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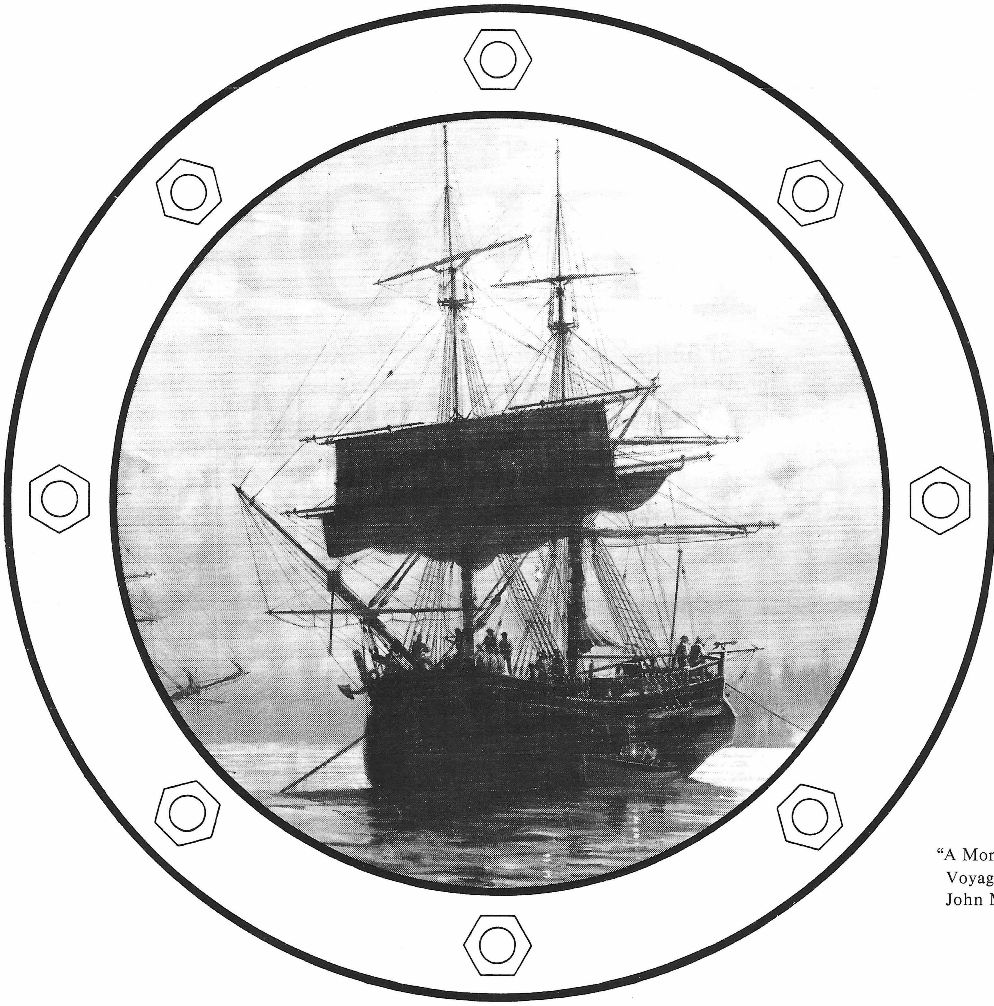

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Simplified Tidal Analysis and Prediction

by
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INTRODUCTION

Tidal analysis and prediction appears to be a very complicated process involving the apparent motions of the moon, sun and planets, and the rotation of the earth. Indeed, the mathematics relating the gravitational attractions of these bodies to the movement of the tides can be quite complex. However, for routine tidal analysis and prediction it is not necessary to know the derivations of most of the mathematical expressions and constants and, if one is prepared to accept a number of pre-calculated constants, both analysis and prediction can easily be done on a small personal computer or pocket calculator. In this paper a very simplified description of tidal analysis and prediction is given along with three BASIC computer programs. The programs will give results that are accurate to a few decimetres in height and a few tens of minutes in time most of the time and for most stations. However, they are NOT as accurate as and are NOT intended as a substitute for the Tide and Current Tables and should not be used for any purpose other than to learn more about the subject.

In its simplest form the tide can be visualized as the sum of a number of cosine waves with different phases, amplitudes and periods. The formula for predicting the tide level "y" at any given time "t_i" is:

$$y(t_i)=Z_o+\sum_{j=1}^{M} a_j \cdot f_j \cdot \cos(2\pi(\sigma_j \cdot t_i + V_j - g_j)) \quad (1)$$

where Z_o is the mean water level above the tidal datum and a_j and g_j are the tidal constituent amplitudes and phase lags. The constants Z_o, a_j and g_j are obtained from a tidal analysis of a series of tidal height observations at a particular site. For the moment, they should be treated simply as a set of numbers that describe the tides at a site.

The constants f_j and V_j are called the astronomical arguments and are different for each constituent j; f_j are factors varying with a cycle of 18.6 years that can be considered as constant during any given year. V_j (usually written as "$V_j + u_j$" in tidal literature) are phase angles that reference the cosine argument to a universal time and space origin. σ_j are the constituent frequencies.

Up to sixty constituents are often used for the Canadian Tide and Current Tables High and Low water predictions. However, sufficient accuracy for most practical purposes can be obtained by using only the 11 constituents listed in Table 1.

Symbol	Description	Frequency (degrees/hour)
Z_o	elevation of mean sea level above Chart Datum	
O_1	principal lunar declinational diurnal constituent	13.94303558
P_1	principal solar declinational diurnal constituent	14.95893136
K_1	combination of lunar and solar declinational diurnal constituents	15.04106863
μ_2	smaller lunar elliptic constituent	27.96820848
N_2	larger lunar elliptic semi-diurnal constituent	28.43972957
M_2	principal lunar semi-diurnal constituent	28.98410425
S_2	principal solar semi-diurnal constituent	30.00000000
K_2	combination of lunar and solar declinational semi-diurnal constituent	30.08213726
M_4	shallow water constituent	57.96820850
MS_4	shallow water constituent	58.98410424

Table 1: Tidal Constituent Descriptions

Tidal constituents are grouped, as described by the subscripts, according to the number of tidal cycles they tend to generate per day. They are also grouped according to their principal cause; constituents with letters near M have a primarily lunar origin while those near the letter S have a solar origin. Chart Datum is a low water level to which tide table predictions and depths on nautical charts are referred. It is always below the National Geodetic Vertical Datum (which is a mean water level datum) in tidal waters but usually above the NGVD on inland waters such as the Great Lakes. For further details see Forrester(1983).

The following two tables list the values of f_j and V_j for the above constituents for the period 1985 to 1999.

Year	O_1	K_1	M_2, N_2 μ_2, MS_4	K_2	M_4
1985	1.140	1.086	0.974	1.226	0.949
1986	1.168	1.104	0.967	1.285	0.935
1987	1.182	1.112	0.964	1.315	0.928
1988	1.180	1.111	0.964	1.310	0.930
1989	1.161	1.100	0.969	1.270	0.939
1990	1.128	1.079	0.977	1.203	0.955
1991	1.081	1.051	0.988	1.115	0.976
1992	1.024	1.015	1.000	1.016	1.000
1993	0.960	0.976	1.013	0.922	1.025
1994	0.897	0.937	1.024	0.842	1.048
1995	0.844	0.905	1.032	0.785	1.065
1996	0.812	0.886	1.037	0.754	1.075
1997	0.808	0.883	1.038	0.750	1.076
1998	0.832	0.897	1.034	0.772	1.069
1999	0.879	0.926	1.027	0.821	1.054

Table 2: Astronomical factors f_j for 1 January of each year. (S_2 and P_1 are always 1.000)

Year	O_1	K_1	μ_2	N_2	M_2 MS_4	K_2	M_4
1985	134	005	275	298	137	189	274
1986	233	007	117	311	238	194	116
1987	331	009	319	324	340	198	319
1988	069	012	162	336	081	203	162
1989	142	015	315	312	158	210	316
1990	240	017	157	324	259	214	159
1991	339	018	359	337	001	217	001
1992	079	019	200	349	101	218	203
1993	154	019	353	323	178	218	355
1994	256	018	194	335	278	215	196
1995	000	016	035	349	018	210	036
1996	105	012	236	358	118	204	237
1997	185	010	028	332	194	199	028
1998	290	006	229	083	294	193	228
1999	035	003	070	354	034	187	068

Table 3: Astronomical arguments V_j for 0000 1 January each year. (S_2 is always 000, P_1 is always 350)

TIDE PREDICTION

As described in the introduction the height $y(t_i)$ at a particular time t_i is calculated using Equation (1). All the constants necessary to carry out this calculation were given in Tables 1 through 3 except the tidal constituent amplitudes and phase lags which are specific to each port. The amplitudes and phase lags for all the reference ports in the Canadian Tide and Current Tables are tabulated in Appendix A.

To illustrate the procedure the height of the tide at Saint John, N.B. will be calculated for 12 noon, 18 August 1987. The first step is the calculation of the time t_i in hours. It is simple to verify that 18 August 1987(a non-leap year) is day 230 (this is usually called the Julian Day) and that the total number of hours in the year to 12 noon is:

(230 - 1)*24 + 12 = 5508 hours

The contribution from each of the constituents can then be computed as follows:

Z_o		= 4.420
O_1	$a_1 * f_1 * \cos(2\pi(\sigma_1 \cdot t + V_1 - g_1))$	
	0.12*1.182*cos(2π(13.943035538 *5508+331-118))	= 0.124
P_1	$a_2 * f_2 * \cos(2\pi(\sigma_2 \cdot t + V_2 - g_2))$	
	0.06*1.000*cos(2π(14.95893136 *5508+350-137))	= -0.058
K_1	similar to above	= 0.028
μ_1	similar to above	= -0.013
N_2	similar to above	= 0.323
M_2	as above	= -2.767
S_2	as above	= 0.457
K_2	as above	= 0.014
M_4	as above	= -0.024
MS_4	as above	= 0.005
TOTAL (tide height at 1200, 18 Aug. 87)		= 2.51m

The tide height at Saint John, predicted by the Tide Tables for this time is 2.3 m. The 0.2 m difference is indicative of the accuracy of this simplified approach.

The Simplified Tide Prediction program listed in Appendix B uses the approach just illustrated. A sample output from the program is shown in Figure 1. The program has been deliberately kept simple to illustrate the approach. A number of refinements that production programs usually have and which the reader may wish to incorporate are:

1. All tidal constituent data in a separate data file instead of data statements as in the program. It is also usual to list the name of the station with the output.
2. Optional hourly heights or high/low water predictions. The times and heights of high/low tide are usually found using a Newton type of iteration process. Extra care must be used in selecting the times of high/low water in areas where the tides are mixed mainly diurnal such as, for example, the Northumberland Strait and the Pacific Coast.

```
START DATE(DD,MM,YR)? 01,03,87
NO. DAYS ? 5
STATION NO. ? 65
DATE    0100 0200 0300 0400 0500 0600 0700 0800 0900 1000 1100 1200
        1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 2400
1 387   8.02 7.01 5.34 3.39 1.67 0.65 0.61 1.59 3.31 5.31 7.06 8.16
        8.35 7.61 6.10 4.15 2.23 0.85 0.38 0.96 2.42 4.34 6.23 7.62
2 387   8.19 7.83 6.63 4.87 2.95 1.38 0.59 0.80 1.97 3.76 5.69 7.27
        8.13 8.09 7.17 5.57 3.67 1.93 0.82 0.64 1.45 3.01 4.90 6.61
3 387   7.74 8.04 7.47 6.14 4.37 2.59 1.25 0.72 1.17 2.46 4.22 5.98
        7.31 7.91 7.65 6.62 5.04 3.28 1.79 0.98 1.08 2.05 3.63 5.37
4 387   6.84 7.68 7.73 6.99 5.62 3.95 2.37 1.29 1.03 1.64 2.96 4.59
        6.13 7.18 7.53 7.12 6.05 4.57 3.04 1.84 1.32 1.62 2.67 4.16
5 387   5.69 6.88 7.45 7.30 6.48 5.16 3.65 2.32 1.51 1.44 2.14 3.38
        4.83 6.10 6.90 7.06 6.57 5.56 4.25 2.97 2.05 1.76 2.19 3.21
```

Figure 1: Sample output from Simplified Tide Prediction Program

3. Tide predictions at time intervals more or less frequently than once per hour.

After starting the program by typing "RUN" the operator is asked for the start date, the number of days of predictions desired and the station number. The output consists of a header indicating the predictions are to be in two lines per day starting at 0100 and 1300 followed by the data in metres. The day, month and year are listed to the left of each prediction line.

TIDAL ANALYSIS

The basic problem of tidal analysis is, given a set of observed tidal heights and their corresponding times, to compute a set of tidal constituent amplitudes and phase lags.

In Equation (1) there are 2M+1 unknowns where M is the number of constituents. Let N be the number of observations. Then, assuming N > 2M+1, the most common optimization technique for dealing with such problems, and the one used here, is the method of least squares that minimizes the sum of the squares of the residuals. Equation (1) can be rewritten as:

$$y(t_i) = Z_o + \sum_{j=1}^{M} \{ C_j \cdot \cos(2\pi(\sigma_j \cdot t_i + V_j)) + S_j \cdot \sin(2\pi(\sigma_j \cdot t_i + V_j)) \} \qquad (2)$$

$$\text{where} \quad a_j = \sqrt{(C_j^2 + S_j^2)} \, / \, f_j \qquad (3)$$

$$\text{and} \quad g_j = \arctan(S_j / C_j) \qquad (4)$$

The relationship between the unknowns Z_o, C_j, S_j and observations y_i is now linear and Equation (2) can be rewritten in matrix notation as follows:

$$Y = A \cdot X \qquad (5)$$

where $Y = (y_1, y_2, y_3, \ldots)^T$ is called the observation vector,

$X = (Z_o, C_1, S_1, C_2, \ldots)^T$ is called the solution or parameter vector, and

$$A = \begin{bmatrix} 1 & \cos(2\pi(\sigma_1 \cdot t_1 + V_1)) & \sin(2\pi(\sigma_1 \cdot t_1 + V_1)) & \cos(2\pi(\sigma_2 \cdot t_1 + V_2)) & \ldots \\ 1 & \cos(2\pi(\sigma_1 \cdot t_2 + V_1)) & \sin(2\pi(\sigma_1 \cdot t_2 + V_1)) & \cos(2\pi(\sigma_2 \cdot t_2 + V_2)) & \ldots \\ 1 & \cos(2\pi(\sigma_1 \cdot t_3 + V_1)) & \sin(2\pi(\sigma_1 \cdot t_3 + V_1)) & \cos(2\pi(\sigma_2 \cdot t_3 + V_2)) & \ldots \\ & \vdots & \vdots & \vdots & \end{bmatrix}$$

is called the design matrix.

As described in Wells and Krakiwsky (1971) the least squares criterion states that the "best" estimator of X is the estimator which minimizes the sum of the squares of the weighted residuals:

$$\hat{V}^T \cdot P_y \cdot \hat{V} = \text{minimum} \qquad (6)$$

where the residual vector $\hat{V}$ is defined as:

$$\hat{V} = A \cdot \hat{X} - Y \qquad (7)$$

and the weight matrix P_y, which will be discussed later, is simply a square positive definite symmetric matrix. Combining equations (6) and (7):

$$F = (A \cdot \hat{X} - Y)^T \cdot P_y \cdot (A \cdot \hat{X} - Y) = \text{minimum} \qquad (8)$$

To minimize this function:

$$\frac{\partial F}{\partial \hat{X}} = \frac{\partial F}{\partial(A \cdot \hat{X} - Y)} \cdot \frac{\partial(A \cdot X - Y)}{\partial \hat{X}}$$

$$= 2(A \cdot \hat{X} - Y)^T \cdot P_y \cdot A = 0$$

which reduces to:

$$A^T \cdot P_y \cdot A \cdot \hat{X} - A^T \cdot P_y \cdot Y = 0 \quad (9)$$

Equations (9) are called the normal equations and if $A^T \cdot P_y \cdot A$, called the matrix of the normal equations, is non-singular then there is a unique least squares estimator for X given by:

$$\hat{X} = (A^T \cdot P_y \cdot A)^{-1} \cdot A^T \cdot P_y \cdot Y \quad (10)$$

If the weight matrix P_y equals the identity matrix I it effectively disappears from equation (10) which becomes:

$$\hat{X} = (A^T \cdot A)^{-1} \cdot A^T \cdot Y \quad (11)$$

This is the standard form of most least squares tidal analysis programs (e.g. Foreman, 1977). That is, most tidal analysis programs assume that all tidal height and time measurements are measured to the same accuracy i.e., are assigned equal weights. While this is clearly not true, as anyone who has tried to read a tide staff when waves are present will verify, usually the problem is so over determined(i.e. there are usually so many more height measurements than parameters) that a few inaccurate readings do not affect the accuracy of the final solution. However, it is a simple matter to account for the accuracy of the tidal height observations in the least squares solution via the weight matrix P_y. For a detailed discussion of the weight matrix see Wells and Krakiwsky(1971). For the remainder of this development it is assumed that the weight matrix is diagonal with diagonal elements equal to the inverse of the variances of the individual height measurements. It is also assumed that estimates of the variances σ^2 (i.e. standard deviation squared and not to be confused with the tidal frequencies discussed earlier which also used σ) of each of the height measurements is available. The following simple computation scheme for equations (10) is used in the Simplified Tide Analysis Program presented in Appendix C. A sample output from the program is shown in Figure 2. In the program the variances are all set to 1 in line 40.

Rewriting Equation (10) as:

$$X = B^{-1} \cdot D \quad (12)$$

the elements of B and D are easily computed as follows:

$$b_{ij} = \sum_{k=1}^{N} a_{ki} \cdot a_{kj} / \sigma_k^2 \quad (13)$$

$$d_i = \sum_{k=1}^{N} a_{ki} \cdot y_k / \sigma_k^2 \quad (14)$$

where a_{ij} are the elements of the design matrix A and σ_k^2 are the variances associated with height observations. Equations (13) and (14) are convenient computationally and are also efficient from a computer memory point of view since only one row of the design matrix A is needed at a time and not the whole matrix. To find the solution vector X matrix B must be inverted and post-multiplied by D.

As illustrated by the program listing in Appendix C, the frequencies, astronomical arguments and related data are found in the first five data lines starting at line 1000. The observed time and height data then follow in the format: day, hour, minute and height.

The observed data must meet several minimum requirements for the analysis results to be accurate:

1. Length of Record
   For the 11 constituents chosen it is necessary to have readings that span a period of at least 6 months.
2. Frequency of Readings
   For certain periods during the six months readings should be taken at least every 3 hours and preferably every hour.
3. Times of Readings
   The readings should be spread out throughout the tidal cycle and throughout the 6 month period. The readings should not all be observed at high/low tide or all at half tide; they should be observed at both high/low tide (to establish the amplitudes) as well as during the rising and falling tide (to establish the phase lags or timing).
4. Number of Readings
   The larger the number of readings the more accurate will be the results. Theoretically, provided that requirements 1 through 3 are met, only 21 readings are needed to determine the 21 constituent amplitudes and phase lags. However, they probably would not be very accurate.

190	16	0	1.31
190	17	0	1.64
190	18	0	2.76
190	19	0	4.38
190	20	0	6.05
190	21	0	7.36
190	22	0	7.99
190	23	0	7.81
400	40	0	0.00

AMP	PHASE	C	S
4.420			
0.120	118.0	-0.0666	0.1254
0.060	136.7	-0.0439	0.0413
0.160	136.1	-0.1281	0.1232
0.020	60.0	0.0095	0.0166
0.600	314.0	0.4017	-0.4158
3.010	342.0	2.7596	-0.8964
0.480	16.0	0.4613	0.1321
0.140	18.9	0.1742	0.0598
0.050	166.4	-0.0450	0.0109
0.010	206.7	-0.0086	-0.0043

```
CALCULATE RESIDUALS(Y/N) ? y
2  0  0  7.48  7.47  0.01
2  1  0
```

Figure 2: Sample Output from Simplified Tide Analysis Program

After the program is started it lists the data as it is read and equations (13) and (14) are evaluated. Shown above are the last several observations (although the day 400 is printed it is not used - it simply tells the program there is no more data) followed immediately by the header and the tidal constituent amplitudes and phases in metres and degrees respectively. Also listed are the C and S terms described in equation (2). The constituents are listed in the same order as in Table 1.

SEQUENTIAL TIDAL ANALYSIS

A sequential least squares analysis is a special case of the Kalman filter. The Kalman filter is used to calculate least squares weighted estimates of parameters in dynamic time-varying systems. The linearized Kalman filter equations are:

$$\hat{X}_{k/k-1} = F_k \cdot \hat{X}_{k-1} \qquad (15)$$

$$N_{k/k-1} = F_k \cdot N_{k-1} \cdot F_k^T + Q_k \qquad (16)$$

$$G_k = N_{k/k-1} \cdot A_k^T \cdot (R_k + A_k \cdot N_{k/k-1} \cdot A_k^T)^{-1} \qquad (17)$$

$$\hat{X}_k = \hat{X}_{k/k-1} + G_k \cdot (y_k - A_k \cdot \hat{X}_{k/k-1}) \qquad (18)$$

$$N_k = (I - G_k \cdot A_k) \cdot N_{k/k-1} \qquad (19)$$

Equations (15) and (16) compute estimates of the unknowns X and the unknown covariance matrix N at time k from their values at time k-1. In a non-time-varying situation such as tidal analysis these equations disappear (i.e. F becomes an identity I and Q does not exist). See Gelb(1974) for a more detailed description. Equations (17),(18), and (19) are known as the sequential least squares adjustment equations in the surveying literature (Vanicek and Krakiwsky, 1982). G is known as the gain matrix, R is the observation covariance matrix (i.e. $P_y = R^{-1}$) and the other terms were defined earlier.

Before continuing it is instructive to reduce the sequential adjustment equations to their simplest form to see how the different parameters interact. Instead of a tidal analysis let the model be the measurement of the length of a rod. If the measurement y and unknown x are both the length of the rod A becomes an identity I (i.e. it disappears). Also, all the matrices become single numbers: the covariance matrix N becomes the unknown variance σ_x^2 and the observation covariance matrix R becomes the observation variance σ_y^2. Equations (17), (18) and (19) become:

$$y_k = \sigma_{xk-1}^2 / (\sigma_{yk}^2 + \sigma_{xk-1}^2) \qquad (20)$$

$$x_k = x_{k-1} + g_k \cdot (y_k - x_{k-1}) \qquad (21)$$

$$\sigma_{xk}^2 = (1 - g_k) \cdot \sigma_{xk-1}^2 \qquad (22)$$

To see how the sequential adjustment works assume that the latest observation y_k is very good. σ_{yk}^2 is then very small and g_k tends to a value of 1. In equation (21) when g_k is equal to one x_{k-1} cancels from the right hand side and x_k equals the latest observation y_k. Furthermore, the good quality of the latest observation causes the new σ_{xk}^2 to be smaller, indicating that the estimate of the length is now better. Conversely, if the latest observation is very poor, σ_{yk}^2 is very large and g_k tends to zero and the opposite effect is observed.

The program listed in Appendix D uses equations (17), (18) and (19) to do a sequential tidal analysis. In the program the observation variance R is set equal to 0.001 (= 3 cm.²). In practice the observed height y and variance R could be obtained from the mean and standard deviation squared of 2 or 3 minutes of one second water level measurements.

The main advantage of this algorithm is that it is not necessary to re-analyze all the data again if additional data is observed. At any step if the latest unknown vector x and its corresponding covariance matrix N are known the analysis can resume with the new data. That is, all the information from the earlier data is contained in N and X. This is also an ideal algorithm for real time tidal analysis in a digital tide gauge.

For a single run with a given set of data the sequential tidal analysis approach is very similar computationally to the conventional approach used in Appendix C. However, frequently a month or so of data is obtained at a site and analyzed and a year or so later a further month or so of data is obtained. Using the conventional approach the earlier data must be retrieved and all of the data must be processed simultaneously. In effect this amounts to re-processing the original data again. Using the sequential approach, as calculation can simply proceed with the new data. Under this condition the sequential approach is clearly superior.

Since the title of this paper is "Simplified" tidal analysis and prediction it is probably not appropriate to discuss the sequential approach further. Therefore, in conclusion, for those who would like to pursue this new approach further, it is very interesting to also watch the variances of the various constituents and especially the covariances between the constituents as the processing proceeds and to compare the results with the respective Rayleigh Criteria. It is easier to observe if the covariance matrix N is first transformed from C and S to amplitude and phase.

When the sequential tide analysis program is running, it lists the following information as each successive reading is processed:

day, hour, min, y, y-calc, Z_o, Amplitudes of O_1, P_1..
Phase lags of O_1, P_1..

Shown below are the first 10 minutes of the data provided in the program listing which is for Saint John, N.B.(Station Number 65). Notice how large the difference (y-calc.) is at the start and how it decreases as the estimates of Z_o and the constituents improve with each new observation.

1	0	0	7.84	3.14	1.29	1.52	1.60	1.65	1.46	1.49	1.56	1.63	1.17	1.46	1.56
						35	37	39	34	34	35	38	51	34	35
1	1	0	7.52	-4.61	1.06	1.12	1.20	1.33	0.79	0.83	1.01	1.28	1.71	0.87	1.37
						35	30	29	24	20	14	12	72	329	340
1	2	0	6.41	1.14	1.37	1.32	1.44	1.57	0.90	0.93	1.08	1.29	1.64	0.47	1.00
						28	28	30	26	24	19	16	69	280	312
1	3	0	4.79	-0.94	1.22	1.08	1.29	1.51	0.80	0.88	1.17	1.52	1.73	0.21	0.27
						19	16	18	360	358	359	3	83	130	307
1	4	0	3.04	0.04	1.27	1.10	1.31	1.53	0.77	0.85	1.14	1.49	1.76	0.20	0.26
						19	16	18	360	358	358	2	82	126	312
1	5	0	1.60	0.17	1.45	1.20	1.37	1.57	0.68	0.77	1.08	1.47	1.88	0.24	0.18
						21	20	22	356	354	353	357	83	110	323
1	6	0	0.90	0.20	1.57	1.32	1.38	1.49	0.66	0.78	1.14	1.60	1.91	0.32	0.16
						32	31	31	350	347	349	355	88	102	289
1	7	0	1.14	0.18	1.66	1.42	1.36	1.37	0.70	0.85	1.25	1.76	1.85	0.38	0.26
						43	43	42	345	343	347	356	92	107	282
1	8	0	2.31	0.24	1.88	1.48	1.28	1.21	0.76	0.94	1.36	1.87	1.72	0.44	0.33
						53	54	51	340	341	348	359	95	129	305
1	9	0	4.07	0.26	2.39	1.40	1.05	0.92	0.85	1.02	1.42	1.85	1.56	0.51	0.33
						63	63	55	334	339	349	4	93	171	359

Figure 3. Sample output from Simplified Sequential Tide Analysis Program

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APPENDIX A

Tidal Constituent amplitudes a_j (second line in metres) and phase lags g_j (third line in degrees).

No.				Name	Latitude		Longitude			Time Zone
Z_o	O_1	P_1	K_1	μ_2	N_2	M_2	S_2	K_2	M_4	MS_4
0065				Saint John, N.B.	45 16 N		66 04 W			+4.0
4.42	0.12	0.06	0.16	0.02	0.60	3.01	0.48	0.14	0.05	0.01
	118	137	136	061	314	342	018	016	167	206
0365				Yarmouth, N.S.	43 50 N		66 07 W			+4.0
2.47	0.11	0.05	0.14	0.01	0.35	1.66	0.27	0.08	0.02	0.00
	109	122	122	306	280	306	336	337	298	328
0490				Halifax, N.S.	44 40 N		63 35 W			+4.0
1.02	0.04	0.03	0.11	0.02	0.14	0.63	0.14	0.04	0.04	0.02
	039	064	063	216	213	234	262	256	038	168
0576				Point Tupper, N.S.	45 36 N		61 22 W			+4.0
0.89	0.05	0.02	0.07	0.02	0.12	0.60	0.14	0.04	0.05	0.02
	291	346	353	211	208	228	262	256	019	142
0612				North Sydney, N.S.	46 13 N		60 15 W			+4.0
0.69	0.08	0.03	0.08	0.02	0.08	0.37	0.11	0.03	0.01	0.00
	232	256	264	209	216	237	277	272	209	009
0665				Port aux Basques, Nfld.	47 35 N		59 09 W			+3.5
1.13	0.09	0.03	0.08	0.02	0.10	0.44	0.13	0.04	0.01	0.00
	182	200	199	243	254	273	305	307	228	025
0835				Argentia, Nfld.	47 18 N		53 59 W			+3.5
1.31	0.09	0.03	0.08	0.03	0.15	0.70	0.20	0.05	0.05	0.02
	117	132	130	228	225	237	271	274	175	288
0905				St. John's, Nfld.	47 34 N		52 42 W			+3.5
0.76	0.07	0.02	0.08	0.02	0.07	0.36	0.15	0.04	0.01	0.01
	080	105	109	200	200	216	258	260	347	130
1430				Nain, Labrador(Nfld.)	56 32 N		61 41 W			+4.0
1.46	0.08	0.03	0.09	0.02	0.16	0.76	0.28	0.08	0.00	0.01
	102	121	126	172	184	203	232	233	031	042
1630				Pictou, N.S.	45 41 N		62 42 W			+3.5
1.19	0.18	0.07	0.21	0.01	0.10	0.42	0.10	0.04	0.01	0.01
	235	273	267	238	252	282	331	330	325	035
1700				Charlottetown, P.E.I.	46 13 N		63 08 W			+4.0
1.68	0.23	0.08	0.25	0.04	0.16	0.72	0.18	0.06	0.02	0.01
	239	273	266	301	277	307	012	007	080	181
1805				Shediac, N.B.	46 15 N		64 32 W			+4.0
1.04	0.24	0.08	0.26	0.00	0.04	0.15	0.04	0.01	0.02	0.02
	230	250	255	156	242	300	060	055	268	016

1915	Rustico, P.E.I.				46 28 N		63 17 W			+4.0
0.52	0.18	0.06	0.18	0.02	0.04	0.16	0.05	0.02	0.01	0.01
	230	261	256	161	150	170	234	240	137	247
2000	Lower Escuminac, N.B.				47 05 N		64 53 W			+4.0
0.70	0.20	0.06	0.21	0.02	0.06	0.26	0.06	0.02	0.02	0.01
	212	231	237	112	109	123	164	163	092	222
2165	Dalhousie, N.B.				48 04 N		66 23 W			+4.0
1.53	0.20	0.06	0.22	0.06	0.18	0.76	0.19	0.04	0.03	0.01
	204	226	224	110	079	093	138	127	190	002
2310	Pointe St.-Pierre, P.Q.				48 38 N		64 10 W			+5.0
0.76	0.18	0.06	0.19	0.02	0.08	0.35	0.10	0.02	0.01	0.00
	187	210	208	034	030	048	084	073	280	000
2550	Harrington Harbour				50 30 N		59 29 W			+4.0
1.07	0.14	0.05	0.15	0.02	0.12	0.53	0.17	0.05	0.01	0.00
	186	201	203	278	296	316	340	341	116	172
2780	Sept-Iles, P.Q.				50 13 N		66 24 W			+5.0
1.50	0.20	0.07	0.21	0.04	0.19	0.91	0.29	0.08	0.01	0.01
	184	191	204	356	018	040	075	067	265	274
2980	Pointe-au-Pere, P.Q.				48 31 N		68 28 W			+5.0
2.26	0.22	0.08	0.25	0.05	0.26	1.28	0.42	0.11	0.02	0.00
	180	200	206	356	030	055	090	088	080	223
3250	Quebec (Lauzon), P.Q.				46 50 N		71 10 W			+5.0
2.62	0.22	0.05	0.23	0.10	0.30	1.82	0.42	0.13	0.28	0.15
	245	269	267	314	158	184	226	225	278	327
3325	Grondines, P.Q.				46 35 N		72 02 W			+5.0
2.29	0.15	0.03	0.14	0.05	0.12	0.77	0.17	0.06	0.21	0.10
	298	328	331	028	249	274	316	316	106	153
3460	Port-Alfred, P.Q.				48 20 N		70 52 W			+5.0
2.77	0.23	0.07	0.25	0.06	0.36	1.81	0.60	0.16	0.09	0.04
	191	204	211	035	047	071	110	102	141	211
3480	Chicoutimi, P.Q.				48 26 N		71 05 W			+5.0
2.44	0.21	0.08	0.23	0.05	0.32	1.58	0.47	0.13	0.25	0.12
	204	220	222	041	065	088	126	129	128	166
4140	Fobisher Bay, N.W.T.				63 43 N		68 32 W			+4.0
5.94	0.11	0.06	0.18	0.09	0.68	3.45	1.17	0.33	0.06	0.02
	068	099	100	170	193	222	269	268	311	026
5560	Resolute, N.W.T.				74 41 N		94 54 W			+6.0
0.94	0.11	0.06	0.20	0.01	0.08	0.46	0.19	0.05	0.00	0.00
	194	244	249	327	339	005	050	043	000	000
6485	Tuktoyaktuk, N.W.T.				69 27 N		133 00 W			+7.0
0.33	0.02	0.01	0.03	0.00	0.02	0.12	0.05	0.01	0.00	0.00
	090	052	060	122	079	102	143	106	188	197

7020 Sooke, B.C. 48 22 N 123 44 W +8.0
1.94 0.35 0.17 0.57 0.02 0.09 0.44 .13 0.03 0.02 0.01
135 144 146 008 032 051 066 053 353 004

7120 Victoria, B.C. 48 25 N 123 22 W +8.0
1.88 0.37 0.20 0.63 0.02 0.09 0.37 0.10 0.02 0.02 0.01
137 148 149 020 063 086 094 100 358 024

7160 Port Townsend, Wash. 48 08 N 122 46 W +8.0
1.50 0.44 0.00 0.67 0.02 0.17 0.68 0.19 0.00 0.04 0.02
139 000 148 031 098 120 129 000 319 332

7180 Seattle, Wash.(U.S.A.) 47 36 N 122 20 W +8.0
2.00 0.46 0.26 0.84 0.04 0.24 1.07 0.26 0.08 0.02 0.01
143 154 156 016 111 139 157 158 097 118

7330 Fulford Harbour, B.C. 48 46 N 123 27 W +8.0
2.26 0.43 0.23 0.75 0.02 0.12 0.58 0.14 0.04 0.01 0.01
146 158 160 037 115 141 157 159 007 018

7735 Vancouver, B.C. 49 17 N 123 07 W +8.0
3.06 0.47 0.27 0.86 0.01 0.19 0.93 0.23 0.06 0.01 0.01
156 170 170 065 144 167 189 184 176 185

7795 Point Atkinson, B.C. 49 20 N 123 15 W +8.0
3.09 0.48 0.27 0.86 0.02 0.18 0.92 0.23 0.06 0.01 0.00
152 163 166 068 135 159 180 179 168 164

8074 Campbell River, B.C. 50 01 N 125 14 W +8.0
2.92 0.50 0.26 0.85 0.03 0.17 0.83 0.21 0.05 0.09 0.04
151 162 164 058 123 148 163 163 269 285

8120 Owen Bay, B.C. 50 19 N 125 13 W +8.0
2.69 0.38 0.21 0.68 0.05 0.18 0.85 0.28 0.07 0.01 0.01
140 150 152 009 063 088 100 095 080 108

8280 Alert Bay, B.C. 50 35 N 126 56 W +8.0
2.86 0.31 0.16 0.52 0.03 0.25 1.27 0.41 0.11 0.02 0.01
128 134 136 357 007 028 050 040 003 050

8575 Port Alberni, B.C. 49 14 N 124 49 W +8.0
1.89 0.00 0.12 0.39 0.02 0.19 0.96 0.27 0.07 0.00 0.00
000 122 126 325 343 004 024 015 007 001

8615 Tofino, B.C. 49 09 N 125 55 W +8.0
2.12 0.24 0.12 0.39 0.02 0.20 0.99 0.28 0.08 0.02 0.01
116 118 121 336 348 008 030 021 017 039

8976 Bella Bella, B.C. 52 10 N 128 08 W +8.0
2.84 0.29 0.14 0.46 0.03 0.26 1.31 0.40 0.11 0.01 0.01
124 128 131 345 357 018 040 031 354 028

9354 Prince Rupert, B.C. 54 19 N 130 20 W +8.0
3.85 0.31 0.16 0.51 0.04 0.39 1.94 0.64 0.17 0.01 0.00
132 137 139 009 015 036 059 051 243 000

