AN OUTLINE OF THE TELEMETRY SYSTEMS USED BY THE TIDES AND WATER LEVELS DEPARTMENT OF THE CANADIAN HYDROGRAPHIC SERVICE

by G. Dohler

ABSTRACT

For the last several years various telemetry systems have been employed by the Marine Sciences Directorate, Environment Canada, to transmit tide and water-level data.

Gauging stations along our coasts and in the Great Lakes - St. Lawrence River System have been equipped successfully with instruments to obtain real time data for better water management.

This paper describes in general terms, the four different systems presently in use, and gives an example of how the data are used in automated hydrographic surveying. Location and approximate capital and operating costs, as well as the man-years required to maintain, modify and to expand the facilities, are shown.

INTRODUCTION

Since the turn of the century, the demand in Canada for more accurate and more up-to-date information on water levels and currents along our coasts and in the Great Lakes - St. Lawrence River System has continued unabated.

Long periods of data records are essential in the design and construction of marine works; after construction, safe and economical navigation demands that real time water level data be constantly available to shipping. In cases where it was difficult to fix responsibility for shipping disasters, there has been a tendency to settle the blame on a lack of accurate information on tides, currents and water levels in the area.

Agencies set up to warn of natural disasters, such as flooding which endangers life and property, must be in possession of the data upon which they can make accurate forecasts and issue timely warnings.

Land elevations on topographical maps prepared by aerial photogrammetry are referenced to a certain tide stage, and hydrographic charts and soundings are based on a common vertical datum. With the growing emphasis on automated hydrography, real time tidal observations should be part of any modern survey.

There is in fact, no area of activity involving coastal zones, whether it be marine works, navigation, fisheries, recreation, or resource exploration and exploitation, in which real time data do not play an important part.

Because of the ever-changing tides, the process of sampling data for any of the purposes mentioned can be both complicated and time-consuming, and the data should therefore be available in computer applicable form at as early a stage in the process as possible.

THE DEVELOPMENT OF THE SYSTEMS

Instruments to measure water-level changes have been in use for over a century. Perhaps it is not wrong to say that these instruments have been the first scientific recording devices to document geophysical events. Types and models have changed throughout the years, but in principle, the system has remained the same, namely a pulley, activated by a float and counterweight, drawing the changing water level on chart paper at a convenient ratio.

The large-scale computerization of standard work routines has raised the question of whether existing procedures for measuring water-level changes and other hydraulic parameters can yield data in a form compatible with computer processing requirements. An added consideration is the fact that the electronic-age pressure transducer may be used to replace conventional float-operated devices with significant saving in cost.

Because of the convenience of operation which they offer, remote-controlled, unattended data-sampling stations are increasingly in demand. The special equipment in these stations is activated and data retrieved by a signal carried over any medium suitable for speech transmission, such as underground or submerged cables and overhead wires. Wireless communication facilities may be used where distances between remote stations and central control stations are considerable.

The method of transmission selected will depend on how the data are to be used by the requesting agencies, on the public requirement, on the standard of accuracy required, and on economic factors.

Data processing centres could process the data almost instantaneously, in a form suitable for analysis by user agencies, freeing personnel previously employed in this area for more productive work.

There is no doubt that data quality is important, but it is essential that a new emphasis be placed on acquiring large bodies of data and making this available to the users on a continuous basis or upon request.

And in achieving both speed and economy in building up substantial bodies of data, the equipment and methods of modern technology should be used to the best advantage.

For many years the Tides and Water Levels Section of Marine Sciences Directorate has been developing tide and water-level recording systems specially designed for telemetric applications. The data may be obtained on interrogation by simple telephone call over rented telephone line, or by using radio carrier techniques or telex facilities.

The development of these systems has kept abreast of the development of modern data-processing techniques and forms part of the overall program of the Section.

THE TONE-FREQUENCY SYSTEM (figure 1)

This system employs the frequency variation principle, since it is independent of input levels at the receiver side and permits a simultaneous transmission of several data on one channel.

Except for the radio frequency carrier, where some vacuum tubes are used, the device is completely transistorized.

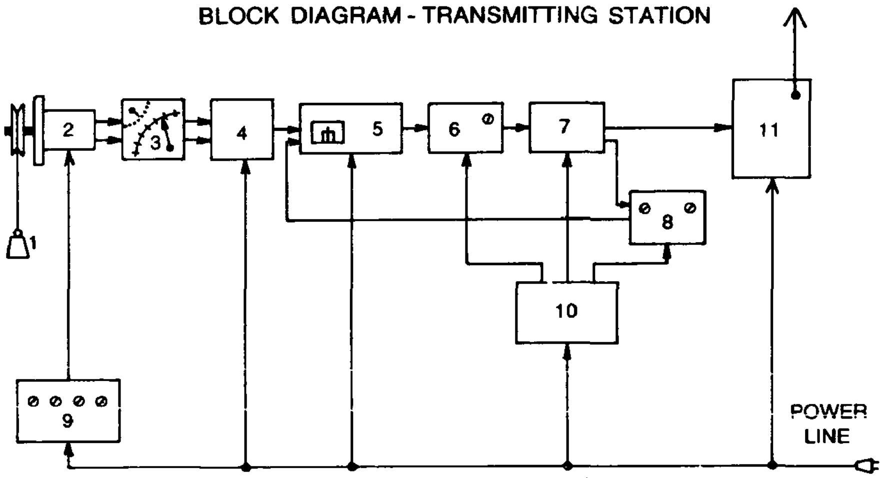
Method of Operation.

The frequency variation principle works as follows : a DC value is converted at the audio frequency transmitter into an AC value with a frequency which depends on the magnitude of the DC value. The total range to be measured, therefore, is transformed into a frequency range. This alternating current is then used for the transmission of data. The medium for transmission can be either a pair of metallic conductors or a radio frequency carrier which is modulated by the alternating current. At the receiving end, the signal is demodulated and a linear relationship between the frequency of the alternating current and the magnitude of the DC current is restored.

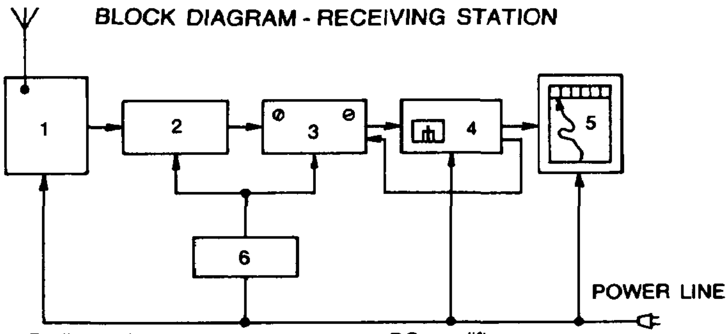
For transmitting the measuring data, a relatively broad frequency band is used. A broad band is used to keep the error in transformation from AC to DC at a minimum. The frequency band employed is narrow enough, however, to permit the use of several channels over the audio frequency range.

