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“Ordnance Survey data collection and  
mapping of tidal features”

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# ***Ordnance Survey data collection and the mapping of tidal features - a review of policy, methods and potential analysis***

***Brian Baily<sup>1</sup>***

## ***Abstract***

Tidal lines have often been recorded on maps and have the potential to aid the understanding of coastal processes to help inform predictions of coastal change and associated sea level rise. One of the principal forms of cartographic tidal data available is Ordnance Survey mapping which has periodically reviewed and displayed tidal line data. Initially, the Ordnance Survey collected the data using land survey techniques and later developed remote sensing based approaches. This review examines the approach of the Ordnance Survey to the mapping of tidal lines on the maps of England and Wales from 1868 until the 1960s.

## ***Introduction***

Coastal erosion, coastal flooding and rising sea defence costs are an increasingly difficult issue for many cities and regions around the British Isles. Data which can inform, improve and help justify coastal management policy and practice is imperative for those concerned with coastal management and policy. More recent data is now collected and available from various bodies including local councils, the Environment Agency and groups such as the Channel Coast Observatory ([www.channelcoast.org](http://www.channelcoast.org)). Longer-term data sets relating to coastal change are less widely available and are often difficult to collect or expensive to obtain. One form of data which has been used as evidence of longer-term coastal change is that of tidal line data from cartographic sources.<sup>2</sup> More generally, maps of various kinds have been widely used for many forms of coastal research from vegetation studies through to geomorphological investigation. For those concerned with historical coastal change, the selection of source evidence used in the research is often dependent upon the scale of the features under examination and the degree of change which may have occurred. Earlier maps of the coast are often unreliable and of limited use for coastal research, especially those studies which analyse geomorphological change. Later maps, in contrast, may have the potential for providing valuable information for those concerned with longer-term coastal behaviour.

The research discussed here is principally concerned with the historical evolution of tidal line mapping on Ordnance Survey maps. In particular, it examines the evolving policy in relation to Ordnance Survey tidal line lines and reviews the data collection techniques used. In contrast to other studies which have examined spatial inaccuracies in the cartographic medium, this research examines the rationale, policy and practice behind the mapping of tidal lines

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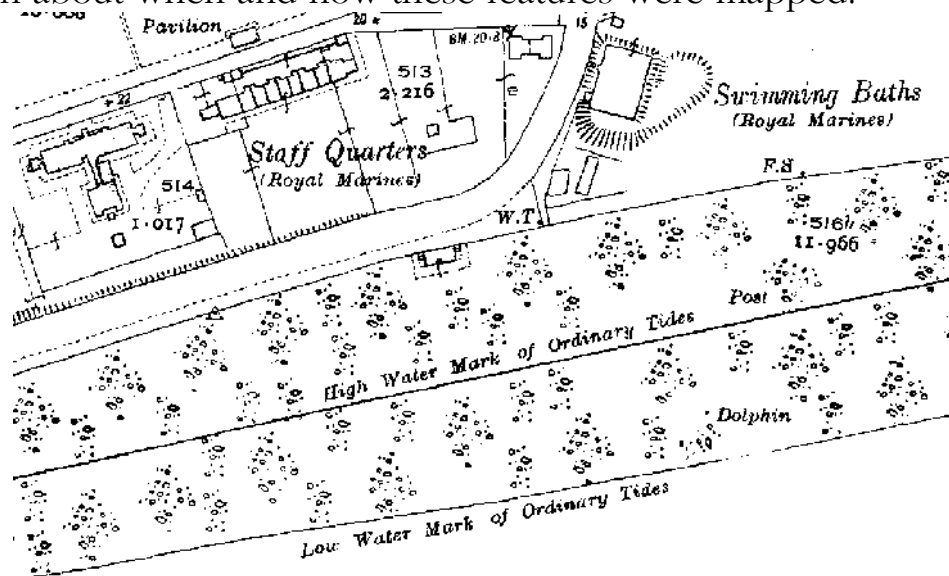
<sup>1</sup> The author is lecturer in the Department of Geography, University of Portsmouth.

<sup>2</sup> See, for example, B Baily and P Collier, 'The development of photogrammetric mapping techniques of tidal lines by the Ordnance Survey', *Cartographic Journal* 47 (3) (2010), 262-269 and J M Hooke and R C Riley, 'Historical changes on the Hampshire coast 1870-1965', *Proceedings of the Hampshire Field Club Archaeological Society* 47 (1991) 203-24.

and asks whether this makes these features suitable for any reasonable analysis of coastal change.