Appendix B

```
10 REM SIMPLIFIED TIDE PREDICTION - NOVEMBER 1987
20 REM S.T.GRANT, REGIONAL TIDAL OFFICER
30 REM CANADIAN HYDROGRAPHIC SERVICE
40 REM BEDFORD INSTITUTE OF OCEANOGRAPHY
50 REM P.O. BOX 1006
60 REM DARTMOUTH, N.S.
70 REM CANADA, B2Y 4A2
80 REM
100 DIM GT(10),AT(10),F(10),V(10),AF(10), NDAYS(12)
110 DIM STNN(40)
120 REM — V DATA(1987) —
130 DATA 331,350,009,319,324,340,000,198, 319,340
140 REM — AF DATA(1987) —
150 DATA 1.182,1.000,1.112,0.964,0.964,0.964,1.000,1.315,0.928,0.964
160 REM — F (FREQUENCY) DATA —
170 DATA 13.94303558,14.95893136,15.04106863,27.96820848
180 DATA 28.43972957,28.98410425,30.00000000,30.08213726
190 DATA 57.96820850,58.98410424
200 REM — NO. DAYS TO START OF EACH MONTH
210 DATA 0,31,59,90,120,151,181,212,243,273,304,334
220 PI = 3.1415926535#
230 REM READ DATA
240 FOR I = 1 TO 10:READ V(I):NEXT I
250 FOR I = 1 TO 10:READ AF(I):NEXT I
260 FOR I = 1 TO 10:READ F(I):NEXT I
270 FOR I = 1 TO 12:READ NDAYS(I):NEXT I
280 INPUT "START DATE(DD,MM,YR)";DA,MO,YR:INPUT "NO. DAYS ";NODS
290 JD = NDAYS(MO) + DA:IF YR MOD 4=0 AND JD>59 THEN JD = JD + 1
300 SDAY = JD + NODS - 1
310 INPUT "STATION NO. ";STNO:K = 0
320 K = K + 1
330 READ STNN(K):IF STNN(K)<0 THEN 380
340 READ Z:FOR I = 1 TO 10:READ AT(I):NEXT I
350 FOR I = 1 TO 10:READ GT(I):NEXT I
360 IF STNO=STNN(K) THEN 400
370 GOTO 320
380 PRINT "STATION NO. ";STNO;" NOT AVAILABLE"
390 STOP
400 PRINT "DATE    0100 0200 0300 0400 0500 0600 0700 0800 0900 1000 1100 1200"
410 PRINT "        1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 2400"
420 PRINT""
430 PRINT USING "##";DA;MO;YR;:PRINT " ";
440 FOR I = 1 TO 24
450 H = Z
460 FOR J = 1 TO 10
470 H = H + AF(J)*AT(J)*COS((V(J)-GT(J)+((JD-1)*24+I)*F(J))*PI/180)
480 NEXT J
490 PRINT USING " #.##";H;:IF I=12 THEN PRINT "":PRINT "       ";
500 NEXT I
510 PRINT ""
520 IF JD>=SDAY THEN STOP
530 JD = JD + 1:DA = DA + 1:IF DA>(NDAYS(MO+1)-NDAYS(MO)) THEN 550
540 GOTO 430
550 MO = MO + 1:DA = 1:GOTO 430
1000 DATA 65,4.42,0.12,0.06,0.16,0.02,0.60,3.01,0.48,0.14,0.05,0.01
1010 DATA 118,137,136,061,314,342,016,019,167,207
1020 DATA 365,2.47,0.11,0.05,0.14,0.01,0.35,1.66,0.27,0.08,0.02,0.00
1030 DATA 109,122,122,306,280,306,336,337,298,328
1040 DATA 490,1.02,0.04,0.03,0.11,0.02,0.14,0.63,0.14,0.04,0.04,0.02
1050 DATA 039,064,063,216,213,234,262,256,038,168
1060 DATA 576,0.89,0.05,0.02,0.07,0.02,0.12,0.60,0.14,0.04,0.05,0.02
1070 DATA 291,346,353,211,208,228,262,256,019,142
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1080 DATA 612,0.69,0.08,0.03,0.08,0.02,0.08,0.37,0.11,0.03,0.01,0.00
1090 DATA 232,256,264,209,216,237,277,272,209,009
1100 DATA 665,1.13,0.09,0.03,0.08,0.02,0.10,0.44,0.13,0.04,0.01,0.00
1110 DATA 182,200,199,243,254,273,305,307,228,025
1120 DATA 835,1.31,0.09,0.03,0.08,0.03,0.15,0.70,0.20,0.05,0.05,0.02
1130 DATA 117,132,130,228,225,237,271,274,175,288
1140 DATA 905,0.76,0.07,0.02,0.08,0.02,0.07,0.36,0.15,0.04,0.01,0.01
1150 DATA 080,105,109,200,200,216,258,260,347,130
1160 DATA 1430,1.46,0.08,0.03,0.09,0.02,0.16,0.76,0.28,0.08,0.00,0.01
1170 DATA 102,121,126,172,184,203,232,233,031,042
1180 DATA 1630,1.19,0.18,0.07,0.21,0.01,0.10,0.42,0.10,0.04,0.01,0.01
1190 DATA 235,273,267,238,252,282,331,330,325,035
1200 DATA 1700,1.68,0.23,0.08,0.25,0.04,0.16,0.72,0.18,0.06,0.02,0.01
1210 DATA 239,273,266,301,277,307,012,007,080,181
1220 DATA 1805,1.04,0.24,0.08,0.26,0.00,0.04,0.15,0.04,0.01,0.02,0.02
1230 DATA 230,250,255,156,242,300,060,055,268,016
1240 DATA 1915,0.52,0.18,0.06,0.18,0.02,0.04,0.16,0.05,0.02,0.01,0.01
1250 DATA 230,261,256,161,150,170,234,240,137,247
1260 DATA 2000,0.70,0.20,0.06,0.21,0.02,0.06,0.26,0.06,0.02,0.02,0.01
1270 DATA 212,231,237,112,109,123,164,163,092,222
1280 DATA 2165,1.53,0.20,0.06,0.22,0.06,0.18,0.76,0.19,0.04,0.03,0.01
1290 DATA 204,226,224,110,079,093,138,127,190,002
1300 DATA 2310,0.76,0.18,0.06,0.19,0.02,0.08,0.35,0.10,0.02,0.01,0.00
1310 DATA 187,210,208,034,030,048,084,073,280,000
1320 DATA 2550,1.07,0.14,0.05,0.15,0.02,0.12,0.53,0.17,0.05,0.01,0.00
1330 DATA 186,201,203,278,296,316,340,341,116,172
1340 DATA 2780,1.50,0.20,0.07,0.21,0.04,0.19,0.91,0.29,0.08,0.01,0.01
1350 DATA 184,191,204,356,018,040,075,067,265,274
1360 DATA 2980,2.26,0.22,0.08,0.25,0.05,0.26,1.28,0.42,0.11,0.02,0.00
1370 DATA 180,200,206,356,030,055,090,088,080,223
1380 DATA 3250,2.62,0.22,0.05,0.23,0.10,0.30,1.82,0.42,0.13,0.28,0.15
1390 DATA 245,269,267,314,158,184,226,225,278,327
1400 DATA 3325,2.29,0.15,0.03,0.14,0.05,0.12,0.77,0.17,0.06,0.21,0.10
1410 DATA 298,328,331,028,249,274,316,316,106,153
1420 DATA 3460,2.77,0.23,0.07,0.25,0.06,0.36,1.81,0.60,0.16,0.09,0.04
1430 DATA 191,204,211,035,047,071,110,102,141,211
1440 DATA 3480,2.44,0.21,0.08,0.23,0.05,0.32,1.58,0.47,0.13,0.25,0.12
1450 DATA 204,220,222,041,065,088,126,129,128,166
1460 DATA 4140,5.94,0.11,0.06,0.18,0.09,0.68,3.45,1.17,0.33,0.06,0.02
1470 DATA 068,099,100,170,193,222,269,268,311,026
1480 DATA 5560,0.94,0.11,0.06,0.20,0.01,0.08,0.46,0.19,0.05,0.00,0.00
1490 DATA 194,244,249,327,339,005,050,043,000,000
1500 DATA 6485,0.33,0.02,0.01,0.03,0.00,0.02,0.12,0.05,0.01,0.00,0.00
1510 DATA 090,052,060,122,079,102,143,106,188,197
1520 DATA 7020,1.94,0.35,0.17,0.57,0.02,0.09,0.44,0.13,0.03,0.02,0.01
1530 DATA 135,144,146,008,032,051,066,053,353,004
1540 DATA 7120,1.88,0.37,0.20,0.63,0.02,0.09,0.37,0.10,0.02,0.02,0.01
1550 DATA 137,148,149,020,063,086,094,100,358,024
1560 DATA 7160,1.50,0.44,0.00,0.67,0.02,0.17,0.68,0.19,0.00,0.04,0.02
1570 DATA 139,000,148,031,098,120,129,000,319,332
1580 DATA 7180,2.00,0.46,0.26,0.84,0.04,0.24,1.07,0.26,0.08,0.02,0.01
1590 DATA 143,154,156,016,111,139,157,158,097,118
1600 DATA 7330,2.26,0.43,0.23,0.75,0.02,0.12,0.58,0.14,0.04,0.01,0.01
1610 DATA 146,158,160,037,115,141,157,159,007,018
1620 DATA 7735,3.06,0.47,0.27,0.86,0.01,0.19,0.93,0.23,0.06,0.01,0.01
1630 DATA 156,170,170,065,144,167,189,184,176,185
1640 DATA 7795,3.09,0.48,0.27,0.86,0.02,0.18,0.92,0.23,0.06,0.01,0.00
1650 DATA 152,163,166,068,135,159,180,179,168,164
1660 DATA 8074,2.92,0.50,0.26,0.85,0.03,0.17,0.83,0.21,0.05,0.09,0.04
1670 DATA 151,162,164,058,123,148,163,163,269,285
1680 DATA 8120,2.69,0.38,0.21,0.68,0.05,0.18,0.85,0.28,0.07,0.01,0.01
1690 DATA 140,150,152,009,063,088,100,095,080,108
1700 DATA 8280,2.86,0.31,0.16,0.52,0.03,0.25,1.27,0.41,0.11,0.02,0.01
1710 DATA 128,134,136,357,007,028,050,040,003,050
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1720 DATA 8575,1.89,0.00,0.12,0.39,0.02,0.19,0.96,0.27,0.07,0.00,0.00
1730 DATA 000,122,126,325,343,004,024,015,007,001
1740 DATA 8615,2.12,0.24,0.12,0.39,0.02,0.20,0.99,0.28,0.08,0.02,0.01
1750 DATA 116,118,121,336,348,008,030,021,017,039
1760 DATA 8976,2.84,0.29,0.14,0.46,0.03,0.26,1.31,0.40,0.11,0.01,0.01
1770 DATA 124,128,131,345,357,018,040,031,354,028
1780 DATA 9354,3.85,0.31,0.16,0.51,0.04,0.39,1.94,0.64,0.17,0.01,0.00
1790 DATA 132,137,139,009,015,036,059,051,243,000
1800 DATA -1
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Appendix C

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10 REM SIMPLIFIED TIDE ANALYSIS - NOVEMBER 1987
20 REM S.T.GRANT, REGIONAL TIDAL OFFICER
30 REM CANADIAN HYDROGRAPHIC SERVICE
40 REM BEDFORD INSTITUTE OF OCEANOGRAPHY
50 REM P.O. BOX 1006
60 REM DARTMOUTH, N.S.
70 REM CANADA, B2Y-4A2
80 REM
100 DIM A(21),B(21,21),X(21),AT(10),GT(10)
110 DIM C(21,21),D(21),F(10),AF(10),V(10)
120 M = 21:PI = 3.1415926535#:R = 1!
129 REM
130 REM READ FREQUENCIES(F),NODAL MODULATIONS(AF) AND
132 REM ASTRONOMICAL ARGUMENTS(V)
133 REM
135 RESTORE 1000
140 FOR I = 1 TO 10:READ F(I):NEXT I
150 FOR I = 1 TO 10:READ AF(I):NEXT I
160 FOR I = 1 TO 10:READ V(I):NEXT I
165 REM GOTO 910:REM SEE LINES 910 TO 1000
169 REM
170 REM SET X AND B ARRAYS TO ZERO TO START
171 REM
190 FOR I = 1 TO M:X(I) = 0!:NEXT I
200 FOR I = 1 TO M:FOR J = 1 TO M:B(I,J) = 0!:NEXT J:NEXT I
204 REM
205 REM READ TIMES(DDD,HH,MM) AND TIDE HEIGHTS Y AND CONVERT
207 REM TIMES TO TOTAL HOURS, DDD IS JULIAN DAY.
210 REM CHECK FOR END OF DATA BY NOT 0 < DAY < 366
211 REM
215 RESTORE 1100
220 READ T1,T2,T3,Y:PRINT T1,T2,T3,Y:IF T1<0 OR T1>366 THEN 430
230 TI = (T1-1)*24 + T2 + T3/60
249 REM
250 REM CALCULATE DESIGN MATRIX A
251 REM
265 A(1) = 1
270 FOR I = 2 TO M STEP 2
280    A(I) = COS((TI*F(I/2)+V(I/2))*PI/180)
290    A(I+1) = SIN((TI*F(I/2)+V(I/2))*PI/180)
300 NEXT I
301 REM
302 REM FIND MATRICES B AND D IN THE EQUATION B.X = D
303 REM B = (At.A) AND D = At.Y
304 REM WHERE t SIGNIFIES TRANSPOSE
305 REM
310 FOR I = 1 TO M:FOR J = 1 TO M
320    B(I,J) = B(I,J) + A(I)*A(J)/R
340 NEXT J:NEXT I
350 FOR I = 1 TO M
360    D(I) = D(I) + A(I)*Y/R
370 NEXT I
```

```
390 GOTO 220
400 REM
401 REM END OF DATA. NOW INVERT B AND POST MULT. BY D TO
402 REM SOLVE FOR X
403 REM
430 NI = M:GOSUB 800
440 FOR J = 1 TO M:X(J) = 0
450    FOR I = 1 TO M:X(J) = X(J) + B(J,I)*D(I)
460 NEXT I:NEXT J
469 REM
470 REM READ THE DATA AGAIN AND COMPUTE THE RESIDUALS TO SEE
471 REM HOW GOOD THE CONSTITUENTS FIT THE DATA.
472 REM
540 PRINT ""
545 PRINT " AMP.   PHASE      C       S":PRINT USING "#.###";X(1)
550 FOR I = 2 TO M STEP 2
560    AT(I/2) = SQR(X(I)^2 + X(I+1)^2)/AF(I/2)
570    GT(I/2) = ATN(X(I+1)/X(I))*180/PI
580   IF X(I) < 0 THEN 610
590   IF X(I+1) < 0 THEN GT(I/2) = GT(I/2) + 360
600   GOTO 620
610    GT(I/2) = GT(I/2) + 180
620 REM
640    PRINT USING "#.###";AT(I/2);
650    PRINT "   ";
660    PRINT USING "###.#";GT(I/2);:PRINT "    ";
662 PRINT USING "##.####";X(I);:PRINT "    ";:PRINT USING "##.####";X(I+1)
670 NEXT I
680 REM
682 REM IF REQUESTED READ THE DATA AGAIN AND COMPUTE THE RESIDUALS
684 REM AND RMS RESIDUAL TO SEE HOW GOOD THE CONSTITUENTS FIT THE DATA.
686 REM
690 PRINT "":INPUT "CALCULATE RESIDUALS(Y/N) ";IYN$
700 IF IYN$="Y" OR IYN$="y" THEN 710
705 STOP
710 RESTORE 1100:SU = 0
720 READ T1,T2,T3,Y:IF T1<0 OR T1>366 THEN 750
725 TI = (T1-1)*24 + T2 + T3/60:H = X(1)
730 FOR J = 1 TO 10
735 H = H + AF(J)*AT(J)*COS((V(J) - GT(J) + TI*F(J))*PI/180)
740 NEXT J:PRINT USING "###";T1;T2;T3;:PRINT USING "###.##";Y;H;Y-H
745 SU = SU + (Y-H)^2:GOTO 720
750 SU = SQR(SU):PRINT "RMS RESIDUAL ";SU
760 STOP
800 REM MATRIX INVERSE IN PLACE
810 FOR K = 1 TO NI:FOR J = 1 TO NI
820      IF J<>K THEN B(K,J) = B(K,J)/B(K,K)
830   NEXT J
840    B(K,K) = 1/B(K,K)
850  FOR I = 1 TO NI:IF I=K THEN 880
860     FOR J = 1 TO NI:IF J<>K THEN B(I,J) = B(I,J) - B(I,K)*B(K,J)
870     NEXT J:B(I,K) = -B(I,K)*B(K,K)
880  NEXT I
890  NEXT K
900  RETURN
902 REM THE LINES FROM HERE TO 980 ARE USED TO CREATE TEST DATA LINES
904 REM ALONG WITH LINE 165. TO USE, ENABLE 165 AND TYPE RUN.
906 REM ENTER LINE NUMBER, DAY NO. AND HOUR AND A DATA LINE WITH 4 HOURS
908 REM OF DATA WILL BE TYPED. TO ADD IT TO THE PROGRAM USE UP ARROW TO
909 REM PLACE CURSOR OVER THE NEW LINE AND HIT RETURN.
910 RESTORE 920
920 DATA 4.42,0.12,0.06,0.16,0.02,0.60,3.01,0.48,0.14,0.05,0.01
925 DATA 118,137,136,061,314,342,016,019,167,207
930 READ Z:FOR I=1 TO 10:READ AT(I):NEXT I
```

```
932 FOR I=1 TO 10:READ GT(I):NEXT I:ICTR = 0
935 INPUT "LINE NO. ",LN:INPUT "DAY ",ID:INPUT "HOUR ",HR
940 PRINT USING "####";LN;:PRINT " DATA ";
942 ICTR = ICTR + 1
945 TI = (ID-1)*24 + HR:Y = Z
950 FOR J = 1 TO 10
955 Y = Y + AF(J)*AT(J)*COS((V(J)-GT(J)+TI*F(J))*PI/180)
960 NEXT J
965 PRINT USING "###";ID;:PRINT ",";:PRINT USING "##";HR;:PRINT ",00,";
967 PRINT USING "#.##";Y;
970 IF ICTR=4 THEN 975
972 PRINT ",";:HR = HR + 1:GOTO 942
975 PRINT ""
980 STOP
1000 DATA 13.94303558,14.95893136,15.04106863,27.96820848
1010 DATA 28.43972957,28.98410425,30.00000000,30.08213726
1020 DATA 57.96820850,58.98410424
1030 DATA 1.182,1.000,1.112,0.964,0.964,0.964,1.000,1.315,0.928,0.964
1040 DATA 331,350,009,319,324,340,000,198,319,340
1100 DATA  2, 0,00,7.48, 2, 1,00,7.90, 2, 2,00,7.45, 2, 3,00,6.23
1110 DATA  2, 4,00,4.54, 2, 5,00,2.78, 2, 6,00,1.43, 2, 7,00,0.85
1120 DATA  2, 8,00,1.26, 2, 9,00,2.54, 2,10,00,4.35, 2,11,00,6.21
1130 DATA  2,12,00,7.65, 2,13,00,8.33, 2,14,00,8.10, 2,15,00,7.02
1140 DATA  2,16,00,5.32, 2,17,00,3.37, 2,18,00,1.64, 2,19,00,0.57
1150 DATA  2,20,00,0.45, 2,21,00,1.31, 2,22,00,2.90, 2,23,00,4.80
1160 DATA  3, 0,00,6.50, 3, 1,00,7.60, 3, 2,00,7.88, 3, 3,00,7.29
1170 DATA  3, 4,00,5.99, 3, 5,00,4.28, 3, 6,00,2.57, 3, 7,00,1.33
1180 DATA  3, 8,00,0.91, 3, 9,00,1.45, 3,10,00,2.81, 3,11,00,4.61
1190 DATA  3,12,00,6.39, 3,13,00,7.68, 3,14,00,8.21, 3,15,00,7.86
1200 DATA  3,16,00,6.70, 3,17,00,4.98, 3,18,00,3.10, 3,19,00,1.50
1210 DATA  3,20,00,0.61, 3,21,00,0.66, 3,22,00,1.64, 3,23,00,3.27
1220 DATA  5, 0,00,3.63, 5, 1,00,5.36, 5, 2,00,6.78, 5, 3,00,7.58
1230 DATA  5, 4,00,7.60, 5, 5,00,6.84, 5, 6,00,5.48, 5, 7,00,3.86
1240 DATA  5, 8,00,2.36, 5, 9,00,1.40, 5,10,00,1.24, 5,11,00,1.94
1250 DATA  5,12,00,3.30, 5,13,00,4.94, 5,14,00,6.44, 5,15,00,7.44
1260 DATA  5,16,00,7.71, 5,17,00,7.20, 5,18,00,6.02, 5,19,00,4.44
1270 DATA  5,20,00,2.81, 5,21,00,1.56, 5,22,00,1.01, 5,23,00,1.32
1280 DATA  6, 0,00,2.39, 6, 1,00,3.93, 6, 2,00,5.54, 6, 3,00,6.81
1290 DATA  6, 4,00,7.47, 6, 5,00,7.39, 6, 6,00,6.60, 6, 7,00,5.28
1300 DATA  6, 8,00,3.74, 6, 9,00,2.36, 6,10,00,1.53, 6,11,00,1.45
1310 DATA  6,12,00,2.17, 6,13,00,3.46, 6,14,00,4.98, 6,15,00,6.34
1320 DATA  6,16,00,7.20, 6,17,00,7.39, 6,18,00,6.87, 6,19,00,5.75
1330 DATA  6,20,00,4.28, 6,21,00,2.81, 6,22,00,1.72, 6,23,00,1.30
1340 DATA 11, 0,00,4.09,11, 1,00,3.01,11, 2,00,2.27,11, 3,00,2.12
1350 DATA 11, 4,00,2.59,11, 5,00,3.58,11, 6,00,4.81,11, 7,00,5.96
1360 DATA 11, 8,00,6.77,11, 9,00,7.06,11,10,00,6.76,11,11,00,5.92
1370 DATA 11,12,00,4.72,11,13,00,3.43,11,14,00,2.36,11,15,00,1.79
1380 DATA 11,16,00,1.87,11,17,00,2.57,11,18,00,3.68,11,19,00,4.89
1390 DATA 11,20,00,5.90,11,21,00,6.49,11,22,00,6.53,11,23,00,6.04
1400 DATA 20, 0,00,4.45,20, 1,00,5.85,20, 2,00,6.83,20, 3,00,7.19
1410 DATA 20, 4,00,6.85,20, 5,00,5.93,20, 6,00,4.65,20, 7,00,3.29
1420 DATA 20, 8,00,2.20,20, 9,00,1.66,20,10,00,1.86,20,11,00,2.75
1430 DATA 20,12,00,4.10,20,13,00,5.53,20,14,00,6.66,20,15,00,7.22
1440 DATA 20,16,00,7.08,20,17,00,6.31,20,18,00,5.08,20,19,00,3.67
1450 DATA 20,20,00,2.41,20,21,00,1.62,20,22,00,1.53,20,23,00,2.17
1460 DATA 35, 0,00,3.21,35, 1,00,4.83,35, 2,00,6.30,35, 3,00,7.28
1470 DATA 35, 4,00,7.55,35, 5,00,7.08,35, 6,00,5.97,35, 7,00,4.48
1480 DATA 35, 8,00,2.96,35, 9,00,1.81,35,10,00,1.34,35,11,00,1.67
1490 DATA 35,12,00,2.71,35,13,00,4.16,35,14,00,5.62,35,15,00,6.74
1500 DATA 35,16,00,7.27,35,17,00,7.10,35,18,00,6.27,35,19,00,4.99
1510 DATA 35,20,00,3.54,35,21,00,2.28,35,22,00,1.57,35,23,00,1.59
1520 DATA 60, 0,00,8.14,60, 1,00,8.02,60, 2,00,7.01,60, 3,00,5.34
1530 DATA 60, 4,00,3.39,60, 5,00,1.67,60, 6,00,0.65,60, 7,00,0.61
1540 DATA 60, 8,00,1.59,60, 9,00,3.31,60,10,00,5.31,60,11,00,7.06
```

```
1550 DATA 60,12,00,8.16,60,13,00,8.35,60,14,00,7.61,60,15,00,6.10
1560 DATA 60,16,00,4.15,60,17,00,2.23,60,18,00,0.85,60,19,00,0.38
1570 DATA 60,20,00,0.96,60,21,00,2.42,60,22,00,4.34,60,23,00,6.23
1580 DATA 100, 0,00,4.33,100, 1,00,3.30,100, 2,00,2.54,100, 3,00,2.27
1590 DATA 100, 4,00,2.58,100, 5,00,3.41,100, 6,00,4.51,100, 7,00,5.61
1600 DATA 100, 8,00,6.41,100, 9,00,6.74,100,10,00,6.52,100,11,00,5.81
1610 DATA 110,12,00,1.83,110,13,00,3.03,110,14,00,4.51,110,15,00,5.89
1620 DATA 110,16,00,6.83,110,17,00,7.14,110,18,00,6.78,110,19,00,5.85
1630 DATA 110,20,00,4.55,110,21,00,3.22,110,22,00,2.17,110,23,00,1.69
1640 DATA 120, 0,00,7.49,120, 1,00,7.81,120, 2,00,7.35,120, 3,00,6.19
1650 DATA 120, 4,00,4.59,120, 5,00,2.92,120, 6,00,1.58,120, 7,00,0.95
1660 DATA 120, 8,00,1.19,120, 9,00,2.23,120,10,00,3.76,120,11,00,5.35
1670 DATA 130,12,00,4.86,130,13,00,3.52,130,14,00,2.36,130,15,00,1.70
1680 DATA 130,16,00,1.75,130,17,00,2.52,130,18,00,3.82,130,19,00,5.28
1690 DATA 130,20,00,6.54,130,21,00,7.27,130,22,00,7.31,130,23,00,6.67
1700 DATA 155, 0,00,2.85,155, 1,00,3.63,155, 2,00,4.64,155, 3,00,5.60
1710 DATA 155, 4,00,6.26,155, 5,00,6.49,155, 6,00,6.22,155, 7,00,5.54
1720 DATA 155, 8,00,4.58,155, 9,00,3.54,155,10,00,2.68,155,11,00,2.22
1730 DATA 170, 0,00,1.50,170, 1,00,2.25,170, 2,00,3.56,170, 3,00,5.08
1740 DATA 170, 4,00,6.41,170, 5,00,7.25,170, 6,00,7.40,170, 7,00,6.83
1750 DATA 170, 8,00,5.67,170, 9,00,4.18,170,10,00,2.71,170,11,00,1.63
1760 DATA 170,12,00,1.24,170,13,00,1.64,170,14,00,2.74,170,15,00,4.23
1770 DATA 170,16,00,5.73,170,17,00,6.89,170,18,00,7.45,170,19,00,7.28
1780 DATA 170,20,00,6.45,170,21,00,5.12,170,22,00,3.62,170,23,00,2.31
1790 DATA 180, 0,00,6.53,180, 1,00,7.11,180, 2,00,7.09,180, 3,00,6.46
1800 DATA 180, 4,00,5.35,180, 5,00,4.00,180, 6,00,2.71,180, 7,00,1.81
1810 DATA 180, 8,00,1.56,180, 9,00,2.02,180,10,00,3.05,180,11,00,4.36
1820 DATA 180,12,00,5.58,180,13,00,6.42,180,14,00,6.71,180,15,00,6.42
1830 DATA 180,16,00,5.62,180,17,00,4.51,180,18,00,3.34,180,19,00,2.44
1840 DATA 180,20,00,2.08,180,21,00,2.39,180,22,00,3.30,180,23,00,4.55
1850 DATA 190, 0,00,5.46,190, 1,00,3.84,190, 2,00,2.34,190, 3,00,1.31
1860 DATA 190, 4,00,1.04,190, 5,00,1.59,190, 6,00,2.84,190, 7,00,4.42
1870 DATA 190, 8,00,5.93,190, 9,00,6.97,190,10,00,7.31,190,11,00,6.91
1880 DATA 190,12,00,5.87,190,13,00,4.44,190,14,00,2.96,190,15,00,1.80
1890 DATA 190,16,00,1.31,190,17,00,1.64,190,18,00,2.76,190,19,00,4.38
1900 DATA 190,20,00,6.05,190,21,00,7.36,190,22,00,7.99,190,23,00,7.81
1910 DATA 400,40,00,0.00
```

Appendix D

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10 REM SIMPLIFIED SEQUENTIAL TIDE ANALYSIS - NOVEMBER 1987
20 REM S.T.GRANT, REGIONAL TIDAL OFFICER
30 REM CANADIAN HYDROGRAPHIC SERVICE
40 REM BEDFORD INSTITUTE OF OCEANOGRAPHY
50 REM P.O.BOX 1006
60 REM DARTMOUTH, N.S.
70 REM CANADA, B2Y 4A2
80 REM
100 DIM A(21),N(21,21),X(21),AF(10),V(10)
110 DIM G(21),TE(21),F(10),AT(10),GT(10)
120 M = 21:PI = 3.1415926535#:R = .001
130 REM
140 REM READ FREQUENCIES(F), MODULATIONS(AF) AND ASTRO. AGRS.(V)
150 REM
160 RESTORE 1000
170 FOR I = 1 TO 10:READ F(I):NEXT I
180 FOR I = 1 TO 10:READ AF(I):NEXT I
190 FOR I = 1 TO 10:READ V(I):NEXT I
200 REM  GOTO 900:REM SEE LINES 900 TO 980
210 REM
220 REM INITIALIZE ARRAYS
230 REM
240 FOR I = 1 TO M:X(I) = 1!:FOR J = 1 TO M:N(I,J) = 0
```

```
250 IF I = J THEN N(I,J) = 1
260 NEXT J:NEXT I
270 REM
280 REM READ TIMES(DDD,HH,MM) AND TIDE HEIGHTS Y AND CONVERT
290 REM TIMES TO TOTAL HOURS. DDD IS JULIAN DAYS.
300 REM CHECK FOR END OF DATA BY NOT 0 < DAY < 366
310 REM
320 READ T1,T2,T3,Y
330 TI = (T1-1)*24 + T2 + T3/60
340 IF T1<0 OR T1>366 THEN STOP
350 A(1) = 1
360 FOR I = 2 TO M STEP 2
370    A(I) = COS((TI*F(I/2)+V(I/2))*PI/180)
380    A(I+1) = SIN((TI*F(I/2)+V(I/2))*PI/180)
390 NEXT I
400 TF = 0
410 FOR I = 1 TO M:TE(I) = 0
420 REM
430 REM COMPUTE   TE = N * A
440 REM
450 FOR J = 1 TO M:TE(I) = TE(I) + N(I,J)*A(J):NEXT J
460 REM
470 REM COMPUTE   TF = TE * A   =   A * N * A^T
480 REM
490 TF = TF + TE(I)*A(I):NEXT I
500 REM
510 REM COMPUTE GAIN G
520 FOR I = 1 TO M:G(I) = TE(I)/(TF + R):NEXT I
530 AX = 0
540 FOR I = 1 TO M:AX = AX + A(I)*X(I):NEXT I
550 DF = Y - AX
560 REM
570 REM COMPUTE NEW ESTIMATES OF X
580 REM
590 FOR I = 1 TO M:X(I) = X(I) + G(I)*DF:NEXT I
600 FOR I = 1 TO M:FOR J = 1 TO M
610 REM
620 REM COMPUTE NEW ESTIMATE OF N
630 REM
640 N(I,J) = N(I,J) - G(I)*TE(J)
650 NEXT J:NEXT I
660 REM
670 REM CONVERT C & S TO AMPLITUDE AND PHASE LAG BEFORE PRINTING
680 REM
690 FOR I = 2 TO M STEP 2
700    AT(I/2) = SQR(X(I)^2 + X(I+1)^2)
710    GT(I/2) = ATN(X(I+1)/X(I))*180/PI
720    IF X(I)<0 THEN 750
730    IF X(I+1)<0 THEN GT(I/2) = GT(I/2) + 360
740    GOTO 760
750    GT(I/2) = GT(I/2) + 180
760 NEXT I
770 PRINT USING "###";T1;T2;T3;:PRINT USING " #.##";Y;
780 PRINT USING " ##.##";DF;:PRINT USING " #.##";X(1);
790 FOR I = 1 TO 10
800 PRINT USING " #.##";AT(I);
810 NEXT I:PRINT ""
820 PRINT "                    ";:FOR I = 1 TO 10
830 PRINT USING " ### ";GT(I);
840 NEXT I:PRINT ""
850 REM FOR I = 1 TO M:PRINT "ROW ";I;" ";
860 REM FOR J = 1 TO M:SI = N(I,J):PRINT FNTR(SI*10);
870 REM NEXT J:PRINT " ":NEXT I
880 GOTO 320
```

```
900 REM THE LINES FROM HERE TO 995 ARE USED TO CREATE TEST DATA.
902 REM TO USE ENABLE LINE 170 AND TYPE RUN.
904 REM ENTER LINE NUMBER, DAY NO. AND HOUR AND A DATA LINE WITH 4 HOURS
906 REM OF DATA WILL BE TYPED. TO ADD IT TO THE PROGRAM USE UP ARROW TO
908 REM PLACE CURSOR OVER THE NEW LINE AND HIT RETURN.
910 RESTORE 915
915 DATA 4.42,0.12,0.06,0.16,0.02,0.60,3.01,0.48,0.14,0.05,0.01
920 DATA 118,137,136,061,314,342,016,019,167,207
925 READ Z:FOR I = 1 TO 10:READ AT(I):NEXT I
930 FOR I = 1 TO 10:READ GT(I):NEXT I:ICTR = 0
935 INPUT "LINE NO. ";LN:INPUT "DAY ";ID:INPUT "HOUR ";HR
940 PRINT USING "####";LN;:PRINT " DATA ";
945 ICTR = ICTR + 1
950 TI = (ID-1)*24 + HR:Y = Z
955 FOR J = 1 TO 10
960 Y = Y + AF(J)*AT(J)*COS((V(J)-GT(J)+TI*F(J))*PI/180)
965 NEXT J
970 PRINT USING "###";ID;:PRINT ",";:PRINT USING "##";HR;:PRINT ",00,";
975 PRINT USING "#.##";Y;
980 IF ICTR=4 THEN 990
985 PRINT ",";:HR = HR + 1:GOTO 945
990 PRINT ""
995 STOP
1000 DATA 13.94303558, 14.95893136, 15.04106863, 27.96820848, 28.43972957
1005 DATA 28.98410425,30.00,30.08213726,57.96820850,58.98410424
1010 DATA 1.182,1.000,1.112,0.964,0.964,0.964,1.000,1.315,0.928,0.964
1015 DATA 331,350,009,319,324,340,000,198,319,340
1020 DATA  1, 0,00,7.84,  1, 1,00,7.52,  1, 2,00,6.41,  1, 3,00,4.79
1025 DATA  1, 4,00,3.04,  1, 5,00,1.60,  1, 6,00,0.90,  1, 7,00,1.14
1030 DATA  1, 8,00,2.31,  1, 9,00,4.07,  1,10,00,5.97,  1,11,00,7.51
1035 DATA  1,12,00,8.33,  1,13,00,8.24,  1,14,00,7.28,  1,15,00,5.64
1040 DATA  1,16,00,3.69,  1,17,00,1.88,  1,18,00,0.65,  1,19,00,0.35
1045 DATA  1,20,00,1.06,  1,21,00,2.57,  1,22,00,4.47,  1,23,00,6.25
1050 DATA  5, 0,00,3.63,  5, 1,00,5.36,  5, 2,00,6.78,  5, 3,00,7.58
1055 DATA  5, 4,00,7.60,  5, 5,00,6.84,  5, 6,00,5.48,  5, 7,00,3.86
1060 DATA  5, 8,00,2.36,  5, 9,00,1.40,  5,10,00,1.24,  5,11,00,1.94
1065 DATA  5,12,00,3.30,  5,13,00,4.94,  5,14,00,6.44,  5,15,00,7.44
1070 DATA  5,16,00,7.71,  5,17,00,7.20,  5,18,00,6.02,  5,19,00,4.44
1075 DATA  5,20,00,2.81,  5,21,00,1.56,  5,22,00,1.01,  5,23,00,1.32
1080 DATA  7, 0,00,1.67,  7, 1,00,2.73,  7, 2,00,4.18,  7, 3,00,5.65
1085 DATA  7, 4,00,6.78,  7, 5,00,7.33,  7, 6,00,7.19,  7, 7,00,6.39
1090 DATA  7, 8,00,5.13,  7, 9,00,3.68,  7,10,00,2.42,  7,11,00,1.67
1095 DATA  7,12,00,1.64,  7,13,00,2.34,  7,14,00,3.55,  7,15,00,4.95
1100 DATA  7,16,00,6.18,  7,17,00,6.95,  7,18,00,7.10,  7,19,00,6.59
1105 DATA  7,20,00,5.54,  7,21,00,4.19,  7,22,00,2.86,  7,23,00,1.91
1110 DATA 14, 0,00,6.43, 14, 1,00,5.71, 14, 2,00,4.63, 14, 3,00,3.46
1115 DATA 14, 4,00,2.51, 14, 5,00,2.09, 14, 6,00,2.33, 14, 7,00,3.19
1120 DATA 14, 8,00,4.43, 14, 9,00,5.70, 14,10,00,6.69, 14,11,00,7.16
1125 DATA 14,12,00,7.03, 14,13,00,6.31, 14,14,00,5.13, 14,15,00,3.76
1130 DATA 14,16,00,2.51, 14,17,00,1.70, 14,18,00,1.58, 14,19,00,2.15
1135 DATA 14,20,00,3.26, 14,21,00,4.57, 14,22,00,5.74, 14,23,00,6.50
1140 DATA 50, 0,00,4.22, 50, 1,00,5.82, 50, 2,00,7.05, 50, 3,00,7.61
1145 DATA 50, 4,00,7.39, 50, 5,00,6.48, 50, 6,00,5.08, 50, 7,00,3.53
1150 DATA 50, 8,00,2.18, 50, 9,00,1.37, 50,10,00,1.33, 50,11,00,2.08
1155 DATA 50,12,00,3.43, 50,13,00,5.00, 50,14,00,6.38, 50,15,00,7.21
1160 DATA 50,16,00,7.31, 50,17,00,6.70, 50,18,00,5.53, 50,19,00,4.07
1165 DATA 50,20,00,2.68, 50,21,00,1.69, 50,22,00,1.39, 50,23,00,1.87
1170 DATA 100, 0,00,4.33,100, 1,00,3.30,100, 2,00,2.54,100, 3,00,2.27
1175 DATA 100, 4,00,2.58,100, 5,00,3.41,100, 6,00,4.51,100, 7,00,5.61
1180 DATA 100, 8,00,6.41,100, 9,00,6.74,100,10,00,6.52,100,11,00,5.81
1185 DATA 100,12,00,4.74,100,13,00,3.55,100,14,00,2.53,100,15,00,1.98
1190 DATA 100,16,00,2.05,100,17,00,2.74,100,18,00,3.85,100,19,00,5.08
1195 DATA 100,20,00,6.12,100,21,00,6.71,100,22,00,6.73,100,23,00,6.18
1200 END
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Creating a Shellfish Toxin Chart Using CHS/CARIS

by
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INTRODUCTION

On December 16, 1987 a request was received, from within the Department of Fisheries and Oceans, for a chart on which the levels of toxicity of east coast shellfish could be displayed. After some preliminary discussion, it was decided to use two separate techniques to develop the chart. These were:

1. manually, using an existing CHS chart, and;
2. digitally using existing linework and symbols, and the "extended graphics" capabilities of the CHS/CARIS system to create topology for colour-filling polygons.

