40 YEARS OF CHANGE. RECENT EVOLUTION OF THE PORT STEPHENS FLOOD TIDE DELTA

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Abstract

Bathymetry within the eastern parts of Port Stephens is dominated by an extensive flood tide delta, stretching from the ocean entrance, westward to Corlette and Corrie Island. The delta is changing and the slow but incessant variation in the form of the Port presents a series of ongoing and fluid challenges relating to managing the foreshore both to the north and south of the waterway.

This paper presents a comparison between two historical bathymetric surveys, from 1969 and 2007. Change over the entire flood tide delta has been estimated along with comparisons within more localised, but important locations. The methods used have required consideration of the likely accuracy and resolution of the available data. Our comparison reveals a number of both broad scale and more localised trends of evolution that have relevance to managing locations around the foreshore.

The paper discusses the evolutionary mechanisms with particular reference to the findings of previous research. Recent management actions, the mechanisms leading to the management challenges and a discussion of potential medium term future issues arising from the ongoing evolution are discussed within the paper.

Background

Based on recent study experience within the Eastern Basin of Port Stephens, we were interested in examining the broad scale historical morphological changes, through the comparison of comprehensive hydrosurveys from 1969 and 2007. We are unaware of such a comparison being undertaken to date. In addition, more localised analyses were also undertaken, within areas where the overall comparison revealed interesting trends.

The work is of interest as there are a number of foreshore locations adjoining this delta where the movement of sand is causing ongoing problems through foreshore erosion or the undesirable shoaling of areas of importance for navigation and/or tidal exchange. Management often involves the relocation of such sand, which can be an expensive and thankless task. Natural processes tend to continue their quest to move sand from areas where we would prefer it to stay, into areas where it causes problems for human activities.

Study area

The flood tide delta of Port Stephens extends westward from the entrance of Port Stephens with its leading edge descending into deeper water to the north of Corlette. The flood tide delta is a Holocene feature which is classically understood to be moving westwards into Port Stephens under the combined action of wind and waves (Thom et al. 1992). However, a closer look at bedforms and historical behaviour across the delta would suggest a more spatially complex pattern of evolution (Frolich, 2007). The response of foreshores adjoining the flood tide delta varies depending on local circumstances.

