University of Southern Queensland

Faculty of Engineering and Surveying

Determination of Mean High Water Mark within New South Wales

A dissertation submitted by

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ABSTRACT

The boundary between water and land is one of the most ancient boundaries used by society. Despite the long history of usage, society has found that the land/ sea zone is not a definite boundary. The influences on a tidal boundary are many, from gravitational and centrifugal forces acting on the earth to the many local variations that can shape a tide. From this active interface between water and land, a surveyor must determine a precise boundary. The aim of this project is to develop a system of procedures that will help to define this dynamic boundary.

Developing a procedure manual will involve researching and evaluating the current guidelines, regulations and survey techniques used in determining tidal boundaries. This research will allow the development of a system that will guide a land surveyor when determining Mean High Water Mark boundaries along tidal land. These guidelines will be applied to a tidal boundary on the Central Coast of New South Wales, so as to validate the procedures.

This project has found that using tidal information collected over a long period of time at a tide gauge would increase the accuracy of determining a tidal plane. By comparing the tidal data of a site that does not have long term tidal data with a control gauge, which does have long term tidal data, a reliable answer can be achieved. Therefore a procedure was developed to guide a surveyor through the determination of a Mean High Water Mark within New South Wales.

The procedure manual will introduce a system in the techniques to follow in determining a water boundary. The user of the manual will be aware of the various issues faced in establishing a tidal boundary and this manual will allow them to make the informative decisions. It is recommended that this manual be incorporated into any survey company’s quality control management system.

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Certification

I certify that the ideas, designs and experimental work, results, analysis and conclusions set out in this dissertation are entirely my own efforts, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

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Signature

27/1/05

Date

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NOMENCLATURE

The following abbreviations have been used throughout the text and bibliography: -

MHWM	Mean High Water Mark
MHW	Mean High Water
AHD	Australian Height Datum
LTO	Land Title Office
LPI	Land and Property Information
DP	Deposited Plan
SLR	Sea Level Rise
GPS	Global Positioning Systems
DCDB	Digital Cadastre Data Base
ICSM	Intergovernmental Committee on Surveying and Mapping

CHAPTER 1

INTRODUCTION

> *'The true nature of the boundary surveyor's role lies not in theories of exact measurement but in the proposition that the basic determinant of the limits of any region in respect of which some person or body holds exclusive legal rights is not a matter of surveying but a matter of law'* (Hallmann, 2000).

1.1 The Problem

The above quotation indicates that a surveyor's role is to not only mark the boundaries of land accurately but also ensure that the boundaries defined are legally sustainable over time. The interface between water and land is dynamic, conventional boundaries may be two to three dimensional (i.e. X, Y, Z) but tidal and non tidal boundaries are unique due to their fourth dimension – time (Cole, 1997).
This is true of tidal and non-tidal boundaries as redefinitions of a water boundary may yield significantly varying results over a short period of time.

With the determination of any boundary the question of accuracies that are obtainable should be asked. Harcombe (1985) notes that the following question must be addressed when defining the position of Mean High Water Mark (MHWM).

> *'Is the approximation of mean high water mark under investigation technically correct?'*

Here he refers to the New South Wales Surveying Regulations 2001 clause 55(4) quoting that a surveyor should determine mean high water mark with ‘appropriate accuracy’. But there is no linear indication of what this accuracy should be. In New South Wales guidelines for determining tidal boundaries have been published but only advise on legislation affecting tidal boundaries and list methods for determining tidal boundaries but do not advise on the issues faced when physically measuring these boundaries. When a method is picked to determine a tidal boundary all guidelines and manuals are there ‘*to assist Surveyors in using their professional judgement’* (SOM, 1999) but do not quote what accuracies may be achieved and where accuracies are quoted they do not cite evidence to the claim. There is no clarification of the techniques used for determining tidal boundaries and no procedural methods that can be relied upon when determining these boundaries.

The use of tidal analysis by early surveyors for determining high water mark was rarely used and the understanding of the concepts of accretion and erosion were not understood (Gordon, 2003). In many cases in Australia, Mean High Water property boundary determinations were only approximated by early surveyors (Moore, 1968). These flaws make it difficult or even impossible to make a comparison between the original and present Mean High Water Mark (MHWM) positions. When assessing a claim for accretion or erosion it is mandatory that the original MHWM be shown (as required by most ’surveyors practice manuals in the different states). It will be demonstrated in this research project that the positioning of a MHWM boundary is by no way precise. But it is essential that standard procedure(s) be adopted therefore eliminating any ambiguity in the determination of the current MHWM.

1.2 Research Aim

The aim of this research is to clarify the legal and physical implications associated with determining tidal boundaries within New South Wales and to develop procedures for determining tidal boundaries (defined in Appendix A).

The objectives are to assist a surveyor in determining a water boundary using current legislation and alerting them to possible issues that may be faced when determining boundaries. The outcome will inform the reader of the various issues faced when determining a tidal boundary so as to allow for an informative and correct decision in determining tidal boundaries.

1.3 Justification

> *‘Riparian and littoral property is often subject to public regulation, creating regulatory limit lines different from property lines. Their locations can affect the utility of real property and can therefore be as important, or even more important, than the actual property boundary’* (Browns, 2003).

The above quotation indicates the importance of determining the correct position of a non- tidal or tidal boundary. This may involve re-establishing a previously determined boundary or assessing the affects of avulsion in establishing the position of a new boundary. Both may affect the value of a property by increasing or decreasing the physical area of the lot or the position of a building setback from water boundary. *Pascale v Sutherland Shire Council (1995)* illustrates the importance of correctly defining the present Mean High Water Mark as definition can significantly affect the position of the building setback (see figure 1).

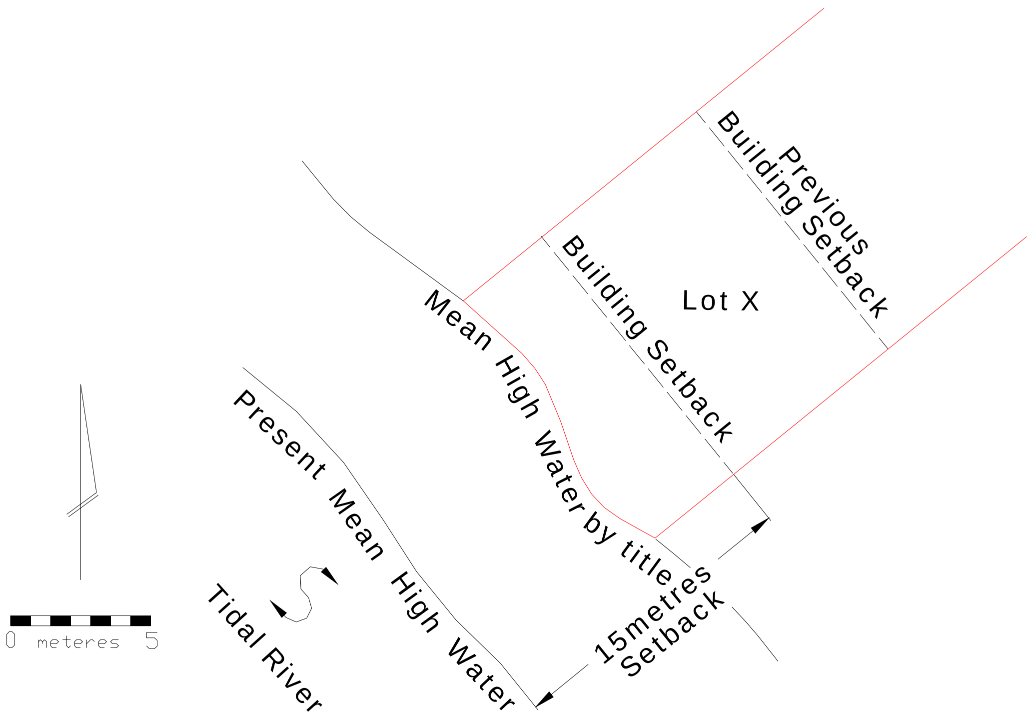

Figure 1. - Illustrated example of the importance of Mean High Water position and building setback.

Tidal boundaries are ambulatory, meaning that the boundary will fluctuate over time. Clause 55(4) of the New South Wales Surveying Regulations 2001 states the mean high water mark must be determined with appropriate accuracy by a surveyor. How accurate should the determination be and how long should this ambulatory definition last? In the United States there was a 1974 study, which showed that a 0.03 metre difference in the establishing of the high water mark datum had a $3 million impact on property values along the Atlantic and Gulf coast (Nichols and McLaughlins 1984). With approximately 50,000 properties within New South Wales with tidal frontage (Jones, 2002) and with the value that water frontages carry today, the impact of an approximate tidal line needs to be definitely considered in today's society in terms of land value.

1.4 Scope Of Research

The scope of my project is to investigate current legislation and guidelines that assist a land surveyor in establishing a tidal boundary, assess the accuracies of each technique used for determining Mean High Water Mark tidal plane and to construct a procedural manual for future determinations within New South Wales.

The Literature Review in Chapter 2 will illustrate the current guidelines and regulations for determining tidal boundaries within New South Wales. From this the examination on how legal precedents has affected the determination of tidal boundaries and how the determination of water boundaries affects the doctrine of accretion and erosion. The last section of the Literature Review is reviewing the limited number of other tidal boundary techniques and their accuracies used around Australia and other parts of the world.

The research method is divided into two sections. The first section is the construction of a procedure manual when determining a Mean High Water Mark using the techniques outlined by the Manual of the New South Wales Integrated Survey Grid (1976). These methods are as listed: -

1. Levelling from a benchmark.
2. Levelling from a Local Tide Gauge.
3. The Range Ratio Method.

The format of the procedural manual will be based on the Association of Consulting Surveyors Australia, and the Model Quality System Survey Procedure Manual for cadastral and topographic surveys. The procedure manual will be divided into following subsections: -

1. Introduction
2. Search and locality information.

3. Determining the tidal plane.
4. Positioning the tidal plane
5. Establishing the previous tidal boundary.
6. Survey plan and report requirements.

The second section of the research method is to apply the procedures to a case study to validate the procedures.

A conclusion will be drawn in Chapter 6 and recommendations will be made for further research.

1.5 Summary: Chapter 1

Water boundaries are widely used all around the world. Despite the long history of usage, water boundaries are probably the most widely contested boundary in today's society (Cole 1997,99. xi). This is because of the dynamic nature of a land/water boundary. The surveyor is in a unique role of providing a linkage between the scientific determination of a tidal boundary and the law.

This dissertation aims to address the legal and practical problems faced by a land surveyor when attempting to establish a Mean High Water Mark boundary within New South Wales and provide clarification through the aid of a procedural manual.

The current legislation, guidelines, legal precedence and methods for determining tidal boundaries are discussed in chapter 2, Literature Review. The chapter summarises the state of knowledge with regards to legislation, guidance and how it affects the surveyor and their professional survey practice within New South Wales and other states.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction.

This chapter will serve as a review of past and present literature on the determination of tidal boundaries within New South Wales. This review will help to develop procedures for determining Mean High Water Mark (MHWM) within New South Wales.

Therefore the aim from this literature review is to appraise the current knowledge base in the methods used in determining tidal boundaries under the guidelines set by state authorities.

This will be achieved by discussing the legislation, legal precedence and survey techniques and practices introduced by the New South Wales State Government and authorised institutions. Comparisons with other state guidelines will indicate similarities in techniques used for determining water boundaries and assist in assessing the deficiencies found within these current guidelines.

2.1 Mean High Water As A Boundary

The accurate determination and representation of natural water boundaries is an important aspect of both the planning and implementation phases of the management of coastal zones (Horlin, 1990). States have adopted different positions for defining tidal boundaries. Within each state there are various departments and authorities that have responsibilities in the decision making process within the land/sea zone. Hirst & Todd (2003) put forward a view that the administration of the land/sea zone requires a clear definition of the extent of defined tidal boundaries and to be able to position these lines out on site.

The origin of a *Water Mark* boundary comes from the English law derived to deal with the rivalry between kings and nobles over the ownership of the booty from shipwrecks (Baldwin, 1982: Coutts, 1987). The water marked the boundary wherever it lay.

Lord Chief Justice Hale first espoused the definition of the boundary between land and sea in his treatise ‘ De Jure Maris’ in 1666 (Coutts, 1987). He reasoned that the rights to the monarch extended only ‘ to land that is usually overflowed of the sea at ordinary high tides’ and defines the right as to where the sea ends not where the land starts (Baldwin, 1982). Coutts (1987) states in this sense ‘Mean High Water as a boundary was developed to define the balance or remainder, rather than as an attempt to delineate the land itself’. Cole (1997), Blume (1995) and Gordon (2003) refer to the Hale’s use of the term ‘ordinary’ tides as being incorrect taking into account the understanding we have today about tides and how they can affect the positioning of a tidal boundary.

The above definition would be clarified in the judgement of the *Attorney General v Chambers*. In this case the Crown retained the seashore therefore stopping the mining of coal within this zone. The judgement states that the Crown (at that time being Queen Victoria) had a claim that ‘*extended landwards as far as high water mark at ordinary monthly spring tides*’. The judgement would also clarify what tides would be excluded from ordinary tides. Blume (1995) discusses that there is great variation in terminologies for defining Mean High Water (MHW) in legislations and guidelines within New South Wales, which has lead to confusion in how MHWM should be calculated.

An example of this confusion can be demonstrated in the definitions for MHWM found in the Surveying Regulations 2001 and those found in the Hallmann, 2004 and the Manual of the New South Wales Integrated Survey Grid (1976). VanderNie

(2003) states that New South Wales is no exception to variations of terminologies, for example, in Queensland Mean High Water Spring is commonly referred to as MHW (Hirst & Todd, 2003). As shown in figure 2 the difference can be significant. To position a tidal boundary precisely the same precision is required in definitions.

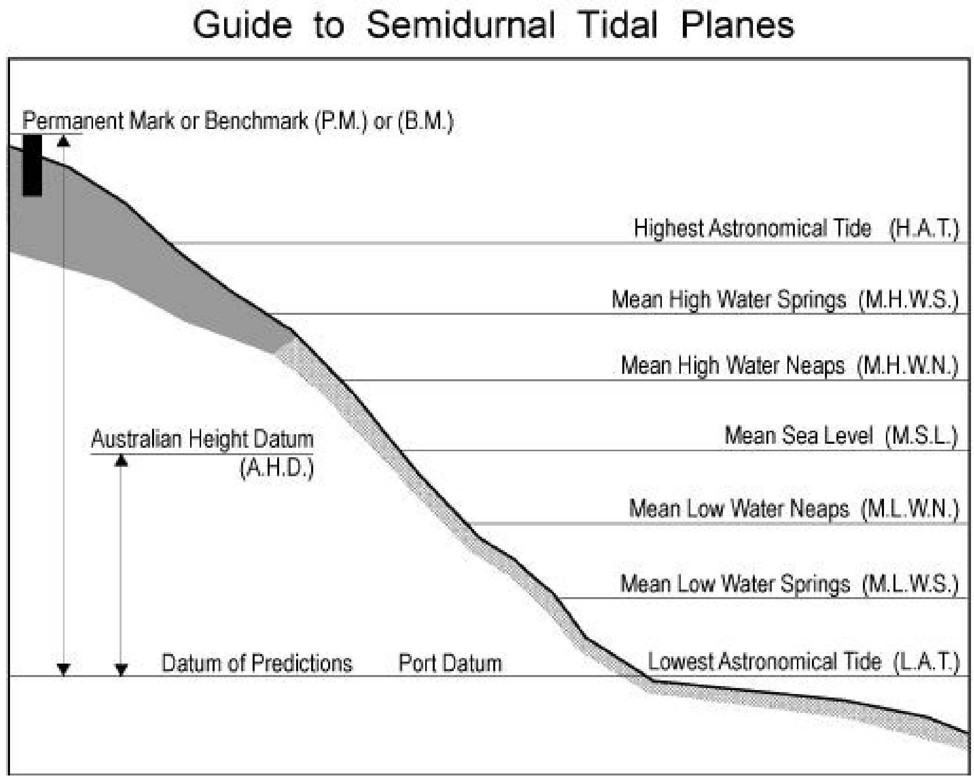

Figure 2. Guide to semi-diurnal tidal planes (MSQ Qld, 2004).

2.2 The Suitability Of Mean High Water Mark As A Boundary

The suitability of MHWM as a boundary along the coastal fringe has been questioned by many (Moore, 1968; Coutts, 1987 and Gordon, 2003).

> *'The fallacy of this method is that it really establishes a level at which the High Water occurs, rather than a position in the horizontal plane. If the particular coastline is a stable one, then there is unlikely to be a foreseeable problem' (Coutts, 1987; 555).*

However, the open coast beaches of much of Australia are far more dynamic in nature than the tides. Where a tide may fluctuate from zero to 2 metres vertically along a beach the beach itself can fluctuate horizontally by 10 to 30 metres in a single tide (Gordon, 2003; 6). The profile of a beach is dynamic and can change from day to day, changing with it the boundary. Baldwin (1982), Coutts (1989) and Gordon (2003) note that there is little point in accurately determining a boundary position that will be devastated by the next minor storm.

The Coastal Protection Amendment Bill 2002 was passed to address the shortcomings with common law rights of the doctrine of accretion and erosion. Its aim was to holt the loss of public access along foreshore and to stop the one way activity of owners claiming accretion but not surrendering claim to erosion, as shown in figure 3 (Jones, 2002 & Gordon, 2003).

The amendment to the Coastal Protection Act 1979 mainly concentrated on the issue of public access along foreshore areas and how redefining the position of mean high water will affect access rights. No longer does the theory of gradual and imperceptible change only apply to claims of accretion but now includes the assessment of indefinite sustainability, geomorphological processes and public access.

Knowledge of the geomorphological processes that form our coastal and estuary foreshores is required in the assessment of the ‘sustainability’ of a claim for accretion or erosion under the guidelines of the amended Coastal Protection Act 1979. After a MHWM determination has been made, both the Department of Lands (Gardner, 2004, per comm., 6 April) and Surveyor General’s Direction 2004 recommend that professional advice or evidence should be obtained from experts, such as coastal engineers, on the affects of accretion or erosion when assessing and submitting a claim along a foreshore.

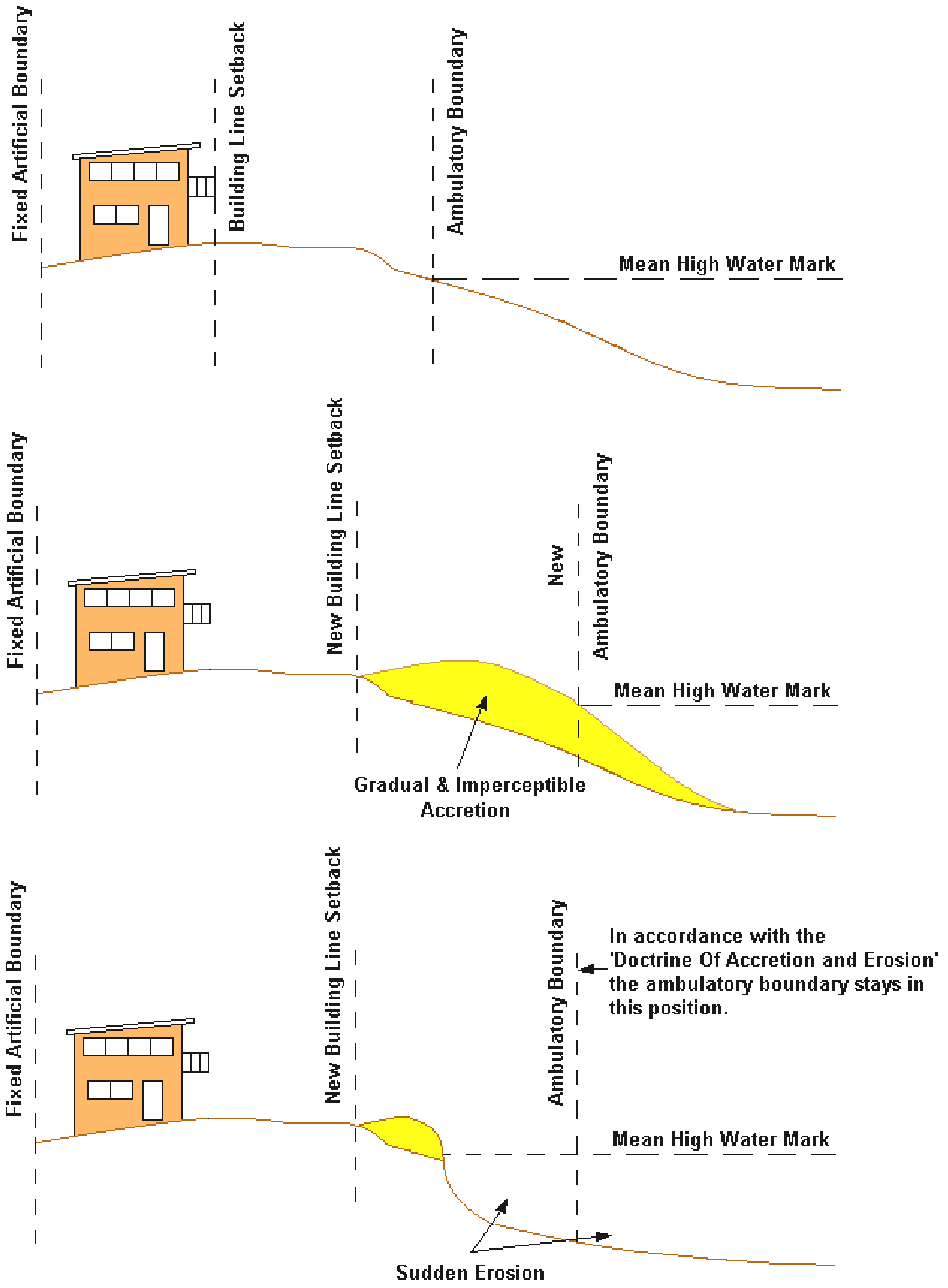

Figure 3: Accretion and Erosion Along A Dynamic Coastline (Thom, 2003).

2.3 The Importance Of Case Law And Water (Tidal) Boundaries

When a property has a natural boundary that is water the determination of that boundary:

> '*…invokes questions of fact and law, perhaps more so than is the case for artificial boundaries'* (Hallmann, 1973: 187).

Therefore many legal principles must be taken into consideration when disputes are presented to the courts.

Many legal rules and principles have been deduced from the many detailed law reports that accompany a judgement for a case. Hallmann (1973, pp251) notes that '*case law is not a system of law'* as decisions made by judges are not statute law but can contribute to the establishment of legislation (Butt, 1983).

Definitions in tidal terminology have been contested since *Attorney General v Chambers* to the present, State of Queensland v Beames [2002] QCA 209. Two American cases, City of Los Angeles v Borax Consolidated Limited (1935) and Luttes v State of Texas (1958). These cases deal with the time period for determining a tidal plane. These and many other cases illustrate how legal precedence has influenced the procedures in calculating and therefore positioning tidal boundaries. The survey techniques used in a MHWM determination have never been challenged in the New South Wales courts.

