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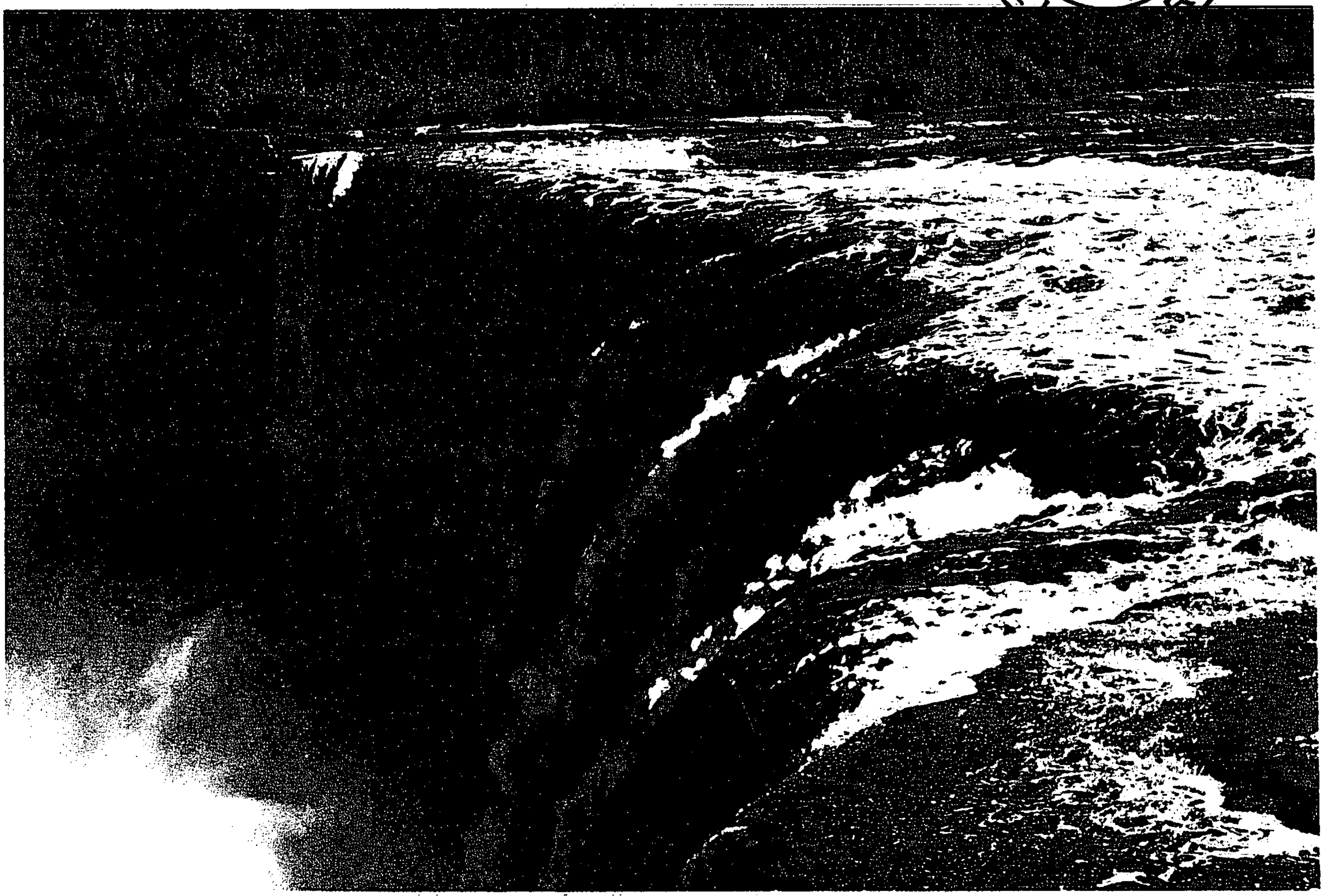
HYDAC-100—An Automated System for Hydrographic Data Acquisition and Analysis

Y.L. Durette and P. Zyma



TECHNICAL BULLETIN NO. 105

(Résumé en français)

INLAND WATERS DIRECTORATE
WATER RESOURCES BRANCH
OTTAWA, CANADA

Fisheries and Environment Canada
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CONTENTS

CONTENTS (Cont'd)

TABLES

ILLUSTRATIONS

ILLUSTRATIONS (Cont'd)

ABSTRACT

In recent years there has been an increasing demand for more complete and accurate information on hydrological and geomorphological processes in Canadian waters. Obtaining this type of information requires collection of massive amounts of data, rapid editing of all data and careful analysis of the results.

To cope with these demands, the Sediment Survey Section of the Applied Hydrology Division has developed an automated high-speed data collection and processing system (HYDAC-100) and a computerized data reduction and analysis system (HYDRA).

This paper provides information on the development and description of the HYDAC-100 system, a description of the survey methods to which the HYDAC system may be applied, the typical HYDAC-100 survey procedure, the development and description of the HYDRA system and an outline of possible future developments.

RÉSUMÉ

Au cours des dernières années, la demande d'informations complètes et exactes sur les processus hydrologiques et géomorphologiques de cours d'eau canadiens a accusé une hausse sensible. L'obtention de telles informations se fonde sur l'emmagasinage d'un grand nombre de données, le traitement rapide des données recueillies et l'analyse rigoureuse des résultats obtenus.

C'est en réponse à la demande que la Section de l'étude des sédiments, Division de l'hydrologie appliquée, a élaboré un système automatisé rapide d'emmagasinage et de traitement des données (HYDAC-100) ainsi qu'un système informatisé de réduction et d'analyse des données (HYDRA).

Le présent rapport fournit des renseignements qui portent sur l'élaboration et la description du système HYDAC-100, sur les méthodes d'étude auxquelles le système HYDAC peut s'appliquer, sur la méthode d'étude type de l'HYDAC-100, sur l'élaboration et la description du système HYDRA de même que sur les possibilités d'applications futures.

HYDAC-100—An Automated System for Hydrographic Data Acquisition and Analysis

Y.J. Durette and P. Zrymiak

Introduction

An electronic data-collecting system, HYDAC-100, has been developed by the Sediment Survey Section of the Applied Hydrology Division, Environment Canada, to facilitate the collection, reduction and analysis of data required to study sedimentation rates and distributions in rivers, reservoirs and estuaries. The data collection system is composed of two dynamic distance-measuring devices, an echo-sounder/digitizer, a precision electronic digital clock, a data coupler, a magnetic tape recorder, a line printer, a programmable calculator, and a plotter. The system is coupled with a series of computer programs to process and analyze the data and has been instrumental in keeping up with the increasing demand for studies on hydrological and geomorphological processes in Canadian waters without an increase in personnel.

In fact, since 1973, the first year of operation, approximately 30 surveys ranging from simple capacity surveys to complete geomorphological studies have been carried out through the use of the HYDAC-100 system. These surveys were conducted on water bodies across Canada from Vancouver to Cape Breton Island. Also, one survey was conducted on Sherburne reservoir in Montana for the International Joint Commission in co-operation with the United States Geological Survey.

System Development

Following specifications prepared by the Sediment Survey Section, experts from the electronic industries developed an automated Hydrographic Data Acquisition System, designated as HYDAC-100. The specifications were based on criteria such as:

1) System modularity;

   a) to permit ease of transport,
   b) to simplify repairs or replacement while in the field,
   c) to permit multipurpose use of individual components if required outside the system.

2) Field dependability of components: components must be reliable under extreme climatic conditions and rugged environment.

3) Measuring equipment accuracy; standards set for previous survey methods must be met or exceeded.

4) Repairs or maintenance for components must be available in most major Canadian centres.

5) Physical size and power requirements; the entire system must be tailored for installation in the cabin of a 32-foot boat and powered by available electrical sources.

6) Data accumulation speed and formatting; the maximum recording cycle time must be in the order of two seconds per cycle to maintain necessary data acquisition density at survey speeds of up to 20 knots. The system must be capable of interrogating up to 10 peripheral devices with outputs of 10 BCD (Binary Coded Decimal) characters each, of collating this data, inserting housekeeping characters and outputting the result, in any desired format, simultaneously, onto at least three output devices.

7) Cost and projected operational costs; the cost of the system must be within the capital budget of the Division and the projected operational costs must not exceed the 'operations' budget of the Section.

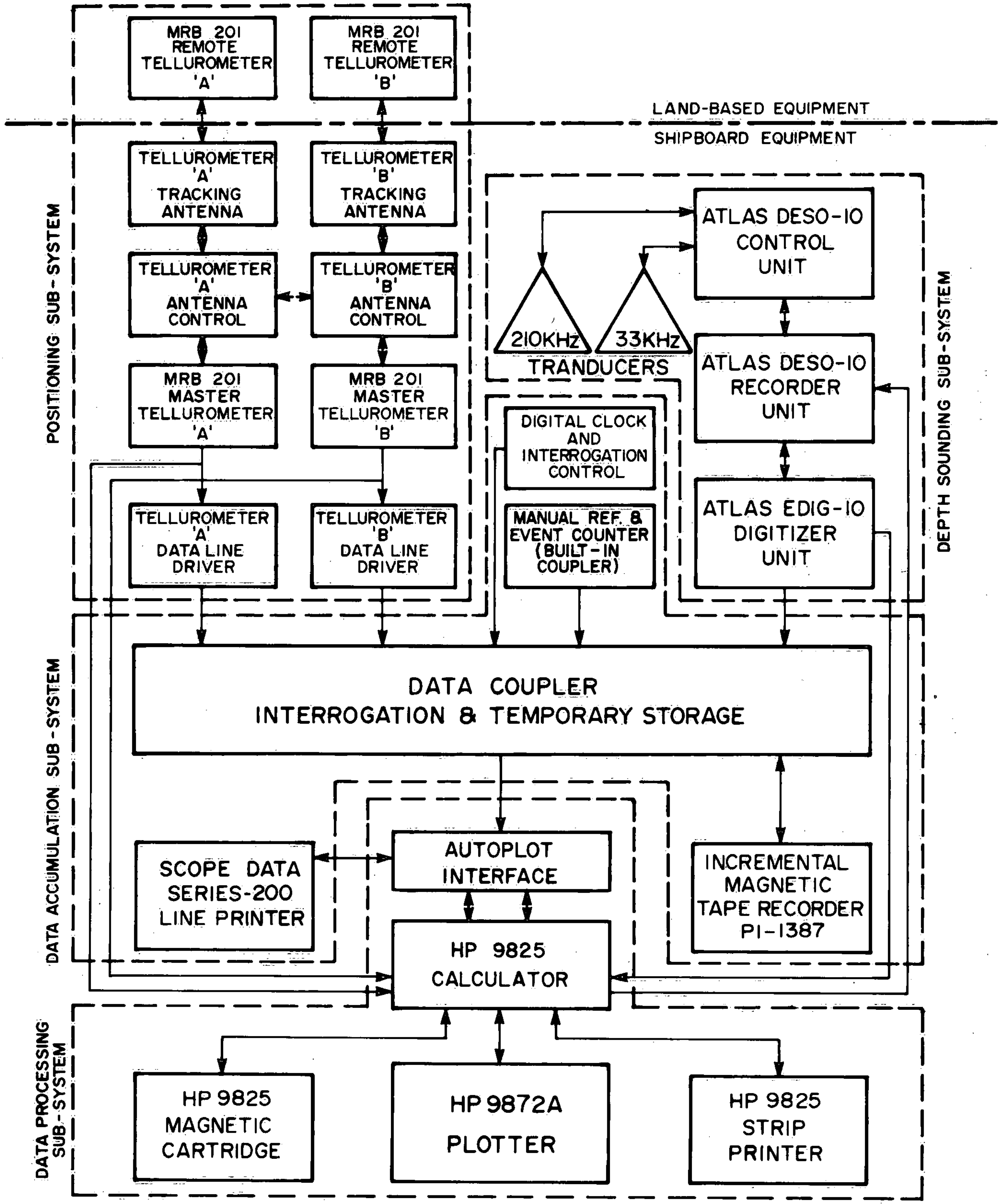
The system now being used by the Sediment Survey is presented schematically in Figure 1. Table 1 gives the physical characteristics and power input or output of individual components and the following is a description of each sub-system.

System Description

Data Accumulation Sub-System

This particular sub-system consists of a digital clock with integral interrogation control, a data coupler with built-in manual reference and event counter unit, an incremental magnetic tape recorder and a digital line printer.

The digital clock, a Monitor Labs instrument Model 3100, provides a time reference to the water level data (especially important where the stages are rapidly changing such as in estuaries and tidal reaches). This unit also has a built-in, time-dependent, programmable interrogation control which is capable of initiating interrogation commands from once a second to once every nine days.



THE HYDAC-100
A HYDROGRAPHIC DATA ACQUISITION SYSTEM
FIGURE 1

Table 1. Physical Characteristics and Power Input or Output of Individual Components of HYDAC-100 System

COMPONENT	NO. OF UNITS	SIZE	WEIGHT	POWER
Positioning Sub-System				Input
Master Tellurometer	2	35 x 33 x 30 cm	14.0 kg	4.0 A at 12 VDC
Remote Tellurometer	2	35 x 33 x 30 cm	13.5 kg	2.7 A at 12 VDC
Tracking Antenna Control Unit	2	29.5x20.5x14.6 cm	4.1 kg	1 A to 4 A at 12 VDC
Tracking Antenna	2	30 x 30 x 45 cm app.	11.5 kg	Power from Control Unit
Data Line Driver	2	10 x 10 x 15 cm app.	2.0 kg	12 VDC (negligible)
Depth Sounding Sub-System				
Atlas DESO-10 Control Unit	1	44.4x38.9x30.4 cm	18.0 kg	2.5 A at 24 VDC
Atlas DESO-10 Recorder Unit	1	44.6x44.0x20.2 cm	21.0 kg	
Atlas EDIG-10 Digitizer Unit	1	48.5x13.3x31.0 cm	12.0 kg	.63 A at 24 VDC
Transducer 33 kHz	1	27.6 cm diameter	6.5 kg	Power from Control Unit
Transducer 210 kHz	1	7.5 cm diameter	1.5 kg	Power from Control Unit
Data Accumulation Sub-System				
Data Coupler with Manual Ref. & Counter	1	50.29x48.3x17.8 cm	10.0 kg	.87 A at 115 VAC
Digital Clock with Interrogation Control	1	50.29x48.3x8.9 cm	6.82 kg	.13 A at 115 V
Line Printer	1	49.5x44.5x14 cm	18.2 kg	.74 A at 115 VAC
Magnetic Tape Recorder	1	37.15x26.4x15.3 cm	7.73 kg	3.33 A at 12 VDC
Data Processing Sub-System				
Autoplot Interface	1	50.8x15.2x33.0 cm	6.4 kg	.39 A at 115 VAC
Calculator (with Cassette & Printer)	1	15 x 50 x 45 cm	16.0 kg	1.5 A at 115 VAC
X-Y Plotter	1	18.9x49.7x45.5 cm	18.2 kg	2.1 A at 115 VAC
Miscellaneous				Output
Power Supply No. 1 (in Instrument Rack) 3 - 12 VDC Outlets 3 - 115 VAC Outlets 1 - 24 VDC Outlet	1	31.0x38.9x15.3 cm	18.2 kg	25 A at 12 VDC 2.1 A at 115 VAC 15 A at 24 VDC
Power Supply No. 2 Square Waves	2	20 x 20 x 25 cm	7.0 kg	2.61 A at 115 VDC 2.61 A at 115 VAC
Power Source - HD Diesel Battery - Model GP-4D	2	58 x 30 x 28 cm	50.0 kg	24 VDC
Alternator - HD Delcotron	1	20 cm diameter	10.0 kg	65 A at 24 VDC

The heart of the HYDAC-100 is the data coupler, a Monitor Labs instrument Model 4200. This instrument is capable of interrogating up to 10 peripheral devices with outputs of 10 BCD characters each. The coupler temporarily stores the data, inserts housekeeping characters and outputs the results in the following format:

1)	Point Number	(3 digits)	event counter
2)	Run Number	(2 digits)	manual reference
3)	Sector Number	(2 digits)	
4)	Year (current)	(2 digits)	
5)	Tellurometer A distance	(5 digits)	
6)	Tellurometer B distance	(5 digits)	
7)	Depth	(4 digits)	
8)	Time (hour and minute)	(4 digits)	

A Precision Instrument, PI-1387, incremental magnetic tape recorder stores the raw data for "in-house" processing. This low-power recorder, designed for long-term unattended data collection, is a 7-track 200-BPI, write-only unit with internal Inter-Record Gap (IRG) and End-of-File Gap (EOF) generation.

