MEAN HIGH WATER MARK REVISITED

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ABOUT THE AUTHOR

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He was registered as a Surveyor in 1958 and after working in various private practices in Sydney, was employed by the Western Pacific High Commission from 1961 to 1963, working as a Surveyor in the British Solomon Islands and the Gilbert Islands.

From 1963 to 1966, Peter worked for a hydrographic survey company in waters around the north of Australia and New guinea.

Since being with the Maritime Services Board, Peter has been associated with a variety of land and hydrographic survey matters and has been particularly involved with tides and mean sea level. He is a Fellow of the Institution of Surveyors, Australia and a Commander in the Royal Australian Navel Reserve.

Abstract

In the past many papers have been published in journals and presented at conferences on the subject of "Mean High Water Mark". It would therefore seem logical that in New South Wales the meaning of the expression is reasonably well understood, its value in any area can be readily determined and methods for field location clearly established. Unfortunately, it is sometimes heard said that little of this is true. In an endeavour to give some understanding to problems associated with the subject, a review of the basis of mean high water mark including history and practices is presented and suggestions provided to help improve the present situation.

Background

In New South Wales, Crown Grants for coastal lands were bounded by the sea without saying how that boundary was defined. Presumably, though, the boundary was the "seashore" for by English Royal prerogative the seashore - the area between high and low waters - had at all times belonged to the Kings and Queens of the realm - and we inherited English law. The question which naturally arises is what is the landward limit of the seashore, the upper limit to which Royal prerogative extends? That was the basis of the often quoted case associated with tidal boundaries of *Attorney General v Chambers*. In that case, the Attorney General took action to retain the seashore for the Crown and so prevent that land being used for mining of coal. It was claimed by the Attorney General that the seashore vested in Her Majesty (Queen Victoria) "extended landwards as far as high water mark at ordinary monthly spring tides". The Defendants, who had erected embankments on the seashore and underneath were working valuable coal mines, claimed "the Crown's right did not extend landwards beyond the line of high water mark or ordinary neap tides". (These mines were at the middle of the South Coast of Wales.)

As this case is so important in understanding tidal boundaries it is worthwhile to consider not only the judgement but also the evidence presented leading to the judgement, even though it occurred over 140 years ago.

Lord Chief Justice Hale's seventeenth century treatise "De Jure Maris" dealing with the rights of the Crown in the seashore received much comment including the following passages:

- "It is certain that that which the sea overflows, either at high spring tides, or extraordinary tides, comes not as to this purpose under the denomination of *littus maris:* and consequently the King's title is not of that large extent, but only to land that is usually overflowed at ordinary tides."

- "The high spring tides ... those tides that happen at the two equinoctials ... doth not *de jure communi* belong to the Crown."

- "The spring tides which happen twice every month, at full and change of the moon, and the shore in question is by some opinion not denominated by these tides neither, but the land overflowed with these fluxes ordinarily belong to the subject *prima facie*, unless the King hath a prescription to the contrary. And the reason seems to be, because for the most part of lands covered by these fluxes are dry and maniorable; for at other tides the sea doth not cover them ...."

- "Ordinary tides are neap tides, which happen between the full and change of the moon; and this is properly *littus maris* ... that which is covered by the ordinary flux of the sea, is the business of our present enquiry."

The Solicitor - General included the following in his argument:

- "With reference to the word "ordinary", that must be intended to comprehend such phenomena as are of the most common occurrence, and the word itself is just as applicable to spring as neap tides."

Counsel for the Defendant included:

- "Lord Hale, defining the shore to be that space usually overflowed at ordinary tides, excludes all spring tides."

The two Judges assisting the Lord Chancellor included the following in their joint opinion:

- "what, in the absence of all evidence of particular usage, is the limit of the title of the Crown to the seashore? ... the extent of this *"littus maris"* (to which the Crown is quite clearly entitled)?"

- "(Another Judge)... says that it is clear according to our law it is not the limit of the highest tides of the year, but the limit reached by the highest ordinary tides of the sea which is the limit of the shore belonging *prima facie* to the Crown. What then are these "highest ordinary tides?" Now we know that in fact the tides of each day, nay even each of the tides of each day, differ in some degree as to the limit which they reach. There are the spring tides at the equinox, the highest of all. These clearly are excluded in terms by Lord Hale ... for though in one sense they are ordinary i.e. according to the usual order of nature ... they do not ordinarily happen, but only at two times of the year."

- "But then we have Lord Hale's authority, De Jure Maris, who says, "Ordinary or neap tides which happen between the full and change of the moon" are the limit ... and he excludes the spring tides of the month, assigning as the reason that the "lands covered with these fluxes are for the most part of the year dry and maniorable," i.e. not reached by the tides."

- "What are then the lands which for the most part of the year are reached and covered by the tides? The same reason that excludes the highest tides of the month ... excludes the lowest high tides for (they) happen as often as each other. The medium tides therefore of each quarter of the tidal period afford a criterion which we think may best be adopted. It is true of the limit of the shore reached by these tides that it is more frequently reached and covered by the tide than left uncovered by it. For about three days it is exceeded, and for about three days it is left short, and on one day it is reached. This point of the shore therefore is about four days in every week, i.e., for the most part of the year, reached and covered by the tides. And as some not indeed perfectly accurate construction, but approximate, must be given to the works "highest ordinary tides" ... we think, after fully considering it, that this best fulfills the rules and the reasons for it, given in our books."

- "In our opinion, the average of these medium tides in each quarter of a lunar revolution during the year gives the limit."

The Lord Chancellor included the following in his final statement:

- "The right is confined to what is covered by "ordinary" tides, whatever be the right interpretation of that word."

- "What is the meaning of ordinary? It is evidently a word of doubtful import."

- "Lord Hale gives no absolutely decided opinion; but he evidently leans very strongly against the right to the land covered only by spring tides ... then he describes ordinary tides as if synonymous with neap tides. This leaves the question very much at large, and there is very little of modern authority."

