

GUIDANCE NOTES FOR THE DETERMINATION OF MEAN HIGH WATER MARK FOR LAND TITLE SURVEYS

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Introduction

- 1.0 The Common Law cadastral boundary between the land and the sea is "the line of medium high tide between the springs and neaps" (Attorney General vs Chambers 1854) that is to say the line along the foreshore corresponding to the level of mean high water. While this may be a very convenient definition in the legal sense, in practice it can be one of the most difficult and time-consuming definitions required of the surveyor.
- 1.1 Fortunately common sense has prevailed and as confirmed by Chief Surveyors throughout New Zealand the usual practice is to survey the practical boundary between the land and the sea, for example the foot of the cliff, toe of bank, edge of vegetation, highest line of driftwood etc. This has the advantage of being a meaningful and recognisable boundary capable of quick definition rather than an imaginary line subject to continual or even daily change. For the sake of conformity and in accordance with land transfer requirements this line as depicted on the survey plan is called Mean High Water Mark, but it could equally be called Mean High Water Springs Mark, especially when the line depicted is say the toe of a bank beyond which the tide normally never reaches.
- 1.2 The validity of this assumption is confirmed by a brief examination of the Secondary Ports Table in the Nautical Almanac which shows that the difference between MHW (Springs) and MHW (Neaps) is quite small (0.1m at Napier, Wellington and Lyttelton) although somewhat larger on the Tasman side (0.6m at Westport and Port Taranaki). The difference between MHWS and MHW would be approximately half of these amounts.
- 1.3 Although the figures quoted are indicative only it is interesting to note that the range of the tides is generally small in this country (2.7m in Auckland) compared with many other parts of the world (up to 16m in Nova Scotia). A map illustrating the range of the tides round the New Zealand coast is attached as Appendix 'D'.
- 1.4 The introduction of the Resource Management Bill and the concept of marginal strips in the Conservation Law Reform and State-Owned Enterprises Acts has focussed attention upon the determination of Mean High Water Springs. A brief note on this aspect is included with each of the methods described.

A list of definitions of some of the terms used is attached as Appendix 'E'.
- 1.5 An illustration of the saltgrass *Salicornia Australis* is also included. On harbour mudflats and shell banks the seaward edge of *Salicornia* is a good indication of MHWM. Present evidence suggests that it only descends spasmodically below by small amounts. When available it provides a useful check on the results obtained by other methods (Appendix 'F').

- 1.6 When carrying out a survey for title purposes the report should clearly describe the method used in defining the seaward boundary. If difficulties are anticipated the proposed method should first be discussed with the Chief Surveyor. The survey plan should always show the nature of the foreshore, and any permanent or semi-permanent features such as walls, fences, toe of bank etc. should be fixed and shown. This will enable the layman to relate the position of MHW to the plan and is also useful information for subsequent surveys, accretion claims, etc.
- 1.7 There is a mistaken belief held by some surveyors that once the height of mean high water has been established from long-term tidal records (usually at a Standard Port) then it is a simple matter to establish MHW by levelling from the nearest Survey Control mark, even when the job site is many miles away from the standard tide gauge. This method is only capable of producing reliable results if the job is situated within a few kilometres of the gauge and should always be checked by physical evidence or actual observation on a calm day of a high tide predicted to coincide with mean high water. The actual height of the tide should afterwards be confirmed with the Port Authority.
- 1.8 In surveys of high-value beach properties, if the owner is not prepared to accept a practical definition of the boundary (toe of bank, edge of vegetation, etc.) then the height of MHW must be carefully established at the job site either by using the Eduction or Range-Ratio method as described in Sections 4.0 and 5.0, or by setting up an automatic tide gauge for at least one month and correcting the result obtained to obtain the 19 year mean equivalent, using the procedure described for the Range-Ratio method. The resulting height should be tied to suitable bench marks. Once this has been accomplished, the line of MHW should be set out along the beach by levelling and fixed by survey.

As the profile of a sandy beach is continually changing even in partly-protected harbour situations, this setting-out exercise should be repeated every 2-3 months for a whole year. From these surveyed positions the average position of MHW may be determined and taken as the boundary.

From a beach monitoring survey carried out over a 12 month period at Takapuna and Milford Beaches in Auckland, which cannot be classed as fully exposed, it was found that the position of MHW typically varied by 9 metres and at one position by 17.5 metres due to changes in the beach profile.

2.0 PRACTICAL METHODS OF DETERMINING MHWMARK AND MHWSMARK FOR LAND TITLE PURPOSES

- 2.1 In the past a variety of approximate methods have been used particularly when only low value land is affected. The early Surveyors in New Zealand quite often used the edge of vegetation or toe of bank or dune and this practice has continued in use throughout New Zealand where low value land is involved and there is no dispute. The main reasons for using this definition for the boundary between land and sea were that besides being the most obvious and most permanent, it was also the interpretation of the common law principle as quoted by Lord Chancellor Cranworth in his decision in the case *Attorney General v Chambers* (1854) viz. "That principle I take to be that it (land not included in a Crown Grant) is land not capable of ordinary cultivation or occupation being for the most part not dry or manoriable." The term "high water mark at ordinary tides" was first used in the Crown Grants Act 1866 and in subsequent Crown Grants Acts of 1883 and 1908. It would therefore appear that where the Crown Grant was dated before 1866 and there was no evidence to the contrary i.e. MHW was not referred to in the Grant - then there is no necessity for using MHW and any definition should be simply based on the above principle. The physical description of the boundary should be shown on the plan and no reference made to MHW unless it is proven that for practical purposes on the particular site they coincide.
- 2.2 Other methods in the past included using the line of debris or flotsam and jetsam after calm weather and predicted mean tides, or observing two or more high tides in calm weather and predicted from the tide tables to coincide with mean high water.
- 2.3 The MHW was sometimes set out as a contour using established benchmarks and a height relationship determined at the nearest primary tide gauge. This is not an accurate method as MHW is not a level line and frequently varies by up to 0.2m within a few kilometres and sometimes by a much greater amount over longer distances due to the nature and reasons for flood tides and the restrictions and configurations of harbours.
- 2.4 The above methods may still be adequate where only low value land is involved. However, where the land has a high value and the position of the MHW will determine the position of a right line boundary, or a claim for accretion is being made, or an existing or proposed reclamation is involved, then more accurate methods are required.

3.0 MEAN HIGH WATER VALUES AT FOUR MAIN PORTS

The following table has been provided by the Surveyor-General. The Department of Survey and Land Information holds digitised hourly height values for these ports from which the mean of all recorded high waters has been deduced. The data has been extracted for complete Metonic cycles (18.6 years) and includes the N₂ constituent.

At the present time similar data is not available for any other ports.

Auckland

Mean High Water: 3.03m above the zero of the automatic tide gauge and predictions.

Mean Sea Level: 1.823m above tide gauge zero. (Data taken from 19 year period 1969-1987.)

Wellington

Mean High Water: 1.53m above the zero of the automatic tide gauge and predictions.

Mean Sea Level: 1.029m above tide gauge zero. (Data taken from 19 year period 1968-1986.)

Lyttelton

Mean High Water: 1.92m above the zero of the automatic tide gauge.
1.21m above the zero of the predictions.

Mean Sea Level: 1.065m above zero of tide gauge. (Data taken from 18 year period 1969-1986.)

Dunedin

Mean High Water: 1.88m above the zero of the automatic tide gauge.
1.84m above the zero of the predictions.

Mean Sea Level: 1.088m above zero of tide gauge. (Data taken from 20 years between 1963-1987.)

- 3.1 A table prepared by the Auckland Harbour Board is also attached as Appendix 'G'. This contains much interesting and useful information but should not be used indiscriminately if maximum accuracy is required. Note for example that some of the levels are taken from the Nautical Almanac and do not therefore include the N_2 constituent. Note also that the value of 1.753 for Mean Sea Level is based on records for the period 1909-1946, whereas the value given in paragraph 3.0 (1.823) is based on records from 1969-1987 and indicate a rise of 0.070m in M.S.L. in 40 years.

It is presumed that other Port Authorities will have similar data sheets available for use by surveyors.

The most recent table prepared by Ports of Auckland is attached as Appendix 'H'.

- 3.2 Note that when comparing field observations with data from an automatic tide gauge the tide gauge recordings will be shown in Standard Time and a correction may be required for Daylight Saving Time. This is illustrated in the worked example diagrams for Appendix 'C'. Regard must also be paid to Daylight Saving Time when using tide tables.

4.0 **THE RANGE-RATIO METHOD** (See Appendix 'R')

This method, recommended by the 1925 Survey Regulations and repeated in the article "Water Boundaries" by F.J. Kearns in the New Zealand Surveyor for August 1980 has been frequently used. It is recognised as the standard method of tidal datum transfer in many countries. It should only be used however when it is known that the range between MHW and MHWS as a proportion of the mean tide range at the site is likely to be very similar to the proportion between the same ranges at the reference station. This is generally not the case in harbours where various restrictive factors cause the water surface to slope by varying amounts and therefore this method should not be used in harbours if an accuracy better than $\pm 0.15\text{m}$ is required.