2.4 How Tidal Determinations Affect Accretion and Erosion

The position of a tidal boundary determination will be influenced by the affects of accretion or erosion upon that site. Accretion and erosion are caused by the natural or artificial imperceptible changes in the position of the shoreline over a period of time (Horlin, 1990, Harcombe, 1985, Hanna, 1989 & others). The inaccuracy in the techniques used to determine tidal planes is questioned by Songberg (2004) as a cause for variations in tidal boundary positions and not always from the action of erosion and accretion. The accuracies of different survey techniques used in defining a tidal boundary must be understood, because the decision made by a surveyor may be tested in court; the surveyor must ensure that his opinion is correct and true (Lambden & De Rijcke, 1996:180).

2.5 Legislation Affecting New South Wales Tidal Boundaries.

The type of water body, tidal or non-tidal, adjacent to land will affect what laws, acts and regulations that apply. It is the surveyor's responsibility to satisfy the applicable laws, acts and regulations when defining a water boundary.

Where land is bounded by tidal water, the common law rule is that the boundary is the MHWM (Hallmann, 2004). The definition for MHWM is setout in Clause 55(2) & (3) in the New South Wales Surveying Regulations 2001. Inconsistencies in definitions were discussed in Chapter 2.1.

The land between mean high water (MHW) and low water mark (LWM), i.e. foreshore, and the land below low water mark belong, at common law, to the Crown. The Crown is presumed to own the bed of tidal rivers up to the HWM (Hallmann, 2004).

Therefore approval from the Minister administering the Crown Land Act or any other owner of the adjoining land below MHW is required for the MHWM determination (Clause 55(6) of the New South Wales Surveying Regulations 2001). Approval of the Minister or adjoining owner to water boundary changes are set out in Clause 58 (1) and (2) in the Surveying Regulations.

Amendments made to the Coastal Protection Act have brought about changes to the Doctrine of Accretion and Erosion. From these changes, the NSW Department of

Land require a surveyor to confirm each part of a MHWM determination by completing an appropriate checklist - Appendix B (SGD, 2004).

2.6 Survey Requirements When Determining Tidal Boundaries Within New South Wales

Surveying Regulations 2001, as amended by the Surveying Regulations 2003, instructs a surveyor on the methods that should be used when surveying in an urban or rural environment. Amendments to the doctrine of erosion and accretion, vide Section 55N of the Coastal Protection Act 1979, are important alterations to the regulations.

Surveyors must obtain all relevant information i.e. search etc on the subject site to be surveyed in accordance with Surveying Regulations 2001 Part 3 Measurement and Calculations Section 13.

Clauses 20 and 59 of the Surveying Regulations 2001 require the position of all natural features to be accurately located. Clause 55 (4) of the Regulation advises that MHWM must be determined with appropriate accuracy.

Clause 55 (5) of the Surveying Regulations 2001 says that all seawalls and reclaimed land must be shown on a plan of survey. Clause 9 requires that the description of any substantial structure and/or fence within 1 metre of the boundary to be shown on the survey plan.

Clause 57 (1) of the Act stipulates that where a landward boundary of an existing reservation of stipulated width has not be defined by a survey the boundary must be defined by right lines (artificial lines) approximately parallel to the line of mean high water. This boundary may require approval by the Crown if no previous approval had been granted by this Act or previous Regulations under this Act; Clause 57(3).

Clause 59 (1) to (3) are concerned with the calculation of the areas of land abutting a natural feature. Appropriate accuracies must be used. All natural features must be described on the survey plan and the bearing and distances between end points of radiations or offsets defining the natural feature must be shown (as well as overall area of land abutting the natural feature).

Part 6 of the Surveyors General's Directions 2004 outlines the administrative procedures for establishing mean high water mark and re-establishing the original boundary along non-tidal waters. The methods of determination of MHWM are to be found in part 6, section 22 of the Manual of the New South Wales Integrated Survey Grid.

Part 7 set outs the approval requirements from the Department of Land for MHWM definitions when substantial change has occurred from the previous plan and when definitions is effectively the same as the previous plan.

2.7 Tidal Or Non Tidal Waters Status

Part of the procedure of preparing a survey plan and defining an ambulatory boundary is confirming that the foreshore is tidal as required by Clause 55 (3) of the Surveying Regulations 2001. Hurcum (1992) notes that if a tidal status is not properly identified then the non-tidal or tidal determination of a property may be a waste of time.

Difficulties can be faced when determining tidal limits by mere observations (DLWC, 2004). Towards the limits of tidal influence, a tide may only last approximately one hour and therefore go unnoticed by casual observations. The actual limit of tidal influence varies over time, depending on the freshwater flows of upstream river and creeks and the natural variability of the tides (DLWC, 2004). The next paragraph illustrates the difficulties faced when determining the tidal limit.

The Hawkesbury River is approximately 140 kilometres long and figure 4 shows a gravel bar that is approximately one kilometre below the downstream of the tidal limits. The bar is exposed 90 % of the time and the rise in river level is approximately 0.2 metres (It is assumed from this example that spring and neap high tides are within the tidal range 0.2 metres). It illustrates the difficulties of casually observing tidal influences and therefore it would be wise to observe or record the influence of the tide for at least a period of one day.

Low tide High tide

Figure 4 Hawkesbury River, New South Wales (DLWC, 2004)

Tidal status may be confusing in coastal lagoons. In these cases refer to Part 3 of the Surveyor Generals Directions as it refers to the Crown Land Act 1989 for the redefinition of non-tidal waters. Some court decisions have held that marine lagoons can be considered non-tidal under certain circumstances and therefore MHWM determinations and the doctrine of accretion and erosion does not apply.

2.8 Methods Of Determination

> *'It is one thing for a court, of whatever jurisdiction, to sit in judgement on a set of circumstances and determine where a tidal boundary should lie and another to actually physically delimit such a boundary on the ground'* (Horlin, 1990).

In most states within Australia there are laws and regulations that define tidal definitions but there is minimal guidance on how to determine tidal planes and relate them to the cadastre.

The following will outline the various methods available as stipulated by controlling authorities for surveyors to use when determining a tidal boundary.

2.8.1 Procedures Within New South Wales

In New South Wales the Surveyor General's Direction, 1999, advises that some methods of determination of MHWM are contained in part 6,section 22 of the Manual of the New South Wales Integrated Survey Grid, 1976 (ISG 1976). The three methods described in the ISG 1976 are the levelling from a benchmark, levelling from a local tide gauge and the Range Ratio method.

The Direction also informs that current tidal plane statistical data should be obtained from the Department of Commerce (now Manly Hydraulic Laboratory, part of the Department of Public Works and Services).

2.8.2 Procedures Within Other States And Countries

The following section will outline the techniques adopted by some States within Australia, as well as New Zealand and the United States of America. From this brief overview it can be seen that there are only a handful of techniques that are used for determining a tidal boundary. Accuracies of these methods are discussed later.

The determination of a tidal plane using the ratio of tide ranges observed at two stations is a widely used method. Methods range from the Range Ratio method (ISG 1976) or the Standard Method widely used in the United States of America (Cole 1997 & NOAA 2003). There are other ratio methods listed in SOM, 1996 Cole, 1997 and NOAA, 2003 that have different tidal characteristics. Simplified methods for determining tidal planes, based on tidal range ratios are setout in the South Australian Manual of Survey Practice (Section 12.4, Methods For Determining MHWM). The South Australian Manual of Survey Practice and Hanna (1989) both discuss using methods that use the water level to transfer tidal benchmarks without considering tidal gradients.

The use of statutory heights on a recoverable datum, preferably Australian Height Datum (AHD), for determining MHWM is used widely throughout Australia. It is referred to in the ISG Manual, South Australian Manual of Survey Practice (Section 12, Natural Boundaries) and Western Australian Survey and Plan Practice Manual 2003 (Chapter 5, Surveys of Water Boundaries). In the USA it is also widely used, Cole (1997).

Levelling from a local tide gauge is a prescribed method in Queensland, Western Australia, South Australia, New Zealand and the USA. All referred to in their manuals as mentioned above.

Biological methods of identifying MHW are referred to in the New Zealand Cadastral Survey Guidelines (Section 3 of part 11.5.12 -Tidal Boundaries) and South Australian Manual of Survey Practice (Section 12, Natural Boundaries). The tide coordinated aerial photograph method (Cole, 1997) combined with vegetation and ground truth points is also an accepted method used in the USA.

2.9 Accuracies In Determining Mean High Water

The horizontal uncertainty in the location of a boundary is directly proportionate to the vertical error of the tidal datum calculated and surveyed out in the survey field (NOAA, 2003 & Songberg, 2004). The accuracy of any procedure needs to be known so it can be used appropriately when surveying.

2.9.1 Accuracies When Levelling From A Benchmark

Even with an Australian Height Datum (A.H.D.) value for MHWM, Blume (1995) notes that the integrity of the original levelling or relevelling method of adjustment and general movement of the surrounding area can challenge the reliability of the benchmarks being used. Blume (1995) also points out that the A.H.D. value given for MHWM for one side of a bay or river may not be accurate for the other side. Harcombe (1985) and Hanna (1989) also note some of the pitfalls in using this method. Accurate methods and adjustments may be used to transfer a datum across the water body but a misclose may result if it is compared with other established benchmarks. Both sides of the water body may have fully adjusted benchmarks but both sides may not be connected or compatible with each other.

The assumption that an A.H.D. level is not accurate around all areas of an estuary or lake is also examined by Songberg (2004). He points out that a level network to establish A.H.D. that surrounds a water body may be many kilometres long and that the 'associated errors may induce an apparent tidal difference where there is none'. Songberg demonstrates the above potential problem using an area around Lake Macquarie. Lake Macquarie is a large tidal lake just south of Newcastle in New South Wales. It has a narrow channel that restricts the flow from the lake out into the sea and vice versa.

The approximate AHD level for MHW along the shore of Lake Macquarie can range between 0.75 to 0.150 metres AHD. There is a sparse network of tide gauges around the lake that have been tied to an AHD level network (see figure 5) and from this tidal gradients have been calculated. As seen on figure 5 the linkage between gauges is reliant on a level network run around the perimeter of the lake. If the level run was started from Swansea near the lake's entrance and followed the perimeter of the lake around to the western side to Dora Creek the resulting order of accuracies would be up to ± 55mm (3^{rd} order accuracy). The approximate MHWM levels for Lake Macquarie are within the accuracies required. Although the western foreshores of

Lake Macquarie are relatively flat and any variation in height can make a significant difference in the location of the MHWM (Ferrier, 1985). As discussed in NOAA, 2003, significant horizontal errors are a function of both the slope of land and the uncertainties in the position of a tidal plane.

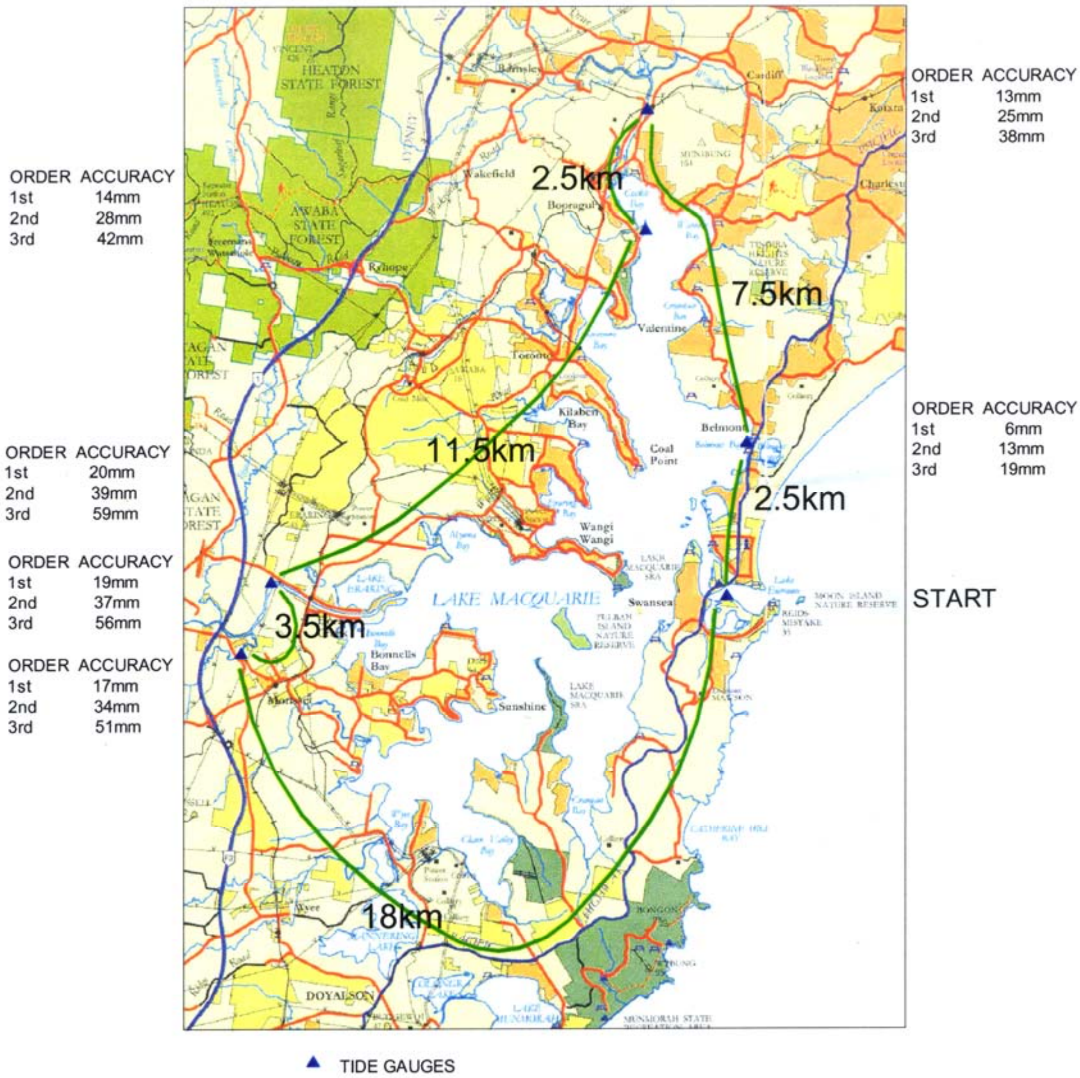

Figure 5 Lake Macquarie, New South Wales (Songberg, 2004)

Songberg (2004) questions the accuracy of A.H.D values for MHWM supplied by Manly Hydraulic Laboratories (MHL), part of the Department of Public Works and Services, as they do not indicate what height accuracy the values are. At present MHL are considering an accuracy of ± 0.05 metres with all MHWM determinations issued (P. Davidson, per. com., 24/7/2004). Blume (1995) cautions that AHD values must be confirmed for a tide gauge that is used for establishing MHWM so as to comply with survey regulations. The Crown or other approving authorities will supply MHWM values on AHD for tidal boundary determination. Therefore caution must be taken when given data from approving authorities, as there is no indication of how accurate the supplied height is.

The use of the 'Levelling From A Bench Mark' method cannot be used within estuaries or streams unless reliable tidal gradients can be obtained, Harcombe (1985) and Hanna (1989). The Manual of the New South Wales Integrated Survey Grid (1976) demonstrates that differences of up to ± 0.10 metre over relative short distances. Tidal gradient issues are further discussed in section 2.9.3.

2.9.2 Accuracies When Levelling From Local Tide Gauge

So as to obtain an accurate result the ISG Manual suggests that tide observations should be taken over a 12-month period to minimise the affects of the 'influences tending to disturb the rhythmical flow of the tide' (ISG, 1976). It also provides a simpler alternative to the above by observing tides for one lunation of 29 days. The manual states that the determination is approximate but then quotes an accuracy of ± 0.015metres for height. Songberg (2004) states that 'the manual does not cite any references as to where or how this accuracy is derived'.

Figure 6 shows all of the spring and neap tidal observations for Camp Cove, Sydney Harbour, during the period starting 1 July 1999 to 30 June 2000. A yearly and lunar month average can be calculated (Songberg, 2004). The chart shows an 80 cm variation in the tidal range from a low of 96cm to a high of 216cm. A comparison is shown in Table 1 illustrating the means of high tides over a series of 29-day lunation. Also shown is a 29 day 12 hours 44 minutes and 2.8second mean values, the precise time the moon takes to complete one phase.

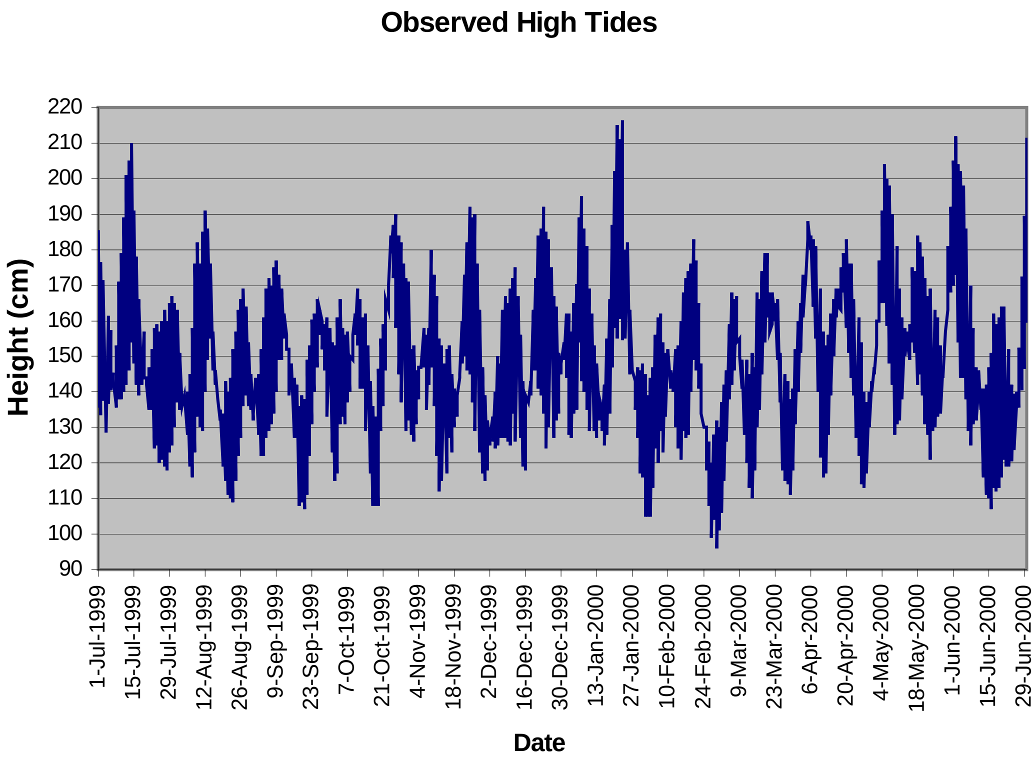

Figure 6 Observed High Tides, Camp Cove, Sydney Harbour (Songberg, 2004).

29 Day Cycle	Mean cm	Variance Mean cm	Lunar Month	Mean cm	Variance Mean cm
1	151.9	3.2	1	151.7	3.3
2	143.8	-4.9	2	143.8	-4.5
3	143.9	-4.8	3	144.8	-3.6
4	147.4	-1.3	4	149.4	1.0
5	148.8	0.1	5	148.0	-0.4
6	145.0	-3.7	6	145.1	-3.3
7	151.1	2.4	7	155.1	6.7
8	147.2	-1.6	8	143.1	-5.3
9	138.8	-10.0	9	139.9	-8.5
10	153.3	4.5	10	154.2	5.9
11	156.1	7.4	11	155.0	6.6
12	157.4	8.7	12	150.3	2.0
Yr Mean	148.7		Yr Mean	148.4	
Maximum	157.4		Maximum	155.1	
Minimum	138.8		Minimum	139.9	
Diff	18.7		Diff	15.2	
Stdev	5.5		Stdev	5.1	

Table 1 Observed High Tides Over One Lunation at Camp Cove, Sydney Harbour (Songberg, 2004).

From the mean value of twelve lunations for one year, it can be seen that the accuracy quoted by the Manual of the New South Wales Integrated Survey Grid of ± 0.015metres cannot be achieved. Some differences are up to 0.1 metres (shown in the variance mean columns), which is seven times greater than the required accuracy. There is a possibility that a surveyor could go to a site in one period of lower mean value and disagree by as much as 0.19 metre with another surveyor who fixed the mean high water during a period of high mean value.

Songberg (2004) and Blume (1995) demonstrate the variation in MHW, as shown in the Figure 7, over a period of approximately 80years. The MHW varies from a low of 1.38 metres to a maximum of 1.56 metres, which is a difference of approximately 0.2 metres. The largest variation from one year to the next is 0.083 metres. It is possible for a surveyor to establish a boundary one year and to find the next year that it has moved up or below the original determination the next.

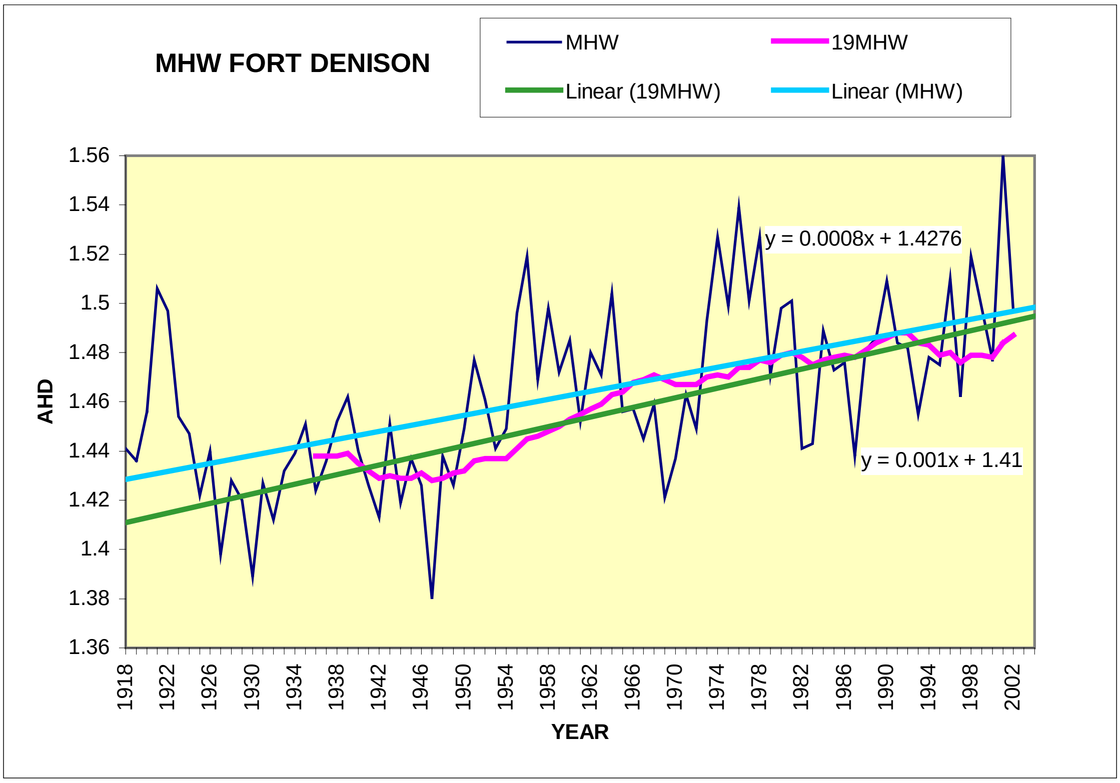

Figure 7 Mean High Tide at Fort Denison, Sydney Harbour (Songberg 2004)

Another problem faced by a surveyor determining the mean value for MHWM is that most tidal data supplied is at least a couple of years old. MHWM should be determined at the location at the time of survey (Hallmann 2004 pp13.39 & Songberg, 2004). If the surveyor does not use measurements at the time of survey, and they use the values that are out of date, this could cause considerable error as described above. Cole (1997), NOAA (2003) & Songberg (2004) suggested that it is more desirable to recalculate the more current epoch than rely on old published data that has been supplied by controlling authorities. NOAA (2003) and Songberg (2004) suggest the use of either the 19 year average mean or the trend line determined over the longest possible recorded history of a tide gauge to be the most reliable estimate of MHWM. Harcombe (1985) and others site the case, *City of Los Angeles v Borax Consolidated Limited 1935*, as stating that 19 years is a sufficient span of observation time to determine MHWM to a degree of certainty. Manly Hydraulic Laboratories at present use 10-19 year averages and are now looking at introducing an adjustable yearly MHWM level to counter the affects of sea level rise (Judge, 2004, per com., 20 August).

