HISTORICAL FLOODING REVIEW AND FLOOD RISK MAPPING STUDY FOR COX'S COVE

Report to:

Canada-Newfoundland Flood Damage
Reduction Program
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Department of Environment and Lands
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December 1988

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December 16, 1988

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4th Floor
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Attention: Mr. Robert Picco

Gentlemen:

We are pleased to submit the final report entitled "Historical Flooding Review and Flood Risk Mapping Study for Cox's Cove". The comments and suggestions from the Technical Committee on the previous draft report have been incorporated in this final report.

We would like to express our sincere thanks to you and other members of the Committee for your cooperation and assistance throughout this study.

Yours very truly,

MARTEC LIMITED

James L. Warner

Dr. J.L. Warner, PEng
Vice-President

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1.0 INTRODUCTION

Under the auspices of the governments of Canada and the Province of Newfoundland, the Flood Damage Reduction Program has identified several locations throughout Newfoundland that warrant a flood risk study. Two of these locations are Cox's Cove and Parson's Pond. This report deals with the flooding at Cox's Cove and corresponding documentation for Parson's Pond can be found in a separate report.

The flooding characteristics of Cox's Cove (49°08'N, 58°08'W), situated in the Bay of Islands, have been examined and the 1 in 20 year and 1 in 100 year flooding events determined. Information on historical flooding of the community and the technical methodology used to calculate and map the flood plain is also included in this report.

A location map of the study area is presented in Figure 1.1.

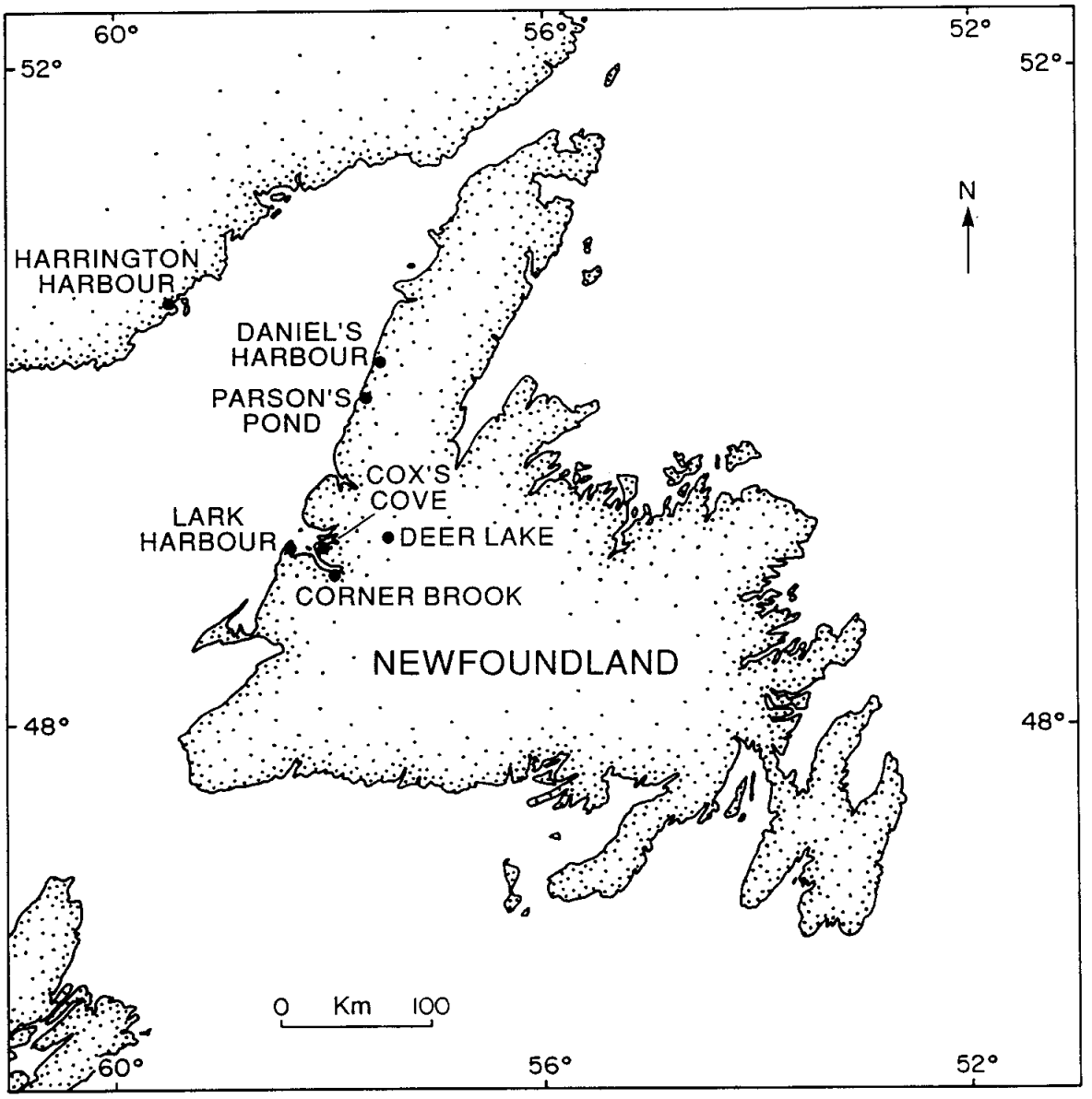


FIGURE 1.1

LOCATION MAP

2.0 PHYSIOGRAPHY

The Community of Cox's Cove is located on the Middle Arm in the Bay of Islands, approximately 24 km NNW of Corner Brook (see Figures 2.1 and 2.2). The Bay of Islands is a fjord-type estuary characterized by a system of deep basins and a sill at its mouth. Middle Arm is one of three basins in the Bay.

Cox's Cove extends from its northernmost point, Cox's Point, about 1.5 km to the south and east along a crescent shaped beach. A steep ridge (1:15) running south from Cox's Point, and a hill to the southeast mark the limits of the community.

Cox's Brook enters the community from the south following a meandering path through a low lying bog until it flows to the sea through an opening in the beach. The fluvial sediment transported by Cox's Brook eventually settles either within this marshy bog, or on the deltaic foreshore flats on the seaward side of the beach.

The water level of Cox's Brook is governed not only by the rate of fresh water discharge, but also by the sea level at its mouth. During the 12 hour tidal cycles, the level in the brook fluctuates in response to the variations in the head difference between the fresh and sea water. The greater head difference at low tide allows a faster discharge rate which causes the water level in the brook to drop. Alternatively, when the sea level rises, a reduced head difference diminishes the discharge rate and produces a back-up effect, causing the level in the brook to rise. When the sea level rises to a point above the water level of the brook's mouth, not only is the fresh water discharge reduced to zero but an incursion of sea water results. The joint occurrence of large tides and storm surge results in flooding of the low lying areas of the Cox's Cove community.

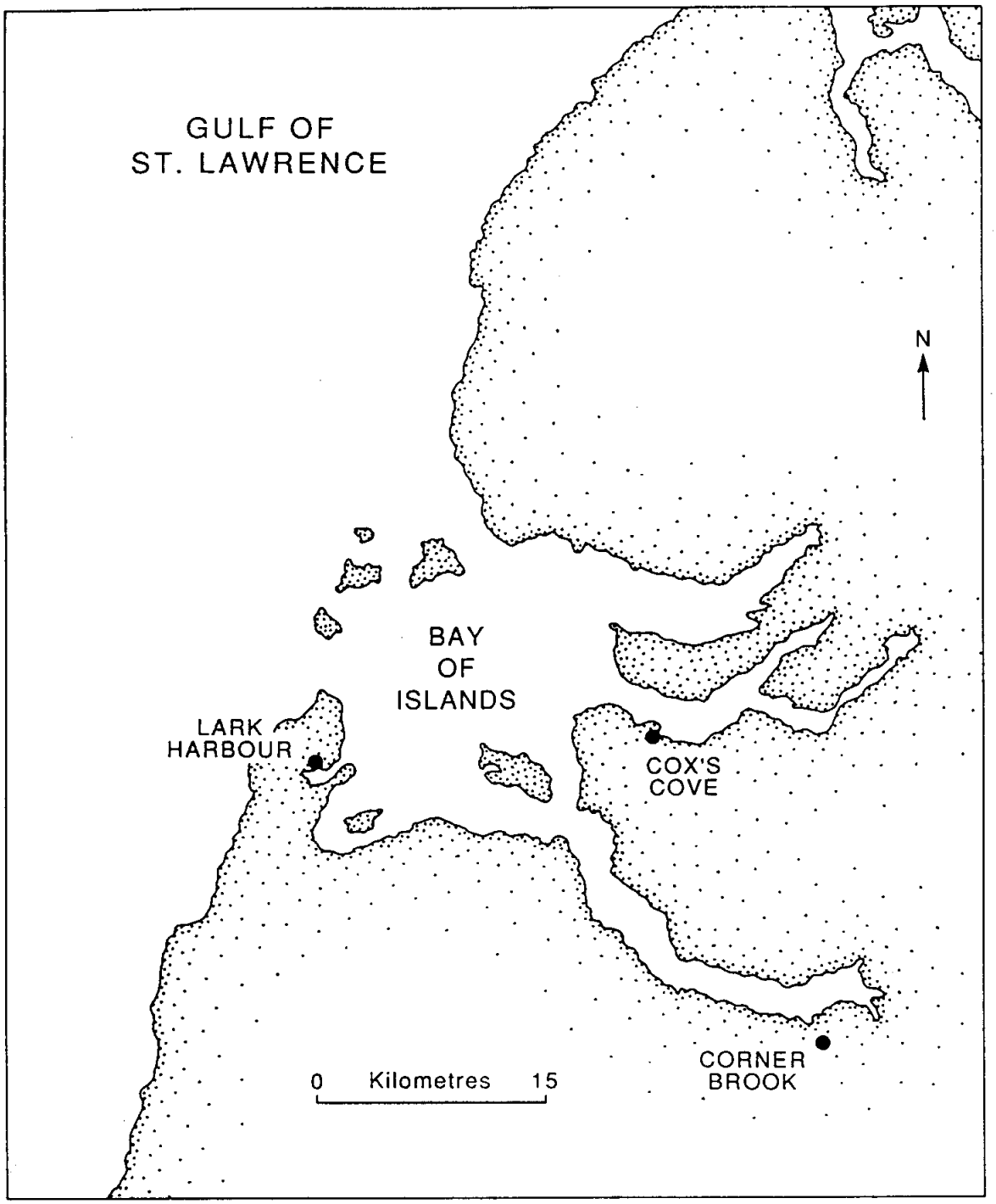


FIGURE 2.1

BAY OF ISLANDS REGION

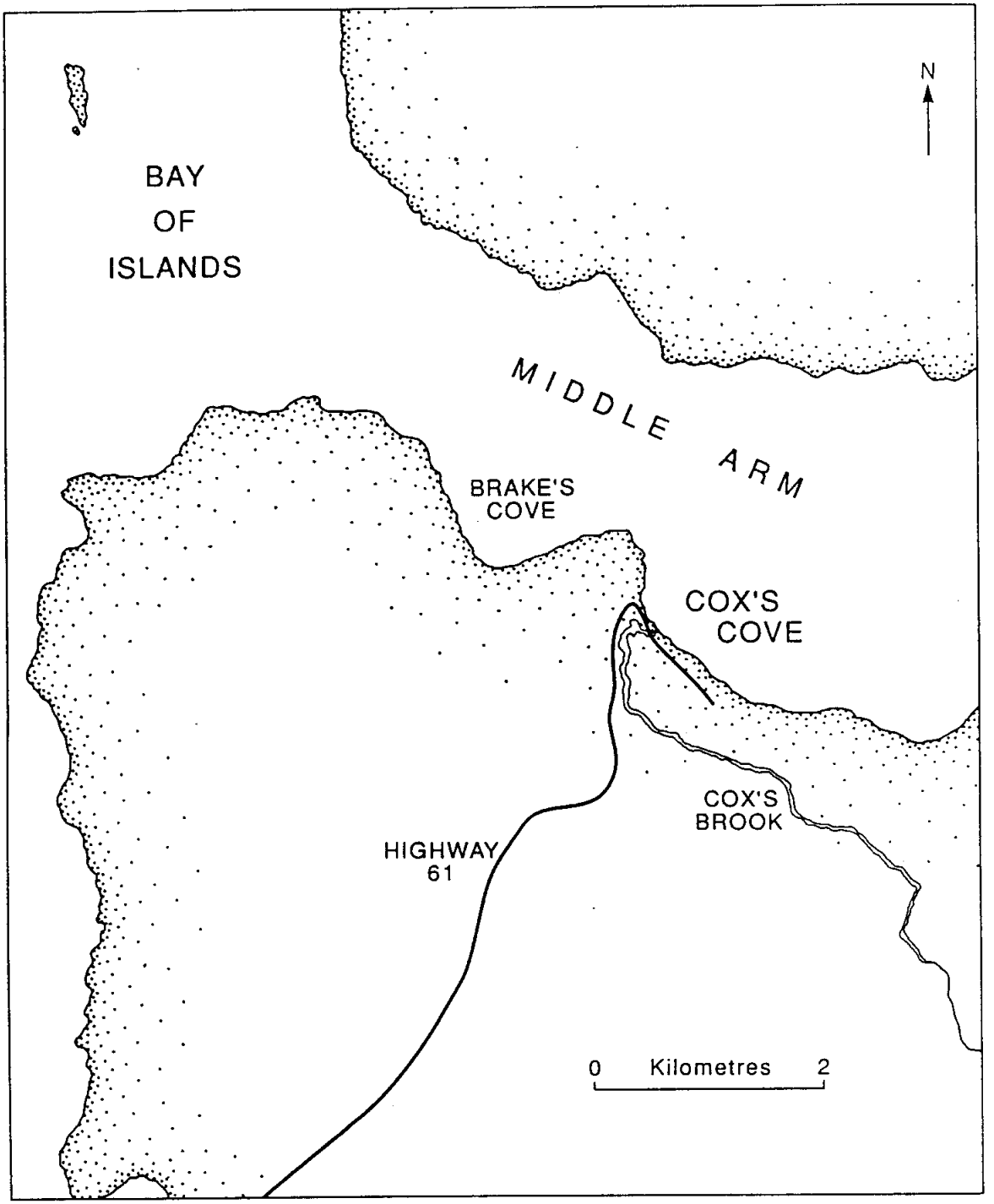


FIGURE 2.2

COX'S COVE REGION

Flooding of a different nature has occurred at locations along the beach front of Cox's Cove. This flooding is essentially overtopping of the breakwaters by seawater during extreme storm conditions and high water levels.

The source of the largest variation in the sea level in the area is the tide, which is classified as a mixed, mainly semidiurnal type. Details of the tidal regime have been calculated by the Canadian Hydrographic Service from water level data collected at Lark Harbour (49°6'N, 58°22'W) near the entrance to the Bay of Islands. This tidal regime is characterized by two highs and two lows each lunar day (about 24 hr. 50 min.) with a noticeable difference in height between two successive high, or two successive low tides. A fortnightly cycle dominates the variations giving high water levels at new and full moon (fortnightly) increasing the tidal range from a mean value of 1.4 m up to 2.1 m.

Figure 2.3 illustrates the seasonal variation in the water level in the Bay of Islands (as recorded at Lark Harbour). The tide data represent the mean and standard deviation of the monthly maximum water level due to the tide over a 12 year period (1976-1987). The tidal component alone has a definite maximum in the November to January period, with negligible changes in the standard deviation of the monthly maxima. The tide and surge combined, that is the actual water level recorded over a 20 year period at Lark Harbour, shows much greater interannual variability in the monthly maximum (as evidenced by the larger standard deviation), but a definite increase during the October to January flooding season.

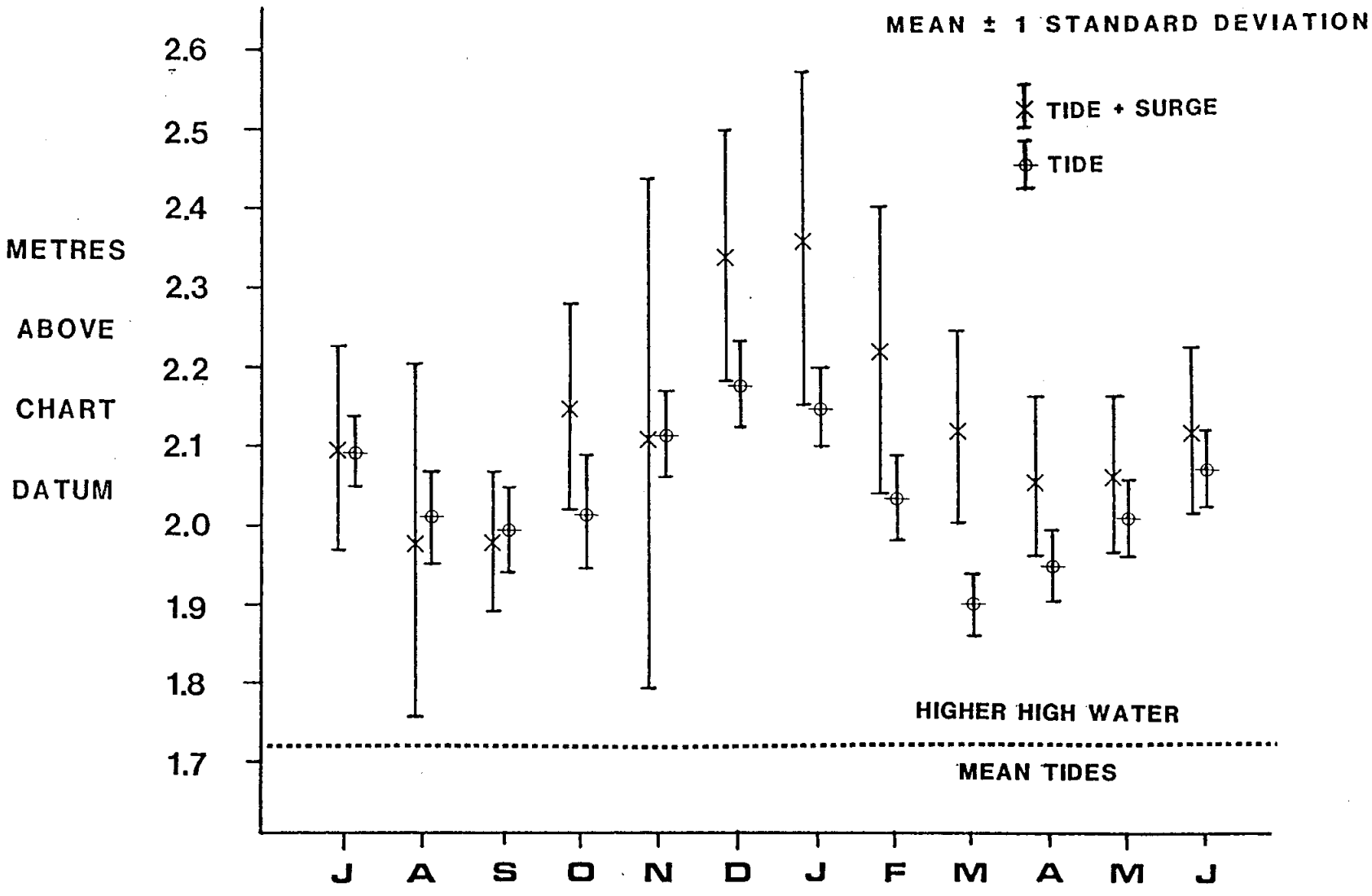


FIGURE 2.3

SEA LEVEL STATISTICS FOR BAY OF ISLANDS

3.0 CLIMATOLOGY

The precipitation regime in the Cox's Cove area has been reviewed using data collected at Corner Brook (less than 25 km distant) over a thirty year period (1951-1980). Table 3.1 shows the monthly variation in rainfall, snowfall, total precipitation and the number of days with measureable precipitation. It can be concluded that November to January represent months when Cox's Brook can be expected to have high discharge rates. This is due not only to the total precipitation but to the mix of rainfall and snowfall, where rainfall can cause the snow in the watershed to melt and contribute to the fresh water discharge rate of Cox's Brook. The influence of ice jamming does not appear to be a factor in the flooding of Cox's Cove as indicated in Section 4.0 on historical flooding of the area.

The beach at Cox's Cove faces the northeast and it is storm waves from this direction that are most likely to runup and overtop the breakwater. Northeasterly winds would be required to generate these waves over the roughly 10 km fetch along Penguin Arm. Because the width of this generating region is relatively narrow, about 2 km, the effective fetch is reduced to about 40 percent the actual distance, or 4 km (Shore Protection Manual, 1977). Using wind statistics collected at the Deer Lake airport, 45 km to the east, the maximum hourly wind speed measured is 80 km/hr. Oriented directly along the fetch axis, and given the deep water of Middle and Penguin Arm, the maximum wave height expected at the entrance to Cox's Cove is 1.5 m (Shore Protection Manual, 1977).

Storm surges are due to the combined influence of physiographic and climatological factors. Flooding events can result from any or all of three processes that cause surges: the stress of storm winds on the sea surface causing it to pile up, the inverted barometric effect near the low pressure storm centre causing the sea surface to rise, and a long surface wave that is generated by the two previous effects which can refract and steepen as it travels shoreward.

TABLE 3.1

MONTHLY PRECIPITATION STATISTICS
(Corner Brook 1951-1980)

	J	F	M	A	M	J	J	A	S	O	N	D
Mean Rainfall (mm)	29	15	24	28	58	74	74	95	92	103	92	39
Mean Snowfall (cm)	104	74	58	25	5	0	0	0	0	6	39	100
Total Precipitation (mm)	133	89	82	53	63	74	74	95	92	109	131	139
Number of Days with Precipitation	24	18	17	14	13	13	13	15	14	18	20	23

Total precipitation ≈ rainfall + one-tenth snowfall

A day with precipitation is one on which at least 0.2 mm of precipitation is recorded.

Source: Atmospheric Environment Service (1982)

Of the 36 severe storms catalogued in the Gulf of St. Lawrence between 1957 and 1983, just over one third occurred during the period between late October and early January (Lewis and Moran, 1984). These storms are centred over areas of low pressure. Consequently, in addition to the direct influence of the wind on the sea surface causing the sea level to rise as it approaches the coast, the decreased atmospheric pressure also results in an increased sea level. For example, taking normal atmospheric pressure as 101 kPa, a storm with a central pressure of 95 kPa allows the sea level to rise as much as 6 cm. Once past the sill of the Bay of Islands, water is sufficiently deep to allow a storm surge to propagate into the Cox's Cove area with little attenuation.

4.0 HISTORICAL FLOODING

Flooding at Cox's Cove has occurred both in the bog area and along the beach front. Foreshore flooding is most likely to occur during periods of high sea levels, large waves and onshore winds. Cox's Brook overflow and flooding is most prone to high sea levels and large fresh water discharge rates. Similar physical environmental factors can cause both conditions and consequently the community has suffered widespread flooding in the past. The effects of ice jamming the outflow of water from Cox's Brook to the sea has not had any major influence on the flooding characteristics of the area.

There have been two significant flooding events documented at Cox's Cove. The sources of information describing these floods include local residents, the regional newspapers, and two publications of Environment Canada (White 1984, and Kindervater, 1980). Figure 4.1 shows the flood plain as determined using the anecdotal data of these flood events. Description of two major flood events are as follows:

a) November 1955

A storm on November 26 and 27, 1955 that combined high winds and seas, and 30-40 mm of rainfall affected several Bay of Islands' settlements. The absence of high water levels reduced the extent of property damage in the bog area of Cox's Cove. Vessels moored in the cove, and pulled up onto the slipways along the beach, suffered damage.

b) December 1977

Widespread flooding along the western coast of Newfoundland occurred during the high tides and the strong winds during December 11 and 12, 1977. The water levels in Cox's Brook rose to the point where virtually all of the bay area, about 0.1 square kilometres (23 acres) was under water. This flooding event approximately doubled the area of the bog that suffers from annual flooding.