A digital line printer is used to provide a hard copy backup to the tape data. This instrument is a Scope Data series 200 printer using a non-impact 7 x 9 dot matrix print head. The unit is equipped with a keyboard option and will print asynchronously up to 120 characters per second, 80 characters per line and 6 lines per inch.

Positioning Sub-System

The dynamic positioning of the survey launch is accomplished through two systems of electronic range-measuring equipment, namely MRB 201 tellurometers. Each system consists of a remote unit on shore, a tracking antenna, a tracking antenna control, a master unit, and a data line driver on board the survey vessel. The MRB 201 was designed as a direct ranging system utilizing phase comparison techniques and operating on a microwave carrier of 3000 MHz modulated by measuring frequencies in the order of 1.5 MHz. The accuracy of the MRB 201 system under dynamic conditions is ± 1.5 metres for maximum range up to 50 km assuming reasonable line-of-sight conditions. The speed of operation for the said range and accuracy is in the order of 30 knots. The system also has integral duplex radio voice communication ensuring continuous shore station contact.

The MRB 201 is designed with a dual master/remote facility. The master and remote therefore are basically the same with the exception that the master is equipped with a plug-in Digital Range Integrator (DRI). The DRI presents a continuous and instantaneous visual display of the range and also provides an electrical output of this range in BCD form. This output is connected directly to the Data Accumulation Sub-System. Additionally, the DRI is equipped with a dynamic memory which, in effect, stores the slant range velocity. Whenever the true signal is temporarily lost, which is the major problem with systems limited by line-of-sight, the DRI reverts to the memorized phase and continues to provide, in this case, estimated range data. Provided no violent manoeuvres are made during the period of lost signal, the readings are still extremely accurate. The remote instrument is also equipped with a plug-in unit, a Dial Readout (DRO), which permits static measurements to an accuracy of ±.5 metres ± 3 x 10^{-6}d, where d is the distance being measured.

A variety of antennas and reflectors are available for the MRB 201 system. In this system the remote units are equipped with standard rectangular paraboloidal reflector and dipole which has a vertical and horizontal beam width of 20° and 24° respectively. The master units on board the survey vessel are equipped with a double tracking antenna system. The tracking antenna consists of a motor-driven microwave reflector and dipole contained in a waterproof casing. This mast-mounted remote-controlled antenna is capable of scanning automatically through 360° and locking in the direction of maximum signal strength, that is, in the direction of the remote station. The reflector-dipole combination has the same beam width as the standard MRB 201 dipole and one complete rotation can be performed in less than 10 seconds. The cabin-mounted control provides the facility for directing the antenna according to several modes of operation including manual, automatic, and external. It also has a scan interval selector and a motor-driven pointer which is automatically synchronized to the direction the antenna is pointing.

Depth-Sounding Sub-System

This sub-system comprises an Atlas-DESO-10 control unit and recorder unit with two transducers of different frequencies, 210 kHz, and 33 kHz, and an Atlas-EDIG-10 digitizer unit.

The system uses ultrasonic waves for depth measurement. A short sound pulse is emitted by a transducer in the form of an 8° beam vertically towards the bottom. Part of the sound energy is reflected and returns as an echo to the same transducer, which operates as transmitter as well as receiver, eliminating the possibility of angular errors in shallow depths. The time between the emission of the sound pulse and the return of its echo is proportional to the depth. Upon detection of the echo a black mark is recorded on the paper. Since the paper moves at a constant speed, the following echo leaves another black mark beside the preceding. This produces, with extended sounding, a graphic recording in the form of a continuous curve presenting a true picture of the bottom. The accuracy of measurement is dependent on the accuracy of reading from the recording paper, ± 5 cm optimum. The range of the system is 0 to 280 metres.

The recorder can operate simultaneously on both transducer frequencies. It is equipped with a 210 kHz transducer which detects and allows the recording of the low-density sediment deposits and a 33 kHz transducer which penetrates to enable the recording of the layering effect of previous sediment deposits which have compacted to higher densities.

The recorder unit includes the recorder and all elements for fine adjustments, and operational control.

The control unit includes pulse generators, amplifiers, control devices and power supply on exchangeable printed circuit boards, and all elements for coarse adjustment. It has two sets of coarse adjustments, that is, one for each transducer.

The Atlas-EDIG-10 digitizer evaluates and provides a digital output of the depth, thus establishing the connection between the DESO-10 and the Data Accumulation Sub-System. The extraction and evaluation of the first ground echo, as it is of primary interest, is accomplished by a built-in filtering logic which examines a pulse sequence with a definite frequency. This pulse sequence is determined in the period between transmission and reception of the ground echo. The smallest measuring unit is 5 cm. The logic is assisted by the following filtering sequence: time-dependent gain control (TVC), amplitude-dependent gain control (AVC), digital comparison of two successive soundings, electronic interlocking against unintentional interference echos or echo drop-out and reverberation screening. This filtering ensures reliable working of the system, without the need for readjustment, over longer periods of time or in cases where considerable changes in depth are experienced. As mentioned previously, the DESO-10 can record on two frequencies simultaneously, but the evaluation in the EDIG-10 can be carried out on only one frequency at a given time. The range of the present digitizer is from 0 to 99.95 metres.

Data Processing Sub-System

This sub-system was added to the basic system, as outlined above, in 1976. The main reasons for this addition were to simplify the monitoring of performance of all instruments; optimize the quality of the data collected by improving the survey coverage and provide a continuous plot of the survey launch position.

The Data Processing Sub-System consists of an autoplot interface, a programmable calculator, and an X-Y plotter. The sub-system is complemented by a software package prerecorded on a magnetic tape cartridge.

The autoplot interface is the link between the data coupler and the calculator. It is a custom-built unit which in the "on-line" mode is capable of storing the survey data from the data coupler as well as the monitoring pulses from the measuring instruments, and converting this information into a compatible format and outputting the information to the calculator. It also outputs event mark pulses to the Atlas-DESO-10 recorder which marks the depth-sounding chart for future reference. In the "off-line" mode the interface provides a means of transferring the data stored on the calculator cartridge onto the digital line printer.

The programmable calculator is a Hewlett-Packard 9825A unit with programming capabilities approaching minicomputer standards. The calculator is equipped with a 16K-byte memory, a string and advance programming ROM, a plotter and general and extended I/O ROM, and an internal strip printer and magnetic tape cartridge drive. The calculator is connected to the X-Y plotter through HP-IB interface 98034A.

The X-Y plotter is a Hewlett-Packard 9872A micro-processor-based plotter. It incorporates a stepper motor drive system to accomplish addressable moves as small as 0.025 mm and a four-pen selection possibility through programming. Additionally, it has 38 different built-in instructions with such capabilities as point-digitizing, labeling, and axes generation.

The software package consisting of four programs and four general utility files is contained on both tracks of a pre-recorded magnetic tape cartridge in eight file blocks as follows:

File Number	Description
0	Driver Program
1	Preplot Program
2	On-Line Program
3	Data Dumping Program
4	Data File
5	Error Message File
6	On-Line Special Function Key Statements
7	Message File for Dump Program

Upon initialization of a survey period the driver program is automatically loaded into the calculator and starts to run. This program is to assist the operator in the selection and loading of the desired program into the calculator's memory.

The preplot program provides the user with the facility to prepare plotter charts for use during the on-line operation mode. All dimensioning and plotting is in metric units. Each chart is prepared with a border, grid intersection marks along the border and is annotated with the following parameters:

a) Minimum X(E) limit of the chart
b) Minimum Y(N) limit of the chart
c) Maximum X(E) limit of the chart
d) Maximum Y(N) limit of the chart
e) Chart Number
f) Chart Scale
g) Grid Intersection Interval

These chart parameters are also recorded on the program cartridge (data file) for future use in the on-line program, along with the tellurometer shore station positions. The tellurometer positions are plotted automatically on all the charts upon which they fall. Survey lines are also plotted on all the charts except the Index Chart. The orientation of the survey lines is selectable and is relative to the base line between the shore stations. The user also selects a reference point through which the reference survey line passes. The survey lines are drawn on either side of this reference survey line at the user-specified interval. Generally, a number of charts are preplotted to cover the whole survey. Chart 1 is prepared to a scale that will encompass the entire survey area and shows all the survey lines. Chart 1A, the Index Chart, is prepared to the same scale and chart limits as Chart 1. It denotes all the sub-areas which are delineated by rectangles. The corresponding chart number of each sub-area is shown at the bottom left corner of each rectangle. Then Charts 2, 3, 4, etc. are prepared corresponding to the number of sub-areas.

The on-line program enables the data-processing sub-system to monitor the data collection, to warn the operator of instrument malfunctions and to plot the survey launch position on the pre-plotted charts. The monitoring portion of the program consists of the following:

1) Interrogation of status flags, such as tellurometer A signal, tellurometer B signal, echo-sounder digitizer response and magnetic tape inter-record gap pulse. Points with estimated tellurometer distances are plotted on the chart with a circle.

2) Examination of each positioning data point by checking for closure and plotting position on the chart (i.e. off-chart or on-chart), by calculating the theoretical accuracy and angle of cut, and by computing the straight line distance between each data point and comparing it to a user-specified maximum increment.

The on-line program also allows the calculator to store the questionable positioning data on the tape cartridge and to initiate event (fix) marks at preselected intervals on the echo-sounding chart. This is particularly useful when the depths of sediment layers are required. The points which correspond to fix marks are plotted as a cross (+) and are numbered with the data point number on the chart. These "fix" points are also recorded on the tape cartridge.

The above program also provides the system with a sampling mode of operation for position fixing when sediment sampling or any other related sampling is conducted. In this mode, fixes are generated when a sample fix push button is activated. These fixes are recorded on the data cartridge. Additionally, in this mode, the operator has the option of selecting whether the plotter pen plots points up to the fix position or simply tracks without marking the chart up to the fix position. In either case the fix will be plotted with a cross (+) and labeled with the data point number.

Upon completion of a survey day or at the end of the entire survey, the data dumping program provides the user with the facility to dump "print-out" the data stored on the tape cartridge onto the Data Accumulation Sub-System line printer through the autoplot interface. The user can select the type of data point "fix" to be printed out by the following parameters:

a) Printout all fixes
b) Printout a selected fix
c) Printout only sampling fixes
d) Printout all on-line fixes
e) Printout on-line fixes except those with estimated tellurometer distances
f) Printout only fixes with estimated tellurometer distances
g) Printout on-line fixes with accuracies better than 3 metres
h) Printout on-line fixes with accuracies worse than 3 metres
i) Printout on-line fixes with no depths.

Finally, the above software package has a number of error recovery routines and operational facilities available through the calculator function keys.

Survey Launch and Transportation

The HYDAC-100 is mounted in a 32-foot shallow-draft aluminum survey launch, the HY-SE-SUSY (Hydrographic and Sediment Survey System). This craft was built to the Sediment Survey Section specifications. It is capable of operating safely in less than a metre of water and on most lakes and rivers can be taken up to shore for ease of loading and unloading survey equipment. It has a 4-degree hull slope, is powered by two 455 cu in. Oldsmobile V-8 marine engines coupled to two Berkley jet drives and is capable of 35 knots cruise speed.

The HY-SE-SUSY is transported on a custom-built three-axle, 8½ foot wide trailer which permits access to Canadian highways without special permits. It is equipped with a keel roller system making it possible to launch and load the craft at typical public ramps.

The combined weight of the survey instruments, HYDAC-100, HY-SE-SUSY and trailer is approximately 12 000 lb. It is hauled with ease by a 1-ton, four wheel drive truck operated by a member of the survey crew.

Survey Methods

Survey Objectives

The object of any hydrographic survey is to collect water depths, reference the position of each depth with regard to some shore position and record the data for future use.

The purpose of collecting this data is to portray the bed configuration of a selected area of a body of water. Depth measurements, a product of the hydrographic survey, are subtracted from the water surface elevation to provide a bed elevation at each measuring point. By referencing this data point to a common coordinate system, an exact position for each elevation is obtained. The elevation and position of each point is then entered into a large core computer. Output data from the computer defines the bed configuration of the body of water. Using this data, a capacity figure may be developed or a contour map may be generated.

Note that the hydrographic surveys conducted by the Sediment Survey Section are primarily used to determine the morphology of the bed of a body of water. Henceforth, these surveys shall be referred to as morphological surveys.

Methods of Survey

There are several methods available for conducting morphological surveys, however, the two methods most frequently employed are the Range Line Survey Method and the Area Survey Method.

Range Line Method

In the Range Line Method, control lines are established on a body of water at preselected locations. Each line is terminated by a large visible target. The distance between targets and points of known elevation are established during the ground control survey. The survey procedure for this method consists of traversing the body of water on the line, measuring depths at changes in the bed slope, obtaining a distance from one of the shore stations (targets) to each point where a depth is collected, and measuring the water surface elevation. Data between range lines is interpolated using conventional methods.

With the availability of large core computers, the volume of morphological data which may be handled has increased dramatically. As a result, the once-popular Range Line Method is giving way to the more accurate Area Survey Method.

Area Survey Method

In the Area Survey Method, data points are collected over an area of water according to some preselected pattern. The survey procedure for this method consists of establishing the water surface elevation, fixing shore positions, measuring depths with simultaneous referencing to the shore positions and traversing the body of water according to some survey pattern previously established.

One advantage of this method is the relative freedom of movement of the survey launch. Straight lines are not required as in range line surveys, but rather a survey pattern to ensure no data gaps or line overlaps exist.

Control Systems

There are two horizontal control systems which may be used on either of the morphological survey methods. These are the open system and the closed system. The terms open and closed refer to the horizontal ground control used to reference the shore stations. The system selected for use on any survey is dependent on the size and shape of the water body.