Globally tide gauges have indicated a rise in sea level of between 0.1 to 0.25 metres over the last century (Denys and Hannah, c.1998.). As shown on figure 8 there is a predicted rise in the sea level of approximately 0.5 metres in the next 50 years (IPCC, 1995).

The recommended practices for calculating a tidal datum are discussed in NOAA, (2003,) Cole (1997) and DLWC (2003). As mentioned previously, the averaging of 19 years of tidal data is seen as the most accurate estimate of MHWM. The standard deviation of the calculated result is in the 0.01 to 0.02 metres range for this period of time (NOAA, 2003). If shorter observation times are required then tidal data is averaged over this time and compared with the tidal data of the same period from an established gauge with at least 19 years of records (NOAA, 2003).

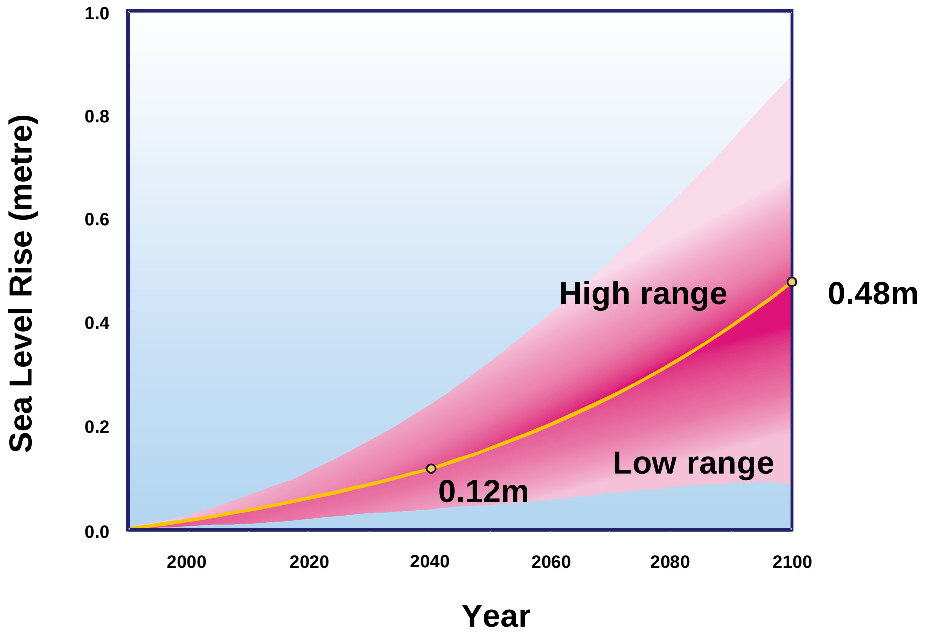

Figure 8 – Rise in sea level (Watson, 2004)

The use of an in-situ tide gauge is recommended by Cole (1997) and Harcombe (1985) as giving a ‘better estimate’ of MHWM. Blume (1994) questions the real value of using a local tide gauge in determining a tidal value, due to the commercial cost and the delivery time frame of a survey plan. Harcombe (1985) discusses the need for portable automatic solid-state tide gauges that can record one lunation of tidal data for mean high water mark determinations.

The definition of MHWM adopted by different bodies is also a matter of concern as explained by Blume (1995) and Songberg (2004). The exclusion of some tidal observations in the calculating of MHWM may not be within the definition as handed down by court case, *Attorney General v Chambers*, this being the accepted legal definition (see chapter 4.2). All tides, except those in flood or extreme conditions, are considered in the calculation of a MHWM plane (DLWC, 2003 & NOAA, 2003). This accuracy issue is faced by all of the methods when determining and calculating a MHWM plane.

2.9.3 Accuracies Using Range Ratio

In theory the relationship of MHW along any estuary or coastline is constant over time (Songberg, 2004). Travelling up the coast or along an estuary the tidal gradient would rise or fall in a ratio that is constant but not necessarily equal between different locations. Figure 9 depicts what the tidal gradient should look like over time.

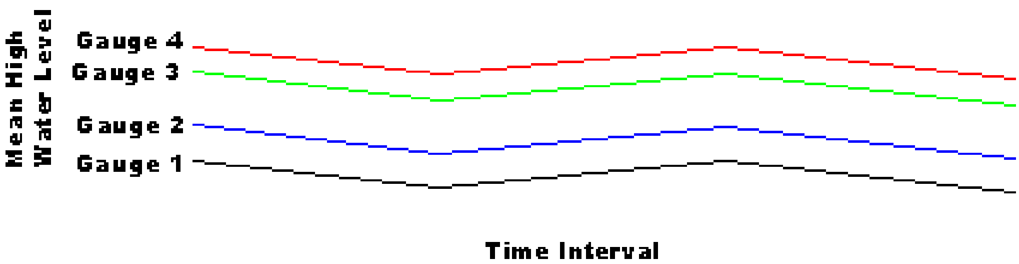

Figure 9 Ideal Tidal Gradient

Using the tidal gradient information Songberg (2004) demonstrates that the relationship between gauges is not a consistent relationship, which the range ratio method relies on. He explains that there is over a 0.1 metre variation between the 10-year mean and the MHW for any one-year. Taking the highest and lowest values there is over a 0.2 metre difference in MHW levels. Using this data surveyors would find that the ratio varies from year to year and hence there is movement in the boundary.

Songberg (2004) continues to demonstrate the MHW gradients along the New South Wales Coast by using Middle Harbour, Sydney, as a reference gauge and assigning the other gauges along the coast as field gauges. Using the yearly MHW spring, MLW spring and the10 year average for mean sea level each yearly MHW was calculated using the range ratio method from Sydney. The Manual of the New South Wales Integrated Survey Grid states that 'fairly accurate values of mean high water' can be achieved when observing one day's semi diurnal tidal range when transferring the tidal plane using the Range Ratio method. As seen in figure 10, this may not be the case as variations of up to 0.2 metres may occur over very short periods of time. To increase the accuracy of this method, use simultaneous observation from various established gauges with at least 19 years of tidal records (Cole 1997 & NOAA 2003).

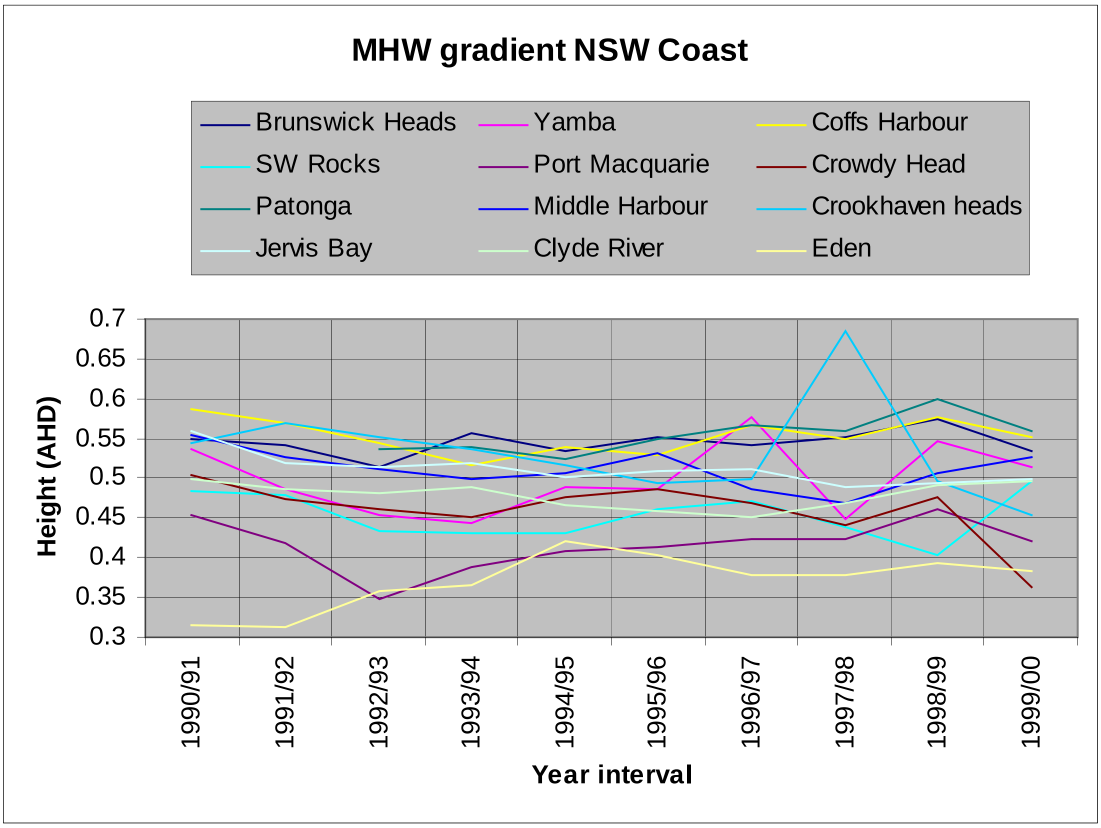

Figure 10 Tidal Gradients Along the New South Wales Coast (Songberg, 2004).

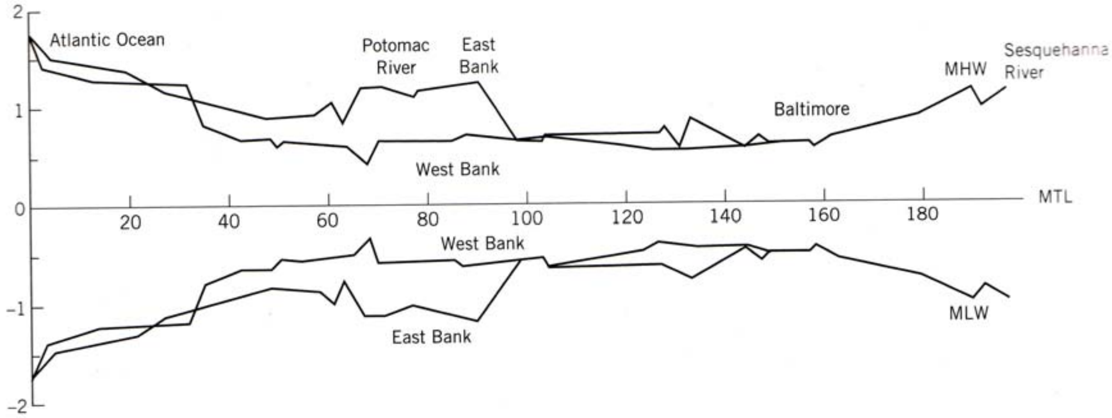

Figure 11 Tidal datum heights along Sesquehanna River, USA (Cole, 1997, pp.20)

Figure 11 shows that local variations in tidal gradients can also change from bank to bank along an estuaries or streams (Cole, 1997). Therefore the accuracy of transferring a MHWM level from one side of an estuary to another is questionable.

Cole (1997) and NOAA (2003) note that vertical datum should not be transferred into areas of differing hydrographic characteristics. This could be an estuary leading into a bay or a tide gauge in the ocean being used to determine the level within a harbour. The Manual of the New South Wales Integrated Survey Grid also advises that the accuracies of observation can be affected by abnormal weather or flood conditions and that observations of tides should be taken at periods of spring tide at the time of new and full moons.

2.9.4 Other Methods

Tidal coordinated aerial photographs can be used in areas where dense vegetation is not obscuring the land/water interface Cole (1996). Harcombe (1985) and Horlin (c.1990) report that remote sensing techniques using black and white infrared serial photography have been used to accurately locate both MHW and MLW. There is no mention of what accuracies were achieved. Cole (1996) reinforces the benefits of using aerial techniques as field staff and equipment in remote areas would be an expensive exercise. There are many inherent inaccuracies in digital data, e.g scale; this combined with physically realising a water boundary makes the use of aerial photographs for cadastral purposes extremely difficult. Hirst &Todd (2003) adds that it is difficult enough to determine a high tide line of a beach within 2-5 metres on the ground and therefore even more so from the air.

The use of the biological profile methods in conjunction with remote sensing techniques are accepted methods used within the United States of America, (Harcombe 1985 & Cole 1997). It is claimed in the United States that the determination of MHW can be accurately positioned when using the location of mangroves and salt resisted marshes together with aerial photogrammetry (Maloney and Ausness, 1974). In Victoria, there are two plant types, White Mangrove growing below Mean High Tide and salt marsh located between Mean High Tide and Spring Tide. The seaward side of salt marsh is precise for Mean High Tide (Sherwood, 1976 as cited by Blume, 1995). The Surveyors Board of Victoria does not accept this approach as being accurate (B Ross 2004, per comm., 22 July). The South Australian Manual of Survey Practice also mentions that the seaweed line method is to be avoided by surveyors not experienced in determining MHWM. They should choose more objective methods. The top of oyster growth about a pier is very close to the MHW line but at present there is no evidence on the potential accuracy of this biological indicator (Songberg, 2004).

The vegetation test may be combined with the locating of control points by field survey methods to provide interpolation from aerial photography of the line between points, therefore eliminating gross errors and achieving higher accuracies (Horlin, 1990). Maloney and Ausness (1974) claim that the use of this technique was more accurate and economical than field surveys. Research by Freedman & Higgins, c.2001 suggests that there are positional errors in tidal boundaries where biological indicators are used. Songberg (2004) suggests that further studies on the accuracies of boundary determination are required before such methods are adopted.

Hirst &Todd (2003) state that even if tidal variations are allowed in the determination of a tidal boundary from one point to another, the issues of instability and irregularity in terminology and techniques, result in inherent uncertainty.

2.10 Summary: Chapter 2

This review has called upon a breadth of material available which provides a good indication of the complexities involved in determining an ambulatory boundary within New South Wales. The research project has by no means discussed all the issues faced when assessing a tidal boundary determination but has addressed the issues faced when determining a current MHWM.

The project methodology used for this research project is discussed in the next chapter (chapter 3).

CHAPTER 3

RESEARCH METHOD

3.1 Introduction

This chapter will describe the methodology that was employed to develop a procedure manual for determination Mean High Water Mark (MHWM) within New South Wales.

The aim of this chapter is to discuss the methods used in accessing information, calculating tidal planes, techniques used in the field and presenting a survey plan and report.

The analysis is organised into three sections. The first section describes what format the manual will follow. The next section describes how the procedure manual for determining MHWM was formatted. The final section explains how the procedure manual was validated.

3.2 Procedure Manual Format

A procedure manual is a vital part of a surveying firm's quality control system that ensures that a task is performed with precise and clear instructions. It is important that these procedures are flexible, so as to cope with the varying scenarios a MHWM determination can offer.

Chapter 3 – Research Method

All procedures will be in accordance with the Surveying Regulations 2001 and Surveyor General's Directions 2004. The user of the manual will be able to incorporate the procedure into the Department of Lands 'Checklist for Water Boundary Consent' (Appendix B).

The format for the procedure manual is based on the Model Quality System Survey Procedure Manual, written by the Association of Consulting Surveyors Australia (ACS), for cadastral and topographic surveys. The ACS manual is widely used by the surveying community around Australia and was seen as the best layout for this procedure manual.

The Format for each part of the procedure manual will be as follows: -

- Procedure Title – very brief explanation of what the procedure covers.
- Purpose – a concise description of the procedure.
- Scope – explains what the procedure covers and does not cover. Explains when the procedure should be used and not used.
- References – lists manuals and policies used in the procedure.
- Procedure - Data Search – acquiring all relevant information for determining ambulatory boundary.
  Field Survey – a step-by-step instruction on the procedures to be followed.
  Survey Plan and Report Preparation – requirement in presenting boundary determination.
- Definitions – explains any technical term used in the procedure.
- Appendices – further information as required by the procedures.

3.3 Mean High Water Mark Procedure

The following are the individual sections that will make up the procedure manual and were selected as major parts for determining a tidal boundary.

- Search and locality information.
- Determining and positioning a tidal boundary.
- Survey plan and report requirements.

The following sections outline the preparation of the procedure manual in accordance with legislation and recommended guidelines. All stages of the procedure manual will require the surveyor's signature and a date to verify the work has been done and checklist completed.

3.3.1 Search And Locality Procedure

The establishing of a tidal boundary requires preliminary investigation before the surveyor can visit the site. This will involve searching for geographical names, property titles, historical survey plans, tidal data and benchmarks on Australia Height Datum (AHD). This section is relevant to the procedure manual, as Clause 13 of the Surveying Regulations 2001 states that: -

> '*a surveyor must obtain all relevant information on public record with government departments and public authorities necessary to locate or relocate the boundaries of any land to be surveyed……*'

Title, historical and geographical name searches are required to be undertaken on all sites to be surveyed in order to ascertain who the owners of the land above and below the Mean High Water (MHW) are and to determine if there are any encumbrances on the title, such as leases of land below MHW or restrictions on the use of the land above MHW. The historical plan search will allow the surveyor to examine and re-establish the original boundaries and MHWM. The procedure manual states the various ways of obtaining the search. The user can access the information by the following: -

- the Internet
- approved information brokers
- the search facilities within the Land Titles Office within the Land and Property Information centre, Sydney

The method by which information will be obtained for all parts of the procedure manual will be through the Internet. This is seen as the most accessible method of obtaining information. As Internet addresses may change over time, the manual will include mailing addresses. Figure 12 and 13 are examples of the many Internet sites used in the procedure manual.

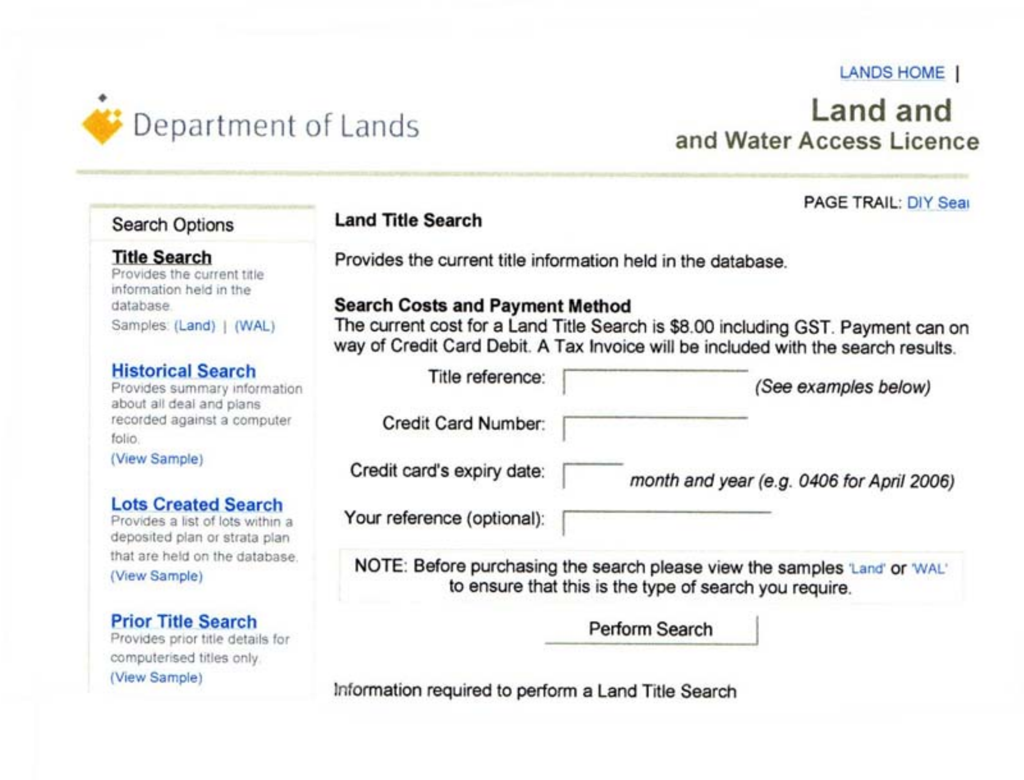

Figure 12 - Land Title Search Web Page, Department of Lands.

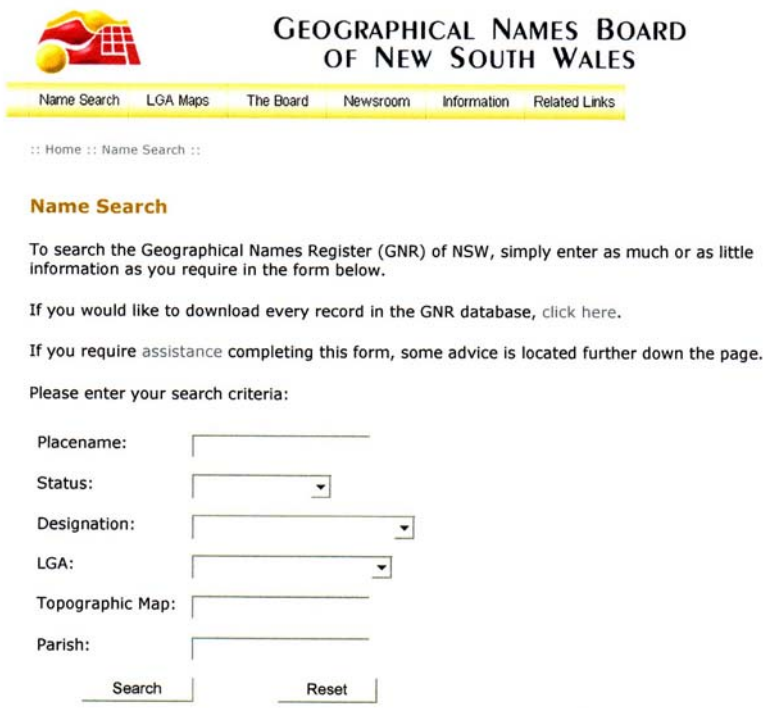

Figure 13 - Geographical Names Board of NSW Web Page.