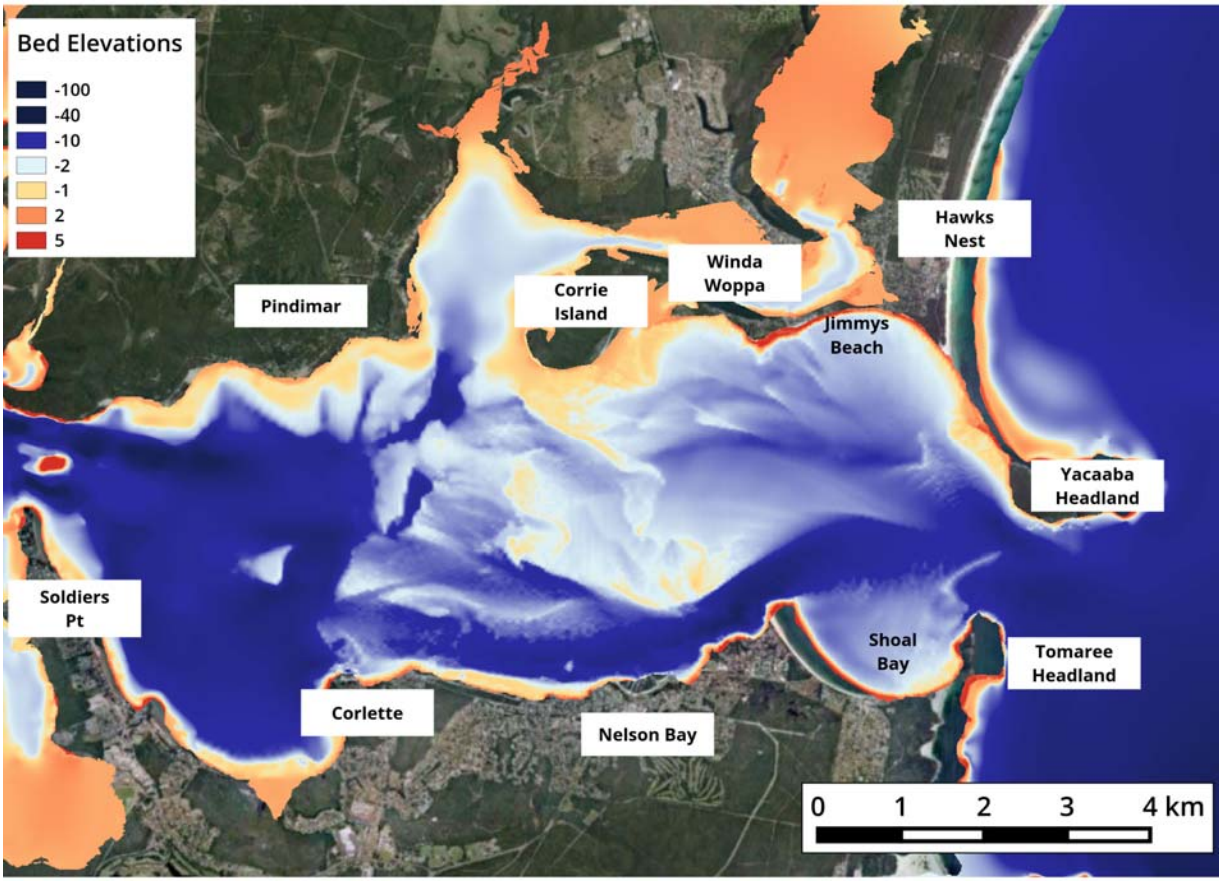

Figure 1 Flood Tide Delta within the Eastern Basin of Port Stephens

Foreshore problem areas

Shoal Bay and Halifax Park

Problem areas historically studied by the authors include Shoal Bay, Corlette, Jimmys Beach and Winda Woppa. Shoal Bay is the easternmost embayment on the southern side of Port Stephens, located just to the west of Tomaree Head. Erosion along Shoal Bay has been documented since the 1960's (Lord et al., 1995). The beach here is known to be subject to westward sediment transport (Lord et al., 1995; Watson, 1997). That westward transport acts to widen the beach at the western end of Shoal Bay, which is highly reflective and aligned almost parallel to the crests of refracted ocean swell at this location. Intermittently, sand builds up to such an extent that westward bypassing occurs around Nelson Head. Aerial photography shows that this occurred in the 1950's and 1960's and subsequently in 2010/2011 causing the burial of highly valued sponge gardens at Halifax Park (BMT WBM, 2011). Recently, the sand has largely cleared from the intertidal zone and comparable photographs from July, 2011 and November 2015 are shown in Figure 2.

Jimmy's Beach and Winda Woppa

Jimmy's Beach has received much attention, given its status as a key NSW coastal erosion "hot spot". Residential development at the beach began some time around the 1960's and, since that time, average recession in the order of 1m/year has been experienced (Vila-Concejo et al., 2010; Watson, 2000). Studies by the Public Works Department in the 1980's and 1990's pointed towards the eastward transport of eroded sand at the shoreline. However, research work from the University of Sydney implied alongshore transport towards the <u>west</u> along Jimmy's Beach (Cholinski, 2004 referenced in Vila-Concejo et al., 2007). A sand wave feature at the eastern extremity of the beach has been studied in detail (Vila-Concejo et al., 2010, 2009, 2007) concluding that the westerly transport was not that clear cut. The prevailing position at the present time appears to be that, considering all driving processes, the dominant direction of sand transport is eastwards from the area of most severe erosion, fronting The Boulevard, Hawks Nest, where the net transport direction reverses, resulting in the formation of the sand wave (Jiang et al., 2013). However the situation is complex and transport will be in different directions at different times. Furthermore, in the vicinity of Barnes Rock, a few hundred metres west of the most severely eroding location, it appears that the dominant transport direction may switch towards Winda Woppa (i.e. westwards).

Thom et al (1992) provided a comparison of historical surveys since the 1860's which demonstrated the historical growth, (until around 1910), shortening and then final destruction of a feature known as "Myall Point". This feature was a substantial sand spit extension of Winda Woppa, projecting towards the south west, but parallel and to the east of Corrie Island. The Lower Myall River coursed between this spit and Corrie Island before discharging into Port Stephens. Based on the accounts of community members, it is understood that destruction occurred during a major storm in the late 1920's (Thom et al, 1992). Aerial photography from the 1950's onwards has shown that Winda Woppa spit, the remaining root of Myall Point, has grown westwards over the past six decades, pinching the channel of the lower Myall River against Corrie Island. Overall, some 750m of extension to Winda Woppa spit has occurred since 1950, with ~300m of that occurring between 1990 and 2010 (BMT WBM, 2011). The patterns of erosion and accretion to the west of Barnes Rock indicate that a significant portion of the sand needed to extend the spit has resulted from the recession of the shoreline to the immediate west of Barnes Rock, although sand moving into the compartment from the east of Barnes Rock cannot be ruled out.