Also the method requires a tide pole to be set up at the job site capable of measuring both high and low water, sometimes a difficult or impossible requirement in harbour mudflat situations. It is capable of producing good results on the open coast, but as already noted an accurate determination in that situation is seldom required.

It is based on the following formulae using the notation:

MHW	=	19 year mean high water) Values obtained from
MTL	=	19 year mean tide level) published data such
MLW	=	19 year mean low water) as Appendix 'H'
MR	=	19 year mean range)
TL	=	Observed mean tide level	
R	=	Observed range of tide	
s	=	Subscript to denote site station	
c	=	Subscript to denote control station	

The first formula calculates the 19 year mean range:

$$MR_s = \frac{MR_c \times R_s}{R_c} \quad (1)$$

The second formula calculates the 19 year mean tide level:

$$MTL_s = TL_s - (TL_c - MTL_c) \quad (2)$$

The third formula calculates the 19 year mean high water:

$$MHW_s = MTL_s + \frac{MR_s}{2} \quad (3)$$

Combining (2) and (3) gives the following:

$$MHW_S = TL_S - (TL_C - MTL_C) + \frac{MR_S}{2}$$

By definition $TL_S = HW_S - \frac{R_S}{2}$

Hence $MHW_S = (HW_S - \frac{R_S}{2}) - (TL_C - MTL_C) + \frac{MR_S}{2}$

Mean High Water Springs for the site may be determined by substituting the 19 year range between MHWS and MLWN at the control station for the value of MR_C in formula (1).

5.0 THE EDUCATION METHOD

This method, first published in 1982 by Dr W.S. Maddux of the New Jersey Department of Environmental Protection, is used to extrapolate local tidal data by simultaneous comparison of partial tidal cycles. Mean high water at the site of the survey can be determined from observations taken at times close to high water and comparing these with observations of the same tide taken at the control station. For this reason it is possible to use the method in harbour mudflat situations where observation of the full range of the tide is either inconvenient or impossible, thus making the range-ratio method impracticable.

5.1 Basic Requirements

It is necessary to have access to tidal data from a **reference station** where an automatic tide gauge is in continuous operation and records for at least one half of a Metonic cycle (i.e. 9.3 years) have been analysed. In New Zealand this would usually be one of the Standard Ports listed in the Nautical Almanac where records are maintained by the relevant Port Company/Harbour Board.

The second requirement is a **control station** where an automatic tide gauge has been established at some time in the past for at least one lunar month or preferably 6 months from which tidal data is available and bench marks related to the tide gauge are recoverable. It is necessary for the control station to be "hydrographically close" i.e. to have similar tidal characteristics to the **site station**.

If the site station is hydrographically close to the reference station the latter may also be used as the control station.

5.2 **Summary of Procedure** (See Appendix A for Notation and Diagrams)

5.2.1 **Office Work for Reference Station**

Average the predicted high and low water values as given in the Tide Tables for the day of observation (D) with the corresponding values for the day before (D-1) and the day after (D+1) always using 2 high and 2 low values for each day to obtain the daily predicted half-tide level.

$$\begin{aligned} \text{PTL} &= \text{Predicted half-tide level for day of observation} \\ &= \frac{1}{3} \left[\text{HTL}_{D-1} + \text{HTL}_D + \text{HTL}_{D+1} \right] \end{aligned} \quad (1)$$

Where HTL_D is the average of 2 high waters and 2 low waters predicted for day D etc.

If a calendar day lacks a predicted high or low water due to the progression of the diurnal lag "borrow" the value from the day before or after using the value which occurs nearer to midnight to complete the set of 2 highs and 2 lows for each day.

From the predicted high water for the tide observed subtract the PTL and subtract half the 19 year mean range of the reference station to obtain the predicted range anomaly:

$$\text{RA}_R = \text{HW}_R - \text{PTL} - \frac{1}{2} \text{MR}_R \quad (2)$$

5.2.2 **Office Work for Control Station**

Calculate RA_C (the range anomaly at the control) by multiplying RA_R by the ratio of the mean range at the control to the mean range at the reference.

$$\text{RA}_C = \text{RA}_R \times \frac{\text{MR}_C}{\overline{\text{MR}}_R} \quad (3)$$

Care should be taken to ensure that predicted tides are properly matched to the observed tides with due regard to the time difference between the reference and site stations. Any misidentification cannot be detected in the calculations.

5.2.3 *Field Observations*

If a primary tide gauge exists within a reasonable distance of the job site and has similar tidal and meteorological characteristics a readout of the gauge can be obtained from the relevant Harbour Board. However there may be a more suitable secondary tide station closer to the job for which tidal datums have been established but the gauge removed. It will then be necessary to establish a tide staff at both the control tide station i.e. the secondary tide station, and on the job to enable simultaneous readings to be taken. A section of plastic tape refill for a staff can be secured to a board with a 1cm diameter clear plastic tube strapped alongside as a stilling device. The staff at the job site can be set firmly at any arbitrary level just below MHW. At least 2 permanent benchmarks should be established and a relationship determined by levelling between them and the tide staff.

Using tide prediction tables, determine a day when high tide will equal or just exceed MHW. If a strong anticyclone is present allow for the lower than predicted high water by using the difference between the forecast barometric pressure and that used to produce the tide tables - 1014mb. (Diff. of 1mb = 1cm.) Man the tide staff early enough to include the reduced range anomaly at both the control and site. Each observer simultaneously reads the water elevation on his staff every six minutes until the tide has peaked and then receded the same amount on the falling tide. Of course, only the observer at the control staff knows when to stop reading the staff, so it is convenient to be in two way radio contact. Do not stop the observations too soon as the time of tide may be later at the study site. Repeat this operation during a second tide cycle to guard against gross error or unusual conditions. If the computations for two cycles do not check to your satisfaction, a third set of observations may be desirable for increased accuracy. Best results are obtained when the sea is calm, the wind less than 10 knots and the tide just exceeds MHW.

Analysis of Field Observations

5.2.4 *Determine the range anomaly at the site as follows:*

Plot the observed elevations for each station as ordinates versus their corresponding times as abscissae. Use scales of 1:2 vertical and 1 hr = 4cm horizontal.

On the plot of observed control station water elevations vs. time, scale down from the observed peak elevation a distance equal to the absolute value of RA_C and draw a horizontal line. Determine the exceedence time difference, T_e , between the intersections of the line just drawn with the ascending and descending limbs of the tidal curve.

Apply the time span, T_e , from the control curve to the plot of elevation vs. time for the site station and find that elevation which was exceeded for the time span, T_e , at the site station.

Scale the difference between this elevation and the observed peak elevation at the site to obtain the value of RA_S . Apply a negative sign to RA_S if RA_C as obtained in step 5.3 is negative, a positive sign if RA_C is positive.

5.2.5 Compute the level anomaly at the control and site stations:

$$LA_S = LA_C = HW_C - RA_C - MHW_C \quad (4)$$

(Note the assumption that the level anomaly is identical at the control and site stations).

5.2.6 Determine the value of mean high water at the site station:

$$MHW_S = HW_S - LA_S - RA_S \quad (5)$$

5.2.7 Determination of Mean High Water Springs:

The established value for MHWS at the control station is substituted in the formula at (4):-

$$LA_C = HW_C - RA_C - MHWS_C$$

The value of MHWS at the site may then be determined as follows:-

$$MHWS_S = HW_S - LA_S - RA_S \quad (6)$$

The following note on the Eduction Method is taken from the paper published by Dr Maddux (Ref. 10 Appendix 'J').

5.3 Factors Affecting Accuracy:

In relative terms, the assessment and correction of the value of RA_S is less likely to cause significant error in determination of mean high water from short observations than is the correction for LA_S . However, the estimation of possible and probable errors varies with particular conditions.

Clearly, the successful use of the mean range ratio to transfer $\frac{1}{2}R_R$ to $\frac{1}{2}R_C$ as illustrated previously implies that the smaller quantity RA_R can be transferred to RA_C with equal relative accuracy and greater absolute precision in proportion to the ratio of the range anomaly to the semi-range. Thus, it is the transfer from the control station to the site location that requires consideration.

If the time-height observations at the two locations are extended to cover a vertical range somewhat greater than that of the educed range anomaly at the control, the behaviour of the control to subordinate transfer function may be better evaluated. Plot the data in the usual fashion of height as a function of time for each location. Then horizontal lines can be placed on the control station graph at convenient δH_C intervals (e.g. 2cm) downward from the peak and the corresponding exceedence time for each height determined. The control exceedence times are then applied to the site station graph and the corresponding level changes, δH_S , are determined for each δH_C . A third plot of δH_S versus δH_C can now be made, and the similarity of the behaviour of the water levels at the two places may be evaluated. If the curves are the same at both places, the δH_S versus δH_C graph will be a straight line with a slope of 1. If the curves are similar in shape with different ranges, the slope of the graph (range ratio) will be other than 1. Curvature of the plot will measure the relative distortion of the wave form between the stations. The "scatter" of the individual points, the departure from linearity, and the repeatability of results from tide to tide can all be weighed in judging the confidence to be placed in the extrapolation.