Another important part of the procedure manual is the confirming of the tidal status of a water frontage property. Using Internet or approved information brokers, historical survey plans and parish maps will be used to check the tidal status of a property. The procedure for confirming tidal status is in accordance with Clause 55(3) of the Surveying Regulations 2001and the requirement of the Department of Lands Checklist (appendix B).

Part 1 of the Surveyor General's Direction 2004 requires that any tidal gradients or analysis for MHWM in New South Wales be obtained from the Manly Hydraulic Laboratories (MHL), which is part of the Department of Public Works and Services. Again the Internet was the method used for accessing tidal information. Figure 14 is an example of the request form used.


NSW Department of Commerce

Manly Hydraulics Laboratory

Home | Search | Contact Us | About MHL | Client Pages | Services | Facilities | Data Online | Request Data | Real Time Data | Tide Charts | MHL Mapping System

Request Data

Name *:
Organisation:
Phone Number *:
Fax Number:
Email Address *:
Address
City:
Postal code:
Delivery Address:
Delivery instructions: O Mailed O Couriered O Faxed O Emailed
Media type: O Printout O 3 1/2 disk O Email

*** Name and either Phone or Email are required inputs.**

Data Type: Combination

If you are unsure of the station name or need to search for a particular station, look here.

Station Name	Date From	Date To	Data Presentation Format

Additional Information

Figure 14 - Example of a Manly Hydraulic Request Form.

All tidal data was checked for anomalies, such as the effects of local floods and other hydrological influences and then related to a datum within its region, usually AHD. Tidal data was filtered for tidal anomalies using MHL analysis software package called INTERACTIVE program DBSPR V1.0.

Part 7.2.2 and 8 of the Surveyor General's Direction, 2004 requires that all MHWM determinations be referenced to AHD and Part 5 of the Surveyor General's Direction, 2004 requires that all plans of survey, including redefinitions, are connected to established marks with Map Grid Australia (MGA) coordinates. This information is supplied by the Survey Control Information Management System (SCIMS) at the Land and Property Information (LPI) centre and can also be accessed via the Internet.

3.3.2 Format For Determining And Positioning Tidal Plane

All surveying requirements that are setout in the procedure manual for determining MHWM are in accordance with the Surveying Regulations 2001 and the Surveyor General's Direction (2004). The primary survey techniques used in the procedure manual are those setout in part 6, section 22 of the Manual of the New South Wales Integrated Survey Grid (1976). They are as follows:

1. Levelling from a benchmark.
2. Levelling from a Local Tide Gauge.
3. The Range Ratio Method.

Research papers and studies were reviewed in the Chapter 2 – Literature Review – to assess the current state of knowledge in the survey techniques used to determine MHWM. The main issue addressed was the accuracies that could be expected when using varying survey techniques. It was seen that all of the techniques referred to in the Manual of the New South Wales Integrated Survey Grid had major problems achieving the accuracies claimed by the manual.

The use of an AHD benchmark to determine MHWM will be the first choice in the procedure manual when a statutory authority has a reliable height for MHWM. This height is calculated from approximately 10 to 19 years of recorded tidal data and is accurately tied to Australian Height Datum (AHD). After this the use of a local tide gauge, Range Ratio method or a combination of both will be controlled by the availability of tidal data or the distance the datum must be transferred from the benchmark or tide gauge.

To allow for a consistent answer when calculating a MHWM the tidal data of a subject site will be compared to the tidal data of an established long-term tidal gauge

(19 years of records/ 10 years minimum) for the same period. It is accepted that 19 years is a sufficient time to determine MHW to a degree of certainty (refer 2.3 & 2.9). The method adopted by the procedure manual was the use of reliable tidal data recorded for at least 10 to 19 years; over 19 years a standard deviation for a MHWM determination will be around ± 0.02 metres (refer Chapter 2.9.2).

The Manual of the New South Wales Integrated Survey Grid (1976) refers to the 'Levelling from a Local Tide Gauge' that has been established for one lunation. This can lead to significantly different answers over time, as referred to above. The procedure manual will adopt the principle that the MHWM should be calculated over a long period of time. Therefore the 'Levelling from a Local Tide Gauge' method will require an adjustment to correlate the MHWM calculated at the subject site to the long-term reading of an established tide gauge. The only difference in this technique to the Range Ratio method is that it uses a lunation (or more) of tidal data from a local tide gauge. The Range Ratio method only requires consecutive high and low tides. The procedure manual will require at least three consecutive tides to be measured for the Range Ratio method to improve the accuracy of a determination. As well as being used to establish a height the Range Ratio method will be used in the procedure manual for verifying a MHWM height. This will involve recalculating the height at a different time other than the time of survey.

When it was required to observe and compute simultaneous tidal information for a local and control tide gauge, the National Oceanic and Atmospheric Administration (NOAA) method of computing tidal datums at short-term stations was used.

The method used by the NOAA is a follows:

1) Select a time period for simultaneous observations at the local tide gauge and an established tide gauge. Select an established tide gauge (control) with a minimum of 10 years of tidal data. Ensure the local site and control are similar in tidal characteristics and surroundings.

2) Obtain data from both sites over the same period. Correct data for ambiguities (i.e. flood affected, bad data, etc) and calculate tidal components for the period at subject site. Methods used for calculating statistical data are discussed further on.
3) Obtain the accepted tidal components for the control gauge from MHL.
4) Compute the ratios in the tidal parameters, using the Range Ratio formula (see below), and apply differences to subject site data.
5) When calculating simultaneous observations a standard deviation of ± 0.03 metres or less should be achieved over three tidal cycles, for the determination of a MHWM plane.

The following method was used in the calculation of mean differences and ratios in tidal parameters between the subject site gauge to be surveyed and the established tide gauge. The formulae and components are explained as follows.

Range Ratio Method Approx. MHW $= M.T.L._2 + K_1 + K_2$

Where $K_1 = M.T.L._0 - M.T.L._1$

$$K_2 = \frac{L.T.R. * O.R._2}{2 * O.R._1}$$

$M.T.L._2$ = Mean of observed High Water at site gauge (m) (M.T.L is Mean Tide Level).
$M.T.L._0$ = Long term value on the gauge of mean tide level at automatic gauge (m).
$M.T.L._1$ = Mean of observed High Water and Low Water at automatic gauge (m).
L.T.R = Difference between Mean High Water and Mean Low Water at automatic gauge (m).
$O.R._2$ = Observed range at site gauge (m).
$O.R._1$ = Observed range at automatic gauge (m).

The following statistics were used in the calculation of tidal datums for calculating the mean tidal range and for assessing the precision of that value.

- The Mean – is the average of the observations in a sample. It is the sum of all the data and divided by the total number of that data.

$$\mu = \frac{x_1 + x_2 + \ldots + X_n}{n}$$

Where μ = mean, x = observation (m) and n = total number of observations.

- The variance – is a measure of how spread out the distribution is. It is calculated as the average squared deviation of each number from its mean.

$$\sigma^2 = \frac{1}{n - 1} \Sigma (x_1 - \mu)^2$$

Where μ = mean, x = observation (m), n = total number of observations, and σ^2 = variance

- The standard deviation – measures spread by looking at how far the observations are from their mean. It is calculated as the square root of the variances.

$$\sigma = \sqrt{\sigma^2}$$

Where σ^2 = variance and σ = standard deviation

For the above computations, Microsoft Excel worksheets were used for the ease of arranging data and calculating statistical information.

A tidal staff placed in a protected position out in the tidal zone, will be used for measuring high and low water levels out on site. The measuring of the water level where it intersects the land is not seen as accurate due to wave and wind disturbance on the surface of the water (although in some circumstances this may be the only method). To ensure that the correct levels for low and high water are obtained observations will be taken 30 minutes before and after predicted tides as shown on tide charts.

The method used for establishing a MHWM boundary line out on site was by using the staking method. The staking method involved differentially levelling from an established benchmark that was related to a level for MHWM. Differential levelling is the operation of determining differences of elevation by measuring vertical distances directly on a graduated staff with the use of a levelling instruments such as a dumpy level or theodolite (USQ, 2000). This MHWM level was transferred to the foreshore by assuming that MHW is a contour in the immediate area and tracing that contour by conventional levelling methods. This technique is used in the procedure manual and is in accordance with the survey requirements of parts 3 to 5 of the Surveying Regulations 2001 and Surveyor General's Directions, 2004.

The use of differential levelling in locating the position of the MHWM was used in the procedure manual. This allowed the surveyor to physically see the position of the boundary at the time of survey and therefore allows for any adjustments to be made on the position of the determination. It is common to adjust tidal boundary positions on flat or irregular foreshores. Survey field techniques for differential levelling used in the procedure manual are in accordance with company procedures and Surveying Regulations.

3.3.3 Establishing Previous Mean High Water Mark

The procedures are prepared in accordance with Surveyor General's Direction 2004 parts 3, 4, 6, 7 and 10. These all relate to the requirements for any cadastral survey from 'Controls for Cadastral Surveys' through to the requirement of the 'Surveying of Crown Land'. Also adhered to was the

legislation setout by the Surveying Regulations 2001 dealing with cadastral surveys and natural boundaries.
The plan of redefinition was calculated on a survey office software package called Liscad 6.2 and exported to AutoCAD for the drafting of the final plan

3.3.4 Format For Survey Plan And Report

Plan preparation was in accordance with the draft Surveyor General's Directions 2004 for 'Water as a Boundaries Procedures' and Registrar General's Directions for Deposited Plans. All references to drafting requirements will be for either computer aided drafting (CAD) or free hand drafting.

Where consent is required for a change in position of MHWM, a comprehensive report is required in accordance with the Part 7.2.2 and 8.2 of the Surveyor General's Directions No.6 (2004) and Clause 58(2) of the Surveying Regulations 2001. The procedure manual will format this report in accordance to the information requirements set out by the above noted directions and regulations. The procedure manual will not cover all aspects of erosion and accretion or legal precedence upon MHWM claims, but it will give advice on basic principles and where this information and advice should be obtained.

3.4 Validation Of Procedures

A case study was selected to validate the procedure manual for determining MHWM. This would allow any shortcomings in the procedure manual to be found and to be discussed.

Patonga, on the Central Coast of New South Wales, was the site chosen because of the ease of access to the MHWM from the public reserve, which surrounds the entire peninsula. Under the guidance of the procedure manual an optimum time was chosen to survey the site.

Under the guidance of the procedure manual the position of the current MHWM was established. All methods for positioning a MHWM boundary were used in the procedure manual to evaluate the accuracy of the determination. An authorized AHD height for MHWM was used to define the boundary. This determination was checked by using data collected from the local Patonga tide gauge, which was calculated and adjusted against an established tide gauge in Middle Harbour, Sydney. The last technique used to validate the position of the MHWM, was the use of the Range Ratio method. This was achieved by measuring three different gauge sites (Patonga, Ettalong and Middle Harbour) and calculating the ratios between each site.

The position of the previous MHWM will be established using normal cadastral techniques. This will include looking for original survey marks and reinstating the subject boundaries. Comparisons can be made between the original and current position of the MHWM to see if a change in position has occurred. The procedure manual will recommend what course of action is required within current guidelines and legislation.

3.5 Summary Chapter 3

This chapter has discussed the methods used for constructing a procedure manual for establishing a MHWM boundary. The procedure manual discussed in Chapter 4 can be used as part of a company's quality control system. This will allow employees to formally check that each part of a determination complies with both legislation and the firm's standards.

CHAPTER 4

PROCEDURE MANUAL

4.1 Introduction

This chapter will set out the procedures to be followed to allow a surveyor to establish or re-establish a Mean High Water Mark (MHWM) boundary within New South Wales. These procedures can be part of any surveying company's quality control for establishing a tidal boundary.

The aim of this chapter is to establish a clear and well-organised set of procedures that allow the user to determine a MHWM boundary.

The manual will be structured to allow the surveyor to be aware of the benefits and limitations of each technique used to determine a MHWM, while combining recommendations with legislation and guidelines required by the State's controlling authorities.

4.2 Procedure For A Mean High Water Mark Survey

4.2.1 Purpose

This document describes the tasks to be undertaken when carrying out a Mean High Water Mark (MHWM) survey within New South Wales. In addition to ensuring that all client requirements are addressed, it is intended to ensure that requirements of the Department of Lands, Land Titles Office and any statutory authorities are satisfied.

4.2.2 Scope

The following procedures will cover all classes of a MHWM determination survey, undertaken by a firm, which includes boundary identification surveys, detail surveys and plans of MHWM redefinition. Activities associated with initial client dealings, establishing job files, and invoicing are detailed in the company's procedures for dealing with client instructions and project administration.

4.2.3 References

4.3 - Procedures for Data Search Requirements.
4.4 - Procedures for Levelling From A Bench Mark.
4.5 - Procedures for Levelling From A Local Tide Gauge.
4.6 - Procedures for using Range Ratio Method.
4.7 - Procedures for Levelling & Positioning a Horizontal Plane.
4.8 - Procedures for Establishing Previous Mean High Water Mark.
4.9 - Procedures for Plan Presentation.
4.10 - Procedures for Reporting on Determination.

4.2.4 Responsibilities

The Principal shall not approve any Procedure that does not use the following format.

Approved by:___________________

Date:___________________

4.2.5 Client Instructions

Determination of client requirements, cost estimates, indexing, allocation of the survey, invoicing and archiving of files shall be undertaken in accordance with company’s procedures for client instructions and project administration. A job file for each survey will have been created by the receptionist and placed in the work pending file in accordance with company’s procedures for client instructions and project administration. This procedure manual is to be used to accurately determine the position of MHWM. Refer to Clause 29 of the Surveying Regulations 2001 for guidance in surveys not requiring strict accuracy while using this manual.

4.2.6 Data Search

The Searcher shall undertake a data search for each job to fulfil requirements described on the company’s job instruction form. Data search procedures are described in 4.3.

4.2.7 Field Survey

The project surveyor shall undertake the field survey in accordance with survey techniques explained in procedures 4.4 to 4.7. For deciding on which method to use to establish MHWM refer to the procedure flowchart (figure 15 on page 49). Conduct of the survey and marking requirements shall comply with the company’s standards, Surveyor General’s Directions and the Survey Act and Regulations. All equipment used shall have a current calibration/testing status in accordance with company’s procedures for measuring equipment testing and maintenance. Where the project surveyor uses any equipment other than the permanently allocated equipment set, this shall be noted in accordance with company procedure.

Approved by:____________________

Date:____________________

4.2.8 Boundary Definition For Reinstating Previous MHWM

All fieldwork and computations required in the reinstatement of boundaries will be in accordance will Surveying Regulations, Surveyor General's Directions and company procedures. See 4.8 for specific instructions for reinstating previous MHWM position.

4.2.9 Plan Preparation

Recommended practices for detail and identification surveys and statutory requirements for survey plans of MHWM redefinitions are setout in procedure 4.9.

4.2.10 Survey Reports

The project surveyor will be required to prepare a survey report with all MHWM determinations - see procedure 4.10.

Approved by:____________________

Date:____________________

4.2.11 Definitions

MHWM	Mean High Water Mark
AHD	Australian Height Datum
SGD	Surveyor General's Direction, 2004
MGA	Map Grid of Australia
LPI	Land and Property Information Centre
LTO	Land Title Office
MPAD	Maritime Property & Assets Division
MHL	Manly Hydraulic Laboratories
SCIMS	Survey Control Information Management System
GPS	Global Positioning System
CAD	Computer Aided Drafting

4.2.12 Appendices

Registrar General's Directions 2002

Surveyor General's Directions 2004

Surveying Regulations 2001

Department of Lands Checklist 6.2 for 'Water as a Boundary'

Survey Act and other relevant Acts and Regulations.

Manual of the New South Wales Integrated Survey Grid, 1976

Approved by:____________________

Date:____________________

Procedure Flowchart

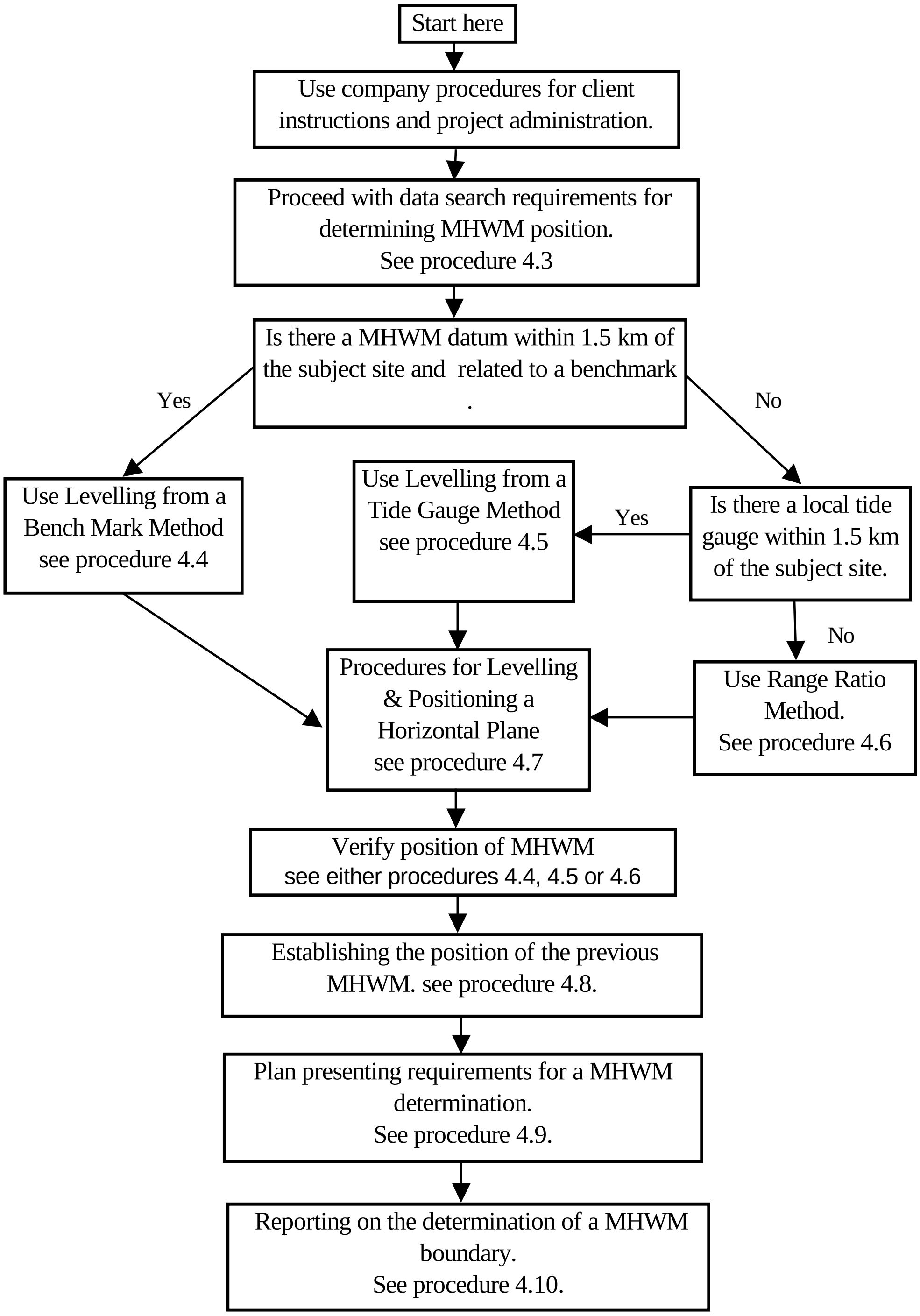

Figure 15 Procedure Flowchart

Approved by:___________________

Date:___________________

4.3 Procedure For Data Search Requirements

Introduction - This is to give guidelines on the procedures that should be followed when ordering a search and other information used for the determining of a MHWM boundary within New South Wales.

Scope - The procedure following will encompass all cadastral search and tidal information requirements when determining a MHWM for cadastral purposes within New South Wales. This will include contact information, such as Internet and mailing address, for land title search and tidal data.

Responsibilities - The Principal shall not approve any Procedure that does not use this format.

Procedure

<u>Checking Geographical Names</u>: -

- Checking the geographical names of the site and adjoining water is accessed by contacting the Geographical Names Board at the LPI (Appendix C) or the website, www.gnb.nsw.gov.au/lgamap/search, and entering the required information.
- Confirm procedure by marking 'Y' in items 1 and 2 in Checklist- 6 (Appendix B).

<u>Acquiring Map Reference And Details</u>: -

- All state survey marks have MGA coordinates of varying accuracies and can be obtained from SCIMS at the LPI (Appendix C) or the Internet at http://scims.lands.nsw.gov.au/scims.html. Joining fees and data costs can be obtained from the website.

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Date: ____________________

- Rough coordinates can be scaled from any topographic map with MGA coordinates. This is sufficient for the approximate location of a site for the purposes of the Department of Land.
- Confirm procedure by marking 'Y' in items 1.1 in Checklist- 6 (Appendix B).

Acquiring Search On Tidal Status: -

- References or symbols shown on historical survey plans must be checked against Parish maps to confirm tidal status. This will also apply when a title diagram does not show the tidal status of a water frontage. Parish maps can be obtained from the LPI (Appendix C) or in a digitised format from the Internet at http://www.lands.nsw.gov.au/MapsAndPhotos/ParishMaps/default.htm.
- When there are doubts on the tidal status of a water frontage, contact MHL (Appendix C) to confirm the tidal status. The surveyor must observe at least one tidal cycle out on site.
- Refer to part 4 of the Surveyor General's Direction 2004 for marine water bodies, such as lagoons, that have been judged non-tidal.
- Confirm procedure by marking 'Y' in items 2.1 in Checklist- 6 (Appendix B).

Data Search Information: -

- Title, registered and unregistered information can be obtained from the LPI (Appendix C) or over the Internet via the Integrated Titling System at http://www.lands.nsw.gov.au/Records/PropertyInformation/default.htm. Search costs can be obtained from the website. Follow companies procedures for ordering and checking data search.
- Confirm that the landward boundary of a reservation fronting tidal water has been recorded by a plan of survey. Refer to Clause 57 (1 & 3) Surveying Regulations 2001 for instructions if otherwise.
- Confirm procedure by marking 'Y' in items 3.1 to 3.4 in Checklist- 6 (Appendix B).

Approved by: ____________________

Date: ____________________

Benchmark Information: -

- Bench Marks on AHD can be obtained from the SCIMS at the LPI (Appendix C) and can also be accessed via the Internet at http://scims.lands.nsw.gov.au /scims.html. Joining fees and data costs can be obtained from the website.
- Search for the nearest accurate benchmark can be done by using either the name or number of the survey mark or using the various arrays of coordinate searches. An accuracy Class of "LD" or "B" or better should be obtained for the benchmark (SGD – sec. 7.22 & 8.2).
- Confirm procedure by marking 'Y' in item 3.5.1 in Checklist- 6 (Appendix B).