Transmitter Station.

The transmitter station consists of the originator, audio frequency transmitter, and radio frequency transmitter.



1. Float
2. Water level to current converter
3. Coarse and fine range current indicator
4. Time switch
5. Equalizing amplifier
6. Current to frequency converter
7. Audio frequency amplifier
8. Frequency to current converter
9. Current supply and calibration controls
10. 12V-Power supply
11. Radio transmitter



1. Radio receiver
2. Audio frequency amplifier
3. Frequency to DC converter
4. DC-amplifier
5. Strip chart recorder
6. 12V-Power supply

FIG. 1. — Tone-Frequency System.

Originator.

The originator consists of a mechanical measuring device which is directly coupled to a precise, sliding-brush potentiometer. Any change in the mechanically-measured value alters the position of the sliding-brush in the potentiometer. The potentiometer is part of a calibrated bridge circuit fed by a stabilized voltage supply. The varying electrical potential from the potentiometer is fed through the indicating instrument, causing a movement of the pointer in the instrument and a simultaneous change in audio frequency.

Audio Frequency Transmitter

The units of the frequency transmitter are shown in figure 1. It is the task of the tone frequency generator to transform the measured direct-current potential supplied by the Originator into an alternating current. A direct-current compensator acts as a control to maintain a smooth DC signal, regardless of the small fluctuations in the AC line voltage.

The direct-current signal voltage is fed to the coils of an oscillator circuit; the inductive value of the coils varies in relation to the direct-current applied. This change in inductive value causes a change in the oscillating frequency, which is in the audio range of alternating current.

However, the relationship between direct current and frequency is not linear, but by feedback from the compensator mentioned above linearity is substantially improved.

The audio frequency is fed through an amplifier to the input of the radio transmitter.

Radio Equipment.

Any transmitter and receiver may be used provided that the transmitter can be modulated with the respective audio channel, and has the power output necessary to cover the desired distance, and can operate continuously on a clear channel. The receiving equipment should be capable of delivering a minimum of 3 volts RMS undistorted audio output.

Receiver Station.

The receiver station consists of the radio frequency receiver and the audio frequency receiver and chart recorder.

Audio Frequency Receiver.

The incoming alternating voltage from the audio frequency receiver is amplified and passed to a DC converter which operates according to the method of inversely-charged condensers. In design, it corresponds exactly to the transmitter, except that it serves here for the evaluation of the incoming frequency.

The low-level DC voltage derived from the frequency fed to the DC converter is passed through a compensating amplifier to drive the recorder.

Construction of the audio frequency transmitter and receiver is such that each element performs only a certain function. Plug-in units performing the same functions at both the transmitter and receiver are interchangeable. The units are arranged on base plates with the inputs and outputs on a terminal board provided with jumpers to facilitate interchange.

THE PULSE-FREQUENCY SYSTEM (figure 2)

In earlier equipment, data were received in analog format only; new systems recently acquired provide digital recording at the transmitting station and an analog trace at the receiving side, plus additional devices if necessary. One requirement that has become evident is the provision for battery operation, particularly in the transmitting station, in case of power failure.

Transmission of the data is carried out according to the pulse-frequency system. In other words, the measured value will be transmitted according to a frequency power-time-unit dependency. At the sampling stations, a potentiometric transducer precedes the sound transmission and converts

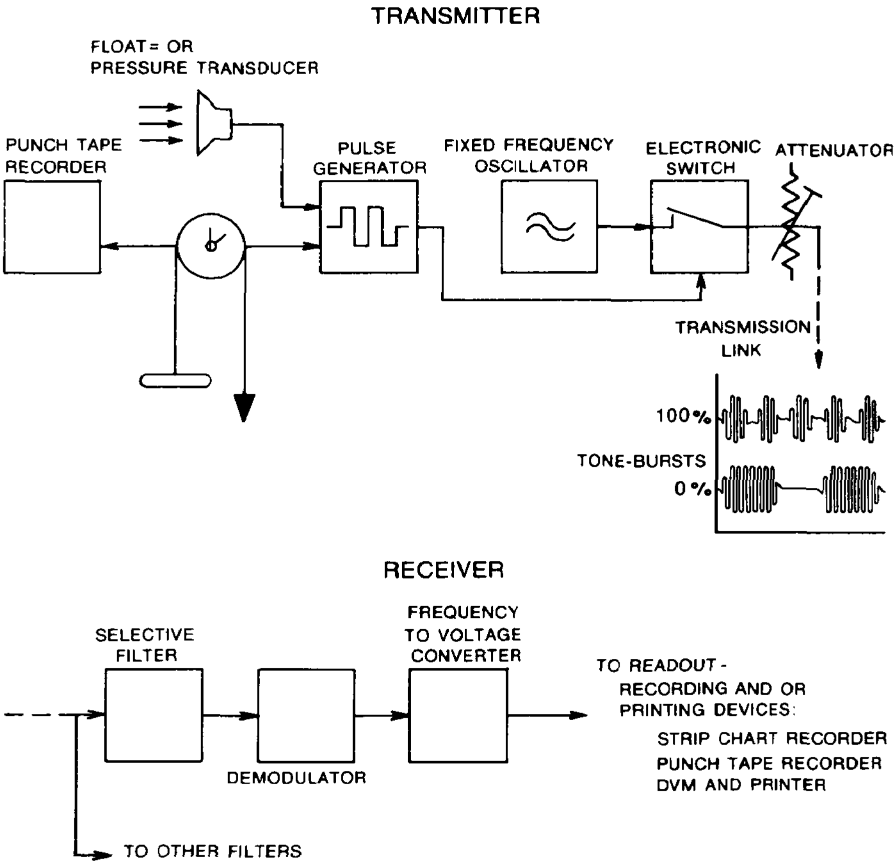


Fig. 2. — Pulse-Frequency System.

the resistance or voltage values into a pulse-frequency. This frequency continuously follows the changing measuring values in an envelope between 5 and 15 cycles per second. The measuring value 0% equals 5 cycles per second and the value 100% equals 15 cycles per second of the pulse-frequency.

At the central or receiving station, the modulated signal is transformed into DC pulses; a converter provides the necessary direct current to operate the recording or indicating equipment. The transmission error will not exceed 1.5% within a temperature range of −20 to +60 degrees centigrade. Twenty-four channels can be used for this type of data transmission because of the uniform oscillation pattern within these channels.