***Tidal line mapping by the Ordnance Survey – an evolving approach***

Tidal lines are one form of physical feature which appear on Ordnance Survey maps (*figure 1*). In practice, on some maps it is possible to identify tidal lines going back to the eighteenth century, although it is more common for earlier maps to have simply recorded the sea/land interface. Potentially, these lines may be useful indicators of sea level rise, beach erosion and accretion or beach narrowing. The comparison of the movement of these lines for geomorphological research is compounded by errors in the cartographic medium and the uncertain nature and definition of the features defined by these early coastal surveys. Consequently, any research which wishes to use these features as evidence of coastal change also needs to ascertain accurately the exact details of what tidal features were recorded in the field along with information about when and how these features were mapped.



*Figure 1. An example of early tidal line mapping from the Eastney beach area of Portsmouth*

The mapping of tidal lines became widespread from the nineteenth century onwards. Tidal lines were surveyed by Ordnance Survey teams in the field using ground survey techniques. This practice continued until after the Second World War when experiments with aerial survey were carried out to try and improve the collection of tidal line data and reduce the associated costs.<sup>3</sup> Ground survey data collection often involved manual surveying but also at times included field sketching of features. The important aspect for coastal change researchers is that the primary reason for the Ordnance Survey collection of tidal line data was as a boundary delineation feature and not to record a geomorphological feature in the field (in contrast to a cliff edge for example).

<sup>3</sup> Baily and Collier, *op cit*.

The Ordnance Survey archival files at The National Archives<sup>4</sup> reveal that tidal lines were surveyed and displayed on maps primarily:

- a. *To delineate the boundary between the foreshore which, prima facie, belongs to the Crown and other property*
- b. *To delineate the limits of jurisdiction of the harbour authorities and the line below which the Minister of Transport and Civil Aviation exercises control over works in the interests of navigation*
- c. *To delineate the high and low water lines on Admiralty charts and Ordnance Survey maps*
- d. *To indicate, on engineers' plans certain maximum and minimum heights for such projects as coast protection against flooding and sewerage, etc.*

The Ordnance Survey policy on tidal line mapping was an evolving process subject to internal review and legal changes in the definitions of boundaries which the Ordnance Survey was legally obliged to collect. Early Ordnance Survey maps often plot the high and low water marks of Ordinary Spring Tides (this still applies to all maps of Scotland), whilst later maps show the ordinary/mean tidal level. The origins of the mapping of tidal line data can be traced back to the Ordnance Survey Act 1841, paragraph 1, which required Justices of the Peace to appoint meresmen to assist the Master General and Board of Ordnance in 'examining, ascertaining and marking out the reputed boundaries of each County, City, Borough, Town, Parish'.<sup>5</sup> Important changes occurred during the middle of the eighteenth century which influenced the Ordnance Survey approach to the particular features collected in the field during a tidal survey. Before 1868, the boundaries of a parish had been defined as the high water line of a tide, therefore many extra parochial places including the foreshore were outside of their parish boundary and exempt from the Poor Laws. In 1868, however, the Poor Law Amendment Act was passed which resulted in the parish boundary's extension to the low water line. Thus, it became legally necessary for the Ordnance Survey to map the low water line in the same way as any other boundary and they were legally obliged to show this feature on the map in question. In the subsequent surveys of 1870s onwards, the Ordnance Survey carried the parish boundaries to the low water mark of ordinary tides, as this now defined the seaward extent of the city, parish and town etc. It is also important to note at this stage that the surveys from this period onwards clearly and consistently plotted the position of the ordinary tide (later changed to medium tides in August 1935), whereas in some earlier cases the tide measured had been a spring tidal line. The definition of the boundary of the low tide line was clarified further when the Lord Chancellor (Lord Cranworth) legally recognised the high and low water mark of an ordinary or average tide as the boundary of the foreshore in 1854. In contrast to this, the

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<sup>4</sup> *Survey of tides 1946-53*, TNA PRO OS 1/561.

<sup>5</sup> House of Commons, 'Ordnance Survey: A Bill. To Authorize and Facilitate the Completion of a Survey of Great Britain and the Isle of Man', 24 May 1841. House of Commons Parliamentary papers, Online Proquest Information, 2005.