Closed System

This system is most frequently used in small bodies of water (1 to 25 km^2). In this system, all the shore stations are referenced to one common base line. Figures 2(a) and 2(b) display possible closed system control configurations for both the Range Line Method and Area Survey Method. In Figure 2(a) all range lines are fixed to the base line; in Figure 2(b) the advance shore positions are tied to base shore positions using horizontal ground control surveys.

The advantage of the closed system, particularly when it is combined with a rough grid survey pattern in the area method, is that total coverage of a body of water may be obtained.

Open System

In a large body of water where the area is generally greater than 25 km^2, logistics, costs of handling extremely vast volumes of data, and low sedimentation rates with respect to capacity make it impractical to survey it in its entirety. In a situation such as this, the open system is used for horizontal control. In the open system, shore stations are not referenced to a common base line. As shown in Figures 3(a) and 3(b) range lines and sectors are established at different locations along the length of the body of water. Here a sector is defined as that portion of a body of water controlled by two specific shore positions and surveyed as a homogeneous section. Each line and sector is representative of the portion of the body of water in which it is located. Interpolations are made for that portion of the body not surveyed.

In effect, the open system is similar to that of cross-section profiling. However, data obtained for a sector area provide a more accurate representation of the bed than does a single profile. Also, data generated by interpolation between sectors would be more accurate than data generated by profiles.

Survey Quality

The quality of a survey is directly related to the accuracy of the equipment and the coverage of the survey area.

In this case, accuracy refers to the inherent accuracy of the equipment used for measuring depth and distance. A numeric value for percent error of individual equipment was discussed previously in the system description.

CLOSED CONTROL SYSTEM

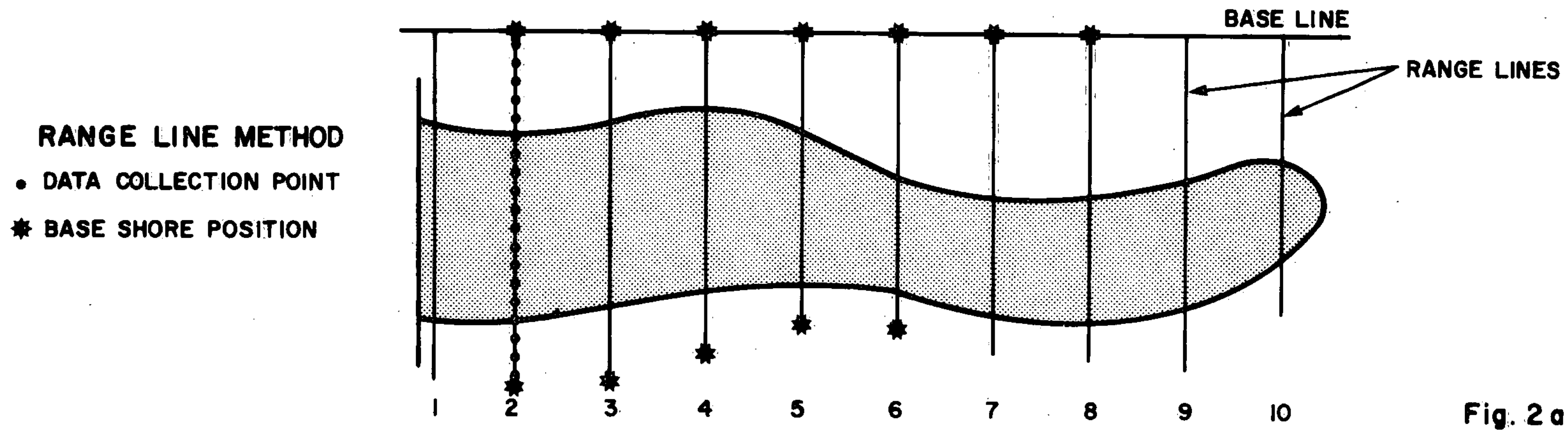


Fig. 2a

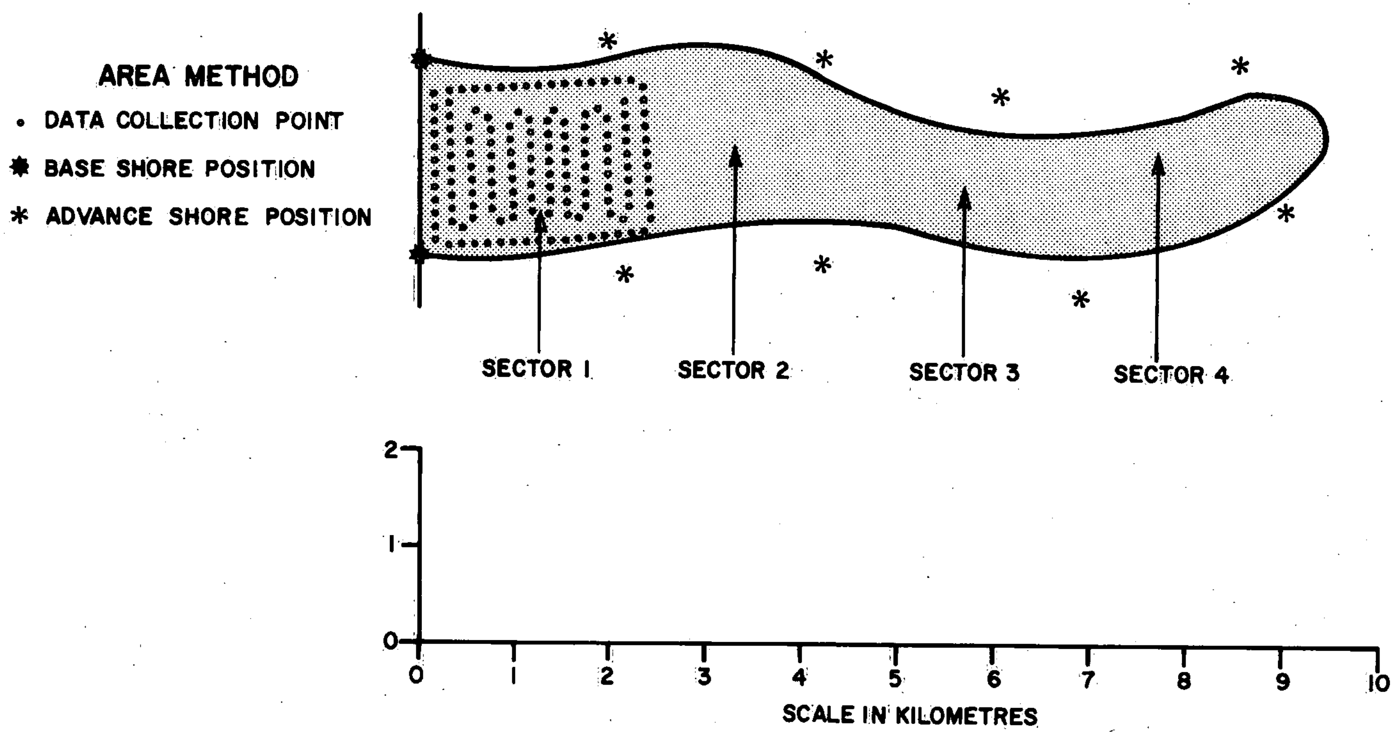


Fig. 2b

OPEN CONTROL SYSTEM

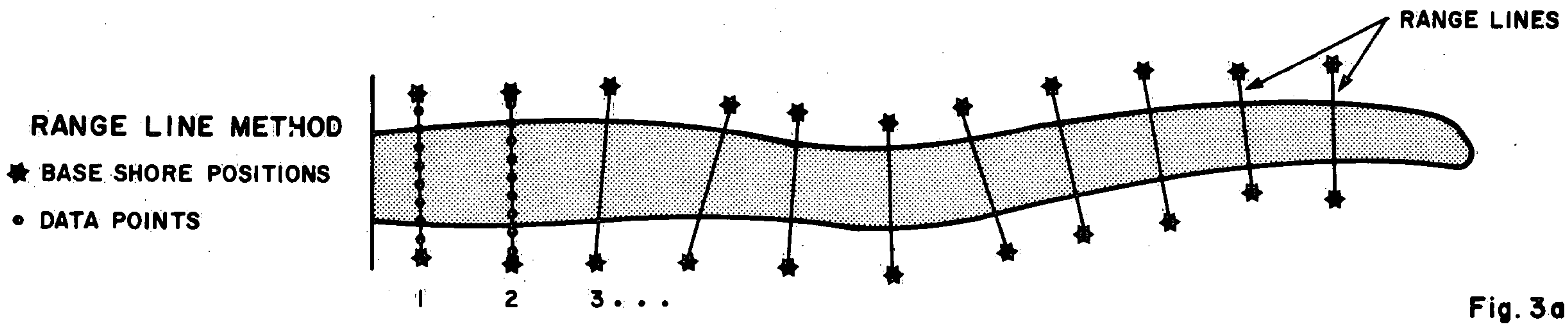


Fig. 3a

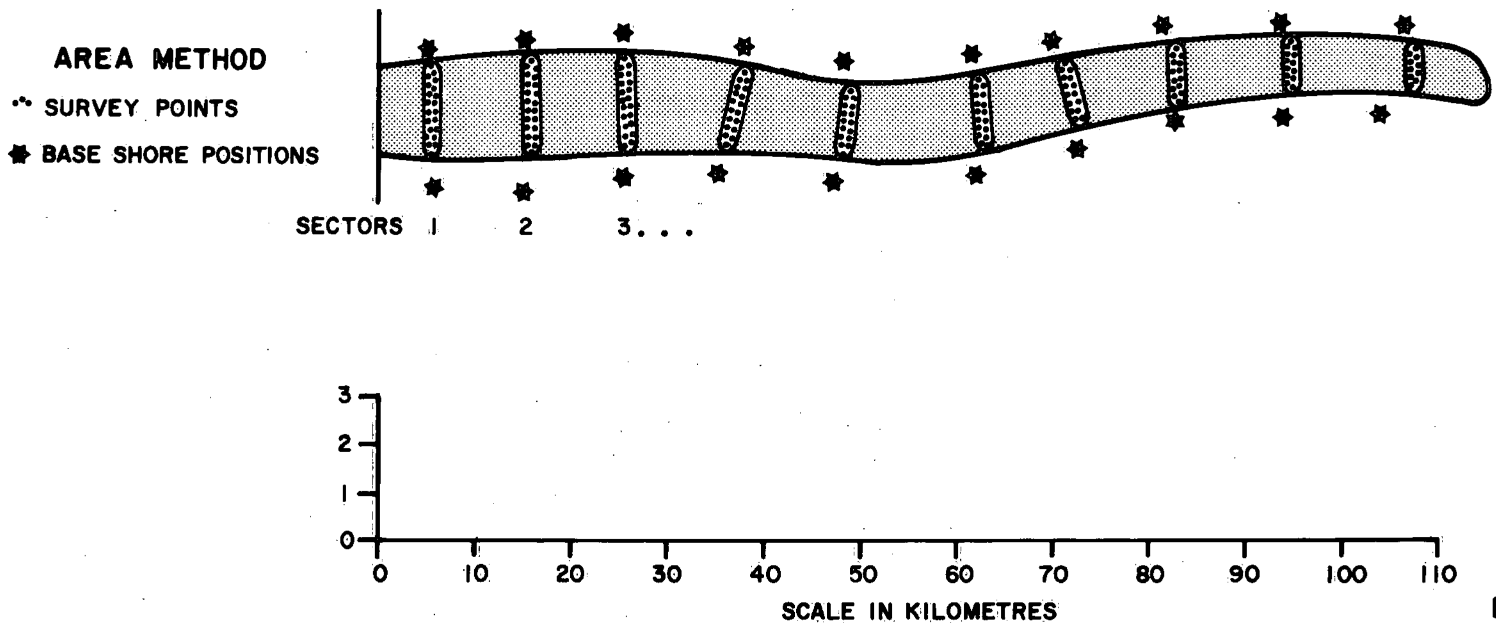


Fig. 3b

The coverage obtained while collecting morphological data is a function of the number of data points collected and the position of each point. Good coverage is necessary in order to accurately describe the bed configuration. In the Range Line Survey Method, data points need only be collected at points on the profile where there is a slope change. As a result, good coverage for a flat bed profile requires only few data points, whereas good coverage for a rough undulating bed requires numerous data points.

In order to obtain good coverage using the Area Survey Method, the survey pattern selected must reflect the bottom conditions. In a flat bed area, a grid pattern utilizing large spacing between grids would be sufficient. However, if the bed is rough, a very fine grid with a high density of points is necessary. (See Table 2.)

Survey Procedure

Reconnaissance of Study Area

If it is established that a HYDAC survey is capable of providing data required for a particular study, a preliminary survey of the study area should be conducted.

While at the site, the observer should pay particular attention to the following points:

1) size and shape of study area,
2) surrounding land and shore conditions,
3) water conditions, and
4) underwater terrain.

Using the size and shape of the body of water as a guide, the survey method and system may be selected. If a body of water is small with an irregular shoreline such as a reservoir in a young valley, the Area Method of surveying would be selected with a closed system for horizontal control, whereas the Range Line Method and open system of control may be used for a capacity study on a man-made canal.

Particular attention should be given to shore conditions and land surrounding the study area. Selection of shore stations for horizontal control is largely dependent on the visibility from the point. The time required to conduct a survey is partially dependent on the number of control points. Generally speaking, survey control points should be kept to a minimum.

Intense weed growth in a body of water may interfere with sounding results and the propulsion system of the launch. A survey in a shallow, weedy pond should be conducted early in the year prior to pronounced weed growth.

If possible the observer should attempt to determine the conditions of the bottom, for these conditions are also a guide in survey method and control system selection. Another factor which bed conditions will affect is the density of data collection. Suggested data density ranges for various bed conditions are listed in Table 2. Finally, the observer should keep in mind that the information collected in this preliminary survey will be the determining factor in selecting the manner in which the survey will be conducted.

Table 2. Point Elevation Data Quantity per Square Kilometre (Area Survey Method)

BED CATEGORY	DEGREE OF SURVEY		
	DETAILED	GENERAL	RECONNAISSANCE
1 Rough Bed (Frequent major slope changes)	2500* to 3500	1500 to 2500	800 to 1500
2 Relatively Smooth Bed (occasional major slope changes)	1500 to 2500	800 to 1500	400 to 800
3 Smooth Bed (slope changes gradual)	800 to 1500	400 to 800	100 to 400

* The indicated density range for point elevation data required in each category is a function of the smoothness of the bed.

Survey Planning

Once a preliminary survey has been completed, a detailed plan of the survey should be prepared. The following points should be considered:

1) Selection of shore station locations--Occasionally it is possible to select shore stations prior to a morphological survey. In such case, air photo interpretation, combined with notes from a preliminary survey, should be sufficient information to select suitable sites.

2) Planning of control ground surveys--By this time a system for horizontal control has been selected. A plan is now established to carry out the necessary horizontal and vertical ground control surveys.

Other points which must be considered are manpower requirements for survey purposes and data reduction, selection of launch sites, living arrangements for crew and, most important, the funding for the survey.