Acquiring Tidal Information For MHWM: -

- AHD reduced levels for MHWM can be obtained from either MHL or the MPAD (Appendix C) for areas specified in Sections 7 & 8 of the Surveyor General's Direction 2004. Check that heights provided are on AHD (and at what accuracy) or other datum. Request for information on any benchmarks placed within the vicinity of the site to be surveyed.
- Check when the MHWM level was calculated, as old data will need to be corrected for rise in sea level. Correct MHWM level for sea level rise by subtracting the current year from the year the MHWM was calculated and multiplying it by 2mm.
- Tidal data for calculating or predicting MHWM is accessed from the MHL (Appendix C). Refer to procedure 4.5 and 4.6 for specific requirements. Check that heights provided are on AHD (and at what accuracy) or some other datum. If another datum is used check how it relates to the tide gauge. Request for information on any benchmarks placed within the vicinity of the site to be surveyed.

Approved by: ____________________

Date: ____________________

- Low tide is ideal for establishing the tidal plane out in the field. Tidal predictions can be made using a tide chart or MHL have a website at http://www.mhl.nsw.
gov.au/www/tidtab.htmlx. Time differences will have to be allowed for where locations are outside Sydney Harbour as shown on tide charts and on the web page (Appendix C).
- Confirm procedure by marking ‘Y’ in items 3.5.2 & 3.5.4 in Checklist- 6 (Appendix B).

4.4 Procedure When Levelling From A Benchmark

Introduction - The following are procedures when determining a MHWM within close proximity of an established tide gauge that has been related to AHD.

Scope - When a MHWM datum is known within an area and is related to a benchmark then this procedure can be used. The datum must only be used within the vicinity of where it is specified (approx 1.5 km). If tidal gradients are not available, then judgement will have to be used when transferring a MHWM datum from the coastline into an estuary or when transferring a datum along an estuary. In these cases other methods may have to be used as outlined in procedures 4.5 and 4.6. The following procedure is not to be solely relied upon for the determination of MHWM and should be checked by other methods as listed in the procedure manual.

Approved by: ____________________

Date: ____________________

References

4.2.7 - Field Survey

4.3 - Procedures for Data Search Requirements.

4.5 - Procedures for Levelling From A Local Tide Gauge.

4.6 - Procedures for using Range Ratio Method.

4.7 - Procedures for Levelling & Positioning a Horizontal Plane.

Responsibilities - The Principal shall not approve any Procedure that does not use the following format.

Procedure

Information And Method: -

- All data requirements used for this procedure will follow Procedure 4.3.
- Where a MHWM and benchmark heights are related to the same datum, then differential levelling will be used to transfer the MHWM datum to the site requiring determination.
- The AHD value used as the bases of the definition for MHWM must be verified by a closing level traverse between Permanent Marks that have accurate heights of accuracy Class ‘LB’ or ‘B’ (SGD – sec. 7.22 & 8.2).
- Verifying MHWM Position - Procedure 4.5 or 4.6 can be used to verify that no gross errors have occurred in the determination.
- If a subject site is between two adjacent tide stations on the same datum, then the difference between MHWM elevations of the two stations can be proportioned according to the distance the survey site is from either control tide gauges. This can be used as an approximate check on MHWM determination.

Approved by: ____________________

Date: ____________________

- Procedure 4.3 was used to determine an approximate time for a survey to proceed. This will also allow the position of the established MHWM to be verified by recording the time when water level intersects the determined boundary. The tidal position can be confirmed by MHL supplying a time when MHWM should occur at the site.
- Confirm procedure by marking 'Y' in items 7 in Checklist- 6 (Appendix B).
- Checks of determination should be within ± 0.10 metres. If error is greater than this contact MHL for advice.
- Proceed to Procedure 4.8.

4.5 Procedure When Levelling From A Local Tide Gauge

Introduction - The following are procedures when determining a MHWM using a local tide gauge.

Scope - When there is no MHWM on a known datum such as AHD then the use of a local tide gauge should be used to determine the required plane. The following procedure explains where to locate, what to record and how to calculate a reliable MHWM plane. The MHWM datum must only be used within the vicinity of the tide gauge (within 1.5km). When no tidal gradients are available, then judgement will have to be used when transferring a MHWM datum from the coastline into an estuary or when transferring a datum along an estuary. In this cases use procedure 4.6. The procedure outlined below is not to be solely relied upon for the determination of MHWM and should be checked by other methods as listed in the procedure manual.

Approved by: ____________________

Date: ____________________

References

4.2.7 - Field Survey

4.3 - Procedures for Data Search Requirements.

4.6 - Procedures for using Range Ratio Method.

4.7 - Procedures for Levelling & Positioning a Horizontal Plane.

Responsibilities

The Principal shall not approve any Procedure that does not use the following format.

Procedure

Information And Equipment -

- All equipment and field techniques are in accordance with procedures noted in 4.2.
- All data requirements used for this procedure will follow Procedure 4.3.

Positioning Of Local Tide Gauge And Benchmarks -

- Contact MHL (Appendix C) for installation of a tide gauge at a site. MHL will collect and process data for a fee. Fee information is available on application (Approx costs $3000 for one lunation i.e. 29 days).
- When locating a position for a local tide gauge the site must be protected from the wind, affects of waves and any possible collision with boats. Attach gauge to jetty or other permanent structure for rigidity and security.

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Date: ____________________

- A benchmark will be placed along the shoreline close to the local tide gauge. The difference between the tide gauge zero on the tidal staff (placed next to the gauge) and benchmark will be determined. This benchmark will then be related to MHWM when calculated and also used to check if the gauge has been disturbed. The placement and installation of a benchmark near the tide gauge is in accordance with company procedures.
- The tide gauge is to be calibrated in accordance with MHL procedures for establishing temporary tide gauges and is to be automatically recorded in accordance with MHL procedures for tidal data gauges.

Tidal Data Requirements: -

- When calculating a value for MHWM from a local tide gauge then simultaneous observations with an established (control) tide gauge are required. The control gauge must have a minimum of 10 years of tidal records and have similar topographic and hydrographic surroundings (i.e. both tide gauges are on the open coast or in an estuary).
- The gauge is required to measure all spring and neap high and low water levels (day and night) for a minimum period of one full lunation. Tidal data must be recorded every 15 minutes. A lunation being the period between successive new moons (29.531 days).
- The affects of abnormal meteorological and tidal conditions should be taken into account when deciding on a recording schedule and when assessing the final data of the local tide gauge.
- In periods of floods, data may have to be ignored and re-observed. Care should be taken that tidal field observations are not affected by flood conditions, which can seriously affect the accuracy of the data.

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Date: ____________________

- When calculating simultaneous observations a standard deviation of ± 0.03 metres or less should be achieved over three tidal cycles, for the determination of a MHWM plane. Follow procedure 4.7 for calculating differences between site and control tide gauges.
- In areas where there are no established tidal gauges, such as remote areas, the length of observations should be taken over one lunation cycle or longer, so that satisfactory results will be obtained.
- It is recommended when determining the tidal plane on a very flat foreshore that several lunation periods should be observed.
- When MHL have been contracted to calculate the reduced level of MHWM for a tide gauge, the following must be requested; tidal data analysis for MHWM determination, the height of the benchmark placed near the gauge and the height of zero mark on the staff placed near the tidal gauge. Also confirm if there are any other benchmarks within the vicinity that the tide gauge has been tied to for height. These could be used to check the tide gauge.
- All levelling and locating of the MHWM position are in accordance with Procedure 4.7.

<u>Verifying Mean High Water Mark Position</u>: -

- If earlier tidal data for tidal gauge is available then recalculate the tidal lunation to check the current result. When data is not available it is recommended that the observation of another lunation of tides take place to check the results.
- Use procedure 4.7 to independently check that no gross error has occurred in the determination.

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Date: ____________________

- Procedure 4.3 was used to determine an approximate time for a survey to proceed. This will also allow the position of the established MHWM to be verified by recording the time when water level intersects the established boundary. The tidal position can be confirmed by MHL supplying a time when MHWM should occur at the site. Confirm procedure by marking ‘Y’ in items 7 in Checklist- 6 (Appendix B).
- If a subject site is between two adjacent tide stations on the same datum, then the difference between MHWM elevations of the two stations can proportioned according to the distance the survey site is from either control tide gauges. This can be used as an approximate check on MHWM determination.
- Checks of determination should be within ± 0.10 metres. If the error is greater than this contact MHL for advice.
- Proceed to Procedure 4.8.

4.6 Procedure When Using Range Ratio Method

Introduction: - This is to give guidelines on the procedures that should be followed when determining of MHWM within New South Wales when using Range Ratio Method.

Scope: - The procedure covers the steps to be followed when establishing a MHWM value at a site requiring determination, using a distant established tide gauge. The Range Ratio Method is used when the high and low water can be measured for consecutive tides. Where possible procedures 4.5 and 4.6 should be used in preference to this unless specified otherwise.

Approved by: ____________________

Date: ____________________

Chapter 4 –Procedure Manual

References

4.2.7 -Field Survey
4.3 - Procedures for Data Search Requirements.
4.4 - Procedures for Levelling From A Bench Mark.
4.5 - Procedures for Levelling From A Local Tide Gauge.
4.7 - Procedures for Levelling & Positioning a Horizontal Plane.

Responsibilities: -The Principal shall not approve any Procedure that does not use the following format.

Procedure

Information And Equipment: -

- All equipment and field techniques are in accordance with procedures noted in 4.2.7.
- All data requirements used for this procedure will follow Procedures 4.3.

Determining Mean High Water Mark Plane: -

- Recording heights for high and low water levels should be taken where there is relatively low wave and wind disturbance.
- Refer to 4.5 for the positioning of a local tide gauge.
- It is advisable that the observation of tides should be taken during a period of spring tides at the time of new moon not affected by abnormal weather conditions or floods. Use a tide chart to find times when new moons occur or use MHL website at http://www.mhlnsw.gov.au/www/tidtab.htmlx.

Approved by: ____________________

Date: ____________________

- When calculating a value for MHWM using Range Ratio it is advisable that the control gauge must have a minimum of 10 years of tidal records and have similar topographic and hydrographic surroundings (i.e. both tide gauges are on the open coast or in an estuary).
- Short-term observations of 2 or 3 tidal cycles can be recorded in a field book when observed but long-term observations (lunation of tidal cycles) will require the use of an automatic recording tide gauge.
- The following procedures will be followed when observing:
  1.) Select time periods for simultaneous observations at the local tide gauge and an established tide gauge. Select an established tide gauge (control) with a minimum of 10 years of tidal data. Ensure that the local site and control are similar in tidal characteristics and surroundings.
  2.) Obtain data from both sites over same period. Correct data for ambiguities (i.e. flood affected, bad data, etc) and calculate tidal components for calculation over the period of time at subject site.
  3.) Obtain the accepted tidal components for the control gauge from MHL.

$M.T.L._2$ = Mean of observed high water at site gauge (m) (M.T.L is Mean Tide Level).
$M.T.L._0$ = Long term value on the gauge of mean tide level at automatic gauge (m).
$M.T.L._1$ = Mean of observed high water a low water at automatic gauge (m).
L.T.R.= Difference between Mean high water and Mean low water at automatic gauge (m).
$O.R._2$ = Observed range at site gauge (m).
$O.R._1$ = Observed range at automatic gauge (m).

4.) Compute the ratios in the tidal parameters, using the following formula, and apply differences to subject site data.

Approved by: ____________________

Date: ____________________

5.) When calculating simultaneous observations a standard deviation of ± 0.03 metres or less should be achieved over three tidal cycles, for the determination of a MHWM plane.

Range Ratio Method Approx. MHW $= \text{M.T.L.}_2 + K_1 + K_2$

Where: - $K_1 = \text{M.T.L.}_0 - \text{M.T.L.}_1$

$$K_2 = \frac{\text{L.T.R.} * \text{O.R.}_2}{2 * \text{O.R.}_1}$$

- All levelling and locating of MHWM position are in accordance with Procedure 4.7.

Verifying Mean High Water Mark Position: -

- On a day that suits the conditions as previously stated use the Range Ratio method to independently check that no gross errors have occurred in the determination.
- Procedure 4.3 was used to determine an approximate time for a survey to proceed. This will also allow the position of the established MHWM to be verified by recording the time when water level intersects the established boundary. The tidal position can be confirmed by MHL supplying a time when MHWM should occur at the site. Confirm procedure by marking ‘Y’ in items 7 in Checklist- 6 (Appendix B).
- Checks of determination should be within ± 0.10 metres. If the error is greater than this contact MHL for advice.
- Proceed to Procedure 4.8.

Approved by: ___________________

Date: ___________________

4.7 Procedure For Levelling & Positioning A Horizontal Plane

Introduction: -This is to give guidelines on the procedures that should be followed when levelling in the position of a MHWM plane and then locating these points using survey techniques.

Scope: - Once the MHWM elevation has been calculated using either procedure 4.4 to 4.6, then this plane must be located on the ground as points. These points will be located and related to survey control points.

References

4.4 - Procedures for Levelling From A Bench Mark.
4.5 - Procedures for Levelling From A Local Tide Gauge.
4.6 - Procedures for using Range Ratio Method.

Responsibilities: - The Principal shall not approve any Procedure that does not use the following format.

Procedure

<u>Levelling Position Of MHWM</u>: -

- All equipment and field techniques are in accordance with procedures noted in 4.2.7.
- Any tide below MHW is ideal for establishing the MHWM boundary out in the field. To access tidal information refer to procedure 4.3.
- The MHWM boundary will be located on the ground by levelling from a benchmark that is related to the MHWM level. These level points will be located by conventional levelling methods, which will follow the contour of the foreshore in the immediate area.

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Date: ____________________

- All levelling runs should be closed back onto the original benchmark or another related benchmark to check for any gross errors.
- Benchmarks should be placed within the subject site and levelled to the original benchmark or local tide gauge with AHD or other known datum. The placement and installation of a benchmark is in accordance with company procedures.
- Where possible connect any calculated MHWM determinations to a benchmark with an AHD value with an accurate height of accuracy Class ‘LB’ or ‘B’ (SGD – sec. 7.22 & 8.2).
- Surveys using GPS equipment to establish the MHWM position, must use approved GPS survey techniques to achieve an accuracy Class “B” or better (Cl.23 - Surveying Regulations 2001)

<u>Locating Horizontal Plane</u>: -

- Once the MHWM contour has been determined stakes can be placed at deflection points along the contour. These points represent the intersection of a horizontal plane with land, which can then be located as a line for cadastral purposes using conventional survey techniques.
- A control survey should be traversed adjacent to the MHWM so as to radiate stakes representing points along the MHWM. To ensure that each point is radiated the stake should be removed after it has been located.
- In accordance with Clause 9 & 55(5) Surveying Regulations 2001 all encroachments and features along the MHWM should be located. This can be done while locating the MHWM.
- These points and lines are to be tied to the local cadastral information in accordance with SGD, Surveying Regulations 2001 and company procedures.

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Date: ____________________

- All survey plans of MHWM redefinition are to be connected to State Survey Control marks in accordance with Part 10 SGD, Clause 3 Surveying Regulations 2001 and company procedures.
- Return to the procedure used to determine MHWM plane and verify position of MHWM boundary as recommended in each procedure.
- Proceed to Procedure 4.8.

4.8 Establishing Previous Mean High Water Mark

Introduction: - This is to give guidelines on the procedure that should be followed when establishing the previous position of a Mean High Water Mark (MHWM) within New South Wales.

Scope: - The procedure covers the steps to be followed when establishing the position of a previous MHWM. This procedure will cover all classes of MHWM determination survey undertaken by a firm including boundary identification surveys, detail surveys and plans of redefinition. All the procedures described will be used on all classes of survey unless specified otherwise.

References

Procedures 4.3 – Procedures for Data Search requirements.

Responsibilities: - The Principal shall not approve any Procedure that does not use this format.

Procedure

- To establish the previous position of the MHWM for a subject site a full title and historical search will be undertaken as instructed in procedure 4.3.

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Date: ____________________

- Using survey techniques find and connect to by measurement all original survey marks related to the position of the previous MHWM determination. The project surveyor will then reinstate the corners and the line of the original MHWM using the original dimensions as shown on the plan of survey. Conduct of the survey and marking requirements shall comply with the company standards, SGD and the Survey Regulations.
- To establish the original line of the MHWM the project surveyor will have to scale distances from the original plan, if there are no dimensions shown.
- Erroneous survey information may occur on some plans and it is up to the surveyor to re-establish the position of the original MHWM to their best ability. For erroneous or confused survey information refer to the appendix A of the SDG.
- The current position of MHWM located by procedure 4.7 must be connected by survey to the previous MHWM now located.

4.9 Plan Presentation Of Mean High Water Mark Determination

Introduction: - This is to give guidelines on the procedure that should be followed when presenting a plan showing MHWM.

Scope: -The procedure covers the requirements when presenting a survey plan of MHWM redefinition for approval by the Department of Lands and Land Titles Office within New South Wales. Also covered are the recommendations for detail and identification plans within New South Wales.

Responsibilities: - The Principal shall not approve any Procedure that does not use this format.

Approved by: ____________________

Date: ____________________

Procedure

- Specific requirements for plans of MHWM redefinition are explained in Section 2 of the Surveyor General's Direction 2004.
- Plans for proposed registration at Land Titles Office are prepared in accordance with requirements as described in the Registrar General's Directions for Plan Preparation (Chapter 4). This can be accessed via the Internet at http://www.lpi.nsw.gov.au/publications/rgdirections/plans /RGs_Directions_Plans.htm.
- The placement of a benchmark on or near the site and connecting it to AHD should be shown on detail and identification surveys. The reduced level adopted for MHWM on AHD should also be shown on these plans. The source from where information is obtained for tidal calculations and AHD levels should also be noted on the plan.
- The drafter shall follow the company's procedures for drafting all plans prepared using CAD or by freehand. All drafting validation is in accordance with company's procedures for plan validation and authorisation before a plan is lodged or passed to the client.

4.10 Reporting On Mean High Water Mark Determination

Introduction: - This section is to give guidelines on reporting on the procedures that were used in determining a MHWM boundary and clarifying the legal and physical implications of any differences between the previous and current MHWM definitions.

Approved by: ____________________

Date: ____________________

Chapter 4 –Procedure Manual

Scope: - All MHWM determinations require reports; this allows other surveyors to re-establish the same tidal position. The following format is recommended when reporting on the determination of a MHWM boundary and where significant changes have occurred between the previous and current position of the MHWM. The report will also indicate what paths are to be taken if the plan of redefinition is to comply with the Coastal Protection Act 1979 or if a previous MHWM definition is found to be incorrect.

References: - Procedure 4.3- Procedures for Data Search Requirements.

Responsibilities: - The Principal shall not approve any Procedure that does not use this format.

Procedure

- To allow quick referencing between a surveyor and any other user of the report a file reference should be shown in accordance with the company's procedures.
- A full description of the site including the property address, lot number, plan number, locality, county and parish should also be included.
- Specific requirements for reporting on MHWM determinations are explained in Surveyor General's Directions 7.2.2, 8.2 and Department of Lands Checklist 6 (Appendix B).
- Confirm that each requirement is answered by marking 'Y' in all items in the Department of Lands Checklist 6 (Appendix B).
- The reports written for detail or identification surveys will not require the depth of evidence that a survey plan of re-definition requires. A brief report is recommended covering the requirements of the Department of Lands Checklist 6 (Appendix B).

Approved by: ____________________

Date: ____________________

- The report will briefly explain the reasons for the difference in position between the previous and current MHWM. This brief assessment should note if the changes were:
  - the result of a natural process.
  - caused by a deliberate act.
  - caused from the proprietors erect structures to protect their land from erosion but not for reclamation.
  - caused by a sudden storm.
  - horizontal progressed rather than vertical silting.
  - not noticeable from day to day, week to week and month to month.
  - predominantly long-term steady movement, be it by water or other natural agents.

  Reporting on this will validate the current MHWM definition by clarifying why there are differences between the current and previous definitions.
- Advise on how the determination of MHWM is affected by the Coastal Protection Act 1979. Advise on what course of action should be followed to deal with the requirement of Section 55N of the Coastal Protection Act 1979 are described in Sections 6, 7.2 and 8 of the Surveyor General’s Direction 2004.
- If it is ascertained that an error has occurred in the previous definition of a MHWM boundary then procedures for reporting on the mistake can be followed as setout in ‘Redefinition Plans’ - Appendix A of the Surveyor General’s Direction 2004.

Approved by: __________________

Date: __________________

4.11 Summary: Chapter 4

This chapter covers the procedures to be used when determining MHWM from the search requirements through to the presentation of a plan and report. Each stage of the MHWM determination can be checked against the checklist as shown in appendix B. By following the procedures and checklist, the Surveyor will introduce quality control for all aspects in the determination of the tidal boundary.

The next chapter will validate the procedures by establishing a MHWM along a beach and estuary on the Central Coast of New South Wales.

CHAPTER 5

VALIDATION

(CASE STUDY – PATONGA)

5.1 Introduction.

This chapter will analyse and discuss how the procedure manual was used to establish a Mean High Water Mark (MHWM) boundary along a coastal and estuary strip of land within New South Wales.

The aim of this chapter is to validate a procedure manual used in determining MHWM boundaries. This will be achieved by applying the procedures to a case study and analysing the results.

The case study will provide information on all of the aspects of a survey from the methods used to establish MHWM through to the reporting of its determination.

5.2 The Site.

Patonga is the most southerly beach on the Central Coast of New South Wales. It is located 97 km north of Sydney via the Newcastle Freeway. Patonga is situated on the Hawkesbury River just inland from the mouth of Broken Bay. Its main beach, Brisk Bay, faces southeast towards Broken Bay and is partially exposed to the influence of the Pacific Ocean (appendix D). At the southern tip of the Patonga peninsula there is an ancient tidal inlet, Patonga Creek that snakes inland. There are also large stands of mangroves around the estuarine mudflats opposite the survey site.

The site was chosen because of the easy access to the MHWM from the public reserve, which surrounds the entire peninsula. The effects of ocean swell off the

Pacific Ocean influences the shoreline of Patonga Beach, while the estuary is well protected from the influence of the swell by the shape of the peninsula that forms Patonga (Figure 16). The assessment of the effects of erosion or accretion on both foreshores will be influenced by their exposure to the open coast. There is approximately 800 metre of foreshore and the reserve is approximately 2.4 hectares.

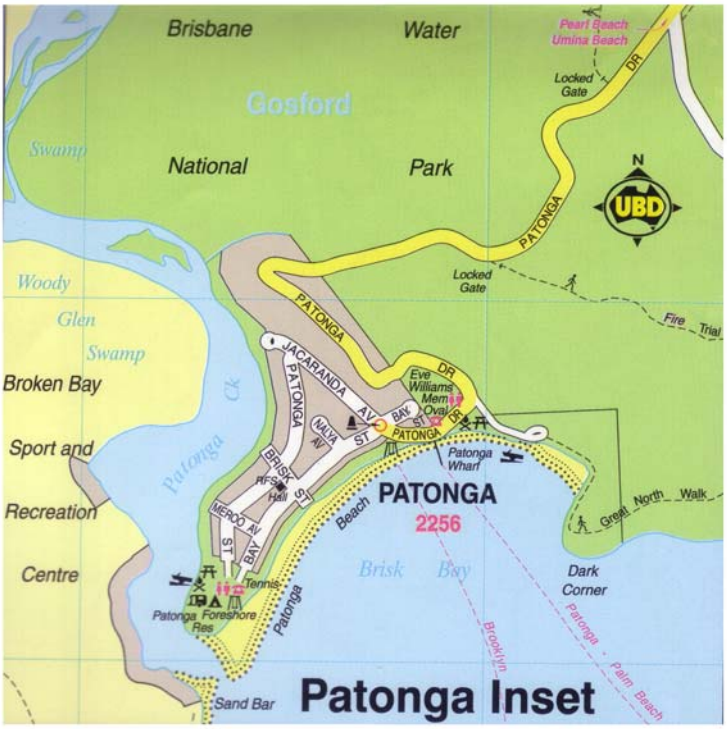


Figure16 Location Plan, Patonga, New South Wales (UBD, 2001).

