TIDE LEVELS

AND

DATUM PLANES

ON THE

PACIFIC COAST OF CANADA

From determinations by the Tidal and Current Survey
up to the year 1923

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GENERAL INDEX

GEOGRAPHICAL REFERENCES AND DUPLICATED NAMES; the Data being included with the Tidal Stations referred to. (Arranged alphabetically.)

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By W. Bell Dawson, M.A., D.Sc., M.Inst.C.E., F.R.S.C., Superintendent of the Tidal and Current Survey of Canada

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In any tidal observations, the two essentials are the correct time and a plane of reference for height; as these are the co-ordinates of the tidal curve. The main object of the Tidal Survey, as a branch of the Marine Department, is to deal with the time of the tide; since this is the matter of chief importance to navigation. In the strong tidal currents of the Pacific coast, it is information as to the time of slack water that is most wanted by the mariner, as well as for water transportation generally in the coal and lumber industries. To determine reliable levels, which can only be obtained from tidal observations, is very important, however; and much trouble has been taken to secure them, and to place them on a satisfactory basis. They are essential in harbours for construction purposes and for dredging; in marine surveys, a Low-water datum is required; and a correct determination of Mean Sea-level is needed as a basis for extended levelling, as well as for contoured maps.

The importance of publishing such results is emphasized by what has occurred in British Columbia. Bench-marks, carefully established, are now useless because the record of their elevations is lost through fire; the loss of level notes or the destruction of a Primary Bench-mark leaves elaborate surveys with uncertainty in their datum planes, which it is extremely difficult to re-determine satisfactorily. By publication, these records might have been preserved; and a large amount of good work, and subsequent trouble and expense in replacing it, would have been saved.

It has therefore seemed desirable to include with the tide levels, the data for the Low-water datum established during the British Admiralty surveys on these coasts, as well as for the chart work of the Canadian Hydrographic Survey.

Characteristics of the tide.—In all parts of the world, the tides are found to accord with the varying movements and distances of the moon and the sun. In the North Atlantic, where they were first studied, it happens that they are chiefly influenced by the moon's phases. It was thus supposed that the primary characteristic of all tides was a marked alternation in height from Springs to Neaps in the period of the synodic month.

The tide of the Pacific, however, can best be described as a declination tide. Its leading feature is a pronounced diurnal inequality in time and height; which accords with the declination of the moon and this is also subject to an annual variation with the change in the declination of the sun. The period in which the diurnal inequality recurs is the tropical or declination-month, of 27·3 days; which is shorter than the synodic month of 29·5 days, and gradually falls back through its period in successive months.

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This inequality is greatest when the moon is at its maximum declination north or south of the equator; and when crossing the equator it disappears and the two tides of the day become equal in height. The effect of the sun's declination is also large relatively to the lunar effect; and consequently there is a marked difference in height and range between the solstice when the effect is greatest, and the equinox when the solar effect disappears. The extreme tides of the year necessarily occur at the nearest point to the solstices at which the moon reaches its maximum declination.

A tide of this character is apt to be termed irregular by the mariner; as the tropical or declination-month, which is its governing period, is less familiar and less noticeable than the synodic month of the moon's phases. It is evident, however, that this tide is perfectly astronomical; and when reduced by harmonic analysis, its prediction is just as definite as for any other type of tide.

The Spring and Neap tides are thus reduced to a secondary feature which is often obscured by the stronger characteristics of the tide. They can still be distinguished on the open coast however; on the West side of Vancouver island and along the northern coast to Prince Rupert. But in the Strait of Fuca and the region of the Strait of Georgia, where many of the more important harbours are situated, the declinational features are dominant.

In the Strait of Fuca, at Victoria and Esquimalt, the tide frequently becomes diurnal, with only one high water and one low water in the 24 hours of the day. In the Strait of Georgia, the high waters are nearly at the same level whereas the two low waters of the day may have a large difference in height. The diurnal inequality thus influences low water much more than high water; and consequently the height of low water is extremely variable, so that care and system is specially needful in establishing a Low-water datum. On the other hand in dealing with time values, low water is the strongly accentuated tide, and the time-difference at low water between one locality and another, is very constant; whereas the smaller variation in level at high water, makes the time-values for high water less definite.

In this type of tide, in which the low-water level is so susceptible to inequality, there is also an appreciable variation during the 19-year lunar cycle. In this period, the range in the moon's declination varies from 18 degrees north and south of the equator, in some years, to 28 degrees north and south in other years. The variation in the average level of lower Low Water in the Strait of Georgia from this cause, is three-quarter foot; which is too large to ignore when different years are compared. In determining the Low-water datum or comparing extreme tides, the position of the particular year in the cycle may therefore have to be taken into account.

Tide gauge.—A registering instrument which gives a continuous tide curve, is highly desirable if not essential, in dealing with this type of tide; for with observations in the daytime only, there is no certainty that the highest and lowest tides of the day are obtained. The instrument is set to accord with a tide scale; but it is not assumed that the accord is perfect. Comparative readings for height are taken twice a day, and any difference between the registering instrument and the scale is allowed for in the reduction of the observations. A similar system of comparison enables the time to be kept correctly.

Tide scale.—The zero of the scale is set below the level of the lowest low water, so that the extremes may be recorded on the instrument which is set with it. It is divided into feet and tenths; and for accurate reading, the time at which the water level reaches one of the divisions is noted, rather than making an estimate of fractional parts. A wooden scale with painted divisions does not last long; as in these warm waters, green weed coats the scale, and continual cleaning effaces the paint even if well varnished. An iron scale, enamelled back and front to prevent rust, and with divisions in black and white enamel, made up in lengths of five feet, has proved entirely satisfactory. The level of the zero of the scale is determined relatively to a permanent Bench-mark; and any change, because of accident or settlement, can thus be detected and allowed for.

Bench-mark.—A Bench-mark is always placed near the tide gauge, for reference in the observations, and to record the tide levels permanently. In the larger harbours, its elevation can be determined relatively to some existing datum. But as a rule, an elevation of 100·00 feet is assumed for the Bench-mark, which obviates any negative values in the tide levels.

Low-water datum.—For a primary determination of this datum, a complete year of tidal observations is required. The lowest Low Water in each month is taken, the average level of these is found, and the datum is made slightly lower than this average level. This is not too extreme, but is low enough to leave only a few negative Low Waters in the Tide Tables. Some of the older datums in British Columbia are in accord with this method of determination.

With a shorter series of observations, the Low-water datum can be determined in relation to a Reference station by one of the methods herein described. The early datums, used for the reduction of soundings during the Admiralty chart surveys with the "Egeria", have been carefully checked by the methods indicated; and nearly all of them have been accepted by this Survey as satisfactory .

It is important that the Low-water datum should have the same relation to Low Water throughout any region; as otherwise the rise of the tide, which is measured from the datum, would not be consistent. It is also highly desirable to use the same datum level for the chart soundings and for the zero level for the height of the tide in the Tide Tables; so that these may be correlated with each other.

It is well to have a good series of observations as a basis for the Low-water datum at a new locality. When decided upon, it becomes known as a reading on the face of the tide scale. It can then be ruled as a horizontal line across the face of each tide diagram, with allowance for the comparisons. This ruled line is thus at a truly constant elevation in relation to the tide curves, and with reference to the Bench-mark. In this system there are three advantages: (1) A definite elevation is known on each diagram, which makes the tidal record self sufficient and no longer dependent on the setting of a tide scale which may be disturbed or destroyed. (2) The height of the tide can be scaled directly from the datum line, which is true and reliable, for any tidal purpose. (3) Tide levels when determined, can readily be reduced to elevations with direct relation to the Bench-mark. They thus finally become independent of both the tide scale and the Low-water datum.

Tide levels.—It is clear that ultimately the Low-water datum as well as all tide levels, such as extreme tides and average levels, depend on the preservation of the local Bench-mark. For greater security, the Bench-marks have been duplicated at important localities such as the heads of inlets, which may become railway terminals. The best solution would be to have these local Bench-marks connected with the general system of levelling; which may be possible even on the Pacific coast, except in the case of islands.

It may be noted however, that if the Bench-mark should be destroyed, the rise of the tide and extreme tide levels still remain known in relation to the Low-water datum. It may be possible also to re-determine this datum, with fair approximation, by comparison with the Reference station in the region.

In the tide levels here given, the elevation of the zero of the tide scale, as used at the various localities, is often omitted as unnecessary; because the scale has served its purpose and is not longer indispensable to the reduction of the observations.

At many localities, the data now published may give little more than the relation of the Low-water datum to the Bench-mark. But wherever tidal observations have been obtained by the Tidal Survey with a registering tide gauge, any other tide levels required can be worked out at any time. Additional information, such as extreme tides or the average level of any class of tides, can always be reduced to an elevation for engineering purposes.

Mean Sea-level.—This level is best determined from the hourly ordinates of the tide, measured from the Low-water datum, which represents a constant elevation from year to year. This is a more accurate and definite method, than to take the Half-tide level between high and low water, especially in a region where the inequalities are so large. The value for Mean Sea-level is thus determined primarily as a height above the datum, in each year of observation; and it can then be brought to an elevation relatively to a Bench-mark.

Such determinations have been made at three points in the vicinity of Vancouver, and at three other localities on the mainland between Vancouver and Alaska. Also on Vancouver island, at Victoria in the south, at the northern end of the island, and at a locality on the middle of the West coast. The values in the leading harbours and at the Reference tidal stations, are based on 10 to 16 complete years of observations; and at three of the localities indicated, on three to seven years of observations; which makes them all reliably accurate. The Geodetic Survey of Canada has made use of the determination at Vancouver for precise levels in southern British Columbia; and those in the north and on Vancouver island are available when required. Mean Sea-level will no doubt eventually become the general datum level for the whole of Canada.

Methods of Reduction

Range and ratio.—In dealing with the declinational type of tide, the best procedure at any secondary tidal station, is first to determine the ratio of the range at the locality to the Reference station in the region. The rise at the two places cannot be used for comparison, as the low-water level from which the rise is measured, is itself so variable and undefined at the outset. A ratio is

also required in determining the Low-water datum. This datum should have a similar relation to low water at all localities throughout the region; and the best comparison-level that can be used in determining the datum is the average level of lower Low-water. The primary datum at the Reference station was originally determined from the level of the lowest low water that occurred in each month throughout the year, by taking the average of these lowest levels. This being accepted as the zero level for the Tide Tables, all other localities in the region must be brought into relation with it. When the datum is thus consistent, the rise of the tide will also be consistent throughout the region; and the rise at any locality can be found by applying a ratio to the height in the Tide Tables. The same datum is also used for the chart soundings, so that the rise of the tide can be added to these to find the total depth available.

It has been found that the best range to adopt for comparative purposes, is the difference in level between average lower Low Water and average higher High Water. For convenience, this may be termed the Central Range. The average levels should be computed from one lunar month; and if the observations at a new locality are simultaneous with the Reference station, any one month can be used as a basis for determining the Central Range and the ratio, as well as the datum. This may be necessary for a chart survey, when a Low-water datum is required as soon as possible; but it is highly desirable to bring the values to an annual average, to make them comparative with other localities.

Annual averages.—The annual average is the mean of the values found for a month at the solstice and a month at the equinox. If a year's observations are available, both the solstices and both the equinoxes can be obtained. The month taken, is 29 days; as this is a compromise between the synodic month (29½ days) and the declinational month (27½ days). The solsticial month is a period of 29 days with the solstice as its central day; being thus from June 7 to July 5 inclusive, or from December 7 to January 4. Similarly, the equinoxial month has the equinox for its central day, and is from September 7 to October 5 inclusive, or from March 7 to April 4. Any one of these periods takes the lunar variations, during the course of the month, correctly into account.

The values thus found, serve a double purpose; as the height of average lower Low Water is the reference level by which the datum is determined; and the height of average High Water, which is also computed, defines the mean rise of the tide above datum. The following values for Sand Heads, the Reference station in the Strait of Georgia, will exemplify the method indicated, and show also the amount of variation in that strait. They are from observations for a mean year in the 19-year lunar cycle (1899 to 1900) midway between the extreme years in the range of the moon's declination; and all heights are from the Low-water datum, as established for the Tide Tables.

	Feet	Annual average
Higher H. W. Mean of Solsticial months	13·37	12·78
" " Equinoxial months	12·19	
Lower L. W. Mean of Solsticial months	2·43	2·81
" " Equinoxial months	3·20	
Central Range; in Mean year of cycle		9·97

Variation during the lunar cycle.—Three selected years for Sand Heads, from observations and predictions in the Tide Tables, at the maximum, mean and minimum of the 19-year lunar cycle, were reduced; to obtain values for the average of all High Waters, higher High Waters, and lower Low Waters; and from these the Central Range was deduced. By thus determining the variation during the cycle, values became available for the determination of the ratio and the datum at any locality where observations were obtained in any year. This was specially serviceable in dealing with observations during the Admiralty chart surveys; and others which were not simultaneous with the Reference station.

The leading results are here given. The years are 1904-05 at minimum, 1899-1900 at mean, and 1912-13 at maximum. Each year is independently computed (except lower Low Water for the year of mean range in declination, which is averaged with partial results from two other years) and each value is brought to its annual average for the year, by the method shown above.

Position in 19-year Cycle.	Central Range.	Lower L.W.
Year of minimum range in the moon's declination.....	9·53	3·03
Year of mean range.....	9·97	2·66
Year of maximum range in the moon's declination.....	10·40	2·33

Although average lower Low Water is thus 2½ or 3 feet above datum, it is to be noted that in each of these years there are tides that fall to datum or below it.

Determination of datum.—At a new locality, a tide scale is placed with its zero well below the lowest low water, so that all tides may be recorded on the registering instrument set with it. In the Admiralty surveys, the zero was sometimes as much as 5 or even 8 feet below the datum adopted. The average height of lower Low Water above the zero is determined from the observations as a reading on the face of the scale. This can best be done at the end of the season, or after a full year of observations is obtained; unless there is need to decide on a datum at once after the first month. The average height of higher High Water is determined similarly, as a reading on the scale. The difference between these is the Central Range, which can thus be found independently of any datum. These values should all be determined from a solsticial and equinoxial month, to bring them to an annual average, as explained.

These average heights are computed for the Reference station in the same periods; either from simultaneous observations or from the heights in the Tide Tables. The procedure is then as follows:—

From the Central Range at the new locality and at the Reference station, find the ratio of the ranges, as explained. Then find the average height of lower Low Water above datum at the Reference station, for the same period as at the new locality if observations are simultaneous, or under similar conditions; and multiply this height by the ratio as found. The result is the difference of level from average lower Low Water to the truly corresponding datum at the locality. By subtracting this difference from the scale reading found for lower

Low Water, the true Low-water datum at the locality is found as a reading on the face of the tide scale.

The methods here explained are exemplified by the computation which is given for the ratio at Telegraph harbour herein, and the Low-water datum at Union; and it will therefore be unnecessary to give further illustrations in figures. It is thus also clear that the method enables any Low-water datum, already existing, to be checked to see whether it accords truly with the datum at the Reference station, or with other localities in the region.

Datum elsewhere than in the Strait of Georgia.—Where the Low-water level does not have such an extreme variation as in the Strait of Georgia, a correct Low-water datum at a new locality may be found by a simpler procedure, as follows:—

Take the readings of a few low waters on the tide scale at the locality, choosing the lowest possible; and deduct from these the height of the same low waters at the Reference station for the region, as given in the Tide Tables. The average reading on the tide scale as thus found will be the datum at the locality, provided that the range of the tide is nearly the same. If the proportionate range is appreciably different, the heights of low water at the Reference station should be multiplied by the ratio for the locality, before being deducted from the Low-water readings.

The series of localities along the more open coasts of British Columbia, for which the rise is given in the Tide Tables, are now sufficient to enable the ratio to be found at any new settlement in relation to the Reference station for its region. This ratio is applicable to the small difference of level between the datum and low water at the Reference station, so that an approximate value for the ratio will give a closely correct result.

Datum Planes at Victoria

At Victoria and Esquimalt, the planes of reference were formerly in much confusion, no less than eight datum planes existing; and as most of these were defined by some reference to the tide, such as high water, mean sea-level or low water, it appeared in place for the Tidal Survey to make the endeavour to correlate these into one system. The Superintendent of the Survey took this up in 1905, when he had the opportunity to examine original plans and notes in various offices in Victoria, and to discuss matters personally with the engineers who were conversant with the questions at issue. He also had special levels run for three and a half miles, to connect Esquimalt with Victoria. It will make the matter clear to follow the chronological order; and for all practical purposes, it was found that anything previous to 1880 could be disregarded.

In correlating the various datum planes with each other, it could not be assumed that the tide levels referred to, such as high water and low water, were identical in each case; and the various reference levels are thus quite indefinite unless fixed by a Bench-mark. There are several Bench-marks in Victoria for which elevations are known with reference to more than one datum; but the resulting difference instead of being constant, was found to vary within the limits of an inch or two, and in some cases the relation has had to be determined

by averaging such differences. But there are four of the datum planes which are referred to an individual Bench-mark, and these four are the most important from a tidal point of view. All the planes of reference at Esquimalt have also been connected with this same Bench-mark, by the levels of the Tidal Survey; and in a later year, levels connecting Esquimalt with Victoria were again run by the Geological Survey. The discrepancy between the two series of levels was 0·06 foot, and a mean of the two series is adopted in the final values.

The Bench-mark referred to, is at the northeast corner of Wharf and Fort streets in Victoria, which is near the water front. The building at this corner, occupied in 1905 by the Hamilton Powder Company's offices, has a sandstone foundation below the brickwork; and the top course of this foundation, which is nearly on the level with the sidewalk, forms the door sills on the Wharf street front of the building. The point used as a Bench-mark is the surface of the sandstone, below the brickwork, at the street corner, usually termed the plinth; or else the southern end of the first door sill, which is two and a half feet from the corner. The level of these two points is identical. For brevity, we may term this the Primary Bench-mark.

Hudson's Bay Company datum.—This is chiefly of importance because used as the basis of a contoured plan of Victoria made by Mr. G. Hargreaves in 1883. The datum is defined as 100 feet below an assumed elevation for high water. This is in itself quite indefinite; but in making the plan, Mr. Hargreaves checked all his levels back to the Primary Bench-mark already described; its elevation being 127·11 feet above the Hudson's Bay datum. This value is marked on the original plan in the City Hall; and it serves to fix the datum in elevation.

City datum for Victoria.—This datum was established by Mr. E. A. Wilmot, when laying out a sewerage system for the city in 1890 to 1892. It was originally known as the City Sewer datum; and it was adopted by the City council about 1893, as the City datum for Victoria, while Mr. Wilmot was City Engineer. Why the original Hudson's Bay datum was not adopted in place of this, is not clear; as it differs only a few inches from it. Mr. Hargreaves' contoured plan has since been extended with reference to the City datum; and in the list of Bench-marks at the City Hall, the entries are not infrequently for the old datum, especially in some districts; so that much caution is required in making use of the elevations given.