The range anomaly and the level anomaly should be considered together in critical situations. Clearly, since the range anomaly can be known in advance of field work, the observer may choose to observe tides for which RA_R has small or zero predicted values and so control the possible errors in RA_S .

The importance of LA_C can be illustrated by a hypothetical extreme case: Assume a situation in which the site station lies landward of a sill with a limiting elevation of 15cm below mean MHW_C level. Suppose observations are made on a day when the TL_C value at the control station seaward of the sill is 30cm below mean half-tide level (i.e. $LA_C = 30\text{cm}$) and the predicted semi-range at the control is 7.5cm greater than the mean semi-range (i.e. $RA_C = +7.5\text{cm}$). Clearly no valid mean high water determination could be made for the site station under these circumstances.

Although the observed tide does not theoretically have to reach MHW_M when using the eduction method, it is essential that this is achieved in situations involving mudflats where the possibility of restricted tidal flows and flood sills exist.

Overall, the variance of mean high water determinations contributed by using the differential correction of RA_S in the suggested procedure can be kept small compared to the variance contributed by the LA_C determination.

Experience to-date shows that where the subordinate (site) station is "hydrographically close" to the control station, the standard deviations of mean high water determinations based on single tide observations compare very well with the assigned uncertainties of secondary and tertiary datums for the control station. If repeated determinations are made with significantly different LA_C values, and the resulting mean high water values obtained at the subordinate station show close agreement, then it is reasonable to assume that the control station is suitably related to the subordinate location and that the assumption that $LA_S = LA_C$ is valid.

6.0 COMPARISON OF METHODS

Results obtained by using the Range Ratio and the Eduction Methods are compared with the value derived from observations taken over a five-month period at the Leigh Marine Laboratory in the table below. The records from an Ellwood automatic tide gauge for the period 1 February to 20 June 1986 were analysed by the RNZN Hydrographic Office. The Auckland Tide Gauge was used as the Reference Station and the following data from the Harbour Board publication S90/27 was used in the calculations:

MHW 3.05 MTL 1.82 MR 2.45

From the analysis, M.S.L. at Leigh = 1.93 and the mean of all high waters = 2.82. An adjustment of -0.03 was then applied to correct for the difference between M.S.L. at Auckland for the same 5-month period (1.86) and the primary value for M.S.L. at Auckland (1.82). This was calculated as follows:

$$(1.82-1.86) \times \frac{\text{MR at Leigh}}{\text{MR at Auckland}}$$

$$\text{i.e. } -0.04 \times \frac{2(2.82-1.93)}{2.45} = -0.03$$

Levels are in metres above the tide gauge zero.

Determination of Mean High Water Level at Leigh			
Date	Range-Ratio	Eduction	5-month Analysis
21.12.85	2.82	2.83	
4. 3.86	2.84	2.83	2.82
28.4.86	2.80	2.82	-0.03
Mean	2.82	2.83	2.79

7.0 THE NAUTICAL ALMANAC

Tide tables derived from the Nautical Almanac should be used to determine predicted tide times and heights. Whilst much of the other information included is of interest it is intended for navigational use and is not suitable for determination of MHW where accuracy is required.

In recommending the use of the Eduction Method for accurate determinations it was hoped that the Secondary Ports listed in the Almanac would provide a network of suitable control stations but it is now known that in most cases the levels given were calculated from an analysis of short-term observations. Also, the N_2 constituent produced by the moon's elliptical orbit is excluded and the tables do not therefore indicate the full range of the tides.

8.0 **ACCURACY OF DETERMINATIONS**

Tidal datums (MSL MHW etc.) derived from observations carried out over 1 year cannot be guaranteed to achieve an accuracy better than $\pm 10\text{cm}$. Similarly, tidal datums derived from observations carried out over 1 month cannot be guaranteed to achieve an accuracy better than $\pm 25\text{cm}$.

These accuracies can be improved to $\pm 2\text{cm}$ and $\pm 4\text{cm}$ respectively if datums derived from the same periods of time at the primary station are compared with the 19 year mean, and the difference applied to the short term observations at the subordinate station after adjustment for any difference between the tidal range at the two stations. It is essential that the primary station selected is "hydrographically close" (i.e. has similar tidal characteristics) to the site of the survey.

Accuracy of short term determinations and transfers of tidal datums can be significantly affected by meteorological conditions and the New Zealand Nautical Almanac explains this in some detail.

If the job site is a substantial distance from the control site, barometric pressure should be recorded at both sites and a correction based on the average difference between the sites over at least the six hours prior to high tide may be significant. As a useful approximation a difference of 1 millibar represents 1cm difference in sea level.

In estuarine mudflat situations where observation of the tidal range is very difficult the Eduction method has proved to be successful and should provide an accuracy within $\pm 5\text{cm}$ provided the site is "hydrographically close" to the control station and several observations are carried out in calm weather on tides which are very close to MHW (or MHWS). The Secondary Ports Table in the Nautical Almanac can be used as a guide to "hydrographically close" situations.

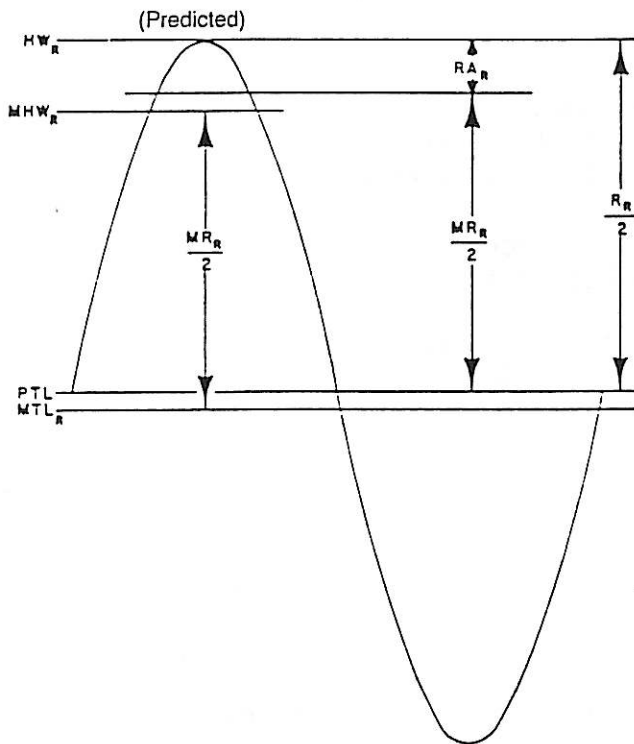
APPENDIX "A"

Notation

MHW 19 year mean high water.
 MTL 19 year mean tide level.
 MR 19 year mean range.
 TL Half Tide Level at time of individual semi-diurnal tide.
 R Range of individual semi-diurnal tide.
 HW Peak elevation of individual semi-diurnal tide.
 PTL Prediction of half Tide Level:
 The elevation about which each tide is predicted to oscillate, as calculated on a daily basis.

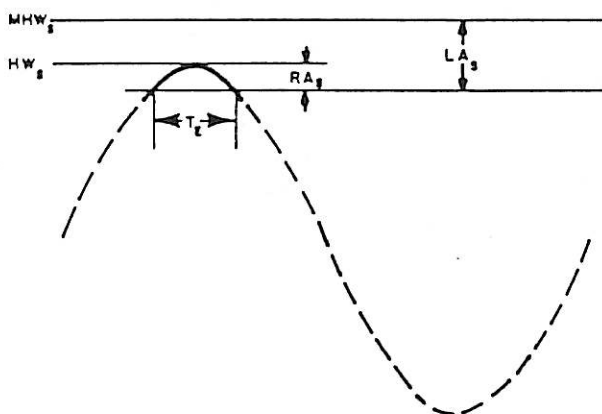
LA Level Anomaly:
 Difference of an individual semi-diurnal tide's level from mean tide level.
 RA Range Anomaly:
 Difference of the half-oscillation of an individual semi-diurnal tide from the half-oscillation range of a semi-diurnal tide of mean range.
 TE Exceedance Time.

Subscripts R, c, s are used for values at the reference, control and subordinate or site stations, respectively.