5.3 Procedures For A Mean High Water Mark

The determination of the tidal boundary will follow the requirements of the procedure manual as set in Chapter 4. The relevant pages and parts of the required checklist should be signed off as each procedure is completed. For the purpose of this exercise it is assumed that each sheet has been signed.

5.4 Acquiring Search And Geographical Names

Geographical names of the locations and waterways to be surveyed were checked by accessing the website as setout in procedure 4.3. Patonga, Patonga Creek and Brisk Bay were the correct geographical names for their locations. Most survey plans and titles were available from the Land and Property Information (LPI) website as layout in procedure 4.3 to enable the surveyor to establish the present MHWM and to reinstate the previous MHWM as shown on D.P.8549 (appendix E). An authorised searcher had to be used to gain Crown Land Portion plans with reference number greater than 70000 as they have not yet been scanned for the Internet.

5.5 Tidal Status

Both Patonga Beach and Brisk Bay face southeast towards Broken Bay and are partially exposed to the influence of the Pacific Ocean. It is obvious that the beach is subject to tidal influences. There are no dams or weirs affecting the flow of the tides into the estuary. The parish map shown in appendix F also shows that the waterway along the Hawkesbury River is tidal. The original land grant and our subject survey plan, D.P.8549, states that the boundary is along ‘High Water Mark’ and ‘Mean High Water Mark’ respectively. By following procedure 4.3 it can be confirmed that the water boundary of the reserve is tidal.

5.6 Gaining Bench Mark Information

Following procedure 4.3, benchmark data was accessed via the Internet using the Survey Control Information Management System (SCIMS) at the LPI. An example of the output data is shown in appendix G.

5.7 Acquiring Tidal Heights And Information

A height for MHWM on Australian Height Datum (AHD) was accessed from the Manly Hydraulic Laboratories (MHL) as setout in procedure 4.3. The reduced level for Mean High Water (MHW) at Patonga was 0.554 metres (m) Australian Height Datum with a mean standard deviation of ± 0.023 metres (appendix H). Also shown at the bottom of the page of appendix H is the statement that all '…tidal plane heights only approximately related to AHD' and '…users should independently verify the suitability of this data'. This meant that the AHD height for MHWM had to be checked.

The position of MHWM related to the zero mark on the tide gauge staff was given as - 0.42m. This was confirmed out on the site using the State Survey Mark (SSM) 94488 that was related to AHD with a Class 'B' accuracy (refer 4.3). When surveyed, the reduced level for the MHWM position on the tide gauge staff was RL 0.55 m AHD. The level supplied by MHL for MHWM was considered satisfactory because the difference between the benchmark and the tide gauge was only - 0.004 m. Therefore the height supplied by MHL was confirmed using procedure 4.3.

Tidal information for the Local Tide Gauge and Range Ratio methods were collected from MHL. It was confirmed that all tidal data had been corrected for meteorological and tidal anomalies by MHL (refer 4.5). The data obtained for Middle Harbour gauge station was referenced to Camp Cove Zero Datum, which is 0.925 metres below AHD; this was confirmed by MHL but the accuracy could not be verified. It was not critical that AHD level should be confirmed, as a ratio of differences in high and low tides would be measured not their relationship to AHD heights.

Tidal predictions were accessed from the MHL Web page for the 7th August 2004 as setout in the 4.3 of the procedure manual. Allowing for a 10-minute delay for the tide to be at high or low tide at Patonga compared with Middle Harbour, Sydney, it was found that the best approximate times to measure low tide was at 7.10 am and high tide at 1.40 pm. As high tide was approximately 0.5 metres AHD there was plenty of time to position the MHWM boundary after measuring low tide. Due to time limitations with the use of equipment and labour it was decided not to undertake the survey during a period of spring tides or at a time of a full moon (refer 4.6) – (which was taking place approximately one week later).

Much time was allocated in obtaining information to check the datum of the tide gauge with AHD. Further research is required on the possibilities of establishing a data set on the accuracies of heights issued from tidal gauges. The tidal datum may vary as shown by a variance factor but the heights should be set at specified accuracies as set by the Standards and Practices for Control Surveys (SP1, 2002).

5.8 Establishing Mean High Water

All methods were used in the determination of the tidal plane, as setout in procedures 4.4 to 4.6 of the manual. This was done so as to validate the MHWM boundary.

5.8.1 Levelling From A Benchmark

The accuracy of the field equipment used in the survey was checked using procedure 4.2.7 and all data requirements were obtained and checked in accordance with procedure 4.3 as follows.
The reduced level of 0.554 m AHD for Patonga had been verified as referred in Chapter 5.7. The information supplied was for the period, 1990 to 2000, and no adjustment was made for the rise in sea level. An approach to adjusting this height might be to recalculate the epoch between 1994 and 2004 or over a 19-year period of 1985 to 2004. As discussed in Chapter 2.1 the present definition for the MHW refers to the spring high and low water levels used to calculate its position. There is no mention of time periods involved in observing these components. Yet MHL, the Manual of the New South Wales Integrated Survey Grid and others use a long period

of time (usually10 to 19 year) to calculate a tidal datum. Definitions on how tidal datum should be calculated needs further research.

Both State survey coordination marks shown on appendix M, SSM94488 and PM83069, were used as AHD benchmarks and for azimuth. A control traverse was closed for levels and horizontal position as required by procedure 4.7 and Surveying Regulations 2001. The MHWM was levelled in from all the control traverse stations using a value of 0.554 A.H.D (figure 17).

Figure 17 Levelling in position of MHWM.

Each point was then radiated from each of the control stations in accordance with procedure 4.7. All encroachments and features along the MHWM were surveyed while locating the MHWM.

As required by the Department of Lands Checklist, Item 7, (appendix B) a time was recorded when the water intersected the flags that established MHWM. The time was approximately between 1:15 pm and 1:30 pm, this agreed with the data supplied (appendix I). The procedure manual also recommends that the MHWM plane be checked by at least one other procedure. Both methods 4.5 and 4.6 in the procedure manual were used to validate the determination.

5.8.2 Levelling From A Local Tide Gauge

Tidal data was obtained from MHL for the period beginning July 2002 through to June 2003. The reason for this is that the use of a previous lunation would independently check the determination (refer 4.5).

Figure 18 Tide gauge at Patonga

The tide gauge was already installed on the main transport jetty at Patonga (figure 18). A lunation (29 days) of data was observed between the dates of the 9/7/2002 to the 7/8/2002. All data had been adjusted for height and corrected (refer 5.6).

Section 4.6 of the procedure manual for calculating MHWM from a local tide gauge was applied. An established tide gauge at Middle Head, Sydney, was used as the control for the simultaneous observations. Both Patonga and Middle Harbour gauges are situated in similar surroundings close to the coast (see appendix D) and therefore are not seriously influenced by the estuaries that run past them.

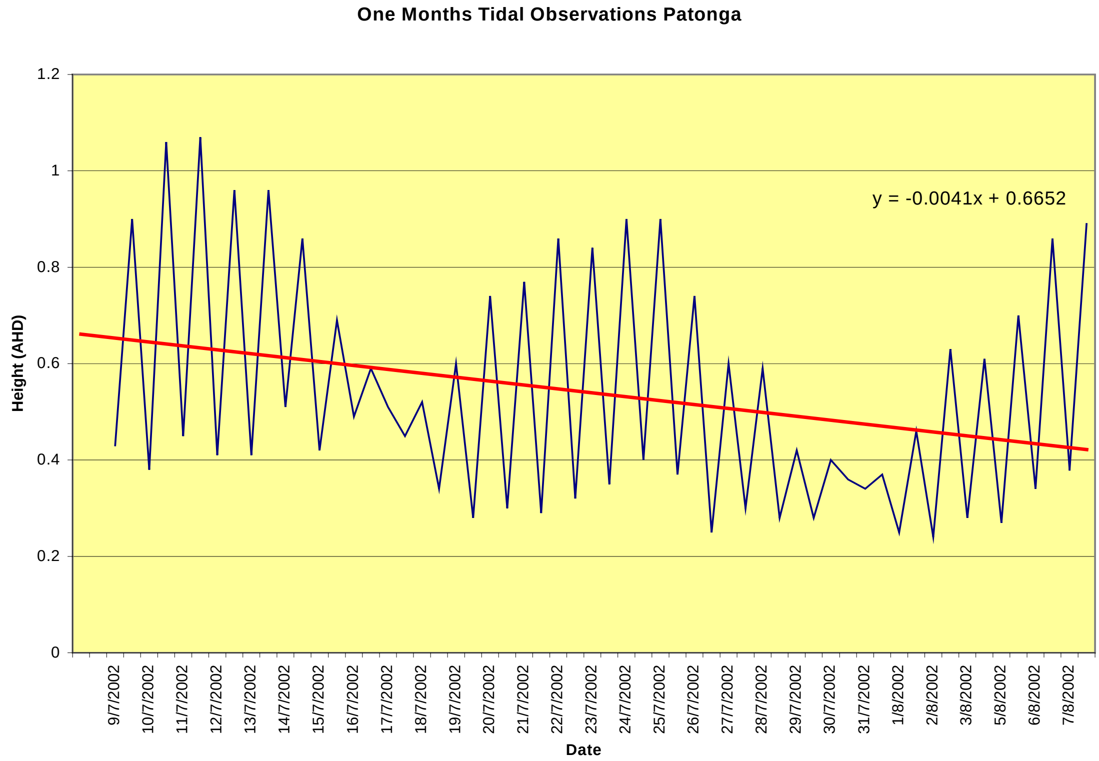


Figure 19 Lunation of high and low water levels at Patonga

The graph above (figure 19) represents the tidal data collected at Patonga in the nominated period. Simultaneous observations were also collected at the Middle Harbour gauge. Examples of the data supplied from MHL are attached to appendix J. From this data, all tidal components were calculated for both local and control gauges to be used in the Range Ratio formula (appendix J).

The MHW observed over the lunation was 0.519 m AHD and 0.537 m AHD for Middle Harbour and Patonga respectively. Adjustments were made to correlate the MHWM level to the long-term value for Middle Harbour of 0.512 metres AHD. The adjusted level for Patonga was now 0.530 metres AHD. The Range Ratio method is now used to verify the tidal plane established in the previous section.

5.8.3 Range Ratio Method

Simultaneous observations were taken at the site gauge at Patonga and at the automatic tidal gauges at Ettalong, approximately 5 kilometres to the northeast of the site, and at Middle Harbour, Sydney. Procedure 4.6 was used to guide all field and calculation techniques. Observations were taken at high and low tide over one day, but it was not possible to observe tides during a period of spring tides due to time limitations with the use of equipment and labour. The tide staff affixed adjacent to the tide gauge at Patonga (figure 20) was used to read the water level at both high and low tide.

Figure 20. Tide Staff at Patonga

The zero reading on the tide gauge staff was connected to SSM94488 for AHD height. Field observations were recorded at prearranged times (see 5.6) with the automatic recordings at each tide gauge to allow for simultaneous readings of the tides. The tidal data components were calculated from the field data and data supplied by MHL as required for the formula in procedure 4.6. These components were then entered into the Range Ratio formula for MHWM levels at Patonga. See appendix K for data and calculations.

Both field observations and tide gauge data recorded at Patonga were calculated. The answers ranged from 0.44 to 0.547 metres AHD for MHWM. The difference between the calculated levels using Middle Harbour and Ettalong control gauges is due to Ettalong being situated at the mouth of a narrow estuary, which feeds into the Brisbane Waters. The tidal gradient between the Hawkesbury River and Brisbane Waters is approximately 0.25 metres, which affects the MHWM at Ettalong. Appendix K also shows a calculated height for Ettalong using Middle Harbour as the control gauge. The MHWM level for Ettalong is 0.4 metres AHD with a standard deviation of ± 0.031 metres as supplied from MHL and calculated by range ratio method is 0.47 metres AHD. For this reason the long established tide gauge at Ettalong was not used to check MHWM at Patonga.

Another reason for differences between answers are due to measuring inaccuracies as on shore waves, wash from boats and the slight swell made it difficult to read the staff. Readings averaging every 20 seconds over 2 minutes was the approach used. A reduced level of 0.516 metres AHD was adopted as the MHWM level using the Range Ratio technique, as it is assumed for this technique that there was no tide gauge at Patonga.

5.9 Results

From the methods mentioned there is a difference in the MHWM result of approximately 0.05 metres vertically. To improve the results of the Local Tide Gauge and Range Ratio methods more lunation and tidal cycles should be observed. As recommended in the procedure manual and by the National Oceanic and Atmospheric Administration in the USA (NOAA, 2003) - refer to Chapter 2 – a standard deviation of ± 0.03 should be achieved between each calculated lunation and tidal cycle. The standard deviation for the lunation of observed tides at Patonga was ± 0.24 m (appendix I) and the standard deviation for 80 years of observations at Fort Denison, Sydney is approximately ± 0.03 m. The required standard deviation of ± 0.03 m for three tidal cycles or lunation does not appear to be achievable. Further research will be required to see if this is correct.

With an average slope of approximately 1: 10 for most of the shoreline along Patonga this will make a vertical error of 0.05 metres, approximately 0.5 metres horizontally. Tidal boundary re-establishment in areas of mangroves and sand flats would show where care in survey and tidal determination is needed. Extreme caution is needed in these situations as a few centimetres vertically may mean several metres horizontally. Research is required on finding a system that is fair and equitable for both owners above and below MHWM when determining boundaries in areas where survey techniques are not accurate enough.

As shown in the Literature Review in Chapter 2 the error for establishing a MHWM plane can be up to ± 0.1 metres vertically. The unacceptable standard deviation for the tidal data observed over a lunation does not mean the procedure manual has achieved an unsatisfactory answer for MHWM. The manual has achieved an answer by two methods, which agree within 0.05 m and have been validated by the long term tide gauge level.

5.10 Establishing Previous Mean High Water Mark

A traverse was established to reinstate the rear boundaries that fronted the 100-foot (30.48 metres) reserve. The corners and angles have been reinstated so that the 100-foot (30.48 metres) reserve, as shown on D.P.8549 and D.P. 9408, can be projected out to re-establish the position of the original MHWM. This is part of the requirements of Part 7.22 of the Surveyor General's Directions 2004.

The traverse was run from the northeast corner of Brisk Bay and it headed in a southwesterly direction along the beach of Brisk Bay. It continued in a north westerly direction along Brisk Street until it intersected with Patonga Creek, from here it headed in a north easterly direction to intersect with Jacaranda Street. The traverse was closed back onto the origin by traversing down Jacaranda Street to Brisk Bay. The angular and linear misclose of the traverse was acceptable and within the guidelines of the Surveying Regulations 2001 clause 25 and 26.

The traverse was also tied to establish State survey coordination marks as specified by Surveyor General's Directions 2004 for plans of redefinition. The misclose between Map Grid Australia (MGA) coordinates was within the allowable range as setout in Clause 27 of the Surveying Regulations 2001.

An azimuth was adopted from D.P.832588 (refer appendix K) due to the plan being related to original rock marks from D.P.8549. The reinstatement of the boundaries between the 100-foot (30.48 metres) reservation and the adjoining lots along Brisk Bay were adjusted to fit with the reference mark found at the corner of lot 212 in D.P.231290 (refer appendix K). There was approximately 0.15 metres excess between the reference marks and no marks were found between these reference marks. The reinstatement of Brisk Street was undertaken by adopting the reference marks along the alignment. All marks were found to fit within 0.03 metres with the subject survey plan (D.P.8549). The next stage was the reinstatement of the 100 feet reserve (30.48 metres) along Patonga Creek starting from Brisk Street. At the corner of lot 1 in D.P.561540 (refer appendix K) a reference mark was adopted. Again no marks were found between Brisk Street and Jacaranda Avenue. At Jacaranda Avenue a peg and survey nail in a fence was found at the corners of lots 128 and 130 in D.P. 9408 respectively. There was an excess of 0.4 metres between marks, which was proportioned along the reserve boundary. Due to the shortage of time it was not possible to look for more survey marks to investigate why there was so much excess. The fences adjoining Jacaranda Avenue were of little help as there were many metres out of position.

Using the survey information obtained out in the field, a line representing the approximate original MHWM was plotted 100 feet (30.48 metres) parallel to the rear of the adjoining lots to the reserve. This was compared with the original MHWM, as shown on D.P.8549 and D.P. 9408, and differences were noted in the following plan and report (refer 5.11 & 5.12).

Just like determining a current MHWM boundary, the reinstating of a previous tidal boundary can be fraught with problems. The reinstating of the boundaries along Brisk Bay was successful due to original survey marks being found. This was not the case along Patonga Creek, where next to no marks were found. The procedure manual explains how to reposition a previous MHWM but the accuracy of this position is dependent on what survey marks are found. All surveys marks must be looked for so that the previous position of MHWM is valid.

5.11 Presentation Of Mean High Water Mark Determination

The processed information from the surveying software package was exported to a drafting package called AutoCAD. The plan of MHWM redefinition (figure 21) is in accordance with procedure 4.9. See appendix L for smaller scale plot.

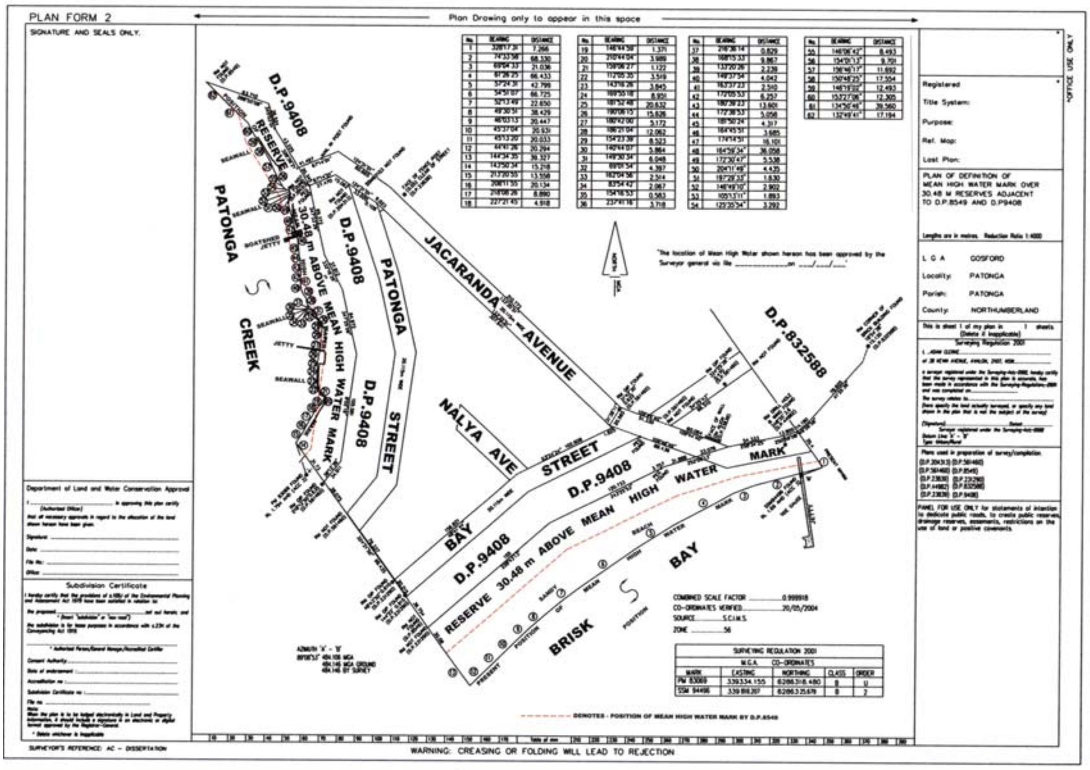


Figure 21 Plan of Redefinition.

The plan shown in figure 21 would be presented to the Department of Land as both original and current MHWM are to be shown as required in Sections 7.2 Surveyor General's Direction 2004. Once the MHWM definition is approved the plan is presented to the Land Title Office without the original MHWM shown.

Using bearing and distances to show the position of MHWM will enable other surveyor to easily compare later determinations. It is not necessary to show a benchmark or adopted MHWM height but the procedural manual requires that one is placed and recorded (not on the approved Plan of Redefinition). By using the recommendations of the procedural manual and following required legislation future MHWM determinations will be easily compared with past definitions and validated.

5.12 Reporting On The Mean High Water Mark Determination

The following is a survey report that will validate the MHWM determination and fulfill the requirements as setout in Procedure 4.10 for water boundary consent from the Department of Lands.

File Reference: - AC Dissertation Date: 1st November 2004.

This report is on the determination of a Mean High Water Mark (MHWM) along a 30.48 metres Public Reserve adjacent to D.P.8549 and D.P. 9408. This Reserve is located along Brisk Bay and Patonga Creek within the locality of Patonga, Parish of Patonga and County of Northumberland.

The title search showed that William Thurlow purchased the land in 1839 from the Crown. Within the grant there was a reservation of '*all land within One hundred feet of high water mark on the Sea coast and on every Creek, Harbour and inlet*'. A subsequent owner Thomas Shakespeare then subdivided the land in 1916. It is impossible to re-establish the original 1837 MHWM, as there is no survey information shown. The last plan to define the MHWM was D.P. 8549 (appendix E) in 1916 and therefore this plan was used to reinstate the landward reserve and tidal boundaries. This boundary will be referred to as the 'previous' MHWM as it may not be the original position as shown in 1837.

There is a sandy beach along Brisk Bay that has a southeast aspect towards Broken Bay and is partially exposed to the influence of the Pacific Ocean. The only structure along the beach is a concrete jetty constructed at the eastern end of the subject survey area (figure 17, page 15).

The surveyed foreshore of Patonga Creek is mainly sandy with one small pocket of mangroves situated approximately halfway (Figure 22 & 23). There are various improvements to be found along the creek foreshore such as a boatshed, several small seawalls and a storm water outlet.

Figure 22. Sandy foreshore and jetty along Patonga Creek

Figure 23. Mangroves on Patonga Creek

The determination of the MHWM was carried out on the 7th August 2004. At the time of determination the weather conditions for the area were overcast with occasional light showers with a light southwesterly breeze. All tidal levels and information were supplied by Manly Hydraulics Laboratory (MHL - part of the New South Wales Department of Public Works and Services). MHL supplied a level for MHWM at Reduced Height (RL) 0.554 AHD. Benchmarks SSM 94488 and PM83069 were used to establish this datum (appendix G). By using tidal gauge information (appendix J & K) for Patonga Jetty and Middle Harbour the tidal determination was cross checked by various methods. Crosschecks were within 0.05 a metre of the datum adopted for MHWM; this was seen as a satisfactory.