Range of Transmission.

With a cable of 0.8 mm in diameter, distances of up to 50 km can be covered with a high level of dependability without interference from neighbouring channels. Where greater distances are involved, the range may be increased by amplifiers.

Structure.

All functional units of the system are on plug-in printed circuit boards. A hermetically-sealed container protects the units from mechanical damage and proper contact is ensured by indirect plug-in devices. The operation of each unit is described on the front plate and the units are clamped to the cassette by a mechanical locking device. Uniformly-wired cassettes are available to contain the various units, thus allowing choice of layouts according to the job to be done.

Operation and Expansion.

The equipment can be operated without any complicated setting or equalization procedures. This has been made possible by the high degree of reliability of the electrical components. Testing cases are fitted to the front plates of the units to make it possible to test the characteristics and operational values by using simple metering devices. Checking can be carried out without feedback and the transmission is neither interrupted nor affected.

Expansion or conversion can be done without operational interruption and without altering the electrical values of the units. This applies also to replacements, whose changeability is guaranteed.

The punch paper tape recorder presents the measured values in four digits on an eight-level tape at regular intervals.

Radio Equipment.

Any transmitter and receiver may be used provided the transmitter can be modulated with the respective audio channel, and has the power output necessary to cover the desired distance and can operate continuously on a clear channel. The receiving equipment should be capable of delivering a minimum of 3 volts RMS undistorted audio output.

THE TELE-ANNOUNCING SYSTEM (figure 3)

The system consists of :

(a) A data transmitter mounted over a stilling well; analog data are converted into electrical digits by means of a device which incorporates a chain pulley and float.

(b) A memory unit which can store minimum or maximum water-level information and ten successive water levels.

(c) An announcing unit which, when addressed, announces the existing water level, the rising or falling tendency, the last high or low water or any of the other stored data.

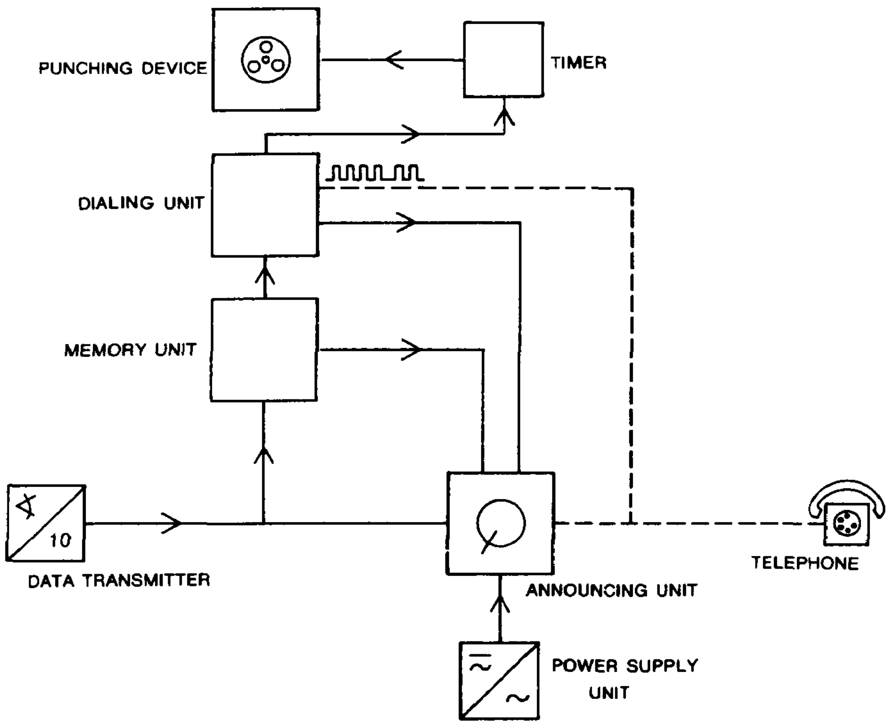


FIG. 3. — Tele-announcing system.

(d) A dialing unit which automatically calls a predetermined party in the event of an unusual water-level condition.

(e) A power supply to convert the 117-volt, 60-cycle line voltage into the voltages required by the operating parts of the unit.

The tele-announcer is installed in place of an ordinary telephone set and addressed by dialing the number of the telephone line. The ringing current activates a relay which closes the DC line and initiates the internal sequence of operation. Upon completion of this sequence, the unit disconnects itself and is then ready for another telephone call.

In the case of an unusual water-level change, the dialing unit produces a series of pulses corresponding to a codified call number and switches on the tele-announcer. All necessary information is stored in a magnetic disk on a number of separate tracks. These tracks contain station identification, numerals, tendency, and end-of-announcement track. A sequential switching arrangement provides the right order of tracks to be played back. Sequence of numerals in the instantaneous water-level announcement is determined by the position of the digitizer in the data transmitter. The sequence of numerals of the stored data is determined by the memory relays in the memory unit.

On receiving a call, in the event of an unusual water-level change, an Ott Punch Paper Tape Recorder is activated to store over a pre-set time period, water-level changes at one-minute intervals. This data is available immediately or shortly after the event to the authorities concerned. The punch paper tape is laid out in such a way that telex facilities can be used.

THE DATA TELEX SYSTEM (figure 4)

The Data Telex Network is used to collect data from gauge stations.

Gauge stations are equipped with a Hagenuk water-level recorder which incorporates a tape punch using the 8-level ASCII code. Readings can be recorded on the tape at one hour or at 15-minute intervals.

When the accumulated data are required at the data centre, a signal is generated from the data centre which will start the "tape feedout" from the recorder.

The tape punch and the transmitter are separated by approximately fifteen inches. In order to get all the data on the punched tape, it is necessary to "feed out" this fifteen inches of accumulated tape. The process will take about six minutes. A second call is then generated with a special code which will start the transmitter sending the accumulated data from the gauge house.

An 8-level punch (carriage return) is automatically inserted after each 24-hour operation by the Hagenuk recorder. This 8-level punch will automatically stop the transmitter.

