66.960	13.5	11:30 PM	17.260	106.920	13.4
11:40 PM	18.760	133.560	13.3	11:50 PM	15.800	153.720	13.8	12:00 AM	17.372	170.280	14.2

Table 3
CURRENT METER DATA

LOCATION: OAK CREEK POWER PLANT
STATION NUMBER: 72-2-4TH

SURVEY: 72-2

METER STARTING DATE: JUNE 6, 1972 8:00

METER IN WATER: JUNE 6, 1972 11:00

Date: July 14, 1972

Time	SPEED (cm/sec)	DIR (°)	TEMP (°C)	Time	SPEED (cm/sec)	DIR (°)	TEMP (°C)	Time	SPEED (cm/sec)	DIR (°)	TEMP (°C)
12:10 AM	.000	149.760	8.9	12:20 AM	.000	133.560	9.8	12:30 AM	.000	130.680	8.4
12:40 AM	.000	132.480	8.6	12:50 AM	.000	131.460	8.7	1:00 AM	.000	132.840	9.3
	.000	145.300	8.7		.000	147.600	8.6		.000	147.960	8.6
	.000	151.560	8.6		.000	157.320	8.5		.000	169.200	8.4
	.000	165.600	8.7		.000	161.640	8.9		.000	162.720	8.6
	.000	158.400	8.3		.000	160.920	8.2		.000	163.080	9.0
	.000	156.600	8.4		.000	159.480	9.0		.000	158.760	9.4
	.000	159.480	8.6		.000	156.960	8.8		.000	158.760	8.7
	.000	160.560	8.8		.000	163.800	8.9		.000	164.160	8.7
	.000	165.240	9.4		.000	167.760	9.3		.000	167.040	9.1
	.000	250.920	8.7		.000	162.360	8.7		.000	160.560	8.7
6:10 AM	.000	169.920	8.9		.000	167.040	8.6	6:30 AM	.000	116.640	8.5
	.000	165.960	8.4	6:20 AM	.000	166.680	8.7		.000	167.040	8.4
	.000	166.320	8.3		.000	164.880	8.3		.000	171.720	8.3
	.000	166.660	8.5		.000	161.640	8.0		.000	164.160	8.1
	.000	163.440	8.7		.000	149.400	8.3		.000	147.960	8.2
	.000	167.400	8.2		.000	169.920	8.3		.000	153.000	8.8
	.000	143.640	8.8		.000	.720	8.8		.000	185.400	9.0
	.000	165.400	8.8		.000	189.360	8.8		.000	.360	8.9
	.000	191.160	8.9		.000	192.600	9.3		.000	191.520	9.4
	.000	190.800	9.1		.000	187.200	9.3		.000	45.000	9.3
	.000	1.080	9.4		.000	1.440	9.3		.000	182.880	9.1
	.000	185.040	9.3		.000	174.240	9.1		.000	172.440	9.0
	.000	167.760	9.0		.000	167.760	9.3		.000	175.680	9.3
12:10 PM	.000	167.760	9.0	12:20 PM	.000	180.000	9.0	12:30 PM	.000	169.560	9.1
12:40 PM	.000	164.160	9.0	12:50 PM	.000	161.280	9.1	1:00 PM	.000	159.480	9.5
	.000	163.800	9.4		.000	157.320	9.0		.000	167.040	9.6
	.000	142.920	8.9		.000	151.560	8.8		.000	155.880	8.7
	.000	154.800	8.6		.000	163.080	9.5		.000	160.560	9.0
	.000	120.600	10.6		.000	160.200	9.5		.000	164.160	9.1
	.000	165.240	9.6		.000	139.320	8.9		.000	158.400	9.0
	.000	160.560	8.1		.000	160.560	8.7		.000	168.480	8.9
	.000	172.440	8.9		.000	161.640	8.3		.000	172.800	9.1
	.000	167.560	9.4		.000	174.240	8.6		.000	170.280	8.6
	.000	167.400	8.6		.000	188.640	8.5		.000	86.040	8.0
	.000	194.400	7.7		.000	205.200	7.6		.000	196.560	8.1
6:10 PM	.000	205.560	7.5	6:20 PM	.000	211.320	7.8	6:30 PM	.000	217.080	7.4
	22.808	64.440	16.0	Temp. Jump	25.548	86.760	15.8		25.904	69.120	16.2
	25.240	56.880	16.2		23.600	68.760	15.6		22.608	52.920	16.0
	25.240	85.680	15.8		24.320	79.920	14.3		25.548	58.320	16.1
	25.404	158.400	16.2		.000	126.360	16.0		.000	129.600	16.0
	.000	101.160	16.1		25.240	143.640	15.7		.000	92.880	16.0
	.000	133.920	15.8		.000	117.000	15.7		.000	114.840	15.8
	.000	113.400	15.6		.000	175.680	10.0		.000	86.760	16.0
	.000	64.440	15.6		.000	155.880	16.0		.000	169.920	15.7
	.000	137.520	15.5		.000	150.430	15.2		.000	217.080	15.2
11:10 PM	25.548	151.200	15.5	11:20 PM	.000	149.040	15.5	11:30 PM	.000	155.880	15.2
11:40 PM	.000	138.960	15.8	11:50 PM	25.404	147.600	15.7	12:00 AM	25.240	175.680	15.5