This datum, like the Hudson's Bay datum, is based on an assumed elevation of 100·00 feet for high water; but the levels assumed for high water were determined independently and do not correspond. The datum itself is fixed, however, with reference to the Primary Bench-mark, at the corner of Wharf and Fort streets; for which the elevation above this datum is 126·76. This figure is taken from Mr. Wilmot's original level notes; and it is so entered also in the list of City Bench-marks.

There are a few other City Bench-marks for which elevations are still to be found with reference to the Hudson's Bay datum. From the comparisons they afford, the difference of 0·35 foot is considered by the Engineering staff at the City Hall to be the most accurate that can be arrived at; and this value is the same as the difference given by the Primary Bench-mark.

Royal Engineers' datum at Victoria.—This datum is defined as Mean Sea-level. Its relation to the City datum has been obtained from seven of the Bench-marks established in Victoria by the Royal Engineers, for which elevations were determined by Mr. Wilmot in his sewerage levels. The seven differences are as follows: 3·88, 3·88, 3·77, 3·70, 3·74, 3·76 and 3·75 feet. The resulting mean value is 3·78 feet below elevation 100·00; which places the Royal Engineers' datum at 96·22 feet above the City datum. The reason for the considerable variation in the difference is not evident. Mr. Wilmot's levels are always carefully checked, no total closing error of more than 0·03 being found in his notes; and the residual error would be half of this. It is equally difficult to admit the error to be actual, in Bench-marks established by the Royal Engineers. In any case, the resulting mean value must be very close to the truth.

The question of the true elevation of Mean Sea-level, we will discuss later, in the light of other determinations.

Public Works datum.—This is a Low-water datum established by Mr. F. C. Gamble while Resident Engineer of Public Works; and although now superseded, it has its importance because of its relation to the early charts of Victoria harbour; and it was also the datum of tidal observations taken by this department from 1893 until May, 1897, when the Public Works office was removed to New Westminster. It was thought to be most definitely fixed, with reference to a series of Bench-marks around the harbour; but unfortunately all record of these was lost by the destruction of the Public Works documents in the fire at New Westminster in September, 1898. The persevering efforts made to re-establish this datum were without result until a clue was obtained in 1905.

The Public Works datum was originally the zero of a tide scale set by Mr. Gamble to coincide with 2 feet 8 inches on a scale on the Hudson's Bay Company's wharf; this being said to be the lowest level of low water which had been noted. The zero on the new scale as thus set, was taken to represent the low-water mark at Spring tides; and 9 feet on the scale, to represent high water at Spring tides; as explained in a report by Mr. Gamble to his department in August, 1894.

When Mr. Wilmot was establishing the City Sewer datum for Victoria in January, 1891, he accepted the level of 9 feet on the Public Works tide scale, as high water at Spring tides; and he took this as elevation 100·00 feet for the City Sewer datum. The elevation of the zero of the Public Works tide scale is thus 91·00 feet above the City datum; and also according to Mr. Wilmot's original level notes, the elevation, above the zero of the scale, of the standard Bench-mark at the corner of Wharf and Fort streets, is 35·76 feet; which affords its elevation above the City datum as already cited. These correlations were brought to light in 1905, with the collaboration of the Superintendent of Tidal Surveys when in British Columbia in that year.

The early chart of Victoria harbour, issued in 1896, was made from two sources; the outer harbour being from a survey by Lieutenant B. M. Chambers, R.N. It has been ascertained that a plan of the inner harbour was made before 1895 by Mr. P. Summerfield, who was employed by Mr. Gamble to do so; and this must have existed when the chart of 1896 was compiled. From a careful correlation of this material, it appears that the plane of reference for the sound

ings in the inner harbour on these early charts, was the Public Works datum; of which the elevation was definitely ascertained in 1905, as explained.

Tidal Survey datum, and Chart datum.—This is the Low-water datum which is used for the height of the tide in the Tide Tables, since these were first published for Victoria. After the early tidal observations obtained by the Public Works Department, the next observations were taken by Mr. F. N. Denison, of the Meteorological Service, beginning in 1900. They were obtained with a registering tide gauge of large scale, placed on the wharf at the foot of Broughton street; to investigate the relation between the secondary tidal undulations and weather conditions. At that date, the Public Works tide scale no longer existed, and all records regarding the elevation of the datum had been lost in the fire of 1898. On consultation with Mr. Gamble and Mr. Worsfold of that department, a plane of reference was adopted to correspond as nearly as might be with the former Public Works datum. Much trouble was also taken to obtain an elevation for the datum by comparing the new tidal record with the chart soundings; and with this object special soundings were taken in the harbour on level shoals. Simultaneous observations of the water level at Victoria and Esquimalt were also made, in the hope of obtaining a connection there.

This illustrates the difficulty of re-establishing a datum when it is lost; and it was essential at the time to have a datum for reference, not only for the tidal observations but also for dredging operations in the harbour. When the true elevation of the Public Works datum was discovered in 1905, as already explained, it was found that the new datum of Mr. Denison's observations was distinctly lower than the former one, being at 90·40 feet above the City datum. It was thought best, however, to adopt it as the datum for Tidal Survey purposes; since it corresponded well with the actual level of low water, and it was already in use for dredging which was in progress. It had also been cited by Mr. Thos. C. Sorby, on the plan of Victoria harbour which he compiled and published in 1904. It was thus undesirable to make another change; and it is now accepted generally as the datum for Victoria, and used for the more recent Admiralty charts of Victoria harbour.

For the first few years from 1900, when the tidal observations were begun, the datum was merely defined by a measurement vertically downward from a marked point on the wharf flooring near the tide gauge; and was liable to be lost if any change in the timberwork or any repair was made. Steps were therefore taken by the Tidal Survey in 1905 to establish the datum permanently with reference to a Bench-mark, which was set in the rock near the tide gauge, and was connected by instrumental levelling with the Primary Bench-mark on Wharf street; the elevations being given below. All the earlier datum planes in Victoria were thus brought into true relation with the tide levels which can now be deduced from the long series of observations since 1900.

The first Tide Tables for Victoria were published in 1901, based on an analysis of the early Public Works observations, corrected to the datum adopted by the Tidal Survey. An additional year of record was obtained from Mr. Denison in 1904; and from 1909 to the present time (1923) he has continued

the observations under the direction of the Tidal Survey, with assistance from the Public Works Department in maintaining the levels in a truly constant relation to the datum adopted from the beginning of the observations.

Bench-marks.—The Tidal Survey had placed two Bench-marks to which all tide levels are referred; and these, with the Primary Bench-mark, are described as follows:—

Tidal Survey Bench-mark of 1905.—At the rear of the old Custom House building on Wharf street at the foot of Broughton street near the tide gauge. The top of a brass bolt drilled vertically into the granite rock, at 16 feet from the northwest corner of the building, with the letters " B.M." cut beside it on the sloping surface of the rock. Elevation above the Tidal Survey datum, or zero of the tide tables, 15·40 feet.

Primary Bench-mark.—On the building at the northeast corner of Wharf and Fort streets, occupied by the Hamilton Powder Company's offices. The top of the sandstone foundation below the brickwork, at the street corner, nearly on a level with the sidewalk. The surface of the same course of sandstone forms the door sills along the Wharf street front of the building. The southern end of the door sill next the corner, is used as a City Bench-mark. Its level is identical with the point above described. Elevation above the Tidal Survey datum, 36·36 feet; and above the Victoria City datum, 126·76 feet.

Tidal Survey Bench-mark of 1919.—For greater convenience in reference, a Bench-mark was placed on the Post Office building, described as follows: A brass bolt set horizontally into the champfered course of the foundation; in the angle formed by the west side of the projection on the frontage of the building on Courtenay street. Elevation, 134·36 feet.

This datum is thus 9·60 feet below the level for high water, which was taken as 9 feet on the tide scale placed by the Public Works Department; and which was made 100·00 feet in establishing the City datum. The Tidal Survey datum is thus at elevation 90·40 feet above the City datum.

The datum thus established has now been adopted by the Public Works Department as well as for the harbour chart; and also by the Hydrographic Survey as the Low-water datum for the Victoria region.

Geological Survey datum.—For the contoured map of the southern end of Vancouver island, begun in 1909 by the Geological Survey, the datum adopted was Mean Sea-level as determined by the Tidal Survey at Victoria from the first three years of tidal observations obtained. The elevation resulting was 96·68 feet above the Victoria City datum, which was communicated to Mr. R. H. Chapman of that Survey. The Geological Survey levels extended as far as Sidney, and served to connect the tide levels there with Victoria.

High-water level.—In British Columbia as well as some other provinces, the high-water line is the legal boundary of properties, whether farms or city lots, which front on the sea. There is seldom however, any physical definition of what high water is; although it appears to be assumed that it is the highest ordinary level to which the tide rises, apart from storm tides when the water may be driven unusually far in. The high-water line may also be considered as the limit of jurisdiction of Harbour Commissioners in the various ports. Its correct determination is thus a matter of importance.

In Eastern Canada, the high-water line may be defined in most localities as the average level of high water at Spring tides, provided that the inequalities affecting it are not too large. But on the Pacific coast, especially in Fuca and Haro straits and around the Strait of Georgia, where most of the large harbours are situated, the Spring tides are illusory; because the most dominant feature in the tide is diurnal inequality. It is thus the average level of the higher of the two tides of the day that should properly be taken as the high water level.

It is not practically possible to give such a definition of high water as to enable any surveyor to determine its level by observing the tide for a few days. The only satisfactory method is to arrive at a true and reasonable value by the reduction of a good series of tidal observations; and to bring the resulting level to an elevation referred to a Bench-mark. A surveyor can thus obtain the elevation at once and without peradventure, and he can then lay out the high water line correctly, by instrumental levelling, as a contour along the front of any property on the shore.

The high-water level has been determined in this way by the Tidal Survey, at Victoria and Vancouver, from tidal observations as recorded by registering gauges in each harbour. The result as determined for Victoria is the average level of the higher High Water on each day, during two years from March 1, 1909, to February 28, 1911. The values for the years taken separately, differed only 0·06 foot from the average of the two years, which indicates the degree of accuracy from a single year. The result was 8·51 feet above the Tidal Survey datum, or at elevation 98·90 feet above the City datum; the odd one-hundredth of a foot being negligible.

In accordance with the desire of Engineers in Victoria to establish a definite elevation for high water, this result was communicated to Mr. A. W. P. Wilby, District Engineer of the Marine Department, with whom the question had already been discussed. On submission to the Committee of Engineers in Victoria, this elevation for high water was adopted by a resolution passed on November 14, 1913.

Later, in 1919, the Superintendent of Tidal Surveys again discussed the question with the provincial authorities. It was agreed that as a property limit and also as the boundary of harbour areas, the high-water line should be based upon higher High Water, as explained; and the Tidal Survey was requested to submit the correct levels for the leading harbours, and to state the extent of shore line to which they would apply. The elevation of high water had been computed in that year, on the same basis, for Vancouver and for the lower Fraser river; and the resulting elevations were adopted by the Geological Survey for their contoured map of the Burrard inlet region, then under survey. These results for the mainland as well as for Victoria, Union and Comox, were communicated in October, 1919, to the Deputy Minister, the Surveyor General, Lands department, and to the Provincial Engineer. The level of high water for all these localities is computed on a consistent system, so that they may be in harmony with each other. It was also explained that the Victoria level can be used as far as Sooke in the one direction and half way to Sidney in the other; the level at Sidney being more than half a foot higher, as the range of the tide is 13 per cent greater there.

The elevation of high water at the other localities referred to, will be given with their own series of tide levels.

Datum Planes at Esquimalt

Some valuable planes of reference exist at Esquimalt, more especially the Low-water datum for the tidal observance which the Public Works Department have taken there. As the harbours of Victoria and Esquimalt both open on the Strait of Fuca at a distance of only three miles from each other and the range of the tide is only one per cent greater at Esquimalt, the tide levels at both places must coincide closely. The chief reason apparent for any want of correspondence in the data, is their determination in different years.

At the dry dock, there are two scales of feet cut on the masonry, one inside and the other outside the dock gate. These consist of Roman numerals, six inches high; the lower edges of the numerals being the even feet. The lowest figure is V, where the arc of the invert meets the side of the dock. The zero for the heights of both scales is the level of the invert forming the dock sill. To verify this, check measurements were taken which indicate that there cannot be more than a quarter of an inch of discrepancy between the scales and the invert. Strictly speaking, the level herein termed the Dock sill, is the elevation of the zero of the inside scale, taken from the figures as actually cut

To correlate the Esquimalt data with Victoria, the Tidal Survey in the spring of 1905 arranged with Mr. G. Hargreaves to connect the Bench-marks at Victoria by instrumental levels with the Esquimalt dry dock. These levels were run both ways over the distance of $3\frac{1}{2}$ miles, with a closing error of 0·04 foot. In a subsequent year (1909) the Geological Survey carried levels from Esquimalt to Victoria, which showed a discrepancy of 0·063 foot with the mean result of Mr. Hargreave's levels, and a correction of 0·05 foot was accepted. This gave for the dock sill, referred to the City datum at Victoria, the elevation of 71·50 feet, which is an important correlation in relation to other datums.

Dry Dock datum.—Used in the construction of the dry dock, from 1883 to 1886. The datum is defined by an assumed elevation of 50·00 feet for ordinary high water at Esquimalt. It is also stated in the Engineer's levels, that this elevation for high water is the same as 26 feet 6 inches above the sill of the dock; but this may be only approximate, as the dry dock was not completed when the datum was established. After inquiry from all available sources of information, and the most careful correlation of the levels, there is still some uncertainty in the elevation of this Dry Dock datum, as well as the Royal Engineers' datum at Esquimalt which is correlated with it. It may be well, however, to give concisely the relations on which they are based, so far as these have been ascertained, in case plans referred to these datums may be required for reference.

The Bench-mark by which the Dry Dock datum was originally fixed was a ring bolt on the Admiralty pier; but this has been built over, and is now lost. This ring bolt was also the initial Bench-mark in the Royal Engineers' survey. Fortunately a record of its elevation with reference to both datum planes exists in the level notes. The relation between the two is thus accurately known; the resulting difference being 47·665 feet, which is accordingly the elevation of the Royal Engineers' datum above the Dock datum.

The data above cited were given by Lieut. G. C. E. Elliott, R.E., in January, 1902, before the Royal Engineers left the country, in reply to inquiries. There

is still a difficulty in re-determining the original Dock datum, except indirectly in relation to the Royal Engineers' datum for which other Bench-marks exist.

Royal Engineers' datum.—This was used in surveys made by Lieut. Lang in 1885 to 1889. The datum is defined as Mean Sea-level, which was originally determined in relation to the Dock datum, and thus fixed with reference to the lost Bench-mark. Another Royal Engineers' Bench-mark exists in this vicinity however; on the retaining wall built on the south side of the Esquimalt road, opposite Signal hill; a broad arrow cut on the side of the wall facing the road, at 46 feet from its eastern end. The elevation of this Bench-mark, as given by Lieut. Elliott, is 37·24 feet above the Royal Engineers' datum.

This Bench-mark was connected with the dry dock by instrumental levels which were run by the Tidal Survey in 1905; being carried both ways with a closing error of 0·02 foot, which was averaged out. The difference of level from the Bench-mark to the dock sill was found to be 61·51 feet; and the Royal Engineers' datum would thus be 24·27 feet above the dock sill, or 95·77 feet above the City datum at Victoria.

The elevation of the Dry Dock datum is in turn deducible from the reliable difference with the Royal Engineers' datum above cited. The elevation 50·00 on the Dock datum is thus found to be actually 26·60 feet above the dock sill, instead of 26 feet 6 inches as supposed; a discrepancy not unlikely in the circumstances.

In this series of connections, the real difficulty arises from the value which results for the elevation of the Royal Engineers' datum at Esquimalt, which is intended to be Mean Sea-level. The value as here found, namely 95·77 differs by half a foot from the Royal Engineers' value at Victoria, which is 96·22. To account for this there are two explanations possible: (1) that there is an actual difference in Mean Sea-level in the two different years in which the determinations were presumably made at the two places; or (2) that at one locality the determination was made accurately from the height of the tide hour by hour, and at the other the Half-tide level was taken between successive high waters and low waters. The long-continued tidal observations now available at Victoria afford a basis of comparison to show how much of this large discrepancy can be explained under either of these alternatives.

The variation in Mean Sea-level from one year to another appears to be greater in the Pacific than in the Atlantic. The values at Victoria show an extreme variation of 0·48 foot in the fourteen years of observations now obtained. The variation may thus be considerable when special years are selected.

The type of tide on the Pacific coast, because of the pronounced diurnal inequality, gives rise to a large difference between true Mean Sea-level and the Half-tide level. To make the comparison, the level of half tide was determined from the two highest tides in each month and the two lowest in the month at Victoria during a period of two years in 1895 to 1897. The comparison of the result with the true determination of Mean Sea-level in those years, showed a difference of 1·08 feet between the two methods.

It may thus be possible to account for the amount of the discrepancy sought; but it is necessary to suppose that the determinations at Esquimalt and

Victoria were made, either in years which happen to give the limiting extremes in value, or else by two distinctly different methods; which is not very satisfactory as an explanation.

Public Works datum.—This is the Low-water datum established at Esquimalt by Mr. G. A. Keefer when Resident Engineer of Public Works. It is determined from the level of the lowest low water in each month, by taking the mean of these throughout the year. It is fixed with reference to the sill of the dry dock, at 19 feet 6 inches above it, on the inside masonry scale.

It is to be noted that this datum is fixed by a direct reading on the dock scale itself; and not by any correlation with the Dry Dock datum. The accepted levels connecting Esquimalt with Victoria, give for the elevation of this datum, 91·00 feet above the City datum at Victoria which is thus the same as the original Public Works datum there.

The zero level for the tidal observations at Esquimalt, which were begun by the Public Works Department in 1897, was fixed at two feet below this datum; so that the tide gauge might record the lowest low waters. These observations from 1919 onward, are being continued under the supervision of the Tidal Survey, with the same zero level for the tide gauge; its zero being thus at 1·40 feet below the Tidal Survey datum which is used for the final reduction of the record.

Low-water datum at Esquimalt.—On consultation with the Public Works engineers at the District office of that department in Victoria in 1919, it was decided to adopt the same elevation for the Low-water datum at Esquimalt as at Victoria, namely, 90·40 feet. This corresponds to 18·90 feet on the inside scale of the dry dock. The datum of the Admiralty chart of Esquimalt harbour is thus defined, as well as by reference to the Tidal Survey Bench-mark; which makes the datum the same as for Victoria. The Hydrographic Survey has also adopted this datum for chart work in the Esquimalt district.

Geodetic Survey of Canada.—This Survey has not yet begun operations on Vancouver island; but the accurate determinations of Mean Sea-level made by the Tidal Survey at Victoria, as well as at the north end and on the west coast of Vancouver island, are available when required.