Ground Survey

The two controls required for a morphological survey are vertical and horizontal. To establish these controls, ground surveys are frequently necessary. The term ground survey refers to a land based survey as opposed to surveying from a floating vessel.

Vertical Control

The vertical control required for a morphological survey is the elevation of the water surface at the point of depth measurement. One method of obtaining vertical control on the survey location is to install water level recorders at the upstream and downstream ends of the survey site. An alternative method is to transfer elevations to a temporary bench mark near the selected shore stations. The accuracy to which the elevation is transferred should be one order higher than the accuracy attained by the sounding device. At the time of the HYDAC survey it would then be a simple operation to obtain water surface elevation by transferring elevations from the previously mentioned point.

Horizontal Control

In the open system, the ground survey requirement for the Range Line Method is a profile from upper targets and bench marks to water's edge and a distance between targets or bench marks. For the Area Method the horizontal control consists of distance measurement between shore stations.

In the closed system, the ground survey requirement for the Range Line Method is similar to that of the open system. However, the left target of each range line falls on the base line. See Figure 2(a) for an example. For the Area Survey Method, all advance shore control stations are tied together (referenced to the base shore stations). This is done by either triangulation (distance and angle measurement) or trilateration (distance measurement only).

The HYDAC Survey

The following procedure is generally adhered to in conducting a typical capacity or contour survey using the HYDAC-100 survey system, the survey launch (HY-SE-SUSY), the trailer and towing vehicle.

The body of water on which the morphological survey will be conducted is a reservoir. The survey method used will be the Area Survey Method on a grid pattern.

Prior to any survey, general vehicle, launch and equipment maintenance is carried out. The survey launch is transported to the survey site and launched. All equipment is then unpacked, assembled and prepared for surveying.

The launch is navigated to the shore stations where remote tellurometers are set up. If the distance between the remote tellurometers is still unknown, a separation distance is obtained using either the remote tellurometers or some other horizontal survey equipment. Elevations are transferred from a point of known or datum elevation to the water surface using a leveling instrument.

The launch is then moved to some other point in the reservoir where instrumentation checks are made. These checks include tellurometer zero compensation adjustment and calibration of the Atlas echo-sounding equipment using a bar check or a recently developed calibration transducer. At this point all the remaining equipment is powered up.

A grid plot of the sector is generated by the Hewlett-Packard 9825A programmable calculator on the Hewlett-Packard 9872A plotter. The grid pattern and size are those deemed necessary as a result of the reconnaissance survey.

All equipment is tuned and set on standby. When the launch is taken to a nearshore position, the equipment is enabled and data collection begins. The initial run on each sector is termed the perimeter run. It is run counterclockwise to place the transducers as near to the boundary of the survey area as possible. The remainder of the survey is conducted within the perimeter run along preplotted grid pattern lines.

On completion of the sector, the shore-based tellurometers are picked up and moved to the advance control stations for the next sector. On completion of the study, end-of-file gaps are recorded on the magnetic tape which stores the data, the tape is rewound, removed from the recorder and sent to headquarters for editing.

The system is disassembled and secured for transport. The launch is loaded on its trailer and preparations are made for transport to the next survey site.

The following is an example of a typical HYDAC-100 survey. In 1972, a morphological survey using a prototype HYDAC system was conducted in Saskatchewan on a portion of Lake Diefenbaker known as the Swift Current Creek delta. Figure 4, entitled Volumetric Survey, Swift Current Creek delta, is a diagram showing that part of the reservoir on which the survey was carried out. The boundaries of the study area are Range 15 (R15) and Range 17 (R17) in Lake Diefenbaker and Range 16 (R16) in the Swift Current Creek.

The Area Survey Method was used in conjunction with a closed horizontal control system. Base shore stations are identified in Figure 4 as points A and B; advance shore positions are identified as C and D.

Figure 5 displays the results of the volumetric survey in the form of a computer-generated contour map. Visible as dots on the figure are the positions where data points were acquired.

Figure 6, a three-dimensional computer plot of the Swift Current delta, displays the bed of the old South Saskatchewan River channel and the Swift Current Creek channel as it enters the area now flooded by Lake Diefenbaker. Future surveys of the area will produce data from which sedimentation rates may be computed.

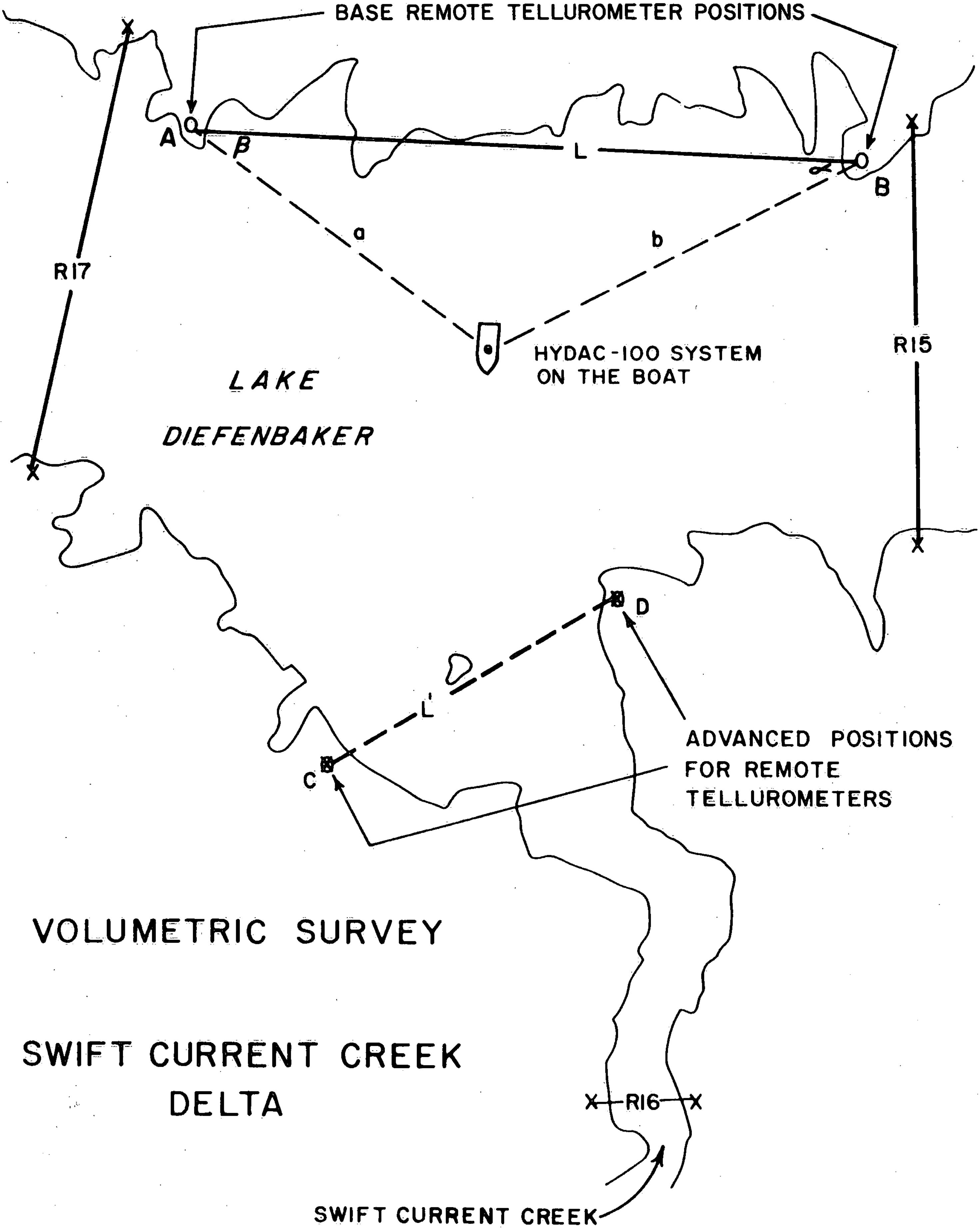
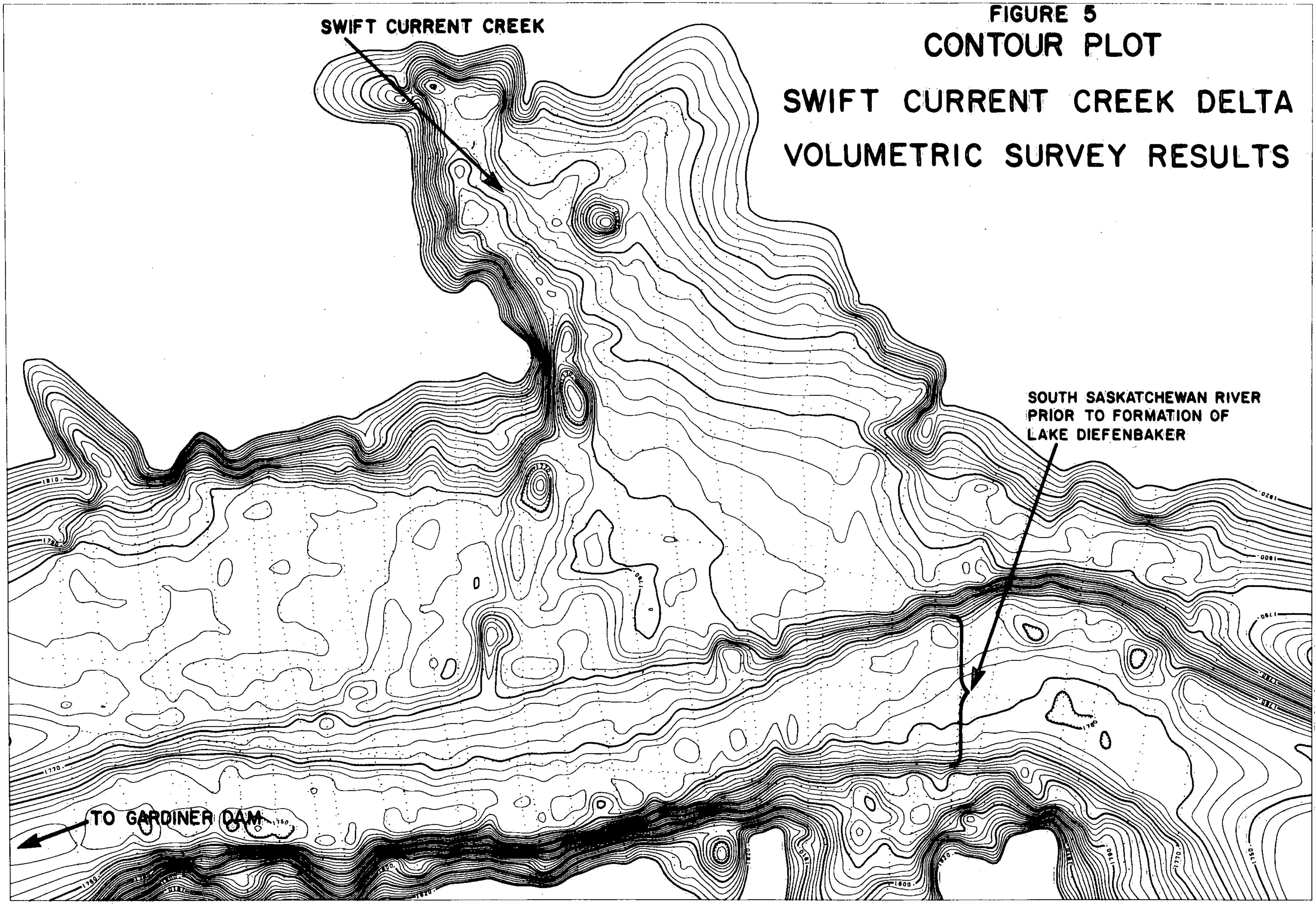

BASE REMOTE TELLUROMETER POSITIONS
A
β
L
α
B
a
b
R17
R15
HYDAC-100 SYSTEM
ON THE BOAT
LAKE
DIEFENBAKER
D
L'
C
ADVANCED POSITIONS
FOR REMOTE
TELLUROMETERS
VOLUMETRIC SURVEY
SWIFT CURRENT CREEK
DELTA
R16
SWIFT CURRENT CREEK

FIGURE 4

FIGURE 5
CONTOUR PLOT
SWIFT CURRENT CREEK DELTA
VOLUMETRIC SURVEY RESULTS



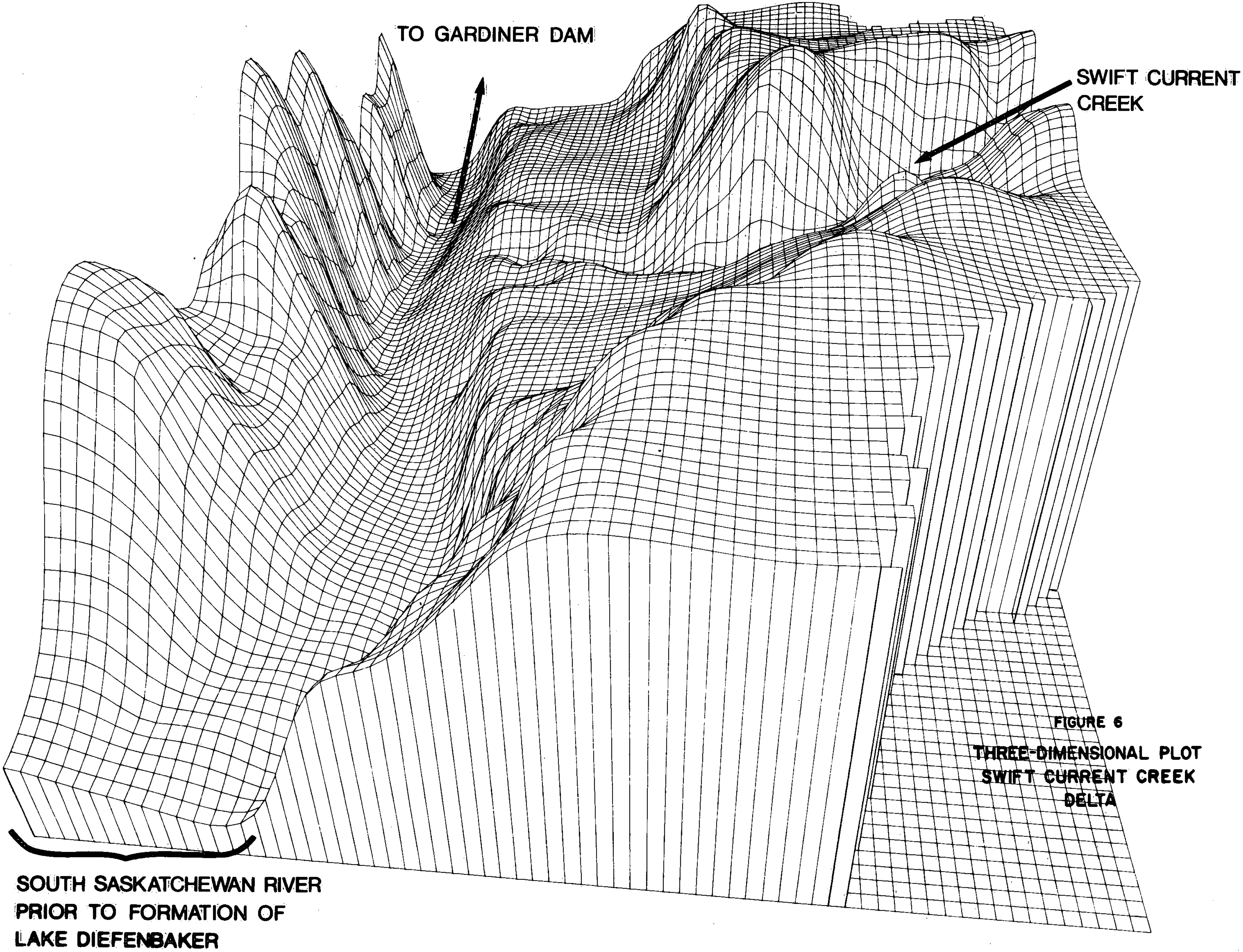


FIGURE 6

THREE-DIMENSIONAL PLOT SWIFT CURRENT CREEK DELTA

Data Reduction and Analysis

Data Preparation and Reduction

Since the main portion of the data is stored on magnetic tape, most of the data preparation and reduction is performed in-house with the aid of a digital computer.