Scottish maps followed the historic practice of measuring the mean spring tide position except where Udal Law operates.<sup>6</sup>

### ***Defining and mapping a tidal line***

Tidal lines are represented on several different types of maps including Admiralty charts and Ordnance Survey maps. However, as the agencies concerned were mapping different variants of tidal lines, the lines depicted on these maps are essentially different physical features. As referred to above, the Ordnance Survey maps (after the 1868 judgment) depict the high and low water marks of ordinary tides in relation to the Ordnance Survey datum relevant at the time of survey. Admiralty charts, in contrast, show the tidal lines of the highest or lowest astronomical tides related to the Admiralty chart datum (2.7 m below Ordnance Survey Datum Newlyn). The different datums and features collected prevented the two bodies sharing map data. However, there are numerous references in the archives of The National Archives relating to the Ordnance Survey's using the raw soundings data from the Admiralty which was adjusted accordingly and used to plot the low water mark in inaccessible areas. The representation of tidal lines on maps varies depending on the tidal characteristic surveyed and the datum used. As a result, a variety of different terms and acronyms are found on different maps from the various agencies concerned. Oliver<sup>7</sup> notes that tidal lines of spring tides marked on maps before 1868, may be marked as mean tide lines and that since circa 1950 the date of survey of the tidal lines and their revision date have been consistently shown on the 1:2500 and 1:1250 maps. The list below exemplifies the typical nomenclature used in various maps and charts:

- MH/LWS Mean high/low water springs
- MH/LWN Mean high/low water neaps
- MH/LW Mean high/low water
- H/LWMOT High/Low water mark of ordinary tides
- H/LWMMT High/Low water mark of medium tides
- H/LAT Highest/Lowest astronomical tide
- H/LWOST High/Low water mark of ordinary spring tides

The Ordnance Survey maps appear to have three broad periods where the names for tidal lines changed on the printed medium. The earliest maps refer to ordinary tides (1868 onwards), which was later changed to medium (1935 onwards) and eventually from 1965 onwards mean tides (*table 1*).

Ordnance Survey policy and obligations regarding the collection of tidal lines are extremely important in relation to the final features displayed on the

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<sup>6</sup> For a more detailed discussion of the legal definitions of the foreshore see D J McGlashan, R W Duck, and C T Reid, 'The foreshore: geographical implications of the three legal systems in Great Britain', *Area* 36 (4) (2004), 338-347 and D J McGlashan, R W Duck, and C T Reid, 'Defining the foreshore: coastal geomorphology and British Laws', *Estuarine, Coastal and Shelf Science* 62 (2005), 183-192.

<sup>7</sup> R Oliver, *Ordnance Survey maps a concise guide for historians*, Charles Close Society, 1993.

<i>Abbreviation</i>	<i>Dates covered</i>	<i>Full definition (England and Wales)</i>
H/LWMOT	December 1868 to August 1935	High / Low water mark of ordinary tides
H/LWMMT	August 1935 to March 1965	High / Low water mark of medium tides
MHW/MLW	March 1965 to present	Mean High / Mean Low water

*Table 1. The various nomenclature of tidal lines as shown by Ordnance Survey from 1868*

maps. However, for those wanting to use tidal line data for geomorphological research, it is also necessary to consider the practical realities of collecting this form of data in the field. In reality, it is likely that some of the largest discrepancies in the data may exist where different survey methods were used, or in some cases where secondary data was utilised. Numerous questions arise which need to be considered in relation to the reliability, the repeatability and comparability of the different surveys. Influential variables between coastal areas may exist and influence the quality of the results obtained; these include meteorological conditions, local geomorphology at the time of survey, tide prediction accuracy, accessibility (especially of the low water line) and coastal type. One particularly important factor in tidal line surveying was the accuracy of the predictions of the tidal times themselves. Admiralty tide tables were used to predict when an ordinary or medium tide would occur, predicted from an estimate calculated from the 18.6 year metonic cycle. Whilst these tide tables are accurate for the specified purpose, relatively small differences between the predicted and actual tides could have serious impacts on tidal lines and the subsequent surveyed line. Getting the correct timing of the optimum tidal condition was essential for field survey teams to be able to put aside all other work and survey the tidal line for the short period when it was at the correct position. As this research reveals, later attempts to match the actual and predicted tide times in the field were met with mixed results.

The instructions given to surveyors and superintendents are clear about the conditions which control whether a tide is suitable for survey. In 1932, the OS instructions to be used for revision in the field state that if ‘the tide was not ordinary another tide must be taken’.<sup>8</sup> In this case the term ‘ordinary’ relates to either unacceptable meteorological conditions or problems with the predicted and actual tide time. The local conditions would clearly have influenced the state and exact timing of a tide. The temporal uncertainty and meteorological conditions may have affected the low water line more than the high water mark, as this was more susceptible to slight changes in conditions. An appendix to the *Ordnance Survey field bulletin 31*,<sup>9</sup> states that the high water mark

<sup>8</sup> Ordnance Survey, *Instructions to field revisers 1/2500 scale*. London: HMSO, 1932.