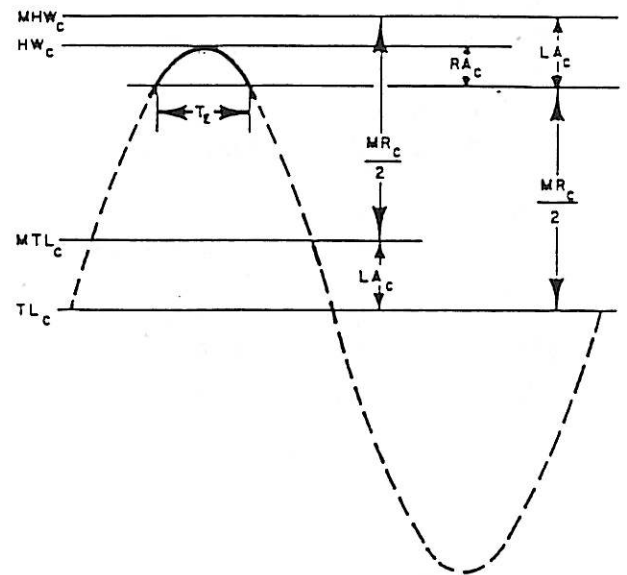
AT THE REFERENCE STATION

(Primary tidal station)



AT THE SUBORDINATE STATION

(Site station)



AT THE CONTROL STATION

(Secondary tidal station)

EQUATIONS

$$PTL = \frac{1}{3} (HTL_{R_{D-1}} + HTL_{R_D} + HTL_{R_{D+1}}) \quad (1)$$

$$RA_R = HW_R - PTL - \frac{MR_R}{2} \quad (2)$$

$$RA_C = RA_R \times \frac{MR_C}{MR_R} \quad (3)$$

$$LA_S = LA_C + HW_C - RA_C - MHW_C \quad (4)$$

$$MHW_S = HW_S - RA_S - LA_S \quad (5)$$

FIGURE 1. Relationships of quantities. Diagrams show height against time for one semi-diurnal cycle at each location. Required observation periods are in solid heavy line.

TABLE SETOUT FOR CALCULATION

Standard Range Ratio Method

At Station	No.	Calc.	Description
Reference	1		H.W. observed
Reference	2		L.W. observed
Reference	3	$(1 + 2) \times 0.5$	half Tide Level
Reference	4	$1 - 3$	half Range
Reference	5	3 - Data	3 - Mean Tide Level
Reference	6	$\text{Data} \div (1-2)$	Mean Range \div Observed Range
Site	7		H.W. observed
Site	8		L.W. observed
Site	9	$(7 + 8) \times 0.5$	half Tide Level
Site	10	$7 - 9$	half Range
Site	11	10×6	half R x Range ratio
Site	12	$9 - 5$	Mean Tide Level
Site	13	$11 + 12$	M.H.W.

Eduction Method

At Station	No.	Calc.	Description	Notation
Reference	1		H.W. predicted	HW_R
Reference	2		half Tide predicted	PTL
Reference	3		half Mean Range 19 yr	$0.5 \times MR_R$
Reference	4	$1 - 2 - 3$	Range Anomaly	RA_R
Control	5		half Mean Range (data)	$0.5 \times MR_C$
Control	6	$(4 \times 5) \div 3$	Range Anomaly	RA_C
Control	7		H.W. observed	HW_C
Control	8		Mean H.W. (data)	MHW_C
Control	9	$7 - 6 - 8$	Level Anomaly	LA_C
Site	10		H.W. observed	HW_S
Site	11		Range Anomaly (graph)	RA_S
Site	12	$10 - 11 - 9$	M.H.W.	MHW_S

Appendix 'C'

Worked Example using Education Method to Determine MHW at Shoal Bay, Auckland

Shoal Bay Site 27/11/87

$$1. \quad PTL = \frac{1}{3} [HTL_{R_{D-1}} + HTL_{R_D} + HTL_{R_{D+1}}] = 1.76$$

$$2. \quad RA_R = HW_R - \frac{PTL}{2} - \frac{MR_R}{2} = 3.10 - 1.76 - 2.45 = 0.12$$

$$\therefore \text{Scaled } RA_S = 0.11$$

$$3. \quad LA_S = LA_C = HW_C - RA_C - MHW_C = 3.17 - 0.12 - 3.05 = 0.00$$

$$4. \quad MHW_S = HW_S - RA_S - LA_S = 1.41 - 0.11 - 0.00 = \underline{1.30} \text{ above zero on tide pole}$$

Shoal Bay Site 23/12/87

$$1. \quad PTL = 1.75$$

$$2. \quad RA_R = 3.30 - 1.75 - 2.45 = 0.32$$

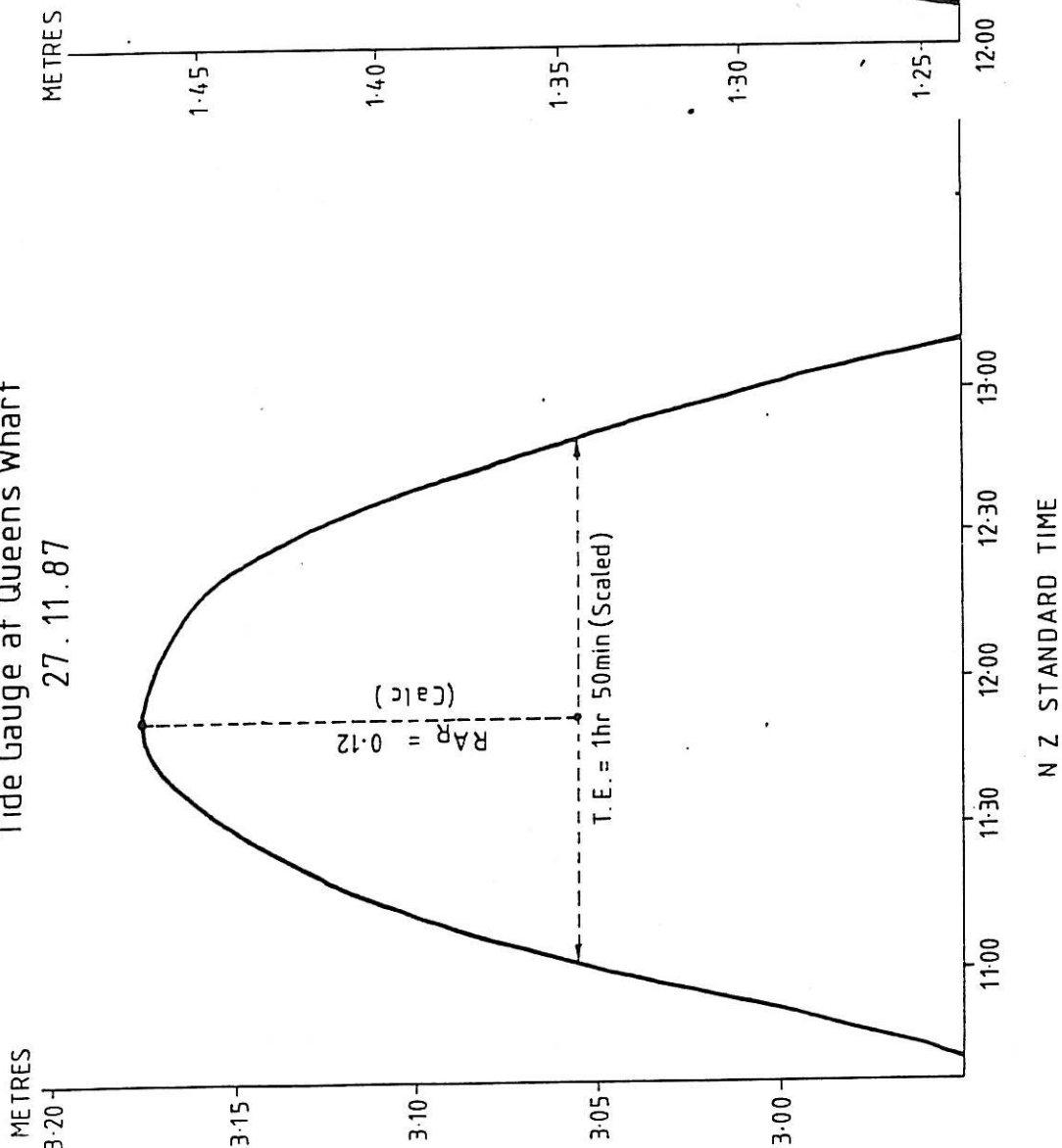
$$\therefore \text{Scaled } RA_S = 0.34$$