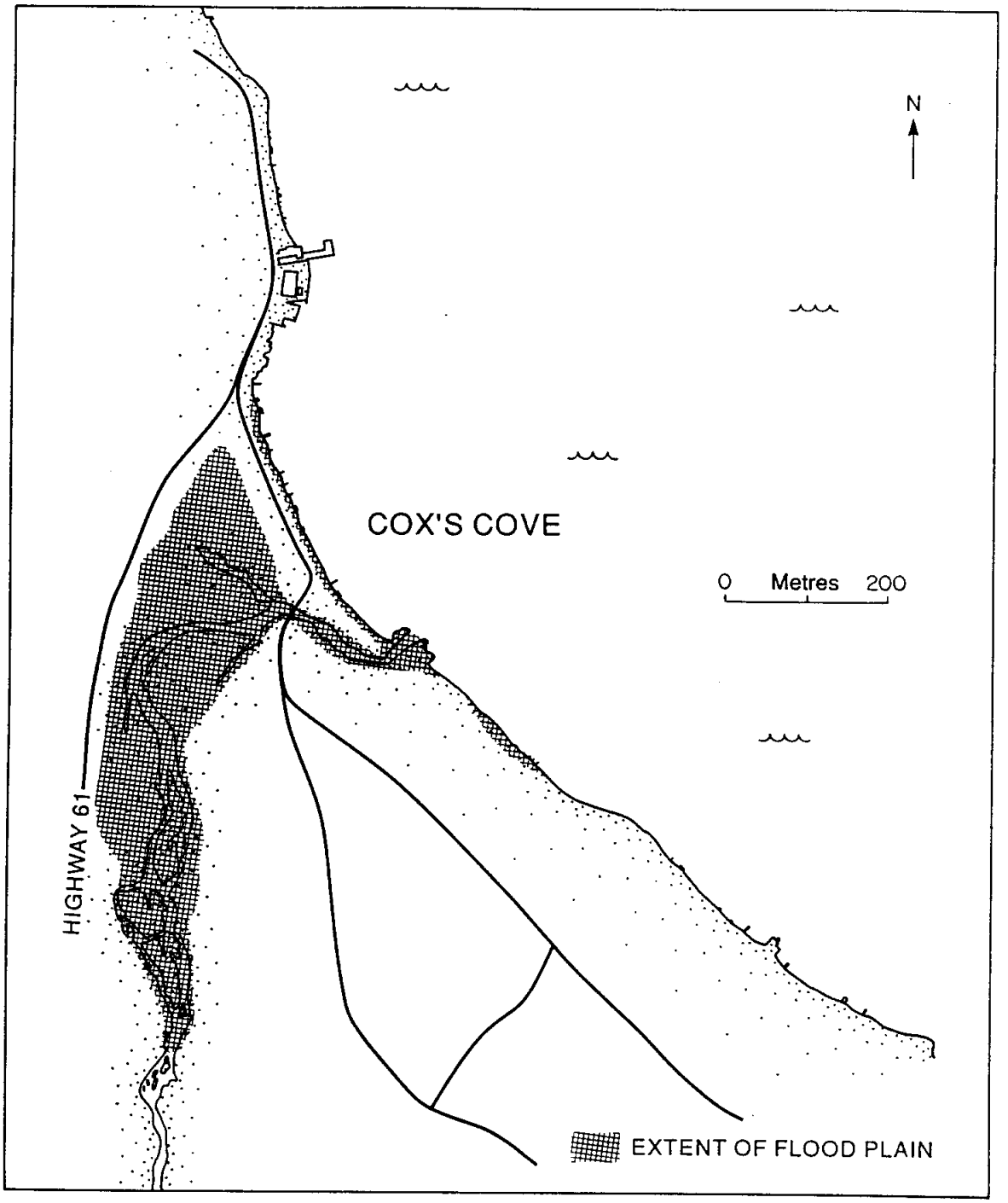


FIGURE 4.1

HISTORICAL FLOOD PLAIN AT COX'S COVE

Flooding of the foreshore was also extensive during this period. The combination of high sea levels and large waves caused overtopping of the breakwater and washed away parts of the coast road, damaged slipways and vessels, and flooded homes.

The water level gauge located at Lark Harbour was unfortunately out of service during this flooding event and consequently there is no means to calibrate the flood levels during this storm with the remainder of the Lark Harbour 20 year record. Other data exists, however, that provides an indication of the relative severity of physical factors, such as tides and winds, that were experienced during this storm.

A catalogue of severe storms off Canada's east coast (Lewis and Moran, 1984) identifies the storm of December 1977 as having a central pressure of 97 kPa over Anticosti Island at midday on the 10th. A high pressure ridge showed its movement eastwards allowing the storm to intensify rapidly over the following 24 hours reaching its lowest central pressure of 95.6 kPa. Winds in the area, as recorded at Daniel's Harbour on Newfoundland's west coast, exceeded 80 km/hr for a 12 hour period from 1700 hrs 10 December to 0500 hrs 11 December, with a maximum value of 100 km/hr at 2000 hrs 10 December. The wind direction remained relatively steady, from the southwest, during the storm.

The tides at Lark Harbour during the 10th-12th December 1977 were also larger than usual due to astronomical forcing. A maximum tidal height of 1.04 m above mean water level has been determined by using the known tidal characteristics of the area (see Section 8.1). This value slightly exceeds the high water level due to the average large tides of 1.03 m above mean water level.

5.0 METHODOLOGY

The variations of the water levels, and hence the flooding characteristics, of Cox's Cove are due to the interaction of meteorological, hydrological, and oceanographic processes and their modification by local conditions. Maximum water levels, corresponding to the 1 in 20 and 1 in 100 flood events, are calculated by determining the rises in water level from all of the relevant contributing factors and fitting them to an appropriate flood frequency distribution.

The methodology used to determine the extreme water levels is a two step process. The first includes the collection, analysis and interpretation of the appropriate physical information. The second stage involves the extrapolation of these data to the 1 in 20 and 1 in 100 flood limits and their associated confidence intervals.

Figure 5.1 shows a flowchart of the methodology.

The main physical factors that govern the flooding at Cox's Cove have been identified as:

a) extreme sea levels;
b) river backup and overflow due to increased sea level and fresh water runoff; and
c) runup and overtopping of high waves.

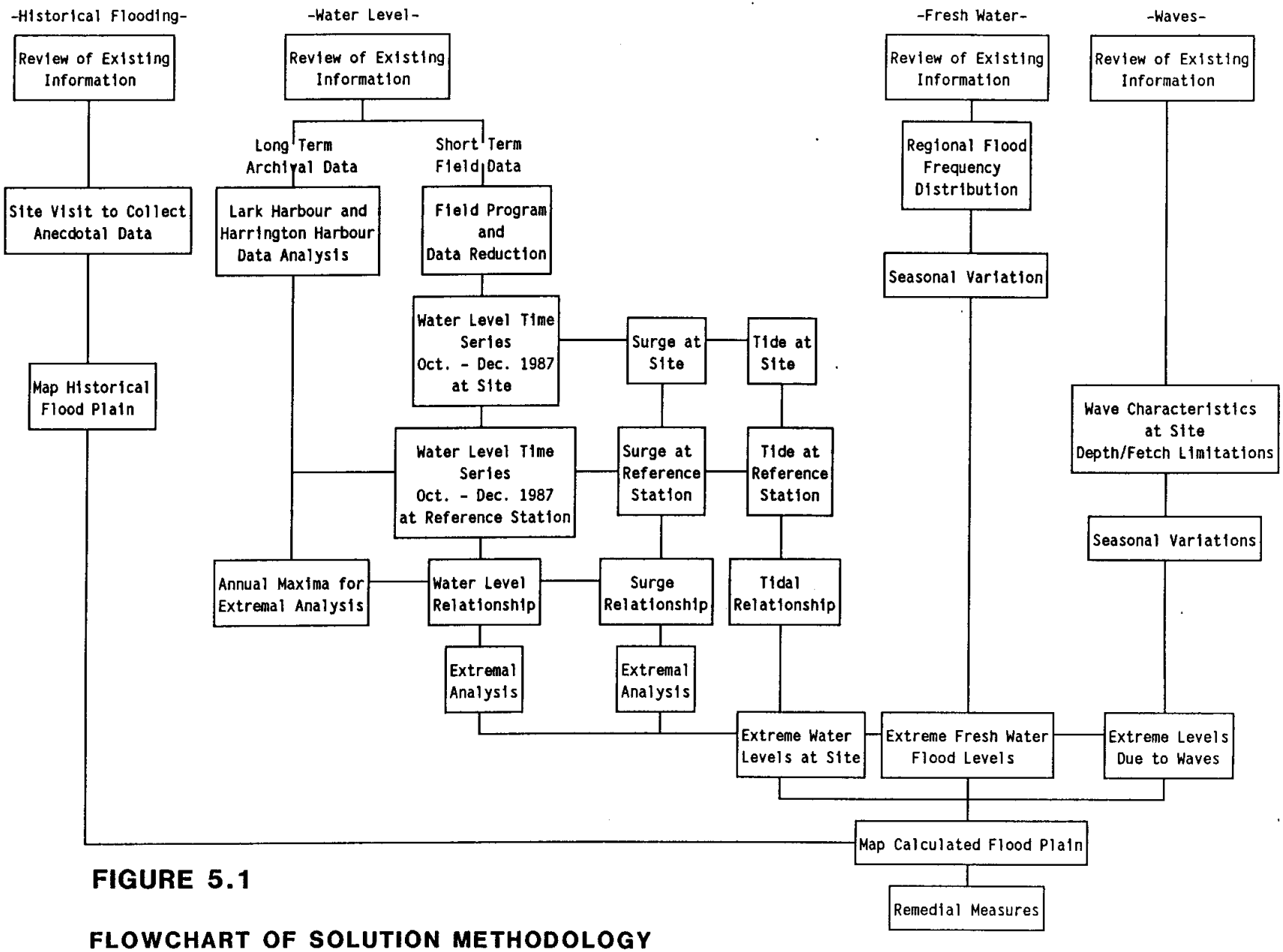


FIGURE 5.1

FLOWCHART OF SOLUTION METHODOLOGY

6.0 THE FIELD PROGRAM

In order to acquire sufficient data from which to obtain the necessary information concerning the water level regime at Cox's Cove, a field program was designed and implemented. The objective of the field program was twofold; first a site visit was required to collect anecdotal information relating to the flooding characteristics of Cox's Cove. The second purpose was to collect sufficient water level data at the location in order to relate the water level regime at Cox's Cove to that of Lark Harbour. Lark Harbour was chosen as a reference location because it is the closest point to the study site at which a long term water level record (required for the extremal analysis) is available.

A monitoring period of at least 10 weeks, from October to December 1987, was chosen. This allowed sufficient water level data to be collected in order to carryout the tidal and correlation analyses required to establish the relationship between Lark Harbour and Cox's Cove. In addition, water levels would be gathered during the season of the year when the flooding potential has been shown, historically, to be the greatest.

The actual work in the field was carried out during October 2-8, 1987 and January 7-10, 1988, which mark the deployment and recovery dates for the instrumentation.

During both visits anecdotal information, relevant to the flooding at Cox's Cove, was gathered. Regional insight into the situation was provided by Departments of Environment and Lands and Municipal Affairs officials (R. Saunders, and M. Stratton). The Mayor of Cox's Cove, A. Park, and residents having property within the historical flood plain also contributed to the identification of probable flooding mechanisms and their limits.

In order to promote the probability of a good data return, a backup system of data collection was included in the monitoring program. This entailed the installation of two automatic recording instruments, as well as an individual from the local community to document 'events' using a scale fastened to the fish plant pier as a reference.

Two types of water level recording devices were used; a float gauge and a pressure gauge.

The float gauge instrumentation consists of a float and counterweight located in the stilling well, and the recorder housed in the gauge shelter. A schematic of the arrangement is shown in Figure 6.1.

A thin wire connected to the float passes over a pully on the recorder and is attached to the counterweight at the other end. As the float rises with the tide, the pen on the recorder scribes a line on the paper which is advancing by means of a clockwork mechanism. The stilling well physically filters out the effect of the high frequency fluctuations of waves on the float by restricting the flow of water into it.

The float gauge instrumentation was installed at the south east corner of the fish plant pier. The gauge shelter was constructed in the lee of a storage shed to afford protection from the prevailing winds and the work on the pier. The stilling well, which was made from 20 cm diameter PVC pipe, sealed at the bottom, and having a 2 cm hole drilled below the water line to filter the wave effects, was positioned in a water depth of 2 m below mean sea level. A carpenter's scale was secured to the face of a support piling. This was used to relate the geodetic datum (in reference to the decking of the pier) with the water level as scribed by the float gauge pen on the recording paper.

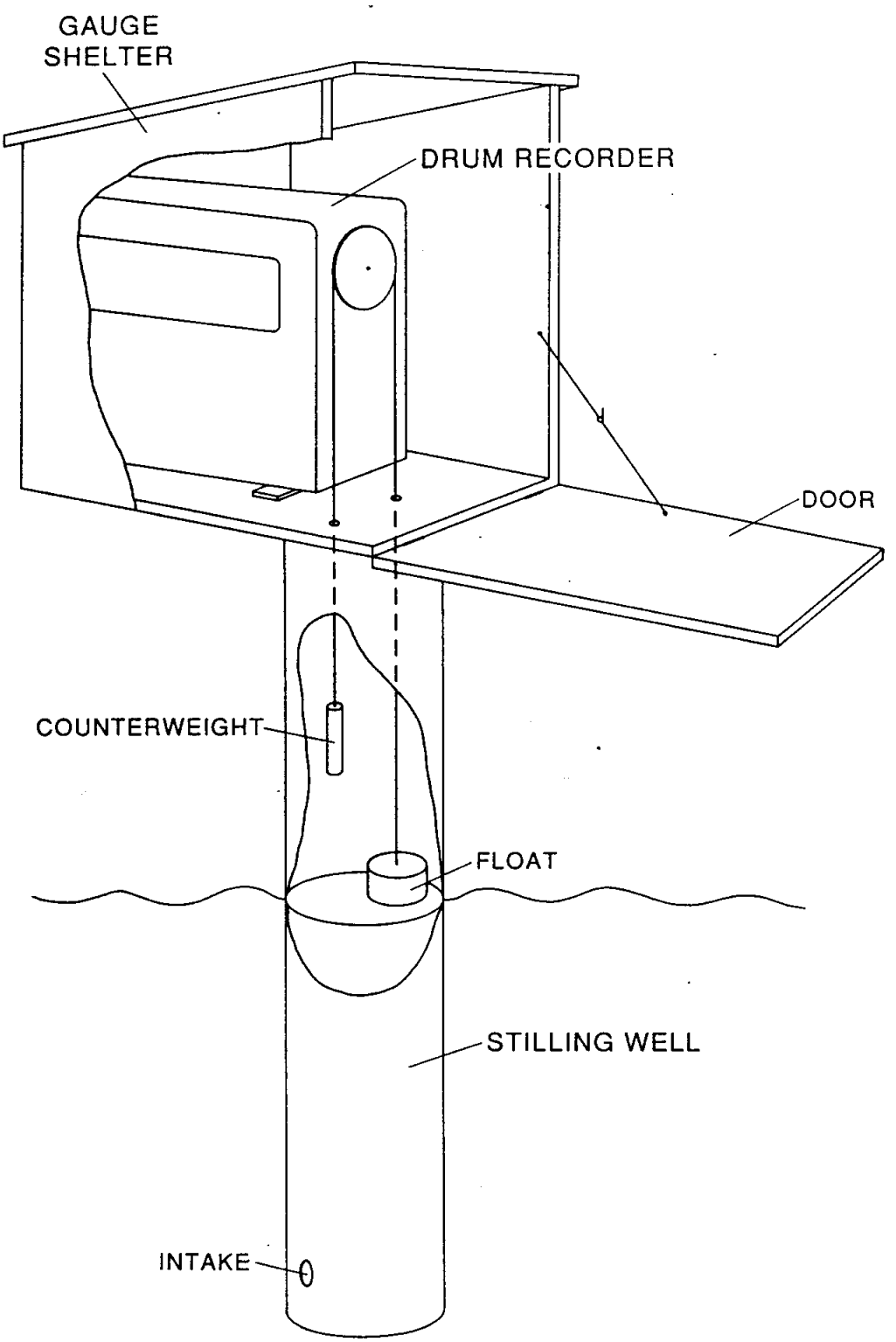


FIGURE 6.1

FLOAT GAUGE INSTRUMENTATION

The pressure gauge used was an Aanderra WLR-5 type recording instrument anchored to the sea floor. A sampling rate of 1 record every 30 minutes was chosen with an integration time of 27 seconds. At the instrument depth of 27 m the pressure variations due to surface waves are filtered out of the recorded data.

The accuracy of the pressure gauge is 0.01% of the full scale range, and the resolution is 0.001% of the full scale range. The full scale range is determined by the maximum pressure the sensor in the instrument can withstand. The instrument at Cox's Cove was rated to 270 m (0-400 psi) providing an accuracy of ±2.7 cm and a resolution to within ±.027 cm.

A schematic of the mooring arrangement is shown in Figure 6.2. Recovery of the instrument is accomplished by either hauling up one of the marker lines, or, if the floats have been taken, by a grappling hook snagging the ground line. The position of the mooring was chosen to avoid local vessel traffic and its distance from the shore (approximately 500 m minimum) and water depth (27 m) was selected to afford protection from shoaling waves and shore ice, while providing a record of water level variations in the vicinity of the Cox's Brook outflow. The location of the instruments is shown in Figure 6.3.

On November 6, 1987, a storm hit the Bay of Islands, characterized by high water levels (up to 1.3 m above mean sea level) and winds from the southeast to southwest up to 60 km/hr. Damage on the Cox's Cove fish plant pier was sustained which included the float gauge instrumentation. Inspection of the recording unit revealed that the clockwork mechanism was no longer reliable and the unit was returned for repair. Consequently, the monitoring period of the float gauge was restricted to 31 days (7 October to 7 November).

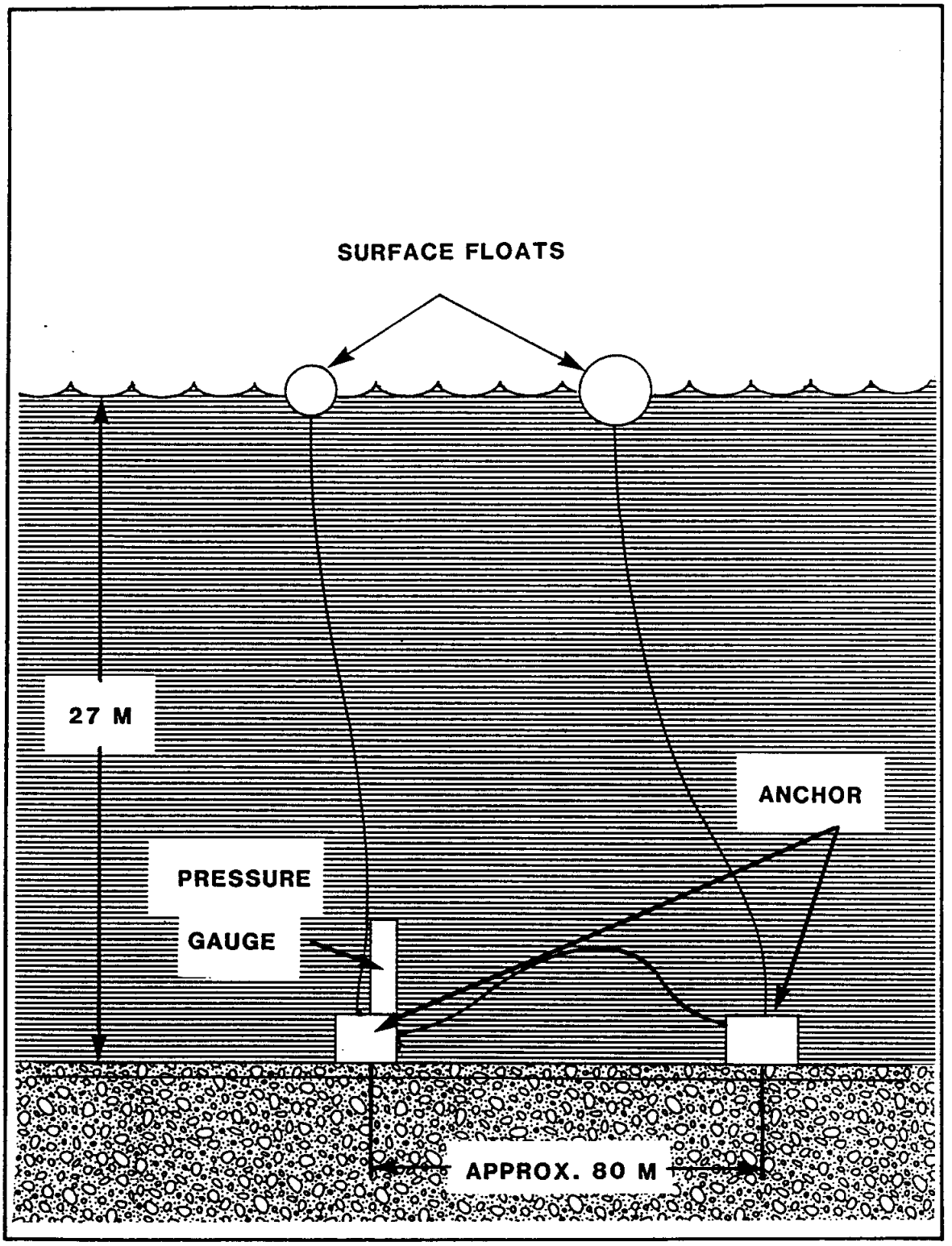


FIGURE 6.2

MOORING ARRANGEMENT AT COX'S COVE

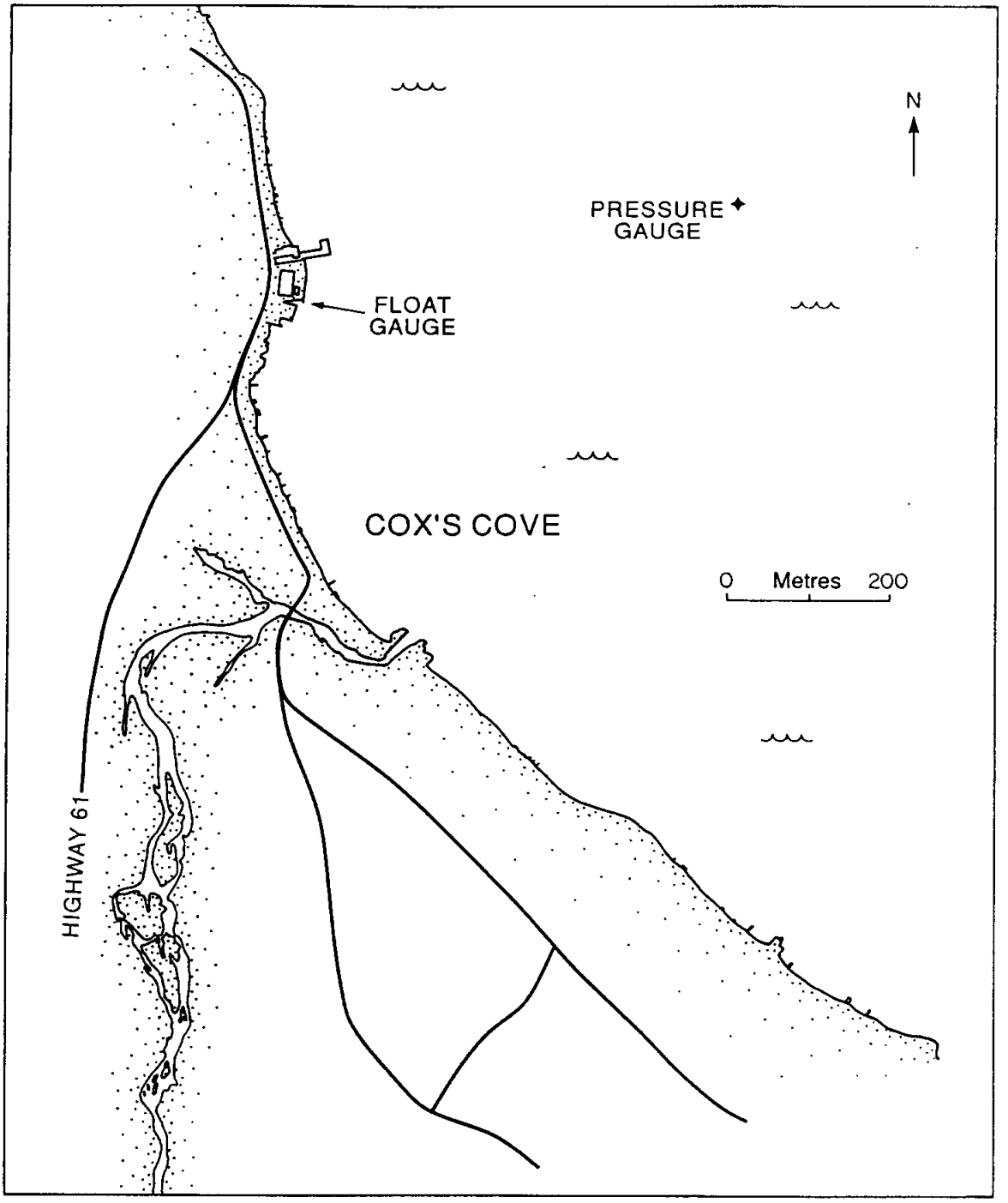


FIGURE 6.3

INSTRUMENT LOCATIONS - COX'S COVE

As stated previously the recovery of the pressure gauge moored in Cox's Cove was planned for early January 1988. Unseasonable cold conditions during the last week in December, and winds from the north and east on 30 December, resulted in a collection of 'slob' ice forming in Cox's Cove. This pancake like ice, about 1 m in diameter and 5-10 cm thick, filled Cox's Cove and when blown offshore with the southwesterly winds of New Year's Eve, was able to carry off the instrumentation and its mooring.

After a severe snowstorm that affected the west coast of Newfoundland during the first week in January the recovery team from Halifax arrived in Cox's Cove on the 7th of January. Dragging the sea bottom and conducting a visual search of the shores of Penquin and Goose Arms did not lead to recovery of the pressure gauge mooring.

7.0 DATA PROCESSING

The water level information available from the Cox's Cove field program is contained in an analogue record of water level from 7 October to 7 November 1987. These data were periodically verified during the monitoring period using the scale on the fish plant piling. The analogue data were digitized at 30 minute intervals. Figure 7.1 shows a plot of the October data; a gap in the data exists (23 October) because of a timing error that was correced later that day.

A complete listing of the Cox's Cove water level data, and the data from Lark Harbour for the corresponding period is provided in Appendix A.