Referring to the flowchart of Figure 7, the procedure is as follows:

a) The water levels recorded on a strip chart gauge recorder are digitized and computed to give values at 15-minute intervals.

b) The land survey of the shore locations is computed from triangulation data and an x-y coordinate system established. Accuracy cannot be overstressed for this phase of the procedure, as the entire survey relies on this information.

c) If dual frequency echo sounding was performed, the multiple layers must be digitized for each location.

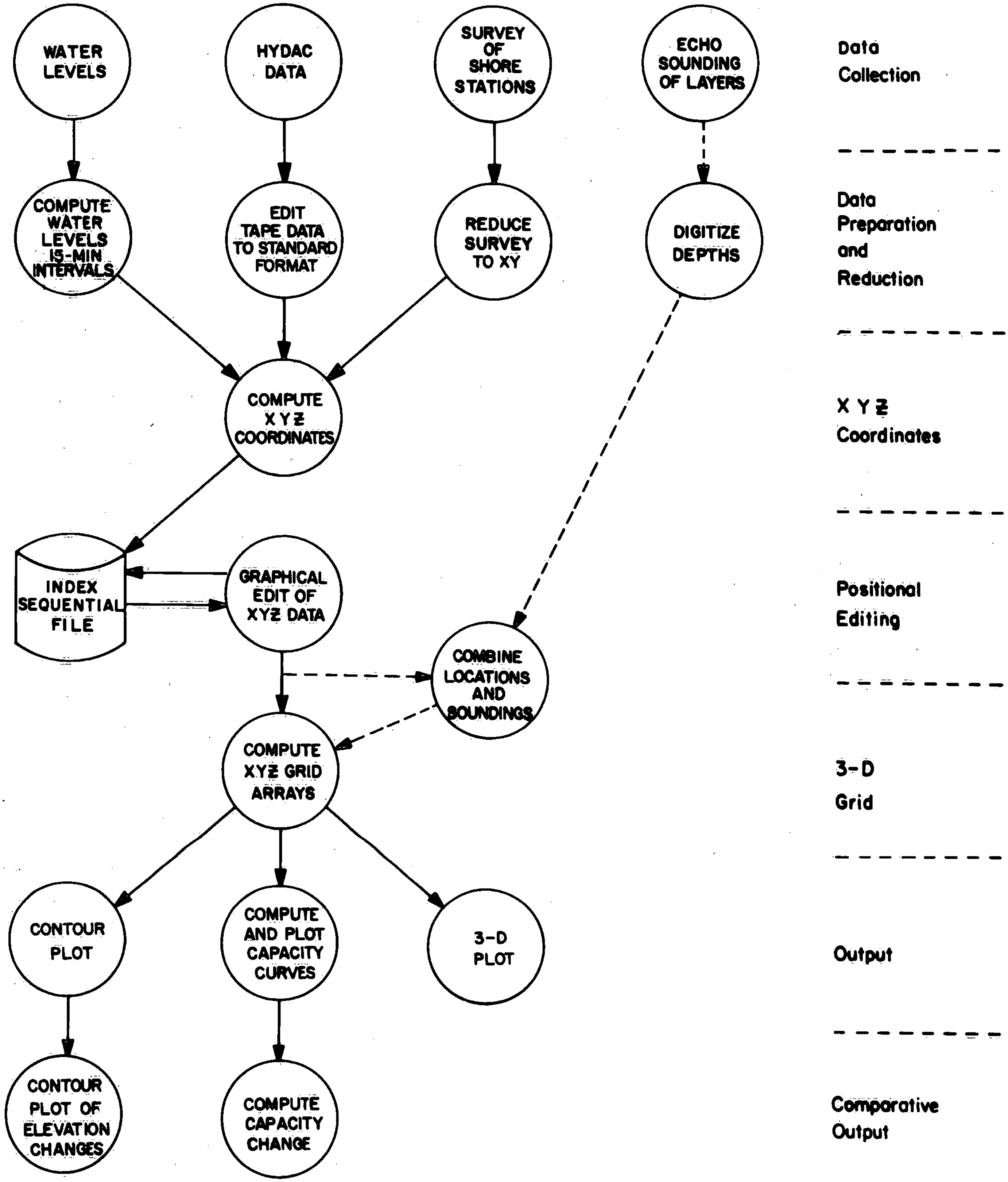
X-Y-Z Coordinate Computations

The X-Y-Z coordinates for each data point are computed by the following procedure:

a) The data is computed by RUNS and SECTORS such that each sector may be adjusted to reflect the conditions under which the survey was conducted.

  i) date of survey for correlation with water levels
  ii) depth of transducer below water
  iii) shore position locations with respect to coordinate system
  iv) maximum and minimum depths permitted and maximum change in depth between points for filtering out erroneous soundings
  v) sector location in relation to the base line
  vi) maximum distance between consecutive points for filtering out the erroneous tellurometer readings
  vii) elevation adjustments to bring water level gauges to common datum (usually GSC datum).

FIGURE 7
HYDRA* SYSTEM FLOWCHART



* HYdrographic Data Reduction and Analysis

b) The X, Y coordinates are calculated using the Cosine Law, as shown in Figures 8 and 9, then translated to the coordinate system.

c) The Z coordinate computations are based on the assumption that the slope of the water surface between two water level gauges is linear. Elevation changes between the 15-minute values of water levels at each station are again assumed to be linear to establish 1-minute intervals. The slope of the surface between the two gauges is then computed for each 1-minute interval. The Z coordinate for each data point is then calculated by computing the resultant distance between the data point and the governing water level recorder and multiplying the distance by the slope of the water surface. The result is added or subtracted as required to the recorded water elevation, and the water depth as determined by the echo sounding is subtracted to determine the bottom elevation.

Positional Editing

The positional editing consists of a visual examination of the data point plot for each sector. These points must plot consecutively in a continuous pattern which is examined for points which deviate from the pattern. Elevation of points at intersections of runs are checked to ensure proper alignment.

Module Selection

In order to produce contour plots of the body of water the data must be transformed into a uniform grid system. This is performed by a software package developed and marketed by California Computer Products (Calcomp) known as the General Purpose Contour Program (GPCP). In order to produce a grid spacing small enough to reflect the sampling spacing, the survey is divided into modules which can be handled by the available 310K words of computer memory. To preserve continuity between neighbouring modules the areas of the modules overlap about 10 per cent during construction of the grid arrays.

In order to ensure that only the surveyed area is considered in any computations using the grid arrays, the boundary conditions such as shoreline and islands must be determined. GPCP then includes or excludes the grid squares based on whether the centroid of the grid square is inside or outside the boundary as illustrated in Figure 10. For identification and computation purposes, the grid squares are assigned a value of "0" if they are inside the boundary

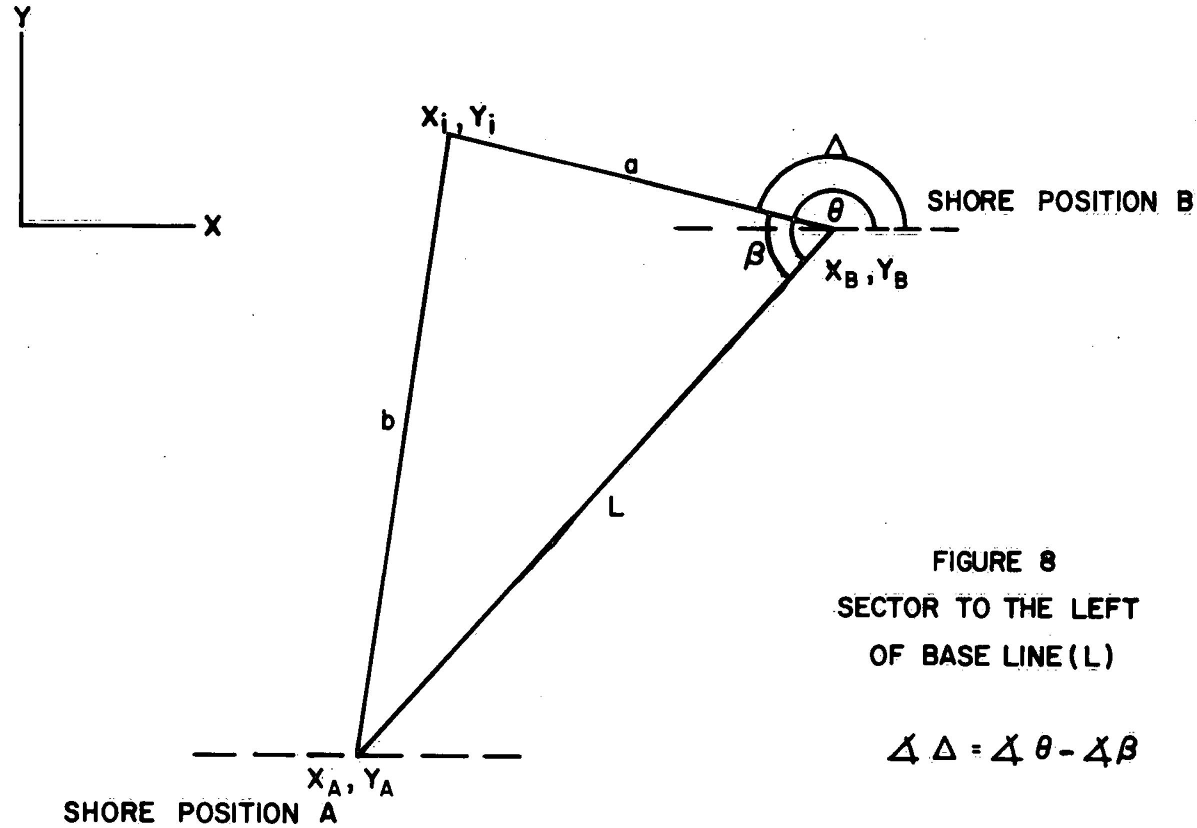


FIGURE 8
SECTOR TO THE LEFT
OF BASE LINE (L)

$$\measuredangle \Delta = \measuredangle \theta - \measuredangle \beta$$

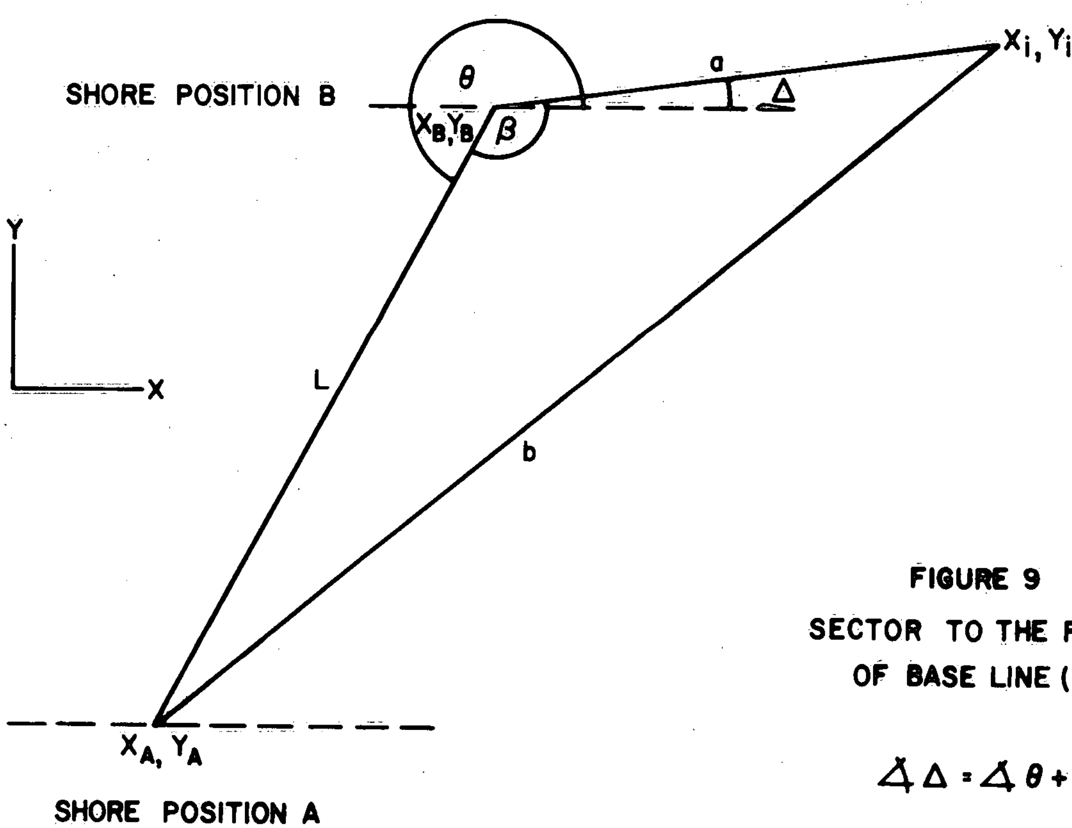


FIGURE 9
SECTOR TO THE RIGHT
OF BASE LINE (L)