$$3. \quad LA_S = 3.36 - 0.32 - 3.05 = -0.01$$

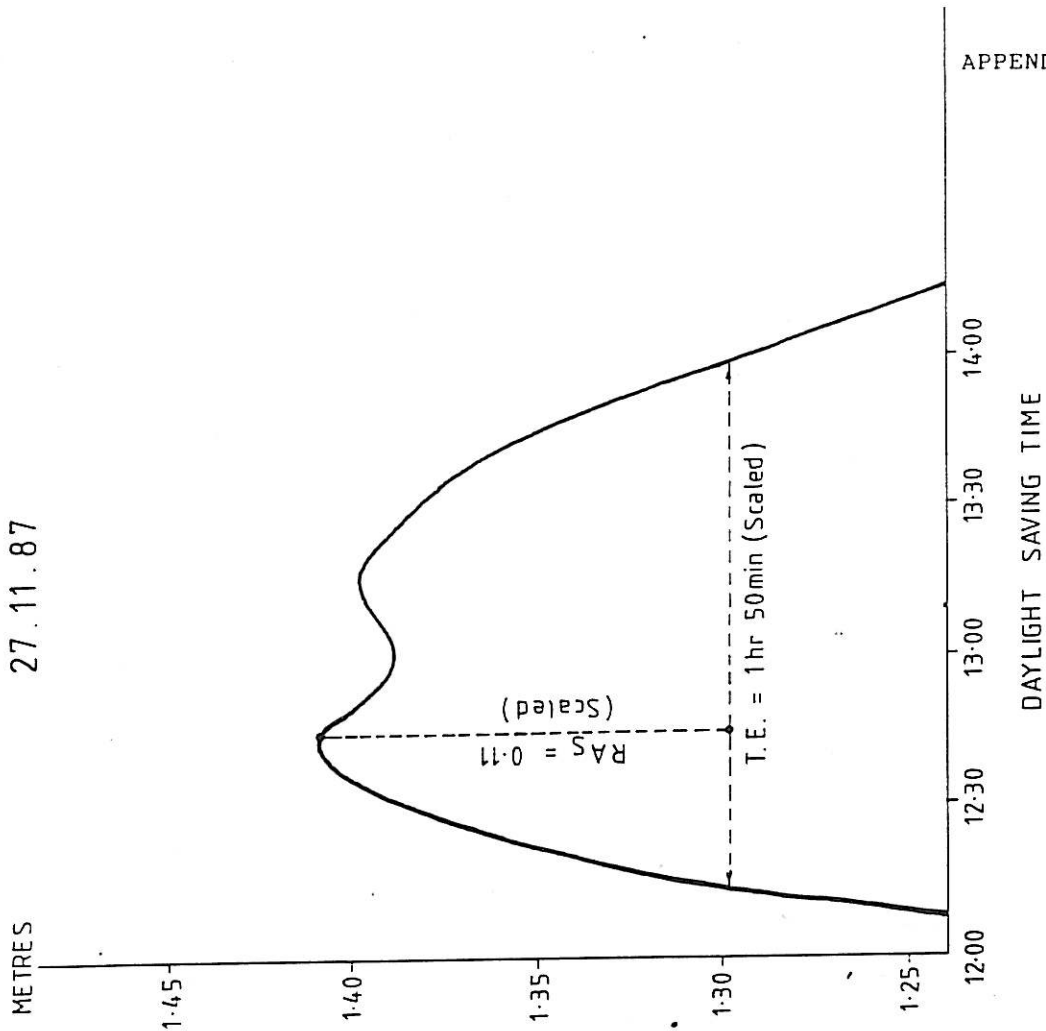
$$4. \quad MHW_S = 1.63 - (-0.01) - 0.34 = \underline{1.30} \text{ above zero on tide pole}$$

Note: All predicted data was taken from the NZ Nautical Almanac. Other data from the Auckland Harbour Board tide gauge records. Field observations were made on the dates shown.

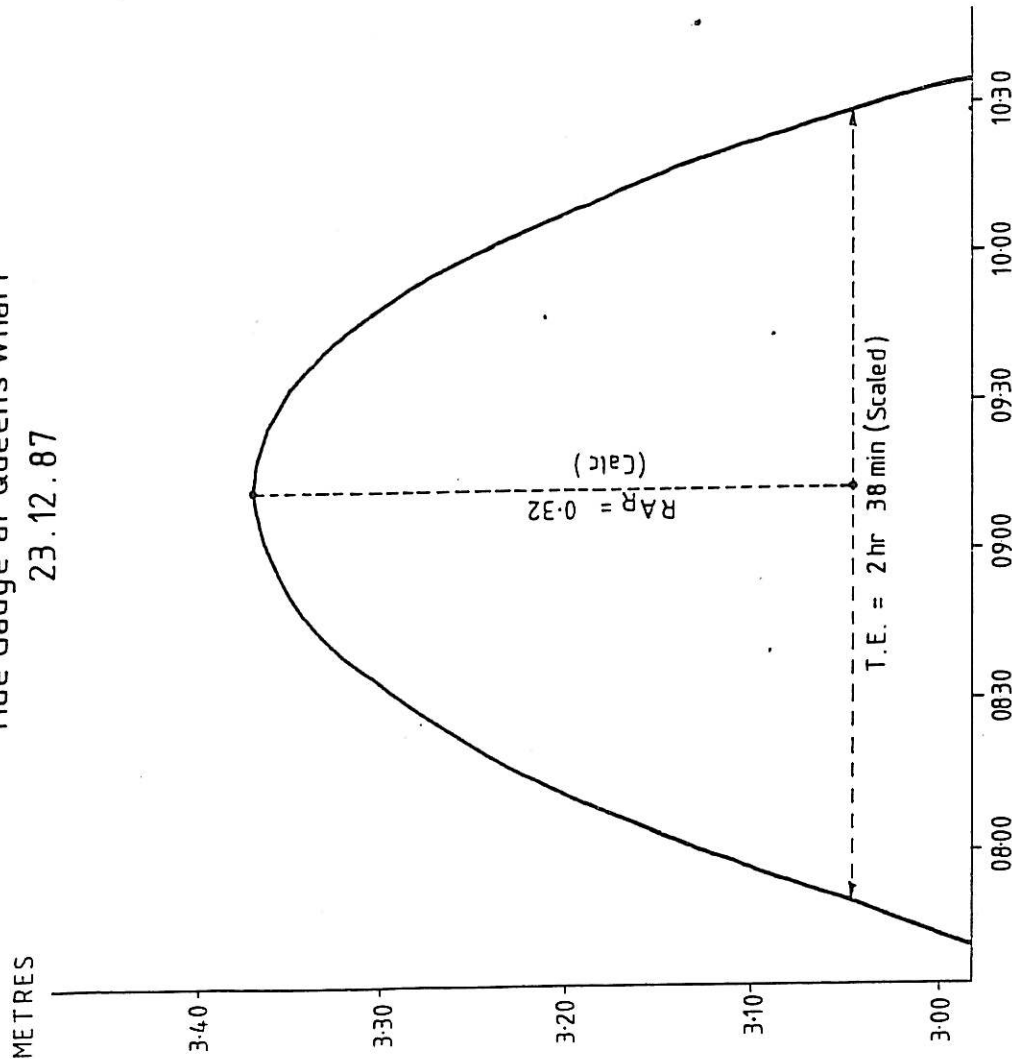
Reference Station
Tide Gauge at Queens Wharf
27.11.87



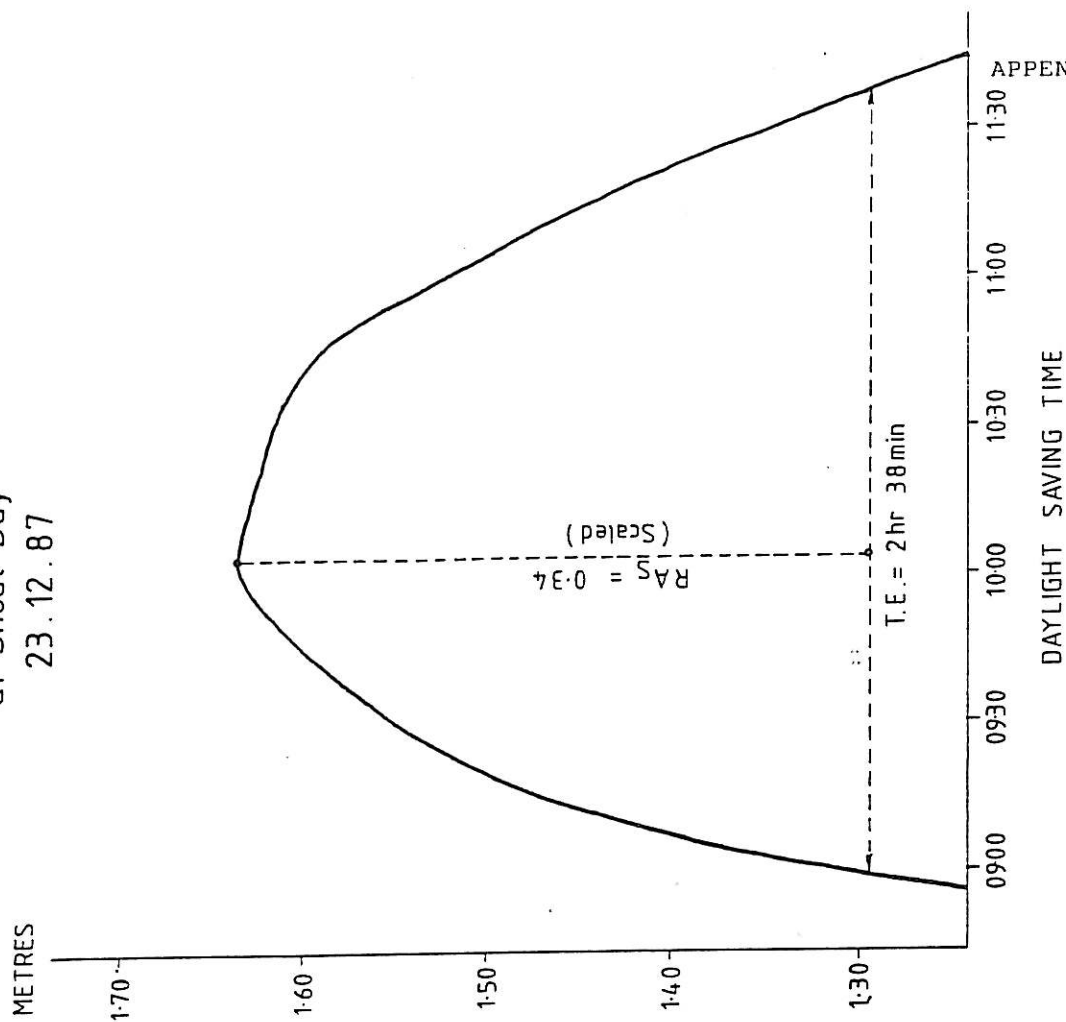
Tide Pole Readings
at Shoal Bay
27.11.87