<sup>9</sup> *Survey of tides 1946-53*, TNA PRO OS 1/561.

generally presents fewer problems for ground survey as a clear mark is usually left by the tides (*e.g.* wet water line or a seaweed line). However, the document also suggests that the survey of the low water mark in the field is much more difficult given the limited temporal period available before the tide turns. Surveyors are told that as much as possible should be surveyed in a short period as is feasible ‘the normal field method of surveying the Low Water Mark was to select a time from the Admiralty Tide Tables when the actual Low Water Mark was predicted to be close to the computed Low Water Mark of Medium Tides. All other work could then be put aside and a greatest effort made to survey as much of the water line as possible in the short time the actual water level could be regarded as being identical with LWMMT.’<sup>10</sup>

Trying to establish the accuracy of surveyed tidal lines is an extremely difficult as Close notes ‘Local conditions vary, and it is impossible to lay down the best method of checking and ensuring accuracy in different cases and Division’.<sup>11</sup> No formal standard of accuracy was set by the Survey Act of 1841, Section 1 of the Act refers only to the collection of reputed boundaries. In 1947, it was decided that for Ordnance Survey purposes, it is plan position which matters as this determines areas. No absolute standard of accuracy was specified because of the variations in local conditions and individual surveys. Ordnance Survey policy was therefore to ‘make a good honest attempt’ to map the low water line without an ‘undue expenditure of money’.<sup>12</sup> In contrast, in surveying the high water mark the Ordnance Survey aimed to be more precise as this can be more ‘exactly determined’.<sup>13</sup> Nevertheless, in 1955 an attempt to estimate potential horizontal accuracies related to foreshore gradient and tidal variation was calculated for tidal line data (*table 2*).

<i>Foreshore gradient</i>	<i>Time period equivalent to</i>	<i>Accuracy horizontal distance +/-</i>
1:500	3 inch rise and fall of the tide	38.1 m
1:200	6 inch rise and fall of the tide	30.6 m
1:100	9 inch rise and fall of the tide	22.8 m
1:20	12 inch rise and fall of the tide	15.24 m

*Table 2. A suggested 1955 accuracy statement of air survey of tides (TNA PRO OS 1/945)*

### ***Collecting the data – ground and photogrammetric surveying of tidal lines***

The definition of the tidal line as a boundary required the Ordnance Survey to survey, map and publish the feature. Admiralty tide lines were already being recorded but could not be accepted by the Ordnance Survey because of the

<sup>10</sup> *Tide lines high and low water mark 1951-74*, TNA PRO OS 11/46.

<sup>11</sup> C F Close, *Instructions to examiners and field revisers*, Southampton: Ordnance Survey, 1912.

<sup>12</sup> *Tide lines high and low water mark 1951-74*, TNA PRO OS 11/46.

<sup>13</sup> *ibid.*

‘Admiralty policy of adopting independent chart datum’ and because ‘The Low Water mark now being adopted on Admiralty charts is that of lowest astronomical tide (LAT). This low water line is clearly contrary to that defined by the Lord Chancellor in 1854’.<sup>14</sup> Before the advent and adoption of suitable photogrammetric techniques, the main method for capturing tidal line data was by using field survey (*figure 2*). The instructions given to Ordnance Survey



*Figure 2. A volunteer holds a chalkboard displaying the tide and time during a tidal survey in 1952 (TNA PRO OS/561)*

surveyors state that particular care has to be exercised in the surveys of high and low water lines that they are made at specified tides and ‘superintendents must arrange to make the most of the time available’.<sup>15</sup> The practicalities involved in surveying these features are recognised and the guidelines to surveyors crucially state that ‘The high-tide line will in all

cases be surveyed, but the low-tide line may often be left with advantage to the examiner to insert at the discretion of the division officer’.<sup>16</sup> This may suggest that examiners were to be given the flexibility to sketch the low water line, or, as the records imply, leave this to be inserted at a later date. Other historical records also show that in estuaries and other inaccessible areas, the Ordnance Survey could use the Admiralty survey data to plot the low water line providing the relevant adjustments were made. The high tide lines appear to have presented less difficulty in relation to accessibility and survey, or marking for subsequent surveying. At the designated time the surveying team would mark out the area where the water was or had been or use other physical features to determine this. With regard to the high water line, this is defined as ‘generally marked by seaweed which can be pegged out and surveyed at leisure’.<sup>17</sup> As discussed above, the tides, although predictable, could be variable in their exact timing and behaviour. In England and Wales, the 1882 instructions state that the tidal lines to be surveyed in the field should be the tide lines half-way between neaps and springs (mean or ordinary tides). To do this the instructions suggest that the Divisional Officer should calculate, where Admiralty tide tables allow, for an ordinary tide level for both high and low water marks. The instructions

<sup>14</sup> *Instructions to surveyors*, TNA PRO OS 45/8, OS 307.