Figure 5

Graphs of Temperature vs. Time for Stations 8 and 4

- * Possible internal waves of near-inertial period (16 hr.)
See Mortimer, C.H., 1971: Large-Scale Oscillatory Motions and Seasonal Temperature Changes in Lake Michigan and Lake Ontario. Special Rept. 12. Center for Great Lakes Studies. Univ. of Wisconsin-Milwaukee
- + Sudden increase in temperature indicating release of Sedar mechanism.

Figure 6

Recovery Dates of Current Meters
from Survey III

Figure 7

NOTICE — LOST

A number of scientific instruments used by the University of Wisconsin-Milwaukee to study current and temperature changes in Lake Michigan broke loose from their moorings about 14 July and floated off. Some sets of equipment were recovered near Sheboygan but several others are still at large. We are asking for the help of boat owners and beachcombers in locating the remaining instruments.

The instrument strings consist of one or two four-foot long net bags of plastic balls for flotation, about 100 feet of 3/8 inch wire rope and miscellaneous fittings, and two or three heavy (about 50 lbs.) metal cannisters. Some of the cannisters were blue with a fin-like attachment and others were black with four antennae. However, their appearance may have been modified considerably during their journey up the lake. The plastic balls were lightweight, hollow, two inches in diameter, and colored either red or black. There was a raised rib around the equator.

If anyone finds a concentrated patch, between twenty-five and fifty, of these balls on the beach or in the open lake, please carefully note the position and call us (collect) at the numbers listed below.

If someone does spot a floating bag of balls or any of the other equipment described above, please note its position and immediately call the Coast Guard or our offices (collect). Some of the pieces are too heavy to safely bring aboard small boats. It would be sufficient to drag them into shallow water so that they wouldn't drift away.

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III. Data Analysis

3.1 Data Reduction

After the meters had been recovered from the Lake, they were brought back to the Center where the tape used to record the data were retrieved. The tape cartridges contained digital information on speed, direction and water temperature at ten-minute intervals. Since the data were recorded on 1/4 inch magnetic tape in a Binary Coded Decimal Format, the data were transcribed to 1/2 inch computer compatible magnetic tape using the Braincon Digital Magnetic Tape Processor. The computer compatible tape was then sent to the Madison Campus Computer Center for cataloging for use in the computer.

After the computer tape was catalogued, the data were converted from the free format in the original form to card image form for use on the Univac 1108. In order to perform this conversion, a tape dump of the raw data was first obtained to determine the nature of data. After the conversion to card image form, the data were then transcribed into 'real' data. An example of the data is illustrated in Table 4.

3.2 Comments on the Data

Preliminary analyses of the data show that fairly good data were obtained in spite of the few problems associated with them, such as the tape cartridges not winding correctly or the tapes being cut, noise from within the system, slight reverse rotation of the Savonius rotor, and parity errors.

The malfunctioning of the tape cartridge resulted in the magnetic tape's not winding properly and leaving a large section of the tape free and unwound in the current meter. As a result, data from only part of the period during which the meters were in the lake were available. This problem occurred in four of the retrieved current meters. It is hoped that the new types of tape cartridge which thus far has not exhibited the same deficiency will eliminate this problem.