Reference Station
Tide Gauge at Queens Wharf
23.12.87



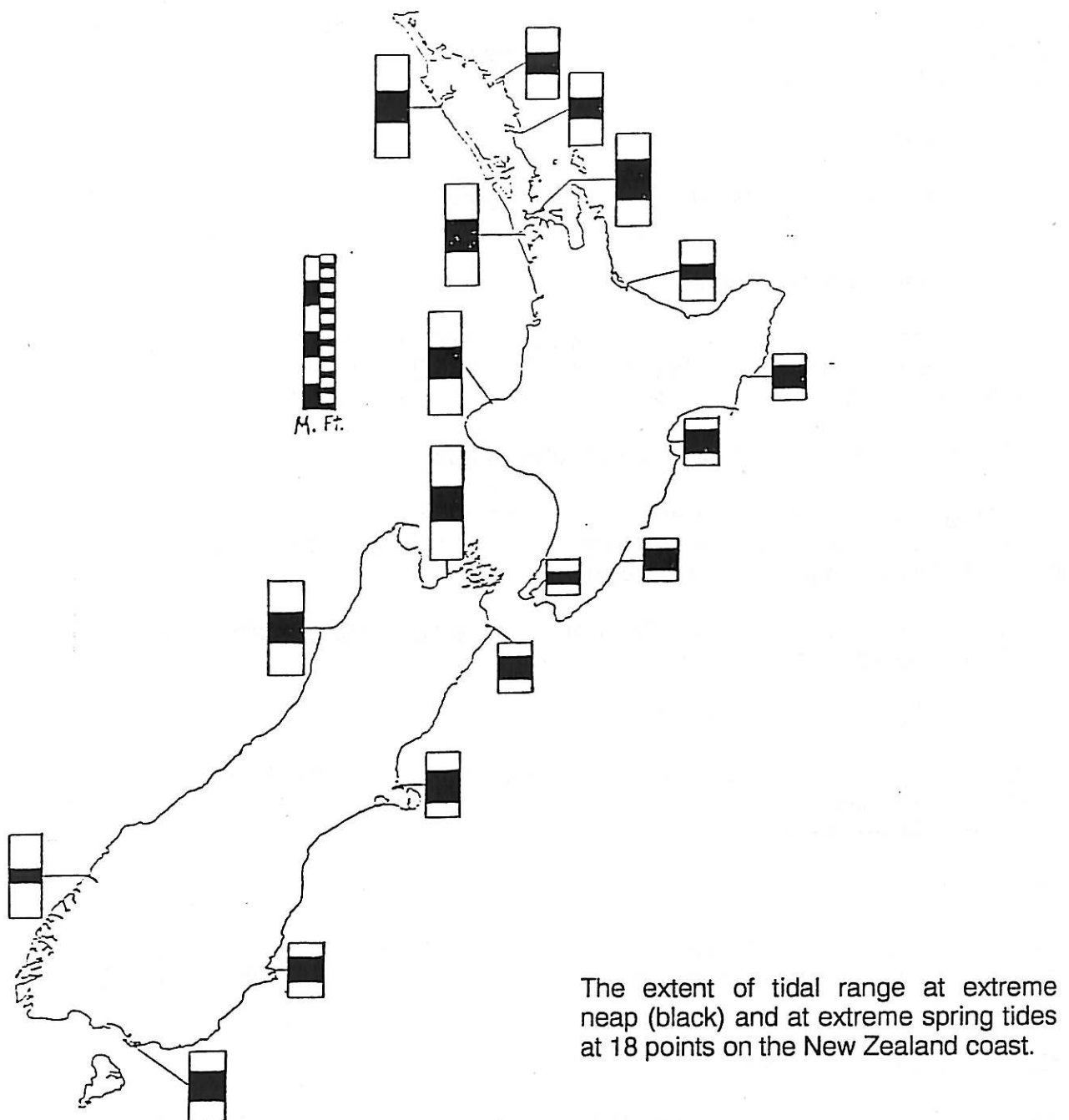
Tide Pole Readings
at Shoal Bay
23.12.87



APPENDIX 'C.2'

Original Scales
Vertical 1:4
Horizontal 40mm to 1hr

THE RANGE OF THE TIDES



(Source: Morton and Miller 1968)

Definitions**Mean Sea Level:**

This is the average level of the sea in all states of oscillation, and is taken as the average level which would exist in the absence of all tidal forces. For use as a datum it is frequently determined in practice by taking the mean of the hourly heights of the tide over a period of at least 19 years.

Mean Tide Level:

This is the average of all high and low water heights sometimes referred to as half tide level.

Mean High Water Springs and Mean Low Water Springs:

The average of the heights of each pair of successive high waters, and of each pair of successive low waters during that period of about 24 hours in each semi-lunation (approximately every 14 days), when the range of the tide is greatest.

Mean High Water Neaps and Mean Low Water Neaps:

The average of the heights of each pair of successive high waters, and each pair of successive low waters respectively during that period of about 24 hours in each semi-lunation, when the range of the tide is least.

Mean High Water and **Mean Low Water** are the average heights of all high water levels and all low water levels respectively.

High Water Mark at Ordinary Tides:

This term is used in the Crown Grants Act 1908 to describe the limit of the seaward boundary of land titles and in practice has been accepted as coinciding with the definition of Mean High Water above.

Ordinary Spring Tides:

This term is used in the Harbours Act 1950 and the Conservation Act 1987 and has in practice been accepted as coinciding with the definition of Mean High Water Springs above.

Relationships Between the above Definitions:

Mean sea level values supplied by Harbour Boards are quite often Mean Tide levels. However the difference is generally quite small provided values are based on observations over 19 years and can be safely ignored for most practical purposes. At Waitemata and Wellington Harbour gauges, mean tide level is less than 1cm above mean sea level (Lee, 1953). Mean tide level derived from only a few years may however differ from a long term mean sea level by several centimetres.

Mean high water does not necessarily coincide with the mean of MHWS and MHWN but can be accepted to agree within a few centimetres, until more reliable figures are provided.

3. Definitions

STANDARD PORTS: Standard Ports are those for which tidal predictions are provided in the form of daily tables giving the times and heights of high and low waters. All times in these tables are in New Zealand Standard Time. Predicted Heights are in metres and are based on the Chart Datum of the largest scale Chart of the place.

SECONDARY PORTS: Secondary ports are those for which daily predictions are not provided. Data sufficient for calculating times and heights at these ports and places are given after the Standard Port predictions in this book. Secondary Ports are grouped under Standard Ports with a similar tidal pattern.

MEAN SEA LEVEL (M.S.L.): The average level of the sea surface over a long period, preferably 18.6 years, or the average level which would exist in the absence of tides.

MEAN HIGH WATER SPRINGS (M.H.W.S.) AND MEAN LOW WATER SPRINGS (M.L.W.S.): The average of the levels of each pair of successive high waters, and of each pair of successive low waters, during that period of about 24 hours in each semi-lunation (approximately every 14 days), when the range of the tide is greatest.