DATUM PLANES AT VICTORIA AND ESQUIMALT

The relation of the various datum planes may be summarized as follows, when reduced throughout to the City datum of Victoria:

	Elevation.
Tidal Survey Bench-mark of 1905; in rear of the old Custom House building, near the tide gauge; as already described	105·80
Primary Bench-mark, corner of Wharf and Fort streets; as already described	126·76
Tidal Survey Bench-mark of 1919; on the side of the Post Office building, fronting on Courtenay street; as already described	134·36
Extreme High Water at Victoria. (See details given below.)	102·20
High Water level, taken as 9 feet on the Public Works scale, and adopted as elevation 100·00 in establishing the City datum	100·00

High Water. Average level as a property boundary; being the average of the higher High Waters throughout the year	98·90
Mean Sea-level; from the hourly ordinates of the tide during ten complete years of observation, up to 1916; at 6·164 feet above the Tidal Survey datum	96·56
Former Public Works datum at Victoria; the zero of their tide scale in 1893 to 1897	91·00
Datum established at Esquimalt in 1897 for the Public Works tidal observations; at 19 feet 6 inches above masonry sill of Dry Dock. (As determined by the levels connecting with Victoria.)	91·00
Average level of the lowest Low Water in each month during the two years, 1895 to 1897; at 0·28 and 0·32 foot above Tidal Survey datum. Average elevation resulting	90·70
Similar average level for the one year 1903 to 1904	91·20
Tidal Survey datum, and zero for the heights in the Tide Tables; now adopted as the Low-water datum for both Victoria and Esquimalt, and for the harbour charts	90·40
Extreme Low Water at Victoria. (See details given below.)	89·30
Sill of masonry Dry Dock at Esquimalt; as determined by the equated levels of the Tidal Survey and the Geological Survey	71·50
City datum at Victoria	0·00

MEAN SEA-LEVEL AS DATUM, AND EXTREME TIDES

	Elevation.
Extreme High Water at Victoria, during three years observation, from 1895 to 1897 and 1903 to 1904. Occurred 1896, January 26	102·20
Extreme High Water at Esquimalt, between 1906 and 1916, as noted by J. E. Jeffcott, Engineer of the Dry Dock. At 30 feet 6 inches on Dock scale, in 1909 on Jan. 19	102·00
Extreme High Water at Victoria, from 1909 to 1917. Occurred 1914 January 11	101·80
Mean Sea-level; based on reduction of three years of early observations in 1895 to 1897 and 1903 to 1904. Accepted by the Geological Survey in 1909, as datum for their contoured map. (See later determination)	96·68
Mean Sea-level; Royal Engineers' datum at Victoria, at 3·78 feet below 100·00 on the City datum	96·22
Mean Sea-level; Royal Engineers' datum at Esquimalt, in surveys of 1885 to 1889; as derived from their Bench-mark at Signal hill	95·77
Low-water datum at Victoria and Esquimalt	90·40
Lowest Low Water at Victoria, during three years observation, from 1895 to 1897 and 1903 to 1904. Occurred 1895, June 24	89·45
Extreme Low Water, midwinter of 1916-17. Occurred 1916 December 25 and 1917 January 21 and 22. (All three tides within 0·05 foot of each other.)	89·30
Extreme Low Water at Esquimalt, between 1906 and 1916, as noted by J. E. Jeffcott. At 17 feet 6 inches on Dock scale, in 1912 on July 15, during a gale	89·00

Mean Sea-level at Victoria.—The determination in each complete year is from the hourly ordinates of the tide. The variation in the values is considerable on the Pacific coast generally; but the variation from year to year is an actual one, as shown by the close correspondence of the Victoria values with the determinations at Point Atkinson in the Strait of Georgia. The early years, 1895 to 1897, are corrected for the difference in the datum level. All the values are measured from the Tidal Survey datum at elevation 90·40 feet above the City datum.

	Feet
One year from April, 1895, to April, 1896	6·328
" " April, 1896, to April, 1897	6·376
" " March, 1903, to March, 1904	6·143
" " February, 1909, to February, 1910	6·023
" " March, 1910, to March, 1911	6·028
" " March, 1911, to March, 1912	6·086
" " March, 1912, to March, 1913	6·005
" " March, 1913, to March, 1914	6·174
" " March, 1914, to March, 1915	6·304
" " March, 1915, to March, 1916	6·172
" " March, 1916, to March, 1917	5·893
" " March, 1917, to March, 1918	5·990
" " March, 1918, to March, 1919	6·249
" " March, 1919, to March, 1920	5·904

The average value 6·164 or elevation 96·56 feet, based on the first ten years' observations, was communicated to the Provincial Engineer of Public Works in 1919; and may be considered as an accurate determination. It is given as the final value in the list of elevations.

Such a series might be expected to show any variation in Mean Sea-level during the 19-year lunar cycle, if this were appreciable. On the other hand, the extreme levels of high water and low water are accentuated in the years of maximum range in the moon's declination. The turning points of the cycle are as follows:—

Maximum range (28° 44′ N. and S.) ..1894, September.
Minimum range (18° 10′ N. and S.) ..1904, March.
Maximum range (28° 44′ N. and S.) ..1913, May.
Minimum range (18° 09′ N. and S.) ..1922, September.

Datum Planes at Vancouver

The original plane of reference at Vancouver was the Canadian Pacific Railway datum, which was established about 1886, when the present site of Vancouver was a forest. It was decided upon by Mr. H. J. Cambie, the first Resident Engineer; but in more recent years other datums have been introduced by other railway companies, which have only tended to create confusion. The original Bench-mark to which this datum was referred, was cut on the masonry of the former Canadian Pacific Railway station building; and its elevation is

given in the following list, because of the comparisons with it which exist in old records. Before this station was demolished in 1912, the Tidal Survey placed another Bench-mark in the vicinity, and the original elevations have thus been preserved.

In 1891, when a survey of Vancouver harbour was made by Mr. W. J. Stewart, of the Marine Department, the Low-water datum was decided upon. When observations of the tide were begun in 1901 by the Tidal Survey, this datum was adopted to bring the height of the tide into conformity with the chart soundings. From this datum in turn, the value of Mean Sea-level was accurately determined from a long series of tidal observations, before the Geodetic Survey began its operations in British Columbia in 1914.

The only other natural level is high water; which it is important to determine correctly, as it is the legal boundary in the Province of British Columbia for properties with a shore frontage. An assumed level for high water was used as a basis for the Canadian Pacific Railway datum; and the city of North Vancouver has also adopted a high-water level as the City datum there. The actual elevations of these various assumed levels will be given.

All the levels will be given with reference to the Canadian Pacific Railway datum, as it was the primary one in the region; and all levels will thus be brought to a consistent series of elevations. Definite differences between the various datums have been ascertained, so that they can all be correlated with the tide levels established by the Tidal Survey.

Canadian Pacific Railway datum.—Defined as 100·00 feet below ordinary high water; and fixed with reference to the original Bench-mark on the former Canadian Pacific Railway station building. This Bench-mark was the surface of the granite sill of the most easterly door on the north side of the station; marked with a broad arrow and the letters "B.M." Although now demolished, its elevation is important as other datums were referred to it up to 1912. Elevation above Canadian Pacific Railway datum, 108·35 feet.

City datum for Vancouver.—On this datum, elevation 100·00 is supposed to be extreme high water; but the level adopted is higher than the highest tide ever recorded. The datum is fixed with reference to the original Canadian Pacific Railway Bench-mark above described; its elevation above the City datum being 107·10 feet. The City datum is thus 1·25 feet above the Canadian Pacific Railway datum; this difference being generally accepted by engineers.

Chart datum.—The Low-water datum for the reduction of the soundings was established by Mr. W. J. Stewart, of the Marine Department, when making the survey of Vancouver harbour in 1891. It was originally fixed with reference to a broad arrow cut on one of the iron piles supporting the railway wharf. The datum was afterwards referred to the original Canadian Pacific Railway Bench-mark already described; it being stated on the early charts of Vancouver harbour that the soundings are reduced to a level of 23 feet 7 inches below that Bench-mark. This makes the elevation of the Low-water datum, 84·77 feet. In 1905, the broad arrow on the iron pile still existed; and the Superintendent of Tidal Surveys obtained its elevation above the City datum, which agreed with this level within 0·05 foot, the discrepancy being almost certainly due to settlement; as the settlement up to 1908 amounted only to 0·10 of a foot. The elevation above the City datum thus affords a good check.

This Low-water datum of the chart has been adopted by the Tidal Survey as the zero level for the Tide Tables; and its elevation has been carefully maintained throughout the tidal observations at Vancouver from 1905 to the present date.

Tide scale.—This scale, with divisions in enamel for durability, was placed on a pile at a new Canadian Pacific Railway wharf in 1905; the zero being set about 2½ feet below the Low-water datum so that the lowest tides would be recorded on the registering gauge which was set with it. The pile was a very solid one, of Australian hardwood. The original elevation of the zero in 1905 was 82·30 feet, and little settlement occurred until 1913 when there was dredging alongside the wharf and stone filling around the piling, which brought the zero of the scale to 82·11 feet. In the nine years following, the scale rose a few hundredths, as piling usually tends to work up; the elevation of the zero in 1922 being 82·17 feet. At that elevation, the Low-water datum is at the reading 2·60 on the face of the scale.

This explanation is given as an example in illustration of the following principles which the Tidal Survey has always observed: (1) The impossibility of setting and maintaining a tide scale at an absolute elevation such as the Low-water datum; (2) the desirability of setting the zero of the scale a foot or so below the lowest probable tides, to make sure that they will all be recorded; (3) the final reduction of the observations to the true Low-water datum, by the careful levelling of the tide scale from year to year, so that its zero is at all times definitely known to the nearest 0·01 of a foot; (4) in case of resetting the tide scale because of accident, the new elevation of the zero enables the reduction to be carried on just as before, without any peradventure.

Bench-marks.—The Tidal Survey Bench-mark, established in 1912. On the north side of the Welton Block occupied by the Royal Transfer Company, at the door giving entrance to the lowest floor, at the foot of the ramp to the wharves. The Bench-mark is the surface of the stone door sill at its west end; marked with an inverted broad arrow, and the letters "B.M." Connected by instrumental levelling with the original Bench-mark of the Canadian Pacific Railway, before it was demolished. Elevation 111·22 feet.

This is now the Primary Bench-mark to which the tide levels are referred. Its elevation above Mean Sea-level as determined by the Tidal Survey is 18·42 feet, which affords the basis for the levelling of the Geodetic Survey of Canada in southern British Columbia. Two other Bench-marks were also established in this neighborhood by the Tidal Survey for greater security; and their relative elevations have been checked by the precise levels of the Geodetic Survey:—

On the north front of the Customs Examining warehouse, there are three doors opening on the wharf level. The Bench-mark is the top of a brass bolt, set obliquely into the masonry plinth at about six feet west of the most easterly door. Elevation, 124·92 feet. This elevation was also checked by the Canadian Pacific Railway engineers.

On the Post Office building, at the door near the northeast corner opening on Granville street, giving entrance to the basement. The point used as a Bench-mark is the north end of the lower of the two stone steps. Elevation, 147·75 feet.

High-water level.—Throughout British Columbia, the High-water line is the legal boundary of properties which front on the sea, and it may thus also be considered as the limit of jurisdiction of Harbour Commissioners in the various ports. The best method of determining the high-water levels from tidal observations, when dealing with the type of tide found on the Pacific coast, has been explained in connection with this level at Victoria. The method was discussed with the Provincial authorities in Victoria in 1919, and met with their concurrence, as already mentioned.

The problem at Vancouver was less simple than at Victoria on an open coast. The question came up for decision in 1918 when the Geological Survey contemplated the survey for a contoured map of Burrard inlet and the Lower Fraser region. It was desirable that the High-water line should have the same elevation throughout the whole of Burrard inlet, although the rise of the tide is four per cent greater at the head and in the North arm.

The average level of higher High Water in Vancouver harbour, on each day during two complete years, was determined as a basis; and on discussion of the question with Mr. W. H. Boyd, Chief Topographer of the Geological Survey, it was decided to adopt an even 13 feet above the Low-water datum, as best meeting the requirements of the case. This level was also accepted by the City Engineer of Vancouver. The High-water level for Vancouver harbour and Burrard inlet is therefore defined as follows:—

	Feet
Above the Low-water datum of the chart and the zero level of the Tide Tables	13·00
Elevation above the Canadian Pacific Railway datum	97·77
Elevation above the Geodetic Survey datum, which is Mean Sea-level	4·97

This High-water level is 2¼ feet lower than the elevation 100·00 which was originally taken as high water in fixing the Canadian Pacific Railway datum, as this was rather extreme; and it is 1·00 foot above the level of Mean high water adopted as the datum for North Vancouver, which corresponds fairly well with a general average level if the Half tides are included.

This level, accompanied by references to Bench-marks for the convenience of surveyors, was discussed in 1919 with Mr. A. H. Reed, the Harbour Master, and was by him submitted to the Vancouver Harbour Commissioners; but at that date, they were unwilling to adopt it, although it was explained that it would be shown as the High-water contour line on the Geological Survey map. A further communication was sent in September, 1921, to Mr. W. G. Swan, Chief Engineer of the Harbour Commissioners; explaining that this elevation for the High-water level had been adopted by the Geological Survey, and communicated to the Lands Department of the Province at their request, with the corresponding level in other harbours.

Tide levels at Vancouver.—The datum planes and other tide levels are here given with reference to the Canadian Pacific datum, which serves to correlate them with each other by bringing them into one uniform series. The main relations between the various datums as here stated, as well as those on the Fraser river, were first published in January, 1906, in the earlier edition of "Tide

Levels and Datum Planes ". They were included later in a compilation prepared by Mr. A. G. Dalzell in 1917, as secretary of a committee appointed by the Vancouver branch of the Engineering Institute.

	Elevation.
Tidal Survey Bench-mark, on the stone door sill of the Welton Block, as described	111·22
Original Bench-mark on the former Canadian Pacific Railway station building, demolished in 1912; already described	108·35
Extreme High Water of December 1887, which reached the grate bars of the Hastings saw-mill during a heavy gale	100·70
Extreme High Water of January, 1914. (See details of extreme tides given below)	100·50
Level of High Water adopted as elevation 100·00 in establishing the Canadian Pacific Railway datum	100·00
High Water. Average level as a property boundary for Burrard inlet generally; based on the average of the higher High Waters. At 13·00 feet above the Low-water datum	97·77
North Vancouver datum; being the level assumed for Mean High Water. At 12·00 feet above the Low-water datum	96·77
Mean Sea-level; from the hourly ordinates of the tide during seven complete years of observation, up to 1912; at 8·034 feet above the Low-water datum. This is the elevation of the Geodetic Survey datum	92.80
Low-water datum of the chart of Vancouver harbour and zero level for the heights in the Tide Tables. At 23·58 feet below the original Canadian Pacific Railway Bench-mark	84·77
Extreme Low Water of May, 1919. (See details of extreme tides given below.)	83·20
City datum for Vancouver, and datum of the B.C. Electric Railway. At 1·25 feet above the Canadian Pacific Railway datum	1·25
Canadian Pacific Railway datum, at 100 feet below the level adopted in 1886 for High Water	0·00

Extreme Tides.—The highest tide yet recorded in Vancouver harbour, occurred in December, 1887, during a heavy gale. It reached the grate bars of the Hastings saw-mill; and its elevation was determined at the time by Mr. H. J. Cambie as 100·70 feet, or 15·93 feet above the present Low-water datum. Another extremely high tide occurred during a westerly gale in 1894, said to have been even higher by three inches; but the date and the actual level reached could not be ascertained definitely.

With the declinational type of tide in which the extremes are due to diurnal inequality, they usually occur near the solstices when the effect of the sun's declination is added to the lunar influence. The most extreme tides recorded by the registering tide gauge since 1905, are here given.

	Elevation.
Extreme High Water during a heavy gale, 1913, November 29; at 15·60 feet above the Low-water datum	100·35
Extreme High Water, 1914, January 26; at 15·75 feet above datum	100·50
In the nine years between 1912 and 1920, four other tides occurred in December and January which reached or exceeded elevation 100·00	—
Low-water datum in Vancouver harbour; being the Chart datum and Tidal Survey datum	84·77
Extreme Low Water; 1916, January 4; at 1·50 feet below the Low-water datum	83·25
Extreme Low Water; 1919, May 30; at 1·55 feet below datum	83.20

Mean Sea-level.—The determination in each complete year is from the hourly ordinates of the tide. The variation in the values from year to year is undoubtedly an actual one, due to some physical cause; and the variation is considerable on the Pacific coast generally. When the Geodetic Survey began operations in southern British Columbia in 1914, an average value from seven complete years was available; the resulting elevation being 8·034 feet above the Low-water datum. As this is now the datum level of the Geodetic Survey, and has thus come to be generally accepted, it is undesirable to alter it; as the average from later years will not differ appreciably from it.

The hourly ordinates of the tide, from which the yearly values of Mean Sea-level are derived, are measured from the Low-water datum which the Tidal Survey has maintained at a truly constant elevation throughout the years of observation. All changes due to alteration of the tide scale or any settlement from year to year, are carefully allowed for, in the reductions; as at all the permanent tidal stations. The values given are thus above the Low-water datum at the constant elevation of 84·77 above the Canadian Pacific Railway datum.

	Feet.
One year from March, 1902, to March, 1903	8·083
" " October, 1905, to October, 1906	8·045
" " October, 1906, to October, 1907	8·080
" " October, 1907, to October, 1908	8·016
" " October, 1908, to October, 1909	8·048
" " November, 1909, to November, 1910	7·977
" " January, 1911, to January, 1912	7·990
" " January, 1912, to January, 1913	8·034
" " January, 1913, to January, 1914	8·046
" " January, 1914, to January, 1915	8·203
" " January, 1915, to January, 1916	8·152
" " August, 1916, to August, 1917	7·848
" " September, 1917, to September, 1918	8·053
" " September, 1918, to September, 1919	8·156
" " September, 1919, to September, 1920	7·890

The general average of the 15 years is 8·035 which is practically identical with the average of 8·034 which is the elevation of Mean Sea-level taken as the

datum in the Geodetic Survey. In regard to the variation, it will be noted that the extreme low values of 1916-17 and 1919-20 are also the two lowest at Point Atkinson in the open Strait of Georgia, at Victoria, and at Clayoquot on the open Pacific; although the period in months is not quite the same. Similarly, the extreme high value in 1914-15 is also the highest at Victoria during the same series of years, as well as at the other two stations. It seems evident therefore that these variations are a general feature of the whole region; when determinations are made with such accuracy as to give comparisons within these narrow limits.

Port Moody.—Tidal observations were obtained here in 1912; the tide gauge being placed at the wharf of the B.C. Oil Refinery Co. at 2,800 feet west of the Canadian Pacific Railway station.

Bench-mark; in the concrete foundation of the stock tanks of the Refinery Company, on the side facing the water; the centre of a brass bolt drilled in horizontally and set with cement, at 3 feet from the east end and 11 inches above the working platform.

	Elevation.
Elevation of Bench-mark, as described	100·00
Low-water datum; determined relatively to the Vancouver datum by the standard method, at 1·00 foot on the tide scale	74·08
Zero of the tide scale as set in 1912	73·08

North Arm.—Observations obtained in 1912; the tide gauge being placed at the Power Station of the B.C. Electric Railway Co. in the North Arm of Burrard inlet.

Bench-mark; in a concrete pillar of the wharf at the south side of the slipway, being the eighth pillar from the south end of the wharf; the centre of a brass bolt set horizontally into the pillar at 9 inches from the face and 4 feet above the sloping surface of the slip, and just about High-water mark.