<sup>15</sup> *ibid*, page 4.

<sup>16</sup> *ibid*, page 5.

<sup>17</sup> *ibid*, page 5.



also state that, where it is not possible to survey on the mean tidal period, the survey should be done at the fourth tide before new and full moon. However, as the Ordnance Survey notes these tide levels may vary a good deal at times from the true mean.<sup>18</sup>

One crucial factor which would have affected these surveys would have been the meteorological effects, especially wind conditions and the barometric pressure. Once again this will differ depending upon the type of coastline being surveyed and will vary over relatively short temporal periods. In rockier coastlines, the weather conditions would have been less important whilst on wider, flatter beaches the meteorological conditions would have been crucial to the position of the line. In rocky coasts, it is argued, tidal levels varying a foot or more in the actual and predicted tidal levels 'may make no practical alteration in the position of the line surveyed, but on sand flats, two or three inches difference may alter the position of the tide line greatly'.<sup>19</sup> The instructions for surveyors go on to state 'that the level of any particular tide may be very considerably affected by wind and weather, and selected tides should only be utilised under normal conditions'.<sup>20</sup>

The guidance given seems to accept that the unpredictability of the potential tidal effect on the surveyed line and that the small changes in tidal level may well be crucial and the effects of the meteorological conditions would have been extremely important. One thing which was extremely problematic for the Ordnance Survey was the effect of barometric pressure which would also have impacted upon the corresponding tidal height. In relation to a query concerning the effect of barometric pressure, the Ordnance Survey Deputy Director of Field Surveys records in 1953 that the surveyors 'do not allow for this and neither is there any way of doing so'.<sup>21</sup> This potentially could be an important determinant of whether the tidal line data are suitable for geomorphological analysis. Different barometric pressures could alter the tidal level reached which is recognised by the Ordnance Survey who state that 'a one inch difference in barometric pressure could make a difference of up to 12 inches in the tidal level, which, as already noted, would make a large difference on a flatter foreshore'.<sup>22</sup>

The field survey itself was carried out over a short time period and as a result was to be carried out whereby 'every available surveyor should be told off to such a portion of the tide line as he can complete without fail within the time at his disposal'.<sup>23</sup> In 1959, the Ordnance Survey state that the HWM is easier to mark either by using the jetsam line or by staking out the highest tide

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<sup>18</sup> Ordnance Survey, *Instructions for 1:1250 field and office examination and revision* (The Green Book), Southampton: Ordnance Survey, 1948.

<sup>19</sup> *Instructions to surveyors*, TNA PRO OS 45/8, OS 307, page 5.

<sup>20</sup> *ibid*, page 4.

<sup>21</sup> *Survey of tides 1946-53*, TNA PRO OS 1/561.

<sup>22</sup> *ibid*.

<sup>23</sup> *Instructions to surveyors*, TNA PRO OS 45/8, OS 307, page 4.

line reached. However, the Ordnance Survey<sup>24</sup> also notes that experience has shown that the mapping of the HWM has three potentially serious problems. Firstly, the tide level may be wrong and different from that predicted. Secondly, local configurations along the coast may alter the tide locally. Finally, the line being surveyed is on a surface which is liable to alteration and varies according to recent conditions. In contrast to the high water line, the low water mark often presented a very difficult feature to survey on the ground. One example of this is the difficulty of surveying across mudflats or other unstable areas or in areas where the tide retreated over long distances (*e.g.* Morecambe Bay). The instructions suggested that the surveying teams should be in position ready to survey this line an hour before the predicted low tide level, in order to take the fullest advantage of the period of slack water for the survey for the half hour or so before and after the low tide.<sup>25</sup> In many cases the low water line was manually surveyed, with evidence suggesting that a mud and water allowance was sometimes given to surveyors who became wet or dirty whilst surveying the low water line.

Ground survey could be hazardous and impractical along many areas of the coastline and the actual collection of the data itself presented insurmountable difficulties. In particular, in some tidal areas the tide retreated so far that ground survey of the low water line was both dangerous and difficult. Even when the coast was accessible, the short window when the low tide level was in the correct position meant that only a limited stretch of coast could be surveyed at any one time. Of increasingly important concern to the Ordnance Survey were the costs involved with detailed ground survey of coastal lines. Photogrammetric techniques were increasingly applied to other areas of mapping and the field survey section of the Ordnance Survey decided to test their suitability for tidal surveys. Photogrammetric data collection potentially offered a series of challenges, in particular capturing the imagery when the tide was in the correct position and when weather conditions were acceptable. There was also the issue of photogrammetric ground control which meant that coastal photography would need to cover areas of land where control points could be fixed.