The manual method, using an existing chart and coloured magic markers, was the fastest and satisfied the immediate need. The digital techniques were used in a parallel exercise to explore the feasibility of responding to urgent requests using digital data. This exercise took full advantage of the power of the CHS/CARIS system, including its ability to process topological data structures and to output full colour graphics on an electrostatic plotter.

A colour chart was produced by following the digital approach and this paper is the result of a "post-mortem" of the project. It examines the problems encountered, the solutions and the potential benefits of applying such an approach to other applications.It also makes recommendations as to how to better respond to similar requests in the future. These issues are discussed under four topics:

1. A source of suitable digital data.
2. The making of the first chart.
3. Applying lessons learned to subsequent projects.
4. Opportunities for using this technology for other applications.

A SOURCE OF DIGITAL DATA

When the Canadian Hydrographic Service is asked a question such as, "What digital data are available for the Maritimes?" it is difficult to answer. Is it possible to query a data base and obtain a listing of existing digital charts on the east coast of Canada? Can a Digital Data Library (DDL) be consulted for a list of digital files on the east coast? At present, the answer is NO and, in this instance, the Chart Production Group at Headquarters was simply asked if there was a digital chart file of the east coast in the office. There are different reasons for this.

Neither a data base nor an up-to-date, national, Digital Data Library for CHS nautical charts exists. There once was a DDL in Ottawa but it has not been kept up to date and the most recent entry is dated 1985. If, in fact, there had been a DDL reference to a specific chart file, it is unlikely that the file would have been up-to-date and obtaining a current version of the file may have entailed requesting the file from the appropriate regional office. There are several factors that must be considered in answering the question "WHY is this the situation?".

The official output of nautical chart production in the CHS is the paper chart and digital chart files used in the compilation and drafting of the paper chart are not necessarily updated to be as complete as the paper chart at the time of its release. Since the digital chart files have no official status they are not archived in a central location nor are they maintained on a regular basis.

CHS has the technical expertise and the tools to address the issue of an inventory of digital chart files. There are several approaches that could be explored:

1. The CHS source data base (HYDROGRAPHIC DATA data base) on the System 2000 data base management system is used by Central and Arctic Region to record chart maintenance information and could easily record the existence of digital chart files. It already has fields to record actions (such as update date) and has the capability to do area searches plus other data base type searches.

2. Definitely the chart inventory and production monitoring data base (CHAINS) on DATATRIEVE also has the ability to list all charts with limits inside a specified geographic area. However, the data base does not yet contain the limits of all the CHS charts.

   Each record in CHAINS has a field to indicate whether or not there is a DDL entry for that chart, either "Y" plus the entry date or "N". CHAINS, when used by a knowledgeable operator, can be used to locate and derive the sort of information required.

3. A longer term solution would involve creating a Chart Data Base on the commercial Data Base Management System (DBMS) that will be used for the CHS Information System. This data base would combine the maintenance functions now included in the source data base with an inventory of digital chart files and the capability of updating the digital files to support future applications such as Print-On-Demand (POD) and the Electronic Chart. If the human resources were available, this could be done in parallel with the Québec data base pilot project.

The answer to the question, "Was suitable digital information readily available?" is a qualified "yes". In the future, effective response to this type of situation implies easy location and retrieval of digital files. The current state of the DDL does not allow this. As a minimum, CHAINS and the DDL should be used to maintain this information on digital files for the entire CHS, files should be archived at a central location, all historical files converted so that they can be read on the current system and the centrally archived files updated whenever the region updates their version of each file.

MAKING THE FIRST CHART

The file received from Chart Production was for Chart 4000, which had been produced on an earlier version of the computer assisted cartographic system, thus it had to be converted to a new data format. It took an afternoon to perform the conversion, window out the required section of the chart, add names and remove the navigation aids. The CHS/CARIS cartographic editor's (CARED) parallel line generator was used to create an enclosing boundary along the shoreline of the affected areas. The area between the boundary and the shoreline was later colour filled according to information provided by fisheries officials.

This project took a total of 3 days. The time taken to generate the final product was not a function of the process being difficult or lengthy. It was more a matter of the process being new and the operators being forced to find their way along a learning curve as the documentation was followed, ambiguous points debated and a trial and error approach applied. Several tricks were attempted. Some paid off; some didn't.

A large proportion of the time was spent correcting linework which had originally been digitized as "spaghetti". Data containing lines which may cross each other are commonly referred to as "spaghetti". Such data constitutes a rather unstructured organization, especially in relation to topological data. Topology is defined as the relationship of the basic graphical elements to each other. For example, knowing which lines meet at the same point, which lines form a closed area (i.e. a polygon), or whether a polygon contains another polygon (USL, 1987).

The editing of the file included making sure that lines which would eventually form polygon boundaries either had no breaks in them or if they did, that the end point of one line was within a small tolerance of the start of the next line. In the future, slight changes in digitizing methodology would result in a significant reduction in this type of editing.

Although it took the better part of three days to learn how to use the topological software in the system, build the topology and generate the final plot, the experience gained would allow the same task to be performed again in a fraction of the time.

Was the expertise available to take full advantage of the capabilities of the system? Yes and no. The operators had a firm knowledge of CHS/CARIS and CARED up to the point where it was time to start the process of topological data creation from "spaghetti" linework. The total previous experience with topology amounted to that gained by watching a small, simple data set being digitized and then building the topology for it. This "ideal" data set, digitized with the intention of creating topology, was vastly different from the situation within which this product was created. Numerous errors were encountered, all of which required examination, reference to the documentation and correction. One result of the project was a quick, hands on, education in topological error detection, interpretation and correction.

To respond to a similar request in the future, there should be several people who have a full working knowledge of all aspects of CHS/CARIS. This requires thorough training, not on a small and error-free data set, but on a realistic data set, which will present, in a learning environment, the problems the user is likely to encounter while working on digital chart files. A file for a small chart or an inset should be suitable for a training project.

Overall, this exercise was beneficial for several reasons, including:

1. learning, first hand, what sort of training will be required for cartographers to effectively use the full system;

2. providing an estimate, in terms of both quantity and type, of errors to be expected in the future and a basis for estimating the time required to prepare other charts for topological processing. The chart used as the data source was representative of the type of data and style of digitizing used in the CHS, and ;

3. determining what the "extended graphics" compo-

nent of the CHS/CARIS system can do for the CHS. This exercise was witnessed by many and several good ideas were presented.

MAKING THE SECOND CHART

A request for CHS to produce a second toxicity chart was made late in the afternoon of Wednesday, January 6, 1988. It was to delineate, for the media, the areas deemed safe for harvesting shellfish. Six copies were required for a press conference that was to be held at 10 a.m. the next morning.

This chart covered a slightly smaller geographic area than the first one, and contained much less detail. The only polygons that were to contain colour were the safe areas, and they were to be filled in green. As well, the original boundaries separating areas of differing levels of toxicity were adjusted as specified by fisheries officials. The ability to respond to the request and change limits, scale and boundaries to suit the situation demonstrates one of the major benefits of digital data.

The experience gained on the first chart, as predicted, resulted in creating the second product in less than 8 hours. The finished product was delivered on time for the press conference, where it was seen on national television.

OTHER APPLICATIONS

How can this new knowledge be applied to the CHS? There are many ways that the power of CHS/CARIS, topology, the electrostatic plotter and the knowledge gained during this project could be used in the CHS today. For example:

Chart production

With minimal changes to the current digitizing process, all new charts can be digitized so that topology can be created quite easily. This would result not only in an increase in the number of digital data files available for production of the traditional paper chart, but would also provide the additional benefit of a ready-to-use source of data for use in electronic chart development, chart patches and electrostatic plotting.

Notices to Mariners

The generation of patches using this technique could be faster and cheaper. This implies that the digital chart files would also be kept current, possibly by the Notices to Mariners personnel, thereby reducing the amount of work required for a new edition of the chart.

Chart Catalogues, Status of Surveys, 5 Year Plans, Field Sheet Indices

Once these documents are digitized and the topology created, this type of document could be more easily managed, updated, electronically distributed to any of the CHS regional offices and any number of copies printed on demand. Topological structures make it possible to study geographical and numerical relationships between different themes on the document and provide a link into the database world.

Low Volume Charts

There are many charts with sales of less than five, ten, 25 and 50 copies per year. These numbers are far below the minimum number of copies generated by the traditional printing press, which is geared towards volume output. It is in this situation that the printing of a large number of charts, which cost $0.40 per chart per year to store, could be avoided in favour of using the electrostatic printing process where it would be possible to print a number of charts which is more in line with the demand.

Print On Demand (POD)

Over the longer term, it may prove feasible to have plotters located in chart distribution offices where up-to-date charts could be printed and sold as needed (Vachon, 1987).

SUMMARY

This project was a positive experience, especially for the CHS Headquarters staff, in that it was possible to demonstrate the benefits and potential of digital data and the CHS/CARIS system to meet unanticipated and changing demands. The project also identified deficiencies in the manner in which CHS manages digital chart files and identified present data capture practices that create problems when the digital data are used for a slightly different application. It also indicated both the level of training required to harness the potential of the CHS/CARIS system and provided CHS staff with a benchmark by which to measure the difficulty of applying a similar approach to different applications.

At some point the CHS will probably want to start using topology in day to day chart production and special project activities. There are steps, which do not require any additional software for the CHS offices, that the cartographer can take now to simplify this transition. All the cartographer has to do when digitizing is to ensure that all lines which should terminate at another line actually do end. Linework, such as shoreline, should not contain unnecessary breaks but should be continuous whenever possible.

The Canadian Hydrographic Service must, implicitly, have the ability to inventory and manage digital chart files. Today this is not the case. The software required to perform this task is neither expensive nor is it complicated. In the long term, the functions of a Chart Data Base will be encompassed in the CHS Information System along with many other data bases. However, an immediate solution is required for the relatively simple, yet vital task, of digital chart file management.

To reiterate, the old Digital Data Library was not a database in the common sense of the term, but it was an invaluable mechanism for managing an ever-increasing inventory of digital chart files. While the original DDL software is outdated, the idea is not. The costs and benefits of the options set out earlier should be weighed and a solution chosen that can be implemented in the same time frame as the policies are established to support such a system. A technical solution will not solve an organizational problem, and if there is neither a commitment to create complete digital chart files nor a commitment to load and maintain a DDL, the currency of the data in the DDL will remain suspect.

Creating digital chart files today, that can support topology, will give the CHS the flexibility to respond to special projects, (such as the shellfish toxin chart) and to have data ready for other developments such as the electronic chart and full colour electrostatic printing.

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"Yes, I got the times - five minutes for the first set, four for the second set!"

Legal Jurisdiction Over the Titanic

by
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Geomarine Associates Limited
and
I. Townsend Gault and D. VanderZwaag
Dalhousie University
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This paper was originally presented at OCEANS '87 in Halifax, Nova Scotia on September 29, 1987. It has been revised for LIGHTHOUSE. Certain of the legal arguments have appeared briefly in Townsend Gault and VanderZwaag (1987).

Aboard the ship, whatever hope of dawn
Gleamed from the Carpathia's riding lights was gone,
For every knot was matched by each degree
Of list. The stern was lifted bodily
When the bow had sunk 300 feet, and set
Against the horizon stars in silhouette
Were the blade curves of the screws, hump of the rudder.
The downward pull and after buoyancy
Held her a minute poised but for a shudder
That caught her frame as with the upward stroke
Of the sea a boiler or a bulkhead broke.

The TITANIC by E.J. Pratt (1935), p.41

ABSTRACT

The search for the R.M.S. TITANIC is reviewed and the actual location of the wreck of the TITANIC is examined with respect to the physical location of the continental shelf edge, the continental slope and the base of the continental slope. The originally reported Mayday location and the actual wreck site are both about 600 kilometres southeast of the nearest shoreline at Cape Race in the Canadian province of Newfoundland and Labrador. As such, the wreck is well beyond the nominal 200 nautical mile limit of the Exclusive Economic Zone (EEZ) or Fishery Zone. The United States, France and Britain have all done serious scientific survey work at the site; Canada has almost entirely depended on the work of other nations for its scientific knowledge of the area.

The requirements of Article 76 of the 1982 Law of the Sea Convention, to which Canada is a signatory, are examined to define the limit to Canada's "juridical continental shelf" in the area of the site. High resolution geological data are sparse in this area, but there are reasonable bathymetric data. Canada has recently published a new contoured bathymetric map of the Tail of the Bank area. By all criteria of Article 76 the TITANIC lies within Canada's continental margin and within the juridical shelf of Canada. A detailed map of the various limits is provided.

The Law of the Sea Treaty, the U.S. Congress' TITANIC bill, Canada's own legislation and other international laws are examined as to their ability to regulate activities at the location. Canada's rights to regulate activities over the TITANIC are examined in light of its failure to do survey work to date, its failure to exercise direct jurisdiction or to even observe during the U.S. and French TITANIC expeditions. Four options for Canada are discussed: regulation of salvage, shared rights to artifacts, historical preservation and international control.

Canada is seen as the only nation with any possible jurisdiction in the policy vacuum. This paper does not discuss or promote Canada's fifth option; to do nothing but address diplomatic notes to foreign parties.

INTRODUCTION

It may well be that Canada's greatest contribution to the lore and knowledge of the R.M.S. TITANIC is the epic poem of E.J. Pratt (1935) or the recovery of its dead by the cable ships MINIA and MACKAY BENNETT out of Halifax and by the MONTMAGNY dispatched from Sorrell, Quebec by the Canadian Department of Marine and Fisheries. Halifax may best be remembered as the grave site of about 150 of the TITANIC's victims. Halifax and Canada will not be remembered as the home of the oceanographic and naval vessels or of the technology which went out and

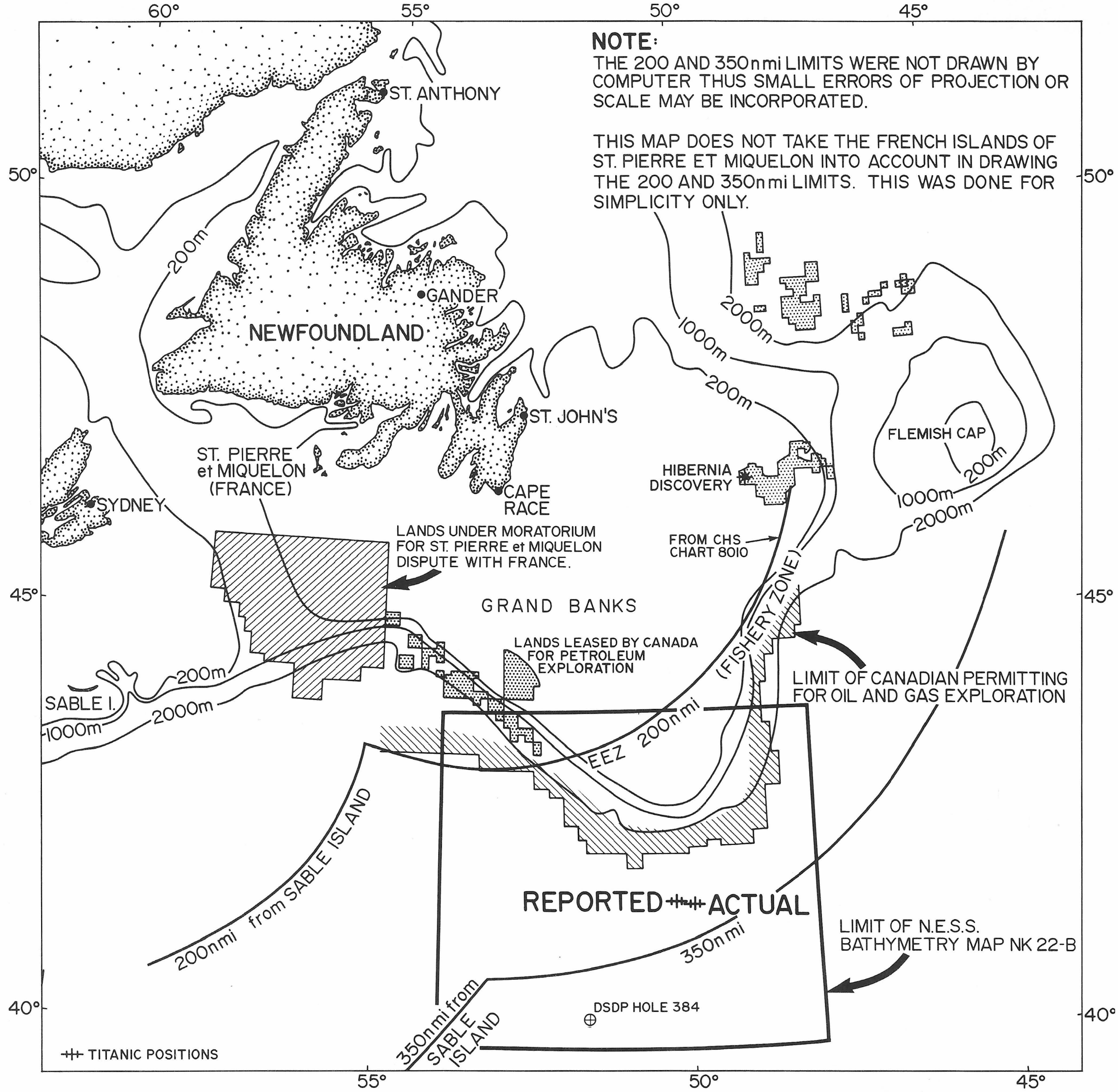

Figure 1: Reported and Actual Position of the TITANIC Relative to the Grand Banks

searched for and found the TITANIC between 1978 and 1985, its exploration in 1986, and its artifact salvage in 1987. Canada to date has not contributed to the protection of the site.

As the TITANIC set out on her maiden voyage from Southampton, England to New York just after midday on Wednesday, April 10, 1912 she was, at 892.5 ft (272 m) length overall, with a beam of 92.5 ft (28.2 m), a keel to boat deck height of about 100 ft (30.5 m), a gross tonnage of 46,238 tons and with a displacement tonnage of 52,310 tons, the world's largest and most luxurious liner; even by today's standards the TITANIC is quite a large vessel. Yet about 110 hours later the TITANIC lay broken in two and scattered on the floor of the Atlantic in close to 12,450 ft (3,795 m) of water on the continental rise south of the Grand Banks of Newfoundland, the victim of a collision with an iceberg (Figure 1). Of the 2,201 persons on board only 711 survived leaving at least 1,490 persons as victims (British inquiry figure; figures vary up to 1,522 dead).

The TITANIC disaster provided valuable lessons in marine safety and vessel design. It prompted the formation of the International Ice Patrol and led to the full acceptance of the wireless for communication. It also scored the psyche of America (and Europe) perhaps as does the loss of any leviathan, when the technology fails to perform or is overpowered; the TITANIC, the Hindenburg zeppelin, the Ocean Ranger, the Challenger spacecraft. Myths grew up and controversy continued to surround the event such as that of the role of the vessel CALIFORNIAN and its captain Stanley Lord.

The reopening of the discussion of the CALIFORNIAN's role (Padfield, 1965; The Mercantile Marine Service Association, 1968) led to a realization by many that the TITANIC's official position given out by wireless on the night of the disaster was incorrect and was too far west. The C.Q.D. or Mayday signal, which was first sent by the TITANIC (call sign MGY) at about 0015 ship's time April 15, 1912 was 41°46'N, 50°24'W; 10 minutes later this was corrected to 41°46'N and 50°14'W and was heard by Cape Race, the CARPATHIA and the YPIRANGA. The 41°46'N, 50°14'W position has thus remained as the official reported position of the wreck for some 75 years (Figure 1).

This paper will examine the position of the wreck of the TITANIC vis-a-vis Canada's juridical shelf and the limit of the continental margin of Canada as defined by Article 76 of the 1982 United Nations Convention on the Law of the Sea (and we would assert that customary international law, that is, law outside the convention regime, accords with Article 76. We will continue to make reference to Convention provisions for easy reference). We will then examine the legal jurisdiction at the site of the wreck's several sections and over the related debris field.

THE SEARCH

Many have the impression from the American-dominated media that the Americans found the TITANIC. It is true that very early on September 1, 1985 the KNORR of the Woods Hole Oceanographic Institution (WHOI), trailing a video-camera package with the acronym of 'ARGO', finally captured the now-famous frame with the boiler lying on the ocean floor. However, the KNORR's work was only a part of a Franco-American expedition wherein the French survey vessel N/O LE SUROIT of l'Institut Francais de Recherche pour l'Exploitation de la Mer (IFREMER) had spent July 1 to August 9, 1985 steadily swath-mapping the ocean floor using the deep-towed French SAR side-scan sonar. Indeed, co-chief scientist Jean-Louis Michel of IFREMER was the chief watchkeeper at the controls of ARGO on the KNORR at the moment of discovery, and Robert Ballard, the WHOI co-chief scientist, was off watch and in his bunk at that moment.

We should all recognize that the successful IFREMER-WHOI search was, like most science, the result of an accumulation of knowledge and data - plus good gear and crew, hard work and perhaps a little luck. Peter Padfield (1965) deserves the first credit for his analysis of positions of the TITANIC and the various rescue vessels. Certainly the likes of James McFarlane of International Submarine Engineering Ltd. of Port Moody, British Columbia, built on Padfield's analysis in his assessment of the true position and in his search proposal (1974) made to the Canadian Broadcasting Corporation. John Gratton was clearly using some of the same analysis in Christopher Dobson's documentary in NOW magazine (1979) as was Douglas Woolley in Elston (1982) and as was Ruffman (1982). John Pierce of Wales who went out and relocated and then salved the LUSITANIA had a similar analysis of position (personal communication February 8, 1984, Salem, New Hampshire).

The site of the official reported position (41°46'N, 50°14'W) became a magnet for oceanographers. At least two WHOI, two reported U.S. Navy and one Lamont Doherty Geological Observatory cruises all went through the area, perhaps looking for a tell-tale, 100 foot high, sharp bump on an echo sounder. The French on CHARCOT Ch 06 in 1969 had a look. One of the standard oceanographic sections runs right down 50°W and a map of all stations from Canada's Marine Environmental Data Service (MEDS) shows that a very large number of foreign and a lesser number of Canadian vessels have traversed the area taking bottle casts and bathythermograph stations.

The first bottom work at the site was that of Al Chandler and Emory Kristof of the National Geographic Magazine in April of 1978. They did two boomerang camera stations from the U.S. Coast Guard Cutter EVERGREEN and demonstrated 100 feet (30.5 metres) of visibility with low currents at the site (personal communication, Emory Kristof, May 26, 1987; Ryan and Rabushka, 1985). Then the British on DISCOVERY Cruise III, Leg 2 passed through the area in July 1980, towing their low-frequency swath-mapper GLORIA. GLORIA was run in 3 trapezoidal boxes through the TITANIC area and with its very broad range almost certainly insonified the TITANIC. However, GLORIA is a low-frequency tool and has a very low ping rate and cannot resolve features much better than to a 1:250,000 scale; the TITANIC was not seen on this long-range side-scan sonar instrument. However, the Titanic Canyon and various drainage channels on the continental rise were seen and mapped (personal communication, Peter M. Hunter, Institute of Oceanographic Sciences, Godalming, England, May 19 and June 12, 1987; I.O.S., 1980). Canada has never worked in the area (Atlantic Geoscience Centre, 1984) except for a recent 1987 geological/geophysical cruise on CSS HUDSON.

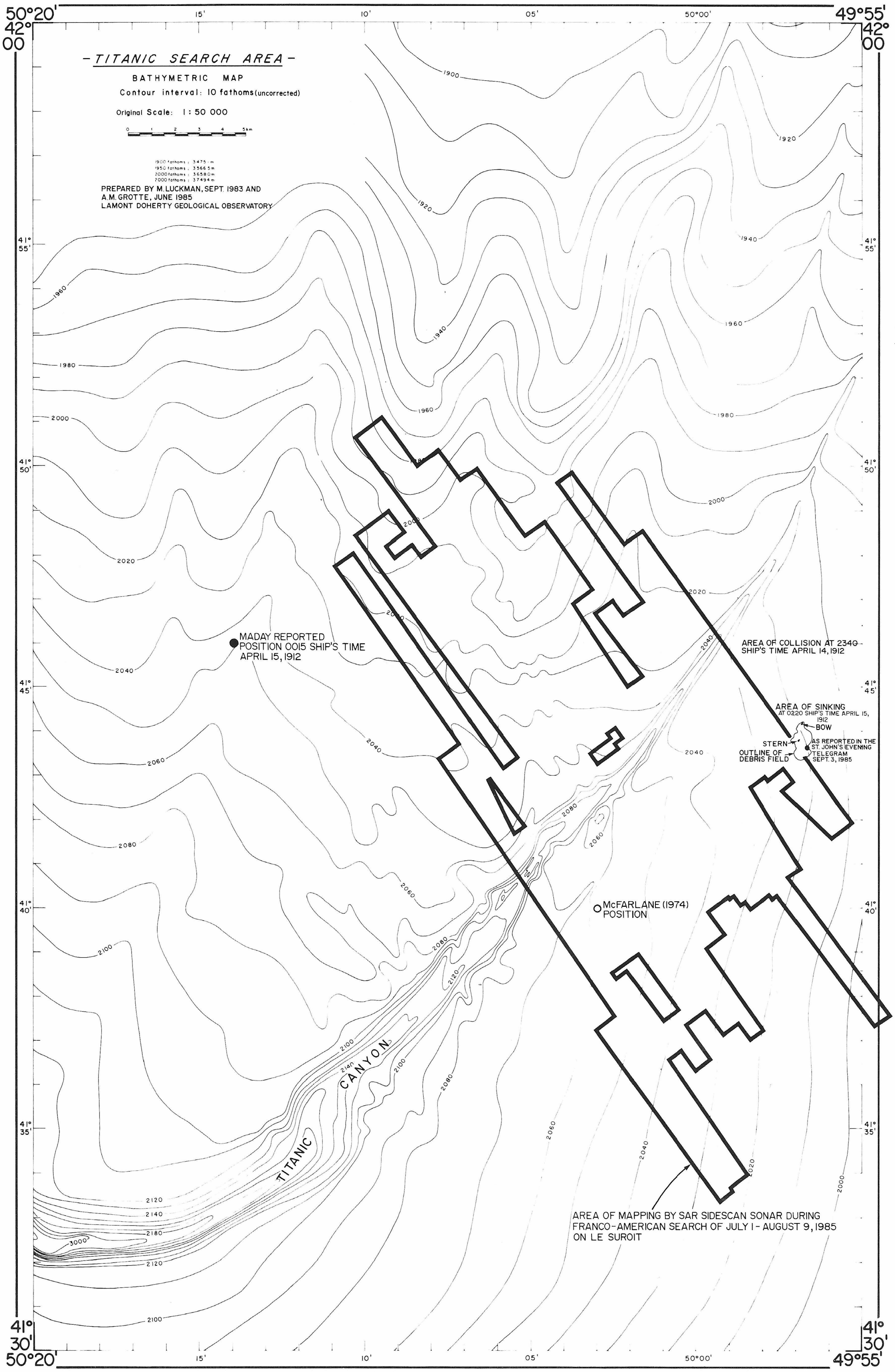

Figure 2: Bathymetric Map of Grimm Search Area

The first searches with a serious chance of success were those financed by the Texas Oil entrepreneur Jack Grimm of Grimm Oil Company in Abilene, Texas. Grimm entered into various agreements with the Lamont Doherty Geological Observatory of Columbia University (LDGO) (and indirectly with Scripps Institution of Oceanography of the University of California). William B. F. Ryan of LDGO along with Fred Speiss of Scripps variously organized three cruises to the TITANIC area (Ryan, 1983b; 1985) on behalf of the three investor-formed corporations. TITANIC '80, Inc. used the Tracor vessel H.J.W. FAY in 1980 and a prototype swath-mapper known as SEAMARC I to map a large area around the official reported position and to the east (Ryan, 1980; 1983b; Ryan and Speiss, 1984). TITANIC '81 Inc. returned in 1981 on board R/V GYRE of Texas A and M University for further bottom mapping (Ryan, 1982; 1983b) and again TITANIC '83 Inc. returned for a brief program in the area on board LDGO's R/V CONRAD (Ryan, 1983a; Ryan and Champeau, 1983). Hoffman and Grimm (1982) wrote a book on the first two year's of work with the prophetic title "Beyond Reach"; Grimm was never able to confirm that his efforts discovered the TITANIC though when the LDGO side-scan data are re-examined it may well be that, with hindsight, the TITANIC can be seen as a formerly unrecognized reflection or shadow.

The Grimm data was all put in the public realm in a timely manner by LDGO after each year's data were worked up and reported on (Ryan, 1985). All data were made available to John Pierce of Wales, who was considering an expedition in 1983-84 (personal communication, John Pierce, February 1984). When WHOI and IFREMER were planning their 1985 expedition a full copy of the LDGO-Scripps data was provided to WHOI (Ryan, 1985) and the full Grimm data was personally reviewed by Jean-Louis Michel of IFREMER in conjunction with William Ryan of LDGO before LE SUROIT's cruise began (personal communication, W.B.F. Ryan, 1985).

The Franco-American expedition of 1985 clearly profited from the Grimm surveys and avoided needless repetition of certain areas, especially to the west; LE SUROIT did not even survey the area of the reported position (figure 2). Time was lost to heavy seas (Ryan and Rabushka, 1985) and eventually time for LE SUROIT ran out without success. As it turned out the northeasternmost swath of the SAR missed the TITANIC on its outermost edge by about 20 metres and passed over a portion of the debris field, but did not recognize the small targets (personal communication, Rick Chandler of WHOI at Ocean's Forum, Sidney, B.C., September 15, 1986).

With LE SUROIT of IFREMER having mapped and eliminated 80% of the defined search area the KNORR of WHOI took over and began to systematically tow the ARGO camera package along the northeast extension of the LE SUROIT's survey area until the September 1, 1985 discovery was made (figure 2). KNORR had exhausted 80% of its allotted time and the discovery came just in time to allow the spectacular photos of September 1985's newspapers to be ferried by helicopter back to St. John's, Newfoundland. However, the exact position was kept a carefully guarded secret.

The detailing of the wreck concluded after a few days in September, 1985 and the KNORR and the crew returned to their home port of Woods Hole for the well-deserved accolades (Oceanus, 1985; TITANIC Historical Society, Inc., 1985a; b; Ballard and Michel, 1985; Lauzon, 1986). The French-American joint venture apparently collapsed almost immediately and in 1986 WHOI alone returned to the site with the R/V ATLANTIS II with her submersible ALVIN and its tethered remotely-operated vehicle JASON Jr. for another photographic feast over 11 dives (Ballard, 1986; 1987a; b). In the summer of 1987 the French returned on the NADIR with their deep-diving submersible NAUTILE for the British-registered consortium Oceanic Research and Exploration Ltd. Forty-six days were spent on site with over 22 dives accomplished and more than 300 objects recovered for preservation and eventual museum display and touring; the sponsors have indicated that the artifacts will not be put up for sale, though some television revenues are clearly anticipated. The French, too, have not given out the exact location of the wreck.

THE EXACT LOCATION OF THE TITANIC

Neither WHOI nor IFREMER gave out the wreck's exact position in the first two years after the discovery. Fairly elaborate precautions were taken, from reporting the KNORR's daily position as always at the official reported position, through to altering the location map to show the wreck slightly mis-located in relation to Titanic Canyon in the first National Geographic article (Ballard and Michel, 1985). Ryan and Rabuska (1985) reported that as KNORR was preparing to head home on September 5 or 6, 1985, "... an aircraft appeared overhead and circled for more than an hour. It had no identification markings. Ballard believes it was taking a navigational fix on the TITANIC's position, the exact co-ordinates of which he has kept secret."

In fact no one need have gone to such trouble since the coordinates were already out having been published on Tuesday, September 3, 1985 with a reasonable degree of accuracy in the St. John's, Newfoundland, Evening Telegram (Anonymous, 1985). Two helicopter flights were flown from St. John's to the KNORR to remove videotape and photos while it was

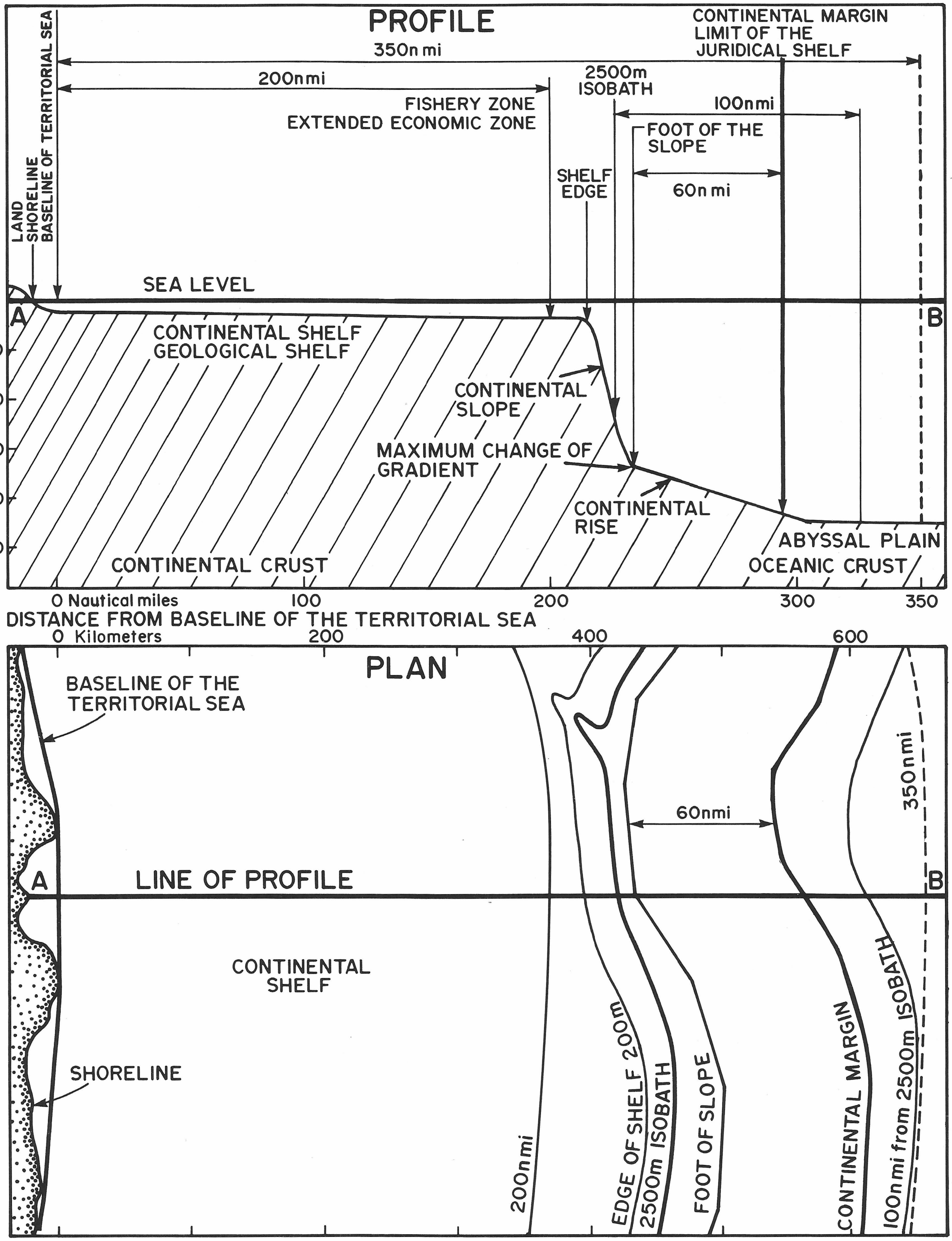

Figure 3: Lines Required by Article 76 of Law of the Sea to Determine Continental Margin

on the TITANIC site, with a third as the vessel began to steam home September 6, 1985. Understandably the helicopter crew were concerned about positioning. The aircrew of Sealand Helicopters Ltd's. Super Puma was provided only the official reported position for their flight. After the first flight on Monday, September 2, 1985 The Evening Telegram gave the flight front page coverage and stated (p. 1, col. 1), "One major problem encountered by the crew of the helicopter was getting [the] exact location of the navy ship [KNORR]. The crew had been given a location 41°46'N, 50°14'W, but the actual location was 41°43.6'N, 49°56.7'W, a difference of 13 [nautical] miles." (In fact, the actual location of the TITANIC is 13.2 n mi; 15.2 st mi; 24.48 km to the ESE of the official reported position.)

This position may be checked using IFREMER's SAR side-scan mosaic (1986) and their bathymetry map with sedimentary features added (Cochonat and Ollier, 1986) along with the depths of 12,400 or 12,500 ft (3780 to 3810 m) which were variously given out (ignoring the 13,000 ft or 2167 m depth which was occasionally used and which is clearly incorrect). The helicopter position plots exactly along the northeast margin of the IFREMER side-scan mosaic.

To find the TITANIC one need only survey NW-SE along the northeast margin of the IFREMER survey area on their side-scan mosaic (Figure 2) to the east of Titanic canyon. Sophisticated gear may not be needed; Ryan and Rabuska (1985) report that after the first discovery of debris by ARGO and during a repair to the sled, "... an ancient [survey] fathometer at work on the KNORR, similar to a fishing boat's fish finder or echo sounder, returned the first clue as to the exact whereabouts of the TITANIC's massive hull." (See also Uchupi, 1988 figure 3 for a 12 kHz echogram over the bow section.) It has also been reported that the bow section points NNE (personal communication, Rick Chandler of WHOI at Ocean's Forum, Sidney, B.C., September 15, 1986) and is about 130 m long. The stern section lies some 600 yd astern of the bow section and is rotated 180° with respect to the bow. The National Geographic article of December 1986 provides a two-page linear drawing of the site to scale with the unmarked grid lines probably spaced at 200 yards (Ballard, 1986).