At the time of writing, a dredging operation was underway to cut a channel across the end of Winda Woppa Spit, with the spoil used to (i) nourish Jimmy's Beach, (ii) nourish key areas to the west of Barnes rock where recession is particularly pronounced at the present time; and provide a stockpile for future nourishment operations. Photographs of this operation are presented in Figure 3.

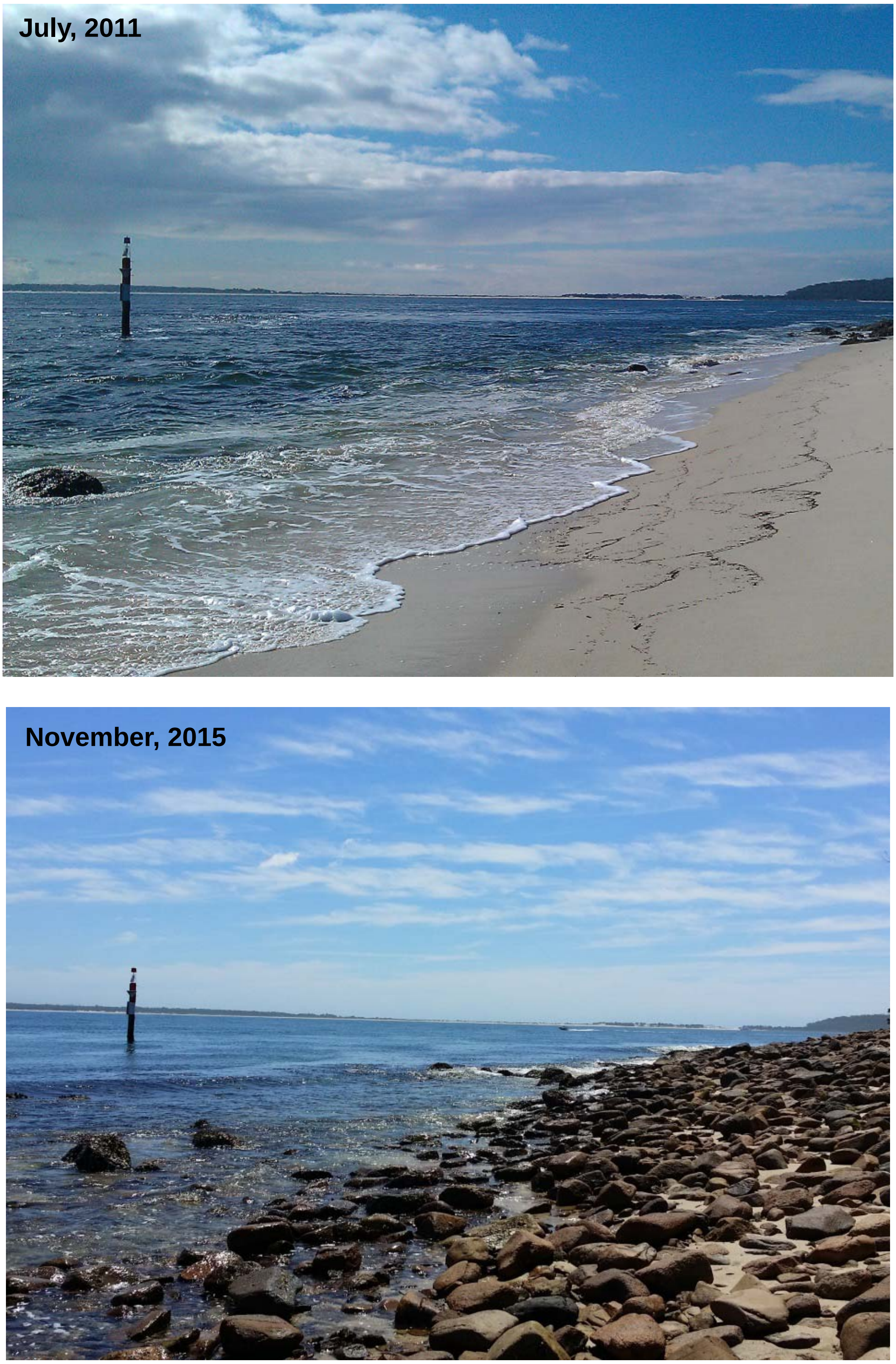

Figure 2 Comparison of Foreshore at Halifax Park, 2011 and 2015

Figure 3 Recent (October, 2015) Dredging and Nourishment Operations at Winda Woppa (Top) and Jimmy's Beach (Bottom) Respectively