Initially, experiments took place in 1947 at two field sites (Bournemouth / Boscombe and Weston-super-Mare) during the summer of 1947 with the field sites being selected for the different coastal features they contained. The initial photogrammetric experiments took place during May and June 1947 with photography being captured at a scale of 1:11,000 and 1:22,000. The camera used was a K17 which had a 152mm lens. The main aim of the research led by the field section was to concentrate on the suitability of photogrammetric techniques to map the low water line. The high water line it was suggested presented less of a problem and could be surveyed with 'generally little

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<sup>24</sup> *Survey of tides 1946-53*, TNA PRO OS 1/561.

<sup>25</sup> *Instructions to surveyors*, TNA PRO OS 45/8, OS 307, page 5.

difficulty on the ground'.<sup>26</sup> The original experimental design highlighted the following questions which the experiments needed to solve:<sup>27</sup>

- a. *Identification of the best photographic material in varying conditions. In particular, whether false colour infra-red film was better at showing the water marks left by the tide.*
- b. *The best specifications for height, scale etc. This involved working out how much of the beach could be photographed within a particular tidal window at a scale which allowed identification of the tidal features.*
- c. *How much latitude the RAF could be given in the flying period without producing any appreciable error in the position of the tidal line.*
- d. *How to plot the LWMMT when the line is very far from the land.*
- e. *Compare ground survey data with the data collected from the aerial photographs for data collected at the time of photographic exposure but also to compare with data ground surveyed thirteen months earlier.*
- f. *To check that the RAF could record the given area within the time latitude.*

The scale of the original aerial photography was selected so that at least half (preferably 60%) of the aerial photograph was on the landward side of the coast, which would make the identification of ground control easier. The photography capture times had been calculated from the Admiralty tide tables on the basis of allowing a difference in tide level between the actual and predicted tide level of one foot. However, at the Weston-super-Mare site, it is noted that, as the tide varies by thirty-one feet, this allowance may be too little and at Bournemouth and Boscombe it is suggested that one foot may be too great a degree of latitude to give.

The experiments by the Ordnance Survey demonstrated the important effects of local topography and sea defence structures on tidal positions. During the experiment, poles were inserted along the foreshore marking the tide at different points along the beach. These poles were then surveyed and it was noted that the time of the tide on any one day was not the same at all poles with a variation from 5 minutes late to 25 minutes early from the predicted tide time. The conclusion from the observed tidal behaviour on the beach is that 'if it does exist it is a further indication that tides are so irregular that highly accurate surveys of the tide lines are unjustified and meaningless'.<sup>28</sup> The field report goes on to note that 'Poles inserted in the middle of the 1st period were reached by the returning tide considerably before the middle of the 2nd period. The average for the 17th May was 16 minutes early. The average for 18th May was 36 minutes early'.<sup>29</sup> Later checks on tide times and tables led to the conclusion that the tide tables should be treated with extreme caution when deciding exact tidal positions. This inconsistency in the predicted and actual tidal position was reflected across the Boscombe experimental site and indeed

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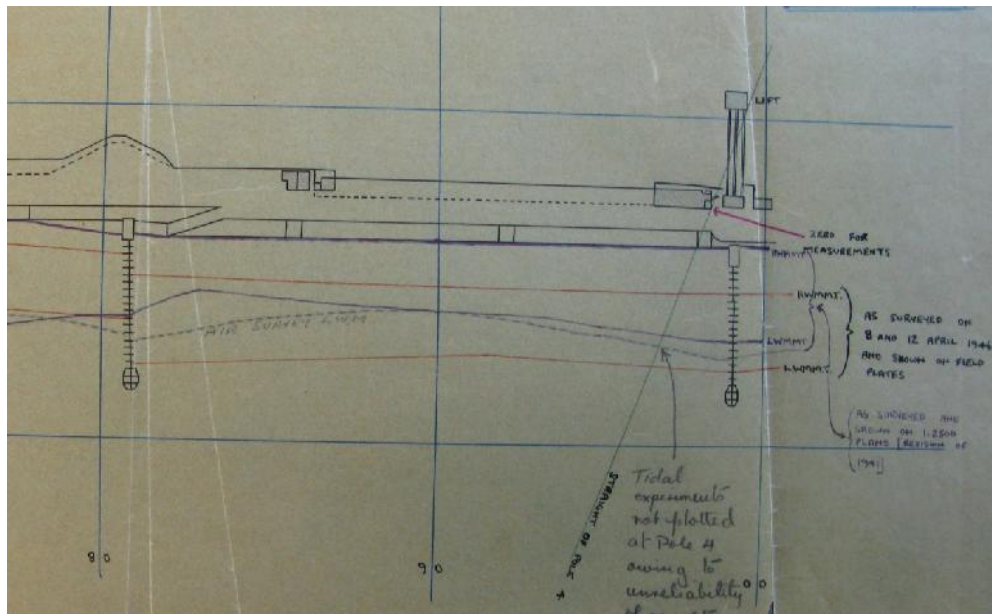
<sup>26</sup> *Survey of tides 1946-53*, TNA PRO OS 1/561.