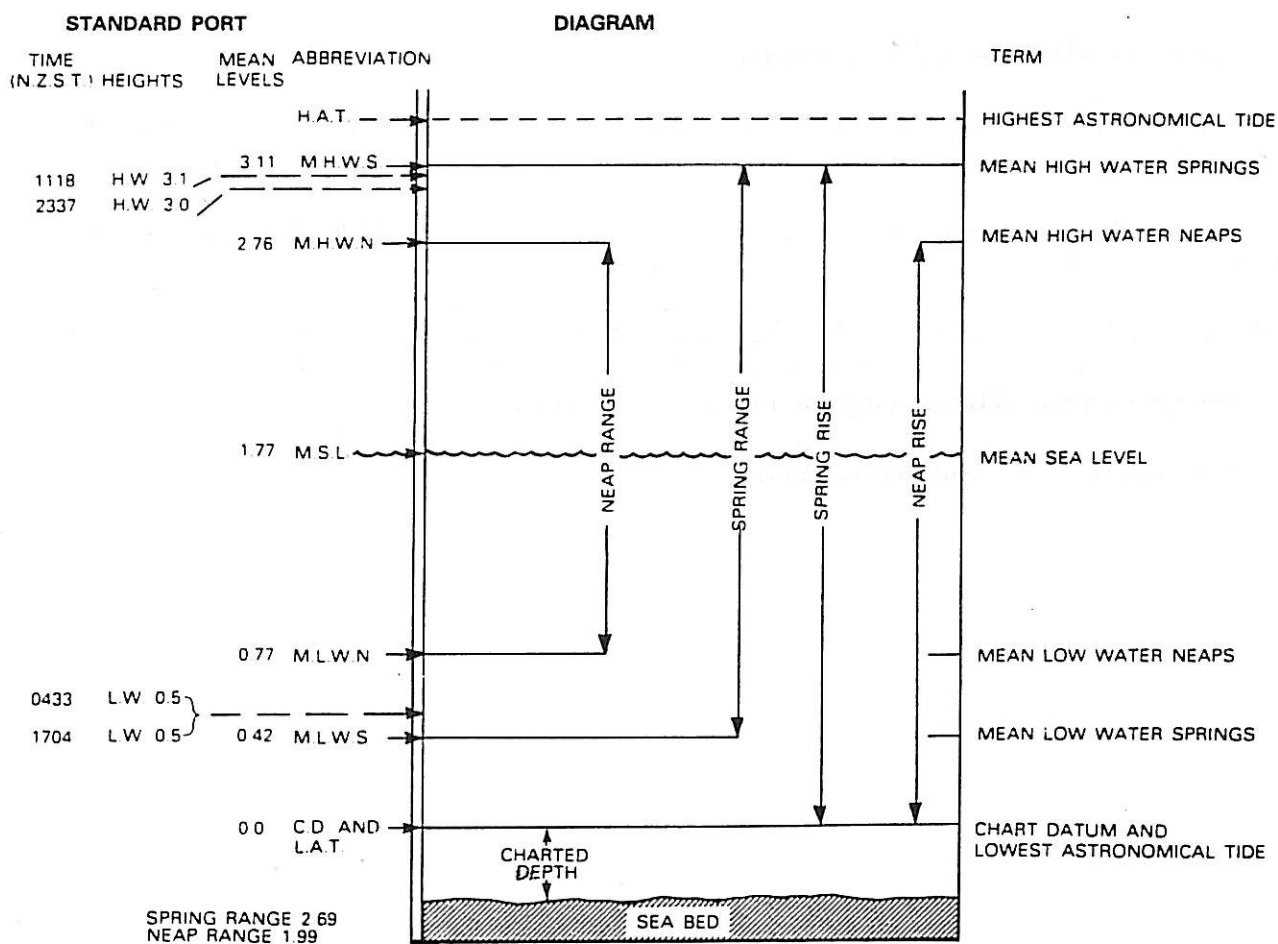
MEAN HIGH WATER NEAPS (M.H.W.N.) AND MEAN LOW WATER NEAPS (M.L.W.N.): The average of the levels of each pair of successive high waters, and of each pair of successive low waters, during that period of about 24 hours in each semi-lunation, when the range of the tide is least.

CHART DATUM (CD): A water level so low that the tide will but seldom fall below it. When meteorological conditions are such that sea level is lowered, the tide will fall below the predicted low water heights, and at a place where Chart Datum is at a comparatively high level, the actual depths at or near low water may be considerably less than charted.

HIGHEST AND LOWEST ASTRONOMICAL TIDE (H.A.T. AND L.A.T.): The highest and lowest tidal levels which can be predicted to occur under average meteorological conditions. Modern chart datums are set at the approximate level of Lowest Astronomical Tide (L.A.T.) and Tide Tables list the predicted height of Tide above Chart Datum. It should be noted that water level may fall below the level of L.A.T. if abnormal meteorological conditions are experienced.

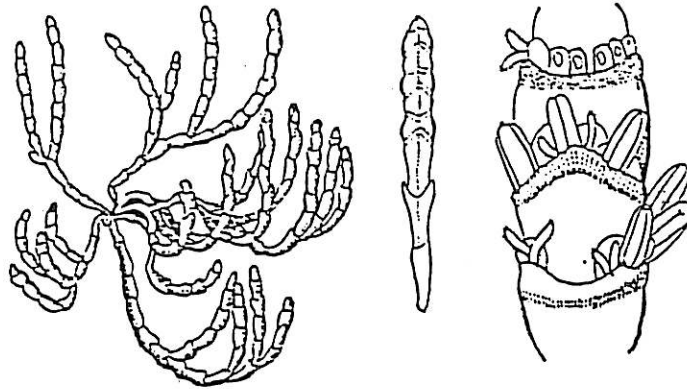
DIAGRAM TO ILLUSTRATE THE MEANING AND APPLICATION OF THE TERMS DEFINED ABOVE

1. The diagrammatic illustration is on the right.
2. On the left, the tidal heights for a port are shown and these are related to the diagram.



CAUTION: (1) In certain circumstances a tide at low water may fall below the level of Chart Datum thus giving depths less than the charted depth.

(2) The times predicted for high and low water can be affected by changes in the force and direction of the wind and by changes in the barometric pressure. It will generally be found that the heights are increased with on-shore and decreased with off-shore winds. Sea level rises as the barometer falls, and vice versa, approximately 1 cm for each millibar.



SALICORNIA AUSTRALIS (Glasswort)

The name comes from the old-time use of the soda-rich ashes of plants of this genus in glass making.

The jointed stems are often reddish and grow to a foot long from rock crevices or on wide areas of salty flats.

Salicornia is found throughout New Zealand and the Chatham Islands. It does best on shell banks or muddy shingle as it needs good aeration and drainage. On raised banks in tidal estuaries it forms broad carpets, mauve to coppery red in distant view.

(Source: Moore, L.B. 1963, Morton and Miller 1968)

APPENDIX "G"

LEVELLING DATUMS			SOUNDING DATUMS		
	feet	metres	metres	feet	
Lands and Survey B.M. CC.63	10.767	3.288	5.031	16.507	
A.H.B. B.M. Lead Arrow	10.707	3.263	5.005	16.42	
	7.38	2.25	3.99	13.10	Highest recorded tide 26.3.1936
Old Auckland Tramway Datum	5.76	1.756	3.5	11.5	ENGINEERING HIGH WATER
	4.58	1.40	3.14	10.30	(for design purposes) MEAN HIGH WATER SPRINGS (Note 1)
Mean High Water	4.30	1.31	3.05	10.01	
Old A.R.A. & A.C.C. Datum	3.90	1.189			
	3.67	1.12	2.86	9.38	MEAN HIGH WATER NEAPS (Note 1)
	0.09	0.03	1.77	5.81	MEAN SEA LEVEL (Note 2)
MEAN SEA LEVEL (1990-1946)	0.03	0.009	1.753	5.75	
L & S Auckland Datum 1946	0.00	0.000	1.743	5.72	
COMMON DATUM 1 JAN 1973					
	-3.03	-0.92	0.82	2.69	MEAN LOW WATER NEAPS (Note 1)
	-3.8	-1.1	0.6	2.0	MEAN LOW WATER
	-4.41	-1.34	0.40	1.31	MEAN LOW WATER SPRINGS (Note 1)
Zero on Automatic tide gauge	-5.72	-1.743	0.000	0.00	A.H.B. SOUNDING DATUM
Queen's Wharf 1 January 1973					Navy Dept. <u>CHART DATUM</u>
Old zero on automatic gauge (L.W.S.T.) (Obsolete)	-6.22	-1.896	-0.15	-0.50	Old A.H.B. Sounding Datum
	-6.66	-2.030	-0.29	-0.94	Lowest recorded tide 7.6.1925
Auckland Dock Sill (A.D.S.) (Obsolete)	-9.22	-2.810	-1.067	-3.50	Auckland Dock Sill

NOTES

1. Levels for M.H.W.S., M.H.W.N., M.L.W.N., & M.L.W.S. are from the table of mean levels, 1983 on p.61 of the New Zealand Tide Tables.