	Elevation.
Surface of flooring of wharf	107·24
Bench-mark, as described	100·00
Low-water datum; determined relatively to the Vancouver datum by the standard method; at 0·72 foot on the tide scale	85·37
Zero of the tide scale as set in 1912	84·65

The comparative rise of the tide throughout Burrard inlet is given below. The ratios are based directly on the simultaneous observations of 1912, and the rise corresponds with the annual average. The values given thus indicate the relative rise to the average level of all high waters, and the percentage of rise relatively to Vancouver.

Vancouver	Average rise, 11·48 feet.	Per cent, 100
Port Moody	Average rise, 11·94 feet.	Per cent, 104
North Arm	Average rise, 11·98 feet.	Per cent, 104

The Lower Fraser River, and New Westminster

The tidal portion of the Fraser river maintains its ordinary width as far as Garry Point, and then spreads out into a delta of channels between sand flats as far as Sand Heads, where the outer edge dips off steeply into deep water. These flats are all submerged at high tide; and the channels are now partially directed and controlled by embankments and dredging. The rise of the tide is 12 feet at Sand Heads, 6 feet ordinarily at New Westminster which is 16 miles above Garry Point, and it is felt as far up as Sumas except during the freshet in the river.

The Public Works Department established three registering tide gauges on the Lower Fraser in 1895; at New Westminster, Garry Point and Sand Heads; until the lighthouse there was replaced by a light-ship. The two other tide gauges, with new instruments supplied by the Tidal Survey are still in operation.

Fraser River Datum.—This is the Public Works datum for all elevations along the Lower Fraser as far as the head of tide water. All these elevations, including New Westminster itself, can thus be referred to one uniform standard, which is specially convenient in dealing with freshet levels along the river. The datum was originally established about 1895, by Mr. F. C. Gamble, who determined it from the level of the lowest low water in each month, by taking the mean of these throughout the year. It is thus the Low-water datum for the area of the submerged delta and for a few miles near the mouth of the river; very suitable for dredging which is mostly in that region. In going up the river, the river slope soon brings low water to a higher elevation; and at New Westminster, the low-water level is 7·00 feet above datum. A Bench-mark was placed on the Post Office building to fix this datum by Mr. G. A. Keefer, when he became Resident Engineer of Public Works.

Bench-mark; on the stone cap, on the west side of the steps at the main entrance of the Post Office on Columbia street; marked with a broad arrow, with the letters "B.M." above it. The elevations are as follows, with relation to the various datums in the region:—

	Feet.
Bench-mark above Fraser River datum	52·34
Bench-mark above Geodetic Survey datum	43·62
Bench-mark above Canadian Pacific Railway datum in Vancouver, as determined by the Geodetic Survey levelling	136·42

The Bench-mark of the Geodetic Survey on the west side of the Post Office, marked 11-J, is 0·50 foot higher than this; as determined by the City Engineer and the Public Works Department.

Sand Heads Tide Gauge.—This registering gauge was operated by the Public Works Department for nine years from 1895. It was placed on the group of piling supporting the lighthouse then situated beyond the edge of the sand banks of the delta. The zero of the tide scale for the gauge coincided with the Fraser River datum.

Although there were serious interruptions in the record, six complete years were obtained for reduction by the Tidal Survey; and Tide Tables were

published in 1901 for Sand Heads, which proved an excellent reference station for harbours throughout the Strait of Georgia. After the Sand Heads lighthouse was removed, observations were continued by the Tidal Survey since 1914 at Point Atkinson; the tide gauge being placed in a cove adjoining the point, known as Caulfeilds landing, which until recently was the Pilot station. The tidal conditions there are practically identical with Sand Heads; both places being on the open Strait of Georgia and only 16 miles apart.

Mean Sea-level.—The values of Mean Sea-level are deduced from the hourly ordinates of the tide above the zero of the Sand Heads tide scale; this zero representing the Fraser River datum and the Low-water datum for the submerged delta and mouth of the river.

	Feet.
One year from May, 1895, to May, 1896	8·458
" " October, 1896, to October, 1897	8·416
" " November, 1898, to November, 1899	8·474
" " November, 1899, to November, 1900	8·561
" " January, 1901, to January, 1902	8·425
Mean value for the five years	8·467

The last year, in 1903 to 1904, is omitted because of possible silting at the site of the gauge.

The following series for the open Strait of Georgia were obtained in later years at Point Atkinson. To make the observations truly comparable with Sand Heads, the greatest care was taken in establishing a corresponding Low-water datum, in relation to the mean low water level. From the best comparisons between the two places, the datum at Point Atkinson is somewhat lower in elevation than at Sand Heads, due to the slightly greater range there. It may be assumed that Mean Sea-level is the same at the two places, within the possible limits of its variation in a different series of years; and on this assumption the Low-water datum is 0·21 foot lower, which corresponds closely with the amount required by the determination of the ratio of the ranges. The values at Point Atkinson are as follows:—

	Feet.
One year from May, 1914, to May, 1915	8·877
" " May, 1915, to May, 1916	8·717
" " May, 1916, to May, 1917	8·483
" " May, 1917, to May, 1918	8·692
" " May, 1918, to May, 1919	8·777
" " May, 1919, to May, 1920	8·481
" " May, 1920, to May, 1921	8·716
Mean value for the seven years	8·678

Correlations.—The correlation of Mean Sea-level and the Low-water datum at Vancouver, with Sand Heads and Point Atkinson, has been a matter of difficulty; largely because of the characteristics of the tide in the Strait of Georgia,

where the two High Waters and the higher Low Water are not far from the same level, and lower Low Water usually falls a long way below these. The total range of the tide is thus largely due to the heavy drop to lower Low Water; and great care is required in correlating the Low-water datum at different localities in the Strait, especially as the change in the moon's declination in the 19-year lunar cycle has a very appreciable effect upon the level of lower Low Water. In comparing observations in different years, the position of the year in the cycle has therefore to be taken into account. In establishing the Low-water datum at Point Atkinson for the new series of observations there, all such variations were allowed for, to make it correspond truly with Sand Heads.

It is unadvisable to enter upon any elaborate discussion of the correlation of the Low-water datum and Mean Sea-level in the open Strait of Georgia with Vancouver; although there are some discrepancies still unexplained. The chief importance of the matter is that the tide levels on the open side of Vancouver, in English bay and False creek, undoubtedly correspond with the Strait and the Lower Fraser, and may not be identical with the tide levels in Vancouver harbour within First Narrows. Some facts which affect the question, in relation to the type of tide here dealt with, it may therefore be well to state.

(1) The tide levels at Sand Heads are measured primarily from the zero of the scale attached to the piling; and in establishing the Fraser river datum, by instrumental levels from New Westminster to the scale, the last sight from the sand banks to the scale was a long one. It is thus possible from the standpoint of precise levelling, that the zero of the scale does not correspond exactly with the datum as defined by the Bench-mark in New Westminster; and it is from this zero that Mean Sea-level is computed.

(2) A correct comparison may be obtained with the tide station at Point Atkinson, if sufficiently accurate levels can be obtained to detect any difference. The difficulty in the levelling is the circuitous route around Burrard inlet, or the long sights required across the Narrows. This station is beyond any influence of the outflow from Burrard inlet.

(3) It is probable that the mean elevation of high water is closely the same in Vancouver harbour as in the open Strait, because high water does not vary in level as rapidly as low water. On this assumption, a comparison of the difference in elevation between the average level of high water and Mean Sea-level, shows it to be the same at Vancouver and Point Atkinson within half an inch. The fall from Mean Sea-level to low water is less likely to be identical; and the same method of comparison indicates a difference in elevation of about an inch in average Low Water, between Vancouver harbour and the open Strait.

It is to be noted that any residual uncertainties that may thus exist, do not affect the datums themselves; which are all definitely defined with reference to Bench-marks.

High Water and Low Water on the Fraser River.—The average level of higher High Water at Sand Heads and at New Westminster was found to have the same actual elevation, when there is no freshet. The reason that it is not higher at New Westminster, appears due to the inflow into Pitt lake, which causes the up stream of the flood to continue after the tide begins to fall. It is not to be supposed, however, that the water surface is truly level at any one moment; as the time of high water is an hour later at New Westminster than at Sand Heads.

The level of higher High Water at Sand Heads was determined, as well as at New Westminster, in four months at the four quarters of the year in three different years apart from the freshet level; and the elevation of 12·80 feet above the Fraser river datum was adopted as the High-water line. In English bay and False creek, it should have the same elevation; as the tide there corresponds with the open Strait of Georgia.

For low water, the conditions are very different. The Low-water level is necessarily higher in elevation in proceeding up the river; and the decrease in range is in reality due to this. At a discussion in July, 1919, between Mr. A. C. T. Shepherd, of the Geological Survey, Mr. W. P. Gross, of the Public Works Department, and the Superintendent of Tidal Surveys, a series of seven steps for the Low-water datum was decided upon, from the zero level at Sand Heads to Douglas island above New Westminster. These steps rose usually by 1¼ feet in level, and the extent of each along the river was defined. The two highest were for the New Westminster reach at elevation 7·00 above datum, to leave this unchanged; and for the Port Mann reach at elevation 8·00 feet, extending into the Pitt river as far as the Canadian Pacific Railway bridge.

These results were communicated to the Resident Engineer of Public Works; and to the Chief Topographer of the Geological Survey; and the elevations indicated were adopted for the High-water and Low-water contours along the Fraser river on the Geological Survey map which was under survey at that date.

New Westminster.—The city datum for New Westminster is 17·45 feet higher than the Fraser River datum. The Low-water datum is defined on the harbour plan of New Westminster, by Mr. A. O. Powell in 1911, as 7·00 feet above the Fraser River datum, as already stated. This level is found to correspond (within 0·15 foot) with the average level of the lowest Low Water in each month, apart from the freshet season; as determined from nine months in three different years. The rise of the tide above this Low-water level (in ordinary months when there is no freshet) is 45 per cent of the height at Sand Heads. In the freshet months, the level of lower Low Water is elevated from 7 feet above the datum to 12 feet; and the rise of the tide from that level is then 20 to 30 per cent of the height at Sand Heads. The actual elevation of High Water is thus higher in the freshet months; although the range is so much reduced. The levels referred throughout to the Fraser River datum, are as follows:—

	Elevation.
Bench-mark of the Geodetic Survey, No. 11-J, on west wall, Post Office building	52·84
Bench-mark of the Public Works Department, at main entrance to Post Office on Columbia street; as described	52·34
City datum for New Westminster; the zero level for city elevations	17·45
High Water during freshet. Average level of higher High Water in June, in three different years. At 3·70 feet above the 12-foot level for average low water during the freshet	15·70
High Water. Average level for the Lower Fraser river, based on the average of the higher High Waters	12·80
(The rise above the 7-foot datum level at New Westminster is thus 5·80 feet.)	
Usual level of Low Water at New Westminster during the freshet months. Approximately	12·00
Geodetic Survey datum; being Mean Sea-level in Vancouver harbour, at 8·034 above the Low-water datum there. Mean of seven years between 1902 and 1912	8·72
Mean Sea-level; computed from the zero of the tide scale at Sand Heads, corresponding with the Fraser River datum. Mean of five years between 1895 and 1902	8·47
Low-water level in the Port Mann reach above New Westminster; and in Pitt river as far as the Canadian Pacific Railway bridge	8·00
Low-water datum in the harbour of New Westminster	7·00
Low-water level, in a series of five intermediate steps to the delta of the Fraser river	——
Fraser River datum; corresponding closely, if not absolutely, with the zero of the original tide scale of 1895 to 1904, at Sand Heads	0.00

False Creek and English bay.—This side of Vancouver, fronting on the Strait of Georgia, must be included with it as regards tidal questions. The rise of the tide and the tide levels are the same as for Sand Heads and Point Atkinson; although in establishing a tidal station to replace Sand Heads, that Point was preferred to make sure of being quite free from any local influence due to the inflow and outflow of Burrard inlet.

The High-water line for English bay and False creek can be taken as the same as already found for the lower Fraser. Mean Sea-level must be identical with Sand Heads and Point Atkinson, when any possible difference in the Low-water datum from which it is measured, is allowed for. The Low-water datum is in correspondence with Point Atkinson and Sand Heads, as the following comparisons will show.

Low-water datum.—Tidal observations were taken in False Creek in 1919 and 1920; the tide gauge being placed at the dock of the B. C. Electric Railway Co. The tide scale was set to correspond with the zero level at Point Atkinson; and from 30 simultaneous observations at the lower Low Waters during three autumn months, the zero of the tide scale at False Creek was found to be

0.02 foot lower. The following comparative levels could therefore be deduced:—

Elevation of zero of False Creek tide scale, by instrumental levelling from a City Bench-mark. Above C. P. Railway datum	82·26
Face reading of the Point Atkinson datum on the False Creek tide scale, with allowance of 0·02 foot difference	1·78
Elevation of Point Atkinson Low-water datum as thus transferred to False Creek	84·04

A comparison can thus be obtained with the original Sand Heads datum, by means of the connection from Vancouver to New Westminster by the Geodetic Survey levels. Although the connections are circuitous, from Point Atkinson by False Creek to Sand Heads, the result shows that there can be no discrepancy of importance in any of the relative datum levels, when the final results correspond so closely. The correlation at New Westminster, already stated, gives the following result:—

Fraser River datum, or Low-water datum at Sand Heads above the Canadian Pacific Railway datum in Vancouver; from the difference of the two elevations for the Bench-mark on the New Westminster Post Office	84.08

Pitt river and lake.—Tidal observations were taken at Coquitlam in 1912; the gauge being erected on the west side of Pitt river, 450 feet Southwest of the C. P. Railway bridge. The elevation of the zero of the tide scale above the Fraser River datum, was determined by Mr. F. P. Wilson of Messrs. Wilson and Lake. The average elevation of low water was approximately 8·00 feet above that datum, which corresponds with the Low-water datum in this reach of the Fraser river. Any definite tide levels required can be obtained from the record.

At Pitt lake, Mr. Wilson obtained tidal observations in October 1912, simultaneously with Coquitlam; by means of scale readings. The range of the tide at different times in the month, varies from 1·50 to 1·80 feet.

Sumas.—This is the head of tide on the Fraser river. The range is 0·80 foot ordinarily; but during the freshet, there is no rise of tide.

Haro Strait and the Gulf Islands

Surveys were carried on in this region as a basis for Admiralty charts in 1898 to 1905, with the "Egeria" under Admiral Sir J. F. Parry when Captain, Admiral F. C. Learmonth, and other Naval officers. Tidal observations were obtained during these surveys in some harbours, at which Low-water datums were established. These datums are here indicated; and they were adopted by the Tidal Survey wherever suitable. The datum was always correlated with low water at Sand Heads by the standard method, or with simultaneous observations at Point Atkinson; to make the rise of the tide comparable throughout the region.

Sidney.—Tidal observations were obtained here in 1909 and 1912. There was an Admiralty Low-water datum here, for the surveys above mentioned, at 9 feet below a broad arrow on a pile of the railway wharf. In 1909, during the levelling by the Geological Survey under Mr. R. H. Chapman for the contoured map of southern Vancouver island, Sidney was connected with the Victoria datum. The correlations thus established will be explained.

Tidal Survey Bench-mark; situated 6½ feet North of the point at which the street line on the North side of Beacon Street intersects the High-water line. The top of a brass bolt drilled into the granite rock on the North side of the Government wharf, at 143 feet from the outer abutment and 11½ feet from the side of the wharf. Marked by the letters "T.S." above and "B.M." below.

	Elevation.
Top of the outer concrete abutment of the wharf	102·71
Bench-mark as above explained	100·00
Low-water datum adopted by the Tidal Survey	92·92
Zero of tide scale in 1909, at elevation 92·37 and in 1912 at elevation	92·42

According to the Geological Survey levels, the elevation of the Bench-mark above the City datum for Victoria, is 96·80 feet. The original Admiralty datum, although the broad arrow no longer exists, is also described as corresponding to a height of 18 feet 10 inches above the sill of the Esquimalt dry dock, which defined the Admiralty datum. It is a question whether it is right to assume that the Low-water datum at Sidney is intended to be at the same absolute elevation as at Esquimalt, when the range of the tide at Sidney is 13 per cent greater. On this assumption, however, the following elevations are obtained above the City datum for Victoria; and the elevation of the High-water line is added for comparison.

	Victoria City Datum
Bench-mark at Sidney above City datum for Victoria, from Geological Survey levels	96·80
High Water. Average level of higher High Water at Sidney; at 9·96 feet above the Tidal Survey datum	99·68
High Water. As adopted at Victoria as a property boundary, as explained	98·90
Admiralty Low-water datum, at the elevation above indicated, relatively to the Dock Sill	90·33

The datum, on the above assumption, is thus 0·61 foot higher than the Low-water datum as now found from the tidal observation. But if allowance were made for the greater range of the tide, it would probably correspond very closely with the original chart datum.

Tod Inlet.—Tidal observations were obtained here in 1912; the tide gauge being placed at the wharf of the Vancouver Portland Cement Co. The elevations are referred to the datum adopted by the Engineers of that Company; the level of the sub-floor of the stream turbine house, before the cement surfacing was put on, being originally taken as elevation 100·00 feet.

Bench-mark; the top of a vetical iron bolt, projecting 3 inches from the ground, at 2¼ feet East of the side of door of turbine house. Elevation above the Company's datum, 100·40 feet.

	Elevation.
Reference point; the top of foundation of chimney at the Southeast corner	103·53
Surface of flooring of wharf; at 5·70 feet above extreme High Water as accepted by the Engineers of the Cement Company	96·00
Highest High Water in 1912; on November 11	88·80
High Water. Average level of High Water, reduced to annual value	86·47
Low-water datum; a determined by the standard method of the Tidal Survey	76·73
Extreme Low Water; the lowest observed in eight years by the Engineers of the Cement Company	75·00

Cowichan.—The tide here corresponds closely in its general characteristics with Port Townsend in Puget Sound; and the time relations with various tidal stations have been determined to see whether Cowichan would answer as a reference station for the turn of the tidal streams in this region. Tidal observation were obtained for a full year in 1913 to 1914; and again for eight months, from August 1918 to March 1919.

There is an Admiralty Bench-mark here; but its relation to the chart datum could not be ascertained. The Low-water datum was therefore determined independently by the standard method; and with the advantage of a complete year of observations, it was based on a reduction of four months at the four quarters of the year, to obtain a true average. The tide scales were at quite different elevations for the two sets of observations; but the face reading of the datum on the scale was correctly determined in each case, in the usual way. The extreme tides are those that occurred during the year 1913 to 1914, which is near the extreme in the 19-year cycle.

	Elevation.
Admiralty Bench-mark; a broad arrow cut on a large rock, about 75 feet West of the shore end of the wharf in Cowichan bay. Elevation adopted	100·00
Exceptional High Water during a storm; occurred in 1913 on November 29	99·60
Extreme High Water when undisturbed; in 1913 on December 31	98 70
High Water. Average level of High Water, reduced to annual value	95·52
Low-water datum, as adopted	85·54
Extreme Low Water in 1913. Occurred June 6	85·10
Extreme Low Water in 1914. Occurred June 9	85·00

A general comparison of the tide levels in this region, is given under Telegraph harbour.