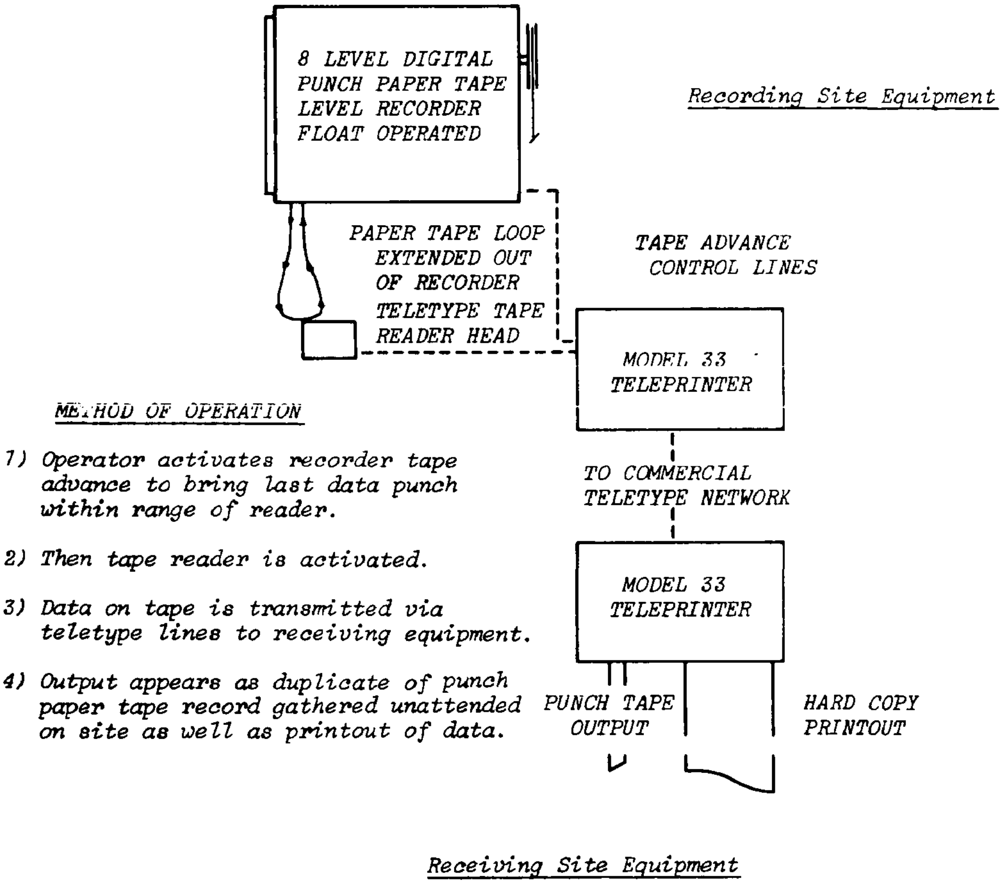


FIG. 4. — Telex system.

By assembling a special extension cable harness, the Model Telex 33 transmitter will be located on a special bracket under the Hagenuk recorder, remote from the Model 33 teleprinter.

Connected to a time-sharing computer, this system provides relatively low-cost, real time data acquisition, data storage, computation and formatting. A terminal at Tides and Water Levels in Ottawa, and a PDP 10 computer in Toronto are in use. Other agencies can now access the PDP 10 at any time for up-to-date water-level reports.

EXAMPLE OF REAL TIME DATA APPLICATION

The Data Telex system has been employed for the last two years to assist hydrographic parties in the reduction of soundings along the St. Lawrence River (figure 4).

Sounding Reduction (General).

If chart soundings are to be shown within the 20-metre contour to a fraction of a metre, then the reduction procedures employed by hydrographic services, with respect to water-level changes, should reflect this standard of accuracy. The ideal reduction factor at the sounding location should provide identical information on the depth, regardless of the gauging station (within a reasonable distance) from which the observed water level was obtained.

The water level in an area can be estimated from the observed water level by means of the following linear equation (KU, 1970) :

$$y(t) = \int g(\tau) \, . \, x(t - \tau) \, d\tau$$

where $y(t)$ and $x(t)$ are the water level for the sounding area and from the gauging station respectively, $g(\tau)$ is a weighting factor.

The degree of complexity of the expression for $g(\tau)$ depends on the distance, the tidal characteristics of the area, and the required accuracy of the estimation.

Because of the fairly uniform tidal response in most areas, the equation can be simplified as :

$$y(t) = \mathrm{R}\, x(t - \tau)$$

where R is an amplification factor, and τ is a time lag. These parameters can be estimated using co-tidal charts and reduction tables.

A co-tidal chart may consist of equal time lines and and equal range lines of the tide, or equal phase lines and equal amplitude lines of a specific tidal constituent. Charts and reduction tables are constructed from the tidal response of the basin, obtained from numerical computation, or from analysis of observed data and a knowledge of the tidal propagation.

Sounding Reduction, using Temporary Gauges.

Normally during a survey, temporary gauges are installed, and the records obtained are then used to determine the reduction manually by using the gauge data directly as recorded or modified and in conjunction with co-tidal charts. To maintain temporary gauges in satisfactory operating condition throughout the sounding operation presents several problems, and manual computation of the reduction is cumbersome and time-consuming.

Sounding Reduction, using a Permanent Gauge.

During the development of a system to automate the gathering and processing of hydrographic survey data by the Canadian Hydrographic

Service, the sounding reduction process can be incorporated into the system. The reduction factors within the area of sounding will be computed from real time gauge data at permanent stations and supplied in a computer-compatible format, such as punch cards, punch paper tape or magnetic tape for further computer application (See figure 5).

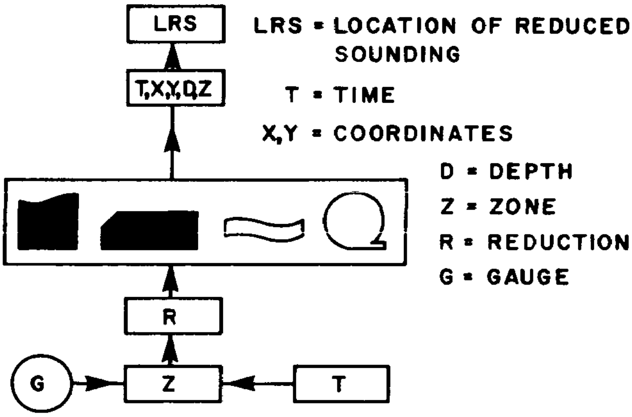


FIG. 5

A computer programme developed by the Tides and Water Levels Section is now available to carry out all computations and prepare the required data reports. (See figures 6 and 7 respectively).

It may be noticed in figure 7 that the largest reduction factor, depending on a falling (F) or rising (R) tide is always selected. The field sheet or sounding-data bank must contain certain identification, such as dates, times, *x* and *y* coordinates, and perhaps zones of the tidal propagation relative to the gauges being used. (See figure 8).