2. M.S.L. from p.6 of the N.Z. Tide Tables.

	COMPARISON OF DATUMS WAITEMATA HARBOUR	DRAWN J.H.R.	DRAWING S90/27 Supersedes S90/21
		DATE JAN 1983	
		SCALE	

APPENDIX "H"

LEVELLING DATUMS	DO NOT SCALE		SOUNDING DATUMS
	metres	metres	
LANDS & SURVEY B.M. C.C. 63	3.289	5.031	
A.H.B. B.M. Lead arrow	3.263	5.005	
	2.25	3.99	Highest recorded tide 26.3.1936
Old Auckland Tramway Datum	1.756	3.5	ENGINEERING HIGH WATER
	1.40	3.14	MEAN HIGH WATER SPRINGS (Note 1)
	1.29	3.03	Mean High Water
Old A.R.A. & A.C.C. Datum	1.189		
	1.06	2.80	MEAN HIGH WATER NEAPS (Note 1)
	0.09	1.83	MEAN SEA LEVEL (Note 2)
MEAN SEA LEVEL (1909-1946)	0.009	1.753	
L & S Auckland Datum 1946	0.000	1.743	
COMMON DATUM 1 Jan 1973			
	-0.89	0.85	MEAN LOW WATER NEAPS (Note 1)
	-1.0	0.7	Mean Low Water
	-1.23	0.51	MEAN LOW WATER SPRINGS (Note 1)
Zero Automatic Tide Gauge	-1.743	0.000	SOUNDING DATUM
Queens Wharf 1 Jan. 1973			CHART DATUM R.N.Z.N.
Old zero automatic tide gauge (L.W.S.T.)	-1.896	-0.15	Old A.H.B. Sounding Datum
	-2.030	-0.29	Lowest recorded tide 7.6.1925
Auckland Dock Sill (A.D.S.) obsolete	-2.810	-1.067	Auckland Dock Sill

NOTES

1. LEVELS FOR M.H.W.S., M.H.W.N., M.L.W.N. & M.L.W.S. are from the table of mean levels 1990 on page 26 of the N.Z. Nautical Almanac.
2. M.S.L. from page 25 of the N.Z. Nautical Almanac.

COMPARISON OF DATUMS WAITEMATA HARBOUR	DRAWN C. TUBBS		SCALE	
	DATE JULY 1990		JOB NO:	
	DRAWING S/90/29		SECTION	SHEET A4
				REV.

REFERENCES

1. Admiralty Tidal Handbook No. 2 - Datums for Hydrographic Surveys.
2. Attorney-General vs Findlay (1919) NZLR 513 GLR 207.
3. Baldwin A.J. - Seaward Coastal Boundaries. NZ Surveyor No. 260 1982.
4. Cole George M. - Tidal Boundary Surveying. Proceedings of the ACSM 37th Annual Meeting. Spring 1977.
 - Evaluation of Various short-term methods for determining Local Tidal Datums. Proceedings of the ACSM 39th Annual Meeting. Spring 1979.
 - Proposed New Method for determining MHW Elevations in Inter-tidal Zones. Papers of ACSM Annual Meeting. Feb. 1981.
5. Coutts B.J. - Mean High Water as a Cadastral Boundary. NZ Surveyor Vol. XXXIII(6) 1987.
6. Grant S.T. and O'Reilly C.T. - A new look at Tidal Datum Transfers. Papers of XVIII F.I.G. Congress Vol. 4 June 1986.
7. Kearns F.J. - Water Boundaries. NZ Surveyor No. 257 1980.
8. Kirk R.M. - Measuring and Monitoring the Coast. NZ Surveyor No. 262 1983
9. Lee L.P. - Mean Sea Level and Mean High Water Mark. NZ Draughtsman's Journal No. 9 Vol. 1 1953.
10. Maddux W.S. - Datum Extrapolation by Simultaneous Comparison of Partial Tidal Cycles. Surveying and Mapping Vol. 42 No. 2 1982.
11. Moore L.B. - Plants of the New Zealand Coast. 1963.
12. Morton J.E. and Miller M. - The New Zealand Sea Shore. Collins 1968.
13. Nicholls S. - Tidal Boundary Delimitation: Some North American perspectives. NZ Surveyor Vol. XXXIII(6) 1987.
14. O'Hargan P.T. - Tidal Datums for Estuarine Research. Papers ACSM 40th Annual Meeting. Spring 1980.
 - Near Shore Tidal Boundary Location - The State of the Art in Florida. Surveying and Mapping Vol. 38 No. 3 1978.

15. Smith K.H. - Queensland's Coastal Land Boundaries. Paper 22nd Aust. Survey Congress - 1980.
16. Weidener J.P. - Surveying the Tidal Boundary. Surveying and Mapping Vol. 39(4) 1979.
17. Young N.A.F. - Tidal Analysis and Implications to Surveying. NZ Surveyor No. 270 1987.
18. New Zealand Nautical Almanac (Published Annually) Ministry of Transport, Wellington.

APPENDIX R. DETERMINATION OF MEAN HIGH-WATER MARK AND MEAN SEA-LEVEL.

Land abutting on tidal waters is bounded by the line of ordinary high-water mark, or, more precisely, the line of mean high water taken over a period of 370 days. On the open seashore mean high-water mark is a contour-line which can be easily determined by a series of tidal observations extending over the above-mentioned period. In the case of tidal estuaries and rivers mean high-water mark usually departs from a level line, and usually requires for its exact determination that similar tidal observations at the extremities and at suitably placed intermediate stations of the boundary to be fixed are available.

Mean sea-level is now used exclusively as the datum for all surveys on land by the Lands and Survey Department. It may be established within a small fraction of a foot by continuous tidal observations for a period of 370 days, and is that surface which the water of the ocean would form if it were not disturbed by the attraction of the sun and moon and the force of the wind. Information regarding the bench-marks connected with the automatic tide-gauges from which the mean sea-level was determined at Auckland, Wellington, Lyttelton, Port Chalmers, Nelson, and Westport, is published in the annual report on the survey operations, 1908-9, by T. Humphries, Surveyor-General.

PRACTICAL DETERMINATION OF MEAN HIGH-WATER MARK.

Where a standard tidal station has been in operation so long that the reading of the mean high tide on the tide-gauge is accurately known, the height of the mean high tide at other places in the vicinity can be deduced sufficiently accurately for the practical determination of high-water mark by reference to the standard station.

On any day if high water of a particular tide agrees with the mean high tide at the standard station, then high water of that tide indicates mean high-water mark along the foreshore at all other localities in the vicinity. As, however, the above agreement is a rare occurrence the high water of a tide at the standard station falls above or below the gauge reading of mean high tide by an amount which can be ascertained by observation. At any other place of observation the difference between high water of the above tide and mean high-water mark can be obtained by the following rule: As the range of the tide at the standard station is to the range of the same tide at place of observation, so is the difference between high water and mean high tide at the standard station to the local difference between observed and mean high tide.

Let R and D represent the range of the tide and the difference between high water and mean high tide respectively at the standard station on certain day; R' and D' the corresponding quantities of the same tide at the place of observation; then by the above-stated rule

$$\begin{aligned} R : R' &= D : D' \\ \text{therefore } D' &= D \frac{R'}{R} \end{aligned}$$

The quantity thus found applied to the local reading of high tide gives the height of mean high-water mark. The signs of D and D' will be positive or negative according as the observations are taken about the time of spring or neap tide, respectively.

Having thus ascertained mean high-water mark, an easy mode of defining it on the foreshore of the area to be surveyed is to wait until the level of the water reaches the reading of mean high tide on the tide pole, and then have assistants placed to insert stakes along the contour of the water-line on the edge of the foreshore, which may afterwards be connected to the traverse.

The above method of defining mean high-water mark is only applicable to sheltered harbours and inlets during favourable weather conditions when there is no swell bearing along the coast-line.

In most cases, after determining the height of mean high tide at a station, it will be necessary to use the theodolite or level to run the line of mean high-water mark along the edge of the foreshore. When the survey is extensive the line of mean high tide is not on a horizontal surface; then several suitably placed stations may be required at which the tidal observations to determine the mean high tide are made and the work done in sections.

At the following standard tidal stations the mean high tide has been determined from tide-gauge records and connected to bench-marks; Auckland, 9.73 ft.; Wellington, 4.64 ft.; Bluff, 8.27 ft.; Westport, 8.60 ft. The above figures are the readings on the tide-pole corresponding to mean high-water mark.

And the Surveyors' Board doth hereby declare that such amendments shall come into force as from the date of gazetting hereof.

Made at Wellington this 8th day of April, 1925, at a meeting of the Surveyors' Board at which the Surveyor-General was present.

W. T. NEILL,
Surveyor-General and Chairman of Surveyors' Board.
M. CROMPTON-SMITH,
Secretary of Surveyors' Board.

Approved in Council, this 1st day of June, 1925.

F. D. THOMSON,
Clerk of the Executive Council.
CHARLES FERGUSON, (Governor-General).

By Authority: W. A. G. SKINNER, Government Printer, Wellington. — 1925.

Note: The term "standard tidal station" referred to is equivalent to the "control station" in Sections 4.0 and 5.1.