Fulford Harbour.—The Post Office name for this locality is South Saltspring island. Observations were obtained here between 1918 and 1923. The

Bench-mark is an inverted broad arrow, cut in the rock just below the church on the North side of the harbour. The broad arrow is quite close to an old ring bolt. It was placed by the Tidal Survey in 1918.

	Elevation.
Bench-mark, as described	100·00
High Water. Average level of High Water, reduced to annual value	100·45
Low-water datum; by standard method, checked by comparison with simultaneous observations at Cowichan and Bedwell harbour	90·70

Bedwell Harbour.—The Post Office name of this locality is South Pender. The Bench-mark defining the Admiralty datum, established by Captain Parry during the Admiralty surveys of 1905, is a broad arrow at the northern end of the small bay North of Hay Point. It is cut in the face of the rocky cliff, above High-water mark. The Low-water datum is at 17 feet 11 inches below this broad arrow. See Chart No. 2840.

The Low-water datum here and at Telegraph harbour were carefully compared with the Sand Heads datum, by determining the difference below the average height of all low waters at each place, with allowance for the proportionate ranges, and other variations. The datum at all three localities was thus found to correspond well; which brings the rise of the tide also into good agreement.

Tidal observations were obtained here for 9 months in 1905; and later by the Tidal Survey in 1919 to 1920 and 1922 to 1923, when the same Low-water datum was used, as originally established.

	Elevation.
Admiralty Bench-mark as above described; elevation assumed	100·00
Extreme High Water in 1905; on October 6	93·75
High Water. Average level of High Water, reduced to annual value.	91·60
Low-water datum; as defined, at 17·92 feet below the Bench-mark. Maintained for all the tidal observations	82·08
Lowest Low Water during the observations of 1905; occurred June 16. (In the Sand Heads Tide Tables, the lowest low water in the middle of June, also fell to datum)	82·05

Hope bay.—In North Pender island. Tidal observations were obtained here in 1918. The Bench-mark placed by the Tidal Survey, is a broad arrow cut in the rock, on the South side of the approach to the wharf.

	Elevation.
Bench-mark as described; elevation assumed	100·00
High Water. Average level of High Water, reduced to annual value.	99·71
Low-water datum; determined from the observations as explained	89·60

Mayne.—In Active Pass. Tidal observations were obtained here in 1918. The Bench-mark defining the Admiralty datum is a broad arrow cut on the southern face of Parson rock, in Miners bay. This is a conspicuous angular block resting on the ledge rock at the High-water line, about 200 yards North of the English church. The Low-water datum is at 18 feet 1 inch below the broad arrow.

This datum was found to be too low relatively to others in the region, when comparisons were made by the standard method; and a datum one foot higher was adopted for the Tidal Survey observations. This was the more allowable, as the chart datum in the region appears to be based primarily upon the Bench-mark at Georgina Point at the mouth of Active Pass, described below, and the relation between these has not been determined by instrumental levelling.

	Elevation.
Bench-mark at Mayne; as above described; elevation assumed.. ..	100·00
High Water. Average level of High Water reduced to annual value..	94·10
Low-water datum; as adopted by the Tidal Survey..	82·92
Admiralty Low-water datum; at 18 feet 1 inch below the Bench-mark.	81·92

Bench-mark at Georgina point; in the small bay on the South side of the point. Low-water datum at 17 feet 9 inches below a broad arrow cut in the perpendicular face of the rock about 20 yards eastward of the inner end of the boat wharf. See Chart No. 3520.

During the Admiralty surveys under Captain Parry, tidal observations were taken at Georgina Point in the day time only, from August to October in 1904.

Ganges harbour.—On the East side of Saltspring island. The Admiralty Low-water datum is at 10 feet 3 inches below the top of the highest of the two drying rocks situated in the small bay immediately westward of the rocky point from which the wharf is built out. See Chart No. 3029.

This datum was adopted in the tidal observations of 1915; the datum being determined as a face reading on the tide scale when the water level was even with the top of the rock indicated.

	Elevation.
Bench-mark; the level of the top of the rock indicated..	100·00
Low-water datum; at 10·25 feet below this..	89·75

Telegraph harbour.—On the West side of Kuper island, and on the same body of water as Chemainus and Ladysmith; the three places being within seven miles and within sight of each other from the water. During the Admiralty surveys, this harbour served as a port of reference for a number of other places amongst the Gulf islands in the Strait of Georgia; and by careful comparisons for both time and height, it was thus possible to bring all the localities into relation ultimately with Sand Heads.

Tidal observations during the Admiralty surveys were obtained here by Captain J. F. Parry, R.N., day and night continuously, from April to November in both 1904 and 1905. Further observations were obtained by the Tidal Survey for 6½ months in 1919 and 1920. The original Low-water datum here and in the neighbouring harbours, are thus defined:—

The Low-water datum at Telegraph harbour is referred to a Bench-mark and also to a natural rock. The Bench-mark is a broad arrow cut in the North-east face of the bare rocky islet situated between Hudson island, and Foster point on Thetis island. It is 35 feet from the summit of the islet, which is two feet above high water. The datum is 12 feet 10 inches below the broad arrow.

It is also 7 feet 2 inches below the highest part of the westernmost of the drying rocks lying just outside the low-water line, off the Indian Industrial school. See Chart No. 714.

The Low-water datum at Chemainus is at 18 feet 7 inches below a broad arrow cut in the northern face of the small islet in the bay, lying close off shore, about 600 yards South from the lighthouse. See Chart No. 3029.

The Low-water datum at Ladysmith is at 4 feet 2 inches below the top of the highest of the Cluster rocks, off the Dunsmuir islands. See Chart No. 714. This locality was formerly known as Oyster harbour.

Tidal observations were taken here for six weeks in the season of 1904. The time and range of the tide were found to be absolutely identical with Telegraph harbour.

The following table shows the relative height of the tide throughout the area of the Gulf islands and in the Strait of Georgia. The heights are the annual averages, taken as the mean between the values for the solsticial and equinoxial months. The value for average lower Low Water thus represents about half the diurnal inequality in low water. The "Central Range" is the difference between this average level of lower Low Water and the average level of higher High Water. The first three localities are for the year 1913 to 1914, which was at the maximum range in the moon's declination in the 19-year lunar cycle; and to make the observations at Telegraph harbour in 1904 comparable, which is a minimum year in the cycle, the necessary correction has been made.

Annual Averages	Sand Heads	Port Townsend	Cowichan bay	Telegraph harbour
Higher High Water	12·67	10·88	10·88	10·95
All High Waters	11·79	10·27	10·10	10·22
Lower Low Water	2·47	2·19	2·12	2·18
Central Range	10·20	8·69	8·76	8·77

The proportionate rise of the tide is obtained from the ratio of the Central Range at any locality with the reference tidal station. As a further check on the ratio of Telegraph harbour to Sand Heads, because of its being used as a secondary port of reference as explained, the Central Range was computed in three different months of 1904, for comparison with Sand Heads.

Position of Month	Sand Heads	Telegraph harbour	Ratio (Percentage)
Solsticial month; June 7 to July 5	10·33	8·83	85½
Intermediate month, between these	9·54	8·30	87
Equinoxial month; Sept. 7 to Oct. 5	8·63	7·36	85

This comparison serves to show how closely a true ratio can be obtained, if similar conditions are observed. In this case, the mean ratio adopted is 86 per cent.

The general tide levels for Telegraph harbour are here given. They may be taken as the same, relatively to datum, for Chemainus and Ladysmith. They also serve to indicate, for the region of the Gulf islands, the range of the tide and its variations.

	Elevation.
Admiralty Bench-mark at Telegraph harbour; the broad arrow on the rocky islet as described. Assumed elevation	100·00
Extreme High Water in 1919; occurred December 24	100·40
Highest High Water in the season of 1904, occurred June 19	99·05
Average level of higher High Water; the mean of a solsticial and an equinoxial month	98·22
High Water. Average level of High Water, reduced to annual value	97·56
Low-water datum, as above described; at 12 feet 10 inches below the Bench-mark	87·16
Lowest Low Water in the season of 1904; occurred June 13	87·35
Extreme Low Water in 1919; occurred December 7	86·20
Zero of the tide scale in the Admiralty observations of 1904 and 1905; at 8·00 feet below datum	79·16

In addition to Active Pass, where the datum and Bench-marks have already been described, there are Low-water datums in the three other passes between the Gulf islands, which are referred to on the Admiralty charts. The tidal observations during the chart surveys of 1904 and 1905, obtained as readings on tide scales, are also indicated. They have served as a basis for the time-differences for the tide, as published in the Tide Tables.

Porlier Pass.—Between Valdes and Galiano islands. Low-water datum at 11 feet 2 inches below the top of Black rock. See Chart No. 3029.

Tidal observations taken for a short period in 1905.

Gabriola Pass.—Between Gabriola and Valdes islands. Tidal observations taken in the day time only, for three weeks in August, 1904. The range is the same as at Telegraph harbour. This pass is little used for navigation.

Dodd Narrows.—Between Mudge island and Vancouver island. Low-water datum at 20 feet 6 inches below a broad arrow cut on the western face of a large rock lying 75 feet eastward of the inner end of the Government wharf at Percy anchorage on Gabriola island, which is within a mile of the narrows. See Chart No. 3029.

Tidal observations taken at Percy anchorage in the day time only, for nearly six weeks in October and November, 1904. The time of the tide at Dodd narrows was found to be identical with Percy anchorage, from 27 simultaneous observations carefully taken.

Open Strait of Georgia; West Side

Nanaimo.—The Admiralty chart survey was made by Commander M. H. Smyth, R.N., in 1899; and tidal observations were taken in that year, day and night for seven weeks, from March 25 to May 12. On the chart of the harbour, No. 573, the Low-water datum is defined as follows:—"The Datum to which the soundings are reduced is 18·6 feet below the summit of the masonry beacon on Beacon Rock (liable to alteration); or 10·4 feet below the top of the vertical metal rod forming the Dominion Government Bench-mark, on the rocky foreshore north of the Steamer wharf." The Bench-mark referred to, was placed by the Tidal Survey in 1906; the relation to it being established by Captain F. C. Learmonth, R.N., in 1907. The levels taken by the Tidal Survey in 1909 show that the two references for the datum as above given, do not quite coincide; the discrepancy being 0·15 foot. The reference to the Tidal Survey Bench-mark is to be preferred, as more definite and more accessible.

This Admiralty datum, however, is too low as shown by comparison with Sand Heads. The average level of lower Low Water during the only complete month available in the observations of 1899, was computed for Nanaimo and for Sand Heads, from simultaneous observations. The level of the datum relatively to this value for low water, at the two places, with allowance for the ratio of the ranges, showed the datum at Nanaimo to be 0·52 foot too low. It is not advisable, however, to make any alteration in the datum; especially as it has been correlated with the City levels in Nanaimo. The basis used may not correspond exactly with the Admiralty datum as defined from the Bench-mark, because of the discrepancy mentioned.

Tidal Survey Bench-mark; the top of a vertical bolt, at about half-tide level, on the rocky foreshore. Its position is 156 feet North 55°East from the Northeast angle of the base of the Custom House buildings. A broad arrow is cut on the rock alongside the bolt, with the letters "B.M." beside it.

For additional security, another Bench-mark was placed on the Custom House building. It is a broad arrow cut on the South-east side of the door in the rear wall of the building, facing the sea; at 12½ inches above the stone door sill.

An approximate value for Mean Sea-level was obtained from these observations; as they were continuous day and night during seven weeks. To derive the best advantage from the period available, two lunar months were taken, from the beginning and back from the end, although these necessarily overlapped somewhat. From the average levels of high water and low water in each of these months, the resulting height of the Half-tide level above the Admiralty datum was 9·46 feet. The Half-tide level at Sand Heads was then found from simultaneous observations in the same two months, which gave the difference between this level and true Mean Sea-level as there determined. The difference when increased in the ratio of the ranges between Nanaimo and Sand Heads, showed that the Half-tide level at Nanaimo was 0·30 foot lower than Mean Sea-level; and by applying this correction, the value 9·76 feet was obtained for Nanaimo which is the best that these limited observations can afford.

The tide levels here given are chiefly derived from one lunar month, April 1 to 30, in the Admiralty observations of 1899.

	Elevation.
Bench-mark on Custom House; as described	141·55
Summit of masonry beacon on Beacon Rock; originally at 18·60 feet above the Admiralty chart datum	108·20
Highest High Water in April, 1899	104·60
Average level of higher High Water during the month of April	103·48
High Water. Average level of High Water reduced to annual value	102·81
Tidal Survey Bench-mark; the top of bolt as described	100·00
Mean Sea-level; approximate value at 9·76 feet above datum, as explained	99·36
Average level of lower Low Water during the month of April	92·81
Lowest Low Water throughout the seven weeks observations in 1899. Occurred April 28	90·20
Admiralty chart datum; as defined on the harbour chart, by the reference to the Tidal Survey Bench-mark above cited	89·60

It was noted by Commander Smyth during the chart survey, that the tides at Nanaimo are very irregular. It is also stated by captains of coasting steamers, that the wind affects the height of high water; a Northwest wind lowering it one foot and a Southeast wind raising it two feet.

A tidal station has not been established here by the Tidal Survey; as Nanaimo would not answer as a port of reference for the Strait of Georgia as well as Point Atkinson does.

The points along the coast where a Low-water datum was established during the Admiralty surveys under Captain Parry, R.N., are given below. The tidal observations then obtained have been utilized as a basis for the time-differences in the Tide Tables.

Departure bay.—Three miles north of Nanaimo. Low-water datum at 18 feet 4 inches below the summit of Black rock, in the northern part of the bay. See Chart No. 2512. Tidal observations were taken in the day time only, for about six weeks in July and August, 1904.

Hammond bay.—Low-water datum at 4 feet 6 inches below the top of Clarke rock. See Chart No. 579. Tidal observations were taken in the day time only, for nearly three weeks in July, 1904.

Nanoose.—Low-water datum at 11 feet below the top of a small rock lying 175 yards to the westward of the northern and highest of Entrance rocks. See Chart No. 585.

Tidal observations were taken day and night from October 22 to November 16, in 1903; and in the day time only, for five weeks in July and August, 1904, for comparison with Telegraph harbour.

Comox, and Union in Baynes sound.—The Admiralty chart survey was made by Commander Smyth in 1898, and the Bench-mark at Comox serves to define the datum for the whole extent of Baynes sound. It is of the more importance as tidal observations were secured at Union wharf in this sound with

a registering tide gauge, for fifteen months in all, in the course of the years 1898 to 1900. By means of comparative observations made at the time, the datum has also been carried northward to Mitlenatch island, and to Quathiaski cove near Seymour Narrows. The former name of Comox was Port Augusta.

The note on the general chart of Baynes sound is as follows:—"The soundings are reduced to 23·9 feet below the level of the slab at Goose Spit Magnetic Observation Spot". This spot is marked by a triangle on the charts of Baynes sound and Comox, Nos. 333 and 3127. The following details were noted by the Superintendent of Tidal Surveys in 1905, which will enable it to be found and identified.

The Magnetic Observation spot is on the Northwest shore of Goose spit, in the second small bay West of the Admiralty building and wharf. It is between the last two rifle butts towards the Southwest end of the spit, and ten feet back from the edge of a low bank running along the beach. It consists of a cement slab, about 16 inches square, set level with the surface of the sandy ground. It is marked "*Mag. Obsy. Egeria, 1898,*" in letters of lead let into the slab. Its level is about ten feet above high water mark.

There is another Observation spot, for latitude and longitude, which is farther to the Southwest and farther back from the shore. It is a similar slab of cement; but it is a few inches above the ground, and differently marked, and cannot be mistaken for this one.

On a memorandum accompanying the tidal observations at Union, it is stated that the level of 23·9 feet below the slab at Goose Spit, corresponds to 4 feet 10 inches on the tide scale at Union Wharf; which is the datum to which the soundings were reduced, and also the lowest water obtained throughout the whole period of observation. This gives a very definite connection between the Bench-mark at Comox and the tidal observations.

The Low-water datum as thus defined, when compared with observations at Sand Heads in the same year, was found to be altogether too low. To make the comparison, it was first necessary to compute the Central Range at the two places under similar conditions, and to find the ratio of the rise with Sand Heads.

	Feet.
At Union; average level of higher High Water, being the mean of monthly values at the solstices and equinoxes in 1898-1899. Above chart datum	16·17
Average level of lower Low Water, computed in the same way. Above chart datum	4·83
Central Range at Union; by difference	11·34
Central Range at Sand Heads, for a position in the 19-year lunar cycle which is at one-third of the way from a mean year towards a maximum year	10·12
Ratio of range at Union to Sand Heads. (11·34/10·12)	1·12
(That is, 12 per cent greater at Union.)	

	Feet
At Union; height of lower Low Water above chart datum. Average for the year, from mean of values at solstices and equinoxes, as above..	4·83
Average height of lower Low Water above datum at Sand Heads, multiplied by ratio 1·12; giving corresponding value for Union..	2·71
Chart datum at Union, too low relatively to Sand Heads..	2·12

The ratio was also checked by a direct comparison with simultaneous observations at Sand Heads in three lunar months, in the same way as at Telegraph harbour. The relation of the chart datum to the correct Low-water datum for the locality, was also checked in two other ways; because of the importance of the result for the area of Baynes sound. These check determinations gave the values 2·00 and 2·17 feet; the mean of these being practically the same as the above.

As there was a full year of tidal observations at Union, from April 1898 to June 1899, obtained continuously with a registering tide gauge, the tide levels were fully worked out. The results serve also to show the variations in the level of high water and low water in these regions.

	Elevation.
Admiralty Bench-mark at Comox; the surface of the slab at Goose Spit as described. Assumed elevation..	100·00
Extreme High Water, at 18 feet 8 inches above datum; in 1898 on December 18..	94·75
Average level of higher High Water; the mean of the two solsticial and the two equinoxial months in 1898 to 1899..	92·27
High Water. Average level of High Water, reduced to annual value.	91·31
Average level of lower Low Water; the mean of four months at the four quarters of the year..	80·93
Average level of the lowest Low Water in each half month throughout one year..	78·80
Low-water datum adopted by the Tidal Survey. Determined by the standard method, based on simultaneous observations at Sand Heads..	78·22
Admiralty chart datum; being the lowest Low Water throughout the 13½ months of observations..	76·10
Lowest Low Water observed; occurred in 1898 on June 4. (The simultaneous tide at Sand Heads fell to 1·20 feet below datum there)..	76·10
Zero of tide scale at Union Wharf; at 4 feet 10 inches below Admiralty datum..	71·27

Strait of Georgia; East Side

Point Atkinson.—The registering tide gauge is at the wharf, in a rocky cove just East of the point, known as Caulfeilds. Three eye-bolts set in the rock, are used as Bench-marks for the observations.

Bench-mark A.—The top of an eye-bolt close to the wharf approach on the North side, about extreme High-water level; and about 80 feet along the approach from the shore end of the wharf. (The eye of this bolt is now broken off.) Original elevation 100·00 feet.