Corlette

Corlette Beach is located on the southern side of Port Stephens, near the eastern end of the flood tide delta. The beach spans between Sandy Point and “The Anchorage” marina at Corlette Head. The shoreline here is subject to net westward alongshore transport, and there has been a progressive pattern of erosion and subsequent foreshore protection around Sandy Point from east to west since the area was first settled in the post WWII period (Whitehead & Associates, 2015). The marina was built in the early 1990’s. This involved construction of a shore normal breakwater at the western end of Corlette Beach which, as predicted by Geomarine (1991), has caused the western end of the Beach to widen as sand accumulates adjacent to the breakwater. The western end has accreted, while the eastern end of the beach has eroded over the past 20-25 years. In effect the beach has rotated. The differences in character at the western end of the beach between 1992 and 2015 are illustrated in Figure 4. Although this location is well inside the entrance, near the western extent of the flood tide delta, ongoing changes are still problematic, and erosion at the foreshore of Conroy Park is an ongoing challenge.

Summary

It is of interest to understand how the ongoing, broad scale evolution of the delta may be affecting change along the fringing foreshores. Such an understanding helps decision makers assess the futility or long term implications of adopting foreshore management strategies such as structural protection or beach nourishment.

Surveying, available plans and GIS processing

By comparing elevations in Geographical Information System (GIS) we can assess how much different areas are accumulating or losing sand. However, the way in which different data sets were collected needs to be considered to understand the errors that might arise from the analysis.

For this paper, we have used hydrosurveys from 1969 and 2007. In 1969, hydro surveying methods were much different to those applied today. Essentially, three coordinates are required to capture an individual sounding. The horizontal (x & y) coordinates would have been captured by locating the vessel using on-shore mechanical theodolite stations and triangulation.   Depths would typically have been recorded using echo sounder but recorded to a paper trace with the point of horizontal fixes were marked manually on the trace,. Key issues with these methods included (i) difficulty in accurately triangulating a vessel location, which may be subject to drifting or pull by tidal currents and winds; (ii) no compensation for boat movements; and (iii) variations in the tide level to which soundings were reduced based on manual tide readings taken at intervals during the survey. In comparison, more recent (i.e. 2007) hydrosurveys, use more accurate positioning (GPS), and far more accurate depth measurements using an echo sounder with on board adjustments made to compensate for boat movements. Due to the ease of data collection, the density of survey points presently collected is much greater than that which could be achieved historically.

Figure 4 Changes in the Beach near the western end of Conroy Park, 1992 (Top) and 2015 (Bottom)

Beyond differences in the capture of data, post processing has also changed. In 1969, reduction and mapping of the data would have been completed manually. More recently, the entire process is handled digitally, with records captured on the vessel transferred directly to mapping systems wherein the survey plans are prepared.

The issue of differing datums to which the surveys are reported is also noteworthy. For the 2007 hydrosurvey, the survey has been reported to Australian Height Datum. The 1969 hydrosurvey was reduced to the low water mark on the Tomaree Tide Gauge. The known elevation of zero on the Tomaree tide gauge was compared to information available on the NSW SCIMS database, and it was determined that the existing level is at least reasonably close to the zero point which would have existed in 1969.

For the 2007 hydrosurvey, x, y, z triplets were available digitally, loaded into GIS and used to generate a digital elevation model using a multi-level b-spline approximation algorithm. Hydrosurvey lines were typically spaced at no more than 50m giving excellent coverage of the Eastern Basin of Port Stephens. In comparison, the 1969 hydrosurvey was only available as a scanned, low resolution plan, which needed to be georeferenced and orthorectified within the GIS (scaled, rotated and stretched to match the shape of Port Stephens, using known, fixed locations). Furthermore, the values of individual soundings could not be determined reliably. For this reason, only the contours were digitised. It is not considered reasonable to derive a digital elevation model from these contours as (i) there are large shallow areas to the north of the basin which are not well covered by contours; and (ii) generating a DEM from the contours (themselves a product of interpolation between the original soundings) would result in smoothing of the actual surveyed surface, taking our results further from the original surveyed data than the plotted contours. We understand that the Office of Environment and Heritage has now located more detailed sounding plans, which are being digitised for future analysis.