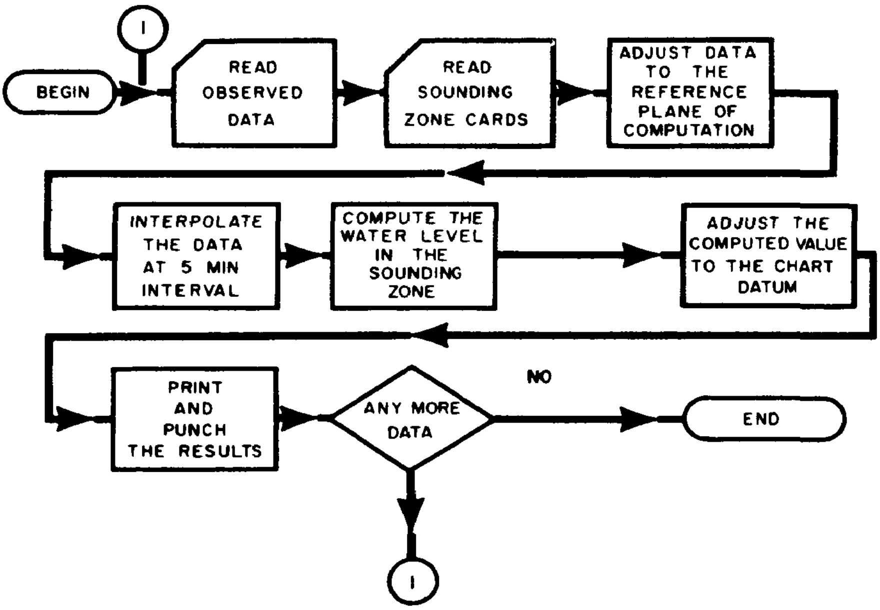


FIG. 6. — Sounding Reduction Program.

ZONE....	1	2	3			1	2	3	
LEVEL FT.	HR.:MIN.	HR.:MIN.	HR.:MIN.		LEVEL FT.	HR.:MIN.	HR.:MIN.	HR.:MIN.	
10.50					3.5C				
11.50	00:15	00:10	00:25		3.00				
12.00					3.50				
11.50					4.00				
11.00	00:30	00:20	00:40		4.50	06:05	05:35	06:15	
10.50	00:40	00:35	00:50		5.00	06:30	06:10	06:40	
10.00	00:55	00:50	01:05		5.50	06:45	06:35	06:55	
9.50	01:10	01:05	01:20		6.00	07:00	06:50	07:10	
9.00	01:20	01:20	01:30		6.50	07:15	07:05	07:25	
8.50	01:35	01:35	01:45		7.00	07:25	07:20	07:35	
8.00	01:50	01:50	02:00		7.50	07:40	07:35	07:50	R
7.50	02:05	02:05	02:15		8.00 ←	07:50	07:50	08:00	
7.00 ←	02:15	02:20	02:25		8.50	08:05	08:05	08:15	
6.50	02:30	02:40	02:40	F	9.00	08:20	08:20	08:30	
6.00	02:45	02:50	02:55		9.50	08:35	08:40	08:45	
5.50	03:00	03:10	03:10		10.00	08:50	09:00	09:00	
5.00	03:15	03:30	03:25		10.50	09:10	09:20	09:20	
4.50	03:40	04:05	03:50		11.00	09.35	09:55	09.45	
4.00	05:30	04:40	05:40		11.50	10:15	10:50	10:25	

FIG. 7

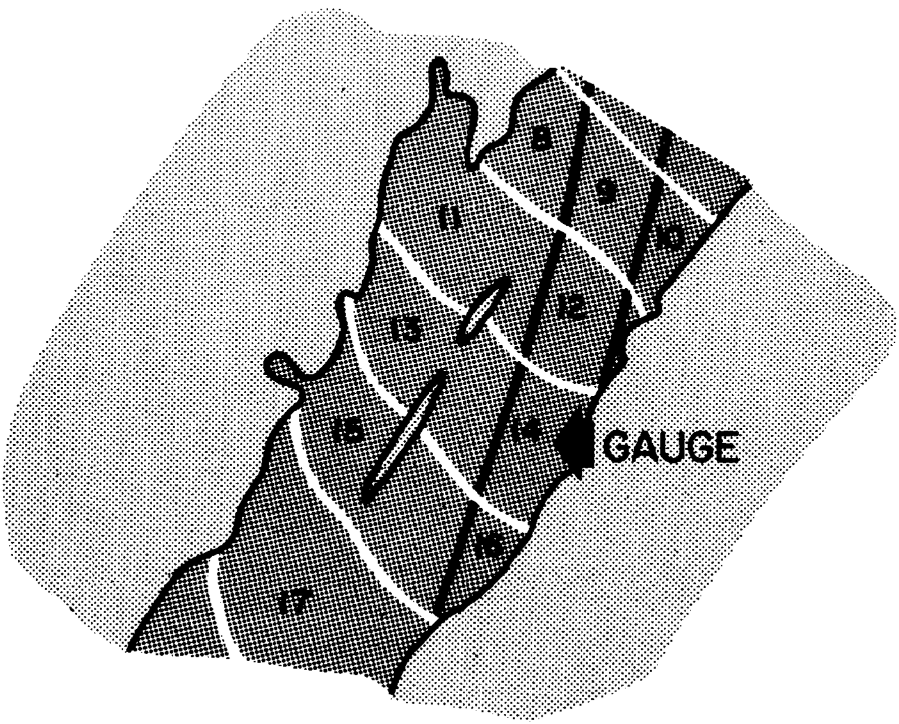
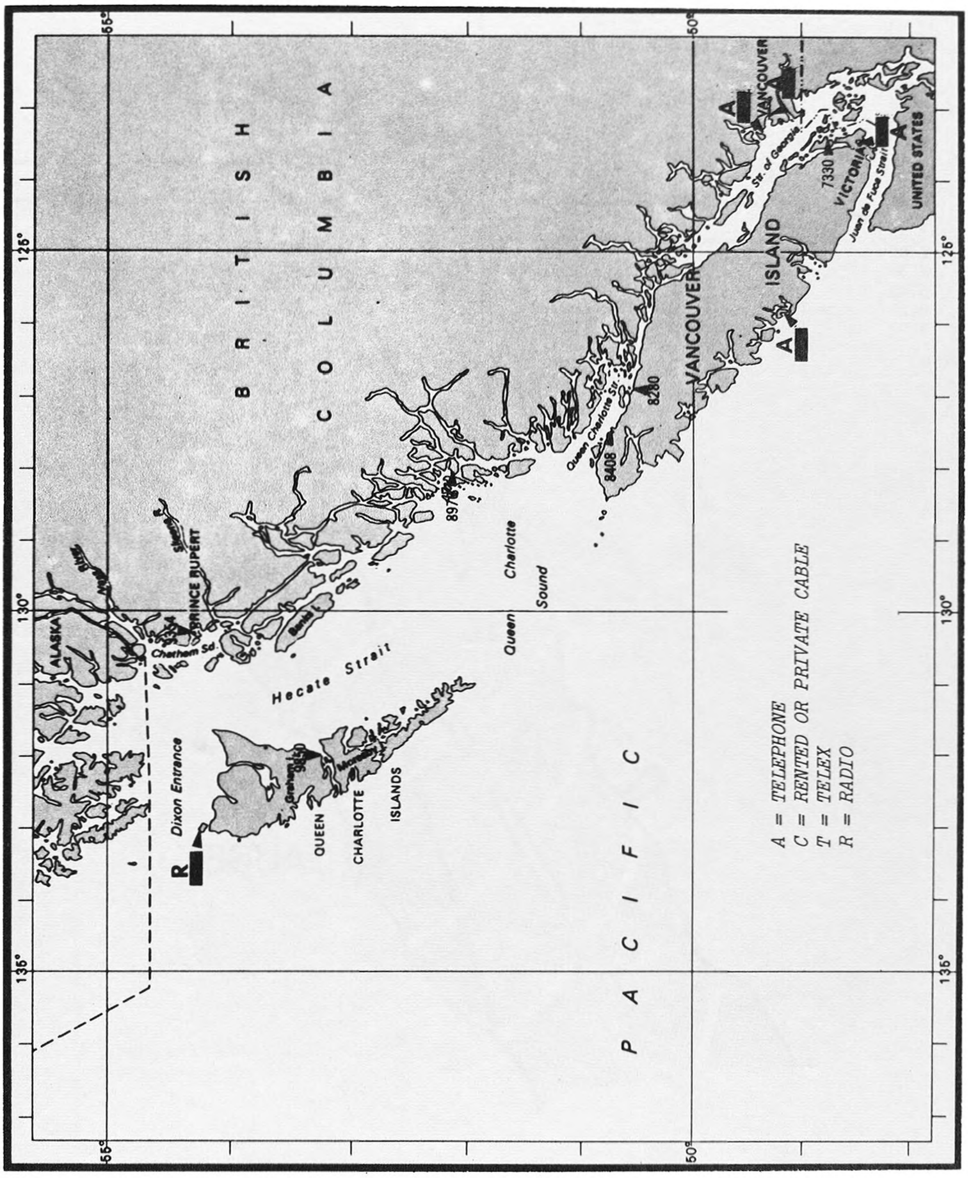