$$\measuredangle \Delta = \measuredangle \theta + \measuredangle \beta$$

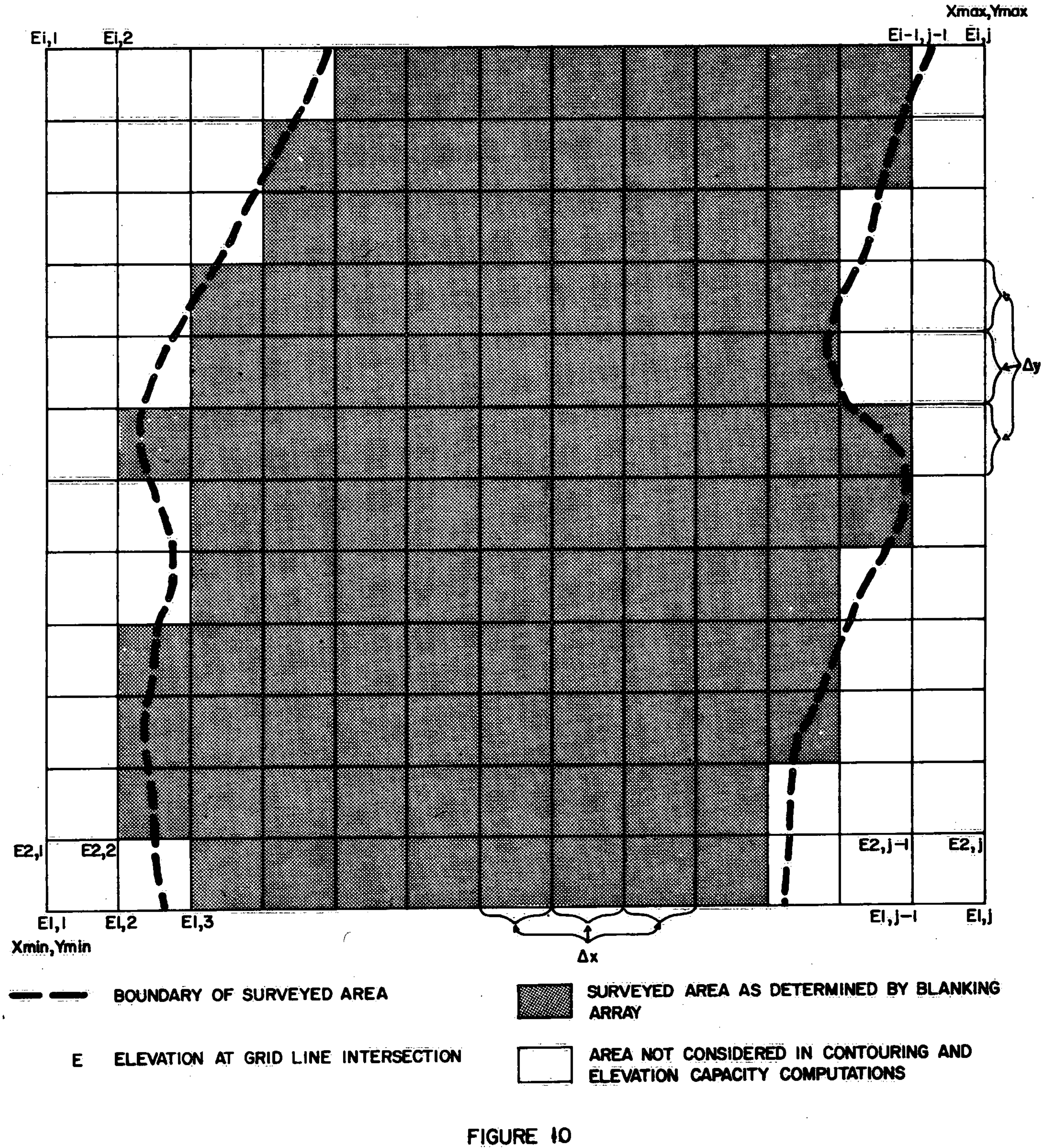


FIGURE 10

THEORETICAL DEFINITION OF COMPUTER-GENERATED BLANKING ARRAY

and a "1" if outside the boundary as illustrated on Figure 11, which is a computer-generated blanking array of Module 1 (Squamish River Estuary Surveys).

Contour Plots

The contours are plotted according to GPCP formulation. Briefly, each grid square is further subdivided into a sub-grid made up of cells. Mesh point values for each of the cells are computed by interpolation from the main grid, and contour lines are drawn by straight lines joining equal elevation values within the sub-grid.

Elevation Capacity

The grid and blanking arrays are used to compute the elevation-capacity table and curve. This is performed by sub-dividing the module into horizontal slices with the thickness of the slice or elevation increment ΔZ defined by the user. Figure 12 illustrates this approach and gives the mathematical formulation used. Briefly, the points with elevations located in the slice under consideration are counted, assigned an area (the area is equal to the area of one grid square and depends on grid interval selected) and multiplied by half the elevation increment ($\frac{1}{2}\Delta Z$). The reason for this is that half the points are below and half above the mean elevation of the increment, assuming random scatter about the mean. The volume obtained for the above is then added to the volume obtained by multiplying the full elevation increment by the area obtained from the sum of all points whose elevations are below the elevation of the increment under consideration as given by Equation 1 (Fig. 12). The total capacity of the body of water is obtained by summing up the volumes of all horizontal slices as given by Equation 2.

The area normally assigned to each elevation point is equal to the area of a grid square. However, since each elevation point is at a grid intersection, the area assigned to each elevation point comprises $\frac{1}{4}$ of the area of each of the four squares surrounding the point. This formulation is not necessary for points located in positions other than at the water-land boundary or at the interface between two modules. At the boundaries however, this formulation provides a greater degree of accuracy. Figure 13 illustrates the water-land boundary condition and Figure 14 illustrates the condition at the interface between two modules. As shown in either case, the total area assigned to each elevation point under these conditions depends on whether the four grid squares surrounding the point are considered inside or outside the survey boundary.

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1 GRID SQUARES OUTSIDE SURVEYED BOUNDARY

0 GRID SQUARES INSIDE SURVEYED BOUNDARY

FIGURE II

COMPUTER GENERATED BLANKING ARRAY OF MODULE I

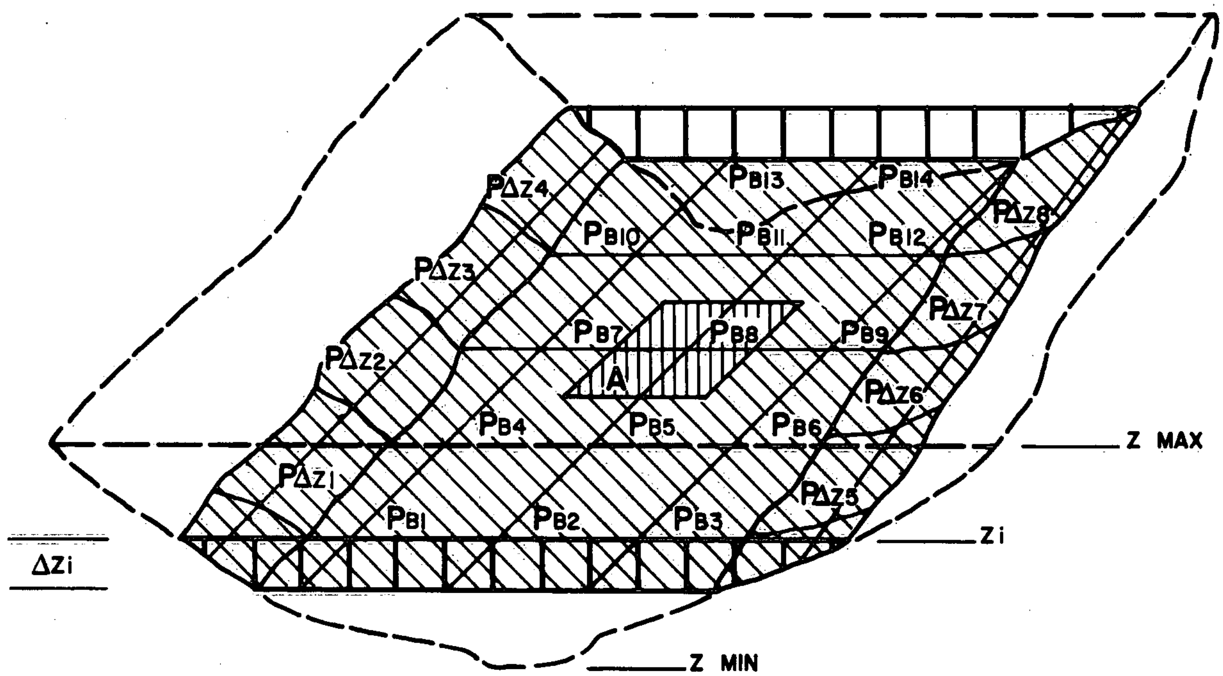

FIGURE 12

ELEVATION-CAPACITY COMPUTATION

$$V_{\Delta z_i} = \frac{1}{2}\,\Delta z_i \left(\sum_{z_i-\Delta z_i}^{z_i} A\,P_{\Delta z_i} \right) + \Delta z_i \left(\sum_{Z\,MIN}^{z_i-\Delta z_i} A\,P_B \right) \tag{1}$$

and $$V_{TOT} = \sum_{Z\,MIN}^{Z\,MAX} V_{\Delta z_i} \tag{2}$$

where $V_{\Delta z_i}$ — the volume of the horizontal slice under consideration.

Δz_i — elevation increment defined by the user.

A — Area assigned to each elevation point.

$P_{\Delta z_i}$ — elevation point residing within the elevation increment under consideration.

P_B — elevation points below the elevation $z_i - \Delta z$

V_{TOT} — total volume of water beneath the surveyed area considered.

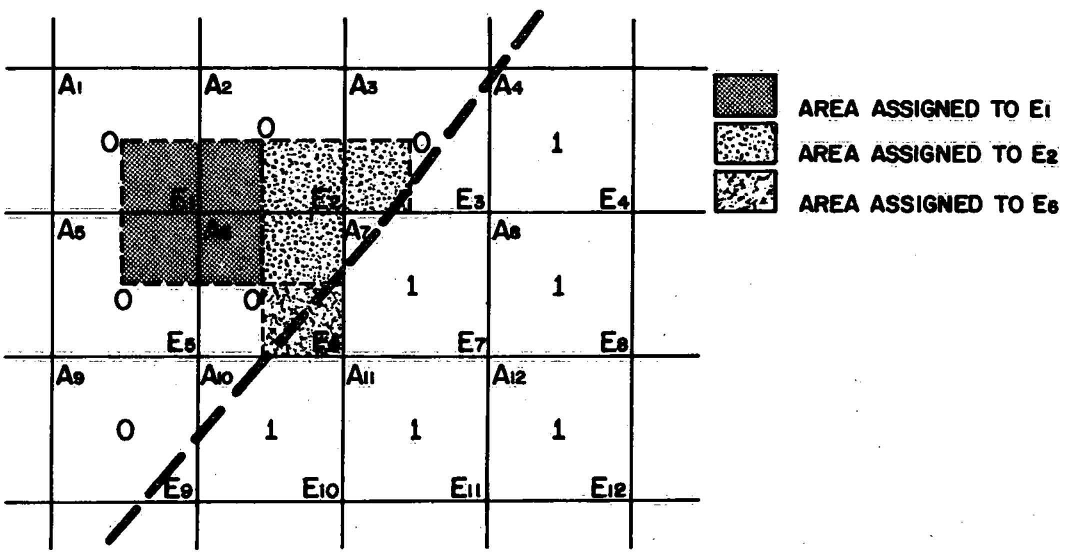

FIGURE 13

AREAS ASSIGNED TO ELEVATIONS AT SHORELINE BOUNDARY

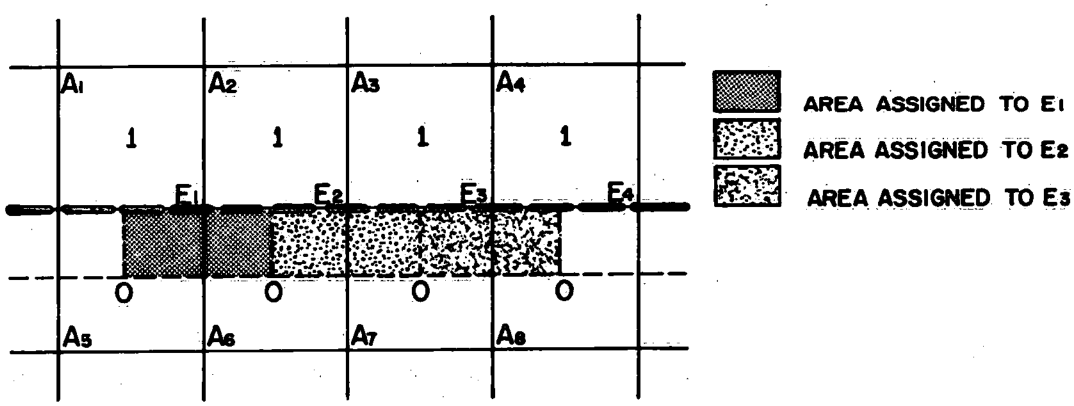

FIGURE 14

AREAS ASSIGNED TO ELEVATIONS AT BOUNDARY BETWEEN MODULES

Based on the above computation the results are readily depicted in the form of tables or curves or both.

Contour Plot of Elevation Differences

This procedure utilizes the grid intersection elevations interpolated by the computer from the field data of two consecutive surveys, compares coincident elevations and generates an array of elevation differences. This array is then used as direct input to contour plotting without any further interpolation.

The prime stipulation in this procedure is that boundary coordinates, grid intervals and scales for each set of data compared are identical. Any deviation will give erroneous results.

Presentation of Data Outputs

The following examples are typical outputs from consecutive surveys in the Squamish River Estuary, B.C., where river diversion works established to create a deep water port appear to be pushing the delta out into Howe Sound at an accelerated rate (Tables 3 and 4; Figs. 15 - 19).

Conclusion and Future Considerations

The evolution of the HYDAC-100 and the HYDRA systems from their first introduction in 1973 have proven to be valuable assets to the Sediment Survey program. A number of geomorphological studies which were practically impossible without quick and efficient data collection and analysis are now being carried out by the Sediment Survey Section. Also, systems of this nature have demonstrated a potential for efficient collation of data used as input to mathematical models and to provide data for studies such as the determination of bed load transport through the measurement of migrating dunes.

Other advantages of the HYDAC-100 are that the system can be transferred to any vessel capable of powering and housing it. It can also be operated in shallow, fast-flowing water at high survey speed by few personnel. Previously a crew of eight was required to conduct a conventional survey, while now a much more comprehensive and accurate survey can be conducted in less than half the time with a quarter of the staff and at a lower cost.