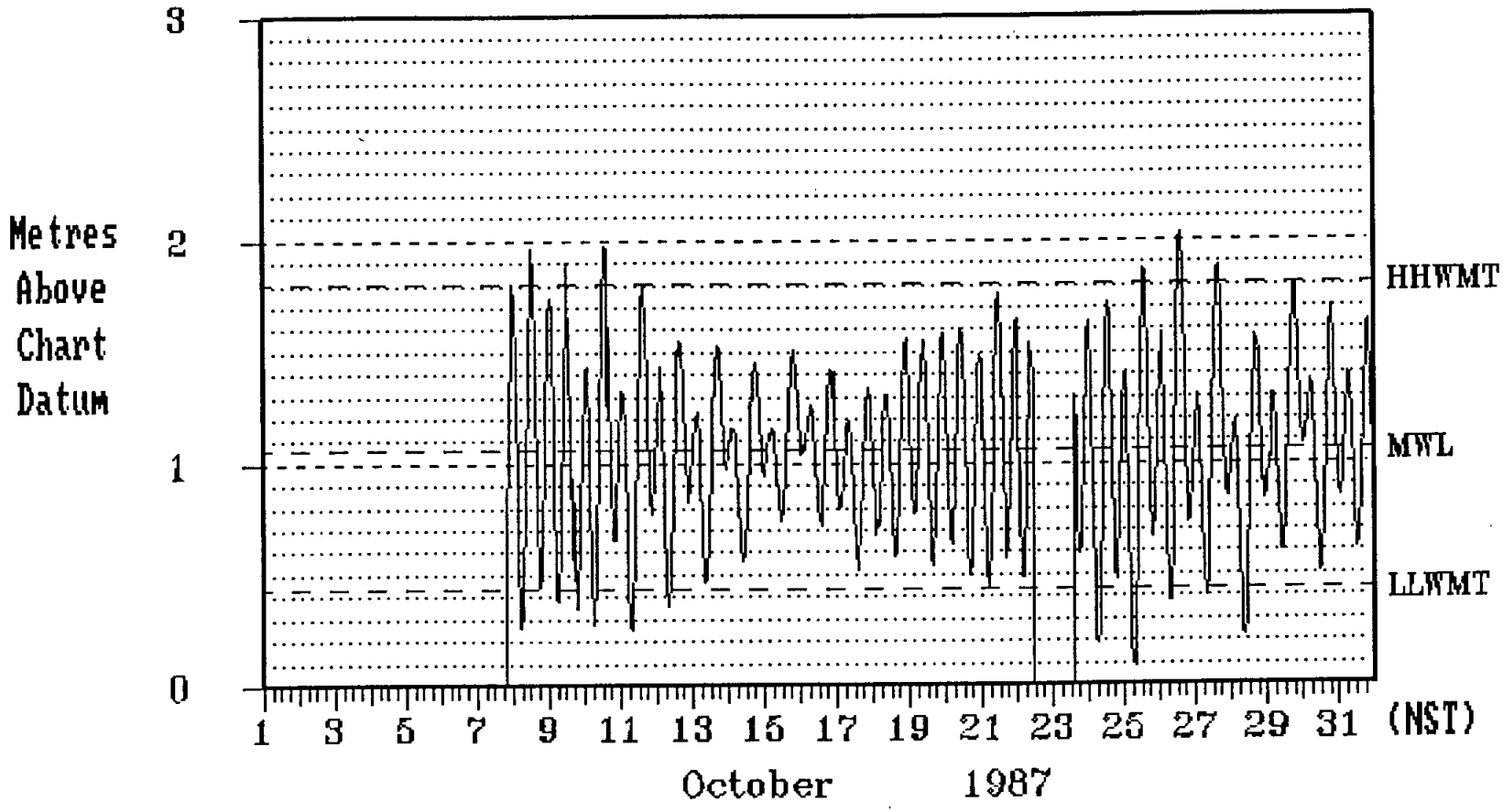


FIGURE 7.1

WATER LEVEL MEASURED AT COX'S COVE

8.0 DATA ANALYSES

Three phases were used to evaluate the water level regime at Cox's Cove for use in an extremal analysis suitable for establishing flood limits. The first phase involved a tidal analysis of the observed water levels at Cox's Cove and for a corresponding period at Lark Harbour. Having established the tidal characteristics, the water level fluctuations due to the tides were subtracted from the observed level record to give a time series of the non-tidal, or surge component. The next phase consisted of a cross correlation analysis between first the observed water levels, and then the calculated surge levels, at Cox's Cove and Lark Harbour. This was done to quantify the relationship between the water levels, and surges, at the two locations. The third phase, an extremal analysis, extrapolated the long term water level from Lark Harbour, appropriately transfered to represent Cox's Cove, to provide water levels at recurrence intervals of 1 in 20 and 1 in 100 year, with their 90% confidence limits. Each of these three phases of the data analysis is described in the following sections of this report.

8.1 Tidal Analysis

The time series of actual water levels measured during the field observation period at Lark Harbour and Cox's Cove were analyzed for their harmonic characteristics to determine the tidal constituents at each location.

The harmonic analysis is based on the principle that the tidal component of the water level record consists of the sum of a number of components with known harmonic frequencies. These harmonic frequencies are often called tidal constituents. For example, the principal lunar semi-diurnal constituent (the M_2 tide) has a frequency of 0.0805 cycles/hr, which corresponds to a fluctuation over a 12.42 hour cycle, (i.e. about twice a day).

In carrying out the analysis, the characteristics of 69 known tidal constituents are fitted to the observed water level time series. Amplitudes (which relate to the energy of the constituent) and Greenwich phase lags (which relate to the timing of the constituent) are determined for as many constituents as possible, depending on the length of the record.

Table 8.1.1 shows the principal tidal constituents that were resolved from the water level records from Lark Harbour and how they combine to give a time series of water level fluctuations due only to tides. The tidal constituents for Cox's Cove are given in Table 8.1.2. These tidal constituents were subsequently used to generate a time series of water level changes due to the tidal potential which, when subtracted from the observed water levels, results in a time series of storm surge (i.e. the fluctuation of water levels due to non-tidal forces).

Figures 8.1.1 and 8.1.2 each shows three curves. Two of the curves are centered on mean water level (MWL), the solid line representing observed water levels and the dashed line representing the tidal potential determined as described above. The third curve, positioned along the bottom axes of the figures, represents the residual storm surge signal that remains after the tides have been removed. It can be seen that the tides provide the principal contribution to the water level fluctuation.

8.2 Correlation Analysis

The storm surge (i.e non-tidal fluctuations) at Cox's Cove (determined as described in Section 8.1) was compared to the corresponding Lark Harbour storm surge record.

Figure 8.2.1 shows the storm surge records at Cox's Cove and Lark Harbour varying about the mean water line. The plot of the differences

TABLE 8.1.1

PRINCIPAL TIDAL CONSTITUENTS DERIVED FROM LARK HARBOUR DATA

Constituent	Frequency (hr^{-1})	Amplitude (m)	Greenwich Phase (degrees)
Mean water level, Z0	0.0000	1.0963	0.00
Lunar semidiurnal, M_2	0.0805	0.4961	327.85
Solar semidiurnal, S_2	0.0833	0.1510	335.55
Lunar elliptic semidiurnal, N_2	0.0790	0.0888	312.86
Lunisolar diurnal, K_1	0.0418	0.1438	202.79
Lunar diurnal, O_1	0.0387	0.1317	199.71

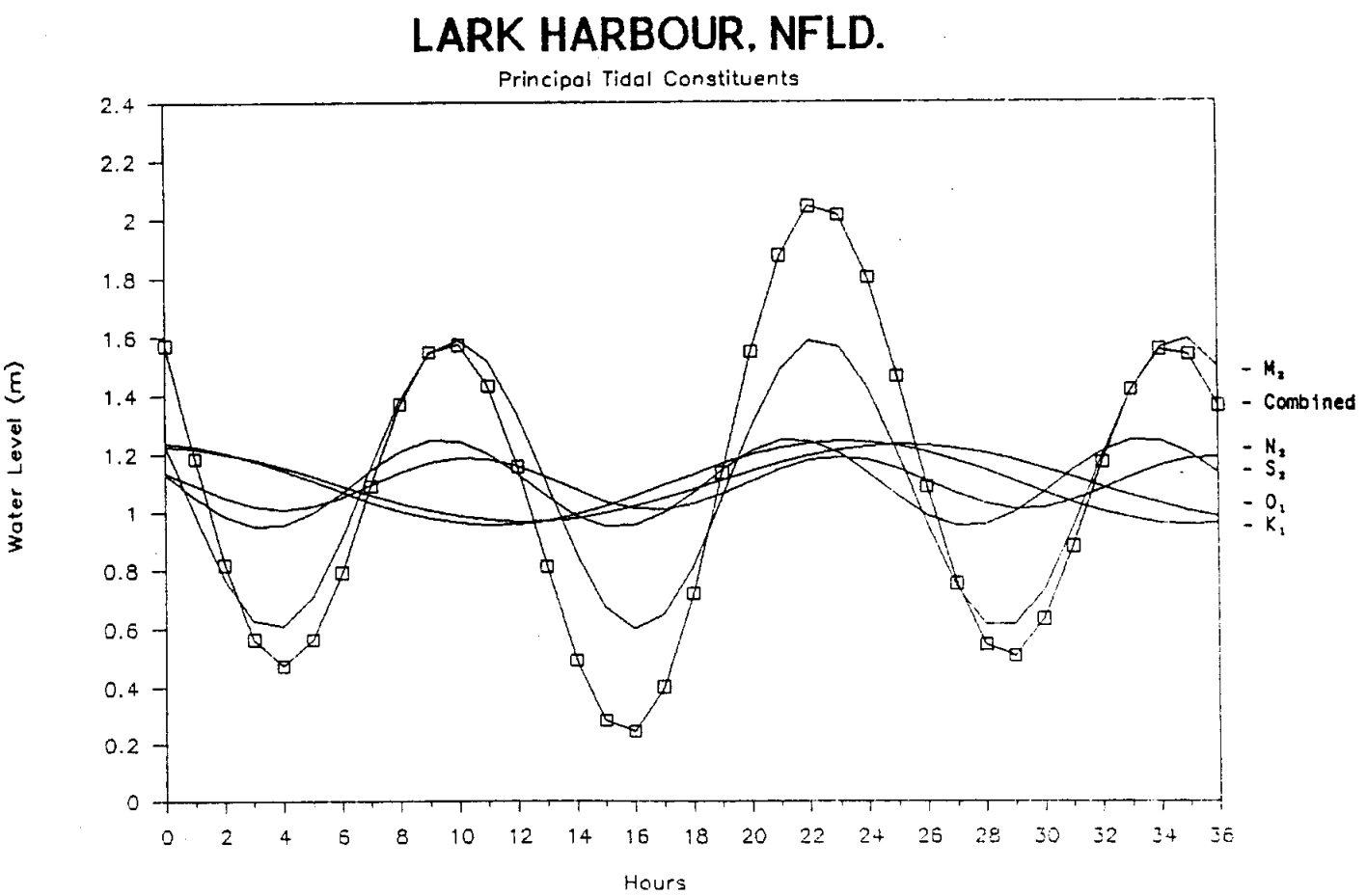
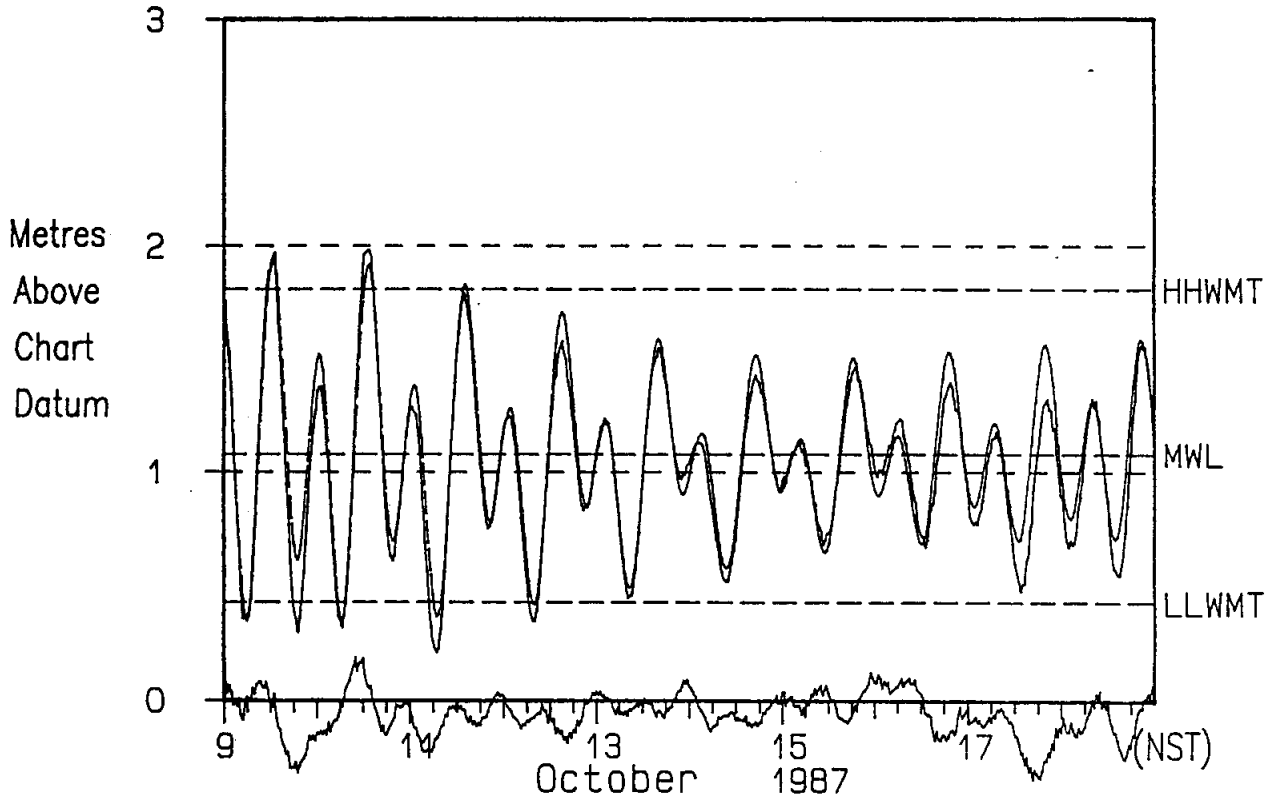


TABLE 8.1.2

PRINCIPAL TIDAL CONSTITUENTS DERIVED FROM COX'S COVE DATA

Constituent	Frequency (hr^{-1})	Amplitude (m)	Greenwich Phase (degrees)
Mean water level, Z0	0.0000	1.0665	0.00
Lunar semidiurnal, M_2	0.0805	0.4782	332.28
Solar semidiurnal, S_2	0.0833	0.1910	338.79
Lunisolar diurnal, K_1	0.0418	0.1114	202.66
Lunar diurnal, O_1	0.0387	0.1578	206.99
MSF	0.0028	0.0162	348.51
M3	0.1207	0.0046	28.87
SK3	0.1251	0.0001	354.15
M4	0.1610	0.0092	39.88
MS4	0.1638	0.0017	59.16
S4	0.1666	0.0019	335.93
2MK5	0.2028	0.0053	206.88
2SK5	0.2084	0.0037	219.87
M6	0.2415	0.0059	254.17
2MS6	0.2443	0.0004	304.28
2SM6	0.2471	0.0020	80.56
3MK7	0.2833	0.0026	218.84
M8	0.3220	0.0004	358.28



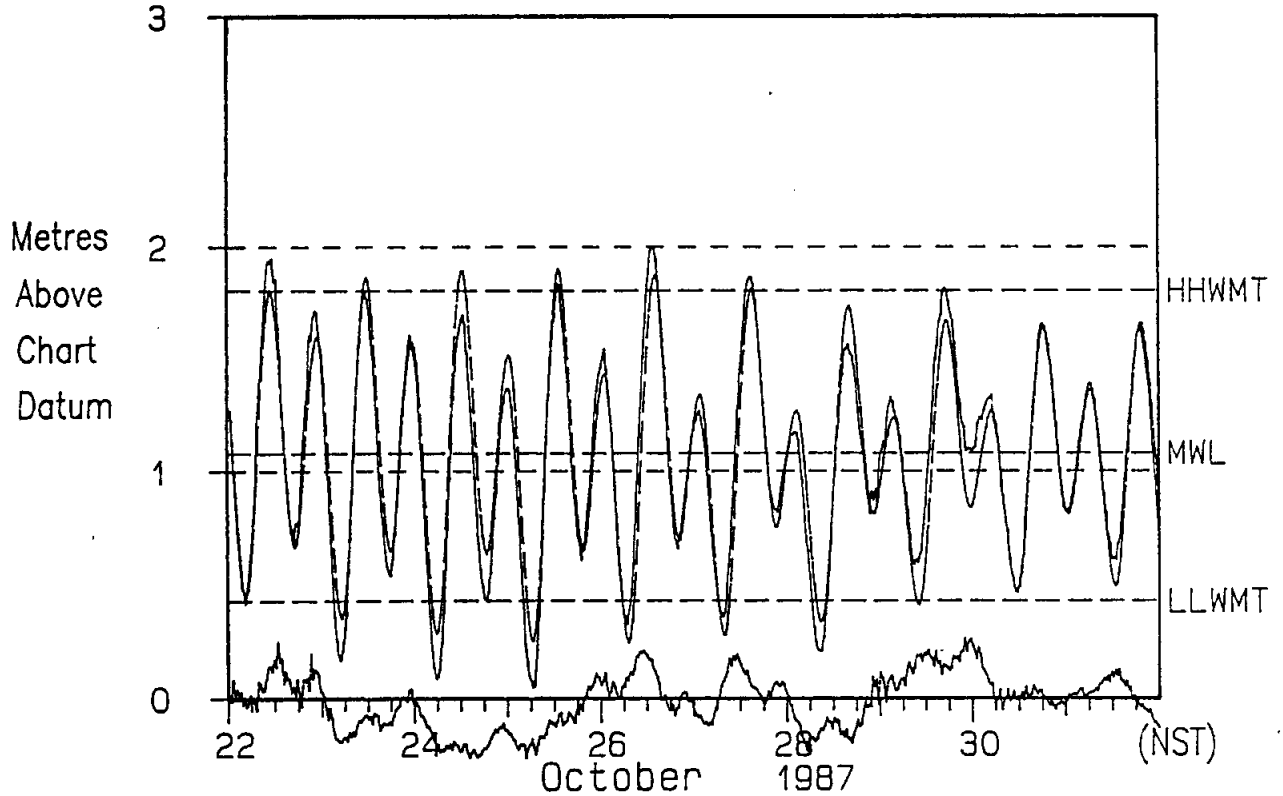


FIGURE 8.1.1

SURGE AT LARK HARBOUR

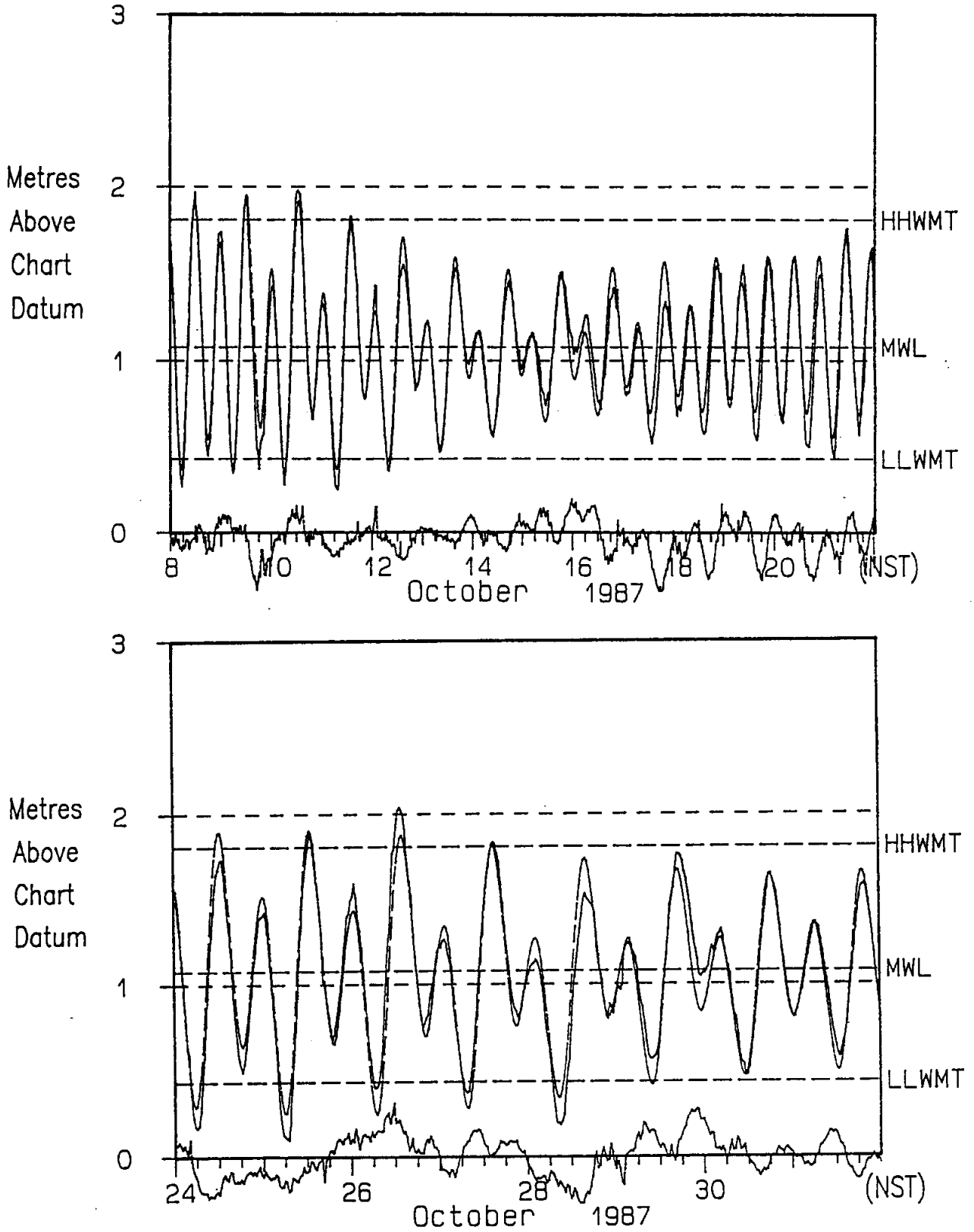
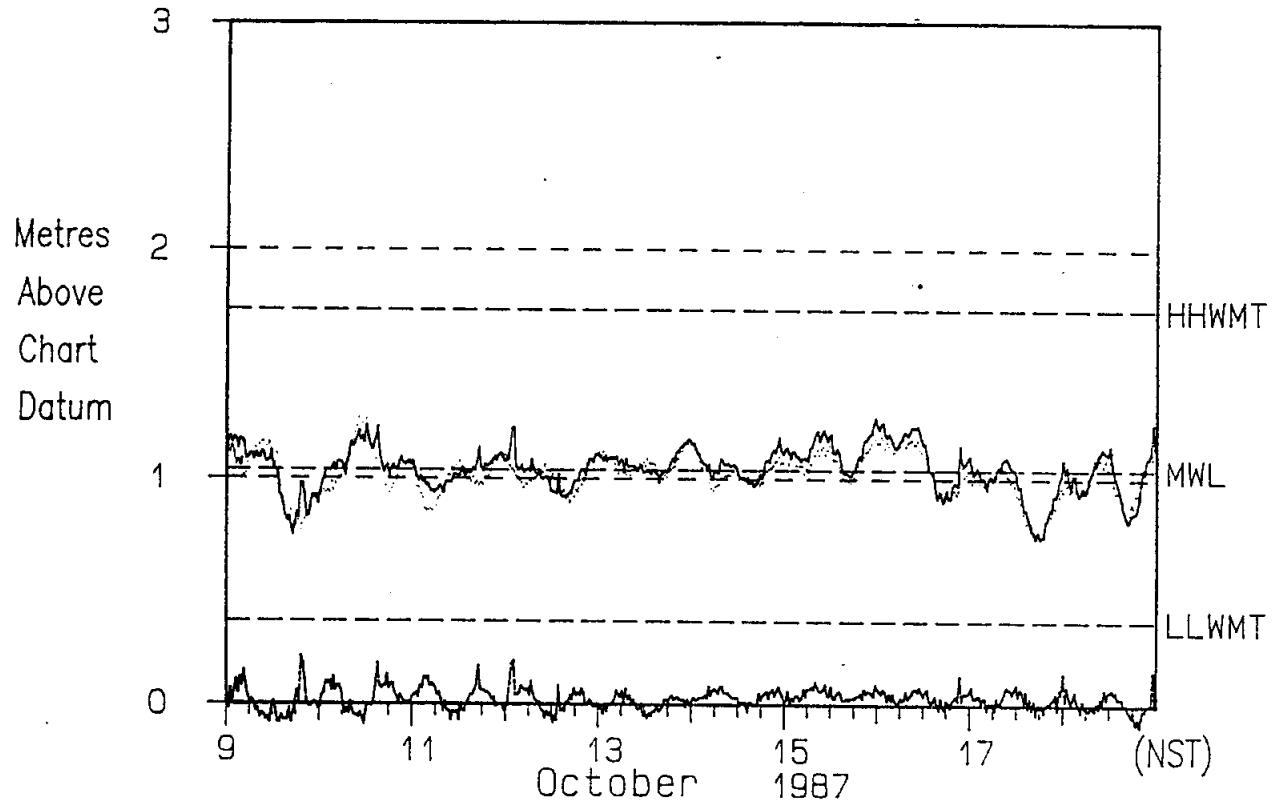


FIGURE 8.1.2

SURGE AT COX'S COVE



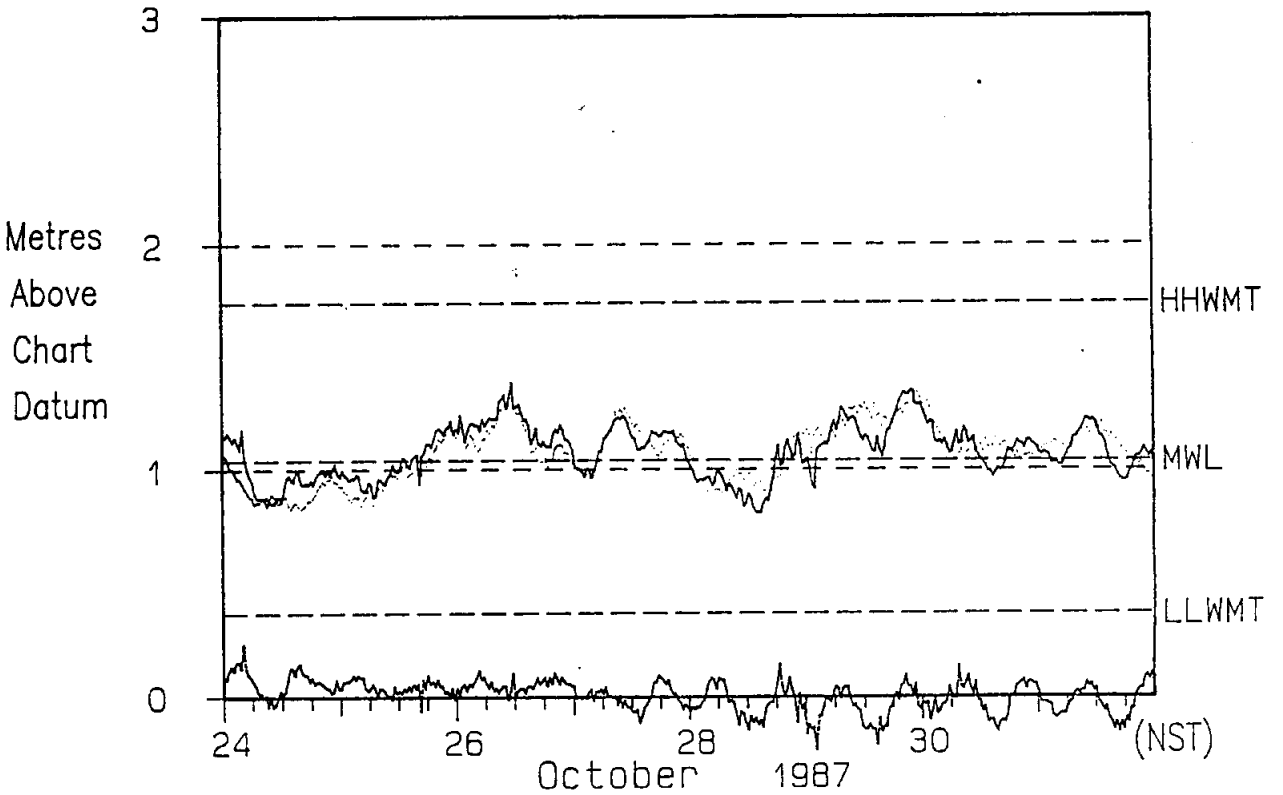


FIGURE 8.2.1

DIFFERENCE IN SURGE AT COX'S COVE AND LARK HARBOUR

in these two storm surge records is positioned along the bottom axis of the figures. The plots show that at Lark Harbour and Cox's Cove the surge records closely resemble each other throughout the entire recording period.