FIG. 8

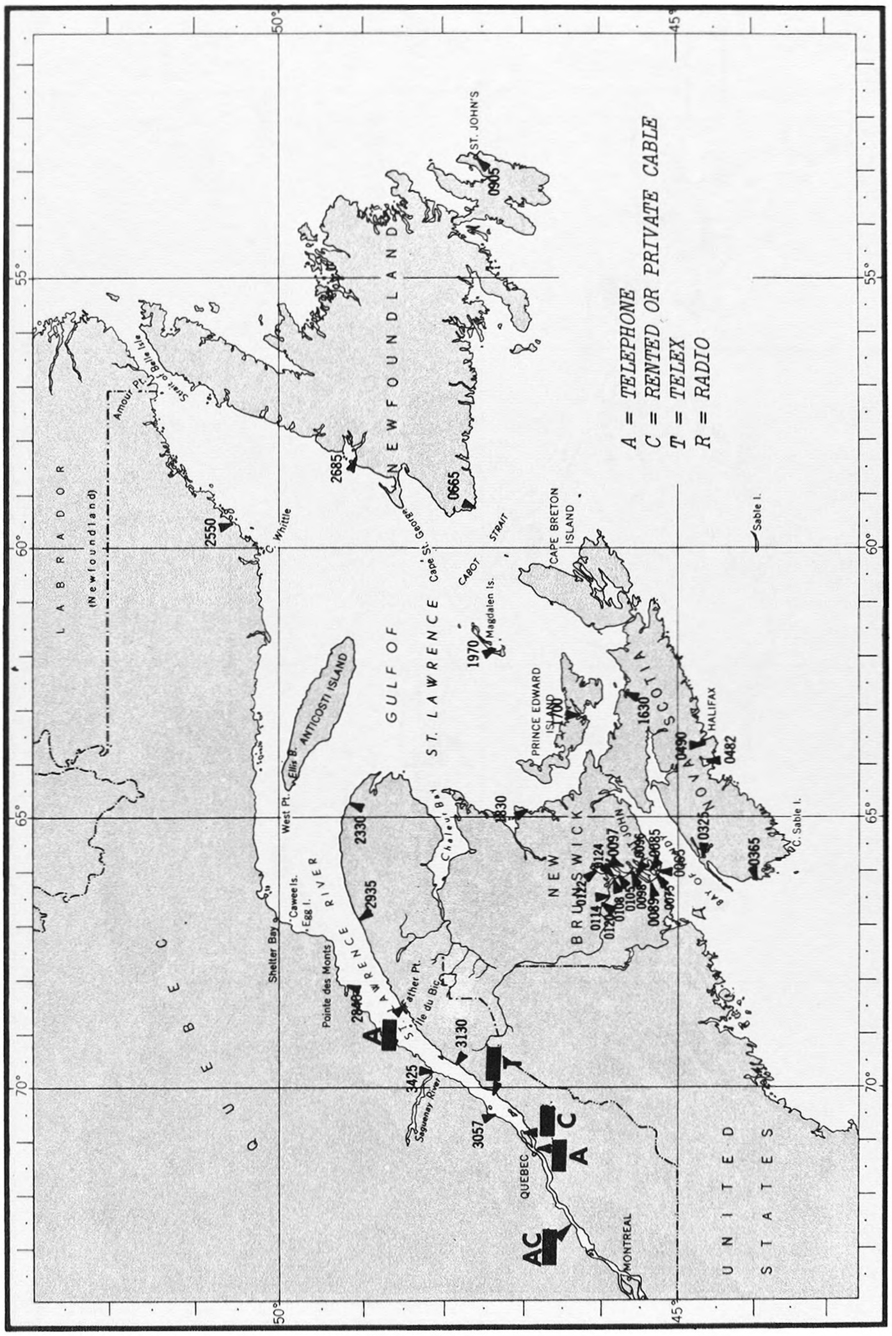
There is no doubt that the use of the aforementioned method will enhance the accuracy of soundings carried out in shallow waters.