The analysis of GIS undertaken in this study has involved the comparison of areas shallower and deeper than the contour elevations in the 1969 hydrosurvey. The way in which these have changed over the four decades between surveys provides some insight into ongoing evolution of the flood tide delta.

Analysis and results

While the 1969 plan contours were used in the analysis, contours were generated from the DEM generated from the 2007 hydrosurvey, to match the elevations present on the 1969 plans. It is the areas encompassed by both sets of contours that have been used in the analysis presented here.

A control area for analysis was established covering the flood tide delta, but limited to areas that were below -1m AHD in both data sets and completely enclosed by the contours present on the 1969 plan. The area adopted is shown on Figure 5

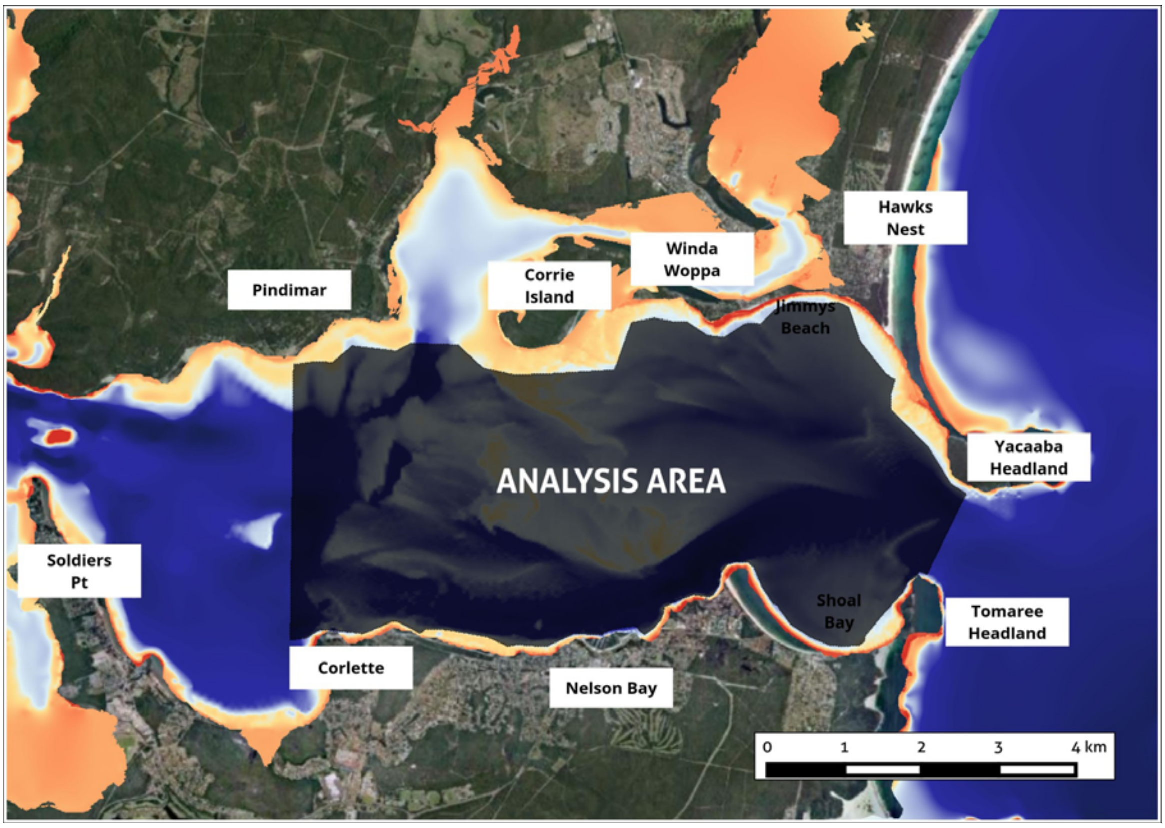

Figure 5 Analysis Extents

The contours were used to determine the depth distribution of the total area (~29.5 km^2) within this analysis polygon. The results are presented in Table 1.