- "We can only look to the principle of the rule which gives the shore to the Crown. That principle I take to be that it is land not capable or ordinary cultivation or occupation, and so is in the nature of unappropriated soil ... the reasonable conclusion is, that the Crown's right is limited to land which is for the most part not dry or maniorable."

- "The learned Judges whose assistance I had in this very obscure question point out that the limit indicating such land is the line of the medium high tide between the springs and the neaps."

- "I therefore concur with the able opinion of the Judges."

Exactly what did the Judges say? "What are then the lands which for the most part of the year are reached and covered by the tides? The medium tides therefore of each quarter of the tidal period ... This point of the shore therefore is about four days in every week, i.e., for the most part of the year, reached and covered by the tides". To determine "this point" it would seem high waters at the equinoxes should be excluded as they are not "ordinary". The Judges certainly didn't say the average of **all** high waters each month over a year.

Another case often referred to is *Tracey Elliot v Earl of Morley*. In this case the point is made that "the line of ordinary high tides ... is the line of the medium high tide between the springs and the neaps, ascertained by taking the average of these medium tides during the year." It would certainly seem that AG v Chambers was used for reference but it is not known why "ordinary" was introduced or why it was necessary to use the expression "the line of ordinary high tides."

New South Wales

The NSW Department of Lands "Regulations for the Employment of Licensed Surveyors 1914" stated at paragraph 56: "High Water Mark shall be defined as the mean high tide mark between high water spring and high water neap tides". Appendix C to the Regulations stated "observations extending over at least twelve months are necessary to obtain accurate results" and "a mean of all the high tide readings on a gauge during one lunation will give approximately the level required". Here there seems a contradiction. "Between high water spring and high water neap tides" gets back to AG v Chambers but the statement is then made that for one month "mean of all high tide readings". Why are "spring" and "neap" specifically mentioned in paragraph 56 instead of "all", if "all" was intended? We may never know.

Appendix C also stated: "In all estuaries where automatic tide gauges are established the level of Mean High Water as recorded thereon is to be adopted and the level at which Mean High Water is defined is to be referred to the zero of such gauge and recorded on the plan."

The Regulations of 1914 were superseded by "Survey Directions 1963". They stated at Appendix "G": "Mean High Water ... is defined as the mean of all high tides, including both spring and neap tides, taken over a long period" and "for a satisfactory determination the mean of all high tides over a full lunation period of twentynine days should be obtained by means of a tide gauge". The basis for the statement "is defined" is unknown but it is clearly stated that it is "all" tides. What constitutes "a long period" is not stated.

"Survey Directions 1981" followed and it is stated at Direction 3.9 "mean high water mark definitions are set out in the Manual of the New South Wales Integrated Survey Grid". The inference here is that there is more than one definition.

The "Manual of the New South Wales Integrated Survey Grid" NSW Department of Lands, Sydney, January 1976 (ISG Manual) contains at paragraph 22.2 only one definition and it is the same as given in Survey Directions 1963. In paragraph 22.5.2 reference is made to "observations extending over at least twelve months are necessary to obtain accurate results" as well as twentynine days for an approximate level.

The "NSW Surveyor General's Directions for Survey Practice - No.6 Water as a Boundary - Procedures" October 1994 does not define mean high water but refers to the ISG Manual.

As well as Regulations/Directions there is also legislation. Regulation 34 of the "Survey Practice Regulations 1933" (Amended 1964) states "High water mark in a document relating to land shall, unless a contrary intention appears, be taken to mean the line of mean high tide, between the ordinary high water spring and ordinary high water neap tides". This is certainly not in accordance with Survey Directions 1963 which state "all" high tides and contain no mention of "ordinary", "spring" or "neap".

The Survey Practice Regulations 1933 were superseded by "Survey Practice Regulation 1990" which were amended 1 October 1994. The definition of mean high water given in clause 57(1) is the same as in Survey Practice Regulations 1933, except that the word "must" is now used in place of "shall". On the basis that the definition in paragraph 22.2 of the ISG Manual has not been repealed, there are now two current definitions in NSW for mean high water and the definitions are different. Does one follow the ISG Manual and use "all high tides, including both spring and neap tides" or follow the 1990 Regulation and come to grips with "ordinary high water spring and ordinary high water neap tides"? To quote the Lord Chancellor in AG v Chambers: "what is the meaning of ordinary? It is evidently a word of doubtful import".

Authors of text books and other writings applicable to New South Wales were no doubt each influenced by contemporary legislation and regulations for there is:

- "the rule is that the grant extends to *mean* high water mark" (Willis, 1945). "Mean (or medium) high water mark is the line defining the mean between the high tides at ordinary spring and neap tides" (Willis, 1945 and Sloane, 1989). The basis for the "rule" is not explained by Willis.

- "mean high water mark is the line of medium high tide between the ordinary spring and neap tides" (Baalman and Wells, 1952).

- "local mean high water mark ... is the mean of all ordinary local high tides, including the spring and neap, as read over a sufficiently long period of time. The tides must be in evidence for more than half of each and every year" (Hallmann, 1973). Elsewhere in his book, Hallmann also states "mean high water mark (is) the mean of all high tides ...". It is not known why "local" and "ordinary" are used in the first definition but not the second or if any distinction between the two definitions is intended. "More than half of each and every year" has a resemblance to "about four days in every week, i.e., for the most part of the year" but on its own, could be misleading.

None of authors attempts to explain for the benefit of readers the meaning of the word "ordinary". A notable variation to the above quotations is:

- "Mean high water mark is the line of medium high tide between the highest tide each lunar month (the springs) and the lowest each lunar month (the neaps), averaged out over the year" with AG v Chambers quoted as a reference (Butt, 1988).

Because of the dangers always associated with selected quotations and matters taken out of context, reference to the full cases, reports, text books and allied references is advised and fully recommended to those who wish to gain a wider appreciation of the many factors associated with the general subject of mean high water mark as a boundary.