Thus the position of the TITANIC is no longer a secret. Indeed the actual geographic co-ordinates were released in Canada at OCEANS '87 with the publication of Ballard's book on the discovery (1987) (see footnote). Anyone who wishes to, can relocate it with a minimum of difficulty and minimum of equipment. While a sophisticated visit to the wreck on the floor of the ocean is clearly only available to three or four major oceanographic nations of the world, any person with a strong winch and a long wire can now try their hand at blind dredging if they are so inclined.

DETERMINATION OF THE JURIDICAL SHELF

The Law of the Sea Treaty requires nations to define their baselines from which the breadth of the territorial sea is measured, a 200 n mi (370.64 km) Exclusive Economic Zone (EEZ) and the outer limit to their claimed continental margin or what is known as the "juridical shelf" edge. Key to determining the juridical shelf edge is determining the "foot of the continental slope" which Article 76, paragraph 4(b) defines as, "In the absence of evidence to the contrary, the foot of the continental slope shall be determined as the point of maximum change in the gradient at its base."

This definition, based as it is only on morphology (bathymetry), is fraught with interpretation difficulties as the Grand Banks - Tail of the Bank example shown here will more than demonstrate. Clearly the "point of maximum change in the gradient" was intended to be a point where the gradient reduced (rather than where the gradient increased) in the direction of the regional slope of the bottom, but does not reverse (Figure 3). It is not as clear that the point was intended to be at the "base" of the "geological" continental slope where it meets the "geological" continental rise rather than being allowed to fall at the bottom of the continental rise where it meets an abyssal plain (Figure 3). We are faced with this problem in two of our ten profiles (G and H) used to determine the foot of the continental slope off the southern Grand Banks (Figures 4, 5 and 6).

Had it been possible to persuade the drafters of Article 76's paragraph 4(b) it should have read, "..., the foot of the continental slope shall be determined <u>using marine geological horse sense</u>, as the point of maximum decrease in gradient at its base." It seems obvious that Gardiner and Robinson (1977), Gardiner (1978), Hedberg (1979) and Emery (1981) were all reaching for this sort of a definition using a certain amount of geological horse sense.

Similarly the drafters of Article 76 in requiring lines to be drawn 60 n mi (111.19 km) and 100 n mi (185.32 km) from the line at the foot of the slope (paragraph 4(a)(ii)) and from the 2500 m isobath (paragraph 5) respectively did not conceive of the deep re-entrants which can occur in these lines where the continental slope is cut by wide, deep erosional canyons. We would again advocate the use of common

Footnote:
The co-ordinates are: centre of bow: 41°43'57"N, 49°56'49"W; centre of boiler field 41°43'32"N, 49°56'49"W; stern section 41°43'35"N, 49°56'54"W. The September 3, 1985 St. John's Evening Telegram position was only 300 metres out (figure 2). Uchupi et al. (1988) later give slightly different co-ordinates and a detailed map of the wreck and the debris field.

sense and smooth these lines delineating the foot of the continental slope and the 2500 m isobath by drawing baselines using the same rules as the Law of the Sea Treaty does for drawing the baselines "from which the breadth of the territorial sea is measured" (Kapoor and Kerr, 1986) i.e., straight lines no longer than 24 n mi (44.47 km). We show one such example with dotted lines in the northeast quadrant of Figure 7 at the foot of Jackman Canyon.

Kerr and Keen (1985) developed a useful table for the interpretation of paragraphs 4, 5, and 6 of Article 76. We present a revised version of their table (page 38) with some additional steps to allow for the problems cited above. The revised table includes a small correction to the table as found in Kerr and Keen (1985) and again in Kapoor and Kerr (1986) wherein the limit of the continental margin must be within 100 n mi of the 2500-m isobath (Article 76, paragraph 5). We have also developed a diagrammatic profile and plan similar to Hedberg's (1979) figure 1 to illustrate the different components of Article 76 and Table 1 as they actually emerged in the Law of the Sea Treaty (Figure 3).

This figure and our work in this paper do not fully address paragraph 4(a)(i) of Article 76 wherein a nation is allowed to claim out beyond the foot of the continental slope to a point where the thickness of sedimentary rocks in the sedimentary wedge at the foot of the slope reduces to 1% of the distance back to the line drawn at the foot of the continental slope. Seismic profiling data are fairly thin in this area and as will be seen below such data are not necessary to establish conclusively that the TITANIC lies within Canada's juridical shelf. The 1% thickness line will be the subject of a later piece of work as will the clause in paragraph 6 of Article 76 whereby the absolute limit of 350 n mi (648.62 km), which was designed to prevent creeping jurisdiction, "does not apply to submarine elevations that are natural components of the continental margin, such as its plateaux, rises, caps, banks and spurs."

THE LIMIT OF THE CONTINENTAL MARGIN OFF THE TAIL OF THE BANK

Canada has recently produced a new, fully revised, bathymetric map in the National Earth Science Series at a 1:1,000,000 scale of the Tail of the Bank and the area to the south as far as latitude 40°N (de Loe and Warren, 1987). The new map displays the bathymetry in 100 m contours corrected for the velocity of sound (Figure 4). Ten straight profile lines were chosen so as to pass from the geological shelf down the continental slope to abyssal depths. The profiles were chosen so as to pass down the continental slope on the inter-canyon lobes and thus to avoid the confusion and anomalies introduced by crossing the deeply incised shelf-edge canyons. Even as it was, profile B crosses the head of Cameron Canyon and profiles D, E and F all cross portions of Titanic Canyon (Figure 5) as originally defined on Luckman and Grotte's map of the bathymetry from the various Grimm-sponsored searches (1983 and 1985).

Of these ten profiles only one, profile D through the TITANIC area, shows the classic and indisputable shape of Hedberg (1979) and Emery (1981) with a clear point at the "foot of the continental slope" which can "be determined as the point of maximum change in the gradient at its base" and separating the continental slope and continental rise (Figure 6). A reasonable point of maximum change of gradient can be chosen on eight of the profiles (Figures 5 and 6) but on two profiles G and H (Figure 6) there is not an obvious continental rise and there is not an obvious break in the slope gradient to mark a "foot". The most obvious break and "point of maximum change in the gradient at its base" is the change as one goes out onto the Sohm Abyssal Plain (Figure 6) at about 5000 m.

This is where we have used the "geological horse sense" we advocate in applying Article 76. Rather than choosing the two points of maximum change of gradient on Profiles G and H which are clearly at the base of the geological continental rise, we have gone back up the profiles to choose logical points at other, but lesser, changes of gradient. We have not accepted the possible alternative base of the slope shown on Figure 7. The TITANIC is well inside a line drawn 60 n mi from the foot of the continental slope (Figure 7).

The 200 n mi limit and 350 n mi limit were drawn on map NK 22-B along with a line 100 n mi from the smoothed 2500 m isobath. Computers were not used thus there may be small errors incorporated because of the projection and scale. Kapoor and Kerr (1986) caution that "great care should be taken to draft these limits" and recommend using proper geodetic calculations. They note, "It will be more accurate to calculate specific points along the lines than to attempt to draw them graphically on charts" (p.64). The TITANIC is well inside the absolute limit of the line drawn 100 n mi from the 2500 m isobath. It is also about 25 n mi (46 km) inside the absolute limit of the 350 n mi line (Figure 7).

The limit of the Continental Margin of Canada off the Tail of the Bank is made up of portions of three lines. In two places the limit defined by the line drawn 100 n mi from the foot of the slope must be reduced to the lesser limit defined by the 350 n mi limit or the 100 n mi limit from the 2500 m isobath (Figure 7). The indisputable outer limit of the continental margin as drawn on Figure 7 has not been drawn in 60 n mi straight line segments as required by paragraph 7 of Article 76. By the time Canada formally submits its information on the limits of the continental shelf beyond 200 n mi to the

Commission on the Limits of the Continental Shelf set up under Annex II as required in paragraph 8 of Article 76, we may expect a new edition of bathymetry map NK22-B and our determinations may well be refined. The final limit to the continental margin must be finally listed as a series of fixed points, defined by co-ordinates of latitude and longitude. While the Law of the Sea Treaty appears not to address the datum to be used, we would advocate that NAD '85 should be used and that with future changes of the worldwide horizontal datum, the fixed points of a boundary would be simply transformed to the new datum and given new slightly adjusted co-ordinates.

Regardless of any changes that may come with the refinement of the lines drawn in this analysis the R.M.S. TITANIC clearly lies within the continental margin of Canada and lies on the juridical shelf of Canada.

OTHER GEOLOGICAL CONSIDERATIONS

As noted earlier, this paper does not attempt to deal with "the 1% thickness line", partly because it is not necessary to define the TITANIC's position on the juridical shelf and partly because data on sediment thickness are scarce. Grant (1977 and 1979) has analysed seven participation deep seismic lines that

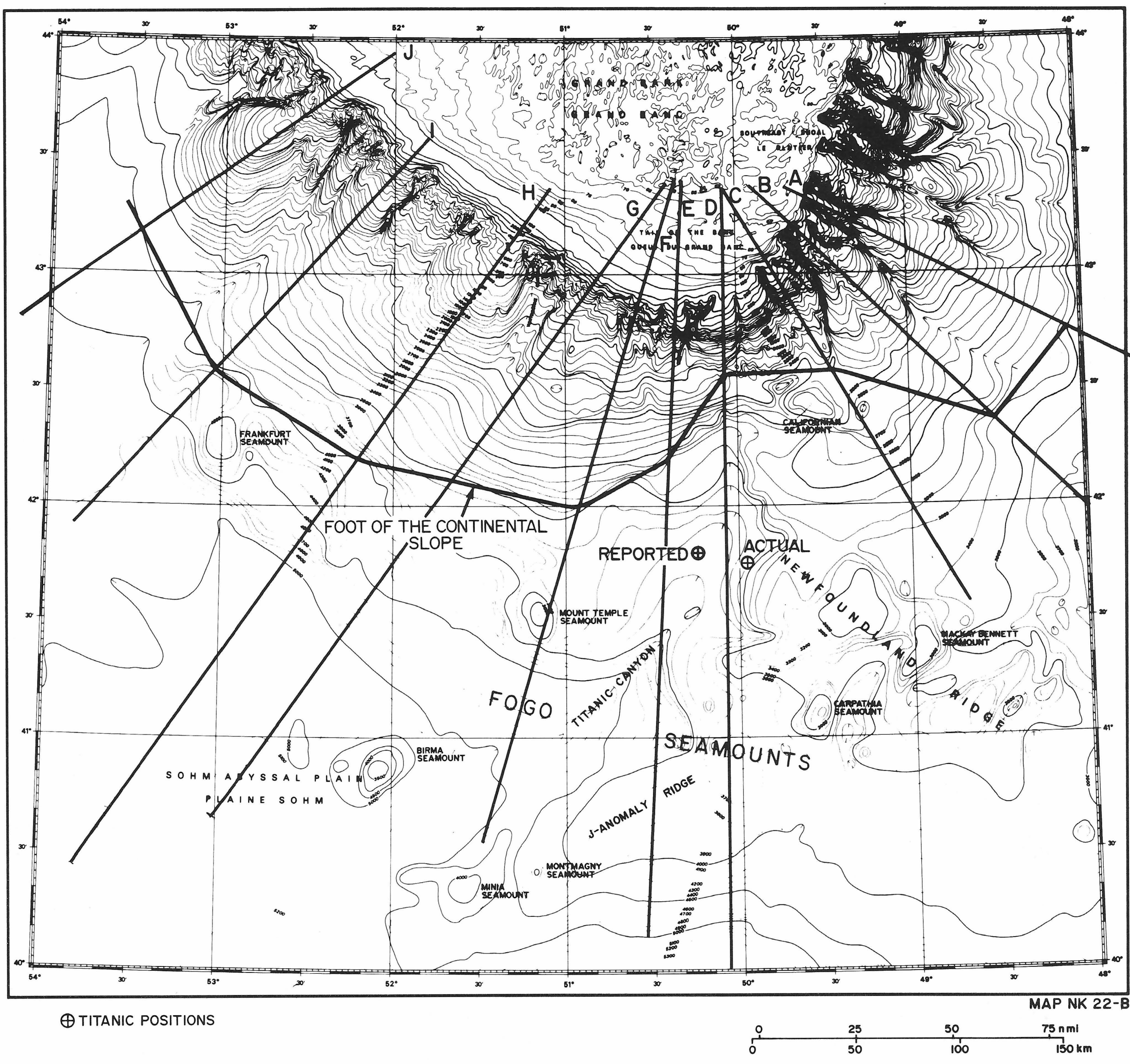

Figure 4: Profiles Used to Determine the Foot of the Continental Slope

ran well beyond the foot of the continental slope out onto the J-Anomaly Ridge and the Newfoundland Ridge. Grant (1977) concluded, "The Newfoundland Ridge, therefore, is interpreted as an area of subsided continental crust rather than a ridge of oceanic crust. The J magnetic anomaly intersects this complex, and the physiographic ridge associated with this anomaly may also be continental in origin." These two physiographic features are seen on figures 4 and 7. We have added to figure 7 Grant's line showing the maximum extent of sedimentary rocks inferred on the basis of physiography and Grant's seismic. No isopach map of the sedimentary rocks on these two physiographic features or elsewhere along the margin has been constructed, thus the 1% thickness line cannot yet be constructed in the area of the TITANIC south of the Tail of the Bank.

Grant's suggestion that the Newfoundland Ridge is "an area of subsided continental crust" leaves open the possibility that Canada may choose to extend its continental margin beyond 350 nautical miles in this area under the provisions of paragraph 6 of Article 76. A more detailed understanding of continental breakup and subsequent drift in this area will lead to a better understanding of whether the Newfoundland Ridge (or the J-Anomaly Ridge) "are natural components of the continental margin" of Canada (or for that matter of northern Africa or of southern Spain and Portugal).

Regardless of these future understandings and adjustments to Canada's limit of the continental margin, the TITANIC will continue to lie on Canada's juridical continental shelf. A number of legal ramifications flow from this fact.

WHO THEN HAS WHAT RIGHTS OVER THE WRECK AND ITS ARTIFACTS?

The legal situation regarding the wreck of the TITANIC has all the makings of a wonderful law school exam question. A British-registered ship sinks in International waters 75 years ago (in April 1912), taking with it over 1500 people and (according to rumour) millions of dollars in jewels and artifacts. The wreck is discovered by an American scientific expedition which, supported by the U.S. Congress, seeks to have the site protected. A subsequent French scientific expedition recovers a number of artifacts from the site of the wreck and opens a potential Pandora's box. It is possible that further expeditions will explore the wreck for commercial purposes. Certainly, it would be neither difficult nor outrageously expensive, but profitable, to do so.

One could further complicate the issue by reference to admiralty law, in particular the law of salvage. The appropriate principles here are summed up thus: "finders keepers, sleepers weepers." In other words, if you find something, you should take it, if you sit on your rights you will lose them. Some survivors from the TITANIC, and descendants of those who lost their lives in the disaster, might lay claim to some of the artifacts which may be recovered. What rights, if any, do they have? Or, assuming that these treasures were insured and payments made under appropriate insurance policies, what rights have these insurance companies, if still in business, acquired by way of subrogation?

A recent British decision concerning rights to salvaged contents of the LUSITANIA, sunk in 1915 by a torpedo from a German submarine, may be a bad omen for such claimants. In Pierce v. Bemis [1986], 1 All E.R. 1011 (Q.B.D.), the court, in deciding whether the Crown or private salvors had rights to contents of the LUSITANIA found outside British territorial waters, indicated that after a lapse of 67 years the original owners of the contents should be considered to have abandoned their property. The court found in favour of the salvors since none had a better title than their possessory right.

For Canada, the basic question is whether it wishes to sit back and see a free-for-all developing over the TITANIC and its treasures. If there are no strong feelings one way or the other, then Canada should continue to follow its present course - doing precisely nothing, except sending diplomatic notes to other potentially interested governments. However, if Canada wishes to do something to prevent unrestricted exploitation of the TITANIC, what options are available?

We can turn this question around a bit by asking a more general one - assuming that it has been decided that subjecting the wreck of the TITANIC to "grave robbers" is undesirable, who has the jurisdiction, actual or potential, to do anything about it? One answer is - Canada.

The only connection this country has with the TITANIC is the fact that the extension of seabed mineral rights formulated by international law (and given expression by Article 76 of the 1982 United Nations Convention on the Law of the Sea) changed the status of the TITANIC's resting place so that it now forms part of Canada's ("legal", not "geological") continental margin. But over this area Canada exercises only sovereign rights to explore and exploit natural resources (Article 77 of the Convention) and to regulate marine scientific research. The Convention fails to deal directly with the status of wrecks on the continental shelf and only has two provisions dealing with archaeological or historical finds. Article 149, which provides that objects of an archaeological and historical nature found beyond the limits of national jurisdiction must be preserved for the benefit of all mankind, does not cover the TITANIC situation since the TITANIC lies on the Canadian continental margin. Article 303, which gives states a

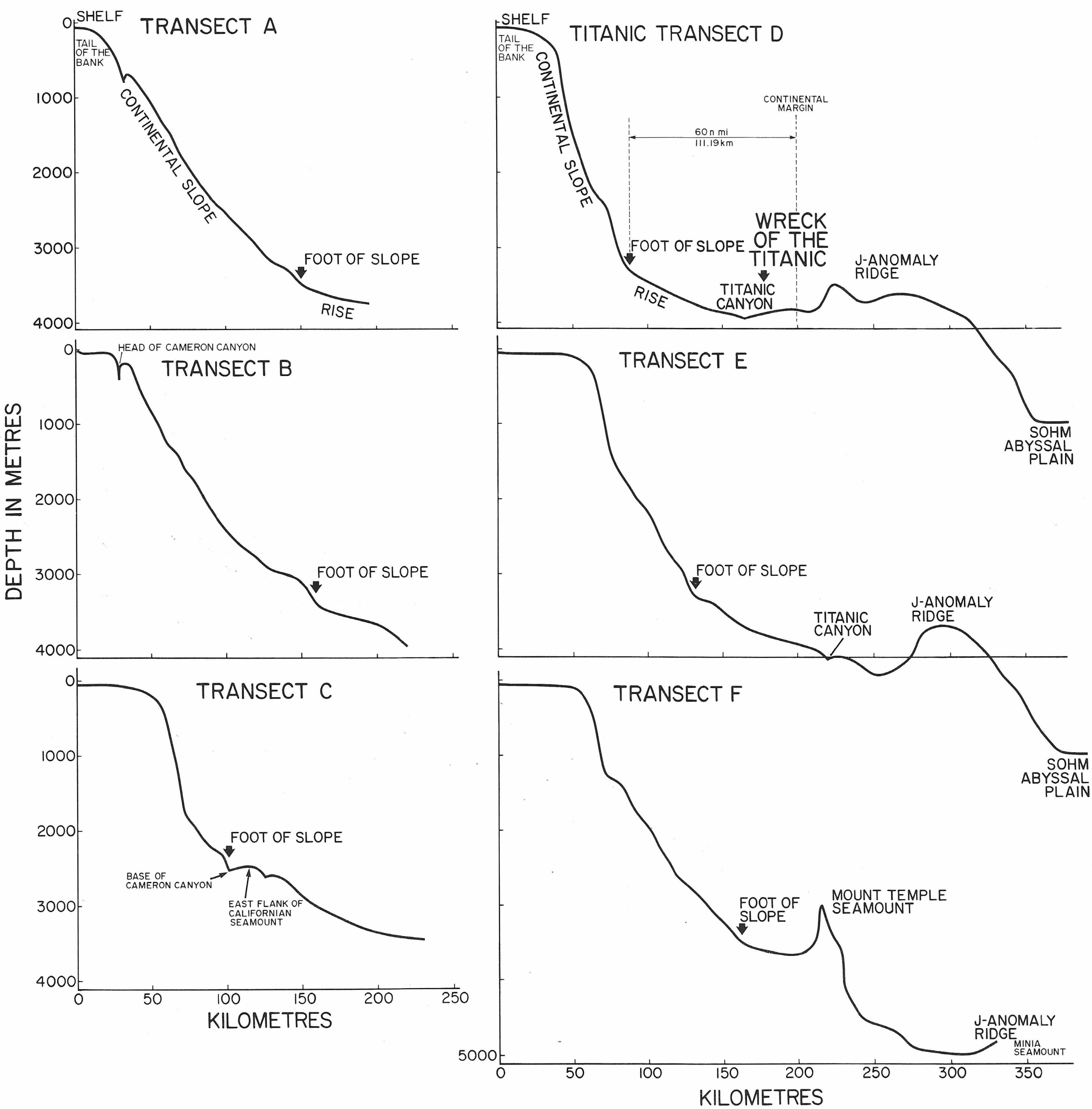

Figure 5: Bathymetric Profiles A, B, C, D, E and F Showing Foot of the Continental Slope

general duty to protect archaeological and historical objects found at sea, allows a coastal state to regulate removal of objects from waters of the contiguous zone (out to a maximum of 24 nautical miles from the territorial sea baselines), but is silent as to regulatory rights in the other national zones - the Exclusive Economic Zone and the continental shelf.

Another uncertainty is the extent of regulatory control granted by Article 246 to the coastal state over marine scientific research on the continental shelf. Do the activities of underwater photography and side-scan sonar documentation of wreck sites or salvage constitute marine scientific research on the continental shelf? If so, the Convention would require coastal state consent which must be given in normal circumstances. Article 246(5) allows a state to withhold consent if marine research "is of direct significance for the exploration and exploitation of natural resources, whether living or non-living". Arguably, a shipwreck is not a natural resource but a human-created construct. So what can Canada do, always assuming that, on a matter of policy, it has been decided to do something.

One answer to this question is to build on the protective principle outlined above and consider developing rules of international law to cover the situation of the TITANIC and other wrecks. A useful parallel is the doctrine of the continental shelf itself. Continental shelf rights evolved from 1945 onwards because coastal states wished to avoid a free-for-all on the shelf: a "perilous scramble", as Lord Asquith termed it in an early (1950) continental shelf case, the Abu Dhabi Arbitration. The only alternatives to anarchy were either concerted international action (not a viable possibility in the 1940s and 1950s), or placing the resources of the shelf under the jurisdiction of the adjacent coastal state. The latter course was followed.

Surely it is at least arguable that the same principle might be applied to wrecks on the continental margin? Again, there are only two alternatives to a free-for-all: international action or the jurisdiction of the adjacent coastal state. The coastal state would be a logical choice simply because it already has jurisdiction on the continental margin for other purposes including the right to explore and exploit the seabed and to regulate marine scientific research.

However, it might be argued, this would further interfere with the freedom of the seas and the rights of others. However, the "freedom of the seas" is a concept dealing with rights of navigation, which would not be affected here. It is difficult to see whose rights would be adversely affected by such a move on Canada's part. As with the development of continental shelf rights, an extension of jurisdiction as outlined above might restrict the rights of some individuals, but would not affect the rights of other states. In international law, this is all important.

It does not follow, of course, that Canada should claim complete ownership of the TITANIC. This would not be necessary, any more than it was necessary for coastal states to claim ownership of the continental shelf after 1945 (international law only allows coastal states certain rights on the shelf for the purposes of mineral exploration and exploitation).

At least four major policy options appear to be open to Canada as to the scope of rights claimed:

1. Regulation of Salvage: Canada could require all potential salvors to obtain a Canadian permit

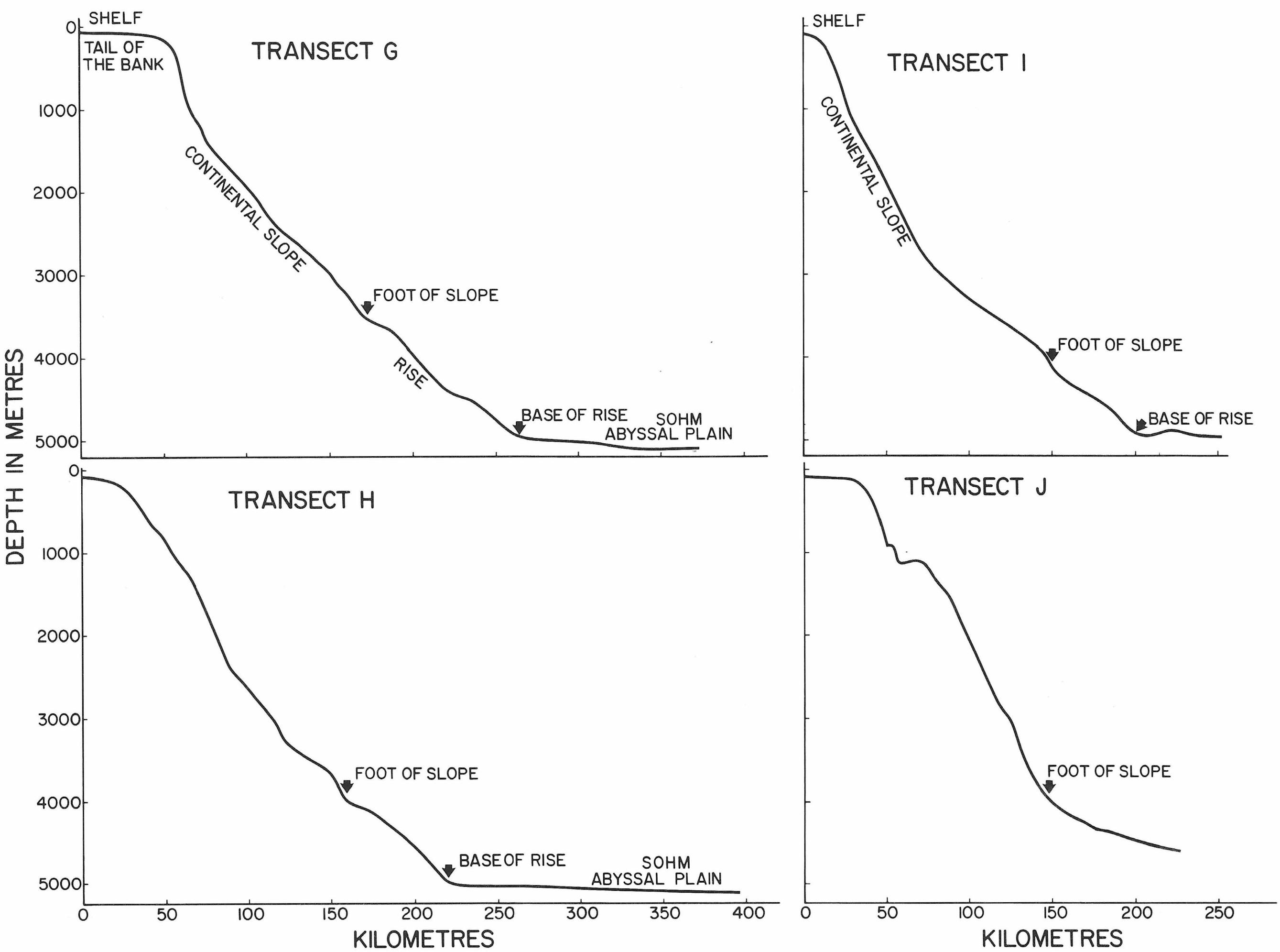

Figure 6: Bathymetric Profiles G, H, I, and J Showing Foot of the Continental Slope

which would only be given if a number of requirements were met such as the salvor being a reputable educational, governmental or scientific organization or the venture being supervised by a qualified marine archaeologist.

2. Shared Rights to Artifacts: Besides regulating the right to regulate salvage operations, Canada could claim the right to a certain share of the objects recovered for display in Canadian museums.
3. Historical Preservation: Canada could prohibit all salvage activities in a designated geographical area around the TITANIC and could regulate scientific investigations to assure the avoidance of damage to artifacts or to the hull. Canada might also require active participation in scientific projects and assure full disclosure of all research findings.
4. International Control: Even if Canada were to make a unilateral claim to jurisdiction over the TITANIC in order to secure short-term protection, Canada could also seek to negotiate an international framework to protect or salvage the vessel. The United States has already indicated a preference for international protection of the wreck site by passing the R.M.S. Titanic Maritime Memorial Act of 1986 (Public Law 99-513). The Act encourages international efforts to establish an international agreement designating the TITANIC as an international maritime memorial in order to protect the scientific, cultural and historical significance of the vessel and directs the Secretary of State to enter into negotiations with the United Kingdom, France, Canada and other interested nations. There has to date been no success with this initiative.

Canada has been a leader in developing the law of the sea in the past through such measures as invoking a 100-nautical mile pollution prevention zone in arctic waters and subsequently pushing for inclusion of the ice-covered waters provision (Article 234) in the 1982 United Nations Convention on the Law of the Sea. Once again Canada is faced with a creative opportunity to unilaterally forge new legal principles to protect important national and international interests.

However, the legal choice may be exceedingly difficult. While unilateral extension of jurisdiction over the TITANIC offers the opportunity to shut the lid on desecrations of an historic maritime site for private gain, a broadening of Canadian jurisdiction over the continental shelf might be viewed by other states as a form of "creeping jurisdiction". Not all states would necessarily accept a Canadian claim to extend functional jurisdiction, and Canada might be faced with having to enforce a new legal regime. Given existing maritime jurisdictional disputes with France over the offshore boundaries of St. Pierre and Miquelon and with the United States over the legal status of the Northwest Passage, Canada may be extremely hesitant to stir-up an additional jurisdictional conflict.

Of course Canada could express its intention to protect the site of historic wrecks in such a way that it would appear more like an invitation to other coastal states to do likewise, rather than throwing down the jurisdictional gauntlet. Confrontation with other countries could be avoided by floating a trial balloon by way of a suitably worded ministerial statement rather than by proceeding at once to legislation.

Perhaps the only factor that could change the Canadian position would be a strong voicing of public opinion that Canadians are willing to accept the opening of a new Pandora's box to close another.

CONCLUSION

Although we have focussed on the TITANIC, much of what we have had to say concerning the possible development of international law to protect the sites of marine disasters is applicable to all wrecks, especially those "time capsules", wrecks of historic interest. The point is, international law has, to some extent, ignored the transnational legal problems arising here.

International law is a dynamic, not static, concept. It depends on state initiatives for new development. Arguably, a new development may be required to protect wrecks. We are not arguing that such a step should be taken, but should perhaps be considered by Canada - and other countries. Marine archaeological advocacy is beyond the scope of this paper. Rather, we have attempted only to show how wrecks such as that of the TITANIC may be protected, once the policy decision in favour of such protection has been taken.

Too often, we assume that international law (or domestic law) has answers for everything. This is mistaken. The Law of the Sea Convention does not address each and every aspect of the law of the sea and maritime jurisdiction. The present legal uncertainty surrounding the TITANIC is proof of that. Such uncertainties can be resolved, at some risk. Developing new rules of international law involves sticking your neck out. As regards the TITANIC, the only legitimate neck (in the absence of appropriate international action) can only be that of Canada.

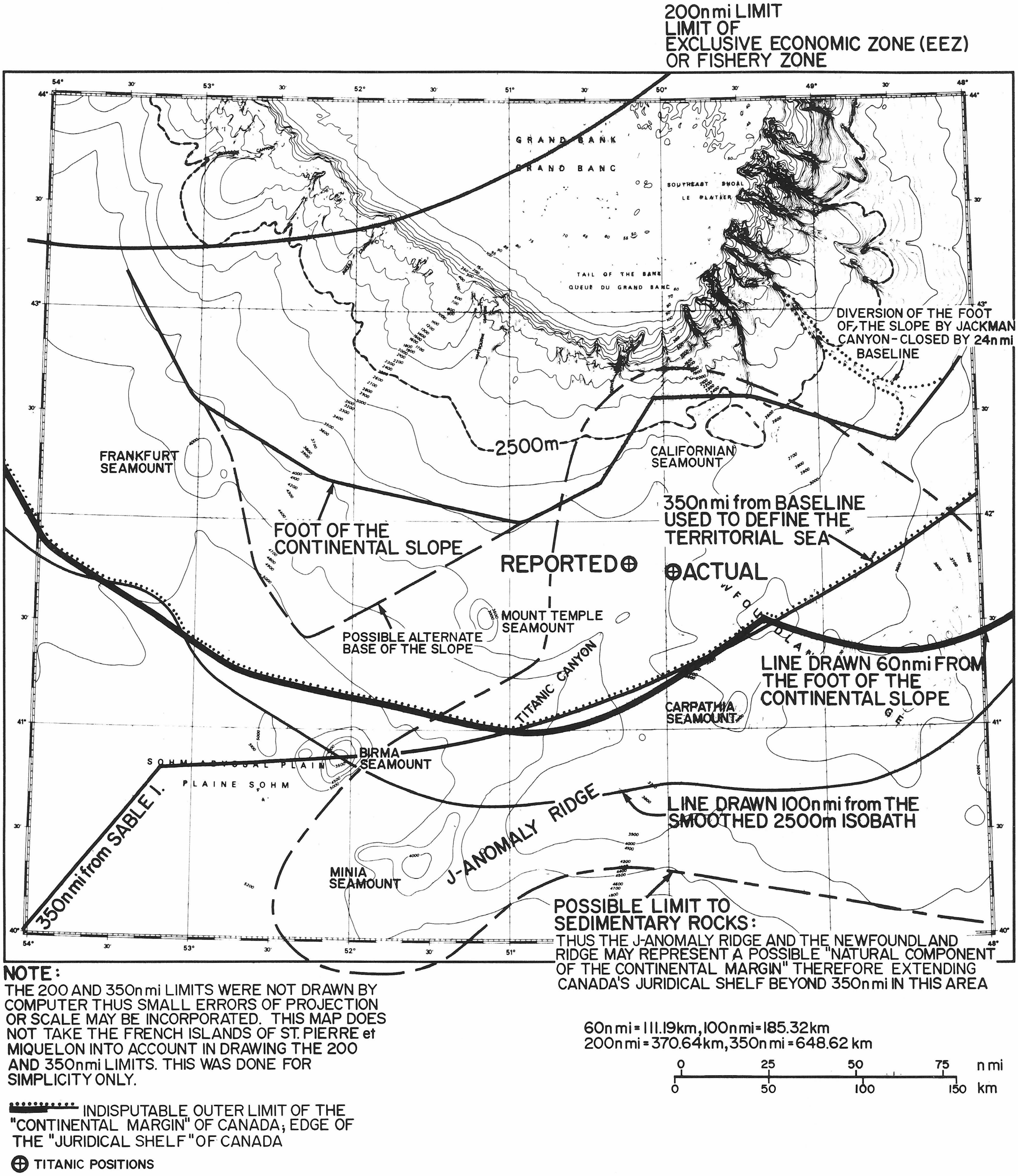

Figure 7: Interpreted Bathymetry Map Showing Lines Defined in Article 76 of Law of the Sea Treaty

Table 1
Practical Sequence of Tasks to Locate the Juridical Shelf Edge or Outer Limit of the Continental Margin
(modified from Kerr and Keen, 1985; Kapoor and Kerr, 1986)

1. **Determine:**
   a. baselines (the low water line as marked on large-scale charts) from which the breadth of the territorial sea is measured
   b. 200 and 350 nautical mile lines from the baselines.
   c. 2500 metre bathymetric isobath.
   d. baselines along 2500 metre isobath with maximum baseline 24 nautical miles in length across the mouths of canyons incised into the continental slope.
   e. 100 nautical mile line beyond the 2500 metre isobath baseline.
   f. which representative straight line profiles will be chosen for analysis to pass from geological shelf edge to abyssal depths. Avoid, as much as possible, disruptive topographic features such as canyons and isolated highs. No straight line segment between points on the final line, drawn 60 nautical miles from the line drawn at the foot of the continental slope, can be longer than 60 nautical miles.
   g. the foot of the slope (this is the point of maximum decrease in gradient at the base of the continental slope). Smooth the line along the foot of the slope using baselines up to 24 nautical miles long.
   h. 60 nautical mile line beyond the foot of the continental slope.
   i. the points where the ratio x=(sediment thickness/distance to foot of slope)=0.01.

2. **Then, a coastal state may claim the furthest of:**
   a. 200 nautical mile line (Exclusive Economic Zone or EEZ).
   b. 60 nautical mile line beyond the foot of the continental slope.
   c. line joining points where ratio x=0.01 (1% thickness line).
   d. some combination of 2.a., 2.b., and 2.c.

3. **This claim must be within:**
   a. 350 nautical mile line, or
   b. line drawn 100 nautical miles beyond 2500 metre isobath.

4. **Unless:**
   a. a submarine elevation is a natural component of the continental margin (plateau, rise, cap, bank, spur). In this case 350 nautical mile limit does not apply.

Five minutes more, the angle had increased
From eighty on to ninety when the rows
Of deck and porthole lights went out, flashed back
A brilliant second and again went black.
Another bulkhead crashed, then . . .

. . . the liner took
Her thousand fathoms journey to her grave.
* * * * *
And out there in the starlight, with no trace
Upon it of its deed but the last wave
From the TITANIC fretting at its base,
Silent, composed, ringed by its icy broods,
The gray shape with the paleolithic face
Was still the master of the longitudes.

The TITANIC by E.J. Pratt (1935), p.42

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Des Barres and the Atlantic Neptune

by
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Joseph Frederick Wallet Des Barres was born in Switzerland in 1727 of French protestant (Huguenot) parents. He was educated in mathematics and enrolled in the Royal Military College at Woolwich, England, where he specialized in surveying and fortification engineering.

He was stationed in Louisbourg and Quebec during the Seven Years War. In Montreal he served as an engineer and was sent with his squadron to St. John's Newfoundland to rout the French in 1762. While in St. John's, Des Barres met Captain James Cook who was a military surveyor on the staff of Lt. Jeffery Amherst. Des Barres taught Cook control surveying and Cook, in turn, instructed Des Barres in hydrography. Between 1777 and 1783, under the direction of the British Admiralty, Des Barres compiled and printed the charts of the Atlantic Neptune. As a reward for his service, he was appointed the first Lt. Governor of the colony of Cape Breton and later as the third Lt. Governor of Prince Edward Island.