Table 1 Depth distribution across entire analysis area

Depth Band (m AHD)	Area in 1969	Area in 2007
Above -3	**19.6%**	**16.0%**
-3 to -6	**35.1%**	**33.5%**
-6 to -11	**29.8%**	**32.4%**
-11 to -16	**10.1%**	**11.4%**
-16 to -21	**3.8%**	**4.5%**
Below -21	**1.6%**	**2.2%**

Around 2% of the area is below -21m AHD. The patterns show that the area which is shallow (above -6m AHD) is reducing, while the area sitting in bands below -6m AHD are increasing. This is consistent with an overall deepening of the flood tide delta. The results are also consistent with an overall loss of sediment from the flood tide delta, which is surprising, as common understanding would point towards the flood tide delta moving into the Port, and the westward boundary of the area being analysed extends well beyond the "dropover" of the delta into the deeper water of the estuarine basin. Typically, sandy sediment moving into the Port would deposit close to the edge of the dropover. Given the extent of the analysis area, we would expect the volume of sediment present would remain fairly constant.

While investigating further, a series of figures attributed to Roy (1974) were uncovered. One of particular relevance to the present study is replicated as Figure 6. This shows analysis similar to that described above. However, in this instance, the exact extents of the polygon in question are unknown. The pattern of decrease in area shallower than 18 feet (~ -5.5 m to an unknown datum) and an increase in area which is deeper has been apparent for around the past century at least, suggesting that the trend demonstrated in Table 1 is sound.

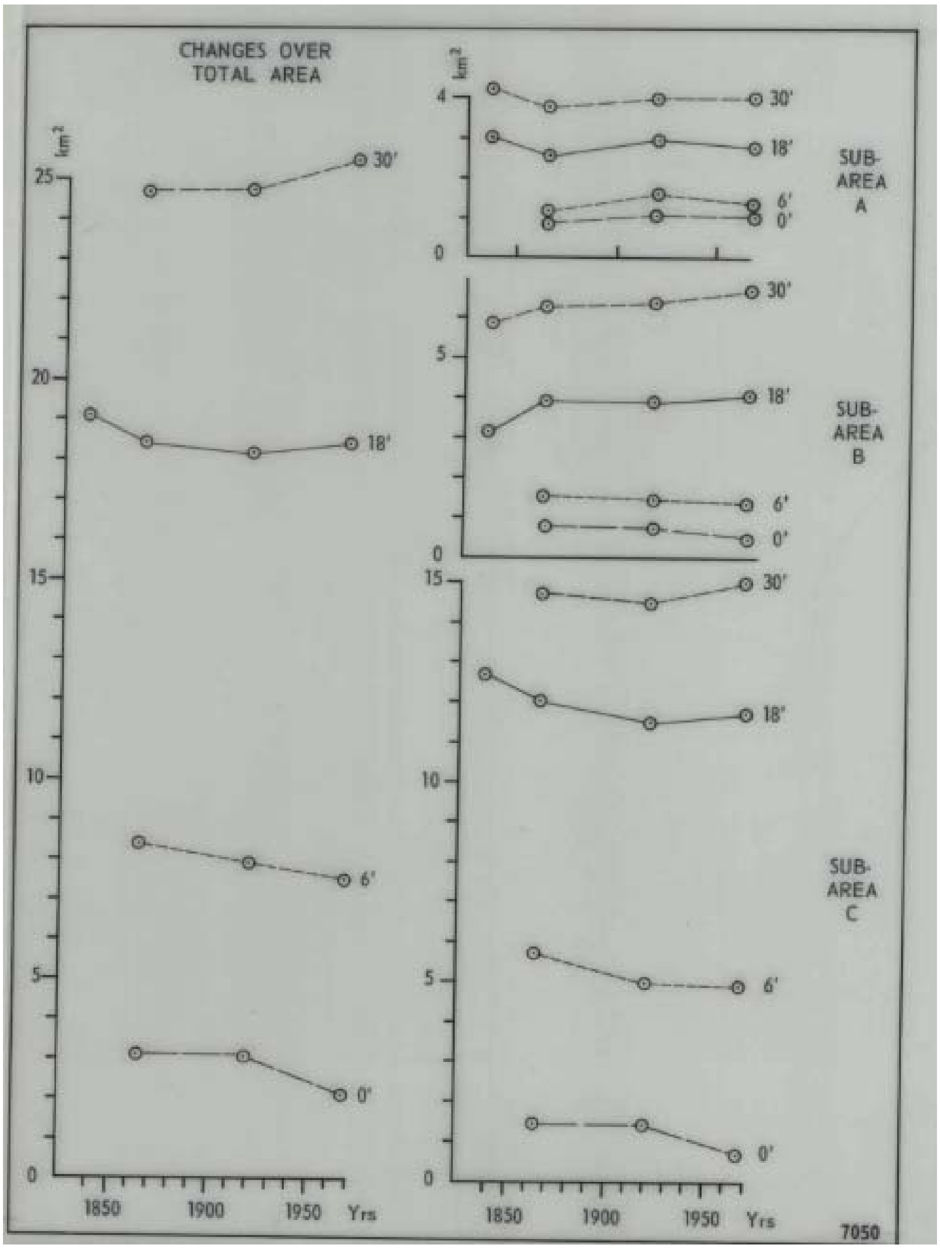

Figure 6 Analysis attributed to Roy (1974) from an apparently unpublished document. The locations of sub-areas A, B and C are unknown at the present time