Practices in Other Areas

Queensland "As a deliberate practice, they (Queensland Surveyors) have established foreshore boundaries by traversing the edge of useable land" (Smith, 1980). In his paper, Smith points out that in Queensland the practice is to adopt a boundary which can be seen and understood. Such a boundary "is usually permanent" for it could be the edge of land-based grasses, the toe of a well vegetated and reasonable slope dune or the limit of boulders, rocks or shingle "irrespective of where they lie in relation to tidal levels". However, "having recognised the virtue in adopting a discernible, unambiguous physical feature as a land boundary, as a general rule they then proceeded to describe it as "high water mark!".

The boundary of land fronting tidal waters in Queensland was first described in the Harbours Act 1955 as "ordinary high water mark at spring tides", generally referred to as mean high water springs. As this is a higher line than "mean high water" which is shown on survey plans, the effect is to reduce landward areas. There is now interest in what a Court would decide - the surveyed feature or high water mark as defined in common law where there is a significant variation between the two. "This is becoming a serious issue with the increasing value of waterfront land" (Cislowski, 1995).

Victoria "The shoreline of the sea in Victoria is defined by the common law line known as Mean High Tide which is the average of all high tides" (Sherwood, 1976). Although this can be determined by a tide gauge, Sherwood points out that "In Victoria, there are two plant alliances which indicate MHT. They are the White Mangrove (Avicennia Marina) growing below MHT and saltmarsh located between MHT and spring tide. Both are accurate for plotting and the seaward side of saltmarsh is precise for MHT". It is understood this approach is not officially endorsed in Victoria as a reliable method.

Tasmania No relevant legislation has been enacted in Tasmania. In a compendium of information (Lewis & Hoyle, c.1975) compiled as lecture notes for courses conducted by the University of Tasmania as part of the Batchelor of Surveying Degree, it is stated that terms employed in Tasmanian grants and conveyances included high water mark, the saltwater, to the seashore, shore etc. Because of case law and clear intention, the current legal definition is taken to be mean or ordinary water mark. The notes also quote the definition "of local mean high water mark" as given by Hallmann.

South Australia The South Australian "Manual of Survey Practice" Volume 2 produced by the Department of Environment and Natural Resources and approved and issued by the Surveyor General states at 12.3: "The limit of the State's cadastre is taken as being the Medium (Mean) High Water Mark. By definition this is the line defining the mean of all high tides including spring and neap tides taken over a sufficiently long period." A definition of mean high water mark as given by Hallmann is also quoted but it is a different definition to that quoted in the University of Tasmania compendium. The Manual has methods for setting-out mean high water mark with the comment "it will generally be preferable to obtain expert advice, for example from Department of Marine and Harbors or the Flinders Tidal Institute".

Western Australia "The boundary of land fronting tidal waters is High Water Mark ... (and) when applied to tidal waters means the ordinary High Water at Spring tides" (Cribb, 1994). Because of the complex tidal regime in Western Australia, ranging from semi-diurnal (twice daily) in the North to diurnal (daily) in the South, the use of tidal data has not been fully adopted. "The practical approach adopted by surveyors in the past was to select a position on the ground taking due regard of local evidence in the form of debris etc".

Northern Territory Mean high water mark being the mean between the high tides at ordinary spring and neap tides is the boundary of tidal waters unless otherwise stated. Some aboriginal land granted under Commonwealth legislation has a low water mark boundary. "Almost all land fronting the Territory coast is held either under pastoral lease or is aboriginal freehold granted under Commonwealth legislation. Very few freehold parcel boundaries are defined by tidal boundaries - most are defined by surveyed right lines. I am not aware of any instance where a tidal boundary has been physically located in the field" (Menzies, 1994).

Commonwealth of Australia "Survey Practice Directions 1987" which are applicable to Commonwealth Territories (as distinct from Commonwealth land within States) contains the same definition for MHW as the NSW Survey Practice Regulations 1933.

New Zealand For land abutting onto tidal waters, the boundary by virtue of s 35 of the "Crown Grants Act 1908" is mean high water mark being "the line of high water mark at ordinary tides" (McRae, 1993). In the case *Attorney General v Findlay* the boundary was taken to be "the line of medium high tide between the spring and neap tides, ascertained by tracing the average of those medium tides in each quarter of a lunar revolution during the year". Another statement is "Fortunately common sense has prevailed and ... throughout New Zealand the usual practice is to survey the practical boundary between the land and the sea, for example the foot of the cliff, toe of bank, edge of vegetation, highest line of driftwood, etc. For the sake of conformity and in accordance with land transfer requirements this line as depicted on the survey plan is called mean high water mark but it could equally be called mean high water springs mark" (Baker & Watkins, 1991). Their paper also includes an illustration of the saltgrass Salicornia Australis (Glasswort) "which is a good indication of MHWM".

USA In the Californian Courts of Appeals case *Los Angeles v Borax Consolidated* the Circuit Judge, after saying "that the "ordinary high tide" is the average of all the high tides" went on to say "there is no inherent reason why the highest tide nearest to the full and new moon should be excluded from the average ... it is obvious that these spring tides must be included in the tides to be averaged if we are to determine the line usually reached, that is, reached on the average, by the high tide". After commenting on the AG v Chambers decision of "the average of these medium tides in each quarter of lunar revolution during the year", the Judge stated "our increased knowledge of the effect of the moon and sun upon the tides ... has fixed the boundary ... (as) a mean of all the high tides ... in order to ascertain the mean high tide line with the requisite certainty needed in fixing the boundary line of valuable tidelands an average of 18.6 years should be determined ... this mean high tide line is the one usually referred to by the United States Government". (A period of 18.61 years is the cycle of the moon's nodes around the lunar orbit.)

The subsequent Supreme Courts of the United States appeals case *Borax Consolidated v Los Angeles* affirmed the decision of "the average height of all the high waters ... over a considerable period of time" and that "an average of 18.6 years should be determined as nearly as possible".