<sup>27</sup> *ibid.*

<sup>28</sup> *ibid.*

<sup>29</sup> *ibid.*

the average across the whole experiment showed that the tide was 25 minutes earlier than predicted (*figure 3*). The tidal fluctuation resulted in spatial differences, which at one period, led to a discrepancy of nineteen links (nearly 4 metres) across the beach when the tide should have been in the same position. The surveyor writing the report noted that ‘although working to a definitive system, (the tides tables) are exceedingly irregular and are not worthy of any accurate survey’.<sup>30</sup> The imprecise nature of the optimum tidal conditions in turn led to difficulties in capturing the photography at the correct moment. It also suggested that many previous ground surveys were recording tides in the different positions from the ‘true’ average.



*Figure 3. A section of one of the plans produced by the original beach experiment. This shows the plotted survey lines for the Boscombe beach area (TNA PRO OS 1/561)*

The photogrammetric experiments also highlighted the importance of the influence of short-term changes in geomorphological conditions. ‘It may be noted that movement of sand on the beach appears to take place to such an extent as appreciably alter the position of the tide lines on a beach in a short space of time’.<sup>31</sup> Levels recorded of subsequent tides also show the effect of the wind on wave set up and run up, with levels of the tide recorded on a calm day in different positions from those on a windy day.

The early photogrammetric experiments concluded that air survey offered a more reliable method of obtaining a smooth line than ground survey. In particular, the advantages of photogrammetric plotting were immense in areas of mudflats and sandbanks, although the comparison experiments at Weston-super-Mare had to be cancelled as the surveyors were unable to get to the low water line because of the soft mud, perhaps in itself showing the need for aerial survey of tidal lines. One of the interesting outcomes of the field experiment at

<sup>30</sup> *Survey of tides 1946-53*, TNA PRO OS 1/561.

<sup>31</sup> *ibid.*

the Boscombe site was the comparison of the ground survey tidal lines with those derived using photogrammetric techniques. The results were positive with a reasonable match between the ground and air surveys, suggesting that continuity would not be severely affected by switching techniques. It was noted that in areas with a more complicated local topography, differences were found particularly where groynes had been installed. The initial air survey experiments also concluded that air survey offered a more reliable method of obtaining a smooth line than ground survey. The photogrammetric experiments also exposed the dynamic nature of tidal lines as recorded by the surveys. In particular, the results revealed that, although there was a broad agreement between the aerial and ground survey for the same time in 1947, there existed a large disparity between these lines and a ground survey in the same area recorded thirteen months earlier in April 1946. The research report also states that the lines recorded showed considerable differences between the ground survey of 1946 and a similar survey of 1941. The report continues that surprisingly the largest changes had occurred in the high water line showing the potential differences which could naturally occur. The report of the aerial photogrammetric tests demonstrated that the variation within the high and low water line recorded in the field was not consistent or uniform. Indeed, the surveyors report suggests that 'as expected, the position of LWMMT has changed more than the position of HWMMT but their changes of both are so great that I think they provide the strongest possible argument for the exclusion of both high and low water marks from the 1/1250 plans'.<sup>32</sup> The Director of Field Surveys in response notes that tidal line mapping is always going to be problematic and that trying to find a consistent feature is 'a tendency to hunt for the unattainable'.<sup>33</sup>

The early experiments by the Ordnance Survey demonstrated that photogrammetric mapping of the tide lines was economic, practical and as reliable as ground survey and in using infra-red film better at mapping the low water line. Aerial survey evolved to replace ground survey as the main technique used to capture tidal line information. By 1964, the archival evidence suggests that aerial survey was the normal method for revision of the low water mark. In particular, it is noted that the ability of photogrammetric plotting to provide a continuous line rather than a series of points has a significant advantage over ground survey. In responding to a query concerning mapping methods in 1955 the Ordnance Survey Deputy Director of Field Surveys notes that the main error associated with aerial tidal mapping is in the actual and predicted tide levels. In particular, the timing of flights is seen as crucial, and any flexibility is governed by the gradient of the cross shore profile. Limits were set for different foreshore gradients which indicated the degree of flexibility which could be exercised when taking the photography. In reality, it was necessary to give the RAF temporal latitude of one foot above and below the

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<sup>32</sup> *Survey of tides 1946-53*, TNA PRO OS 1/561.