Since we are interested in using the long term historical water level data at Lark Harbour to predict surge effects at Cox's Cove, we need to know quantitively how much of the variation in surge at Cox's Cove can be explained by the variation in surge at Lark Harbour.

The difference between the Cox's Cove and Lark Harbour water levels is small. Both the tidal regime and the surge regime at the two locations differ only within the measuring accuracy of the data collection instrumentation. As such the water level data gathered at Lark Harbour can be used without modification to represent the fluctuations in water level at Cox's Cove.

The Pugh and Vassie (1980) joint probability method utilizes convolution of the probability density fluctuations (pdf) of the tide and surge to calculate exceedance probabilities for extremal analysis. Because the pdfs of Cox's Cove are essentially the same as those of Lark Harbour, there is no advantage to applying this technique. Consequently, the conventional extremal analysis methodology, as described in Section 8.3, has been used.

8.3 Extremal Analysis

The maximum sea levels for several return periods were determined by:

a) Examining 21 years of sea surface elevation data collected at Lark Harbour;

b) Assessing the validity of the statistical assumptions used in extrapolating the data to long return periods;

c) Fitting the water level data to several extremal frequency distributions, and

d) Identifing the statistical distribution that best fit the data.

The data used in the calculation of maximum sea levels were the monthly instantaneous maximum values of water levels collected by the Canadian Hydrographic Service at Lark Harbour. These data, gathered from 1966 to 1986 are related to Chart Datum which refers to the plane of lowest normal tides.

A reduced data set consisting of the 18 annual maximum water levels was then determined (see Table 8.3.2). A complete set of 21 annual maxima could not be resolved due to the data gaps in the Lark Harbour record. The data return from the Lark Harbour gauge was determined to be approximately 78 percent. There were sufficient water level data available to provide a statistically sound data base for the extremal analysis. Because the extremal analysis procedure uses a time scale of years to express the maximum values (e.g. 1 in 20 year, 1 in 100 year, etc.) it is important to define an appropriate surge year for the sea level. To accommodate the seasonal variation due to river runoff and storm activity within one twelve month period, a surge year from July to June was selected.

Martec's suite of extreme value analysis computer programs includes two originally developed by the Inland Waters Directorate of Environment Canada; programe NONPARA which tests the validity of the assumptions made of the input data, and program FDRPFFA which fits the data to several frequency distributions.

Since a statistical frequency analysis assumes that the sample to be analyzed is a reliable set of measurements of independent random events from a homogeneous population, the validity of this assumption was tested using the following nonparametric tests:

- The Spearman rank order correlation coefficient for independence and trend;

- The Mann-Whitney U statistics for homogeneity of split sample means;

- The Wald-Wolfowitz R statistic for any difference in homogeneity of split samples, and

- The number of runs above and below the median for general randomness.

The monthly water level maxima data were ranked and sorted as required for the various tests. The relevant test statistics and their significance levels were calculated and tabulated for each characteristic of the data set under consideration. The results of the statistical significance tests were used to determine whether more than one population is present in the data due to the evolution in time of the physical processes that cause the variation in the water level.

The nonparametric tests revealed that the set of water level values that comprised the annual maxima were statistically independent and homogeneous at a one percent significance level. In addition, the data set was random and exhibited no trend at the one percent significance level. These tests for independence, trend, homogeneity and randomness indicated that the data set was suitable for the calculation of extreme values. The results of the tests are included in Table 8.3.1.

TABLE 8.3.1

TESTS FOR INDEPENDENCE, TREND, HOMOGENEITY AND RANDOMNESS

LARK HARBOUR, NEWFOUNDLAND, ... WATER LEVEL DATA 1966-1986 3 MISSING YEARS

Spearman Rank Order Serial Correlation Coeff. for Independence = -.2289 D.F. = 15 Students T = -.911
From Table Critical T Value at 1 Percent Significance Level TCR.01 = 2.602
Not Significant

Spearman Rank Order Serial Correlation Coefficient for Trend = .0718 D.F. = 16 Students T = .288
From Table Critical T Value at 1 Percent Significance Level TCR.01 = 2.921
Not Significant

Mann-Whitney Split Sample Test for Homogeneity Mann-Whitney U = 40.0
From Table Critical U Value at 1 Percent Significance Level UCR.01 = 14.0
Not Significant

Wald-Wolfowitz Split Sample Test for Homogeneity. Ties in Different Subsamples, Test Invalid.

Runs Above and Below the Median Test for General Randomness RUNAB = .11
N1=9 N2=9 Acceptable Range at 5% Significance Level is 6. to 14. Inclusive. Not Significant

As part of the extremal analysis, the magnitudes of the measured parameters were fitted to frequency distributions and then extrapolated from the recorded events to extreme return periods. Since it is possible to fit several distributions to the sample data, and obtain several different estimates for a given extreme event, a variety of frequency distributions were tested. The distribution that was best fit by the data was used to provide the extreme values.

The following distributions were fitted:

- Gumbel I;
- Lognormal;
- Three-Parameter Lognormal, and
- Log-Pearson type III.

The means by which the sample data are fitted to the frequency distribution was achieved by using the method of maximum likelihood. The parameters of the distribution were estimated to maximize the probability that the sample was obtained from the particular distribution being considered. In situations where a maximum likelihood fit of a selected distribution to the water level data was not possible, the method of moments was used.

The standard deviation, coefficient of skew and coefficient of kurtosis of the input data were calculated for each distribution. These sample statistics were then compared with the theoretical characteristics of the selected distributions to determine which distribution the data most closely follows. The extremes and their asymptotic errors of estimate were then computed for selected return periods for each distribution.

The fundamental tenet of selecting the flood frequency distribution is to choose the one that the data best fit, therefore, the Three-Parameter Lognormal is the most appropriate representation of the water level regime at Lark Harbour, and Cox's Cove. Table 8.3.2 gives the relevant parameters of the distribution, Table 8.3.3 provides the extreme values at specific return periods, and Figure 8.3.1 shows the data, the fitted distribution and the 90% confidence limits.

The plot of extreme event data of Figure 8.3.1 shows that the long-term water level distribution curve has only a small slope and thus there are not large changes in water level values over various return periods.

It can be seen from the extremal analysis that the 1:5, 1:20 and 1:100 year return periods are 2.555 m, 2.717 m and 2.904 m, respectively, above chart datum, a change of 0.349 m for this range of return periods.

8.4 Fresh Water Influence

Fresh water floods can contribute to the flooding of the bog area of Cox's Cove if the flood coincides with high sea water level. The largest annual fresh water flood is expected during the spring runoff period, however, a significant proportion do occur during the winter period as discussed in Section 3.0.

The overall (fresh water and salt water) flooding season for Cox's Cove has historically been found to be the winter period (November through January) when the peak sea levels occur as described above. As described below, it was determined that the Cox's Cove flooding was controlled by sea levels not by fresh water influence even though fresh water influence during a storm surge event impacts on the predicted flood levels and therefore cannot be ignored. Based on this, the flows associated with different probabilities of exceedance for winter fresh water floods were required. These flows have been estimated as 0.75 of the

TABLE 8.3.2

EXTREMAL ANALYSIS OF LARK HARBOUR/COX'S COVE
WATER LEVEL DATA

Ordered Input Data (m above) Chart Datum	Geodetic Datum	Surge Year	Probability	Return Period
2.79	1.75	1970	.041	24.342
2.58	1.54	1981	.095	10.511
2.57	1.53	1966	.149	6.703
2.56	1.52	1983	.203	4.920
2.56	1.52	1985	.257	3.887
2.51	1.47	1968	.311	3.212
2.49	1.45	1977	.365	2.737
2.49	1.45	1969	.419	2.384
2.47	1.43	1971	.474	2.112
2.44	1.40	1965	.528	1.895
2.42	1.38	1979	.582	1.719
2.39	1.35	1982	.636	1.573
2.37	1.33	1974	.690	1.450
2.35	1.31	1972	.744	1.344
2.33	1.29	1978	.798	1.253
2.30	1.26	1986	.852	1.174
2.30	1.26	1967	.906	1.104
2.28	1.24	1973	.960	1.042

	Input Data	Three-Parameter Lognormal Transformation
mean	2.4556	-1.1956
standard deviation	.100	.4041
coefficient of skew	.7935	-.1260
coefficient of Kurtosis	4.6276	2.9764

TABLE 8.3.3

WATER LEVEL AT LARK HARBOUR/COX'S COVE FOR SELECTED RETURN PERIODS

Three-Parameter Lognormal Distribution fitted by Maximum Likelihood

Return Period (year)	Estimate (m above)		90% Confidence Limits (m above)	
	Chart Datum	Geodetic Datum	Chart Datum	Geodetic Datum
5	2.55	1.52	2.47 - 2.63	1.45 - 1.59
10	2.63	1.60	2.52 - 2.74	1.49 - 1.71
20	2.71	1.68	2.56 - 2.87	1.52 - 1.83
50	2.82	1.78	2.59 - 3.05	1.56 - 2.01
100	2.90	1.86	2.61 - 3.19	1.57 - 2.16
200	2.98	1.95	2.61 - 3.35	1.58 - 2.31

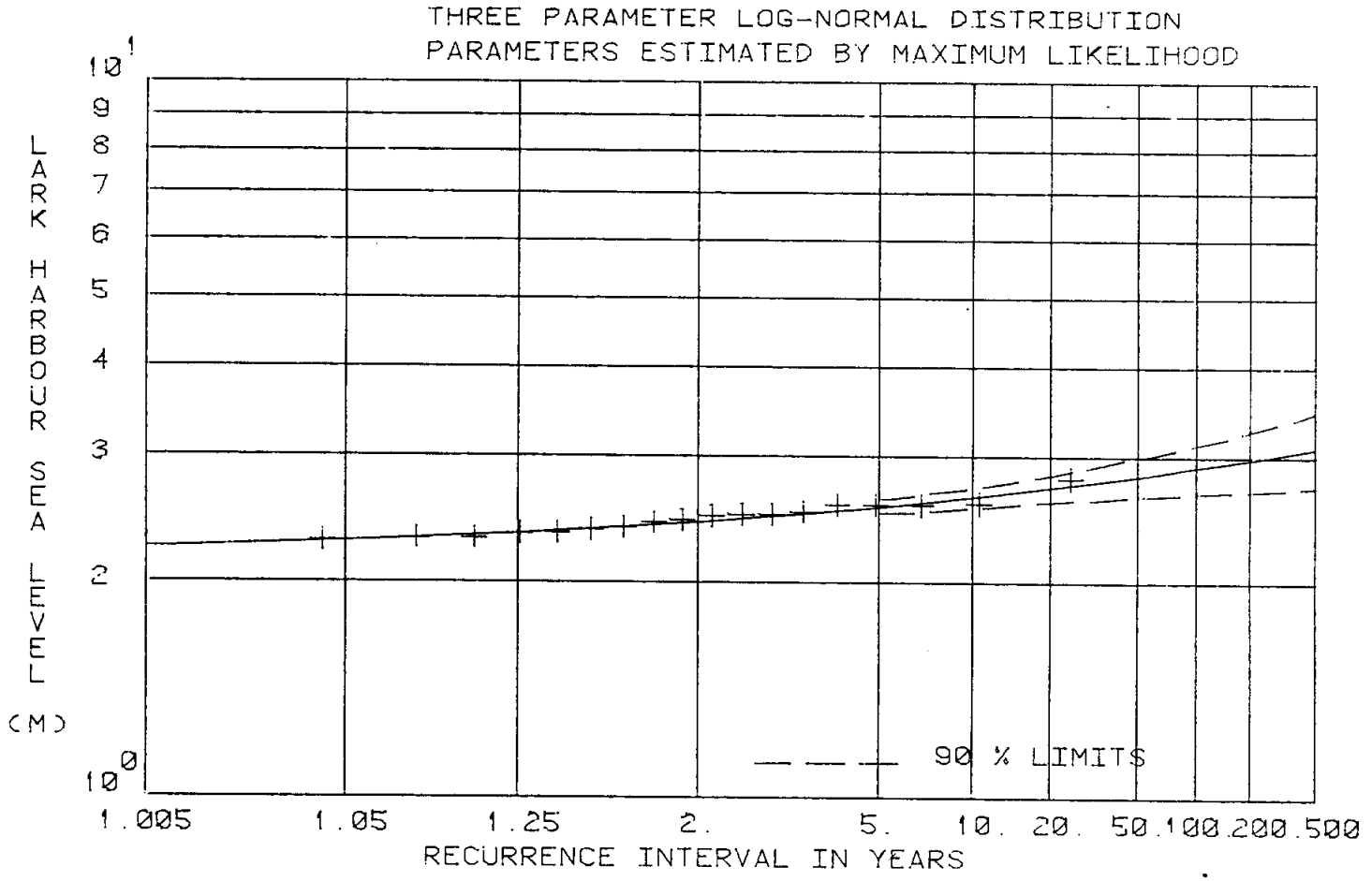


FIGURE 8.3.1

EXTREME EVENTS AT COX'S COVE

annual instantaneous peak. This factor was determined from comparisons of instantaneous annual, daily annual, and daily winter flows maxima (Surface Water Data, Atlantic Provinces Inland Water Directorate (1960-1987), Water Resources Branch, Water Survey of Canada, Ottawa). Annual flood probabilities have been estimated using the Regional Flood Frequency formulae from the Regional Flood Frequency Analysis for the Island of Newfoundland (1984), as summarized in Table 8.4.1.

With the influence of fresh water inflow, combined with sea level, there are a number of scenarios by which the same Cox's Cove flood level can be achieved. Each of these possible scenarios has a joint, or combined, probability of exceedance. In order to establish the 1:20 (i.e. the 5% per annum probability of exceedance) and the 1:100 year (i.e. the 1% per annum probability of exceedance) water levels in the Cox's Cove area, the probabilites of exceedance were calculated as the product of the two independent probabilities for each possible combination of high sea level and fresh water inflow. The possible combinations ranged from the 1:1 to the 1:100 year events for both sea level events and winter floods. The method used was to digitize both of the probability of exceedance functions into 1/10 of a year sections (i.e. the 1:1, 1:1.1, 1:1.2 .... 1:99.8, 1:99.9, 1:100 year events) for sea levels and flows and then consider all possible combinations of the two events.

The numerical model used to calculate the results of all combinations of events was based upon an average channel cross section area for Cox's Brook seaward of the bridge and the following equation defining discharge rate as a function of the water's surface slopes from upstream of the bridge to downstream of the channel (i.e. the open coast) locations:

$$Q = \frac{1}{n} AR^{2/3} \sqrt{S}$$

TABLE 8.4.1

COX'S COVE BROOK FLOOD FREQUENCIES

Frequency of Excedence	Annual Instantaneous* Flood Peak (m^3/s)	Winter Instantaneous Flood Peak (m^3/s)
50%	31.6	23.7
20%	39.2	29.4
10%	49.2	36.9
5%	55.9	41.9
2%	64.7	48.5
1%	71.5	53.6

Physiographic Data

Drainage area, DA	= 58 km^2
Mean Annual Runoff, MAR	= 1100 mm
Area Controlled by Lakes and Swamps	= 68%
Shape	= 1.80

*Entire island formulae applied as outlined in the Regional Flood Frequency Analysis for the Island of Newfoundland (1984).

where:

Q = the discharge m^3/s

n = Mannings n (ranging from 0.025 to 0.035), from Streeter, 1975

A = cross sectional area of the channel =

$$\frac{h_1 + h_2}{2} \times w \ (m^2)$$

h_1 = depth of flow upstream of the bridge

h_2 = depth of flow at the open coast (i.e. the sea level above the channel bottom)

w = the width of the channel = 14.3 m

R = the hydraulic radius = cross sectional area divided by wetter perimeter =

$$A/\left[2\left(\frac{h_2 + h_2}{2}\right) + w\right]$$

S = the surface slope = $(h_1 - h_2)/L$

L = length of the channel = 175 m

The storage capacity of the bog was investigated and found to be virtually negligible when elevated sea levels restricted fresh water outflow. For example, the 1:20 year winter flow combined with an average yearly high sea level would result in the bog area flooding from elevation +1.3 m (the sea level) to + 1.9 m (the equilibrium level) in less than 15 minutes. For this reason, and because over 95% of the peak fresh water discharge would be continuous over a high tide cycle, steady state conditions were assumed for the hydraulic calculations.

In the final analysis the above proved to serve only as a check because the worst case was found to be the result of the 1:20 and 1:100 year sea levels coupled with the average annual winter fresh water peak flow (i.e. the 1:1 year event) of approximately 20 m^3/s. For example, the 1:20 year sea level combined with the 1:5 year fresh water flow would have a probability of exceedance less than or equal to 1:100 year, however, the flood level in the bog area for this (and all other 1:100

year combinations) was found to be less than the flood level produced by the 1:100 year sea level combined with the 1:1 year fresh water flow.

The resultant maximum 1:20 and 1:100 year flood levels in the bog were found to be (including channel entrance and exit losses) + 1.90 m and +2.20 m respectively (based upon the predicted extreme sea levels) and the 1:1 year fresh water flow rate.

The fresh water flow results in a surcharge of the bog flood level of 0.185 and 0.36 m (above the 1.68 and 1.86 m values taken from Table 8.3.3) for the 1:20 and 1:100 flood events respectively.

These values were based upon a conservative estimate of the channel roughness, dimensions, and the average winter brook flow. As a result, they could probably be reduced somewhat but data is not currently available to justify a more rigourous analysis.

As discussed in Section 8.2, the correlation between Lark Harbour water levels and Cox's Cove water levels was quite good (within the measuring accuracy of the instruments) and so the estimates of extreme sea level from Table 8.3.3 were used (rather than the upper 90% confidence limit). This was done because coupling the conservative approach to freshwater influence described above with the conservative upper 90% confidence limit of extreme sea levels would produce an overly conservative (and unrealistic) flood level. Similarly, since the wave runup and overtopping predictions are based on conservative assumptions, the standard estimates of extreme sea levels were used in the following sections (rather than the upper 90% confidence limits) to avoid over predicting extreme event flooding.

8.5 Wave Runup and Overtopping at Cox's Cove

The maximum height of a wave travelling in deep water is limited by a maximum wave steepness for which the wave form can remain stable. This limiting steepness is approximately $H_o/L_o = 0.142$ (from the U.S. Army Corps of Engineers Shore Protection Manual (SPM), 1977) where H_o is the deep water wave height and L_o is the wave length in deep water. When the waves move into shallow water, this limiting steepness decreases being a function of both the relative depth d/L (where d = water depth and L = wavelength) and the slope of the bottom. As a wave moves into shallow water, it will steepen up to a point where wave breaking will commence and a rough estimate of the breaking wave height, H_b, to the depth at the point of breaking, d_b , is given (SPM, 1977) as $d_b/H_b = 1.28$. The actual ratio depends upon the beach slope and the full analysis has been used in determining the breaker wave height as outlined in SPM, 1977.

The determination of the wave run-up on the beach involves the establishment of the largest wave that can impact on the beach berm.

The wave run-up is defined as the vertical distance above the existing water level that the wave propagating to shore will reach. Based upon field observations and hydrographic charts, an average representative cross-sectional profile was determined. Since the waves are depth limited, detailed wave hindcasting was not necessary. Because of this the SMB (Sverdrup-Munk-Bretschneider) method of wave hindcasting (as presented in SPM, 1977) was used. To determine the wave run-up, the procedure followed was also as per the U.S. Army, Corps of Engineers Shore Protection Manual (SPM), 1977.

The worst case event for wave runup at Cox's Cove would be generated by a high water level coupled by strong winds from the direction of maximum fetch for Cox's Cove which is from the northeast. This fetch is

approximately 10 km long and since it is along a narrow body of water, the effective fetch length is reduced by 60% (SPM, 1977) to 4 km. The occurrence of high water levels in the Bay of Islands area is not dependent upon high northeast winds (but rather overall weather patterns in the Gulf) and thus northeast winds and high water levels can therefore be treated as independent events. The Deer Lake weather station provides the most representative wind data for NE winds in the Bay of Islands area.