Dr. G.N.D. Evans, his biographer, describes Des Barres' work on the Atlantic Neptune as a "magnificent contribution to hydrography and a classic of the minor arts". An exhibit of the charts contained in Books I and II of the Atlantic Neptune was held recently at the Public Archives of Nova Scotia in Halifax. The purpose of the charts and indeed the purpose of the exhibit is best left to Des Barres himself. As quoted from the title page of the Atlantic Neptune the charts show "the sea coast of Nova Scotia exhibiting the diversities of the coast, and face of the country near it: the banks, rocks, shoals, and soundings, together with remarks and directions for the convenience of navigation and pilotage".

The exhibit contains all the charts from Books I and II of the Atlantic Neptune published between 1777 and 1783. An original feature was the inclusion of a single page reference - a forerunner of today's Chart 1. A comparison with the present day surveyed coastline shows painstaking attention to accuracy and detail. The most obvious differences were in longitude, a reflection of the difficulty of keeping accurate time for extended periods.

In viewing this exhibition one is struck by the finely executed views used on most of the charts. They tell a story themselves of the history, of the ships depicted in many of them to provide scale, and of Des Barres himself. The explanatory text that is provided for each chart not only describes the chart, the views, and the methods of surveying but also indicates Des Barres' propensity for renaming geographical features for politically influential people of Georgian England. It is suspected this was an attempt to ingratiate himself and ensure continued financial support for his charting endeavours.

Also on display are some of Des Barres' original notes, particularly impressive when one considers they were done, under field conditions, in pen and ink. Also on exhibit are some of the original copper printing plates, a drafting set made for George III, and a set of Des Barres' charts that belonged to Admiral Nelson. A technical section on projections, papermaking, engraving and printing, rounds out the exhibition.

The curator for this exhibit was Water K. Morrison, Cartographer Emeritus at the Nova Scotia College of Geographic Sciences.

An Analysis of Chart Sales

by
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Ottawa
and
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Ottawa

INTRODUCTION

Do chart sales start climbing in spring or does the season really begin as early as Christmas? Do the best selling 20% of the Recreational Charts make up 20% or 90% of total recreational sales? How do sales on the East Coast compare with the Great Lakes region? These questions are but a few of the many that chart producers have regarding the distribution, seasonality and volatility of their products.

Until recently, many of the questions that production staff wanted to ask could not be answered, since distribution figures were kept on a yearly basis only. Starting in 1986, however, distribution of each chart handled by the Ottawa Chart Distribution Centre was recorded monthly. These figures form the basis of this report. The raw figures were transformed into useful information by first asking questions like those above and then trying to arrange the data in a form that would answer those questions.

The data were tabulated and stored in such a way that they could be sorted according to different criteria, and also so that they could readily be converted into graphic form for easier assimilation. For example, Figure 1 answers the question "Is there a different yearly sales pattern between East Coast and Great Lakes Charts?" By plotting each area's monthly sales total throughout the year, it is easy to see that while Great Lakes charts are strongly seasonal, East Coast charts are much less affected by seasonal fluctuations. Other graphical examples are described below, as are some numerical manipulations.

A word of caution; the results presented here do not include Pacific Region charts or distribution figures. Further, they deal only with the year 1986. It would take many years' repeated observations before trends could be established with any rigor. However, the findings for 1986 all make sense, they all agree with the collective but unwritten knowledge of CHS staff. For this reason, the authors consider the 1986 figures to be good indications of trends and behaviors of chart sales. It is reasonable to assume that other years will be similar to 1986 but that there will be some variability from year to year. A multitude of factors could cause fluctuations or stability in any particular year's sales. And no system of examining the past can ever totally predict the future.

THE DATA

The data table presented here (see Table 1) displays yearly sales arranged in ascending or descending order, depending on which end one reads from. (Editor's note: Only the top 20 and bottom 15 charts are represented in the table. For a complete table, several pages long, please contact the author.) Simply by introducing order to the sales, comparisons can more easily be made between charts, and their respective statistics may be more easily referenced. One may also ask more global questions or make more global observations from this listing. For example, the single top-selling chart outsells the bottom-selling one hundred and sixty-one charts! This requires some counting, as would trying to determine what percent of charts accounted for fifty percent of sales, or how many charts make up the lowest ten percent of sales. Below, the table is converted into figures that make the process easier, but first the paper describes some of the other numbers found in the table.

There are some dangers in merely listing chart numbers since the uninitiated have no idea what a chart may cover. However, each block of numbers is a series, 1000s covering the St. Lawrence and Ottawa Rivers, 2000s the Great Lakes, 3000s the Pacific but not included in this paper, 4000s Nova Scotia, Newfoundland and the Gulf of St Lawrence, 5000s Labrador and Hudson Bay, 6000s the smaller lakes, and 7000s the Arctic. Charts can be specified further by referring to the chart title. In 1986, of the best-selling ten charts, three were in the St Lawrence Seaway, three were in Lake of the Woods, two were in Georgian Bay, one was in the Trent-Severn and one was in the Rideau Waterway. At the opposite end of the table, eight of the worst-selling ten were Arctic Charts, one covered Lac La Ronge, while Playgreen Lake was the worst of all.

Besides each month's sales and the total sales for the year, the table shows cumulative sales for the year and cumulative percent of total sales. The next column shows average monthly sales and next to it the

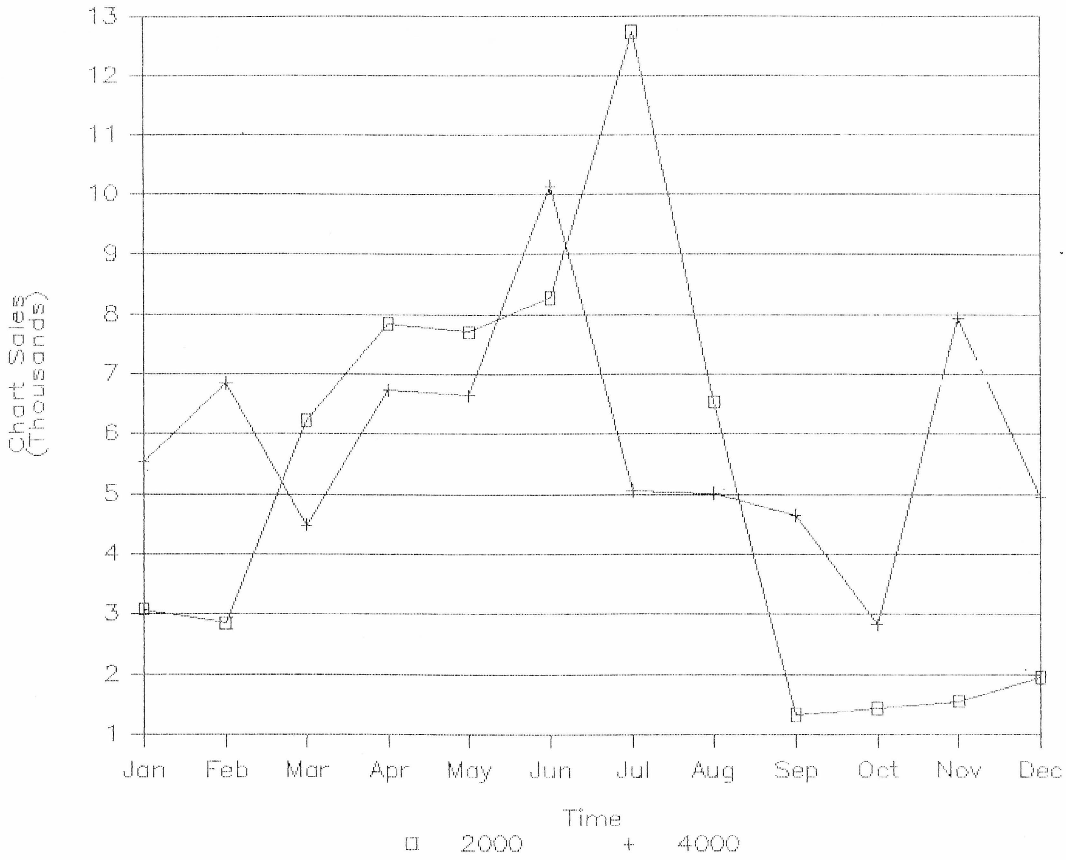

Figure 1: Monthly Sales Great Lakes versus East Coast (1986)

trimmed monthly average (calculated by dropping the highest and lowest month and averaging the remaining ten months). This was calculated because there was interest in the effect that extremes such as a large order might have on monthly sales, but this measure was found to be of limited value. The trimmed average is almost always higher than the ordinary average, indicating that the low extreme is further from the average than is the high extreme. Considering that many (537) charts have zero sales for at least one month, this observation is not surprising.

Maximum and minimum monthly sales for each chart are tabulated and show the range of sales over the year. The greater the range, the more variable a chart's distribution. The Standard Deviation is included since it is a measure of the "volatility" or variability between months. For the same average sales, larger Standard Deviations mean more variability.

This ordered table of numbers, though useful, can be made more useful and much easier to read when converted to graphic forms as shown below.

GRAPHICS

Sales by Series

Figure 2 is a histogram of chart sales against chart number, with chart numbers arranged in ascending order. This graph shows that the spread of sales is large and that there are a large number of poor sellers. A cross-series comparison reveals that the 1000 and 2000 series sell much better on an individual basis than does the 4000 series, but there are considerably more 4000 series charts. (In fact, total sales for the 4000 series is higher than the 1000 or the 2000.) This observation can be interpreted in several ways; is the 4000 series schemed correctly, or do Maritimers spend less money on charts than do Ontario and Quebec residents, or is it simply the fact that there is less traffic in the more remote areas?

To get a different view of the same data, Figure 2 can be re-ordered, drawing it this time by descending sales(Figure 3). This quickly shows that a small percentage of charts are big sellers, that another twenty percent sell well, but that there are large groups that do not sell well at all. Were the CHS a commercial manufacturer, it would look very hard at why these low-end items sell so poorly, and consider modifying them or dropping them from the product line altogether.

Sales by Month

How do charts perform on a month-to-month basis? Figure 4 shows how total chart sales vary through the year. There is a more than doubling from January to June, July stays strong, then a drastic reduction occurs, terminating in October. No surprises here; the nature of the Canadian seasons dictates the

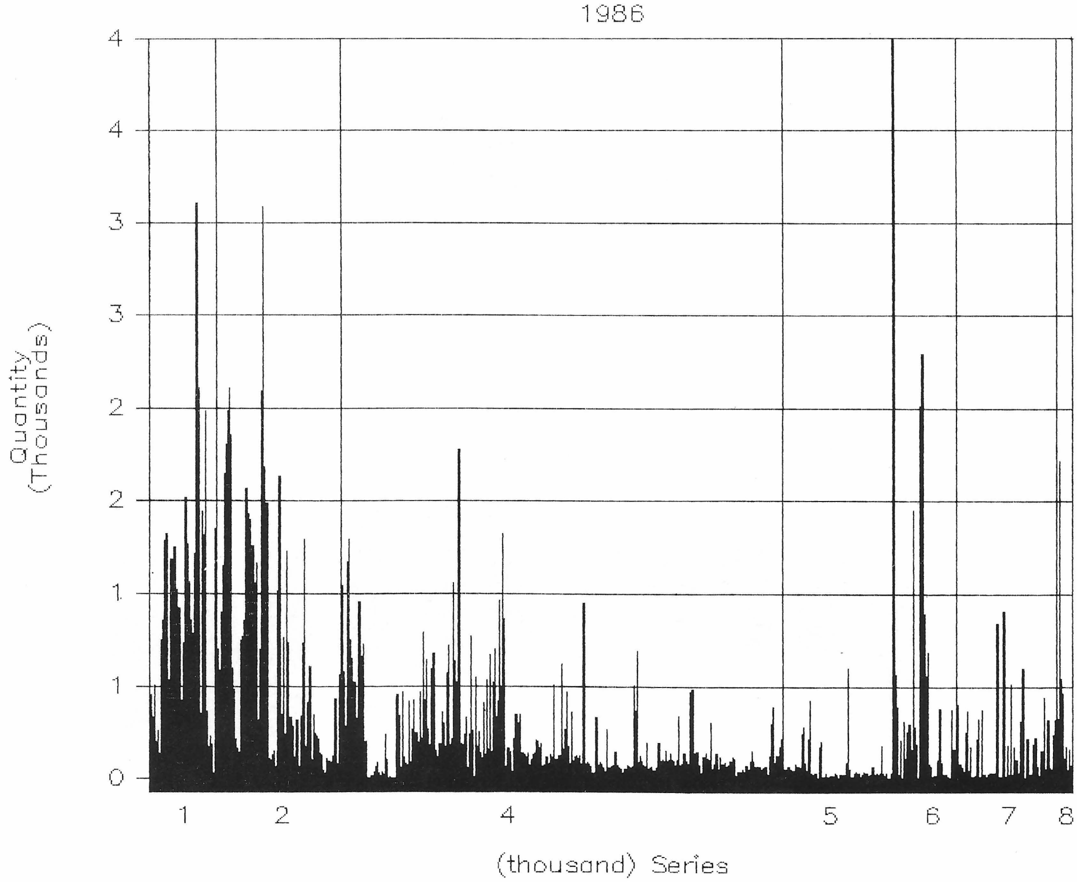

Figure 2: Sales by Series (1986)

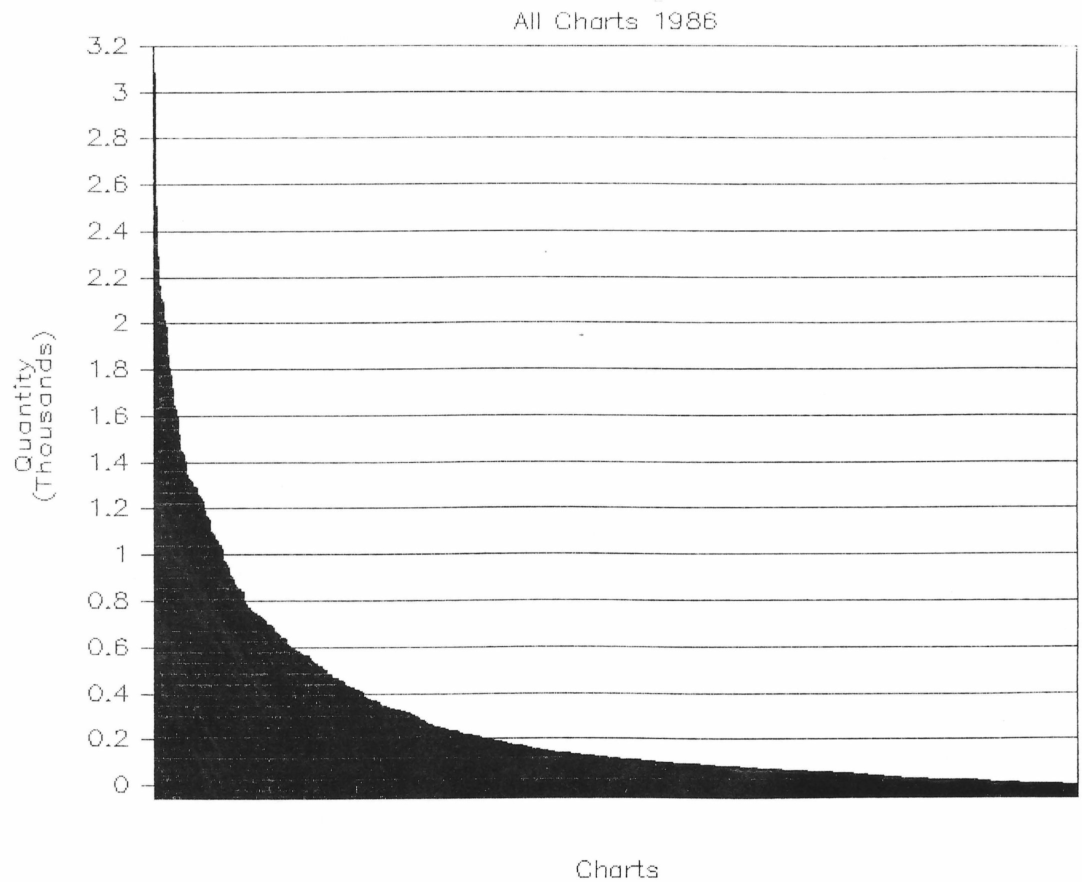

Figure 3: Descending Sales (All Charts 1986)

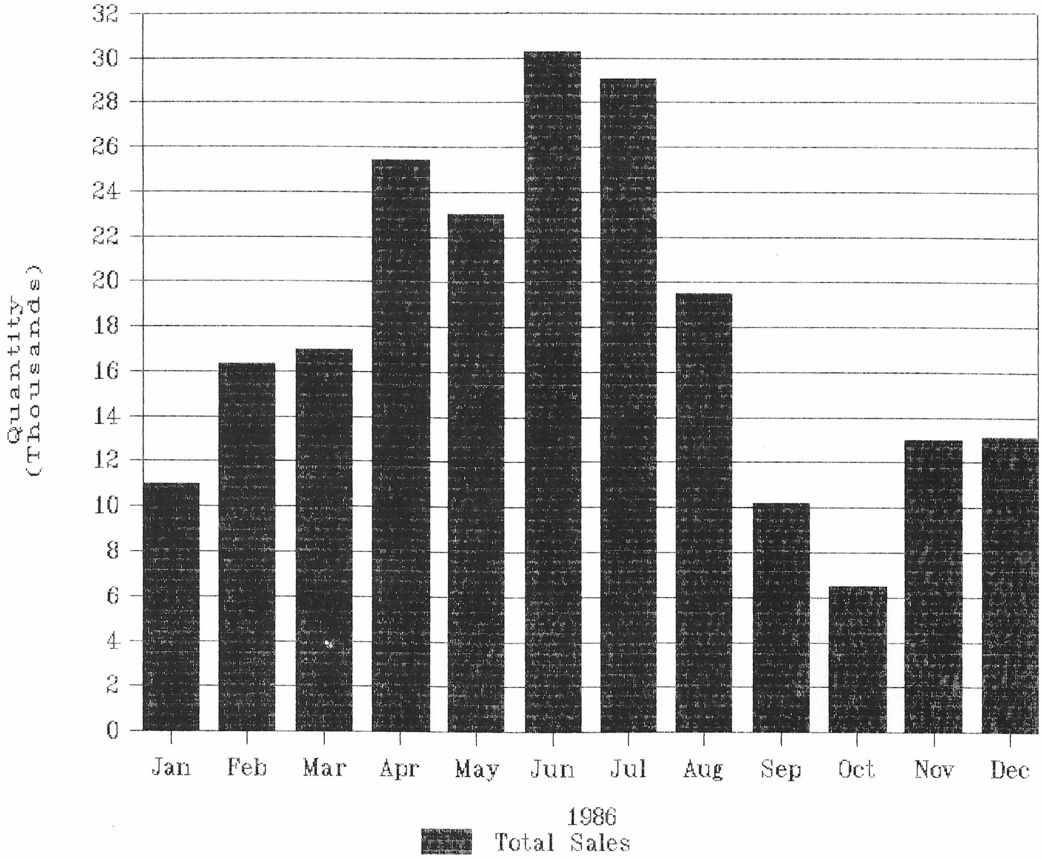

Figure 4: Total Chart Sales by Month

general form of this graph. Whether April really is a local peak perhaps corresponding to the opening of commercial navigation, why February and March are so strong, and why the year bottoms in October and not in January are matters for speculation. It is also obvious that releasing charts in the fall after the season has ended is undesirable.

Do all charts follow this seasonal pattern? The original figure shows that, overall, Great Lakes charts certainly do, while the seasonality of East Coast charts is not so evident. The chart series needs to be studied more closely and over a longer period of time before a firm picture of their seasons emerges.

The Lorenz Curve

The concept of chart sales comparisons can be further examined by drawing Lorenz Curves. (Figure 5). In an idealized world, CHS would like all charts to sell equally well, since they require about the same effort to produce. However, the Data Tables show that sales are disproportionate. The Lorenz Curve elegantly shows the degree of imbalance. These graphs are a two-way percentage cumulation, simple to read after a little study. Choose a point anywhere on the curve. The coordinates of the point are percentage values indicating some proportion of charts which make up some proportion of sales. For example, on Figure 5, the Lorenz Curve of Arctic charts, the diamond on the curve shows that the bottom-selling 55 percent of the charts make up only ten percent of the sales.

The appeal of the Lorenz Curve is the flexible way in which it can be read. For example, properties of the top-selling charts can also determined from the same graph; for the Arctic Series, ninety percent of sales come from the top selling 45 percent of charts. From a purely Chart Production point of view, one might hope that all charts would sell equally well, that is the bottom -selling 60 percent would constitute 60 percent of sales. This is clearly not the case and one should speculate as to why.

THREE-DIMENSIONAL GRAPHS

The final graph (Figure 6) is an attempt to combine the two concepts of how well charts sell overall in relation to one another, and the monthly variability of chart sales. Along the bottom axis of this graph are categories into which each chart was sorted by sales for each month. For example, the category 11-20 means that a certain chart sold between 11 and 20 copies that month. The vertical axis shows the frequency or number of times this occurred for each month. The extreme range over which charts sell makes the axes on this graph difficult to construct (and to read). Note the break in scale on the horizontal axis at the 100 sales per month point, and the change in the frequency scale at 100 times per month. Also, September has been

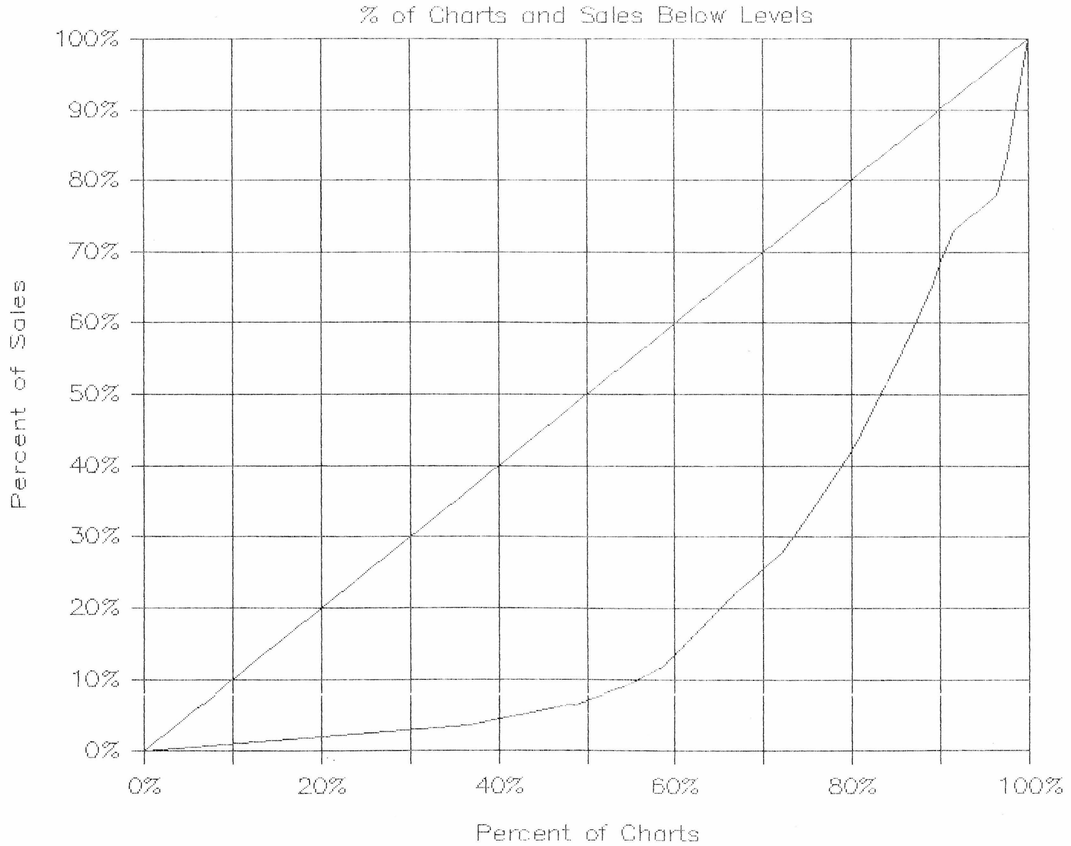

Figure 5: Lorenz Curve (Arctic Charts 1986)

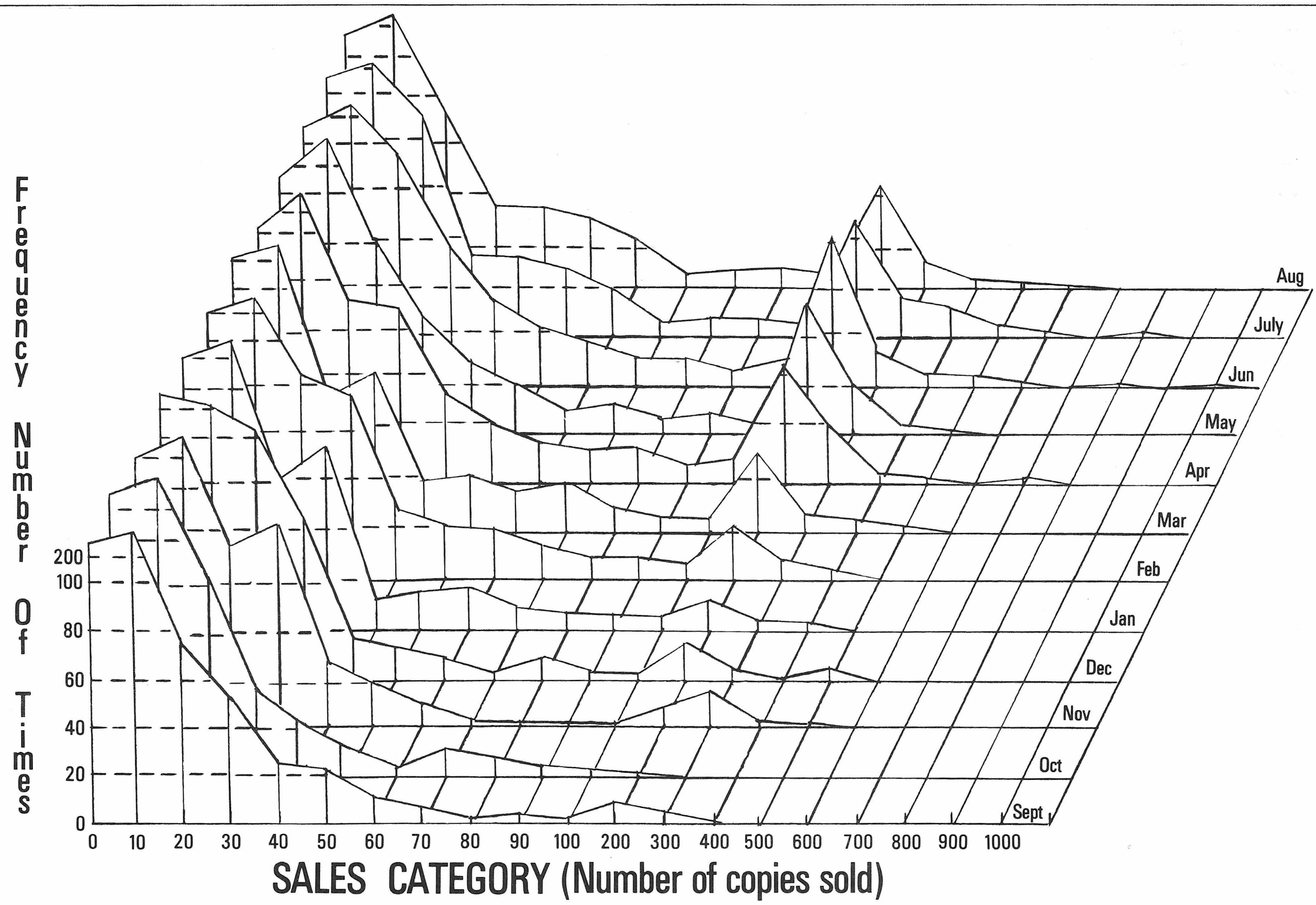

Figure 6: Sequential Histograms (1986)

placed nearest to the viewer to avoid hiding too much data "behind" other parts of the graph. Despite these difficulties, the graph does show some valuable information.

The 101-200 category shows where the greatest quantities of charts are sold. From close to zero in October, this category rises steadily until March when it soars to perform strongly through to August. This trend is mirrored in the ranges from about thirty up to one hundred. The only other discernable trend is that of zero sales; the largest number of zero sales (over 250) occurred in September with a steady decline to less than 100 the "following" August. There does not appear to be any trend in the 1-10 and 11-20 categories whose values do not appear to fluctuate strongly.

CONCLUSIONS

This paper has brought some meaning and understanding to chart sales by using some simple ordering and a few graphics. These and more sophisticated analyses could be produced automatically from the daily invoices were a proper computerized inventory system in place. This paper gives a rough guide to the specifications of part of such a system.

The data here is for only one year and does not include sales from the Pacific Region distribution centre. Future work must extend the time series and include Pacific charts.

In such a preliminary analysis as this, there are bound to be alternative interpretations as well as unremarked phenomena. The authors invite readers' comments on any aspect of the work.

Finally, the seasonal nature of most chart sales must be emphasised. Does the effort to print charts respond well enough to this pattern? Should charts be classified by likely sales and accorded a commensurate level of effort? Drawing a few pictures based on numbers helps CHS understand these types of questions better.

Table 1: Decreasing Total Sales

Chart	M	O	N	T	H	S	-	1	9	8	6		Total	Cumm	% of	Av	Trim Av	Max Mon	Min Mon	Stand
No	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sales	Sales	Total	Sales	Sales	Sales	Sales	Dev
2202	143	54	97	158	190	981	701	595	16	26	20	105	3086	3086	1.446	257.2	308.6	981	16	305.55
1420	26	45	118	248	301	566	749	496	99	37	52	42	2779	5865	2.747	231.6	277.9	749	26	235.97
1419	25	46	114	241	247	492	770	416	67	22	38	31	2509	8374	3.923	209.1	250.9	770	22	228.33
6214	8	101	390	677	41	256	303	382	100	18	3	13	2292	10666	4.996	191.0	229.2	677	3	203.79
6213	103	113	186	477	219	506	323	173	10	34	5	13	2162	12828	6.009	180.2	216.2	506	5	167.25
1421	25	53	104	248	175	461	541	339	55	21	49	40	2111	14939	6.998	175.9	211.1	541	21	173.83
2028	132	80	450	352	311	191	255	184	37	19	20	74	2105	17044	7.984	175.4	210.5	450	19	135.61
2201	189	126	198	254	268	364	314	205	44	42	13	80	2097	19141	8.966	174.8	209.7	364	13	109.57
6212	75	157	247	365	175	458	220	287	8	19	5	0	2016	21157	1.911	168.0	201.6	458	0	146.47
1513	30	86	388	249	106	391	395	197	65	19	6	57	1989	23146	10.843	165.8	198.9	295	6	146.62
2025	120	65	392	216	335	190	426	107	38	15	19	65	1988	25134	11.774	165.7	198.8	426	15	140.57
2029	93	102	415	235	340	168	261	124	31	18	19	57	1863	26997	12.646	155.3	186.3	415	18	125.66
2024	97	57	383	208	246	189	403	124	22	1	21	57	1807	28804	13.493	150.6	180.7	403	1	131.84
4320	108	139	14	228	59	368	123	114	129	65	401	32	1780	30584	14.327	148.3	178.0	401	14	118.62
8007	6	84	32	21	175	30	51	36	37	21	225	1003	1721	32305	15.133	143.4	172.1	1003	6	267.02
2203	64	50	19	430	156	216	377	277	19	7	24	42	1681	33986	15.920	140.1	168.1	430	7	144.04
2023	64	52	281	138	254	191	358	181	55	1	17	53	1645	35631	16.691	137.1	164.5	358	1	110.81
2239	105	68	294	213	137	173	349	185	23	12	19	53	1631	37262	17.455	135.9	163.1	349	12	105.81
2063	85	68	162	204	186	182	289	191	59	84	50	41	1601	38863	18.205	133.4	160.1	289	41	75.58
1410	25	97	72	235	216	205	233	171	56	32	52	24	1518	43081	18.916	126.5	151.8	233	24	97.75
6101	0	0	0	2	1	0	0	1	0	0	0	1	5	213429	99.979	0.4	0.5	2	0	0.64
6209	0	0	0	2	3	0	0	0	0	0	0	0	5	213434	99.981	0.4	0.5	3	0	0.95
7170	0	0	0	1	0	0	0	0	4	0	0	0	5	213439	99.983	0.4	0.5	4	0	1.11
5410	2	0	0	2	0	0	0	0	0	0	0	0	4	213443	99.985	0.3	0.4	2	0	0.75
5455	1	0	0	0	0	1	1	1	0	0	0	0	4	213447	99.987	0.3	0.4	1	0	0.47
5801	0	2	0	0	0	0	2	0	0	0	0	0	4	213451	99.989	0.3	0.4	2	0	0.75
6247	0	0	0	0	3	0	0	0	0	1	0	0	4	213455	99.991	0.3	0.4	3	0	0.85
7520	0	0	0	3	0	0	0	0	1	0	0	0	4	213459	99.993	0.3	0.4	3	0	0.85
5406	1	0	0	2	0	0	0	0	0	0	0	0	3	213462	99.994	0.3	0.3	2	0	0.60
7181	0	0	0	2	1	0	0	0	0	0	0	0	3	213465	99.995	0.3	0.3	2	0	0.60
7851	0	0	0	2	1	0	0	0	0	0	0	0	3	213468	99.997	0.3	0.3	2	0	0.60
4062	0	2	0	0	0	0	0	0	0	0	0	0	2	213470	99.998	0.2	0.2	2	0	0.55
4063	0	2	0	0	0	0	0	0	0	0	0	0	2	213472	99.999	0.2	0.2	2	0	0.55
7430	1	0	0	1	0	0	0	0	0	0	0	0	2	213474	100.000	0.2	0.2	1	0	0.37
7521	0	0	0	1	0	0	0	0	0	0	0	0	1	213475	100.000	0.1	0.1	1	0	0.28

The Hydrographer: Chronic Sufferer of V.E. ?

A Monograph by
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Canadian Hydrographic Service
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Within my realm of acquaintances, there is no one who has walked on the sea floor. Many, including myself, have swum the deeps and, normally, enjoyed the scenery. This experience, however, still lacks the sensation that one is accorded when walking over earthly terrain.

A hydrographer deals with the quantitative experiences that are unbiased by the qualitative experiences of first-hand contact with the sea floor. Once that depth has been obtained, especially a peak sounding, the red pencils come out, co-ordinates are determined and plans made to return to the area to examine that "shoal". Shoals and their mental perception are the topic of this monograph.

At this juncture I am not concerned with the probabilities of detecting shoals, be they artificial or natural. This topic has been addressed by others. I would like to discuss the implications of the techniques used by a hydrographer to determine depths and the influence they have on his ability to effectively derive the desired results.

A hydrographer of the 80's normally uses active remote sensing devices, such as acoustic echo sounders with analog chart recorders, to obtain his data. This device has a failing, which has long been evident in stereoscopic photo-interpretation, namely V.E. Vertical Exaggeration is the ratio of the vertical scale to the horizontal scale. In aerial photography it is determined by the geometry of the camera and stereo viewing systems. On the analog depth record it is influenced by the ratio of chart scale to distance travelled over the ground, as well as the depth scale setting. The net effect of a large ratio of V.E. is to persuade the data interpreter that there is extreme terrain relief. This sensation immediately manifests in the hydrographer a driving compulsion to examine the "hazard".

Sounding operations should attempt to minimize V.E. to a ratio approaching 1. This can be attained by synchronizing the speed of the launch with the paper advance speed and by selecting the appropriate vertical scale or "phase" on the sounder. The net result is that, during scaling, the bottom is portrayed in a truer perspective which leads to the selection of only the significant peaks for further examination.

Figures 1 to 4 are graphs that portray the effect of V.E. as seen on analog sounding records with the same data points plotted. Each graph is for the same horizontal scale or paper speed. The vertical scales are related to sounder phase scales of 0 to 25, 0 to 50 and 0 to 100 metres. The speed of the launch is 16 knots, and has been kept constant for all the graphs. The effect of V.E. is evident in the comparison of figure 1, which conveys the impression of significant peaks, with figure 4, which seems to portray a rolling topography.

The numeric values for V. E. for each of these figures can be found in table 1. It shows that the V.E. value for the 0 to 25 metre scale varies from 120 (most V.E.) to 30 just by changing the paper speed. This factor of 4 reduction is constant for vessel speed changes as shown in the table. By setting paper speed according to vessel speed we can approach a V.E. of 1.

Analog records with large vertical scales (such as 0 to 25 metres) were necessary for depth resolution when depths were manually scaled. But the use of digital information has increased to the stage where most hydrographic data are recorded and processed digitally. When processing digital data the values in table 1 take on increased significance. Now the analog record is mainly used to verify digitally recorded data. A sounder scale of 0 to 100 metres has a net effect of minimizing V.E. and therefore aiding the "mental picture" when resolving data snags.

Within the hydrographic community there are only a few geomorphologists. The shape of the sea floor is a result of complex inter-related variables which are self-creating and modifying. To extract a valid data set to represent the real world on a document such as a field sheet, the selected depth should be truly representative. The data should be able to support associated disciplines that use the data for purposes other than navigation. In order to attain this goal a "feeling" for the sea floor geomorphology is a must. This adds further credence to the argument for collecting "true perspective" analog data.