Table 4
CURRENT METER DATA

LOCATION: OAK CREEK POWER PLANT

SURVEY: 72-2

STATION NUMBER: 72-2-4TH

METER STARTING DATE: JUNE 6, 1972 8:00 METER IN WATER: JUNE 6, 1972 11:00 Date: June 10, 1972

Time	SPEED (cm./sec.)	DIB (°)	IEMP (°C)	Time	SPEED (cm/sec)	DIB (°)	IEMP (°C)	Time	SPEED (cm/sec)	DIB (°)	IEMP (°C)
12:10 AM	17.476	147.600	6.3	12:20 AM	17.552	159.840	6.3	12:30 AM	16.520	146.160	6.2
12:40 AM	15.800	115.560	6.2	12:50 AM	16.520	126.720	6.2	1:00 AM	15.800	144.720	6.2
	16.880	136.080	6.2		15.800	151.200	6.2		16.520	134.280	6.2
	15.800	161.640	6.1		16.160	161.640	6.1		15.800	150.480	6.1
	16.520	151.920	6.1		16.160	134.280	6.1		16.160	145.440	6.1
	16.520	169.200	6.1		16.880	155.160	6.1		14.608	175.320	6.1
	17.476	177.480	6.1		16.160	139.680	6.1		17.476	159.840	6.1
	17.476	120.960	6.1		17.372	166.320	6.1		18.400	164.160	6.1
	18.040	157.320	6.1		18.760	145.800	6.1		19.096	120.960	6.1
	19.096	126.000	6.1		17.476	127.800	6.1		18.400	180.000	6.1
	18.400	146.520	6.0		19.096	137.520	6.0		17.552	131.040	6.0
	18.400	163.440	6.0		18.040	149.040	6.1		18.400	159.480	6.1
6:10 AM	17.552	153.000	6.1	6:20 AM	19.384	139.680	6.1	6:30 AM	19.604	146.160	6.1
	19.384	140.040	6.1		17.476	111.600	6.1		19.384	171.000	6.1
	19.096	149.040	6.1		17.476	133.560	6.1		17.372	110.520	6.1
	17.096	128.880	6.1		16.880	126.000	6.1		17.260	130.320	6.0
	17.552	147.600	6.0		19.096	155.880	6.1		17.552	147.960	6.1
	17.476	123.840	6.1		17.552	143.280	6.1		17.552	136.080	6.1
	17.552	148.320	6.1		17.096	136.800	6.1		17.552	150.480	6.1
	17.372	144.360	6.1		17.476	151.560	6.1		17.260	154.440	6.1
	17.096	159.840	6.1		17.552	153.360	6.1		17.552	140.040	6.1
	18.040	129.600	6.1		17.552	137.160	6.1		16.520	135.720	6.1
	17.096	124.560	6.1		17.476	149.040	6.1		17.260	150.120	6.1
	17.552	138.600	6.2		16.880	135.360	6.2		17.476	138.240	6.1
12:10 PM	17.096	150.840	6.1	12:20 PM	17.476	125.640	6.1	12:30 PM	17.260	136.800	6.1
12:40 PM	17.476	154.080	6.1	12:50 PM	18.040	133.200	6.1	1:00 PM	18.040	168.480	6.1
	17.552	167.760	6.1		16.520	150.480	6.1		16.160	162.360	6.1
	14.608	128.160	6.1		15.800	155.880	6.1		17.476	142.200	6.1
	16.520	155.880	6.2		16.160	156.600	6.1		16.160	137.880	6.1
	16.160	123.480	6.1		15.080	140.040	6.2		16.520	157.680	6.2
	15.080	135.720	6.2		14.608	138.240	6.2		14.000	126.720	6.2
	13.280	139.680	6.2		15.800	141.120	6.3		16.160	147.240	6.3
	14.608	140.400	6.3		14.216	147.600	6.3		14.608	110.160	6.3
	11.920	120.240	6.2		14.000	113.040	6.2		13.280	111.600	6.2
	.000	.000	.0		14.608	140.760	6.2		14.608	133.920	6.2
	14.000	133.920	6.2		14.000	137.880	6.2		14.216	137.160	6.1
6:10 PM	14.000	133.560	6.1	6:20 PM	12.560	132.480	6.1	6:30 PM	14.000	133.200	6.1
	14.000	147.960	6.1		14.000	117.720	6.1		13.280	108.000	6.1
	14.000	134.280	6.1		12.560	131.760	6.1		12.560	123.120	6.1
	14.216	127.440	6.2		11.920	126.000	6.2		10.480	111.240	6.2
	10.840	132.120	6.2		11.920	131.040	6.2		11.200	113.040	6.1
	11.560	131.760	6.1		11.920	120.600	6.1		11.920	131.760	6.1
	10.840	146.160	6.1		13.280	154.440	6.2		14.216	149.400	6.2
	15.080	137.880	6.2		14.216	154.080	6.2		14.608	150.120	6.2
	13.280	141.120	6.2		11.560	160.560	6.1		10.480	168.120	6.2
	10.840	155.520	6.1		10.480	129.600	6.1		10.480	137.160	6.2
11:10 PM	10.120	152.640	6.1	11:20 PM	10.120	146.160	6.1	11:30 PM	10.120	133.560	6.2
11:40 PM	9.616	134.280	6.2	11:50 PM	7.808	148.320	6.2	12:00 AM	8.096	156.240	6.2

Noise within the system caused the tape cartridge to record this noise as an alphameric datum when a numeric datum should have been recorded. This problem could be corrected by replacing the affected data by either a straight or weighted average of the surrounding data.