In the Supreme Court of Texas Case *Luttes v State* it was stated "in all the year ... undoubtedly leaves a question as to what year is meant. Does it mean the last calender year expiring before the litigation or some other effort to fix the boundary on the ground, or some earlier year with a higher water level ... it would hardly appear within the reasonable intendment of the law that we should forget the later years and fix the line ... according to the one more remote year".

In dissenting with the judgement in this case, one of the Judges said in relation to tide gauges "the height of the water on the tide gauge is not the same as the height of the water that rolls up or is blown up on the shore ... if the tide gauge is accepted as the absolute determinate in placing or locating the shoreline, then we are establishing a rather artificial line ... there is evidence that tide gauges register differently ... because of the variable sizes of the (water inlet) hole ... to permit surveyors to rely on mathematical computations using such sparsely located tide gauges as are available, in order to determine the shoreline at any given point, would be adding artificiality to artificiality ... the bench or shelf created by God Almighty, not by tide gauges, surveyors or level rods -is nature's answer to the boundary between sea and upland".

Not all of the coastal States in the USA adopt mean high water - various States adopt mean low water, mean higher high water for Spanish and Mexican grants, highest winter tide and upper reaches of the wash of the waves (O'Hargan, 1976). There have also been attempts to define tidal boundaries by biological methods but there is comment that the National Ocean Survey had "lack of success with vegetation approaches in establishing a mean high water line ... delineating a mean high water line by way of conventional surveying techniques with verification of other fields of expertise, including ecological, firmly disproved any similarity between the two lines" (Porro, 1978).

Institution of Surveyors, Australia Following a suggestion (source unknown) that there was a need to pursue and advocate for Australia a single definition of high water mark to define the seaward extent of land and that this be done via the Law Reform Society, a Technical Sub-Committee was formed by the Institution and Terms of Reference drafted. Each Division of the Institution was requested in 1977 to forward definitions or interpretations relied upon in determining high water mark for the several types of land tenure in their State. Responses were received and a "Report on Tidal Boundaries" prepared. The Report was put to the Council of the Institution which on 16 April 1982 resolved at C82.1 "that the Report and all correspondence be sent to a recognised School of Surveying in Australia for further research and the Terms of Reference be broadened to cover all aspects of tidal boundaries" (Fuller, 1995). Resulting action is not readily apparent.

Determining a Mean High Water Mark (MHWM) Value

Returning to New South Wales, Fort Denison in Sydney Harbour is reasonably well known as the location of a principal tide gauge and records exist from 1873 to the present. To obtain uniformity in establishing mean high water mark for boundary purposes, in 1882 a plug was inserted in the northern wall of the Department of Lands building, Sydney, and inscribed with heights above mean high tide and mean sea level. Following further tidal studies and levelling connections to Fort Denison, the inscribed values were altered in 1891 and again in 1897. Following further tidal studies, a value for MHW resulted in 1.442 metres (4.73 feet) above the present tide gauge zero and was computed as the mean of all high waters recorded for the thirtyone years ending December 1927. This value was retained by the Maritime Services Board (MSB) until the end of 1994.

Therefore regardless of one month/ one year/nineteen years, a value determined at Sydney over thirtyone years was then used for a further sixtyseven years without review or challenge. This is in spite of a value of 4.69 feet (source unknown) published in Survey Directions 1963 and 1.469 metres (determined over the nineteen year period 1951 to 1969) published in the ISG Manual.

Because records in excess of one hundred years at Fort Denison show there are annual variations as well as a gradual rise in sea level the MSB has decided that the value for mean high water at Fort Denison will be determined over periods of nineteen years reviewed every five years (Ireland, 1994). Annual values 1918 to 1994 for MHW at Fort Denison, nineteen year means and the effect of reviews each five years based on 1993 are shown in **Table 1** and **Figure 1**. Administrative procedures to be followed by Surveyors requiring to establish MHWM boundary in Sydney Harbour - and other localities to which the MSB has title - are set-out in section 4.2 of Surveyor General's Directions No.6. Administrative procedures for MHWM definition for the remaining tidal waters in the State are given in section 4.1.

Just as the MSB has a long history of gaining tidal information in its Ports, so has NSW Public Works an even longer history of obtaining water level information over the whole of the State's tidal waterways. As part of its responsibilities as an engineering organisation, Public Works has a programme of recording water levels and flood heights for coastal engineering and flood mitigation studies. Water levels recorded at approximately 110 locations along the NSW coastline and estuaries could be of use to others with other requirements and this includes Surveyors who may wish to obtain a MHW value. Locations of NSW Public Works water level recorders are shown in **Table 2**.

Public Works in itself has no direct need for MHW values which are purely a by-product of tidal analyses carried out from records obtained from the water level recorders. Nevertheless, records in many instances extend well over a year and are a very good source for MHW information. However, it is up to Surveyors using that information to satisfy themselves of the relationship of a MHW value to zero of the water level recorder, the relationship of that zero to bench marks and the relationship of those bench marks to the datum being used for survey purposes (Smith, 1995). Errors of assumption at these elementary steps are easily made. This particularly applies when trying to establish a tidal gradient - hence MHW value - between water level recorders and between such recorders in tidal lakes.

The fact that Public Works MHW information may exist does not mean they are obliged to supply that information to others or accept responsibility for the values. Regulation 57(3) of Survey Practice Regulation 1990 requires a Surveyor to determine MHW "with appropriate accuracy" and this could mean the Surveyor setting-up a specific gauge for a particular purpose - it is up to the Surveyor to decide.