Since 1983 I have kept a "diary" of shoal depth obtained during examination of peaks that appeared on regular sounding lines. In 95% of the cases the depth

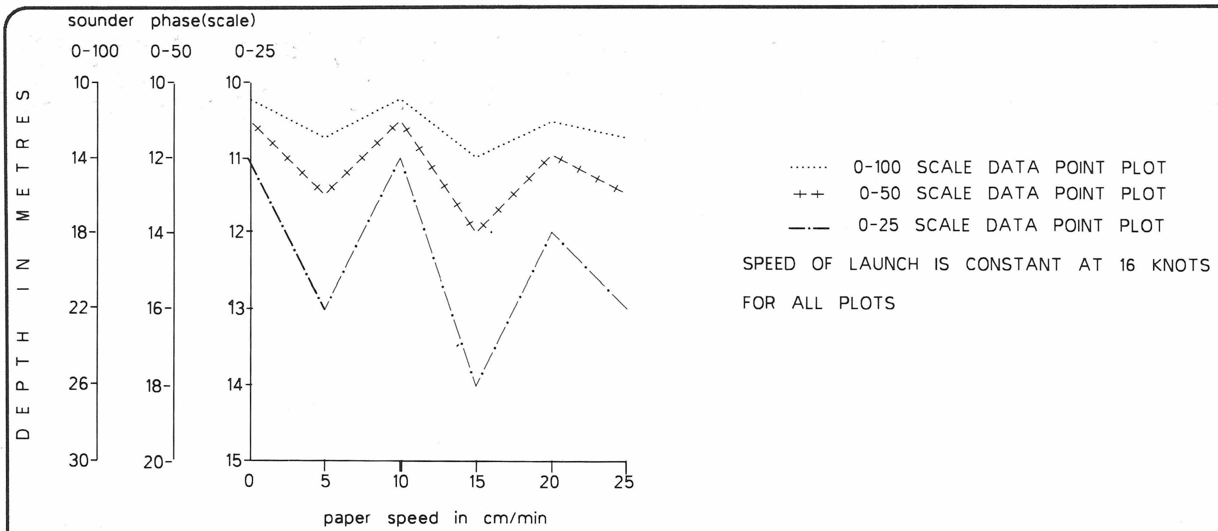

Figure 1: Paper Speed 1

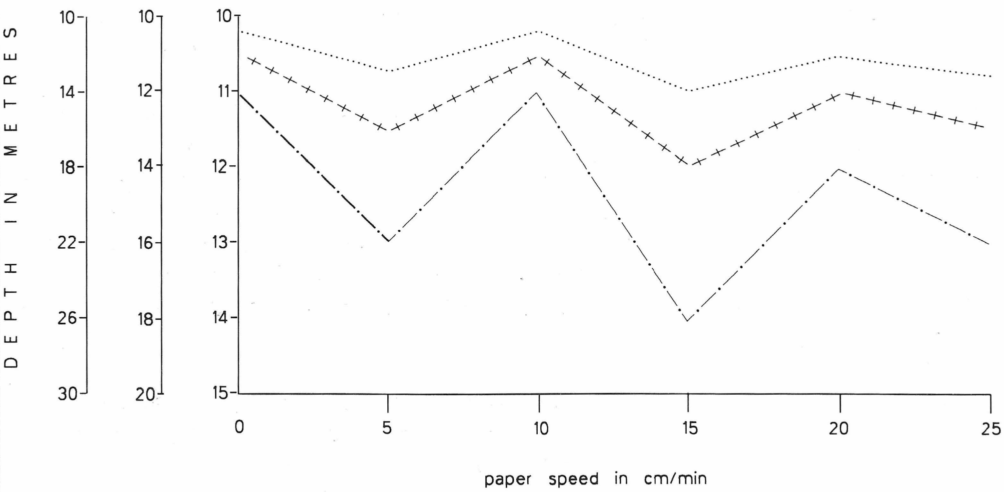

Figure 2: Paper Speed 2

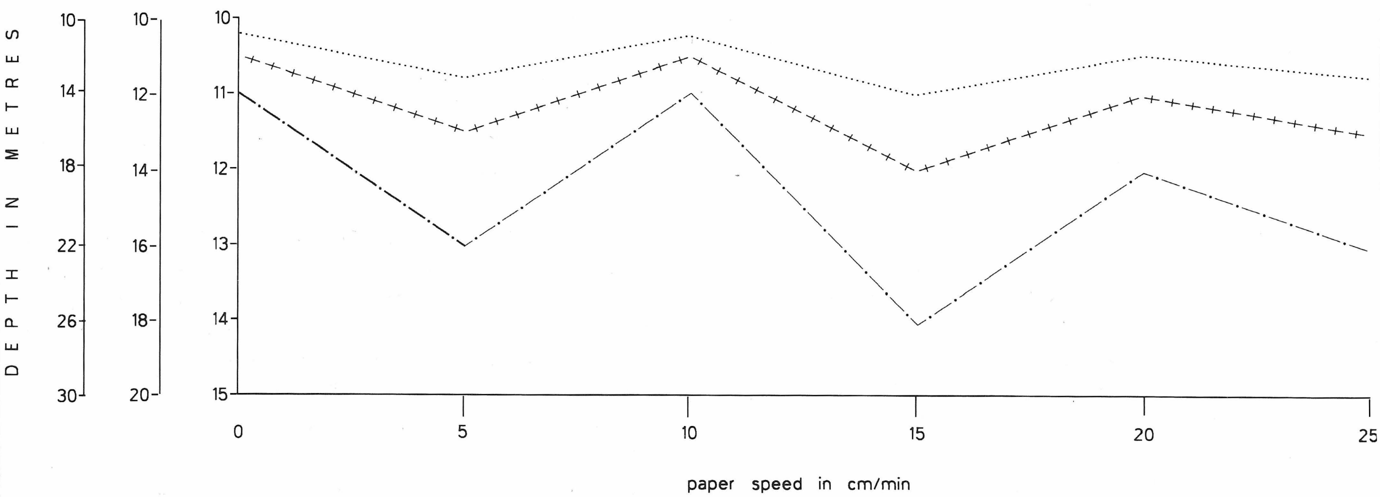

Figure 3: Paper Speed 3

changed by less than 0.5 metre. In 4.7% of the cases the depth change was between 0.6 and 1.5 metres. The depth changed by more than 1.5 metres in only 0.3% of all shoal examinations. These values may indeed demonstrate that correct and verifiable depths are being obtained. But it also demonstrates that the process used for selecting peaks requiring further examination may by inappropriate. This is attributable to V. E. No effort was made to visualize sea floor topography. This led to the selection of insignificant depths for further examination. The sounder/launch data collection system was incorrectly operated, with no regard for V. E.

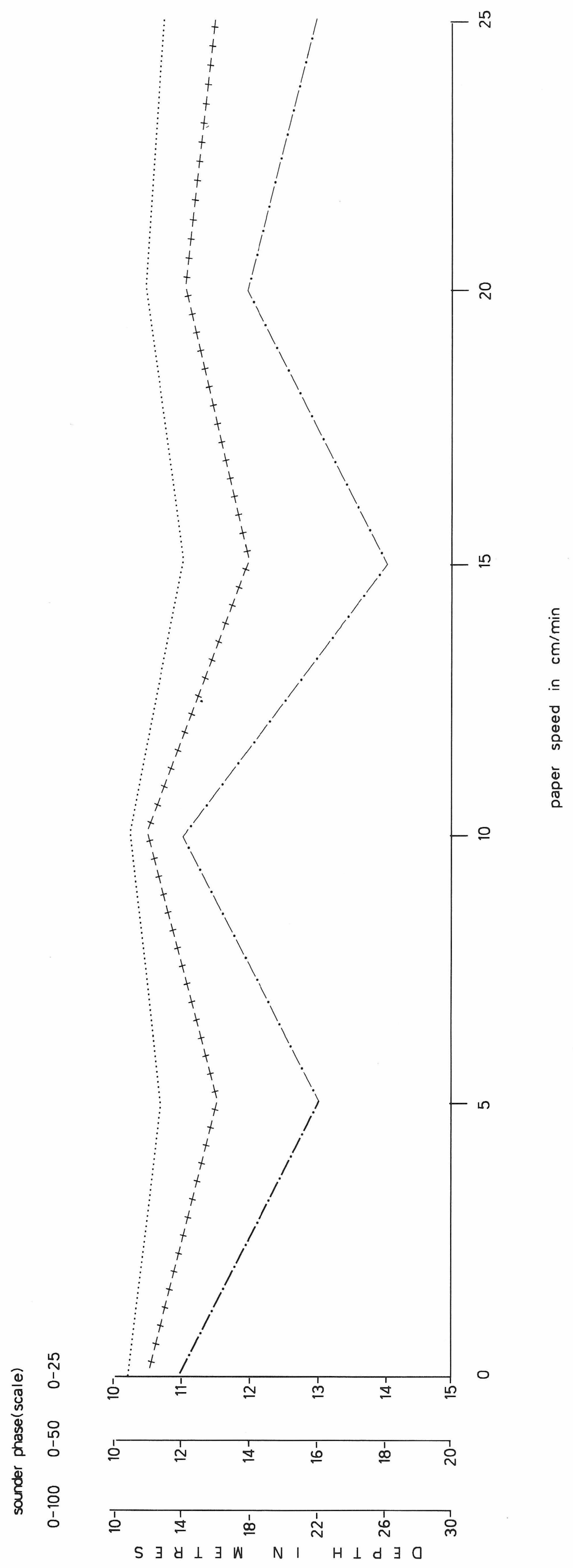

Figure 4: Paper Speed 4

Vertical Exaggeration and the effect it has on the work load during a survey operation, needs to be addressed in order to allow increased time for more significant work. Many within the hydrographic community may be at variance with my definition of a shoal, which does not solely rely on the 10% rule of deviation from surrounding depths. Proponents of the 10% rule will centre on the 0.3% of the cases where depths did vary by more than 1.5 metres, to argue that if all peaks are not examined there is no way of knowing what is significant and what is actually a hazard. My response is that by understanding V. E. the selected peaks requiring examination would decrease, with a corresponding increase in depth changes resulting from investigations of more significant sea floor features. Time for regular sounding operations is made available and productivity increases.

My intention in writing this monograph is to increase the hydrographer's awareness of Vertical Exaggeration and its effect on survey activities. The next time you are examining a shoal and you can't find the peak that was detected on initial contact, take faith. The peak may never "physically" have been there.

A final point on the 0.3% case where depths change by more than 1.5 metres: during the 1987 field season in Hudson Bay a six metre shoal was examined. It was located 13 kilometres off shore, where surrounding depths of 50 metres were found just 300 metres from the shoal. This shoal was not found on a regular sounding line. It was found by a commercial carrier with a draft of 7.9 metres. Fortunately it passed a corner of the shoal where the depth was 10 or 12 metres. I would appreciate hearing about similar cases, because I have another article in mind entitled "Shoals - the ones that got away".

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Editor's note: Any comments on shoal examinations and V.E. would be most welcome either as letters to the editor or as future Lighthouse articles.

Table 1
Vertical Exaggeration Numeric Values

VERTICAL EXAGGERATION = VERTICAL SCALE / HORIZONTAL SCALE

VERTICAL SCALE 0-25 METRES

		PAPER SPEED 1	2	3	4
LAUNCH	30	120	60	40	30
SPEED	15	60	30	20	15
(KNOTS)	7.5	30	15	10	7.5

VERTICAL SCALE 0-50 METRES

		PAPER SPEED 1	2	3	4
LAUNCH	30	60	30	20	15
SPEED	15	30	15	10	7.5
(KNOTS)	7.5	15	7.5	5	3.75

VERTICAL SCALE 0-100 METRES

		PAPER SPEED 1	2	3	4
LAUNCH	30	30	15	10	7.5
SPEED	15	15	7.5	5	3.75
(KNOTS)	7.5	7.5	3.75	2.5	1.875

A Hydrographic Information System

by
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ABSTRACT

Data bases will form the infrastructure of the information age and as such, existing data bases must be restructured and interfaced to permit external access in the context of information systems. This paper sets out the Canadian Hydrographic Service (CHS) concept of a hydrographic information system and examines the issues that must be addressed to support present and future users. This includes the impact on organizations of establishing, maintaining and using such an information system. The impact includes the need for new hardware, procedures and training of personnel as well as organizational changes to establish the infrastructure necessary to support the concept of collecting, storing, managing, using and disseminating digital data. The broader issue of the infrastructure needed to support the information age in general is also discussed. These issues will be discussed in the context of the CHS concept.

INTRODUCTION

The information age that many foresaw during the 1970's has finally dawned. The technology to create and manage a large data base, to network data bases together into information systems and to rapidly disseminate data is now available. At the same time, the ability of organizations to collect digital data is increasing at an alarming rate, creating a requirement not only to efficiently manage these digital data but also to respond to users' demands for digital data. Attempting to respond to user demand has brought with it the realization that much of the power of digital data cannot be tapped if these data remain in application specific formats.

It is essential that existing data bases, that will form the corner stone of the information age, be restructured to provide information for numerous applications in an accessible, generic form. This involves much more than solving the technical puzzle of networking existing data bases. Data base management systems (DBMS) have the power to store and manage data in a form that is independent of applications and to provide multiple users with different views of the same data. However, a system that addresses the needs of all applications in an organization tends to cut across internal political boundaries within that organization. Thus organizational changes are also required to provide the supporting policies and procedures that are essential to the success of such an endeavour.

This paper will review the introduction of computers to hydrographic and cartographic applications and the characteristics of the systems that evolved, outline the general principles of data base management systems and geographic information systems, discuss the impact of the information age organizationally and the infrastructure needed to support the challenge presented by the concept of the information age. Particular issues will be examined in the context of the Canadian Hydrographic Service situation.

DIGITAL DATA BACKGROUND

The hydrographic community began to develop computer based routines to collect, store and use digital data in the late 1960's and early 1970's. These developments have progressed at different rates in different hydrographic offices, with the rate of development depending upon many factors, including available resources and the philosophy of management regarding digital data. While some present day operations such as sweep and LIDAR surveys collect so much data that it would be virtually impossible to process these data without the assistance of computers, in most hydrographic offices, the hard copy field sheet remains the official return of survey and the paper chart the final product.

In the hydrographic application, computers were used to perform a variety of tasks associated with positioning computations, the display of these positions and the combining of positions and depths. The output demanded by the users was a facsimile of the manually produced field sheets, thus features that were not collected digitally were manually added to the hard copy with the digital file not always reflecting these changes. Since the hard copy field sheet was the official return of survey, the digital files remained the responsibility of the various development groups and did not conform to uniform standards of content or presentation. The hard copy also remained the medium of data exchange and there was not a great need to interface computer systems or exchange digital data files. The fact that the data, the processing routines and the computer systems were so intimately interwoven made such an interchange of digital data for different applications difficult if not impossible.

Computer assisted techniques were also introduced to the cartographic process during the late 1960's and early 1970's. Certain tasks such as the drawing of chart borders and lattices could be done very efficiently using a computer based drafting system. However, the introduction of the computer into the compilation process was more difficult because these users also demanded a tool that would produce graphic products that were duplicates of the output by manual processes (i.e. a chart produced by computer assisted techniques had to look exactly like a manually prepared chart). Therefore, the early computer assisted drafting systems were used to digitize manually compiled charts and then perform "computer assisted drafting" (editing, adding symbology, etc.) operations on the digitized data. Additional information such as nomenclature and other text was added manually. The digital file that was stored was an unsymbolized, incomplete digital chart file with a data structure tied to the particular version of the processing routines that were used to create each file.

The unreasonable expectations of users, the preoccupation with duplicating manual processes with the graphic representation as the end product, the inadequacy of the technology, the absence of standards and policies regarding the procedures for storing digital data, and the limited definition of the data to fit the existing processing routines all led to the limited acceptance of digital data. The "dawn" of the information age that development people predicted in the 1970's was ahead of its time in both the acceptance of the idea and the technology required to support the concept. Variations of this scenerio paralleled the implementation of most computer applications in a file based world and will complicate the networking of these data into data bases and information systems.

DATA BASES

The first data base management systems grew out of file based systems. In a file based system, each user or group of users develops application programs to operate on data, based on the physical structure of the data records and the contents of the various fields within the records. Because these routines are intimately related to the physical location of data in the files, any change in the data structure (adding one character to a field, adding one new field) forces the user to modify the application programs. As the number of applications grow so does the effort required to effect changes, thus inhibiting the ability of these systems to respond to change.

With a data base management system, the data base system assigns the physical storage details to the data and the application programs are designed to operate on the data, based on the names of records and fields. In other words, the physical characteristics of the data are not hard coded into the application programs. Each application routine represents a user view of the parts of the data base of interest to that particular user and the re-definition of the physical structure of the data within the data base does not affect the application programs that operate on an extract of that view. This increases the flexibility of such a system in meeting future user requirements. This concept is illustrated in Figure 1.

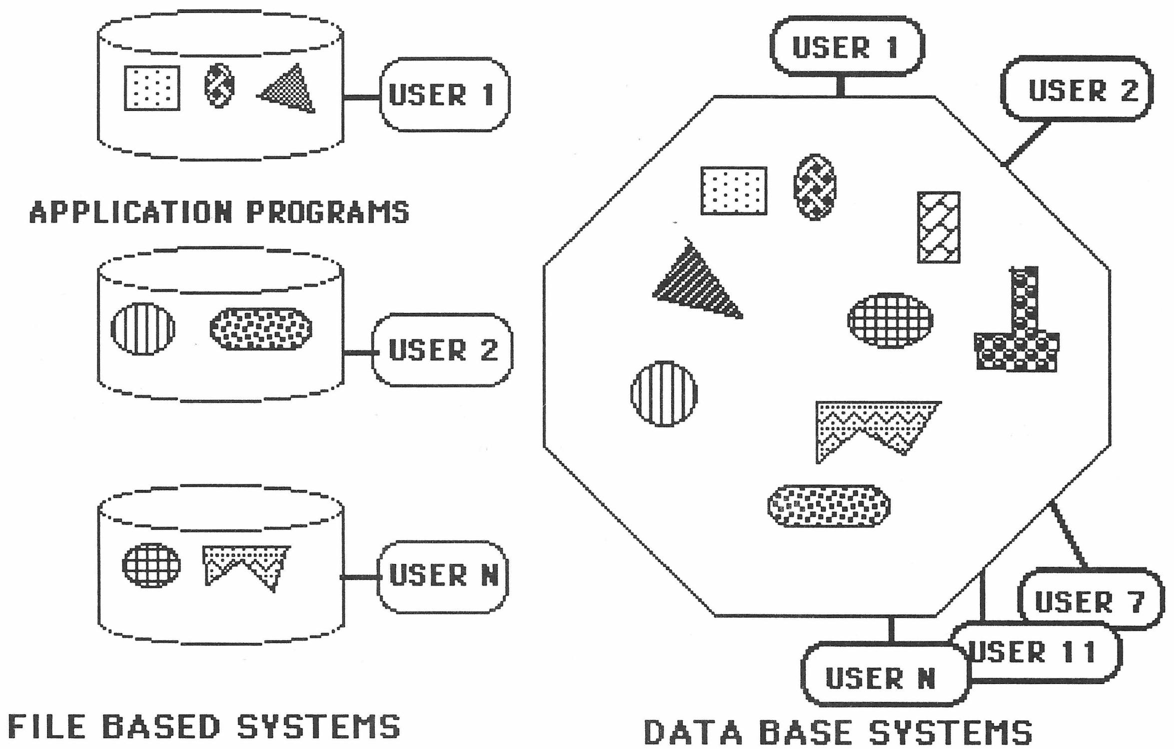

Figure 1: Data Base System

There are three classical data base management systems (DBMS), or data base models; hierarchical, network and relational [Peuguet, 1984]. The following is a brief explanation of each type of DBMS. These data base models and how hydrographic data would fit into each are graphically illustrated in Figure 2.

The hierarchical model organizes data in an inverted tree-like structure with parent and sibling relationships. Each sibling can have only one parent so that data are organized within the data base as a series of trees. A chart could be the root (parent), its siblings would be the field sheets (fair sheets), the siblings of each field sheet would be the dayboat files, and so on. Thus, hydrographic data would be stored on the basis of charts. To find all the soundings that appear on one chart would be an efficient search, but to find all the charts that a particular sounding appeared upon would entail searching every branch of every tree. This model works well for fixed procedures but does not lend itself to easy modification to meet unanticipated demands.

The network model differs from the hierarchical one in that a data object may be a member of more than one set. For example, a sounding may simultaneously be related to many charts, a geographic unit such as a degree square and a source. This allows for fast retrieval of related data and has proven useful in many business applications [DPA Group, 1985]. However, the design must consider these connections and a user requires a knowledge of the lower level structure of the data base in order to map out efficient searches of the data base. Like the hierarchical model, this model does not lend itself to easy change to respond to new applications.

The relational model is based on mathematical set theory, stores data in tables (called relations) and allows users to define relationships between tables and the columns (called domains) and rows (called tuples) that make up the tables. It is the most flexible form of data base and the most user friendly since the user need not learn a low level, procedural language in order to use the data base. This flexibility is particularly appealing to the hydrographic situation where all of the demands of the information age are not yet known. There may, however, be a performance penalty to pay as a price for the increased flexibility when one is dealing with large volumes of data.

In the course of the CHS study of the service's needs and available options it was discovered that none of the commercial data base management systems supported the type of graphics that were necessary to display and edit spatial hydrographic and cartographic data. However, there were a group of integrated systems named Geographic Information Systems evolving that had integrated high resolution graphics with various commercial DBMS.

A Geographic Information System (GIS) is the name given to a group of information management systems that provide not only the capability to manage textual data but also the ability to display and edit digital, geographically referenced graphical data. These systems recognize that spatial (geographically referenced) data and thematic (descriptive) data are different and can efficiently integrate file based graphics systems with table based commercial data base management systems, in effect offering systems that are built on the strengths of both models.

There are also data base machines that are a hardware product that acts as a front end processor to speed up searches of data base management systems. These machines are very efficient at repeating the same process but they will not be considered until the form of a CHS Information System is more clearly defined.

DEVELOPING A DATA BASE MANAGEMENT CONCEPT

In order for information systems to adequately address the information needs of an organization, the system designers must study the organization and compile an Information Resource Plan. This plan contains detailed information on the data stored, the processes supported and the interrelationships between data elements and the existing hardware and software associated with each. With such a top-down approach, it is possible to assess the impact on the whole organization of each decision regarding information systems.

CHS Data Base Management Concept

The Canadian Hydrographic Service adopted such a process. In late 1984 a Data Base Project Team was established to develop a hydrographic data base for the whole organization. This group represented each of the five CHS offices and the major applications of the Service. The Team developed a general information system concept based on the stated requirements of users and a conscious decision not to be constrained by present technological and resource limitations [CHS Data Base Project Team, 1986]. It was recognized that such constraints might, nevertheless, have to be applied later and a compromise system developed.

The concept identified the sources of data required to support the two major applications of the hydrographic office (hydrography and cartography) and because of the complexity of the resulting model (with numerous data sources not in digital form, some supporting other applications as well as hydrography and cartography, etc.) it was decided to focus initially on the detailed digital data base requirements of these two applications. The concept provided for interfaces to (or

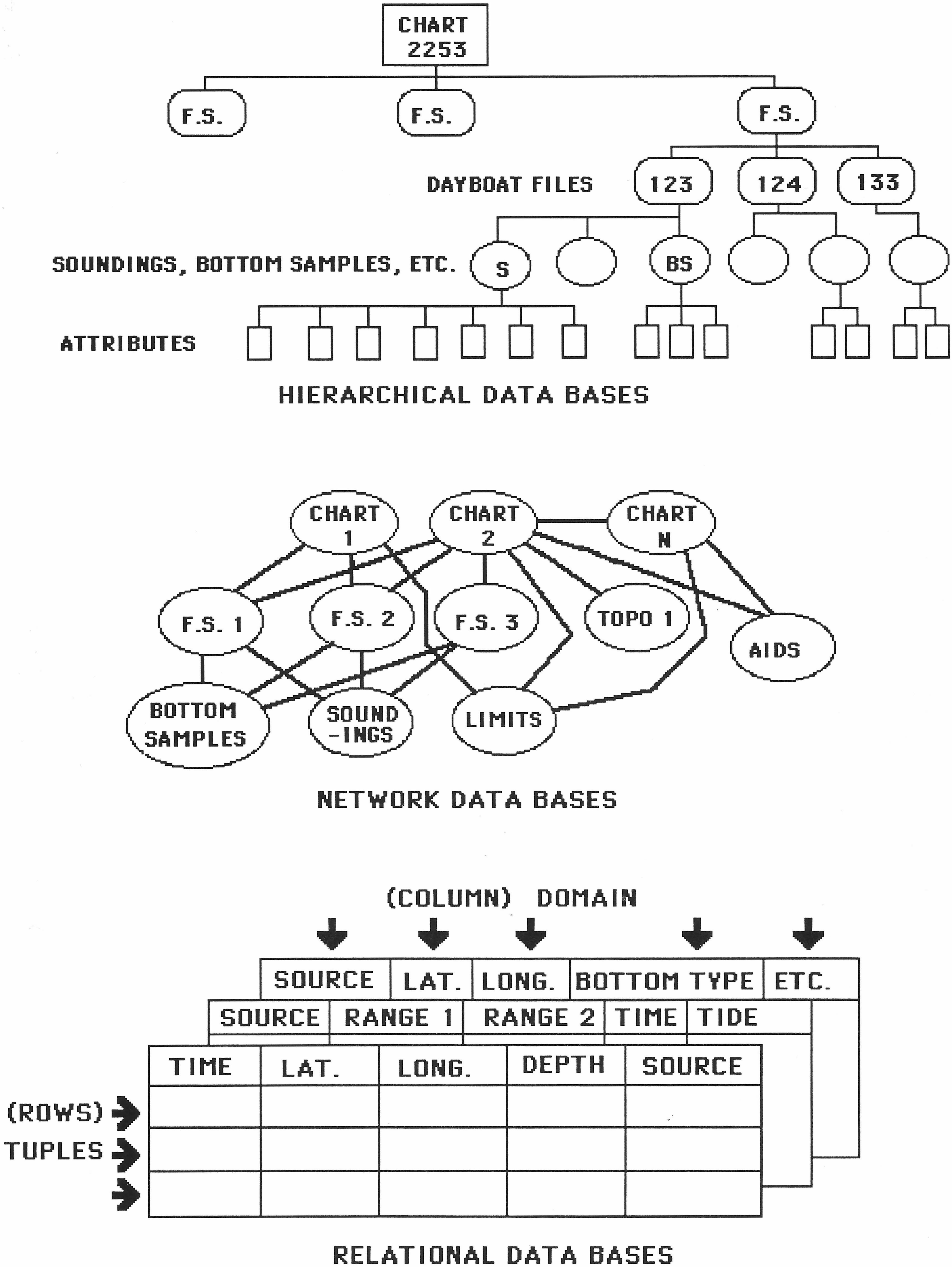

Figure 2: Classical Data Base Models

integration of) associated data bases required to support the hydrographic and cartographic applications.

It was foreseen that the data needed to support hydrographic and cartographic applications from other data types not presently in digital form could be included as layers within the original bathymetric data base, in effect expanding that data base into an information system. It was also anticipated that various users would access the information system directly, view data on-line, update appropriate layers, etc. and that the system would contain preparation capability to present data to users in the scale, projection, etc. of the user's choice.

The whole concept was based on the premise that data would be validated upon input and that data available to or accessible by users would be these validated data. General guidelines were set out regarding the validation of new bathymetric data, the level of data to store and the digitization of hard-copy historic bathymetric data for data base input. The CHS concept is illustrated in Figure 3.

The Canadian Hydrographic Service used contracted expertise to study the data storage requirements of the Service and the processes that the Service supported at present and expected to support in the future. This information was combined with the project team's database management system concept to develop Conceptual Data and Process Models of the organization. The consultants also compiled a series of reports covering such topics as expected data volume, preliminary data definitions for each type of data, the evaluation of optional systems, recommendations and test criteria to be used in selecting a prototyping system [DPA GROUP, 1985-86].

Functional Modelling

A functional model combines the conceptual models with the physical characteristics of the hardware and software of the chosen system. This can be either a paper exercise, where a design is developed based on the specifications of the system and very well defined requirements, or via a prototyping operation where a system is acquired with the knowledge that it will be a "throw-away" system and the detailed management system requirements are developed by a trial and error approach. The objective of the latter approach is to develop a practical design based on user input, and thus avoid the surprises that too often occur when an analyst develops a system to "do what he/she thought the user wanted".

The CHS chose the prototyping approach using a Geographic Information System (CARIS which has an INGRES DBMS imbedded in it) because the needs of CHS were not well defined and this new concept of an information system where data were independent of applications was not well understood. A tendency for discussions to migrate from the details of storing bathymetric data, to the interfacing to other data bases, to the preparation of output for this or that application, to the problems of managing the digital output of cartography all helped foster many individual interpretations of the overall concept. The prototyping operation forced these issues to be separated and placed in their proper perspective.

It was discovered that there were really two separate issues. The management of data to support numerous applications and the management needs within applications that are the users of these data. This separation of functions was not always defined in the file based systems of the past, where the data definitions were often limited to the attributes or grouping of attributes needed to satisfy a particular application or application routine. As such, presentation criteria, such as feature coding, often combined a number of attributes into a single code that was not easily decoded to recover the original attributes when adapting the data to another application.

The definition of data, totally independent of applications, is critical to achieving the flexibility necessary to adapt systems to support future requirements. However, it is recognized that within each application there are also requirements to manage the data that are used to produce their respective output products, and to manage these products themselves. CHS decided to concentrate on the problem of managing data to support applications in general and to address the detailed need of the various applications later.

Mapping and charting data are unique in that they contain both attributes that describe the data (thematic attributes) and attributes related to the geographic position of the data (spatial attributes). While Geographic Information Systems support these type of data, one must decide how and where to store the different types of attribute data within the GIS. The CHS was faced with three options:

1. Store as much data as possible in the spatial portion (graphics) and overflow attributes in the DBMS portion.
2. Store all attribute data except positional information (X,Y,Z) in the DBMS and only store X,Y,Z in spatial portion.
3. Store all point data in the DBMS, line data in the spatial portion and convert to the spatial format for graphical viewing, editing, etc.

The first option optimizes the display of the data and the use of it for cartographic applications. However, the spatial portions of GISs are file based and as such, the future flexibility of the system to expand

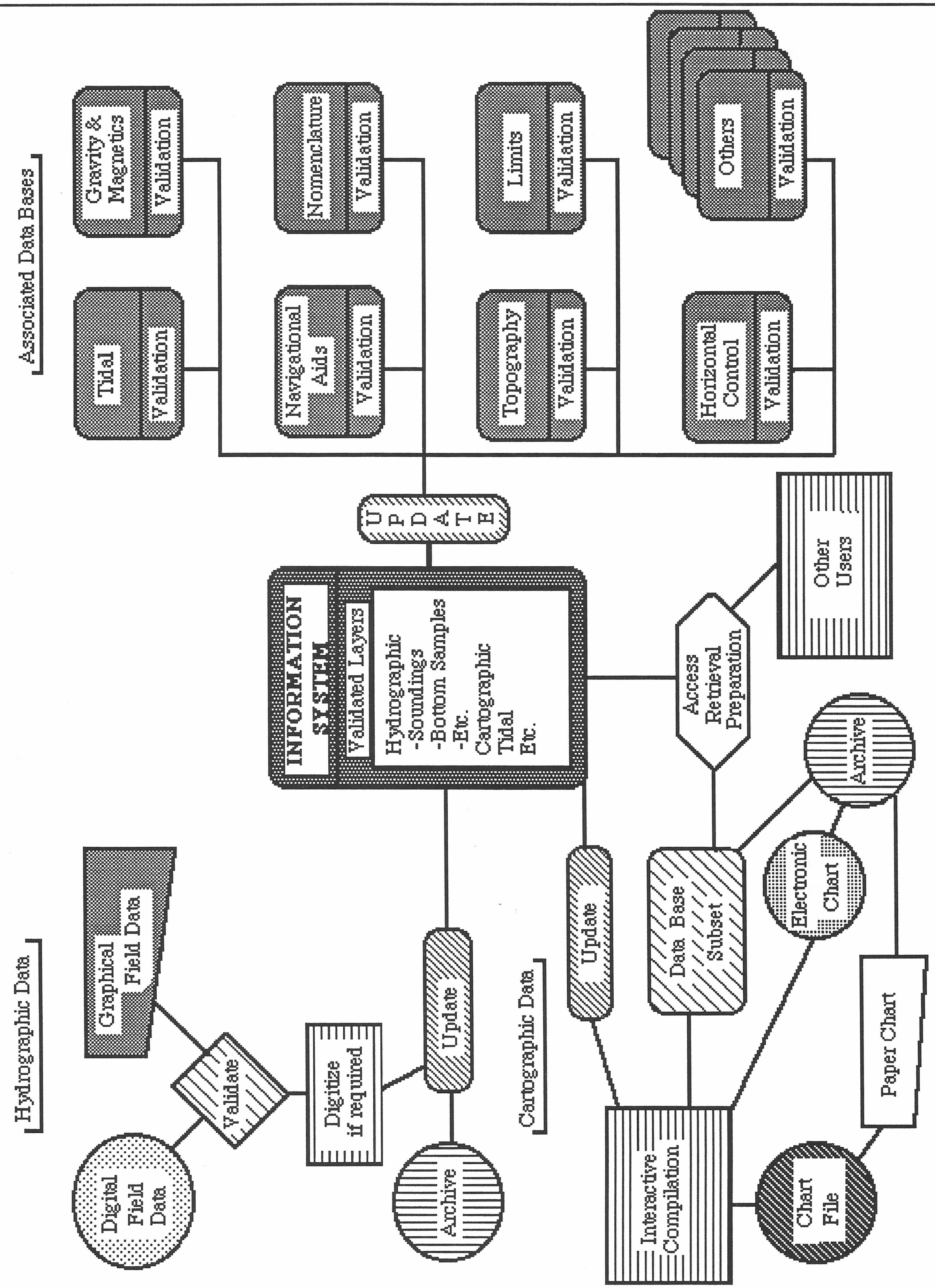

Figure 3: CHS Data Base Concept

without affecting application routines is hampered. Also, many of the positive features of DBMSs such as security, multi-user updates and data / application independence would not apply to the majority of the data in the GIS.

Option 2 combines the data managing power of the DBMS with the presentation capabilities of the spatial portion of the GIS. However, not storing positional information in the DBMS does create problems for partitioning the DBMS portion and increases the importance of the key between the graphics files in the spatial portion and the DBMS tables. If the key was corrupted in the graphics it would be possible to lose the corresponding attributes in the DBMS. A question that must be answered here is, "Do you want to display data base contents on-line for browsing, updating, etc?"

The CHS thought that they did, but during the CHS prototyping exercise, it was discovered that it was not practical to display the data from the information system and perform on-line browsing and updates. A data set of approximately 500,000 soundings and associated line work, control, names. etc which corresponds to the area of an extract for a 1:60,000 scale chart took 4 hours to draw on the screen. Once drawn, the data were too dense to read and the memory of the Tektronix 4125 terminal had been exceeded, thus it was not possible to perform operations on the data. Therefore, it was decided that it was really only practical to perform graphical operations on extracts of the data set. If this approach to graphical representation is employed, it lessens the impact of format conversion on such a system.

Option 3 provides the best security, flexibility and management capability to manage **point data**. Relational DBMS tables do not handle **line data** efficiently, therefore, for the present, line data would remain in a graphics format. A conversion to graphics would be required to display extracts of these data for editing, etc. To support browsing, it would be possible to store duplicate coordinates in the spatial portion of the GIS (with those in the DBMS being the secure values). This could facilitate searches by first identifying the sources that exists in a geographic area and then searching the DBMS based on sources. While this option provides maximum flexibility, the overhead cost of conversions to graphics to display data and the impact of increased volume on performance must be determined.

The examination of the above issues during the prototyping led the CHS to recognize the difficulty of addressing different data types at the same time and the need to separate data management from the presentation requirements of the major application, cartography. It was decided to follow a step by step approach and to further divide the issues by concentrating first on solving the management problems of one type of data, **point bathymetric data**, which constitutes by far the greatest volume of data to be managed. CHS will then address the networking of other data bases (including detailed development of those that do not presently exist in an accessible digital form) and the management needs of the cartographic application. When one examines the situation in this light, the problems are less complex and can be addressed in a systematic manner. This revised CHS Information System Concept is illustrated in Figure 4.

If one treats a data base for bathymetric data as a large warehouse where goods are accepted in a standard form, stored and retrieved from storage when required, and then output in a standard form, the system is much easier to visualize. Such an approach facilitates input from numerous sources because an operator can instruct the system as to how to read data from an ASCII type file and the DBMS will assign the internal data structure. The internal data structure can change to accommodate new data types, attributes, etc but a standard output format can be maintained for any one view of the data. This ability to output data in a standard format allows applications to develop their own routines to operate on the data. In the case of the CHS cartographic application, it would be possible to optimize selection, data synthesization, contouring and mosaicing routines to that particular application. Similar benefits would accrue to other applications.

The next phase of the prototyping will address the managing of **bathymetric data** in the following manner. All point data (at field sheet density) will be stored in the INGRES relational DBMS that is imbedded in the CARIS system and the DBMS tables will be keyed by source. This data base will be partitioned by area, data from the same source will not be split between tables and the tables of each partition will be stored off-line. This off-line approach is taken because of the volume of these data (estimated to increase at the rate of several gigabytes a year), the fact that these data are fairly static and the fact that most applications requiring these data can function with a 24 hour turn around time between request for data and delivery.

It is recognized that a conversion is required to present data from such a bathymetric data base to the cartographic application in a useable form. This will not be addressed in detail until the feasibility of the selected approach is determined during the prototyping. However, efforts are underway within the cartographic application to develop data synthesization techniques to render these dense data legible to cartographers. Pilot projects in interactive compilation of charts from digital data are also being carried out to identify and develop procedures.