Along the beach that adjoins Brisk Bay the difference between the current position of MHWM is approximately 30 metres southeast of the previous MHWM position. The Patonga Creek redefinition is from about nil to approximately 10 metres different to the original position (refer appendix L). There are a number of reasons why there are significant differences between the position of the MHWM by D.P.8549 and the present position. The following sections are some of the reasons why differences have occurred.

The beach that fronts Brisk Bay is affected by the dynamics of the Pacific Ocean. A Parish map from 1933 (appendix F) shows the position of the 'beach' some distance south of the original MHWM. It can only be guessed that either a storm or a series of storms deposited huge amounts of sand along the foreshore or that the original MHWM definition was vastly out of position. Further investigation will be required if application for redefinition is submitted.

Figure 24. Boatshed along Patonga Creek.

The erosion and accretion along Patonga Creek is due to a combination of natural and manmade influences. The northern section of the reserve has eroded away due to natural causes, as there is minimal disturbance by man to this area. Further south along the creek numerous small retaining walls and a boatshed have been built with the effect of causing erosion in some areas and accretion in others (refer figure 24). Other than a small protrusion out into the creek, the accretion and erosion seems to be the result of natural processes and is not a deliberate act to claim accretion. This is probably the case, as no one would gain benefit from the effects of accretion onto a public reserve.

The redefinition of the MHWM boundary will not affect the public access, as it is already public reserve. This part of Section 55N of the Coastal Protection Act 1979 would be meet. Under Section 55N the new definition of MHWM must demonstrate a perceived trend to indefinitely sustain any new accretion by natural means. It will be necessary to employ professional engineers in coastal and estuary hydrodynamic to report on the history of accretion and quantify the accretion trends. Also, reporting on the physical processes that will affect the foreshore and how climate change will impact on the subject foreshore.

5.13 Summary: Chapter 5

The research outcome was a set of procedures that will allow a surveyor to check and apply all requirements needed in the defining of a MHWM limit. The solution to obtaining a reliable result using a short-term observation at a gauge will benefit surveyors who need to estimate a MHWM boundary to within ± 0.05 to 0.1 metres. The requirement to obtain consistent results over a tidal cycle or lunation requires more research.

The results from the case study at Patonga illustrates that a MHWM boundary can be determined successfully using the procedure manual as setout in Chapter 4. It can be seen that the procedure manual can only guide the surveyor, as each determination of a MHWM can be vastly different.

CHAPTER 6

CONCLUSION

6.1 Introduction

This chapter will discuss if the research project has achieved the aim of clarifying the legal and physical implications associated with determining tidal boundaries and the development of a procedure manual for defining a MHWM boundary.

6.2 Achievement Of Objectives

One of the objectives of this research project was to clarify the legal and physical implications associated with determining a tidal boundary within New South Wales. From the review of the current state of knowledge in both the physical and legal components required in establishing tidal boundaries, it was found that there were inconsistencies in both the legal and physical components.

The project clarifies that the use of MHWM as a boundary is by no way a precise determination. The research project has demonstrated that there are physical limitations to precisely positioning a tidal boundary. Using current techniques in calculating a tidal plane, a surveyor will only achieve an answer of between ± 0.05 to 0.1metres at best. With further research it might be possible to achieve a vertical difference of a couple of centimetres. But this may extend many metres horizontally when transferred to a low-lying area. An equitable system of defining water boundaries in low-lying areas should be addressed.

From the development of the procedure manual the user can be guided and instructed on the best method to use in determining a MHWM. The manual clarifies the legal and physical requirements needed to determine a MHWM and therefore eliminates any ambiguities. It also alerts the user to potential issues that may be faced in the field or office. This manual can be incorporated as part of a surveying company's quality control system.

To fulfil the objectives of the research project the procedure manual was used on a case study on the Central Coast of New South Wales. The redefinition of the tidal boundary was successfully achieved using the guidelines setout by the manual. Some of the accuracies stipulated by the procedure manual were not met and more case studies will be required to see if they could ever be achieved.

6.3 Conclusion: Chapter 6

The procedures established in this research project will assist surveyors in the field to determine Mean High Water Mark boundaries within New South Wales, using current legislation to alert them to any possible issues they may face and also assist in the initial stages of preparing and retrieving information for a Mean High Water Mark determination.

University of Southern Queensland
Faculty of Engineering and Surveying

ENG 4111/4112 Research Project
PROJECT SPECIFICATION

FOR: **Adam Clerke**

TOPIC: Determination of Mean High Water Mark

SUPERVISOR: Mr Peter Gibbings
Faculty of Engineering and Surveying

ENROLMENT: ENG 4111 – S1, X, 2004
ENG 4112 – S2, X, 2004

PROJECT AIM: The project aims to clarify the legal and physical implications associated with determining tidal boundaries and to develop a procedural manual for determining tidal boundaries.

PROGRAMME: Issue A, 22 March 2004

1. Research the current guidelines and regulations for determining tidal boundaries.
2. Evaluate and identify the deficiencies with the above guidelines and recommend changes.
3. Research information on the doctrine of accretion and erosion.
4. Construct guidelines for land surveyors to follow when assessing changes to land along tidal boundaries.
5. Research legal precedents that have given rise to tidal boundary determination.
6. Analyse the problems associated with these legal decisions and translate to guidelines for land surveyors.
7. Evaluate techniques used to determine tidal boundaries.
8. Re-establish a tidal boundary using methodology as set out above.

AGREED: A. Clerke (Student) [signature] (Supervisor)

(Dated) 29 / 3 / 04

Appendix E

Department of Lands
CHECK LIST
FOR
WATER BOUNDARY CONSENT, INCLUDING MEAN HIGH WATER MARK

Details of the following items should be included in the application as appropriate.

ITEM	PROCEDURE	Y	N	N/A
1	Lot identifier and street address. (Check with Geographical Names Board See www.gnb.nsw.gov.au/lgamap/search)			
1.1	Topographical map reference and details.			
2	Name of waterway - (Check with Geographical Names Board).			
2.1	Is the water body tidal?			
2.2	Is the correct tidal / non-tidal symbol shown.			
3	**Search Information.**			
3.1	Copy of original grant/title – to establish extent of title.			
3.2	Copy of the current title			
3.3	Complete historical set of plans including - Full copies of DP's used in the boundary definition and adjoining DP's. (These can be returned if requested)			
3.4	Copies of any unregistered plans and/or other documents which support or assist the definition.			
3.5	**Public authority search.**			
3.5.1	SCIMS Search (Level data)			
3.5.2	AHD Level of MHWM (Manly Hydraulics Laboratory) (Tidal Analysis)			
3.5.3	Local Council (Public Access)			
3.5.4	Department of Commence (Tidal gradients)			
3.5.5				
3.5.6	Other			
4	**Report describing the method used to determine the boundary. The report should include, if appropriate :**			
4.1	Basis and method of determining the location of the MHWM or bank.			
4.2	Details of any differences between the observed location of the present MHWM or bank and previous definition/s. Give considered, qualified reasons for the difference (eg. erosion / accretion / error in prior survey, flood or reclamation).			
4.3	Position of all improvements relative to boundary shown on plan.			
4.4	Information and / or statutory declarations from eye witnesses (e.g. long term residents).			
4.5	Professional Advice or evidence (e.g. land / estuary studies, geotechnical evidence, soil/bore hole samples, etc).			
4.6	Description of the land and land use. (e.g. whether natural, developed or affected by man).			
4.7	Provide photographs – current, and historical. Terrestrial and aerial if appropriate with boundary superimposed.			
5	**Modified Doctrine of Accretion**			
5.1	Is the new MHWM definition indefinitely sustainable by natural means?			
5.2	Is Public Access likely to be restricted or denied?			
6	Copy of Fieldnotes (relating to the measurement of the MHWM).			
7	Observed a MHW tide to confirm definition ?			
8	Fee.			
9	Three (3) signed copies of plan			

Name of Surveyor: ______________________

Date: ______________________

Signed by Surveyor: ______________________

Appendix B

Addresses of Approving Authorities and Information Suppliers

Land & Property Information
Queens Square Building
1 Prince Albert Road,
SYDNEY NSW 2000
Phone: 9228 6798
Or
GPO Box 15
SYDNEY NSW 2001

Department of Lands
Crown Land NSW
P O Box 2185
DANGAR NSW 2309
Phone: (02) 4960 5000
Fax: (02) 4960 5020

Department of Lands
Website: www.lands.nsw.gov.au

District Offices

PARRAMATTA: (Metropolitan Office)
10 Valentine Avenue
Parramatta NSW 2150
(PO Box 3935 Parramatta 2124)

GRAFTON:
98 Victoria Street
(Locked Bag 10)
Grafton NSW 2460

MAITLAND:
Cnr Newcastle Rd & Bank St
(PO Box 6)
East Maitland NSW 2323

TAREE:
98 Victoria Street
(PO Box 440)
Taree NSW 2430

NOWRA
5 O'keefe Avenue
(PO Box 309)
Nowra NSW 2541

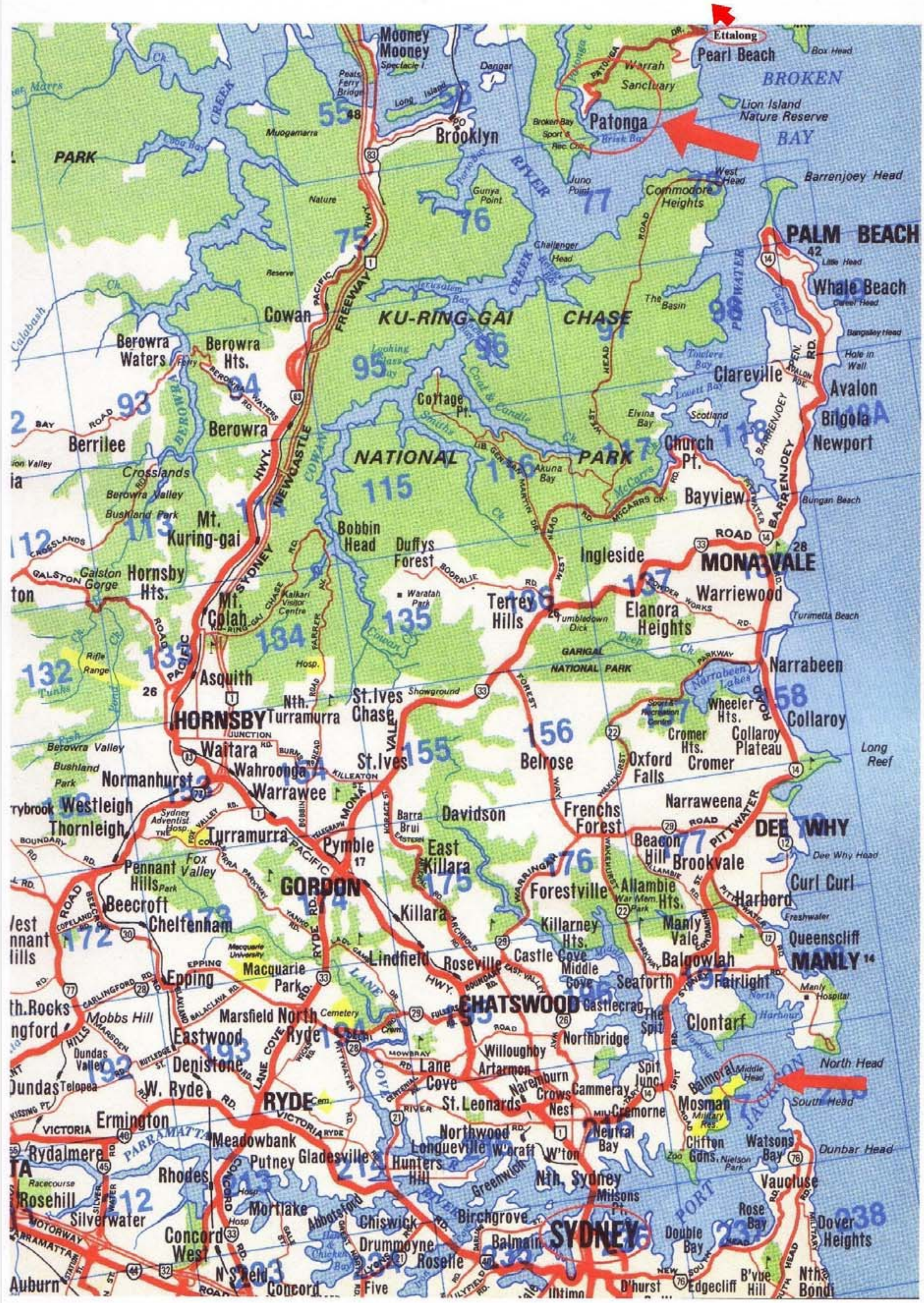
ORANGE
92 Kite Street
(PO Box 2146)
Orange NSW 2800

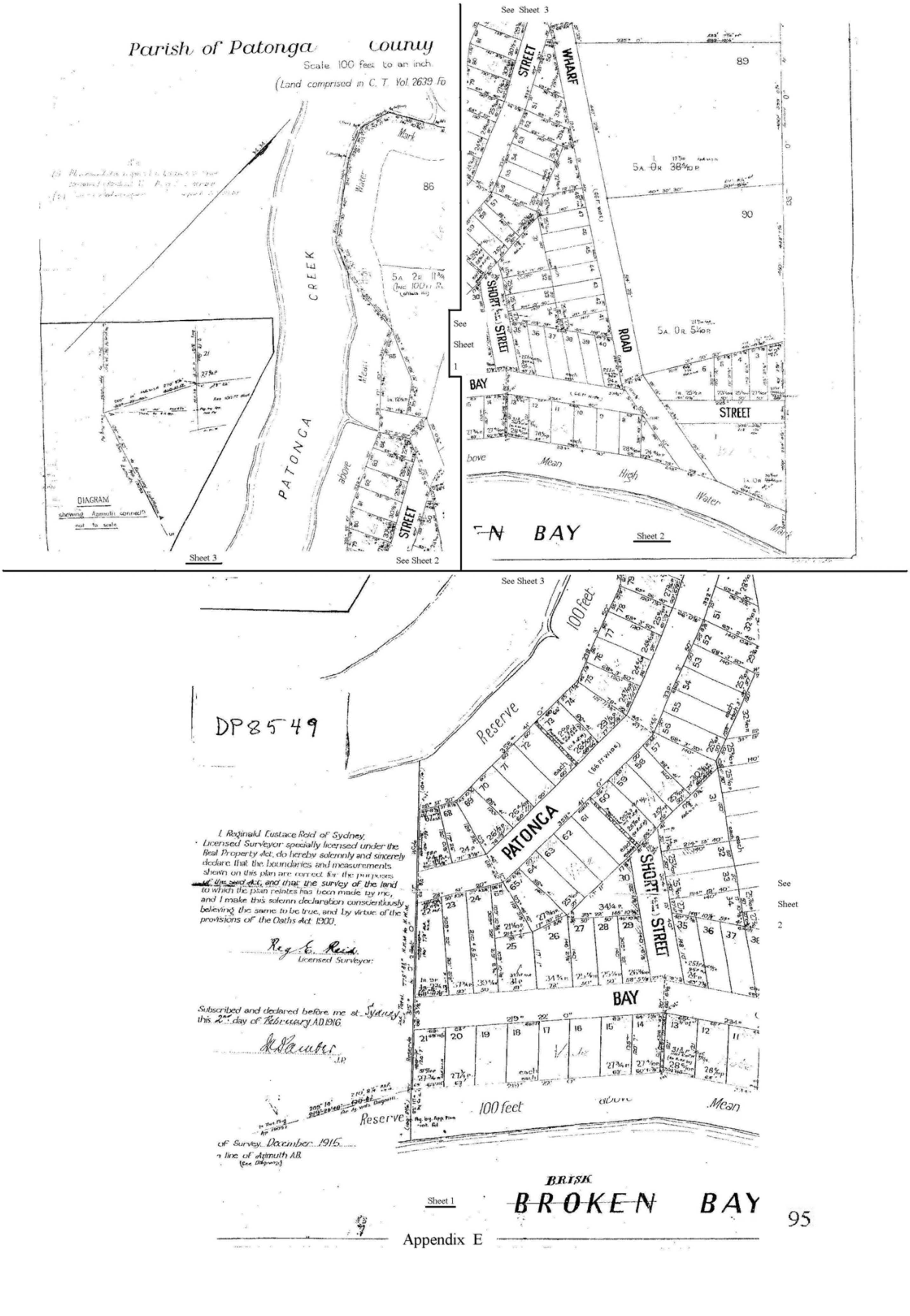
Maritime Property & Assets Division (MPAD) Office Location
Sydney Harbour, Newcastle Harbour, Port Kembla and Botany Bay
Survey & Spatial Information Branch
MPAD
PO Box R228
Royal Exchange
Sydney NSW 1223
Phone: (02) 9563 8836
Fax: (02) 9563 8800

Manly Hydraulics Laboratory Office Location
Manly Hydraulics Laboratory
110B King Street
Manly Vale
NSW 2093
Phone: (02) 9949 0200
Website: www.mhl.nsw.gov.au

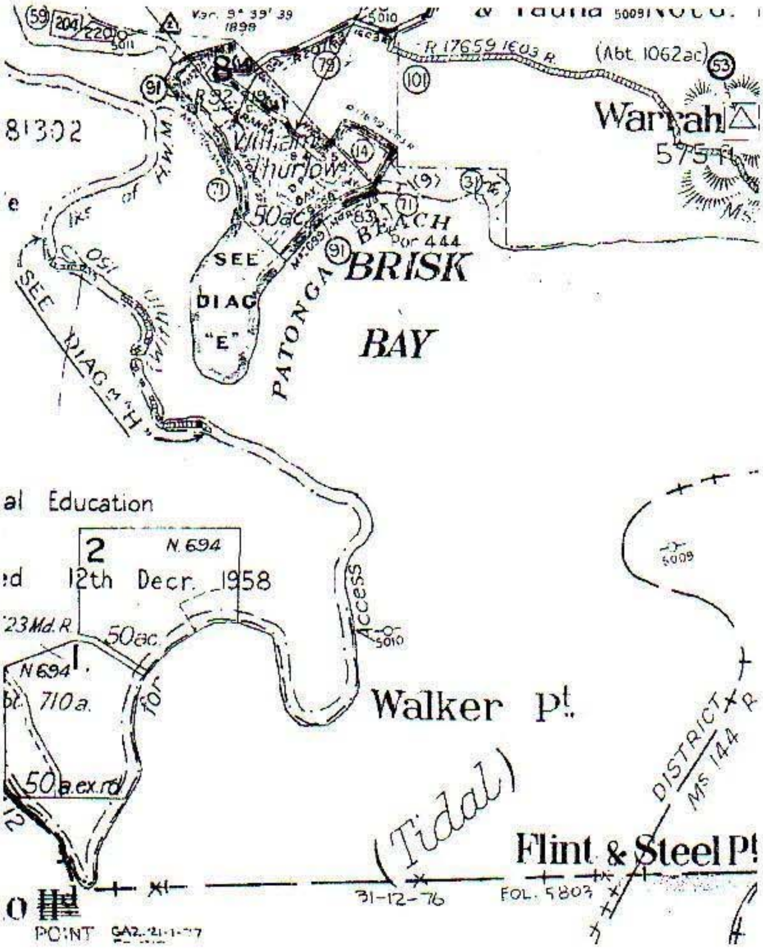
Appendix C

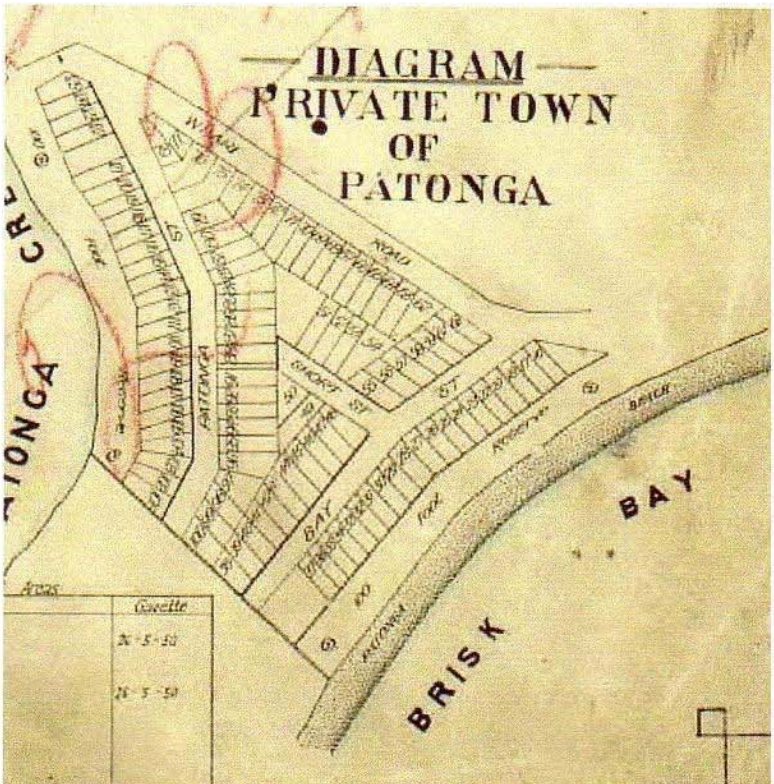
Appendix D - Location Plan, Sydney to Patonga, New South Wales (UBD, 2001).