Bench-mark B.—A rounded point of rock 4 inches from a bent eye-bolt, and thus marked by it; at 52 feet Northwest of A. Elevation 94·31 feet.

Bench-mark C.—The higher of two eye-bolts set within 3 inches of each other, under the wharf at its shore end; at 89 feet west of A, and 82½ feet Southwest of B. Elevation 93·79 feet.

	Elevation.
Extreme High Water; occurred in 1920 on December 30..	100·95
Average level of higher High Water; the mean of a solsticial and an equinoxial month in 1914	98·31
High Water. Average level of High Water, reduced to annual value.	97·50
Mean Sea-level; from the hourly ordinates of the tide during seven complete years of observation, from 1914 to 1921; at 8·678 feet above the Low-water datum..	93·93
Low-water datum; maintained throughout the observations..	85·25
Average level of the lowest Low Water in each month, during one year 1914 to 1915; at 0·12 foot below datum..	85·13
Extreme Low Water; at 1·65 feet below datum. Occurred in 1919 on December 7..	83·60

The year for which this Low-water value is computed is near the maximum in the 19-year lunar cycle of declination; and in differing only 0·12 foot in such a year from the adopted datum, it shows the close correspondence with the original Sand Heads datum, which was computed by the same method; although the year in which the computation was there made is not known.

Squamish.—At the head of Howe Sound. Observations were obtained here in 1917; and in 1918 a value of Mean Sea-level was desired by the Geological Survey for a contoured map of the neighbouring Britannia mines. An approximate value was computed from two months observations, which was communicated to Mr. K. G. Chipman of that Survey.

Tidal Survey Bench-mark; a broad arrow of sheet metal on top of the cap of the Pacific Great Eastern railway wharf at Squamish; directly over the eighth pile from the outer corner of the wharf on the West side.

	Elevation.
Bench-mark as above described..	100·00
Mean Sea-level; from the hourly ordinates of the tide during two months in 1917; at 8·98 feet above datum..	86·93
Low-water datum; determined to correspond with the datum at Point Atkinson, by simultaneous comparisons..	77·95

As the tidal observations were begun in August, the value of Mean Sea-level is not affected by any influence that the spring freshet in the Squamish river may occasion.

Powell River.—In the tidal observations now taken for some years by the Resident Engineer of the Powell River Company, the elevation of mean low tide is taken as 102·00 feet above the Company's datum; and the zero of the tide scale is two feet lower, at 100·00 feet. The extreme tides observed are as follows:—

Extreme High Water, about elevation..	117·00
Extreme Low Water, somewhat below elevation..	100·00

Lund.—Tidal observations were obtained here in 1909; the tide scale being placed on the West side of the Government wharf.

Bench-mark; the top of a brass bolt set vertically into the granite rock, about the level of extreme high water; at 12 feet from West side of Thulin Brothers' rear storehouse, near the head of the wharf. Elevation, 100·00 feet.

	Elevation.
Extreme High Water in 1909. Occurred November 1	100·20
High Water. Average level of High Water reduced to annual value ..	97·21
Low-water datum; determined to correspond with Sand Heads by the standard method	83·65
Lowest Low Water during the observations in 1909. Occurred August 2	83·60

A special determination of the Central Range was made at Lund, to determine accurately the ratio of the rise with Sand Heads, near the Northern end of the Strait of Georgia. The Central Range was determined for four consecutive months; and from the curve of variation the mean annual value was found for comparison with Sand Heads. The resulting ratio was 1·14 or 14 per cent greater. This accords with the ratio 1·12 at Union in Baynes Sound on the opposite side which is not so far north; and it affords a check on the proportion in the increase in rise throughout the Strait of Georgia. A similar comparison for Bute inlet based on two months, shows a further increase of 5 per cent from Lund to the head of the inlet.

Whaletown.—On Cortes island. Observations during 6½ months, from August 1916 to February 1917.

Deceit bay.—In Redonda island. Observations in the season of 1917. The observations were taken at these two localities to obtain the maximum tide at the head of the strait of Georgia; but it was found that the range continued to increase to the head of Bute inlet.

Bute inlet.—From the viewpoint of the tide, this inlet constitutes the extreme northern end of the Strait of Georgia, and the rise here attains its maximum. Observations were obtained at the head of this inlet in 1909; the locality being indicated on the map as Waddington harbour, although there is no wharf or settlement there. The registering gauge was set between piles specially driven to support it. This may prove in future, however, a point of communication with the interior, by the Homathko River.

Bench-mark; the top of a brass bolt set vertically into granite rock about 500 feet Southwest along the shore from the only stream running down the cliff

near the mouth of the Homathko river on the West side. At low tides, the bar dries to the mouth of this stream. The bolt is about 2 feet below high water. Elevation, 100·00 feet.

	Elevation.
Highest High Water during two months in 1909. Occurred September 30	102·50
High Water. Average level of High Water determined from two months centering on the equinox, with correction to annual value	100·41
Lowest Low Water during two months in 1909. Occurred August 31	87·00
Low-water datum, determined by the standard method; based on the equinoxial level correlated with the corresponding value at Sand Heads	86·35

Region of Johnstone Strait

This name may be given to the complex network of passages and inlets between the northern end of the Strait of Georgia and Queen Charlotte sound for an extent of 85 miles. Tidal features are here illustrated which are extremely interesting. The high water of the ocean at the northern end is practically simultaneous with low water in the Strait of Georgia, and vice versa. There is thus at times a difference of level equal to the whole range of the tide at the two ends of these passages, which may well account for the violence of the currents in the passes and narrows. Also, the rise of the tide decreases continuously from both the northern and southern end of the network of passages towards the middle, whereas the strength of the currents increases until a culmination is reached at Seymour Narrows. The least range of the tide in the region thus coincides with the greatest strength of the current, which accords perfectly with hydraulic principles.

The only straight series of passages in this network, follows the east coast of Vancouver island which is almost unindented. This is adopted as the main route of navigation, by way of Discovery passage and Johnstone strait. It is along this line also that the Low-water datums for the charts during the Admiralty surveys were established. Observations of the tide were then obtained along this line of passages, at six localities for short periods, in 1899 to 1903. The efforts of the Tidal Survey in more recent years, have been chiefly devoted to the turn of the currents and the time of slack water, for the benefit of general navigation and the lumber industry. Tidal observations have been obtained at a few leading points however.

It was thought well to establish a port of reference at the middle of the length of the coast of British Columbia, near the northern end of Vancouver island; and two tidal stations were equipped in Hardy bay and in Rivers inlet at Wadhams, which were maintained for some years. It was found possible however to refer the whole series of tides to Sand Heads and to Port Simpson, both for time and height, without the need of an intermediate Reference station. The dividing line between the two, falls in this region where the tide has its least range; the line running transversely across the various passages from Seymour Narrows to the Yuculta. South of this line, the rise can be referred by a ratio to Sand Heads, and north of it by a ratio to Port Simpson.

The early Admiralty observations have all been utilized to obtain these ratios. The more recent observations by the Tidal Survey supplement these, as they are chiefly on the lateral passages and inlets of the network. Many localities in the region which are named Ports and Harbours are uninhabited; and it may therefore suffice to give a list of the Low-water datums used for the charts and a table of the ratios and rise of the tide. The information regarding the datum at this series of localities, has been furnished by Captain J. F. Parry, R.N., who was in charge of the Admiralty surveys in this region from 1898 onward, with H.M.S. " Egeria."

The Central Range as given in the table may not always be comparable between one locality and another; because it is not always possible to bring it correctly to its annual value when the observations are of short period. The Ratio is truly correct however, as it is derived from a comparison which is either with simultaneous observations at the Reference station or is computed under similar conditions. Auxiliary comparisons were often made with Lund or with Alert Bay, where the observations were longer; and the final ratio as given will enable the rise to be found correctly from the Tide Tables for the Reference station. The Mean rise as here stated is also consistent throughout.

Where observations have been obtained with registering tide gauges, further tide levels can always be deduced from the record; which will be of service to any settlements or industrial establishments that may come into existence in the future.

Mitlenatch island.—Eight miles E. S. E. from Cape Mudge. Tidal observations taken day and night from May 29 to June 6 in 1899, simultaneously with the observations at Union in Baynes sound; for comparison of time and datum. See Chart No. 580.

Quathiaski cove.—Discovery passage. Low-water datum at 10 feet below a broad arrow cut on the side of a boulder at the inner end of the wharf. See Chart No. 3162.

Tidal observations taken day and night from May 8 to June 4 in 1899.

By comparison of the day tides during 16 days in May, with the simultaneous observations taken at Union, the elevation of the general datum for Baynes sound was found to be at 5 feet 8 inches on the Quathiaski tide scale.

It was thus intended to make the datum the same as in Baynes sound. As the Bench-mark here cannot now be found, the datum can best be redetermined by simultaneous comparisons with Point Atkinson, based on the observations of 1923 and the new Bench-mark established by the Tidal Survey. The range is practically the same as at Sand Heads, the ratio being 0·96 as found from a simultaneous comparison with Sand Heads in 1899 and a comparison with Lund; the mean of the two being accepted.

Gowlland harbour.—In Discovery passage. Low-water datum at 9 feet 3 inches below a broad arrow cut in the rock at the south-east extreme of Gowlland island. See Chart No. 3178.

Menzies bay.—At south end of Seymour Narrows, in Discovery passage. Low-water datum at 4 feet 6 inches below the base of the beacon on Defender shoal in the bay. See Chart No. 538.

Nymphe cove.—At the mouth of Menzies bay, and at the south end of Seymour Narrows. Tidal observations were taken here day and night for nearly two months, from June 19 to August 14 in 1900. Also, by the U. S. Coast and Geodetic Survey on the opposite side of the Narrows, in the day time only, throughout the season of 1897.

The rise here appears to be somewhat irregular, as might be expected at the balancing point between the northern and southern tides. The average rise derived from the observations in 1897 is 1·18 feet more than in 1900. On account of the crucial importance of this locality, ratios were deduced from simultaneous comparisons in 1900 with Sand Heads and Alert bay; as well as check comparisons with Lund; which were averaged with the results in 1897. The ratio is the lowest in the region.

Chatham point.—The dividing point between Johnstone strait and Discovery passage. Low-water datum at 18 feet below a broad arrow cut in the face of the rock on the north side of the small islet lying $\frac{1}{8}$ mile west of Turn island, and close off the south shore of Thurlow island. See Chart No. 3260.

Tidal observations taken day and night, from July 21 to August 30 in 1900.

Vere cove.—In Thurlow island, Johnstone strait. Low-water datum at 11 feet 8 inches below the top of Dorothy rock. See Chart No. 581.

Salmon river.—Post Office name, Sayward. Observations were obtained by the Tidal Survey in 1916, at the mouth of this river opposite Hardwick island; and a Bench-mark established.

Bench-mark; a bolt drilled horizontally into the rock on the shore facing the wharf; at 42 feet south from the third face pile from the inside corner of the wharf.

Blinkinsop bay.—Johnstone strait. Low-water datum at 7 feet 6 inches below the top of a large boulder lying three-quarters of a cable north-east of Point George. See Chart No. 3271.

Tidal observations taken day and night for 19 days in September, 1900. Although the observations are so short, a fair value for the ratio is obtained by a comparison with 12 simultaneous ranges at Alert bay. The range proving so nearly the same as at Salmon river, a mean value for the ratio is adopted in the Tide Tables for both localities.

Port Harvey.—Johnstone strait. Low-water datum at 11 feet 11 inches below a broad arrow cut on the rocks on the main shore abreast of Tide Pole islet. See Chart No. 634.

Growler cove.—In Cracoft island, Johnstone strait. Low-water datum at 11 feet 8 inches below the top of the outer rock in the southern corner of the cove. See Chart No. 3387.

Farewell harbour.—Formed by a group of islands off Blackfish sound. Low-water datum at 20 feet 4 inches below the top of the big boulder at Boulder point, the south-west extreme of Berry island. See Charts Nos. 581 and 3387.

Alert bay.—In Cormorant island, Broughton strait. Low-water datum at 17 feet 6 inches below a broad arrow cut in a large boulder beside the roadway, 100 yards west of the saw mill of the Indian Industrial school. See Chart No. 3271.

Tidal observations taken on a registering gauge, being thus continuous day and night, from June 6 to September 19 in 1900. These observations were long enough to enable true annual averages to be found. Several of the other localities were therefore compared in the first place with Alert bay, before being finally brought into relation with Port Simpson.

Port McNeil.—Vancouver island. Low-water datum at 10 feet 3 inches below the top of Eel reef. See Chart No. 3417.

Beaver harbour.—Vancouver island. Low-water datum at 13 feet below the top of Cormorant rock. See Chart No. 2067.

Blunden harbour.—Queen Charlotte sound. Low-water datum at 20 feet 8 inches below a broad arrow cut in the rock at the southern extreme of Byrnes island, just above high water. This also corresponds with 5 feet below the top off Moore rock, off the west side of the Bonwick islands. See chart No. 3448.

Tidal observations taken on a registering gauge, being thus continuous day and night, from July 14 to October 16 in 1903. The lowest tide observed, fell to the datum level on August 22.

The tide here is practically identical with Port Hardy, directly opposite on Vancouver island; and the tide levels may be taken as the same in relation to the Low-water datum.

Shushartie bay.—South side of Goletas channel. Low-water datum at 10 feet 5 inches below the top of Dillon rock. See Chart No. 3430.

Bull harbour.—In Hope island, mouth of the Goletas channel. Low-water datum at 10 feet below the top of the large boulder off the south-east corner of Indian island. See Chart No. 3443.

Southgate harbour.—In North channel, mouth of Queen Charlotte sound. Low-water datum at 18 feet below the summit of Tide rock at the southern entrance of the anchorage. See Chart No. 3462.

Simultaneous tidal comparisons with Blunden harbour in 1903, show that the time and range of the tide at the two places are identical; and the datum is the same as determined in Blunden harbour.

On the channels and inlets to the eastward of the main waterway along which all the above localities lie, observations have been obtained by the Tidal Survey, during the investigation of the currents in this region. Some of these were taken as readings on tide scales; but at the two following localities registering tide gauges were erected.

Shoal bay.—At the east end of Thurlow island, 11 miles north of the Yuculta rapids; during the season of 1916. The rise here corresponds with the amount found in Johnstone strait, as nearly opposite as may be.

Knight inlet.—Observations during the season 1917, at Glendale cannery about the middle of the length of the inlet. The rise is much greater than anywhere else in the region; and this inlet may therefore be considered as the head of Queen Charlotte sound, in the same sense that Bute inlet is the head of the Strait of Georgia.

In Wellbore channel in 1916, and in Chatham channel and at Green Point in Cordero channel in 1917, scale readings were taken during the observations of the current, to obtain the time of high and low water.

Locality	RATIO With Alert bay	L.L.W. above datum	Central Range	Rise to average H.W.	RATIO With Sand Heads
	Percentage	Feet	Feet	Feet	Percentage
Lund, Strait of Georgia	.....	3·08	11·04	13·56	1·14
Quathiaski cove	.....	—	—	11·41	0·96
Nymphe cove	.....	2·21	8·54	10·23	0·86
SEYMOUR NARROWS					With Port Simpson
Nymphe cove	0·78	(As	above.)	.....	0·55
Chatham Point	0·83	2·44	9·36	10·80	0·59
Salmon river	0·98	—	10·98	13·21	0·71
Blinkinsop bay	0·97	—	—	12·87	0·69
Alert bay	1·00	2·90	11·18	13·04	0·71
Blunden harbour	1·05	3·05	11·49	13·62	0·74
Port Hardy	1·06	3·04	11·65	13·93	0·75
Wadhams, Rivers inlet	1·02	2·90	11·20	13·35	0·72
Other channels					
Shoal bay	.....	—	9·76	11·90	0·64
Knight inlet	.....	—	13·76	16·20	0·86

Port Hardy.—On Queen Charlotte sound, at the northern end of Vancouver island. Maintained continuously as a tidal station for three years, from July 1905 to October 1908; and during the season of 1909.

Bench-mark; a copper bolt, $1\frac{1}{4}$ inches diameter, drilled into the rock on the north side of the Government wharf. It is 58 feet from the first pile bent

of the wharf at the shore end, and 8 feet from the side of the wharf. It is about two feet below extreme high water. The elevation assumed for the top of this bolt is 100·00 feet.

	Elevation.
Cap of wharf at site of the tide gauge in 1905	107·37
Extreme High Water during the three years observations; occurred in 1908 on January 4	102·75
Exceptionally High Water in 1905; occurred December 26	102·05
Bench-mark, as above described	100·00
High Water. Average level of High Water, reduced to annual value.	97·64
Average level of the lowest Low Water in each month of the year; the mean for three years being 0·59 foot above datum	83·96
Low-water datum adopted	83·37
Extreme Low Water during the three years of observation; occurred in 1907 on November 6	83·05

From an accurate reduction according to the standard method, it was found that the datum as adopted is 0·34 foot too low, relatively to Wadhams and Port Simpson. This correction is made on the rise as given in the Tide Tables; but it in no way affects the tide levels here given in relation to the Bench-mark.

Seymour Inlet.—Connected with Queen Charlotte sound by a narrow entrance at the inner end of Slingsby channel, which leads into a series of six inlets and sounds branching off each other. The longest runs in 35 miles from the entrance, and their total area is approximately 110 square miles. This is developing as a lumber region.

Observations were taken for three days at the highest tides in October, 1915, at a point half a mile inside the entrance narrows. These afforded the ranges on five tides for comparison with simultaneous tides at Wadhams, where the range is the same as in Queen Charlotte sound. The ratio of the range within the entrance to the open sound, was thus found to be 65 per cent. Although the current pours in and out in a torrent at high and low water, there is not time for so large an area to fill up and empty out.

This example is of interest in showing the conditions that may obtain when a large inlet has a restricted entrance. The tidal behaviour is the opposite of the usual inlet with parallel sides; as in these, the rise of tide at the head is greater by 4 per cent or more, than at the mouth; provided that the depth is great throughout. Burrard inlet affords a type which is somewhat intermediate in character.

The Northern Coast

Wadhams.—In Rivers inlet, on the South side. A registering tide gauge was placed here in July of 1905, and maintained for six years until September 1911.

Bench-mark; a brass bolt set horizontally into the rock at the South side of the bay in which Wadhams' cannery is situated. It is 55 feet from the point at which the rock begins, which rises to the southward into cliffs. Its level is reached by unusually high tides.

	Elevation.
Extreme High Water; occurred in 1906 on December 17	101·20
Highest High Water in 1905; on October 1	100·70
Bench-mark, as above described	100·00
High Water. Average level of High Water reduced to annual value; being the mean of two years observations	97·69
Mean Sea-level. From the hourly ordinates of the tide during five complete years, from 1906 to 1910. At 8·744 feet above the Low-water datum	92·33
Average level of lower Low Water; based on four months at the four quarters of the year, in two different years	86·50
Average level of the lowest Low Water in each month of the year; the mean for the two years 1906 and 1907, being 0·24 foot above datum	83·83
Low-water datum adopted. (This datum corresponds accurately with the determination by the standard method)	83·59
Extreme Low Water, during the two years 1906 and 1907. Occurred in 1907 on January 13	82·65

Kildala.—At the head of Rivers inlet. In 1909, from August 22 to September 17, scale readings were obtained in the daytime only, giving the time and height of high water and low water.