Finally, to meet our own projected study and field research requirements and because of the high demand by other government agencies for morphological studies conducted through the use of the

SEDIMENT SURVEY SECTION
OTTAWA, ONT.
MAY 3 1976

SQUAMISH ESTUARY 1973 MODULE 1

ELEVATION - CAPACITY TABLE

ELEVATION (FT)	ACC. VOLUME (ACRE-FT)	ELEVATION (FT)	ACC. VOLUME (ACRE-FT)	ELEVATION (FT)	ACC. VOLUME (ACRE-FT)	ELEVATION (FT)	ACC. VOLUME (ACRE-FT)
-87.50	.0	-75.00	2.8	-62.50	12.3	-50.00	31.6
-87.00	.0	-74.50	3.1	-62.00	12.8	-49.50	32.6
-86.50	.0	-74.00	3.4	-61.50	13.3	-49.00	33.7
-86.00	.1	-73.50	3.6	-61.00	13.9	-48.50	34.7
-85.50	.1	-73.00	3.9	-60.50	14.4	-48.00	35.7
-85.00	.1	-72.50	4.1	-60.00	15.0	-47.50	36.8
-84.50	.2	-72.00	4.4	-59.50	15.6	-47.00	37.8
-84.00	.3	-71.50	4.7	-59.00	16.3	-46.50	38.9
-83.50	.4	-71.00	4.9	-58.50	17.0	-46.00	40.0
-83.00	.5	-70.50	5.2	-58.00	17.7	-45.50	41.1
-82.50	.5	-70.00	5.5	-57.50	18.5	-45.00	42.2
-82.00	.6	-69.50	5.8	-57.00	19.2	-44.50	43.3
-81.50	.7	-69.00	6.2	-56.50	19.9	-44.00	44.5
-81.00	.8	-68.50	6.6	-56.00	20.7	-43.50	45.8
-80.50	.9	-68.00	7.0	-55.50	21.5	-43.00	47.0
-80.00	1.1	-67.50	7.4	-55.00	22.3	-42.50	48.2
-79.50	1.2	-67.00	7.9	-54.50	23.1	-42.00	49.5
-79.00	1.3	-66.50	8.3	-54.00	24.0	-41.50	50.8
-78.50	1.5	-66.00	8.8	-53.50	24.9	-41.00	52.0
-78.00	1.6	-65.50	9.3	-53.00	25.8	-40.50	53.3
-77.50	1.8	-65.00	9.7	-52.50	26.8	-40.00	54.6
-77.00	2.0	-64.50	10.2	-52.00	27.7	-39.50	56.0
-76.50	2.2	-64.00	10.7	-51.50	28.7	-39.00	57.3
-76.00	2.4	-63.50	11.2	-51.00	29.6	-38.50	58.7
-75.50	2.6	-63.00	11.7	-50.50	30.6	-38.00	60.0

SEDIMENT SURVEY SECTION
OTTAWA, ONT.
MAY 3 1976

SQUAMISH ESTUARY 1973 MODULE 1

ELEVATION - CAPACITY TABLE

ELEVATION (FT)	ACC. VOLUME (ACRE-FT)	ELEVATION (FT)	ACC. VOLUME (ACRE-FT)	ELEVATION (FT)	ACC. VOLUME (ACRE-FT)	ELEVATION (FT)	ACC. VOLUME (ACRE-FT)
-37.50	61.4	-25.00	99.9	-12.50	173.5	0.00	689.3
-37.00	62.8	-24.50	101.6	-12.00	185.2		
-36.50	64.2	-24.00	103.3	-11.50	198.2		
-36.00	65.6	-23.50	105.1	-11.00	212.5		
-35.50	67.0	-23.00	106.9	-10.50	227.9		
-35.00	68.5	-22.50	108.7	-10.00	244.3		
-34.50	70.0	-22.00	110.6	-9.50	261.7		
-34.00	71.5	-21.50	112.4	-9.00	280.0		
-33.50	73.0	-21.00	114.3	-8.50	299.1		
-33.00	74.6	-20.50	116.3	-8.00	318.9		
-32.50	76.1	-20.00	118.2	-7.50	339.4		
-32.00	77.6	-19.50	120.2	-7.00	360.5		
-31.50	79.1	-19.00	122.2	-6.50	382.1		
-31.00	80.7	-18.50	124.2	-6.00	404.1		
-30.50	82.2	-18.00	126.2	-5.50	426.5		
-30.00	83.8	-17.50	128.4	-5.00	449.4		
-29.50	85.4	-17.00	130.6	-4.50	472.6		
-29.00	86.9	-16.50	133.1	-4.00	496.1		
-28.50	88.5	-16.00	135.7	-3.50	519.7		
-28.00	90.1	-15.50	138.5	-3.00	543.5		
-27.50	91.7	-15.00	141.6	-2.50	567.5		
-27.00	93.3	-14.50	145.2	-2.00	591.7		
-26.50	94.9	-14.00	149.8	-1.50	615.9		
-26.00	96.5	-13.50	155.9	-1.00	640.3		
-25.50	98.2	-13.00	163.7	-.50	664.8		

SEDIMENT SURVEY SECTION
OTTAWA, ONT.
MAY 3 1976

SQUAMISH ESTUARY 1974 MODULE 1

ELEVATION - CAPACITY TABLE

ELEVATION (FT)	ACC. VOLUME (ACRE-FT)	ELEVATION (FT)	ACC. VOLUME (ACRE-FT)	ELEVATION (FT)	ACC. VOLUME (ACRE-FT)	ELEVATION (FT)	ACC. VOLUME (ACRE-FT)
-82.50	.0	-70.00	.8	-57.50	3.4	-45.00	7.9
-82.00	.0	-69.50	.9	-57.00	3.5	-44.50	8.1
-81.50	.0	-69.00	.9	-56.50	3.6	-44.00	8.4
-81.00	.1	-68.50	1.0	-56.00	3.8	-43.50	8.6
-80.50	.1	-68.00	1.0	-55.50	3.9	-43.00	8.9
-80.00	.1	-67.50	1.1	-55.00	4.1	-42.50	9.2
-79.50	.1	-67.00	1.1	-54.50	4.2	-42.00	9.5
-79.00	.1	-66.50	1.2	-54.00	4.4	-41.50	9.8
-78.50	.2	-66.00	1.3	-53.50	4.6	-41.00	10.2
-78.00	.2	-65.50	1.3	-53.00	4.8	-40.50	10.5
-77.50	.2	-65.00	1.4	-52.50	5.0	-40.00	10.8
-77.00	.3	-64.50	1.6	-52.00	5.2	-39.50	11.1
-76.50	.3	-64.00	1.7	-51.50	5.4	-39.00	11.5
-76.00	.3	-63.50	1.8	-51.00	5.6	-38.50	11.8
-75.50	.3	-63.00	1.9	-50.50	5.7	-38.00	12.1
-75.00	.4	-62.50	2.1	-50.00	5.9	-37.50	12.4
-74.50	.4	-62.00	2.2	-49.50	5.1	-37.00	12.8
-74.00	.4	-61.50	2.3	-49.00	6.3	-36.50	13.1
-73.50	.5	-61.00	2.5	-48.50	6.5	-36.00	13.4
-73.00	.5	-60.50	2.6	-48.00	6.7	-35.50	13.7
-72.50	.6	-60.00	2.7	-47.50	6.9	-35.00	14.1
-72.00	.6	-59.50	2.8	-47.00	7.0	-34.50	14.5
-71.50	.7	-59.00	3.0	-46.50	7.2	-34.00	14.9
-71.00	.7	-58.50	3.1	-46.00	7.4	-33.50	15.3
-70.50	.8	-58.00	3.2	-45.50	7.6	-33.00	15.7

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MAY 3 1976

SQUAMISH ESTUARY 1974 MODULE 1

* ELEVATION - CAPACITY TABLE *

ELEVATION (FT)	ACC. VOLUME (ACRE-FT)	ELEVATION (FT)	ACC. VOLUME (ACRE-FT)	ELEVATION (FT)	ACC. VOLUME (ACRE-FT)	ELEVATION (FT)	ACC. VOLUME (ACRE-FT)
-32.50	16.1	-20.00	32.6	-7.50	216.6		
-32.00	16.6	-19.50	33.5	-7.00	239.2		
-31.50	17.0	-19.00	34.5	-6.50	262.4		
-31.00	17.5	-18.50	35.5	-6.00	285.7		
-30.50	18.0	-18.00	36.5	-5.50	309.3		
-30.00	18.4	-17.50	37.5	-5.00	332.9		
-29.50	18.9	-17.00	38.6	-4.50	356.8		
-29.00	19.4	-16.50	39.7	-4.00	380.8		
-28.50	20.0	-16.00	40.9	-3.50	405.0		
-28.00	20.5	-15.50	42.0	-3.00	429.4		
-27.50	21.0	-15.00	43.2	-2.50	454.0		
-27.00	21.6	-14.50	44.6	-2.00	478.7		
-26.50	22.2	-14.00	46.1	-1.50	503.5		
-26.00	22.9	-13.50	48.0	-1.00	528.3		
-25.50	23.6	-13.00	50.8	-.50	553.3		
-25.00	24.3	-12.50	55.1	0.00	578.3		
-24.50	25.0	-12.00	61.3				
-24.00	25.8	-11.50	70.7				
-23.50	26.6	-11.00	83.8				
-23.00	27.4	-10.50	99.2				
-22.50	28.2	-10.00	115.9				
-22.00	29.0	-9.50	133.9				
-21.50	29.9	-9.00	153.1				
-21.00	30.7	-8.50	173.3				
-20.50	31.6	-8.00	194.6				