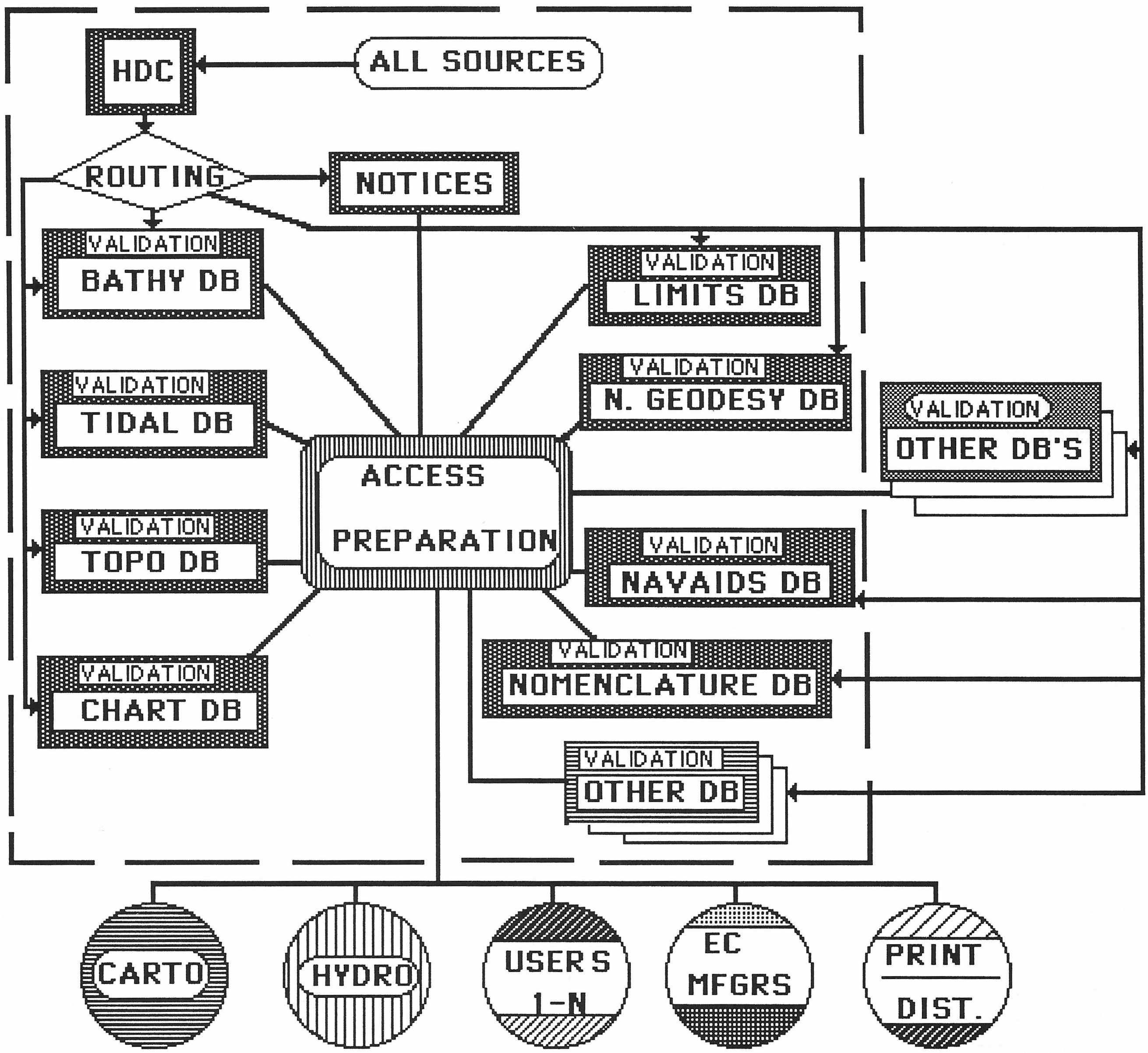

Figure 4: CHS Information System

The ability to discover the problems of conceptual solutions before you have committed your organization to a course of action is one of the real benefits of prototyping. And it is often easier for the user, who is very much an amateur in the system development field, to recognize that while a particular proposed solution may be technically feasible, it violates some principle of the data or the processes that must be supported.

Overview

The hydrographic offices of the world are faced with the problem of managing an ever increasing volume of digital data and there does not appear to be an off-the-shelf solution to all the problems. The Canadian Hydrographic Service is not alone in addressing this issue. The Australian Hydrographic Office has just awarded a contract to GEOVISION of Ottawa to develop a HYDROGRAPHIC INFORMATION SYSTEM (HIS) and the United States National Ocean Survey (NOS) is also studying similar issues. The NOS have also modified their concept to recognize that there are two separate operations to be addressed, the management of data independent of applications and the management of data subsets and products corresponding to one specific application, chart production. They are investigating issues such as the performance one can expect from various approaches when you have a multi-gigabyte data base, data base machines, optical storage, etc.

These issues are set out in detail in a paper that Robbie Wilson, National Ocean Survey, presented at the American Society of Photogrammetry and Remote Sensing / American Congress of Survey and Mapping (ASPRS/ACSM) conference in Baltimore in April, 1987. [Wilson, 1987]. He stresses data independence as the key to being able to respond to future change and sets out the following benefits of managing these data in a DBMS:

- allows users multiple views of the data
- reduction of data duplication
- sharing of data
- controlled redundancy
- ensures data integrity
- privacy and security
- data accessibility and responsiveness
- better management of data
- differing views of the same data via primary and secondary keys

Most of these benefits are very difficult to achieve if a graphic based system is used to manage data. CHS shares the concern about performance degradation as data volume increases and will be conducting tests as the prototyping proceeds. However, the price of ignoring the support for the independence of data available in DBMSs in favour of optimizing the throughput of digital data for a short term production gain in marine cartography may well mean that the information age for the hydrographic community will be pushed back another decade. And the more data each organization has in application-dependent formats, the more difficult and costly will be future reorganizations of data to meet new requirements.

ORGANIZATIONAL ISSUES

The availability of modern technology and even the funding to put a DBMS in place, cannot guarantee the success of a project, such as the implementation of a hydrographic information system, if the organizational changes needed to support the system are not made. James Martin [MARTIN, 1982] estimates that 80% of the data base installations over the 5 years from 1977-82 failed to show savings in software application maintenance due, not to faults in the design, but to the fact that the system cut across internal political boundaries within the organization and management did not change their policies and procedures to support the DBMS. In effect, people continued to use the system as they had their file-based system.

The emerging importance of data as an asset to organizations and the requirement to manage these data to meet the needs of both existing and future applications means that organizations must identify where an INFORMATION DIVISION, BRANCH, ETC. fits into their organization charts. The need for the data and the management of these to be independent of applications must be considered when deciding where the function should be located. The Québec Region of the CHS established an INFORMATION DIVISION of equal importance to ACQUISITION (bathymetric & tidal), DEVELOPMENT and CHART PRODUCTION, with the chief of each Division reporting to the Director of Hydrography.

At the present time the Canadian Hydrographic Service, and I would suspect most other hydrographic offices, do not have much strength in data base management support personnel. With the decision as to where a DBMS belongs in an organization, also comes the requirement to identify an internal organizational structure and the personnel to staff the positions. This structure must ensure that policies and procedures needed to support the operation of the system and maintain the integrity of the data are enforced. In times of Government downsizing and constraint, this will undoubtedly mean the retraining of existing personnel. Since all of these issues takes time to plan and implement, they are not easily implemented if one views this as a catch-22 situation and waits until a DBMS is in place before acting.

INFRASTRUCTURE

Funding for hardware and software must be identified and the implementation approach adopted will undoubtedly depend on the available funding. At the present time it is very difficult to acquire funding, within government departments, for new projects. If accessible data bases are to be put in place and networked together to form the infrastructure of the information age, then governments must be convinced to view data bases and the networking of data bases as INFRASTRUCTURE, much as they regard the roads. The governments do not ask "who can I sell this road to" before they build a road. The road systems are infrastructure, built for the people, to support commerce, etc. So why ask, "who will buy bathymetric data?", or other types of data. This too is somewhat of a catch-22 situation.

The CHS now receives weekly requests for digital bathymetric data and with these data readily available, in an accessible and standard form, the demand will undoubtedly rise. One can predict requests for data to produce thematic paper charts for fishing, exploration and other applications and data for the manufacture of electronic charts. Once GPS and digital maps are available in automobiles, the volume of sales will force the price of the technology down and the demand for low cost recreational boating electronic charts will skyrocket. If the hydrographic offices of the world can not meet the demands, someone else will supply unofficial, unverified data and it will no longer be possible for the hydrographic offices to maintain control over the quality of the data used for these products.

Data content standards within an organization are important and will increase in importance when numerous data bases are accessible by many users for numerous applications. The networking of these data bases to form information systems also require communication standards. These are parts of the infrastructure that must be addressed quickly before a number of de facto standards arise. The CHS and other government agencies, including the Ontario Ministry of Natural Resources, are investigating a communications interchange format called MACDIF (Mapping And Charting Data Interchange Format) [IDON,1986] for the transmission of map and chart data. This format is based on an internationally accepted standard for the transmission of graphic and text data.

Canada has also developed satellite broadcasting technology that permits data to be broadcast at speeds of 6.3 million baud. The CHS has been investigating this technology as a potential networking tool to connect regional data bases in the 5 offices of CHS and to support a concept of printing up-to-date charts on demand. The system has been tested for the latter application with chart files broadcast from Ottawa to a printer in Dartmouth, N.S. and to a second receiver in Calgary. This approach also has the potential to support future products such as the electronic chart, possibly with the broadcasting of up-to-date chart data directly to ships.

It appears that while the establishment of accessible networked information systems are technically feasible, a great deal of effort is required to establish the infrastructure required to implement such a concept. Neil Anderson has drawn an analogy between the situation with data bases now and the situation with electricity in North America in the 1930's. In the case of electricity, standards were established (120 volt AC, 60 cycle in North America) but wide spread use of this technology did not occur until the United States' government commenced construction of dams, power plants and distribution lines under Roosevelt's "NEW DEAL" [N. Anderson, 1986]. These projects used job creation to develop an INFRASTRUCTURE that would benefit all citizens. A similar approach may be possible for the creation of data bases and the networking of data bases into information systems.

CONCLUSIONS

The Canadian Hydrographic Service and other hydrographic offices are addressing the issue of digital data base management. It has become obvious that data independence from applications is paramount if the systems being developed are to meet the changing requirements of existing and future applications. There is also a parallel requirement to manage data subsets and products within various application, but in particular within the cartographic application.

Addressing organizational issues such as where data base management and information systems belong in an organization, the changes to policies and procedures required to support the operation of these systems and the identification and training of the necessary personnel all must be dealt with to benefit from these concepts.

The establishment of the infrastructure to make existing data bases accessible, to network data bases into information systems and to develop standards for data content and communication must all be addressed. It may be necessary to view this infrastructure in a manner similar to how one views the road system or the power distribution systems.

Although technically feasible, considerable coordinated effort is required to achieve the goal of accessible, networked expert data bases outlined in Figure 5.

These are indeed exciting times with technology providing capabilities that were not possible only a few years ago. The challenge facing the Canadian Hydrographic Service, other hydrographic services and mapping agencies, is how to take advantage of these advances and how to best incorporate the ones that will yield the most benefits to meet the challenges of the information age.

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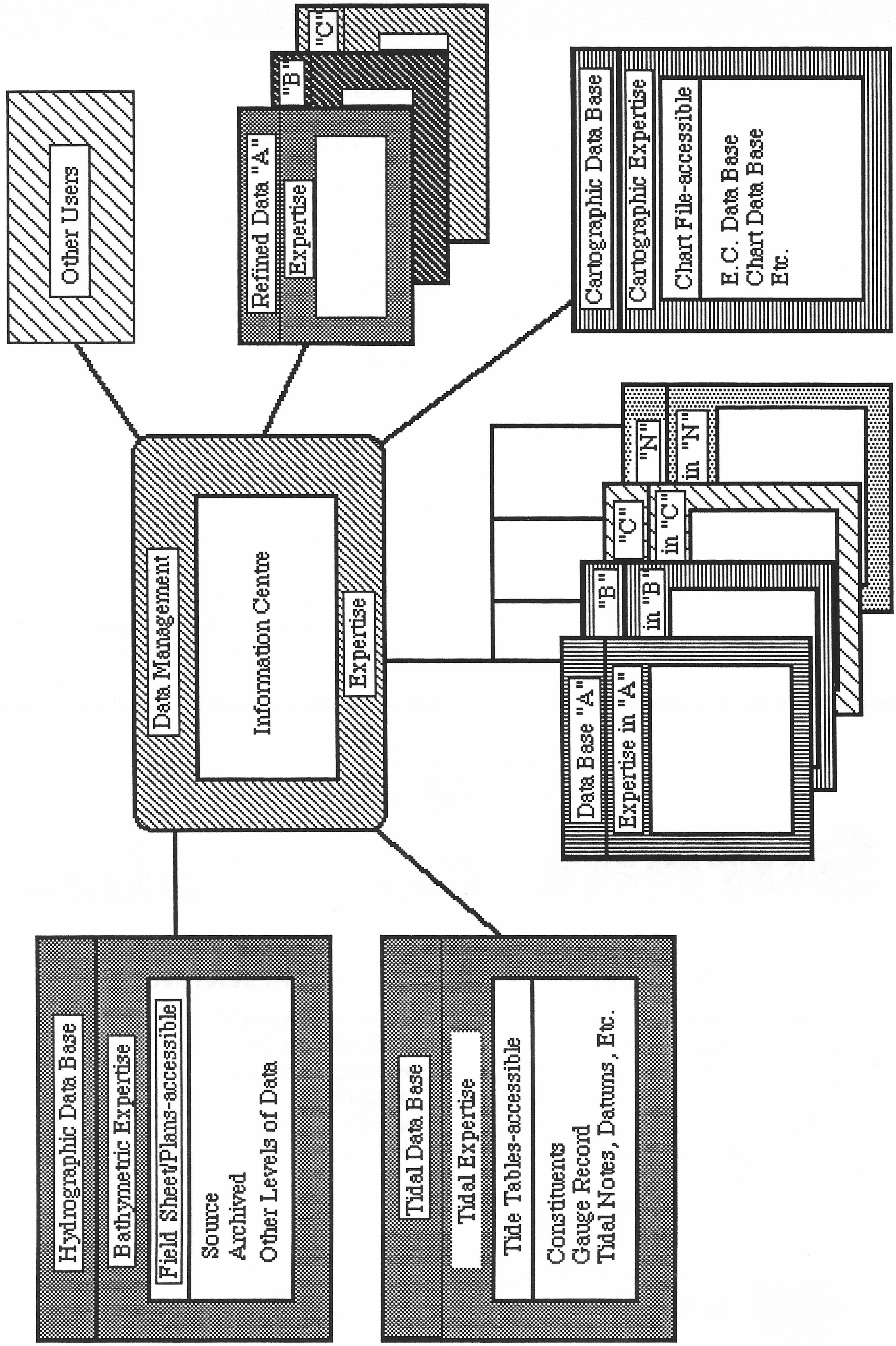


Figure 5: Information Centre

Poet's Corner

When the disco beat is calling
And the shades of night are falling,
Do I get my dancing shoes on? - not a chance.
I ignore the lure of lasses
As I trudge off to my classes
And close my mind to thoughts of sweet romance.

While others are out drinking
I sit studying, pondering, thinking,
Like a hermit in a Himalayan cave;
I'm aware of deviation,
Its effects on navigation
And the interlocking force of wind and wave.

I know all the cloud formations,
Each and every Pulstrac station,
I've memorized each manual and text.
But there's only one thing wrong.
I've been cooped up for so long,
I've forgot about the birds, the bees and sex.

R/Cdr Alexander Roulstone, JN
Oakville Power Squadron

Hydrographic Training in Malaysia

by
Hans J. Gray

ABSTRACT

During the first five months of 1987, I was fortunate enough to be working in S.E. Asia well away from Vancouver's dreary winter weather. My mission was to teach a basic hydrography course to a group of Malaysian students. This project was part of a three year program funded principally by the Canadian International Development Agency, and supported by the Institution of Surveyors, Malaysia and the Canadian Institute of Surveying.

This account describes some of my experiences during that stay in Malaysia and the period leading up to the training course.

INTRODUCTION

In the fall of 1981, I completed the Canadian Hydrographic Service (CHS) Hydrography II Course of advanced study in Ottawa. It was this, plus 16 years of hydrographic survey experience, which contributed to my selection by the Canadian Institute of Surveying (CIS) with the concurrence of the Institution of Surveyors Malaysia (ISM), to be principal lecturer and co-ordinator for this course. The training was divided into ten weeks of classroom work, followed by ten weeks of practical field work.

In November 1986, I traveled to Ottawa to visit the Training and Standards Branch of the Canadian Hydrographic Service and spoke with the senior staff there. They were, as I had hoped, very supportive and passed on many useful tips concerning the teaching and organizational aspects of the project. The Training Branch also supplied the majority of the course material. This material included course notes, some tests, diagrams and a video tape, covering most of the technical subjects in the classroom work.

The subjects covered in the classroom included: Land Surveying, Projections, Hydrography, Tides & Water Levels, Electronic Positioning, Introduction to Computers, Cartography, Seamanship & Navigation, Meteorology, Introduction to Marine Geophysics, Engineering Hydrography, Field Sheets, An Overview of Marine Law and Project Planning.

I departed Vancouver for Kuala Lumpur (K.L.) via Hong Kong during the first week of January 1987, accompanied by Mr. T.D.W. McCulloch, Project Manager for the C.I.S. Mr. McCulloch has been a major force in developing the assistance program in Hydrography, Marine Cartography and related disciplines in Malaysia, of which this course was only a part. His extensive experience in Malaysia led to the conclusion that sending a hydrographer halfway around the world with a stack of course material and expect him to single handedly coordinate and complete the program, was a difficult task. During my first two weeks stay in K.L., I was introduced to all the people who were supporting the project and could assist in keeping problems to a minimum, allowing me to concentrate on the course itself.

KUALA LUMPUR

Kuala Lumpur, or K.L. as it is known, is the capital of Malaysia and is located on the western side of the Malay Peninsular at an approximate latitude of 3 degrees North. The city is about one hundred years old and has a population of around one million. The climate is equatorial. There is no dry season: precipitation is approximately 2500 mm per year. Mean temperatures vary 2 degrees per year with 32C maximums and 23C minimums, while humidity varies from 99% to 60%. It is a cosmopolitan city with excellent facilities. A garden city abounding in tropical plants and flowers, it is one of the show pieces of Southeast Asia. The population of the country is roughly split 53% Malay, 36% Chinese, 10% Indian, and 1% others. The percentage of Malays in the cities is somewhat lower than this, with more Malays living in rural areas. There is great energy being directed to bringing in greater numbers of Malays into commerce.

CLASSROOM TRAINING

This course was too large to be taught by one person in ten weeks. Therefore certain subjects were put forward as being suitable or preferable to be taught by Malaysians. These were selected on the basis of subjects which should have substantial local knowledge input such as meteorology, seamanship and navigation, projections (this will be enlarged on later) and cartography. It also included subjects for which Malaysia is recognized as having considerable educational expertise already such as land surveying. The ISM was asked to arrange for lecturers to cover these areas. Upon my arrival in K.L. several meetings were held to finalize the scheduling and staffing. The lectures were split as follows:

Canadian Hydrographer: Hydrography, Tides and

Water Levels, Electronic Positioning, Introduction to Marine Geophysics, Engineering, Hydrography and Project Planning.

Department of Surveys and Mapping, Land Surveys: Land Surveys, Projections and Marine Law.

Local survey company: Introduction to computers.

Royal Malaysian Navy: Cartography and Field Sheet preparations. This agency is responsible for marine charting. Several officers contributed to the course.

Marine Department: Seamanship and Navigation.

Meteorological Department: Meteorology.

The guest lecturers were asked to present their subjects in addition to their regular work load and must be commended on their excellent effort under often difficult circumstances.

Establishing and amending the timetable was a major time consumer during the entire classroom section of the course. Many times a lecturer would telephone before his lecture to postpone his class to another day. However, all the work was completed, revised and examined within the prescribed schedule. Some examination results were not available until field work was nearly complete.

Classroom facilities were provided in an air-conditioned meeting room at the headquarters ISM in Petaling Jaya (P.J.), an industrial suburban centre midway between downtown K.L. and the K.L. International Airport at Subang. Secretarial and general office services were also supplied by ISM. The students were from various backgrounds, but CIDA suggested that the racial split of the class should approximate the national make-up. There was also encouragement to include at least one female student.

The final make-up of the class was: three Malay men, a graduate of surveying, a graduate of marine studies and a technologist; one Malay woman, a graduate of surveying and marine studies; one Indian man, a technologist with 10 years of hydrographic experience; and three Chinese men, all graduates in surveying.

The students were employed by the Department of Surveys and Mapping, the Marine Department, the Klang Port Authority and private survey companies.

As with any group of students their abilities and aptitudes varied greatly - some had no practical survey experience, others had many years. However, all had a desire to do well and all worked hard with the more advanced ones assisting those having trouble when required. At the end of the whole course, I had a much better understanding of the country and its people, and the students had a little more respect and understanding of each other, plus a better knowledge of hydrography. In a multi-racial society such as Malaysia, the various ethnic groups seldom mix by choice. This leads to many misunderstandings between them. The students learned, among other things, that they could work together in teams to get the job done, even during the Muslim fasting month of Ramadan, when the Muslim half of the class abstained from food and drink during daylight hours.

Teaching in Malaysia has its own "flavour". The national language is Bahasa Malaysia. However, as a legacy from colonial days and due to the demands of international trade, English is widely used. I had no major problem being understood, although I had some problems understanding the students on occasion, as they can be high speed orators!

Once the classroom examinations had been written and the theoretical portion of the course was completed, the students felt more at ease with my style and with the subject in general. After a one-week break, we were ready to commence the practical work. The purpose of the field work, which consumed half of the total course time, was to put into practice as much as possible of what we had learned in the classroom, and for each student to produce a field sheet.

FIELD WORK

The field work was conducted at Port Klang, about 35 kms west of Petaling Jaya in the estuary of the Klang River. The Marine Department was kind enough to supply office space in their headquarters at dockside. Equipment, boats and shore support personnel were also supplied by the Department with assistance from the Port Klang Authority and the Surveys Mapping Department. Some computing facilities were supplied by a private survey firm.

Due to logistical considerations, financial restrictions and time constraints, efforts were concentrated on the Port Klang area. Since most of the students would be working in coastal areas, it was suggested that a large scale survey would be the most practical. The Port Authority was approached to determine their requirements in the area. They outlined an area which needed to be surveyed and we agreed to cover as much of the area as time allowed. There were also control network extensions required a few kilometers away which were reconnoitered, but these were not completed due to a lack of time.

Projections, grids and distance units must be studied at some length prior to attempting survey computations in Malaysia. Firstly, the area is covered by a Rectified Skew Orthomorphic (R.S.O.) Projection on a modified Everest Spheroid. This projection had been chosen to keep scale factor values down to a manageable level. However, original coordinates may be published in feet or yards and great care must be exercised in converting these coordinates into metres, as the feet used are Indian feet not Imperial or International feet. Although the difference is small, it becomes significant when converting coordinates. Secondly, each state has its own survey grid based on a Cassini Projection used mainly for cadastral work. This is not suitable for control survey calculations due to the fact that the scale factor varies with azimuth. Therefore, state control points must first be converted to R.S.O., in International Metres and then used in computations. Most charting is done on a Mercator projection. It is clear from this that there is some advantage to having local input for teaching Projections as they apply to Malaysia!

Many existing control points were used for the field work, but primary triangulation stations combined with solar azimuth observations were used to establish a new network of coordinate values. Vertical control was brought in from the federal second-order network and sounding datum was established to coincide with published chart datum.

Shoreline plots were supplied by the Port Authority and were revised by sextant, mini-ranger, traversing and radials. Soundings were obtained with Raytheon 719C fathometers. Positions were obtained by theodolite intersection, range/bearing and range/range using Mini-Ranger III equipment. Currents were measured by float tracking on both ebb and flood spring tides. Tidal heights were visually observed from a newly installed tide staff near the centre of the project.

The majority of the work was completed in small open boats. The students were able to experience all major aspects of the field work in person and each was involved in the various phases including: bush clearing, beacon and monument construction, control observations and computation, boat steering and operation, sounding, positioning, data reduction and field sheet production. Each student was required to produce a field sheet and a project report, and these were graded.

All eight students passed the classroom examinations. The practical standard did not approach the classroom grades considering the emphasis on accurate, legible and complete field sheets. However, everyone attained an acceptable standard.

CONCLUSION

The presentation of the certificates, which were supplied by CHS, was kindly carried out by His Excellency The High Commissioner for Canada at his residence in Kuala Lumpur. This informal occasion marked the official completion of the course.

In 1986, three Malaysian students traveled to Canada to attend the Hydrography I training for twenty weeks. In many ways there are advantages to conducting the course in Malaysia, because the course can be tailored to the specific needs of that class while covering the entire syllabus. This may not be possible when "guests" attend CHS training programmes which are necessarily geared towards the Canadian Hydrographic Service activities. Examples used are Canadian and field work is carried out under Western conditions with well serviced equipment. Actual local conditions play a very important role: available equipment must be used, local assistants must be trained and Malaysian requirements must be met. This course went a long way to satisfying these requirements, and I feel very fortunate to have been able to contribute something towards that.

I would like to thank the Institution of Surveyors Malaysia and the Canadian Institute of Surveying for getting together with the Royal Malaysian Navy and the Canadian Hydrographic Service to organize and support the course. Also, thanks to the Canadian International Development Agency for its financial and other support, the survey firm of Jurukur Perunding and the Canadian High Commission in Kuala Lumpur for their assistance. Tom McCulloch provided valuable assistance and the McElhanney Group Ltd. gave me the opportunity to take part in the project. Thanks for the encouragement.

News From Industry

THE HYDROGRAPHIC SOCIETY

The Hydrographic Society, with members drawn from over 70 countries, has five national branches as well as its London-based activities. These branches have their own meetings and seminars each year, and are located in Launceston, Tasmania; Copenhagen, Denmark; Riyswijk, Netherlands; and Rockville MD, USA.

Ir. J.G. Riemersma of the Netherlands has recently been elected President of The Hydrographic Society, taking over from Professor Sir Hermann Bondi at the AGM in October 1987. Ir. Riemersma is Chairman of Commission 4 of the Fédération Internationale des Géomètres (FIG) and has recently retired from Shell International in The Hague. He is also a member of the Netherlands Commission on Geodesy as well as being the sole surveying representative on the Navigation Advisory Committee of the Paris-based European Space Agency.

The Netherlands Branch is especially active these days as they will be hosting the Hydro 88 Conference in Amsterdam in November 1988. This conference will be co-sponsored by Lloyd's List and FIG Commission 4 [Hydrography].

SURNAV

The Canadian Department of National Defence has ordered another four Krupp Atlas Electronik Polarfix range-azimuth laser position-fixing systems from Surnav Corporation of Nepean (Ottawa) to add to those already in service. These will be used on the degaussing ranges at naval bases on the east and west coasts of Canada. The operation, which necessitates a continuous high degree of positional accuracy for checking the magnetic anomolies of ships, involves dynamic determination of the ship's bow and stern positions by the Polarfix at given points while under way. Surinav has also received an order for a Polarfix System from the Department of Public Works in Edmonton, Alberta. This brings the total number of Polarfix systems in Canada to fifteen.

QUBIT

Qubit (UK) report several successful trials using their TRAC IVB integrated navigation & positioning system in combination with Fairey's Trail Blazer ROV and the Waverley 3000 Plus Sidescan Sonar.

Using such off-the-shelf systems gives great flexibility because each is very portable. The various systems can be brought together and used in small craft-of-opportunity wherever the need arises, even in applications requiring precise positioning for subsea inspection and seafloor mapping.

Successful tests have been run using the system in dhows, fishing vessels and survey launches.

KLEIN ASSOCIATES

Klein Associates Inc. report that they now have a network of 45 sales and service agencies throughout the world, servicing their Sonar customers in over 50 countries. They are active in Side Scan Sonar and Sub-Bottom Profiling Systems, and have recently been marketing a new digital dual-frequency sonar.

FLUID ENERGY

Would you believe a tourist submarine with lots of window seats diving to 250 feet with 50 passengers? Fluid Energy (UK) has built two of these, now in service in St. Thomas and Bermuda to let tourists explore sunken reefs and wrecks in comfort! Five more are now being built; four for the tourists in Finland, Korea, Japan and Saipan, and the fifth is a 100-passenger version for the USSR Gas Ministry.

QUESTER TANGENT CORPORATION

Quester Tangent Corporation is pleased to announce a new generation ISAH system. By combining the software enhancements necessary to meet the various Canadian Hydrographic Service regional requirements with a significant level of upgrades developed to offer commercial clients enhanced graphic displays and acoustic positioning/tracking system and side scan sonar capabilities, an ISAH system which offers an outstanding array of powerful enhancements has been completed. Enhancements include:

- a highly developed, user friendly, operator interface
- a powerful, efficient, multi-sensor multi-lop, multi-station, integrated navigation and positioning function
- side-scan sonar tow-fish positioning and coverage display capabilities
- graphics displays of survey actions which, by operator selection, can incorporate coastal features such as coastline, routes, waypoints, grids, local hazards, exams, vessel track lines, side-scan tow-fish positions and coverage, survey areas, and both primary and secondary vessel positions
- real time plotting of the survey operation
- display screen dumps in full graphics format

- expanded fix mark, event and line number, data formatting and recording functions
- full acoustic tracking and positioning capabilities
- inter-system calibration capabilities.

The first client to benefit from this next generation ISAH is the National Safety Council of Australia (NSCA) who have purchased ISAH to meet their subsea search and recovery needs aboard their vessel BLUE NABILLA. NSCA are also the first users of our new "back-lit" LCD helmsman's display.

Over the past few months the majority of our business travel at Quester Tangent has been to Australia in support of recent sales and increased marketing activities in this area.

TERRA SURVEYS LTD.

Lidar data processing for the 1987 West Coast LARSEN survey incorporated shoreline mapping detail collected by an RC-10 photogrammetric camera. The photogrammetric information nicely complements the Lidar water depth data by further delineating the high water line, foreshore limits, visibility limits and probable zones of heavy kelp growth. The combined capability of the Lidar and photogrammetric camera is an effective survey system for precise mapping of coastal areas. Some of the West Coast survey results will be part of a Terra exhibit to be displayed by Jim Vosburgh at the upcoming Oceanology International '88 to be held during March at Brighton, England.

Later on, in April, Terra will be participating in the U.S. Hydrographic '88 Conference held in Baltimore, Maryland. Paul Conrad will be attending and has had two technical papers accepted for presentation at the conference.

Recent near-shore hydrographic and sub-bottom profiling jobs have really shown the effectiveness of the ESPRIT laser rangefinder for near-shore positioning. The system's ease of operation and range to 5 km greatly facilitates the launch positioning and track recovery.

MESOTECH AND SIMRAD SUBSEA

The Canadian Hydrographic Service has ordered two Simrad EM 100 multi-beam echo sounder systems from Mesotech of Vancouver.

This state-of-the-art swath sounder installation has 32 separate sounder beams and gives continuous 100% coverage of the bottom over a swath width of 2.5 times depth. Measurements are compensated for vessel movements as well as sound velocity variations, and thus offer a remarkable level of precision, productivity and consistency for hydrographic surveys.

The new systems will be installed on the CSS LOUIS M. LAUZIER and on a new yet-to-be-launched survey vessel. The CHS will probably begin using this new survey sweep system in the Gulf of St. Lawrence.

CENTRAL BRANCH

General

Our local Branch Executive for 1988 is:

Vice-President:	Sam Weller
Secy.-Treasurer:	Terese Herron
Executive Members:	Raj Beri
	Al Koudys
	Brian Power
	Dave Pugh
	Bruce Richards
	Boyd Thorson
	Keith Weaver

Our congratulations to two of our families on the recent addition of potential future hydrographers: Kyle and Janet Moate - Ian Alistair on 14 November 1987; Roger and Marion Robitaille - Jay Joseph, on 30 December 1987.

Congratulations to Dave Pugh on attaining his Canada Lands Surveyor qualification! He did well on his exams, and his credentials have now been accepted. Twelve other Central and Arctic Region Hydrographers wrote the CLS exams this spring, and we wish them all success.

Central Branch ended 1987 with 71 paid-up members, and since our last Lighthouse report we have added several new people to our ranks: Alfie Yip, H.B. Macdonald, Frank Delph, Joseph Delle Fave and Tein Vu. Welcome to Central Branch of CHA, and we look forward to seeing you at Branch events, and introducing you to your fellow members. Your first beer is on us!

Julia Browning has been thoroughly enjoying her year in the South Pacific. She has kept us green with envy with her letters telling of encounters with kangeroos and Koala Bears in Australia, and she expects to be coming home in May. More details of her adventures are given in our Central Branch newsletters.

Branch activities

During 1987 we sponsored a wide variety of events, including technical seminars and luncheon seminars with invited speakers as well as our regular business meetings. We are continuing our seminar series in 1988, and continue to alternate our business meetings between noon and evening so that all our members have a chance to get to at least half of them. Evening meetings feature an invited speaker after the business, and pizza is served later. Good social occasions! All our functions have been well received by our members and are a lot of fun. We look forward to getting to know our members better as these events continue.

Our 17th Annual H2O Bonspiel held on 14 February 1988 was a great success and a fun day, with 47 curlers participating. Thanks to our generous sponsors there were prizes for everyone! And our congratulations to the winning teams: in first place - R.Solvason, L.Belitski, S.Rhamey and M.Jones; in second place - R.Covey, K.Dexel, J.Dixon and R.Dermott.

We especially thank the sponsors for their support: CHA Film Club, CHA Central Branch, Digital Equipment of Canada Ltd., J.M. Ellis Ltd., Klein Associates Inc., McQuest Marine, Marshall Macklin Monaghan Ltd., Norman Wade Company Ltd., R.C. Marine Electronics Ltd., Rapid-grafic Inc., Royal Bank of Canada, Surnav Navigation Systems and Terra Surveys Ltd.

Sponsors were invited to bring their own teams, and this year the Norman Wade team was: Dave Fudge, Bill Dorion, Shirley Fudge and Colleen Kennedy. Now is the time to get your teams lined up for next year. The ice is already booked!

Branch Personalities and History File

A new venture suggested and being developed by Raj Beri is a Personalities & History file. The idea is to maintain a brief file on each of our members so that we can write short profiles for Social Notes in Lighthouse or a newsletter when people move on to better things. This is working well, and we have collected a brief biography on many of our Branch and International Members.

G.E. Wade Essay Award

One major activity we have recently instituted is the G.E. Wade Essay Award. This award is in honour of a fine man and meticulous surveyor. Gerry was a Central Branch member very active in both CHA and educational fields, and we thought it very fitting to honour his memory with an Essay Award.

This award consists of two First Prizes of $100.00 (or Second Prizes of $50.00) to be awarded each year to the best essays on any hydrographic or cartographic subject, technical or human interest. The competition is open to full-time students enrolled in any hydrographic or cartographic courses, and entries are to be submitted directly to Central Branch by May 29 of each year. The essays should preferably be 1,500 to 2,500 words in length, and winning essays will be submitted to Lighthouse for possible publication.

This year our Branch Executive is particularly active, and 1988 promises to be our best year yet. All in all our Branch has a lot of fun!

International Members

International Membership in the CHA is available to people who are not resident in Canada but would like to be members of the CHA, and the Annual Membership fee is $30.00 (Canadian) for 1988. Several new International Members have joined in the past year, and we extend a warm welcome to each of them: Lt.-Cdr. Larry Robbins, Executive Officer of HMNZS Monowai, New Zealand; Nasir bin Ahmad, Senior Land Surveyor in Selangor, Malaysia; Harri Kalaja, a geophysicist with the Helsinki University of Technology; Maarten Beisterveld, a student at HZS "Amsterdam", the Netherlands; Francis Charles, head of Hydrographic Unit, Trinidad & Tobago; Matt Murphy, director of the Sherkin Island Marine Station in Ireland; Ian M.M. Taylor, a freelance land and hydrographic surveyor in England; Karl Stertzbach, a navigation engineer with NCS International in Texas, and; Dip.Ing. Soegeng Soebagio, an engineer with Geobecon Surveys, Indonesia.

Two of our own Central Branch members have "graduated" and are now on our International roll: Lt.-Cdr. Frank Rossi, with NOAA in Washington DC, USA, and Simon Baksh, with the Hydrographic Unit, Trinidad & Tobago.

The National President has arranged that the International Membership will be administered by Central Branch, and as well as receiving their copy of Lighthouse, International Members receive the Central Branch newsletter to keep them in touch with CHA activities. This newsletter brings news of other members, minutes of each Central Branch meeting, notice of future functions, and some discussion of items of concern to the members. News of the other Branches is also included. During 1987 Central Branch produced five of these newsletters, and copies went to all local and International Members, and copies were also sent to the other CHA Branches.

CENTRAL AND ARCTIC REGION CHS SWEEP SYSTEM UPDATE

The following report on the Central and Arctic Region sweep system is by Paul Davies and George Fenn. The sweep was used for the first time in the region in 1987. A more complete report on the sweep system will appear in a future edition of Lighthouse.

Background

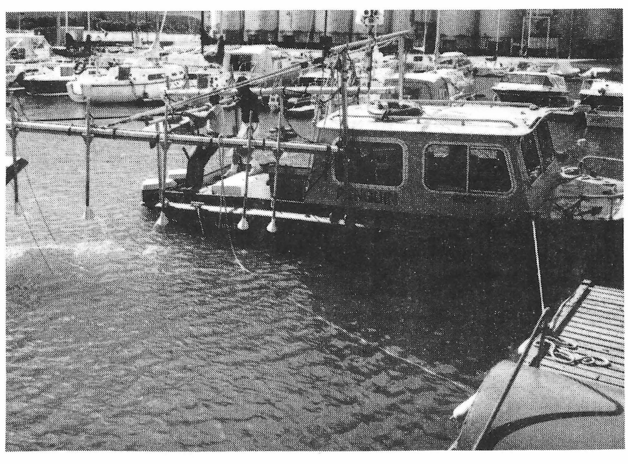
The Canadian Hydrographic Service (CHS), Central and Arctic Region (C&AR), acquired the Navitronics Seadig 201 Electronic Sweep in June 1986. It was transferred from the CHS Atlantic Region when the CSS SMITH was commissioned with a new Navitronics sweep package.