Some hydrographic offices use their automated sounding procedures to read predicted tidal heights rather than the observed values. While such a procedure may be applicable for soundings at greater depths, a real



BRITISH COLUMBIA
ALASKA
PRINCE RUPERT
Chatham Sd.
Dixon Entrance
Hecate Strait
QUEEN CHARLOTTE ISLANDS
Queen Charlotte Sound
Queen Charlotte St.
VANCOUVER ISLAND
VANCOUVER
VICTORIA
Str. of Georgia
Juan de Fuca Strait
UNITED STATES
P A C I F I C
A = TELEPHONE
C = RENTED OR PRIVATE CABLE
T = TELEX
R = RADIO
8408
8260
7330
55°
50°
125°
130°
135°

Fig. 9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T = TELEX
R = RADIO
LABRADOR
(Newfoundland)
QUEBEC
NEWFOUNDLAND
GULF OF ST. LAWRENCE
ANTICOSTI ISLAND
CABOT STRAIT
CAPE BRETON ISLAND
PRINCE EDWARD ISLAND
NEW BRUNSWICK
NOVA SCOTIA
UNITED STATES
ST. JOHN'S
HALIFAX
QUEBEC
MONTREAL
Sable I.
C. Sable I.
Magdalen Is.
Cape St. George
C. Whittle
Strait of Belle Isle
Amour Pt.
West Pt.
Ellis B.
Shelter Bay
Pointe des Monts
Cawee Is.
Egg I.
Saguenay River
Chaleur Bay
BAY OF FUNDY
2550
2685
0665
0905
1970
1700
1630
0490
0482
0325
0365
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2840
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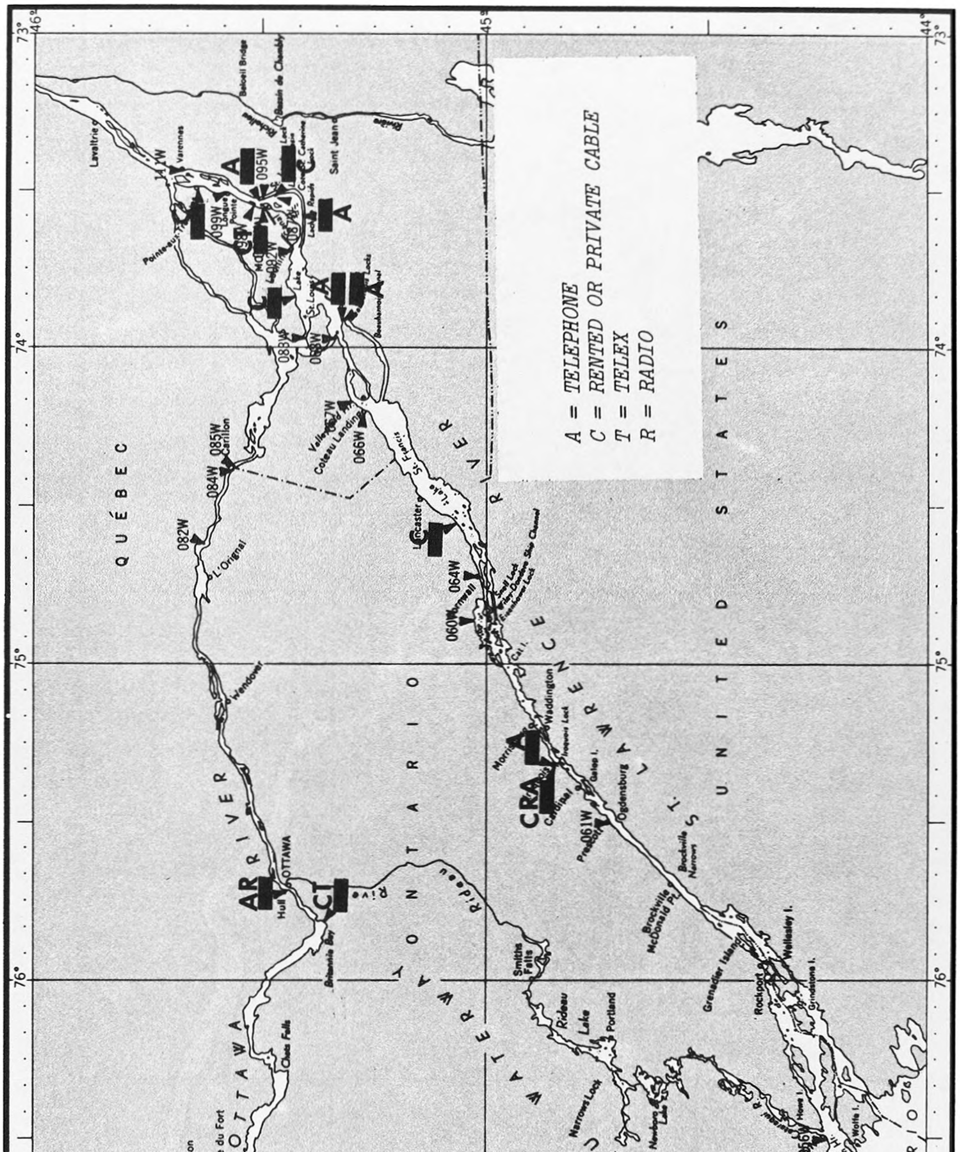
60°
65°
70°
45°