An overland to overwater correction factor should be applied if detailed calculations are required to design coastal works. As a means of making a preliminary assessment of the coastal wave run-up, a conservative high wind can be taken as the maximum hourly recorded from 1965-80 of 80 km/hr. Even though this observation was reported to be from the WSW direction, it can serve as an upper limit estimator for conservative values in calculating wave run-up. From Figure 8.5.1 an 80 km/hr wind blowing for half an hour or more would produce a maximum significant wave height of 1.37 m and a period of 4.25 seconds. This wave would break at a height of roughly 2 m (see Figure 8.5.2) on a bottom slope of 1:10 (estimated offshore bottom slope) in approximately 2.2 m water depth (see Figure 8.5.3). With the shoreward edge of the foreshore flats at an elevation of 1 m above geodetic datum (i.e. Mean Water Level), it can be seen that these waves would, in fact, break before the shoreline if the water level was 1.68 m (1:20 year event) to 1.86 m (1:100 year event). These water levels of 1.68 and 1.86 m would result in depths of water at the toe of either the breakwater or seawall of 0.68 m and 0.86 m. From field observations the foreshore flats slope at approximately 1:100 (the nearshore bottom slope). Using the procedures outlined in SPM (1977) (see Figure 8.5.4), the largest waves which could reach and break on the face of the breakwater and seawall would be 0.58 m and 0.73 m in height (1:20 and 1:100 year water levels) with a 4.25 second period. These waves would have deep water wave heights of approximately 0.45 m and 0.63 m (see Figure 8.5.5) which could be generated with 32 and 40 km/hr

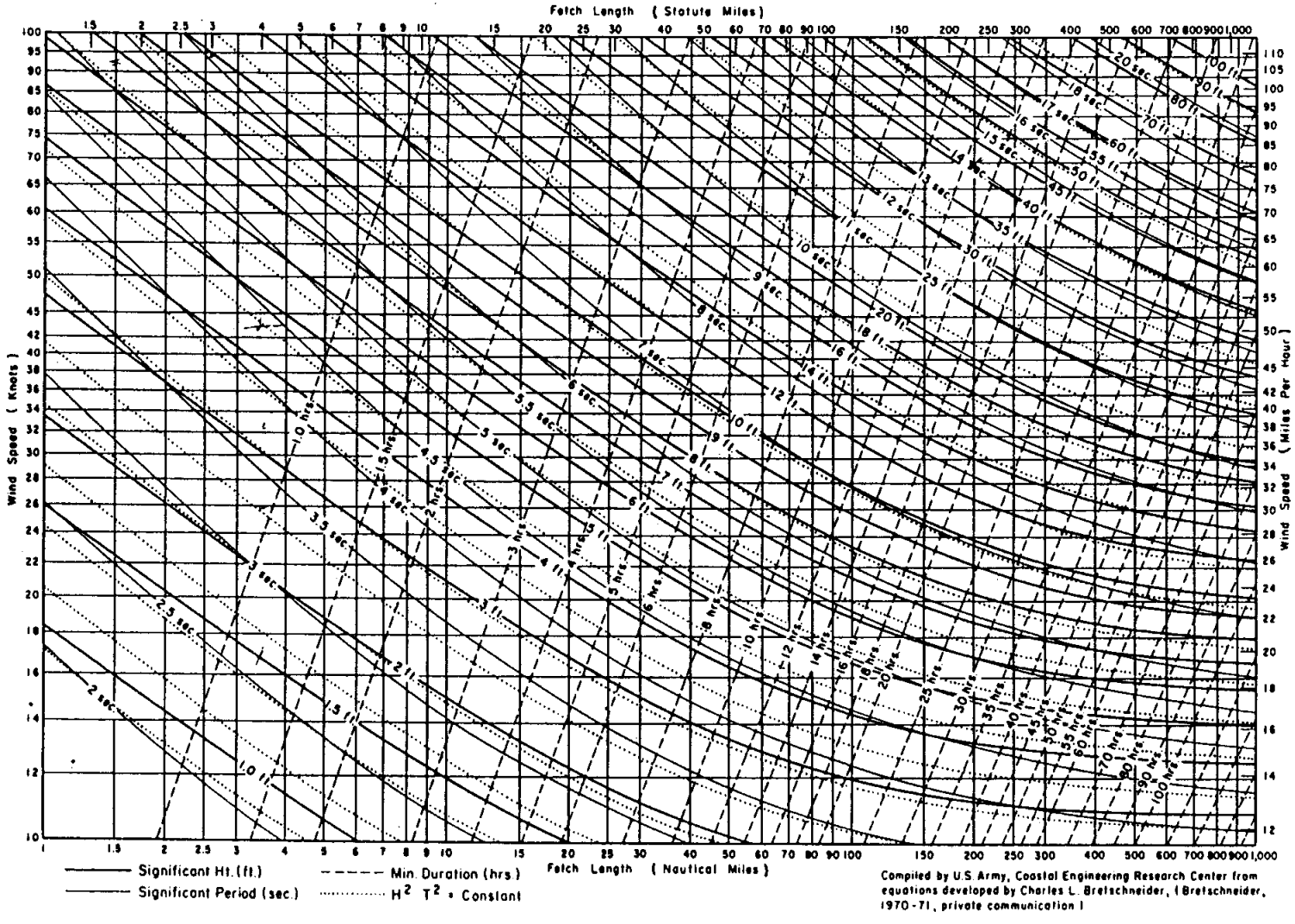


FIGURE 8.5.1

DEEPWATER WAVE FORECASTING CURVES AS A FUNCTION OF WIND SPEED, FETCH LENGTH, AND WIND DURATION (FOR FETCHES 1 TO 1,000 MILES) (FROM FIGURE 3-15 OF SPM, 1977)

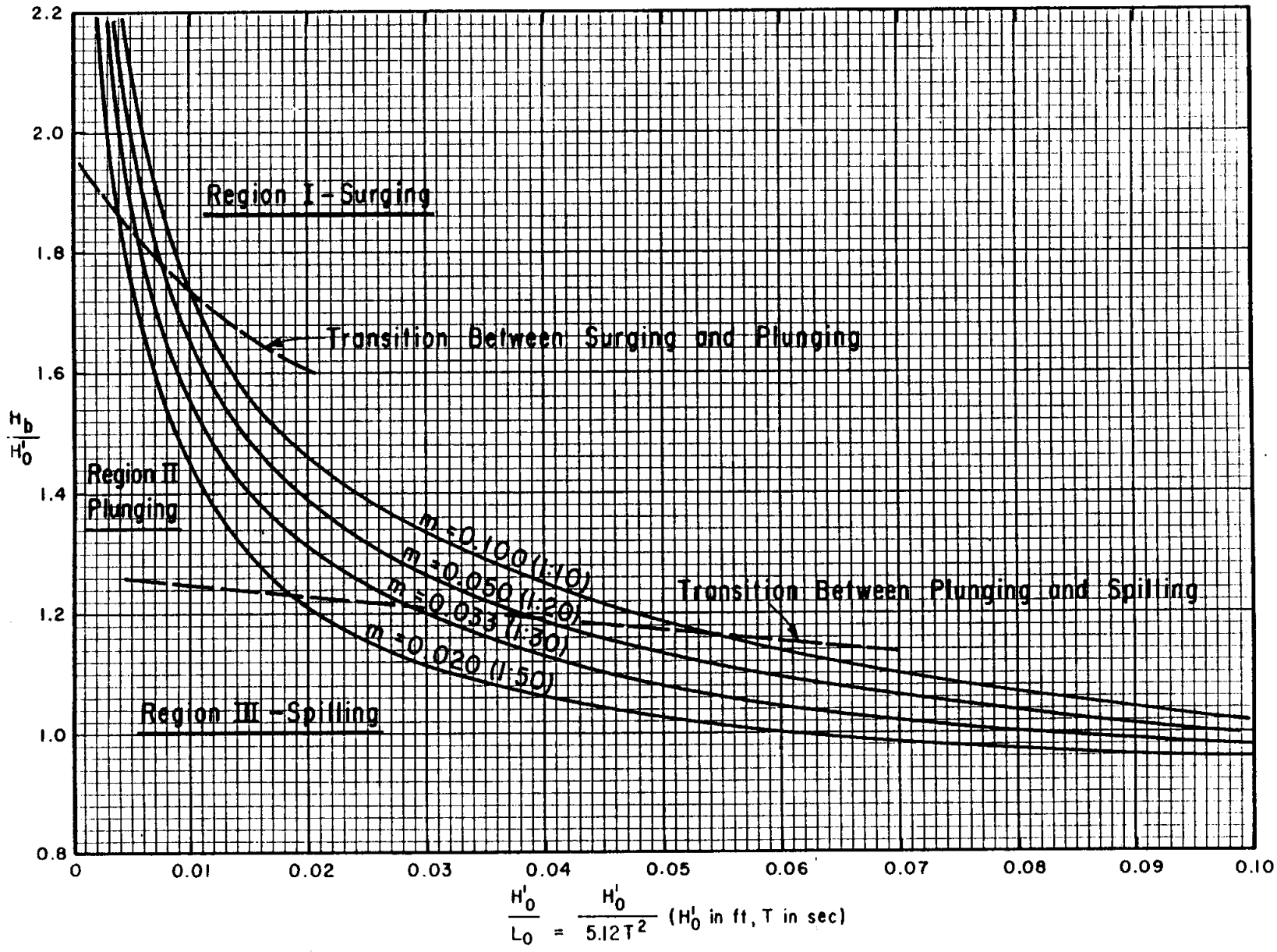


FIGURE 8.5.2

BREAKER HEIGHT INDEX VERSUS DEEP WATER WAVE STEEPNESS
(FROM FIGURE 2-65 OF SPM, 1977)

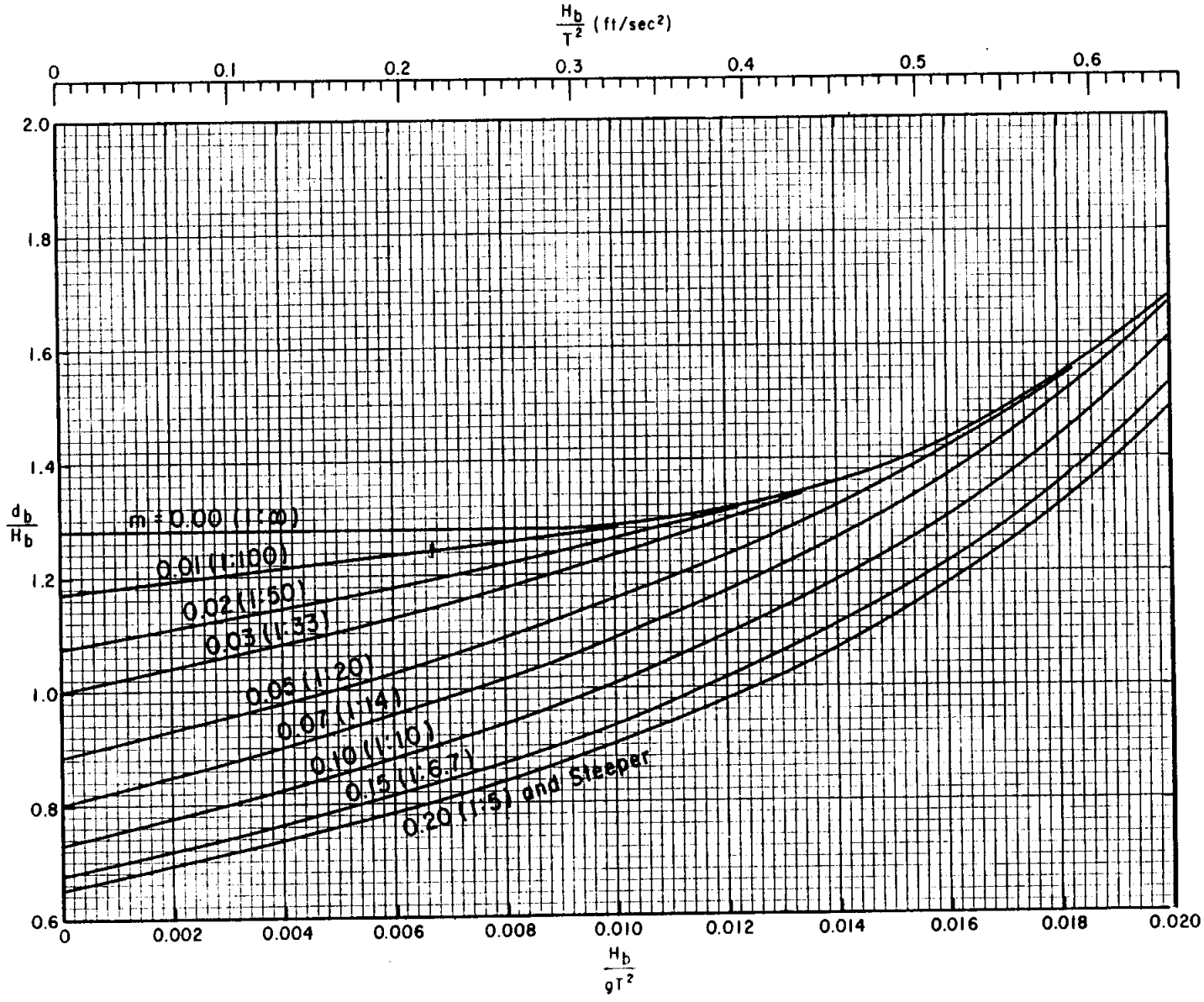


FIGURE 8.5.3

DIMENSIONLESS DEPTH AT BREAKING VERSUS BREAKER STEEPNESS
(FROM FIGURE 2-66 OF SPM, 1977)

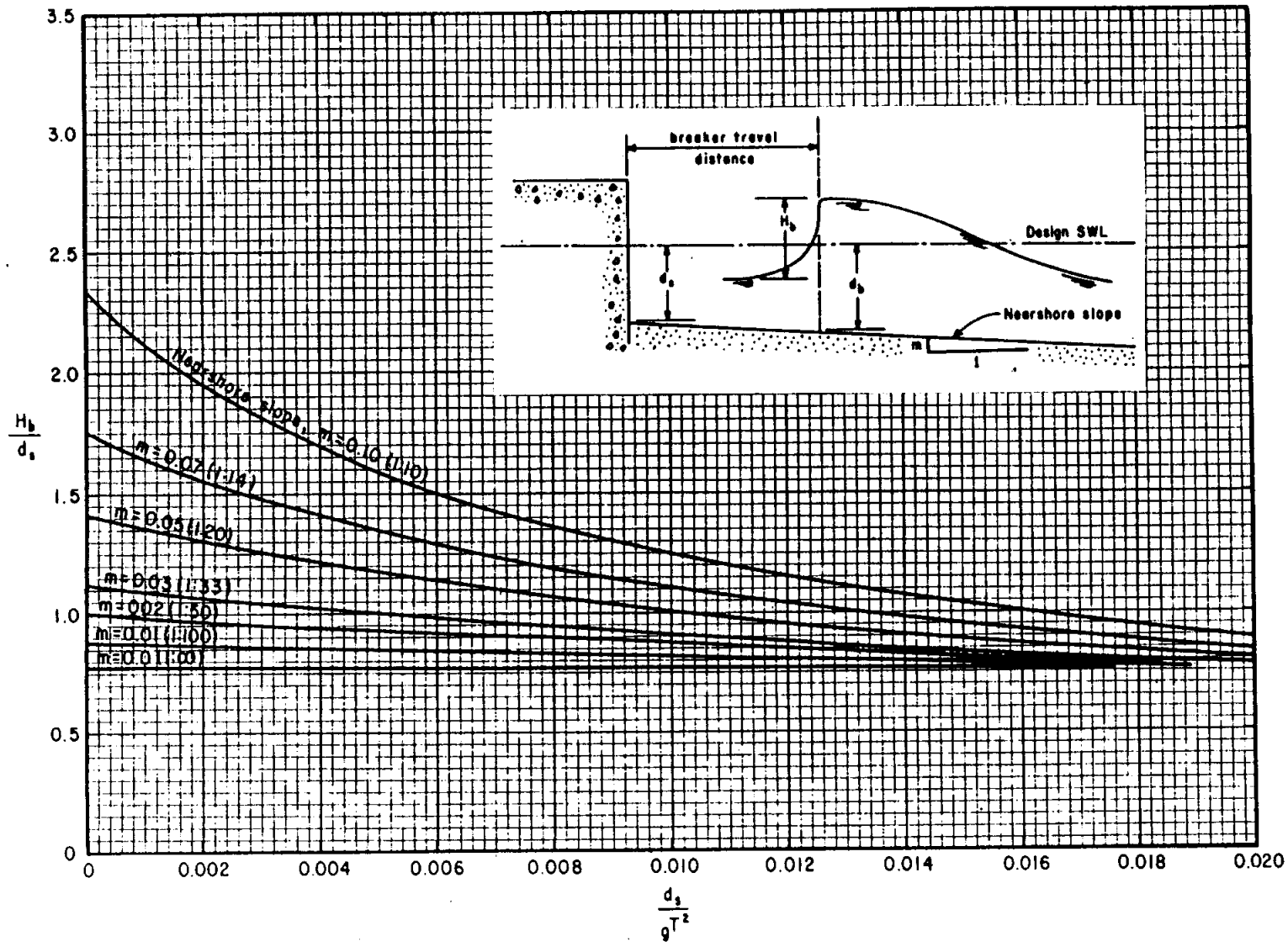


FIGURE 8.5.4

DIMENSIONLESS DESIGN BREAKER HEIGHT VERSUS RELATIVE DEPTH AT STRUCTURE (FROM FIGURE 7-4 OF SPM, 1977)

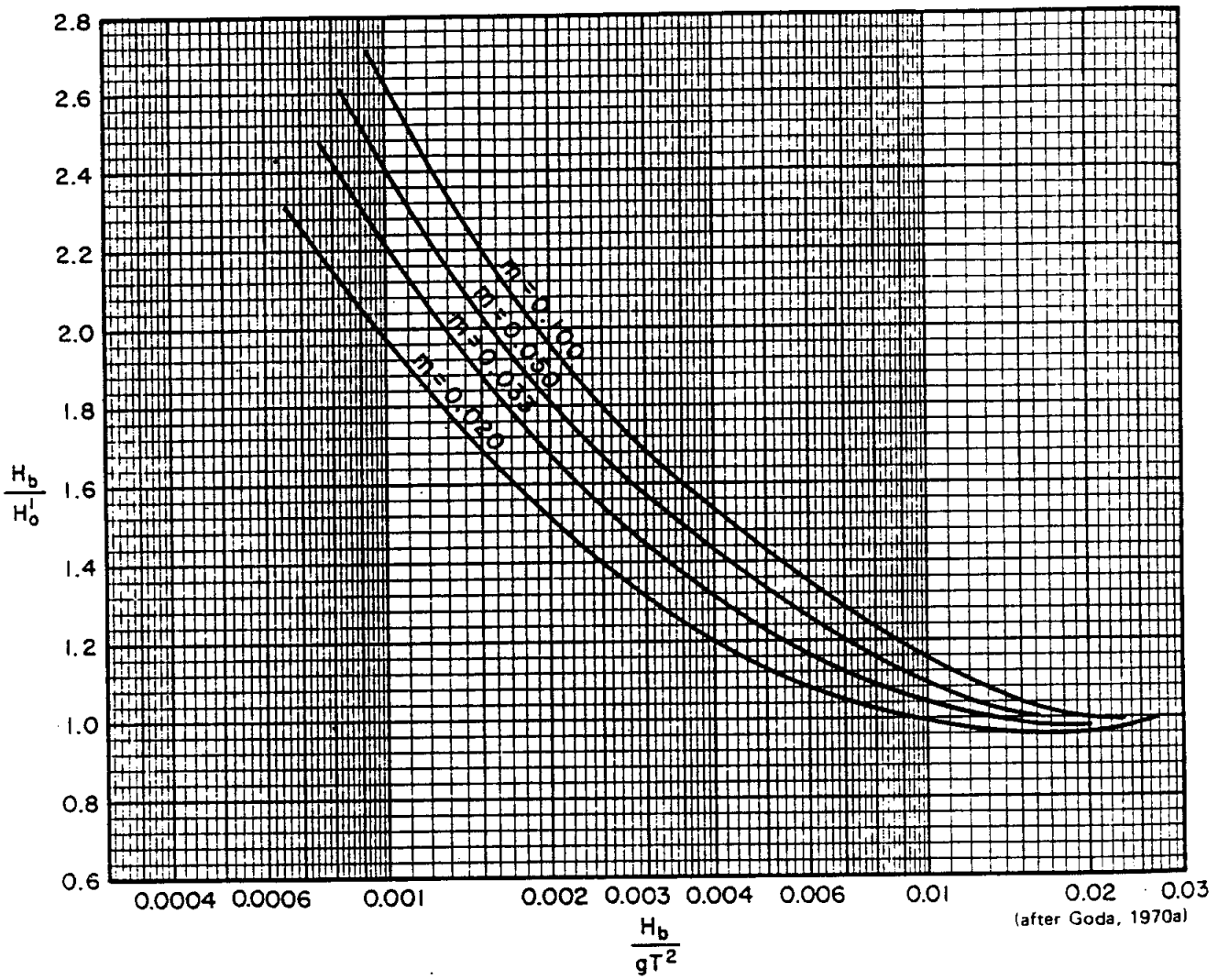


FIGURE 8.5.5

BREAKER HEIGHT INDEX H_b/H_o' VERSUS H_b/gT^2
(FROM FIGURE 7-5 OF SPM, 1977)

winds blowing from the NE for about an hour. It is not unreasonable to assume that northeast winds of this magnitude could occur at some time during high sea level events. Higher winds from the NE would produce waves which break on the foreshore flats. Longer duration of NE winds would not increase the wave heights due to the limited fetch. Winds from other directions would produce smaller waves due to limitation in fetch length. Thus, the worst case situation for wave runup and overtopping would result from the longest period waves breaking on the face of the coastal structure or embankment. This would be with 0.58 and 0.8 m high waves of approximately a 4 second period during the 1:20 and 1:100 year sea levels, respectively.

From field observations and 1:2500 scale topographic mapping, it was determined that at Cox's Cove there are three different types of shorelines where these waves will impact. South of the brook channel there is a bank sloping at approximately 1:7, north of the channel there is a rubble mound breakwater with a front slope of approximately 1:1.5 to 1:2 extending for a length of roughly 150 m, and north of that there is vertical crib-work (in various states of repair).

As discussed above, the worst case for run-up and overtopping occurs when waves break at the toe of the berm. With any reasonable storm, the majority of waves are so large thay they break seaward of the berm but they contain sufficient energy that they can reform and propogate inshore as smaller waves. Also, some of the smaller waves in the wave train may be of small enough amplitude that they can reach the berm. Figure 8.5.6 shows an example of this breaking process. The vertical scale is exaggerated in this figure and the process will be similar to that shown with or without the presence of sand bars. For the reasons outlined above, a conservative (i.e. high) estimate of runup and overtopping can be obtained by assuming a continuous train of waves breaking at the toe of the beach berm. The fetch and storm limited sea state for this area is presented above.

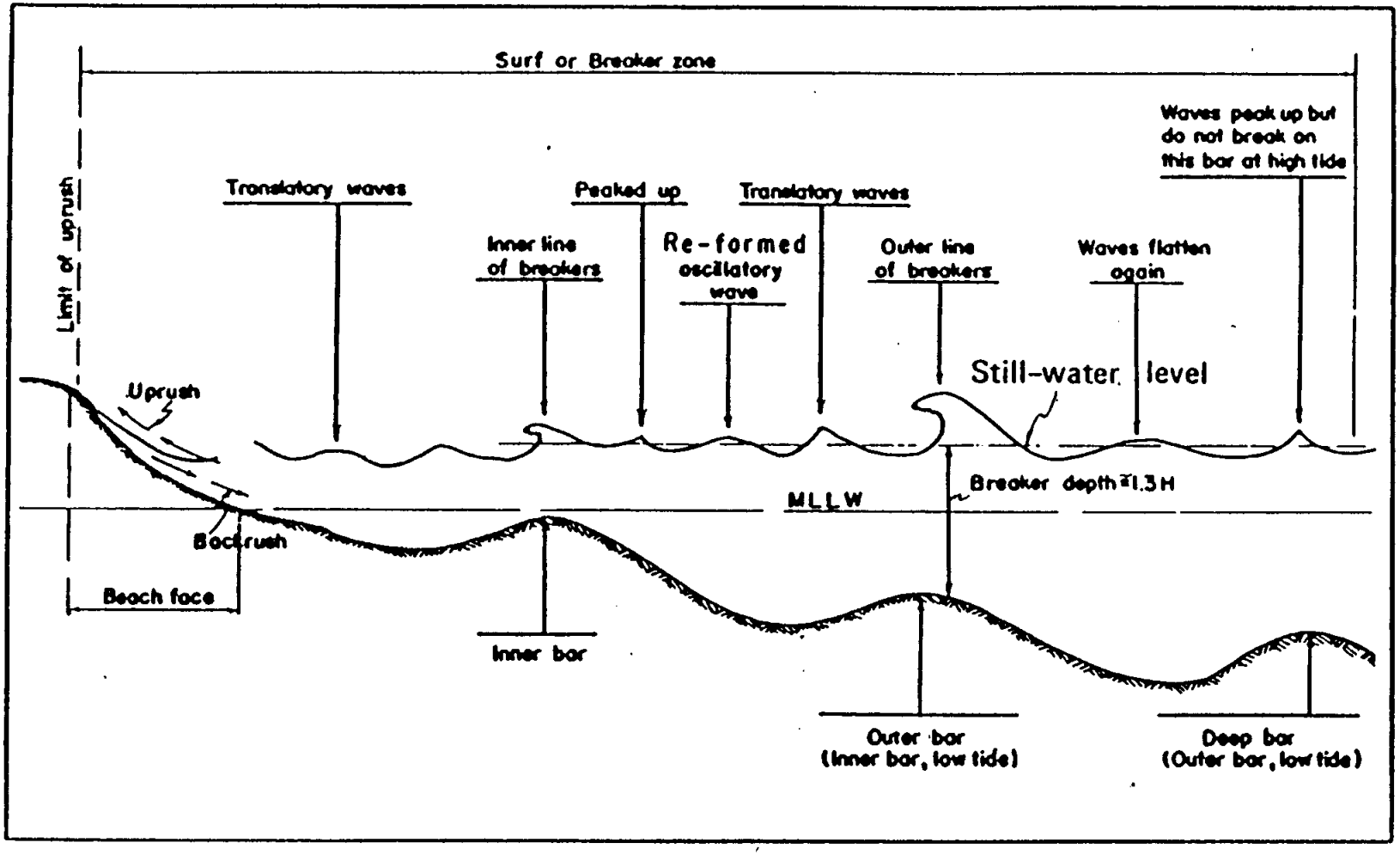


FIGURE 8.5.6

SCHEMATIC DIAGRAM OF WAVES IN THE BREAKER ZONE
(FROM FIGURE A-2 OF SPM, 1977)

By taking the elevation of the toe of the beach bearm to be +1.0 m (as discussed above), the depth of water at the toe of the berm (d_s) is 0.68 m and 0.86 m for the 1:20 and 1:100 year events. From these, by interpolating between the predictions of Figures 8.5.7 and 8.5.8, the uncorrected runup predictions were obtained. According to the SPM (1977) procedure, these were corrected for scale effects using Figure 8.5.9. The H=1.5' to 4.5' curve was used since $H_{1:20}$=0.58 m = 1.9 ft and $H_{1:100}$ = 0.73 m = 2.4 ft. The resulting predicted runup on smooth impermiable slopes was corrected for the roughness and permeability of a sandy slope according to SPM (1977) procedures. For this it was assumed that a sand and grass berm would be roughly equivalent to either fitted concrete blocks or a grass slope and thererby a representative correction factor of 0.8 to 0.9 was obtained from Table 7-2 of SPM (1977) for the bank south of the channel. Similarly, the cribwork and breakwater roughness were approximated by a layer of quarrystone for a correction factor of 0.8 from Table 7-2 of SPM (1977).

As discussed above, following the SMP (1977) procedures, correcting for scale effects and berm roughness, the runup elevations were calculated for each of these types of shoreline for the 1:20 and 1:100 year events. During the 1:20 year event the runup on the 1:7 bank would extend to an elevation of 2.4 to 2.8 m (depending on the bank roughness), the runup on the breakwater would reach an elevation of 2.4 m, and the runup on the vertical crib-work would be 2 to 2.2 m (depending on the roughness of the structure).

Based upon the above, the impact of the runup is discussed below for each of the three coast types at Cox's Cove.

For the 1:100 year event the runup would extend to elevations of between 2.7 and 3.7 m on the 1:7 slope (depending on how rough the bank is); 2.6 to 2.7 m on the rubble mound berm; and 2.5 to 2.8 m on the vertical wall, again depending on the roughness of the crib-work.