Paragraph 22.6 of the ISG Manual states further information can be obtained from the Survey Branch, Department of Public Works (PWD). Because of changes in responsibilities within the PWD since the ISG Manual was prepared, it is now NSW Public Works Manly Hydraulics Laboratory (MHL) which holds the water level database and all enquiries should be directed to it. Similarly, because of changes within the MSB, enquiries should be directed to a particular MSB Port. Current contact officers are:

			Telephone No.	Facsimile No.
MSB	Sydney/Botany Bay	Survey Manager	(02) 364 2195	(02) 364 2188
	Port Kembla	Property Manager	(042) 75 0143	(042) 74 6309
	Port of Newcastle	Port Surveyor	(049) 27 2439	(049) 27 2429
NSW	Public Works MHL	Senior Project Engineer	(02) 949 0200	(02) 948 6185

Although paragraph 22.4 of the ISG Manual states information for tide gauges additional to the five given in the schedule to that paragraph will be released as it becomes available, there have been no such releases and there is no present intention to prepare information for release.

TABLE 1 - Annual Mean High Water above zero of Fort Denison Tide Gauge, Nineteen Year Means and Values (Rounded Down) based on five year reviews of the Ninteteen Year Means.

YEAR	M.H.W (m)	19 YEAR MEANS (m)	5 YEAR VALUES (m)	YEAR	M.H.W (m)	19 YEAR MEANS (m)	5 YEAR VALUES (m)
1918	1.441			1957	1.469	1.446	
1919	1.436			1958	1.498	1.448	1.44
1920	1.456			1959	1.472	1.450	
1921	1.506			1960	1.485	1.453	
1922	1.497			1961	1.452	1.455	
1923	1.454			1962	1.480	1.457	
1924	1.447			1963	1.471	1.459	1.45
1925	1.422			1964	1.504	1.463	
1926	1.440			1965	1.456	1.464	
1927	1.398			1966	1.457	1.468	
1928	1.428			1967	1.445	1.469	
1929	1.420			1968	1.459	1.471	1.46
1930	1.389			1969	1.421	1.469	
1931	1.427			1970	1.437	1.467	
1932	1.412			1971	1.463	1.467	
1933	1.432			1972	1.449	1.467	
1934	1.439			1973	1.493	1.470	1.46
1935	1.451			1974	1.527	1.471	
1936	1.424	1.438		1975	1.499	1.470	
1937	1.436	1.438		1976	1.539	1.474	
1938	1.452	1.438		1977	1.501	1.474	
1939	1.462	1.439		1978	1.527	1.477	1.47
1940	1.440	1.435		1979	1.471	1.476	
1941	1.426	1.432		1980	1.498	1.479	
1942	1.413	1.429		1981	1.501	1.480	
1943	1.451	1.430	1.43	1982	1.441	1.478	
1944	1.419	1.429		1983	1.443	1.475	1.47
1945	1.437	1.429		1984	1.489	1.477	
1946	1.426	1.431		1985	1.473	1.478	
1947	1.380	1.428		1986	1.476	1.479	
1948	1.438	1.429	1.42	1987	1.438	1.478	
1949	1.426	1.431		1988	1.481	1.481	1.47
1950	1.449	1.432		1989	1.486	1.484	
1951	1.477	1.436		1990	1.509	1.486	
1952	1.461	1.437		1991	1.484	1.488	
1953	1.441	1.437	1.43	1992	1.482	1.488	
1954	1.449	1.437		1993	1.455	1.484	1.48
1955	1.496	1.441		1994	1.477	1.483	
1956	1.519	1.445					

TABLE 2 - Locations of Water Level Recorders established by NSW Public Works

STATION	STATION	STATION	STATION
Tweed Heads (0)	Wooli Ent	Forster (0)	Windsor
Letitia 2A	Wooli Caravan Park	Tuncurry	Freemans Reach
Letitia 2B	Coffs Harbour (0)	Tiona	Sydney Middle Hbr (0)
Barneys Point	Coffs Creek	Port Stephens (0)	Picnic Point D/S
Tumbulgum	Newports Creek	Stockton Bridge	Milperra
Murwillumbah	Boambee Creek	Hexham Bridge	Lansdowne Bridge
Dry Dock	Repton	Raymond Terrace	Cutler Road
Cobaki	Bellingen	Green Rocks	Irelands Bridge
Terranora	Newry Island	Morpeth	Scrivener Street
Kynnumboon	Macksville	McKimms Corner	Port Hacking (0)
Kingscliff	S W Rocks	Wallis Creek D/S	Shoalhaven Heads
Brunswick Heads (0)	Smithtown	Hinton Bridge	Wharf Road
Mullumbimby	Kempsey	Dunmore Railway	Crookhaven Heads
Ballina (0)	Euroka	Paterson Bridge	Greenwell Point
Byrnes Point	Port Macquarie (0)	Swansea	Nowra Bridge
Woodburn	Settlement Point	Belmont	Jervis Bay (0)
Tuckombil Bridge	Wauchope Rwy Bridge	Marmong Point	Burrill Lake
Tuckombil Floodgate	Telegraph Point	Cockle Rwy Station	Batemans Bay
Coraki	North Haven	Morisset	Princess Jetty
E Gundurimba	Laurieton West	Ettalong	Quarry Wharf
Tuncester	West Haven	Koolewong	Moruya Hospital
Woodlawn College	Crowdy Head (0)	Wharf Street	Bermagui (0)
Yamba (0)	Harrington	Gentlemans Halt	Merimbula Wharf
Maclean	Croki	Gunderman	Merimbula Lake
Brushgrove	Farquhar Inlet	Webbs Creek	Pambula Wharf
Grafton	Taree	Lower Portland	Eden (0)
Palmers Island	Wingham	Sackville	

NOTE: (0) denotes Ocean Recorder

Having gone to great trouble to obtain tidal and bench mark information and a value (or values, depending upon tidal gradient and length of tidal frontage) for MHW at a place of survey, there is no requirement for that value to be recorded on the plan of survey. (Note it was a requirement of the Regulations of 1914.) Although the value may possibly be mentioned in the Surveyor's report to the Department of Conservation and Land Management supporting the MHWM definition, it does not appear in any other publically available document. How, then, can a following Surveyor, without first going through the same process to obtain the same MHW and bench mark information, certify the MHWM boundary is substantially the same? A system of openly recording on a lodged plan values such as MHW at a local/convenient tide gauge (if used) and MHW adopted at the place of survey together with associated bench marks would make resurveys that much simpler. Apart from plan preparation costs, the process should cost no more than at present for theoretically that should be what Surveyors are already doing to comply with existing Regulations and Directions. A direct corollary would be the present requirement under clause 35 of Survey Practice Regulation 1990 to place reference marks in relation to boundaries. Such marks apply in a horizontal sense. A bench mark (or marks) along a tidal frontage would define MHWM in a vertical sense.