Fig. 10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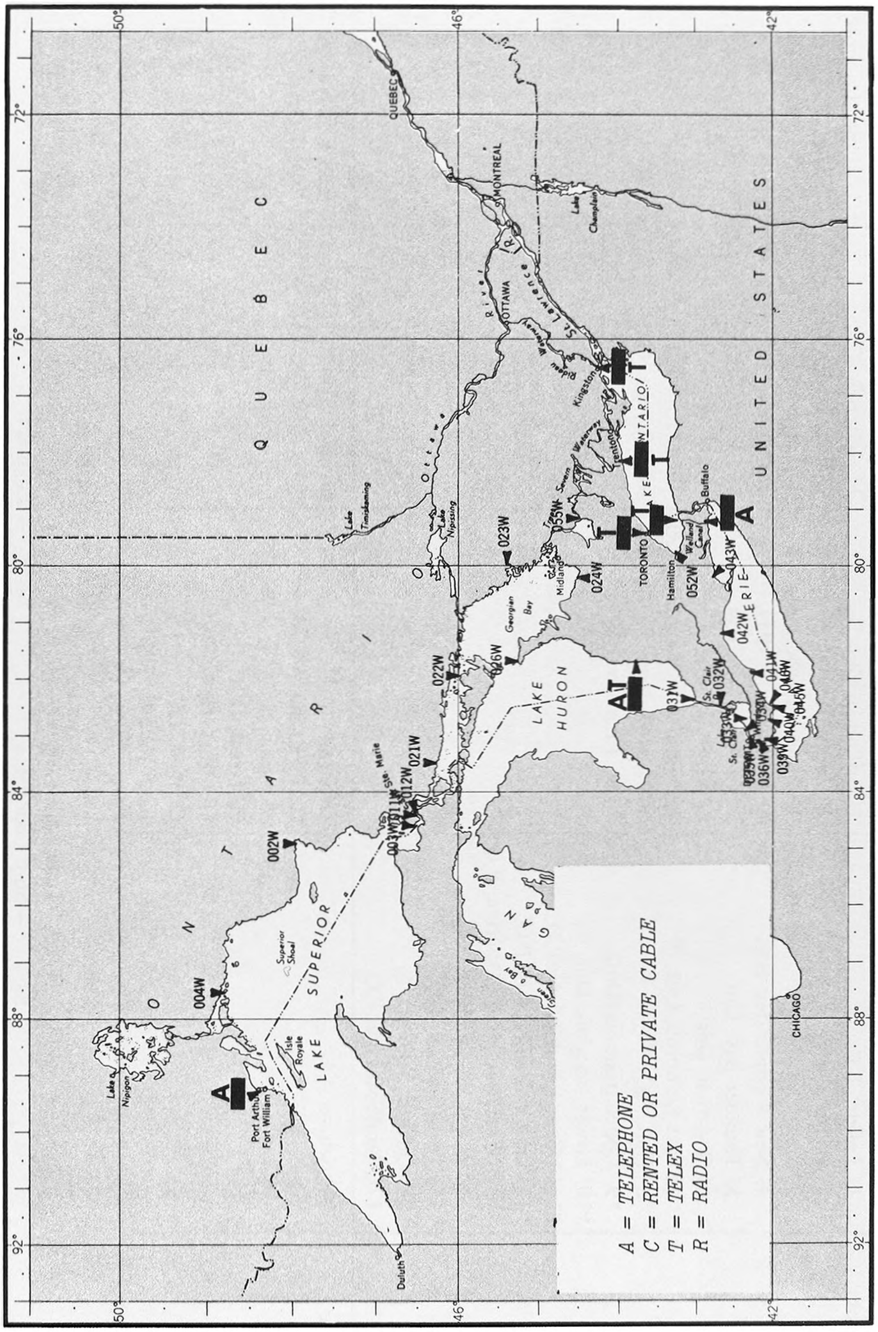
C = RENTED OR PRIVATE CABLE
T = TELEX
R = RADIO
QUÉBEC
ONTARIO
UNITED STATES
OTTAWA RIVER
ST. LAWRENCE RIVER
RIDEAU WATERWAY
L. ONTARIO

FIG. 11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R = RADIO
QUEBEC
ONTARIO
UNITED STATES
MONTREAL
OTTAWA
TORONTO
Kingston
Hamilton
Buffalo
Midland
CHICAGO
Duluth
Port Arthur
Fort William
LAKE SUPERIOR
LAKE HURON
Georgian Bay
Lake Nipissing
Lake Timiskaming
Lake Nipigon
Lake Champlain
Isle Royale
Superior Shoal
Welland Canal
Ste. Marie
Trenton
St. Clair
004W
002W
003W
011W
012W
021W
022W
023W
024W
026W
031W
032W
042W
043W
052W
055W

Fig. 12

Tides and Water Level – Data Telemetry

Basic data transmission via	Automatic announcing	Rented or private wire	Telex	Radio
From	1/ Tofino, B.C. 2/ Victoria, B.C. 3/ Steveston, B.C. 4/ New Westminster, B.C. 5/ Thunder Bay, Ont. 6/ Goderich, Ont. 7/ Port Colborne, Ont. 8/ Hull, P.Q. *9/ Upper Iroquois, Ont. *10/ Lower Iroquois, Ont. *11/ Upper Beauharnois, P.Q. *12/ Lower Beauharnois, P.Q. *13/ Upper Cote Ste. Catherine, P.Q. *14/ Lower St. Lambert, P.Q. 15/ Trois-Rivières, P.Q. 16/ Quebec, P.Q. 17/ Pointe-au-Pere, P.Q.	1/ Britannia, Ont. 2/ Upper Iroquois, Ont. 3/ Summerstown, Ont. 4/ Pointe Claire, P.Q. 5/ Ice Structure, P.Q. 6/ K.E.P. Montreal, P.Q. 7/ Pointe Aux Trembles, P.Q. 8/ Trois-Rivières, P.Q. 9/ St. Francois, P.Q.	1/ Goderich, Ont. 2/ Port Weller, Ont. 3/ Toronto, Ont. 4/ Cobourg, Ont. 5/ Kingston, Ont. 6/ K.E.P. Montreal, P.Q. 7/ St. Jean Port Joli, P.Q. 8/ Britannia, Ont.	1/ Upper Iroquois, Ont. 2/ Hull, P.Q. *3/ Langara, B.C.
To	Anywhere	Ottawa, T.W.L. 1 Cornwall, S.C. 2 3 Montreal, S.C. 4 5 6 7 Montreal, H.B. 5 Montreal, H.M. 5 Quebec, T.C. 8 9 Ice Structure, ENG. 5	Ottawa, T.W.L.	Ottawa, T.W.L. 1 2 Prince Rupert 3

Legend

T.W.L. – Tides and Water Levels
S.C. – Ship Channel
H.B. – Harbour Board
H.M. – Harbour Master
T.C. – Traffic Control
ENG. – Engineer
* Requested

FIG. 13

time access to observations for surveying in shallow waters is a necessity for future automated hydrographic surveys.

LOCATION AND COST

The location of key gauging stations in Canada for which data telemetry is now in existence or has been proposed are shown in figures 9, 10, 11 and 12. Figure 13 is a list of these stations, showing locations, transmitting facilities available, and the points in Canada at which the data transmissions may be received. Detailed costs in Canadian dollars and the necessary technical man-years required to maintain the system are shown in figure 14.

Tides and Water Level – Data Telemetry

	Automatic Announcing	Rented or private wire	Telex	Radio	Total
Capital cost					
Instruments	68 000	27 000	16 000	18 000	129 000
Accessories		1 800	800	6 000	8 600
Operating cost					
Rental	2 040	8 640	7 680	-	18 360
Installation & Maintenance	5 100	2 700	2 400	900	11 100
Man years					
Installation & Maintenance	0.6	0.4	0.5	0.2	1.7
Salaries	7 200	4 800	6 000	2 400	20 400

Fig. 14

The system has been operational in stages since 1960, and has proven to be of great value to ships, traffic control boards, engineers and the Canadian maritime public.

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