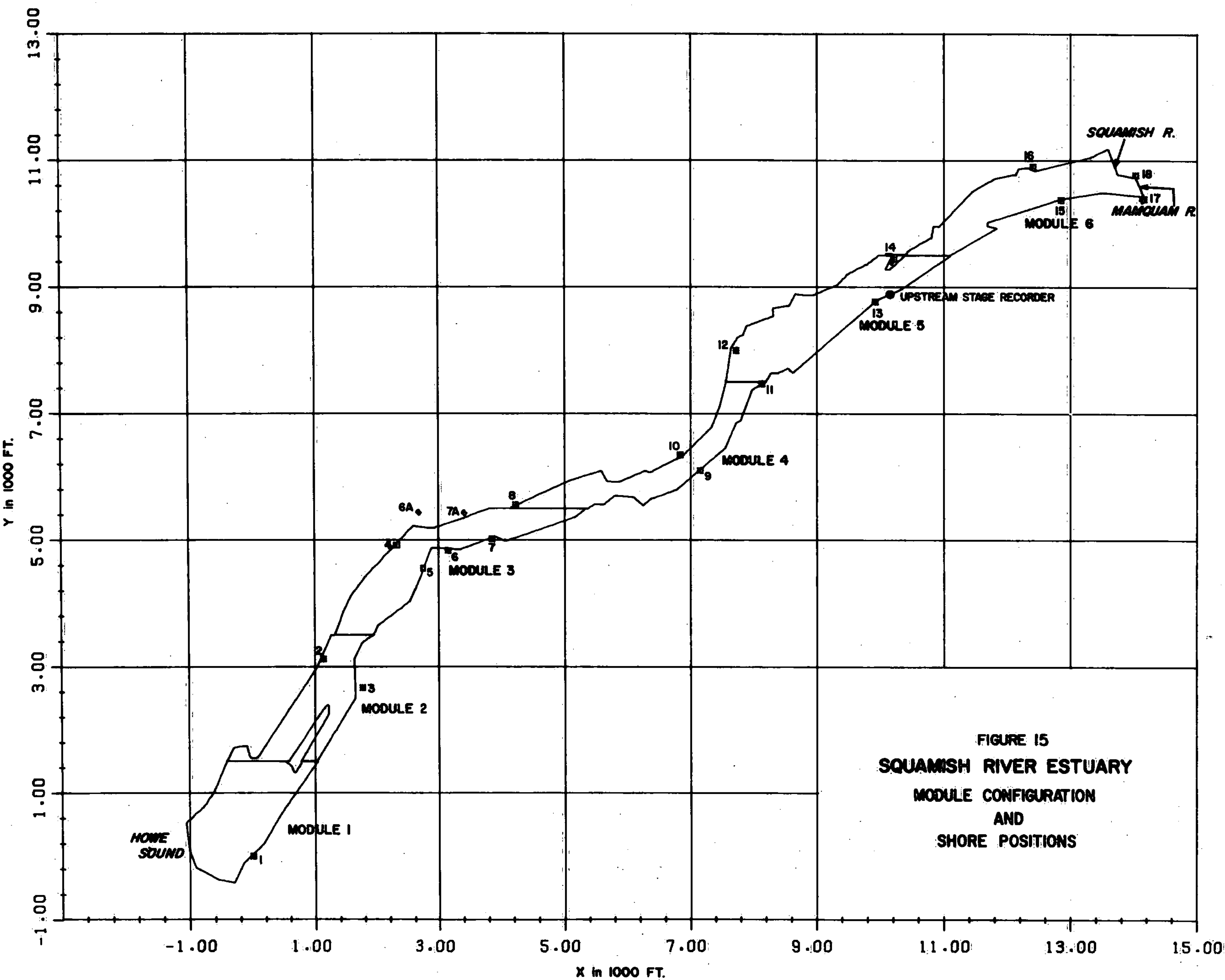


FIGURE 15
SQUAMISH RIVER ESTUARY
MODULE CONFIGURATION AND SHORE POSITIONS

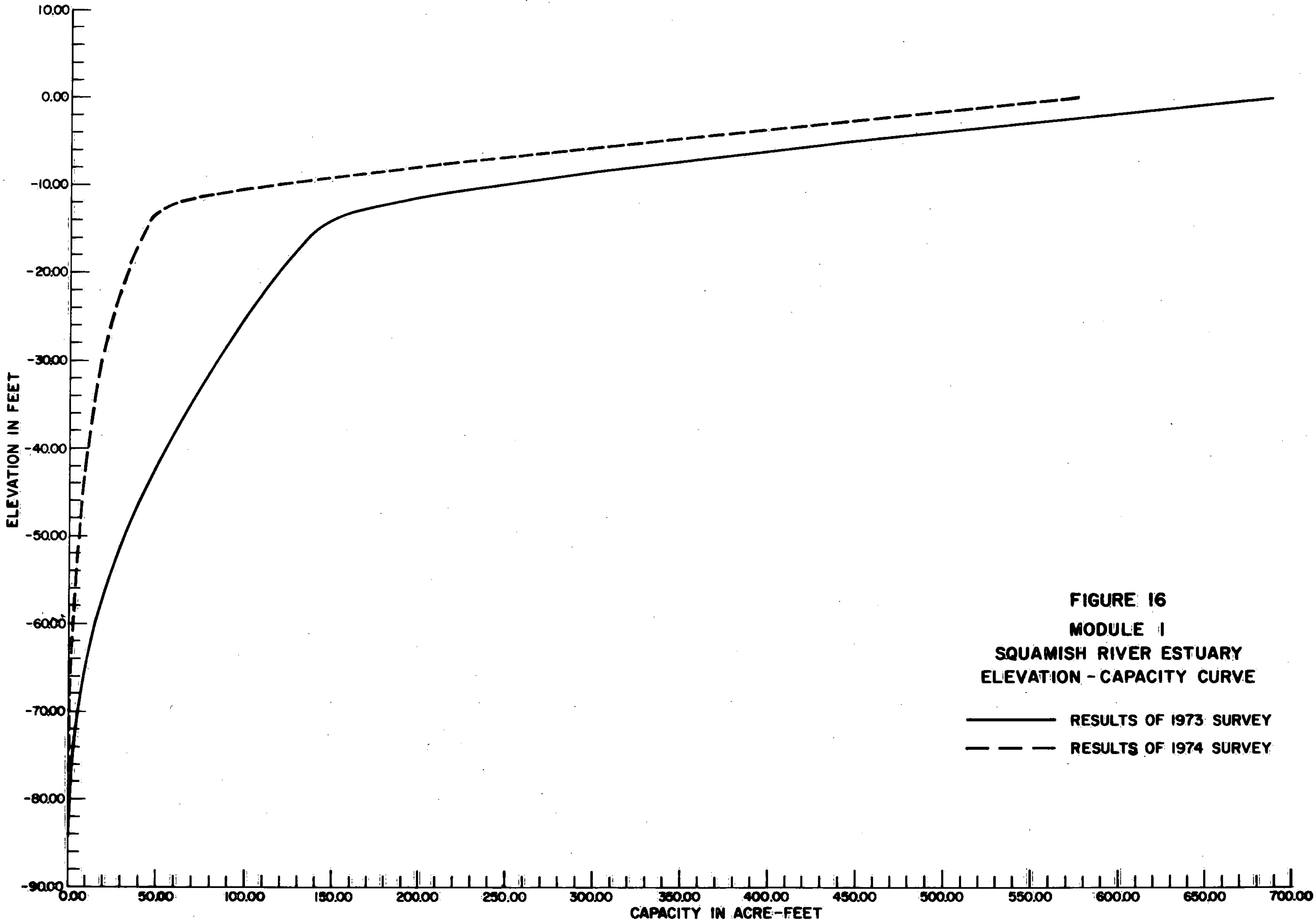


FIGURE 16
MODULE I
SQUAMISH RIVER ESTUARY
ELEVATION - CAPACITY CURVE

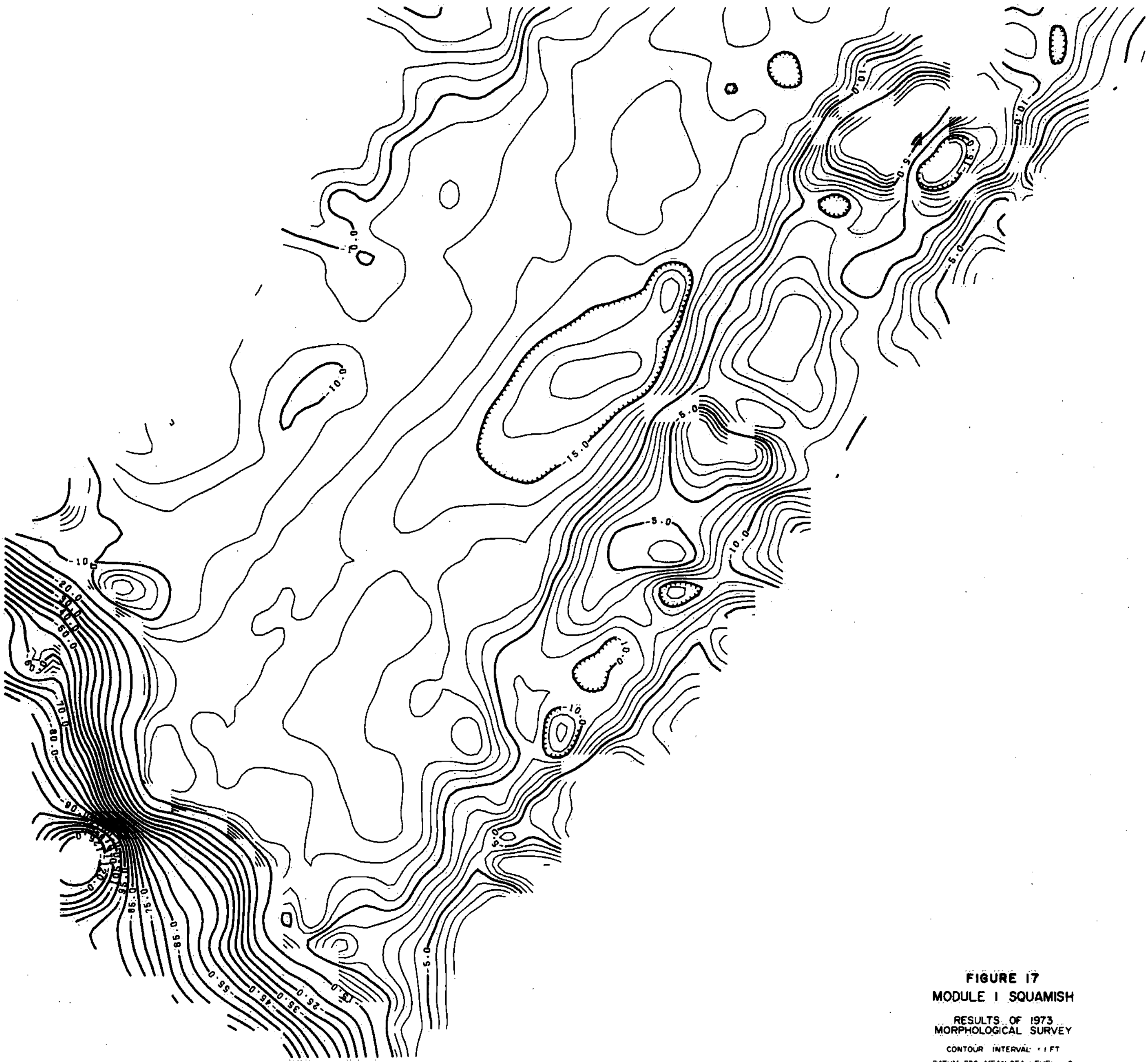


FIGURE 17
MODULE 1 SQUAMISH

RESULTS OF 1973
MORPHOLOGICAL SURVEY

CONTOUR INTERVAL = 1 FT
DATUM, GSC - MEAN SEA LEVEL = 0

100 50 0 100 200 300 400
SCALE IN FEET

FIGURE 18
MODULE 1 SQUAMISH

RESULTS OF 1974
MORPHOLOGICAL SURVEY

CONTOUR INTERVAL = 1 FT.
DATUM; GSC-MEAN SEA LEVEL = 0

100 50 0 100 200 300 400

SCALE IN FEET

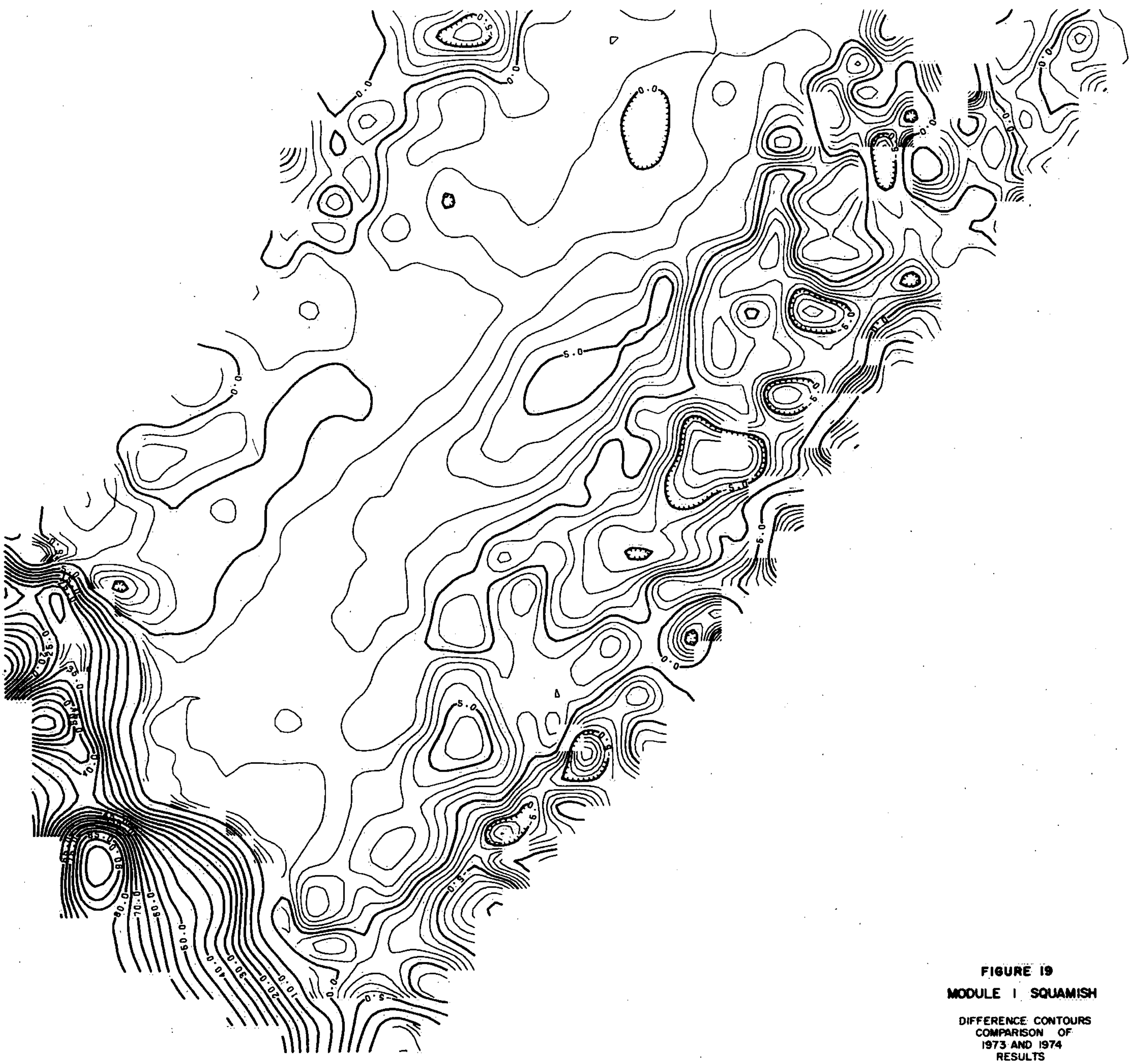


FIGURE 19

MODULE 1 SQUAMISH

DIFFERENCE CONTOURS
COMPARISON OF
1973 AND 1974
RESULTS

CONTOUR INTERVAL = 1 FT.

NOTE: NEGATIVE CONTOURS ARE EROSION
POSITIVE CONTOURS ARE DEPOSITION

0 50 100 150 200 FEET

HYDAC-100, the Sediment Survey Section has proceeded with the development of an updated hydrographic data acquisition system. The new system, the HYDAC-200, which will be operational in the near future, is illustrated schematically in Figure 20.

Bibliography

Calcomp (1971), A General Purpose Contouring Program, Users Manual (Revised 1973), Anaheim, California.

Hewlett-Packard Calculator Products Division, Operation Manuals for HP 9825A and HP 9872A, Ottawa, Ontario.

Krupp Atlas Elektronik (1969), Operation Manuals for Atlas DESO-10 and EDIG-10, Bremen, West Germany.

Marinav Corporation (1976), HYDAC-100 Autoplot Interface Technical Manual, Ottawa, Ontario.

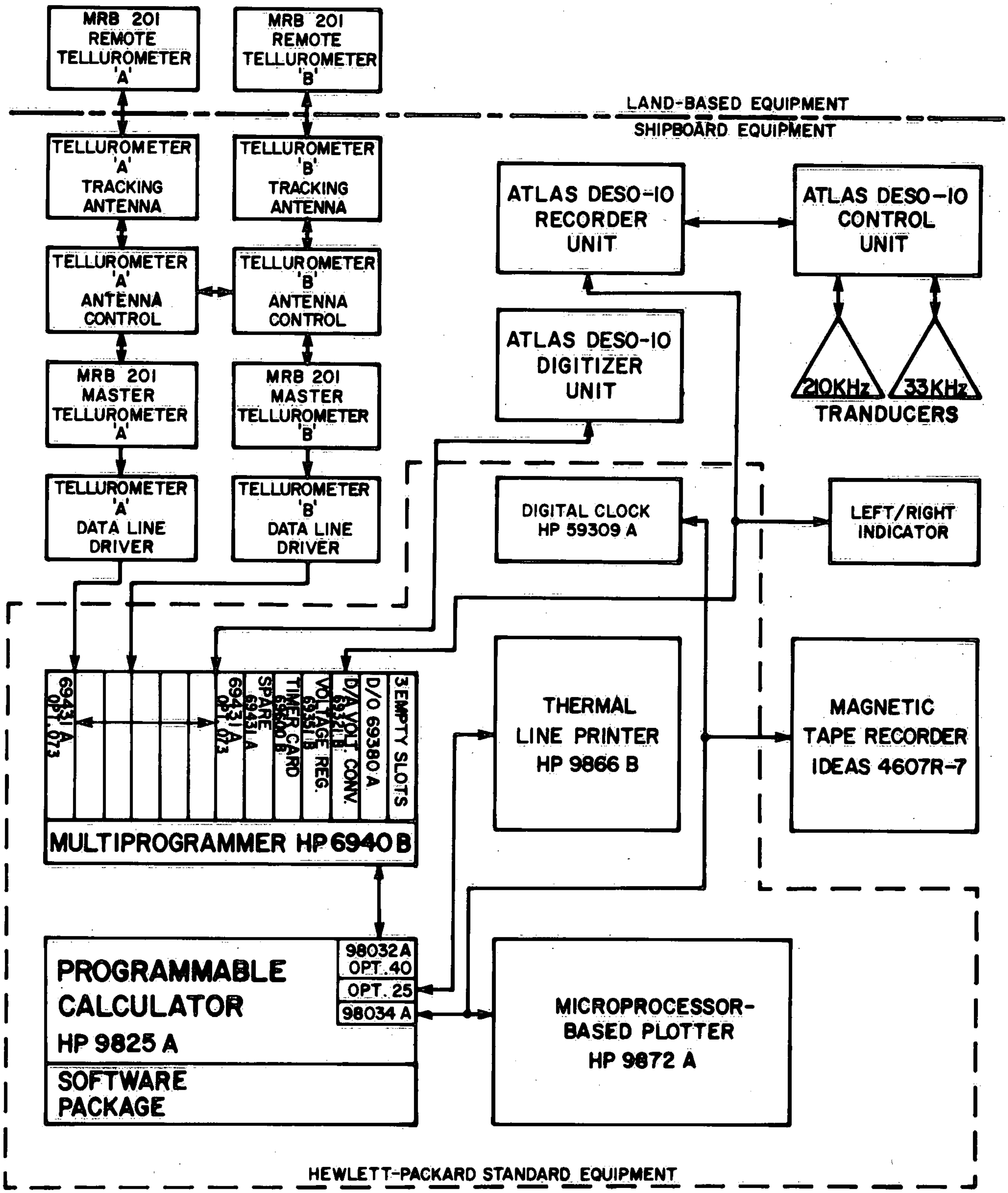
Marinav Corporation (Report No. 9873-1204/TR, July, 1976), Description of Software Programs for the HP 9825 Calculator Developed for Environment Canada, Ottawa, Ontario.

Marshall, A.G., Development of the MRB 201/301. Tellurometer Division of Plessey, Cape, South Africa.

Sediment Survey Section, Applied Hydrology Division, Water Resources Branch, Fisheries and Environment Canada, Progress Report (1974), Squamish River Estuary Morphological Survey, Ottawa, Ontario.

Tellurometer Division of Plessey, Operation Manual for MRB 201 and Tracking Antenna, Cape, South Africa.

Wiebe, K. and Brimley, W.A. (1978). A Bathymetric Survey of the Mira River. Paper Presented at the Atlantic Provinces Hydrotechnical Conference, February 12-14, 1978, Halifax, Nova Scotia.



HYDAC-200

A HYDROGRAPHIC DATA ACQUISITION SYSTEM

FIGURE 20