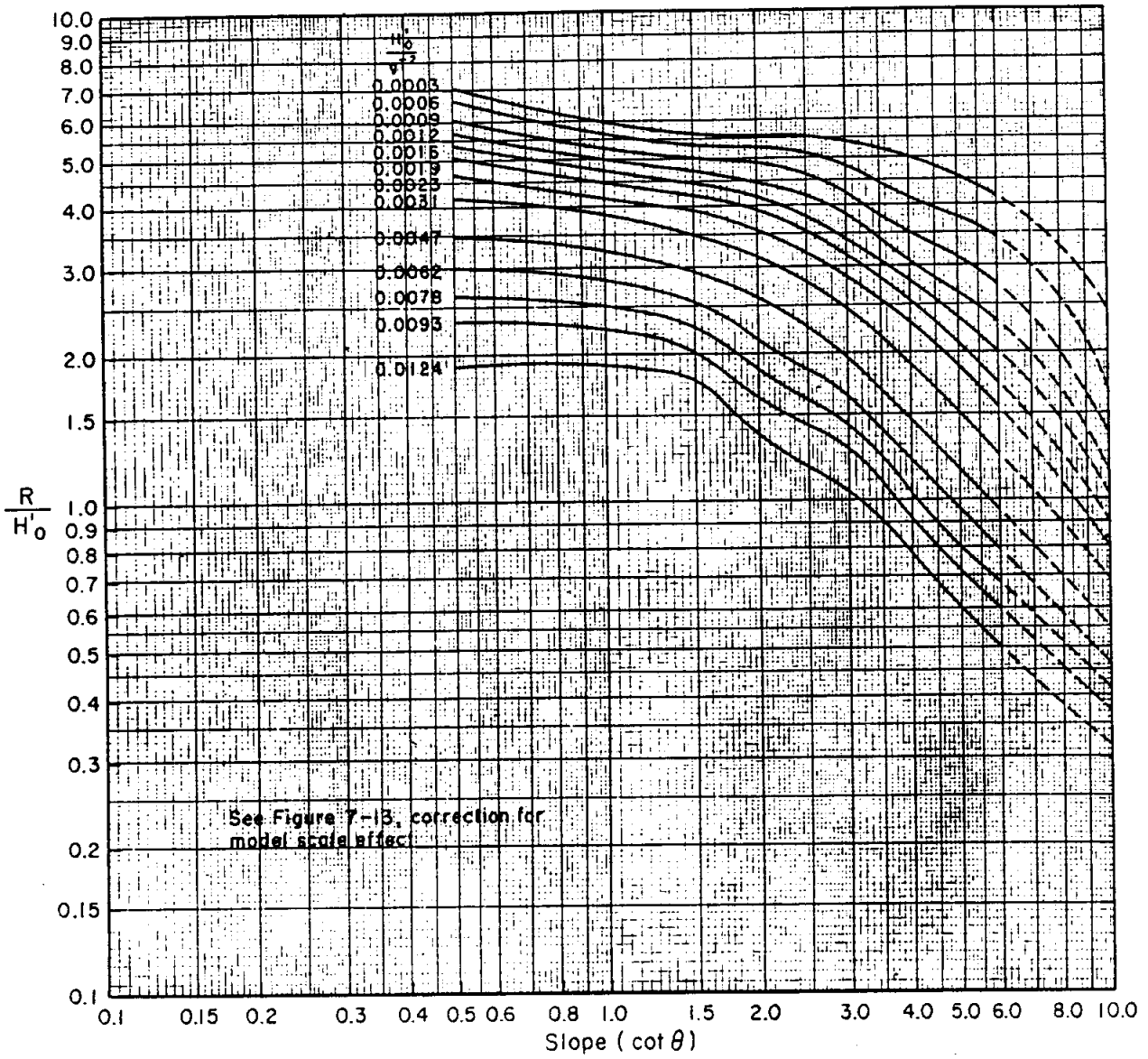


FIGURE 8.5.7

WAVE RUNUP ON SMOOTH, IMPERMEABLE SLOPES
WHEN $d_s/H_o' \approx 0.80$ (FROM FIGURE 7-10 OF SPM, 1977)

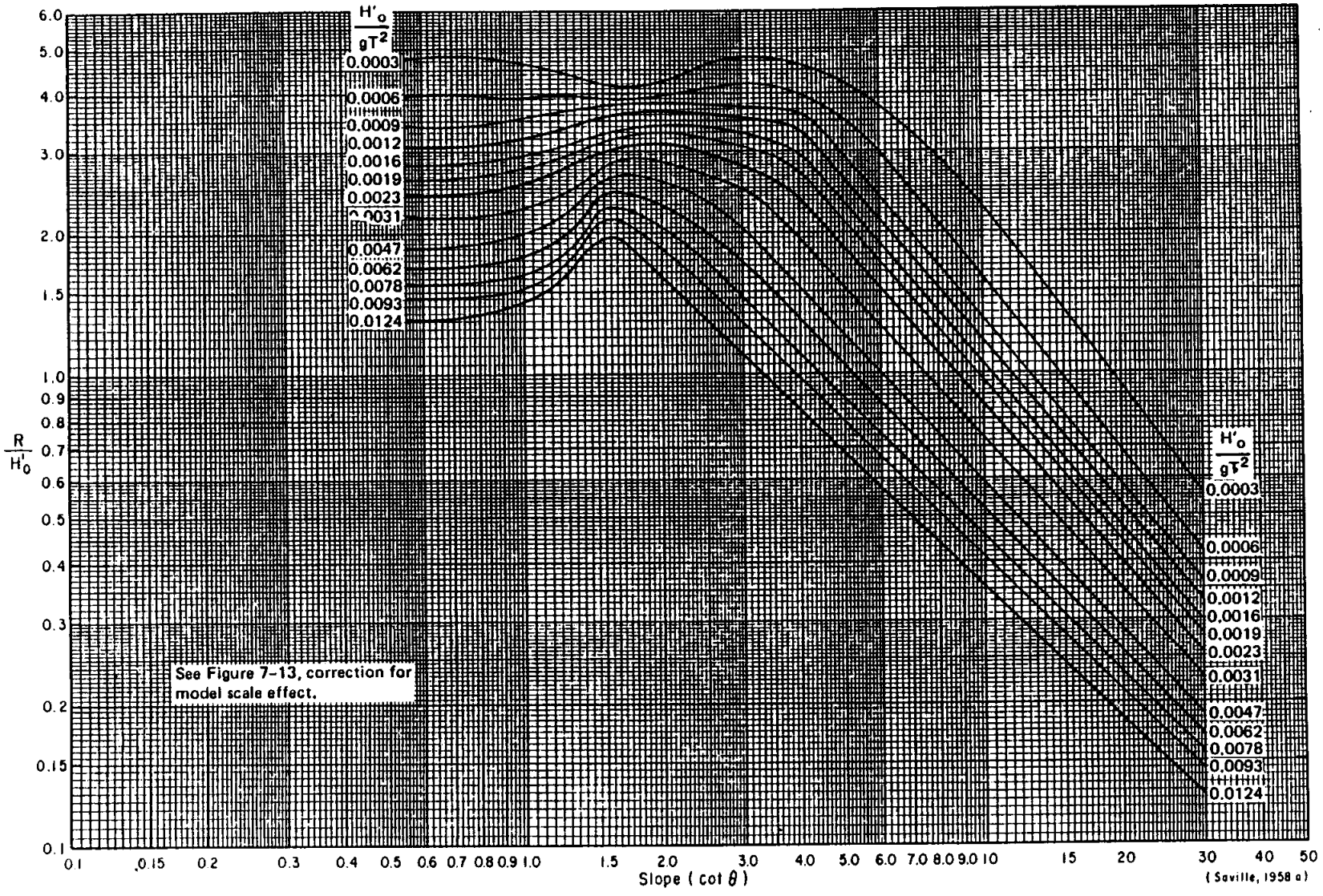


FIGURE 8.5.8

WAVE RUNUP ON SMOOTH, IMPERMEABLE SLOPES
WHEN $d_s/H'_o \approx 2.0$ (FROM FIGURE 7-11 OF SPM, 1977)

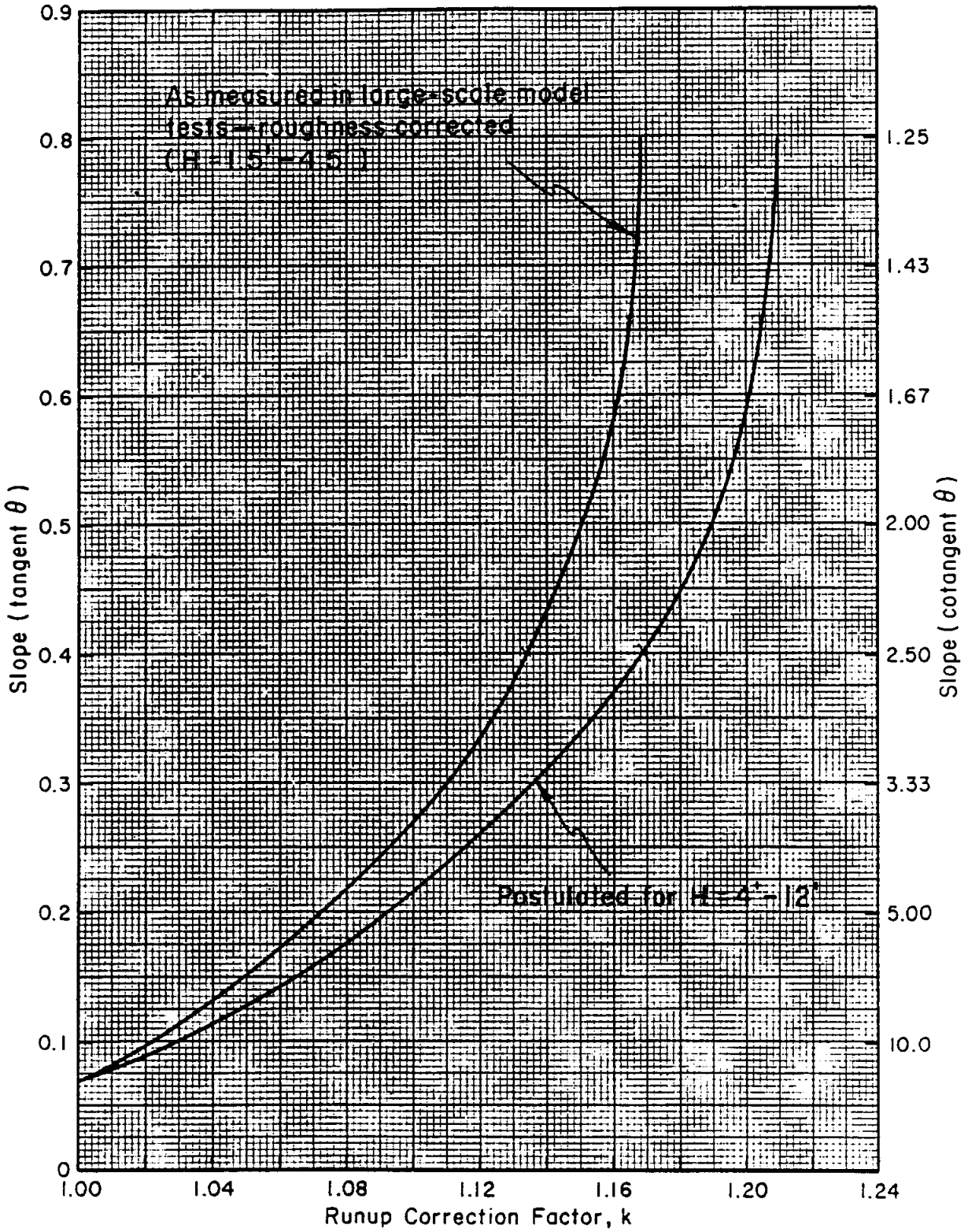


FIGURE 8.5.9

RUNUP CORRECTION FOR SCALE EFFECTS
(FROM FIGURE 7-13 OF SPM, 1977)

In the area south of the channel a conservative estimate of the extent of coastal flooding (including wave runup) would be the 2.8 and 3.7 m contour levels for the 1:20 and 1:100 year events respectively.

The rubble mound breakwater has a crest elevation of 2.5 to 3 m and so some minor overtopping could occur during the 1:100 year event but not with the 1:20 year event.

In the area north of the rubble mount breakwater there would be little or no overtopping of the road during the 1:20 year event but seaward of the road there could be property damage due to wave action as there would be during the 1:100 year event and as has been reported from historical accounts of the flood damage. The 1:100 year event could result in some overtopping of the road along this section of the coast.

Based on the (limited) overtopping calibration coefficients in SPM (1977) (see Figure 8.5.10 as an example) the rates of overtopping for the cribwork have been estimated using equation 7-10 of SPM (1977). These overtopping rates have been increased by 55% (SPM, 1977) to account for the possibility of a strong onshore wind assisting the overtopping process. There will be strong onshore winds when there are waves breaking on the shore.

The resulting overtopping rate would be approximately 12 m^3/s over the 200 m length of coastal road if a representative 1:100 year runup of +2.6 m is used and an average road crest elevation of +2.2 is assumed. Such a volumetric rate of additional sea water entering the bog by overtopping would only marginally increase the flow through the channel and thereby would increase the bog water level only slightly (i.e. less than 5 cm).

Based upon the above, the major concern with wave runup is damage to shoreline properties during the 1:20 year event and particularly during the 1:100 year event. Waves overtopping the road do not appreciably increase flooding of the bog area.

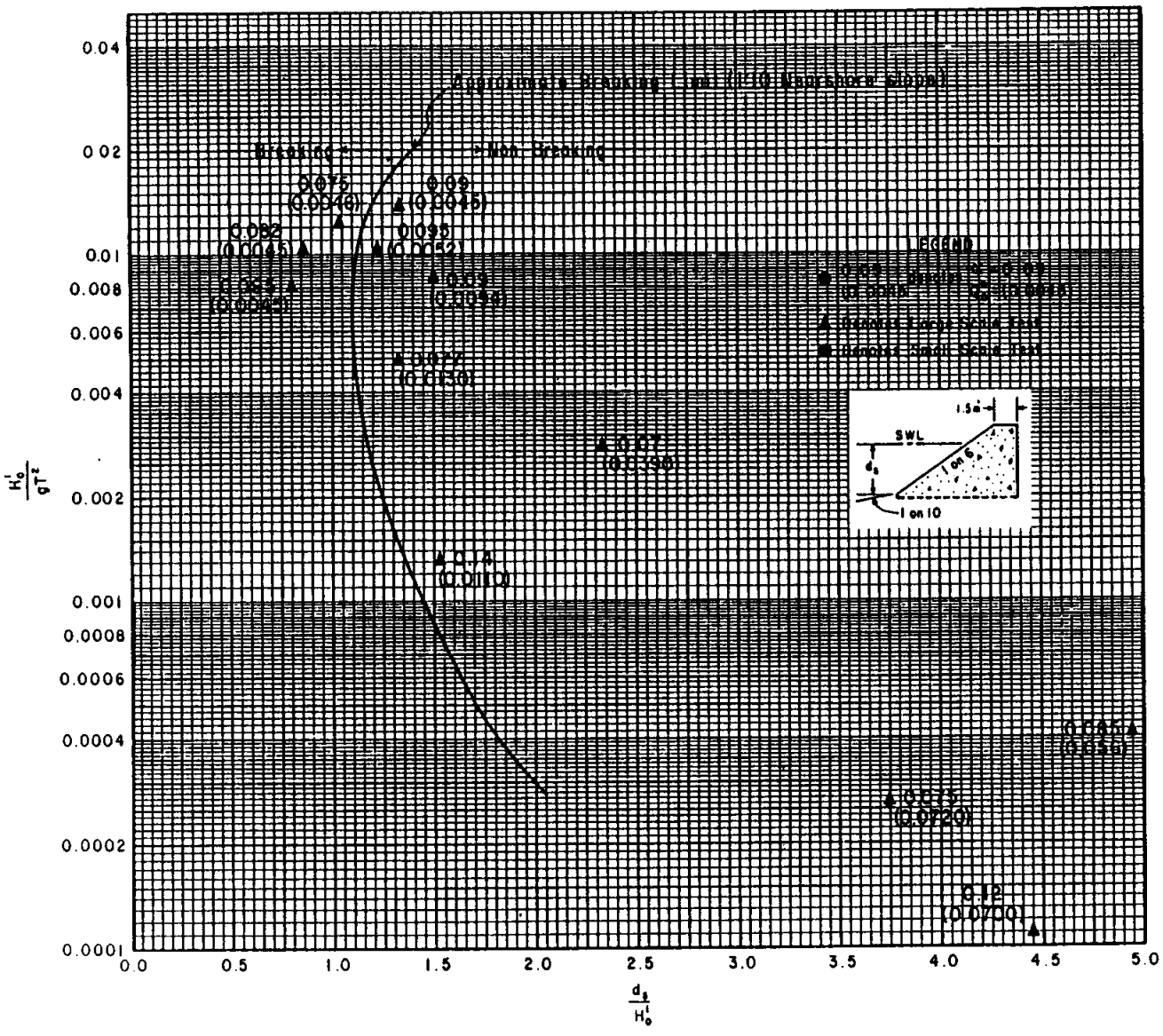


FIGURE 8.5.10

OVERTOPPING PARAMETERS α and Q_o^*
(FROM FIGURE 7-27 OF SPM, 1977)

9.0 FLOOD LEVEL CONTOURS

The respective 1:20 and 1:100 year flood levels for the Cox's Cove bog area were calculated to be 1.90 and 2.20 m above local geodetic datum (Section 8.4). For the coastal area the 1:20 and 1:100 flood levels are +2.8 m and +3.7 m southeast of the channel, +2.4 m and 2.7 m seaward of the breakwater running northwest of the channel and +2.2 and +2.8 m in the area northwest of the rubble mound breakwater (Section 8.5).

The areas affected by the flood levels listed above are shown in Appendix B.

10.0 REMEDIAL MEASURES

Annual flooding of the Cox's Cove bog area occurs which could be eliminated by dyking the banks of the brook. The bog area of Cox's Cove has effectively no storage capacity to aid in reducing large event peak flood levels and so dyking the brook will not significantly increase these peak levels in the brook channel. However, for the reasons discussed below, this measure by itself would not reduce the flooding associated with the 1:20 and 1:100 events (particularly the 1:100 year event).

If the brook was dyked there could be flooding of the bog area because the overtopped sea water (when the sea level is high enough that waves can overtop the road) would be trapped behind the dyke. The bog could continue to flood with sea water up to the level of the dyke crest (or at least up to the previous flood levels if abideau gates or check valves were incorporated in the dyke). To provide effective protection against the rarer flooding events, the elevation of the coastal road would have to be increased and/or a seawall would have to be built. The above requirement for a seawall would definitely exist during the 1:100 year event which has a high enough sea level to clearly show the potential for waves overtopping the road in the absence of a seawall.

The overtopping predictions should be made more accurately (considering random wave effects, roughness of the seawall, etc.) if such remedial measures are considered economically attractive. Rather than build a seawall, it may be more economical to relocate the exposed residences or simply dyke the brook and then provide flood relief assistance for property owners who suffer damage due to "overtopping induced flooding" which occasionally results from larger events that have longer return intervals than approximately 1:20 years.

As an alternative to remedial measures intended to reduce flooding, measures can be adopted which accept the existing flood levels but reduce the damages suffered during flooding. Such measures include zoning regulations concerning land use in the flood plain, flood proofing exposed existing properties, and/or purchases of properties subjected to flooding by one or more levels of government.

Zoning regulations can be used to prevent or restrict new development in areas subject to flooding unless they meet strict "flood proofing" specifications. Public lands can be zoned for recreational use or leased agriculture to prevent new construction in areas at risk of flooding.

Some examples of flood proofing include raising buildings (new and/or existing) on piles, building dykes around the exposed property, and sealing the structure up to the predicted flood elevation.

Government acquisition of certain properties may be a potential means of reducing the damage to private property caused by flooding but will probably be cost prohibitive in most cases. Individual properties would have to be considered separately to evaluate the cost:benefit ratio of that versus one of the other methods of reducing flood damage.

11.0 CONCLUSIONS AND RECOMMENDATIONS

The flooding at Cox's Cove is predominatly caused by high sea levels. High fresh water flow from Cox's Brook adds to the total flood elevation but the sea level at the coast remains the dominant factor. When high winds accompany the high sea levels, as is the usual case, waves can cause damage to shoreline properties, and in extreme events (1:100 year) result in waves overtopping of the coastal road. The volume of water introduced to the area behind the coastal road does not significantly add to the flood levels in the bog area.

The extreme sea levels (1:20 and 1:100 year) were obtained by correlating the short record of water level obtained at Cox's Cove as part of this study with water levels at Lark Harbour recorded during the same period. The Lark Harbour location has 21 years of water elevation data which were then used in an extremal analysis (Section 8.3) and these values were used (since the short term records showed a 1:1 correlation within instrument accuracy) to provide extreme event predictions for Cox's Cove. These water levels were used in conjunction with knowledge of the normal channel hydraulics of the creek (predicted from the creek geometries) to predict the associated flood levels in the land areas adjacent to the creek (Section 8.4). The procedures of SPM (1977) were used to predict the quantity of wave overtopping along the open coast which were found to have no influence (less than 0.05 m) on the predicted flood levels in the area behind the coastal beach (Section 8.5). All of the affected areas are shown on the map in Appendix B.

Perennial flooding of the bog area could be controlled by dyking the banks of the brook. However, waves overtopping the coastal road during major events (1:20 year or greater) could result in the same flood levels in the bog area because the dyke could then prevent the overtopped water from returning to the sea via the brook.

Major coastal protection works (i.e. seawalls and/or breakwaters) would be required to effectively reduce the areas of the 1:20 and 1:100 year flood events. As discussed in Section 10.0, there are other methods of reducing flood damage by proper planning, zoning, etc.

Protective works would have to be carefully designed so that their presence did not hinder the normal commercial fishing activities of the residents they are to protect. An offshore breakwater to protect the coast from wave action (particularly during high sea levels) might be the only practical approach to reduce the flood area but the high cost could be unjustifiable. If coastal remedial works are considered to be a potentially viable solution, then more detailed investigation into the joint probabilities of local onshore winds and high sea levels should be conducted to determine the extent of coastal works required.

Regardless of whether or not any remedial works are determined to be economically attractive, land use should be controlled by the introduction of appropriate zoning regulations.