<sup>33</sup> *ibid.*

low water mark alongside which other suitable meteorological conditions were required.

As well as the aerial photogrammetric tests using conventional aeroplanes, further experiments were performed during 1967/8 using helicopter photography to map tidal lines between Loch Sunart and the Isle of Mull.<sup>34</sup> The principal aim of the experiment was to discover if suitable photographs could be obtained using helicopters (*Figure 4*). The results concluded that the quality of the photography varied depending upon the stability of the helicopter and the results of the experiment were mixed, partly due to the poor weather



*Figure 4. Surveyors preparing the helicopter for a tidal line survey experiment in 1968 (TNA PRO OS 13/19)*

during the test period. In particular, it was found that on a straight line the helicopter took reasonable photography. However, when the pilot needed to make small adjustments to speed or direction a loss of photographic quality was recorded. Costs of image capture were slightly lower than the fixed-wing equivalent (£10.10s.4d [£10.52] for helicopter compared to £12.18s.10d [£12.94] for fixed wing) largely due to the higher camera amortisation rate from fixed wing aircraft. However, it was acknowledged that costs

from plotting from helicopter photography would be higher. The conclusions drawn from the experiments were that helicopter photography would only be suitable when 'circumstances preclude conventional air survey or ground methods'.<sup>35</sup>

In some ways aerial survey and photogrammetry improved the mapping of tidal lines, making a smoother more consistent feature. However, the same controlling factors such as tidal unpredictability, local geomorphological conditions still applied alongside the additional factor of obtaining the appropriate flying conditions for the survey. As the Ordnance Survey commented the greatest advantage of air survey was 'To make a good honest attempt to find out where LWM is at a predicted time of the Mean Low Tide (springs in Scotland) without undue expenditure of money. Air survey methods are used to reduce costs where necessary'.<sup>36</sup> For coastal researchers, one major advantage of aerial survey and photogrammetric mapping is that the existence of the photography allows

<sup>34</sup> Field experiment 269, TNA PRO OS 13/19.

<sup>35</sup> *ibid.*

<sup>36</sup> *Tide lines high and low water mark 1951-74*, TNA OS 11/46.

researchers to revisit the mapped site at later dates to review or check the data collected and, if necessary, to re-measure it themselves.<sup>37</sup>

### **Discussion**

Long term data indicative of coastal change is sparse and until the advent of regular coastal aerial survey, has to some extent had to place a degree of faith in those collecting the data. This review and other associated research into the ground survey of tidal lines and the photogrammetric collection<sup>38</sup> suggest that it is not legitimate to accept the tidal features presented on maps at face value alone. Principally, it is clear that the tidal lines were collected as a boundary feature rather than as a geomorphological feature. Whilst this may be well known and established within the specialist cartographic community, there is perhaps a tendency in other areas to treat tidal lines in the same manner as building outlines or coastal cliff lines. Tidal lines presented on maps offer one of the few potential sources of evidence of longer-term coastal change. This research has shown that tidal lines represent an honest, clearly defined attempt to map a regularly changing feature which is fit for the purpose relating to the reason it was being collected. From the archival evidence, it is clear that the extent of the lines was clearly defined after the Lord Chancellor's 1868 judgment. Likewise, researchers can be confident that the instructions for surveyors ensure that there were rigorous controls on the quality of the field survey. However, the reality is that by their very nature tidal lines are mobile temporary features, which in many cases are difficult, dangerous and impractical to survey. Practical considerations of accessibility, safety considerations, and time restrictions are important to recognise and make allowances for. Likewise, it is necessary to accept the variable behaviour of tides and the effect of local meteorological and geomorphological conditions. Within The National Archives there exist numerous enquiries concerning the accuracy of tidal lines. These queries emanate from the Ordnance Survey and from the general public at large. The answer which probably best sums up the advice for those wishing to use this data is given by the Director General of the Ordnance Survey in response to a query regarding tidal line accuracy's 'Tidal lines marked on Ordnance Survey plans thus represent an honest attempt to portray the position of the High and Low Water Marks of mean tides on a certain date. The Department is legally bound to show these tide lines; but at the same time the impracticability of great precision and liability to frequent changes, in tide lines is recognised'.<sup>39</sup>

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<sup>37</sup> B Baily and P Collier, 'The development of photogrammetric mapping techniques of tidal lines by the Ordnance Survey', *Cartographic Journal* 47 (3) (2010), 262-269.

<sup>38</sup> *ibid.*

<sup>39</sup> *Survey of tides 1946-53*, TNA PRO OS 1/561.