General Note

On the extent of coast from Queen Charlotte sound to Dixon entrance, it is the time of the tide which is chiefly of importance in relation to the turn of the current in the channels and passages. For the height of the tide, comparative values are here given for a series of localities from Wadhams to Port Simpson where registering tide gauges have been placed. The data will afford a basis for the tide at any intermediate localities which may develop as settlements.

On this coast, the Spring and Neap tides can be distinguished, but the diurnal inequality is still large. The values are based on one lunar month at the autumnal equinox; and they are all simultaneous in the year 1909, with the exception of Bella Bella, Lowe inlet and Claxton, which are in other years although in an equinoxial month.

To facilitate the comparison, the heights at each locality are measured from a zero level which is the mean of the two lowest consecutive Low Waters during the month in question; the diurnal inequality being thus eliminated. The Mean Range as here given, is the difference between the average levels of high and low water in the month chosen; which at least gives values that are comparative.

Locality	Lowest L.W.	Highest H.W.	Average L.W.	Average H.W.	Mean range
	Feet	Feet	Feet	Feet	Feet
Wadhams, in Rivers inlet	0·00	14·85	2·46	11·35	8·89
Namu, on Fitz Hugh sound	0·00	14·75	2·44	11·34	8·90
Bella Coola, at head of Burke channel	0·00	16·40	2·92	12·93	10·01
Bella Bella, on Lama passage	0·00	13·20	1·95	11·18	9·23
Hartley bay, in Wright sound	0·00	18·25	2·85	14·14	11·29
Kitimat, at head of Douglas channel	0·00	18·70	3·30	14·88	11·58
Lowe inlet, off Grenville channel	0·00	19·55	3·31	15·42	12·11
Claxton; entrance to Skeena river	0·00	20·10	3·37	17·11	13·74
Port Essington on Skeena river	0·00	21·90	3·20	17·70	14·50
Port Simpson	0·00	21·35	4·14	17·21	13·07

There is thus a general increase in the rise of the tide along the coast from south to north. Also, the rise is least on the open coast, and increases in the inside channels and towards the head of the inlets.

When registering tide gauges are used, the tide levels can always be deduced from the record, either as elevations with reference to a Bench-mark, or in relation to the Low-water datum.

Namu.—On Fitz Hugh sound. Tidal observations in the season of 1909. The tide gauge was placed at the cannery wharf.

Bench-mark; the top of an iron ring-bolt let into the rock, at the foot of the steps leading down from the wharf; at 38 feet back from the head of the wharf and 14 feet from its West side.

Bella Coola.—At the head of Burke channel. A wide valley opens back from here along the Bella Coola river, which is becoming settled. Tidal observations in the season of 1909. The tide gauge was placed at the wharf which is against the cliffs at the end of a long approach. For greater security in maintaining the levels, three Bench-marks were established.

Bench-mark No. 1. A brass bolt set horizontally into the rock, about five feet above extreme high water, and marked by the letters " B.M." cut on the face of the rock beside it; situated at 500 feet shorewards from the prominent point around which the wharf bends.

Bench-mark No. 2. The top of a long iron drift bolt driven through an inside stringer, securing the wharf to the cliff. The bolt runs 24 inches into the rock. It is situated 26 feet from the corner of the freight shed on the wharf.

Bench-mark No. 3. A bench chiselled into the face of the rock near the iron bolt above described, with a vertical line below it, forming a "T". Cut as a precaution in case the iron bolt is disturbed.

	Elevation.
Bench-mark No. 1. The brass bolt	102·85
Bench-mark No. 2. Top of iron bolt	100·00
Bench-mark No. 3. Chiselled in rock	99·41
Highest High Water during one equinoxial month in 1909	97·35
Average level of High Water during the same month	93·86
Average level of Low Water during this month	83·85
Lowest Low Water during this month	80·25

Ocean Falls.—An industrial establishment in Cousins inlet. Tidal observations were obtained here with a registering tide gauge in 1911 and 1912, and again in 1922, with the co-operation of the Hydrographic Survey. The Low-water datum of the chart is at 6·80 feet below the datum adopted for construction purposes by the Pacific Mills Company.

In 1922, the following levels were obtained by Captain J. H. Knight of the Hydrographic Survey, with reference to the Bench-mark on the large chimney.

	Elevation.
Elevation of Bench-mark	118·00
Surface of wharf planking	116·20
Low-water datum; at 1·00 foot on tidal scale of 1922	93·20
Zero of tide scale in 1922	92·20

Bella Bella.—On Lama passage. Tidal observations from July 1905 to March 1907, taken at old Bella Bella in McLaughlin bay. (See data in the general table.)

Surf inlet.—Off Laredo channel. A Bench-mark was placed here by the Hydrographic Survey in 1914. It is a brass bolt set vertically in the granite rock, on the eastern side of the wharf at the head of Surf inlet, about 12 feet from its inshore end. The Low-water datum of the chart is at 20·37 feet below this Bench-mark.

Borrowman bay.—On the West coast of Aristazabal island. A Bench-mark was established here by the Hydrographic Survey, to define the datum in the chart surveys of 1922. The Bench-mark is a brass bolt cemented flush in the rock, on the southern point of the entrance to Turtish harbour, at the bottom of Borrowman bay. The Low-water datum is at 18·30 feet below this Bench-mark, and the zero of the tide scale at 21·20 feet below it.

Griffith harbour.—On Banks island. A Bench-mark was placed here in 1921 to define the chart datum. It is a brass bolt set in the rock East of Birch Point, in the harbour. The Low-water datum is at 21·90 feet below this Bench-mark.

Hartley bay.—In Wright sound; on the point of land between Grenville channel and Douglas channel which leads to Kitimat. Tidal observations in the season of 1909. The tide gauge was placed at the wharf of the Hartley bay Lumber Co.

The Bench-mark established here, was set in the first large rock across the little bay on the East side of the wharf at the end of the beach running from the inner end of the wharf; a brass bolt drilled into the rock, slightly above extreme high water. The zero of the tide scale as set, being known with relation to the Bench-mark, the tide levels can be reduced to elevations from the record itself.

Kitimat.—At the head of Douglas channel. A trail leads across from here to the Skeena river. Tidal observations in the season of 1909. The Bench-mark established here, was set at the northerly end of a small ridge of rock, on the North side of the wharf; the top of a brass bolt drilled into the rock, at 86 feet from the inner end of the wharf where it meets the village sidewalk.

	Elevation.
Bench-mark as described; elevation	100·00
Highest High Water during one equinoxial month in 1909	102·90
Average level of High Water during the same month	99·10
Average level of Low Water during this month	87·52
Lowest Low Water during this month	83·55
Zero of tide scale in 1909	79·52

Lowe Inlet.—A small inlet or deep bay on the East side of Grenville channel. Tidal observations in 1905. (See data in the general table).

Chismore passage.—Tidal observations were obtained here in 1909, with a registering tide gauge, in co-operation with the Hydrographic Survey; at a point known as Camp Plaisance, opposite Lewis island. The Low-water datum was brought into relation with the determination made at Claxton by Captain Musgrave in 1907, by means of simultaneous comparisons in 1909. The datums here and at Claxton, were also correlated directly with the Low-water datum at Prince Rupert.

Claxton.—This locality commands the entrance to the Skeena river; and it represents the tide at the mouth of the estuary, with little effect from the river influence. Tidal observations were obtained here in 1907, and in 1909 to 1910; the observations taken in 1909 affording comparison for the datum in Chismore passage for the Hydrographic chart surveys.

Bench-mark placed in 1907; the top of an iron rod, $\frac{7}{8}$ inch in diameter, drilled into the rock at 29 feet from the face of cribwork along the shore, and 167 feet from the West side of the stageway to the Power house of the Claxton cannery.

	Elevation.
Flooring of wharf at site of tide gauge; elevation in 1909	104·60
Extreme High Water, pointed out by residents as occurring in December, 1908	102·05
Bench-mark as above described; elevation	100·00
Highest High Water during one equinoxial month in 1907	99·15
Lowest Low Water during the same month	78·40
Low-water datum; at 1·00 foot on the tide scale	77·57
Extreme Low Water; at 0·75 foot on the tide scale at several dates during the observations of 1907 and 1908	77·32
Zero of tide scale of enamelled iron, placed at the Northwest corner of the Cannery wharf in 1908; at same elevation as original scale of 1907	76·57

Port Essington.—On the Skeena river. Observations were obtained here with a registering tide gauge, from 1909 to 1911; making two full years with an interruption of two months.

Bench-mark; near the East side of the most easterly of the wharves of the Anglo-British Columbia Canning Company towards the Ecstall river. The eye of a ring-bolt in the solid rock at 85 feet back from the front of the wharf, and 14½ feet from its East side.

	Elevation.
Surface of wharf at site of the tide gauge	105·10
Exceptional High Water in 1910 on October 20	104·45
Bench-mark as above described; elevation	100·00
Highest High Water during one equinoxial month in 1909	103·05
Average level of High Water during the same month	98·84
Average level of Low Water during this month	84·34
Lowest Low Water during this month	80·65
Zero of tide scale of enamelled iron, placed at the Northeast corner of the wharf in April 1911. (Set 0·08 foot lower than original scale of 1909 which was carried away in February 1911	77·76

Ecstall river.—A tributary of the Skeena river locally known as the Hocksall. Tidal observations with a registering gauge were obtained on the Ecstall river at the mouth of Falls river in 1912, from May to November. They afforded tidal data in connection with a proposed power development at that point.

Port Simpson.—A registering tide gauge was first placed here in 1902, and has now been maintained for twenty years but with many interruptions; chiefly owing to the difficulty of making repairs, the instability of timber work because of the teredo, and the change of observers. It is most excellent as a Reference station however; as it is directly opposite Dixon entrance and it is entirely free from local disturbance of the tide. Prince Rupert has proved quite unsuit-

able for a Reference station because the complex of inlets in which it is situated give rise to pronounced undulations in disturbed weather, which make the time of high and low water uncertain in making comparisons with other localities.

The whole northern coast system of British Columbia can be referred to Port Simpson, including the Queen Charlotte islands; and it was thus possible to dispense with the stations in the region of Queen Charlotte sound, at Port Hardy and Wadhams, for reference purposes. Port Simpson affords the basis also for the calculation of slack water in the northern narrows and passages. It has therefore been perseveringly maintained.

The zero of the original tide scale was adopted as the Low-water datum; and although liable to alteration and renewal, it has been maintained within 0·09 foot of its original elevation, the error being allowed for in the reductions. It was found advisable to raise the datum half a foot, as it was too low relatively to Prince Rupert and Wadhams, after very elaborate comparisons; based chiefly on the ratios of rise and on Mean Sea-level. The new datum at 0·50 foot higher, is used in the Port Simpson Tide Tables for 1923 and onward; and reductions here given which depend on datum, such as Mean Sea-level, conform to it. It is to be noted however, that this change does not affect elevations, or ratios based on range which is a difference of level.

This alteration in the datum will also bring it into better accord with the chart datum used for the open waters of Dixon Entrance, which was taken as one foot on the Port Simpson scale. For deep sea soundings, the accord will be sufficiently close.

The elevation of 100·00 feet was assumed for a reference point first used, which was cut on the rocky shore but is difficult to find. In 1905 a more suitable Bench-mark was established, thus described: The top of a brass bolt with a round head, drilled into the rock in the rocky foreshore which extends northward from the Hotel Northern. This rocky part of the foreshore is dry at half tide. The bolt is to the West of the wharf, at 174 feet from the angle between the side of the wharf and the hotel platform.

	Elevation.
Cap of the pile wharf, beside the tide gauge	109·10
Extreme High Water during eleven years of observation; occurred in 1914 on October 19	105·50
Next highest High Water, in 1908 on January 4	105·40
Average level of higher High Water; based on four months at the four quarters of the year, in two different years	100·81
High Water. Average level of High Water, reduced to annual value; being the mean of two years observations	99·90
Bench-mark; the top of brass bolt as described	98·91
Mean Sea-level. From the hourly ordinates of the tide during 13 complete years, between 1902 and 1920. At 12·067 feet above the Low-water datum adopted. (See details below)	93·46
Average level of lower Low Water; based on four months at the four quarters of the year, in two different years	85·31

	Elevation.
Average level of the lowest Low Water in each month of the year, for the two years 1911 to 1913; at 0·63 above the datum as adopted.	82·02
Low-water datum. Adopted for the zero of the Tide Tables of 1923 and onward; at 0·50 foot on the original tide scale..	81·39
Zero of the original tide scale of 1902; used as the Low-water datum or zero of the Tide Tables up to 1922..	80·89
Lowest Low Water recorded by the tide gauge during eleven years of observation; occurred in 1906 on May 10	80·40
Extreme Low Water; in 1908 on January 5, determined approximately..	79·80

The elevation of the zero of the tide scale in the various years since 1902, due to settlement or replacement, has varied from 80·80 in 1911 to 80·91 in 1922 as extreme limits. In the reductions, the original elevation of 80·89 feet has been used throughout as a basis; any variation from this, as shown by instrumental levelling in the various years, being allowed for.

Mean Sea-level.—The determination in each complete year is from the hourly ordinates of the tide. There are several interruptions, but the years obtained now cover a lunar cycle of nineteen years. The datum from which the heights are measured, has been maintained truly uniform; the values given being from the Low-water datum at elevation 81·39 feet.

One year from December, 1902 to December, 1903	12·157
" " February, 1904 to February, 1905..	12·083
" " February, 1905 to February, 1906	12·155
" " March, 1906 to March, 1907	12·027
" " March, 1907 to March, 1908	11·949
" " April, 1908 to April, 1909..	11·902
" " August, 1911 to August, 1912	11·992
" " August, 1912 to August, 1913	12·143
" " August, 1913 to August, 1914	12·328
" " August, 1914 to August, 1915	12·327
" " October, 1916 to October, 1917	11·824
" " May, 1918 to May, 1919	12·147
" " May, 1919 to May, 1920	11·834
General average, above the Low-water datum..	12·067

Prince Rupert—It will be unnecessary to detail the difficulty in the early days in maintaining Bench-marks and levels. The primary Bench-mark was covered with buildings; another cut on the rock to replace it, was blasted away in extending the railway; and it is largely due to the efforts of the Tidal Survey that the levels have been maintained at all.

The first Low-water datum, was established in 1906 by Mr. J. H. Bacon when Harbour Engineer. It was the lowest Low Water in the summer of that year, and represents extreme low water. For the chart survey of 1906 and 1907, a datum at 1·00 foot higher was decided upon by Captain P. C. Musgrave and Mr. G. B. Dodge, as being in better accord with low water; and this datum was accepted by the Tidal Survey. An elevation of 100·00 feet was adopted

for the original Harbour datum; and the Low-water datum of the Chart and Tide Tables is thus at elevation 101·00 feet; to avoid disturbing the original harbour levels.

The Prince Rupert datum was extended to Metlakatla and Inverness on the Skeena river, by the levelling of the Grand Trunk Pacific railway; the tide scales at these localities being thus correlated with it.

When the early tidal observations were begun in December 1906, under the supervision of the Harbour Engineer, a tide scale was set with its zero at the datum, namely 100·00 feet; and when a larger recording gauge was installed in 1909, with a view to continuous observations, a tide scale of enamelled iron was placed at this level; which owing to alterations, was reset in 1911. By 1912, there was a concrete wharf which afforded a site for a permanent Bench-mark; and from personal investigation on the ground by the Superintendent of Tidal Surveys, the probable error in the elevations determined for the early tide scales was reduced to 0·05 of a foot, notwithstanding the destruction of Bench-marks.

As the zero of the tide scale is a foot below the datum, the recording instrument which is set with it, will register the lowest tides. From 1911 onward, there is no uncertainty in the levels; and although the zero of the tide scale has varied within the limits of 0·07 foot in different years since then, this has been definitely allowed for.

The position of the concrete wharf as it stood in 1912, is as follows: From the point of intersection of the line of manholes on McBride Street with the outer edge of the road-bed of the railway, it is 45 feet eastward to the West side of the concrete wharf. The manholes are taken for alignment, as they were built before the street was brought to grade.

Bench-mark No. 1.—A brass bolt set vertically into this wharf, its top being flush with the surface of the concrete; at 16 feet 4 inches from the shore end, and 15 inches from the West side. (This should enable the bolt to be found even if sheds are built on the wharf; and because of this contingency it was set in flush). Elevation of top of bolt, 131·03 feet.

Bench-mark No. 2.—A broad arrow cut on the rock of a side-hill cutting, facing the harbour, and marked "B.M." Situated about 360 feet West of the point of intersection above described. Elevation, 133·22 feet.

The Low-water datum at Prince Rupert is in good accord with Port Simpson since the alteration in that datum already indicated. The ratio of the range to Port Simpson is 1·05, or 5 per cent greater. Hence the tide levels determined for Port Simpson, relatively to the datum there, should be correct when measured from the Prince Rupert datum, if increased by five per cent.

	Elevation.
Surface of concrete wharf at the foot of McBride Street; same as elevation of Bench-mark	131·03
Extreme High Water during eleven years of observation since 1909; occurred in 1914 on October 19, same date as at Port Simpson.	126·40
Annual extreme. In the seven years from 1913 to 1920 the highest tide of the year (with the exception of 1919) was not less than 24·15 feet above datum	125·15

	Elevation.
Mean Sea-level. From the hourly ordinates of the tide during 10 complete years, between 1906 and 1918. At 12·521 feet above the Low-water datum	113·52
Average level of the lowest Low Water in each month of the year, for the two years 1911 to 1913; at 0·56 foot above the Low-water datum	101·56
Low-water datum at Prince Rupert; being the Chart datum and the zero level of the Tide Tables	101·00
Zero of tide scale from the beginning; set at the Harbour datum of 1906, which was 1·00 foot below the datum adopted. (Maintained very nearly at this elevation since; in 1922 being at 100·05 feet).	100.00
Extreme Low Water during the 12 years of observation from 1906 to 1920. Occurred in the midwinter of 1919-1920, on December 7 and January 5	99·80

The close correspondence of the Low-water datum at Prince Rupert with the adopted datum at Port Simpson, is shown by the following comparison of low-water levels on simultaneous tides. The values given are determined from the lowest low-water in each of the 13 lunar months of the year, by taking their average level above datum in each year; with the final mean value for the two years.

AT PORT SIMPSON; LOW WATERS:—

Year 1911-1912. Lowest in each month; average	0·56	Mean, 0·68
Year 1912-1913. Lowest in each month; average	0·80	

AT PRINCE RUPERT; LOW WATERS:—

Year 1911-1912. Lowest in each month; average	0·48	Mean, 0·59
Year 1912-1913. Lowest in each month; average	0·70	

Mean Sea-level.—The determination in each complete year at Prince Rupert is from the hourly ordinates of the tide; and the heights are measured from the Low-water datum. Some of the years missing at Port Simpson were here obtained; and the two series thus supplement each other.