Parish of Patonga County
Scale 100 feet to an inch.
(Land comprised in C. T. Vol. 2639 Fo
PATONGA CREEK
above Mean Water Mark
86
5A 2R 11¾P (Inc 100ft R.)
DIAGRAM
shewing Azimuth connectn
not to scale
STREET
Sheet 3
See Sheet 2
See Sheet 3
WHARF ROAD
SHORT STREET
BAY STREET
89
90
5A 0R 38¾P
5A 0R 5¼P
See Sheet 1
above Mean High Water Mark
-N BAY
Sheet 2
See Sheet 3
DP8549
Reserve
100 feet
PATONGA
SHORT STREET
BAY
See Sheet 2
I, Reginald Eustace Reid of Sydney, Licensed Surveyor specially licensed under the Real Property Act, do hereby solemnly and sincerely declare that the boundaries and measurements shewn on this plan are correct for the purposes of the said Act, and that the survey of the land to which the plan relates has been made by me, and I make this solemn declaration conscientiously believing the same to be true, and by virtue of the provisions of the Oaths Act 1900.
Reg. E. Reid.
Licensed Surveyor
Subscribed and declared before me at Sydney this 2nd day of February AD 1916
J.P.
of Survey December 1915
line of Azimuth AB (See Diagram)
Reserve
100 feet above Mean
Sheet 1
BRISK
BROKEN BAY

Appendix - F Parish Maps





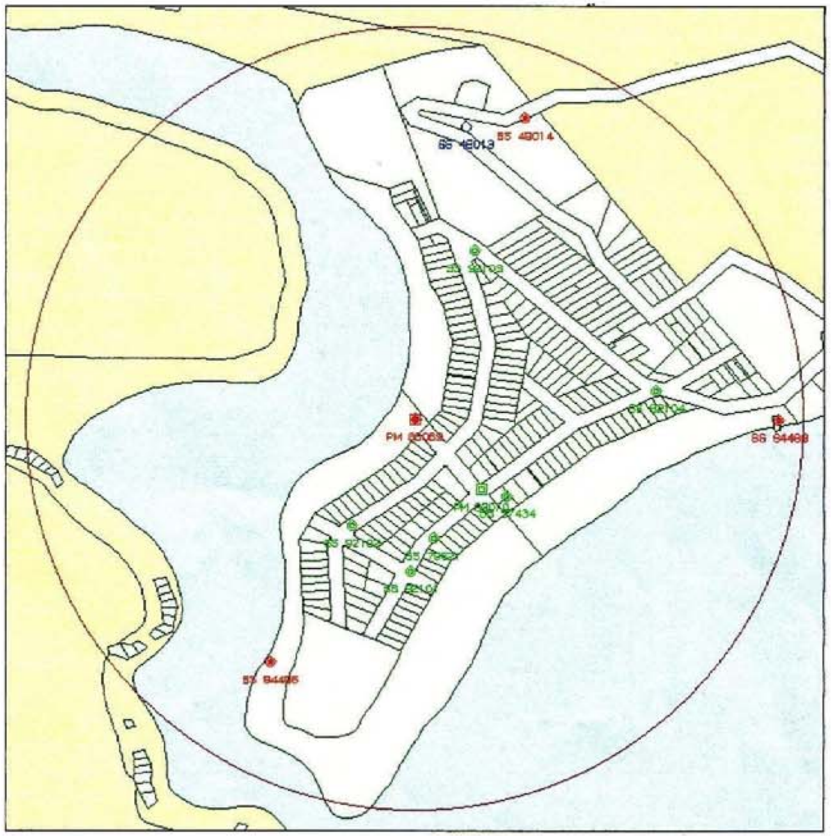
SCIMS
Mark Plot

Department of Lands
Reliable from the ground up

500 Metre DCDB Plot Centered About Mark:

PM 83069

New Radius: 500 metres   Redraw



Plot Legend   Print Page

SCIMS Survey Marks

Mark Report

Department of Lands

Type	Number	Station Name	Status
SS	94488		

Alias

Location	Suburb
GROUND LEVEL	PATONGA

	Latitude	Longitude	Acc	Class	Order	Source	Date
GDA94	-33 33 02.54582	151 16 28.50673	2	B	2	228354	14-APR-2003

	MGA Easting	MGA Northing	MGA Zone	CSF	Convergence
GDA94	339818.207	6286325.679	56	0.999916	-0° 57' 13"

	Latitude	Longitude	Acc	Class	Order	Source	Date
AGD66	-33 33 08.22797	151 16 24.36664	2	B	2	202397	20-DEC-1996

	Easting	Northing	Zone	CSF	Convergence
AGD66 (AMG)	339713.764	6286135.991	56	0.999916	-0° 57' 16"
AGD66 (ISG)	325391.613	1286174.776	561	0.999948	0° 09' 04"

	Height	Acc	Class	Order	Source	Date
AHD71	1.694	4	B	2	202396	20-DEC-1996

Date Placed	Placed By	Monument Type
	NOT AVAILABLE	UNKNOWN

Appendix H

Table 98 NSW Tidal Plane Analyses – Hawkesbury River

System: Hawkesbury River
Datum: AHD

RECORDING STATION	PATONGA										
AWRC No	212440										
LATITUDE	33°33'S										
LONGITUDE	151°16'E										
YEAR	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/00	Mean ± SD
TIDAL PLANES (millimetres)	AMPLITUDE										
HHWSS			1000	1002	986	1010	1026	1022	1060	1019	1016 ± 22
MHWS			660	664	647	675	691	685	721	682	678 ± 23
MHW			536	538	524	550	567	560	599	558	554 ± 23
MHWN			411	412	400	425	444	434	477	435	430 ± 24
MSL			24	26	7	37	57	46	92	53	43 ± 26
MLWN			-362	-360	-385	-352	-330	-342	-292	-329	-344 ± 28
MLW			-487	-486	-509	-477	-453	-467	-414	-452	-468 ± 29
MLWS			-612	-612	-632	-602	-577	-593	-536	-576	-593 ± 30
ISLW			-854	-854	-875	-841	-816	-833	-778	-817	-834 ± 30
TIDAL RANGES (millimetres)	AMPLITUDE										
MNR (MHWN-MLWN)			773	773	785	777	774	776	769	763	774 ± 6
MR (MHW-MLW)			1023	1024	1032	1027	1021	1027	1013	1010	1022 ± 7
MSR (MHWS-MLWS)			1272	1275	1279	1277	1268	1278	1256	1257	1270 ± 9
R. (HHWSS-ISLW)			1853	1856	1861	1851	1841	1855	1838	1836	1849 ± 9
TIDAL CONSTITUENTS (millimetres)	AMPLITUDE										
M2			511	512	516	514	510	514	506	505	511 ± 4
S2			125	126	123	125	124	126	122	123	124 ± 1
K1			148	147	149	147	147	147	149	148	148 ± 1
O1			95	95	94	92	92	94	94	93	94 ± 1
TIDAL CONSTITUENTS (degrees)	PHASE										
M2			239.7	238.8	239.3	238.9	239.1	297.4	239.5	239.3	247 ± 21
S2			264.3	263.6	263.8	262.7	262.8	323.8	262.8	263	271 ± 21
K1			119.1	119	118.5	118.4	118	149.2	119	119.1	123 ± 11
O1			80.3	80.1	81.4	80.4	81.8	110.1	80.8	80.5	84 ± 10
RESIDUAL ERROR (millimetres)	ROOT MEAN SQUARE										
			71	85	84	80	82	78	88	83	81 ± 5
DATA ANALYSED (%)	YEARLY PERCENTAGE										
			86	100	84	100	100	100	100	100	96 ± 7
EVENTS	*	*				*	*			*	
COMMENTS	Site commissioned in June 1992.										

The information supplied has been collected for use by the Department of Land and Water Conservation and the tidal plane heights only approximately relate to Australian Height Datum (AHD) or other specified datum. Other users should independently verify the suitability of this data for their particular use.

Station : BRISBANE WATERS, PATONGA

Appendix I

Start : 0000:01/07/2002
End : 2345:30/06/2003
Datum : AUSTRALIAN HEIGHT DATUM
File created by PM using INTERACTIVE program STDSPRX V1.0 at 1345:11/08/2004

,	m				
8/7/2002 0:00	-0.4	8/7/2002 4:00	0.05	8/7/2002 8:00	0.25
8/7/2002 0:15	-0.43	8/7/2002 4:15	0.1	8/7/2002 8:15	0.2
8/7/2002 0:30	-0.43	8/7/2002 4:30	0.13	8/7/2002 8:30	0.16
8/7/2002 0:45	-0.44	8/7/2002 4:45	0.18	8/7/2002 8:45	0.12
8/7/2002 1:00	-0.43	8/7/2002 5:00	0.24	8/7/2002 9:00	0.06
8/7/2002 1:15	-0.42	8/7/2002 5:15	0.27	8/7/2002 9:15	0.04
8/7/2002 1:30	-0.43	8/7/2002 5:30	0.31	8/7/2002 9:30	-0.05
8/7/2002 1:45	-0.41	8/7/2002 5:45	0.32	8/7/2002 9:45	-0.11
8/7/2002 2:00	-0.39	8/7/2002 6:00	0.33	8/7/2002 10:00	-0.12
8/7/2002 2:15	-0.31	8/7/2002 6:15	0.39	8/7/2002 10:15	-0.18
8/7/2002 2:30	-0.27	8/7/2002 6:30	0.35	8/7/2002 10:30	-0.25
8/7/2002 2:45	-0.25	8/7/2002 6:45	0.37	8/7/2002 10:45	-0.31
8/7/2002 3:00	-0.18	8/7/2002 7:00	0.37	8/7/2002 11:00	-0.32
8/7/2002 3:15	-0.15	8/7/2002 7:15	0.34	8/7/2002 11:15	-0.36
8/7/2002 3:30	-0.05	8/7/2002 7:30	0.36	8/7/2002 11:30	-0.37
8/7/2002 3:45	-0.01	8/7/2002 7:45	0.31	8/7/2002 11:45	-0.35

	Sydney	Patonga
High (H)	0.519	0.537
Low (L)	-0.546	-0.550
H+L	1.065	1.087
(H+L)/2	0.533	0.544
$M.T.L._2$		-0.007
$M.T.L._0$	0.007	
$M.T.L._1$	-0.014	
L.T.R.	1.008	
$O.R._2$		1.087
$O.R._1$	1.065	
K_1	0.021	
K_2	0.514	
MHW_{PAT}		0.528

Range Ratio Method Approx.

MHW = M.T.L.2 + K1 + K2

Where $K_1 = M.T.L._0 - M.T.L._1$

$K_2 = \dfrac{L.T.R. * O.R._2}{2 * O.R._1}$

$M.T.L._2$ = Mean of observed high water at site gauge (m) (M.T.L is Mean Tide Level).

$M.T.L._0$ = Long term value on the gauge of mean tide level at automatic gauge (m).

$M.T.L._1$ = Mean of observed high water an low water at automatic gauge (m).

L.T.R.= Difference between Mean high water and Mean low water at automatic gauge (m).

$O.R._2$ = Observed range at site gauge (m).

$O.R._1$ = Observed range at automatic gauge (m).

Appendix J

Range Ratio Calculations

	Sydney	Patonga
	Auto	Site
	Gauge	Gauge
High	0.555	0.590
Low	-0.415	-0.420
	0.970	1.010
	0.485	0.505
$M.T.L._2$		0.085
$M.T.L._0$	0.007	
$M.T.L._1$	0.070	
L.T.R.	1.008	
$O.R._2$		1.010
$O.R._1$	0.970	
K_1	-0.063	
$K_{2\,PAT}$	0.525	
MHW		**0.547**

	Sydney	Patonga
	Auto	Field
	Gauge	Obs.
High	0.555	0.560
Low	-0.415	-0.400
	0.970	0.960
	0.485	0.480
$M.T.L._2$		0.080
$M.T.L._0$	0.007	
$M.T.L._1$	0.070	
L.T.R.	1.008	
$O.R._2$		0.960
$O.R._1$	0.970	
K_1	-0.063	
$K_{2\,PAT}$	0.499	
MHW		**0.516**

	Sydney	Ettalong
	Auto	Site
	Gauge	Gauge
High	0.555	0.517
Low	-0.415	-0.229
	0.970	0.746
	0.485	0.373
$M.T.L._2$		0.144
$M.T.L._0$	0.007	
$M.T.L._1$	0.070	
L.T.R.	1.008	
$O.R._2$		0.746
$O.R._1$	0.970	
K_1	-0.063	
K_2	0.388	
MHW		**0.469**

	Ettalong	Patonga
	Auto	Site
	Gauge	Gauge
High	0.517	0.590
Low	-0.229	-0.420
	0.746	1.010
	0.373	0.505
$M.T.L._2$		0.085
$M.T.L._0$	0.036	
$M.T.L._1$	0.144	
L.T.R.	0.728	
$O.R._2$		1.010
$O.R._1$	0.746	
K_1	-0.108	
K_2	0.493	
MHW		**0.470**

	Ettalong	Patonga
	Auto	Field
	Gauge	Obs.
High	0.517	0.560
Low	-0.229	-0.400
	0.746	0.960
	0.373	0.480
$M.T.L._2$		0.080
$M.T.L._0$	0.036	
$M.T.L._1$	0.144	
L.T.R.	0.728	
$O.R._2$		0.960
$O.R._1$	0.746	
K_1	-0.108	
K_2	0.468	
MHW		**0.440**

Range Ratio Method Approx.

MHW = M.T.L.2 + K1 + K2

Where $K_1 = M.T.L._{-0} - M.T.L._{-1}$

$$K_2 = \frac{L.T.R. * O.R._{-2}}{2 * O.R._{-1}}$$

$M.T.L._{-2}$ = Mean of observed high water at site gauge (m) (M.T.L is Mean Tide Level).

$M.T.L._{-0}$ = Long term value on the gauge of mean tide level at automatic gauge (m).

$M.T.L._{-1}$ = Mean of observed high water an low water at automatic gauge (m).

L.T.R.= Difference between Mean high water and Mean low water at automatic gauge (m).

$O.R._{-2}$ = Observed range at site gauge (m).

$O.R._{-1}$ = Observed range at automatic gauge (m).

Example of Tidal Data

Station : BRISBANE WATERS PATONGA
Start : 0000:07/08/2004
End : 0000:08/08/2004
Datum : AUSTRALIAN HEIGHT DATUM
File created by AJ using INTERACTIVE program DBSPR V1.0 at 0940:

	m
7/8/2004 0:00	0.43
7/8/2004 0:15	0.44
7/8/2004 0:30	0.45
7/8/2004 0:45	0.44
7/8/2004 1:00	0.43
7/8/2004 1:15	0.43
7/8/2004 1:30	0.41
7/8/2004 1:45	0.35
7/8/2004 2:00	0.33
7/8/2004 2:15	0.3
7/8/2004 2:30	0.29
7/8/2004 2:45	0.25
7/8/2004 3:00	0.18
7/8/2004 3:15	0.13
7/8/2004 3:30	0.05
7/8/2004 3:45	0.02
7/8/2004 4:00	-0.03
7/8/2004 4:15	-0.1

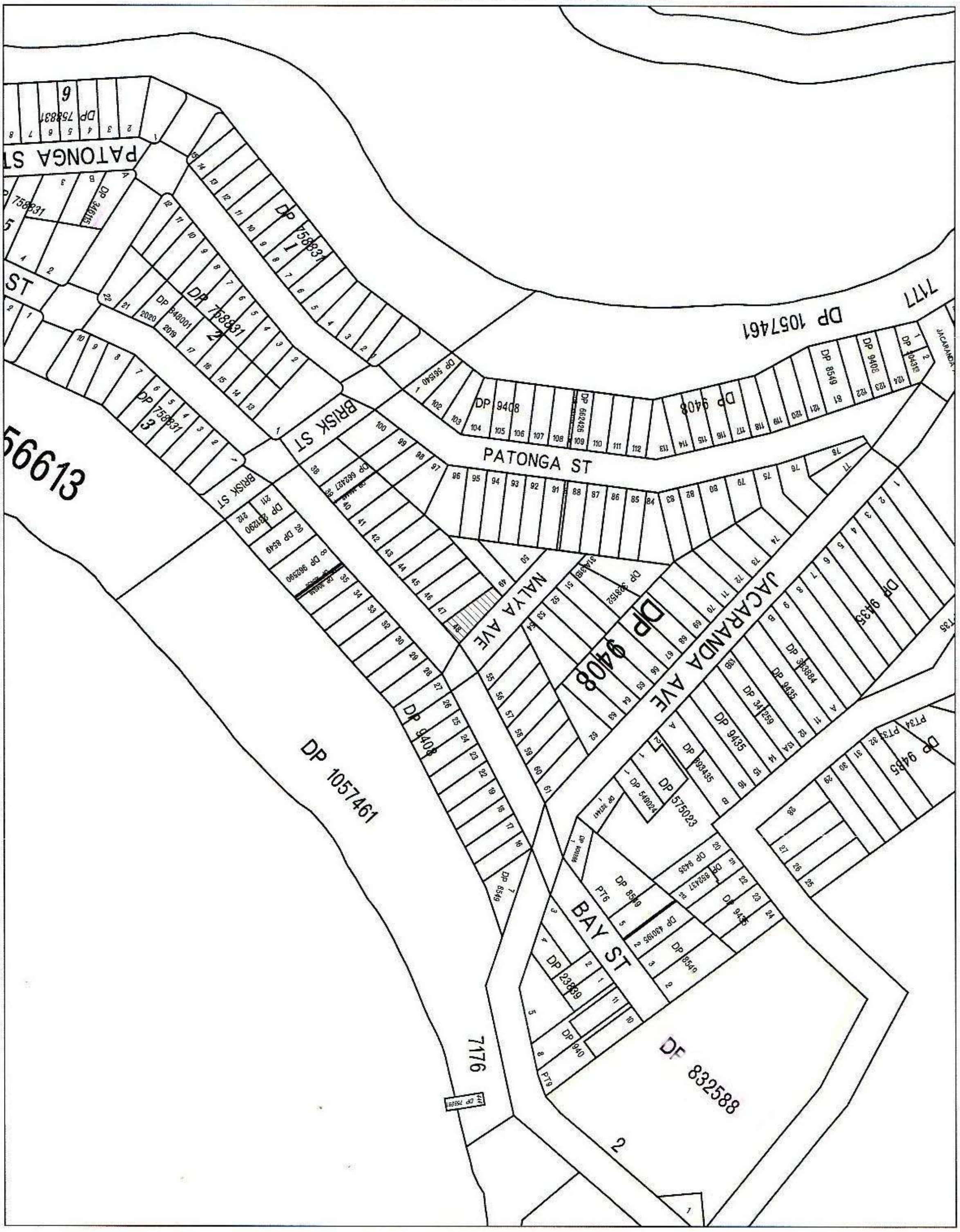
Station : SYDNEY TIDE GAUGE
Start : 0000:07/08/2004
End : 0000:08/08/2004
Datum : ZERO CAMP COVE (subtract 0.92 for AHD)
File created by AJ using INTERACTIVE program DBSPR V1.0 at 1624

	m
7/8/2004 0:00	1.34
7/8/2004 0:15	1.35
7/8/2004 0:30	1.34
7/8/2004 0:45	1.35
7/8/2004 1:00	1.33
7/8/2004 1:15	1.33
7/8/2004 1:30	1.32
7/8/2004 1:45	1.26
7/8/2004 2:00	1.26
7/8/2004 2:15	1.19
7/8/2004 2:30	1.16
7/8/2004 2:45	1.14
7/8/2004 3:00	1.07
7/8/2004 3:15	1.03
7/8/2004 3:30	0.97
7/8/2004 3:45	0.91
7/8/2004 4:00	0.88
7/8/2004 4:15	0.82

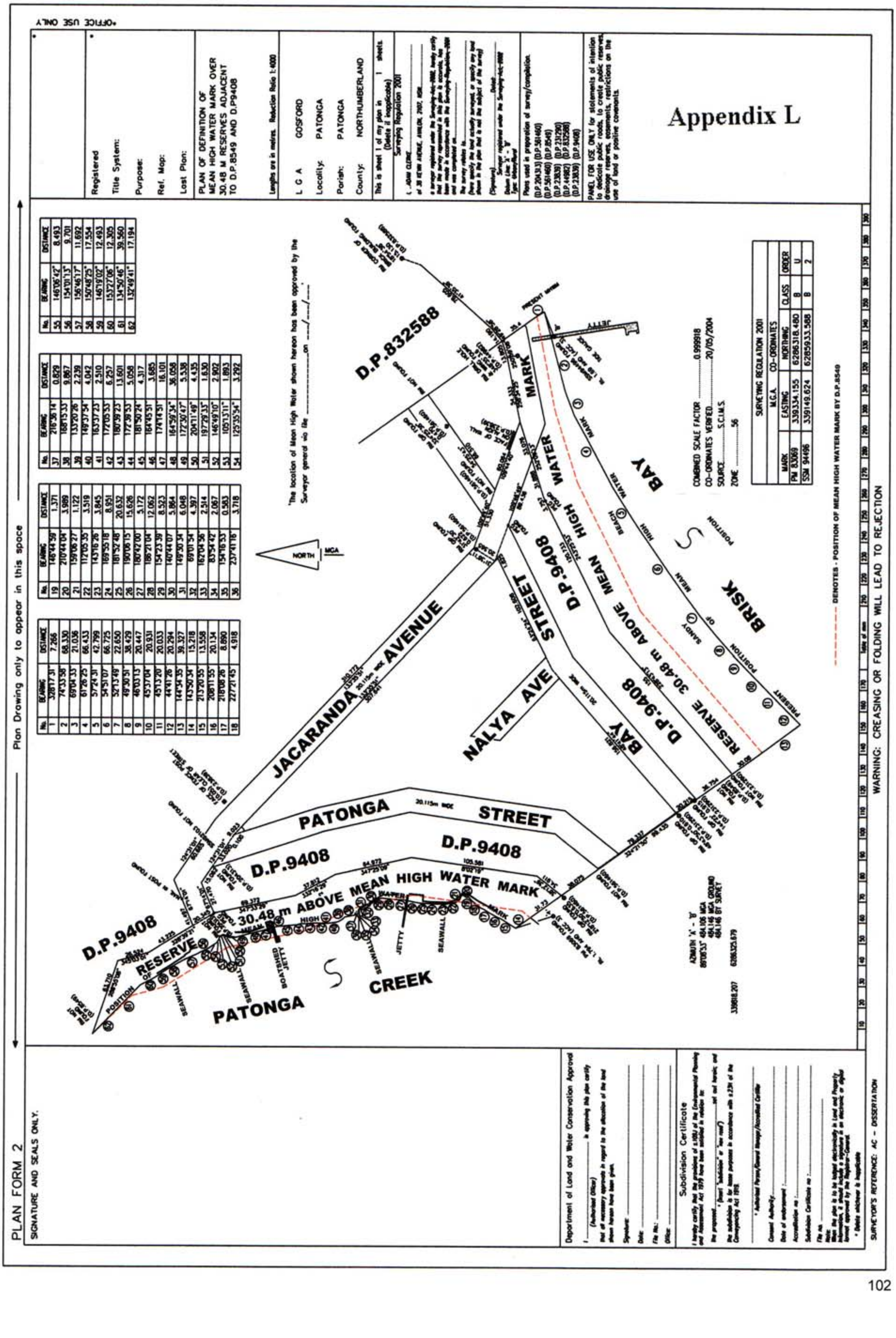
Appendix K

DEPARTMENT OF LANDS Box 136

CADASTRE (Report 1 of 3 Reports)
Date: 16-JUL-04 2:40pm Enquiry: Lot 48 DP9408



Appendix L


PLAN FORM 2
SIGNATURE AND SEALS ONLY.
Plan Drawing only to appear in this space
*OFFICE USE ONLY
PLAN OF DEFINITION OF MEAN HIGH WATER MARK OVER 30.48 M RESERVES ADJACENT TO D.P.8549 AND D.P.9408
L G A GOSFORD
Locality: PATONGA
Parish: PATONGA
County: NORTHUMBERLAND
JACARANDA AVENUE
PATONGA STREET
NALYA AVE
BAY STREET
D.P.9408
D.P.832588
30.48 m ABOVE MEAN HIGH WATER MARK
RESERVE
BRISK BAY
PATONGA CREEK
NORTH
MGA
DENOTES - POSITION OF MEAN HIGH WATER MARK BY D.P.8549
WARNING: CREASING OR FOLDING WILL LEAD TO REJECTION
SURVEYOR'S REFERENCE: AC - DISSERTATION

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