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APPENDIX A

WATER LEVEL DATA AT COX'S COVE AND LARK HARBOUR

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.1  6.35 0. 0. .35 -105 '    WATER LEVEL AT COX'S COVE, NFLD.'
011087 311087

        011087 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
        021087 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
        031087 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
        041087 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
        051087 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
        061087 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
        071087 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
               0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.830
               0.970 1.130 1.330 1.430 1.570 1.810 1.730 1.690
        081087 1.630 1.530 1.330 1.170 1.030 0.830 0.650 0.530
               0.370 0.310 0.270 0.330 0.390 0.530 0.730 0.910
               1.090 1.230 1.430 1.590 1.730 1.830 1.890 1.970
               1.840 1.830 1.730 1.570 1.390 1.210 1.030 0.830
               0.730 0.530 0.480 0.450 0.510 0.530 0.630 0.750
               0.930 1.130 1.310 1.450 1.540 1.690 1.730 1.730
        091087 1.740 1.690 1.550 1.430 1.260 1.050 0.930 0.770
               0.630 0.450 0.390 0.380 0.400 0.450 0.590 0.730
               0.910 1.130 1.310 1.440 1.600 1.740 1.890 1.900
               1.410 1.430 1.380 1.230 1.130 0.950 0.730 0.570
```

	0.930	0.730	0.550	0.510	0.440	0.390	0.350	0.480
	0.570	0.680	0.830	1.010	1.110	1.210	1.250	1.350
101087	1.420	1.430	1.410	1.320	1.190	1.060	0.930	0.750
	0.650	0.530	0.430	0.350	0.280	0.350	0.440	0.610
	0.730	0.910	1.120	1.330	1.460	1.630	1.740	1.930
	1.970	1.980	1.970	1.960	1.910	1.260	1.610	1.430
	1.250	1.130	1.010	0.830	0.770	0.720	0.660	0.660
	0.730	0.820	0.880	0.970	1.070	1.170	1.230	1.310
111087	1.330	1.320	1.290	1.270	1.170	1.070	0.930	0.810
	0.650	0.530	0.410	0.330	0.270	0.260	0.250	0.280
	0.410	0.530	0.670	0.830	1.030	1.190	1.330	1.460
	1.610	1.680	1.730	1.790	1.770	1.730	1.680	1.570
	1.490	1.440	1.230	1.090	1.010	0.900	0.830	0.790
	0.780	0.810	0.830	0.910	0.990	1.050	1.100	1.170
121087	1.230	1.330	1.430	1.430	1.230	1.170	1.090	1.010
	0.870	0.770	0.670	0.560	0.530	0.430	0.370	0.360
	0.400	0.430	0.510	0.630	0.760	0.880	0.980	1.110
	1.230	1.330	1.510	1.490	1.530	1.550	1.540	1.510
	1.450	1.390	1.330	1.230	1.130	1.070	0.990	0.910
	0.830	0.850	0.860	0.870	0.890	0.970	1.030	1.080
131087	1.130	1.160	1.210	1.210	1.230	1.220	1.190	1.130
	1.070	0.950	0.880	0.790	0.650	0.630	0.530	0.490
	0.470	0.480	0.500	0.540	0.630	0.730	0.810	0.930
	1.050	1.160	1.250	1.360	1.430	1.480	1.480	1.530
	1.530	1.510	1.450	1.400	1.350	1.290	1.190	1.150
	1.080	1.040	1.000	0.990	0.980	1.010	1.030	1.050
141087	1.100	1.120	1.140	1.160	1.160	1.160	1.160	1.120
	1.120	1.010	0.960	0.920	0.840	0.760	0.750	0.680
	0.610	0.580	0.570	0.560	0.590	0.630	0.680	0.730
	0.800	0.900	1.000	1.090	1.160	1.240	1.320	1.350
	1.400	1.430	1.460	1.420	1.400	1.400	1.340	1.260
	1.220	1.170	1.090	1.060	1.060	0.980	0.950	0.970
151087	1.000	1.010	1.020	1.080	1.110	1.120	1.140	1.140
	1.160	1.160	1.140	1.100	1.110	1.060	1.030	0.990
	0.940	0.840	0.820	0.810	0.770	0.740	0.770	0.810
	0.780	0.840	0.940	1.010	1.050	1.100	1.180	1.260
	1.320	1.380	1.440	1.470	1.500	1.510	1.460	1.440
	1.430	1.360	1.300	1.240	1.180	1.160	1.140	1.070
161087	1.040	1.060	1.080	1.050	1.070	1.120	1.140	1.160
	1.170	1.200	1.230	1.260	1.260	1.260	1.220	1.160
	1.120	1.080	1.020	0.960	0.920	0.860	0.800	0.760
	0.770	0.740	0.720	0.780	0.860	0.900	0.920	1.020
	1.120	1.160	1.250	1.350	1.360	1.370	1.420	1.410
	1.360	1.300	1.410	1.260	1.160	1.090	1.030	0.980
171087	0.890	0.810	0.800	0.820	0.810	0.820	0.860	0.900
	0.910	1.010	1.070	1.100	1.130	1.180	1.190	1.160
	1.160	1.120	1.070	0.990	0.900	0.820	0.760	0.690
	0.600	0.590	0.540	0.520	0.570	0.600	0.660	0.720
	0.800	0.880	1.000	1.060	1.140	1.200	1.300	1.320
	1.340	1.300	1.310	1.240	1.180	1.140	1.060	1.040
181087	0.900	0.860	0.740	0.680	0.730	0.740	0.710	0.730
	0.800	0.900	0.950	1.030	1.130	1.210	1.260	1.310
	1.300	1.310	1.280	1.240	1.160	1.070	0.980	0.940
	0.800	0.700	0.640	0.600	0.580	0.580	0.590	0.640
	0.710	0.820	0.950	1.060	1.160	1.260	1.370	1.480
	1.540	1.530	1.560	1.510	1.460	1.500	1.300	1.220

191087	1.120	1.040	0.930	0.880	0.790	0.780	0.780	0.790
	0.840	0.940	1.000	1.060	1.170	1.360	1.380	1.430
	1.480	1.520	1.550	1.480	1.440	1.340	1.240	1.110
	1.010	0.880	0.770	0.660	0.580	0.560	0.540	0.560
	0.620	0.720	0.780	0.880	1.040	1.160	1.260	1.360
	1.470	1.560	1.580	1.580	1.540	1.520	1.400	1.320
201087	1.200	1.060	0.960	0.830	0.740	0.700	0.660	0.640
	0.690	0.750	0.830	0.940	1.060	1.200	1.310	1.380
	1.500	1.580	1.590	1.600	1.570	1.520	1.430	1.320
	1.140	1.000	0.960	0.800	0.610	0.520	0.510	0.510
	0.500	0.560	0.660	0.760	0.850	0.990	1.100	1.240
	1.320	1.420	1.490	1.490	1.480	1.470	1.360	1.260
210187	1.160	1.060	0.880	0.780	0.660	0.560	0.500	0.460
	0.430	0.500	0.620	0.720	0.840	0.900	1.160	1.290
	1.400	1.560	1.660	1.720	1.760	1.760	1.680	1.580
	1.490	1.360	1.240	1.060	0.910	0.810	0.720	0.630
	0.570	0.640	0.690	0.760	0.850	0.870	0.980	1.230
	1.350	1.480	1.560	1.620	1.640	1.650	1.300	1.260
221087	1.103	0.983	0.823	0.703	0.613	0.493	0.503	0.483
	0.593	0.663	0.753	0.863	1.103	1.283	1.463	1.543
	1.533	1.473	1.453	1.433	1.423	1.403	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231087	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	1.305	1.115	1.035	0.805
	0.705	0.655	0.605	0.595	0.635	0.725	0.845	0.955
	1.105	1.245	1.365	1.445	1.565	1.635	1.635	1.585
241087	1.545	1.465	1.315	1.135	0.995	0.805	0.625	0.585
	0.345	0.225	0.195	0.195	0.195	0.245	0.385	0.555
	0.745	0.905	1.105	1.265	1.405	1.545	1.635	1.665
	1.715	1.725	1.655	1.515	1.365	1.265	1.105	0.905
	0.765	0.655	0.555	0.515	0.475	0.525	0.605	0.705
	0.825	0.925	1.065	1.155	1.275	1.375	1.385	1.395
251087	1.415	1.345	1.245	1.105	0.965	0.805	0.665	0.505
	0.315	0.195	0.115	0.105	0.095	0.085	0.185	0.385
	0.545	0.715	0.905	1.125	1.305	1.505	1.605	1.705
	1.785	1.865	1.845	1.755	1.645	1.555	1.425	1.285
	1.005	0.985	0.875	0.805	0.725	0.665	0.695	0.765
	0.845	0.925	1.015	1.155	1.265	1.385	1.405	1.485
261087	1.505	1.585	1.505	1.365	1.305	1.205	1.065	0.905
	0.765	0.605	0.545	0.425	0.385	0.385	0.405	0.475
	0.585	0.805	0.985	1.185	1.305	1.525	1.755	1.785
	1.905	2.005	2.025	2.005	1.985	1.885	1.705	1.605
	1.515	1.305	1.155	1.045	0.905	0.805	0.735	0.755
	0.785	0.805	0.905	0.965	1.015	1.105	1.175	1.215
271087	1.255	1.295	1.305	1.285	1.215	1.175	1.065	0.905
	0.805	0.715	0.635	0.525	0.485	0.425	0.405	0.415
	0.485	0.585	0.705	0.835	1.005	1.165	1.305	1.425
	1.545	1.665	1.725	1.805	1.865	1.875	1.865	1.815
	1.765	1.645	1.525	1.385	1.265	1.165	1.055	0.965
	0.905	0.885	0.845	0.865	0.905	0.985	1.015	1.055
281087	1.105	1.145	1.155	1.165	1.185	1.165	1.125	1.065
	0.965	0.825	0.725	0.665	0.545	0.435	0.325	0.235

	0.235	0.225	0.245	0.285	0.425	0.535	0.605	0.765
	0.955	1.075	1.165	1.265	1.365	1.445	1.535	1.575
	1.545	1.535	1.515	1.505	1.465	1.265	1.165	1.125
	1.065	0.945	0.855	0.835	0.925	0.905	0.865	0.925
291087	1.005	1.025	1.005	1.035	1.245	1.285	1.305	1.305
	1.265	1.225	1.205	1.145	1.005	0.935	0.905	0.805
	0.705	0.625	0.605	0.605	0.615	0.625	0.665	0.745
	0.885	1.005	1.105	1.205	1.325	1.505	1.555	1.605
	1.705	1.805	1.805	1.795	1.765	1.705	1.665	1.585
	1.505	1.395	1.305	1.245	1.185	1.095	1.085	1.105
301087	1.105	1.125	1.145	1.215	1.265	1.235	1.275	1.325
	1.335	1.365	1.325	1.245	1.185	1.145	1.105	0.955
	0.865	0.845	0.745	0.625	0.585	0.575	0.505	0.515
	0.555	0.625	0.715	0.805	0.925	1.025	1.165	1.305
	1.405	1.505	1.605	1.685	1.695	1.655	1.625	1.585
	1.485	1.385	1.265	1.195	1.105	1.005	0.935	0.885
311087	0.845	0.845	0.885	0.925	0.975	1.005	1.075	1.155
	1.205	1.265	1.325	1.385	1.405	1.385	1.375	1.305
	1.235	1.155	1.075	1.005	0.905	0.805	0.745	0.685
	0.635	0.615	0.655	0.705	0.745	0.815	0.925	1.045
	1.145	1.255	1.365	1.465	1.545	1.615	1.625	1.635
	1.595	1.515	1.435	1.355	1.225	1.085	0.995	0.865

.2 6.35 0. 0. .35 -105 ' WATER LEVEL AT LARK HARBOUR, NFLD.'
011087 311087

011087	1.010	1.030	1.080	1.120	1.190	1.260	1.290	1.300
	1.350	1.350	1.350	1.320	1.260	1.240	1.140	1.100
	0.990	0.920	0.880	0.800	0.770	0.760	0.790	0.770
	0.810	0.880	0.960	1.050	1.170	1.260	1.390	1.450
	1.560	1.640	1.720	1.750	1.750	1.750	1.720	1.650
	1.590	1.500	1.420	1.350	1.270	1.200	1.100	1.060
021087	1.060	1.160	1.240	1.180	1.250	1.270	1.340	1.400
	1.470	1.520	1.690	1.720	1.750	1.730	1.650	1.640
	1.700	1.530	1.360	1.290	1.300	1.100	0.960	0.860
	0.830	0.750	0.680	0.610	0.700	0.790	0.790	0.800
	0.910	1.130	1.280	1.340	1.360	1.500	1.570	1.600
	1.540	1.490	1.390	1.340	1.260	1.090	0.920	0.870
031087	0.770	0.650	0.600	0.680	0.690	0.690	0.760	0.910
	0.990	1.090	1.180	1.270	1.360	1.420	1.450	1.400
	1.360	1.320	1.280	1.180	1.040	0.950	0.840	0.720
	0.570	0.500	0.460	0.440	0.360	0.450	0.520	0.600
	0.690	0.860	0.990	1.150	1.280	1.440	1.490	1.580
	1.600	1.620	1.550	1.510	1.400	1.250	1.150	1.030
041087	0.840	0.720	0.640	0.550	0.500	0.510	0.540	0.550
	0.630	0.810	0.900	1.040	1.160	1.310	1.340	1.490
	1.470	1.460	1.450	1.400	1.290	1.160	1.020	0.930
	0.750	0.640	0.480	0.440	0.400	0.390	0.400	0.530
	0.540	0.780	0.960	1.080	1.310	1.480	1.670	1.820
	1.860	1.930	1.960	1.940	1.890	1.800	1.730	1.570
051087	1.370	1.190	1.030	0.920	0.830	0.720	0.680	0.750
	0.700	0.800	0.920	1.030	1.200	1.360	1.490	1.670
	1.720	1.830	1.780	1.800	1.710	1.650	1.390	1.310
	1.140	0.940	0.750	0.600	0.500	0.400	0.350	0.320
	0.400	0.510	0.650	0.780	0.970	1.170	1.360	1.500
	1.630	1.780	1.880	1.940	1.910	1.860	1.760	1.620
061087	1.480	1.260	1.080	0.920	0.760	0.610	0.470	0.440
	0.390	0.480	0.550	0.700	0.840	1.050	1.230	1.410
	1.550	1.710	1.800	1.870	1.880	1.850	1.730	1.600
	1.430	1.250	1.060	0.890	0.700	0.540	0.440	0.350
	0.290	0.290	0.360	0.440	0.580	0.750	0.930	1.100
	1.270	1.410	1.550	1.610	1.700	1.690	1.640	1.570
071087	1.430	1.270	1.090	0.910	0.730	0.550	0.410	0.290
	0.240	0.230	0.260	0.340	0.480	0.630	0.820	1.030
	1.200	1.360	1.520	1.640	1.700	1.770	1.710	1.670
	1.540	1.380	1.190	1.020	0.830	0.590	0.450	0.320
	0.250	0.190	0.160	0.220	0.320	0.470	0.610	0.840
	1.010	1.210	1.350	1.490	1.600	1.730	1.700	1.700
081087	1.570	1.460	1.260	1.120	0.930	0.740	0.600	0.450
	0.310	0.250	0.270	0.320	0.380	0.550	0.750	0.970
	1.110	1.320	1.500	1.660	1.810	1.850	1.940	1.920
	1.930	1.760	1.730	1.510	1.310	1.110	0.940	0.750
	0.660	0.480	0.480	0.460	0.520	0.560	0.660	0.820
	1.020	1.180	1.370	1.480	1.680	1.700	1.770	1.760
091087	1.760	1.620	1.540	1.370	1.150	1.000	0.810	0.690
	0.480	0.360	0.360	0.370	0.380	0.450	0.620	0.750
	0.970	1.170	1.360	1.510	1.660	1.820	1.890	1.890
	1.930	1.970	1.810	1.660	1.520	1.320	1.140	0.950
	0.810	0.600	0.480	0.390	0.360	0.300	0.360	0.450

	0.560	0.690	0.840	1.010	1.100	1.210	1.270	1.360
101087	1.380	1.380	1.310	1.230	1.090	1.000	0.810	0.690
	0.570	0.450	0.370	0.350	0.320	0.370	0.480	0.600
	0.760	0.960	1.170	1.390	1.500	1.690	1.830	1.960
	1.970	1.980	1.980	1.950	1.820	1.680	1.530	1.360
	1.170	1.050	0.880	0.760	0.680	0.630	0.610	0.630
	0.720	0.780	0.860	0.960	1.070	1.160	1.230	1.280
111087	1.290	1.270	1.260	1.190	1.100	0.950	0.820	0.690
	0.570	0.440	0.330	0.260	0.230	0.210	0.230	0.310
	0.400	0.560	0.700	0.900	1.060	1.230	1.360	1.530
	1.610	1.710	1.760	1.790	1.750	1.690	1.640	1.510
	1.410	1.270	1.160	1.030	0.950	0.850	0.780	0.750
	0.760	0.780	0.840	0.910	0.990	1.050	1.130	1.190
121087	1.230	1.240	1.250	1.240	1.190	1.130	1.040	0.930
	0.800	0.710	0.600	0.520	0.430	0.380	0.350	0.350
	0.390	0.450	0.540	0.690	0.790	0.930	1.020	1.190
	1.280	1.400	1.430	1.520	1.550	1.580	1.530	1.500
	1.410	1.370	1.260	1.190	1.080	1.030	0.920	0.860
	0.830	0.850	0.840	0.860	0.900	0.980	1.030	1.100
131087	1.140	1.200	1.210	1.240	1.230	1.220	1.180	1.110
	1.010	0.910	0.850	0.730	0.650	0.560	0.510	0.450
	0.460	0.460	0.500	0.560	0.650	0.730	0.860	0.960
	1.110	1.200	1.300	1.390	1.460	1.490	1.510	1.550
	1.540	1.490	1.430	1.390	1.320	1.250	1.170	1.120
	1.050	1.020	0.980	0.970	0.990	0.990	1.030	1.040
141087	1.070	1.100	1.120	1.130	1.130	1.130	1.120	1.090
	1.040	0.970	0.900	0.850	0.780	0.710	0.670	0.600
	0.560	0.530	0.520	0.520	0.560	0.600	0.650	0.700
	0.800	0.890	0.990	1.080	1.190	1.230	1.310	1.350
	1.400	1.430	1.410	1.400	1.360	1.350	1.280	1.230
	1.160	1.100	1.050	1.000	0.980	0.920	0.910	0.960
151087	0.980	0.950	1.010	1.050	1.090	1.080	1.100	1.120
	1.130	1.090	1.100	1.030	1.040	0.980	0.960	0.890
	0.860	0.780	0.760	0.740	0.680	0.700	0.730	0.730
	0.750	0.810	0.890	0.950	1.000	1.080	1.160	1.230
	1.300	1.350	1.410	1.440	1.460	1.470	1.410	1.410
	1.360	1.310	1.240	1.180	1.130	1.120	1.050	1.000
161087	0.980	1.010	1.010	0.990	1.050	1.070	1.120	1.110
	1.150	1.190	1.220	1.230	1.240	1.230	1.160	1.130
	1.080	1.030	0.950	0.890	0.860	0.780	0.740	0.720
	0.710	0.670	0.700	0.770	0.840	0.860	0.910	1.040
	1.090	1.170	1.270	1.330	1.350	1.380	1.400	1.380
	1.320	1.280	1.280	1.240	1.110	1.040	0.980	0.920
171087	0.810	0.780	0.770	0.780	0.770	0.810	0.830	0.870
	0.930	1.000	1.070	1.090	1.150	1.150	1.180	1.150
	1.130	1.070	0.990	0.920	0.830	0.770	0.690	0.600
	0.560	0.520	0.480	0.510	0.510	0.610	0.630	0.740
	0.780	0.920	1.000	1.070	1.140	1.230	1.300	1.310
	1.330	1.280	1.280	1.190	1.200	1.070	1.010	0.900
181087	0.880	0.780	0.700	0.670	0.700	0.680	0.690	0.730
	0.830	0.880	0.960	1.050	1.150	1.220	1.270	1.330
	1.290	1.320	1.250	1.230	1.090	1.040	0.920	0.880
	0.730	0.650	0.580	0.570	0.550	0.550	0.590	0.640
	0.730	0.850	1.000	1.090	1.240	1.320	1.460	1.530
	1.560	1.550	1.560	1.510	1.460	1.350	1.300	1.180
191087	1.100	0.980	0.900	0.830	0.770	0.740	0.760	0.780

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221087 1.270 1.230 1.000 0.890 0.730 0.630 0.490 0.470
       0.420 0.470 0.560 0.650 0.770 0.890 1.180 1.340
       1.460 1.600 1.760 1.890 1.940 1.930 1.950 1.850
       1.860 1.650 1.520 1.270 1.180 1.020 0.910 0.770
       0.740 0.680 0.770 0.760 0.790 1.020 1.140 1.280
       1.350 1.610 1.590 1.690 1.720 1.710 1.610 1.530
231087 1.410 1.230 1.030 0.920 0.720 0.510 0.360 0.260
       0.190 0.170 0.210 0.280 0.370 0.550 0.700 0.900
       1.070 1.280 1.460 1.580 1.690 1.770 1.800 1.770
       1.720 1.590 1.510 1.360 1.200 0.990 0.870 0.760
       0.650 0.580 0.550 0.540 0.620 0.720 0.840 0.970
       1.130 1.260 1.360 1.440 1.560 1.610 1.570 1.530
241087 1.480 1.360 1.190 1.030 0.850 0.660 0.510 0.360
       0.230 0.140 0.090 0.100 0.130 0.240 0.380 0.570
       0.750 0.960 1.120 1.320 1.450 1.560 1.620 1.670
       1.700 1.660 1.540 1.400 1.280 1.140 0.970 0.810
       0.680 0.570 0.500 0.440 0.430 0.470 0.550 0.660
       0.790 0.900 1.040 1.150 1.260 1.310 1.360 1.370
251087 1.360 1.290 1.190 1.040 0.880 0.740 0.580 0.430
       0.240 0.170 0.100 0.080 0.050 0.060 0.190 0.360
       0.520 0.700 0.910 1.130 1.330 1.470 1.600 1.690
       1.780 1.840 1.830 1.720 1.630 1.510 1.400 1.240
       1.080 0.920 0.850 0.720 0.680 0.610 0.660 0.700
       0.810 0.890 1.010 1.140 1.280 1.360 1.430 1.460
261087 1.510 1.550 1.460 1.350 1.260 1.170 1.010 0.830
       0.660 0.540 0.470 0.380 0.360 0.330 0.390 0.450
       0.580 0.780 0.950 1.150 1.330 1.510 1.660 1.790
       1.890 1.980 2.000 2.000 1.950 1.850 1.680 1.560
       1.440 1.260 1.100 0.970 0.870 0.730 0.690 0.660
       0.710 0.760 0.830 0.910 0.970 1.060 1.140 1.180
271087 1.220 1.250 1.270 1.240 1.180 1.110 0.990 0.880
       0.740 0.650 0.560 0.470 0.400 0.380 0.360 0.380
       0.440 0.580 0.660 0.840 0.980 1.170 1.310 1.450
       1.570 1.680 1.800 1.850 1.870 1.870 1.840 1.770
       1.660 1.540 1.390 1.260 1.150 1.070 0.940 0.890
       0.850 0.830 0.820 0.850 0.920 0.980 1.020 1.080
281087 1.110 1.160 1.160 1.170 1.170 1.140 1.050 0.960
       0.840 0.710 0.650 0.540 0.430 0.320 0.250 0.220
       0.210 0.210 0.270 0.370 0.450 0.570 0.680 0.870
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	1.000	1.150	1.220	1.350	1.430	1.540	1.550	1.570
	1.530	1.520	1.470	1.410	1.280	1.180	1.120	1.060
	0.940	0.870	0.810	0.910	0.870	0.920	0.860	1.050
291087	1.090	1.130	1.100	1.230	1.290	1.330	1.310	1.270
	1.240	1.210	1.150	1.060	0.930	0.900	0.830	0.720
	0.620	0.590	0.610	0.600	0.630	0.650	0.760	0.850
	0.990	1.090	1.210	1.310	1.500	1.560	1.670	1.700
	1.800	1.820	1.810	1.760	1.710	1.680	1.580	1.490
	1.370	1.310	1.220	1.200	1.090	1.100	1.100	1.090
301087	1.100	1.110	1.210	1.240	1.230	1.270	1.300	1.320
	1.330	1.340	1.240	1.200	1.150	1.110	0.930	0.870
	0.790	0.740	0.610	0.550	0.530	0.470	0.480	0.500
	0.580	0.630	0.790	0.870	0.990	1.120	1.280	1.380
	1.470	1.580	1.650	1.660	1.650	1.610	1.540	1.490
	1.380	1.270	1.190	1.090	1.000	0.910	0.840	0.820
311087	0.830	0.830	0.870	0.920	0.970	1.050	1.130	1.200
	1.240	1.300	1.360	1.390	1.390	1.360	1.320	1.240
	1.180	1.090	1.010	0.900	0.820	0.710	0.680	0.610
	0.620	0.610	0.680	0.710	0.800	0.890	1.030	1.120
	1.260	1.330	1.470	1.520	1.620	1.630	1.640	1.590
	1.530	1.440	1.360	1.230	1.090	0.970	0.850	0.740

.1 6.35 0. 0. .35 -105 ' WATER LEVEL AT LARK HARBOUR, NFLD.'
011187 301187

011187	0.630	0.580	0.530	0.570	0.570	0.600	0.670	0.780
	0.860	0.960	1.070	1.150	1.220	1.280	1.280	1.250
	1.230	1.170	1.090	0.980	0.860	0.770	0.650	0.560
	0.470	0.440	0.430	0.420	0.430	0.490	0.580	0.700
	0.850	0.960	1.090	1.260	1.380	1.470	1.520	1.590
	1.590	1.550	1.460	1.400	1.300	1.190	1.020	0.890
021187	0.750	0.660	0.620	0.540	0.540	0.550	0.600	0.670
	0.800	0.940	1.100	1.240	1.360	1.450	1.540	1.600
	1.600	1.540	1.470	1.380	1.250	1.120	0.960	0.810
	0.640	0.540	0.430	0.360	0.320	0.340	0.380	0.440
	0.560	0.720	0.870	1.000	1.160	1.300	1.400	1.510
	1.560	1.580	1.540	1.510	1.370	1.260	1.140	1.020
031187	0.850	0.680	0.560	0.520	0.420	0.390	0.380	0.470
	0.580	0.700	0.840	0.990	1.170	1.340	1.480	1.590
	1.670	1.790	1.790	1.730	1.680	1.600	1.430	1.280
	1.140	1.000	0.810	0.740	0.600	0.460	0.410	0.440
	0.510	0.580	0.670	0.860	1.020	1.160	1.260	1.450
	1.550	1.610	1.620	1.670	1.610	1.490	1.350	1.240
041187	1.080	0.890	0.710	0.620	0.510	0.440	0.420	0.400
	0.470	0.590	0.710	0.870	1.060	1.270	1.460	1.620
	1.740	1.860	1.990	2.030	1.990	1.910	1.840	1.720
	1.590	1.400	1.230	1.060	0.910	0.770	0.670	0.620
	0.600	0.650	0.710	0.810	0.930	1.070	1.200	1.340
	1.470	1.560	1.620	1.650	1.650	1.590	1.480	1.360
051187	1.160	1.030	0.870	0.750	0.580	0.480	0.390	0.350
	0.320	0.390	0.510	0.640	0.820	1.010	1.190	1.380
	1.550	1.720	1.830	1.920	2.060	2.030	2.000	1.880
	1.760	1.660	1.460	1.280	1.100	0.960	0.820	0.700