One year from December, 1906, to December, 1907	12·529
" " December, 1907, to December, 1908	12·516
" " April, 1909, to April, 1910	12·469
" " June, 1910, to June, 1911	12·447
" " February, 1912, to February, 1913	12·451
" " February, 1913, to February, 1914	12·767
" " February, 1914, to February, 1915	12·771
" " February, 1915, to February, 1916	12·536
" " February, 1916, to February, 1917	12·305
" " February, 1917, to February, 1918	12·419
General average, ten years	12·521

It will be noticed that the highest and lowest years in the series are in accord with Port Simpson, which shows that the variation is actual, as the determinations are entirely independent. The difference in the height of Mean Sea-level above datum at the two places, accords within one per cent with the ratio of the ranges; which is an indirect check on the relative accord of the Low-water datum at the two localities.

Naas river.—At the Mill bay cannery at the mouth of Naas bay. Tidal observations were obtained here during three months in 1913, with a registering gauge.

Granby bay.—Off Observatory inlet. The Low-water datum and a Bench-mark for reference, have been established here by the Hydrographic Survey, in 1916.

Bench-mark; a brass bolt on the southern face of a conspicuous vertical rock which bears 127° from true North, and is 540 feet distant from the inshore end of the old wharf at Anyox. The Low-water datum is 23·08 feet below this Bench-mark.

Stewart.—At the head of Portland Canal. Tidal observations were obtained here during the season of 1912; and the following Bench-marks were placed for reference.

Bench-mark No. 1. In the face of the cliff, at 50 feet due South of the South end of the wharf; the centre of a brass bolt let into the rock, nearly horizontally, at 3½ feet above the plank walk and about 8 feet above extreme high tide. Elevation 100·00 feet.

Bench-mark No. 2. A broad arrow, with the letters "T.S." above it, chiselled into the concrete foundation of a boiler facing the lane in rear of the Columbia building on Fifth Street. This building belongs to the Portland Canal Lumber Co., and is in the South-east corner of Lot 3, Block 15, town of Stewart. Elevation, 92·46 feet.

The groove of this broad arrow is at the level of an extreme high tide that occurred in 1909 on November 27. It was marked by Mr. Charles Smith on the door jamb of his store building on the flats; its elevation being transferred by instrumental levelling.

	Elevation.
Bench-mark No. 1; the brass bolt as described	100·00
Surface of flooring of the wharf	95·11
Bench-mark No. 2; on concrete foundation as described, and marking extreme high water	92·46
Highest High Water in season of 1912; nearly the same level on several dates	89·80
Lowest Low Water recorded; on August 13	65·90

Queen Charlotte Islands

Parry passage.—At the Northwest extreme of the Queen Charlotte islands, inside of North island. A Bench-mark and datum were established here during

the Admiralty surveys in 1907, under Captain F. C. Learmonth; and tidal observations were obtained at Dadens in this passage, during nine weeks in that year.

Bench-mark; the top of a brass bolt, marked with a broad arrow, set vertically in a rock forming the East extreme of the drying ledges on the West side of the boat cove fronting Dadens village; immediately northward of Lucy island and 112 yards eastward of the semi-detached islet (20 feet high) off Village Point, which forms the West point of the cove.

Low-water datum of the chart, at 13·33 feet below the Bench-mark; which corresponds to 9·25 feet below half-tide level as here determined. This corresponds also to 8·83 feet below the highest part of the drying Douglas rock, situated 0·31 of a mile S. 73½° W. (true) from Gunia Point. See Chart No. 3716.

Naden harbour.—During the Admiralty surveys of 1907 above referred to, a datum was established here; and tidal observations were obtained during 10 weeks.

Bench-mark; on a large isolated boulder about 6 feet high, near the High-water line, on the West shore of Alexandra Narrows, exactly opposite George Point, which is distant from it 800 yards S. 86° E. (true). On the seaward face of this boulder, there is a remarkable natural shelf, 3 feet long and a foot wide, about 4 feet from the ground. The Bench-mark is a brass bolt set horizontally into this boulder, projecting 2 inches and marked with a broad arrow, at 9 inches below the shelf and 4 feet 2 inches below the top of the boulder.

Low-water datum, at 16·90 feet below the Bench-mark. See Chart No. 3716.

Masset harbour.—Situated within the entrance to Masset inlet. A Bench-mark and datum were established here during the Admiralty surveys in 1907 under Captain Learmonth, and tidal observations were obtained at Camp Point during six months. Further observations were obtained at New Masset during four months in 1910 by the Hydrographic Survey under Captain P. C. Musgrave, when the whole of the inlet and lake were charted.

From the wharf at Old Masset, where the Indian village is, to New Masset, is 2½ miles; and from New Masset to Camp Point is 2 miles.

The Admiralty Bench-mark is on a large isolated boulder about 4 feet high on the East side of Masset inlet, near the High-water line, abreast of the low grassy spit fronting the tidal lagoon; at about 300 yards northward of Camp Point. The Bench-mark is a metal bolt with a broad arrow cut upon it, which is set horizontally into the Northwest side of this boulder at one foot below the top, and projects 2 inches from it.

Low-water datum of the chart at 11·75 feet below the Bench-mark; which also corresponds to 6¾ feet below the highest part of a detached drying rocky ledge (Davy Ledge) situated about 7 cables S. 78° E. from the South extreme of South-east Striae islet. See Admiralty chart of Masset harbour, and the Hydrographic Survey chart of 1910.

The tide gauge erected by the Hydrographic Survey in 1910, was placed at the wharf at New Masset. The zero of the tide scale was set at 1·00 foot below the Low-water datum, to secure a record of the lowest tides.

Richards island.—Just outside the entrance to Juskatla inlet, on the South side of the lake or wide expanse which forms the head of Masset inlet. A Bench-mark and datum were established here by the Hydrographic Survey in 1910, under Captain Musgrave; and tidal observations were obtained during four months. The tide gauge was situated on the North-west extreme of this small island.

Bench-mark, a brass bolt set into the vertical face of the rocky point forming the North-west extreme of Richards island; marked with a broad arrow and the letters " H. S." chiselled on the rock beside it.

Low-water datum, at 12·10 feet below the Bench-mark.

The rise of the tide in the expanse at the head of Masset inlet is 81 per cent of the rise at New Masset near the mouth of the inlet; as deduced from observations which were simultaneous during 3½ months in 1910.

The following comparative values can be given for the North coast of the Queen Charlotte islands. The " Highest Rise " in 1907 may not be strictly comparative at the various localities, because the observations in Parry passage and at Naden harbour were short and not simultaneous. The mean values are all closely correct, especially those for Masset harbour and Richards island, as they are both from observations in 1910, which were largely simultaneous at the two places.

Locality	Highest Rise in 1907	Mean Spring Rise	Mean Neap Rise
	Feet	Feet	Feet
Parry passage; at Dadens	15·65	12·50	9·75
Naden harbour	18·75	13·10	10·25
Masset harbour	12·65	9·45	7·30
Richards island, in Masset inlet	—	6·95	5·80

Port Louis and Otard bay.—On the West coast of Graham island. A trail leads from Otard bay to the head of Naden harbour.

A Bench-mark was established by the Hydrographic Survey on the shore of Tingley cove, on the South side of Port Louis. It is a brass bolt set in the eastern face of a vertical rock about 525 feet West from the point forming the eastern entrance of the small bay at the Southern extreme of Tingley cove.

The Low-water datum for the chart of this region, is at 15·81 feet below the Bench-mark.

Skidegate inlet.—Tidal observations with a registering tide gauge were obtained at Queen Charlotte city, on the North side of this inlet, with the co-operation of the Hydrographic Survey, in 1911, 1913 and 1915; with further observations beginning in 1923. The tide gauge was placed at the Government wharf situated to the East of the Saw mill wharf.

Bench-mark; a copper bolt in the South face of a rocky point 230 feet S. 34 degrees E. from the inner end of the Government wharf.

Low-water datum, at 26·74 feet below this Bench-mark; and at 2·00 feet on the tide scale as set in 1911. This datum corresponds to ordinary low water; and it is used for the whole of Skidegate inlet and approaches. It is not as low relatively, as the datum elsewhere; and may require revision.

Sand spit.—A tide gauge was placed at this spit, on the outside of Shingle bay, to ascertain the amount of rise in the open, at the mouth of Skidegate inlet, for comparison with the rise within the inlet. Observations were obtained here in June and July of 1915, simultaneously with Queen Charlotte city.

From a comparison of the range of twelve simultaneous tides, the range within the inlet is only 0·14 of a foot greater than at Sand pit; or one per cent more.

Pacofi.—At the head of Selwyn inlet. The name is made from the first letters of Pacific Coast Fishing Company which has a large establishment here. Tidal observations were obtained here, in co-operation with the Hydrographic Survey, in 1910, 1911, 1912 and 1913, making up 19 months in all.

Bench-mark; a brass bolt set into the North-west corner of the concrete basement of the Fertilizing building of the Pacofi company. The Low-water datum for the harbour chart of Pacofi and for Thurston bay in Selwyn inlet, is at 20·80 feet below this Bench-mark. The series of observations obtained here, will enable any tide levels desired to be worked out from the record; as already noted for other localities.

Remark.—The datum at the various localities on both sides of Hecate strait, for which charts have been issued by the Hydrographic Survey, has been determined with relation to Port Simpson by comparisons at the lowest tides indicated in the Tide Tables.

West Coast of Vancouver Island

Quatsino.—In Quatsino sound. Tidal observations were obtained here in the seasons of 1920 and 1921, in co-operation with the Hydrographic Survey under Commander J. H. Knight. The registering tide gauge was placed at the Government wharf at Quatsino settlement, North-east of Limestone island. Observations were also obtaind in 1920, at Port Alice in this sound with a tide scale; for comparison with Quatsino and to establish a datum there also.

Bench-marks and datum.—At Quatsino; a brass bolt let into the rock at 37 feet South-east from the inshore end of the Government wharf. Low-water datum, at 14·72 feet below this Bench-mark, and at 1·00 foot on the tide scale as set in 1920 and in 1921. This corresponds with the datum at Clayoquot.

At Port Alice; the North-west corner of the concrete floor of Acid Tower, on the wharf. Low-water datum at 21·24 feet below this; and at 4·50 feet on the tide scale there used.

	Elevation.
Bench-mark at Quatsino; the bolt as described	100·00
High Water. Average level of higher High Water at ten Spring tides; May to September in 1920	99·33
Average of both the High Waters in the day, at nine Neap tides, during the same period	96·46
Low Water. Average level of lower Low Water at Spring tides, during the same period	87·38
Lowest Low Water; occurred in 1920 on June 18	86·10
Low-water datum; at 14·72 feet below the Bench-mark	85·28
Zero of the tide scale as set in 1920 and 1921	84·28

Clayoquot.—The Reference station for the West coast of Vancouver island; situated in Clayoquot sound, on Low peninsula opposite Stubbs island, in the mouth of the sound; now named Tofino. When tidal observations were begun here in 1905, the tide gauge was placed at a small wharf which was extended to deep water for the purpose, situated near the telegraph office. When the new wharf was built, the gauge and the tide scale were transferred to it in September, 1908, where they have been maintained to date.

The tide levels have been accurately maintained throughout, with reference to the Bench-mark; although the tide scale has been reset several times, and some settlement took place during the early months at the new wharf. The only uncertainty occurred in 1911; the scale when visited in June being found 0·54 foot lower than previously. It was assumed that this change had occurred suddenly, during a storm in February; and the reductions were made on this basis. Since the scale was reset in 1911, it has remained within 0·07 foot in elevation up to 1922, as shown by instrumental levelling in the various years.

Because of the importance of this station and its isolation, a reference mark was established in 1912 in addition to the Bench-mark.

Bench-mark of 1905; the top of a brass bolt drilled vertically in diorite rock, at 23½ feet from the shore end of the old wharf, on its East side. It is about the level of high water.

Reference Bench-mark of 1912; on the concrete door sill in the foundation of the Life-boat station, at the West end of the sill close to the door jamb. Also, the lower edge of a groove in the concrete on the West side of the doorway at 2·00 feet above the sill.

	Elevation.
Bench-mark of 1905; the top of the bolt	100·00
Reference Bench-mark, on door sill of Life-boat house	99·16
Reference groove, at 2·00 feet above door sill	101·16
Extreme High Water in 1905; occurred on December 25	101·50
Extreme High Water during eight years, from 1913 to 1920; occurred in 1913 on November 26	101·60
Mean Sea-level, from the hourly ordinates of the tide during 14 complete years, from 1905 to 1920; at 7·255 feet above datum. (See details below)	94·26

	Elevation.
Low-water datum; maintained at a constant elevation throughout the observations	87·00
Lowest Low Water, next to the extreme low; occurred in 1919 on May 30 and in 1920 on May 19	86·30
Extreme Low Water during eight years; occurred in 1917 on January 23	86·20
Zero of tide scale; since a new enamelled iron scale was placed on a heavy copper-painted pile in August, 1912, the zero has remained within 0·01 of a foot up to 1922	84·50

Mean Sea-level.—The series of years obtained here, which is very continuous, is valuable for reference; as it represents the open Pacific Ocean unaffected by local influences. The only value that is possibly questionable, is for the year 1910 to 1911, because of the disturbance of the tide scale already referred to. The value is accepted, however, as the differences which it gives with near-by years are confirmed by the Prince Rupert series.

One year from October, 1905, to October, 1906	7·307
" " October, 1906, to November, 1907	7·344
" " September, 1908, to September, 1909	7·211
" " October, 1909, to October, 1910	7·331
" " October, 1910, to October, 1911	7·317
" " October, 1911, to October, 1912	7·191
" " October, 1912, to October, 1913	7·304
" " October, 1913, to October, 1914	7·442
" " October, 1914, to October, 1915	7·519
" " October, 1915, to October, 1916	7·289
" " October, 1916, to October, 1917	6·965
" " November, 1917, to November, 1918	7·198
" " November, 1918, to November, 1919	7·179
" " November, 1919, to November, 1920	6·973
Average of the 14 years	7·255

It is to be noted that the years in the series which are unusually high or low, are in accord with the corresponding years at Port Simpson and Prince Rupert. This not only confirms the accuracy of these independent determinations, but also indicates that the influences which cause variation in Mean Sea-level must be general on the whole extent of the coast.

Bamfield.—The Pacific Cable station at four miles from Cape Beale, at the mouth of Barkley sound. The tide gauge was placed at the wharf immediately below the Cable offices; and observations were obtained from February, 1903, to June, 1904, with the exception of one month.

Bench-mark; the top of a brass bolt set vertically into a shelf of the rock at 20 feet from the South-east corner of the wharf, about the level of high water.

Low-water datum at 10·60 feet below the Bench-mark, and at 1·00 foot on the tide scale.

	Elevation.
Bench-mark; bolt as described	100·00
Low-water datum to which the observations are reduced	89·40
Zero of the enamel tide scale during the period of the observations	88·40
Zero of the tide scale, as found in August, 1905	88·33

Alberni.—Known originally as New Alberni; at the head of Alberni Canal which runs in from Barkley sound. The tide gauge was placed at the wharf belonging to Mr. A. E. Waterhouse, and observations were obtained from June, 1909, to January in 1910. Further observations were obtained by the Hydrographic Survey under Captain Musgrave, for a few days in the autumn of 1912 and for a month in the spring of 1913. The tide scale set by the Tidal Survey in 1909 was then still in place, and at the same elevation, as found by instrumental levels in August of 1912. The same Low-water datum as originally established was therefore used in the Hydrographic chart survey. The position of the original Bench-mark is carefully given, as it is now partially covered by the railway embankment.

Bench-mark of 1909; the top of a brass bolt set at a slant into the sloping face of an outcrop of slaty rock, about four feet below high water, on the lot of Mr. A. E. Waterhouse. It is at 83½ feet from the front of his store and 32 feet from the South corner of an office building on the South-east side of the wharf approach, and also 48 feet from the Eastern corner of the wharf. Elevation 100·00 feet.

The elevation of this Bench-mark above the datum of the Esquimalt and Nanaimo Railway, as determined by the Canadian Pacific Railway engineers, is 10·37 feet.

Reference Bench-mark of 1912; on the concrete foundation of the boiler of Mr. Bird's saw-mill, near the most westerly corner; the surface of the concrete at a point marked by a vertical groove in the brickwork above. Elevation 105·67 feet.

Another reference point was established on the concrete foundation of the engine of this Saw-mill, for greater security.

	Elevation.
Level of flooring of new Canadian Pacific Railway wharf	109·64
Flooring of the Waterhouse wharf, in 1909	107.35
Extreme High Water during the eight months of the observations in 1909 to 1910	106·00
Reference Bench-mark on foundation of boiler, as described	105·67
Solsticial High Water in 1909 on June 19	104·30
Bench-mark of 1909; the top of bolt as described	100·00
Solsticial Low Water in 1909 on June 18	92·45
Low-water datum of the tidal observations and of the chart; at the zero of the tide scale	91·25
Extreme Low Water during the eight months of the observations in 1909 to 1910	90·95
Datum of the Esquimalt and Nanaimo Railway; at 10·37 feet below the Bench-mark	89·63

Port Renfrew.—In San Juan bay, at the mouth of the Strait of Fuca. Tidal observations were obtained here in the season of 1909.

Bench-mark; on the Northeast side of the wharf, opposite the part which is built of cribwork, and 460 feet back from the head; the top of a brass bolt set vertically into the slaty rock, at 14 feet 8 inches from the side of the wharf and 332 feet from the shore side of the concrete abutment supporting the wharf. It is about two feet below extreme high water.

	Elevation.
Cap of the wharf, at the head	109·52
Bench-mark; top of bolt as described	100·00
Zero of tide scale, as set in 1909	89·56

Sooke.—At the mouth of Sooke inlet, on the Strait of Fuca. Tidal observations were obtained here from May, 1910, to April, 1911.

Bench-mark; a broad arrow cut on the face of a granite boulder at 60 feet from the shore end of the Government wharf, and directly behind the South end of the office building of J. H. Tedd and Son's cannery.

	Elevation.
Bench-mark; the broad arrow above described	100·00
Low-water datum, as determined by the standard method at 2·04 feet on the tide scale	83·25
Zero of the tide scale, as set in 1910	81·21

Additional tide levels.—It is to be noted that at any of the tidal stations described, it is always possible to work out the tide levels, such as extreme tides or average values, from the record obtained. In the methods employed by this Survey, the zero of the tide scale used is connected by instrumental levelling with the Bench-mark, and the record made by the registering tide gauge is correlated with the tide scale by a system of comparisons. It is thus possible at any time to reduce the tide levels to elevations with reference to the Bench-marks that have been established; if such data are required by Engineers for construction purposes or other uses. It is only necessary that the record itself should be preserved, and that the local Bench-marks are not destroyed.

Tidal Survey Staff.—The headquarters staff of the Survey, in addition to the Superintendent, and the Tidal observers in the various coast regions, is as follows:—

S. C. Hayden, Tidal and Current surveyor for the Pacific coast.

H. W. Jones, Tidal and Current surveyor for the Eastern coast of Canada.

R. B. Lee, Junior Tidal Surveyor; and reduction of records.

S. L. Howell, Clerk-stenographer.