Following the lead of Roy, 1974, we have also examined selected sub-areas to identify patterns of evolution. We have adopted areas that were covered with a reasonable density of contours and were of particular interest in terms of evolution of the delta. Four areas (A through D) were established and the extent of these is shown in Figure 7. The analysis undertaken for the full analysis area was repeated for each sub area and the results are discussed below.

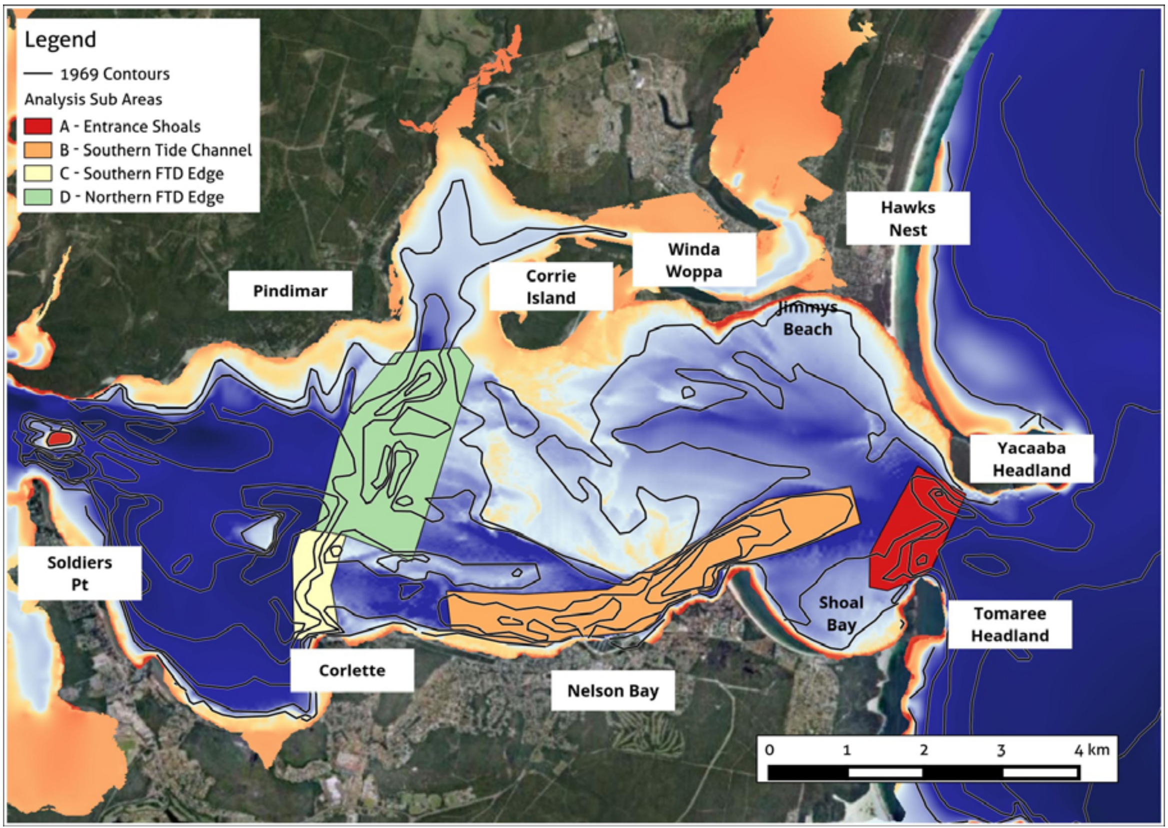

Figure 7 Sub-area Analysis Results

Sub-Area A – Entrance Shoals

The analysis results for Sub-Area A are presented in Table 2.