	0.630	0.580	0.570	0.660	0.750	0.910	1.010	1.220
	1.400	1.580	1.620	1.690	1.790	1.840	1.810	1.700
061187	1.630	1.430	1.320	1.110	0.970	0.810	0.710	0.650
	0.610	0.550	0.570	0.680	0.790	0.980	1.160	1.350
	1.550	1.760	1.910	2.050	2.170	2.240	2.300	2.290
	2.240	2.090	1.950	1.780	1.600	1.410	1.250	1.090
	0.940	0.830	0.750	0.730	0.700	0.780	0.850	0.950
	1.050	1.180	1.300	1.390	1.500	1.570	1.620	1.600
071187	1.550	1.500	1.330	1.210	1.050	0.910	0.760	0.610
	0.520	0.450	0.470	0.490	0.590	0.690	0.910	1.110
	1.320	1.490	1.700	1.890	2.040	2.110	2.200	2.230
	2.260	2.130	2.040	1.880	1.780	1.560	1.370	1.230
	1.070	0.950	0.840	0.770	0.700	0.750	0.790	0.910
	0.970	1.070	1.200	1.260	1.390	1.470	1.520	1.530
081187	1.530	1.480	1.350	1.210	1.090	0.950	0.780	0.660
	0.560	0.450	0.380	0.310	0.420	0.430	0.620	0.690
	0.880	1.040	1.290	1.380	1.570	1.670	1.810	1.890
	1.890	1.930	1.880	1.790	1.640	1.540	1.360	1.290
	1.130	0.980	0.870	0.790	0.720	0.670	0.670	0.730
	0.800	0.900	1.000	1.160	1.280	1.350	1.440	1.480
091187	1.510	1.520	1.470	1.400	1.290	1.150	1.010	0.900
	0.820	0.710	0.620	0.590	0.530	0.550	0.580	0.640
	0.710	0.850	1.010	1.150	1.290	1.420	1.560	1.630
	1.770	1.800	1.900	1.840	1.820	1.700	1.640	1.520
	1.400	1.290	1.160	1.040	1.010	0.930	0.910	0.900

	0.980	0.990	1.060	1.130	1.240	1.310	1.340	1.370
101187	1.400	1.380	1.360	1.320	1.220	1.120	0.990	0.880
	0.730	0.640	0.540	0.450	0.340	0.320	0.320	0.370
	0.380	0.460	0.580	0.710	0.880	1.000	1.100	1.230
	1.340	1.450	1.520	1.540	1.600	1.610	1.580	1.500
	1.430	1.380	1.300	1.200	1.130	1.030	1.020	0.950
	0.930	0.930	0.950	1.000	1.080	1.100	1.140	1.190
111187	1.230	1.250	1.230	1.230	1.210	1.170	1.080	1.000
	0.880	0.780	0.680	0.610	0.520	0.490	0.440	0.430
	0.400	0.440	0.560	0.600	0.730	0.820	0.960	1.090
	1.180	1.280	1.330	1.460	1.550	1.590	1.600	1.570
	1.550	1.480	1.430	1.360	1.290	1.200	1.110	1.030
	0.990	0.950	0.920	0.910	0.960	1.010	1.050	1.060
121187	1.120	1.180	1.230	1.230	1.290	1.300	1.260	1.160
	1.210	1.100	1.050	0.960	0.910	0.850	0.780	0.680
	0.750	0.770	0.680	0.680	0.810	0.890	0.980	1.040
	1.080	1.250	1.310	1.370	1.470	1.580	1.610	1.610
	1.640	1.610	1.570	1.480	1.510	1.340	1.350	1.240
	1.340	1.110	1.080	1.150	1.200	1.170	1.150	1.200
131187	1.250	1.210	1.250	1.300	1.340	1.320	1.370	1.360
	1.420	1.330	1.250	1.170	1.210	1.090	1.120	1.020
	0.950	0.880	0.920	0.850	0.800	0.780	0.840	0.890
	0.940	0.980	1.010	1.070	1.140	1.260	1.280	1.310
	1.350	1.400	1.400	1.410	1.350	1.300	1.220	1.150
	1.080	1.030	0.930	0.870	0.830	0.820	0.810	0.830
141187	0.840	0.850	0.930	0.980	1.060	1.110	1.210	1.230
	1.290	1.320	1.370	1.360	1.350	1.310	1.280	1.230
	1.160	1.110	1.060	1.000	0.970	0.960	0.970	0.920
	0.990	1.010	1.100	1.120	1.220	1.270	1.350	1.410
	1.470	1.500	1.530	1.540	1.530	1.490	1.450	1.390
	1.300	1.210	1.130	1.040	0.950	0.860	0.800	0.740
151187	0.710	0.710	0.700	0.710	0.760	0.820	0.890	0.950
	1.030	1.080	1.130	1.180	1.220	1.210	1.200	1.170
	1.120	1.060	1.010	0.940	0.850	0.770	0.730	0.700
	0.620	0.630	0.670	0.710	0.750	0.830	0.920	1.000
	1.080	1.170	1.230	1.260	1.320	1.330	1.320	1.280
	1.220	1.170	1.060	0.960	0.860	0.740	0.610	0.540
161187	0.470	0.410	0.400	0.420	0.440	0.490	0.580	0.680
	0.780	0.890	1.000	1.080	1.150	1.210	1.230	1.220
	1.190	1.120	1.060	1.020	0.920	0.810	0.710	0.660
	0.630	0.570	0.550	0.560	0.620	0.660	0.730	0.830
	0.890	0.940	1.040	1.110	1.160	1.170	1.220	1.200
	1.220	1.150	1.090	1.010	0.950	0.850	0.770	0.680
171187	0.600	0.530	0.520	0.510	0.470	0.510	0.580	0.680
	0.760	0.880	0.970	1.060	1.130	1.230	1.290	1.330
	1.310	1.280	1.230	1.180	1.100	1.010	0.930	0.820
	0.690	0.610	0.530	0.510	0.500	0.490	0.510	0.530
	0.610	0.680	0.800	0.890	0.950	1.020	1.100	1.210
	1.220	1.190	1.160	1.140	1.090	0.940	0.890	0.790
181187	0.690	0.570	0.520	0.420	0.380	0.430	0.450	0.490
	0.590	0.760	0.880	1.000	1.150	1.350	1.470	1.530
	1.630	1.690	1.690	1.650	1.600	1.490	1.360	1.290
	1.150	1.010	0.890	0.840	0.740	0.700	0.720	0.770
	0.830	0.880	1.030	1.120	1.240	1.370	1.470	1.550
	1.610	1.610	1.640	1.530	1.510	1.400	1.290	1.180
191187	1.040	0.910	0.820	0.690	0.630	0.590	0.590	0.610

	0.690	0.800	0.920	1.080	1.200	1.380	1.540	1.660
	1.760	1.800	1.860	1.860	1.810	1.730	1.610	1.500
	1.380	1.210	1.050	0.920	0.800	0.710	0.650	0.590
	0.630	0.670	0.770	0.840	0.970	1.070	1.210	1.280
	1.370	1.430	1.480	1.490	1.450	1.350	1.270	1.150
201187	1.010	0.830	0.720	0.580	0.490	0.400	0.340	0.320
	0.350	0.440	0.550	0.690	0.860	1.050	1.240	1.400
	1.510	1.660	1.830	1.810	1.920	1.820	1.840	1.600
	1.650	1.430	1.330	1.090	1.010	0.830	0.730	0.590
	0.580	0.540	0.580	0.610	0.680	0.800	0.940	1.100
	1.160	1.280	1.300	1.350	1.430	1.370	1.380	1.430
211187	1.260	1.180	1.050	0.930	0.700	0.660	0.610	0.660
	0.590	0.730	0.840	0.970	1.080	1.180	1.390	1.620
	1.770	1.820	1.970	2.010	2.040	2.070	1.970	1.890
	1.800	1.820	1.620	1.410	1.290	1.130	1.050	0.950
	0.860	0.870	0.870	0.900	0.850	0.900	1.080	1.160
	1.260	1.470	1.600	1.640	1.690	1.860	1.880	1.730
221187	1.760	1.650	1.500	1.320	1.220	1.050	0.930	0.740
	0.730	0.760	0.620	0.750	0.880	1.040	1.060	1.370
	1.640	1.810	1.860	2.060	2.140	2.250	2.240	2.280
	2.150	2.010	1.850	1.740	1.600	1.500	1.280	1.110
	1.030	0.950	0.850	0.830	0.870	0.850	0.890	1.040
	1.210	1.270	1.360	1.430	1.540	1.560	1.640	1.650
231187	1.560	1.490	1.420	1.300	1.100	0.880	0.730	0.620
	0.540	0.450	0.380	0.370	0.400	0.500	0.610	0.730
	0.970	1.220	1.410	1.540	1.740	1.900	2.000	2.060
	2.090	2.100	2.060	1.980	1.830	1.640	1.480	1.340
	1.170	1.010	0.850	0.770	0.730	0.710	0.660	0.690
	0.780	0.880	0.930	1.010	1.100	1.190	1.250	1.290
241187	1.290	1.260	1.250	1.140	1.000	0.840	0.710	0.570
	0.440	0.330	0.200	0.130	0.110	0.130	0.170	0.280
	0.390	0.580	0.760	0.990	1.170	1.340	1.500	1.660
	1.780	1.890	1.910	1.950	1.850	1.790	1.680	1.540
	1.360	1.230	1.080	0.940	0.800	0.740	0.690	0.680
	0.700	0.760	0.830	0.910	1.010	1.100	1.190	1.260
251187	1.280	1.340	1.320	1.310	1.240	1.120	0.950	0.870
	0.740	0.590	0.450	0.370	0.310	0.200	0.170	0.200
	0.250	0.370	0.500	0.640	0.780	0.970	1.150	1.280
	1.380	1.540	1.680	1.740	1.740	1.720	1.670	1.560
	1.490	1.370	1.230	1.070	0.960	0.830	0.750	0.650
	0.590	0.590	0.640	0.660	0.740	0.830	0.920	0.970
261187	1.090	1.130	1.200	1.180	1.240	1.170	1.160	0.980
	0.950	0.800	0.710	0.550	0.480	0.360	0.290	0.250
	0.240	0.260	0.290	0.400	0.520	0.650	0.770	0.970
	1.090	1.240	1.300	1.500	1.560	1.640	1.660	1.590
	1.530	1.520	1.430	1.250	1.160	1.030	0.920	0.790
	0.730	0.620	0.590	0.610	0.620	0.620	0.660	0.780
271187	0.830	0.890	0.950	1.030	1.070	1.090	1.130	1.110
	1.060	0.970	0.910	0.780	0.680	0.580	0.530	0.410
	0.340	0.300	0.300	0.310	0.350	0.420	0.520	0.650
	0.780	0.910	1.030	1.150	1.290	1.400	1.480	1.560
	1.590	1.570	1.520	1.470	1.360	1.250	1.140	1.040
	0.910	0.790	0.700	0.640	0.600	0.580	0.580	0.670
281187	0.680	0.770	0.860	0.980	1.000	1.080	1.160	1.240
	1.240	1.240	1.200	1.160	1.070	1.000	0.900	0.800
	0.740	0.650	0.600	0.510	0.490	0.490	0.540	0.590

	0.670	0.770	0.920	1.010	1.120	1.210	1.350	1.450
	1.560	1.550	1.590	1.570	1.580	1.430	1.350	1.250
	1.160	0.990	0.860	0.730	0.640	0.570	0.510	0.470
291187	0.460	0.530	0.610	0.680	0.710	0.830	1.000	1.090
	1.120	1.190	1.320	1.280	1.240	1.210	1.200	1.110
	1.020	0.930	0.830	0.740	0.650	0.590	0.560	0.540
	0.540	0.610	0.680	0.720	0.860	0.990	1.100	1.180
	1.300	1.410	1.490	1.520	1.530	1.520	1.480	1.400
	1.300	1.180	1.100	0.970	0.840	0.690	0.590	0.520
301187	0.540	0.520	0.480	0.500	0.570	0.710	0.790	0.880
	1.000	1.110	1.240	1.320	1.390	1.360	1.410	1.320
	1.280	1.220	1.140	1.070	0.890	0.830	0.710	0.650
	0.580	0.600	0.570	0.630	0.680	0.800	0.900	0.920
	1.060	1.300	1.330	1.450	1.520	1.560	1.550	1.590
	1.500	1.440	1.300	1.270	1.150	1.030	0.850	0.790

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  1  6.35 0. 0. .35 -105 '   WATER LEVEL AT LARK HARBOUR, NFLD.'
011287 311287

                011287 0.690 0.640 0.640 0.640 0.640 0.700 0.780 0.920
                       1.080 1.180 1.300 1.400 1.550 1.610 1.690 1.730
                       1.740 1.650 1.620 1.500 1.480 1.310 1.220 1.150
                       1.040 0.970 0.890 0.830 0.850 0.890 1.010 1.170
                       1.240 1.380 1.480 1.580 1.790 1.890 2.040 2.000
                       1.960 1.880 1.940 1.810 1.660 1.520 1.360 1.210
                021287 1.080 0.920 0.780 0.740 0.650 0.610 0.700 0.780
                       0.840 0.960 1.160 1.280 1.410 1.500 1.600 1.690
                       1.800 1.820 1.810 1.770 1.720 1.610 1.480 1.340
                       1.240 1.160 1.030 0.920 0.830 0.810 0.860 0.840
                       0.870 1.010 1.130 1.270 1.330 1.470 1.580 1.700
                       1.700 1.760 1.760 1.730 1.610 1.570 1.400 1.270
                031287 1.150 1.010 0.890 0.770 0.730 0.660 0.600 0.650
                       0.800 0.920 1.000 1.140 1.370 1.530 1.650 1.760
                       1.930 1.990 2.060 2.020 2.000 1.890 1.780 1.640
                       1.510 1.380 1.190 1.070 0.930 0.820 0.760 0.740
                       0.740 0.760 0.840 0.940 1.050 1.130 1.260 1.350
                       1.460 1.510 1.550 1.570 1.550 1.470 1.360 1.240
                041287 1.150 0.990 0.840 0.690 0.570 0.490 0.440 0.430
                       0.440 0.540 0.680 0.800 0.980 1.150 1.310 1.490
                       1.660 1.800 1.920 1.980 2.000 2.000 1.980 1.890
                       1.760 1.580 1.470 1.300 1.160 1.020 0.950 0.840
                       0.790 0.770 0.830 0.900 0.950 1.040 1.190 1.260
                       1.350 1.460 1.520 1.520 1.530 1.520 1.460 1.380
                051287 1.210 1.130 0.990 0.890 0.690 0.590 0.560 0.500
                       0.440 0.490 0.550 0.670 0.760 1.030 1.070 1.320
                       1.500 1.750 1.800 1.960 2.100 2.160 2.110 2.070
                       2.060 1.780 1.740 1.540 1.350 1.230 1.130 0.900
                       0.830 0.790 0.760 0.700 0.760 0.880 0.920 1.070
                       1.190 1.320 1.370 1.490 1.550 1.560 1.530 1.630
                061287 1.440 1.430 1.280 1.150 0.990 0.830 0.780 0.740
                       0.650 0.610 0.630 0.690 0.770 0.920 1.040 1.190
                       1.370 1.560 1.660 1.740 1.890 1.990 2.000 2.010
                       2.030 1.960 1.830 1.740 1.590 1.440 1.300 1.180
                       1.060 0.930 0.830 0.810 0.800 0.830 0.890 0.980
                       1.100 1.230 1.280 1.400 1.470 1.520 1.550 1.580
                071287 1.580 1.480 1.380 1.240 1.130 1.020 0.870 0.730
                       0.670 0.580 0.520 0.490 0.500 0.580 0.680 0.780
                       0.930 1.070 1.240 1.350 1.460 1.600 1.710 1.710
                       1.720 1.740 1.720 1.670 1.490 1.350 1.200 1.080
                       0.890 0.800 0.650 0.590 0.510 0.480 0.490 0.590
                       0.630 0.750 0.830 0.960 1.040 1.110 1.210 1.180
                081287 1.240 1.270 1.240 1.110 1.030 0.900 0.780 0.660
                       0.560 0.470 0.380 0.330 0.330 0.340 0.400 0.500
                       0.640 0.760 0.890 1.050 1.240 1.350 1.460 1.550
                       1.630 1.690 1.680 1.660 1.610 1.520 1.420 1.290
                       1.200 1.060 0.960 0.830 0.750 0.680 0.670 0.650
                       0.720 0.750 0.840 0.920 1.030 1.100 1.170 1.240
                091287 1.260 1.270 1.250 1.210 1.120 1.020 0.920 0.800
                       0.680 0.550 0.500 0.430 0.390 0.370 0.420 0.450
                       0.560 0.660 0.820 0.950 1.100 1.240 1.380 1.500
                       1.610 1.700 1.740 1.780 1.760 1.730 1.640 1.580
                       1.470 1.370 1.260 1.160 1.040 0.930 0.880 0.860
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	0.850	0.840	0.880	0.960	1.030	1.080	1.150	1.220
101287	1.280	1.290	1.310	1.300	1.290	1.200	1.130	1.030
	0.950	0.830	0.750	0.630	0.570	0.540	0.530	0.500
	0.530	0.600	0.720	0.810	0.920	1.040	1.190	1.310
	1.400	1.480	1.540	1.610	1.660	1.640	1.610	1.550
	1.490	1.410	1.310	1.200	1.100	1.020	0.950	0.880
	0.860	0.850	0.860	0.860	0.900	0.990	1.050	1.100
111287	1.170	1.210	1.250	1.290	1.280	1.260	1.240	1.170
	1.090	1.020	0.940	0.840	0.760	0.660	0.610	0.580
	0.560	0.560	0.590	0.670	0.750	0.790	0.900	1.060
	1.190	1.270	1.330	1.410	1.520	1.520	1.560	1.470
	1.570	1.450	1.440	1.320	1.250	1.140	1.070	0.980
	0.930	0.810	0.890	0.920	0.870	0.860	0.940	1.090
121287	1.100	1.110	1.240	1.280	1.310	1.330	1.380	1.350
	1.290	1.300	1.290	1.250	1.070	1.050	0.940	0.880
	0.870	0.910	0.850	0.860	0.890	0.970	1.040	0.990
	1.330	1.390	1.470	1.560	1.640	1.750	1.630	1.650
	1.700	1.610	1.620	1.580	1.530	1.440	1.260	1.190
	1.090	1.020	0.910	0.890	0.840	0.850	0.890	1.000
131287	0.840	1.060	1.110	1.110	1.140	1.180	1.230	1.380
	1.260	1.340	1.160	1.240	1.230	1.050	0.990	0.940
	0.830	0.840	0.750	0.800	0.730	0.750	0.760	0.810
	0.930	1.000	1.110	1.220	1.240	1.310	1.420	1.500
	1.490	1.570	1.510	1.490	1.450	1.320	1.260	1.160
	1.130	1.020	0.970	0.910	0.860	0.740	0.780	0.760
141287	0.770	0.870	0.840	0.890	0.990	1.070	1.080	1.150
	1.250	1.250	1.360	1.300	1.270	1.170	1.190	1.100
	1.030	0.970	0.890	0.810	0.760	0.740	0.730	0.740
	0.740	0.830	0.860	0.880	1.000	1.050	1.120	1.200
	1.300	1.320	1.390	1.410	1.370	1.350	1.280	1.220
	1.190	1.080	0.990	1.010	0.890	0.830	0.800	0.750
151287	0.780	0.770	0.840	0.860	0.910	1.000	1.090	1.170
	1.270	1.310	1.340	1.430	1.450	1.430	1.430	1.360
	1.340	1.250	1.230	1.120	1.010	0.920	0.860	0.790
	0.780	0.820	0.810	0.860	0.900	1.010	1.020	1.060
	1.140	1.150	1.270	1.320	1.350	1.360	1.310	1.260
	1.240	1.210	1.140	0.950	0.970	0.890	0.780	0.710
161287	0.700	0.720	0.710	0.740	0.810	0.840	0.950	1.070
	1.170	1.290	1.400	1.450	1.540	1.580	1.630	1.660
	1.700	1.570	1.520	1.470	1.390	1.280	1.190	1.090
	0.980	1.000	0.970	0.960	0.980	1.000	1.090	1.140
	1.210	1.280	1.390	1.460	1.490	1.550	1.570	1.520
	1.520	1.480	1.410	1.280	1.330	1.220	1.180	1.010
171287	0.880	0.830	0.810	0.780	0.890	0.990	0.960	1.170
	1.150	1.330	1.440	1.620	1.690	1.790	1.940	1.900
	1.910	1.880	1.880	1.840	1.710	1.610	1.490	1.430
	1.300	1.170	1.110	1.040	0.960	0.920	0.950	1.030
	0.970	1.070	1.070	1.200	1.310	1.290	1.370	1.420
	1.400	1.490	1.350	1.300	1.140	1.170	0.990	0.900
181287	0.730	0.660	0.620	0.530	0.450	0.470	0.510	0.590
	0.720	0.890	1.020	1.220	1.340	1.530	1.660	1.800
	1.990	1.980	2.010	2.020	1.960	1.910	1.780	1.620
	1.520	1.400	1.270	1.150	1.060	1.020	0.970	0.960
	0.940	0.980	1.050	1.140	1.230	1.280	1.360	1.420
	1.480	1.480	1.500	1.460	1.390	1.270	1.160	1.020
191287	0.890	0.740	0.610	0.490	0.390	0.350	0.340	0.370

	0.430	0.550	0.690	0.870	1.050	1.250	1.410	1.580
	1.720	1.860	1.940	2.030	2.000	1.970	1.880	1.770
	1.620	1.510	1.340	1.190	1.050	0.950	0.820	0.760
	0.730	0.750	0.790	0.850	0.930	1.030	1.140	1.220
	1.290	1.350	1.390	1.400	1.390	1.340	1.240	1.110
201287	0.990	0.850	0.680	0.510	0.420	0.290	0.230	0.160
	0.180	0.180	0.320	0.450	0.680	0.850	1.020	1.220
	1.430	1.630	1.780	1.850	1.960	2.010	1.990	1.910
	1.790	1.690	1.550	1.390	1.200	1.070	0.960	0.820
	0.700	0.660	0.660	0.710	0.730	0.820	0.920	1.080
	1.170	1.230	1.270	1.350	1.410	1.420	1.370	1.260
211287	1.130	1.000	0.830	0.660	0.490	0.360	0.260	0.170
	0.070	0.080	0.110	0.180	0.320	0.500	0.710	0.900
	1.130	1.330	1.550	1.690	1.860	1.940	2.060	2.040
	2.040	1.970	1.870	1.710	1.530	1.420	1.250	1.140
	0.990	0.930	0.830	0.800	0.780	0.830	0.970	1.070
	1.230	1.300	1.440	1.570	1.650	1.700	1.730	1.670
221287	1.670	1.540	1.430	1.280	1.050	0.900	0.740	0.530
	0.380	0.280	0.210	0.160	0.190	0.310	0.430	0.590
	0.780	1.000	1.220	1.420	1.560	1.730	1.850	1.950
	1.980	1.950	1.860	1.780	1.650	1.490	1.310	1.160
	1.030	0.860	0.700	0.620	0.600	0.600	0.640	0.700
	0.790	0.930	1.090	1.200	1.300	1.420	1.530	1.580
231287	1.600	1.590	1.530	1.380	1.240	1.070	0.950	0.780
	0.640	0.500	0.400	0.320	0.320	0.330	0.390	0.520
	0.670	0.860	1.060	1.260	1.450	1.650	1.810	1.960
	2.050	2.140	2.150	2.100	2.000	1.890	1.750	1.590
	1.390	1.220	1.040	0.880	0.770	0.690	0.610	0.640
	0.690	0.750	0.810	0.940	1.040	1.180	1.260	1.350
241287	1.400	1.450	1.440	1.400	1.290	1.170	1.030	0.900
	0.740	0.590	0.440	0.340	0.250	0.200	0.160	0.220
	0.310	0.430	0.570	0.750	0.930	1.100	1.270	1.450
	1.600	1.710	1.780	1.870	1.900	1.840	1.740	1.690
	1.560	1.410	1.240	1.120	0.950	0.840	0.750	0.690
	0.680	0.670	0.730	0.770	0.860	0.990	1.100	1.180
251287	1.270	1.330	1.380	1.400	1.410	1.350	1.240	1.170
	1.070	0.920	0.770	0.620	0.470	0.360	0.300	0.260
	0.250	0.250	0.320	0.430	0.550	0.670	0.870	1.070
	1.160	1.310	1.490	1.600	1.650	1.690	1.720	1.720
	1.620	1.550	1.430	1.300	1.130	1.030	0.890	0.770
	0.710	0.680	0.670	0.740	0.750	0.870	0.980	1.100
261287	1.210	1.370	1.460	1.540	1.560	1.640	1.620	1.620
	1.500	1.470	1.300	1.200	1.050	0.920	0.770	0.680
	0.630	0.590	0.520	0.570	0.630	0.700	0.760	0.930
	1.070	1.200	1.300	1.410	1.530	1.590	1.620	1.640
	1.630	1.580	1.510	1.400	1.260	1.130	1.000	0.870
	0.750	0.680	0.640	0.610	0.590	0.620	0.690	0.770
271287	0.880	1.010	1.100	1.200	1.260	1.330	1.410	1.470
	1.490	1.480	1.420	1.320	1.230	1.120	1.040	0.930
	0.840	0.730	0.660	0.600	0.610	0.610	0.660	0.740
	0.850	0.950	1.080	1.180	1.280	1.370	1.480	1.550
	1.600	1.630	1.620	1.560	1.460	1.350	1.250	1.140
	1.010	0.880	0.790	0.710	0.670	0.630	0.650	0.660
281287	0.750	0.840	0.940	1.050	1.150	1.260	1.350	1.430
	1.510	1.550	1.580	1.560	1.540	1.460	1.390	1.300
	1.240	1.140	1.060	0.970	0.910	0.850	0.830	0.830

	0.860	0.900	0.980	1.050	1.120	1.180	1.280	1.360
	1.420	1.460	1.520	1.510	1.490	1.410	1.320	1.240
	1.150	1.030	0.910	0.820	0.720	0.660	0.610	0.620
291287	0.620	0.710	0.740	0.810	0.880	1.050	1.170	1.270
	1.330	1.430	1.500	1.560	1.590	1.600	1.590	1.540
	1.470	1.380	1.280	1.190	1.120	1.010	0.920	0.860
	0.850	0.830	0.820	0.850	0.910	1.020	1.090	1.150
	1.200	1.330	1.380	1.440	1.480	1.550	1.470	1.420
	1.350	1.310	1.190	1.160	1.010	0.910	0.830	0.790
301287	0.710	0.730	0.750	0.810	0.820	0.960	1.050	1.180
	1.400	1.420	1.590	1.740	1.870	1.900	2.020	2.080
	2.060	1.990	1.950	1.860	1.930	1.830	1.720	1.530
	1.500	1.330	1.280	1.130	1.130	1.150	1.220	1.150
	1.170	1.190	1.270	1.240	1.240	1.220	1.150	1.180
	1.060	1.010	0.850	0.700	0.610	0.530	0.430	0.290
311287	0.220	0.130	0.040	0.020	0.070	0.110	0.210	0.290
	0.400	0.560	0.740	0.900	1.090	1.180	1.320	1.480
	1.620	1.630	1.620	1.590	1.590	1.510	1.430	1.280
	1.180	1.130	1.090	0.970	0.900	0.850	0.930	0.930
	1.000	1.060	1.160	1.240	1.320	1.320	1.370	1.430
	1.490	1.460	1.390	1.370	1.310	1.190	1.140	0.990

APPENDIX B

FLOOD RISK MAP FOR COX'S COVE