Such bench marks need not necessarily be connected to Australian Height Datum or any other datum. They only need to be referenced vertically to the MHWM boundary, be clearly described and reasonably permanent. Whilst the values between MHW and the bench marks will change over time due to fluctuations of mean high water, they would nevertheless be a record of how the MHW boundary was defined and be a considerable benefit in the future.

Survey Determination

Regardless of all the textbooks, lecture notes, reports and papers relating to field determination of MHWM, site conditions combined with available information and the inventiveness of Surveyors will always override "what the book says". Three methods are described in paragraph 22.5 of the ISG Manual.

1. **Levelling from Bench Mark**.

This description refers to conventional levelling related to Australian Height Datum (AHD) in association with the five established gauges (Camp Cove, Fort Denison, Newcastle, Port Kembla and Coffs Harbour) given in the schedule in paragraph 22.4 of the Manual. Of course, the method may be applied to any tide gauge which has bench marks whether or not related to AHD and this is where care **must** be taken. **Is the MHW value at the tide gauge directly related to and on the same datum as the gauge bench marks?** Unless these two fundamental points are verified the rest of the exercise could not only be a complete waste of time and effort but the Surveyor concerned could also be questioned on professional negligence for determining a boundary in an incorrect position. (Implications for indemnity insurance form another subject.) Having established that the MHW value and bench marks are correctly related to each other and to AHD and with a knowledge of the MHW value at the place of survey in relation to the tide gauges, it would then be equally negligent to assume that the AHD value of MHW at the place of survey could be obtained by deduction. In the ideal world, yes, it possibly could. In practice, there are so many factors which destroy this concept. The integrity of the original levelling/relevelling, the nature of the levelling adjustment and disturbance/natural movement of bench marks are all simple examples of how what appears to be valid information can be misleading. There is only one way for a Surveyor to be satisfied that the best available result is achieved - check/verify every step of the process. Previous attention has been drawn to this and is repeated here to emphasise its importance. This also raises the point that an AHD value given to MHW on one side of a bay or river may not automatically apply on the other side. The value could be accurately transferred across the waterway by a Surveyor using a form of levelling appropriate for the circumstances but a misclose could result when connected to AHD values on the other side. This is due to levelling and adjustments on one side possibly not being compatible with levelling and adjustments on the other side because of no direct connection between the two sides, even though both sides are said to be on AHD.

2. Levelling from a Local Tide Gauge.

What is, in fact, described is the use of a tide gauge to give "an approximation of the height of MHW to ± 0.015 metres". The word "level" is used once and there is no mention of levelling. Sound advice is given to factors to be considered when determining a value over twentynine days but it would be more good luck than good management if the perfect or even near to perfect combination of factors could be obtained. Even then, it is problematical as to whether the resulting value for MHW at the gauge would be within ± 0.015 metres of the long term value. In **Table 3** are the monthly values of MHW above zero of the Fort Denison tide gauge for 1994. It is acknowledged that, being monthly, they are all but one in excess of twentynine days (actually, the full lunation period to an observer on the earth is 29.53 days) but even so, it may be seen that the monthly values vary from 1.414 metres to 1.598 metres. It should be noted that Fort Denison is not regarded as being subject to influencing wave action, wind conditions, flood or fresh conditions. In view of the amount of tidal information now available in NSW it would be only on rare occasions that a Surveyor on a "one-off" basis would need to obtain and establish a tide gauge for twentynine days, attend to calibration, oversee and verify twentyfour hours per day operation, ensure proper vertical connections and finally obtain a result. The next question would be what does that result mean? Deciding how to apply that result to give a credible MHW value at the place of survey could be difficult to resolve. It all depends upon the purpose of the survey/the reasons for obtaining observations over twentynine days.

3. The Range Ratio Method.

This is a very simple, effective way to transfer a water level by observing high and low water levels for two consecutive tides at a place of survey and then obtaining the levels of the corresponding high and low waters at an automatically recording tide gauge with long term values. Paragraph 22.5.3 of the ISG Manual states "a fairly accurate value of MHW may be obtained" and use of a formula will give "approximate MHW". In one of the terms in the formula reference is made to the previously mentioned five established gauges but of course the method can be used in conjunction with any gauge with reliable long term values. Use of a gauge with long term values in the same waterway as the survey site would certainly seem preferable to using an established gauge possibly hundreds of kilometres away where meteorological conditions at the time of survey could be completely different. Unfortunately, the diagram and formula given in the ISG Manual appear quite daunting and there is no worked example. In essence, all that is needed are two tide readings at the place of survey, the corresponding tides and a long term value at an established location and simple arithmetic. The Range Ratio Method has been described as "recognised as the standard method of tidal datum transfer in many countries" and "because of restrictive factors should not be used in harbours if an accuracy better than ± 0.15 metres is required" (Baker & Watkins, 1991).

Mean High Water by Tide Gauge Analysis

Although regulations, Directions, Manuals etc all refer to mean of high waters, whether they be "all", "ordinary" etc the long term value of MHW at an established gauge in NSW is not necessarily the result of methodically meaning the usually two high water values per day over a year for a number of years. Observed (recorded) high water values are used at Fort Denison (and at other MSB Ports) where the MSB has a need for that value in order to determine its own MHWM boundary. For the remainder of the State's tidal waterways which are Crown land and where tide gauges/water level recorders have been established for engineering purposes, MHW is mathematically determined from constituents resulting from an harmonic analysis of automatically recorded tidal information over the full range of the tide day by day, year by year. Among the many constituents provided by an analysis are two which can be used to calculate MHW - the value for mean sea level (MSL) and the value for M_2 being the twice daily tide generating force attributed to the moon. The sum of MSL and M_2 gives MHW.