Due to the method in which current speed was calculated, a slight reverse rotation of the Savonius rotor caused a large fictitious speed reading. This type of error is described as "backup" error in the flow chart (Figure 8). Since this reversal of rotation occurred because of a jarring of the meter when no current was present, these high readings can be replaced by zero value.

Parity errors are the most difficult to recover. Fortunately, only one of the tape cartridges has had parity errors. At present the best approach appears to be to recover as much data as possible from the block within which the parity error occurred and to substitute the missing data, provided the time period for the missing data is not too long.

IV. Plans for Future Work

4.1 Introduction

A reorganization of the plans for future work has been deemed necessary due to the premature release of the Sedar mechanisms resulting in a 'great setback' in our research program. Since great priority was placed on searching for the lost meters, the analysis of data from the first survey has been delayed considerably. The plans for future work, described in the next two sections, can be divided into two categories: the analyses of the data obtained from the first two surveys, and the continuation of the field work program with revisions in the use of the Sedar system.

Figure 8
FLOW CHART FOR DATA ANALYSIS

4.2 Analyses of Existing Data

A summary of the analyses of existing data is given in Figure 8 . The analyses can be divided into three main sections, data reduction, data processing, and data analysis. The data reduction consisted of transcribing the raw data from 1/4 inch magnetic tapes to 1/2 inch computer compatible tapes. Then the tapes were catalogued at the Madison Computer Center for use on the computer. The data were converted to card image form and recorded on another computer tape. Card image form of the data was produced so that the data could be used by the Univac 1108 computer. After the data conversion into card image form had been done, the raw data were calibrated to give 'real' data of current speed, direction and temperature. The data reduction section has thus far been completed. Each of the steps in this section took a considerable amount of time since computer programs had to be written for each type of conversion of data. The approximate time period required for each step in this section does not include the time required for writing the computer programs but indicates the time required for processing of future data.

The data processing section will consist of removing any type of error which may be found in the data. The first of these is the "backup" error mentioned previously and will be eliminated by replacing the high readings by zero values. Checking for smoothness of data will eliminate any 'noise' readings. The timing checks, by comparing the time plots of the data concerned, will eliminate any time discrepancies which may arise between different current meter data. Computer programming will again be necessary for each process.

After the completion of data processing, data analysis will be started to determine the characteristics of nearshore circulation.

In order to put the data in useable form for the analyses the lake currents will be converted into vector form and component form. This data will be used to obtain progressive vector diagrams and histograms of speed and direction. These two types of analyses will be used to determine net current flow within the current meter network. From this the amount of volume transport can be estimated. Also the analyses can be used to determine the predominant speed and direction of the lake currents.

Another analysis which will be applied is spectral and cospectral analysis of the current meter data to determine coherence and phase relationships between lake currents at various stations.

Wind data will also be obtained and analyzed as described in the flow chart. Then the results from these analyses will be combined with those from the current meter data and investigations will be made to determine whether there are any correlations between lake and wind data. The result of this type of investigation could lead to the possibility of predicting the behavior of nearshore lake circulation by observing the characteristics of wind near the lake. The above comparison and the current meter data analyses will take longer than the data reduction and processing sections since computer programs must be written for each step and the procedures involved are more complicated than those of the first two sections.

4.3 Field Work Program

A summary of the field work program together with the times required for each step is given in Figure 9. The times stated are very approximate since it is difficult to estimate the time required for each step.

The field work program will not be restarted until the

Figure 9
FLOW CHART FOR FUTURE FIELD PROGRAM

current meters and the Sedars have been inspected and repaired. The Sedar mechanisms will need major rebuilding since water leaked into them and some of the metallic components rusted. When the full extent of the damage can be assessed, the manufacturer will be asked to advise on what must be done and what help he is willing to give, bearing in mind that he did not warn us on possible premature releases.

After this initial work, the current meters will be checked for calibration with the help of the manufacturers. Then dry runs will be made to ensure that the meters are in fact functioning properly.

The system for releasing the mooring line will be reviewed and revised to protect against any future accidents. Some possibilities are devising additional coding of Sedar releases, using a mechanical timer to arm the release mechanism prior to the desired release time; and an additional tethering line. The new 'safe' system will be tested out in the lake on a trial basis before future field work is continued. Upon completion of this phase of the study, a new set of current meters will be installed using the current meter network pattern used previously in Surveys II and III.