The sweep package included 28 Reson transducers, 2 Hewlett Packard 9836 computers (HP 9836), 2 Tandberg TDC 3000 digital cartridge recorders, 1 depth pre-processor (DPP 1B), 2 thermal printers, 1 Hydrographic Data Handler (HDH 1) and 2 Multichannel sounders (MCS). A path guidance unit (PGU), 1 Depth Pre-processor 2B (DPP 2B) and a digital compass were later purchased for the system. CHS (Atlantic) kept the Gyro Compass and an extra multichannel sounder as spares for the CSS SMITH.

The system did not include processing hardware or software. However, processing software was acquired from CHS (Atlantic) at a later date and modifications were made to allow data processing on existing C & AR software. A MicroVAX II computer was used to process the data in the field.

A 6.4 metre aluminum hull Monark work boat was used as the initial test launch. Booms, transducer struts and rigging were manufactured by a marine company in Oakville. The boat has an overall sweep path of 12 metres. The basic launch design worked well, but more cabin and deck space were needed for successful sweep operations. In the interim, modifications were made to the prototype. Transducers were installed in the hull, the cabin extended and a water cooled A.C. generator installed. The Bayfield Institute (BI) boat shop built the transducer pods and floats for the ends of the booms.

At this time, Mini-Ranger III was the only system CHS (C & AR) had that was compatible with the sweep software. Trials were completed in Hamilton



Boom Deployment

Harbour and the equipment was brought up to a stage of data collection, but not the capability of processing.

During the winter of 1986/87 a larger launch was acquired through the BI boat shop. The launch was not yet built, so some modifications were incorporated by the builder. The new launch is a 7-metre Procor, built by Eastern Equipment of Montreal. The Department of Fisheries & Oceans purchased 9 boats of this design and had modifications made to the CHS sweep boat. Basically the boat is an aluminum, cathedral hull style, work boat similar to a Monark. Modifications included enlarged cabin, saddle fuel tanks (in lieu of day tanks), and larger engines (twin 90 h.p. Evinrude outboards versus twin 70 h.p. outboards). The boat was outfitted with the original booms and the Navitronic sweep equipment was rack mounted inside the cabin. A Raytheon Universal Graphics Recorder (UGR) and a Ross transducer were added to the system. To position the launch CHS (Quebec) loaned the region an Altas Polarfix for the field season.

1987 Field Season

The major headaches during the 1987 survey season were the transducers in the hull. Due to the cathedral hull design, aeration caused a major problem. Other problems were also encountered. The UGR Raytheon recorder has a digital output and noise on the recorder graph often interfered with the 12 bottom traces. Although trends were not hard to distinguish, air bubbles, fish, weeds and noise often made anomaly verification impossible. Cabin temperature reached in excess of 30C in mid summer. The steering system tended to pull hard to the right. The compass was one part of the system that was not functional during the field season. It appeared that either the electronics or the metal structure of the boat caused the compass to read incorrectly. This was noticed on numerous occasions when tied alongside a wall with a known bearing. For work carried out during 1987, crabbing was not a problem, therefore negating the need for the compass. During the 1988 season more time will be available to solve this problem. The launch also has a few other minor problems which will be rectified prior to the 1988 field season.

The launch PENGUIN arrived in Collingwood on July 10 along with the Polarfix from CHS (Quebec). Most of the next two weeks was spent getting the sweep equipment calibrated and becoming familiar with the Polarfix. One hydrographer and one electronic technician attended a short SURNAV course on the Polarfix, given in early April to the Department of Public Works (DPW) in Toronto. Hydrographic staff and Research and Development spent the next two weeks working on the sweep system hardware and on the processing system. The sweep boat began sounding an area previously sounded by conventional methods to get data for processing, to debug the system, to become familiar with the system and to try different sweep sounding techniques.

On July 31 the sweep was returned to BI to have a representative of Navitronics go over the system and for the hydrographer assigned to the sweep to attend a Navitronics course. The Sweep returned to Collingwood on August 18 and after a short test in Collingwood was sent to Owen Sound to sound the inner harbour. Good agreement was obtained when compared to the sounding done conventionally.

At this point the field survey decided to use the sweep in Thornbury at a scale of 1:1,000. The area within the harbour (very small, tight area) was sounded. However, the harbour is shallow with a very soft mud and weed-infested bottom. As a result many bad depths crept into the data. The UGR was unable to clearly distinquish between noise and a true anomaly therefore leaving the processor no option but to have the boat return to the area for further investigation.The outer area of Thornbury was then sounded with the sweep. Conventional launch check lines were run throughout the area and good agreement was obtained. The sweep data appeared to be 2 to 3 decimetres shallower but this is reasonable when considering the sweep is 100% bottom coverage on line spacing when compared to the conventional single transducer launch. The Polarfix worked fine throughout the survey contrary to reports from other users of problems.

From the area swept, 88 shoals were located and were re-sounded perpendicular to the original sweep lines. After this exercise, 18 shoal points were still dubious as to their existence. The other 70 agreed with the initial sounding lines. At this point in time the end of the field season was near and the 18 shoals did not get resolved. The plan is to examine these shoals by sweep and conventional launch during the 1988 field season.

Sweep Sounding - Owen Sound harbour

In conversing with hydrographers in the Atlantic Region it appears that at times they have to re-sound an area up to five times to verify if a shoal exists. Many problems are caused by weed and schooling fish.

During the fall of 1987 one final test was carried out with the sweep boat. Some positions of bottom objects appeared to shift if swept in different directions. This was also verified by CHS (Atlantic) and by DPW (Atlantic). Although the shifts we found were in the order of 2 metres, a number of tests were carried out for verification. A submerged float was deployed 4 metres off the bottom and the sweep boat ran a series of lines over it in different directions. The final plot showed the buoy had moved depending on launch speed and direction. Again, action will be taken on this matter to rectify the problem before the 1988 field season.

1988 Field Season

During the fall of 1987 three auto tracking systems were evaluated by C & AR. They included the Atlas Polarfix, Navitrack 1000, and the Geodimeter IMS Autotracker. The successful system will be used with the Navitronic Seadig 201 sweep system in the Napanee River and Telegraph Narrows area of the Bay of Quinte in 1988.

Prior to the field season the hull transducers will be modified to permit better data collection. It is anticipated that the sweep data will be used to produce field sheets assisted by conventional launches to do the areas not swept.

SECTION DU QUEBEC

Depuis novembre dernier, deux réunions du conseil d'administration 1987 ont eu lieu. Les principaux points soulevés furent: le bilan du colloque, la révision de la constitution, l'organisation de l'assemblée générale annuelle et la vérification comptable des livres de l'Association.

Une soirée-conférence "Les opérations portuaires" s'est tenue le 21 octobre 1987 à Québec. Jean-Claude Michaud, capitaine du Port de Québec, a suscité l'intérêt des nombreux participants.

L'une des réalisations majeures de la Section du Québec demeure la tenue du colloque **L'hydrographie: dimension essentielle aux sciences de la mer**, les 19 et 20 novembre derniers à Rimouski. L'événement a obtenu un franc succès. En effet, près de 200 personnes ont participées aux différentes activités et ont visitées la vingtaine d'exposants présents. Plusieurs documents ont été produits et sont disponibles au bureau de l'Association; ce sont le compte rendu des conférences, un volume relié de plus de 200 pages, et une production de six vidéocassettes présentant les 17 conférences du colloque.

Le projet parrainé par la Section du Québec, qui a permis l'embauche de deux employés chargés de l'organisation du colloque, se termine le 26 février 1988. Pour l'année en cours, l'Association a présenté au ministère de l'Emploi et de l'Immigration du Canada, trois autres projets. Celui soumis dans le cadre du Programme de développement de l'emploi fut refusé. Une demande de subvention a également été faite pour le programme Assurance-chômage-Article 38. Les objectifs du projet sont: la réalisation d'un kiosque, de documents et d'activités d'information sur l'hydrographie; la mise en place d'une structure d'organisation pour la tenue d'un colloque international sur l'hydrographie; la participation à la production de la revue LIGHTHOUSE et l'élaboration d'un dossier de financement permettant la création de poste permanent au bureau de l'Association. Un dernier projet s'adressant aux étudiants, Défi 88 a été présenté. Celui-ci porte sur la production de documents vidéo sur l'hydrographie et les sciences de la mer.

Actuellement, la Section du Québec compte 97 membres, une augmentation de 38% par rapport à l'année précédente. Mentionnons également la grande diversité des adhérents à l'Association. En effet, 28% de ceux-ci travaillent au Service hydrographique du Canada, les autres membres proviennent du milieu collégial et universitaire, d'institutions telles l'Institut de marine et l'I.N.R.S., de corporations de pilotes et d'entreprises privées (firmes de consultants, arpenteurs-géomètres, etc.).

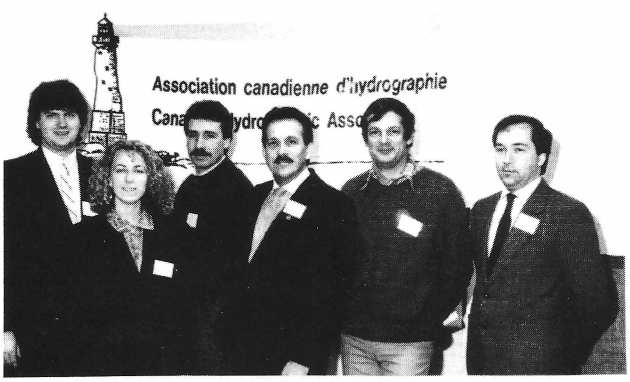
Le siège social de la Section du Québec demeure à l'Institut de marine du Cégep de Rimouski, au 53, rue St-Germain ouest. Ceci grâce à la collaboration de la direction de l'institution qui a mis à notre disposition, un local spacieux et les équipements de bureau nécessaires.

Siège social de l'ACH, Section du Québec
Institut de marine de Rimouski

Local de l'Association

L'Association a tenu son assemblée générale annuelle, le 30 janvier 1988 à Rimouski. Près de 30 membres y ont assisté. A cette même assemblée, un nouvel exécutif a été élu. Puisqu' aucun candidat ne s'est présenté au poste de vice-président, il a été proposé que le vice-président soit élu parmi les membres de l'exécutif, lors de la première réunion du conseil d'administration. Suite à cette première réunion tenu le 8 février dernier à Rimouski, le conseil d'administration 1988 de la Section du Québec se compose de:

Yvon Boulanger	Vice-président
Normand Doucet	Secrétaire-trésorier
Denis Hains	Conseiller spécial
Patrick Hally	Conseiller
Jacinthe Cormier	Conseiller
Pierre Michotte	Conseiller



Conseil d'administration 1988: Section du Québec D. Hains, J. Cormier, P. Hally, Y. Boulanger, P. Michotte, N. Doucet

Yvon Boulanger, Vice-président

Monsieur Yvon Boulanger, vice-président de l'Association est arpenteur-géomètre et professeur à l'Institut de marine du Cégep de Rimouski.

Lors de l'assemblée générale annuelle, les membres présents ont pus assister à un souper-conférence. Monsieur Georges Drapeau, professeur-chercheur à l'I.N.R.S.-Océanologie, a entretenu l'auditoire de relation entre la sédimentologie et l'hydrographie.

Le programme d'activité de la Section du Québec, pour l'année en cours, comporte 6 activités, dont 5 soirées-conférences et une activité spéciale. Afin de bien rejoindre tous les membres, les activités seront réparties comme suit: une activité à Montréal, deux à Québec et trois à Rimouski.

L'adresse postale de l'Association, Section du Québec est la suivante:
C.P. 1447, Rimouski Québec, G5L 8M3, Tél. (418) 723-1831.

CAPTAIN VANCOUVER BRANCH

A new executive has been elected for this season and a special conference sub-committee has been established. The elected executives are:

Vice-President	Mr. Robert Lyall
Secretary/Treasurer	Mr. Rick Bryant
Executive Member	Mr. Carl Christensson
Executive Member	Mr. Bill Risk
Executive Member	Mr. Louis Schoolkate

The Captain Vancouver Branch of the CHA is now entering its third year of operation. The membership has grown to fifty and the energetic support of many has kept our branch interesting and vital. The branch continues to meet its objectives by holding regular technical meetings for our members.

This year will be especially busy as the branch puts its plans in place to host the 1989 CHA Conference. The Vancouver Trade and Convention Centre will provide an excellent international venue for the

"Voyage of Discovery". We hope all members will set sail for Vancouver in March 1989.

The conference sub-committee is chaired by Mr. Gordon Murray. Mr. Murray was the first branch Vice President and the membership is grateful for his successful efforts to establish our branch.

The Captain Vancouver Branch continues to work with the Pacific Branch of the CHA and has established a good relationship with the Hydrographic Society (Seattle Branch). We are looking forward to further cooperation with these groups this season.

Best regards and good luck to all branches for 1988.

OTTAWA BRANCH

Branch Activities

The annual general meeting of the Branch was held on Jan. 26, 1988; the 1988 executive was elected:

Vice-President	Dick MacDougall
Secretary-Treasurer	Sheila Acheson
Executive Members	Diana Pantalone
	Marilyn van Dusen
	Kathy Young
	Terry Tremblay

The Branch held three noon hour seminars during the fall of 1987:

Dave McKellar, of the Mapping and Charting Establishment (DND), presented a talk and demonstration of a PC computer based video mapping and charting system capable of overlaying data base data on a background which is a video image of a map or chart. The system is capable of storing the video images of up to 200 geographically referenced maps and charts on a single optical disc and is being tested for such applications as search and rescue planning.

Harold Tolton, of SURNAV, presented a seminar on positioning systems entitled 'Positioning - The Plus/Minus Factor (Is That Rock Really There?)'.

Tim Evangelatos, of the Canadian Hydrographic Service, supplied a very entertaining and thought provoking video on the latest in computer generated animation.

In mid-December 1987, once again the Branch hosted a very successful Christmas luncheon, where both present and past members of CHA and their friends met to celebrate the holidays. The Branch is grateful to those who donated gifts for door prizes: Terra Surveys Ltd., International Datacasting Corporation, Gentian Electronics Ltd., Universal Systems Ltd., Pantalone and Barnett Travel Agency, Alexander's on the Island Restaurant, and Canadian Hydrographic Service.

To stimulate interest in developing a new CHA logo, Ottawa Branch held a contest for the best logo design. The winning design was the joint submission of Jake Kean and Dick MacDougall. All nineteen designs entered in the contest have been sent to the National President.

Personal Notes

Ottawa Branch is happy to welcome Richard Lambert as a new member of our Branch. Richard has just moved to Ottawa where he has accepted a permanent position as an analyst/programmer at CHS headquarters.

Kathy Young left her job with the Canadian Hydrographic Service to take up a new post within Fisheries and Oceans at 200 Kent Street. We wish Kathy the best in her career and welcome the fact that she will remain on the CHA executive for 1988.

After 37 years with the Canadian Hydrographic Service, Hiro Furuya retired in November 1987. Hiro spent some of the early years of his career as a hydrographer on board the CSS Acadia. He then went on to become to become the Chief of Chart Production, and then the Chief of Training and Standards. Many of his friends and colleagues saw Hiro off in style with a luncheon at Gow's Restaurant at Dow's Lake Pavillion. We wish Hiro and Grace the best in this new phase of their lives.

The Branch was saddened to learn of the death of Ron Logan in November 1987. Ron had retired in 1985 after 35 years with the Canadian Hydrographic Service.

Mike Casey is the the President of the Pacers' Speed Skating Club of Ottawa, the best speed skating club in Ottawa, if not the entire country! Mike recently won two Bronze Medals at an international competition in Quebec City.

Activities by Members

Neil Anderson participated in the national conference on Technology and Innovation held in Toronto in January, at which the Prime Minister announced the government's policy on science and technology.

George Yeaton attended meetings of the CLS Board of Examiners held in Vancouver, in January 1988, where future developments in the CLS system were discussed. George also attended the January 1988 meetings of the Canadian Committee on Survey

Control, along with representatives of the Geodetic Survey of Canada and of the provincial governments.

In February, 1988 Neil Anderson was in Rockville, Maryland for meetings of the St. Lawrence Seaway Working Group. This working group consists of representatives of the Canadian Hydrographic Service, the US National Ocean Service, the St. Lawrence Seaway Authority, the St. Lawrence Seaway Development Corporation, and the Canadian Coast Guard.

Harold Tolton attended the Brighton Oceanology show in March, followed by a combined business/pleasure trip to Singapore and Vancouver.

Mike Casey chaired a workshop session on User Interfaces at the January 1988 GPS User / Suppliers Workshop in Ottawa. This workshop brought approximately 50 individuals involved in supplying GPS equipment and services together with an equal number of users and potential users.

Congratulations to Quebec Branch on the success of their Colloque in November, 1987. As usual, they lead the way in advancing the participation of the private sector.

Papers/ Presentations
Neil Anderson presented a lecture on "Electronic Communication of Digital Mapping and Charting Data" at the Dept. of Survey Engineering at the University of New Brunswick.

Neil Anderson and Mike Casey, "Electronic Charts - The Canadian View", Society of Naval Architects and Marine Engineers, Ship Operations Management and Economics Symposium, New York City, Sept. 1987.

Mike Casey and Gerard Lachappelle, " Performances du GPS pour la localisation en mer - Experiences canadiennes", Colloque: L'hydrographie, dimension essentielle aux sciences de la mer, Rimouski, P.Q., November 1987.

Mike Casey, " Profondeur: Balayage acoustique et sondage au laser (LARSEN)", Colloque: L'hydrographie, dimension essentielle aux sciences de la mer, Rimouski, P.Q., November 1987.

Gerard Lachapelle, Mike Casey, and R. Steeves, "Satellite-Based Precise Radio Navigation: Achievements and Prospects", presented by G. Lachapelle at the Fourth Canadian Aeronautics and Space Institute Conference on Astronautics, Ottawa, Ont., November 1987.

Tim Evangelatos, Jim Feeley and C.D. O'Brien, " A Format for the Telecommunication of Chart Data", Royal Institute of Navigation International Conference, London, U.K., Sept. 1987

David Gray and P.K. Mukherjee, "Inter-Jurisdictional Boundaries in Tidal and Non-Tidal Rivers", Oceans 87, Halifax, N.S., Sept. 1987.

P.K. Mukherjee, Ron Macnab, and Richard Buxton, "The 1982 UN Convention on the Law of the Sea and the Outer Limit of the Continental Shelf: Some Practical Difficulties for Wide Margin States", Oceans 87, Halifax, N.S., Sept. 1987.

P.K. Mukherjee lectured on "The Legal Implications of the Placement and Maintenance of Navigational Aids" at the CCG Training Institute at Cornwall, Ont., Feb. 1988.

P.K. Mukherjee spoke on "International Perspectives in Maritime Law and the Shipping Legislation of Trinidad and Tobago" at the Conference on Trinidad and Tobago Shipping Legislation held in Port of Spain, Trinidad in October, 1987.

PACIFIC BRANCH

New Executive
The new Pacific Branch Executive for 1988 is:

Vice-President	Mike Woodward
Secretary	Carol Nowak
Treasurer	John Larkin
Membership and Social	George Schlagintweit
Newsletter	Sharon Thomson
Seminars	Jim Vosburgh

Recent Seminars and Tours
A noon seminar and demonstration of equipment was given by Optical Storage Systems of Vancouver, with an overview of CD-ROM, WORM and WORP technologies - hope you are up on your acronyms. Gigabyte storage in a launch system could revolutionize the echo sounding process.

Willie Rapatz spoke at a luncheon seminar on his trip to China for an international tsunami warning conference. New theories about the Great Wall were explored.

Ardene Philp and Ozzie Ross participated in the Senior Cartographers' Seminar in Ottawa during October.

A tour of the NOAA and PMC facilities in Seattle was attended by four carloads; Puffers, Recently Reformed, Yuppies, and the Meat Wagon. The tour included the Pacific Marine Environmental Labs, Pacific operations Group (tides), Nautical Charting Branch, the NOAA ships, and the Electronic Engineering Branch. Fun was had by all. Special thanks to Tom Richards of NOAA and Jim Vosburgh of Terra for a well organized trip.

Mike Woodward and Kal Czotter gave a lunchtime talk on the low power bubbler tide gauge.

CHS Activities

Barge "PENDER", with George Eaton in charge and Frank Coldham as 2-I-C, will be anchored all summer near Port Hardy at the north end of Vancouver Island. The goal is to survey a large portion of Queen Charlotte Strait, an area known for its rugged seas and numerous shoals. The Micro Vax and ISAH will be some of the tools used on this project.

"CSS J.P. TULLY" will be operating in an adjoining area of Queen Charlotte Strait with Tony Mortimer in charge and Mike Woods as 2-I-C. Positioning will come from Syledis, being borrowed from Quebec Region for the job. This survey is to end in early June. The Tully will then sail from IOS in early July for the Beaufort Sea, with Barry Lusk replacing Tony's command.

"CSS RICHARDSON", Kalman Czotter in charge with Mike Ward as 2-I-C (two man survey party), will be in the Charlottes. They are planning to complete the Approaches to Cumshewa Inlet with 380 shoal exams left to be done. Kal intends to use a low power bubbler tide gauge for this survey.

Education

George Eaton and Mike Woods spent a sunny week in San Jose, California, at a GPS course. With a little time to spare, George took Mike down to the Hurst Castle south of San Jose and showed him the old family plantation.

CLS exams were written in early February by Alex Raymond, Barbara Kerr, Mike Ward, Ernie Sargent, and Ken Halcro. Best of luck!

Congratulations to Barbara Kerr and Bruce Lewis for successfully completing the Hydro II course in November. Congratulations to Murray Farmer and Al Schofield on their successful completion of the Carto II course.

Bruce Tuck recently spent a few weeks on exchange with Nautical Charting in Seattle, Washington and in Rockville, Maryland. He feels it was a very enriching experience.

Rob Hare is working hard and doing well with Survey Engineering at the University of Calgary. Keep it up!

Social Events

Pacific Branch is hosting its first annual H20 Bonspiel on Sunday, March 27. We are hoping for a big turnout, with lots of fun and prizes to be had by all.

Personal News

Skip Bruce Lewis with Alex Raymond, John Larkin, and George Schlagintweit continue to be the undefeated top IOS curling team. Ron Woolley and his recent fiancée spent a two week dive holiday in Cazoumel, Mexico. Congratulations to Kal Czotter on his recent marriage to Joan. John Larkin and family travelled to Ontario and PEI to visit family and friends. W.S. (Sev) Crowther is finally moving into his new home just up the road from IOS. By the time this issue of Lighthouse hits the stands, he and Dianne should be starting to feel settled. Baby! David and Tracy Jackson - a girl; Shannon Christine. Bill Crawford helped share the Olympic Flame on the Island Highway and he hasn't taken off his tracksuit since.

The hydrographic data centre has taken on two new staff - Valerie Thompson Williams and Valerie Evans. They are replacing Tracy Jackson who left to pursue her new career in motherhood.

Austin (Ozzie) Ross turned in his "checking kit" after 37 years in the CHS. At a luncheon on February 12, tributes and presentations were made on behalf of Atlantic and Central Regions, along with Headquarters. His friends in Pacific Region presented him with a mountain bicycle and then a parting shot - a deluge of elastic bands. The CHS wishes Ozzie all the best in the future.

Stan Huggett has announced his retirement from the CHS after 35 years of service. He was an active member of the CHA, serving two terms of office as Vice-President of Pacific Branch. The CHS will miss Stan's enthusiasm for hydrography and ships, as well as his casual disregard of bureaucracy. There will be a dinner/dance in Stan's honour on Friday, June 10th, to which all are cordially invited. Speeches will be kept (cut) short - for further information please contact W.J. Rapatz.

ATLANTIC BRANCH

The executive for the coming year are:

Vice-president	Charlie O'Reilly
Secretary-Treasurer	Odette Nadeau
Executive members	Dave Blaney
	Walter Burke
	Mike Ruxton
	Steve Grant

'We wish him all the best in his retirement years.' So it was with mixed feelings that we bid farewell on March 31, 1988 to R.M. (Mike) Eaton after his 31 years with CHS. Mike has always been a strong supporter of the CHA, and he was in fact one of the original four Founding Fathers who first conceived the idea of the CHA back in 1966. Over the years Mike has contributed many articles to our journal Lighthouse - notably on Radio-Positioning Aids such as Satellite Navigation and Loran-C which were his specialties, but also on a variety of other subjects. Mike has always been our expert on Sat-Nav, so we hope he passed all that inside knowledge and expertise on to his colleagues and successors before he walked off into his well-earned retirement. Leave us your address and phone number, Mike!

On December 12, 1987, four participants from CHS put on a play called "Newton's Crest" at the annual B.I.O. Christmas concert. The aspiring theatrical types were Debbie Hepworth, Judy Lockhart, Bruce Anderson and Chris Rozon. We have not hear any critics' reviews, so it is supposed they will return to the briny deep.

In March 1988 Atlantic Branch produced an 8-page newsletter. This was the first fruit of what is hoped will be a continuing venture, and Charlie O'Reilly (Branch Vice-President and newsletter Editor-in-Chief) says all contributions are most welcome. This first newsletter was mainly concerned with the topic of incorporation of the CHA, but it also included details of the 1988 budget and other newsy items.

The Nova Scotia Museum of the Atlantic is the proud guardian of our retired survey ship CSS ACADIA - the Old Lady of the CHS fleet. The ACADIA retired in 1969 after untold years of service to Atlantic hydrography, and the Museum asked us to mention two Big Events coming up: on May 8, 1988 there will be a Birthday Party for the ACADIA in celebration of the anniversary of her first arrival in Canada in 1913, and on July 8, 1988 a big Reunion for the members and family of crew and hydrographic staff who worked with ACADIA over the years. Should be fun, so if you or a relative served with the ACADIA give Marvin Moore of the Museum a call at (902) 429-8210 for more details. See you there!

PRAIRIE SCHOONER BRANCH

We held our Annual General Meeting on December 3, 1987 and elected our Branch Executive for 1988:

Vice-President	Dave Thomson
Secretary-Treasurer	Bob Ireland
Executive Members	Ken Simpson
	Bruce Calderbank
	Hal Jones
	Jeff Oland

This was a joint meeting co-hosted by the Edmonton Branch of the Canadian Institute of Surveying and Mapping, and our guest speaker was Dennis Hosford of the Alberta Land Surveyors Association. He spoke on the ALS's position on the "Integrated Survey Profession", and this was followed by a lively discussion. The Prairie Schooner Branch members thank Dennis for presenting the ALS's objectives and for patiently answering the questions from the audience.

Recent news is that ALS is progressing on new legislation on this matter, with voting scheduled for the end of April 1988. Watch the next issue of Lighthouse for further news!

Our Branch members have keeping very busy lately with projects both in Canada and abroad. A few highlights:

- Bruce Calderbank has recently returned from Turkey. He was doing work there on Quality Control with offshore construction and positioning systems.
- The gang at Cansite have been very involved with airborne gravity and survey projects, recently being active in South Yemen and Jordan.
- Challenger Surveys were doing Legal survey work and helicopter positioning around Alberta as well as offshore positioning and ice floe monitoring in the Beaufort Sea.
- The Group at McElhanney are keeping busy with surveying and positioning projects around the country and abroad, recently working in Brazil, Sarawak and Taiwan.
- The Nortech crew are also involved in far-distant projects, using the Global Positioning System to position an oil rig move off Mozambique and another off Morroco.
- Ken Simpson is back warming up in Calgary after an extended tour of seismic surveying in the Arctic.

Business prospects for our members and their profession look very good for 1988, or at least better than in '86 and '87!

The members of our Branch are far flung around Alberta, and we have a Branch newsletter to help us keep in touch. We published two of these during the year and another went out in April 1988.

Recently published by the International Hydrographic Bureau:

PP-06	**Report of Proceedings of the XIIIth International Hydrographic Conference,** May 1987 (English)	75.00 FF
PP-05	**IHO Yearbook 1988** — particulars and addresses of Hydrographic Services throughout the world (English/French)	60.00 FF
MP-005	**Standards of Competence for Hydrographic Surveyors.** Part 1 (English, French, Spanish), 5th Edition, August 1987	15.00 FF
SP-44	**IHO Standards for Hydrographic Surveys** **Classification Criteria for Deep Ocean Soundings** **Procedures for Elimination of Doubtful Data** 3rd Edition, November 1987 (English/French)	50.00 FF
SP-50	**IHO Tidal Constituent Bank — Station Catalogue** (English/French)	30.00 FF
MP-008	**List of Sheets of 'Chart Symbols and Abbreviations' published by Various Maritime Countries,** 6th Edition, November 1987 (English/French)	15.00 FF
BP-0004	**Information Concerning Recent Bathymetric Data — List No. 17,** December 1987 (English/French)	25.00 FF

Bathymetric charts available from the I. H. Bureau:

BP-001	**General Bathymetric Chart of the Oceans (GEBCO),** 5th Edition (1:10M), series of 18 sheets Price per sheet	35.00 FF

The following publications are in the process of preparation:

MP-004	**Chart Specifications of the IHO** (in 6 sections)	Price to be announced
SP 32	**Hydrographic Dictionary,** 4th Edition	—
SP 47	**Training and Technical Assistance in Hydrography,** 2nd Edition	—

A complete List of all IHB Publications for 1988 can be obtained gratis by writing to the

INTERNATIONAL HYDROGRAPHIC BUREAU
BP 445
7 avenue Président J.F. Kennedy
MC 98011 MONACO CEDEX

March 1988

Lighthouse

Journal of the Canadian Hydrographic Association

LIGHTHOUSE originally began as an internal newsletter of the Canadian Hydrographers' Association (CHA) in the winter of 1969. It was conceived as a means of stimulating discussion between the branches of CHA. Over theyears, **LIGHTHOUSE** has become Canada's national hydrographic journal. It still remains faithful to the original goal of providing a mix of technical, historical and social information of interest to hydrographers and cartographers. But its circulation has expanded to include over 1,000 individuals, companies and hydrographic organizations in Canada and around the world!

1988 Rate Card Information

POSITIONING

The acceptance and positioning of advertising material is under the sole jurisdiction of the publisher. However, requests for a specified position will be considered if the position premium of $25 has been included in the insertion order.

MECHANICAL REQUIREMENTS

Advertising material must be supplied by the closing dates as camera-ready copy or film negatives (Colour ads must be film negatives). Copy preparation, including colour, bleed and photos will be charged at the printer's cost plus 10%. Proofs should be furnished with all ads.

Single-page inserts will be charged at a full page body rate. Material must be supplied by the client. Page size must conform to the single page insert trim size (below).

PUBLICATION SIZE

Publication Trim Size: 8 1/2" x 11 1/2" (Width x Length)
Live Copy Area: 7" x 10" Bleed Size: 8 3/4" x 11 1/4"
Single Page Insert Trim Size: 8 1/4" x 10 3/4"

Standard Ad Sizes:
Full Page: 7" x 10" 1/2 Page: 6 7/8" x 4 3/4" or 3 3/8" x 9 3/4"

CLOSING DATES

LIGHTHOUSE is published twice yearly in April and November. The closing dates are March 15th and October 15th respectively.

PRINTING

Offset screened at 133 lines per inch.

RATES (All rates are quoted in Canadian Funds)

	B &W	Colour	
		Spot*	Four
Outside Back Cover	NA	NA	850
Inside Cover	200	250	700
Body, Full Page	175	225	550
Half Page	125	175	550
Single-page Insert	175	225	550
Professional Card	50	100	550

*Spot Colour (Orange, Red or Blue)

All rates net to publisher - no provision for commissions or discounts.

RATE PROTECTION

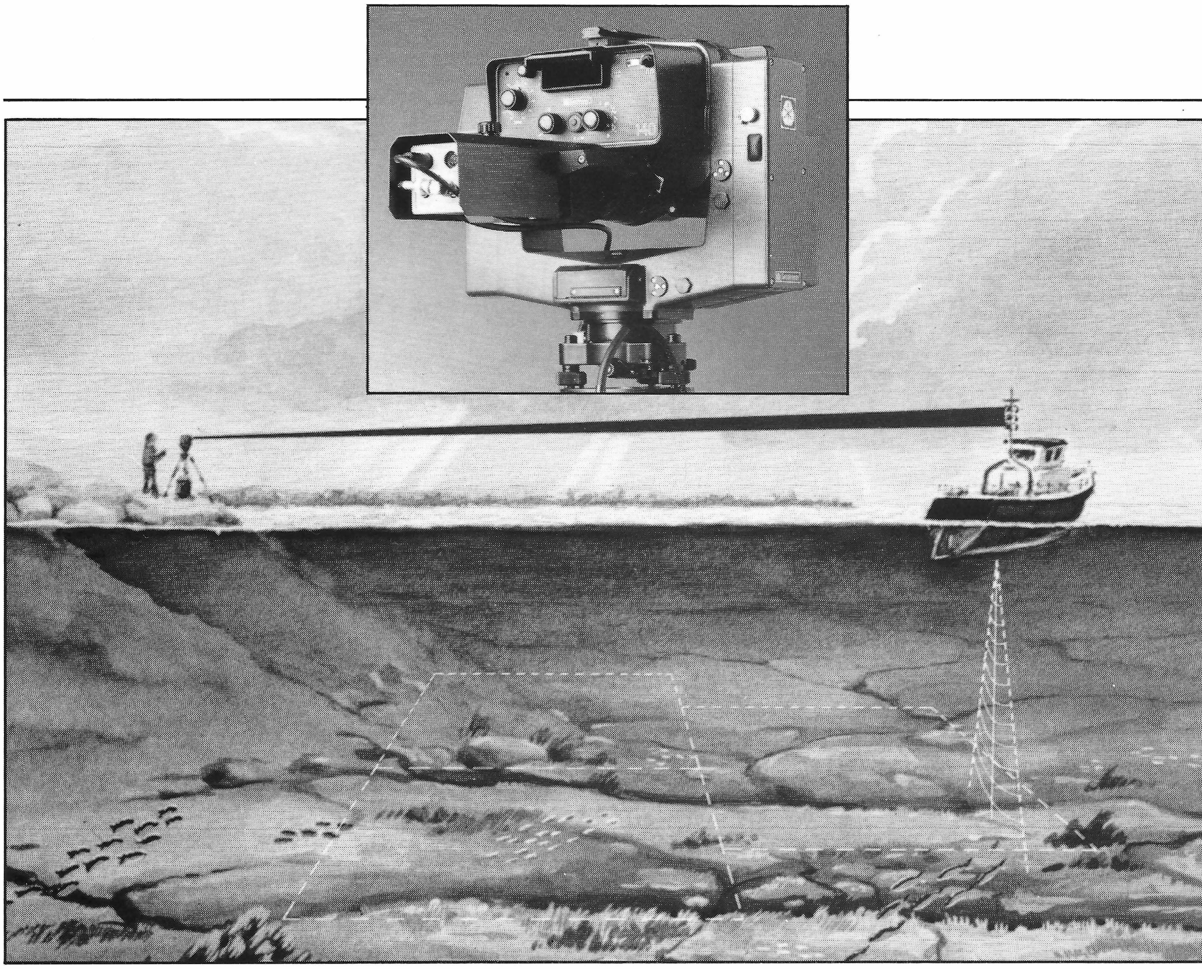
Advertisers will be protected at their contract rates for the term of their contracts up to one year. Cancellations are not accepted after closing date.

All advertising material should be directed to:

Mr. D. St. Jacques
Advertising Editor, LIGHTHOUSE
867 Lakeshore Rd.
Burlington, Ontario
L7R 4A6

Telephone: (416) 336-4857

Geodimeter® Paints the Picture



An accurate picture of your seabed depends on precise vessel positioning. **Geodimeter®** has the solutions for all of your near and inshore survey applications.

Our advanced **140s** and **140H Total Station Positioning Systems** continuously locate and record the exact position of a vessel, even when moving at speeds of up to 8 knots.

You may store positional data at the shore station with **Geodat Data Recorders,** or simultaneously transmit with exceptional accuracy to on-board computers.

Whether you're dredging, mapping, laying cable or pipe, or determining volumes, **Geodimeter® 140s** or **140H** is the positioning system for your every requirement.

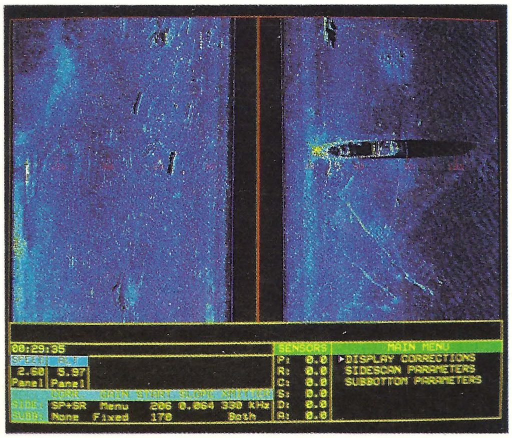
Let us complete the picture for you! Please contact us today for additional information, or a field demonstration of **Geodimeter® Hydrographic Positioning System.**

Geodimeter®

Nothing else quite measures up...

Geodimeter® of Canada Ltd.
41 Horner Avenue, Unit 5
Toronto, Ontario
M8Z 4X4
(416) 252-4691
Toll Free 1-800-268-0375

NO OTHER SIDE SCAN SONAR COMES CLOSE



Monitor displays sidescan data, sub-bottom data, time, sensor status and menu information.

Model 972 SIDE SCAN Sonar features:

- Display resolution 1280 x 1024 x 128
- Undistorted side scan displays with the water column removed and corrected for slant range and towfish speed
- Available simultaneous side scanning and sub-bottom profiling
- Available towfish sensors: speed, roll, pitch, compass, depth and altitude

MESOTECH SYSTEMS LTD

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Port Coquitlam, B.C., Canada V3C 4T3
Tel: (604) 464-8144 Telex: 0636700310
Fax: (604) 941-5423