For all practical purposes, MSL being the mean of hourly heights of the sea over a year at Fort Denison may be considered the same as mean tide level (MTL) being the mean of all tides, high and low. The long term (nineteen years 1975 to 1993) value at For Denison for MTL is 0.95 metres and M_2 by tidal analysis from 1985 to 1993 is 0.50 metres. They result in a MHW value of 1.45 metres which is 0.03 metres lower than from long term (1975 to 1993) observed high waters. M_2 is a fairly consistent value, varying by only a few millimetres for analyses of different years. MTL, however, is quite a variable. For example, the 1990 value for MTL is 0.99 metres above gauge zero and for 1993 is 0.92 metres above. Using these values, MHW in 1990 is 1.49 metres and in 1993 is 1.42 metres. Thus the indications are that at Fort Denison use of tidal constituents gives a result of within 0.1 metres of the long term value obtained directly from recorded high waters. The agreement at other locations would depend upon examination of recorded high waters. It must not be overlooked that records from a tide gauge/water level recorder include flood and fresh conditions which, according to paragraph 22.5.2 of the ISG Manual, "should, of course, be avoided." Identifying flood and fresh conditions and then culling them from recorded tides would be a complex task.

As the value for M_2, the amount by which MHW is above MSL, is 0.5 metres at Fort Denison, it explains why it is sometimes heard that in NSW, MHW is half a metre above AHD. (AHD is mean sea level for the years 1966 to 1968.) Whilst generally speaking this is roughly true for the open coastline, it certainly does not apply in estuaries or tidal rivers.

Testing the MHW value at Fort Denison Against AG v Chambers

Having determined a long term (1975-1993) value of 1.48m for MHW at Fort Denison using all recorded tides including those at equinoxes, springs and neaps, how does this value compare with the criterion adopted in AG v Chambers ("This point of the shore therefore is about four days in every week, i.e., for the most part of the year, reached and covered by the tides")?

Obviously it is impossible to tell for the judgement refers to days per week over a year, not heights, in order to determine "the average of these medium tides in each quarter ...." The test is therefore not just the value but whether the value satisfies "about four days in every week, i.e., for the most part of the year."

The MHW value at Fort Denison for 1994 is 1.477m. High waters recorded in 1994 can therefore be compared with the long term value of 1.48m to see how often 1.48m is "reached and covered." (The close agreement between the two values is sheer co-incidence.) In **Table 3** is shown the number of days per month and for the year when tides "reach and cover" - exceed - 1.48m. The result? Over the year, the long term mean high water value is reached and covered 5.3 days out of seven. Therefore the long term value of 1.48m fails the test because in 1994 it is reached and covered in excess of about four days out of seven.

Mean High Water Springs

Reference has been made previously to the use in other areas of mean high water springs (MHWS) as a line adopted in practice for mean high water. What is MHWS?

It is an expression used in tidal studies in areas where generally there are two tide cycles per day of similar nature i.e., semi-diurnal. In terms of a harmonic analysis, it is mean sea level (MSL) plus the twice daily tide generating forces of the moon (M_2) and the sun (S_2), i.e. MSL plus M_2, as for mean high water, plus S_2. In areas where there are diurnal or a mixture of diurnal and semi-diurnal tides, the expression MHWS does not apply. For the NSW coastline, MHWS can be used.

As with M_2, S_2 is also a fairly constant value and at Fort Denison is 0.12 metres. Therefore, if MHW is 1.48m at Fort Denison, MHWS is 1.60 metres. In **Table 3** is shown the number of days per month and for the year when tides "reach and cover" - exceed - 1.60 metres. The result? Over the year 1994, the mean high water springs value is reached and covered 3.4 days out of seven. Therefore the MHWS value also fails the test but it is certainly closer to passing than the MHW value.

TABLE 3 - 1994 monthly Mean High Water above Zero of Fort Denison Tide Gauge and number of days per month where High Water exceeds 1.48 metres and 1.60 metres being long term (1975-1993) Mean High Water and Mean High Water Springs

MONTH	MHW(m)	DAYS ABOVE 1.48M	DAYS ABOVE 1.60m	MONTH	MHW(M)	DAYS ABOVE 1.48m	DAYS ABOVE 1.60m
January	1.598	29	26	July	1.452	22	15
February	1.425	19	8	August	1.414	22	15
March	1.488	23	16	September	1.473	28	13
April	1.508	21	14	October	1.428	18	10
May	1.535	27	17	November	1.494	22	13
June	1.491	23	16	December	1.422	22	13

Average for year	1.477m
Days above 1.48m	276 (5.3 out of 7 for the year)
Days above 1.60m	176 (3.4 out of 7 for the year)

To Summarise

The 1854 judgement contains an early example of a "performance indicator in measurable terms." The level reached four days out of seven, for the most part of the year. The Judges considered that this would be the limit of the shore belonging to the Crown and would approximately fit with a term previously used - "highest ordinary tides." They then called this "the average of these medium tides in each quarter of a lunar revolution during the year." In concurring with the opinion of his assisting Judges, the Lord Chancellor referred to this same limit as "the line of the medium high tide between the springs and the neaps."

Ever since, others have taken the Lord Chancellor's words and applied their own interpretations without looking behind the words and seeing how they were obtained. Possibly the reason is that although they may have been fluent with words, they simply didn't understand tides. The chain of events that has lead to the current terms and definitions and the need to change the words previously used has really never been explained.

With the benefit of tide records at Fort Denison and modern terminology it is possible to revisit the 1854 judgement and for New South Wales determine what does meet the criterion set by the Judges. Mean High Water, being the mean of all high waters over a year? Mean High Water Springs derived from a mathematical application of tidal constituents? Something else unexplored? With the answer to this question and then drafting one plain English expression we would be in a position to remove many of the mysteries and uncertainties associated with establishing MHWM as a boundary.