Table 2 Depth distribution across sub-area A

Depth Band (m AHD)	Area in 1969	Area in 2007
Above -3	~	~
-3 to -6	31.2%	10.7%
-6 to -11	39.9%	42.0%
-11 to -16	23.2%	36.8%
-16 to -21	5.2%	9.5%
Below -21	0.5%	1.0%

Sub-Area A is around 1.1km^2 in size covering notable shoals between the headlands of Port Stephens. As for the broader flood tide delta, this area has deepened over time. As the area deepens, the degree to which waves are refracted by the shoals reduces. This, along with changes in the shape of the shoal will affect the degree and direction of wave focussing caused by these shoals, and hence the location and extent of foreshore erosion and sand movement as local wave conditions change at the shore.

Sub-Area B – Southern Tide Channel

The analysis results for Sub-Area B are presented in Table 3

Table 3 Depth distribution across Sub-Area B

Depth Band (m AHD)	Area in 1969	Area in 2007
Above -3	~	~
-3 to -6	31.2%	10.7%
-6 to -11	39.9%	42.0%
-11 to -16	23.2%	36.8%
-16 to -21	5.2%	9.5%
Below -21	0.5%	1.0%

Along the southern or main tidal channel of the Port, the 3.3km^2 area again displays a pattern of overall deepening. This is particularly marked with an apparent transfer of very shallow area (between -3 and -6m AHD) to a moderately deep area (-11 to -16m AHD) over the 40 year period. The pattern is consistent with widening of the main tidal channel. Along with changes to other tidal channels, a continuation of this process is likely to result in an increase in the efficiency of tidal exchange within the Port over time.

Sub-Area C – Southern Flood Tide Delta Edge

The analysis results for Sub-Area C are presented in Table 4.

Table 4 Depth distribution across Sub-Area C

Depth Band (m AHD)	Area in 1969	Area in 2007
Above -3	~	6.6
-3 to -6	8.8	11.7
-6 to -11	30.8	27.2
-11 to -16	25.9	17.8
-16 to -21	34.1	33.1
Below -21	0.4	3.7

This area covers around 0.75km^2 where the main (southern) tidal channel meets the deeper estuarine basin of the Port, to the west of Corlette. Unlike sub-areas A & B this area is shallowing. The shallowing is consistent with ongoing accumulation of sand deposited by the tidal channel, implying that sand transport is flood tide dominated at this location. This assumption is consistent with observations of the alignment and historical movement of bed forms as documented by Geomarine (1988).

Sub-Area D – Northern Flood Tide Delta Edge

The analysis results for Sub-Area D are presented in Table 5.

Table 5 Depth distribution across Sub-Area D

Depth Band (m AHD)	Area in 1969	Area in 2007
Above -3	14.2%	10.2%
-3 to -6	54.4%	39.4%
-6 to -11	30.3%	30.4%
-11 to -16	12.2%	13.5%
-16 to -21	2.7%	5.5%
Below -21	0.7%	1.0%

This area, which covers the intersection of the minor (northern and middle) tidal channels of the Port, seems to display a reverse pattern to that of sub-area C with overall deepening indicated. Considering the location and coverage of this area, it is consistent with ebb tide dominated transport and the erosion of the leading face of the flood tide delta in this location. The pattern is broadly consistent with, but not exactly the same as, patterns modelled by Jiang et al, 2013. These indicate an ongoing widening and eroding of the northern and middle tidal channels, but with transport towards the entrance of the Port.

Discussion and conclusions

The comparison of hydrosurvey data from 1969 and 2007 was limited by the availability and scale of the 1969 hydrosurvey data. Digitising of the original soundings from large scale plans will go some way towards addressing this.

The patterns uncovered by the analysis indicate that there has been a net deepening trend across the flood tide delta, although this trend may be particularly focussed on the widening and deepening of the main tidal channels. The changes do point to an ongoing loss of sand from the flood tide delta. While some of this sand may have worked its way onshore and subsequently along shore, for example the growth of recurved spits to the south of Corrie Island, the patterns suggest that there is no feed of sediment into the entrance from offshore.

Much of the change is occurring along the main tidal channels, which are tending to deepen, and within areas where those channels meet the ocean or the estuarine basin of the Port. Ongoing deepening, exacerbated by sea level rise, will alter the way that the tides and waves propagate across the shoals of the flood tide delta. In turn, this will modify the wave and current energies experienced at the foreshores of the Port. The historical trends presented here between 1969 and 2007 may not continue into the future and care should be taken in extrapolating these results, or rates of foreshore erosion and accretion. Planning and management strategies adopted at various locations along these foreshores need to bear in mind the possibility of a changing environment.

Acknowledgements

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