The intent - the limit of the Crown to the foreshore - will not have changed, only the way that intent is expressed (just as others in the past have also tried to describe that intent). In all of these deliberations, the intent at the time of the original Crown Grants should also be considered. The opportunity would also be available to acknowledge and accept that mean high water mark as a boundary is not only ambulatory in its recognised horizontal sense for decreed natural conditions but also vertically as a result of the natural condition of change in sea level. This is something that may not have been evident or measurable in 1854 or simply the Judges may not have been told. It is not mentioned in the report of that case.

Conclusion

Those attending this Conference form in NSW a significant proportion of practical field Surveyors and experienced examiners of Surveys dealing with high water mark as a boundary. If it is felt that the subject really is adequately covered and understood and satisfactorily applied in theory and in practice, then at least this paper presents an insight into some history of the subject and activities of others. On the other hand, if it is felt there is a need for further guidance, assistance or clarification with any of the aspects presented, an indication as to what is needed and how it should be pursued would allow action to be taken. If action is required it will need to be properly planned, managed and directed. Change will not happen on its own. Government Surveyors in NSW have been leaders in the past - there is no reason why that should not continue in the present and into the future.

Acknowledgment

The interest shown by Surveyors and others not only in NSW but also in other States of Australia and overseas and their willingness to exchange information in order to promote a deeper knowledge and understanding in the subject is openly acknowledged and appreciated.

> *"Judges and Juries may be required to follow after the Surveyor over the same ground and that it is exceedingly desirable that he (the Surveyor) govern his actions by the same lights and rules that will govern theirs."*
>
> *Attributed to Mr Justice Coolley*
> *Michigan Supreme Court*

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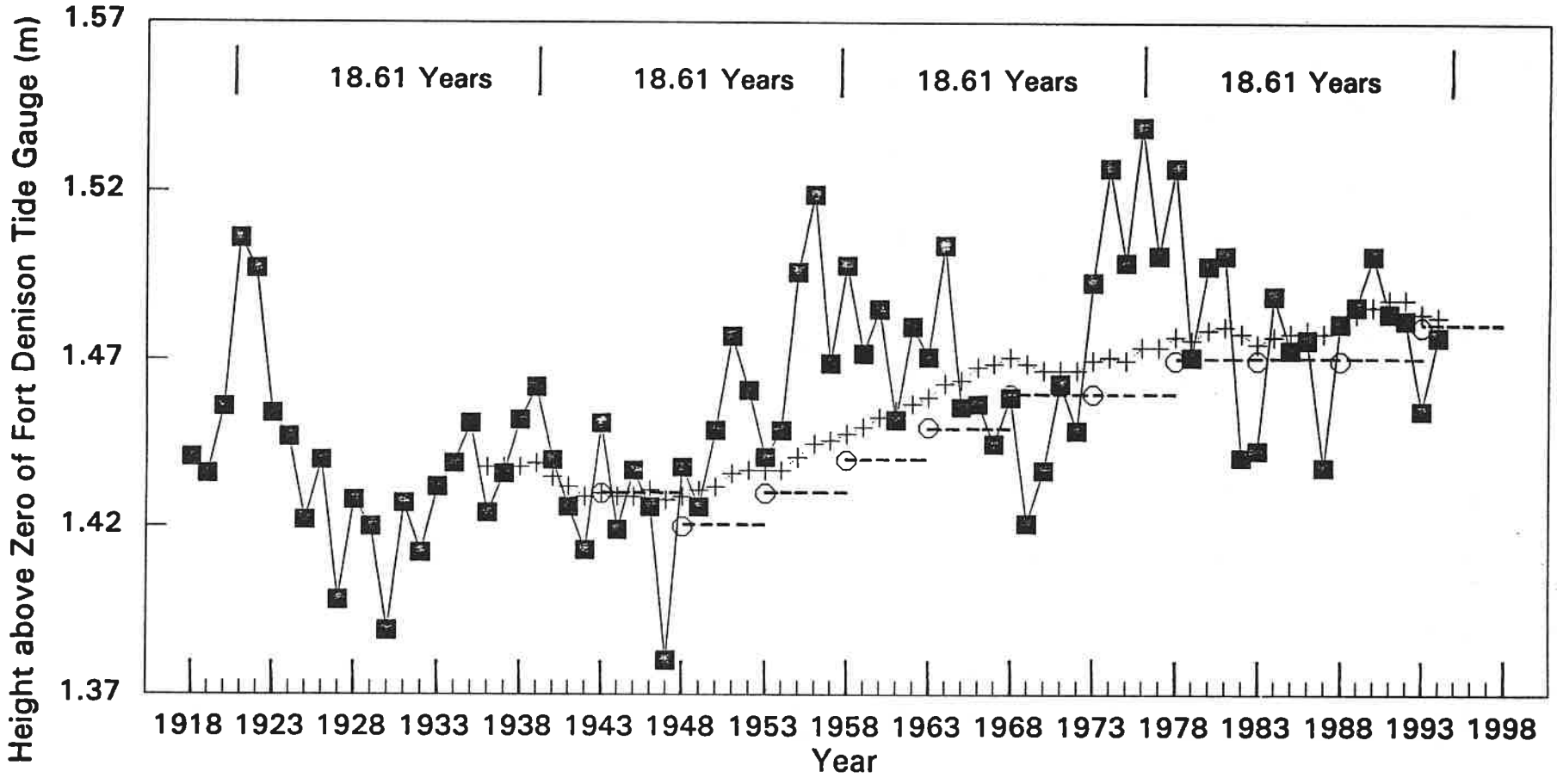

Figure 1: Mean High Water Fort Denison - 1918 to 1994

Annual MHW, Nineteen Year Means and Five Year Values, as in Table 1.

■ ANNUAL + 19 YR MEANS ⊖ 5 YR VALUES